Fissile Material (Cutoff) Treaty

Scope and Verification

IPFM
INTERNATIONAL PANEL ON FISSILE MATERIALS

R. Rajaraman

Jawaharlal Nehru University, New Delhi

Co-chair, IPFM

Acknowledgements

- Ambassador Lüdeking
- Dr. Tariq Rauf
- Mr. R. Sturm

About IPFM

- Over the past six decades, nuclear danger has expanded from the threat posed by the vast nuclear arsenals created by the superpowers in the Cold War.
- To encompass the proliferation of nuclear weapons to additional states and now also to terrorist groups.
- To reduce this danger, it is essential to secure and to sharply reduce all stocks of highly enriched uranium and separated plutonium, the key materials in nuclear weapons, and to limit any further production.
- The mission of the IPFM is to advance the technical basis for cooperative international policy initiatives to achieve these goals.
- IPFM was established in January 2006 with MacArthur Foundation 5-year grant

21 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)

9 Non-weapon States

- Jean du Preez (South Africa)
- José Goldemberg (São Paolo, Brazil)
- Martin B. Kalinowski (Hamburg, Germany)
- Jungmin Kang (Seoul, South Korea)
- Miguel Marín-Bosch (Mexico City, Mexico)
- Arend Meerburg (Den Haag, Netherlands)
- 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 Reports 2006, 2007, and 2008

Research Reports

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

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

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

#4 Spent Nuclear Fuel Reprocessing in France
by Mycle Schneider and Yves Marignac (April 2008)

#5 The Legacy of Reprocessing in the United Kingdom
by Martin Forwood (July 2008)

Forthcoming Research Reports

Verification of an FMCT in Weapon-state Reprocessing Plants
by Shirley Johnson

Toward elimination of HEU as a Reactor Fuel
by Ole Reistad, S. Hustveit

Consolidation of Nuclear Materials in Russia
by Pavel Podvig

The History of Fast Breeder Reactors
by Tom Cochran, Gennadi Pshakin, M.V. Ramana, Mycle Schneider, and Tatsujiro Suzuki

We hold our full panel meetings twice a year in capitals around the world, where we also try to have interactive sessions with government officials and NGOs. (Ex: Ottawa, London, and The Hague. Next one in Beijing)

Global Fissile Material Report 2008

Scope and Verification of a Fissile Material (Cutoff) Treaty

(www.ipfmlibrary.org/gfmr08.pdf)

FM(C)T Project

- Country perspectives from 8 weapon states and 3 non-weapon states with important nuclear programs (Germany, Japan and South Africa)

  Available at www.ipfmlibrary.org/FMCT-Perspectives.pdf

- A Draft Treaty

- An approach to verification

Today's Panel Presentation

- The main undertakings in the IPFM draft FM(C)T treaty
  Ambassador Arend Meerburg (The Netherlands, ret.)

- Verification at reprocessing plants
  Shirley Johnson (IAEA, ret.)

- Verification at enrichment plants
  Dr. Alexander Glaser (Princeton University)

- Verification of non-diversion of naval HEU
  Dr. Alexander Glaser

- Managed access at military nuclear facilities
  Prof. Frank von Hippel (Princeton University)

Fissile Material (Cutoff) Treaty

Design Choices

IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

Arend Meerburg

Former Ambassador of The Netherlands

IAEA General Conference, October 1, 2008

IPFM Choices on Two Major Issues

- Verification: Yes and by the IAEA.

  NPT is verified in non weapon states, FM(C)T imposes verification measures on the weapon states. Creates also basis for verification of serious nuclear disarmament measures.

- Pre-existing civilian stocks and materials declared excess for all military purposes: Subject to IAEA monitoring.

  Otherwise would have two segregate pre-existing from post-FM(C)T materials in civilian sector.

Thus: A One-way Street to Safeguards

- The Treaty provides that no new fissile materials can be produced for weapons. Consequence: safeguards on new fissile production for civilian or non-explosive purposes needed. Leads to safeguards also on existing fissile materials for civilian and for non-explosive purposes, as well as material declared as excess.

  Also: IAEA monitoring of HEU declared excess for weapons use but reserved for military (e.g. naval propulsion) reactor fuel.

- Nuclear disarmament measures should lead to more excess material, to be brought under safeguards.

Article I: Basic Undertakings

1. *Each State Party undertakes not to produce fissile material for nuclear weapons or other nuclear explosive devices.*

   Also: Non-circumvention clauses and commitment to decommission unused reprocessing and enrichment facilities.

5. *Each State Party undertakes not to use for nuclear weapons or other nuclear-explosive devices fissile materials:*

   i. In its civilian nuclear sector
   ii. Declared as excess for all military purposes
   iii. Declared for use in military reactors.

Article II: Definitions

- *"Fissile material" means:*

  i. Plutonium of any isotopic composition except plutonium whose isotopic composition includes 80 percent or more plutonium-238 [IAEA definition of "direct-use" material]

  ii. Uranium containing uranium-235 and/or uranium-233 in a weighted concentration equivalent to or greater than 20 percent uranium-235.
  [Definition of HEU extended to U-233]

  iii. ...

Article II: Definitions, cont'd

- *"Producing fissile material" means:*

  i. Separating fissile materials mentioned in paragraph 1 from fission products through reprocessing or any other process.

  ii. Enriching any mixture of uranium isotopes to a weighted concentration of uranium-235 and uranium-233 equivalent to or greater than 20 percent uranium-235.

  iii. Increasing the fraction of plutonium-239 in plutonium by any isotopic separation process.

- *"Production facility" means:*

  Any facility in which any production of fissile material as defined in Paragraph II.2 is carried out or could be carried out.

Article III: Verification (1/3)

1. *Each State Party undertakes to accept IAEA safeguards to verify its obligations under Article I as described in this Article.*

2. *For those States Parties having a comprehensive safeguards agreement with the IAEA incorporating IAEA-document INFCIRC/153 (corrected) as well as the Model Protocol Additional to the Safeguards Agreements (INFCIRC/540), no further agreements with the IAEA are necessary under this Treaty, unless that State Party intends to use fissile materials for military non-explosive purposes, in which case additional safeguards or arrangements are needed.*

Article III: Verification (2/3)

1. *States Parties not having a comprehensive safeguards agreement … undertake to accept safeguards in an appropriate safeguards agreement to be concluded with the IAEA to verify their obligations under Article I, including:*

   i) The non-production of fissile materials for nuclear weapons or other nuclear explosive devices and to that end:

      a) The disablement, decommissioning and dismantlement of production facilities or their use only for peaceful or military non-explosive purposes, and

      b) The absence of any production of fissile materials without safeguards

Article III: Verification (3/3)

1. *States Parties not having a comprehensive safeguards agreement ... undertake to accept safeguards in an appropriate safeguards agreement to be concluded with the IAEA to verify their obligations under Article I, including:*

   [...]

   ii) The non-diversion to nuclear weapons, other nuclear explosive devices or purposes unknown of:

   a) All civilian fissile materials, including in spent fuel,

   b) All fissile materials declared excess to any military purpose.

   c) All fissile materials declared for military non-explosive purposes

Safeguarding Pu Recycle Facilities in Nuclear Weapon States under an FMCT

S.J. Johnson

International Panel on Fissile Materials
IAEA General Conference, Vienna, 1 Oct. 2008

THE SAFEGUARDS CHALLENGES OF NUCLEAR WEAPON STATES

- Facilities design and operator equipment and measurement systems not SG ‘friendly’.
- Resource intensive for equipment, inspections and travel.
- High cost for retrofitting and redesigning SG measurement/monitoring systems.
- Restricted access due to commercial sensitivity, security concerns or radiological hazards.
- Travel logistics to enter and/or travel within the State.

