BACKGROUND

THE CURRENT CRISIS IN NUCLEAR ARMS CONTROL
LANDMARK NUCLEAR ARMS CONTROL TREATIES

ANTI-BALLISTIC MISSILE TREATY
(1972–2002)

The ABM Treaty barred the United States and Russia from deploying nationwide defenses against strategic ballistic missiles. The United States withdrew in 2002.

Source: U.S. Missile Defense Agency

INTERMEDIATE NUCLEAR FORCES

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.

Source: www.defenseimagery.mil

START & New START

START and New START requires the United States and Russia to reduce and limit their deployed strategic weapons. New START will expire in 2026.

Source: Alexander Zemlianichenko, Associated Press

For details, see 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.

Source: NASA

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**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).

Source: NASA

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**COMPREHENSIVE TEST BAN TREATY**
(1996, not in force)

The CTBT bans all nuclear explosions in all environments.

As of Oct. 2022, signed by 186 states, ratified by 176 states; enters into force when 44 “nuclear capable” states have ratified the treaty.

Source: Reuters

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
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
There remain about 13,000 nuclear weapons in the world today.
THE PAST

THE ERA OF “NATIONAL TECHNICAL MEANS”
“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/
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)

STRATEGIC ARMS LIMITATION TALKS (SALT)

BACKGROUND
Upon signing the NPT in July 1968, President Johnson announced that the United States and the Soviet Union would begin discussions on “the limitation and the reduction of both strategic offensive and defensive systems.”

In May 1972, signature of two basic SALT I documents: an Interim Agreement (SALT I) and the ABM

SCOPE
Under the Interim Agreement (SALT I), the parties undertake to “freeze” the number of ICBM and SLBM launchers at their current levels at the time (and for a period of five years)

Under the ABM, the parties undertake “not to deploy ABM systems for a defense of the territory of its country”

Source: Richard Nixon Foundation & Library (top) and U.S. Air Force (bottom)
1. For the purpose of providing assurance of compliance with the provisions of this [Interim Agreement], each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.

2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this Article.

3. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this [Interim Agreement]. This obligation shall not require changes in current construction, assembly, conversion, or overhaul practices.
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
RESOLUTION OF SATELLITE IMAGERY

Resolution scales with diameter of the lens and inversely with altitude
(e.g. 8 cm resolution for a 2.4 m lens and an altitude of 300 km)

Source: B. Jasani and G. Stein, Commercial Satellite Imagery. A Tactic in Nuclear Weapon Deterrence, Springer, 2002 (left) and Google Earth (Right)
The United States of America was not involved in the catastrophic accident during final launch preparations for the Safir SLV Launch at Semnan Launch Site One in Iran. I wish Iran best wishes and good luck in determining what happened at Site One.
more recent past &

THE PRESENT

THE ERA OF ONSITE INSPECTIONS
INTERMEDIATE NUCLEAR FORCES (INF) TREATY

SCOPE
Eliminated all ground-launched ballistic and cruise missile (and their launchers) with ranges between 500 km and 5,500 km
Treaty banned missiles tipped with both nuclear and conventional warheads, but did not cover air-launched and sea-launched missiles

ALLEGATIONS
Since 2014, the United States had been accusing Russia of violating the treaty by testing a ground-launched cruise missile to intermediate range
The missile was later identified as the 9M729
Russia too accused the United States of violating the treaty by deploying Mark 41 Vertical Launching Systems (Mk 41 VLS) in Eastern Europe

COLLAPSE
The United States withdraws from the INF Treaty in August 2019 after formally announcing its decision to do so in February 2019
President Trump first mentioned intention to withdraw in October 2018; according to Article XV of the treaty, withdrawal takes effect six months after giving formal notice of the party’s decision to withdraw
VERIFYING THE INF TREATY

ONSITE INSPECTIONS

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

Source: Harahan, 1993

VERIFIED ELIMINATION

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)

