

Science for Nuclear Arms Control

Lecture II: Nuclear Diplomacy

Prof. Dr. Malte Götttsche
Nuclear Verification and Disarmament Group

Physics Institute III B
RWTH Aachen University
goettsche@nvd.rwth-aachen.de

CERN Academic Training, 7 February 2024

Nonproliferation

The Non-Proliferation Treaty 1968

Separation of members into non-nuclear weapon states (NNWS) and nuclear weapon states (NWS), based on whether they had tested weapons before 1967

Articles I/II

- NNWS: not manufacture or acquire nuclear weapons, not to seek assistance
- NWS/NNWS: Not transfer nuclear weapons to NNWS

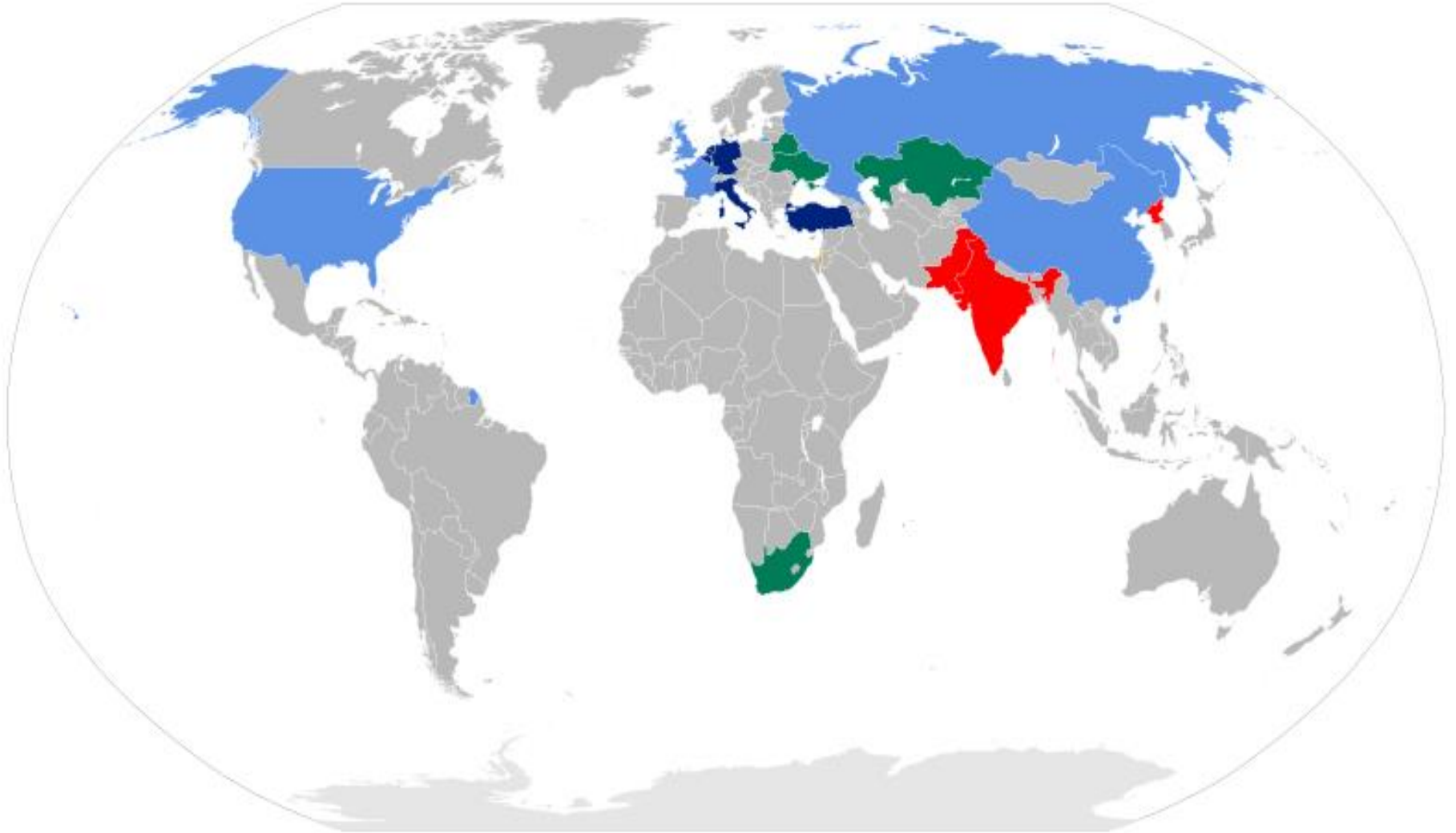
Article IV

- NWS/NNWS: inalienable right to develop research, production and use of nuclear energy for peaceful purposes
- NNWS should be supported in building nuclear energy programs

Article VI

- “Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to [...] nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.”

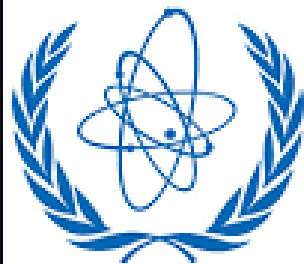
The Non-Proliferation Treaty



Safeguards

Article III

- “Each **non-nuclear-weapon State Party** to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency [...], for the exclusive purpose of verification of the fulfilment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. [...] The safeguards required by this Article shall be applied on **all** source or special fissionable material in all peaceful nuclear activities [...]”