REDUCTION OF COST AND INSPECTION EFFORT BY:

- Use of new verification and monitoring tools and methods,
  - Unattended systems,
  - Continuous process monitoring,
  - Remote monitoring, and
  - Short Notice Random Inspections (SNRI).
- May be some reduced confidence in meeting the IAEA timeliness and detection requirements;
- [Introduction of a State Level Approach]

SAFEGUARDS APPROACHES FOR:

- Operating facilities for civilian use;
- Operating facilities for military purposes;
- Shut-down and closed-down facilities;
- Future facilities.

OPERATING CIVILIAN PLANTS

- 6-8 SNRI/year to replace continuous inspections and monthly IIVs;
  - Advanced declarations of operational schedules; and
  - Continuous and timely declarations of material flows and inventories.
- Verification of major Pu flows using unattended measurement/monitoring systems with random sampling during SNRI.
- Added assurance through in-process flow monitoring, Flow Sheet Monitoring of ANM, etc.
- Simultaneous PIV with related facilities.
- Design Information Verification.

INSPECTION EFFORT FOR EXISTING OPERATING FACILITIES

Activity/facility	Inspections/ year	Duration (days)	Number of inspectors per action	Total person days/yr
Short notice random inspection	8	5	3	120 PD
Physical inventory inspection	1	10	5	50 PD
Other activities				30 PD
TOTAL				**200 PD**
RRP	**Continuous**	**250 days oper. + shut-down**	**4 insp./3 shifts +1-2 insp./ day**	**1200 PD**

EQUIPMENT AND INSTALLATION COSTS (per facility)

- Hardware and software (IAEA) ------- ~ $13 million
  - ~ 20% of the cost for RRP
  - Some reduction for Euratom States
- Installation costs (Operator/State) --- ~ $5.2 million
- Maintenance and replacement (IAEA/Operator) -- ----- ~ $0.9 million/yr.
- Analytical services (IAEA) --------------- TBD per site

OTHER FACILITIES

OPERATING MILITARY FACILITIES

- SG Approach designed on a case-by-case basis.
- Sensitivity of design and enrichment of military fuel.
- Some 'masking' of process may be required.

SHUT-DOWN/CLOSED-DOWN FACILITIES

- Confirm facility status with random inspections/visits.
- Satellite or areal imaging.
- C/S or process monitoring, including reagents and off-gases.

FUTURE FACILITIES

- Safeguards 'friendly' plant design.
- Similar SG Approach as in non-NWS facilities.

SUMMARY OF THE ......

Application of International Safeguards

- Introduce random, short-notice inspection activities to provide more unpredictability and reduce costs;
- Install unattended measurement systems;
- Make use of remote monitoring and C/S, where possible;
- Require near real time reporting by operators.

- Some reduced confidence in meeting current SG Criteria for existing plants, with focus on operational parameters;
- Make use of regional inspection/monitoring capabilities;
- Monitor shut-down and closed-down plants;
- Design safeguards into future plants to meet SG Criteria;

Verification at Enrichment Facilities

IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

Alexander Glaser

Princeton University

IAEA General Conference, October 1, 2008

HEU Production Periods

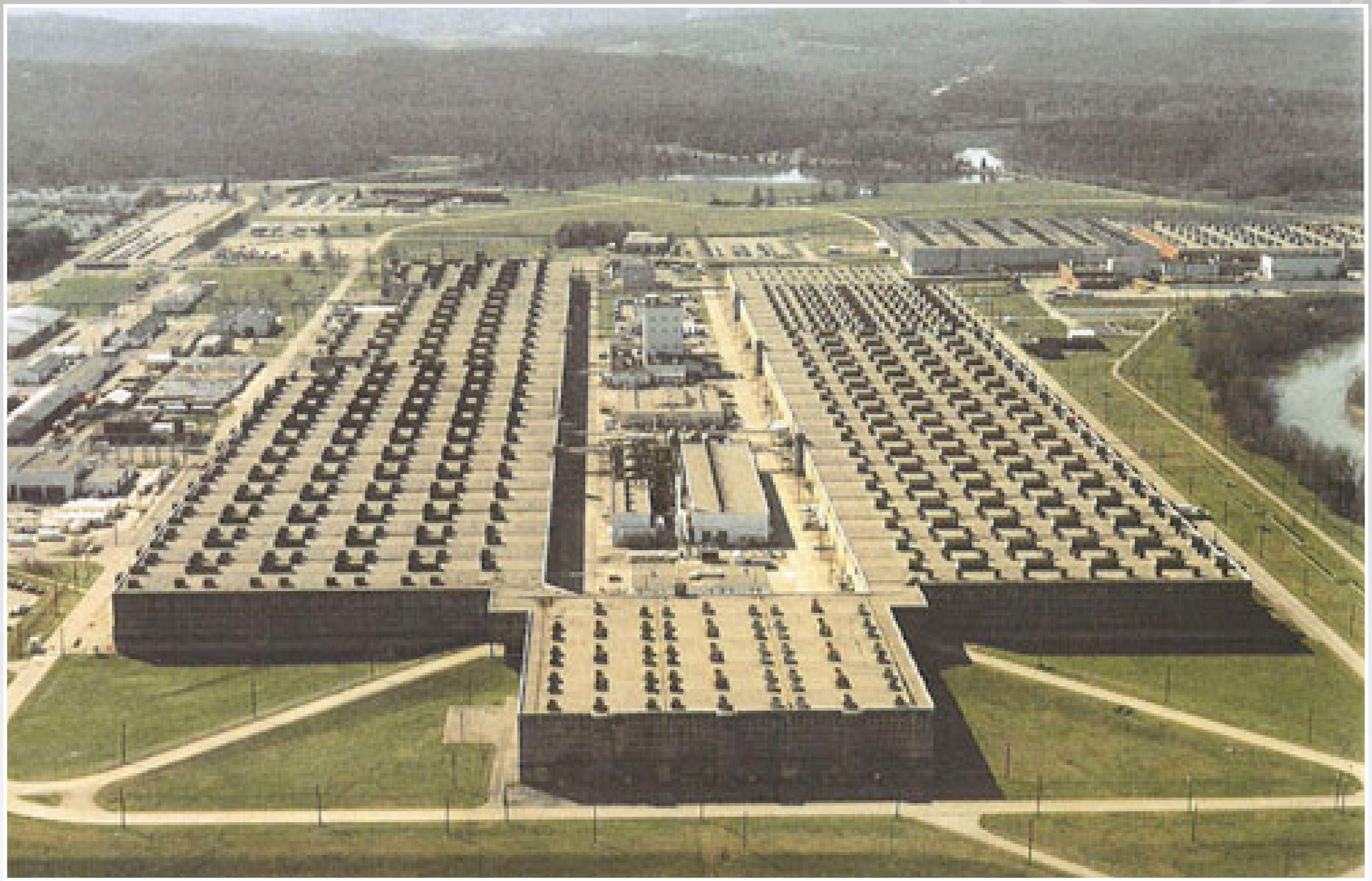
(in nuclear weapon states)

