Performance Assessments for Design Reviews

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Outline

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- Regulatory Requirements
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- Performance Assessment
- Usefulness of Performance Assessments in Design Change
- Summary

Objectives

- Provide a regulatory context for repository design and performance assessment in the United States
- Summarize the evolution of the design of the potential Yucca Mountain repository
- Examine how design influences performance assessments, and how they influence design evolution

Background

- DOE has studied Yucca Mountain for more than two decades as a potential site for the disposal of high-level radioactive waste
- Repository design and performance assessments continuously evolve
- Independent NRC performance assessments support pre-licensing interactions and will aid in potential licensing reviews
- NRC regulations require performance assessment as part of the compliance demonstration of repository safety
- Performance assessment quantitatively evaluates overall system's ability to achieve post-closure performance objectives specified in NRC regulations

NRC Regulatory Requirements: 10 CFR Part 63 (NRC, 2001)

- Requires DOE to propose a design
- Requirements focus on overall system performance—a performance-based regulation
- Defense-in-depth, at least two barriers to isolate waste—a natural and an engineered barrier system
- Performance confirmation program
  - confirm the assumptions, data, and analyses that led to findings permitting construction of repository and subsequent emplacement of waste.
  - indicates whether subsurface conditions are within limits assumed in the licensing reviews and that natural and engineered barriers are functioning as intended.

Evolution of DOE's Yucca Mountain Repository Design

- Late 1980's
- Design change in 1992
- 1998 Viability Assessment
- 2002 Site Recommendation
- Potential 2006 changes

Design in the Late 1980's

- Vertical (drilled into the drift floor) and horizontal boreholes (drilled into drift walls)
- Short (for one or two waste packages) and long boreholes (for more packages)
- 300 yr design life
- 3 PWR or 4 BWR fuel assemblies per package (3 KW maximum thermal output)
- More than 50,000 waste packages would be required

Repository Design in 1992

- Emplacement concept changed from boreholes to horizontal drifts
- Larger (i.e., 21 PWR or 44 BWR assemblies) but fewer waste packages (~10,000)
- Waste package life increased significantly

Viability Assessment Design

- Various corrosion resistant materials tested: Alloys 625, 825, and 22
- DOE selected 20 mm (~0.75 in) thick Alloy 22 inner shell for corrosion resistance—the superior properties of Alloy 22 were independently evaluated by CNWRA/NRC
- 100 mm (~4 in) thick carbon steel (Alloy 516) outer shell for structural strength and corrosion allowance
- Concrete liner inverts in emplacement drifts
- Uniformly spaced waste packages

Site Recommendation Design (2002)

- DOE design considers increased corrosion resistance, limited groundwater contacting waste, and increased waste package structural strength against rockfall and seismicity
  - waste package
    - 25 mm (~1 in) thick Alloy 22 outer shell for corrosion resistance
    - 50 mm (~2 in) thick nuclear grade 316 stainless steel inner shell
    - an extra Alloy 22 lid to provide an additional barrier against corrosion
    - structural material supports the thinning of the corrosion resistant material over time
  - drip shield
    - defense against dripping water and rockfall on the waste package
    - 15 mm Titanium grade 7 plates for water diverting surfaces and grade 24 for structural members
    - protection with different class of alloys
    - corrosion resistant and structural strength

Site Recommendation Design (cont'd)

- Alternative thermal options for flexibility
  - hot drift cold pillars for shedding water in between drifts
  - drift wall temperature maintained at below boiling

- Drip shield emplaced just before closing the repository

- Backfill considered on and off

Potential 2006 Design Changes

- DOE is proposing a canister for transport, aging, and disposal (TAD) by minimizing handling of bare fuel assembly at the repository operations area

- TADs will be transferred to the aging pad or to the waste package without being opened

