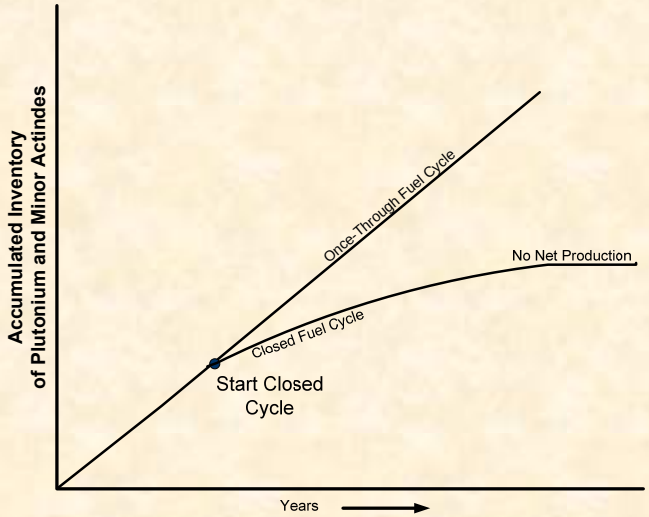
Proliferation Resistance During Spent Fuel Recycle

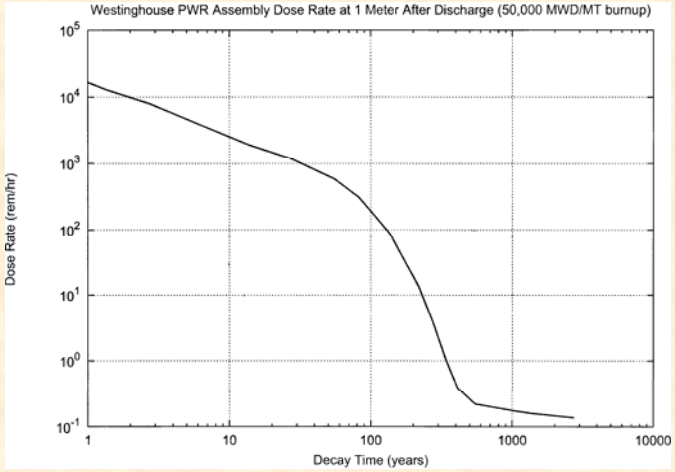
Emory D. Collins

March 6, 2006

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

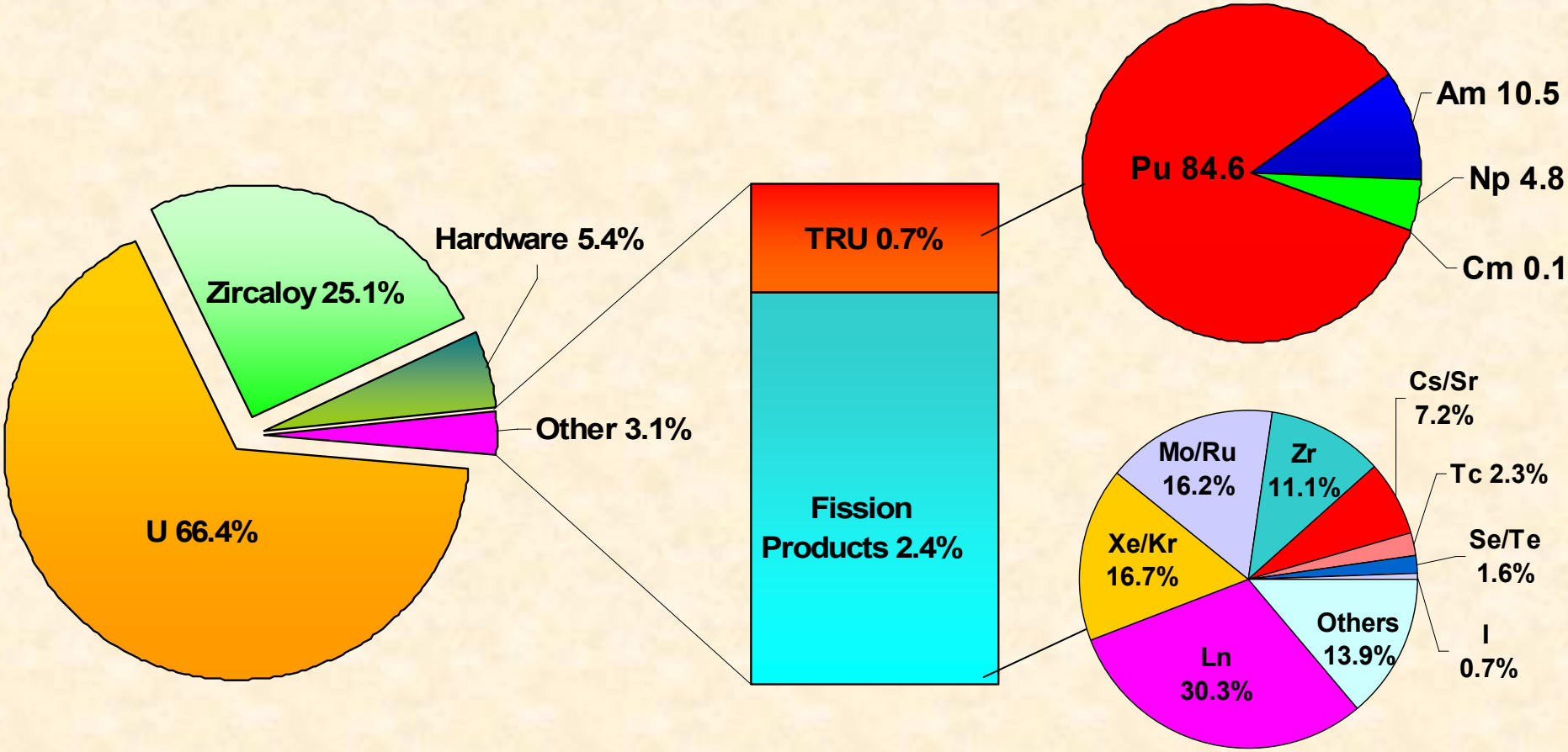
Spent Fuel and Plutonium Inventory Growth with Once-Through Fuel Cycle





