U.S. DEPARTMENT OF ENERGY | Nuclear Energy

High Burnup Spent Fuel Dry Storage and Transportation

Ned Larson
Office of Nuclear Energy

UFD Annual Meeting
June 7, 2016
UNLV

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UFD Milestone Types

Milestone Type	Number of Milestones
M2	20
M3	23
M4	37
M5	1
Total	81

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UFD M2 Milestones

Level	WP TItle	WBS Level 5	MS Title	Estimated Finish	Actual Finish
M2	DR Salt R&D - SNL	1.02.08.03.09.03	Proceedings from the 6th US/German Workshop on Salt Repository Research, Design and Operations	1/31/2016	1/18/2016
M2	ST Field Demonstration Support - PNNL	1.02.08.02.01.04	Sister Pin Test Plan	4/29/2016	4/28/2016
M2	ST Experiments - SNL	1.02.08.02.02.05	Canister Mock-up weld Residual Stress Final Report.	6/30/2016	
M2	Field Test Design - SNL	1.02.08.03.08.08	Deep Borehole Field Test Conceptual Design Report	6/30/2016	
M2	Project Integration and Concept Evaluation - SNL	1.02.08.03.08.09	Deep Borehole Field Test Project Plan, Revision 1	6/30/2016	
M2	Program Planning - SNL	1.02.08.05.03.01	Draft Program Plan for the Permanent Disposal of High-Level Radioactive Waste and Spent Nuclear Fuel from Defense and Department of Energy Research and Development Activities	7/29/2016	
M2	ST Experiments - ANL	1.02.08.02.02.01	Documentation of Data Collection of Lower Temp Fuel Cladding Ring Compression Tests	8/30/2016	
M2	Site Characterization - SNL	1.02.08.03.08.07	Deep Borehole Field Test Laboratory and Borehole Testing Strategy	8/31/2016	
M2	Site Geoscience Data Evaluation - SNL	1.02.08.03.08.06	Integrated Geoscience Data and Evaluation of Geologic Conditions for the Deep Borehole Field Test Site	9/9/2016	
M2	ST Experiments - ORNL	1.02.08.02.02.03	Documentation of Data Collection of CIRFT Tests (update of FY15 report)	9/15/2016	
M2	DR Argillite Disposal R&D - SNL	1.02.08.03.02.07	Evaluation of Used Nuclear Fuel Disposition in Clay-Bearing Rocks	9/15/2016	
M2	ST Transportation - SNL	1.02.08.02.04.02	Develop test plan for future rail transportation tests	9/15/2016	
M2	Project Integration and Concept Evaluation - SNL	1.02.08.03.08.09	Deep Borehole Disposal Safety Analysis	9/16/2016	
M2	Establish organizational framework to meet regulator expectations - SNL	1.02.08.05.03.02	Generic Organizational and Procedural Framework for DOE Managed HLW and SNF Licensing	9/16/2016	
M2	DR Crystalline Disposal R&D - SNL	1.02.08.03.03.08	Evaluation of Used Nuclear Fuel Disposition in Crystalline Rocks	9/21/2016	
M2	Complete and populate online waste library (OWL) - SNL	1.02.08.05.01.04	The On-line Waste Library (OWL): Usage and Status Report	9/23/2016	
M2	DR International Disposal R&D - LBNL	1.02.08.03.05.01	International Collaboration Activities in Different Geologic Disposal Environments	9/23/2016	
M2	ST Analysis - PNNL	1.02.08.02.03.03	High Heat Load Thermal Analysis	9/29/2016	
M2	EBS concepts and thermal analysis - SNL	1.02.08.05.02.01	Status of Progress Made Toward Preliminary Design Concepts for the Inventory in Select Media for DOE Managed HLW/SNF	9/30/2016	
M2	Total system performance assessment - SNL	1.02.08.05.04.06	Status of Progress Made Toward Safety Analysis and Technical Site Evaluations for DOE Managed HLW and SNF	11/3/2016	

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FY16 Storage and Transportation R&D Funding

FY16 Funds Storage and Transportation R&D Activities	Total
S&T Activities	**$7,300,000**
ST Analysis	$775,000
ST Experiments	$3,400,000
ST Field Demonstration Support	$2,300,000
ST Security	$25,000
ST Transportation	$800,000
EPRI - DOE High Burnup Demonstration Project	**$4,500,000**
High Burnup Cask Demo Project	$4,500,000
Grand Total	**$11,800,000**

