

Title: FISSILE MATERIAL DISPOSITION AND PROLIFERATION RISK

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FISSILE MATERIAL DISPOSITION AND PROLIFERATION RISK

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ABSTRACT

The proliferation risk of a facility is dependent on the material attractiveness, level of safeguards, and physical protection applied to the material in conjunction with an assessment of the impact of the socioeconomic circumstances and threat environment. Proliferation risk is a complementary extension of proliferation resistance. We believe a better determination of nuclear material proliferation can be achieved by establishing the proliferation risk for facilities that contain nuclear material. Developing a method that incorporates the socioeconomic circumstances and threat environment inherent to each country enables a global proliferation assessment. In order to effectively reduce the nuclear danger, a broadly based set of criteria is needed that provides the capability to relatively assess a wide range of disposition options/facilities in different countries and still ensure a global decrease in proliferation risk for plutonium.

I. INTRODUCTION

As the quantity of weapons-usable nuclear material increases, the proliferation risk of that material increases. Recent proliferation events (FSU material smuggled to Germany) demonstrate that the proliferation of weapons usable nuclear material and nuclear technologic capability and expertise has become one of the predominant threats to US and global security. US and international efforts must focus on the threat of global or regional proliferation now that the

threat of a nuclear exchange no longer dominates our attention. Various individuals, groups, and nations have a strong motivation to acquire weapons-usable nuclear material rather than to produce it because there is significant cost and time expense related to the development of the necessary infrastructure for production. Nuclear proliferation risk is based on various material, protection, and socioeconomic related dimensions and the source, technical capability, and persistence of the potential purchaser. Some of the proliferation risk dimensions are material form; physical access to material during processing, storage, and transportation; the degree of safeguards and security applied; the economic conditions and pay for workers and guards; and the political stability of responsible government authorities. Potential purchasers (threat) are, for example, a terrorist group or national government. A national government may present a valid threat if it has demonstrated a desire and technical capability to develop a nuclear program. The dismantlement and disposal of fissile material must assure against the possibility of material proliferation.

In addition to studying the technologic feasibility and cost of various disposition options (vitrification, burial, conversion to MOX fuel, ...), the impact of proliferation risk requires investigation. Prioritizing which sites should initially contribute material for disposition and assessing the proliferation risk of any sites associated with the disposition process are important factors in decreasing the potential for proliferant activities. As indicated in Fig. 1, determining the proliferation risk of various facilities/sites

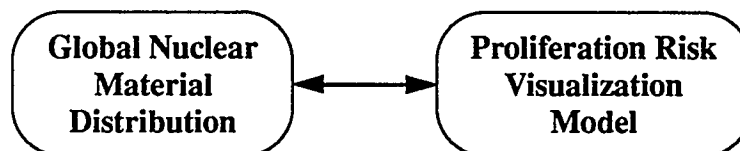


Figure 1. Proliferation risk analysis is dependent on the distribution of nuclear material.

prior or during the disposition process, requires the collection and correlation of all relevant information and data into a model capable of supporting systems studies and analysis.

II. GLOBAL NUCLEAR MATERIAL CONTROL MODEL

During the last year we have developed the foundation of a disposition and proliferation risk systems analysis capability, the Global Nuclear Material Control (GNMC) model. This prototype model, developed on a Sun workstation, permits us to conduct systems studies and analysis on the elements and factors that affect and are associated with the inventory of nuclear material. The GNMC has analytic computational capabilities in the following areas: management, protection, control, and accounting (MPC&A) safeguards and security resource allocation, material disposition options, and material production and dismantlement (proliferation source). The GNMC provides a representation of this information and the data related to nuclear facilities/sites and the inter- and intra-country nuclear material distribution. The GNMC characterizes site and facility information, nuclear material inventory data, and nuclear material production capabilities. Specific analytic capabilities have been included to calculate the future production of nuclear material, alternative disposition options, and to estimate future inspection resource requirements for nuclear material MPC&A required to meet International Atomic Energy Agency (IAEA) safeguards and security criteria. In addition to the GNMC effort we have been researching an analytical model for determining the proliferation risk of specific countries/sites/facilities, within the context of the GNMC.

