

# NUCLEAR ARMS CONTROL & VERIFICATION

HOW I LEARNED TO STOP WORRYING AND LOVE TO DISMANTLE THE BOMB

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Revision 0





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# BACKGROUND

THE CURRENT CRISIS IN NUCLEAR ARMS CONTROL

# LANDMARK NUCLEAR ARMS CONTROL TREATIES

## ANTI-BALLISTIC MISSILE TREATY

(1972–2002)



Source: U.S. Missile Defense Agency

The ABM Treaty barred the United States and Russia from deploying nationwide defenses against strategic ballistic missiles

The United States withdrew in 2002

## INTERMEDIATE NUCLEAR FORCES

(1988–2019)



Source: [www.defenseimagery.mil](http://www.defenseimagery.mil) (now inactive)

The INF Treaty required the United States and Russia to eliminate all ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 kilometers

## START & New START

(1994–2009, 2011–2026)



Source: Alexander Zemlianichenko, Associated Press

START and New START requires the United States and Russia to reduce and limit their deployed strategic weapons

New START expires in 2026  
(currently “suspended”)

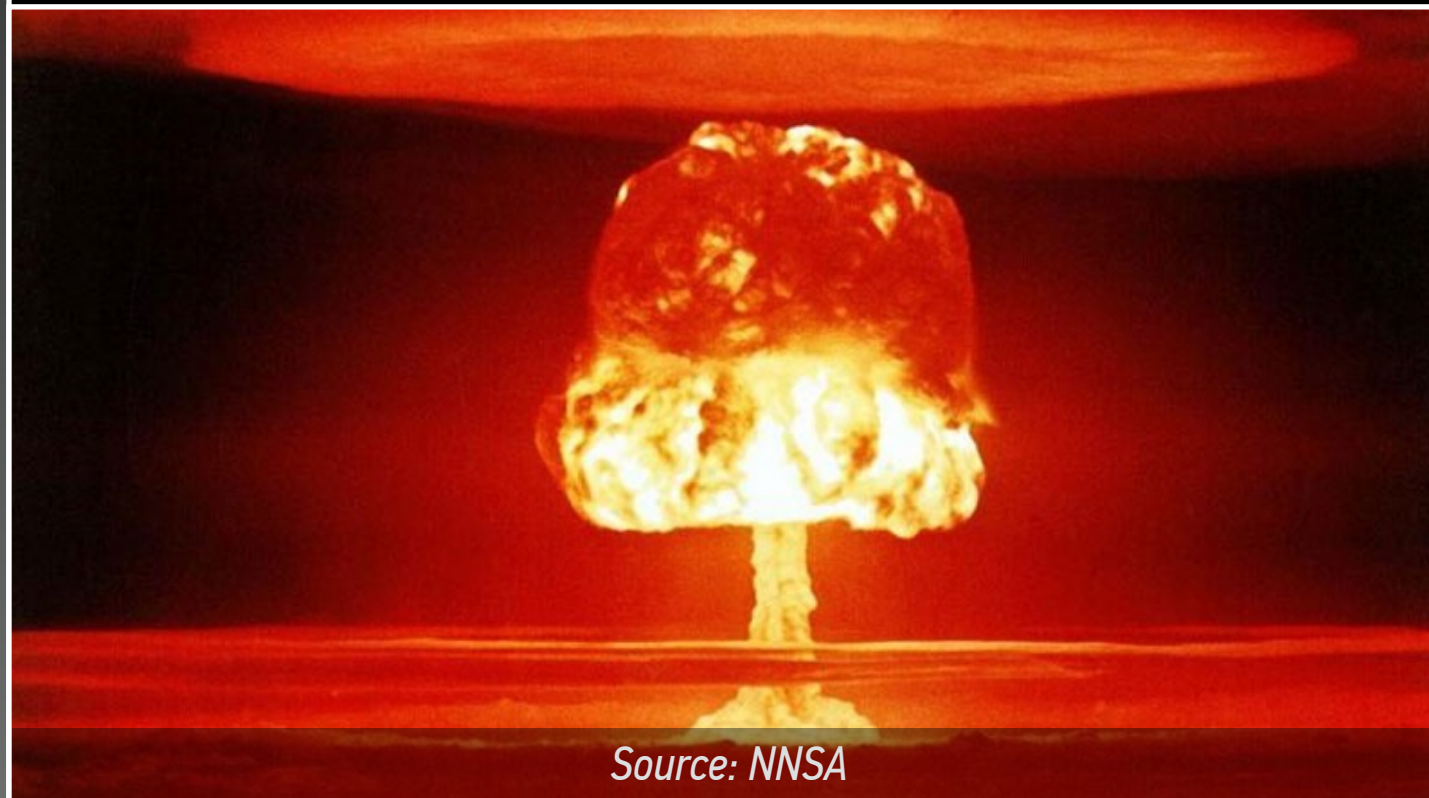
For details, see [www.armscontrol.org/factsheets/USRussiaNuclearAgreements](http://www.armscontrol.org/factsheets/USRussiaNuclearAgreements)



# LANDMARK NUCLEAR ARMS CONTROL TREATIES

## LIMITED TEST BAN TREATY

(1963)



The LTBT (or PTBT) bans testing of nuclear weapons in the atmosphere, in outer space, and under water

Original members are the United States, the United Kingdom, and the Soviet Union; France and China never joined

