

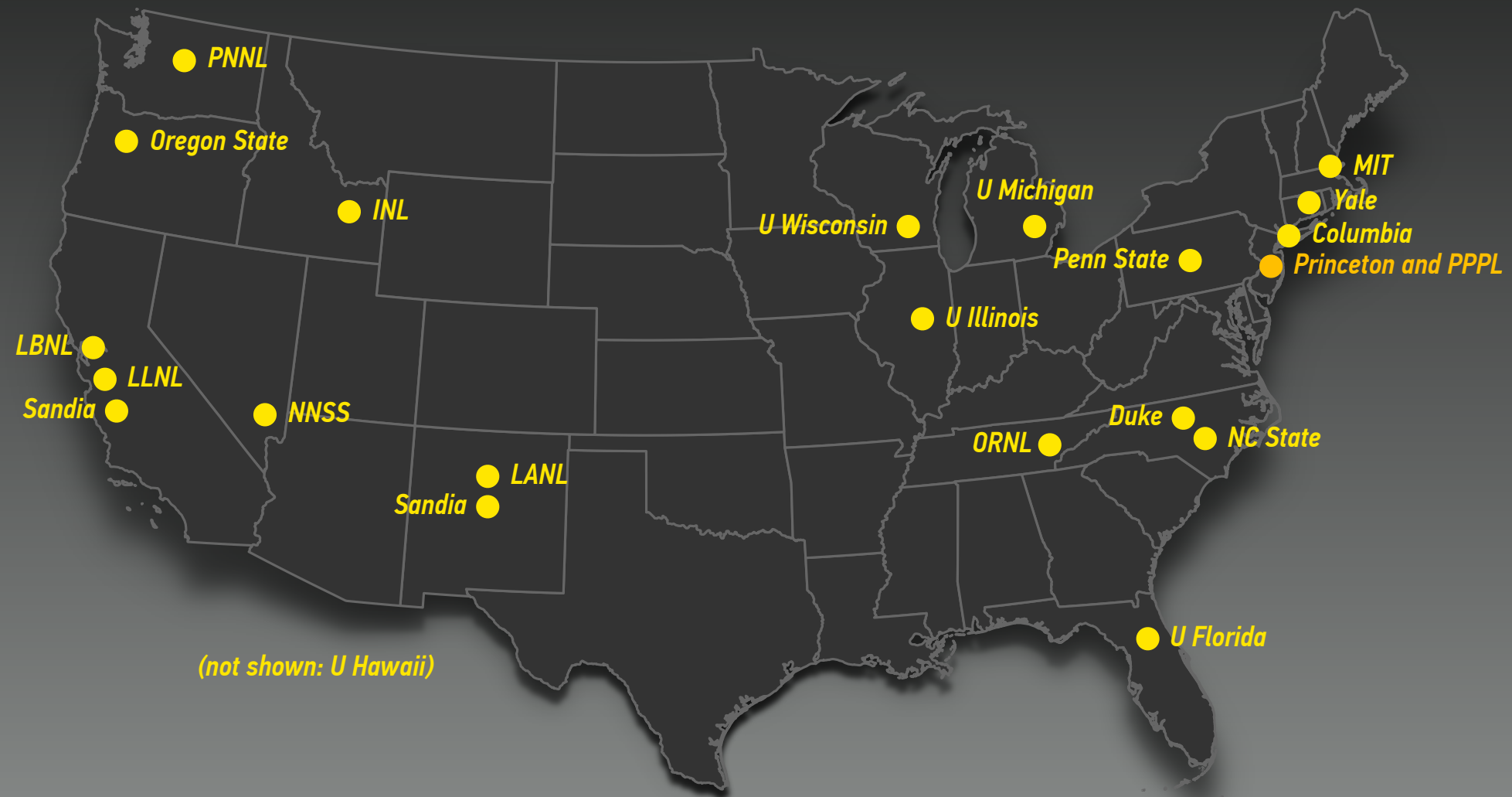
HOW TO DISMANTLE AN ATOMIC BOMB

Nuclear Arms Control in Full-Motion Virtual Reality

Tamara Patton and Alexander Glaser
SRI International
Princeton, NJ, February 24, 2017

CONSORTIUM FOR VERIFICATION TECHNOLOGY

A FIVE-YEAR PROJECT FUNDED BY THE U.S. DEPARTMENT OF ENERGY



13 U.S. universities and 9 national labs, led by University of Michigan
Princeton participates in the research thrust on disarmament research
(and leads the research thrust of the consortium on policy)

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, CTBT0)



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

THOUSANDS OF NUCLEAR WEAPONS

ARE CURRENTLY IN RESERVE OR AWAITING DISMANTLEMENT



W87/Mk-21 Reentry Vehicles in storage, Warren Air Force Base, Cheyenne, Wyoming
Photo courtesy of Paul Shambroom, www.paulshambroom.com

WHAT'S NEXT FOR NUCLEAR ARMS CONTROL?

2015 STATEMENT BY JAMES MATTIS

“The nuclear stockpile must be tended to and fundamental questions must be asked and answered:

- We must clearly establish the role of our nuclear weapons: do they serve solely to deter nuclear war? If so we should say so, and the resulting clarity will help to determine the number we need.*
- Is it time to reduce the Triad to a Diad, removing the land-based missiles? This would reduce the false alarm danger.*
- Could we re-energize the arms control effort by only counting warheads vice launchers?*
- Was the Russian test violating the INF treaty simply a blunder or a change in policy, and what is our appropriate response?”*

General James N. Mattis, USMC (Ret.)
Former Commander, United States Central Command

Senate Armed Services Committee
Global Challenges and U.S. National Security Strategy
January 27, 2015



WHAT IS TO BE VERIFIED?

VERIFICATION CHALLENGES OF NUCLEAR DISARMAMENT



1. VERIFYING NUMERICAL LIMITS OF DECLARED NUCLEAR WARHEADS

Requires techniques to account for (and identify) nuclear warheads in storage
for example, using (hashed) declarations, special tags, and/or unique identifiers (UIDs)



2. CONFIRMING THE AUTHENTICITY OF NUCLEAR WARHEADS

Requires dedicated inspection systems
for example, based on radiation-detection techniques (passive/active, neutron/gamma)

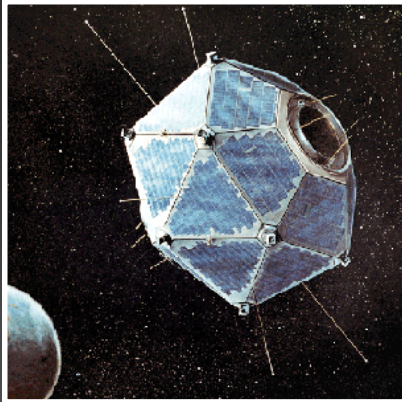


3. ESTABLISHING CONFIDENCE IN THE ABSENCE OF UNDECLARED STOCKS OR PRODUCTION

How to make sure that no covert warheads / materials exist outside the verification regime?
No silver bullet, but many different techniques and approaches

