# THE END OF NUCLEAR ARMS CONTROL AND NONPROLIFERATION?

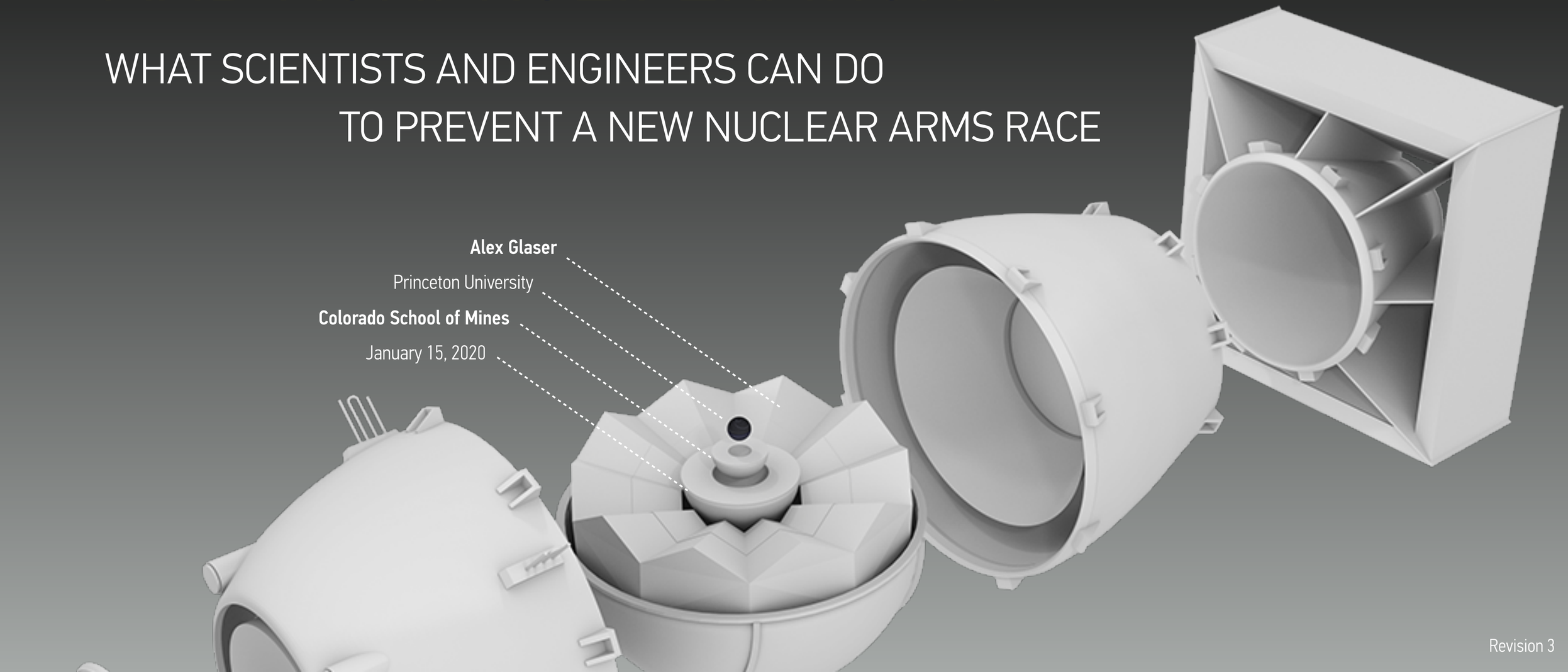
## WHAT SCIENTISTS AND ENGINEERS CAN DO TO PREVENT A NEW NUCLEAR ARMS RACE

**Alex Glaser**

Princeton University

**Colorado School of Mines**

January 15, 2020



Revision 3

# 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*

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, 2011–2021)


*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 will expire in 2021

For details, see www.armscontrol.org/factsheets/USRussiaNuclearAgreements

# NUCLEAR NON-PROLIFERATION TREATY

## 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

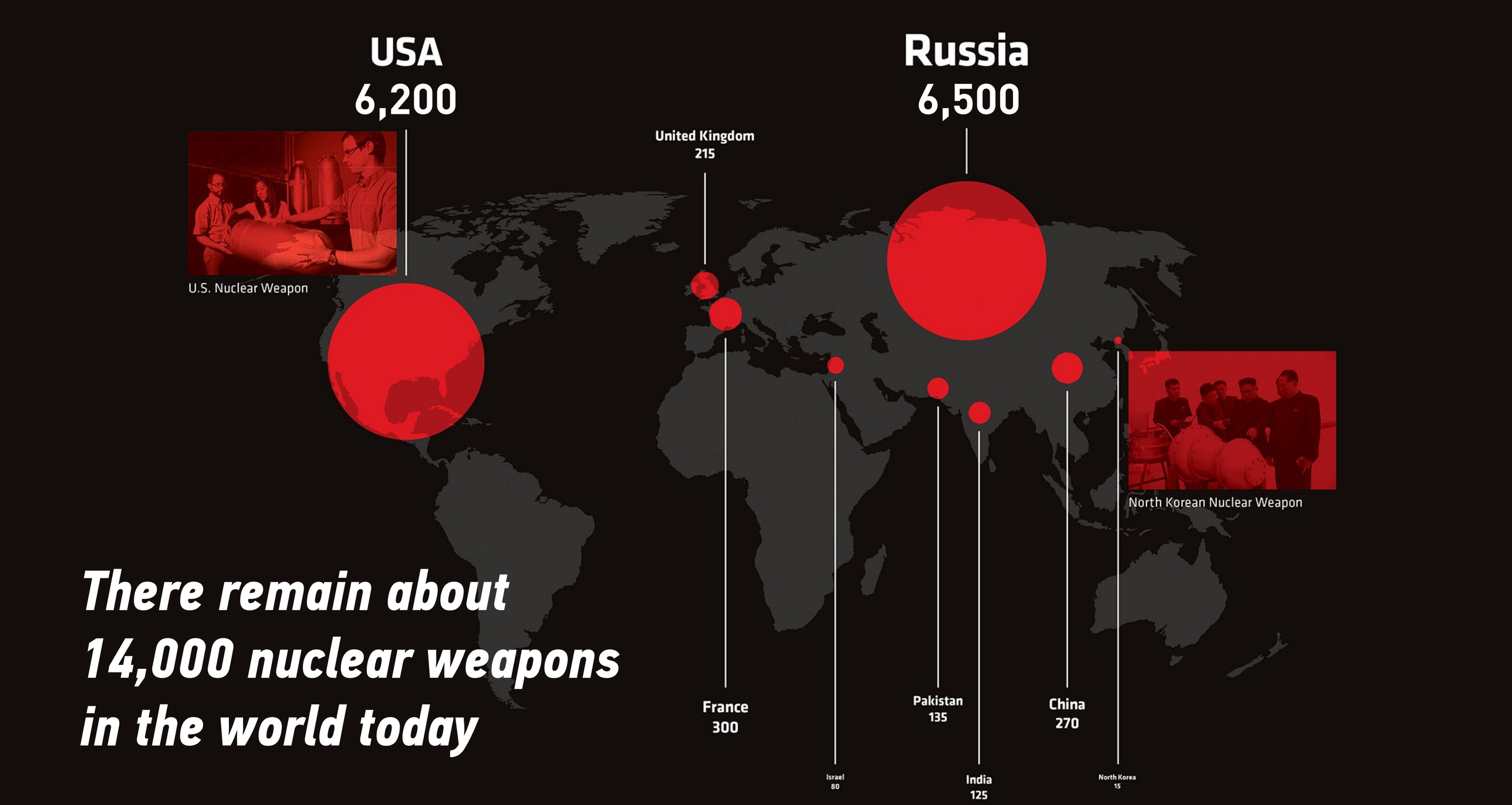
## THE NPT IS IN CRISIS ALSO

Insufficient progress in the areas of nuclear arms control and disarmament

Commitments of the 2000 Final Document (“13 Steps”) and the 2010 Final Document (“Action Plan”) largely unfulfilled … and 2020 Review Conference coming up

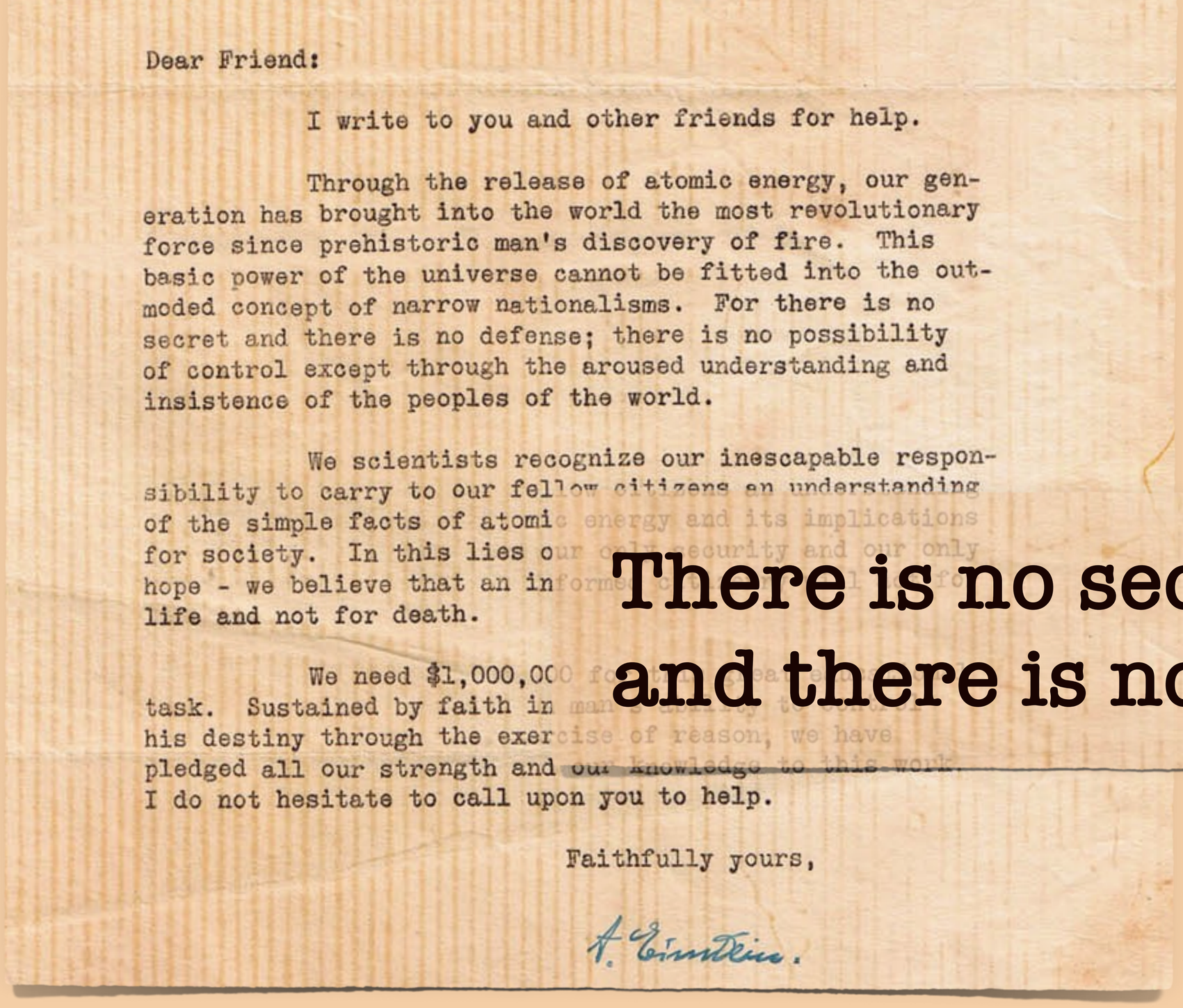
*Source: International Atomic Energy Agency*

