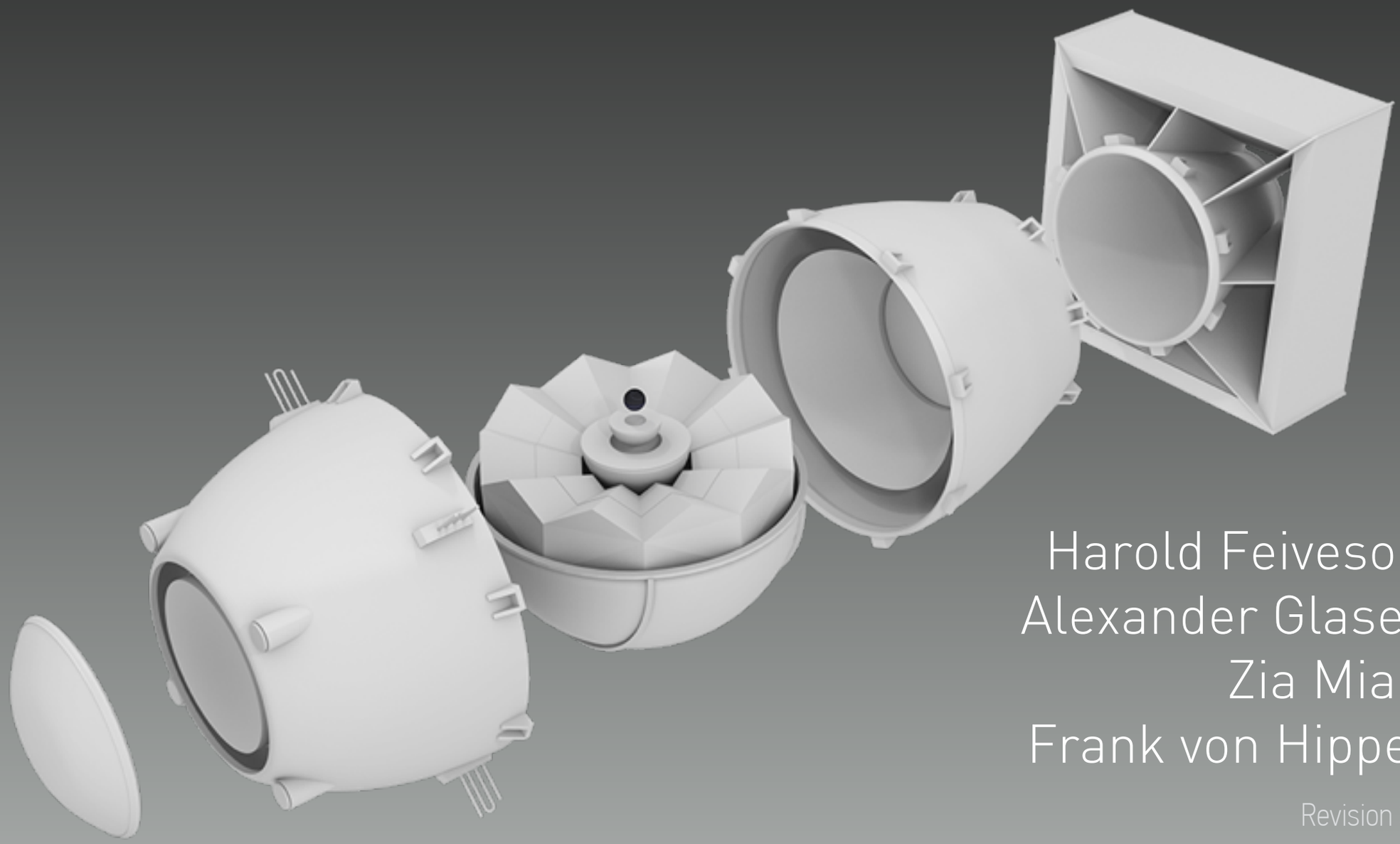
UNMAKING THE BOMB

A FISSILE MATERIAL APPROACH TO NUCLEAR DISARMAMENT AND NONPROLIFERATION



Harold Feiveson
Alexander Glaser
Zia Mian
Frank von Hippel

Revision 3e

PART 1

HOW THE NUCLEAR WORLD EMERGED

EVERYTHING BEGINS WITH URANIUM

Open pit uranium mine, Namibia
Source: www.wikipedia.org, Ikiwaner

Uranium ore (carnotite)
Source: www.mikalac.com

MAKING FISSILE MATERIALS

A TALE OF TWO URANIUM ISOTOPES

HIGHLY ENRICHED URANIUM (TYPICALLY: 90% U-235)

Made by isotope separation using, for example, gas centrifuges

Used in a simple gun-type assembly in Hiroshima bomb (50–60 kg)

A special concern for nuclear terrorism (“improvised nuclear device”)

PLUTONIUM (ALMOST ANY COMPOSITION, MADE FROM U-238)

