Neutron Resonance Transmission Tomography for Zero-Knowledge Warhead Verification

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Introduction
The national laboratories specify seven primary qualities needed for a viable verification system (Hamilton 1999):

- preventing unauthorized operation and use,
- preventing classified data,
- preventing unauthorized and undetected modification of the system,
- not producing false negatives,
- being transparent (to facilitate inspection),
- including diagnostics that verify correct operation without disclosing classified data,
- detecting errors during operation.

Approaches can be template-based or attribute-based with active or passive interrogation. Previous approaches have utilized electronic information barriers to protect sensitive design information, including CIVET (Brookhaven 1988), TRIS (Sandia 2000), and NMIS (Oak Ridge 1990).

More recent work has utilized zero knowledge protocols and physical cryptography as an alternative to electronic encryption (Glaser 2014). This experimental utilizes physical-cryptography and epithermal neutron imaging for information-secure and isotopically sensitive warhead verification.

NRTA
A new verification system using epithermal neutron transmission analysis. Using TOF techniques with 1 to 20 eV neutrons, NRTA can be used to determine the isotopic compositions of interrogated warheads.

Materials
Molybdenum and tungsten for Pu-239 and Pu-240 for various pit configurations. Using a power law spectrum with a slope of -1.35 (slope of neutron flux from target 1), the following spectra is obtained:

Chi-Squared Tests
All chi-squared tests were conducted with 91 degrees of freedom corresponding to 91 equally sized bins between 0.2 eV and 18 eV. The p=0.001 critical value for a chi-squared test with 91 degrees of freedom is 138. Chi-square increases linearly with time for this experimental set up.

DT Simulations
Examining the potential use of a thermalized DT-source for an epithermal imager. The source is surrounded with a sphere of borated polyethylene and thermalized in boron plated collimator. The detector is shielded with a boron and cadmium shield.

Experimental Approach
The experimental setup consists of two objects: a "pit/hoax" object and a piece of encrypting foil. Using a tomographic-like process, rotations of the pit are combined with randomized changes in the thickness and enrichment of the foil. By comparing the signatures from NRTA, the interrogated object can be verified as genuine or hoax.

The planned pit and hoax combinations for the experimental set up are shown below:

The holder consists of a mounting plate for the beam line as well as the holder assembly for the sample.

Neutron absorption resonances are plotted for a variety of plutonium isotopes. The unique shapes of these spectra allow precise reconstructions of isotopic abundances in interrogated material (Hielke 2018).