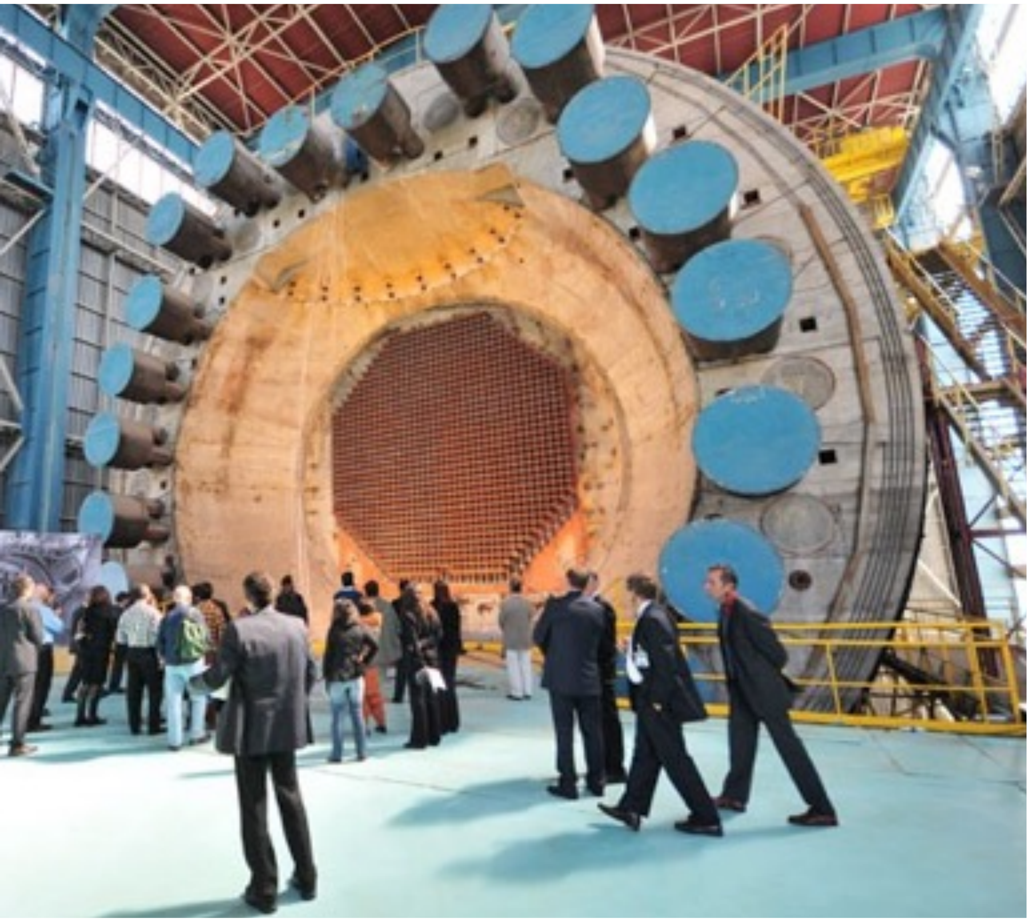


FISSILE MATERIAL STOCKPILE DECLARATIONS AND COOPERATIVE NUCLEAR ARCHAEOLOGY

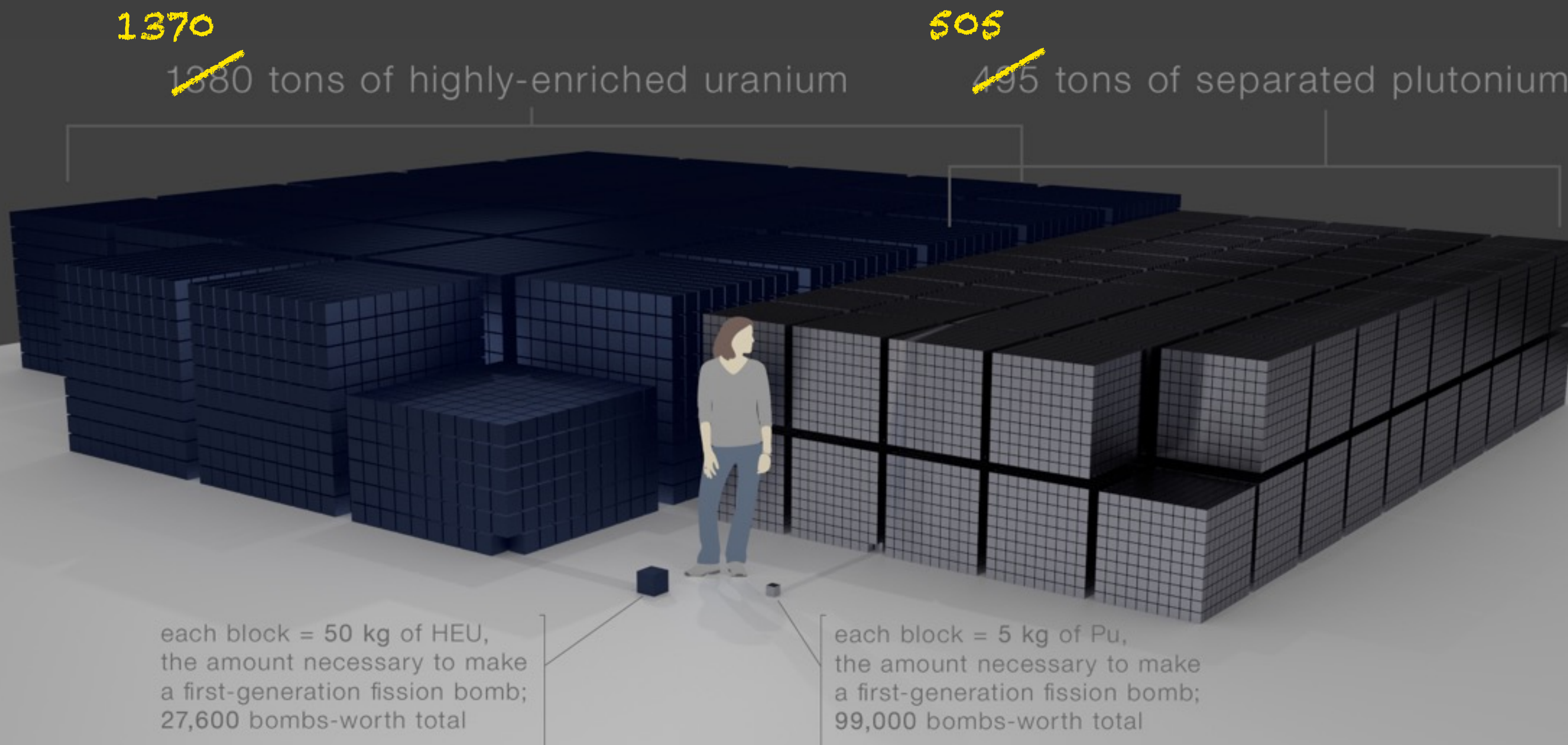
Alexander Glaser

Princeton University

United Nations Institute for Disarmament Research
Palais des Nations, Geneva, June 1, 2016

