SAND2014-19168PE

Exceptional service in the national interest

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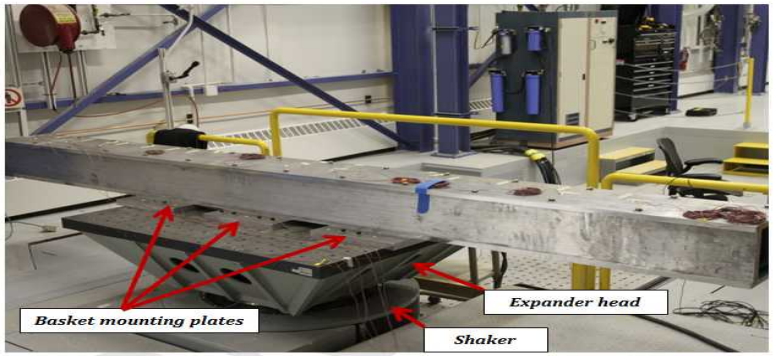

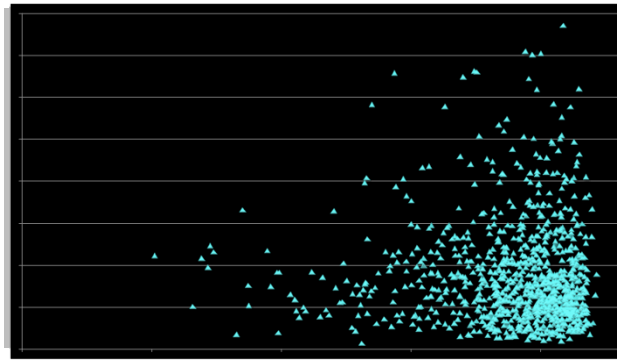

Current US DOE Used Fuel Disposition Storage and Transportation R&D Activities

Ken Sorenson and Sylvia Saltzstein, Sandia National Labs

2nd RCM on Demonstrating Performance of SNF and Related Storage System Components During Very Long-Term Storage

13 November 2014, Tokyo, Japan

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Used Fuel Disposition R&D Campaign

Mission and Participations

The DOE Office of Used Nuclear Fuel Disposition Research and Development and nine national laboratories participate in the DOE Office of Nuclear Energy's "Used Fuel Disposition Campaign"

Campaign Mission:
to identify alternatives and conduct scientific research and technology development to enable storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles

Sandia National Laboratories

Los Alamos National Laboratory

Pacific Northwest National Laboratory

Argonne National Laboratory

Sandia National Laboratories

Berkeley Lab

SRNL Savannah River National Laboratory

INL Idaho National Laboratory

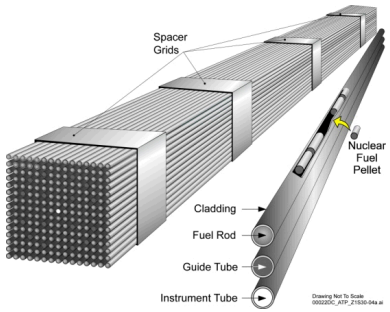
ornl Oak Ridge National Laboratory

Science in the National Interest
Lawrence Livermore National Laboratory

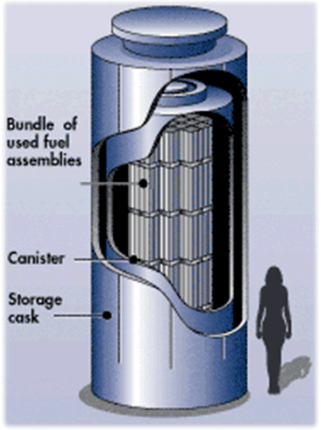
Contents

Overall Storage and Transportation R&D Objectives

- Status of High Burn-up related R&D work
  - Experiments
  - Transportation
  - Analysis
  - Security