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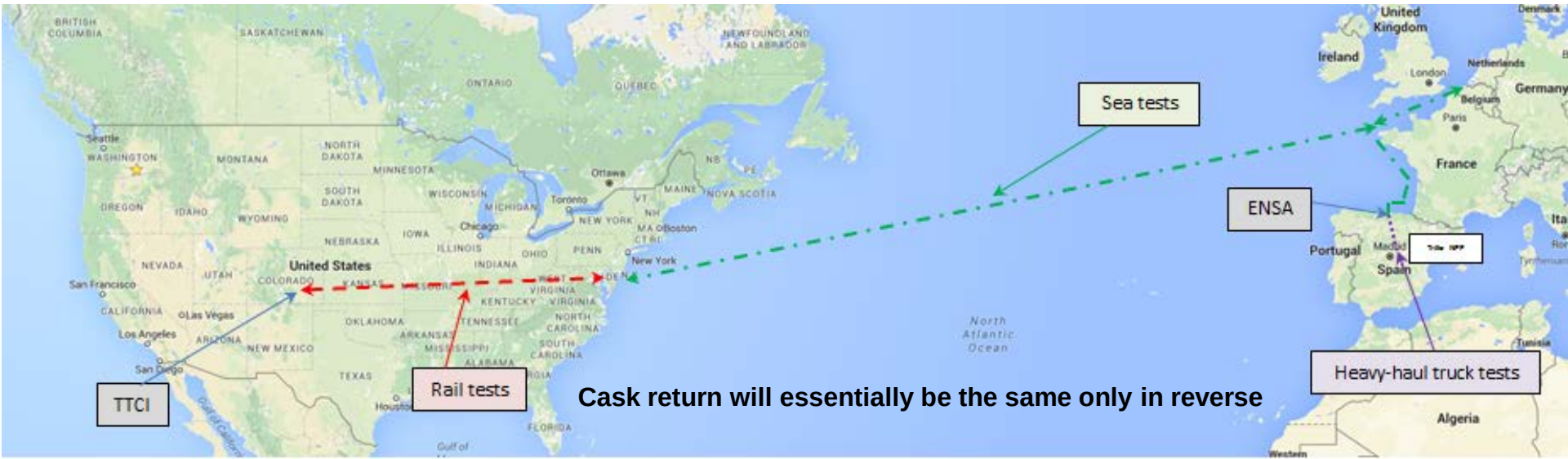
Joint ENSA – DOE Handling and Transportation Test

- **Work with ENSA to gather both handling and transportation data**
- **Almost all types of handling and transportation will be experienced**
  1. Heavy-haul truck from Santander, Spain to Trillo NPP
  2. Coastal sea shipment from Santander to a large European port: e.g., Zeebrugge, Belgium
  3. Ocean transport from Zeebrugge to an Eastern U.S. port (e.g., Baltimore)
  4. Commercial rail shipment from U.S. Eastern port (e.g., Baltimore) to Pueblo, CO
  5. Testing at Transportation Technology Center, Inc. (TTCI) in Pueblo, CO