Revision 2

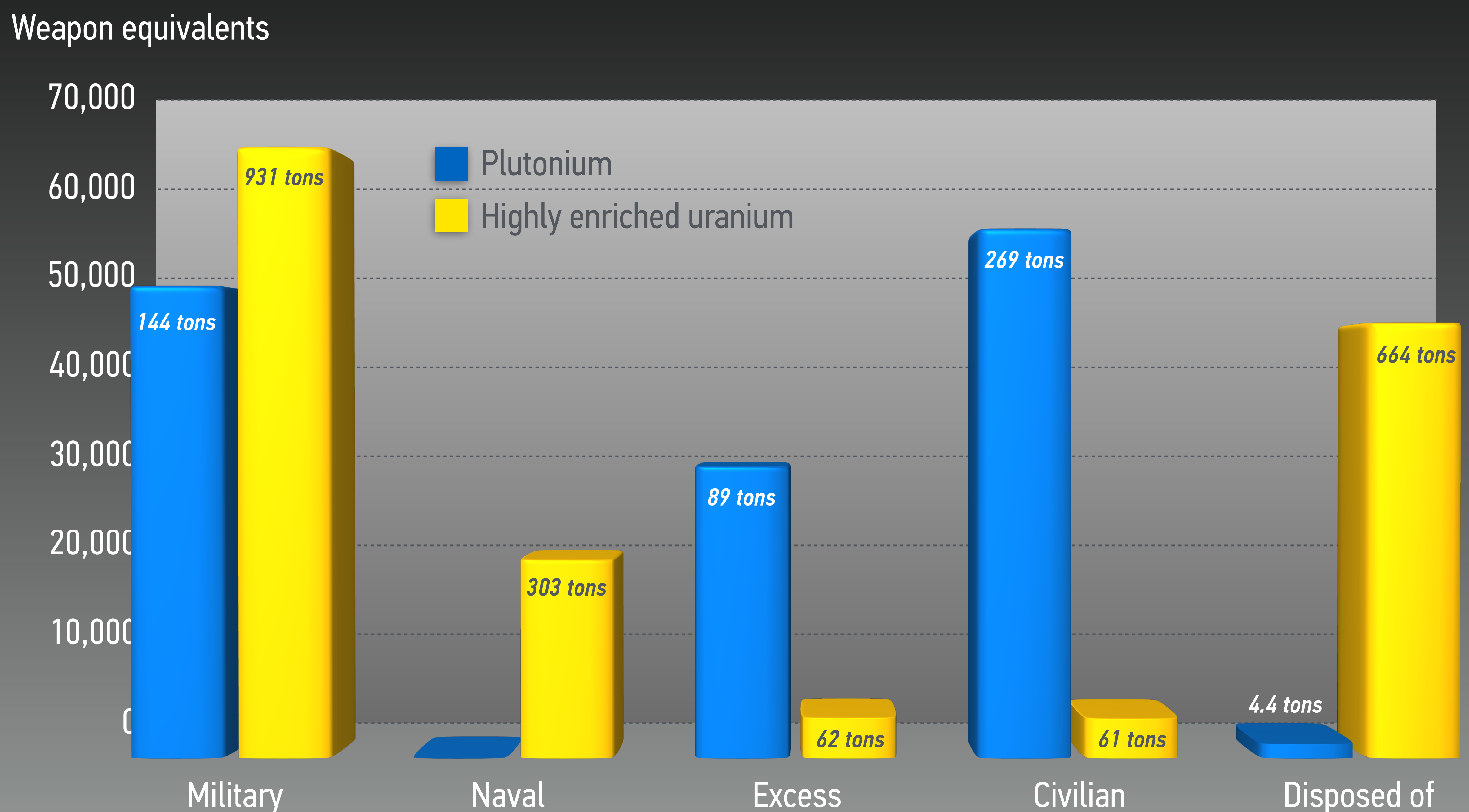
World Stockpiles of Fissile Materials



Graphic by Alex Wellerstein, nuclearsecrecy.com

FISSILE MATERIALS BY CATEGORY

GLOBAL STOCKPILE OF PLUTONIUM AND HIGHLY ENRICHED URANIUM, 2015



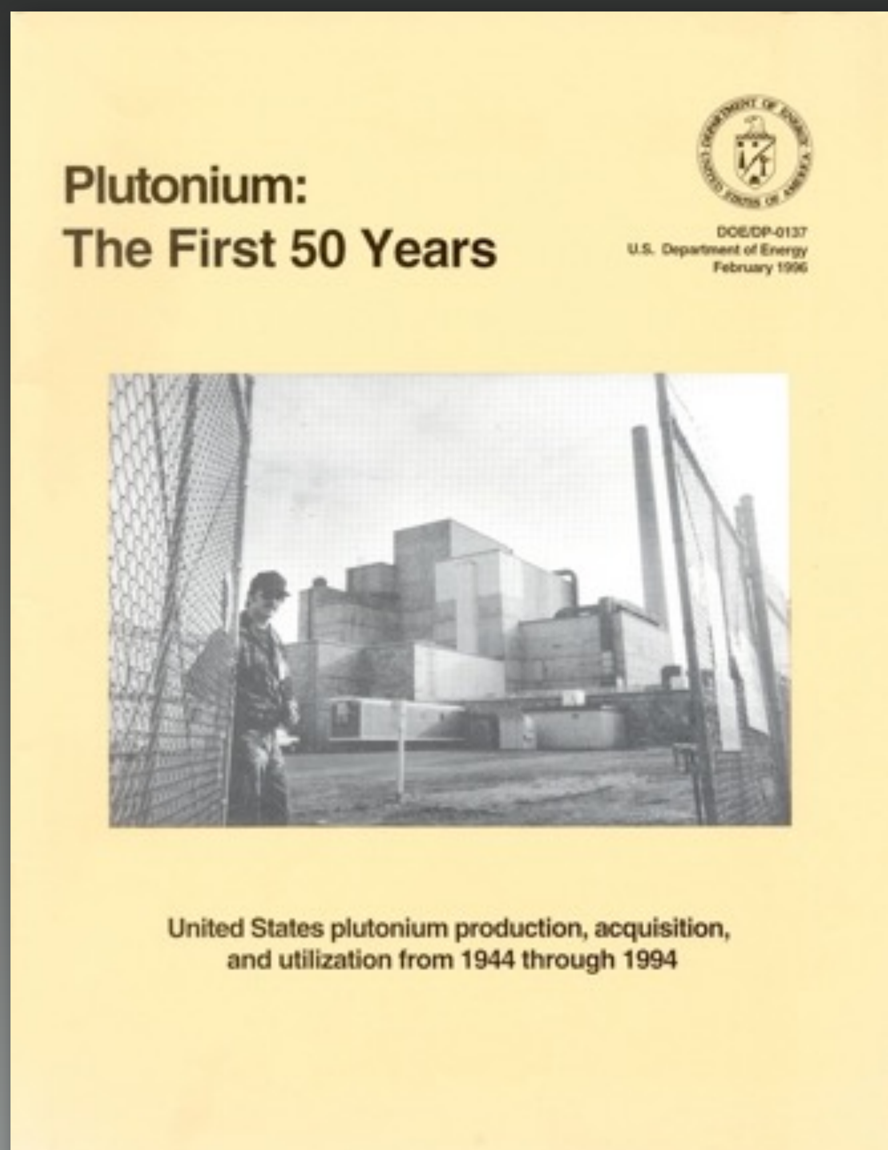
Assumptions for weapon equivalents: 3 kg of weapon-grade plutonium, 5 kg of reactor-grade plutonium, 15 kg of highly enriched uranium
(As of 2015, more than 220,000 weapon-equivalents in the global stockpile of fissile material)
Source: *Global Fissile Material Report 2015,* International Panel on Fissile Materials, Princeton, NJ, www.ipfmlibrary.org/gfmr15.pdf

