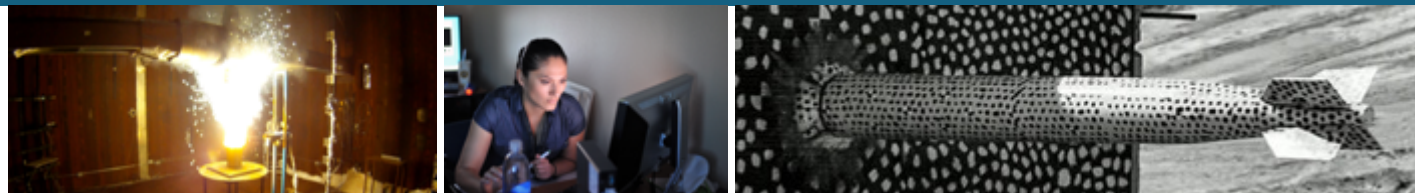Sandia National Laboratories

SAND2021–1940PE

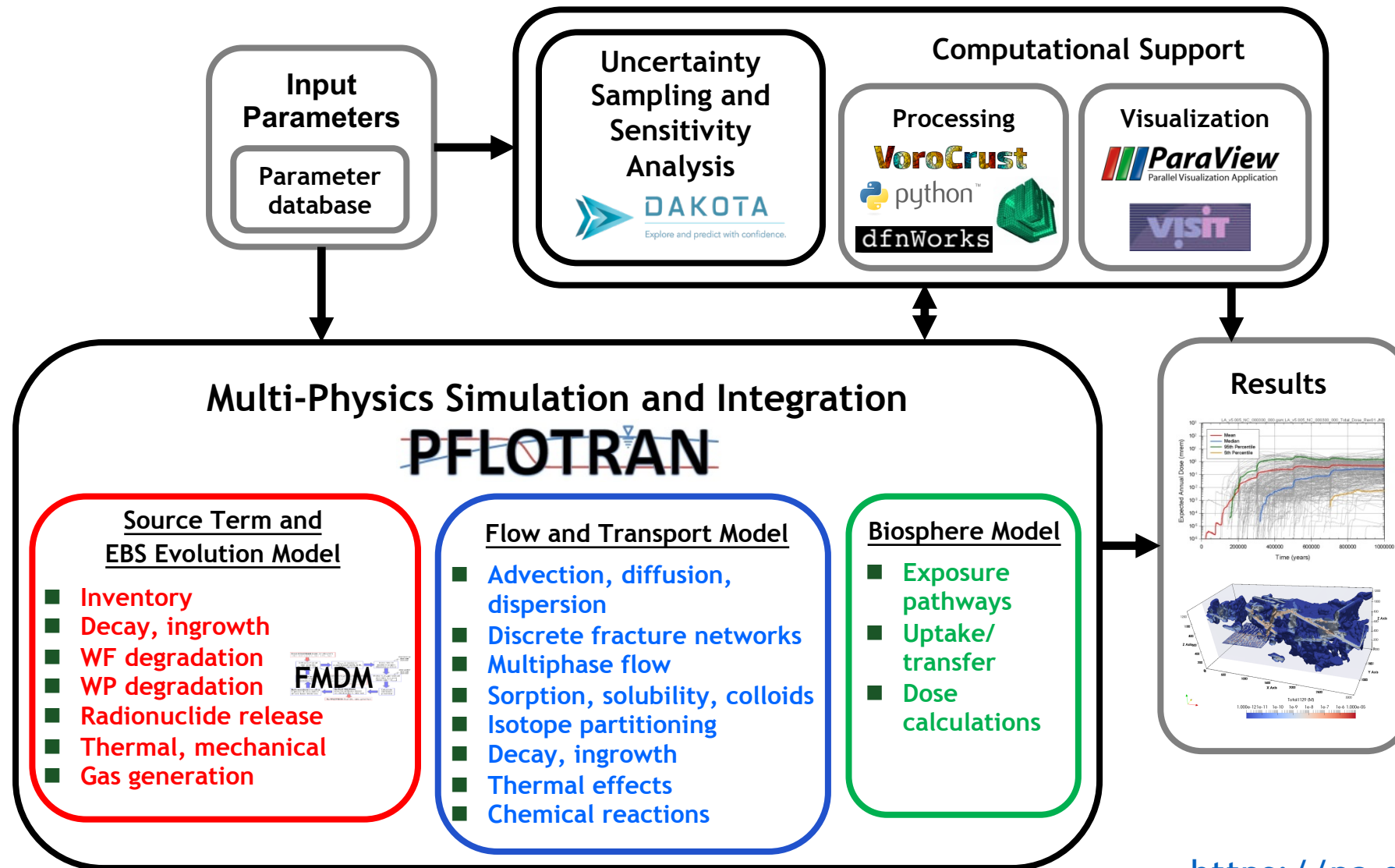# Development of Geologic Disposal Safety Assessment (GDSA) Framework