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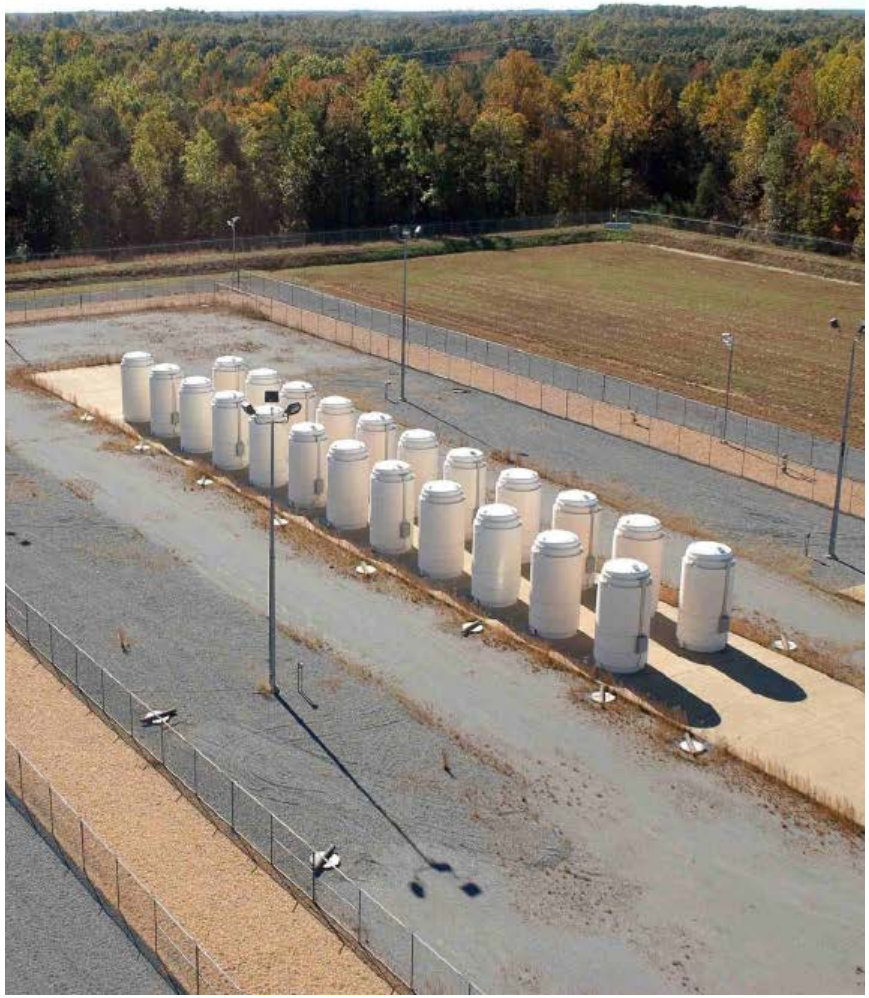
High Burn-up Confirmatory Data Project: Dry Storage R&D Project

- **Major Steps**
  - Loading a commercial storage cask with high burn-up fuel in a utility storage pool
    - Well understood fuel
    - Cask outfitted with temperature instrumentation for monitoring
  - Drying of the cask contents using typical process
  - Housing cask at the utility's dry cask storage site
    - Monitored and externally inspected until the first internal inspection at 10 years
  - Determining details of where and how the cask will be opened will be solved at a later date.



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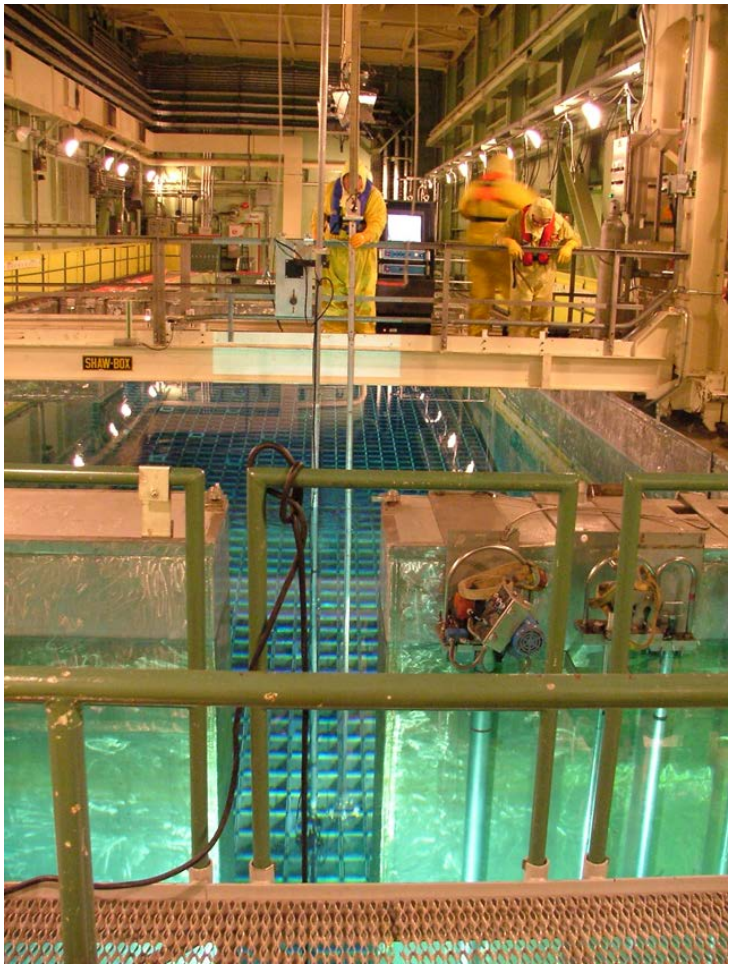
Activities for the EPRI Contract 2013-2018

