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Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives

January 1997

Note to Reader: The Vitrification Alternatives set forth for disposition are in some respects listed as variants rather than separate alternatives in the Storage and Disposition of Weapons-Usable Fissile Materials Draft Programmatic Environmental Impact Statement (MD-DPEIS). Specifically, the adjunct melter and Can-in-Canister options are listed as variants rather than alternatives. In addition, the DPEIS notes that disposition alternatives may be combined but does not specify those potential hybrids.

For storage alternatives, the MD-DPEIS assesses all materials in the Department of Energy's stockpile including strategic reserves; the MD-DPEIS also includes sub-alternatives which exclude strategic reserve storage. The Draft Programmatic Environmental Impact Statement for Stockpile Stewardship and Management (DOE/EIS-0236, February 1996) assesses three sites (the Oak Ridge Reservation, Pantex and the Nevada Test Site) potentially involved in the storage of strategic reserve materials. The alternatives reviewed in this assessment focus on the alternatives in the MD-DPEIS.

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The United States Department of Energy

Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives

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Executive Summary

With the end of the Cold War, the United States and Russia are dismantling thousands of nuclear weapons. Hundreds of tons of weapons-usable fissile materials -- plutonium and highly-enriched uranium (HEU) -- are excess to military needs. Approximately 175 tons of U.S. HEU and 50 tons of U.S. plutonium is currently considered excess, including 38.2 tons of weapon-grade plutonium.

The question of what will happen to these vast stockpiles of excess fissile material -- enough for tens of thousands of nuclear bombs -- is central to the future of nuclear arms reduction and nonproliferation. Secure storage and disposition of these materials could help lock in nuclear arms reductions now underway, thus building international confidence and providing a basis for future reductions. Ensuring that these materials do not fall into the hands of rogue states or terrorist groups is also a paramount concern. As President Clinton has said, "Reducing the size of nuclear stockpiles and enhancing the security of nuclear materials is of vital importance to our national security."

In the United States, a major initiative is underway to provide for the safe storage and disposition of fissile materials. A broad range of studies and analyses have been undertaken, designed to provide the information necessary for a national decision on storage and disposition options by the end of 1996. A screening process was completed in March 1995 which identified the reasonable alternatives for further consideration. Three categories of information concerning these reasonable alternatives are being prepared to support the Record of Decision, including assessments of: environment, safety, and health impacts; cost, schedule, and technical maturity; and nonproliferation and arms reduction impacts, the subject of this report.

This report has been prepared by the Department of Energy's Office of Arms Control and Nonproliferation (DOE-NN) with support from the Office of Fissile Materials Disposition (DOE-MD). Its purpose is to analyze the nonproliferation and arms reduction implications of the alternatives for storage of plutonium and HEU, and disposition of excess plutonium, to aid policymakers and the public in making final decisions. While this assessment describes the benefits and risks associated with each option, it does not attempt to rank order the options or choose which ones are "best." It does, however, identify steps which could maximize the benefits and mitigate any vulnerabilities of the various alternatives under consideration. The report has been reviewed by an independent Task Force of the Secretary of Energy's Advisory Board (SEAB); a letter from the Task Force is attached as Appendix B. The report has also been reviewed by the relevant agencies of the U.S. government, prior to being released for public comment.

Scope of This Report

This report addresses the alternatives for:

- storage of U.S. weapons-usable fissile materials (both plutonium and HEU) in DOE's inventory, including excess material and material required for national defense; and
- disposition of U.S. excess plutonium.

Storage of both excess and reserve materials will be required at least until disposition of the excess material is complete, which is likely to take decades. Disposition of excess HEU is not addressed in this report, as the Department has already issued a Record of Decision on disposition of excess HEU.

Alternatives Under Consideration

Storage of Weapons-Usable Fissile Material. Four options for storage of weapons- usable fissile materials are under consideration, and are addressed in this report:

- No action—leaving most plutonium and highly enriched uranium stored where it is currently located, with only minimal upgrades to existing facilities as required by regulations;
- Upgrade In Place—partial consolidation, while leaving most plutonium stored where it is currently located, but with substantial upgrades to existing facilities, or construction of new ones to meet updated DOE standards;
- Consolidation—building a single modern storage facility for plutonium in the DOE inventory, except for working stocks at operational sites; or
- Co-location—storing both DOE's plutonium and HEU stockpiles in a single consolidated facility.

On December 9, Secretary of Energy Hazel O'Leary announced the Department's preferred alternative for storage, which includes consolidation of storage at existing facilities, and reducing the number of facilities where material is stored from seven to five sites.

Disposition of Excess Plutonium. Three broad classes of plutonium disposition alternatives are being considered:

- No-Action - Indefinite storage.
- Reactors—Use of plutonium as fuel for light-water reactors (LWRs) or Canadian Deuterium-Uranium (CANDU) reactors;
- Immobilization—Mixing the plutonium into large, stable glass or ceramic waste forms, which would also contain intensely radioactive fission products;
- Deep Boreholes—Burial of plutonium in 2-4 kilometer deep boreholes.

DISCLAIMER

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On December 9, Secretary of Energy Hazel O'Leary announced the Department's preferred alternative for disposition of excess plutonium. The preferred alternative involved pursuit of both reactor-based and immobilization-based disposition alternatives; the so-called Hybrid option.

Plutonium Disposition Background and Objectives

Plutonium and HEU are the essential ingredients of nuclear weapons. Several kilograms of plutonium, or several times the amount of HEU, is enough to make a nuclear bomb. With access to sufficient quantities of these materials, most nations and even some subnational groups would be technically capable of producing a nuclear weapon; therefore controls on access to these materials are the primary technical barrier to nuclear proliferation in the world today. Yet since the collapse of the Soviet Union, there have been several confirmed cases of theft of weapons-usable nuclear materials, leading the Director of Central Intelligence (DCI) to warn that these materials are more available than ever before in history. The United States and Russia each have hundreds of tons of excess material.

Given this situation, U.S. objectives relating to the storage and disposition of excess fissile materials were summarized by the U.S. National Academy of Sciences (NAS) Committee on International Security and Arms Control in its 1994 report, *Management and Disposition of Excess Weapons Plutonium*:

> "The primary goal in choosing options for management and disposition of excess nuclear weapons and fissile materials should be to minimize the risks to national and international security posed by the existence of this material. This security goal can be divided into three main objectives:
>
> 1) to minimize the risk that weapons or fissile materials could be obtained by unauthorized parties;
>
> 2) to minimize the risk that weapons or fissile materials could be reintroduced into the arsenals from which they came, halting or reversing the arms reduction process; and
>
> 3) to strengthen the national and international control mechanisms and incentives designed to ensure continued arms reductions and prevent the spread of nuclear weapons."

The NAS committee's report identified the continued existence of vast quantities of excess weapons-usable fissile materials as a "clear and present danger to national and international security," and recommended that these stockpiles be reduced as quickly as practicable. The U.S. government and the broader international community agree on the need for action: at the Moscow Nuclear Safety and Security Summit in April 1996, for example, the leaders of the

Group of Seven industrialized democracies (including the United States) and Russia focused attention on the problems posed by stockpiles of excess fissile materials, and agreed that these stockpiles should be reduced as quickly as practicable, under effective nonproliferation controls.

The NAS committee recommended that the objective of disposition be to meet the "Spent Fuel Standard" -- that is, to transform the excess weapons plutonium so that it would be roughly as inaccessible and unattractive for weapons use as the much larger quantity of plutonium that exists in spent fuel from commercial nuclear power reactors. Each of the three classes of disposition alternatives could potentially meet the Spent Fuel Standard. Because gaining access to weapons-usable nuclear material is the most difficult part of acquiring nuclear weapons, the NAS committee also recommended that until excess plutonium is transformed into forms meeting the Spent Fuel Standard, it should, to the extent practicable, be protected and accounted for as effectively as intact nuclear weapons themselves are -- a goal it called the Stored Weapons Standard. The Department of Energy's materials disposition program has adopted both of these recommended standards.

Disposition of excess plutonium poses more complex challenges than disposition of excess HEU. HEU can be blended with non-chain reacting U-238 to produce low-enriched uranium (LEU), which is a valuable commercial fuel for nuclear power reactors and cannot be used to make nuclear weapons without complex and technologically demanding re-enrichment. The United States has agreed to purchase LEU blended from 500 tons of Russian excess HEU over the next 20 years, for sale on the commercial market, and has announced similar plans to blend down its own excess HEU. It is assumed that excess and non-excess HEU will have been relocated to the Oak Ridge Reservation prior to any action taken under the PEIS. All of the actions taken with respect to HEU will be accomplished according to strict DOE security and safeguard procedures.

Since nearly all isotopes of plutonium can be used in nuclear weapons, weapons plutonium cannot simply be blended with other plutonium to make it unusable in nuclear weapons. Separating plutonium from other elements with which it might be mixed or from irradiated reactor fuel containing plutonium requires only well-understood chemical processing techniques which are within the capability of many states and even sub-national groups. Moreover, plutonium's toxicity and the need for stringent security and safeguards during handling makes it more expensive to fabricate reactor fuel from plutonium than to buy uranium fuel on the commercial market, even if the plutonium itself is "free" (i.e., having come from excess weapons stockpiles). Hence, disposition of plutonium will cost the government hundreds of millions or even billions of dollars, whether it is used as reactor fuel or disposed of as waste.

The United States does not encourage the civilian use of plutonium, and does not itself engage in reprocessing for the purposes of either nuclear explosives or nuclear power generation. Disposition of excess plutonium, regardless of the specific option chosen, will not change this basic fuel cycle policy. Any option chosen for plutonium disposition will be used only for the specific mission of addressing the security risks posed by the stockpiles of excess plutonium that already exist in the DOE inventory. No reprocessing or recycling of this material or of other civilian spent fuel is implied or contemplated. The licenses and approvals that will be sought for the facilities necessary for plutonium disposition will be limited specifically to that mission, and will not authorize any broader civilian plutonium use.

Factors for Analysis

This assessment of the nonproliferation and arms reduction implications of the storage and disposition alternatives under consideration is based on technical and policy factors.

Technical factors include:

- how rapidly the option could be implemented (both time to start and time to finish), which determines how soon the benefits of plutonium disposition could be achieved. Time to start is particularly important in gaining domestic and international credibility and confidence in the disposition process;
- the degree to which the option could ensure that plutonium could not be stolen or diverted during the process by a host or sub-national group, coming as close as possible to the degree of protection afforded for intact nuclear weapons;
- the degree to which the option would permit international monitoring, to confirm U.S. commitments that excess fissile material will never again be used in weapons; and
- the degree to which the option would result in a form that is as unattractive and inaccessible for the host government or a sub-national group for use in weapons as plutonium in spent power reactor fuel, meeting the Spent Fuel Standard.

Policy factors include:

- the impact on Russian programs for disposing of surplus plutonium, which is a major motivation for U.S. action;
- the effect on nuclear arms reduction efforts, including the extent to which U.S. decisions ensure the irreversibility of the arms reduction process;
- the impact on nonproliferation efforts, such as demonstrating the U.S. commitment to its obligations to nuclear arms reduction under the Treaty on the Nonproliferation of Nuclear Weapons (NPT);
- the impact on fuel cycle policy and choices by other nations, since the United States does not encourage civilian use of plutonium but seeks to eliminate excess stockpiles of HEU and plutonium ; and

- the political implementability of each alternative, since selecting an option with low chances for achieving success in a timely manner will affect all of the other policy factors.

Each of these technical and policy factors must be balanced in judging the relative nonproliferation and arms reduction merits of each disposition alternative. Policy-makers must judge for themselves the relative importance of these differing criteria.

Descriptions of the Plutonium Disposition Options

Initial Processing. Excess plutonium in the DOE inventory includes a variety of forms, almost all of which will require some processing to prepare them for disposition. Plutonium weapons components, or "pits," will be disassembled and, for some disposition alternatives, disassembled and converted to oxide using an integrated process known as the Advanced Recovery and Integrated Extraction System (ARIES). Other forms may go through acid dissolution and precipitation steps for purification. These initial steps are some of the most proliferation-sensitive stages of the disposition process, since they involve large-scale handling of plutonium in forms that would be very attractive to a potential proliferator -- and at the beginning of the process, the pits contain sensitive weapons design information as well. Since the reactor options require pure oxide for fuel fabrication, they require somewhat more initial processing of impure forms of excess plutonium. The United States does not currently have an operational industrial-scale facility for this initial processing, so facilities would have to be modified or new facilities built.

LWRs. In the LWR option, the excess plutonium would be used as fuel for nuclear power reactors. The use of reactor-grade plutonium fuel in LWRs is already under way on a substantial scale in Europe, and the technology is fully demonstrated. Plutonium oxide produced in the initial processing would be mixed with uranium oxide to form a mixed oxide, or MOX. This MOX powder would be pressed into pellets, which would be sintered, ground, and assembled into rods, which would be loaded into fuel assemblies. The fuel assemblies would be transported to reactors and used as fuel. This MOX fuel could be used in existing reactors or partially-completed reactors, or, for a higher initial capital cost, new reactors could be built. A few reactors could transform 50 tons of excess weapons plutonium into spent fuel in 15-20 years of operation. Only a fraction of the plutonium would be consumed, but the remainder would be embedded in massive, intensely radioactive spent fuel assemblies, posing a significant barrier to its re-use in nuclear weapons. The spent fuel would be similar in most respects to the spent fuel these reactors produce in any case, and could be stored safely and securely for a substantial period pending the availability of a geologic repository. Like the initial processing, MOX fuel fabrication would be a particularly proliferation-sensitive step, as it involves complex and large-scale processing of bulk plutonium powders. The United States does not currently have operational industrial-scale MOX fabrication facilities, so existing facilities would have to be modified or new facilities built. Using existing, operational MOX fabrication facilities in Europe for initial MOX fabrication while U.S. MOX capabilities are being brought on-line could allow an early start on this option, but would involve intercontinental transport of plutonium and transfer of security responsibilities to another country.

CANDUs. The CANDU option is similar to the LWR option, except that Canadian heavy-water reactors rather than U.S. light-water reactors would be used. As in the LWR case, the initial plutonium processing and MOX fabrication would be done in the United States. Existing CANDU reactors are believed to be capable of handling MOX fuel in 100 percent of their reactor cores, although this is not yet demonstrated. CANDU reactors use small, portable fuel bundles, and fuel bundles can be removed without shutting down the reactor; thus, CANDU reactors require more intensive safeguards and security arrangements than LWRs. The small spent fuel bundles would be mounted together in large trays, to produce items of similar size, mass, and radioactivity to LWR spent fuel assemblies. For the CANDU option, substantial international transport of plutonium would be required, particularly if a parallel approach was pursued in which Russian excess weapons plutonium was also burned in CANDU reactors.

Homogeneous Vitrification. In this option, the plutonium would be mixed with glass powder and intensely radioactive fission products, and fed into a glass melter. The molten, intensely radioactive plutonium-bearing glass would be poured into two-ton containers and allowed to harden. Like spent fuel, the resulting glass logs could be stored safely and securely for decades, pending the availability of a geologic repository. Unlike the LWR MOX option, this approach has not been demonstrated on a large scale, and therefore faces a larger number of technical uncertainties. It may face fewer political uncertainties, however, as it does not involve the use of plutonium in commercial reactors. The immobilization process, like MOX fabrication, would be a particularly proliferation-sensitive step, involving large-scale bulk handling of plutonium. Existing melters for high-level radioactive waste are not appropriately designed for handling plutonium. Either a new facility could be built on a "green field," or an additional "adjunct" melter could be added in the building housing the large high-level waste vitrification plant at an existing facilities, such the Savannah River Site Defense waste Processing facility (DWPF). This approach would also meet the Spent Fuel Standard. Though the plutonium would remain weapon-grade, both weapon-grade and reactor-grade plutonium can be used for nuclear explosives.

Homogeneous Ceramic Immobilization. The ceramic immobilization option is similar to the homogeneous vitrification option, except that the immobilized form would be produced by pressing and heating the plutonium with other material to form a mineral-like ceramic. While there is much less industrial experience with immobilization of nuclear wastes in such ceramic forms than there is with vitrification, the ceramic forms are expected to have good long-term performance in a geologic repository, as they are designed to be similar to natural minerals that have been stable for millions of years. A new facility would need to be built for this option.

Can-in-Canister Immobilization. In the can-in-canister approach, the plutonium would be immobilized in small cans of glass or ceramic without the addition of radioactive wastes. These cans would be arrayed inside one of the large canisters currently being used for high-level-waste glass, and the canister would then be filled with intensely radioactive waste glass. Thus, the radiation field outside the canister would be similar to that in the homogeneous immobilization cases, but the radioactive fission products would not be mixed directly with the plutonium itself. While some concerns about the current design have come to light, a new design is now being developed, intended to ensure that it would be very difficult to remove the plutonium cans from the larger canisters. This option could rely on existing glove-box facilities for immobilizing the plutonium, and the existing vitrification operation at Savannah River or other existing facility for filling the canisters with wastes. Because of this potential reliance on existing facilities, this option could potentially start more rapidly than the homogeneous immobilization approaches.

Electrometallurgical Treatment. In this immobilization concept, plutonium metal and oxides would be converted to chlorides through dissolution in a molten salt solution. The resulting plutonium salts and intensely radioactive fission products would then be absorbed on mineral materials known as zeolites, which would be mixed with glass powder and then pressed and heated (as in the ceramic case) to produce a mineral-like form known as a glass-bonded zeolite. Canisters filled with this immobilized form would be stored for an interim period and then shipped to a geologic repository. As in the other options, the initial processing of the plutonium and production of the immobilized form would be proliferation-sensitive steps involving large-scale bulk handling of the plutonium. This approach would also meet the Spent Fuel Standard. This process is less well developed than the other immobilization options; several of the steps have not yet been demonstrated at substantial scale with the materials required for this mission. This process could rely on existing facilities at Argonne National Laboratory-West in Idaho, or this process could potentially be performed at other sites.

Deep Borehole Direct Emplacement. Burial in deep (2-4 kilometer) boreholes is another alternative for disposition of excess weapons plutonium. The depth of the holes would make it difficult for the plutonium to reach the accessible environment or for anyone to retrieve it without the authorization of the host state. Thus the *location* of the material, rather than its physical transformation, would prevent its reuse in weapons. The state where the borehole was located could recover the material; the technology for deep drilling to connect with a specific location is long demonstrated in the mining and oil industries. In the direct emplacement option, the various forms of excess plutonium would be converted to oxide and loaded into measured, tagged, and sealed cans (each containing approximately 4.5 kilograms of plutonium), which would be shipped to the borehole, loaded into canister, and lowered into the hole. Less bulk processing of the plutonium would be required than in any of the other options. After the canisters had been emplaced, the hole would be filled and sealed.

Deep Borehole Immobilized Emplacement. In the immobilized emplacement option, the plutonium would be immobilized in ceramic pellets before being placed in the borehole. The process of producing these pellets would be very similar to the process of producing sintered MOX fuel pellets, though no similar quality standards would have to be met. To ensure long-term protection against a possible accidental chain reaction, in the current concept the ceramic pellets would contain only 1 percent plutonium by weight; moreover, at the borehole site, they would be mixed with an equal number of pellets containing no plutonium at all (reducing the average loading to 0.5% plutonium), and all the pellets would be mixed into a clay grout. This grout-pellet mixture would be put directly down the borehole, without any cans or containers. The borehole would then be filled and sealed.

Conclusions

Storage

Each of the options under consideration for storage of U.S. weapons-usable fissile materials has the potential to support U.S. nonproliferation and arms reduction goals, if implemented appropriately.

Each of the storage options could provide high levels of security to prevent theft of nuclear materials, and could provide access to excess materials for international monitors.

Making excess plutonium and HEU available for bilateral U.S.-Russian monitoring and IAEA safeguards, while protecting proliferation-sensitive information, would help demonstrate the U.S. commitment never to return this material to nuclear weapons, providing substantial arms reduction and nonproliferation benefits in the near term.

Disposition of U.S. Excess Plutonium

The nonproliferation and arms reduction advantages and disadvantages of the plutonium disposition options under consideration are summarized in Figure ES-1. Key conclusions from the analysis in this report include:

Each of the options for disposition of excess weapons plutonium that meets the Spent Fuel Standard would, if implemented appropriately, offer major nonproliferation and arms reduction benefits compared to leaving the material in storage in directly weapons-usable form. Taking into account the likely impact on Russian disposition activities, the no-action alternative appears to be by far the least desirable of the plutonium disposition options from a nonproliferation and arms reduction perspective.

Carrying out disposition of excess U.S. weapons plutonium, using options that ensured effective nonproliferation controls and resulted in forms meeting the Spent Fuel Standard, would:

-- reduce the likelihood that current arms reductions would be reversed, by significantly increasing the difficulty, cost, and observability of returning this plutonium to weapons;

-- increase international confidence in the arms reduction process, strengthening political support for the nonproliferation regime and providing a base for additional arms reductions, if desired;

-- reduce long-term proliferation risks posed by this material by further helping to ensure that weapons-usable material does not fall into the hands of rogue states or terrorist groups; and

-- lay the essential foundation for parallel disposition of excess Russian plutonium, reducing the risks that Russia might threaten U.S. security by rebuilding its Cold War nuclear weapons arsenal, or that this material might be stolen for use by potential proliferators.

Choosing the "no-action alternative" of leaving U.S. excess plutonium in storage in weapons-usable form indefinitely, rather than carrying out disposition:

-- would represent a clear reversal of the U.S. position seeking to reduce excess stockpiles of weapons-usable materials worldwide;

-- would make it impossible to achieve disposition of Russian excess plutonium;

-- could undermine international political support for nonproliferation efforts by leaving open the question of whether the United States was maintaining an option for rapid reversal of current arms reductions; and

-- could undermine progress in nuclear arms reductions.

The benefits of placing U.S. excess plutonium under international monitoring and then transforming it into forms that met the Spent Fuel Standard would be greatly increased, and the risks of these steps significantly decreased, if Russia took comparable steps with its own excess plutonium on a parallel track. The two countries need not use the same plutonium disposition technologies, however.

As the 1994 NAS committee report concluded, options for disposition of U.S. excess weapons plutonium will provide maximum nonproliferation and arms control benefits if they:

-- minimize the time during which the excess plutonium is stored in forms readily usable for nuclear weapons;

-- preserve material safeguards and security during the disposition process, seeking to maintain to the extent possible the same high standards of security and accounting applied to stored nuclear weapons (the Stored Weapons Standard);

-- result in a form from which the plutonium would be as inaccessible and unattractive for weapons use as the larger and growing quantity of plutonium in commercial spent fuel (the Spent Fuel Standard).

In particular, in order to achieve the benefits of plutonium disposition as rapidly as possible, and to minimize the risks and negative signals resulting from leaving the excess plutonium in storage, it is important for disposition options to begin, and to complete the mission, as soon as practicable, taking into account nonproliferation, environment, safety, and health, and economic constraints. Timing should be a key criterion in judging disposition options. Beginning the disposition quickly is particularly important to establishing the credibility of the process, domestically and internationally.

Each of the options under consideration for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others.

Each of the options under consideration for plutonium disposition can potentially provide high levels of security and safeguards for nuclear materials during the disposition process, mitigating the risk of theft of nuclear materials.

Each of the options under consideration for plutonium disposition can potentially provide for effective international monitoring of the disposition process.

Plutonium disposition can only reduce, not eliminate, the security risks posed by the existence of excess plutonium, and will involve some risks of its own:

-- Because all plutonium disposition options would take decades to implement, disposition is not a near-term solution to the problem of nuclear theft and smuggling. While disposition will make a long-term contribution, the near-term problem must be addressed through programs to improve security and safeguarding for nuclear materials, and to ensure adequate police, customs, and intelligence capabilities to interdict nuclear smuggling.

All plutonium disposition options under consideration would involve processing and transport of plutonium, which will involve more risk of theft in the short term than if the material had remained in heavily guarded storage, in return for the long-term benefit of converting the material to more proliferation-resistant forms.

Both the United States and Russia will still retain substantial stockpiles of nuclear weapons and weapons-usable fissile materials even after disposition of the fissile materials currently considered excess is complete. These weapons and materials will continue to pose a security challenge regardless of what is done with excess plutonium.

None of the disposition options under consideration would make it impossible to recover the plutonium for use in nuclear weapons, or make it impossible to use other plutonium to rebuild a nuclear arsenal. Therefore, disposition will only reduce, not eliminate, the risk of reversal of current nuclear arms reductions.

A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries. This could increase the proliferation risk if it in fact led to significant additional separation and handling of plutonium. On the other hand, if appropriately implemented, plutonium disposition might also offer an opportunity to develop improved procedures and technologies for protecting and safeguarding plutonium, which could reduce proliferation risks and would strengthen U.S. efforts to reduce the stockpiles of separated plutonium in other countries.

Large-scale bulk processing of plutonium, including processes to convert plutonium pits to oxide and prepare other forms for disposition, as well as fuel fabrication or immobilization processes, represents the stage of the disposition process when material is most vulnerable to covert theft by insiders or covert diversion by the host state. Such bulk processing is required for all options, however; in particular, initial processing of plutonium pits and other forms is among the most proliferation-sensitive stages of the disposition process, but is largely common to all the options. More information about the specific process designs is needed to determine whether there are significant differences between the various immobilization and reactor options in the overall difficulty of providing effective assurance against theft or diversion during the different types of bulk processing involved, and if so, which approach is superior in this respect.

Transport of plutonium is the point in the disposition process when the material is most vulnerable to overt armed attacks designed to steal plutonium. With sufficient resources devoted to security, however, high levels of protection against such overt attacks can be provided. International, and particularly overseas, shipments would involve greater transportation concerns than domestic shipments.

Conclusions Relating to Specific Disposition Options

The reactor options, homogeneous immobilization options, and deep borehole immobilized emplacement option can all meet the Spent Fuel Standard. The can-in-canister design is being revised to increase the difficulty of removing the cans from the canisters, with the goal of meeting the Spent Fuel Standard. The deep borehole direct emplacement option substantially exceeds the Spent Fuel Standard with respect to recovery by subnational groups, but could be more accessible and attractive for recovery by the host state than spent fuel.

The reactor options have some advantage over the immobilization options with respect to perceived irreversibility, in that the plutonium would be converted from weapons-grade to reactor-grade, even though both weapons and reactor-grade plutonium can be used to pruduce nuclear weapons. The immobilization and deep borehole options have some advantage over the reactor options in avoiding the perception that they could potentially encourage additional separation and use of civilian plutonium, which itself poses proliferation risks.

Options that result in accountable "items" whose plutonium content can be accurately measured (such as fuel assemblies or immobilized cans without fission products in the "can-in-canister" option) offer some advantage in accounting to ensure that the output plutonium matches the input plutonium from the process. Other options (such as homogeneous immobilization or immobilized emplacement in deep boreholes) would require greater reliance on containment and surveillance to provide assurance that no material was stolen or diverted -- but in some cases could involve simpler processing, easing the task of providing such assurance.

It appears likely that the option of using excess weapons plutonium as MOX in U.S. LWRs could be implemented relatively quickly, and meet the other criteria outlined above. The principal uncertainty in this case relates to the potential difficulty of gaining political and regulatory approvals for the various operations required.

Compared to the LWR option, the CANDU option would involve more transport, and more safeguarding issues at the reactor sites themselves (because of the small size of the fuel bundles and the on-line refueling of the reactors). Demonstrating the use of MOX in CANDU reactors by carrying out this option for excess weapons plutonium disposition could somewhat detract from U.S. efforts to convince nations operating CANDU reactors in regions of proliferation concern not to pursue MOX fuel cycles, but these nations are likely to base their fuel cycle decisions primarily on factors independent of disposition of this material. Disposing of excess weapons plutonium in another country long identified with disarmament could have significant symbolic advantages, particularly if carried out in parallel with Russia. Disposition of Russian plutonium in CANDU reactors, however, would require resolving additional transportation issues and additional questions relating to the likely Russian desire for compensation for the energy value of the plutonium.

Like the reactor options, the immobilization options have the potential to be implemented relatively quickly, and to meet the other criteria outlined above. They face somewhat less political uncertainty but somewhat more technical uncertainty than the reactor options.

The likelihood of very long delays in gaining approval for siting and construction of deep borehole sites represents a very serious arms control and nonproliferation disadvantage of the borehole option, in either of its variants. While the deep borehole direct-emplacement option requires substantially less bulk processing than the other disposition options, that option may not meet the Spent Fuel Standard for retrievability by the host state, as mentioned above. Any potential advantage from the reduced processing is small compared to the large timing uncertainty and the potential retrievability disadvantage.

Similarly, the electrometallurgical treatment option, because it is less developed than the other immobilization options, involves more uncertainty in when it could be implemented, which represents a significant arms reduction and nonproliferation disadvantage. It does not appear to have major compensating advantages compared to the other immobilization options.

The "can-in-canister" immobilization options have a timing advantage over the homogeneous immobilization options, in that, by potentially relying on existing facilities, they could begin several years sooner (and the schedule is somewhat less uncertain). As noted above, however, modified systems intended to allow this option to meet the Spent Fuel Standard are still being designed.

Implementation Steps

Continued cooperation with Russia to ensure that Russia moves in parallel with U.S. efforts to place excess plutonium under international monitoring and then transform it into forms that meet the Spent Fuel Standard is key to achieving critical benefits from U.S. safeguards and plutonium disposition activities. U.S. and Russian officials have agreed that the goal should be parallel reductions to roughly equal levels of plutonium remaining in military stockpiles. A formal U.S.-Russian agreement governing such steps could have significant benefits.

Fulfilling the Moscow Nuclear Safety and Security Summit agreement to apply IAEA safeguards to excess fissile materials "as soon as it is practicable to do so" would have substantial nonproliferation and arms reduction benefits. As directed by President Clinton, DOE is continuing to work to maximize the quantities of U.S. excess materials made eligible for IAEA safeguards.

Since a substantial fraction of these materials is in classified forms and cannot be processed to unclassified forms for a substantial period, placing this material under safeguards in the near term would require developing modified safeguards measures that could allow credible IAEA monitoring of material in classified form without compromising information that would contribute to nuclear proliferation. Additional declassification -- particularly of the average amount of plutonium in a pit, and related passive radiation signatures -- could facilitate development of a credible safeguards regime in a manner consistent with national security requirements.

Bilateral U.S.-Russian monitoring of fissile materials removed from dismantled weapons can be an important complementary measure for achieving U.S. arms reduction and nonproliferation goals. Efforts to negotiate and implement a Mutual Reciprocal Inspections (MRI) regime are continuing.

As agreed at the Moscow Nuclear Safety and Security Summit, U.S. disposition activities seek to "reduce stocks of separated plutonium and highly-enriched uranium ... as soon as practicable." .

Similarly, U.S. storage and disposition activities seek to ensure that weapons-usable fissile materials "are stored and handled under physical protection, accounting and control measures that meet the highest international standards and that ensure effective non-proliferation controls" -- another agreed goal of the Moscow Nuclear Safety and Security Summit.

Steps to Maximize Benefits and Minimize Vulnerabilities

For whatever disposition options are chosen, steps to maximize the benefits and minimize the liabilities, have the potential to substantially improve the net nonproliferation and arms control impact of disposition.

For all alternatives, working to ensure that Russia took comparable steps in parallel with the United States on a comparable time-scale would greatly increase the benefits, and decrease the risks, of the U.S. actions.

The likelihood of political and regulatory obstacles delaying implementation of plutonium disposition could be reduced through clear action by the President and Congress designating plutonium disposition as a priority national security activity, combined with a determined effort to make the case to relevant stakeholders as to why plutonium disposition was needed.

Keeping the U.S. public and the international community informed of the purposes and progress of U.S. weapons-usable fissile material storage and disposition efforts, including a high-profile effort to emphasize the U.S. commitment to reducing its stockpiles of excess fissile material, will be critical to achieving the maximum nonproliferation and arms reduction benefit from these efforts.

Verifying the progress of U.S. efforts by placing excess materials under bilateral U.S.-Russian monitoring and IAEA safeguards as rapidly as practicable, and continuing such monitoring through the disposition process, would make a major contribution to the nonproliferation and arms reduction benefits of the storage and disposition alternatives.

Maintaining stringent standards of domestic safeguards and security throughout the disposition process, as called for by the Stored Weapons Standard, can help reduce the short-term proliferation vulnerabilities involved in the bulk processing and transport of plutonium required for all the disposition options.

Minimizing the amount of transport of plutonium in attractive forms, including co-locating some key facilities at the same sites, would help minimize the potential vulnerability to theft by overt attack on shipments of plutonium.

Continued development and implementation of improved international safeguards approaches could help reduce potential proliferation risks in bulk handling of plutonium (required to different degrees by all disposition options).

If the reactor alternatives are chosen, the potential for perceptions that U.S. fuel cycle policy had changed could be mitigated by clear and authoritative statements outlining precisely how the chosen option fits within broader U.S. fuel cycle policy, including emphasis on the national security imperatives, its costs, and commitments that the plutonium facilities would be used only for once-through processing of the already existing stockpile of separated plutonium.

For the can-in-canister option, continuing the current effort to develop a design that would preclude easy removal of the cans from the canisters would help to ensure that this option can meet the Spent Fuel Standard and thereby contribute to the arms reduction and nonproliferation benefits of the option.

For the immobilization options, ensuring that sufficient radiation barriers are included to deter theft and processing of the materials would mitigate what would otherwise be a potential disadvantage of these approaches.

For the borehole options, it will be difficult to mitigate the nonproliferation and arms reduction liability posed by the very large uncertainty in when they could be implemented, arising from the difficulty of gaining political approval and licenses for a borehole site. But if this option, is chosen, efforts could be made to mitigate this liability as much as possible by moving quickly to initiate the siting effort and seeking supporting legislation.

For options involving NRC-regulated facilities, it will be important to ensure that security forces have legal authority to use deadly force if necessary to prevent theft of fissile material, as DOE security forces have today.

For foreign implementation variants (including initial MOX fabrication in Europe and MOX irradiation in Canadian CANDU reactors), the United States will have to transfer security responsibility for the material to another nation during a portion of the mission. This potential disadvantage could be substantially mitigated by reaching agreements to ensure that stringent security, accounting, and safety are maintained while the material is outside of the United States.

For variants involving use of foreign MOX capabilities, the potential for encouraging additional civilian recycling of plutonium could be reduced by avoiding, to the extent practicable, providing financing for major expansions of foreign MOX capabilities, or ensuring that these expansions would be used only for the plutonium disposition mission.

Table ES-1: Nonproliferation and Arms Control Advantages and Disadvantages of the Plutonium Disposition Alternatives

	Light Water Reactors	CANDU Reactors
Advantages	♦ Meets Spent Fuel Standard ♦ Proven Technology ♦ Timely Start-up ♦ Isotopic Conversion[a] ♦ Initial European MOX fabrication offers earlier start-up	♦ Meets Spent Fuel Standard ♦ Timely Start-up ♦ Isotopic Conversion[a] ♦ Potentially fewer political, licensing obstacles ♦ Potential for parallel US-Russian activity ♦ Moves plutonium to a third country (though other plutonium remains)
Disadvantages	♦ Potentially controversial, licenses and approvals could be delayed ♦ Could provide additional argument to advocates of plutonium recycle ♦ Accounting uncertainties in bulk processing ♦ European start-up option requires overseas transport, and transfer of security responsibility	♦ Increased international transport, especially for Russian plutonium ♦ Foreign control, transfer of security responsibility ♦ CANDU reactors have smaller, portable fuel bundles, on-line refueling, creates additional safeguards issues. ♦ Accounting uncertainties in bulk processing ♦ Validation of MOX use in CANDU might encourage other international use of MOX in CANDUs ♦ Russian compensation issue, if parallel Russian option pursued.

a - Weapons-grade and reactor-grade plutonium can both be used in a nuclear weapon.

	Homogeneous Glass	Homogeneous Ceramic	Can-In-Canister, Glass or Ceramic	Electro-metallurgical
Advantages	♦ Meets the Spent Fuel Standard ♦ Avoids questions about U.S. fuel cycle policy ♦ Potential for reduced public concern, compared to reactor options ♦ Potentially fewer bulk processing steps than reactor options ♦ Avoids transport-to-reactors step ♦ Complex purification of impure forms not required	♦ Meets the Spent Fuel Standard ♦ Avoids questions about U.S. fuel cycle policy ♦ Potential for reduced public concern, compared to reactor options ♦ Potentially fewer bulk processing steps than reactor options ♦ Avoids transport-to-reactors step ♦ Complex purification of impure forms not required	♦ Timely start-up ♦ Potential use of existing DOE facilities limits potential for approval delays ♦ Avoids questions about U.S. fuel cycle policy ♦ Potential for reduced public concern, compared to reactor options ♦ Potentially fewer bulk processing steps than reactor options ♦ Avoids transport-to-reactors step ♦ Complex purification of impure forms not required	♦ Meets the Spent Fuel Standard ♦ Avoids transport-to-reactors step ♦ Complex purification of impure forms not required
Disadvantages	♦ Less technically mature than LWR option ♦ No isotopic conversion[a] ♦ Bulk processing to difficult-to-measure form raises accounting issues	♦ Less technically mature than LWR option ♦ No isotopic conversion[a] ♦ Bulk processing to difficult-to-measure form raises accounting issues	♦ New can design to ensure system meets Spent Fuel Standard not yet complete ♦ Less technically mature than LWR reactor options ♦ No isotopic conversion[a]	♦ Less mature than other immobilization alternatives ♦ Use of technology derived from reprocessing may provoke opposition ♦ Bulk processing to difficult-to-measure form raises accounting issues

	Direct Emplacement Borehole	Immobilized Emplacement Borehole
Advantages	♦ Fewer Bulk Processing Steps than Reactor or Immobilization alternatives ♦ Substantially exceeds Spent Fuel Standard for recovery by subnational groups	♦ Meets Spent Fuel Standard for host state ♦ Substantially exceeds Spent Fuel Standard for recovery by subnational groups
Disadvantages	♦ Very large start-up uncertainty due to potential delays in siting approvals and license, public acceptability issues. ♦ More recoverable by the host state than plutonium in spent fuel, potentially raising international perception issues	♦ Very large start-up uncertainty due to potential delays in siting approvals and license, public acceptability issues.

	Hybrid (Reactor + Immobilization)	No Action Alternative (Indefinite Storage)
Advantages	♦ Meets the Spent Fuel Standard ♦ Two complementary options provide higher overall confidence in program implementation ♦ Timely start-up, schedule advantages ♦ Complex purification of impure forms not required	♦ No large-scale bulk processing of plutonium required; minimizes near-term technical proliferation vulnerability
Disadvantages	♦ Approvals for both types of facilities required, potential for increased political controversy	♦ Does not meet Spent Fuel Standard; material remains in directly weapons-usable form indefinitely ♦ Fails to meet U.S. objectives and commitments to reduce excess material stockpiles ♦ Could undermine perceptions of U.S. commitment to irreversible arms reductions, with negative arms reduction and nonproliferation impacts ♦ Would likely result in Russian excess plutonium also remaining in directly weapons-usable form indefinitely, with increased long-term potential for theft or reversal of arms reductions ♦ Sensitive to unforseeable political changes and instabilities

I. Introduction

With the end of the Cold War, the United States and Russia are dismantling thousands of nuclear weapons. Hundreds of tons of weapons-usable fissile materials -- plutonium and highly-enriched uranium (HEU) -- are no longer needed for national defense. This material is referred to as "excess." The United States has made a commitment that the fissile materials it declares excess will never again be used for nuclear weapons.

The question of what will happen to these vast stockpiles of excess fissile material -- enough for tens of thousands of nuclear bombs -- is central to the future of arms reduction and nonproliferation. Secure storage and disposition of these materials could help lock in nuclear arms reductions now underway, thus building international confidence and providing a basis for future reductions. Ensuring that these materials do not fall into the hands of rogue states or terrorist groups is also a paramount concern. Reducing these excess stockpiles, by transforming them into forms that would be difficult to re-use in weapons, would send a clear signal to the world that the arms reductions now underway would not be reversed. As President Clinton has said, "Reducing the size of nuclear stockpiles and enhancing the security of nuclear materials is of vital importance to our national security."

U.S. objectives relating to the storage and disposition of excess fissile materials were summarized by the Committee on International Security and Arms Control of the U.S. National Academy of Sciences (NAS) in its 1994 report, *Management and Disposition of Excess Weapons Plutonium*:

> "The primary goal in choosing options for management and disposition of excess nuclear weapons and fissile materials should be to minimize the risks to national and international security posed by the existence of this material. This security goal can be divided into three main objectives:
>
> 1) to minimize the risk that weapons or fissile materials could be obtained by unauthorized parties;
>
> 2) to minimize the risk that weapons or fissile materials could be reintroduced into the arsenals from which they came, halting or reversing the arms reduction process; and
>
> 3) to strengthen the national and international control mechanisms and incentives designed to ensure continued arms reductions and prevent the spread of nuclear weapons."

DOE's analyses of the alternatives for disposition of excess weapons plutonium, including this assessment, have built on the foundation provided by this report and its 1995 companion volume, and have come to broadly similar conclusions.

Relatively small amounts of fissile material -- several kilograms of plutonium, or roughly three times the amount of HEU -- are potentially enough to make a nuclear weapon. With such materials in hand most nations, and even some terrorist groups, would be able to produce a nuclear device. Hence, limits on access to these materials -- the essential ingredients of nuclear weapons -- are the principal technical barrier to nuclear proliferation in the world today. Following the breakup of the Soviet Union, reported incidents of theft and smuggling of nuclear materials have increased dramatically, posing an urgent new nonproliferation challenge.

The continued existence of vast quantities of excess weapons-usable fissile materials has been described by the National Academy of Science as a "clear and present danger to national and international security." Safe and secure management of this Cold War legacy is essential, to prevent these materials from ever being returned to nuclear weapons, either by national governments or by sub-national groups that might illegally acquire them. The dangers and the imperative for action have been recognized by the international community. The United States, Russia, and other leading industrialized nations are working together to assess ways to safely and securely store these stockpiles and reduce them over time. Because of these dangers, and the potential arms reduction and nonproliferation benefits of disposition of these materials, there is a general consensus -- reflected in the statement of the Moscow Summit on Nuclear Safety and Security in April 1996 -- that decisions on management and reduction of these stockpiles should be made and implemented as quickly as practicable.

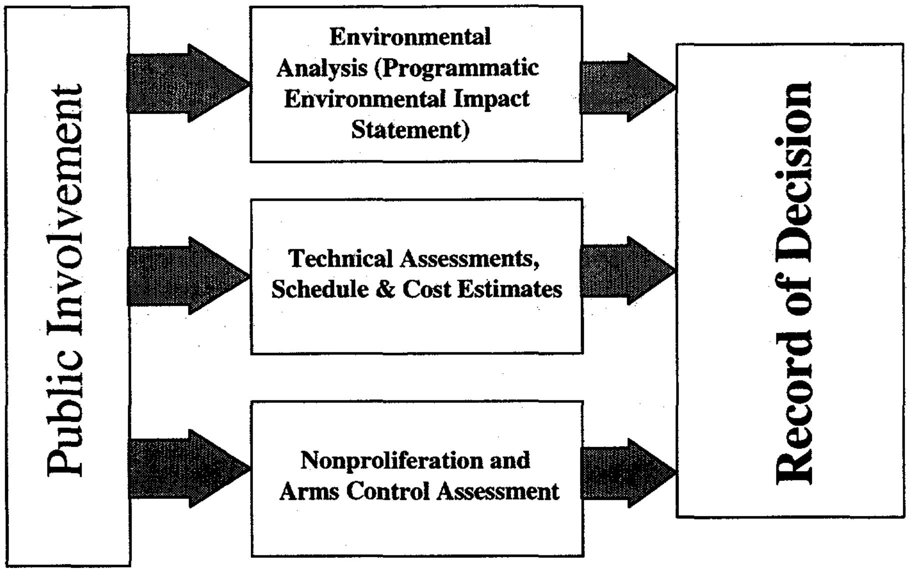
Supporting a Decision: An Open Process

In the United States, a major initiative is underway to provide for the safe storage and disposition of excess fissile materials. A broad range of studies and analyses are ongoing, designed to provide the information necessary for a national decision on storage and disposition alternatives by the end of 1996. This assessment, prepared by the Department of Energy's Office of Arms Control and Nonproliferation (DOE-NN) with support from the Office of Fissile Materials Disposition (DOE-MD), is part of that effort. Its purpose is to analyze the nonproliferation and arms reduction implications of the alternatives for storage of plutonium and HEU, and disposition of excess plutonium, to aid policymakers and the public in making final decisions. While this assessment describes the benefits and risks associated with each alternative, it does not attempt to rank order them. It does, however, identify steps which could maximize the benefits and mitigate any vulnerabilities of the various alternatives under consideration.

Current programs related to storage and disposition of weapons-usable fissile materials are based on President Clinton's September 27, 1993 Nonproliferation and Export Control Policy Statement, Presidential Decision Directive (PDD) 13, and subsequent directives and agreements. Under the President's September, 1993 policy statement, U.S. policy is to 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." In particular, the President's statement called for U.S. excess fissile materials to be placed under international safeguards, and called for "a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations."

In response to The President's September, 1993 statement, an interagency group was established under the joint chairmanship of the Office of Science and Technology Policy and the National Security Council, to oversee plutonium disposition efforts and to ensure that the views of all relevant agencies were appropriately considered. The Department of Energy, as the agency with primary responsibility within the United States government for the management and disposition of plutonium, established the Office of Fissile Materials Disposition, which is responsible for carrying out the fissile materials storage and disposition mission.

Three types of information will support the choice of preferred alternatives for storage and disposition of weapons-usable fissile materials. (See Figure 1-1.) First is information related to environment, safety, and health. In compliance with the National Environmental Policy Act (NEPA), the Department of Energy's Office of Fissile Materials Disposition (DOE-MD) prepared the *Final Programmatic Environmental Impact Statement (PEIS) on Weapons-Usable Fissile Materials Storage and Disposition*. (Disposition of surplus HEU has been addressed in the *Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement* published in June, 1996, and the Record of Decision signed in July, 1996). These documents analyze the environment, safety, and health implications of the various alternatives for storage and disposition of plutonium and HEU under consideration by the U.S. government.



Decision Inputs and Process
Figure 1-1

The second category of information needed to support a decision is data on the cost, schedule, and technical feasibility and maturity of each of the alternatives under considerations. These issues are addressed in the *Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition,* prepared by DOE-MD and released in its final form on October 31, 1996. These documents were also issued in draft form and opened to public comment periods.

This assessment has also gone through an intensive process of review, to ensure its accuracy, objectivity and completeness. Although not a part of the formal NEPA process, this assessment has been prepared in a manner that provided the fullest possible opportunity for public input, and is being considered with the other reports in selecting a Record of Decision for storage and disposition of weapons-usable fissile materials.

This assessment builds on a broad base of previous and ongoing work, including the NAS committee reports already mentioned and other non-governmental analyses. In particular, this study draws from the nonproliferation and arms control analyses of the alternatives that have been prepared for DOE-MD by the laboratory teams analyzing each of the alternatives, with the help of the Safeguards and Security Team established by DOE-MD, and on the recent study of the Proliferation Vulnerability Red Team established by DOE-MD to identify near-term technical proliferation vulnerabilities affecting the disposition alternatives and options for mitigating them. [1]

The outline of this assessment was released for public comment on July 1, 1996, and comments received were used in conjunction with the outline to prepare this initial draft. The assessment has been reviewed and commented on by a Task Force selected by the Chairman of the Secretary of Energy's Advisory Board (SEAB) (See Appendix A). A letter from the Task Force is attached as Appendix B. The draft assessment was revised to reflect the comments of the SEAB Task Force, after which the study was reviewed and commented on by the interagency group on plutonium disposition, and revised again for release for public comment. A letter from the whole SEAB to Secretary Hazel O'Leary is included as Appendix C. This assessment has gone through an intensive review process, including 15 public meetings in 10 cities over 8 months and has been commented on by over 100 people and organizations through mail, electronic mail, telephone and in public meetings. Appendix E is a comment response section which lists comments made on the Draft Assessment and includes DOE responses to those comments. Appendix F lists all people and organizations that commented on the assessment or attended a public meeting.

Scope of This Assessment

This assessment addresses the alternatives for:

- storage of U.S. weapons-usable fissile materials (both plutonium and HEU) in DOE's inventory, including excess material and material required for national defense; and
- disposition of U.S. excess plutonium.

Because none of the disposition alternatives for plutonium or HEU can be accomplished for decades, storage of excess fissile materials will be required for at least that long. The material that will remain in the U.S. military stockpile will require storage for as long as that stockpile exists. Thus, storage of both excess and reserve materials, including both plutonium and HEU, is considered in this assessment.

Disposition, by contrast, is relevant only for materials that are in excess to defense needs. Only disposition of excess plutonium is addressed in this assessment, because disposition decisions concerning excess HEU have already

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[1] *Proliferation Vulnerability Red Team* Report draft, Sandia National Laboratories, Octobert 1996. The technical analyses contained in the Red Team report contributed greatly to the analyses in this assessment. This "Red Team" report was prepared by an independent group of U.S. national laboratory employees who were tasked with producing an "independent technical assessment of potential proliferation vulnerabilities associated with plutonium disposition options". The Red Team's mandate focused only on technical issues, not policy issues, and only on near-term vulnerabilities, not potential near-term or long-term benefits. Therefore the conclusions in this broader assessment do not in all cases parallel those contained in the Red Team report.

been made through a process that culminated in the issuance of the *Final Environmental Impact Statement on the Disposition of Surplus Highly Enriched Uranium* (June 1996) and the subsequent Record of Decision signed on July 19, 1996. The Record of Decision stated that the United States will blend down and sell for reactor fuel most of the roughly 175 metric tons (MT) of HEU that has been declared to be excess to U.S. defense needs.

HEU, which is over 20% U-235 can be blended with non-chain reacting U-238 to produce low-enriched uranium (LEU), which can be sold for use as nuclear reactor fuel on the commercial market but that cannot be used directly to make nuclear weapons. Different isotopes of an element are chemically virtually identical; the separation of heavy isotopes of an element (such as U-238) from lighter isotopes of an element (such as U-235) is a complex technical task. Diluting U-235 with large quantities of U-238, therefore, makes it impossible to fabricate nuclear weapons from it without technologically demanding re-enrichment. The remainder of this U.S. excess material, whose impurities make it economically impractical for use as reactor fuel, will be blended to LEU and disposed of as waste.

Since nearly all isotopes of plutonium can be used in nuclear weapons, excess plutonium cannot simply be blended with other plutonium to make it unusable in nuclear weapons. There is no plutonium isotope available in adequate quantities with which to blend down either weapons-grade or the plutonium in spent reactor fuel to make them non-weapons-usable. Separating plutonium from other elements with which it might be mixed or from unirradiated reactor fuel containing plutonium requires only well-understood chemical processing techniques that are within the capability of many states and even sub-national groups.

Moreover, plutonium's toxicity and the need for stringent security and safeguards during handling make it more expensive to fabricate reactor fuel from plutonium than it is to buy uranium fuel on the commercial market, even if the plutonium itself is "free" (i.e., having come from excess weapons stockpiles). Hence, disposition of plutonium will cost the government hundreds of millions or billions of dollars, whether it is used as reactor fuel or disposed of as waste. Finally, U.S. plutonium disposition could have or could be perceived to have an impact on decisions related to the separation and use of plutonium in the civilian fuel cycle in other countries.

Storage of Weapons-Usable Fissile Material. Four alternatives for storage of weapons- usable fissile materials are under consideration, and are addressed in this assessment:

- No action—leaving most plutonium stored where it is currently located, with only minimal upgrades to existing facilities as required by regulations;

- Upgrade In Place—partial consolidation, while leaving most plutonium stored where it is currently located, but with substantial upgrades to existing facilities, or construction of new ones to meet updated DOE standards;
- Consolidation—building a single modern storage facility for plutonium in the DOE inventory, except for working stocks at operational sites; or
- Co-location—storing both DOE's plutonium and HEU stockpiles in a single consolidated facility.

Each alternative must be evaluated to assess its ability to provide effective safeguards and security to ensure that no material could be stolen. Policy factors must also be considered, including the degree to which each alternative could support bilateral or international monitoring of U.S. excess fissile materials, while protecting classified information whose compromise could contribute to nuclear proliferation or other security threats to the United States. It is also important to consider each alternative's impact, if any, on storage of weapons-usable fissile materials in Russia and other countries, and on the arms reduction and nonproliferation regimes.

Disposition of Excess Plutonium. Three broad classes of plutonium disposition alternatives are being considered:

- Reactors—Use of plutonium as fuel for light-water reactors (LWRs) or Canadian Deuterium-Uranium (CANDU) reactors;
- Immobilization—Mixing the plutonium into large, stable glass or ceramic waste forms, which would also contain intensely radioactive fission products;
- Deep Boreholes—Burial of plutonium in 2-4 kilometer deep boreholes.

Hybrid alternatives, in which more than one of these classes of alternatives would be pursued for different portions of the excess plutonium, are also under consideration. In addition, the "No Action" alternative -- leaving the excess plutonium in storage indefinitely -- is also being considered, as required by NEPA. For each alternative, there are a number of possible variants.

These alternatives for storage and disposition were identified as the reasonable alternatives in a screening process conducted by the Department of Energy's Office of Fissile Materials Disposition in compliance with the National Environmental Policy Act, which was completed in March 1995.[2] These alternatives closely parallel those identified in the 1994 NAS committee report.

It is important to understand that any alternative chosen for plutonium disposition will be used only for the specific mission of addressing the special security risks posed by the stockpiles of excess plutonium that already exist in the DOE inventory. Use of some of this excess plutonium in reactors would not

[2] U.S. Department of Energy, DOE/MD-0002, *Summary Report of the Screening Process,* March 29, 1995.

represent any change in U.S. fuel cycle policies, which do not encourage separation and recycling of plutonium. No reprocessing or recycling of this material or of other civilian spent fuel is implied or contemplated.

Each of the three classes of disposition alternatives could potentially meet the "Spent Fuel Standard"—that is, they would make the excess weapons plutonium as inaccessible and unattractive for use in weapons as the much larger and growing quantity of plutonium in spent fuel from commercial nuclear power plants worldwide. (All currently operating commercial nuclear power plants produce plutonium mixed in their spent fuel as an inevitable byproduct of their operations; this plutonium cannot be used in nuclear weapons unless it is chemically processed to separated it from the intensely radioactive spent fuel.) This goal for plutonium disposition was recommended by the 1994 NAS committee report, and has been endorsed by the U.S. government. (The definition of the Spent Fuel Standard was modified to include the word unattractive by the Department of Energy.)

The reactor and immobilization alternatives would both result in massive, intensely radioactive waste forms (spent fuel in the case of reactors, massive canisters of glass or ceramic with fission products in the case of immobilization) that would be stored for an interim period before being sent to a geologic repository. No reprocessing to recover plutonium from any of these waste forms is envisioned. In each case, significant cost, time and effort would be required from anyone attempting to recover plutonium from such forms—just as is the case for plutonium in spent fuel. The deep borehole alternative would rely on the great depth at which the plutonium would be buried, rather than the size, mass, and radioactivity of the waste form, to make the plutonium costly and difficult to recover. In each case, however, it would still be possible to recover the plutonium; the security risk posed by this material would be greatly reduced, but not eliminated.

Because gaining access to fissile materials is the most difficult part of building a nuclear weapon, the NAS committee recommended that, until the Spent Fuel Standard has been achieved, the essential fissile ingredients of nuclear weapons should, to the extent practicable, be guarded just as carefully as intact nuclear weapons are—a goal the NAS committee called the "Stored Weapons Standard." This standard has also been endorsed by the U.S. government for the plutonium disposition mission.

Factors for Analysis

This assessment of the nonproliferation and arms reduction implications of the storage and disposition alternatives under consideration is based on technical and policy factors.

Technical factors include:

- how rapidly the alternative could be implemented (both time to start and time to finish), which determines how soon the benefits of plutonium disposition could be achieved. Time to start is particularly important in gaining international credibility and confidence in the disposition process;
- the degree to which the alternative could ensure that plutonium could not be stolen or diverted during the process, coming as close as possible to the Stored Weapons Standard;
- the degree to which the alternative would permit international monitoring, to confirm U.S. commitments that excess fissile material will never again be used in weapons; and
- the degree to which the alternative would result in a form that is as unattractive and inaccessible for use in weapons as plutonium in spent power reactor fuel, meeting the Spent Fuel Standard.

Policy factors include:

- the impact on Russian programs for disposing of its surplus plutonium, which is a major motivation for U.S. action;
- the effect on nuclear arms reduction efforts, including the extent to which U.S. decisions ensure the irreversibility of the arms reduction process;
- the impact on nonproliferation efforts, such as demonstrating the U.S. commitment to its obligations to nuclear arms reduction under the Treaty on the Nonproliferation of Nuclear Weapons (NPT);
- the impact on fuel cycle policy and choices by other nations, since the United States does not encourage civilian use of plutonium but seeks to eliminate excess stockpiles of HEU and plutonium ; and
- the political implementability of each alternative, since selecting an alternative with low chances for achieving success in a timely manner will affect all of the other policy factors.

Each of these technical and policy factors must be balanced in judging the relative nonproliferation and arms reduction merits of each disposition alternative. Policy-makers must judge for themselves the relative importance of these differing criteria.

Plan of This Assessment

The remainder of this assessment analyzes the nonproliferation and arms reduction implications of the alternatives for storage of plutonium and HEU, and disposition of excess plutonium. Section 2 provides background essential to the issue, including the purposes of storage and disposition of excess fissile materials, the quantities of material that have been declared excess, the linkages and differences between U.S. and Russian storage and disposition efforts, international cooperation in these areas, and relevant international arms reduction and nonproliferation efforts and agreements. Section 3 describes the key technical and policy factors that must be considered in analyzing the nonproliferation and arms reduction implications of each alternative. Section 4 analyzes the arms reduction and nonproliferation implications of each of the storage alternatives under consideration, while Section 5 does the same for each of the plutonium disposition alternatives. Section 6 outlines steps that could be taken to maximize the benefits and minimize the dangers of each alternative, and Section 7 presents conclusions.

2. Background and Context

Unprecedented reductions in nuclear arms are now under way in both the United States and the former Soviet Union. Thousands of nuclear weapons have been dismantled and many more have been removed from their launchers; hundreds of nuclear missiles and bombers have been destroyed; and all the states of the former Soviet Union except Russia have agreed to join the Nuclear Nonproliferation Treaty (NPT) as non-nuclear-weapon states and are returning all Russian nuclear weapons to Russian territory. Russia has joined the United States in agreeing to deep reductions in nuclear weapons in bilateral treaties and through other initiatives, such as tactical nuclear weapon drawdowns, that have reduced the amounts of fissile material needed for national defense in both countries. Hundreds of tons of plutonium and HEU are now excess to defense needs.

At the same time, international efforts to prevent the spread of nuclear weapons are being strengthened in response to new challenges. The international community has agreed to extend the NPT indefinitely, and negotiations to further strengthen the international nuclear safeguards system are ongoing. Yet the accumulation of large stockpiles of fissile materials from both weapons dismantlement and civilian programs, coming at a time of sweeping economic and political changes in the former Soviet Union, is posing unprecedented challenges for safe and secure control of these dangerous materials.

Objectives: Nonproliferation and Arms Reduction

Given this situation, the United States government seeks to reduce existing stockpiles of nuclear weapons in a stabilizing manner, and to prevent the spread of nuclear weapons to additional countries. As noted in the introduction, the fundamental objective of U.S. programs for storage and disposition is to ensure that this excess material is never again used in nuclear weapons. This goal includes:

- helping to prevent nuclear proliferation by ensuring that these materials do not fall into the hands of states or groups seeking to build nuclear weapons;
- helping to ensure that nuclear arms reductions cannot be easily reversed, both by political and legal means (such as verified commitments not to reuse this material in weapons), and by making such reuse technically difficult, unattractive, time-consuming and costly; and
- helping to strengthen the nonproliferation and arms reduction regimes, in part by demonstrating the U.S. commitment to irreversible reductions in nuclear arsenals.

Achieving these objectives will inevitably require close cooperation with Russia, including secure storage and disposition of its excess fissile material as well. Indeed, a central purpose of disposition of U.S. excess fissile materials is to help achieve disposition of excess Russian fissile materials, which will serve U.S. security by ensuring against both the possibility that these materials might be stolen and find their way into the hands of a rogue state or terrorist group, or the possibility that Russian materials might someday be returned to weapons to rebuild a Cold War weapons stockpile.

U.S. policies to achieve these objectives were set by President Clinton in his Nonproliferation and Export Control Policy Statement in September, 1993; in the President's subsequent summit statements with Russian President Yeltsin; and in his directives to remove large quantities of fissile material from the U.S. stockpile available for nuclear weapons in March, 1995, and to increase efforts to cooperate with Russia in ensuring secure management of nuclear weapons materials, in September, 1995.

The President directed an increased emphasis on preventing the spread of nuclear weapons, specifically including "a comprehensive approach to the growing accumulation of fissile materials." As part of that comprehensive approach, U.S. policy is to 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."