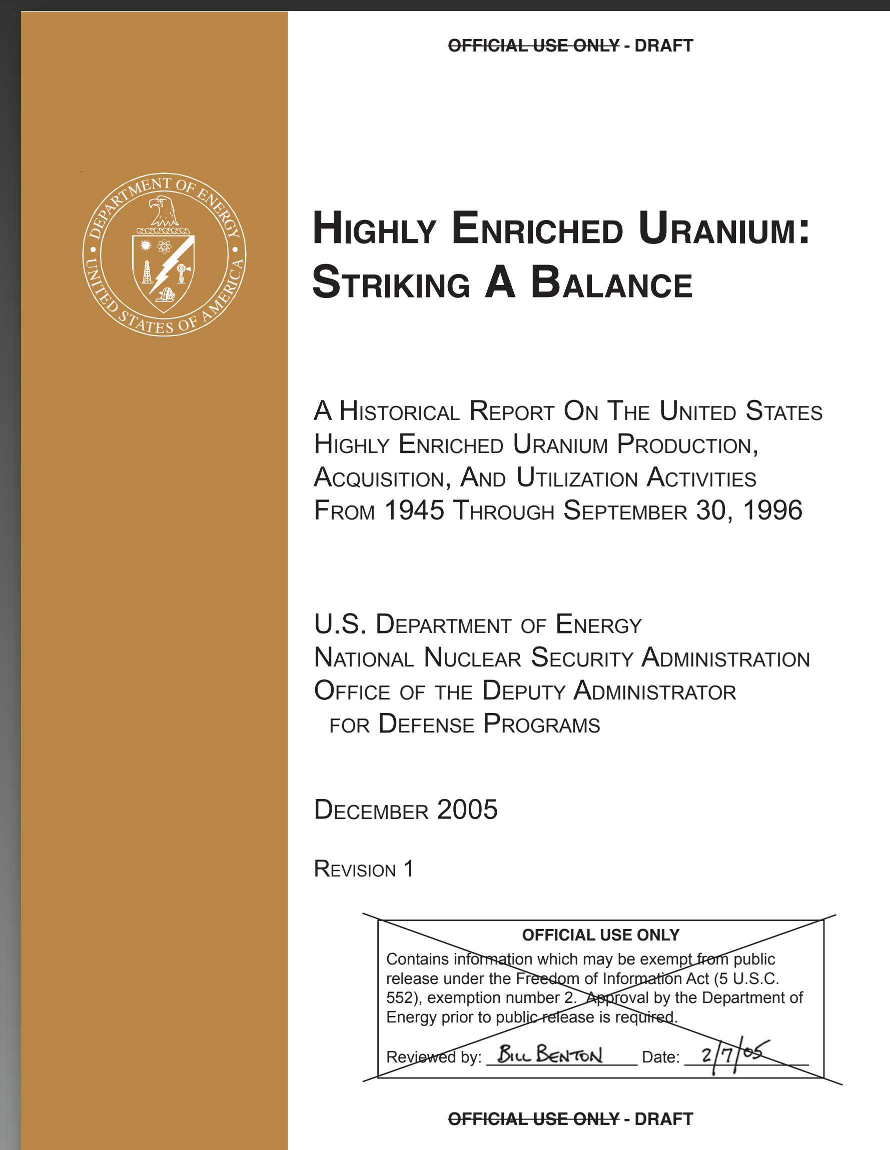
DECLARATIONS

OF FISSILE MATERIAL STOCKPILES

THE UNITED STATES HAS ALREADY MADE BASELINE DECLARATIONS

(BUT COULD UPDATE THEM MORE FREQUENTLY)