- Acquire the cask
- Modify the cask lid for instrumentation
- Develop a design and licensing basis document
- Submit License Amendment Request
- Extract sister rods
- Plan the fuel loading
- Ship sister rods
- Secure the license amendment
- Load fuel in the cask
- Store the cask at North Anna
- Begin monitoring the cask and take internal gas samples

Note: Indicates completed activities



North Anna Pool and Fuel Handling

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TN32B Cask is being Prepared

TN 32B cask leaving Precision Custom Components in York, PA

TN 32B cask being placed in Columbiana Hi Tech Building in Greensboro, NC

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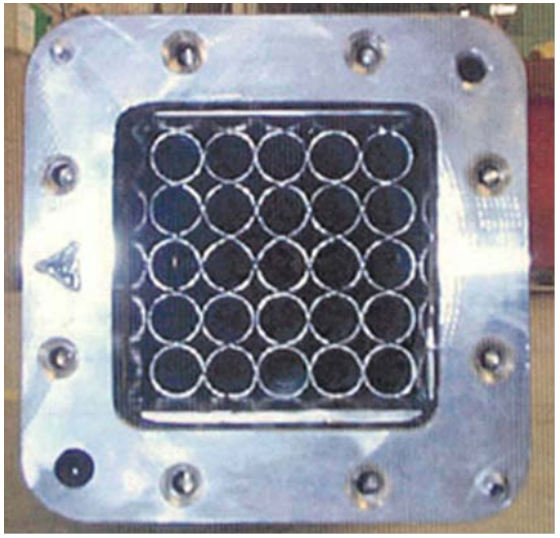
Sister Rod Selection

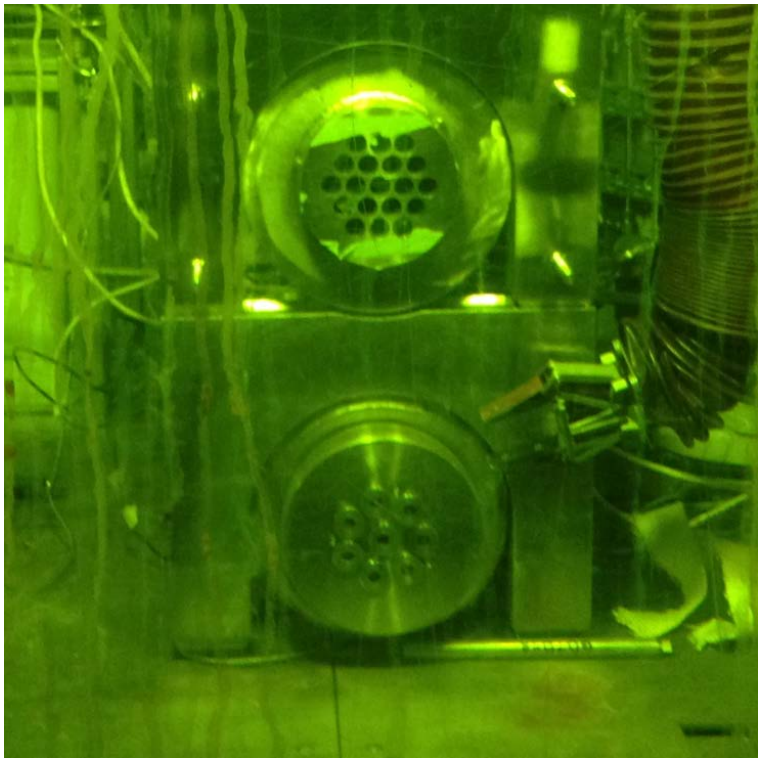
- **Individual rods have been pulled to perform characterization and material property tests to obtain initial cladding conditions prior to storage**
- **25 fuel rods from representative fuel assemblies**
- **These rods will form the baseline for pre- storage characterization**
  - Nine Areva M5™ rods
  - Nine Westinghouse Zirlo™ rods
  - Four Westinghouse Low-tin zircaloy-4 rods
  - Three Westinghouse standard zircaloy-4 rods



