Title: Two-Black Box Concept for Warhead Verification

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Intended for: Program Review

Issued: 2017-03-06
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Two-Black Box Concept for Warhead Verification

State Department Verification Fund Review

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3/9/2017
• We have created a possible solution to meeting the requirements of certification/authentication while still employing complicated criteria
  – We have specifically addressed the question of nuclear warhead verification
• The team at LANL included members from NEN-2 and XCP-3 who have been involved in various aspects of arms control research including the WMC, NA-243 projects, and E2E
• Technical solutions to protecting information from the host in an inspection environment needs to be assessed by those with specific expertise but, LANL can still study the verification problem
• This concept intentionally keeps analysis hidden from host
  – Provides ambiguity
  – Allows for complex analysis
  – Requires analysis be jointly destroyed after measurements

• Follow on
  – Work with NA-243 to further develop details

• The two-black box framework developed provides another potential solution to the confidence vs. certification paradox
The confidence certification paradox in warhead verification

- The host wants to be able to certify that the measurement is not revealing classified information
- The monitor wants to be able to have confidence that the item is a warhead
- If the host knows the monitor’s methods they can design spoof items
- Once the monitor loses physical control of the instrumentation, verifying that the instrumentation has not been tampered with is difficult
  - Simple discrete analog components
  - Tags and seals
- Traditional solutions have focused on relying on simple attributes but this limits the confidence when the host knows what is being evaluated
The team involved in the two-black box project

- Katherine Frame (PI): Developed the plan for this project, provided technical expertise in aspects of certification in real nuclear facilities
- Edward McKigney: Provided technical expertise related to analysis techniques of data measured in arms control scenarios
- Morag Smith: Provided technical expertise on concepts of operations in warhead verification scenarios
- Cameron Bates: Lead technical work on project. Provided technical expertise in data acquisition and analysis
Project Execution

• Funded for FY16 originally
• NA-243 and WMC work delayed progress
  – Practical aspects are tied tightly to real implementation issues
• Previous NA-243 study was finished in FY2016
• This work fit appropriately been previous study and next study
  – De-conflicting funding and limiting cross-iteration
• We will produce document on study results before the end of FY17
What is new about the two-black box concept

• **Split the measurement system into three components**
  – Measurement hardware – jointly designed built by monitor installed at host facility permanently (Radiation detectors, X-ray machine)
  – Open measurement acquisition and analysis – jointly designed and permanently installed (Power supplies control software, data acquisition, agreed upon analysis)
  – Closed analysis – Monitor brings to inspection, connects to open measurement and analysis. Both parties verify expected behavior. Perform verification.
  – Destroy hardware to satisfaction of both parties

• **This technique enables more complex analysis**
  – Only computational limitation is what can be put in the box

• **This adds ambiguity to what is being assessed**
  – Much more difficult to have confidence in a spoof

• **Any classified information derived from analysis is destroyed along with the box**

• **Monitor has confidence in box because they maintain control over it until it is destroyed**
Non-destructive assay equipment

- **Neutron detectors**
  - Presence of neutron sources (include U, Pu) and limited information about their configuration

- **Gamma-ray detectors**
  - Detect unique emissions from radioactive isotopes
  - Determine ratios of different radioactive isotopes
  - Detect presence of hydrogenous material via capture gamma-rays

- **X-ray imaging**
  - Tells difference between high-Z and low-Z materials

- Jointly designed by monitor and host
- Built by monitor
- Brought to facility and certified by host
- Tags and seals installed by monitor

*These instruments are illustrative not a requirement*
Open Analysis

• **Neutron detectors**
  – Calculate moments of the neutron multiplicity

• **Gamma-ray detectors**
  – Calculate isotopic ratios given known detector efficiency curve
  – Calculate absolute emission rate for each gamma-ray energy

• **Radiography**
  – Acquire data and process image to pass to closed analysis

• **Data quality/instrument performance checks**
• **COTS hardware**
• **Jointly designed by monitor and host**
• **Built by monitor**
• **Brought to facility and certified by host**
• **Tags and seals installed by monitor**
Closed Analysis (the “black-box”)

- Combine data from all open analysis in closed analysis box
- **Example:**
  - Calculate $^{239}\text{Pu}/^{240}\text{Pu}$ ratio from gamma-ray spectrum
  - Calculate fissile mass from neutron multiplicity analysis
  - Use multiplicity/neutron rate along with capture gamma-rays to calculate hydrogenous moderator thickness

- **Portable hardware**
  - Harden against electronic attack

- **Encrypted software**
  - Protection from host

- **Verifiable destruction:**
  - Ball mill (turn hardware to dust)
Protecting information on the black box

• After scoping the problem and consulting subject matter experts at LANL we realized that anything more than notional concepts are better left to appropriate agencies

• How hard this is depends on how analysis is treated
  – Is it state proprietary information
    • No consequence beyond the treaty itself if host accesses information
  – Is it classified
    • At what level

• Our basic concept
  – Data exists on encrypted internal flash drive that requires some multi-factor authentication from monitor to be decrypted
  – Data resides in memory unencrypted during the analysis process
  – Box is a faraday cage with hardened power supply input
  – Data from open analysis is transmitted via fiber

• Is this enough?
Concept of operations

Prior to first monitoring visit

- Design of measurement system
- Construction of measurement system
- Monitor evaluation of measurement system
- Host evaluation of measurement system
- Ship to host site

Monitoring visit

First visit?

- Yes
  - Assembly of measurement system
  - Installation of measurement system
  - Host test cases

- No
  - Check of measurement system storage
  - Installation of monitor software

- Monitor functional testing
- Warhead confirmation measurements
- Removal of monitor software
- Destruction of monitor software media

Final visit?

- Yes
  - Storage of measurement system
  - Monitors' departure

- No
  - Disposition of measurement system
Conclusions and Future work

• The two black-box concept is one possible solution to aspects of the certification/authentication problem

• No fundamental limitations to bringing a “black-box” into a US facility
  – Likely additional precautions would be necessary

• Protection of information stored on a disk that has to be accessed during the monitoring process is non-trivial
  – LANL overestimated our ability to address these issues ourselves (underspent)

• The concepts developed here will be further elaborated on in a follow-up study looking at a more specific implementation with NA-243