Source: Paul Shambroom (top), U.S. Department of Energy (middle), and Google Earth (bottom)

VERIFICATION APPROACHES



1. NATIONAL TECHNICAL MEANS

Largely non-cooperative, perhaps with provisions not to interfere
Not relevant here (but satellites now also privately operated)



2. TRANSPARENCY AND DATA EXCHANGE

Essential for IAEA Safeguards, based on material accountancy and bookkeeping
Measurements typically do not play a central role here



3. ONSITE INSPECTIONS

Most effective in monitoring compliance, but also most controversial
Generally considered highly intrusive; many opportunities for “smart measurements”

BUILDING FROM LIVE EXERCISES

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► 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: a weapon state and a non-weapon state.

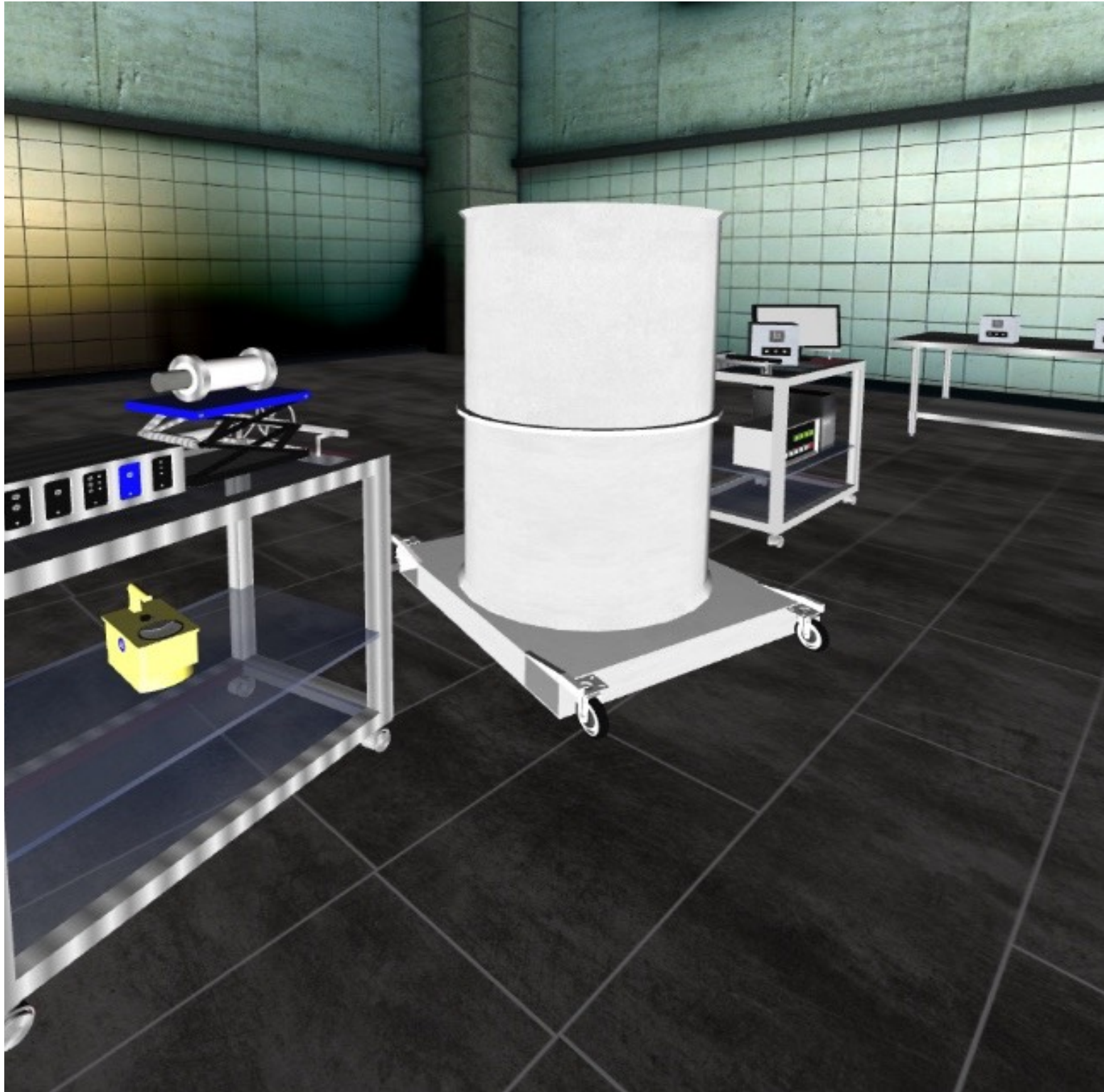
Inspectors deployed a number of techniques and processes, including radiation monitoring, tags and seals, digital photography of the tags and seals, CCTV cameras, and an information barrier system for gamma measurements.

► 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.



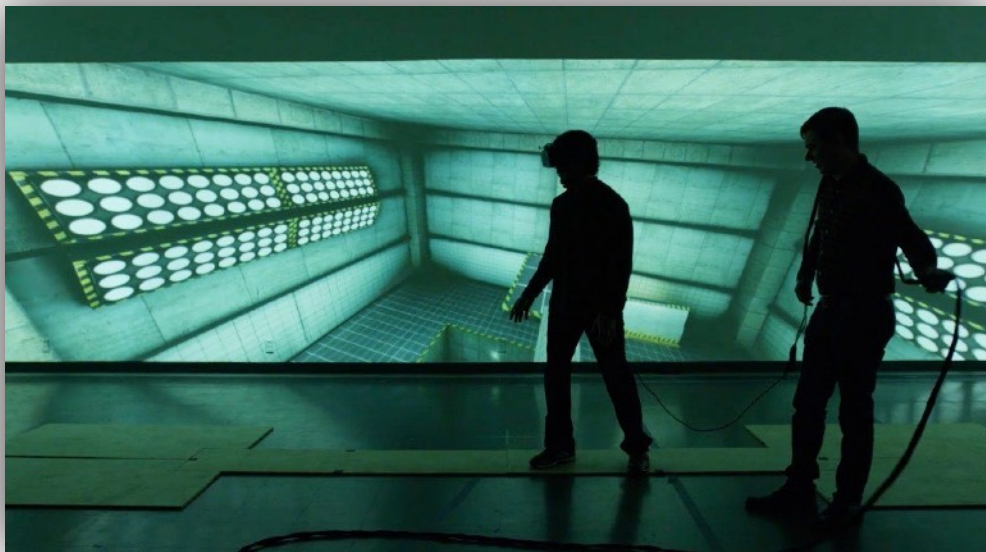
Images from the UK-Norway Initiative



“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.”