III. PROLIFERATION RISK MODEL

The distinction between proliferation resistance and risk requires clarification. The proliferation resistance of nuclear material is dependent on the material attractiveness in association with the level of safeguards and physical protection applied, shown in Fig. 2. The degree of safeguards and security applied domestically and internationally is related to a material attractiveness determination. Criteria have been developed by the IAEA, the Department of Energy (DOE), and the Nuclear Regulatory Commission (NRC) for evaluating the relative attractiveness of nuclear materials for use in weapons. These criteria are used for the purpose of applying a ranked safeguards approach so that materials that are most easily used for nuclear weapons purposes are assigned increased safeguards. Summarized in Table 1, these criteria are generally based on the time that would be required to process the material into weapons-grade, the technical difficulty of that processing, and the quantity of material considered significant for the development of a weapon. Although the criteria differ slightly, especially for the significant quantity value, there is similarity and overlap amongst the related attractiveness concepts and levels. The 1994 National Academy of Sciences (NAS) study [1] suggested using the "spent fuel standard" as a metric for evaluating the proliferation resistance associated with options for the final disposition of plutonium from nuclear weapons declared excess to military purposes. The "spent fuel standard" simply stated means that excess weapons' plutonium is made as inaccessible for weapons use as the large amounts of plutonium in commercial spent fuel. The spent fuel standard is a material attractiveness

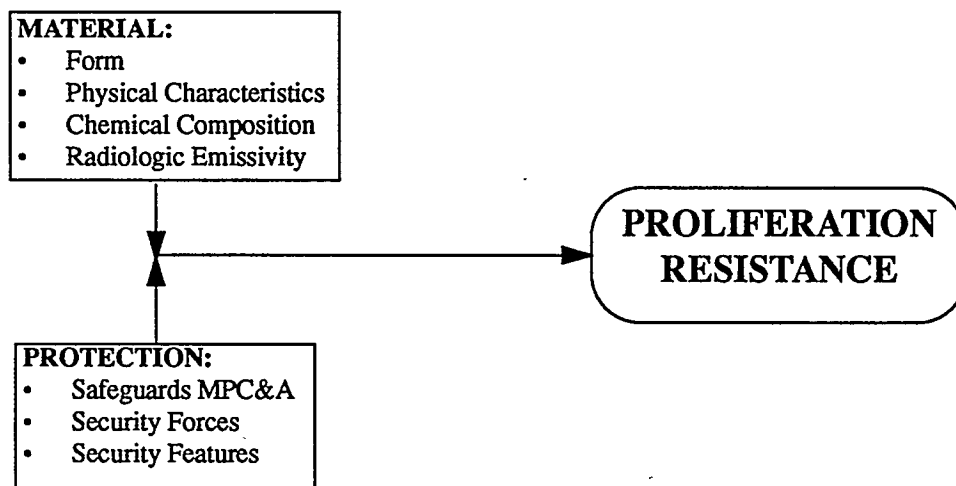


Figure 2. Elements of proliferation resistance.

TABLE 1. Material Attractiveness Criteria to Determine Ranked Safeguards and Security.

Criteria	IAEA	DOE	NRC
Significant Quantity	8 kg	2 kg	2 kg
Attractiveness of material for weapons use.	Difficulty & time of processing required for usable form	Amount of processing required for usable form	Quantity of material and degree of self protection
High and low of the attractiveness level range ¹ .	High - Separated Pu Low - Fuel Assembly	High - Assembled weapon or device Low - Highly irradiated forms	High - Large qty. & low self protection ² Low - Small qty. & high self protection

1) The DOE range of levels in order of decreasing attractiveness are: assembled weapons; directly convertible materials such as pits; high-grade materials such as oxides; low-grade materials such as process residues; and highly irradiated forms. 2) High self protection for Pu is defined as Pu in radioactive material with a total external radiation dose rate in excess of 100 rems/h at

concept, it defines proliferation resistance in terms of the self-protecting attributes of the material and its need for chemical processing. Proliferation resistance neglects the impact contributed by the threat environment and the socioeconomic circumstances.

