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IMPLEMENTATION OF SAFEGUARDS & SECURITY FOR FISSILE MATERIALS DISPOSITION REACTOR ALTERNATIVE FACILITIES

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ABSTRACT

The Department of Energy is analyzing long-term storage and disposition alternatives for surplus weapons-usable fissile materials. A number of different disposition alternatives are being considered and include facilities which provide for long-term and interim storage, convert and stabilize fissile materials for other disposition alternatives, immobilize fissile material in glass and/or ceramic material, fabricate fissile material into mixed oxide (MOX) fuel for reactors, use reactor based technologies to convert material into spent fuel, and dispose of fissile material using a number of geologic alternatives. Although areas which are applicable to all of the possible disposition alternatives will be discussed, particular attention will be given to the reactor alternatives which include existing, partially completed, advanced or evolutionary light water reactors (LWRs), and Canadian deuterium uranium (CANDU) reactors. The various reactor alternatives are all very similar and include plutonium (Pu) processing which converts Pu to a usable form for fuel fabrication, a MOX fuel fab facility located in either the U.S. or in Europe, U. S. LWRs or the CANDU reactors and ultimate disposal of spent fuel in a geologic repository. There are many possible variables to the reactor alternatives and they include government or private ownership, type of reactor, location of facilities and co-location of selected facilities.

This paper will focus on how the objectives of reducing security risks and strengthening arms reduction and nonproliferation will be accomplished and the possible impacts of meeting these objectives on facility operations and design. Some of the areas in this paper include: 1) domestic and international safeguards requirements, 2) non-proliferation criteria and measures, 3) the threat, and 4) potential proliferation risks, the impacts on the facilities, and safeguards and security (S&S) issues unique to the presence of Category I or strategic special nuclear material.

INTRODUCTION

The DOE established the Fissile Materials Disposition Program (FMDP) to address the disposition alternatives applicable to the long-term storage and disposition of surplus fissile material. Within this program, a team was formed to focus on the non-proliferation and S&S needs of the various long-term storage and disposition alternatives being considered. The primary program goal is to render weapons-usable fissile material inaccessible and unattractive for weapons use while protecting human health and the environment. The National Academy of Sciences (NAS) recommended the Pu disposition efforts attain the "spent fuel standard". This standard would require that the final disposal form be as difficult or unattractive as the recovery of residual Pu from spent commercial nuclear fuel. When this standard has been achieved, the proliferation risk is generally considered the same as that associated with the much larger inventory of residual Pu in commercial spent fuel. Technologies that go beyond the spent fuel standard are not currently being considered in this program.

The 1994 NAS report on the disposition of excess weapons Pu stated that reduction of risk of proliferation by unauthorized parties, reduction of risk of reintroduction of materials into arsenals and the strengthening of national and international control of fissile materials are necessary. After the initial screening process, eleven Pu disposition alternatives were selected as reasonable alternatives for further evaluation during the FMDP decision phase. They included two alternatives concerning the emplacement in deep boreholes, four alternatives concerning immobilization of the Pu and five reactor related alternatives. This paper discusses the reactor alternatives. The five reactor alternatives include:

- Burning in existing U.S. LWRs with ultimate repository disposition.

- Burning in CANDU heavy water reactors with spent fuel disposal by the Canadian utility.
- Burning in evolutionary or advanced LWRs with ultimate repository disposal.
- Burning in partially completed LWRs with ultimate repository disposition.
- Transfer to the Euratom market for mixed oxide (MOX) fuel and reactor burning.

There could potentially be a very large number of variants for these reactor alternatives. For the reactor alternatives, differences exist in the reactor type (BWR, PWR, CANDU); reactor status (existing, partially completed, new); number of reactors (2-4), location of reactors (in U.S., Canada, Europe); reactor owner (private, government owned contractor operated, Canada), location of fuel fabrication facility (U.S., Europe); and possible co-location of the MOX and Pu processing facilities.

