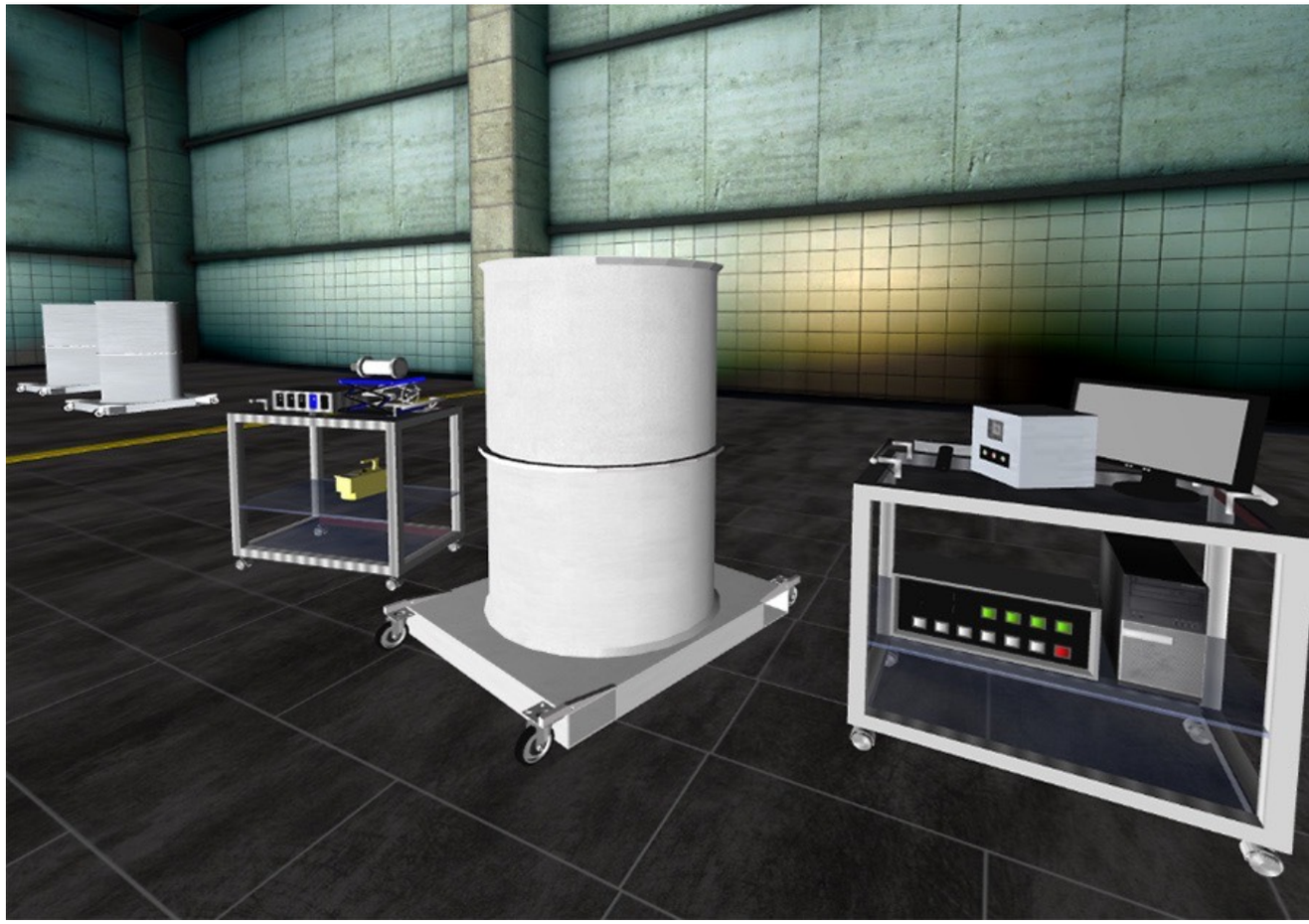


TREATY VERIFICATION

Closing the Gaps with New Technologies and Approaches

Alexander Glaser and Tamara Patton

2016 CVT Annual Meeting, Ann Arbor, Michigan

PRINCETON UNIVERSITY

Revision 5a

CONSORTIUM FOR VERIFICATION TECHNOLOGY

BACKGROUND

TWO WAYS OF APPROACHING THE VERIFICATION PROBLEM

Technology-focused and mission-focused approach;

CVT seeks to combine both; unique opportunities for synergisms given diversity of 12 + 9 CVT partner institutions and groups

POLICY RESEARCH THRUST: A TREATY ENABLING APPROACH

Emphasizes mission-focused dimension (as defined by existing and expected future treaties); support and guide CVT technology developments toward specific treaty applications; track emerging technologies

Source: University of Michigan (top) and state.gov (bottom)

RELEVANT NUCLEAR ARMS CONTROL TREATIES AND AGREEMENTS

NUCLEAR NON-PROLIFERATION TREATY

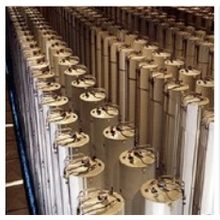
Bans the acquisition of nuclear weapons by non-weapon states and commits the five weapon states to nuclear disarmament; verified by IAEA safeguards

BILATERAL/MULTILATERAL NONPROLIFERATION AND ARMS-CONTROL AGREEMENTS

Protocols negotiated to ensure compliance with specific agreements, for example: the *Joint Comprehensive Plan of Action* (JCPOA, July 2015) and the *Plutonium Management and Disposition Agreement* (PMDA, 2000/2010)

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

VERIFICATION OF BILATERAL AND MULTILATERAL AGREEMENTS

JOINT COMPREHENSIVE PLAN OF ACTION (JCPOA)

July 2015, between EU3+3 (France, Germany, United Kingdom + China, Russia, United States) and Iran

- Containment and surveillance of centrifuge (rotor and bellow) production
- Online (real-time) enrichment monitoring
- Monitoring of ore-concentrate production and procurement channels

Note: Provisions and measures should not be considered setting precedents for any other state

PLUTONIUM MANAGEMENT AND DISPOSITION AGREEMENT (PMDA)

2000/2010 (amended), between the Russian Federation and the United States

Envisioned detailed verification provisions to ensure that "the monitoring Party has the ability independently to confirm that the terms and conditions of the Agreement with respect to disposition plutonium, blend stock, conversion product, spent plutonium fuel, and disposition facilities are being met." (Annex on Monitoring and Inspections)

