SAND2019-13833C

ANS Winter Meeting & Expo

2019 NUCLEAR TECHNOLOGY FOR THE U.S. AND THE WORLD

Options for Modifying Existing and Future DPCs for Disposal

Ernest Hardin[1], Abdelhalim Alsaed[2] and Branko Damjanac[3]

[1]Sandia National Laboratories; [2]Enviro Nuclear Services; [3]Itasca Consulting Group

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Disclaimer

This is a technical presentation that does not take into account contractual limitations or obligations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment.

To the extent discussions or recommendations in this presentation conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this presentation in no manner supersedes, overrides, or amends the Standard Contract.

This presentation reflects technical work which could support future decision making by DOE. No inferences should be drawn from this presentation regarding future actions by DOE, which are limited both by the terms of the Standard Contract and a lack of Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

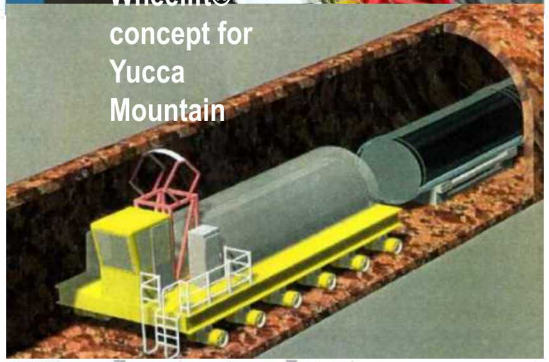
Approved for Unclassified, Limited Release (Sandia Tracking #1033174).

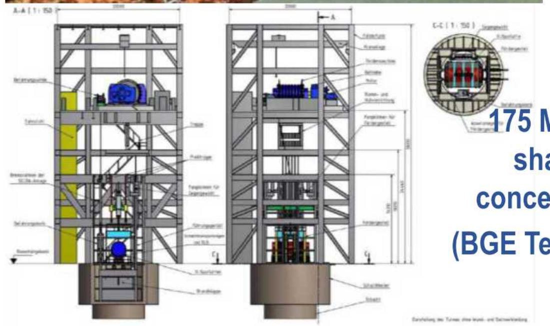
Summary of 2013–2017 Studies on Technical Feasibility of Direct Disposal of CSNF in DPCs

- **Technical evaluation results in major areas:**
  - Safety of workers and the public
  - Engineering feasibility
  - Thermal management
  - Postclosure criticality control
- **"Direct disposal" is possible with all geologic settings evaluated (based on low probability of criticality)**
  - Thermal and postclosure criticality constraints would vary for different settings
- **Additional considerations:**
  - Overall engineered and natural barrier performance (e.g., overpack, host geologic media)
  - DPC basket designs impact structural longevity if packages are breached and flooded
- **Major recommendations:**
  - Investigate fillers for existing DPCs
  - Investigate consequences of postclosure criticality on repository performance

Managing Heavy Packages

- **Handling/Packaging: Use Current Practices**
- **Surface-Underground Transport**
  - Shallow ramp (~3% grade, standard rail)
  - Spiral ramp (~10% grade, rubber-tire)
  - Linear ramp (>10% grade, funicular)
  - Heavy shaft hoist
- **Drift Opening Stability Constraints**
  - Salt (a few years with little attention; longer with maintenance; creep is thermally activated)
  - Hard rock (50 years or longer; for some hard rock formations without rock bolts/maintenance)
  - Sedimentary (50 years possible; longer depending on geologic setting and maintenance)



