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Safeguards Material Attractiveness Level Criteria—History and Prognosis

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Abstract

Application of the concept of nuclear material attractiveness level as a criterion in grading safeguards and security protection requirements has had a profound effect on the DOE complex. Nuclear material attractiveness level refers to the attractiveness of various forms of material as a target for theft or diversion. Evolution of the attractiveness level concept has progressed from the 5630 series of DOE Orders (1979–1980) to the current orders (DOE O 474.1, 1999) and is still continuing to evolve. Recently, consideration of such issues as material disposition and safeguards termination has affected the attractiveness level concept. The concept has been exported to the Russian Federation as a result of the joint US/Russian MPC&A upgrade program. This paper summarizes the history of the concept, describes its impacts on safeguards systems, and discusses possible future developments.

Introduction

The graded safeguards concept was formally defined and introduced in DOE Orders, 5630 series, published in 1980. It was further expanded in DOE Orders, 5633 series, published in 1988. The primary objective of formally defining the graded safeguards concept was to convey in a technically defensible manner that all quantities and compositions of nuclear materials were not of equal value and importance relative to national security. As a result, it was believed that nuclear safeguards program requirements, i.e., physical protection, accountability, and material control, should be tailored and applied to the spectrum of nuclear materials in a manner appropriate to the strategic importance and use of these materials. While the graded safeguards concept considers both the category of material (quantity) and the attractiveness level of the material (composition), this paper will focus primarily on the evolution of the material attractiveness level as a criterion in grading safeguards and security requirements, the impacts that the attractiveness level criterion has had on safeguards systems, and possible future developments.

Nuclear material attractiveness/attractiveness level (AL) refers to the relative attractiveness of different amounts of various chemical and physical forms of nuclear materials as targets for theft or diversion. Inherent in the definition is the assumption that the intended use of stolen material is the development of a nuclear weapon or improvised nuclear device (IND). In addition to material quantity, AL is dependent on two factors: (1) portability of the material (i.e., ease of acquisition and removal, which may also impact probability of detection), and (2) ease of conversion to a weapon-usable form. Portability is primarily dependent on the size and mass of the items containing the nuclear material; ease of conversion depends upon the chemical form and the presence or absence of other materials.

Evolution

AEC Manuals and Appendices, 7400 Series. Before 1980, DOE nuclear facilities utilized the regulations and requirements prescribed in the Atomic Energy Commission (AEC) Manuals and Appendices, 7400 series, for establishing and maintaining safeguards and security programs. These documents were largely silent with regard to the graded safeguards concept. The only criteria that could be considered an application of graded safeguards were the separation of nuclear materials into three classifications (special, other, and source) and the definition of differing accounting units (e.g., kilograms, grams, tenths of grams, hundredths of grams, etc.) for the various nuclear materials. Otherwise, these regulations did not identify any further gradation in the requirements for the protection, accountability, and control of nuclear materials.

The early graded safeguards practices were quite limited and were applied to materials according to their strategic importance without regard for quantity or attractiveness of the material. Graded safeguards practices were applied according to material classification (special, other, or source). Materials deemed special nuclear materials (SNM) were given more importance than materials designated as other nuclear materials or source materials. However, plutonium and uranium enriched in ^{233}U and ^{235}U (the materials identified as special nuclear materials) were usually given equal importance from a safeguards perspective. Likewise, there were no distinctions for gradation made within a material type, e.g., scrap and residues within a material type were typically provided the same level of control and accountability as feed and product material.

It is of interest that AEC Appendix 2401-071-A, "Physical Security Standards," issued in August 1961, defined security requirements based on three degrees of accessibility. These were an accessible form that was easily prepared for use as a nuclear explosive, a workable form for materials that required difficult processing steps for conversion, and an inaccessible form for materials that require very complex processing steps for use as nuclear explosives. However, this categorization of materials did not carry over into the 7400 series orders.

DOE Orders 5630 Series. In 1980, DOE promulgated its own regulations, DOE Orders, 5630 series. These orders formally defined the graded safeguards concept and required facilities to establish and follow a graded safeguards program. The following is a quote taken directly from DOE Order 5630.2 relative to defining graded safeguards and requiring facilities to implement this program concept.