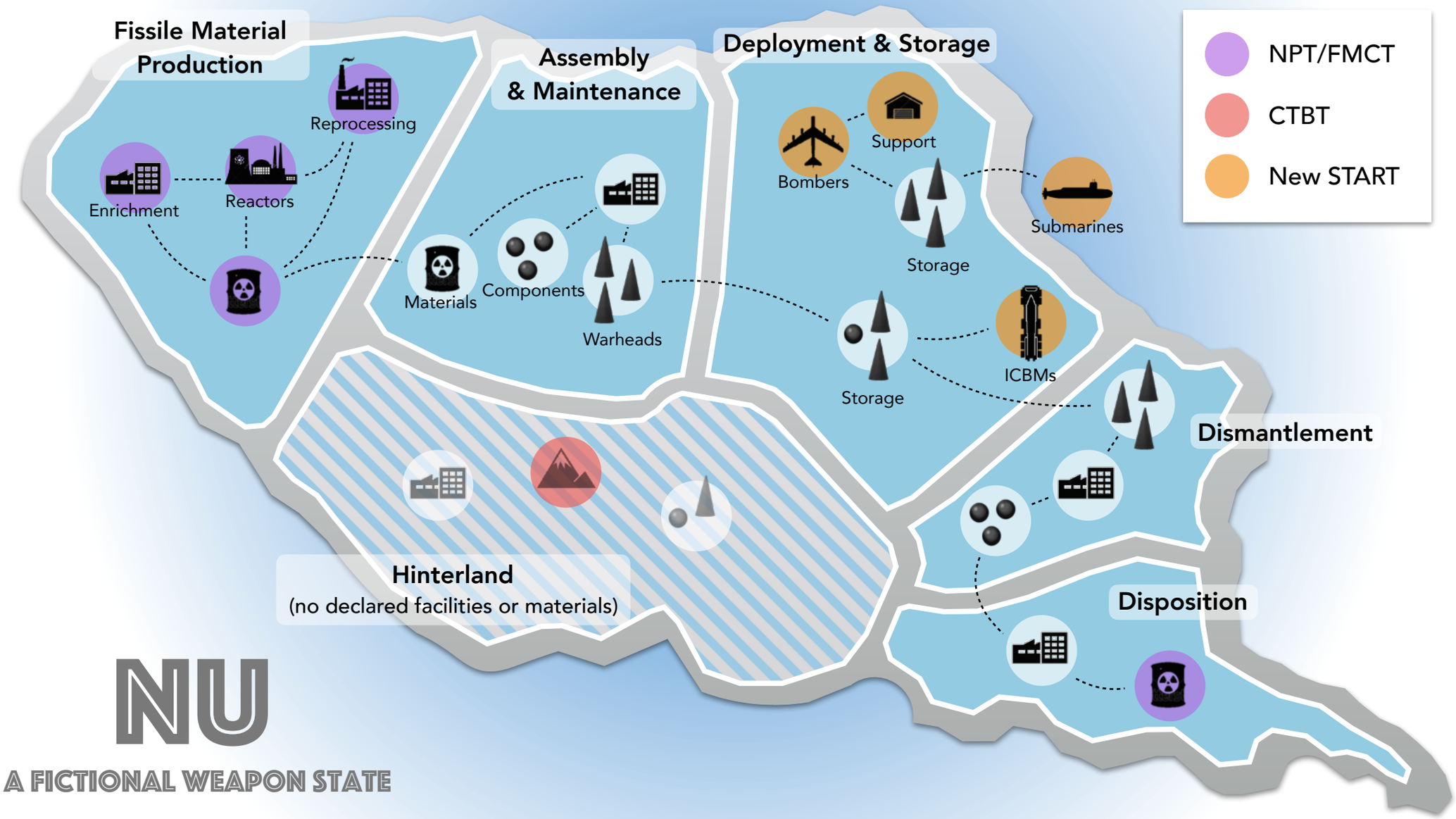
Source: Wikimedia (bottom)

Mapping Nuclear Verification

"Placing CVT Projects on the Map"

MAPPING NUCLEAR VERIFICATION

CVT projects help strengthen existing verification technologies and approaches, close the remaining gaps, and address emerging challenges



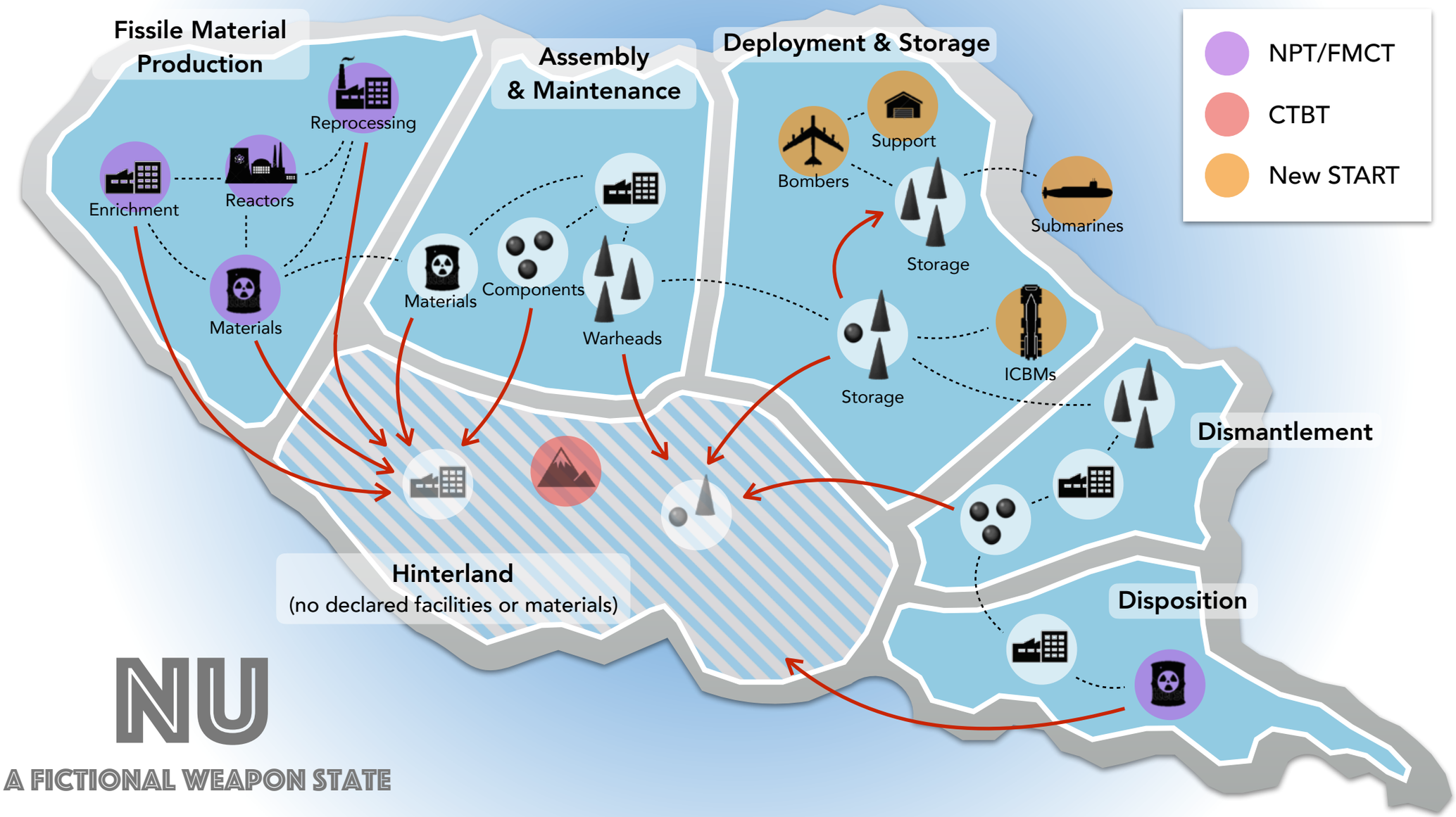
NU

A FICTIONAL WEAPON STATE

www.verification.nu

MAPPING NUCLEAR VERIFICATION

CVT projects help strengthen existing verification technologies and approaches, close the remaining gaps, and address emerging challenges