IAEA

International Atomic Energy Agency

Atoms for Peace and Development

Safeguards

Verifying declared nuclear materials

Nuclear material accountancy

- On-site inspections in nuclear facilities
- Remote monitoring



Safeguards

Iraq:

- Undeclared research into uranium enrichment technology
 - Undeclared import of uranium stocks
 - Significant research in nuclear weapons design before 1991
- UNSCOM (UN Special Commission) 1991-1997
- Later: UNMOVIC (until war)



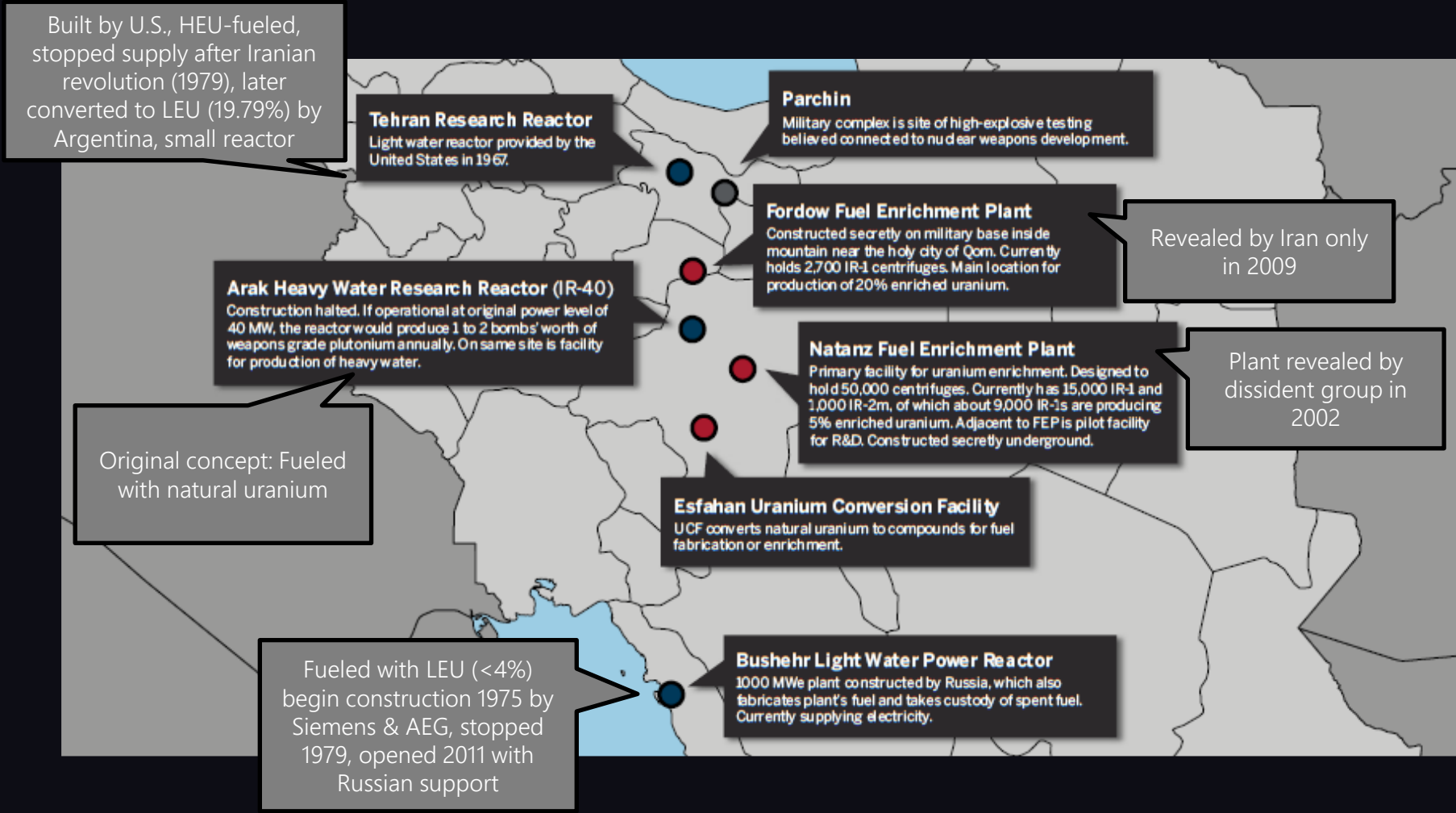
Safeguards

Verifying undeclared nuclear materials and activities: The Additional Protocol

- Challenge inspections
- Open Source Analysis (e.g. satellite imagery, trade data)



Current nonproliferation matters



Joint Comprehensive Plan of Action (JCPOA)

