Scope &Verification of a Fissile Material (Cutoff) Treaty: Progress Report from the International Panel on Fissile Materials (IPFM)

Frank von Hippel, IPFM co-chair

Belfer Center for Science and International Affairs, Kennedy School of Government

Harvard University, Dec. 9, 2008, 9:30 AM

About the IPFM

Established Jan 2006 with MacArthur Foundation 5-year grant.

Mission: to help inform international policy on methods to:

- *Achieve irreversible nuclear-warhead reductions,*
- *Strengthen the nonproliferation regime, and*
- *Reduce dangers of nuclear terrorism.*

Members from *Brazil, China, France, Germany, India, Ireland, S. Korea, Japan, Mexico, Netherlands, Norway, Pakistan, Russia, S. Africa, Sweden, U.K. and U.S.*

(10 non-weapon & 7 nuclear-armed states)

22 Members (from 16 states)

7 Weapon states

Anatoli Diakov (Moscow, Russia)
Pervez Hoodbhoy (Islamabad, Pakistan))
Li Bin (Beijing, China)
Yves Marignac (Paris, France)
Abdul H. Nayyar (Islamabad, Pakistan)
R. Rajaraman (Co-Chair, New Delhi, India)
M.V.Ramana (Bangalore, India)
Mycle Schneider (Paris, France)
Shen Dingli (Shanghai, China)
Frank von Hippel (Co-Chair, Princeton, USA)
William Walker (St. Andrews, UK)

10 Non-weapon states

Jean du Preez (S.Africa)
José Goldemberg (São Paolo, Brazil)
Martin B. Kalinowski (Hamburg, Germany)
Jungmin Kang (Seoul, South Korea)
Patricia Lewis (Ireland)
Miguel Marin-Bosch (Mexico City, Mexico)
Arend Meerburg (Den Haag, Netherleands)
Henrik Salander (Stockholm, Sweden)
Ole Reistad (Olso, Norway)
Annette Schaper (Frankfurt, Germany)
Tatsujiro Suzuki (Tokyo, Japan)

Princeton University Researchers

Harold Feiveson
Zia Mian
Alexander Glaser

Completed Reports (available at www.fissilematerials.org)

Global Fissile Material Report 2006

Fissile Materials in South Asia: Implications of the US-India Nuclear Deal
-- Zia Mian, A.H. Nayyar, R. Rajaraman, M.V. Ramana (July 2006)

Japan's Spent Fuel and Plutonium Management Challenges
-- Tadahiro Katsuta and Tatsujiro Suzuki (September 2006)

Managing Spent Fuel in the United States: The Illogic of Reprocessing
-- Frank von Hippel (January 2007)

Global Fissile Material Report 2007

Reprocessing in France -- Mycle Schneider and Yves Marignac (May 2008)

Legacy of Reprocessing in the United Kingdom -- Martin Forwood (July 2008)

Global Fissile Material Report 2008 (October 2008)

Country Perspectives on the Challenges to a Fissile Material (Cutoff) Treaty

Some forthcoming IPFM reports

Draft FM(C)T -- Li Bin, John Burroughs, Merev Datan,Jean duPreez, Rebecca Johnson, Fred McGoldrick, Arend Meerburg, Henrik Salander, Tom Shea, Princeton group [doesn't mean all agreed]

Toward elimination of HEU as a Reactor Fuel

--Ole Reistad, S. Hustveit [short version in *Nonproliferation Review*]

Consolidation of Nuclear Materials in Russia, Pavel Podvig

History of Fast-neutron (Breeder) Reactors

-- Tom Cochran, Alex Glaser, Walt Patterson, Gennadi Pshakin, M.V. Ramana, Tatsujiro Suzuki

Global Fissile Material Report 2008

Scope and Verification of a Fissile Material (Cutoff) Treaty

(www.ipfmlibrary.org/gfmr08.pdf)

Overview

1. Nuclear Weapon and Fissile Material Stockpiles and Production

A Verified Fissile Material (Cutoff) Treaty

2. Why an FM(C)T is Important
3. Design Choices: Scope and Verification

Verification Challenges

4. Uranium Enrichment Plants
5. Reprocessing Plants
6. Weapon-origin Fissile Material: The Trilateral Initiative
7. HEU in the Naval-reactor Fuel Cycle
8. Challenge Inspections at Military Nuclear Sites
9. Shutdown Production Facilities

Appendix: Fissile Material and Nuclear Weapons

IPFM Design Recommendations for FM(C)T design

1. **Should be verified, like the NPT.**

2. **By the IAEA**

3. **Should include verified commitments that civilian stocks and stocks declared excess for military purposes will not be used for weapons.** [*This is why we call it an FM(C)T.*]

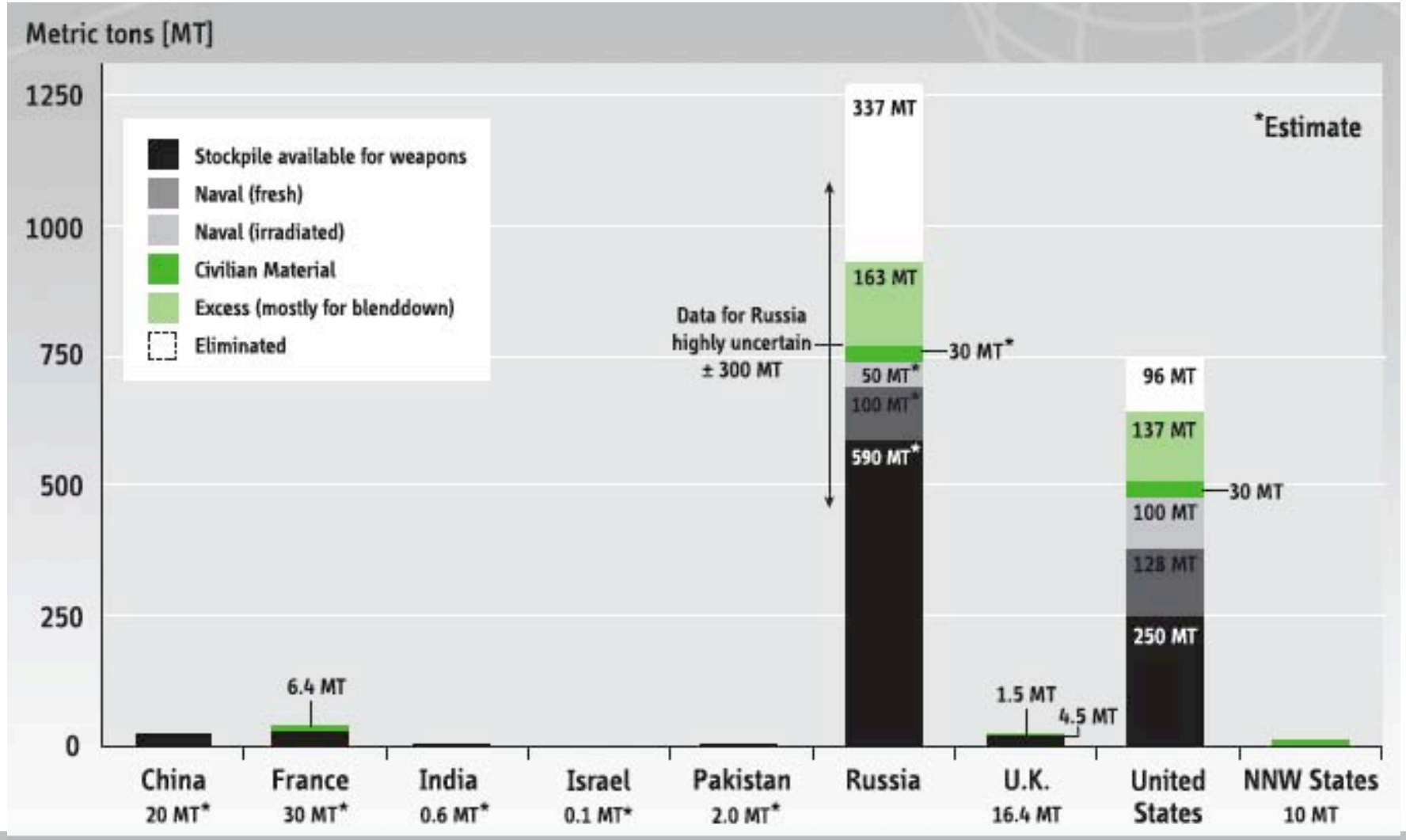
4. ***Could* include verified commitments that pre-existing fissile material used for military but non-weapon purposes (primarily naval fuel) will not be used for weapons.**

   The U.S. has reserved for future naval-reactor fuel use 128 tons of excess weapon-grade uranium (enough for 5,000 nuclear weapons). Russia presumably has a similar naval HEU stockpile.