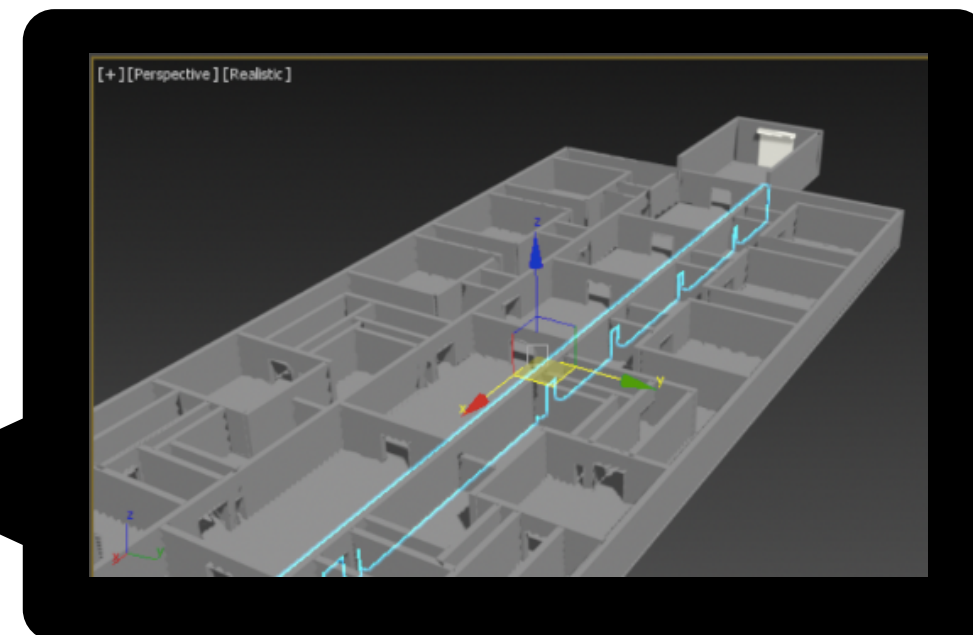
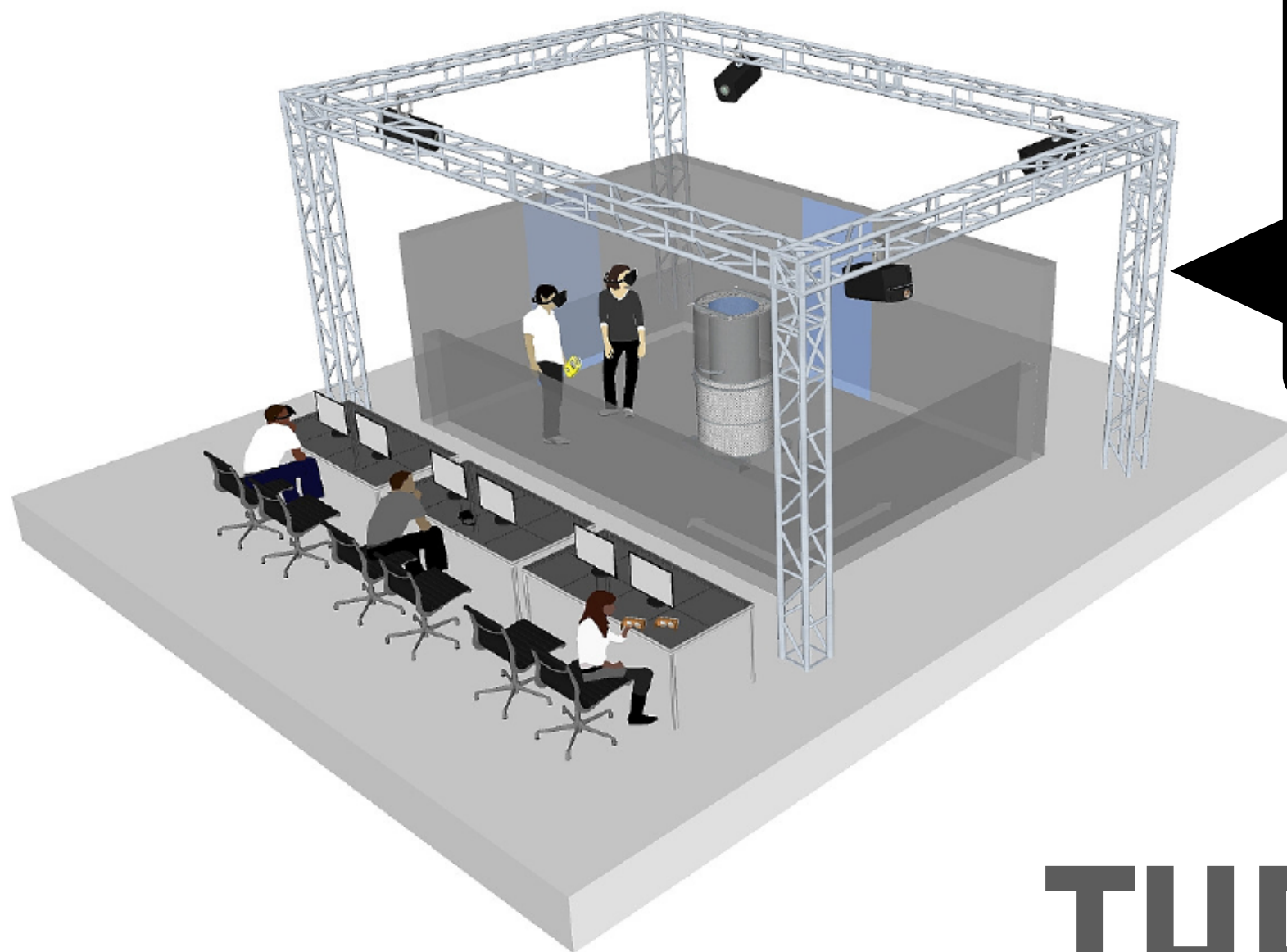
“

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

SIMULATION

DESIGN

TEACHING

NEGOTIATION

TRAINING

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

- Explore differences in protocols for different technologies, e.g. attributes vs. template-matching
- 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?

