Office of Defense Nuclear Nonproliferation
Research and Development

University and Industry Technical Interchange (UITI 2015) Review Meeting

Treaty Verification: Characterizing Gaps and Emerging Challenges

CVT – Consortium for Verification Technology

May/June 2015

Alexander Glaser
Princeton University

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RELEVANT NUCLEAR ARMS CONTROL TREATIES

NUCLEAR NON-PROLIFERATION TREATY

Bans the acquisition of nuclear weapons by non-weapon states and commits the five weapon states to nuclear disarmament; verified by IAEA safeguards

COMPREHENSIVE TEST BAN TREATY

Bans all nuclear explosions in all environments and would be verified by extensive verification mechanisms (International Monitoring System, CTBTO)

FISSILE MATERIAL (CUTOFF) TREATY

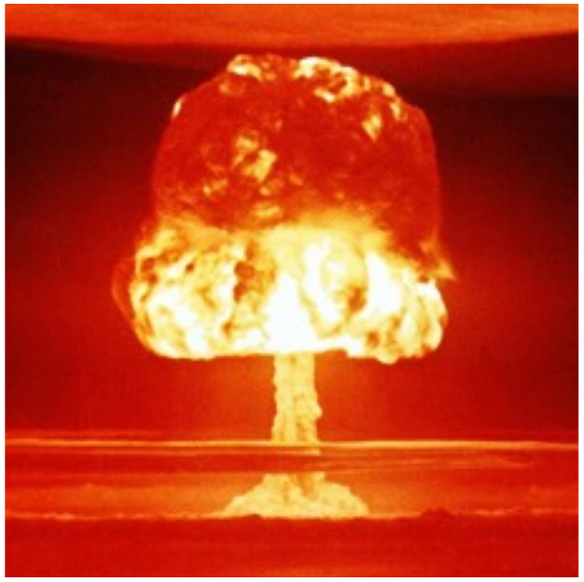
At a minimum, treaty would ban fissile material production for weapons purposes; Issue about treaty scope: Would it also cover existing stocks?

NEXT-GENERATION NUCLEAR DISARMAMENT TREATIES

Agreements that place limits on total number of nuclear warheads in arsenals would pose qualitatively new verification challenges

Comprehensive Test Ban Treaty

Scope and Verification of the CTBT



SCOPE OF THE TREATY

The CTBT bans all nuclear explosions in all environments

Signed by 183 states, ratified by 164 states (as of May 2015)

Enters into force when 44 “nuclear capable” countries have ratified

VERIFICATION OF THE TREATY

At the time of signature, it was assumed that the IMS would achieve a detection probability of 90% for a 1-kiloton (well-coupled) test

In the early 2000s, detection limit was revised to about 0.1-kilotons

Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty
Committee on International Security and Arms Control, National Academy of Sciences, Washington, DC, 2002