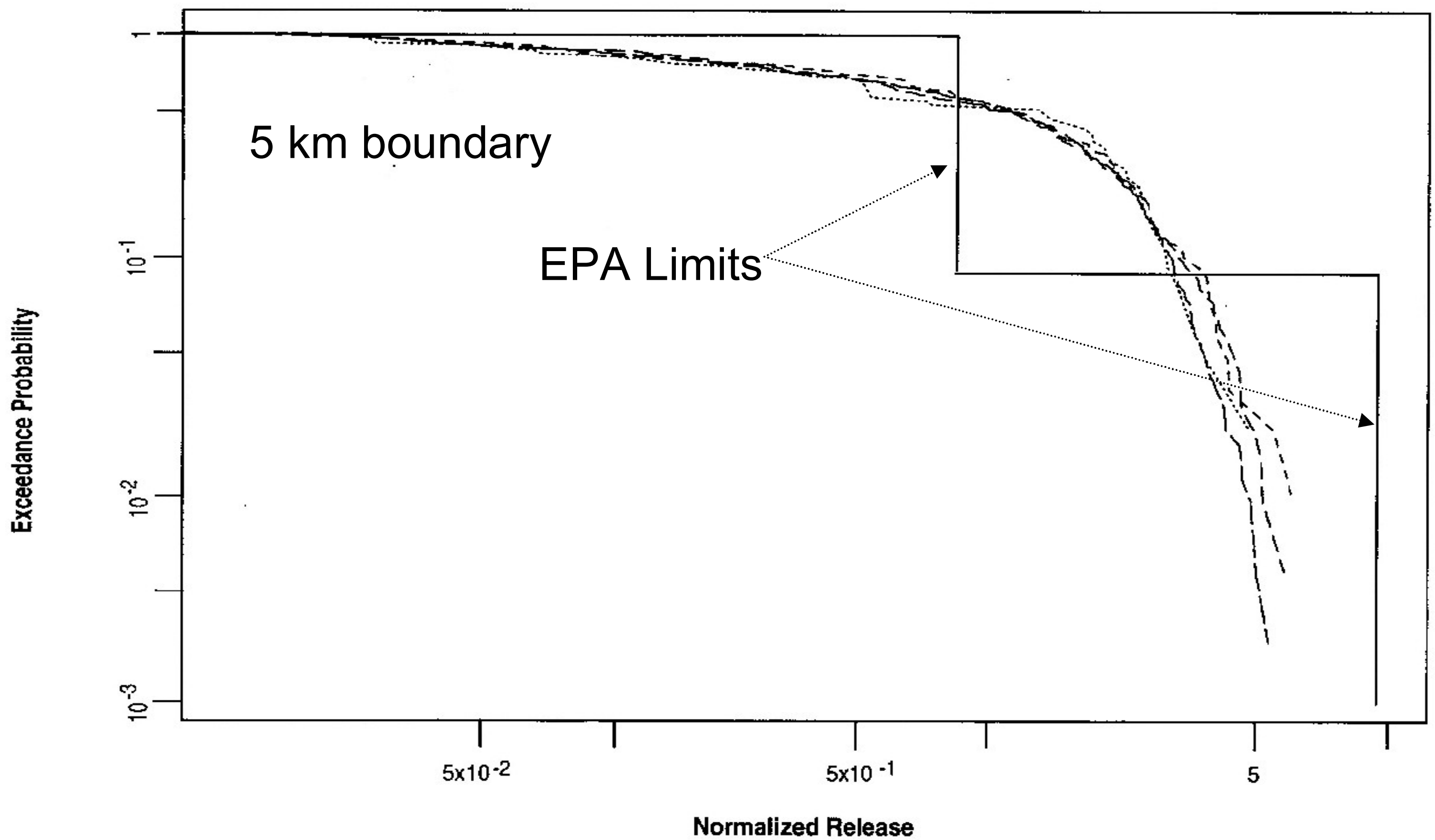
Evolution of Yucca Mountain Performance Assessments

