IPNDV Working Group 3: Technical Challenges and Solutions
Nuclear Material (9)—Technology Data Sheet

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Nuclear Material (NM) Technology Name: Radiation Templates

Physical Principle/Methodology of Technology:

A radiation template is a data set of radiation signatures from weapons or weapons components. These radiation signatures are pre-defined before monitoring use and mutually agreed upon by treaty partners. The template is intended to provide a unique set of radiation signatures that are used to provide confirmatory verification of an inspectable item against a "trusted" item's data set (thus, establishing a reference or baseline template). Template-based systems were developed to allow comparison of radiation signatures of an item over time.

The reference radiation template is stored on a data storage device and is a part of a larger system that includes a radiation measurement system with hardware and software that perform data acquisition, processing, and data output to the user. (Note: This summary paper focuses on the radiation template used within the larger system and will not provide additional information on the template-based measurement system.)

The type of data stored as the radiation template will vary depending upon the radiation measurement system. Measurement data collected from radiation detection technologies that can be stored as the radiation template include the following examples: count rates in specified gamma-ray energy regions; derived information, such as gamma-ray peak areas; and coincidence waveforms or other neutron interrogation derived information.

Template matching allows verification of the identity of an item and the approach could use any of the radiation detection systems. The template approach is based upon initialization of a "trusted" item by establishing the template through a combination of procedures. Typically, the initialization procedures involve inspecting/authenticating the radiation detection equipment that will be used to make the measurements, verifying the authenticity of the reference item (i.e., using random inspection or an attribute measurement), measuring/collecting radiation signatures on the reference item, and securely storing the reference template. The confirmation of the identity of an inspected item involves comparison of radiation signatures with the reference, "trusted" item's template using a computer algorithm.

Potential Monitoring Use Cases (pre-dismantlement, dismantlement, post-dismantlement, storage stage):

Radiation templates can be used with radiation detection technologies for pre-dismantlement, dismantlement, post-dismantlement, and storage of weapons or weapons components.

Used to measure U, Pu, or U and Pu:

When the radiation template is used with radiation detection systems, U, Pu, U and Pu can be measured.

For detection technologies, what does the method determine/measure (e.g., presence of nuclear material, isotopics, mass, etc.):

This technology uses template matching to confirm the identity of an inspected item with the template from a "trusted" item based upon the radiation signatures stored as the template.

Physical Description of Technology (e.g., approximate size, weight):

The radiation template is a data set stored onto a data storage device that is used as a component of radiation measurement systems. Figure 1 shows the Trusted Radiation Identification System (TRIS) memory storage device and aluminum housing. The TRIS iButton, which stores the template, is less than 4 cm in diameter and houses one memory device (1.7 cm in diameter) inside the enclosure.

Figure 1: The memory devices used to store the TRIS template (left), and the iButton (right) which is an aluminum housing for the memory devices storing the template information. (Photo Credit: Sandia National Laboratories)

Time Constraints (e.g., measurement times including distance from object, time to install the equipment):

Minimal time (less than one minute) to attach the cable for the memory device to the system. TRIS (Trusted Radiation Identification System) is used as an example template-based system for the time constraints: Setup of TRIS equipment – 10-15 minutes; obtaining measurements and performing calculations with TRIS – 10-15 minutes per item, typically measured at 1 m from the object.

Measurement time to measure 500 g of Pu (0.1 $^{239}Pu/^{240}Pu$) or 500 g of ^{235}U at 1 m from the surface of the container (order of magnitude: seconds, minutes, hours, days):

Using TRIS as an example template-based system, TRIS measurements consist of a 1-minute background measurement followed by a 1 minute spectrum collection. This measurement time was determined to be adequate through a comprehensive series of measurements on relevant items.

Will this method work in the presence of shielding? If so, what is the maximum amount of shielding that will still allow the method to work?

It will depend upon the radiation measurement technology selected to make the radiation template, such as gamma or neutron detection technologies.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

The radiation detection system's hardware and software that are used are custom-designed for simplicity. Most of the challenges lie in working with public/private keys for the template, if the template contains sensitive information.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

Secure storage of digitally signed templates for future comparative measurements is required for a sensitive radiation template. Additional infrastructure requirements will be based upon the radiation detection system chosen for the radiation template.

Technology Limitations/Variations (e.g., detection limits for nuclear material, operational temperature range, differences in technology detector materials):

Challenges for template-based approaches:

- Protecting sensitive information in the template, if required
- Ensuring that an authentic item is used to produce the reference template
- Selecting a set of unique radiation signatures for a detection technology
- Confirming the identity of items as radiation signatures change from the original item through any processing or work on the item

Information Collected by the Technology (used to help determine if an information barrier is required for use):

The radiation template of classified or sensitive items must be protected.

Safety, Security, Deployment Concerns:

There are no safety or deployment concerns except those that would be associated with the radiation detection system. Data security for the classified data stored as the radiation template is typically addressed by hardware data encryption on the storage device and software encryption of the data by the system.

Technology Development Stage (Technology Readiness Level, TRL):

There are numerous custom-designed radiation storage devices for the radiation templates that have been developed by the U.S. national laboratories and used for monitoring demonstrations (TRL 7). The laboratories continue to upgrade and improve the existing systems and the associated components.

Additional System Functionality (e.g., outside the monitoring use case):

Custom-designed to eliminate extraneous functionality.

Where/How the Technology Is Currently Used (e.g., international safeguards, border protection):

Radiation template systems, such as the Radiation Measurement System, have been used to support U.S. domestic safeguards applications for material control and accountability.

Examples of Equipment:

All systems listed below use radiation templates and were custom designed.

Manufacturer	Equipment/ System Name	Radiation Template Information
Brookhaven National Laboratory	Controlled Intrusiveness Verification Technology (CIVET)	Passive high-resolution gamma spectral data

Sandia National Laboratories	Radiation Inspection System (RIS)	Passive low-resolution gamma spectral data
Sandia National Laboratories	Radiation Measurement System (RMS)	Passive low-resolution gamma spectral data
Sandia National Laboratories	Trusted Radiation Identification System (TRIS)	Passive low-resolution gamma spectral data
Sandia National Laboratories	Next Generation—Trusted Radiation Identification System (NG-TRIS)	Passive low-resolution gamma spectral data
Oak Ridge National Laboratory	Nuclear Material Identification System (NMIS)	Passive high-resolution gamma spectral data; active neutron temporal and frequency data

References:

Seager, K.D., Mitchell, D.J., Laub, T.W., Tolk, K.M., Lucero, R.L., Insch, K.W., "Trusted Radiation Identification System" SAND2001-1866C (Sandia National Laboratories, 2001), available at https://www.nti.org/media/pdfs/SNL-12_SAND2001-1866C.pdf?_=1438113127.