# NUCLEAR WEAPONS




***There remain about 14,000 nuclear weapons in the world today***

*Hans Kristensen, Matt Korda, and Robert Norris, Nuclear Notebook, Federation of American Scientists and thebulletin.org/nuclear-risk/nuclear-weapons/nuclear-notebook/*



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 only security and our only hope - we believe that an informed citizenry will force constructive action for life and not for death.

We need $1,000,000 for this [illegible] task. Sustained by faith in man's ability to shape 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.

*Albert Einstein on behalf of the*
*Emergency Committee of Atomic Scientists*
*Princeton, NJ, December 1946*

# There is no secret, and there is no defense.

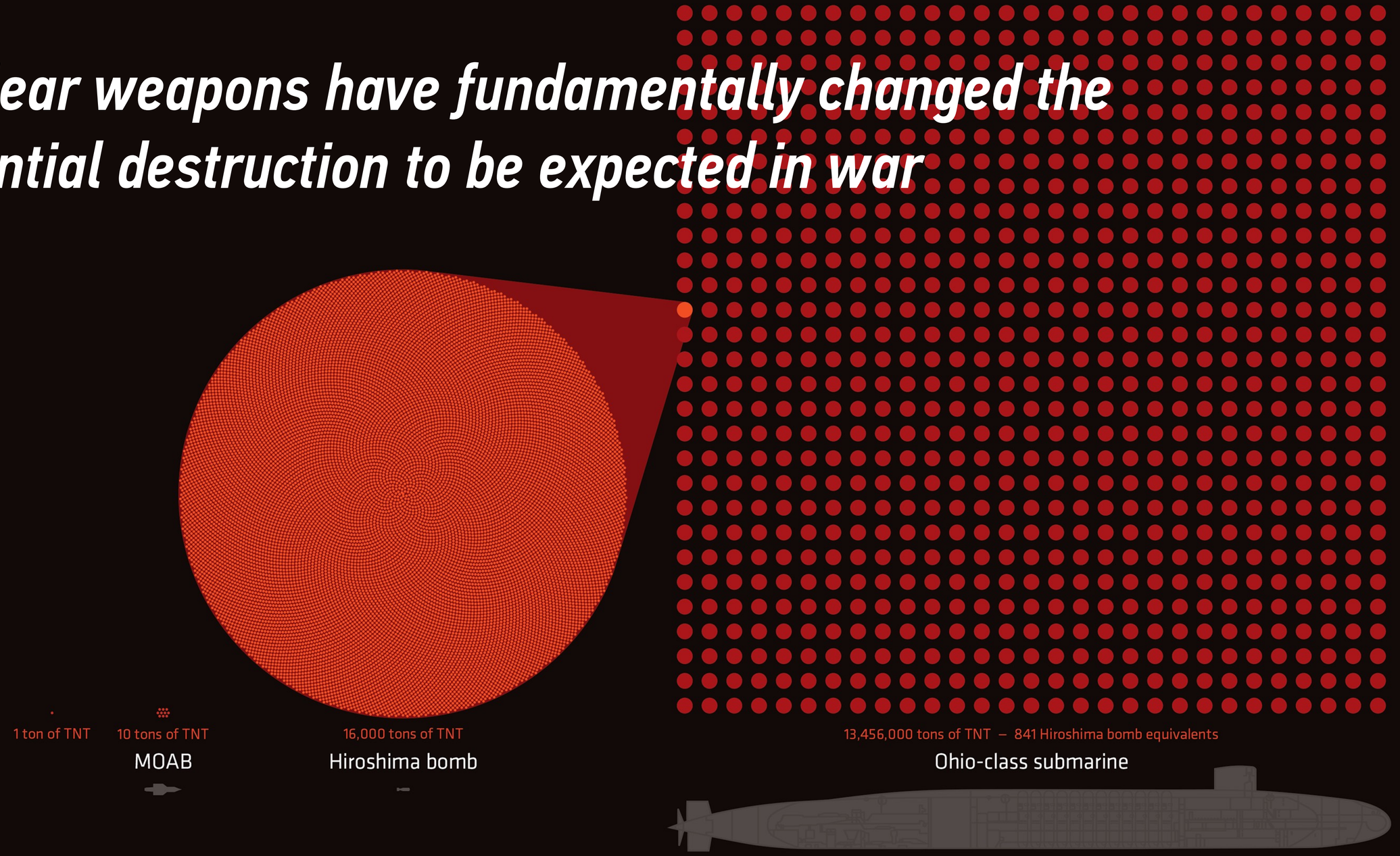
# 75 YEARS OF NUCLEAR WEAPONS

## SMALLER, LIGHTER, MORE DESTRUCTIVE

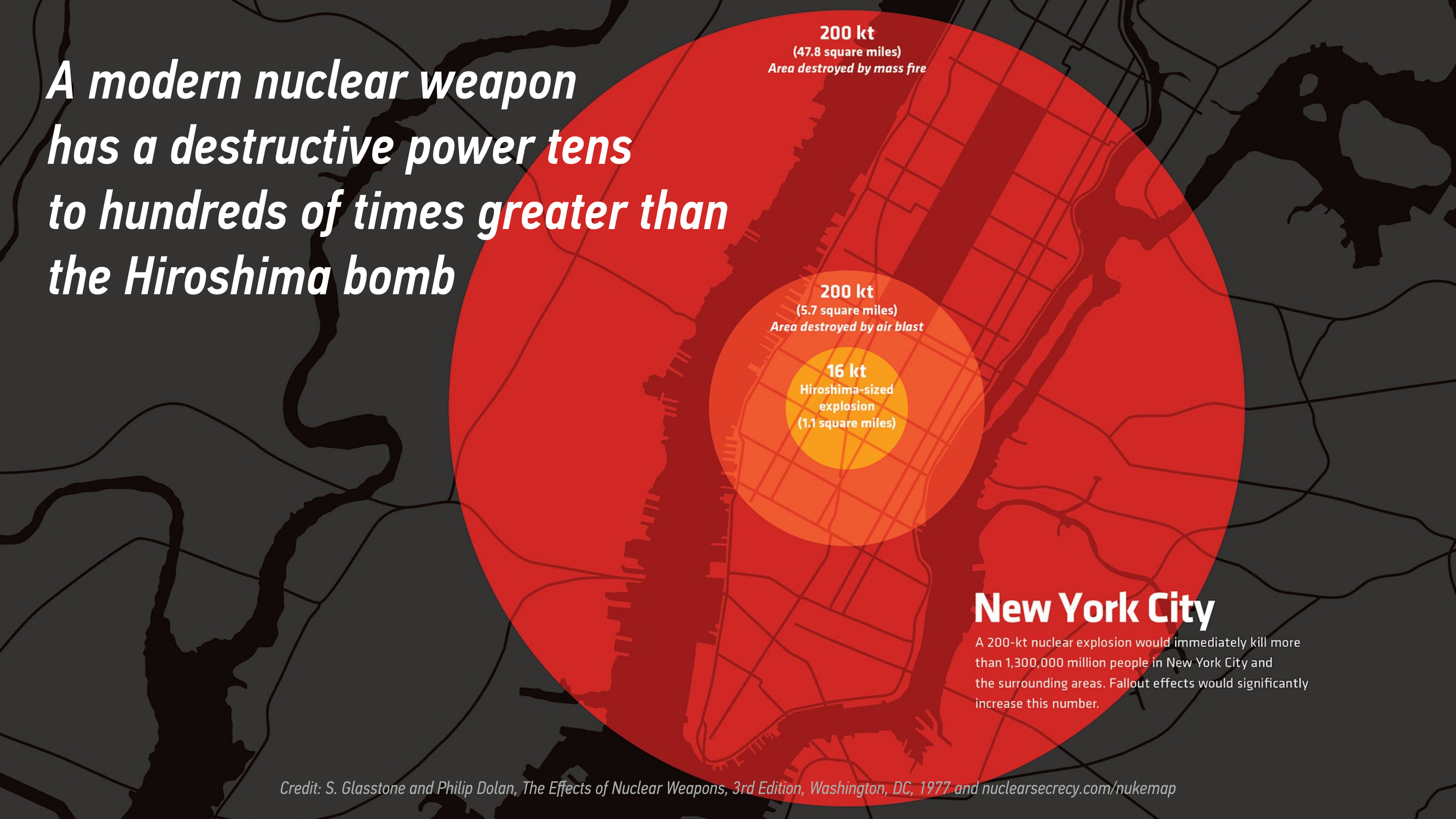
U.S. W80-4 cruise missile warhead
*Source: NNSA/Sandia National Laboratory*


