

Getting bomb fuel out of medicine

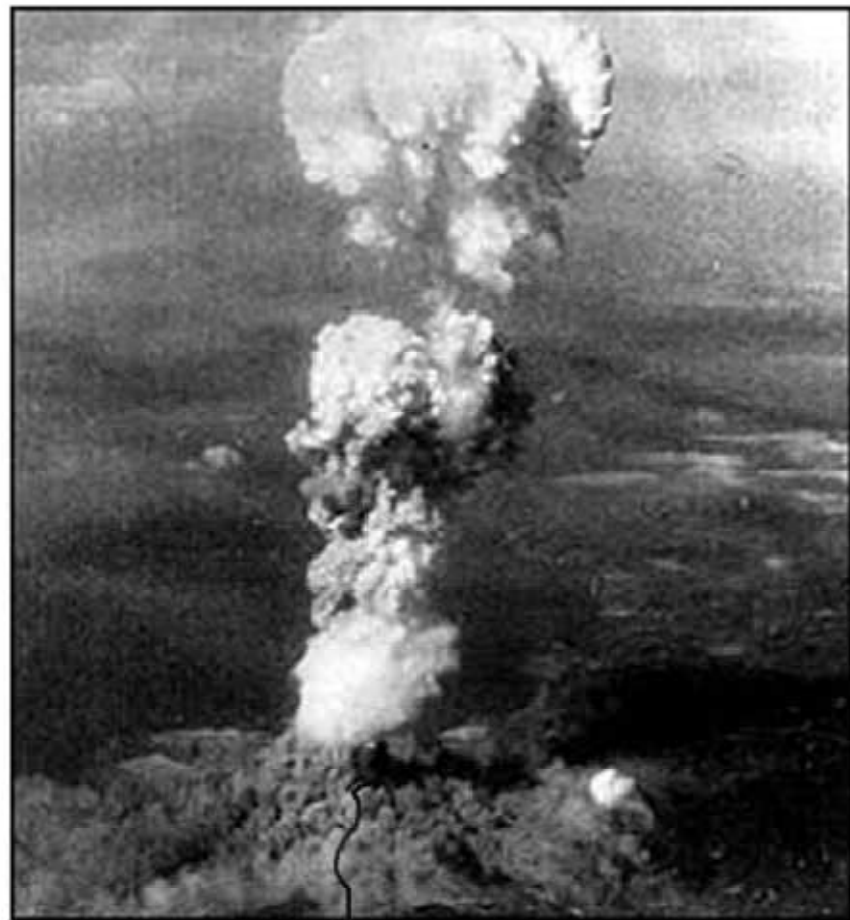
**International Campaign to Abolish Nuclear
Weapons**

Medical Association for Prevention of War (Australia)

International Physicians for the Prevention of Nuclear War

Tilman Ruff

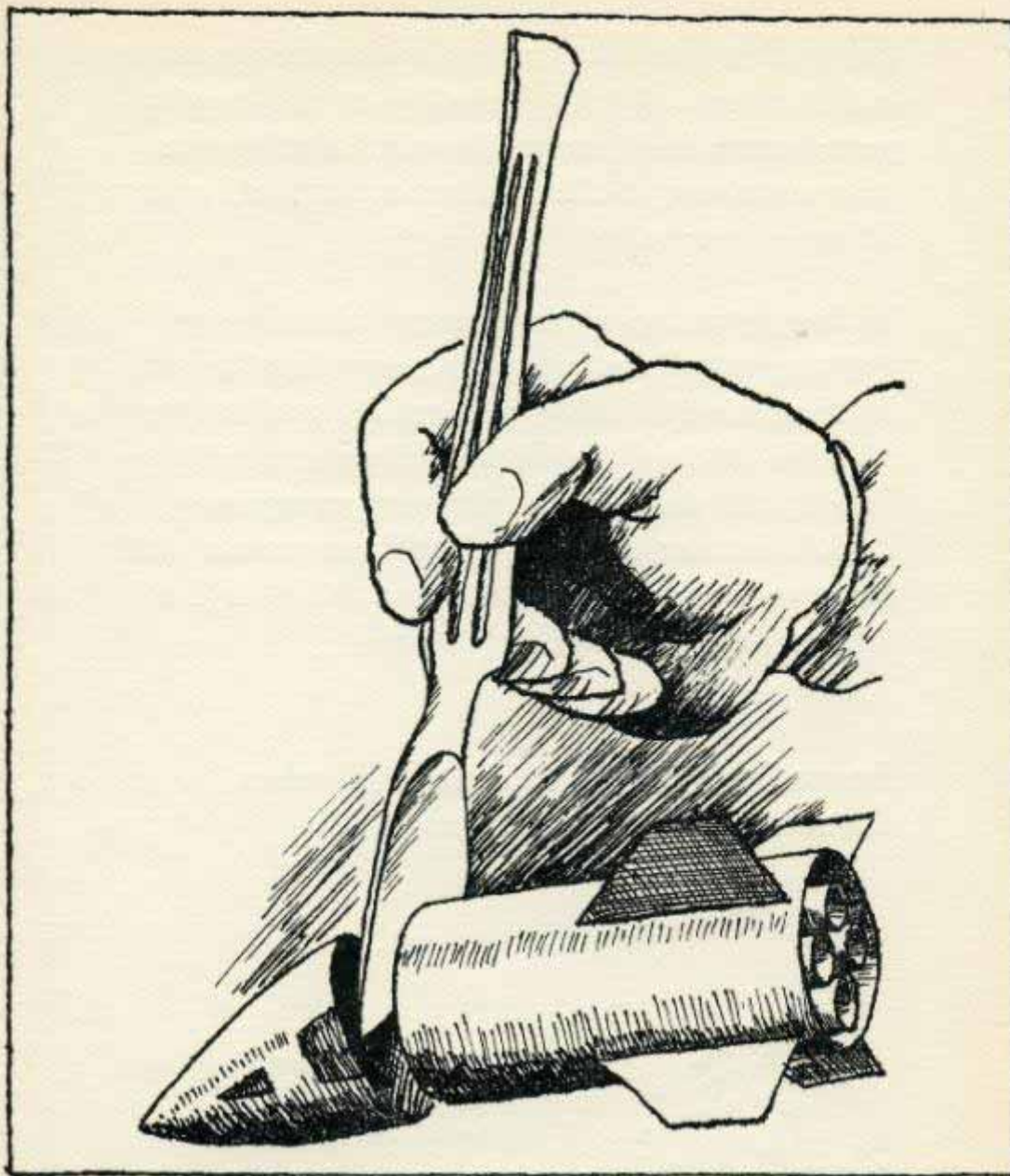
IPPNW Student World Congress 26 Aug 2010



Leunig

Health professionals and the bomb

- Fissile materials for nuclear weapons:
 - Highly enriched uranium (HEU)
 - Plutonium
- End to production, elimination and control of fissile materials is key to abolishing nuclear weapons
- HEU is still used in the production of radiopharmaceuticals
- A completely avoidable proliferation, terrorist and accident danger
- IPPNW has contributed to progress in removal of HEU from medical isotope production but further work is needed

