NON-REACTOR ALTERNATIVES FOR PLUTONIUM DISPOSITION

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SPENT FUEL STANDARD

• “Spent fuel standard” (SFS) concept for excess plutonium disposition
  – To render separated plutonium “roughly as inaccessible for weapons use as the much larger and growing stock of plutonium in civilian spent fuel”: National Academy of Sciences, 1994
  – Intrinsic properties of the waste form only

• Chief attributes:
  – Mass and bulk of disposition item
  – Plutonium chemical dilution
  – “Self-protecting” radiation barrier (e.g. cesium-137)
  – Plutonium isotopic composition much less important
Numerous technical alternatives to irradiation for plutonium disposition have been considered
- Immobilization with vitrified ("glassified") high-level waste and disposal in a mined repository (originally Yucca Mountain)
  - Homogeneous
  - "Can-in-Canister"
- Immobilization without radiation barrier and
  - Co-disposal with spent fuel
  - Burial in deep boreholes
- Mixture with chemically inert materials and burial in the Waste Isolation Pilot Plant (WIPP) (now called "Downblending and Disposal")
Figure 4. (a) Vitrification Variation 3 is a "can-in-canister" concept in which plutonium (Pu) immobilized in borosilicate glass is poured into a can, which is then placed in (b) canisters into which molten high-level-waste glass from the Defense Waste Processing Facility at Savannah River is poured. The outer canister provides an external radiation barrier.
ONE-TRACK PROGRAM

• DOE initially pursued a two-track approach: MOX and “can-in-canister” immobilization
  – DOE originally determined that both met the SFS
  – Considerable R&D on both MOX and immobilization options
  – Pilot ceramic immobilization plant was installed at Lawrence Livermore National Laboratory

• In 2002, DOE cancelled the immobilization program to focus exclusively on MOX
  – Although its analysis showed that immobilization was the lower-cost option, DOE asserted that Russia would never accept an all-immobilization option because it did not change the isotopic composition of the plutonium and hence was not irreversible

• This decision caused additional difficulties and delays
  – Complicated disposition pathway for impure, non-pit plutonium
ROLE OF RADIATION BARRIER

• The NAS judged that chemical dilution without a radiation barrier was not sufficient to meet SFS
  – Experienced chemists can recover plutonium from any form given sufficient time and resources
  – Radiation barrier should be high enough to preclude chemical processing in gloveboxes

• In 2000, NAS further refined the SFS
  – Judged that research and testing was needed to determine whether heterogeneous “can-in-canister” immobilization met the SFS
IS THE SPENT FUEL STANDARD STILL NECESSARY?

• Now that the current life-cycle cost of MOX is approaching $40 billion, NNSA is reconsidering MOX and, more generally, the costs and benefits of meeting the SFS
  – Would immobilization still be significantly cheaper and faster today than MOX? (Probably not, but not as expensive as NNSA Options Study)
  – What are the current security and non-proliferation objectives of plutonium disposition? Is the spent fuel standard still necessary?
  – Can more credit be given for dilution and other mechanical and chemical barriers to separation? Can more weight be given to extrinsic rather than intrinsic barriers?
DOWNBLENDDING AND DISPOSAL: THE POSITIVES (as of 2/13/14)

• WIPP: an operating geologic repository for DOE transuranic (TRU) waste near Carlsbad, New Mexico
• DOE has already downblended and disposed of 4.8 MT of excess plutonium in WIPP
• Current cost of packaging plutonium for WIPP at the Savannah River Site is $100,000/kg – several times less than the cost of MOX fuel fabrication alone
• Savannah River Site reports that 1 MT Pu/year can be packaged for WIPP using existing infrastructure (compared to current commitment of 1.3 MT/yr)
• NNSA projected cost to dispose of 34 MT of Pu in WIPP as $8.8 billion --- 3-4 times cheaper than MOX
DOWNBLENDING AND DISPOSAL: THE NEGATIVES (as of 2/14/14)
THE WIPP OPTION

• Assuming the kitty litter fiasco eventually will be resolved, there are other considerations:
  – Statutory capacity (Land Withdrawal Act)
  – WIPP Waste Acceptance Criteria
  – EPA requirements in 10 CFR 191, 194
  – security objectives of Pu disposition (transparency, irreversibility)
WIPP CAPACITY

• Land Withdrawal Act limits the WIPP capacity to 175,600 m$^3$ of TRU waste
  – Contact-handled: surface dose rate < 200 mrem/hr
  – Remote-handled: 200 mrem/hr ≤ SDR < 100 rem/hr

• 1988 DOE-NM agreement limits the total volume of remote-handled TRU waste to 7,080 m$^3$