Performance Assessment: 1980's Design

NRC, 1992: NUREG-1327, Figure 9-17

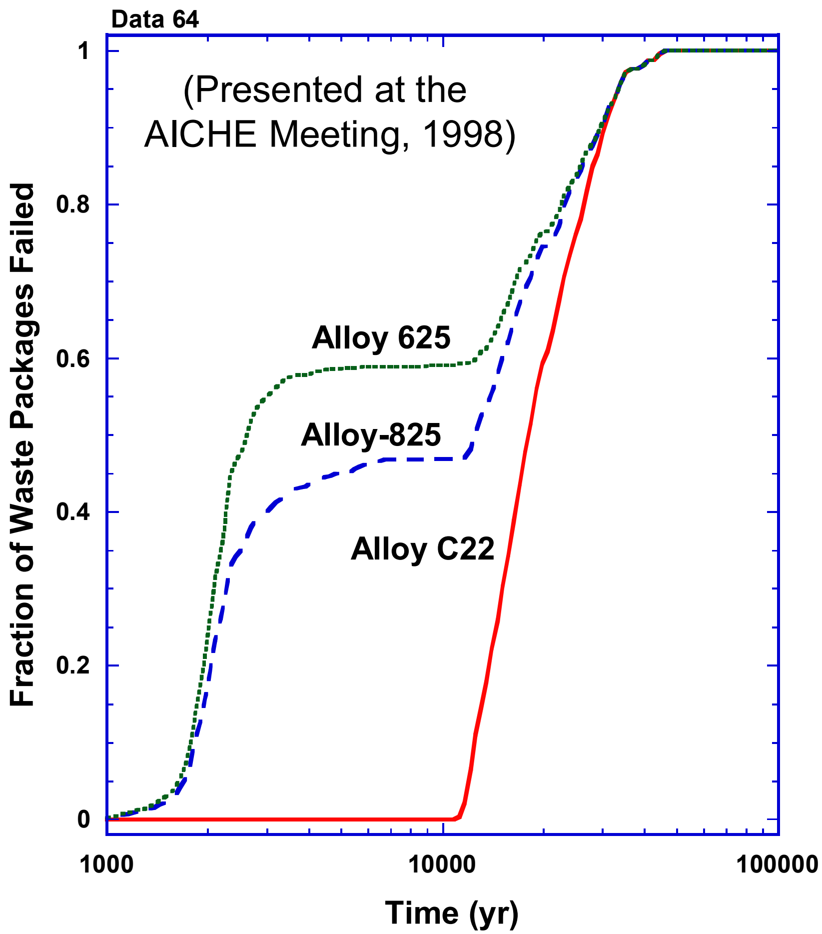
10,000 years
5 km compliance boundary

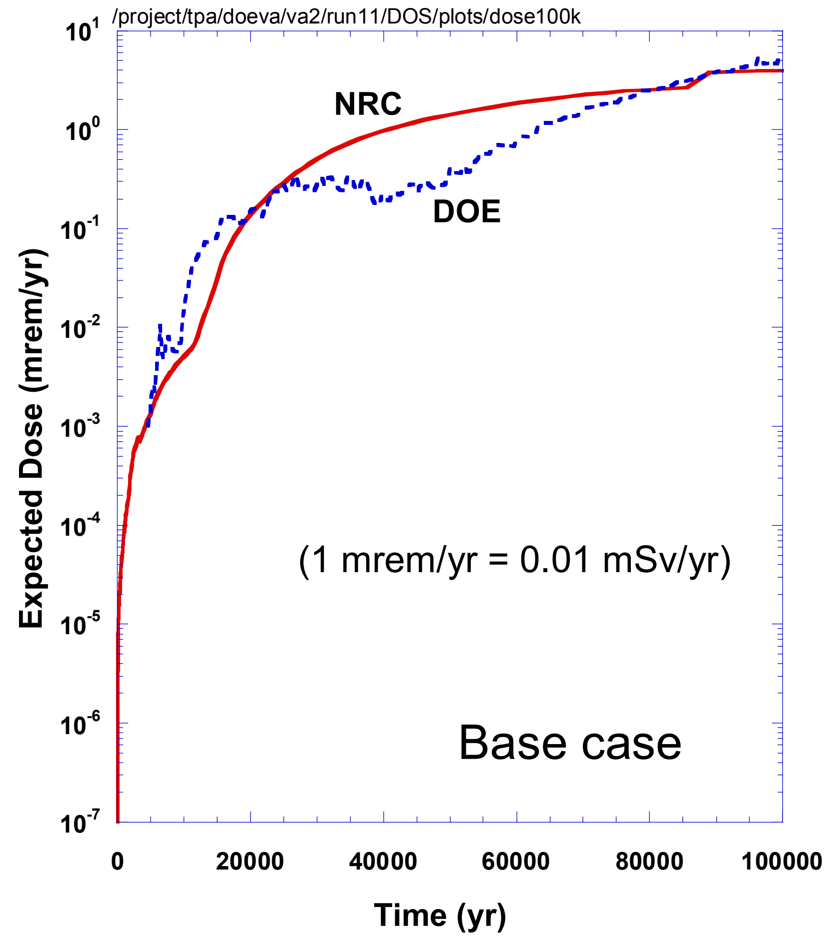
Performance Assessment Prediction: 1992 Design



Total CCDF for Effective Dose Equivalent from significant scenarios (NRC, 1995) NUREG-1464, Fig. 9-7b, IPA 2

Performance Assessment: Viability Assessment (1998)

