High Burnup Spent Fuel Data Project

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NUCLEAR WASTE TECHNICAL REVIEW BOARD
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U.S. DEPARTMENT OF ENERGY

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Why Do a "Demonstration"?

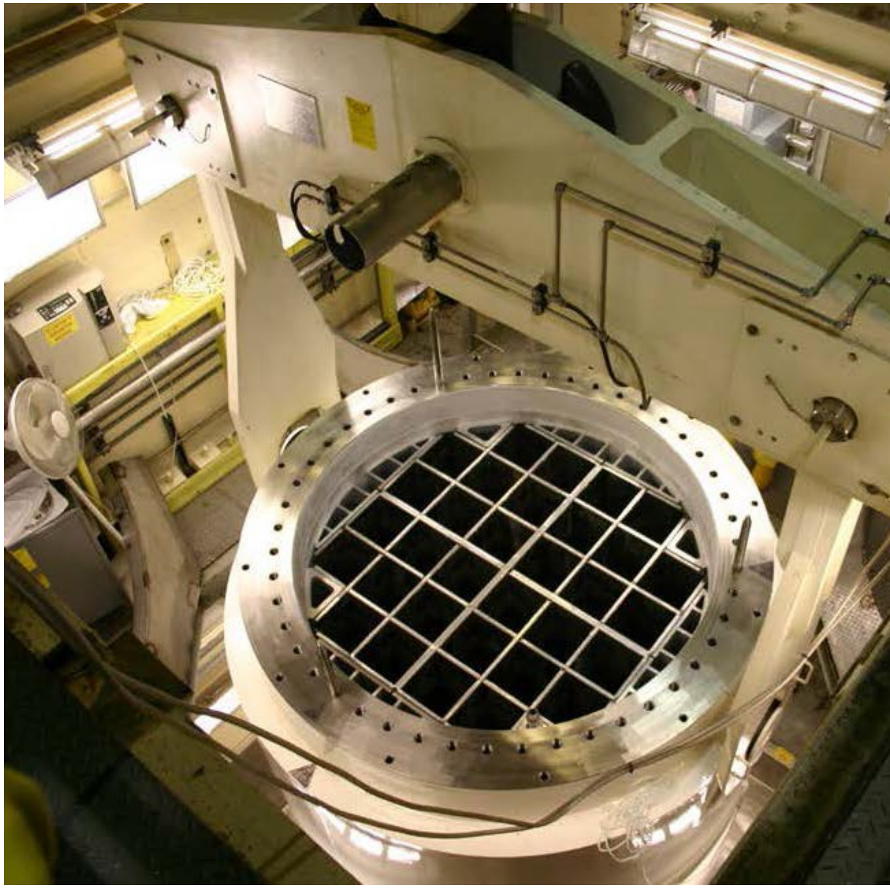
- **Collect data to validate and confirm the technical basis for extended storage of high burnup spent fuel**

- **Similar to demonstration performed on low burnup fuel stored ~15 years in a CASTOR V/21 cask**

High Burnup Spent Fuel Data Project Objectives

Involves

- Loading a commercial TN-32B storage cask with high burnup fuel in a utility storage pool
  - Well characterized fuel (Zircaloy-4, low-tin Zircaloy-4, ZIRLO™, and M5®-clad high burnup fuels)
  - Cask outfitted with additional instrumentation for monitoring
    - 7 lances each with 9 TCs axially spaced
  - License amendment required for lid design, high burnup fuel and additional heat load
- Dry the fuel using typical process
- Store cask at the utility's Independent Spent Fuel Storage Installation (ISFSI)
- Take temperature measurements and gas samples
- The issue of where the cask will be opened after the storage period will be solved at a later date.



This is where the cask will be held at North Anna for 2-3 weeks after it is loaded.

