THE END OF NUCLEAR ARMS CONTROL AND NONPROLIFERATION?

WHAT SCIENTISTS AND ENGINEERS CAN DO TO PREVENT A NEW NUCLEAR ARMS RACE

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Princeton University
Colorado School of Mines
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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


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 and New START requires the United States and Russia to reduce and limit their deployed strategic weapons. New START will expire in 2021.

Source: Alexander Zemlianichenko, Associated Press

For details, see www.armscontrol.org/factsheets/USRussiaNuclearAgreements
THE NPT TURNS FIFTY

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

2010–2019 was the first decade since the end of World War II without a new weapon state

THE NPT IS IN CRISIS ALSO

Insufficient progress in the areas of nuclear arms control and disarmament


Source: International Atomic Energy Agency
NUCLEAR WEAPONS
There remain about 14,000 nuclear weapons in the world today.

Dear Friend:

I write to you and other friends for help.

Through the release of atomic energy, our generation has brought into the world the most revolutionary force since prehistoric man's discovery of fire. This basic power of the universe cannot be fitted into the outmoded concept of narrow nationalisms. For there is no secret and there is no defense; there is no possibility of control except through the aroused understanding and insistence of the peoples of the world.

We scientists recognize our inescapable responsibility to carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications for society. In this lies our security and our only hope - we believe that an informed and conscious public will bring the greatest good for all life and not for death.

We need $1,000,000 for the beginning of this task. Sustained by faith in his destiny through the exercise of reason, we have pledged all our strength and our knowledge to this work. I do not hesitate to call upon you to help.

Faithfully yours,

A. Einstein.
75 YEARS OF NUCLEAR WEAPONS
SMALLER, LIGHTER, MORE DESTRUCTIVE

U.S. W80-4 cruise missile warhead
Source: NNSA/Sandia National Laboratory

North Korean two-stage weapon
Source: KCNA

Primary
Typically 3–4 kg of plutonium

Secondary
Typically 15–25 kg of enriched uranium
Nuclear weapons have fundamentally changed the potential destruction to be expected in war.
A modern nuclear weapon has a destructive power tens to hundreds of times greater than the Hiroshima bomb.

Even a “limited” nuclear war has global environmental consequences

Smoke from a regional nuclear war between India and Pakistan

Day 4: May 18th

Day 7: May 21st

Credit: Alan Robock and Luke Oman, climate.envsci.rutgers.edu/nuclear and www.atmos-chem-phys.net/7/2003/2007; see also, Toon et al., Science Advances, October 2019
The catastrophic effects of nuclear weapons are not limited to the intended target.

A counterforce attack on the Kozelsk missile field (about 150 miles from Moscow) would cause several million deaths in the region.

An Insane Idea?

Guaranteeing that an adversary would have to launch a massive attack against the heartland
# WHEN TRUTH IS STRANGER THAN FICTION