Source: www.defenseimagery.mil

PERIMETER CONTROL

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

Source: Author

J. P. Harahan, On-Site Inspections Under the INF Treaty, U.S. Department of Defense, Washington, DC, 1993
A fast-neutron detector used in verification of the INF Treaty

Ronald I. Ewing and Keith W. Marlow

Nuclear Instruments and Methods in Physics Research, A299 (1990) 559-561

North Holland

We describe the design and calibration of the neutron-deflection equipment used as a support of the INF Treaty, and some measurements made on boron blocks. The fast-neutron detector, consisting of two 70" gas proportional tubes in a cadmium-covered polyethylene moderator, produces about 67 counts/s/100 eV of (1/2) neutrons/\(\text{cm}^2/	ext{s}). This device is used to determine the spatial patterns of neutrons emitted from the nuclear weapons on the missile.

1. Introduction

The INF Treaty [1] provides for the use of radiation detection devices to ensure that a fissile 500-seat missile (a treaty-limited ICBM) is not contained in the category of a SS-20 missile (two semiconductor-based) housed in a former SS-10 base. The Treaty created the Special Verification Commission (SVC) to work out details of the Treaty, including the use of radiation detection devices. The SVC agreed on the use of a detector of fast and thermal neutrons installed outside the container containing the missile. Neutrons are produced by transmutation fission in the radionuclides of the nuclear warheads, leaked in the reentry vehicles on the missiles. The SS-25 contains one warhead and the SS-38 has three. Cooperative measurements (the Bir-alschmich) were performed for the Soviet Union using the neutron detector described here to determine the spatial patterns of neutrons from each of the two missile types.

2. Detector design

The SVC agreement called for the measurement of the neutron pattern using a single channel of neutron detection. The neutron detector had to be easily portable, small enough to resolve the spatial patterns of the neutrons, and sufficiently sensitive to accomplish the measurement in a reasonable amount of time. Neutrons are emitted from the plutonium with a continuous energy distribution. The SVC agreed on these criteria to ensure the integrity of the warhead and the missile, particularly the hydride in the high explosives of the warhead. Calculations indicate that a sensitive fraction of the neutrons outside the warheads will be "cold" energy greater than 0.01 eV.

The principal elements of the neutron detector are shown in fig. 1. The two He gas tubes are inserted into the polyethylene moderators, whose diameters are 30.4 x 263 x 6.15 cm. Fast neutrons are slowed to thermal energy in the moderator by elastic collisions, principally with hydrogen. These thermal neutrons can be detected by the 8He, 14C) reaction in the gas proportional counter tubes, which are nominally 2.5 cm in diameter, 25 cm in active length, and filled with He in a pressure of 10 atm. The tubes are inserted into holes drilled through the 28.3 cm thick of the polyethylene moderator. The neutron detector lies at the end of the tube to capture externally produced thermal neutrons. The arrangements of accommodation and data was designed, on the basis of earlier studies, to produce an...
START & NEW START

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

Both sides met this target early

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

Source: Randy Montoya

Edward Ift, “Verification Lessons Learned from the INF, START I, and New START Treaties,” 55th Annual INMM Meeting, July 2014
SO WHAT?
WHAT IS NEW HERE AND WHY DOES IT MATTER?

(skip)
COSTS OF U.S. NUCLEAR FORCES, 2018–2046

Billions of 2017 Dollars

- Modernization
- Operation and Sustainment
- NC3
- Weapons laboratories

~ $22 billion

TECHNOLOGIES ON THE HORIZON

NEW TYPES OF DELIVERY SYSTEMS

In addition to replacing and modernizing existing weapon systems, new types of weapons and delivery systems are being introduced by several nuclear weapon states; these include, in particular, hypersonic weapons and various “exotic” Russian systems.

