SAND2015-7725PE

Exceptional service in the national interest

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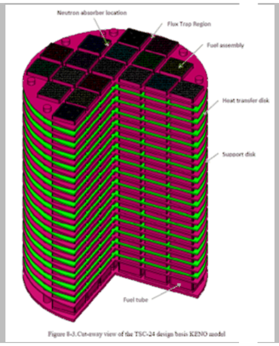

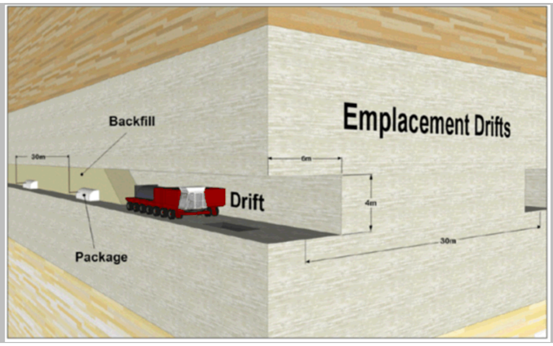

UFD Activities in the Back-End of the Fuel Cycle

Materials Protection Accounting and Control Technologies (MPACT) Working Group Meeting

September 15-17, 2015

Sylvia Saltzstein

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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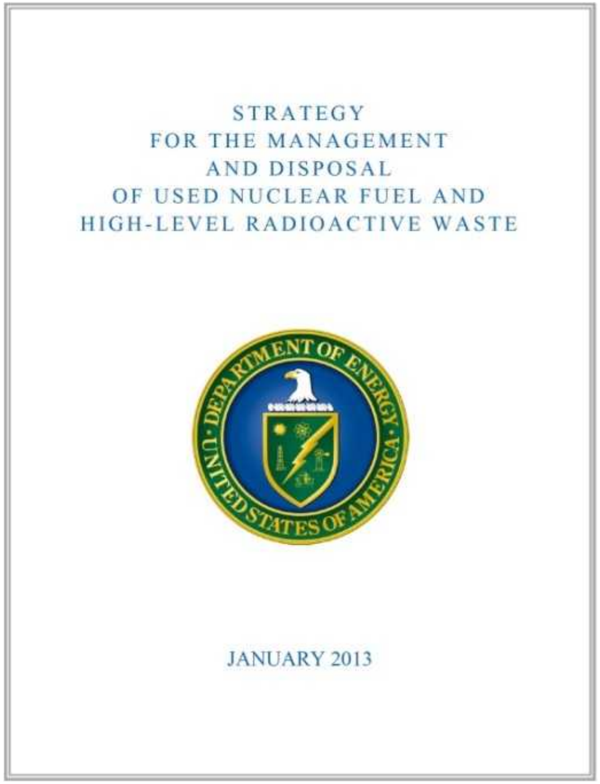
U.S. Strategy for UNF and HLW Management

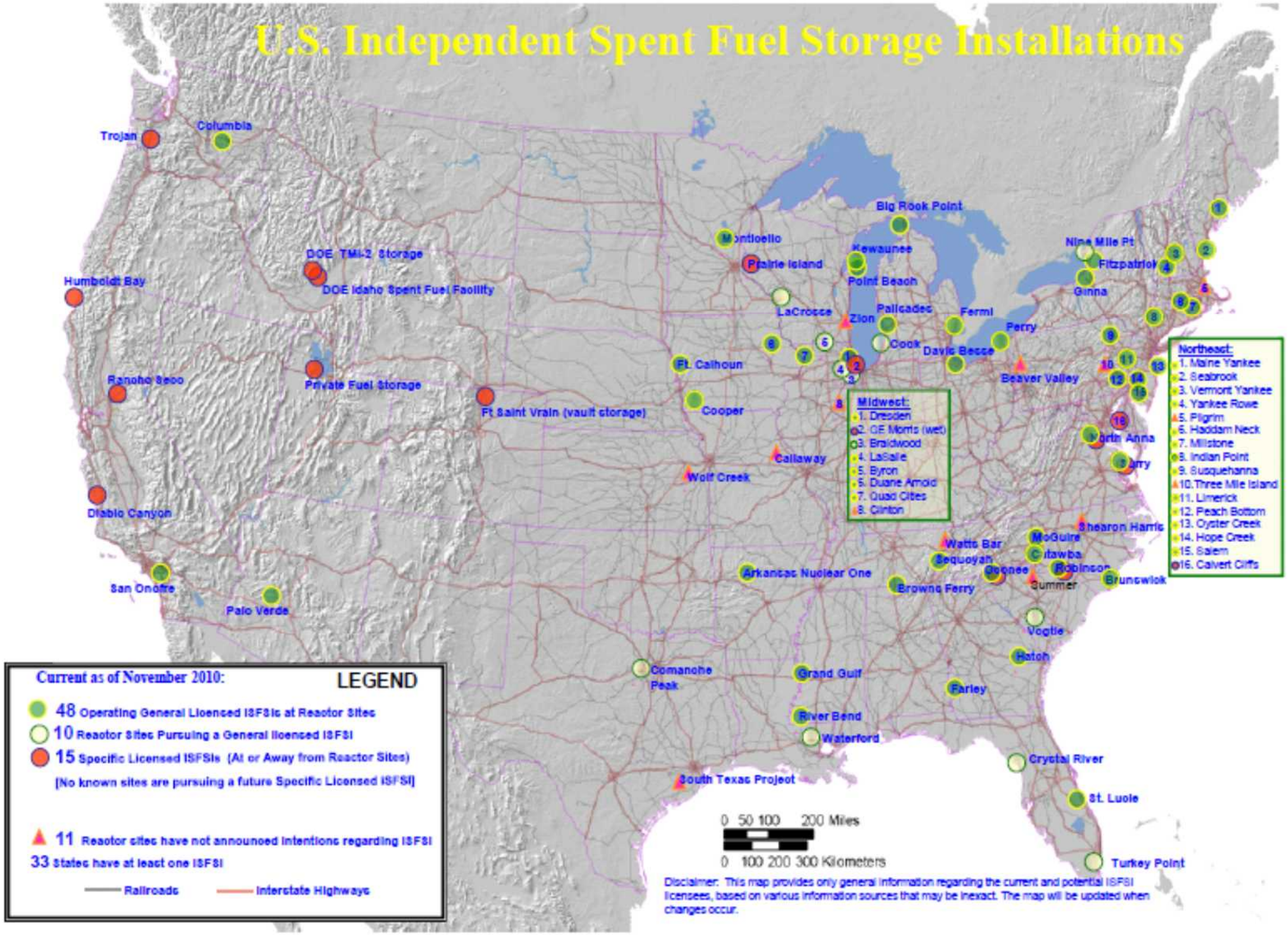
DOE Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste **issued January 2013**

The Strategy outlines a 10-year program of work:

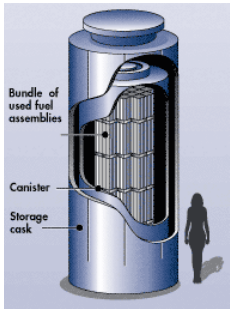
- **Pilot begins operation in 2021**
- **Consolidated Storage Facility by 2025**
- **Repository by 2048**



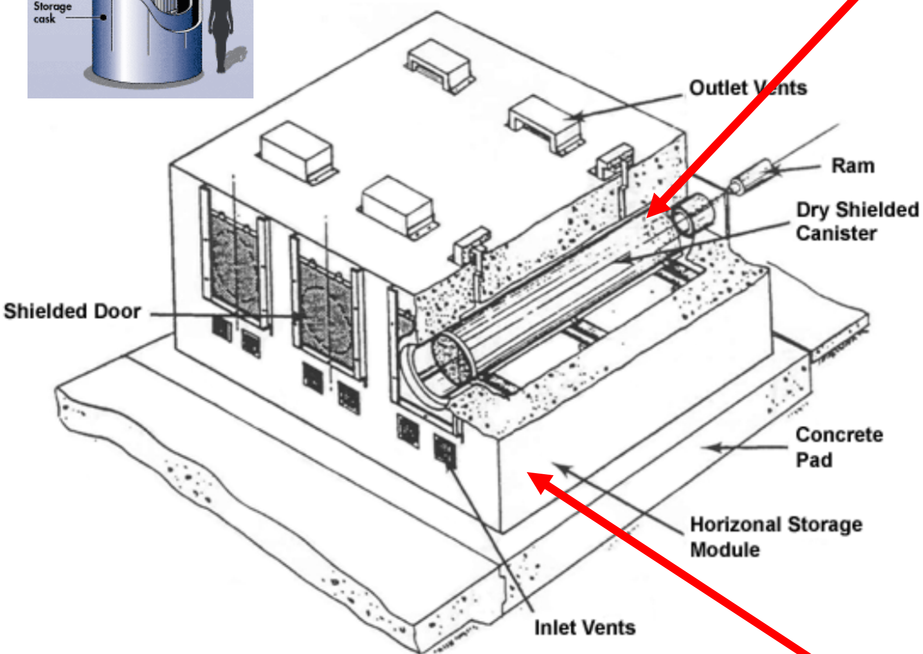
Currently, UNF is Stored all over the Country

