NMMSS 2011
Users Annual Training Meeting
San Diego, CA
May 17-19, 2011
Accountability | Accuracy | Compliance

NMMSS, Nuclear Archaeology, and the Verification of Nuclear Disarmament

Alexander Glaser

Department of Mechanical and Aerospace Engineering
and Woodrow Wilson School of Public and International Affairs
Princeton University

A New Era of Transparency?

United States

May 2010 Declaration of U.S. Nuclear Weapon Stockpile

"As of September 30, 2009, the U.S. stockpile of nuclear weapons consisted of 5,113 [active and inactive] warheads. This number represents an 84 percent reduction from the stockpile's maximum (31,255) at the end of fiscal year 1967, and over a 75 percent reduction from its level (22,217) when the Berlin Wall fell in late 1989."

Increasing Transparency in the U.S. Nuclear Weapons Stockpile, U.S. Department of Defense, Fact Sheet, May 3, 2010
available at www.defense.gov/npr, mirrored at www.ipfmlibrary.org/gov10.pdf

United Kingdom

March 2009 and May 2010 Declarations

"Our operationally available warheads now number fewer than 160"

UK Prime Minister Gordon Brown, March 2009

Total number of nuclear weapons in the UK stockpile does not exceed 225

UK Foreign Secretary William Hague, May 2010, www.twitter.com/WilliamJHague

(4 submarines x 16 missiles per boat x 3 warheads per missile = 192 warheads)

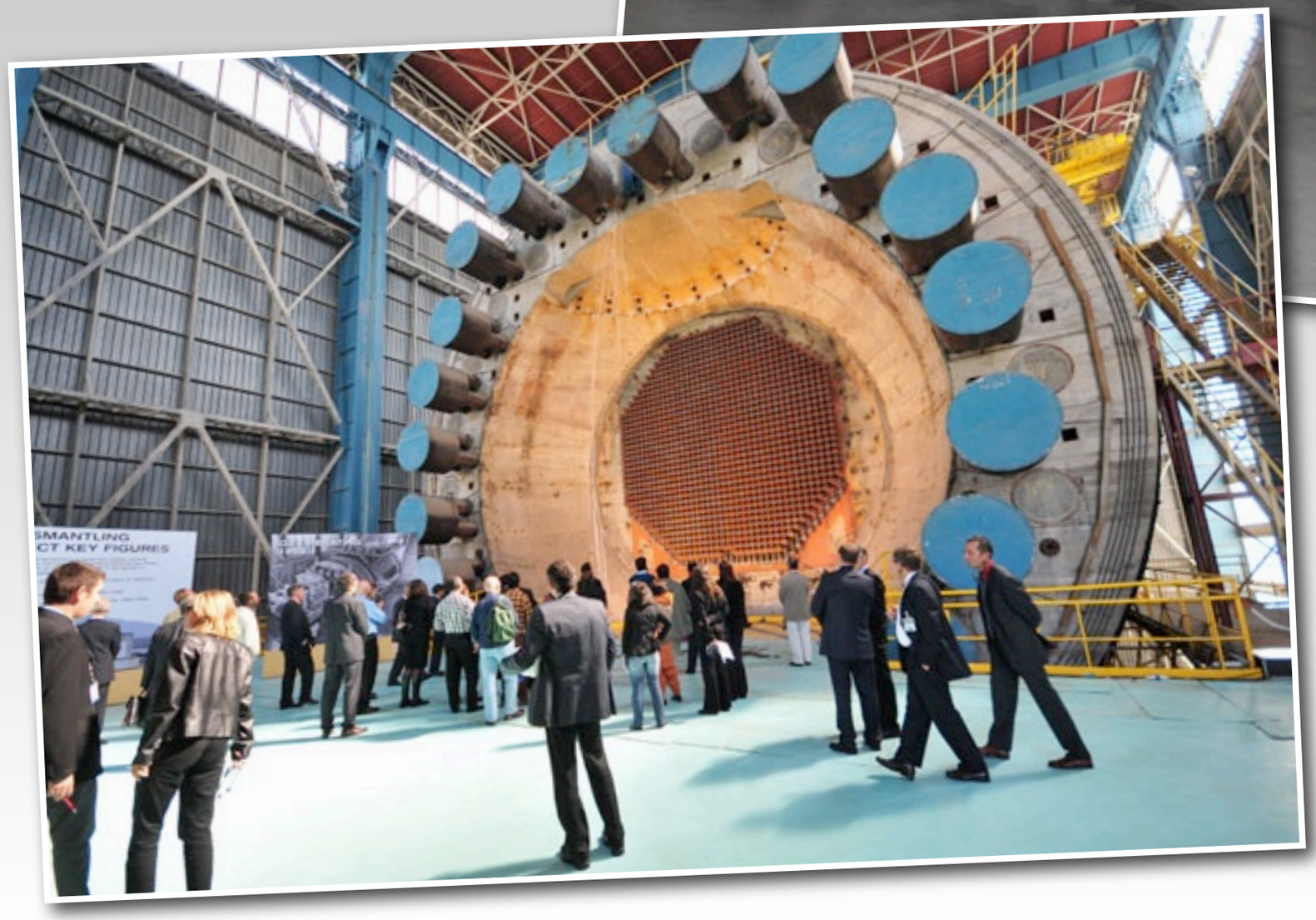
France

March 2008 Announcement by French President N. Sarkozy

"I can tell you that our arsenal will include fewer than 300 nuclear warheads. [...]

I have decided to invite international experts to observe the dismantlement of our Pierrelatte and Marcoule military fissile material production facilities."