In furtherance of this objective, President Clinton has taken the following steps with respect to U.S. fissile materials:

- directed that over 200 tons of weapons-usable fissile material be permanently removed from the stockpile available for defense purposes;
- publicly committed that these excess materials will never again be used for nuclear weapons;
- directed that U.S. excess materials be placed under International Atomic Energy Agency (IAEA) safeguards, to build confidence in the commitment to use materials only for peaceful purposes;
- directed that ways be found to reduce stockpiles of excess weapons-usable fissile materials as quickly as practicable.

President Clinton has also made working with Russia to reduce its stockpiles of excess fissile materials -- including the Russian HEU Purchase Agreement, under which the United States is purchasing 500 metric tons of HEU blended down into low-enriched uranium for use as power reactor fuel, and cooperation to find the best alternative for plutonium disposition -- a central part of a comprehensive program of U.S.-Russian cooperation to ensure safe and secure management of these dangerous nuclear materials. These initiatives, carefully considered by all the relevant agencies of the U.S. government, have broad bipartisan and public support, as they are targeted to support U.S. arms reduction and nonproliferation objectives.

Arms Reduction Benefits. These steps help to ensure that current arms reductions will not be reversed and are an integral part of the U.S. strategy to work with Russia to reduce nuclear stockpiles -- and, thereby, to reduce the nuclear threat. The United States cannot expect Russia to reduce its stockpiles of fissile materials or place them under international monitoring unless we are prepared to do the same. These steps are also an integral part of the U.S. strategy to fulfill our international commitment to pursue irreversible reductions in nuclear arms, and continue the arms reduction process. Removing large stockpiles of the essential ingredients of nuclear weapons from the U.S. defense stockpile, placing them under international safeguards, and transforming them into forms that are not suitable for use in nuclear weapons without significant recovery efforts will help demonstrate to Russia and to the world that our commitment to irreversible nuclear arms reductions is genuine.

Nonproliferation Benefits. At the same time, these steps play a critical role in U.S. efforts to stem the spread of nuclear weapons. Nothing could be more central to U.S. security than ensuring that the essential ingredients of nuclear weapons do not fall into the hands of rogue states or terrorist groups. Secure storage of U.S. and Russian excess fissile materials, followed by secure and timely disposition, will help ensure that these materials cannot be stolen or diverted for hostile purposes. The clear demonstration of U.S. commitment to irreversible arms reductions resulting from the initiatives just described will help build continued international political support for maintaining and strengthening the global nonproliferation regime; indeed the parties to the NPT called for the United States and Russia to place their excess materials under safeguards at the 1995 Review and Extension Conference for the treaty. That global structure is founded on a basic bargain, that the states without nuclear weapons agree to give up the possibility of acquiring them and to accept inspections of their nuclear activities, in return for the nuclear-weapon states agreeing to pursue an end to the arms race, make available the peaceful benefits of nuclear energy and for all states to pursue general and complete disarmament.

U.S. policies are designed to ensure excess fissile materials will never again be returned to weapons, through a step-by-step process. These steps are all geared to help create symbolic, institutional and physical barriers to the potential reversibility of arms reductions.

Step 1: Political Barriers to Reversibility. The first step in this process is declaring that certain stockpiles of material are excess, and will never again be used in nuclear weapons. This commitment provides *political barriers to reversibility*. As early as 1993, the United States Government was moving firmly toward this objective with President Clinton's September announcement that, to demonstrate that U.S. excess material would never be returned to weapons, it would be submitted to IAEA safeguards, creating a political barrier to the reincorporation of these materials into the military stockpile. By 1994, the first 10 tons of U.S. excess HEU had been committed to peaceful purposes and placed under international safeguards. Then, on March 1, 1995, President Clinton announced that he was permanently removing an additional 200 tons of fissile material -- enough for many thousands of nuclear weapons -- from the stockpiles available for defense purposes. Today, some 225 tons of U.S. fissile material has been declared excess.

Step 2: Verifiable Barriers to Reversibility. The second step in this process is to place the excess material under some form of bilateral or international monitoring, such as IAEA safeguards, to demonstrate to the world that it is being used only for peaceful purposes. This provides *verifiable barriers to reversibility.* President Clinton has specifically called for placing U.S. excess fissile materials under safeguards. Today, some 10 tons of HEU at the DOE facility Oak Ridge, Tennessee and 2 tons of plutonium at DOE sites at Hanford, Washington, and Rocky Flats, Colorado are under IAEA safeguards. An additional 13 tons of HEU has been designated as eligible for safeguards. At Presidential direction, DOE has developed a plan to greatly expand the quantities of excess U.S. material eligible for international safeguards. Expansion of such safeguards, however, must be consistent with protecting classified information that could contribute to nuclear proliferation, as well as with environment, safety, and health requirements and budget constraints. The United States has also been working with Russia to develop a bilateral regime of Mutual Reciprocal Inspections (MRI) of the plutonium and HEU from dismantled weapons -- agreed to in principle, but not yet implemented -- and to encourage Russia to also place its excess material under IAEA safeguards.

Step 3: Legal Barriers to Reversibility. A potential third step would be to reach formal, legally binding agreements confirming that these materials will never again be used for weapons. Reversal would then require not just a change in government policy, but the abrogation of an international agreement. None of the nuclear arms reduction agreements reached between the United States and Russia formally requires the dismantlement of the nuclear weapons themselves (as opposed to the missiles and launchers that carry them), or the safeguarding or disposal of any of the fissile material those weapons contain. Moreover, the U.S. and Russian voluntary safeguards agreements with the IAEA permit either country to place material under safeguards and then withdraw it from safeguards again, should they choose to do so. A new agreement could be reached, however, which would require permanent safeguards, as are required for certain materials in non-nuclear-weapon states party to the NPT, or a bilateral U.S.-Russian agreement on the fate of these materials could also be reached.

Step 4: Physical Barriers to Reversibility. The fourth potential step is to create *physical barriers to reversibility.* Plutonium disposition alternatives that meet the Spent Fuel Standard would add significantly to the time, cost, and effort

-- as well as the observability -- of any attempt by the United States or Russia to recover the plutonium for use in weapons. By making reversal of the current arms reductions more difficult and costly, disposition would make it less likely to occur, and build international confidence that the United States (and Russia, if disposition were also carried out there) were genuinely committed to nuclear arms reductions that would not be reversed. At the same time, by putting these materials into forms that could not be used in nuclear weapons without significant efforts, disposition of excess fissile materials will substantially reduce the long-term proliferation risk these materials pose. Hence, the President's September, 1993 statement called for a "comprehensive review of long-term options for plutonium disposition," and subsequent directives have directed DOE to prepare a specific plan for implementing disposition. Since all of the plutonium disposition alternatives under consideration would take decades to implement, however, the essential first step to ensure nonproliferation is to provide safe, secure, and inspectable storage for these excess nuclear materials.

Reducing Excess Plutonium Stockpiles

Stockpiles of separated, directly weapons-usable plutonium will continue to pose a substantial security risk for as long as they exist. Therefore, U.S. policy is to seek to reduce such stockpiles as quickly as practicable, while ensuring stringent nonproliferation controls. That is the fundamental purpose of plutonium disposition. Disposition of this excess material will help reduce the risk that these materials will be re-used in nuclear weapons, by transforming them in ways that would make it difficult, costly, time-consuming, and easily observable to reuse them in nuclear weapons. It is important to understand, however, that under each of the disposition alternatives under consideration, it would still be possible to recover nuclear materials that could be used to make nuclear weapons. These disposition alternatives would increase the difficulty, cost, and observability of taking such a step. Disposition of excess plutonium, by making it as inaccessible and unattractive for use in nuclear weapons as the plutonium in spent fuel, would:

- reduce the likelihood that current arms reductions would be reversed, by significantly increasing the difficulty, cost, and observability of returning this plutonium to weapons;
- increase international confidence in the arms reduction process, strengthening political support for the nonproliferation regime and providing a base for additional arms reductions, if desired; and
- reduce long-term proliferation risks posed by this material by making it substantially less accessible and attractive to would-be proliferators.

The advantages of plutonium disposition, however, should not be overstated, or the risks ignored:

- Because all plutonium disposition alternatives would take decades to implement, disposition is not a near-term solution to the problem of nuclear theft and smuggling. While disposition will have major long-term security benefits, the near-term problem must be addressed through programs to improve security and accounting for nuclear materials, and to ensure adequate police, customs, and intelligence capabilities to interdict nuclear smuggling.
- All plutonium disposition alternatives under consideration would involve processing and transport of plutonium, which will create more proliferation vulnerabilities in the short term than if the material had remained in heavily guarded storage required under the stored weapons standard. This near-term risk must be weighed against the long-term benefit of converting the material to more proliferation-resistant forms.
- Both the United States and Russia will still retain substantial stockpiles of nuclear weapons and weapons-usable fissile materials even after disposition of the fissile materials currently considered excess is complete. Therefore, disposition will only reduce, not eliminate, the risk of theft of nuclear materials.
- None of the disposition alternatives under consideration would make it impossible to recover the plutonium for use in nuclear weapons, or make it impossible to use other plutonium to rebuild a nuclear arsenal. Therefore, disposition will only reduce, not eliminate, the risk of reversal of current nuclear arms reductions.
- A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries; if this in fact led to significant additional separation and handling of weapons-usable plutonium, that could itself pose proliferation risks.[3]

There is a broad bipartisan consensus that reducing U.S. and Russian stockpiles of excess plutonium as rapidly as practicable would benefit U.S. and international security, and President Clinton has directed that this goal be pursued. That was also the recommendation of the 1994 NAS committee report, which pointed to the "clear and present danger" posed by excess fissile materials, and recommended that the United States and Russia pursue disposition alternatives that "minimize the time during which the plutonium is stored in forms readily usable in nuclear weapons." The NAS committee argued that although plutonium disposition would take decades, it was still an urgent problem, and that the speed with which disposition could be accomplished was "one of the key criteria by

[3] On the other hand, if appropriately implemented, all alternatives might also offer an opportunity to demonstrate improved procedures and technologies for protecting and safeguarding plutonium, which might then be adopted by other countries and thereby reduce proliferation risks.

which disposition options should be judged." A 1995 study by the American Nuclear Society, *Protection and Management of Plutonium,* reached broadly similar conclusions, as have a wide range of studies and analyses by environmental and arms control groups and other non-governmental organizations.

This broad support for plutonium disposition has also been reflected in Congressional support for the budget for DOE's plutonium disposition program. In the fiscal 1997 defense authorization bill, for example, Congress authorized the Administration's plutonium disposition request in full, and directed the President to prepare, for submission with the fiscal 1998 budget request, a comprehensive program including "plans for reducing United States and Russian stockpiles of excess plutonium." Those plans must include "consideration of the feasibility and desirability of a U.S.-Russian agreement governing plutonium disposition," the "specific technologies and approaches to be used for disposition of excess plutonium," and "an assessment of the options for United States cooperation with Russia in the disposition of Russian plutonium."[4] Finally, the international community has also expressed strong support for plutonium disposition, as described below.

Fissile Materials: How Much is Excess?

On March 1, 1995, President Clinton announced that he was permanently removing 200 tons of fissile material -- enough for several thousand nuclear weapons -- from the stockpiles available for defense purposes, declaring them excess to defense needs.

This announcement followed a careful deliberative process to determine how much fissile material was still required to support the future U.S. nuclear weapon stockpile and the Navy's needs for naval propulsion. The number of nuclear weapons that will remain in the active stockpile, the weapons and fissile materials that would be held in reserves, and the quantity of HEU that would be needed each year to fuel the nuclear reactors in Navy ships were all considered. The Nuclear Weapons Council, a group that includes the Deputy Secretary of Defense, the Vice Chairman of the Joint Chiefs of Staff, and the Deputy Secretary of Energy, made recommendations to the President concerning how much fissile material was still required for U.S. defense needs, based on the Nuclear Weapons Stockpile Memorandum signed by the President, and future plans for the Navy. President Clinton's decision was based on this Nuclear Weapons Council recommendation, after review by all the relevant agencies of the government.

At the time of President Clinton's announcement, a total of 213 tons of HEU and plutonium had been declared excess to military needs with 10 tons of HEU and one-half ton of plutonium already under IAEA safeguards. The President's

[4] *Congressional Record*, House, July 30, 1996, p. H9077.

announcement covered only HEU and weapons-grade plutonium; since then, it has been determined that the fuel-grade and reactor-grade plutonium in DOE's inventory is also excess to military needs. (While this fuel-grade and reactor-grade material did not come directly from the weapons program, it is within DOE's inventory and potentially available for weapons; in the past, the United States has produced substantial quantities of weapons-grade plutonium by blending super-grade plutonium with fuel-grade or reactor-grade material. All of these grades of plutonium can be used to manufacture nuclear weapons.)

Today, therefore, the U.S. inventory of excess weapons-usable fissile materials includes over 225 metric tons of material, including:

- 38.2 metric tons of weapons-grade plutonium;
- 13.2 metric tons of fuel-grade plutonium;
- 1.2 metric tons of reactor-grade plutonium; and
- 175 metric tons of HEU.

The total quantity of plutonium declared excess, over 50 metric tons, is roughly half of the 99.5 metric tons now in DOE's inventory or in nuclear weapons held by the Department of Defense. This represents a major commitment on the part of the United States to substantially and permanently reduce its nuclear arsenal. The 175 metric tons of HEU declared excess represents a smaller proportion of the total U.S. HEU inventory, because the HEU which is suitable for use in naval reactors has largely been retained in military stockpiles for that purpose.

The United States will continue to review its military requirements as the international situation evolves, and may declare additional material excess in the future. Additional arms reduction agreements, should they be reached, could result in additional material being declared excess. Increasing the quantities of material declared excess would be expected to have additional arms reduction and nonproliferation benefits; these potential benefits will have to be weighed against future U.S. military requirements in making decisions concerning whether to remove additional material from the stockpile available for weapons.

U.S. excess fissile material is in a variety of forms at several locations. (See Table 2-1.) Of the excess plutonium, a substantial fraction is in the form of plutonium weapons components, or "pits." 21.3 tons of the excess plutonium is in pits from already dismantled weapons stored at Pantex, or in pits of weapons still awaiting dismantlement. Additional excess pits are stored at other sites as well. All told, the excess plutonium is estimated to include approximately 32.5 metric tons of material from weapons dismantlement and other high-purity weapons-grade metal and oxide. The excess also includes approximately 17.5 metric tons of lower purity or non-weapons grade metals and oxides, and various forms of plutonium-bearing materials including unirradiated reactor fuel, plutonium halides and other compounds. In addition to these materials, there are estimated to be 3.9 tons of plutonium in buried and stored waste materials at various sites; while these are counted as waste rather than excess material, they represent additional materials that will never be returned to weapons use.

TABLE 2-1 Excess Weapons Grade Plutonium (MT Pu)

Location	Metal	Oxide	Reactor Fuel	Irradiated Fuel	Other Forms	**Total**
Pantex/Future Dismantlements	21.3	--	--	--	--	**21.3**
Rocky Flats	5.7	1.6	--	--	4.6	**11.9**
Hanford Site	<0.1	1.0	--	0.2	0.5	**1.7**
Los Alamos	0.5	<0.1	<0.1	--	1.0	**1.5**
Savannah River	0.4	0.5	--	0.2	0.2	**1.3**
INEL	<0.1	--	0.2	0.2	<0.1	**0.4**
Other Sites	<0.1	--	--	<0.1	<0.1	**0.1**
Total	**27.8**	**3.1**	**0.2**	**0.6**	**6.4**	**38.2**

Note: Totals may not add up to rounding to the nearest tenth of a metric ton.
Source: "Plutonium: The First 50 Years" U.S. Department of Energy, February 1996, DOE/DP-0137.

Most of these forms will require substantial pre-processing to prepare them for any of the plutonium disposition alternatives. The specific types of processing needed, however, will vary depending on the initial form of the material and the specific disposition alternative for which it is to be prepared. Some of the material would require extensive and costly processing before it could be used as reactor fuel.

The plutonium and HEU that will be retained to support military missions are primarily metal (including weapons components) and oxides. These materials are stored at Pantex, Savannah River Site, Rocky Flats Environmental Technology Site, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Argonne National Laboratory-West, Idaho National Engineering Laboratory, and Hanford.

Storage and Disposition in Russia: Linkages and Differences

A primary argument for disposition of U.S. excess weapons plutonium is that U.S. action will likely be necessary to convince Russia to carry out disposition of its own excess weapons plutonium. We cannot expect Russia to be willing to eliminate its vast stockpiles of excess plutonium and HEU unless we are willing to take comparable steps ourselves. Reducing these stockpiles would increase U.S. and international confidence that current nuclear arms reductions would not be reversed, and reduce risks of nuclear proliferation from theft of this nuclear material.

Managing the hundreds of tons of weapons-usable fissile materials now resulting from the dismantlement of tens of thousands of nuclear weapons is an unprecedented challenge. Russia must face this challenge in the midst of continuing political, economic, and social transformations. The current situation in the former Soviet Union makes secure storage and disposition of weapons-usable fissile materials both more important and more difficult to achieve.

In its 1994 report, the NAS committee categorized the nuclear risks resulting from the breakup of the Soviet Union into three broad categories, including risks of:

- "breakup," meaning the possibility that more than one nuclear-armed state might result from the breakup of the Soviet Union;
- "breakdown," meaning the potential for erosion of security and accounting for weapons-usable fissile materials (and potentially nuclear weapons themselves); and
- "breakout," meaning the risk that current nuclear arms reduction agreements and pledges might be repudiated in order to reconstitute a nuclear arsenal of Cold War size.

Each of these risks is relevant to the problem of storage and disposition of weapons-usable fissile materials. The risk of "breakup" has now been largely resolved: all of the non-Russian states of the former Soviet Union have joined the NPT as non-nuclear weapon states, and agreed to send the nuclear weapons on their soil back to Russia. All nuclear weapons have already been removed from Ukraine, Kazakhstan, and all the smaller non-Russian states; only Belarus has a few Russian nuclear weapons remaining on its soil, and these are expected to be returned to Russia shortly. This resolution represents a major victory for international arms reduction and nonproliferation efforts, benefiting the security of the United States, the former Soviet states, and the international community. The disposition of excess HEU played a critical part in achieving this success: the Trilateral Agreement between the United States, Russia, and Ukraine, under which Ukraine agreed to become nuclear-weapons-free, contained a key provision under which Russia is providing Ukraine with compensation for the value of the nuclear weapons removed from Ukraine, in the form of fuel for Ukraine's power plants equivalent to the uranium from those nuclear weapons.

The risk of "breakdown," though perhaps overstated by that term, is a significant one. Russian officials acknowledge that the Soviet Union's security and accounting systems for nuclear materials were not designed to cope with the situation that now exists, and need to be modernized. Already, a number of thefts of kilogram quantities of potentially weapons-usable materials have been confirmed. Because disposition of excess plutonium will take decades to accomplish, disposal of excess material is not the most urgent step to resolve the potential proliferation threat posed by the current situation in the former Soviet Union: the key first step is to ensure that all weapons-usable nuclear materials in both the United States and the former Soviet Union are secure and accounted for. The United States, Russia, and the other states of the former Soviet Union are undertaking a major cooperative effort to achieve this objective, working together at dozens of individual sites where weapons-usable materials are stored.

In addition, the United States is providing assistance to Russia in the construction of a safe and secure storage facility for excess plutonium and HEU from dismantled weapons. Construction of this facility, at the Mayak site near the city of Chelyabinsk, has begun, and is expected to be completed in 1998 or 1999. Only excess material from dismantled weapons is to be stored at this facility: other weapons-usable fissile material will continue to be stored at a variety of other sites.

Like the United States, Russia has already made a decision to blend its excess HEU to low-enriched uranium (LEU) for sale to the United States. In the HEU Purchase Agreement, the United States and Russia have agreed that over the next 20 years, the United States will purchase low-enriched uranium blended from 500 tons of Russian HEU from dismantled weapons. The expected purchase price is in the range of $12 billion, though the specific price will vary over time with market conditions; this cost will be recovered through sales of the LEU on the commercial market for reactor fuel. Six tons of HEU was blended and delivered in the first year of deliveries, and 12 tons is expected to be delivered this year.

As in the United States, disposition of excess Russian plutonium poses more difficult challenges than HEU disposition. Like the United States, Russia has no operational industrial-scale facilities to convert plutonium weapons components into forms suitable for disposition, or to fabricate plutonium into reactor fuel or immobilize it for disposal. Unlike the United States, Russia's planned civilian nuclear fuel cycle policy is to reprocess plutonium from spent fuel and eventually recycle it in nuclear reactors. Russia's Ministry of Atomic Energy (MINATOM), therefore, is focusing on alternatives for disposition of excess weapons plutonium that focus on its use as fuel for nuclear reactors, and rejects immobilization alternatives. MINATOM views the problem of disposition of excess weapons plutonium as an integral part of its plans for civilian use of plutonium in commercial reactors, and hopes to find the funds to build new generations of plutonium-burning reactors. Yet in the difficult economic situation that Russia currently faces, it has been difficult to find significant resources for major new nuclear projects, including plutonium disposition.

Nevertheless, the United States has been working closely with Russia to explore whether there are options for disposition of Russian plutonium that could gain Russian, U.S., and international support, and for which sufficient financing might be made available. This is a critical effort because U.S. and Russian plutonium disposition efforts are integrally linked. As a fundamental part of irreversible nuclear arms reductions, disposition of excess weapons plutonium is likely to require some form of reciprocity or parallelism between the United States and Russia. As John H. Gibbons, President Clinton's Science and Technology Adviser, has said: "Neither the United States nor Russia is likely to be willing to eliminate its stockpile of thousands of bombs' worth of excess plutonium while the other side keeps its stockpile in reserve. So this job is going to be done together, or not at all."

As Gibbons went on to point out, "that does not necessarily mean, however, that the specific technology that is right for the United States is right for Russia." The United States and Russia have significantly different existing nuclear infrastructure, experience, and policies, as well as very different economic circumstances -- making it quite possible that the best disposition alternative for the United States will be different from the best disposition for Russia. Thus, while parallelism could have some advantages, the United States should not feel constrained to choose a particular alternative just because that is the alternative Russia appears likely to take.

Indeed, in ongoing studies of plutonium disposition, the U.S. and Russian governments have already agreed on these basic principles. One of the key conclusions of the U.S.-Russian joint study on plutonium disposition is that "The United States and Russia need not use the same disposition technology." The report continues, however, that "disposition of excess weapons plutonium should proceed in parallel, with the goal of reducing to equal levels of military plutonium stockpiles." Unclassified estimates indicate that Russia has approximately 200 tons of separated plutonium, including 30 tons of civilian separated plutonium which was never designated for weapons use. Reducing to a level of military plutonium matching the stockpile the U.S. currently plans to retain would mean Russia would need to declare over 100 tons of weapons plutonium excess, as well as the 30 tons of civilian material.

Unlike the United States, however, Russia has not made a specific declaration that particular quantities of material are excess to its military needs. Nevertheless, it has made a number of agreements and pledges with similar effect. The HEU Purchase Agreement just mentioned indicates clearly that Russia has at least 500 tons of excess HEU -- and Russia has made inquiries about additional sales on the international market. As noted above, Russia and the United States have agreed in principle that none of the tens of tons of plutonium and HEU Russia will store in the facility being built with U.S. assistance will ever again be used in nuclear weapons -- meaning that this material is also excess.

In their May, 1995 summit statement, President Clinton and President Yeltsin made a public commitment that neither country would use material declared excess, civilian material, or newly-produced material in nuclear weapons. Hence, the 30 tons of civilian plutonium oxide in storage at Mayak is excess to nuclear weapon needs. In addition, Russia publicly declared in October 1994 that it had ceased using plutonium from its three plutonium production reactors in nuclear weapons, and that none of this newly-produced material would ever again be used in weapons. (These reactors continue to operate because they provide needed heat and power for the nearby regions and the material is being separated since the fuel is not suitable for long-term storage.) Thus, the roughly three tons of weapons-grade plutonium produced since then should also be considered excess, along with whatever additional quantities of plutonium are produced in the future, before these reactors are shut down or converted to a fuel cycle that no long produces substantial quantities of weapons-grade plutonium.

International Concern and Cooperation

Plutonium disposition affects not only the United States and Russia, but the entire world. The P-8 countries (the Group of 7 plus Russia are referred to as the Political 8 or P-8) have recognized that effective management of the vast stockpiles of nuclear material resulting from the ongoing dismantlement of tens of thousands of nuclear warheads is a critical component of the arms reduction process.

Even before the collapse of the Soviet Union, cooperation in storage and disposition of excess fissile materials was among the first projects in cooperative threat reduction discussed by then Secretary of State James Baker and then Soviet Foreign Minister Eduard Shevardnadze. Almost immediately after coming to power, Russian President Boris Yeltsin reiterated President Gorbachev's pledges to dismantle additional tens of thousands of nuclear weapons, pledged to shut Russia's remaining plutonium production reactors by the year 2000, and raised the problem of managing the plutonium from dismantled nuclear weapons in discussions with President Bush. To address this new issue, National Security Advisor Brent Scowcroft requested the National Academy of Sciences to make recommendations concerning U.S. policies in dealing with excess plutonium, which resulted in the Academy's 1994 report.

The Clinton Administration placed new attention and focus on this issue, proposing an international ban on production of fissile materials for weapons, and establishing new efforts to find the best solution to disposition of the huge excess stockpiles of plutonium. At their January, 1994 summit, President Clinton and President Yeltsin reached agreement on several key points. First, they agreed on the objective of ensuring the "transparency and irreversibility" of nuclear arms reductions. They directed their experts to develop specific measures to achieve these objectives, with "particular attention...to materials released in the process of nuclear disarmament and steps to ensure that these materials would not be used again for nuclear weapons." In particular, they directed their experts to jointly "study options for the long-term disposition of fissile materials, particularly of plutonium, taking into account the issues of nonproliferation, environmental protection, safety, and technical and economic factors."

The study called for by the two Presidents has been prepared by a joint Plutonium Disposition Steering Committee, and will be released in September. A program of U.S.-Russian joint experiments, analyses, and technology demonstrations designed to pave the way for eventual implementation of disposition options is planned. In addition, the United States and Russia have established a bilateral group of senior, independent scientists to make recommendations to the two Presidents concerning plutonium disposition options, building on the work of the government-level Steering Committee.

Other countries are concerned as well. The understandings reached in connection with the recent indefinite extension of the NPT make it clear that the non-nuclear-weapon states will keep close watch on whether, in their view, the major nuclear weapon states are fulfilling their legal obligations to pursue arms reductions and eventual disarmament. As noted above, removing large quantities of nuclear material from the U.S. stockpile, placing it under international safeguards, and converting it to forms that make it as inaccessible and unattractive for weapons use as plutonium in spent fuel can make a major contribution to building international confidence in the arms reductions process -- which in turn will strengthen international support for maintaining and strengthening the nonproliferation regime.

Moreover, other countries, like the United States, are cooperating with Russia on plutonium disposition technologies. France and Germany, in particular, have substantial cooperative programs underway to examine issues related to the possible use of excess weapons plutonium as fuel for nuclear reactors, and Canada is beginning a joint effort with Russia to examine the feasibility of using Russian excess weapons plutonium as fuel in Canadian CANDU reactors. Other countries are financing parallel work through the International Science and Technology Center in Moscow, which the United States, Japan, and a broad range of European countries help finance.

In 1995, the leaders of the P-8 focused in their summit statement on implementation of the START II treaty, dismantlement of retired nuclear weapons, and measures to ensure "that the fissile material from these weapons is rendered unusable for weapons purposes" as the key next steps on the arms control agenda, saying that "the disposal of weapons-grade plutonium deserves particular attention. These leaders then agreed to hold a major Nuclear Safety and Security Summit, focusing in part on these issues, in Moscow in April of 1996.

The Moscow nuclear summit focused intensive high-level international attention on the problem of managing excess fissile materials. At the Moscow nuclear summit, the leaders of the P-8 nations strongly supported many of the basic principles of U.S. policy in this area. They agreed that it was essential:

- that "fissile material designated as no longer required for defense purposes will never again be used" in nuclear explosives;
- to ensure that these materials "are stored and handled under physical protection, accounting and control measures that meet the highest international standards and that ensure effective non-proliferation controls";
- to place these materials under International Atomic Energy Agency safeguards "as soon as it is practicable to do so."
- to "reduce stocks of separated plutonium and highly-enriched uranium ... as soon as practicable."
- to ensure that the result of disposition is that these materials are "transformed into spent fuel or other forms equally unusable for nuclear weapons" (the Spent Fuel Standard).

The P-8 leaders agreed that both use as reactor fuel and vitrification (i.e., immobilization in glass with fission products), followed by secure and permanent disposal, were reasonable options for achieving the Spent Fuel Standard. They welcomed ongoing and planned international cooperation in this area, including plans for technology demonstrations and pilot projects, and called for an international experts meeting to take place in France by the end of 1996. The Summit, the planned experts' meeting, and other meetings to follow are providing a crucial mechanism to begin establishing the international cooperation likely to be necessary (particularly in the case of Russian plutonium) to complete the plutonium disposition mission.

Treaties, Agreements, and Negotiations

Decisions concerning the storage and disposition of excess fissile materials are being made in the context of a broad range of international treaties, agreements, and negotiations designed to reduce nuclear arms and stem their spread, and will be designed to contribute to these efforts.

Nuclear Arms Reduction Treaties, Pledges, and Negotiations. Since the late 1980s, the United States, the Soviet Union, and now the Russian Federation, have reached several agreements and made a variety of unilateral pledges calling for substantial reductions in their deployed nuclear forces. In combination, the two Strategic Arms Reductions Treaties (START I and START II) call for each side to reduce its deployed strategic nuclear forces to roughly one-third of their peak Cold War levels, eliminating hundreds of strategic launchers, and impose stringent verification requirements, including on-site inspections. The Lisbon Protocol to START I, signed after the breakup of the Soviet Union, requires Ukraine, Kazakhstan, and Belarus to send all the nuclear weapons on their soil back to Russia, and join the nuclear Nonproliferation Treaty (NPT) as non-nuclear-weapon states.

START I and the Lisbon Protocol are ratified and in force, and their implementation is well under way; Kazakhstan and Ukraine are already nuclear-weapon-free, and the last nuclear weapons are expected to be removed from Belarus shortly. START II has been ratified by the U.S. Senate, but has not yet been ratified by the Russian Duma, and has not yet entered into force.

In addition to these treaties covering long-range strategic forces, the Intermediate-Range Nuclear Forces (INF) Treaty called for the elimination of all medium-range and intermediate-range land-based missiles on each side, which has now been completed. Russia and the United States have also each made unilateral pledges to drastically change their tactical nuclear force deployment policies, and eliminate many thousands of tactical nuclear weapons.

The United States and Russia have agreed to begin discussing measures that might be included in a follow-on agreement once START II is ratified. Vice President Gore said publicly during the NPT Extension Conference that the new international conditions after the end of Cold War will "permit -- and indeed require -- additional progress in reducing the size and structure" of U.S. and Russian nuclear forces. The United States and Russia have agreed that additional discussions on nuclear arms agreements will begin when START II is ratified by the Russian parliament.

These agreements and pledges mean that thousands of nuclear weapons are being removed from active, deployed nuclear forces. Thousands of these nuclear weapons, and hundreds of tons of fissile material once associated with military programs, are no longer needed for military purposes, and hence are "excess."

The START and INF treaties, however, focus on reducing nuclear-equipped missiles, aircraft, and launchers, not the nuclear weapons they carry. These treaties and agreements do not require either the United States or Russia to eliminate or even to account for any nuclear weapons or any of the fissile material they contain. Nevertheless, both the United States and Russia are currently dismantling thousands of nuclear weapons each year, and both have indicated that they plan to carry out disposition of hundreds of tons of excess fissile material.

Agreements specifically focused on warhead dismantlement and fissile material disposition could potentially be reached in the future.[5] The United States

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[5] At present, the only agreement between the United States and Russia related to fissile material disposition which is currently in place is the HEU purchase agreement, under which the United States is purchasing low enriched uranium blended down from 500 MT of highly enriched uranium from Russian weapon stockpiles over the next 20 years for approximately $12 billion. This material will be sold on the commercial market for nuclear power reactor fuel. In addition to this material, the United States has

and Russia have long been discussing measures related to improved security and openness with respect to nuclear weapons and fissile materials. In particular, as noted above, the two countries have been negotiating a set of information exchanges related to their stockpiles of nuclear weapons and fissile materials, and mutual inspections of certain stocks of fissile materials, collectively designed to ensure the "transparency and irreversibility" of nuclear arms reductions. These negotiations, which also relate to applying international safeguards to excess fissile materials, are collectively called the "Safeguards, Transparency, and Irreversibility" (STI) talks.

Nuclear Nonproliferation Treaties, Pledges, and Negotiations. The United States and Russia are also key parties to a broad range of international nuclear nonproliferation agreements, the most significant of which is the Treaty on the Nonproliferation of Nuclear Weapons (NPT). This agreement, which was indefinitely extended in 1995, currently has over 180 member nations and commits nuclear weapon and non-nuclear weapon states to work to prevent the proliferation of nuclear weapons. This agreement is widely considered to be the cornerstone of the nonproliferation regime, and its importance to global peace and security cannot be overemphasized.

The NPT represents a bargain between the five declared nuclear-weapon-states (the United States, Russia, Britain, France, and China) and all of the other parties, designated as non-nuclear-weapon states. The non-nuclear-weapon states agreed not to manufacture or otherwise acquire nuclear weapons or other nuclear explosives, and to accept international safeguards on all their peaceful nuclear activities to confirm that commitment. In return, the nuclear weapon states agreed to negotiate in good faith toward ending the nuclear arms race and eventual disarmament, not to assist non-nuclear weapon states to acquire nuclear weapons, and to make available the peaceful benefits of nuclear energy. Because of the inherent distinction in the NPT between nuclear-weapon-states and non-nuclear-weapon states, the treaty has occasionally come under criticism from some non-nuclear-weapon states (who represent an overwhelming majority of the parties to the treaty). Clear demonstrations that the nuclear powers, including the United States, are serious about their commitment to irreversibly reducing their nuclear arsenals are essential to the long term vitality of the NPT and the international nonproliferation regime. Fundamentally, the nonproliferation regime will continue to improve if it continues to receive the political support of its members -- and most of those members believe that further progress in permanently reducing nuclear weapons is an essential quid pro quo for their agreement to forego the nuclear option.

For this reason, the agreed document on "Principles and Objectives for Nuclear Non-Proliferation and Disarmament" from the 1995 Review and

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determined that its excess stocks of highly enriched uranium (some 175 MT) will also be blended down to low enriched uranium and sold off for use in nuclear reactor fuel.

Extension Conference, which agreed to extend the treaty indefinitely, reaffirmed the importance of "the determined pursuit by the nuclear weapon states of systematic and progressive efforts to reduce nuclear weapons globally, with the ultimate goal of eliminating those weapons" in ensuring the effective implementation of the NPT. The recent completion of a Comprehensive Test Ban Treaty, called for in the preamble of the NPT and specifically called for by 1996 by the Review and Extension Conference, is an important milestone in fulfilling this commitment. The Review and Extension Conference also emphasized the need for excess fissile materials to be permanently removed from the stockpiles available for weapons, concluding that these materials "should, as soon as practicable, be placed under Agency safeguards."

Many states have entered into binding nonproliferation commitments in addition to those of the NPT. Several nuclear-weapon-free zone treaties, for example, have been agreed, as have even more restrictive nuclear agreements in some areas, such as the Korean Peninsula, where the Republic of Korea and the Democratic People's Republic of Korea have agreed not to have facilities for either plutonium reprocessing or uranium enrichment.

The NPT and many of these other nonproliferation commitments are verified by International Atomic Energy Agency safeguards. IAEA safeguards are designed to detect the diversion of a significant quantity of nuclear materials to nuclear explosive purposes, and provide assurance that such diversions have not occurred and states are complying with their nonproliferation obligations. The effectiveness and credibility of IAEA safeguards is fundamental to the international nonproliferation regime. Traditionally, at the instruction of the member states, the IAEA focused primarily on inspecting declared nuclear material at declared sites. In recent years, however, and particularly after the revelation of Iraq's large secret nuclear weapons program, new attention has been focused on measures to detect undeclared activities at secret locations. The 1995 Review and Extension Conference agreed that "the Agency's capability to detect undeclared nuclear activities should be increased." A major international effort to strengthen IAEA safeguards is now underway, known as the "93+2" program. In some regions, IAEA safeguarding efforts are supplemented through cooperation with regional safeguarding agencies, such as EURATOM, the nuclear arm of the European Union.

Under the NPT, non-nuclear-weapon states are obligated to accept IAEA safeguards on all their civilian nuclear activities -- so-called "full-scope" safeguards. Since the IAEA does not monitor weapons or military materials, the nuclear-weapon-states do not have similar obligations. However, each of the declared nuclear weapon states have entered into "voluntary offer" agreements with the IAEA, under which they voluntarily make certain facilities on their territory eligible for IAEA safeguards. These voluntary offer agreements help build confidence in the nuclear-weapon states' commitment to international safeguards, reduce the extent of discrimination between nuclear and non-nuclear weapon states, and give the IAEA experience in safeguarding complex nuclear facilities. It is important that U.S. efforts to place excess material under international safeguards are managed in a way to build international confidence in the credibility of the safeguards system, rather than undermining it or exacerbating discrimination between nuclear and non-nuclear weapon states. Unlike the non-nuclear-weapon states, however, both the U.S. and Russian voluntary offer agreements give them the right to remove material from eligibility for safeguards at any time. Thus, if the goal were to create a binding and verified commitment that excess material would never again be used in weapons, some additional agreement or commitment would be required.

Supplementing these international commitments and verification regimes is a system of internationally coordinated export controls, controlling exports of materials and technologies that could contribute to nuclear weapons programs. The Nuclear Suppliers' Group (NSG), for example, represents the major nations that provide nuclear-related products and services to other countries, and meets to coordinate agreed export control policies. Like IAEA safeguards, the international export control system has been significantly strengthened in recent years, particularly after revelations of Iraq's covert effort to circumvent export controls and purchase the essential technologies for a nuclear weapons program. The NSG has now agreed not to undertake major new nuclear exports to countries other than the declared nuclear weapon states that do not accept full-scope IAEA safeguards, and to control the export of dual-use items. A variety of nuclear supply agreements also form part of the international nonproliferation structure: the United States, for example, has reached bilateral nuclear cooperation agreements with the European Union, Japan, and other countries that include a range of important nonproliferation commitments, required under the Atomic Energy Act and the Nuclear Nonproliferation Act of 1978.

Security for nuclear materials, and other measures to prevent nuclear theft and smuggling, are also key elements of international efforts to prevent the spread of nuclear weapons. Each state handling nuclear materials bears primary responsibility for ensuring their security. Given the dire threat that could be posed by plutonium or HEU falling into the hands of a terrorist group or rogue state, however, the international community has a legitimate interest in ensuring the adequacy of individual states' protection of these materials.

The international Convention on the Physical Protection of Nuclear Materials specifies physical protection measures that should be applied, particularly in international shipments of nuclear materials, and the NSG guidelines also specify measures to be taken by states receiving materials from NSG member states. In addition, the International Atomic Energy Agency has issued non-binding recommendations on security measures to be taken, drawn up by physical protection experts from around the world. All of these guidelines, however, are expressed in broad and general terms, to allow for the substantial differences in approach that exist among states: some states, for example, rely primarily on armed guards to ensure security at nuclear facilities, with relatively little reliance on sophisticated technologies, while other states have no armed guards at all, even at facilities with substantial quantities of plutonium and HEU, relying on technological barriers and the possibility of an armed police response once alarms were set off to provide protection. As noted earlier, the economic, political, and social transformations in the former Soviet Union have significantly weakened the nuclear security systems there, creating new nuclear proliferation concerns that represent part of the rationale for carrying out disposition of excess fissile materials.

Preventing nuclear proliferation in the long run also requires strenuous efforts to address the "demand side" -- working to resolve the security concerns and other pressures that lead nations to seek to acquire weapons of mass destruction. Thus, for example, efforts to resolve conflicts in the Middle East, South Asia, and elsewhere also represent key parts of the overall global nonproliferation effort.

For as long as nuclear weapons have existed, controlling plutonium and HEU -- their essential ingredients -- has been recognized as fundamental to any effort to control nuclear proliferation. Thus, by far the most intensive IAEA safeguards are applied to facilities that handle large quantities of plutonium and HEU, and controls on civilian nuclear trade in these materials is very stringent. The United States has undertaken a comprehensive approach for controlling the proliferation risks posed by growing stockpiles of plutonium and HEU.

First, the United States is playing a leading role in the international effort to negotiate an international convention banning the production of plutonium and HEU for nuclear explosives, or outside of international safeguards -- known as the "fissile cutoff." The United Nations General Assembly unanimously endorsed the negotiation of a multilateral, non-discriminatory and effectively verifiable fissile materials cutoff treaty. Efforts are underway at the Conference on Disarmament in Geneva to begin negotiating such an agreement. At the Review and Extension Conference, the parties to the NPT endorsed "the immediate commencement and early conclusion of negotiations" on a "non-discriminatory and universally applicable" fissile cutoff. Most of the declared nuclear weapon states, including the United States and Russia, have already declared that they have ceased producing fissile materials for nuclear weapons. The United States and Russia are now working together to convert the last three Russian plutonium production reactors, which are still operating because they provide needed heat and power for local communities. Clearly, ceasing the production of additional weapons plutonium is a critical part of the overall effort to limit and reduce these dangerous stockpiles.

Second, the United States is working to ensure that excess plutonium and HEU removed from nuclear weapons is securely stored, placed under international inspection, and ultimately transformed into spent fuel or other forms equally difficult to use in nuclear weapons. That is the principal subject of this assessment.

Third, the United States seeks to limit the accumulation of stockpiles of plutonium and HEU in the civil sector as well, and to ensure that where these materials do exist they are subject to the highest standards of safety, security, and international accountability. While maintaining our commitments as a reliable nuclear supplier, including existing long-term prior consent arrangements for the use of U.S.-origin materials in Europe and Japan, the United States does not encourage reprocessing and recycle of civilian plutonium, and therefore does not itself engage in reprocessing for either nuclear explosives or nuclear power generation. (Some reprocessing is underway in the United States to mitigate the safety risks from some nuclear materials.)

The United States has actively sought to limit the stockpiling of plutonium from civil nuclear programs; for example, in discussions in Vienna with the other major nations involved in plutonium fuel cycles, substantial agreement has been reached on improving transparency in the management of separated civilian plutonium, and the United States has proposed that countries make commitments that existing stockpiles of separated civilian plutonium -- currently amounting to over 120 tons of plutonium, all of it usable in nuclear weapons -- would be limited and reduced over time. At the same time, the United States seeks to minimize the civilian use of HEU, particularly through efforts to convert civilian research reactors to the use of low-enriched uranium fuels, which cannot sustain the explosive chain reaction needed for nuclear weapons.

3. Assessing the Nonproliferation Implications of Alternatives for Storage and Disposition of Weapons-Usable Fissile Materials

Each alternative for storage and disposition of weapons-usable fissile materials has implications for nuclear arms control and nonproliferation efforts. The criteria applied in evaluating these implications fall in 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 those related to the effect the United States' decisions will have on its current and future nuclear nonproliferation and arms reduction efforts. (Section 6 identifies steps that may contribute to maximizing benefits of individual alternatives and minimizing liabilities.)

Technical and Policy Factors

Technical factors affect the technical ability to ensure that nuclear material is not stolen by unauthorized parties or returned to weapons use by the host state during storage and disposition processes, or after disposition is complete. For example, a disposition alternative that involved many complex and difficult-to-measure material processing steps could pose substantial difficulties in providing sufficient security and accounting to ensure and verify that no material was stolen. Another disposition alternative which left the material in a form from which high-quality weapons material could be recovered relatively easily might do less to ensure that arms reductions would be difficult and costly to reverse than other alternatives would.

Policy factors affect the United States' ability to maintain and strengthen international efforts to reduce nuclear arms and stem their spread, including the overall approach to the use of weapons-usable material in the civilian nuclear fuel cycle. For example, implementing a disposition alternative that made the U.S. excess weapons material difficult and costly to retrieve could help demonstrate our commitment to irreversible nuclear arms reductions, which in turn could significantly contribute to U.S. efforts to negotiate reductions in other nations' nuclear arms, and strengthen international political support for tougher measures to prevent the spread of nuclear weapons. A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries; if this in fact led to significant additional separation and handling of weapons-usable plutonium, that could itself pose proliferation risks. Alternatively, by implementing stringent standards of security and accounting in its disposition programs, the United States might be able to develop and demonstrate improved procedures and technologies for protection and safeguarding of plutonium, which might be applied in other states as well, reducing proliferation risks.

Thus, both technical and policy factors must be carefully considered under each alternative in making an overall nonproliferation and arms reduction assessment of the alternatives for storage and disposition of excess weapons-usable materials.

Criteria for Storage of Weapons-Usable Fissile Materials

The nonproliferation and arms reduction implications of storage alternatives are less complex than those for plutonium disposition, because the primary choices under consideration with respect to storage of weapons-usable fissile materials relate simply to the specific sites where the material will be stored. These criteria refer only to *interim* storage of the excess material; continuing storage indefinitely (the no-action alternative for plutonium disposition) must be considered as one of the disposition alternatives, using the criteria for disposition alternatives described below.

Technical Factors

The principal technical factor involved in storage decisions is the ability to continue to provide highly effective safeguards and security, to continue to ensure that no nuclear material could be stolen. All facilities under consideration will have safeguards and security specified by DOE orders for facilities handling nuclear weapons or separated plutonium and highly-enriched uranium. All systems meeting these requirements are expected to be highly effective. However, the amount of transportation required for particular alternatives, or the ability in some alternatives to build new, specially-designed security systems that may have higher levels of effectiveness are factors to be considered.

Policy Factors

There are two main policy factors related to storage of fissile materials. The first is the degree to which each storage alternative could support bilateral or international monitoring, while protecting classified information. The second consideration is the impact, if any, of each alternative on storage of weapons-usable fissile materials in Russia and other nuclear weapon states or advanced nuclear industrial states, and on the arms reduction and nonproliferation regimes.

Criteria for Plutonium Disposition

Technical Factors

Each of the stages of plutonium disposition poses nonproliferation and arms reduction risks. The risks associated with each stage of the disposition process -- and "standards" for measures to mitigate these risks -- were summarized by the NAS Committee on International Security and Arms Control in its 1994 report:

> *Risks of Storage*: Prolonged storage of excess weapons plutonium would mean a continuing risk of breakout, as well as of theft from the storage site. In addition, extended storage of large quantities of excess fissile materials, particularly in the form of weapons components, could undermine the arms reduction and nonproliferation regimes. Thus, long-term disposition alternatives should minimize the time during which plutonium is stored in accessible forms. The timing for each long-term disposition alternative is dependent on three factors: its technical readiness or uncertainty, the speed with which public and institutional approval could be gained, and the time required to implement it once developed and approved.
>
> *Risks of Handling*: Nearly all disposition alternatives other than indefinite storage require processing and usually transportation of plutonium in ways that could increase access to the material and complicate accounting for it, thus increasing the potential for diversion and theft. In order to ensure that the overall process reduces net security risks, an agreed and stringent standard of security, safeguards, and accounting must be maintained throughout the disposition process, approximating as closely as practicable the security and accounting applied to intact nuclear weapons. The committee calls this the "stored weapons standard."....
>
> *Risks of Recovery*: A third key security criterion for judging disposition alternatives is the risk of recovery of the plutonium after disposition. The committee believes that alternatives 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. Alternatives that left the plutonium more accessible than this existing stock would mean that this material would continue to pose a unique safeguards problem indefinitely. Conversely, as long as civilian plutonium exists and continues to accumulate, alternatives that went further than the spent fuel standard and sought to eliminate the excess weapons plutonium entirely would provide

little additional security, *unless the same were done with the much larger amount of civilian plutonium.*

In the analyses of the technical factors related to each disposition alternative considered in this assessment, criteria similar to these are given different names to improve clarity. "Risks of Storage" are referred to as "Schedule"; "Risks of Handling" are referred to as "Risks of Theft or Diversion in Process"; and "Risks of Recovery" are referred to as "Risks of Recovery and Re-Use in Weapons".

As the NAS committee pointed out, the schedule for implementing an alternative is a critical factor, because it determines how rapidly the benefits of plutonium disposition can be achieved, and the technical and policy liabilities related to continued storage in directly weapons-usable form reduced.

Similarly, assuring against theft or diversion of strategically significant quantities of material by the host state, is also critical to the objectives of arms reduction and nonproliferation, as is assuring that the material is transformed in ways that make its recovery and re-use in weapons difficult, costly, time-consuming, and observable.

Protecting Attractive Nuclear Material: The Stored Weapons Standard

Fissile materials are the essential ingredients of nuclear weapons, and hence must be stringently protected and accounted for. Much of the knowledge needed to produce a first-generation nuclear weapon of the types that destroyed Hiroshima and Nagasaki is now widespread. But both plutonium and highly-enriched uranium are difficult and expensive to make: limited access to these materials is the principal technical barrier to nuclear proliferation in the world today. With access to appropriate fissile material, many nations and even some sub-national groups could potentially produce a nuclear weapon. Hence, some nations or groups may be willing to pay hundreds of millions or even billions of dollars for the material necessary to build a small stockpile of nuclear bombs. Therefore, it is essential that security and accounting systems be effective enough to prevent any theft of nuclear material that could be used to make a bomb: plutonium and HEU must be protected more effectively than even gold and diamonds are protected.

Not all types of nuclear material would be equally useful to a potential illicit bomb-maker. Some types of material, such as metallic plutonium or HEU, could be used directly in a nuclear weapon without any chemical processing. Other types of nuclear material, such as plutonium in radioactive spent nuclear fuel, would require complex chemical processing steps before they could be used in a weapon. These types of material would therefore be less attractive targets for theft, and require somewhat less security than do directly weapons-usable materials. Similarly, stores of fissile material containing much less than the amount of material needed for a bomb require less security than stores containing enough material for many bombs.

For these reasons, DOE has developed a "graded safeguards system" applying different levels of security and control to different types and amounts of nuclear material. Each type of material is graded on the basis of its "attractiveness" to a potential proliferator -- that is, how easily it could be used to make a nuclear bomb. Table 3-1 shows the different levels in DOE's graded safeguards system.

Type of Material	Attractiveness Level	Safeguards Category (I = Greatest Concern) Versus Quantity of Contained Material (kg)							
		Pu or U-233				U-235			
		I	II	III	IV	I	II	III	IV
Weapons[a]	A	Any quantity is Category I							
Pure products[b]	B	>2	.4-2	.2	<.2	>5	1-5	.4-1	<.4
High-grade materials[c]	C	>6	2-6	.4-2	<.4	>20	6-20	2-6	<2
Low grade materials[d]	D	NA	>16	3-16	<3	NA	>50	8-50	<8
All other materials[e]	E	any reportable quantity is Category IV				any reportable quantity is Category IV			

NOTE: Reportable quantities are 1g of Pu-239 to Pu-242 and enriched uranium, .1g of Pu-238, NA = not applicable
a. Assembled weapons and test devices.
b. Pits, major components, buttons, ingots, recastable metals, directly convertible materials.
c. Carbides, oxides, solutions of >25 g/L, nitrates, etc., fuel elements and assemblies, alloys and mixtures, UF_4 or UF_6 at 50% or more enrichment.
d. Solutions of 1-25g/L, process residues, requiring extensive processing, moderately irradiated material, Pu-238 (except in waste), UF_4 or UF_6 at 20-50% enrichment.
e. Highly irradiated forms, solutions of <1g/L, uranium in any form or quantity containing greater than 20% U-235.

DOE's Graded Safeguards System
Table 3-1

Because getting hold of the fissile material needed for a nuclear bomb is the key step toward actually being able to make a bomb, the 1994 NAS committee report recommended that to the extent possible, security and accounting for separated plutonium and HEU should meet the same high standards applied to protecting and keeping track of nuclear weapons themselves -- a concept the NAS called the "Stored Weapons Standard." DOE's Materials Disposition program has adopted this recommendation. In other words, the most attractive types of material in the graded safeguards system -- material that could be used directly in nuclear weapons or could be readily converted for such use -- will, to the extent practicable, be protected and accounted for just as well as nuclear weapons themselves are. For example, the Materials Disposition Program intends to transport excess weapons plutonium and fresh nuclear fuel containing excess weapons plutonium in the same Safe, Secure Transports (SSTs) used to transport nuclear weapons.

Processing and transport of nuclear material, however, inevitably involves greater near-term risks than storage in a high-security, continuously monitored vault. The NAS committee recognized this, and described the Stored Weapons Standard as a goal to be approached as closely as practicable, not a standard that must always be continuously achieved. The proliferation vulnerability Red Team has concluded that every one of the alternatives for plutonium disposition alternatives must pass through some steps that do not meet the Stored Weapons Standard, and cannot be made to do so with any feasible application of resources. In other words, there will be some short-term increase in proliferation risk resulting from disposition activities -- in return for the large long-term reduction in risk once disposition is complete. With appropriate application of safeguards and security resources, however, this short-term increase in risk can be reduced to a low level, so that disposition programs overall clearly reduce rather than increase net proliferation risk.

Box 3-1

Reactor-Grade and Weapons-Grade Plutonium in Nuclear Explosives

Virtually any combination of plutonium isotopes—the different forms of an element having different numbers of neutrons in their nuclei—can be used to make a nuclear weapon. Not all combinations, however, are equally convenient or efficient.

The most common isotope, Pu-239, is produced when the most common isotope of uranium, U-238, absorbs a neutron and then quickly decays to plutonium. It is this plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors. As fuel in a reactor is exposed to longer and longer periods of neutron irradiation, higher isotopes of plutonium build up as some of the plutonium absorbs additional neutrons, creating Pu-240, Pu-241, and so on. Pu-238 also builds up from a chain of neutron absorptions and radioactive decays starting from U-235.

These other isotopes create some difficulties for design and fabrication of nuclear weapons. First and most important, Pu-240 has a high rate of spontaneous fission, meaning that the plutonium in the device will continually produce many background neutrons, which have the potential to reduce weapon yield by starting the chain reaction prematurely. Second, the isotope Pu-238 decays relatively rapidly, thereby significantly increasing the rate of heat generation in the material. Third, the isotope Americium-241 (which results from the 14-year half-life decay of Pu-241 and hence builds up in reactor-grade plutonium over time) emits highly penetrating gamma rays, increasing the radioactive exposure of any personnel handling the material.

Because of the preference for relatively pure Pu-239 for weapons purposes, when a reactor is used specifically for creating weapons plutonium, the fuel rods are removed and the plutonium is separated from them after relatively brief irradiation (at low "burnup"). The resulting "weapons-grade" plutonium is typically about 93 percent Pu-239. Such brief irradiation is quite inefficient for power production, so in power reactors the fuel is left in the reactor much longer, resulting in a mix that includes more of the higher isotopes of plutonium. In the United States, plutonium containing between 80 and 93 percent Pu-239 is referred to as "fuel-grade" plutonium, while plutonium with less than 80 percent Pu-239 -- typical of plutonium in the spent fuel of light-water and CANDU reactors at normal irradiation -- is referred to as "reactor-grade" plutonium.

All of these grades of plutonium can be used to make nuclear weapons. The only isotopic mix of plutonium which cannot realistically be used for nuclear weapons is nearly pure Pu-238, which generates so much heat that the weapon would not be stable. (International rules require equal levels of safeguards for all grades of plutonium except plutonium containing more than 80% Pu-238, which need not be safeguarded.)

Designing and building an effective nuclear weapon using reactor-grade plutonium is less convenient than using weapon-grade plutonium, for several reasons. Some nuclear weapons are typically designed so that a pulse of neutrons will start the nuclear chain reaction at the optimum moment for maximum yield; background neutrons from Pu-240 can set off the reaction prematurely, and with reactor-grade plutonium the probability of such "pre-initiation" is large. Pre-initiation can substantially reduce the explosive yield, since the weapon may blow itself apart and thereby cut short the chain reaction that releases the energy. Nevertheless, even if pre-initiation occurs at the worst possible moment (when the material first becomes compressed enough to sustain a chain reaction), the explosive yield of even a relatively simple first-generation nuclear device would be of the order of one or a few kilotons. While this yield is referred to as the "fizzle yield," a 1-kiloton bomb would still have a radius of destruction roughly one-third that of the Hiroshima weapon, making it a potentially fearsome explosive. Regardless of how high the concentration of troublesome isotopes is, the yield would not be less.

Dealing with the second problem with reactor-grade plutonium, the heat generated by Pu-238 and Pu-240, requires careful management of the heat in the device. There are well developed means for addressing these problems and they are not considered a significant hurdle to the production of nuclear weapons, even for developing states or sub-national groups. The radiation from Americium-241 means that more shielding and greater precautions to protect personnel might be necessary when building and handling nuclear explosives made from reactor-grade plutonium. But these difficulties are not prohibitive. While reactor-grade plutonium has a slightly larger critical mass than weapon-grade plutonium (meaning that somewhat more material would be needed for a bomb), this would not be a major impediment for design of either crude or sophisticated nuclear weapons.

The degree to which these obstacles can be overcome depends on the sophistication of the state or group attempting to produce a nuclear weapon. At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that). At the other end of the spectrum, advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapons-grade plutonium. The greater radioactivity would mean increased radiation doses to workers fabricating such weapons, and military personnel spending long periods of time in close proximity to them, and the greater heat and radiation generated from reactor-grade plutonium might result in a need to replace certain weapon components more frequently. Proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device.[6]

Every state which has built nuclear weapons from plutonium to date has chosen to produce weapons-grade plutonium for that purpose. States have been willing to make large investments in some cases to acquire weapon-grade rather than reactor-grade plutonium: the United States, for example, in the 1980s, considered spending billions of dollars on the Special Isotope Separation facility to enrich reactor-grade plutonium to weapon-grade. The disadvantage of reactor-grade plutonium is not so much in the effectiveness of the nuclear weapons that can be made from it as in the increased complexity in designing, fabricating, and handling them. The possibility that either a state or a sub-national group would choose to use reactor-grade plutonium, should sufficient stocks of weapon-grade plutonium not be readily available, cannot be discounted.

In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states. Theft of separated plutonium, whether weapons-grade or reactor-grade, would pose a grave security risk.

[6] See W. G. Sutcliffe and T.J. Trapp, eds., *Extraction and Utility of Reactor-Grade Plutonium for Weapons*, Lawrence Livermore National Laboratory, UCRL-LR-115542, 1994 (S/RD). ~~[xxx update reference it actually came out in 1995]~~
The Pu-240 content even in weapons-grade plutonium is sufficiently large that very rapid assembly is necessary to prevent pre-initiation. Hence the simplest type of nuclear explosive, a "gun type," in which the optimum critical configuration is assembled more slowly than in an "implosion type" device, cannot be made with plutonium, but only with highly enriched uranium, in which spontaneous fission is rare. This makes HEU an even more attractive material than plutonium for potential proliferators with limited access to sophisticated technology. Either material can be used in an implosion device.

Making Nuclear Material Unattractive: The Spent Fuel Standard

The fundamental purpose of disposition of excess fissile materials is to help ensure that these materials will never again be returned to weapons, by transforming them in ways that would make it difficult and costly to retrieve them for use in weapons. It is important to understand, however, that in every one of the disposition alternatives under consideration, it would still be possible to recover nuclear materials which could be used to make nuclear bombs: disposition would only increase the difficulty, cost, and observability of taking such a step, not preclude it entirely.

A key question here is "how much is enough?" How inaccessible and unattractive for weapons use must the plutonium be, before disposition can be said to have met its goals? To answer this question, the NAS committee pointed out that there is a large quantity of other plutonium in the world, most of which currently exists in highly radioactive spent fuel from commercial nuclear power reactors. (All currently operating commercial power reactors produce plutonium in their spent fuel as an inevitable byproduct of their operation. Approximately 800 tons of plutonium exists in spent fuel today, much more than the amount in military stockpiles.) Thus, if weapons plutonium were transformed so as to make it as inaccessible and unattractive for use in nuclear weapons as plutonium in spent fuel, it would become only one part of a much larger stockpile that the international community must deal with in any case, and would no longer add significantly to global nuclear weapons risks or present a significantly more attractive target for diversion . Thus, the NAS recommended that the national objective should be to make the excess weapons plutonium "roughly as inaccessible for weapons use as the much larger and growing quantity of plutonium that exists in spent fuel from commercial reactors." They called this concept the Spent Fuel Standard. The DOE Materials Disposition program has also adopted this recommendation, with the clarification that the disposition alternatives should make the plutonium as *unattractive* and as *inaccessible* for retrieval and weapons use as the residual plutonium in spent fuel from commercial reactors.