> *Operations offices and facilities shall establish and follow a graded safeguards program for SNM. Graded Safeguards is the concept of providing the greatest relative amount of control and effort to that SNM which is most effectively used in a nuclear explosive device. This means that plutonium-239, uranium (≥ 20% U-235), and uranium-233, in the form of metal and compounds should receive more stringent controls than special nuclear material that must be processed, transmuted, or enriched*

to make it useable in an explosive device. Material in the most useable form must be inventoried frequently, placed under the tightest administrative controls, and, according to DOE Order 5632 series requirements, must be subject to the most stringent physical security measures.

The orders also prescribed various graded safeguards applications. Special nuclear materials were deemed more important than source and other nuclear materials. The graded safeguards concept also effectively ranked the materials within the special nuclear material category. Two kilograms of plutonium and ^{233}U were provided the same level of protection, accountability, and control as five kilograms of uranium enriched to greater than 20 percent in the isotope ^{235}U. For details refer to Fig. 2 of DOE Order 5630.2, entitled Material Control and Accountability Categorization of Nuclear Material.

DOE Order 5630.2 prescribed different inventory frequencies for the various category levels of nuclear materials. For details refer to Fig. 3 of DOE Order 5630.2, entitled Minimum Graded Nuclear Material Program Requirements. Additionally, this order began to vary the measurement requirements for material transfers between DOE nuclear facilities. That is, time requirements were established for completing measurements for category I and II transfers.

The 1980 DOE Order 5630.2 also initiated defining attractiveness levels for the special nuclear materials, but only in the category I area. The order identified two attractiveness levels, A and B. Attractiveness level A included the compositions of special nuclear materials that are considered directly usable in constructing an IND. Attractiveness level B included the compositions of special nuclear materials that only after being subjected to some limited processing could be usable in constructing an IND. These attractiveness levels were not at this time applied to category II and III levels of SNM. And, of course, at this time, category IV materials consisted entirely of non-SNM materials. For details refer to Fig. 4 of DOE Order 5630.2, entitled Example Ranking of SNM According to Possible Attractiveness for Diversion.

Although, the DOE Order 5630.2 was silent on the subject of rollup, it was nevertheless an important part in determining the category level of a facility, MBA, or inventory item.

Category I quantities of SNM were determined based on the following criteria:

- plutonium and/or ^{233}U when the plutonium and/or ^{233}U content is 2000 grams or more;
- uranium 235 (contained in uranium enriched to 20% or more in the isotope ^{235}U) alone, or in combination with plutonium and/or ^{233}U when (multiplying the plutonium and/or ^{233}U content by 2.5) the total is 5000 grams or more.

As one can readily ascertain from the above, in the absence of consideration of material attractiveness, a facility could be classified as category I with minimal amounts of SNM. The resources required to protect a category I facility are substantial. Thus it became necessary to further grade the safeguards program to protect facilities in accordance with the graded safeguards concept, i.e., "*the concept of providing the greatest relative amount of control and effort to that SNM which is most effectively used in a nuclear explosive device.*"

DOE Orders 5633 Series. In 1983, DOE issued its first document on threat guidance relative to theft and diversion of special nuclear materials. The threat guidance identified various adversarial acts, material targets, and potential consequences associated with losses of SNM. The primary concern of the early threat guidance, consistent with the graded safeguards concept, was the loss of special nuclear material that could be readily used to construct a nuclear explosive device.

In 1987, following issuance of a set of safeguards and security inspection standards and criteria, DOE convened a task force to revise all of the safeguards and security orders. The intent was to update the order requirements and to ensure that the requirements were consistent with the inspection standards and criteria. Accordingly, the task force established several committees to revise the various safeguards and security orders.

The committee responsible for revising the material control and accountability orders agreed that further definition of the graded safeguards concept was needed. The committee agreed early on that the graded safeguards concept should focus on variety of factors, not just material quantities, in establishing appropriate protection, accountability, and control requirements. Some of the other factors considered were: material composition, radiation levels, processing requirements, volume and mass, packaging and handling requirements, and accumulation time frames. All of these factors in one way or another affected the attractiveness of SNM to an adversary. After several meetings with weapon engineers, threat-awareness personnel and experienced safeguards and security personnel developed the graded safeguards table that is used today and is included in DOE Order 5633.3. For details refer to Table I-4 of DOE Order 5633.3, entitled Graded Safeguards, or to DOE Manual 474.1-1.