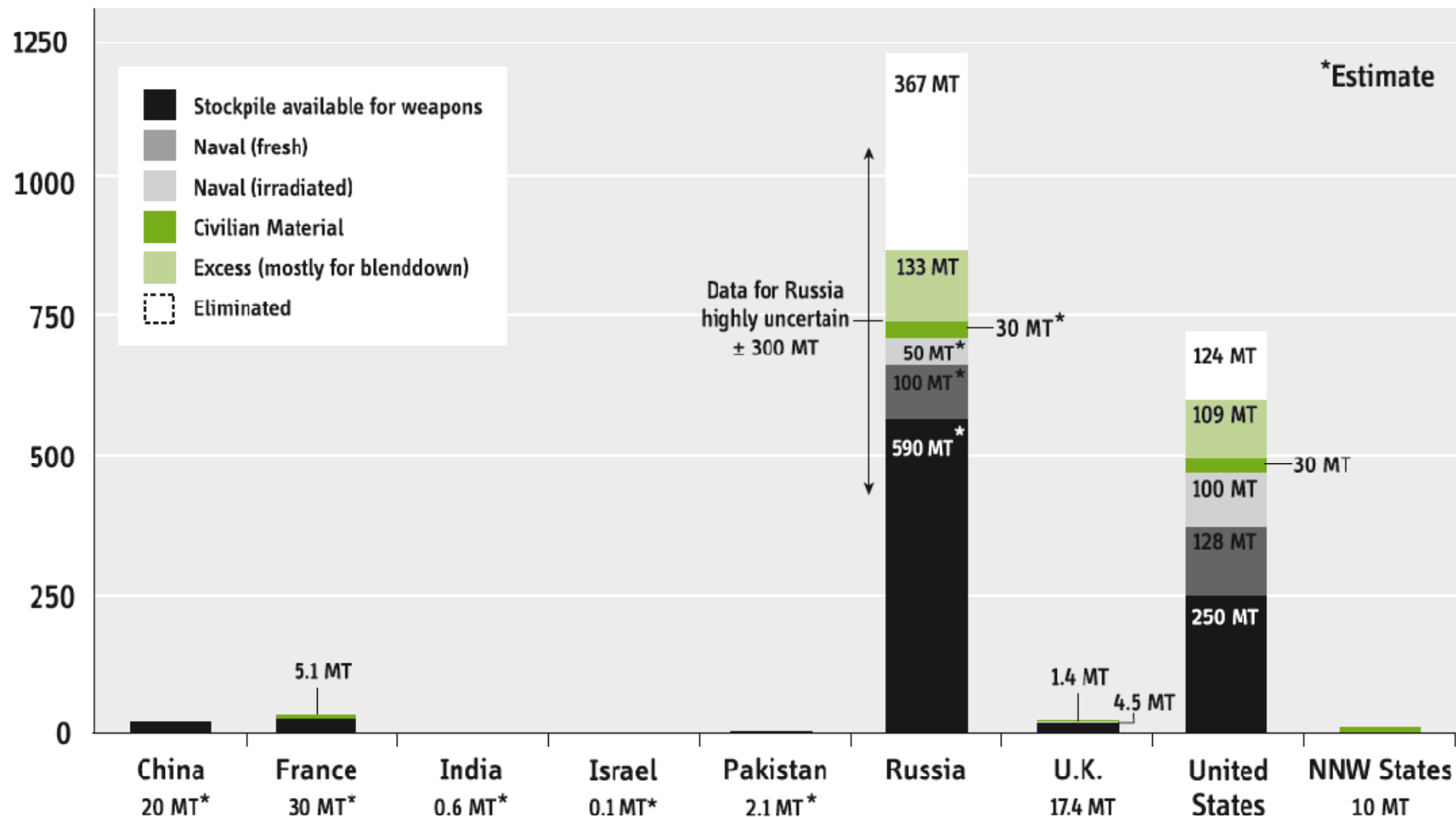


Zeichnung: H. Jo. Eggstein (DDR)

Global Fissile Material Report 2009

Total: 1600 ± 300 tons
HEU mid 2009

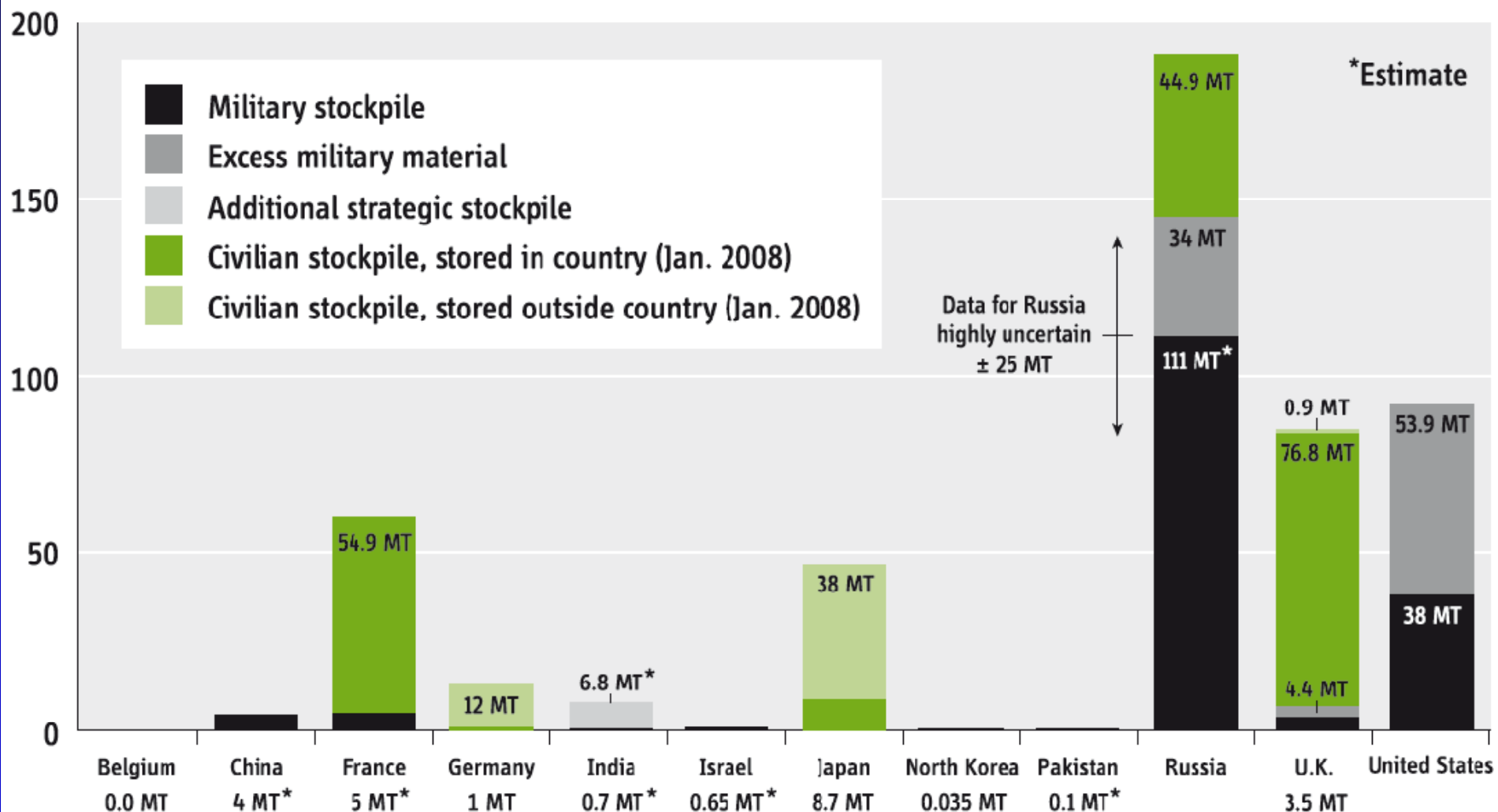
Metric tons [MT]



Global Fissile Material Report 2009

Total: 500 ± 25 tons
sep Pu mid 2009

Metric tons [MT]



Civilian HEU

- HEU reactors (mostly research) widespread – US and Russia – ‘Atoms for Peace’
- Still 140 HEU-fuelled nuclear reactors – 71 in Russia, with still no policy for domestic clean-out
- HEU completely removed from 16 countries
- 40 countries with HEU, 28 countries with enough HEU to make ≥ 1 nuclear weapon
- Tens of tons of HEU reactor fuel at civilian facilities, much with inadequate security
- Any uranium enrichment facility can make HEU
- Clandestine enrichment facility difficult to detect

HEU fuelled research reactors

	Russia	China	Eu	US	Other	Total
Steady state	20	3	12	11	23	69
Pulsed/ critical assembly	51	1	6	8	5	71
Total	71	4	18	19	28	140
Civilian	54	4		12	27	111
Military	17	-	3	7	1	29

