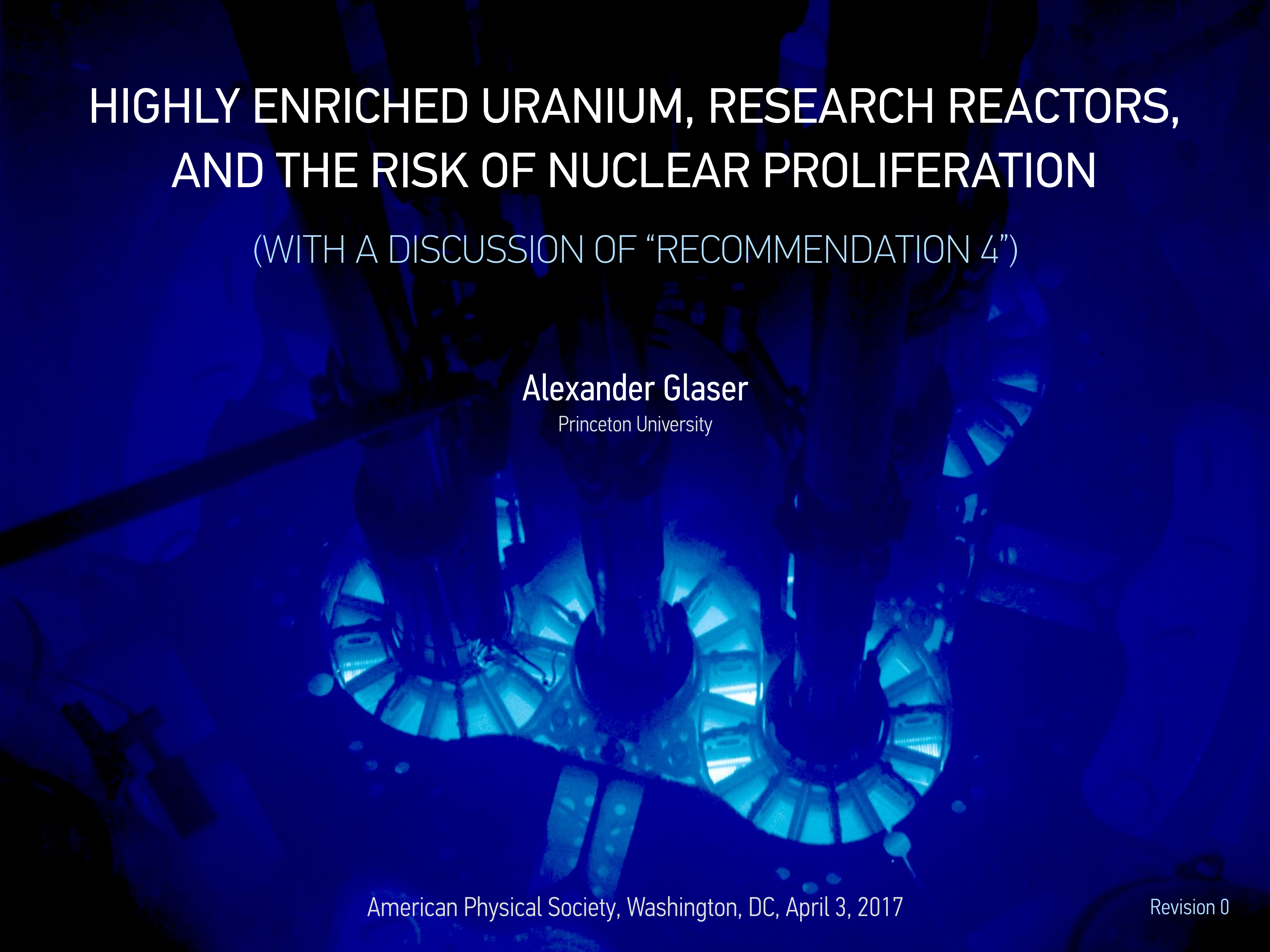


HIGHLY ENRICHED URANIUM, RESEARCH REACTORS, AND THE RISK OF NUCLEAR PROLIFERATION

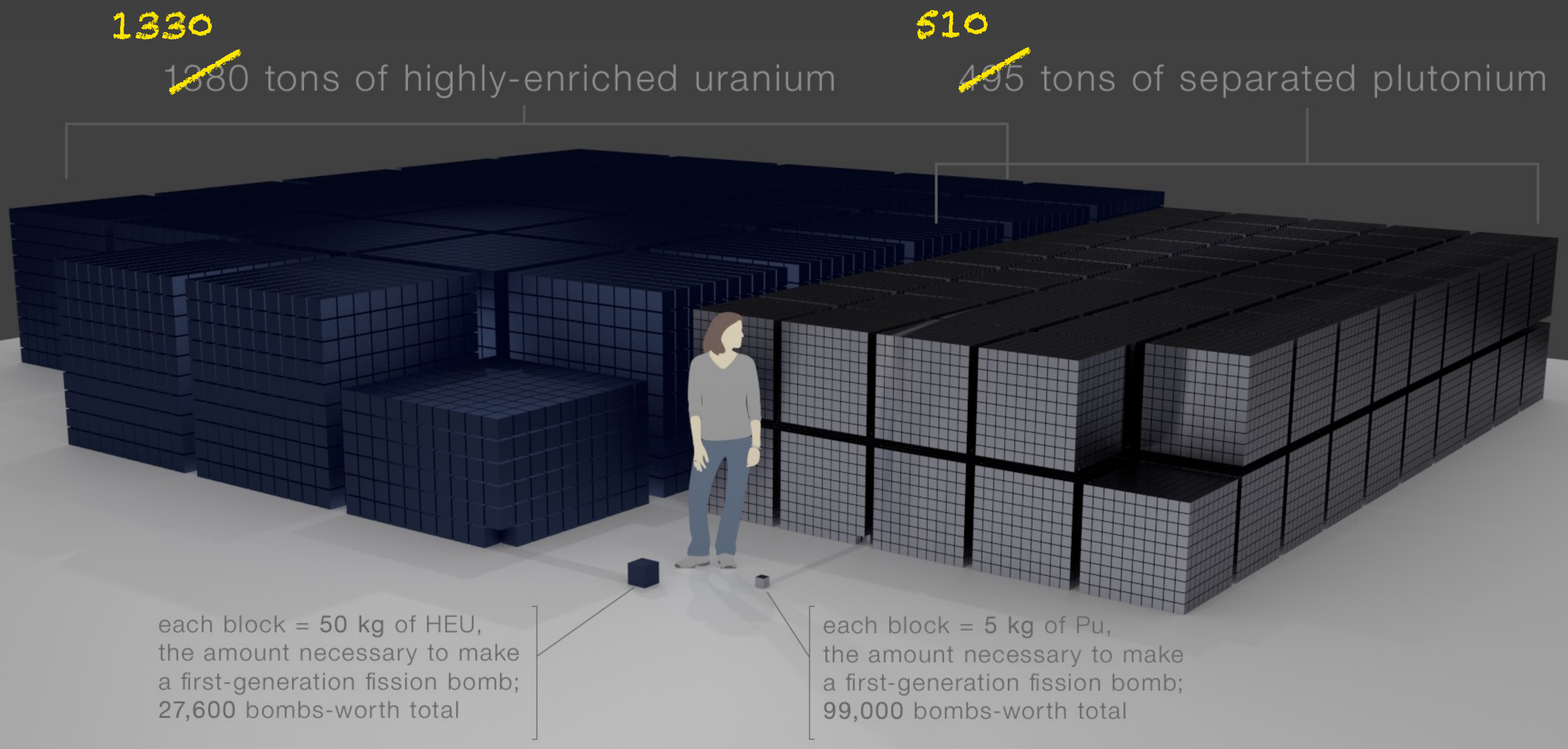
(WITH A DISCUSSION OF “RECOMMENDATION 4”)

Alexander Glaser
Princeton University