## SELECTED INCIDENTS OF NEAR NUCLEAR USE

<table>
<thead>
<tr>
<th>Date</th>
<th>Incident</th>
<th>States involved</th>
<th>Cause</th>
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</thead>
<tbody>
<tr>
<td>October 1962</td>
<td>Operation Anadyr</td>
<td>Soviet Union</td>
<td>Miscommunication</td>
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<tr>
<td>27 October 1962</td>
<td>British nuclear forces during the Cuban missile crisis</td>
<td>United Kingdom</td>
<td>Conflict escalation</td>
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<tr>
<td>27 October 1962</td>
<td>Black Saturday</td>
<td>United States</td>
<td>Conflict escalation and miscommunication</td>
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<tr>
<td>22 November 1962</td>
<td>Penkovsky false warning</td>
<td>Soviet Union</td>
<td>Espionage</td>
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<tr>
<td>October 1973</td>
<td>1973 Arab–Israeli war</td>
<td>Israel</td>
<td>Conflict escalation</td>
</tr>
<tr>
<td>9 November 1979</td>
<td>NORAD: Exercise tape mistaken for reality</td>
<td>United States</td>
<td>Exercise scenario tape causes nuclear alert</td>
</tr>
<tr>
<td>3 June 1980</td>
<td>NORAD: Faulty computer chip</td>
<td>United States</td>
<td>Faulty computer chip</td>
</tr>
<tr>
<td>25 September 1983</td>
<td>Serpukhov-15</td>
<td>Soviet Union</td>
<td>Technical error</td>
</tr>
<tr>
<td>7–11 November 1983</td>
<td>Able Archer-83</td>
<td>Soviet Union, United States</td>
<td>Misperception of military training exercise</td>
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<tr>
<td>18–21 August 1991</td>
<td>Failed coup</td>
<td>Soviet Union</td>
<td>Loss of command and control structure</td>
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<tr>
<td>25 January 1995</td>
<td>Black Brant scare</td>
<td>Russia</td>
<td>Mistaken identity of research rocket launch</td>
</tr>
<tr>
<td>May–June 1999</td>
<td>Kargil crisis</td>
<td>India, Pakistan</td>
<td>Conflict escalation</td>
</tr>
<tr>
<td>December 2001–October 2002</td>
<td>Kashmir standoff</td>
<td>India, Pakistan</td>
<td>Conflict escalation</td>
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Source: Patricia Lewis, Heather Williams, Benoît Pelopidas, and Sasan Aghlani, Too Close for Comfort Cases of Near Nuclear Use and Options for Policy, Chatham House, April 2014
The Royal Ministry of Foreign Affairs presents this note to inform you that the scientific rocket campaign currently conducted in the coastal area of the Norwegian military range has been scheduled to commence tomorrow, January 25th. Due to the potential impact area of the rockets, which might affect the coastal area, the Royal Ministry requests that you inform your national authorities accordingly.

The launching of the rockets can take place between 0500 LT and 1200 LT. The sector within which the rockets will fall is defined as follows:

2A. Impact area for 1st stage Viper 3 A/Dart Falling Sphere:
A sector with origin in the launch point coordinates:
N 69° 17' 40" E 15° 01' 15"
True bearing: 270° - 020°
Sector length: 4 nautical miles

2B. Impact area for final impact of Viper 3 A/Dart Falling Sphere:
A circle with radius 25 nautical miles from a predicted impact point N 70° 10' E 15° 45'

The Royal Ministry would be grateful if you could convey this information to your national authorities.

No reply to this note is necessary.

The Royal Ministry of Foreign Affairs avail itself of this opportunity to renew to the Heads of Mission in Oslo the assurances of its highest consideration.

Oslo, 21 December 1994
SO WHAT
WHAT IS NEW HERE AND WHY SHOULD I CARE?
Dear Friend:

I write to you and other friends for help.

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We need $1,000,000 for this great educational task. Sustained by faith in his destiny through the exercise of his reason, the scientist has pledged all our strength and our knowledge to this work. I do not hesitate to call upon you to help.

Faithfully yours,

F. Einstein.
COSTS OF U.S. NUCLEAR FORCES, 2018–2046
AND THE MODERNIZATION “BOW WAVE”

Billions of 2017 Dollars

NEW TECHNOLOGIES

NEW TYPES OF DELIVERY SYSTEMS

In addition to rebuilding the entire nuclear triad, for the time up to 2100, new types of weapons and delivery systems are being introduced by the United States and others; 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 military weapons systems are “back” (Space Policy Directive-4).

Autonomous weapons systems, conventional for now … but potentially dual capable.

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

<table>
<thead>
<tr>
<th>NUCLEAR WEAPONS MAY BE PERCEIVED AS “MORE USABLE”</th>
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<tr>
<td>Nuclear weapons with lower yield (5–7 kt) delivered with “pinpoint” accuracy</td>
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<td>Belief that missile defenses may be effective against an adversary’s retaliatory strike</td>
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<td>2018 Nuclear Posture Review expanded conditions for possible nuclear weapons use</td>
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<td>Nuclear weapons and related systems predate digital electronics and are “tightly coupled”</td>
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<tr>
<td>Several types of systems may be exposed to attack (via network, supply chain, etc.)</td>
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<tr>
<td>Modern cyber threats further increases the risk of miscommunication and miscalculation</td>
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</tbody>
</table>

Source: Castle Bravo (top) and [wikimedia.org/pdphoto.org](http://wikimedia.org/pdphoto.org) (bottom)
“WE CANNOT INNOVATE OUR WAY OUT OF THIS”

It is much harder (and more expensive) to develop a new type of weapon system than to develop (cheap) countermeasures for that same weapon.
RESEARCH AGENDA

FOR SCIENTISTS AND ENGINEERS
HOW DID I GET INTO THIS? NEUTRONICS!

