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THE ATTRIBUTE MEASUREMENT TECHNIQUE

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ABSTRACT
Any verification measurement performed on potentially classified nuclear material must satisfy two seemingly contradictory constraints. First and foremost, no classified information can be released. At the same time, the monitoring party must have confidence in the veracity of the measurement. An information barrier (IB) is included in the measurement system to protect the potentially classified information while allowing sufficient information transfer to occur for the monitoring party to gain confidence that the material being measured is consistent with the host's declarations concerning that material.

The attribute measurement technique incorporates an IB and addresses both concerns by measuring several attributes of the nuclear material and displaying unclassified results through green (indicating that the material **does** possess the specified attribute) and red (indicating that the material **does not** possess the specified attribute) lights. The attribute measurement technique has been implemented in the AVNG, an attribute measuring system described in other presentations at this conference.

In this presentation, we will discuss four techniques used in the AVNG: (1) the IB, (2) the attribute measurement technique, (3) the use of open and secure modes to increase confidence in the displayed results, and (4) the joint design as a method for addressing both host and monitor needs.

THE CHALLENGE
We anticipate a scenario in which the owner of a nuclear material, item, or process (the host party) makes a declaration concerning that item to another entity (the monitoring party). The monitoring party must verify this declaration. This nuclear measurement problem sounds straightforward, except that the nuclear item, and therefore radiation measurements made on the item, may be classified. Thus, the measurement challenge includes the two competing constraints:

1. The host party must be assured that classified information cannot be released. This assurance is documented through the process of certification.
2. The monitoring party needs to have confidence as to the veracity of the material declaration. This confidence is generated through the process of authentication.

Addressing either concern individually is uncomplicated, but in this case, both must be addressed simultaneously. In the remainder of this paper, we will discuss one approach to this challenge.

THE INFORMATION BARRIER

The use of nondestructive assay (NDA) radiation measurements to assay nuclear material is well known. Interpretation of such measurements is complicated when the nuclear material has classified characteristics. If the item and measurement results are potentially classified, an information barrier (IB), as shown in Fig. 1, can be used to protect the classified information [1]. All classified items, measurement systems, and data are kept inside the IB so that a monitor outside of the barrier cannot observe it.

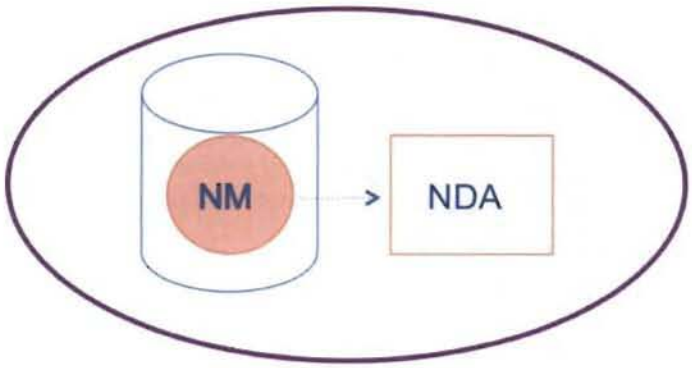

Fig. 1. A conceptual IB. The nuclear material and all measurement equipment are surrounded by a barrier that keeps any classified information inside and monitoring party outside.

Although Fig. 1 makes the IB seem simple—draw a purple line round the measurements and everything is fine—a successful IB must be more than the single barrier shown in this simple pictorial representation. The IB includes many layers of protection relying on (1) hardware, (2) software, and (3) procedural elements, as well as combinations of these types. Thus, the IB is built with "defense-in-depth" so that a single failure cannot result in information release and the entire system is fault-resistant and tolerant of faults in individual components.

ATTRIBUTE MEASUREMENT SYSTEMS

The closed IB described above can, relatively easily, protect any classified information contained inside. However, the verification challenge also requires that the monitoring party have confidence in the host declarations concerning the item within the barrier. A small and carefully controlled amount of information must be allowed to penetrate the barrier to satisfy the monitoring party's "confidence" needs while still meeting the host party's "protection" requirements.

One way of achieving this "controlled opening in the IB" is the attribute measurement system (AMS) shown schematically in Fig. 2 [2]. As before, the nuclear material, measurement systems, and all classified data are contained within the IB. The (potentially classified) measurement results are turned into unclassified attributes in the threshold comparison analyzer. The unclassified attribute information, in the form of yes (meets the attribute) or no (does not meet the attribute) signals, passes through the IB in the data barrier. The function of the data barrier components is to ensure that only unclassified signals can be passed to the operator display. This display, typically using red and green lights, is the output of the system that is observable by the monitoring party.

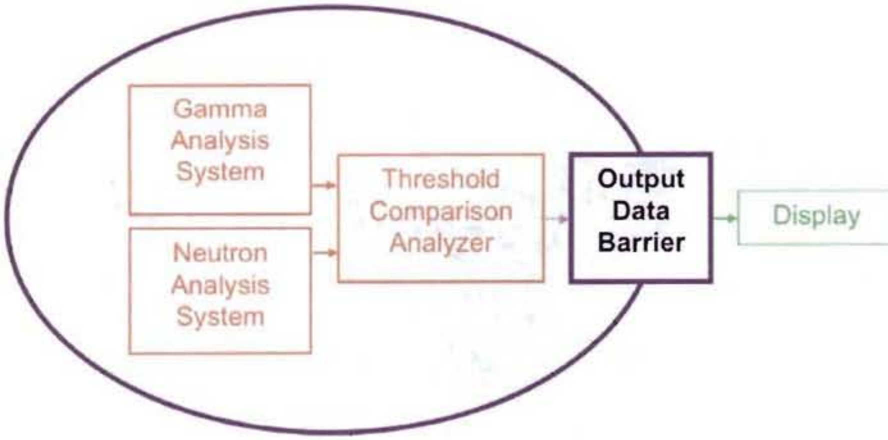

Fig. 2. An example of an AMS incorporating neutron and gamma detection systems. The Russian AVNG and similar systems use ^{3}He-based neutron detectors and high-purity germanium (HPGe) gamma detectors. Components potentially containing classified information are shown in red, IB components in purple, and unclassified components in green.