Figure 6: Uranium Pathway Restrictions

	Before Interim agreement reached (Nov. 2013) ¹	JCPOA physical limits (10–15 years)	
First-gen (IR-1) centrifuges	18,472	Capped at 6,104	Operation of advanced centrifuges at Natanz and Fordow
Second-gen (IR-2) centrifuges	1,008	None ²	
Breakout time ³	1–2 months	Approximately 12 months	< 1 month
R&D of new centrifuge technology	Unconstrained	Constrained	3,500 kg < 5%
Stockpile of low-enriched UF ₆ ⁴	7,154 kg ⁵	Capped at 300 kg ⁶	
Stockpile of 20%-enriched UF ₆	196 kg ⁷	None	570 kg < 20% 130 kg < 60%
Maximum enrichment level	No restrictions	3.67%	IAEA monitoring continues with limitations
Centrifuge production	Unconstrained	Constrained to producing only replacement IR-1 for 10 years; no production of IR-6 or IR-8 for 8 years	

Current state: IAEA Director General, Report to the Board of Governors "Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015)," GOV/2023/57, 15/11/2023

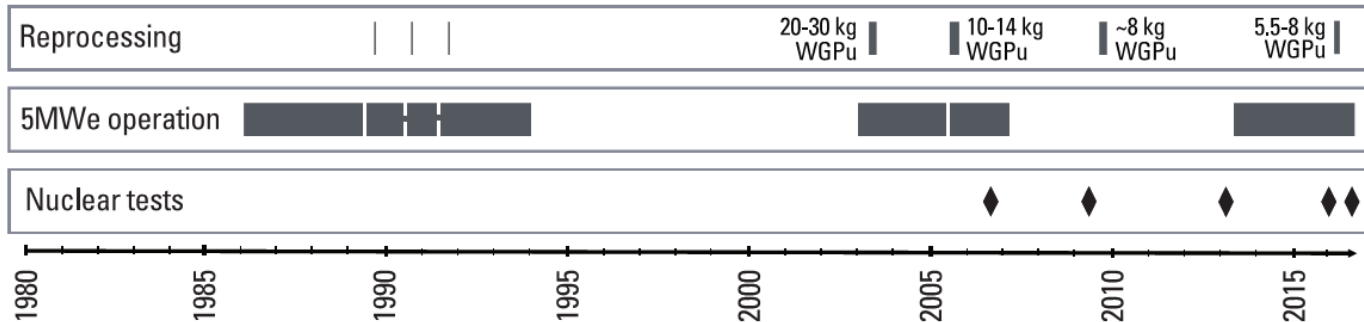
North Korea's proliferation

- **20-25 MWth** graphite-moderated, gas-cooled reactor: natural uranium fuel
- 8 MWth Soviet IRT-2000 research reactor: HEU fuel (last Russian supply 1990)
- **100 MWth** Experimental Light Water Reactor: 3,5% enriched fuel (construction finished?)
- Radiochemical Laboratory: Reprocessing

In addition: Uranium path.

Presumably plenty of enriched uranium to produce plutonium with 100 MWth reactor

Estimating North Korean fissile material production



S. Hecker, C. Braun and C. Lawrence, North Korea's Stockpiles of Fissile Material, Korea Observer 47:4, 2016

25-48 kg plutonium

600-950 kg HEU

→ 20-60 nuclear weapons

38 NORTH, Estimating North Korea's Nuclear Stockpiles: An Interview With Siegfried Hecker, 30 April, 2021

Banning nuclear weapon tests

Comprehensive Test Ban Treaty

- Prohibits all nuclear weapons explosions
- Signed in 1996, but not yet in force
- Required ratifications: China, Egypt, India, Iran, Israel, North Korea, Pakistan, Russia, United States



