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Next-Generation Arms-Control Agreements Based on Emerging Radiation Detection Technologies

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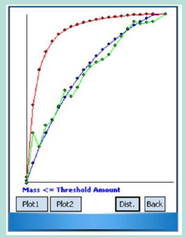
Abstract

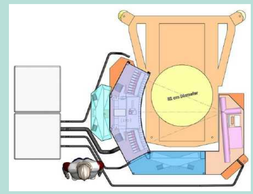
The next generation of arms-control agreements may require increased verification regimes to achieve new ambitious objectives that have not been implemented in any past or current agreements. Increased verification would need to be more intrusive to achieve confidence that states are complying with their obligations, which could include verifying nuclear warheads and weapon dismantlement. Any such agreement must ensure compliance to achieve strategic stability, but cannot risk the disclosure of sensitive information. New technologies based on radiation detection have been developed, or are being developed to meet this challenge. This paper is part one of a two-part project being conducted for the 2018 Nuclear Scholars Initiative hosted by the Project on Nuclear Issues (PONI), that examines how new technologies may affect the structure of future hypothetical treaties. Part one of this work identifies emerging technologies based on radiation detection and how they could be deployed in an agreement. It also examines what structures could be included in a hypothetical agreement. Part two will create a hypothetical arms-control agreement that uses the identified technologies and treaty structures to evaluate which technologies are suited to verify different objectives in the scenario. Gaps that currently exist and would benefit from future technical development will also be explored. Part two will be submitted for publication to PONI.

Attribute Measurements

- Ortec Fission Meter with a software based information barrier (IB) (LLNL)
- NMIS and FNMIS –Measures Pu and U presence, Pu and U fissile mass, Pu-240 content, U-235 enrichment, etc. with a D-T neutron generator and organic scintillators (ORNL)
- UK-Norway Initiative - HPGe paired with an IB to measure isotopic presence or ratios, red and green LEDs to indicate success/failure



Fission Meter IB



FNMIS

UK-Norway IB

P. L. Kerr, "Fission Meter Information Barrier Attribute Measurement System: Task 1 Report: Document existing Fission Meter neutron IB system," LLNL-TR-726602, 2017.
Daniel Archer et al., "Fieldable Nuclear Material Identification System," (paper presented at the INMM 51st Annual Meeting, Baltimore, MD, July 11-16, 2010).
https://ukni.info/project/information-barrier/

Template Matching

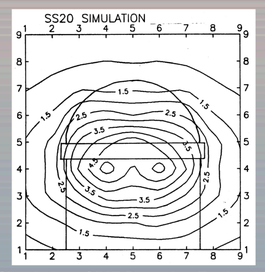
- TRIS – Trusted Radiation Identification System, low resolution NaI with a trusted processor
- Several "zero knowledge" measurement systems

Trusted Radiation Identification System

Deployed Systems

Neutron Detectors used for INF, START, and New START

- INF – ~~Measured neutron flux to discriminate SS-20 and SS-25~~
- New START – Absence Measurements only



Simulation of INF Detection Equipment

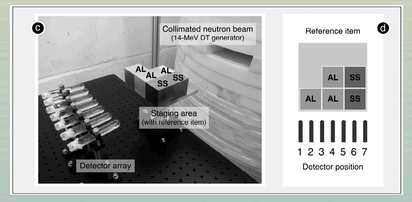
New START Radiation Detection Equipment

Ronald Ewing and Keith Marlow, "A fast-neutron detector used in verification of the INF Treaty," Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 299, no. 1-3 (December 1990): 559-61. doi:10.1016/0168-9002(90)90843-U.

Zero Knowledge

Avoid measuring sensitive information while still allowing Treaty Accountable Item (TAI) confirmation

- Neutron radiography with bubble detectors (Princeton)
- Physical cryptographic radiography (MIT)
- CONFIDANTE – compares two TAIs using time encoded neutron detection (SNL)



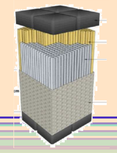
Neutron Radiography with Bubble Detectors (Princeton)

Sébastien Philippe et al., "A physical zero-knowledge object-comparison system for nuclear warhead verification," *Nature Communications* 7, no. 12890, (2016).

Imaging Systems

Imaging systems are intrusive in general, would likely require better information protection for adoption

- Thermal neutron (BNL)
- Fast neutron coded-aperture (ORNL)
- ~~MINER - Mobile Imager of Neutrons for Emergency Responders (SNL)~~
- Single volume scatter camera (UM, SNL & NC State)



SNL Single Volume Scatter Camera

Agreement Structures

- Number and Type of Participants
- Duration
- Provisions for Compliance
- Internal Organization
- Systematic or differentiated obligations
- Status of Weapons

David A. Koplow, "Eve of Destruction: Implementing Arms Control Treaty Obligations to Dismantle Weaponry," *Harvard National Security Journal* 8, (2017): 158-238, accessed February 12, 2018, http://harvardnsj.org/wp-content/uploads/2017/02/4-Koplow.pdf.

Algorithms

Some algorithms can characterize TAIs, others protect sensitive information

- Neutron multiplicity
- Time-of-flight fixed by energy estimation
- ~~Time correlated pulse height distributions~~
- Information barrier for radiography image verification
- One way transforms (imaging)

Conclusions and Future Work

- Advanced methods allow for warhead verification but are intrusive
- Confidence in information barriers is critical for more intrusive technologies
- Zero knowledge systems are promising from an information protection standpoint because no sensitive information is collected
- Future hypothetical treaties may look different than U.S. – Russia treaties, e.g. differentiated obligations, multilateral, warhead dismantlement

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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