Highly enriched uranium and plutonium elimination programs

Pavel Podvig
Russian Nuclear Forces Project
RussianForces.org

24th ISODARCO Winter Course
Eliminating Nuclear Weapons and Safeguarding Nuclear Technologies
Andalo (Trento) – Italy
09-16 January 2011

International Panel on Fissile Materials

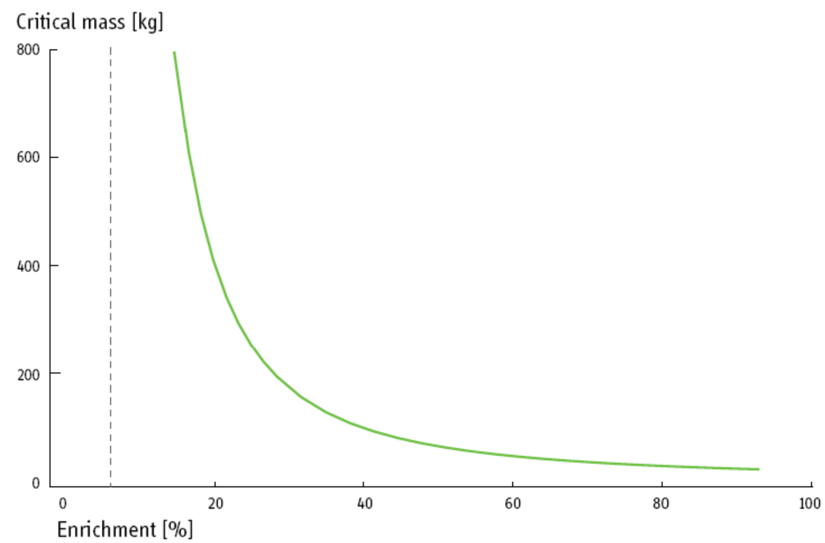
- International Panel on Fissile Materials
- Co-chairs
  - Prof. Rajaraman
  - Prof. Frank von Hippel
- Web site: www.fissilematerials.org
- Blog: www.fissilematerials.org/blog

Fissile materials

- Capable of sustaining a chain reaction
- Uranium-235
- Plutonium-239
- Others
  - U-233, Np-237, Pu-241, Am-241, …

Highly-enriched uranium

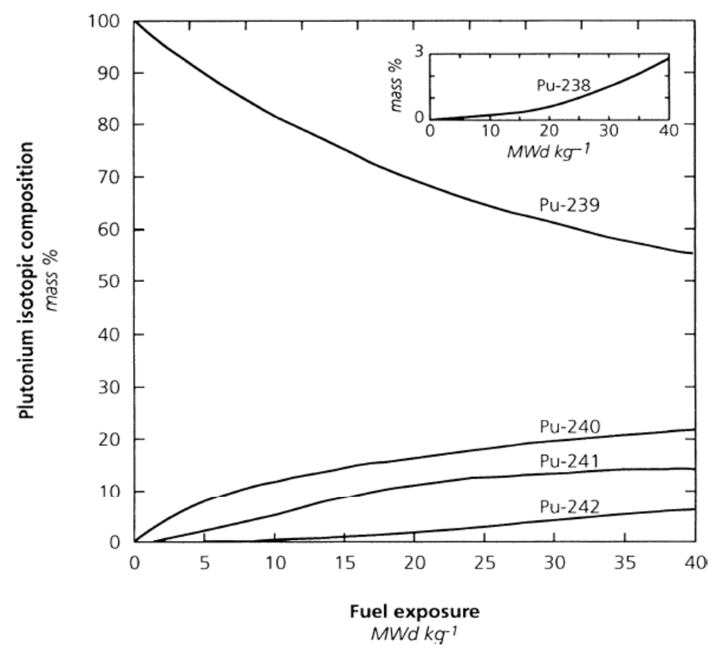
- Natural uranium:
  - 0.7% U-235 + U-238
- Highly-enriched uranium:
  - >20% U-235
- Weapon-grade uranium:
  - ~90% U-235