The proliferation **risk** of a facility is dependent on the material attractiveness, level of safeguards, and physical protection applied to the material in conjunction with an assessment of the impact of the socioeconomic circumstances and threat environment. Proliferation risk is a complementary extension of proliferation resistance. We believe a better determination of nuclear material proliferation can be achieved by establishing the proliferation risk for facilities that contain nuclear material. Developing a

method that incorporates the socioeconomic circumstances and threat environment inherent to each country enables a relative global proliferation assessment. This is important if the criteria adopted by the US is to be a model for global fissile material disposition. In order to effectively reduce the nuclear danger, a broadly based set of criteria is needed which provides the capability to relatively assess a wide range of disposition options/facilities in different countries and still ensure a global decrease in proliferation risk for plutonium. The effectiveness of safeguards can only be determined when it is considered with respect to the current socioeconomic circumstances and threat environment, otherwise the level of safeguards only indicates the proliferation resistance of a disposition facility. Depicted in Fig. 3

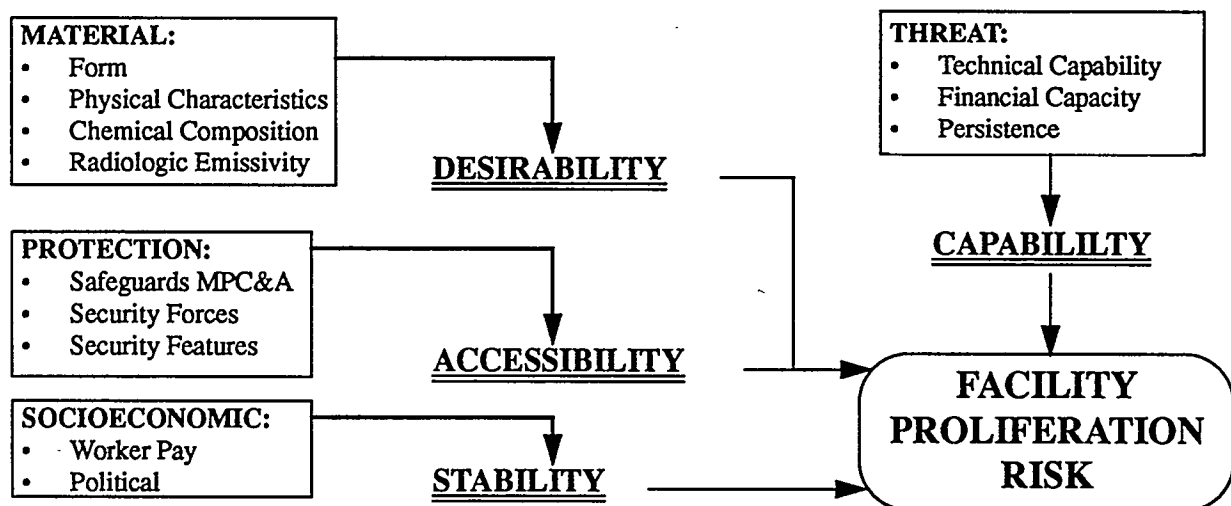


Figure 3. Dimensions of facility proliferation risk.

are the four components that comprise the proliferation risk analytic model; material desirability, protection accessibility, socioeconomic stability, and threat capability.

A. Material Dimension of Proliferation Risk

The material dimension is determined by a number of components related to the physical attributes of the material. The form of the material with respect to the actual physical characteristics, chemical composition, and radiological emissivity influence the desirability of the material and hence the proliferation risk of that material. The physical characteristics, weight, and size affect a proliferator's ability to transport the material. For example, a plutonium pit resulting from dismantlement is more easily concealed and transported than a spent fuel assembly. The chemical composition of the material influences the level of technical knowledge and capability a proliferator must have, as well as the time it takes to produce a weapons-usable form. Plutonium metals, carbides, and oxides require no or little processing to manufacture enough material in a usable form. Whereas, plutonium in spent fuel requires time-consuming and complex processing to manufacture enough material. Finally, the radiological emissivity of the material imposes restrictions on handling and shielding requirements, which increase the time and complexity to process the material. Spent fuel requires remote handling equipment and shielding to prevent lethal radioactive dosing. Quantitative measures exist for this dimension, such as size, weight, and rems/h at 1 meter. The desirability of the material is dependent on the physical characteristics, chemical composition, and radiological emissivity of the material. Material resident at a particular facility that is desirable, results in greater proliferation risk for that facility.