American Physical Society, Washington, DC, April 3, 2017

Revision 0

World Stockpiles of Fissile Materials

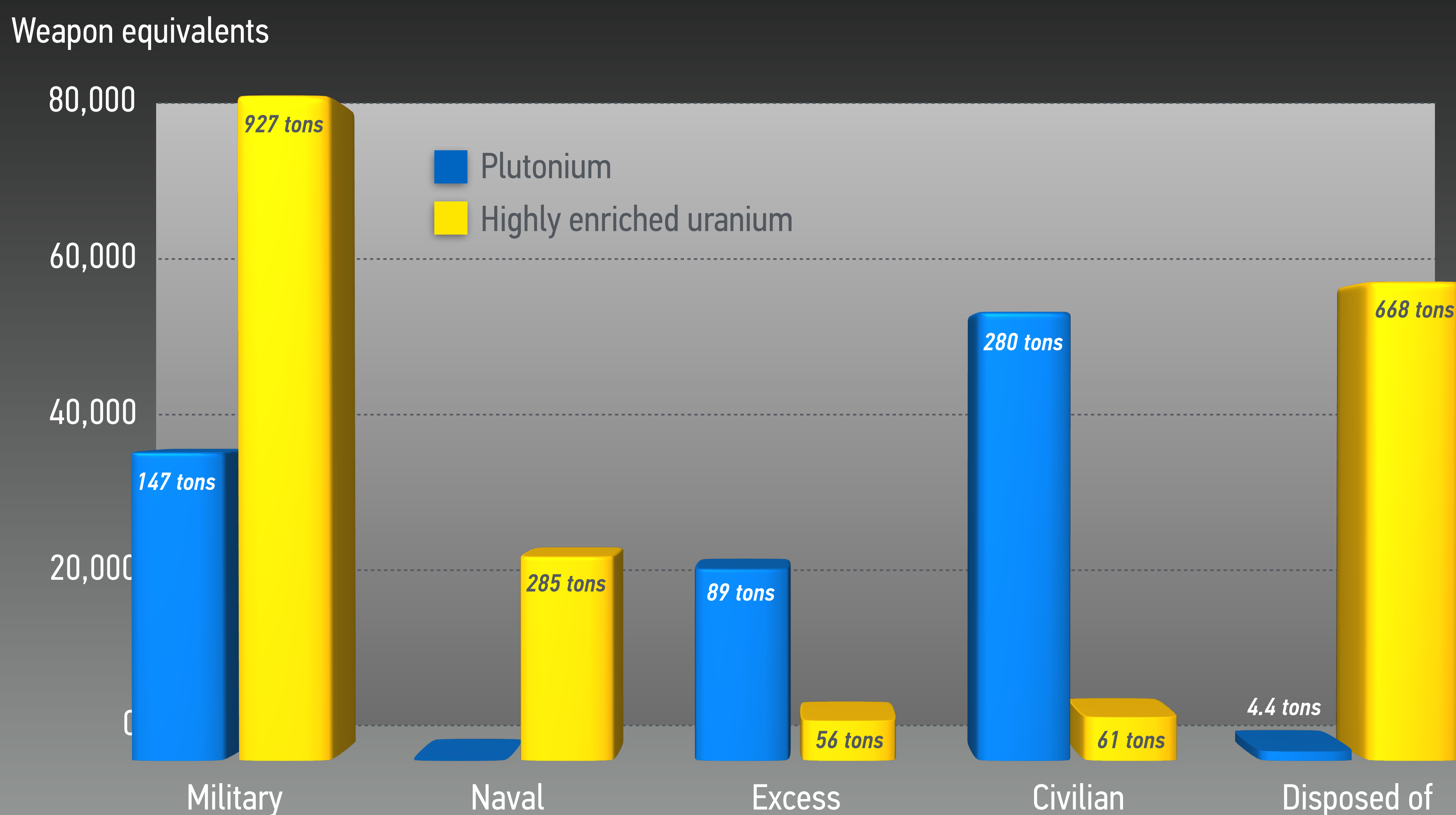


Graphic by Alex Wellerstein, nuclearsecrey.com

Global Fissile Material Report 2017, International Panel of Fissile Materials, Princeton, NJ, forthcoming