All of the reactor alternatives consist of a Pu processing facility, MOX fuel fabrication facility, reactors, and high-level waste repository. The Pu processing facility receives a variety of Pu feed material and converts this material into Pu oxide. The MOX fuel fabrication facility purifies, blends and prepares MOX pellets. These pellets are then loaded into fuel rods and made into fuel bundle assemblies. The various reactors generally include fresh MOX receipt and storage, burning in the reactor core and spent fuel storage in a storage pool and/or dry spent fuel storage. The repository consists of a surface facility for the receipt and handling of the material and a subsurface facility for the permanent isolation of the material.

APPLICABLE SAFEGUARDS REQUIREMENTS

Domestic Safeguards

Both DOE and Nuclear Regulatory Commission (NRC) guidelines may apply depending on the facility. NRC licensed operations (e.g. commercial reactors) are expected to remain under NRC jurisdiction. Some facilities, particularly those which might have classified material, may remain under DOE control. Domestic S&S is comprised of two subsystems, nuclear materials control and accounting (MC&A) and physical protection required for protection of special nuclear material (SNM) and nuclear weapons against threats of diversion and theft. Domestic safeguards is primarily concerned with unauthorized actions by individuals and/or subnational groups. The S&S requirements for this alternative are primarily driven by the attractiveness of the material as defined in DOE Order 5633.3B. The Pu processing, MOX fuel fab and reactor facilities will be a Category I facility.

For the reactor alternatives, it is assumed that the Pu processing facility will be a DOE facility and not subject to NRC (even when it is a co-functional facility with the fuel fabrication). The remaining facilities will be governed by NRC guidelines if they are located in the U.S..

Table 1. DOE Attractiveness Categories and Quantities from DOE Order 5633.3B

	Attract. Level	PU/U-233 Category (Quantities in kgs)			
		I	II	III	IV^a
Weapons	A	All Quant -ities	N/A	N/A	N/A
Pure Products	B	≥ 2	≥ 0.4 < 2	≥ 0.2 < .4	< 0.2
High-Grade Material	C	≥ 6	≥ 2 < 6	≥ 0.4 < 2	< 0.4
Low-Grade Material	D	N/A	≥ 16	≥ 3 < 16	< 3
All Other Materials	E	N/A	N/A	N/A	Report-able Quantities

a/ The lower limit for category IV is equal to reportable limits in this Order

International Safeguards

The International Atomic Energy Association (IAEA) is the primary agency for international safeguards (ISG). ISG is also comprised of two subsystems, nuclear materials accountancy and materials containment and surveillance (C/S) required to satisfy international inspection agreements. The applied C/S provides continuity of knowledge during inspector absences and provides supplemental information to assure inventory values when measurement uncertainties might lead to the conclusion of inventory discrepancies. The focus is on the independent verification of material use through material accountancy programs and C/S systems. IAEA inspections are conducted to verify the facility's declared nuclear inventory values. The safeguards requirements for this alternative will be based on IAEA Information Circulars and negotiated facility agreements. Nuclear material for this alternative falls under the IAEA categories of unirradiated direct use (e.g. Pu metal and compounds, MOX powder and pellets, MOX fuel rods and assemblies) and irradiated direct use (e.g. MOX fuel in the reactor core, spent MOX fuel). To achieve consistency among all long-term storage and disposition alternatives being considered in this program, the following specific *assumptions* will be made:

- Material under IAEA safeguards will remain so
- Material not declared excess to stockpile and the strategic reserve will be exempt from IAEA safeguards
- Excess unclassified material may be offered by DOE to the IAEA for IAEA safeguards and will remain under those safeguards
- Excess classified materials will not be offered for IAEA safeguards until classified/restricted information has been properly protected.