Fissile-material Stockpiles: HEU

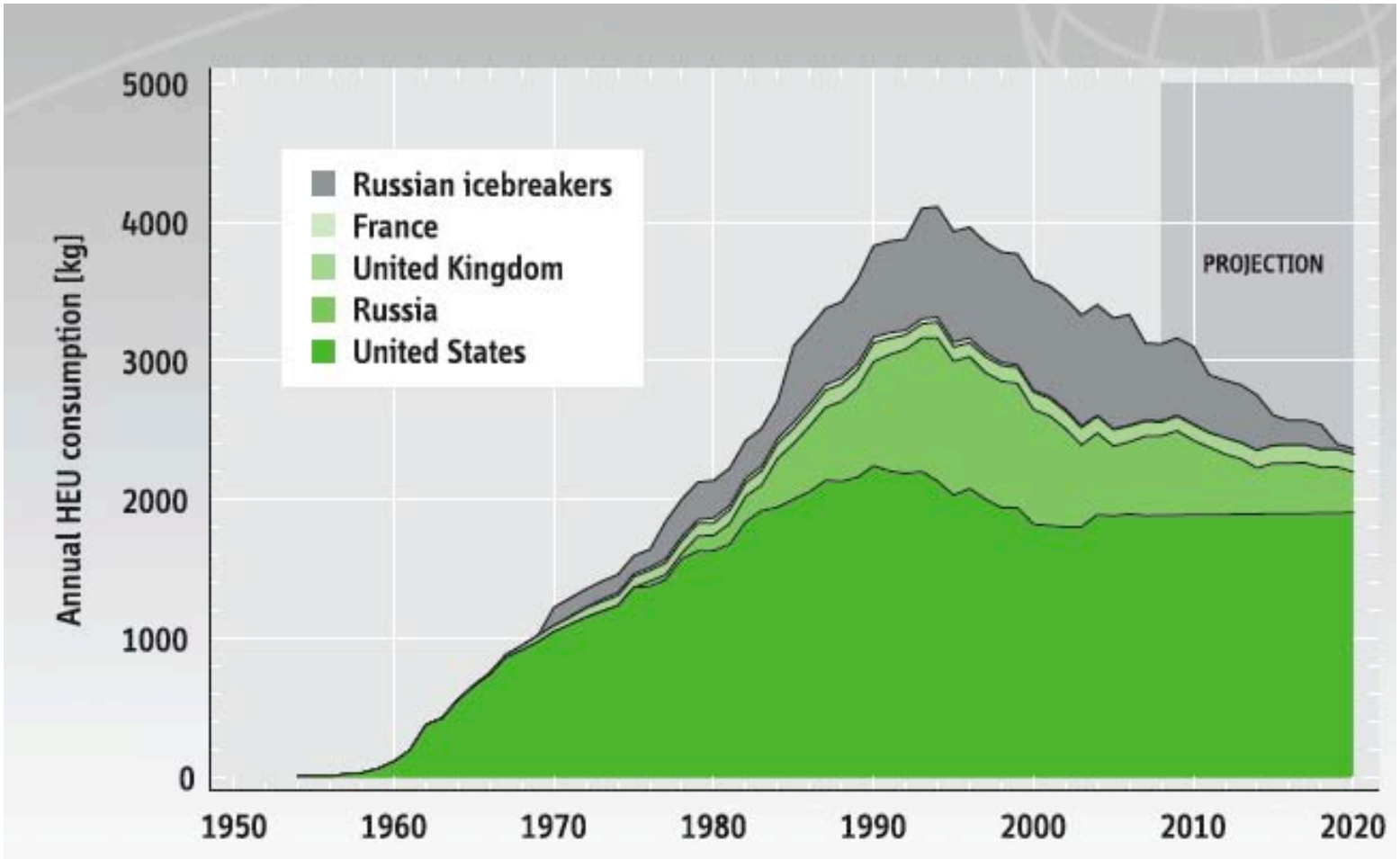
1600±300 tons total: weapons-55%; naval fuel-20%; excess-20%; civilian-5%

P-5 not producing, Pakistan producing for weapons, India for naval fuel, (Israel…?)

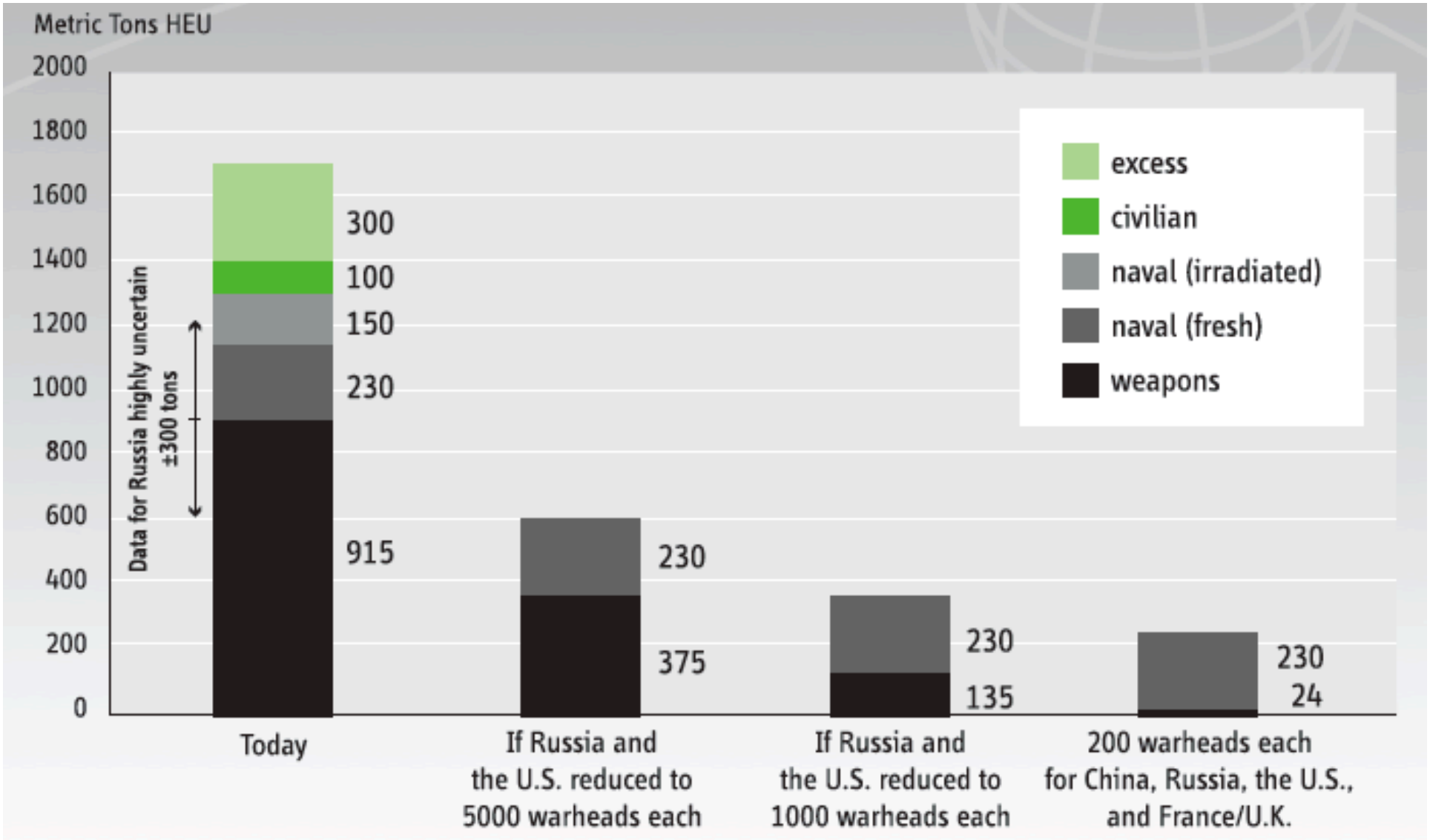


Naval HEU Use

(Ole Reistad, Styrkaar Hustveit)



