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OAK RIDGE NATIONAL LABORATORY

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FMDP Reactor Alternative Summary Report Vol. 1—Existing LWR Alternative

Reactor Alternative Team

Fissile Materials Disposition Program

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1. Introduction

Significant quantities of weapons-usable fissile materials [primarily plutonium and highly enriched uranium (HEU)] are becoming surplus to national defense needs in both the United States and Russia. These stocks of fissile materials pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential for environmental, safety, and health (ES&H) consequences if surplus fissile materials are not properly managed.

1.1 Weapons-Usable Plutonium Inventories—A Cold War Legacy

The first and second Strategic Arms Reductions Treaties (START I and START II) call for deep reductions in the strategic nuclear forces of both the United States and the former Soviet Union. In addition, in the aftermath of the Cold War, both the United States and Russia have initiated unilateral steps to increase the pace of strategic disarmament. Under START and subsequent unilateral initiatives, some 10,000 to 20,000 warheads in the United States (and a similar or greater number in the former Soviet Union) could possibly be declared "surplus" to national security needs. Thus, significant quantities of weapons-usable fissile materials have or will become surplus to national defense needs in both the United States and Russia.

1.2 Recent Developments

In September 1993, President Clinton issued the U.S. Nonproliferation and Export Control Policy,[1] which commits the United States to undertake a comprehensive management approach to the growing accumulation of fissile materials from dismantled nuclear weapons. This policy directs that the United States will do the following:

- *Seek to eliminate, where possible, 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.*
- *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 the study.*

Further, in January 1994, President Clinton and Russia's President Yeltsin issued the *Joint Statement Between the United States and Russia on Nonproliferation of Weapons of Mass Destruction and Means of Their Delivery*. In accordance with these policies, the focus of the U.S. nonproliferation efforts is fivefold: to secure nuclear materials in the former Soviet Union; to ensure safe, secure, long-term storage and disposition of surplus fissile materials; to establish transparent and irreversible nuclear reductions; to strengthen the nuclear nonproliferation regime; and to control nuclear exports.

To demonstrate the U.S. commitment to the five objectives articulated in the joint statement, President Clinton announced on March 1, 1995, that 200 metric tons (MT) of U.S. fissile materials (~38.2 MT of which is weapons-grade plutonium) had been declared surplus to U.S. nuclear defense needs.[2] In addition, it is anticipated that several metric tons of reactor-grade material containing weapons-usable plutonium will be declared surplus in the future. Thus, it appears that ~50 MT of weapons-usable plutonium will become surplus to U.S. defense needs. Russia has designated ~50 MT of weapons-usable plutonium and 400 MT of HEU to be surplus to its national defense needs.

1.3 The Danger Posed by Surplus Plutonium Inventories

In its 1994 study, *Management and Disposition of Excess Weapons Plutonium*,[3] the National Academy of Sciences (NAS) stated, *"The existence of this surplus material constitutes a clear and present danger to national and international security."* In many respects, the nuclear threat posed by this material is now more diffuse, harder to manage, and more dangerous than the nuclear tensions of the Cold War era. The international community is concerned about the adequacy of safeguards and security (S&S) of this material, the dangers associated with the potential proliferation of nuclear weapons, and the potential for environmental, safety, and health (ES&H) consequences if surplus fissile materials are not properly managed. In a joint communiqué from the Moscow Nuclear Safety Summit,[4] the leaders of the seven largest industrial countries and the Russian Federation endorsed the need to render surplus plutonium in Russia and the United States as proliferation-resistant as possible.

In June 1994, the Department of Energy (DOE) issued a Notice of Intent to prepare a "Programmatic Environmental Impact Statement (PEIS) for Long-Term Storage and Disposition of Weapons-Usable Fissile Materials" and to issue a Record of Decision (ROD) regarding long-term storage and disposition of weapons-usable fissile materials. The primary goal of disposition is to render weapons-usable fissile materials inaccessible and unattractive for weapons use while protecting human health and the environment. In its 1994 report, the NAS recommended that plutonium disposition strategies endeavor to attain the "Spent Fuel Standard" (SFS). The NAS defined the SFS as follows:

> *We believe that options for the long-term disposition of weapons plutonium should seek to meet a "spent fuel standard"—that is, to make this plutonium roughly as inaccessible for weapons use as the much larger and growing quantity of plutonium that exists in spent fuel from commercial reactors*.[3]

DOE has subsequently revised the SFS definition:

> *...make the plutonium as unattractive and inaccessible for retrieval and weapons use as the residual plutonium in the spent fuel from commercial reactors.*

The enhanced SFS makes explicit the concepts of material attractiveness and potential use in weapons, which were implicit in the NAS definition.