Nicholas Sarkozy, President of the French Republic
Presentation of *"Le Terrible"* in Cherbourg
21 March 2008



Picture galleries available at
www.francetnp2010.fr

Fissile Material Stocks

Global Fissile Material Report 2008

Scope and Verification of a Fissi

Third annual report of the International Panel on

Global Fissile M
Report 2009

A Path to Nuclear Disarma

Fourth annual report of the Inter

Global Fissile Material
Report 2010

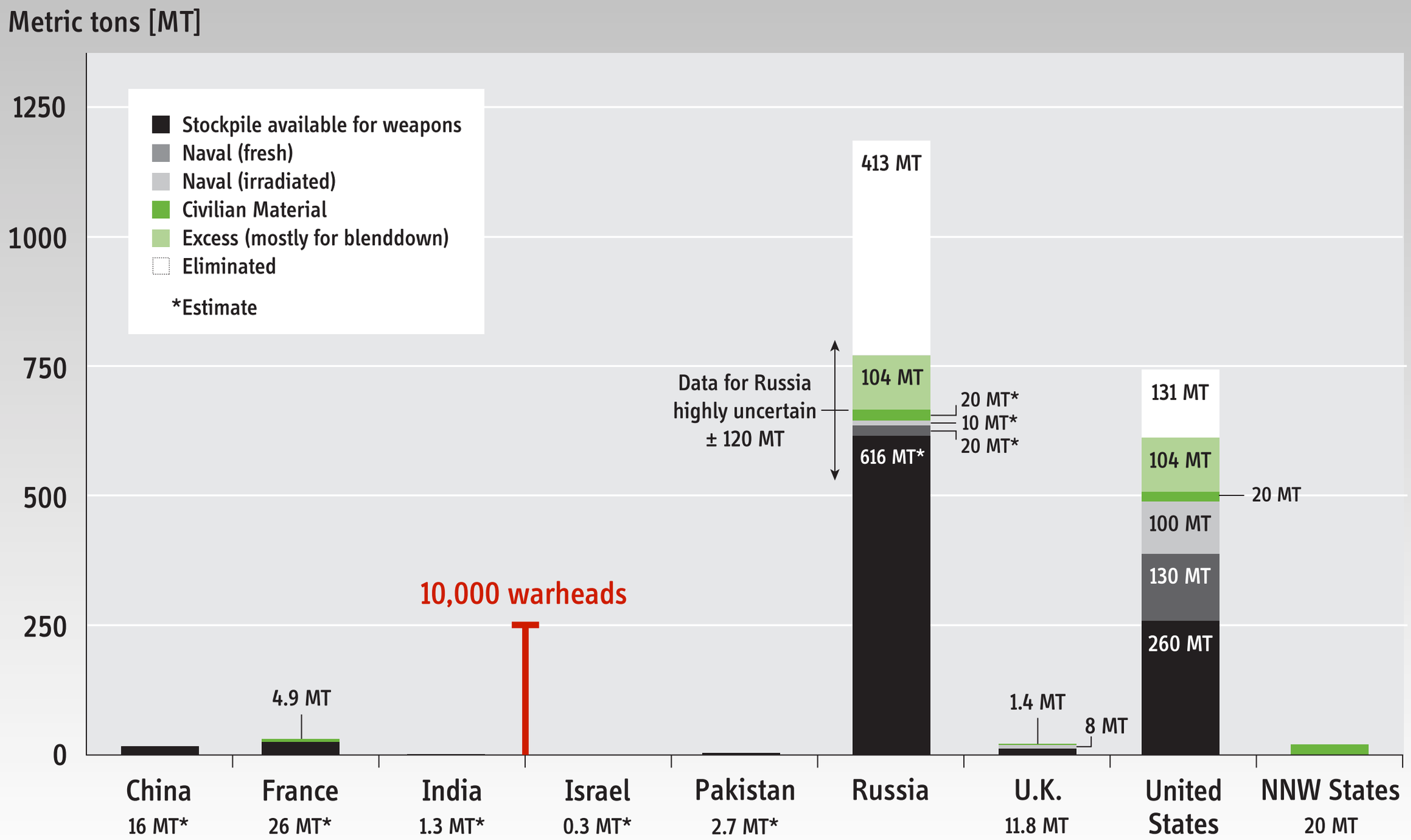
Balancing the Books: Production and Stocks