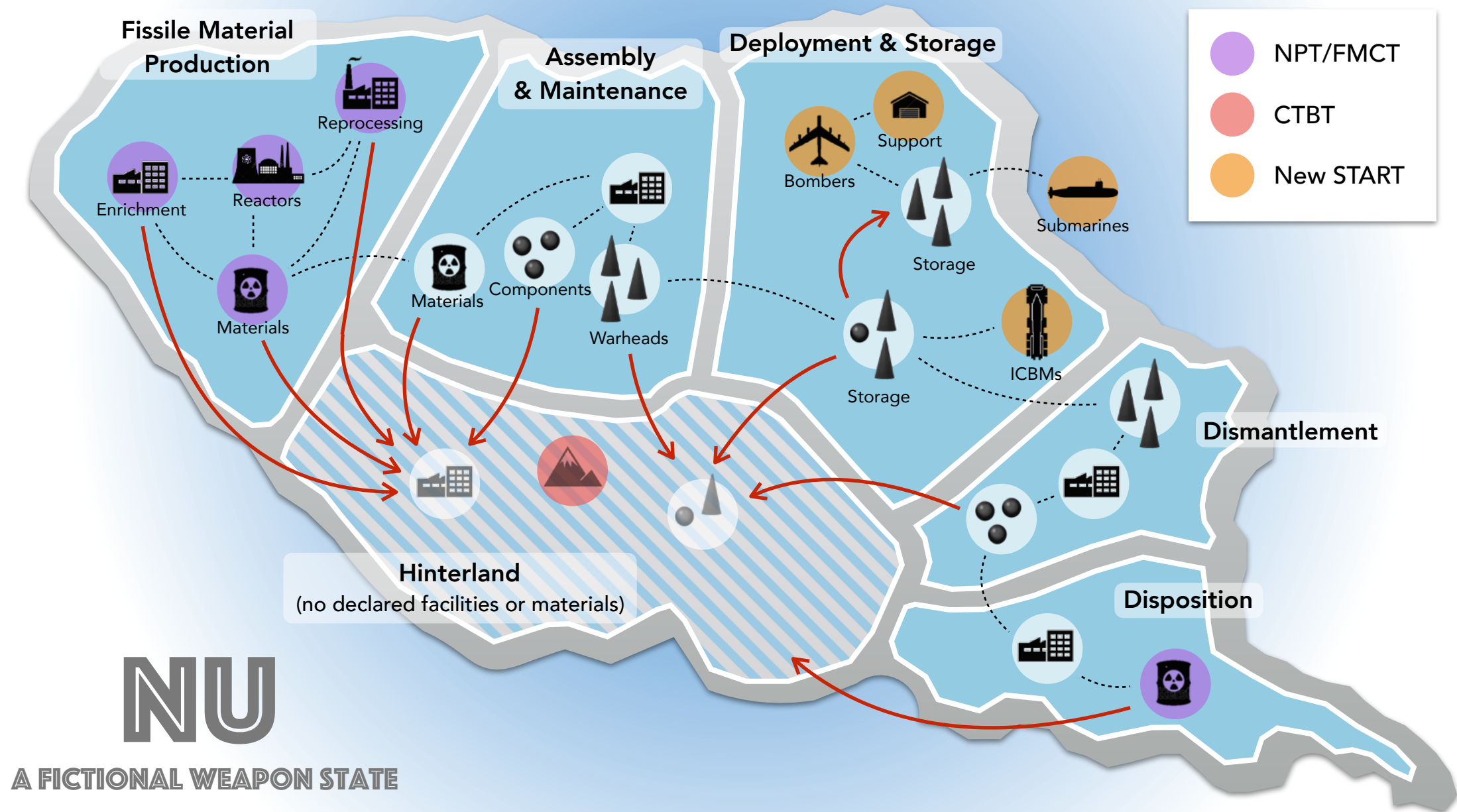
Elements of a

CASE STUDY

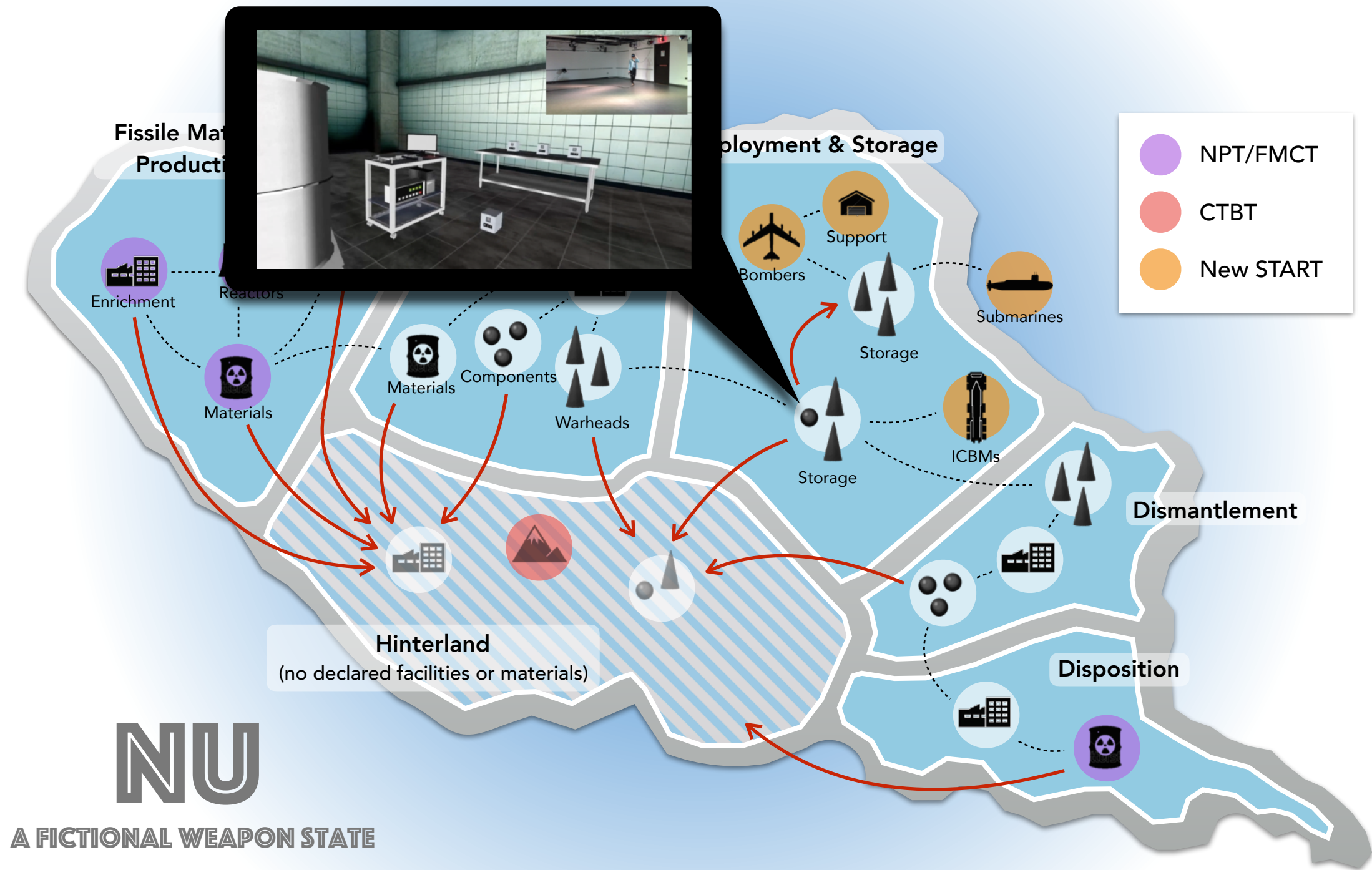
Refining a Verification Approach

MAPPING NUCLEAR VERIFICATION

www.verification.nu

