

THE END OF NUCLEAR ARMS CONTROL AND NONPROLIFERATION?

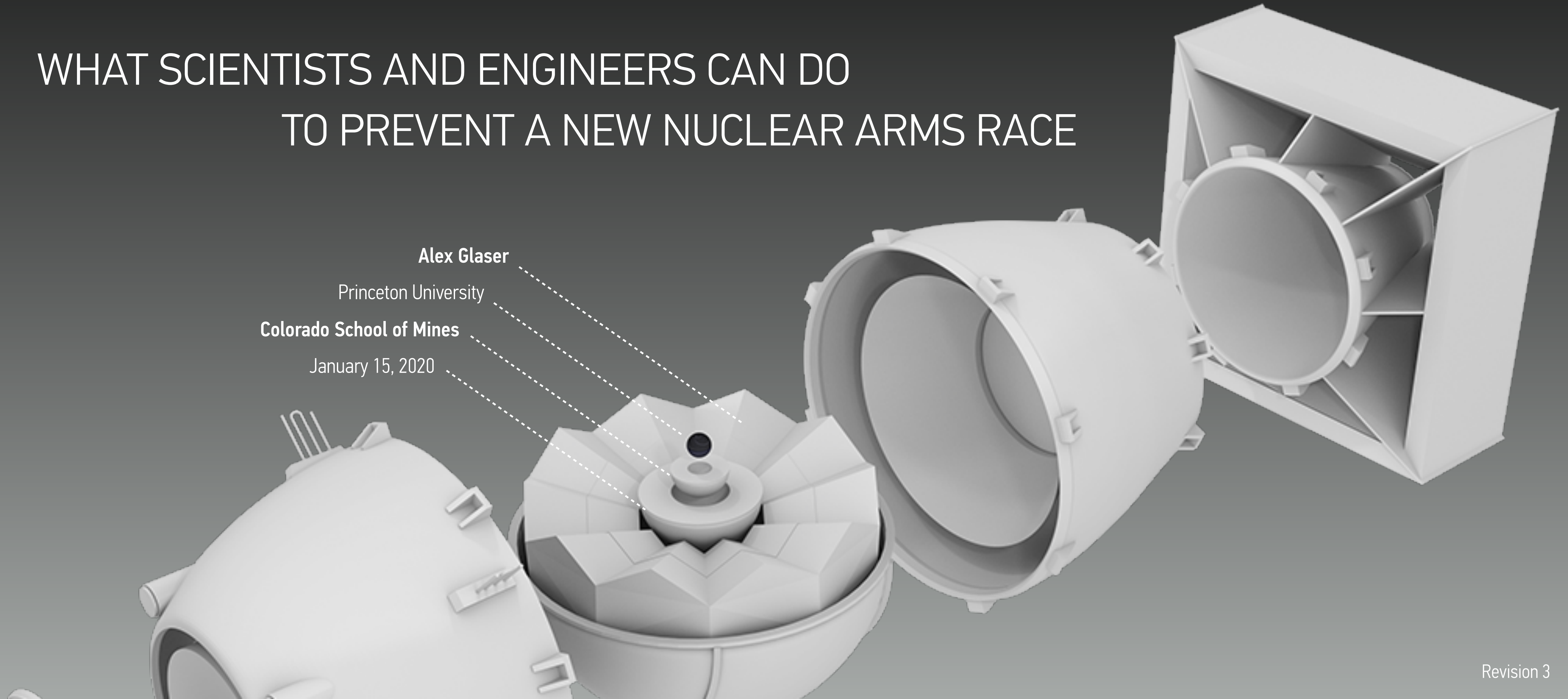
WHAT SCIENTISTS AND ENGINEERS CAN DO
TO PREVENT A NEW NUCLEAR ARMS RACE

Alex Glaser

Princeton University

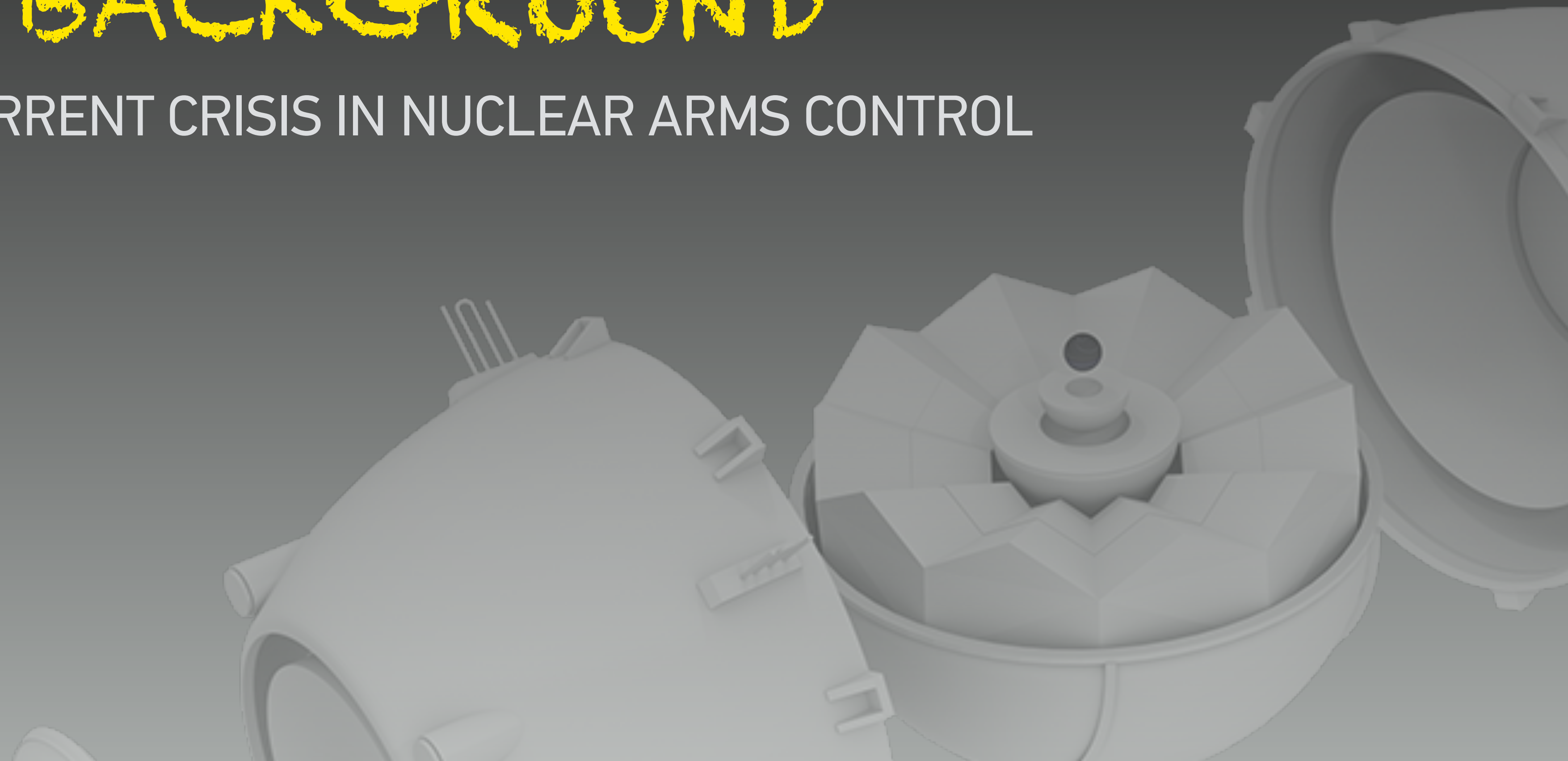
Colorado School of Mines

January 15, 2020



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



USA
6,200



U.S. Nuclear Weapon

Russia
6,500



United Kingdom
215



215

France
300



France
300

Israel
80



Israel
80

Pakistan
135



Pakistan
135

India
125



India
125

China
270



China
270



North Korean Nuclear Weapon

North Korea
15

North Korea
15

***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 only security and our only hope - we believe that an informed citizenry is the only life and not for death.

We need \$1,000,000 for this great task. Sustained by faith in man's ability to control 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

