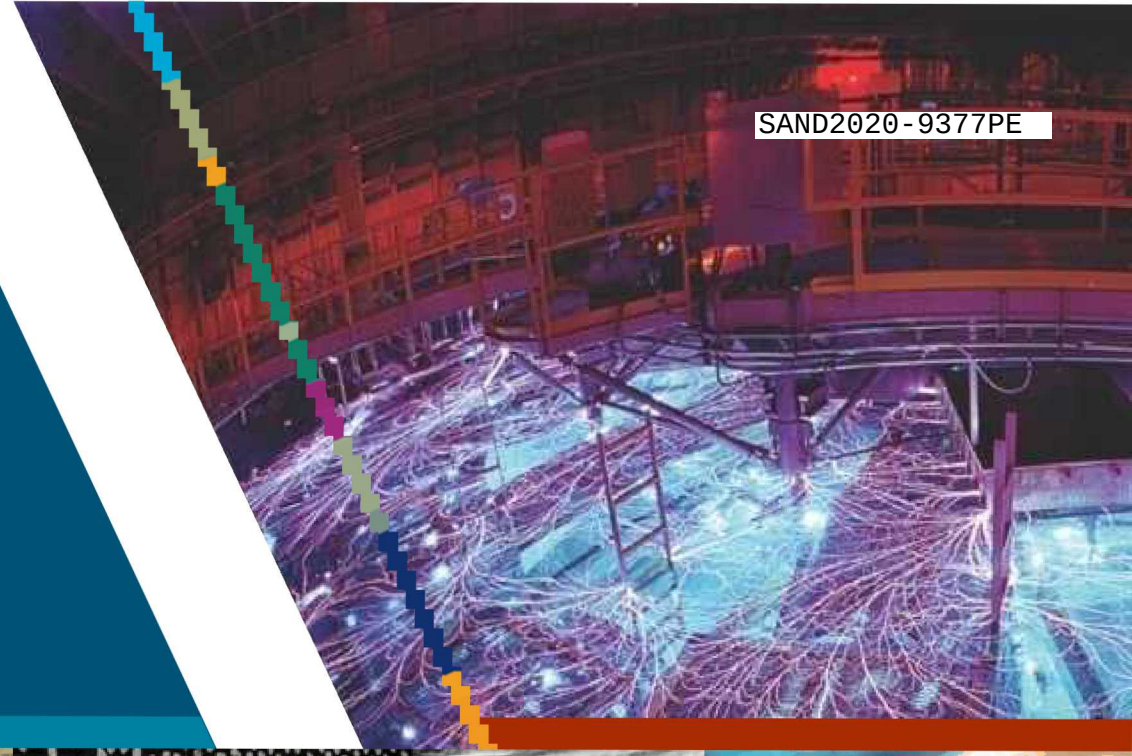


Exceptional service in the national interest

GEO 491 - Career Paths in Geoscience

September 11, 2020 (via Zoom)

Kristopher L. Kuhlman, PhD

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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.

About Me

1994-1998: BS Geological Engineering, Colorado School of Mines

1998-2002: Groundwater modeling consultant (Los Angeles, CA)

2002-2008: PhD Hydrology, University of Arizona

2008-now: Sandia National Laboratories

Careers in Geoscience: Outline

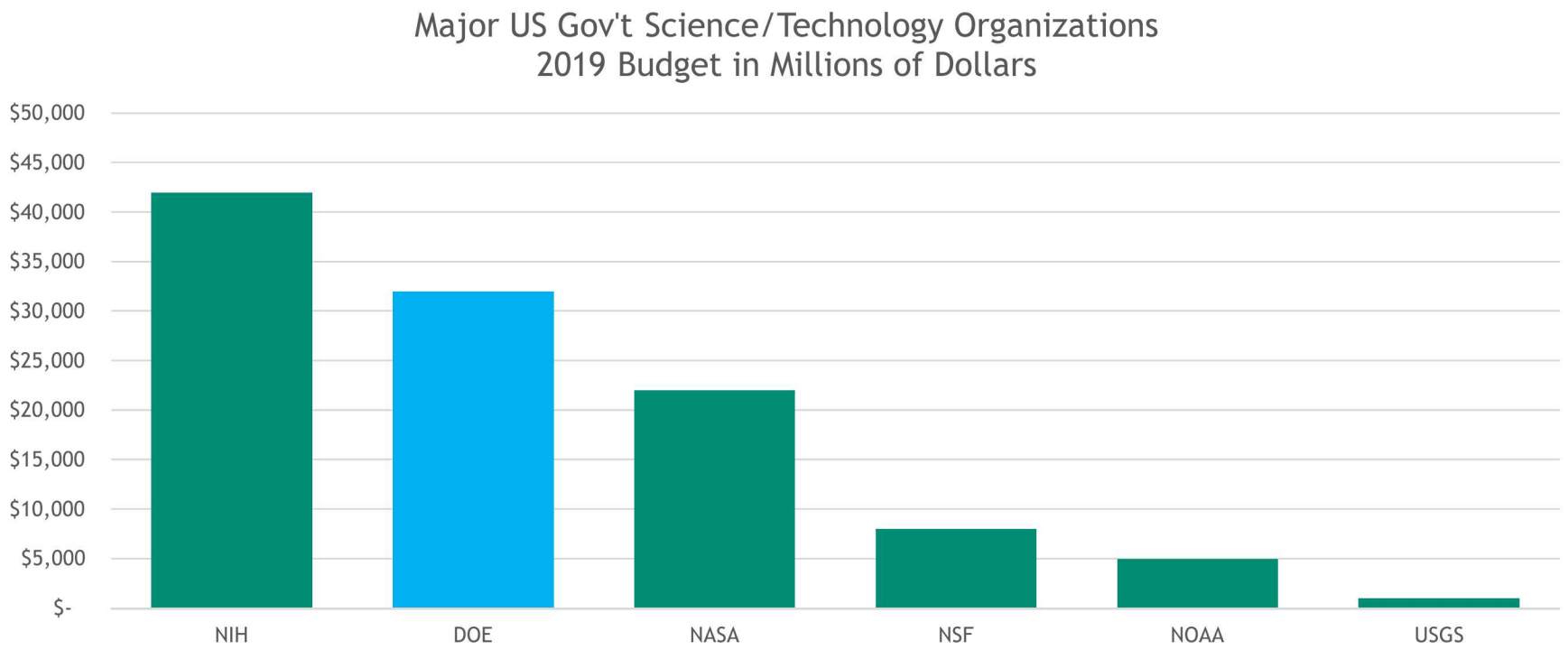
1. What are the US National Labs?
2. What is Sandia?
3. What do I do at Sandia?
4. Thoughts about Career Paths
5. Discussion

What are DOE National Labs?

Department of Energy: National Labs

Department of Energy (DOE) is major funder of technology & research

About ½ of DOE budget funds National Lab system



NIH: National Institutes of Health

NASA: National Aeronautics & Space Administration

NSF: National Science Foundation

NOAA: National Oceanic and Atmospheric Administration

USGS: US Geological Survey

Source: Congressional Budget Office www.cbo.gov

DOE National Lab System: 17 labs

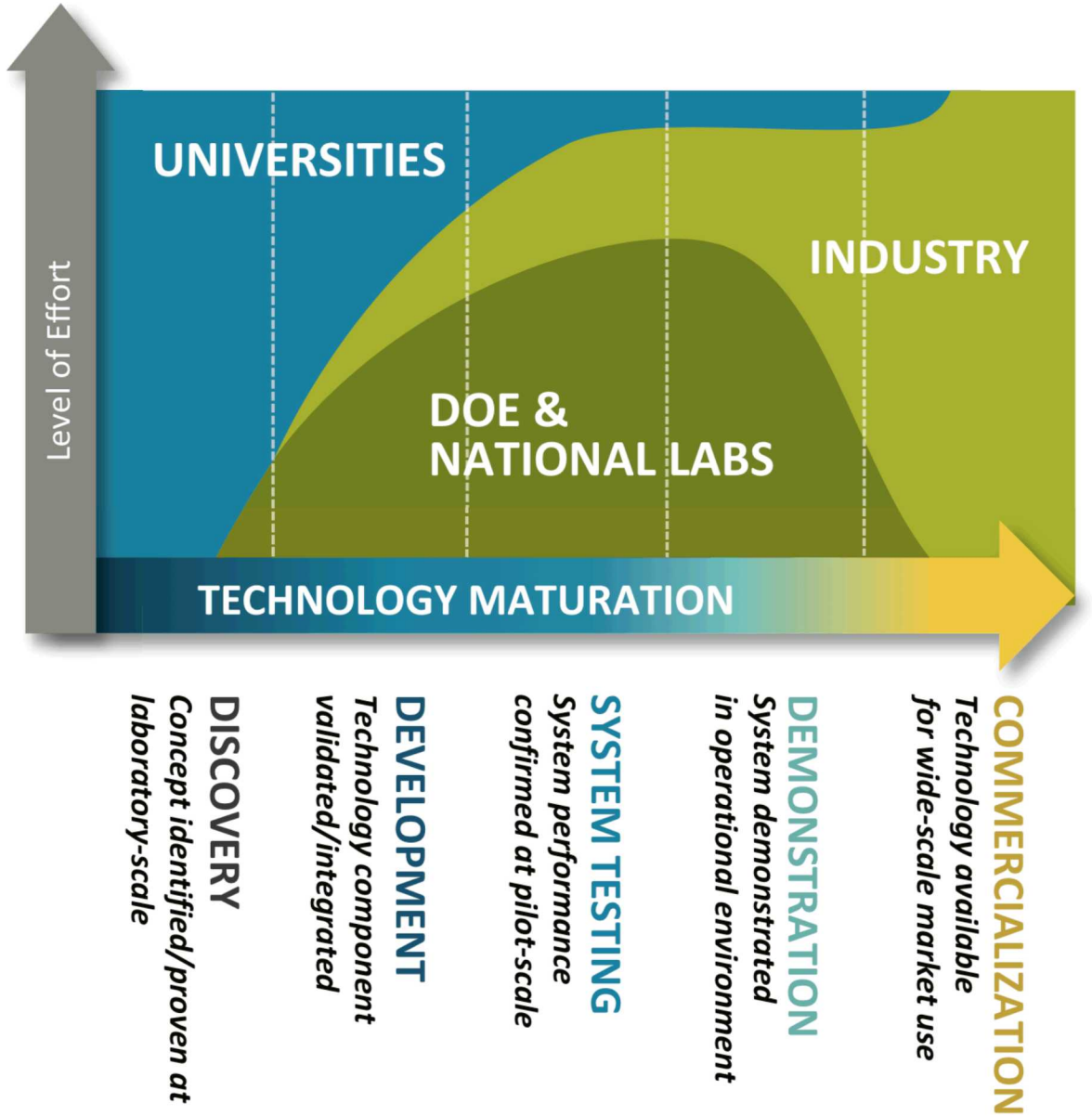
Source: “DOE State of the National Labs Report” (2017)