Made from U-238 in a nuclear reactor and separated from spent fuel

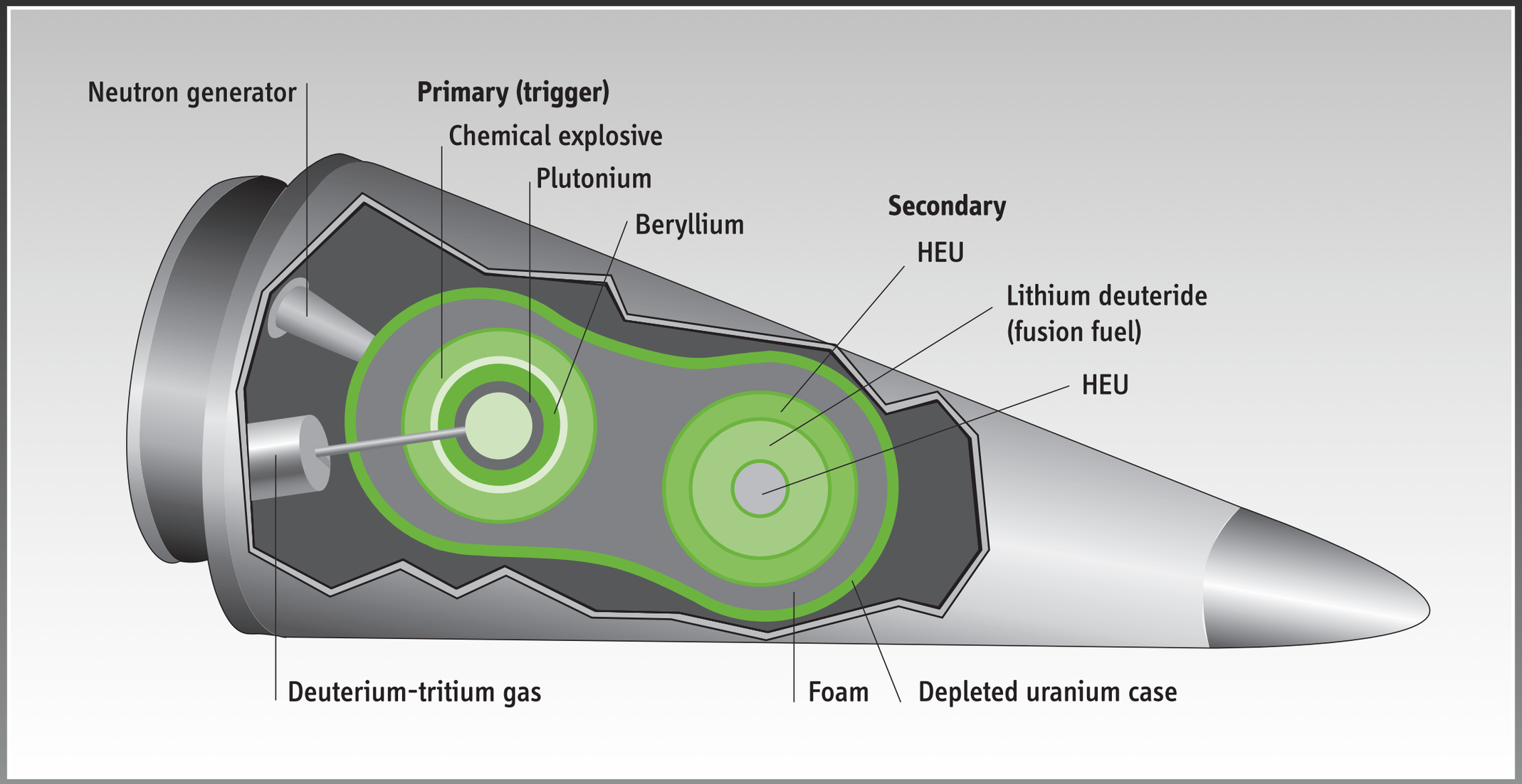
Used in implosion assembly in Nagasaki bomb (6 kg)

Small critical mass, preferred in modern fission primaries

Sources: www.usec.com, www.centrusenergy.com (top) and commons.wikimedia.org, user: Nanking2012 (bottom)

MODERN THERMONUCLEAR WARHEAD

Typically contains an average 3–4 kg of plutonium and 15–25 kg highly enriched uranium



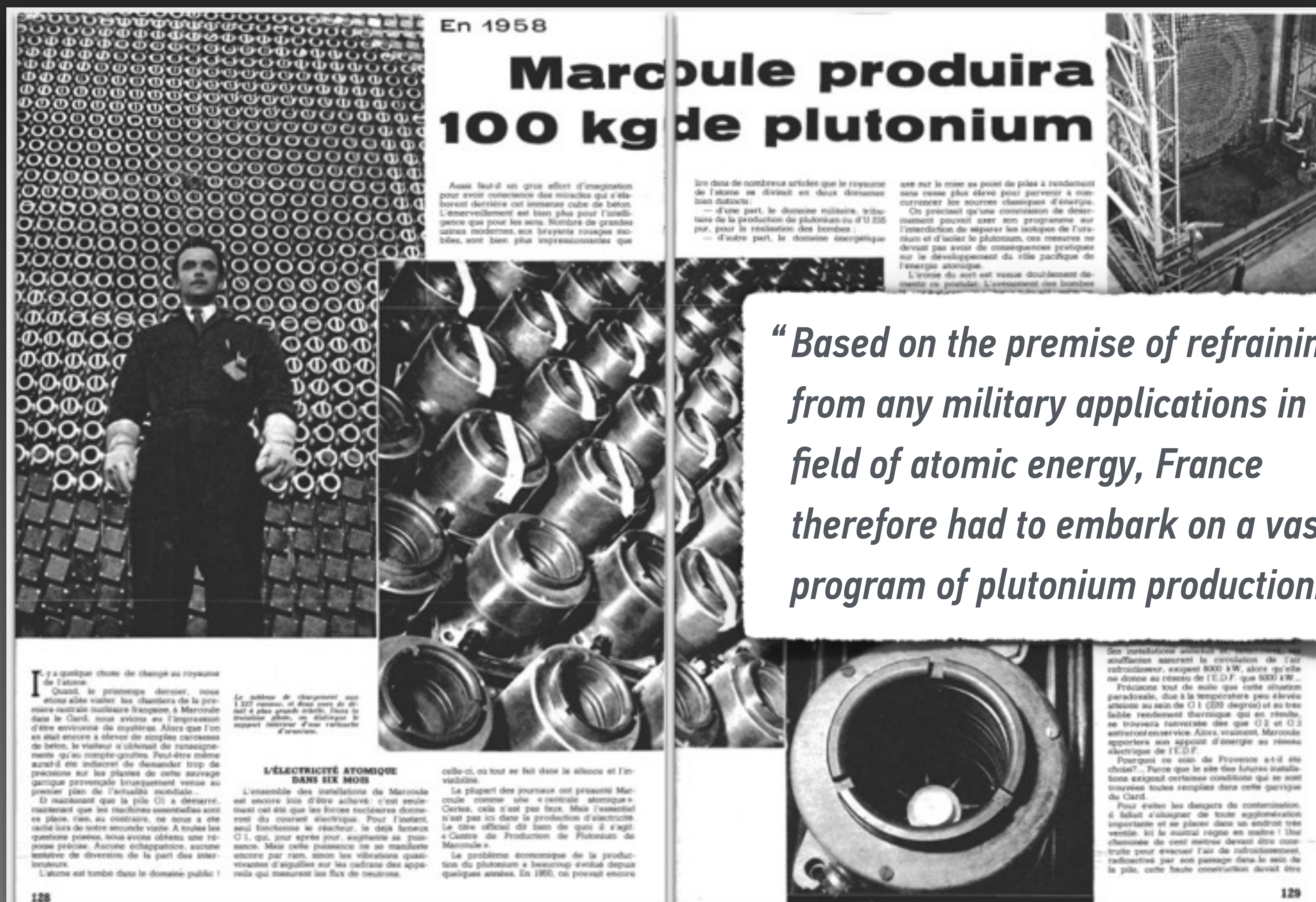
Adapted from Final Report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the Peoples Republic of China ("Cox Report"), U.S. House of Representatives, 3 January 1999

