Nonproliferation and Arms Control Impacts on Declared Excess Fissile Material

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Submitted to: DOE Spent Nuclear Fuel & Fissile Material Management
Reno, Nevada
June 16-20, 1996
NONPROLIFERATION AND ARMS CONTROL IMPACTS
ON DECLARED EXCESS FISSILE MATERIAL

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ABSTRACT

The presence of nuclear materials derived from dismantled nuclear weapons presents new safeguards and security issues for international inspections, for example, inspections by the International Atomic Energy Agency. The requirements of an IAEA inspection under existing guidance and the areas of conflicting interests are discussed. Possible solutions to these issues are presented. Experiences with actual inspections of material at the Y-12 facility at Oak Ridge and the Rocky Flats Environmental Technology Site are presented. A technique to recast some of the material is discussed. A new nondestructive assay/verification instrument that may satisfy the requirements of an inspection is described.

I. INTRODUCTION

A series of events started with President Clinton's speech to the United Nations on 27 September 1993, in which he stated "...the U.S. will:...Submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency...". This was followed by the joint statement issued on 16 March 1994 by Secretary of Energy O'Leary and Russian Minister of Atomic Energy Mikhailov that "announced their intention to host reciprocal inspections by the end of 1994 to facilities containing plutonium removed from nuclear weapons." On 1 March 1995, President Clinton stated "I have ordered that 200 tons of fissile material...be permanently withdrawn from the United Stated nuclear stockpile...never again to be used to build a nuclear weapon."

These initiatives have set a new precedent for the inspection by international agencies of materials derived from the dismantlement of nuclear weapons and the nuclear weapons complex. The United States has been actively interacting with the International Atomic Energy Agency (IAEA) and other international agencies (through bilateral agreements) to perform these inspections and prepare for further inspections. The Y-12 facility at Oak Ridge, Rocky Flats Environmental Technology Site (RFETS), and Hanford have already had inspections on selected materials. These declared excess fissile materials were non-strategic and had been withdrawn from defense applications. However, with the 200 ton fissile materials initiative, classified materials could potentially be included in the inspection regime. This presents challenges to the inspection regime. Many aspects of the design of nuclear weapons components are classified. Depending on the specific methods that are used, inspections of these components have the potential to reveal this information to the inspectors. The requirement to protect sensitive nuclear weapon design information creates a dilemma for international inspections. On the one hand, inspection procedures that limit access to sensitive information, because of the need to protect it, may not provide the level of assurance or confidence that is desired. On the other hand, inspection procedures that expose enough information to provide high confidence may reveal information that increases the risk of nuclear weapons proliferation.
II. IAEA INSPECTION REQUIREMENTS

The primary objective of IAEA safeguards "...is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons, other nuclear explosive devices, or for unknown purposes, and the deterrence of such diversion by the risk of early detection." IAIA safeguards is not designed to prevent or deter unauthorized possession of nuclear material. The two important components of IAEA safeguards to accomplish their primary objective are nuclear material accountancy, and containment and surveillance.

Nuclear material accounting establishes the quantities of nuclear material present within defined areas and the changes in these quantities that take place within defined periods of time. This means the accounting system of the IAEA is based on the mass of the material of each item in the inventory. To accomplish this activity, IAEA inspectors inspect the accounting records and material transactions reported by the operators of the facility being inspected. They make independent measurements of the safeguarded nuclear material. This can either be a nondestructive assay of the material, and/or a sample taken for chemical analysis at the Agency's Safeguards Analytical Laboratory. These activities are aimed at verifying the inventory. The accountancy verification goal is defined as the "minimum quantity of nuclear material which, if diverted at a facility, should...be detected by the application of nuclear material accountancy measures along with a low risk of false alarm...[For] item facilities...the goal is equal to one significant quantity of nuclear material...[For] bulk handling facilities...the goal depends on the nature of the facility, the quantities of material handled, and the effect of measurement uncertainties...". For plutonium, the IAEA identifies 8 kilograms as one significant quantity. For highly-enriched uranium (HEU), uranium enriched to 20% and above in the isotope $^{235}\text{U}$, the IAEA identifies 25 kilograms of $^{235}\text{U}$ as one significant quantity.

Complimentary to nuclear material accountancy is containment and surveillance. Containment measures take advantage of physical barriers such as walls, containers, tanks or pipes, to restrict or control the movement of or access to nuclear material. Such measures help to reduce the probability that undetected movements of nuclear material or equipment can take place. Containment measures may involve the application of devices such as uniquely identified tamper-indicating seals to ensure that any change in the sealed inventory will be detected. Surveillance means both human and instrumental observation to detect undeclared movements of nuclear material, tampering with containment, fabrication of false information, or tampering with safeguards devices. Surveillance may involve the use of tamper-resistant automatic cameras or other devices to monitor changes in containment or to observe changes.

