The Nuclear Waste Dilemma

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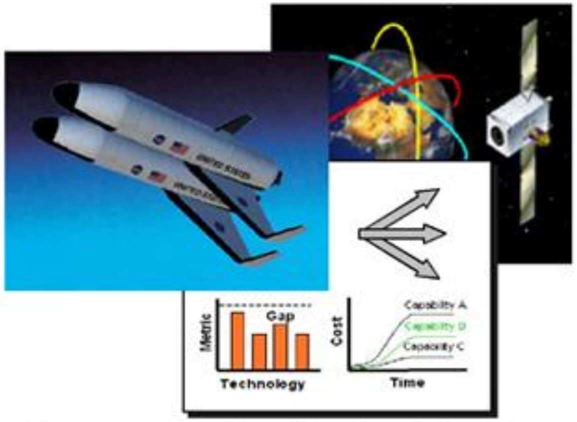
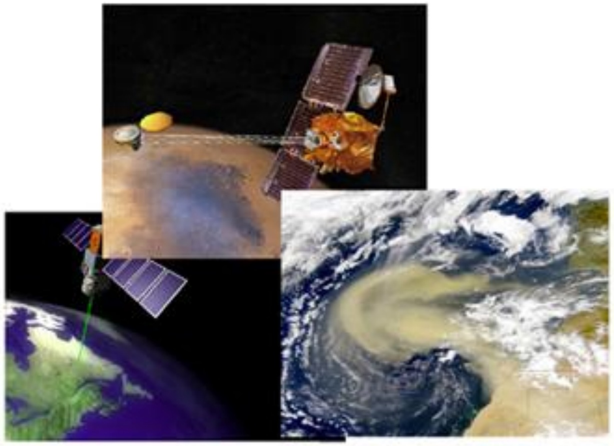
Langley Areas of Expertise