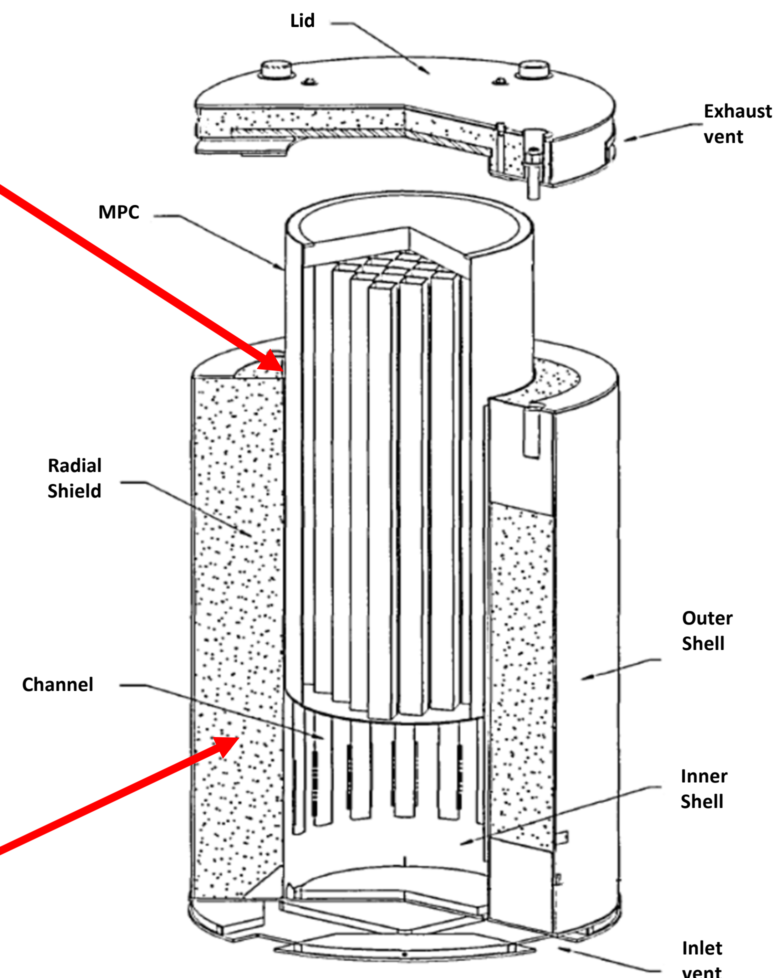


Interim Storage Systems (Welded) are in two General Configurations.



Stainless Steel (304)



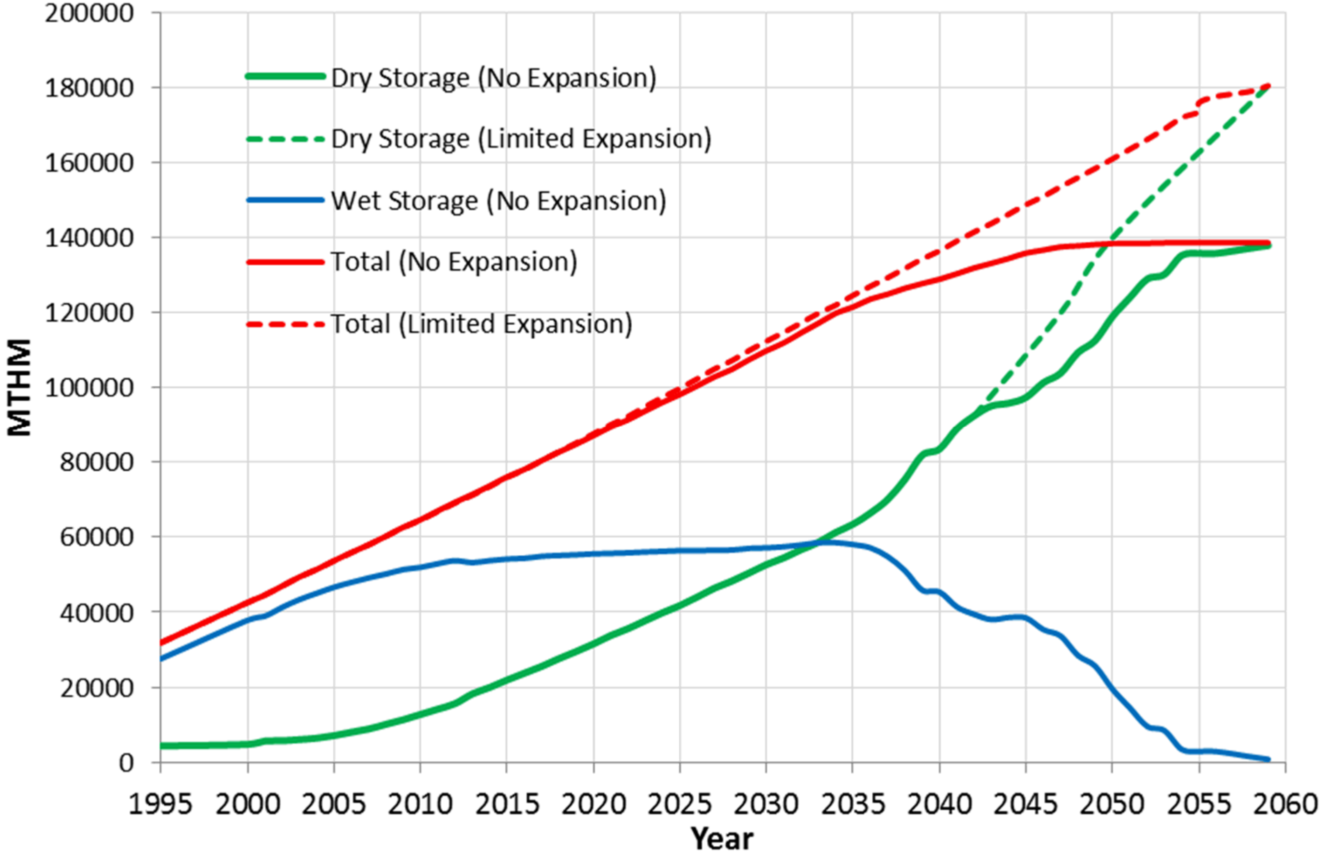


Concrete

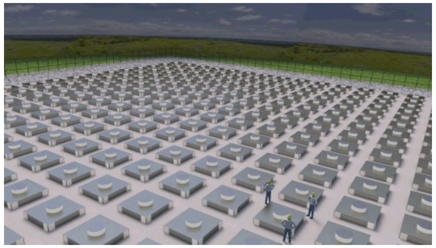
Horizontal (e.g., Areva TN)

Vertical (e.g., Holtec)

We may have 8000-9200 Dual Purpose Canisters by the time a Repository Should Open.



Holtecinternational.com



IAEA.org

Source: Hardin, E., C.T. Stockman, E.A. Kalinina and E.J. Bonano 2013. "Integration of Long-Term Interim Storage of Spent Fuel with Disposal." ASTM Committee C26-Nuclear Fuel Cycle Workshop, Avignon, France. 17-21 June, 2013.

Projection of MTHM inventory in wet and dry storage by 2060 if no new nuclear plants open and current plants have 60-year lifetime.