CTBTO

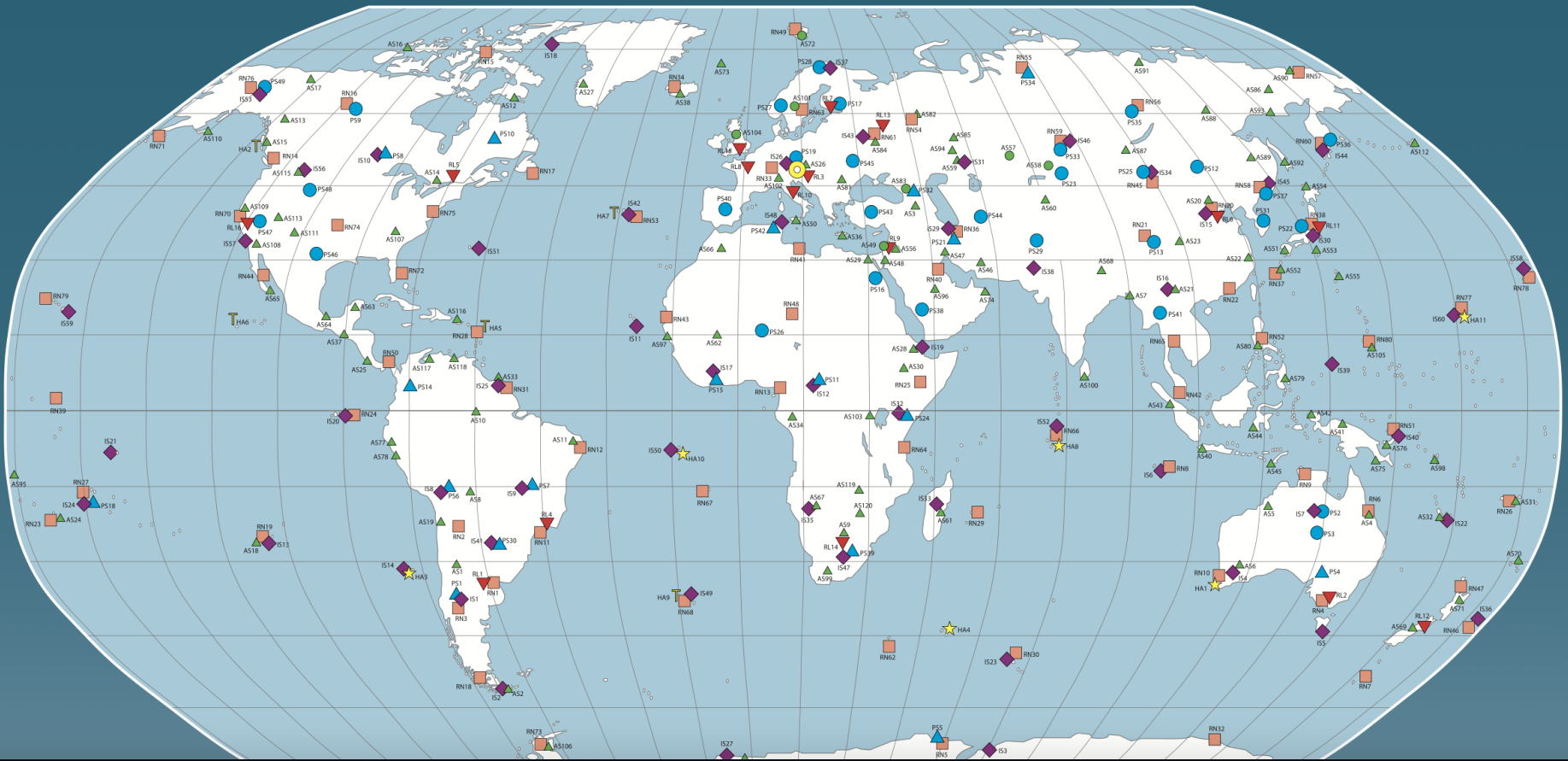
- Comprehensive Test Ban Treaty Organisation in place
- includes the Provisional Technical Secretariat, tasked with the establishment of a comprehensive verification regime:
- International Monitoring System, International Data Center & On-Site Inspections



International Monitoring System

seismic, hydroacoustic, infrasound and radionuclide monitoring

INTERNATIONAL MONITORING SYSTEM



Radionuclide monitoring

The *smoking gun*: Was an explosion nuclear?

- 80 radionuclide stations
- Radioactive isotopes arrive through atmospheric transport
- Gamma measurements using air filters or air pumped through charcoal purification device



Radionuclide station RN73, Palmer Station, USA, CTBTO

North Korean nuclear tests



Solid Earth, 10, 59–78, 2019
<https://doi.org/10.5194/se-10-59-2019>
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Solid Earth 

A multi-technology analysis of the 2017 North Korean nuclear test

Peter Gaebler¹, Lars Ceranna¹, Nima Nooshiri², Andreas Barth³, Simone Cesca², Michaela Frei¹, Ilona Grünberg¹, Gernot Hartmann¹, Karl Koch¹, Christoph Pilger¹, J. Ole Ross¹, and Torsten Dahm²

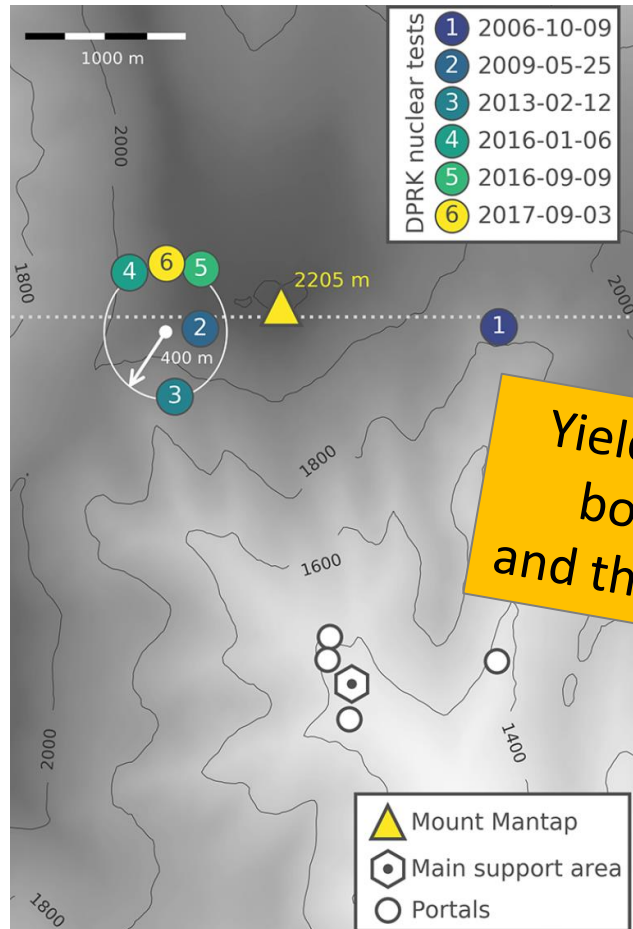
¹BGR, Federal Institute for Geosciences and Natural Resources, Hannover, Germany