These material accountancy measures and containment and surveillance can be intrusive activities at the facility. Weapon component design information cannot be transferred under current law or guidance. This information cannot be revealed during any inspection because this would violate the Atomic Energy Act and the Treaty on the Nonproliferation of Nuclear Weapons. This dictates severe restrictions on activities that can occur during an inspection on certain items included in the Presidential statements. Before regular IAEA inspection activities can begin at a site, a facility attachment is negotiated between the host facility and the IAEA to identify the inspection activities. This may dictate a new regime for IAEA inspections. This may define a transparency regime. "Transparency" can be defined as measures that a country can take to build international confidence that it is abiding by treaties, agreements, or unilateral declarations while minimizing operational impact on facilities and loss of information that could negatively impact national security or result in proliferation of weapons design information. This may dictate new types of instruments and methods that can be used in these inspections. Although the IAEA has extensive experience with safeguards on plutonium and HEU, it has no experience with safeguarding nuclear weapon components. Special procedures must be considered for this type of material.

III. OPTIONS FOR IAEA INSPECTIONS

A. Measurement of Nonsensitive Attributes

Traditional IAEA safeguards nondestructive assay (NDA) measurements rely on high-resolution gamma-ray spectroscopy, neutron coinci-
dence/multiplicity counting, and calorimetry. These instruments cannot be applied to sensitive materials because of the information derived from the measurements. Thus, other measurement techniques must be considered, assuming no changes in the Atomic Energy Act and the Treaty on the Nonproliferation of Nuclear Weapons. The following discussion is not an exhaustive list of measurement possibilities. It indicates some types of measurements that can be made that do not reveal sensitive information.

1. Total Gamma-Ray/Neutron Dose Rate. The technique of measuring the total radiation (neutron plus gamma ray) dose outside a component storage container is well understood. The difficulty with this technique from the standpoint of verification is that it only allows the inspector to ascertain that the material in the container is radioactive. It provides low confidence that the material is either plutonium or HEU.

2. Relative Temperature. The idea of measuring only a relative temperature rise of a component storage container above ambient room temperature arose out of concern that full calorimetry would reveal the mass of the plutonium. The measurement of the relative temperature rise of a plutonium-component storage container implies the presence of a heat-generating object. Such an object could be a strongly alpha- or beta-radioactive material such as americium, plutonium, or fission products. Thus, the temperature by itself does not necessarily imply the presence of plutonium. One could conceive of spoofing such a system by replacing the component with, for example, a battery and a coil of wire. However, if normal precautions such as tags and seals are used, such a spoof would be easily discovered on later inspections. This technique would provide low confidence that the material in the container was plutonium rather than some other alpha emitter and is not appropriate for HEU because of negligible heat generation.

3. Low-Resolution Gamma-Ray Spectroscopy. The use of single-channel, low-resolution gamma-ray spectroscopy is specifically addressed by classification guidance with respect to its application to weapons. The caveats are that classified information must not be revealed by such measurements, and the gamma-ray energy chosen must be less than 300 keV. This presents added difficulties to protect sensitive information about uranium components.

B. Measurement of Sensitive Attributes that only Disclose Nonsensitive Information

Quantitative nondestructive assay methods were developed to produce the most accurate and precise quantitative measurements of nuclear materials possible. They would all reveal sensitive weapon component information if they were applied, without modification, to the verification of nuclear weapons components. Passive/active neutron multiplicity counting, high-resolution gamma-ray spectroscopy, fast-neutron interrogation, calorimetry, and radiography will all give detailed information about the item being measured. Thus, these instruments used as currently designed without any means to protect the sensitive data, are not an acceptable measurement program.

In the early 1980s, as part of the Hexapartite Safeguards Project (HSP), the concept of measuring sensitive information and releasing only nonsensitive information essential to verification decisions was implemented by the Los Alamos National Laboratory for IAEA inspections of gas centrifuge enrichment plants. (The HSP consisted of six holders of the gas centrifuge enrichment technology, United States, United Kingdom, Germany, Netherlands, Japan, Australia, and the IAEA and EURATOM inspection authorities.) Information released to the inspector allows a verification decision but does not reveal sensitive process information.