CRITERIA AND MEASURES FOR NON-PROLIFERATION

The evaluation of the reactor alternatives must be done for both the domestic and international perspectives and are based on two important factors, the "threat" and the "regimes" that exist to address these threats. The areas of responsibility can be separated naturally into national and international. The responsibility of the host nation government is to prevent unauthorized access to its material either by groups within its own organization such as disgruntled workers or by other national or international terrorist groups, criminal organizations, etc. The responsibility of the international group is to prevent the host country from diverting or retrieving material that has been declared surplus. This gives a very clear delineation of the threats associated with each criterion.

A number of criteria have been identified for evaluating the various alternatives. Two of these criteria involve S&S and nonproliferation and are:

- Resistance to theft or diversion by unauthorized parties
- Resistance to retrieval, extraction and reuse by the host nation.

The first criterion involves domestic S&S while the second involves ISG. Measures have been developed for each of these criteria, as well as other factors, to evaluate the various alternatives. The evaluation will address requirements and measures and identify the proliferation risk at each of the various steps in the alternative and the non-proliferation discriminators for the alternatives. Proliferation risk is or has been defined in terms of material form, physical environment, and the level of S&S or ISG that is applied to the material.

The first criterion addresses the risk of theft of weapon-usable nuclear material primarily during transportation, storage, and processing, as well as the risk of theft after disposition is completed. The measures identified for this criteria are the environment, material characteristics, and S&S. The environment includes processing steps, throughput, inventory, and transportation. Throughput for bulk operations is particularly important. The material form attractiveness is based on physical, chemical, or nuclear (isotopic and radiological) makeup of the nuclear material and on the presence of other fissile materials. Based on the form of the material, the need to protect classified information, the nuclear material accountability system, the uncertainty of nuclear measurements, and the accessibility of the material are all measures of S&S.

For the second criterion, the difficulty of detection of diversion, retrieval, and extraction activities for a significant quantity (SQ) of material depends on the environment, material characteristics, and ISG. The environment includes bulk throughput, inventory, and processing steps. Detection difficulty and IAEA material characteristics are used to assess the material characteristics. The type of nuclear accounting system, the measurement uncertainty, classified information, and accessibility are all factors of ISG. In addition, the irreversibility of the material form is important for assessing its reuse in nuclear devices The irreversibility primarily depends on the material form and location.

THREAT

The threats can be defined as:

- theft (unauthorized removal of material by a group outside of the host nations nuclear organization),
- diversion (unauthorized removal of material by a member of the host nations own nuclear organization or unauthorized removal of material by the host nation itself in violation of the international regime before final disposition has taken place),
- retrieval (unauthorized access by the host nation in violation of the international regime after final disposition or unauthorized access by outside groups after final disposition), and
- conversion (the converting of retrieved material back into weapons form either by the host nation or other outside groups).

For the first criterion, the primary concern is theft of fissile material. Theft or diversion of material refers to both overt and covert actions to remove material from the facility and might utilize stealth and deception as well as possible help from an "insider". This is perpetrated by unauthorized parties including terrorists, subnational groups, criminals, and disgruntled employees.

For the second criterion, the concern is the diversion of material before final disposition by the state itself, retrieval of material after final disposition by the state, and conversion of the material back into a weapons useable form by the state. This refers to covert attempts to remove material from the system by the host nation or state. The threat for this criterion is the host nation. Although the host nation may choose to use overt measures to obtain material and/or weapons design information, the greatest concern is with covert attempts.

POTENTIAL PROLIFERATION RISKS AND S&S FACILITY IMPACTS & ISSUES

It is assumed that all facilities will meet the necessary S&S requirements and that these measures will help mitigate any risks. Still the threats to facilities will be different depending on the form of the material, the activities at the facility, and the barriers to theft and diversion (both intrinsic to the material and also to the facility). For each of the facilities in the reactor alternatives there exists a potential risk of theft and/or diversion. The remainder of this section will briefly discuss each of the facilities/activities for the reactor alternatives. Table 2 summarizes some of the information discussed in this section. The inherent risks to proliferation, attributes which affect proliferation resistance, facility impacts, and issues will be discussed.