Some of the more significant program changes between the graded safeguards program specified in DOE Order 5630.2 and DOE Order 5633.3 were:

- established five attractiveness levels
  a. weapons,
  b. pure products,
  c. high-grade materials,
  d. low-grade materials,
  e. all other materials;
- established quantity ranges for each attractiveness level (refer to Table I-4 of DOE Order 5633.3);
- eliminated the quantitative combination of multiple material types;
- established a new method for determining effective quantities within a single material type (refer to Table I-5 of DOE O 5633.3); and
- defined and incorporated a credible rollup concept.

From the above list, the most challenging concept for facilities to interpret and implement has been credible rollup. This is especially true when dealing with SNM residue categories. Currently, most people tend to focus primarily on the ease or difficulty of process recovery of the material. It is important, however, to consider other factors (such as processing efficiencies, material volume and mass needed to derive a category I quantity, as well as the credibility and probability of a successful theft scenario) that might affect the likelihood of obtaining a category I quantity of material. If one remembers the underlying theme of graded safeguards, it is the concept of providing the greatest relative amount of control and effort to that SNM that can be most easily be converted into a nuclear explosive device.

DOE Manual 474.1-1. During the mid to late 90s, additional material control and accountability concepts were developed and added to the regulations to help guard against the loss of a category I quantity of material. These concepts are:

- Safeguards Termination Limits (Refer to Table I-2, DOE M 474.1-1);
- Retained Waste Criteria (Refer to Table I-3, DOE M 474.1-1); and
- that holdup, material retained in processing, be considered to be category I until determined otherwise.

The intent of these MC&A concepts is to guard against locating appreciable quantities of residues containing easily recoverable material in areas that may be readily accessible to adversaries and to guard against inadvertently leaving potentially large quantities of attractive material in equipment after a facility or building is closed and awaiting decontamination and decommissioning. Large quantities of attractive materials would pose a high risk if a facility were left unprotected and unmonitored. DOE M 474.1-1 clearly states that these materials are not exempt from MC&A requirements simply because they are deemed no longer needed or deemed economically recoverable.

Future Developments

In general, application of the graded safeguards principle has increased efficiency of the protection of nuclear materials. The implementation of the use of material attractiveness has refined the approach to graded safeguards. As a result, there has been improvement in the allocation of safeguards resources to protection of the most attractive material (targets). However, there are several areas where improvement is needed.

- Sites have not always applied graded safeguards appropriately to the threat.
- Vague policy, particularly in the area of credible rollup, has resulted in inconsistent application of safeguards requirements. Rollup needs further development. Additional clarification needs to be provided regarding the various material compositions within an attractiveness level. Various material compositions that cannot be combined for processing should not be considered equally for rollup purposes. Also, provisions should be made for assessing the credibility of rollup combinations in specific applications (e.g., attractiveness level D materials in drums, where material from several drums would have to be combined involving multiple attempts, etc.). Consideration should also be given to utilization of monitoring technologies that may negate the credibility of rollup.
- Recent changes in material disposition policy have resulted in some confusion in the application of graded safeguards. Many sites consider the policy to dispose of material as waste as a reason to reduce safeguards on attractive materials before their disposition. The policy for safeguards for such material needs clarification.
- The basis for attractiveness level determination could be improved. The division between levels A and B is very clear. The separation of levels B and C is also unambiguous because it is based on the 50-atom-percent level for material to be directly used to make a weapon or IND. The

breaks between attractiveness C and D, and D and E, are not as clear and should be revisited. There should also be additional discussion concerning material acquisition challenges and time-lines and material removal factors, such as total mass, volume, number of removal attempts, and any equipment handling assistance requirements.

- As existing spent fuel in storage is aging and cooling, additional consideration should be given to better defining graded requirements for intermediate-level irradiated forms of material.