The inaccessibility and unattractiveness of plutonium in spent fuel arises from several factors. (See "The Spent Fuel Standard: How Accessible Is Plutonium in Spent Fuel?" p. 48.) The plutonium is chemically diluted with other elements in the spent fuel, meaning that the spent fuel has to be chemically processed to separate the plutonium (known as "reprocessing.") The spent fuel is intensely radioactive, though this radioactivity declines over time (after about a decade of cooling, the remaining radioactivity declines by half every 30 years). As a result, the chemical processing must be done remotely in special facilities equipped with shielding to protect the workers from the radiation. In the case of light-water reactors, the most common type, the fuel is in massive fuel assemblies requiring special handling equipment to move. Finally, commercial spent fuel contains more of the isotopes of plutonium that are less desirable for weapons purposes than does weapons-grade plutonium, somewhat complicating the construction of nuclear explosives from this material. Nuclear weapons can be made from either reactor or weapons-grade plutonium, however.

The Spent Fuel Standard does not mean that weapons plutonium must literally be transformed into spent fuel. Nor is it necessary that the final product of a disposition alternative have all of the characteristics of spent fuel just described for the alternative to meet the objective. Rather, the idea behind the Spent Fuel Standard is to create a variety of barriers to recovery and weapons use of the weapons plutonium which, between them, would make it roughly as inaccessible and unattractive as the plutonium in spent fuel. The Spent Fuel Standard is a broad target area, not a single point on some imaginary graph of proliferation resistance. The NAS committee study, for example, concluded that plutonium vitrified with highly radioactive fission products, or plutonium buried in miles-deep boreholes, would be as inaccessible for use in weapons as plutonium in spent fuel, and thus would meet the Spent Fuel Standard.

The logic of the spent fuel standard is clear. If plutonium disposition alternatives succeed in making it as difficult to recover the excess weapons plutonium and make bombs from it as it would be to recover and make bombs from the plutonium that already exists in spent fuel, then the excess weapons plutonium will become only one small part of a larger issue that must be managed in any case, and will no longer pose any unique security threat. Alternatives that left the weapons plutonium more accessible than this standard would mean that this material would continue to pose a unique risk of theft or remilitarization indefinitely. Conversely, spending additional time and resources making excess weapons plutonium even *more* inaccessible and unattractive for weapons use than plutonium in spent fuel would have little security benefit, because in that case those who might seek to acquire nuclear weapons would still have the potential possibility of recovering plutonium from commercial spent fuel.

Types of Threats

The potential threats considered in this assessment include illicit removal, either overtly or covertly, of plutonium-bearing material for use in nuclear weapons by either unauthorized parties or by the host nation. It is critical to differentiate between unauthorized and host-nation threats, and covert and overt means, because these possibilities raise very different security issues and require very different measures to address them.

Host State Diversion or Recovery. One possibility is that the host state where the disposition activities were underway -- the United States or Russia, in the case of most disposition alternatives -- might attempt to divert nuclear materials during the various processes of storage and disposition, or recover them after disposition was complete, for use in nuclear weapons.

Given the new reality of ongoing nuclear arms reductions, neither the United States nor Russia is likely to seek to re-use any of their excess material to re-build their nuclear arsenals in the near term. In the Clinton-Yeltsin summit statement of May 1995, the United States and Russia publicly committed themselves never to use material declared excess in nuclear weapons. During the course of storage and disposition, it is likely that additional political and legal commitments to this effect will be made. Thus, a decision to re-use this material in weapons would mean repudiating a range of commitments, and would only be conceivable in the context of a radically changed international security environment that seemed to require the reconstruction of Cold War nuclear arsenals.

An obvious question that arises in considering plutonium disposition is: why should the United States spend a great deal of money to make it difficult for itself to get its own plutonium back, should it choose to do so in the future? The short answer is that the United States needs to do so if it is to expect Russia to take comparable steps, and to build international confidence that our commitment never again to use these materials in weapons is not likely to be reversed. The goal of making it difficult for the host nation to reuse plutonium for weapons once it has been declared surplus and entered into the disposition process is fundamental to two of the objectives identified by the NAS committee report: (1) minimizing the risk that the materials could be reintroduced into the arsenals from which they came, thereby halting or reversing the arms reduction process, and (2) strengthening the national and international control mechanisms and incentives designed to ensure continued arms reductions and prevent the spread of nuclear weapons.

Thus, despite the low probability of any effort by the United States or Russia to divert material during processing, or to recover it after disposition was complete, it is critical that U.S. disposition programs demonstrate to Russia and the international community that any significant diversion would be readily detected, and that any significant recovery of the material would be observable, costly, and time-consuming -- in particular, that they result in an end state that meets the Spent Fuel Standard. Both the United States and Russia have sophisticated nuclear complexes, and would be able to recover plutonium from any of the disposition forms under consideration, should they choose to do so, but disposition could increase the detectability, cost, and delay involved in such an effort, and thereby decrease the probability of a decision to undertake it.

The United States and Russia are nuclear weapon states that already possess thousands of nuclear weapons, and will continue to possess substantial nuclear arsenals for some time to come. Therefore, diversion or recovery of a few kilograms of material by either of these countries would not be strategically significant. Thus, while IAEA safeguards applied under the U.S. and Russian voluntary offer agreements are traditionally designed with the same detection goal as safeguards applied in non-nuclear-weapon states (that is, detecting removal of as little as eight kilograms of plutonium, one "significant quantity" in IAEA parlance), that goal is more than would really be required to provide assurance that neither the United States nor Russia were removing strategically significant quantities of material from the process.

In alternatives in which non-nuclear-weapon states such as Canada or Belgium would serve as the host state for part of the disposition operations, the issues would be substantially different. Since neither of these countries are weapon states, diversion of even a single significant quantity would be enough for a bomb; in addition, in these states, IAEA safeguards are mandatory, rather than voluntary. Both of these states have excellent nonproliferation credentials.

In short, for operations in the United States or Russia, tons of material would have to be diverted or recovered to be strategically significant, and international monitoring could easily detect any diversions or recovery on such a scale. (Indeed, to assure the full credibility of these safeguards and minimize discrimination, it is likely that, as in the case of the current voluntary offer agreement, the detection goal the IAEA will aim for, whether it is achieved or not, will be one significant quantity of plutonium, or eight kilograms.) Thus, *covert* diversion and recovery can be effectively ruled out as a possibility if effective international monitoring is applied to the process.

Theft by Unauthorized Parties. Another possibility is that material might be stolen by unauthorized parties -- either in process, or after disposition was complete. Subnational criminal or terrorist groups, for example, might launch an overt armed attack on a processing facility or a material shipment in an effort to steal plutonium. Alternatively, insiders at a processing facility might attempt to covertly steal plutonium and smuggle it out of the facility. A theft of plutonium could lead to a subnational group attempting to make a crude nuclear weapon, or the thieves could provide the material to a proliferating state, which might use it to produce more sophisticated nuclear weapons. Subnational groups could range from lone individuals (who are highly unlikely to be able to gain access to plutonium in the United States or to do very much with it if they did) to large and sophisticated groups with many members, substantial financing, and significant technical expertise.

Unlike the host state case, theft of even a tiny fraction of the total amount of excess weapons plutonium could pose a major security threat. Four kilograms of plutonium -- less than one part in ten thousand of the total excess stock -- is theoretically enough to make a nuclear weapon. As recent confirmed seizures of stolen weapons-usable nuclear material in Europe and the former Soviet Union make clear, the threat of proliferation resulting from theft of nuclear materials is very real.

Barriers to Using Excess Material In Nuclear Weapons

A variety of measures can help limit the chance that either the host state or an unauthorized party would use excess material in weapons, imposing different barriers which must be overcome. How large these barriers are -- how much overall proliferation resistance or diversion resistance a system offers -- is not measurable, and therefore no effort at quantitative estimation is made in this assessment.

The Proliferation Vulnerability Red Team developed a useful framework for describing the different types of barriers that would face any effort to use excess materials in nuclear weapons. This framework focuses on questions such as: how accessible is the material? How observable would any effort to remove it and recover it be? What utility would the material have for making a bomb if it was acquired? What types of measures affect the accessibility, observability, and utility? (These measures include physical protection, material control and accounting (including both domestic and international monitoring), the environment in which the material is located, and the form of the material itself.) Finally, how much do the barriers rely on institutional measures (such as monitors and guards), and how much do they rely on the intrinsic properties of the material itself or its inaccessible location?

Figure 3-1 provides a graphical depiction of this framework, showing the general classes of barriers (accessibility, observability, utility) across the top, and the measures that could be used to create these barriers (physical protection, material control and accounting, the environment in which the material exists, and the form of the material itself) down the left. As the figure shows, physical protection, material control and accounting, and the environment have no impact on the utility of the material once it was acquired; that is affected only by the form of the material. Similarly, material control and accounting does not in itself limit the accessibility of the material in the absence of physical protection -- it only contributes to the observability of any effort to get to it for use in weapons. (Material control measures could frequently provide an alarm that would allow physical protection forces to respond however; ideally, all of these measures are integrated in a complete system.)

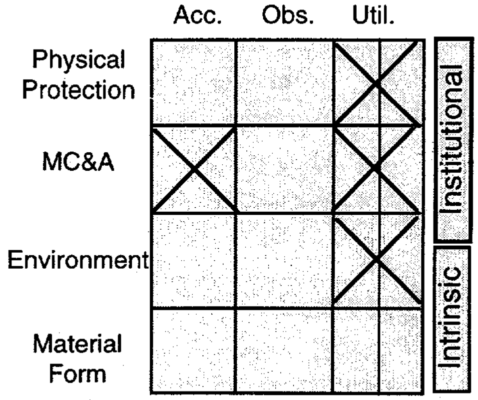

Figure 3-1 Proliferation Resistance Framework

In the Red Team's framework, *accessibility* barriers make it difficult to access and remove plutonium-bearing material from within a disposition process. Armed guards, secure vaults, an environment such as buried in a deep borehole, and highly radioactive materials could all contribute to accessibility barriers. *Observability* barriers make it difficult to access and remove material without being detected and recognized, and hence increase the likelihood of recapture and recovery of the material. All of the categories of measures on the left-hand side of the chart could potentially contribute to observability. The *utility* category refers to the usefulness of the material for making nuclear weapons once it is acquired: how difficult would it be to recover the plutonium from the material, and to make weapons of the type desired from the plutonium recovered. In general, only the form of the material itself affects utility. The relative significance of each of these types of barriers depends in large part upon the type of threat scenario under consideration.

Categories of Contributing Measures and Features. A wide range of diverse features and measures associated with the plutonium disposition processes contribute to the various components of proliferation resistance. These have been grouped into the four broad categories represented by the rows in the figure above: physical protection, MC&A, environment, and material form.

The "physical protection" category includes measures implemented by the host state to deter, detect, delay, and deny any attempt by unauthorized parties to remove material. They contribute to the accessibility and observability barriers. Physical protection measures are provided by and under the direct control of the host nation, and therefore have no bearing upon considerations of host diversion. International safeguards have no protective role in limiting access to the material.

The "MC&A" category includes the domestic material control and accounting measures which, along with physical protection measures, constitute domestic safeguards. Both DOE and NRC regulations call for graded domestic safeguards based upon material attractiveness (quantity and form), with the most stringent requirements applied to materials of greatest strategic value. The MC&A category also includes the material accountancy and complementary containment and surveillance measures which constitute international safeguards. The international safeguards provide a means for the international community to verify the host's system of accounting for plutonium-bearing material, and thus a means of detecting illicit diversion by the host nation. This category of measures contributes only to the observability barriers.

The "environment" category represents a diverse set of features inherently associated with the conditions under which the material is located within a particular stage of the disposition process. These features contribute most directly and strongly to the accessibility component of proliferation resistance, in terms of its exposure to opportunities for illicit removal. For example, the exposure of material stored in sealed containers within a continuously monitored vault which is infrequently accessed is inherently less than material being handled by technicians within a processing facility. Some features within the "environment" category can also contribute to the observability barrier. For example, material sealed within an underground repository is not only inherently difficult to reach, but the access operations may require the use of heavy equipment over long periods of time, making them difficult to conceal. All of the features in this category are relevant to the proliferation resistance against threats from unauthorized parties. Some features, such as geologic depth, can also provide significant resistance against host diversion.

The final category of features which influence proliferation resistance is material form. These are intrinsic properties associated with the plutonium-bearing material. The properties of primary relevance include plutonium dilution, size and mass, chemical form, and the presence and intensity of an ionizing radiation barrier. Collectively, these can contribute to all of the barriers. Plutonium in the form of pits or cans of concentrated plutonium oxide contribute essentially nothing to proliferation resistance. These are significant quantities of plutonium in packages that are relatively easy to carry and conceal, and which require minimal processing to be usable for weapons. In the immobilization and reactor disposition alternatives, the material form properties listed above are all altered for the effect of significantly increasing their contribution to proliferation resistance.

Institutional vs. Intrinsic Contributions. It is also important to consider the relative reliance upon institutional versus intrinsic contributions to proliferation resistance. Institutional measures are those contributors to proliferation resistance that require the effective performance of people and institutions, including physical protection, MC&A, and part of the environment category. Intrinsic features of a disposition process are those that still contribute to proliferation resistance if the performance of people is removed from consideration. The material form and much of the environment category are intrinsic contributors to proliferation resistance.

The excess plutonium entering the disposition processes is in a condition which relies primarily upon institutional measures for proliferation resistance against threats from unauthorized parties. However, these provide essentially no barriers to the ability of the host to rapidly reuse this material in nuclear weapons. All of the plutonium disposition processes result in end states for which intrinsic properties contribute significantly to proliferation resistance, and for which there is less reliance upon institutional measures.

Example: Stored Pits at Pantex. Nuclear weapons and plutonium pits in storage at Pantex are afforded a very high level of security, representing the Stored Weapons Standard. Figure 3-2 depicts some of the components contributing to proliferation resistance for such conditions. High proliferation resistance against threats by unauthorized parties is provided primarily by institutional measures, such as the strict access controls and real-time monitoring associated with the multi-tiered, high security posture. Storage of plutonium in pit form provides no barrier to reassembly into weapons by the host nation; currently, no international monitoring is in place at Pantex, so even an observability barrier is not necessarily present (though should the United States restart assembly of nuclear weapons, it would rapidly become widely known, given the openness of U.S. society).

PROLIFERATION RESISTANCE - STORED PITS

	ACCESSIBILITY	OBSERVABILITY	UTILITY	
PHYSICAL SECURITY DOE Category 1 facility	•Heavily armed, high posture security force. •Strict access controls.	•Multi-tier, real time access monitoring. •Perimeter intrusion detection.		Institutional
MC&A Real-time monitoring.		•Periodic audits. •Item accountability. •Zero measurement errors. •Environmental monitors		Institutional
ENVIRONMENT Container in hardened vault.	•Minimal activity. •Multi-ton barrier at vault entrance. •Restricted openings. •Unauthorized access penalties.	•Real-time access monitoring. •Minimum activity area.		Intrinsic
MATERIAL FORM Pits.	•Small portable units.	•Low intrinsic signatures.	•Directly usable material.	Intrinsic

Figure 3-2 Proliferation Resistance of Stored Pits

Example: Commercial Spent Fuel. Since the goal of U.S. disposition programs is to meet the Spent Fuel Standard, another useful example of this approach is the case of commercial spent fuel. The Spent Fuel Standard itself refers to the intrinsic properties of the material and the environment; however, since spent fuel itself poses some proliferation risk, institutional measures continue to be needed to provide some level of protection and monitoring for spent fuel. For example, proximity of a reactor site security force contributes significantly to the accessibility and observability barriers against unauthorized theft, and IAEA safeguards could provide a mechanism for international observability of diversion by the host state.

PROLIFERATION RESISTANCE - COMMERCIAL SPENT FUEL

	ACCESSIBILITY	OBSERVABILITY	UTILITY	
PHYSICAL SECURITY NRC licensed security systems.	•Armed plant security force nearby. •Site access restrictions.	•Perimiter intrusion detection.		Institutional
MC&A IAEA Safeguards.		•Periodic audits. •Item accountability. •Zero measurement errors.		
ENVIRONMENT Dry cask storage.	•Massive sealed container. •Heavy lift equipment needed.	•Access delays & signatures. •Minimum area activity.		
MATERIAL FORM Spent fuel bundles.	•Hazardous proximity without shielding. •Heavy handling equipment needed.	•Distinctive, difficult to mask signatures.	•Lethal proximity without shielding. •Complex chemistry. •Degraded isotopics.	Intrinsic

Figure 3-3 Proliferation Resistance of Spent Fuel

Policy Factors

Assessments of the policy factors relating to the nonproliferation and arms reduction impacts of plutonium disposition alternatives are inevitably more subjective than assessments of the technical factors. Nevertheless, the impact of different disposition alternatives on global nuclear arms reduction and nonproliferation efforts must be carefully considered in choosing a preferred alternative for plutonium disposition. The choice of plutonium disposition alternatives can influence the likelihood of achieving disposition of Russian excess plutonium, using methods that benefit U.S. security; the prospects for achieving further nuclear arms reductions; the prospects for preventing nuclear proliferation, including international political support for the nonproliferation regime; and choices relating to the use of weapons-usable materials in the civilian nuclear fuel cycle. Moreover, the political implementability of each alternative must be carefully considered, as that will affect the likelihood of success in implementing the alternative, and the schedule for implementation.

Impact on Russian Programs

Russia is the only other nation that currently possesses large quantities of excess weapons plutonium. A key motivation for disposition of U.S. excess plutonium is to encourage disposition in Russia, using approaches that would ensure effective nonproliferation controls. Each alternative's ability to contribute to that objective, and to U.S.-Russian cooperation in this area, must be carefully assessed.

Impact on Nuclear Arms Reduction Efforts

A major goal of any decision to carry out disposition of excess U.S. fissile materials is to strengthen ongoing nuclear arms reductions efforts, and lay the basis for further arms reduction agreements, should a decision be taken to pursue such agreements. In particular, as noted above, the United States seeks to ensure that the nuclear arms reductions now underway will not be reversed, and fissile material disposition programs can play a key role in demonstrating the lengths to which the United States is willing to go to meet that objective. Therefore, a major consideration in assessing any disposition alternative is its potential impact on efforts to achieve irreversible nuclear arms reductions.

Impact on Nonproliferation Efforts

The United States is and must remain a leader in the international arms control and nonproliferation arena. Its actions and statements related to nuclear weapons policies are observed closely by allies and other states. As noted in the previous section, implementation of plutonium disposition alternatives that met the spent fuel standard could have a significant positive impact on international perceptions of U.S. and Russian seriousness in meeting their NPT commitments to pursue an end to the arms race, with the goal of eventual disarmament.

Implementation of effective plutonium disposition alternatives could also have significant impacts on other nonproliferation agreements and negotiations. For example, placing excess material under safeguards and carrying out disposition could help address the issue of existing stockpiles of fissile material, which has been controversial in the fissile cutoff negotiations Whether U.S. and Russian disposition choices and the way they are implemented would affect other countries' nuclear programs and choices should also be considered. States potentially affected by decisions concerning management of nuclear materials include other nuclear weapon states, industrialized non-nuclear-weapon states, developing non-nuclear-weapon states, states outside the nonproliferation regime (such as India, Pakistan, and Israel), and other states which may be seeking to acquire nuclear weapons.

Impact on Fuel Cycle Policies and Choices

Several countries around the world use separated plutonium in their civilian nuclear fuel cycles. While the plutonium used in these programs is typically reactor-grade, such material can also be used in nuclear explosives, and therefore poses a significant proliferation risk. Because of the potential proliferation risk posed by large-scale handling and use of weapons-usable material, "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," while encouraging more restrictive arrangements limiting plutonium use in regions of proliferation concern[7].

A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries; if this in fact led to significant additional separation and handling of weapons-usable plutonium, that could itself pose proliferation risks. Alternatively, implementation of plutonium disposition with stringent security and accounting measures approximating as closely as practicable the Stored Weapons Standard could create opportunities to demonstrate improved procedures and technologies for protecting and safeguarding weapons-usable materials, which could reduce proliferation risks. These factors must be considered, among others, in analyzing the overall nonproliferation and arms reduction impact of the individual alternatives.

Both plutonium disposition and avoiding encouragement of civil use of plutonium are intended to serve the overall U.S. policy objective of reducing the risk of nuclear proliferation. Generally, civilian use of plutonium increases proliferation risks primarily when it involves additional separation of plutonium. Actions by nations to reduce their existing, already-separated stockpiles of plutonium, whether by disposal of this material or by burning it as fuel in reactors, under effective nonproliferation controls, are generally consistent with the objectives of the President's September, 1993 policy statement. That is why the statement links the objective of avoiding encouraging civilian use to refraining from *reprocessing* in the United States; the language of the directive was carefully crafted to avoid foreclosing the alternative of using already reprocessed weapons plutonium in reactors for disposition.

A simple way of formulating the U.S. nonproliferation policy approach is as follows: Separated plutonium poses higher proliferation risks than unseparated plutonium. Therefore, to the extent practicable, all the plutonium in the world that is unseparated ought to stay that way, and all the plutonium in the world that is separated ought to get unseparated (i.e., be put into a form meeting the Spent

[7] Nonproliferation and Export Control Policy Statement, The White House, September 27, 1993.

Fuel Standard) as quickly as practicable, while ensuring effective nonproliferation controls. This formulation is completely consistent with both disposition alternatives involving disposal, and those involving the use of plutonium as reactor fuel, *as long as such alternatives do not lead to additional reprocessing or other actions that would substantially counteract their nonproliferation benefit.* For each of the alternatives, the extent to which they might encourage or discourage civilian use of plutonium is addressed in this assessment.

Political Implementability

No decision on any of the alternatives can be made in a vacuum. In order to gain the benefits associated with disposing of excess materials, the United States must be able to implement any decision in a timely fashion. As noted earlier, both the time to start and the time to finish plutonium disposition are important factors in gaining the nonproliferation and arms reduction benefits of plutonium disposition. Getting started quickly is likely to be particularly important in establishing international credibility for the overall disposition effort. The technical maturity of each alternative and the time required to implement it are addressed in the *Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition*[8], as are the costs of each alternative, which could also affect its implementability.

Political implementability is also a key factor in the time required to implement a selected alternative. An alternative that was widely opposed by the public, creating uncertainty about the ability or willingness over the long-term to implement would be unlikely to offer a realistic prospect of achieving the benefits of plutonium disposition in a timely way. Thus, for each alternative, political implementability is also a key factor to be considered.

Box 3-2
The Spent Fuel Standard: How Accessible Is Plutonium in Spent Fuel?

The goal of U.S. plutonium disposition programs is to achieve the Spent Fuel Standard -- that is, to make excess weapons plutonium as inaccessible and unattractive for recovery and use in nuclear weapons as the much larger quantity of plutonium in commercial spent fuel. This raises two obvious questions: how difficult is it to recover plutonium from commercial spent fuel and use it in weapons, and how do the various proposed forms for plutonium disposition compare in this respect?

The difficulty of recovering plutonium from spent fuel or other disposition forms clearly depends on the resources of the state or group seeking to recover it. A weapon state with large reprocessing plants available, for example, could use those facilities to

[8] Issued by the Office of Fissile Materials Disposition, U.S. Department of Energy, October 31, 1996. 1996.

recover plutonium from spent fuel with little difficulty, and could fabricate weapons from that plutonium: time, cost, and observability would be the principal issues. At the other end of the spectrum, a subnational group that would have to build a facility for chemically separating plutonium from spent fuel without being detected, steal spent fuel without being caught, complete the processing without being stymied by unexpected difficulties and without being detected, and then produce a nuclear weapon without any prior experience, could be expected to face significantly greater difficulties.

Four primary factors affect the usefulness of civilian spent fuel as a potential weapon material: (1) the intense radioactivity of the fission products in the fuel (which decays with time); (2) the need for chemical separation of the plutonium from the fuel (which must be done by remotely operated equipment as long as the fuel remains intensely radioactive); (3) the isotopic composition of the plutonium (reactor-grade plutonium being a less desirable weapons material than weapons-grade plutonium); and (4) if the party in question does not already have spent fuel in its possession, the difficulty of acquiring it. The difficulty of overcoming these factors depends on the resources of the state or group trying to do so.

Subnational Groups

As described in the Red Team report, it would be possible in principle for even a relatively small sub-national group of extremely dedicated, well-trained individuals to:

- build, over a period of half a year or more, in an unexceptional warehouse-sized building, a makeshift chemical processing facility for plutonium separation, with crude shielding and crude capabilities for remotely-controlled operation of the facility;
- steal spent fuel from cooling ponds or storage casks (possibly using explosives to open the storage casks), hauling the fuel away to the processing facility by truck or by helicopter;
- chop the spent fuel into pieces, dissolve it, and separate out the plutonium in the chemical processing facility over a period of two months or more;[9] and
- build one or more nuclear weapons from the separated plutonium.

All the essential processes for plutonium separation from spent fuel are authoritatively described in the open literature, and the requisite technologies are available on the open market. All the chemicals involved are widely available, used for a variety of other industrial purposes. Rather than building the large, sophisticated, and expensive facilities needed to separate plutonium on a commercial scale, a potential proliferator could rely on simple and relatively low-cost facilities, designed to separate enough plutonium for a few weapons, with little attention to safety and health. The individuals who stole the spent fuel, and who worked to process it at such a simple

[9] The IAEA's Standing Advisory Group on Safeguards Implementation has estimated that the time required to convert plutonium in spent fuel into a weapon would be one to three months, compared to seven to ten days for metallic plutonium.

facility, would receive radiation doses large enough to increase their risk of cancer, but not large enough to be immediately debilitating. Depending on the dedication of the members of the group, the prospect of such radiation doses might not be a sufficient deterrent.[10]

The barriers to accomplishing such an effort successfully and without detection should not be underestimated, however. In processing the spent fuel, the greatest difficulties would arise from the need, because of the radioactivity, to carry out all the main steps with remotely operated equipment. The subnational group would need to include individuals with chemical and engineering knowledge, and actual experience in nuclear material processing would be a significant benefit to such a group. The cost of the facility -- not considered by the Red Team -- would also be substantial. Although the processes and technology of reprocessing are unclassified, the experience gained in actually operating reprocessing plants is not widely available, and the group could encounter unexpected complications and difficulties in separating the plutonium, as several nations have. But the intense radioactivity of the fuel, and the consequent need for the operators to remain behind radiation shielding, would increase the difficulty of making changes in the processing and equipment to deal with initial difficulties.

The larger barrier would be carrying the whole operation to a conclusion without being detected and stopped. While a terrorist group could potentially defeat the security where spent fuel or other plutonium disposition forms are stored, spent fuel could not be removed covertly, without detection. The group removing the material would almost certainly be pursued. The intense radioactivity of the fuel would make the vehicle carrying it easier to detect. Even if the group succeeded in removing the fuel and transporting it to the processing facility without giving away the location of the processing facility, the group would have to take into account the fact that intensive efforts would be made to find and recover the spent fuel in the many weeks before processing was complete and the plutonium was separated. A crude facility such as that envisioned by the Red Team would emit volatile gaseous fission products into the atmosphere, making it much easier to detect. Even a more sophisticated facility including fission product removal would release radioactive isotopes of krypton into the atmosphere, which can be detected. Thus, the probability that the group would be found and stopped before the plutonium had been successfully separated would be quite high -- and the intense radioactivity of the fuel would be a major factor contributing to that probability. Even if the group could successfully separate the plutonium without being stopped, designing and building an implosion-type nuclear weapon (the only type possible with plutonium) would require knowledgeable individuals in several disciplines, and some testing of the high-explosive assembly -- which would provide additional

[10] The question of how easy such "quick and dirty" reprocessing might be has been debated for many years. For useful discussions, see, for example, U.S. Congress, General Accounting Office, *Quick and Secret Construction of Plutonium Reprocessing Plants: A Way to Nuclear Weapons Proliferation?,* General Accounting Office, EMD-78-104 (Washington D.C.: U.S. Government Printing Office, October 6, 1978), and W.G. Sutcliffe and T.J. Trapp, eds., "Extraction and Utility of Reactor-Grade Plutonium for Weapons," Lawrence Livermore National Laboratory, UCRL-LR-115542, 1994 (S/RD).

opportunities to detect the group's activities. Perhaps for these reasons, as far as is known *there has never been an attempt to steal spent fuel, anywhere in the world.*

Proliferating States

For a proliferating state, rather than a subnational group, the difficulties would be somewhat reduced. A state that already possessed spent fuel of its own would not have to worry about acquiring spent fuel to be processed.[11] However, most states operating nuclear power reactors have full-scope safeguards on their peaceful nuclear activities, including their spent fuel. Removal of the spent fuel from safeguards and sending it to a (possibly covert) processing facility would be a violation of the state's nonproliferation commitments. This violation would be detected at the next regular inspection of the spent fuel (which typically occur once every several months), and would be likely to provoke intensive diplomatic action (possibly including international sanctions or other measures), as well as intensive efforts to locate and inspect any covert processing facility where the fuel might have been sent. No state has ever attempted such an approach to acquiring nuclear weapons: there are no cases in which any state has decided to remove spent fuel from international safeguards.

A state that already had operational, unsafeguarded plutonium separation facilities (such as India or Israel) would, in principle, be able to reduce the cost and time required to substantially increase its unsafeguarded plutonium stockpiles by acquiring spent fuel from abroad. Substantial international political opprobrium would be attached to any association with stolen spent fuel, however. There is no evidence that any countries with such unsafeguarded facilities have ever attempted to acquire spent fuel from abroad, rather than producing plutonium itself.

A state which had no spent fuel of its own, and therefore had to acquire such material by theft, as in the case of a subnational group, would face difficulties similar in some respects to those faced by a subnational group. The theft of the spent fuel would likely be detected, and it would be difficult (though not impossible) to transport the material back to the state that wanted to use it for weapons without detection. Similarly, once there, it would be difficult (though not impossible) for the state to process it and separate the plutonium without detection. The international community's options for action if such a facility were detected, however, would be far more limited than the options available to a state that detected a subnational group carrying out similar activities on its territory. Here, too, a state with no experience in reprocessing could expect to encounter some difficulties in its first efforts. Access to experts with experience in such processing could significantly ease the task.

[11] Most industrialized countries and a few developing countries have nuclear reactors, and therefore have spent fuel on their territory from which they could seek to separate plutonium, should they make a decision to do so. Many developing countries, however, including many of those that raise the most significant nuclear proliferation concerns, do not have commercial power reactors and therefore do not possess commercial spent fuel containing plutonium. Similarly, subnational groups that might choose to attempt to build nuclear weapons do not have access to spent fuel except by stealing it.

Weapon States With Reprocessing Capabilities

For major nuclear weapon states such as the United States or Russia, the issues involved are quite different. These states already have large, operational reprocessing facilities designed to separate plutonium from spent fuel, and their ability to do so is not in question.

If either the United States or Russia chose to rebuild a nuclear arsenal of Cold War size, however, using plutonium from spent fuel or other plutonium disposition waste forms would be significantly more time-consuming and costly than using already separated plutonium. To recover 50 tons of plutonium from typical commercial spent fuel (which contains roughly 1 percent plutonium by weight) would require processing some 5,000 tons of spent fuel. In either the United States or Russia, this would take years to accomplish. The cost would also be substantial. Even if the cost of government-financed reprocessing using facilities that already exist is assumed to be significantly lower than the price of just under $1000 per kilogram currently quoted by commercial reprocessors, separating plutonium from 5,000 tons of spent fuel would cost billions of dollars. Such an operation would involve, in effect, going back to the massive scale of plutonium production operations that existed at the peak of the Cold War.

The plutonium recovered from this spent fuel would be reactor-grade, rather than weapon-grade. While either the United States or Russia could produce reliable and effective nuclear weapons from reactor-grade plutonium should they choose to do so, historically both countries have chosen to produce weapon-grade plutonium for their nuclear arsenals. Neither the United States nor Russia would be likely to choose to recover reactor-grade plutonium for use in their nuclear arsenals unless an international situation arose in which there appeared to be a need to acquire large stockpiles of plutonium for weapons more quickly than would be possible by producing new weapons-grade plutonium in reactors. In such a circumstance, however, reactor-grade plutonium could be used.

Recovering Plutonium From Disposition Waste Forms

No matter what disposition option is chosen, plutonium that could be used in nuclear weapons could still be recovered. Plutonium disposition can only reduce, not eliminate, the risk that this plutonium will someday be returned to nuclear weapons. Overall, the difficulty of recovering plutonium from the various proposed plutonium disposition waste forms would be generally similar to the difficulty of recovering plutonium from commercial spent fuel, though the specifics would vary significantly.

In the case of spent MOX fuel, for example, the spent fuel would be virtually identical to the spent fuel just discussed, except that it would have several times as much plutonium by weight (in some proposed cases, between 2.5 and 3 percent plutonium in MOX spent fuel, compared to roughly 1 percent in LEU spent fuel). This would reduce the amount of material that would have to be reprocessed to recover a given amount of plutonium. On the other hand, MOX spent fuel is somewhat more difficult to dissolve than LEU spent fuel. For states planning to use existing reprocessing plants to recover plutonium, some plant modification could be needed, and for subnational groups or states planning to carry out plutonium separation for the first time, the likelihood of encountering unexpected difficulties would be modestly increased, compared to commercial LEU spent fuel.

In the case of immobilized forms, somewhat different chemical processes would be needed, which have never been demonstrated on a large scale. To separate plutonium from borosilicate glass, the glass would have to be crushed and dissolved in acid. A number of separation steps would be needed to separate the plutonium from the large quantities of silica in the glass. The overall level of effort required to implement these processes would not be greatly different from separating plutonium from spent fuel, for either subnational groups or states, although unlike in the spent fuel case, existing facilities would have to be significantly modified, or new facilities built -- and in a process that has never been industrially demonstrated, some unexpected difficulties would be likely. The loading of plutonium currently planned for the homogeneous vitrified forms is roughly 5 percent by weight, so a smaller total amount of material would have to be processed to recover a given amount of plutonium than would be the case for commercial spent fuel.

The chemical processes needed to recover plutonium from the ceramic immobilized forms would be very different, and have not been demonstrated. The overall level of effort required to separate plutonium from ceramic material also incorporating a substantial radiation barrier, however, would again be broadly similar to that required to separate plutonium from commercial spent fuel. Since some of the needed processes have not been published authoritatively, subnational groups might be somewhat less confident in their ability to recover plutonium from these forms. For a state such as the United States or Russia, it is likely that large new facilities would have to be built to recover plutonium from these forms. Current designs of the ceramic forms include 12 percent by weight plutonium, significantly reducing the amount of material that would have to be processed for recovery.

For the can-in-canister immobilization forms, the difficulty of recovering the plutonium would depend in significant part on whether the plutonium-bearing cans could be readily removed from the canisters containing the radiation barrier. As described in the Red Team report, in current preliminary can-in-canister designs, it would in principle be possible for either a subnational group or the host state to destroy the canisters and remove the cans, which could then be processed in glove-box facilities without requiring remote handling. This would represent a significant reduction in the overall effort required for recovery. A new approach is already being designed however, intended to make it very difficult to remove the cans from the surrounding canisters: if successful, this could potentially make the recoverability of these forms similar to that of the other immobilized forms.

The Meaning of the Spent Fuel Standard

Fundamentally, the Spent Fuel Standard implies that it should be as hard to recover plutonium from the disposition waste forms and for weapons production as it would be to do the same with the much larger quantity of plutonium in commercial spent fuel. The overall *effort* required, and the *likelihood of success*, should be roughly similar.

A broad range of different types of material can achieve this goal. The Spent Fuel Standard does *not* imply that excess weapons plutonium must literally be transformed into spent fuel; rather, it implies that whatever form it is transformed into should be as inaccessible and unattractive for use in weapons as plutonium in commercial spent fuel. Immobilized forms, for example, also meet the Spent Fuel Standard. The Spent Fuel Standard does not imply that disposition forms must have specific levels of radiation, plutonium concentration, or mass, but rather that the combination of these factors should be sufficient to meet the goals of inaccessibility and unattractiveness. In other words, if one were to create a graph of radiation field, plutonium concentration, chemical processing difficulty, and so on, the Spent Fuel Standard would not be a specific point on the graph, but a broad and somewhat amorphous region.

It should be noted that commercial spent fuel itself varies significantly in many of these characteristics. Spent fuel that is forty years old is only half as radioactive as spent fuel that is 10 years old. The radiation field from CANDU spent fuel is much lower than the radiation field from LWR spent fuel, because the CANDU fuel bundles are smaller and contain less material. Spent fuel from fast-neutron reactor cores contains a much higher percentage of plutonium, which is closer to weapon-grade, than spent fuel from LWRs or CANDUs; plutonium in the breeding blankets of fast-neutron reactors is typically weapon-grade or even super-grade.

Some basic features of material that meets the spent fuel standard can be identified, however. Both the NAS report that coined the term and subsequent DOE studies have concluded that for material to meet the Spent Fuel Standard by virtue of the form of the material itself (rather than its location, in the case of the deep borehole options), the plutonium, like plutonium in spent fuel, must be:

- substantially diluted in other material, typically down to 1-15 percent (so that major chemical processing is required to recover it);
- intensely radioactive, typically at hundreds or thousands of rads per hour at one meter (so that theft of the material is more difficult, and remote operations are needed for the chemical processing);
- contained in items of large size and mass, typically more than half a ton in weight and more than a meter in length (so that special lifting equipment or means to divide the items into smaller parts are needed to remove the material, covert theft becomes

effectively impossible, and the radiation barrier is increased compared to smaller items containing less radioactive material).[12]

The Spent Fuel Standard in itself, however, does not imply any hard and fast limits for the specific levels of dilution, radioactivity, or mass that must be met. The plutonium in typical commercial spent fuel is also reactor-grade, which reduces its attractiveness for use in weapons somewhat. As described elsewhere, however, both weapon-grade and reactor-grade plutonium can be used in weapons, so this difference in itself is not decisive.

If the excess weapons plutonium is transformed in ways that meet the Spent Fuel Standard, the material will be substantially more inaccessible and unattractive for weapons use than separated plutonium, reducing the risk that the excess weapons plutonium will ever again be used in nuclear weapons.

Nonetheless, all of the disposition forms would continue to pose some security risk, as commercial spent fuel itself does. Plutonium could still be recovered from any of these forms, if enough resources were applied to the task. Therefore a reduced level of institutional measures -- including some guarding, and some international inspection -- will have to continue to be applied to these materials, just as similar measures are applied to commercial spent fuel today. When the excess plutonium is transformed into forms meeting the Spent Fuel Standard, it will no longer pose a unique security threat, and the immediate job of plutonium disposition will be complete. But the excess weapons plutonium will then be one small part of a larger issue that society must ultimately address: what to do with spent fuel and other nuclear wastes. If the benefits of plutonium disposition are to be attained as quickly as possible, however, it is critical that this immediate mission not wait until consensus on the broader questions of the future of nuclear waste and nuclear power has been achieved.

Radiation: The Decaying Barrier

The proliferation risk posed by spent fuel grows with time as its radioactivity becomes less intense. Ten years after leaving the reactor, the dose rate from a spent fuel assembly irradiated to a typical burnup would be well over 1,000 rads per hour at 1 meter from the center of the bundle. The radioactivity then declines by roughly 50 percent every 30 years. Thus, a century after the fuel is discharged from the reactor, only one-eighth of this level of radioactivity would remain. The same is true for the immobilized forms envisioned for plutonium disposition, which also rely on fission products with roughly 30-year half-lives for their radiation barrier.

How long it would take to reach the point at which remote processing, the largest single obstacle to plutonium recovery, would no longer be needed depends on how much

[12] CANDU fuel bundles are relatively small and portable individually. For plutonium disposition, 40 of these bundles would be mounted on a tray, creating a unit with size, weight, and radiation barrier broadly similar to an LWR assembly.

radiation the workers in the facility would be willing to tolerate and what precautions were taken to protect them. DOE, NRC, and the IAEA consider materials emitting more than 100 rads per hour at 1 meter to be sufficiently self-protecting to require a lower level of safeguarding. Spent fuel of typical burnup would take more than 100 years to decay to this dose rate. It should be noted, however, that the Red Team report concludes that radiation fields of several hundred rads per hour or more would be needed to provide a significant deterrent to physical removal of the spent fuel, and similar dose rates would be needed to ensure that shielding would be needed to allow processing to be done without inflicting lethal doses of radiation on those doing the processing.

Thus, unless something additional is done to make this material more inaccessible, over the long term spent fuel will pose an increasing security risk. As described in the Red Team report, geologic disposal would be one effective approach for reducing this risk to low levels, once the repository had been closed and sealed. At the same time, the NAS Committee on International Security and Arms Control and other groups have recommended that some level of conceptual research be continued on concepts which might be able to consume the plutonium nearly completely.

4. Alternatives for Long-term Storage of Weapons-Usable Fissile Materials

Description of Long-term Storage Alternatives

Safe and secure storage is required for DOE's inventories of both plutonium and HEU, including both excess material and material that will remain in reserve to support military programs. For excess materials, provision must be made to support international inspection. DOE expects that approximately 20,000 storage positions will be needed to store 50 metric tons of excess plutonium, and an additional 5,000 positions will be needed for plutonium that will remain in strategic reserves. In the future, additional dismantlement and stabilization activities could increase the number of storage positions required to 40,000. For HEU, DOE expects to store 6,000 cans and 8,500 drums.

Alternatives for long-term storage of fissile materials include both the sites where the material would be stored, and the configuration in which it would be stored. Alternatives for the sites include: No Action; Upgrade Facilities at Multiple Sites; Consolidation of Plutonium Storage; and Co-location of Plutonium and HEU Storage. Descriptions of the alternatives are given in depth in the PEIS, and are repeated here only to the extent necessary for identification of the potential nonproliferation impacts.

Near-term choices with respect to the form of the material to be stored are limited, as the United States does not currently have an operational industrial-scale plutonium conversion facility. Thus, plutonium will largely be stored in the forms in which it currently exists (including pits and other forms), until such a processing facility is established and can process the plutonium into forms suitable for disposition. HEU will be processed to other forms as necessary for disposition, using existing facilities. Fissile materials that will remain in reserve to support military programs (both plutonium and HEU) will be stored in forms suitable for use in military programs, including in the form of weapons components.

No Action Alternative

The no-action alternative for storage would keep current stocks of fissile materials in their current locations. Materials would remain in place until disposition took place. The only changes from existing storage would be essential upgrades in facilities to meet evolving environmental, safety, and health requirements for storage.

Plutonium under the no-action alternative would be stored at these DOE locations:

- Hanford Site
- Idaho National Engineering Laboratory (INEL)
- Pantex Plant
- Rocky Flats Environmental Technology Site (RFETS)
- Savannah River Site (SRS)
- Los Alamos National Laboratory (LANL).

LANL is not under consideration as a permanent storage facility for excess plutonium, but does currently have plutonium that has been declared excess and which, under the no-action alternative, would remain in place. About 85% of the plutonium so far declared excess is located at two sites, Pantex and RFETS.

Since the Y-12 facility at Oak Ridge Reservation (ORR) has already been designated as the DOE interim storage location for unirradiated HEU, it is assumed that excess and non-excess HEU have been relocated to ORR prior to any action taken under the PEIS. Thus, the no-action alternative does not involve any other sites than ORR for purposes of HEU storage.

Hanford Site. Hanford would continue to store plutonium-bearing materials in storage vaults and approved vault-type rooms of its Plutonium Finishing Plant, with clean out, stabilization, and storage as required by environmental considerations. Hanford would transform metal and oxide materials to forms meeting DOE storage standards by 2002.

INEL. Weapons-usable plutonium at INEL is stored in the Argonne National Laboratory- West (ANL-W) facility, where it would remain in forms deemed most stable in site-specific studies.

ORR. HEU would continue under the no-action alternative to be stored in existing buildings at ORR's Y-12 site. Non-excess HEU would remain there indefinitely; excess HEU would remain there until removed for disposition.

Pantex. All site plutonium holdings relevant to the Storage and Disposition program would continue to be stored in the storage bunkers in Zone 4 at Pantex. As specified in the Corrective Action Plan for Pantex, some operating structures would be improved to reduce dispersal probabilities. Facility improvement actions are already in progress, as are management and training improvements. In this alternative, the strategic reserve plutonium would primarily be stored at Pantex, to support stockpile management.

RFETS. Plutonium at RFETS is in the forms of metal, oxides, solutions, and scrap or residues. The scrap and residues there are not currently under the scope of the PEIS, although some may be after stabilization activities are complete. Under the no-action alternative, plutonium-bearing materials subject to this PEIS may be placed in metal or oxide forms and transferred into a single facility.

SRS. Plutonium at SRS is in various forms, including metals, oxides, solutions, residues, special isotopes, and spent fuel. Under the no-action alternative SRS will continue to store these materials in forms and facilities found to be most stable in site-specific studies. Solutions in F-Area are already being converted to plutonium metal, which will be stored in a vault there. Solutions in H-Area have been studied in a separate environmental impact statement and will be stabilized to remove certain safety vulnerabilities that have been identified. Pu-242 isotope inventories at SRS have been identified as useful for future research and development activities and are analyzed in the environmental impact statement for the Stockpile Stewardship and Management Program. Finally, other plutonium metal or oxides resulting from stabilization actions will be stored in accordance with DOE storage standards, some in a new facility scheduled for completion in 2001.

Upgrade at Multiple Sites

Under this alternative, plutonium stored at Hanford, INEL, Pantex, and SRS would remain in long-term storage at those sites, in modified or new facilities. Plutonium at RFETS, as well as the smaller amount at LANL, would be relocated to one or more of the other sites. HEU in storage at ORR would also remain in modified facilities. The following paragraphs indicate the actions necessary at the different locations. Detailed capacity analyses in the draft PEIS include storage with and without additional material from RFETS, which could all go to one location or be distributed among several locations.

Hanford. Storage alternatives identified in the draft PEIS include modifying the existing Fuels and Materials Examination Facility, and upgrading the Hanford storage capability through new construction. (The alternatives were designed to provide long-term storage for materials containing approximately 4 MT of plutonium.)

INEL. INEL upgrades would include modification of existing facilities and construction of new ones within the ANL-W area.

Pantex. Existing facilities in Zone 12 South of the Pantex facility would be modified for long- term storage; the draft PEIS also analyzes construction of new facilities in Zone 12. The upgrade would provide a capacity of 3000 shipping packages per year with storage capacity of 20,000 positions for excess plutonium, in addition to 5000 positions for non-excess plutonium.

ORR. Under this alternative, HEU would be stored in existing facilities at Y-12, after some modification to convert material processing facilities into storage areas.

SRS. Under the upgrade alternative, SRS would construct a new long-term storage facility to provide approximately 2000 storage positions for plutonium currently on site.

Consolidation of Plutonium

Under this alternative, a new, consolidated facility would be selected to store the entire DOE inventory of both excess and non-excess plutonium. The new facility would be at one of six locations: Hanford, INEL, ORR, Pantex, SRS, or the Nevada Test Site (NTS). Materials would be stored in the form of pits from disassembled weapons, metals, or oxides. The consolidated facility would include capabilities for material handling, material storage, support laboratory operations, waste management, and support functions. It would have a design life of 50 years; would have the capability of offering excess materials for international inspection; and would have a capacity to receive 6,000 shipping packages per year (6,000 pits or 5,000 pits and 1,000 non-pit packages). It would be built in two phases. Each phase would provide 20,000 storage positions, in modules of 5,000, resulting in a total capacity of 40,000 storage positions, of which 35,000 would be for excess materials.

Consolidation of plutonium storage at Hanford, INEL, or SRS would entail the construction of new buildings in addition to the use of existing facilities. At Pantex, less new construction would be required by taking advantage of existing storage capabilities.

A new facility would also be required if plutonium were consolidated at ORR; but since the HEU storage at Y-12 would remain, this alternative technically results in a co-location of plutonium and HEU, and is discussed in the next alternative.

Collocation of Plutonium and HEU

Under this alternative, a new facility at a DOE location would be constructed for long-term (50 year) storage of all plutonium and all non-excess HEU. Excess HEU, which is scheduled for relatively near-term disposition by blending to LEU, would remain in existing storage at the Y-12 facility. It is assumed that all excess HEU in the complex will have been relocated to Y-12 by the time this PEIS goes into effect.

The new facility would be located at one of the six candidate locations: Hanford, INEL, NTS, ORR, Pantex, or SRS. It would be a new stand-alone facility, with two possible exceptions: at NTS, consideration could be given to the use of P-tunnel with suitable new and modified drifts; and at ORR, consideration could be given to the use of existing or modified Y-12 facilities for HEU storage. At any of the other four sites, a completely new facility would be constructed.

If any site other than ORR were selected for the new collocated storage facility, non-excess HEU would be moved from the Y-12 facility to the new co-located facility. If ORR were selected for the co-located facilities, HEU (non-excess as well as excess) might continue to be stored at Y-12.

Nonproliferation and Arms Reduction Analysis of the Storage Alternatives

This section addresses the nonproliferation and arms reduction benefits and liabilities of the four alternatives being considered. The no-action alternative is taken as a baseline case; that is, benefits and liabilities are described by comparing the consequences of each alternative compared to doing nothing beyond minimal essential upgrades.

Technical Factors

In all of the storage alternatives, the material remains in directly weapons-usable form, which would not meet the Spent Fuel Standard, the key objective of U.S. disposition programs. Resistance to proliferation or re-use in weapons would rely entirely on institutional measures (stringent security, along with peaceful use assurances and international monitoring for excess material), not on characteristics of the material itself. Hence, the key technical factor is the ability to provide high security against theft (international safeguards are addressed under policy factors).

Protecting Against Theft of Nuclear Material

All of the storage alternatives under consideration can provide high levels of security against theft of weapons-usable fissile materials by unauthorized parties. All would be designed to meet DOE requirements for facilities storing highly attractive materials such as plutonium and HEU, and domestic safeguards and security systems meeting these requirements are expected to be highly effective. The cost of achieving this objective would vary, however: the alternatives involving construction of new consolidated facilities would involve higher investment costs in return for lower long-term operations costs. Construction of new facilities would also make it possible to design modern security and accounting systems from the ground up.

The consolidation and co-location alternatives would involve additional transport of weapons-usable fissile material. From a nonproliferation standpoint, there is a certain increased vulnerability any time material is moved. This vulnerability is least in the No Action and Upgrade at Multiple Sites alternatives, since smaller amounts of material would be moved, primarily the plutonium now stored at RFETS. The co-location alternative would have the greatest vulnerability, because all the material would have to be moved, except the material already located at the chosen site. Under the Stored Weapons Standard however, materials being shipped would be accorded the same levels of protection that would be given to nuclear weapons in transit, reducing the potential vulnerability. If sufficient resources are provided for security for the shipments, high levels of assurance against theft in transit could be provided.

Whether such shipments would in fact be additional to shipments that will be required in any case would depend on the eventual disposition alternatives chosen, and the location of the facilities needed to implement them. If a consolidated storage site were located at the same site as a plutonium processing facility for plutonium disposition, for example, then all the materials would eventually have to be shipped to that site for processing in any case, and shipping them there for storage would not increase the total amount of transport required.

Policy Factors

Allowing For International Inspection

All of the alternatives could potentially allow excess materials to be made available for international monitoring -- including bilateral U.S.-Russian monitoring and IAEA safeguards.

The No Action and Upgrade at Multiple Sites alternatives, however, would involve the greatest difficulty and the most impacts on other activities from international monitoring, for two reasons. First, the sites where the material is currently stored were not designed with international monitoring in mind, and experience to date suggests that preparing them for the presence of international inspectors may be costly, particularly in light of the need to avoid interference with other defense-related activities at those sites which are not intended to be subject to verification. (This is likely to be more of a problem in the case of IAEA inspection than in the case of inspection by Russia, which is also an advanced nuclear-weapons state.) Second, the No Action and Upgrade at Multiple Sites alternatives would require safeguarding a larger number of sites, increasing safeguards costs and complexity.

The facilities for the consolidation and co-location alternatives would be designed specifically to provide opportunities for international monitoring. In particular, excess and non-excess materials would be physically separated (for example in different modules of the storage facility), so that inspectors could have free access to inspectable materials without creating a risk of compromising potentially sensitive information related to non-excess materials. In order to maximize the benefits of facilities designed for monitoring, it would be important to involve the IAEA at an early stage of the facility design, so that inspection considerations could be taken into account. The Department of Energy has already begun consultations with the IAEA on the design of a new storage vault at the SRS to facilitate IAEA safeguards on the contents.

Monitoring Classified Forms

President Clinton has directed DOE to seek to maximize the amount of U.S. excess material made eligible for IAEA safeguards, consistent with nonproliferation, environment, safety, and health, and economic constraints. A substantial fraction of the excess material, however, is currently in classified forms such as weapons components, which could not be placed under IAEA safeguards in the traditional way without revealing information that would contribute to nuclear proliferation -- precisely the opposite of the purpose of putting the materials under safeguards.

Two approaches are being taken to address this issue. First, since Russia is an advanced nuclear weapon state, there are some types of information that could be revealed to Russian inspectors without compromising U.S. national security, which could not be revealed to international inspectors. As noted in Section 2, the United States and Russia have agreed in principle to establish a regime of Mutual Reciprocal Inspections (MRI) to confirm the stockpiles of plutonium and HEU removed from nuclear warheads. U.S. and Russian experts have demonstrated inspection procedures and technologies that could be used to confirm that the material in a canister under inspection was consistent with a plutonium pit. These techniques, however, would reveal some information which is currently classified as Restricted Data, and therefore under the Atomic Energy Act, an Agreement for Cooperation is required to provide the legal basis for exchanging such information. Negotiations on such an agreement were undertaken in 1995, but were never completed, and therefore MRI inspections have not yet been implemented. The United States and Russia, however, are seeking ways to move this initiative forward, and both remain committed to the concept of bilateral monitoring of excess material.

Second, it is possible that some modified form of IAEA monitoring could be developed which would provide credible assurance that excess material was not being used for military purposes, but would not reveal proliferation-sensitive information. Since a large fraction of the excess material will remain in classified forms for years to come (because of the current lack of facilities to convert it to other forms), developing such a modified monitoring approach would be a key contribution to implementing President Clinton's directive to maximize the quantity of material made available for safeguards. At National Security Council direction, this concept is under interagency review. Secretary of Energy Hazel O'Leary and Russian Minister of Atomic Energy Victor Mikhailov met with

IAEA Director-General Hans Blix in mid-September 1996 to discuss the issues surrounding IAEA safeguards on excess fissile materials and establish a process for moving forward.

Encouraging Consolidation

The consolidation and co-location alternatives could have an additional nonproliferation advantage, in encouraging other countries to carry out similar consolidation. While the U.S. sees no serious problems in maintaining physical control over materials even at large numbers of sites, this may not be the case in other countries. In the nations of the former Soviet Union, for example, the United States has been working to encourage consolidation of materials at a smaller number of sites, as part of the cooperative effort to improve security and accounting for plutonium and HEU at all the locations where they are stored. Reducing the number of locations means that improved security can be achieved at lower cost. Thus, consolidation of U.S. materials could be of benefit to the extent that it encourages similar consolidation elsewhere.

Overall, the differences among the Multiple Site, Plutonium Consolidation, and Collocation alternatives do not appear to be large from a nonproliferation and arms reduction point of view. To be sure, there would be some benefit from having fewer sites to safeguard and declare; thus, the two consolidation alternatives would be slightly preferable. However, the difference between safeguarding and declaring materials at six sites versus one or two sites does not appear to be of great significance. In either case, the material can be protected against theft, and made as accessible for inspection as classification considerations permit.

5. Alternatives for Disposition of Excess Plutonium

The following sections describe the technical and policy factors affecting the nonproliferation and arms reduction implications of each of the disposition alternatives. For each alternative, a description of the basic characteristics of the alternative is provided, followed by an analysis of the technical factors and the policy factors affecting its impact on nonproliferation and arms reduction.

All the facilities and operations involved in plutonium disposition will have stringent domestic safeguards and security to prevent theft of nuclear material. All are expected to be placed under international safeguards and/or bilateral monitoring, except where doing so would reveal classified weapons design information, to assure the world that the United States is fulfilling its commitment to irreversible nuclear arms reductions.

FIRST STEPS: PROCESSING OF PLUTONIUM PITS AND OTHER FORMS

All disposition alternatives will require plutonium processing facilities that can convert the plutonium from the forms in which it currently exists into other forms suitable for disposition. A large portion of the excess plutonium is currently in the form of weapons pits, most of which are currently stored at the Pantex Plant in Amarillo, Texas. The remaining excess material is stored at several other sites in metal, pure and impure oxides, and a variety of scrap, residues, and alloys that may require various types of chemical processing prior to disposition. The United States does not currently have an operating industrial-scale facility capable of carrying out the necessary plutonium processing. Therefore, one or more new plutonium processing facilities will have to be built, or existing DOE facilities will have to be substantially modified to serve this purpose. This initial processing represents a significant fraction of the total cost of plutonium disposition and may be the most proliferation-sensitive step in the entire process.

Pit Processing

Description

The plutonium which is in pits must be converted to other forms for disposition. This step raises particularly significant proliferation issues, because it involves bulk processing of tons of plutonium in directly weapons-usable forms (with the inevitable associated accounting uncertainties), and conversion of plutonium initially in classified forms whose specific design is highly sensitive.

DOE is currently demonstrating new technology for pit disassembly/conversion, known as the Advanced Recovery and Integrated Extraction System (ARIES). A full-scale prototype system capable of handling over 200 pits per year will be tested at the Los Alamos National Laboratory by the end of 1997. The United States has offered to provide this technology to Russia or to work toward combining portions of this technology with Russian technologies. The ARIES system begins with a system similar to a can opener, which cleanly cuts the hollow pit into two halves, or hemishells. The plutonium is removed from each hemishell using a hydride-dehydride process: hydrogen gas is let into the system, which forms a plutonium hydride. The plutonium hydride flakes off from the pit shell into a crucible waiting below. The crucible is heated, which drives off the hydrogen, leaving plutonium metal. The hydrogen then goes back upward and forms more plutonium hydride, and cycles around in this way until all of the plutonium has been removed from the pit shell.

The plutonium metal can also be directly converted to oxide, so the system has the flexibility to produce either plutonium metal ingots or cans of plutonium oxide. The plutonium is carefully measured both before and after the process, using new approaches developed specifically for this process. The end result of the process is a sealed and welded can containing a precisely measured quantity of plutonium. Once the plutonium has been loaded into these cans and sealed, the cans can then be handled as individual "items," which can simply be counted and checked to ensure that they have not been tampered with, with essentially zero error. The process produces thousands of times less waste than previous processes relying on aqueous dissolution. The particular site where an industrial-scale facility for pit conversion would be built has not yet been selected.

Technical Factors

Because such a facility would bulk-process tons of separated weapons-usable plutonium each year, some uncertainties in material accounting would be inevitable (see "Accounting for Nuclear material in a Comprehensive Safeguards System,," p. 69). Recent standards issued by the European Community's nuclear agency (EURATOM), and endorsed by the IAEA, indicate that currently achievable measurement accuracy for plutonium metal or oxide is in the range of 99.85% (for random errors).[13] Thus, the uncertainties over a year's time in measuring the input and output of tons of nuclear material would ultimately amount to tens of kilograms. This does *not* mean, however, that tens of kilograms of material could be stolen without detection. Material accounting is only part of a multi-layered system designed to provide defense in depth against any theft of nuclear material. Stringent standards of physical protection, and containment and

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[13] S. Deron, et al., "1993 International Target Values for Uncertainty Components in Fissile Isotope and Element Accountancy for the Effective Safeguarding of Nuclear Materials", International Atomic Energy Agency, Vienna, STR-294, Rev. 1 (February, 1994).

surveillance can provide assurances that no significant thefts of nuclear material have occurred.

Policy Factors

Converting plutonium from weapons components to non-military, unclassified forms would represent an important first step toward ultimate disposition of the material. This step would contribute to international confidence in the process of nuclear arms reductions, particularly if the unclassified material resulting from the process were made available for international inspection.

At the same time, international monitoring of pit processing itself could raise difficult issues, because the design of the pits contains classified nuclear weapons design information. Only after the pits have been converted to metal ingots or oxides which no longer contain classified weapons design information could the material be placed under traditional IAEA safeguards. Thus, one approach would be to make only one part of the facility, which did not contain classified material, eligible for IAEA inspection. As noted earlier, a modified version of IAEA safeguards could potentially be developed which could be applied to material in classified forms without revealing information that would be useful to potential proliferators is currently under review. It is clear, however, that IAEA inspectors from non-nuclear-weapon states could not be allowed direct access to pits without compromising weapons design information that could be of use to potential proliferators.

The United States and Russia may also decide to apply bilateral monitoring measures to such facilities. Since both the United States and Russia already have advanced nuclear weapon design knowledge, there may be some information which could be exchanged bilaterally which would not be appropriate to make public or to provide to an international organization such as the IAEA. Once the United States and Russia complete an agreement providing the basis for exchanging classified nuclear information, the procedures to be used for inspection of pits in storage (known as Mutual Reciprocal Inspections or MRI) could potentially be adapted to contribute to bilateral monitoring of pit conversion plants.