B. Protection Dimension of Proliferation Risk

The protection dimension is determined by the physical access to material during processing, storage, and transportation and the degree of safeguards and security applied. Physical access is related to the quantity and type of impediments imposed around the processing, storage, and transportation of the material and the degree to which these impediments can be defeated or compromised. Generally, the greater the number and type of impediments the less accessible the material becomes and the lower the proliferation risk. Some of the typical components to consider as part of physical access are gates, guards, monitors, physical structure, penetration difficulty, facility isolation, and for a processing facility, the degree it is automated (preventing worker access). Components to consider as part of safeguards are automated accounting systems and containment and surveillance systems. Quantitative measures exist for this dimension, such as type and quantity of barriers and quality and quantity of safeguards systems. Safeguards and

security are dependent on the material accounting and control technology and the containment and surveillance technology. The more safeguards and security technology utilized at a facility the less accessible and hence, the less likely material theft and diversion occurs. The less accessible material is at a facility the lower the proliferation risk for that facility.

C. Socioeconomic Dimension of Proliferation Risk

The socioeconomic dimension is dependent on the economic conditions and pay for workers and guards and the political stability of responsible government authorities. This is at least partially a subjective measure. However, by using it to conduct relative comparisons between sites and states, it is an important element in an assessment of proliferation risk. By including this dimension we are able to include assessments, evaluations, or information that exist and to provide a basis by which proliferation comparisons and ranking can be made. For example, one way to defeat or compromise the physical access impediment component of the protection dimension is to bribe workers or guards, which will occur with more success if the bribee is economically distressed. In politically unstable states the proliferation risk increases due to the lack of authoritative control, the perception that there are no responsible authorities, and when there is no authority to impose punishment. Quantitative measures exist for this dimension, such as gross domestic product, per capita income, cost of living, and unemployment rate. The quantitative measures are supplemented by qualitative measures such as political stability, level of civil strife, type of political regime, and political leadership assessments. Associated with decreased socioeconomic stability is increased proliferation risk.

D. Threat Dimension of Proliferation Risk

A proliferation threat can come from a criminal, terrorist, sub-national organization, or national government. Disposition facilities and sources for fissile material are of particular concern in, for example, the states of the FSU, the threshold weapon states (India, Israel, and Pakistan), and the potential weapon states (Iran, North Korea, and Iraq). In the FSU, accounting for nuclear materials has been limited but physical protection measures have been strong. However, there are recent signs that the physical protection system may be eroding and that the criminal and terrorist threats in these countries have increased. All three of the threshold states are reported to have nuclear weapons production capability with a limited stockpile. The potential states, Iraq and North Korea, have clearly had proliferant activities and Iraq is suspected of having a clandestine nuclear weapons program. Associated with a threat is a degree of persistence or commitment and technical capability and financial capacity to successfully obtain and process

fissile nuclear material into a usable form. The proliferation risk of a disposition related facility can be strongly affected by a broad spectrum of completely divergent threats; a well funded, organized, and technically capable terrorist group desiring fissile material; or the political decision of a nation to initiate a weapons program. The complexity, time, and cost of the processes required to recover a significant quantity of material through chemical reprocessing or isotopic enrichment is a measure of the difficulty of processing and inversely, the isotopic quality of the material. This measure of difficulty indicates the level of technical capability and resources required by the threat to be successful. Quantitative measures exist for this dimension, such as chemical form, isotopic concentration, process facility needs, and time and cost to process a significant quantity, which can be utilized to determine the threat's required level of technical capability and financial capacity. Threats with technical capability, financial capacity, and political or ideological commitment increase the proliferation risk.

E. Interdependence of Dimensions

The components of the proliferation risk elements: material desirability, socioeconomic stability, threat capability, and protection accessibility are interrelated. Variations in one component either necessitate a responsive change in another component or alter the proliferation risk assessment of a disposition facility. The following variations in the proliferation risk dimension components illustrate some of these interdependencies. The material form influences the safeguards MPC&A; materials in item form are more readily safeguarded than materials in bulk form where measurement uncertainties complicate precise accounting for the material. Radioactive emissivity influences the technical capability and financial capacity required by the threat; radioactivity increases the self-protective nature of the material which makes theft and transport more complex. Economic deprivation of workers or guards influences the security features and security forces; unpaid workers are more likely to divert material for criminal or terrorist threats. Political agreements and policies are only valid if they are durable; political instability creates opportunity for proliferation threats. Examination of the interdependencies and trade-offs between all of these components is necessary to achieve a proliferation risk assessment and to determine the efficacy of safeguards.