'Civilian' HEU

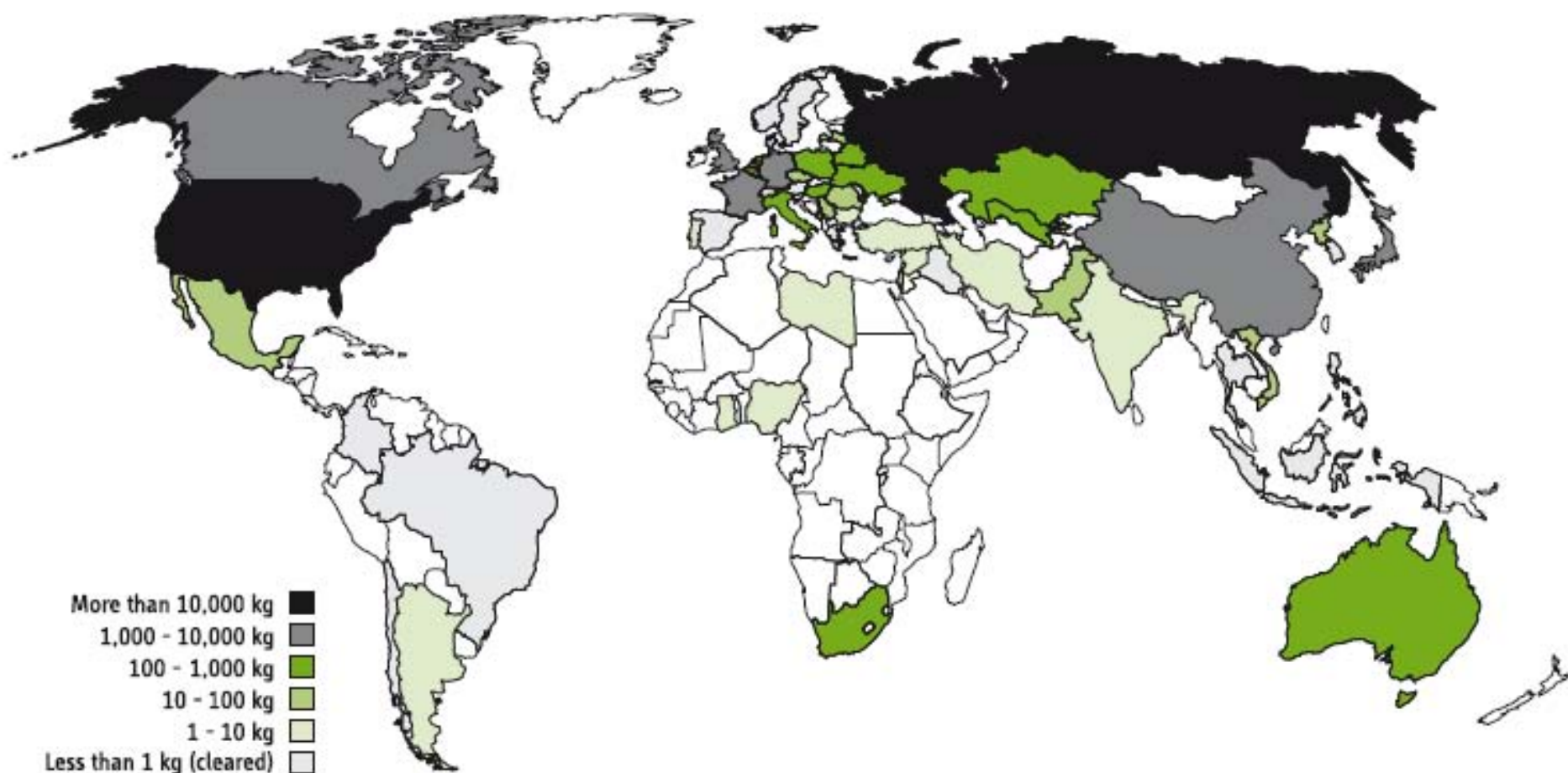


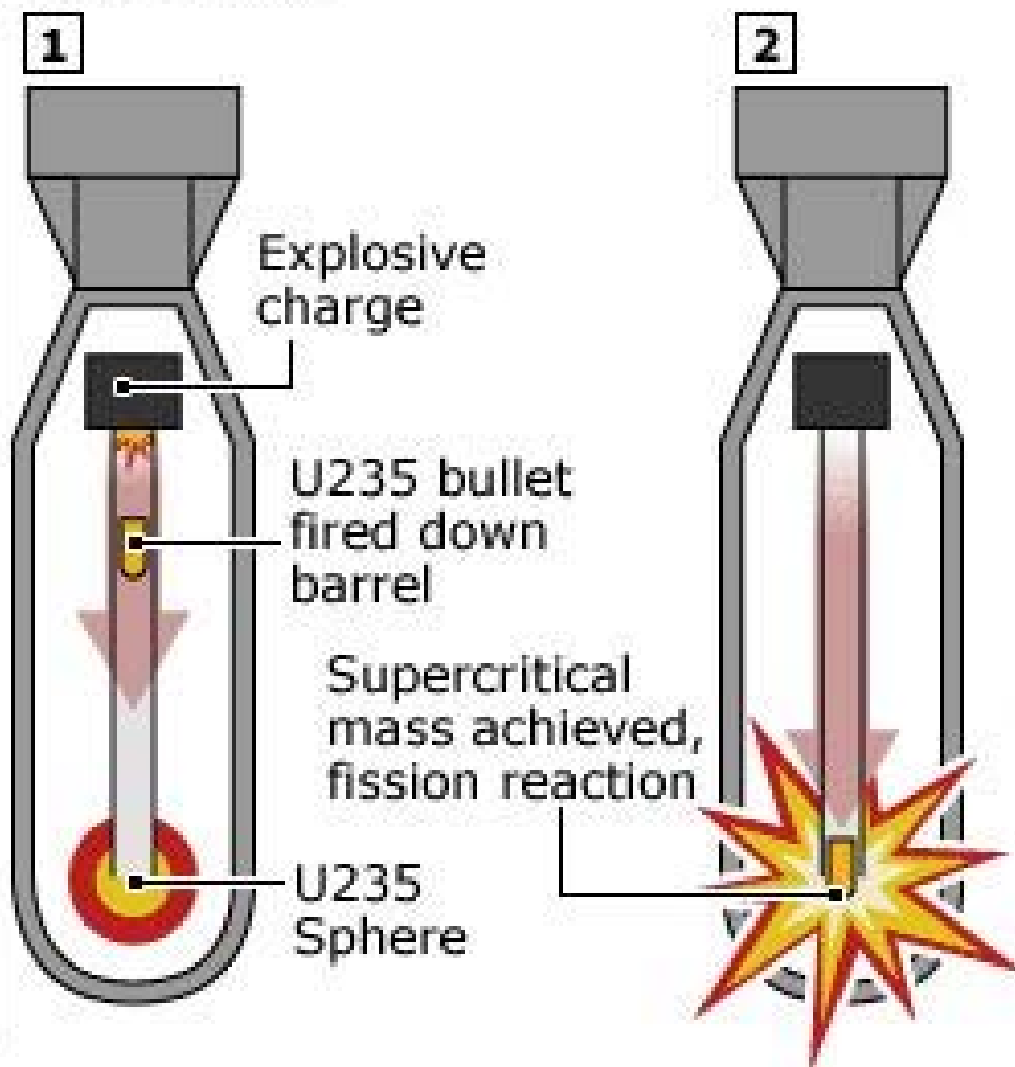
Figure 1.3. Civilian HEU is still distributed around the globe in large quantities. International efforts

100 sites in 40 countries where the material can be found in significant quantities, at operational or

Hiroshima bomb: highly enriched uranium

Gun-triggered fission bomb

'Little boy'
dropped on
Hiroshima, 1945



HEU gun type nuclear weapon

- Hiroshima bomb 60 kg 80% U235
- Overdesigned
- Most HEU >90%
- Design can be optimised using freely available computer codes
- Don't need gun or propellant – gravity suffices
- Could potentially be rapidly assembled on site

Nuclear terrorism

We don't know what a terrorist nuclear device will look like

➤ a 100-pound mass of uranium dropped on a second 100-pound mass, from a height of about 6 feet, could produce a blast of 5 to 10 kilotons – Dr. Frank von Hippel, Princeton

(cited in <http://www.scribd.com/doc/211771/US-Nuclear-Weapons-Complex-Y12-and-Oak-Ridge-National-Laboratory-at-High-Risk>)



Above: traditional concept of “suitcase nuke”

Below: Art installation by Gregory Green, “Nuclear Device #2 (10 Kilotons Plutonium 239),” 1997

HEU is readily smuggled

- Twice in past 2 y, Tom Cochran and Matthew McKinzie from NRDC have helped an ABC News team smuggle a drink-can size cylinder of DU (radiation signature comparable to HEU) through radiation detectors at US ports
- U-232 gamma signature potentially detectable – but half Russian HEU, and all HEU produced in Pakistan or Iran likely to have none; and 1mm of lead would shield effectively
- 42 million containers entered US ports in 2005

