Los Alamos
NATIONAL LABORATORY

EST. 1943

The hydrogeology of thermally active energy waste in bedded salt

Philip H. Stauffer

Tuesday, September 24th

175-4

Los Alamos NATIONAL LABORATORY EST. 1943

LA-UR-19-29296

LA-UR-XX-XXXXX

Co-authors

Hakim Boukalfa, Eric Guiltinan, Michelle Bourret, Terry Miller, Brian Dozier, Shawn Otto, Douglas Weaver

- Los Alamos National Laboratory

Kris Kuhlman,

- Sandia National Laboratory

Jonny Rutqvist

- Lawrence Berkeley National Laboratory

MOTIVATION

Los Alamos NATIONAL LABORATORY EST. 1943

The United States needs to find a long-term solution for nuclear waste

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

DOE-Nuclear Energy(DOE-NE) is researching "Generic Repository concepts through the Spent Fuel and Waste Disposition Program

Clean. Reliable. Nuclear.

Salt, argillite, and crystalline are the three primary geologic targets

MOTIVATION

The United States needs to find a long-term solution for nuclear waste

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

DOE-Nuclear Energy(DOE-NE) is researching "Generic Repository concepts through the Spent Fuel and Waste Disposition Program

Clean. Reliable. Nuclear.

Salt, argillite, and crystalline are the three primary geologic targets

MOTIVATION

Los Alamos
NATIONAL LABORATORY
EST. 1943

The United States needs to find a long-term solution for nuclear waste

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

DOE-Nuclear Energy(DOE-NE)
is researching
"Generic Repository concepts
through the
Spent Fuel and Waste Disposition Program

Clean. Reliable. Nuclear.

Salt, argillite, and crystalline are the three primary geologic targets

Why Salt ?

Salt long-term benefits as disposal medium

- Low connected porosity (0.1 vol-%) and permeability ($\leq 10^{-22}\ m^2$)
- High thermal conductivity ($\sim 5\ W/(\mathrm{m} \cdot \mathrm{K})$)
- No flowing groundwater (≤ 5 wt-% water)
- Plastic salt flows back around waste

Process-level Modeling Goals

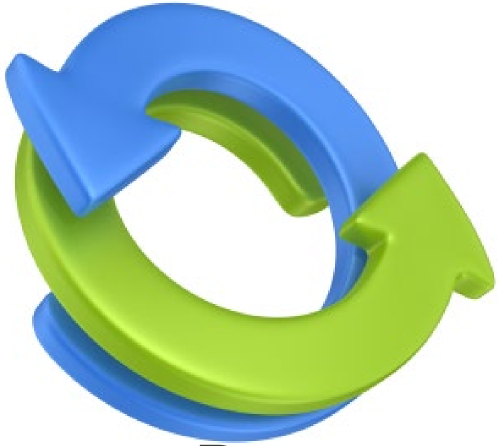
Demonstrate understanding of repository processes

Gain confidence in long-term predictions

Uncertainty reduction

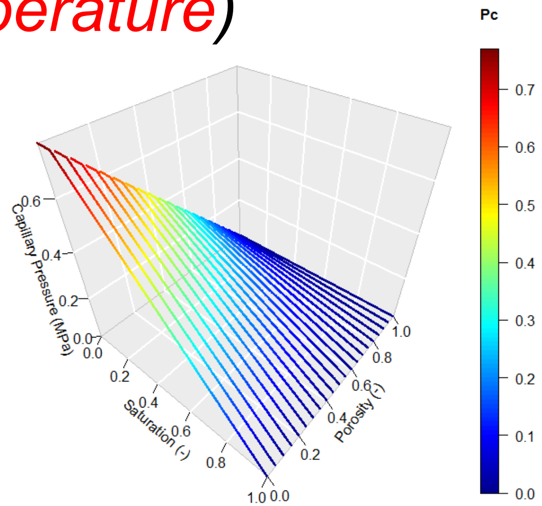
Integrate process-level physics into performance assessment

Understand the role of pore water, fluid inclusions, and mineral dehydration

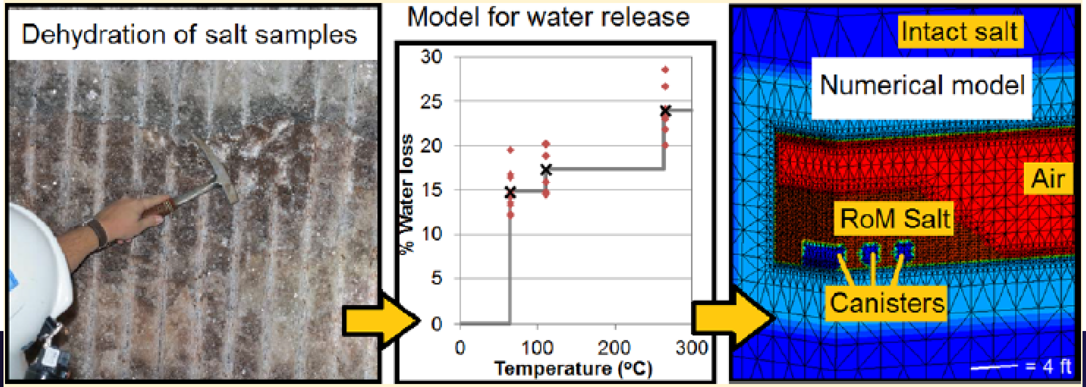


Salt THMC Couplings

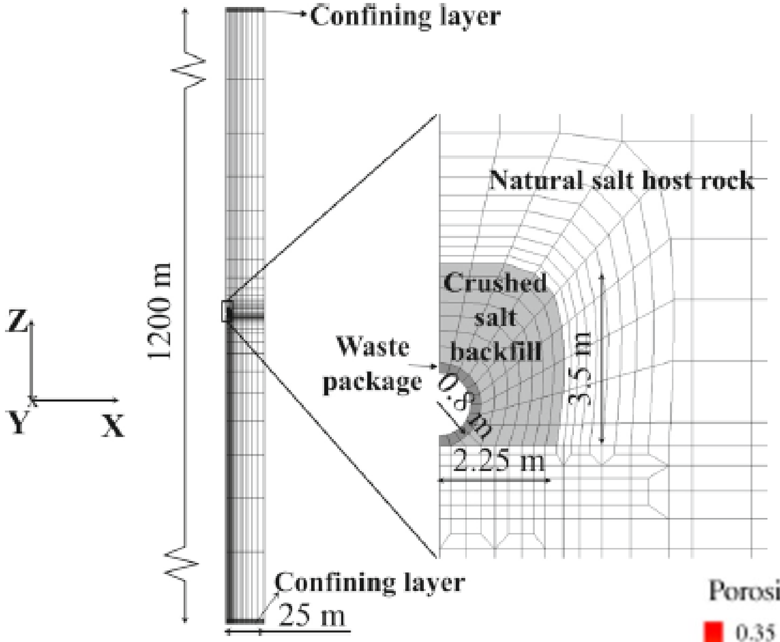
Deformation (strain)	***F***(*stress, time, saturation, temperature*)
Vapor pressure lowering	***F***(*capillary pressure, salinity*)
Porosity	***F***(*dissolution, precipitation, stress, strain*)
Thermal conductivity	***F***(*porosity, saturation, temperature*)
Permeability	***F***(*dissolution, precipitation, porosity, saturation*)
Capillary pressure	***F***(*porosity, saturation, temperature*)
Water vapor diffusion	***F***(*porosity, saturation, temperature*)
Clay dehydration	***F***(*temperature*)
Salinity	***F***(*temperature*)



Environmental Science & Technology



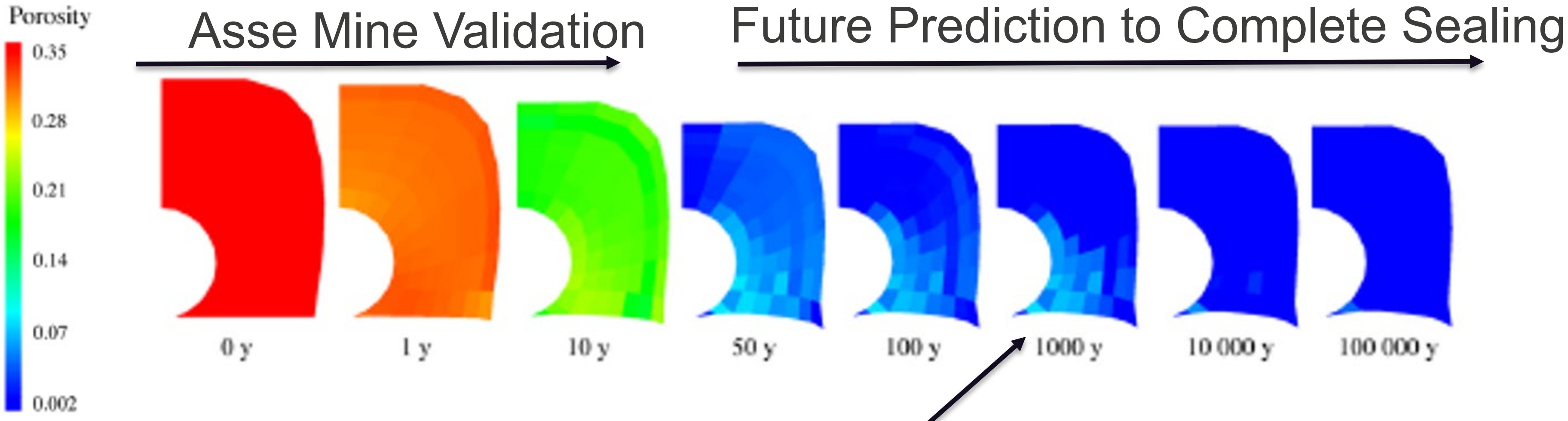
THMC: Long-term Compaction and Sealing Example