## THRESHOLD TEST BAN TREATY

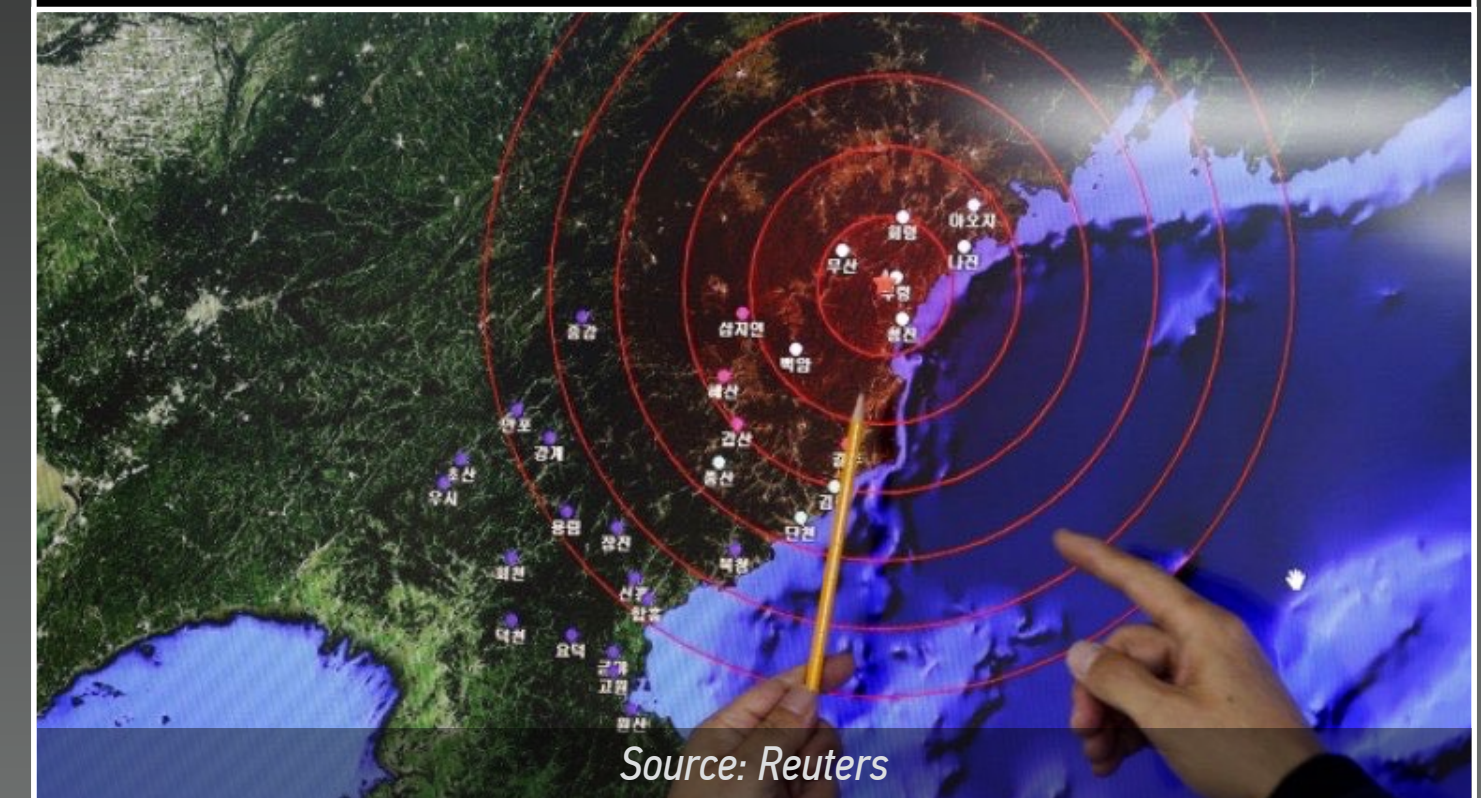
(1974/1990)



The Treaty on the Limitation of Underground Nuclear Weapon Tests (TTBT) between the United States and the Soviet Union prohibits tests with an explosive yield exceeding 150 kt(TNT)

## COMPREHENSIVE TEST BAN TREATY

(1996, not in force)



The CTBT bans all nuclear explosions in all environments

As of Oct. 2023, signed by 187 states, ratified by 178 states; enters into force when 44 “nuclear capable” states have ratified the treaty

Nuclear capable (“Annex II”) states that haven’t ratified the CTBT are China, Egypt, India, Iran, Israel, North Korea, Pakistan, and the United States; [www.ctbto.org/map/#status](http://www.ctbto.org/map/#status)



# NUCLEAR NON-PROLIFERATION TREATY



## THE NPT HAS RECENTLY TURNED FIFTY

Promises nuclear disarmament and access to civilian nuclear power in exchange for all other parties to forgo nuclear weapons; nearly universal today

2010–2019 was the first/only decade since the end of WW II without a new weapon state



## THE NPT IS IN CRISIS (ALSO)

Insufficient progress in the areas of nuclear arms control and disarmament

Commitments of the 2000 Final Document (“13 Steps”) and the 2010 Final Document (“Action Plan”) unfulfilled; 2020 Review Conference (held in August 2022) was a failure