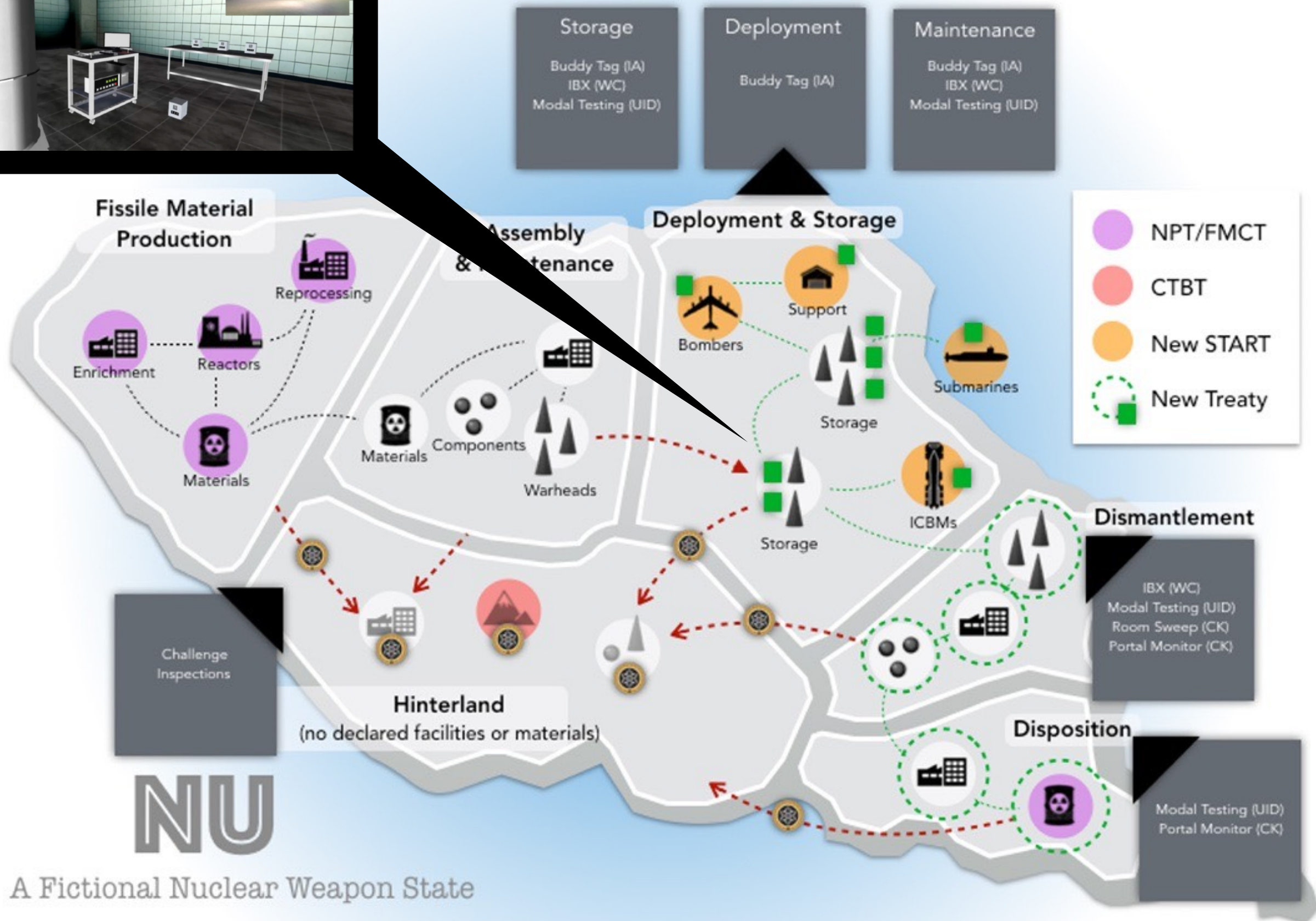


MAPPING NUCLEAR VERIFICATION



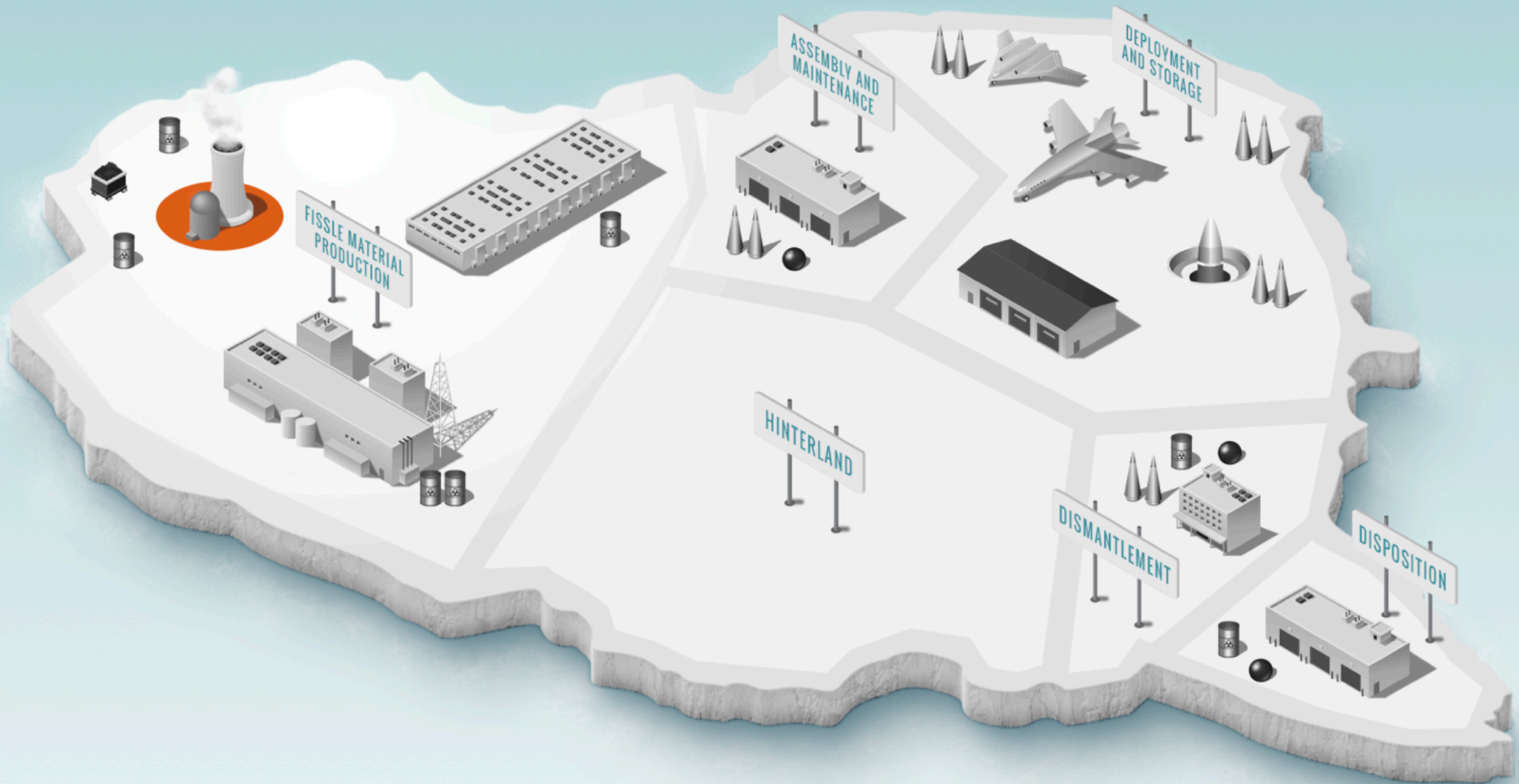
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A FICTIONAL WEAPON STATE





