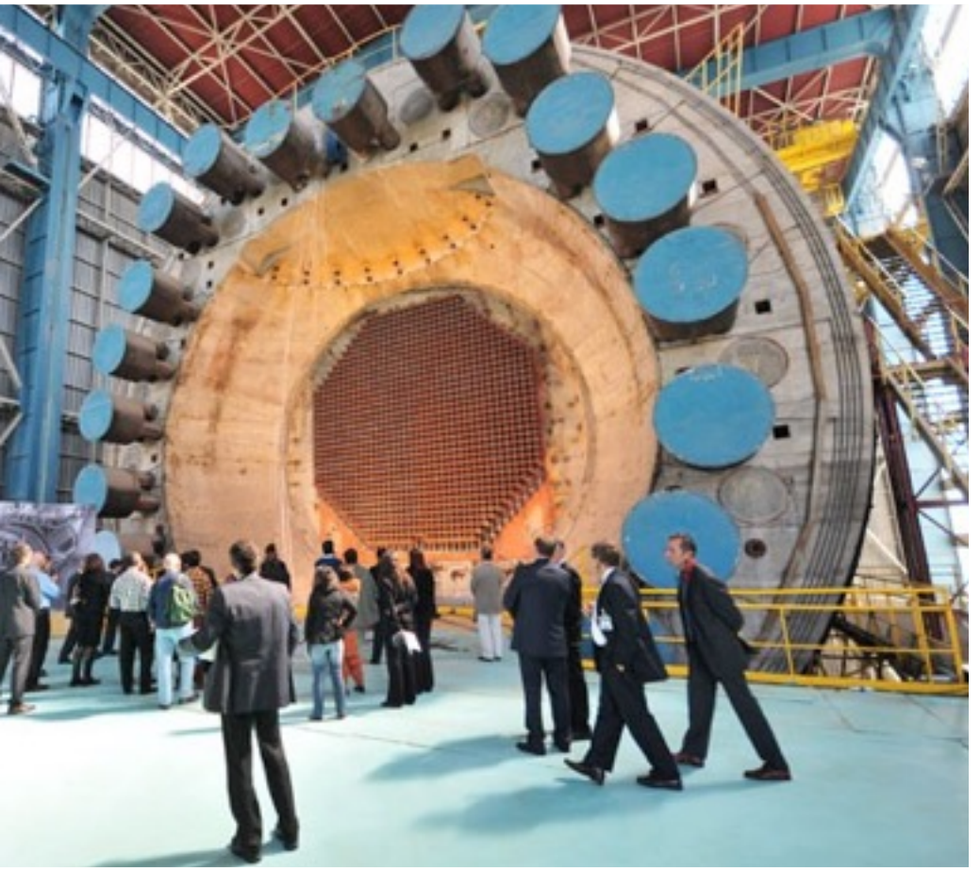


FISSILE MATERIAL STOCKPILE DECLARATIONS AND COOPERATIVE NUCLEAR ARCHAEOLOGY

Alexander Glaser

Princeton University

IPFM Meeting
Washington, DC, March 15, 2016

Revision 1

2010 NPT REVIEW CONFERENCE

SELECTED ACTION ITEMS FROM FINAL DOCUMENT

Action 19: Transparency and Verification for Nuclear Disarmament

"All States agree on the importance of supporting cooperation among Governments, the United Nations, other international and regional organizations and civil society aimed at increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament."

Action 21: Standard Reporting Form

"As a confidence-building measure, all the nuclear-weapon States are encouraged to agree as soon as possible on a standard reporting form and to determine appropriate reporting intervals for the purpose of voluntarily providing standard information ..."