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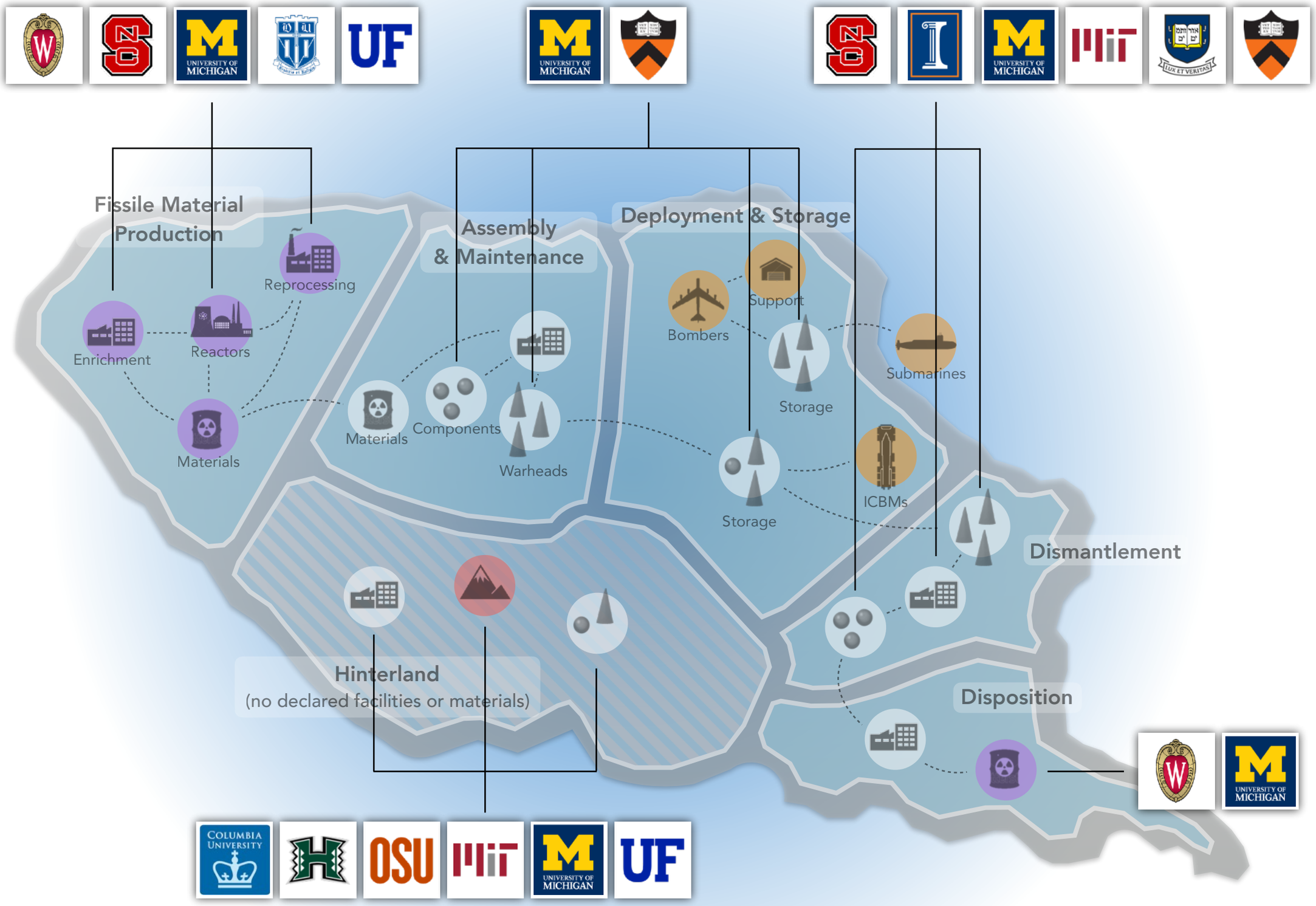
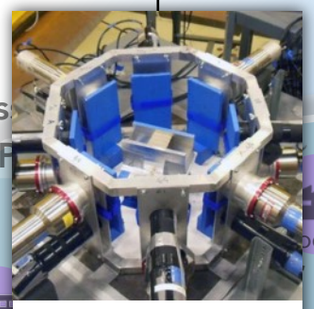
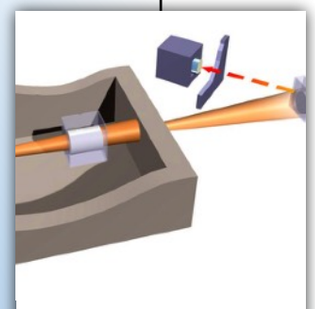

Fissile Material Production
Assembly & Maintenance
Deployment & Storage
Reprocessing
Enrichment
Reactors
Materials
Materials
Components
Warheads
Bombers
Support
Storage
Submarines
Storage
ICBMs
Dismantlement
Hinterland
(no declared facilities or materials)
Disposition



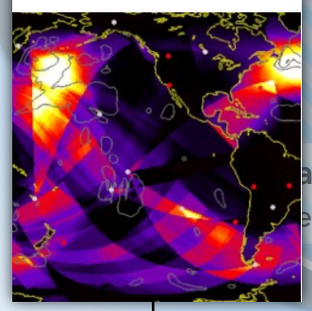
Fast neutron multiplicity counter

Buddy Tag (joint with Sandia)

Neutron Coincidence Anisotropy Setup



Nuclear resonance fluorescence



Next-generation Infrasound Sensors

Agent-based fuel-cycle simulator

Adding New Dimensions to Verification Research

ADDING NEW DIMENSIONS TO (OUR) RESEARCH ON NUCLEAR VERIFICATION

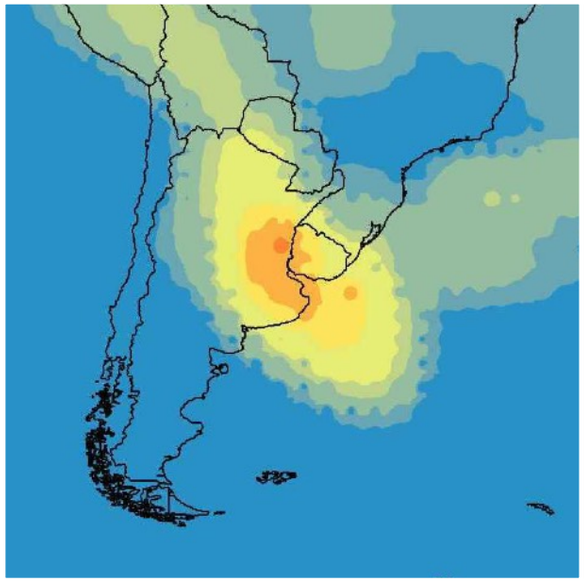
1. Enabling Transparency Without Intrusiveness
2. Using Historic Data and Records to Validate Modern Technologies
3. Leveraging the Wisdom of the Crowd

TRANSPARENCY SCORECARD 2016

INFORMATION ON NUCLEAR WARHEAD AND FISSILE MATERIAL INVENTORIES AND STATUS

	United States	Russia	Britain	France	China
Number of total warheads	Approximate	No	Yes (upper limit)	Yes (upper limit)	Relative (out of date)
Number of deployed warheads	Yes (strategic only)	Yes (strategic only)	Yes (planned)	Yes	No
Dismantlements	Yes	No	Yes (no details)	Yes (no details)	No
Verification	Partial	Partial	No	No	No
Fissile material stockpiles	Yes	No	Yes (no details)	No	No
Production histories	Yes	No	No	No	No
Excess/Disposal	Yes (nothing new)	Yes (nothing new)	Yes (nothing new)	No	No
Verification	Partial	Partial (but no longer)	Partial (some plutonium)	No	No

TRANSPARENCY WITHOUT INTRUSIVENESS



STANDOFF DETECTION AND (WIDE-AREA) REMOTE MONITORING

Thrust Area 4 (Detection of Undeclared Facilities and Inaccessible Facilities)

- Waveform techniques: Seismic and infrasound signatures (CTBT)
- Radionuclide signatures (NPT, FMCT, CTBT)

  Atmospheric transport modeling, emission source terms, advanced detectors

R. S. Kemp, "Environmental Detection of Clandestine Nuclear Weapon Programs," *Annu. Rev. Earth Planet. Sci.,* 44 (1), 2016

NON-INTRUSIVE APPROACHES FOR (ONSITE) INSPECTIONS

- Unattended inspection systems
- Information barriers (based on software and hardware)

  Example: Analog-to-digital signal converter (Buhler, Wehe, and Flynn, U Mich)
- Virtual Proofs of Reality (S. Philippe et al.)