Large, Hot DPCs May Have to Cool for Centuries Before Disposal.

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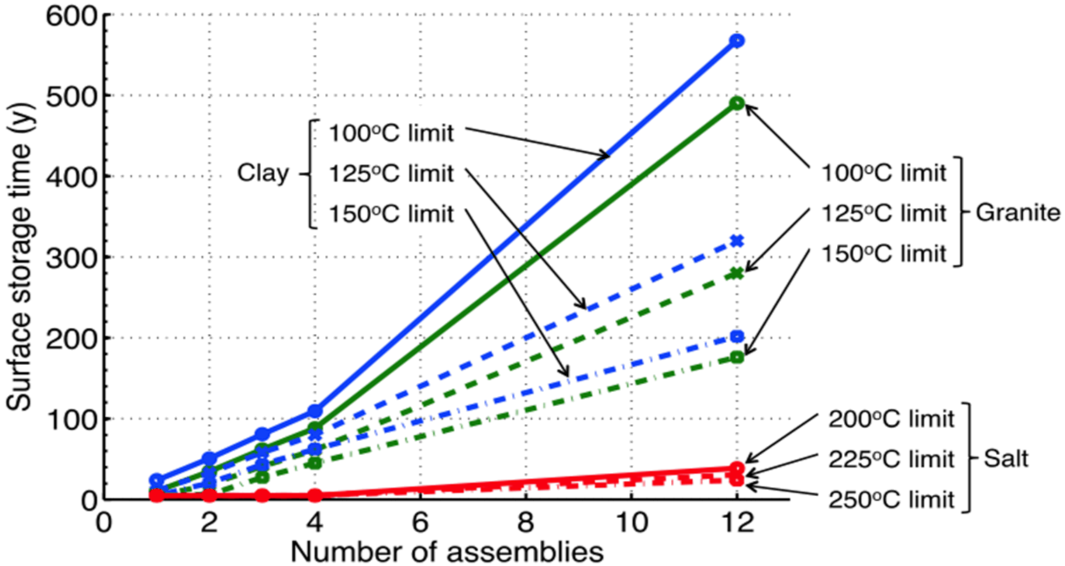
Temperature limits based on current international and previous U.S. concepts:

- 100°C for clay buffers and clay/shale media (e.g., SKB 2006)
- 200°C for salt (e.g., Salt Repository Project, Fluor 1986)

Final temperature constraints will be site- and design-specific

Decay Storage Needed to Meet WP Surface Temperature Limits vs. WP Size or Capacity (PWR Assemblies; 60 GWd/MT Burnup)



Thermal conductivity for all media selected at 100°C.

Source: Hardin et al. FCRD-USED-2012-000219 Rev. 2. 2012

Repository thermal constraints can be met by:

1) Aging
2) Ventilation in the repository
3) Decreasing package thermal output (size and burn-up)
4) Increasing package and drift spacing in the repository

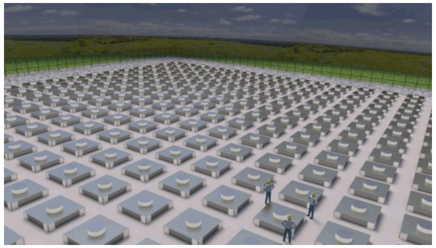
Nrc.gov

Problem: We will have ~10,000 DPCs, many of which are to hot and heavy to directly dispose.

- We will have thousands of DPCs by the time a repository is scheduled to open.
  - Many may require decades of cooling time before transportation and storage.
  - Many may require centuries of cooling time before geologic disposal.

- The current method of packaging is not a workable solution and forces us into one of three options:
  - Repackage
  - Find a way to dispose
  - Leave them in place

Holtecinternational.com



Long Term Storage

Can We Store Long-Term?

Degradation mechanism of concern Stress Corrosion Cracking: Can the Stainless Steel Canister last long enough?

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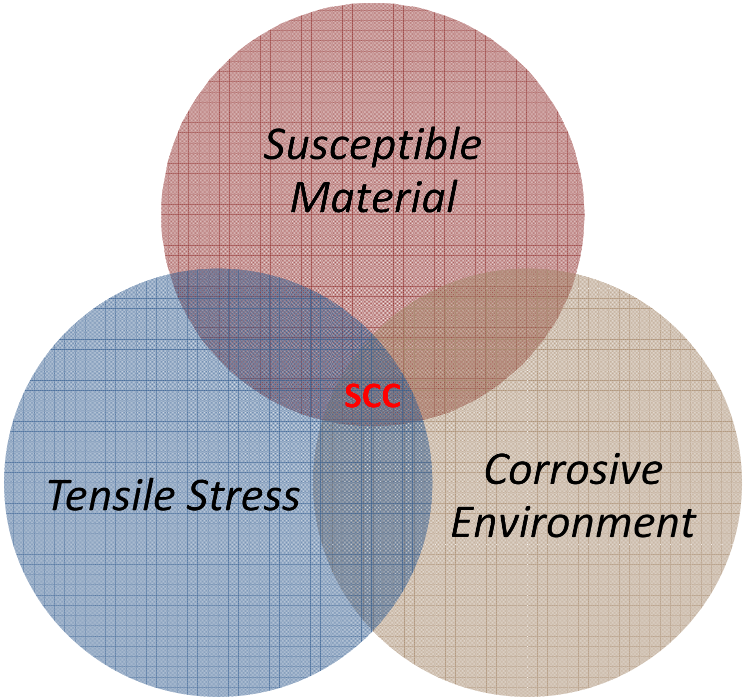


Questions that need to be answered:

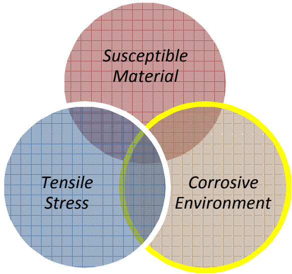
1. Will a chloride bearing environment form on the surface of the containers?
2. Is the material of construction for fielded interim storage containers susceptible?
3. Is there a sufficiently large tensile stress to support crack initiation and propagation in fielded interim storage containers?

Is the dust on DPCs Corrosive?

Calvert Cliffs, Hope Creek and Diablo Canyon – Dust Sample Results

Typical Calvert Cliffs Analytical Results

Ion	EPRI #1 filter	EPRI #1 pad	EPRI #4 filter	EPRI #4 pad
Na^{+}	19.2	14.8	n.d.	11.3
K^{+}	18.1	13.7	1.05	7.75
Ca^{+2}	77.1	20.6	24.1	153
Mg^{+2}	16.9	6.0	1.95	17.6
F^{-}	0.30	0.61	n.d.	n.d.
Cl^{-}	5.64	n.d.	n.d.	3.10
NO_3^{-}	21.3	9.09	4.34	14.2
SO_4^{-2}	89.7	51.5	48.0	291
PO_4^{-3}	6.68	2.05	0.45	n.d.
Total mass, µg	255	118	80	498