North Korean two-stage weapon
*Source: KCNA*

# *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*

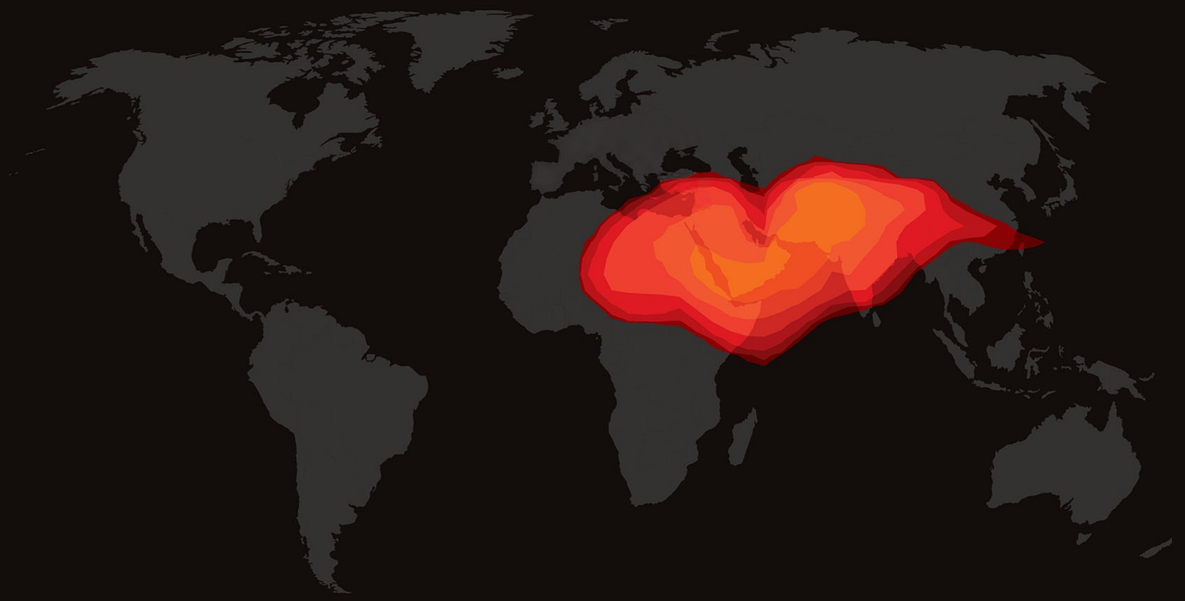



*Credit: S. Glasstone and Philip Dolan, The Effects of Nuclear Weapons, 3rd Edition, Washington, DC, 1977 and nuclearsecrecy.com/nukemap*

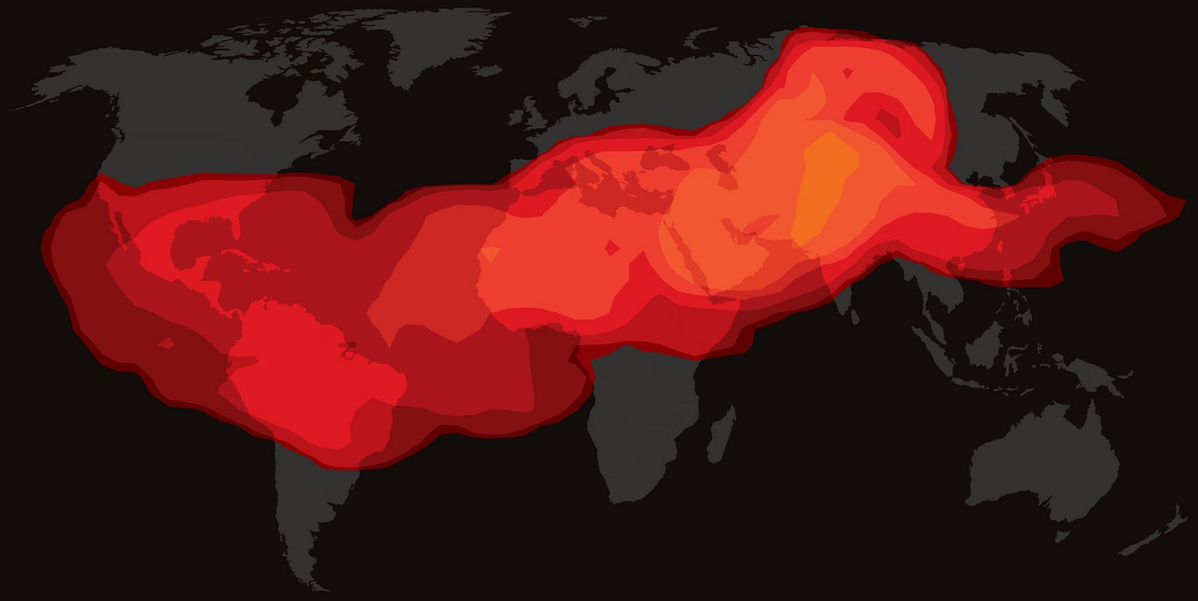
# *Even a “limited” nuclear war has global environmental consequences*

## Smoke from a regional nuclear war between India and Pakistan

**Day 4:** May 18th



**Day 7:** May 21st



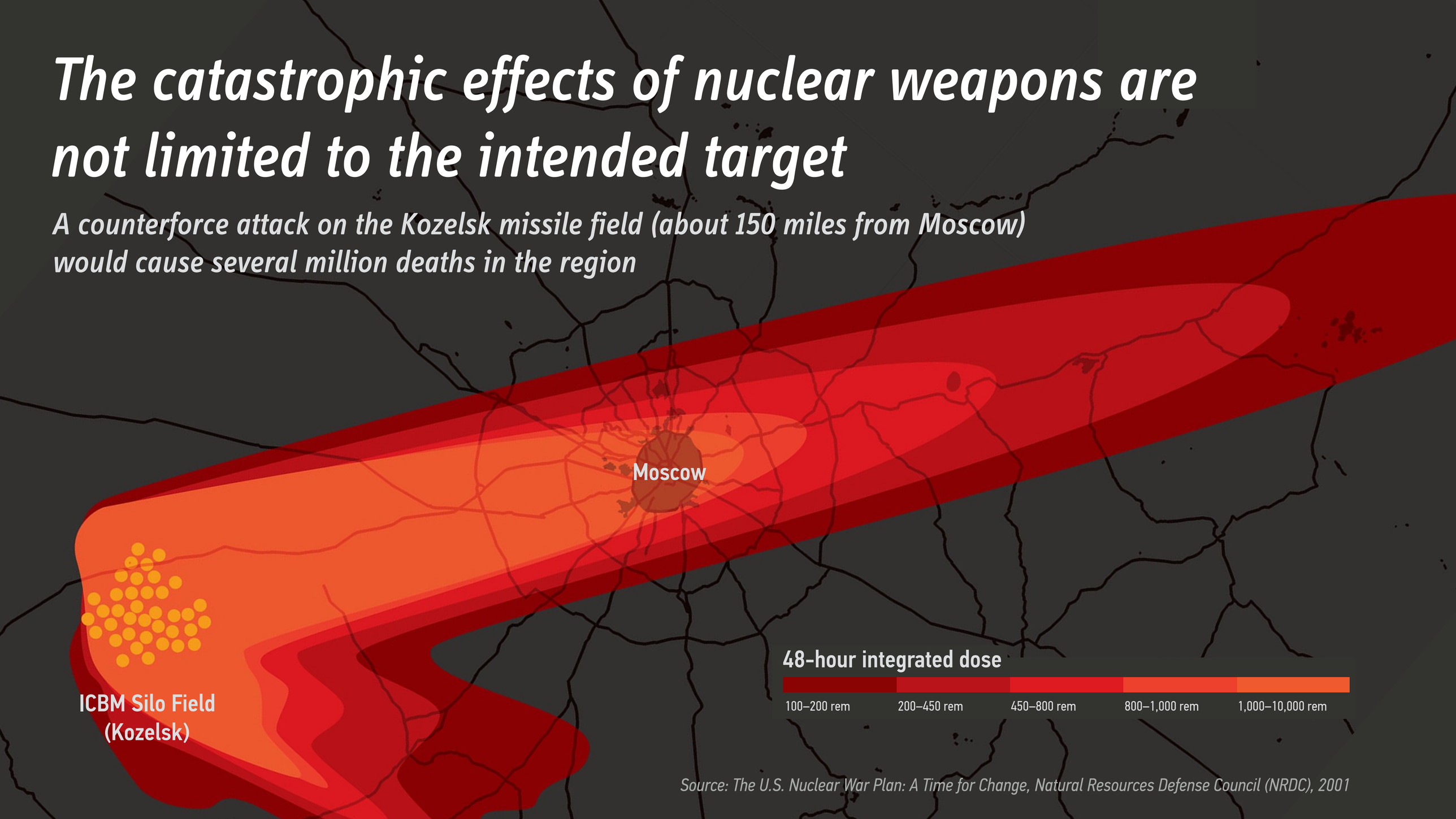
**Black Carbon Absorption Optical Depth**

1 0,7 0,5 0,3 0,1 0,07 0,05 0,03

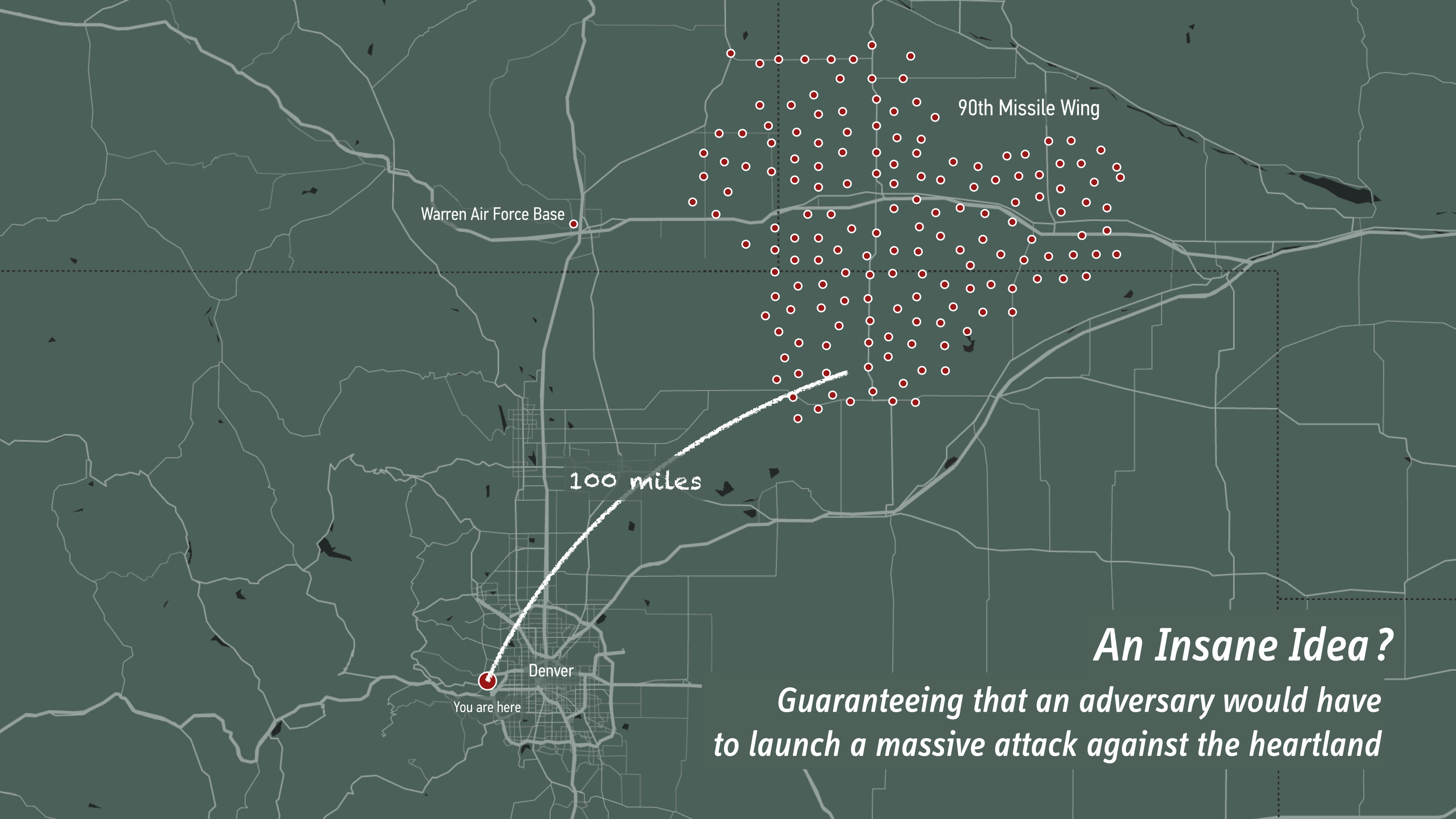
*Credit: Alan Robock and Luke Oman, climate.envsci.rutgers.edu/nuclear and www.atmos-chem-phys.net/7/2003/2007; see also, Toon et al., Science Advances, October 2019*