FRANCE

AMBIGUITY BY DESIGN

HIDING IN PLAIN SIGHT

EARLY PLUTONIUM PRODUCTION FOR “PEACEFUL PURPOSES”



> *“Based on the premise of refraining from any military applications in the field of atomic energy, France therefore had to embark on a vast program of plutonium production.”*

Sciences et Avenir, March 1956

FRANCE

HOW MUCH FISSILE MATERIAL IS ENOUGH?

FRANCE HAS FEWER THAN 300 NUCLEAR WEAPONS TODAY

The amount of fissile material in this weapons stockpile

is on the order of 1–1.5 tons of plutonium and 3–5 tons of HEU

FRANCE HAS MATERIAL FOR 1000+ NUCLEAR WEAPONS

Based on our estimates, on the order of 70–80% of the military plutonium and HEU are outside the weapons stockpile (and without apparent military use)

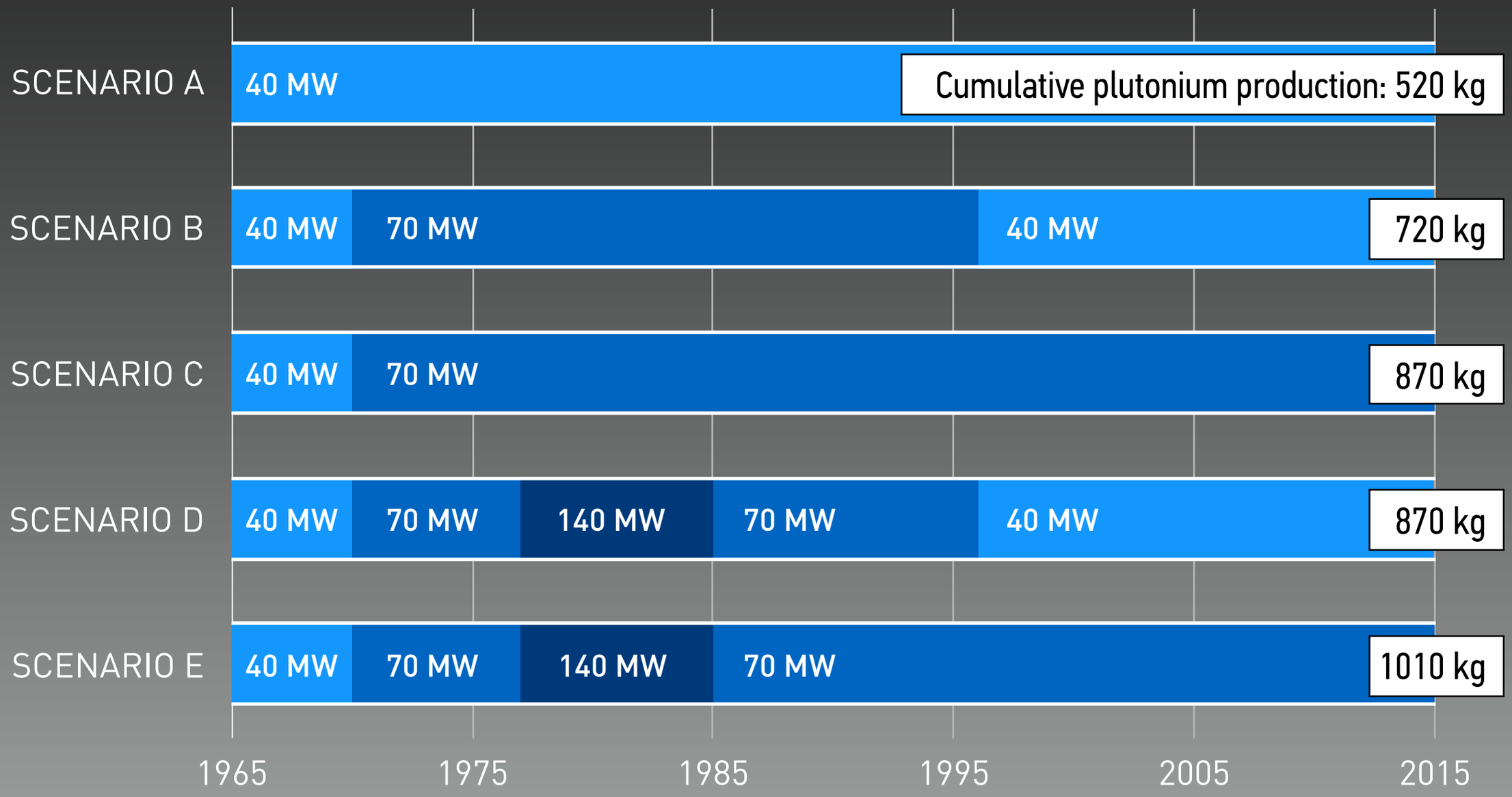
Sources: www.defense.gouv.fr (top) and www.francetnp.fr (bottom)