Flight Through All Atmospheres

Engineering & Safety Center

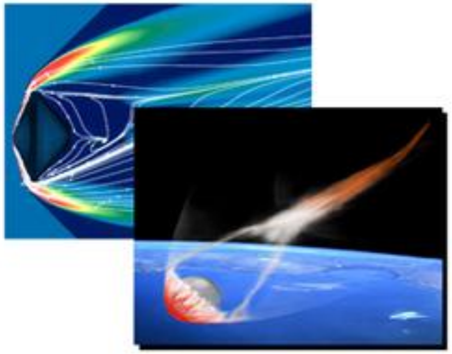


Systems Analysis, Engineering, & Integration



Characterization of all Atmospheres

Structures & Materials



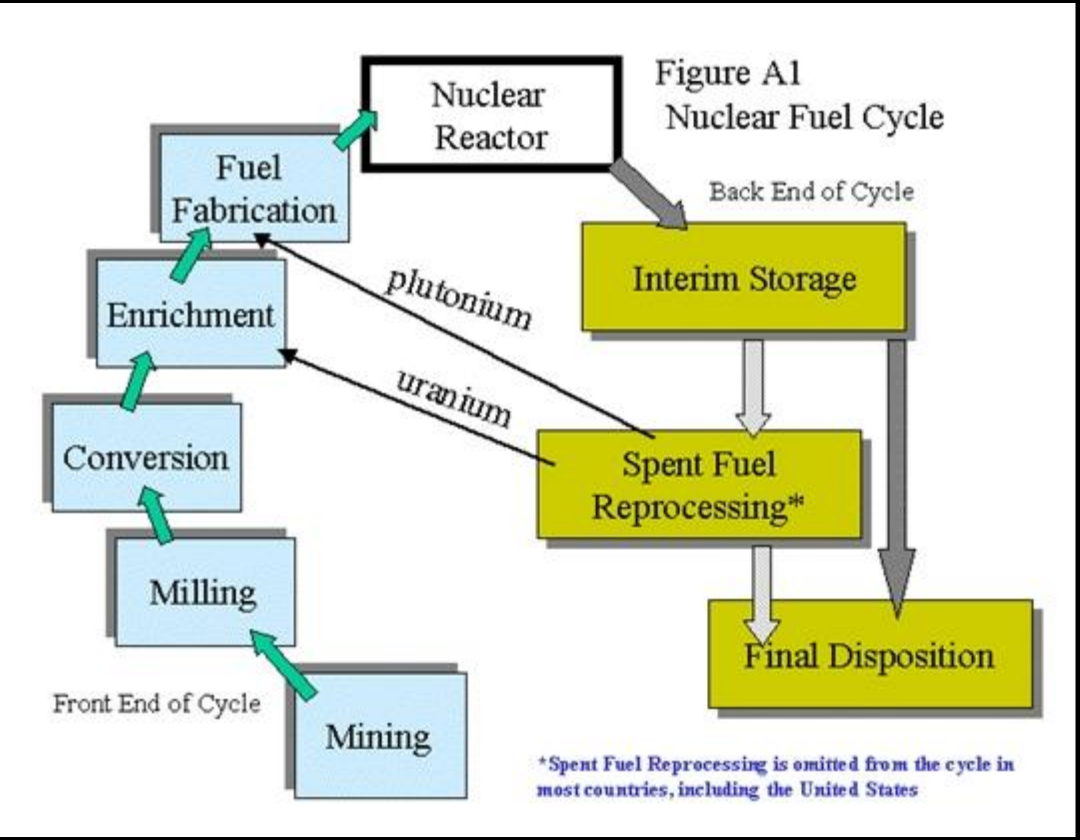
Entry, Descent, & Landing

So Why NASA/Nuclear Energy??

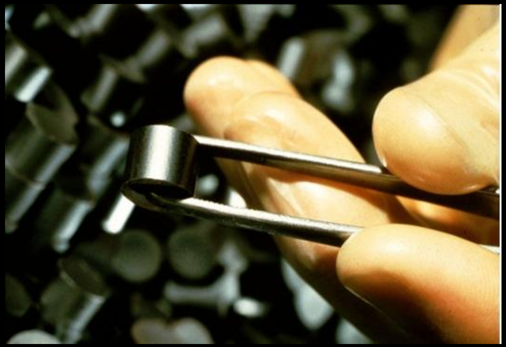
- NASA exploration and science mission objectives driven by energy requirements
  - SNAP– 238 Pu-- thermoelectric power for deep space probes---only 8% efficient
  - Some consideration of small nuclear reactor for moon base, Mars, etc.

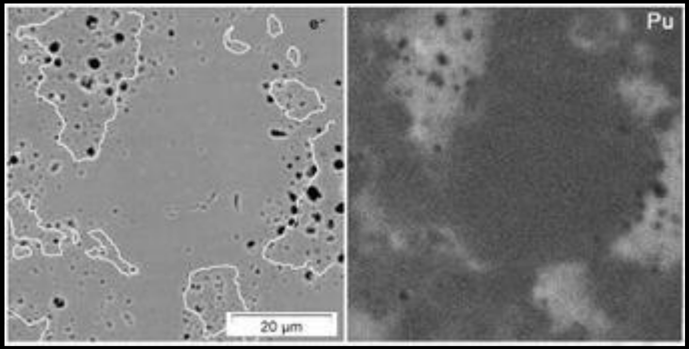
- 15 Years at Hanford/ PNNL
  - Group led USA development of Waste Forms and “standard” tests, containers, shipping casks
  - Repository relevant leach tests, radioisotope migration rates in soil, radiation effects, etc.

