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Nonproliferation Impacts Assessment for the Management of The Savannah River Site Aluminum-Based Spent Nuclear Fuel

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United States Department of Energy
Office of Arms Control and Nonproliferation

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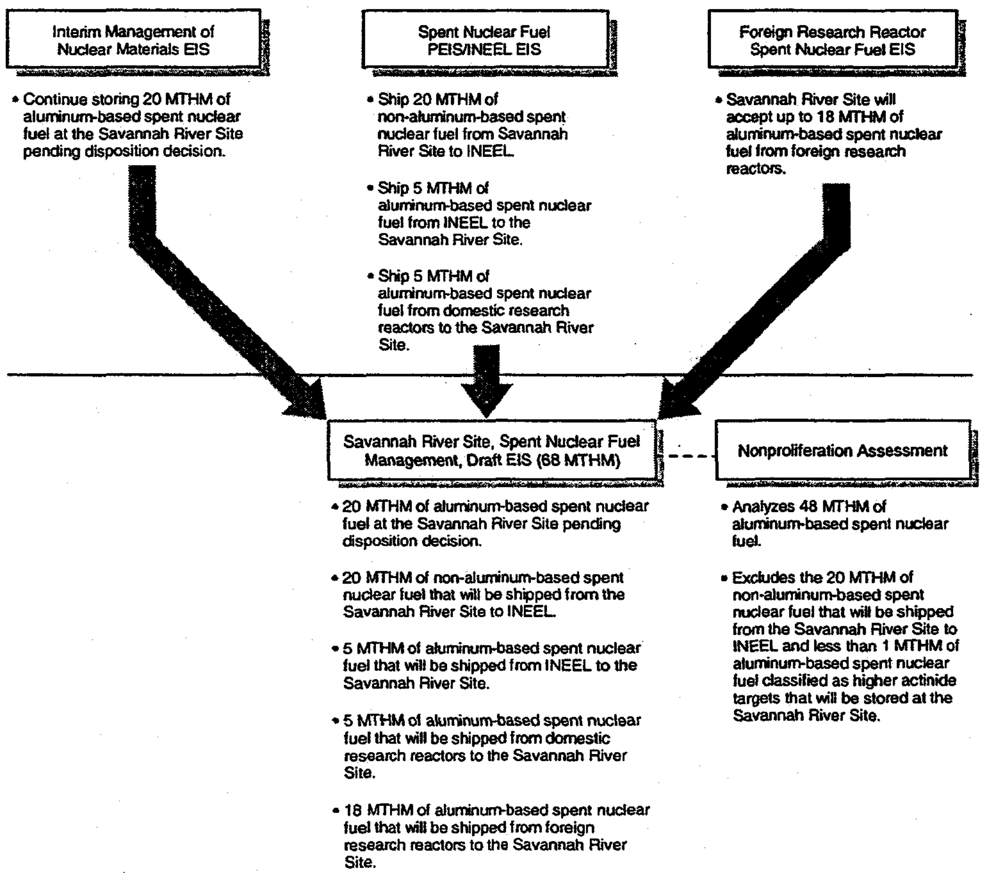
TABLE OF CONTENTS

ES.0 EXECUTIVE SUMMARY

ES.1 The Savannah River Site Aluminum-Based Spent Nuclear Fuel - Background

Over the past four years, the Department of Energy (DOE or the Department) has issued three environmental impact statements (EISs) related to the management and ultimate disposition of aluminum-based spent nuclear fuel and targets (collectively referred to as spent nuclear fuel). These EISs have resulted in decisions to stabilize most of the aluminum-based spent nuclear fuel that was in storage at the Savannah River Site in 1995 and to ship additional aluminum-based spent nuclear fuel to the Savannah River Site.

Figure ES-1. Origin of Material Addressed in the Draft EIS



The *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement* (draft EIS) being issued simultaneously with this assessment addresses how to manage the aluminum-based spent nuclear fuel that is currently located or is expected to be received at the Savannah River Site, including how to place these materials in forms suitable for disposition in a geologic repository (see Figure ES-1). In total, this draft EIS addresses 48 metric tons of heavy metal (MTHM) of aluminum-based spent nuclear fuel.[1] This fuel is currently located at the Savannah River Site, the Idaho National Environmental and Engineering Laboratory, domestic research reactors, and foreign research reactors.

ES.2 Purpose of This Assessment

On May 13, 1996, the United States established a new, 10-year policy to accept and manage foreign research reactor spent nuclear fuel containing uranium enriched in the United States.[2] The goal of this policy is to reduce civilian commerce in weapons-usable highly enriched uranium (HEU), thereby reducing the risk of nuclear weapons proliferation, as called for in President William Clinton's September 27, 1993, Nonproliferation and Export Control Policy (see Appendix A).

Two key disposition options under consideration for managing this fuel include conventional reprocessing[3] and new treatment and packaging technologies. The Record of Decision specified that, while evaluating the reprocessing option, "DOE will commission or conduct an independent study of the nonproliferation and other (*e.g.*, cost and timing) implications of chemical separation of spent nuclear fuel from foreign research reactors." DOE's Office of Arms Control and Nonproliferation conducted this study consistent with the aforementioned Record of Decision.

This report addresses the nonproliferation implications of the technologies under consideration for managing aluminum-based spent nuclear fuel at the Savannah River Site. Because the same technology options are being considered for the foreign research reactor and the other aluminum-based spent nuclear fuels discussed in Section ES.1, this report addresses the nonproliferation implications of managing all the Savannah River Site aluminum-based spent nuclear fuel, not just the foreign research reactor spent nuclear fuel.

The combination of the environmental impact information contained in the draft EIS, public comment in response to the draft EIS, and the nonproliferation information contained in this report will enable the

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[1]Along with the aforementioned 48 MTHM of aluminum-based spent nuclear fuel, the *Savannah River Site, Spent Nuclear Fuel, Management Draft Environmental Impact Statement* addresses 20 MTHM of non-aluminum-based spent nuclear fuel that DOE has decided to ship to the Idaho National Environmental and Engineering Laboratory in the *Record of Decision for the Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*. In addition, the draft EIS also addresses less than 1 MTHM of aluminum-based higher actinide targets that are not included in this assessment that will continue to be stored at the Savannah River Site. This assessment excludes these materials because shipment to the Idaho National Environmental and Engineering Laboratory and continued onsite storage do not raise the same nonproliferation issues that are raised by the technology options DOE is considering for placing the spent nuclear fuel in a form suitable for ultimate disposition.

[2]*Record of Decision for the Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel*, 61 Federal Register 25092 (1996).

[3]"Reprocessing" and "chemical separation", as used in this report, as synonymous and are used interchangeably.

Department to make a sound decision regarding how to manage all aluminum-based spent nuclear fuel at the Savannah River Site.

ES.3 Fuel Groups Addressed In This Assessment

Because aluminum-based spent nuclear fuel varies significantly in size, physical and chemical properties, fissile material content, and radionuclide inventories, DOE has classified the 48 MTHM of aluminum-based spent nuclear fuel addressed by this assessment into four separate groups. Most of the items contain HEU, and nearly all contain modest quantities of plutonium. The descriptions presented below indicate which groups include HEU-containing items and which contain modest amounts of plutonium. Because the chemical and physical properties of the spent nuclear fuel varies among the four groups, not all technologies can be used for all of the fuel groups. This section and Table ES-1 provide more detail on each fuel group. Section ES.4 describes which technology options can be used for which fuel groups.

Table ES-1. Fuel Groups

Fuel Group	MTHM	MTRE*	% of MTRE
Uranium and Thorium Metal Fuels	19	610	2%
Material Test Reactor-Like Fuels	26	30,800	97%
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging	2	470	1%
Loose Uranium Oxide in Cans	0.7	NA	NA
Total	47.8	31,880	100%

*MTRE = Materials Test Reactor Equivalent. An MTRE is a qualitative estimate of spent nuclear fuel volume that provides information on the amount of space needed for storage. An MTRE of Materials Test Reactor-Like Fuels would usually be one fuel assembly.
Source: *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement*

Uranium and Thorium Metal Fuels. This group consists of uranium and thorium metal fuels. It includes Experimental Breeder Reactor-II and Sodium Reactor Experiment fuels currently stored in canisters in the Receiving Basin for Offsite Fuel. It also includes a core filter block at the Idaho National Environmental and Engineering Laboratory and unirradiated targets intended to be used for plutonium production. While this group contains a modest amount of fissile plutonium (about 114 kilograms), it does not contain any HEU. This group comprises approximately 2 percent of the volume (in MTRE) of aluminum-based fuel that DOE expects to manage at the Savannah River Site. Because the fuel in this group is made of unalloyed metal, it is more dense than most of the other spent nuclear fuel considered in this assessment and represents approximately 40 percent of the heavy metal mass of aluminum-based fuels to be managed at the Savannah River Site.

Materials Test Reactor-Like Fuels. This group, which consists primarily of Materials Test Reactor fuels and other fuels of similar size and composition, represents about 97 percent of the volume of aluminum-based fuel that DOE expects to manage at the Savannah River Site. Most domestic and foreign research reactors use Materials Test Reactor fuels, which have a flat or curved plate design. Although these fuels come in a variety of shapes and compositions, the active fuel region is typically about 2 feet (0.6 meters) long and the overall assembly is about 4 feet (1.2 meters) long. The cross-section of an assembly is approximately square, about 3 inches (8 centimeters) per side. Most of the items in this group are located at foreign and domestic research reactor sites, but are scheduled to be shipped to the Savannah River Site. Approximately 70 percent of the assemblies in this group contain HEU and the remainder contain LEU.

HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging. Materials in this group are similar in composition to Materials Test Reactor-Like Fuels. Much of this fuel currently is at other DOE sites or in other countries, but is scheduled to be shipped to the Savannah River Site. This group represents about 1 percent of the volume of aluminum-based spent nuclear fuel that DOE expects to manage at the Savannah River Site. The majority of items in this group contain HEU. One item in this group contains plutonium.

Loose Uranium Oxide in Cans. This group consists of loose powdered uranium oxide that contains fission products distributed in the material. All of the items in this group contain HEU. The material is stored in aluminum cans, and probably would not be acceptable in its current form for disposal in a repository. Most of the items in this group have yet to be produced at foreign research reactors sites, but are eligible to be shipped to the Savannah River Site.

ES.4 Technology Options Considered In This Assessment

This report addresses the nonproliferation implications of technology options that DOE is considering for managing aluminum-based spent nuclear fuel.[4] In this report, the nine processes DOE is considering have been grouped into six technology options: direct disposal/direct co-disposal, melt and dilute, electrometallurgical treatment, conventional reprocessing/chemical separation, mechanical dilution, and vitrification. This section individually describes each of the six technology options. Because no new technology can be used to manage all of the spent nuclear fuel considered in this assessment (due to the timing of when new treatments will be available), DOE will need to select more than one technology option for managing the aluminum-based spent nuclear fuel (see Table ES-2).

[4] As described in the draft EIS, the Research Reactor Spent Nuclear Fuel Task Team considered 11 processes for managing this spent nuclear fuel. DOE has already excluded two of these from further consideration. DOE rejected chloride volatility because, given the lack of experimental work on it to date, the time and expense required to overcome the technical risks associated with this option were deemed to be too great. DOE also rejected can-in-canister, which is a leading contender for disposition of excess weapons plutonium, for application to aluminum-based fuel because of technical problems. The molten high-level waste glass in the outer canister could cause the aluminum-based fuel in the cans to melt, which could degrade the performance of the high-level waste glass and make it difficult to control the geometry of the fuel matrix (if that were desired).

Table ES-2. Technology Options and Applicable Fuel Groups

Fuel Group	Direct Disposal/ Direct Co-Disposal	Melt and Dilute	Electrometallurgical Treatment	Conventional Reprocessing	Mechanical Dilution	Vitrification Technologies
Uranium and Thorium Metal Fuels	Yes[a]	Yes[b]	Yes	Yes	No	Yes
Materials Test Reactor-Like Fuels	Yes	Yes	Yes	Yes	Yes	Yes
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging	Yes	Yes	Yes	Yes	Yes	Yes
Loose Uranium Oxide in Cans	No	Yes	Yes	Yes	No	Yes

a. "Yes" indicates that the technology could be applied to the fuel group. "No" indicates that the technology could not be applied to the fuel group.
b. One item in the Uranium and Thorium Metal Fuels group, the ARMF Core Filter Block, contains some corrosion-resistant metal that would be incompatible with the melt and dilute technology. However, all other materials in this fuel group are compatible with the melt and dilute technology.
Note: Because of the timing of when new treatments will be available, no new technology can be used to manage all of the spent nuclear fuel considered in this assessment.
Source: *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement*

Direct Disposal/Direct Co-disposal. Under this option, spent nuclear fuel would be managed in a transfer and storage facility. It would be cropped, vacuum dried, and placed in stainless-steel canisters with a neutron poison. The canisters would be filled with an inert gas, welded closed, and placed in dry storage to await shipment to a geologic repository. Under the direct disposal technology option, the filled canisters would be disposed of between waste packages of commercial spent nuclear fuel. Under the direct co-disposal technology option, the spent nuclear fuel canisters would be placed in waste packages that also contain vitrified high-level waste. This technology is not a separations technology and does not produce separated HEU or plutonium. The direct disposal/direct co-disposal technology is considered an option for fuels in all groups *except* Loose Uranium Oxide in Cans. This technology option is not being considered for Loose Uranium Oxide in Cans because these fuels might contain particulates that are not expected to be acceptable in the geologic repository.

Melt and Dilute. Under this option, spent nuclear fuel would be managed in two facilities: one for transfer and treatment and another for storage. Treatment would consist of melting and, if the spent nuclear fuel contained HEU, blending with depleted uranium and additional aluminum as necessary to produce a low enriched uranium-aluminum melt. Neutron poison material would also be added as necessary. The resulting material would be placed in canisters, and the canisters would be transferred to a storage facility to await shipment to a geologic repository. Actinides and most fission products would remain in the final form; however, some fission products would be volatilized during the melting process. This technology is not a separations technology and does not produce separated HEU or plutonium. This technology is being considered for spent fuel in all four fuel groups.

Electrometallurgical Treatment. This technology option is a separations technology that produces separated HEU as an intermediate product and separated LEU as a final product. This technology option does not separate plutonium from the fission products. However, adding a plutonium separations capability to this option would be easier than adding such a capability to any of the non-separations technology options. Under this option, spent nuclear fuel would be cropped and dried in a transfer and storage facility and then transferred to a treatment facility. It would be shredded, compacted, and melted into metal ingots. The ingots would be sequentially placed in two electrorefiners, the first of which would remove the aluminum and the second of which would remove the uranium. The uranium would then be transferred to a melter and mixed with depleted uranium to produce LEU with a U-235 enrichment of 5 percent. Fission products and non-uranium actinides (including any plutonium) remaining in the second electrorefiner would be incorporated into high-level waste, which would be vitrified and placed in storage awaiting shipment to a geologic repository. Aluminum from the first electrorefiner would be disposed of as low-level waste. This technology is considered an option for spent fuels in all four spent nuclear fuel groups.

Conventional Reprocessing/Chemical Separation. This technology option is a separations technology that produces separated HEU as an intermediate product and separated LEU and plutonium as final products. Under this option, spent nuclear fuel would be processed in the F and H Area Canyon facilities. Fuel would be transferred directly from wet storage to the canyon facilities where it would be dissolved in nitric acid, and the solutions clarified and purified. A solvent extraction process would then be used to remove the fission products, leaving a nitrate solution mixture of uranium and other actinides, including plutonium. For fuel containing HEU, a second solvent extraction step would separate the uranium, and the HEU nitrate would be diluted to about 5 percent U-235 either within H Canyon or in adjoining H Area storage tanks. Non-HEU containing fuels would be processed in this manner in F Canyon. The F Canyon uranyl nitrate product would not contain HEU, would require no isotopic dilution, and would be transported to H Area storage facilities. The uranyl nitrate from either canyon could be made available for commercial sale. Most of the plutonium processed using this technology is present in non-HEU fuels and would be processed through F Canyon. This plutonium would be recovered in the F Canyon facilities, reduced to metal, and subsequently stored and managed with surplus weapons plutonium already in storage at Savannah River Site. This technology is considered an option for spent fuels in all groups.