- Thermal-mechanical-induced compaction most important **at this scale** (LBNL Blanco-Martin et al., 2018)

TOUGH-FLAC SIMULATIONS

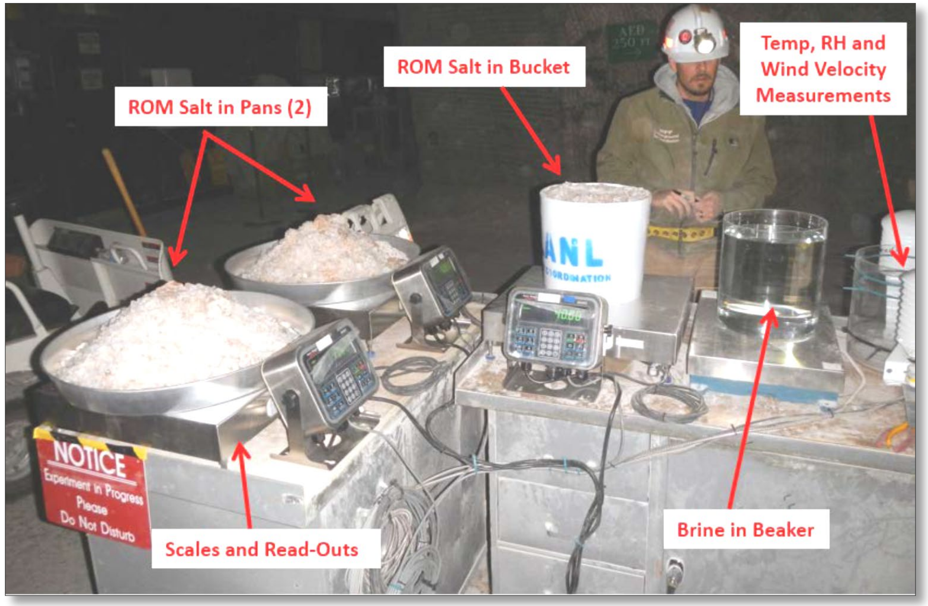
BERKELEY LAB



Simulation indicates areas of 10% porosity at 1000 years (permeability ≈ 10^{-15} m^2)

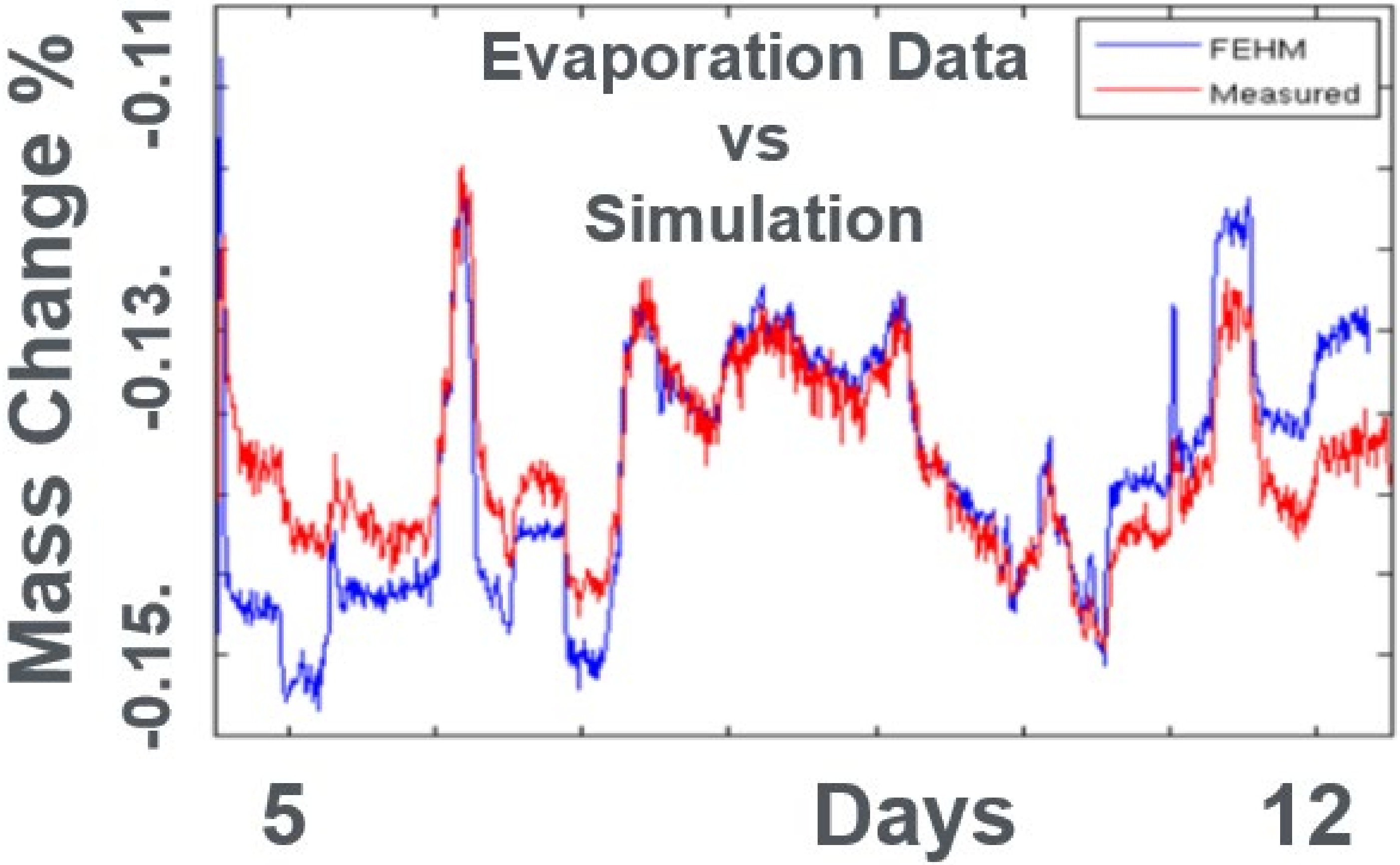
THC Coupling: Evaporation example

- WIPP evaporation experiment



- Simulated using FEHM

  fehm.lanl.gov



Simulation driven with changing drift air humidity

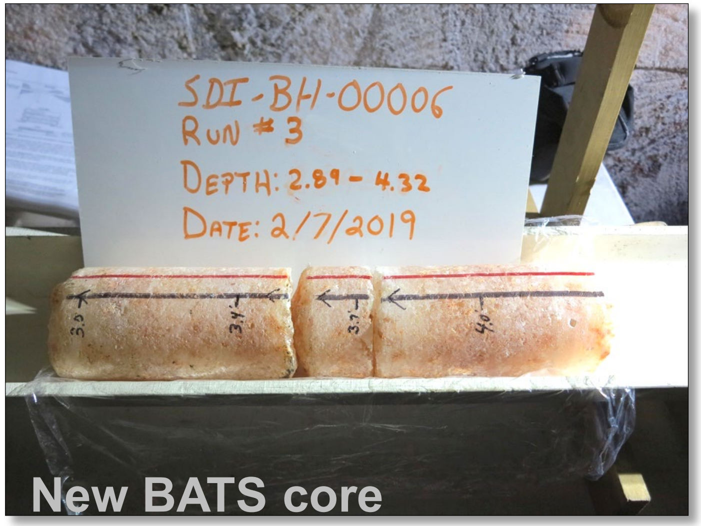
LA-UR-XX-XXXXX

What Are We Doing?