	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

Oak Ridge Gaseous Diffusion Plant K-25

(demolition underway)

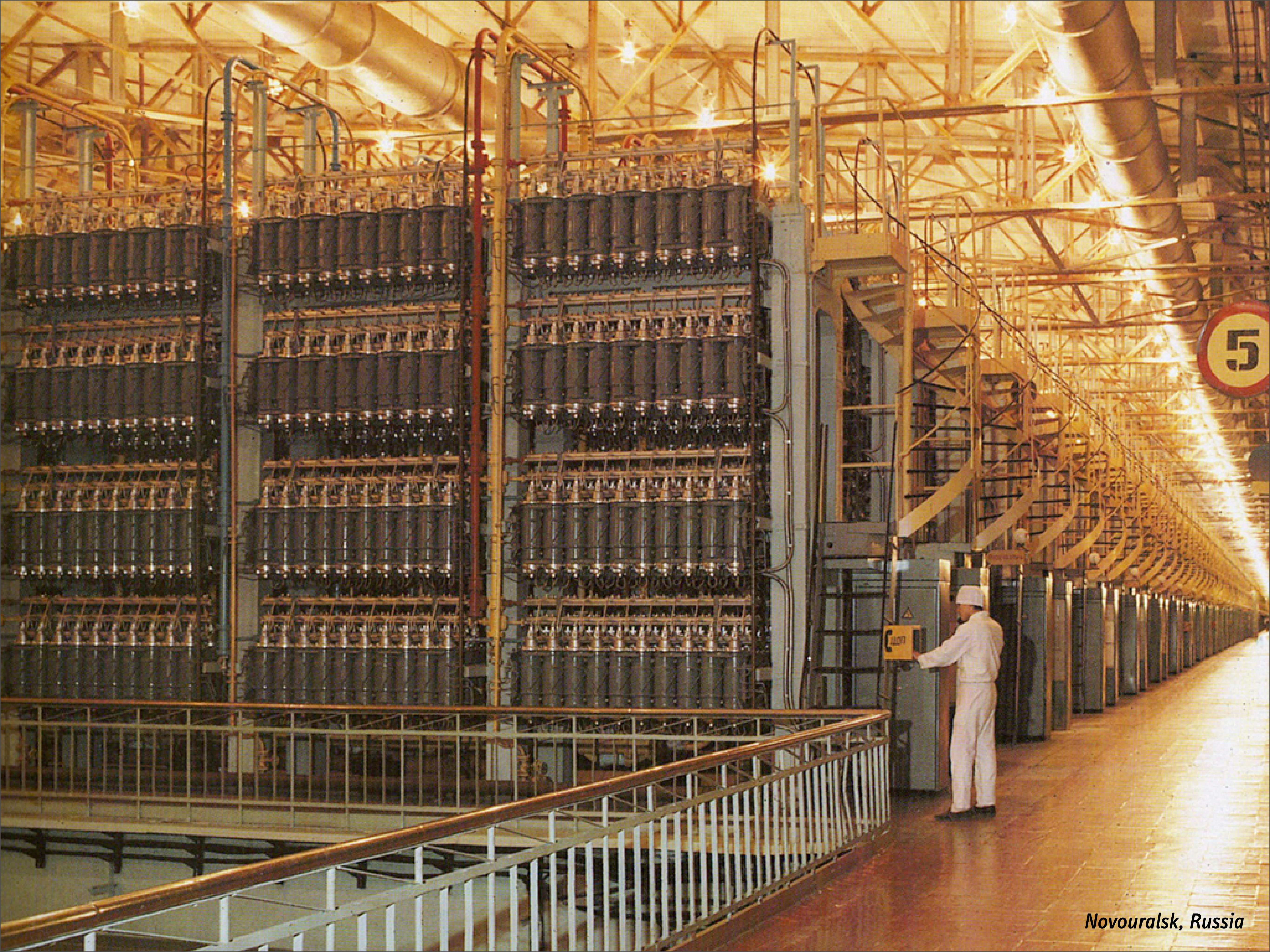


Centrifuge Enrichment Facilities

(as currently expected for the year 2015)

	Country	Facility	Safeguards Status	Capacity [tSWU/yr]
Non-weapon states	Brazil	Resende	Yes	120
	Germany	Gronau	Yes	4,500*
	Iran	Natanz	Yes	250
	Japan	Rokkasho	Yes	1,050
	The Netherlands	Almelo	Yes	3,500
Weapon states	France	George Besse II	(Yes)	7,500
	U.K.	Capenhurst	Yes	4,000
	United States	Piketon, Ohio	offered	3,500
		Eunice, NM	offered	3,000
		Areva, Idaho	(offered)	3,000
	China	Shaanxi	(Yes)	1,000*
		Lanzhou II	offered	500
	Russia	Angarsk II	(offered)	5,000
		4 others	No	about 30,000
	India	Rattehalli	No	4-10
	Pakistan	Kahuta	No	15-20

*after planned expansions are complete



Novouralsk, Russia

Verification at Previously Operating Enrichment Facilities

Whenever possible, environmental sampling techniques could be used as one of the primary methods to assure that no HEU is produced

Installation/Use of Continuous (or Portable) Enrichment Monitors

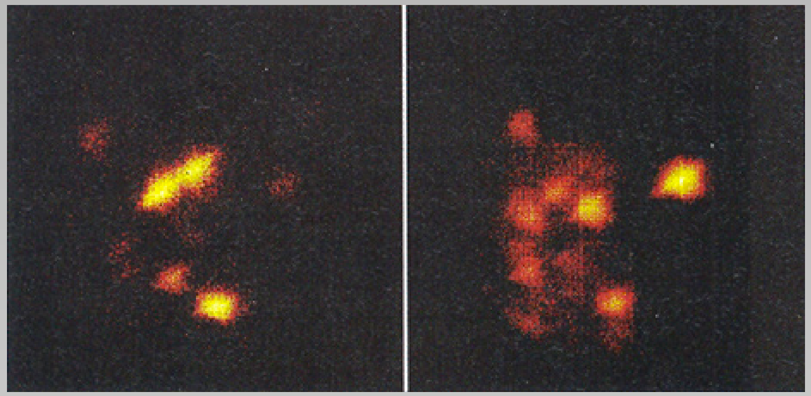
to improve timeliness of detecting covert HEU production

Used in some Urenco facilities

Needs specially-designed instruments for use in facilities using Russian centrifuge technology
Now installed in Chinese facility (IAEA 2006 Annual Report)

Environmental Sampling

(and Identification of HEU Particles from Historic Production)



Images of micron-sized uranium particles made with a Secondary Ion Mass Spectrometer

Left: U-235 Concentration
Right: U-238 Concentration

Isotopic Baseline

Baselines (e.g. U-234 and U-236 fraction as a function of U-235 enrichment) are characteristic for the feed composition and production process

Particle Age

Based on fractional concentration of decay products, particularly challenging for uranium

Accurate for large (microgram) samples

Could particles be used that have been obtained with swipe sampling techniques ?