²GFZ, German Research Centre for Geosciences, Potsdam, Germany

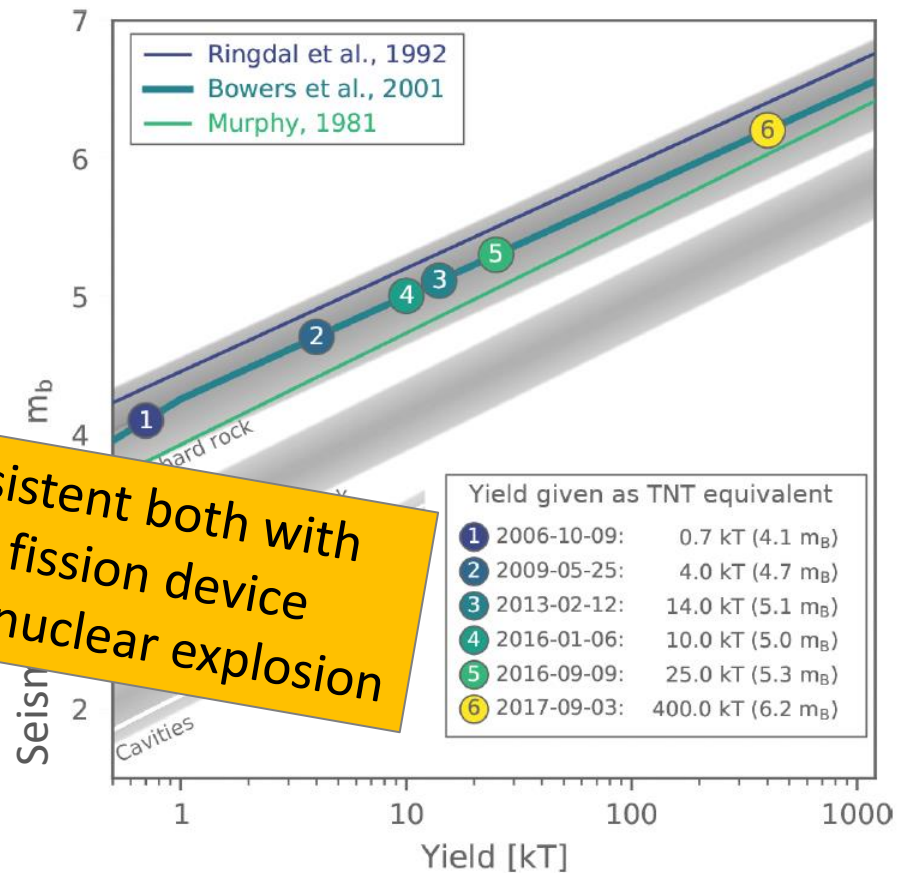
³KIT, Karlsruhe Institute of Technology, Karlsruhe, Germany

North Korean nuclear tests

Seismic monitoring



Location uncertainty < 100 m



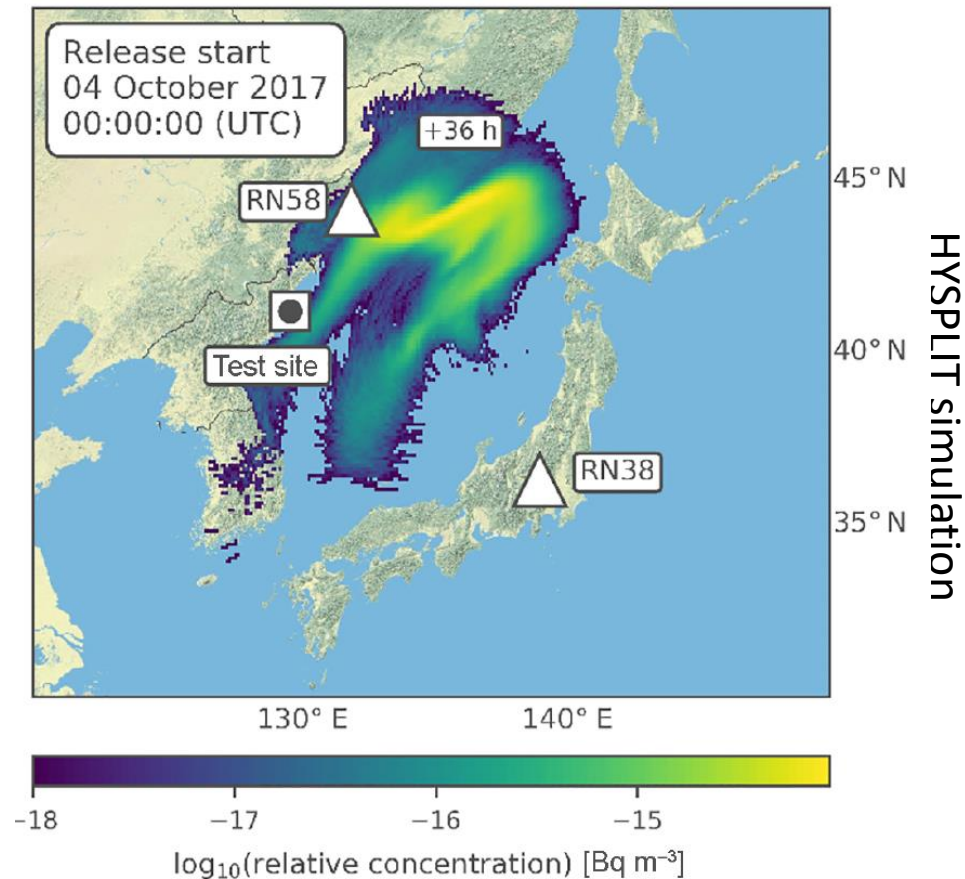
Yield consistent both with boosted fission device and thermonuclear explosion