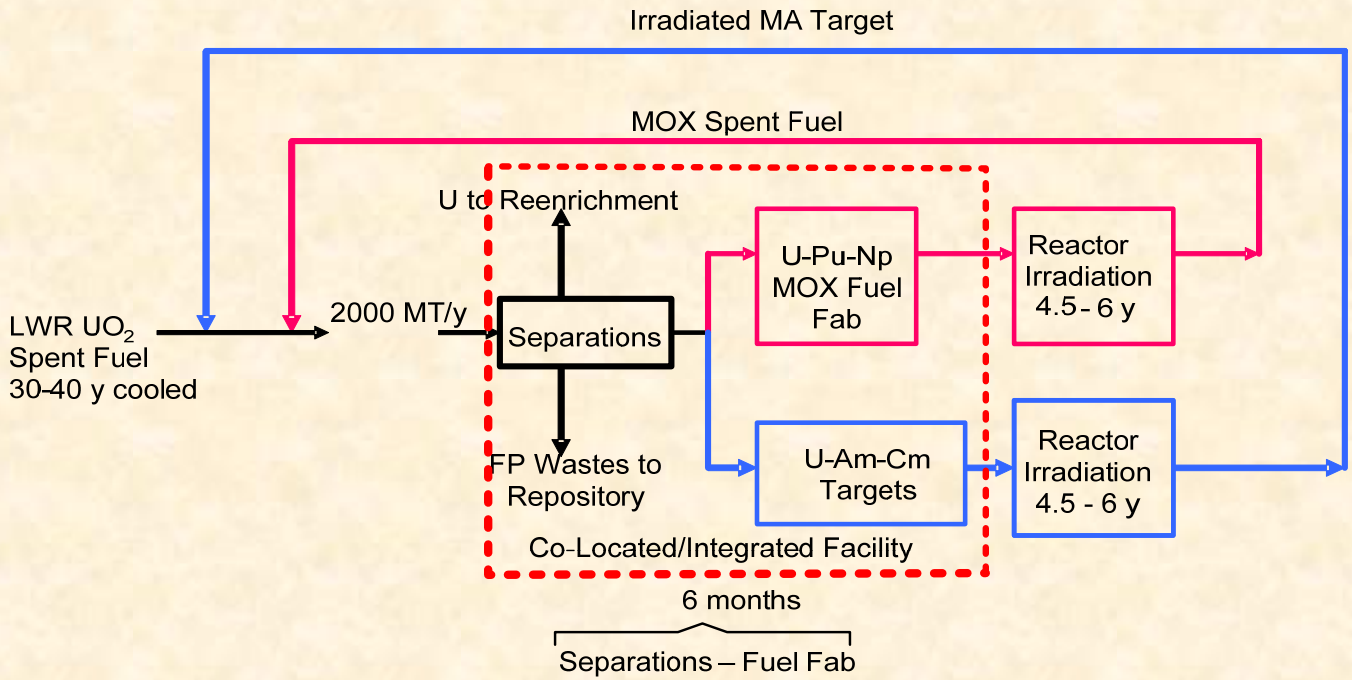
- **Additional spent fuel storage is required**
  - **Multiple repositories**
  - **Dry storage at reactor sites or special monitored retrievable storage (MRS) sites**
  - **Substantial costs**
- **Increased safeguards concerns over the unconstrained growth of fissile materials, together with decreasing radiation protection ("plutonium mines")**
- **Closing the fuel cycle sooner stabilizes the inventory growth and can stop the need for increased storage space**