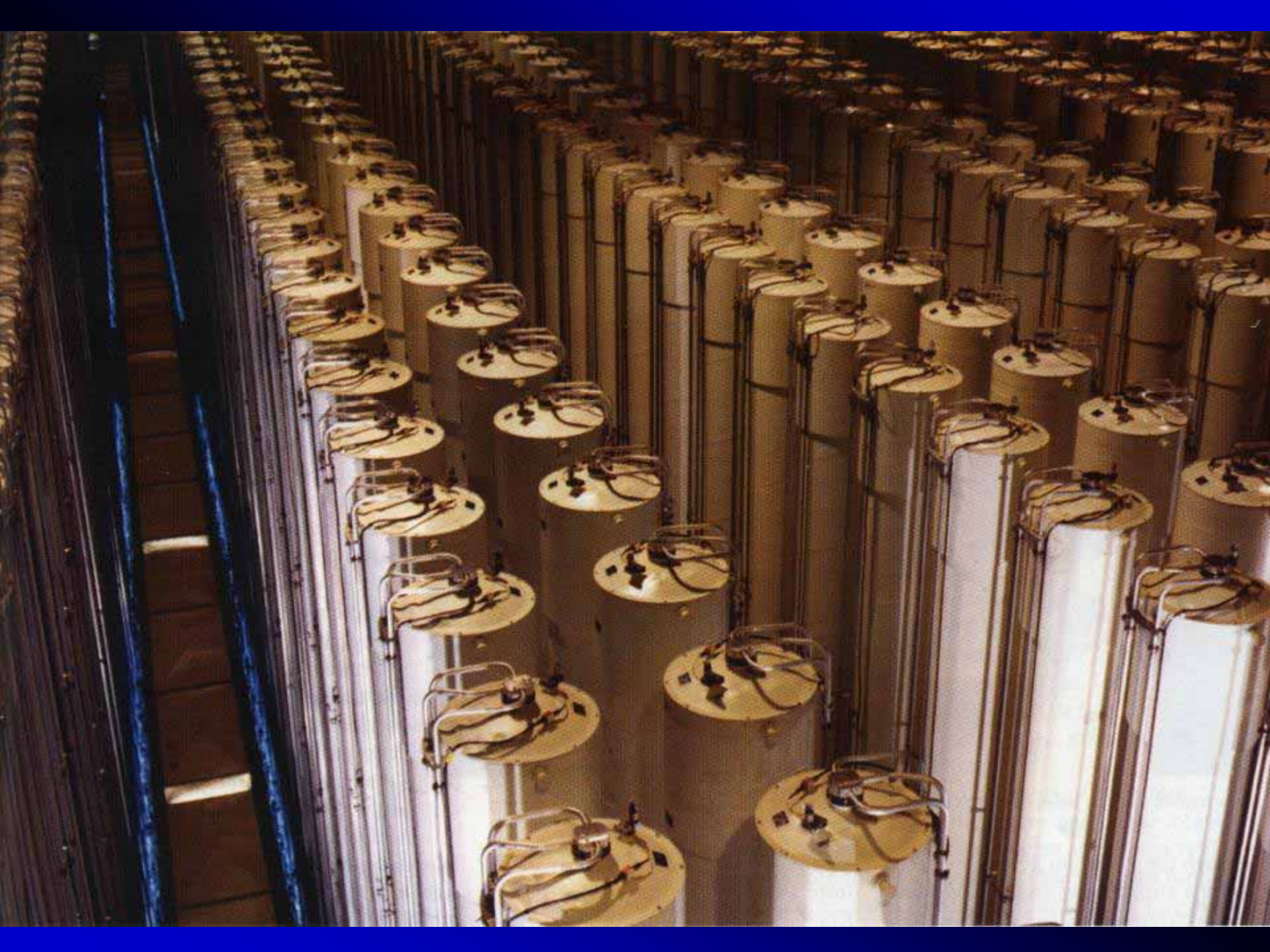
Cochran TB, McKinzie MG. Detecting nuclear smuggling. Sci Am
2008 (24 March)

Fissile materials

Weapon yield	Weapons grade plutonium	Highly enriched uranium
1 kiloton	1 – 3 kg	2.5 – 8 kg
20 kiloton	3 - 6 kg	5 – 16 kg

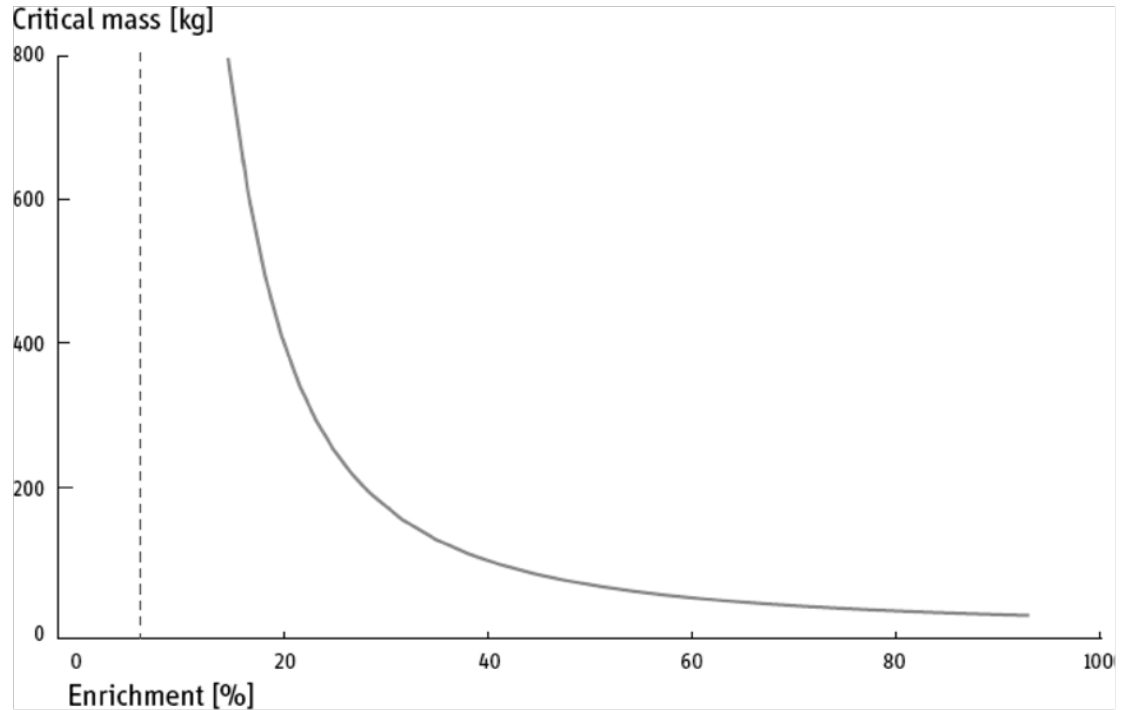
- Global stockpiles:
- **Highly enriched uranium (HEU)**
 - 1700 (1400 -2000) tons HEU
 - US-Russia military stockpile 600-1200 tons (~25 -50,000 nw)
- **Separated plutonium**
 - 500 tons
 - ½ weapons, ½ civilian
 - All weapons usable