High Burnup Spent Fuel Data Project Participants

- **A contract was awarded to EPRI on April 16, 2013**

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Dominion

AREVA Federal Services
AREVA Transnuclear
AREVA Fuels

Westinghouse

NAC INTERNATIONAL

- **National Laboratories**

Sandia National Laboratories

INL Idaho National Laboratory

Pacific Northwest NATIONAL LABORATORY

Argonne NATIONAL LABORATORY

OAK RIDGE National Laboratory

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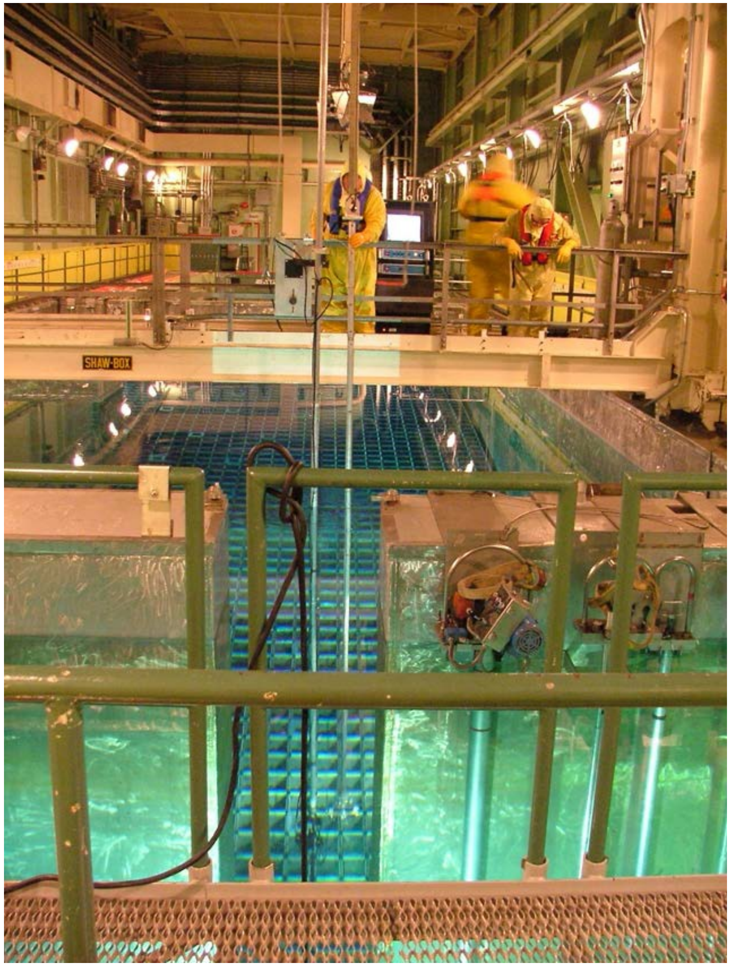
Activities for the EPRI Contract 2013-2018

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



North Anna Pool and Fuel Handling

Next Contract Activities 2018 to 2027

- **Continue to monitor and record temperatures and potentially take additional internal gas samples**
- **Ship the cask to a hot cell facility**
  - Eliminates the need to rewet the cask and fuel
- **Open the cask after 10+ years, visually examine assemblies, and extract some fuel rods**
- **Perform testing on the extracted rods for comparison to previously tested sister rods**
- **Prepare report on the effects on the fuel that can be attributed to dry storage operations**

Process for Monitoring the Cask

- **Cask cavity data acquisition will capture the full evolution of draining, drying, and cooling to equilibrium**
  - Thermocouple data recorded on a data logger at regular intervals
- **After backfill and pressurizing, the cask will remain in cask prep bay for 2-3 weeks for cavity temperature, pressure, and gas composition monitoring**
- **Periodic cavity gas samples will be obtained and analyzed**
  - Fission gas
  - Hydrogen content
  - Oxygen content
  - Moisture data will provide immediate valuable insight to cask drying method

Licensing

- **Cask to be loaded is a TN-32B cask**
  - Initially fabricated and certified to meet CoC 72-1021 requirements
  - Cask is capable of storing high burnup fuels, but storage of high burnup fuel wasn’t a priority at the time this cask was originally licensed
- **The Design and Licensing Basis Document provides the analytical bases and conclusions for departures from the existing approved analyses in the General License TN-32 FSAR**
  - New lid design completed
  - New criticality safety analysis (including poison rod assemblies) completed
  - New thermal analysis completed
  - New radiological analysis completed
- **Dominion submitted a License Amendment Request (LAR) for North Anna’s site specific ISFSI license**