1996 and 2001 U.S. Declarations on Plutonium and HEU

POSSIBLE REPORTING FORM

FOR A FISSILE MATERIAL (BASELINE) DECLARATION

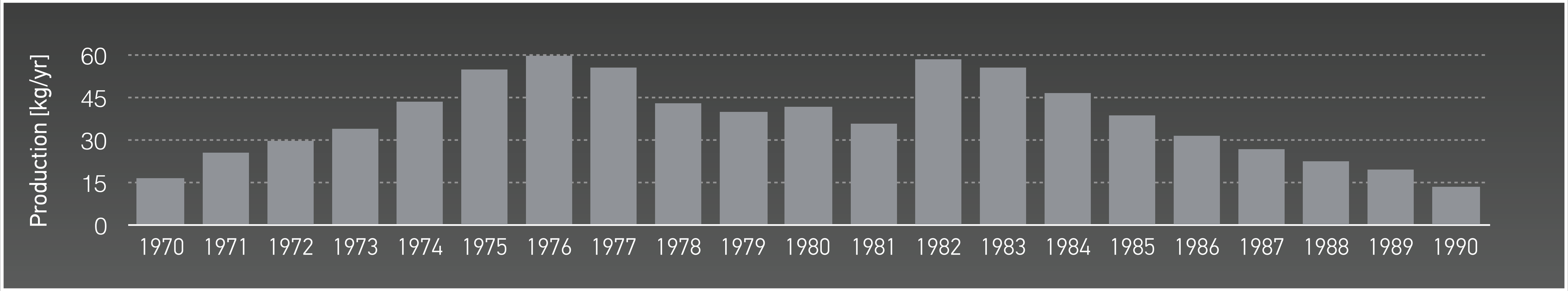
	HEU	Plutonium
Inventory as of (DATE)	------------------------	------------------------
Military, available for weapons	------------------------	------------------------
Military, reserved for non-weapon purposes	------------------------	------------------------
Military, in irradiated fuel	------------------------	------------------------
Excess military, not available for IAEA safeguards	------------------------	------------------------
Civilian, not available for IAEA safeguards	------------------------	------------------------
Civilian, available for IAEA safeguards	------------------------	------------------------
Excess military, available for IAEA safeguards	------------------------	------------------------

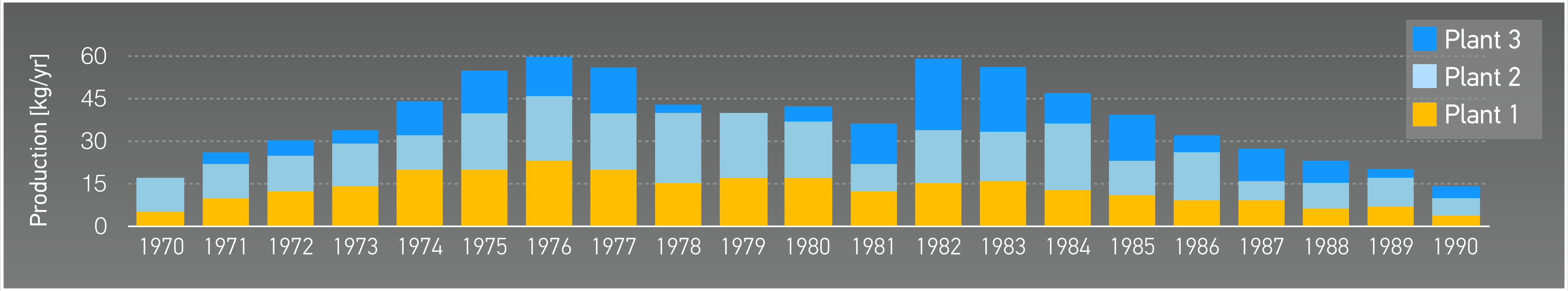
Specifying average isotopics (uranium-235 content in HEU and plutonium-239 in plutonium) would enable further consistency checks of the declarations