Global fissile material report
2007 www.fissilematerials.org

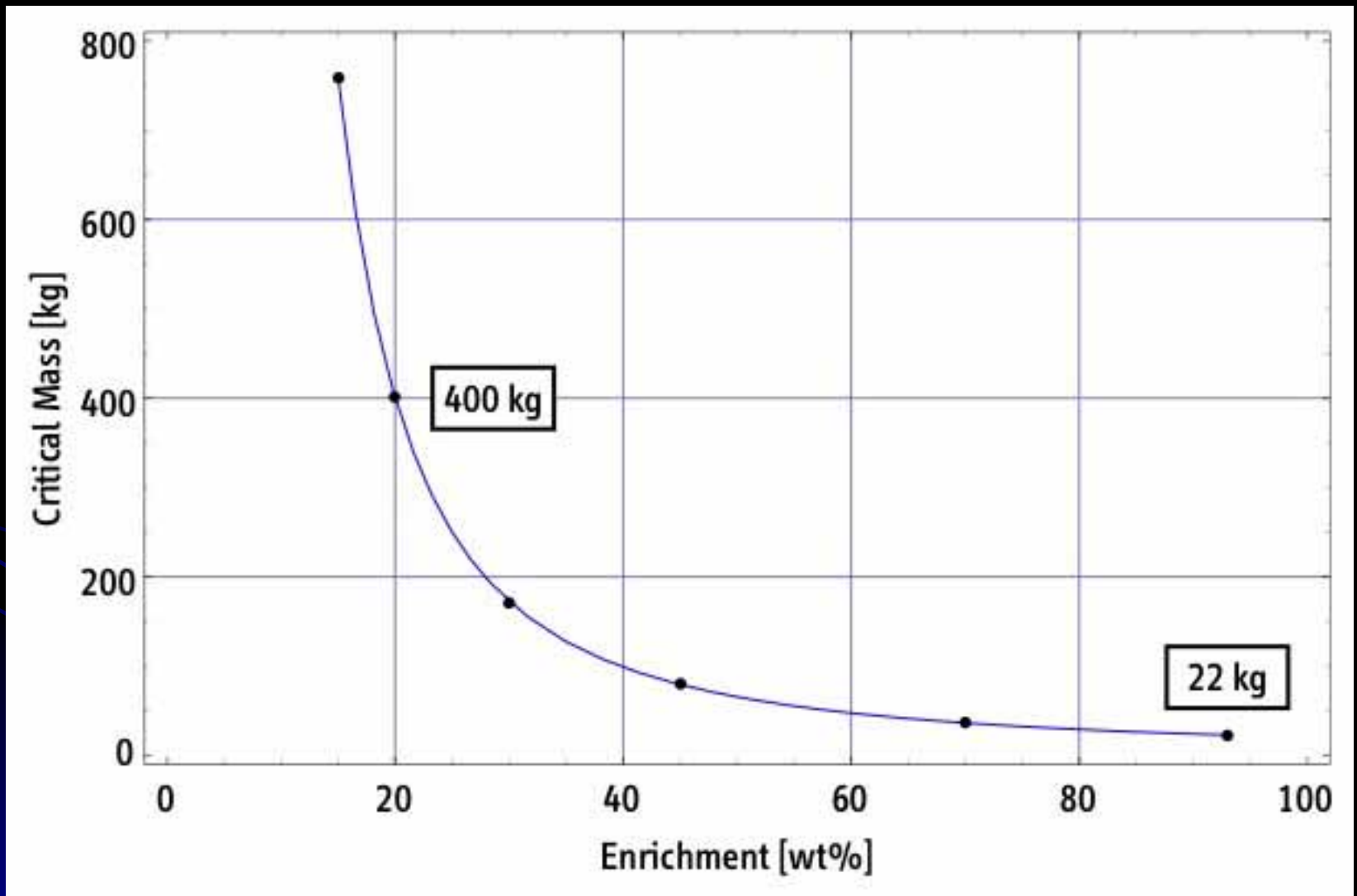


Uranium enrichment

- Natural uranium = 0.7% U-235
- Weapons grade $\geq 80\%$ - usually enriched to $\geq 90\%$, but lower % still usable
- HEU = $>20\%$
- Reactor grade 3-5%
- 2/3 of work to weapons grade
- Material, equipment, expertise identical



Critical mass as function of uranium enrichment (with a beryllium reflector)



Nuclear terror...

“... terrorist groups have been trying aggressively to obtain nuclear materials ...”

- 1993: 40 kg weapons grade U seized in Odessa
Barnaby F, Dirty bombs and primitive nuclear weapons. Oxford Research Group June 2005
- Dec 1994: Czech police seize 4 kg HEU. ...
- Oct 2001: Turkish police arrest 2 men with 2.56 pounds weapons grade uranium.
- *Al-Qaida* agents have tried to buy uranium from South Africa, and have made repeated trips to three central Asian states to try to buy weapons grade material or complete nuclear weapons...”

Helfand I et al. Nuclear terrorism. BMJ 2002; 324:356-9.

- IAEA Illicit Trafficking Database:
>1326 confirmed incidents 1993-2007
– 15 involving HEU or plutonium



Fissile material insecurity



- Truck carrying 140 kg plutonium at petrol station in France : October 2004

- **Illegal nuclear trafficking networks**

- A Q Khan network

- “the Wal-Mart of private proliferation” (ElBaradei)
 - Centrifuge design and components, Chinese nuclear weapons designs
 - Transit points and dealers in ~ 30 countries
 - Supplied at least Iran, Libya, North Korea
 - Implausible could have acted without government
 - Protected by Pakistan government
 - ElBaradei: Khan “the tip of an iceberg”
 - Uncertain if network disrupted or persists

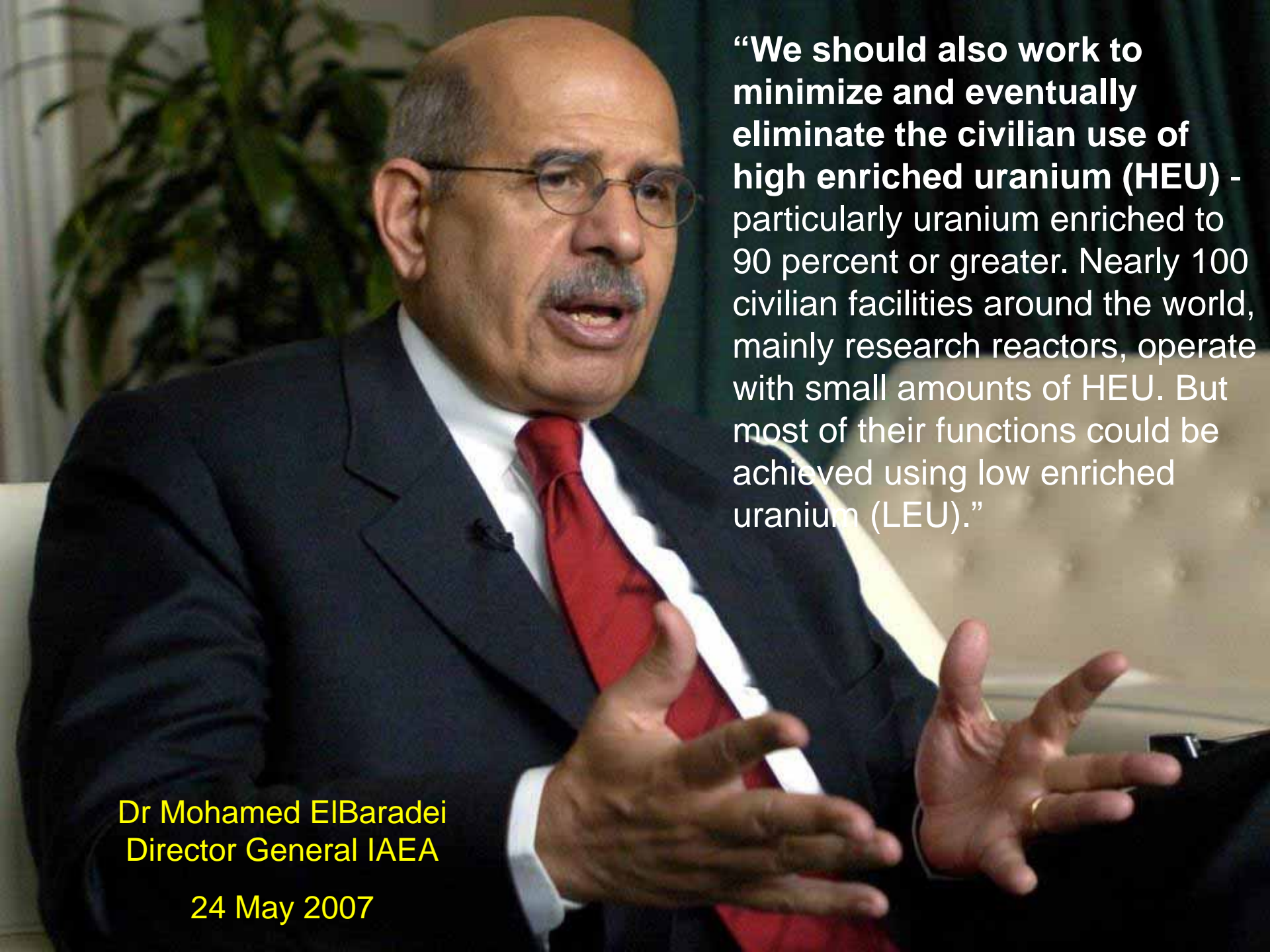
Cirincione J et al. Deadly arsenals. 2nd ed. Carnegie Endowment for International Peace. 2005

Bomb-grade uranium in the marketplace

- **URGENT**...phasing out the use of highly enriched uranium in civil commerce and removing weapons-usable uranium from research facilities around the world and rendering the materials safe.'