PRESENTED BY

Emily Stein, Sandia National Laboratories, USA

IAEA URF Network Meeting
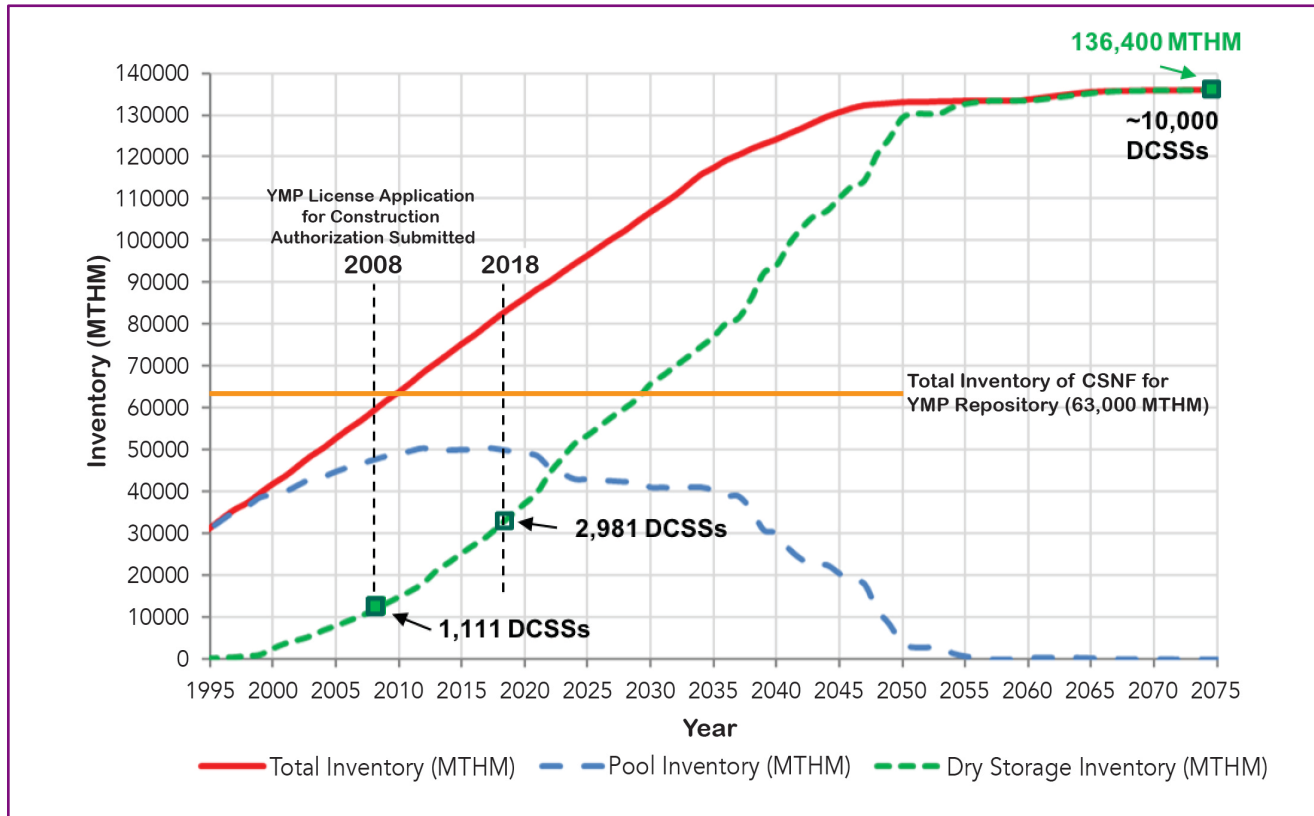23 February, 2021
Virtual Meeting (WebEx)

SAND2021-xxxx PE

Geologic Disposal Safety Assessment Framework

Input Parameters

> Parameter database

Uncertainty Sampling and Sensitivity Analysis

DAKOTA
Explore and predict with confidence.