Source: International Atomic Energy Agency







**USA**  
**5,300**



U.S. Nuclear Weapon

**Russia**  
**5,900**



United Kingdom  
215



France  
300



Israel  
80



Pakistan  
135



India  
125



China  
400



North Korea  
15



North Korean Nuclear Weapon

*There ~~are~~ remain about  
12,500 nuclear weapons  
in the world today*



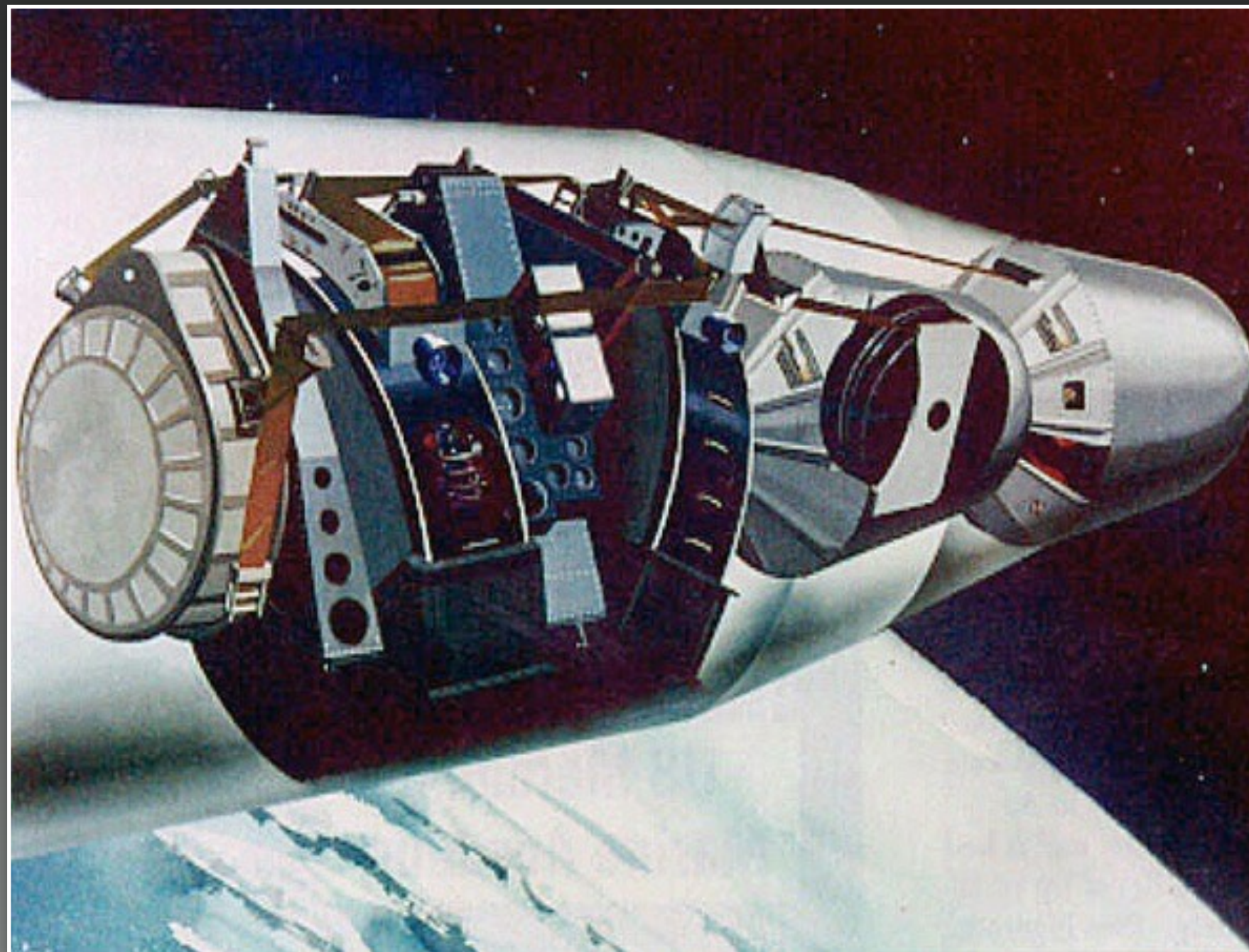
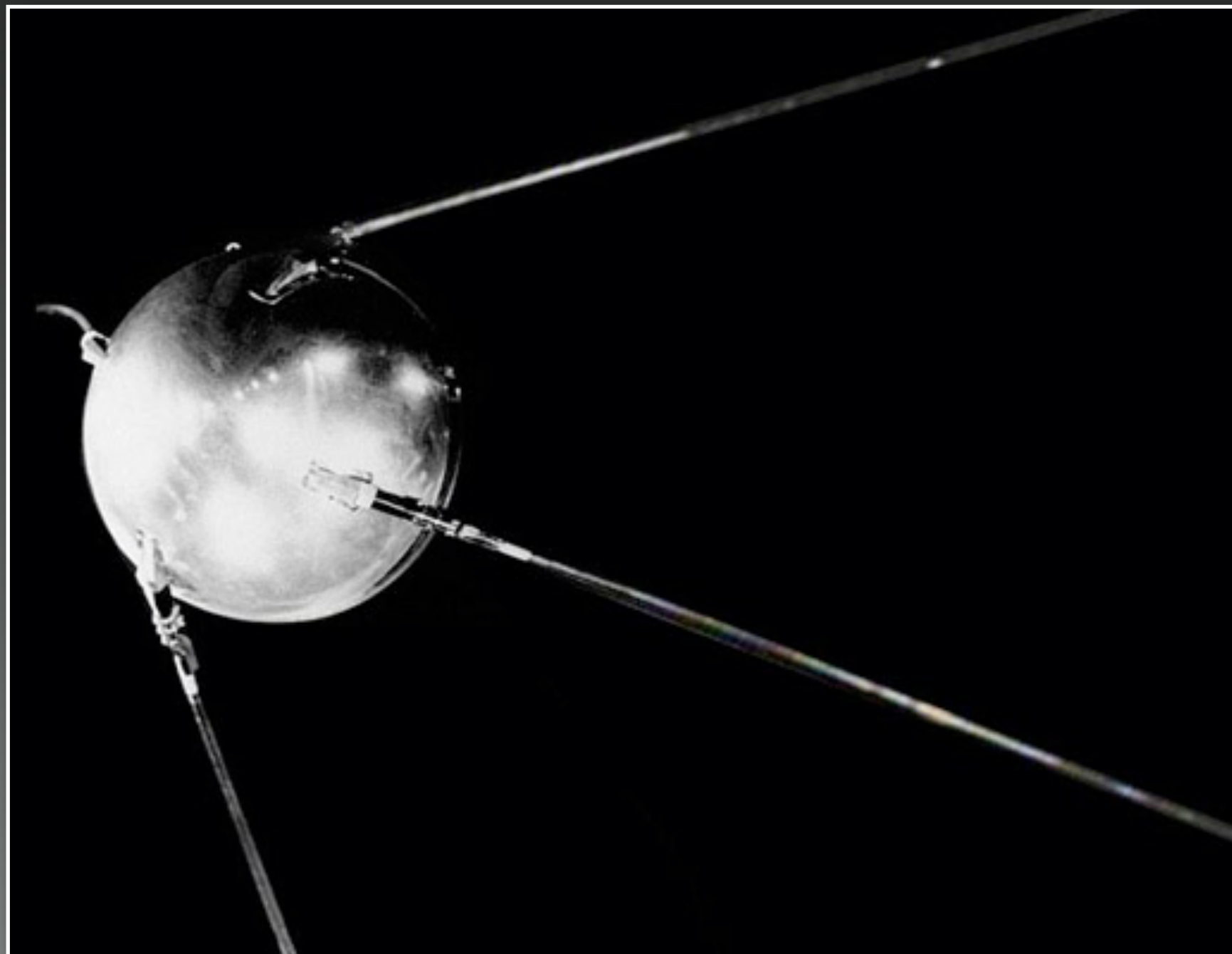
# VERIFICATION

(WHY & HOW)



# “THE GAME CHANGER”

FROM SPUTNIK 1 (OCTOBER 1957) TO THE FIRST RECONNAISSANCE SATELLITES (CORONA SERIES, 1959–1972)



Sputnik: 83.6 kg (in orbit), 58 cm diameter, operational for 3 weeks, decay of orbit after 3 months, about 1400 orbits of earth