Source: M. Schöppner (top) and IAEA (bottom)

USING HISTORIC DATA AND RECORDS TO VALIDATE MODERN TECHNOLOGIES AND CONCEPTS

DATA RESCUE

Paul Richards (Columbia)

- Millions of (analog) seismograms exist in little-used archives

  Great majority of nuclear test explosions, including almost all atmospheric explosions, occurred prior to the era of digital recording

- Detector hardware and algorithms have become much more powerful

NUCLEAR ARCHAEOLOGY

- Reconstructing historic fissile material production using nuclear forensic techniques
- Need to determine which artifacts (including operating and other records) ought to be preserved to further strengthen this process
- Test beds for nuclear archaeology to develop and demonstrate the methods

Source: U.S. Department of Energy (top) and francetnp.gouv.fr (bottom)

LEVERAGING THE WISDOM OF THE CROWD

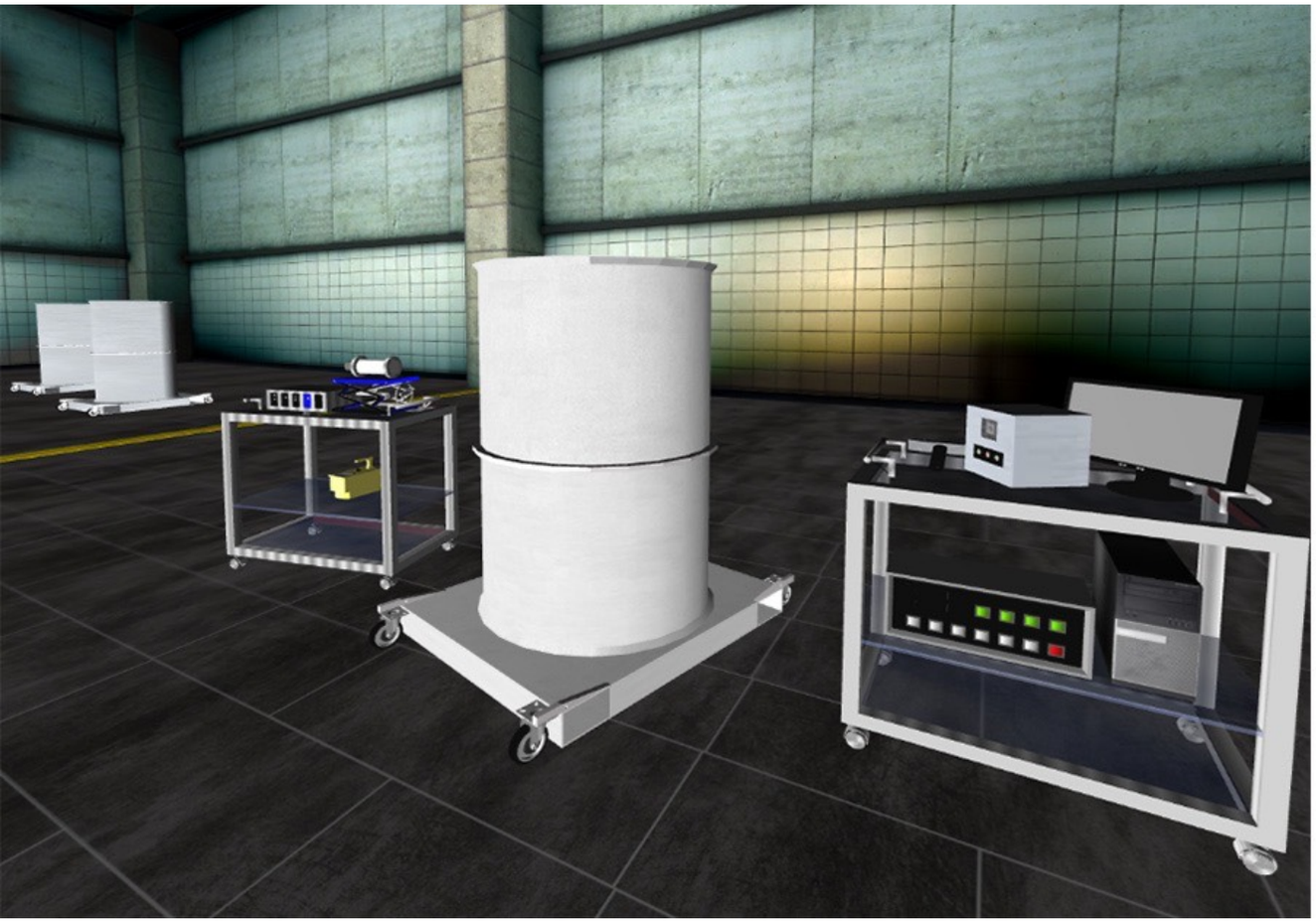
UBIQUITOUS SENSORS, OPEN-SOURCE SOFTWARE AND HARDWARE

- Listening to the (mobile) crowd
  Example: Infrasound App for CTBT Verification (M. Garcés, U Hawaii)
- Recruiting the crowd: Verification Challenges
- Toward common computing platforms (LLNL/Sandia, Greg White)

VIRTUAL REALITY FOR NUCLEAR VERIFICATION

- Enables collaborations between researchers and governments
- High level of accessibility and flexibility
- No risk of exposing proliferation-sensitive information