Within the last few years, the Controlled Intrusiveness Verification Technology (CIVET) concept was proposed by Brookhaven National Laboratory for bilateral verifications of treaty-limited items. The CIVET concept consists of hardware, software, and procedures integrated with various sensor technologies. It is designed for the purpose of permitting an inspecting party to perform a high-confidence inspection while at the same time providing assurance to the inspected party that sensitive data are not revealed to the inspector. It can be applied, for example, to radiography scans and high-resolution gamma-ray spectroscopy data. The CIVET concept is considered as primarily an application of computer-security technology involving such techniques as...
removable memory, encryption, bilateral authentication, and seals.

In a CIVET system: (a) the hardware is specially designed to minimize the opportunity for clandestine data storage or transmission; (b) the software is developed to perform all data acquisition, data analysis, and template comparison with minimal operator input, and to display verification conclusions containing no sensitive information; and (c) the inspection procedures are intended to prevent any unauthorized access to or modification of the equipment in order to prevent possible compromise of sensitive information, while allowing use of the equipment to make reliable, high-confidence inspection measurements. CIVET instruments are intended to have enough built-in "intelligence" that they can draw reliable verification conclusions based on analysis of intrusive data without revealing any of that data to the inspectors. Major issues to be addressed include software development, electronics design, authentication of hardware and software, authentication of the template used for data analysis, assurance that the equipment can neither store nor transmit sensitive data, tamper protection, and security procedures for joint use by the inspectorate and the facility operator.

IV. IAEA INSPECTION EXPERIENCES AT THE Y-12 FACILITY AT OAK RIDGE AND THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

There are considerable quantities of enriched uranium, produced for use in U.S. nuclear weapons, now stored at the Y-12 facility at Oak Ridge. At the time the inspections were being proposed (1994), Y-12 operated a foundry that could melt the HEU metal and cast it into right circular annuli, thereby eliminating any classified information that had been associated with the material prior to casting. About ten metric tons of this HEU was placed in a dedicated vault at Y-12, and the facility was added to the “Eligible Facility List,” making the vault (and its resident HEU) eligible for IAEA inspection. The Agency conducted its initial inventory verification in September 1994.

When it became clear that material at RFETS would be offered to the IAEA for inspection, DOE and the Site conducted a careful review of the entire inventory and found that there was no measurable material at RFETS that was not classified. But DOE and the U.S. Government felt that it was very important that the U.S. continue to demonstrate to the world that the U.S. was, and is, committed to nuclear dismantlement. A review of the reasons for classification of the nuclear material was undertaken, and it was decided that the composition of plutonium oxide could be revealed without compromising our national security. Shortly thereafter, nearly one metric ton of plutonium oxide was placed in a dedicated vault at RFETS, and the IAEA conducted its first inspection and verification of the plutonium in December 1995.

These two actions at Y-12 and RFETS helped initiate the implementation of President Clinton’s directive to withdraw up to 200 tons of excess nuclear material from the defense stockpile. They also appear to be the last steps that can be taken until the issue of sensitive information is resolved. The Y-12 foundry is no longer operating, and no one is certain when it will resume. The plutonium oxide that RFETS has withdrawn is the only unclassified, measurable plutonium available. Plutonium “pits” hold a fair fraction of the tonnage needed to reach President Clinton’s ultimate goal, but pits cannot be assayed by the IAEA because doing so would reveal classified information to the Agency. Until the IAEA considers a different approach for verifying the U.S.’s voluntary declarations, or the U.S. develops methods for measurement of sensitive attributes that only disclose nonsensitive information, it will be very difficult for President Clinton’s initiative to progress.

V. ADVANCED RECOVERY AND INTEGRATED EXTRACTION SYSTEM (ARIES)

Advanced Recovery and Integrated Extraction System (ARIES) is an automated system supported extensively under the Material Disposition program which will extract the plutonium from excess weapons pits into ingot form. The advantage of the system is that most classification issues related to this plutonium material are unclassified. Through the additional step of recasting the ingot materials into a uniform mass (e.g., 4.5 kg), the output of the system (i.e., the material itself) will typically be completely declassified. This of course assumes that all infor-
information related to its origination pit, weapon, or weapon’s system is removed.

Because the output of uniform plutonium ingots is in unclassified form, this material can easily be verified and measured by the IAEA. As a final caveat, there must be continued vigilance to assure against the unintentional disclosure of unclassified details that could reveal classified information such as average or specific pit mass.

Although there is a certain amount of interest in monitoring pits early within this process, this appears to necessitate a modified international inspection regime which would be less than acceptable. Clearly, the optimal time for inspection for the IAEA would be at the output of this system.