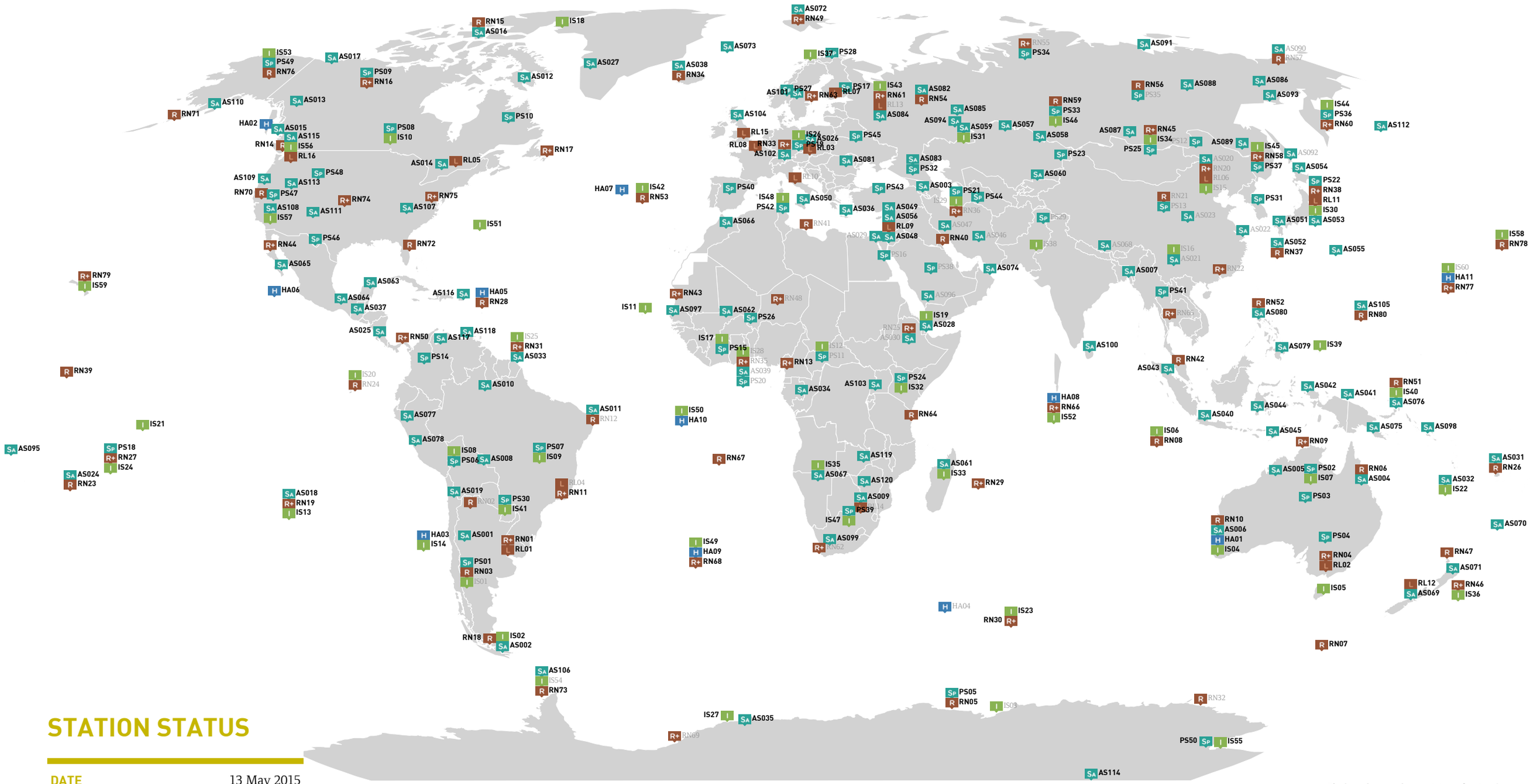
Source: Castle Romeo Test (1954, top) and Radionuclide Station RN56, Russian Federation, www.ctbto.org (bottom)

INTERNATIONAL MONITORING SYSTEM

GLOBAL OVERVIEW - CERTIFIED STATIONS AND NON-CERTIFIED STATIONS

13 MAY 2015

CTBTO PREPARATORY COMMISSION | preparatory commission for the comprehensive nuclear-test-ban treaty organization