Schultz GP, Perry WJ, Kissinger HA, Nunn S. A world free of nuclear weapons. Wall Street Journal, 4 January 2007. p. A15.

A photograph of Dr. Mohamed ElBaradei, Director General of the IAEA, speaking. He is a middle-aged man with a mustache and glasses, wearing a dark suit, white shirt, and red tie. He is gesturing with both hands while speaking. The background is slightly blurred, showing a green plant on the left and a light-colored wall on the right.

“We should also work to minimize and eventually eliminate the civilian use of high enriched uranium (HEU) - particularly uranium enriched to 90 percent or greater. Nearly 100 civilian facilities around the world, mainly research reactors, operate with small amounts of HEU. But most of their functions could be achieved using low enriched uranium (LEU).”

**Dr Mohamed ElBaradei
Director General IAEA**

24 May 2007

WEAPONS OF TERROR

Freeing the World of Nuclear,
Biological and Chemical Arms

What must be done:

...

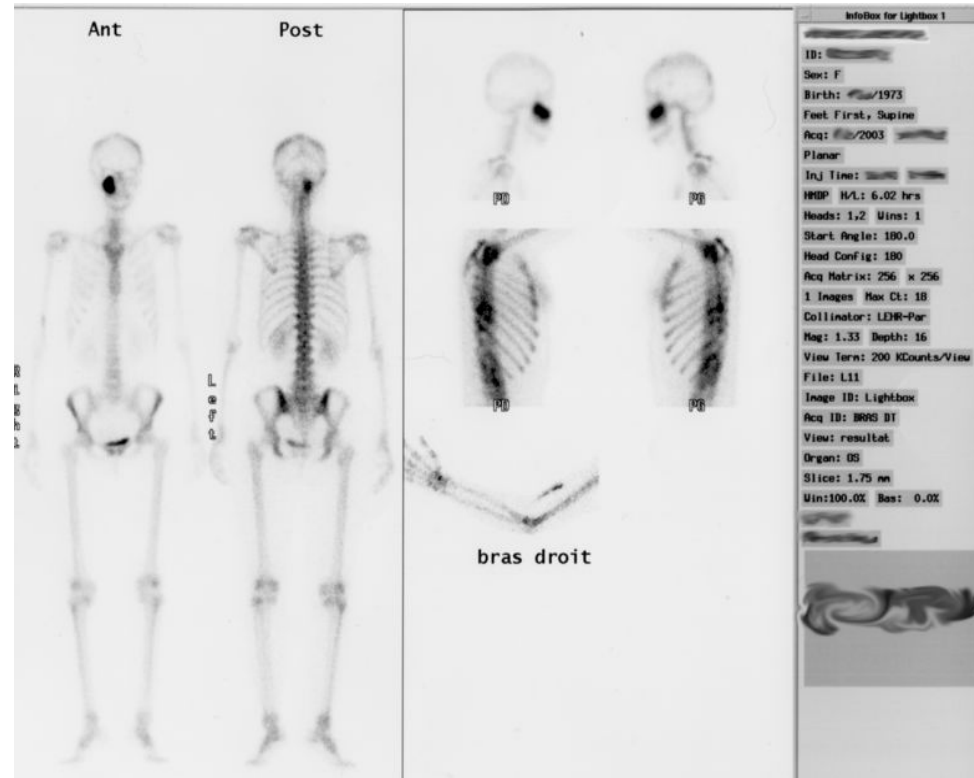
“Prohibit the production of fissile material for nuclear weapons and phase out the production of highly enriched uranium.”

WMD Commission 2006

Medical isotopes

Technetium-99 (Tc-99m)

- 'workhorse' isotope
- >75% per cent of medical isotope procedures worldwide
- 25 million procedures pa
- favoured isotope tracer in bone scans, thyroid scans
- $T_{1/2} = 6$ hours
- NM departments buy precursor, **molybdenum** (Mo-99, $T_{1/2} = 66$ hours)
- Expanding use esp cardiology
- Wide global variation in usage



HEU and nuclear medicine

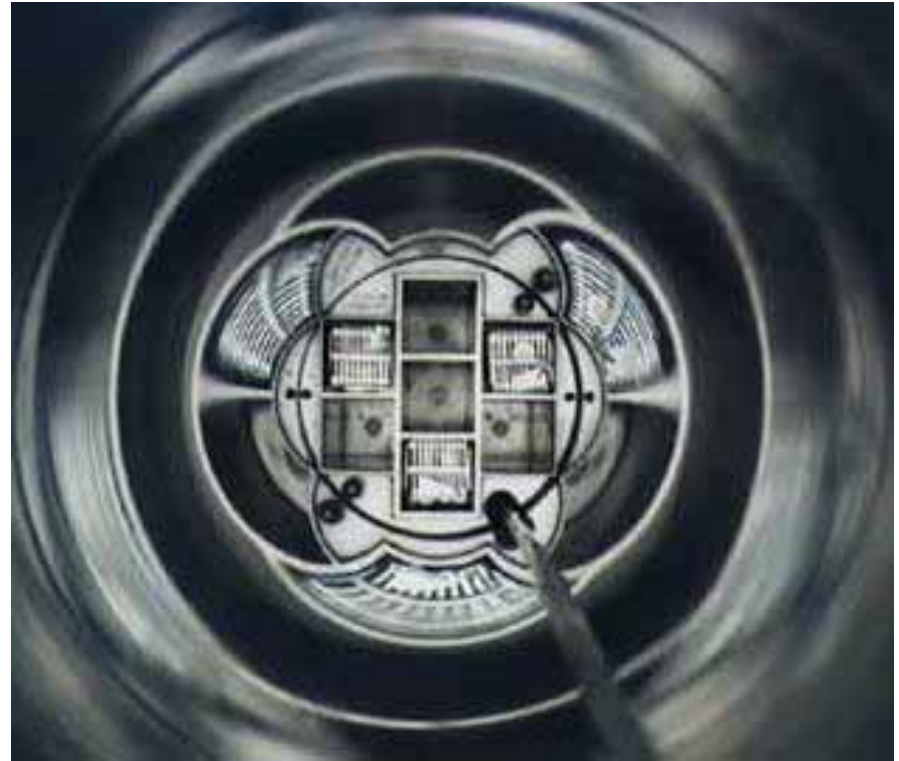
- > 95% of the world's radiopharmaceuticals are derived from bomb grade Highly Enriched Uranium (HEU)
- HEU use
 - Reactor fuel +/-
 - 'Targets'



Uranium fuel pellets

Isotope production

- neutron bombardment of HEU '*targets*' to produce radioisotopes for nuclear medicine
- some reactors also still use HEU as *reactor fuel*
- process consumes < 3% of the available U-235
- **So: 'used' target = still bomb-grade uranium**