FISSILE MATERIALS BY CATEGORY

GLOBAL STOCKPILE OF PLUTONIUM AND HIGHLY ENRICHED URANIUM, 2016



Assumptions for weapon equivalents: 4 kg of weapon-grade plutonium, 5 kg of reactor-grade plutonium, 12 kg of highly enriched uranium
(As of 2016, more than 220,000 weapon-equivalents in the global stockpile of fissile material)

HEU PRODUCTION HAS LARGELY ENDED

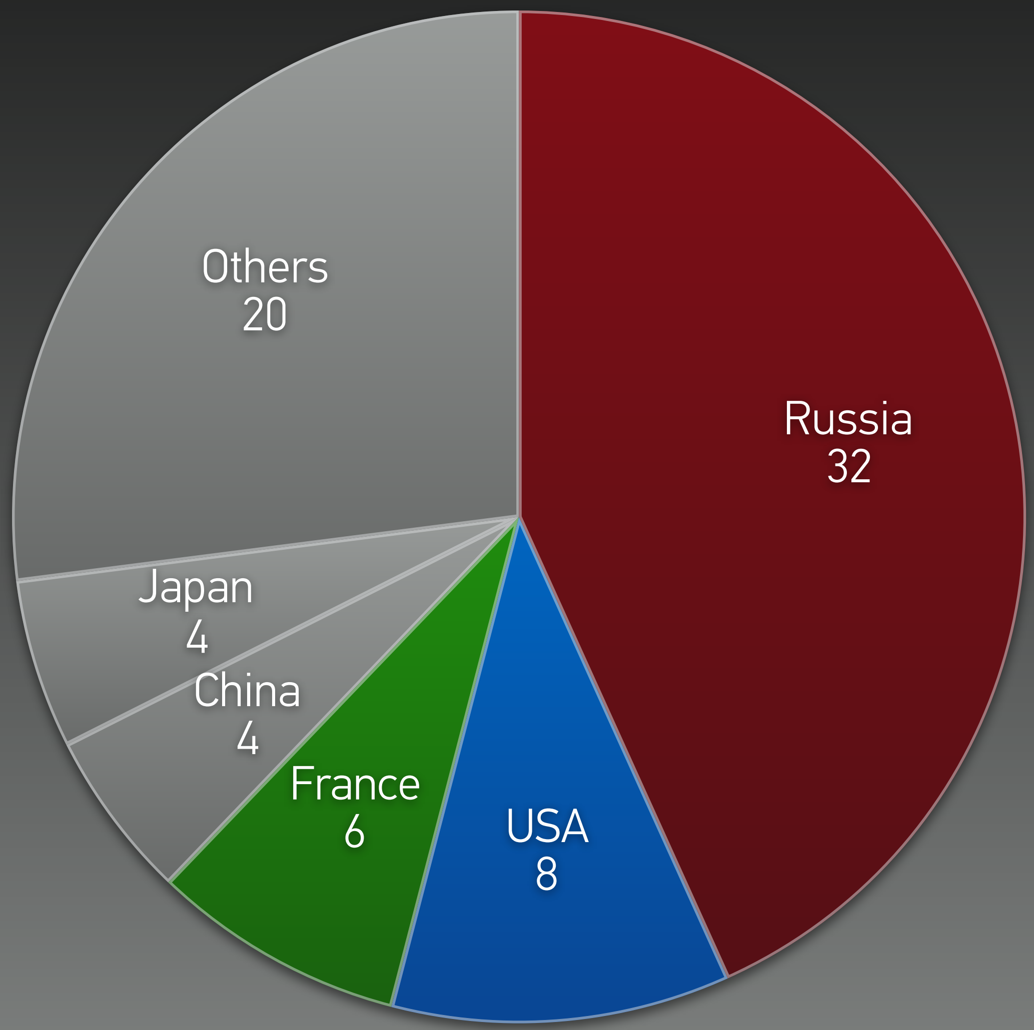
BUT CONTINUES IN NON-NPT WEAPON STATES … AND NOW AGAIN IN RUSSIA

Country	Military HEU production
United States	1944–1992 *(since 1964 for naval fuel only)*
Russia	1949–1987/88 *(but restarted civilian in 2012)*
United Kingdom	1953–1963 *(but imports from United States)*
China	1964–1987/89 *(unofficial)*
France	1967–1996