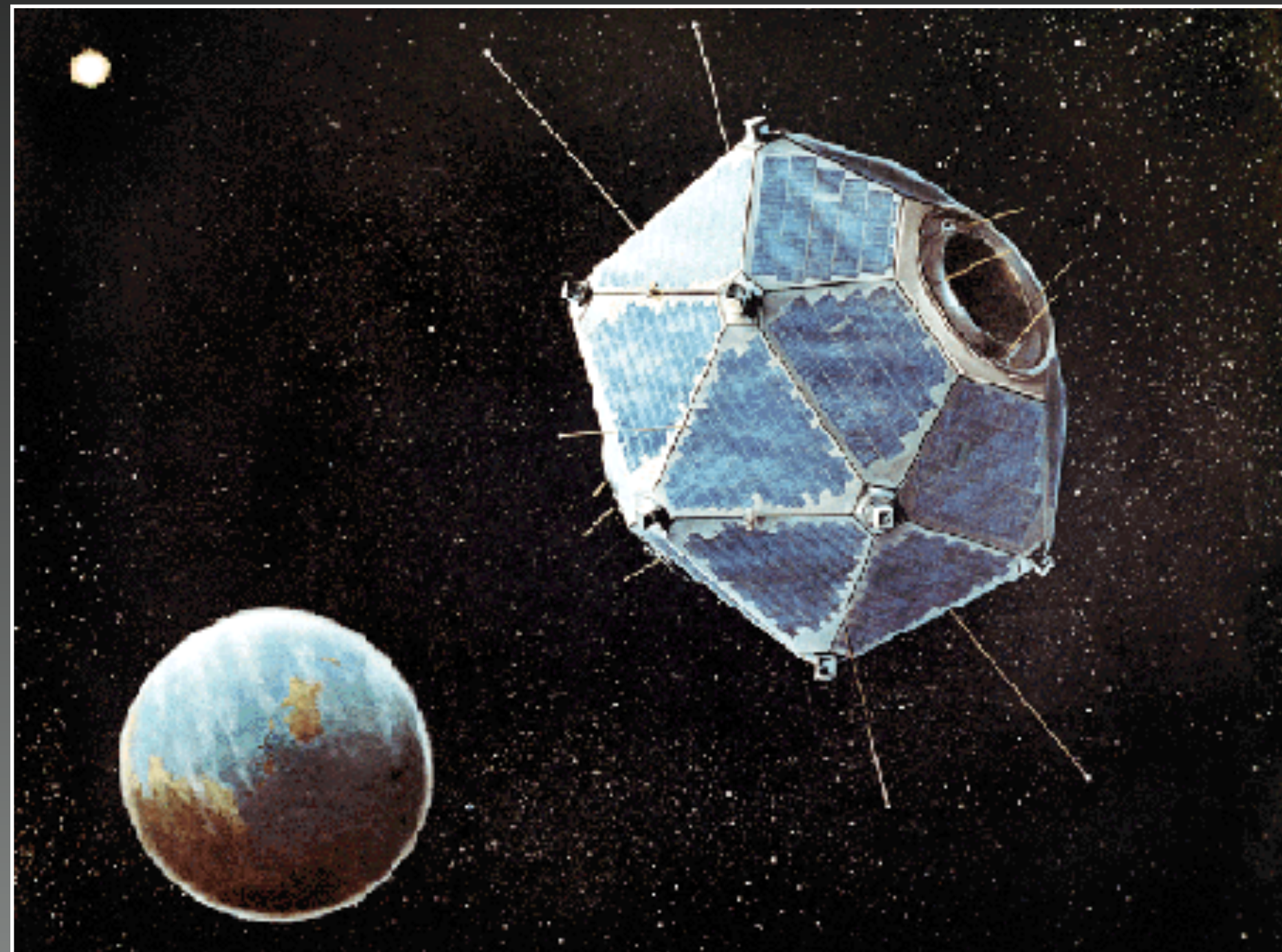
Corona series: 144 launches, more than 800,000 photographs returned

[www.nro.gov/History-and-Studies/Center-for-the-Study-of-National-Reconnaissance/The-CORONA-Program/](http://www.nro.gov/History-and-Studies/Center-for-the-Study-of-National-Reconnaissance/The-CORONA-Program/)



# USING SATELLITES FOR VERIFICATION PURPOSES

VELA (1963–1984) AND NAVSTAR/GPS (SINCE 1978)



Part of the system of “national technical means” to monitor compliance with the 1963 Limited Test Ban Treaty  
(Satellites used non-imaging photodiodes to monitor light levels)



Navstar-2F Satellite (“GPS Block IIF”), U.S. Air Force

Insert shows the Space and Atmospheric  
Burst Reporting System (SABRS-2)



*It is one of the great ironies of the Cold War that techniques developed for threat assessment and war planning made it possible for the two bitter rivals to agree on limits to some of their more destructive and destabilizing weapons without the aid of on-site inspections.*

*Allan S. Krass, The United States and Arms Control, 1997*



# VERIFYING THE INF TREATY

(1988–2001, 2019)

## ONSITE INSPECTIONS



*U.S. inspectors at Votkinsk, 1988/89 (Source: Harahan, 1993)*

Five types of (intrusive) onsite inspections until 2001, i.e., ten years after completion of the elimination phase of the treaty

Inspection types included: Baseline, Perimeter and Portal Continuous Monitoring (PPCM), Elimination, Closeout, and Short-Notice

Altogether about 850 onsite inspections under INF

## VERIFIED ELIMINATION



*Source: [www.defenseimagery.mil](http://www.defenseimagery.mil) (now inactive)*

Verified elimination of almost 2,700 missiles

This included 846 U.S. systems (BGM-109G GLCM, Pershing 1a, and Pershing II) and 1,846 Soviet systems (SS-4, SS-5, SS-12, SS-20, SS-23, and SSC-X-4)

## PERIMETER CONTROL



*Source: Author*

Perimeter and Portal Continuous Monitoring at Votkinsk, Russia, and at Magna, Utah

An industrial x-ray machine (CargoScan) was used at Votkinsk to confirm that only permitted single-warhead ICBMs (SS-25) were being produced

J. P. Harahan, *On-Site Inspections Under the INF Treaty*, U.S. Department of Defense, Washington, DC, 1993



# START & NEW START

(1994–2009, 2011–2026)

## SCOPE



START-I required a 40% reduction in deployed strategic nuclear weapon systems (ICBMs, SLBMs, and heavy bombers)

New START limits total number of deployed strategic warheads to 1,550 on each side

(Russia “suspended” New START in 2023)

## VERIFICATION APPROACH



START-I used “counting rules” to facilitate verification (e.g. a fixed number of warheads were attributed to a particular missile type)

As INF, strong emphasis on data exchange and onsite inspections (more than 1,100 START inspections until 2009)

## New START vs START



“Simplified and less costly”

More realistic counting (“actual” number of warheads)

Limited number of onsite inspections

Two vs twelve types of inspections (Type 1 and 2)

UIDs now on all delivery systems

No open display of mobile ICBMs

Edward Ifft, “Verification Lessons Learned from the INF, START I, and New START Treaties,” *55th Annual INMM Meeting*, July 2014



WHAT NEXT?



# NUCLEAR DISARMAMENT VERIFICATION

OVERLY COMPLICATED ... OR RELATIVELY SIMPLE?