ISRAEL

A TURNKEY FISSILE MATERIAL PRODUCTION COMPLEX

DIMONA REACTOR, 1964–2014

POSSIBLE OPERATIONAL HISTORIES AND CUMULATIVE PLUTONIUM PRODUCTION



MORE THAN EVER EXPECTED?

50 YEARS OF PLUTONIUM PRODUCTION AT DIMONA, 1964–2014

ISRAEL HAS AVAILABLE A LARGE PLUTONIUM STOCKPILE

Estimated inventory on the order of 850 kg ± 130 kg

with a current production rate of 10–18 kg/year, depending on power level of Dimona (40–70 MW thermal)

PLUTONIUM MOST LIKELY A "BYPRODUCT" TODAY

Israel's arsenal is believed to include 100–150 warheads; if our estimates are correct, Israel has plutonium for 2–3 times as many warheads (and could cease fissile material production)

Sources: authors' archives (top) and Channel 10 (bottom)

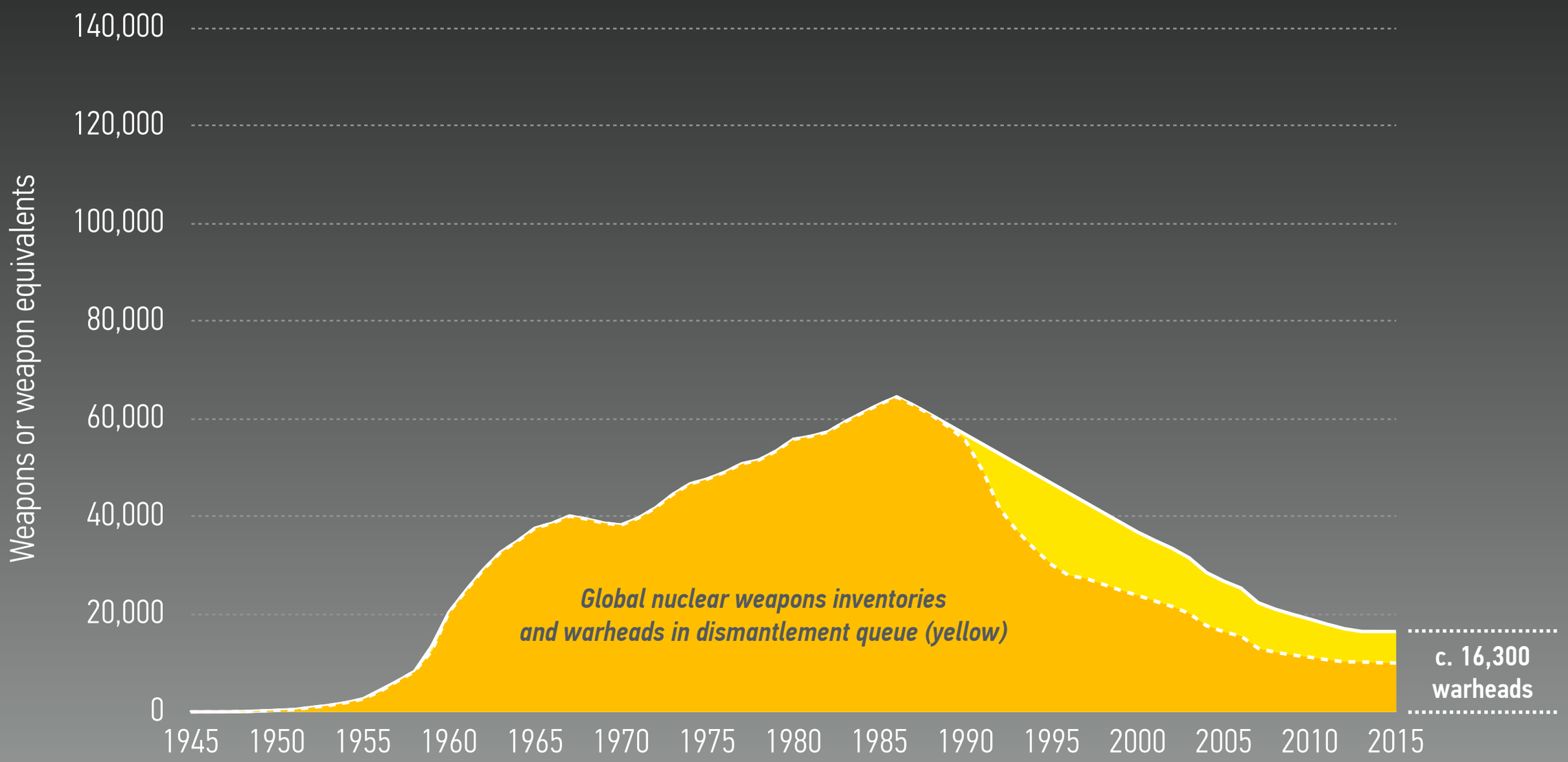
SO, WHERE ARE WE NOW?

