U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

General Postclosure Seismic Approach

Presented to:

Nuclear Waste Technical Review Board
Joint Meeting of the Natural System and Engineered System Panels

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Objectives

- **Provide overview of technical approach for postclosure analysis of seismic response**
- **Describe scope and status of each component of technical approach**
- **Overview will be followed by detailed briefings on**
  - **Postclosure ground motion analysis**
  - **Drift stability (rockfall): seismic and thermal**
  - **Structural response of Engineered Barrier System (EBS) components**
  - **Implementation in Total System Performance Assessment (TSPA)**

Scope of Technical Approach

- **Focus on 10,000 year postclosure regulatory period**
- **Low probability ground motions must be considered:**

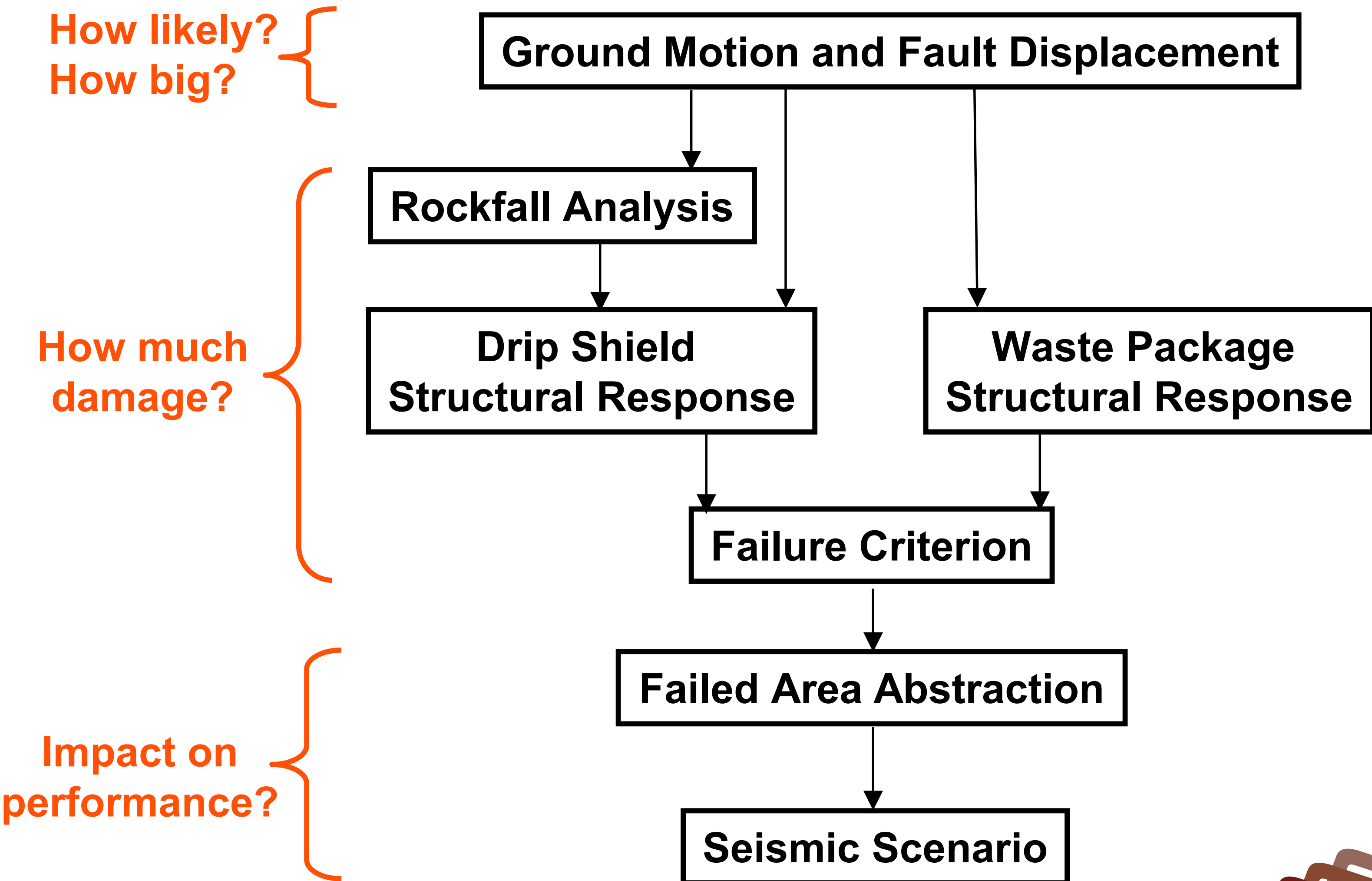
  **"§63.114--Requirements for performance assessment.
  Any performance assessment used to demonstrate compliance with §63.113 must: (d) Consider only events that have at least one chance in 10,000 of occurring over 10,000 years."**