TRANSPARENCY SCORECARD, 2016

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Number of total warheads	Approximate	No	Yes (upper limit)	Yes (upper limit)	Relative (out of date)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
International R&D Activities	Yes	No	Yes	No	Some

DECLARATIONS

OF FISSILE MATERIAL STOCKPILES

POSSIBLE REPORTING FORM

FOR A FISSILE MATERIAL DECLARATION

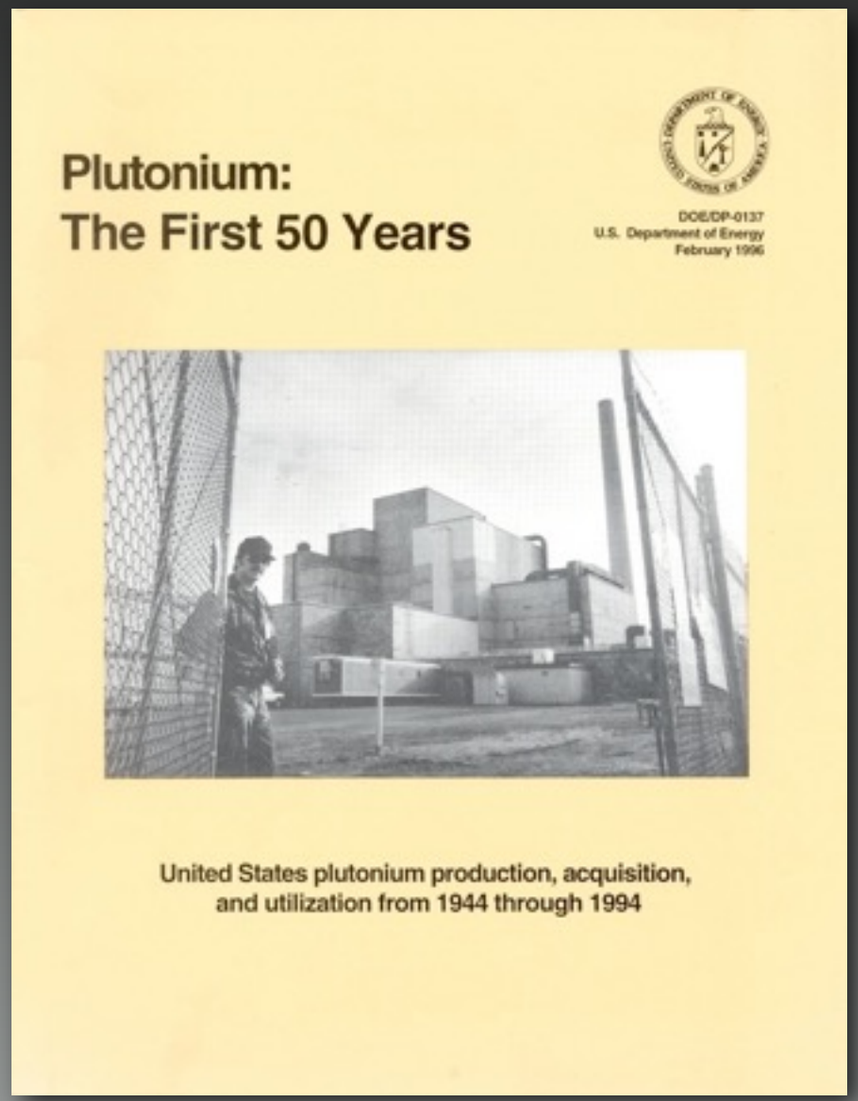
	HEU	Plutonium
Inventory as of (DATE)	.....	.....
Military, available for weapons	.....	.....
Military, reserved for non-weapon purposes	.....	.....
Military, in irradiated fuel	.....	.....
Excess military, not available for IAEA safeguards	.....	.....
Civilian, not available for IAEA safeguards	.....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