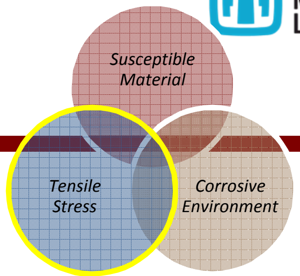


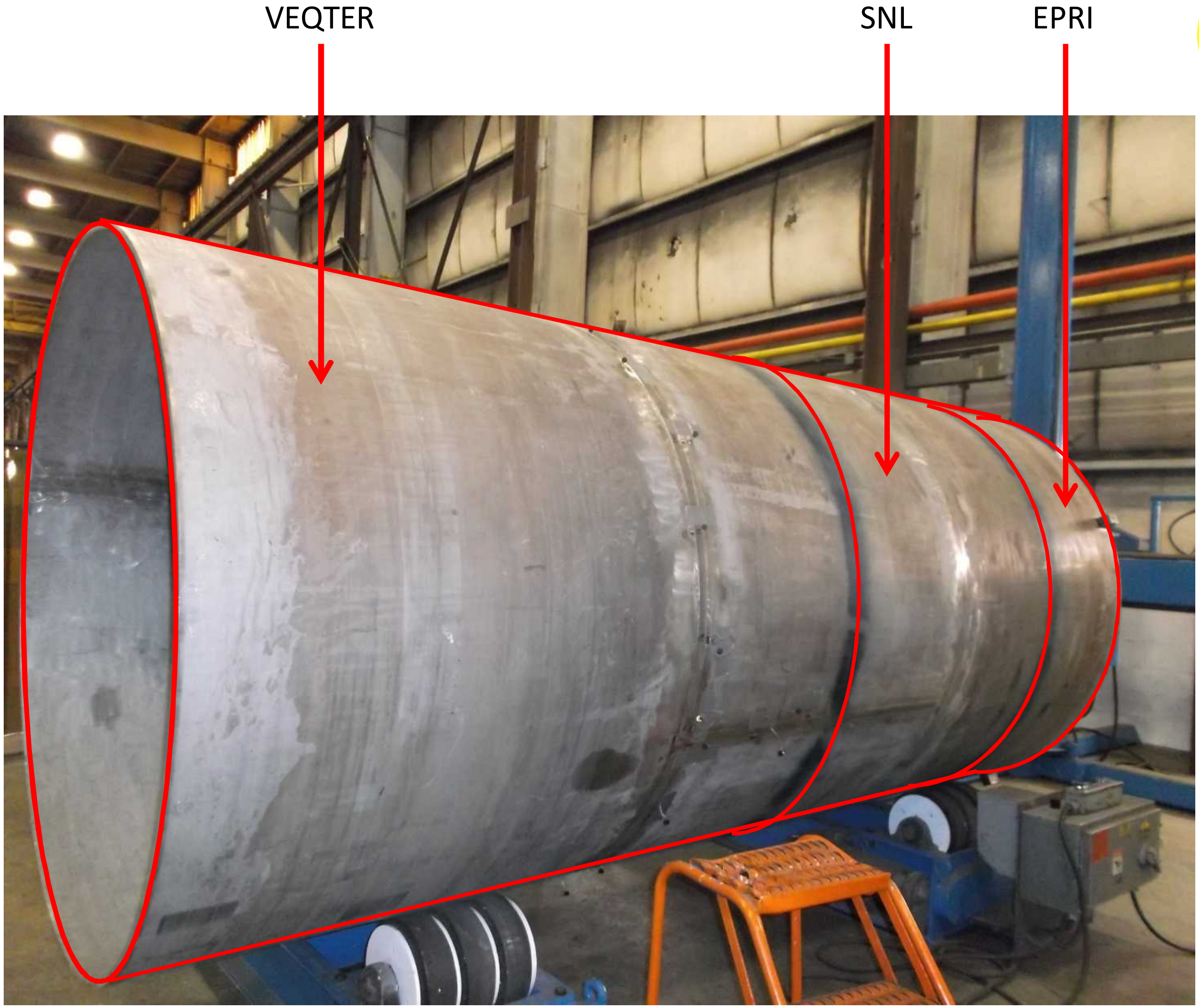
- Chloride bearing salts likely in some locations

Future work:

Understanding potential brine chemistry on container surface. Which salts last on the container?
How does this vary around the country Are there geographic locations that we need to watch closely?
How susceptible is the metal to the concentrations of salts we see in the samples?

Is there enough tensile stress to allow a crack to propagate through?





In FY16, residual stress will be quantified at welds, weld repairs, heat affected zones, and away from welds.

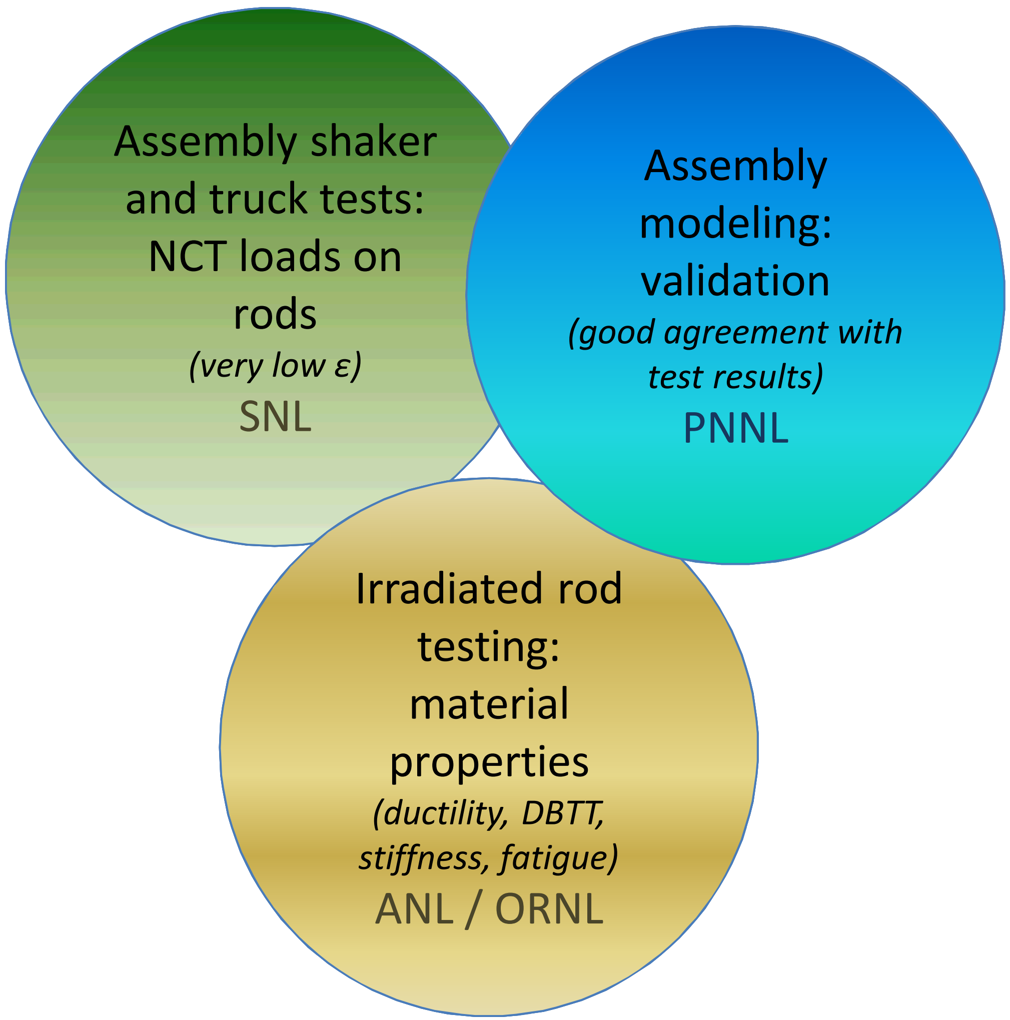
Summary and Future Direction

- Large existing fleet of storage containers made from welded 304SS, located at both marine and inland sites
  - ☑ Material known to be susceptible to SCC
  - – Chloride bearing salts likely in some locations
  - – Residual stresses at welds could be significant and tensile in nature

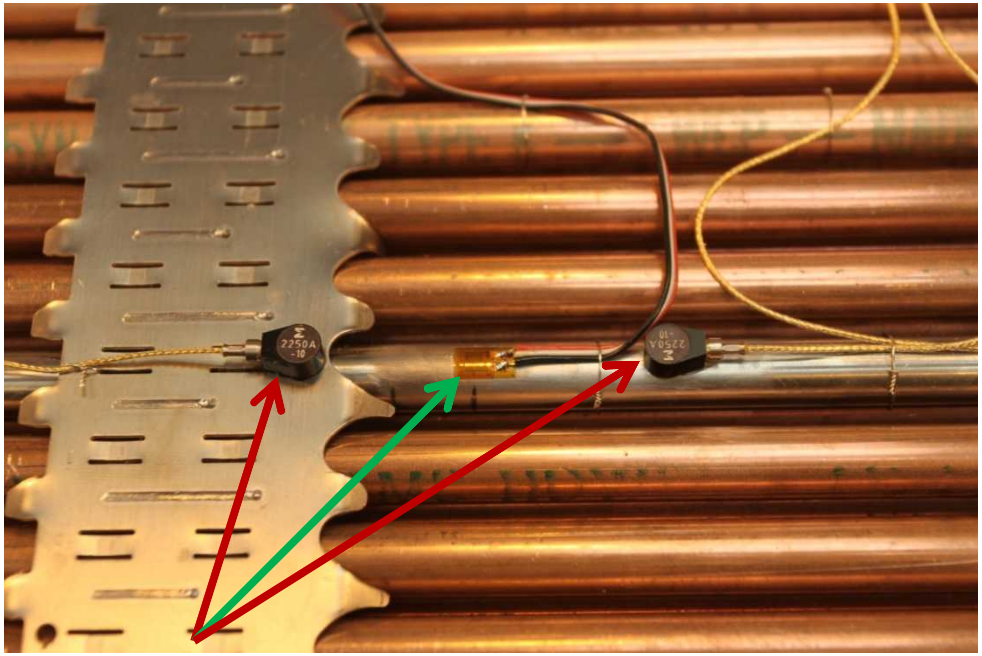
- Moving Forward, research will focus on
  - – Quantifying residual stress state at welds and weld repairs in full scale mock-container
  - – Exploring susceptibility of welded material to both localized corrosion and stress corrosion cracking initiation and propagation