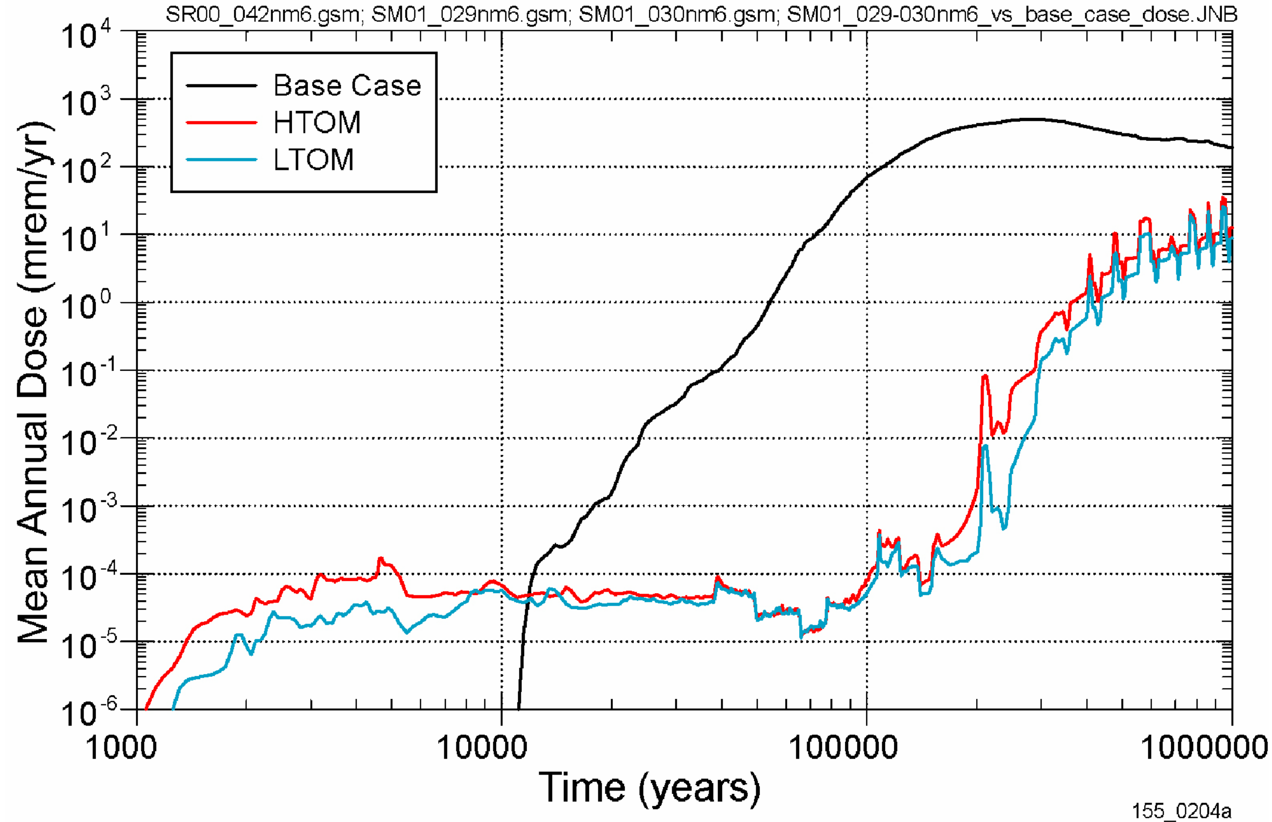




Mohanty, S., 1999. TPA 3.2 Total-System Results, DOE/NRC Technical Exchange on TSPA of Yucca Mountain, San Antonio, TX, May 25-25, 1999.

Performance Assessment: Site Recommendation (2002)

DOE Calculation of Dose



Summary of Peak Dose Performance Results (HTOM: High-Temperature Operating Mode; LTOM: Low-Temperature Operating Mode; Basecase: TSPA-SR) (Bechtel SAIC Company, LLC, 2001, Figure 4.1-1) (1 mrem/yr = 0.01 mSv/yr)

Post-Site Recommendation Period Performance Assessments

- Based on Site Recommendation Design, but more analyses for increased realism

- Examples: drift and drip shield stability, and drip shield-waste package interaction