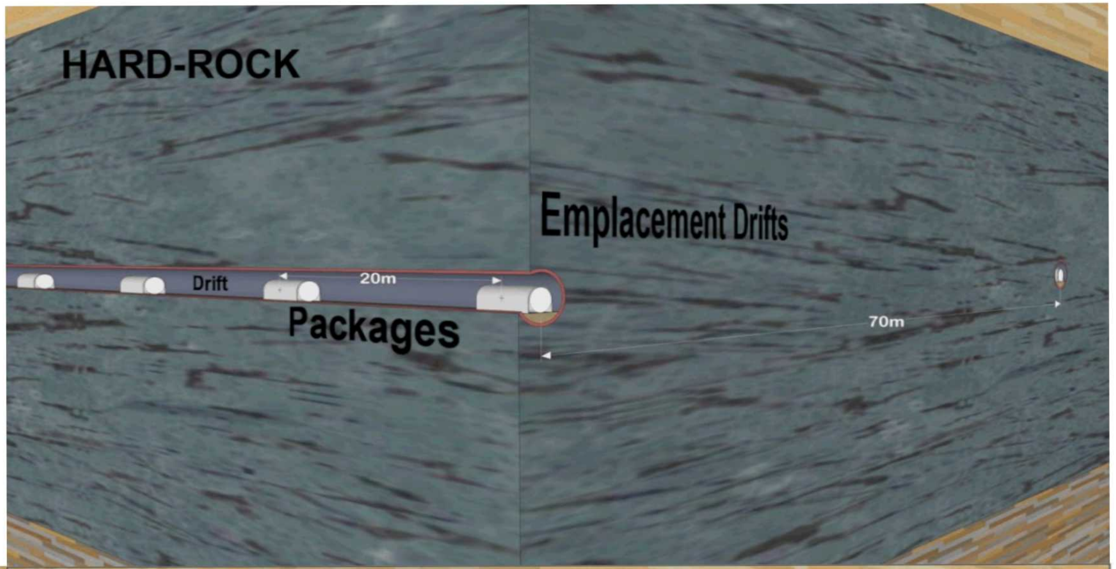


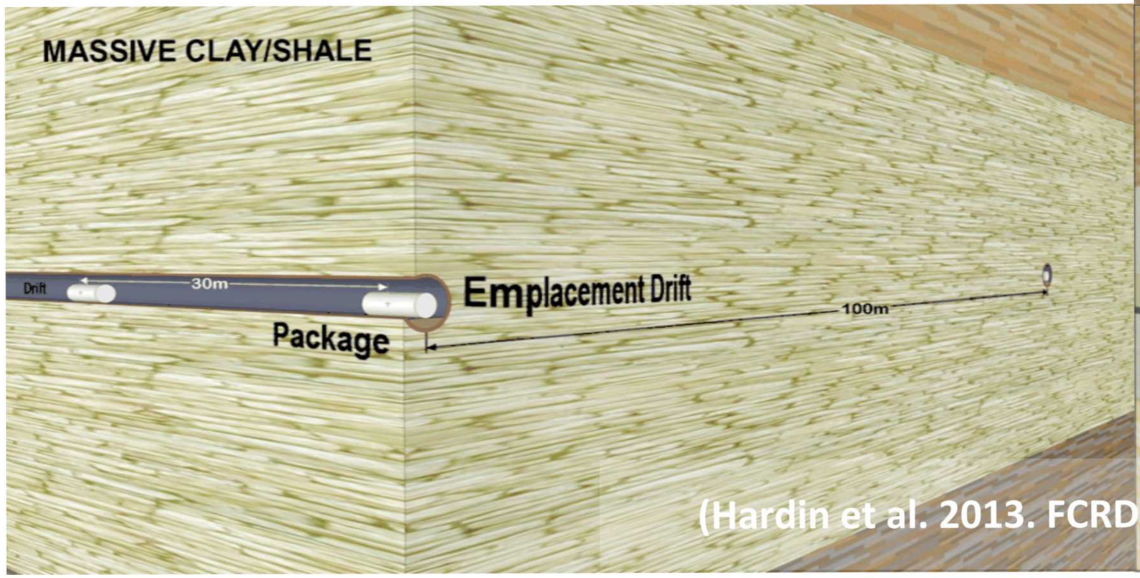
Sandia National Laboratories

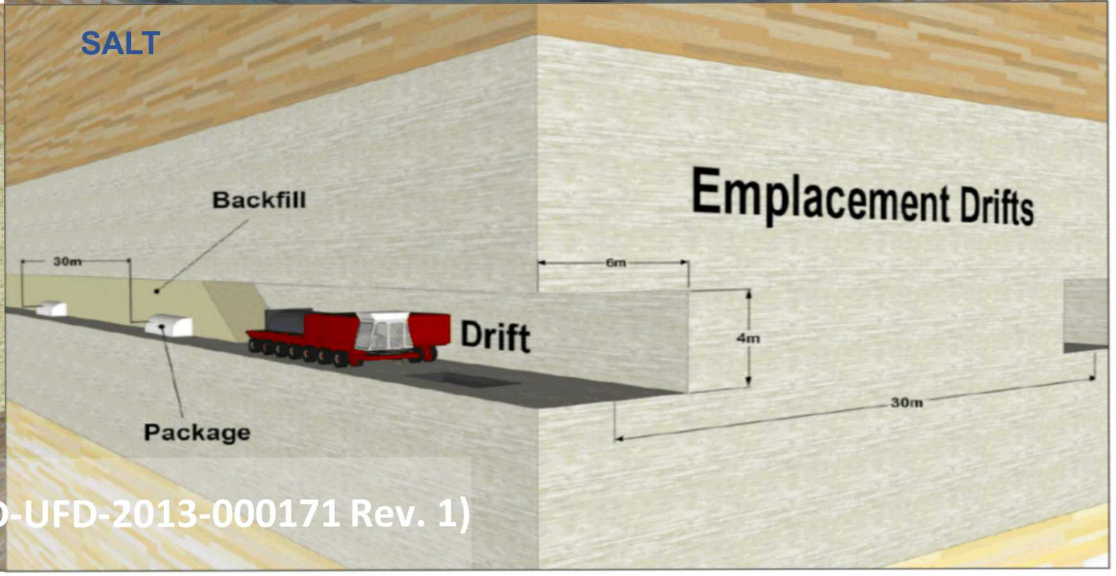
ANS

DPC Direct Disposal Concepts: Repository Engineering

- Engineering challenges are feasible
- Shaft or ramp transport
- Axial in-drift emplacement
- Heat removal by ventilation possible
- Backfill before closure (except unsat.)
- Likelihood of waste package breach and flooding varies







(Hardin et al. 2013. FCRD-UFD-2013-000171 Rev. 1)

Managing Decay Heat

- **Thermal analysis for 32-PWR assemblies (a common DPC size)**
- **SNF decay heat curves cross horizontal lines for each disposal concept; read down for aging time to meet peak temperature target.**
- **Heat dissipation is best for salt and unbackfilled concepts**
- **Backfill constraints dominate (where backfill is used, with a temperature limit)**