Either bilateral or IAEA monitoring of such a facility should be able to ensure, with high confidence, that the declared excess materials are, in fact, being converted to other forms, and that no strategically significant diversion is occurring. This international monitoring of the excess plutonium, in combination with monitoring measures for material still in classified forms (such as MRI), will allow the United States and Russia to demonstrate to each other and to the international community that disposition is being carried out under stringent nonproliferation controls, and that the excess material is not being diverted for re-use in weapons.

Converting pits to unclassified forms would have the advantage of making possible broader international inspection regimes without revealing classified information. Although pit processing poses one of the most sensitive stages in the disposition path, it may be worth considering beginning conversion as rapidly as practicable -- without waiting for the availability of other disposition facilities (MOX fabrication, vitrification, or boreholes). If the United States had successfully reached agreement on and implemented a modified safeguards regime for monitoring material in classified form, the advantages of such early pit conversion would be somewhat reduced.

Processing Plutonium in Other Forms

Description

Other forms of excess plutonium include metal, pure oxides, impure oxides, unirradiated experimental plutonium fuel of various kinds, scrap, irradiated fuels, and a wide variety of plutonium-bearing residues from past processing operations. In most cases, these materials must also undergo some level of processing before disposition.

The specific type of processing needed would depend on the type of material and the disposition alternative it was being prepared for. Relatively pure metal or oxides would require only modest processing to prepare them for the disposition alternatives. In the case of less pure materials, processing could involve dissolving the material in acid or molten salt, followed by various chemical steps to precipitate the plutonium from the resulting solution or molten mixture. In some cases, repeated purification steps would be needed.

The reactor alternatives under consideration would require pure plutonium oxide as input material for fuel fabrication. (Use of fuel made with impure materials, even if it eventually proved to be possible without compromising reactor safety, would require a lengthy and costly fuel development and testing program.) Many of the impure forms and residues that exist at DOE facilities would require a complex and expensive series of purification steps to produce a sufficiently pure oxide for use as reactor fuel. The immobilization and borehole alternatives, by contrast, can handle wider variations in the characteristics of the input materials. One or two processing steps might be sufficient to produce material good enough for immobilization. Indeed, some impure oxides and residues could probably be immobilized "as is." Some of the residues, however, are likely to require at least some processing even for the immobilization alternatives: for example, plutonium forms containing halides (fluorides, chlorides, and similar compounds) would typically be chemically processed to remove these highly reactive materials before immobilization, so that these materials did not disrupt the formation of appropriate glass or ceramic forms.

Technical Factors

Some of these processing steps will be particularly proliferation-sensitive, for a variety of reasons. Most plutonium residues, for example would not be very attractive targets for theft, but processing them to an oxide form that concentrates the percentage of plutonium would increase their attractiveness, thus also increasing proliferation risk. (This is the only step involved in disposition that actually produces material that is *more* attractive for use in weapons than the original material -- but this increase would be only temporary, as disposition would then result in a substantially less accessible and attractive material.) Moreover, while the pure metals and oxides could be accurately measured and would require relatively little processing, the impure oxides, scrap, and residues would be difficult to measure with high accuracy -- and since one could not confirm exactly how much plutonium had entered the process, it would be impossible to confirm, through material accounting alone, that the plutonium at the end was the same amount as the plutonium at the beginning, without any significant losses to theft or waste. The EURATOM safeguards agency estimates that scrap can only be measured to an accuracy of plus or minus 5-7 percent (using non-destructive assay techniques) -- and some of the impure forms and residues in the DOE complex may be even more difficult to measure than typical scrap.

Moreover, the more steps of chemical processing and purification that are required, the more accounting uncertainties there would be, and the more opportunities for insiders in the processing facility to divert some of the material from the process streams. Thus, extremely effective material control and physical protection systems would be needed to provide the required assurance that no material could be stolen. It should be noted, however, that some processing is common to the all the alternatives -- although the processing would necessarily be somewhat more complex and extensive if the residues were to be prepared for use as reactor fuel rather than being immobilized.

Policy Factors

Since these other forms of plutonium are not coming directly from the dismantlement of nuclear weapons, processing them to prepare them for disposition would likely do less to build international confidence in arms reductions than would converting weapons components such as pits, although these steps would still have some benefits. Preparing for disposition of tons of material, even if not in weapons component form, would be a contribution to arms reduction objectives, and could encourage similar actions by Russia with their excess plutonium from non-weapon sources.

In general, the characteristics of plutonium metals, oxides, alloys, scraps, and residues are not classified, so this facility (or this area of the overall plutonium conversion facility, if processing of these materials and of weapons components were done in the same building) could be made subject to IAEA safeguards. There would be inherent measurement uncertainties that would limit the ability of material accounting alone to accurately match inputs to outputs. Nevertheless, international monitors could confirm that tons of material were being prepared for disposition, and that no strategically significant quantities of material had been removed from the process for re-use in nuclear weapons. Bilateral U.S.-Russian monitoring could also provide such assurance.

TABLE 5-1 Characteristics of Final Disposition Forms

	Item Size (m)	Item Mass (kg)	%Pu in Material by Weight	Pu/Item (kg)	Mass for 8kg Pu	Radiation (rads/hr, 1m)	% Pu-240 & above
Spent LWR LEU Fuel	4.2 x .2 x .2	658	1%	5	1,053	600	~35%
Spent LWR MOX Fuel	4.2 x .2 x .2	658	2.9%	15	351	600	40%
Spent CANDU MOX Fuel (40 bundle tray)	1 x .5 x .2	1,000	1.2% - 1.4%	10 12	800 670	~ 500	48%
Immobilized Glass Canister (Can-in-Canister)	3 x .6	2,200	10% / 5%	51	80 / 160	200-500	6.5%
Immobilized Ceramic Canister (Can-in-Canister)	3 x .6	2,200	12% / 5%	58	66 / 160	200-500	6.5%
Immobilized Glass Canister (homogeneous)	3 x .6	2,200	5%	84	160	200-500 or 1,000 (new)	6.5%
Immobilized Ceramic Canister (homogeneous)	2.4 x .4	1,400	12%	80	66	200-500 or 1,000 (new)	6.5%
Immobilized Canister (electro-metallurgical)	3 x .6	2,000	5%	52	77	1,000	6.5%

Table 5-1 shows the characteristics of the final forms for the various disposition alternatives. The characteristics of commercial spent fuel from light water reactors are also shown, for comparison. The chart shows the overall size of each item (length, height, and width, or length and diameter); the mass of each item; the percentage of plutonium in the material; the total amount of plutonium in each item; the mass of material that would have to be removed to recover a nominal IAEA "significant quantity" of 8 kilograms of plutonium; the radiation barrier posed by each item (in rads per hour at 1 meter from the surface, 30 years after irradiation for the reactor options, or 30 years after fabrication for the immobilization options); and the isotopic characteristics of the plutonium (shown as the percentage of isotopes higher than Pu-239). For the can-in-canister alternatives, two figures are shown for the percentage of plutonium by weight and the mass of material for 8 kilograms of plutonium: the first refers to the loading of plutonium in the small cans, and the second the average loading in the overall canister containing the cans. Figures for the borehole alternatives are not shown, because these alternatives gain their proliferation resistance primarily from geologic isolation in the borehole, rather than from the characteristics of the waste form itself.

Box 5-1
Accounting for Nuclear Material In A Comprehensive Safeguards System

Measurement of nuclear material, like bulk measurement of other materials, is never perfect. Just as the oil on a supertanker cannot be measured accurately enough to ensure that every gallon loaded onto the ship is delivered to the customer, so in facilities handling tons of plutonium each year, it is impossible, with current or foreseeable technology, to provide assurance solely by measuring the material that every kilogram of plutonium is accounted for. This does *not* mean that many kilograms of material could be stolen or diverted without detection, however. Material accounting, while a "measure of fundamental importance" (as it is described in IAEA parlance), is supplemented by other measures in comprehensive safeguards systems, to form a defense in depth against any attempt to steal or divert nuclear materials.

Domestic safeguards systems are designed to prevent theft of material by unauthorized parties. Physical protection measures such as guards, fences, secure vaults, and the like provide security for the nuclear material. Material control measures such as alarms, and monitoring of material provide rapid indication of any unauthorized tampering with nuclear material, allowing security forces to respond. Material accounting measures -- including measurements of material, careful records to account for movements and processing of material, tamper-resistant seals, statistical analyses of measurement errors and uncertainties, and the like -- do not in themselves protect against theft: rather, they provide the opportunity to detect a loss if one should occur, and, when the books balance, provide assurance that the other measures have been effective in preventing any theft. Thus, while uncertainties in material accounting are important, they do not in themselves mean that a domestic safeguards system cannot be effective.

International safeguards are designed by international monitoring agencies to detect (and therefore, one hopes, deter) any diversion of nuclear material by the host state, and to provide assurance that such diversions have not occurred. International safeguards are based on a comprehensive system that includes material accountancy -- to detect material unaccounted for (MUF) that could, in some cases, suggest potential losses -- and containment and surveillance measures, similar to those referred to as material control in domestic safeguards, which help detect any unauthorized tampering with equipment or removal of nuclear material. In the international safeguards context, effective material accounting is even more important, as physical protection measures applied by the host state would not prevent the host state itself from diverting nuclear material. It should be noted, however, that international safeguards over disposition processes taking place in the United States or Russia would be monitoring states that already possess thousands of nuclear weapons and tens of tons of nuclear material. While the diversion of a few kilograms or tens of kilograms of plutonium by a non-nuclear-weapon state could pose a dire security threat, for the United States or Russia, such an amount would be only a tiny fraction of the nuclear stockpiles they already possess.

For international safeguards to work, the state being inspected itself needs to have an effective state system of accounting and control (SSAC) for nuclear material. The state system must include measurements of the amount of nuclear material on hand, evaluations of the accuracy of those measurements, procedures for evaluating accumulations of inventory and unmeasured losses, detailed record-keeping procedures, and procedures for providing this information reliably to international monitors. To accomplish their task, international monitors review the information provided by the SSAC, and independently check selected measurements -- much as bank auditors check the accuracy of some records, but do not attempt to count all of the money in the bank. Indeed, the IAEA's member states require it to make full use of the host state's systems and avoid unnecessary duplication of the state's accounting and control activities. Containment and surveillance measures complement material accounting, providing "continuity of knowledge" about the facilities operations between IAEA inspections, and ensuring that material is not removed through key potential diversion pathways and key items are not tampered with. In international safeguards practice, the IAEA owns all the containment and surveillance equipment it relies on, and normally provides its own equipment at a facility. In rare instances where the IAEA can use operator supplied equipment (i.e., dual-use equipment where data is used by both the operator for their purposes, and the IAEA for its purposes) the IAEA performs an independent authentication of any data provided by the operator-supplied equipment. Although the effectiveness of containment and surveillance measures cannot be quantified as material accountancy measures are, containment and surveillance measures allow monitors to evaluate the significance of any MUF figures, and provide a measure of confidence that potential diversion paths are not being used to remove material from a process or facility. To ensure that no potential diversion pathways are going unnoticed, and all the processes are being effectively measured, it is essential for the IAEA to have complete design information about the facility; IAEA inspectors verify the design information provided by member states.

Material Unaccounted For

When nuclear material is in the form of individual "items" -- such as weapon pits or fuel assemblies -- these items can be counted exactly, just as money in a bank is. As long as none of the items is missing, and there are measures to ensure that any tampering with the individual items would be detected, there can be essentially complete assurance that no theft has occurred.

By contrast, when nuclear material is in bulk form -- in powders, solutions, and the like -- accounting must rely on imperfect measurement of the bulk material. All of the disposition options involve bulk-processing steps during which material accounting would have to rely on such bulk measurements. Because each measurement of nuclear material has some uncertainty, the measurements of material coming in and out of a particular facility will never quite match: there will always be some "material unaccounted for," or MUF, even if in reality no plutonium at all has been lost. MUF -- known in U.S. domestic safeguards as the "inventory difference," or ID -- is the difference between the measurements of a facility's initial inventory and inputs, minus the final inventory and the outputs:

MUF= initial inventory + inputs - ending inventory - outputs.

This difference can be either positive (suggesting that there is less material present than there ought to be), or negative (suggesting that there is more material present than expected, based on the previous measurements). These measurement uncertainties create "noise" that makes small diversions more difficult to detect. Typically, the threshold at which it is possible to tell the difference between a random variation in measurement and an actual loss or diversion of nuclear material is about two or three times the usual uncertainty in measurement, or MUF. Thus, if the uncertainties in measurement at a particular facility are, for example, ten kilograms a year, material accounting alone could not reliably detect diversions of less than 20 or 30 kilograms over a year's period.

Over the last several decades, enormous effort has gone into improving measurements of nuclear material, to minimize the MUF problem and improve material accounting's ability to provide assurance that material has not been diverted. Figures endorsed by the IAEA as "the latest international standards" for nuclear material measurement -- representing the best results actually achieved in day-to-day operation of industrial nuclear facilities -- were published in 1993 by ESARDA, the safeguards research arm of EURATOM, the nuclear agency and safeguards authority of the European Community. For U.S. plutonium disposition, it is assumed in this assessment that the 1993 ESARDA Target Values will be used at facilities for domestic safeguards and by IAEA inspectors. ESARDA Target Values for some materials found in the proposed disposition options are summarized in Table 5-2.

TABLE 5-2.
ESARDA Target Values for Materials In the Disposition Options

	RANDOM	SYSTEMATIC
Pu, PuO_2	0.15%	0.10%
MOX	0.55%	0.20%
SOLUTION	0.40%	0.25%
SCRAP (CHEM)	5.0%	0.50%
SCRAP (NDA)	7.0%	5.0%
ASSEMBLIES	1.5%	1.0%

Thus, at a facility handling 5 tons per year of plutonium metal and oxide (such as a plutonium pit conversion facility), the systematic measurement error, or MUF, would not be expected to be less than 5 kilograms per year (based only on the throughput, ignoring the facility's inventory), meaning that material accounting alone would not be expected to be able to detect diversions of less than 15 kilograms over a year's time.

The real MUF that will be achieved in real plants is much more complex to estimate, as it is very dependent on the specific design of the facility and the processes used in it. In general, the MUF will be significantly larger than a simple calculation like the one above would suggest, because of the uncertainties in measuring the inventory in the plant, the complexities of the various processing steps, difficulties in accounting for unmeasured accumulations within the plant and unmeasured losses, and the like. The facilities and processes to be used in the disposition options are not yet specified in enough detail to allow accurate quantitative assessments of likely MUF in these facilities.

Containment and Surveillance

As noted earlier, in modern comprehensive safeguards systems, material accounting is never acting alone in providing assurance that diversion and theft have not occurred. For protection against theft, domestic safeguards include both physical protection measures and material control, as well as material accounting. For example, in DOE Category I facilities (such as those handling bulk processing of plutonium), closed-circuit TV would monitor any actions taken with plutonium, alarm systems would detect unauthorized access to plutonium areas, and portal monitors at all exit points would detect plutonium being removed from the facility. In the event of a larger than expected MUF, material control and physical protection records can be checked to determine whether there are any anomalies that could suggest that the MUF is the result of an actual loss of material.

In the international safeguards context, material accounting is complemented by containment and surveillance. Cameras and other monitoring systems, along with tamper-resistant seals, provide additional confidence that nuclear material has not been tampered with, and that none of the known diversion paths have been used to remove nuclear material surreptitiously. For example, if one imagined a process in which plutonium which had been accurately measured was simply poured from one vessel into another, and this occurred under continuous monitoring to ensure that all the plutonium went from one vessel to the other, the vessels were inspected to ensure that they had no means for removing plutonium surreptitiously, and the original vessel was monitored after the operation to ensure that no significant amount of plutonium remained, one could provide high assurance that no plutonium had been diverted during that process even if it was impossible to measure the plutonium after it was poured into the second vessel. (In fact, in some plutonium disposition processes, it will be difficult or impossible to measure the plutonium in the final form, so such reliance on containment and surveillance will be necessary.) Real plutonium handling processes are inevitably more complex than this theoretical example, requiring monitoring at a significant number of points to provide confidence.

An important feature of modern systems is known as "dual-mode" containment and surveillance -- system designs that provide two means for maintaining containment and surveillance at each key point, and that ensure that a single failure (such as a failure of electrical power in the plant) could only disable one of the two systems at a time.

Unlike material accounting, where the MUF can be estimated numerically, the contribution of containment and surveillance to safeguards effectiveness cannot be quantified. But it is nonetheless a key factor: it is wrong to say that a safeguards system is ineffective solely because material accounting alone cannot eliminate significant measurement uncertainties.

Improving Bulk-Processing Safeguards

There will always be some uncertainty in measuring nuclear material in bulk forms. Nonetheless, there are a variety of opportunities for improving safeguards over bulk processing, some of which are already being implemented at large modern facilities.

Near Real-Time Accounting. Traditionally, nuclear material measurement approaches required plants to shut down periodically for a full inventory of the nuclear material. This meant that accounting discrepancies would only show up as often as inventories were taken, and plant operators sought to limit the frequency of inventories, to keep plants operating as much of the time as possible. In recent years, new techniques for estimating and measuring the material in process have been developed, which allow for "near real-time accounting" (NRTA). The technique relies on frequent physical inventories to supplement flow measurements, generally through the use of in-process instruments that do not interfere with process operations. The objective of NRTA is to improve the sensitivity and timeliness of detection through the use of statistical tests specifically tailored to the sequential nature of the data. NRTA allows facilities to meet the international safeguards requirement, for directly weapons-usable material, of measuring the material balance on at least a monthly basis. For diversions that take place quickly -- several kilograms of plutonium being removed from a process during the course of a day, for example -- NRTA provides both improved timeliness of detection and greater detection sensitivity (since the uncertainties in measurement accumulate over a shorter period of time). Specific statistical tests have also been designed to detect protracted diversions or losses. NRTA does not in itself, however, improve the accuracy of the measurements in a facility: the annual MUF in a facility still could not be reduced below the levels described above using currently available measurement technology, even with NRTA. NRTA could be applied to all of the bulk processes involved in the different plutonium disposition options.

Appropriate Process Design, Including Increased Automation. Processes can be designed to incorporate better measurement techniques and process operation and process control features that reduce MUF. Careful process design is essential to meet the best-practice targets described above, but will not in itself make it possible to reduce MUF below those levels. It is essential for safeguards considerations to be brought into the design of these processes from the beginning, to ensure the maximum practicable safeguards effectiveness for the overall process.

Diversion of nuclear material from facilities can also be minimized by automating to the degree possible the handling of the nuclear material. Through automation, human access to the material is minimized, reducing possibilities for theft or diversion. At the same time, however, automation also limits inspectors' access.

Improved Containment and Surveillance. Like material accounting, containment and surveillance measures can also be improved. In recently implemented safeguards systems for large facilities, containment and surveillance measures, including a broad array of seals, cameras, and process monitoring equipment, play an increasing role. Over time, efforts are being made to combine material accounting and containment and surveillance measures into a fully integrated safeguards system. The possible use of additional containment and surveillance measures is being considered: for example, information from the state's own physical protection systems (such as portal monitors) could help provide confidence that no nuclear material had been removed from a facility that was not declared to inspectors.

In short, bulk processing of nuclear material is the point in the disposition process when the material is most vulnerable to covert attempts by insiders to steal material, or covert attempts by the host state to divert material. Materials accountancy is a fundamental measure for monitoring these processes, and is quite effective, but significant irreducible measurement uncertainties remain. Containment and surveillance measures provide a critically important complement to material accounting in a comprehensive safeguards system.

REACTOR ALTERNATIVES

Light-Water Reactors

Description

One disposition alternative is to use the plutonium as fuel in light-water reactors (LWRs), the type of reactor currently in commercial operation in the United States and the most common type in other countries. There are two types of LWR design, known as pressurized-water reactors (PWRs) and boiling-water reactors (BWRs). Both types are in operation in the United States. The PEIS also analyzes evolutionary LWRs.

The LWR alternative would involve converting the plutonium from pits and other forms to plutonium oxide, mixing that material with uranium oxide to form a mixed oxide (MOX), fabricating fuel from this mixed oxide, irradiating that fuel in reactors, and then safely managing the spent fuel. The mixture of plutonium and uranium in the fuel would contain between 3 percent and 7 percent plutonium by weight, depending on the specific reactor and fuel design used. The reactors might be loaded with full (100%) MOX cores, or they might use such fuel in only a portion of their cores, with the rest using low-enriched uranium fuel. The use of full-MOX cores would decrease the number of reactors that would have to be used to carry out disposition at the rate made possible by the capacity of the MOX fuel fabrication plant, but may require additional control system modifications to ensure that the reactors meet the same safety standards as they would using their customary uranium fuel.

Under this alternative, a portion of the plutonium would be fissioned in the reactor, and the remainder would be imbedded as a small percentage of the material in highly radioactive spent fuel assemblies. This would not pose any significantly greater proliferation risk than the much larger and growing quantity of spent fuel from commercial reactors that already exists in the United States and other countries around the world. The isotopic mix of the plutonium would be changed from weapons-grade to reactor-grade, but this would not provide a substantial nonproliferation benefit, as reactor-grade plutonium can be used in nuclear explosives without requiring any greater sophistication than weapons-grade material.

MOX fuel made from reactor-grade plutonium is in use on an industrial scale in several other countries, including Germany, France and others (generally with one-third of the reactor core using MOX, and the rest traditional uranium fuel), and the process is, therefore, fully technically demonstrated. The use of MOX made from weapons plutonium as not yet been demonstrated, but such demonstrations are planned, and no special technical problems are anticipated. No U.S. reactors, however, are currently using, or are licensed to use MOX fuel. Moreover, the United States does not currently have an operational industrial-scale facility for producing such fuel, though small experimental batches are being produced at the TA-55 facility at the Los Alamos National Laboratory. Some existing DOE facilities could provide infrastructure that could be adapted for a MOX production plant, or a new plant could be built on a "green field."

The LWR disposition would involve the following technical steps relevant to its nonproliferation and arms reduction implications, following the initial processing steps described above:

- transport of tagged and sealed containers of plutonium oxide from the plutonium processing facility to the fuel fabrication facility (this step could be largely eliminated if the two are in the same building)
- fabrication of MOX fuel, including:
  - opening Pu oxide containers
  - blending of plutonium and uranium oxides (possibly in several steps)
  - milling mixed oxide to appropriate consistency
  - pressing of mixed oxide into pellets
  - sintering of pellets (baking at high temperatures)
  - grinding of pellets to appropriate shape and finish
  - loading of pellets into fuel rods, and finishing of rods
  - assembly of fuel rods into fuel assemblies, and finishing of assemblies
  - storage of material in various forms at several points in the process
  - inspection and assay steps at several points
  - processing of scrap and rejected products, return of material to beginning of the process.
- transport of MOX fuel assemblies to reactors
- storage of fresh MOX fuel assemblies at reactors
- loading of MOX fuel assemblies into reactors, followed by irradiation
- unloading of spent MOX fuel assemblies into spent fuel pools
- storage of spent MOX fuel assemblies in spent fuel pools and possibly dry casks
- loading of spent fuel into casks and transport to a geologic repository (possibly initial transport to an away-from-reactor interim storage facility)
- emplacement of casks containing spent MOX fuel assemblies in a geologic repository
- monitoring of emplaced spent fuel (50-100 years)
- closure of the geologic repository

A number of features of this sequence are important to note. The most proliferation-sensitive steps are those in which the material, in forms attractive to a potential proliferator, is going through bulk processing and long-distance transportation.[14] The initial processing of plutonium, which is largely common to all alternatives, is among the most sensitive steps. If the reactor alternatives were used for plutonium currently in impure forms and residues, several complex bulk-processing steps would be required to purify the plutonium beyond those needed for the immobilization or borehole alternatives.

Long-distance transportation of plutonium in attractive forms will be required (possibly several times) and they will have to be protected. Finally, once the MOX fuel has been irradiated in the reactor, it is in a form that meets the Spent Fuel Standard. It is important to note that once this has been achieved, the spent fuel is similar to other spent fuel, and can be stored safely and securely for decades. Thus, as in the case of the immobilization alternatives, the precise date when a geologic repository might become available is not a critical factor for the LWR alternative.

Technical Factors

Schedule[15]

Under the LWR alternative, it would require approximately 13 years before large-scale fabrication and irradiation of MOX fuel made in U.S. facilities could begin. Thus, all the overall policy risks associated with leaving the excess material in storage would continue, at least for that 13-year period. Using existing European MOX fuel fabrication facilities until U.S. fabrication facilities become available could accelerate the schedule by as much as four years. Under current concepts, in which four or five reactors using 100% MOX cores would be used, 50 tons of excess plutonium could be irradiated in about 12 years of reactor operations, meaning that all 50 tons of excess plutonium could be converted to forms meeting the spent fuel standard within 25 years of a decision to proceed. If new facilities were built for plutonium processing and MOX fabrication, rather than modifying existing facilities, the time required would be somewhat longer (and somewhat more uncertain). The same would be true for using new or partially completed reactors, rather than irradiating the MOX fuel in LWRs that are already operational. In either of these cases, therefore, the risks of storage would be perpetuated for a longer time. For those variants involving the use of neutron absorbers within the MOX fuel (which could potentially make it possible to safely use higher percentage loadings of plutonium in the MOX fuel itself), a significant fuel development program would be needed to prove out this novel approach, and this would involve some schedule uncertainty as well. Moreover, as

[14] Co-location of processing and MOX fabrication facilities with current plutonium storage sites would reduce transport of some of the more attractive forms of plutonium such as weapon pits and separated Pu oxide.

[15] Schedule estimates are based on the results contained in the Technical Summary Report prepared by the Department of Energy's Office of Fissile Material Disposition and released on July 17, 1996. These schedules are estimates and may under or over-estimate the amount of time required.

noted below, these schedule estimates are uncertain, because of political implementability issues. Thus, it is possible that the period of storage would, in the end, be significantly longer than expected.

Risks of Theft or Diversion in Process

MOX Fabrication: After the initial processing stages common to all alternatives, the risk of attempted covert theft of material for the LWR alternative is greatest during the MOX fabrication process, when the material is undergoing several complex bulk processing steps. The material would become a less attractive target for theft over time.

The material would arrive as pure plutonium oxide powder, a highly attractive material to a potential proliferant. The plutonium oxide would then be mixed with large quantities of uranium oxide. The resulting MOX powder would no longer be directly weapons-usable; chemical separation of the uranium from the plutonium (requiring acid dissolution followed by purification) would be necessary before the plutonium could be used for nuclear weapons. Moreover, since the plutonium itself would be only a few percent of the MOX powder, many times as much material would have to be stolen to get enough plutonium to make a bomb, making covert theft more difficult to achieve. After the MOX powder was fabricated into pellets and loaded into sealed rods, there would no longer be uncertainties in accounting for it: each rod could simply be counted and checked for tampering to provide assurance that no theft had occurred (a process known as "item accounting.") Once the rods were assembled into fuel assemblies, the resulting assemblies would still be item-accountable, and would be massive (nearly 700 kilograms apiece for PWR assemblies, roughly 300 kilograms for BWR assemblies), making them impossible for one individual to carry, and making covert theft effectively impossible. The assemblies would then be shipped to reactors for irradiation.

Nevertheless, it is important to understand that fresh MOX fuel remains a material in the most sensitive safeguards category, because plutonium suitable for use in weapons could be separated from it relatively quickly and easily. Hence, U.S. policy and international physical protection standards require the same level of physical protection and control over fresh MOX fuel assemblies as would be applied to pure plutonium metal or oxide, and the IAEA applies the same level of safeguards.

While the plutonium form at the end of the MOX fabrication process would be a less attractive target for theft and easier to safeguard than the plutonium form at the beginning of the process, the process itself would involve a number of complex steps that would both introduce some material accounting uncertainties and provide insiders within the plant access to materials, increasing the risks of covert insider theft. These risks can be substantially mitigated with the application of appropriate safeguards and security resources. As with other large bulk-processing facilities, there will be uncertainties in accounting for the nuclear material, and these uncertainties cannot be eliminated with present or projected technology (see "Material Accounting in a Comprehensive Safeguards System," p. 70). Precise measurements of the plutonium would be taken at several stages as the material moved through the several processing stages in the MOX fabrication plant. Each measurement, however, would have some irreducible uncertainty. Recent standards issued by the European Community's nuclear agency (EURATOM), endorsed by the IAEA, indicate that currently achievable measurement accuracy for plutonium oxide is in the range of 99.9% (for systematic errors). Mixing the plutonium oxide with uranium oxide complicates the task of measuring the amount of plutonium somewhat, resulting in an estimated achievable measurement accuracy of 99.8%. Though these uncertainties are very small (thanks to modern nuclear material accounting technology), in a plant that processes tons of plutonium every year through a complex series of individual bulk-handling steps, it will not be possible to avoid accounting uncertainties that amount to tens of kilograms a year or more.

This does *not* mean, however, that tens of kilograms of material could be stolen or diverted without detection. As described elsewhere, in domestic safeguards systems nuclear material accounting is only one part of a multi-layered system designed to provide defense in depth against any possible theft of nuclear material. Television monitors and other continuous monitoring systems, alarms, portal monitors that could detect the removal of nuclear material from any of the exits to the facility, and a wide range of other material control and physical protection technologies would provide high levels of assurance that no nuclear material was being stolen -- just as similar systems in place at DOE sites processing equally attractive nuclear material do today. Any MOX facility built in the United States for plutonium disposition would have to meet stringent standards for material control, accounting, and physical protection. These standards have been steadily improved for decades, and offer a substantial base of experience for providing assurance that no material had been stolen during processing. Once the MOX pellets were pressed, sintered, ground, and loaded into sealed rods, the material could be monitored with item accounting -- simply counting the rods, and checking to ensure that they had not been tampered with -- with no uncertainties in the measurement. These rods would then be assembled into large fuel assemblies, which would be stored at the facility until they were shipped to reactors for irradiation.

There is a significant base of international experience in applying international safeguards to MOX fabrication facilities, although only one plant -- the MELOX plant in France -- is as large and as automated as the plant envisioned for plutonium disposition has begun operation. In general, the operators of these facilities and the international safeguarding agencies (IAEA and EURATOM) agree that these plants can be effectively protected and safeguarded -- both for the domestic safeguards mission of detecting and preventing theft of nuclear material by unauthorized parties, and for the international safeguards mission of detecting diversion by the host nation. Providing assurance that the host nation has not diverted a few kilograms of material is inherently more difficult than providing assurance that a few kilograms have not been stolen by unauthorized parties, because the host nation, which includes all the operators of the plant, could potentially have built diversion pathways into the plant or tampered with operating records, measurement information and the like. Nevertheless, the parties to the Nonproliferation Treaty have repeatedly stated their confidence that the IAEA safeguards system provides adequate assurance that states are fulfilling their obligations not to divert material under safeguards to military purposes.

As noted above, accounting uncertainties in large bulk-handling facilities make it impossible, through materials accounting alone, to meet the IAEA's stated goal of detecting a diversion of one "significant quantity" (defined by the IAEA as 8 kilograms of plutonium) within one month. While the IAEA regards material accounting as the safeguards measure of "fundamental importance," significant reliance must also be placed on containment and surveillance measures, which would help detect the specific actions needed to divert nuclear materials (such as siphoning material off from a processing line, tampering with measurements to cover the diversion, and the like). Providing barriers to undetected removal of material from safeguarded facilities, being able to detect unauthorized presence in sensitive areas or removal of materials (in real time or even after the fact), and other features of containment and surveillance are important contributions to the overall safeguards system, although the level of assurance provided by containment and surveillance measures is impossible to quantify.

Moreover, in a number of cases, the experience at real facilities has not been quite what was hoped for in the planning stages. Unexpected problems in the fabrication process have led to quantities of material piling up in difficult-to-measure forms, as dust in plutonium-handling glove-boxes, plated on to pipes, caught in air purification filters, and the like. (Material held up in process in this way is referred to as "hold-up.") In a Japanese plutonium processing plant, for example, the amount of MOX powder held up in the processing lines of a MOX facility grew to several significant quantities of plutonium, so that the uncertainty in measuring the material from outside the sealed glove-boxes was itself close to a significant quantity. The IAEA negotiated an agreement with the owner of the facility to implement a schedule of selective clean outs so that the powder could be collected and accurately accounted for. While good engineering and increased plant automation can reduce these types of problems, real plant experience is rarely identical to what is projected. Placing a major emphasis in the design phase on the ability to accurately monitor and account for materials is critical to effective safeguards.

In the case of a MOX plant in a nuclear weapons state such as the United States or Russia, assuring that no diversion had occurred that would be large enough to have any significant impact on the nuclear stockpile of the host state would be straightforward. Nonetheless, to ensure the credibility of the international safeguards system and avoid discrimination between nuclear weapon states and non-nuclear-weapon-states, the rules and procedures the IAEA uses when safeguarding facilities in nuclear-weapon-states are generally the same as those used in non-nuclear-weapon states.

Assuming that a MOX facility in the United States for disposition of excess plutonium would be made eligible for IAEA safeguards, and that the IAEA would choose to implement safeguards on that facility, the IAEA would conduct inspections at intervals of not more than one month plus one week, and a full physical inventory of the plant at least once a year. During inspections, plutonium oxide and MOX powder, pellets, and scrap would be inspected; samples of pellets would be taken at the station where they are loaded into the rods at least four times per year, or, in a plant where the loading is done with automatic equipment, a fuel rod scanner might be used instead of pellet sampling.

Transport: When attractive nuclear material is being shipped from one place to another, it is essential to ensure high levels of security, to prevent theft by an overt attack on the shipment. Such overt attacks to seize a shipment have occurred for centuries in the case of shipments of money and other valuable materials. While no such seizure of nuclear weapons materials has ever been recorded, it is a possibility that must be guarded against.

Several transport steps may be involved in the LWR alternative:

- transport of plutonium metal, oxide, and other forms from the sites where it is currently located to the plutonium processing facility (which may be located at one of those sites);
- transport of plutonium oxide from the processing facility to the MOX fabrication plant (unless the two facilities are combined into one);
- transport of fabricated MOX fuel assemblies from the MOX plant to the reactor sites;
- transport of spent MOX fuel from the reactor sites to a geologic repository or interim storage site.

In each of these cases, the material would be shipped in tagged and sealed containers, to ensure that no material could be removed without detection during the shipment. In the first three transport steps, the plutonium forms would be in the most sensitive safeguards category, requiring the highest standards of security. In keeping with the Stored Weapons Standard, DOE intends to use the same Safe, Secure, Transports (SSTs) for these shipments that are used for shipment of intact nuclear weapons, with similar security forces and other measures to protect the shipments. The level of assurance against possible attack during transport can be increased to essentially any desired level by applying more resources such as money, security forces, or technology.

The security risks posed by transportation of nuclear material can be minimized by minimizing the amount of transportation required. Unfortunately, however, no quantifiable measure can adequately assess which alternatives pose the greatest risk. In its 1994 report, the NAS committee proposed minimizing the number of "ton-miles" of transportation required for each alternative. However, "ton-miles" are not a fully accurate measure of the transport risk. A transport step that requires shipping the material only 100 miles down the highway provides an opportunity for theft, but shipping the material 1000 miles does not provide ten times as much opportunity. A shipment that requires delegating security to a different security force, which might occur when material crosses international boundaries, involves different security considerations from a shipment that does not. A shipment widely known to cross a single bridge (or other similar bottleneck) to get to its destination provides a much better target for attack than a shipment of the same distance that can follow any one of many different routes. One shipment carrying a ton of nuclear material provides only one opportunity for theft, while ten shipments each carrying 100 kilograms of plutonium would provide ten opportunities to steal enough material for more than ten nuclear weapons -- yet each of these approaches would count as only one ton-mile.

Even without quantitative measures, however, it can clearly be seen that particular steps would mitigate the transportation risk. Putting the plutonium processing and MOX fabrication operations in the same facility, for example, would eliminate entirely the transport step during which the material is in its most attractive form. Minimizing the number of sites to which plutonium in attractive forms had to be shipped, and the distance between those sites, would also help reduce the risks, and the costs of mitigating them.

Reactor Site Storage and Handling: Reactor sites in the United States already have significant security requirements, to prevent sabotage of the reactor. Since the low-enriched uranium fuel these reactors normally use does not contain unirradiated weapons-usable material, however, the reactors do not have the security procedures necessary for protecting such material, and additional storage areas and security would have to be provided. In particular, in some states guards at licensed commercial facilities (as opposed to DOE or DOD facilities) do not have legal authority to use deadly force to protect nuclear material. Rules would need to be changed to ensure that the guard force had recognized authority to take appropriate action to prevent an attempted theft. (The same would also be true of the MOX fabrication plant, if it was a commercially-licensed facility rather than a DOE facility.) With sufficient resources applied to the problem, it should not be difficult to provide effective security for the material at the reactor sites.

Risks of Recovery and Re-Use in Weapons

Use of excess weapons plutonium as MOX in LWRs would transform this material into intensely radioactive spent fuel. Only a fraction of the plutonium would actually be consumed in the reactor, but the remainder would be imbedded in massive, intensely radioactive spent fuel assemblies, and its isotopic composition would be transformed from weapon-grade to reactor-grade (a broad category). All grades of plutonium, however, with the exception of relatively pure Pu-238, can be used for nuclear explosives. (See "Reactor-Grade and Weapon-Grade Plutonium in Nuclear Explosives," p. 34.) This spent fuel would be similar in most respects to the far larger (and growing) stockpiles of LWR spent fuel that already exist. (See Table 5-1.) The MOX spent fuel would have somewhat higher concentrations of plutonium than spent uranium fuel (typically 2-5%, depending on the initial concentration of plutonium in the MOX fuel and the length of time it remained in the reactor, compared to just under one percent for spent uranium fuel), but overall its inaccessibility and unattractiveness for use in nuclear weapons would be quite similar to that of other spent fuel, thus meeting the Spent Fuel Standard. (See "The Spent Fuel Standard: How Accessible is Plutonium in Spent Fuel?," p. 48) The excess weapons plutonium would no longer pose a unique security hazard, but would be simply one part of a larger issue which society must address eventually in any case. When first removed from the reactor, the fuel would emit a radiation field of tens of thousands of rads per hour at one meter from the assembly -- enough to quickly incapacitate and eventually kill any potential thief trying to remove the material without substantial radioactive shielding equipment. After ten years, the radiation level would have decreased to a few thousand rads per hour or less as the shortest-lived radioactive isotopes decayed away. After that, the radiation would decrease by roughly half every 30 years. For decades, this spent fuel would be so radioactive that the remaining plutonium could only be recovered in shielded reprocessing facilities, increasing the cost and complexity of recovery, particularly for subnational groups.

The spent fuel assemblies would be so large and radioactive that covert theft or diversion would be effectively ruled out: only overt removal of the material would be a realistic possibility. Any attempted theft of the material would require a dedicated team willing to suffer large doses of radiation, along with substantial equipment for accessing and removing the spent fuel from the storage facility and carrying it away. The host state, should it choose to overtly recover the material, would be able to separate the plutonium in a reprocessing facility.

Implementation Variants

U.S. Implementation Variants: There is a wide range of possible variants of the LWR alternative for excess plutonium disposition. For reactors, alternatives include:

- existing, operational LWRs
- completion and use of partially completed LWRs
- construction and use of new evolutionary LWRs

In any of these alternatives, the reactors could be privately owned and operated, as reactors typically are in the United States today, or they could be owned and/or operated by the government. (Existing reactors, for example, might conceivably be purchased or leased from private utilities.) The reactors could be located in a variety of different areas of the United States.

In addition, the number of reactors employed in the mission could vary considerably. To implement disposition of 50 tons of plutonium over roughly 25 years from the date of a decision, 4-5 reactors would have to be used, if the reactors used MOX fuel in 100% of their reactor cores, with a few percent plutonium by weight in the MOX. If multiple reactors were located at a single site, only one to three sites might be required. If the reactors used MOX in only one-third of their reactor cores (as is the common practice in Europe), the number of reactors would have to be increased to 12 or more. To accomplish disposition more quickly, even more reactors would be needed. On the other hand, the number of reactors needed could potentially be reduced to two or three if the percentage of plutonium in the MOX could be increased, and the time for disposition were stretched out to 30 or 35 years.

Whether the reactors used are existing facilities, partially completed, or new, or whether they are owned by the government or the private sector, should have only modest impacts on the technical nonproliferation and arms reduction issues associated with this alternative. Variants using new or partially completed reactors would take somewhat longer to begin (and the uncertainty in the time to start would be larger, given the political and regulatory obstacles to bringing new reactors on-line in the United States), perpetuating the risks of storage for a longer time. New reactors, on the other hand, could potentially be built on a single existing DOE nuclear site, taking advantage of existing safeguards and security infrastructure -- and if it were on the same site as the pit-processing and MOX fabrication plant, one transportation step could potentially be avoided. (As noted above, however, if sufficient resources are applied to protecting the shipments of plutonium, the risk of theft during transport can be reduced to very low levels in any case.)

Similarly, reactors that used MOX in 100% of their reactor cores would have the obvious advantage of substantially reducing the number of reactors needed to accomplish the mission (and thereby reducing the number of sites that would have to be guarded against theft, and the amount of transportation required), but the 100% MOX approach could take somewhat longer to develop and implement, since it is not the approach already being used in other countries. (A likely variant would be to combine the virtues of an early start and reducing the number of plants required by starting with partial-core MOX and then moving to 100% MOX cores as the needed development and licensing efforts are completed.)

There is a clear tradeoff between accomplishing disposition more rapidly (which would end the risks of storage more quickly) and using more reactors (which would require protection of more sites). Disposition of a given amount of excess plutonium could be accomplished more quickly if a larger number of reactors (supported by larger MOX fabrication and plutonium processing plants) were used. The larger supporting plants would be more costly, as would licensing the larger number of reactors required for use of MOX fuel. In making final decisions concerning the particular variants to be implemented (which may not be part of the Record of Decision to be issued in 1996), policy-makers will have to decide which they consider more important -- faster disposition, or limiting the number of reactors and the size of the supporting facilities.

Similar variants in the MOX fabrication and plutonium processing facilities are also possible, including:

- size and capacity of the facilities
- co-location of plutonium processing and MOX fabrication in one facility
- modification of existing facilities, or construction on new, "greenfield" sites
- government or private ownership of the facilities

As just mentioned, one important design choice is the capacity of these facilities: facilities capable of handling 5 tons of plutonium per year, for example, would be large and expensive, but could process all 50 tons of excess plutonium in 10 years from start-up. That would only be a significant advantage, however, if sufficient reactor capacity were available to irradiate the plutonium fuel at a similar pace.

Putting the plutonium processing and MOX fabrication together at one facility would largely eliminate one transportation step -- the need to ship tens of tons of plutonium oxide to the MOX plant. As noted above, however, while the MOX fabrication plant could be placed under traditional IAEA safeguards, parts of the pit conversion facility could not be. If a single plant was used for both purposes, arrangements would have to be made for safeguards to apply to some parts of the facility while other parts remained off-limits -- but precedent for such arrangements already exists, such as at the Y-12 plant at Oak Ridge.

If existing facilities at DOE nuclear sites were modified for these purposes, the safeguards and security systems could rely in part on existing infrastructure. New facilities, however, could also be built at DOE nuclear sites and make use of much of this infrastructure. Government or private ownership of the facilities should not make a major difference in the ability to provide nonproliferation assurance: facilities owned by private contractors are already fabricating fuel from similarly attractive nuclear-weapons material, and have been for decades, in the case of fuel for the Navy's nuclear propulsion systems. As noted earlier, however, in the case of a private facility, it would be necessary to ensure that the guard force had appropriate authority needed to use deadly force if necessary to prevent a theft of nuclear materials.

Foreign Implementation Variants: The nonproliferation and arms reduction implications of variants making use of foreign facilities are potentially more significant. In Europe, France, Belgium, and the United Kingdom already have MOX fabrication plants in operation, and several other countries are already using MOX fuel produced in these plants (made from civilian reactor-grade plutonium) in their commercial LWRs. In some circumstances, use of these already licensed and operational facilities could speed up the process of disposition. Several approaches that would make use of these existing capabilities are possible:

- fabrication of initial demonstration fuel assemblies in European plants
- fabrication of the first reactor cores in European plants, while U.S. plants are being brought into operation
- fabrication of a large fraction or all of the U.S. stockpile of excess weapons plutonium in European plants
- fabrication of a large fraction or all of the U.S. stockpile of excess weapons plutonium in European plants, followed by irradiation of the MOX fuel in European reactors.

(In the Draft PEIS, only the first two approaches were considered "reasonable" and only for the near-term, as explained in the draft PEIS.

Japan also has a small MOX facility and a larger plant under construction, but Japan has so far indicated that it is not interested in receiving weapons-grade plutonium from the United States or Russia.

Each of these European variants would raise both technical and policy issues. First, from a technical point of view, each would require shipment of weapons-grade plutonium from the United States to Europe (and most would require return shipment of fabricated MOX fuel). Such intercontinental shipments would raise more serious security concerns than those raised by shipment within the United States. Similar shipments of civilian reactor-grade plutonium from Europe to Japan have proved to be highly controversial. While the United States has certified that arrangements for these shipments provide effective protection against theft, some non-government experts have raised concerns, and it is clear that the security provided such shipments to date is not similar to the security the United States has provided for shipments of U.S. nuclear weapons to and from Europe; maintaining such a similarity is the principle of the Stored Weapons Standard.

Moreover, once in Europe, security would be handled by the individual state rather than by the United States, meaning that different safeguards and security procedures would apply. The United States government has certified its acceptance that European plutonium-handling facilities have safeguards and security that provide effective protection for weapons-usable plutonium, and these countries are already handling plutonium made from U.S.-origin materials on a large scale. Indeed, both plutonium and HEU have been shipped between the United States and Europe in the past. Nevertheless, effective steps for transferring security responsibility for bulk processing of large quantities of U.S. weapons-usable material to other countries would have to be taken if such alternatives were to be pursued. European facilities were designed for civilian purposes, so their specific security procedures do not parallel those in the U.S. nuclear weapons complex. European MOX fabrication would, therefore, be less likely to approach the Stored Weapons Standard. Transfer of security responsibilities would have to be handled with considerable care.

Belgium, which is the European country with the most extensive MOX fabrication experience, is a non-nuclear-weapons state and a party to the Nonproliferation Treaty. If Belgian facilities were to be used for fabrication of MOX from weapons-grade plutonium, the requirements for successful implementation of international safeguards would be stringent. Long-standing international policy, however, supported by the United States, is that the same level of safeguards is required for separated reactor-grade plutonium, which the Belgian facilities have handled for many years.

If the excess weapons plutonium were fabricated in Europe into MOX fuel for use in U.S. reactors, the plutonium would have to be shipped both to and from Europe, as plutonium oxide and as fabricated MOX fuel. Fabricating plutonium into MOX in Europe and irradiating it in European reactors would have quite different implications. Only one transoceanic shipment would be required, and with the plutonium staying in Europe rather than returning to the United States, the United States would be unable to recover it for use in weapons. This would achieve a level of irreversibility beyond the Spent Fuel Standard. It should be remembered, however, that the much larger quantities of plutonium present in other spent fuel would continue to exist in the United States.

Impact on Russian Programs

This alternative is similar to alternatives Russia is considering for disposition of Russian excess weapons plutonium. Some analysts have suggested that it could be difficult to reach agreement with Russia on disposition of Russian plutonium unless both countries use closely matching technologies for disposition. Informal U.S.-Russian discussions to date, however, have resulted in a mutual understanding that while the two countries' plutonium disposition programs should proceed in parallel, they need not use the same disposition technologies. Given the very different nuclear infrastructures, fuel cycle policies, and economic situations in the two countries, it is possible that the best alternatives will be different in each country. In other words, while the LWR alternative would allow for the possibility of parallel disposition in the United States and Russia, other alternatives would also allow for parallel programs using differing technologies.

The reactor alternatives, including the LWR alternative, would convert the weapons plutonium to reactor-grade, while the immobilization and borehole alternatives would not. Nearly all grades of plutonium, however, can be used to produce nuclear explosives. Some analysts contend that the reactor alternatives would offer greater assurance of irreversibility to Russia and the international community, because a major weapons state such as the United States or Russia would be more likely to recover weapons-grade plutonium from an immobilized form than to use reactor-grade plutonium recovered from spent fuel. Some also argue that Russia might not be willing to burn its plutonium in reactors, thereby converting it to reactor-grade plutonium, if the United States was planning on immobilizing its excess plutonium, leaving it in weapon-grade form.

Several points should be made. First, as noted, the United States and Russia have already reached an informal understanding, specifically in the context of a study that considered reactor, immobilization, and borehole alternatives, that disposition technologies need not be the same in the two countries. Second, immobilized forms would offer high confidence of irreversibility (although material could be recovered from any of the disposition forms under consideration). To recover the plutonium from the immobilized forms for use in weapons would cost the United States billions of dollars, and, unless all environmental and review requirements were somehow waived, the recovery could take many years. It is highly unlikely that the United States or Russia would spend billions of dollars to put plutonium into a form from which it would subsequently cost billions more to recover it, if they were not serious about their commitment never again to use this material in weapons. Third, while weapons-grade plutonium is the preferred material for the weapons program of a nuclear weapons state (as evidenced by the fact that all of them have produced such material for their weapon programs), reactor-grade plutonium could also be considered for such a rearmament program. Thus, while the policy implications of leaving the material in weapons-grade form should certainly be considered, it does not appear that this would be a critical discriminating factor between the immobilization and reactor alternatives. Lastly, any effort to recover the plutonium would be highly observable, given bilateral or international monitoring, providing the other side an opportunity for timely response. This would help provide confidence that reversal is unlikely.

Impact on Nuclear Arms Reduction Efforts

As with other alternatives that meet the Spent Fuel Standard, implementing the LWR alternative (particularly with Russia also carrying out disposition of its plutonium) would have the benefits of plutonium disposition described in Section 2, including helping to lock in current nuclear arms reductions and reduce the risk of reversal; laying a basis for further reductions, if desired; and building international confidence in the arms reduction process.

Impact on Nonproliferation Efforts

Implementing the LWR alternative or other alternatives meeting the Spent Fuel Standard, by demonstrating that the leading nuclear weapon states were working to fulfill their NPT commitments to pursue permanent nuclear arms reductions and eventual disarmament, would help increase international support for maintaining and strengthening the international nonproliferation regime,. This could help make agreement on measures such as strengthened international safeguards or a fissile cutoff convention easier to achieve.

If the United States used the disposition program to demonstrate and implement new improved procedures and technologies for protecting and safeguarding nuclear material which approached the Stored Weapons Standard, this could potentially put the United States in a leadership position to encourage adoption of such improved procedures and technologies in other countries, which could reduce proliferation risks. This advantage could potentially be achieved with any of the disposition alternatives under consideration.

In addition, given the limits on current European MOX production capacity, the fabrication of U.S. or Russian excess weapons plutonium in Europe could displace fabrication of reactor-grade plutonium, thus resulting in accumulation of additional reactor-grade stockpiles. If some European capacity would otherwise be idle, however, because no firm contracts were in place for fabrication of the substantial existing stocks of reactor-grade plutonium, it might be possible to carry out fabrication of limited quantities of MOX from excess weapons plutonium without substantially adding to plutonium accumulations elsewhere. While the United States believes that protection for existing accumulated stockpiles of separated plutonium is adequate, it seeks to reduce such accumulations worldwide, in order to reduce the proliferation risks they pose

Impact on Fuel Cycle Policies and Choices

A decision to use excess weapons plutonium as MOX fuel in LWRs could be perceived as a change in the U.S. fuel cycle policy of not encouraging the separation and recycling of plutonium. In fact, such a decision would not represent any change in U.S. fuel cycle policies, but would relate only to the specific mission of addressing the security risks posed by the stockpiles of excess plutonium that already exist in the DOE inventory. No reprocessing or recycling of this material or of other civilian spent fuel is implied or contemplated. The licenses and approvals that will be sought for the facilities necessary for plutonium disposition will be limited specifically to that mission, and will not authorize any broader civilian plutonium use.

Nevertheless, advocates of the use of plutonium fuels in other countries would be likely to use the argument that the United States had changed is position, and that plutonium fuels were now playing a key role in nuclear disarmament, to help promote their cause. If this, in fact, led to decisions in other countries to pursue additional reprocessing and bulk-handling of separated plutonium, it could result in additional proliferation risks. This is an important policy issue in considering the LWR MOX alternative.

It is unlikely, however, that a decision to use MOX fuel in the United States would, in and of itself, result in substantial additional reprocessing and use of MOX fuel in other countries. Decisions concerning reprocessing and use of MOX fuel in most nations are based on factors relating to cost, waste management, perceptions of uranium availability and the need for energy security, and political and bureaucratic imperatives. Historically, U.S. policies have had some influence on decisions in other countries, but major plutonium programs remain in place in Western Europe and Japan despite past U.S. efforts to encourage countries to consider the proliferation risks of such programs. Already, as part of its policy of remaining a reliable nuclear partner, the United States has reached agreements with its European and Japanese allies granting long-term consent for them to reprocess plutonium from U.S.-origin materials and use it as MOX fuel. The United States will stand by these commitments. It is possible that a U.S. decision to use excess weapons plutonium as MOX could be a factor in the decision-making of less developed countries on plutonium recycle issues, though here, too, other aspects of U.S. policy (including the incentives and disincentives provided for particular choices) are likely to be more influential. Use of MOX by the United States might, in some rare cases, provide modest political cover for would-be proliferent states to pursue and justify plutonium production capabilities. Such cases are likely to be rare, and the impact of a U.S. MOX disposition program rather modest.

The potential impact of encouraging plutonium use could be mitigated by several steps. If this alternative is chosen, high-level U.S. officials should clearly outline how this approach fits within broader U.S. fuel cycle and nonproliferation policies. In particular, such a statement should make clear that this step is being taken only to eliminate a stockpile of separated, weapons-usable plutonium that already exists, and does not represent any change in the underlying U.S. approach to the nuclear fuel cycle; that this material will be used in reactors once-through, without reprocessing, as other reactor fuel is in the United States; and that the plutonium fuel fabrication facilities needed to implement this alternative will be shut down permanently as soon as disposition of excess weapons plutonium is complete, rather than being used for a broader plutonium fuel cycle industry in the United States. In effect, U.S. policy is that separated plutonium poses greater proliferation risks than unseparated plutonium, and that therefore, to the extent practicable, all plutonium that is unseparated should stay that way, and all plutonium currently separated should become unseparated -- i.e., be transformed into forms meeting the Spent Fuel Standard -- as rapidly as practicable, while ensuring effective nonproliferation controls. Use of excess weapons plutonium as fuel in LWRs would be consistent with this policy.

The way in which this alternative is implemented, including placing the facilities under international safeguards and maintaining stringent standards of security and accounting throughout, will also be important. It would probably also be useful to limit implementation of this alternative to a small number of reactors, making clear that the overwhelmingly predominant U.S. approach remained once-through use of low-enriched uranium fuel.

Given these factors, and the potential mitigating steps, it does not appear that a decision to use excess weapons plutonium as MOX in U.S. LWRs, under appropriate nonproliferation conditions, would fundamentally undermine U.S. fuel cycle policy or contribute substantially to proliferation risks. Nevertheless, policy-makers will have to consider the potential impact on U.S. fuel cycle policies when choosing preferred plutonium disposition alternatives.

Foreign Implementation Variants. The variants in which U.S. weapons plutonium might be fabricated into MOX in Europe could raise additional issues. If U.S. contracts provided the funding to build new MOX fabrication capabilities that would then continue to be used for civilian MOX production after the weapons plutonium disposition was completed, that could reduce overall costs of the plutonium fuel cycle for the customers of European fuel cycle companies, and hence could be construed as encouraging reprocessing. Such additional capacity, however, would also help reduce existing stockpiles of separated plutonium, which is a U.S. policy goal. If, on the other hand, U.S. contracts simply made use of capacity at existing or already planned facilities, the only potential aspect of "encouragement" would be providing financing to facilities and fuel-cycle companies involved in plutonium recycle; the United States regularly contracts with these firms for other services in any case.

If it were determined that a particular approach to using European facilities would encourage additional reprocessing and recycle of plutonium, the potential proliferation risks resulting from that would have to be balanced against the potential benefit of achieving a more rapid start on disposition of U.S. excess weapons plutonium. DOE-MD estimates that use of European facilities to fabricate initial test assemblies and possibly the first reactor cores (while U.S. facilities were being built and licensed), could accelerate the start of disposition by approximately four years. For this limited initial quantity of MOX fabrication, new MOX facilities in Europe would not be needed, and only a limited amount of funding would be provided to existing MOX facilities.

Policy-makers will need to judge how much initial MOX fabrication contracts in Europe would in fact encourage additional reprocessing, and decide if the benefit of an earlier start on plutonium disposition is worth the potential cost. If a decision to use plutonium facilities in Europe was made, it would be important for the United States to stress that this did not represent a change in its fuel cycle policy, and was being done for the benefit of gaining an early start on the disposition process.

Political Implementability

A decision to use plutonium fuel in U.S. reactors would be highly controversial, and the potential for opposition introduces significant uncertainties in estimating the schedule for implementation of the LWR alternative. Historically, schedule estimates for major nuclear projects (and a variety of other large government projects) have tended to be optimistic. The U.S. system for review and approval of large nuclear projects creates a variety of opportunities for opponents of a project to intervene and attempt to delay or derail the effort. New facilities involve a long series of actions for design, engineering, and construction, any of which can be delayed.

Substantial segments of the U.S. public are seriously concerned about the safety of nuclear reactors and other nuclear facilities, and about plutonium in particular. Any proposal to use plutonium as reactor fuel is likely to generate significant opposition, and, in all likelihood, legal actions to attempt to stop the project in the courts. On the other hand, industry groups and some non-governmental organizations will likely be active supporters of these alternatives, in part because they can be more closely integrated with Russian efforts on plutonium disposal. Strong Presidential and Congressional support, with the clear linkage that disposition is an integral part of the process of nuclear disarmament, will likely be needed to gain political approval for implementation of reactor alternatives in the United States. The prospect that disposition will result in reduced nuclear security dangers can help overcome concerns about perceived safety hazards posed by nuclear-related facilities and operations.

While the use of existing LWRs for plutonium consumption would require amending current licenses to use MOX fuel, gaining these license amendments would be considerably less complicated than completing new reactors and obtaining licenses for their operation.

Canadian Deuterium-Uranium (CANDU) Reactors

Description

Another reactor alternative under consideration is to fabricate the excess weapons plutonium into MOX fuel for use in Canadian CANDU reactors. Canada has agreed, in principal, to the use of MOX fuel containing weapons plutonium in Canadian-based CANDU reactors using a once through fuel cycle. Under this proposal, Canada would burn both U.S. and Russian excess weapons plutonium in its reactors, in a parallel program. Canada is taking part in experiments and studies with both the United States and Russia. The principal Canadian nuclear utility, Ontario Hydro, has been supportive of this idea. The reactors proposed for use are those at the Bruce nuclear power station in Ontario.

For U.S. excess weapons plutonium, the plutonium processing and fuel fabrication operations would take place in the United States, as in the LWR alternative. Canada is not proposing to do any handling of weapons-usable plutonium in Canada other than in the form of already fabricated and sealed fuel bundles. These fabricated bundles would be shipped to the Canadian reactors from the U.S. fuel fabrication facility (and, potentially, from a Russian fuel fabrication facility). Studies indicate that CANDU reactors could handle MOX in 100% of their reactor cores, at a loading of 1-3% plutonium in the fuel. This loading is somewhat lower than could be used in LWRs (because CANDUs normally use natural uranium with only 0.7% U-235, rather than low-enriched uranium with 3-5% U-235, which is used in LWRs); this lower loading would mean that a larger total quantity of MOX would have to be fabricated for a given amount of plutonium, but that less plutonium would be present per unit of volume. Disposition of fifty tons of plutonium could be accomplished in 15 years of reactor operations (which might begin roughly a decade from now, for a total time of approximately 25 years), in a program in which two of the eight plants at the Bruce station would begin operation for five years using current fuel designs with a relatively low loading of plutonium in the MOX, followed by four reactors operating for approximately 10 years using an advanced fuel design (only now being tested) that could incorporate a higher plutonium loading. Unlike the LWR case, however, MOX use in CANDUs has never been commercially demonstrated, though there is some base of experimental experience. The

CANDU MOX alternative is therefore not quite as technically mature as the LWR MOX alternative.

The spent fuel, in the CANDU alternative, would remain in Canada under safeguards for disposal with other spent fuel from Canadian CANDU reactors. Thus, the plutonium would not be available to the United States or Russia for recovery and use in nuclear weapons (though both countries would have other plutonium in spent fuel they could recover should they choose to do so). CANDU reactors normally operate on natural uranium fuel, which contains only 0.7% of the usable isotope U-235; adding plutonium to the fuel would make it possible to get much more energy out of each kilogram of fuel, allowing it to remain in the reactor longer (known as higher "burn up"). Thus, using plutonium fuel, the utility could cut the amount of spent fuel produced by these reactors each year in half, reducing the utility's eventual costs for spent fuel storage and disposal.