Unloading fuel from a research reactor

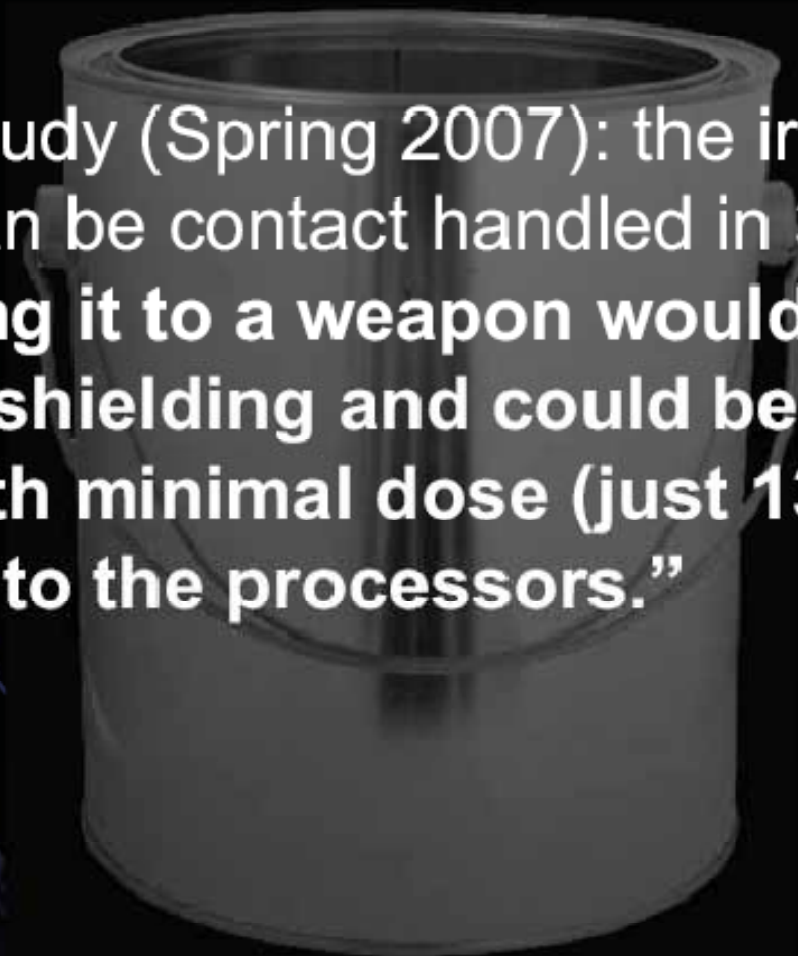
Feasibility of Non-State Actors Acquiring HEU from Mo-99 Target Waste

- Isotope waste is particularly vulnerable: it is very highly enriched and relatively lightly irradiated
 - Solid Mo-99 target waste: oxide mix in 80 gram containers (easily transportable)
 - Processing liquid HEU target waste from production of Mo-99 to get metal: well-known process

Feasibility of Non-State Actors Acquiring HEU from Mo-99 Target Waste

Argonne study (Spring 2007): the irradiated target material can be contact handled in 3 years:

“converting it to a weapon would not require elaborate shielding and could be performed in a garage with minimal dose (just 13-37 mrem/hour per gram) to the processors.”



Suppliers of radiopharmaceuticals

4 major competitors

1. MDS Nordion (Canada)
 2. Covidien
(formerly Tyco Healthcare /
Mallinckrodt (Netherlands))
 3. Institut National des
Radioéléments (Belgium)
 4. NECSA (South Africa)
- >95 per cent of
the global supply
 - 7 different
reactors



NRU Reactor at Chalk River, Canada,
where MDS Nordion irradiates HEU
targets to produce medical isotopes

Tc-99m Production: major producers

CANADA
NRU reactor
(Chalk River)
_ employs 93%
enriched
uranium
targets

BELGIUM
BR-2 reactor
(Mol)
_ employs 74-
93% enriched
uranium
targets

FRANCE
Osiris
(Saclay)
_ employs 93%
enriched
uranium
targets

NETHERLANDS
HFR
(Petten)
_ employs 93%
enriched
uranium
targets

**SOUTH
AFRICA**
SAFARI
(Pelindaba)
_ employs 36-
45% enriched
uranium
targets

Target supply

Target
irradiation

Mo-99

Mo-99

Mo-99

Mo-99

Mo-99

CANADA
MDS Nordion
(Kanata)

BELGIUM
Institut des
Radioéléments
(IRE) (Fleurus)

NETHERLANDS
Covidien formerly
Mallinckrodt
(Petten)

SOUTH AFRICA
NTP Radioisotopes
(PTY) Ltd.
(Pelindaba)

Isotope
processing

Tc-99m
generator

Tc-99m
generator

Tc-99m
generator

Tc-99m
generator

WORLDWIDE DISTRIBUTION

Thousands of companies distribute technetium generators to hospitals and laboratories around the globe



Distribution of
Tc generators

Hazard 1: supply threatened

CANADA

NRU reactor

- Criticality: **1957**
- About 40% of world production
- Current license expires: **2011**
- MAPLE reactor project cancelled, **May 2008**

BELGIUM

BR-2

- Criticality: **1961**
- About 30% of European (10% global) production
- Shutdown planned: **2016**

FRANCE

Osiris

- Criticality: **1966**
- About 3% of global production
- Jules Horowitz reactor – online in **2014?**

NETHERLANDS

High Flux Reactor (HFR)

- Criticality: **1961**
- 60-70% of European (30% global) production
- To be replaced by Pallas reactor in about **2015**

SOUTH AFRICA

SAFARI reactor

- Criticality date: **1965**
- About 15% of world production

Over 90% of world production happens at reactors built in the 1950s and early 1960s.

As use of Tc-99m increases, future production is not assured.

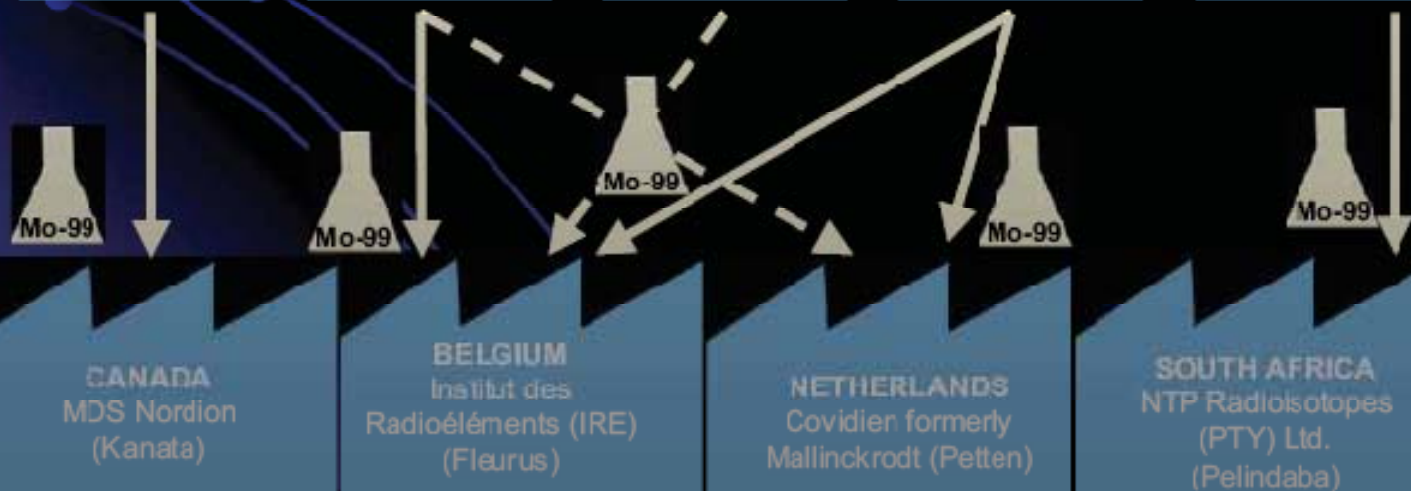


Table 1: Reactors producing ^{99}Mo for major international distributors in 2005.¹⁰

Reactor/Country	Power (MWt)	Initial Operation (shutdown)	Percent of year operating	Distributor	Av/Peak production (% world demand)
NRU/Canada	135	1957	86	MDS-Nordion	40/80
HFR/Netherlands	45	1961	79	Mallinckrodt	20/30
				IRE	10/20
BR2/Belgium	100	1961	31	Mallinckrodt	5/15
				IRE	4/20
Osiris/France	70	1964	60	IRE	3/20
FRJ-2/Germany	23	1962 (2006)	57	IRE	3/10
SAFARI South Africa	20	1965	86	NTP	10/45
Other				Other	5/10
				Total	100/250

From HEU to LEU

Low enriched uranium-LEU

- targets < 20 % U-235
- suits Mo-99/Tc-99m production
- *not* usable for weapons
- Argentina, Indonesia and Australia use LEU targets (<5% of market)



New OPAL reactor, Sydney: LEU fuel and targets

Tc-99m: scaling up new (LEU-based) production

ARGENTINA

RA-3 reactor

- First to convert to LEU targets (regular production since Oct. 2002)
- Only reactor currently producing hundreds of Ci of Mo-99 from LEU on a weekly basis

AUSTRALIA

OPAL reactor (constructed by INVAP)

- Employs LEU targets
- Plans to become major Tc-99m producer

INDONESIA

GA Siwabessy research reactor

- Converting to LEU targets

EGYPT

ETRR-2 Reactor (constructed by INVAP)

- Operating since 1988
- Radioisotope production planned

UNITED STATES

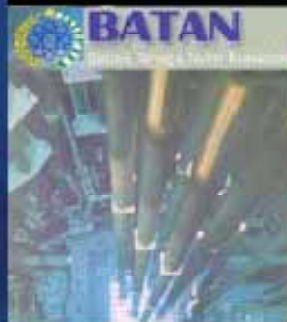
- Missouri University Research Reactor (MURR), investigating LEU-based production (30-50% U.S. demand by 2010?)

