A Global Cleanout of Nuclear-weapon Materials

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The questions

- What is fissile material and how much is there?

- Where is it and what is it being used for?

- What we are doing to reduce the stocks and the number of locations where fissile materials can be found?

- What more should we be doing?
Fissile materials are the essential materials for making nuclear weapons.

The most abundant are:

- **Highly enriched uranium** (HEU, uranium containing more than 20% chain-reacting U-235 -- usually more than 90% -- about 1,600,000 kg (about 60,000 bombs worth)

- **Plutonium separated from irradiated reactor fuel** -- about 500,000 kg (about 100,000 bombs worth)

*The fission of 1 kilogram of HEU destroyed Hiroshima.*

*The fission of 1 kilogram of plutonium destroyed Nagasaki.*

More is necessary for a bomb because you need a **supercritical mass** to make a nuclear explosion.
Supercritical mass  
Each fission on average causes at least one fission

subcritical mass  
Too many neutrons leak out to sustain a chain reaction

Figure 1.48. Effect of increased mass of fissionable material in reducing the proportion of neutrons lost by escape.
Hiroshima was destroyed by a supercritical mass made in a gun barrel (about 60 kilograms of HEU)

Terrorists could make a bomb with HEU
Implosion (Nagasaki) designed for plutonium is more efficient but more difficult

Figure 1.53. Principle of an implosion-type nuclear device.
Most HEU is a Legacy of the Cold War
(end 2006, great uncertainty about what Russia has)
Cleaning out the HEU legacy of Atoms for Peace

U.S. and USSR shipped abroad for research-reactor fuel enough HEU for hundreds of Hiroshima bombs. Even more to domestic nuclear R&D sites (*especially in Russia*).
Slow progress on Global HEU cleanout

DOE program launched in 1978 to convert reactors to low-enriched uranium (LEU).
Still about 140 operating HEU-fueled research reactors worldwide.
Rate of conversion now up to several per year.

But conversion focus on high-powered research reactors. Critical assemblies (zero-power reactors) and pulsed reactors account for about half of HEU-fueled reactors. Some have huge inventories of barely irradiated HEU.

Also Russia has not yet decided to convert its own reactors.
At Brataslava summit Russia and U.S. agreed to cooperate on HEU cleanout in “third countries.”
Russia has interpreted that to mean not in Russia.
A Russian critical facility (zero-power reactor) with tons of HEU in tens of thousands of disks

The Director of the facility agrees that he does not need the weapon-grade uranium and is willing for it to be blended down. The DOE is willing to finance this blend down but Rosatom has not given permission for a discussion.
A Russian pulsed reactor whose core contains enough barely irradiated weapon-grade uranium for 15 Hiroshima bombs

The operators are interested in doing a U.S.-funded assessment of the feasibility of converting to low-enriched uranium but have not received permission from Rosatom to do so.
Russia’s HEU-fueled Icebreakers (15 reactors on 9 ships)
Deputy Director of base arrested in 2003 for nuclear-material theft.
Nuclear Threat Initiative offered to fund conversion feasibility study in 2004.
The Russian Institute was interested but the contract has not been signed.
What if Russia and U.S. reduced warheads, blended down all excess HEU, and eliminated all civilian use of HEU?

(non-Russian/U.S. stocks total about 90 tonnes)

Naval stocks would be a growing fraction of the problem.
Could U.S., Russia & U.K. shift to LEU fuel like France?
Global stocks of separated plutonium -- a huge disposal problem
(metric tons, end 2005)

Most separated plutonium in France and UK from civilian reprocessing

U.S. excess plutonium will cost >$10 billion to dispose.
Global plutonium: Potential for reductions
(non-Russian/U.S. weapon stocks about 13 tons)

Civilian stocks are a growing complication
Plutonium separation debate in the U.S.: Nuclear utilities want DOE to start removing spent fuel from reactor sites but Yucca Mountain is not available

(Maine Yankee, 543 tonnes spent fuel ≈ 27 years from 1000-MWe reactor)
DOE proposes to reprocess the spent fuel and use fast-neutron burner reactors to fission the plutonium

Reprocessing plant becomes interim storage for huge volume of complex radioactive wastes ($80 billion cleanup estimate for much smaller U.K. facility, not including plutonium disposition costs, Nuclear Decommissioning Authority, March 2006).

40-75 1000-MWe liquid sodium-cooled fast-neutron reactors

$30+ billion +$1+ billion/yr?

Reprocessing plant(s)

$0.3 billion/yr

Fuel fabrication plant(s)

On-site spent fuel

$0.3 billion/yr

Reprocessing plant

Cs-137, Sr-90 storage (200-300 years)

Other radioactive waste

Radioactive uranium

$40-150 billion subsidy? Very unlikely to be funded.
Separated plutonium can be carried away easily.  
Spent fuel is self-protecting for more than a century.

Separated plutonium

5 pounds of Pu in light-weight container. Three cans enough for Nagasaki bomb. Can be processed in a glove box.

Spent fuel assembly
(1000 pounds and 12 feet long)

12 pounds Pu. Lethal gamma dose in 20 minutes 50 years after discharge. Requires 20-ton transport container & remote handling behind thick walls to recover.
Proposed change to U.S. nonproliferation policy

Since India used its first plutonium separated with U.S. assistance to make a bomb in 1974, U.S. policy has been:

“We don’t reprocess. You don’t need to either.”

Very successful: No additional countries have launched “civilian” reprocessing in the past 30 years and several have stopped.

Bush Administration has proposed a new policy:

“Do as we say, not as we do.”

Already counterproductive: South Korean nuclear establishment wants to reprocess (DOE has invited South Korean researchers to collaborate on reprocessing R&D) and Areva wants to build the world’s biggest reprocessing plant for the U.S. and then export smaller copies to other countries.
What is the matter with interim on-site dry-cask storage?

- Cost is 1/10 of cost of separation and transmutation
- Accident/terrorism risks to fuel in dry-cask storage negligible compared with risk for fuel in reactor cores or storage pools.
- All U.S. sites with operating nuclear power plants can accommodate spent fuel from 60 years of operation.
- Anti-nuclear groups no longer oppose interim on-site dry-cask storage if it is “hardened.”

Eventually, spent fuel will have to be moved from the sites. But no reason to panic.

_GNEP is a panic “solution.”_
Conclusions

We have to get rid of about 1500 tons of stuff. We have made a good start with excess weapons HEU.

Civilian HEU cleanout is going in the right direction but zero-power and pulsed reactors must be included and Russia must be persuaded to join in.

Naval HEU will become an increasingly large fraction of the problem unless it is addressed.

Disposition of separated plutonium is hugely expensive. DOE is not succeeding in getting rid of the 45 tons it has declared excess but proposes to spend tens of billions of dollars to separate many hundreds of tons more.