WHO CAN MAKE FISSILE MATERIAL TODAY

ENRICHMENT AND REPROCESSING FACILITIES WORLDWIDE

NUCLEAR WEAPONS AND FISSILE MATERIALS

GLOBAL INVENTORIES, 1945–2014

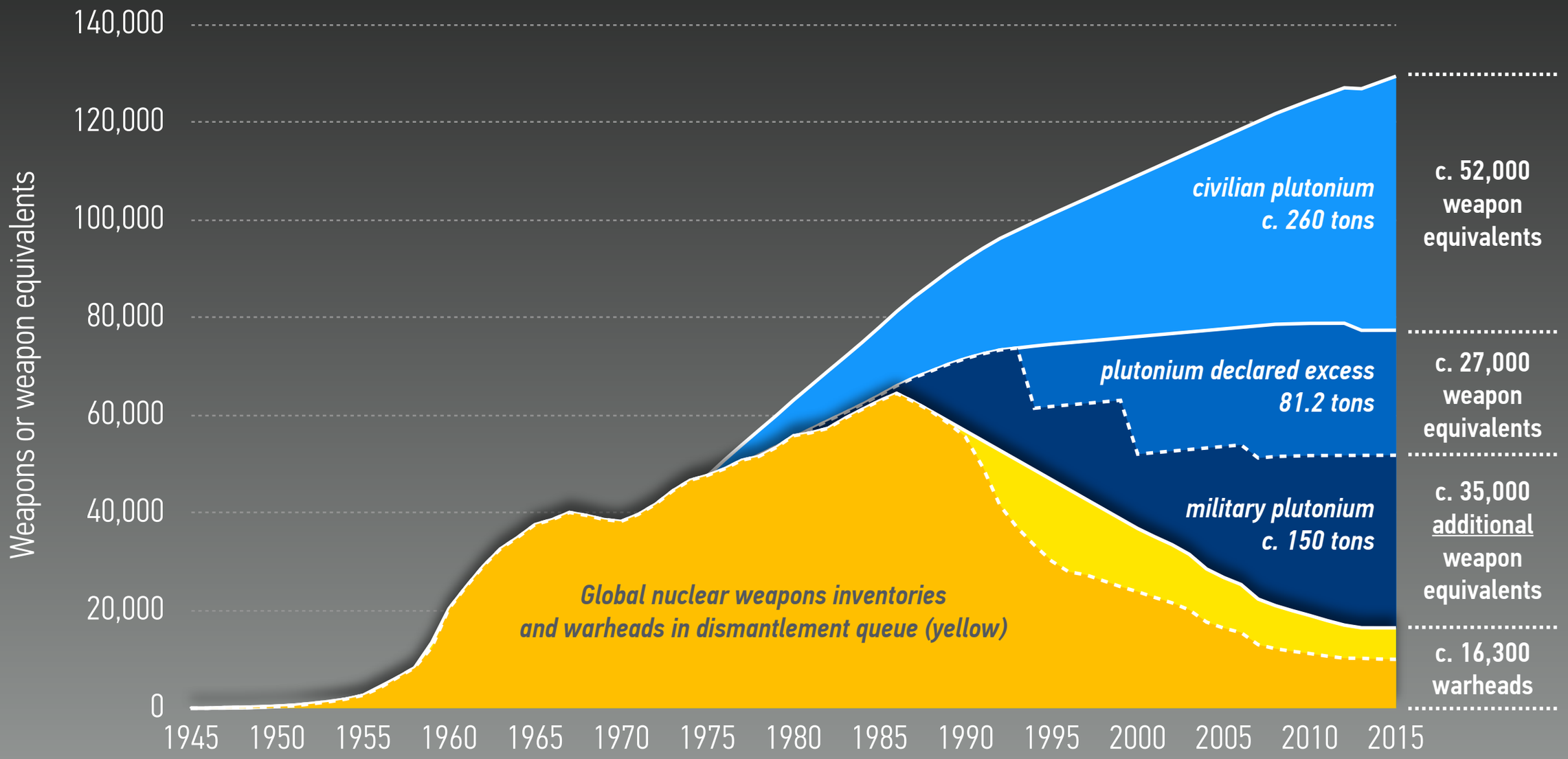


Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," *Bulletin of the Atomic Scientists,* 69 (5), 2013, 75–81