Discover the Possibilities



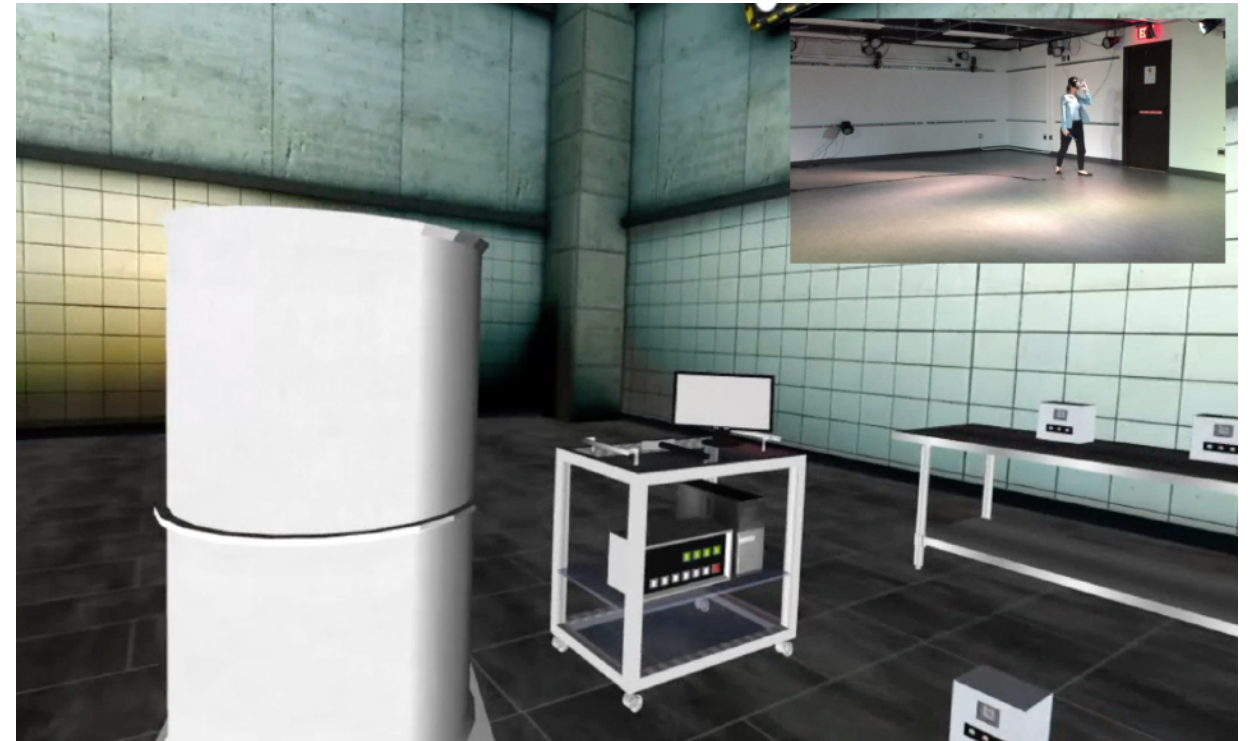
VIDEO

nuclearfutures.princeton.edu/vr



SCENE 1

Buddy tags at a storage site



SCENE 2

Buddy tags with a possible UID system

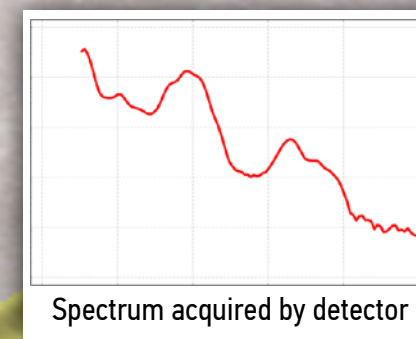
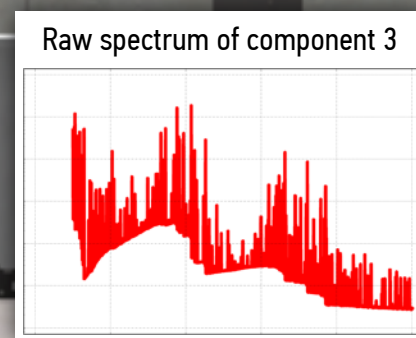
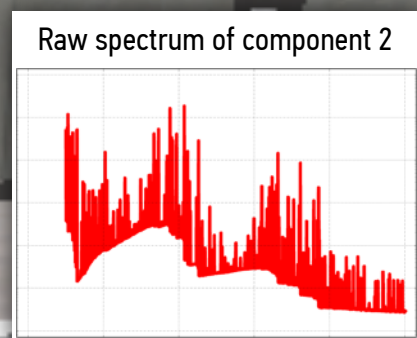
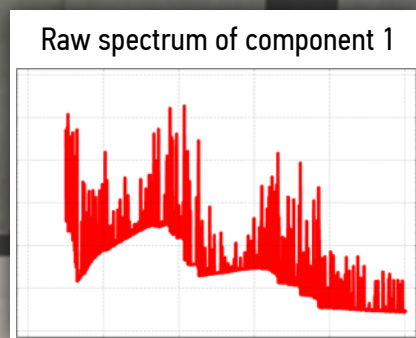
www.youtube.com/watch?v=AMSvrxg-at4 (silent) and *www.youtube.com/watch?v=PVR-ioOoOhg* (sound)