http://energy.gov/sites/prod/files/styles/



www.nrc.gov/waste/spent-fuel-storage/

www.connyankee.com/

Storage and Transportation R&D Objectives

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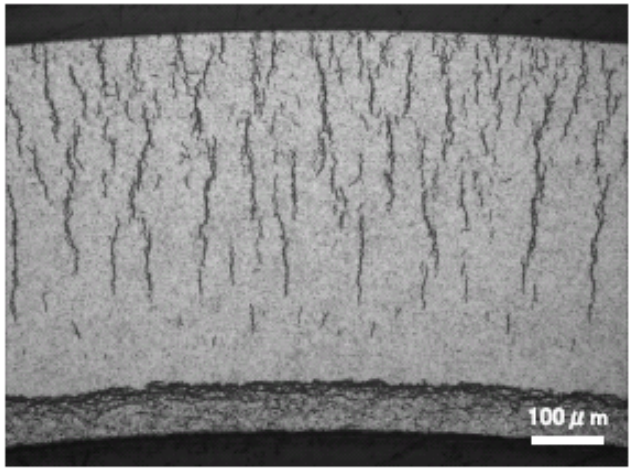
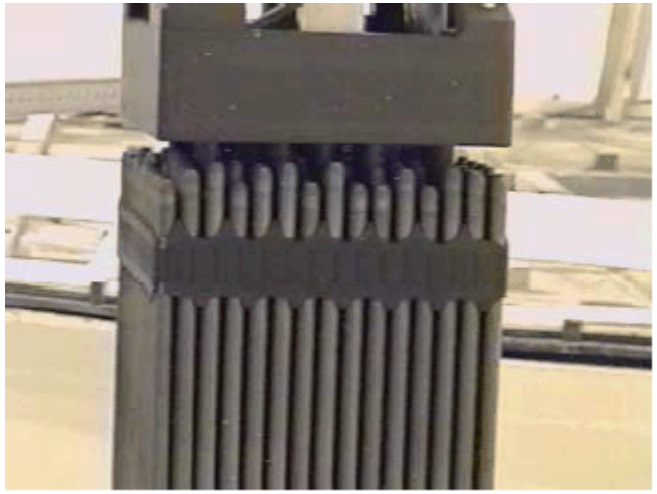
Overall Objectives:

1. *Develop technical bases for fuel retrievability and transportation after long term storage.*
2. *Develop the technical bases to demonstrate high burn-up used fuel integrity for extended storage periods.*
3. *Develop the technical basis for transportation of high burnup fuel.*





R&D Efforts Stem from "High" and "Medium" Gaps

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System Component	Issue	Importance of R&D
Cladding	**Annealing of Radiation Effects**	**Medium**
	Oxidation	**Medium**
	H_2 effects: Embrittlement	**High**
	H_2 effects: Delayed Hydride Cracking	**High**
	Creep	**Medium**
Assembly Hardware	**Stress corrosion cracking**	**Medium**
Neutron Poisons	**Thermal aging effects**	**Medium**
	Embrittlement and cracking	**Medium**
	Creep	**Medium**
	Corrosion (blistering)	**Medium**
Canister	**Atmospheric corrosion (marine environment)**	**High**
	Aqueous corrosion	**High**

Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

R&D Efforts Stem from "High" and "Medium" Gaps

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System Component	Issue	Importance of R&D
Bolted Direct Load Casks	**Thermo-mechanical fatigue of bolts/seals**	**Medium**
	Atmospheric corrosion (marine environment)	**High**
	Aqueous corrosion	**High**
Overpack and Pad (Concrete)	**Freeze/Thaw**	**Medium**
	Corrosion of steel rebar	**Medium**

Cross-cutting or General Gaps

- ***Temperature profiles for fuel*** — ***High***
- ***Drying issues*** — ***High***
- ***Monitoring*** — ***High***
- ***Subcriticality*** — ***High***
- ***Fuel transfer options*** — ***High***
- ***Re-examine INL dry cask storage*** — ***High***