Source: Authors



FULL MOTION VR

Refining Verification Approaches for Nuclear Arms Control

BUILDING FROM LIVE EXERCISES

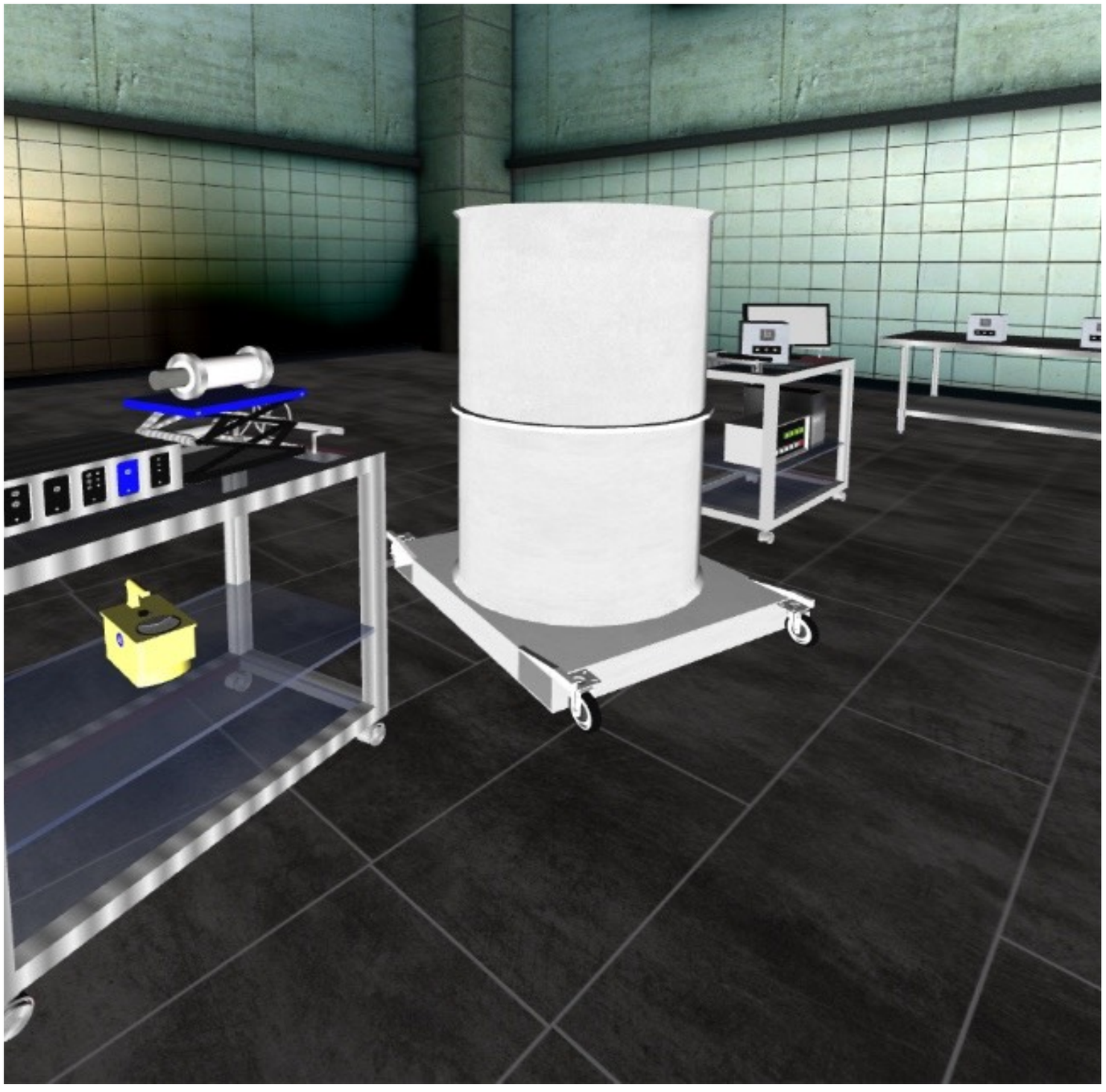
➤ UK-Norway Initiative

UKNI Managed Access exercises took place in Norway in 2008 and 2009, and in the UK in 2010. The exercises were underpinned by a framework which included a hypothetical Treaty between two fictitious countries: the NWS 'Torland' and the NNWS 'Luvania'. The Luvanian Inspectors deployed a number of techniques and processes, including radiation monitoring, tags and seals, digital photography of the tags and seals, CCTV cameras, and an information barrier system for gamma measurements.

➤ UK-US Cooperation

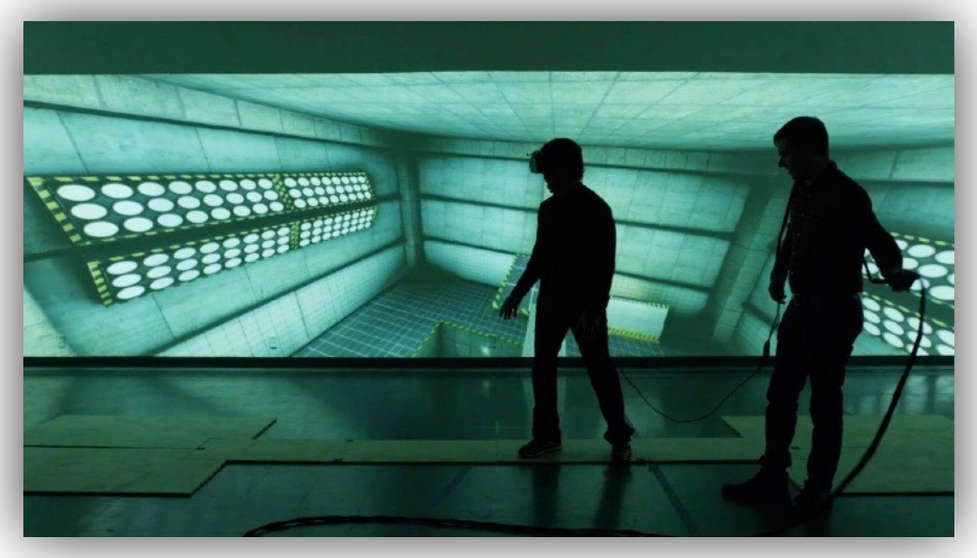
From 2002 through 2011, the United Kingdom and United States conducted four major managed access exercises, concluding with an extensive Warhead Monitored Dismantlement exercise.

Images from the UK-Norway Initiative



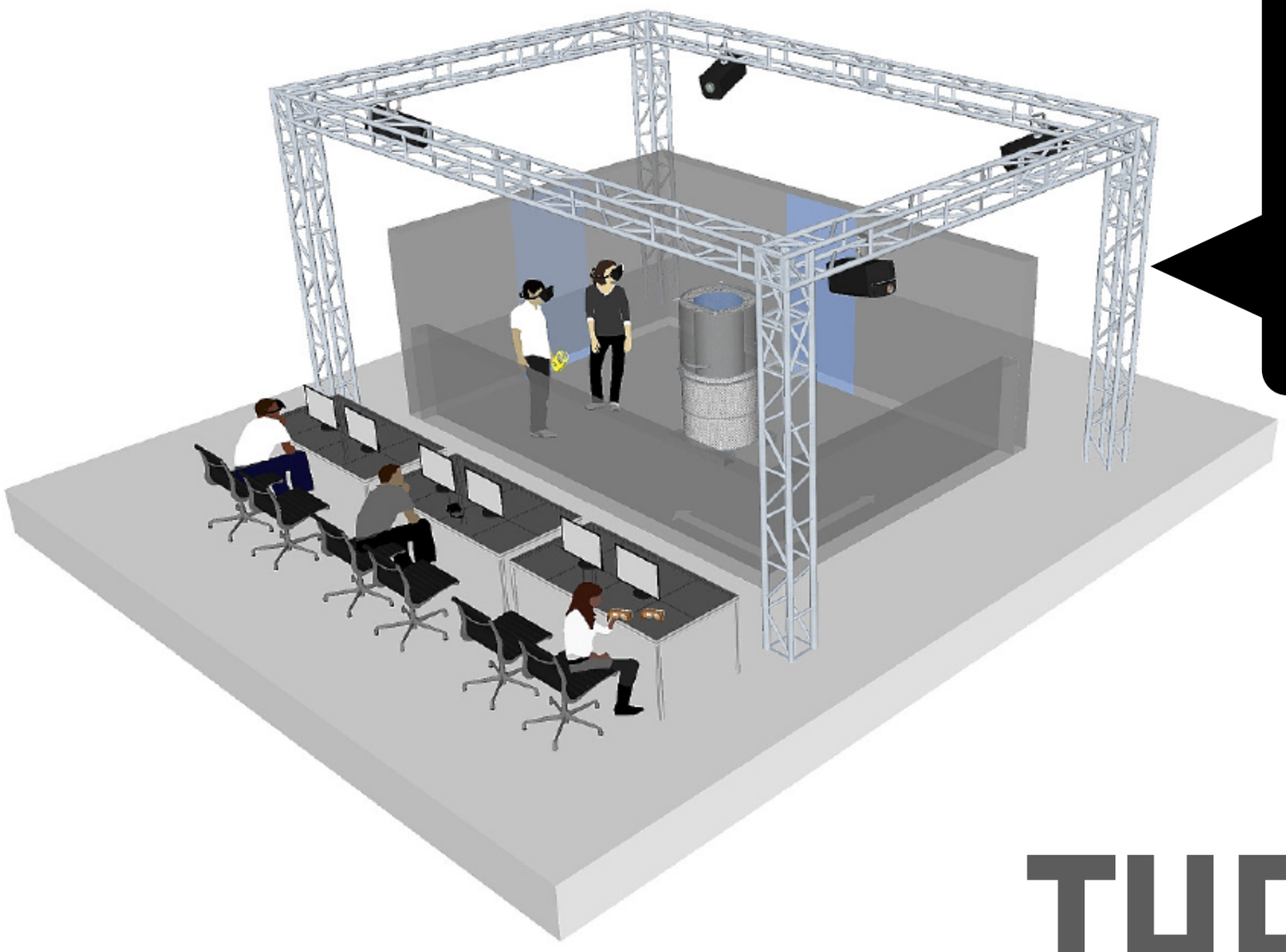
“FMVR provides a flexible and powerful way to extend the research community's ability to examine larger numbers of options and technology combinations for verification approaches.”