Nuclear Reactors/ Fuel Cycle

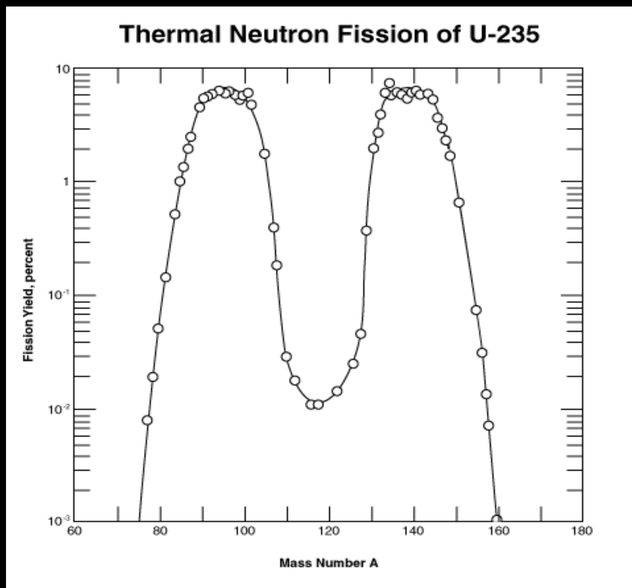


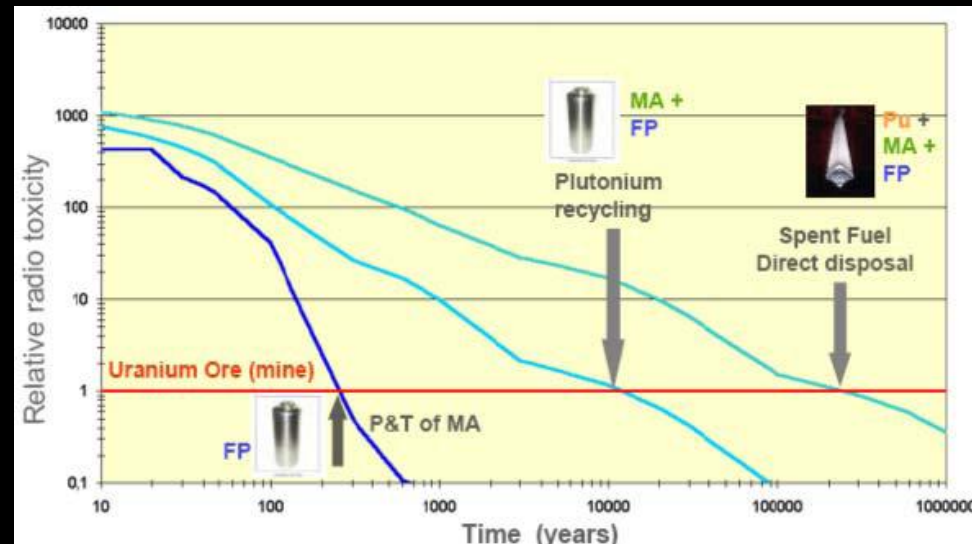
Nuclear Fuel





Nuclear Fission/radioisotope hazard





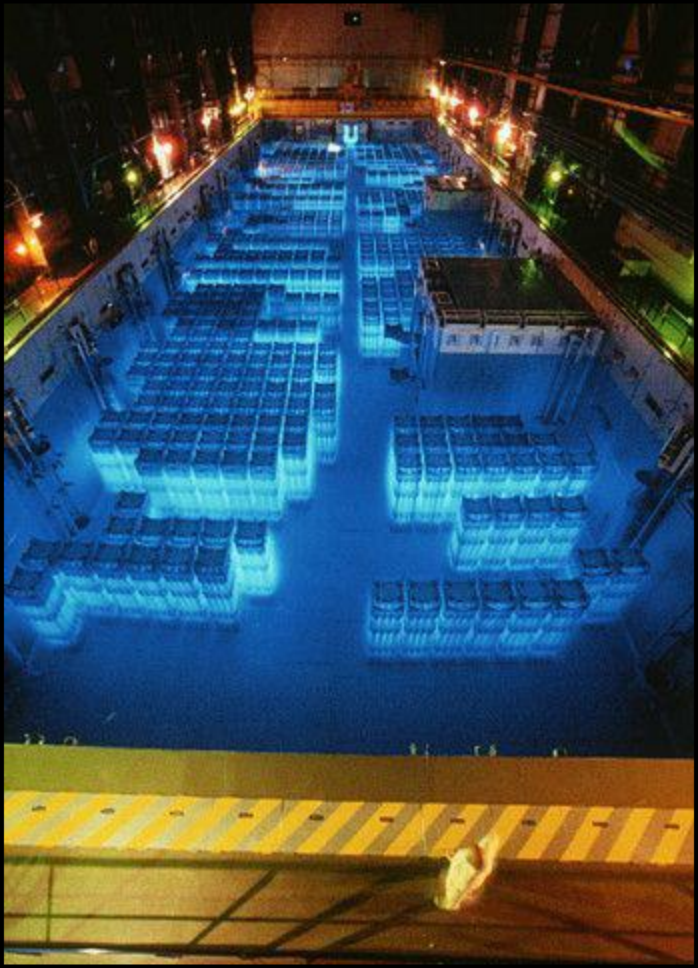
Fission products include every element from zinc through to the lanthanides; in two peaks, one in the second transition row (Zr, Mo, Tc, Ru, Rh, Pd, Ag) and higher mass numbers (I, Xe, Cs, Ba, La, Ce, Nd). Many fission products are either non-radioactive short-lived radioisotopes. Others are medium to long-lived radioisotopes such as ^{90}Sr, ^{137}Cs, ^{99}Tc and ^{129}I. In addition, neutron capture by U yields higher mass number actinides, especially Pu 239, major long lived hazards.