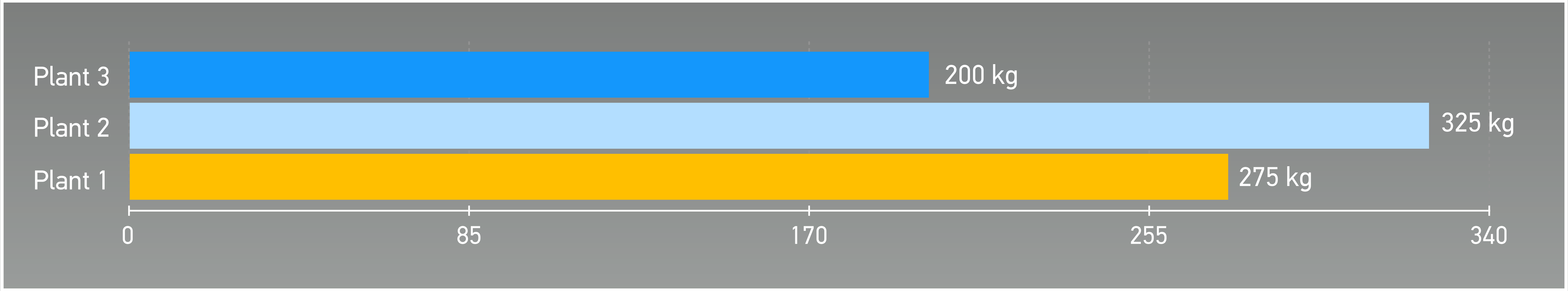
Global Fissile Material Report 2013, International Panel on Fissile Materials, Princeton, October 2013, www.ipfmlibrary.org/gfmr13.pdf

NOTIONAL PRODUCTION SCENARIO

(AND ALTERNATIVE WAYS OF DECLARING HISTORIC FISSILE MATERIAL PRODUCTION)







VERIFICATION OF BASELINE DECLARATIONS

AND THE CASE FOR NUCLEAR ARCHAEOLOGY

PUBLIC HISTORIC DOCUMENTS CAN OFTEN HELP RECONSTRUCT PRODUCTION HISTORIES

(MUCH BETTER WOULD BE FORMAL DATA EXCHANGES OF HISTORIC PRODUCTION RECORDS)

Hague et de la Cogema a été de minimiser les faits et leurs conséquences possibles, afin de rassurer l'opinion publique française et la clientèle étrangère, faisant prendre ainsi

G3 (taux de combustion compris entre 700 et 1200 MWJ/t) et le combustible EDF (taux de combustion atteignant 5000 MWJ/t.)

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Tonnage G2, G3	190	130	320	620	640	760	850	820	960	730	890
Tx de combustion . . .	100	100	100	200	200	300	300	300	400	400	450
Tonnage EDF . . . . . —	—	—	—	—	—	—	—	—	—	—	—

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Tonnage G2 G3	530	570	460	480	240	280	260	170	non connu	non connu	190
Tx de combustion . . .	450	450	500	600	700	800	1000	1200			1200
Tonnage EDF					113	8	25	120	245	280	310

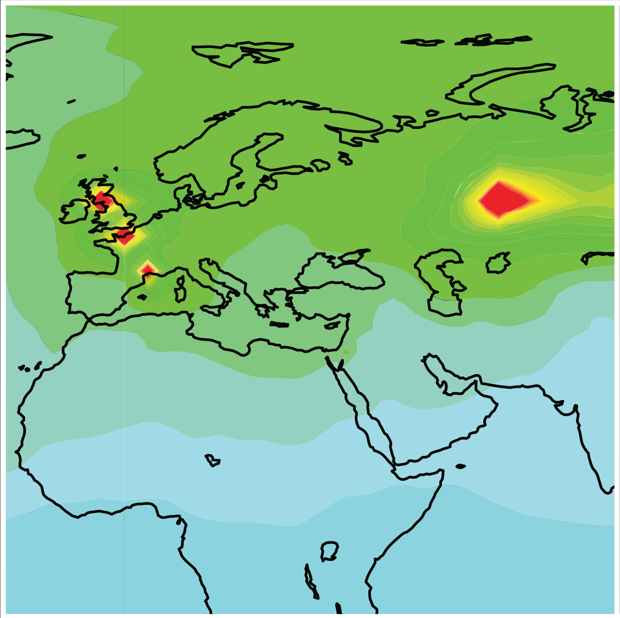
Si jusqu'aux années 1972-73 les tonnages retraités sont très élevés, une des raisons essentielles en est le faible taux de combustion des combustibles.

Le tonnage retraité diminue ensuite sensiblement en

ne. Il est également inférieur aux prévisions faites par la Cogéma au début de l'année 1980 puisque 310 tonnes ont été retraitées alors que les prévisions étaient 365 tonnes.

Le retraitement des combustibles irradiés: La situation de la Hague et Marcoule, Analyses et positions de la CFDT
Rayonnement, Syndicat National du Personnel de l'Energie Atomique, No. 92, Février 1981

WILL WE EVER KNOW HOW MUCH FISSILE MATERIAL EXISTS WORLDWIDE?