Figure 10. Magnitude–yield relation curves for different geological settings. Numbered circles indicate the six North Korean nuclear tests. Gray background shading represents lower and upper boundary literature values for the different environments.

North Korean nuclear tests

Radionuclide monitoring

- RN58 operated in October, increased Xe-133 activity was measured
- This would be consistent with delayed releases from test cavity.
- But no proof.



Deterrence, arms control
and disarmament

Deterrence

- Prevention of nuclear first strike by second strike capability
- "Strategic stability" / mutual vulnerability
- To prevent major conflict among nuclear-protected powers
- Arms control for mutual security



Mexican standoff in Quentin Tarantino's *Reservoir Dogs*

Arms control and its demise

- Intermediate Nuclear Forces Treaty, cancelled, removed all intermediate range forces (< 5500 km)
- Open Skies Treaty, allowed for oversight flights, cancelled by US and Russia

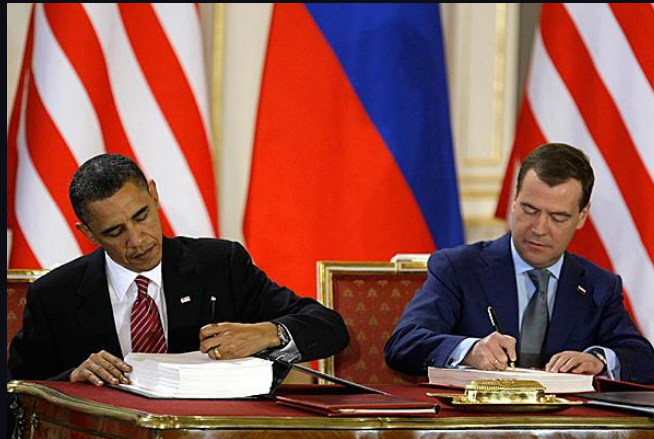


Pershing II (Mutlangen, Germany)

Strategic arms control

New START Treaty (2010)

- Bilateral US-Russian arms control
- Last agreement in a series initiated during the Cold War
- Limits deployed delivery systems to 700
- Limits deployed warheads to 1550, no limits on total warheads
- Verification regime
- Agreement on extension reached in last minute, 2021
- Treaty expires 2026, currently suspended. Limited prospects of negotiations for successor during war.