Reported Detection Limits for Various Isotope-Ratio Analysis Techniques

Technique	Reported Detection Limits (for Actinides)	Advantage	Disadvantage
High-Efficiency TIMS	10^4-10^6 atoms	High Precision	Time-consuming sample preparation Hydrocarbon interferences
Multi-Collector ICP-MS	10^4-10^6 atoms	High Precision	Isobaric and molecular interferences Memory effect
RIMS	10^6-10^8 atoms	High Selectivity Less Interference	Time-consuming sample preparation

TIMS: Thermal ionization mass spectrometry; ICP-MS: Inductively coupled plasma mass spectrometry;
RIMS: Resonance ionization mass spectrometry

Data from various sources, summarized in S. Bürger et al., "Isotope Ratio Analysis of Actinides, Fission Products, and Geolocators by High-Efficiency Multi-Collector Thermal Ionization Mass Spectrometry," forthcoming.

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

Highly Enriched Uranium in the Naval-reactor Fuel Cycle

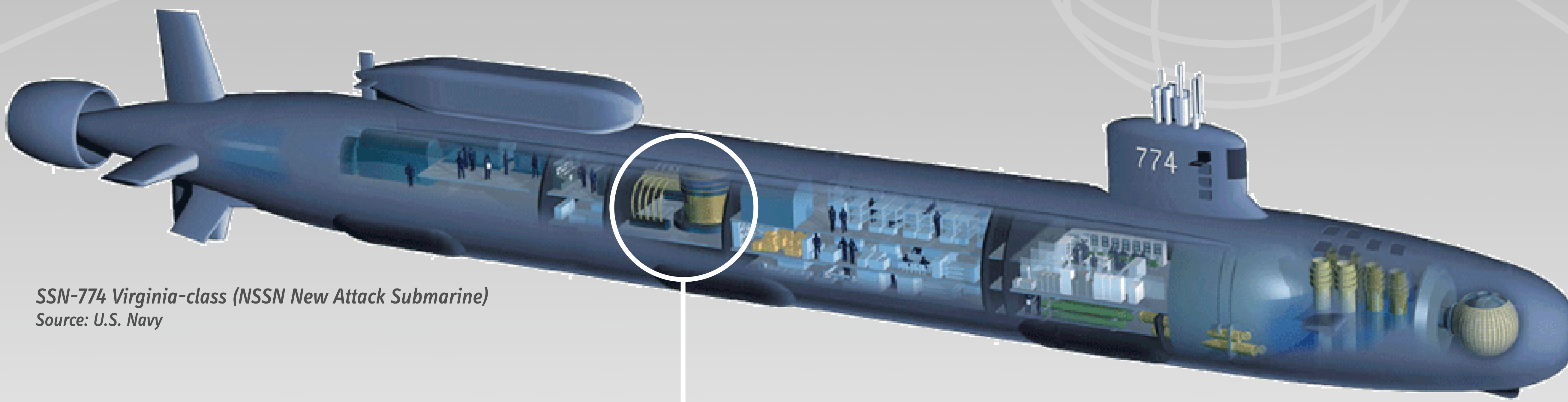
IPFM
INTERNATIONAL PANEL ON FISSILE MATERIALS

Alexander Glaser

Princeton University

IAEA General Conference, October 1, 2008

HEU Stockpiles for Naval Fuel



SSN-774 Virginia-class (NSSN New Attack Submarine)
Source: U.S. Navy

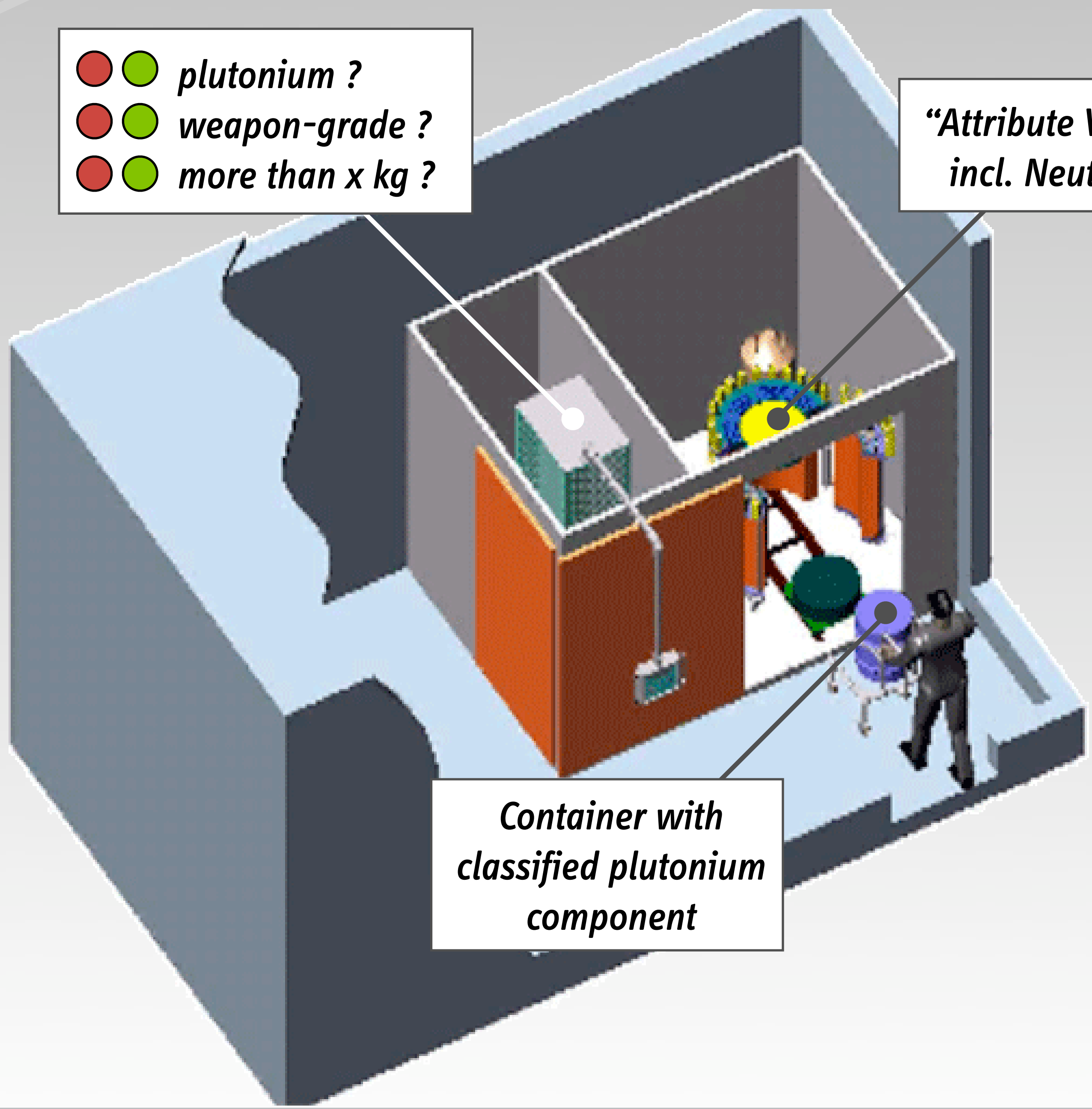
The United States, Russia, and the United Kingdom use HEU to fuel naval vessels
(mostly submarines; the U.S. and U.K. vessels are fueled with weapon-grade uranium)