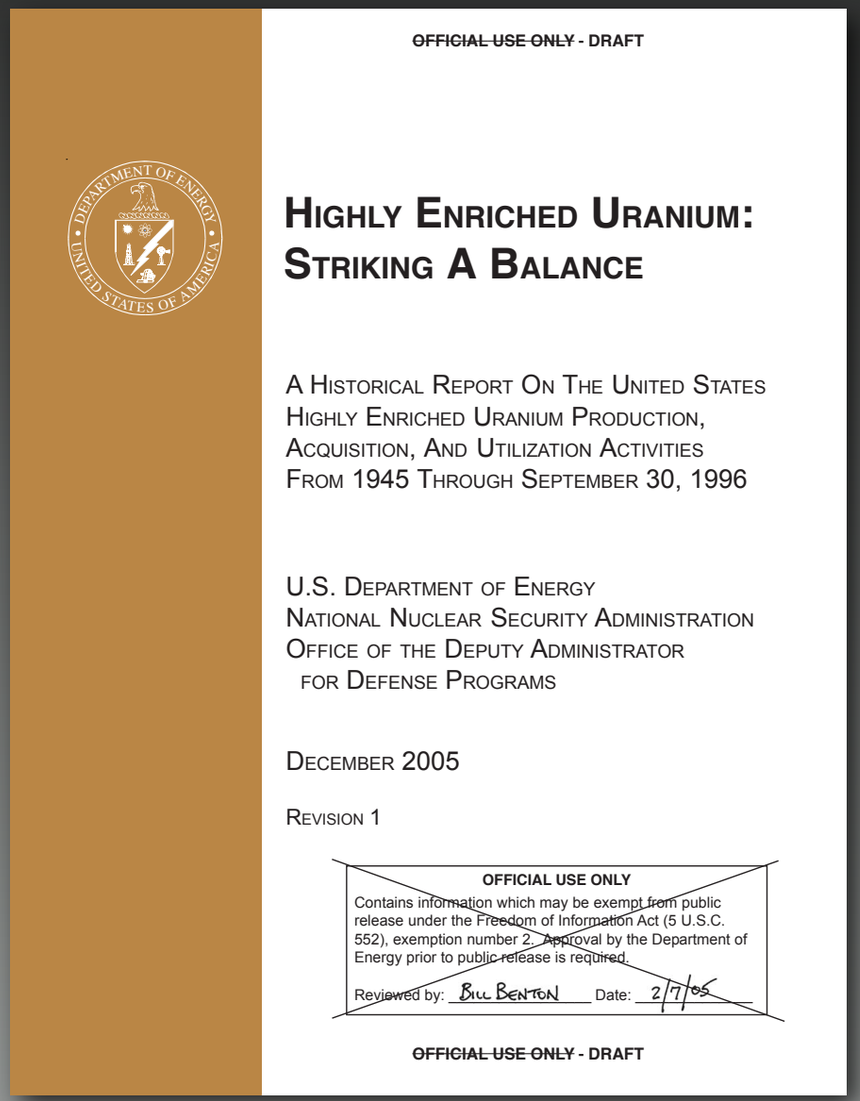
Specifying average isotopics (uranium-235 content in HEU and plutonium-239 in plutonium) would enable further consistency checks of the declarations

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

THE UNITED STATES HAS ALREADY MADE BASELINE DECLARATIONS

(BUT COULD UPDATE THEM MORE FREQUENTLY)