DOE National Lab System

National Labs

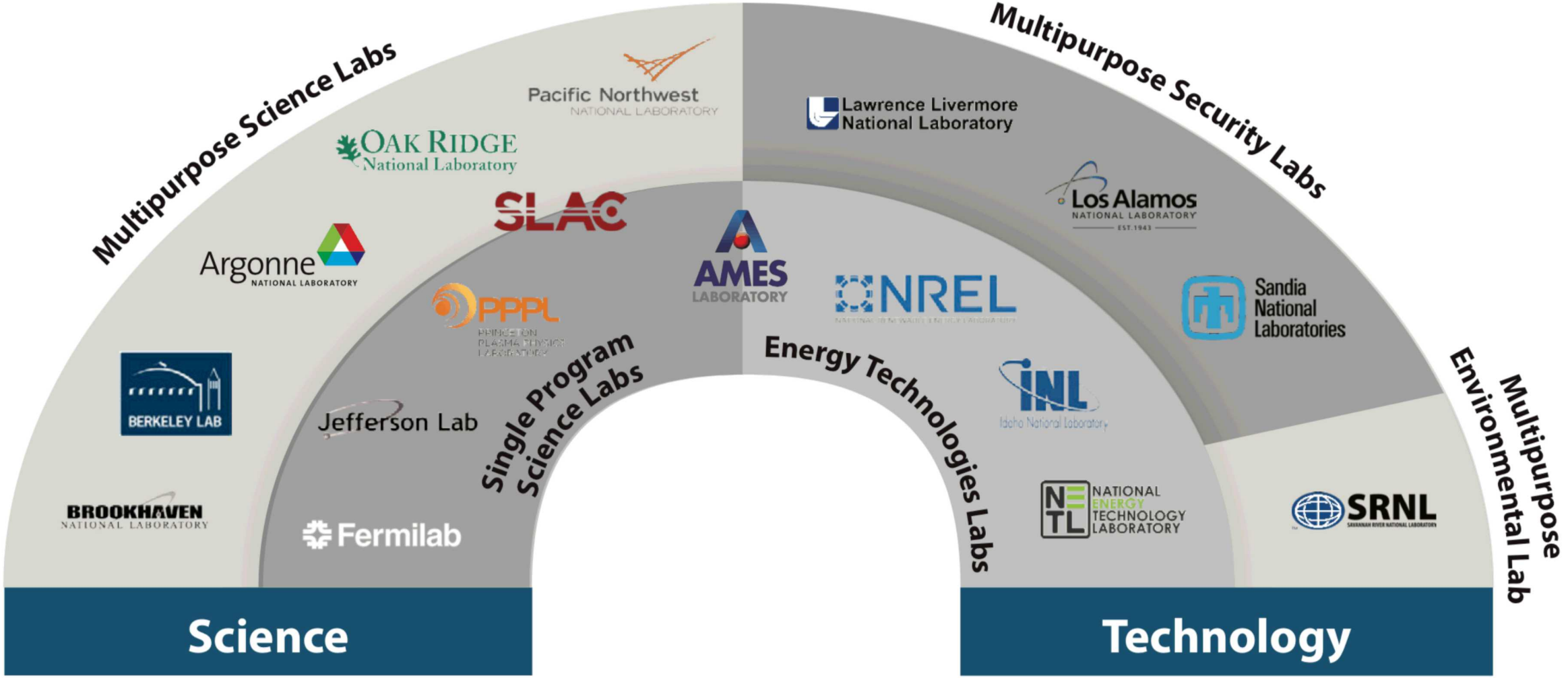
1. More staff, fewer students than university
2. Started from Manhattan Project (WWII project to develop nuclear bombs)
3. Wide range of missions
4. May not compete with industry

Ex: Particle accelerators, clean rooms, supercomputers, hydrofracking, DNA decoding, space probe power …



Source: "DOE State of the National Labs Report" (2017) and "75 Breakthroughs by America's National Laboratories" (2018)

DOE National Lab System



Source: "DOE State of the National Labs Report" (2017)

DOE National Lab System

Up to 75 year history

115 Nobel Prizes total

Discovered 22 elements

~11,000 peer-reviewed papers/year

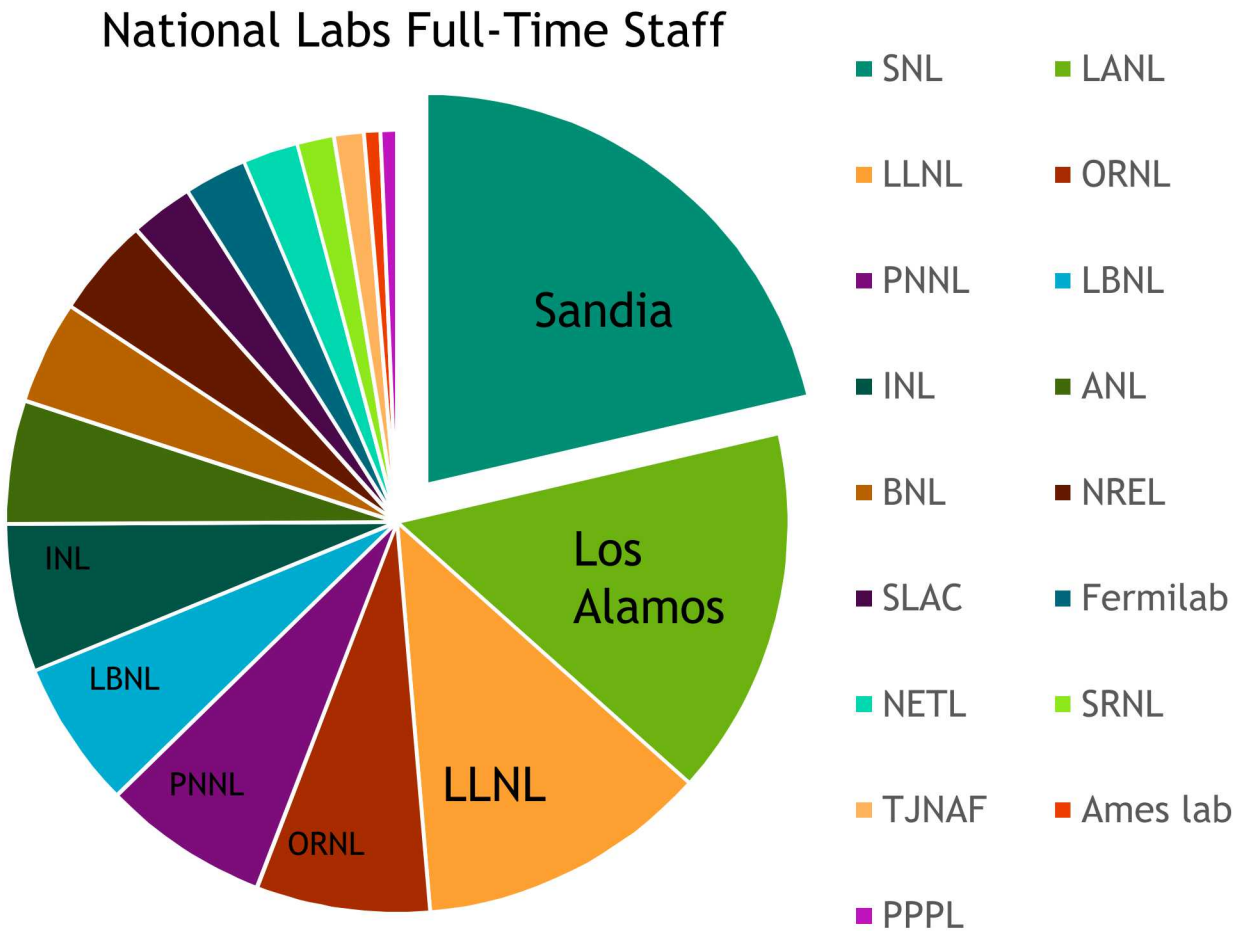
57,000 full-time employees

>20,000 scientists/engineers

2,300 post-docs

2,000 grad students

3,000 undergrads



Ames Laboratory (Ames)
Argonne National Laboratory (ANL)
Brookhaven National Laboratory (BNL)
Fermi National Accelerator Laboratory (FNAL)
Idaho National Laboratory (INL)
Lawrence Berkeley National Laboratory (LBNL)
Lawrence Livermore National Laboratory (LLNL)
Los Alamos National Laboratory (LANL)
National Energy Technology Laboratory (NETL)
National Renewable Energy Laboratory (NREL)
Oak Ridge National Laboratory (ORNL)
Pacific Northwest National Laboratory (PNNL)
Princeton Plasma Physics Laboratory (PPPL)
Sandia National Laboratories (SNL)
Savannah River National Laboratory (SRNL)
SLAC National Accelerator Laboratory (SLAC)
Thomas Jefferson National Accelerator Facility (TJNAF)

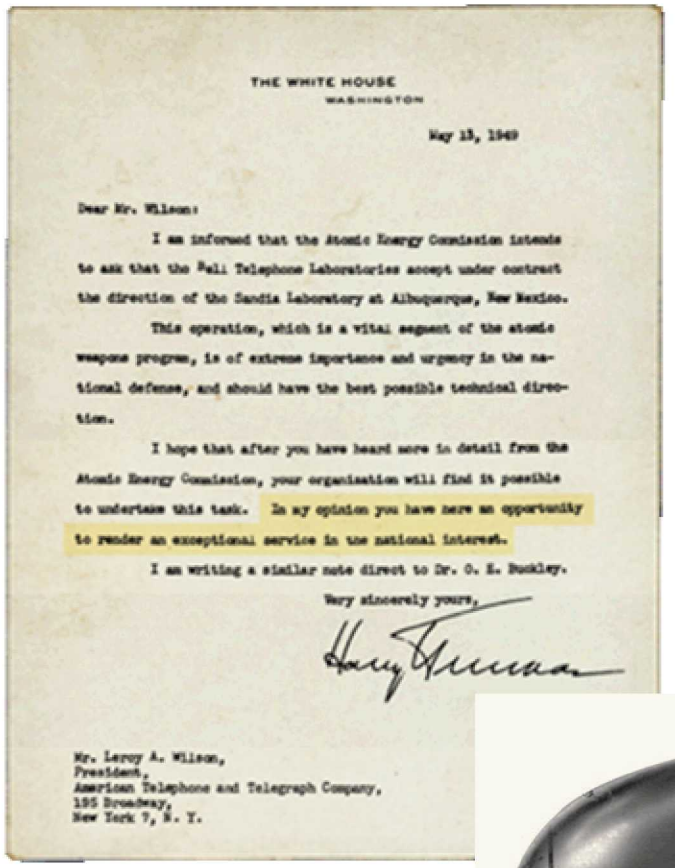
Source: "DOE State of the National Labs Report" (2017)

What is Sandia?