- Drip shields are also considered to be load transfer barriers in the analyses

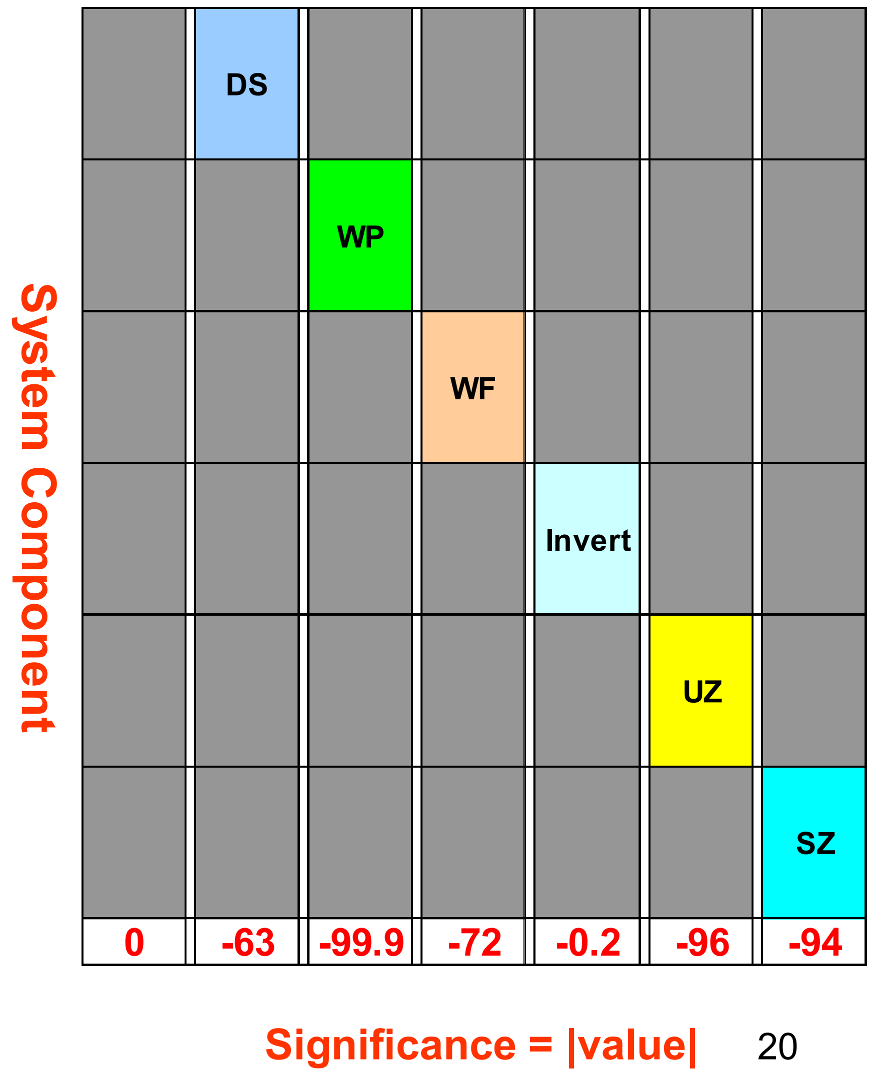
- Analyses indicated that the drip shields may not withstand the load generated by the volume of rockfall rubble estimated by NRC. DOE, in response, proposed a modified design
  – increased height of drip shield so that the deflected drip shield would not contact the waste package
  – Increased structural reinforcement in drip shield design

Usefulness of Performance Assessment in Design Change

- Performance assessment evolves with each iteration
  - uses the current design, and research and development information
  - initial scoping calculations use initial best estimates
  - concurrent laboratory tests and detailed modeling help refine/replace the best initial estimates
  - if predicted responses deviate significantly from regulatory performance criteria, the design may be revised further or additional data collected for the next iteration
  - if not, the measured values may be used only to refine the best initial estimates

Usefulness of Performance Assessment in Design Change (cont'd)

- Performance assessment may be an effective aid in design review by identifying
  - components that are not significant even if whole EBS makes significant contribution
  - components that could be detrimental to performance of other components
  - a component that is (i) risk-significant or (ii) insignificant to waste isolation, but significant to pre-closure operational safety



Summary and Conclusion

- From the regulatory standpoint, any proposed design must meet both long-term performance and operational safety requirements

- The importance of performance assessments in guiding design reviews is a function of the estimated performance (e.g., dose) and uncertainties in relation to the regulatory threshold and the sensitivity of performance to design parameters.

- Because large uncertainties are associated with the long compliance period, DOE is required to consider design modifications and account for design modification even after the license application is submitted.

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