NUCLEAR WEAPONS AND FISSILE MATERIALS

GLOBAL INVENTORIES, 1945–2014

THE CASE OF SEPARATED PLUTONIUM



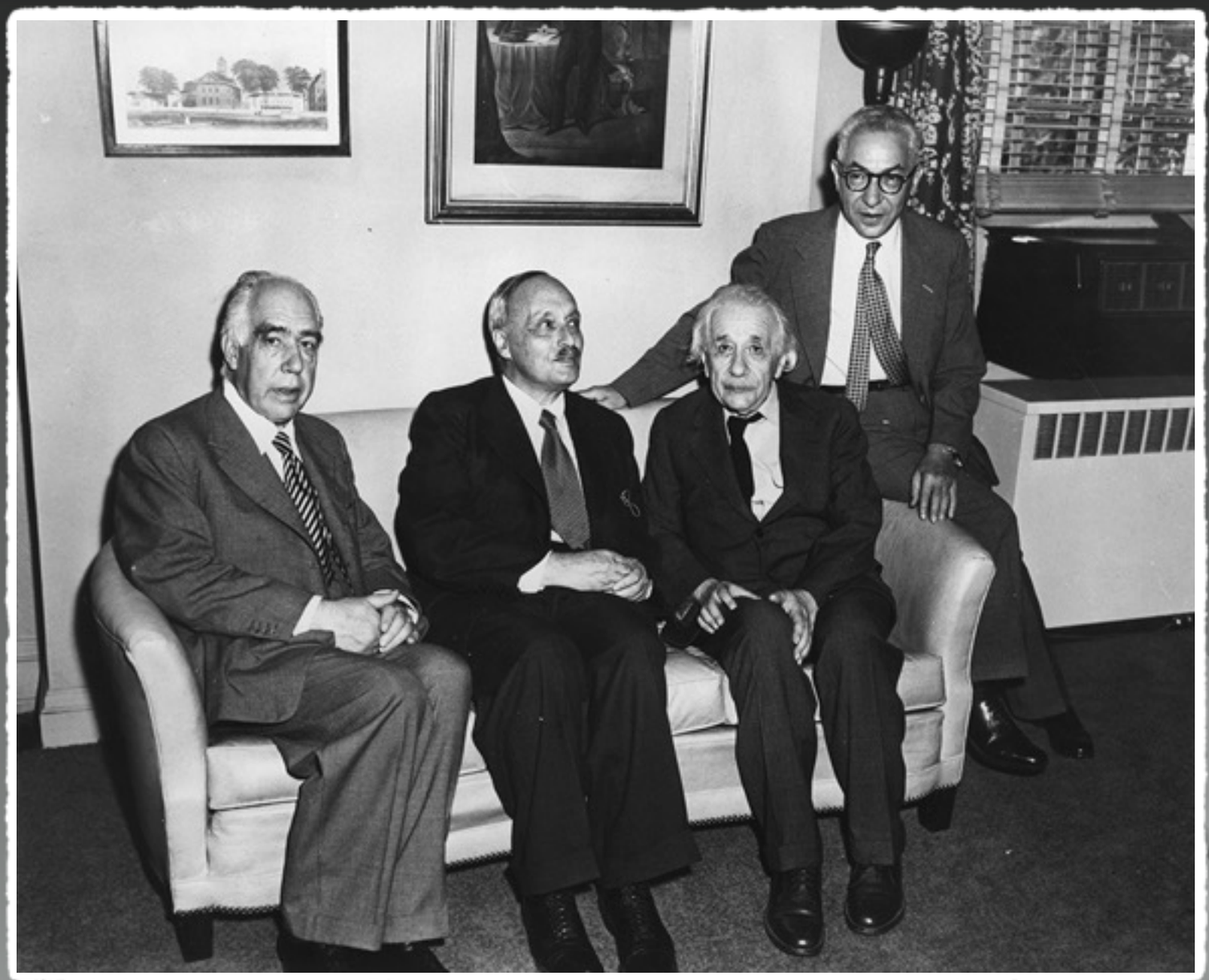
Hans M. Kristensen and Robert S. Norris, "Global Nuclear Weapons Inventories, 1945–2013," *Bulletin of the Atomic Scientists,* 69 (5), 2013, 75–81
Fissile material estimates and weapon-equivalents are authors' estimates; assuming an average of 3 kg for weapon-grade and 5 kg for reactor-grade plutonium per weapon

PART 2

WHAT IS TO BE DONE

“A PERPETUAL MENACE TO HUMANKIND”