The steps in the CANDU alternative would largely be similar to those for the LWR alternative: converting plutonium from pits and other forms to plutonium oxide, transporting that material to a fuel fabrication plant (unless plutonium processing and fuel fabrication were located at the same facility), mixing that material with uranium oxide to form a mixed oxide (MOX), fabricating fuel from this mixed oxide, irradiating that fuel in reactors, and then safely managing the spent fuel. The principal differences would be the shipment to Canada, the fact that the material would remain in Canada after disposition and the different fuel type and reactor operations for CANDU reactors. The greatest proliferation concerns, as with the LWR alternative, would arise from the pit processing and MOX fuel fabrication steps. Clearly, detailed intergovernmental agreements would be required to manage the international transfers of MOX fuel that would be involved in this case.

Technical Factors

Schedule

The CANDU alternative is estimated to require approximately 10 years from a decision to proceed before large-scale fabrication and irradiation of MOX fuel made in U.S. facilities could begin -- a couple of years less than in the LWR case, primarily because the CANDU reactors with their on-line refueling capability can more rapidly undertake test and demonstrations of the final versions of the MOX fuel. Atomic Energy of Canada, Limited (AECL) believes that an early start could be made without reliance on European facilities, by fabricating initial test bundles at laboratory-scale facilities at Los Alamos and Chalk River. Under current concepts, in which two CANDU reactors using current fuel designs would be used for 5 years, then increasing to four reactors with a new fuel design allowing a higher plutonium loading, 50 tons of excess plutonium could be irradiated in 14 years of reactor operation. Hence, disposition of all 50 tons would be completed within 24 years of a decision to proceed, assuming that the reactors remained operational during that time. As in the LWR case, these estimates are uncertain, in part because of issues relating to licensing and political approvals (see "Political Implementability," p. 98.)

Risks of Theft or Diversion in Process

MOX Fabrication: All of the issues described above for the plutonium processing plant and the MOX fabrication plant would also apply in the CANDU case. The process of manufacturing CANDU MOX fuel would be very similar in the nonproliferation and arms reduction pros and cons to the process of fabricating LWR MOX fuel, described above.

When complete, the CANDU fuel bundles would be much smaller and more portable than LWR fuel assembles -- half a meter long and 10 centimeters across, weighing about 20 kilograms, compared to PWR assemblies which are eight times as long, twice as wide, and weigh some 700 kilograms. Thus, CANDU fuel bundles could be removed by a potential thief without special lifting equipment, while LWR fuel assemblies could not.

Transport: The CANDU alternative would involve both longer-distance transportation than most of the domestic LWR alternatives, and transport across international boundaries, with the associated hand-over of security responsibilities to Canada. Even if the MOX fabrication plant were located to minimize the transport distance to Canadian reactors it would still require long-distance transportation of plutonium from the various sites, all of which are thousands of kilometers from the Bruce station. The limited number of crossing points and other shipping choke points pose additional logistical and security problems in the use of Canadian reactors.

More significant, perhaps, is the crossing of international boundaries and the hand-over of security responsibilities. Each nation has responsibility for protection of nuclear materials on its territory. Canadian security procedures, while likely to be highly effective, have not been designed for the protection of intact nuclear weapons, and thus would likely deviate from the Stored Weapons Standard as it is implemented in the United States. Negotiation between the United States and Canada, however, could potentially lead to an agreement to implement stringent security standards approaching the Stored Weapons Standard for this material coming from the United States, and possibly to include some U.S. role in the security arrangements for this material after it crosses the border.

Storage and Handling at the Reactor Sites: As in the case of the LWR alternative, new secure areas would have to be provided for storage of fresh MOX fuel at the reactors sites; security for this fuel would have to be somewhat tighter than in the LWR case, given the potential portability of the MOX fuel bundles.

More importantly, operating practices for CANDU reactors differ considerably from those for LWRs, in ways that make it easier to remove nuclear material. Unlike LWRs, CANDU reactors can have fuel added and removed while the reactor is operating -- so-called "on-line refueling." Essentially, as a fresh fuel bundle is inserted at one end of one of a set of tubes in the reactors, a spent fuel bundle is pushed out the opposite end. In the LWR case, no fuel can be removed unless the reactor is shut down.

The potential for on-line refueling makes CANDU reactors much more "safeguards-intensive" than LWRs are, because inspectors or automated monitors must be able to detect a removal of fuel that could occur at any time, rather than only when the plant is visibly shut down. This feature of CANDU reactors makes Canada one of the countries in the world with the most IAEA inspections: half of the entire IAEA safeguards budget each year is spent in either Canada, Germany, or Japan (the latter two countries are the non-nuclear-weapon states with the most extensive civilian handling of weapons-usable plutonium). With fuel assemblies containing weapons-grade plutonium, strengthened safeguards and security procedures will be necessary at the CANDU reactor sites, including the possible use of constant inspector presence or continuous remote monitoring. In this case, since the host state is a non-nuclear-weapon state, safeguards must be able to detect diversion of less than a single significant quantity of plutonium. Diversion scenarios could include, for example, producing "dummy" fuel elements with natural uranium, with the same serial numbers as the MOX fuel elements, and loading them into the reactor in place of the MOX fuel elements, from which the plutonium would then be separated. Safeguards systems designed to detect any diversion of CANDU bundles are already in place at Canadian reactors.

Ultimately, with the application of sufficient safeguards resources, it should be possible to provide high levels of assurance that none of the fuel elements could be stolen or diverted without detection at a CANDU reactor, just as it should be possible to do so for LWRs. The safeguards resources required in the CANDU case would be higher, but safeguards resources and proliferation risks would still be significantly less than those associated with the plutonium processing and MOX fabrication facilities in any case.

Risks of Recovery and Re-Use in Weapons

CANDU spent fuel would differ from LWR spent fuel in several ways affecting its nonproliferation and arms reduction characteristics. The small size and relatively low burn-up of the CANDU MOX bundles would mean that each bundle would give off a less intense radiation field than would an LWR fuel assembly -- less than 100 rad per hour at one meter 10 years after irradiation. Below this level, the fuel would no longer be considered "self-protecting," in

IAEA parlance, and would require a higher level of safeguarding than more radioactive spent fuel.

The small size and low plutonium loading of the CANDU MOX fuel elements, however, also means that a substantial number of them would have to be removed to acquire enough plutonium for a single nuclear weapon. A single CANDU spent fuel bundle would weigh only about 24 kilograms and after irradiation would contain only one-quarter to one-third of a kilogram of plutonium, whereas a single spent LWR MOX fuel assembly would provide enough plutonium for a weapon.

To address the relatively low radiation barrier, for plutonium disposition some 40 of the spent CANDU MOX fuel bundles would be permanently mounted together on a mounting tray, creating a large, heavy object with an intense combined radiation field, similar in may respects to an LWR fuel assembly. The trays would weigh about one metric ton, would contain a total of 10-12 kilograms of plutonium, and would have a radiation field of several hundred rads per hour at one meter thirty years after irradiation. (See Table 5-1.)

Thus, as with an LWR assembly, it would not be possible for one or two individuals without special equipment to remove the spent fuel bundles from storage. While it would in principle be possible to remove the bundles from the mounted group and handle them individually, it would also be possible in principle to remove individual fuel rods from an LWR assembly and handle them individually.

The difficulty of recovering plutonium from spent CANDU MOX fuel would be quite similar to the difficulty of recovering plutonium from spent LWR fuel, as the basic materials from which the fuel is composed are identical. Thus the CANDU alternative, like the LWR alternative, would meet the Spent Fuel Standard. There is no industrial-scale experience reprocessing CANDU spent fuel, but this would not appear to pose a significant obstacle to any nation or group that wanted to recover plutonium from this material. Despite the lower burn-up to which the fuel bundles in a CANDU reactor would be subjected compared to an LWR (9,700 to 17,100 MWD/MTHM, depending on whether the current fuel type or the CANFLEX fuel type is used, compared to 32,000 to 45,000 MWD/MTHM for the LWR alternatives), the other characteristics of the reactor ensure that a substantial number of neutrons would be absorbed by the plutonium, converting it to reactor-grade just as in an LWR.

In the CANDU alternative, the location of the plutonium-bearing spent fuel outside of the physical control of the United States and Russia would effectively preclude potential re-use of the material by these states. Both states, however, possess substantial quantities of other spent fuel from which plutonium could be recovered should a decision be taken to do so.

Policy Factors

Impacts on Russian Programs

Like the LWR alternative, the CANDU alternative would more closely parallel alternatives being considered by Russia than would the immobilization or deep borehole alternatives. Further, the CANDU alternative would provide the potential opportunity for both Russia and the United States to dispose of their excess material in the same reactors at the same time, in a third country. Such an identical disposition strategy could have symbolic benefit, though it does not appear to be a pre-requisite for accomplishing the plutonium disposition mission.

If such an identical approach were to be pursued, even more substantial transport security issues would be raised by the need to transport tens of tons of weapon-grade plutonium in the form of fabricated MOX fuel bundles from Russia to Canada. While removing the plutonium from both Russia and the United States is an advantage of the CANDU alternative, this removal would occur over a period of decades, after the major bulk processing steps of concern had already been carried out in the state from whose weapons the material came. The potential impacts of delays in making the CANDU alternative available -- as might be caused, for example, if an unforeseen problem arose with demonstrating the safety of full-core MOX use in CANDU reactors, which has not yet been demonstrated -- would be even more important, delaying Russian disposition as well.

Another question that needs to be resolved is what sort of compensation Russia would require in order to send its excess plutonium to Canada as MOX for use in Canadian reactors. Russian officials have stated that they believe the energy in excess plutonium is an extremely valuable resource. Possible requirements for large payments for the excess plutonium could pose obstacles to implementing this alternative if it is selected.

Impact on Nuclear Arms Reduction Efforts

As with other alternatives that meet the Spent Fuel Standard, implementing the CANDU alternative (particularly if Russia carried out a parallel program) would have the benefits of plutonium disposition described in Section 2 of this assessment, including helping to lock in current nuclear arms reductions and reduce the risk of reversal; laying a base for further reductions, if desired; and building international confidence in the arms reduction process. The CANDU alternative, in removing the plutonium to a third country, would go beyond the Spent Fuel Standard in ensuring that neither the United States nor Russia would have immediate physical access to the material.

Impacts on Nonproliferation Efforts

Any step that helps to lock in the irreversibility of arms reductions would have a beneficial affect on the international nonproliferation regime and help demonstrate to the international community that the United States is living up to its commitments under the NPT and elsewhere.

The use of CANDU reactors, however, would put an additional strain on the IAEA, requiring significant resources to safeguard these facilities. One important question in this regard is who would pay for the application of international safeguards. Unlike the United States, Canada is a non-nuclear-weapon state party to the NPT, where application of safeguards to all civilian nuclear facilities is legally required. Legally mandated safeguards activities are traditionally paid for out of the regular IAEA budget (rather than through voluntary contributions), and the budget that member states have granted the IAEA has not kept pace with the expanding scope of required IAEA safeguards activities (indeed, Canada has been among the states most opposed to increases in the regular IAEA budget). The resources required for enhanced safeguards at CANDU reactors handling fuel made from weapons-grade plutonium, while small compared to the other costs of plutonium disposition, would be quite significant in the context of the small annual IAEA safeguards budget, and quite difficult for the IAEA to bear in its already budget-constrained circumstances. So far, IAEA safeguards on excess materials in the United States have been paid for voluntarily by the United States, but there are a variety of good and long-standing reasons why implementation of legally required IAEA activities has not in the past relied on voluntary contributions. This is a policy and budget issue that would have to be resolved if the CANDU alternative were to be pursued.

Impact on Fuel Cycle Policies and Choices

The use of CANDU reactors to burn MOX fuel containing U.S. excess plutonium would raise the same policy implications associated with the MOX alternative for U.S. LWRs, and some additional issues as well.

Unlike in the U.S. case, the CANDU alternative would mean encouraging the use of plutonium fuel in a foreign non-nuclear-weapon state which is not currently using plutonium fuels. The significance of the difference between U.S. and foreign use of such fuels would have to be considered in assessing this alternative.

Another significant issue to be considered in the CANDU case is the fact that to date, unlike in the case of LWRs, MOX use in CANDU reactors has not been commercially demonstrated. Plutonium disposition in CANDU reactors would provide such a commercial demonstration, which could facilitate or encourage the use of MOX in CANDUs in other countries' civilian fuel cycles. Technically validating the use of plutonium fuel in CANDU reactors could undermine U.S.

efforts to convince other countries operating CANDU reactors in regions of proliferation concern not to pursue a plutonium-based fuel cycle in their CANDU reactors. Most countries, however, are likely to base their decisions on recycling of plutonium primarily on factors independent of any such disposition program, and it is not clear that any particular nation's decision would be substantially affected. Policy makers will need to consider whether this commercial-scale demonstration of MOX use in another reactor type is a sufficiently negative implication to overshadow the favorable aspects of the CANDU approach.

Political Implementability

The alternative of using Canadian reactors could potentially be somewhat easier to implement than the LWR MOX alternative, since there may be better cooperation between Canadian facilities and licensing authorities and less public resistance to new missions for existing reactors than in the United States. The possibility of delays in completing and gaining approval for the plutonium processing and MOX fabrication facilities would be essentially the same as in the LWR case, since those facilities would still be built in the United States. The fact that the plutonium would be shipped away from the United States and spent fuel would not be returned might reduce opposition in the United States. In the CANDU case, it would be in Canada rather than the United States that approvals for use of plutonium fuels in reactors would have to be gained; whether this means a greater or lesser possibility of delay is difficult to say. The lack of a base of commercial experience with the use of MOX fuel in CANDU reactors could lead to additional licensing delays. On the other hand, the relationship between regulators and operators in Canada is traditionally more cooperative than it is in the United States, which could ease the licensing task.

To date, the Canadian government and the Ontario Hydro utility have been supportive of the CANDU alternative, and initial consideration of the alternative has not provoked widespread opposition. The public and institutional issues on both sides of the border associated with transporting plutonium to another country would create additional schedule uncertainty, however. As in the LWR case, therefore, it remains possible that the period of storage would, in the end, be significantly longer than currently expected.

IMMOBILIZATION ALTERNATIVES

Homogeneous Glass Immobilization: Adjunct or Greenfield Melters

Description

Another possible disposition alternative is to mix the plutonium with glass and intensely radioactive fission products (either high-level waste or Cs-137), producing massive and highly radioactive glass "logs" containing plutonium. In several countries including the United States, radioactive high-level waste is being incorporated into molten glass, in a process known as vitrification. This process could also be used for disposition of plutonium, although adding substantial quantities of plutonium to this process has not been demonstrated on an industrial scale. While the plutonium in the immobilization alternatives would remain weapon-grade, nearly all grades of plutonium can be used in nuclear explosives. (See "Reactor-Grade and Weapon-Grade Plutonium in Nuclear Explosives," p. 34.) Existing melters, which were not designed to handle fissile materials, would not be suitable for immobilizing plutonium under this alternative. Therefore, variants of this approach are being considered, including one in which a small "adjunct" melter would be added within the existing building housing the huge Defense Waste Processing Facility (DWPF) vitrification plant at the Savannah River Site ("adjunct melter") and another in which a new vitrification facility would be built on an as-yet unused site ("greenfield melter"). In the first case, the fission products would come from a portion of the Savannah River high-level waste (supernate from the HLW tanks), while, in the second case, the fission products could be Cs-137, currently stored in chloride capsules at Hanford.

The percentage of plutonium in the final glass, and the amount of radiation in the glass, would both affect the attractiveness of the material for possible recovery of the plutonium; these parameters can be chosen by the designer, within a wide range. Current plans assume a loading of roughly five percent by weight plutonium in the glass. For the alternative involving a new vitrification facility, Cs-137 currently stored in capsules at Hanford could be used to provide a radiation barrier, with the goal of creating a radiation field of 1,000 rads per hour at one meter from the log, thirty years after the glass logs were fabricated. For the adjunct melter in the vitrification facility at Savannah River, waste from the tanks at Savannah River would be used for the radiation barrier, and since this waste has decayed significantly already, the radiation barrier would be lower -- approximately 200-500 rads per hour at one meter 30 years after fabrication. This radiation level is comparable to, but lower than, the radiation from LWR spent fuel 30 years after irradiation. (See Table 5-1.) The Nuclear Regulatory Commission and IAEA standard for when nuclear material is radioactive enough to be considered "self-protecting" against theft is 100 rads per hour at one meter.

In the homogeneous glass immobilization approach, the plutonium and fission products would be dissolved together in the glass in the large glass logs. (Other immobilization approaches are described below). This would involve several steps. First, as in the case of the reactor alternatives, plutonium in pits and other forms would be processed to oxide as a feed material. In the immobilization case, however, this material need not be pure, and a number of complex purification steps required for the reactor alternatives could be bypassed. Then, in a first stage of vitrification, the plutonium oxide would be fed into a melter along with small glass pebbles (known as glass "frit") and neutron-absorbing materials to ensure that no accidental chain reaction ("criticality accident") could occur. This first-stage melter would produce glass frit with the plutonium and neutron absorbers dissolved within it. This frit would then be fed into a second melter along with fission products. The molten glass from this melter, with both plutonium and fission products dissolved in it, would be poured into large canisters, after which the canisters would be decontaminated and cooled. The canisters would be massive (2 meters high, weighing some 2 tons each) and highly radioactive, making it difficult or impossible to steal them without special handling equipment, or to recover the plutonium without special shielded chemical processing. The glass logs, like spent fuel from the reactor alternatives, would be stored for an interim period and then disposed of in a geologic repository.

Thus the homogeneous immobilization alternative involves a series of steps, in some ways similar to the LWR disposition alternative:

- transport of tagged and sealed containers of plutonium oxide from pit conversion facility to the vitrification facility (this step could be largely eliminated if the two are co-located)
- vitrification of the plutonium, including:
  - opening Plutonium oxide containers
  - blending of plutonium oxide, neutron absorbers, and glass frit
  - melting the plutonium-glass mixture in a primary melter, to produce a glass frit with dissolved plutonium
  - melting both the plutonium-glass frit and fission products in a secondary melter
  - pouring the plutonium-plus-fission-product glass into large canisters
  - sealing, cooling, and decontaminating the canisters
  - storage of material in various forms at several points in the process
- storage of canisters of glass containing plutonium and fission products
- loading of canister into casks and transport to a geologic repository
- emplacement of casks containing canisters in a geologic repository
- monitoring of emplaced canisters (50-100 years)
- closure of the geologic repository

As in the reactor cases, the most proliferation-sensitive steps in the process are the early ones, when the material is in forms that would be quite attractive to a potential proliferator, and is going through bulk processing and long-distance transportation. The most sensitive steps are the initial plutonium processing (common to all alternatives, although with fewer purification steps in the case of the immobilization and borehole alternatives), and the vitrification (broken down into its individual steps above), both of which would require bulk processing of several tons of plutonium each year, all of it in very attractive forms. The canisters can be stored safely and securely for decades. Thus, as in the case of the reactor alternatives, the precise date when a geologic repository might become available is not a critical factor for the immobilization alternatives.

Technical Factors

Schedule

The homogeneous vitrification alternative is estimated to require approximately 12 years before large-scale vitrification of excess plutonium could begin, using either an adjunct melter or a new facility. This is essentially the same as the LWR alternative, to within the uncertainties of the estimates. All of the vitrification operations for 50 tons of excess plutonium could be completed in just under 10 years of operation, so that the entire effort would require approximately 21 years from a decision to proceed.

These estimates are also uncertain. As noted above, schedule estimates for major projects of this kind have traditionally been optimistic. Mechanisms for overseeing and regulating operations within the DOE complex are currently in flux. Schedule uncertainties could result if formal independent regulation is imposed on DOE operations or if vitrification were to take place at a new plant under NRC regulation, requiring licensing for construction and/or operation of facilities. (The same would be true for the pit conversion facility required for all alternatives, and for the MOX fabrication plant required for the immobilization alternatives, if these facilities were owned by DOE.

Key technical uncertainties that could affect the schedule include determining how much plutonium can be dissolved in specific glass formulations (and at what rate), and qualifying the vitrified logs for emplacement in a geologic repository. (The logs would not be produced until there was high confidence they would be acceptable waste forms for emplacement in a repository; otherwise, there would be a substantial risk that the plutonium would be immobilized and then would have to be separated and immobilized again in some other form that was acceptable for geologic disposal.)

Risks of Theft or Diversion in Process

Vitrification: Eliminating the complex purification steps required if plutonium currently in impure forms is to be prepared for use as reactor fuel would eliminate some opportunities for access and some accounting uncertainties, resulting in a modest reduction in the proliferation risk expected from the plutonium processing operations. The most serious concerns in those operations, however, come from the activities that are carried out for either the reactor or the immobilization alternatives.

Like the MOX fabrication plant in the reactor alternatives, the vitrification plant would be a large bulk-processing facility handling tons of plutonium in extremely attractive forms every year, posing a variety of opportunities for insiders at the plant to have access to the material, and a variety of accounting uncertainties. In both cases, material accounting -- measuring the plutonium going into the process and the plutonium coming out, to contribute to assurance that no substantial quantity of plutonium had been removed from the process -- would be an essential component in the overall defense-in-depth against theft or diversion of nuclear material. The plutonium in the initial glass form (before it had been mixed with fission products) could be measured with means similar to those used to measure fresh MOX fuel when it has first been produced. If the glass was carefully blended to ensure that there were no variations in the amount of plutonium in different parts of the glass, it should be possible in principle to measure the plutonium in this initial glass form as accurately as fresh MOX fuel can be measured -- that is, to an accuracy of approximately 99.8% (for systematic errors). This has not yet been demonstrated, however. If the glass were not blended and homogeneous, the uncertainty in measurement would be substantially higher than in the MOX case.

Once the plutonium glass frit had been blended with fission products to produce the final glass canisters, however, it would no longer be possible with current technology to accurately measure the amount of plutonium in the glass -- just as it would not be possible to accurately measure the plutonium in spent fuel from the reactor alternatives. In the reactor case, however, the accurately-measured fresh fuel would enter the reactors as individual items, which could be easily accounted for; in the vitrification case, the accurately measured plutonium glass would enter the second melter as tiny glass pebbles or powder, requiring a heavy reliance on containment and surveillance measures to ensure that all of the plutonium-bearing glass in fact goes into the melter and is incorporated into the final form. Since the final form could not be accurately measured to confirm that, the reliance on containment and surveillance at that point in the process would be nearly total. Some would argue, therefore, that the accounting uncertainties facing a vitrification plant are more significant and fundamental than those facing a MOX plant. (The situation for the can-in-canister alternatives would be more similar to that for a MOX plant; see discussion below.) New technologies are under development which may improve the ability to measure plutonium in forms such as radioactive glass.

On the other hand, the overall complexity of the bulk-handling processes in a vitrification plant might be somewhat less than in a MOX plant. Rather than blending uranium and plutonium oxides, reblending them to get the desired percentage of plutonium, milling them, pressing them into pellets, sintering the pellets, grinding the pellets, and loading the pellets into rods, all that has to happen in a vitrification plant is for the plutonium to be mixed with glass and neutron absorbers in a primary melter, and then for that mixture to be poured into a secondary melter with fission products (and possibly additional glass). Some IAEA safeguards experts have expressed the view that despite the difficulties of accounting for the final form, it would be easier in some respects to safeguard a vitrification plant, where safeguards could focus on measuring the input material and the initial plutonium-glass form, and then observing to ensure that all of the initial plutonium-glass form went into the secondary melter to be mixed with intensely radioactive material.

Overall, the difference in proliferation risk between a MOX plant and a vitrification plant would appear to be relatively modest. A MOX plant has some advantages because the technology of safeguarding such facilities is well-demonstrated, and the material can be accurately measured and then placed into large "items" (fuel assemblies) for insertion into the reactor. A vitrification plant has some advantages in that the steps may be somewhat simpler and easier to observe, but the material is processed in bulk into a final form that cannot be accurately measured. Neither type of facility could provide assurance through material accounting alone that every kilogram of plutonium was present and accounted for. But either type of facility, with appropriate resources devoted to providing a broad-ranging defense-in-depth against theft or diversion, could provide substantial levels of overall nonproliferation assurance. More information on the specific processes is needed before it can be determined whether the material accounting issues in a plutonium immobilization facility would be more or less severe, or roughly similar, to those which have been experienced in MOX fabrication facilities.

The vitrification plant would be placed under IAEA safeguards, as the MOX plant would for the reactor alternatives. Some new procedures would have to be developed, as no vitrification operations involving large quantities of plutonium have existed in the past, so no specific approaches to safeguarding them have yet been developed. Nevertheless, as in the MOX case, it should be straightforward for the IAEA to certify to the world that the United States is in fact transforming weapons plutonium into vitrified glass forms, and has not diverted any strategically significant amount (tons) of the excess material back to military purposes.

Transport: If the vitrification facility or facilities was appropriately located, the scale of transportation of plutonium in attractive forms that would be required might be significantly less than in the reactor case. Plutonium in its various forms would have to be transported from the several sites where it is now located to the plutonium processing facility, and from there to the vitrification facility (if the two were not located together). After that, however, the plutonium would not be transported again except when the large and radioactive glass logs were transported to a geologic repository. As in the reactor case, SSTs, with security similar to that applied to protect intact nuclear weapons, would be used for shipment of plutonium in attractive forms. As noted above, if enough resources are applied to security, these measures can provide high assurance against theft in transit.

Risks of Recovery and Reuse in Weapons

The homogeneous vitrification alternative would embed the excess weapons plutonium in huge, intensely radioactive glass logs. Each log would weigh roughly 2 tonnes, with a radiation field of either 200-500 rads per hour (in the adjunct melter case, 30 years after fabrication) or 1000 rads per hour (in the greenfield facility case, 30 years after fabrication). Each would contain 80-90 kilograms of plutonium. None of the plutonium would actually be fissioned or otherwise destroyed in the vitrification process (as a fraction of it would be in the reactor cases), and the plutonium would remain weapon grade, rather than being converted to reactor grade. Nearly all grades of plutonium, however, can be used to produce nuclear explosives. Compared to commercial spent fuel assemblies, the glass logs would be even more massive (roughly 3-4 times as heavy), but somewhat (at least in the adjunct melter case); they would contain several times as much plutonium in each unit; and, as noted, the plutonium would be weapons-grade. (See Table 5-1.) As in the spent fuel case, covert theft or diversion would be essentially ruled out; only overt threats to this material would be plausible.

To recover the plutonium from this glass would require a set of steps generally similar to recovering plutonium from spent fuel. The canisters would have to be opened, the glass crushed and then dissolved (probably in strong, boiling nitric acid), and the plutonium precipitated out from the resulting solution. Extensive purification would be needed, particularly to deal with the large quantities of silica in the glass, which would have a tendency to "gum up the works." All of this would have to be done remotely, from behind radiation shielding, because of the radiation from the fission products in the glass. While the processes required for recovering the material from glass are relatively straightforward, they have not been demonstrated on an industrial scale and have not been widely published, as they have in the case of spent fuel. This might provide some advantage in resistance to recovery, though the greater simplicity of the glass material might be a modest disadvantage. Overall, assessments indicate that the unattractiveness and inaccessibility of the plutonium in such glass logs for recovery and reuse in nuclear weapons would be roughly comparable to that of spent fuel, thus meeting the Spent Fuel Standard. The National Academy of Sciences reached the same conclusion in its report that coined the Spent Fuel Standard.

Policy Factors

Impacts on Russian Program

Russian officials have clearly stated their intention to dispose of excess plutonium by burning it in reactors, and have indicated that they have no intention of pursuing immobilization or other disposal alternatives, except perhaps for plutonium-bearing residues and wastes. Therefore, the immobilization alternatives would not offer a near-term likelihood of implementing identical approaches for U.S. and Russian excess weapons plutonium.

Some analysts have argued that the United States should pursue a disposition path that is also acceptable to Russia for its own plutonium, in order to have the maximum possible influence on Russian activities and ensure that disposition of Russian surplus material moves forward. U.S. and Russian officials have agreed, however, that given the different economics and nuclear infrastructures in the two countries, Russia and the United States may find it in their interests to pursue differing, but parallel, paths on disposition of excess materials. It would appear, therefore, that a U.S. decision to immobilize plutonium through vitrification would still allow the United States to positively influence Russian actions in support of common goals.

As noted above, some analysts have also pointed out that the immobilization alternatives would leave the plutonium in weapon-grade form, and questioned whether this would offer as effective assurance of irreversibility to the international community as alternatives that would convert the material to reactor-grade. Specifically, they have questioned whether Russia would be willing to burn its excess plutonium in reactors, thereby converting it to reactor-grade, while U.S. excess plutonium remained weapon-grade in an immobilized form. These issues are addressed above, in the discussion of the LWR MOX alternative. The bottom line is that the immobilization alternatives would also provide substantial demonstration of irreversibility to the international community, and the United States and Russia have already agreed informally that it would be possible for one state to pursue the immobilization alternative while the other pursued the reactor alternative. Thus, while the policy implications of leaving the material in weapons-grade form should certainly be considered, it does not appear that this would be a critical discriminating factor between the immobilization and reactor alternatives.

It has been argued that the homogeneous immobilization alternative offers greater assurances against plutonium re-use than the can-in canister approach, since extraction of plutonium from glass logs that also contained intensely radioactive fission products might be more difficult than recovering plutonium from the can-in-canister alternatives. (See the can-in-canister alternative section, below). Both approaches to immobilization, however, would require a major investment in resources to immobilize the plutonium, and in either case a substantial investment of resources would be needed to recover it. In either case, recovery would be time-consuming and highly observable.

Impact on Nuclear Arms Reduction Efforts

As with other alternatives that meet the Spent Fuel Standard, implementing the homogeneous immobilization alternative (particularly with Russia also carrying out disposition of its plutonium) would have the benefits of plutonium disposition described in Section 2, including helping to lock in current nuclear arms reductions and reduce the risk of reversal; laying a basis for further reductions, if desired; and building international confidence in the arms reduction process.

Impacts on Nonproliferation Efforts

Similarly, implementing the homogeneous vitrification alternative or other alternatives meeting the Spent Fuel Standard, by demonstrating that current arms reductions could not be easily reversed, would help increase international support for maintaining and strengthening the international nonproliferation regime, by demonstrating that the leading nuclear weapon states were working to fulfill their NPT commitments to pursue nuclear arms reductions and eventual disarmament. This could help make agreement on measures such as strengthened international safeguards or a fissile cutoff convention easier to achieve. As with other alternatives, immobilization alternatives could be used to demonstrate and implement new procedures and technologies for protecting and safeguarding nuclear materials, approaching the Stored Weapons Standard, which could reduce proliferation risks by encouraging implementation of such improved procedures and technologies in other countries.

Impact on Fuel Cycle Policies and Choices

A decision to immobilize and dispose of excess plutonium would be fully consistent and supportive of current U.S. fuel cycle policies not to engage in the civil use of plutonium. Such an approach would provide a clear demonstration of the U.S. view that plutonium is not a valuable material in the current civilian fuel market. Unlike the use of plutonium for MOX in reactors, this alternative has none of the perceived weakening of U.S. policy on plutonium use and, therefore, could be used to support the current U.S. policy not to encourage civilian use of plutonium. It is unlikely, however, that a U.S. decision to vitrify excess plutonium would in and of itself result in significant reductions in the amount of plutonium separated and processed in other countries. Nevertheless, it could be argued that such an additional demonstration of the U.S. decision not to engage in the plutonium fuel cycle might be useful in setting an example that other countries might follow in the future as they make fuel cycle decisions.

Political Implementability

To date, the non-governmental organizations who most frequently oppose major nuclear projects have been more supportive of the immobilization alternatives than of the reactor alternatives, suggesting that the immobilization alternatives may face fewer legal and political obstacles on the path to approval and operation. However, groups that favor reactor-based alternatives may object to the pursuit of this alternative on the grounds that it does not track closely enough with Russian plans (see section on Russian impacts).

This alternative, however, would require the construction of adjunct or new facilities, creating licensing (or approval) and site uncertainties which may in turn delay implementation. Building entirely new facilities would inevitably involve more potential impacts, and therefore more potential for opposition, licensing or approval difficulties, and delay, than the adjunct alternative, which would make partial use of existing facilities.

All of the immobilization alternatives, like the reactor alternatives, would eventually require a geologic repository. Local communities may seek increased assurance that a geologic repository will soon become available before agreeing to interim storage of the disposition waste forms in their areas. This could be particularly true of the immobilization alternatives, as the existing reactor alternatives make use of reactors that would be producing plutonium-bearing spent fuel in any case.

Homogeneous Ceramic Immobilization: Greenfield Facility

Description

Another immobilization possibility is to incorporate plutonium and fission products into a ceramic material, rather than glass. While borosilicate glass has been chosen by countries throughout the world as the waste form of choice for disposal of HLW, ceramic forms offer some potential advantages as well. In particular, ceramics could be designed to contain high loadings of plutonium and to be very similar to certain naturally occurring rocks, which are known to have been stable for hundreds of millions if not billions of years. Indeed, a leading candidate for the ceramic form is known as Synthetic Rock, or SYNROC.

The basic processes for producing a ceramic form would be somewhat different from those for producing the glass form just described. As in the vitrification case, the plutonium would be converted to oxide as feed, and the oxide would not have to be purified. The plutonium oxides would be dissolved to form plutonium nitrates. These would be mixed with neutron absorbers, fission products, and the materials that would form the ceramic, in a blend tank. The mixture would then be heated, loaded into a "bellows" -- a container with compressible sides -- and hot-pressed to form a dense, hard ceramic. Under current plans, the ceramic might contain as much as 12% plutonium by weight: each hot-pressed bellows would contain about 33 kilograms of ceramic, including about 4 kilograms of plutonium. Twenty of these bellows would be loaded together into a canister, which would contain two-thirds of a ton of ceramic, and about 80 kilograms of plutonium. Since no substantial-scale facility currently exists which is capable of carrying out the needed processes for ceramic production, a new facility would be built. The radiation field from such a canister would be designed to be similar to that from the glass canisters, described above. The canisters would be stored for an interim period and then sent to a geologic repository.

Thus the sequence of steps for the ceramic alternative would be identical to the vitrification case, with the exception that the primary and secondary mixing and melting steps in the vitrification case would be replaced by dissolution of the plutonium oxide to form nitrate, a single blending step, and hot pressing in the bellows.

Technical Factors

Schedule

The homogeneous ceramic immobilization alternative is estimated to require approximately 12 years before large-scale vitrification of excess plutonium could begin, using a new facility, the same as the homogeneous vitrification alternative. All of the immobilization operations for 50 tons of excess plutonium could be completed in just under 10 years of operation, so that the entire effort would require approximately 21 years from a decision to proceed. The uncertainties in this approach would be generally similar to those described above for the homogeneous vitrification alternative. There is, however, somewhat more uncertainty in the development of the industrial-scale processing plant for the ceramic alternative, since unlike vitrification, there is as yet no industrial-scale experience with ceramic immobilization of nuclear wastes. As in the vitrification case, a key technical uncertainty affecting the schedule is the need to qualify the immobilized product as an acceptable waste form for emplacement in a geologic repository.

Risks of Theft or Diversion in Process

The issues and concerns related to proliferation and arms reduction risks during processing for the ceramic immobilization alternatives are largely identical to those for the vitrification alternative. The number and complexity of the bulk-handling steps is roughly similar for the two (possibly even fewer for the ceramic alternative, since it does not include two separate immobilization steps as the vitrification alternative does). The issue of the impossibility (with current technology) of accurately measuring the material in the final form is just as substantial a concern as it is in the homogeneous vitrification case.

Risks of Recovery and Reuse in Weapons

Here, too, the issues would be generally similar to those in the vitrification case, with some exceptions. As in that case, the final product would be a massive and intensely radioactive form containing substantial quantities of plutonium. The product would contain substantially more plutonium than commercial spent fuel (12 percent by weight compared to 1 percent), and that plutonium would be weapons-grade. (See Table 5-1.)

Unlike spent fuel, however, there are no published flow-sheets outlining the chemical process for separating plutonium from ceramic forms. Processes for this purpose have been sketched out (based on chemical processes used in industry to recover titanium from titanium ores), but they have not been demonstrated on any significant scale. Very high temperatures would be needed for these processes, and some problems would almost certainly be encountered on a first attempt. The processes required are generally somewhat more complex than those required for separation of plutonium from spent fuel or glass. Therefore, this form was judged in the Red Team assessment to have a slightly higher resistance to recovery than spent fuel. On the other hand, as the Red Team pointed out, the fundamental chemistry of recovering plutonium from ceramics is known, and information will spread; the Red Team, therefore, did not consider the absence of a demonstrated flow sheet a substantial additional barrier to recovery of this material decades in the future, when disposition is complete. Homogeneous ceramic immobilization is judged to meet the Spent Fuel Standard.

Policy Factors

Impact on Russian Programs

The impact of this alternative on Russian programs would be roughly similar to that of the homogeneous vitrification alternative. Immobilization could proceed in parallel with Russian reactor-based disposition alternatives, achieving the Spent Fuel Standard in each country.

Impact on Nuclear Arms Reduction Efforts

The impact of this alternative on nuclear arms reduction efforts would also be roughly similar to that of the homogeneous vitrification alternative. This alternative may have modestly greater benefits in ensuring the irreversibility of arms reductions, since the recovery of materials from ceramic form have not been technically demonstrated and are not widely understood -- a fact that could be stressed to underscore the benefits of this alternative if it were selected. There is little doubt, however, that either the United States or Russia would be able to develop and implement a process to recover plutonium from this material, so this difference should not be relied on as a key discriminating factor between the glass and ceramic alternatives.

Impact on Nuclear Nonproliferation Efforts

Similar to the homogeneous vitrification alternative, above..

Impact on Fuel Cycle Policy and Choices

Similar to the homogeneous vitrification alternative, above.

Political Implementability

The political implementability of the ceramic immobilization alternative would be similar to the homogeneous vitrification alternative described above. In the ceramic case, an entirely new greenfield facility would be needed (though it would probably be built on an existing DOE site), raising additional issues of legal and political approvals compared to the use of existing or adjunct facilities.

Glass or Ceramic Can-in-Canister Immobilization: Existing Facilities

Description

The "can-in-canister" approach is an alternative to homogeneous immobilization. In this approach, small cans of glass or ceramic would be produced that contained plutonium and neutron absorbers but not fission products. These cans could therefore be produced in relatively inexpensive glove-box facilities at existing sites, rather than requiring expensive remotely-operated systems to handle the intense radiation from HLW or Cs-137. These cans would then be arrayed on a rack inside each of the large canisters used for example, for Savannah River HLW glass, and the HLW glass would be poured into the canister, surrounding the plutonium-bearing forms and imbedding them within a large and intensely radioactive glass log similar to the glass logs described above. In current concepts, each canister would have imbedded within it approximately

20 cans, containing 2-3 kilograms of plutonium each. Since the small cans could be produced in glove-box facilities without requiring heavy shielding, and the canisters would be filled with HLW glass as part of normal HLW vitrification operations at Savannah River, this alternative could rely essentially on modifications and upgrades to existing facilities, rather than requiring new ones.

The manufacturing steps for small cans of glass would be identical to the steps for the initial glass frit, described above. A somewhat different approach would be used to produce the ceramic: after mixing and initial heating, the ceramic material and plutonium would be "cold pressed" to compact them as much as possible without heat, and then baked ("sintered") to form the final ceramic. (This process is not used with the fission products because the fission products would tend to boil off during the sintering process.) This cold-pressing process offers greater simplicity and greater throughput, and is nearly identical to the processes used to produce sintered pellets for MOX fuel, giving it a base of proven production experience.

Technical Factors

Schedule

The can-in-canister immobilization alternatives could be done somewhat more quickly than the other alternatives, because the plutonium immobilization could be accomplished in existing glove-box facilities without heavy shielding, and the filling of the canisters with HLW glass would be done as part of normal operations at the Savannah River HLW vitrification facility. Both the glass and the ceramic can-in-canister approaches are estimated to require approximately 9 years before large-scale vitrification of excess plutonium could begin, using existing facilities. Immobilization operations for 50 tons of excess plutonium could be completed in just under 10 years of operation, so that the entire effort would require approximately 18 years from a decision to proceed -- approximately 7 years less than required for the reactor operations (though those alternative could be accomplished somewhat more quickly if more reactors and a larger MOX plant were used).

Because of the potential reliance on existing rather than new facilities, not only is the schedule shorter for these alternatives, but the uncertainties in the schedule estimates are somewhat less severe. The issues relating to qualification of the waste form for eventual emplacement in a geologic repository would also apply to this alternative.

Risks of Theft or Diversion in Process

In most respects the proliferation risks associated with bulk processing of plutonium involved in this alternative are similar to those described above for the homogeneous immobilization alternatives. But there are some important differences.

In particular, the small cans of glass or ceramic containing plutonium could be accurately measured (assuming that appropriate blending had been done to ensure homogeneity). These cans, containing measured quantities of plutonium, could be treated as individual "items" that would be placed inside the glass canisters. This would be similar to placing spent fuel assemblies into a reactor for irradiation. Thus, the issue described above, concerning the inability to measure to confirm that all the bulk plutonium-glass powder got into the final glass form, would not be a problem in this case: it would be easy to ensure that each of the plutonium cans which had been measured was appropriately emplaced in the glass canister (though as with spent fuel, one still could not accurately measure the final, intensely radioactive form). Thus, the can-in-canister variants have a material-accounting advantage compared to the homogeneous immobilization variants. The cold pressing process used for the small ceramic cans in this case may also have a modest advantage over the homogeneous immobilization alternatives in having greater simplicity and a smaller number of steps. Because all variants rely on a defense-in-depth against theft or diversion, however, a material accounting advantage does not necessarily translate directly into a significant advantage in proliferation resistance; other aspects of the defense-in-depth can in some cases make up for material accounting difficulties.

Risks of Recovery and Re-Use in Weapons

As in the homogeneous vitrification case, the can-in-canister immobilization alternative would result in plutonium inside massive, intensely radioactive glass logs. These would pose a significant barrier to any attempt to steal the plutonium, and would effectively rule out the possibility of covert theft. Since the HLW stored at Savannah River would be used to fill the canisters, the radiation level is expected to be approximately 200-500 rads per hour at one meter thirty years after fabrication of the canisters. (See Table 5-1.)

The difficulty of recovering the plutonium from the can-in-canister forms would depend to a significant degree on the internal can's design, which has not yet been finalized. Some analyses have suggested that it would be relatively easy for either the host state or a sub-national group that had overcome the facility's security force and gained access to the vitrified logs to separate the internal canister from the external radioactive glass(perhaps using explosives) and remove the inner cans containing only plutonium and no fission products. These could then be processed later in relatively inexpensive glove-box facilities, with no need for shielding against intense radioactivity.[16] A similar concern arises concerning possible retrievability by the host state. It appears, however, that design modifications to the can-in-canister approach could make removing the cans from

[16] See, for example, the detailed discussion in the Proliferation Vulnerability Red Team Report.

the canister very difficult -- for example, designing the inner cans so that they would also shatter as the outer glass shattered, leaving no individual cans to "pick out" from the resulting intensely radioactive mass of smashed glass.

If the cans could be readily removed, processing to recover the plutonium would be easier than it would be for the homogeneous forms, where the plutonium and fission products would be intimately mixed together. The general chemical issues would be similar to those described above, but the chemistry would not have to be carried out remotely, with shielding; that would reduce the time and resources required to build appropriate facilities, reduce the risk of failure to the potential proliferator, and reduce the mystique of "deadly radiation." For the host state, it would mean that existing glove-box facilities could be used to recover the plutonium, rather than having to modify large shielded reprocessing facilities for that purpose. Unless the can-in-canister approach were carefully designed to make removal of the cans containing only immobilized plutonium very difficult, the can-in-canister form may be less resistant to recovery than the Spent Fuel Standard suggests. However, it does appear likely that such careful design would be successful in making the cans very difficult to separate whole from the larger bulk of intensely radioactive glass. The Office of Fissile Materials Disposition has initiated a design program to produce a new design in 1997 and begin testing it immediately thereafter.

Some have argued that the can-in-canister approach would not offer as strong an assurance of irreversibility to the international community, because the United States would be able to recover the cans containing only immobilized weapons-grade plutonium relatively easily, and then recover that plutonium without great expense. Given the environment, safety, and health regulations and review requirements that currently exist in the U.S. complex, however, it might be quite difficult for the United States to develop a straightforward process for recovering these cans; only if there were a real consensus that a national security emergency required a much larger nuclear stockpile, necessitating quick access to larger stockpiles of plutonium, might these requirements be waived. In any case, such a decision to remove the canisters in any significant amounts would be highly observable. Overall, while it would probably be cheaper for the United States or Russia to recover plutonium from can-in-canister forms than it would be to do so from homogeneous immobilized forms (again, depending in part on the design of the internal cans), nevertheless the can-in-canister forms would provide a significant physical barrier to reversibility.

Policy Factors

Impact on Russian Programs

The impact of this alternative on Russian programs would probably be generally similar to those of the homogeneous immobilization alternatives. While it is likely that the United States could recover plutonium from a can-in-canister form somewhat more easily than it could be recovered from an immobilized form, there is as yet no evidence that Russian interest in pursuing parallel disposition with the United States would be undermined by pursuit of a can-in-canister approach. Moreover, the ability to begin such disposition quickly would demonstrate to Russia and the rest of the world that the United States is serious about disposing of its excess materials. Carrying through on the revised can design intended to preclude easy removal of intact cans from the canisters will be important in mitigating potential perceptions of reversibility associated with the can-in-canister approach.

Impact on Nuclear Arms Reductions

The impact on nuclear arms reductions would be generally similar to those for other immobilization alternatives, except for the possible increase in the recoverability of the immobilized plutonium. That issue would have to be addressed through design of the can-in-canister forms and monitoring, to provide assurances that the plutonium could not be easily recovered from the surrounding materials. Policy-makers will need to weigh the possibly greater recoverability of this alternative, with its implication for the signal sent to other countries concerning the degree of irreversibility of U.S. arms reductions, against the possibly more rapid implementation possible for this alternative, using existing facilities.

Impact on Nonproliferation Efforts

Similar to those for other immobilization alternatives, with the caveats regarding recoverability described above.

Impact on Fuel Cycle Policies and Choices

Similar to those for other immobilization alternatives.

Political Implementability

Similar to other immobilization alternatives using pre-existing facilities.

Electrometallurgical Treatment

Description

In this immobilization concept, plutonium metal and oxides would be converted to chlorides through dissolution in a molten salt solution. The resulting plutonium salts would be blended with cesium chloride to provide a radiation barrier in the final product, and then these mixed salts would be sorbed on materials known as zeolites. These would be mixed with glass frit and poured into a bellows similar to that use for the production of ceramics. Hot pressing of the bellows would melt the glass frit and form a mineral-like form known as a glass-bonded zeolite. Several bellows containing these forms would be loaded into each canister (with a size, weight, and radiation field similar to those for the other immobilization alternatives). The canisters would be stored for an interim period and then shipped to a geologic repository. Except for the initial steps involving dissolution in molten salt, the steps in the process are similar to those for the ceramic immobilization alternative. This process is more developmental than the other immobilization alternatives; several of the steps have not yet been demonstrated at substantial scale with the materials required for this mission.

Technical Factors

Schedule

The electrometallurgical treatment alternative is estimated to require approximately 13 years before large-scale immobilization of excess plutonium could begin, using the existing facility at Argonne National Laboratory-West in Idaho or another facility at another site. All of the immobilization operations for 50 tons of excess plutonium could be completed in just under 10 years of operation, so that the entire effort would require approximately 22 years from a decision to proceed.

The technical uncertainties facing this approach are greater than those for the other immobilization alternatives, as the overall process is still developmental and not all of the aspects of it have been fully demonstrated. The key technical issue that could substantially affect the schedule is the need to qualify the proposed waste form for emplacement in a geologic repository. A recent NAS committee study on the technical aspects of this approach raised questions concerning the long-term performance of the proposed waste form in a geologic repository. More development would be required before it could be determined with confidence that this approach is viable for plutonium disposition. Overall, the schedule uncertainty for this alternative is higher than for the other immobilization alternatives.

Risks of Theft or Diversion in Process

The electrometallurgical treatment concept would be similar in many -- though not all -- respects to the ceramic alternatives described above. Like other immobilization alternatives, the electrometallurgical treatment alternative is believed to be capable of accepting impure forms of plutonium (though this is one of the aspects that has not yet been demonstrated); and like other alternatives, the immobilization facility itself would be a large plutonium bulk-handling facility, involving opportunities for access to the material and material accounting uncertainties. The principal differences compared to the ceramic immobilization described above relate to the molten salt dissolution steps. In these steps, the plutonium would be in a bulk form in the molten salt; material accounting and control for these steps would be a particular challenge. The molten plutonium salt would be blended in bulk form with Cs-137 to provide a radiation barrier -- but as in the other cases, once the radiation barrier had been added, current technology would not be adequate to accurately measure the plutonium content of the resulting form. Thus, as in the case of homogeneous glass or ceramic immobilization, at one step nearly complete reliance would have to be placed on containment and surveillance to ensure that all of the plutonium that entered the process in fact went into the blend to produce the final plutonium form, rather than being diverted along the way.

Risks of Recovery and Re-Use in Weapons

In general, the difficulty of recovering the plutonium from the electrometallurgical immobilization form should be comparable, overall, to the difficulty of recovering plutonium from the homogeneous glass forms. The canisters in which the glass-bonded zeolite would be placed would be slightly smaller than the canisters in the vitrification case. Using Cs-137 from the Hanford capsules, the radiation barrier is expected to be 1000 rads per hour at one meter 30 years after fabrication.

Policy Factors

Impact on Russian Programs

The impact of this alternative on Russian programs would be roughly similar to that of the other immobilization alternatives. Immobilization could proceed in parallel with Russian reactor-based disposition alternatives, achieving the Spent Fuel Standard in each country. Technical uncertainties, however, create significant uncertainty as to when this alternative could begin; as in other cases, delays on the U.S. side could potentially result in corresponding delays on the Russian side.

Impact on Nuclear Arms Reductions

Like the other immobilization alternatives, electrometallurgical treatment could provide an acceptable approach to demonstrating the irreversibility of nuclear arms reductions. Some uncertainties exist concerning how difficult it would be to recover plutonium from the proposed glass-bonded zeolite forms.

Impact on Nonproliferation Efforts

In most respects, the impact of electrometallurgical treatment on nonproliferation agreements and negotiations would be similar to those of other immobilization alternatives.

Impact on Fuel Cycle Policy and Choices

A decision to dispose of excess plutonium in a glass-bonded zeolite form would be fully consistent with current U.S. fuel cycle policies. Unlike the other immobilization alternatives, however, electrometallurgical treatment was developed for the purpose of reprocessing and recycle of plutonium. Pursuing this technology would be perceived by some as encouraging continued development of this type of reprocessing technology. It should be noted, however, that the reprocessing approach on which electrometallurgical treatment is based never results in fully separated, weapons-usable plutonium; it was specifically designed to be somewhat more proliferation-resistant than other plutonium fuel cycle approaches. Use of this alternative for plutonium disposal would probably not result in significant additional reprocessing in other countries..

Political Implementability

A number of non-governmental organizations have strongly opposed electrometallurgical treatment technology, and have sued the Department of Energy in an attempt to prevent a demonstration of this technology for potential use in processing HEU spent fuel in the DOE inventory. (A request for an injunction was denied in court, and the demonstration has moved forward.) These groups have expressed concern about continued U.S. support for reprocessing technologies, and the process's ability to extract weapons-usable HEU from HEU-bearing spent fuel. While there would be no HEU in the feed material for plutonium disposition (and therefore no possibility of the process resulting in separated HEU), some opposition to implementation of this technology could be expected, were it to be selected. Policymakers will need to judge the likelihood that such opposition would succeed in delaying implementation of the electrometallurgical treatment alternative.

DEEP BOREHOLE DISPOSAL

Direct Emplacement

Description

Burial in deep (2-4 kilometer) boreholes is another alternative for disposition of excess weapons plutonium. The depth of the holes would make it difficult for the plutonium to reach the accessible environment or for anyone to retrieve it without the authorization of the host state, as described below. Thus the *location* of the material, rather than its physical transformation, would prevent its reuse in weapons. Safeguards could be applied to help detect any attempt at retrieval.

In the direct emplacement alternative, the various forms of excess plutonium would be converted to oxide and loaded into measured, tagged, and sealed cans (each containing approximately 4.5 kilograms of plutonium), which would be shipped to the well-head above the borehole. Any voids in the cans would be filled with some type of grout. At the well-head, the cans would be loaded into canisters (approximately 9 per canister), which would be lowered down into the hole. The canisters might fill, for example, the lower 2 kilometers of a 4-kilometer deep hole. After the canisters had been emplaced, the hole would be filled and sealed.

Technical Factors

Schedule

Preliminary estimates suggest that emplacement of plutonium in deep boreholes could begin in 10 years, including time for necessary siting and legal steps for the borehole site. In current approaches, the time for emplacement is assumed to be 10 years, though this could be compressed to as little as three years, if desirable. (The plutonium processing facility may not be able to provide the material rapidly enough to accommodate such an accelerated schedule; moreover, if the United States and Russia are pursuing disposition programs in parallel, and Russia is pursuing another alternative requiring a longer period to implement, it may not be possible to take advantage of this potential schedule acceleration.) Given the political difficulties of gaining approval and licenses for a borehole site, however, these timing estimates are highly uncertain (see "Political Implementability," p. 119).

Risks of Theft or Diversion in Process

The borehole direct emplacement alternative requires less bulk processing of plutonium than any other alternative. Transportation requirements are also modest. After the initial processing of pits and other forms to oxide, the cans would simply be shipped to the well-head, loaded into canisters, and lowered down the hole. The plutonium in the cans would be carefully measured, and the cans would then be tagged and sealed so that they could be treated as individual items for accounting purposes. Indeed, for this approach it is conceivable that much of the initial processing of non-pit forms could also be skipped, so that reactor fuels, residues, and a variety of other forms could simply be put in cans and emplaced. Accounting uncertainties and opportunities for theft would be lower than for the other alternatives.

As in the other disposition alternatives, the IAEA would be asked to monitor the borehole operation. After the plutonium left the pre-processing facility, none of the feed materials should any longer be in classified forms, and IAEA inspectors should be able to have access to all the steps in the process, including monitoring emplacement in the borehole. After emplacement, however, it would obviously not be possible to measure the material to ensure that all of the input material was in fact present in the borehole emplacement. Simple surveillance, however, could ensure that each of the measured and sealed cans was emplaced in the borehole.

Risks of Recovery and Re-Use in Weapons

Recovering material from a sealed borehole would require a major drilling operation, requiring substantial resources and time. Such an operation would be quite observable. As with other planned repositories, some level of institutional safeguarding would still be required: relatively simple monitoring approaches (such as unattended seismic sensors) could provide high confidence that no re-drilling was occurring. Thus, the borehole alternative would essentially completely preclude the possibility that anyone other than the host state itself could gain access to the material. Even for the host state, retrieval would involve some time and cost. While drilling back into the hole could be effectively prevented by adding drill diverters and a variety of other barriers as the hole is filled in and sealed, it would also be possible to drill a separate hole aimed at connecting with the plutonium at depth. The technology of such deep drilling to a specific designated point, to connect to a pre-existing hole, has long been demonstrated in the mining and oil industries. Once recovered, in the direct emplacement case, the plutonium would be in extremely attractive forms for re-use in nuclear weapons. In short, for preventing proliferation the borehole alternative far exceeds the Spent Fuel Standard, but the direct emplacement borehole alternative would be more attractive for recovery by the host state than plutonium in spent fuel.

Policy Factors

Impacts on Russian Program

As with other disposal alternatives, the borehole alternative would not offer a near-term likelihood of implementing identical approaches for U.S. and Russian excess weapons plutonium, since Russian officials have clearly stated their intention to use Russian excess plutonium as fuel in nuclear reactors. Nevertheless, as with other disposal alternatives, U.S. and Russian disposition could proceed in parallel using different technologies, achieving the Spent Fuel Standard in each country. In the case of borehole direct emplacement, however, the potential perception that the United States could readily drill to recover the material could negatively affect Russian willingness to carry out more irreversible approaches with its own excess plutonium.

Uncertainties about the ability to gain political approvals and licenses for a borehole facility, moreover, could result in delaying not only U.S. plutonium disposition but Russian plutonium disposition as well, should this alternative be selected, as Russia is unlikely to carry out disposition of a substantial fraction of its excess plutonium if the United States is leaving its own excess plutonium in directly weapons-usable form.

Impact on Nuclear Arms Reduction Efforts

Because of the potential perception of recoverability by the host state, the deep borehole direct emplacement alternative could have fewer benefits for nuclear arms reductions than other alternatives meeting the Spent Fuel Standard. Moreover, delays in implementing the borehole alternative, should they occur, could have substantial negative impacts, and delay achieving the benefits of plutonium disposition.

Impacts on Nonproliferation Efforts

Similarly, because the potential perception of recoverability by the host state, the deep borehole direct emplacement alternative could have fewer nonproliferation benefits than other alternatives meeting the Spent Fuel Standard. Uncertainties about the ability to open and operate a facility, moreover, could create uncertainties in other countries about the credibility of the U.S. commitment to irreversible disposition of this material.

Impact on Fuel Cycle Policies and Choices

As with other disposal alternatives, a decision to dispose of excess materials in a deep borehole would be fully consistent and supportive of current U.S. fuel cycle policies not to encourage the civil use of plutonium, demonstrating clearly the U.S. view that in the current market, plutonium is a dangerous liability rather than a valuable asset.

Political Implementability

The schedule uncertainties facing the borehole alternative are more severe than those facing the other alternatives. The experience of the last four decades is instructive: No country in the world has yet succeeded in gaining public approval and licenses for geologic disposal of high-level nuclear waste. The United States has been attempting to do so for some decades, and while progress toward a determination of the suitability of the Yucca Mountain site is being made, the official estimate is that even if that site is found to be suitable, it will not begin accepting wastes until 2010. That estimate is three years *later* than current preliminary estimates for opening a borehole facility for plutonium disposition (even though borehole siting, design, and licensing efforts have not yet even begun).

While the plutonium to be disposed of in the borehole alternative would be orders of magnitude less hazardous than the spent fuel and HLW scheduled to be emplaced in Yucca Mountain or a similar repository, and a strong argument can be made that the great depth of the borehole would reliably prevent any of the material from reaching the accessible environment, siting and gaining public approval for such a facility can still be expected to be extremely difficult. Moreover, the borehole will be a new type of repository with which U.S. regulatory authorities have no experience, and collecting data to accurately characterize the geologic conditions at the bottom of the borehole will be much more difficult than it is in the case of a shallow mined repository such as Yucca Mountain. Therefore, it is effectively impossible to estimate reliably when, in fact, a borehole for plutonium disposal could be sited, built, and licensed for operations.

All of the alternatives would eventually require a geologic repository for final disposal of their wastes, so these considerations apply in some respects to all of them. But in the reactor and immobilization alternatives, the material could be transformed into forms meeting the spent fuel standard, which could be safely and securely stored for decades, regardless of whether the issues relating to opening a geologic repository had been resolved. Only the borehole alternative relies on geologic disposal itself to achieve its proliferation resistance -- and therefore would not achieve that proliferation resistance if public opposition and other siting difficulties prevented the borehole from opening. Policy makers will need to keep these uncertainties in mind as they consider this alternative.

Immobilized Emplacement

Description

In the immobilized emplacement alternative, the plutonium would be immobilized in ceramic pellets before being placed in the borehole. a cold-pressing process similar to that for the ceramic can-in-canister approach described above would be used; indeed, the process would be very similar to the process of producing sintered MOX fuel pellets, though no similar quality standards would have to be met. The plutonium in the ceramic pellets would be carefully measured, and the pellets would then be shipped to the borehole site. To ensure long-term protection against a possible accidental chain reaction, in current plans the ceramic pellets would contain only 1 percent plutonium by weight; moreover, at the borehole site, they would be mixed with an equal number of pellets containing no plutonium at all (reducing the average loading to 0.5% plutonium), and all the pellets would be mixed into a grout consisting of kaolinite clay. This grout-pellet mixture would be put directly down the borehole, without any cans or containers. The borehole would then be filled and sealed.

Technical Factors

Schedule

The estimated schedule for the immobilized emplacement alternative is the same as for the direct emplacement alternative. In this case, since more plutonium processing would be needed before emplacement, it is even less likely that the plutonium processing facility could process the plutonium quickly enough to support accelerating the emplacement schedule to only three years.

The licensing or approval uncertainties for the immobilized alternative would be somewhat less than those for the direct emplacement alternative, as the demonstrated ability of the ceramic form to remain stable for millions of years would provide a substantial additional safety argument, as would the absence of any containers that might have void spaces that would allow deep water to flow upward toward the surface, potentially carrying plutonium contamination with it. Nevertheless, the principal uncertainties relating to public acceptance and siting would still apply.