Fifth annual report of the International Panel on Fissile Materials

IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

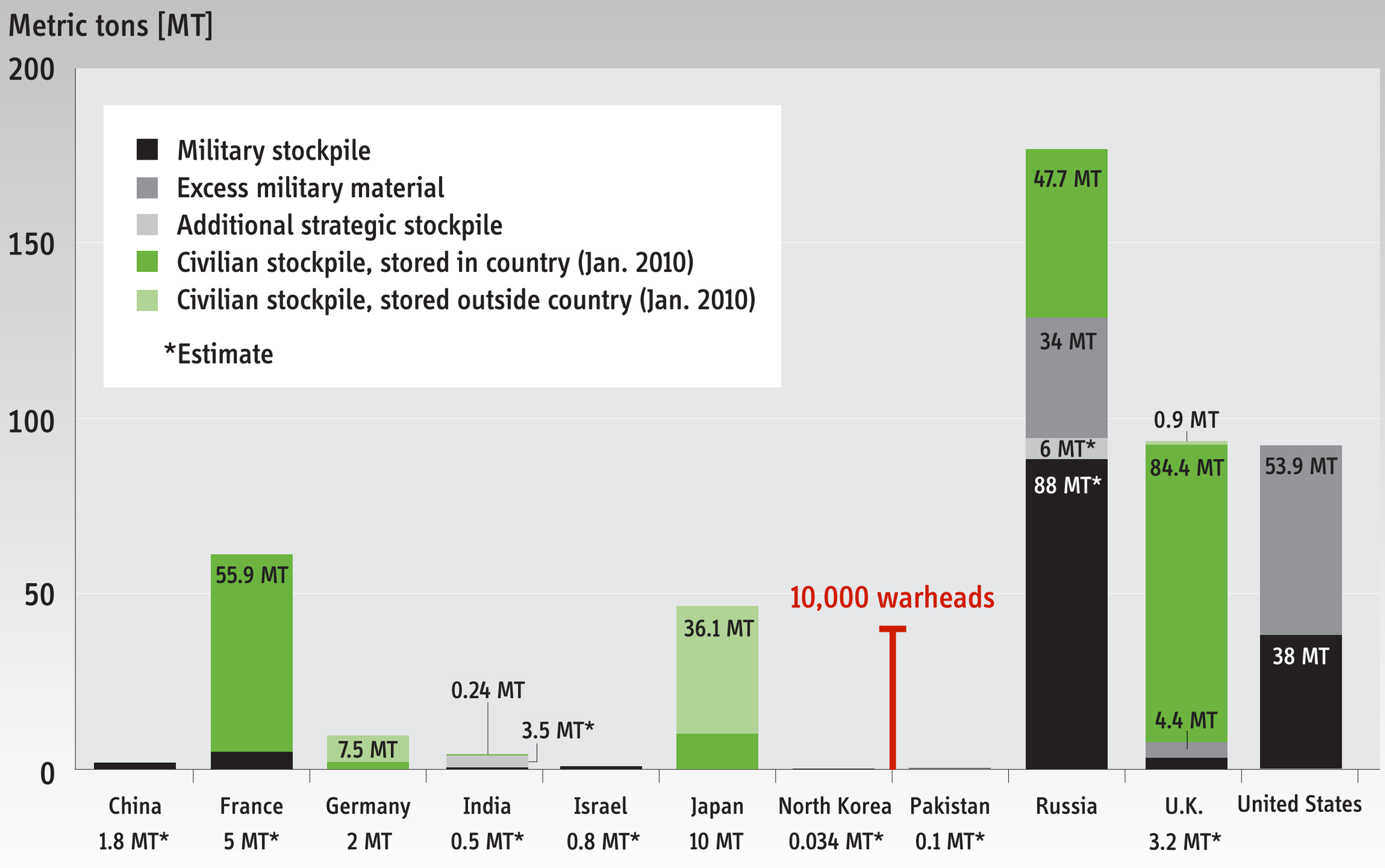
HEU Stockpiles, 2010

Global stockpile is about 1475 tons, about 99% is in weapon states



Plutonium Stockpiles, 2010

Global stockpile is about 485 tons, more than half is civilian and this stock is growing



Fissile Material Declarations

Content of Declarations and Sequencing of Information Release

	Level of Detail	Example
Initial Declarations *(unverified)*	Aggregate	Total inventory
	By Type	Historical production data for different materials (and selected characteristics)
	By Site / Facility	Same by site/facility
Verified Declarations	By Item	Location, mass, composition of each item or container

Content of Initial Declarations

1. **Material available for weapons**
   (in warheads, warhead components and working stocks)
2. **Material that has been declared excess for weapons purposes**
3. **Highly enriched uranium for naval and other military-reactor use**
4. **Civilian material**

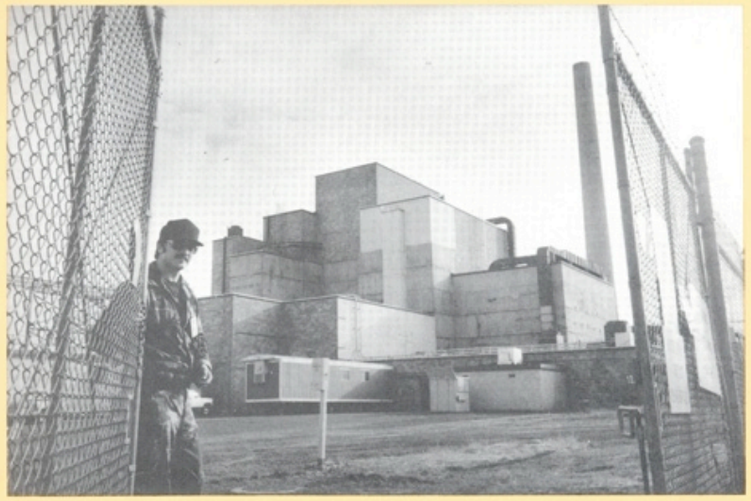
Declarations organized along those lines would not go (far) beyond what the United States and the United Kingdom have already made public

The 1996 and 2001 U.S. Declarations

(based on NMMSS)

Plutonium:
The First 50 Years

DOE/DP-0137
U.S. Department of Energy
February 1996



United States plutonium production, acquisition, and utilization from 1944 through 1994

~~OFFICIAL USE ONLY~~ - DRAFT

HIGHLY ENRICHED URANIUM:
STRIKING A BALANCE

A HISTORICAL REPORT ON THE UNITED STATES
HIGHLY ENRICHED URANIUM PRODUCTION,
ACQUISITION, AND UTILIZATION ACTIVITIES
FROM 1945 THROUGH SEPTEMBER 30, 1996

U.S. DEPARTMENT OF ENERGY
NATIONAL NUCLEAR SECURITY ADMINISTRATION
OFFICE OF THE DEPUTY ADMINISTRATOR
FOR DEFENSE PROGRAMS