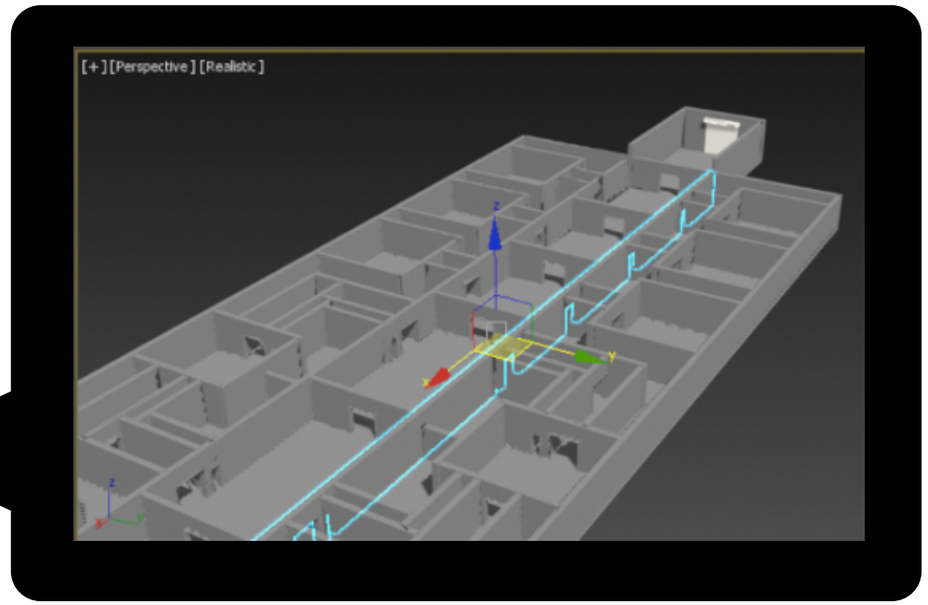
“The brain doesn't much care if an experience is real or virtual.



Jim Blascovich and Jeremy Bailenson
Infinite Reality: The Hidden Blueprint of Our Virtual Lives

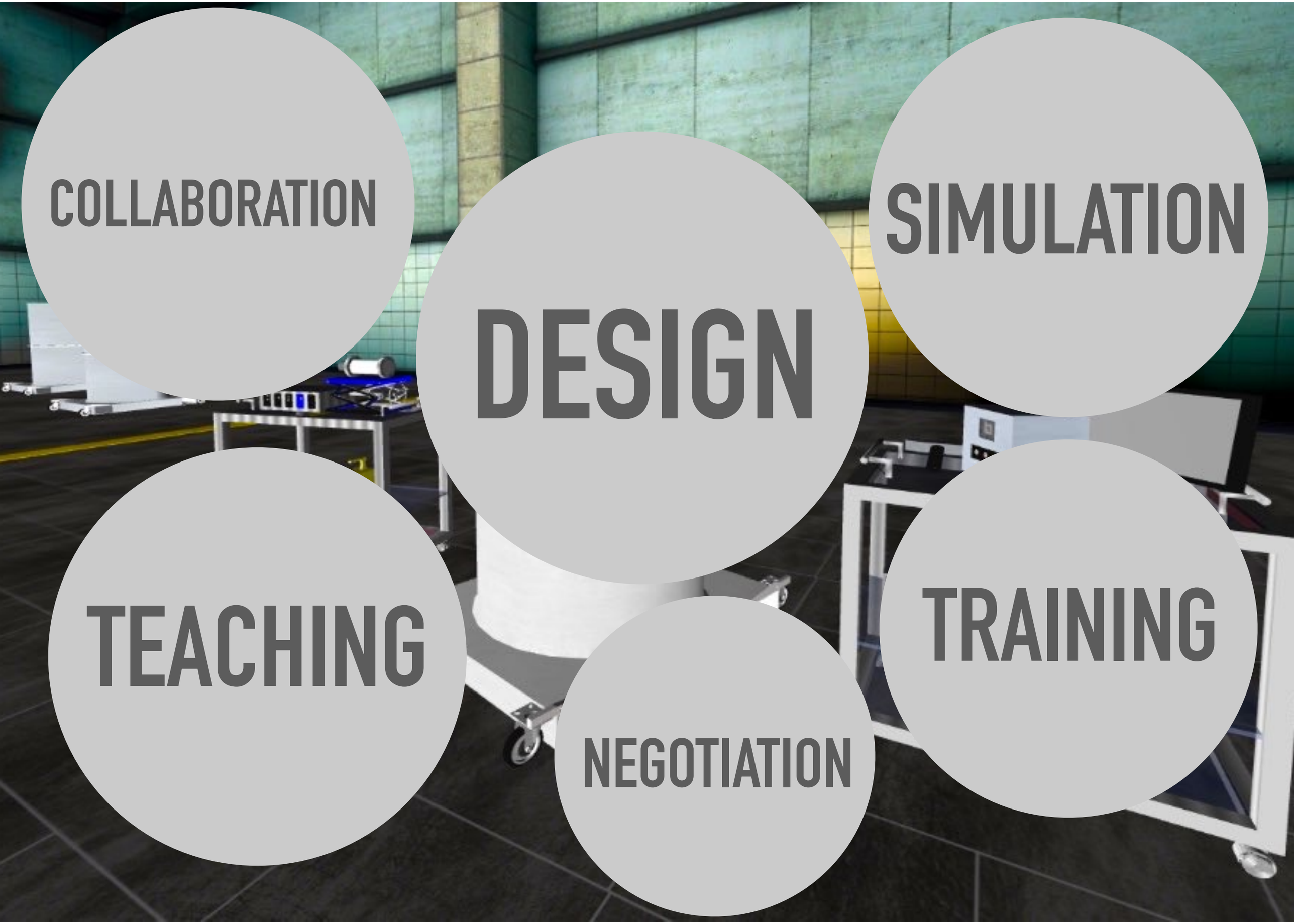
More to explore: www.youtube.com/watch?v=9jx2YWzxvbs