The SFS does not imply that conversion of the plutonium to spent nuclear fuel (SNF) is the *only* way to achieve the SFS, but rather that approaches should effect an equivalent level of proliferation resistance. Thus, achieving the SFS provides increased proliferation resistance by transforming surplus fissile materials into a less accessible form; it leads to decreased reliance on institutional barriers to protect the material from theft or diversion.

"...make the plutonium as unattractive and inaccessible for retrieval and weapons use as the residual plutonium in the spent fuel from commercial reactors."

1.4 DOE's Role in Plutonium Disposition

Following President Clinton's September 1993 nonproliferation policy announcement, an Interagency Working Group (IWG) was established to conduct a comprehensive review of the options for disposition of surplus plutonium from nuclear weapons activities of the United States and the former Soviet Union. The IWG is cochaired by the White House Office of Science and Technology Policy and the National Security Council. In response to the President's nonproliferation policy, Secretary O'Leary created a department-wide project for control and disposition of surplus fissile materials on January 24, 1994. Later that year, this project became the Office of Fissile Materials Disposition (DOE/MD). The DOE has a lead role within the IWG for evaluating technical options and developing analyses of economic, schedule, environmental, and other aspects of potential disposition options.

Figure 1.1 is a simplified illustration of the overall fissile materials disposition decision process. The purpose of the process is to provide an orderly analysis of potential alternatives for plutonium disposition as input to the ROD. The detailed evaluation consists of a thorough assessment of the reasonable alternatives to be presented in the PEIS, along with a parallel, two-step process that includes technical, economic, and nonproliferation analyses. This evaluation will determine preferred alternatives and ultimately support the ROD.

The screening process, the first step in implementing the President's September 1993 Nonproliferation Policy, was completed in March 1995 with the publication of DOE's Summary Report of the Screening Process.[5] That report summarized the results of a study conducted to identify a spectrum of reasonable alternatives for long-term storage and disposition of surplus weapons-usable materials (plutonium, HEU, and ^{233}U). Thirty-five alternatives

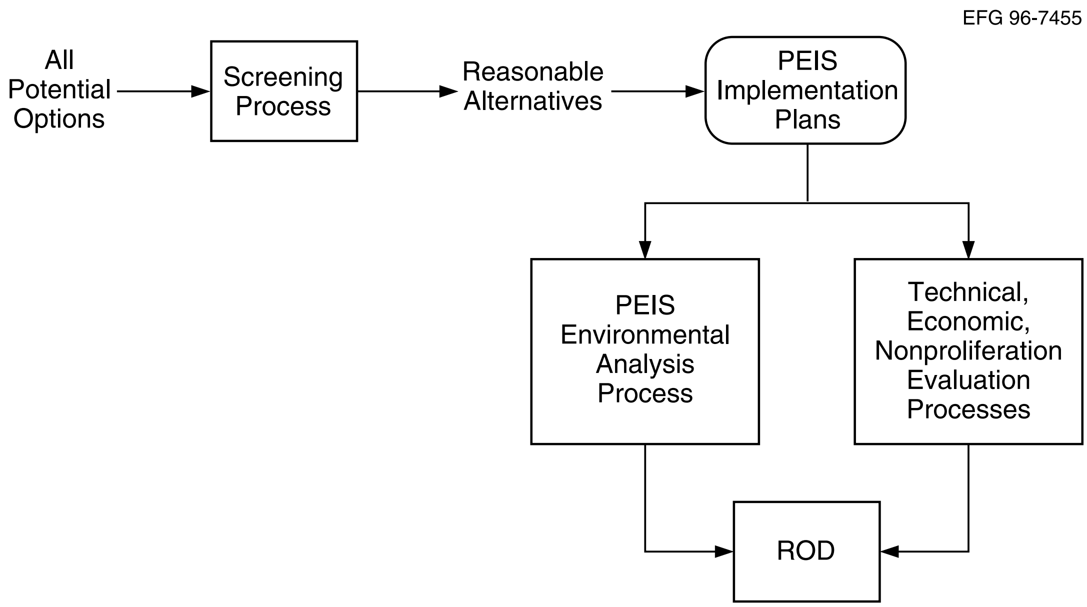

Figure 1.1. Fissile Materials Disposition Program ROD process

for plutonium disposition were considered in the screening analysis. Sixteen of these alternatives involved the use of uranium/plutonium mixed-oxide (MOX) fuel in nuclear reactors to convert the plutonium to a form similar to that contained in commercial spent nuclear reactor fuel.