NAC LWT basket for shipping rods

Sister Rod Testing

- Sister rods were shipped from North Anna to ORNL in early 2016
- Sister Rods are in an Oak Ridge National Lab hot cell



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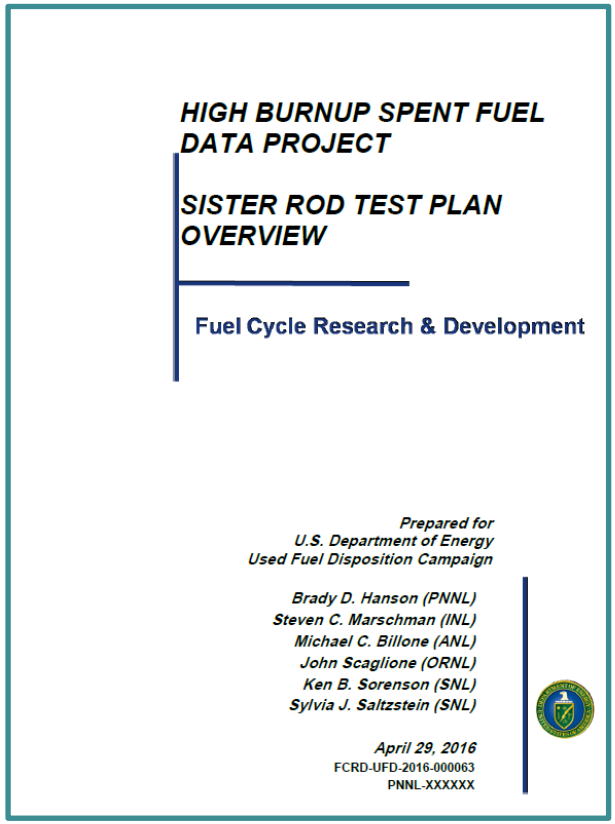
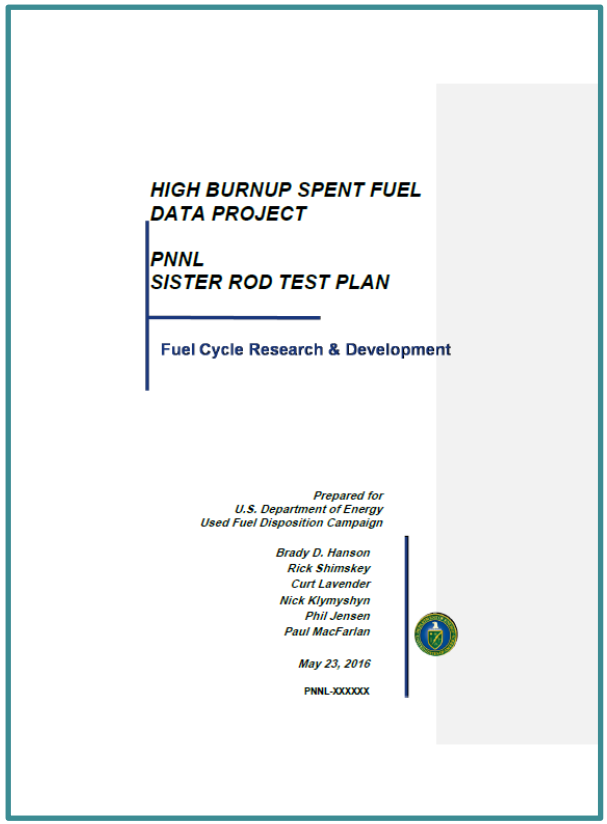
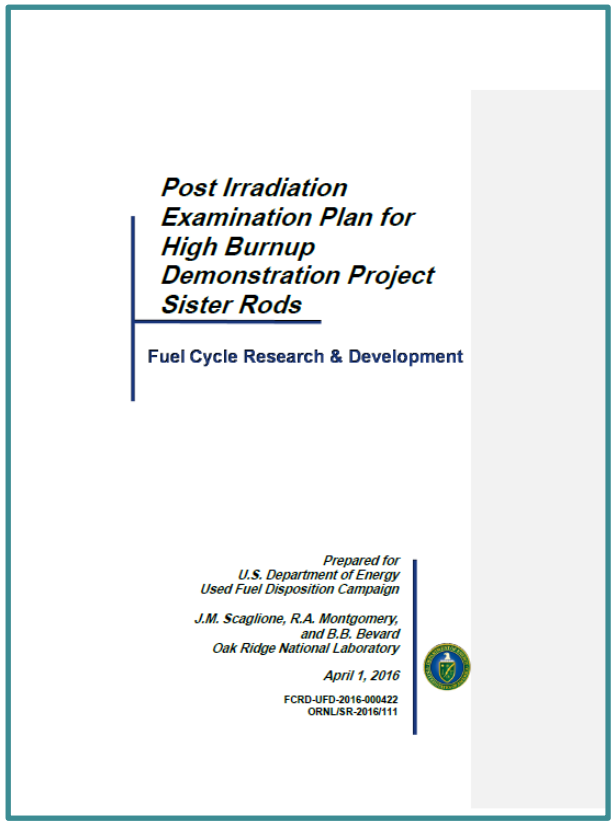
Sister Rod Test Plans