Plutonium Processing

For this facility, most of the material is in a very attractive form with minimal intrinsic barriers. In the case of pit conversion, the attractiveness decreases from IB to IC (see Table 1). For oxides and other high-grade material, the attractiveness level remains at IC. In some cases the feed material may be low-grade material and the attractiveness may actually increase from IID to IC. The material is transportable. Material received into this facility (e.g. pits and containers with tamper indicating devices (TIDs)) would utilize item accountancy. Once the material has been removed from the "container", then bulk accountancy would be necessary. Except for the pits and containers with TIDs, many of the operations will involve hands-on activities and the material is very accessible. The items being handled are not particularly large and do not require any special handling equipment (SHE). Most of the operations will be performed inside a glovebox. Because pits and some other weapons material are being processed, some of the material will be classified. The presence of classified material further complicates safeguards with respect to international inspection and material may not be under ISG unless restricted data could be protected. This may also apply to waste streams. In most cases, the material is in a very pure form, such as a metal or oxide, and its isotopic composition makes it readily usable for a nuclear device. Based on the quantity and attractiveness of the material, the facility will need to be a category I facility. There are a large number of complex processing steps with a relatively high bulk throughput. This combination provides increased opportunities for covert theft and diversion. Waste streams containing fissile material will be generated and thus require monitoring to detect possible diversion. There will be no intrasite transport movements (e.g. outside of the MAA). Safe secure transports (SSTs) will be necessary to deliver and pick up the material. In addition, many of the processes involve bulk material and therefore, bulk accountability measurements which would utilizing destructive assay and other non-destructive assay (NDA) techniques. For a high throughput facility, there are increased opportunities for possible covert theft and diversion. In the case of an overt theft attempt, the targets of greatest concern would be the pits and pure metal and oxides which are transportable.

Because this facility will involve large quantities of bulk material and very high throughputs it may be very difficult to detect the diversion of a significant quantity of material using material accountability alone. It will be necessary to have additional S&S measures to ensure that material is not being diverted. Material balance areas (MBAs) and nuclear measurement points need to be located in bulk processing areas to minimize the uncertainty of material accountability. All movement of fissile material across security or MBA boundaries must be monitored (i.e. bulk and item movements and waste streams). Increased use of operations that minimize access to nuclear material is needed. This could include the use of automated or robotic devices, remote handling and other barriers to minimize the accessibility to the material. Bulk material which is not in bulk process operations should be stored TID indicating containers to help minimize the opportunities for diversion. In addition, classified information will need to be protected beyond what might currently be necessary. This is only an issue for the Pu processing facility where some of the material input to this facility is pits and perhaps other classified information which under current laws can not be divulged to IAEA inspectors (e.g. disclosure of weapons design information violates the Atomic Energy Act and the 1978 Nuclear Nonproliferation Act). Therefore, at least part of this facility may not be under ISG, and verification by the IAEA is not possible until agreements between the IAEA and the U.S. can be accomplished. A number of different alternatives are being considered to address this problem. They include processing weapons related components and material and making it available for the IAEA only after the material has been converted into a declassified form and the use of modified IAEA safeguards until the material is unclassified.

MOX Fuel Fabrication

This facility will be a category I facility with a high bulk throughput. No intrasite transport will be required outside the MAA and again, SSTs will be used to both deliver and pickup the material. Waste streams containing fissile material will be generated. As in the case of the Pu processing facility, the initial feed materials (e.g. oxide and unirradiated fuel) are very attractive material (IC), the facility operations involve a large number of processing steps, and handling of bulk material which is relatively accessible. The intrinsic attributes of this material are the same as described above for the Pu processing facility. Once the material has been blended, it becomes a less attractive target. It would be slightly more difficult to convert to a weapons usable form because the concentration of the Pu is lower and more material would be required to acquire a significant quantity. Once the MOX is placed into fuel rods and then fuel assemblies, its chemical, isotopic and radiological attributes would not change, but the mass/dimensions of the "containers" would increase. This makes the material more difficult to move and more difficult for diversion and overt theft. During the initial processing operations, bulk accountancy would be conducted until the material is placed into the fuel rods. During these initial process steps, the material is very accessible. Although devices are being developed to perform NDA on fuel rods and assemblies, this is still a very time consuming activity. Once the material is placed inside the fuel rods it is no longer accessible and item accountancy is used. The possibility for diversion is reduced because the fuel rods and assemblies are quite large and require SHE, The applied C/S measures can more easily detect diversion attempts.