SANDIA'S HISTORY IS TRACED TO THE MANHATTAN PROJECT

…In my opinion you have here an opportunity to render an exceptional service in the national interest.

- July 1945
  Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949
  Sandia Laboratory established
- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–2017
- Honeywell: 2017–present



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.

SANDIA IS A FEDERALLY FUNDED RESEARCH AND DEVELOPMENT CENTER (FFRDC) MANAGED AND OPERATED BY

National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc. (NTESS)

Government owned, contractor operated (GOCO)

FFRDCs are long-term strategic partners to the federal government, operating in the public interest with objectivity and independence and maintaining core competencies in missions of national significance

SANDIA HAS FACILITIES ACROSS THE NATION

Activity locations

- Kauai, Hawaii
- Waste Isolation Pilot Plant, Carlsbad, New Mexico
- Pantex Plant, Amarillo, Texas
- Tonopah, Nevada

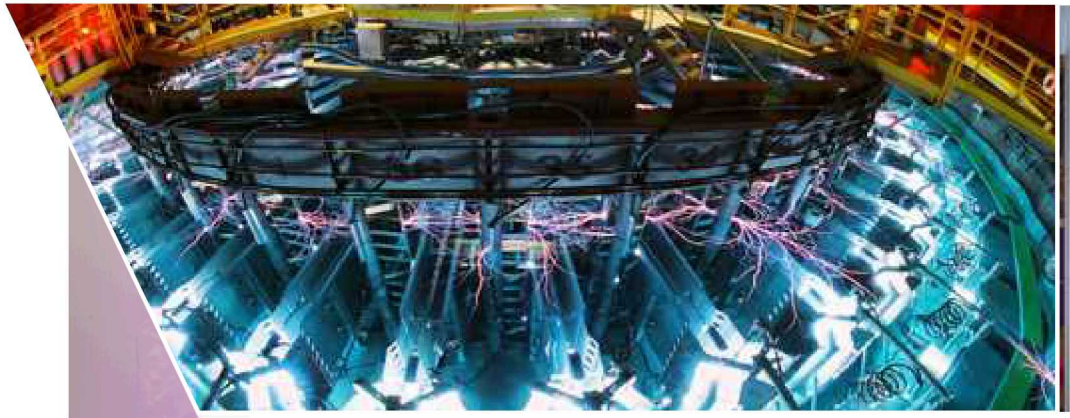
Main sites

- Albuquerque, New Mexico
- Livermore, California

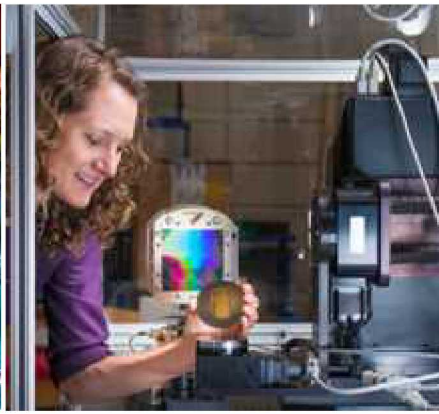
ADVANCED SCIENCE & TECHNOLOGY

Research Foundations ... ral role in mission delivery

Nanodevices & Microsystems

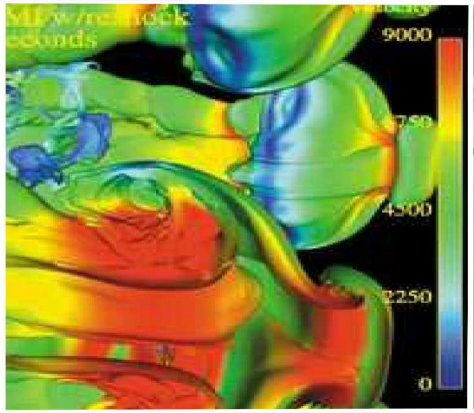


Radiation Effects & High Energy Density Science



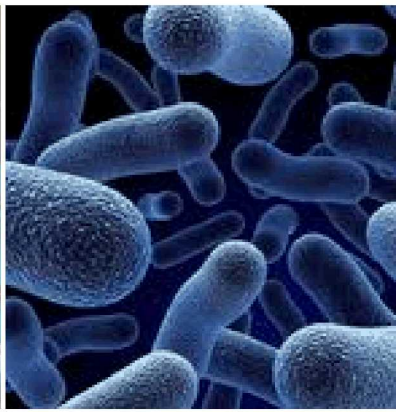
Materials Science

Computing & Informa



Engineering Science

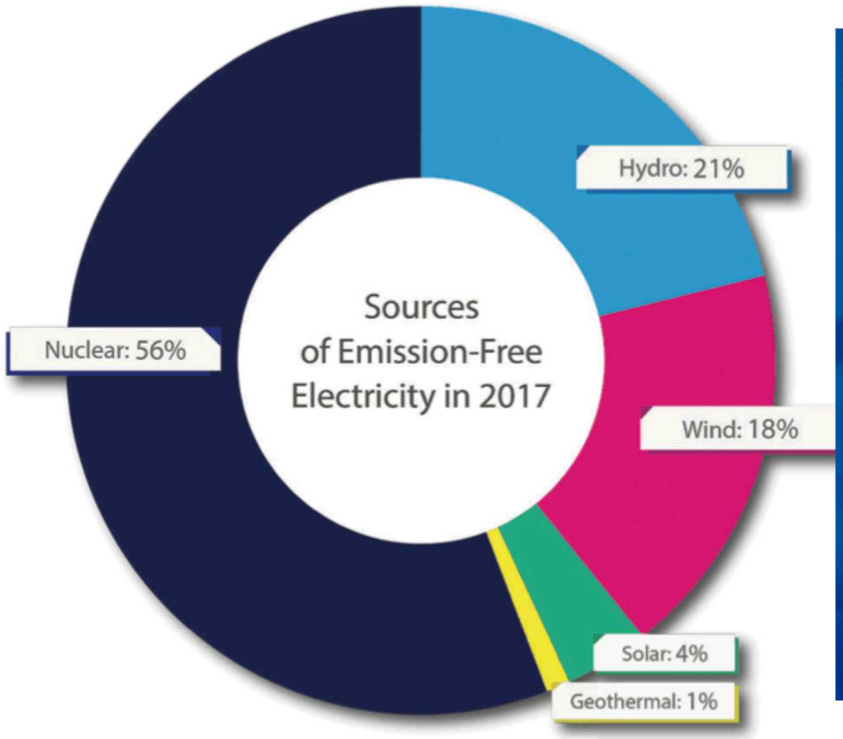
Geoscience (~150 staff)

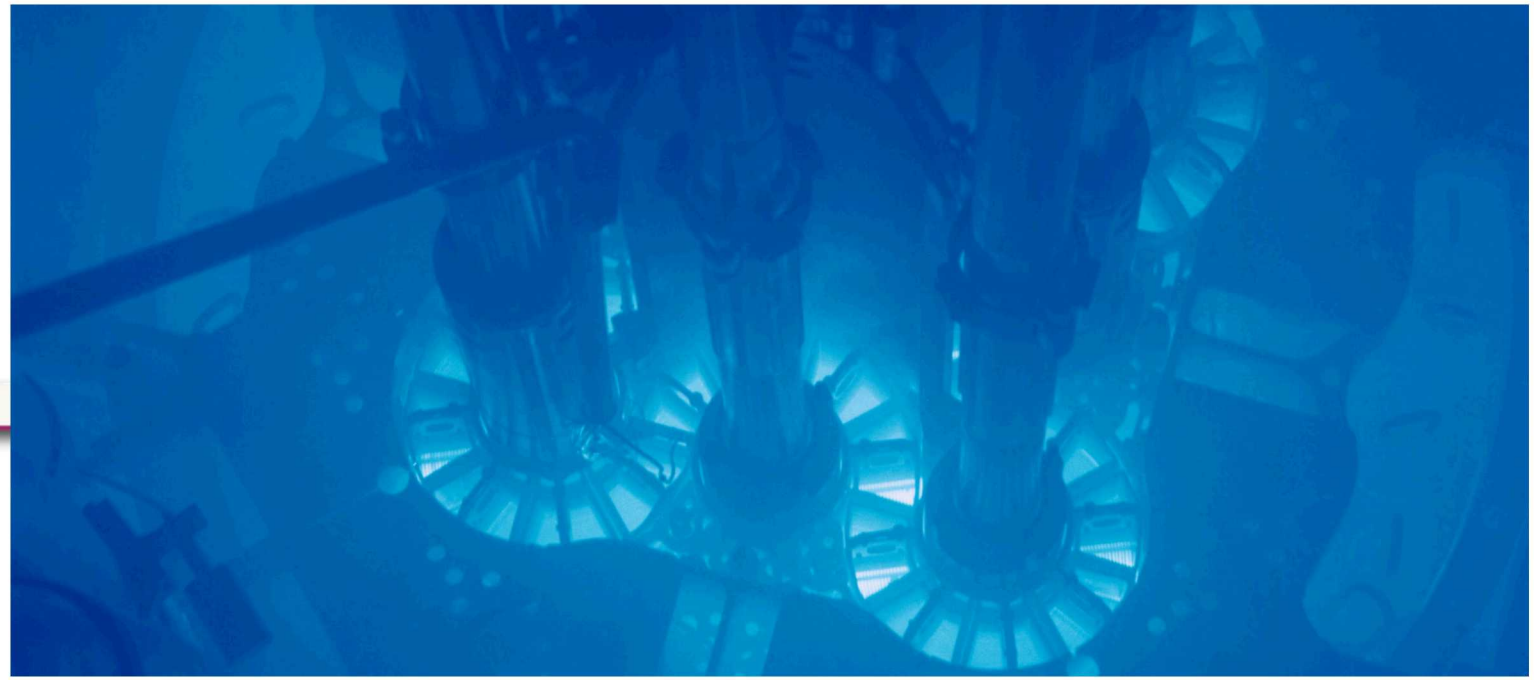


Bioscience

What do I do at Sandia?