# *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*




*Source: The U.S. Nuclear War Plan: A Time for Change, Natural Resources Defense Council (NRDC), 2001*




# *An Insane Idea?*

***Guaranteeing that an adversary would have to launch a massive attack against the heartland***

# WHEN TRUTH IS STRANGER THAN FICTION

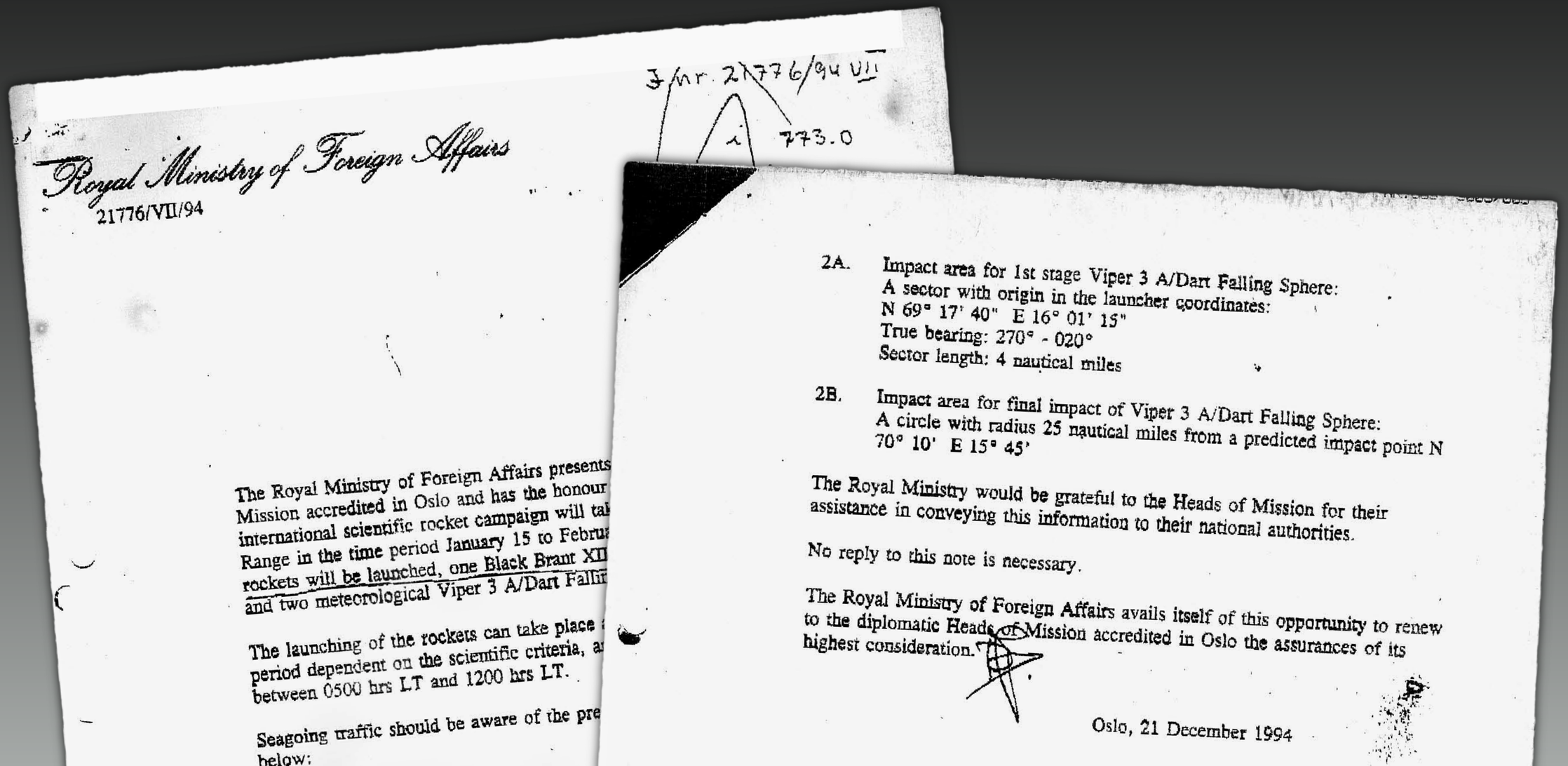
## SELECTED INCIDENTS OF NEAR NUCLEAR USE

| Date | Incident | States involved | Cause |
|---|---|---|---|
| October 1962 | Operation Anadyr | Soviet Union | Miscommunication |
| 27 October 1962 | British nuclear forces during the Cuban missile crisis | United Kingdom | Conflict escalation |
| 27 October 1962 | Black Saturday | United States | Conflict escalation and miscommunication |
| 22 November 1962 | Penkovsky false warning | Soviet Union | Espionage |
| October 1973 | 1973 Arab–Israeli war | Israel | Conflict escalation |
| 9 November 1979 | NORAD: Exercise tape mistaken for reality | United States | Exercise scenario tape causes nuclear alert |
| 3 June 1980 | NORAD: Faulty computer chip | United States | Faulty computer chip |
| 25 September 1983 | Serpukhov-15 | Soviet Union | Technical error |
| 7–11 November 1983 | Able Archer-83 | Soviet Union, United States | Misperception of military training exercise |
| 18–21 August 1991 | Failed coup | Soviet Union | Loss of command and control structure |
| 25 January 1995 | Black Brant scare | Russia | Mistaken identity of research rocket launch |
| May–June 1999 | Kargil crisis | India, Pakistan | Conflict escalation |
| December 2001–October 2002 | Kashmir standoff | India, Pakistan | Conflict escalation |

*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*

# “NO REPLY TO THIS NOTE IS NECESSARY”

## BLACK BRANT XII MISSILE SCARE, JANUARY 25, 1995



Royal Ministry of Foreign Affairs

21776/VII/94

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The Royal Ministry of Foreign Affairs presents
Mission accredited in Oslo and has the honour
international scientific rocket campaign will tak
Range in the time period January 15 to Februa
rockets will be launched, one Black Brant XII
and two meteorological Viper 3 A/Dart Fallin

The launching of the rockets can take place
period dependent on the scientific criteria, a
between 0500 hrs LT and 1200 hrs LT.

Seagoing traffic should be aware of the pre
below:

2A. Impact area for 1st stage Viper 3 A/Dart Falling Sphere:
A sector with origin in the launcher coordinates:
N 69° 17' 40" E 16° 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 to the Heads of Mission for their assistance in conveying this information to their national authorities.

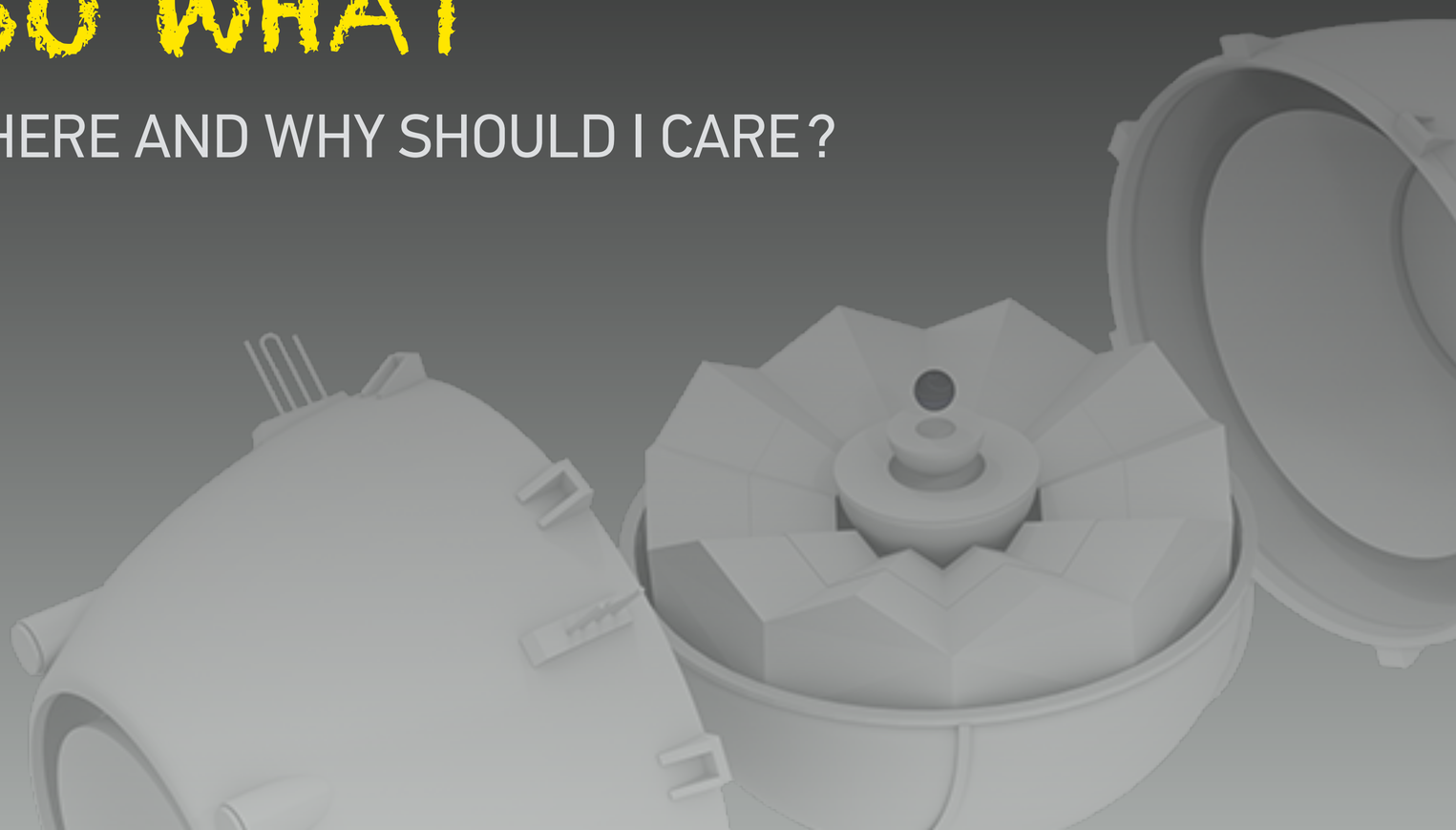
No reply to this note is necessary.