The initial process steps for the MOX fuel fabrication facilities have similar risks to those mentioned for the Pu processing facility and therefore similar measures are needed. Stringent materials accountability measures are needed to ensure that, during the blending processes and fuel rod and assembly fabrication, all nuclear material is accounted for. Nondestructive nuclear measurements for fresh MOX fuel rods and assemblies would help ensure materials accountability after destructive assay is no longer possible. For rods and/or assemblies that are relatively transportable, barriers and controls are necessary to mitigate the threat of theft. For items requiring SHE, appropriate measures need to be in place to monitor and control access to this equipment.

Reactors

Although fresh MOX fuel assemblies are considered category IC SNM, they are only a moderately attractive target for overt theft. The large mass and dimensions of the fuel assembly require the use of SHE which provides increased delay against an overt attack and also helps in detecting any covert adversary activities. Once the fuel assemblies are placed into the reactor core, they are not only inside the reactor containment building, but their intrinsic barriers increase significantly once they have been irradiated. Upon irradiation, they become category IVE SNM and are a low attractiveness target for both overt and covert theft. The low concentration of the Pu in the fuel, Pu isotopics, and the high radiological barrier make diversion more difficult. Once the fuel has been irradiated, the radiological barrier makes handling the material more difficult and its attractiveness for reuse is significantly reduced. If the fuel assemblies are placed into dry spent fuel storage, they still have a significant radiation barrier and when placed in the storage containers, are almost impossible to move without being detected. If, after sufficient time the fuel assemblies are no longer self-protecting (100 rem/hr at 1 m), the material could become category IID. They still are not a particularly high theft target because of the significant external barriers in place. Item accountancy is used to account for fuel assemblies. The application of C/S measures including markings and seals on the assemblies reduces the likelihood for covert diversion. The fuel assemblies are discrete items that reside for long periods at a single location (e.g. reactor core, spent fuel pool, dry storage area). SHE is required to move these assemblies. Once they have been irradiated, remote handling is necessary. The material is generally not very accessible. For spent fuel, some NDA measurements are possible, but at the present time, they are generally used to confirm the presence of the spent fuel and not to accurately account for the material. Using the initial material information and the records from the reactor facility, the quantity of material can be indirectly estimated.

The presence of fresh MOX fuel assemblies is the primary factor affecting S&S and reactor operations. It may affect procedures, personnel qualifications, clearances, and response force requirements. It will be necessary to have a secure area where the SSTs can off-load the fresh fuel assemblies and areas where the necessary nuclear accountability and measurements can be performed. It may be necessary to store fresh fuel assemblies in a vault-like area or possibly storage pool where enhanced delay and access control measures are in place. It is very desirable to minimize the presence of fresh MOX fuel at the reactor site and therefore, it should only be present during core reloading. This may not always be operationally feasible. If fresh MOX fuel is only present during core reloading, then additional temporary S&S measures could be implemented to protect this material and perhaps new costly fresh fuel storage areas could be avoided. The protection against sabotage is no different for MOX fuel than it is for currently used commercial fuel. After the fuel has been irradiated and removed from the core, it will be placed in a storage basin. Item accountability and containment and surveillance measures will be in place. If the fuel is eventually placed into dry storage, appropriate measures are still needed.