Risks of Theft or Diversion in Process

The ceramic immobilization required for this alternative would be a large-scale bulk- processing operation similar in many respects to the fabrication of MOX pellets or the ceramic can-in-canister forms described above. As with other complex bulk processes handling tons of plutonium each year, there would be opportunities for insiders to gain access to the material, and there would be significant material accounting uncertainties. The ceramic pellets containing one percent by weight plutonium would be a much less attractive target for theft than pure plutonium would be, but they would not meet the spent fuel standard, and would have to be protected accordingly. Shipment of the pellets to the well-head would be done with SSTs, just as shipping of pure plutonium in the direct emplacement alternative would be.

While the cans that would be used in the direct emplacement alternative would be tagged and sealed, and could be treated as individual accountable items, in the immobilized alternative there would be no cans: the mixture of pellets and grout would be pumped down the borehole in bulk. This alternative represents a bulk process in which the plutonium going into the process could be measured (by measuring the plutonium content of the pellets), but there would be no possibility of measuring the plutonium again once the process was complete, because the plutonium would then be kilometers below the ground. Therefore, total reliance would have to be placed on containment and surveillance to ensure that all of the immobilized mixture had, in fact, been emplaced.

Risks of Recovery and Re-Use in Weapons

The immobilized emplacement form would be substantially more difficult to recover for use in weapons than the direct emplacement form -- because even once recovered, the immobilized forms would have to be separated to recover the plutonium, and separation of plutonium in very low concentrations from ceramic forms would be difficult and costly. Again, recovery by any one other than the host state would be completely ruled out; and in this case, even for the host nation, recovering this material for use in weapons would be significantly more difficult overall than recovering plutonium from spent fuel. Thus, this alternative would meet or exceed the Spent Fuel Standard.

Policy Factors

Impacts on Russian Program

As with other disposal alternatives, the borehole alternative would not offer a near-term likelihood of implementing identical approaches for U.S. and Russian excess weapons plutonium, since Russian officials have clearly stated their intention to use Russian excess plutonium as fuel in nuclear reactors. Nevertheless, as with other disposal alternatives, U.S. and Russian disposition could proceed in parallel using different technologies, achieving the Spent Fuel Standard in each country. Unlike direct emplacement, the immobilized approach would make the plutonium quite difficult to recover, even for the host state.

Uncertainties about the ability to gain political approvals and licenses for a borehole facility, however, could result in delaying not only U.S. plutonium disposition but Russian plutonium disposition as well, should this alternative be selected, as Russia is unlikely to carry out disposition of a substantial fraction of its excess plutonium if the United States is leaving its own excess plutonium in directly weapons-usable form.

Impact on Nuclear Arms Reduction Efforts

As with other disposition alternatives meeting the Spent Fuel Standard, the deep borehole immobilized emplacement alternative would have the benefits for nuclear arms reduction described in Section 2 of this assessment, including helping to lock in current nuclear arms reductions and reduce the risk of reversal; laying a base for further reductions, if desired; and building international confidence in the arms reduction process. The borehole immobilized emplacement alternative may be perceived as making the plutonium particularly difficult to recover, and therefore offer additional assurances of irreversibility. However, delays in implementing the borehole alternative, should they occur, could have substantial negative impacts, and delay achieving the benefits of plutonium disposition.

Impacts on Nonproliferation Efforts

The benefits of the deep borehole immobilized emplacement alternative for the nonproliferation regime would be similar to those of other alternatives meeting the Spent Fuel Standard. Uncertainties about the ability to open and operate a facility, however, could create uncertainties in other countries about the credibility of the U.S. commitment to irreversible disposition of this material.

Impact on Fuel Cycle Policies and Choices

As with other disposal alternatives, a decision to dispose of excess materials in a deep borehole would be fully consistent and supportive of current U.S. fuel cycle policies not to encourage the civil use of plutonium, demonstrating clearly the U.S. view that in the current market, plutonium is a dangerous liability rather than a valuable asset.

Political Implementability

Similar to that for the direct emplacement alternative, except that immobilization would provide substantial additional safety arguments, which could somewhat mitigate siting and approval difficulties.

HYBRID ALTERNATIVES

Description

DOE is also considering hybrid alternatives, in which more than one of the alternatives just described would be implemented, for different portions of the excess plutonium. For example, the LWR alternative or the CANDU alternative might be used for pure plutonium metal and oxides (such as the material from weapons components), while an immobilization alternative or a borehole alternative might be used for material that would require expensive purification before it could be used for reactor fuel. The balance of how much material went to each alternative could be varied over a wide range. Such hybrid alternatives could allow more rapid implementation of the overall plutonium disposition mission, and would offer additional confidence in success of the overall program, since each technology could provide a backup to the other in case unexpected problems developed. These hybrid alternatives would be somewhat more expensive, however, since facilities for two different approaches would have to be provided.

Technical Factors

In general, the technical factors for the hybrid alternatives are the same as for the individual alternatives that compose them, with a few exceptions. As just noted, the schedule could be accelerated somewhat compared to the individual alternatives, and would suffer from less overall uncertainty, offering an advantage on the schedule criterion. The hybrid alternatives would make it possible to avoid the extensive purification steps that would otherwise be needed to implement the reactor alternatives for the impure plutonium forms -- thus avoiding a significant amount of initial bulk-handling of plutonium, some of it in difficult-to-measure forms. In addition, in the immobilization case, reducing the amount of material to be immobilized would make it possible to concentrate the fission products in existing wastes in a smaller number of plutonium-bearing canisters, increasing the radiation field that could be achieved for each canister, and therefore increasing the difficulty of stealing that material and recovering it for use in weapons.

Policy Factors

The policy implications of pursuing a hybrid alternative would in most cases be similar to those of pursuing the reactor alternatives. There would be some advantages compared to the reactor alternatives alone, in that:

- simultaneously investing in two disposition technologies would further demonstrate U.S. seriousness in moving as quickly as practicable to ensure that this plutonium will never again be used in nuclear weapons; and

- pursuing both a reactor alternative and a direct disposal alternative would preserve a balance between the two, creating somewhat less of an impression of a change in U.S. fuel cycle policies than would a reactor alternative alone.
- Pursuit of the hybrid alternatives might help set a precedent for Russia, which also has residue and other materials which are not well suited for the MOX alternatives. A U.S. decision to pursue MOX and vitrification in unison might provide an incentive for Russia to actively pursue vitrification as a disposition alternative for its impure or dilute plutonium forms.

There are certain liabilities to the hybrid alternatives as well. The most significant of these related to nonproliferation and arms control is the need to gain approval for a larger number of facilities, which would increase somewhat the political hurdles in implementing the hybrid alternative. It is likely that this issue could be addressed by effectively making the case for the disposition mission and by acting early to build a national consensus for such an operation.

THE NO-ACTION ALTERNATIVE

Description

The no-action alternative for disposition would be to leave the excess plutonium in storage, in directly weapons-usable form, indefinitely. The material would presumably continue to be stored at whatever sites were chosen for the storage alternative -- though it is possible that over time, decisions would eventually be taken to move the material to alternative sites.

What form the plutonium would be stored in over the long term is an important question for this alternative. For alternatives involving disposition, it is assumed that the plutonium would be processed from weapons components and other forms to forms suitable for disposition. In a true "no action" alternative, the plutonium would not be processed (except as needed to meet DOE standards for long-term storage); much of it would be stored as weapon pits indefinitely. Alternatively, an alternative could be pursued in which the plutonium pits were converted to oxide and then returned to storage. While the material would still be directly weapons-usable, it would no longer be in the form of weapons components, and could be made available for traditional IAEA safeguards; this could offer some nonproliferation and arms reduction advantages. However, a substantial fraction of the total cost, environmental impact, and proliferation risk of plutonium disposition, results from this initial processing step.

Technical Factors

Schedule

Since the excess plutonium is already in storage, this alternative has, in effect, already begun, and there are no schedule issues.

Risk of Theft or Diversion in Process

For the near term, leaving the plutonium in storage in secure, continuously-monitored vaults would offer the lowest risks of diversion in process of any of the alternatives, because transport and bulk processing of the plutonium would not be required. However, the risks of theft, while small, would continue into the indefinite future, without the prospect of reducing them offered by the other alternatives. As security would be entirely dependent on institutional measures, when extrapolated into the indefinite future, it is difficult to predict whether security could be reliably maintained over periods of hundreds or thousands of years.

Risk of Re-use in Nuclear Weapons

The ease of re-using excess materials in nuclear weapons would be substantially higher for the no-action alternative than for any of the disposition alternatives, especially for material stored as nuclear weapon pits, which could readily be reassembled into nuclear weapons. The risk could be mitigated through institutional measures, including binding international, legal obligations not to use these materials for military purposes, verified with international monitoring. This would offer only political or legal irreversibility, not physical irreversibility; although the political costs of removing the materials from such a legally binding commitment would be a significant barrier to their re-use in nuclear weapons, it would not make it any more intrinsically costly or time-consuming to put the material back into nuclear weapons. The risk could also be modestly mitigated by modifying the pits so that they could not be used in nuclear weapons without being re-manufactured, either by conversion to oxide or through altering their configuration.

Policy Factors

Impact on Russian Programs

Leaving U.S. excess plutonium in storage in directly weapons-usable form would almost inevitably mean that Russian excess plutonium would remain in storage in directly weapons-usable form as well. Russian excess plutonium would therefore remain potentially vulnerable to theft indefinitely, and the possibility that Russia would incorporate it back into nuclear weapons, should political circumstances change and a decision be taken to reverse current arms reductions, would also continue indefinitely.

Impact on Nuclear Arms Reduction Efforts

A decision to leave U.S. excess weapons plutonium in storage in directly weapons-usable form would represent a clear reversal of stated U.S. intentions, and therefore could raise questions about the credibility of U.S. commitments to the irreversibility of nuclear arms reductions. For example, at the Moscow Nuclear Safety and Security Summit in April 1996, the leaders of the P-8 agreed that stockpiles of excess plutonium should be reduced "as quickly as practicable," and the United States and Russia have reiterated that understanding in their joint work on plutonium disposition. Choosing the no-action alternative for disposition would raise questions as to why the United States was suddenly reversing itself and choosing to keep this material available in forms that could be rapidly returned to weapons, and whether this signaled that the United States was reserving the alternative to rapidly reverse its current arms reductions and rebuild a nuclear arsenal of its former size. For both the United States and Russia to leave their excess plutonium in forms that could be readily returned to weapons could undermine prospects for future reductions in nuclear arsenals, and for convincing other states to join in reductions.

As noted above, however, these negative impacts could be somewhat mitigated by political and legal commitments not to return this material to weapons, verified by international monitoring. Any effort to return these materials to weapons would then require abrogating an international agreement, and would be readily observable.

Impacts on Nonproliferation Efforts

For all the reasons just described, choice of the no-action alternative could also have significant negative impacts for the global nonproliferation regime, as it would call into question the permanence of the major nuclear weapon states' commitment to nuclear arms reductions.

The United States and Russia, along with the other nuclear weapon states, have committed themselves under the NPT to pursue in good faith an end to the arms race and eventual nuclear disarmament. The restatement of these commitments was a key factor in obtaining the indefinite extension of this vital treaty. A decision by the United States and Russia to keep their plutonium stockpiles available in forms that could be readily returned to weapons could call these commitments into question. Here, too, however, these impacts could be mitigated through verified legal commitments that these materials would not be returned to military use.

In addition, choosing not to pursue disposition of U.S. excess plutonium would make U.S. diplomatic efforts to limit and eventually reduce stockpiles of such material in other countries more difficult. This could affect the fissile cutoff negotiations (where the problem of stocks already produced has been a controversial issue), and discussions aimed at limiting the accumulation of plutonium in civilian stockpiles. If the United States was doing nothing to reduce its own stockpile of excess weapons plutonium, that could affect its credibility in convincing other countries to reduce their stockpiles, including in areas of proliferation concern, such as the Korean peninsula and South Asia.

Impacts on Fuel Cycle Policies and Choices

A decision to leave U.S. excess weapons plutonium in storage would be intermediate between the reactor alternatives and the disposal alternatives in its impact on overall U.S. fuel cycle policies. Unlike the reactor alternatives, it would not involve civilian use of plutonium, and would not appear to encourage such use; but unlike the disposal alternatives, it would not provide a clear demonstration that the United States sees excess plutonium as a dangerous liability, rather than a valuable asset.

Political Implementability

No additional facilities would have to be approved or licensed to implement the no action alternative for disposition, beyond those that would be used for storage. Moreover, no major new capital investments would be required, and therefore Congressional approval of necessary funding would not be an issue.

Nevertheless, this alternative would be likely to provoke strong negative responses from a variety of stakeholder groups, particularly local communities where excess materials would have to be stored indefinitely. Rather than serving as a storage site for a fixed period of years, with a clearly defined forward path that would eventually remove the plutonium from their community, in this alternative these communities would be asked to serve, in effect, as permanent plutonium stores. In addition, stakeholders who view the mission of disposing of excess materials as important to the future arms reduction and nonproliferation efforts of the United States would likely raise significant objections. In the U.S. legal system, however, it is easier for stakeholders to prevent an action (such as disposition) from being taken than it is to force the government to take such an action.

6. Steps to Maximize Benefits and Minimize Liabilities

All of the alternatives under consideration for disposition of U.S. excess plutonium offer significant benefits for achieving nonproliferation and arms control goals, but each has its own liabilities as well. In conjunction with the choice of a preferred alternative for disposition of excess plutonium, it is important to identify steps that could maximize the potential benefits and minimize the potential liabilities of each option -- even though not all potential liabilities can be completely mitigated.

For All Alternatives

Pursuing parallel steps with Russia. The benefits of placing U.S. excess plutonium under international monitoring and then transforming it into forms that meet the Spent Fuel Standard would be greatly increased, and the risks of these steps significantly decreased, if Russia took similar steps with its own excess plutonium on a parallel track. Indeed, disposition of excess plutonium in either country is unlikely to receive the sustained political support required unless the other country is moving forward on disposition of its excess plutonium as well. As the two sides have agreed in their joint study of plutonium disposition options, U.S. and Russian disposition of excess plutonium should proceed in parallel, with the goal of reducing to equal levels of plutonium remaining in military stockpiles, but the two countries need not use the same disposition technologies. As the U.S. National Academy of Sciences has recommended, to mitigate potential security risks, it is also important to work with Russia to ensure that stringent standards of security and accounting for nuclear materials, approximating the Stored Weapons Standard, are maintained throughout the disposition process. Working with Russia to ensure such a parallel disposition approach would be an important step for any of the alternatives chosen for U.S. plutonium disposition. One possibility to consider is a specific U.S.-Russian agreement governing implementation of disposition of excess fissile materials.

Making the case. The likelihood of political and regulatory obstacles delaying implementation of plutonium disposition could be reduced through clear action by the President and Congress designating plutonium disposition as a priority national security activity. Such action would offer additional benefit if combined with a determined effort to make the case to relevant stakeholders as to why plutonium disposition was needed, and why the chosen options for implementation support national security. Such steps could help mitigate a liability shared to varying degrees by all the alternatives -- schedule uncertainties resulting from the possibility of controversy over and opposition to their implementation.

Keeping others informed. Keeping the U.S. public and the international community informed of the purposes and progress of U.S. weapons-usable fissile material storage and disposition efforts will be critical to achieving the maximum nonproliferation and arms reduction benefit from these efforts. A high-profile effort to emphasize the U.S. commitment to reducing its stockpiles of excess fissile material, and to publicize the various steps in the disposition process, including statements from key U.S. officials outlining their rationale, could contribute significantly. Other countries could be kept directly informed of U.S. efforts and milestones through bilateral and multilateral meetings and other diplomatic channels.

Verifying progress. The United States seeks to demonstrate to the world that its excess fissile materials will never again be used in weapons. Verification will be key to making this demonstration credible. Placing excess materials under bilateral U.S.-Russian monitoring and IAEA safeguards as rapidly as practicable, consistent with nonproliferation constraints, would make a major contribution. Applying international monitoring to the processes of disposition itself, beginning as early in the disposition process as practicable, will also be an important measure to maximize the benefit of disposition. Steps the United States could take toward this goal include:

- Early demilitarization of weapon pits to make possible broader international inspection, and provide a modest initial barrier to reversibility;
- Development of a modified safeguards approach which could allow for safeguards to be applied over classified forms without revealing design sensitive information;
- Declassification, consistent with national security requirements, to allow broader international inspection;
- Establishing, with Russia, a special fund to pay for the added costs to the IAEA of safeguarding excess materials.

Ensuring stringent safeguards and security throughout. Maintaining stringent standards of safeguards and security throughout the disposition process, meeting the Stored Weapons Standard, can help reduce the short-term proliferation vulnerabilities involved in the bulk processing and transport of plutonium required for all the disposition options. At a minimum, the goal must be to ensure that overall, disposition reduces proliferation risks over the long term rather than increasing them. Additionally, the United States should ensure that safeguards and security factors are a primary consideration in the design and construction of new facilities (or in the modification of existing facilities).

Minimizing transport, and the number of sites. Each shipment of weapons-usable plutonium creates a potential vulnerability to theft by overt attack on the shipment. Hence, to the extent possible, the number and length of the shipments required should be minimized. Co-location of major facilities (such as plutonium processing and MOX fabrication or immobilization facilities) can reduce transportation steps substantially. For each shipment, high levels of security, similar to those applied for transport of nuclear weapons, can reduce proliferation risks to low levels. As noted earlier, DOE plans to use the Safe, Secure Transports (SSTs) used for shipping nuclear weapons to ship plutonium for the plutonium disposition mission -- including mixed forms of plutonium, such as fresh mixed-oxide fuel. Foreign variants should require armed escorts for shipments overseas.

Continuing to develop and implement improved safeguards approaches. All of the alternatives face uncertainties in precisely accounting for plutonium when it is being processed in bulk, and in assaying plutonium in difficult-to-measure forms, such as scrap, mixed residues, or radioactive materials such as spent fuel or homogeneously immobilized forms. Uncertainties in bulk processing can be partly (though not completely) mitigated through implementation of state-of-the-art material accounting systems, including near-real-time accounting measures, backed up by advanced containment and surveillance systems, designed to ensure that dual coverage that could not be blocked by any single failure. For maximum effectiveness, such systems should be included in the design of disposition facilities from the outset. Continued research and development on improved means to assay material in difficult-to-measure forms could potentially lead to technologies that could partly mitigate the significant accounting uncertainties currently involved in dealing with such forms.

For the Reactor Alternatives

Clearly outlining the policy.: If the reactor alternatives are chosen, the potential for perceptions that U.S. fuel cycle policy had changed could be substantially mitigated by clear and authoritative statements outlining precisely how the chosen option fits within broader U.S. fuel cycle policy. Such a statement could point out that this use of plutonium in reactors was intended only for disposition of existing stockpiles of excess weapons plutonium, and did not imply any broader change in U.S. fuel cycle policy, or any increased likelihood that the United States would now begin separating additional plutonium for its civilian fuel cycle. It could point out that transforming separated plutonium into spent fuel, in order to reduce existing excess stocks of separated plutonium, is perfectly consistent with a policy that seeks to reduce such stockpiles and not to encourage the separation of additional plutonium. Steps that could be taken to mitigate such concerns include the following:

- commitments not to reprocess the spent fuel from plutonium disposition, or other spent fuel;
- commitments to dismantle facilities following completion of the disposition mission;
- licenses or approvals for disposition facilities restricted only to disposition mission;

- steps to make clear that rather than being profitable, this use of plutonium as reactor fuel involves a substantial cost to the government, and payments to the utilities are required.

Limiting the number of sites. Limiting the use of plutonium to a small number of reactor sites, so that the overwhelming majority of U.S. reactors would continue on the same fuel cycle as before, could help limit possible opposition to the use of MOX in U.S. reactors (as well as the number of separate licensing amendments required), and mitigate possible perceptions of a change in U.S. fuel cycle policy. Since only a small number of reactors is required, and there is no expectation of any broader change in U.S. fuel cycle policy, only specific license amendments for individual reactors, rather than a generic process authorizing the use of MOX in U.S. reactors generally, such as the Generic Environmental Impact Statement on Mixed Oxide (GESMO) that was begun in the 1970s.

For the Immobilization Alternatives

Ensuring removal-resistant can-in-canister designs. As described in the Red Team report, initial designs for the can-in-canister approach would make it possible to smash the large canisters and remove the cans containing immobilized plutonium with no fission products, which could then be chemically processed without requiring shielding and remote operations. The can redesign now underway should mitigate this vulnerability significantly, potentially ensuring that this option could meet the Spent Fuel Standard.

Ensuring radiation levels sufficient to provide significant barriers. As described in the Red Team report, if it is assumed that potential thieves attempting to steal and recover plutonium are willing to take substantial doses of radiation, then very high radiation levels are needed to provide a major barrier against theft. Steps that would increase the radiation barrier in the immobilized forms (such as use of the cesium capsules stored at Hanford, or concentration of the available high-level wastes in a smaller number of canisters, as is possible with the hybrid options) could mitigate this potential vulnerability.

For the Borehole Alternatives

Moving quickly on siting efforts. The largest nonproliferation and arms reduction liability of the borehole alternatives is the very large uncertainty in when they could be implemented, arising from the difficulty of gaining political approval and licenses for a borehole site. This liability cannot be greatly mitigated. But if this option, is chosen, efforts could be made to mitigate this liability as much as possible by moving quickly to initiate the siting effort, and making a determined case that the environmental and safety hazards from a borehole site limited only to excess weapons plutonium would be very small.

For Variants Involving NRC-Regulated Facilities

Ensuring that security forces have authorization to do their job. Currently, security forces at DOE facilities such as Pantex are authorized to use deadly force to prevent any theft of weapons-usable fissile materials. This is not always the case for commercial facilities regulated by NRC. To mitigate any potential vulnerabilities, security forces at all sites involved in the disposition process (whether DOE or NRC regulated or other) should be given the same ability to use deadly force. This would be necessary to maintain security approximating the Stored Weapons Standard.

For the Foreign Implementation Variants

Maintaining stringent security standards. Those alternatives that involve the removal of excess material from the United States (MOX fabrication in Europe and MOX irradiation in Canadian CANDU reactors), require the United States to pass responsibility for security over the material to another nation. While the United States believes that physical protection standards in these countries are adequate, the specific procedures at the relevant civilian facilities in these countries are likely to differ from those applied at nuclear weapons facilities in the United States. For options involving such a transfer of authority, it would be essential to ensure that stringent security, accounting, and safety are maintained while the material is outside of the United States.

Minimizing additions to civilian MOX capabilities. Some options involving the use of foreign MOX plants could provide sufficient contract income to finance the construction of new MOX capacity, which could be used for expanded plutonium fuel cycle operations once the weapons plutonium disposition mission was complete. To mitigate this potential disadvantage if foreign MOX fabrication options are chosen, the United States could seek to make use of existing capacity where possible, rather than financing construction of new capacity.

7. Conclusions

Conclusions On Storage

Each of the alternatives under consideration for storage of U.S. weapons-usable fissile materials has the potential to support U.S. nonproliferation and arms reduction goals, if implemented appropriately.

Each of the storage alternatives could provide high levels of security to prevent theft of nuclear materials, and could provide access to excess materials for international monitors.

Making excess plutonium and HEU available for bilateral U.S.-Russian monitoring and IAEA safeguards, while protecting proliferation-sensitive information, would help demonstrate the U.S. commitment never to return this material to nuclear weapons, providing substantial arms reduction and nonproliferation benefits in the near term.

Conclusions on Disposition of U.S. Excess Plutonium

The nonproliferation and arms reduction advantages and disadvantages of the plutonium disposition alternatives under consideration are summarized in Figure ES-1. Key conclusions from the analysis in this assessment include:

Each of the alternatives for disposition of excess weapons plutonium that meets the Spent Fuel Standard would, if implemented appropriately, offer major nonproliferation and arms reduction benefits compared to leaving the material in storage in directly weapons-usable form. Taking into account the likely impact on Russian disposition activities, the no-action alternative appears to be by far the least desirable of the plutonium disposition alternatives from a nonproliferation and arms reduction perspective.

Carrying out disposition of excess U.S. weapons plutonium, using alternatives that ensured effective nonproliferation controls and resulted in forms meeting the Spent Fuel Standard, would:

- reduce the likelihood that current arms reductions would be reversed, by significantly increasing the difficulty, cost, and observability of returning this plutonium to weapons;
- increase international confidence in the arms reduction process, strengthening political support for the nonproliferation regime and providing a base for additional arms reductions, if desired;

reduce long-term proliferation risks posed by this material by further helping to ensure that weapons-usable material does not fall into the hands of rogue states or terrorist groups; and

lay the essential foundation for parallel disposition of excess Russian plutonium, reducing the risks that Russia might threaten U.S. security by rebuilding its Cold War nuclear weapons arsenal, or that this material might be stolen for use by potential proliferators.

Choosing the "no-action alternative" of leaving U.S. excess plutonium in storage in weapons-usable form indefinitely, rather than carrying out disposition:

would represent a clear reversal of the U.S. position seeking to reduce excess stockpiles of weapons-usable materials worldwide;

would make it impossible to achieve disposition of Russian excess plutonium;

could undermine international political support for nonproliferation efforts by leaving open the question of whether the United States was maintaining an alternative for rapid reversal of current arms reductions; and

could undermine progress in nuclear arms reductions.

The benefits of placing U.S. excess plutonium under international monitoring and then transforming it into forms that met the Spent Fuel Standard would be greatly increased, and the risks of these steps significantly decreased, if Russia took comparable steps with its own excess plutonium on a parallel track. The two countries need not use the same plutonium disposition technologies, however.

As the 1994 NAS committee report concluded, alternatives for disposition of U.S. excess weapons plutonium will provide maximum nonproliferation and arms control benefits if they:

minimize the time during which the excess plutonium is stored in forms readily usable for nuclear weapons;

preserve material safeguards and security during the disposition process, seeking to maintain to the extent possible the same high standards of security and accounting applied to stored nuclear weapons (the Stored Weapons Standard);

result in a form from which the plutonium would be as inaccessible and unattractive for weapons use as the larger and growing quantity of plutonium in commercial spent fuel (the Spent Fuel Standard).

In particular, in order to achieve the benefits of plutonium disposition as rapidly as possible, and to minimize the risks and negative signals resulting from leaving the excess plutonium in storage, it is important for disposition alternatives to begin, and to complete the mission, as soon as practicable, taking into account nonproliferation, environment, safety, and health, and economic constraints. Timing should be a key criterion in judging disposition alternatives. Beginning the disposition quickly is particularly important to establishing the credibility of the process, domestically and internationally.

Each of the alternatives under consideration for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others.

Each of the alternatives under consideration for plutonium disposition can potentially provide high levels of security and safeguarding for nuclear materials during the disposition process, mitigating the risk of theft of nuclear materials.

Each of the alternatives under consideration for plutonium disposition can potentially provide for effective international monitoring of the disposition process.

Plutonium disposition can only reduce, not eliminate, the security risks posed by the existence of excess plutonium, and will involve some risks of its own:

Because all plutonium disposition alternatives would take decades to implement, disposition is not a near-term solution to the problem of nuclear theft and smuggling. While disposition will make a long-term contribution, the near-term problem must be addressed through programs to improve security and safeguarding for nuclear materials, and to ensure adequate police, customs, and intelligence capabilities to interdict nuclear smuggling.

All plutonium disposition alternatives under consideration would involve processing and transport of plutonium, which will involve more risk of theft in the short term than if the material had remained in heavily guarded storage, in return for the long-term benefit of converting the material to more proliferation-resistant forms.

Both the United States and Russia will still retain substantial stockpiles of nuclear weapons and weapons-usable fissile materials even after disposition of the fissile materials currently considered excess is complete. These weapons and materials will continue to pose a security challenge regardless of what is done with excess plutonium.

None of the disposition alternatives under consideration would make it impossible to recover the plutonium for use in nuclear weapons, or make it impossible to use other plutonium to rebuild a nuclear arsenal. Therefore, disposition will only reduce, not eliminate, the risk of reversal of current nuclear arms reductions.

A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries. This could increase the proliferation risk if it in fact led to significant additional separation and handling of plutonium. On the other hand, if appropriately implemented, plutonium disposition might also offer an opportunity to demonstrate improved procedures and technologies for protecting and safeguarding plutonium, which could reduce proliferation risks and would strengthen U.S. efforts to reduce the stockpiles of separated plutonium in other countries.

Large-scale bulk processing of plutonium, including processes to convert plutonium pits to oxide and prepare other forms for disposition, as well as fuel fabrication or immobilization processes, represents the stage of the disposition process when material is most vulnerable to covert theft by insiders or covert diversion by the host state. Such bulk processing is required for all alternatives, however; in particular, initial processing of plutonium pits and other forms is among the most proliferation-sensitive stages of the disposition process, but is largely common to all the alternatives. More information about the specific process designs is needed to determine whether there are significant differences between the various immobilization and reactor alternatives in the overall difficulty of providing effective assurance against theft or diversion during the different types of bulk processing involved, and if so, which approach is superior in this respect.

Transport of plutonium is the point in the disposition process when the material is most vulnerable to overt armed attacks designed to steal plutonium. With sufficient resources devoted to security, however, high levels of protection against such overt attacks can be provided. International, and particularly overseas, shipments would involve greater transportation concerns than domestic shipments.

Conclusions Relating to Specific Alternatives

The reactor alternatives, homogeneous immobilization alternatives, and deep borehole immobilized emplacement alternative can all meet the Spent Fuel Standard. The can-in-canister alternatives are being redesigned to increase the difficulty of removing the cans from the canisters, with the goal of meeting the Spent Fuel Standard. The deep borehole direct emplacement alternative substantially exceeds the Spent Fuel Standard with respect to recovery by subnational groups, but could be more accessible and attractive for recovery by the host state than spent fuel.

The reactor alternatives have some advantage over the immobilization alternatives with respect to perceived irreversibility, in that the plutonium would be converted from weapons-grade to reactor-grade, even though it is possible to produce nuclear weapons with both weapons and reactor-grade plutonium. The immobilization and deep borehole alternatives have some advantage over the reactor alternatives in avoiding the perception that they could potentially encourage additional separation and use of civilian plutonium, which itself poses proliferation risks.

Alternatives that result in accountable "items" whose plutonium content can be accurately measured (such as fuel assemblies or immobilized cans without fission products in the "can-in-canister" alternative) offer some advantage in accounting to ensure that the output plutonium matches the input plutonium from the process. Other alternatives (such as homogeneous immobilization or immobilized emplacement in deep boreholes) would require greater reliance on containment and surveillance to provide assurance that no material was stolen or diverted -- but in some cases could involve simpler processing, easing the task of providing such assurance.

It appears likely that the alternative of using excess weapons plutonium as MOX in U.S. LWRs could be implemented relatively quickly, and meet the other criteria outlined above. The principal uncertainty in this case relates to the potential difficulty of gaining political and regulatory approvals for the various operations required.

Compared to the LWR alternative, the CANDU alternative would involve more transport, and more safeguarding issues at the reactor sites themselves (because of the small size of the fuel bundles and the on-line refueling of the reactors). Demonstrating the use of MOX in CANDU reactors by carrying out this alternative for excess weapons plutonium disposition could somewhat detract from U.S. efforts to convince nations operating CANDU reactors in regions of proliferation concern not to pursue MOX fuel cycles, but these nations are likely to base their fuel cycle decisions primarily on factors independent of disposition of this material. Disposing of excess weapons plutonium to another country long identified with disarmament could have significant symbolic advantages, particularly if carried out in parallel with Russia. Disposition of Russian plutonium in CANDU reactors, however, would require resolving additional transportation issues and additional questions relating to the likely Russian desire for compensation for the energy value of the plutonium.

Like the reactor alternatives, the immobilization alternatives have the potential to be implemented relatively quickly, and to meet the other criteria outlined above. They face somewhat less political uncertainty but somewhat more technical uncertainty than the reactor alternatives.

The likelihood of very long delays in gaining approval for siting and construction of deep borehole sites represents a very serious arms reduction and nonproliferation disadvantage of the borehole alternative, in either of its variants. While the deep borehole direct-emplacement alternative requires substantially less bulk processing than the other disposition alternatives, that alternative may not meet the Spent Fuel Standard for retrievability by the host state, as mentioned above. Any potential advantage from the reduced processing is small compared to the large timing uncertainty and the potential retrievability disadvantage.

Similarly, the electrometallurgical treatment alternative, because it is less developed than the other immobilization alternatives, involves more uncertainty in when it could be implemented, which represents a significant arms reduction and nonproliferation disadvantage. It does not appear to have major compensating advantages compared to the other immobilization alternatives.

The "can-in-canister" immobilization alternatives have a timing advantage over the homogeneous immobilization alternatives, in that, by relying on existing facilities, they could begin several years sooner (and the schedule is somewhat less uncertain). As noted above, however, modified systems intended to allow this alternative to meet the Spent Fuel Standard are still being designed.

Implementation Steps

Continued cooperation with Russia to ensure that Russia moves in parallel with U.S. efforts to place excess plutonium under international monitoring and then transform it into forms that meet the Spent Fuel Standard is key to achieving critical benefits from U.S. safeguards and plutonium disposition activities. U.S. and Russian officials have agreed that the goal should be parallel reductions to roughly equal levels of plutonium remaining in military stockpiles. A formal U.S.-Russian agreement governing such steps could have significant benefits.

Fulfilling the Moscow Nuclear Safety and Security Summit agreement to apply IAEA safeguards to excess fissile materials "as soon as it is practicable to do so" would have substantial nonproliferation and arms reduction benefits. As directed by President Clinton, DOE is continuing to work to maximize the quantities of U.S. excess materials made eligible for IAEA safeguards.

Since a substantial fraction of these materials is in classified forms and cannot be processed to unclassified forms for a substantial period, placing this material under safeguards in the near term would require developing modified safeguards measures that could allow credible IAEA monitoring of material in classified form without compromising information that would contribute to nuclear proliferation. Additional declassification -- particularly of the average amount of plutonium in a pit, and related passive radiation signatures -- could facilitate development of a credible safeguards regime in a manner consistent with national security requirements.

Bilateral U.S.-Russian monitoring of fissile materials removed from dismantled weapons can be an important complementary measure for achieving U.S. arms reduction and nonproliferation goals. Efforts to negotiate and implement a Mutual Reciprocal Inspections (MRI) regime are continuing.

As agreed at the Moscow Nuclear Safety and Security Summit, U.S. disposition activities seek to "reduce stocks of separated plutonium and highly-enriched uranium ... as soon as practicable." .

Similarly, U.S. storage and disposition activities seek to ensure that weapons-usable fissile materials "are stored and handled under physical protection, accounting and control measures that meet the highest international standards and that ensure effective non-proliferation controls" -- another agreed goal of the Moscow Nuclear Safety and Security Summit.

For whatever disposition alternatives are chosen, steps to maximize the benefits and minimize the liabilities, such as those outlined in Section 6, have the potential to substantially improve the net nonproliferation and arms reduction impact of disposition.

APPENDIX A

Secretary of Energy Advisory Board Fissile Material Task Force Members

Chairman

Dr. Allen Sessoms	President, Queens College

Members

Mr. Myron Kratzer	Consultant
Dr. Leon Lederman	Director Emeritus, Fermi National Accelerator Laboratory
Dr. Alexander MacLachan	Senior Vice President and Technical Officer (Retired), E.I. du Pont de Nemours and Company
Dr. Marvin Miller	Research Affiliate, Massachusetts Institute of Technology
Dr. Wolfgang Panosky	Director Emeritus, Stanford Linear Accelerator Center
Mr. John Taylor	Vice President, Nuclear Power (retired), Electric Power Research Institute
Dr. Frank von Hippel	Professor, Center for Energy Environmental Studies, Princeton University

APPENDIX B

Letter from the SEAB Task Force

September 26, 1996

Mr. Robert Hanfling
Secretary of Energy Advisory Board
Putnam, Hayes, and Bartlett
Suite 600, 1776 Eye Street, NW
Washington, D.C.

Dear Bob:

The Task Force on the Non-proliferation and Arms Control Implications of Weapons-Usable Fissile Materials Disposition Alternatives is pleased to present to you our comments on the Department's Non-proliferation and Arms control Assessment of Weapons-Usable Fissile Materials Storage and Disposition Alternatives. We conclude that the report presents an accurate, complete, and objective comparison of the relative strengths and weaknesses, from both technical and public policy standpoints, of the alternatives under consideration by the Department.

Many of our more detailed comments on earlier drafts have already been incorporated into the text. The purpose of the remainder of this letter is to highlight some key elements of the findings and to recommend broad measures which would contribute to success in achieving the goals of the program. These comments are all consistent with the Assessment Report.

Disposition of Excess Weapon Plutonium is Essential

Implementing any of the disposition alternatives that meet the Spent Fuel Standard would offer substantial nonproliferation and arms reduction benefits compared to the "no-action" alternative of leaving the material in storage indefinitely in a directly weapons-usable form. Indefinite storage will undermine, in a fundamental way, long term U.S. objectives and NPT commitments, in particular since governmental and societal stability cannot be assured indefinitely.

A Fast Start on Weapon Plutonium Disposition is Important

In our view, by far the most important statement the U. S. can make about its determination to permanently dispose of plutonium from its dismantled nuclear weapons is to do so at the earliest possible date. An early start on disposition is very important to the credibility of the process and to gaining international confidence in the program.

High priority should be given to implementing the steps necessary to achieve an early start. These steps can and should include clear Presidential direction designating plutonium disposition as a national security priority; supporting congressional legislation; establishment of a dedicated Nuclear Regulatory Commission office to provide expedited review of necessary licenses, with appropriate funding; maximum use of existing, operational facilities; early selection of utilities and fabricators (or joint ventures of these) to implement the MOX portion of the program; and moving forward as rapidly as practicable with conversion of plutonium "pits" to unclassified forms.

An early start should be achieved by pursuing both the reactor and immobilization alternatives in parallel, using existing, operational facilities. Such a parallel effort is highly advisable because of the uncertainties in each alternative and because both may be needed to process the wide range of forms of the excess weapon plutonium material. An early start on the reactor alternative could be pursued by having initial MOX test assemblies and perhaps initial reactor core loadings fabricated in operational European MOX facilities while U.S. fabrication facilities are being prepared. Any such arrangements should ensure stringent safeguards and security for the material while it is outside the United States and are not to be construed as U.S. encouragement of commercial plutonium recycle. Existing facilities at Savannah River should be used for an early start on immobilization of plutonium, moving both options forward in parallel.

Prompt agreement with the Russians on disposition schedules is key to national security and arms reductions objectives and will contribute significantly to an early start. Although it is not essential that the US and Russian disposition processes be the same, joint U.S.- Russian teams should be established to resolve key technical issues of mutual interest.

International Safeguards Should be Applied Early

International Atomic Energy Agency (IAEA) safeguards should be applied to excess fissile material as early in the storage and disposition process as possible. High priority should be placed on developing modified approaches that will provide credible safeguards on classified forms without compromising information that would contribute to nuclear proliferation. In particular, the Task Force believes that declassifying the average amount of plutonium per pit, along with relevant aspects of the passive radiation from pits, would enable the development of a credible safeguards regime while protecting sensitive information. New legal agreements for the implementation of IAEA safeguards should be pursued, based on the arms reduction objectives of the program. Adequate funding should be made available for this purpose outside the regular IAEA budget. This is an important national security issue and should be financed accordingly.

Physical Security is Important

An overriding priority is the safe storage and handling of the excess plutonium and highly enriched uranium prior to, and during, the disposition processes in the U.S. and Russia. In addition to continuing the assistance to Russia to provide safe storage facilities, the U.S.

should make early decisions on excess weapons storage up-grades, consolidation and/or co-location. These decisions are important input to the planning of the disposition process.

As disposition is intended to reduce the risk of proliferation rather than increasing it, it is critical to maintain stringent standards of safeguards and security throughout the process, coming as close as practicable to the level of protection and accounting applied to intact nuclear weapons. Physical security approaches to be applied to all phases of the disposition processes should be developed jointly with Russia, the IAEA, and, where relevant, with other nations involved in the process.

When the plutonium is in bulk form, e.g. in the front end processing of plutonium common to all disposition processes, it is most vulnerable to covert theft by insiders. The disposition facilities should therefore be designed to include containment and surveillance as well as material accountancy. Transport constitutes the mode when the weapons materials would be most vulnerable to overt armed attack. Therefore, the number of facilities to which directly-usable weapon materials needs to be sent should be minimized and facilities should be co-located to the extent practicable.

Irreversibility is Essential

Ensuring irreversibility, and in particular ensuring that the plutonium in the forms and locations resulting from disposition would be roughly as inaccessible and unattractive for use in weapons by the host state as plutonium in commercial spent fuel, is also critical to achieving the objectives of disposition. Achieving this Spent Fuel Standard will contribute to encouraging Russia to take comparable steps in parallel, to reducing the risk of reversal of ongoing arms reductions and laying the basis for further reductions, and to politically strengthening the nonproliferation regime by demonstrating the U.S. commitment that its reductions will not be reversed.

The Task Force had an extensive discussion of the use of weapons-grade and reactor-grade plutonium in weapons. Both types of plutonium can be used to make effective nuclear weapons, either by proliferating states and sub-national groups, or by sophisticated weapon states such as the U. S. and Russia. This issue is addressed in detail in the report. The Task Force agreed that it was extremely important that there be no illusion that reactor-grade plutonium does not pose a proliferation hazard; it does, and must be safeguarded and protected to the same standards applied to weapons-grade plutonium. In this context, while excess weapons plutonium should be the first priority, it is also important to address secure storage, safeguarding, and disposition of the large stockpiles of separated civilian plutonium that currently exist worldwide.

With respect to disposition of excess weapons plutonium, some Task Force members emphasized that as weapons-grade material has always been the material of choice for nuclear-weapon states, converting the excess weapons plutonium to reactor-grade (as the reactor options would do) would offer an additional contribution to the international perception of the irreversibility of U.S. plutonium disposition. Other members pointed out that the United States and Russia could also use reactor-grade plutonium for rearmament should they choose to do so, and concluded that the difference in isotopic grades was not one of the more important aspects of irreversibility.

The Task Force agreed, however, that these differences were not large enough to be determinative in choosing an option, and that disposition of excess plutonium by any means that met the Spent Fuel Standard would be sufficient to create international confidence in U.S. disposition activities.

Plutonium Recycle Concerns Can Be Reduced

The U.S. does not encourage reprocessing and recycling of plutonium, and does not itself engage in reprocessing for commercial purposes. The disposition of excess plutonium, regardless of the specific alternative chosen, does not entail reprocessing of plutonium and does not change this basic fuel policy. Nevertheless, MOX irradiation in the U.S. might be perceived as encouraging commercial plutonium recycle. These concerns can be minimized if the MOX facilities are licensed only for excess plutonium disposition; a commitment is made to dismantle new MOX fabrication facilities after the disposition mission is completed; stringent security is maintained throughout the process including military transport to the extent necessary; and the international security, arms control and nonproliferation benefits of disposing of already reprocessed plutonium from weapons by this method are stressed.

Borehole Alternative Not Credible Near or Medium Term Option

Recognizing the political obstacles to approval of siting and licenses, the deep borehole disposal alternatives are not likely to provide a credible option in the near or medium term. The Task Force believes these approaches should not be relied on for the near-term mission of plutonium disposition, whatever these alternatives may have to recommend them technically. Over the longer term, a geologic repository will eventually be required for commercial and defense wastes, as well as the products of the immobilization and reactor alternatives for plutonium disposition. The Department should continue to work closely with Congress and national regulators with the goal of opening a safe and environmentally sound repository as soon as practicable.

The Task Force appreciated the opportunity to provide these comments as part of the Record of Decision for the disposition of fissile materials from dismantled nuclear weapons.

Sincerely,

SEAB Task Force

Allen L. Sessoms, Chair
Myron Kratzer
Leon Lederman
Alexander MacLachlan
Marvin Miller
Wolfgang Panofsky
John Taylor
Frank von Hipple

APPENDIX C

Letter from the Secretary of Energy Advisory Board

November 6, 1996

Hazel R. O'Leary
Secretary of Energy
1000 Independence Ave. SW
Washington, D.C. 20585

Dear Madam Secretary:

On behalf of the Secretary of Energy Advisory Board, I am pleased to forward to you the Letter Report of the Secretary of Energy Advisory Board Task Force on the Nonproliferation and Arms Control Implications of Weapons-Usable Fissile Materials Disposition Alternatives, which we had an opportunity to review and approve in a public teleconference meeting on November 4, 1996.

During the month of September 1996, the Task Force reviewed the Department's *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Materials Storage and Disposition Alternatives*, in order to ensure that the widest possible range of technical and policy factors were being addressed by the Department's Office of Arms Control and Nonproliferation. Many of the Task Force's detailed comments on earlier drafts were incorporated into the text of the assessment. On November 4, 1996, the Board had an opportunity to fully discuss the letter report, and would like to emphasize several points.

The Board would like to underscore the characterization of fissile material disposition as a National priority issue. We also want to emphasize the substantial effort that will be required by the Department and the Administration in educating the public of its importance to National Security, and in dispelling any misperception that whichever disposition option chosen is inconsistent with current U.S. nonproliferation policy. We strongly agree with the Task Force that it is essential the United States act on this issue quickly, and chose an option that is both transparent and provides the greatest amount of confidence in its irreversibility. We also believe that since it is implausible that Russia will vitrify its plutonium, the best option to ensure that parallel efforts are being taken by both countries is the hybrid approach described in the assessment and letter report.

The Board is pleased to say that it concurs with the Task Force's final conclusion that the report presents "an accurate, complete, and objective comparison of the relative strengths and weaknesses, from both technical and public policy standpoints, of the alternatives currently under consideration by the Department."

The Secretary of Energy Advisory Board was grateful for the opportunity to study this very important matter, and hopes this letter report will assist you in your decision on the Department's preferred options for the disposition of excess weapons-usable fissile materials. We are looking forward to meeting with you at the December 3, 1996, Plenary Meeting.

Sincerely,

Robert I. Hanfling
Chairman
Secretary of Energy Advisory Board

APPENDIX D

SECRETARY OF ENERGY ADVISORY BOARD TERMS OF REFERENCE

Task Force on Nonproliferation and Arms Control Implications
of Weapons-Usable Fissile Material Storage and Plutonium Disposition Alternatives

Terms of Reference

Overview The Secretary of Energy has directed the Office of Arms Control and Nonproliferation to conduct a Nonproliferation and Arms Control Assessment of the Weapons-Usable Fissile Material Storage and Plutonium Disposition Alternatives addressed in the Materials Disposition Programmatic Environmental Impact Statement. This Assessment will help form the basis for a Record of Decision as to how the United States will store and dispose of materials that can be used in nuclear weapons. In order to ensure that the widest possible range of technical and policy factors are addressed fully in the final version of the Assessment, she has directed the Secretary of Energy Advisory Board to form a Task Force, which will be a temporary subcommittee of the Secretary of Energy Advisory Board, to review the draft Assessment.

The anticipated sections of the Assessment include:

a) Technical vulnerability (for theft and diversions) associated with each alternative
b) Policy implications (both positive and negative) associated with each alternative
c) Possible implementation variables to maximize benefits and minimize negative implications (real and perceived).

Objectives

1) The Task Force should conduct a review and analysis of the Nonproliferation and Arms Control Assessment prepared by the Department of Energy's Office of Arms Control and Nonproliferation. In its review, the Task Force should consider the assessment's rationality and consistency in light of relevant U.S. Policies, laws and regulations.

2) Based upon its review, the Task Force should draft comments evaluating the approach, content, completeness, objectivity, and technical rigor of the Assessment. These comments should include recommendations for additions, deletions, or other changes deemed appropriate by the Task Force.

3) As an integral part of this tasking, the Task Force should examine the work of the Office of Material Disposition's Proliferation Vulnerability Evaluation Team. The Proliferation Vulnerability Evaluation Team has been asked to assess the vulnerability of

each of the alternatives to theft and diversion in order to ensure that the Nonproliferation and Arms Control Assessment is consistent with the findings of the Proliferation Vulnerability Evaluation Team's classified report. To that end, the Task Force will have access to members of the technical staff who prepared the vulnerability analyses and should consider their methods, assumptions, and conclusions as part of the review of the Assessment.

4) After considering and commenting on the draft Assessment, the Task Force should consider and recommend steps that could be taken in the implementation of any selected alternative in order to maximize the nonproliferation and arms control benefits and minimize the nonproliferation and arms control vulnerabilities identified in the report.

5) The Task Force should not rank or make an overall recommendation as to which of the alternatives is preferred from a nonproliferation and arms control viewpoint, but should ensure that all technical and policy implications are considered within the context of the report.

6) The Task Force should then submit its comments and recommendations to the Chairman of the Secretary of Energy Advisory Board. The Secretary of Energy Advisory Board will review the Task Force comments and recommendations, consider any other relevant facts it may have and make final comments and recommendations to the Secretary. The comments and recommendations, as approved by the Secretary, will be incorporated into the Assessment, which will then be released for public comment, further modified based upon comments received, and approved by the Secretary, prior to its publication in final form.

APPENDIX E

RESPONSES TO PUBLIC COMMENT

FORMAT:

The Department of Energy received a significant number of responses to the Arms Control and Nonproliferation Assessment of Weapons-Usable Fissile Materials Storage and Excess Plutonium Disposition Alternatives. As it has throughout the development of the Assessment, the Department of Energy's Office of Arms Control has sought to be as responsive as possible to public comments, questions and concerns about these important issues.

The public comments contained in this appendix were received by the Department of Energy during the public comment period (October 1-November 15, 1996). Oral comments made at the 10 public meetings held on the Assessment were not treated as official comments for the record (as noted during the meetings themselves), but written comments received during the meetings are included in this document.

Comments in ***Bold and Italics*** print are unique or symbolic of other comments received by the Department of Energy and are followed by a response. Comments in **Bold** type only are similar to another comment in the section that has received a response and have not received an individualized response. A list of the names of individuals and organizations that submitted comments and/or participated in the development of the Assessment are included as Appendix F.

Note: Unless otherwise noted, the PEIS refers to the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement, issued in December, 1996 (DOE/EIS-0229).

I. COMMENTS RELATED TO THE ASSESSMENT

A. PROCESS

C1) The amount of time provided to review the nonproliferation assessment was not long enough for the public to be genuinely involved in the decision making process and the Department of Energy did not adequately advertise this Assessment or the public meetings held on the Assessment.

R1) The Department of Energy has made diligent efforts to provide adequate time for public review of the Draft Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives. The public was provided 46 days, from October 1 to November 15, 1996, to submit comments, and comments received after November 15 were considered to the extent possible. The draft Assessment was published as soon as it was completed to allow for the longest possible comment period. Comments were also requested from tribes and local, state and federal agencies, including the United States Arms Control and Disarmament Agency during this time. In addition a scoping period with public meetings and a comment period was held in July and August, 1996.

The Department requested that comments on the draft Assessment be submitted by November 15, so that comments could be adequately reflected in the Comment response Document for the Final Assessment and so that the Final Assessment could be completed in time to be considered in the Secretary of Energy's decision, which is anticipated in January, 1997. A Final Assessment and Record of Decision in January, 1997 will demonstrate timely progress in implementing the President's Nonproliferation and Export Control Policy.

Among other things, a January, 1997 decision will also facilitate timely development of the Comprehensive Preparedness Program, which must include plans for reducing stockpiles of excess United States and Russian plutonium, and must be reported with the Fiscal Year 1998 budget submission, under Section 1443 of the National Defense Authorization Act for Fiscal year 1997 (PL 104-201).

The Department of Energy believes that the public involvement in the Assessment has been excellent. Five public scoping meetings on the proposed outline and ten public meetings on the Assessment were held in 12 cities across the United States. Comments on the outline and the draft Assessment were received in person, through the US mail, electronic mail and over a toll-free phone line. Several hundred people participated and over 100 commented on the Assessment. The facts indicate that both stakeholders and the public at large were aware of and, to the extent practical, participated in the development of the Assessment.

Announcements for both the scoping meetings (including the Assessment's proposed outline) and the draft Assessment were published in the Federal Register (Outline - July 1, 1996 / draft Assessment - October 1, 1996). The Department of Energy purchased advertisements, both in local newspapers and on local radio, in each of the cities in which public meetings were held.

The Department of Energy is committed to public involvement in the decision making process on this and other important issues. The Secretary of Energy and other top Departmental officials have been kept informed as to the Assessment's findings and public comments on the draft Assessment, both of which will be factored into the Record of Decision on the storage and disposition of weapons-usable fissile materials.

C2) The time line for comment was too short or not sufficiently publicized. (Nuclear Information and Resource Service, Military Production Network, King, D. Smith, Pu Roundtable, Hanford Watch, Oak Ridge Environmental Peace Alliance - OREPA, Nashville Peace Action, Hanford Advisory Board, Rocky Mountain Peace Center, Oregon Department of Energy)

C3)DOE's haste to begin implementing a policy is precluding adequate public participation; citizens do not have same resources as industry and need more time to evaluate information. (Joan King, League of Women Voters)

C4)The inadequate turnaround time between submission of public comments and issuing a final decision indicates DOE will not seriously consider public comments. (Military Production Network)

C5) For a document of this importance, a longer comment period should be provided. (Oregon Department of Energy)

C6) There was insufficient public notification - the topic deserves at least the same level of public involvement afforded to the PEIS. (D. Smith, Rocky Mountain Peace Center)

C7) U.S. DOE has not adequately described the reasons for the current schedule (Pu Roundtable)

C8) DOE should reopen the EIS and include nonproliferation and other issues. (Oregon Department of Energy, D. Smith)

C9) The issuance date for the draft Assessment should be extended due to the limited amount of time the public was given to prepare their comments before the public meetings were held. Overall, the notification and meeting process could have been implemented much better. (V. Brechin)

C10) The draft Assessment should be incorporated as an integral part of the PEIS. (V. Brechin)

C11) There should be a supplemental PEIS with a minimum 60 day public comment period. (Pu Roundtable)

C12) The small turnout at public meetings was not a reflection of a lack of interest on the part of the public, but rather a measure of the inadequacy of US DOE's public involvement effort. (Oregon Department of Energy)

C13) Meaningful public participation requires more than recording public concerns, it requires responding directly to issues raised. (Military Production Network)

R13) The Department of Energy is committed to an open and genuine dialogue with the public and in involving the public in the decision-making process. To that end, the Department of Energy held 15 public meetings before finalizing the Assessment and has responded to issues raised in written public comments in this Comment Response Document and is incorporating public input into the final Assessment. The comment responses and final Assessment will be available to the Secretary in reaching a Secretary's decision. Public participation is an important part of the Department's decision-making process.

C14) OREPA expressed concern that the public meetings were only a "pretense of public participation. (OREPA, Bailey)

C15) DOE did not involve Native American tribes early enough in the decision making process. (Nez Perce)

R15) The Department of Energy made the proposed outline for the Nonproliferation and Arms Control Assessment public as soon as it was developed. Furthermore, the Office of Arms Control and Nonproliferation, which conducted the Assessment, offered to provide a special briefing for the Indian tribal councils at their annual meeting in Arizona. Furthermore, the Indian nations have been involved in the overall process embodied in the Programmatic Environmental Impact Statement since it was begun in 1994.

C16) Communities which would be directly affected by the outcome of this process were not included in the initial round of public meetings. (Salisbury)

R16) The Department of Energy specifically sought to engage academic institutions in the scoping meetings on the Nonproliferation and Arms Control Assessment in July and August, 1996. This decision was based in large part on the fact that over 50 public meetings had been held as part of the Programmatic Environmental Impact Statement process and the Department had received considerable input on nonproliferation issues during those meetings. Oral comments during the five meetings expressed appreciation that the Department had several public meeting locations. In addition, the Department believes that the entire country has a stake in the nonproliferation and arms control implications associated with the storage of weapons-usable fissile materials and the disposition of excess plutonium. For this reason, the Department solicited public comment through a variety of means in addition to public meetings, including a toll-free phone line, electronic mail and regular mail services.

C17) The DOE proposal to bypass the public completely by asking the President and Congress to declare this issue to be a national security matter is troubling. (Oregon Department of Energy)

R17) The Department has at no time or in any way sought to bypass public participation in this process. On the contrary, the U.S. government clearly recognizes that any decision made by the Department of Energy on this issue will require bipartisan and broad-based public support and has sought to include the public in the entire decision-making process. This is evidenced by the over 60 public meetings held since the process was begun in early 1994 on both the PEIS and Assessment.

C18) The purpose of the Assessment was not made clear to the public. (Rocky Mountain Peace Center)

R18) The purpose for the Assessment was stated in the Federal Register Announcement of July 1, 1996 and was described in detail in the Assessment itself. The Secretary of Energy, based on public input, requested the Department of Energy's Office of Arms Control and Nonproliferation to prepare a thorough assessment of the nonproliferation and arms control implications of the various alternatives being considered by the Department of Energy for the storage and weapons-usable fissile materials and the disposition of excess plutonium. Since the primary reason for pursuing disposition of excess materials is to further the nonproliferation and arms control goals of the United States and its allies and partners, it was determined that a more complete look at these issues was essential in reaching a Record of Decision.

C19) DOE's commitment to public involvement is questionable when the comment period closed on 6 November, two days before the last public meeting on 8 November. (Salisbury)

R19) Because the public meeting in Rocky Flats, Colorado had to be rescheduled from November 4 to November 8, the Department of Energy extended the comment period until November 15 so that participants from Colorado were able to comment after the public meeting there. Comment received after November 15 were considered to the extent possible.

C20) DOE needs to make public the process by which technical data reports will be incorporated. (Wilson)

R20) As explained in the Assessment and in the Final PEIS, the Secretary of Energy will review all relevant information, including the Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition, associated with the storage and disposition of weapons-usable fissile material. Nonproliferation, technical, cost and schedule information, as well as public comments will be assessed and taken into account as the Secretary of Energy prepares to issue a Record of Decision.

C21) DOE should accelerate the action planning/decision-making process, as well as the target schedule, and perhaps even shorten or eliminate the perceived need for a NEPA review in order to move ahead with implementation. (Wilcox)

R21) The Department of Energy has adopted what it believes to be a prudent and efficient schedule which will allow the implementation of any decision with a minimum of delay. The Department of Energy has fully complied with the requirements of the National Environmental Policy Act (NEPA) and will continue to do so in the implementation of its upcoming Record of Decision on storage and disposition matters.

C22) This comment commends DOE for making an effort to disseminate information relating to this important nonproliferation initiative and for encouraging public comment. (Kinnelly)

R22) Comment noted.

B. SCOPE OF REPORT

C1) The question of using excess weapons plutonium as MOX fuel should include a public debate on the U.S. Government's inclination to subsidize the nuclear power industry. (Nuclear Information and Resource Service)

R1) The comment is beyond the scope of the Assessment.

C2) The report must clarify that it refers only to disposition of excess and not all weapons Pu. (Finger)

R2) Comment noted. The Assessment only deals with the disposition of those materials that have been declared excess to U.S. defense needs, or declared surplus in the future, and this point is made in the Assessment.

C3) This campaign will fail to ensure that arms reductions are difficult to reverse because the scope of disposition is limited to only plutonium declared excess and not the significant amount which is held in reserve. (UCS)

R3) It is true that only material declared excess to defense needs by the President is covered under the Nonproliferation and Arms Control Assessment. The Assessment states, however, that the disposition of even this amount of material will help ensure that progress made to date in arms control is not reversed, by removing significant amounts of weapons-usable fissile materials from the defense arsenals of the United States and Russia and by building confidence that both countries are serious about arms reductions. Moreover, while both the United States and Russia will retain the capability to reverse the disposition of material after it reaches the spent fuel standard, such a series of steps would be highly observable, costly and time consuming, thus helping to make arms reductions harder to reverse.

C4) This issue should be assessed not only in terms of nonproliferation and arms control, but should also consider cost, health, and safety. (King, Salisbury)

R4) The Nonproliferation and Arms Control Assessment examined nonproliferation and related issues. Other issues, including health, cost, safety and potential environmental impacts were addressed in the Programmatic Environmental Impact Statement (PEIS) and in other supporting documents, such as the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE/MD-0003 Rev. 1. The Nonproliferation and Arms Control Assessment, the PEIS, the technical and cost reports and public comments will be considered by the Secretary in reaching the Department's decision.

C5)The report needs to assess the relative costs of options. (Rocky Mountain Peace Center, WAND)

R5) The costs of the alternatives are discussed in "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE/MD-0003 Rev. 1.

C6) The report lacks a discussion of the possible use of Pu dispersal as a terrorist weapon. (Peelle)

R6) The draft Assessment discusses the risk that excess plutonium might be stolen and used by either a would be nuclear weapon state or a sub-national terrorist group to produce a "nuclear explosive device." While the use of plutonium in a dispersal weapon is a concern, the primary focus of the assessment and of the disposition effort is to prevent the use of weapons material for nuclear explosive devices.

C7) The purpose of assessing the nonproliferation implications of disposing of excess materials is questionable when so much was not declared excess. (NRDC)

R7) The purpose of the Assessment was to provide both the public and the Department of Energy officials with a thorough analysis of the arms control and nonproliferation implications of the storage and disposition alternatives under consideration by the Department. Issues associated with material not declared excess was outside the scope of the Assessment.