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NE University Programs (NEUP) for Storage and Transportation

Total Available Budget Area and Fiscal Year Award	Total
Storage & Transportation	**$27,433,384**
(11-2987) Anisotropic azimuthal power and temperature distribution on impact on hydride distribution - PSU	$631,957
(11-3117) Life Prediction of Spent Fuel Storage Canister Material - MIT	$899,826
(11-3278) Fuel Aging in Storage and Transportation (FAST): Accelerated Characterization and Performance - TAMU	$4,500,000
(12-3374) Validation Experiments for Spent-Fuel Dry-Cask In-Basket Convection - USU	$690,000
(12-3528) Radiation and Thermal Effects on Used Nuclear Fuel and Nuclear Waste Forms - UTK	$770,000
(12-3545) Concrete Materials with Ultra-High Damage Resistance Capacity For Extended Storage Systems - UH	$800,000
(12-3660) Simulations to Predict Used Nuclear Fuel Cladding Temperatures during Drying and Transfer Ops - UNR	$745,000
(12-3730) Probabilistic Multi-Hazard Assessment of Dry Cask Structures - UH	$865,000
(12-3736) Nonlinear Ultrasonic Diagnosis and Prognosis of ASR Damage in Dry Cask Storage - NU	$885,000
(12-3756) Seismic Performance of Dry Casks Storage for Long-Term Exposure - UU	$873,320
(13-4840) Development of a nano-modified concrete for next generation of storage systems - VU	$795,153
(13-5106) Risk Assessment of Structural Integrity of Transportation Casks - UU	$740,296
(13-5178) Structural Health Monitoring of Nuclear Spent Fuel Storage Facilities - USC	$597,832
(13-5365) Doubling the Life of Concrete Structures - UI	$640,000
(14-7356) Multi-Sensor Inspection and Robotic Systems for Dry Storage Casks - PSU	$3,000,000
(14-7730) Experimental and Modeling of Used Fuel Drying by Vacuum and Gas Circulation for Dry Storage - USC	$4,000,000
(15-9231) Multimodal Nondestructive Dry Cask Basket Structure and Spent Fuel Evaluation - UM	$3,000,000
(15-9318) Innovative Approach to SCC Inspection and Evaluation of Canister in Dry Storage - CSM	$3,000,000
Grand Total	**$27,433,384**

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Independent Research Projects (IRP) 2015

FY 2015 Integrated Research Project Awards			
Title	**Lead University**	**Funding Amount***	**Project Description**
Innovative Approach to SCC Inspection and Evaluation of Canister in Dry Storage	Colorado School of Mines	$3,000,000	Researchers will study the effects of chloride-initiated stress corrosion cracking (CISCC) of dry storage containers. The project will use experimental testing and non-destructive evaluation methods for CISCC that will allow for better prediction and monitoring of materials degradation. Early identification of CISCC occurrence will allow for more responsive corrective actions.
Development of Accident Tolerant Fuel Options For Near Term Applications	Massachusetts Institute of Technology	$3,000,000	Researchers will develop computational tools to evaluate accident tolerant fuel (ATF) options for near term applications. The computational tools will be predominantly developed under the NEAMS framework and will include: RattleSNake, MARMOT, BISON and RELAP-7. These codes will be further enhanced in order to model ATF options.
Computational and Experimental Benchmarking for Transient Fuel Testing	Oregon State University	$4,000,000	Researchers will perform a benchmark of the Transient Reactor Facility located at the Idaho National Laboratory. This benchmark will include two steady state neutronic benchmark problems and two transient benchmark problems. It will include the design, construction and utilization of a full-scale representation of an in-pile flow loop prototype for TREAT and numerical benchmarking against the experimental data gained from the experiment.
Multimodal Nondestructive Dry Cask Basket Structure and Spent Fuel Evaluation	University of Mississippi	$3,000,000	Researchers will use emission source tomography, acoustics and ultrasonic investigation, and muon imaging to evaluate and monitor the structural health of above ground dry storage casks. Partnerships with AREVA and EPRI will provide access to full scale test casks to move technology from the laboratory to the field.
Total		**$13,000,000**	