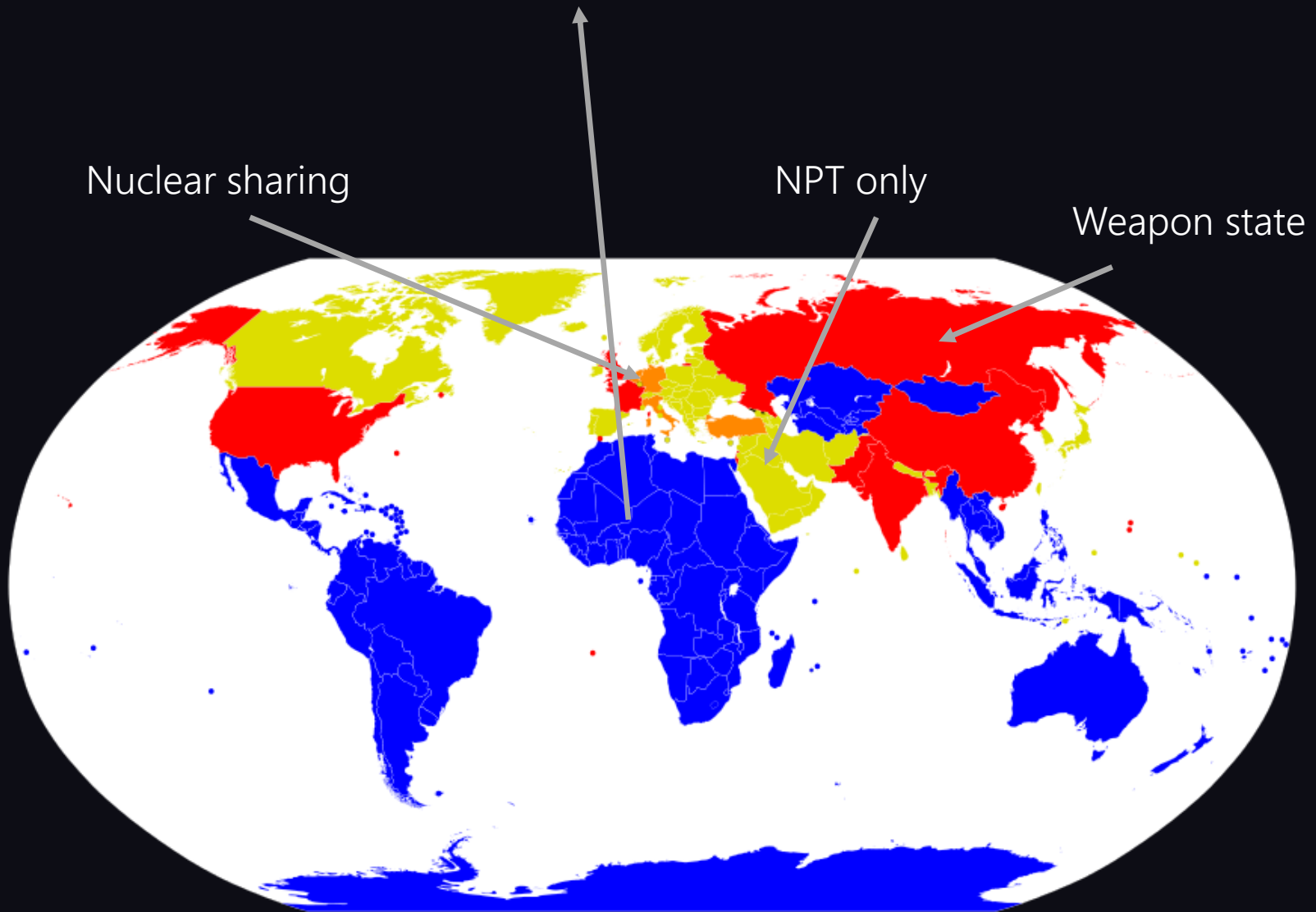


The Non-Proliferation Treaty 1968

Comparison

- Chemical weapons convention
- Biological weapons convention
- No nuclear weapons convention!

Nuclear Weapon Free Zones

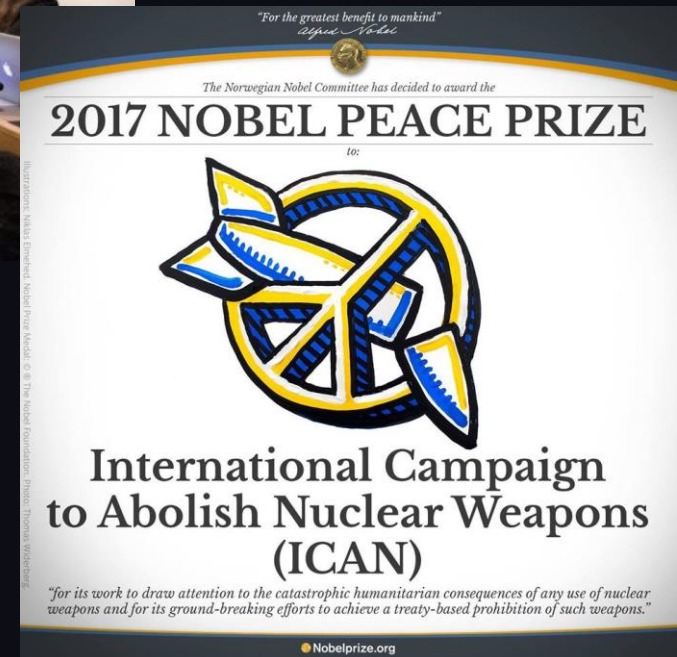


The Ban Treaty

Frustration of many non-weapon states on disarmament

→ Negotiation of Treaty on the Prohibition of Nuclear Weapons (2017)

→ Review Conferences 2021/2023: several NATO states as observers



Nuclear threats and risks

Nuclear threats and risks

“The **United States** would only consider the employment of nuclear weapons in **extreme circumstances to defend the vital interests** of the United States, its allies, and partners.” (2018 U.S. Nuclear posture review)

“The **Russian Federation** shall reserve the right to use nuclear weapons in **response to the use of nuclear and other types of weapons of mass destruction** against it and/or its allies, as well as in the event of aggression against the Russian Federation with the use of **conventional weapons** when the very **existence of the state is in jeopardy.**” (The military doctrine of the Russian Federation, 2015)

“**China** is firmly committed to a nuclear strategy based on self-defence and has upheld its commitment that it would **not be the first to use nuclear weapons at any time and under any circumstances** and that it would unconditionally refrain from using or threatening to use nuclear weapons against non-nuclear-weapon states or nuclear-weapon-free zones.” (Position Paper of the People's Republic of China At the 66th Session of the United Nations General Assembly, 2011)

Implication of the Ukraine war

- Nuclear escalation potential
 - Risk of nuclear weapon use in Ukraine
 - Risk of NATO-Russia nuclear escalation
- Russia's successful deterrence might make nuclear weapons attractive for other states
- Future of European and US-Russian arms control architecture ?

Command and control (U.S.)

