Status of the Yucca Mountain Nuclear Waste Repository

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Used Nuclear Fuel & Defense Waste in Storage
(Metric Tons, end of 2001)

Yucca Mountain

3/7/06 vg 2
Another camera angle--Amargosa Valley
Repository concept
Yucca Mountain
North Portal

3/7/06
Status snapshot

• “The Yucca Mountain Project is currently focused on preparing an application to obtain a license from the U.S. Nuclear Regulatory Commission to construct a repository.”
  --DOE website
  – It has been in this posture for many years
  – In 2002, after several postponements, DOE asked for and got Congress’s authorization to proceed with an NRC application
  – DOE promised it for December 2004 (although the letter of the law says 90 days after Congress’s vote in 2002)
  – After more postponements, DOE gave up forecasting a date
  – In any case, DOE won’t file an NRC application earlier than 2008

• What has been holding it up?
  – In a word, water (and the complications of dealing with it)
  – But I am getting ahead of the story . . .
Why deep geologic disposal?

• 1972 Atomic Energy Commission planned to put High Level Waste in a surface facility at Hanford (it seems to have been forgotten)
  – Surface storage is relatively simple and cheap
  – Requires continued oversight, but has the benefit of allowing error correction
  – Shifting from underground disposal to surface storage was considered a safety advance at the time

• Around 1976 ERDA switched to deep underground *geologic* disposal
  – The driving consideration—pressed by then-NRC chairman—was not safety, but rather the fear of NEPA lawsuits by environmental organizations to stop reactor licensing by arguing that surface storage was not a “permanent solution”
  – Everyone bought into deep geologic disposal—nuclear supporters and detractors, but for opposite reasons
  – (Originally it was a modest project, but then took on a life of its own, with a huge supporting cast, and skyrocketing costs, now approaching $100 billion)
The 1982 law: Nuclear Waste Policy Act

- 1982 NWPA was a grand bargain that set out steps to select and approve geologic repository by evaluating candidate sites
  - DOE to develop, and construct and operate under NRC license
  - EPA to set basic radiation standards

- 1984 DOE issued geologic criteria as required by law;
  - Studied numerous sites in various geologic settings;
  - Got sharply hostile reaction from candidate states--TX, WA, others

- 1987 NWPA amendment--told DOE to only check out Nevada’s Yucca Mountain
  - Basically, politically-weak Nevada lost game of musical chairs
  - Supposedly, DOE was to report back if site was unsatisfactory, but this was unrealistic once bureaucracy and contractors engaged
  - Amendment also created the Nuclear Waste Technical Review Board to oversee DOE’s efforts; the Board has been quite critical

- 1992 Energy Policy Act told EPA and NRC to write YM-specific rules (to jump ahead--these turned out to be weaker than the agencies’ generic rules for waste repositories)
Late 1990s--DOE shifts to package

- Around 1995 new water data turned program on its head
  - more water in mountain (10% by volume) and
  - moving much faster than expected (not “solid rock”—lots of cracks)
- Yucca Mountain would have failed DOE’s 1984 geologic criteria-
  DOE reacted by ignoring (and eventually dropping) the criteria
- \textit{DOE shifted to essentially total reliance on corrosion-resistant package} “. . . our strategy is to keep the waste as dry as possible for as long as possible”
  - Special alloy-covered “extremely durable” \textit{waste packages}
  - Added Titanium \textit{Drip shields} to design--to be placed over the waste packages to protect against dripping water (the name “drip shield” says it all).
DOE conceptual waste package design
DOE conceptual drip shield design
How it’s supposed to fit together in “drift”
Computer simulation key to NRC license

• To get a license DOE has to demonstrate to NRC--by computer simulation--that it meets the EPA radiation dose standard.
• In 2001 EPA promulgated a standard
  – Maximum dose of 15 mrem to sample person
  – At measuring point 18 kilometer away in Amargosa Valley
  – Assume radioactively contaminated water supply is substantially diluted before used by humans
  – Maintain standard for 10,000 years
  – Demonstrate compliance by running many simulations--with random choices of geologic and corrosion parameters to account for data uncertainties--and use averages (so meet 15 mrem on average)
• It turns out to be hard to show compliance for the distant future
  – The infiltrating rainwater picks up lots of minerals
  – The hot waste package corrosion reactions are very complicated
  – The water flow is not well-understood
  – DOE’s computer model enormously complicated--a “black box”
Once packages fail, contaminated water moves fairly rapidly down to the water table which then acts like a conveyer belt to Amargosa Valley.