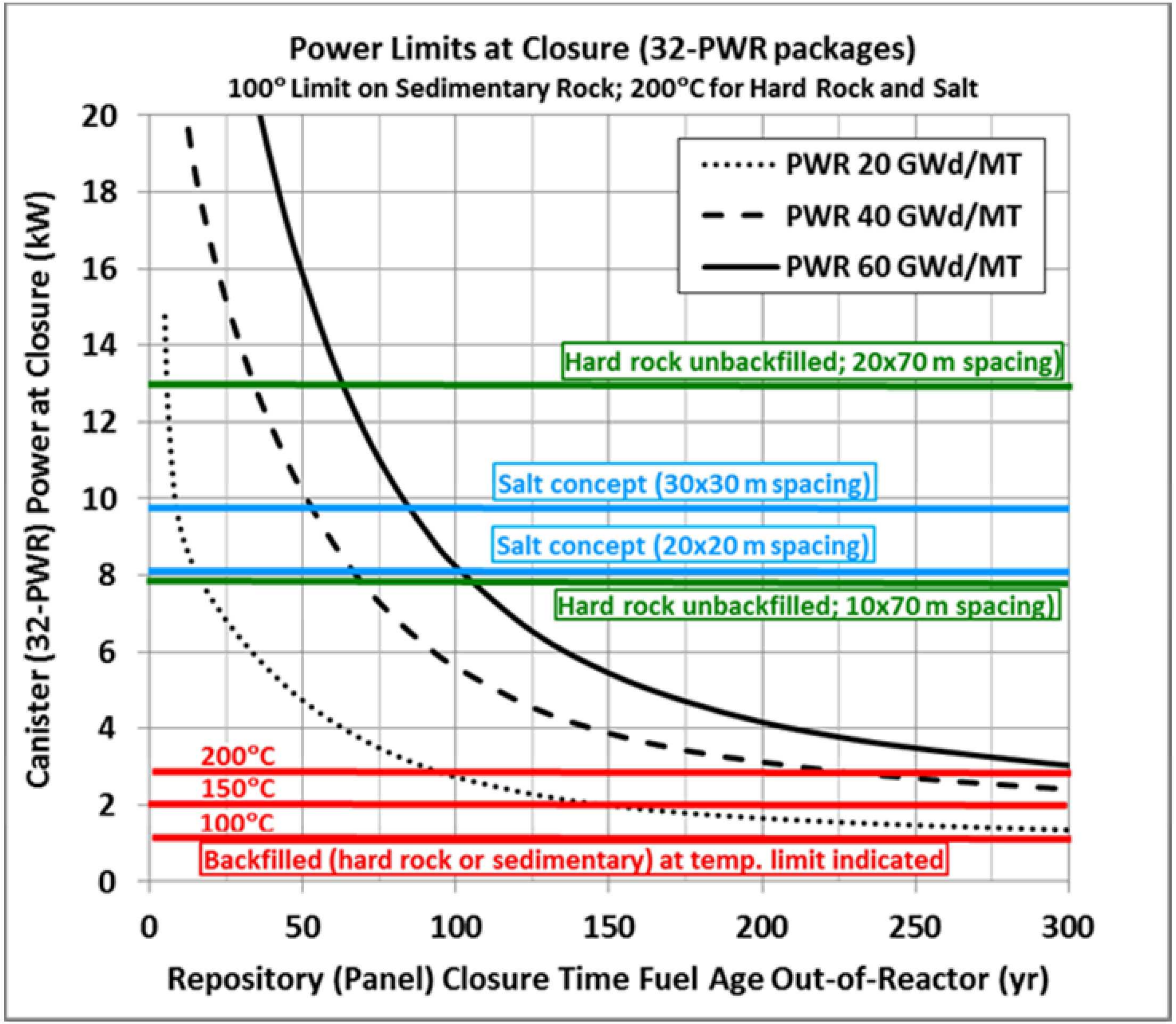


Figure from SNL 2015. *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters.* FCRD-UFD-2015-000129 Rev. 0.

Sandia National Laboratories

ANS

Postclosure Criticality

- **DPCs were designed to remain subcritical during storage and transportation**
- **Stylized analyses show that some (not all) DPCs could achieve criticality during the postclosure period (10^4 years or longer) if:**
  - **The DPC is flooded with groundwater**
  - **Fuel baskets degrade**
  - **Neutron absorbing material configuration is lost**
- **Fuel would remain subcritical if:**
  - **Waste packages remain intact during the regulatory period (any geologic medium)**
  - **Fuel does not flood with water regardless of package integrity (any geologic medium)**
- **Potential postclosure criticality can be managed by:**
  - **Steps to lower the probability of occurrence (the subject of this presentation), OR**
  - **Evaluating postclosure criticality consequences**

Sandia National Laboratories

ANS

Options for Managing Postclosure Criticality (1/6)

1. **Add criticality control features to future DPCs (low probability screening strategy)**

- **Zone loading: Blend fuel assemblies to optimize reactivity (EPRI 2008)**
  - **Include moderator displacement by BPRAs in analysis**
  - **Optimize fuel selection and DPC loading pattern**
- **Corrosion-resistant absorber material: Substitute plates for Boral® in certain basket designs, or use for inserts ("chevron plates") in existing basket designs**
- **Disposal control features: Insert hardware when DPCs are loaded**

EPRI 2008. *Feasibility of Direct Disposal of Dual-Purpose Canisters: Options for Assuring Criticality Control*. 1016629.

Sandia National Laboratories

ANS

Options for Managing Postclosure Criticality (2/6)

1. Add criticality control features to future DPCs, continued

- **Disposal control rods (in PWR fuel guide tubes)**
- **For BWR fuel**
  - **Modify "water rods" (remove valves and insert absorber rods; as needed for reactivity control)**
  - **Corrosion-resistant disposal control blades (may require basket redesign; as needed)**
  - **Corrosion resistant absorber inserts (with sufficient basket-fuel clearance; except edge positions)**
  - **Fuel <u>re-channeling</u> with corrosion-resistant absorber material (< 50% of assemblies)**