Identification of these data gaps are used to inform new initiatives for FY15

Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

Storage & Transportation Management Structure

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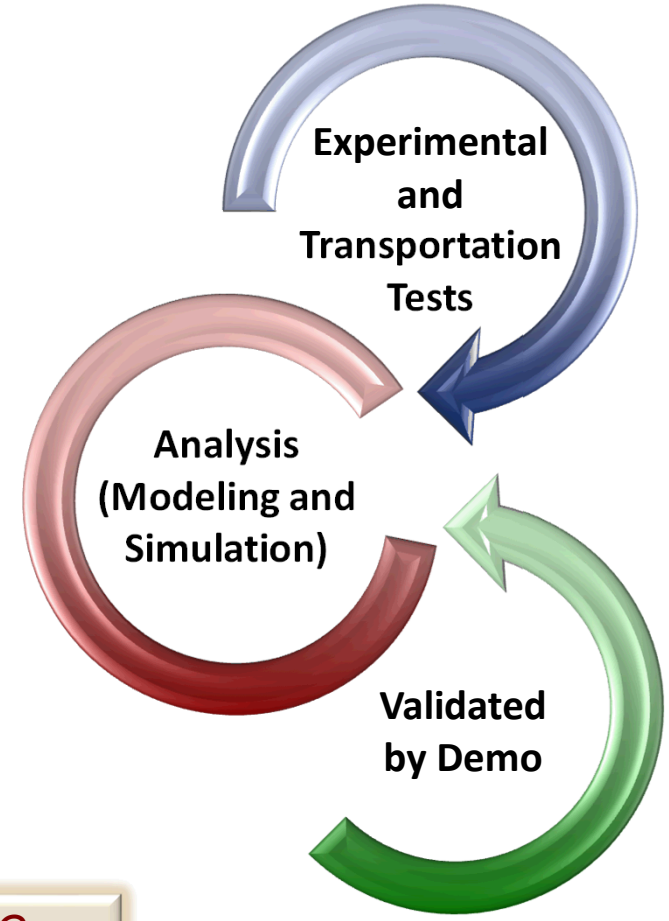
Five Control Accounts are designed to define the work to address the objectives:

- **Experiments**
- **Engineering Analysis**
- **Transportation**
- **Field Demonstration**
- **Security**



R&D Efforts Stem from "High" and "Medium" Gaps
FCRD-USED-2012-000109.

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EXPERIMENTS

Goal : Obtain data to confirm understanding of material degradation effects on cladding and canister materials during long-term storage conditions.

Experiments

Goal : Obtain data to confirm understanding of material degradation effects on cladding and canister materials during long-term storage conditions.

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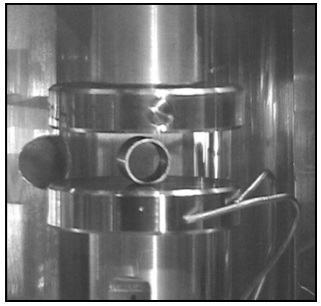
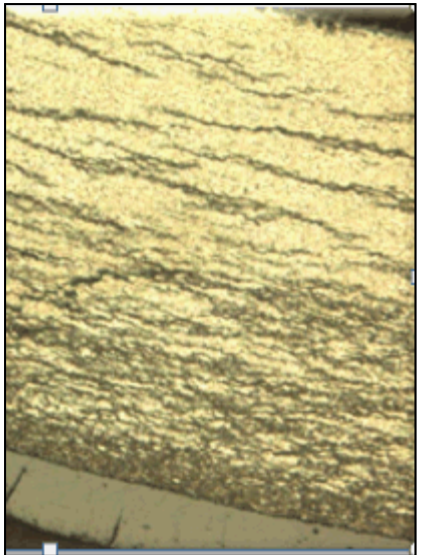
Fuel Cladding