Mechanical Dilution. Under this option, spent nuclear fuel would be mechanically processed to consolidate the fuel and reduce the enrichment level. This option could be performed by either of two technologies: (1) press and dilute, or (2) chop and dilute. Using the press and dilute technology, the fuel would be cropped and vacuum dried and the fuel assemblies would be flattened and pressed into a laminate between layers of depleted uranium to produce packages with an overall low enrichment level. The chop and dilute technology would shred the fuel and mix it with depleted uranium. The mixture would be placed in canisters. The sealed canisters would be placed in dry storage to await shipment to a geologic repository. This technology is considered an option for spent fuels in the following two groups: Materials Test Reactor-Like Fuels, and HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging. It is not being considered for spent nuclear fuel in the Uranium and Thorium Metal Fuels and Loose Uranium Oxide in Cans groups. For the Uranium and Thorium Metal Fuels group, this technology would not address the chemical reactivity of the fuels, and for the Loose Uranium Oxide in Cans fuel group, this technology would not address the potential presence of particulates. For the fuels in these groups, the properties of the final forms produced are not expected to be acceptable in the geologic repository due to either chemical reactivity or the potential presence of particulates. These technologies are not separations technologies and do not produce separated HEU or plutonium.

Vitrification Technologies. Under this option, spent nuclear fuel would be processed using one of three vitrification technologies: (1) dissolve and vitrify, (2) glass material oxidation dissolution system (GMODS), or (3) plasma arc treatment. These technologies are similar in that they all use advanced vitrification-type processes in which the final form contains LEU and other actinides as oxides and most fission products mixed in a glass or ceramic binder. The dissolve and vitrify technology is similar to conventional reprocessing in that the fuel would be cropped and dissolved in a nitric and boric acid solution. However, there would be no separation of fissile material, and depleted uranium would be included in the solution to reduce the U-235 enrichment level to 20 percent or less. The entire mixture would then be vitrified into a final form that contains both fission products and fissionable material. GMODS would process the spent nuclear fuel in a melter with depleted uranium, lead oxide, boron oxide, silicon oxide, and carbon. The final form would contain most of the spent nuclear fuel fission products and the actinides in a glassified mixture of these materials, except most of the lead would be removed and recycled. Under the plasma arc treatment process, spent nuclear fuel would be cut into small pieces using a plasma arc and melted, oxidized, and blended with depleted uranium using a plasma torch in a centrifuge. The resulting slag would be cooled in molds. Using any of these technologies, the final forms would be placed in dry storage prior to shipment to a geologic repository. These technologies are not separations technologies and do not produce separated HEU or plutonium. These technologies are considered options for spent fuels in all groups.

ES.5 Special Safety and Health Considerations

The draft EIS has identified conventional reprocessing as the preferred technology alternative to manage a relatively small volume of aluminum-based spent nuclear fuel at the Savannah River Site (about 3 percent by volume; less than 3,000 MTRE) that presents a potential health and safety vulnerability.[5] That spent nuclear fuel includes the Experimental Breeder Reactor-II fuel, the Sodium Reactor Experiment fuel, the Mark-42 targets and the core filter block from the Uranium and Thorium Metal fuel group; the failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuels and a Mark-14 target from the HEU/LEU Oxides and Silicides fuel group; and the Sterling Forest Oxide (and any other powdered/oxide fuel that may be received at the Savannah River Site while H Canyon is still in operation) from the Loose Uranium Oxide in Cans fuel group.

The Experimental Breeder Reactor-II fuel and Sodium Reactor Experiment fuel are uranium metal that has been declad and stored in canisters in the Receiving Basin for Offsite Fuel. The declad fuels present a potential safety and health vulnerability. Should their existing storage containers leak, the metal fuel would corrode and release fission products to the water of the storage basin. Once the metal of the fuel is wetted, simply repackaging the fuel in a water-tight container would not arrest the corrosion and in fact, could exacerbate storage concerns since potentially explosive hydrogen gas would continue to be generated inside the storage canister as the fuel continued to corrode. An instance of water intrusion and subsequent fuel corrosion has already occurred with one Experimental Breeder Reactor-II canister stored in the Receiving Basin for Offsite Fuel. Additionally, several problems have occurred with other uranium metal fuel in similar storage conditions at the Savannah River Site (*e.g.*, the Taiwan Research Reactor fuel with failed or

[5]It is the preference of the Department of Energy not to utilize conventional reprocessing for reasons other than safety and health. A limited subset of the spent nuclear fuel to be processed may not be compatible with the melt and dilute process for aluminum-based spent nuclear fuel. The benefit of developing a new process to accommodate the small amount of non-standard fuel would be disproportionately small when compared to the cost.

missing cladding that was overpacked in canisters and stored in the Savannah River Site wet basins). DOE addressed these situations by processing the failed or declad fuel in F Canyon to eliminate the safety and health vulnerability.

The failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuel, a sectioned Mark-14 target from the HEU/LEU Oxides and Silicides fuel group, and the Sterling Forest Oxide fuel also present potential safety and health vulnerabilities. The integrity of this fuel was destroyed for research purposes. Then the material was canned and placed in wet storage at the Savannah River Site. A breach of or leak in the cans would expose the interior surfaces of the sectioned fuel to water, contaminating the water in the storage basin with radioactivity, and accelerating the corrosion of the fuel.

A potential safety and health vulnerability also exists for the unirradiated Mark-42 targets from the Uranium and Thorium Metal fuel group and the Sterling Forest Oxide fuel from the Loose Uranium Oxide in Cans fuel group. Should a breach occur in the cladding on the Mark-42 targets or in the canisters of Sterling Forest Oxide fuel, the particulate nature of the nuclear material in the targets and the Sterling Forest Oxide fuel could lead to dispersion of radioactive material in the water of the Receiving Basin for Offsite Fuel. Additionally, the powder form of the Sterling Forest Oxide fuel likely would not be acceptable for placement in a geologic repository based on the requirements of 10 CFR 60 which states that particulate material is prohibited. Although some new treatment technologies could be applied to oxide fuels, there is more uncertainty about the application of these technologies to oxide fuel than to standard uranium alloy fuel.

Although reprocessing is not the most preferred alternative from a nonproliferation perspective, timely alleviation of the aforementioned potential safety and health vulnerabilities may require the use of existing reprocessing facilities.

ES.6 U.S. Nonproliferation Goals

This assessment evaluates the extent to which each technology option supports the U.S. nonproliferation goals, which are summarized below.

- To reduce the risk of nuclear proliferation and for other considerations, the United States neither encourages the civil use of plutonium nor engages in plutonium reprocessing for either nuclear power or nuclear explosive purposes. In addition, the United States works actively with other nations to reduce global stocks of excess weapons-usable material: separated plutonium and highly enriched uranium. Under this policy, the United States honors its commitments to cooperate with civilian nuclear programs that involve the reprocessing and recycling of plutonium in Western Europe and Japan. In all such cases, however, the United States seeks to ensure that the International Atomic Energy Agency (IAEA) has the resources needed to implement its vital safeguards responsibilities, and works to strengthen the IAEA's ability to detect clandestine nuclear activities. The United States seeks to eliminate where possible the accumulation of stockpiles of HEU or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability. The United States also actively opposes, as do other supplier nations, the introduction of reprocessing and plutonium recycling activities in regions of proliferation concern.

- The United States also seeks to minimize the adverse environmental, safety, and health impacts of its management of nuclear materials and activities. This goal includes minimizing the generation of radioactive wastes and ensuring that waste materials are put into forms that can be disposed of safely.

ES.7 Evaluation Factors

To evaluate the extent to which the technology options support the U.S. nonproliferation policy goals, this study evaluates the technology options using technical and policy factors, as explained below.

Technical factors include the degree to which a particular technology would:

- Help ensure that the weapons-usable nuclear material in the spent nuclear fuel could not be stolen or diverted during the process. This includes an assessment of the attractiveness to diversion of materials in process and the ease of providing institutional and inherent security features.

- Facilitate cost-effective international verification and transparency.

- Result in converting the spent nuclear fuel into a form from which retrieval of the material for weapons use would be difficult and unlikely, thus modestly reducing the total stockpile of material readily usable in nuclear weapons.

Policy factors include the degree to which a particular technology would:

- Be consistent with U.S. policy related to reprocessing and nonproliferation.

- Avoid encouraging other countries to engage in the reprocessing of spent nuclear fuel, or undermining U.S. efforts to limit the spread of reprocessing technology and activities, particularly to regions of proliferation concern.

- Support U.S. efforts to convert U.S. and foreign research reactors to low enriched fuels, and avoid creating technical, economic, or political obstacles to implementing the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

- Help demonstrate that any treatment of these spent nuclear fuels will definitely not represent the production by the United States of additional materials for use in nuclear weapons.

- Support negotiation of a nondiscriminatory global fissile material cutoff treaty (FMCT).

ES.8 Conclusion

ES.8.1 PREFERRED ALTERNATIVE: RECOMMENDATION

The *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement* proposes several technology options for managing spent nuclear fuel at the Savannah River Site. The two "preferred" options identified by the draft EIS for the 48 MTHM considered within the scope of this report are melt and dilute and, for a small quantity of material, conventional reprocessing. These technologies would treat specific groups of spent nuclear fuel, as outlined below.

Melt and Dilute. This option has been identified as the preferred method for treating most (about 97 percent by volume) of the aluminum-based spent nuclear fuel considered in this report. This fuel includes the Material Test Reactor-Like fuel, most of the Loose Uranium Oxide in Cans fuel, and most of the HEU/LEU Oxides and Silicides fuel. As a back-up to melt and dilute, the direct co-disposal option would be implemented if melt and dilute were no longer feasible or preferred. It is expected that the melt and dilute operation could begin about 2005 and would continue at least through 2035. The draft EIS states that should any safety and health concerns involving aluminum-based spent nuclear fuel arise prior to the availability of melt and dilute operations, the F and H Canyons would be used to stabilize the material of concern.

Conventional Reprocessing. This option has been identified to manage the small volume of aluminum-based spent nuclear fuel (about 3 percent by volume) that presents a potential safety and health vulnerability. It is the preference of the Department of Energy not to utilize conventional reprocessing for reasons other than safety and health. A limited subset of the spent nuclear fuel to be processed may not be compatible with the melt and dilute process for aluminum-based spent nuclear fuel. The benefit of developing a new process to accommodate the small amount of non-standard fuel would be disproportionately small when compared to the cost.

The spent nuclear fuel to be reprocessed includes the Experimental Breeder Reactor-II fuel, the Sodium Reactor Experiment fuel, the Mark-42 targets, and the core filter block from the Uranium and Thorium Metal fuel group; the failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuels and a Mark-14 target from the HEU/LEU Oxides and Silicides fuel; and the Sterling Forest Oxide from the Loose Uranium in Cans fuel group. Using this technology on this group of materials would like result in the separation of approximately 114 kilograms of plutonium.

The Office of Arms Control and Nonproliferation fully supports the active pursuit of a new treatment technology for the aluminum-based spent nuclear fuel, and views the melt and dilute recommendation as a favorable technology in light of nonproliferation concerns. The case of reprocessing spent nuclear fuel for only explicit safety or health reasons is an extremely important criterion to uphold as an example for other nations. Seen in the context in which about 97 percent (by volume) of the aluminum-based spent nuclear fuel would be treated by melt and dilute, the reprocessing of a small number of spent nuclear fuel items that pose unique safety and health concerns would not unduly damage U.S. nonproliferation efforts. A decision to reprocess a majority of the aluminum-based spent nuclear fuel at the Savannah River Site could negatively affect the credibility of U.S. policy not to encourage reprocessing. Such a decision would also extend the period of time that reprocessing operations must continue at the Savannah River Site - making it more difficult for U.S. efforts to convince other nations not to pursue fuel cycles that increase proliferation risks.

ES.8.2 NONPROLIFERATION IMPACTS OF TECHNOLOGY OPTIONS

There are several options for the effective management of the aluminum-based spent nuclear fuel at the Savannah River Site. With respect to nonproliferation:

- All of the options could reliably discourage any theft or diversion of the material, but some are superior to others.
- All of the options could provide for some form of international safeguarding by the International Atomic Energy Agency (IAEA). The options vary in terms of cost and ease of application.
- All of the options would result in forms from which recovery of uranium or plutonium material for use in weapons would be highly unlikely, although the direct disposal/direct co-disposal option would not blend down the residual HEU to LEU, and the conventional reprocessing option would recover plutonium metal that would be managed as surplus.
- All of the options would be consistent with U.S. nonproliferation policy and would allow for verification approaches that would be acceptable to the United States if implemented in other countries.
- The electrometallurgical treatment and the conventional reprocessing options, by appearing to endorse these separations technologies, could conceivably encourage reprocessing in other countries.
- All of the options have the potential to support fully U.S. efforts to reduce the civil use of HEU, including the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.
- None of these options would appear to be prejudicial to the ability of the United States to submit to international safeguards or monitoring under an FMCT. However, the reprocessing option involves the use of old facilities at the Savannah River Site not specifically designed to facilitate the application of international safeguards. An effective safeguarding regime would likely be difficult due to cost and safety retrofitting concerns.
- The Office of Arms Control and Nonproliferation fully supports the active pursuit of a new treatment technology for the aluminum-based spent nuclear fuel, and views the melt and dilute recommendation as a favorable technology in light of nonproliferation concerns.

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1.0 INTRODUCTION

1.1 The Savannah River Site Aluminum-Based Spent Nuclear Fuel - Background

Over the past four years, the Department of Energy (DOE or the Department) has issued three environmental impact statements (EISs) related to the management and ultimate disposition of aluminum-based spent nuclear fuel and targets (collectively referred to as spent nuclear fuel). These EISs have resulted in decisions to stabilize most of the aluminum-based spent nuclear fuel that was in storage at the Savannah River Site in 1995 and to ship additional aluminum-based spent nuclear fuel to the Savannah River Site.

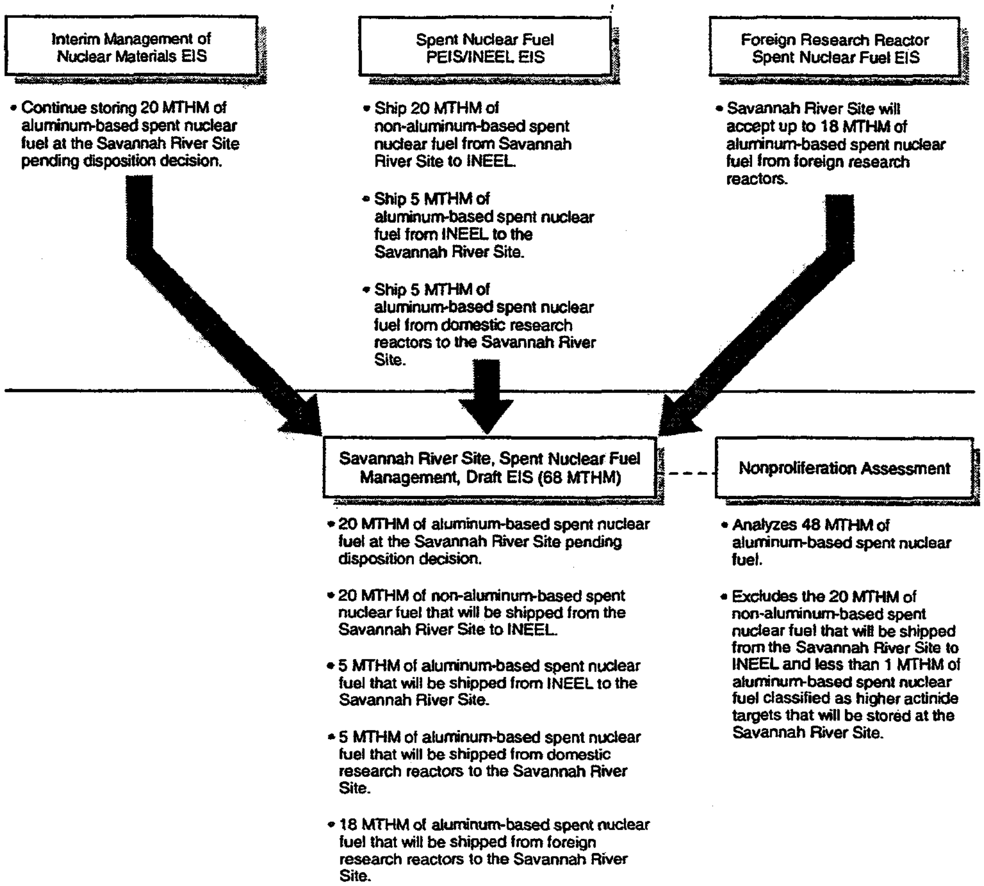
The *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement* (draft EIS) addresses how to manage the aluminum-based spent nuclear fuel that is currently located or is expected to be received at the Savannah River Site, including how to place these materials in forms suitable for disposition. In total, this draft EIS addresses 48 metric tons of heavy metal (MTHM) of aluminum-based spent nuclear fuel. This fuel is currently located at the Savannah River Site, the Idaho National Environmental and Engineering Laboratory, domestic research reactors, and foreign research reactors.

