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Title: Verification of Classified Fissile Material Using Unclassified Attributes

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VERIFICATION OF CLASSIFIED FISSILE MATERIAL USING UNCLASSIFIED ATTRIBUTES

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ABSTRACT

This paper reports on the most recent efforts of U.S. technical experts to explore verification by IAEA of unclassified attributes of classified excess fissile material. Two propositions are discussed: (1) that multiple unclassified attributes could be declared by the host nation and then verified (and reverified) by the IAEA in order to provide confidence in that declaration of a classified (or unclassified) inventory while protecting classified or sensitive information; and (2) that attributes could be measured, remeasured, or monitored to provide continuity of knowledge in a nonintrusive and unclassified manner.

We believe attributes should relate to characteristics of excess weapons materials and should be verifiable and authenticatable with methods usable by IAEA inspectors. Further, attributes (along with the methods to measure them) must not reveal any classified information.

The approach that the we have taken is as follows:

1. assume certain attributes of classified excess material,
2. identify passive signatures,
3. determine range of applicable measurement physics,
4. develop a set of criteria to assess and select measurement technologies,
5. select existing instrumentation for proof-of-principle measurements and demonstration, and
6. develop and design information barriers to protect classified information.

While the attribute verification concepts and measurements discussed in this paper appear promising, neither the attribute verification approach nor the measurement technologies have been fully developed, tested, and evaluated.

INTRODUCTION

This paper documents our efforts to develop an attribute measurement approach for IAEA verification of excess weapon-origin fissile materials in classified forms. The most important consideration in the development of technology for the verification of such materials is the requirement to protect sensitive nuclear weapon design and other classified information from release to unauthorized parties, as required by Article 1 of the Treaty on Nonproliferation and the U.S. Atomic Energy Act, as amended. Unfortunately, we believe that the classical application of all traditional nondestructive methods for performing measurement and monitoring functions will reveal classified information. However, we also believe that it will be possible to construct instruments to analyze sensitive measurement data that would, using "information barriers," present only unclassified results to the inspector.[1,2] Development of a technical approach to attribute verification is ongoing; while significant progress has been made, much remains to be done. The primary challenge will be to develop potential measurement approaches and information barriers that can permit meaningful verification conclusions regarding fissile materials removed from nuclear weapons while protecting sensitive information.

ATTRIBUTE VERIFICATION APPROACH

We are currently pursuing a verification approach based on the measurement of a number of unclassified attributes of fissile material in sensitive form to provide confidence that the material is consistent with its declarations without revealing sensitive information. The purpose of such a verification would be to provide independent confidence that materials are as declared. Measurements of multiple attributes, or multiple measurements of different signatures relating to the same attribute, could, in principle, be used to provide robustness and anomaly resolution options. In addition, these or other attributes could be measured, remeasured, or monitored to provide continuity of knowledge in a nonintrusive and unclassified manner.[3-5]

Our approach was to first assume that certain unclassified attributes of classified excess material will be present in all of the items offered by the host nation for verification. The next step was to identify passive signatures of these potential attributes and unclassified threshold values for each. Then we determined the range of applicable measurement physics and developed a set of criteria to assess and select measurement technologies.[6] Following this, proof-of-principle measurements and demonstration on potential measurement instrumentation were performed. We are beginning the final steps—to design, test, and evaluate information barriers to protect classified information while providing confidence to the inspector that the attribute verification measurements are being performed correctly.

ATTRIBUTES AND SIGNATURES

Some example plutonium attributes of excess weapons materials in classified form are listed in Table 1, along with signatures and potential measurement approaches. Note that the use of multiple attributes may provide robustness and possibly anomaly resolution, but the measurement of two or more attributes of a single item may be connected. For example, an isotopics measurement used to confirm that plutonium is weapons-grade may be needed to complete a neutron- or heat-based mass threshold measurement. If the exact value of the isotopic is sensitive, then the transfer of that data to the mass measurement system can potentially be done "blindly" behind an information barrier.