The Naval HEU Overhang to Nuclear Disarmament

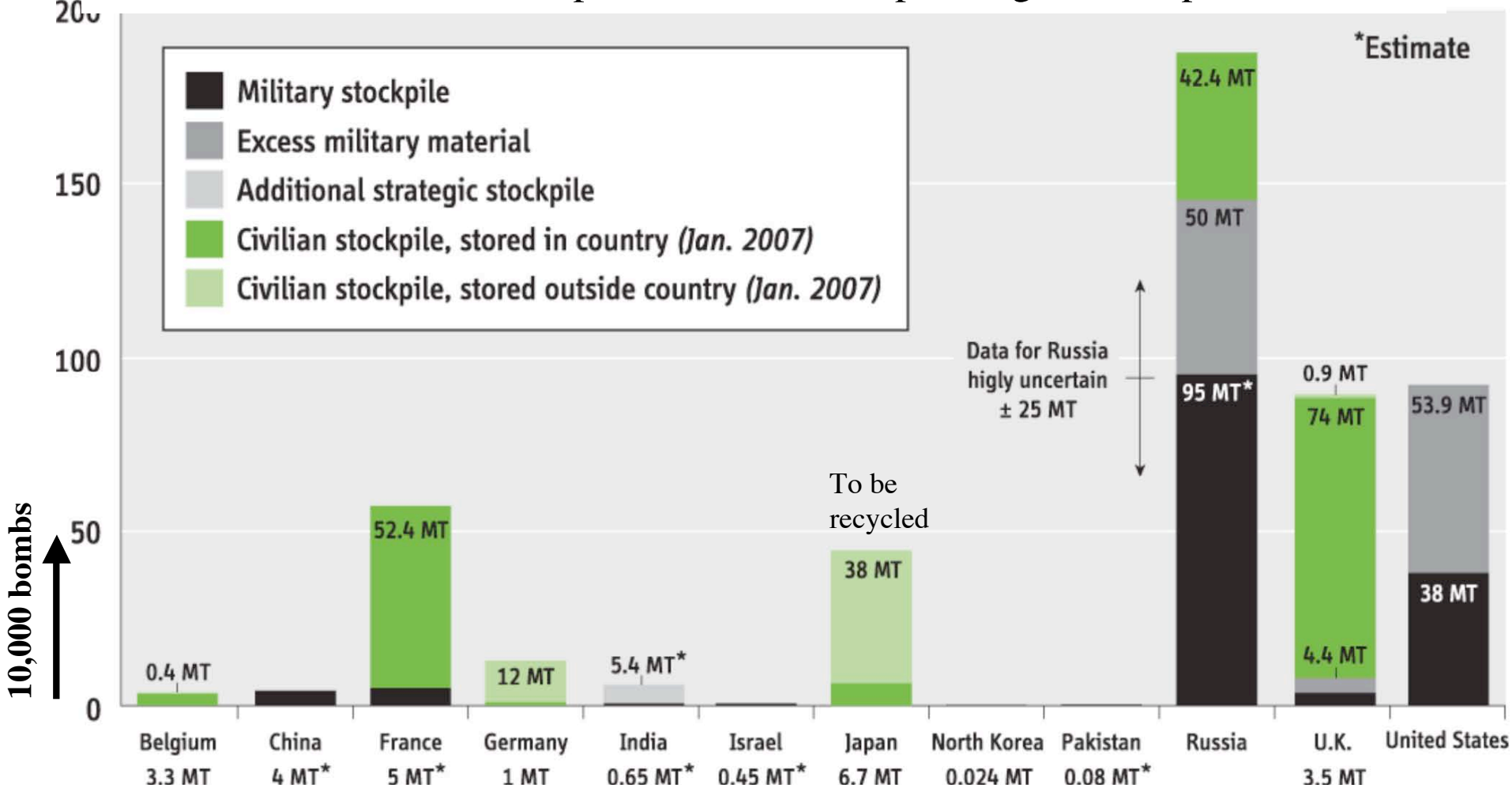


Global stocks of separated plutonium

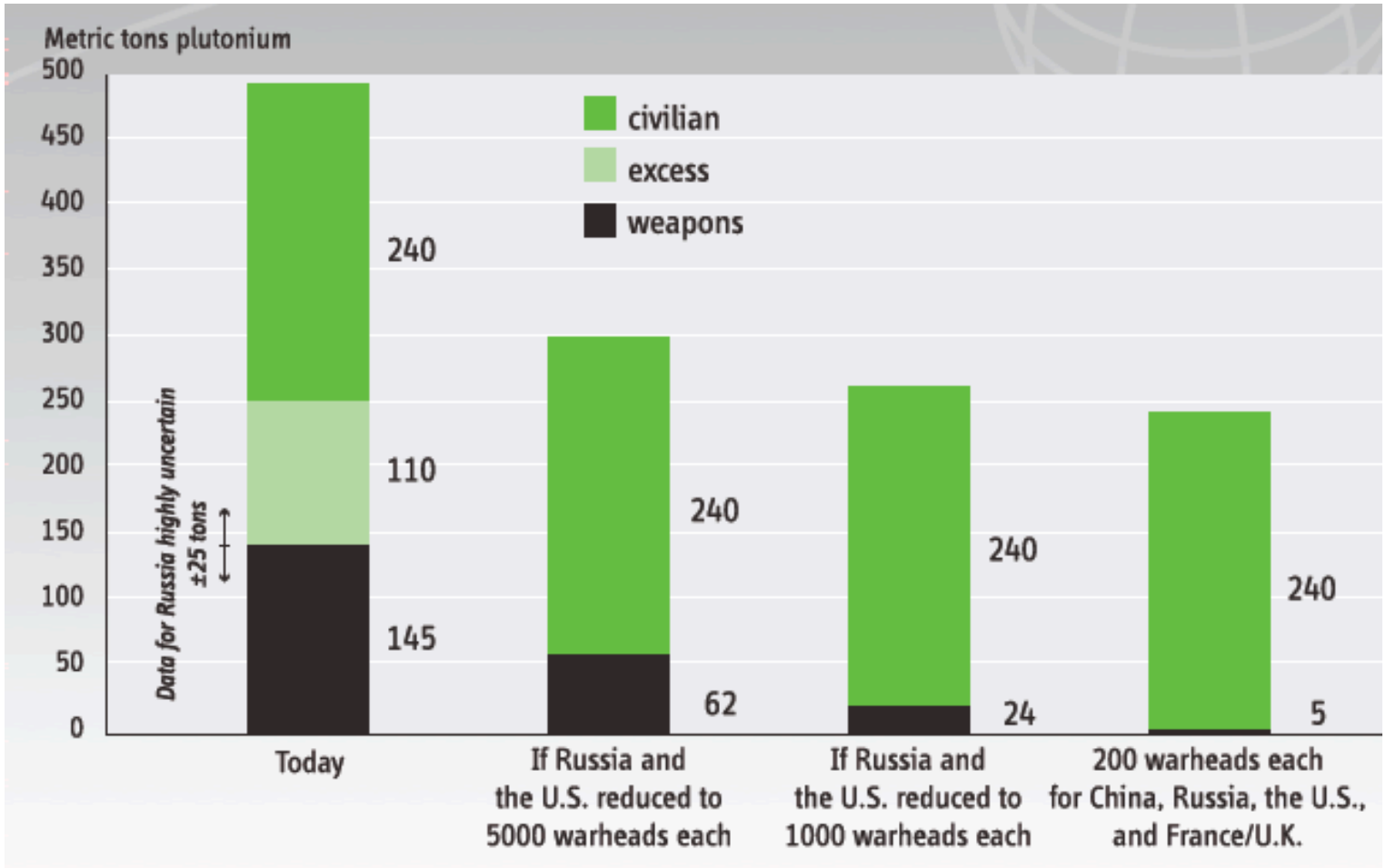
Weapons, 30%; Civilian, 50%; Excess, 20%

P-5 not producing for weapons, India, Israel, Pakistan are.

China, France, India, Japan, Russia, UK separating civilian plutonium



The civilian plutonium overhang to nuclear disarmament



The Bush Administration's verification challenge

"'**Effective verification' of an FMCT cannot be achieved**…even with…verification mechanisms and provisions…so extensive that they could compromise the core national security interests of key signatories, and so costly that many countries will be hesitant to accept them."

-- Conference on Disarmament, May 17, 2006

But FMCT would require of weapon states the same thing that the IAEA is supposed to verify in NPT non-weapon states!

On the other hand, non-weapon states don't have nuclear-weapon complexes or naval fuel cycles (but Brazil soon will).

Verification Challenges

Verifying:

1. **Shutdown of enrichment & reprocessing plants not converted to non-weapons purposes**
2. **Non-diversion of material declared excess for weapons purposes**
3. **Non-diversion at reprocessing plants not designed for safeguards**
4. **Non-production of HEU at enrich. plants that formerly produced HEU**
5. **No undeclared enrichment or reprocessing at military nuclear facilities**
6. **No diversion of HEU from naval or tritium-production-reactor fuel cycles**.

While minimizing extra IAEA safeguards costs.

1. **Verifying shutdown of enrichment & reprocessing plants not converted to non-weapon purposes**

Easy

Satellite monitoring of cooling-tower plumes, infrared monitoring
--Zhang & FvH

Motion activated cameras, radiation sensors and seals on key equipment.