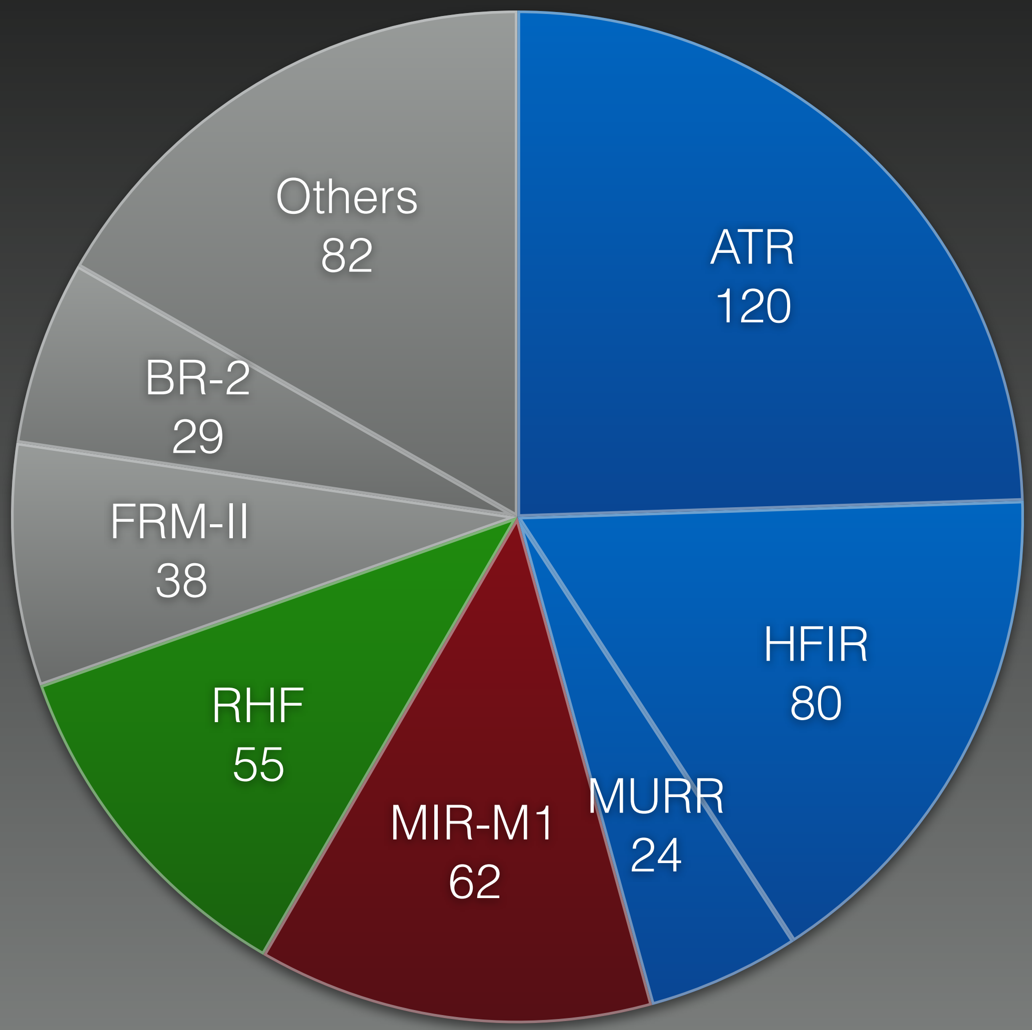
Country	Military HEU production
South Africa	1978–1990
Pakistan	since 1983
India	since 1992
Israel	?
North Korea	ongoing *(status and scale uncertain)*

Global Fissile Material Report 2015, International Panel of Fissile Materials, Princeton, December 2015, www.ipfmlibrary.org/gfmr15.pdf

WHERE (CIVILIAN) HEU IS USED TODAY



Number of HEU-fueled civilian research reactors (74)



Approximate annual HEU consumption (490 kg)

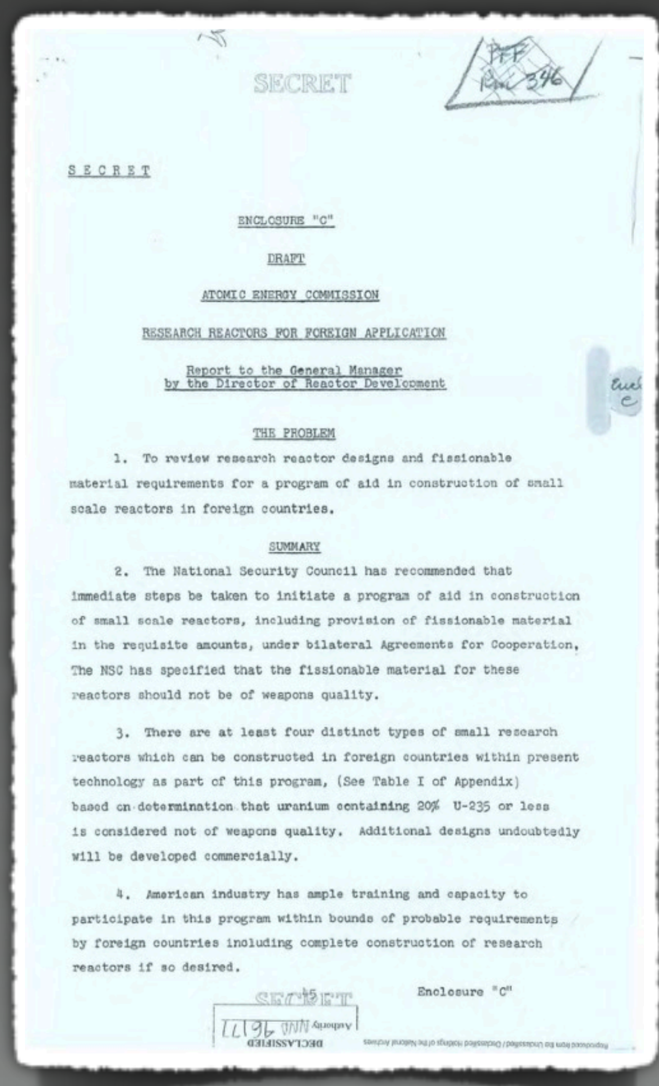
Data from M. K. Meyer, A Global Overview of High Density U-Mo Fuel Development Efforts, *International Symposium on Minimization of Highly Enriched Uranium (HEU) in the Civilian Nuclear Sector: The Way Ahead,* Oslo, Norway, June 17-20, 2006

WHY 20% ?