Repository

The spent fuel is received in shipping casks and the assemblies are removed and placed into disposal casks. The material has low attractiveness. It is highly to moderately radioactive and each cask weighs approximately 125 tons. From 10 to 100 years, the radiological barrier would decrease by an order of magnitude. The material is a low attractiveness target for both covert and overt theft. Although a large amount of material will be entering the repository the process operations are relatively simple and few in number. Again, the operations are on very large discrete items that remain in the drifts where they are placed. Once a drift has been filled, it will be sealed. Item accountability is used for the casks. No access is available to the material itself, although access to the casks is possible. All movements of the casks requires special handling equipment.

Since the radiological barrier is time dependent, it is necessary to utilize other measures to help minimize the threat of diversion. Placement of the material in an underground repository makes retrieval of this material more difficult. The radiological barrier will decrease over a long period of time such that the material will not be self-protecting. Therefore, it is necessary for long-term disposition to make the material as inaccessible as possible and provide for a long period of time. Additional safeguards and C/S measures should be utilized to help protect this material, particularly for long time periods. It is also important that accurate accountability of the material be maintained so there is a high degree of confidence that the material was not diverted and was, in fact, placed into the repository. The casks will be sealed, item accountancy performed, and C/S measures implemented. Methods and procedures for long-term international monitoring are still under development.

Transport

For all category I material, SSTs will be used to move the material between facilities. Only after the MOX fuel has been irradiated will the requirement for SST movement be removed. The transport of SNM has inherently greater risks for overt theft scenarios and a lower risk for covert theft attempts. Minimizing the number and/or duration of the transport steps is desirable. Much of the risk for transportation is related not so much with the actual SST movements, but rather with the shipping and receiving activities at the various facilities. There are no known major impacts on transportation which will result from IAEA safeguards being applied. In the case of shipments by SSTs, "casual" inspection (e.g. an inspection which does not permit measurements or disclosure of sensitive design information about the SST) would be permitted. Tracking and monitoring of shipments by IAEA while enroute would not currently be allowed. In order to meet IAEA safeguards requirements it is likely that IAEA seals would be placed on the individual containers and also on the doors of the SST without interfering with the operational security procedures

IAEA

The philosophies and implementation of ISG (commonly referred to as IAEA safeguards) are substantially different from domestic S&S. IAEA inspections involve different techniques and different goals than domestic S&S inspections. Nuclear measurements play an important role in verifying material accountability. Differences from "book" values and holdup are particularly important for high-throughput processes. Currently the IAEA does not recognize compensatory safeguards measures (e.g. defense-in-depth, item monitoring) that have allowed DOE facilities to extend inventory frequencies. Classified information (as in the Pu processing facility), will need to be protected. It is assumed that all facilities, except the Pu processing facility, will be subject to full IAEA safeguards. It is likely that ISG compliance requirements will require additional accountability verification (e.g. identification, weighing, sampling and analysis and NDA), increased inventories and item checks, C/S measures installed throughout the facilities (e.g. surveillance, seals, monitors, tags), space for inspectors, and equipment for independent measurements by international inspectors.

SUMMARY

It is assumed that all facilities will meet necessary S&S requirements and that appropriate protective measures will be taken. Integration of domestic S&S and

ISG to reduce cost and operational impacts would be beneficial. The final disposition form of the reactor alternatives meets the spent fuel standard. Facilities which handle large quantities of bulk material, have high throughputs, and involve very complex operations have a greater risk that material can be diverted. The Pu processing and MOX fuel fabrication facilities, which are common to all reactor alternatives, are such facilities. In addition, the material is relatively accessible and measurement uncertainty may mean that diversion of a SQ of material may be more likely. As the material is made into items (e.g. fuel assemblies), the likelihood for diversion decreases. After the fuel has been irradiated, the radiation barriers, along with the location and mass of the assemblies, makes theft, diversion and/or retrieval more difficult. Before the material is made into fuel assemblies, it is generally in a form which makes it very attractive and at greater risk for theft, diversion, and reuse. As the material is made into fuel assemblies it becomes a less attractive target. The increased number of moves, miles, and handling steps involved with the transport operations increases the risk for theft and diversion. In general, this proliferation risk can be reduced by minimizing the handling and processing of the material and by applying appropriate S&S measures.