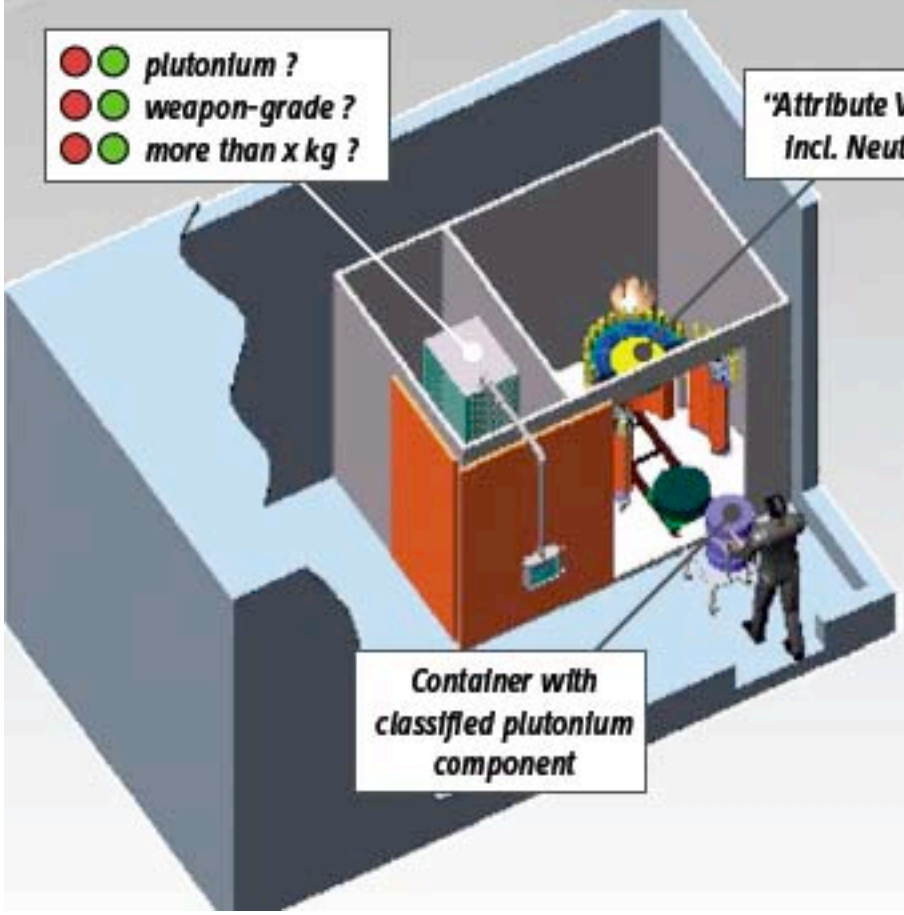
Short-notice random inspections.

Cost would not be high.

China concerned that inspectors would pick up in swipe and environmental samples information relevant to past production *(e.g. production-reactor power [Zhang, unpublished MS]).*

2. Non-Diversion of Material Declared Excess for Weapon Purposes

(while in classified form)



1996-2002 Trilateral Initiative developed approach to determine that a container holds more than a threshold amount of weapon-grade plutonium

Results communicated by red or green lights through information barrier

IPFM is working on corresponding approach for HEU components

3,4. **Half of reprocessing & enrichment plants in nuclear-weapon states already subject to or *offered* for international safeguards**

(5/11 reprocessing plants and 9/14 enrichment plants)

	Reprocessing Plants	Enrichment Plants
China	Yumenzhen (not)	**Shanxi** (IAEA), ***Lanzhou II*** (offered)
France:	**UP1, UP2** (Euratom)	**Georges Besse I/II** (Euratom)
India	**Tarapur** (IAEA, in the past) Kalpakkam (not), Trombay (not)	Ratehalli (not)
Israel	Dimona (not)	
Pakistan	Nilore (not)	Kahuta (not)
Russia	Mayak (not), Seversk (to shut down), Zheleznogorsk (to shut down)	***Angarsk*** (offered to IAEA) Novouralsk (not), Seversk (not), Zelenogorsk (not)
U.K.	**B205, THORP** (Euratom)	**Capenhurst** (Euratom)
U.S.	Savannah R., H canyon (to shut down)	***Eunice***, ***Idaho Falls***, ***Portsmouth CEPs***, ***Wilmingon LEP*** (offered), Paducah GDP (to shut down)

3.Non-diversion at reprocessing plants not designed for safeguards

Rokkasho and Tokai reprocessing plants account for about 20% of IAEA safeguards budget. Mass balance only good to order of 1 percent (80 kg/yr for Rokkasho) (10% for MOX plant). Reprocessing most costly and worst problem for NPT safeguards.

Reduction in Costs Suggested by Shirley Johnson

(formerly responsible for Rokkasho safeguards)

No permanent inspectors or on-site safeguards laboratory

Computer simulation of stocks and flows in plant

Continuous recorded or remote monitoring

Operator near-real-time declarations of

Containment/surveillance

Near real-time declarations of operations

6-8 short-notice random inspections/yr + annual physical inventory.

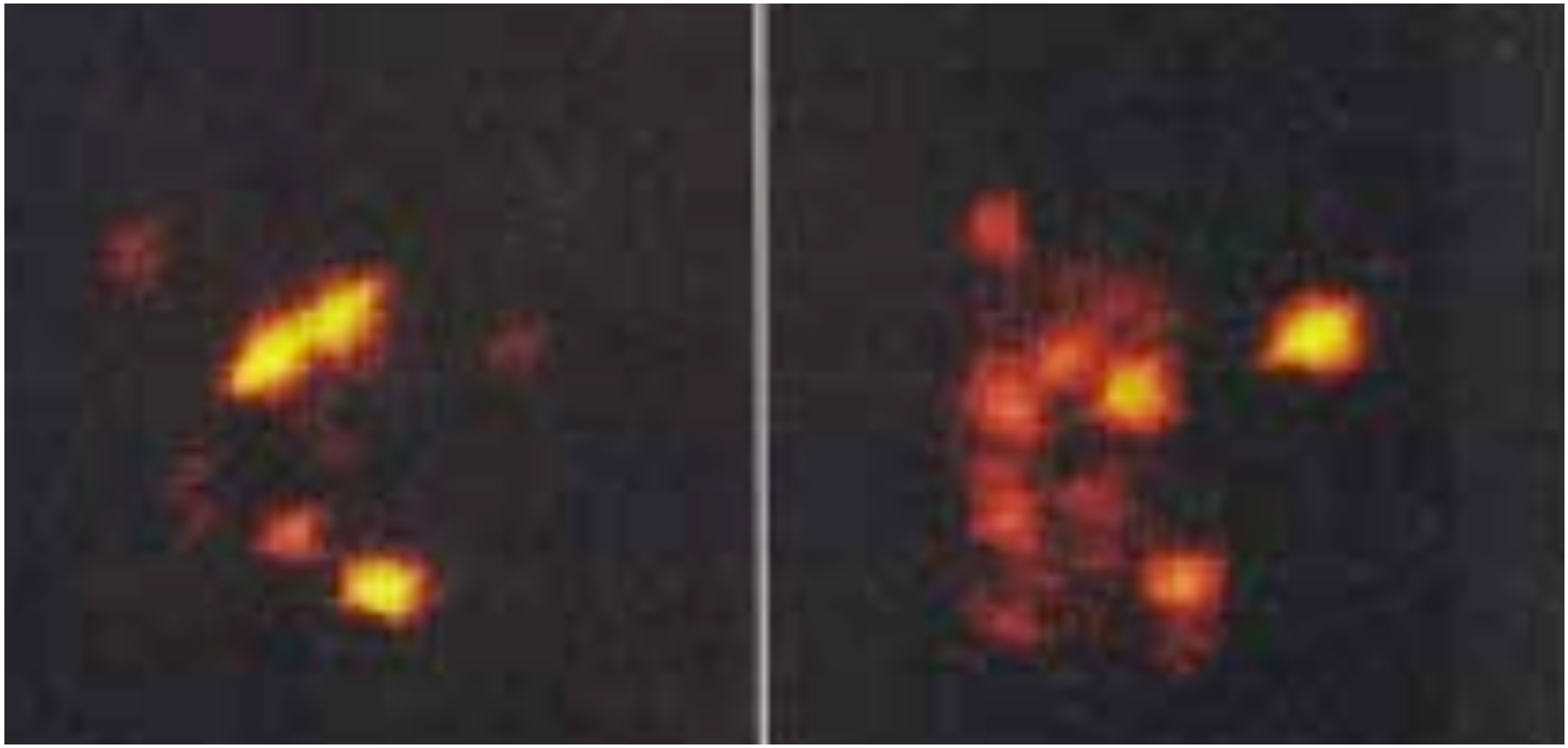
Costs

$13 million for hardware and software vs. $100+ million for Rokkasho

200 person-days of inspection effort (PDI) per year vs. 1200 at Rokkasho

$1.3 million/yr for operations (including $2000/PDI)