Nuclear Energy is >50% of clean energy in US





Spent nuclear fuel is kept in pools or dry-cask storage

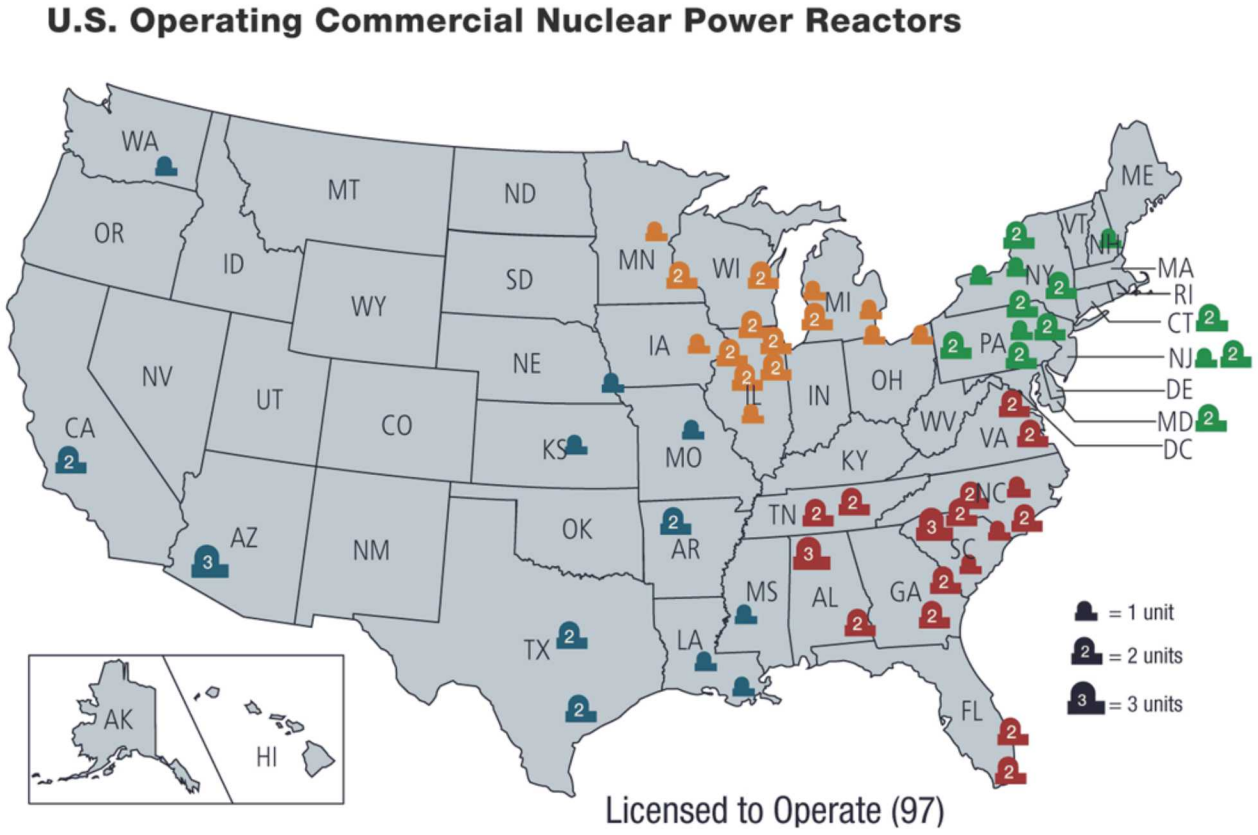
Need a permanent disposal option for heat-generating waste

Source: “Ultimate Fast Facts guide to Nuclear Energy” (2019)

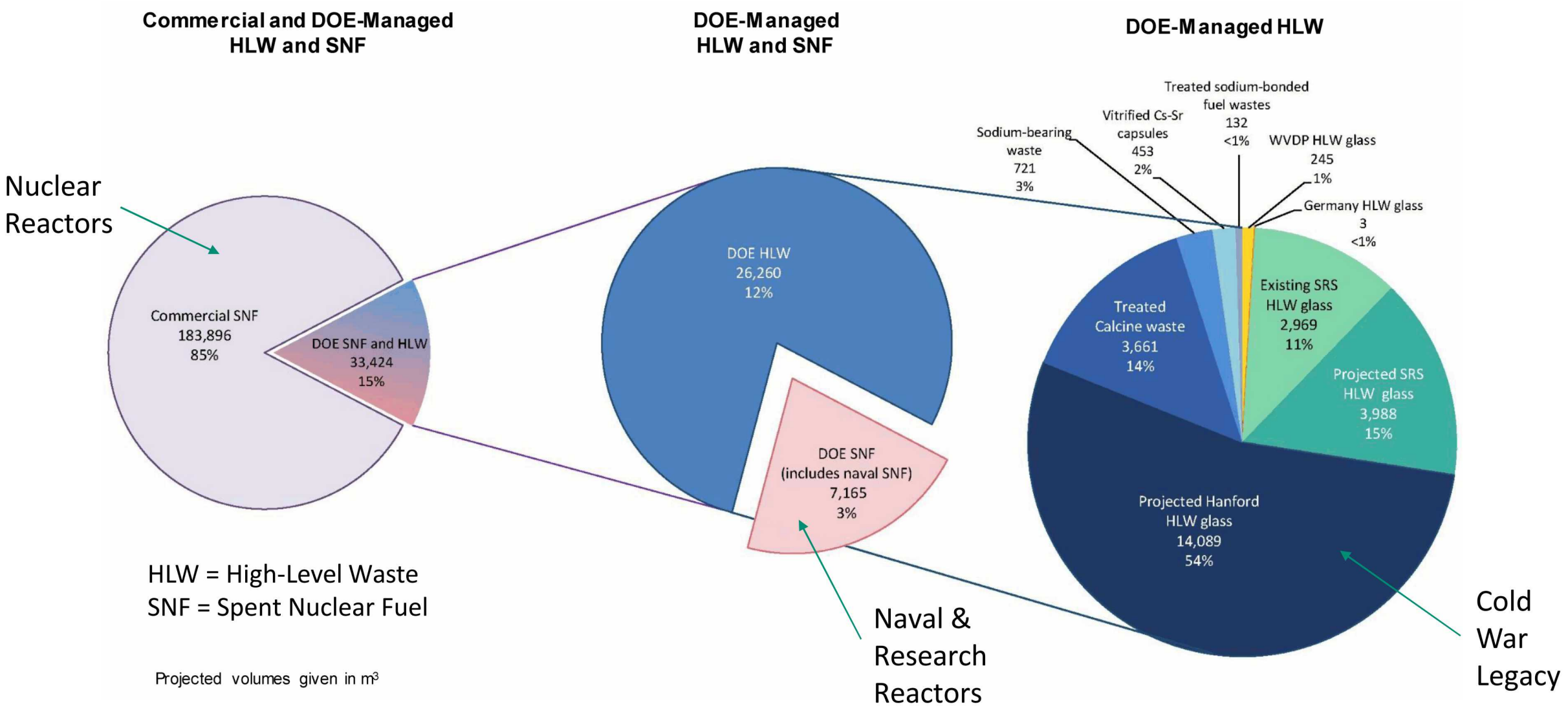
Nuclear Waste Types

US Nuclear waste

1. Power generation
2. Cold War legacy
3. Nuclear Navy
4. Research reactors
5. Medical isotope production



Nuclear Waste Types: By Volume



Source: “Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Fuel” (2014)

DOE Office of Nuclear Energy (DOE-NE)

