MONITORING REGIMES & TECHNOLOGIES FOR ALL-WARHEAD AGREEMENTS

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The National Academy of Sciences, October 23, 2020

Painting by Helen Audrey Schrayer, Acrylic on Canvas, 2017

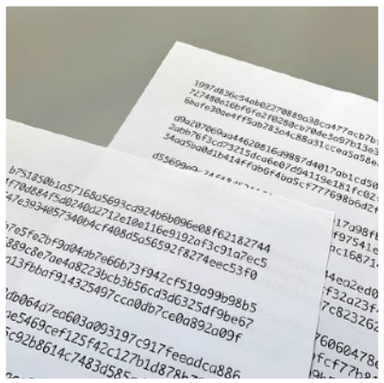
REV 1c

possible

THREE TYPES OF MONITORING REGIMES

MONITORING REGIMES

FOR ALL-WARHEAD AGREEMENTS



1. Absence regime

- Conduct routine & challenge inspections to confirm correctness of declarations
- Accept all items as treaty accountable that the host declared as such
- Only inspect other items present at site to confirm that they are indeed not accountable

2. Limited-access regime

- Conduct routine & challenge inspections to confirm correctness of declarations
- Use serial numbers or unique identifiers to track declared items
- Authenticity of the items themselves is not confirmed

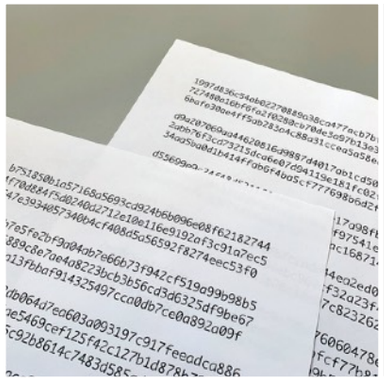
3. Confirmation regime

- Warhead confirmation measurements confirm authenticity of declared nuclear weapons prior to dismantlement (using an attribute or template-matching approach), perhaps also during "life cycle" of (randomly selected) weapons

Source: Author (top and middle), U.S. DOE (bottom)

ABSENCE REGIME

FEATURES OF AN ABSENCE REGIME



BASIC APPROACH

- Conduct routine & challenge inspections to confirm correctness of declarations
- Accept all items as treaty accountable that the host declared as such
- Only inspect other items present at site to confirm that they are indeed not accountable

RELEVANT VERIFICATION TECHNOLOGIES

- Simple radiation (neutron and/or gamma) detection equipment (only as needed)
- No information barriers required

For more, see: Radiation Detection Equipment: An Arms Control Verification Tool, DTRA, 2011

ADVANTAGES & SHORTCOMINGS

- Host can overdeclare inventory (as no items are being identified or tracked)
- Inspector gains no/few insights into operational aspects of the weapons complex

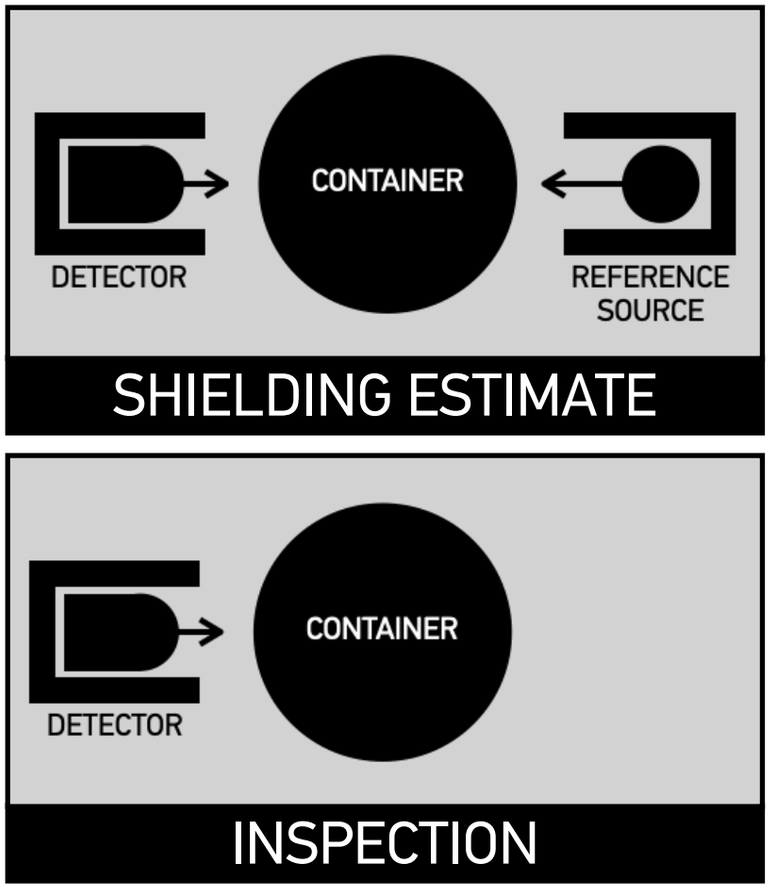
Source: Author (top), www.idealvac.com (middle), and quad-nvp.info (bottom)