- B & W: new solution reactor system

New production using HEU does not make sense.

But can new non-HEU producers gain a significant portion of the market?

- Large capital requirement
- Regulatory intense
- Long "time to market"



Conversion

Oslo IAEA symposium, June 2006

‘The conversion of radioisotope production, specifically Mo-99, to LEU is technically feasible, and ... remaining obstacles to conversion of this activity are ***chiefly of commercial nature.***’

Prof. Jose Goldemberg, International Panel on Fissile Materials

SUMMARY

- conversion from HEU to LEU is possible
- no future needs for HEU identified
- current conversion programmes: successful

Radioisotope Quality Data: Argentina's experience with LEU

	I-131	Ru-103	Sb-125	Cs-137	Sr-90	Gross alpha
HEU (n=28)	2,41E-06	2,77E-07	7,50E-09	2,95E-10	6,88E-09	1,95E-11
LEU (n=48)	1,50E-07	1,67E-08	5,68E-10	3,62E-10	7,88E-10	1,21E-11

- LEU Mo-99 specifications exceed British Pharmacopoeia
- Quality of product is superior to HEU counterpart
- Both are clearly acceptable

Cleaning up

- August 2002, the Vinca Institute of Nuclear Science, Belgrade: removal of 48 kilograms of fresh (unirradiated) HEU research reactor fuel
- The high-flux reactor at Petten in the Netherlands was converted in October 2005



Commercial viability

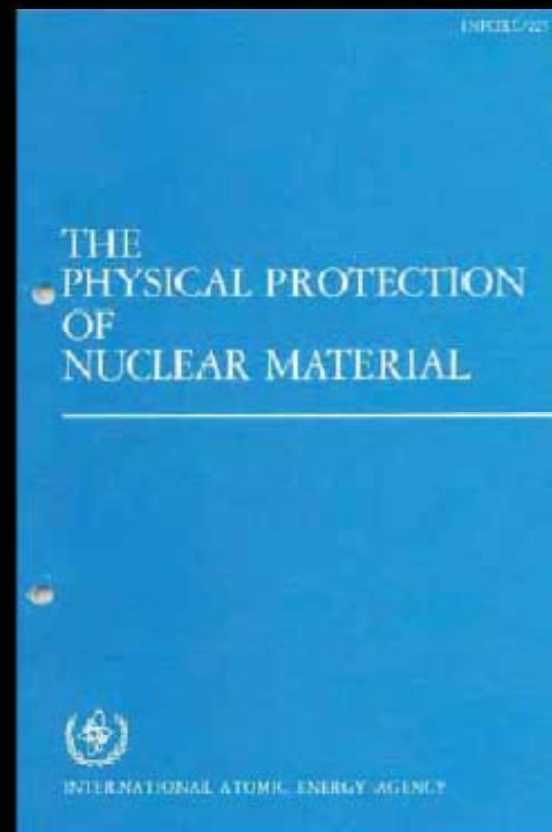
- cost to consumers in most applications would be in the order of 1 -2 % increase
- a very large cost saving: eliminating the very high security costs necessitated by HEU storage and transport

Kahn LH, von Hippel F. How the radiological and medical communities can improve nuclear security.

J Am Coll Radiol 2007;4:248-51.

Reducing the terrorism risk: security upgrades

- Responsibility for nuclear security rests entirely with states
- Many security arrangements today based on considerations of worker safety
- Increasing security will cost far more over the long term than eliminating HEU at a facility



Helsinki 2006: IPPNW campaign

- End medical reliance on HEU
- Eliminate a likely source for the much-feared 'terrorist bomb'
- Block vulnerable pathway to fissile material
- Re-awaken profession to threat of nuclear weapons
- Encourage health professionals to engage
- Clean-up 'our own shop':
First, do no harm



So ... ask:

1. Where do *your* isotopes originate?
2. Are they derived from *HEU*?
3. If so, is there an *alternative* supplier not using HEU? If so, please use them.
4. If not, what is the current supplier doing to *convert* to LEU?

Other options: *non-reactor* produced isotopes

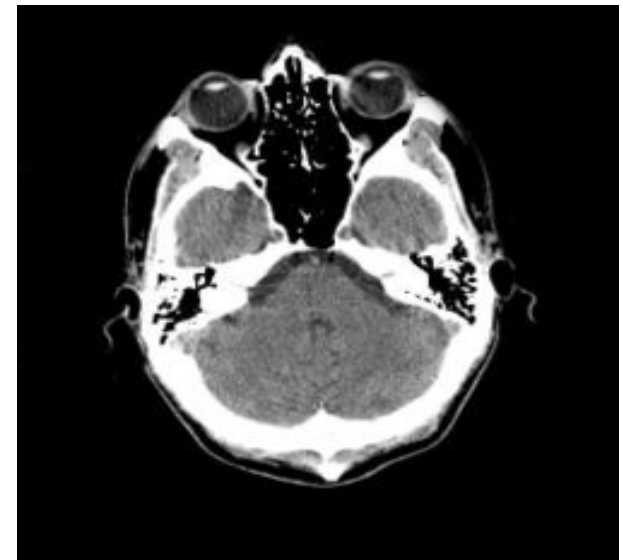
- Cyclotrons and other spallation sources
 - fluorine-18: PET scans
 - thallium-201
 - indium-111
- Potential *non-reactor* routes to Mo-99/Tc-99 exist, but no current commercial projects



Imaging alternatives

Technetium-99m

- Retains important role in medical imaging
- Challenges to Tc-99m:
 - Positron Emission Tomography (PET)
 - Magnetic Resonance Imaging (MRI),
 - Helical, multidetector, high resolution, multislice CT
 - Ultrasound (including echocardiography and Doppler techniques)



Recent developments

- US National Academy of Sciences Report
 - Medical isotope production without HEU, 2008 endorsed goal and feasibility of isotope production without LEU
- Crisis in supply with unreliable, aging reactors
- Canada:
 - Plans for new HEU-using Maple reactors abandoned
 - 2010 funds for R&D for non-reactor isotope production
- President Obama
 - commitment to remove HEU from civilian applications
 - Nuclear Security Summit April 2010
 - Commitments Mexico and Ukraine to remove HEU
- Several producers are shifting to LEU
 - South Africa notable
- Increased investment in new production capacity
 - eg Japan (LEU)

Medical strategies

- Educate colleagues
- Encourage clinicians to ask NM-providers where their isotopes come from, and
- urge a non-HEU source whenever possible
- Optimise use of alternative imaging technologies
- Promote R & D of non-reactor isotopes
- Promote medical association and government policies encouraging elimination of HEU

Current priorities for medical action 1

- US

- pressure on Sen Christopher Bond R-Missouri who is obstructing bill for gov support for non-HEU production and phase-out HEU supply

- Canada

- Commend and encourage investment in non-reactor isotope production R&D
- Conversion of targets to LEU

- Belgium

- BR2 – implementation of commitment to convert from HEU fuel; encourage conversion of targets also

Current priorities for medical action 2

- France
 - New Jules Horowitz reactor under construction should use LEU from outset not HEU fuel initially as currently planned
- Netherlands
 - New HFR reactor under construction at Pallas – clarify nature of targets
- Poland
 - Conversion or closure of HEU-fuelled Maria reactor being used from 2010 to fill supply gaps

Current priorities for medical action 3

- For all current reactors esp using HEU – closure and decommissioning as soon as alternative supply adequate
- Review imaging guidelines to favour non-reactor based (and non-ionising radiation) procedures wherever not disadvantageous to patient care

Conclusions

- Abolition of nuclear weapons is the most critical global public health need
- This will require:
 - Abolishing stockpiles and reducing likelihood of use
 - Preventing horizontal proliferation and terrorist acquisition
 - Secure, consolidate and reduce fissile materials
- “First do no harm”:
 - Medical responsibility to clean-up our own shop and remove proliferation and terrorist dangers associated with use HEU to make radiopharmaceuticals