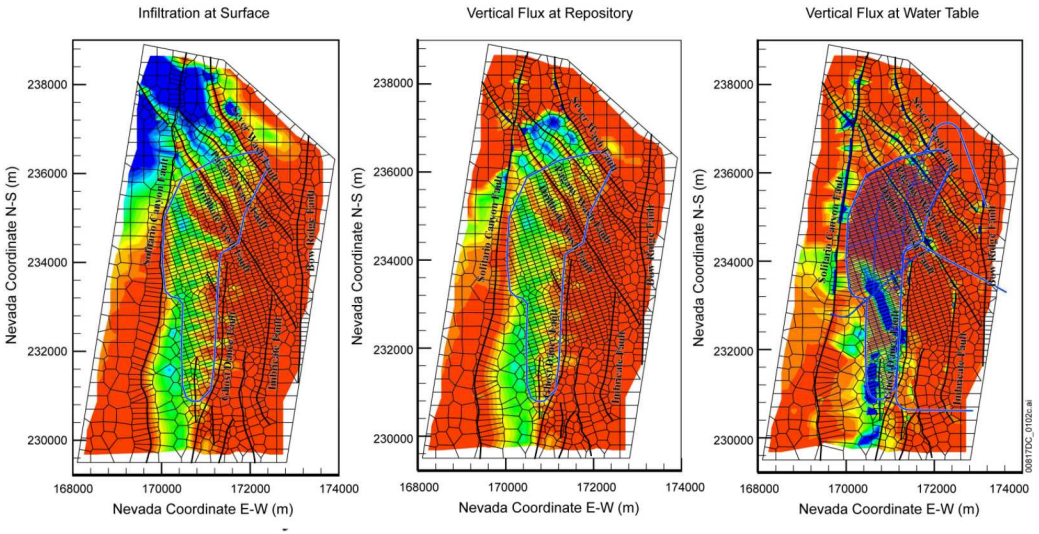
Researching disposal options

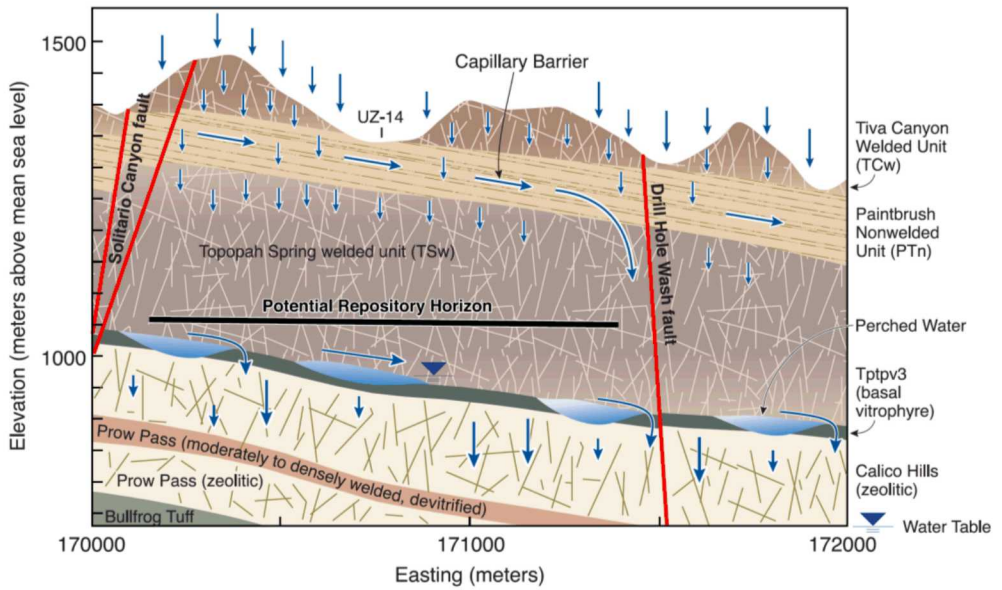
1. Crystalline rock (e.g., granite)
2. Argillaceous rock (e.g., claystone)
3. Evaporite rocks (e.g., salt)

Field experiments for data

Simulate safety of repository

Performance Assessment





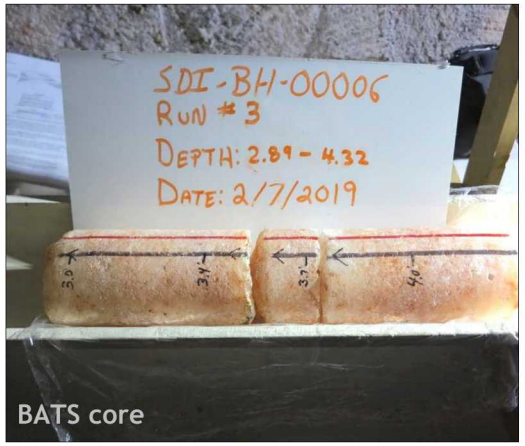
Source: “Repository Science at Sandia: WIPP, Yucca Mountain, and the Path Forward”, P. Swift (2012) SAND2012-6969P.

Brine Availability Test in Salt (BATS)

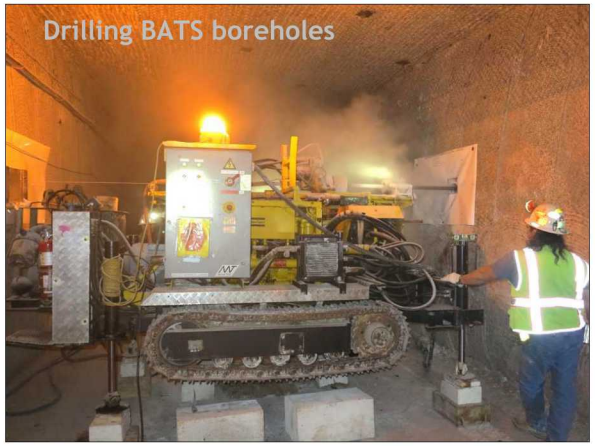
Research into Disposal of High-Level Waste in Salt

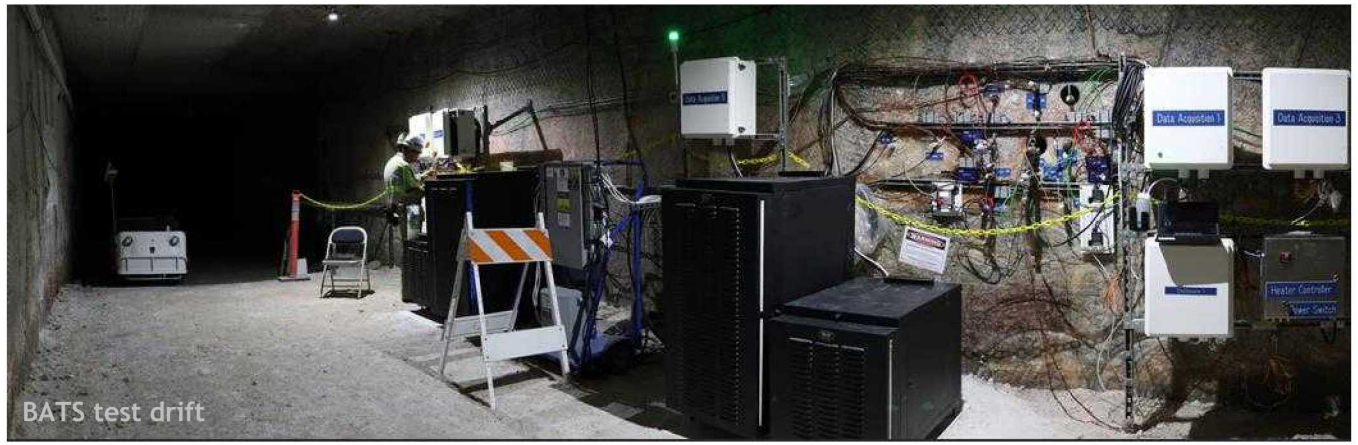
Brine Availability Test in Salt at WIPP (BATS)

Monitoring brine from heated salt using geophysics and sampling.