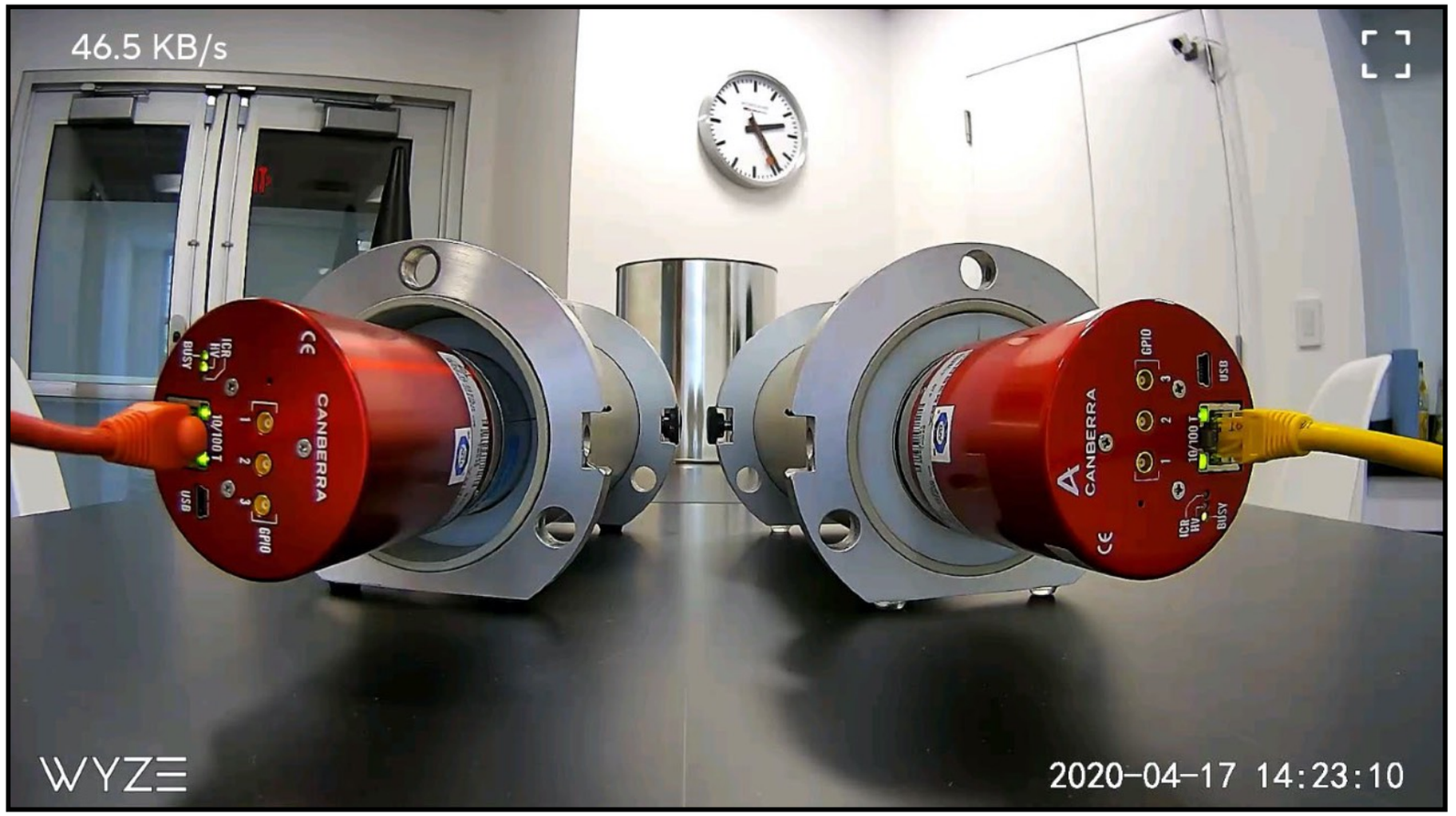
Absence Measurements

Source: Randy Montoya, share-ng.sandia.gov/news/resources/news_releases/treaty_equipment, February 2018

ABSENCE MEASUREMENTS