Computational Support

Processing

VoroCrust
python™
dfnWorks

Visualization

ParaView
Parallel Visualization Application
VisIt

Multi-Physics Simulation and Integration

PFLOTRAN

Source Term and EBS Evolution Model

- ■ **Inventory**
- ■ **Decay, ingrowth**
- ■ **WF degradation**
- ■ **WP degradation**
- ■ **Radionuclide release**
- ■ **Thermal, mechanical**
- ■ **Gas generation**

FMDM

Flow and Transport Model

- ■ **Advection, diffusion, dispersion**
- ■ **Discrete fracture networks**
- ■ **Multiphase flow**
- ■ **Sorption, solubility, colloids**
- ■ **Isotope partitioning**
- ■ **Decay, ingrowth**
- ■ **Thermal effects**
- ■ **Chemical reactions**

Biosphere Model

- ■ **Exposure pathways**
- ■ **Uptake/ transfer**
- ■ **Dose calculations**

Results

https://pa.sandia.gov

US Spent Nuclear Fuel (SNF) and High-Level Waste (HLW) Inventory

Projection assumes full license renewals and no new reactor construction or disposal.
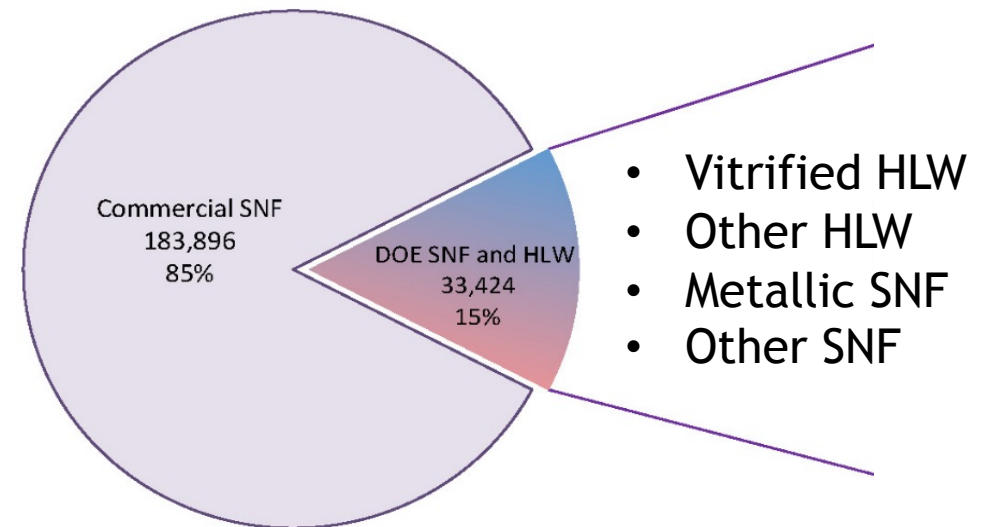CSNF – commercial spent nuclear fuel
DCSS – dry cask storage system
MTHM – metric tons heavy metal
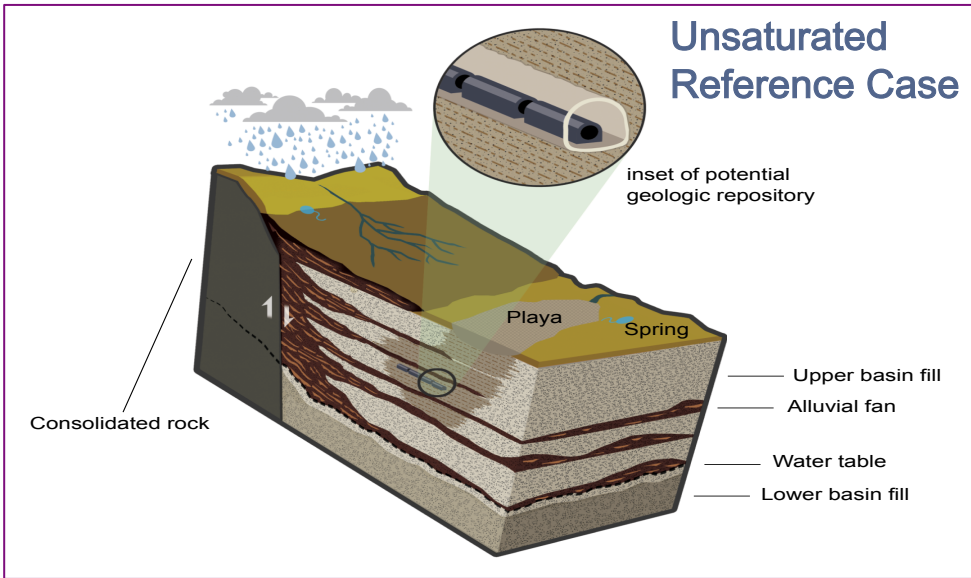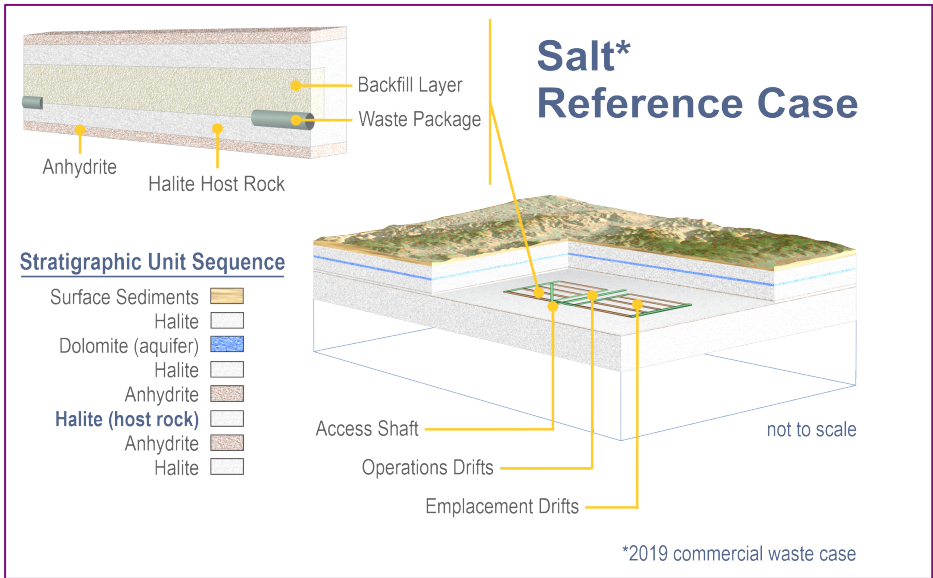YMP – Yucca Mountain Project