Rain, infiltration, radioactive leakage, flow of contaminated water down to the moving water table, which then acts as a conveyer belt to Amargosa valley.
Overhead view of water flow from YM
DOE simulation results

- The next two slides show DOE’s simulation runs from published reports (DOE is keeping its latest results under wraps)
- Each run has different random choices model parameters--from DOE-selected distributions--to account for lack of data
- Quite a spread of results--the simulation sophistication has run way ahead of scientific data (“computing deluge and data drought”)
- The next slide shows DOE can’t meet standard without package and drip shield--the site cannot isolate the radioactivity (as, for example, the WIPP site in New Mexico does)
- The slide after that shows DOE’s base case
  - The very optimistic assumptions about package and drip shield corrosion resistance--that it will be effective for about $10^5$ years--slide the dose peak into the distant future.
  - Reality check: experience with the package alloy goes back only about 20 years and doesn’t cover expected Yucca Mountain conditions
Base Case Seepage Model and Neutralized Waste Packages and Drip Shields
Why worry if peak is in remote future?

- *Because it isn’t necessarily in the remote future*—it could come much earlier.
  - Assumptions about corrosion resistance of “miracle metal” covering of waste package is based on very limited experience
  - DOE rules out possibility of a break in the thin passive film that protects against corrosion (NWTRB Dec 2005 letter to DOE speaks about “continuing concerns”)
  - In reality, no one knows when peak doses would *really* occur.

- It would be naïve to count on drip shields to be installed prior to closure
  - Titanium is expensive, DOE or successor may not do it many decades or centuries from now when it is supposed to be installed
  - Doubtful whether they could do it even if they wanted to--not likely to maintain tunnels and underground transport system for that long
But we’re covered for 10,000 yrs, right?

• Not necessarily
• If DOE is wrong about corrosion resistance of packages, and they leak earlier, the radioactive material will follow Nature’s laws, not EPA’s
• The dose in the early years will then be many times, maybe orders of magnitude, higher than the “allowed dose”
• Because the site can’t isolate the waste by itself, there is no backup for major package failures
• In short, there is no defense-in-depth, the sine qua non of nuclear safety
Court tossed EPA’s YM dose standard

• In 2004 EPA the Court of Appeals threw out a key part of EPA’s 2001 radiation dose standard
  – In 1992 Congress had told EPA to get, and follow, the National Academy’s advice
  – 1995 National Academy report said to apply the dose standard at the (mean) peak dose of computer simulation results
    The peak dose comes after packages fail—so it is a measure of site’s ability to retain radioactivity—the Court understood this!
  – EPA 2001 standard ignored the peak dose
• To meet Court’s objection, in 2005 EPA proposed a new rule
  – Almost the same as the one Court tossed
  – EPA picked 350 mrem (median) for the peak dose—equivalent to about 1,000 mrem (mean), an extraordinarily lax standard
  – By using the median instead of the mean, EPA ignores another NAS recommendation (EPA did this to reject high dose cases)
  – Will end up in Court again if EPA is foolish enough to adopt it
My own view of the project’s status

- DOE has blamed the 2004 Court of Appeals decision and an unfavorable NRC licensing board decision for its delay in filing an NRC application
- The real reason is that DOE has not been ready with a technical story that stands up—one that is based on high quality scientific work
  - Instead of trying to do it right, DOE has continually sought to “fast track” and then run into problems and then tried to muscle its way through
  - The “good science” DOE touts has been primarily directed toward rationalizing political decisions and supporting licensing—*this is not the same as real science*
  - DOE’s Yucca Mountain program management and oversight of contractors has been weak and ineffective,
  - The program has an almost genetic resistance to NRC safety regulation
  - There are serious and continuing QA problems at all levels of the project
  - The lack of openness is not conducive to good science
- DOE’s elaborate computer simulation of the site and package—when it is finally made public—will not stand up to serious scrutiny
  - It is unclear whether the NRC will give it that sort of review
  - But Nevada has assembled a first-rate technical team that will
...and prospects

• DOE Secretary Bodman’s team has tried to fix the project, but the changes raise more questions and introduce new complications:
  – Proposed change to a “clean” canister approach--one canister sealed at reactor and never opened; it makes sense but comes late and transfers uncertain logistical and canister packaging problems to reactor sites
  – 2007 DOE budget lays out a plan (GNEP) to reprocess spent fuel and recycle plutonium in fast reactors so as to use Yucca Mountain for many times the current 100 nuclear power plants--that becomes a whole new ballgame for Yucca Mountain and will undermine the current rationale.