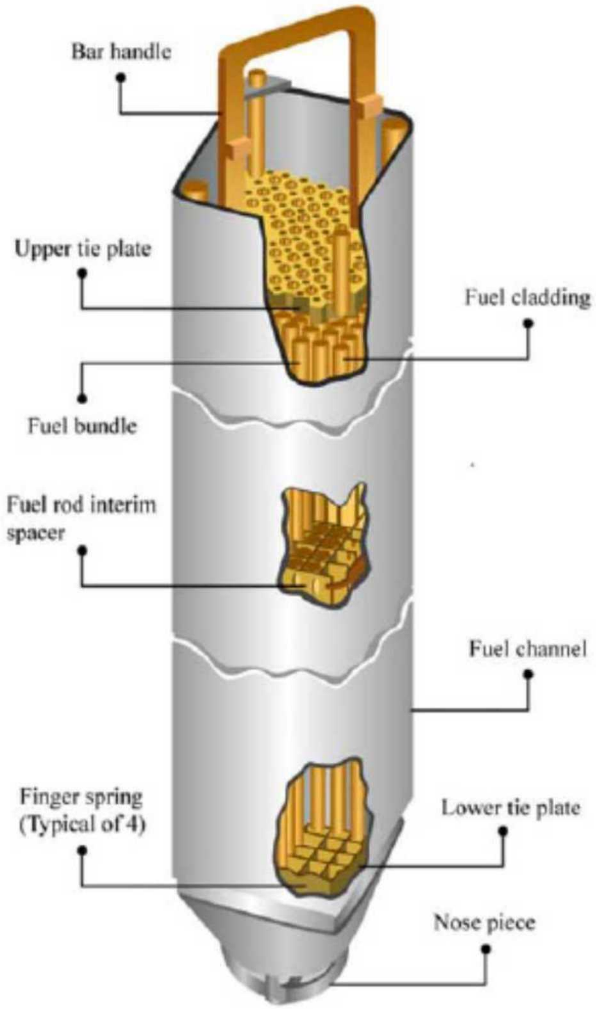


Figure credit:
BWR assembly view
(MIT Open Courseware)