STATION STATUS

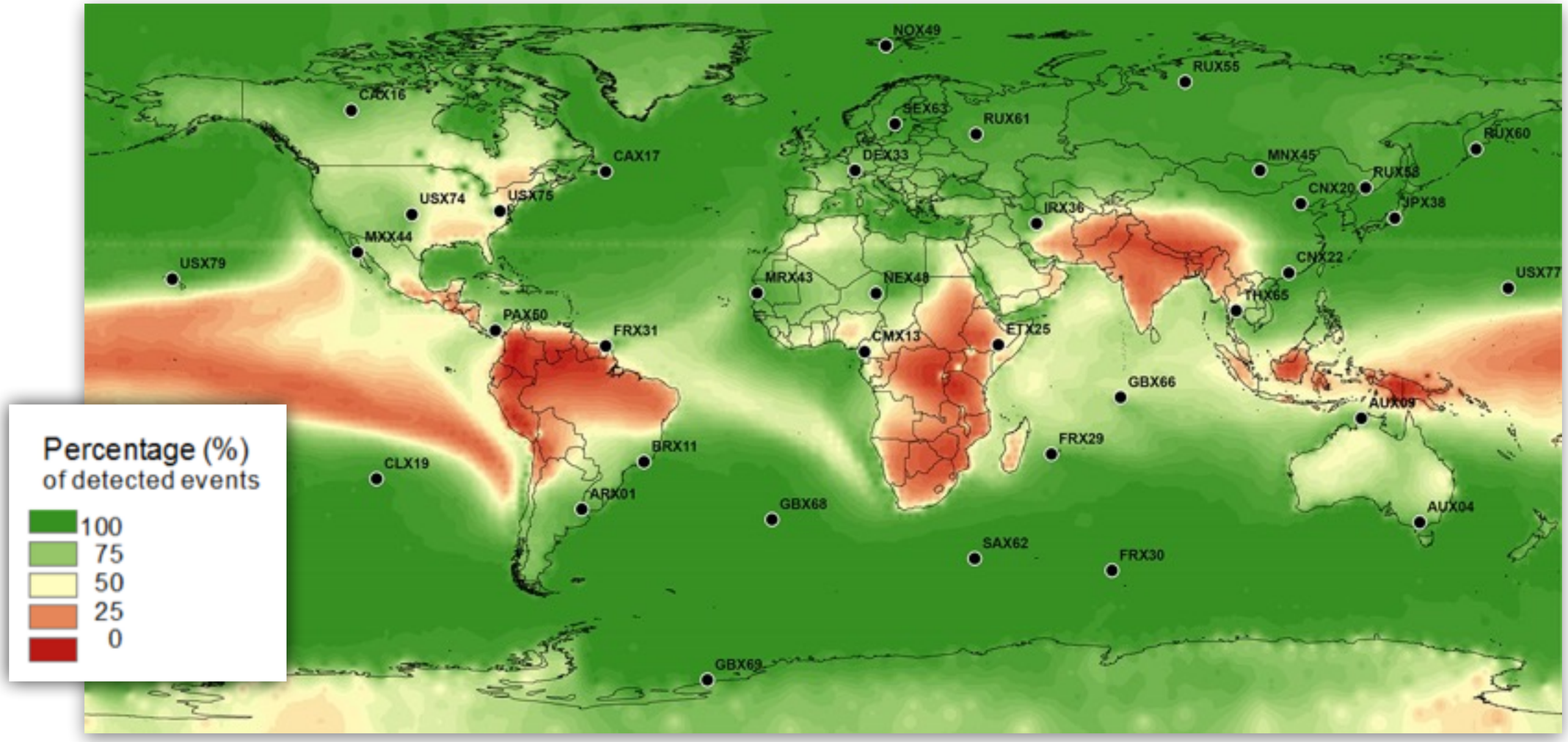
DATE	13 May 2015
TOTAL STATIONS	337
PLANNING	18
UNDER CONSTRUCTION	19
INSTALLED	19
CERTIFIED	281

Sp Primary Seismic | SA Auxiliary Seismic | I Infrasound | H Hydroacoustic | R Radionuclide | R+ Radionuclide w/ Noble Gas | L Radionuclide Lab

WWW.CTBTO.ORG

FINDING (AND CLOSING) THE GAPS IN THE INTERNATIONAL MONITORING SYSTEM

Results from a dedicated study using extensive atmospheric transport modeling of noble gases (assuming 39 operational noble-gas stations and 10^{14} Bq release (1% of underground 1 kt(TNT) explosion)



M. Schoeppner and W. Plastino, "Determination of the Global Coverage of the IMS Xenon-133 Component for the Detection of Nuclear Explosions," *Science & Global Security,* 22, 2014

Fissile Material Cutoff Treaty

SCOPE AND VERIFICATION OF AN FMCT

SCOPE OF AN FMCT

FMCT would ban production of fissile materials for weapon purposes

De-facto FMCT for non-weapon states already exists (NPT)