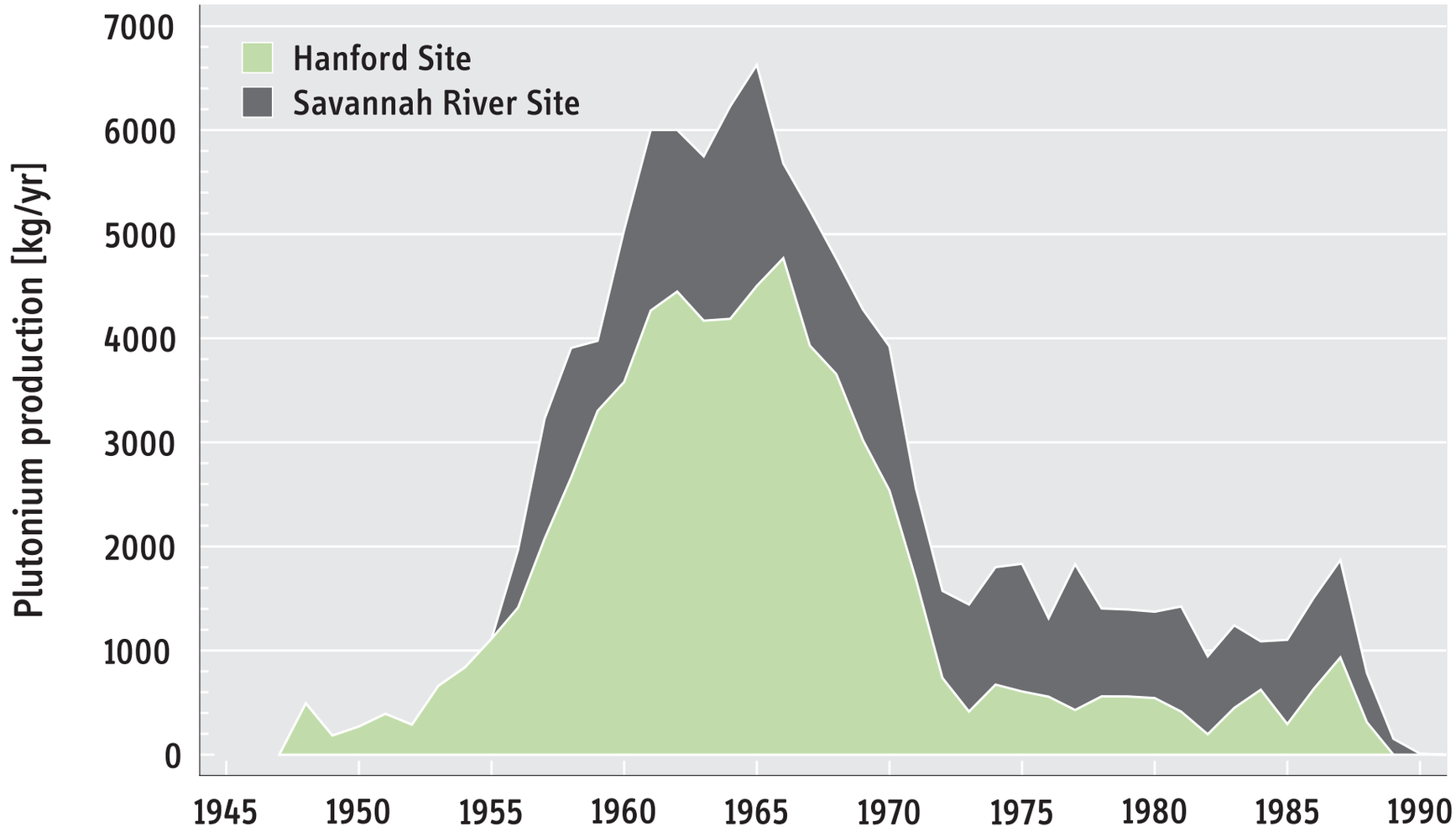


1996 and 2001 U.S. Declarations on Plutonium and HEU

EXAMPLE

ANNUAL U.S. PLUTONIUM PRODUCTION

(THE SAME INFORMATION IS AVAILABLE FOR HEU)