TN32B Cask is being Prepared

TN 32B cask at fabricator

Removing lid to inspect cask after years of storage

Current Project Schedule

High Level Milestones

- 12/31/14: TN completes DLBD
- 1/31/15: AREVA sister rods extracted
- 6/30/15 Westinghouse sister rods extracted
- 8/24/15: Dominion submits LAR to NRC
- 9/25/15: NRC Accepts LAR
- 1/15/16: NRC issues Request for Additional Information (RAIs)
- 1/19/16: Sister rod shipment to ORNL
- 1/31/17: Expected NRC review completion
- 2/15/17: Cask Delivered to North Anna
- 6/30/17: Dry run and functional tests complete
- 7/31/17: Cask loading complete – begin initial monitoring
- 8/21/17: Cask emplaced at pad/Begin at-pad monitoring

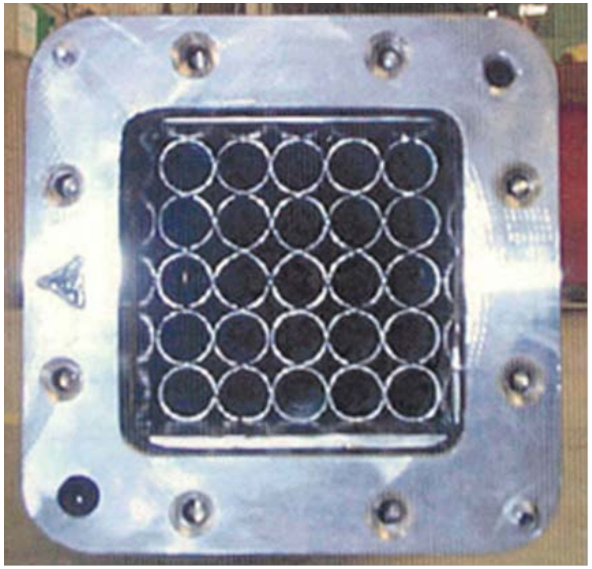
Final Fuel Selection Priorities

- **Fuel Selection was finalized based on the following priorities:**
  1. Get peak cladding temperatures as close to 400°C as possible.
  2. Keep the total cask heat load below the temperature limit on the neutron resin material (149C)
  3. Put one of each of the four kinds of PWR cladding in the center four slots
  4. Surround 4 HBU assemblies in center with high burnup, short-cooled fuel to drive up temperatures.
  5. Place similar assemblies of both ZIRLO™ and M5® in center, middle, and outer rings to obtain a wide variation in temperature.
  6. Thermocouple lance positions: 2 in center, 2 in middle; 3 in periphery; keep some area clear on the lid for the helium overpressure tank et al.