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

Oslo, 21 December 1994

# SO WHAT

WHAT IS NEW HERE AND WHY SHOULD I CARE?



*Albert Einstein on behalf of the*
*Emergency Committee of Atomic Scientists*
*Princeton, NJ, December 1946*

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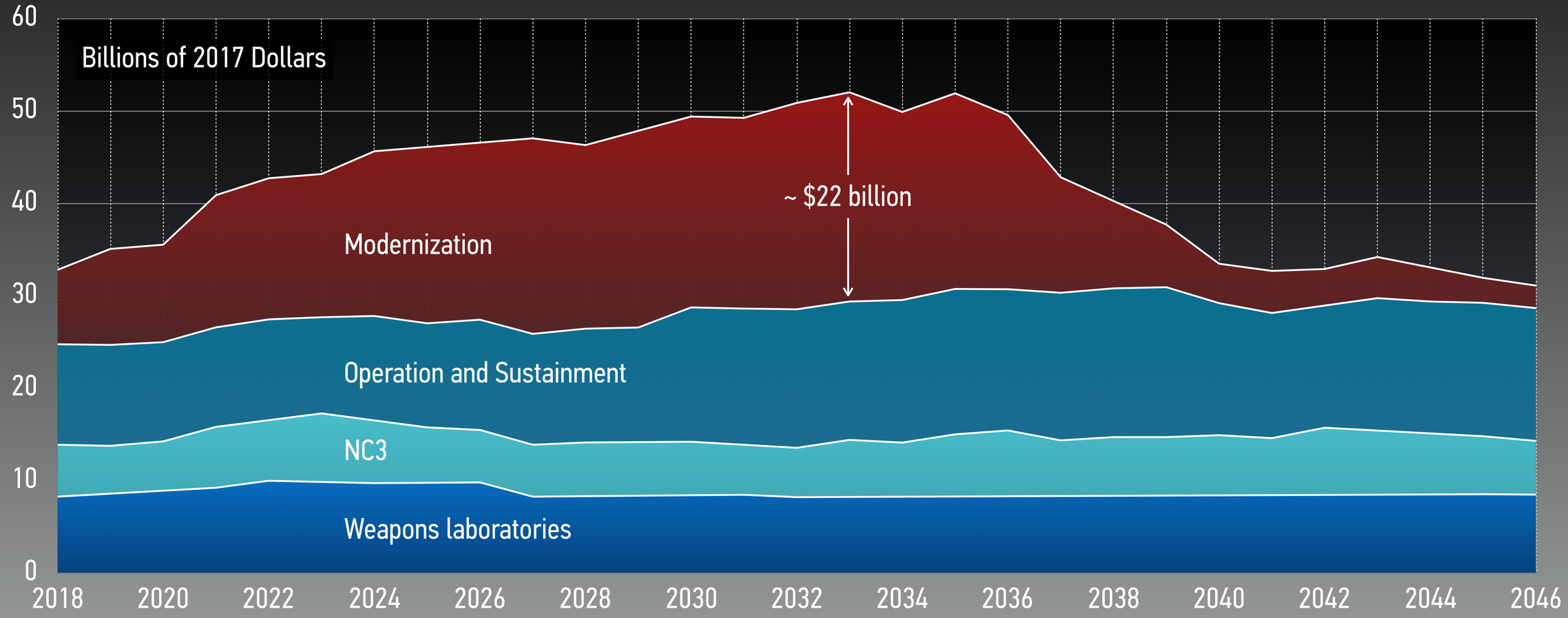
Faithfully yours,

A. Einstein.

**Through the release of atomic energy, our generation has brought into the world the most revolutionary force since prehistoric man's discovery of fire.**

# COSTS OF U.S. NUCLEAR FORCES, 2018–2046

## AND THE MODERNIZATION "BOW WAVE"

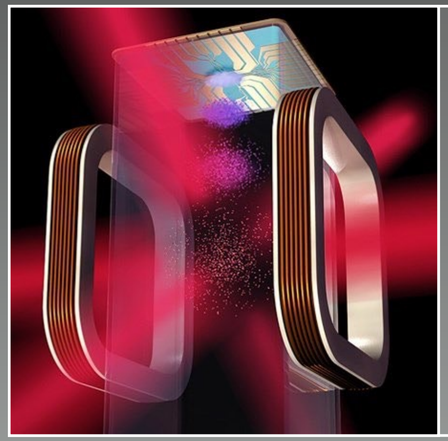



Source: *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046,* Congressional Budget Office, October 2017, www.cbo.gov/publication/53211

# 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

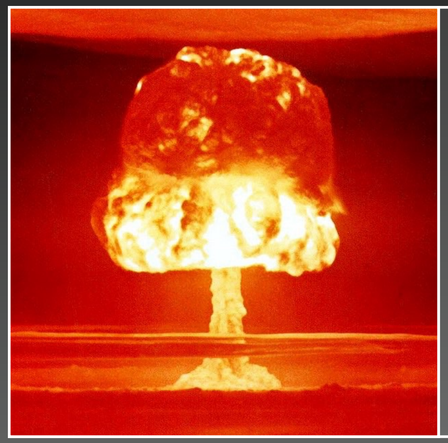
Pinpoint accuracy without relying on global navigation satellite systems (GNSS)

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)*

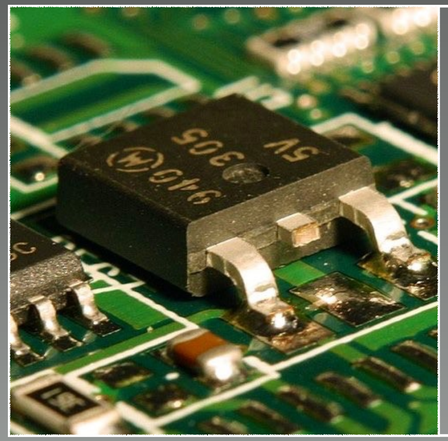
# NEW TECHNOLOGIES
## risks & vulnerabilities



### 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



### 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

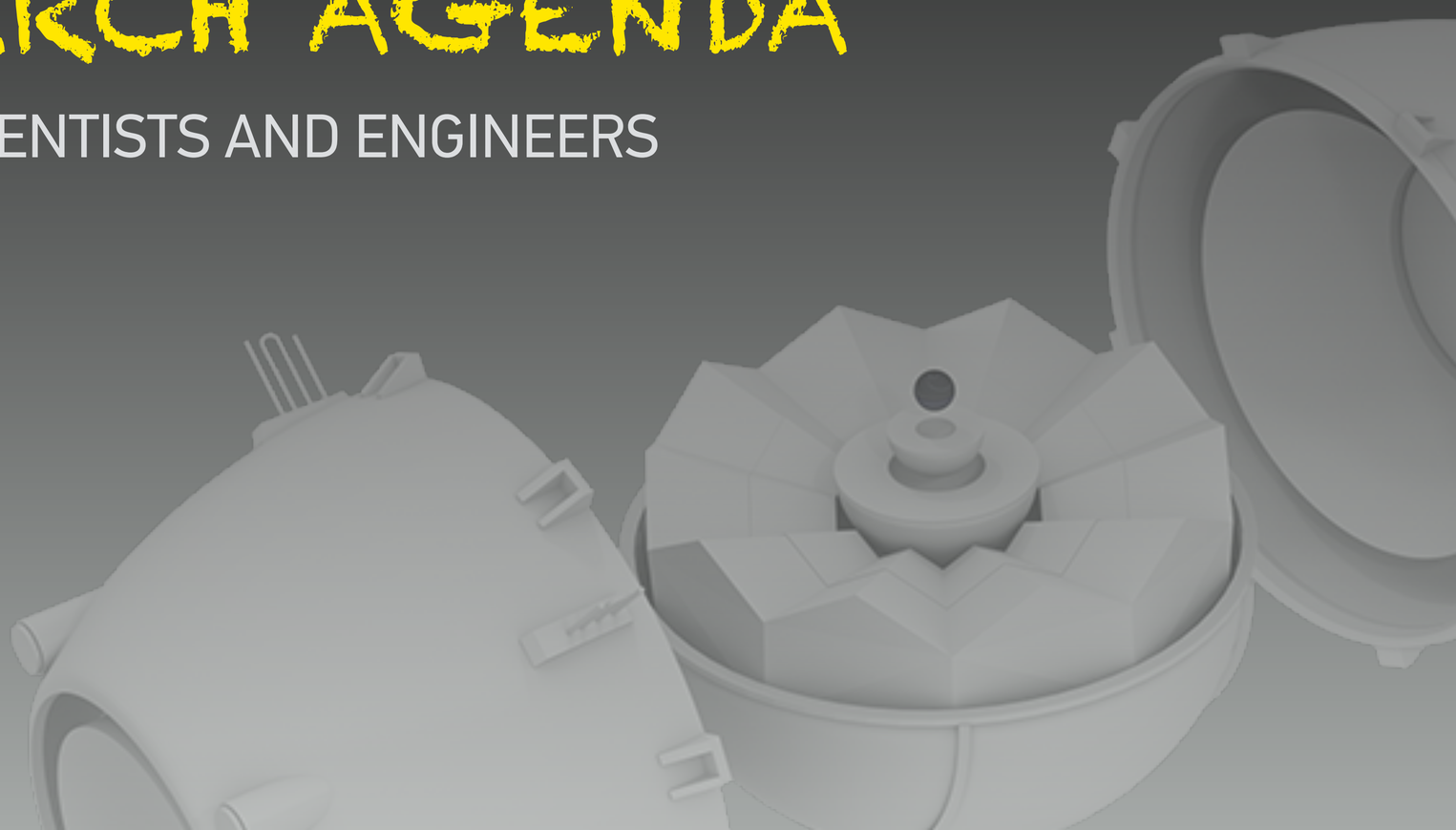
*Source: Castle Bravo (top) and wikimedia.org/pdphoto.org (bottom)*