DECEMBER 2005

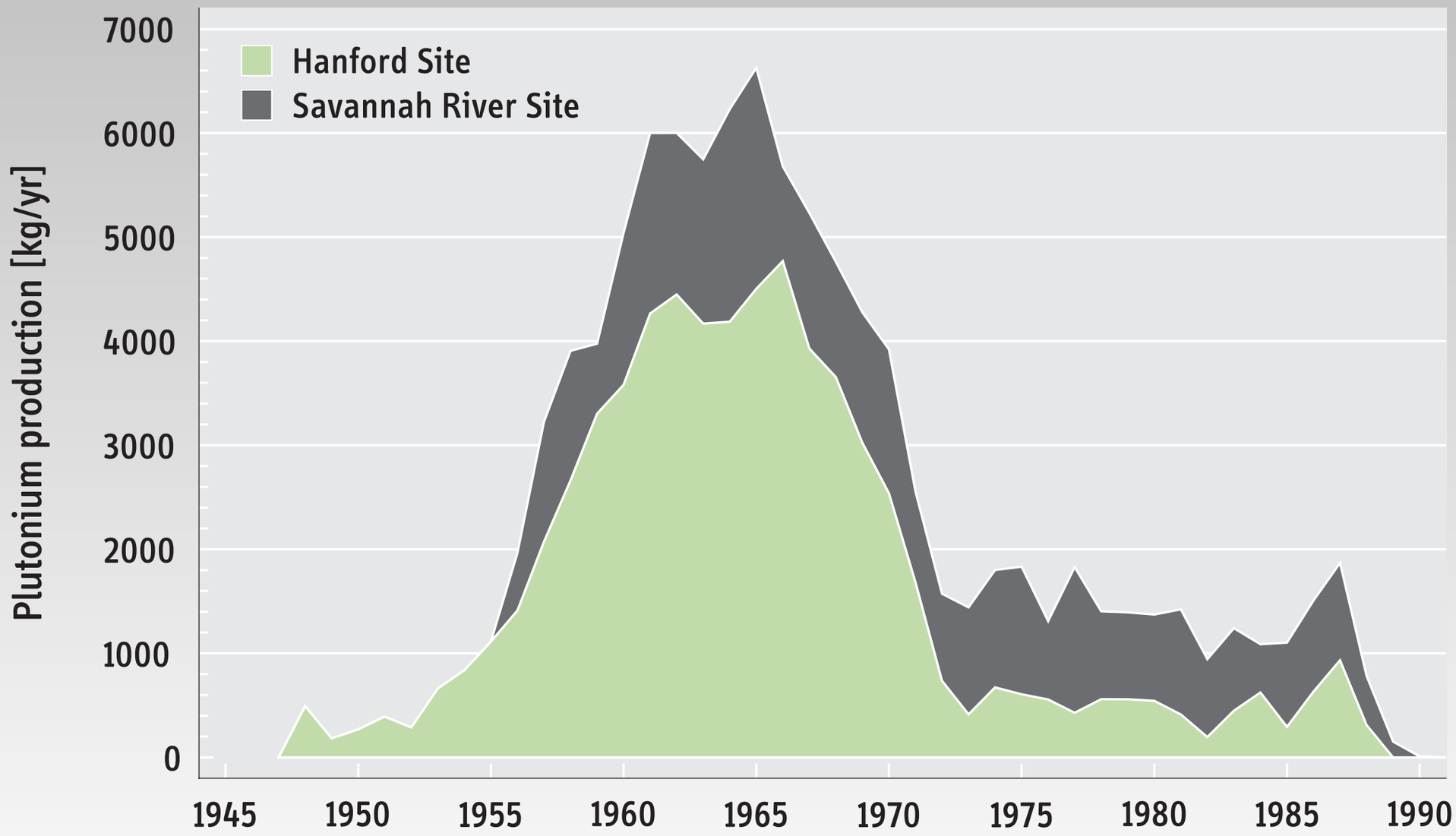
REVISION 1

OFFICIAL USE ONLY
Contains information which may be exempt from public release under the Freedom of Information Act (5 U.S.C. 552), exemption number 2. Approval by the Department of Energy prior to public release is required.
Reviewed by: Bill Benton Date: 2/7/05

~~OFFICIAL USE ONLY~~ - DRAFT

Examples from the U.S. Declarations

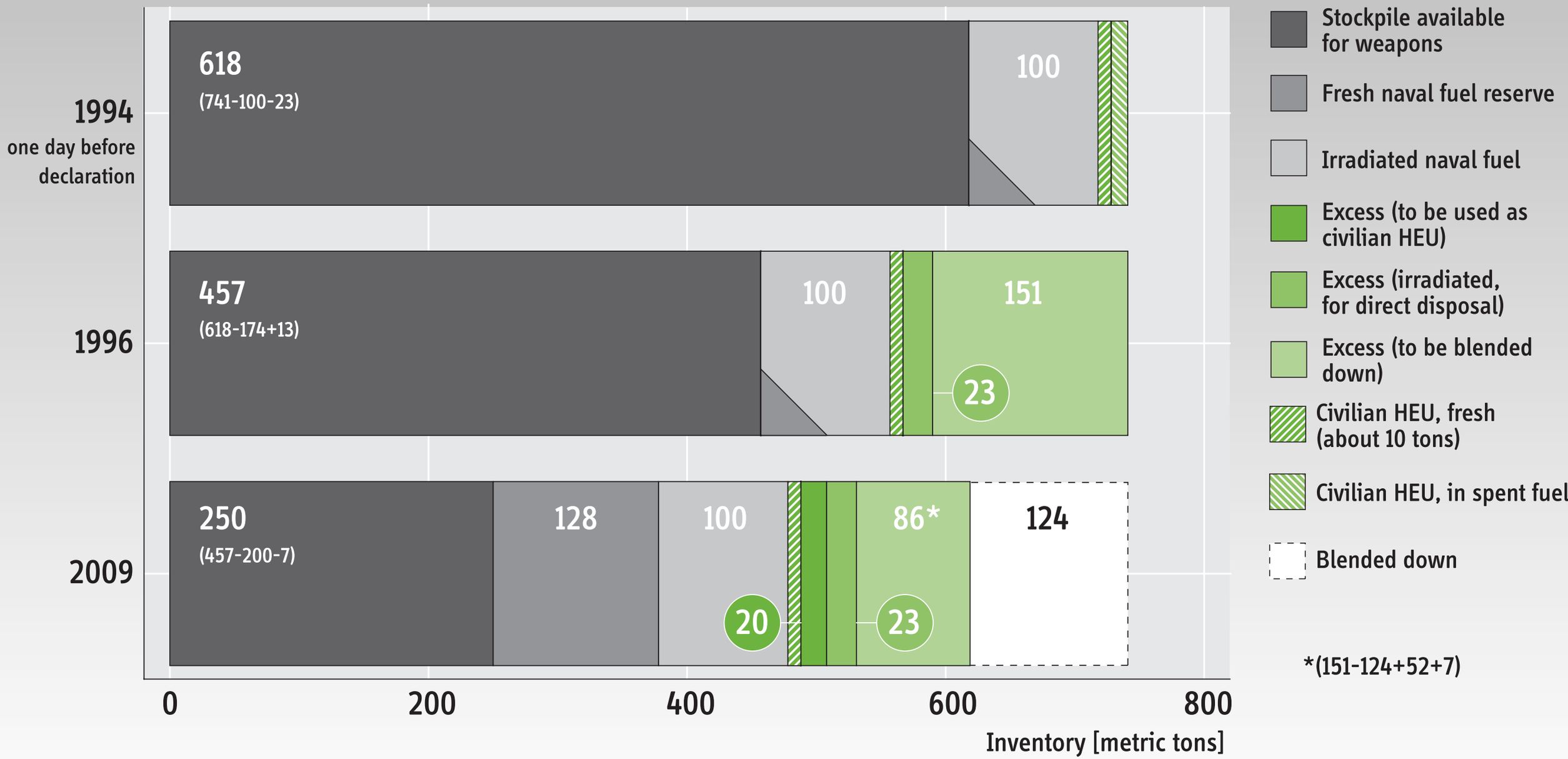
(Plutonium Production by Year and Site)



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

Example from the U.S. Declarations

(Stockpile of Highly Enriched Uranium by Category)