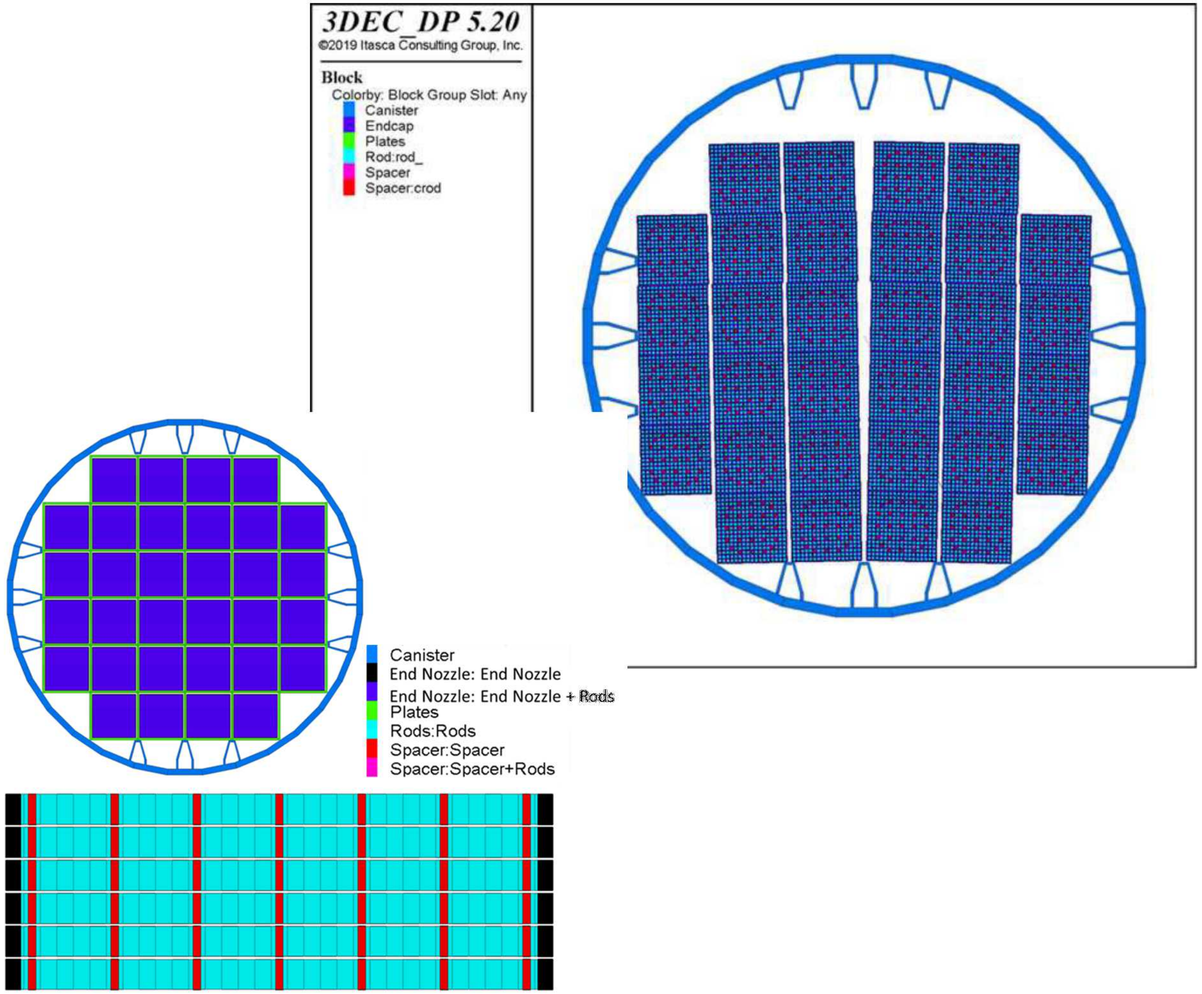
Sandia National Laboratories

ANS

Options for Managing Postclosure Criticality (3/6)

1. Add criticality control features to future DPCs, continued

- **Neutron absorber function can be provided by the basket or the fuel**
- **As the basket and fuel assemblies degrade and collapse, criticality control features (plates, rods, etc.) will move with them**
- **Simulations are being developed to characterize degraded configurations**
- **The evolving configurations are expected to become less reactive**



Source: SNL 2019, Milestone Report M3SF-19SN010305071 (in review).

Options for Managing Postclosure Criticality (4/6)

2. Injectable fillers (low probability screening strategy)

- **Inject material in liquid form, into already-loaded DPCs (use existing or augmented ports)**
- **Material cures or freezes to solid form, with acceptable properties and low final water content**
- **Long-lasting material would exclude groundwater (e.g., cements or molten metals/alloys), and could entrain neutron absorbing materials (e.g., B_4C or gadolinia particles**

Injectable fillers is the only treatment concept proposed that could be applied to the entire fleet of DPCs, both existing and future DPCs, without cutting them open.

Options for Managing Postclosure Criticality (5/6)

Note: This option, if successful, could obviate the need for the foregoing Options 1 and 2.

3. Analyze postclosure criticality consequences (consequence screening strategy)

- **Analyze consequences of postclosure critical events on overall repository performance**
- **Exclude waste package internal criticality from repository performance assessment if consequences are insignificant, OR**
- **Include criticality consequences in repository performance assessment (including performance of engineered and natural barriers)**

Options for Managing Postclosure Criticality (6/6)

4. Repackage in disposal-ready canisters

- **For use in multiple media, canisters would likely have smaller capacity than typical DPCs (e.g., 21-PWR/44-BWR; see ORNL 2015)**
- **Canister/basket design for multiple geologic media depends on an approach to postclosure criticality management (options 1 to 3)**
- **System impacts**
  - **Worker dose**
  - **Complexity, major new facilities**
  - **Estimated cost > $2M per canister**