Figure 1-1 shows the relationship between the three predecessor EISs and the draft EIS. The 1995 *Interim Management of Nuclear Materials Environmental Impact Statement* assessed how the Department should manage the aluminum-based spent nuclear fuel that was in storage at the Savannah River Site. In that EIS, DOE decided to stabilize most of the fuel to correct or eliminate potential safety and health vulnerabilities. The EIS also decided to continue storing 20 MTHM of aluminum-based spent nuclear fuel that was deemed to be stable (*i.e.*, that likely could be safely stored for about 10 more years). This fuel is still in storage at the Savannah River Site.

In the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*, DOE decided to consolidate existing and newly generated aluminum-based spent nuclear fuel (excluding the aluminum-based spent nuclear fuel at the Hanford Site) at the Savannah River Site pending disposition decisions. As a result of this decision, DOE will ship 5 MTHM of aluminum-based research reactor spent nuclear fuel, primarily Advanced Test Reactor fuel, from the Idaho National Environmental and Engineering Laboratory to the Savannah River Site. Also, domestic research reactors will ship another 5 MTHM of aluminum-based spent nuclear fuel to the Savannah River Site. These shipments could continue until 2035.

The *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* established a program under which the Department would accept and manage spent nuclear fuel containing uranium enriched in the United States from foreign research reactors. Under this program, foreign research reactors could ship as much as 18 MTHM of aluminum-based spent nuclear fuel to the Savannah River Site. This acceptance program will be complete by 2009.

Figure 1-1. Origin of Material Addressed in the Draft EIS



1.2 Purpose of This Assessment

On May 13, 1996, the United States established a new 10-year policy to accept and manage spent nuclear fuel, containing uranium enriched in the United States, from foreign research reactors. The Department of Energy (DOE or the Department) announced this policy in the *Record of Decision for the Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* (61 FR 25092). The goal of this policy is to reduce civilian commerce in weapons-usable highly enriched uranium (HEU) and thereby reduce risks of nuclear weapons proliferation, as called for in President William Clinton's September 27, 1993, statement on Nonproliferation and Export Control Policy (Appendix A contains a copy of this policy statement).

In the Record of Decision, DOE indicated that decisions regarding how the accepted materials would be prepared for ultimate disposition would be made after further consideration of technology options. A key question was whether these fuels would be prepared for final disposition by reprocessing[6] (chemical separation) or by a "non-reprocessing, cost-effective treatment and/or packaging" technology. The Record of Decision states that, for the aluminum-based foreign research reactor spent nuclear fuel, the following three-point management strategy would be implemented:

> *1. New Technology Development/Dry Storage.* DOE would embark immediately on an accelerated program at the Savannah River Site to identify, develop, and demonstrate one or more non-reprocessing, cost-effective treatment and/or packaging technologies to prepare the foreign research reactor spent nuclear fuel for ultimate disposal. The purpose of any new facilities that might be constructed to implement these technologies would be to change the foreign research reactor spent nuclear fuel into a form that is suitable for geologic disposal, without necessarily separating the fissile materials, while meeting or exceeding all applicable safety and environmental requirements.
>
> In conjunction with the examination of new technologies, variations of conventional direct disposal methods would also be explored. After treatment and/or packaging, the foreign research reactor spent nuclear fuel would be managed on site in "road ready" dry storage until transported off site for continued storage or disposal. DOE would select, develop, and implement, if possible, one or more of these treatment and/or packaging technologies by the year 2000. DOE is committed to avoiding indefinite storage of this spent nuclear fuel in a form that is unsuitable for disposal.
>
> *2. Potential Chemical Separation/Wet Storage.* Despite DOE's best efforts, it is possible that a new treatment and/or packaging technology may not be ready for implementation by the year 2000. It may become necessary, therefore, for DOE to use the F-Canyon at the Savannah River Site to chemically separate some foreign research reactor spent nuclear fuel elements, while the F-Canyon is operating to stabilize at-risk materials in accordance with the Records of Decision (60FR 65300, December 19, 1995 and 61 FR 6633, February 21, 1996) issued after completion of the *Interim Management of Nuclear Materials Final Environmental Impact Statement* (DOE/EIS-0220 of October 1995). Under current schedules, this chemical separation of foreign research reactor spent nuclear fuel could take place between the years 2000 and 2002. In that event, the foreign research reactor spent nuclear fuel would be converted into [low enriched uranium] LEU and wastes. The high-level radioactive wastes would be vitrified in the Savannah River Site Defense Waste Processing Facility, while other wastes (all low level) would be solidified in the Savannah River Site Saltstone facility. **In order to provide a sound policy basis for making a determination on whether and how to utilize the F-Canyon for chemical separation tasks that are not driven by safety and health considerations, DOE will commission or conduct an independent study of the nonproliferation and other (*e.g.*, cost and timing) implications of chemical separation of spent nuclear fuel from foreign research reactors** (emphasis added). The study will be initiated in mid-1996 and will be completed in a timely fashion to allow a subsequent decision about possible use of the F-Canyon for

[6]For the purpose of this report, "reprocessing" and "chemical separation" are synonymous and are used interchangeably.

chemical separation of foreign research reactor spent nuclear fuel to be fully considered by the public, the Congress, and Executive Branch agencies. Pending disposition of the foreign research reactor spent nuclear fuel by either a new treatment and/or packaging technology or chemical separation in the F-Canyon, the spent nuclear fuel would be placed in existing wet storage at the Savannah River Site.

3. *Spent Nuclear Fuel Monitoring (Wet Storage).* DOE would conduct a program of close monitoring of any foreign research reactor spent nuclear fuel and target material that would be accepted for storage in existing wet storage facilities. DOE is presently unaware of any technical basis for believing that this spent nuclear fuel cannot be safely stored until one or more of the treatment and/or packaging technologies becomes available. Nevertheless, if safety and health concerns involving any of the foreign research reactor spent nuclear fuel elements are identified prior to development of an appropriate treatment and/or packaging technology, DOE would use the F-Canyon to chemically separate the affected spent nuclear fuel elements, if it is still operating to stabilize at-risk materials. (61 Fed. Reg. 25092, 25096 (1996).)

In conjunction with preparing the *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement*, DOE committed itself to assess the issues associated with the potential proliferation risks of aluminum-based spent nuclear fuel that is currently located or is expected to be received at the Savannah River Site. This report, prepared by the DOE's Office of Arms Control and Nonproliferation, fulfills the DOE commitment to assess the nonproliferation aspects of the various technology options the Department is considering for managing aluminum-based spent nuclear fuel. Because the same technology options are being considered for the foreign research reactor and the other aluminum-based spent nuclear fuels discussed in Section 1.1, this report addresses the nonproliferation implications of managing all the Savannah River Site aluminum-based spent nuclear fuel, not merely foreign research reactor spent nuclear fuel.

The aforementioned draft EIS examines the potential environmental impacts of managing the Savannah River Site aluminum-based spent nuclear fuel and preparing it for ultimate disposition.[7] The combination of the information contained in the draft EIS, public comment in response to the draft EIS, and the nonproliferation information contained in this report will enable the Department to make a sound decision regarding how to manage all aluminum-based spent nuclear fuel at the Savannah River Site.

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[7] Along with the aforementioned 48 MTHM of aluminum-based spent nuclear fuel, the *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement* addresses 20 MTHM of non-aluminum-based spent nuclear fuel that DOE has decided to ship to the Idaho National Environmental and Engineering Laboratory in the *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement*. This assessment excludes these materials because shipment to the Idaho National Environmental and Engineering Laboratory does not raise the same nonproliferation issues that are raised by the technology options DOE is considering for placing the spent nuclear fuel in a form suitable for ultimate disposition.

1.3 Fuel Groups Addressed In This Assessment

For two reasons, the aluminum-based spent nuclear fuel addressed by this report poses challenges for ultimate disposition. First, aluminum-cladding is more chemically reactive than the stainless steel and zirconium-cladding used for power-reactor spent nuclear fuel. Second, much of the spent nuclear fuel addressed in this assessment contains HEU. Consequently, potential criticality issues in storage and the geologic disposal must be addressed by one means or another; criticality is of particular concern for the fuel containing HEU (see "Criticality" text box on page 1-7).

Because aluminum-based spent nuclear fuel varies significantly in size, physical and chemical properties, fissile material content, and radionuclide inventories, DOE has classified the 48 MTHM of aluminum-based spent nuclear fuel addressed by this assessment into four separate groups.[8] Most of the items contain HEU, and nearly all contain varying quantities of plutonium. The descriptions presented below and in Table 1-2 indicate which groups include HEU-containing items and which contain modest amounts of plutonium. Because the chemical and physical properties of the spent nuclear fuel varies between the four groups, not all technologies can be used for all of the fuel groups. This section provides more detail on each fuel group. Section 1.4 describes which technology options can be used for which fuel groups.

Table 1-1. Fuel Groups

Fuel Group	MTHM	MTRE*	% of MTRE
Uranium and Thorium Metal Fuels	19	610	2%
Material Test Reactor-Like Fuels	26	30,800	97%
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging	2	470	1%
Loose Uranium Oxide in Cans	0.7	NA	NA
Total	47.8	31,880	100%

*MTRE = Materials Test Reactor Equivalent. An MTRE is a qualitative estimate of spent nuclear fuel volume that provides information on the amount of space needed for storage. An MTRE of Materials Test Reactor-Like Fuels would usually be one fuel assembly.
Source: *Savannah River Site Spent Nuclear Fuel Management Draft Environmental Impact Statement*

[8]DOE has identified a total of five different groups of aluminum-based spent nuclear fuel: Uranium and Thorium Metal Fuels, Material Test Reactor-Like Fuels, Higher Actinide Targets, HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging, and Loose Uranium Oxide in Cans. Items in the Higher Actinide Targets group, which comprises much less than 1 percent of the spent nuclear fuel addressed in the *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement*, are not included in this assessment because they are considered programmatic material (*i.e.*, potentially useful in other DOE programs) being stored pending an evaluation of their disposition. The draft EIS addresses spent nuclear fuel in the Higher Actinide Targets group so that the targets can be transferred to an alternative storage arrangement at SRS until dispositions for the targets are evaluated and made.

Table 1-2. Fuel Groups

Fuel Group	Name	Number of Items	Fissionable Material*	Location
Uranium and Thorium Metal Fuels 19 MTHM	EBR-II Blankets	59 Cans	NU, DU, and Plutonium	SRS
	ARMF	1 Core Filter Block	DU	INEEL
	Sodium Reactor Experiment	36 Cans	Thorium	SRS
	Mark-42	16 Bundles	Plutonium	SRS
Materials Test Reactor-Like Fuels 26 MTHM	Foreign MTR	10,812 Assemblies	HEU	FRR
	Domestic MTR	11,799 Assemblies	HEU	DRR
	MTR	~1,100 Assemblies	HEU	SRS
	Japan Cylindrical MTR	145 Assemblies	HEU	FRR
	Japan Box MTR	28 Assemblies	HEU	FRR
	Tube MTR	4,077 Assemblies	HEU	FRR
	Missouri University Research Reactor	224 Assemblies	HEU	SRS, INEEL, DRR
	Advanced Test Reactor	3,132 Assemblies	HEU	INEEL
	ARMF	67 Assemblies	NU	INEEL
	ARMF	15 Plates	NU	INEEL
	U. of Washington	26 Bundles		INEEL
	Sterling Forest Fuel	200 Assemblies	HEU	SRS
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging 2 MTHM	Mark-14	1 Can	Plutonium	SRS
	Oak Ridge Research Reactor	165 Assemblies	HEU and LEU	SRS
	HWCTR	1 Can	HEU and DU	SRS
	Pin Bundle	12 Bundles	HEU	FRR
	Pin Cluster	2,792 Clusters	HEU and LEU	FRR
	Cornell U. ZPTR	45 Assemblies	LEU	DRR
	Manhattan ZPR	17 Assemblies	HEU	DRR
	Ohio State Reactor	24 Assemblies	HEU and LEU	DRR
	Florida Argonaut	50 Assemblies	HEU	DRR
	Reactor a-Haut Flux	90 Assemblies	HEU	SRS, FRR
	ORNL High Flux Isotope Reactor	1 Can	HEU	SRS
	ORNL High Flux Isotope Reactor	540 Assemblies	HEU	DRR
	ORNL Bulk Shielding Reactor	32 Assemblies	HEU	DRR
	ORNL Tower Shielding Reactor	1 Element	HEU	DRR
	ORNL Tower Shielding Reactor	2 Cans	HEU	DRR
	Sandia Pulse Reactor	43 Assemblies	HEU	DRR
	Oak Ridge Reactor	9 Cans	HEU and LEU	DRR
Loose Uranium Oxide in Cans 0.7 MTHM	Sterling Forest Oxide	676 Cans	HEU	SRS
	Other non-MTR targets	6,750 Cans	HEU	FRR

ARMF–Advanced Reactivity Measurement Facility
DRR–Domestic Research Reactors
DU–Depleted Uranium
EBR-II–Experimental Breeder Reactor–II
FRR–Foreign Research Reactors
HWCTR–Heavy Water Components Test Reactor
INEEL–Idaho National Environmental Engineering Laboratory
MTR–Materials Test Reactor
ORNL–Oak Ridge National Laboratory
NU–Natural Uranium
SRS–Savannah River Site
ZPR–Zero Power Reactor
ZPTR–Zero Power Test Reactor

* Plutonium content is indicated only in fuels with the highest plutonium concentration. However, small amounts of plutonium are present in all uranium-containing fuels that have been irradiated.

Criticality

Nuclear criticality is a fission reaction that occurs in a controlled manner in a nuclear reactor, but must be avoided when fissile material is outside a nuclear reactor. In a state of nuclear criticality, a chain of fission events is self-sustained: neutrons produced in each fission event collide with fissionable isotopes, resulting in a continuous sequence of fission events. Avoiding criticality is one of the fundamental requirements for systems used to manage spent nuclear fuel and other materials containing fissionable isotopes.

Criticality is a concern in spent nuclear fuel having high concentrations of the fissionable isotope uranium-235. DOE will use three methods to control the potential for a nuclear reaction during storage, transport, and repository disposal of spent fuel:

- Incorporating neutron-absorbing poison materials in the form or containers.
- Reducing uranium-235 enrichment levels to the extent practical (20 percent or less uranium-235).
- Limiting the mass loading of fissile uranium-235.

Uranium and Thorium Metal Fuels. This group consists of uranium and thorium metal fuels. It includes Experimental Breeder Reactor-II and Sodium Reactor Experiment fuels currently stored in canisters in the Receiving Basin for Offsite Fuel. It also includes a core filter block at the Idaho National Environmental and Engineering Laboratory and unirradiated targets intended to be used for plutonium production. While this group contains a modest amount of fissile plutonium (about 114 kilograms), it does not contain any HEU. This group comprises approximately 2 percent of the volume (in MTRE) of aluminum-based fuel that DOE expects to manage at the Savannah River Site. Because the fuel in this group is made of unalloyed metal, it is more dense than most of the other spent nuclear fuel considered in this assessment and represents approximately 40 percent of the heavy metal mass of aluminum-based fuels to be managed at the Savannah River Site.

Materials Test Reactor-Like Fuels. This group, which consists primarily of Materials Test Reactor fuels and other fuels of similar size and composition, represents about 97 percent of the volume of aluminum-based fuel that DOE expects to manage at the Savannah River Site. Most domestic and foreign research reactors use Materials Test Reactor fuels, which have a flat or curved plate design. Although these fuels come in a variety of shapes and compositions, the active fuel region is typically about 2 feet (0.6 meters) long and the overall assembly is about 4 feet (1.2 meters) long. The cross-section of an assembly is approximately square, about 3 inches (8 centimeters) per side. Most of the items in this group are located at foreign and domestic research reactor sites, but are scheduled to be shipped to the Savannah River Site. Approximately 70 percent of the assemblies in this group contain HEU and the remainder contain LEU.