USING LOW-RESOLUTION GAMMA SPECTROMETRY





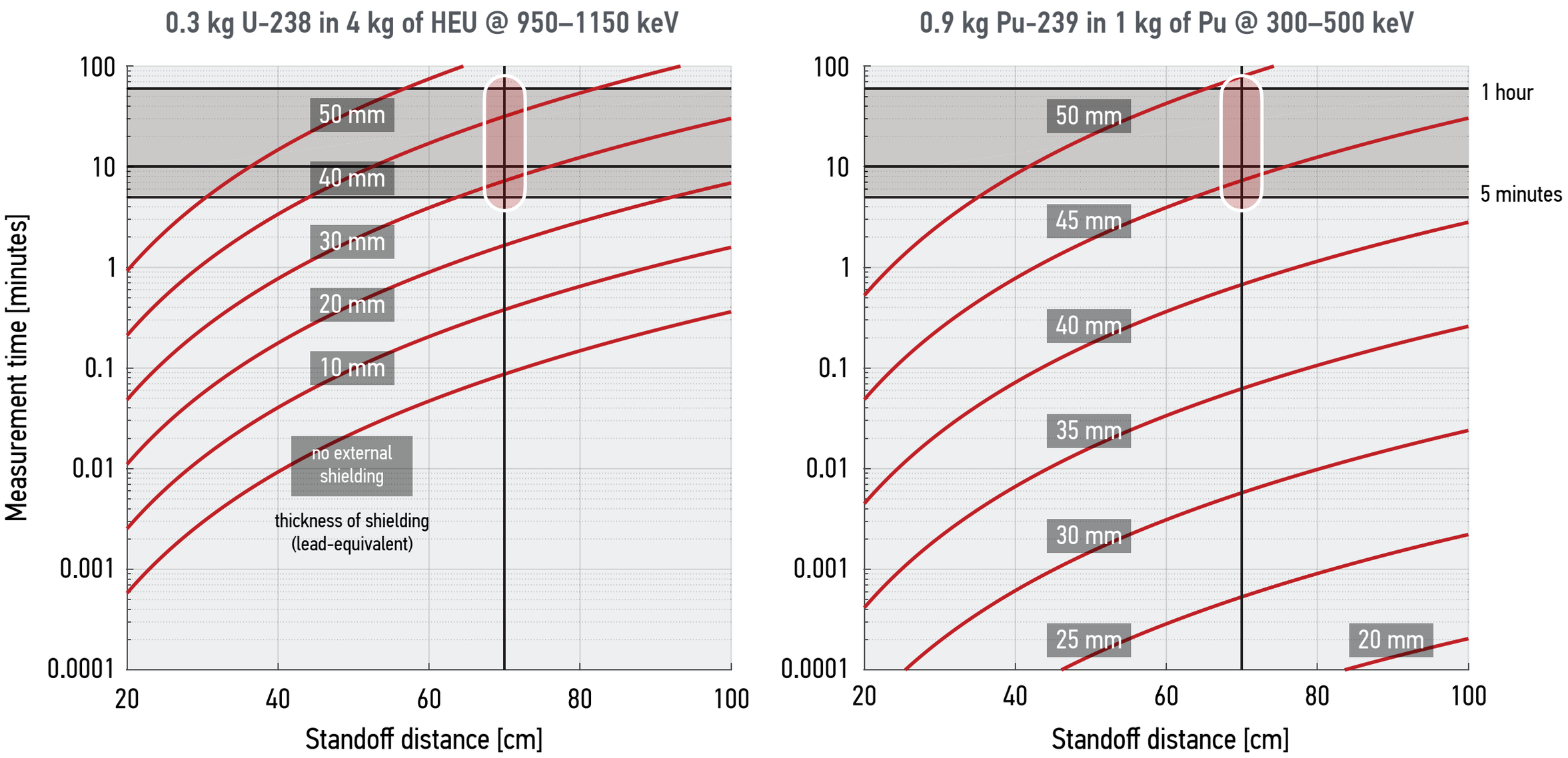
Inspection includes two separate steps to determine (1) amount of shielding in container and (2) emissions from container