# "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?

*Plutonium ring (Source: Los Alamos National Laboratory)*

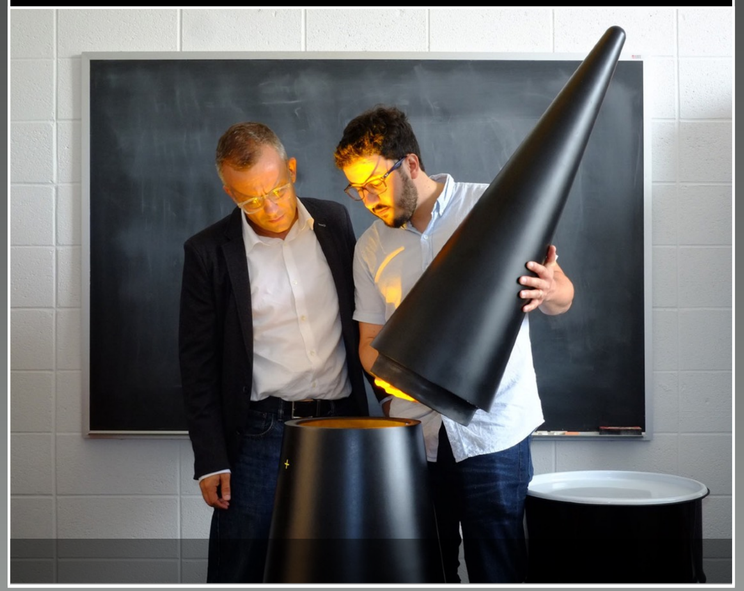
## REACTOR CONVERSION
2000s

Can one use low-enriched uranium in research reactors without performance loss?

*Advanced Test Reactor (Source: U.S. Department of Energy)*

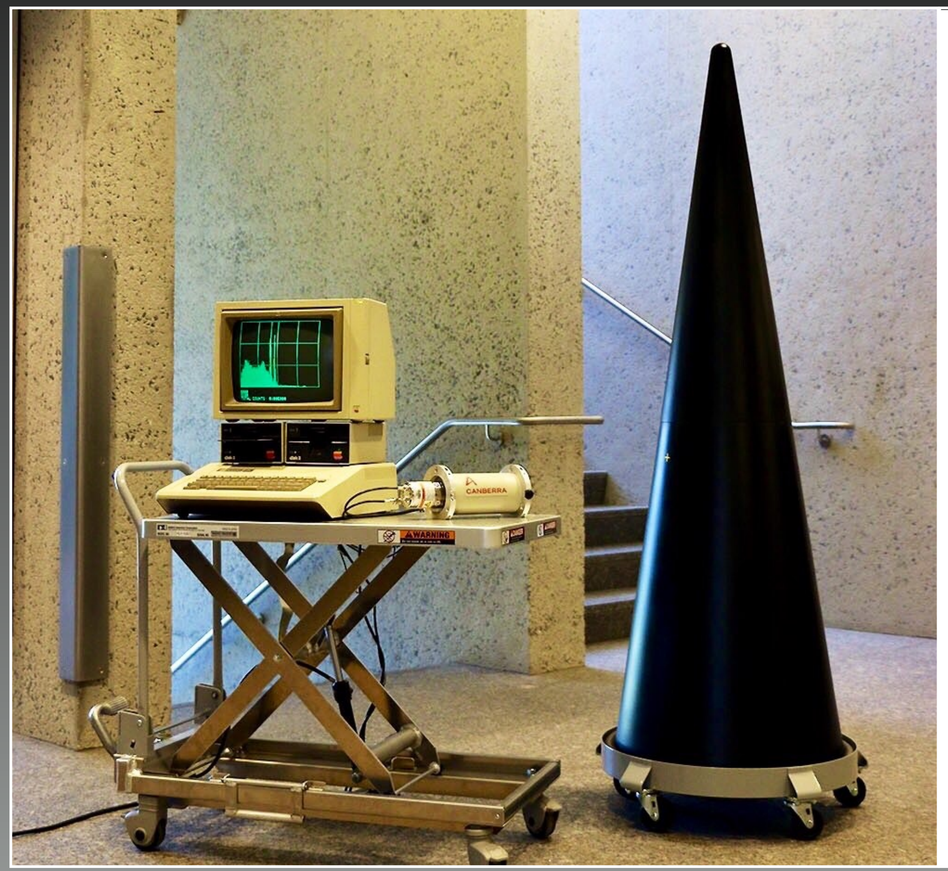
## WARHEAD VERIFICATION
2010s

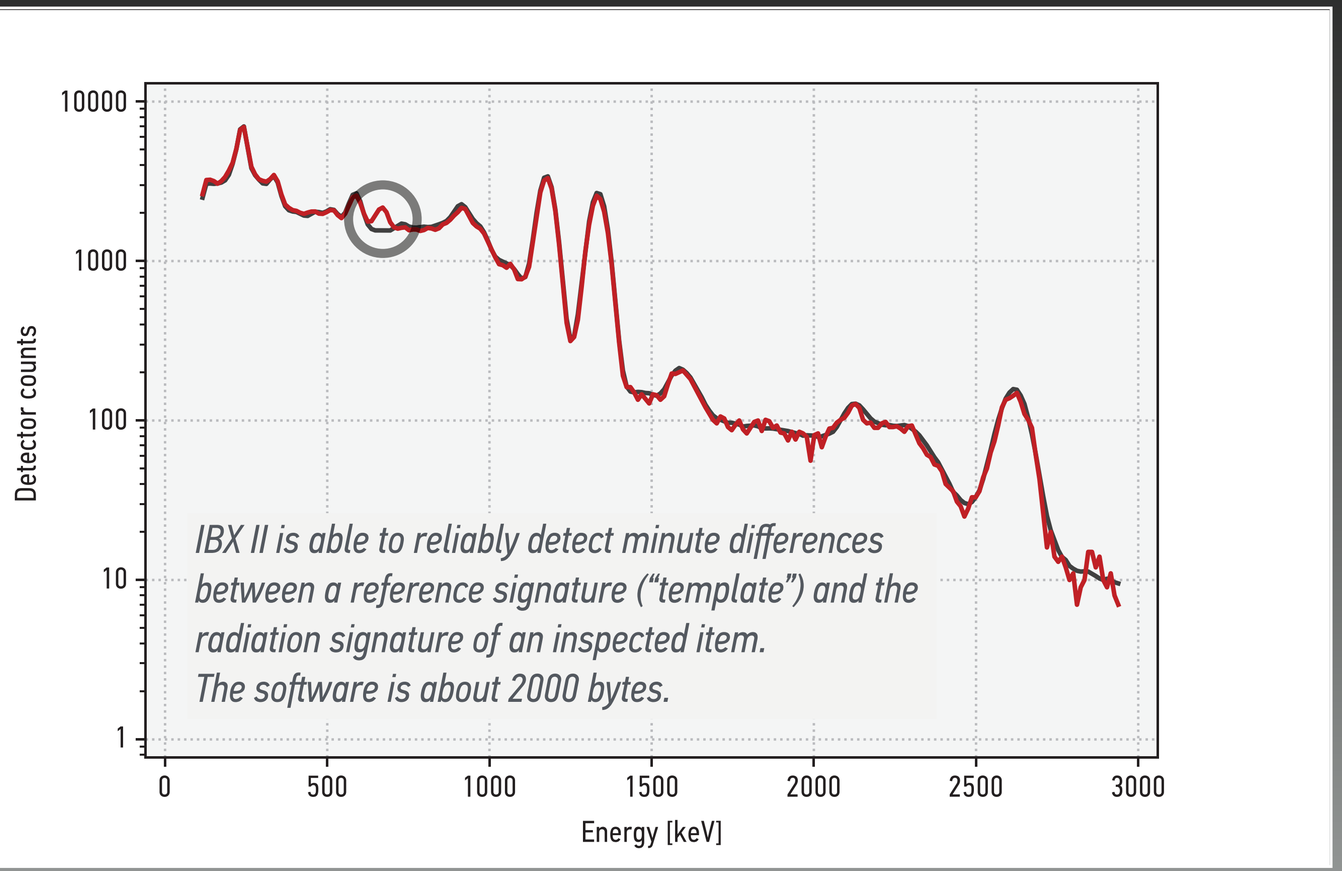
Can one dismantle a nuclear warhead without learning anything about its design?



# INFORMATION BARRIER EXPERIMENTAL II

## "TRUST THROUGH SIMPLICITY AND OBSOLESCENCE"



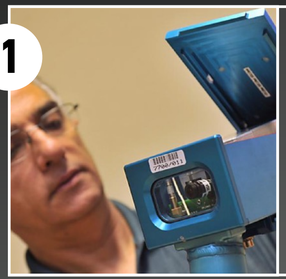




M. Kütt and A. Glaser, "Vintage Electronics for Trusted Radiation Measurements and Verified Dismantlement of Nuclear Weapons," *PLOS ONE,* October 30, 2019

# AREAS OF INTEREST FOR A RESEARCH AGENDA

## SUPPORTING NUCLEAR ARMS CONTROL AND NONPROLIFERATION

1



### MONITORING NUCLEAR-FUEL CYCLE ACTIVITIES

Increasing need/demand for real-time monitoring of nuclear facilities for strengthened safeguards

This could also involve development of new technologies to confirm a freeze of North Korea's program