The U.S. fleet currently requires about 2000 kg of weapon-grade uranium per year

The United States has reserved 128 tons of excess weapon-grade uranium (enough for 5,000 nuclear weapons) for future use in naval reactors

Non-Diversion of Material Declared Excess for Weapon Purposes

(while in classified form)



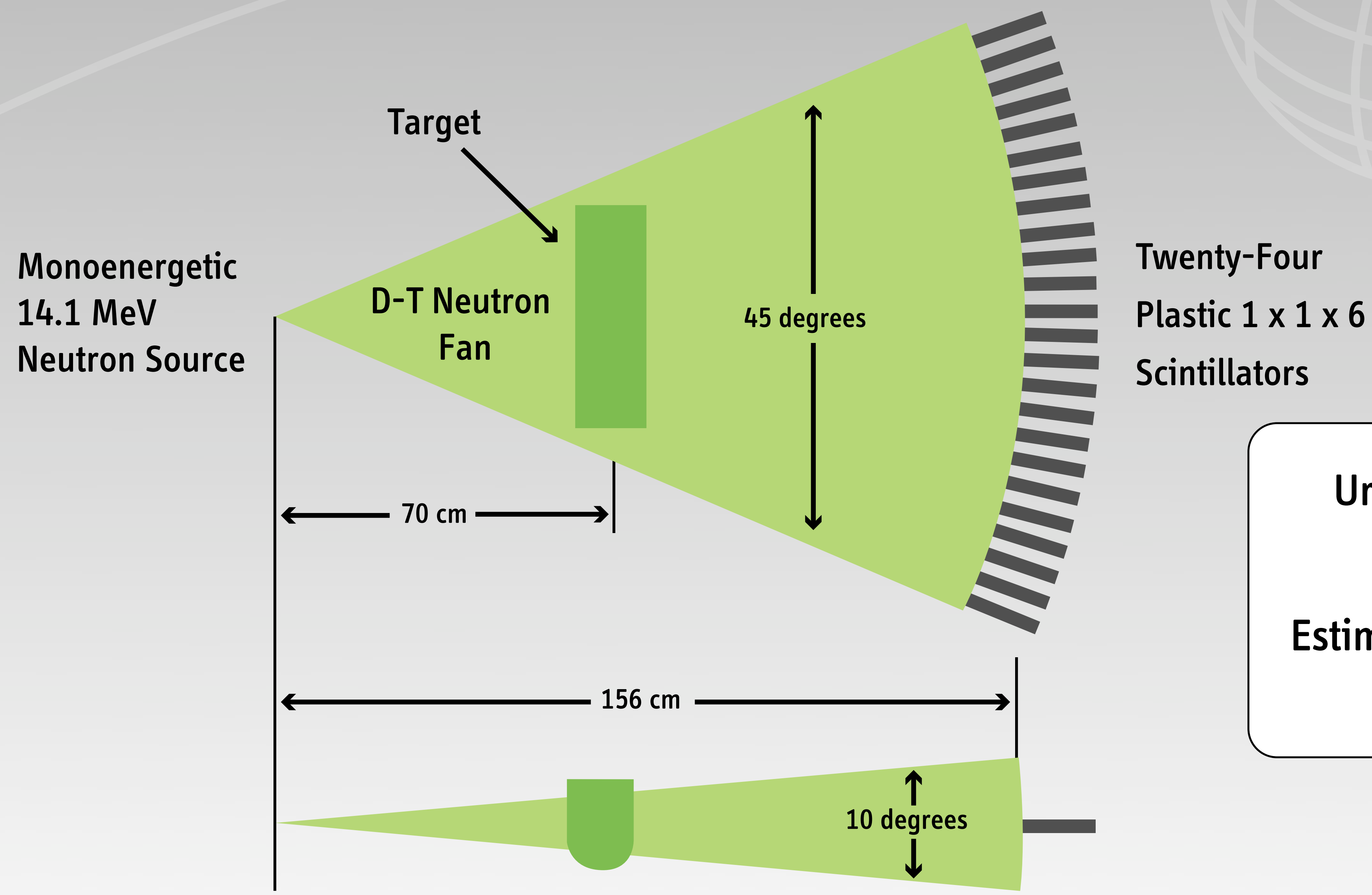
1996-2002 Trilateral Initiative developed approach to determine that a container holds more than a threshold amount of weapon-grade plutonium

Results communicated by red or green lights through information barrier

IPFM is working on corresponding approach for HEU components

Nuclear Materials Identification System

(Oak Ridge National Laboratory)