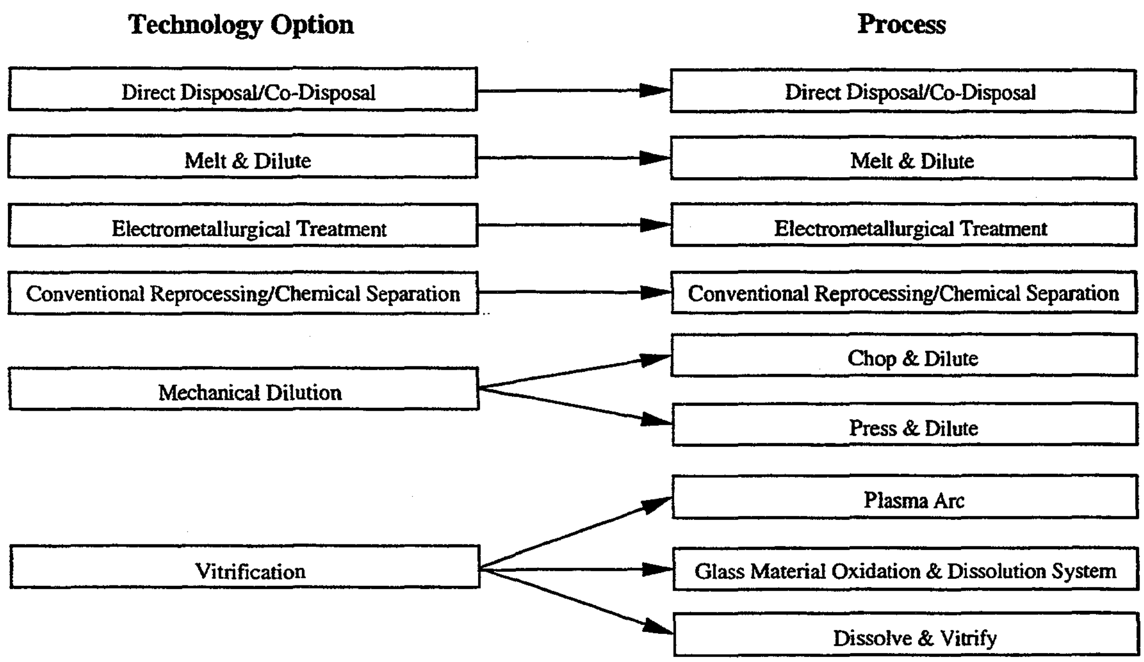
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging. Materials in this group are similar in composition to Materials Test Reactor-Like Fuels. Much of this fuel currently is at other DOE sites or in other countries, but is scheduled to be shipped to the Savannah River Site. This group represents about 1 percent of the volume of aluminum-based spent nuclear fuel that DOE expects to manage at the Savannah River Site. The majority of items in this group contain HEU. One item in this group contains plutonium.

Loose Uranium Oxide in Cans. This group consists of loose powdered uranium oxide that contains fission products distributed in the material. All of the items in this group contain HEU. The material is stored in aluminum cans, and probably would not be acceptable in its current form for disposal in a repository. Most of the items in this group have yet to be produced at foreign research reactors sites, but are eligible to be shipped to the Savannah River Site.

1.4 Technology Options Considered In This Assessment

This report addresses the nonproliferation implications of technology options that DOE is considering for managing aluminum-based spent nuclear fuel.[9] For the purpose of this report, we have grouped the nine processes DOE is considering into six technology options: direct disposal/direct co-disposal, melt and dilute, electrometallurgical treatment, conventional reprocessing/chemical separation, mechanical dilution, and vitrification (see Figure 1-2). This section individually describes each of the six technology options.

Figure 1-2. Technology Options Under Consideration



[9] As described in the draft EIS, the Research Reactor Spent Nuclear Fuel Task Team considered 11 processes for managing this spent nuclear fuel. DOE has already excluded two of these from further consideration. DOE rejected chloride volatility because, given the lack of experimental work on it to date, the time and expense required to overcome the technical risks associated with this option were deemed to be too great. DOE also rejected can-in-canister, which is a leading contender for disposition of excess weapons plutonium, for application to aluminum-based fuel because of technical problems. The molten high-level waste glass in the outer canister could cause the aluminum-based fuel in the cans to melt, which could degrade the performance of the high-level waste glass and make it difficult to control the geometry of the fuel matrix (if that were desired).

As noted above, certain technology options cannot be used for certain categories of spent nuclear fuel. Table 1-3 summarized this relationship, which is further described below.

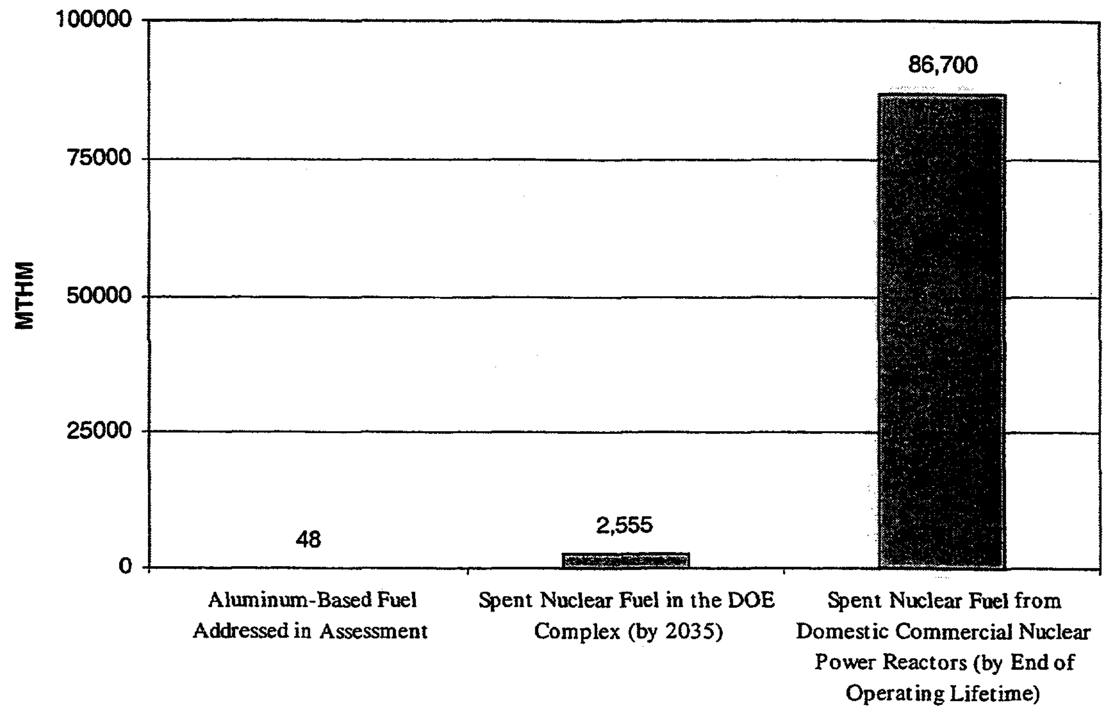
Table 1-3. Technology Options and Applicable Fuel Groups

Fuel Group	Direct Disposal/ Direct Co-Disposal	Melt and Dilute	Electrometallurgical Treatment	Conventional Reprocessing	Mechanical Dilution	Vitrification Technologies
Uranium and Thorium Metal Fuels	Yes[a]	Yes[b]	Yes	Yes	No	Yes
Materials Test Reactor-Like Fuels	Yes	Yes	Yes	Yes	Yes	Yes
HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging	Yes	Yes	Yes	Yes	Yes	Yes
Loose Uranium Oxide in Cans	No	Yes	Yes	Yes	No	Yes

a. "Yes" indicates that the technology could be applied to the fuel group. "No" indicates that the technology could not be applied to the fuel group.
b. One item in the Uranium and Thorium Metal Fuels group, the ARMF Core Filter Block, contains some corrosion-resistant metal that would be incompatible with the melt and dilute technology. However, all other materials in this fuel group are compatible with the melt and dilute technology.
Note: Because of the timing of when new treatments will be available, no new technology can be used to manage all of the spent nuclear fuel considered in this assessment.
Source: *Savannah River Site Spent Nuclear Fuel Management Draft Environmental Impact Statement*

Also, in considering the nonproliferation impacts of the various technology options for the management of this 48 MTHM of spent nuclear fuel, it should be noted that the material addressed in this assessment represents a small fraction of the spent nuclear fuel in the United States. The total amount of spent nuclear fuel projected to be in the DOE complex by 2035 is 2,555 MTHM, while domestic commercial nuclear power reactors are expected to produce a total of 86,700 MTHM of spent nuclear fuel by the end of their currently licensed operating lifetimes (see Figure 1-3). Decisions to mitigate near-term health or safety vulnerabilities related to nuclear material at the Savannah River Site have already been made for about 175 MTHM of spent nuclear fuel, and mitigation actions have already been taken for most of this material; specifically, 167.4 MTHM of this spent nuclear fuel has already been reprocessed.

Figure 1-3. Amount of Spent Nuclear Fuel in the United States



1.4.1 DIRECT DISPOSAL/DIRECT CO-DISPOSAL (NEW PACKAGING TECHNOLOGY)

Under this option, spent nuclear fuel would be managed in a transfer and storage facility. It would be cropped, vacuum dried, and placed in stainless-steel canisters with a neutron poison. The canisters would be filled with an inert gas, welded closed, and placed in dry storage to await shipment to a geologic repository. Under the direct disposal technology option, the filled canisters would be disposed of between waste packages of commercial spent nuclear fuel. Under the direct co-disposal technology option, the spent nuclear fuel canisters would be placed in waste packages that also contain vitrified high-level waste. This technology is not a separations technology and does not produce separated HEU or plutonium. The direct disposal/direct co-disposal technology is considered an option for fuels in all groups *except* Loose Uranium Oxide in Cans. This technology option is not being considered for Loose Uranium Oxide in Cans because these fuels might contain particulates that are not expected to be acceptable in the geologic repository.

1.4.2 MELT AND DILUTE (NEW PROCESSING TECHNOLOGY)

Under this option, spent nuclear fuel would be managed in two facilities: one for transfer and treatment and another for storage. Treatment would consist of melting and, if the spent nuclear fuel contained HEU, blending with depleted uranium and additional aluminum as necessary to produce a low enriched uranium-aluminum melt. Neutron poison material would also be added as necessary. The resulting material would be placed in canisters, and the canisters would be transferred to a storage facility to await shipment to a geologic repository. Actinides and most fission products would remain in the final form; however, some fission products would be volatilized during the melting process. This technology is not a separations technology and does not produce separated HEU or plutonium. This technology is being considered for spent fuel in all four fuel groups.

1.4.3 ELECTROMETALLURGICAL TREATMENT (NEW PROCESSING TECHNOLOGY)

This technology option is a separations technology that produces separated HEU as an intermediate product and separated LEU as a final product. This technology option does not separate plutonium from the fission products. However, adding a plutonium separations capability to this option would be easier than adding such a capability to any of the non-separations technology options. Under this option, spent nuclear fuel would be cropped and dried in a transfer and storage facility and then transferred to a treatment facility. It would be shredded, compacted, and melted into metal ingots. The ingots would be sequentially placed in two electrorefiners, the first of which would remove the aluminum and the second of which would remove the uranium. The uranium would then be transferred to a melter and mixed with depleted uranium to produce LEU with a U-235 enrichment of 5 percent. Fission products and non-uranium actinides (including any plutonium) remaining in the second electrorefiner would be incorporated into high-level waste, which would be vitrified and placed in storage awaiting shipment to a geologic repository. Aluminum from the first electrorefiner would be disposed of as low-level waste. This technology is considered an option for spent fuels in all four spent nuclear fuel groups.

Reprocessing Facilities at Savannah River Site

Two reprocessing facilities capable of separating fissile material are located at the Savannah River Site, H-Canyon and F-Canyon. Constructed in the early 1950s, these facilities initially operated to produce fissile material for national defense purposes. Their operation stopped in the early 1990s as a result of safety concerns and reduced need for nuclear weapons materials. Both facilities have been restarted in recent years to process fissile materials to produce more stable forms suitable for long-term storage, reuse, or disposal. The materials being processed for this purpose include actinide targets; HEU fuel; laboratory solutions; sand, slag, and crucible (containing minute quantities of plutonium); and actinide solutions. The plutonium produced from these activities is prohibited from use in nuclear weapons, and the HEU will be blended to LEU. The schedule for processing materials for which decisions have been made ends in 2001.

1.4.4 CONVENTIONAL REPROCESSING/CHEMICAL SEPARATION

This technology option is a separations technology that produces separated HEU as an intermediate product and separated LEU and plutonium as final products. Under this option, spent nuclear fuel would be processed in the F and H Area Canyon facilities. Fuel would be transferred directly from wet storage to the canyon facilities where it would be dissolved in nitric acid, and the solutions clarified and purified. A solvent extraction process would then be used to remove the fission products, leaving a nitrate solution mixture of uranium and other actinides, including plutonium. For fuel containing HEU, a second solvent extraction step would separate the uranium, and the HEU nitrate would be diluted to about 5 percent U-235 either within H Canyon or in adjoining H Area storage tanks. Non-HEU containing fuels would be processed in this manner in F Canyon. The F Canyon uranyl nitrate product would not contain HEU, would require no isotopic dilution, and would be transported to H Area storage facilities. The uranyl nitrate from either canyon could be made available for commercial sale. Most of the plutonium processed using this technology is present in non-HEU fuels and would be processed through F Canyon. This plutonium would be recovered in the F Canyon facilities, reduced to metal, and subsequently stored and managed with surplus weapons plutonium already in storage at Savannah River Site. This technology is considered an option for spent fuels in all groups.

1.4.5 MECHANICAL DILUTION

Under this option, spent nuclear fuel would be mechanically processed to consolidate the fuel and reduce the enrichment level. This option could be performed by either of two technologies: (1) press and dilute, or (2) chop and dilute. Using the press and dilute technology, the fuel would be cropped and vacuum dried and the fuel assemblies would be flattened and pressed into a laminate between layers of depleted uranium to produce packages with an overall low enrichment level. The chop and dilute technology would shred the fuel and mix it with depleted uranium. The mixture would be placed in canisters. The sealed canisters would be placed in dry storage to await shipment to a geologic repository. This technology is considered an option for spent fuels in the following two groups: Materials Test Reactor-Like Fuels, and HEU/LEU Oxides and Silicides Requiring Resizing or Special Packaging. It is not being considered for spent nuclear fuel in the Uranium and Thorium Metal Fuels and Loose Uranium Oxide in Cans groups. For the Uranium and Thorium Metal Fuels group, this technology would not address the chemical reactivity of the fuels, and for the Loose Uranium Oxide in Cans fuel group, this technology would not address the potential presence of particulates. For the fuels in these groups, the properties of the final forms produced are not expected to be acceptable in the geologic repository due to either chemical reactivity or the potential presence of particulates. These technologies are not separations technologies and do not produce separated HEU or plutonium.

1.4.6 VITRIFICATION TECHNOLOGIES

Under this option, spent nuclear fuel would be processed using one of three vitrification technologies: (1) dissolve and vitrify, (2) glass material oxidation dissolution system (GMODS), or (3) plasma arc treatment. These technologies are similar in that they all use advanced vitrification-type processes in which the final form contains LEU and other actinides as oxides and most fission products mixed in a glass or ceramic binder. The dissolve and vitrify technology is similar to conventional reprocessing in that the fuel would be cropped and dissolved in a nitric and boric acid solution. However, there would be no separation of fissile material, and depleted uranium would be included in the solution to reduce the U-235 enrichment level to 20 percent or less. The entire mixture would then be vitrified into a final form that contains both fission products and fissionable material. GMODS would process the spent nuclear fuel in a melter with depleted uranium, lead oxide, boron oxide, silicon oxide, and carbon. The final form would contain most of the spent nuclear fuel fission products and the actinides in a glassified mixture of these materials, except most of the lead would be removed and recycled. Under the plasma arc treatment process, spent nuclear fuel would be cut into small pieces using a plasma arc and melted, oxidized, and blended with depleted uranium using a plasma torch in a centrifuge. The resulting slag would be cooled in molds. Using any of these technologies, the final forms would be placed in dry storage prior to shipment to a geologic repository. These technologies are not separations technologies and do not produce separated HEU or plutonium. These technologies are considered options for spent fuels in all groups.

1.4.7 SPECIAL SAFETY AND HEALTH CONSIDERATIONS

The draft EIS has identified conventional reprocessing as the preferred technology alternative to manage a relatively small volume of aluminum-based spent nuclear fuel at the Savannah River Site (about 3 percent by volume; less than 3,000 MTRE) that presents a potential health and safety.[10] That spent nuclear fuel includes the Experimental Breeder Reactor-II fuel, the Sodium Reactor Experiment fuel, the Mark-42 targets and the core filter block from the Uranium and Thorium Metal fuel group; the failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuels and a Mark-14 target from the HEU/LEU Oxides and Silicides fuel group; and the Sterling Forest Oxide (and any other powdered/oxide fuel that may be received at the Savannah River Site while H Canyon is still in operation) from the Loose Uranium Oxide in Cans fuel group.

The Experimental Breeder Reactor-II fuel and Sodium Reactor Experiment fuel are uranium metal that has been declad and stored in canisters in the Receiving Basin for Offsite Fuel. The declad fuels present a potential safety and health vulnerability. Should their existing storage containers leak, the metal fuel would corrode and release fission products to the water of the storage basin. Once the metal of the fuel is wetted, simply repackaging the fuel in a water-tight container would not arrest the corrosion and in fact, could exacerbate storage concerns since potentially explosive hydrogen gas would continue to be generated inside the storage canister as the fuel continued to corrode. An instance of water intrusion and subsequent fuel corrosion has already occurred with one Experimental Breeder Reactor-II canister stored in the Receiving Basin for Offsite Fuel. Additionally, several problems have occurred with other uranium metal fuel in similar storage conditions at the Savannah River Site (*e.g.*, the Taiwan Research Reactor fuel with failed or missing cladding that was overpacked in canisters and stored in the Savannah River Site wet basins). DOE addressed these situations by processing the failed or declad fuel in F Canyon to eliminate the safety and health vulnerability.

The failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuel, a sectioned Mark-14 target from the HEU/LEU Oxides and Silicides fuel group, and the Sterling Forest Oxide fuel also present potential safety and health vulnerabilities. The integrity of this fuel was destroyed for research purposes. Then the material was canned and placed in wet storage at the Savannah River Site. A breach of or leak in the cans would expose the interior surfaces of the sectioned fuel to water, contaminating the water in the storage basin with radioactivity, and accelerating the corrosion of the fuel.

A potential safety and health vulnerability also exists for the unirradiated Mark-42 targets from the Uranium and Thorium Metal fuel group and the Sterling Forest Oxide fuel from the Loose Uranium Oxide in Cans fuel group. Should a breach occur in the cladding on the Mark-42 targets or in the canisters of Sterling Forest Oxide fuel, the particulate nature of the nuclear material in the targets and the Sterling Forest Oxide fuel could lead to dispersion of radioactive material in the water of the Receiving Basin for Offsite Fuel. Additionally, the powder form of the Sterling Forest Oxide fuel likely would not be acceptable for placement

[10]It is the preference of the Department of Energy not to utilize conventional reprocessing for reasons other than safety and health. A limited subset of the spent nuclear fuel to be processed may not be compatible with the melt and dilute process for aluminum-based spent nuclear fuel. The benefit of developing a new process to accommodate the small amount of non-standard fuel would be disproportionately small when compared to the cost.

in a geologic repository based on the requirements of 10 CFR 60 which states that particulate material is prohibited. Although some new treatment technologies could be applied to oxide fuels, there is more uncertainty about the application of these technologies to oxide fuel than to standard uranium alloy fuel.

Although reprocessing is not the most preferred alternative from a nonproliferation perspective, timely alleviation of the aforementioned potential safety and health vulnerabilities may require the use of existing reprocessing facilities.

1.5 Nonproliferation Goals

This assessment evaluates the extent to which each technology option supports the U.S. nonproliferation goals. Below, these goals are summarized.

- To reduce the risk of nuclear proliferation and for other considerations, the United States neither encourages the civil use of plutonium nor engages in plutonium reprocessing for either nuclear power or nuclear explosive purposes. In addition, the United States works actively with other nations to reduce global stocks of excess weapons-usable material: separated plutonium and highly enriched uranium. Under this policy, the United States honors its commitments to cooperate with civilian nuclear programs that involve the reprocessing and recycling of plutonium in Western Europe and Japan. In all such cases, however, the United States seeks to ensure that the International Atomic Energy Agency (IAEA) has the resources needed to implement its vital safeguards responsibilities, and works to strengthen the IAEA's ability to detect clandestine nuclear activities. The United States seeks to eliminate where possible the accumulation of stockpiles of HEU or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability. The United States also actively opposes, as do other supplier nations, the introduction of reprocessing and plutonium recycling activities in regions of proliferation concern.

- The United States also seeks to minimize the adverse environmental, safety, and health impacts of its management of nuclear materials and activities. This goal includes minimizing the generation of radioactive wastes and ensuring that waste materials are put into forms that can be disposed of safely.

These goals must be weighed and balanced in making decisions regarding the management of spent nuclear fuel at the Savannah River Site. This assessment focuses primarily on the first of these goals: reducing the risk of nuclear weapons proliferation.

1.6 Technical and Policy Factors Affecting Nonproliferation

Each of the six technology options for managing foreign research reactor spent nuclear fuel has implications for nonproliferation efforts. The criteria applied in evaluating these implications fall into two main categories: technical factors and policy factors. Technical factors are those related directly to the potential accessibility and attractiveness of the materials for use in nuclear weapons, both while they are being processed and in their final form. Policy factors are related to the effect U.S. decisions will have on its current and future nuclear nonproliferation efforts.

1.6.1 TECHNICAL FACTORS

Technical factors used in this assessment focus on ensuring that nuclear material is not stolen by unauthorized parties or diverted to weapons use by the host state, both during and after treatment. For example, an alternative that involves many complex and difficult-to-measure bulk material processing steps could pose substantial difficulties in providing sufficient security and accounting to ensure and verify that no material is stolen. A disposition alternative that leaves the material in a form from which high-quality weapons material could be recovered relatively easily would do less to promote nonproliferation than alternatives that leave the materials in a form from which recovery is more difficult. Technical factors include the degree to which a particular technology would:

- Help ensure that the weapons-usable nuclear material in the spent nuclear fuel could not be stolen or diverted during the process. This includes an assessment of the attractiveness to diversion of materials in process and the ease of providing institutional and inherent security features.
- Facilitate cost-effective international verification and transparency.
- Result in converting the spent nuclear fuel into a form from which retrieval of the material for weapons use would be difficult and unlikely, thus modestly reducing the total stockpile of readily available material readily usable in nuclear weapons.

1.6.2 POLICY FACTORS

Policy factors used in this assessment focus on the ability of the United States to maintain and strengthen international efforts to stem the spread of nuclear arms, including the overall approach to limit, restrict, and minimize the use of weapons-usable material in the civilian nuclear fuel cycle. For example, implementing an alternative that does not prolong the use of U.S. facilities capable of producing weapons-usable material would help demonstrate our commitment to a cutoff of nuclear materials production and support U.S. efforts to strengthen international political support for tougher measures to prevent the spread of nuclear weapons. A U.S. decision to choose a technology that could separate and recycle HEU (even if not operated in that manner) would offer additional arguments and justifications for advocates of the use of reprocessing and recycling technologies in other countries. Alternatively, by implementing stringent standards of security and accounting in its management of nuclear materials and spent nuclear fuel, the United States might be able to develop and demonstrate improved procedures and technologies for protecting and safeguarding that might be applied in other countries as well. This would reduce proliferation risks. Policy factors include the degree to which a particular technology would:

- Be consistent with U.S. policy related to reprocessing and nonproliferation.
- Avoid encouraging other countries to engage in the reprocessing of spent nuclear fuel, or undermining U.S. efforts to limit the spread of reprocessing technology and activities, particularly to regions of proliferation concern.
- Support U.S. efforts to convert U.S. and foreign research reactors to low enriched fuels, and avoid creating technical, economic, or political obstacles to implementing the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.
- Help demonstrate that any treatment of these spent nuclear fuels will definitely not represent the production by the United States of additional materials for use in nuclear weapons.
- Support negotiation of a nondiscriminatory global fissile material cutoff treaty (FMCT), including allowing for the possibility of verification approaches that would be acceptable to the United States.

Each of the technical and policy factors must be balanced in judging the relative nonproliferation merits of each technology option. Decision-makers must judge for themselves the relative importance of these factors.

1.7 Assessment Plan

The remainder of this assessment analyzes the nonproliferation implications of each of the technology options for management of aluminum-based spent nuclear fuel at the Savannah River Site. **Chapter 2** provides background and context essential to the issue, including a more detailed description of the key technical and policy factors to be considered in assessing each technology's nonproliferation impact. **Chapter 3** then considers each technology, providing an assessment based on the factors just described. **Chapter 4** outlines the conclusions of this assessment, including identifying potential steps that could be taken to mitigate any nonproliferation disadvantages of the technologies.

2.0 BACKGROUND AND CONTEXT

The United States has long led global efforts to prevent the proliferation of nuclear weapons and to safeguard weapons-usable fissile materials – separated plutonium and HEU.[11] Because the knowledge needed to make at least a crude nuclear weapon is now widespread, limited access to these essential ingredients of nuclear weapons is the principal technical barrier to nuclear proliferation in the world today. Hence, the United States has placed heavy emphasis on efforts to help monitor, protect, control, account for, and, ultimately, dispose of nuclear materials worldwide.

Highly Enriched Uranium

To produce a nuclear weapon, either of two nuclear materials must be used: HEU (uranium containing at least 20 percent uranium-235) or plutonium. Therefore, the nonproliferation risks associated with HEU are as much of a concern as those associated with plutonium. The atomic bomb dropped on Hiroshima, Japan, during World War II was made using HEU, as were the nuclear detonations conducted by Pakistan in 1998.

In 1996, DOE declared 174.3 metric tons of HEU as excess to national security needs and issued an *HEU Disposition Plan* that identified appropriate pathways for managing excess HEU.

Because of its pivotal role in preventing the proliferation of nuclear weapons and its own extensive nuclear programs and activities, the manner in which the United States manages its nuclear materials has an influence on other states, both by example and in the way it supports U.S. diplomatic efforts and initiatives. U.S. technical and policy choices frequently influence other countries. Thus, management decisions taken in the United States can positively or negatively affect initiatives to further enhance the global nonproliferation regime and bolster the international norm against the acquisition of nuclear weapons. In recent years, the United States has sought to make its nuclear activities increasingly transparent in order to increase international confidence in its global arms control and nonproliferation regime and to encourage similar actions by other countries.

2.1 Controlling Weapons-Usable Materials

The United States places high priority on efforts to control and reduce stockpiles of surplus plutonium and HEU worldwide. Decisions concerning the management of aluminum-based spent nuclear fuel at the Savannah River Site must carefully consider the context of this larger effort.

During the Cold War, DOE's nuclear material activities focused on the production of nuclear materials for nuclear weapons and naval fuel. At the Savannah River Site, the management of spent nuclear fuel generally consisted of short-term storage followed by reprocessing, in most cases to separate material for use in the production of nuclear weapons. Both during the Cold War and since, the United States has devoted considerable effort to ensuring that this material was secure from theft and accounted for. Substantial resources have been devoted to ensuring adequate security and accounting systems while correcting

[11]Separated plutonium, either weapons-grade or reactor-grade and separated HEU (uranium containing 20 percent or more U-235) can be used to manufacture fission explosives; hence, these materials are referred to throughout this assessment as "weapons-usable" materials.

weaknesses in security and accounting systems that have been identified in the past. U.S. material protection, control, and accounting (MPC&A) programs are now regarded as some of the most stringent in the world.

Spent Fuel Standard

The Spent Fuel Standard was recommended by the National Academy of Sciences in 1994. Meeting the Spent Fuel Standard means making the material approximately as inaccessible and unattractive for weapons use as the much larger and growing stock of plutonium that exists in spent nuclear fuel from commercial nuclear-power reactors. In the January 21, 1997 *Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement* (62 Fed. Reg. 3014), DOE adopted the Spent Fuel Standard specifically for the disposition of weapons-usable fissile materials.

With the end of the Cold War, the United States stopped producing plutonium and HEU and determined that over 225 metric tons of the fissile material currently in its stockpile is surplus material that will never again be used in nuclear weapons. President Clinton has directed that U.S. surplus fissile material be placed under international verification, and eventually be physically transformed in ways that would make it far more difficult, costly, time-consuming, and observable to ever use it in weapons again. The Department of Energy has determined that 174 metric tons of surplus HEU will be blended with other uranium to LEU, which cannot be used to produce nuclear weapons. About 85 percent of the LEU will be used to fuel power reactors, and the remainder disposed of as waste.[12] DOE will also dispose of over 52 metric tons of plutonium in accordance with the dual-track decision announced by DOE Secretary Hazel O'Leary in January 1997. Under this approach, the United States will either immobilize the material with radioactive fission products for ultimate disposition, or will combine the plutonium with uranium to produce mixed-oxide (MOX) fuel for once-through use in existing commercial power reactors.[13] The extent to which either or both of these options will be implemented is being determined through a separate decision-making process.[14] Both approaches should produce final forms posing no more proliferation threat than the much larger quantities of plutonium found in spent nuclear fuel from commercial nuclear power reactors. The final forms resulting from either option should therefore meet the National Academy of Sciences' Spent Fuel Standard (see above "Spent Fuel Standard" text box).

In addition to these domestic efforts, the United States has a wide range of programs in place to improve controls over and ultimately reduce stockpiles of surplus weapons-usable material worldwide. Under President Clinton's September 27, 1993, Nonproliferation and Export Control Policy, a key goal of U.S. efforts to prevent the spread of nuclear weapons worldwide is to "seek to eliminate where possible the accumulation of stockpiles of HEU and plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability" (see Appendix A).

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[12]Record of Decision for the Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement, 61 Fed. Reg. 40619 (1996).

[13]Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement, 62 Fed. Reg. 3014

[14]DOE recently issued the Draft Surplus Plutonium Disposition Environmental Impact Statement for public review and comment. The Draft EIS analyzes options that would use the immobilization approach for some of these surplus plutonium elements.

The United States, for example, has for decades been at the forefront of efforts to strengthen the international nuclear safeguards system administered by the IAEA, and to ensure that nuclear materials worldwide are secure from theft or diversions. Efforts by the United States and other nations have recently led to international agreement on a dramatic new strengthening of the IAEA safeguards system. The agreement takes the form of a Model Protocol for safeguards agreements that will significantly expand the access of the IAEA to necessary information and facilities. Much of the technology basic to the nuclear safeguards system worldwide is U.S. technology. The United States has also played a leading role in the development of international standards for the physical protection of nuclear materials. Additionally, the United States cooperates actively with all countries that receive U.S. nuclear exports to ensure that their nuclear materials and facilities are effectively secured.

Since the end of the Cold War, the United States and the states of the former Soviet Union have launched an unprecedented cooperative program to modernize security and accounting systems for weapons-usable materials throughout the former Soviet Union. Security and accounting for many tons of weapons-usable material have already been dramatically improved by this cooperative effort, thus directly reducing proliferation risks that could pose a dire threat to the security of the United States. If adequate funding and cooperation continue, modern safeguards and security systems should be in place at all of the former Soviet facilities handling weapons-usable materials by the end of 2002.[15]

The United States also seeks to reduce Russian weapons-usable fissile material stockpiles in conjunction with efforts to eliminate its own surplus fissile materials. One particularly significant effort in this area has been the agreement to purchase 500 metric tons of HEU from dismantled Russian nuclear weapons over 20 years. This material is being blended down to proliferation-resistant LEU for use as commercial power-reactor fuel, reducing the risk it will ever again be used in weapons. This process provides a commercial product to the United States, and provides much-needed hard currency to Russia. At the same time, the United States is actively cooperating with Russia and other countries to ensure that Russia's stockpiles of surplus weapons plutonium can be reduced in parallel with the U.S. surplus plutonium stockpile. These historic United States-Russian cooperation programs demonstrate the importance both countries place on reducing stockpiles of weapons-usable material and reducing the risk of diversion to domestic or foreign weapons programs.

In addition to these major efforts related to reducing stockpiles of material from weapons programs, the United States also seeks to limit the stockpiling of weapons-usable separated plutonium in civilian nuclear programs worldwide, and to minimize the civil use of HEU. These efforts are discussed in further detail in the next two sections.

These programs are important complements to U.S. and international policies such as the Nuclear Suppliers Guidelines which call for restraint in the transfer of sensitive facilities, technology (including enrichment and reprocessing technologies), and weapons-usable materials. The United States has also played a leading role in developing international programs to limit clandestine enrichment (Iraq) and reprocessing programs (North Korea).

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[15]See *Partnership for Nuclear Security*, United States Department of Energy, January 1997.

2.2 Reprocessing, Proliferation, and U.S. Policy

Conventional reprocessing and recycling of plutonium creates direct and indirect proliferation risks. The direct proliferation risk results from the separation, processing, and transport of many tons of directly weapons-usable material. The indirect risks result from setting a precedent and supporting a global industry and technical community for reprocessing.

Thus, under President Clinton's September 27, 1993, statement on Nonproliferation and Export Control Policy, "the United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes." Under this policy, the United States will continue its commitments not to interfere with civilian nuclear programs that involve the reprocessing and recycling of plutonium in Western Europe and Japan. In regions of proliferation concern, however, the United States actively opposes plutonium reprocessing and recycling. The United States continues to explore means to limit the stockpiling of plutonium from civil nuclear programs, and seeks to minimize the civil use of HEU. The United States participated in the effort to develop an internationally agreed set of guidelines on the management of civil plutonium. In 1997, the United States reached agreement with China, Belgium, France, Germany, Japan, Russia, Switzerland, and the United Kingdom on International Guidelines for the Management of Civil Plutonium, which *inter alia* provides that each state will take into account the need to avoid contributing to the risks of proliferation and the importance of balancing plutonium supply and demand as soon as practical. The guidelines also contain a commitment to transparency in the management of plutonium. In this respect, the countries concerned have undertaken to publish statements explaining their national strategies for nuclear power and the nuclear fuel cycle, including plans for managing national holdings of plutonium, together with annual figures for their holdings of unirradiated plutonium and their estimates of plutonium contained in spent fuel.