*Future nuclear disarmament treaties ... likely will contain more intrusive verification mechanisms, and operate in more challenging environments than any others in history.*

*Statement by the International Partnership for Disarmament Verification (IPNDV), December 2017*

*[2017-2021.state.gov/the-international-partnership-for-nuclear-disarmament-verification-phase-i/index.html](https://2017-2021.state.gov/the-international-partnership-for-nuclear-disarmament-verification-phase-i/index.html)*



*How can the two presidents make the best of their one shot at setting the nuclear table?  
I have some advice for them: Keep it simple.*

*Rose Gottemoeller, June 2021, Lead U.S. negotiator of New START (2009)*

*Photo credit: NATO*

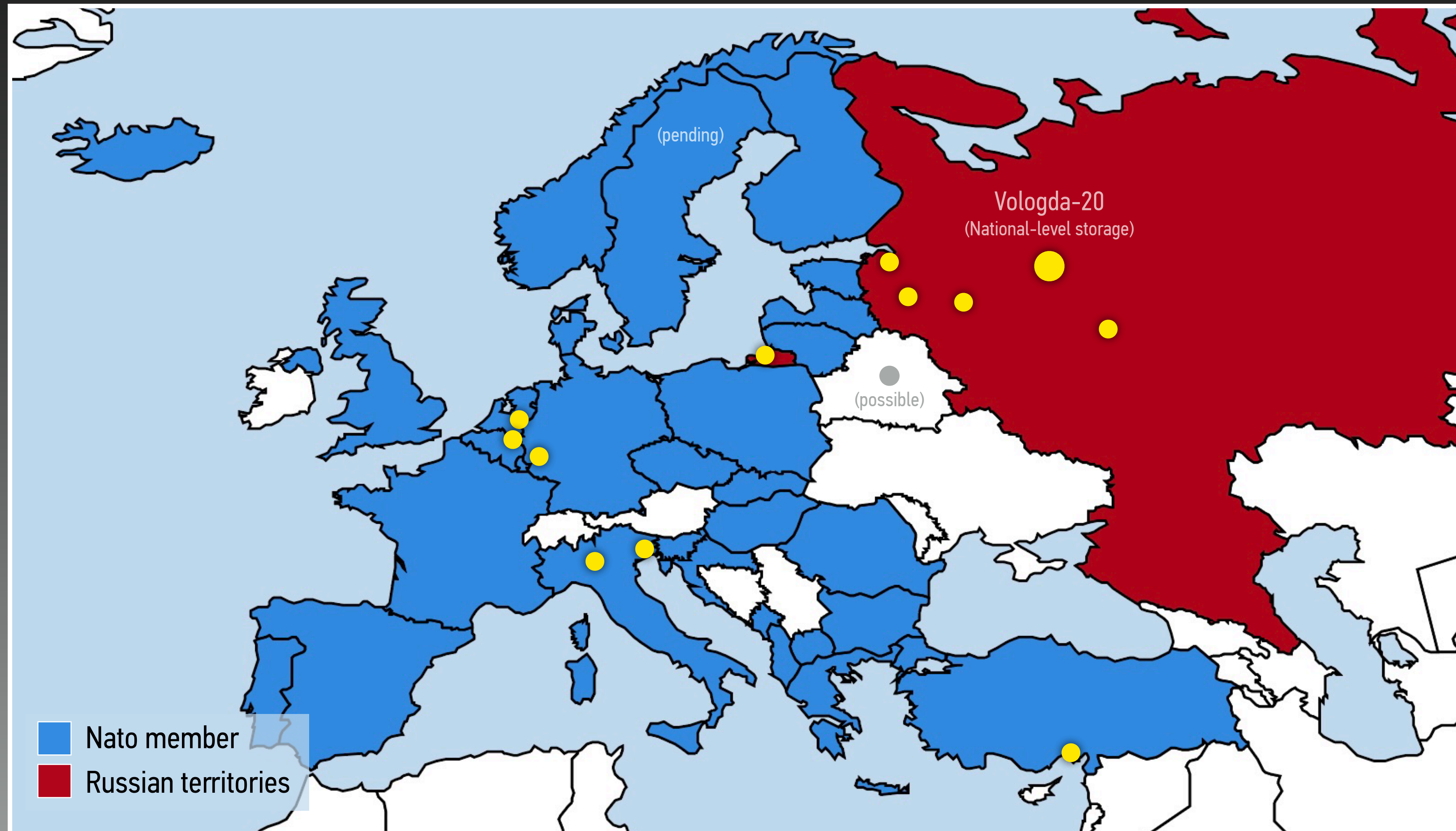


Example #1

CONFIRMING ABSENCE



# NUCLEAR WEAPONS IN EUROPE



*Adapted from Pavel Podvig and Javier Serrat*



# MENZINGEN VERIFICATION EXPERIMENT

UNIDIR & SWISS ARMED FORCES, SWITZERLAND



## EARLIER THIS YEAR IN SWITZERLAND

In March 2023, UNIDIR organized a verification experiment that included a mockup onsite inspection at a former military facility in Menzingen, Switzerland

*P. Podvig (ed.), Menzingen Verification Experiment: Verifying the Absence of Nuclear Weapons in the Field  
United Nations Institute for Disarmament Verification (UNIDIR), Geneva, Switzerland, July 2023*



## ABSENCE MEASUREMENTS

The main objective of the experiment was to examine procedures that could help to confirm the absence of nuclear weapons at a declared military site