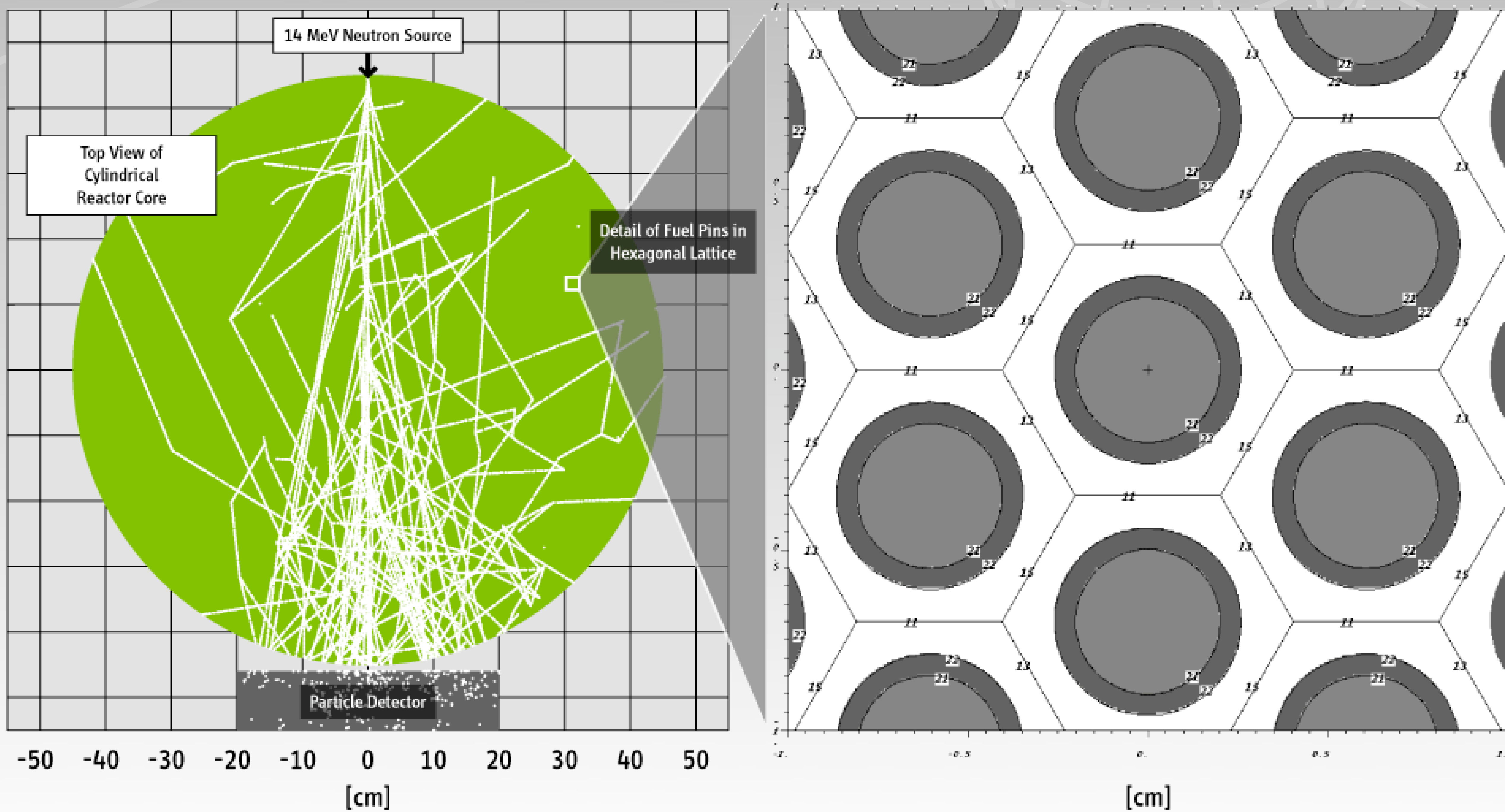


Uranium mass in trough: about 65 kg

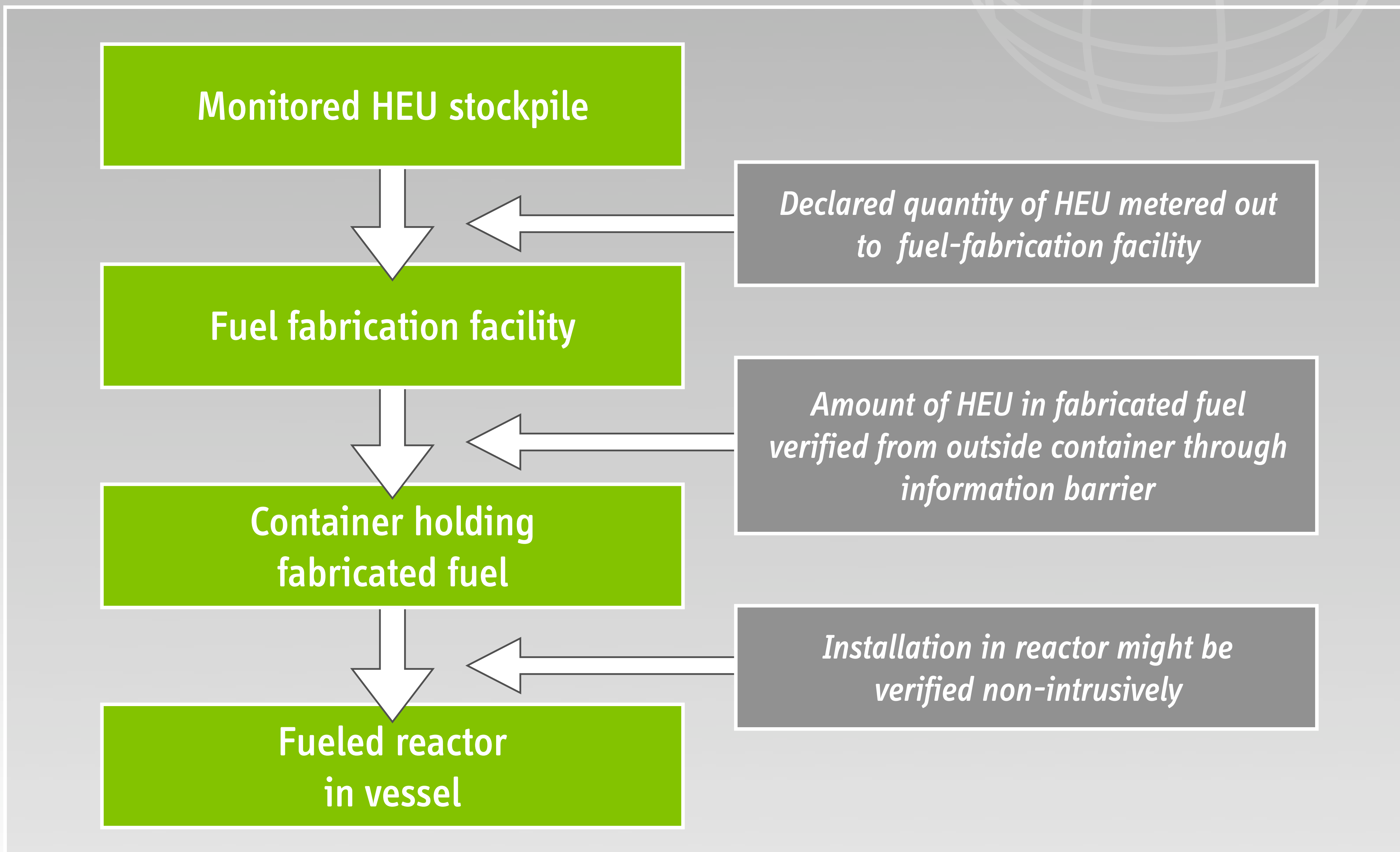
Estimated vs modeled results: < ±3%

B. R. Grogan, J. T. Mihalczo, and J. A. Mullens, *MCNP-PoliMi Simulation of Neutron Radiography Measurements for Mass Determination for a Trough of UO_3*
Institute for Nuclear Materials Management (INMM) 48th Annual Meeting, July 8-12, Tucson, Arizona, 2007