Nuclear Waste Locations

- **DOE site stabilization after huge nuclear development effort 1940-1960**
  - South Carolina, Washington state, Idaho
    - 300,000,000 gallons of HLW in underground steel tanks for 60 years.
    - Liquids/sludge→ dry solids→ glass
  - Numerous lesser problems (LLW, Actinides) several places

- **Nuclear Power plants 40+ years of operation**
  - 104 plants at 60 sites
  - Spent Fuel bundles in water basins 5+ years
  - Dry, above ground storage steel/concrete containment after 5 years

Spent Nuclear Fuel



Spent Nuclear Fuel

- **Typical 1000 MWe reactor generates about 20 m^3 (27 tons) of used fuel per year**
  - After 40 years, USA total mass of spent fuel is about 120,000 tons. About 5% of this, or 6,000 tons is actual fission products. 95% is U 235.

- **Where spent fuel is reprocessed, 3 m^3 of vitrified waste (containing 1.5 tons of HLW) is produced per reactor year of operation**

The Nuclear Waste Dilemma

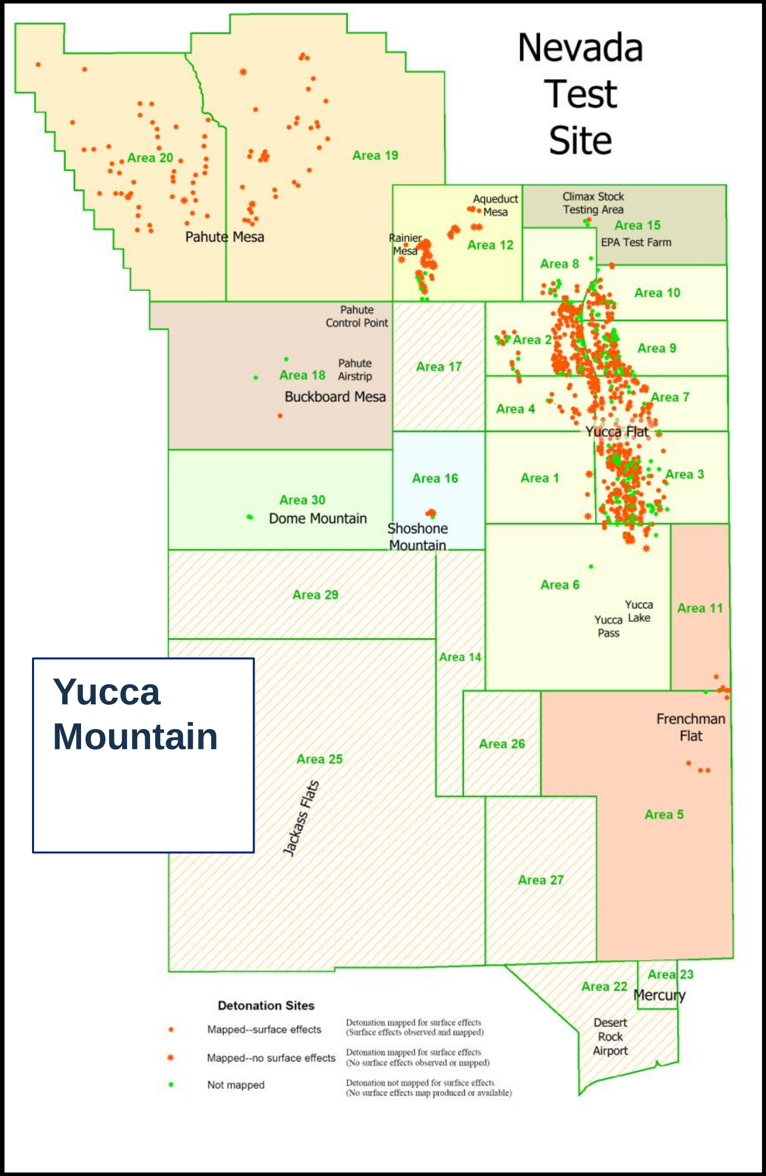
- **Not in my back yard**

- **Spent Fuel repository storage – or better---- reprocessing with recycle of fuel and store waste**
  - Tuff (volcanic)--Yucca Mountain, Nevada
  - Basalt (volcanic)–Hanford, Washington State
  - Salt domes--- midwest, south

- **Yucca Mountain –at edge of Nevada Test site selected in 1987**
  - Several $ billion spent before put on hold 2009, no longer considered acceptable, License application to NRC withdrawn (not accepted)

- **Nevada Test Site**
  - Over 100 atomic bombs detonated (some above ground) during 1950 to 1990
  - One of last tests generated a crater 1000 feet wide by 300 feet deep

Nevada Test Site (20 x 30 miles)



The Nuclear Waste Dilemma

- **10,000 Year repository requirements**
  - It should be noted that during the post 10,000 year period, the projected *median* annual dose of the Monte Carlo runs is typically on the order of three times lower than the *mean* annual dose. Thus, a limit of 350 mrem *median* annual dose is equivalent to about 1,000 mrem (or 1 rem) *mean* annual dose. To appreciate how incredibly permissive this new proposed rule is, we can compare the allowable dose limit with current cancer risk estimates by the