U-235 is difficult to detect, focus on U-238 (1.001 MeV) instead

Certain sensitive objects (e.g. “trainers” with depleted uranium) may also have to be declared as treaty accountable

ABSENCE MEASUREMENTS

USING LOW-RESOLUTION GAMMA SPECTROMETRY



Values are for a 2" x 2" sodium-iodide detector and a point-source of special nuclear material (self-shielding treated separately)

E. Lepowsky, J. Jeon, and A. Glaser, Confirming the Absence of Nuclear Warheads Via Passive Gamma-Ray Measurements, under review

LIMITED-ACCESS REGIME

FEATURES OF A LIMITED-ACCESS REGIME

BASIC APPROACH

- Conduct routine & challenge inspections to confirm correctness of declarations
- Use serial numbers or UIDs to identify (and "track") declared items
- Authenticity of the warheads themselves is not confirmed (but "provenance" is)

RELEVANT VERIFICATION TECHNOLOGIES

- Same as for absence regime, plus chain-of-custody technologies, including tags (UIDs) and seals, possibly also containment & surveillance concepts

On remote monitoring, see: A. Glaser and Z. Mian, Science, 361 (6406), September 7, 2018

ADVANTAGES & SHORTCOMINGS

- Avoids radiation measurements on treaty accountable items, but requires limited access to items for inspection and readout of unique identifiers
- Provides some insights into how declared items move through the weapons complex

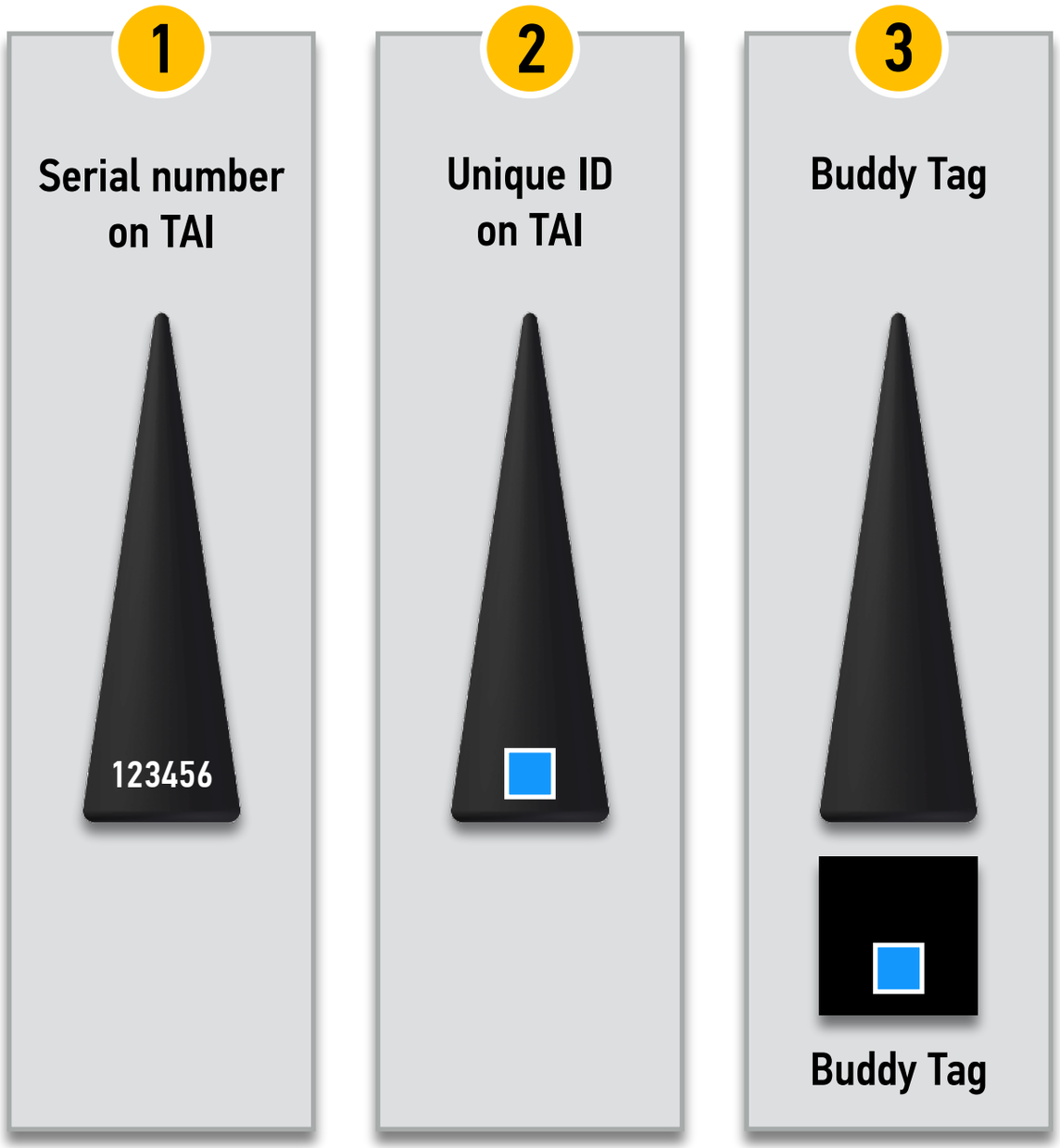
Source: Author (top), Sandia National Laboratories (middle), quad-nvp.info (bottom)

