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EXCESS FISSILE MATERIALS

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NONINTRUSIVE VERIFICATION ATTRIBUTES FOR EXCESS FISSILE MATERIALS

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ABSTRACT

Under U.S. initiatives, over two hundred metric tons of fissile materials have been declared to be excess to national defense needs. These excess materials are in both classified and unclassified forms. The U.S. has expressed the intent to place these materials under international inspections as soon as practicable. To support these commitments, members of the U.S. technical community are examining a variety of nonintrusive approaches (i.e., those that would not reveal classified or sensitive information) for verification of a range of potential declarations for these classified and unclassified materials. The most troublesome and potentially difficult issues involve approaches for international inspection of classified materials. The primary focus of our work to date has been on the measurement of signatures of relevant materials attributes (e.g., element, identification number, isotopic ratios, etc.), especially those related to classified materials and items. We are examining potential attributes and related measurement technologies in the context of possible verification approaches. The paper will discuss the current status of these activities, including their development, assessment, and benchmarking status.

1. INTRODUCTION

With the end of the Cold War, the United States and the Russian Federation are taking unprecedented steps to reduce their nuclear arsenals. Fissile materials once needed to ensure the peace are now no longer required for defense purposes. As nuclear weapons are reduced and weapon programs are downsized, large amounts of weapon-origin plutonium and highly-enriched uranium (HEU) become surplus to defense needs. The international verification of this excess material is seen as desirable. However, proliferation is a great danger, and this excess fissile material is often in classified or sensitive forms. Placing this material under traditional International Atomic Energy Agency (IAEA) safeguards would unquestionably lead to the disclosure of classified weapon-design information, which would violate U.S. law and key provisions of the

Treaty on the Non-Proliferation of Nuclear Weapons (NPT) [1]. Consequently, such an approach is not possible.

Alternative verification techniques, similar to those used by the IAEA for international safeguards but which would not reveal sensitive information, may be possible by means of nonintrusive verification. This is a maturing concept, and the sample technologies that are presented below should be viewed only as examples of a possible solution to one of the key verification challenges of the post-Cold War era.

2. FISSILE MATERIAL ATTRIBUTES AND SIGNATURES

As noted, traditional IAEA safeguards would not be acceptable for excess classified or sensitive materials. Adapting safeguards approaches for the inspection of such materials could involve measuring attributes of an inventory of material in classified or sensitive forms in a manner that does not reveal classified information. Attribute measuring could then be followed by nonintrusive monitoring designed to ensure that the material has not been returned to weapon programs. This could provide confidence that materials placed under inspection are consistent with the declarations without revealing sensitive information. Measurements of multiple attributes, or multiple measurements of different signatures relating to the same attribute, could be used to provide robustness and anomaly resolution.

3. INFORMATION BARRIERS

Our approach is to consider the use of information barriers with intrusive technologies. Such barriers are designed to protect the classified information, perhaps by reporting the results of the measurement as a simple yes or no.

A "defense-in-depth" approach is envisioned which would provide assurance to the inspected party that all sensitive information is protected and to the inspecting party that the measurements are being performed as expected. Physical protection (locks, vaults, surveillance systems, etc.) and data/software protection (encryption, electronic signatures, etc.) of the instruments and computers, which would presumably be controlled by the inspected party, could be used as part of an information barrier scheme. In addition, the inspecting party could use physical tamper-indicating devices (seals, surveillance systems, etc.) to ensure that instruments, computer, and software have not been altered. Finally, an unclassified interface could be used to display and, possibly, record measurement results.

4. EXAMPLE MEASUREMENT TECHNOLOGIES

4.1 High-Resolution Gamma: HPGe

The ability to determine the presence of weapon-grade plutonium in sealed storage containers is of potential utility in this new arms control arena. Lawrence Livermore National Laboratory (LLNL) has developed a technique to determine the ratio of $^{240}\text{Pu}/^{239}\text{Pu}$ based on analysis of the 630–670 keV region in a high-resolution gamma-ray spectrum. Current work is focused on applying this technique to verify a declaration of the presence of weapon-grade plutonium while

seeking to prevent the possible loss of classified or sensitive information. This latter objective is being pursued through the application of an information barrier. If fully realized, such a barrier would not reveal the spectral data or the actual value of the $^{240}\text{Pu}/^{239}\text{Pu}$ ratio.

This technique may prove useful in a nonintrusive verification application where the spectral analysis is restricted to the region between 630 and 670 keV. The code is a variant of the well known MGA code, which has been tested on a large number of plutonium sources in different fissile material containers, and is automated to assure low intrusiveness and repeatable operation. Currently the code only reports the ratio of $^{240}\text{Pu}/^{239}\text{Pu}$ while accounting for the ^{241}Am that underlies the plutonium peaks in this region of the spectrum.