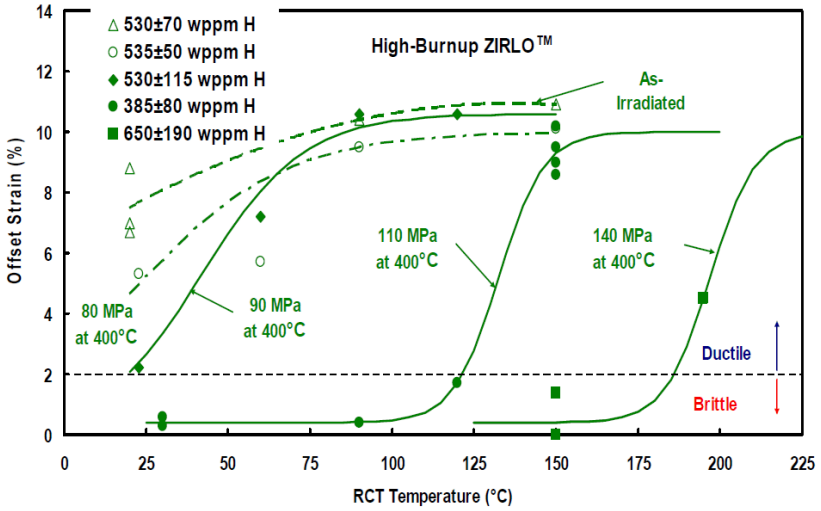
Conduct ring compression and DBTT tests on PWR high burnup spent fuel cladding

- ***Cladding types have significant differences in mechanical performance***
- ***Hydride orientation effects ductility***
- ***Thermal loadings effect hydride orientation and thus, ductility***
- ***Plenum pressures effect ductility***
- ***We are working to understand the coupling of these mechanisms***





Ring compression test on HB Zry-4
UFD Telecon, April 12, 2012
Billone, Liu; ANL



Experiments

Goal: Obtain data to confirm understanding of material degradation effects on cladding and canister materials during long-term storage conditions.

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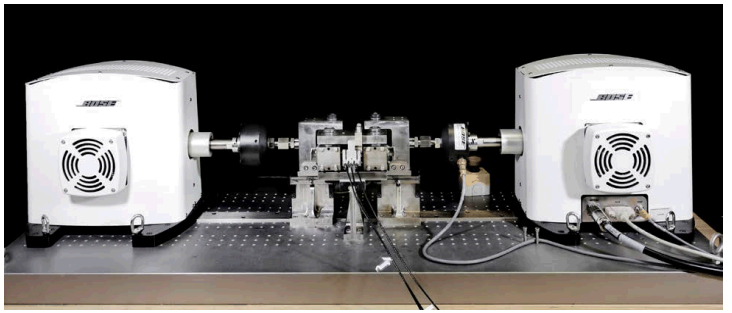
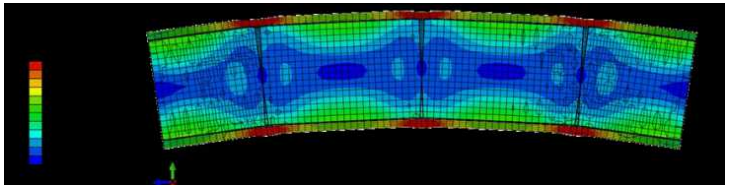
Fuel Cladding

Conduct vibration/fatigue tests on high burnup spent fuel rodlets

- ***Rod stiffness is highly dependent on pellet-to-pellet and pellet-to-clad interaction (i.e., interface bonding)***
- ***Flexural rigidity is inferred through deflection measurements (i.e., rod curvature)***
- ***This interaction acts to strengthen the mechanical behavior of the used fuel. This has positive implications for Normal Conditions of Transport***

Wang, Jy-An, CIRFT Test Framework and its Applications to SNF Vibration Reliability Investigation, 2014 ASTM C26 Committee Meeting, June 10-12, 2014





Jy-An, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

Experiments

Goal: Obtain data to confirm understanding of material degradation effects on cladding and canister materials during long-term storage conditions.