Critical mass of uranium vs. enrichment

Plutonium

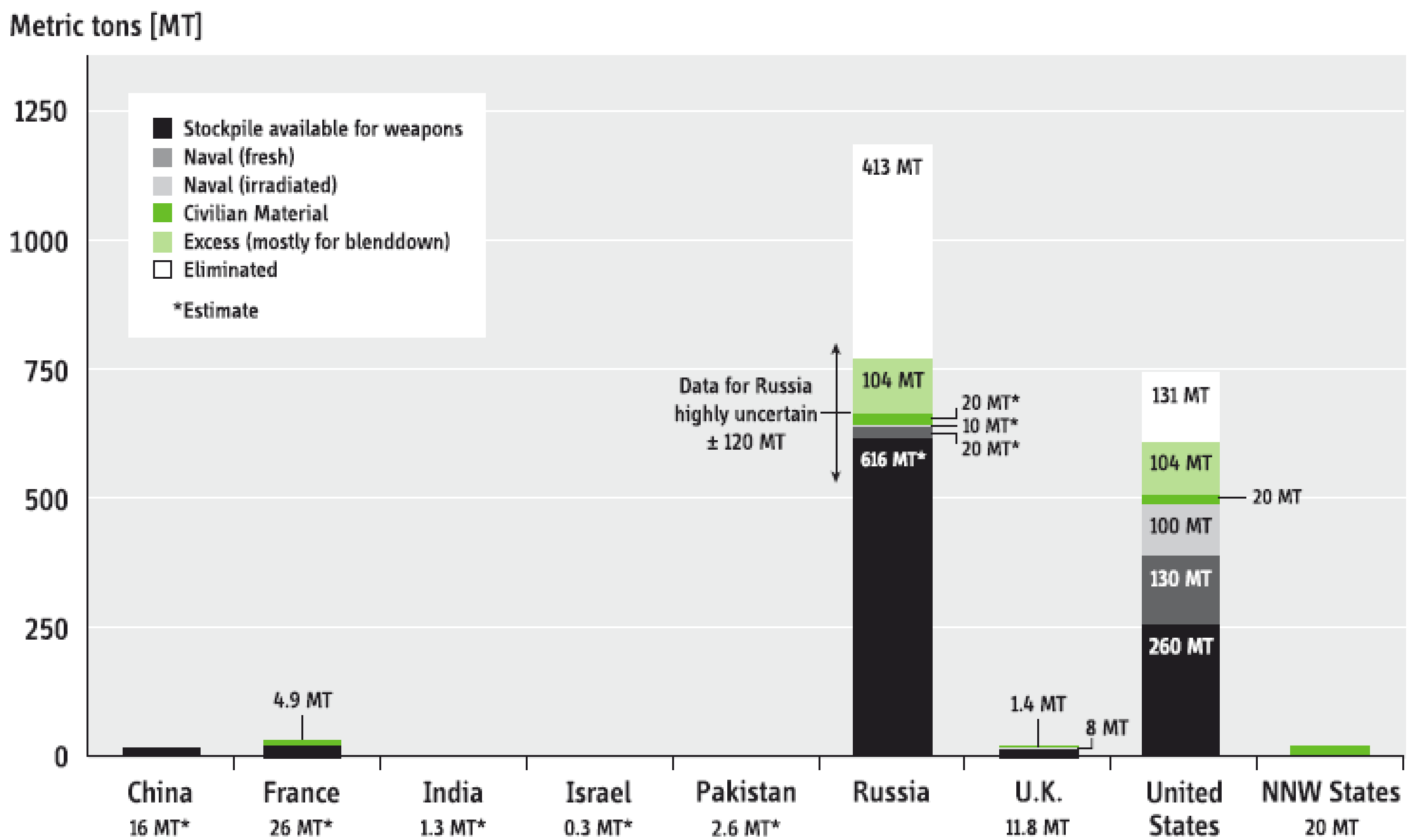
- Does not exist naturally
  - Half-life ~24,000 years
- Produced in reactors
  - U-238 + n -> … -> Pu-239
- Weapon- vs. reactor-grade Pu
  - Pu-239 + n -> … -> Pu-240
  - Weapon-grade: ≤6-10% of Pu-240
  - Reactor-grade: ~25% of Pu-240
  - Both are weapon-usable!