The code has been modified so that it never reveals the spectrum to the operator and reports only whether the $^{240}\text{Pu}/^{239}\text{Pu}$ ratio falls below or above a threshold value. LLNL is attempting to build a combination shield, absorber, and collimator to allow for a wide dynamic range of signals into the system. This would, in principle, allow placement of the detector at a single standard fixed distance from the source and allow for a single standard data acquisition time. It will be important to fully test and evaluate this technique, and the modified code, to ensure they are consistent with agreed objectives, including the protection of classified or sensitive information [2,3].

4.2 Neutron: Multiplicity Counting

Neutron multiplicity counting, like high resolution gamma-ray spectroscopy, is an established technology used by the IAEA for verification of fissile material inventories. For an inventory of classified materials, however, the data that neutron multiplicity techniques provide are also classified. If the requirement is to verify that these materials contain some threshold quantity of plutonium, however, there are no other known techniques that could, in principle, accurately provide this information and could also be authenticated without revealing classified or sensitive information.

One approach being examined at Los Alamos National Laboratory is to consider the use of multiplicity counting with an information barrier. Again the barrier is intended to protect the classified information by reporting the results of the measurement as a simple yes or no. Isotopic information (either as an assumed value or from another protected attribute measurement) is to be securely reported to the multiplicity counting software where it is used to convert the measured ^{240}Pu effective mass to total plutonium. The multiplicity counter would thus allow a determination that the item contained a threshold quantity of plutonium. If the assay falls in the agreed range, only a "yes" would be reported to the inspector.

This approach is well-understood and appears quite robust. For example, the multiplicity counter can distinguish isotopic neutron sources from fissile plutonium. It also can detect poor grade material by measuring the ratio of (alpha,n) neutrons to spontaneous fission neutrons and also by measuring a ring ratio. The latter is the ratio of the total neutron rate in the innermost row of detector tubes to that in the outer most row. Because the innermost tubes are the most sensitive to low-energy neutrons and the outermost are the most sensitive to high-energy neutrons, this ratio is a crude measure of neutron energy. Here, too, testing and evaluation will be essential [4,5].

5. EXAMPLE MONITORING TECHNOLOGIES

5.1 Low-Resolution Gamma: NaI Template

The gamma-ray spectrum of nuclear weapons, weapon parts, and other nuclear materials have unique characteristics due to amounts and thicknesses of the nuclear materials and intervening materials. The gamma-ray spectra of two objects that are of the same type will be very much alike, while the spectra of two objects of different types will be different. An approach is being explored in which a gamma-ray spectrum representative of a given type of object can be compared with a spectrum of another object that is claimed to be of the same type. The identity of the inspected item is confirmed if the spectra are indistinguishable within statistical and measurement uncertainties. While the data being used in the comparison will be highly sensitive, it should be possible to protect the data so that neither the inspecting nor inspected party has exclusive access to the data. If, after full testing and evaluation, this technology is viewed as appropriate, it could make a significant contribution to a nonintrusive monitoring effort [6].

5.2 CZT

Cadmium zinc telluride (CZT) detectors are ideally suited for miniature, low-power nuclear monitoring systems for unattended operation. The high atomic number of CZT crystals ensures a high photoelectric stopping power, whereas the high resistivity of this material ensures both low noise and low power consumption operation. Sandia National Laboratories has developed very low power ($< 1 \text{ mA @ } 3 \text{ V}$) CZT sensor systems capable of measuring the total dose rate from a nuclear material storage container. The current system, which is currently undergoing system testing, is self-contained in a package of approximately 100 cm^3 and is capable of unattended operation for up to five years without external power sources. Information from the dose rate monitoring system can be transmitted via a radio frequency telemetry system and is then disseminated via a Storage Monitoring System architecture that allows secure, periodic readout of the stored nuclear material data from a remote computer server. The acceptability of this feature in a monitoring approach will have to be determined [7].

6. SUMMARY/NEXT STEPS

Members of the U.S. technical community are exploring two proposals: (1) that multiple unclassified attributes can be declared and verified by an international inspectorate in order to provide confidence in the verification of a declaration of a sensitive or classified inventory while protecting the sensitive information; and (2) that attributes can be measured, remeasured, or monitored to provide continuity of knowledge in the irreversibility of the declaration in a nonintrusive (unclassified) manner. At present, the work has only just begun, and it is not now possible to assess their validity. While the concepts and technology approaches associated with these propositions in current U.S. technical work appear promising, neither the attribute verification approach nor the example techniques described in this paper have been fully developed, tested, and evaluated. Extensive technical work is still required in this area.

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