FOR 70 YEARS SCIENTISTS HAVE WARNED OF THE FISSILE MATERIAL DANGER

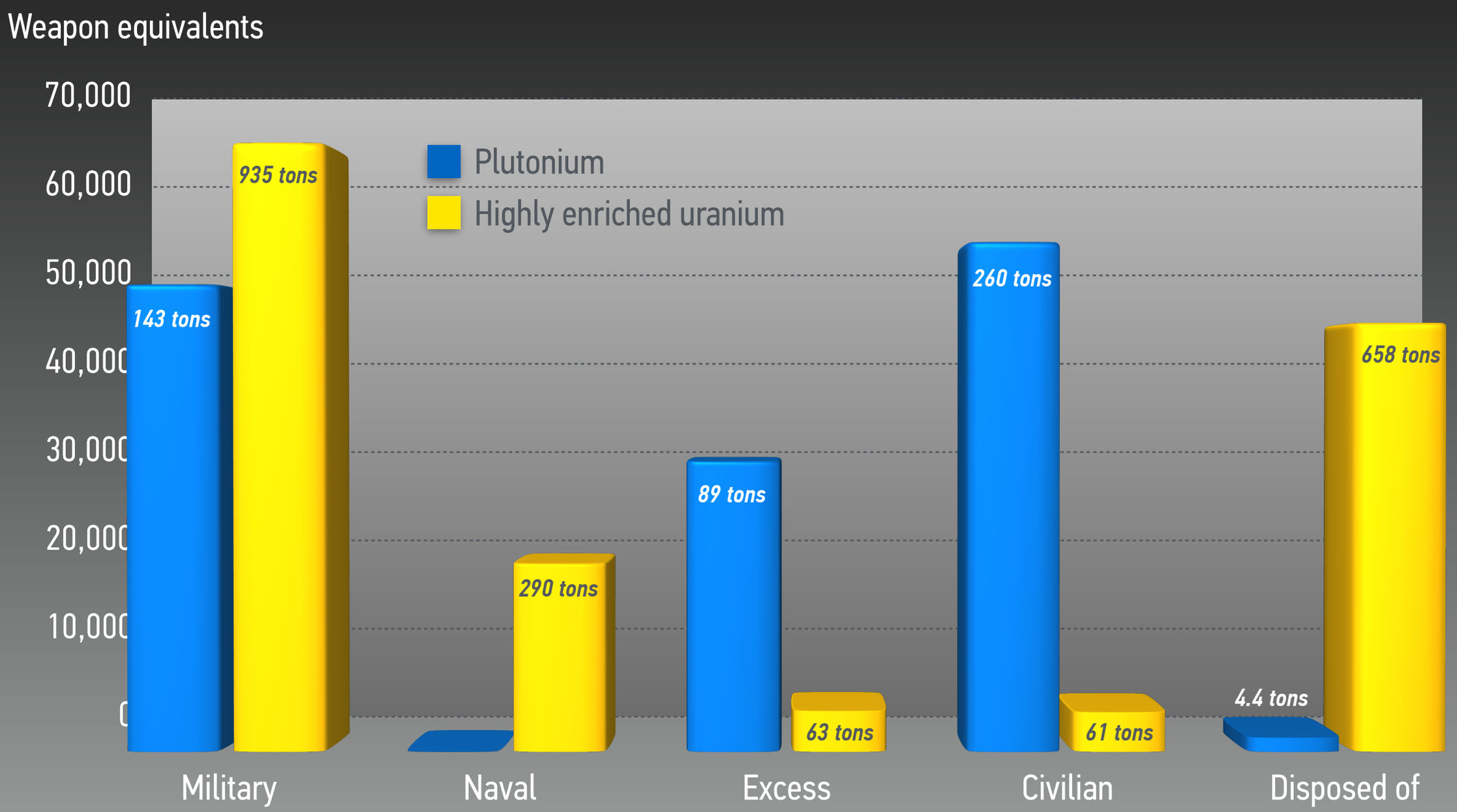


Niels Bohr
James Franck
Albert Einstein
Isidor Rabi

Princeton, NJ
October 1954

FISSILE MATERIALS BY CATEGORY

GLOBAL STOCKPILE OF PLUTONIUM AND HIGHLY ENRICHED URANIUM, 2014



Assumptions for weapon equivalents: 3 kg of weapon-grade plutonium, 5 kg of reactor-grade plutonium, 15 kg of highly enriched uranium

ENDING PRODUCTION AND USE

FISSILE MATERIAL PRODUCTION FOR WEAPONS HAS LARGELY ENDED

(NPT WEAPON STATES STOPPED DECADES AGO)

Shutdown of the last Russian plutonium production reactor ADE-2 in Zheleznogorsk, 2010
Source: U.S. Department of Energy

Demolition of the K-25 uranium enrichment plant began in December 2008 and has been completed in 2012
Source: Bechtel Jacobs

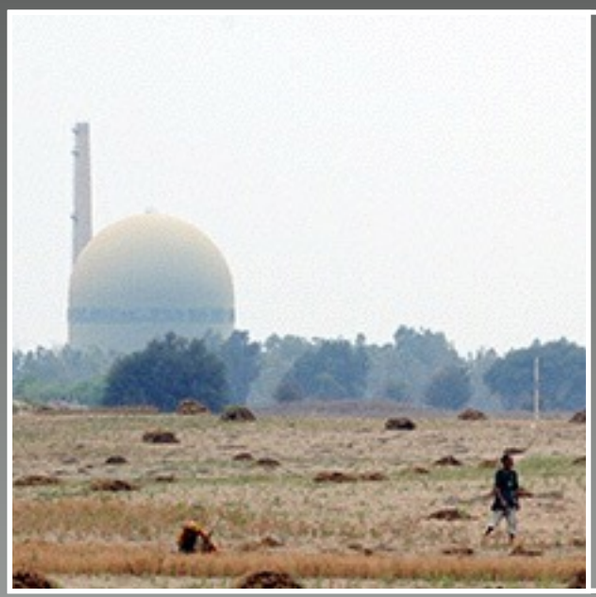
ENDING PRODUCTION

FOR MILITARY AND CIVILIAN PURPOSES

CONTINUING PRODUCTION OF HEU

For military use: Pakistan, India, and possibly North Korea

For civilian use: Russia, reportedly restarted in 2012 (for export)



CONTINUING PRODUCTION (AND SEPARATION) OF PLUTONIUM

For military use: Israel, India, Pakistan, and North Korea

For civilian use: France, Russia, India, (China, Japan)

United Kingdom will end reprocessing around 2020

Sources: U.S. DOE (top) and Getty Images (bottom)

ENDING USE

FOR MILITARY AND CIVILIAN PURPOSES

HEU REACTOR FUEL

US, UK, Russia, India; US has over half of all HEU naval reactors;

Russia has over half of all HEU research reactors; over 125 HEU

research reactors already retired (twice the number converted to LEU)

PLUTONIUM FUEL

France, Germany, the Netherlands, India, (and Japan) use MOX fuel

for power reactors; Russia and China plan to do so;

most countries store their nuclear spent fuel pending final disposal

Sources: U.S. Navy (top) and UK Decommissioning Authority (bottom)

ELIMINATING STOCKPILES

VULNERABILITY OF STORAGE

A MATTER OF TIME

STORING UP TROUBLE

About 100 tons of HEU at U.S. HEUMF, Y-12, Oak Ridge, Tennessee

About 245 tons of civilian plutonium stored at four sites in Europe and Russia (Sellafield, La Hague, Marcoule, Mayak)

JULY 2012 Y-12 BREAK-IN

U.S. DOE finding: “ineptitude in responding to alarms, failures to maintain critical security equipment, over reliance on compensatory measures, misunderstanding of security protocols, poor communications”