Note: Fissile material production for weapon purposes has ended in NPT weapon states

VERIFICATION OF AN FMCT

Verification of the treaty could be partly based on tools and approaches developed for implementation of IAEA safeguards,

but there are some (new) verification challenges in weapon states

Source: hanford.gov (top) and IAEA Imagebank (bottom)

SELECTED VERIFICATION CHALLENGES OF AN FMCT

LEGACY ENRICHMENT AND REPROCESSING PLANTS

Many existing facilities are currently unsafeguarded

Moreover, some weapon states have operational facilities that may have been used for military fissile material production in the past

MILITARY (NUCLEAR) SITES

Weapon states have military nuclear sites where onsite inspections would be challenging

Source: Novouralsk enrichment plant (top) and laser breakdown spectrometry backpack system (Los Alamos National Laboratory, bottom)

Next-Generation Nuclear Disarmament

KEY VERIFICATION CHALLENGES

OF NUCLEAR DISARMAMENT AT LOW NUMBERS

CORRECTNESS OF BASELINE DECLARATIONS

Verification requires warhead counting techniques and, prior to dismantlement, high confidence in the authenticity of the warhead; several approaches under development

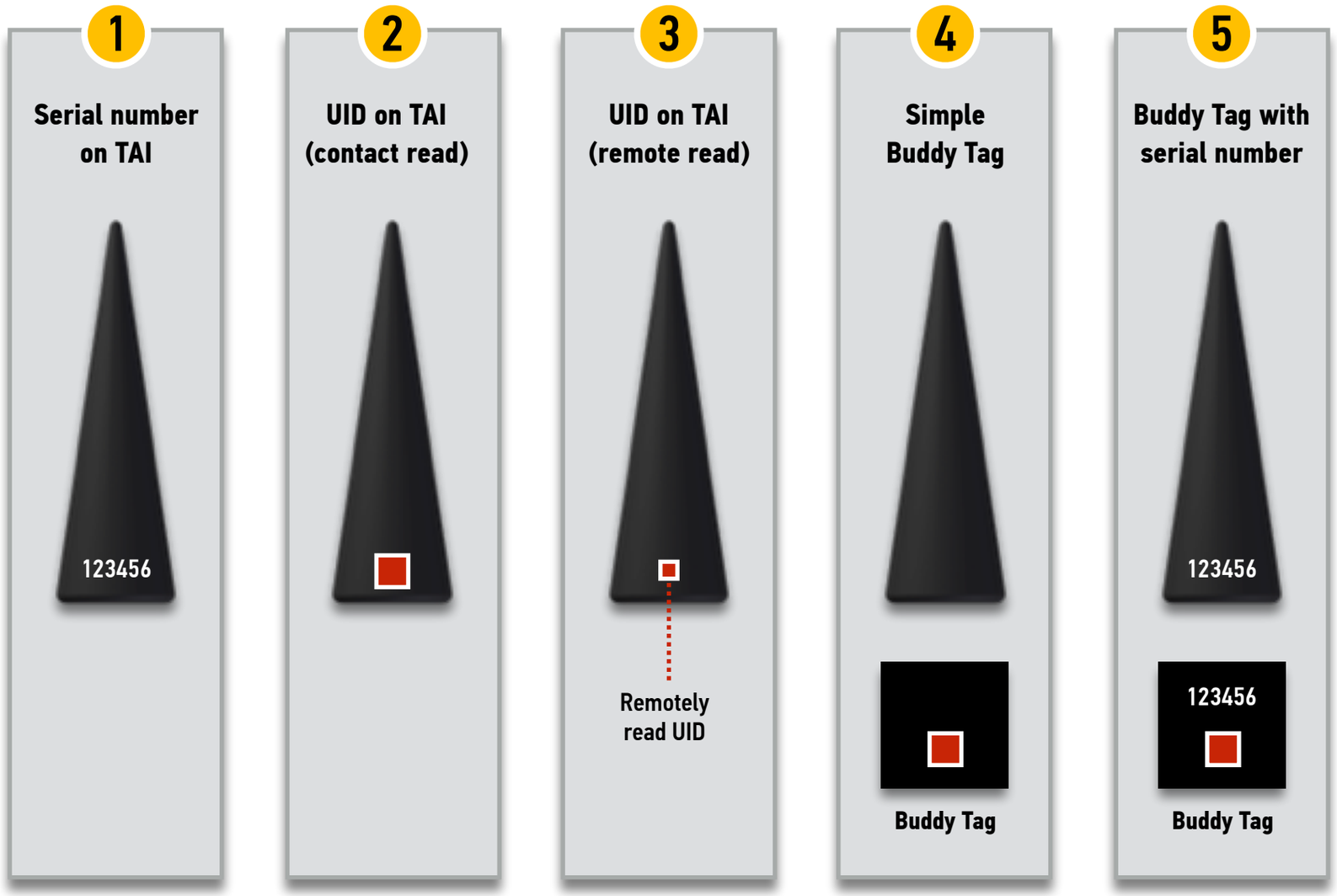
COMPLETENESS OF BASELINE DECLARATIONS

Most promising may be techniques to verify completeness of fissile material declarations; nuclear forensic analysis can be used to estimate historic fissile material production ("nuclear archaeology")

Source: U.S. Department of Energy (top) and U.S. Department of Defense, www.defenseimagery.mil (bottom)

COUNTING OPTIONS

WITH VARIOUS LEVELS OF INTRUSIVENESS AND ROBUSTNESS

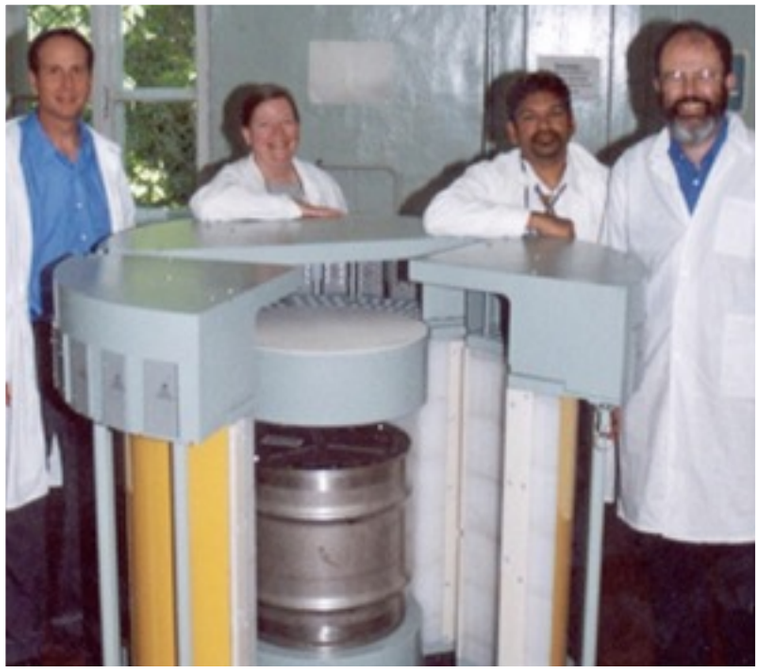


Several CVT participants are working on technologies that will help ensure Continuity of Knowledge (CoK)

(including Chain-of-Custody (CoC) detectors for treaty accountable items or materials)