Any reprocessing of aluminum-based spent nuclear fuel, which is the principal focus of this assessment, at the Savannah River Site, would be significantly different from the conventional reprocessing used to recover plutonium from spent power-reactor fuel for reuse. First, the Department would only reprocess the aluminum-based spent nuclear fuel to prepare this material for geologic disposal, not for either nuclear weapons or a nuclear power program based on plutonium recycling. Second, this reprocessing would recover only small amounts of weapons-usable material. Most of the recovered material would be HEU (with the exception of the metallic uranium fuels from fast-neutron reactor programs), which contains only minor quantities of plutonium. The recovered HEU would be blended to non-weapons-usable LEU before it ever left the reprocessing facility. The major exception is the Experimental Breeder Reactor-II, which has approximately 75 kilograms of plutonium. Should the Experimental Breeder Reactor-II be reprocessed, it would be for safety and health reasons and the resulting plutonium would be declared surplus and managed consistently with other surplus plutonium. In toto, about 114 kg of plutonium will be recovered from the 48 tons of aluminum based spent nuclear fuel.

Selected Events Relating to U.S. Nonproliferation Policy and Fissile Materials

1946	Atomic Energy Act of 1946	The United States prohibited international nuclear cooperation until effective international safeguards were established.
1953	Atoms for Peace	President Dwight Eisenhower delivered his "Atoms for Peace" speech before the United Nations. He called for greater international cooperation in the development of atomic energy for peaceful purposes.
1954	Atomic Energy Act of 1954	Allowed international cooperation in nuclear energy.
1964	U.S. Off-Site Fuels Policy	The United States offered to accept, temporarily store, and chemically separate spent nuclear fuel that contained enriched uranium of U.S. origin.
1968	Nonproliferation of Nuclear Weapons Treaty (NPT)	Promoted nuclear weapons disarmament and non-proliferation. Prohibited the transfer of nuclear weapons technology from nuclear to non-nuclear states.
1976	Nuclear Suppliers Group	Key nuclear supplier countries announced parallel export controls and agreed to "exercise restraint" in transfers of enrichment and reprocessing technology.
1977	Glenn-Symington Amendment to Foreign Assistance Act	Stated that the United States will impose economic sanctions on non-nuclear-weapon states importing enrichment or reprocessing technology, if recipient refused to accept comprehensive IAEA safeguards.
1977	Executive Order on Reprocessing	President Carter announced that the United States would stop reprocessing spent power-reactor fuel and discourage reprocessing abroad.
1978	Nuclear Nonproliferation Act	The United States strengthened nuclear export control and improved restrictions on reprocessing of U.S-origin spent fuel.
1978	RERTR Program	The United States began RERTR program to convert U.S. and foreign research reactors from HEU to LEU fuels.
1988	The United States stopped accepting HEU fuels	The United States stopped accepting spent HEU fuels from foreign research reactors.
1992	The United States stopped accepting LEU fuels	The United States stopped accepting spent LEU fuels from foreign research reactors.
1992	Energy Policy Act (EPACT)	The United States authorized the U.S. Enrichment Corporation to negotiate the purchase of all HEU made available by any State of the former Soviet Union.
1993	U.S./Russian HEU Agreement	The United States agreed to purchase Russian HEU.
1993	U.S. Nonproliferation and Export Policy	The United States reaffirmed that it does not encourage the use of civil plutonium and does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes.
1994	U.S. Material, Protection Control and Accounting Program	The United States launched $800 million program to help secure nuclear materials in former Soviet Union
1996	ROD on Foreign Research Reactor (FRR) program	DOE announced a renewed policy to accept foreign research reactor spent nuclear fuel containing uranium enriched in the United States.
1997	ROD on Storage and Disposition of Weapons-Usable Fissile Materials	DOE decided to dispose of a quantity of weapons-usable fissile materials in a final form that meets the Spent Fuel Standard.

The Nonproliferation and Export Control Policy allows for the possibility that reprocessing might be used to deal with a limited number of unique problems; it specifically precludes reprocessing for nuclear weapons or for power generation, but not for safety and health reasons. For example, at the recommendation of the independent Defense Nuclear Facilities Safety Board, DOE determined that it was necessary to restart reprocessing operations at the Savannah River Site in order to stabilize some materials that posed near-term safety and health vulnerabilities.

Nevertheless, a decision to reprocess the aluminum-based spent nuclear fuel at the Savannah River Site could negatively affect the credibility of U.S. policy not to encourage reprocessing. First, as long as the United States continues to operate some reprocessing facilities, reprocessing advocates in other countries will point to this activity and argue that even the United States understands the need for reprocessing in some circumstances. A decision to reprocess this material would extend the time that reprocessing operations must continue at the Savannah River Site. These concerns apply primarily to conventional reprocessing, which is an established technology used in a small number of countries in commercial-scale operations to recover plutonium from spent fuel. However, these concerns also apply to a lesser degree to the electrometallurgical treatment technology option. Like conventional reprocessing, electrometallurgical treatment is recognized primarily as a plutonium separations technology. In the electrometallurgical treatment technology option evaluated in this assessment, no actual plutonium separations or separations capability are planned. However, reprocessing advocates may argue that minor modifications could be made to provide a plutonium separations capability.

In addition, a decision to reprocess these materials would go to the heart of one of the key elements of the current reprocessing debate – the waste management impacts of reprocessing versus a non-separations based technology for managing spent nuclear fuel. Because most of the aluminum-based spent nuclear fuel to be managed at the Savannah River Site does not pose near-term safety and health vulnerabilities, a decision to reprocess this material would be based on a judgment that this was the best available way to prepare it for safe geologic disposal. Advocates of reprocessing and recycling, recognizing that current and projected low prices for uranium mean that there is no current economic benefit from reprocessing to recover uranium, have increasingly emphasized the purported waste management benefits of reprocessing in making their case. Some officials from Korea and Taiwan, for example, have argued that in small countries such as theirs, it would be very difficult to find an acceptable disposal site for spent power-reactor nuclear fuel, but disposal of high-level waste from reprocessing might pose fewer obstacles. In response, the United States, as well as researchers in many countries, has argued that, for spent power-reactor fuel, reprocessing does not provide any net waste-management benefits and that the siting difficulties and environmental risks associated with establishing a geologic repository for reprocessing wastes will not be in any way substantially less than those associated with a repository for directly disposing of spent nuclear fuel without reprocessing. If the United States decides to reprocess this aluminum-based material to prepare it for geologic disposal, when there is no near-term safety or health need to do so, reprocessing advocates will attempt to argue that even the United States is thereby acknowledging the waste management benefits of reprocessing – despite the clear differences between this material and ordinary spent power-reactor fuel.

Thus, such a decision could make more difficult U.S. efforts to convince other nations not to pursue fuel cycles that increase proliferation risks. If this option is nonetheless judged to be the best available approach, when all factors are considered, energetic efforts should be made to mitigate this potential nonproliferation disadvantage.

2.3 Programs to Reduce the Risk of Nuclear Weapons Proliferation from Civil Use of Fissile Material

The Department has initiated two programs to help reduce the risk of nuclear weapons proliferation posed by the civilian use of fissile materials: the Reduced Enrichment for Research and Test Reactors (RERTR) program and the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

The United States launched the RERTR program in 1978 to reduce and eventually eliminate international traffic in HEU by converting all research reactors from HEU fuels to LEU fuels, thereby reducing the potential for proliferation of HEU. Research reactors have traditionally been the main consumers of HEU in international commerce. Conversion of research reactors has dramatically reduced the demand for HEU internationally. The need for the RERTR program became apparent to U.S. policy makers in the mid-1970s, when evidence suggested that increasing overseas stockpiles of research reactor spent nuclear fuel containing HEU, including those under international safeguards, presented a potential proliferation risk. A diversion of HEU provides a potential proliferant with material that can be relatively quickly fabricated into a nuclear weapon and allows less response time for authorities to react. Additionally, technology was advancing to a point where the majority of research reactors, the main consumers of HEU fuel, could be converted from weapons-usable HEU fuel to LEU fuel without a significant degradation in performance. Over the past two decades, this program has proven to be a tremendous, if not widely known, nonproliferation success story. Approximately 30 foreign reactors and 20 domestic reactors have either switched or are in the process of converting to LEU. Moreover, demand for fresh HEU by foreign reactors has dropped dramatically. The United States has not exported any HEU research reactor fuel since 1992.

President Clinton's statement on Nonproliferation and Export Control Policy gave new emphasis to the RERTR program, reaffirming that "the United States will seek to minimize the civil use of highly enriched uranium." Funding for the research reactor conversion effort, including the resumption of advanced LEU fuels development, have furthered the goals of the RERTR program.

Another key fissile material control program is the U.S. program to accept U.S.-origin spent nuclear fuel containing uranium enriched in the United States from foreign research reactors. Beginning in the 1950s, under the Atoms for Peace Program, the United States was the primary exporter of research reactors and fuel. At first, fuel was leased to the research facility and returned to the United States. Beginning in 1964, the United States began selling fuel to foreign operators and buying it back, paying for the HEU which the United States would recover. The fuel was traditionally reprocessed at the Savannah River Site and the uranium recycled as part of defense programs.

The initial U.S. spent nuclear fuel acceptance policy expired in 1988 for HEU containing uranium enriched in the United States, and in 1992 for LEU. In May of 1996, DOE announced the decision to begin a new program to accept spent nuclear fuel containing uranium enriched in the United States from foreign research reactors. The new acceptance policy will result in the transport of up to 20 metric tons of aluminum-based and TRIGA foreign research reactor spent nuclear fuel to the United States and its management at the Savannah River Site and the Idaho National Environmental and Engineering Laboratory. The goals of the new acceptance policy are to promote the following nonproliferation objectives:

- Ensure fuel containing uranium enriched in the United States is never diverted for use in nuclear weapons.
- Discontinue the civil use of HEU by ensuring that HEU enriched in the United States is not recycled in research reactors.
- Provide additional incentives for reactors to convert from the use of HEU fuel to LEU fuel.

2.4 Building Confidence in the U.S. Commitment Not to Produce Materials for Weapons

With the end of the Cold War, the United States has more plutonium and HEU than necessary for its nuclear arsenal and has stopped production of these materials for nuclear explosives. Therefore, when the Department determined that it was necessary to restart reprocessing operations at the Savannah River Site in 1995, the Department required that none of the uranium or Pu-239 recovered as a result would ever be used in weapons. President Clinton has committed to place this material and other surplus fissile material as soon as practicable under IAEA safeguards in the framework of the voluntary safeguards agreements in place with the nuclear-weapon states.

International verification is not currently in place at the Savannah River Site to confirm these commitments, however. Decisions concerning the management of the aluminum-based spent nuclear fuel at the Savannah River Site should take into account which approaches would best meet the commitments or assure the public and the international community that materials from this spent nuclear fuel are not being used in nuclear weapons. As a practical matter, the amount of weapons-usable material in this spent nuclear fuel is far less than 1 percent of the U.S. stockpile of such materials.

2.5 International Verification: Enabling a Nondiscriminatory, Verified Fissile Material Cutoff Treaty

Another key element of U.S. efforts to improve controls over fissile material worldwide is negotiating a verifiable, global, and nondiscriminatory treaty banning the production of fissile materials for weapons – FMCT. Negotiations on such a treaty begin in January 1999 at the Conference on Disarmament (CD) in Geneva.

Such an agreement is intended to be both verifiable and nondiscriminatory – meaning that its provisions would apply equally to all countries that joined the agreement. If reprocessing operations at the Savannah River Site were ongoing when the agreement entered into force, verification arrangements would have to be developed that could be implemented cost-effectively at the Savannah River Site. Such arrangements would have to be sufficiently stringent to satisfy U.S. security requirements if applied in a similar way in other countries to verify that their reprocessing operations were not producing materials for weapons.

While it is relatively straightforward to confirm that a reprocessing facility is not operating, international verification of reprocessing operations at older reprocessing facilities is more difficult. Facilities, such as those at the Savannah River Site, are designed to be flexible, with many interconnected tanks and processing units, making it difficult to confirm that none of them are being used to clandestinely divert material. Since the facilities have been in use for many years, they are intensely radioactive, making it impossible for inspectors to enter the facility to conduct a "design verification" to make sure that there are no hidden pipes for carrying off solutions containing weapons-usable material. Designing a verification regime for such a facility would be difficult and would have to take into account the standards that the United States would apply to foreign facilities.

The problem posed by older reprocessing facilities will probably have to be faced even if the Savannah River Site reprocessing facilities shut down. Russia in particular has an older reprocessing facility (the RT-1 plant at Mayak) not designed for safeguards, which it currently plans to operate for the foreseeable future. This facility was not designed with safeguards in mind and designing a safeguards regime for this facility will be very complex. There may be opportunities to use the Savannah River Site operations for tests of approaches to solving this verification problem. In any case, decisions concerning the management of aluminum-based spent nuclear fuels at Savannah River Site should take into account the degree to which they support or undermine the objective of a verifiable and nondiscriminatory FMCT.

Fissile Material Cutoff Treaty

On August 11, 1998, the 802nd plenary of the Conference on Disarmament (CD) agreed to establish an ad hoc committee to negotiate a ban on the production of fissile materials for weapons. The decision was based on a United Nations resolution entitled "Prohibition of the production of fissile materials for nuclear weapons or other nuclear explosive devices," which was passed in December 1993.

Once approved by the CD's 61-member nations, the Fissile Material Cutoff Treaty (FMCT) will freeze the production of plutonium and HEU for nuclear weapons. FMCT negotiations promise to be long and difficult due to two key issues: (1) how to effectively verify the ban on fissile material for weapons, and (2) how to address existing stockpiles of unsafeguarded plutonium and HEU.

2.6 Accounting Uncertainties in Bulk Processing

Some options for managing aluminum-based spent nuclear fuel at the Savannah River Site involve bulk processing of weapons-usable materials, which inevitably involves uncertainties in nuclear material accounting. When nuclear materials are packaged in discrete items, they can be individually counted. But when they are processed in bulk form such as in powders, solutions, and molten liquids, they must be measured to confirm the quantity of nuclear material present. While measurement technologies have improved significantly in recent years, all measurements introduce some uncertainty. At the Savannah River Site, for example, the accumulated "inventory differences" (differences between the amount of material that measurements indicated was present at one measurement, compared to the amount when the material was previously measured, often after processing) from 1988 to 1995 amounted to a loss of 45 kilograms of plutonium..

In virtually all cases, such differences result from measurement uncertainties, losses to waste, and material that remains held up in various parts of the system, rather than from actual thefts or diversions. Such accounting uncertainties in bulk processing, however, raise the risk that knowledgeable insiders at a facility could steal or divert material without detection, by keeping the thefts or diversions small enough to remain within the known uncertainties of the measurement system. Theft of material from a reprocessing canyon or similarly intensely radioactive facility by an outsider not familiar with the system would be virtually impossible; the only concern would be the possibility of action by an insider familiar with the use of the equipment that provides protection from radiation, and with the uncertainties of the accounting system. To prevent such an eventuality, DOE facilities have extensive systems of material control and physical protection. Nevertheless, risks are inevitably higher when material is bulk-processed than when it remains in static storage or when processing is based on items that can be counted individually. Those management options that avoid bulk processing offer some nonproliferation advantages over those that require bulk processing.

2.7 Proliferation Risks in Pre-Disposal Transport and Storage, and After Disposal

Storage and transport of items containing weapons-usable material, even with no bulk processing, poses some proliferation risk as well. Some of the spent nuclear fuel to be managed at the Savannah River Site contains significant quantities of HEU and plutonium. Having been irradiated as fuel in research reactors, this material is radioactive. As a result, it is far more difficult to steal and process into a nuclear weapon than unirradiated material would be, thereby reducing its inherent proliferation risk. In general, however, the radiation fields from research reactor fuel are much less intense than those from commercial power-reactor spent nuclear fuel, which undergoes more intensive irradiation. Further, because research reactor fuel contains HEU, it contains higher concentrations of fissile materials than does power-reactor fuel, which contains only modest amounts of plutonium. Moreover, over time, the fission products from this HEU fuel will decay (with a half-life of roughly 30 years) and the radioactivity will decrease. Thus, measures will be needed to ensure that this material is not stolen, either in storage or during transport to a disposal site.