Proposed Setup for Notional Submarine Core



Non-Diversion of HEU Set Aside
For Naval (and Tritium Production) Reactors



Challenge Inspections at Military Nuclear Sites

IPFM
INTERNATIONAL PANEL ON FISSILE MATERIALS

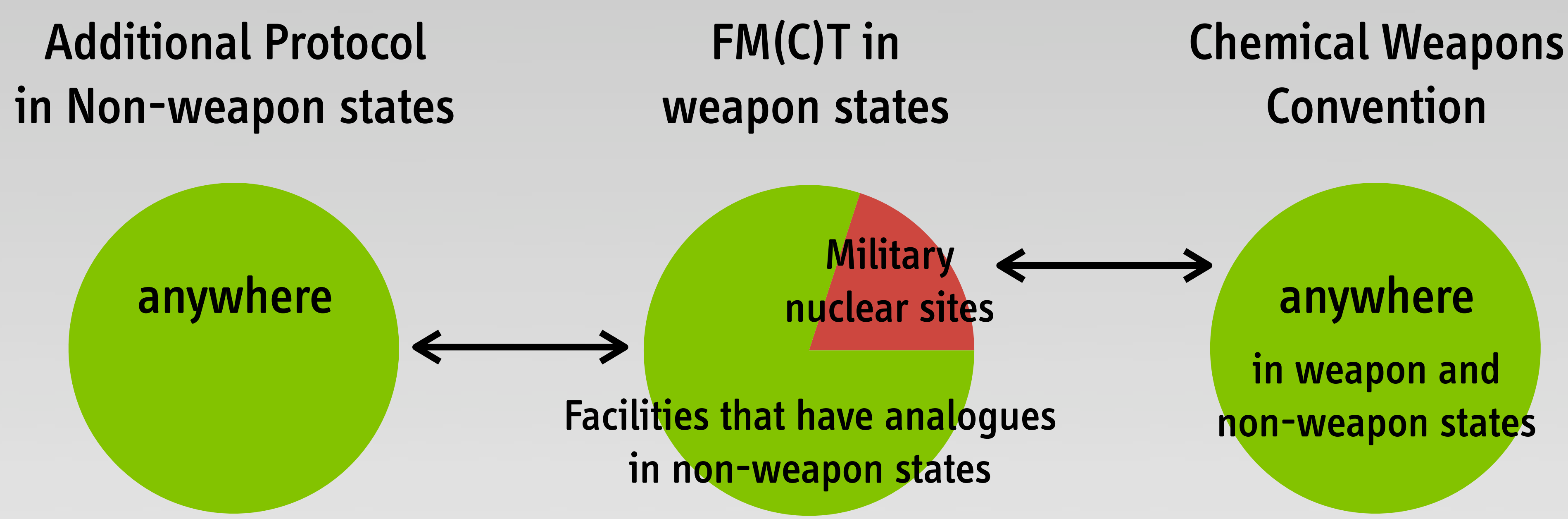
Frank von Hippel
Princeton University
Co-chair, IPFM

IAEA General Conference, October 1, 2008

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

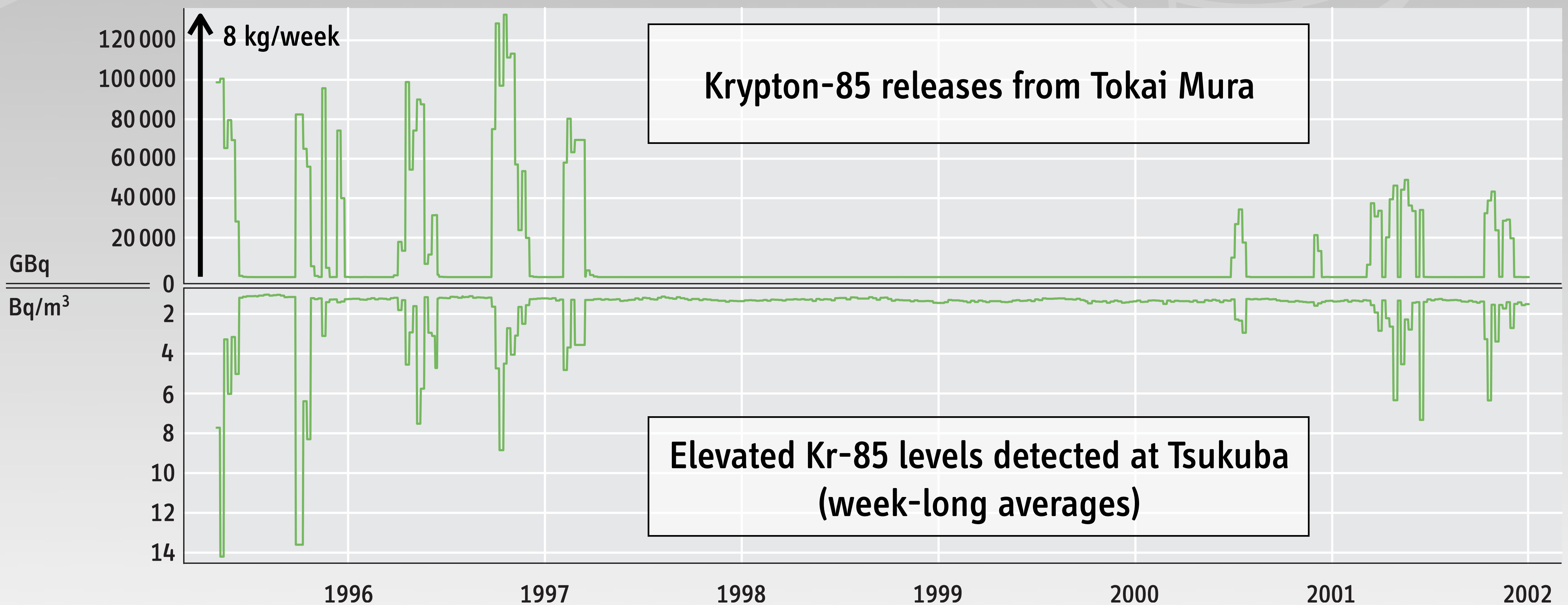
You can take environmental samples off site (Kr-85)