• April 2014 Options Study says that the Land Withdrawal Act will have to be amended to accommodate an additional 34 MT of plutonium: but is this correct?
WIPP CAPACITY

• As of the end of 2012
  – Total TRU volume in WIPP: 85,200 m³
  – Total TRU volume not yet in WIPP: 66,200 m³
  – Total committed waste volume: 151,400 m³
  – Volume available: 24,200 m³
WIPP PLUTONIUM DISPOSAL CONFIGURATION

• Pipe overpack container: 208-liter drum containing a stainless steel inner container

• Criticality considerations limit the amount of plutonium in each pipe overpack container to approximately 200 grams of Pu-239
CRITICALITY CONTROL OVERPACK

• WIPP has certified a “criticality control overpack” that can nearly double the maximum plutonium content of a 208-liter waste drum to 380 grams of Pu-239
• NRC approved the package in 2013
• Excess volume could accommodate 44 MT of plutonium if packed in criticality control overpacks
  – May compete with other waste streams proposed for disposal in WIPP (e.g. non-defense TRU waste)
• With other modifications, even greater quantities of plutonium could be loaded in each drum
OTHER CONSTRAINTS

• 40 CFR 191, 194 impose performance requirements on WIPP for 10,000 years
  – Limit cumulative releases, receptor doses, groundwater contamination
  – Both natural processes and human intrusion must be considered

• An additional 34 MT of plutonium in WIPP will increase the amount of Pu-239 by several times
  – May affect dose consequences of human intrusion scenarios
SECURITY CONCERNS

• Even if the excess plutonium inventory could be buried in WIPP, is that desirable?

• Security aspects:
  – DOE graded safeguards policy
  – Spent fuel standard
  – PMDA commitments
  – International monitoring/verification

• The relevant standards are different and not necessarily consistent
DOMESTIC SAFEGUARDS

• DOE requires termination of safeguards on materials prior to shipment to WIPP
  – WIPP is a “property protection area”

• Generally requires Attractiveness Level E designation
  – DOE-STD-1194-2011: solid Pu item with < 0.1-1 wt% Pu or “highly irradiated” (no specific dose rate)

• DOE allows termination of safeguards on Attractiveness Level D items if security analysis shows no significant increase in risk of theft of a Category II quantity of SNM (16 kg for Pu)
ROCKY FLATS VARIANCE

• In 1998, Kaiser-Hill (Rocky Flats contractor) requested a variance from DOE to allow termination of safeguards on several tons of plutonium-rich residues
• Proposed blending to Attractiveness Level D (Pu < 10 wt-%), packing in POCs, and conducting a security assessment
• Asserted the approach met the SFS even though there was no radiation barrier
  – To acquire a comparable amount of plutonium would require theft or diversion of 127-160 drums weighing 19 to 40 MT and having a volume of 2,000 to 33,300 liters
STARDUST

• Some RF Pu residues required down-blending to below 10 wt-% with a special diluent called “stardust” in order to effectively reduce attractiveness level to D
  – “A mixture of cementing, gelling, thickening and foaming agents” that made it “more difficult and complex to recover, concentrate and purify the plutonium”

• Similar “termination of safeguards” materials (a misnomer) are now being used at SRS to down-blend non-pit Pu authorized for WIPP disposal
SFS EQUIVALENCE?

• Presumably, security assessments have determined that the additional time and resources needed to recover a Category II quantity of Pu from these waste forms justifies termination of safeguards

• TOS actually exceeds SFS because safeguards must be maintained on irradiated fuel

• Does this support a conclusion the SFS can be exceeded through dilution with TOS materials?

• Other options also available for further reducing accessibility of Pu in WIPP disposal drums
  – Dilution below 1% in cement grout
  – Immobilization in refractory materials
GEOLOGIC VERSUS INTRINSIC BARRIERS

• Inherent to the SFS was the understanding that disposition forms would all be in the same boat with civilian spent fuel with regard to final geologic disposal

• Assuming operations eventually resume, a large amount of excess plutonium in could be buried in WIPP faster than irradiated forms awaiting a spent fuel repository

• The geologic barrier is formidable and potentially can further compensate for lack of a radiation barrier

• Radiation barrier will decline over time for disposition forms and spent fuel in above-ground interim storage

• International monitoring easier for a repository than for multiple above-ground storage sites
CONCLUSIONS

• Disposal of excess plutonium in WIPP is proven
• Assuming WIPP resumes operations within several years, it could used for disposing of > 34 MT of Pu far more cheaply than MOX
• Near-term burial of plutonium in a repository is attractive compared to indefinite above-ground storage of highly irradiated disposition forms
• Security analyses should address the additional risks and whether further intrinsic or extrinsic compensatory measures are needed