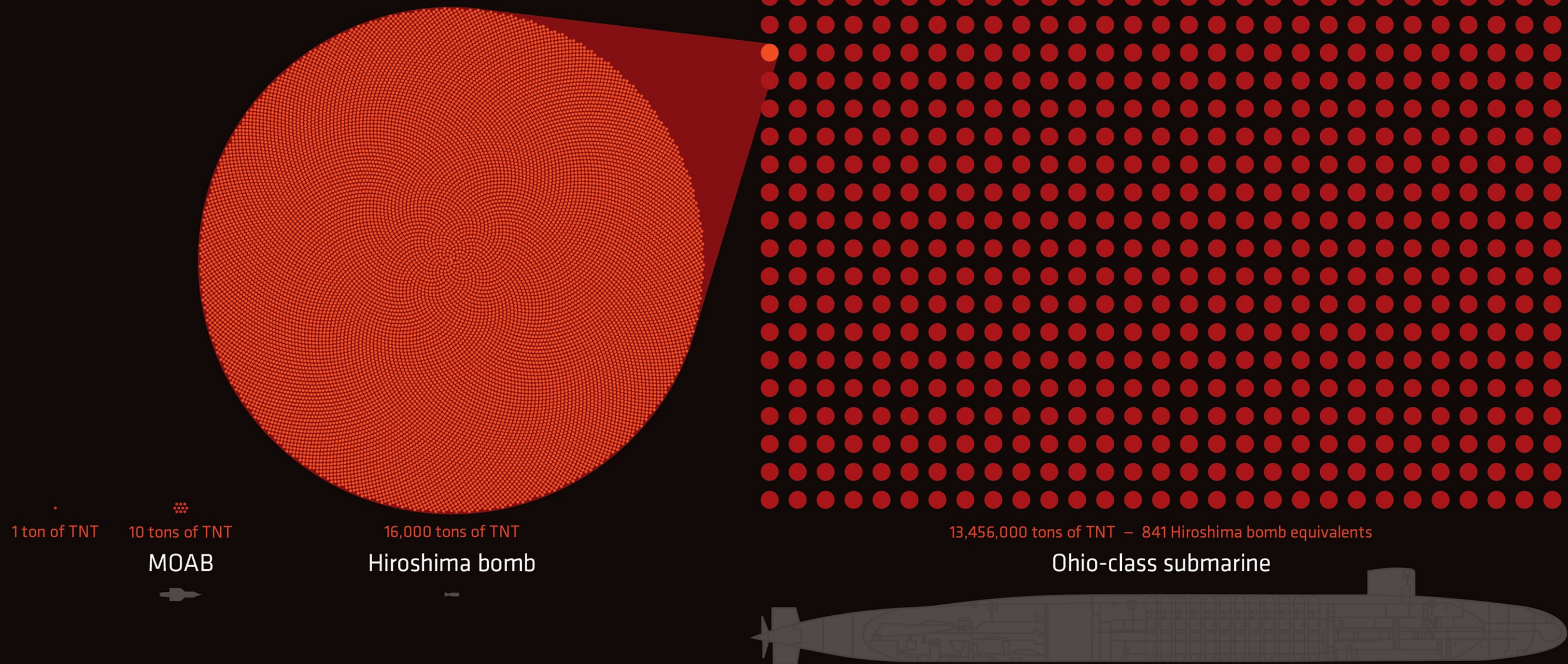


U.S. W80-4 cruise missile warhead
Source: NNSA/Sandia National Laboratory

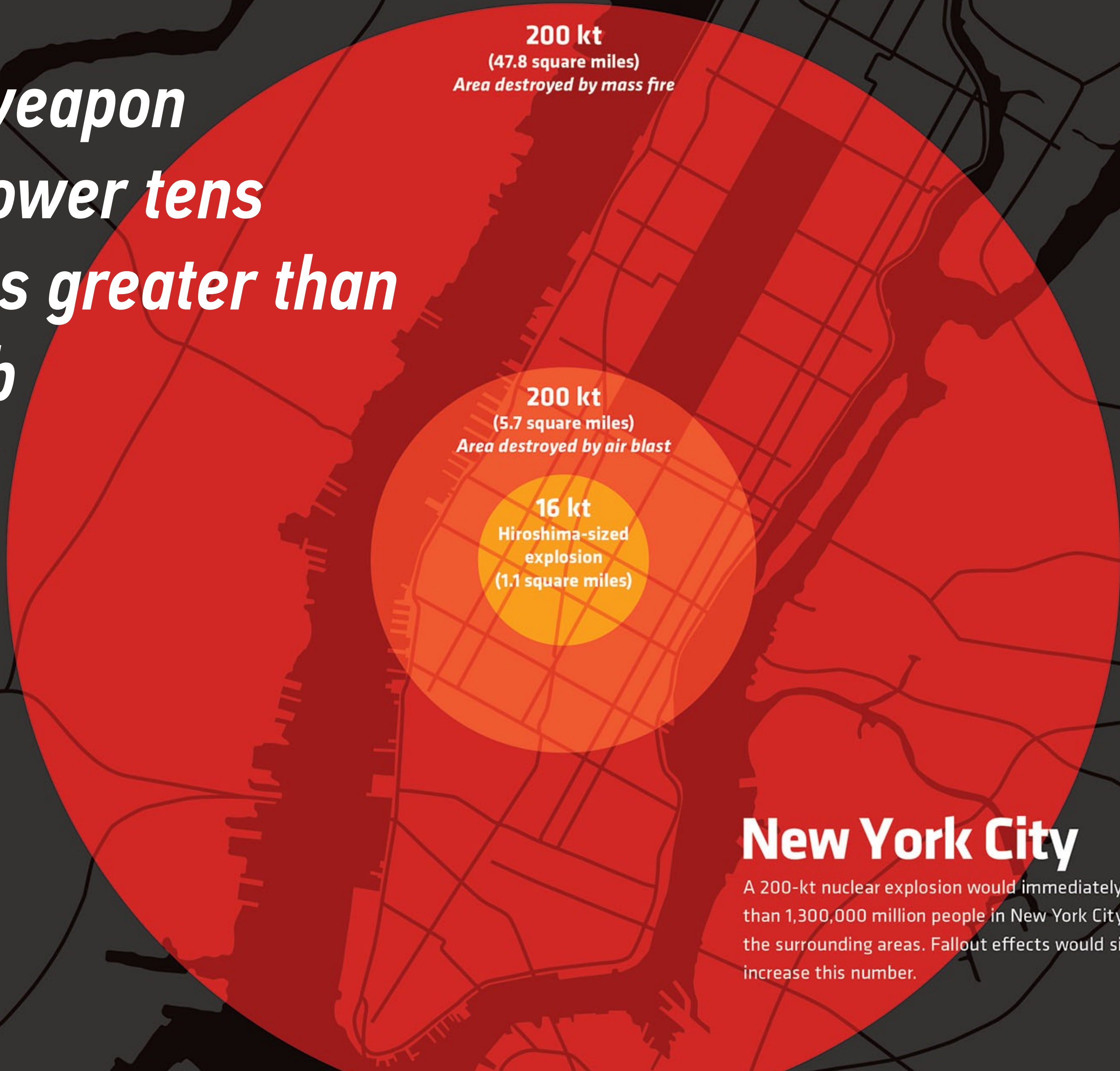


North Korean two-stage weapon
Source: KCNA

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***



New York City

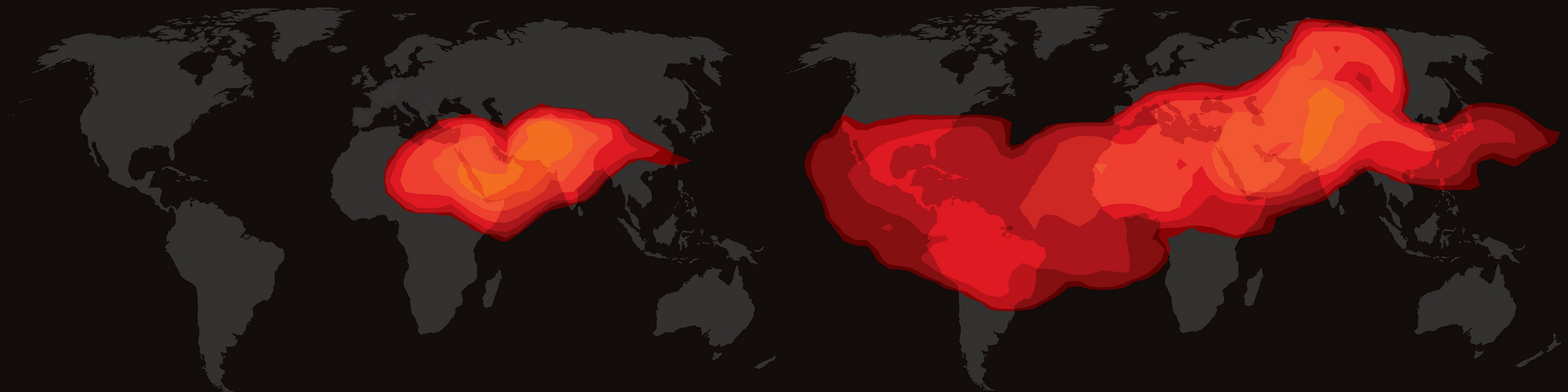
A 200-kt nuclear explosion would immediately kill more than 1,300,000 million people in New York City and the surrounding areas. Fallout effects would significantly increase this number.

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



*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

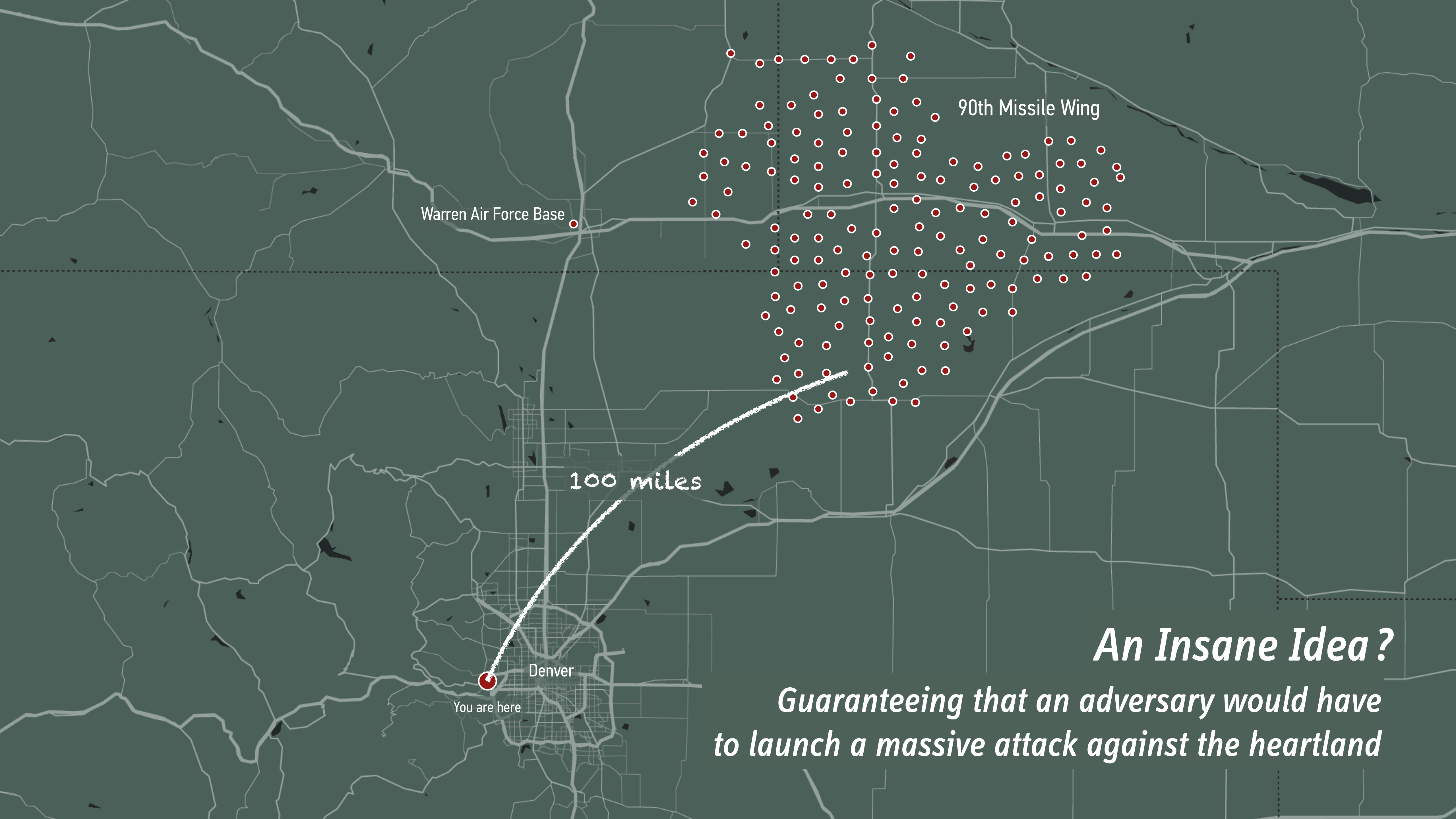
Moscow

ICBM Silo Field
(Kozelsk)

48-hour integrated dose

100–200 rem 200–450 rem 450–800 rem 800–1,000 rem 1,000–10,000 rem

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



Warren Air Force Base

90th Missile Wing

100 miles

Denver

You are here

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

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

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

Seagoing traffic should be aware of the presence of the rockets as follows:

3/nr. 21776/94 VII
773.0

- 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?