BATS core


Drilling BATS boreholes

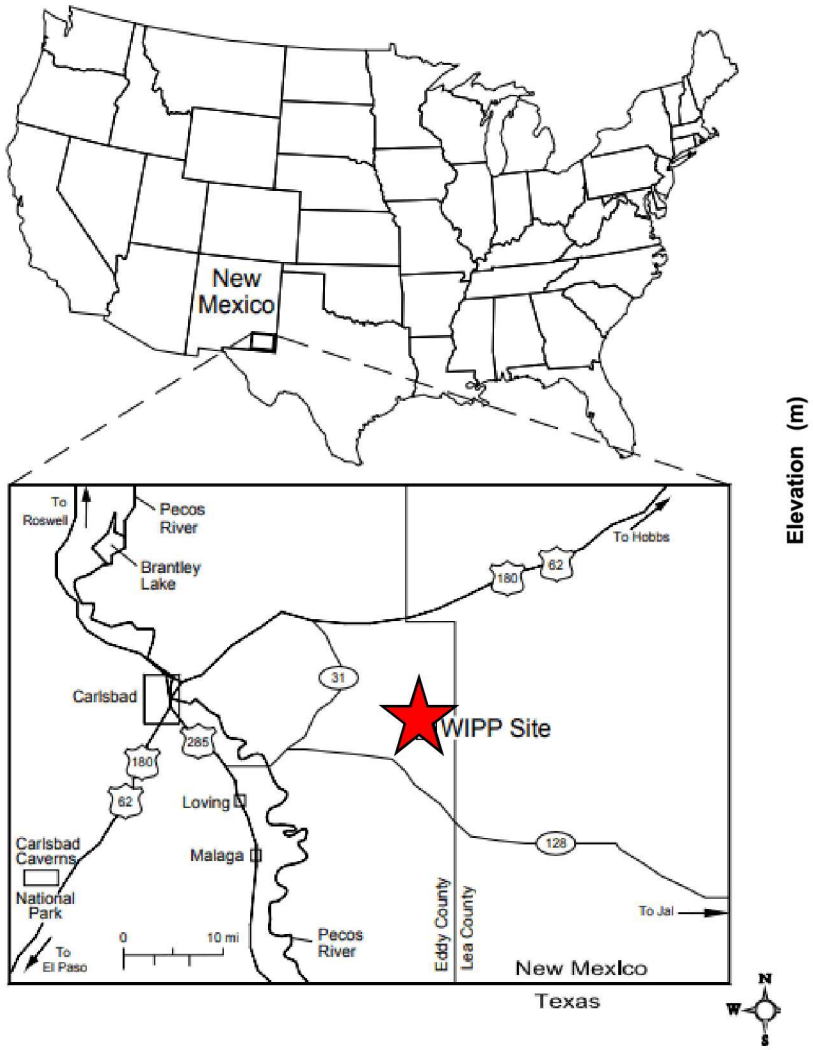

BATS test drift

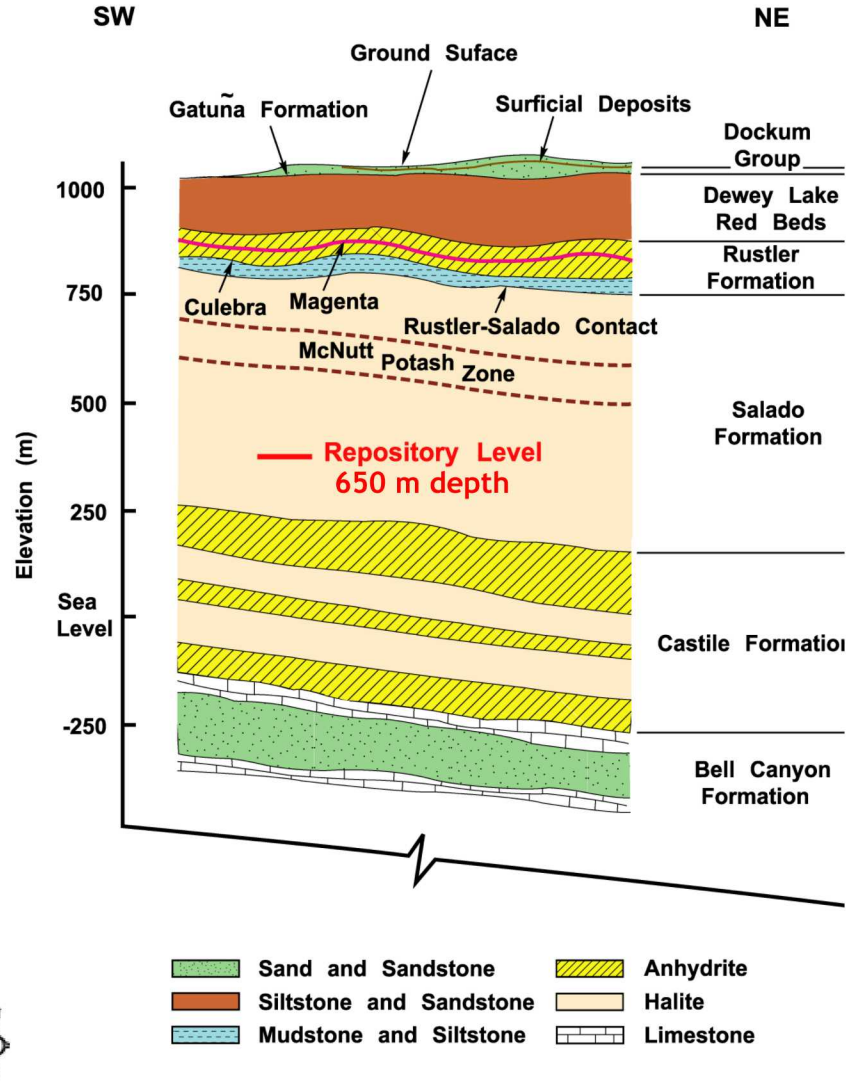
Sandia National Laboratories

Los Alamos NATIONAL LABORATORY EST. 1943

BERKELEY LAB

Waste Isolation Pilot Plant (WIPP): Existing Disposal Facility





WIPP is a repository for TRU (transuranic) waste

1. *WIPP has been operating since 1999*
2. *Cleaning up Cold War legacy*
3. *WIPP allows us to use their facility*

Why Geologic Salt?

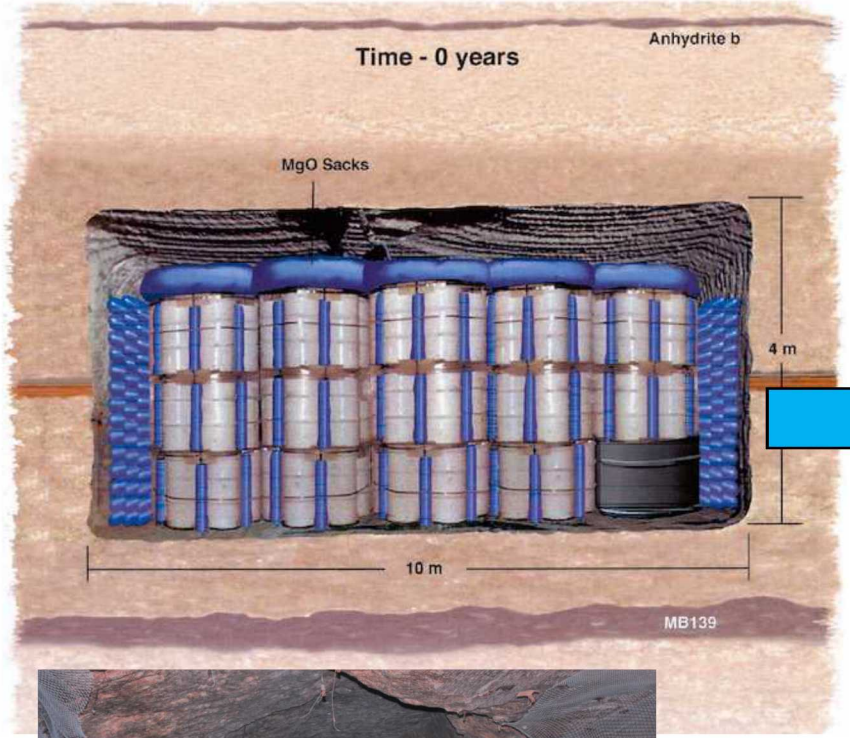
Long-term benefits

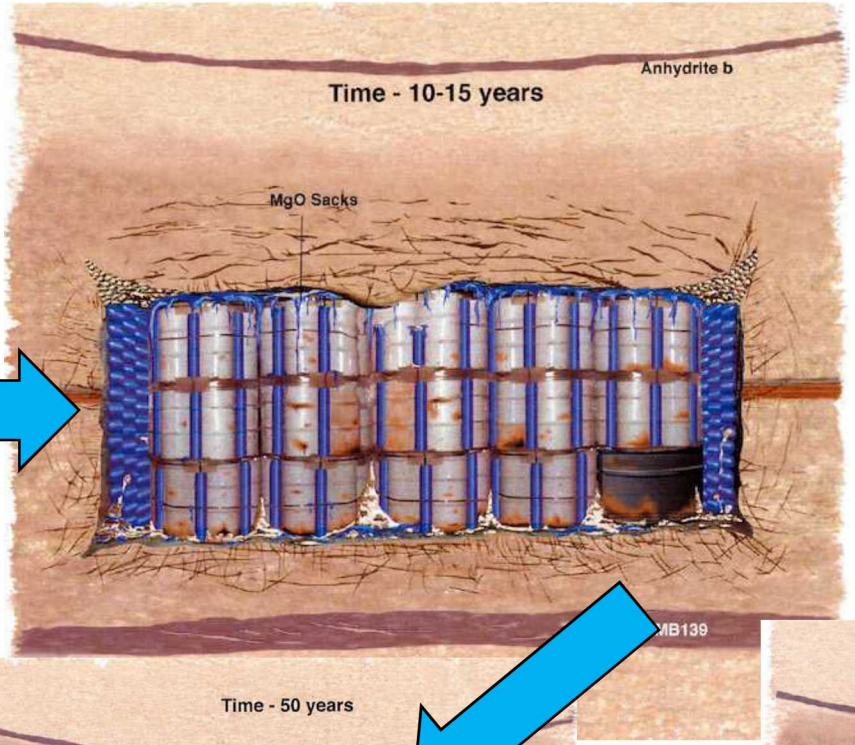
- Low connected porosity (0.1 vol-%) and permeability ($\leq 10^{-22}\ m^2$)
- High thermal conductivity ($\sim 5\ W/(m \cdot K)$)
- No flowing groundwater (≤ 5 wt-% water)
- Hypersaline brine is biologically simple, has less-stable colloids
- Permian salt has been stable for ~250 M yrs
- Excavations, damage, and fractures will creep closed
- Mined salt reconsolidates and heals to intact salt properties

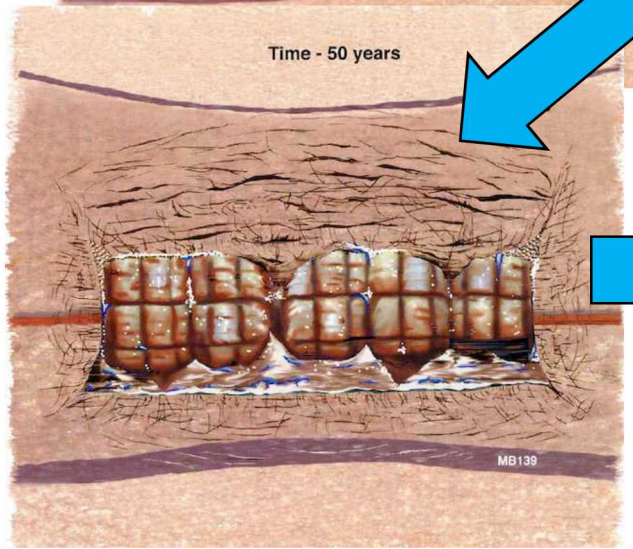
Near-field short-term complexities

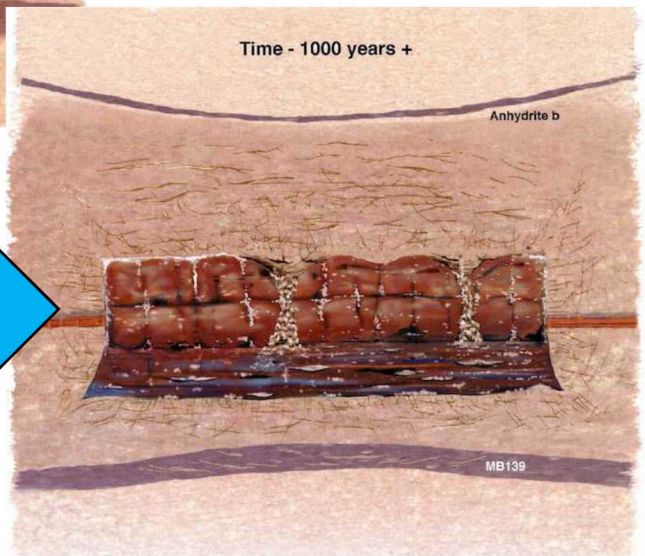
- Hypersaline brine is corrosive
- Salt is very soluble in fresh water
- Salt creep requires excavation maintenance

Creep Closure of Rooms at WIPP









Why is Brine Important in a Repository?