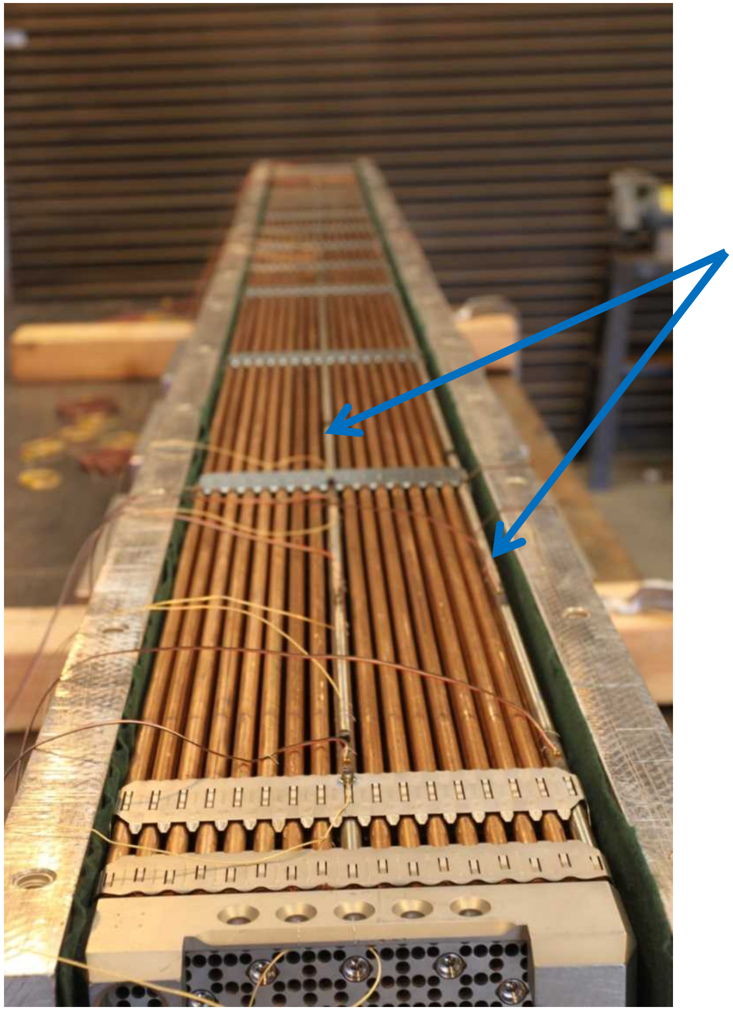
Normal Conditions of Transport Stress and Strain

Can irradiated rods withstand NCT?



A Surrogate Assembly was instrumented to measure stress and strain. Copper and Zirc rods were used that contained both lead rope and Pb and Mo pellets.





We drove it 40 miles over a range of Road Conditions in Albuquerque

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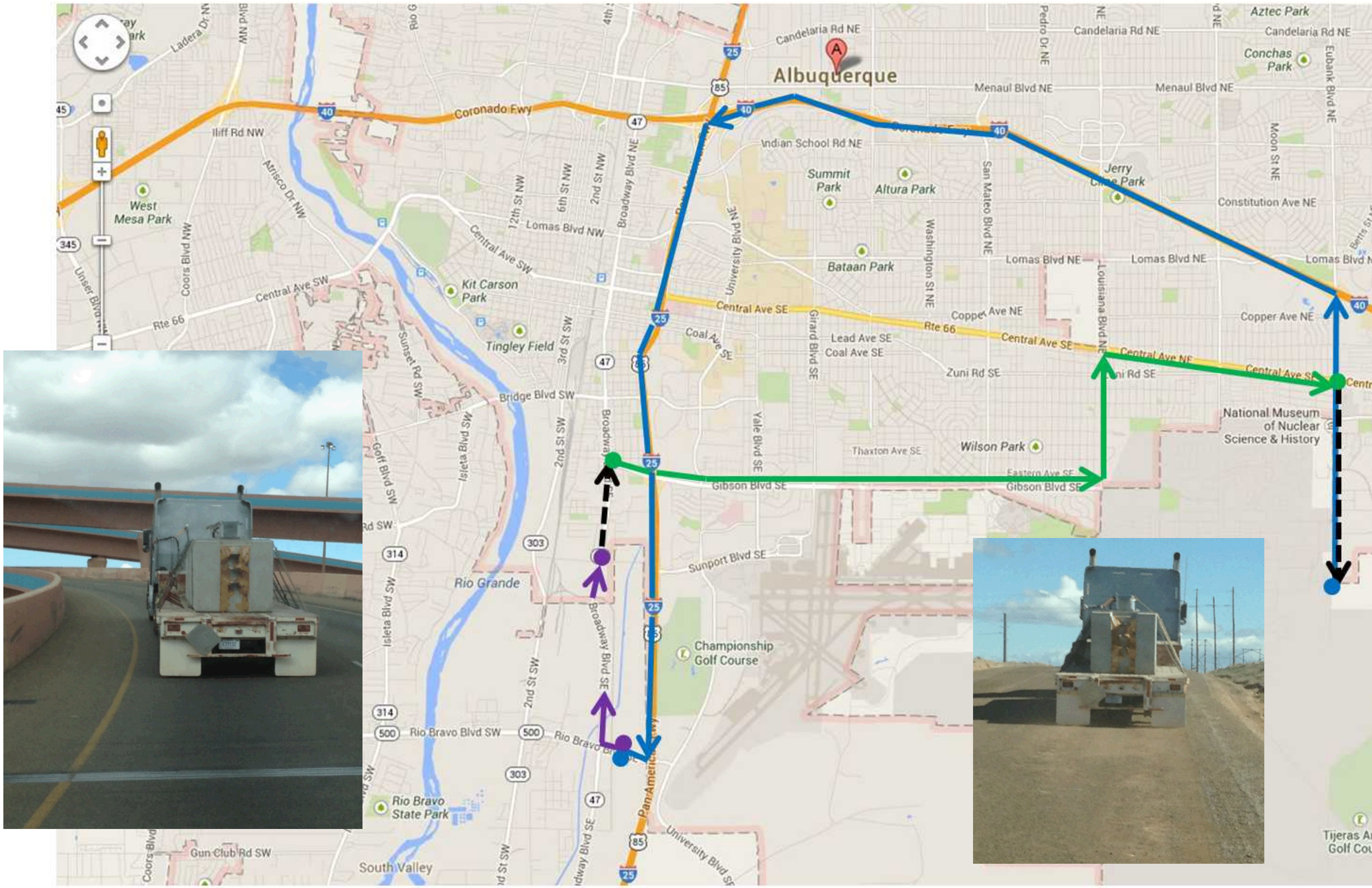
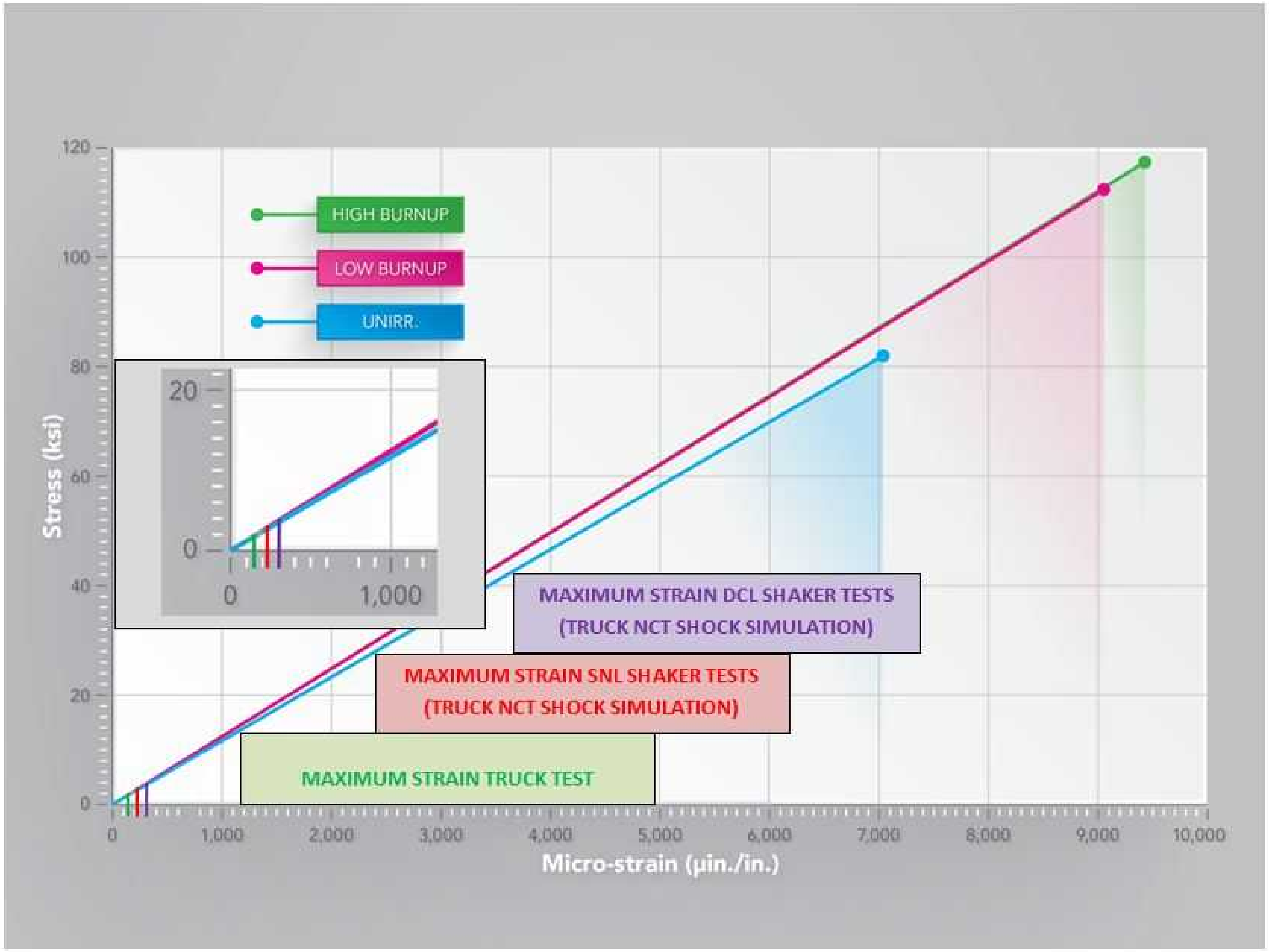