2

### 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)

3

### KNOWING WHAT'S THERE: NUCLEAR ARCHAEOLOGY

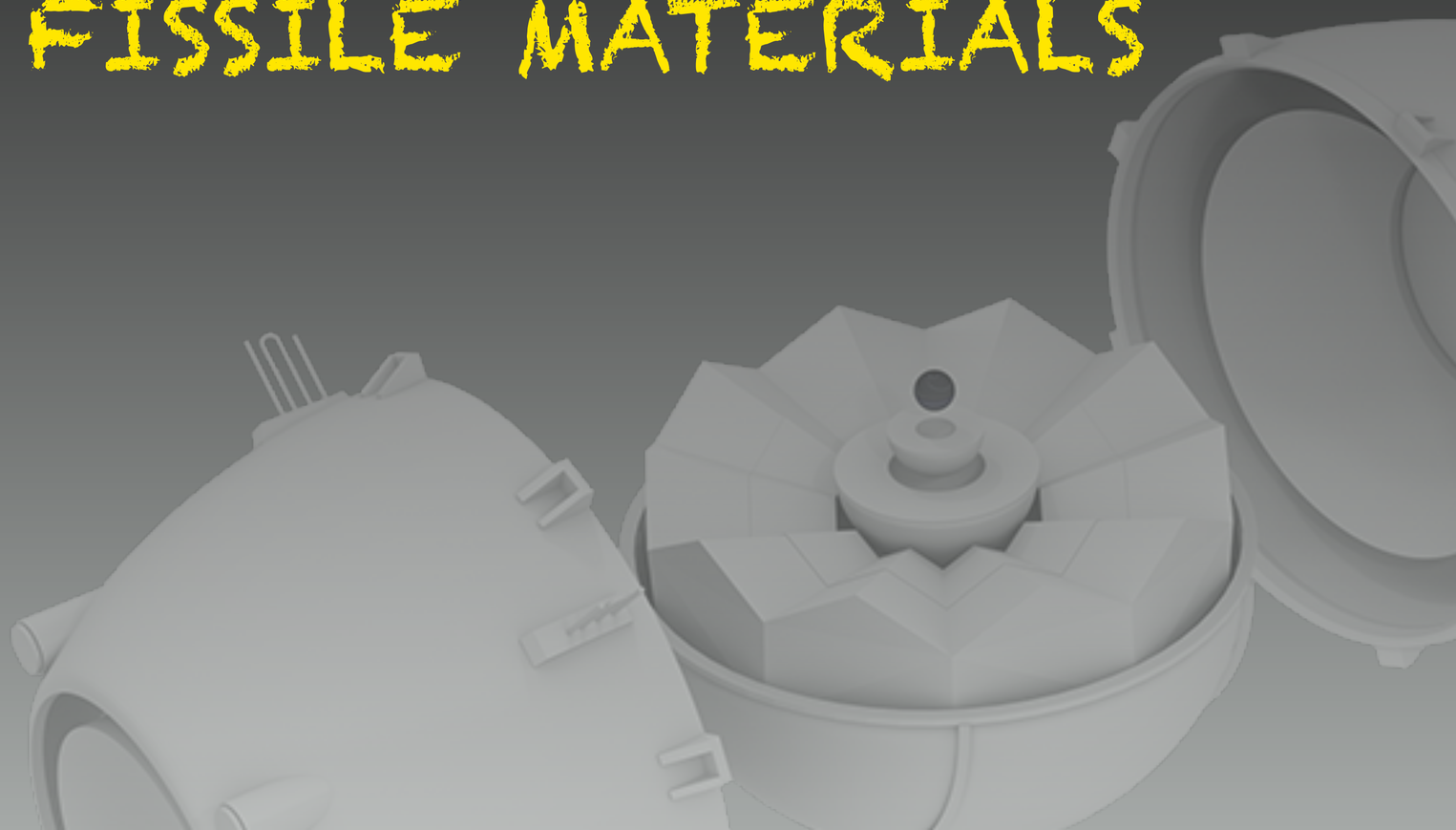
There are large uncertainties in the global inventory of plutonium and highly enriched uranium

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)*

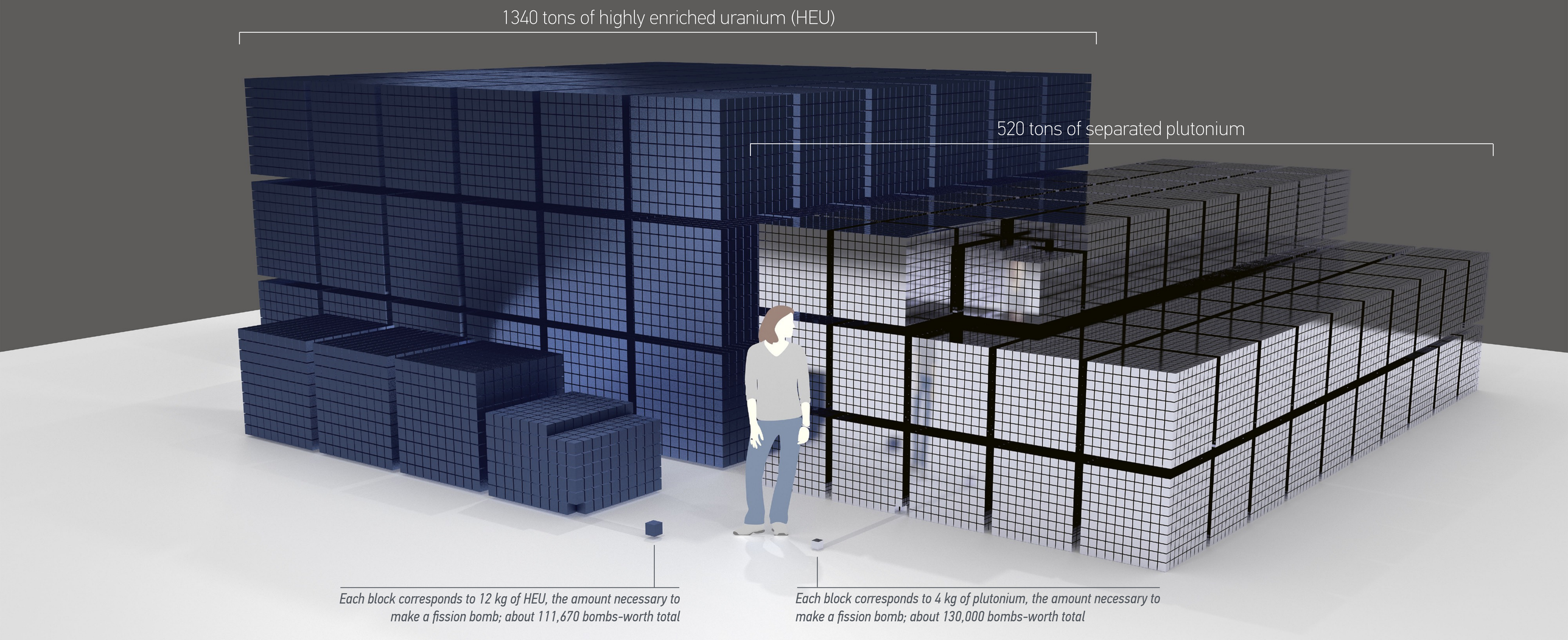
CAPPING THE REBOUND

# DEVELOPING DISPOSITION OPTIONS FOR EXCESS FISSILE MATERIALS



*Graphic/concept by Alex Wellerstein and Tamara Patton*
*Status as of end of 2016*

# *There is enough nuclear explosive material in the world to make over 200,000 nuclear weapons*




*Each block corresponds to 12 kg of HEU, the amount necessary to make a fission bomb; about 111,670 bombs-worth total*

*Each block corresponds to 4 kg of plutonium, the amount necessary to make a fission bomb; about 130,000 bombs-worth total*