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 hope - we believe that an informed citizenry will act for life and not for death.

We need \$1,000,000 for this great educational task. Sustained by faith in man's ability to control 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,

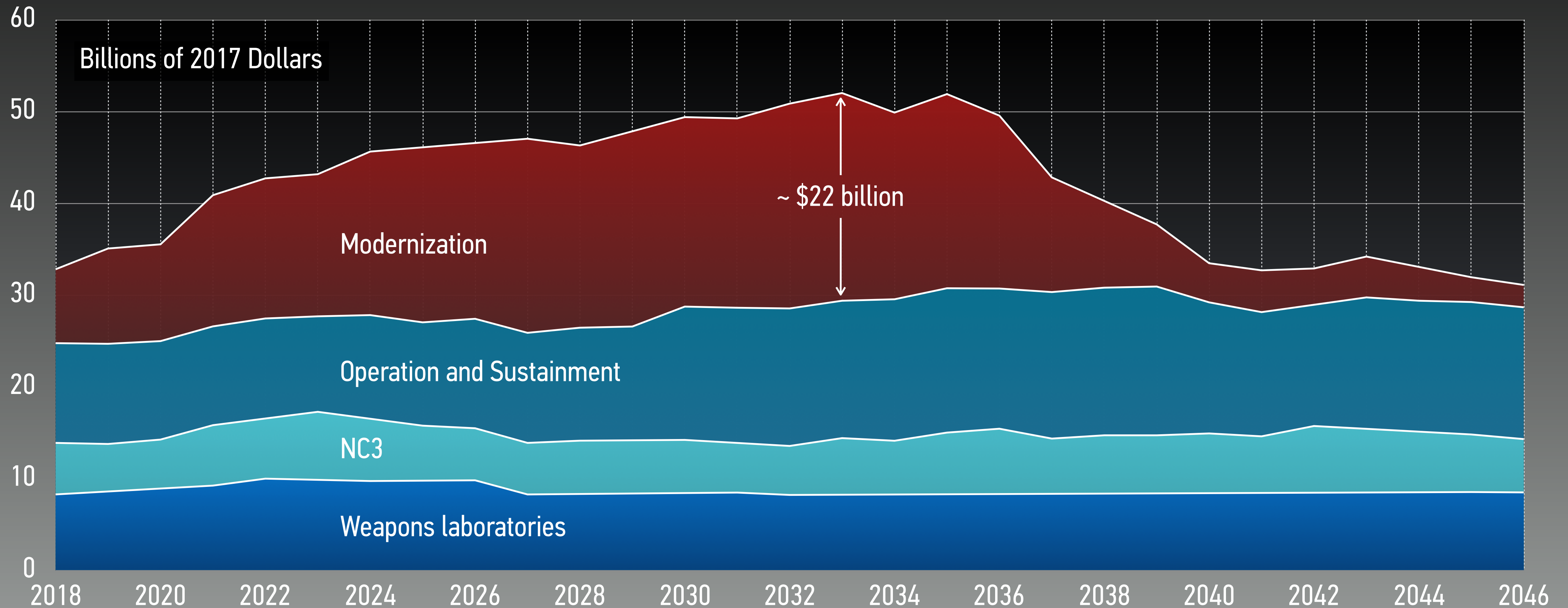
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**Through the release of atomic energy,
our generation has brought into the
world the most revolutionary force since
prehistoric man's discovery of fire.**

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

AND THE MODERNIZATION “BOW WAVE”



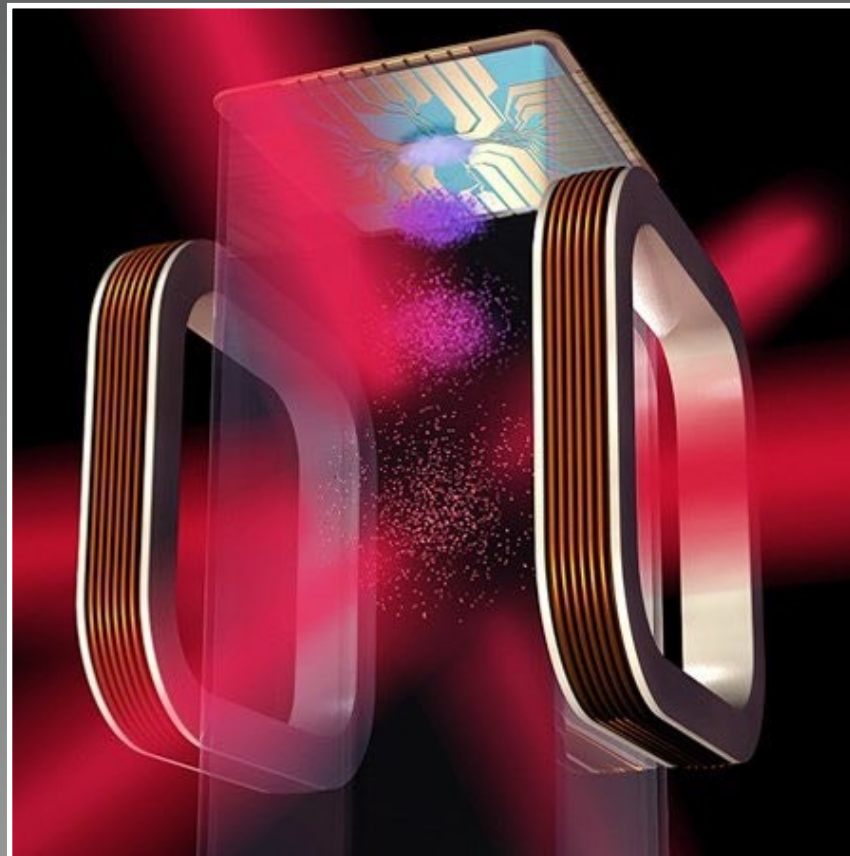
Source: *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046*, Congressional Budget Office, October 2017, www.cbo.gov/publication/53211

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



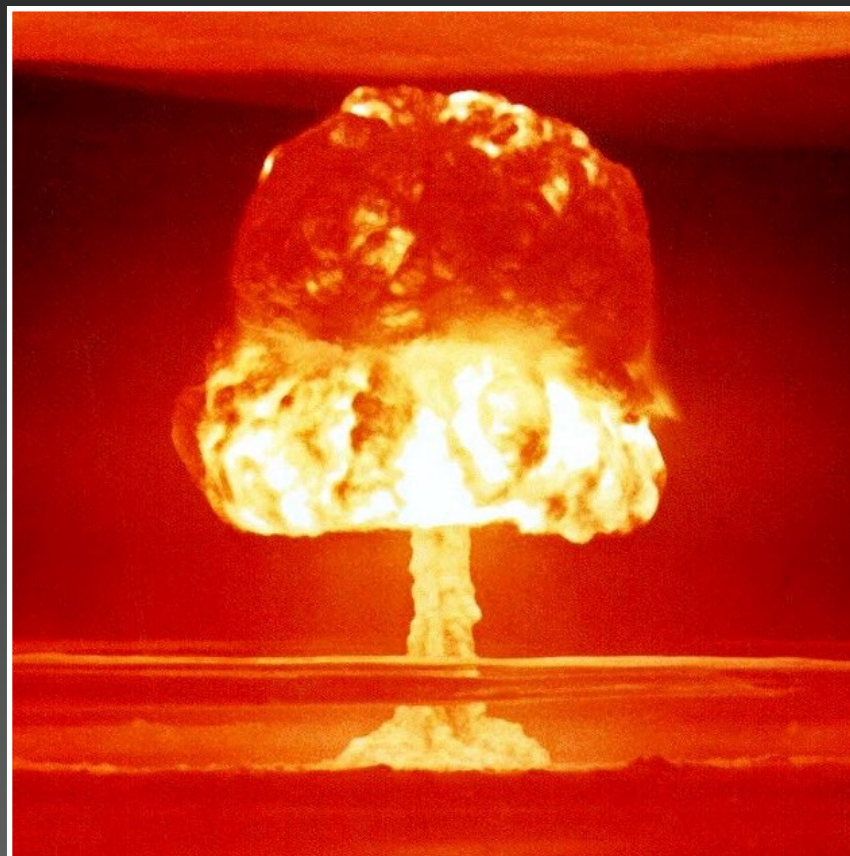
NEXT-GENERATION (“EMERGING”) TECHNOLOGIES

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)