The US and UK Declarations Have Also Emphasized the Challenges of Preparing Them

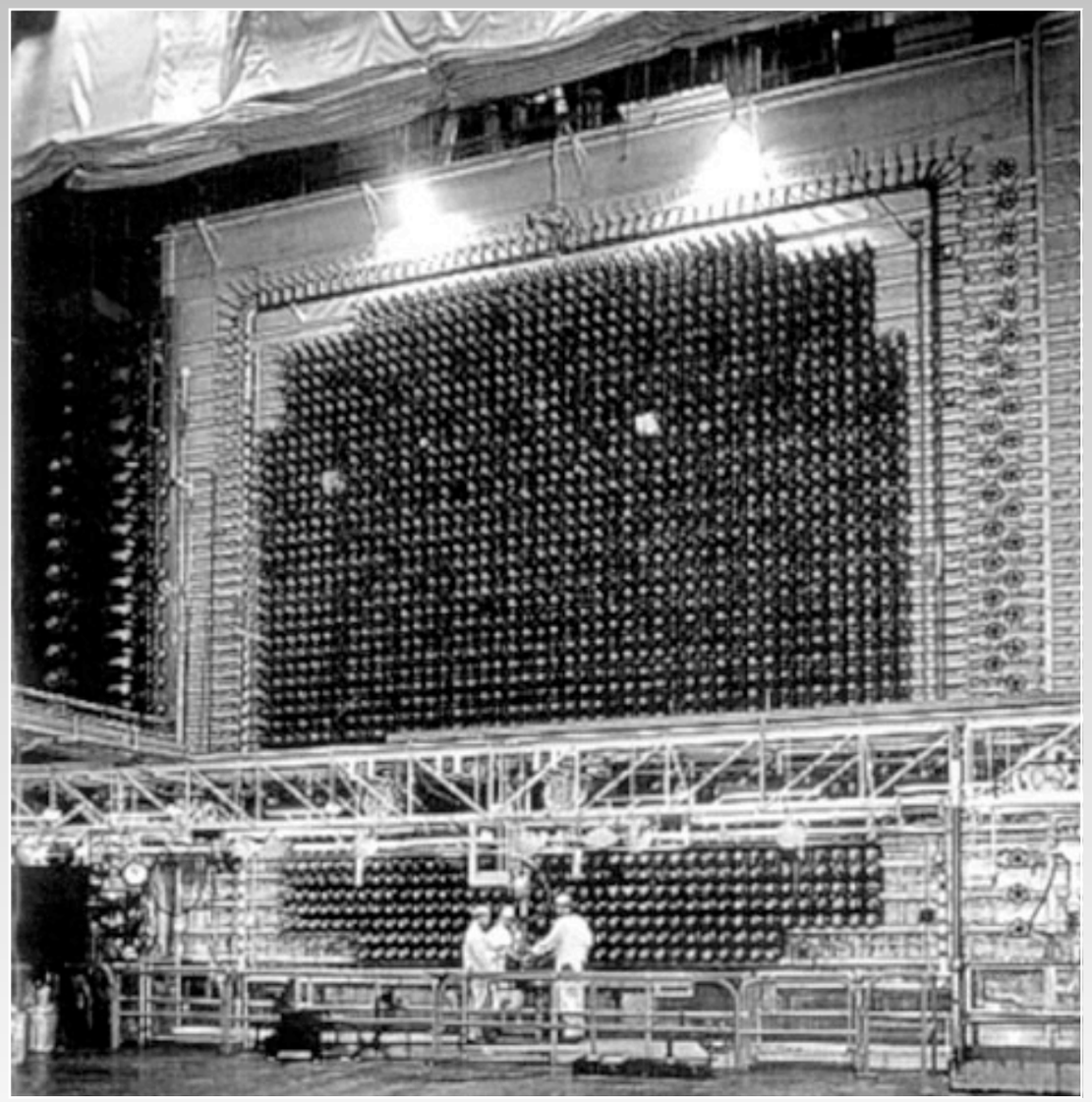
"A major problem encountered in examining the records was that a considerable number had been destroyed from the early years of the programme. [...] Even where records have survived, other problems have been encountered, including: ... [list follows]"

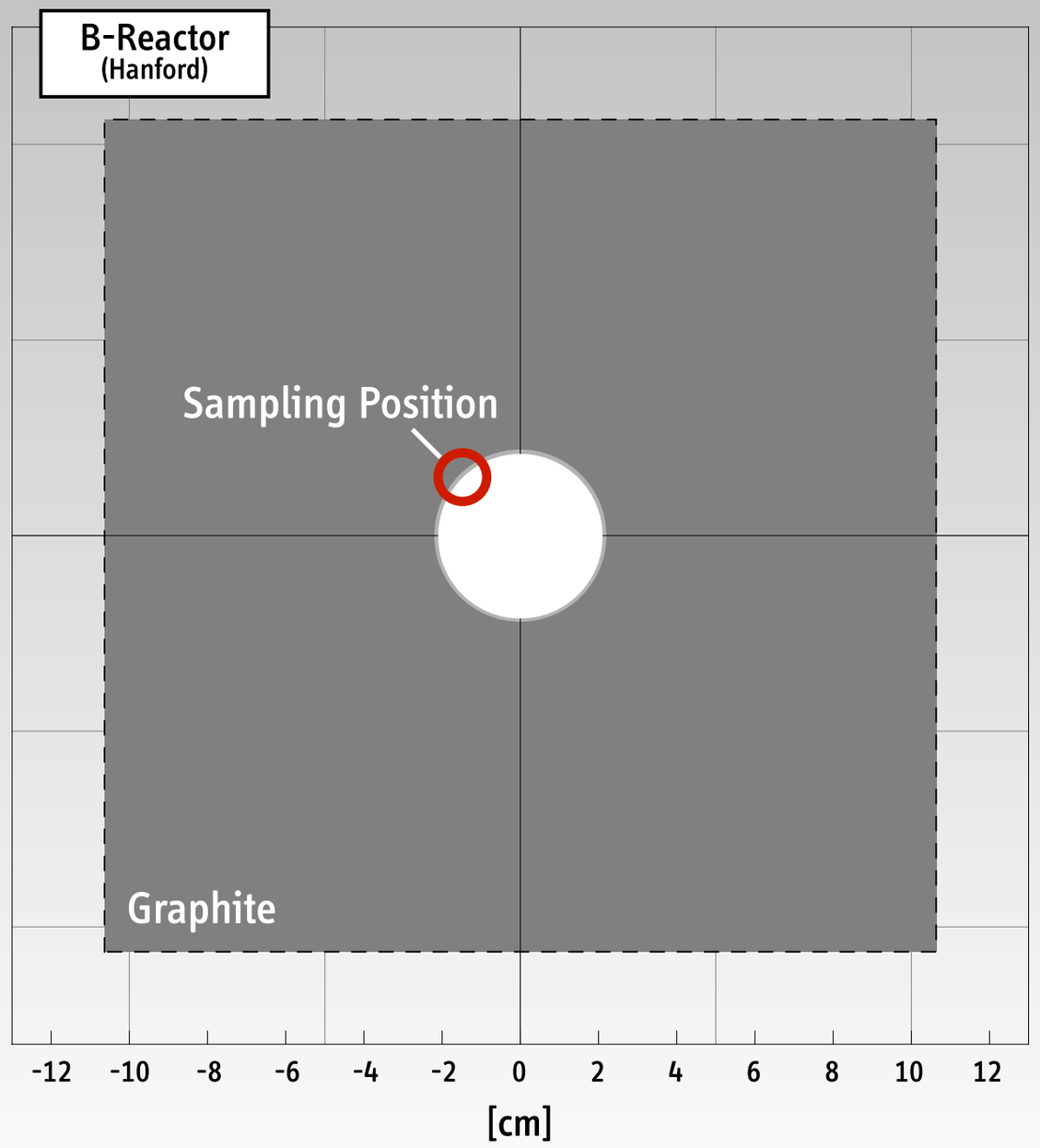
Historical Accounting for UK Defence Highly Enriched Uranium
UK Ministry of Defence, March 2006, www.ipfmlibrary.org/mod06.pdf