IS IT A POLITICAL OR A TECHNICAL DEFINITION?

(IT IS INDEED TECHNICAL)

THE 1954 HAFSTAD MEMO



SECRET

SECRET

ENCLOSURE "C"

DRAFT

ATOMIC ENERGY COMMISSION

RESEARCH REACTORS FOR FOREIGN APPLICATION

Report to the General Manager
by the Director of Reactor Development

THE PROBLEM

1. To review research reactor designs and fissionable material requirements for a program of aid in construction of small scale reactors in foreign countries.

SUMMARY

2. The National Security Council has recommended that immediate steps be taken to initiate a program of aid in construction of small scale reactors, including provision of fissionable material in the requisite amounts, under bilateral Agreements for Cooperation. The NSC has specified that the fissionable material for these reactors should not be of weapons quality.

3. There are at least four distinct types of small research reactors which can be constructed in foreign countries within present technology as part of this program, (See Table I of Appendix) based on determination that uranium containing 20% U-235 or less is considered not of weapons quality. Additional designs undoubtedly will be developed commercially.

4. American industry has ample training and capacity to participate in this program within bounds of probable requirements by foreign countries including complete construction of research reactors if so desired.

SECRET

Enclosure "C"

DECLASSIFIED

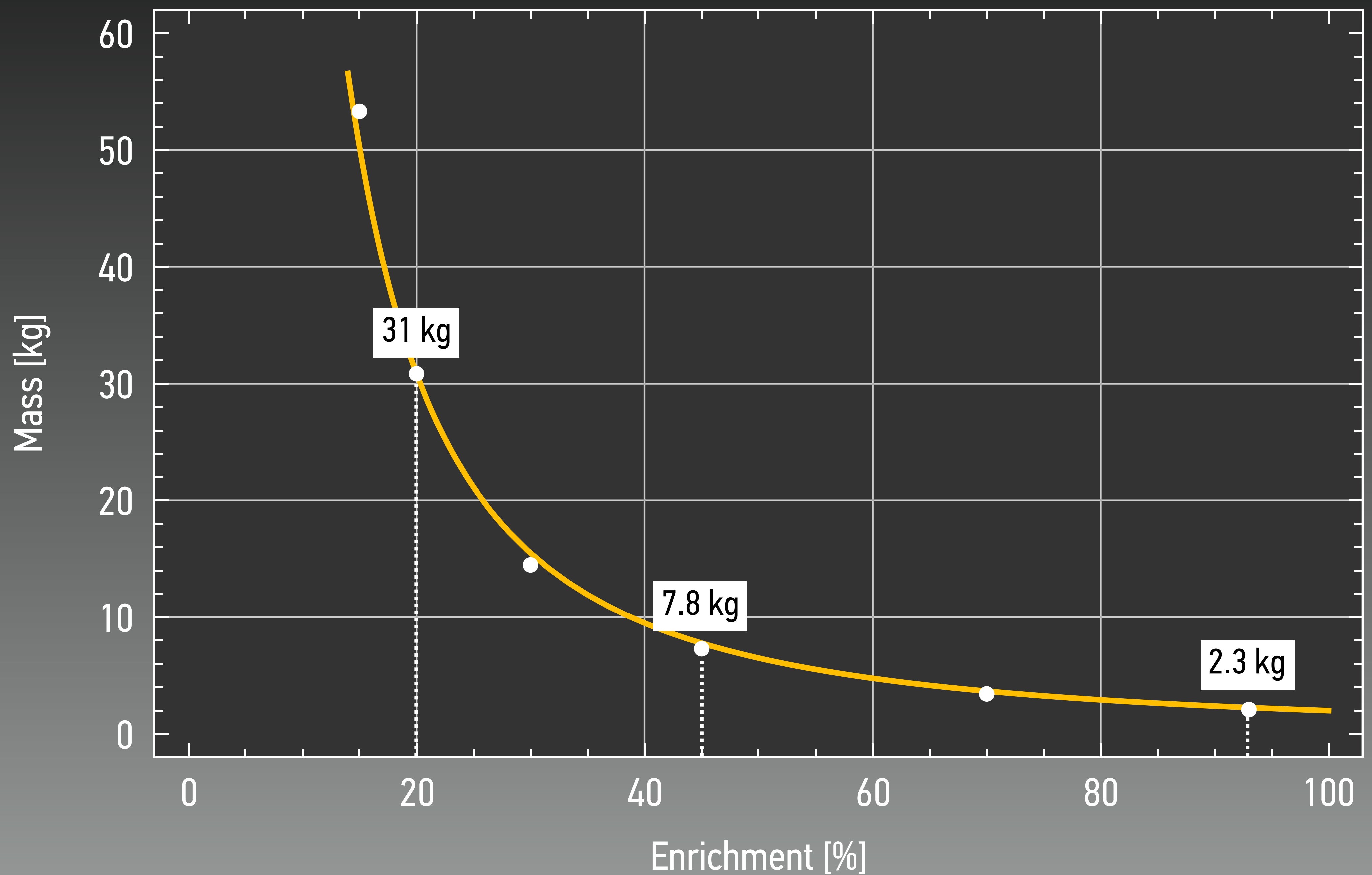
GUIDING PRINCIPLE

No foreign country ought to receive enough material to make a single nuclear explosive device with a yield of one kiloton TNT equivalent.