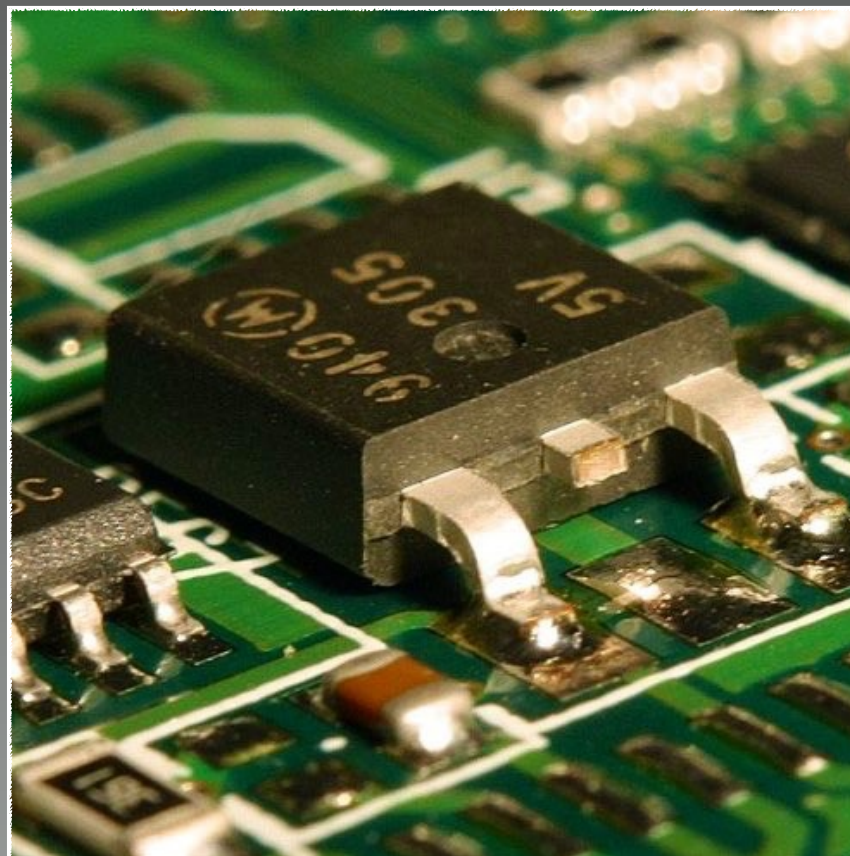
NEW TECHNOLOGIES

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

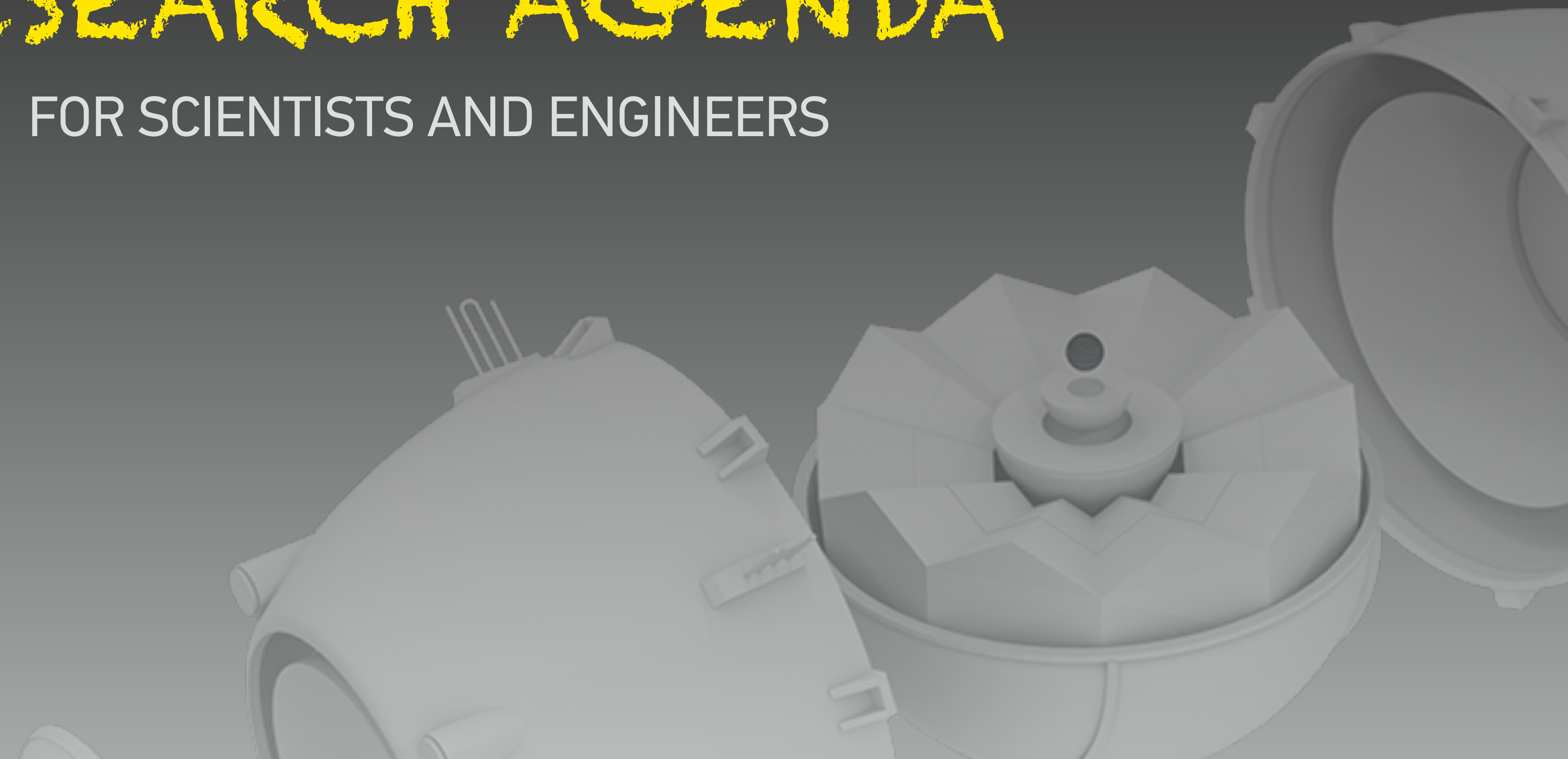
Source: Castle Bravo (top) and [wikimedia.org/pdphoto.org](https://commons.wikimedia.org/wiki/File:Microchip.jpg) (bottom)

"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?

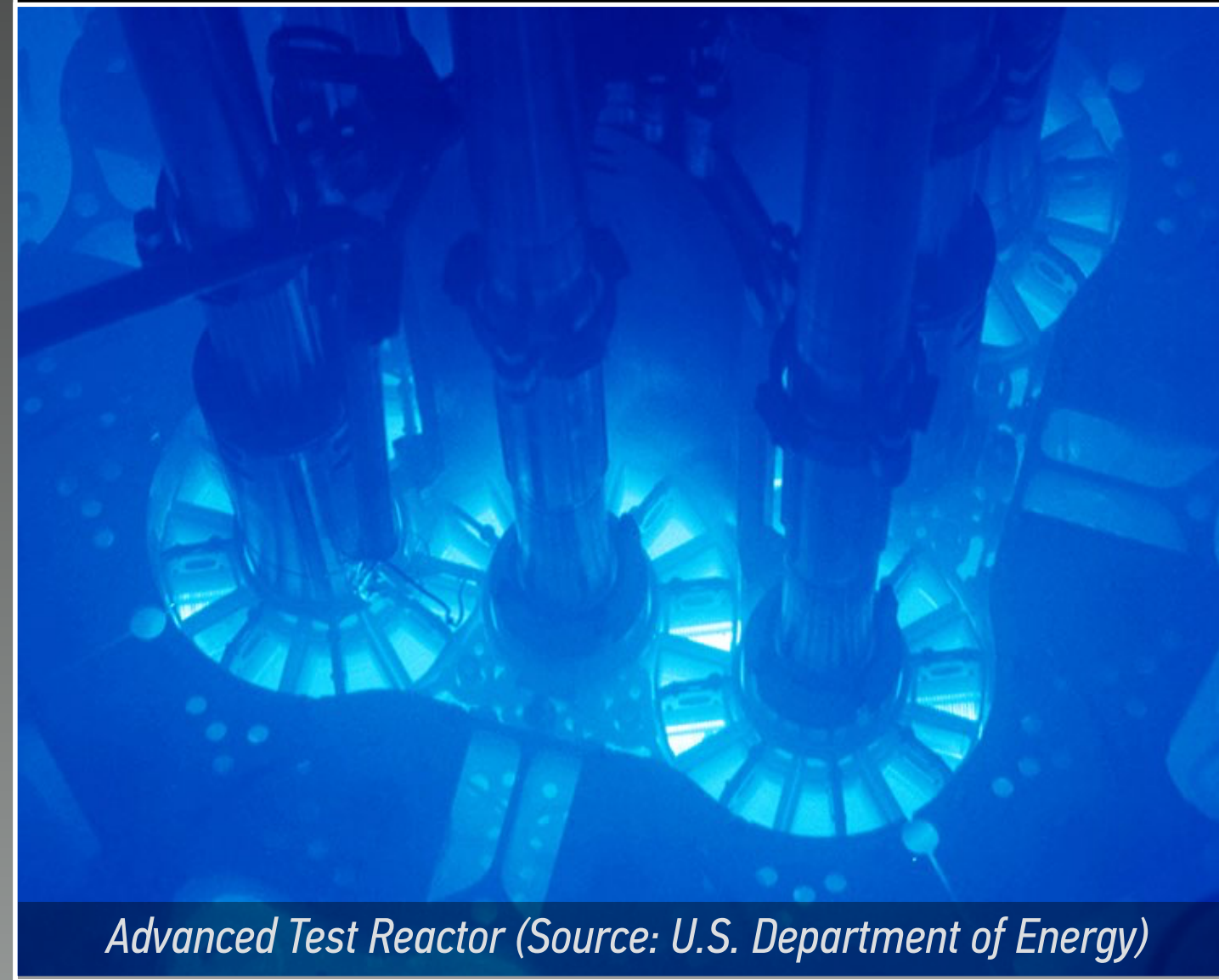


Plutonium ring (Source: Los Alamos National Laboratory)