A Shaker Table was used for Rail Shock and Vibrations.

Measured strains very low relative to elastic limit of Zircaloy

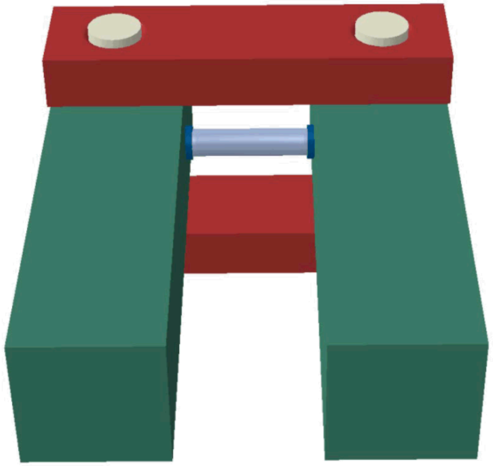


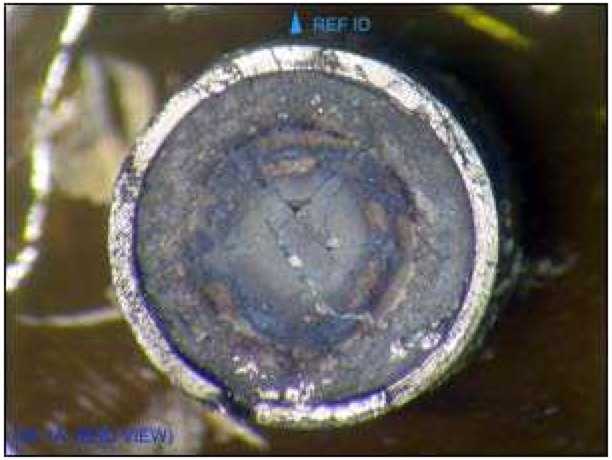
McConnell, FCRD-UFD-2015-000128

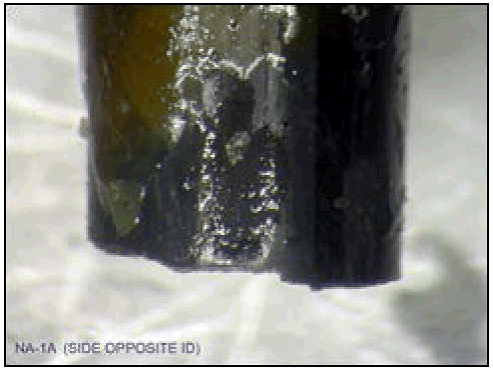
Maximum strain for any of the rail NCT tests was for a shock test (v. vibration): 241 micro-inch/inch

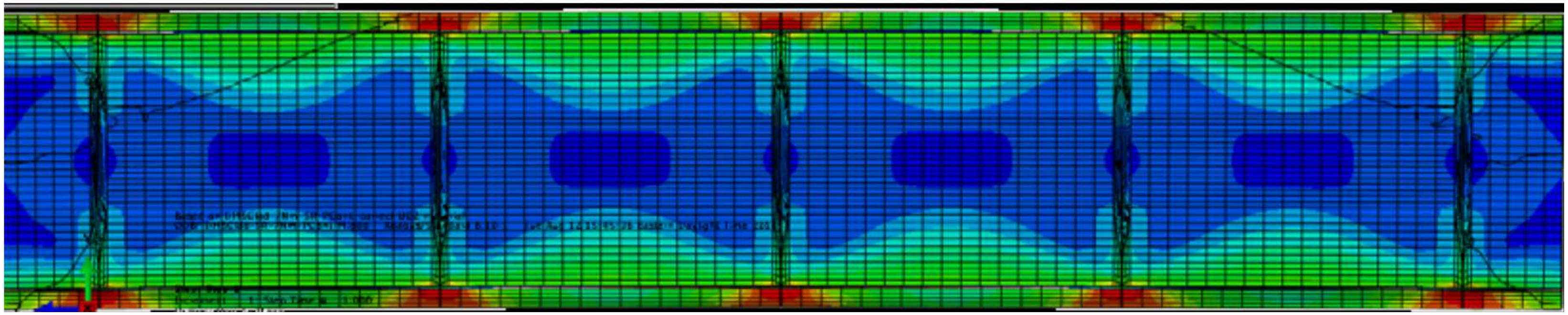
Future work will focus on an over the-rail test with surrogate assemblies in a real cask.

Fatigue and Pellet-Clad Interaction was studied in an ORNL Hot Cell and modeled.