	1 6T0 Zirlo, 54.2 GWd 4.25%, 3cy, 11yr 1013/819W	2 (TC Lance) 3K7 M5, 53.4 GWd 4.55%, 3cy, 8yr 1167/838W	3 3T6 Zirlo, 54.3 GWd 4.25%, 3cy, 11yr 1015/821W	4 6F2 Zirlo, 51.9 GWd 4.25%, 3cy, 13yr 909/757W	DRAIN PORT
5 3F6 Zirlo, 52.1 GWd 4.25%, 3cy, 13yr 914/762W	6 (TC Lance) 30A M5, 52.0 GWd 4.55%, 3cy, 6yr 1276/832W	7 22B M5, 51.2 GWd 4.55%, 3cy, 5 yr 1637/841W	8 20B M5, 50.5 GWd 4.55%, 3cy, 5 yr 1608/827W	9 5K6 M5, 53.3 GWd 4.55%, 3cy, 8yr 1163/834W	10 5D5 Zirlo, 55.5 GWd 4.2%, 3cy, 17yr 906/797W
11 Vent Port 5D9 Zirlo, 54.6 GWd 4.2%, 3cy, 17yr 885/779W	12 28B M5, 51.0 GWd 4.55%, 3cy, 5 yr 1629/837W	13 F40 Zirc-4, 50.6 GWd 3.59%, 3cy, 30yr 696/ - W	14 (TC Lance) 57A M5, 52.2 GWd 4.55%, 3cy, 6yr 1281/835W	15 30B M5, 50.6 GWd 4.55%, 3cy, 5 yr 1614/830W	16 3K4 M5, 51.8 GWd 4.55%, 3cy, 8 yr 1162/803W
17 5K7 M5, 53.3 GWd 4.55%, 3cy, 8yr 1165/836W	18 50B M5, 50.9 GWd 4.55%, 3cy, 5 yr 1625/835W	19 (TC Lance) 3U9 Zirlo, 53.1 GWd 4.45%, 3cy, 10yr 1037/806	20 0A4* Low-Sn Zy-4, 50 GWd 4.0%, 2cy, 22yr 725/665W	21 15B M5, 51.0 GWd 4.55%, 3cy, 5 yr 1629/837W	22 6K4 M5, 51.9 GWd 4.55%, 3cy, 8 yr 1162/803W
23 3T2 Zirlo, 55.1 GWd 4.25%, 3cy, 11yr 1036/838W	24 (TC Lance) 3U4 Zirlo, 52.9 GWd 4.45%, 3cy, 10yr 1031/802W	25 56B M5, 51.0 GWd 4.55%, 3cy, 5 yr 1628/837W	26 54B M5, 51.3 GWd 4.55%, 3cy, 5 yr 1645/846W	27 6V0 M5, 53.5 GWd 4.4%, 3cy, 8yrs 1178/844W	28 (TC Lance) 3U6 Zirlo, 53.0 GWd 4.45%, 3cy, 10yr 1035/804W
	29 4V4 M5, 51.2 GWd 4.40%, 3cy, 8yr 1109/787W	30 5K1 M5, 53.0 GWd 4.55%, 3cy, 8yr 1155/829W	31 (TC Lance) 5T9 Zirlo, 54.9 GWd 4.25%, 3cy, 11yr 1031/833W	32 4F1 Zirlo, 52.3 GWd 4.25%, 3cy, 13yr 918/765W	High Priority Assys