Finally, there may be an opportunity to provide an additional level of confidence or transparency through negotiated bilateral or multilateral arrangements with other weapons states. Such a concept, although pursued at various times, is still in the formative stage and may not, in fact, increase the overall confidence within non-weapons states.

VI. MULTIPLICITY FINGERPRINT DETECTOR FOR WEAPONS COMPONENTS

Verification of nuclear weapons dismantle-ment activities poses many challenges, particularly in the case of radiation measurements. There are important requirements in the area of both data content and protection. Verification measurements must have enough sensitivity to be meaningful while at the same time protecting weapons design information. Clearly, traditional NDA approaches will be too revealing, and other procedures that either severely restrict or eliminate radiation measurements will have questionable meaning because of a lack of sensitivity to the object being verified.

Los Alamos National Laboratory is developing an instrument that may satisfy both requirements. One potential solution is to produce nuclear material “fingerprints” containing both gamma-ray and neutron information that have been mixed, or scrambled, by the physics of the detection process. This detection system is best described as a fast-response, neutron-plus-gamma-ray multiplicity detector. It is composed of an array of boron-loaded plastic scintillators that are optically coupled to bismuth germanate (BGO) scintillators. The two scintillators are coupled so that the light output is collected by a single photomultiplier tube. The plastic scintillator produces pulses from proton recoil events and slow neutron capture [(neutron, alpha) reaction] by $^{10}$B. The plastic scintillator is also sensitive to gamma-ray radiation resulting from Compton scattering within the detector. The BGO scintillators are primarily gamma-ray sensitive. A custom coincidence circuit is employed to process the signals. The result is an output that represents the combination of the BGO and plastic scintillator signals. The multiplicity distribution resulting from the combined detector output contains contributions from the detector as well as from the source. The detector contributes a time-correlated signal through the neutron scatter-and-capture process and through the mechanism of multiple scattering of neutrons and gamma rays. Because the material being measured undergoes fission, it produces a correlated radiation signature of neutrons and gamma rays. The output is a distribution of coincident events. The result is a “multiplicity fingerprint” measurement that is characteristic for certain classes of items.$^{12}$

Currently, data are being collected on many different types of samples to determine the stability and repeatability of the measurements and to characterize the samples by “classes”. Samples have included gamma-ray and single-neutron sources (low multiplicity), californium sources (high multiplicity), and plutonium oxides and ingots. Such measurements will be combined with detailed models of the source and detector physics to provide computer simulations of the proposed measurements. These simulations will provide the basis to evaluate and demonstrate the applicability of the multiplicity fingerprint technique to transparency and IAEA inspections.

VII. DISCUSSION AND SUMMARY

We have presented arguments to demonstrate that placing nuclear material derived from dismantled nuclear weapons under traditional IAEA safeguards is not a viable option. There would be an immediate conflict with the Atomic Energy Act and the Treaty on the Nonproliferation of Nuclear Weapons with obligations not to assist non-nuclear weapon states in acquiring weapons.
We have presented results from actual experiences of IAEA inspection activities at RFETS and at the Y-12 facility at Oak Ridge. There have also been IAEA inspections at a Hanford/Westinghouse facility. The material under IAEA safeguards at these latter two facilities do not have all the material sensitivities associated with them as material derived from nuclear weapon components, and still the implementation of safeguards has been difficult and expensive.

The ARIES process is a viable technique to recast plutonium into standard ingots of unclassified shape of approximately the same mass. However, care must be taken to ensure there is no accounting mechanism that will allow correlating the output to specific input items.

The multiplicity fingerprint counter can yield a signature that is characteristic of certain classes of material. We are still identifying the degree to which quantitative information may or may not be extracted from the data. If the positive aspects of this instrument continue, this may yield a possible solution to the inspection problem. This will not result in the application of traditional IAEA safeguards, but the application of a “transparency” inspection. But the specific IAEA requirements for inspections at these facilities are still under negotiation. The facility attachment agreement for each facility will decide the specifics of the inspection activities at any given facility.

Perhaps for some of these facilities that do have nuclear material derived from dismantled nuclear weapons, a “transparency” regime may be more appropriate than a traditional IAEA safeguards regime. “Transparency” can be defined as measures that a country can take to build international confidence that it is abiding by treaties, agreements, or unilateral declarations while minimizing operational impact on facilities and loss of information that could negatively impact national security or result in proliferation of weapons design information. International safeguards issues can be resolved with careful analysis, preparation, demonstrations, and negotiations.

REFERENCES


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