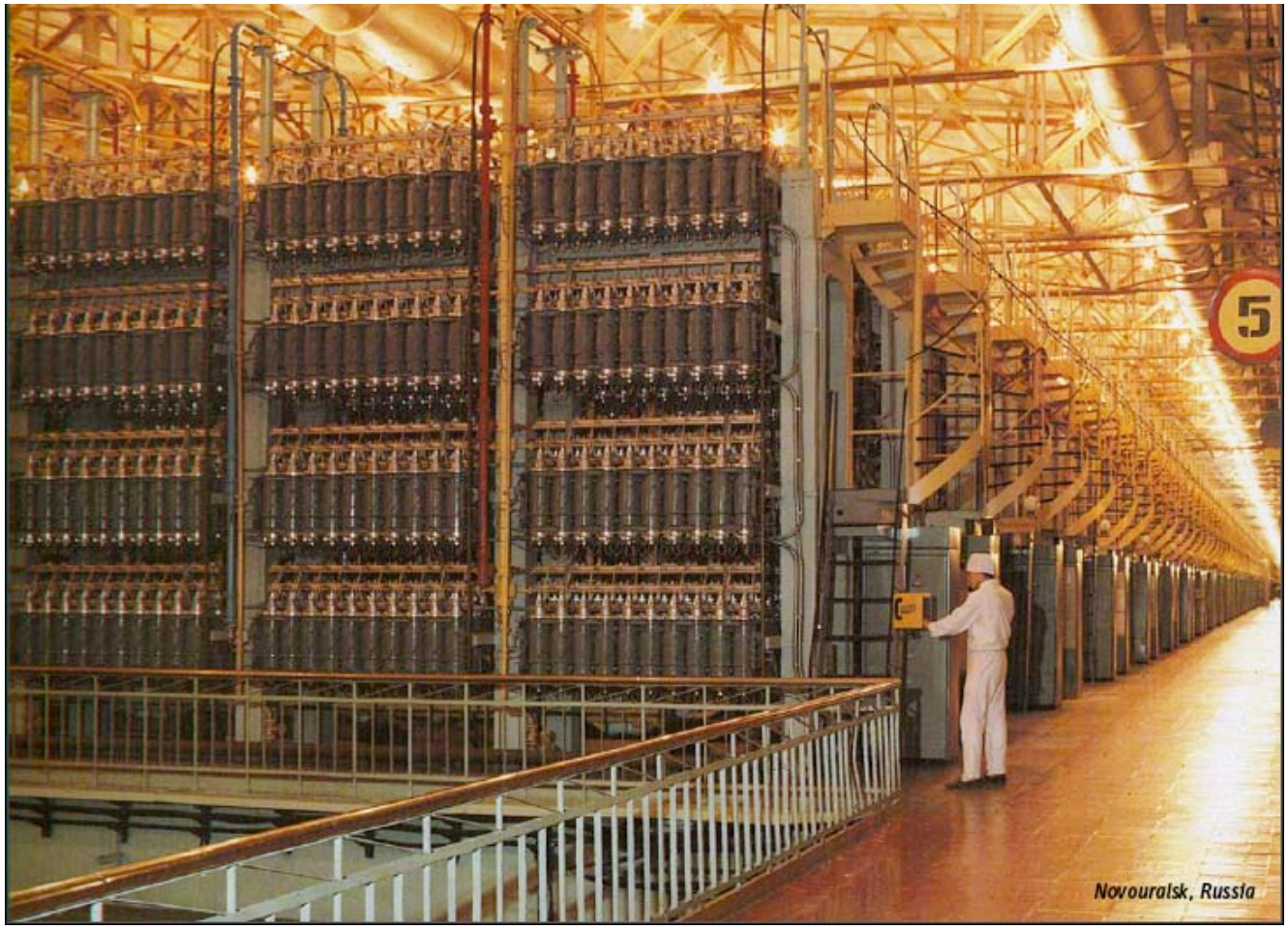
4. **No Undeclared production of HEU**
(HEU usually detected with swipes)



Left, U-235 concentration, right, U-238
(secondary ion-mass spectrometry.

But some facilities have produced HEU in the past

and are huge and not necessarily amenable to conventional safeguards.



Probably could age-date "large" (2-3-micron) particles after 20 years

HEU Production Periods

(in nuclear weapon states)

	Production Start	Production End
China	1964	1987-89
France	1967	1996
India	mid 1990s	*continuing*
Pakistan	1983	*continuing*
Russia	1949	1987-88
United Kingdom	1953	1963
United States	1944	1992*

*1964 for weapons

Small Indian and Pakistani facilities probably amenable to enrichment monitors and mass-balance measurements.

Uranium Age Determination

Number of Thorium-230 Atoms Present in a Highly Enriched Uranium Particle

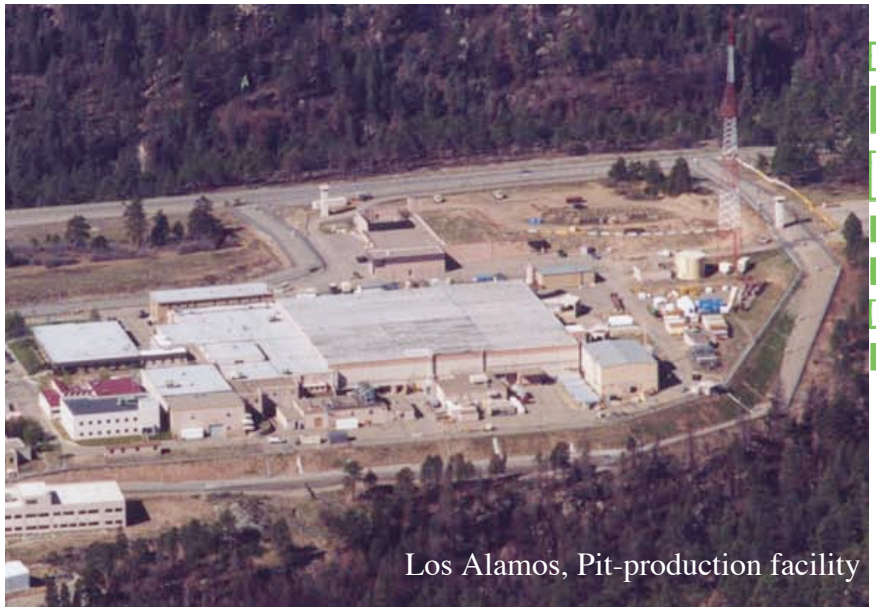
Year of Analysis	Age of Particle	Particle diameter (equivalent)		
		1 micron	2 micron	3 micron
2010	Minimum	9,600	76,700	258,800
	Average	15,200	122,000	411,700
2015	Minimum	11,800	94,100	317,600
	Average	17,400	139,400	470,500
2020	Minimum	13,900	111,500	376,400
	Average	19,600	156,800	529,300

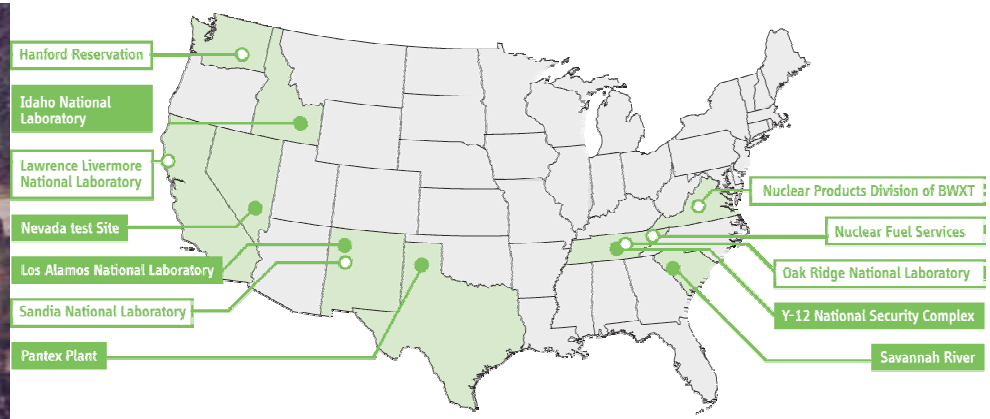
Assumed production year for minimum age: 1988, for average age: 1975
Initial U-234 content in the uranium particle: 1.15%; effective uranium density in particle: 10 g/cc

Detection limit for state-of-the-art isotope-ratio analysis techniques: 50,000-200,000 atoms
Overall experiment efficiency and statistics need additional margin, but the technologies are continuously improving

Analysis by Alex Glaser

5. No undeclared enrichment or reprocessing at military nuclear facilities


Los Alamos, Pit-production facility



Ten U.S. DOE nuclear sites and 2 NRC-regulated naval-fuel fabrication sites
Global Fissile Material Report 2007

Managed-access at military nuclear facilities.