REACTOR CONVERSION

2000s

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

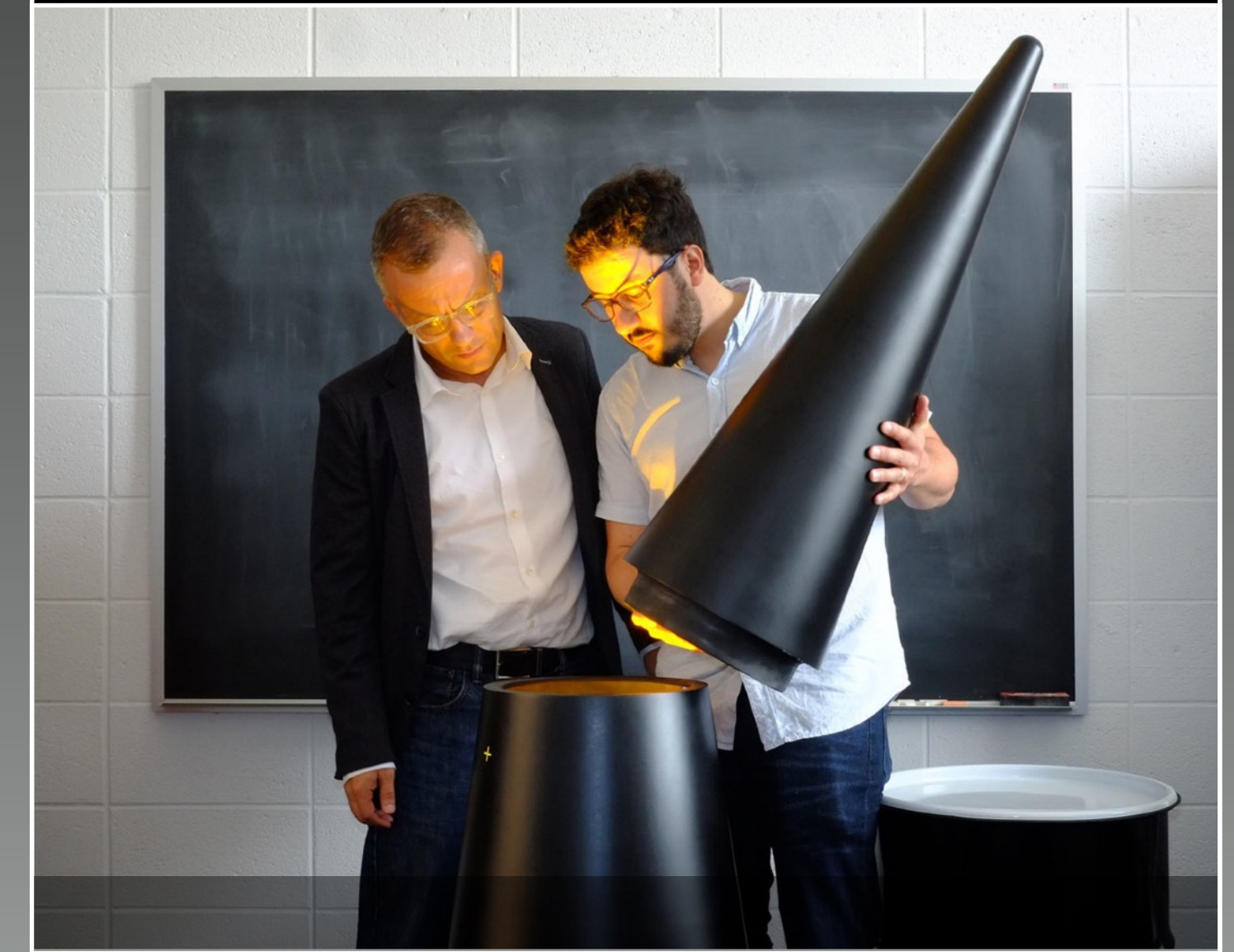


Advanced Test Reactor (Source: U.S. Department of Energy)

WARHEAD VERIFICATION

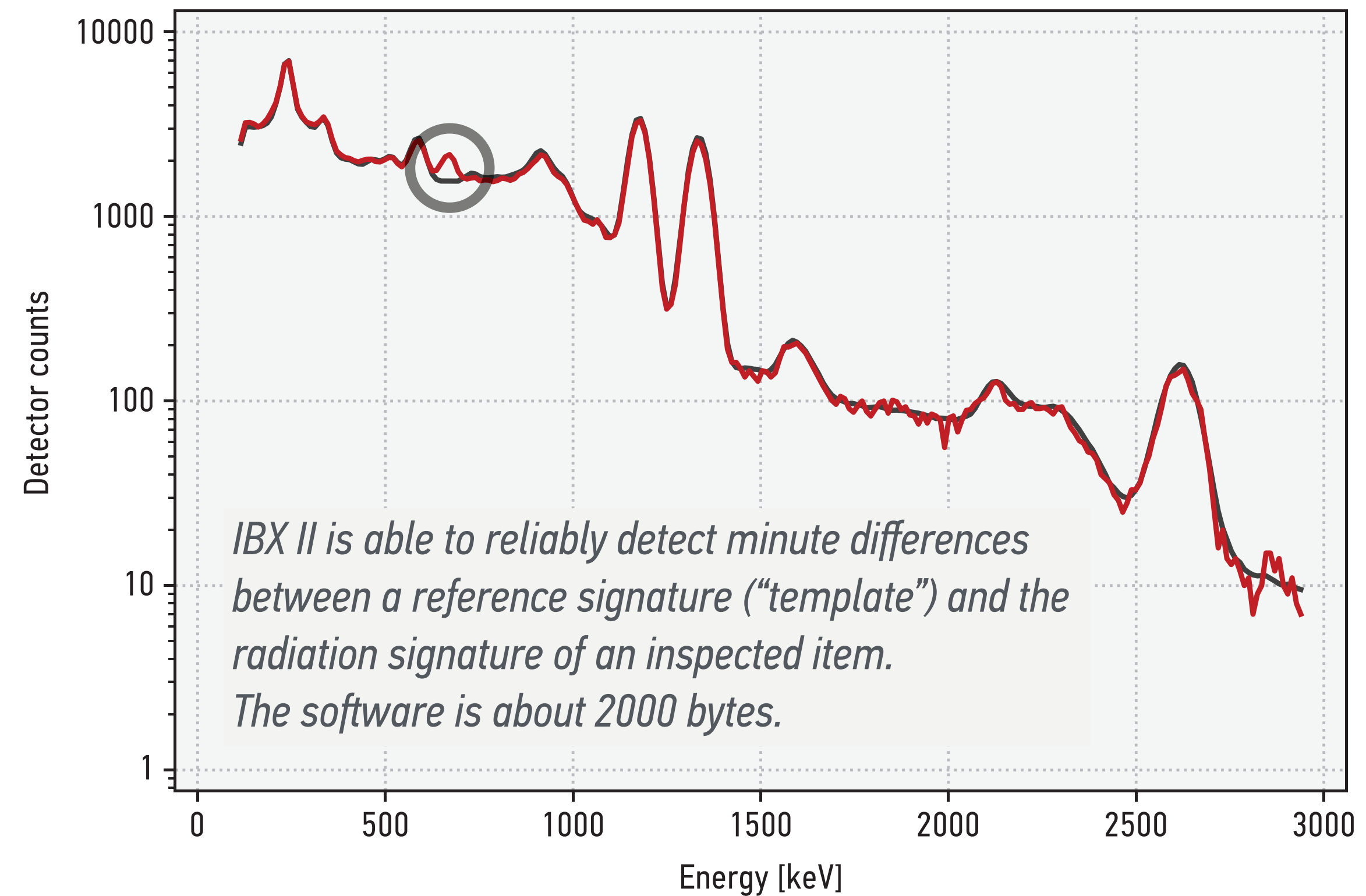
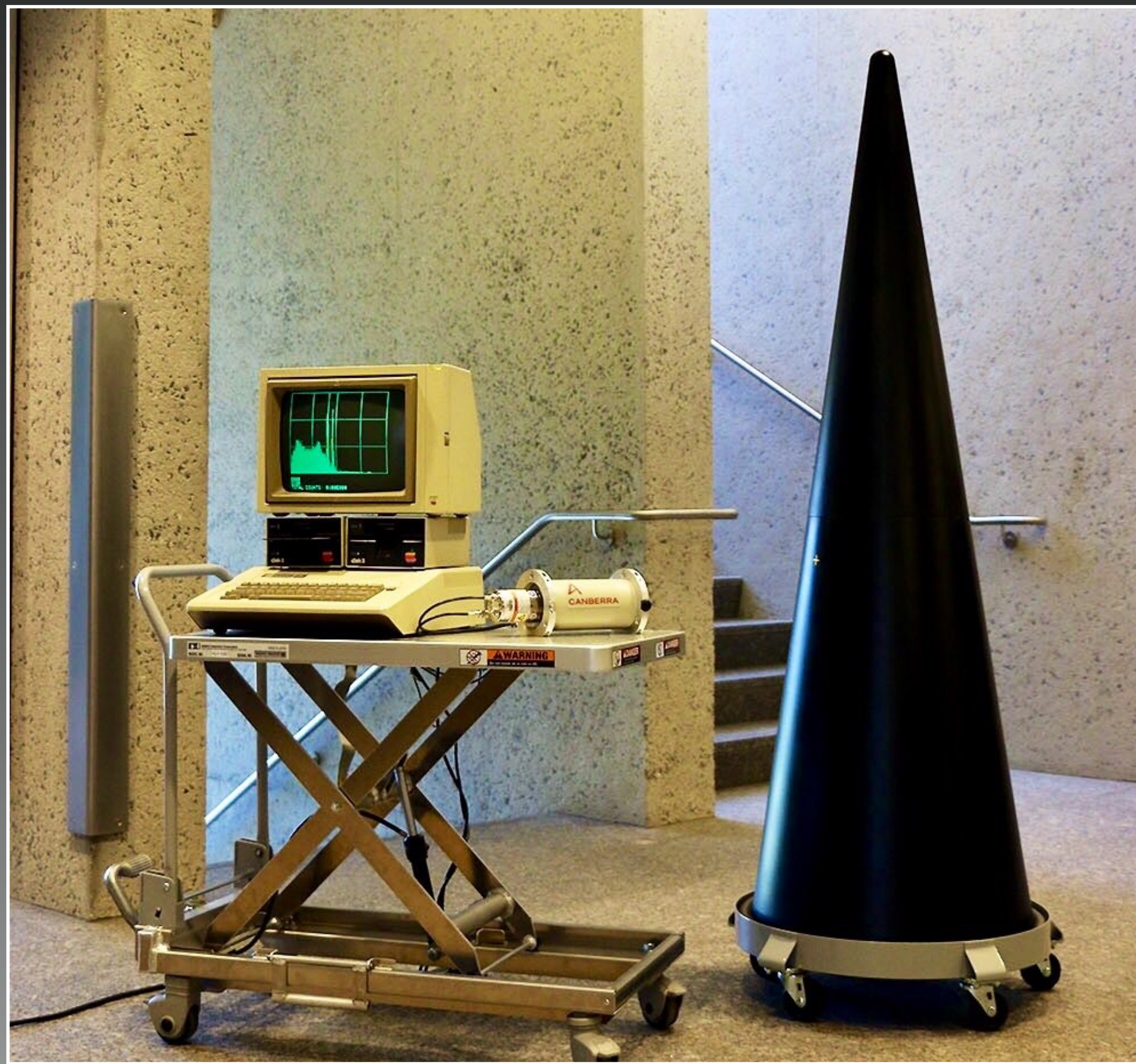
2010s