Five of the reactor-based plutonium disposition alternatives, two borehole alternatives, and four immobilization alternatives were ultimately selected as reasonable plutonium disposition alternatives for further evaluation in the PEIS and detailed technical, economic, and nonproliferation evaluations. The five reactor-based plutonium disposition alternatives are existing light-water reactors (LWRs), [both pressurized water reactors (PWRs) or boiling water reactors (BWRs)]; the Canadian deuterium-uranium (CANDU) heavy-water reactors (HWRs); partially complete LWRs; evolutionary LWRs (ELWRs); and EuroMOX (an alternative in which PuO_2 is transported to Europe, fabricated into MOX fuel in European facilities, irradiated in commercial European reactors, and emplaced in European high level waste (HLW) repositories). The EuroMOX alternative was subsequently dropped from consideration (see Appendix A).

A reactor-based plutonium disposition alternative is defined as the entire sequence of processes and facilities necessary for conversion of stable, stored, weapons-usable plutonium forms into MOX fuel, irradiation of the plutonium bearing MOX fuel in commercial nuclear reactors, and the geologic emplacement of the spent MOX fuel from the reactors (Fig. 1.2). The fabrication and utilization of MOX fuel are well-established, mature commercial technologies. Three commercial MOX fuel fabricators currently exist in Europe, where more than 40 commercial power reactors are licensed to use MOX fuel. Reactor-based disposition of plutonium requires no new or novel technologies or processes and involves no major technical risks. Unlike other plutonium disposition approaches, the reactor-based plutonium disposition alternatives extract and utilize the electric energy generation potential of plutonium by fueling the operation of two or more commercial nuclear power stations.

1.5 Purpose of This Report

Following the screening process, DOE/MD, using its national laboratories, initiated a more detailed analysis of the ten plutonium disposition alternatives that survived the screening process. Three "Alternative Teams" chartered by DOE and comprised of technical experts from across the DOE national laboratory complex conducted these analyses. One team was chartered for each of the major disposition classes (borehole, immobilization, and reactors).

During the last year and a half, the Fissile Materials Disposition Program (FMDP) Reactor Alternative