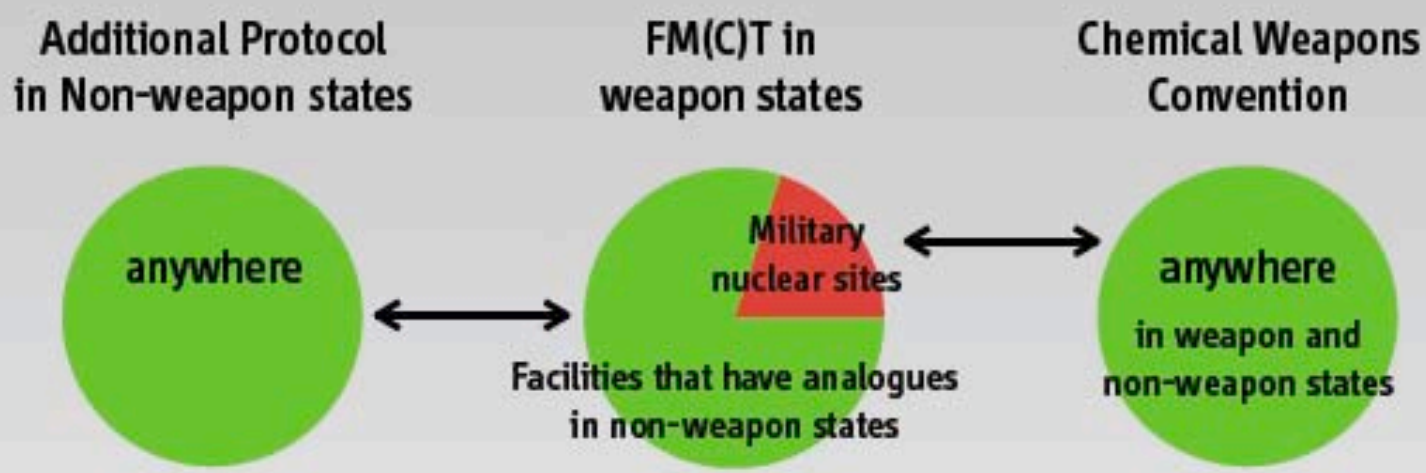
U.S. DOE has instructed its facilities and US NRC has instructed its licensees to prepare for managed access for verification of declarations under U.S. Additional Protocol.

IPFM has been examining how managed access could be used to verify an FM(C)T.

Managed Access Precedents

In non-weapon states: Special inspections under INFCIRC/153, paras. 73, 77.
Complementary access under Additional Protocol, Articles 4-10

In weapon states: Managed access under CWC
Managed access under the U.S.-IAEA Additional Protocol
(limited by the national-security exclusion)



Lessons from Managed Access Under the CWC

You can use powerful analytical instruments *with an information barrier* that allows them to answer preprogrammed questions with a "yes" or "no."

Example: Gas-chromatograph mass spectroscopy with library of 3000 chemical agents and their breakdown products.

You can take environmental samples off site (Kr-85).

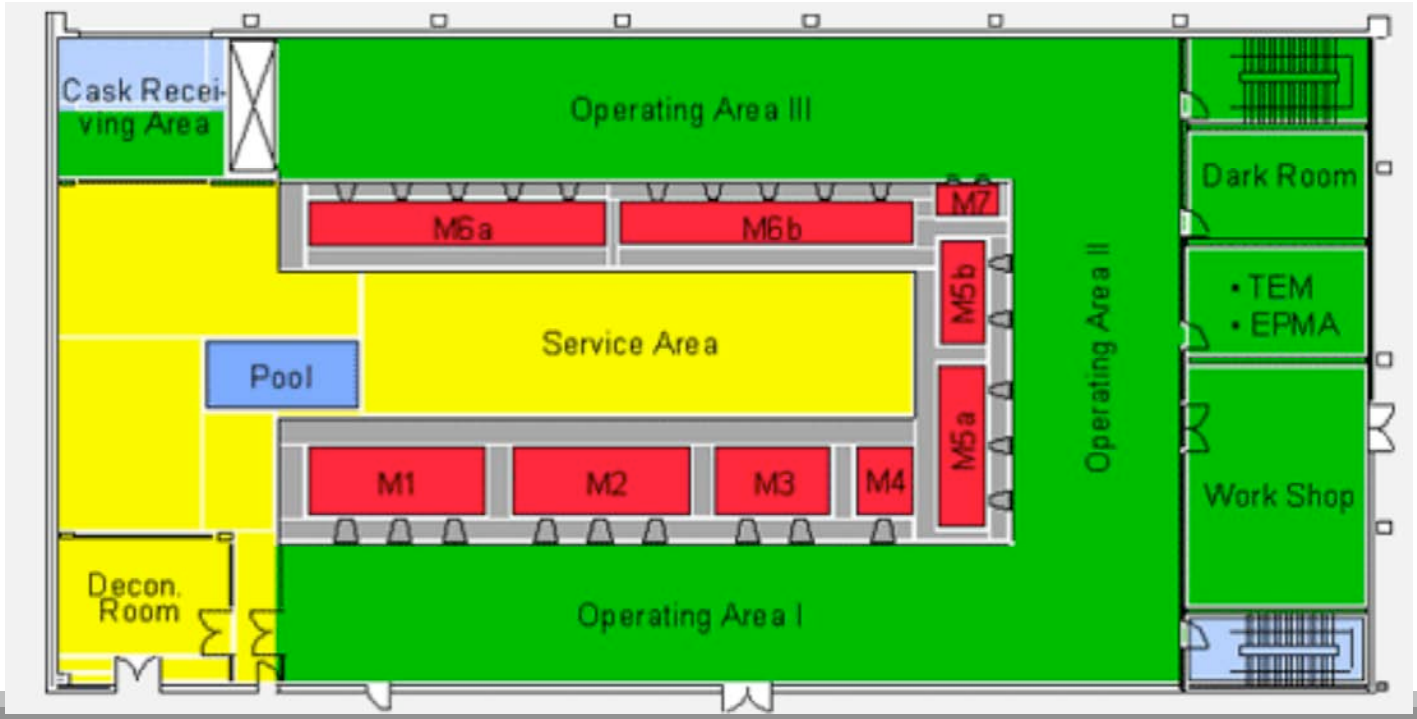
Some measurements that would not reveal sensitive nuclear information

Reprocessing plants & hot cells with reprocessing capabilities: Thick, dense walls for gamma shielding.

High levels of gamma radiation (Geiger counter)

Spent-fuel storage/transfer pools

High-level-waste tanks (hot and gamma emitting)

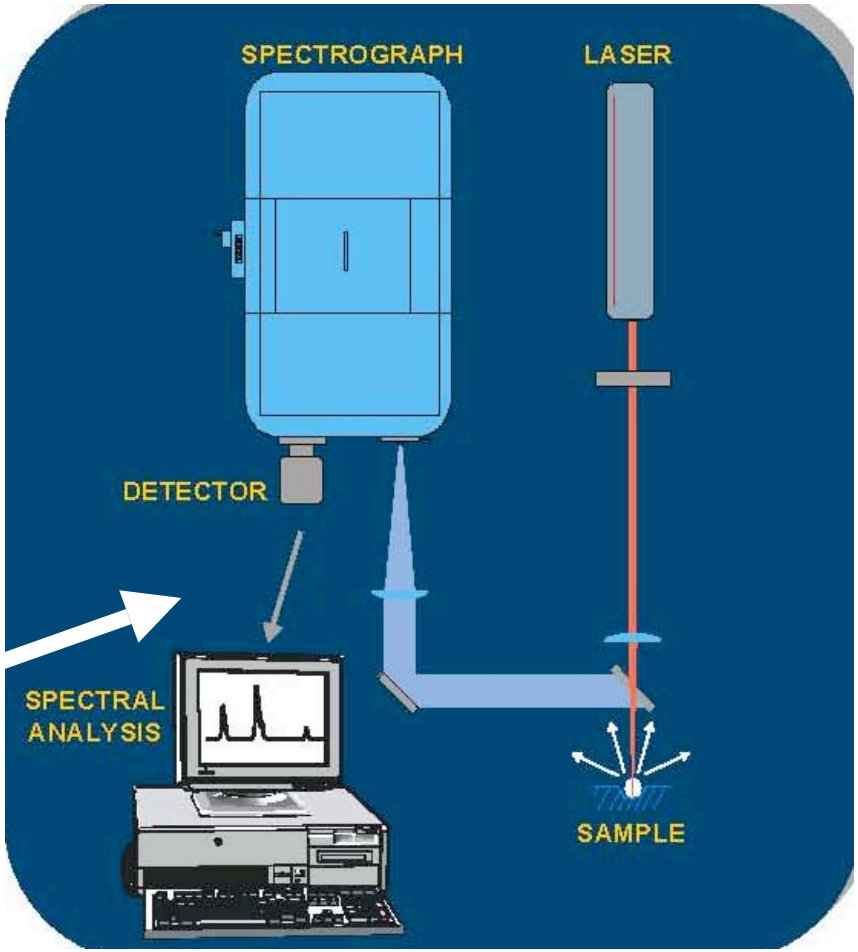


Irradiated Materials Examination Facility at the Korean Atomic Energy Research Institute