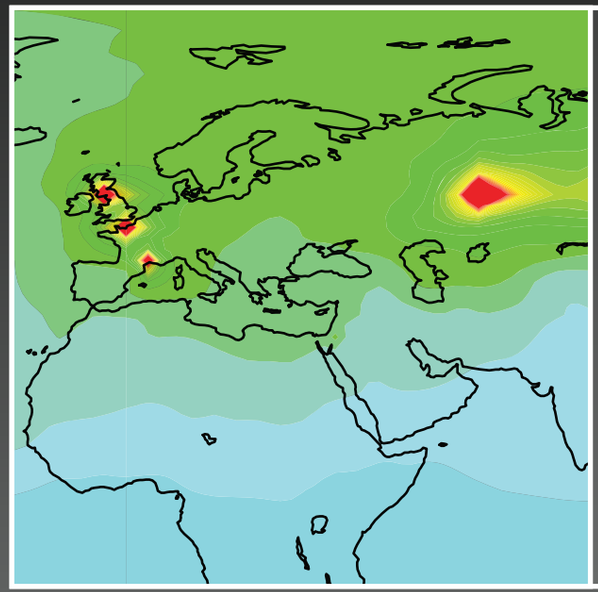


Plutonium: The First 50 Years: United States Plutonium Production, Acquisition and Utilization from 1944 Through 1994
U.S. Department of Energy, DOE/DP-0137, 1996, www.ipfmlibrary.org/doe96.pdf

VERIFICATION OF BASELINE DECLARATIONS

AND THE CASE FOR NUCLEAR ARCHAEOLOGY

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 verification

(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 and thereby verify declar[...]ions of plutonium production in the reactor. In the secon[d] technique, the ratio of th[e ...] of U-235 to that of U-234 in the tails is used [to] determine whether a g[...] in the production of lo[w] enriched uranium, whi[...] uranium 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 thresh[o...]

It is impor[...] capabilities a[...]

a. School of [...]

Science and Global Security, 19:223–233, 2011

ISSN: 0892-9882 print / 1547-7800 online
DOI: 10.1080/08929882.2011.616124

Routledge
Taylor & Francis Group

Nuclear Archaeology for Heavy-Water-Moderated Plutonium Production Reactors

Alex Gasner and Alexander Glaser

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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[...] [h]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, [g]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, [Ba]ltimore, MD, July 11–15, 2010.
[...] Department of Geosciences, for advi[...]
[...] Matos from Argonne Nati[...]
[...] trace anal[...]

Science & Global Security, 22:27–49, 2014

ISSN: 0892-9882 print / 1547-7800 online
DOI: 10.1080/08929882.2014.871881

Routledge
Taylor & Francis Group

Nuclear Archaeology for Gaseous Diffusion Enrichment Plants

Sébastien Philippe and Alexander Glaser

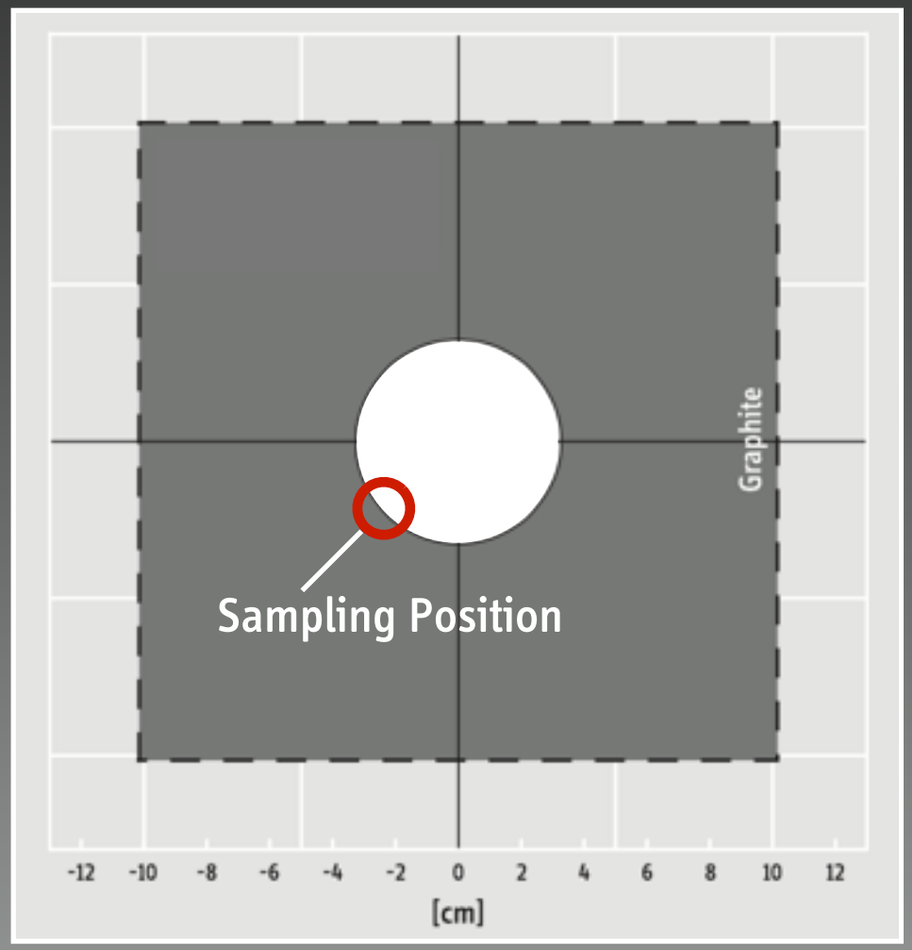
Nuclear Futures Laboratory, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, NJ, USA