Lawrence R. Hafstad, *Research Reactors for Foreign Application (Enclosure "C"),* Washington, DC, 1954, ipfmlibrary.org/haf54.pdf

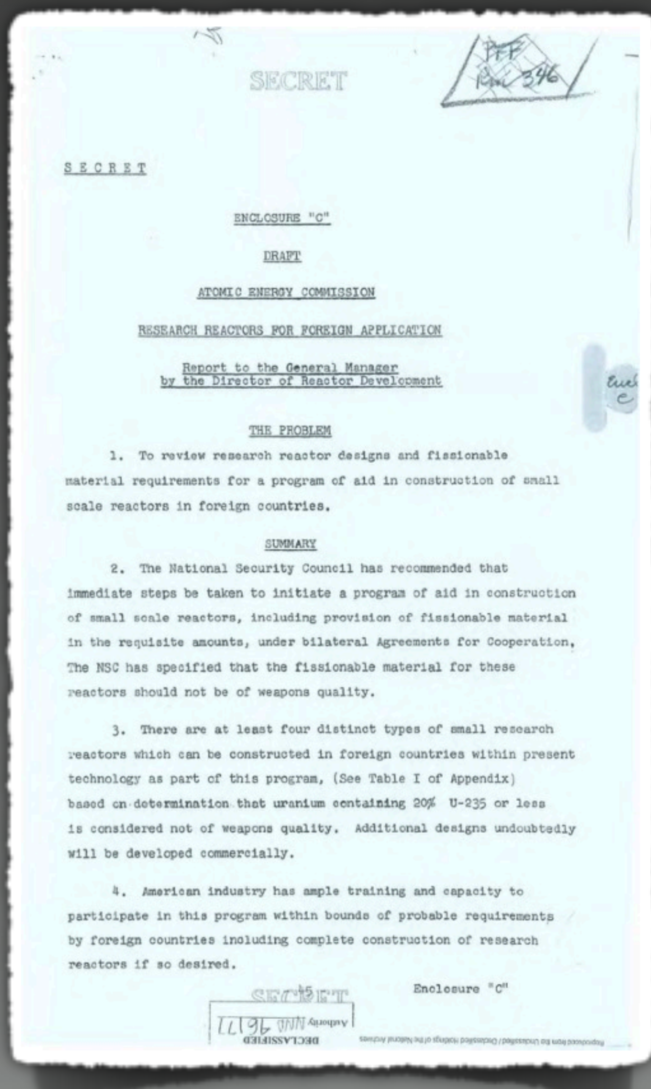
Andrew Brown and Alexander Glaser, "On the Origins and Significance of the Limit Demarcating Low-Enriched Uranium from Highly Enriched Uranium," *Science & Global Security,* 24 (2), 2016, scienceandglobalsecurity.org/archive/sgs24brown.pdf

MINIMUM AMOUNT OF URANIUM REQUIRED FOR A (SMALL) NUCLEAR WEAPON



L. R. Hafstad, *Research Reactors for Foreign Application,* 1954, *op. cit.;* and A. Brown and A. Glaser, *Science & Global Security,* 24 (2), 2016, *op. cit.*

THE 1954 HAFSTAD MEMO



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45

SECRET

Enclosure "C"

FINDINGS AND RECOMMENDATIONS

Only 2.3 kg of weapon-grade (93%-enriched) uranium are needed.

An enrichment of 10 percent was considered “safe in any quantity.”

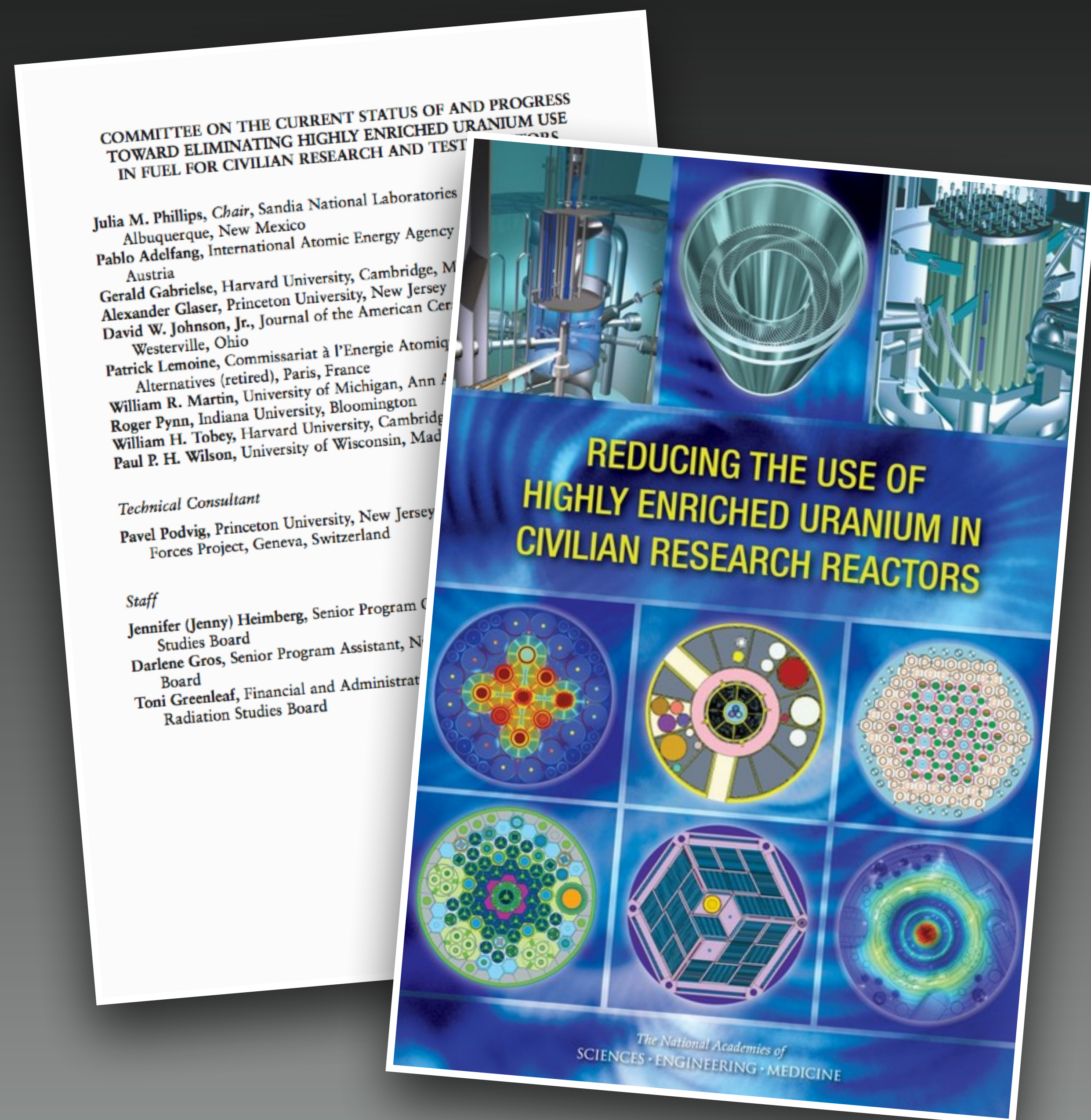
Making a nuclear weapon using 20 percent enriched uranium would “require the utmost ingenuity,” but the minimum amount needed is (still) only on the order of 30 kg.