Modified from Freeze et al. 2019

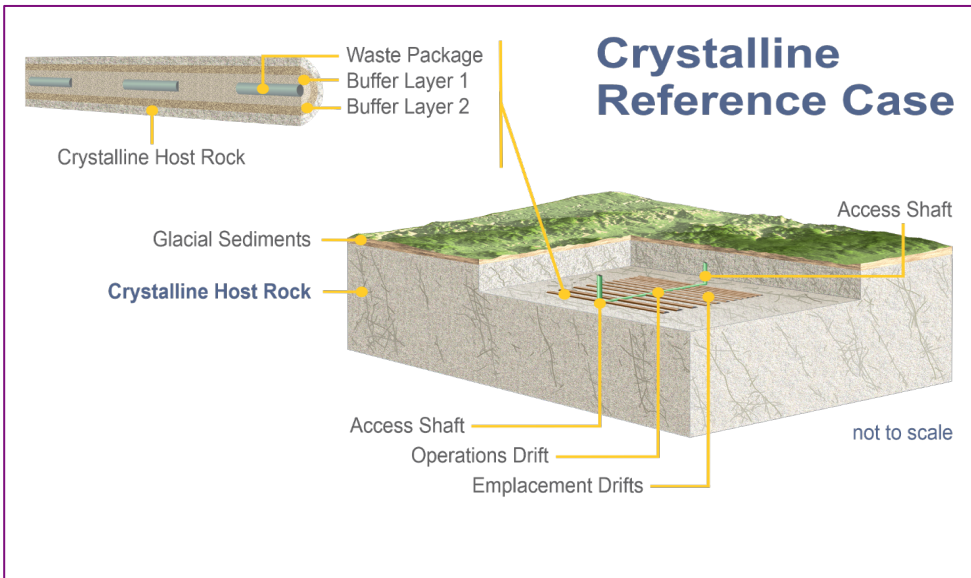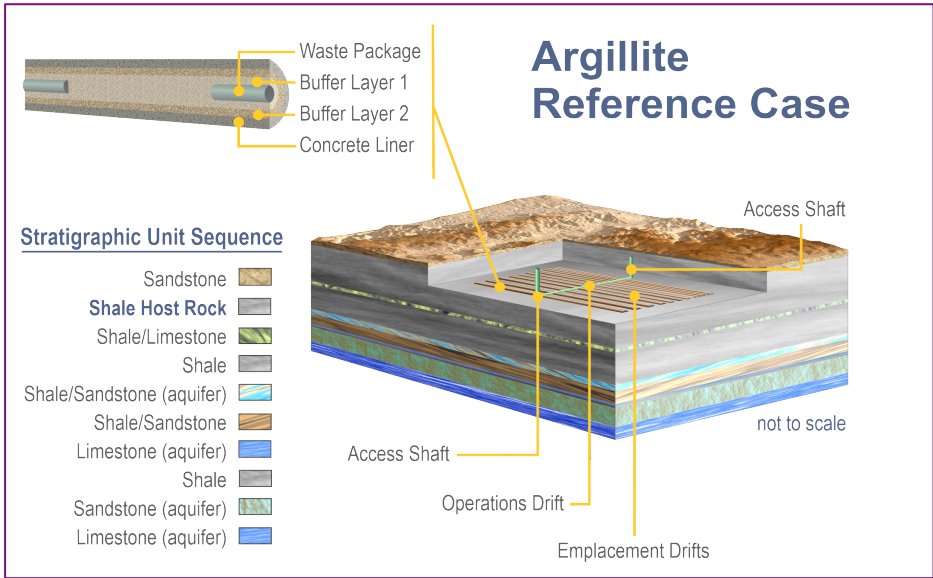Projected volumes in m^3

- Vitrified HLW
- Other HLW
- Metallic SNF
- Other SNF

Commercial SNF volume estimated assuming constant rate of nuclear power generation and packaging in dual purpose canisters of existing design.
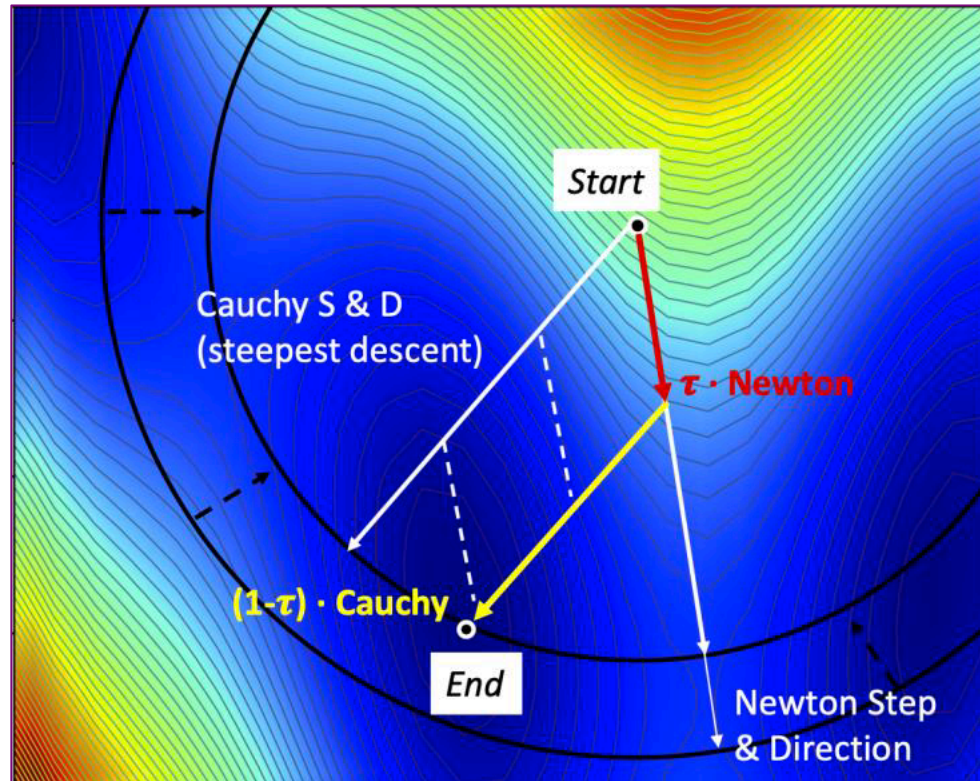
DOE waste volume estimated assuming calcine is treated by hot isostatic pressing, Na-bonded fuels undergo electrometallurgical treatment, Na-bearing wastes undergo fluidized bed steam reforming, and all other HLW wastes are vitrified.