WARHEAD AUTHENTICATION

IMPORTANT PRECEDENTS EXIST AND FUTURE WORK CAN BUILD ON THEM

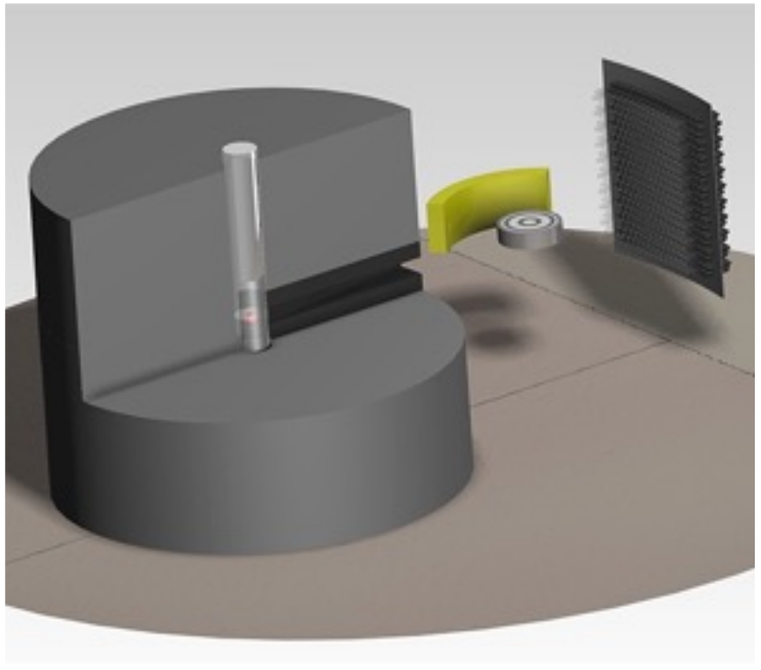


Inspection System developed as part of the 1996–2002 Trilateral Initiative during a demonstration at Sarov

Source: Tom Shea

Liquid scintillator passive well counter to determine the plutonium mass in samples of unknown size

Source: U-Michigan, DNNG



Princeton/Yale setup using a zero-knowledge protocol with 14 MeV neutrons and non-electronic detectors

Source: Sébastien Philippe, Princeton

Several CVT participants are working on technologies that will help enable inspection systems for treaty verification

(e.g. advanced detector technologies; software and hardware for new types of information barriers)

VIRTUAL ENVIRONMENTS

WARHEAD DISMANTLEMENT FACILITY AND MANAGED-ACCESS SIMULATOR

WHY USE VIRTUAL ENVIRONMENTS?

Explore different architectures and inspection protocols

Encourage “trial and error” and “learning by doing”

No classified information at risk

PROPOSED NEW FEATURES

Integration of virtual (real-time) radiation fields

Enable host-vs-inspector game play

Facilitate collaborations between CVT partners

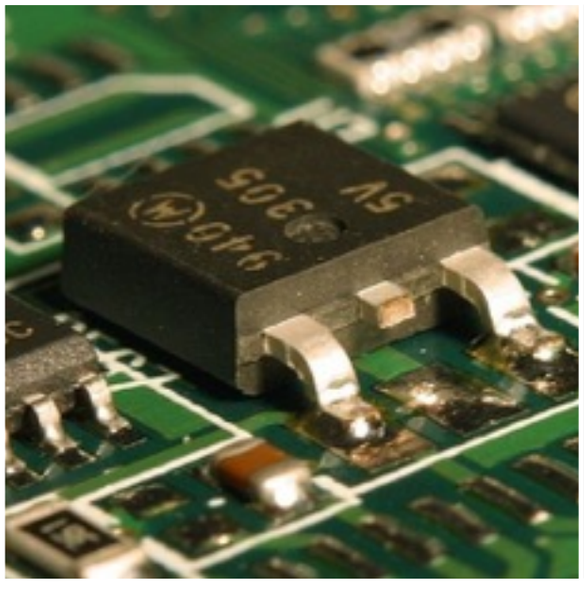
Source: Tamara Patton Schell

“VERIFICATION CHALLENGES”

LEVERAGING THE WISDOM OF THE CROWD

2009 DARPA RED BALLOON CHALLENGE

Ten numbered eight-foot weather balloons deployed at public locations across the continental United States; find and submit the coordinates of all ten balloons as quickly as possible



POSSIBLE VERIFICATION CHALLENGES (RELEVANT) FOR THE CVT

“Stack-Monitoring” Challenge (proposed by Ted Bowyer, PNNL)

“Lifting-the-Tag” Challenge

“Defeating-the-Inspection-System” Challenge