• The administration has announced it will soon propose new Yucca Mountain legislation--a last push to give Yucca Mountain renewed momentum

• In my view it won’t work--the project’s multifarious problems are so deep and pervasive that it will ultimately grind to a halt. It never really made any sense.
Additional slides
One canister for storage and transport?

• Now many types of containers
• Original DOE plan envisaged multiple repackaging--at reactor site, transport, and at Yucca Mountain
• DOE recently realized it would have to *inert* surface YM facilities handling bare, hot, radioactive fuel--at great expense
• DOE now wants to switch to a “mostly” clean operation at Yucca Mountain with canisters sealed at reactor sites and not repackaged for emplacement
• Consequences for reactor sites unclear (welding, hoists . . .)
GNEP: to use YM for 500 reactors?

- Pretty tall agenda
  - Reprocess spent fuel and partition waste (UREX)
  - Leave hottest fission products on surface (cesium 137, strontium 90)
  - Send heavy radioactive isotopes (Pu etc.) to fuel new generation of fast reactors
  - Develop new electrochemical pyro-processing technology for reprocessing and recycling fast reactor fuel
  - Send residue to Yucca Mountain
  - Cost out of sight

- If it works, the right comparison for YM is one in which the diagram’s right-hand side is multiplied, say, five or more times

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.
Dry cask alternative simpler, cheaper
NRC-approved sites--it’s happening
## YM safety regime much weaker than reactors’

<table>
<thead>
<tr>
<th></th>
<th>NRC REACTORS</th>
<th>EPA/NRC YUCCA MOUNTAIN</th>
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<tbody>
<tr>
<td><strong>Basic standard</strong></td>
<td>“Reasonable assurance”</td>
<td>EPA still pushing for weaker “reasonable expectation”*</td>
</tr>
<tr>
<td><strong>Defense in depth</strong></td>
<td>Multi-barrier</td>
<td>Overwhelming reliance on package</td>
</tr>
<tr>
<td><strong>Separate standards for individual barriers</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Allowed dose</strong></td>
<td>~10 mrem/year to an individual <em>continually</em> at highest dose point offsite</td>
<td>EPA Yucca Mountain dose : ~1000 mrem/year on average at 18 km (after diluting the waste stream and prescribing a limited amount of water use per individual)</td>
</tr>
<tr>
<td><strong>Dealing with errors</strong></td>
<td>Corrected through inspection and enforcement</td>
<td><em>Irretrievable</em> after closing, and probably soon after emplacement</td>
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YM rules much laxer than those for WIPP

<table>
<thead>
<tr>
<th></th>
<th>Yucca Mountain, NV</th>
<th>WIPP, Carlsbad, NM</th>
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</thead>
<tbody>
<tr>
<td><strong>Geologic medium</strong></td>
<td>Permeable fractured rock</td>
<td>Dry salt</td>
</tr>
<tr>
<td><strong>Basic approach</strong></td>
<td>Depend principally on package to slow down leakage of radioactive material</td>
<td>Depend on site geology to <em>isolate</em> radioactive materials</td>
</tr>
<tr>
<td><strong>Allowed dose</strong></td>
<td>15 mrem for $10^4$ years and ~1000 mrem after; as a practical matter that makes the standard ~1000 mrem</td>
<td>15 mrem for $10^4$ years but, in practice, forever, because the stuff is not going anywhere</td>
</tr>
<tr>
<td><strong>Measuring point</strong></td>
<td>18 km (plus assume dilution of waste at uptake in biosphere)</td>
<td>5 km</td>
</tr>
</tbody>
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Projected repository temperature

Region of maximum vulnerability