RECONSTRUCTING HISTORIC FISSILE MATERIAL PRODUCTION

Many aspects of declared production histories can be reviewed for consistency even without dedicated verification efforts

(for example, by comparison with historic krypton emissions)

DATA EXCHANGE AND NUCLEAR ARCHAEOLOGY

Verification could begin with data exchanges (e.g. sharing of available operating records) and, eventually, envision onsite inspections

Nuclear archaeology is based on nuclear forensic analysis of samples taken at former production facilities

Source: Ole Ross and www.francetnp2010.fr

Science & Global Security, 1993, Volume 3, pp.237–259
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Nuclear Archaeology: Verifying Declarations of Fissile-Material Production

Steve Fetter[a]

Controlling the production of fissile material is an essential element of nonproliferation policy. Similarly, accounting for the past production of fissile material should be an important component of nuclear disarmament. This paper describes two promising techniques that make use of physical evidence at reactors and enrichment facilities to verify the past production of plutonium and highly enriched uranium. In the first technique, the concentrations of long-lived radionuclides in permanent components of the reactor core are used to estimate the neutron fluence in various regions of the reactor core are used to estimate the neutron fluence in various regions of the reactor core, and thereby verify declar… of plutonium production in the reactor. In the secon… technique, the ratio of th… of U-235 to that of U-234 in the tails is used … determine whether a g… in the production of lo… enriched uranium, whi… which can be used in … "nuclear archaeology," … ties and thereby lay a …

INTRODUCTION

For the first time, … tal proliferation– … reduce their com… than 10,000 by t… South Africa, Ir… nuclear thresho…

It is impor… capabilities ar…

a. School of…

Science and Global Security, 19:223–233, 2011
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ISSN: 0892-9882 print / 1547-7800 online
DOI: 10.1080/08929882.2011.616124

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Nuclear Archaeology for Heavy-Water-Moderated Plutonium Production Reactors

Alex Gasner and Alexander Glaser

Department of Mechanical and Aerospace Engineering, Princeton University Engineering Quadrangle, Olden Street, Princeton, NJ 08544

There is growing interest in a set of methods and tools that can be used to characterize past fissile material production activities, using measurements and sampling at … production and stora… …as been dubbed "nuclear archaeology." The …ology relies on measurements of the isotope … of graphite-moderated plutonium produc- …Method (GIRM) determines the cumulative …hereby estimates the cumulative plutonium …ion of this particular method is that it can …tors, which represent only one class of re- …led plutonium production. In this article, …raphite moderated reactors by analyzing …e support structures and other core com- … We present results of neutronics calcula- …evaluating the robustness of the method … for applications in arms-control treaty

…1.
…ted at the 51st INMM Annual Meeting, …ltimore, MD, July 11–15, 2010.
…Department of Geosciences, for advic…
…Matos from Argonne Nati…
…trace anal…

Science & Global Security, 22:27–49, 2014
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DOI: 10.1080/08929882.2014.871881

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Nuclear Archaeology for Gaseous Diffusion Enrichment Plants