VIRTUAL RADIATION

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- Radiation signatures of materials are relevant for many aspects of nuclear verification, and it is therefore important to include radiation in our models.
- Several previous efforts with static radiation fields
- Our goal: Quasi real-time treatment of nuclear radiation for multiple/movable components and various types of detectors



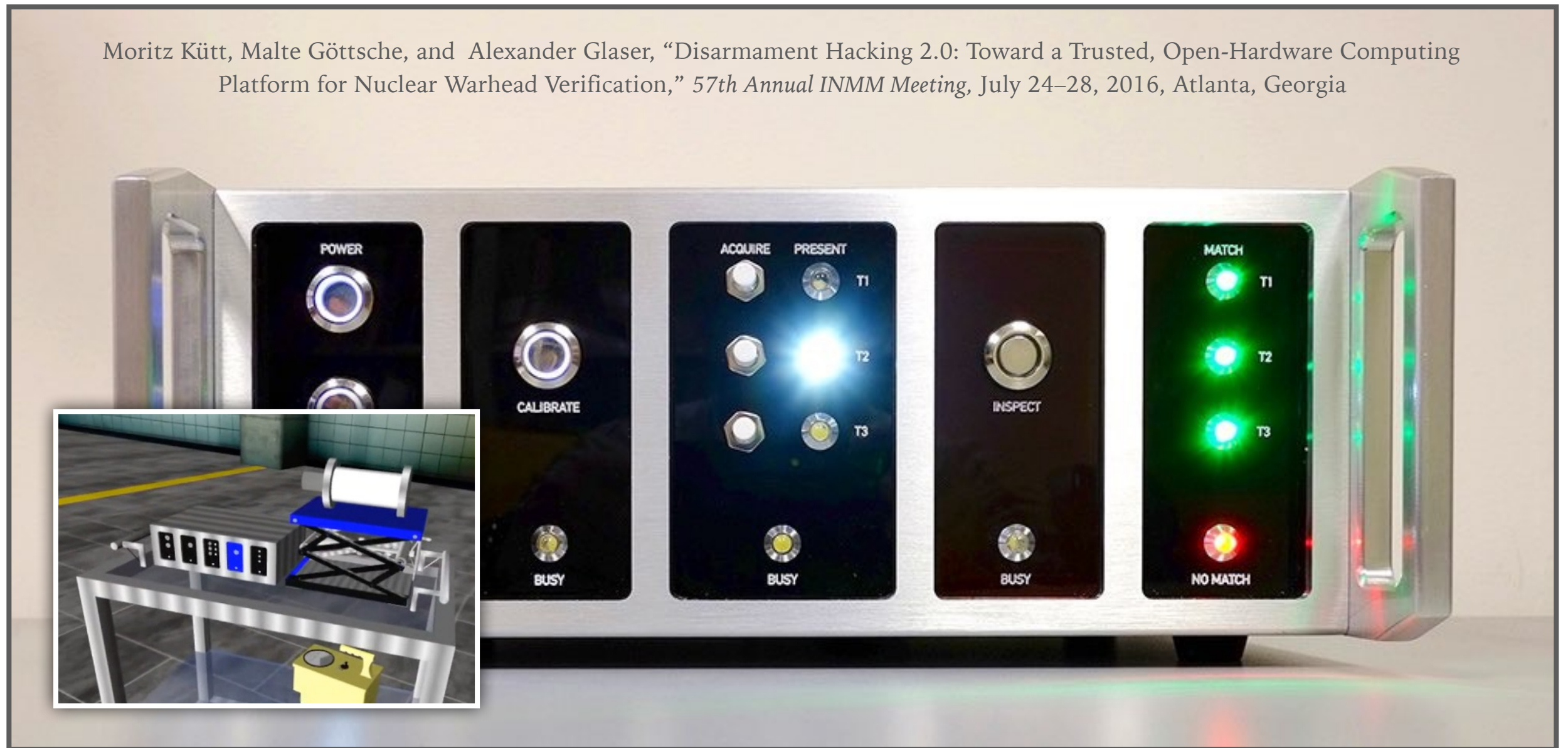
Real-time virtual (gamma) radiation

*with multiple (movable) containerized nuclear components
and selectable inspection systems (based on NaI, HPGe, or other detector types)*