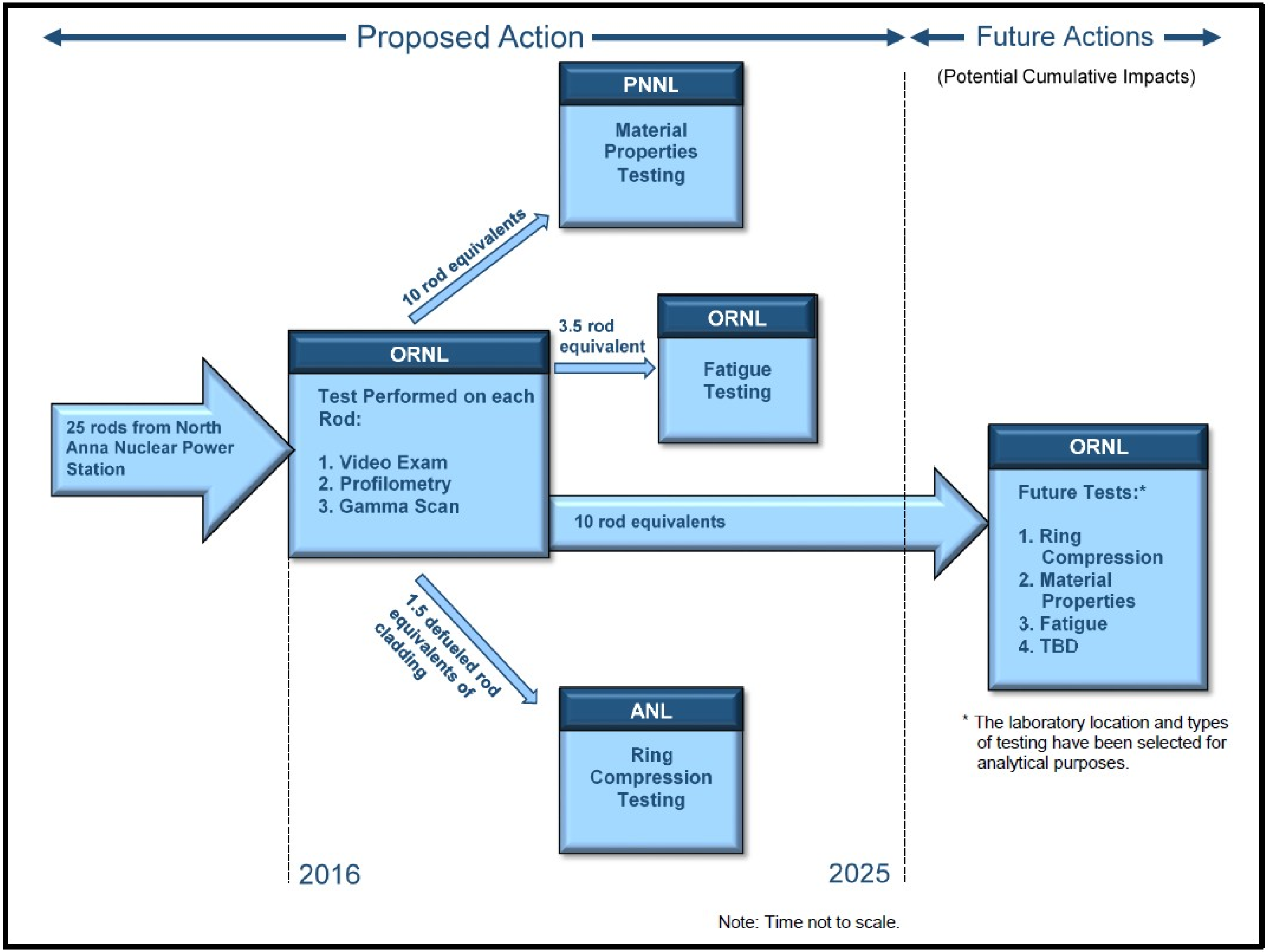
Sister Pin Selection

- **AREVA rods pulled January 2015**
  - Nine AREVA M5® rods
- **Westinghouse rods pulled June 2015**
  - Twelve Westinghouse ZIRLO™ rods
  - Two Westinghouse Low-tin Zircaloy-4 rods
  - Two Westinghouse standard Zircaloy-4 rods
- **Sister rods sent to ORNL on 1/19/2016**
- **Draft Sister Rod Test Plan is being completed and will be shared with others.**
  - Discusses in detail the methodology for selecting the sister pins