Los Alamos NATIONAL LABORATORY EST. 1943

Brine Availability Test in Salt at WIPP (BATS)

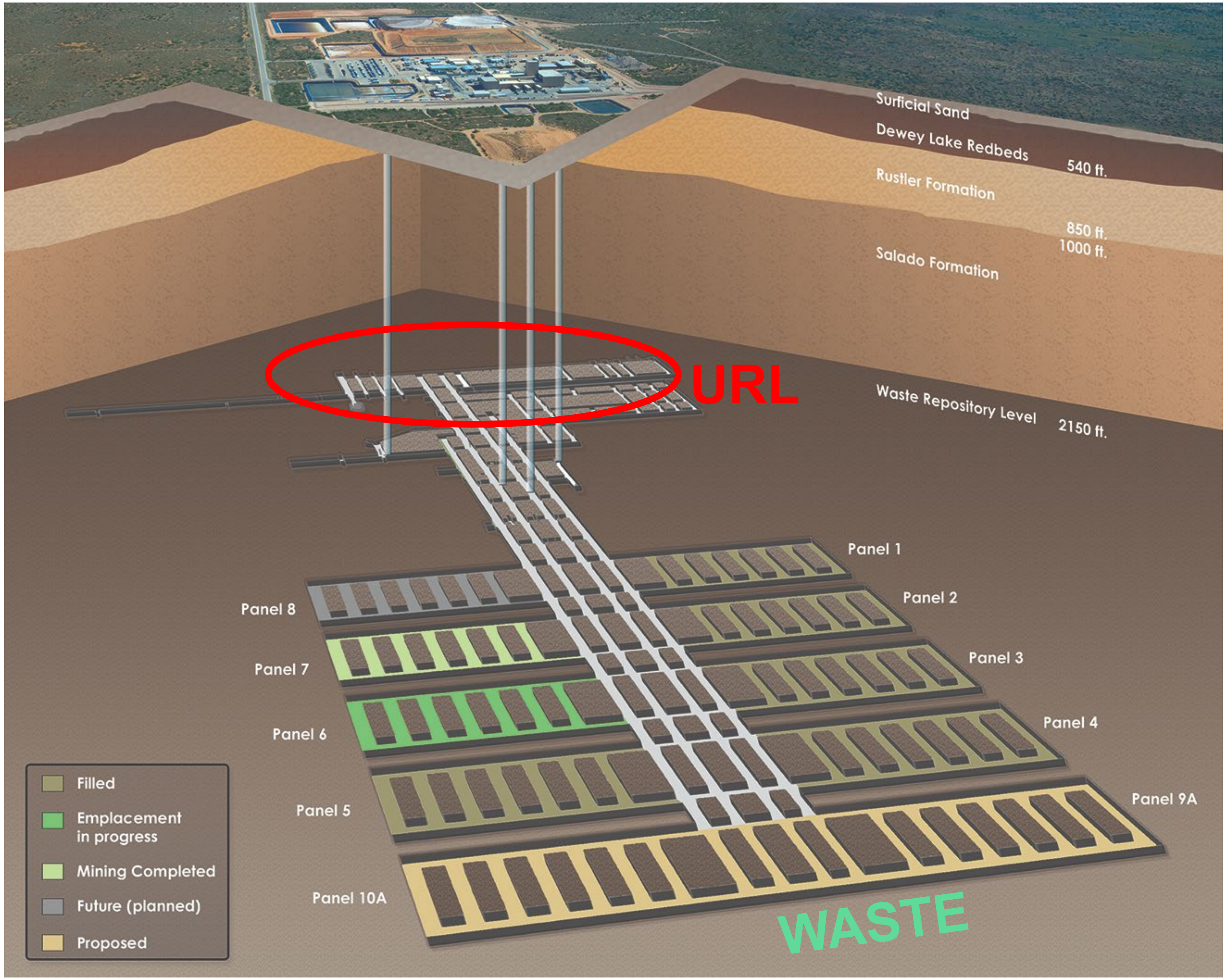
Monitoring brine distribution, inflow, and chemistry from heated salt using geophysical methods and direct liquid & gas sampling.