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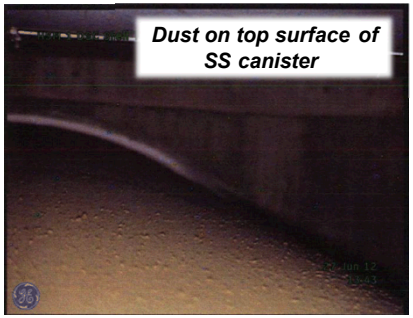
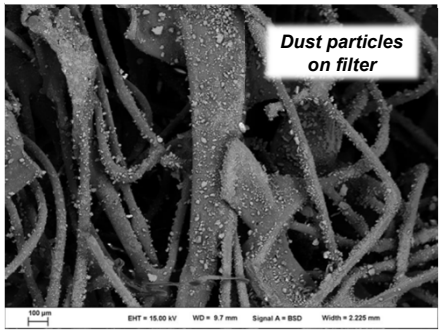
Purpose: Better understand canister degradation, support Aging Management Plans, and license extensions.

- ***Collect data to understand initiating conditions for corrosion conditions and progression of SCC-induced crack growth***
- ***Obtain site data to assess atmospheric conditions and compare with initiating conditions.***
- ***Procure a full scale (diameter) welded SS canister to investigate residual stresses due to plate rolling and welding.***

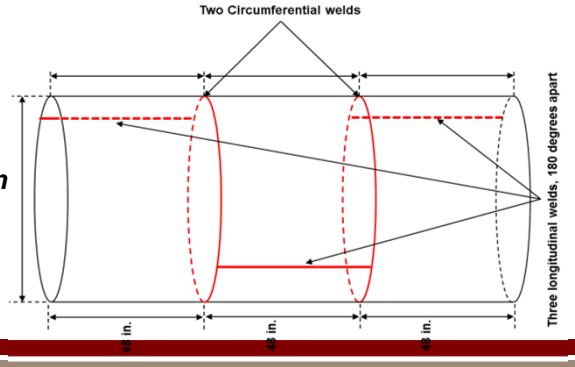

Sea Salt crystal with $MgSO_4$ inside found on Diablo Canyon Canister





Enos, et al., Data Report on Corrosion Testing of Stainless Steel SNL Storage Canisters, FCRD-UFD-2013-000324

Conceptual design for full-scale (diameter) SS welded canister



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TRANSPORTATION

Purpose: Will the fuel remain intact during transportation?

Transportation:

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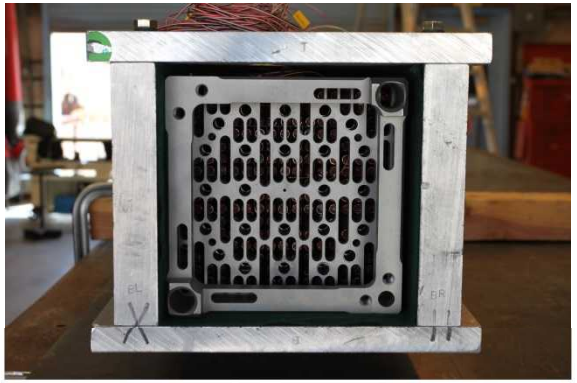
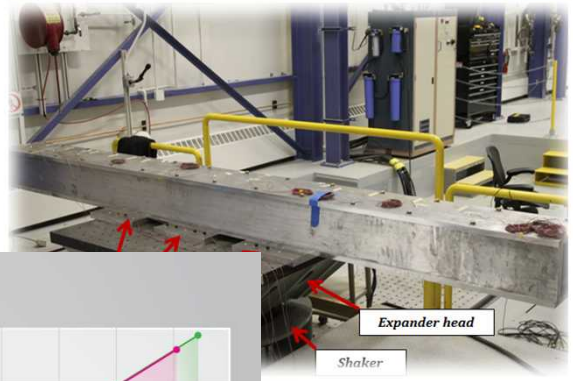
Purpose: Will the fuel remain intact during transportation?