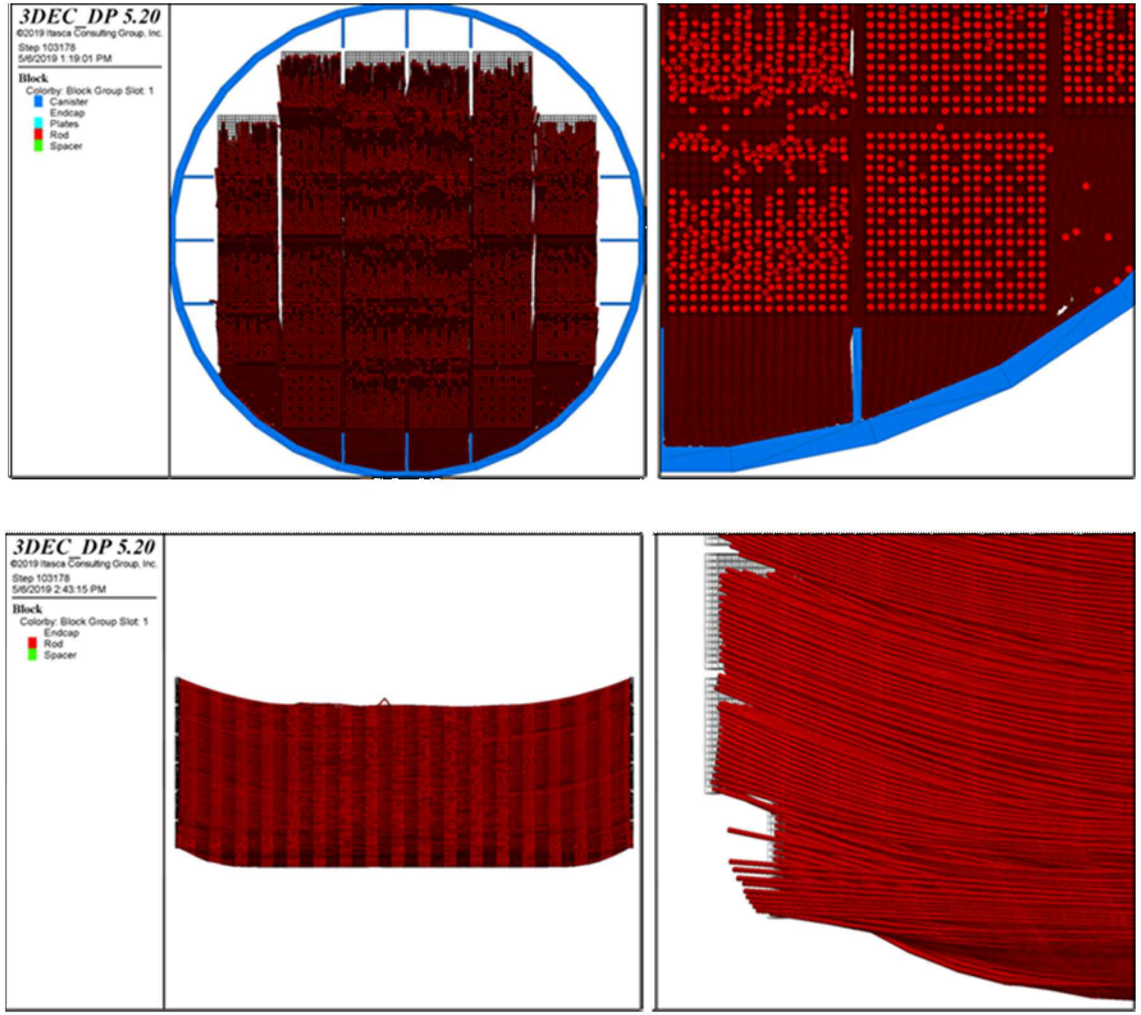
ORNL 2015. Perfo*rmance Specification for Standardized Transportation, Aging, and Disposal Canister Systems.* FCRD- NFST-2014-000579, Rev. 2.

Slide 13

CR(1	Why is this included as an "option for managing Postclosure criticality"...the subject of discussion is "DPC modification"; this is the alternative to directly disposing DPCs Clark, Robert (NE-NEV), 10/18/2019

Can long-term degradation of DPC baskets and fuel assemblies on exposure to groundwater, "turn off" potential criticality events?

- **"Bathtub" could become impossible in unsaturated settings**
- **Basket corrosion and collapse**
- **Seismic loading**
- **Assembly tie-rod failure (rods pull out of nozzles)**



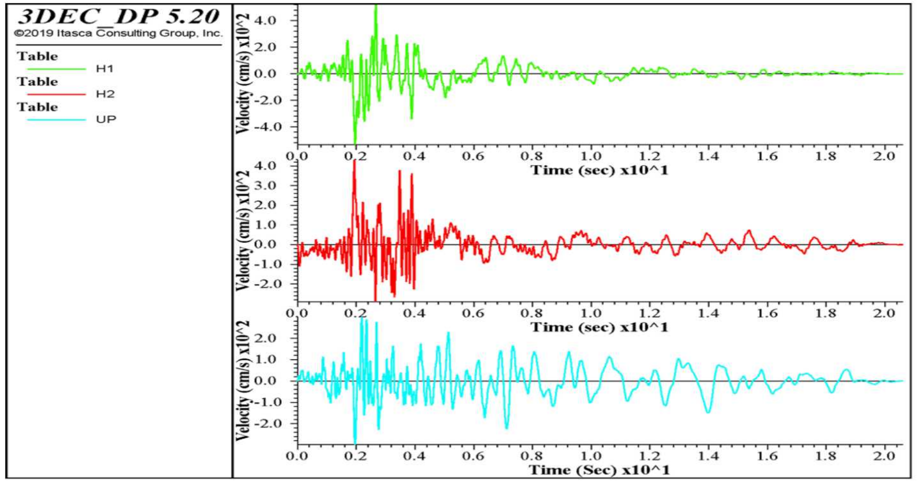
Source: SNL 2019, Milestone Report M3SF-19SN010305071 (in review).