From a presentation by John W. Herczeg to the 2015 Annual Meeting of the National Council on Radiation Protection and Measurements, March 16, 2015

Generic Reference Cases

Argillite Reference Case

Waste Package
Buffer Layer 1
Buffer Layer 2
Concrete Liner

Stratigraphic Unit Sequence

Sandstone
Shale Host Rock
Shale/Limestone
Shale
Shale/Sandstone (aquifer)
Shale/Sandstone
Limestone (aquifer)
Shale
Sandstone (aquifer)
Limestone (aquifer)

Access Shaft
Access Shaft
Operations Drift
Emplacement Drifts

not to scale

Crystalline Reference Case

Waste Package
Buffer Layer 1
Buffer Layer 2

Crystalline Host Rock

Glacial Sediments
Crystalline Host Rock

Access Shaft
Access Shaft
Operations Drift
Emplacement Drifts

not to scale

Salt* Reference Case

Backfill Layer
Waste Package

Anhydrite
Halite Host Rock

Stratigraphic Unit Sequence

Surface Sediments
Halite
Dolomite (aquifer)
Halite
Anhydrite
Halite (host rock)
Anhydrite
Halite

Access Shaft
Operations Drifts
Emplacement Drifts

not to scale

*2019 commercial waste case

Unsaturated Reference Case

inset of potential geologic repository

Consolidated rock
Playa
Spring
Upper basin fill
Alluvial fan
Water table
Lower basin fill

Capability Development in PFLOTRAN for High Heat Loads

High heat loads give rise to:

- Temperature-dependent properties and processes
- Highly nonlinear multiphase flow processes

The Newton Trust Region Dogleg Cauchy method.

The algorithm corrects the Newton step-and-direction by reducing the trust region and adds Cauchy step-and-direction if the solution update can be improved further in the same iteration. NTRDC reduces computation time by a factor of approximately 35.

Mariner et al. 2020

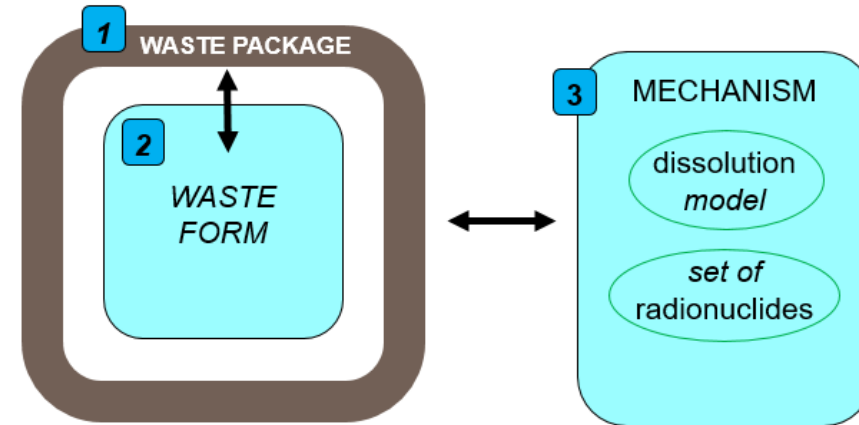# Capability Development in PFLOTRAN for Various Waste Forms