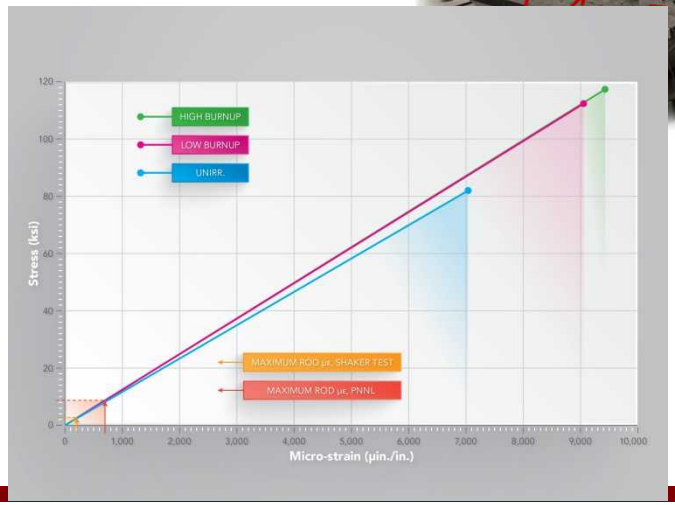
A surrogate assembly was subjected to truck data from a 700 mile trip on a shaker table and 50 miles on a real truck with representative weight.

- ***Data results were >10 times below yield strength.***
- ***The strains measured in both were an order of magnitude lower than either an irradiated or unirradiated Zircaloy rod yield strength.***

If high burnup fuel can maintain its integrity during transport, pressure will be taken off experimental R&D efforts associated with hydride effects on cladding strength and ductility.







Data collection and analysis for NCT loads on a surrogate fuel assembly

Sorenson, K., Determination of Loadings on Spent Fuel Assemblies During Normal Conditions of Transport, SAND2014-2043P.

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ANALYSIS

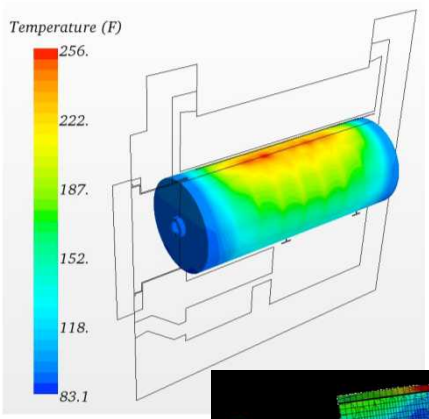
Purpose: Develop predictive models of material behavior to establish the technical bases for extended storage and transportation.

Analysis

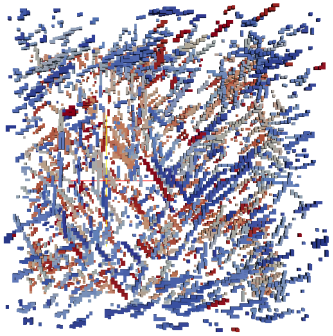
Purpose: Develop predictive models of material behavior

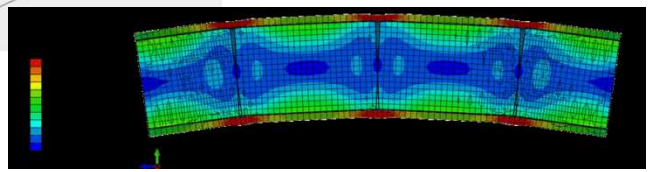
- **Predictive modeling**
  - ***Thermal Analysis (PNNL) to predict cool down, Ductile to Brittle Transition, deliquescence, etc.***
    - ***HBU Demonstration fuel selection and cool down***
    - ***Modern, high heat load, high capacity systems***
    - ***In-service inspections validation data***
  - ***Hybrid hydride reorientation model (SNL)***
  - ***Structural uncertainty analysis at assembly and canister level (PNNL)***
  - ***Finite element analysis validation with CIRFT and application to out-of-cell testing (ORNL)***
- **Thermal profile analyses**
  - ***Detailed thermal analyses for 2-3 licensed dry storage systems (PNNL FY15)***