Photo: A. Glaser

Buddy Tag

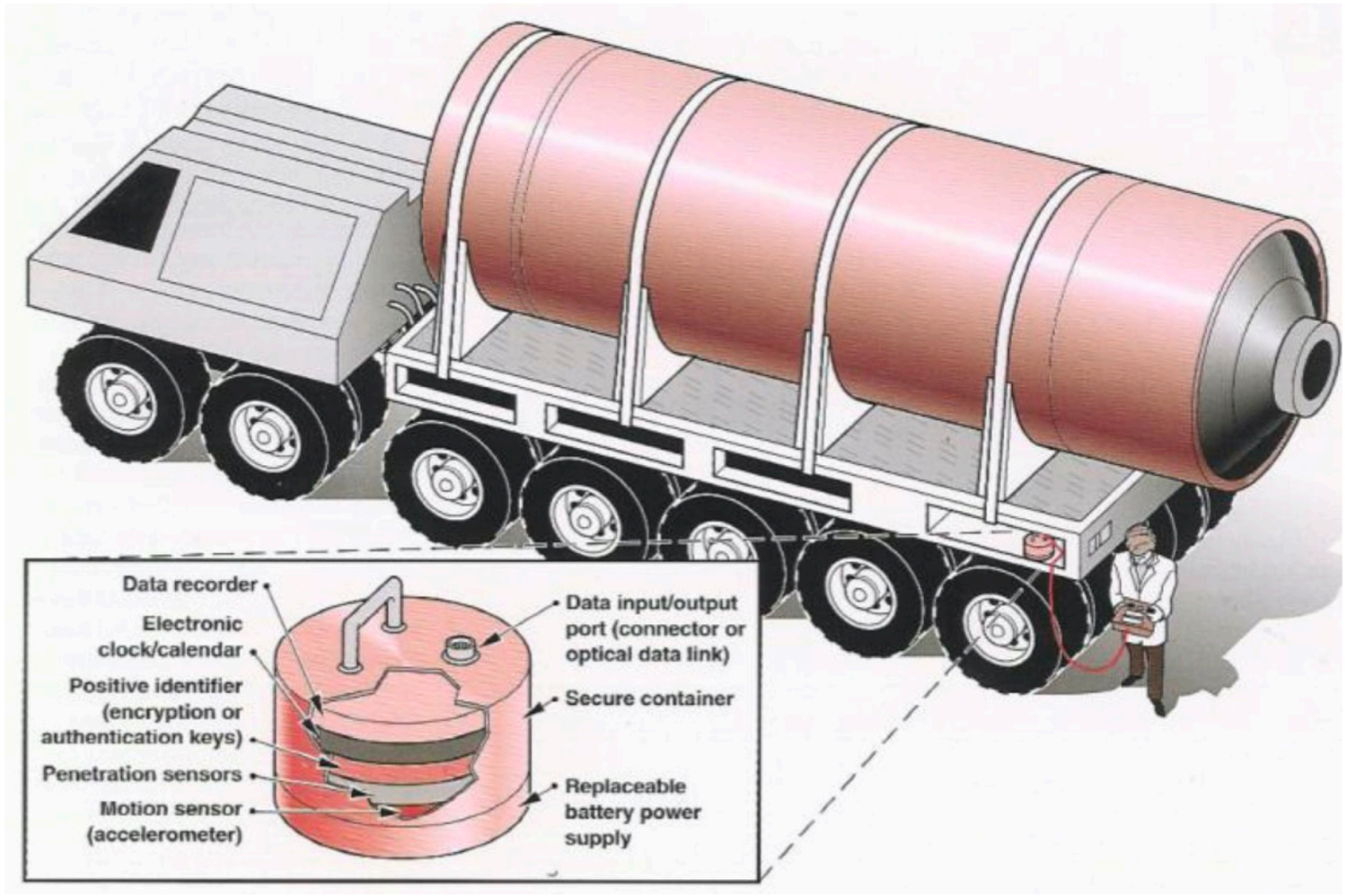
Verification Technology: Unclassified Version, JASON, 1990
Sandia National Laboratories, 1991
Princeton University and Sandia National Laboratories, 2015–2020