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 und[...] gaseous diffu[...]

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

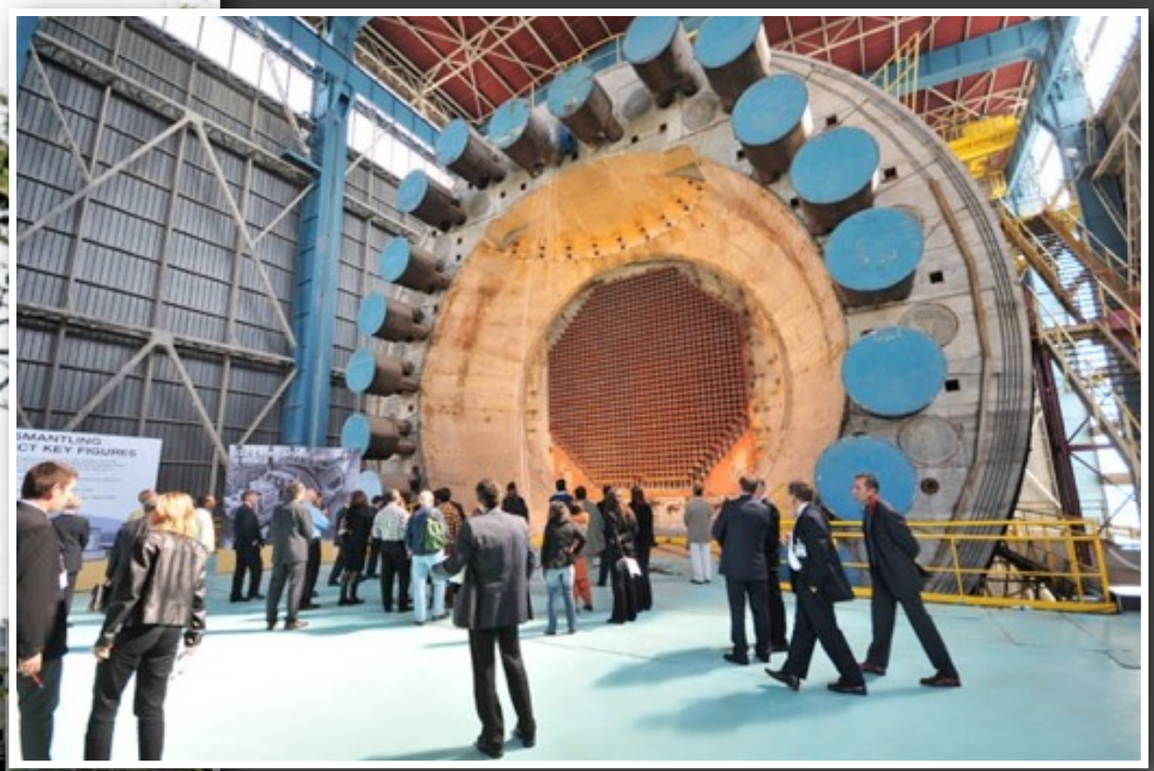
Waste storage

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

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