Verifying Declarations

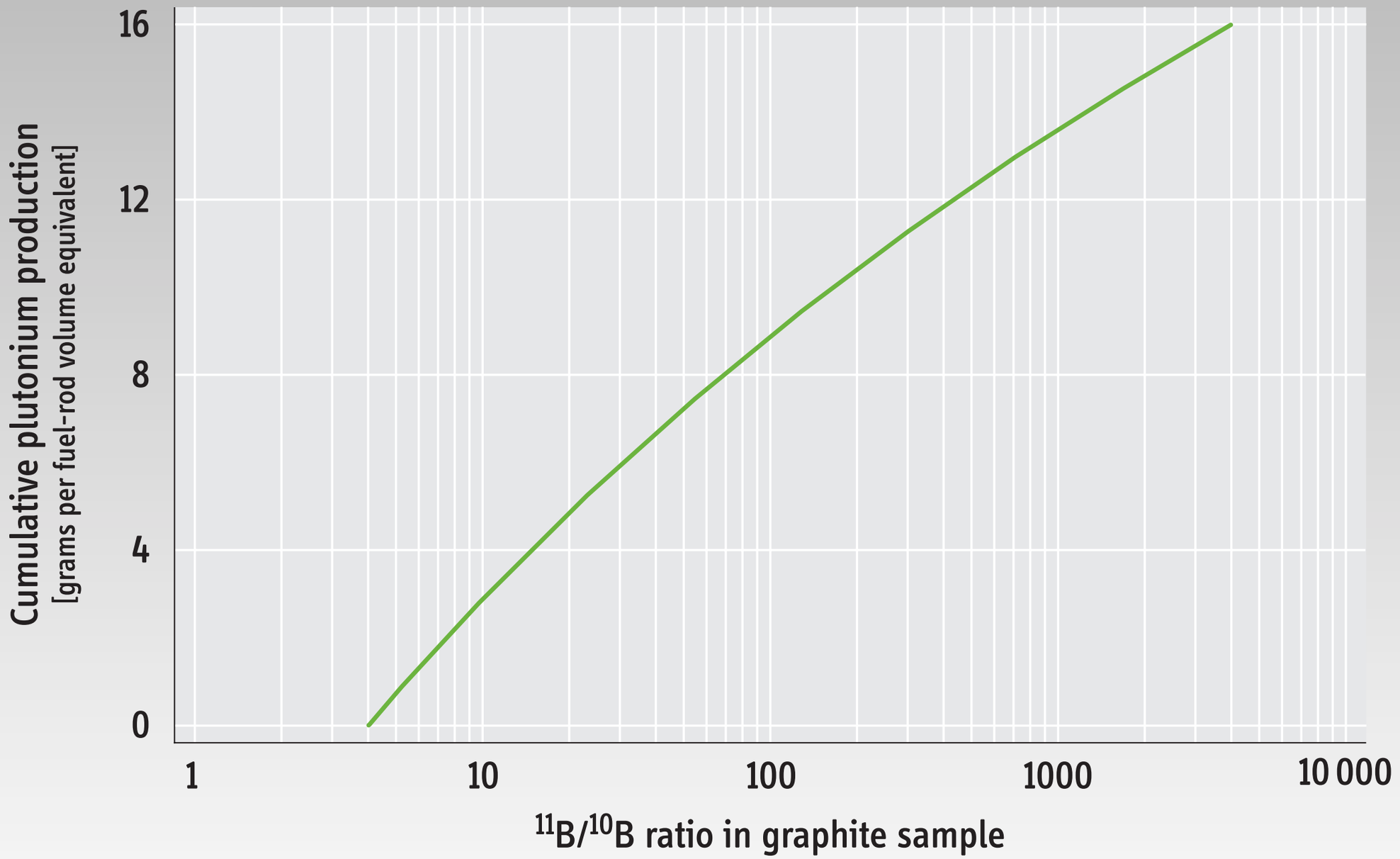
Nuclear Archaeology for Plutonium

(U.S. Hanford B Reactor, 1944–1968)





Graphite Isotope-Ratio Method (GIRM)



Jungmin Kang, "Using Graphite Isotope Ratio Method to Verify DPRK's Declaration of Plutonium Production," *under review*