Sources: U.S. DOE (top) and oakridgetoday.com (bottom)

DISPOSAL STRATEGIES

IRREVERSIBILITY, SECURITY, COST, INTERNATIONAL VERIFIABILITY

DRY CASK STORAGE OF SPENT FUEL

Most countries with nuclear power store their spent fuel pending final disposal in geological repository;

HEU reactor spent fuel also can be stored for such disposal

DEEP BOREHOLE DISPOSAL OF PLUTONIUM

Excess plutonium could be irreversibly emplaced in several kilometer-deep boreholes; holes are then backfilled and sealed;

several tons of plutonium could be disposed in a single borehole

Sources: gns.de (top) and panoramio.com, user: loisiko (bottom)

TRANSPARENCY AND VERIFICATION

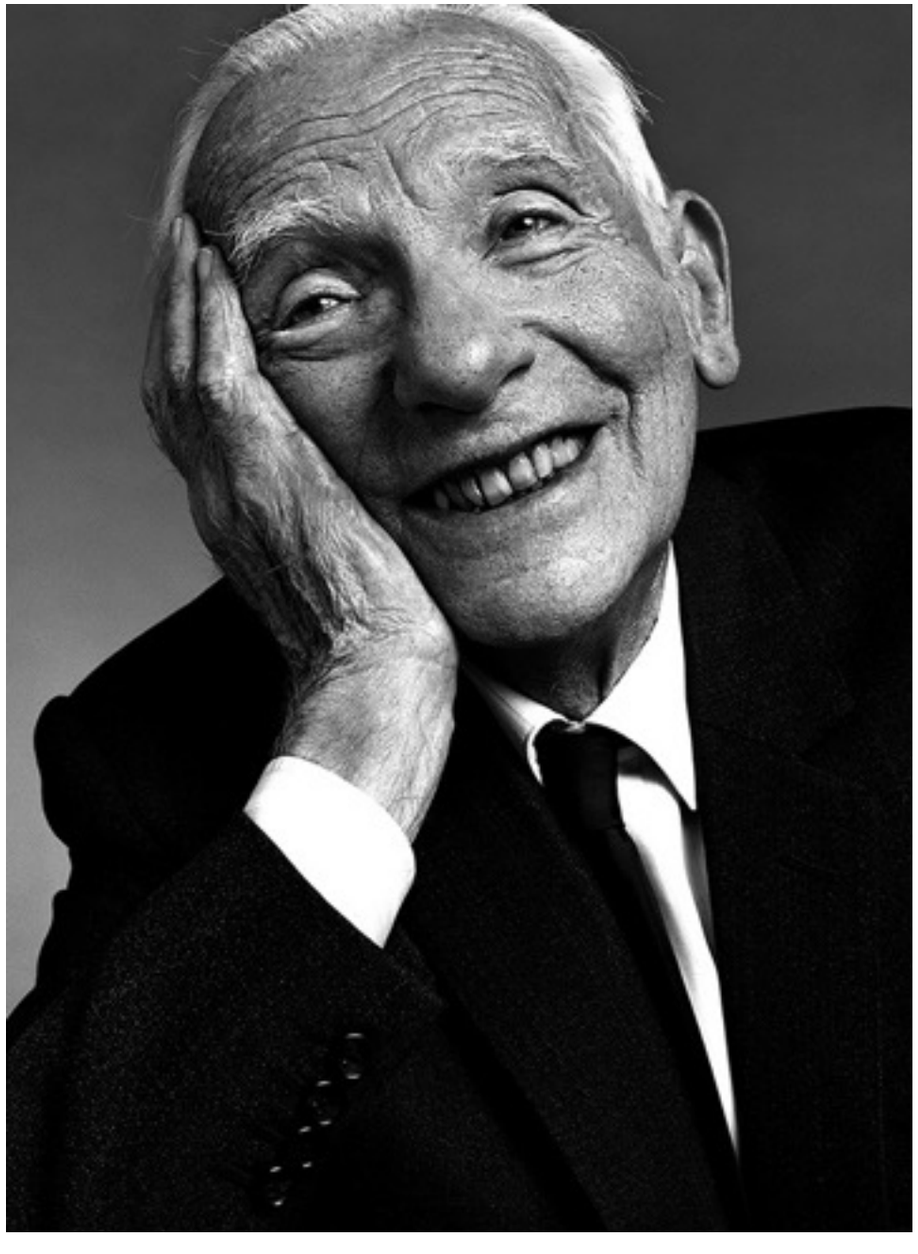
TRANSPARENCY SCORECARD, 2014

INFORMATION ON NUCLEAR WARHEAD AND FISSILE MATERIAL INVENTORIES AND STATUS

	United States	Russia	Britain	France	China
Number of total warheads	Approximate	No	Yes (upper limit)	Yes (upper limit)	Relative (out of date)
Number of deployed warheads	Yes (strategic only)	Yes (strategic only)	Yes (planned)	Yes	No
Dismantlements	Yes	No	Yes (no details)	Yes (no details)	No
Verification	Partial	Partial	No	No	No
Fissile material stockpiles	Yes	No	Yes (no details)	No	No
Production histories	Yes	No	No	No	No
Excess/Disposal	Yes (nothing new)	Yes (nothing new)	Yes (nothing new)	No	No
Verification	Partial	Partial (but no longer)	Partial (some plutonium)	No	No

DISARMAMENT, TRANSPARENCY, VERIFICATION

Leo Szilard, 1898–1964
Credit: AIP Archives



Joseph Rotblat, 1908–2005
Credit: Petter Hönnemann