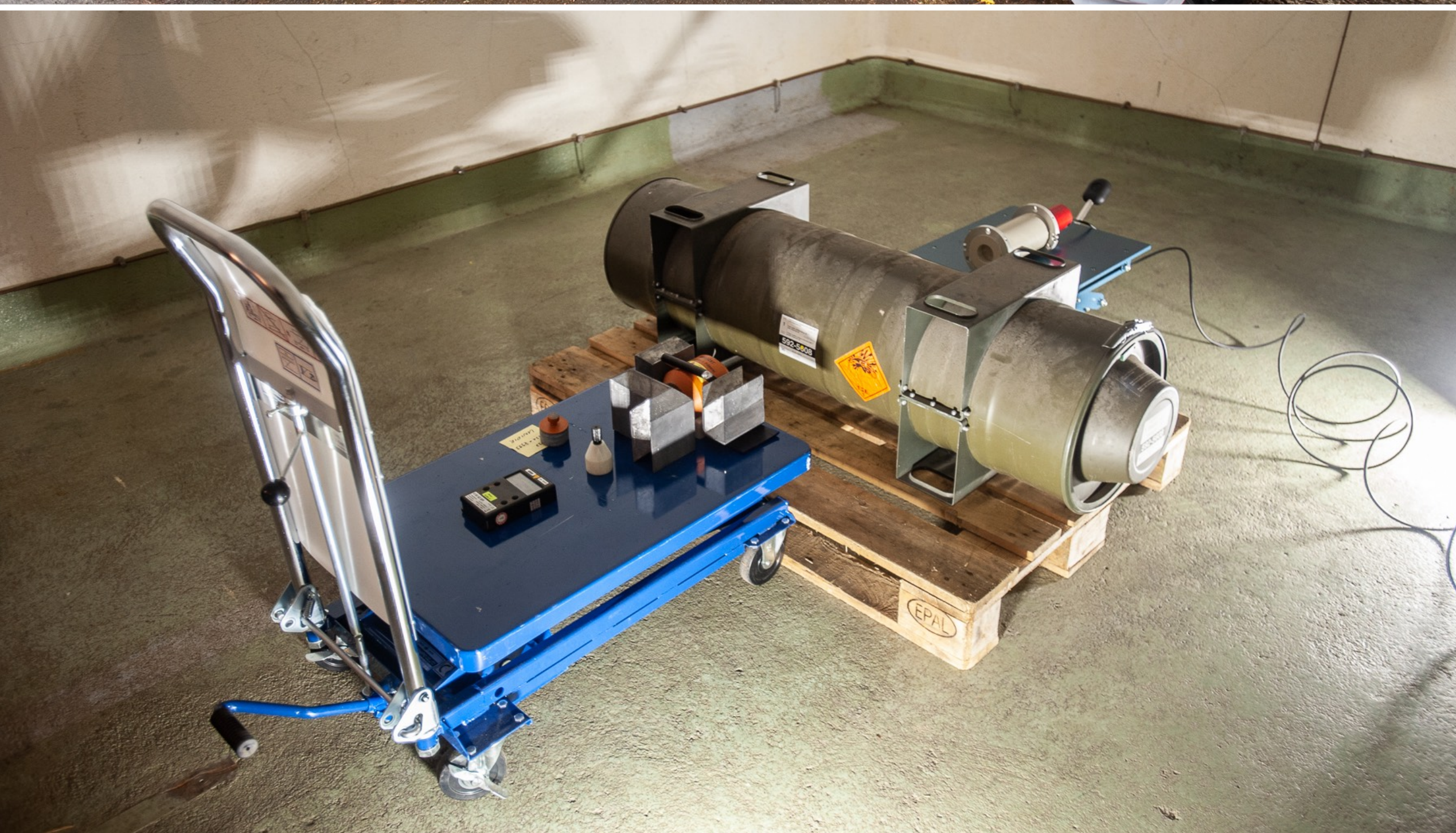
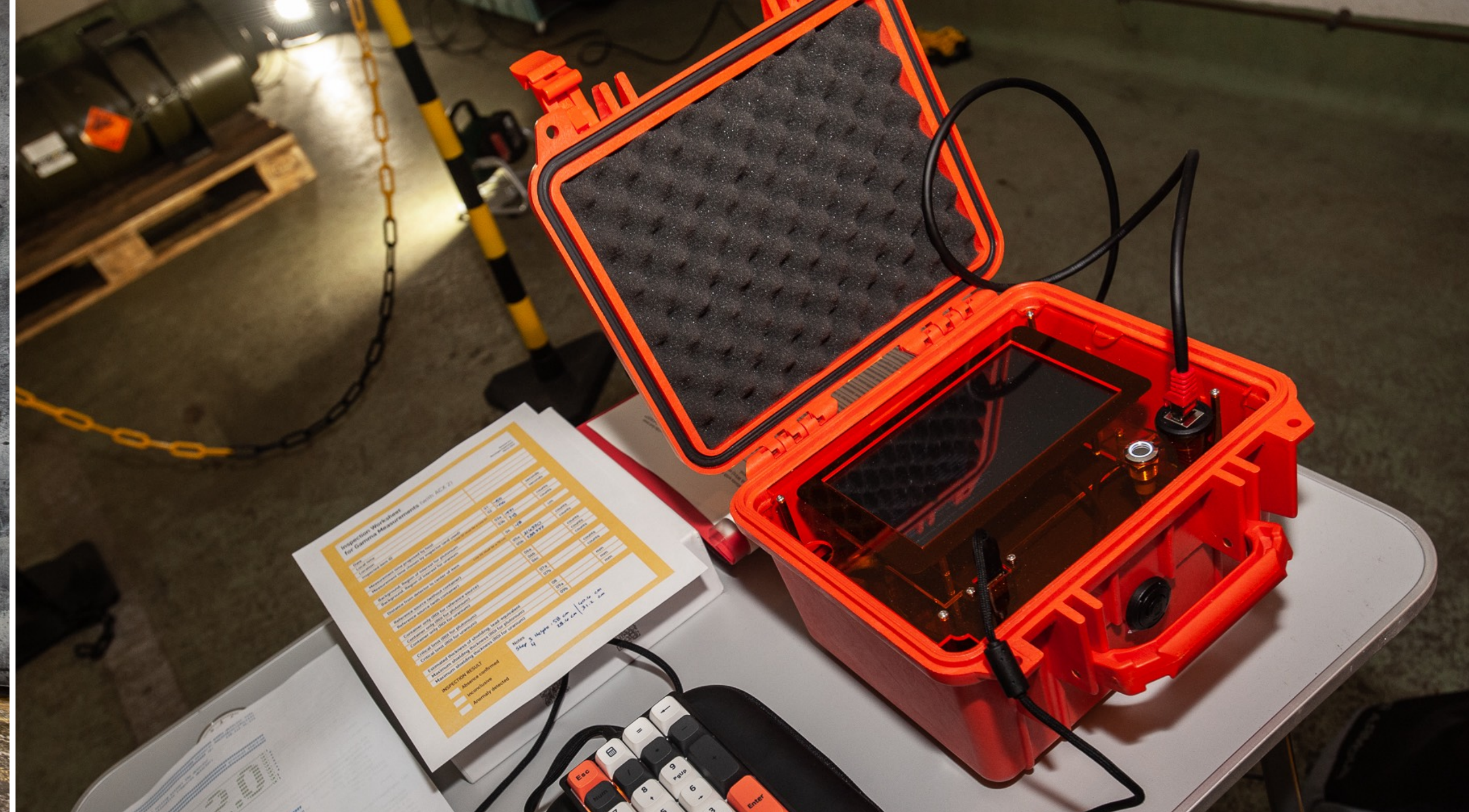
Partly based on (neutron and gamma) radiation measurements; minimum information; no spectra; no data storage