C8) The Assessment should explain the rationale for having a large nuclear weapons "hedge" reserve. (NRDC)

R8) The comment is beyond the scope of the Assessment. The decision of how much material is excess was made by the President on the advice of the Nuclear Weapons Council. Additional material may be declared excess in the future and the Assessment has taken this factor into account.

C9) Further consideration should be given to bulk safe secure transportation of materials for the storage/disposition program, such as rail shipment in lieu of smaller Safe and Secure Transport (SST) motor shipments. (Ehrlich)

R9) As a baseline, the Department of Energy intends to use the same techniques for shipping surplus weapons-usable fissile materials as is used for the shipment of intact nuclear weapons, e.g., SSTs. Rail shipment has predictable routes and is no longer used for the shipment of nuclear weapons.

C. CRITERIA/APPROACH

C1) The Assessment needs to address problems with the spent fuel standard (e.g., ability to reverse measures taken to dispose of Pu according to this standard, the fact that the standard will be applicable only for the next 300 years). (Rocky Mountain Peace Center)

R1) The Assessment analyzes how well the alternatives under consideration by the Department of Energy meet the "spent fuel standard." The "spent fuel standard" concept for plutonium disposition was originally put forward in the National Academy of Sciences 1994 report on Plutonium Management and was adopted in modified form by the Department of Energy as a goal for plutonium disposition mission. The concept has since been adopted by the United States and Russian governments as the ultimate goal for the disposition of excess nuclear material. The Assessment made the assumption that all final forms (either immobilized or irradiated spent fuel) will ultimately end up in a repository, along with other commercial spent fuel (except in the case of the borehole alternatives).

C2) The spent fuel standard is too short-term for the ultimate goal of disposition. (Nashville Peace Action)

C3) The logical consequences of the short range of the spent fuel standard are not examined in the Assessment. (Peelle)

C4) Rating the alternatives against the nuclear weapons standard and the spent fuel standard should be done on a more complex ranking than the "pass/fail" basis which is currently employed in the report. (Peelle)

R4) Meeting the "spent fuel standard" has been internationally accepted as a goal for any plutonium disposition mission. The Assessment takes as a starting point that the "spent fuel standard" is a range, as opposed to a fixed point. There are several components that help define if a particular final form has sufficient *intrinsic* characteristics to ensure that the plutonium contained in a final form is roughly as unattractive and inaccessible for use in nuclear weapons as plutonium contained in commercial spent fuel. An alternative either meets this goal or it does not. The different characteristics of the final forms that could be achieved with the alternatives under consideration are discussed in the Assessment.

C5) The spent fuel standard lacks a clear definition and verification of performance standards. (Salisbury)

R5) The "spent fuel standard" definition was defined by the National Academy of Science and expanded by the Department of Energy. The goal of the spent fuel standard is to transform excess weapons plutonium so that it would be "roughly as inaccessible and unattractive for weapons use" as the much larger quantity of plutonium that exists in spent fuel from commercial nuclear power reactors. This standard has been accepted by the international community, including the United States and Russia, as the goal for excess plutonium disposition.

C6) The Assessment takes liberties with the spent fuel standard, which, as applied by the NAS, means uniformly intermingled and direct contact with fission products. (NEI)

R6) The National Academy of Science defined the spent fuel standard as follows: "to make [excess] plutonium roughly as inaccessible for weapons use as the much larger and growing stock of plutonium in civilian spent fuel." The definition does not include the requirements included in the comment. The Department of Energy expanded the definition so that the spent fuel standard would make plutonium roughly as "inaccessible *and unattractive* for weapons use"(emphasis added). In the DOE or NAS definition, there are no specific requirements for "uniformly intermingled or direct contact with fission products."

C7) The main motivation in coming to a decision should be national/international security and nonproliferation concerns (followed by environmental safety), primarily because U.S. choices are likely to significantly impact Russia's choices. (Rauf, MIIS)

R7) As discussed in the Assessment, the interaction between U.S. and Russian disposition activities is a primary consideration in assessing the nonproliferation and arms control implication of various disposition activities. These factors will have a major influence on any decision on plutonium disposition.

C8) The United States and Russia should pursue parallel policies because it will improve the chances of sticking with the decision, since the whole process will take decades through several government administrations. (Amarillo National Resource Center for Pu)

R8) The United States and Russia both accept the premise that both countries should pursue parallel, but not necessarily identical steps to dispose of excess weapons plutonium. The Assessment notes this fact.

C9) Setting an international example for disposition and nonproliferation objectives should not take precedence over public health and safety. (Klein, Wilson)

R9) Nonproliferation and arms control implications of storage and disposition is one of a number of factors that the Department is considering as it moves toward making a decision on these issues. Environmental, technical, cost, safety and nonproliferation factors will all be taken into consideration. The Department has fully complied with its requirements under the National Environmental Policy Act in its analysis of the reasonable alternatives for the storage and disposition mission. Environmental, safety and health issues are addressed in the PEIS.

C10) Speed/immediate action seem to be the primary consideration in coming to a decision. (Sims, Salisbury)

R10) The Assessment points out the benefits of moving quickly to dispose of U.S. excess plutonium. Nevertheless, the Department of Energy has fully complied with the National Environmental Policy Act and has, in every possible way, sought to maximize public involvement and review of the proposed alternatives.

C11) The report did not comply with the National Environmental Policy Act (NEPA), as environmental analysis is not part of the discussion of alternatives. (Salisbury)

R11) Environmental analyses are included in the PEIS. The Nonproliferation and Arms Control Assessment is not covered under NEPA, although the Department of Energy has sought to maximize public participation in the Assessment and the Assessment will be considered in the Record of Decision.

C12) The draft Assessment should place a much stronger emphasis on the "real" program objective, which is to prevent excess Russian weapons-usable material from being diverted to rogue regimes. (Ehrlich)

R12) The Assessment details at length the multiple goals of plutonium disposition, which include reducing the risk that nuclear materials will be diverted or stolen by national or sub-national proliferators from the Russian Federation.

C13) The decision regarding disposition/storage should not be based on foreign policy criteria, but rather on what is best for the U.S. based on DOE's evaluation of domestic considerations. (Booher)

R13) The prime motivations for pursuing plutonium disposition are based in strengthening U.S. nonproliferation and arms control policies, which at their heart, serve U.S. security interests. Therefore, foreign policy, nonproliferation and arms control implications are assessed as part of the decision-making process of weapons-usable fissile material storage and plutonium disposition.

C14) The draft Assessment compares storage/disposition options and discusses differences in the risks associated with transportation of nuclear material under each option as if there is a significant difference among transportation risks associated with the available options. Transportation risks are minimal among all the options and are not a useful metric in distinguishing which is superior. (Ehrlich)

R14) The Assessment considers transport of nuclear materials to be among the greatest points of vulnerability in the storage and disposition process, since it is harder to guard materials in transit as opposed to materials in secure storage. The Department of Energy is confident, however, that the transport of nuclear materials can be achieved in a safe and secure manner given an adequate allocation of resources. Moreover, transport can be minimized for all action alternatives by co-locating facilities.

D. ASSESSMENT SHORTCOMINGS

C1) The draft Assessment strains to present a balanced approach to all alternatives, but clearly promotes the reactor alternative. (Winchester, Sierra Club National Nuclear Waste Task Force)

R1) The Secretary of Energy Advisory Board (SEAB) Task Force on Plutonium Disposition and the SEAB as a whole have concluded that the "the report presents an accurate, complete, and objective comparison of the relative strengths and weaknesses, from both technical and public policy standpoints, of the alternatives under consideration by the Department." Every effort has been made to present an unbiased assessment, and the Assessment is not biased toward or against any action alternative.

C2) The language of the report wrongly diminishes the importance of diversion of a small but significant amount of material from the United States or Russia, simply because it is such a small part of the overall stockpile. (PSR)

R2) The Assessment discusses the need to ensure that any storage and disposition activities meet the highest international standards for accounting and security of nuclear materials. In no way does the Assessment seek to diminish the internationally recognized importance of protecting "significant quantities" from theft or diversion. The discussion included in the Assessment, however, tries to put some of the risks of diversion in context and, in the case of national covert diversion, finds the threat to be a less credible threat scenario than some of the other potential threats, since both the United States and Russia will retain significant stocks of weapons-usable material in their active nuclear stockpiles, reducing the military utility of relatively small-scale diversions of nuclear materials. Any diversion of nuclear materials, however, would be cause for concern and would be contrary to the stated objectives of the storage and disposition mission.

C3) The report fails to assess the implications of the small amount of materials which were declared excess. (NRDC)

R3) The Assessment was tasked to analyze the nonproliferation and arms control implications of the storage and disposition alternatives under consideration by the Department of Energy. The means by which the material was declared excess or the amounts of material declared excess are not within the scope of the Assessment.

C4) The Assessment does not examine the nonproliferation benefits of single site utilization for co-locating plutonium handling from storage to use as fuel or other disposition. (TRIDEC)

R4) The Assessment points out the risks associated with transport of nuclear materials and recommends minimizing the number of transport legs and the number of sites at which storage and disposition activities will take place.

C5) The Assessment neglects to include practical suggestions (suggested by OREPA prior to the release of the draft) for specific steps that could be taken at Oak Ridge to reduce danger and increase security, which would prove DOE's serious commitment to addressing nonproliferation concerns (e.g., protection from air attacks, storage building safety and reliability, separation of dismantlement and production activities). (OREPA, Nashville Peace Action)

R5) The management of nuclear material under DOE control in the United States meet the highest international standards of safety and security. In the storage and disposition mission, the Department will continue to upgrade security procedures as necessary to ensure the safety and protection of nuclear-related facilities.

C6) The draft fails to consider HEU being stored at unsafeguarded facilities at Y-12. (Military Production Network)

R6) There are significant amounts of weapons usable nuclear material that has not been declared surplus to defense needs and is therefore not going to be placed under international safeguards. To date, however, the United States has placed 10 tons of material at Oak Ridge under IAEA safeguards and continues to work with the International Atomic Energy Agency on the application of safeguards on additional amounts of material.

C7) The Assessment lacked a specific timeline for disposition, beyond anything as general as "in a timely manner." (WAND)

R7) The Assessment made extensive use of other documents prepared by the Department of Energy's Office of Fissile Material Disposition, including the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE-MD-0003 Rev 1, which discusses projected timelines in detail.

C8) References to specific sites should be removed from the draft Assessment, as specific site references may influence future technical and political decision-making processes. (Steffen)

R8) Some of the alternatives in the Assessment for storage and disposition are described using site specific examples. The most prominent of those examples is the potential use of existing vitrification facilities at the Savannah River Site. A decision to select disposition technologies may require additional NEPA analysis which will consider site specific environmental impacts and lead to site selection for disposition activities.

C9) There is no recommendation to the Secretary in favor of one particular option. (Pillay, Salisbury)

R9) The Assessment purposely avoids making a preferred alternative recommendation on the basis of arms control and nonproliferation because there are a number of important criteria that must be considered, each of which might suggest a different preference. The Secretary of Energy requested an objective analysis which presented all relevant nonproliferation and arms control implications, which the SEAB Task Force verified as having been achieved. It was not within the purview of the Assessment to make a specific recommendation as to a preferred disposition path, but to point out the relative benefits and vulnerabilities of the various alternatives and recommend potential implementation steps that could be taken to maximize benefits and minimize vulnerabilities.

C10) Additional conclusions could be drawn in the Assessment as to the relative value of the various options. (Peelle)

C11) The Assessment does not arrive at useful conclusions regarding the alternatives. (NCI)

C12) The conclusions contain too many qualifying words, and, therefore, offer no guidance in selecting one option. (NRDC)

C13) Many alternatives lack a proven technology for implementation. (Salisbury, Devlin)

R13) The Department of Energy recognizes that additional technical research and development needs to be conducted on all of the disposition alternatives but there do not appear, at this time, to be any technical obstacles that cannot be overcome with the appropriate allocation of resources.

C14) The report neglects to indicate which options meet the spent fuel standard and which do not. (NRDC)

R14) The Assessment states that "The reactor alternatives, homogeneous immobilization alternatives, and deep borehole immobilized emplacement alternative can all meet the Spent Fuel Standard. The can-in-canister alternatives are being redesigned to increase the difficulty of removing the cans from the canisters, with the goal of meeting the Spent Fuel Standard. The deep borehole direct emplacement alternative substantially exceeds the Spent Fuel Standard with respect to recovery by sub-national groups, but could be more accessible and attractive for recovery by the host state than spent fuel." In order to be implemented, any of the alternatives would have to meet the spent fuel standard.

C15) The comparative risks of processing steps among disposition options were not adequately analyzed or addressed. (D.Smith)

R15) Many of the processing steps required for any of the disposition alternatives are the same regardless of which alternative is pursued, such as pit disassembly and conversion. The exact processing required for each alternative is discussed in detail and the risks associated with processing required for each alternative are discussed in the Assessment.

C16) Not enough consideration is given to transportation issues. (Devlin)

R16) As a baseline, the Department of Energy intends to use the same techniques for shipping surplus weapons-usable fissile materials as is used for the shipment of intact nuclear weapons, e.g., SSTs.

C17) The report fails to consider the issue of storage after Pu has been converted to the spent fuel standard. (NEI)

R17) The Assessment was asked to assess the nonproliferation and arms control implications associated with the alternatives under consideration by the Department of Energy for plutonium disposition. Once the material has been put into a form that meets the spent fuel standard, it will need to be handled in a manner consistent with the protection provided to other materials that meet the spent fuel standard. The Department intends that this material will be disposed of in a final repository, thus providing additional protection beyond that included in the spent fuel standard.

C18) The high threat of diversion and black market sale or transfer of nuclear material is not given sufficient acknowledgment in the report (Ehrlich)

R18) The Assessment discusses in detail the benefits of pursuing disposition, which include reducing the danger associated with the possible theft and diversion of nuclear material in the former Soviet Union.

C19) This report overstates the risk of illicit diversion of nuclear materials from Russia. (Pillay)

C20) The Assessment does not consider or compare the potential storage/disposition program costs to the cost of addressing a threat of nuclear blackmail, nor does it consider the costs of strategic or tactical defense programs that could be required to neutralize the threat of Russian nuclear material diverted to and weaponized by rogue states. (Ehrlich)

R20) The comment is beyond the scope of the Assessment. Costs of the alternatives are discussed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE-MD-0003 Rev. 1.

C21) The draft Assessment's list of precautions to ensure safety fails to include continuous monitoring and maintenance of containment barriers throughout the radioactive lifetime of the materials in storage. (Oser, Nuclear Guardianship Project)

R21) The Assessment assumes that once the material reaches a form consistent with the spent fuel standard that it will be treated in a manner consistent with spent fuel under IAEA safeguards. Ultimately, all of the material disposed of would be placed in the geologic repository which, once sealed, would not be subject to direct monitoring. The environmental aspects of plutonium disposition are discusses in the PEIS.

C22) The draft Assessment's coverage of issues involved in applying safeguards to specific reactors involved in MOX fuel alternative and to immobilization alternatives could be more complete. (Kinnelly)

R22) Comment noted. Safeguards discussions were treated at a level of detail sufficient for decisions on disposition technologies and strategies. More detail will be required in subsequent phases of the plutonium disposition program.

C23) The definition of "disposal" in draft Assessment is not always clear. (Winchester, Sierra Club National Nuclear Waste Task Force)

R23) The Assessment uses the term "disposal" to mean the process by which excess plutonium is placed in a final form which meets the "spent fuel standard."

C24) The draft Assessment omits any discussion of the health consequences of the various alternatives for workers involved in their implementation, their families, and the communities where they live. (Winchester, Sierra Club Nuclear Waste Task Force)

R24) The environmental and health implications of the storage and disposition alternatives are discussed in the PEIS.

II. COMMENTS RELATED TO STORAGE ALTERNATIVES

C1) Consider the use of a neutron absorber to reduce the risk of concentrated storage. (Kemper)

R1) The alternatives for storage and disposition were selected after a screening process, described in the "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C2) Plutonium should not continue to be stored at Pantex, above a major aquifer, after it is removed from weapons. (Larson)

R2) The environmental aspects of plutonium storage, including impacts on the Ogallala Aquifer, are discussed in the PEIS.

III. COMMENTS RELATED TO DISPOSITION ALTERNATIVES

C3) No systematic study has been completed by the IAEA or other organization on safeguard issues associated with borehole or vitrification options. (Pillay)

R3) The United States has begun the process of working with the International Atomic Energy Agency to develop safeguards procedures for both the storage and disposition of excess nuclear materials. The Assessment recognizes that there is not the same level of safeguards-related experience associated with immobilization or boreholes as exists with the nuclear fuel cycle, but the Assessment (based on the best available information) concludes that safeguard procedures and accounting accuracy for immobilization or borehole would be roughly comparable to those for reactor-based MOX fuel use.

C4) DOE should reconsider the timeframe for implementing the final program for plutonium and fissile material disposition. Beginning implementation in five years and completing it within twenty-five years may be efficient in the short term for rendering materials inaccessible, but the U.S. could be cutting off disposition options based on new, superior technologies by acting in haste to dispose of materials. (Oser, Nuclear Guardianship Project)

R4) Comment noted. The Assessment includes a detailed explanation of the motivation behind near-term action on disposition of excess nuclear materials.

C5) The draft Assessment should emphasize the need for a credible bilateral plutonium disposition program in order to support U.S. and Russian commitments to the Nuclear Nonproliferation Treaty. (Ehrlich)

R5) The Assessment discusses the benefits of disposition in regard to meeting the requirements of the Treaty on the Nonproliferation of Nuclear Weapons.

C6) The high potential for illicit transfer of nuclear material from Russia favors the more reliable and rapid options for plutonium disposition. (Ehrlich)

R6) Comment noted.

C7) There is no genuine "disposition" alternative for disposing of radioactive materials; the only choice is to continue to monitor materials where they are. (Oser, Nuclear Guardianship Project)

R7) Comment noted. The Assessment includes a detailed explanation of the motivation behind near-term action on disposition of excess nuclear materials. The Assessment and the PEIS also consider the No Action alternative for disposition, which would maintain surplus plutonium in storage.

C8) This comment expresses dismay that DOE is even considering transferring nuclear material outside U.S. borders for disposition. (Booher)

R8) The nonproliferation and arms control benefits and vulnerabilities of the CANDU reactor alternative and foreign MOX fuel fabrication are discussed in the Assessment.

A. REACTORS

C1) The draft Assessment is principally a vehicle for recommending the MOX alternative. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R1) The SEAB Task Force and the SEAB as a whole has certified that the Assessment is "accurate, complete and objective." The Assessment is not biased in favor or against any action alternative and, as stated in the Assessment, "[e]ach of the alternatives under consideration for plutonium disposition has its on advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others."

C2) The MOX alternative presents many opportunities for proliferation, since weapons-grade plutonium can be separated from MOX fuel quickly and easily. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R2) The nonproliferation and arms control benefits and vulnerabilities of the reactor alternatives are discussed in the Assessment. It should be noted that all of the alternatives result in a final form from which the plutonium could be recovered for use in nuclear weapons, but not without considerable expense and a high degree of observability.

C3) Choosing the MOX alternative would slow down the entire disposition process, since providing MOX fuel to the reactors which would burn it would require transporting fuel from the fabrication plant to at least twelve reactors, the minimum amount needed to dispose of fifty tons of plutonium. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R3) The Department of Energy is confident that the transport of nuclear material involved in the disposition process can be achieved safely and securely. The number of reactors needed for disposition may vary depending on the implementation plan, but no more than 3-5 reactors would be required to achieve disposition of 50 tons within the given time frame of 25 years. Transport is not a primary driver of the time-lines required to achieve disposition.

C4) The MOX alternative should be rejected since it could involve sending weapons-grade material for processing in Europe while a MOX plant is under construction in

the U.S.; this has transportation security implications. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R4) The nonproliferation and arms control benefits and vulnerabilities of foreign MOX fuel fabrication are discussed in the Assessment. The selection of a reactor-based disposition alternative would not necessarily include the use of overseas MOX fabrication.

C5) The MOX fuel option is the most threatening of those proposed in terms of increased danger of proliferation. (Sanders, Peace Action Texas)

R5) The nonproliferation and arms control benefits and vulnerabilities of reactor-based alternatives are discussed in the Assessment. The Assessment states that "Each of the alternatives under consideration for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others."

C6) Using surplus plutonium in MOX fuel is not an acceptable solution; this alternative would keep these materials in the fuel cycle and would result in additional nuclear wastes for which no permanent means of safe containment has yet been found. (Oser, Nuclear Guardianship Project)

R6) The environmental implications of plutonium disposition alternatives are discussed in the PEIS. The alternative for MOX fuel use, however, would not increase the amount of spent fuel the United States would need to manage, since the MOX fuel would replace light water reactor fuel containing LEU that would otherwise be used in the reactors. For the CANDU alternative, the spent fuel irradiated in Canada would be managed along with the remainder of Canada's spent nuclear fuel.

C7) Burning surplus plutonium as MOX fuel is the most technically secure and cost-effective solution. (Nuclear Fuel Services)

R7) The benefits and vulnerabilities associated with reactor-based alternatives are noted in the Assessment. Cost estimates are discussed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE/MD-0003 Rev. 1.

C8) The draft Assessment does not highlight the value of the opportunity to exceed the spent fuel standard which is afforded by the option of using European MOX facilities for rapid implementation of the LWR alternative. (Kinnelly)

R8) The use of foreign MOX fuel fabrication does not offer an opportunity to exceed the spent fuel standard since MOX made in Europe would be burned and turned into spent fuel. the use of European fabrication could speed up implementation of the alternative and this fact is noted in the assessment. The spent fuel standard is considered sufficient for providing international confidence in the irreversibility of the disposition process.

C9) DOE should select only the best commercial reactors to burn MOX fuel should the reactor option be chosen; those reactors which are likely to offer themselves up for accepting MOX fuel are likely to be those most in need of DOE subsidy. (Booher)

R9) Comment noted. The Department of Energy has not determined which reactors would participate in the disposition of excess plutonium. Any reactor that would participate would need to meet all applicable U.S. laws and regulations on safety, operations and the environment.

C10) DOE should develop a MOX capability in the U.S. rather than shipping plutonium to Europe for processing. (Booher)

R10) Comment noted. Both alternatives are under consideration by the United States. The use of European MOX capacity to produce lead test assemblies for use in U.S. reactors might allow for a more rapid start to the reactor-based disposition alternatives. Conversely, under the Preferred Alternative in the PEIS, DOE would construct and operate a MOX fuel fabrication facility at a DOE site.

C11) The draft Assessment counts as an advantage of the CANDU option the relative lack of political and licensing obstacles while counting potentially controversial licensing approvals and associated delays as a disadvantage of the LWR option. This ignores the existing established LWR facility and fuel licensing processes, which are well-defined and would be much easier technically than using CANDUs, for which a MOX licensing process does not even exist yet. (Ehrlich)

R11) The Assessment acknowledges that licensing and approvals in either the United States or Canada is not a forgone conclusion, which is listed as an advantage of the immobilization/MOX hybrid alternative, which would provide a redundancy in the disposition process should one alternative provide difficult or impossible to implement.

C12) Acceleration of reactor disposition by fabrication of MOX fuel for European reactors is ill-advised because it would require additional transportation, handing off security arrangements to another country, could create a political controversy that would negate any time advantage, and would negatively effect the European plutonium fuel cycle. (UCS)

R12) Comment noted. The nonproliferation and arms control benefits and vulnerabilities of the foreign MOX fuel fabrication are included in the Assessment.

C13) Any "use" of this material raises the risk of proliferation. (D. Smith)

R13) The Assessment notes that the disposition of excess plutonium (i.e., anything other than long-term storage) involves an increased near-term risk of proliferation, due primarily to the transport and processing of the material. These near-term risk, however, must be endured in order to achieve the long-term reduction in proliferation risk associated with putting the material into the spent fuel standard.

C14) If reactor-based disposition strengthens the existing misperception that there is a significant difference in reversibility between reactor-grade and weapons-grade plutonium, it is a disadvantage for the United States in its effort to discourage plutonium fuel cycles internationally. (UCS)

R14) The Assessment and the Department of Energy state and continue to make clear its understanding that both weapons-grade and reactor-grade plutonium can be used to make effective and reliable nuclear weapons. Nevertheless, the Department recognizes the international perception that weapons-grade plutonium is more useful for making nuclear weapons, despite the technical evidence to the contrary. The Department of Energy would, in any decision to use reactors, make clear that the motivation for doing so is to dispose of excess, separated plutonium in a once through process which in no way changes U.S. policy not to encourage the civil use of plutonium.

C15) Burning fuel in commercial power reactors is unacceptable, because even commercial reactor nuclear materials could be used by terrorists. (Reynolds Electrical & Engineering Co., Inc., Women for Peace - East Bay)

R15) All of the alternatives present some proliferation risks which the Department of Energy believes can be mitigated with the appropriate implementation steps and allocation of resources. These risks must be endured to achieve the long term benefits associated with disposition of excess plutonium.

C16) The report neglects to define how to solve the problem of verifying materials for military purposes versus those for disposition if MOX facilities are co-located with defense facilities. (PSR)

R16) Materials not declared excess will not be subject to international safeguards or verification. The Assessment recognizes that co-location of defense-related and non-defense related activities will require special procedures to ensure that U.S. commitments can be verified without compromising national security or classified information. The United States has begun discussions with the International Atomic Energy Agency on the development of appropriate safeguards procedures.

C17) A national policy of burning plutonium as a MOX fuel is adequate for the United States due to tight controls on accountability but is inadequate for Russia, as revealed by recent smuggling attempts. (Reynolds Electrical & Engineering Co., Inc.)

R17) The United States does not have the ability to or the intention of dictating to Russia the method by which it should dispose of its stocks of excess plutonium. The United States is prepared to assist and cooperate with Russia on plutonium disposition to ensure that the highest standards of international security and acceptability are maintained throughout the disposition process. In addition, the United States has begun to discuss with Russia what sort of nonproliferation safeguards it would like applied to the disposition mission in Russia.

C18) The use of MOX fuel as a Pu disposition option has nonproliferation as well as public health/safety risks. (Military Production Network)

R18) The nonproliferation and arms control benefits and vulnerabilities of using MOX fuel to dispose of excess plutonium are discussed in the Assessment. Public health and safety issues are addressed in the PEIS.

C19) Advanced and partially completed reactor options do not meet the "timeliness" criteria because they are technically uncertain, would be difficult to license, and would require large capital outlays. (UCS)

R19) The alternatives under consideration by the Department are the result of a screening process which eliminated those options that did not meet the stated requirements of the disposition mission, including timeliness. That screening process is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C20) The United States lacks MOX facilities, and new construction necessary to implement this option is likely to be opposed. (Campaign for a Prosperous Georgia)

R20) As noted in the Preferred Alternative in the PEIS, a new MOX fuel fabrication facility could be constructed, or potentially, existing buildings could be modified. The Assessment considers potential public opposition to new nuclear facilities. This factor is a major consideration in pursuing the immobilization/MOX hybrid approach, which would provide redundancy in the disposition process should one of the alternatives prove difficult or impossible to implement.

C21) There are legal restrictions which serve as barriers to the MOX option (e.g., in the Public Utility Holding Company Act). (Campaign for a Prosperous Georgia)

R21) Any U.S. disposition activity would fully comply with all applicable U.S. laws and regulations.

C22) In regard to using plutonium for reactor fuel, it is illegal under NEPA law to piecemeal NEPA decisions to limit the choice of reasonable alternatives. (Rickards)

R22) The Department of Energy has fully complied with the requirements of the National Environmental Policy Act in pursuing a decision on weapons-usable fissile material storage and disposition.

C23) The international community clearly favors converting excess weapons-grade plutonium into spent MOX fuels and has not shown interest in other disposition alternatives. (Pillay)

R23) The international community has endorsed the goal of putting all excess plutonium into a form which meets the spent fuel standard, which includes both reactor and non-reactor options.

C24) The report fails to note that use of MOX technology is a superior choice with regard to nonproliferation, because it is the only one that clearly meets the spent fuel standard, that results in the destruction of significant quantities of weapons materials, that has a proven track record, that has the highest degree of irreversibility, and that is the Russian preference). (Commonwealth Edison Company)

C25) Only the MOX option actually converts the materials. (Finger)

C26) The Integral Fast Reactor is the only option which will completely destroy the Pu, but Argonne National Laboratory's nearly completed research and development on this was canceled. (Coalition 21)

R26) The alternatives under consideration by the Department of Energy were developed through a screening process, which is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C27) Use of excess Pu in MOX fuel allows for disposal of spent fuel in a geological repository. (Commander/Herring, Idaho ANS)

R27) Both reactor based and immobilization based options could potentially allow for the disposal of the final form in a geologic repository.

C28) Irradiated MOX fuel will increase thermal load and have an impact on consideration of possible repositories as well as impact waste storage. (Nuclear Information and Resource Service)

R28) The environmental impacts of the various disposition alternatives are discussed in the PEIS.

1. Plutonium Policy

C1) Reactor-based disposition would likely weaken U.S. nonproliferation policy and could potentially encourage civil plutonium use internationally and domestically. (UCS)

R1) The arms control and nonproliferation benefits and vulnerabilities of the reactor-based disposition alternatives are discussed in the Assessment. The Department believes that disposing of excess plutonium by any of the means under consideration that meet the spent fuel standard would improve the nonproliferation and arms control efforts of the United States and its allies, especially through the disposition of Russian excess material. The Assessment recommends steps that would help mitigate any vulnerabilities reactor-based disposition may have on current U.S. policy not to encourage the civil use of plutonium. These include commitments that facilities built for disposition will only accept plutonium declared excess to defense needs and not civilian material, that any material put into the spent fuel standard not be reprocessed or recycled and that facilities only be licensed for the disposition mission and then subsequently dismantled once the disposition mission is completed.

C2) The Assessment opens up the issue of whether the United States should or will reprocess commercial fuel in the future, and this Assessment should not be used in this regard to limit future nuclear power fuel cycles. (Rossin)

R2) The Assessment does not "open up the issue of whether the United States should or will reprocess commercial fuel in the future." The Assessment only considers the future of spent fuel produced in the process of disposing of excess weapons plutonium. The report recommends that the United States commit that this material will never be reprocessed or separated, since that would defeat the purpose of putting the material into the spent fuel standard. Disposition of excess material by any of the means analyzed could be accomplished without any change to existing U.S. policy not to engage in reprocessing for nuclear power or nuclear explosive purposes.

C3) The report must point out that the Russians view weapons materials as a cash asset, and that they will want to benefit from this by using it as fuel. (Finger, Amarillo National Resource Center for Pu)

R3) The Assessment explains in detail that Russia and the United States have different views as to the value of plutonium (Russia viewing it as a national resource for energy production).

C4) The Assessment should place the disposition/storage question in context of U.S. Pu policy since 1977, which has had questionable nonproliferation effectiveness. (R. I. Newman)

R4) The Assessment analyzes the potential impact of the various plutonium disposition alternatives in light of long-standing U.S. policy on the commercial use of plutonium. The Department of Energy is and will continue to be guided by presidential guidance on the civil use of plutonium.

C5) It is clear from the draft Assessment language that there is dissent among the members of the DOE Task Force on the issue of reprocessing, necessitating compromise language to produce a single report. The Assessment therefore gives confusing and misleading guidance on this issue. (Rossin)

R5) The SEAB task Force unanimously agreed that "ensuring irreversibility, and in particular that the plutonium is the forms and locations resulting from disposition would be roughly as inaccessible and unattractive for use in weapons by the host state as plutonium in commercial spent fuel, is . . . critical to achieving the objectives of disposition." There was no disagreement among the SEAB task force on the issue of reprocessing material declared excess of defense needs.

C6) Under the reprocessing proposal, the country would be using commercial reactors for military purposes, which would go against the terms of the NPT. (WAND)

R6) The Department of Energy is not considering any alternative that would involve the reprocessing of material once it is put into the spent fuel standard. Moreover, there is nothing in the Nuclear Nonproliferation Treaty that in any way prohibits the use of civilian reactors for the disposition of excess plutonium. In fact, the disposition of excess plutonium would help the United States fulfill its commitment under Article VI of the NPT to pursue an end to the arms race.

C7) The reactor alternatives are contrary to the Administration's September 1993 policy statement on civil uses of Pu. (NRDC)

R7) U.S. policy, as contained in President Clinton's September 27, 1993 nonproliferation and export control statement read "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." A decision to dispose of excess plutonium through the irradiation of MOX fuel in a once through cycle, without reprocessing of the spent fuel, would be fully consistent with this policy.

C8) The reactor burn option goes against U.S. nonproliferation policy. (Maienschein)

C9) The MOX option is hazardous, more expensive, and it does not set a good international example. (Sims)

R9) Cost and environmental impacts are discussed in the Technical Summary Report and the Programmatic Environmental Impact Statement. The international implications of using MOX is discussed in the Assessment.

C10) The draft Assessment does not consider several risks associated with MOX option, especially the adverse fuel cycle policy signal that would be sent to the international community or the serious implications of treating Pu as an asset rather than as waste. (NCI)

R10) The Assessment considers the potential impact use of reactor-based alternatives could have of the fuel cycle decisions of other countries. It concludes that the high cost associated with disposal of plutonium through reactors could help demonstrate that Pu has a negative value and that, in and of itself, the disposition of excess plutonium in reactor is not likely to lead countries to pursue plutonium based fuel cycles. Moreover, the adoption of the stored weapon standard for all components of the disposition process could help improve international standards of security and control of nuclear materials.

C11) The analysis of the MOX option contained in present draft could do serious damage to U.S. domestic fuel cycle policy and U.S. nonproliferation policy. (NCI)

C12) The decision to undertake MOX disposition will undermine political and economic forces now working effectively against ongoing foreign Pu programs. (NCI)

R12) The Assessment states that "it is unlikely . . . that a decision to use MOX fuel in the United States would, in and of itself, result in substantial additional reprocessing and use of MOX fuel in other countries. Decisions concerning reprocessing and use of MOX fuel in most countries are based on factors related to cost, waste management, perceptions of uranium availability and the need for energy security, and political and bureaucratic imperatives." Any decision to use MOX fuel for excess plutonium disposition would in no way alter U.S. policy not to encourage civil use of plutonium but would be geared to deal with a specific national security priority; disposition of excess plutonium.

C13) A U.S. MOX disposition program would lend support to the false claim that Pu recycle is necessary for waste management. (NCI)

R13) A decision to use MOX fuel for plutonium disposition would not lend support to the those who claim that Pu recycle is necessary for waste management. On the contrary, since the United States would not reprocess the fuel coming out of reactors, it would lend support to those that argue that Pu recycle is not required for waste management and that plutonium in a form that meets the spent fuel standard should not be separated.

C14) A U.S. MOX disposition program would encourage civil use of Pu, thus fundamentally changing U.S. Pu policy. (NCI)

R14) U.S. policy, as contained in President Clinton's September 27, 1993 nonproliferation and export control statement read "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." A decision to dispose of excess plutonium through the irradiation of MOX fuel in a once through cycle would be fully consistent with this policy.

C15) The Assessment neglects to evaluate the nonproliferation implications of demonstrating a CANDU MOX option for programs in other countries, such as India and South Korea. (NRDC)

R15) The fact that CANDUs have not yet been demonstrated to utilize MOX fuel is discussed in the Assessment, as is the risk that validating the use of MOX fuel in CANDU reactors might lead to MOX use in other countries operating CANDU reactors. The report also points out that disposition of excess plutonium through the use of reactors could reinforce U.S. policies to reduce stockpiles of separated fissile materials. The United States does not encourage the civilian use of plutonium and the disposition of excess plutonium will be carried out in a manner consistent with and supportive of U.S. policy.

C16) The decision to undertake MOX disposition will be seized upon by countries pursuing, or interested in pursuing, Pu fuel cycles. (NCI)

C17) The draft Assessment opens the issue of whether the U.S. will at any time in the future begin reprocessing commercial fuel. There is no justification for using an Assessment that is supposed to address disposition issues to limit future nuclear fuel cycle. (Rossin)

R17) The Assessment only deals with materials declared excess to defense needs. In order to build domestic and international confidence in the disposal of weapons-usable fissile material, the Assessment recommends that commitments be made never to reprocess or recover plutonium involved in the disposition program, which would defeat the basic goal of disposition.

C18) The proliferation objection should not be raised for all options that require reprocessing. (Orth)

R18) The Department of Energy is not considering reprocessing of any material once it meets the spent fuel standard.

C19) The MOX option is not incompatible with the Administration's policy against encouraging commercial reprocessing and Pu recycle. (VanDoren)

C20) The U.S. nonproliferation policy that opposes civilian use of Pu is incorrect, and is causing a delay in proceeding with disposition. (Peelle, Rossin, Coalition 21)

R20) The United States is proceeding toward a decision on a strategy for excess plutonium disposition in full compliance with the National Environmental Policy Act and in a manner that will enable the United States to implement any decision it may select. The decision making process is not being delayed as a result of U.S. policies on the civil use of plutonium. The value or validity of current U.S. policy on plutonium is beyond the scope of this assessment.

C21) The reactor burn option is a proven and familiar technology, and is proliferation-resistant. (Hanford Communities)

R21) The demonstrated nature of using MOX in reactors is noted in the Assessment. It should be noted, however, that all of the disposition alternatives, including the use of weapons-grade plutonium in reactors, will require additional research and development in order to proceed with implementation.

C22) The argument that the United States can set a precedent against reprocessing plutonium which may discourage other countries from reprocessing is based on wishful thinking and is unsupported by current circumstances. (Brumbach)

R22) The Assessment was not tasked with assessing the effectiveness of current U.S. policy not to encourage civil use of plutonium. The Assessment analyses the potential impacts of the various storage and disposition alternatives in light of a number of factors, including current U.S. policy.

C23) We cannot say that a U.S. decision to use MOX technology would impact nuclear fuel cycle approaches of other countries, especially since we are only dealing with a limited amount of excess weapons Pu, and are not even referring to civil Pu. (Commonwealth Edison Company)

R23) Comment noted.

C24) Choosing a reactor option would not set a precedent for MOX use, because natural uranium is cheaper. (MIIS)

R24) The Assessment states that using reactor to dispose of excess plutonium would demonstrate that plutonium has a negative value.

C25) The report does not suggest a logical connection between a U.S. decision to reprocess Pu and another country's decision. (Amarillo National Resource Center for Pu)

R25) The Assessment states that "advocates of the use of plutonium fuels in other countries would be likely to use the argument that the United States had changed its position [on civil use of plutonium] and that plutonium fuels were now playing a key role in disarmament, to help promote their cause. If this, in fact, led to decisions in other countries to pursue additional reprocessing and bulk-handling of separated plutonium, it could result in additional proliferation risks. This is an important policy issue in considering the LWR MOX alternative." This statement explains the possible connection between a U.S. decision to use MOX fuels and the possible impact on fuel cycle decisions in other countries. The Assessment goes on to state that "it is unlikely, however, that a decision to use MOX fuel in the United States would, in and of itself, result in substantial additional reprocessing and use of MOX fuels in other countries."

C26) The ultimate decision must set a positive precedent from a nonproliferation perspective, and be made within the context of current U.S. nonproliferation policies and agreements. (MIIS)

R26) Comment noted.

C27) Reactor alternatives would give a policy signal that use of Pu is acceptable, and would support the view that Pu has an economic value and that effective safeguards can be applied. (NRDC)

C28) The MOX option could encourage Pu reprocessing in other countries. (Campaign for a Prosperous Georgia)

C29) The MOX option supports Pu being viewed as an asset rather than a dangerous liability. (King, Rocky Mountain Peace Center, Sims, Women for Peace - East Bay)

C30) The MOX option declares that Pu has asset value and that energy contained within it should be viewed as a national asset. (NCI)

C31) The "non-use-of-plutonium" policy trades an immense, CO_2-free energy resource for a very small reduction in the risk of proliferation. The costs and benefits of the policy should undergo a serious NEPA analysis before it undergirds a major national decision. (W.R. Johnson)

R31) The potential energy value of plutonium is beyond the scope of this Assessment.

C32) The text and footnotes which refer to the U.S. nonproliferation policy on civil use of Pu (p. 15 of the Assessment) are confusing and misleading, which signifies opposing views among members of the SEAB Task Force and an ultimate compromise in order to produce a single document. (Rossin)

R32) The footnote and text cited in the comments are intended to describe two facets of any decision to use MOX fuel for plutonium disposition. On one hand, the Assessment notes the concern that use of reactors could create the international perception that the United States had changed its position not to encourage the civil use of plutonium (which is not the case.) On the other hand, a decision to use MOX could afford the United States with an opportunity to develop and demonstrate improved plutonium handling, security, accounting and safeguards procedures.

C33) The technical and nonproliferation justification for the policy of keeping plutonium out of the U.S. fuel cycle (via not reprocessing) has never been validated. (Rossin)

R33) The comment is outside the scope of the Assessment. U.S. policy, as contained in President Clinton's September 27, 1993 nonproliferation and export control statement read "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." A decision to dispose of excess plutonium through the irradiation of MOX fuel in a once through cycle would be fully consistent with this policy.

C34) U.S. political opposition to reprocessing is a stumbling block to reaching international understandings on excess weapons material disposition. (Rossin)

R34) There is no evidence that suggests that the United States position not to encourage civil use of plutonium and, subsequently, not to reprocess for either nuclear energy of nuclear explosive purposes has in any way impeded international progress on disposing of excess weapons-usable fissile material.

C35) The use of LWRs for disposition would not provide additional arguments to advocates of plutonium recycle, since the program in the U.S. would be limited to between three and five reactors and the U.S. MOX facility would be designed to be suitable only for low-exposure, weapons-grade feed materials. (Ehrlich)

R35) Comment noted.

C36) The argument in the draft Assessment summary that a U.S. decision to choose reactor alternatives for plutonium disposition could offer a justification to countries advocating plutonium recycle is strongly mitigated in the rest of the draft Assessment. (Carron)

R36) Comment noted.

C37) The MOX option reverses the commitment to clean up weapons production sites and promotes a plutonium economy, which increases the possibility of proliferation. (Hall)

R37) On the contrary, there is nothing in the proposed alternatives that will impede or reverse the Department of Energy's commitment to environmental management and restoration. In addition, the Department of Energy, should it pursue reactor-based disposition alternatives, would design the implementation to prevent to the maximum extent possible, the development of a civilian plutonium economy in the United States. Use of MOX fuel in reactors would be limited to the mission of disposition, no new plutonium would be separated or recycled and the facilities involved would only handle plutonium declared excess to defense needs.

C38) Returning to a plutonium economy based on MOX reactor fuel sends a very bad message to other countries about the ultimate U.S. intent. (V. Brechin)

R38) U.S. policy, as contained in President Clinton's September 27, 1993 nonproliferation and export control statement read "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." A decision to dispose of excess plutonium through the irradiation of MOX fuel in a once through cycle would be fully consistent with this policy.

2. Isotopic Conversion

C1) There is no mention of Pu-242 in the Assessment's section of weapons-usable isotopes. (D.Smith)

R1) No separated Pu-242 has been declared excess to defense needs and it is, therefore, not discussed in the Assessment.

C2) The distinction between weapons-grade and reactor-grade plutonium should be a determinative factor in weighing which alternative the United States should favor. (Commonwealth Edison/Duke Power)

R2) The Assessment states that "virtually any combination of plutonium isotopes -- the different forms of an element having different numbers of neutron in the nuclei - can be used to make a nuclear weapons. Not all combinations, however, are equally convenient or efficient." Nuclear weapons can be made from either reactor-grade or weapons-grade plutonium. Based on this fact, isotopic conversion of plutonium is not considered to be a "determinative factor" in achieving the spent fuel standard.

C3) The SEAB Task Force appears divided on how reactor-grade Pu should be evaluated in assessing the proliferation risk. (Rossin)

R3) The letter from the SEAB task force to the Chairman of the SEAB Robert Hanfling states "the task force had a extensive discussion of the use of weapons-grade and reactor-grade plutonium in weapons. Both types of plutonium can be used to make effective nuclear weapons, either by proliferating states and sub-national groups, or by sophisticated weapons states such as the U.S. and Russia." The letter goes on to state that while there were differences of opinion on the benefits of isotopic conversion in "the international perception of the irreversibility of U.S. plutonium disposition" that "The task force agreed . . . that these differences were not large enough to be determinative in choosing an option, and that plutonium disposition by any means that met the spent fuel standard would be sufficient to create international confidence in U.S. disposition activities."

C4) It would be helpful to note that boosted Pu primaries of U.S. warheads are indifferent to pre-ignition (pp. 34-36 of the Assessment). (NRDC)

R4) The design features of U.S. nuclear weapons are classified and can not be discussed in an unclassified report.

C5) The report's assertion that the distinction between weapons-grade and reactor-grade Pu should not influence choosing an option is a very subjective statement and is not credibly justified in the analysis. (Commonwealth Edison Company)

R5) There is clear scientific evidence behind the assertion that nuclear weapons can be made from weapons-grade and reactor-grade plutonium. Since a central goal of plutonium disposition is to help prevent the re-use of this material in nuclear weapons, isotopic conversion is not a technically valid basis on which to achieve this goal.

C6) The draft Assessment statement on page xxiii that "weapons-grade and reactor-grade plutonium can both be used in a nuclear weapon" should be clarified in terms of the different levels of attractiveness of the two materials for weapon-making purposes. (Carron)

R6) The Department has reviewed the statement contained in the Assessment regarding weapons grade and reactor grade plutonium. While there are different technical issues associated with the use of the two materials in nuclear weapons, both can be used to construct modern, reliable and efficient nuclear weapons and the Department is satisfied with the description contained in the Assessment.

C7) Isotopic conversion of Pu should not be promoted as a nonproliferation benefit. (NCI)

R7) The Assessment repeatedly states that both weapons and reactor grade plutonium can be used to produce reliable and efficient nuclear weapons and that, therefore, isotopic conversion is not a major nonproliferation or arms control benefit. Nevertheless, the Assessment takes note of the international perception - right or wrong - that reactor-grade plutonium is less desirable for weapons purposes and recognizes that this may have an advantage in the eyes of some observers of the disposition process in terms of the irreversibility of the disposition process.

C8) The Assessment neglects to give appropriate credit to the reactor option, by not identifying that it destroys most of the weapons grade Pu. (NEI)

R8) Both weapons-grade and reactor-grade can be used by developing states or advanced nuclear states to produce reliable nuclear weapons. The Assessment notes that "the reactor alternatives have some advantage over the immobilization alternatives with respect to perceived irreversibility, in that the plutonium would be converted from weapons-grade to reactor grade, even though it is possible to produce nuclear weapons with both weapons and reactor-grade plutonium."

C9) References in the report and footnotes to the relative usefulness of weapons Pu versus reactor-grade Pu for constructing nuclear explosives are inconsistent. The following description was recommended to provide consistency throughout the Assessment and with the Red Team report: "Weapons-grade plutonium and reactor-grade plutonium can both be used in a nuclear weapon; however, because of its isotopic composition, weapons-grade plutonium is significantly more attractive than reactor-grade plutonium for this purpose." (Amarillo National Resource Center for Pu)

R9) The Assessment has been reviewed and modified to ensure that the discussion of the value of weapons grade and reactor grade plutonium for use in nuclear weapons is consistent. It was not possible to adopt the recommended definition, since it includes inherently subjective terminology (significantly more attractive). The Assessment concludes that reactor-grade plutonium could be used to construct both primitive and advanced, modern and reliable nuclear weapons.

C10) The isotopic composition of Pu is an inappropriate criterion for assessing proliferation risk because it perpetuates the misconception that reactor-grade Pu cannot be used to make weapons. (NCI)

C11) Isotopic conversion does not pose a substantial barrier to re-militarization for the U.S. and Russia and, therefore, does not constitute a compelling argument in favor of the MOX option. (NCI)

C12) The draft Assessment ignores the fact that isotopic conversion in a LWR fuel cycle is much greater than in a 9,000 MWD/MT CANDU fuel cycle. (Ehrlich)

C13) Language in the draft Assessment states that "regardless of how the concentration of troublesome isotopes is, the yield would not be less" is incorrect and should be removed. (Carron)

R13) The statement noted in the Assessment has been reviewed by both nuclear weapon designers and the office of declassification and the Department believe it to be accurate. The statement does assume that the weapon would result in some yield. A non-functioning weapon would, obviously, not result in a yield of not less than 1 kiloton., but it is considered unlikely that a weapon would fail to work based on the isotopic composition of the plutonium used in the weapon.

3. The Plutonium Industry

C1) DOE should draw on industry experience with MOX fuel in dealing with technical, licensing, and regulatory issues associated with implementing this option. (NRDC)

R1) The Assessment considers the ability to implement the various disposition alternatives and has taken into consideration past experience on licensing and operating nuclear facilities in the United States.

C2) The reactor burn option permits recovery of a significant portion of the economic "fuel" value of the plutonium. (Hanford Communities)

R2) The recovery of any "energy value" in the plutonium is beyond the scope of the nonproliferation and arms control Assessment.

C3) The reactor option supports a Pu economy, as it would require investing in facilities involved in Pu recycle, which would revitalize these companies. (PSR, Campaign for a Prosperous Georgia)

R3) The reactor alternatives would not encourage plutonium recycling, or a civilian "plutonium economy." For the reactor alternatives, the MOX fuel would be irradiated in a once-through cycle without reprocessing of the spent fuel, and the MOX fuel would be fabricated only from plutonium declared excess to defense needs.

C4) Japanese and European Pu industries fully recognize and are poised to exploit the economic and political benefits accruing from an end to the U.S. prohibition on domestic use of Pu fuel. (NCI)

R4) A decision to pursue reactor-based disposition of excess plutonium is fully consistent with current U.S. policy on plutonium and would be pursued only to address a high priority national security concern: disposal of excess weapons-usable nuclear materials. Since the facilities involved in disposition would irradiate MOX fuel fabricated exclusively from surplus plutonium and that material would not be reprocessed or recycled, such a decision would not significantly affect U.S. efforts on plutonium use internationally. The Assessment does state that "A U.S. decision to choose reactor alternatives for plutonium disposition could offer additional arguments and justifications to those advocating plutonium reprocessing and recycle in other countries. This could increase the proliferation risk if it in fact led to significant additional separation and handling of weapons-usable plutonium. On the other hand, if appropriately implemented, plutonium disposition might also offer an opportunity to demonstrate improved procedures and technologies for protecting and safeguarding plutonium, which would reduce proliferation risks and would strengthen U.S. efforts to reduce the stockpiles of separated plutonium in other countries."

C5) The nuclear energy industry has a conflict of interest in the MOX option; their actions/recommendations should be considered with this in mind. (Sanders, Peace Action Texas)

R5) Comment noted. Comments are not screened based on the motivation of the person or group that submits them.

C6) There is no advantage to the taxpayer in DOE's subsidizing of weak nuclear electric utilities so that they will burn MOX fuel in their reactors. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R6) The comment is outside the scope of the Assessment.

3. Safeguards and Security

C1) MOX fuel fabrication, transport and storage has many more windows of vulnerability to theft or misuse than the immobilization option. (Nuclear Information and Resource Service)

R1) The Assessment notes that there are more processing steps associated with the reactor-based options than with, per se, immobilization or boreholes. Transport can be minimized in any of the options by co-locating facilities, especially those that present particularly attractive targets for would be thieves. All of the alternatives present some degree of near-term proliferation risk which must be endured in order to achieve the long-term benefits of disposition.

C2) Unirradiated MOX fuel is a security threat which would invite the militarization of civilian reactor sites. (Nuclear Information and Resource Service)

R2) The Assessment recommends providing all portions of the disposition (until the spent fuel standard is achieved) process the same level of protection afforded to intact nuclear weapons. While this would require additional security procedures at NRC facilities, experience demonstrates that sufficient levels of protection can be provided without requiring involvement of the United States military at civilian facilities. In general, security is provided at U.S. DOE facilities by privately contracted security forces.

C3) Civilian reactors or processing facilities involved in the MOX option would need a new level of security which would include the use of deadly force. The NRC should not be subject to provisions of the Atomic Energy Act. (D.Smith)

R3) The Assessment recommends providing security personnel at NRC licensed facilities that are part of the disposition process the same authority to carry firearms and make arrests to protect access to weapons-usable nuclear materials as is available to comparable personnel at Department of Energy facilities. This would expand the provisions provided under Section 161 k of the Atomic Energy Act to NRC facilities involved in disposition.

Anything less could lead to less than adequate security for weapons-usable fissile material being disposed of.

C4) The Assessment should explore the effects of using high explosives against a large spent MOX fuel assembly. (D.Smith)

R4) The use of explosives on a spent MOX fuel assembly would not be useful in recovering significant quantities of weapons-usable fissile material. While such an activity could have environmental consequences, environmental issues are discussed in the PEIS.

C5) Discuss the ways the Department intends to control the uranium/plutonium oxide in fuel rods which could potentially be used for a bomb. (D.Smith)

R5) The Assessment recommends that unirradiated MOX fuel elements be provided the same protection afforded to intact nuclear weapons (the stored weapons standard) precisely because the plutonium in unirradiated fuel could be used to produce nuclear weapons, albeit after some necessary processing. Unirradiated fuel elements would not provide a protective radioactive field and, would therefore, not meet the spent fuel standard.

C6) Safeguards should be used to assure common burn-up rates for all countries involved, and materials inventory control should be overseen by an international body. (Makowitz)

R6) Materials declared excess will be made available for international safeguards and accounting on a schedule consistent with the Department's plan for the disposition of these materials. The shape of any "parallel action" between the United States and Russia is not known and it is not known if it will require "common burn-up rates" for any reactor-based alternatives. This is especially true since isotopic conversion is not a significant determinant in degrading weapons-usability of plutonium.

C7) The Assessment does not consider the "inadequacies" of IAEA safeguards, and specifically the Significant Quantity debate. (NRDC)

R7) The United States considers IAEA safeguard procedures to be fully capable of meeting their goal of detecting in a timely manner any diversion of significant quantities of nuclear materials. Significant quantities (SQs)are defined by the IAEA and the United States continues to work closely with the IAEA to review its practices and procedures in this area.

The IAEA's significant quantities were established in the late 1970s, following lengthy debates in the international safeguards community. Originally, the effort to define significant quantities was intended to answer in *quantitative* terms the following apparently simple question: what level of nuclear material diversion should the IAEA's safeguards system be designed to detect? It was understood from the beginning that there can be no single number that represents the amount of nuclear material required for a nuclear explosive. By 1978, the IAEA had settled on 8 kg for Pu and 25 kg for HEU as single values, but with important caveats. They noted for example that "four factors determine the amount of a particular nuclear material which must be included in a nuclear explosive: design yield, design sophistication or skill, component composition and material isotopic composition."

They also noted that some material would inevitably be lost in processing, so that a proliferator would need to divert more material than the amount that would actually be used in the weapon.

The IAEA's threshold amounts and significant quantities were not intended to represent the *minimum* quantities from which a weapon could be made, although they have sometimes been misinterpreted in this way, even by IAEA officials. Contrary to a common misconception, the IAEA does not ignore amounts of material less than one significant quantity. Rather, the principle of graded safeguards is applied, with the significant quantity serving as a boundary below which safeguards are less intensive, but still present. Thus, safeguards are applied in such a way that the probability of detecting the diversion of 8 kg of Pu is high, while the diversion of lesser amounts would be detected with a smaller probabilities.

The conclusion for IAEA significant quantities is that the numerical values might be refined and better explained, but the numbers are approximately of the right magnitude for the amount of material likely to be used for the fabrication of a first nuclear explosive. Although for the reasons outlined above, a range of values could be justified on a technical basis, and political considerations introduce still further complications in selecting a single precise value for safeguards purposes.

C8) The draft Assessment's view of effectiveness of IAEA safeguards on Pu fuel cycles is not supported by real-world experience. (NCI)

R8) The United States has full confidence in the ability of the International Atomic Energy Agency's capabilities to meet the stated goals of the plutonium disposition mission. The United States and Russia have already begun extensive consultation with the IAEA on the role that organization may play in providing international confidence in the disposition of excess weapons-usable fissile material.

C9) The draft Assessment's claim that the IAEA can achieve 99.9% measurement accuracy for Pu oxide is questionable. (NCI)

R9) The draft Assessment drew upon information provided in Hinton, J.P., et al, "Proliferation Vulnerability Red Team Report," Sandia Report SAN97-8203, October 1996. The measurement accuracy numbers cited in the Assessment come from that document. The "Red Team" cites S. Deron, et al., "1993 International Target Values for

Uncertainty Components in Fissile Isotope and Element Accountancy for the Effective Safeguarding of Nuclear Materials", International Atomic Energy Agency, Vienna, STR-294, Rev. 1 (February, 1994). A copy of this article is available from the Office of Arms Control and Nonproliferation, DOE or through the IAEA.

C10) By positing that current, inadequate international safeguards are sufficient to permit implementation of the MOX disposition option, the draft Assessment undercuts U.S. ability to press for strengthening of international safeguards. (NCI)

R10) On the contrary, the Assessment concludes that "if appropriately implemented, plutonium disposition [involving reactor-based alternatives] might also offer an opportunity to demonstrate improved procedures and technologies for protecting and safeguarding plutonium, which could reduce proliferation risks and would strengthen U.S. efforts to reduce the stockpile of separated plutonium in other countries." Moreover, failure to move toward disposition could seriously reduce the credibility of the United States in its efforts to improve the overall nonproliferation regime, including improvements in the safeguards system.

C11) MOX fabrication plants in Europe have not made sufficient disclosures of the design and operating history of their MC&A systems to permit any conclusion about effectiveness of safeguards at these facilities. (NCI)

R11) The United States has full confidence in the ability of EURATOM and the IAEA to implement its safeguards procedures.

C12) The draft Assessment erroneously suggests that containment and surveillance measures can make up for inadequacies in material accountancy. (NCI)

R12) The Assessment does not suggest that Containment and Surveillance can make up for material accountancy uncertainties. The Assessment does state that accounting is only one part of a comprehensive safeguards system, which also includes and relies on containment and surveillance. The result of a comprehensive safeguards system is that the existence of accounting uncertainties does not mean that nuclear material has been diverted or stolen, since containment and surveillance provides a physical layer of protection against such activities.

C13) The draft Assessment should discuss use of low-level waste stream as a possible diversion pathway for Pu, including a discussion of the current situation at MOX facilities in this respect. (NCI)

R13) Both the Assessment authors and the individual members of the SEAB Task Force reviewed earlier comments along these lines. It was decided by the panel and the Department that this particular issue did not need to be specifically addressed in the Assessment since it was one of the many safeguard and security issues that will need to be addressed in the design and operation of a MOX facility. The overall safeguards for any future MOX fabrication facility or existing reactors will need to be addressed in any implementation plan. Overall, the Assessment concludes that any of the alternatives can be implemented in a way which adequately protects nuclear materials against theft or diversion, with the appropriate allocation of resources.

C14) The draft Assessment's statement that weapons material diversions of less than one ton which occur in nuclear weapon states are not strategically significant undermines confidence in U.S.-Russian nuclear disarmament commitments. (NCI)

R14) Comment noted. The Assessment's language in this respect has been modified. Safeguards will be applied in a manner consistent with the obligations of other states, where detecting the diversion of significant quantities of nuclear material in a timely manner is the goal. Nevertheless, the large stockpiles of nuclear weapons and fissile materials to be maintained by the United States and Russia suggests that the diversion of small amounts of material by the host state is a less credible threat scenario than, for example, covert unauthorized diversion. While safeguards should seek to detect any diversion by any party, it is unlikely that small scale diversions by the United States or Russia could be perceived as "strategically significant."

C15) Safeguards and security problems are most aggravated by options which require turning over nuclear material to the private sector and transporting nuclear material. (Sanders, Peace Action Texas)

R15) Comment noted. The Assessment recommends providing materials in the disposition process the same level of security provided to intact nuclear weapons, which may require changes to existing legislation to provide the necessary security at NRC-licensed, commercial facilities.

C16) The draft Assessment should have a separate section on international safeguards under the "policy factors" relating to each of the disposition alternatives. (Kinnelly)

R16) This option was considered during the screening process and earlier comment period. It was determined that since international safeguards were part of the larger issue of security and the impact on the nonproliferation regime, that safeguard-related topics would be dealt with as part of a larger section. This does not in any way minimize the important role international safeguards will play in providing international confidence in the disposition process.

C17) The MOX option would pose problems for IAEA inspections; it would be better to consolidate plutonium deemed "excess" by the Clinton administration (and therefore subject to IAEA safeguards) in one facility rather than disperse it to a dozen or more commercial reactors. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R17) The disposition of excess materials in numerous facilities will place safeguard burdens on the IAEA. Therefore, the Assessment recommends creating a separate fund to pay for the costs of safeguard inspections and prevent the disposition mission from draining limited safeguard resources from other important missions carried out by the IAEA.

C18) The draft Assessment makes no mention of the fact that IAEA safeguards are not presently applied to U.S. LWRs, and that such safeguards would need to be put into place at each LWR site that would be chosen to participate in the MOX disposition options. (Kennelly)

R18) Comment noted. The Assessment assumes that safeguards could be applied to U.S. light water reactors in the same manner that they have been applied to similar reactors around the world. All civilian LWRs in the United States are on the "voluntary" list of facilities available for the application of IAEA safeguards.