NAC LWT basket for shipping rods

Sister Rod Testing



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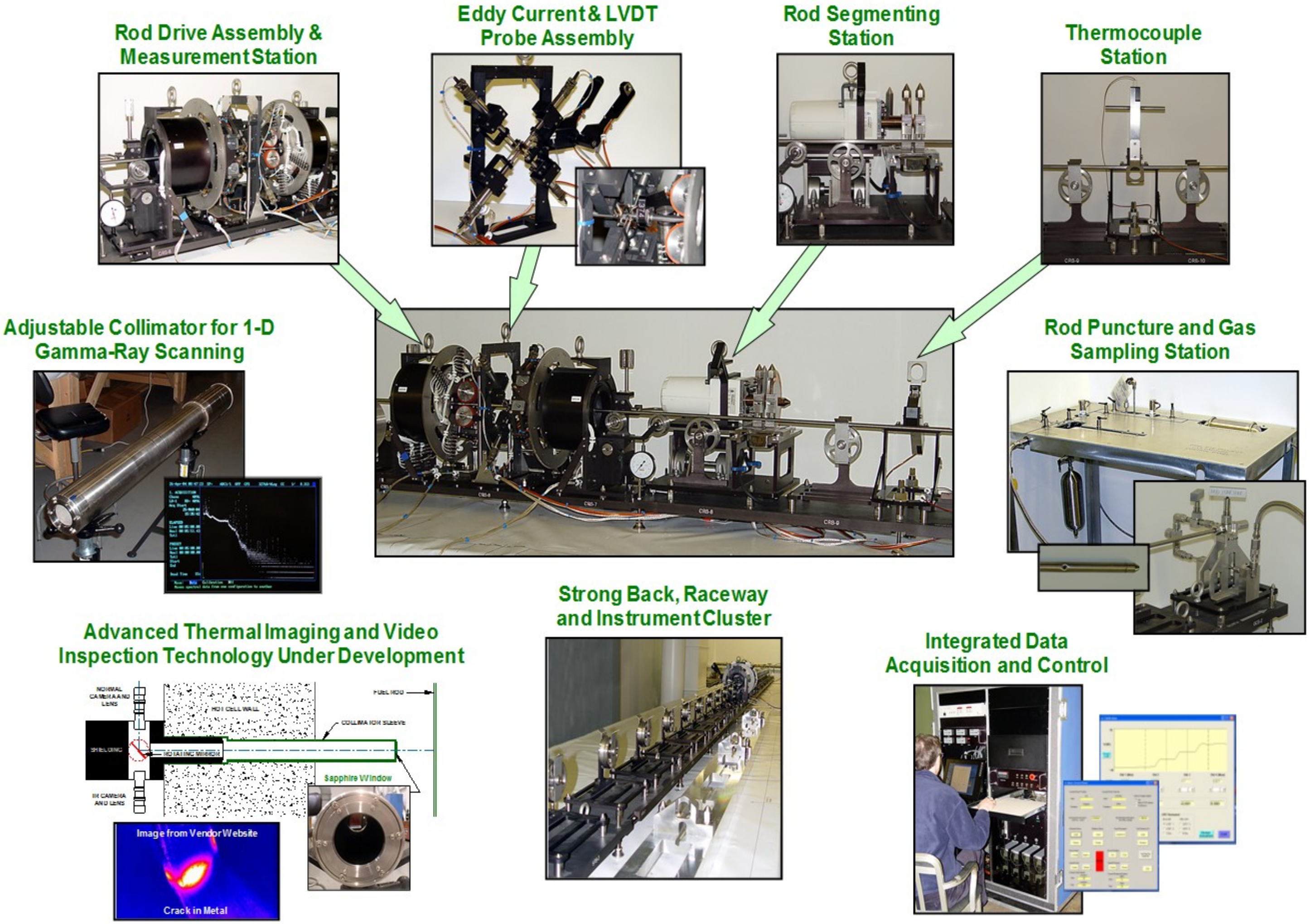
Detailed Characterization Using ORNL ADEPT (Advanced Diagnostics and Evaluation Platform)



High Priority Characterization

- **Non-destructive examination to obtain T0 characteristics to compare against rods extracted after 10+ years of storage**
  - Compare rod length and profilometry data to look for signs of creep
- **Destructive characterization**
  - Rod internal pressure, fission gas release, free volume determination
- **Simulated drying of either intact rods or pressurized rod segments under range of realistic temperatures and hoop stresses (similar to Radial Hydride Treatment performed at ANL) to obtain T1 characteristics.**
- **Clad hydrogen analyses (visual and hot vacuum extraction)**
  - Determine hydride content and distribution (T0 and T1); compare against extracted rods to look for hydrogen redistribution, extent of radial hydride formation, signs of Delayed Hydride Cracking

High Priority Tests

- Test at both T0 and T1
- Determine temperature and strain rate dependencies
- Cyclic Integrated Reversible-Bending Fatigue Tests (CIRFT) to determine fatigue strength and flexural rigidity, modulus of elasticity, effects of fuel/clad composite
  - Examine transient shocks and cumulative effects performance
- Ring Compression Tests (RCT) to determine ductile to brittle transition temperature
- Material properties tests (e.g., yield strength, ultimate tensile strength, uniform plastic elongation) following ASTM-approved methodologies
  - Tube tensile
  - Tube compression
  - Tube burst
- Additional testing based on initial results