Variety of waste forms, e.g.,
- Commercial SNF (UO$_2$)
- Vitrified high-level waste
- Metallic SNF

Variety of dissolution models, e.g.,
- Fractional rate law
- Mixed potential model
- Transition state theory
- Instantaneous degradation

Mariner et al. 2016; 2017

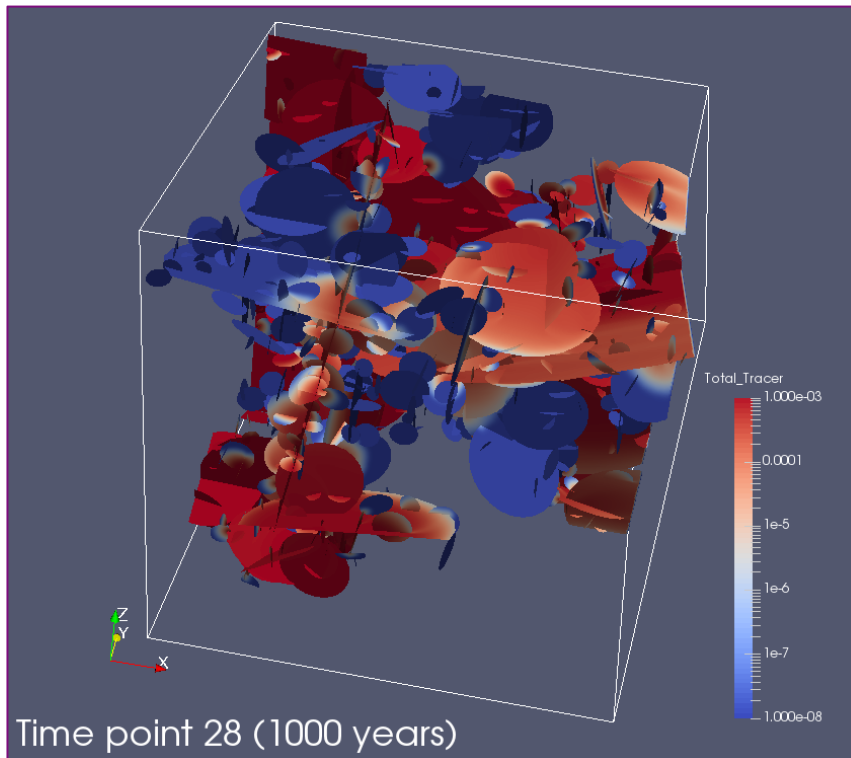# Capability Development in PFLOTRAN for Various Host Rocks