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



INFORMATION BARRIER EXPERIMENTAL II

“TRUST THROUGH SIMPLICITY AND OBSOLESCENCE”

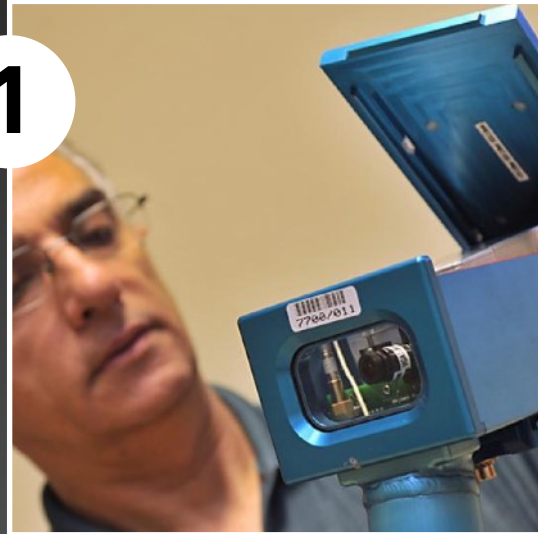


M. Kütt and A. Glaser, “Vintage Electronics for Trusted Radiation Measurements and Verified Dismantlement of Nuclear Weapons,” *PLOS ONE*, October 30, 2019

AREAS OF INTEREST FOR A RESEARCH AGENDA

SUPPORTING NUCLEAR ARMS CONTROL AND NONPROLIFERATION

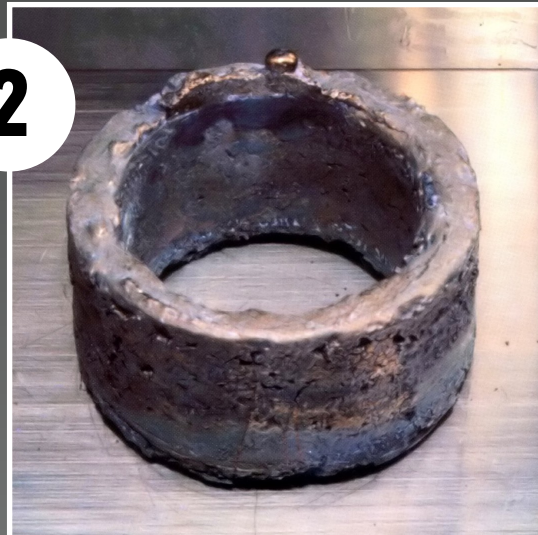
1



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



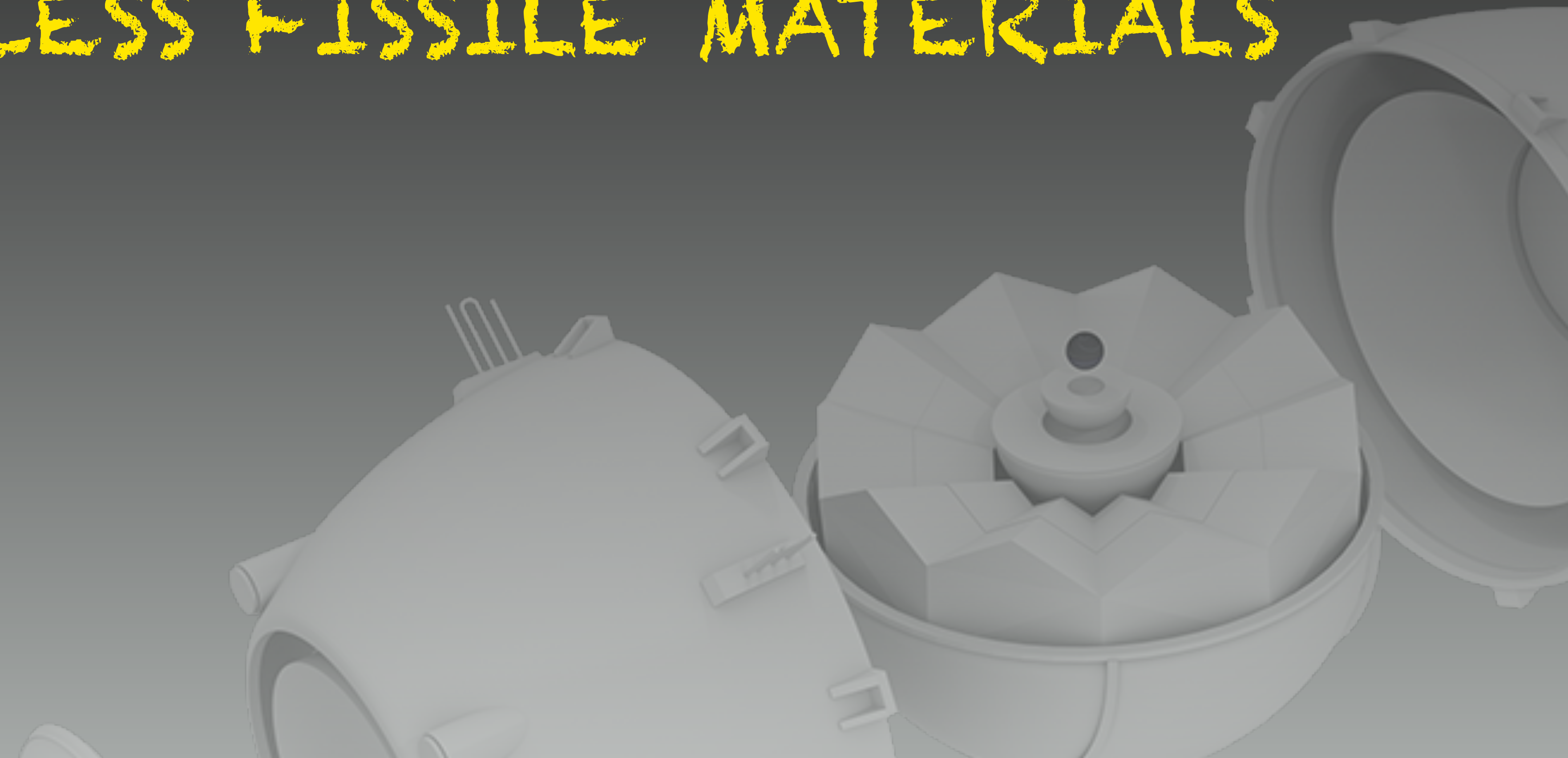
KNOWING WHAT'S THERE: NUCLEAR ARCHAEOLOGY

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

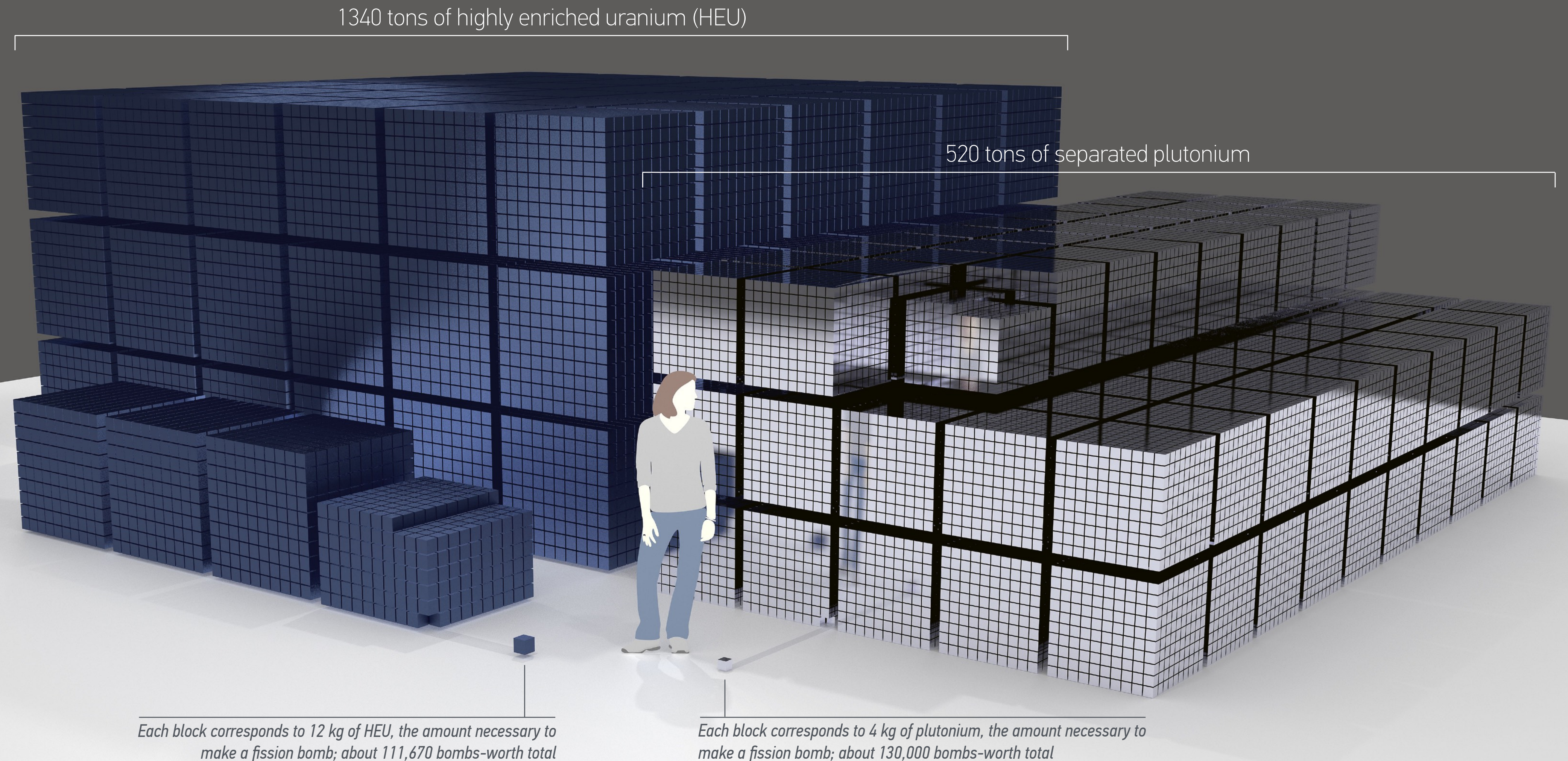
Source: International Atomic Energy Agency (top), Los Alamos National Laboratory (middle), www.francetnp.gouv.fr (bottom)