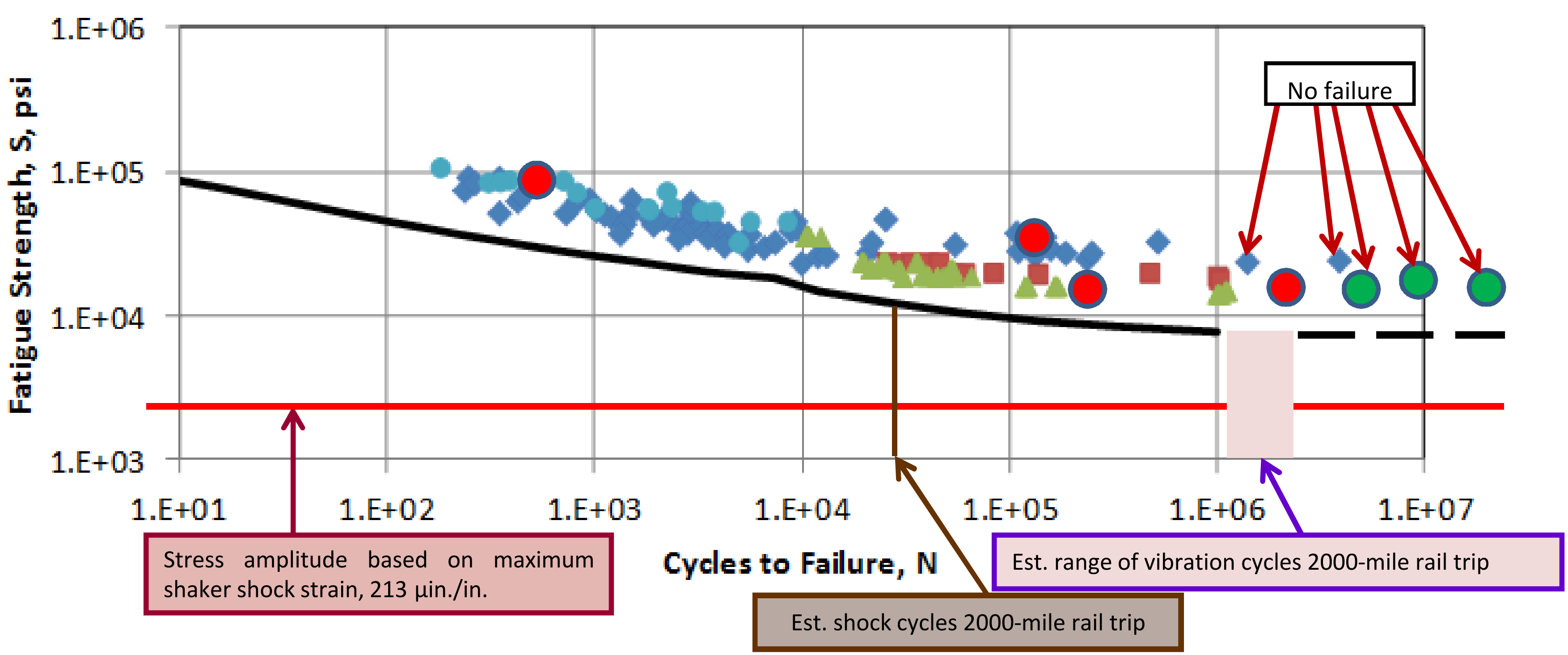




- Results showed the Pellet-Pellet and Pellet-Clad Bonding allowed the pellets to absorb much of the stress. This caused the rod to withstand greater fatigue cycles than anticipated.
- Future work will focus on understanding the degree of bonding at lower burn-up rod ends.

J.-A. Wang, M2-FCRD-UFD-2014-000053

The collection of data show that Normal Conditions of Transport is unlikely to result in failure



Fatigue design curve (▬▬): O'Donnel and Langer, "Fatigue Design Basis for Zircaloy Components," Nucl. Sci. Eng. 20, 1, 1964. (cited in NUREG-0800, Chapter 4)

Data plot courtesy of Ken Geelhood, PNNL
The large circles are ORNL HBR data

Strategic Planning

Are we spending our money effectively?

Are We Doing the Right Work?

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All DOE Storage and Transportation R&D is Prioritized per the *R&D Review & Plan* and *2012 Gap Analysis*

Each deliverable M3 and M2 from 2010-2014 is summarized.

Confirmed that we are still on track with regards to the 2012 Gap Analysis.

Used Nuclear Fuel Extended Storage and Transportation Research and Development Review and Plan

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

Christine T. Stockman (SNL)
Brady D. Hanson (PNNL)
Steven C. Marschman (INL)
Halim A. Alsaed (ENS)
Ken B. Sorenson (SNL)

August 9, 2014
FCRD-UFD-2014-000050

What have we Learned in 5 years? What do we need to learn?

Report looked at each gap from 2012 report and documented:

1. What we have learned in 5 years.
2. What we still need to learn.
3. Revised the ranking.

Gap/Activity	Revised Rank	Initial Rank	Recommended R&D for the Next Three Years
Stress Profiles	1	1	Ongoing
	What we have learned: Initial tests provide promising results that the loads on SSCs under normal conditions for storage and transport are below the failure limits for non-degraded materials.		
	What we still need to learn: Additional information, especially for rail transport that will most likely be the predominant means of transportation, is necessary to determine the various loads. Failure limits of materials can vary depending on the stress mode (e.g., pinch vs. bending); it is also necessary to assure that future tests measure the loads in these various directions.		

FCRD-UFD-2014-000050

DOE High Priority:
Obtain Data on Storage of HBU Fuel

Confirm how High Burnup Fuel will age over ten years in Storage.

DOE Full Scale HBU Confirmatory Demo

Goal: To support license renewals and new licenses for Independent Spent Fuel Storage Installations (ISFSIs), and support transportation licensing for high burnup SNF.

- 32 PWR Assemblies
  - All HBU and as hot as possible
    - 4 types of Cladding
- Obtain baseline data on <25 sister rods. Test plan is in progress in FY16.
- Obtain data on canister
  - Temperature, fission gas, hydrogen, oxygen
- Sister pins were pulled this year. Cask will be loaded with 32 assemblies in 2017 and stored for ten years.

Security

Sam Durbin will present during this meeting.

Disposal

Accomplishments in Disposal Research

- Completed *Evaluation of Options for Permanent Geologic Disposal of Used Nuclear Fuel and High-level Radioactive Waste Inventory in Support of a Comprehensive National Nuclear Fuel Cycle Strategy*
  - Conclusion: multiple disposal options are available for all existing and currently projected waste forms except sodium-bonded fuels, for which more information is needed

- Multiple international collaborations are ongoing and are an integral part of UFD's disposal R&D

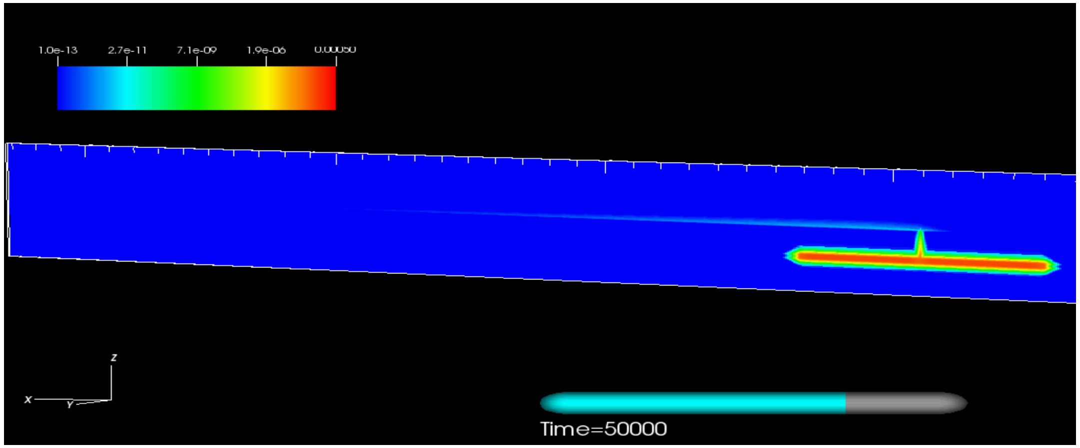
- Updated analyses of dual-purpose canister (DPC) disposal alternatives indicate that DPC direct disposal could be technically feasible, at least for certain disposal concepts

- Identified RD&D needs for evaluating feasibility of deep borehole disposal of small HLW waste forms, providing the foundation for planning a deep borehole field test