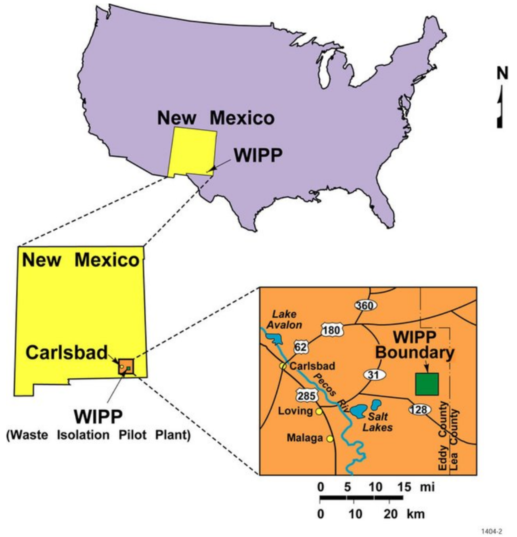


New BATS core

New BATS boreholes

WIPP details





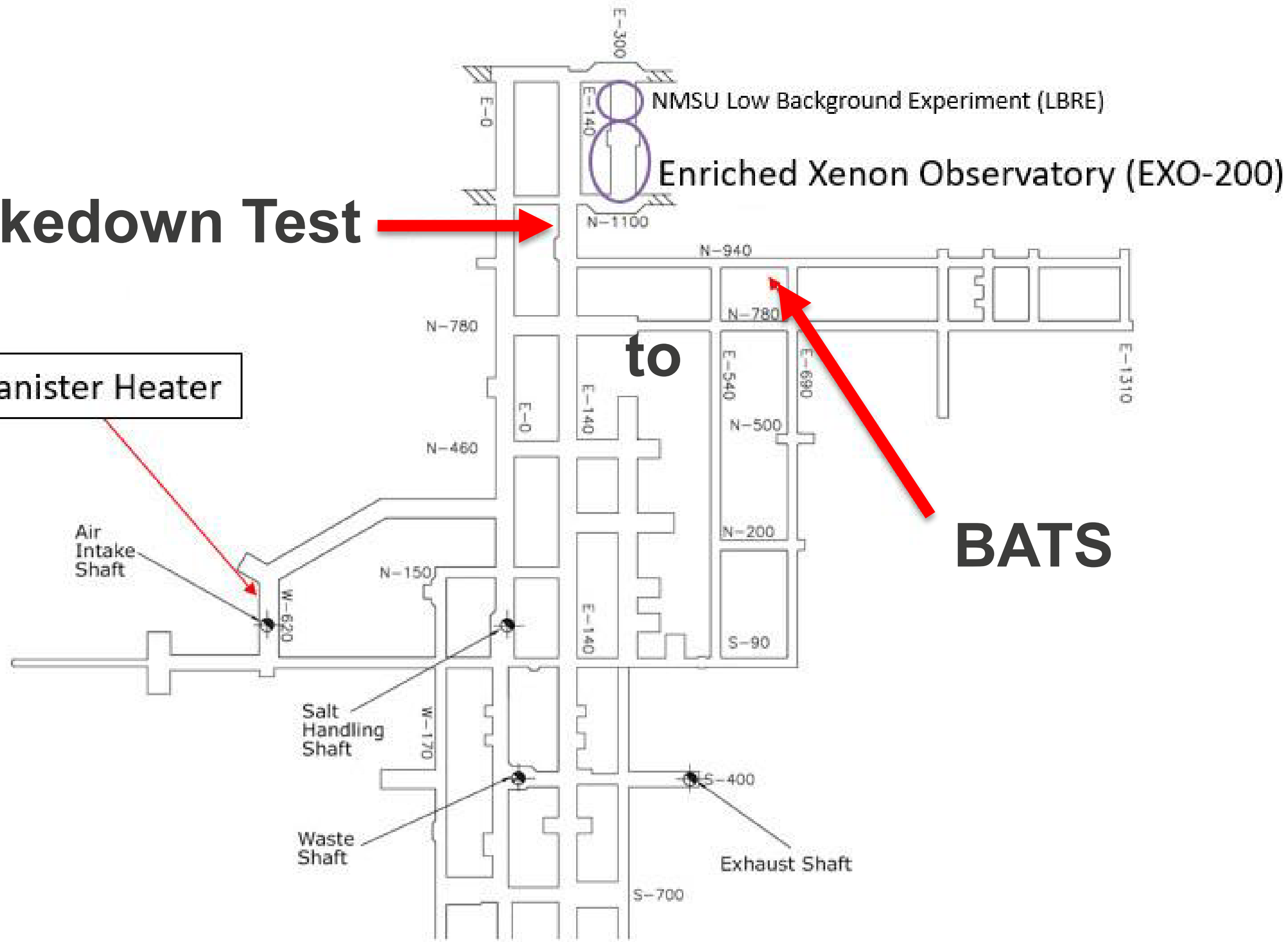
2150 ft bgs

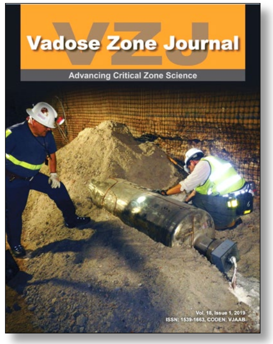
1 mile long

0.5 miles wide

12 miles of drifts

Underground Research Laboratory at WIPP





BATS Shakedown Test : Motivation

Los Alamos NATIONAL LABORATORY EST. 1943

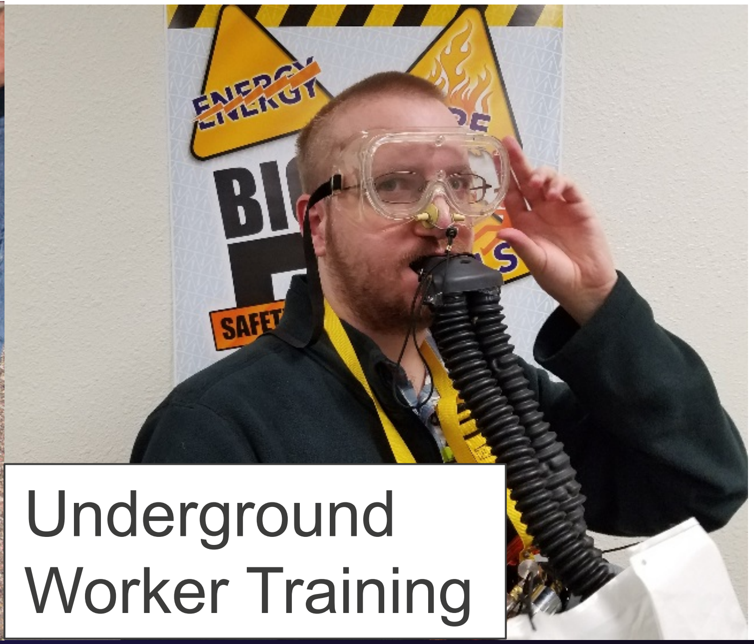
June 2018 – May 2019

Thermal testing in an existing borehole

First thermal borehole test in salt in the USA since the early 1990s

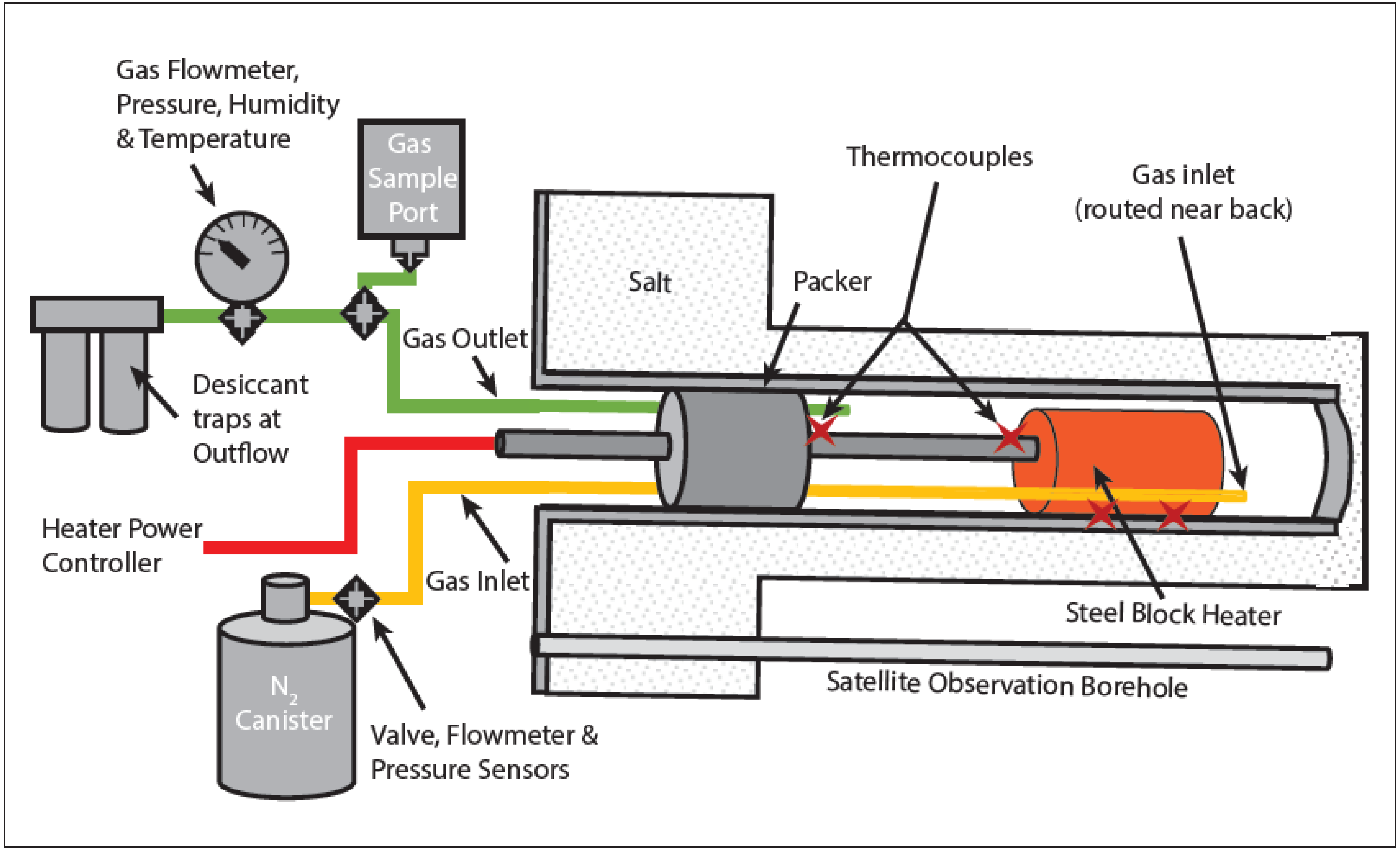
Existing boreholes


Heater design



Underground Worker Training

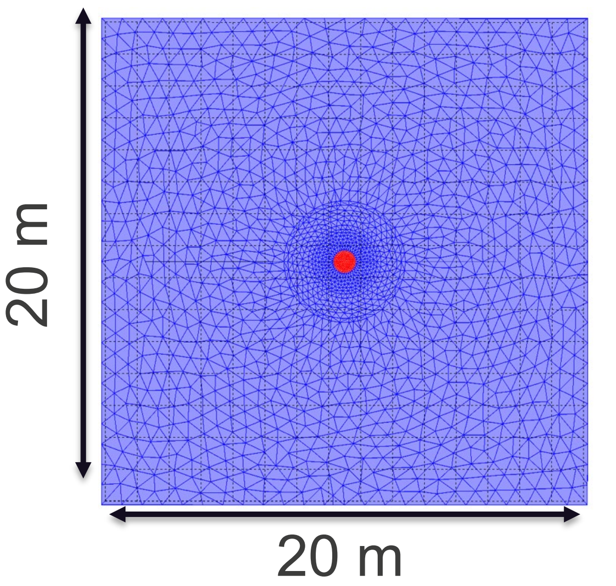
BATS Shakedown Test : Design



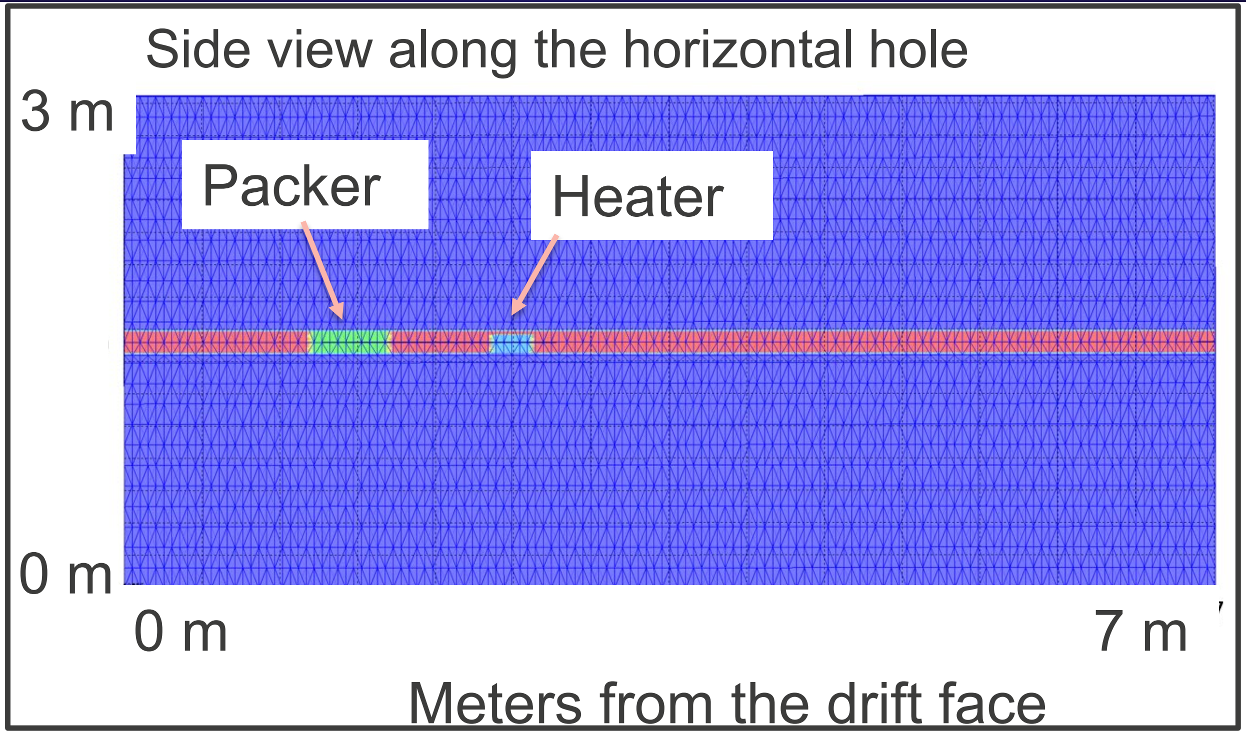
BATS Shakedown: Simulations Assist Design