CAPPING THE REBOUND

DEVELOPING DISPOSITION OPTIONS FOR EXCESS FISSILE MATERIALS



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



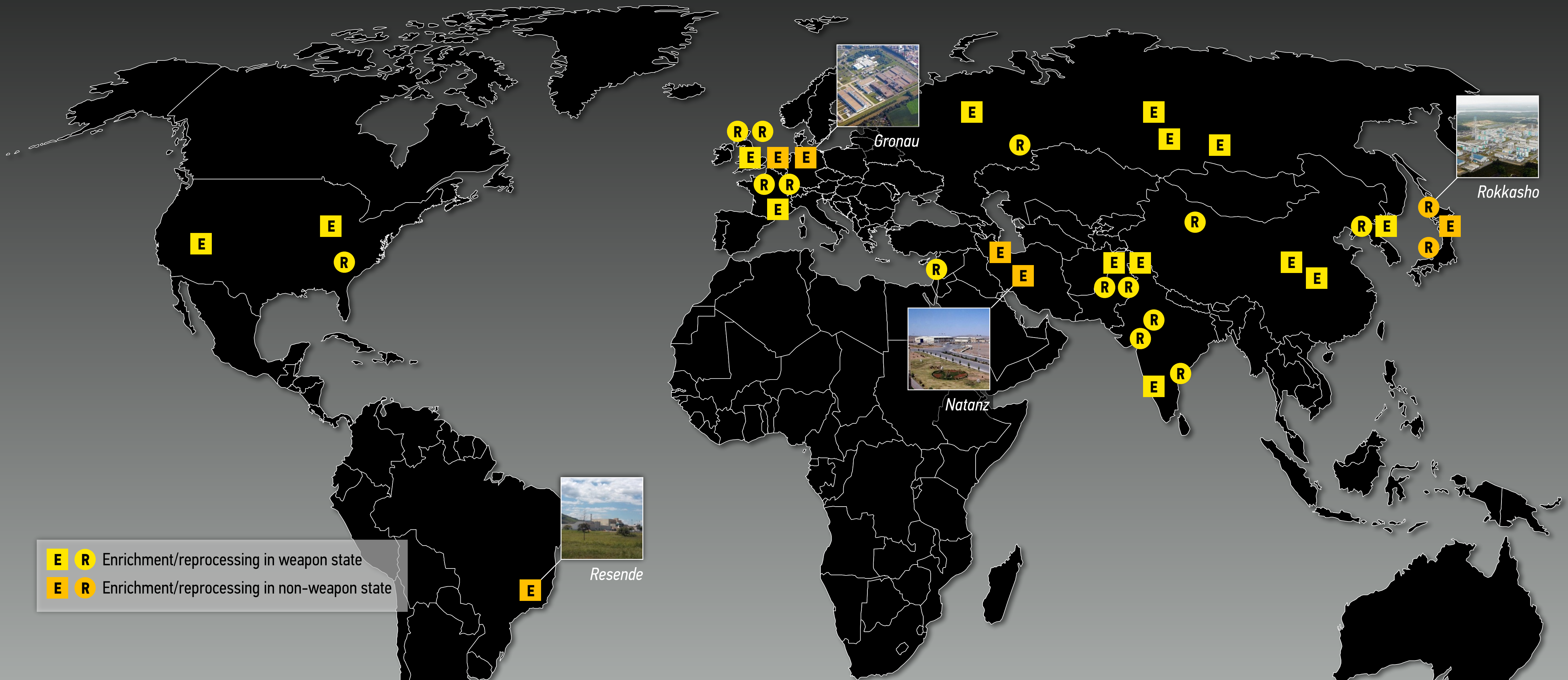
A LARGE FRACTION OF THE WORLD'S FISSILE MATERIAL STOCKPILE IS EXCESS

THE CASE OF PLUTONIUM



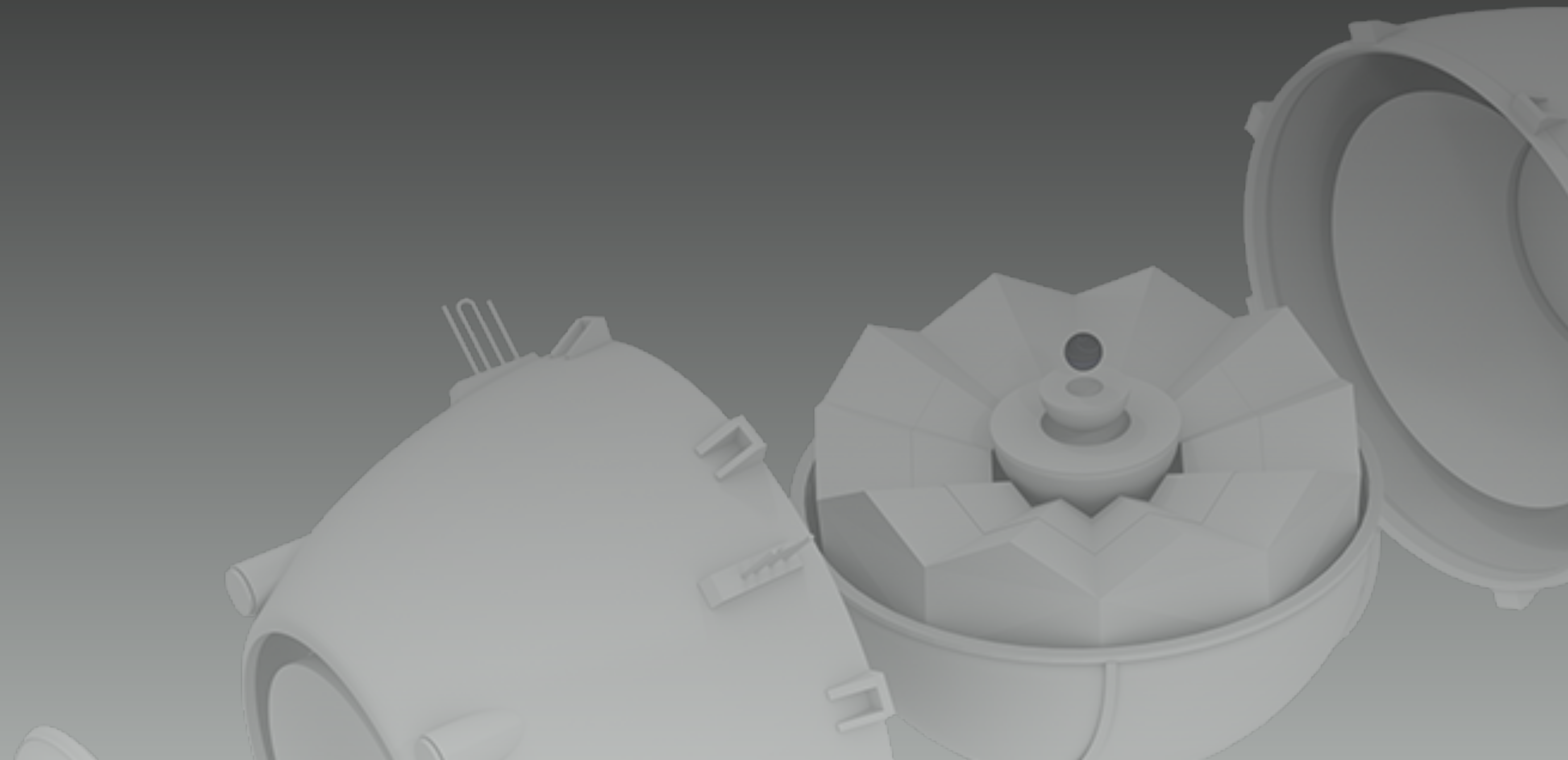
WHO CAN MAKE FISSILE MATERIALS TODAY?