Sébastien Philippe and Alexander Glaser

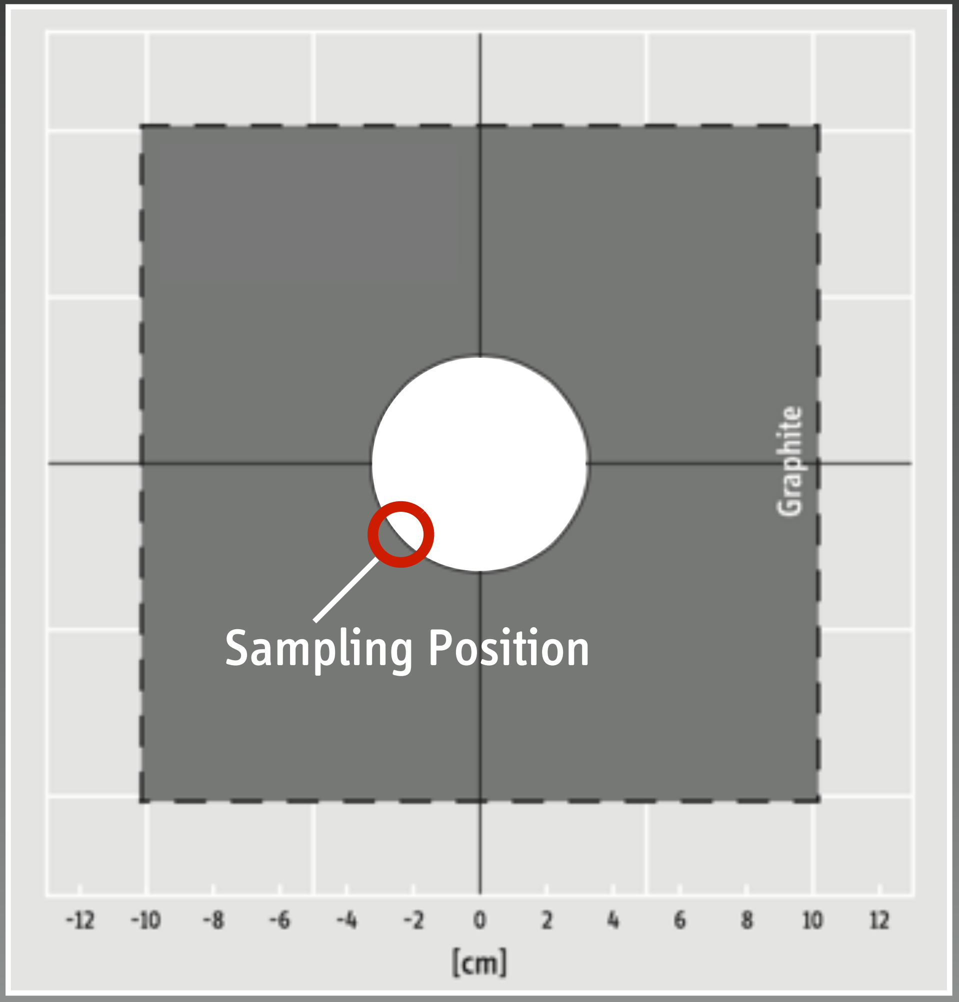
Nuclear Futures Laboratory, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ, USA

Gaseous diffusion was historically the most widely used technology for military production of highly enriched uranium. Since June 2013, all gaseous diffusion enrichment plants worldwide are permanently shut down. The experience with decommissioning some of these plants has shown that they contain large amounts of uranium particles deposited in the cascade equipment. This article evaluates the … uranium particle deposition to unde…

NUCLEAR ARCHAEOLOGY WOULD HAVE BEEN USED TO VERIFY NORTH KOREA'S 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

PLUTONIUM PRODUCTION REACTORS

BY TYPE AND COUNTRY

	Graphite moderated		Heavy-water moderated	
	H_2O cooled	CO_2 cooled	H_2O cooled	D_2O cooled
United States	Hanford			Savannah River
Russia	"Tomsk-7"			
United Kingdom		Calder Hall		
France		G-Series		Célestin
China	"Jiuquan"			
Israel				Dimona
India			Cirus/NRX	Dhruva
Pakistan			Khushab	
DPRK		Yongbyon		

A. Glaser, "Isotopic Signatures of Weapon-grade Plutonium from Dedicated Natural-uranium-fueled Production Reactors and Their Relevance for Nuclear Forensic Analysis," *Nuclear Science & Engineering,* September 2009

PREPARING FOR FUTURE VERIFICATION

MANY DIFFERENT MATERIALS, PROCESSES, AND SITES HAVE BEEN INVOLVED IN FISSILE MATERIAL PRODUCTION

THE CASE OF PLUTONIUM

Source material (Uranium)

Fuel fabrication

Plutonium production

Reprocessing of irradiated fuel

Waste storage

TO ALLOW FOR FUTURE VERIFICATION, STATES COULD:

1. Agree on the most important types of operating records to be preserved
2. Catalogue, characterize, and preserve waste materials

TEST BEDS FOR NUCLEAR ARCHAEOLOGY

To begin countries could offer single sites or facilities as test beds and invite partners with similar production facilities to engage in "site-to-site exercises" to jointly demonstrate verification approaches and measurement techniques

Left: Windscale Piles, www.sellafieldsites.com
Right: G2/G3, Marcoule, www.francetnp.fr

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Left: Windscale Piles, www.sellafieldsites.com
Right: G2/G3, Marcoule, www.francetnp.fr

MANY NON-NUCLEAR WEAPON STATES HAVE CANDIDATE FACILITIES THAT COULD BE USED TO DEMONSTRATE METHODS REQUIRED FOR NUCLEAR ARCHAEOLOGY

NRX, Canada

Ågesta Reactor (105 MWt), near Stockholm, Sweden

"THE CLOCK IS TICKING"

SHUTDOWN ENRICHMENT PLANTS AND PRODUCTION REACTORS ARE BEING DECOMMISSIONED OR DEMOLISHED

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

China's unfinished underground plutonium production complex (Project 816), near Chongqing
Source: CQTV

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