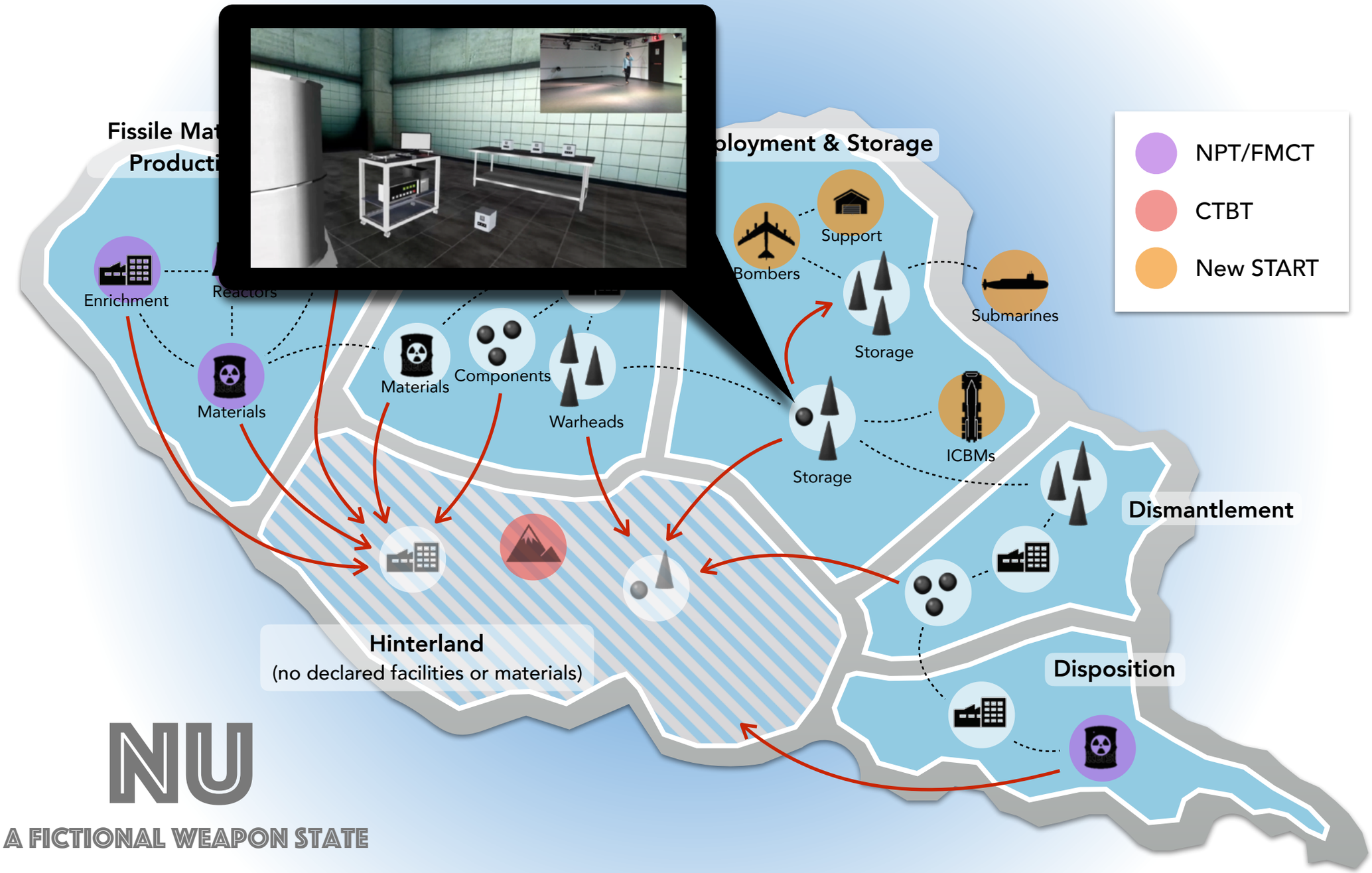


THE SYSTEM

WorldViz Walking Virtual Reality System


COLLABORATION
DESIGN
SIMULATION
TEACHING
NEGOTIATION
TRAINING

MAPPING NUCLEAR VERIFICATION



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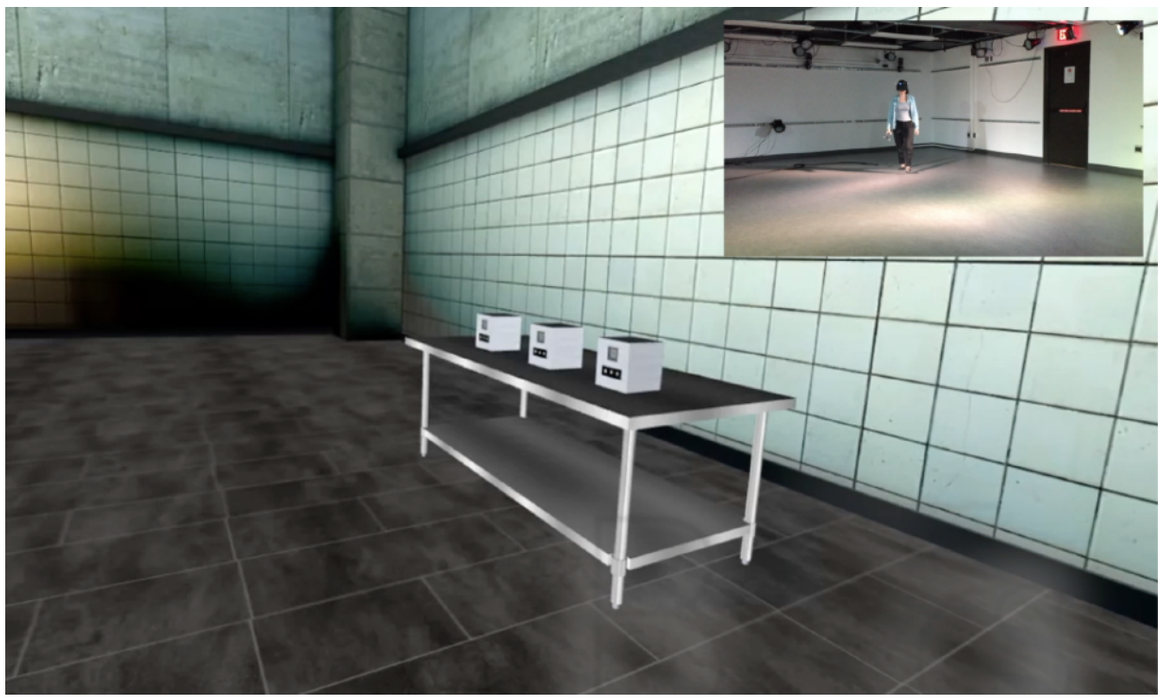
A FICTIONAL WEAPON STATE