ENRICHMENT AND REPROCESSING FACILITIES WORLDWIDE



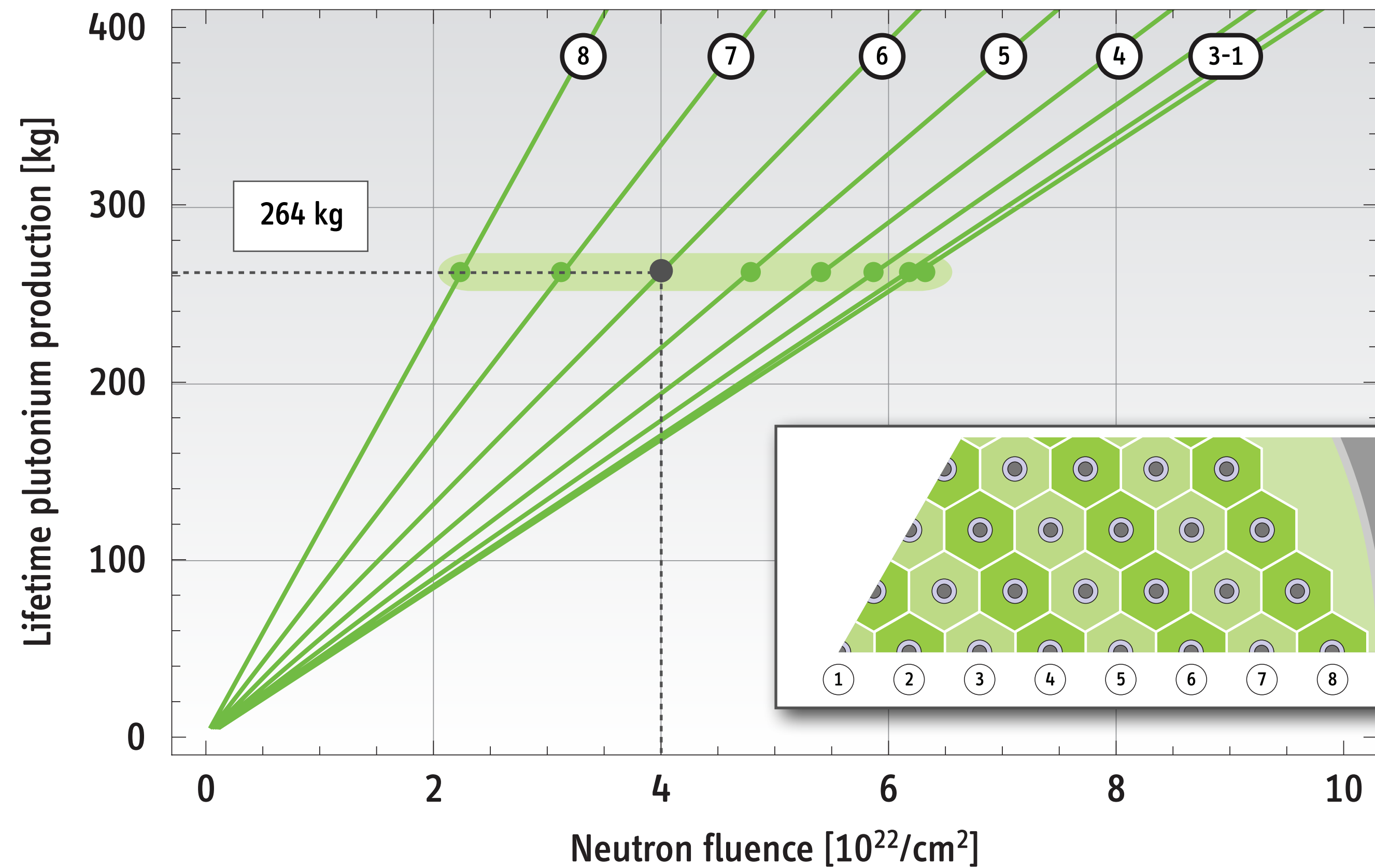
KNOWING WHAT'S THERE

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



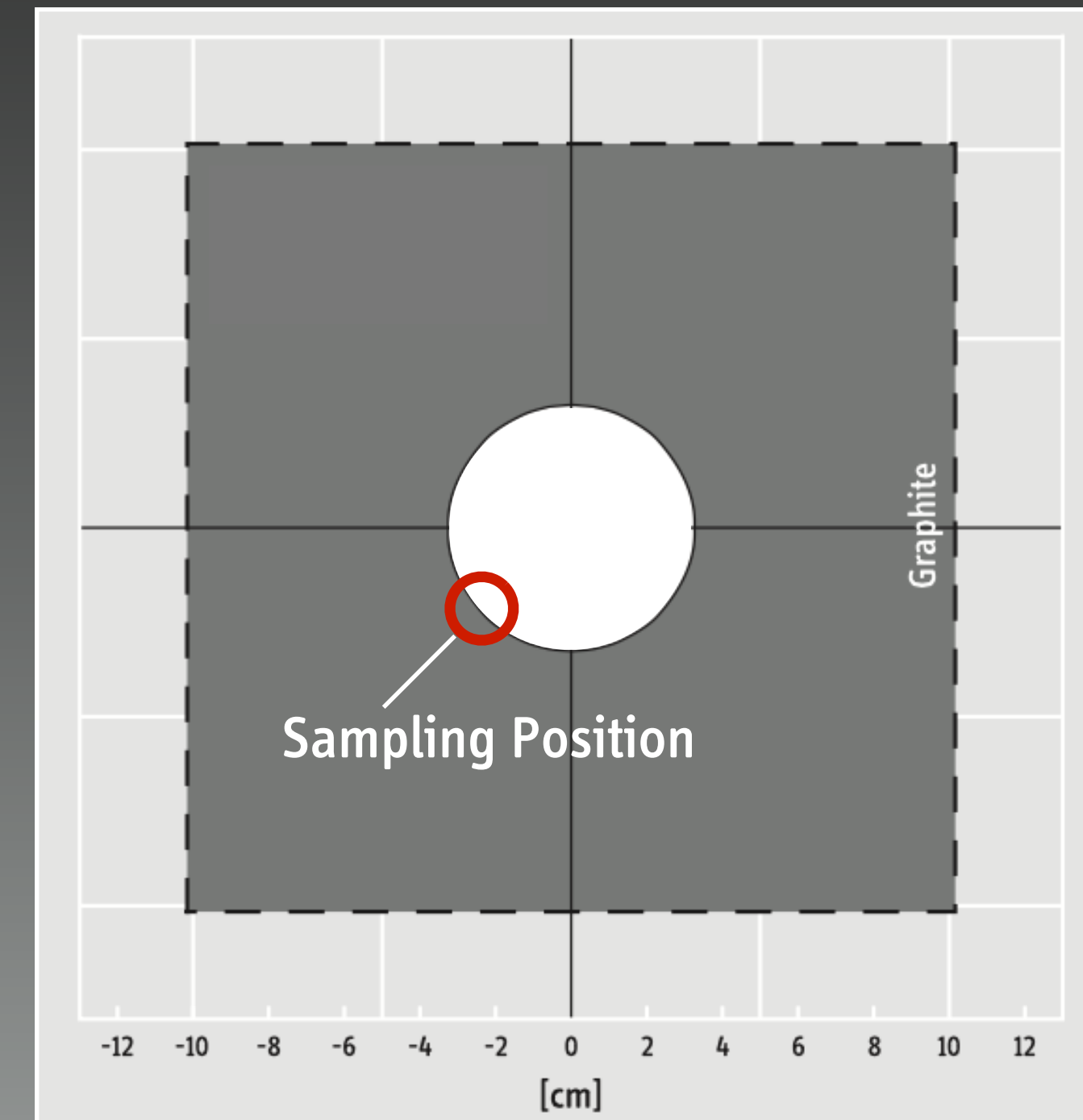
A. Gasner and A. Glaser, "Nuclear Archaeology for Heavy-Water-Moderated Plutonium Production Reactors," *Science & Global Security*, 19, 2011

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

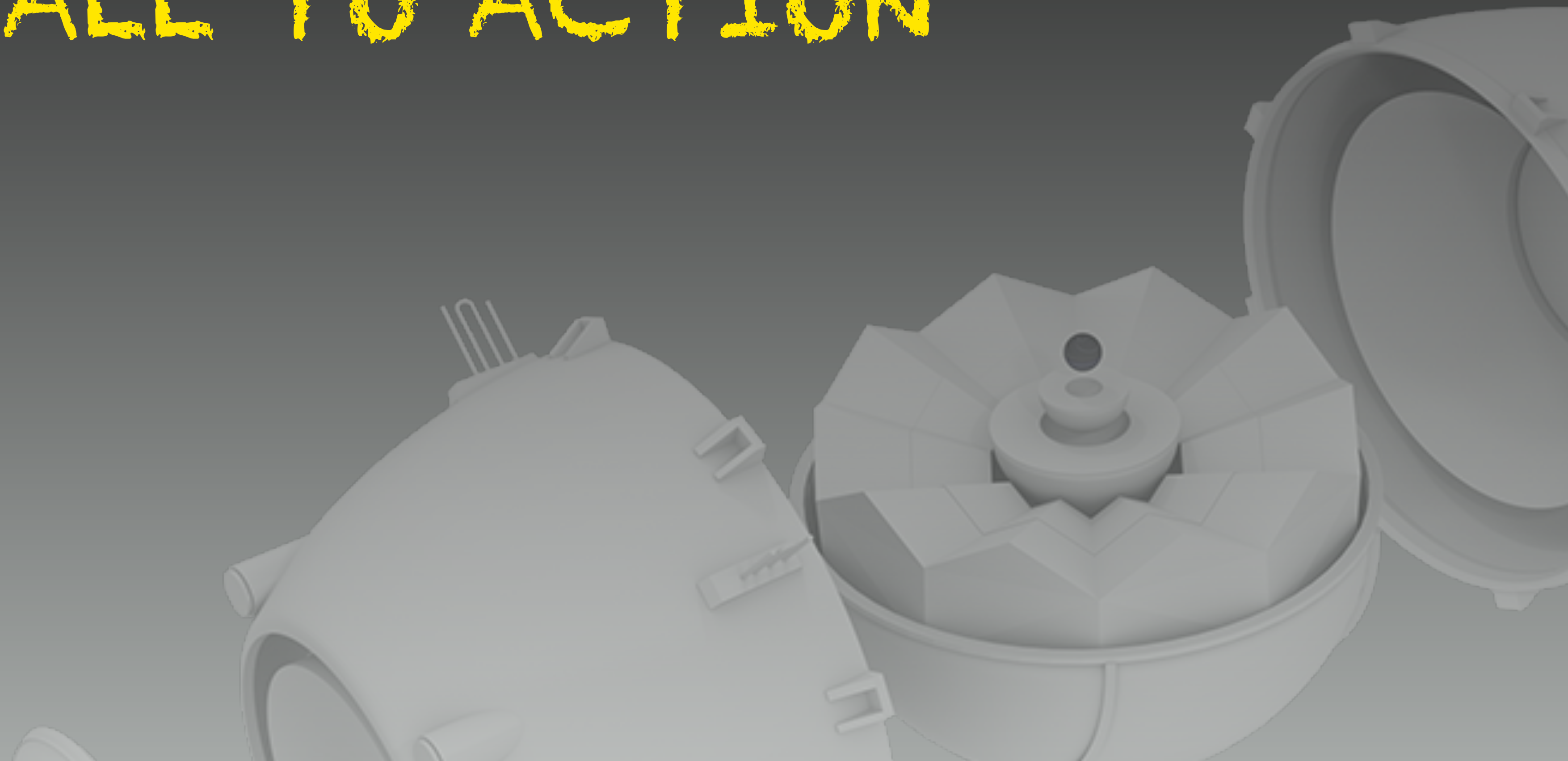


Unit cell of the DPRK Yongbyon reactor



*North Korea's Uranium Mine at Pyongsan
Coordinates: 38.324, 126.437
Source: Google*

CALL TO ACTION



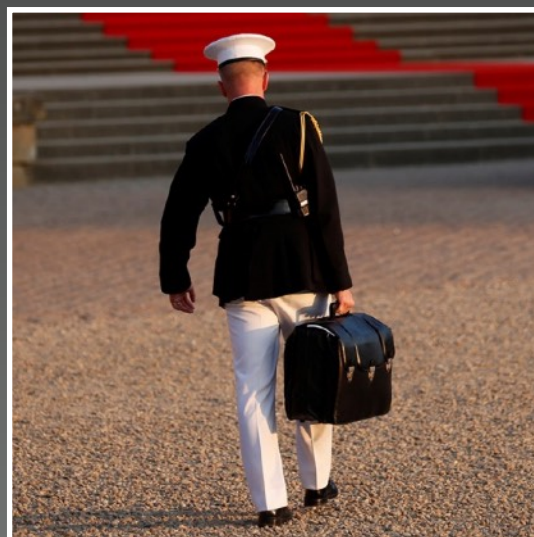
WHAT'S ON THE POLICY MAKERS' AGENDA

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!