Variety of host rocks gives rise to variety of processes affecting flow and transport, e.g.,
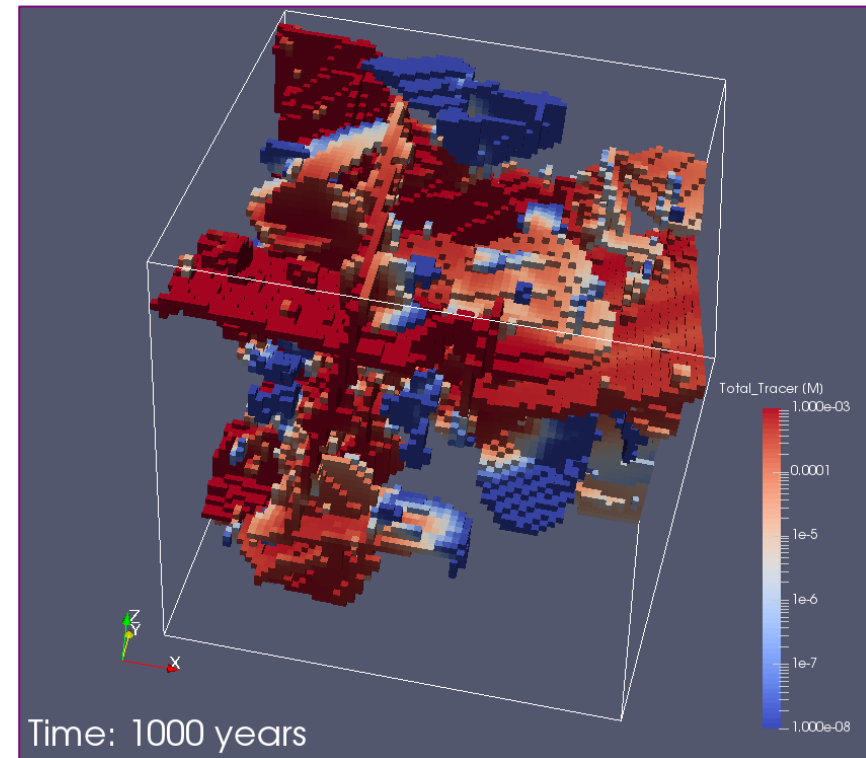
- Salt reconsolidation and creep
- Buffer swelling, erosion, and/or alteration
- Fracture/matrix interactions
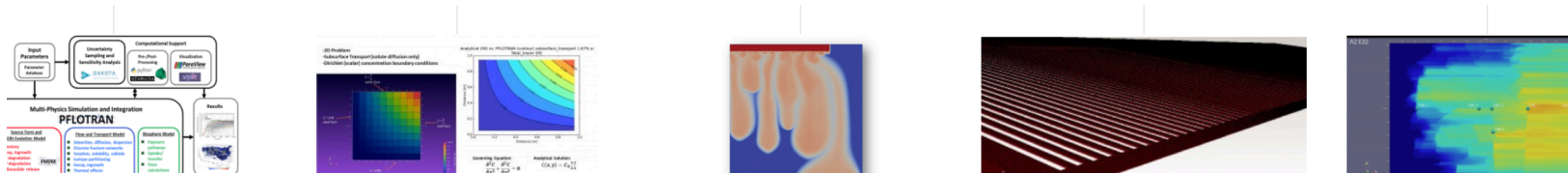
dfnWorks + PFLOTRAN

Discrete Fracture Network

Equivalent Continuous Porous Medium

Stein et al. 2017

GDSA Framework

A Geologic Repository Modeling and Assessment Capability

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Learn more at https://pa.sandia.gov

Freeze, G. A., E. J. Bonano, E. Kalinina, J. Meacham, L. Price, P. N. Swift, A. A. Alsaed, D. A. Beckman, and P. G. Meacham 2019. *Comparative Cost Analysis of Spent Nuclear Fuel Management Alternatives.* SAND2019-6999 Revision 1. Sandia National Laboratories, Albuquerque, NM.

Mariner, P. E., E. R. Stein, J. M. Frederick, S. D. Sevougian, G. E. Hammond, and D. G. Fascitelli 2016. *Advances in Geologic Disposal System Modeling and Application to Crystalline Rock.* FCRD-UFD-2016-000440 / SAND2016-9610R. Sandia National Laboratories, Albuquerque, NM.

Mariner, P. E., E. R. Stein, J. M. Frederick, S. D. Sevougian, and G. E. Hammond 2017. *Advances in Geologic Disposal System Modeling and Shale Reference Cases.* SFWD-SFWST-2017-000044 / SAND2017-10304R. Sandia National Laboratories, Albuquerque, NM.

Mariner, P. E., M. Nole, E. Basurto, T. M. Berg, K. W. Chang, B. J. Debusschere, A. C. Eckert, M. S. Ebeida, M. Gross, G. Hammond, J. Harvey, S. Jordan, K. L. Kuhlman, T. LaForce, R. C. Leone, W. C. McLendon, M. M. Mills, H. Park, F. V. Perry, A. Salazar, D. T. Seidl, S. D. Sevougian, E. R. Stein, and L. P. Swiler 2020. *Advances in GDSA Framework Development and Process Model Integration.* SAND2020-10787R. Sandia National Laboratories, Albuquerque, NM.

Stein, E. R., J. M. Frederick, G. E. Hammond, K. L. Kuhlman, P. E. Mariner, and S. D. Sevougian 2017, April 9-13, 2017. *Modeling Coupled Reactive Flow Processes in Fractured Crystalline Rock.* Paper presented at the International High-Level Radioactive Waste Management Conference, Charlotte, NC.