In this paper, we have presented a discussion of factors to be considered in evaluating a nuclear facility for proliferation risk. This approach compliments the traditional vulnerability assessment (VAs) done by facilities and provides insight into the inherent proliferation risks for the individual processes and the facility. This information can then be used to help in developing the design or measures to help mitigate these risks. All nuclear facilities have an inherent proliferation risk due to their environment, processes, material forms, and available S&S measures. The establishment by DOE/MD of two criteria and the technical approaches to help evaluate the different disposition alternatives clearly indicates the importance of proliferation resistance for any nuclear facility. The evaluation of the various dispositions alternatives is in the early stages. The methodology continues to be developed and results of its application will be available in the future.

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Table 2 - Facility Attributes for Proliferation Resistance Measures

Criterion 1	**Plutonium Conversion**	**MOX Fuel Fabrication**	**Reactor**	**Repository**	**Transport**
Environment # of processing steps Max Pu inventory Bulk Pu throughput # SST trips/miles Fissile material(FM) wastes	• large # of complex processing steps • large Pu inventory • large bulk throughput • FM waste streams • glovebox operations • no intrasite transport	• initially high # proc steps and bulk throughput • for rods/assemblies there are fewer steps and no bulk throughput	• fewer and simpler steps for most reactors • no bulk throughput • low FM waste streams	• very few and simple process steps • no bulk throughput	• # of SST trips and miles • co-functional facility eliminates transport leg between Pu proc and fuel fab • secure SST loading area needed
Material Form DOE material attractiveness Other separated FM present	• matl attractiveness IB -IID • high conc pure metal and oxides • other separated FM is present • low intrinsic barriers • easily transportable	• matl attractiveness IC • high conc oxide initially and blended to lower conc • initially transportable, rods/assys - large size/mass	• matl attractiveness IC to IVE upon irradiation • self-protecting rad barrier • low Pu2 conc • large, massive assemblies	• matl attractiveness IVE • @ 100 yrs radiation less by an order of magnitude • @ 100 yrs % Pu239 higher • very large massive casks	• SSTs move all Cat I material • IVE moved via other means (truck, rail)
Safeguards & Security Accessibility Nuc matl meas accuracy MBA density Type of nuc acct sys Classification	• generally very accessible • primarily bulk nuclear accountability • higher meas uncertainty • classified material • no special handling equip (SHE) needed	• less accessibility for rods and assemblies • initially bulk acct and then item acct for rods/assys • special handling equip reqr for rods/assys	• item accountability • SHE for moving assys • limited access to fresh fuel • NDA very difficult	• item accountability • access to casks but not to the spent fuel • SHE needed to move casks	• item accountability • increased handling of containers • increased nuclear meas required to confirm material acct
Criterion 2					
Detectability Environment Material characteristics Safeguards	• very large throughput • meas uncertainty could result in difficulty in meeting IAEA reqr for SQ • complex processes	• bulk to item acct • large bulk throughput • complex processes	• item accountability • fresh fuel more accessible • large bulk assys	• item accountability • large massive casks • highly irradiated material (time dependent)	• large number of transactions • nuclear meas required for each change of custody • crossing intl boundaries and materials acct • transfer of custody
Irreversibility Material form Material location	• very attractive and accessible material • pure metal, oxide • classified material	• direct use material in fresh fuel, powder, pellets • complex processing • initially high conc of oxide	• irrad fuel - irrad direct use located in dry or wet storage • radiation barrier for spent fuel	• highly irradiated fuel • fuel located in casks and eventually underground	• direct use material before irradiation • increased handling for transport