CFD Thermal Analysis of Dry Storage Casks
Suffield, et al, PNNL-21788

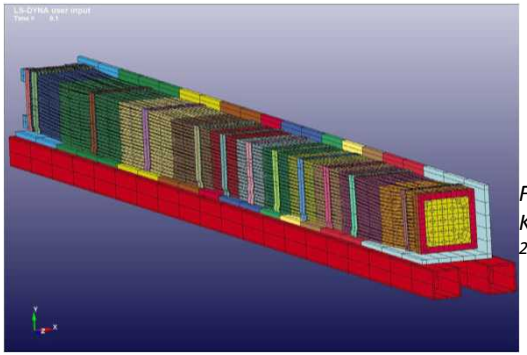


Model for Simulation of Hydride Precipitation, Tikare et al, FCRD-UFD-2013-000251.





Jy-An, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014



FE Models of Assembly
Klymyshyn, et al, PNNL, FCRD-UFD-2013-000168

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SECURITY

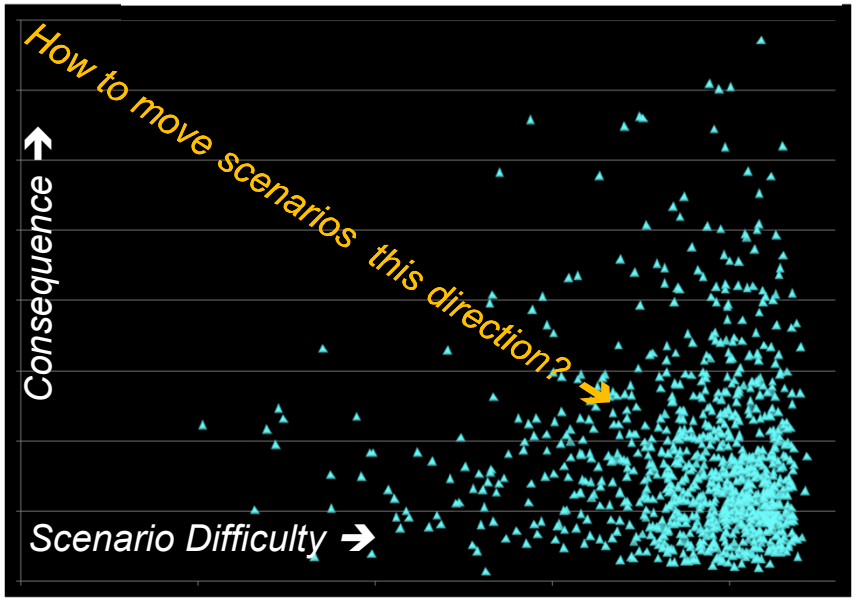
Purpose: Understand our vulnerabilities and how to mitigate risk.

Security

Purpose: Understand our vulnerabilities and how to mitigate risk.

- Assess current regulatory rule-making developments
- Assess security implications related to early shipments of used fuel
- Continue assessment of the regulatory rule-making process and changes being considered for UNF storage and transportation, especially as it relates to de-inventorying orphaned sites
- Conduct relative risk assessments to assess comparative risks given specific types of attack events

Attack scenarios that are both easier and high consequence are of greater risk. Focus security investments on these "high-risk" scenarios.



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STRATEGIC INITIATIVES

Purpose: What are the most important things for us to do?

UNF Extended S&T R&D Review and Plan

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1. Reviewed and summarized all (>180) DOE UFD reports written from 2010 to 2014.