The memorandum went on to recommend exporting enriched uranium up to an enrichment level of 20 percent such that the total amount held by a foreign country does not exceed 30 kg.

Lawrence R. Hafstad, *Research Reactors for Foreign Application (Enclosure “C”),* Washington, DC, 1954, ipfmlibrary.org/haf54.pdf

Andrew Brown and Alexander Glaser, “On the Origins and Significance of the Limit Demarcating Low-Enriched Uranium from Highly Enriched Uranium,” *Science & Global Security,* 24 (2), 2016, scienceandglobalsecurity.org/archive/sgs24brown.pdf

THE 2016 NATIONAL ACADEMIES STUDY



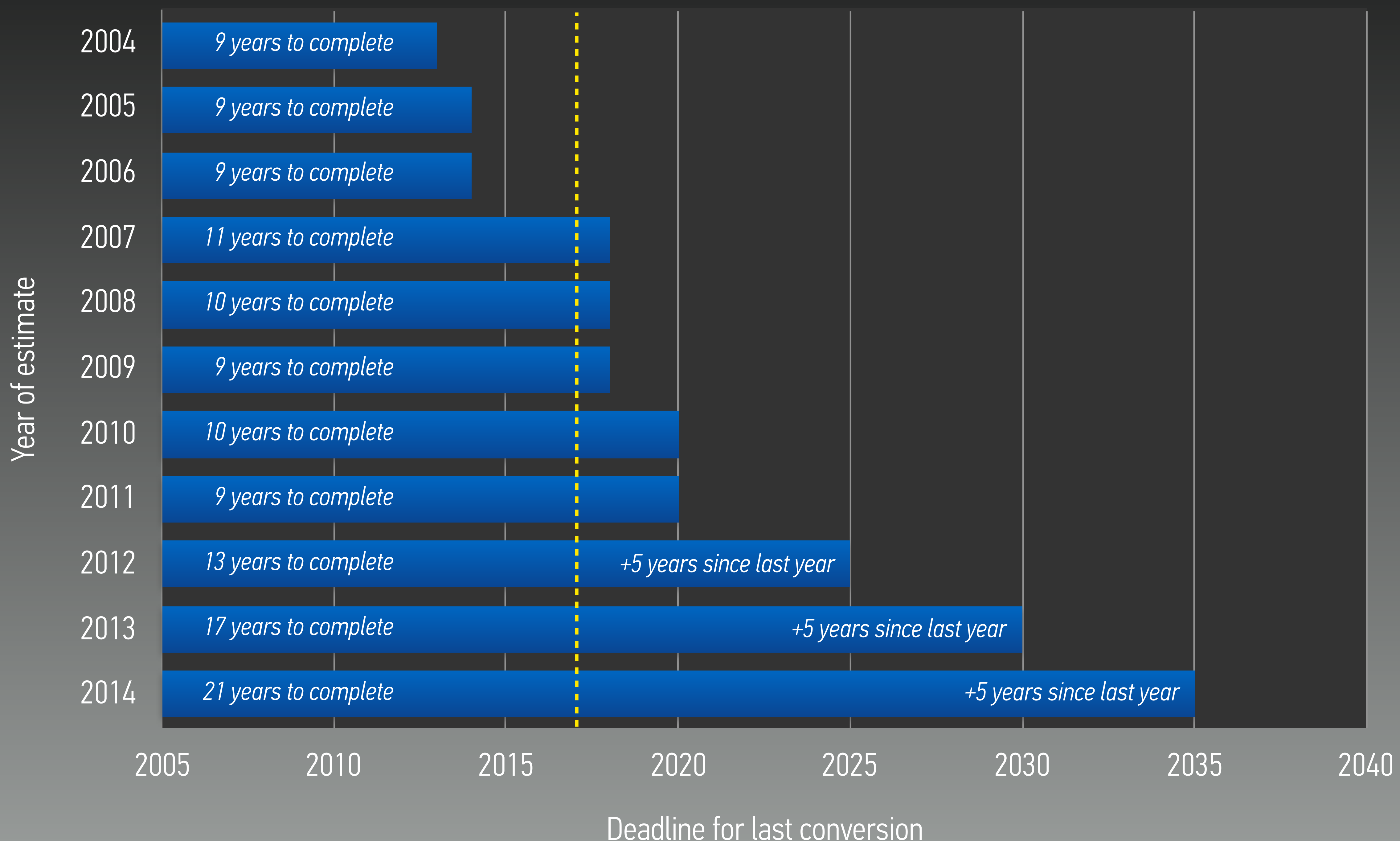
DISCLAIMER: VIEWS ARE MY OWN (AND ARE NOT NECESSARILY THOSE OF THE COMMITTEE)

www.nap.edu/catalog/21818/reducing-the-use-of-highly-enriched-uranium-in-civilian-research-reactors