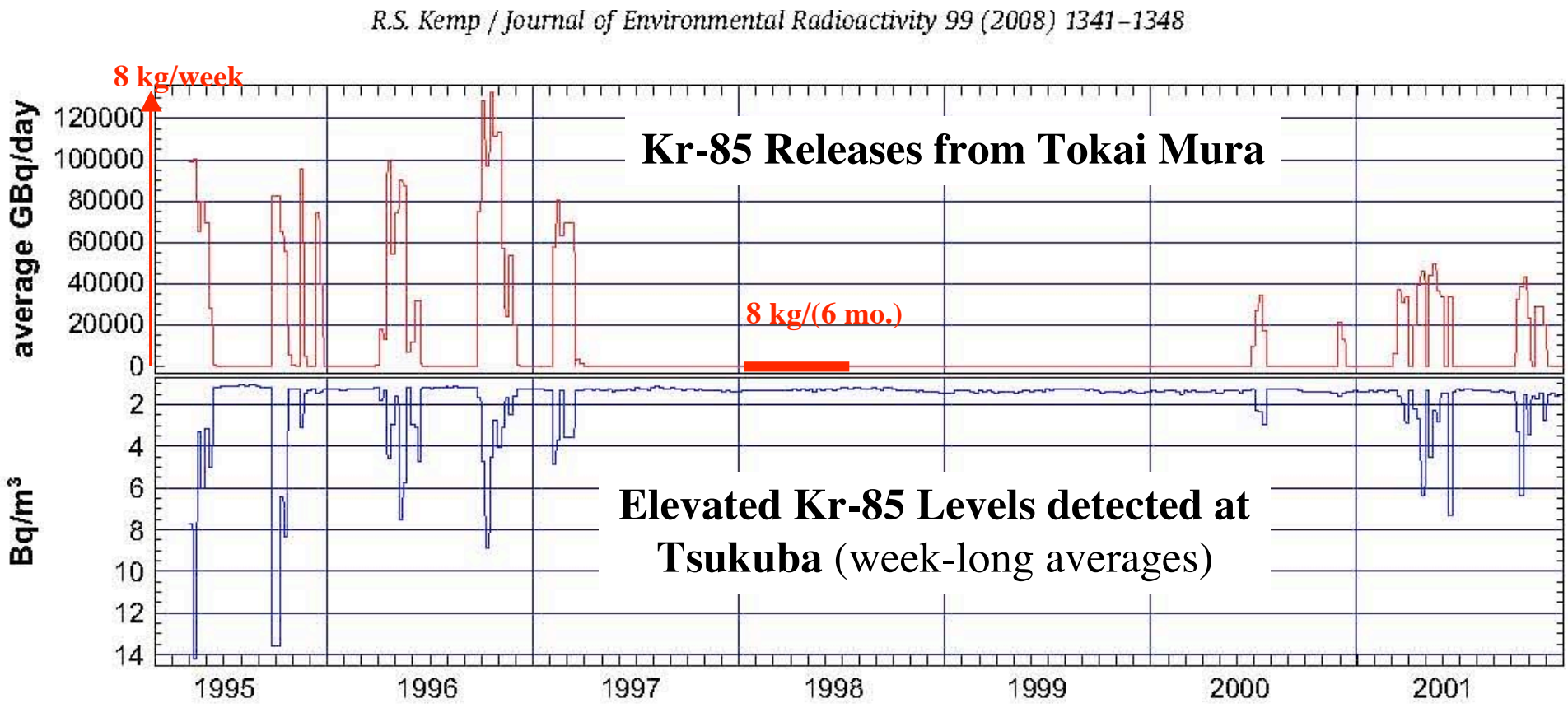
Enrichment plants

Deposits on the wall containing UO_2F_2 (from leaked UF_6)

Laser-induced breakdown spectroscopy.

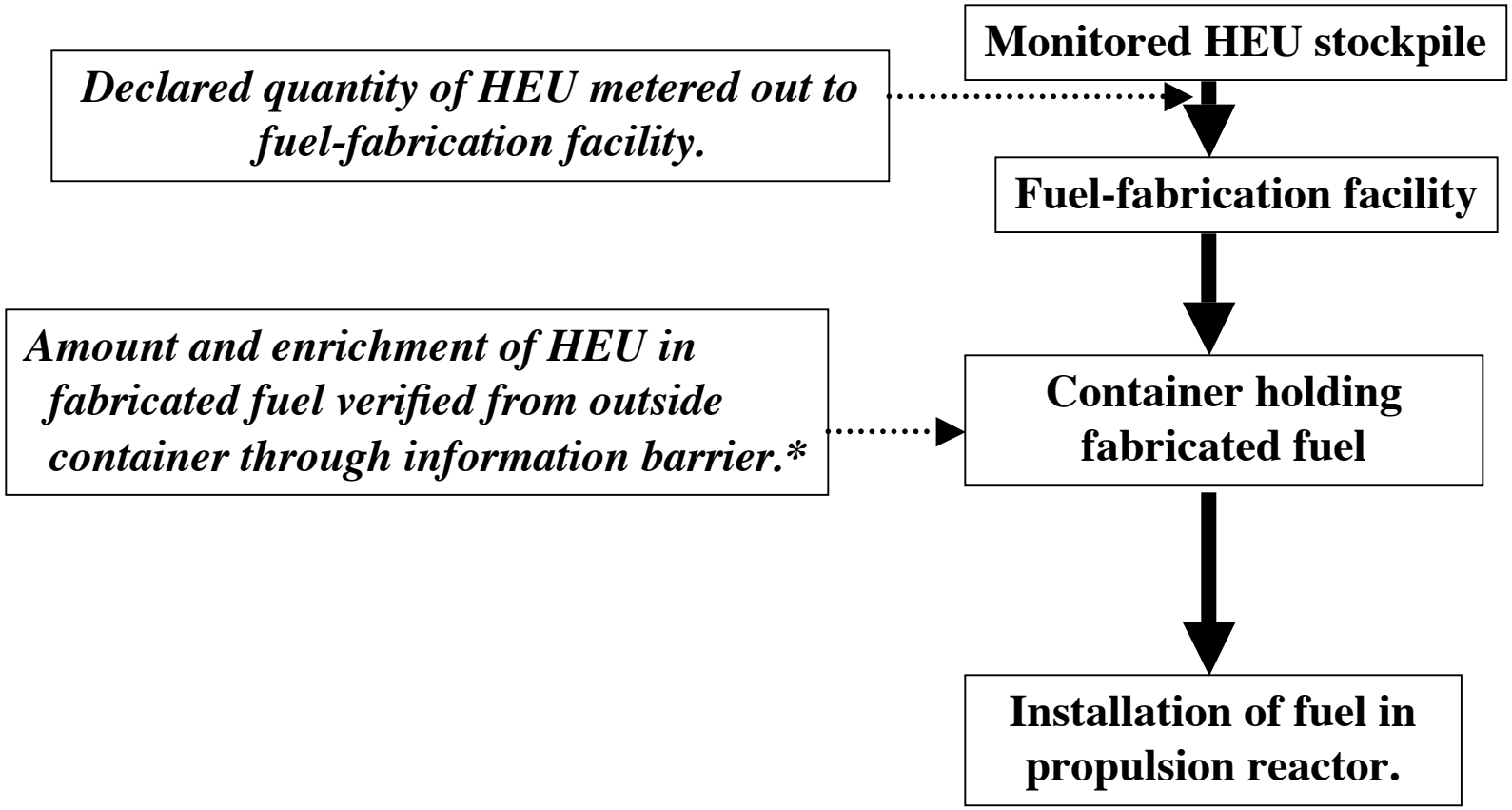


Detection of Tokai Mura krypton-85 releases 60 km away (Kemp & Schlosser, 2008)