F. Country Proliferation Risk

To obtain the proliferation risk assessment for a country, it is necessary to assess all the facilities at all the sites within a country. Figure 4 shows the hierarchical nature of proliferation risk at the country level. The aggregation of proliferation risk for facilities and sites is straightforward. However, the most important assessment is at the facility level. A number of methods, including fuzzy logic and data fusion techniques, will be required to develop and implement the facility proliferation risk assessment capability.

IV. SUMMARY

Evaluating the proliferation risk of proposed disposition facilities or processes for plutonium needs to satisfactorily include the risks from the beginning to the end of the disposition process. To determine these proliferation risks, it is necessary to include the threat environment and socioeconomic circumstances in each country. The "spent fuel standard" provides a proliferation resistance measure, but does not consider the threat environment or socioeconomic circumstances in a country. The level of safeguards applied at a facility only indicates the resistance of the facility to proliferation. The effectiveness of safeguards systems is indicated by the proliferation risk of the facility. Proliferation risk can only be determined when it is considered with respect to the current socioeconomic circumstances and threat environment.

The GNMC establishes the framework and an analytical model for evaluating and assessing the global production, disposition, and international safeguards and security requirements for nuclear material. A benefit of this work is the resulting capability to establish and investigate proliferation risk. By exploiting and utilizing the GNMC framework as the foundation for the development of a proliferation risk system analysis capability, we have the ability to determine the proliferation risk of existing disposition sites/facilities.

REFERENCE

- 1) National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium*, National Academy Press, Washington, D.C. (1994).

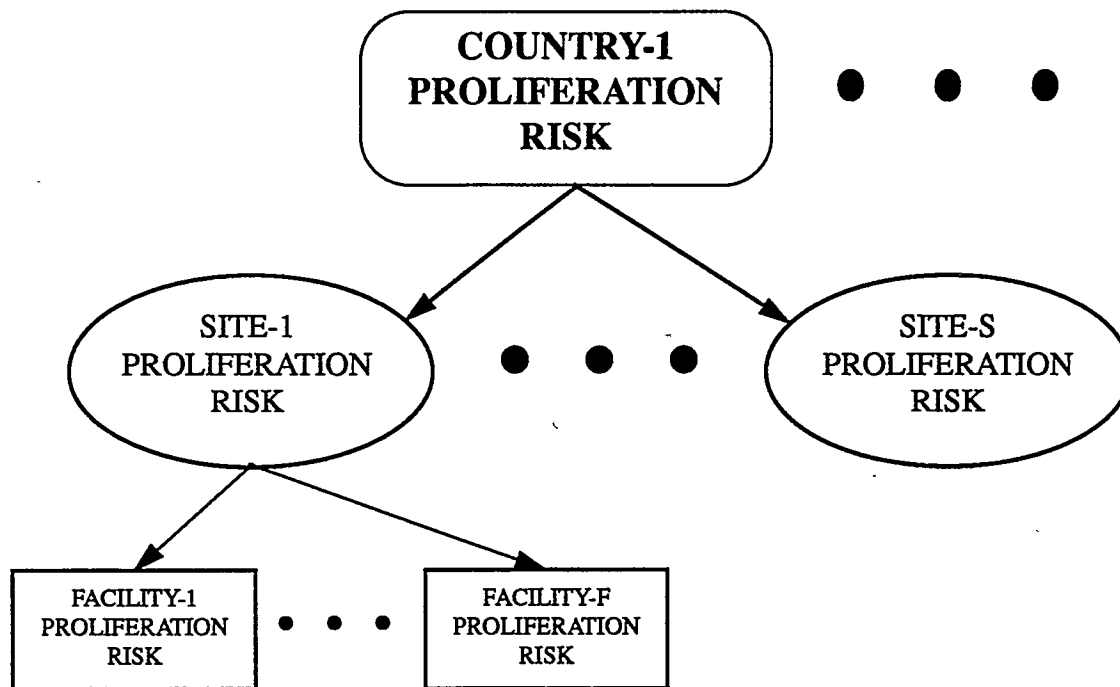


Figure 4. Country proliferation risk depends on proliferation risk at all sites and facilities.