SEVEN RECOMMENDATIONS

1. Develop a 50-year interagency strategy and roadmap for neutron needs
2. Continue the development of very high-density LEU fuels for research reactors
3. Monitor the development of dispersion-type fuels as a backup for U.S. research reactors
4. Pursue an interim solution for conversion of high-performance research reactors
5. Engage Russia in conversion efforts through periodic workshops and scientific exchanges
6. Augment the annual progress reports of the M^3 program
7. Conduct independent technical review for robust project and risk management

TIMELINES HAVE EXPANDED (A LOT)



ENRICHMENT REQUIREMENTS FOR HIGH-PERFORMANCE REACTORS

	U_3Si_2 4.8 g(U)/cc	U_3Si_2 5.8 g(U)/cc	UMo(8wt%) 8.0 g(U)/cc	Monolithic 16 g(U)/cc	Years to conversion
ATR	35–40%	~ 30%	25–30%	LEU	14 years
HFIR	35–40%	~ 30%	25–30%	LEU	17 years
NBSR	~ 25%	LEU	LEU	LEU	12 years
MURR	~ 45%	~ 40%	~ 35%	LEU	12 years
MITR-II	~ 35%	~ 30%	20–25%	LEU	12 years
FRM-II	~ 50%	~ 35%	30%	LEU	n/a
BR-2	~ 27%	~ 22%	LEU	LEU	n/a
JHR	~ 27%	~ 22%	LEU	LEU	n/a
RHF	~ 27%	~ 22%	LEU	LEU	n/a

Only uranium-silicide fuel at 4.8 g(U)/cc would be immediately available
(and make possible an interim conversion on the order of 5 years or less)

INTERIM REDUCTION OF ENRICHMENT LEVEL AND DOWNBLENDING OF STOCKS

Recommendation 4: To achieve the goal of using as little highly enriched uranium as possible during the many years that it will take to design and qualify appropriate low enriched uranium (LEU) fuel, the United States should pursue an interim solution that reduces the civilian use of weapon-grade material.

a. During this interim period, high performance research reactors should use dispersion silicide fuel enriched to the lowest practical level, which can be produced with technologies already known to be reliable. The precise enrichment level can be quickly determined by a focused, small-scale study.

b. The United States should downblend the remaining 20 metric tons of highly enriched uranium (HEU) designated for civilian research reactor use to this lowest practical enrichment level as soon as it has been determined.

c. The interim solution should be pursued in a way that does not compromise the long-term goal of eliminating HEU usage in civilian applications.

WHAT AN INTERIM CONVERSION COULD ACCOMPLISH

Avoid the use of up to 3.4 tons of weapon-grade HEU
between now and 2035

Demonstrate U.S. commitment to international conversion efforts
by maintaining an active domestic program and sustaining the technical expertise in the area

Attract scientists and engineers to work on reactor conversions and fuel development
(who would otherwise find projects with a twenty-year time horizon of little interest)

If down-blending is pursued: Reduce the global stockpile of weapon-grade uranium
Ideally, this material could also be offered for IAEA safeguards

Note: the proposition of an interim conversion step is not new. Both the U.S. RERTR Program and the IAEA International Nuclear Fuel Cycle Evaluation considered 45% as an interim step toward 20% enrichment when adequate fuel for a direct conversion was not available.

A SILENT DISASTER

RESUMPTION OF HEU PRODUCTION IN RUSSIA FOR EXPORT TO WESTERN CUSTOMERS

Основные события 2015 года:

- перевод разделительного производства АО «АЭХК» в режим производства сырьевого гексафторида урана (ГФУ);
- производство ОУП марки «РС-Э» для использования в изготовлении ЯТ для зарубежных АЭС (Темелин, Тяньвань);
- отключение ГЦ пятого поколения в соответствии с запланированным графиком;
- наработка в АО «ПО ЭХЗ» высокообогащенного сырья для производства металлического урана для реактора Мюнхен-II.
- выполнение АО «УЭХК» дополнительных поставок сырьевого ГФУ в Китай.

Main developments in 2015: “Production by the EKhZ [enrichment plant in Zelenogorsk] of highly enriched product for the uranium metal to be supplied to the Munich-II reactor”

First HEU production for civilian purposes; not under IAEA safeguards

Likely to make even more complicated discussions on Fissile Material Cutoff Treaty

www.tvel.ru/wps/wcm/connect/tvel/tvelsite/resources/b0b880004d74273f98d59911c9d6633a/TVEL2015.pdf

fissilematerials.org/blog/2016/07/russia_confirmed_supplyin.html

FINAL THOUGHTS

STATE OF PLAY 2017 AND POSSIBLE NEXT STEPS

STATE OF PLAY 2017

Remaining conversions are “hard” (politically or technically)

Few if any conversions expected for the next decade

Annual HEU demand will remain nearly constant for next 15–20 years

WAY FORWARD / POSSIBLE NEXT STEPS

Consider interim conversion step for remaining high-flux reactors

Remove incentive for ongoing HEU production in Russia

Consider “convert and upgrade” strategies (for research reactors)

Source: Author