PLUTONIUM DISPOSITION
1990s
Can one eliminate or irreversibly dispose 50–100 tons of excess weapons plutonium?

REACTOR CONVERSION
2000s
Can one use low-enriched uranium in research reactors without performance loss?

WARHEAD VERIFICATION
2010s
Can one dismantle a nuclear warhead without learning anything about its design?
IBX II is able to reliably detect minute differences between a reference signature ("template") and the radiation signature of an inspected item. The software is about 2000 bytes.

CAPPING THE REBOUND: DISPOSITION OF EXCESS WEAPONS MATERIALS

Vast amounts of separated plutonium and highly enriched uranium exist; these pose important proliferation risks, but they also pose challenges for nuclear arms control and disarmament (and its irreversibility).

KNOWING WHAT’S THERE: NUCLEAR ARCHAEOLOGY

There are large uncertainties in the global inventory of plutonium and highly enriched uranium. States will have to be confident that undeclared stockpiles do not exist as nuclear arsenals are reduced.

Source: International Atomic Energy Agency (top), Los Alamos National Laboratory (middle), www.francetnp.gouv.fr (bottom)
CAPPING THE REBOUND

DEVELOPING DISPOSITION OPTIONS FOR EXCESS FISSION MATERIALS
There is enough nuclear explosive material in the world to make over 200,000 nuclear weapons.
A LARGE FRACTION OF THE WORLD’S FISSILE MATERIAL STOCKPILE IS EXCESS

THE CASE OF PLUTONIUM

- 56 tons (~14,000 warheads, stockpile today)
- 16 tons (~4,000 warheads, deployed strategic weapons)
- 136 tons (military plutonium)
- 94 tons (excess weapons plutonium)
- 290 tons (separated civilian plutonium)
WHO CAN MAKE FISSION MATERIALS TODAY?

ENRICHMENT AND REPROCESSING FACILITIES WORLDWIDE

- Enrichment/reprocessing in weapon state
- Enrichment/reprocessing in non-weapon state
KNOWING WHAT’S THERE

NUCLEAR ARCHAEOLOGY
NUCLEAR ARCHAEOLOGY

MANY CONCEPTUAL STUDIES (ESPECIALLY ESTIMATING LIFETIME PLUTONIUM PRODUCTION IN REACTORS) BUT NO COMPREHENSIVE FRAMEWORK TO UNDERSTAND UNCERTAINTIES AND NO FIELD TESTS

NUCLEAR ARCHAEOLOGY COULD BE USED TO VERIFY A NORTH KOREAN PLUTONIUM DECLARATION

FORENSIC ANALYSIS OF GRAPHITE SAMPLES COULD CONFIRM TOTAL PLUTONIUM PRODUCTION IN NORTH KOREA WITHIN AN UNCERTAINTY OF $\pm 2$ KG
North Korea's Uranium Mine at Pyongsan
Coordinates: 38.324, 126.437
Source: Google
CALL TO ACTION
WHAT’S ON THE POLICY MAKERS’ AGENDA

ISSUES CURRENTLY BEING CONTESTED IN CONGRESS

**NEW START EXTENSION**
Treaty can be extended by five years (until 2026); Russia has asked to do so
Support in Congress, but little public salience

**NO-FIRST USE AND PRESIDENTIAL LAUNCH AUTHORITY**
Adopt no-first use policy, Smith-Warren (H.R.921/S.272)
Restrict Presidential launch authority (prohibiting first strike), Lieu-Markey (H.R.669/S.200)

**LIMITING MODERNIZATION**
Senate and House split over modernizing silo-based intercontinental ballistic missiles (“GBSD”)
Congress asked for independent assessment of the value of missile defense programs

Source: Joe Klamar/AFP/Getty Images (top), Kevin Lamarque/Reuters (middle), Bob Wickley/Wikimedia Commons (bottom)
Multi-year project with a startup grant from the American Physical Society’s Innovation Fund and in partnership with the APS Office of Government Affairs

“Our goal is to reach out to scientists and engineers in the United States and mobilize those interested in engaging on the nuclear threat and opportunities for its reduction”

Initial participants from the University of Illinois, University of Maryland, Stanford, Berkeley, MIT, and Princeton

Contact: Stewart Prager <sprager@princeton.edu>

Launch later in 2020; reach out to us now!