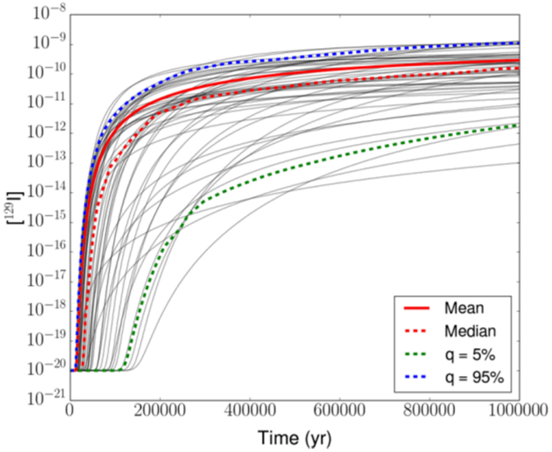
Generic Disposal System Analysis

Probabilistic THC Simulations and Sensitivity Analyses

- Generic salt repository reference case with
  - spatially-varying waste degradation (160 individual waste packages)
  - decay heat and thermal effects
  - fluid flow, radionuclide mobilization and transport, and a coupled biosphere



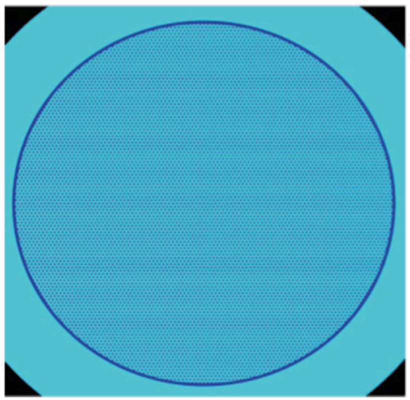
- Sensitivity analyses from 100 realizations with 10 varying parameters



G. Hammond (SNL), G. Freeze (SNL), W.P. Gardner, (SNL), S.D. Sevougian (SNL), D. Sassani (SNL)

Preliminary Study of DPC Direct Disposal Alternatives

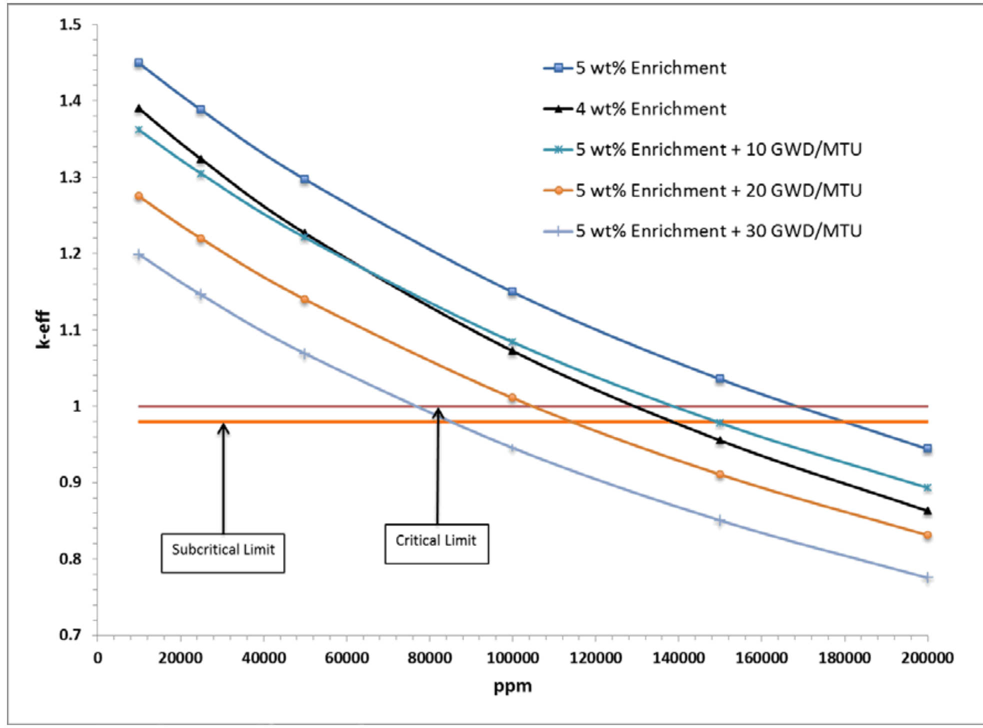
Postclosure Nuclear Criticality of SNF in Dual-Purpose Canisters Flooded with Chloride Brine and Degraded



Bounding-Type Configuration of Fuel Rods in a DPC

Hypothetical Neutron Multiplication Factor (keff) vs. Chloride Concentration

(NaCl saturation at 20°C gives 158,000 ppm chloride)



Conclusion: Groundwater salinity (^{35}Cl) could allow exclusion of postclosure criticality from performance assessment for direct disposal of most DPCs in a salt repository.

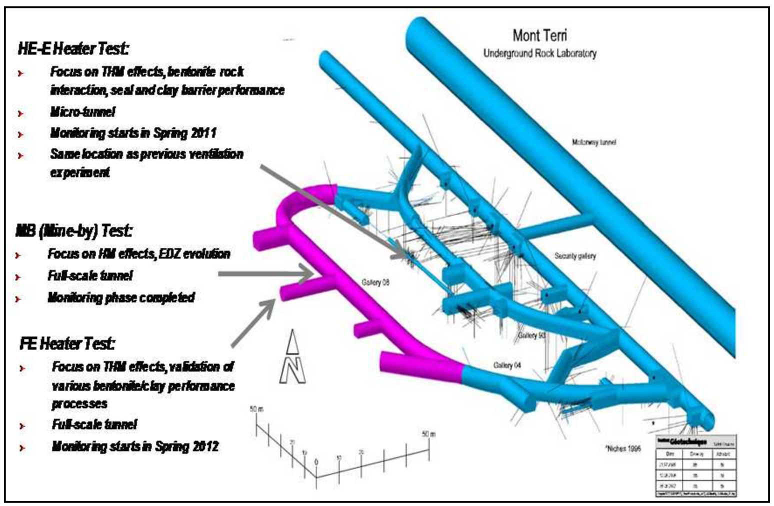
John Scaglione, Justin Clarity and Rob Howard (ORNL); Ernest Hardin (SNL)

Deep Borehole Disposal Concept

- Waste disposal in boreholes in basement rock (granite) at up to 5,000 m depth
- Very old, saline, immobile groundwater
- Borehole diameter 25 to 45 cm
- Up to 400 steel waste canisters for HLW, possibly SNF
- Boreholes would be sealed with clay, cement, concrete
- Sandia leads an ongoing field demonstration project, with drilling planned to begin in 2016

Disposal R&D International Collaboration

Sandia has a leadership role in formal, collaborative R&D arrangements with ongoing programs in Europe and Asia



- **Mont Terri**: Underground research laboratory in clay (Swisstopo, Switzerland)
- **Grimsel**: Colloid Formation and Migration Project in granite (NAGRA, Switzerland)
- **KAERI** Underground Research Tunnel: Borehole Geophysics (South Korea)
- **SKB**: Task Forces on Groundwater Flow and Engineered Barriers at Äspö Hard Rock Laboratory (Sweden)
- **BMWi**: Data exchange for salt repositories at Gorleben and WIPP (Germany)
- **ANDRA**: Natural and Engineered Barriers in clay and shale (France)
- **DECOVALEX**: (Development of Coupled Models and their Validation against Experiments)

Societal Aspects

The science is challenging.
The engineering is challenging.
The societal aspects are challenging.
Together, they make a very difficult issue.

ISF Siting Process:
Who Should Have Veto Power?

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Select all of the following that you think should be allowed to block or veto construction of a proposed interim storage facility for used nuclear fuel.

	%
A majority of citizens, including those in Native American communities, residing within 50 miles of the proposed facilities	66
A majority of voters in the host state, including affected Native American communities	64
The host state's environmental protection agency or its equivalent	55
The Governor of the host state	52
The US Environmental Protection Agency	50
The US Department of Energy	44
The US Nuclear Regulatory Commission	43
Either of the two US senators representing the host state	39
The US congressperson representing the host district	39
The leaders of the host state's legislature	39
Tribal authorities of affected Native American communities	38
Nongovernmental environmental interest groups in the host state	26

(e65)

Questions?