Brine Availability: *Brine distribution in salt & how it flows to excavations*

- Predicting where brine and permeability are around excavations
- Brine causes corrosion of waste package / waste form
- Brine is primary radionuclide transport vector
- Liquid back-pressure can resist drift creep closure

WIPP Room B heated brine migration

WIPP Room J canister tests

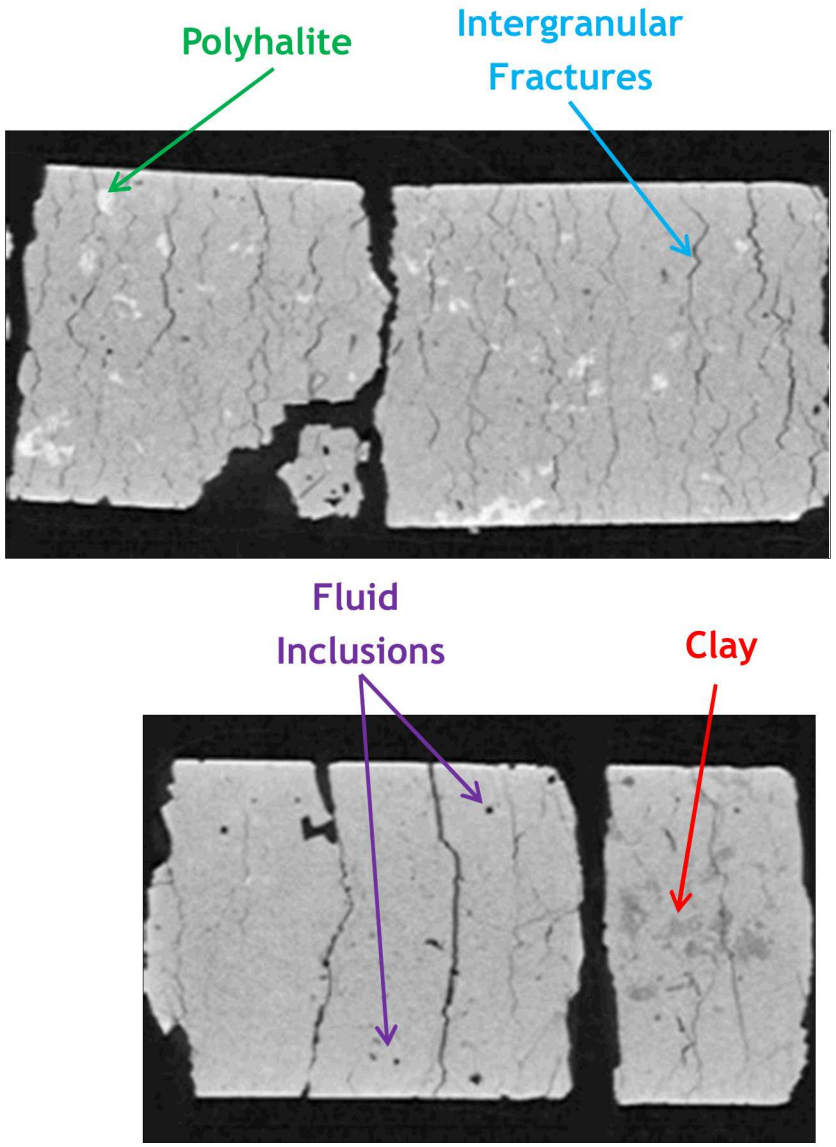
WIPP Room Q brine inflow

WIPP brine permeability testing

Brine in Bedded Salt

- Water types in bedded salt
  1. Disseminated clay (< 5 vol-% total; ~25 vol-% brine)
  2. Intragranular brine (fluid inclusions; 1 – 2 vol-%)
  3. Hydrous minerals (e.g., polyhalite, bischofite, epsomite)
  4. Intergranular brine (between salt crystals; << 1 vol-%)
- These water types:
  - respond differently to heat & pressure
  - have varying chemical composition
  - differ in stable water isotope makeup

WIPP fluid inclusions, 2 mm scale bar
(Caporuscio et al., 2013)



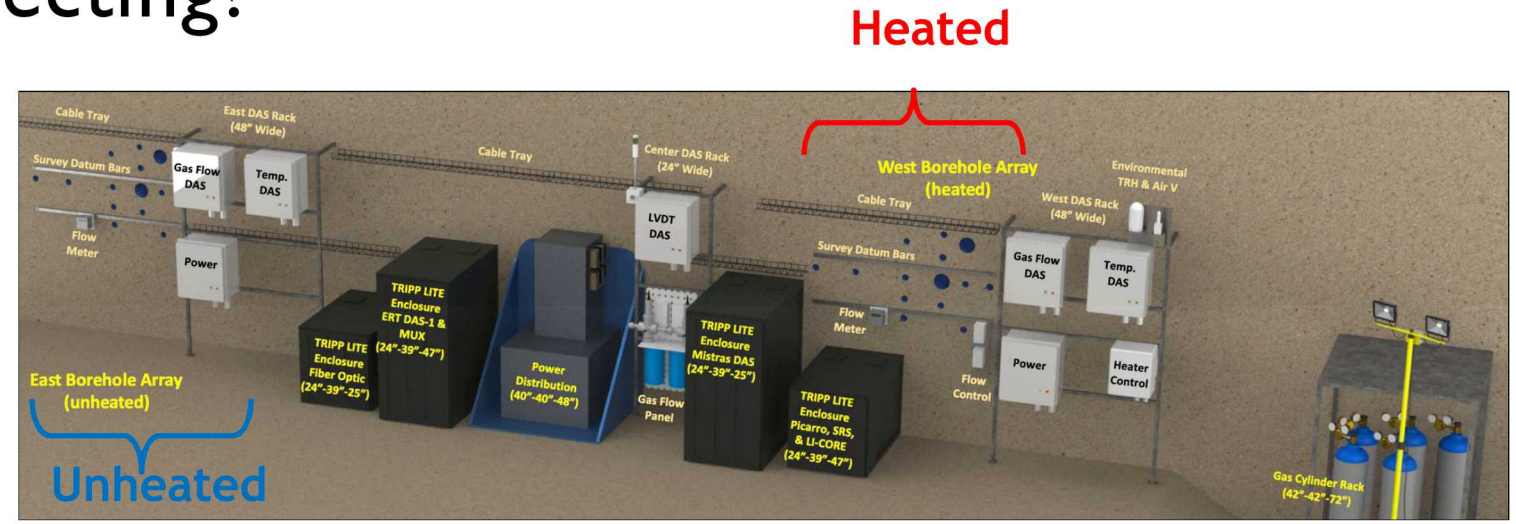
10.1 cm diameter core CT data (Betters et al., 2020)

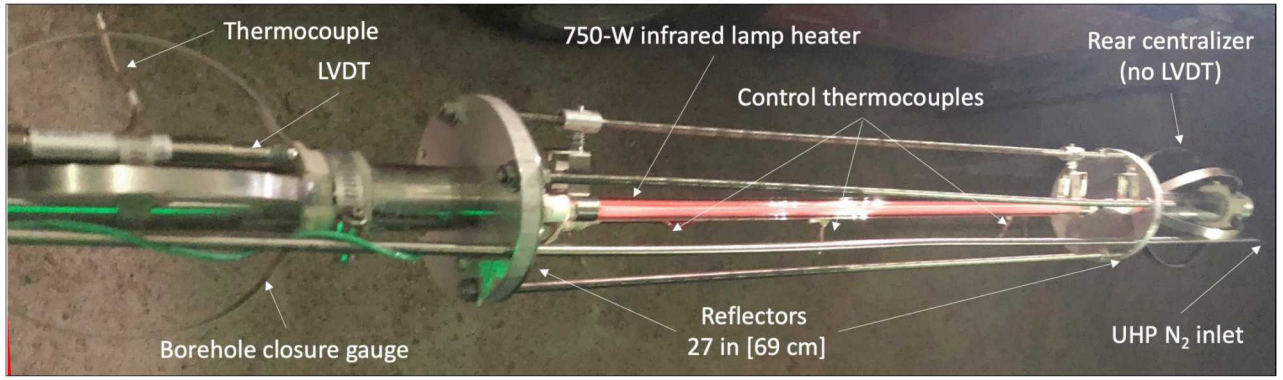
- Damaged zone increases porosity → primary flow path

How do water types contribute to *Brine Availability*?

What Data are We Collecting?

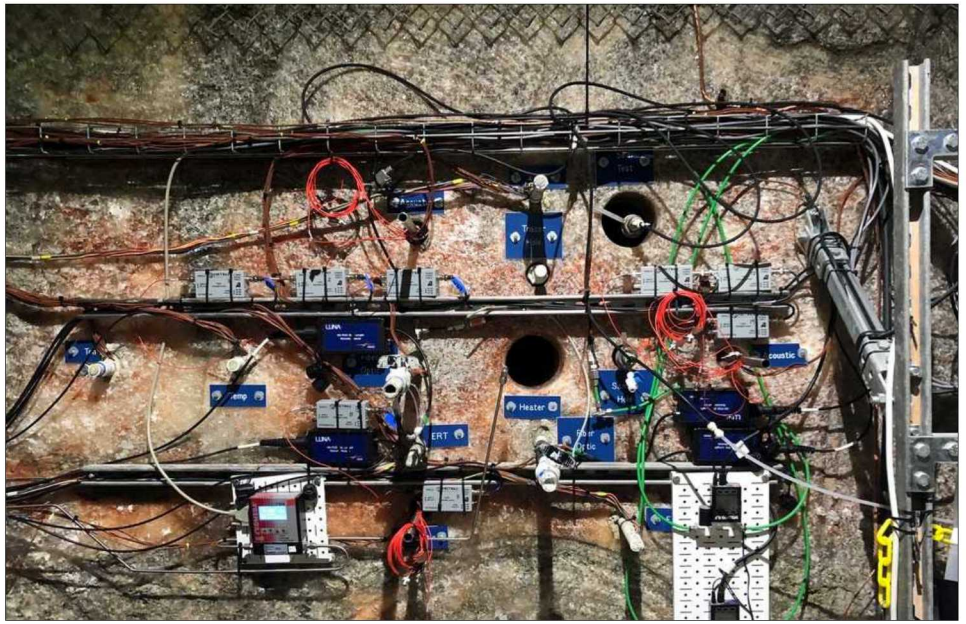
- Two Arrays: Heated / Unheated
- Behind packer
  - Circulate dry N_2
  - Quartz lamp heater (750 W)
  - Borehole closure gage
- Samples / Analyses
  - Gas stream (natural / applied tracers and isotopic makeup)
  - Liquid brine (natural chemistry and natural / applied tracers)
  - Cores (X-ray CT and fluorescence at NETL)
- Cement Seals
  - Sorel cement + Salt concrete: 3-axis strain & temperature
- Geophysics
  - 3× Electrical resistivity tomography (ERT)
  - 3× Acoustic emissions (AE)
  - 2× Fiber optic distributed strain / temperature sensing

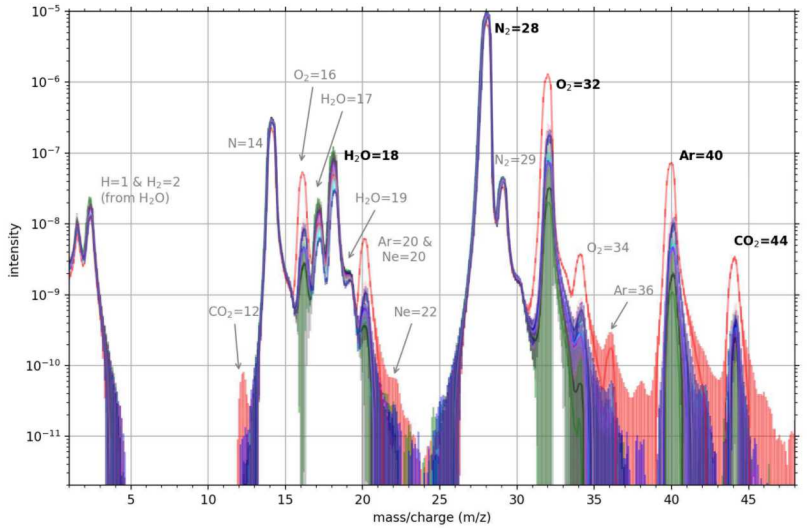




Why are These Data Useful?