C19) MOX fuel introduces unacceptable accounting problems -- we would not be able to determine whether fuel is missing due to accounting error or diversion. (Perkins, Colorado Coalition for the Prevention of Nuclear War)

R19) The comment is not correct. Once plutonium is fabricated into fuel elements, accounting is relative easy, since individual fuel rods can be marked, tracked and routinely accounted for. It is true that MOX fuel fabrication involved some accounting uncertainties, and these are addressed in the Assessment.

B. CANDU

C1) Due to the characteristics of the CANDU reactors, substantially less plutonium can be utilized in a reactor fuel body than in conventional light water reactor design. (TRIDEC)

R1) All of the options under consideration by the Department of Energy would enable the disposition of 50 metric tons of excess plutonium to be disposed of in the 25-30 year time period identified for disposition. Moreover, the lower percentage of Pu by weight on CANDU fuel, as compared with convention MOX fuel from a LWR, is seen as a nonproliferation advantage, since more material would need to be acquired in order to obtain a strategic quantities' worth of weapons-usable fissile material, complicating any covert or overt attempt to divert plutonium.

C2) Exercising the CANDU option in Canada could open the door to MOX use in CANDU reactors in other countries, which would increase proliferation risks. (UCS)

R2) The Assessment notes the concern that validating the use of Pu in CANDU reactors, which has not yet been done, could "undermine U.S. efforts to convince other countries operating CANDU reactors in regions of proliferation concern not to pursue a plutonium-based fuel cycle in their CANDU reactors." The Assessment concludes that "Most countries, however, are like to base their decisions on recycling of plutonium primarily on factors independent on such a program, and it is not clear that any particular nation's decision would be substantially affected."

C3) The Assessment does not adequately address the nonproliferation threat of the Canadian CANDU option, because CANDU reactors are operated in the Republic of Korea, India, Romania, and Argentina, each of which at one time had an active program to develop nuclear weapons. (NRDC)

C4) CANDU is unacceptable, because it gets Canada involved in our nuclear weapons program. (Sims)

R4) The use of CANDU reactors to dispose of excess plutonium would not involve Canada in the U.S. nuclear weapons program. All of the material that might be used in CANDU reactors in Canada would be material that has been declared excess to defense needs and, therefore, would no longer be associated with the U.S. nuclear weapons arsenal. Moreover, the Canadian government has put forward the CANDU alternative in order to further global arms control and nonproliferation goals.

C5) The conclusion can be drawn from the Assessment that the CANDU option is the most favorable, because it has been supported by the Russians, it is the only facility currently compatible with 100% MOX fuel, no weapons Pu would enter Canada, Canada has no facilities for reprocessing/enrichment, Canada already has an extensive safeguards program with the IAEA, and it is the most cost-effective option. (MIIS, Canadian Embassy)

R5) The Assessment concludes that "each of the alternatives under consideration for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others." Factors outside of arms control and nonproliferation are beyond the scope of the Assessment.

C6) The Canadian government expresses willingness to pursue the CANDU option and believes it should be seriously considered if it will help ensure weapons materials are never put back into nuclear weapons. (Canadian Embassy)

R6) Comment noted.

C7) The CANDU option is of interest to the Russians and is consistent with the Russian position that the Pu should be used in a manner which will yield an economic return. (Canadian Embassy)

R7) Comment noted.

C8) An Assessment of transportation of MOX from Russia to Canada is currently underway, which will take advantage of the European experience in transporting commercial MOX fuel. (Canadian Embassy)

R8) Comment noted.

C9) Canadian policy does not exclude use of Pu as a reactor fuel. (Canadian Embassy)

R9) Comment noted.

C10) Implementing the CANDU option would require policy statements from both the United States and Canada stating that this is a one-time deal for a period of about 25 years for the sole purpose of disposing of excess weapons Pu. (Rauf, MIIS)

R10) The Assessment recommend steps to minimize any perceived or real nonproliferation and arms control vulnerabilities associated with the CANDU option, including the need to stress nationally and internationally that the mission of plutonium disposition is a national security priority and that the goals of the program are well defined, both in terms of materials and time scale. Implementation of the CANDU option would require a multilateral agreement with Russia, Canada and the United States. Appropriate restrictions would need to be placed in that agreement.

C11) The Assessment's consideration of using out-of-date CANDU BRUCE reactors with severe material and operational deficiencies undermines the credibility of the CANDU disposition options and lacks credibility as a long-term disposition program. (Ehrlich)

R11) The CANDU alternative will only be viable if the reactors designated for use in Canada will have sufficient operating life-times to meet the needs and goals of the disposition mission.

C12) The CANDU option would subsidize Canadian power producers at the expense of U.S. producers and U.S. jobs. (Ehrlich)

R12) The comment is outside the scope of the Assessment.

C13) The CANDU option is being promoted by Canadian and French interests for economic reasons having nothing to do with nonproliferation goals. (Ehrlich)

R13) The comment is outside the scope of the Assessment.

C14) The ability of the CANDU option to continue the disposition mission is subject to changes in the Canadian government and political situation (Ehrlich)

R14) The CANDU option would only be pursued if the United States and Russian governments are confident in the ability of the alternative program to meet its stated goals in a timely fashion as outlined in the Assessment. Moreover, the same observation can be made about potential changes in the United States of Russia, stressing the need to build public understanding and support for the disposition mission.

C15) Canada and France provide CANDU technology to countries where the U.S. would be prohibited from so doing for nonproliferation policy reasons; selecting the CANDU option would therefore contradict other U.S. nonproliferation policy objectives. (Erlich)

R15) The comment is outside the scope of the Assessment. The United States, France and Canada are all members of the Nuclear Suppliers Group and are active allies in the effort to prevent the proliferation of nuclear weapons.

C16) The draft Assessment's discussion of the CANDU option ignores whether small CANDU fuel cans which would be welded together to create larger bulk packages could just as easily be separated into smaller, original-size fuel modules. (Ehrlich)

R16) The welding together of CANDU bundles is addressed in the Assessment as a measure to provide a sufficient radiological and other intrinsic barriers to theft and diversion. While these bundles could be separated, the process of doing so would be complicated as a result of the high level of radiological exposure to any would-be thief. Moreover, the same applies to MOX fuel bundles, which could be cut apart, albeit as significant risk to the would be thief.

C17) The draft Assessment's discussion of the CANDU option does not mention the benefit of the Canadian offer to accept Russian as well as U.S. excess plutonium, which would ensure that, at least in the final stages, the Russian material would be subject to IAEA inspection. (Kinnelly)

R17) It is anticipated that Russian excess material destined for disposition would be placed under IAEA safeguards in Russia. Moreover, the Assessment does note the benefits and vulnerabilities associated with the CANDU reactor option relating to the joint US-Russian disposition activity and the actual removal of U.S. and Russian plutonium to a third country.

C. IMMOBILIZATION

C1) Immobilization should include more than one fission product (Cs-137) to further complicate any chemical separation. (Brumbach)

R1) The inclusion of Cs-137 in immobilized material is one possibility suggested in the Assessment to ensure that immobilized materials have an intrinsic barrier sufficient to qualify it for the spent fuel standard. Actual implementation of this alternatives, if selected, could possibly involve multiple fission products.

C2) Substituting a mechanical separation step for a chemical separation step may be a significant compromise of the spent-fuel barrier. (Brumbach)

R2) Comment noted.

C3) Immobilization would allow greater co-location of facilities and less transportation of plutonium. (UCS)

R3) co-location and minimizing transport will be taken into consideration in the Any of the alternatives could, conceivable, allow for co-location of all facilities, thus minimizing transport risks.

C4) FMEF at Hanford is an appropriate candidate for conducting immobilization with potentially equal or greater attractiveness than Savannah River. (Steffen)

R4) The SRS was noted as an example of a site for the can-in canister and adjunct melter facilities. Final site selection for implementing any of the alternatives will require additional NEPA documentation.

C5) Immobilization offers the fastest start-up and completion times - particularly the can-in-canister options. (UCS)

R5) Comment noted. In fact, the direct borehole alternative offers the fastest start-up and completion times, excluding the process of site selection and approval.

C6) The can-in-canister approach does not meet the Spent Fuel Standard. The cans could be retrieved and transformed back into weapons-grade plutonium using contemporary technology. (Commonwealth Edison/Duke Power)

R6) The Department of Energy is currently engaged in a research and development program to remedy potential weaknesses in the can-in-canister approach. The Department is highly confident that this engineering problem can be rectified, allowing for the possible use of the can-in-canister approach, but will not select an alternative that does not meet the spent fuel standard.

C7) The Assessment is overly optimistic that additional development work on the can-in-canister option will allow immobilized plutonium to meet the Spent Fuel Standard. Research and development options are not adequately addressed. (Commonwealth Edison/Duke Power)

C8) Can-in-canister does not meet the spent fuel standard, and the report does not properly reflect the problems with research, development, and design which would have to be dealt with for it to meet the spent fuel standard. (NEI)

C9) Vitrification and immobilization require significant technological development and testing. (Finger)

C10) Can-in-canister should not be selected without considering a suitable site for disposal. (Salisbury)

R10) The ultimate disposal site for can-in-canister or reactor-based alternatives will be the geologic repository.

C11) The vulnerability of "can-in-canister" immobilization to Pu recovery by a host state or sub-national group is over-stated. (NCI)

R11) Comment noted.

C12) The electrometallurgical option is technologically immature and does not meet the "timeliness" criteria. (UCS)

R12) The Assessment points out that there are greater technical and, therefore, scheduling uncertainties associated with electrometalurgical immobilization than in any of the other immobilization alternatives.

C13) Options for and answers to questions regarding implementing the vitrification option must be assessed (e.g., viability of additives other than highly radioactive gamma emitters, adding highly radioactive metal jacket to vitrified log rather than highly radioactive gamma emitters to mix, pilot plant to try this option, etc.). (Rocky Mountain Peace Center)

R13) Comment noted.

C14) Vitrification results in the same spent fuel standard as the MOX option, but it eliminates at least two stages of the MOX process which are vulnerable to proliferation. (PSR)

R14) Comment noted.

C15) The immobilization process is highly polluting and renders radioactive materials inaccessible to the application of future technologies for genuine disposal. (Oser, Nuclear Guardianship Project).

R15) The environmental impacts of the immobilization alternative are discussed in the PEIS. The radiological barrier involved in the immobilization alternatives is an integral part of the immobilized final forms meeting the spent fuel standard, and is deemed to have significant arms control and nonproliferation benefits.

C16) The draft Assessment should have a more extensive commentary on the application of safeguards to immobilization facilities. (Kinnelly)

R16) The Assessment notes the fact that there is little experience with safeguarding full-size immobilization facilities. There is considerable experience, however, in safeguarding large, complex bulk plutonium handling facilities. U.S. and foreign experts generally agree that safeguarding such plants is well within the range of capabilities, even though the exact nature of the safeguards process would still need to be work out. These issues have been considered in the review of disposition alternatives.

C17) The draft Assessment should contain more discussion of the vitrification option because of its potential for isolating scrap plutonium. (Winchester, Sierra Club Nuclear Waste Task Force)

R17) The Assessment notes that immobilization is technically well suited to handling some forms of plutonium, including scrap and other dilute or impure forms of plutonium, and that, therefore, immobilization would require less bulk processing steps than the reactor option for such forms of plutonium.

C18) The best options for plutonium disposition are ceramic immobilization, because a chemical process for recovery has not been demonstrated; and can-in-canister, assuming canisters are designed so as to make removing the cans difficult or impossible. (Perkins, Colorado Coalition for the Prevention of Nuclear War).

R18) While the technology required to reprocesses certain immobilized final forms is not yet fully demonstrated, the Assessment concludes that this fact will only remain valid in the near term and that, therefore, it should not be seen as an overwhelming nonproliferation benefit.

C19) Can-in-canister immobilization is the most favorable option, until a domestic U.S. MOX facility is available to permit the reactor option without shipping plutonium to Europe. (Booher)

R19) Comment noted.

D. BOREHOLE

C1) The borehole option does not meet the "timeliness" criteria because it requires licensing and public acceptance of a permanent disposal site. (UCS)

R1) Comment Noted. It should be noted that all of the alternatives under consideration will require additional site selection and public acceptance.

C2) Current experience with the Yucca Mountain National repository provides little assurance that a deep borehole disposal program can be available on a reasonable schedule for the disposal of waste plutonium materials. (TRIDEC)

C3) Would it not be easy to recover canisters of plutonium directly emplaced in a borehole with something like the drilling technology used at NTS (pp. 37-38 of the Assessment). (NRDC)

R3) The Assessment points out some concerns regarding the direct emplacement alternative, although it notes that any such attempt to recover material from a borehole would be readily observable to the international community. Moreover, it is potentially possible for material to be recovered in all of the disposition alternatives under consideration.

C4) Plutonium containing vitrified materials, if retrieved from a borehole, are readily separable to recover the plutonium through known technologies. (TRIDEC)

R4) Comment Noted. The comment also applies to all of the alternatives under consideration by the Department, with the exception of ceramic immobilization. It is expected that the technology needed for ceramic final form recovery will also be well understood if and as the process is pursued.

C5) The borehole option does not meet the spent fuel standard. (Finger, NEI, NRDC)

R5) The borehole alternatives were considered to have several vulnerabilities, including the uncertainties of siting a borehole and the attractiveness of recovered material in the direct emplacement alternative. The isolation of the material and the ease with which any attempted access could be detected were seen as significant nonproliferation and arms control benefits.

C6) Under the deep borehole emplacement option, 4.5kg of Pu exceeds the average amount used in modern U.S. warhead pits (3kg). (NRDC)

R6) Average mass of fissionable material in U.S. nuclear weapons is classified. Safeguards and security applied in the implementation of this alternative, should it be selected, would be designed to prevent the diversion of materials from the disposition process and from its final resting place.

C7) No mining industry data is used to support borehole technology's ability to secure weapons-grade materials, even though the mining industry has a proven capability with drilling boreholes. (Salisbury)

R7) The Assessment notes the mature nature of the drilling industry and the ease with which a borehole could be drilled. In addition, the ability to access material in a borehole through proven drilling techniques is noted in the Assessment.

C8) The deep borehole disposal alternative with immobilized emplacement, including engineered access barriers, is the only option which is permanent and irretrievable that both Russia and the United States can adequately safeguard. (Reynolds Electrical & Engineering Co., Inc.)

R8) Comment noted. While the immobilized borehole has a number of nonproliferation benefits associated with it, the Assessment notes that none of the alternatives would make the plutonium 100 percent irretrievable. In addition, all of the alternatives could be adequately safeguarded.

C9) Immobilized plutonium backfilled by a medium that possesses low structural competence and good plutonium scavenging or isolation properties or plutonium immobilized in a medium with a relatively high compressive strength and low thermal expansion present borehole alternatives which would make recovery very difficult. (Reynolds Electrical & Engineering Co., Inc.)

R9) The exact details of how a borehole would be constructed, should that alternative be selected, has not yet been decided.

C10) The use of shock attenuation barriers such as a gravel girdy would help hydrodynamically isolate specific zones and complicate any attempt to liberate plutonium from the host material by use of high explosives. (Reynolds Electrical & Engineering Co., Inc.)

R10) Comment noted.

C11) The borehole option cannot be taken seriously, since there is no such thing as a geologic formation which has never changed or which we may be certain will not change over the radioactive lifetime of the nuclear materials in question. (Oser, Nuclear Guardianship Project)

R11) The environmental impacts of the various alternatives are addressed in the PEIS.

E. HYBRID

C1) It may be impractical or uneconomical to use some plutonium-bearing material for fabrication into MOX fuel making it necessary to pursue a hybrid disposition program. (Commonwealth Edison/Duke Power)

R1) Comment noted.

C2) A reactor-immobilization hybrid option would require increased safeguarding and transportation of plutonium. (UCS)

R2) Comment noted.

C3) The hybrid approach combines the worst of both approaches. (Maienschein)

R3) The hybrid does require increased licensing and vulnerabilities as identified in the Assessment. The hybrid, however, has important benefits, including most importantly providing stability and assurance that at least one disposition path will be able to succeed.

C4) The hybrid alternative (pursuing both MOX and vitrification) should be dropped from the draft Assessment, since trying to satisfy all parties to the debate will simply cost more. (V. Brechin)

R4) Cost factors are detailed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE-MD-0003 Rev. 1.

F. NO ACTION ALTERNATIVE

C1) The "no action" alternative provides the greatest security against proliferation. In the absence of a clear solution, the U.S. should commit to doing nothing irrevocable for a substantial amount of time, such as fifty years, and continuously renew that commitment in the absence of new, reliable approaches to the problem. (Oser, Nuclear Guardianship Project)

R1) The nonproliferation and arms control benefits and vulnerabilities of No Action are described in the Assessment.

C2) Isolate the materials until a better solution can be reached at a later date. (Sims)

R2) The benefits and vulnerabilities associated with the no-action (indefinite storage) option are noted in the Assessment.

C3) Only the long-term storage alternatives allow for future application of the "safer methods which may be reflected in new or revised policies, procedures, and monitoring programs [draft Assessment language quoted in comment]." (Oser, Nuclear Guardianship Project)

R3) Comment noted. The benefits and vulnerabilities of the no-action alternatives are included in the Assessment.

IV. <u>RECOMMENDATIONS</u>

C1) The United States needs to come to agreement with Russia on a common disposition strategy. (Pillay)

R1) This comment is noted and is contained in the Assessment's recommendations.

C2) Secure excess nuclear materials and place them under IAEA safeguards until a joint disposition strategy has been achieved with the Russians. (Pillay)

R2) Ensuring the security of all nuclear materials - regardless of whether they have been declared excess - is a top national security priority and a focus of U.S.-Russian cooperation. The Assessment and the SEAB Task Force letter notes the benefits of putting material under IAEA safeguards as soon as practical.

C3) Develop U.S.-Russian verification strategy with sufficient transparency to support the disposition mission. (Pillay)

R3) Comment noted.

C4) The disadvantages of long-term storage could be mitigated by joint venture with Russia and other nuclear weapon states to explore and develop alternatives for permanent disposal. (Larson)

R4) Comment noted.

C5) Pursue stabilization and security in the short-term, and take immediate action to develop new technology to ultimately dispose of the fissile materials. (Hanford Watch)

R5) Ensuring the security of U.S. and Russian nuclear materials is receiving top priority but the uncertainties associated with management of fissile materials in Russia support the need to embark on a disposition program as soon as practical.

C6) A new option is needed because all alternatives pose significant risks. Therefore, the only action should be to immediately develop advanced technology to dispose of Pu within 15 years while maintaining a domestic surplus in safe, secure conditions. (Klein)

R6) The alternatives under consideration by the Department of Energy are the result of an extensive screening process. No other alternatives were identified that could meet the requirements of the program, which included a rapid start and completion in a 25-30 year time from the decision to proceed. The screening process is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C7) Safe & secure storage of excess plutonium is favorable until disposition alternatives are improved or a better option is identified. (Grotein, Larson)

C8)Pursue long-term, monitored, retrievable storage on the assumption that we will develop technology sooner than the 24,000 year half-life of Pu that will allow us to

burn it as fuel safely, to dispose of spent fuel, and to use it as fuel for rockets for space exploration. Particularly important because we will likely run out of fossil fuels in the next century. (Kemper)

R8) Irreversibility is noted as an important goal in any disposition alternative. None of the alternatives, however, would be completely irretrievable, allowing for the possible reversal should a clearly more desirable alternative be developed.

C9) Make upgrades at multiple sites to permit long-term storage. Pu stored at Hanford, INEL, Pantex and the Savannah River Site would remain in storage at those sites in modified or new facilities, while Pu at RFETS and Los Alamos National Lab would be relocated to one or more of the four "multiple sites." This alternative minimizes transportation requirements and construction of new facilities. (Commander, Idaho ANS/Herring, Idaho ANS)

R9) Comment noted.

C10) Convert all nuclear materials into spent fuel - the de-facto international standard for plutonium containment. (Pillay)

R10) The United States, Russia and the international community have adopted the "spent fuel standard" as the goal for plutonium disposition. This does not mean, however, that all plutonium must be put into spent fuel.

C11) The United States must not place itself at a perceived or real disadvantage by unilaterally disposing of Plutonium. (Wilson)

R11) Comment noted. The need to pursue parallel disposition with Russia is a vital component of any plans to dispose of excess plutonium in the United States.

C12) Disposing surplus weapons plutonium by irradiating the material in existing light water reactors is clearly the most preferable route for the United States. (Commonwealth Edison/Duke Power)

R12) The benefits and vulnerabilities associated with Reactor-based alternatives are noted in the Assessment.

C13) The NAS recommendation of continued development work on reprocessing and breeder (Integral Fast Reactor) is a promising approach to a proliferation-resistant fuel cycle. (Commander, Idaho Section, ANS)

R13) Comment Noted. The alternatives under consideration by the Department of Energy are the result of an extensive screening process, described in "Summary Report of Screening Process," March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C14) Use of existing DOE facilities for a reactor burn option will achieve the most rapid and cost-effective results (e.g., Hanford could be ready to go in a few years and do all Pu conversion in one "secure federal site"). (Hanford Communities)

R14) Schedule estimates are discussed in the "Technical Summary Report For Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE-MD-0003 Rev 1.

C15) Using fissile material as fuel in Internal Fast Reactors (IFRs) would be the most beneficial option to the environment and would reduce the need to transport materials. (Burns Pointe Reservation)

R15) Environmental impacts of reasonable alternatives are discussed in the PEIS. The alternatives under consideration by the Department are the result of an extensive screening process, described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C16) Under no circumstances use surplus plutonium as MOX fuel. (Grotein)

R16) The use of Plutonium as MOX fuel for the purpose of disposition is a reasonable alternative and is analyzed in the Assessment. The alternatives under consideration by the Department are the result of an extensive screening process, described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C17) If the United States decides to use at least some plutonium as MOX fuel, the government should own all disposition-related facilities and the MOX fabrication plant should have as little capacity as required for timely disposition. (UCS)

R17) Comment noted. These and other similar steps designed to minimize the nonproliferation vulnerabilities associated with the reactor-based options are discussed in the Assessment

C18) DOE should re-focus its attention to developing immobilization options for Pu. (Military Production Network)

R18) The Department of Energy is working on a number of viable alternatives, including immobilization.

C19) Store vitrified logs in conjunction with high-level waste to make them less accessible to potential theft. (Grotein)

R19) Comment noted. The benefits and vulnerabilities of the immobilization alternatives are included in the Assessment.

C20) "Can-in-canister" immobilization is the best alternative for nonproliferation, economic and safety reasons. (NCI)

R20) The nonproliferation and arms control benefits and vulnerabilities of the "can-in-canister" alternative are included in the Assessment.

C21) Utilize the Space Program to remove plutonium from the earth for burial in boreholes on the moon. (Braidfoot)

R21) The comment recommends and alternative that was screened out during a thorough screening process. The screening process is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C22) Another option, although a bit on the "crazy or wacky side," might be to place the waste within a continental plate which is being driven below a colliding plate that would move the waste toward the mantel until harmlessly dispersed within the magma, well below the biosphere or any usable earth crust. Disposal would be permanent and access or recovery would be limited due to the continually moving nature of the disposal medium. (Reynolds Electrical & Engineering Co., Inc.)

R22) The comment recommends and alternative that was screened out during a thorough screening process. The screening process is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

V. COMMENTS OUTSIDE THE SCOPE OF THE STUDY

C1) The Assessment does not consider new geological evidence that DOE has commissioned at INEL to test Dr. Zolweig's (Idaho State University) report on true vulnerabilities, which might eliminate INEL as a potential site. (Rickards)

R1) Waste management of civilian plutonium is beyond the scope of the Assessment, which analyzes nonproliferation and arms control benefits and vulnerabilities for the various alternatives for surplus plutonium disposition.

C2) A proliferation-proof waste-management plan for civilian Pu is needed. (Rocky Mountain Peace Center)

R2) As the Assessment states, "Each of the alternatives under consideration for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others."

C3) According to information from Better World Technology, a technology exists that is capable of neutralizing radioactive waste and making it totally harmless. This was to be demonstrated at a public showing in Philadelphia in September. (Wilson)

R3) The alternatives under consideration were selected after a screening process conducted by the Department of Energy. the screening process is described in "Summary Report of Screening Process", March 29, 1995, Office of Fissile Materials Disposition, Department of Energy.

C4) DOE's piecemeal approach ignores the national initiative to improve public participation in U.S. DOE decisions on nuclear materials disposition known as the National Equity Dialogue. (Hanford Advisory Board)

R4) The Office of Arms Control and Nonproliferation was tasked by the Secretary of Energy with preparing the draft Assessment. It is not involved in decisions on other issues, such as the proposal for a National Equity Dialogue. The Department of Energy prepared the Assessment to ensure that the public and the appropriate decision-makers within the Department are aware of the nonproliferation and arms control implications associated with the alternatives under consideration. Moreover, the public meetings and comments solicited were sought to ensure that all of the benefits and vulnerabilities were brought to the attention of the Department.

C5) DOE's approach to dealing with this issue was found to be "piecemeal", which did not allow the public full participation. (Pu Roundtable, Hanford Watch)

C6) A special commission is needed to update, clarify, and coordinate nuclear management policy. (Sims)

R6) The comment calls for an activity that is outside the scope of the Assessment.

C7) The issue of storage of HEU at Oak Ridge is not adequately addressed, because of the assumption that the current DOE security and safeguards are adequate, which is not true. Need to investigate building safety, collocation of production operations with dismantlement and storage operations, and outdated Safety Analysis Reports for HEU facilities at Oak Ridge. (Nashville Peace Action)

R7) The Department of Energy is satisfied that the safeguard and security procedures at its facilities are adequate.

C8) Disposition should not result in further contamination in Nevada, since they already have a site which must be cleaned up and Nevada has the highest incidence of cancer in the world. (Devlin)

R8) The environmental and health implications of weapons-usable fissile material storage and plutonium disposition are discussed in the PEIS.

C9) Using plutonium for MOX fuel would require a huge capital investment for an uneconomical process, create additional environmental waste, and make LWRs less stable than those utilizing existing LEU. (Grotein)

R9) Cost, environmental and safety issues were outside the scope of the arms control and nonproliferation Assessment. These issues are addressed in other DOE documents, including the programmatic EIS and Technical Summary Report.

C10) Please test your HEPA filters for smaller than .3u particles on your choice of alternatives because of the contradiction of the efficiency claim of 99.97%. (Rickards)

R10) The environmental implications of weapons-usable fissile material storage and plutonium disposition are discussed in the PEIS.

C11) The draft Assessment does not disclose what will happen to mixed wastes once they are "treated" at LLNL; it does not state how LLNL plans to dispose of ash and other residues resulting from the treatment process. (Miller)

R11) The comment is outside the scope of the Assessment.

C12) The Assessment does not address the impact on future generations of making Pu unavailable as an energy resource. (R. I. Newman)

R12) The comment is beyond the scope of the Assessment.

C13) Radioactive waste will be classified, processed, and compacted to allow for long-term burial with the help of a new plant control system (PCS) for the special waste receiving and processing facility (WRAP). (Devlin/Hudlow)

R13) Comment noted. Waste management and waste minimization, however, are beyond the scope of the Assessment.

C14) The transportation and storage of low-level and high-level waste presents a health risk that we consider to be illegal and could be the impetus for filing criminal charges against DOE, DOD, and DOT officials for color of authority in violating EPA laws. (Devlin/Hudlow)

R14) The environmental implications of weapons-usable fissile material storage and plutonium disposition are discussed in the PEIS.

C15) MOX disposition would cost hundreds of millions of dollars more than immobilization. (NCI)

R15) The cost of the various alternatives are discussed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition," October 31, 1996, DOE-MD-0003 Rev. 1.

C16) There is evidence of a higher rate of cladding failure in MOX fuel, resulting in greater plutonium releases to air and water. (Nuclear Information and Resource Service)

R16) The environmental impacts of the various disposition alternatives are discussed in the PEIS.

C17) Nuclear spent fuel can be reprocessed and used for generating electricity that could supply a community with cheap electricity. (Devlin/Hudlow)

R17) The President's Nonproliferation and Export Control Statement of September 27, 1993, "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."

C18) Tritium is priceless and reprocessing it would pay for the clean-up of the entire Nevada Test Site -- the diffusion process to separate the tritium should be implemented immediately. (Devlin/Hudlow)

R18) The comment is outside the scope of the Assessment.

C19) Radioactive contamination at the Nevada Test Site is unique in comparison to all other DOE sites due to the number of nuclear weapons tests which were conducted at this location. (Devlin/Hudlow)

R19) The comment is outside the scope of the Assessment.

C20) The draft Assessment does not identify the programs at LLNL which are the source for nuclear waste. (Miller)

R20) The comment is outside the scope of the Assessment.

C21) The Nevada Test Site Programs Community Advisory Board is concerned that specific plans be established to assure the security and control of the site necessary to protect the public. (Devlin/Hudlow)

R22) The comment is beyond the scope of the Assessment.

C23) In regard to the current low-level waste program at the Nevada Test Site, there is no real physical inspection of the waste being shipped there for disposal, the Ten-Year Plan budget does not include sufficient money to cover the cost of performance Assessments, site closure and long-term monitoring and security, and the waste generator fees do not cover the real life cycle cost for the disposal operations and management costs at NTS. (Devlin/Hudlow)

R23) The comment is beyond the scope of the Assessment.

C24) The State Department should conduct a study of the efficacy of the U.S. supporting greater democratization of weapons-usable fissile materials decisions

through provisions in treaties that support public and indigenous peoples' participation in those decisions. (Nez Perce)

R24) Comment noted. Although the comment is beyond the scope of the Assessment, it has been forwarded to the appropriate office in the U.S. Department of State for consideration.

C25) DOE should take action to improve democratization of the decision making process with regard to weapons-usable fissile material in other countries. (Nez Perce)

R25) The comment is beyond the scope of the Assessment.

C26) This comment objects that no public hearings were held on the stockpile stewardship issue. (Sanders, Peace Action Texas)

R26) The stockpile stewardship program is beyond the scope of this Assessment.

C27) DOE must not initiate any stockpile stewardship programs. (Miller)

R27) The stockpile stewardship program is beyond the scope of this Assessment.

C28) Plans for the National Ignition Facility are in direct violation of the Nuclear Nonproliferation Treaty and the CTBT. (Sanders, Peace Action Texas)

R28) The comment is beyond the scope of the Assessment.

C29) DOE's proposal to create a dump for radioactive material at LLNL Site 300 is still being considered. (Miller)

R29) The comment is beyond the scope of the Assessment.

C30) The pursuit of subcritical underground nuclear tests carried out by weaponeers from LLNL and LANL is in violation of the CTBT. (Miller)

R30) The comment is beyond the scope of the Assessment.

C31) The public does not have access to information regarding risks associated with particular projects at LLNL. (Miller)

R31) The comment is beyond the scope of the Assessment.

C32) DOE has no program for reducing nuclear wastes at their source. (Miller)

R32) The comment is beyond the scope of the Assessment.

C33) Radioactive waste must be contained at the site where it is presently located; DOE must not open any new radioactive waste dumps. (Miller)

R33) The comment is beyond the scope of the Assessment.

ADDENDUM

The following comments were not included in the printing of the Comment Response Section of the *Final Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Materials Storage and Excess Plutonium Disposition Alternatives* due to a logistical error. These comments were considered in the preparation of the Final Assessment.

C1) The can-in-canister immobilization option is the clear [nonproliferation] winner. It is cheaper, faster, more politically acceptable and has less nonproliferation drawbacks than the MOX option.(ISIS)

R1) The Assessment analyzes the nonproliferation and arms control benefits and liabilities of the disposition alternatives and concludes that "Each of the options for plutonium disposition has its own advantages and disadvantages with respect to nonproliferation and arms control, but none is clearly superior to the others." The cost and estimated schedule to completion of various options are discussed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition" Rev.1, October 31, 1996.

C2)Neither the MOX option alone nor the hybrid option beats the can-in-canister immobilization option in terms of schedule and cost. (ISIS)

R2) The cost and schedule aspects of the plutonium disposition alternatives are discussed in the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition" Rev.1, October 31, 1996. While can-in-canister immobilization may be less expensive and take less time to complete than the MOX or immobilization/MOX hybrid alternatives, the additional costs of pursuing the hybrid are not prohibitive and pursuit of the hybrid will allow for greater certainty that one disposition path will succeed in the time frame given for disposition.

C3) Would the US be in a stronger or weaker position to argue against civil plutonium use in other countries if it is pursuing disposition via MOX? (ISIS)

R3) The answer to the comment's question is not conclusive either way. While the United States might (or might not) be in a stronger position to argue against civil use of plutonium if it pursues disposition via the MOX option, the comment fails to take into account the entire range of nonproliferation and arms control goals sought by the United States through its pursuit of disposition. The U.S. policy to not encourage the civil use of plutonium is only one of the issues (albeit an important issue) that the United States must consider as it pursues plutonium disposition. Others issues that are considered include: building international confidence in the disposition process, increasing the ability of the United States to achieve disposition in a given time frame, and helping to achieve irreversibility in the arms reduction process. Moreover, as the Assessment notes, there are both benefits and vulnerabilities associated with the MOX option in regards to the US goal of "not encouraging the civil use of plutonium," which include enhancing the ability of the United States to push for the elimination of existing stockpiles of plutonium.

C4) It is hard to quantify the nonproliferation costs of MOX in terms of foreign fuel cycle policy. (ISIS)

R4) Comment noted.

C5) The MOX option would require more purification and processing of plutonium than immobilization, and thus has a correspondingly higher risk of theft and greater cost. (ISIS)

R5) The nonproliferation and arms control benefits and vulnerabilities of the MOX alternative, including the additional processing required, are discussed in the Assessment. The cost of the various alternatives are discussed on the "Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition" Rev.1, October 31, 1996. While the MOX alternative would require more processing than other options, much of the processing required for disposition must be pursued regardless of the disposition alternative, and the hybrid option might only require samll increases in the amount of processing required since materials could be disposed of by means well suited to their level of purity.

C6) The report's assertion that the MOX plant would be shut down after processing weapons plutonium is highly uncertain. (ISIS)

R6) The Assessment recommends that the United States only license or approve to operate a MOX fabrication plant, should one be built, for the handling of plutonium declared excess to defense needs as a means of ensuring that the MOX-based disposition of plutonium does not create the impression that the United States is reversing its policy on plutonium use. In the "Report of Department of Energy Working Group on External Regulation (DOE/US-0001, December 1996), DOE proposed to seek legislation that would generally require Nuclear Regulatory Commission licenses for new DOE facilities. Therefore, DOE anticipates seeking an NRC license for a MOX fabrication facility at a DOE site, should one be built. The Assessment recommends limiting the license of te MOX facility to disposition of surplus plutonium.

C7) The MOX option must overcome significant political and regulatory obstacles that could prevent or delay its implementation. (ISIS)

R7) The potential obstacles to building and operating MOX-based facilities are discussed in the Assessment, as are the potential difficulties associated with immobilization-based facilities and for the borehole alternatives. Several key facilities will be required regardless of which action alternative for plutonium disposition is chosen (e.g., pit disassembly facility, etc.).

C8) Transportation in general and international transportation in particular should be reduced as much as possible. (ISIS)

R8) The risks associated with the transport of nuclear materials are noted in the Assessment, which recommends adoption of the stored weapons standard for all legs of the disposition process, including transport. The Assessment also recommends ways to reduce transport, including co-location of facilities.

C9) Adoption of the Can-in-Canister alternative would avoid questions about U.S. fuel cycle policy. (ISIS)

R9) The benefits and vulnerabilities of the various options in light of current U.S. fuel cycle policies are discussed in the Assessment. Fuel cycle policies are only one of a number of considerations, however, that are relevant to the disposition of excess plutonium.

C10) While MOX can deal with only part of the material to be disposed of, immobilization can deal with all of it. (ISIS)

R10) In fact, all of the material declared excess to defense needs could be disposed of using any of the action alternatives, although the MOX alternative would require a significant amount of additional processing in order to put relatively impure forms of plutonium into a form that could be used in reactors.

C11) DOE should choose immobilization as the primary disposition technology and continue MOX activities only as a backup plan. (ISIS)

R11) Comment noted.

C12) The Nonproliferation Assessment misses an opportunity to strengthen U.S. policy to not encourage the civil use of plutonium. (ISIS)

R12) The U.S. disposition effort is designed to reduce the risk of nuclear proliferation and to strengthen overall U.S. and global arms control and nonproliferation policy. The Assessment points out the various nonproliferation and arms control benefits and vulnerabilities associated with the various alternatives considered by the Department of Energy for disposition. The assessment notes that "advocates of the use of plutonium fuels in other countries would be likely to use the argument that the United States has changed its position, and that plutonium fuels were now playing a key role on nuclear disarmament, to help promote their cause. If this, in fact, led to decisions in other countries to pursue additional reprocessing and bulk-handling of separated plutonium, it could result is additional proliferation risks. This is an important policy issue in considering the LWR MOX alternative."

APPENDIX F

PUBLIC PARTICIPATION

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Anonymous	Yes	Yes	Richland, WA
Aeby Ian *Northern New Mexico Citizens Advisory Board*		Yes	Northglenn, CO
Aguilar Marie *Environmental Protection Agency*		Yes	Northglenn, CO
Ale May *Supply System*		Yes	Portland, OR
Anawalt William *EH-24*		Yes	Amarillo, TX
Andrews Robert *Lawrence Livermore National Laboratory*		Yes	Oakland, CA
Andrews Richard		Yes	Northglenn, CO
Arnold Ed *Physicians For Social Responsibility, Atlanta*		Yes	North Augusta, SC
Ayukawa Yurika *Physicians For Social Responsibility*	Yes	Yes	Washington,DC
Bailey Susan *Nashville Peace Action*	Yes	Yes	Oak Ridge, TN
Baker Jack W *Washington Public Power Supply System*		Yes	Washington,DC
Beier Ann *Western States Legal Fdn*		Yes	Oakland, CA
Belisle Mavis V *Peace Farm*		Yes	Amarillo, TX
Belsey Dick *Hanford Advisory Board*	Yes	Yes	Portland, OR
Bengelsdorf Harold		Yes	Washington,DC
Berry Len *Tn Dept Of Environment & Conservation*		Yes	Oak Ridge, TN
Betteridge Richard D *Dept Of Energy, Nevada Operations Office*		Yes	Las Vegas, NV
Blazek Mary Lou *Oregon State Dept Of Energy*	Yes	Yes	Portland, OR

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Bliss Henry E *Commonwealth Edison*		Yes	Oak Ridge, TN
Bloomfield Susan *LWV Sierra*		Yes	North Augusta, SC
Bornfleth Bruce *DOE*		Yes	Richland, WA
Booher Sam W	Yes		
Boothe Galen *Mason & Hanger*		Yes	Amarillo, TX
Bouttier Caroline		Yes	Northglenn, CO
Boyle David *Texas A&m University*		Yes	Amarillo, TX
Brandman Charles *PAI Corp.*		Yes	Oak Ridge, TN
Bratcher Leigh *Mason & Hanger Pantex*		Yes	Amarillo, TX
Brechin Vernon J *Tri-valley Cares*	Yes	Yes	Oakland, CA
Brekke David *Sandia Natinoal Labs*		Yes	Oakland, CA
Broderick Nick *Doe/oak Smd - Livermore National Lab Site*		Yes	Oakland, CA
Brown Pam *City Of Richland*		Yes	Richland, WA
Brownell Lorilee *SAIC*		Yes	North Augusta, SC
Brumbach, Ph.d. Steve B	Yes		
Buchanan Ronald		Yes	Washington,DC

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Buckalew Meilly *Kwanitewk Native Resource/network*	Yes		
Buckner Mel R *Westinghouse Savannah River Company*		Yes	North Augusta, SC
Burn Joseph P *Washington Public Power Supply System*		Yes	Richland, WA
Busse James *DOE*		Yes	Washington,DC
Butler Bill		Yes	Amarillo, TX
Campbell Kerry *Pantex Plant Mason & Hanger*		Yes	Amarillo, TX
Cantey Thomas *DOE Savannah River Operations*		Yes	North Augusta, SC
Caperton Chris *Energetics. Inc*		Yes	Washington,DC
Carron Igor *Texas A&m University*	Yes	Yes	Amarillo, TX
Chang Hong-Lae *Kaeri*		Yes	Washington,DC
Chi Hans-wolfgang		Yes	Washington,DC
Chibisov Alex *Russian Embassy*		Yes	Washington,DC
Chun Yong Ciop *Korea Electric Power Corporation*		Yes	Washington,DC
Claussen Ronald L *Raytheon Nculear Inc*	Yes	Yes	Northglenn, CO
Clements Cherry *Womens Action for New Directions*	Yes	Yes	North Augusta, SC
Clements Tom *Greenpeace*		Yes	Washington,DC
Cochran Thomas B *Natural Resources Defense Council*	Yes		
Cole Samuel H *Physicians For Social Responsibility*	Yes	Yes	Northglenn, CO

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Collina Tom *ISIS*		Yes	Washington,DC
Colsi John *Kaiser - Hill*		Yes	Northglenn, CO
Combs Jeff *Ux Consulting*		Yes	Oak Ridge, TN
Commander John C *American Nuclear Society, Idaho Section*	Yes	Yes	Idaho Falls, ID
Cook Thomas L *Los Alamos/DOE NN-43*		Yes	Washington,DC
Cook L *Amarillo National Resource Center for Plutonium*	Yes		
Costikyan Thomas W *Srs Citizens Advisory Board*		Yes	North Augusta, SC
Cowles John O *TRW Environemntal Safety Systems, Inc*		Yes	Washington,DC
Cox Shirley *Lockheed Martin Energy Sys (y-12)*		Yes	Oak Ridge, TN
Cox Grady J		Yes	Richland, WA
Cramer Obed *SAIC*		Yes	North Augusta, SC
Cropper Tom *Multisomah Activitst Solutions, LLC*		Yes	Portland, OR
Culp David *Plutonium Challenge*		Yes	Washington,DC
Daniel Louise *Stand Of Amarillo, Inc*		Yes	Amarillo, TX
Davenport Les		Yes	Richland, WA
Day Dave *IAM*		Yes	Washington,DC
Deaver Boyd *Texas Natural Resources Conser Comm*		Yes	Amarillo, TX
Dellaratta Raphael *Exchange/monitor Publishing*		Yes	Washington,DC

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Denny Craig *KV11-TV*		Yes	Amarillo, TX
Devlin Sally	Yes	Yes	Las Vegas, NV
Dewey Amy *State Senator Teel Bivins*		Yes	Amarillo, TX
Dobbin Ken *Fluor Daniel Northwest*		Yes	Richland, WA
Dolley Steven *Nuclear Control Institute*		Yes	Washington,DC
Doyle George *(Retired)*		Yes	Oak Ridge, TN
Duane John *Westinghouse Savannah River Company*		Yes	North Augusta, SC
Edmondson Richard L *State Of Texas Div Of Emergency Mgnt*		Yes	Amarillo, TX
Ehrlich Edward	Yes	Yes	Oakland, CA
El-sofwany Salma *Dept Of Energy/energy Programs Division*		Yes	Oakland, CA
Eldredge Maureen E *Military Production Network*	Yes		
Erben Randall H *Panhandle 2000*		Yes	Amarillo, TX
Erickson Randall *Los Alamos National Laboratory*		Yes	Northglenn, CO
Evans E. David *Burns Paiute Reservation*	Yes	Yes	Idaho Falls, ID
Fager Cal	Yes	Yes	Northglenn, CO
Fairrow Nannette *Mason & Hanger*		Yes	Amarillo, TX
Feinroth Herbert *Gamma Engineering Corporation*		Yes	Washington,DC
Ferguson Dwight *Nuclear Fuel Services, Inc.*	Yes		
Fertel Marvin S *Nuclear Energy Institute*	Yes		
Finamore Barbara *NRDC*	Yes		

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Finger Harold B		Yes	Washington,DC
Fitzgerald Tom *Kentucky Resources Council, Inc*		Yes	Oak Ridge, TN
Fitzgerald Amy S *Oak Ridge Reservation Local Oversight Committee*		Yes	Oak Ridge, TN
Flangas William		Yes	Las Vegas, NV
Flora Mary		Yes	North Augusta, SC
Forsythe Jan *Lockheed*		Yes	Washington,DC
Freed Sheldon H *Bechtel Nevada*		Yes	Las Vegas, NV
French P Mike *Lai*		Yes	North Augusta, SC
Freund George A *Coalition 21*		Yes	Idaho Falls, ID
Gabbard Alex *Oak Ridge National Laboratory*	Yes		
Garcia Abel A		Yes	Oakland, CA
Gattis Beverly *Stand Of Amarillo, Inc*		Yes	Amarillo, TX
Geddes Richard L		Yes	North Augusta, SC
Gerber Karen		Yes	Northglenn, CO
Gerber Michele S *Fluor Daniel Hanford Co*		Yes	Richland, WA
Goitein Ernest *Peninsula Conservation Center*	Yes		
Goldfield Joe *Cab - Rocky Flats*		Yes	Northglenn, CO
Gould Thomas H *LLNL*		Yes	Oakland, CA
Gray Leonard W *Lawrence Livermore National Laboratory*		Yes	Oakland, CA
Guais Jean-claude *Cogema, Incorporated*		Yes	Washington,DC
Gurka Becky		Yes	Las Vegas, NV

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Haler Larry *City Of Richland*	Yes	Yes	Richland, WA
Hall David	Yes		
Hammond Terry *Hanford Action of Oregon*		Yes	Portland, OR
Harris Bill *Amarillo National Resouce Center For Plutonium*		Yes	Amarillo, TX
Haselton Hal H *Haselwood Enterprises, Inc*		Yes	Oak Ridge, TN
Hatfield Scott F *Peace & Environmental Activitist*		Yes	Northglenn, CO
Hawkins Ron *Paragon Technical Associates*		Yes	Oak Ridge, TN
Heacock Harold *Tricities Industrial Development Council*		Yes	Richland, WA
Henri Victor P		Yes	Oakland, CA
Hermanson Mark *Hanford Advisory Board*		Yes	Richland, WA
Herring Steve *American Nuclear Society, Idaho Section*	Yes		
Hill Leo James	Yes		
Holly Charlotte D *Westinghouse Savannah River Co*		Yes	North Augusta, SC
Holm Victor		Yes	Northglenn, CO
Holman Garry S *Lawrence Livermore Nat Lab*		Yes	Oakland, CA
Holman Mark *Unisys Corp.*		Yes	Portland, OR
Hosford Anne K *Mcdermott, Inc /babcock & Wilcox*		Yes	Washington,DC
Hoyt Richard C *Lockheed Martin Hanford*		Yes	Richland, WA
Hsieh Teh *US DOE/ Oakland*		Yes	Oakland, CA
Hudlow Grant *Allied Science Inc.*		Yes	Las Vegas, NV

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Izatt Ronald D *DOE*		Yes	Northglenn, CO
James John		Yes	Oak Ridge, TN
Jancik Lori *Federation Of Electric Power Companies Of Japan*		Yes	Washington,DC
Jernigan Gail *Westinghouse Savannah River Company*		Yes	North Augusta, SC
Jobe Lowell A *Coalition 21*	Yes	Yes	Idaho Falls, ID
Johnson W Reed	Yes		
Johnsrad Judith H *Ecnp*		Yes	Washington,DC
Jones, Jr. John E *Haselwood Enterprises, Inc*		Yes	Oak Ridge, TN
Kahn Dave		Yes	Idaho Falls, ID
Keel Frances *U.S. DOE*		Yes	Las Vegas, NV
Kemper William A	Yes	Yes	Northglenn, CO
Kennedy Richard T		Yes	Washington,DC
Khlunav Aleksandr *Russian Embassy*		Yes	Washington,DC
Killar Felix *Nuclear Energy Institute*		Yes	Washington,DC
King Henry		Yes	Amarillo, TX
King Joan O *20/20 Vision*	Yes	Yes	North Augusta, SC
Kinnelly Frances *Kinnelly Associates*	Yes	Yes	Washington,DC
Klein Robin *Hanford Action Of Oregon*	Yes	Yes	Portland, OR
Klein Dale *Amarillo Nat Resource Ctr For Plutonium*	Yes		
Knight Paige *Hanford Watch*	Yes	Yes	Portland, OR
Knox John *US DOE SR*		Yes	North Augusta, SC

Participants Name / Organization	Participation By Comments	Attended a Meeting	Location
Kodman Gary P *Battelle*		Yes	Oak Ridge, TN
Koecher Deanne *Amarillo College*		Yes	Amarillo, TX
Kotnik Larry *Power Reactor And Nuclear Fuel Development Corpo*		Yes	Washington,DC
Kovac Francis M *Oak Ridge City Council*		Yes	Oak Ridge, TN
Kraemer Jay *Fried, Frank, Harris, Shriver & Jacobson*		Yes	Washington,DC
Kunert Kristian A *NAC International*		Yes	Washington,DC
Larson Dennis	Yes		
Lawless William *Paine College*		Yes	North Augusta, SC
Ledwidge Lisa *PSR*		Yes	Washington,DC
Lee Kwang Seok *Korea Atomic Energy Research Inst.*		Yes	Washington,DC
Leedom Stephen *U.S. DOE*		Yes	Las Vegas, NV
Lehto Darelynn *Prairie Island Indian Community*		Yes	Oak Ridge, TN
Lemming John F *Mason & Hanger - Pantex*		Yes	Amarillo, TX
Leroy Peter G *Duke Engineering & Services*		Yes	Richland, WA
Leventhal Paul *Nuclear Control Institute*	Yes	Yes	Washington,DC
Limaye Satu *NUMARK ASSOCIATES*		Yes	Washington,DC
Lindsten Don C *Dod*		Yes	Washington,DC
Little Byron *Geomex Minerals, Inc.*		Yes	Northglenn, CO
Loney Erik *KEIR News*		Yes	Richland, WA
Losey David		Yes	North Augusta, SC

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Lyons Blythe *Energy Resources International*		Yes	Washington,DC
Maclean Neil *British Embassy*		Yes	Washington,DC
Madison Robin M *BECHTEL*		Yes	Washington,DC
Maienschein Fred	Yes	Yes	Oak Ridge, TN
Makowitz Henry	Yes	Yes	Idaho Falls, ID
Mann Melissa *Edlow International Corporation*		Yes	Washington,DC
Mardis David *AIMS Engineering*		Yes	Oak Ridge, TN
Marshall Tom W *Rocky Mountain Peace Center*	Yes	Yes	Northglenn, CO
Martilloti Joseph *Texas Dept of Health Bureau of Radiation Control*		Yes	Amarillo, TX
Martin Donna K *Westinghouse Savannah River Company*		Yes	North Augusta, SC
Mayson, Jr. William P		Yes	North Augusta, SC
Mcbride Jim *Amarillo Globe-news*		Yes	Amarillo, TX
McCartney Shawna *Edlow International Company*		Yes	Washington,DC
Mccracken Trish *Augusta Citizens Advisory Board*		Yes	North Augusta, SC
McCraw Neal *Duke Engineering & Services*		Yes	North Augusta, SC
Mcdonell William R		Yes	North Augusta, SC
McGilvary Reuben *Mason & Hanger Corp*		Yes	Amarillo, TX
McKibben J. Malvyn *WSRC*		Yes	North Augusta, SC
McLellen David J *The Canadian Embassy*		Yes	Washington,DC
Meggs Deanna *Oregon State Dept Of Energy*		Yes	Portland, OR
Melese Gilbert		Yes	Oakland, CA

Participants ***Name / Organization***	**Participation By** ***Comments***	***Attended a Meeting***	***Location***
Merritt Alan E *State Of Idaho Inel Oversight Program*		Yes	Idaho Falls, ID
Michaels Gordon *Oak Ridge National Laboratory*		Yes	Oak Ridge, TN
Miles Ricky C *Tva/bellefonte Nuclear Plant*		Yes	Oak Ridge, TN
Miller Barry	Yes		
Mills Robin		Yes	Amarillo, TX
Monroe William E *TDEC/DOE Oversight Division*		Yes	Oak Ridge, TN
Monroe Robert R *Bechtel National, Inc*		Yes	Washington,DC
Moon You-Hyen *Korean Embassy*		Yes	Washington,DC
Moore LeRoy *Rocky Mountain Peace Center*	Yes	Yes	Northglenn, CO
Moyer Robert E *Cogema, Incorporated*		Yes	Amarillo, TX
Myers David *DOE/ORO*		Yes	Oak Ridge, TN
Naughton William F *Commonwealth Edison Company (comed)*	Yes	Yes	Washington,DC
Nelson Ronald		Yes	Richland, WA
Nelson Paul *Texas A&m University*		Yes	Amarillo, TX
Nesbit Steven *Duke Power Co*		Yes	North Augusta, SC
Newlin Michael *Jupiter Corp*		Yes	Washington,DC
Newman R I	Yes		
Nisley Steve S *TDEC/DOE Oversight Division*		Yes	Oak Ridge, TN
North Karen		Yes	Northglenn, CO *Project Pheonix (seti)*
Nurmela Lillian *Women For Peace - East Bay*	Yes	Yes	Oakland, CA

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Ohlsen Reva *Boulder News*		Yes	Northglenn, CO
Okulczyk Gail M *TDEC/DOE Oversight Division*		Yes	Oak Ridge, TN
Olson Mary	Yes		
Oppedal Paul *Kaiser Hill*		Yes	Northglenn, CO
Orth Donald	Yes	Yes	North Augusta, SC
Oser Wendy *Nuclear Guardianship Project*	Yes	Yes	Oakland, CA
Owens Janice *NARUC - Nuclear Waste Program Office*		Yes	Washington,DC
Packan Nicolas *ORNL*		Yes	Oak Ridge, TN
Pare Diantha F *League Of Women Voters*		Yes	Oak Ridge, TN
Park Sang-Kyu *Kaeri*		Yes	Washington,DC
Park Sangryzol *Korea Institue Of Nuclear Safety*		Yes	Washington,DC
Parker Richard L *PAI Corporation*		Yes	Oak Ridge, TN
Patterson Karen *CAB*		Yes	North Augusta, SC
Pearl Lawrence S *Washington International Energy Group*		Yes	Washington,DC
Pearson Victor *Dept Of Energy, Idaho Operations Office*		Yes	Idaho Falls, ID
Peelle Robert	Yes	Yes	Oak Ridge, TN
Penney Samuel *Nez Perce Tribal Executive Committee*	Yes		
Perkins-McLean Vivienne E *Colorado Coalition For The Prevention Of Nuc. Wa*	Yes	Yes	Northglenn, CO
Perrg Rita *Peace Action*		Yes	Oakland, CA
Perry Walter *Doe Oak Ridge Op Office*		Yes	Oak Ridge, TN
Petring John C *Ogden Environmental & Energy Services*		Yes	Washington,DC

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Pierce Ronnie *DOE Amarillo Area Office*		Yes	Amarillo, TX
Pillay K K S *Los Alamos National Laboratory*	Yes		
Porto Frank *DOE Oakland Operations Office*		Yes	Oakland, CA
Pura Carolyn A *Sandia National Laboratory*		Yes	Oakland, CA
Quint Matthew *Embassy of Australia*		Yes	Washington,DC
Rauf Tariq *Monterey Inst Of Intl Studies, Cns*	Yes	Yes	Oakland, CA
Richards, DPM Peter	Yes	Yes	Idaho Falls, ID
Robbins Jennifer *University Of South Carolina*		Yes	North Augusta, SC
Roberts Mardee *The Oak Ridger*		Yes	Oak Ridge, TN
Robinson Perry *Winston & Strawn*		Yes	Washington,DC
Rogers Gordon J *Hanford Advisory Board*		Yes	Richland, WA
Rogers Erin *Rocky Flats Citizens Advisory Board*		Yes	Northglenn, CO
Rossin A. David *Rossin And Associates*	Yes	Yes	Oakland, CA
Rowe Patrick *Reynolds Electrical & Engineering Co.*	Yes	Yes	Las Vegas, NV
Ruddy M. Karen *Amarillo College*		Yes	Amarillo, TX

Participants Name / Organization	Participation By Comments	Attended a Meeting	Location
Rudnick Stan *Argonne National Laboratory*		Yes	Washington,DC
Russo Brian *Reynolds Research Inc.*		Yes	Washington,DC
Saltzman Jerome *DOE*		Yes	Washington,DC
Sandberg Don *Lockheed Martin Hanford Co*		Yes	Richland, WA
Sanders Jan *PEACE ACTION*	Yes	Yes	Amarillo, TX
Schmidt Laura *MSI*		Yes	Washington,DC
Schoett Wolfram *German Embassy*		Yes	Washington,DC
Scott Michael *Duke Engineering and Services, Inc.*		Yes	Las Vegas, NV
Scott Frank *Intl Chemical Worker's Union - 252*		Yes	Oak Ridge, TN
Sea Geoffrey *Atomic Reclamation & Conservation Project*		Yes	Oakland, CA
Sedgely Jeanie D *Rocky Flats Local Impacts Initiative*		Yes	Northglenn, CO
Shapiro Theodore *PAI Co.*		Yes	Oak Ridge, TN
Sims Lynn *Don't Waste Oregon*	Yes	Yes	Portland, OR
Slaughter Gerald		Yes	Oak Ridge, TN
Smith Frank W *Rocky Flats Citizens Advisory Board*	Yes		Northglenn, CO
Smith Doris N *Panhandle Area Neighbors & Land Owners*	Yes		
Smith Benjamin L *Ben Smith Consulting*		Yes	Oak Ridge, TN
Snell Jim *Nashville Peace Action*	Yes	Yes	Oak Ridge, TN
So Dong Sup *KAERI Korea*		Yes	Washington,DC

Participants Name / Organization	Participation By Comments	Attended a Meeting	Location
Sowa Paul *Mason & Hanger*		Yes	Amarillo, TX
Sproul Elizabeth		Yes	Amarillo, TX
Stang John E *Tri-city Herald*		Yes	Richland, WA
Starbuck Kevin *City of Amarillo*		Yes	Amarillo, TX
Steffen Jim M *B&W Hanford Co*	Yes	Yes	Richland, WA
Stelsou Ben		Yes	Oak Ridge, TN
Sullivan Kent *Westinghouse Savannah River Company*		Yes	North Augusta, SC
Szempruch Rich		Yes	Richland, WA
Tanaka Hiroshi *Embassy Of Japan*		Yes	Washington,DC
Taylor Ellen *Lawrence Livermore National Laboratory*		Yes	Washington,DC
Taylor Bill *DOE*		Yes	North Augusta, SC
Thrash Paul		Yes	Oakland, CA
Timmerman Pamela J *US General Accounting Office*		Yes	Northglenn, CO
Transue Martin *Dept Of Energy Rocky Flats Field Office*		Yes	Northglenn, CO
Tuttle John *SAIC*		Yes	North Augusta, SC
Van Doren Charles N *Ogden Environ & Energy Ser*	Yes	Yes	Washington,DC
Vance Dorothy *Women for Peace*		Yes	Oakland, CA
Vasconi William *Intl Brotherhood Of Electrical Workers, Local #*		Yes	Las Vegas, NV
Venetz Ted *Lockheed Martin Hanford Co*		Yes	Richland, WA
Vincent Timothy *Lockheed Martin Energy Systems*		Yes	Oak Ridge, TN

Participants *Name / Organization*	Participation By *Comments*	*Attended a Meeting*	*Location*
Volpentest Sam *Tridec (tri City Economic Development Council)*	Yes		
Walton Barbara A *Citizens Advisory Panel (Oak Ridge)*		Yes	Oak Ridge, TN
Webster MariAnn *Atlanta Chapter of WAND*		Yes	North Augusta, SC
Werth Kenneth *Rocky Flats Citizens Advisory Board*	Yes	Yes	Northglenn, CO
Westcott James E *Retired DOE*		Yes	Oak Ridge, TN
White, Jr. Charlie *Chamber Of Commerce Inel Comm - Self*		Yes	Idaho Falls, ID
Wilcox Robert H *Westinghouse Savannah River Company*	Yes	Yes	North Augusta, SC
Williams Gary		Yes	Amarillo, TX
Williams Ken *Lockheed Martin*		Yes	Oak Ridge, TN
Williams Tom *SRS DOE*		Yes	North Augusta, SC
Wilson Leroy & Aubert	Yes	Yes	Amarillo, TX
Winchester John W *Sierra Club National Nuclear Waste Task Force*	Yes		
Witt Connie *LANL*		Yes	Washington,DC
Wootan David *Fluor Daniel Northwest*		Yes	Richland, WA
Yard Charles R *TDEC/DOE Oversight Division*		Yes	Oak Ridge, TN
Yates Stacy Clapton *KGNC Talk Radio 71*		Yes	Amarillo, TX
Yourish Karen *Weapons Complex Monitor*		Yes	Washington,DC
Zavadowski Richard A *Nuclear Fuel Services, Inc*		Yes	Washington,DC
Zerm Ron W *Metal Trades Council*		Yes	Amarillo, TX