*Source: Pavel Podvig*







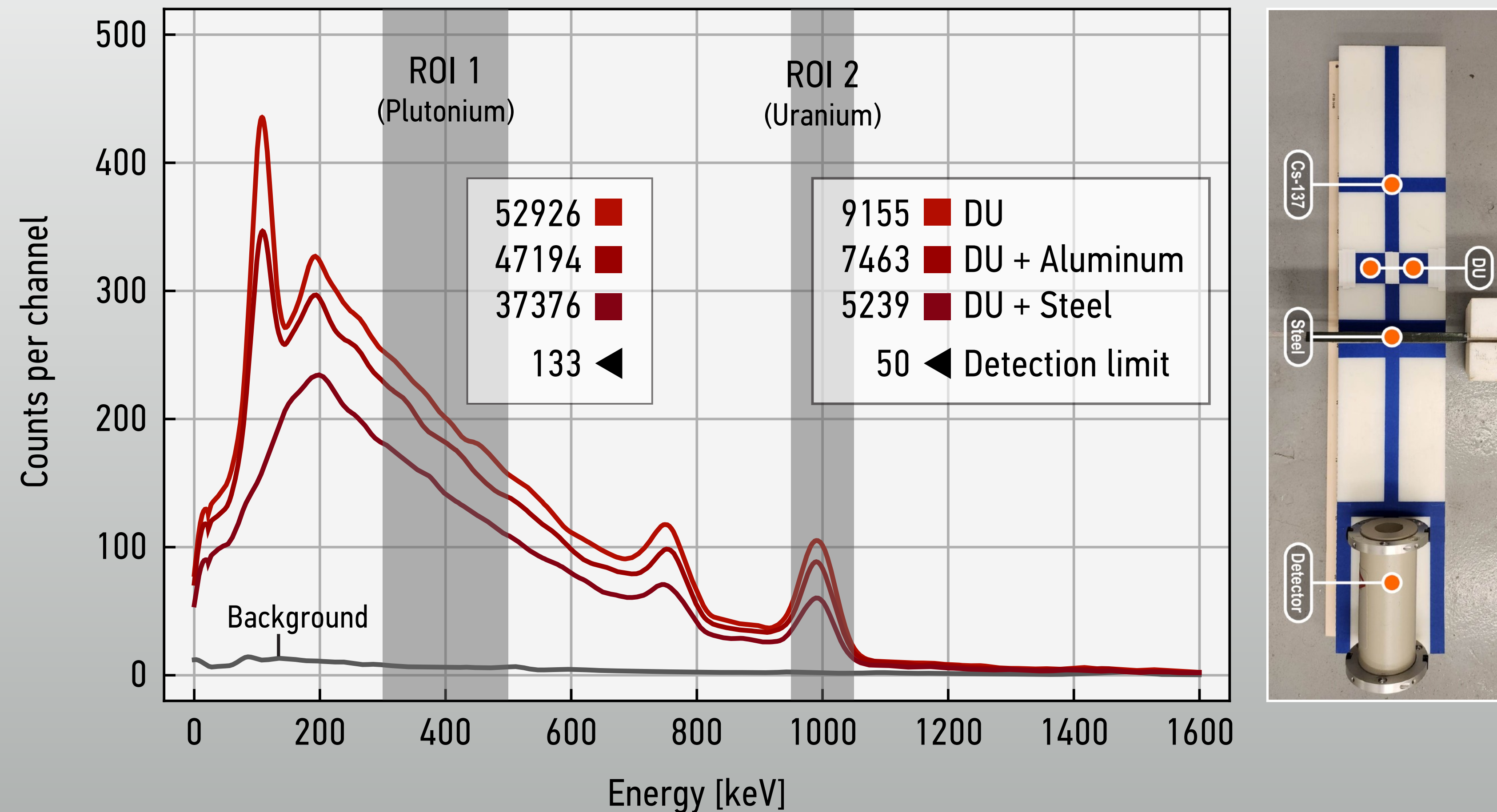


All photos: Pavel Podvig



# LABORATORY ANALOG FOR GAMMA MEASUREMENTS

EXPERIMENTAL SETUP AT PPPL SIMULATING MENZINGEN SITUATION



E. Lepowsky, M. Kreutle, C. Wirz, and A. Glaser, *Ceci N'est Pas Une Bombe*, *Science & Global Security*, September 2023



Example #2

REMOTE INSPECTIONS



# REMOTE & VIRTUAL INSPECTIONS



## PROS & CONS OF ONSITE INSPECTIONS FOR ARMS CONTROL

Onsite inspections remain the “gold standard” for nuclear arms-control verification (and IAEA safeguards) — but inspections tend to be costly and are often considered intrusive



## CAN WE (PHYSICALLY) “SEPARATE” HOST & INSPECTOR ?

Many concerns could be addressed and resolved if inspectors were not “physically” present onsite  
The host performs the prescribed activities onsite, while the inspector follows, influences, or directs the activities remotely

Source: [ukni.info](http://ukni.info) (top) and [microsoft.com](http://microsoft.com) (bottom)