NAS. According to the latest estimates of the NAS' BEIR Committee, absent excess radiation exposure today a woman's lifetime risk of getting cancer is about 37.5 percent, with an 18 percent risk of dying of cancer. Were she exposed to a dose rate of one rem per year over her lifetime, the BEIR VII committee's best estimate is that these risks would increase risk by about 27 percent.
- **Conclusion**
  - So where does all this leave us. We have a proposed geologic repository for spent fuel and high-level waste that was selected through a corrupted site selection process, that cannot meet the original site selection criteria, ……..etc.

A Nuclear Waste Solution

- Stop focus on control for 10,000 years and concurrent assumption of water ingress

- Focus on 200-400 years storage--we will likely have a need/use for materials by then! (Compare 2011 knowledge to 1600 or 1800)

- Do not allow water contact with HLW at all, meaning radiation release to the environment can be effectively zero

Nuclear Waste Solution

- **Decide/ demonstrate that storage of spent fuel at 60 locations --- mainly in east and mid-west is not as safe as repository storage**
  - Repository solution well developed 30 years ago but no sustained political will to proceed

- **Open Yucca Mountain repository and develop second location**
  - Some spent fuel
  - HLW Glass for complex waste
  - Develop other ceramic waste forms for separated, selected elements--- such as actinides, Cs, Sr
  - Keep water out!!

- **Reconsider nuclear options, especially reprocessing**
  - Mixed oxide fuels---breeder reactors---go for it!
  - **If risk/cost too high relative to benefits ----- shut reactors down over next 20 years (still need repository!)**

Nuclear Waste Solution

- Will take extraordinary leadership and long term commitment we have not had in any area except military. USA does not have "energy" policy

- DOE budget will need significant increase (or re-direction) if Nuclear power accepted as option
  - Current Nuclear Technology Division annual budget is less than $1B
    - Budget for HLW-related technology is less than $100M
    - Repository budget is zero
    - Pu 238 production restart is $10M (for NASA)