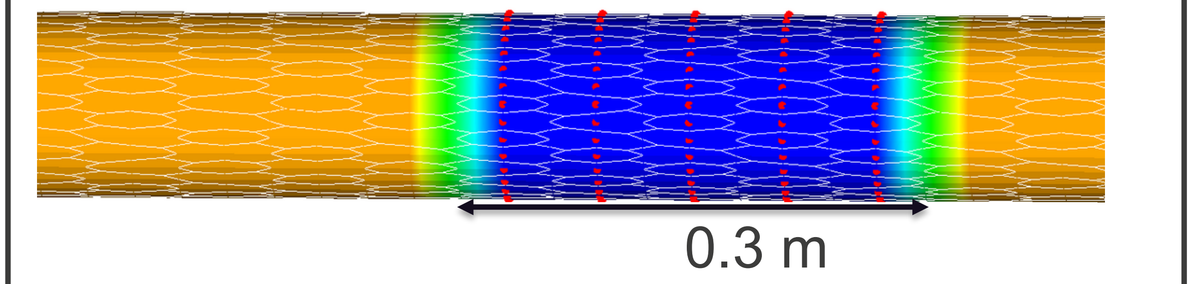
Los Alamos NATIONAL LABORATORY EST. 1943

3D Borehole heater simulation domain



Drift view looking into horizontal hole



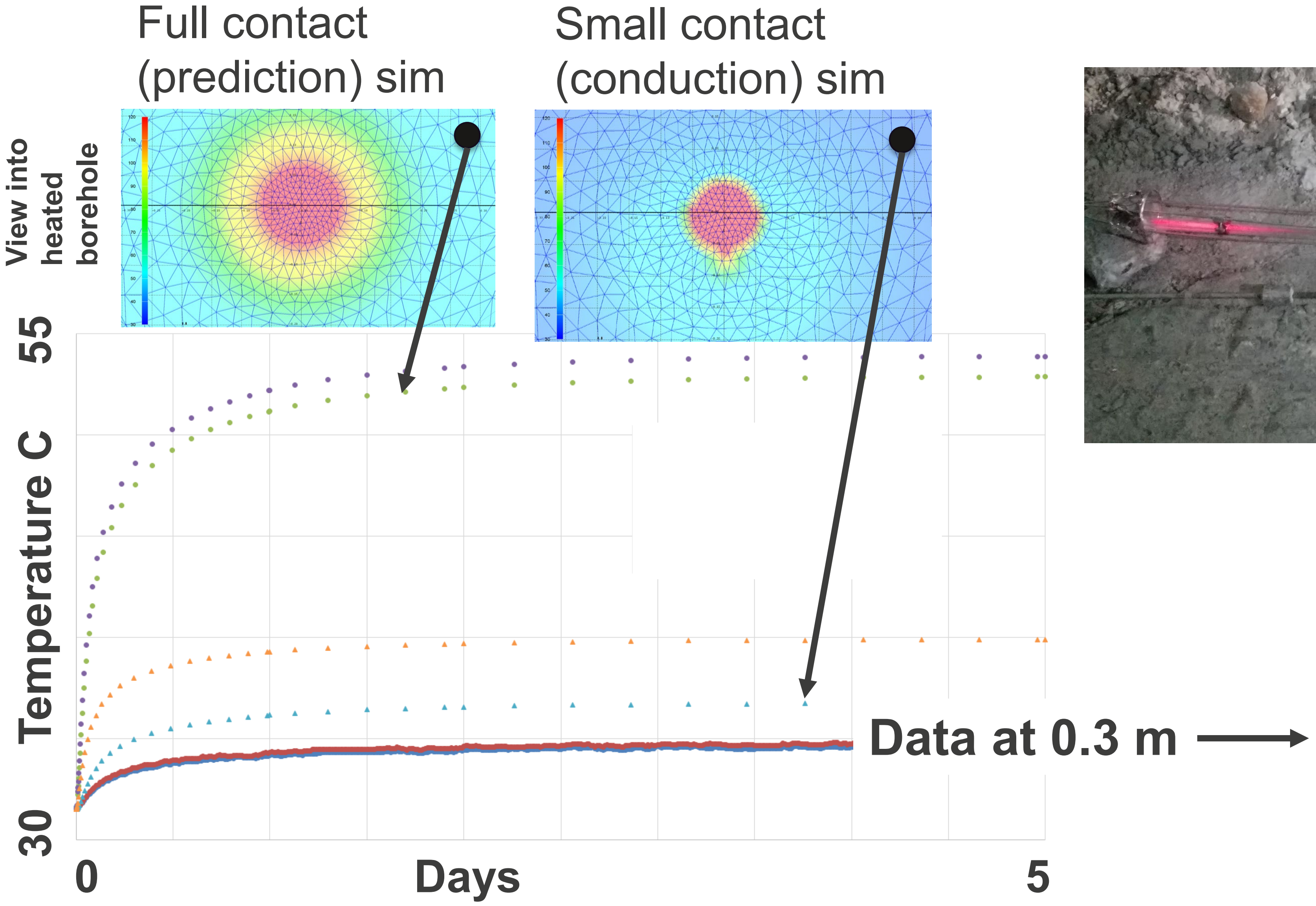


Zoom into the heater mesh

THC Model of Shakedown Test

1 million nodes

BATS Shakedown: Simulations Assist Design

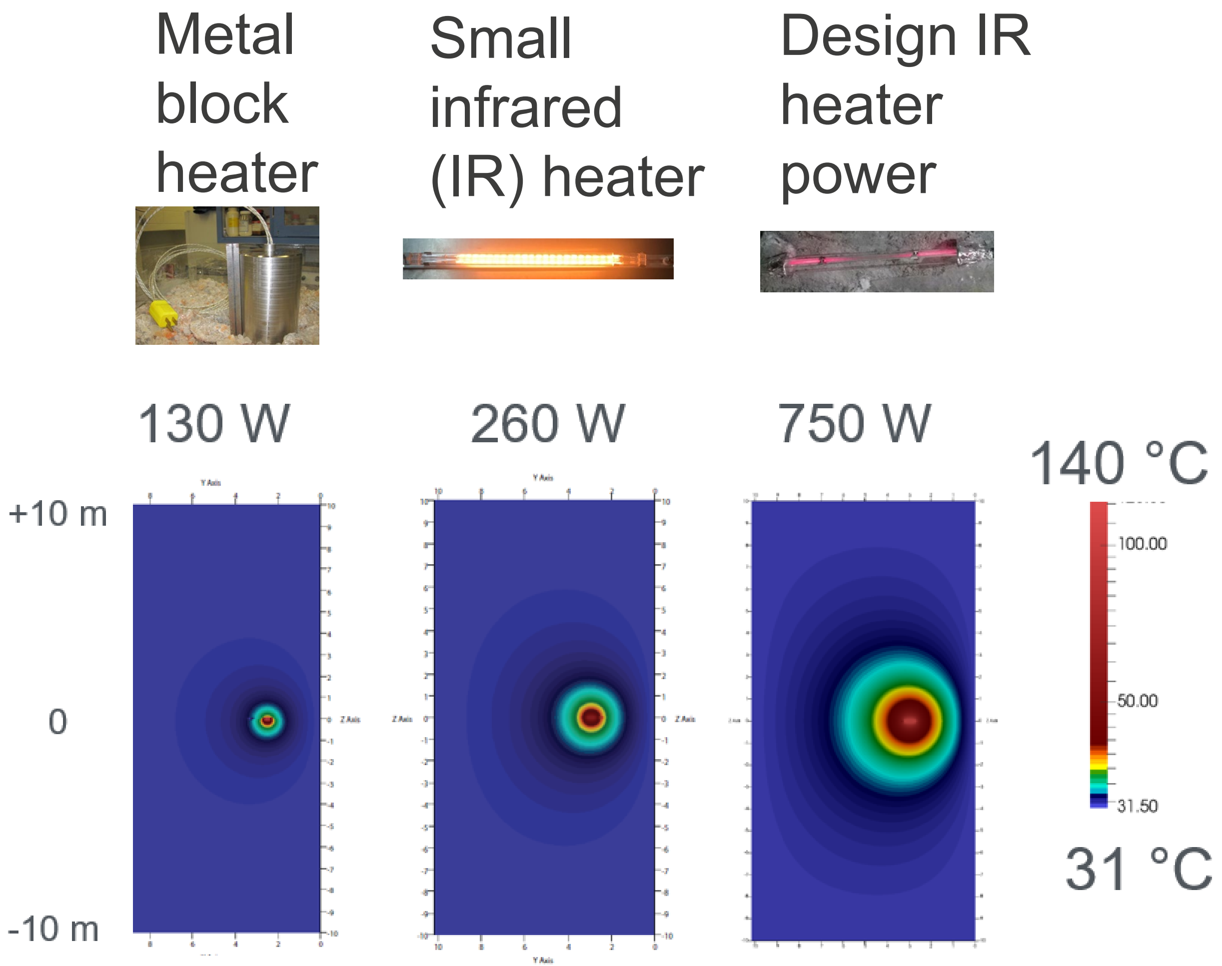


Simulations compared to shakedown data show that **infrared heating** would better transfer heat to the rock salt.