North Korea's Yongbyon Reactor, 2008

Credit: CNN/Brian Rokus

Similar Methods Need to be Demonstrated for Other Types of Production Reactors

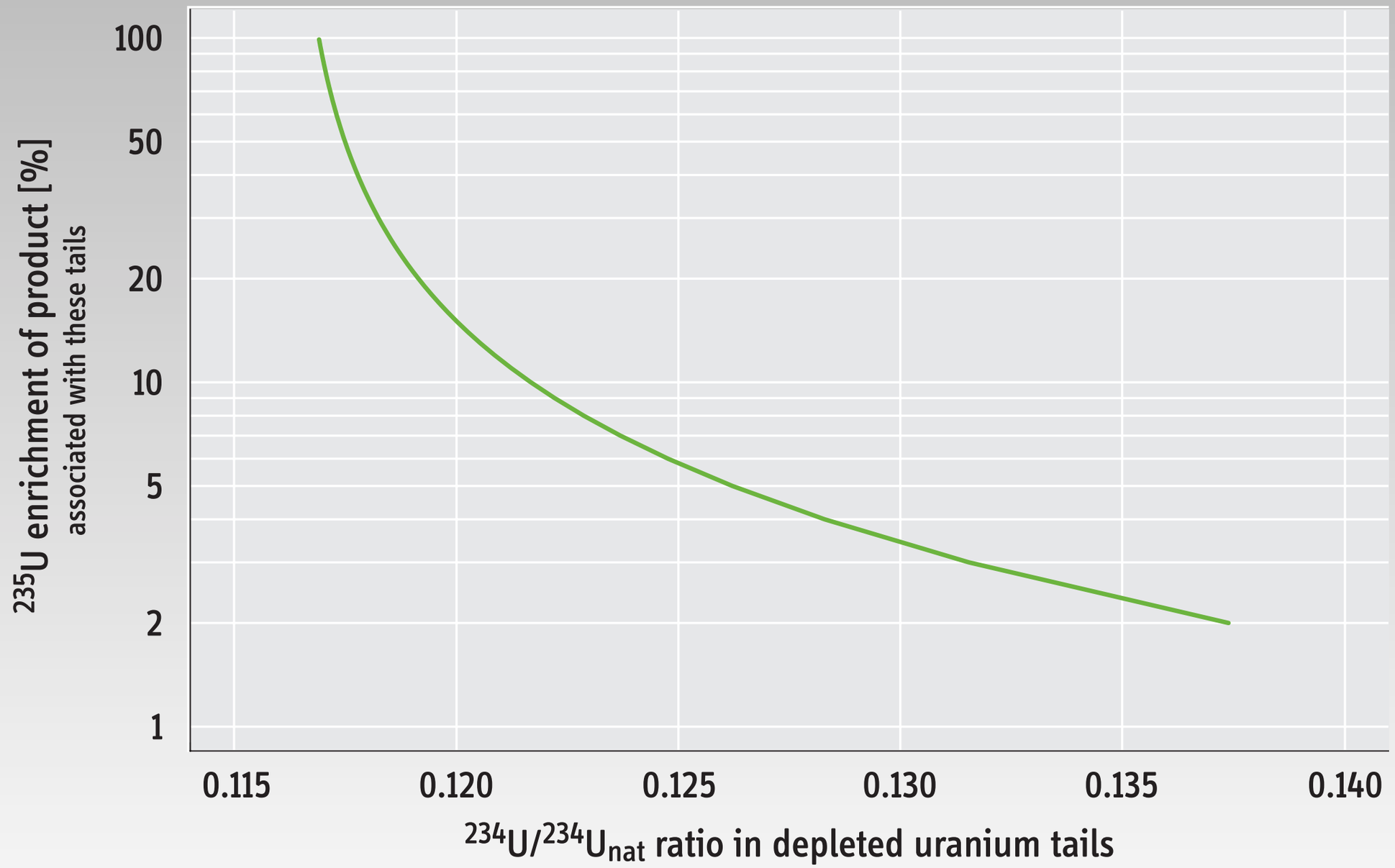
	Graphite moderated		Heavy-water moderated	
	H_2O cooled	CO_2 cooled	H_2O cooled	D_2O cooled
United States	Hanford			Savannah River
Russia	"Tomsk-7"			
U.K.		Calder Hall		
France		G-Series		Célestin
China	"Jiuquan"			
Israel				Dimona
India			Cirus/NRX	Dhruva
Pakistan			Khushab	
DPRK		Yongbyon		

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

Nuclear Archaeology for Uranium Enrichment

(Former Storage area for cylinders of depleted uranium in 2001 at K-25 Site, Oak Ridge, TN)