NEXT-GENERATION (“EMERGING”) TECHNOLOGIES

Pinpoint accuracy without relying on global navigation satellite systems (GNSS)
Space-based weapons systems may have a “come back”
Autonomous weapons systems ... conventional for now, but potentially dual capable

Source: U.S. Department of Defense (top) and NASA/JPL-Caltech (bottom)
NEW TECHNOLOGIES

NUCLEAR WEAPONS MAY BE PERCEIVED AS “MORE USABLE”

Nuclear weapons with lower yield (5–7 kt) delivered with “pinpoint” accuracy
Belief that missile defenses may be effective against an adversary’s retaliatory strike
2018 Nuclear Posture Review expanded conditions for possible nuclear weapons use

Source: Castle Bravo (top) and wikimedia.org/pdphoto.org (bottom)

CYBER VULNERABILITIES

Nuclear weapons and related systems predate digital electronics and are “tightly coupled”
Several types of systems may be exposed to attack (via network, supply chain, etc.)
Modern cyber threats further increases the risk of miscommunication and miscalculation
Despite the remarkable achievements and steady growth of monitoring, data processing and analytical capabilities there are trends in weapon system development which if allowed to continue will outrun the ability of technology to monitor them.

Allan S. Krass, 1985, Proposition #11
THE FUTURE

“MORE AWARENESS & CONFIDENCE WITH LESS ACCESS”
GRAND VERIFICATION CHALLENGES
FOR NUCLEAR ARMS CONTROL AND DEEP(ER) CUTS IN THE ARSENALS

- Confirming the completeness of declared fissile material production (nuclear archaeology)
- Verifying numerical limits on declared nuclear warheads
- Monitoring nuclear warheads in storage
- Establishing confidence in the absence of undeclared stocks or production
- Timely detection of undeclared activities (diversions and rapid breakout)
- Confirming the authenticity of nuclear warheads
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

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.


Photo credit: NATO
Six images captured between August 18, 2018 and August 21, 2018 show the movement of the Tupolev Tu-22M (Backfire) and Tupolev Tu-160 (Blackjack) bombers on the flight line of Engels Air Base, Russia. Sub-daily rapid revisit capability (for SkySat, up to 12 times per day; global average of 7 times per day) may allow “pattern of life” analysis. 

HIGH-DEFINITION VIDEO FROM SPACE

Posted in February 2014, www.youtube.com/watch?v=BsW6IGc4tt0; Skybox Imaging later became Terra Bella, now Planet (Google)
“THINKING OUTSIDE THE BOX”

DEVELOPING ALTERNATIVES TO ONSITE INSPECTIONS FOR (SENSITIVE) FACILITIES

UNATTENDED (REAL-TIME) MONITORING OF NUCLEAR FACILITIES
Opportunities for real-time monitoring of nuclear fuel-cycle facilities
(relevant, in particular, for strengthened IAEA safeguards in uranium enrichment plants)

STANDOFF DETECTION AND (PERHAPS) PERIMETER CONTROL
For facilities where access is initially considered too intrusive, nearby or regional sensors could provide reassurance of compliance; alternatively, concept of “deferred verification” excludes facilities from inspection*

NEVER ACQUIRE SENSITIVE INFORMATION WHEN ONSITE INSPECTIONS ARE NECESSARY
Simplicity and non-intrusiveness as guiding principles (for example, passive systems are preferable to active ones)
Accept “items declared as weapons” and use “absence measurements” (as introduced in START/New START)

*Pavel Podvig and Joseph Rodgers, Deferred Verification, Nonproliferation Review, 26 (3–4), 2019
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.

Can we (physical) “separate” host & inspector?

Can we remotely follow certain (allowed) activities that the host performs?
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).*

A PATH FORWARD

FOR NUCLEAR DISARMAMENT VERIFICATION

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.

RE-IMAGINING NUCLEAR DISARMAMENT VERIFICATION

Explore verification approaches that minimize the need of access to sites and treaty accountable items or avoid measurements on those; consider approaches that offer “on-ramps,” i.e., that start off simple and can accommodate “upgrades” later on.

Source: ukni.info (top) and microsoft.com (bottom)