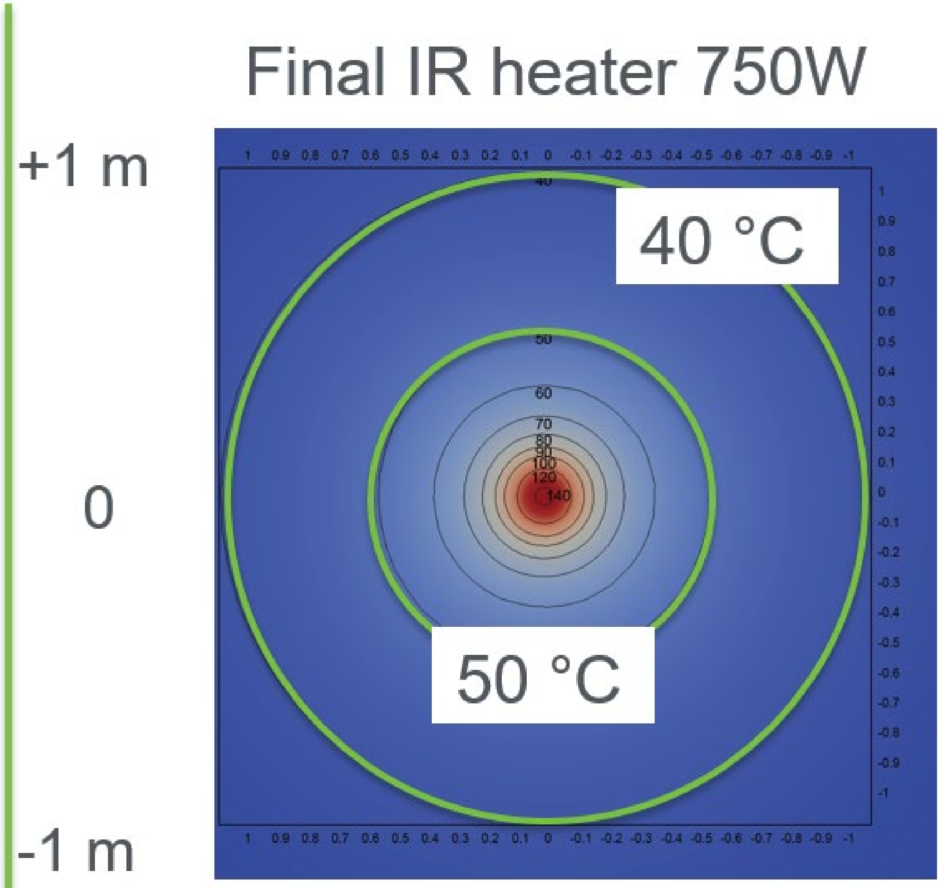
Poorly performing block heater

BATS Shakedown: Modeling Improved Heater Design

Los Alamos NATIONAL LABORATORY EST. 1943



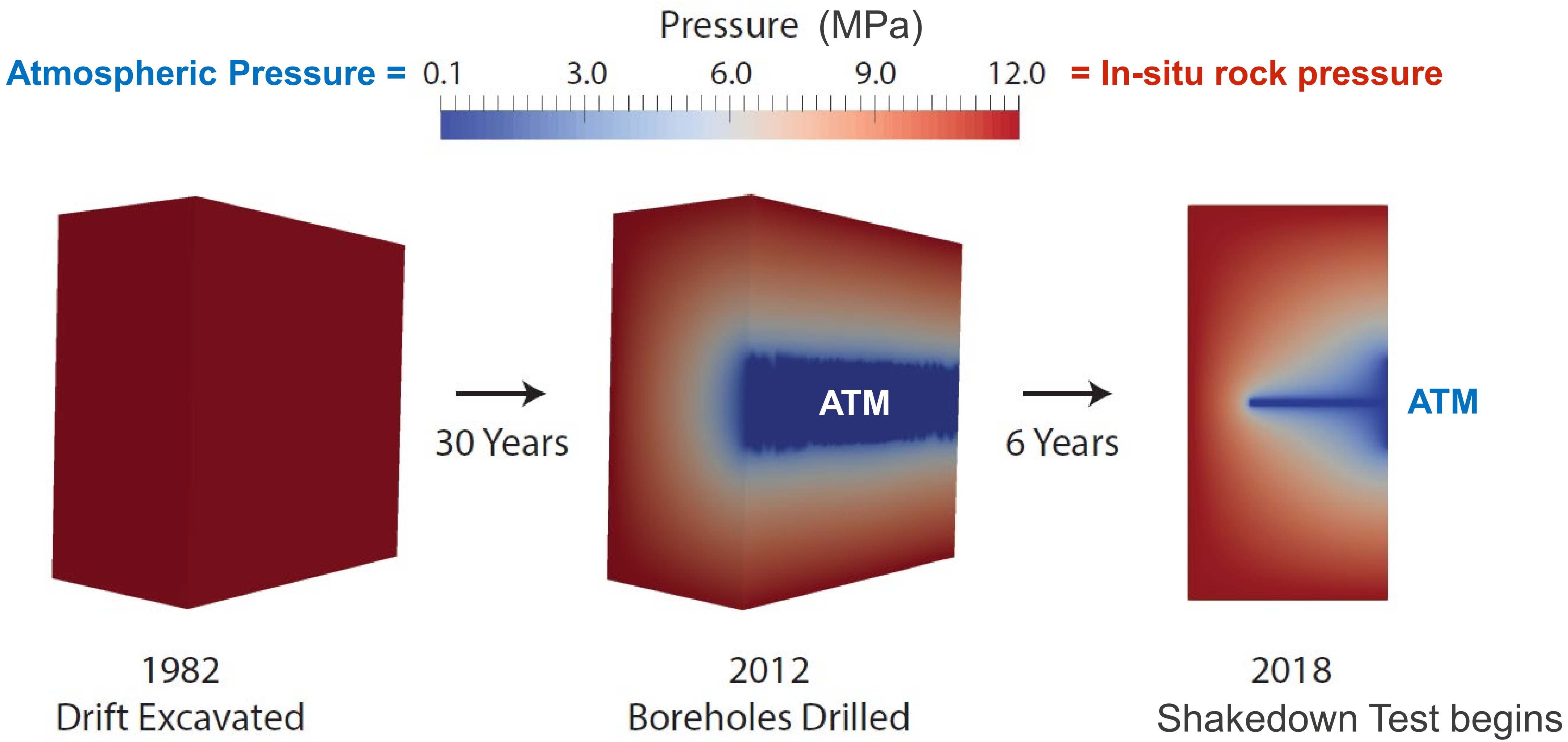
Temperature



Temperature contours °C (@ heater midplane)

BATS Shakedown Test : Pressure decay

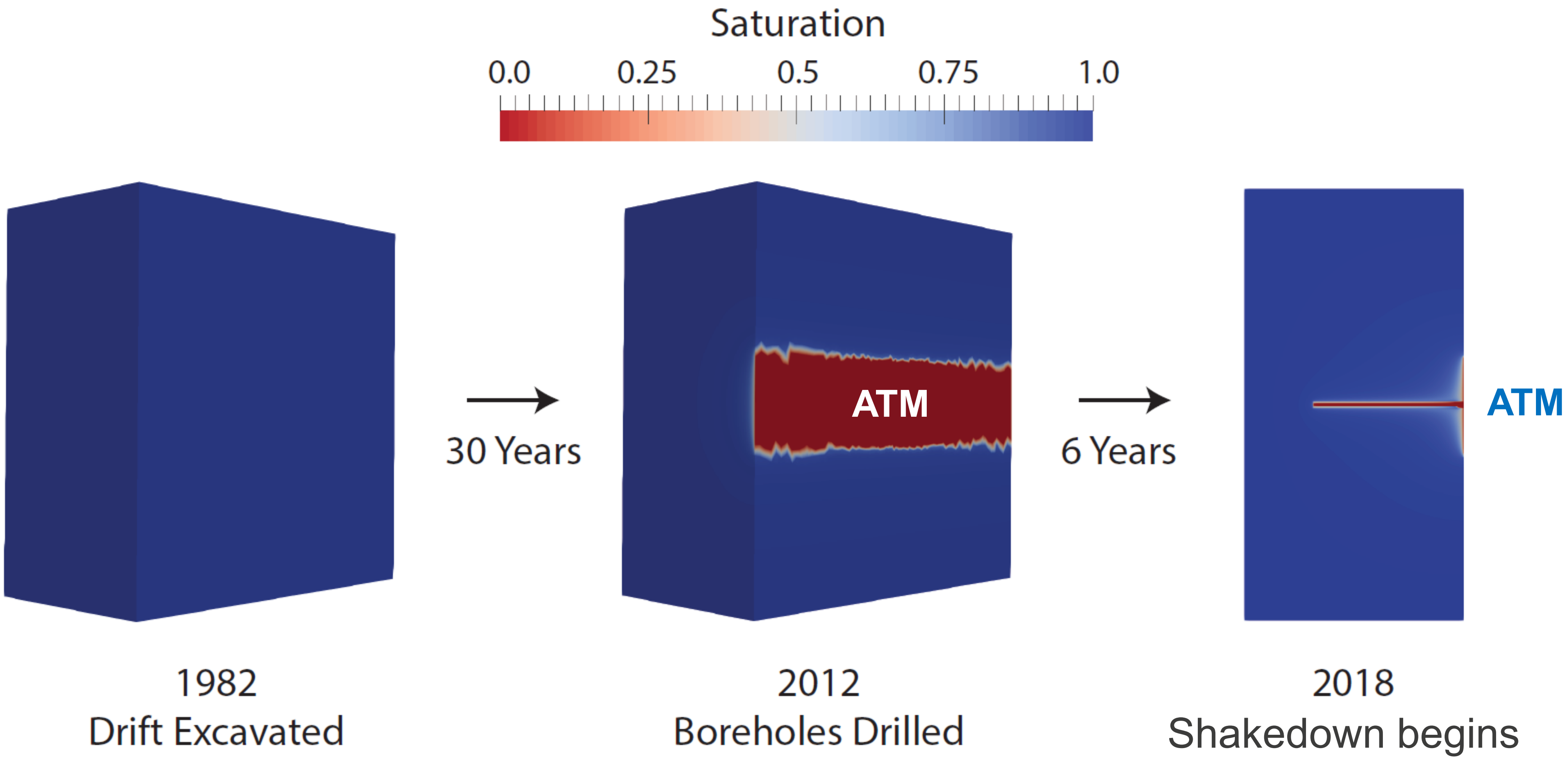
Simulations require long-term pressure decay due to drifts + boreholes