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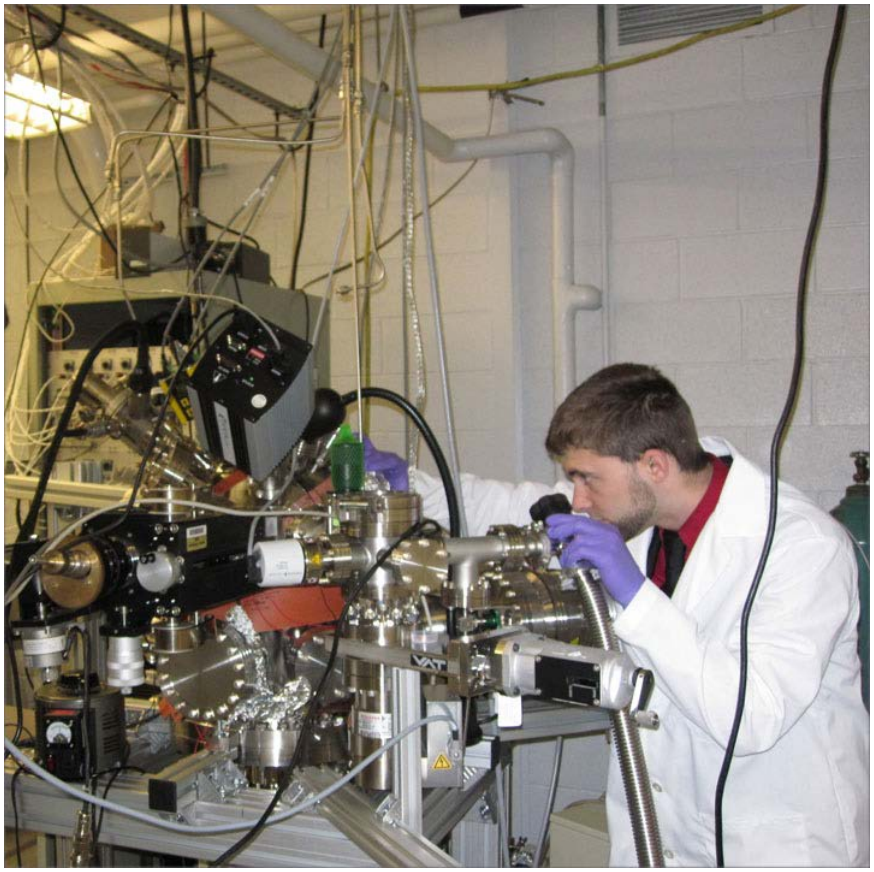
Future NEUP Projects

- **April 26, 2016**
- **DOE is seeking information, comments, feedback, and recommendations from interested parties for future work scope areas for the major NE-funded research programs in the following R&D areas:**
  - **Fuel Cycle Research and Development (FC R&D) Program**
  - Reactor Concepts Research, Development and Demonstration (RC RD&D) Program
  - Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program
  - Nuclear Enabling Technologies (NEET) Crosscutting Technology Development (CTD).NEUP continues to be part of our overall strategy to perform some R&D
- **Getting ready for the next cycle – FY17**
- **Draft Scope of Work submitted to DOE by July 7**



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Innovative Approach to SCC Inspection and Evaluation of Canister in Dry Storage

Purpose: Lifetime extension of dry storage canisters requires thorough understanding of the behavior of the canister material in corrosive environment and the ability to accurately predict and monitor material degradation so that corrective maintenance actions can be taken. In addition, stress prediction capabilities are necessary. Chloride-induced stress corrosion cracking (CISCC) of a spent fuel canister is one of the safety concerns during the dry storage of used nuclear fuel at an Independent Spent Fuel Storage Installations (ISFSIs).