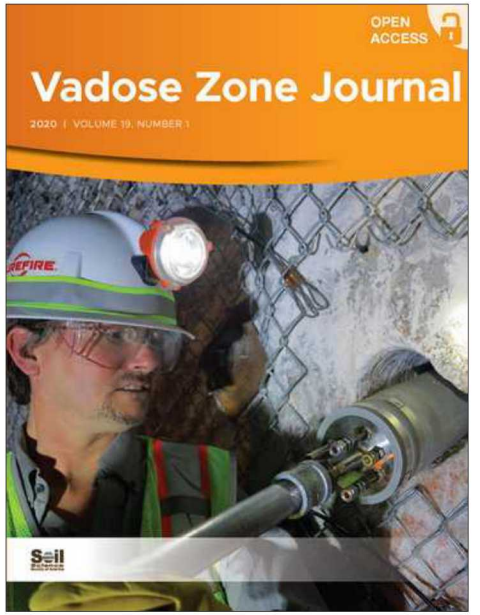
- Brine composition samples / H_2O isotope data
  - Observe change in brine sources with temperature
- Geophysics
  - Evolution of **saturation** / **porosity** / **permeability**
- Temperature distribution
  - More brine at high T (inclusions + hydrous minerals)
  - Salt dry-out near borehole (above boiling)
- Gas permeability and borehole closure
  - Thermal-hydrological-mechanical (THM) evolution of salt
- Tracer migration through salt
  - Monitor brine movement through salt damage zone

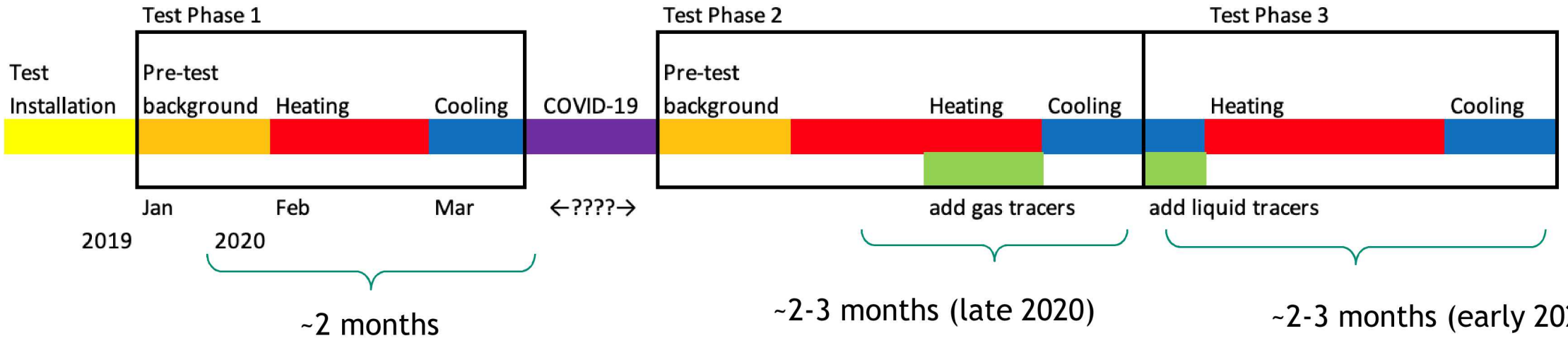




BATS Test Status

- Boreholes drilled (Feb-Apr 2019)
- Installed instrumentation (May-Aug 2019)
- Plumbed and wired experiment (Aug-Oct 2019)
- Currently in COVID-related shutdown
- First BATS publication: Vadose Zone Journal (Apr 2020)
  - "Temperature response and brine availability to heated boreholes in bedded salt"





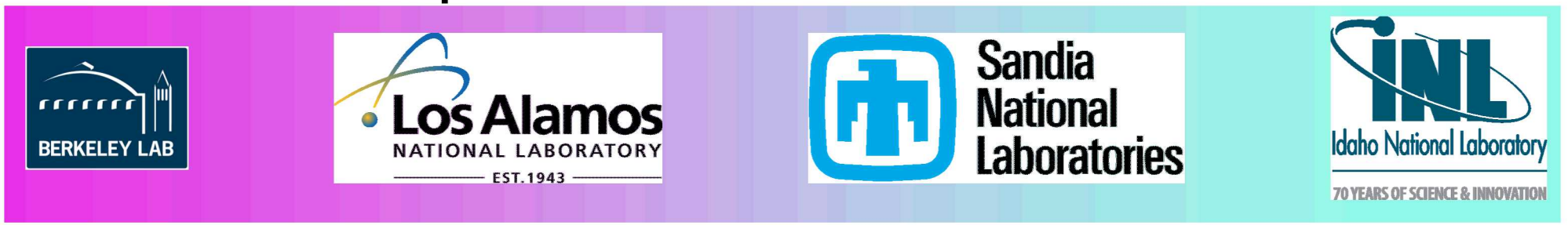
Benefits of Repository Science and BATS Tests

- Collect field data for validating numerical models
  - Complex processes in a salt repository: thermo-hydraulic-mechanical-chemical processes
  - Impacts of heat on amount of brine to expect
  - Make more physically realistic predictions
  - Important data for improving confidence in model predictions to 1,000,000 years
  - Bringing new geophysical/analytical methods to bear on hard problems
- Train a new generation of "repository scientists"
  - Significant testing in 1980s (replace retired staff)
- Build international collaborations
  - Germany, Netherlands, and United Kingdom considering salt for radioactive waste disposal

Thoughts on Career Paths

Spectrum of National Labs

Research Universities

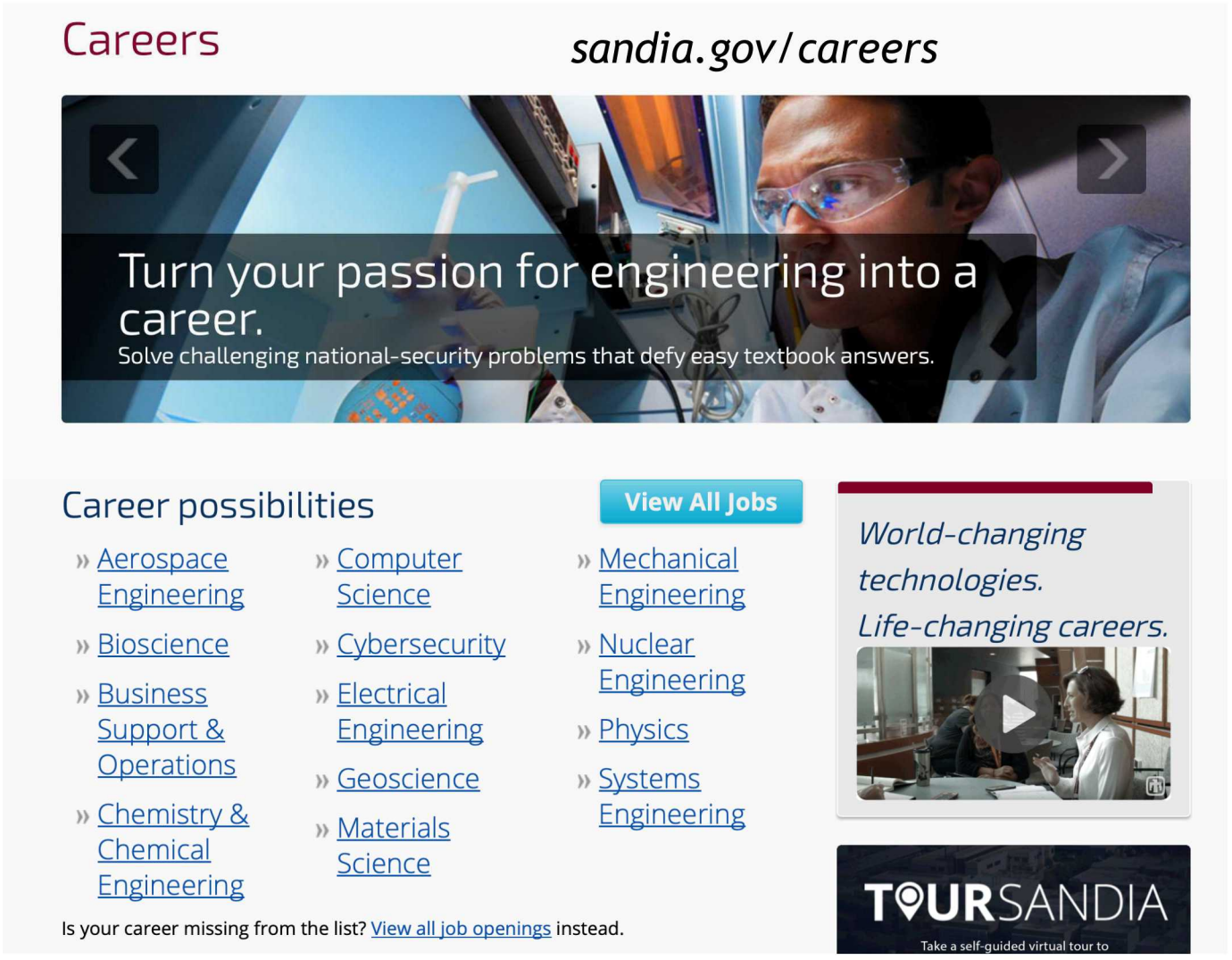


Engineering/ Consulting

- At National Labs:
  - Work on impactful projects
  - Collaborate with universities (i.e., summer students)
  - Changing careers is possible!
- Labs or consulting:
  - Real-world experience before/during grad school

Sandia Opportunities

- Summer internships
  - Deadline in Jan/Feb
- Staff Jobs
  - Keep good grades!
  - US Citizenship (security clearance)
- MS or PhD for technical jobs
- BS for lab technician jobs



Search "Sandia Rocket Sled" or "Sandia Z machine" on YouTube for cool videos!

Thank You!