Composition of U.S. Spent Nuclear Fuel



Average weight composition, PWRs and BWRs, accumulated from 1968 to 2002 and calculated on the basis of 40 years of cooling

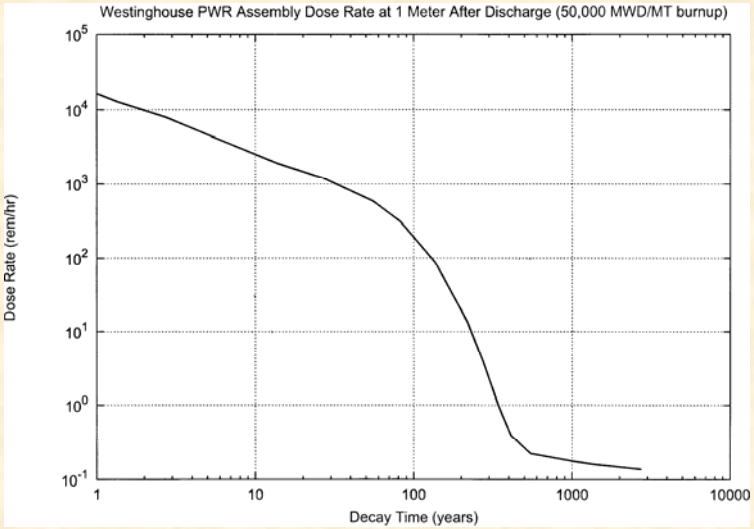
The Partitioning-Transmutation (P-T) Process Must Be Proliferation Resistant



- **AFCI studies clearly show that the separations plant and the fuel/target fabrication plant must be co-located and integrated in a physically protected facility**
- **Most of the fissile inventory is in storage—protected by the high radiation barrier from the fission products**
- **Recycling (reirradiation) of aged fissile material restores the high radiation barrier**

Contribution of TRUs to High Radiation Barrier

Shield Material	Thickness (cm)	TRU	TRU, 0.6% Cs+Sr
None		**0.403 ± 9%**	**96.25 ± 10%**
SS-316	**2.5**	**0.428 ± 2%**	**36.28 ± 12%**
SS-316	**10.5**	**0.295 ± 2%**	**1.273 ± 55%**
SS-316	**24.5**	**0.120 ± 2%**	**0.128 ± 14%**
Poly-ethylene	**2.5**	**0.321 ± 2%**	**94.19 ± 10%**
Poly-ethylene	**10.5**	**0.069 ± 11%**	**55.14 ± 10%**
Poly-ethylene	**24.5**	**0.008 ± 39%**	**21.01 ± 4%**
Lead	**2.5**	**0.436 ± 1%**	**7.522 ± 25%**
Lead	**10.5**	**0.354 ± 2%**	**0.358 ± 2%**
Lead	**24.5**	**0.239 ± 2%**	**0.236 ± 2%**



- **Calculated radiation emissions**
  - **TRUs emit <1 rad/hour at 1-meter distance**
  - **Addition of fission products is necessary to achieve same radiation levels as spent fuel**
- **Addition of minor actinides or fission products to recycled plutonium will increase significantly the costs of fuel fabrication and transportation**
- **A cost/benefit (for proliferation resistance) trade study is needed**

Potential Additives to Plutonium to Enhance "Unattractiveness"

Heat Emitters	**^{238}Pu, ^{90}Sr**
Gamma Emitters	**^{137}Cs, ^{60}Co**
Neutron Emitters	**Cm**

^{238}Pu Composition in Feed for P-T Cycles

30-y Decay Data

Cycle Year	1st 2020-2055	2nd 2055-2090	3rd 2090-2125	4th 2125-2160
^{237}Np, MT/y	1.09	1.40	1.46	1.45
Pu, MT/y	19.6	28.7	33.9	37.0
^{238}Pu, %	1.54	5.73	8.42	9.60
^{239}Pu, %	66.6	53.1	46.4	42.9
^{240}Pu, %	23.8	28.2	27.9	26.4
^{241}Pu, %	3.6	3.9	3.8	3.6
^{242}Pu, %	4.5	9.1	13.6	17.5
Am, MT/y	2.49	4.58	5.82	6.50
^{241}Am, %	92.8	87.5	82.3	77.5
^{243}Am, %	7.1	12.2	17.4	22.2
Cm, MT/y	0.020	0.182	0.442	0.728
^{243}Cm, %	1.3	2.7	1.9	1.4
^{244}Cm, %	83.7	68.3	65.4	63.7
^{245}Cm, %	13.9	25.1	25.9	25.2
^{246}Cm, %	1.0	3.9	6.8	9.8

Summary

- **Recycling stops inventory buildup and restores radiation barrier in spent fuel**
- **Physical safeguards can be enhanced by co-location of separations/fuel fabrication**
- **Addition of fission products to separated plutonium can provide a high radiation barrier, but will add costs**
- **Recycling in LWRs can increase ^{238}Pu concentration**