- **Damage to EBS based on the mean seismic hazard**
- **Damage to EBS represented as failed area that allows flow through the drip shield (DS) and transport from the waste package (WP)**

Key Questions for Technical Approach

- How likely is the ground motion or fault displacement
- How “big” is it
- Is there damage to the drift, to the DS and waste package, or to the cladding
- If yes, what is the impact on long-term performance

Components of the Postclosure Technical Approach



Status of Activities

- Ground motion and fault displacement
  - Defined vibratory ground motions at emplacement drifts (Point B in the Probabilistic Seismic Hazard Analysis (PSHA)) for different ground motion "levels"
    - 15 time histories (accelerograms) developed for 10^{-6} per year level
    - 15 time histories developed for 10^{-7} per year level
    - One time history developed for the 5×10^{-4} per year level
  - Fault displacement defined in PSHA Report
- Rockfall Analysis
  - Analyze impact of vibratory ground motions at the 10^{-6}, 10^{-7}, and 5×10^{-4} per year levels in the lithophysal and nonlithophysal zones
  - Response of rock mass computed with nonlinear models using state-of-the-art codes (UDEC, 3DEC, PFC)
  - Output includes size and velocity of rock blocks ejected from drift walls

Status of Activities
(Continued)

- **Drip Shield Structural Response**
  - Analyze impact of rock blocks on the drip shield
  - Analyze response to vibratory ground motions at the 10^{-6}, 10^{-7}, and 5×10^{-4} per year levels
- **Waste Package Structural Response**
  - Analyze response to vibratory ground motions at the 10^{-6}, 10^{-7}, and 5×10^{-4} per year levels
    - Includes WP-pallet and WP-to-WP interactions
    - Includes variability of friction coefficients
- **Structural response based on detailed finite-element models using state-of-the-art code (LS-DYNA)**
  - Degradation over 10,000 years represented as a reduced thickness for the drip shield and waste package
  - Output is the residual stress from structural deformation

Status of Activities
(Continued)

- **Failure Criterion**
  - Residual stress from permanent deformation is associated with stress corrosion cracking at accelerated corrosion rates
    - Damaged areas have the potential to form pathways for flow and transport
  - Accelerated corrosion rates occur for residual stresses below yield stress. Typical values:
    - 80% to 90% of yield stress for Alloy 22 (WP outer shell)
    - 50% of yield stress for Titanium Grade 7 (DS plates)
  - Accelerated corrosion will damage the WP or DS before ultimate tensile failure is reached

Status of Activities
(Continued)

- **Failed Area Abstraction**
  - Define the distribution for failed area as a function of the magnitude of the ground motion
    - This distribution is referred to as a "response curve." A response curve is similar to a fragility curve
      - » Response curve is a continuous function rather than a fail/no-fail measure of response for a fragility curve
- **Seismic Scenario in TSPA**
  - Separate scenario for low probability seismic hazards
  - Seismic "event" causes failed areas, similar to the patches generated by general corrosion
  - Compute mean dose as probabilistically weighted sum of the dose for the full range of ground motions and fault displacements that can cause damage to the EBS

Notable Conservatisms

- Ground motions do not saturate at high strain levels
- Structural response is conservative
  - Temperature for material properties (150°C) results in conservative values over 97% of the 10,000-year regulatory period (based on High Temperature Operating Mode)
  - Thickness reduction (2-mm) corresponds to high percentile corrosion rates over 10,000 years
    - 88th percentile for corrosion of Alloy 22 (includes microbiologically influenced corrosion (MIC) and aging)
    - 73rd percentile for corrosion of Titanium Grade 7 (top and bottom)
- Damage assessment is conservative
  - Cracks are assumed to propagate through shells and plates, even if only a single zone on the surface of the WP or DS meets the failure criterion for residual stress

Summary

- Ground motions defined for 10^{-6} & 10^{-7} 1/yr levels
- Structural response and rockfall calculations performed for each level using 15 ground motions
  - Degradation included in structural response calculations
- Damage to barriers represented as failed area for flow and transport
  - Based on residual stress from structural deformation
- Failed area abstracted and included in a separate scenario for TSPA-License Application
  - Failed area plays same role in TSPA as waste package degradation model (WAPDEG) calculation of corrosion. Other parts of the TSPA model are identical to the nominal scenario