TAGGING OPTIONS



THE ORIGINAL BUDDY TAG CONCEPT

(FOR MOBILE MISSILES)



Sabina E. Jordan, Buddy Tag's Motion Sensing and Analysis Subsystem, Sandia National Laboratory, Albuquerque, New Mexico, 1991

Jim Fuller, "US START TID Development Program: The Quest for Extreme Security Unique Identifiers (1986–1992)," April 2006

2020 BUDDY TAG PROTOTYPE

A. Glaser and M. Kütt, "Verifying Deep Reductions in the Nuclear Arsenals: Development and Demonstration of a Motion-detection Subsystem for a 'Buddy Tag' Using Non-export Controlled Accelerometers," IEEE Sensors Journal, June 2020
ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9025267

CONFIRMATION REGIME

FEATURES OF A CONFIRMATION REGIME

BASIC APPROACH

- Warhead confirmation measurements confirm authenticity of declared nuclear weapons prior to dismantlement (using an attribute or template-matching approach) and perhaps also during the “life cycle” of (randomly selected) weapons

RELEVANT VERIFICATION TECHNOLOGIES

- Same as absence regime and limited-access regime (tags and seals), but now also major role for radiation detection equipment (active/passive, neutron/gamma, imaging)

For more, see: Yan Jie and A. Glaser, Science & Global Security, 23 (3), 2015

ADVANTAGES & SHORTCOMINGS

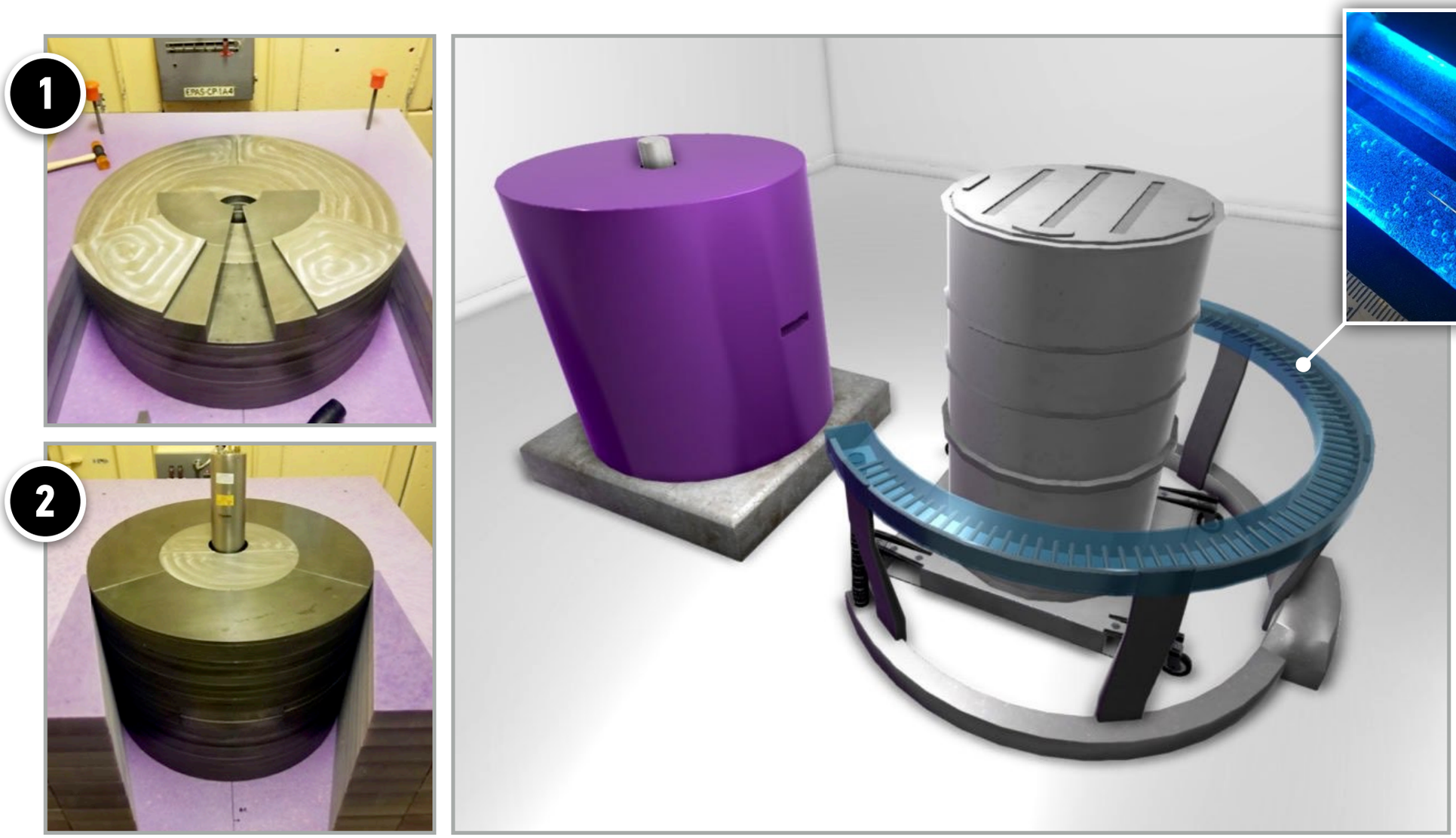
- Provides highest confidence in correctness of declared inventory and reductions
- Highly intrusive; direct access to nuclear weapons raises security concerns
- Authentication & certification of information barriers extremely difficult

Source: U.S. DOE/DOD (top), U.S. DOE (middle), Paul Shambroom (bottom)