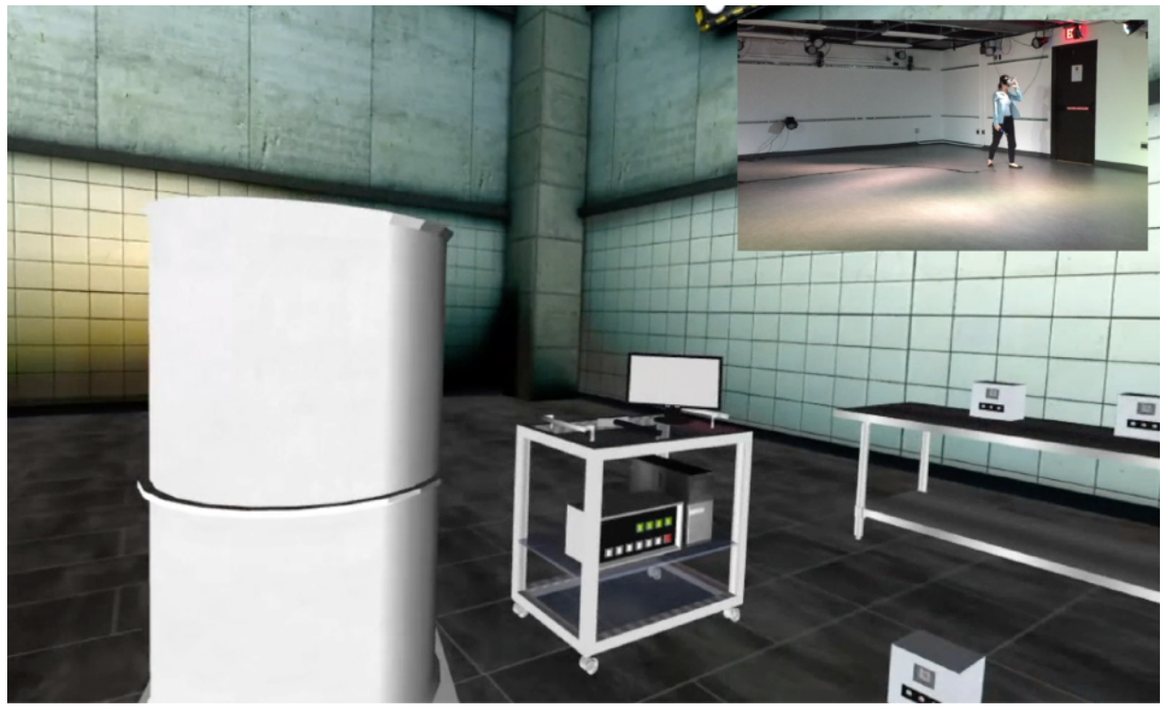
VIDEO

nuclearfutures.princeton.edu/vr



SCENE 1

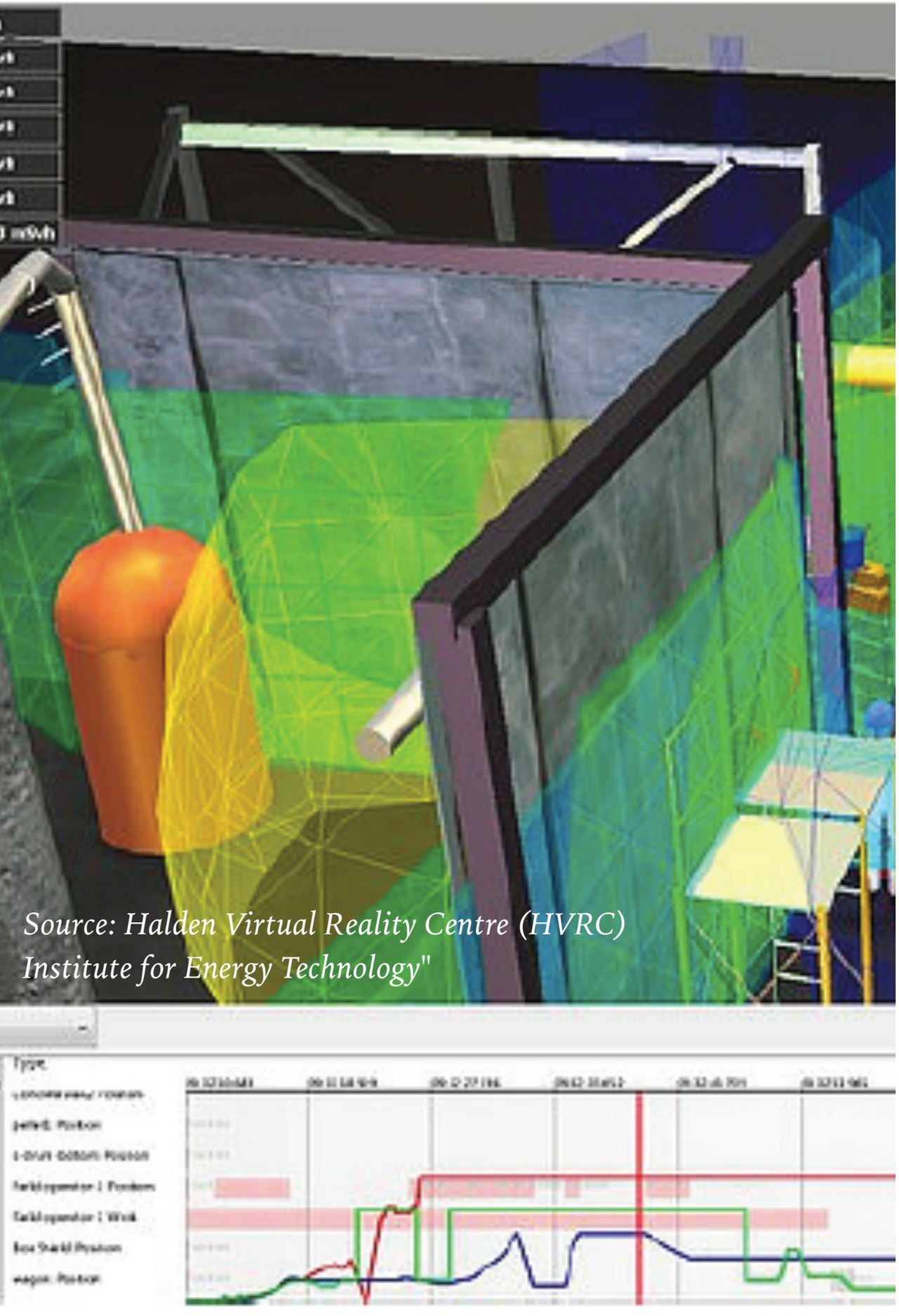
Buddy tags at a storage site



SCENE 2

Buddy tags with a possible UID system

www.youtube.com/watch?v=AMSvrxg-at4 (silent) and www.youtube.com/watch?v=PVR-ioOoOhg (sound)



VIRTUAL RADIATION

- 2006 - Making an "Impact" on Modernizing Nuclear Materials Safeguards and Security, Benny Martinez, Los Alamos National Laboratory
- 2007 - Use Of Virtual Reality To Estimate Radiation Dose Rates In Nuclear Plants, Silas C. Augusto, Instituto De Engenharia Nuclear
- 2010 - Virtual Reality Technologies for Nuclear Safeguards and Security, Emilio Ruiz Morales, European Commission, Joint Research Centre
- 2013 - Real-time, Accurate Radioactive Source Representation for Virtual Reality based Training on Radiation Detection, Teófilo Moltó Caracena, European Commission - Joint Research Centre
- Virtual Education and Research Laboratory (VERL) in the Department of Nuclear, Plasma, & Radiological Engineering at the University of Illinois at Urbana-Champaign

>>> LIVE DEMO

Virtual Radiation

Radiation source will randomly appear in one of these containers.

CAN YOU FIND THE SOURCE?

QUESTION SETS FOR VR

- **1. ARCHITECTURE**
  - Existing versus dedicated facility?
  - Should the structure prioritize disassembly efficiency or verification?
  - How "integrated" can inspectors be in the facility?
- **2. VERIFICATION TECHNOLOGY**
  - Differences in protocols for different technologies (e.g. templates vs attributes)
  - Chain of custody technology: how to track weapons and components?
- **3. MANAGED ACCESS**
  - How can hosts grant inspector confidence without revealing classified information?
  - How can inspectors gain confidence without gathering any proliferation-sensitive information?

COMING UP: STUDENT EXERCISES

- **1. Pilot exercise with Princeton students (2017)**
  - Students will be divided up into two fictional country teams. Both teams will be tasked with negotiating mechanisms for (1) verifying **baseline declarations**, and (2) verifying **weapon confirmation and dismantlement** under an arms control treaty.
  - Students will use FMVR both to assist in designing their verification approach, and to simulate various types of inspections.
  - This pilot exercise will be used to inform best practices for future exercises with other CVT partners, both at Princeton and with remote engagement.
- **2. CVT consortium exercises (2017–2018)**

MORE

nuclearfutures.princeton.edu/vr

www.verification.nu (coming soon)

cvt.engin.umich.edu