PI: Zeev Shayer Colorado School of Mines

Collaborators: David Olson, CSM Stephen Liu, CSM Zhenzhen Yu, CSM Korukonda L. Murty, NCSU Djamel Kaoumi, USC Charles Bryan, SNL David Enos, SNL Brian E. Anderson, LANL Eric Flynn, LANL Jonathan Almer, ANL Peter Kenesei, ANL Donald W. Lewis, CB&I Jeffery Johns, CB&I

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Multimodal Nondestructive Dry Cask Basket Structure and Spent Fuel Evaluation

Purpose: Research and evaluate various non-destructive techniques and technologies that may be used to determine the structural integrity of the nuclear spent fuel rod storage baskets used in above ground dry storage casks. Four technologies will be evaluated: acousto-ultrasonic, linear & nonlinear acoustics, muon tomography, & source emission tomography. Based on the evaluation results, make recommendations to the DOE, provide on-site demonstrations, and provide proposals for field deployable systems.

THE UNIVERSITY OF MISSISSIPPI

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UF UNIVERSITY of FLORIDA

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UNIVERSITY OF SOUTH CAROLINA

OSU Oregon State UNIVERSITY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

AREVA

PI: Dr. Joseph Gladden, University of Mississippi

Collaborators: Prof. James Tulenko, University of Florida; Dr. Lingyu Yu, University of South Carolina; Dr. Haori Yang, Oregon State University; Mr. Ray Phan, AREVA Federal Services LLC; Dr. Jeremy Renshaw,EPRI

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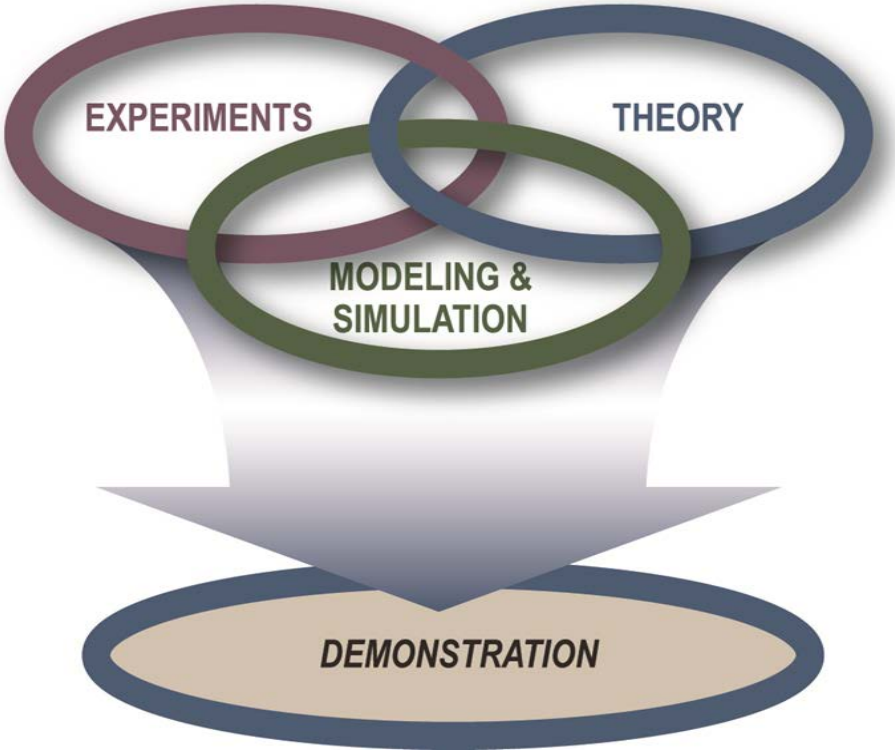
Summary

Technical Direction



Partnerships

- **Industry**
  - Utilities – NEI, EPRI
  - Cask manufacturers
  - Fuel suppliers
  - Rail and trucking companies
- **National Laboratories**
  - 11 National Labs
  - Principal Investigators with needed expertise have been identified
  - Specialized facilities and equipment are available
- **Universities**
  - More than 18 universities are working with UFD
  - Numerous students and professors are involved ($27M)
- **Nuclear Regulatory Commission**
  - Jointly fund research when appropriate
  - Continue some testing NRC began

QUESTIONS / COMMENTS?