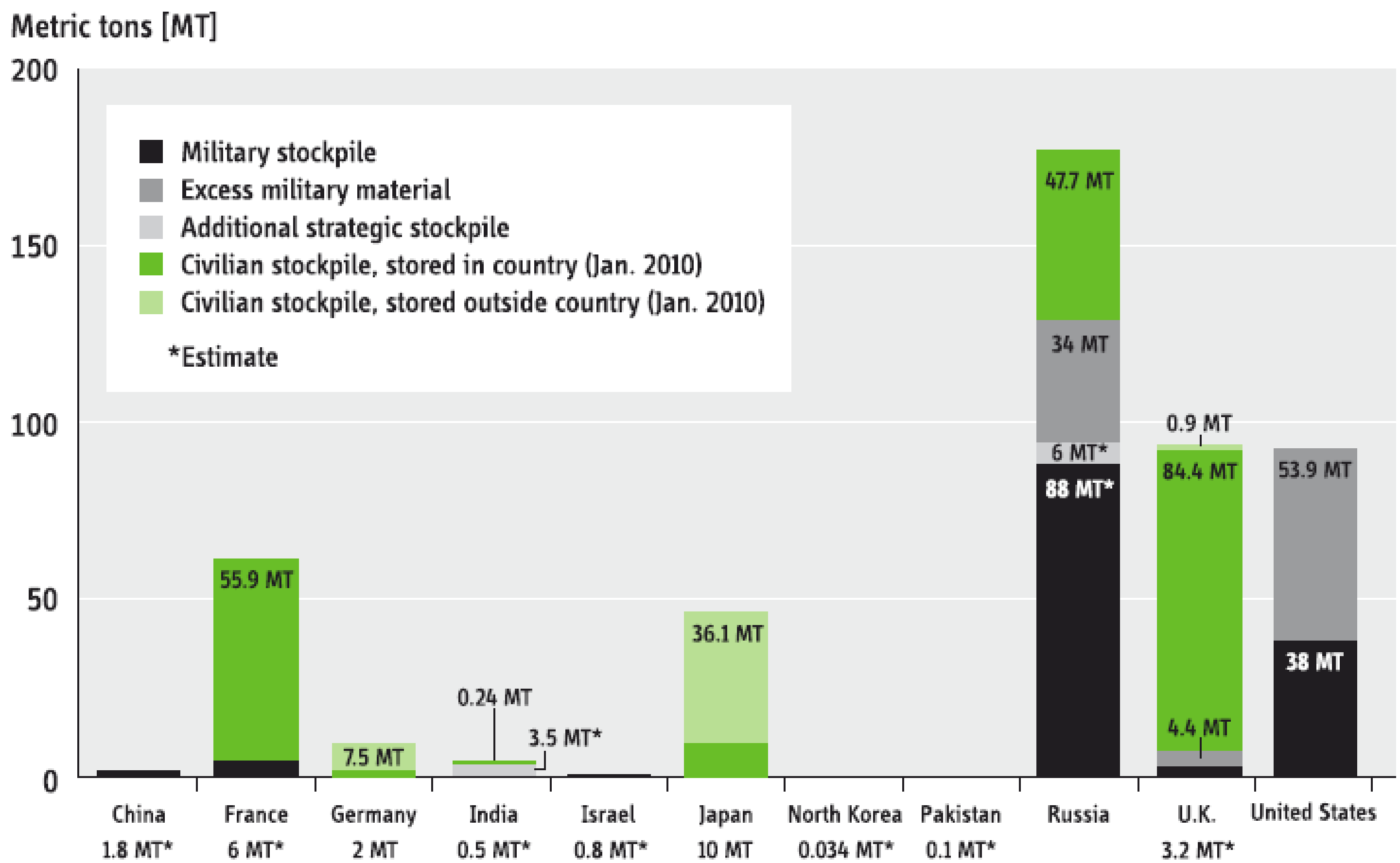
Significant quantities

- Bare sphere critical masses
  - 52 kg of HEU
  - 10 kg Pu-239
- First bombs
  - Little Boy (Hiroshima): ~60 kg of 80% HEU
  - Trinity/Fat Man (Nagasaki): ~6 kg of Pu
- IAEA definitions
  - 25 kg of U-235 in HEU
  - 8 kg of Pu
- Required to build a fission bomb
  - ~12 kg of HEU
  - <4 kg of Pu