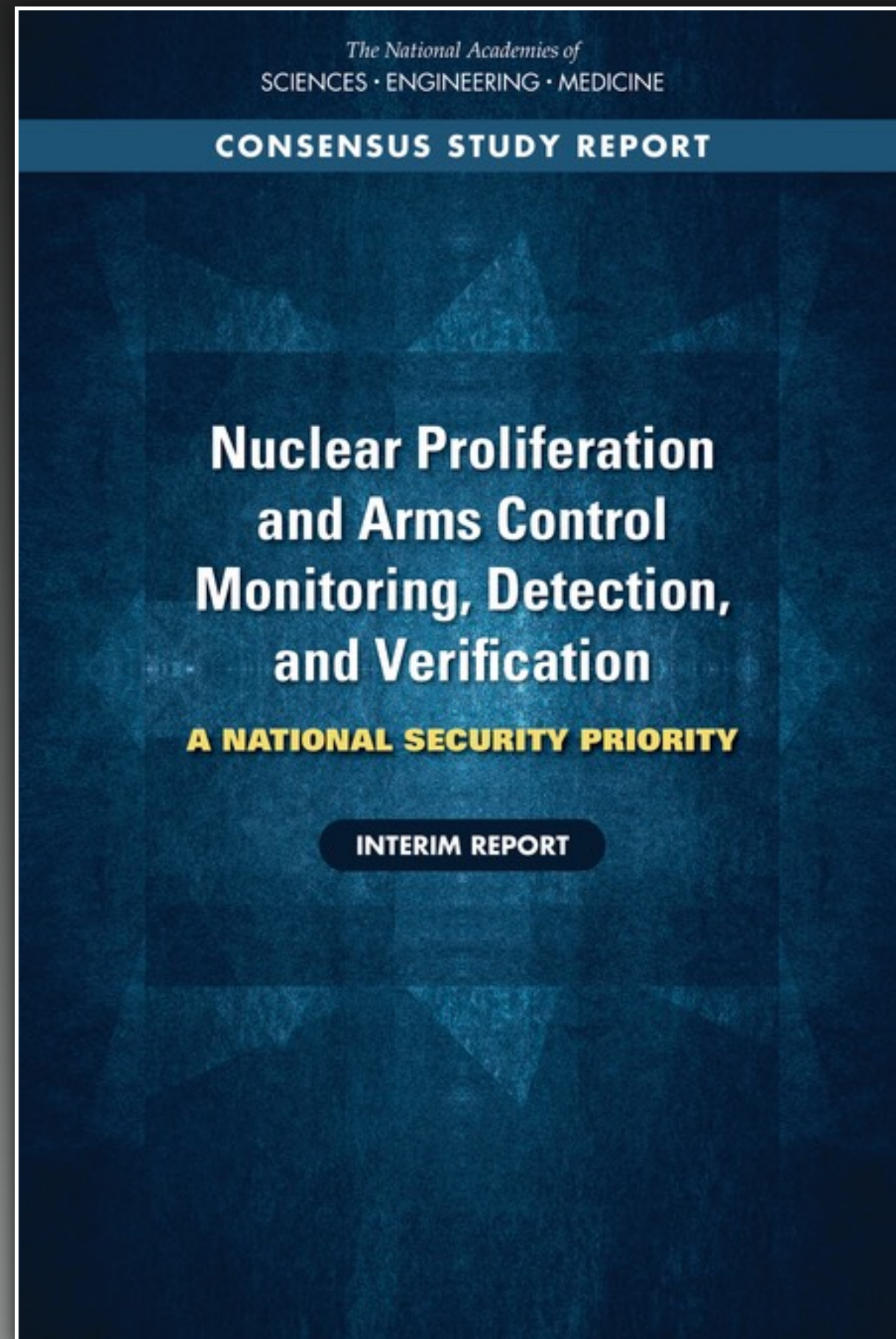


*Mk21 reentry vehicles and containerized W87 warheads at F. E. Warren Air Force Base, Cheyenne, Wyoming, October 1992*

*Source: Paul Shambroom, [paulshambroom.com](http://paulshambroom.com)*



# FINDINGS FROM 2021 NATIONAL ACADEMIES STUDY



## 3.4 MDV FOR ARMS CONTROL

### 3.4.1 Capability Needs

...

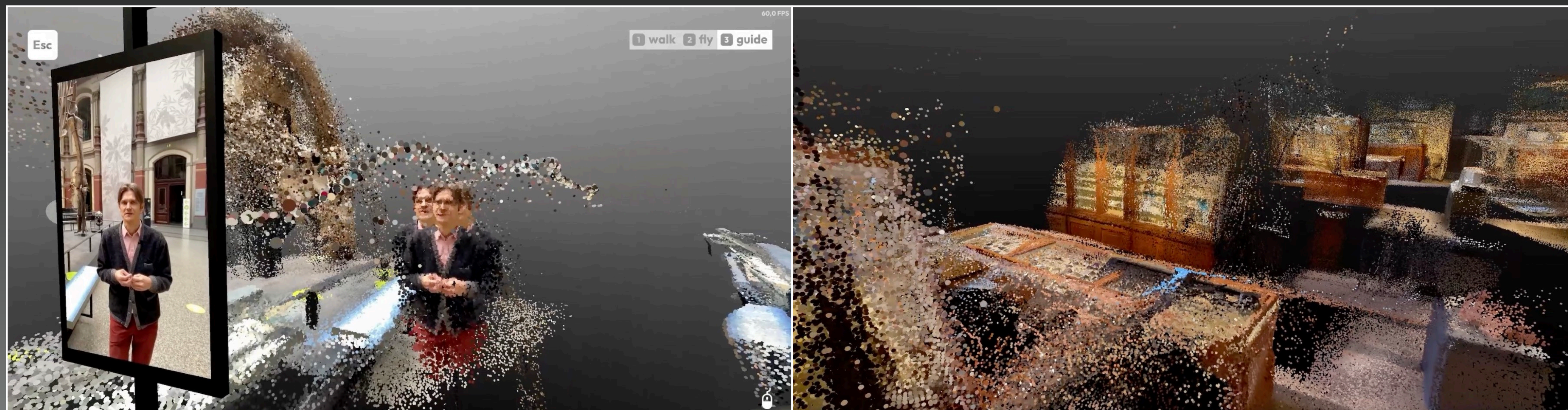
*Treaties that include weapons in storage or weapons designed for shorter-range delivery systems are anticipated to require new MDV techniques. As a minimum, such treaties would likely require access to storage areas either directly or remotely, and confirmation of warhead count (either a baseline confirmation or through routine/challenge inspections).*

*Jill Hruby, Corey Hinderstein, et al., Committee on the Review of Capabilities for Detection, Verification, and Monitoring of Nuclear Weapons and Fissile Material, National Academy of Sciences, Washington, DC, 2021, [doi.org/10.17226/26088](https://doi.org/10.17226/26088)*



# BUT ... HOW TO IMPLEMENT THEM?

## (ONE IDEA)



*Point Cloud Walk*, a software prototype developed by ART+COM ([artcom.de](http://artcom.de)) in 2021/2022 for a museum in Berlin

*Point Cloud Walk* uses a real-time LIDAR scan performed by the host to generate the virtual environment, which the digital visitor can then explore

The prototype also enables interactions between the physical and the virtual worlds and participants

Credit: Jussi Ängeslevä ([angesleva.iki.fi](http://angesleva.iki.fi)) and Jürgen Geuter (ART+COM)



# BENEFITS & CHALLENGES OF REMOTE INSPECTIONS



## BENEFITS (REVISITED)

- Reduced intrusiveness, time, and cost compared to onsite inspections  
*Potentially also of interest for some routine IAEA inspections*
- Reduced security risks of disclosing sensitive information  
*Sensitive details and objects are never modeled*



## CHALLENGES

- Security and integrity of transmitted data
- Live and local verification

*Roger G. Johnston and Jon S. Warner, "Unconventional Approaches to Chain of Custody and Verification"  
51st INMM Meeting, Baltimore, MD, July 2010*

*Source: IAEA (top) and Johnston and Warner, 2010 (bottom)*