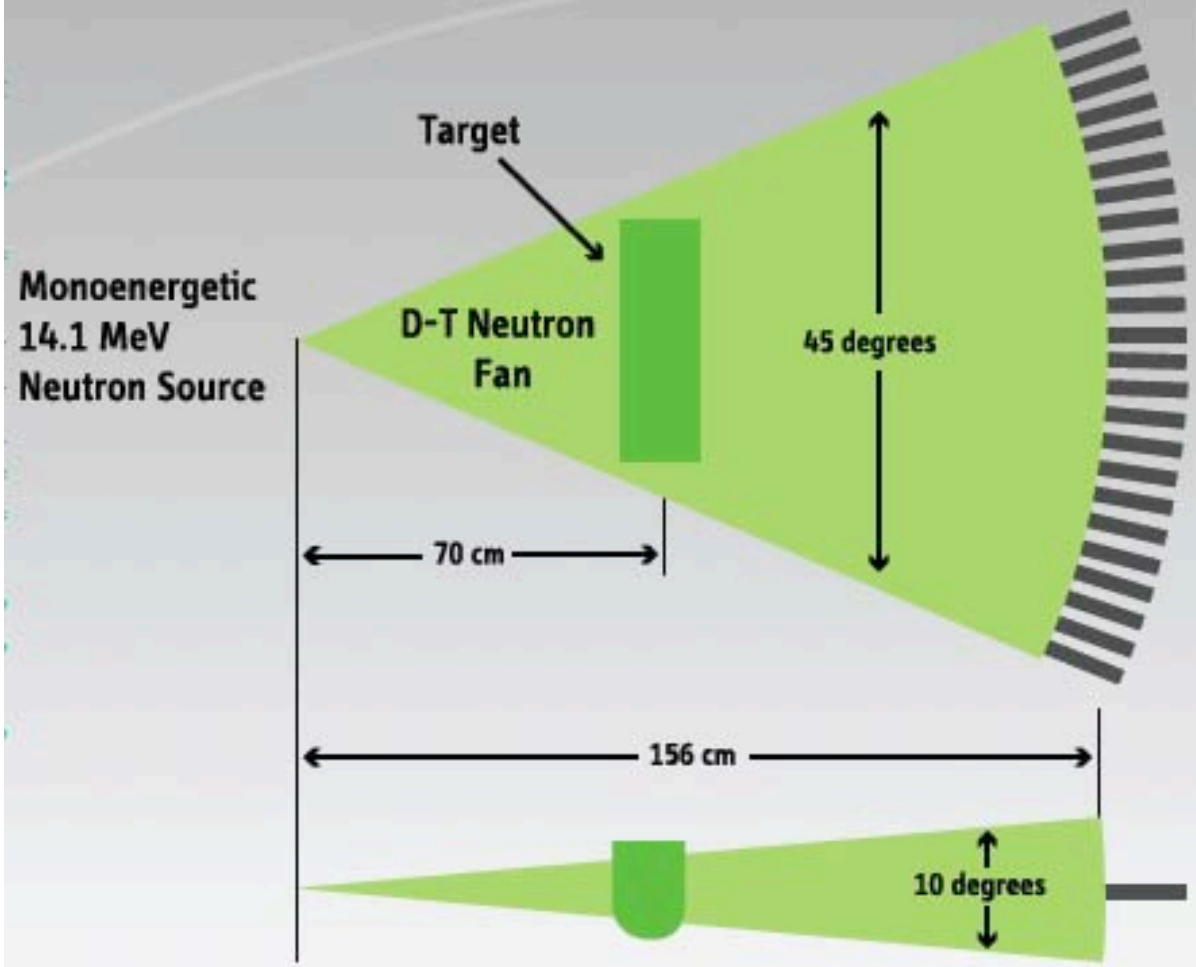
6. No diversion of HEU produced for naval propulsion reactors

(Better would be to shift these reactors over to LEU fuel.)



*Could also be applied to HEU declared excess for weapon purposes still in sensitive form.

Nuclear Materials Identification System



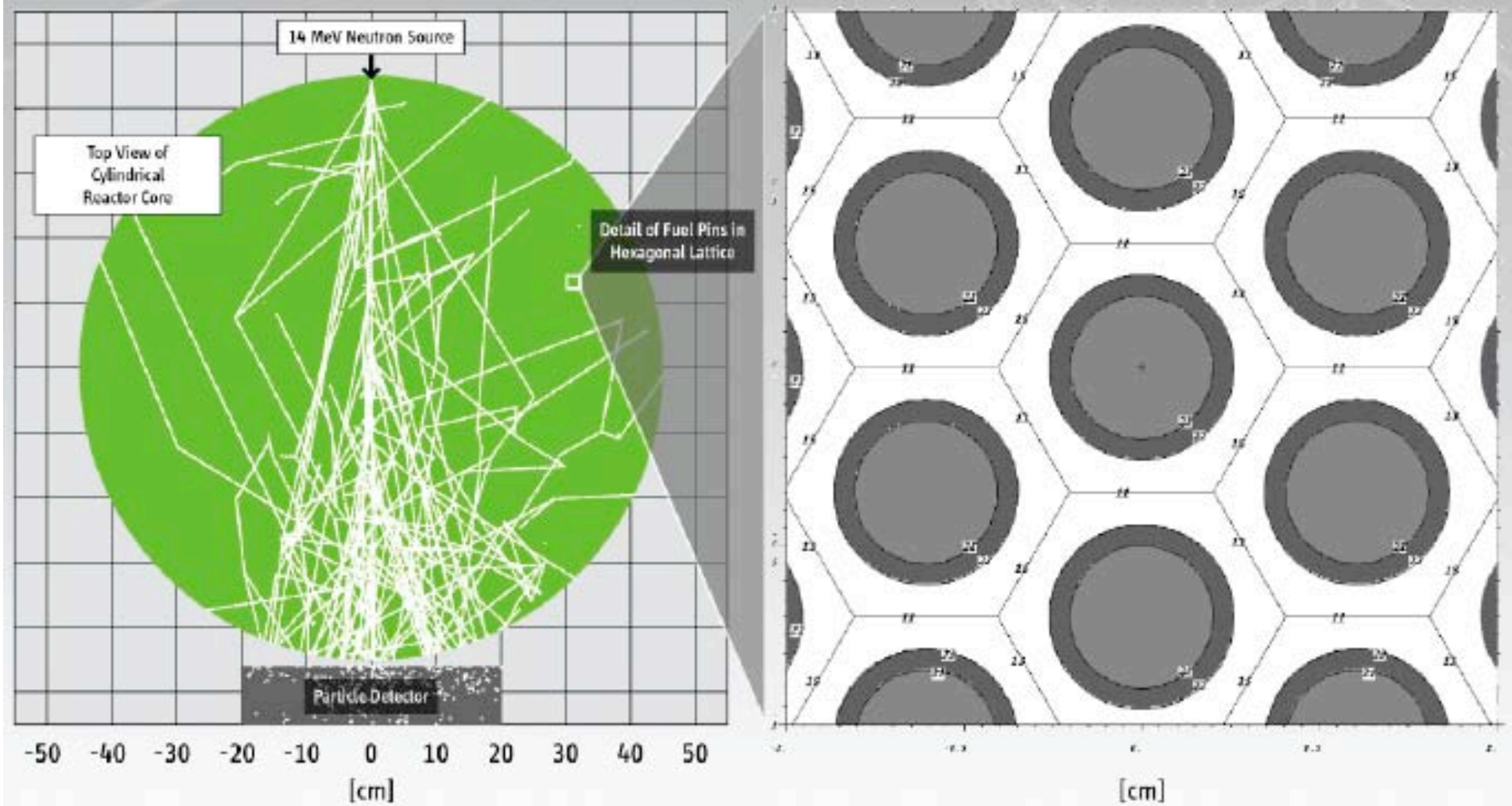
Uranium mass in trough:
about 65 kg

Estimated vs modeled results:
< ±0.8%

B. R. Grogan, J. T. Mihalczo, and J. A. Mullens, *MCNP-PolMi Simulation of Neutron Radiography Measurements for Mass Determination for a Trough of UO_2*
Institute for Nuclear Materials Management (INMM) 48th Annual Meeting, July 8-12, Tucson, Arizona, 2007

Proposed Experimental Setup

for Notional Submarine Core



Analysis by Ferenc Dalnoki-Veress

IPFM Conclusions

- The technical challenges of verifying an FM(C)T are significant but probably less than the political challenges of negotiating it.

- The impact on the IAEA safeguards budget might be less than a doubling.