Current inventories: HEU



Current inventories: Plutonium



Fissile materials: the dangers

- Getting material is the most difficult part of producing a weapon

- Security of the existing stocks
  - Vulnerable to diversion
  - Difficult to account for

- Reconstitution of nuclear weapon arsenals

Challenges of elimination: HEU

- Easy to blend down (mix with U-238) to produce LEU

- But…
  - Still used in naval and research reactors
    - Research reactors: high neutron flux
    - Naval reactors: size, core lifetime

  - Widely used in production of molybdenum-99
    - HEU fueled reactors and HEU targets

Research/isotope production HEU reactors

	Russia and NIS	China	Europe	United States	Other	**Total**
Critical assemblies	36	1	4	5	2	**48**
Pulsed reactors	16	0	3	3	0	**22**
Steady-state reactors (<0.25MW)	2	3	4	1	11	**21**
Steady-state reactors (0.26-10 MW)	7	0	0	2	1	**10**
Steady-state reactors (>10 MW)	9	0	7	4	0	**20**
TOTAL	**70**	**4**	**18**	**15**	**14**	**121**

Naval reactors

	Submarines	Surface military ships	Civilian ships	Total ships (reactors)
China	9	0	0	9
France*	10	1 (2)	0	11 (12)
India	2	0	0	2
Russia	41 (69)	1 (2)	7 (11)	49 (82)
United Kingdom	12	0	0	12
United States	71	11 (28)	0	82 (99)
TOTAL	**145 (173)**	**13 (32)**	**7 (11)**	**165 (216)**

Challenges of elimination: Plutonium

- Military plutonium
  - Hard to secure or dispose of
  - Geologic disposal
    - Mixed with high-level waste
    - Controversial: some view as a source of energy
  - Burning in reactors is not efficient
    - Light-water reactors in MOX fuel
    - Fast reactors
    - Burning supports plutonium economy, which means more Pu

- Civilian plutonium
  - Many countries have active Pu programs
  - Plutonium is accumulated

United States

HEU	Military plutonium	Civilian plutonium
607 tonnes	99.5 tonnes	-

- Material declared excess for military needs
  - 53.9 tonnes of weapon plutonium
  - 194 tonnes of HEU
- HEU: blend-down
- Plutonium: Burn as MOX in light-water reactors
  - 34 tonnes – an agreement with Russia (PMDA)
  - MOX fuel facility being built by Areva ($2.7 billion)
- Submarine reactors will use HEU
- Research/isotope reactors
  - Global Threat Reduction Initiative: Conversion to LEU, removal of HEU
  - Supply of HEU to Canada, France, Belgium continues
- No domestic reprocessing or civilian plutonium

Russia

HEU	Military plutonium	Civilian plutonium
770 tonnes	128 tonnes	47.7 tonnes

- Material declared excess for military needs
  - 34 tonnes of weapon plutonium (+6 tonnes post-1994 Pu not available for weapons)
  - 100 tonnes of HEU (400 tonnes have been down-blended already in the HEU-LEU deal)
- HEU: blend-down
  - Total of 500 tonnes of HEU down-blended to provide LEU for U.S. power reactors
  - 12.6 tonnes – Material Conversion and Consolidation project (+4.4 tonnes scheduled)
- Plutonium: Burn in fast reactors
  - 34 tonnes – agreement with the United States (PMDA)
  - U.S. provides $400 million for fuel fabrication facility
- Naval reactors (submarines, icebreakers) will likely use HEU
- Research/isotope reactors
  - Assists the Global Threat Reduction Initiative fuel removal effort
  - U.S.-funded conversion feasibility studies for 6 reactors
- Reprocessing of VVER-440 fuel, naval and research reactors