BATS Shakedown Test : Saturation decay

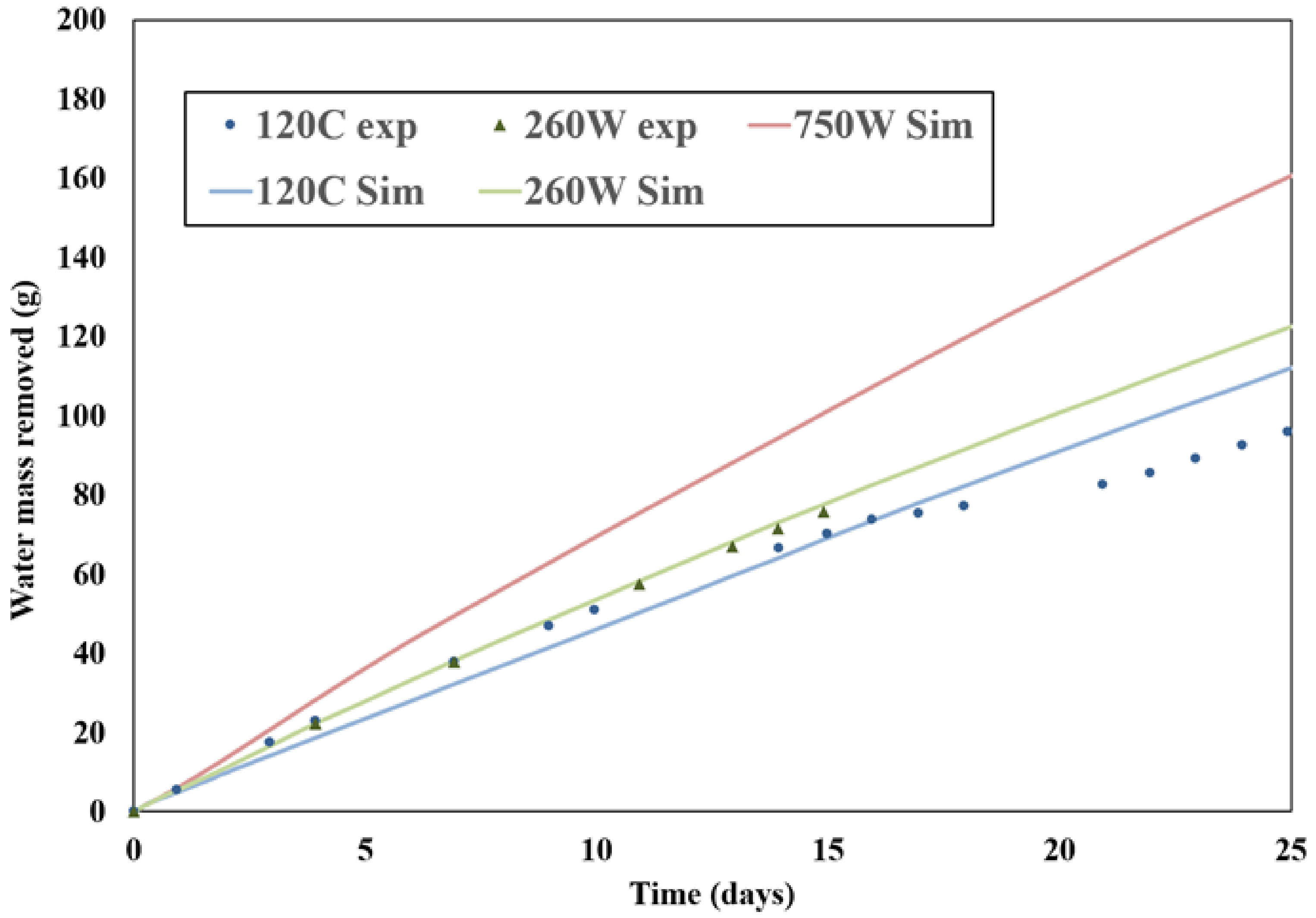
Los Alamos NATIONAL LABORATORY EST. 1943

Simulations require long-term saturation decay due to drifts + boreholes



BATS Shakedown Test : Water production

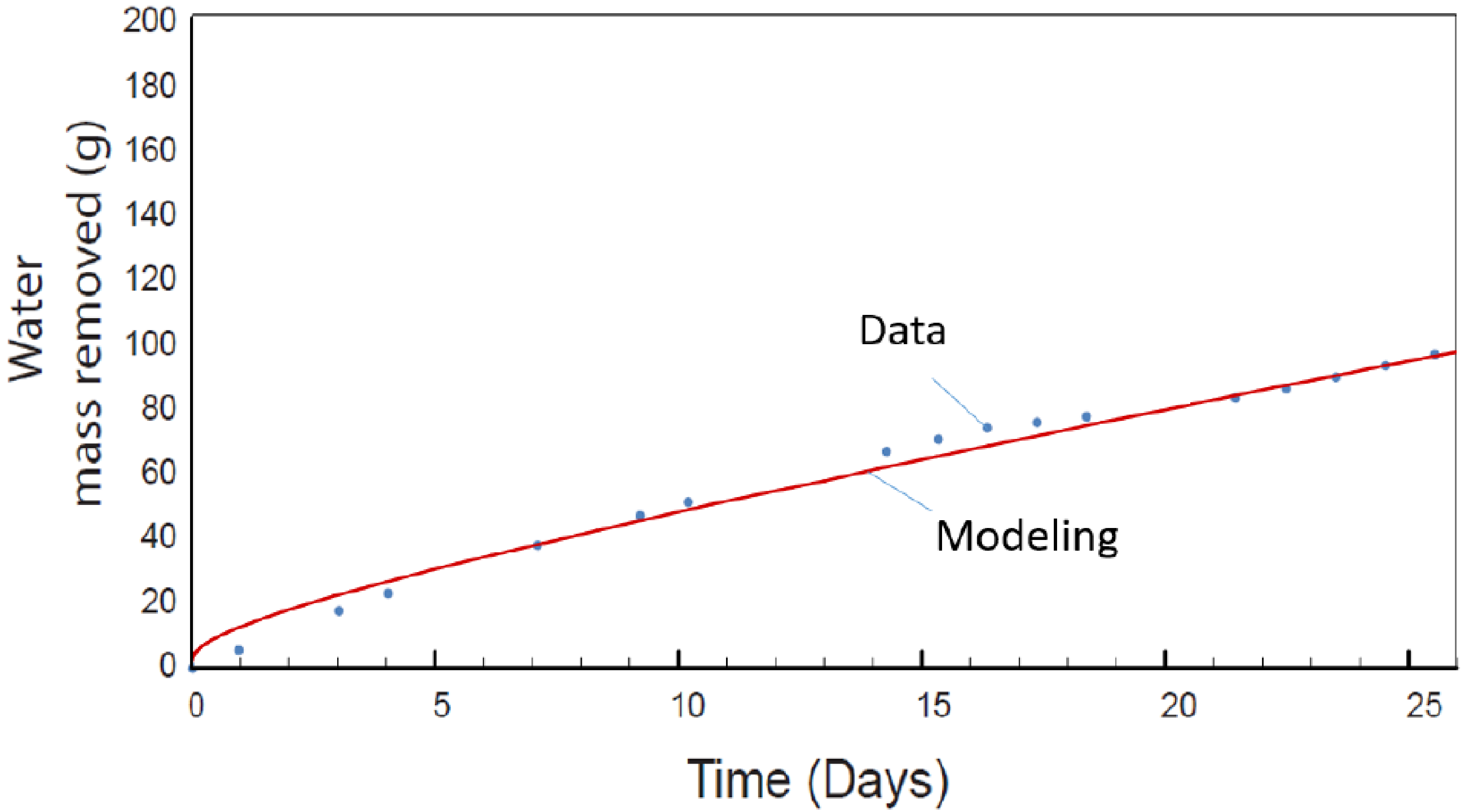
Water flowing into the borehole is extracted by nitrogen gas