# A LARGE FRACTION OF THE WORLD'S FISSILE MATERIAL STOCKPILE IS EXCESS

## THE CASE OF PLUTONIUM

# WHO CAN MAKE FISSILE MATERIALS TODAY?

## ENRICHMENT AND REPROCESSING FACILITIES WORLDWIDE

Gronau

Rokkasho

Natanz

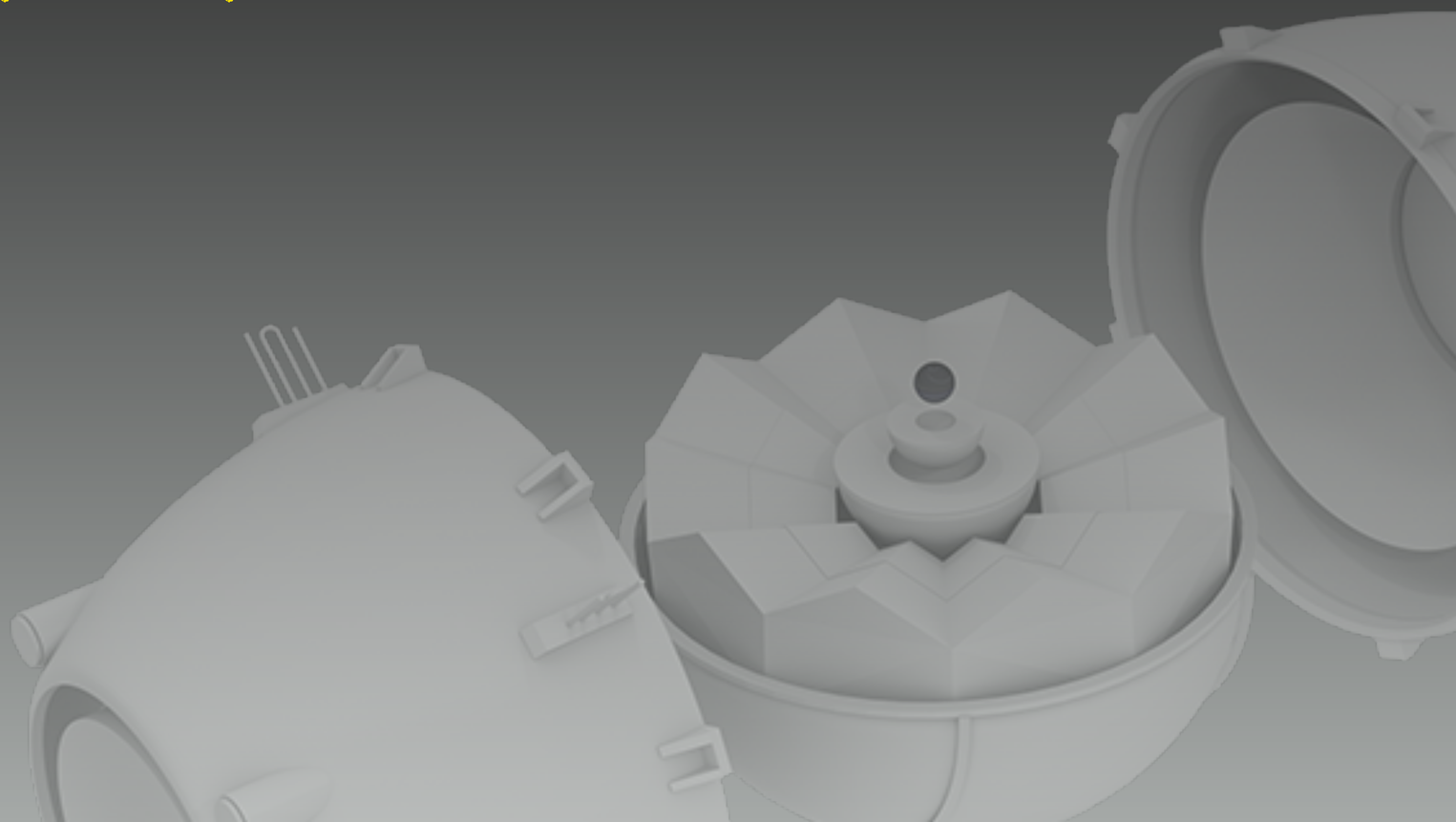
Resende

E R Enrichment/reprocessing in weapon state

E R Enrichment/reprocessing in non-weapon state

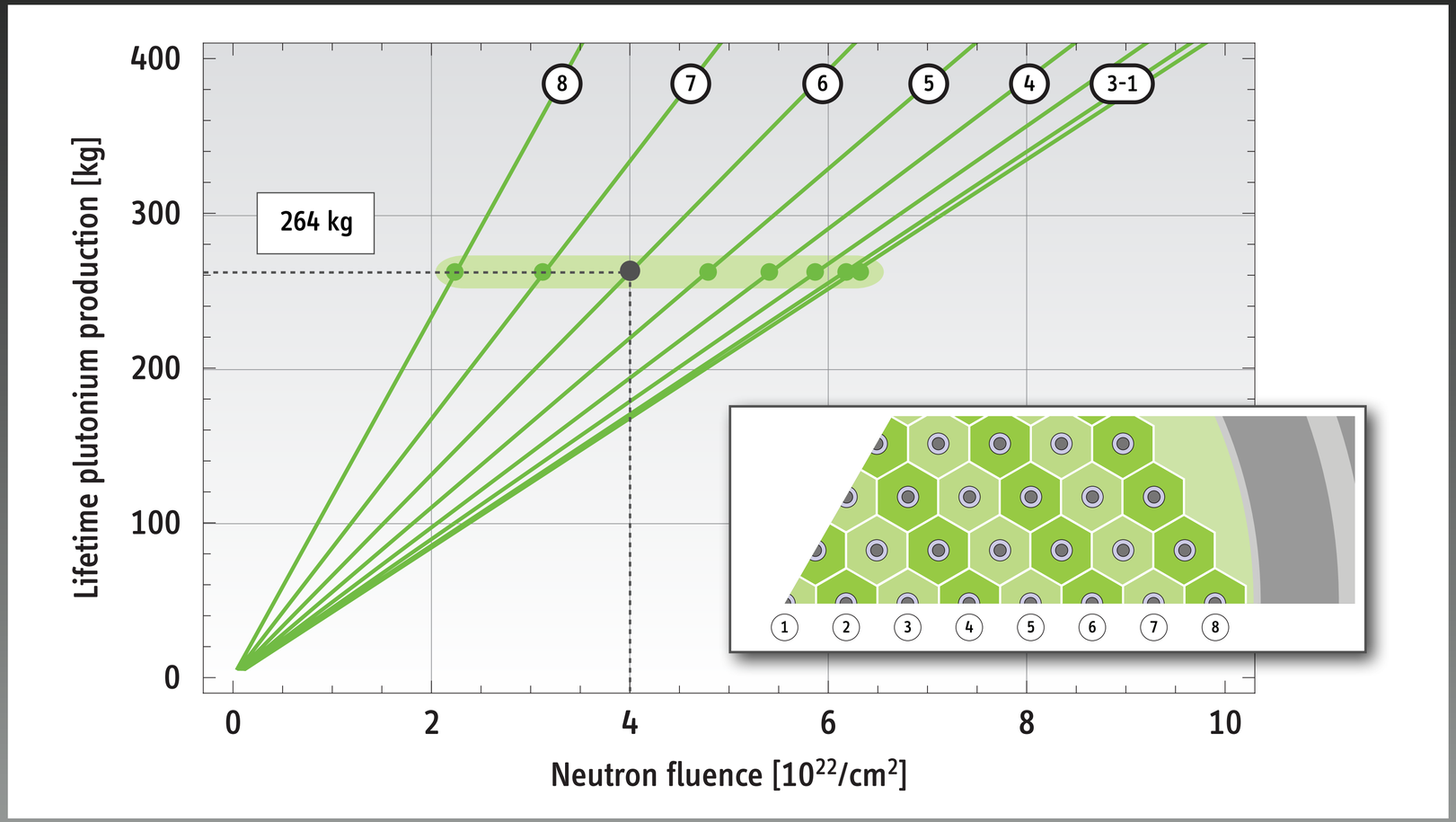
KNOWING WHAT'S THERE

# 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

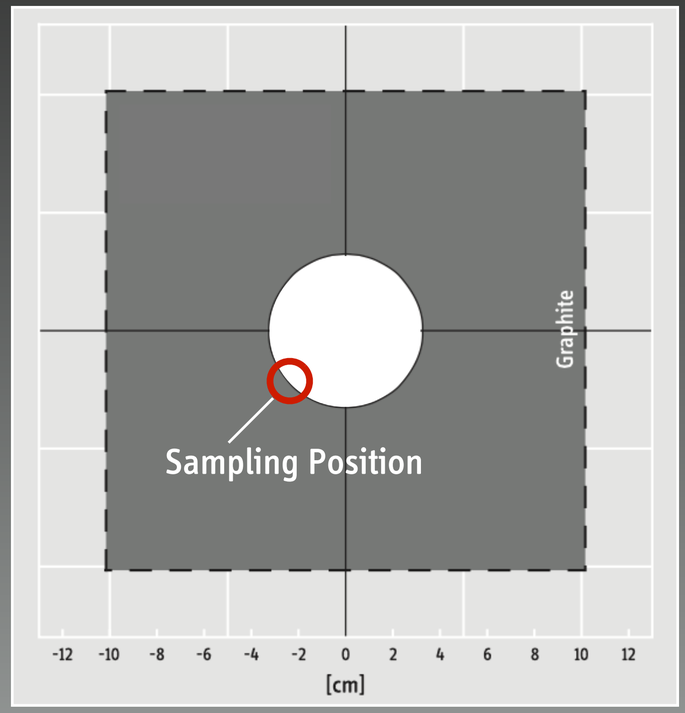



A. Gasner and A. Glaser, "Nuclear Archaeology for Heavy-Water-Moderated Plutonium Production Reactors," *Science & Global Security,* 19, 2011

# 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 ±2 KG

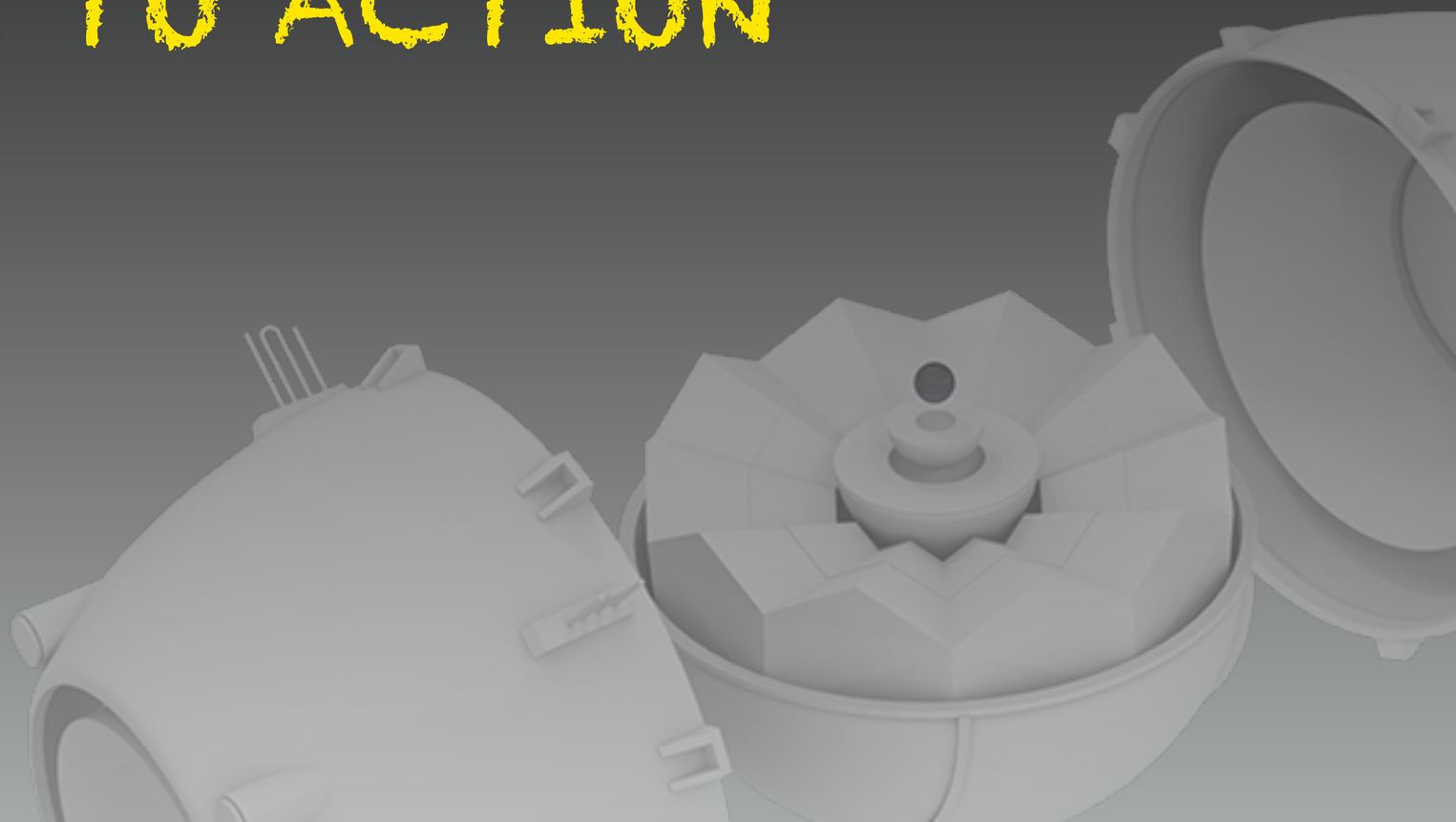

*The banner reads: "Let's protect Dear General Kim Jong Il desperately!"*
*Credit: CNN/Brian Rokus, 2008*




*Unit cell of the DPRK Yongbyon reactor*

*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)*

# PHYSICISTS COALITION FOR NUCLEAR THREAT REDUCTION

www.physicistscoalition.org

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!