United Kingdom

HEU	Military plutonium	Civilian plutonium
21.2 tonnes	7.6 tonnes	80.9 tonnes

- Material declared excess for military needs
  - 4.4 tonnes of weapon plutonium
  - 1.4 tonnes of HEU (declared as civilian)
- Naval reactors (will?) use HEU
- Commercial reprocessing
- No plan to deal with civilian plutonium

France

HEU	Military plutonium	Civilian plutonium
31 tonnes	6 tonnes	56.9 tonnes

- Dismantlement of fissile material production facilities
  - Pierrelatte gaseous diffusion plant
  - Marcoule plutonium production reactors
- Naval reactors use LEU
- Research/isotope reactors
  - HEU supplied by the U.S. and Russia
- Commercial reprocessing of LWR spent fuel, MOX fabrication

China

HEU	Military plutonium	Civilian plutonium
16 tonnes	1.8 tonnes	-

- Production of military material has stopped
- No information on naval reactors
- Plans to develop plutonium-based fuel cycle
  - Reprocessing technology (indigenous and imported)
  - Fast reactors (with Russia's assistance)

Controversies: U.S.-Russian Pu disposition

- 34 tonnes of plutonium on each side to be eliminated

- Plutonium Management and Disposition Agreement of 2000
  - Protocol finalized in April 2010
  - U.S. will provide $400 million to Russia
  - Fast reactors will operate as burners

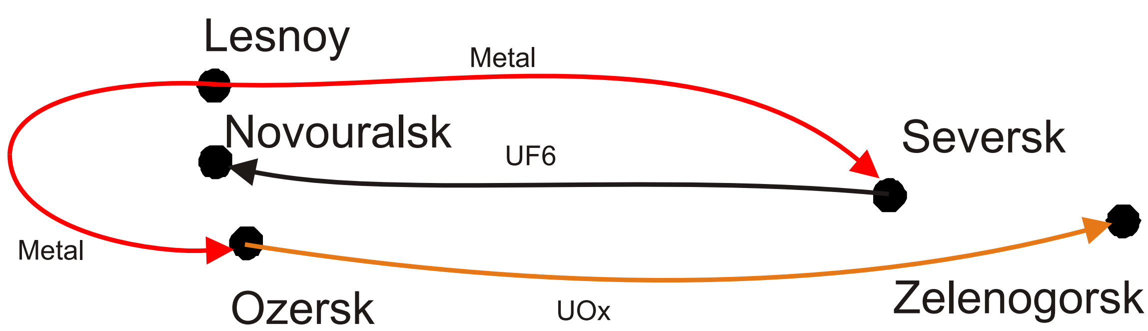
- U.S.: Burning Pu in LWR reactors

- Russia: Burning in BN-600 and BN-800 fast reactors

- U.S. and Russia will provide ~$6-7 billion subsidy to the plutonium economy

Controversies: HEU-LEU Program

- 500 tonnes of Russian HEU to be eliminated
- HEU flows (30 tonnes of HEU/year):



- The program creates risk, not reduces it

Controversies: Rossendorf reactor fuel

- Soviet-built VVR-2 reactor in Rossendorf
  - Shut down in 1991
- 268 kg of HEU in fresh fuel shipped to Russia in 2006
- 951 irradiated fuel assemblies (54.6 kg of U-235) were to be shipped to the Mayak facility in Russia in 2010
- German government blocked shipment citing poor environmental record of Mayak
- Fuel to stay in Ahaus

Progress: Nuclear Security Summit

- United States, April 2010
- 47 states, UN, IAEA, EU
- Work plan, state commitments
- Secure most vulnerable material in 4 years
- Next summit in Seoul in 2012
- Effect is uncertain

What is to be done

- Stop production of fissile materials
- Consolidate and secure existing stocks
- Phase out HEU use
- Stop separation of civilian plutonium
- Conduct full inventory