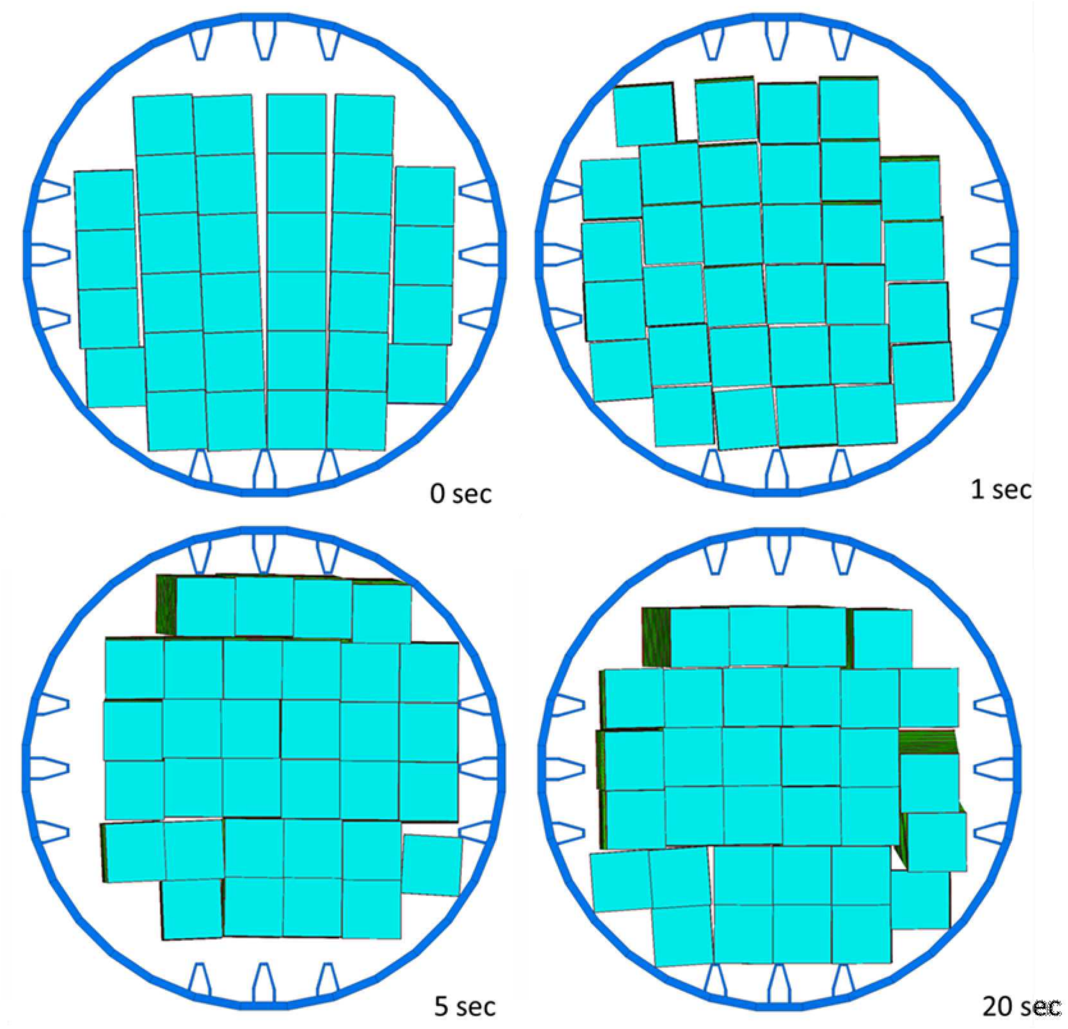
Sandia National Laboratories

ANS

Seismic Response Simulations

- **3D simplified model (SNL 2019)**
- **Basket plates (aluminum based) fully corroded**
- **1.05 m/sec PGV (10^{-5} /yr mean annual exceedance, YM LA)**





Source: SNL 2019, Milestone Report M3SF-19SN010305071 (in review).

Sandia National Laboratories

ANS

Summary

- Multiple, technical options are available for managing postclosure criticality, with DPC "direct disposal"
- Technical feasibility studies are investigating a representative range of options
- Modifications to baskets or fuel could support a low-probability approach to postclosure criticality
- Fuel modifications provide an alternative approach to corrosion resistant absorber plates

Sandia National Laboratories

ANS