2. Categorized UFD Reports into 15 high and medium gaps from previous Gap Analyses.
   - *Hydride reorientation and embrittlement,*
   - *Welded canister-atmospheric corrosion,*
   - *Bolted casks-embrittlement of seals,*
   - *Drying…*

3. Summarized for each gap:
   1. *What we have learned*
   2. *What we still need to learn*
   3. *Revised ranking*
   4. *Determination to continue or defer R&D efforts during the next three years.*

USED NUCLEAR FUEL EXTENDED STORAGE AND TRANSPORTATION RESEARCH AND DEVELOPMENT REVIEW AND PLAN

Fuel Cycle Research & Development

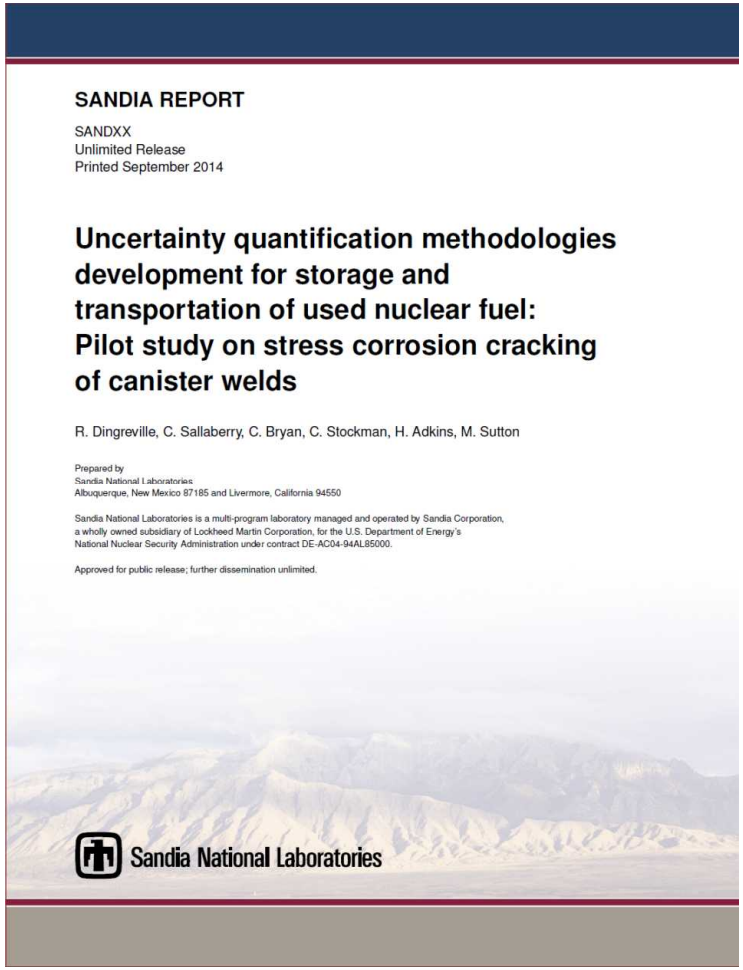
Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

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

Uncertainty Quantification

- **Purpose: To develop a methodology that will identify what data is the most important to close the technical gaps.**
  - ***Identify performance characteristics of a degradation mechanism.***
    - **Ex. CISCC**
  - ***Link the degradation mechanisms to the regulatory requirements.***
    - **Ex. no through-wall crack penetration.**
  - ***Understand the currently available data and identify the uncertainties with that data.***
    - **Ex. Chloride on canister, humidity, temperature, residual stress…**
  - ***Perform decision making analysis***
  - ***Identify most impactful data parameters.***
- **Final product will be a prioritized list of the most and least impactful data to close the gaps.**



SANDIA REPORT

SANDXX
Unlimited Release
Printed September 2014

Uncertainty quantification methodologies development for storage and transportation of used nuclear fuel: Pilot study on stress corrosion cracking of canister welds

R. Dingreville, C. Sallaberry, C. Bryan, C. Stockman, H. Adkins, M. Sutton

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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THANK YOU!

質問

QUESTIONS?