You cannot take on-site samples out of country

You can take photos under the control of the host country

Detection of Tokai Mura Krypton-85 Releases

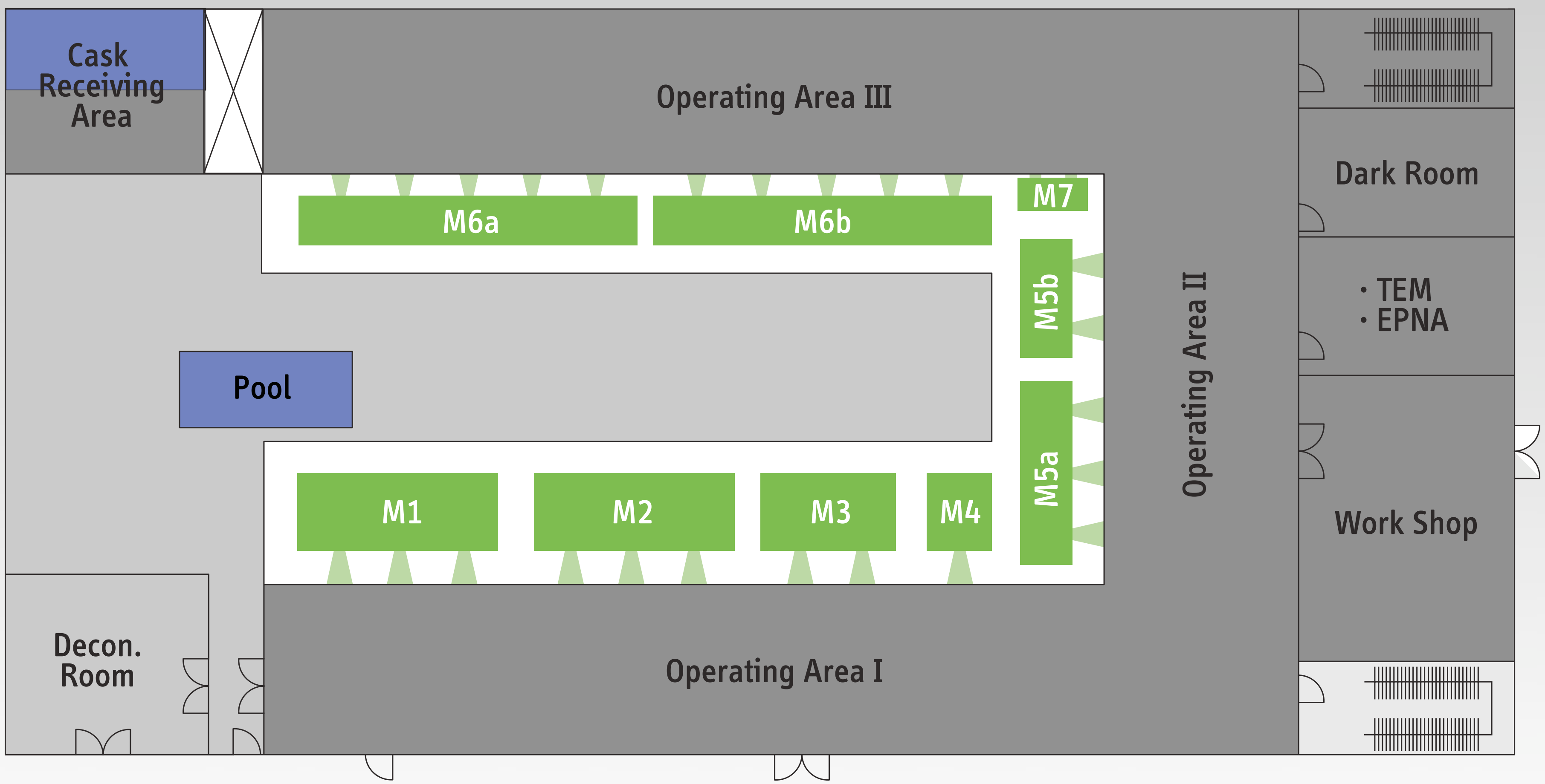
60 km away, Kemp & Schlosser, 2008



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

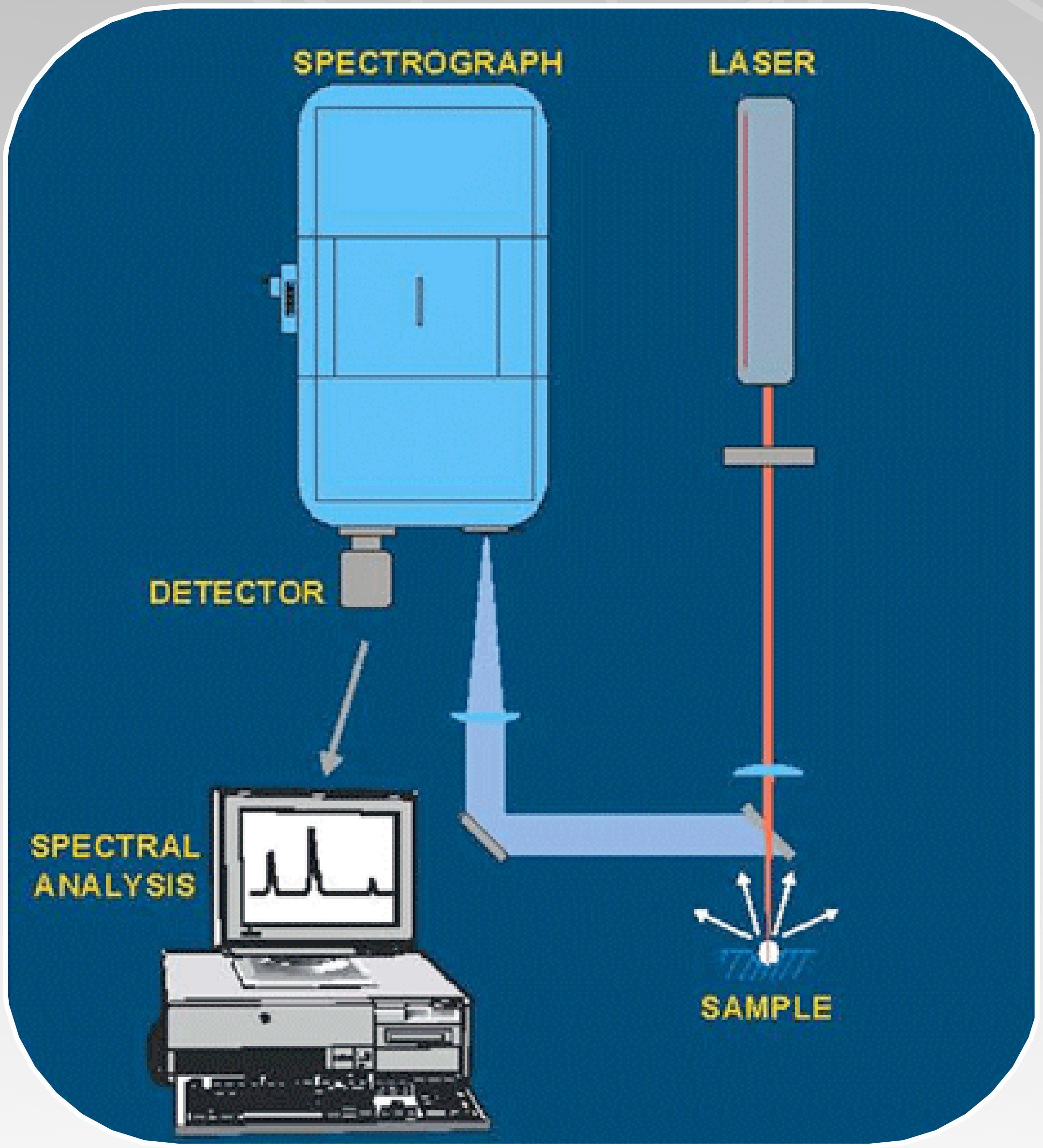
Enrichment Plants

Electromagnetic signals at a
fixed frequency from centrifuge motors

(Habib, Science & Global Security, 2007)

Deposits on the wall containing UO_2F_2
(from leaked UF_6)

Laser-induced breakdown spectroscopy



Conclusion

The technical challenges of FM(C)T verification are significant
but probably not as significant as
the political challenges of FM(C)T negotiation

The costs of FM(C)T verification could be
less than the current IAEA safeguards budget

The technical challenges and costs will come down
as former military production facilities are
shut down and dismantled

Fissile Material (Cutoff) Treaty

Scope and Verification

IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

IAEA General Conference, October 1, 2008