Zero-knowledge Verification

ZERO-KNOWLEDGE VERIFICATION

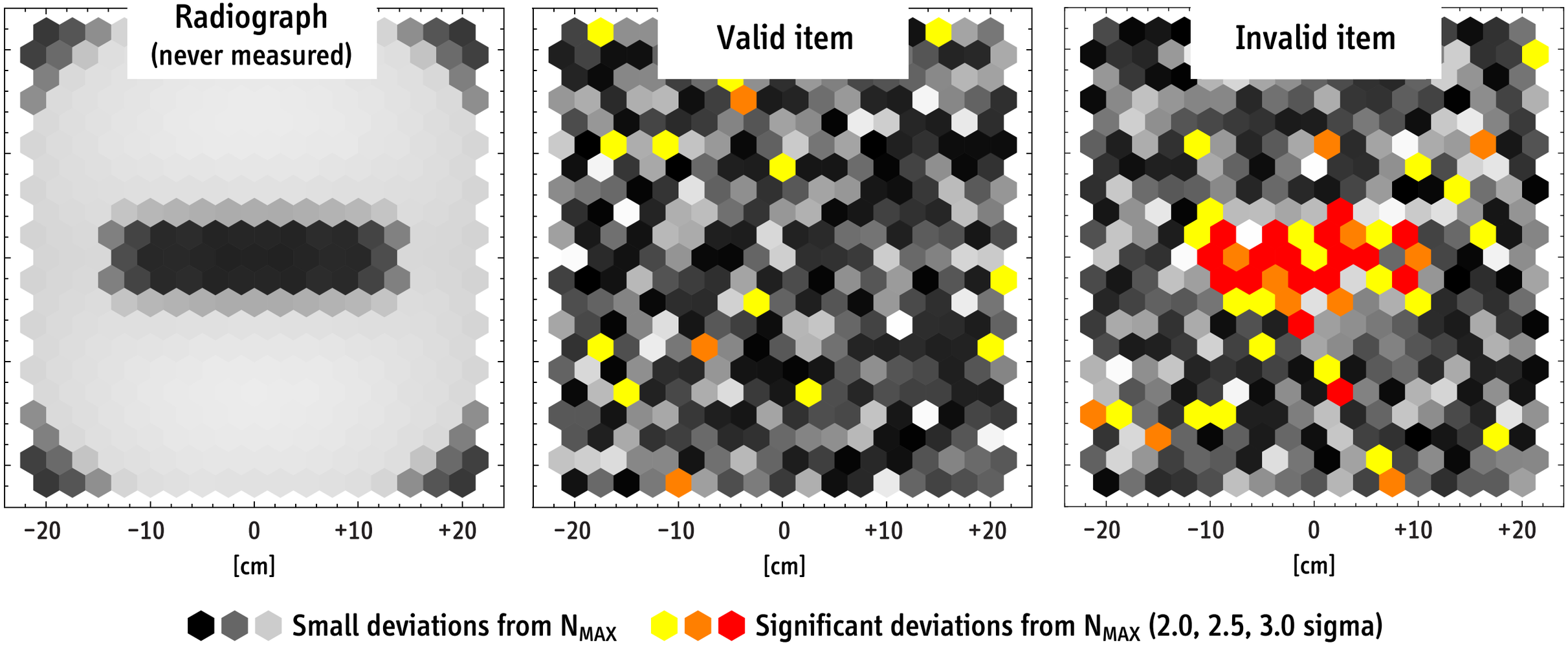
WITH NON-ELECTRONIC, PRE-LOADABLE (BUBBLE) DETECTORS



A. Glaser, B. Barak, and R. Goldston, A Zero-knowledge Protocol for Nuclear Warhead Verification, Nature, 510, June 2014
S. Philippe, R. J. Goldston, A. Glaser, F. d'Errico, Nature Communications, 7, September 2016
M. Hepler, Zero-knowledge Isotopic Discrimination for Nuclear Warhead Verification, PhD Thesis, Princeton University, May 2020

ZERO-KNOWLEDGE VERIFICATION

RADIOGRAPHY WITH 14 MeV NEUTRONS



The revised system can detect substitution of 500 g of uranium-235
limited by counting statistics in bubble detectors (48 detectors, ~350 bubbles per detector)

A. Glaser, B. Barak, and R. Goldston, A Zero-knowledge Protocol for Nuclear Warhead Verification, Nature, 510, June 2014

SUMMARY

MONITORING REGIMES & TECHNOLOGIES FOR ALL-WARHEAD AGREEMENTS

FROM ABSENCE TO CONFIRMATION REGIMES, STEP-BY-STEP

- Several types of approaches are available to verify all-warhead agreements; they range from "simple" (absence) regimes to more rigorous but more intrusive confirmation regimes
- The different regimes can build on each other and be phased in "gradually"

MEANWHILE …

- Warhead dismantlements continue to be unverified, and almost 90% of all nuclear weapons do no longer exist today
- Weapon states ought to begin now to document dismantlements in ways that international inspectors will find credible at a later time

Source: www.idealvac.com (top) and U.S. DOE (bottom)

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