Given the large amount of nuclear material they will ultimately contain and the fact that the radiation barriers associated with spent nuclear fuel will significantly diminish in time, it is widely agreed that continued domestic physical security will be required at permanent geologic repositories. HEU research-reactor fuel would be a more attractive target for recovery than most other material disposed of in a geologic repository. However, given the massive sealed containers in which this material will be stored, and the difficulty of gaining access to the site without detection and response, theft, recovery, or diversion of material for weapons purposes from a repository by any sub-national group is likely to be extremely difficult to achieve. For example, an advisory group recommended in 1994 that the International Atomic Energy Agency not terminate safeguards on spent fuel, even after geologic disposal. However, safeguards to effectively deter mining need not be expensive, but could focus on surveillance, including remote monitoring by satellites. The proliferation risk posed by direct disposal/direct co-disposal of such fuel would still appear to be relatively low, particularly if the fuel were placed in a massive container filled with other intensely radioactive materials. This approach would provide a considerable deterrent to any effort to gain access to the material and remove it.

3.0 NONPROLIFERATION ASSESSMENT

This section evaluates the technology options DOE is considering for managing aluminum-based spent nuclear fuel at the Savannah River Site on each of the technical and policy factors described in Section 1.5. The technical factors used in this analysis include ensuring against theft or diversion, facilitating cost-effective international monitoring, and resulting in a difficult-to-retrieve form – reducing weapons-usable stockpiles. The policy factors used in this analysis include maintaining consistency with U.S. nonproliferation policy, avoiding encouraging plutonium reprocessing, supporting conversion of research reactors to LEU fuels, building confidence that the United States is not producing material for weapons, and supporting negotiation of a verifiable and nondiscriminatory FMCT. Figure 3-1 summarizes the findings regarding the nonproliferation impacts of each technology option. The remainder of this chapter details these findings.

Figure 3-1. Technology Options' Ratings Against Criteria

		Direct Disposal/Direct Co-Disposal	Melt and Dilute	Electrometallurgical Treatment	Conventional Reprocessing	Mechanical Dilution	Vitrification Technologies
Technical Factors	Ensuring Against Theft or Diversion	●	◑	◑	◑	●	◑
	Facilitating Cost-Effective International Monitoring	●	◑	◑	○	●	◑
	Difficult-to-Retrieve Final Form, Reduce Weapons-Usable Stockpile	◑	●	●	○*	◑	●
Policy Factors	Consistency with Nonproliferation Policy	●	●	●	◑	●	●
	Avoiding Encouraging Plutonium Reprocessing	●	●	◑	○	●	◑
	Supporting Conversion of Research Reactors to LEU Fuels and Implementation of Spent Nuclear Fuel Acceptance Program	●	●	●	●	●	●
	Building Confidence that the United States is not Producing Materials for Weapons	●	●	◑	◑	●	●
	Supporting Negotiation of FMCT	●	●	◑	◑	●	●

● Fully meets nonproliferation objectives
◑ Could raise nonproliferation concerns
○ Raises nonproliferation concerns

* Under this option, the plutonium would be separated and added to the surplus plutonium stockpile. In this interim form, it would require a higher level of physical security to protect against diversion.

3.1 Direct Disposal/Direct Co-Disposal

This option does not involve a separations technology that produces separated HEU or plutonium as an intermediate or final product. This option is being considered for three of the four spent nuclear fuel groups addressed in this assessment. It is not being considered for the Loose Uranium Oxide in Cans group.

3.1.1 TECHNICAL FACTORS *(Direct Disposal/Direct Co-disposal)*

Ensuring Against Theft or Diversion. In this approach, no bulk processing of nuclear material would be required. Individual spent nuclear fuel elements could be reliably accounted for as individual items, effectively eliminating material accounting uncertainties. Individual elements would have to be reliably protected against theft (particularly as the HEU fuel elements contain directly weapons-usable nuclear material). Protecting these elements from theft during storage at the Savannah River Site and transport to the repository site, however, is not expected to pose special difficulties. Because this option does not involve any separations, no weapons-usable material is created, and the units of accountability do not change.

Description and Nonproliferation Impacts of Technology Features

Technology Feature	Description	Nonproliferation Impact
Bulk Processing	Processing that involves handling nuclear materials in bulk form, such as in chopped pieces, powders, solutions, and molten liquids, rather than handling individual items.	Because bulk material measurement technologies are imperfect, it is difficult to ensure that the quantity of nuclear material present after the bulk processing step is exactly equal to the amount present before the step.
Separations	In the context of aluminum-based spent fuel, separations technologies (*e.g.*, conventional reprocessing and electrometallurgical treatment) extract uranium from spent fuel. The nonuranium actinides would then be left with the fission products.	Separating fissile materials from fission products takes away the self protection provided by the highly-radioactive fission products. Also, separation reduces the number of steps necessary to make the nuclear materials weapons usable, thereby making it more attractive for weapons use.
New System	Systems that are yet to be completely designed and constructed out of new equipment and components may be installed in either new or existing facilities.	New systems are easier to monitor than are old systems because new systems can be designed to facilitate international verification.

Currently, most spent nuclear fuel elements are sufficiently radioactive to meet DOE and international standards for being "self-protecting" – meaning that the radiation from them would be more than 100 rads per hour at one meter in the air, creating considerable difficulties for anyone seeking to remove and process them without authorization. This radiation barrier will decline with time, however, with a half-life of roughly 30 years. As radioactive decay reduces the level of self-protection, increased physical security measures may be required. The amount of fuel that loses this self-protection because of lengthy storage and decay will depend on the length of time before a geologic repository is available.

After transport to the repository site, spent nuclear fuel canisters would be placed in waste packages also holding substantial quantities of intensely radioactive spent nuclear fuel (in the direct disposal concept) or intensely radioactive high-level waste glass (in the co-disposal concept), and emplaced in the repository. After emplacement in these massive containers of radioactive material and burial in the repository, the risk of theft of this material by unauthorized parties would be significantly reduced.

Facilitating Cost-Effective International Monitoring. Since no bulk processing would be involved, international monitoring and safeguarding of this approach, if desired, should be straightforward and low-cost. Individual canisters of spent nuclear fuel could be tagged and sealed, and checked periodically until loaded in disposal containers. International inspectors could confirm the loading of the canisters into the massive disposal containers, and the sealing of those containers.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. In this approach, the HEU spent nuclear fuel would not be blended to LEU, and the uranium would remain isotopically as potentially weapons-usable material. The spent nuclear fuel would, however, also contain fission products, and would meet the National Academy of Sciences' Spent Fuel Standard. Chemical separation would be required to obtain weapons-usable material. Similarly, the plutonium contained in metal fuels from past fast reactor programs (which is present in substantially larger proportions than the one percent typical of commercial light-water reactor spent nuclear fuel) would not be recovered and processed for further disposition. Over time, the spent nuclear fuel would become a more attractive potential source of weapons material as the radioactivity barrier decays. However, as noted above, theft of this material can be discouraged through the application of stringent safeguards and security measures.

3.1.2 POLICY FACTORS *(Direct Disposal/Direct Co-disposal)*

Maintaining Consistency with U.S. Nonproliferation Policy. This approach would be fully consistent with and supportive of U.S. nonproliferation policies relating to reprocessing and the nuclear fuel cycle. Further, direct disposal/direct co-disposal of spent nuclear fuel without mechanical or chemical processing is the preferred approach for handling commercial power reactor spent nuclear fuel.

Avoiding Encouraging Plutonium Reprocessing. Since no reprocessing would be involved, this approach would avoid any possible encouragement of foreign reprocessing activities. Technical work done on disposal issues and standards could be used by other countries to encourage direct disposal/direct co-disposal.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. This approach would fully support DOE policy to accept foreign research reactor spent nuclear fuels, and prepare them for storage in a road-ready condition for eventual geologic disposal.

Building Confidence That the United States is Not Producing Material for Weapons. Since no mechanical or chemical processing of the material would be involved in this approach, it would be clear that the material was not being recovered to support a weapons program. If desired, relatively low-cost international verification could be implemented to assure that no material was recovered for weapons purposes.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. This option should not raise any difficulties or issues for negotiation of an FMCT. Again, technical information developed could be shared with other countries.

3.2 Melt and Dilute

This option does not involve a separations technology that produces separated HEU or plutonium as an intermediate or final product. This option is being considered for all four spent nuclear fuel groups addressed in this assessment.

3.2.1 TECHNICAL FACTORS *(Melt and Dilute)*

Ensuring Against Theft or Diversion. The melt and dilute option involves bulk processing, with the associated accounting uncertainties. Moreover, there is very limited experience safeguarding such molten blending operations. (Modified approaches would have to be developed.) The processing required is quite simple, however, and with the small amount of material involved, assuring against theft or diversion should not present significant problems.

Facilitating Cost-Effective International Monitoring. Because this option would involve bulk processing, international monitoring (comparable to full safeguards) of the process, if desired, would likely be more costly and intrusive than in the direct disposal/direct co-disposal option. Costs would be reduced and effectiveness increased by the fact that the approach would be carried out in a newly-built melt and dilute system, allowing provisions for the application of safeguards to be integrated into the design of the equipment from the outset. Alternatively, measurement of the material before and after the processing could be accomplished for relatively modest cost – but with some sacrifice in effectiveness.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. Under this option, the HEU in the fuel would be diluted and the final form would contain both LEU and fission products. The resulting final form would be self-protecting and meet the Spent Fuel Standard. The uranium and plutonium in the final form would be present in low enrichment levels and concentrations, respectively. As a result, chemical separation of the plutonium or uranium and re-enrichment of the uranium would be required before the materials could be used in weapons.

3.2.2 POLICY FACTORS *(Melt and Dilute)*

Maintaining Consistency with U.S. Nonproliferation Policy. The melt and dilute option is fully consistent with U.S. nonproliferation policy of converting the HEU into LEU.

Avoiding Encouraging Plutonium Reprocessing. Similarly, the melt and dilute option, which does not involve reprocessing, would not be likely to encourage reprocessing in other countries.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. The melt and dilute option should be capable of fully supporting the Foreign Research Reactor Spent Fuel Acceptance Program.

Building Confidence That the United States is Not Producing Material for Weapons. With a modest level of international safeguarding, it should be straightforward to demonstrate to stakeholders and the international community that the simple processing in this approach does not involve recovery of new material for weapons.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. This approach also should not pose any significant difficulties for negotiation of an FMCT because it does not involve any separations of fissile material.

3.3 Electrometallurgical Treatment

This option involves a separations technology that produces separated HEU as an intermediate product. This option is being considered for all four spent nuclear fuel groups addressed in this assessment.

3.3.1 TECHNICAL FACTORS *(Electrometallurgical Treatment)*

Ensuring Against Theft or Diversion. The electrometallurgical treatment option involves both complex bulk processing of the nuclear material and separation of fissile material. As discussed above, this introduces accounting difficulties, obstacles, or problems. While safeguards concepts have been developed for this process, they have not been demonstrated in detail and there is little experience with them to date. Because it involves the separation of uranium from the fission products, it inherently creates nuclear materials that require protecting. Like other concepts, however, the application of highly effective DOE material control and physical protection procedures at the Savannah River Site would reduce the risk of theft to a low level. Moreover, as in the melt and dilute case, the use of a newly-built treatment system would allow effective safeguarding, accounting, and physical security measures to be designed into the process.

Facilitating Cost-Effective International Monitoring. Because electrometallurgical treatment involves complex bulk processing and is an approach with which there is no significant safeguards experience, establishing effective international monitoring for this approach would be more costly and intrusive than in the direct disposal/direct co-disposal option, if there was a desire to apply full IAEA safeguards to the operation. As in the melt and dilute case, however, the ability to design for safeguards from the outset would reduce the potential problems. Moreover, as in that case, simply measuring the material before and after processing would offer a potential alternative.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. The electrometallurgical treatment approach would dilute the HEU to non-weapons-usable LEU. The very small amount of plutonium in these fuels would remain mixed with fission products and be vitrified in high-level waste, thereby meeting the Spent Fuel Standard.

3.3.2 POLICY FACTORS *(Electrometallurgical Treatment)*

Maintaining Consistency with U.S. Nonproliferation Policy. Pursuit of this technology is not inconsistent with U.S. policy on plutonium reprocessing and the use of plutonium.

Avoiding Encouraging Plutonium Reprocessing. This option, which involves a new separations process, would have more potential to encourage reprocessing in other countries than would the direct disposal/direct co-disposal or melt and dilute options. While no actual plutonium separations or separations capability is planned under this option, minor modifications could be made to provide such a capability. As discussed earlier, extending the time when U.S. separations facilities operate and using a separations process to prepare spent nuclear fuel for geologic disposal (when the fuel does not pose near-term safety and health vulnerabilities) could undermine U.S. credibility in expressing concern to other countries about the proliferation problems associated with usual reprocessing in the nuclear fuel cycle. To mitigate this impact, the United States would want to make very clear the substantial differences between disposal requirements for these fuels and requirements for commercial power-reactor spent nuclear fuel.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. This option should be capable of fully supporting the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

Building Confidence That the United States is Not Producing Material for Weapons. Since this approach would involve bulk processing and separation of HEU (which would be immediately blended to LEU), it would have the potential to raise concerns that material was being produced for weapons, unless international monitoring was put in place to confirm that this was not the case.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach would involve separating HEU from fission products, if an FMCT were in place while this technology was being used, it would be necessary to institute acceptable international verification to confirm that materials were not being produced for weapons. Since the electrometallurgical treatment would be done using a newly-built system, the capability to support international verification could be designed in from the outset.

3.4 Conventional Reprocessing

This option involves a separations technology that produces separated HEU as an intermediate product and separated plutonium as a final product. The HEU would be diluted to LEU and the plutonium would be placed in storage and dispositioned with other surplus weapons-usable plutonium at the Savannah River Site. This option is being considered for all four spent nuclear fuel groups addressed in this assessment.

3.4.1 TECHNICAL FACTORS *(Conventional Reprocessing)*

Ensuring Against Theft or Diversion. The conventional reprocessing option would involve bulk processing of weapons-usable separated HEU and plutonium, the bulk processing would involve some of the accounting uncertainties associated with safeguarding reprocessing plants. Like other concepts, however, highly effective DOE material control and physical protection procedures would reduce the risk of theft to a low level. These measures would need to be applied to HEU during processing but could be scaled back once the HEU is diluted to LEU. For the plutonium, these measures would need to be continued until the separated plutonium is ultimately dispositioned with other surplus weapons-usable plutonium managed at Savannah River Site.

Facilitating Cost-Effective International Monitoring. The conventional reprocessing option would involve the greatest difficulties in providing for cost-effective international monitoring. As discussed in Chapter 2, safeguarding older reprocessing facilities that are already contaminated is quite difficult because design verification would be impossible. Simply measuring the material before and after processing would offer a potential alternative. However, this alternative presents a risk in that significant measurement differences may occur due to measurement uncertainty or material holdup in the processing equipment.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. This option raises nonproliferation concerns with respect to this factor because it would result in a net increase in the stockpile of weapons-usable plutonium. This concern is somewhat mitigated by the fact that the plutonium would be considered surplus and would be managed with other surplus weapons-usable plutonium. Limiting the recovery of plutonium to only that spent nuclear fuel posing a safety and health concern would also serve to mitigate this concern. This option would have no effect on the stockpile of surplus weapons-usable HEU because the HEU produced as an intermediate under this option would be diluted to LEU in the final product, and this option would have no effect on the U.S. weapons stockpiles.

3.4.2 POLICY FACTORS *(Conventional Reprocessing)*

Maintaining Consistency with U.S. Nonproliferation Policy. Use of this technology to mitigate safety and health vulnerabilities is not inconsistent with U.S. policy on plutonium reprocessing and the use of plutonium. This option is, however, inconsistent with U.S. policy because it would increase the U.S. stockpile of weapons-usable plutonium.

Avoiding Encouraging Plutonium Reprocessing. This option would have more potential to encourage reprocessing in other countries than any of the other options for two reasons. First, this option involves the production of separated weapons-usable plutonium, which is precisely the type of activity the United States is trying to discourage. Second, the option would extend the time that U.S. reprocessing facilities operate. Both of these factors could undermine U.S. arguments against reprocessing fuel cycles (see Section 2.2). To mitigate this impact, the United States would want to make very clear the substantial differences between reprocessing these aluminum-based fuels for safety and health reasons and reprocessing commercial power-reactor spent nuclear fuel.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. This option, if successful, should be capable of fully supporting the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

Building Confidence That the United States is Not Producing Material for Weapons. Since this approach would involve bulk processing and separation of weapons-usable plutonium, it would have the potential to raise concerns that material was being produced for weapons unless international monitoring was put in place to confirm that this was not the case.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. Since this approach would involve continued operation of large reprocessing facilities, if an FMCT were in place during the time reprocessing occurs, it would be necessary to institute acceptable international verification to confirm that materials were not being produced for weapons. Since the reprocessing would be done using an older reprocessing plant, this could be difficult.

3.5 Mechanical Dilution

This option does not involve a separations technology that produces separated HEU or plutonium as an intermediate or final product. This option is being considered for two of the four spent nuclear fuel groups addressed in this assessment. It is not being considered for the Uranium and Thorium Metal Fuels and Loose Uranium Oxide in Cans groups.