We have begun to examine how an attribute verification approach could be used to confirm a state's declaration. For example, a number of items might be *declared* to contain *weapons-grade plutonium*. The attribute would be weapons-grade plutonium, and a signature might be the *isotopic ratio of* ^{240}Pu *to* ^{239}Pu. If this isotopic ratio measures less than an agreed-upon value, say 0.1, the weapons-grade plutonium attribute would be confirmed. At this point we ask ourselves several questions. What are the other signatures of this attribute? How can they be measured? How can sensitive information be protected? How can the inspectors authenticate the measurements? How can anomalies be resolved?

Which other attributes or measurement approaches might be complementary to this example thereby potentially providing robustness?

Table 1. Example Plutonium Attributes, Signatures, and Measurement Methods

Attribute	*Relevance*	*Signature*	*Measurement Approach*
Presence of plutonium	Fissile material used in weapons.	Emits neutrons, specific gamma rays	Detect neutrons, specific gamma rays.
Weapon-grade plutonium	High-grade fissile material specifically prepared for weapons.	Emits neutrons, specific gamma rays. Intensity of specific gamma rays indicative of weapon-grade.	Measure ratio of intensities of gamma rays from 240-Pu to 239-Pu.
Threshold plutonium mass	More than a trivial quantity in the container.	Emits neutrons, gamma rays; heat source.	Radiation, spontaneous fission, or heat emission rates.
Heat	Plutonium emits heat.	Heat.	Measure heat output.
Plutonium purity	Fissile materials in weapons are of high purity.	Absence of impurity signatures.	Unknown.
Sameness	In large-scale arms reductions, many items may have similar signatures.	Radiation signature comparison of many items.	Radiation signature template matching.

POTENTIAL MEASUREMENT METHODS

To begin testing the approach discussed above, we focused our attention on three promising measurement approaches for verification of plutonium attributes: high- and low-resolution gamma-ray spectroscopy and passive neutron multiplicity counting. In a collaborative effort involving Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories (SNL), preliminary measurements were made on a number of different U.S. pits to begin evaluation of the attribute verification approach. Three different measurement techniques were applied on these pits. These techniques are briefly described below. For a more detailed description of these technologies, see references 6-8.

The 30-gallon Drum Neutron Multiplicity Counter was developed by LANL to assay plutonium-bearing weapons components. The multiplicity counter might be used to make a determination that the item contained a threshold quantity of plutonium. Isotopic information (either as an assumed value or from another protected attribute measurement) would have to be securely reported to the multiplicity counting software (behind an information barrier) where it is used to convert the measured ^{240}Pu effective mass to total plutonium. The instrument we have tested is located at Rocky Flats Environmental Technology Site and currently is used annually by the IAEA for physical inventory verification of unclassified U.S. excess weapons plutonium currently under their safeguards.

A second technique tested is the LLNL High-Resolution Gamma-Ray Isotopic System that determines the isotopic ratio of ^{240}Pu to ^{239}Pu for plutonium sources in shielded containers to confirm that the plutonium is weapons-grade. The method uses an analysis code called Pu-600 that is a variant of the MGA code presently used by the IAEA. However, unlike MGA, Pu-600 uses only a small portion of the energy spectrum (630-670 keV) to limit the amount of potentially classified information obtained thereby reducing the risk of unintentional loss of sensitive information (although an information barrier will still be needed for use on a classified component or pit).

A third technique, developed by SNL, was tested using two low-resolution gamma-ray instruments. The Remote Inspector System is a portable sensor system that uses a template matching approach designed to confirm the identities of fissile materials in a variety of configurations (containerized pits, bulk materials, etc.). The Radiation Measurement System was designed specifically for pit identification in high radiation fields. While the data used in the comparison is highly sensitive, it should be possible to protect the data so that neither the inspecting nor inspected party has exclusive access to the data. These template approaches are also under consideration in a radiation-based monitoring approach.

The technology approaches associated with attribute verification appear promising; however, the example techniques described above have not been fully developed, tested, and evaluated. Extensive technical work is still required in this area.

CONCLUSION

Attribute measurement techniques for these materials can employ many familiar NDA methods. In general, the preliminary results of the three different measurements performed on classified weapons components appear promising. The use of attributes such as threshold values for isotopic ratios and mass appears to be feasible. However, field implementation of inspection approaches, including the use of information barriers, will require further testing and systems engineering development.

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