Attributes, as measured in an AMS, are nonclassified indicators of potentially classified measurement results. As in the example above, potentially classified information is often made into an attribute by comparing the information with a threshold (i.e., the attribute is "quantity above threshold"). Some potential attributes are the

1. presence of nuclear material,
2. nuclear material mass above a threshold,
3. plutonium isotopic ratio below a threshold, or
4. uranium enrichment above a threshold.

In any fielded implementation of an AMS, the host and monitoring parties would agree on the attributes to be measured (as well as the AMS itself).

The red and green lights, as described in the AMS, generate more monitor confidence than a closed IB would, but not a great deal more. The same red and green lights that cannot display classified information also cannot display enough measurement information to give the monitoring party much confidence in the result. Addition variations to the AMS concept must be used to increase confidence in the system.

AUTHENTICATION

Even though the AMS allows some information to pass through the IB, the IB is still quite effective at reducing the amount of information displayed to the monitoring party. The display of red and green lights does not do a great deal to inspire monitor confidence in the measuring system. Figure 3 shows an example of a closed AMS [3].

Fig. 3. An example of a closed AMS. Even though there is a controlled opening in the IB, this system is still not conveying a great deal information to the monitor.

DUAL-MODE OPERATION

One possibility for increasing monitor confidence is dual-mode operation [4]. One of these modes, termed the classified mode, operates as described above. All openings in the IB are closed, with the nuclear material inside, and the only results display is the simple red/green light panel. All measurements of potentially classified items are performed in the classified mode. Additional security may be gained if the classified mode is made the default mode of the AMS.

A second mode of operation, termed the unclassified mode, is used to generate additional monitor confidence. Doors in the IB may be opened to allow visual inspection of the measurement systems and IB components. More complete data displays (showing spectra, count rates, etc.) may be used in addition to the red/green light display panel. The unclassified mode can be entered only when a known "unclassified" container is present within the AMS. This container, which is used only for unclassified items, is typically mechanically differentiated (via a notch, groove, hole, etc.) from normal storage containers.

The unclassified mode generates additional monitor confidence only if the NDA measurements are the same in both modes. The monitoring party must believe that measurements made in the classified mode, which the party cannot see, are identical to the measurements that were observed in the unclassified mode. One design detail stemming from this requirement is that the measurement systems cannot have any input that changes between unclassified and classified modes. It is acceptable for the measurement systems to inform the rest of the AMS when an operation is complete, but it is not acceptable for the AMS structure to convey any mode information to the measurement systems.

COOPERATIVE DESIGN

Another approach to increasing monitor confidence is a joint (monitor and host) design. In a traditional design sequence, one party designs, builds, and certifies (or authenticates) the measurement system. The second party then authenticates (or certifies) the system. One of the parties must have last access to the system—does the other party still have confidence, or must confidence be established through other means?

In a cooperative design, both parties develop the design together and both parties build systems from that agreed-on design. In this case, both parties are intimately familiar with the design, capabilities, and foibles of the measurement system. In a cooperative scenario, if the host certifies its system and the monitor authenticates its system, then demonstrating the continued equality of the two systems adds to monitor confidence in the host system. In addition to authenticating its copy of the measurement system, the monitoring party is intimately involved with every stage of the design and construction process so that it (the monitoring party) will have a better understanding of, and more confidence in the eventual host-built monitoring system.

Although joint design is important, as with the IB, several details need careful thought. Joint design is one step that can increase confidence, but it does not "solve" the entire authentication problem. A companion paper in this session [5] looks at the practical problems in doing joint work with a party many thousands of miles distant. In a multilateral agreement, it may not be clear who the relevant parties are. It is extremely difficult to truly develop a system jointly with two parties. Adding third parties that must also be convinced adds to the difficulty.

THE AVNG

An AMS application that includes the concepts (IB, AMS, dual operating modes, and partial cooperative design) described in this paper is the AVNG shown in Fig. 4. The AVNG, which is described in this special INMM session, is an AMS built by RFNC–VNIIEF in Sarov, Russia [6]. The AVNG measures the three attributes of "plutonium presence," "plutonium mass >2 kg," and "plutonium isotopic ratio (^{240}Pu to ^{239}Pu) <0.1" and was demonstrated in Sarov for a joint US/Russian audience in June 2009 [7].

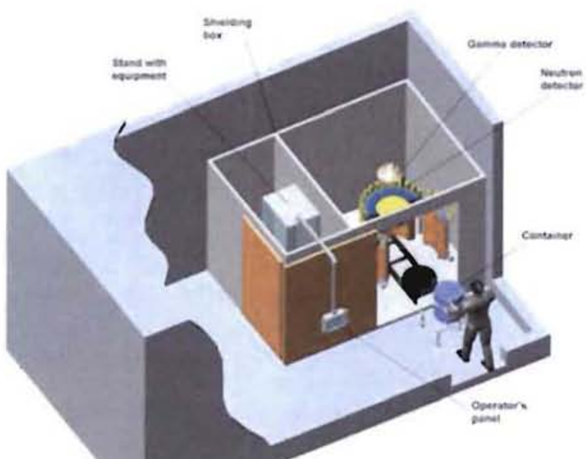

Fig. 4. Conceptual drawing of the AVNG. This system measures neutrons and gamma rays and incorporates the AMS and IB features outlined in this presentation.

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