3.5.1 TECHNICAL FACTORS *(Mechanical Dilution)*

Ensuring Against Theft or Diversion. The mechanical dilution option involves limited (using chop and dilute) or no (using press and dilute) bulk processing of the material without changing the physical phase or chemical makeup of the material. Implementing accounting capabilities that effectively ensure against theft or diversion should not present any problems. Physical security of this option (and all other options) should be adequate to ensure against theft or diversion during processing since all processing would occur at a DOE site.

Facilitating Cost-Effective International Monitoring. Because this option would involve little or no bulk processing of the material and would use newly constructed processing equipment, international monitoring of the process, if desired, would likely be no more costly and intrusive than in the direct disposal/direct co-disposal option, if an approach comparable to full safeguards were pursued.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. This option would produce a final form in which the HEU in the fuel is diluted to LEU, but the mixing would occur at a macro level, rather than at a molecular level. Therefore, recovery of HEU from the final form may be possible through physical sorting followed by reprocessing in a manner that does not require re-enrichment of the uranium. Such a final form would pose higher proliferation risks than other final forms resulting from some of the other bulk processing options (melt and dilute and vitrification), but it would meet the Spent Fuel Standard and would pose lower risk than the final forms produced under the direct disposal/direct co-disposal option.

3.5.2 POLICY FACTORS *(Mechanical Dilution)*

Maintaining Consistency with U.S. Nonproliferation Policy. The mechanical dilution option is fully consistent with U.S. nonproliferation policy of converting the HEU into LEU.

Avoiding Encouraging Plutonium Reprocessing. Similarly, the mechanical dilution option, which does not involve reprocessing, would not be likely to encourage reprocessing in other countries.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. The mechanical dilution option should be capable of fully supporting the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

Building Confidence That the United States is Not Producing Material for Weapons. With a modest level of international safeguarding, it should be straightforward to demonstrate to stakeholders and the international community that the simple processing in this approach does not involve production of new material for weapons.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. This approach also should not pose any significant difficulties for negotiation of an FMCT because it does not involve any separations of fissile material.

3.6 Vitrification Technologies

This option does not involve a separations technology that produces separated HEU or plutonium as an intermediate or final product. This option is being considered for all four spent nuclear fuel groups addressed in this assessment.

3.6.1 TECHNICAL FACTORS *(Vitrification Technologies)*

Ensuring Against Theft or Diversion. The vitrification option involves bulk processing of the material, with associated accounting uncertainties. Moreover, there is very limited experience safeguarding such melting and oxidation operations, and modified approaches to doing so would probably have to be developed. The processing requires more steps than the melt and dilute option and would involve more complex material accounting procedures. Physical security at the Savannah River Site during processing should be adequate to ensure against theft and diversion.

Facilitating Cost-Effective International Monitoring. Because this option would involve bulk processing of the material, international monitoring of the process, if desired, would likely be more costly and intrusive than in the direct disposal/direct co-disposal option, if an approach comparable to full safeguards were pursued. Costs would be reduced and effectiveness increased by the fact that the approach would be carried out in a newly-built system, allowing provisions for the application of safeguards to be integrated into the design of the process from the outset. Alternatively, measurement of the material before and after the processing could be accomplished for relatively modest cost – but with some sacrifice in effectiveness.

Resulting in a Difficult-to-Retrieve Final Form – Reducing Weapons-Usable Stockpiles. This option would produce a final form with proliferation characteristics similar to that of the melt and dilute option: the uranium would be at the same low enrichment level (20 percent or less) and the form would contain fission products, making the form self-protecting. The material would meet the Spent Fuel Standard and would pose less proliferation risk than the far larger quantities of LEU in everyday international commerce, which is a more pure form. The uranium and plutonium contained in the material would also be blended to relatively low concentrations in the same process, requiring chemical separation in order for them to be used in weapons.

3.6.2 POLICY FACTORS *(Vitrification Technologies)*

Maintaining Consistency with U.S. Nonproliferation Policy. The vitrification option is fully consistent with U.S. nonproliferation policy of converting the HEU into LEU.

Avoiding Encouraging Plutonium Reprocessing. The vitrification technologies, which do not involve reprocessing or other separation of fissile material, would not be likely to encourage reprocessing in other countries. However, one of the technologies, dissolve and vitrify, begins with a nitric acid dissolution step, which is very similar to that used in reprocessing and it is conceivable that use of this technology encourages development of reprocessing-like technologies.

Supporting Conversion of Research Reactors to Low Enriched Fuels and Implementation of Spent Nuclear Fuel Acceptance Policy. The vitrification option should be capable of fully supporting the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

Building Confidence That the United States is Not Producing Material for Weapons. With a modest level of international safeguarding, it should be straightforward to demonstrate to stakeholders and the international community that these processes do not involve production of new material for weapons.

Supporting Negotiation of a Verifiable and Nondiscriminatory FMCT. This approach also should not pose any significant difficulties for negotiation of an FMCT because it does not involve any separations of fissile material.

4.0 CONCLUSIONS

4.1 Preferred Alternative: Recommendation

The *Savannah River Site, Spent Nuclear Fuel Management, Draft Environmental Impact Statement* proposes several technology options for managing spent nuclear fuel at the Savannah River Site. The two "preferred" options identified by the draft EIS for the 48 MTHM considered within the scope of this report are melt and dilute and, for a small quantity of material, conventional reprocessing. These technologies would treat specific groups of spent nuclear fuel, as outlined below.

Melt and Dilute. This option has been identified as the preferred method for treating most (about 97 percent by volume) of the aluminum-based spent nuclear fuel considered in this report. This fuel includes the Material Test Reactor-Like fuel, most of the Loose Uranium Oxide in Cans fuel, and most of the HEU/LEU Oxides and Silicides fuel. As a back-up to melt and dilute, the direct co-disposal option would be implemented if melt and dilute were no longer feasible or preferred. It is expected that the melt and dilute operation could begin about 2005 and would continue at least through 2035. The draft EIS states that should any safety and health concerns involving aluminum-based spent nuclear fuel arise prior to the availability of melt and dilute operations, the F and H Canyons would be used to stabilize the material of concern.

Conventional Reprocessing. This option has been identified to manage the small volume of aluminum-based spent nuclear fuel (about 3 percent by volume) that presents a potential safety and health vulnerability. It is the preference of the Department of Energy not to utilize conventional reprocessing for reasons other than safety and health. A limited subset of the spent nuclear fuel to be processed may not be compatible with the melt and dilute process for aluminum-based spent nuclear fuel. The benefit of developing a new process to accommodate the small amount of non-standard fuel would be disproportionately small when compared to the cost.

The spent nuclear fuel to be reprocessed includes the Experimental Breeder Reactor-II fuel, the Sodium Reactor Experiment fuel, the Mark-42 targets, and the core filter block from the Uranium and Thorium Metal fuel group; the failed or sectioned Tower Shielding Reactor, High Flux Isotope Reactor, Oak Ridge Reactor, and Heavy Water Components Test Reactor fuels and a Mark-14 target from the HEU/LEU Oxides and Silicides fuel; and the Sterling Forest Oxide from the Loose Uranium in Cans fuel group. Using this technology on this group of materials would like result in the separation of approximately 114 kilograms of plutonium.

The Office of Arms Control and Nonproliferation fully supports the active pursuit of a new treatment technology for the aluminum-based spent nuclear fuel, and views the melt and dilute recommendation as a favorable technology in light of nonproliferation concerns. The case of reprocessing spent nuclear fuel for only explicit safety or health reasons is an extremely important criterion to uphold as an example for other nations. Seen in the context in which about 97 percent (by volume) of the aluminum-based spent nuclear fuel would be treated by melt and dilute, the reprocessing of a small number of spent nuclear fuel items that pose unique safety and health concerns would not unduly damage U.S. nonproliferation efforts. A decision to reprocess a majority of the aluminum-based spent nuclear fuel at the Savannah River Site could negatively affect the credibility of U.S. policy not to encourage reprocessing. Such a decision would also extend the period of time that reprocessing operations must continue at the Savannah River Site - making it more difficult for U.S. efforts to convince other nations not to pursue fuel cycles that increase proliferation risks.

4.2 Nonproliferation Impacts of Technology Options

There are several options for the effective management of the aluminum-based spent nuclear fuel at the Savannah River Site. With respect to nonproliferation:

- All of the options could reliably discourage any theft or diversion of the material, but some are superior to others.

- All of the options could provide for some form of international safeguarding by the International Atomic Energy Agency (IAEA). The options vary in terms of cost and ease of application.

- All of the options would result in forms from which recovery of uranium or plutonium material for use in weapons would be highly unlikely, although the direct disposal/direct co-disposal option would not blend down the residual HEU to LEU, and the conventional reprocessing option would recover plutonium metal that would be managed as surplus.

- All of the options would be consistent with U.S. nonproliferation policy and would allow for verification approaches that would be acceptable to the United States if implemented in other countries.

- The electrometallurgical treatment and the conventional reprocessing options, by appearing to endorse these separations technologies, could conceivably encourage reprocessing in other countries.

- All of the options have the potential to support fully U.S. efforts to reduce the civil use of HEU, including the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

- None of these options would appear to be prejudicial to the ability of the United States to submit to international safeguards or monitoring under an FMCT. However, the reprocessing option involves the use of old facilities at the Savannah River Site not specifically designed to facilitate the application of international safeguards. An effective safeguarding regime would likely be difficult due to cost and safety retrofitting concerns.

- The Office of Arms Control and Nonproliferation fully supports the active pursuit of a new treatment technology for the aluminum-based spent nuclear fuel, and views the melt and dilute recommendation as a favorable technology in light of nonproliferation concerns.

The nonproliferation disadvantages of the reprocessing option apply to reprocessing in the DOE complex generally, not merely to the aluminum-based spent nuclear fuel to be managed at the Savannah River Site. Therefore, the issues raised in this assessment (including the possibility of international monitoring) should be considered carefully in future decisions concerning the continued operation of DOE reprocessing facilities and possible startup of new reprocessing facilities.

Appendix A. NONPROLIFERATION AND EXPORT CONTROL POLICY STATEMENT

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release September 27, 1993

FACT SHEET
NONPROLIFERATION AND EXPORT CONTROL POLICY

The President today established a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction and the missiles that deliver them. He outlined three major principles to guide our nonproliferation and export control policy:

-- Our national security requires us to accord higher priority to nonproliferation, and to make it an integral element of our relations with other countries.

-- To strengthen U.S. economic growth, democratization abroad and international stability, we actively seek expanded trade and technology exchange with nations, including former adversaries, that abide by global nonproliferation norms.

-- We need to build a new consensus — embracing the Executive and Legislative branches, industry and public, and friends abroad — to promote effective nonproliferation efforts and integrate our nonproliferation and economic goals.

The President reaffirmed U.S. support for a strong, effective nonproliferation regime that enjoys broad multilateral support and employs all of the means at our disposal to advance our objectives.

Key elements of the policy follow.

Fissile Material

The U.S. will undertake a comprehensive approach to the growing accumulation of fissile material from dismantled nuclear weapons and within civil nuclear programs. Under this approach, the U.S. will:

-- Seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability.

-- Propose a multilateral convention prohibiting the production of highly-enriched uranium or plutonium for nuclear explosives purposes or outside of international safeguards.

-- Encourage more restrictive regional arrangements to constrain fissile material production in regions of instability and high proliferation risk.

-- Submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency.

-- Pursue the purchase of highly-enriched uranium from the former Soviet Union and other countries and its conversion to peaceful use as reactor fuel.

-- Explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly-enriched uranium.

-- Initiate a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations. Russia and other nations with relevant interests and experience will be invited to participate in this study.

The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. The United States, however, will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan.

Export Controls

To be truly effective, export controls should be applied uniformly by all suppliers. The United States will harmonize domestic and multilateral controls to the greatest extent possible. At the same time, the need to lead the international community or overriding national security or foreign policy interests may justify unilateral export controls in specific cases. We will reviev our unilateral dual-use export controls and policies, and eliminate them unless such controls are essential to national security and foreign policy interests.

We will streamline the implementation of U.S. nonproliferation export controls. Our system must be more responsive and efficient, and not inhibit legitimate exports that play a key role in American economic strength while preventing exports that would make a material contribution to the proliferation of weapons of mass destruction and the missiles that deliver them.

Nuclear Proliferation

The U.S. will make every effort to secure the indefinite extension of the Non-Proliferation Treaty in 1995. We will seek to ensure that the International Atomic Energy Agency has the resources needed to implement its vital safeguards responsibilities, and will work to strengthen the IAEA's ability to detect clandestine nuclear activities.

Missile Proliferation

We will maintain our strong support for the Missile Technology Control Regime. We will promote the principles of the MTCR Guidelines as a global missile nonproliferation norm and seek to use the MTCR as a mechanism for taking joint action to combat missile proliferation. We will support prudent expansion of the MTCR's membership to include additional countries that subscribe to international nonproliferation standards, enforce effective export controls and abandon offensive ballistic missile programs. The United States will also promote regional efforts to reduce the demand for missile capabilities.

The United States will continue to oppose missile programs of proliferation concern, and will exercise particular restraint in missile-related cooperation. We will continue to retain a strong presumption of denial against exports to any country of complete space-launch vehicles or major components.

The United States will maintain its general policy of not supporting the development or acquisition of space-launch vehicles in countries outside the MTCR.

For MTCR member countries, we will not encourage new space-launch vehicle programs, which raise questions on both nonproliferation and economic viability grounds. The United States will, however, consider exports of MTCR-controlled items to MTCR member countries for peaceful space launch programs on a case-by-case basis. We will review whether additional constraints or safeguards could reduce the risk of misuse of space launch technology. We will seek adoption by all MTCR partners of policies as vigilant as our own.

Chemical and Biological Weapons

To help deter violations of the Biological Weapons Convention, we will promote new measures to provide increased transparency of activities and facilities that could have biological weapons applications. We call on all nations — including our own — to ratify the Chemical Weapons Convention quickly so that it may enter into force by January 13, 1995. We will work with others to support the international Organization for the Prohibition of Chemical Weapons created by the Convention.

Regional Nonproliferation Initiatives

Nonproliferation will receive greater priority in our diplomacy, and will be taken into account in our relations with countries around the world. We will make special efforts to address the proliferation threat in regions of tension such as the Korean peninsula, the Middle East and South Asia, including efforts to address the underlying motivations for weapons acquisition and to promote regional confidence-building steps.

In Korea, our goal remains a non-nuclear peninsula. We will make every effort to secure North Korea's full compliance with its nonproliferation commitments and effective implementation of the North-South denuclearization agreement.

In parallel with our efforts to obtain a secure, just, and lasting peace in the Middle East, we will promote dialogue and confidence-building steps to create the basis for a Middle East free of weapons of mass destruction. In the Persian Gulf, we will work with other suppliers to contain Iran's nuclear, missile, and CBW ambitions, while preventing reconstruction of Iraq's activities in these areas. In South Asia, we will encourage India and Pakistan to proceed with multilateral discussions of nonproliferation and security issues, with the goal of capping and eventually rolling back their nuclear and missile capabilities.

In developing our overall approach to Latin America and South Africa, we will take account of the significant nonproliferation progress made in these regions in recent years. We will intensify efforts to ensure that the former Soviet Union, Eastern Europe, and China do not contribute to the spread of weapons of mass destruction and missiles.

Military Planning and Doctrine

We will give proliferation a higher profile in our intelligence collection and analysis and defense planning, and ensure that our own force structure and military planning address the potential threat from weapons of mass destruction and missiles around the world.

Conventional Arms Transfers

We will actively seek greater transparency in the area of conventional arms transfers and promote regional confidence-building measures to encourage restraint on such transfers to regions of instability. The U.S. will undertake a comprehensive review of conventional arms transfer policy, taking into account national security, arms control, trade budgetary and economic competitiveness considerations.

Appendix B. ACRONYMS

DOE	Department of Energy
EBR II	Experimental Breeder Reactor II
EIS	Environmental Impact Statement
FMCT	Fissile Material Cutoff Treaty
HEU	Highly Enriched Uranium
HLW	High Level Radioactive Waste
IAEA	International Atomic Energy Agency
LEU	Low Enriched Uranium
MOX	Uranium-Plutonium Mixed Oxide
MPC&A	Material Protection, Control, and Accounting Programs
MTHM	Metric Tons of Heavy Metal
MTRLF	Material Test Reactor-Like Fuels
NEPA	National Environmental Policy Act
Pu	Plutonium (Pu-239 is the plutonium isotope with an atomic weight of 239)
ROD	Record of Decision
RERTR	Reduced Enrichment for Research and Test Reactors
TRIGA	Training, Research, Isotope, General Atomics
U	Uranium (U-235 is the uranium isotope with an atomic weight of 235)