Measurements on Uranium Tails

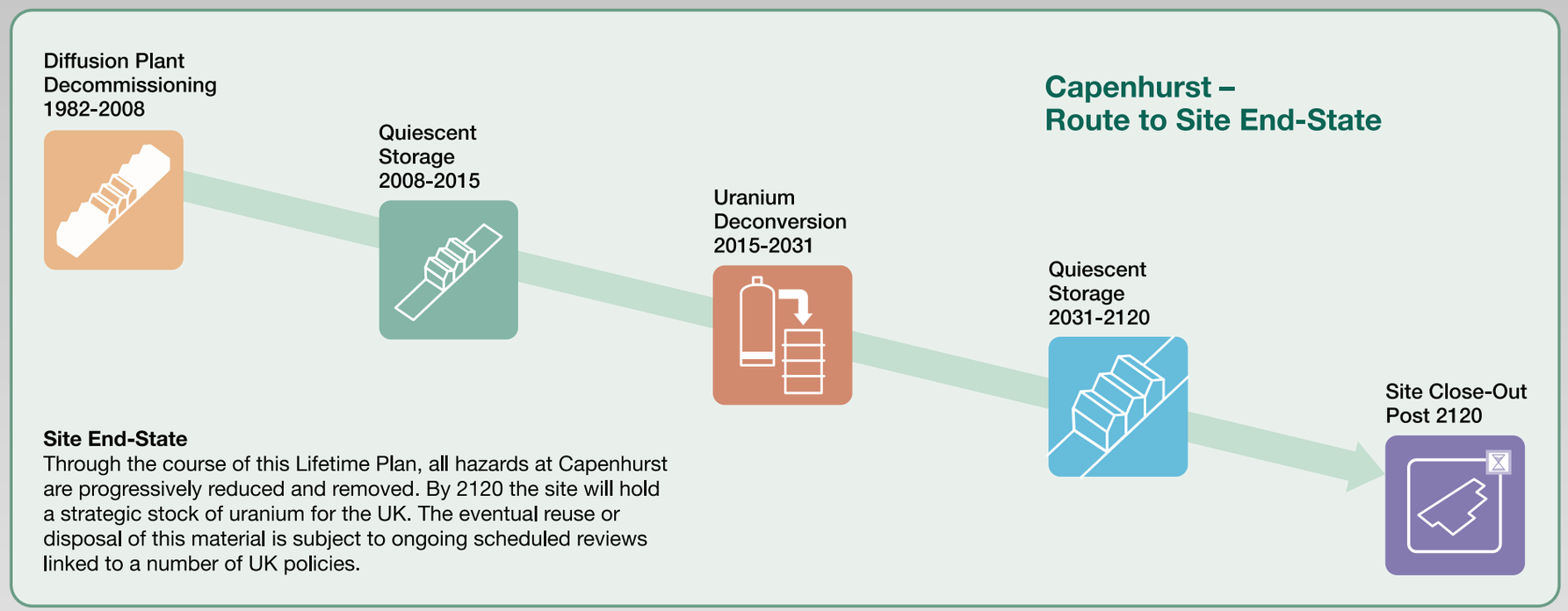


M. Sharp, "Applications and Limitations of Nuclear Archaeology," *in preparation*

Both the US and the UK Are Pursuing UF_6 Deconversion Projects

700,000 metric tons of DUF_6 in storage at Oak Ridge, Paducah, and Portsmouth

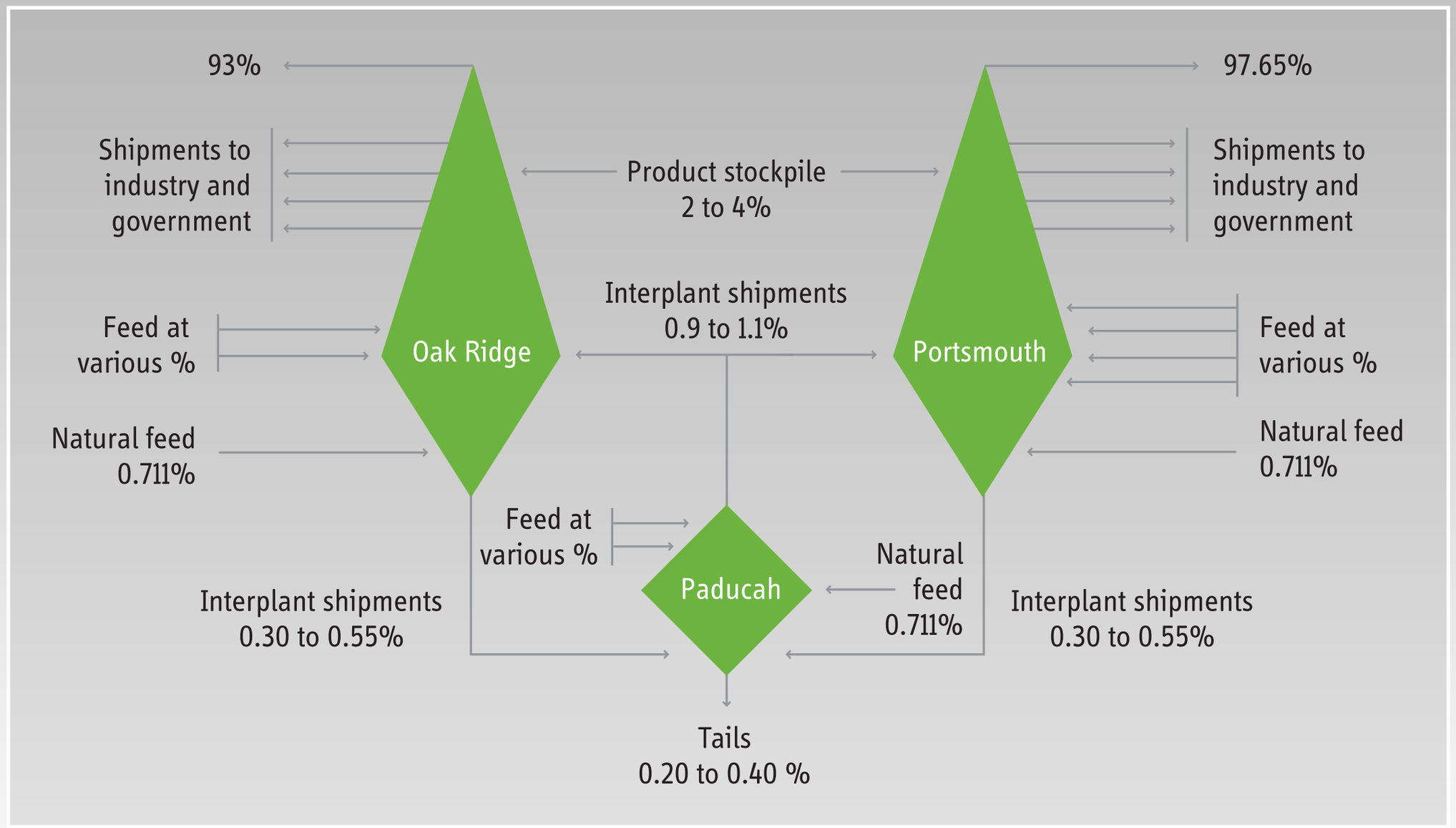
(39,000 cylinders at Paducah and 25,000 cylinders at Portsmouth; deconversion will take about 25 years)



Lifetime Plan: Capenhurst Site Summary
UK Nuclear Decommissioning Authority, 2006, www.ipfmlibrary.org/nda06b.pdf

Weren't the Production Strategies of the P5 Nuclear Weapon States Too Complex to Be Independently Verified?

Integrated Operation of the U.S. Gaseous Diffusion Plants



Highly Enriched Uranium: Striking a Balance. A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996, U.S. Department of Energy, January 2001 (publicly released in 2006), www.ipfmlibrary.org/doe01.pdf

Production Modes Leave Characteristic Signatures in the Fissile Materials

100,000 kg of natural uranium	→ ENRICHMENT →		450 kg of HEU	← INDICATOR: Clean HEU
100,000 kg of natural uranium	→ REACTOR →		70 kg of WPu	← INDICATOR: Low Pu-238 content in plutonium
100,000 kg of natural uranium	→ REACTOR →	ENRICHMENT →	70 kg of WPu plus 320 kg of HEU	← INDICATOR: Low Pu-238 content in Pu and U-236 in HEU
100,000 kg of natural uranium	→ REACTOR →	REACTOR →	70 kg of WPu plus 70 kg of WPu*	← INDICATOR: Low and high Pu-238 content in plutonium

Direct measurements of the fissile materials themselves could considerably enhance confidence in nuclear archaeology (but would require countries to declassify isotopic information)

The Way Forward

NMMSS as a model for other nuclear weapon states?

Uncertainties in military fissile material stockpiles are already significant

NMMSS is essential in keeping these uncertainties as small as possible (and in maintaining confidence in authenticity of the data)

Opportunities for re-measurements and further consistency checks exist

Need to preserve production records, facilities, and (waste) materials in a condition that will permit these measurements

(and future verification of fissile material declarations)

The Way Forward

NMMSS as a model for other nuclear weapon states?

The 2010 NPR has emphasized the importance of work in this area

"Initiating a comprehensive national research and development program to support continued progress toward a world free of nuclear weapons, including expanded work on verification technologies and the development of transparency measures."

Some precedents and many opportunities for cooperative initiatives

Start with joint demonstration exercises
to establish the methods and tools for all types of relevant plants