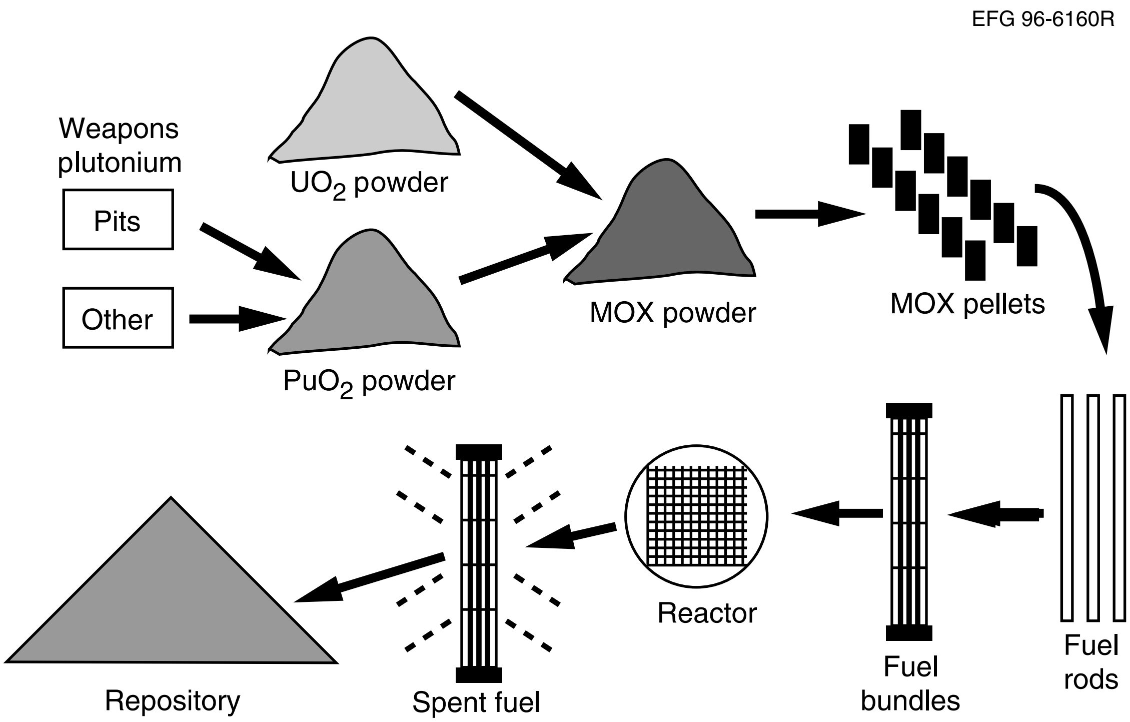

Figure 1.2. Generic reactor alternative

Team (RxAT) has conducted extensive analyses of the cost, schedule, technical maturity, S&S, and other characteristics of reactor-based plutonium disposition. This document (Volume 1 of the four-volume report) summarizes the results of these analyses for the existing LWR plutonium disposition alternative. The results of the RxAT's analyses of the CANDU, partially complete LWR, and evolutionary LWR alternatives are documented in Volumes 2–4 of this report. This multivolume Reactor Alternative Summary Report has been summarized in DOE's recently published FMDP Technical Summary Report (TSR).[6]

Chapter 2 presents the results of all analyses conducted to date for the existing LWR alternative base case. Schedule, cost, S&S, technical viability, transportation, and "other benefits" derived from using this option are discussed for the plutonium processing (PuP) facility, MOX fuel fabrication facility, reactor facility, and repository. Licensing, construction, operations, and decontamination and decommissioning (D&D) are described for each facility.

Chapters 3 through 6 present analyses of variants to the base case LWR alternative. In each chapter, schedule, cost, S&S, technical viability, transportation, and "other benefits" derived from using the option are discussed for the facilities involved. Licensing, construction, operations, and D&D are described for each facility. To minimize repetition, only results that differ from the base case alternative are presented.

Chapter 3 presents an analysis for the existing LWR option in which all facilities are the same as in Chap. 2, except that the MOX fuel fabrication facility is privately owned.

Chapter 4 provides an analysis for an existing LWR option that uses four BWRs and collocated PuP and MOX facilities.

Chapter 5 presents an analysis of the existing LWR option that uses the same plutonium processing and reactor facilities described in Chap. 2, but that starts at an earlier date by initially using PuO_2 from U.S. prototype facilities to feed MOX fuel fabrication facilities in Europe. This variant subsequently shifts to MOX fuel fabricated in the United States.

Chapter 6 presents an analysis of a hybrid option in which 32.5 MT of “clean” surplus weapons-grade plutonium is used as a feed for MOX fuel fabrication and irradiation in an LWR reactor, with the remaining surplus plutonium disposed of by other means (vitrification or deep borehole technology).

Chapter 7 provides a summary discussion of the entire existing LWR alternative. Schedule, cost, S&S, technical viability, transportation, and “other benefits” derived from using this reactor disposition alternative are presented.

Appendixes are provided at the end of the volume to provide additional background and supporting information on the existing LWR alternative.

Appendix A provides summary descriptions for all the reactor alternatives and variants. Appendix B presents the approach to developing the schedule information. Appendix C presents the approach to developing the cost information. Appendix D presents the approach for developing the S&S information. Appendix E presents the quantitative technical viability assessment. Appendix F provides a description of the feed materials. Appendix G provides transportation and packaging information. Appendix H describes the differences between the costs and schedules in the TSR[6] and the costs and schedules in Chapters 2–7 of this report. (The only significant difference is the inclusion of business-negotiable cost items in this report, which is simply the incentive fee to be paid to the utility for use of their reactors.) A glossary is provided in Appendix I.

1.6 References

1. Presidential Decision Directive-13, “U.S. Nonproliferation and Export Control Policy,” September 27, 1993.
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