- President has single control to launch nuclear warheads
- Pressured to make quick decisions (retaliatory response to arriving missile)
- Risk of Launch-on-warning

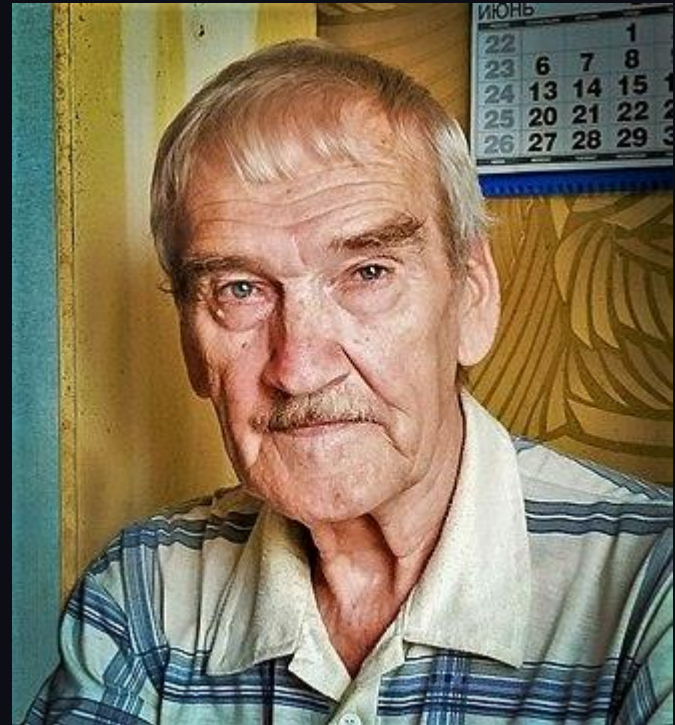


„Nuclear football“

Close calls

1983 Soviet nuclear false alarm incident

- Russian early warning system indicated US missile attack
- In last minute, officer dismissed the warning, preventing retaliatory launch, and accidental nuclear war
- Many other “close-calls”



Stanislav Petrov

Close calls

1995



- Russian missile warning system identified a rocket as a nuclear ballistic missile, on a path from Norway to hit northern Russia.
- Yeltsin was presented the briefcase to authorize a nuclear attack
- Minutes later, it appeared rocket would land beyond Russian territory
- Research rocket to study polar lights

Close calls

2007



© Rich, U.S. Air Force, 2006



Six nuclear-armed cruise missiles were mistakenly loaded onto a B-52 bomber at Minot Air Force Base in North Dakota



Why should nuclear weapons concern you? | Malte Goettsche | TEDxRWTHAachen

1,023 views • May 26, 2020

23 0 SHARE SAVE ...

The roles of scientists

"We appeal as human beings to human beings:
Remember your humanity, and forget the rest." *

* Russell-Einstein Manifesto, 1955

i.a. Max Born, Albert Einstein, Linus Pauling, Joseph Rotblat, Bertrand Russell, 1955

The Russell-Einstein Manifesto

issued in London, July 9th 1955

In the tragic situation which confronts humanity, we feel that scientists should assemble in conference to appraise the perils that have arisen as a result of the development of weapons of mass destruction, and to discuss a resolution in the spirit of the appended draft.

We are speaking on this occasion, not as members of this or that nation, continent, or creed, but as human beings, members of the species Man, whose continued existence is in doubt. The world is full of conflicts; and, overshadowing all minor conflicts, the titanic struggle between Communism and anti-Communism.

PHYSIKALISCHE BLÄTTER

13. JAHRGANG

1957/HEFT 5

Die Göttinger Erklärung

u.a. O. Hahn, W. Heisenberg, M. von Laue, H. Maier-Leibnitz, C.-F. von Weizsäcker

Pugwash Conferences on Science and World Affairs

- Joseph Rotblat: only Manhattan Project scientist to resign on moral grounds
- Pugwash aims to develop and support the use of scientific, evidence-based policymaking, focusing on areas where nuclear and WMD risks are present
- long-standing tradition of 'dialogue across divides' (Nobel Peace Prize 1995): pioneers of "track 2" dialogue

1957, Pugwash, Canada



2015, Nagasaki, Japan



Science Diplomacy

- Diplomacy for Science
 - facilitate international scientific cooperation
- Science for Diplomacy / Science for Peace
 - scientific collaboration to improve international relations (e.g. SESAME synchrotron, Jordan)
- Science in Diplomacy:
 - provide advice to inform and support foreign policy objectives

New frontiers in science diplomacy

Navigating the changing balance of power

January 2010



CELEBRATE
350 YEARS



THE ROYAL SOCIETY



Science in (Nuclear) Diplomacy: Group of Scientific Experts



Geneva, 1978

CTBTO Sepctrum 12, 2009

Science in (Nuclear) Diplomacy

REPORT OF THE SCIENTIFIC ADVISORY GROUP

on the status and developments regarding nuclear weapons, nuclear weapon risks, the humanitarian consequences of nuclear weapons, nuclear disarmament and related issues

TPNW/MSP/2023/8
27 October 2023



DECEMBER 2019

Phase II Summary Report: Moving from Paper to Practice in Nuclear Disarmament Verification



IPNDV
INTERNATIONAL PARTNERSHIP FOR
Nuclear Disarmament Verification