FEHM THC simulation

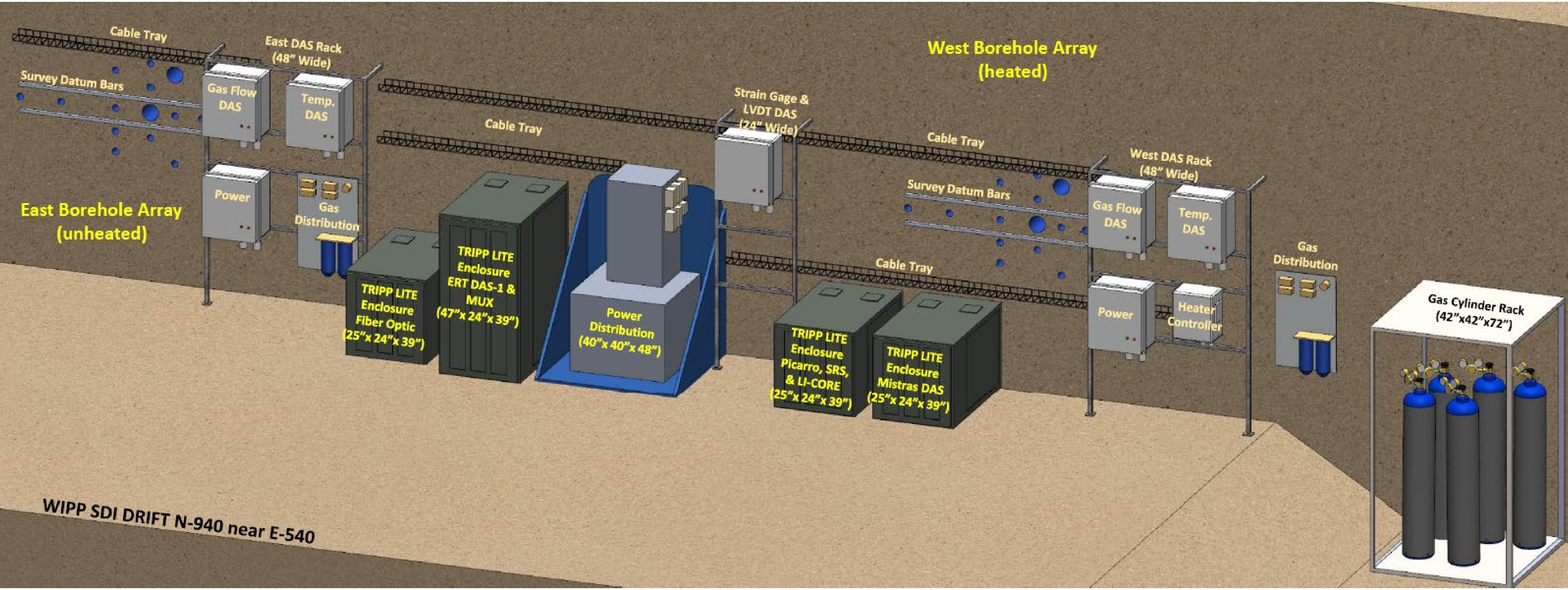
BATS Shakedown Test : Water production

1-D calculation with a boundary at the borehole wall

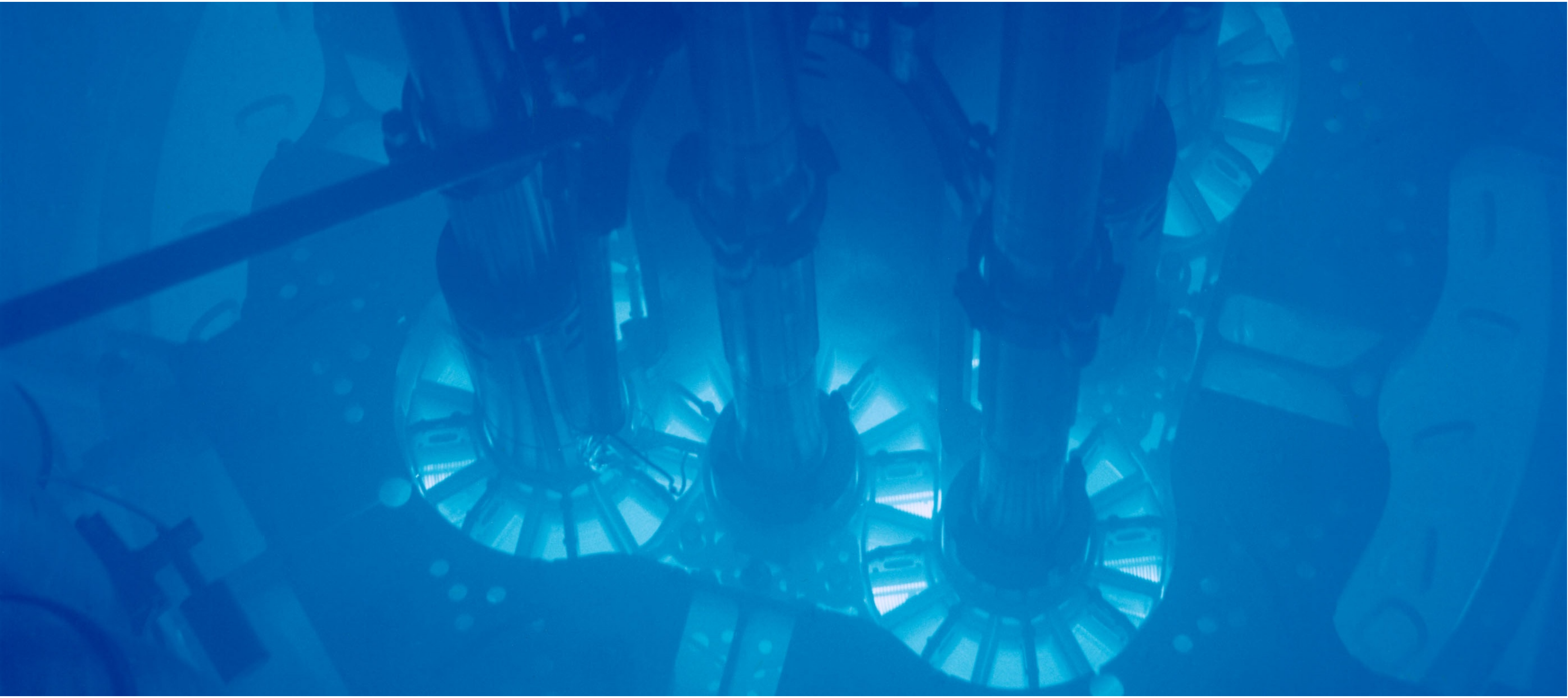


LBNL THMC simulation

Path Forward : BATS test starting Fall 2019



Questions ?



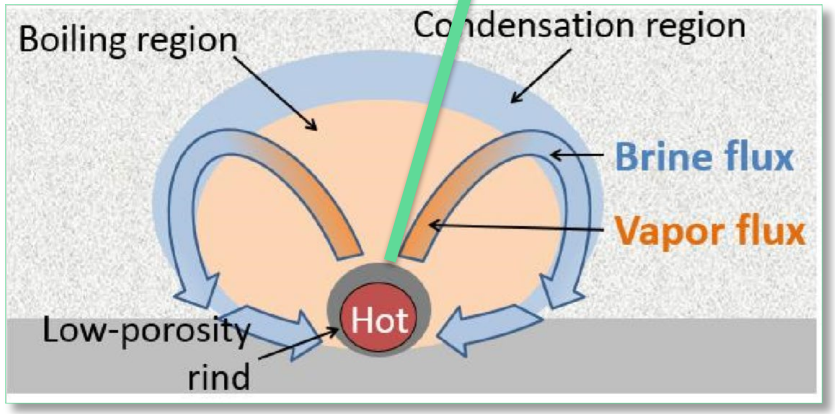
EXTRA SLIDES

Importance of Thermal-Hydro-Mechanical-Chemical (THMC) Processes in Salt

Fluid inclusions

- Performance Assessment
- Safety Case
- Roadmap
- International

Heat Pipe



Salt Complexities

Near-field short-term complexities

- Hypersaline brine is corrosive
- Salt is very soluble in fresh water
- Brine chemistry requires Pitzer
- Salt creep requires drift maintenance

HCl acid destroyed our oven