INFORMATION BARRIER EXPERIMENTAL (IBX) 1/2

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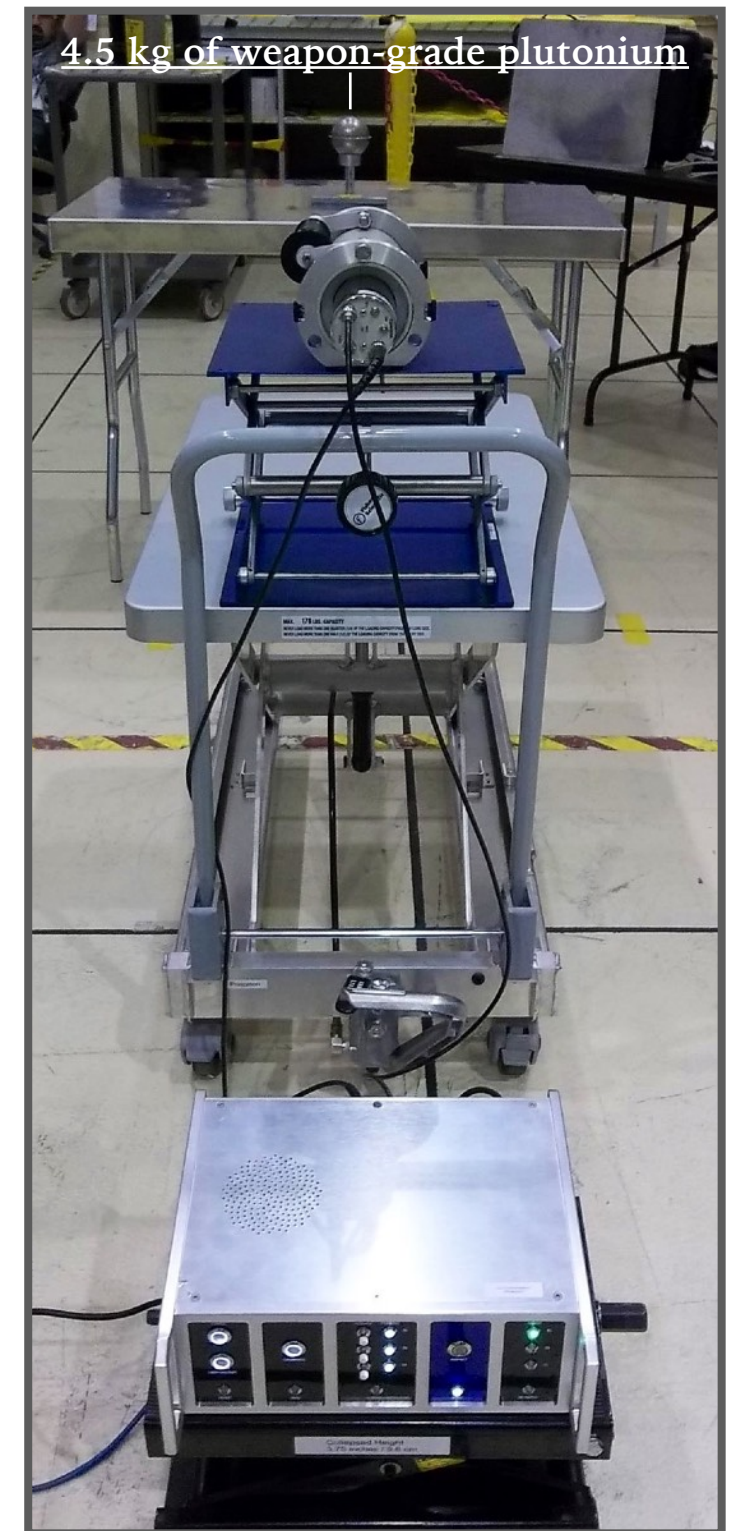
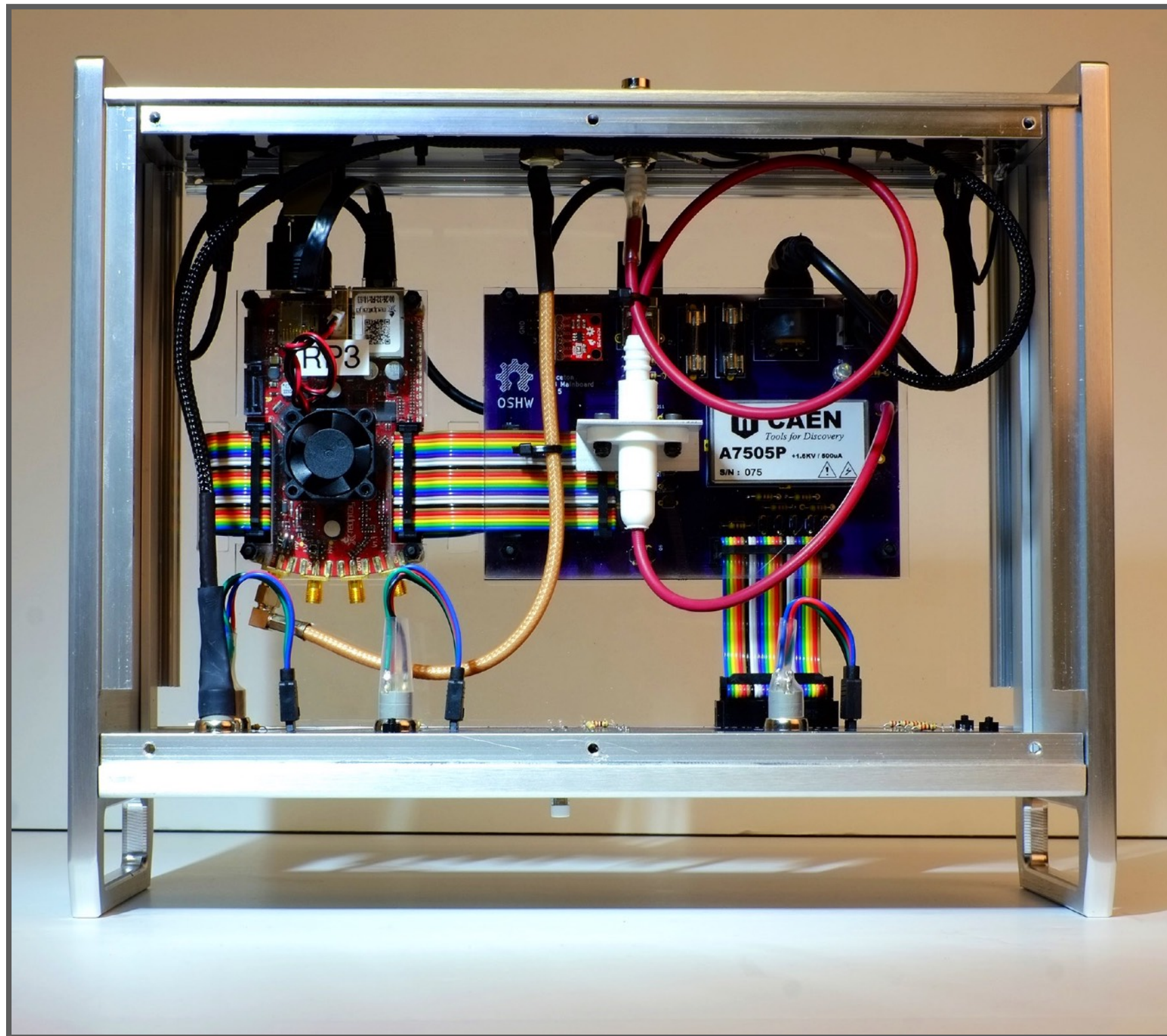
Moritz Kütt, Malte Götsche, and Alexander Glaser, “Disarmament Hacking 2.0: Toward a Trusted, Open-Hardware Computing Platform for Nuclear Warhead Verification,” *57th Annual INMM Meeting*, July 24–28, 2016, Atlanta, Georgia



- Built in Spring 2016 at Princeton University (as part of a final course project)
- Uses template-matching approach with open-source software

INFORMATION BARRIER EXPERIMENTAL (IBX) 2/2

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NEXT STEPS / WAY FORWARD

- Virtual reality offers an exciting new pathway to support experts and governments in developing and refining verification approaches for nuclear arms control
- In particular, collaborative VR exercises may offer environments to explore new concepts for addressing verification challenges (especially those relevant for onsite inspections); VR exercises can therefore lay the basis for live exercises and new policy initiatives
- We hope to hold VR exercises to both engage students on arms-control issues and develop best practices for more formal government exercises

MORE

nuclearfutures.princeton.edu/vr

www.verification.nu (coming early 2017)