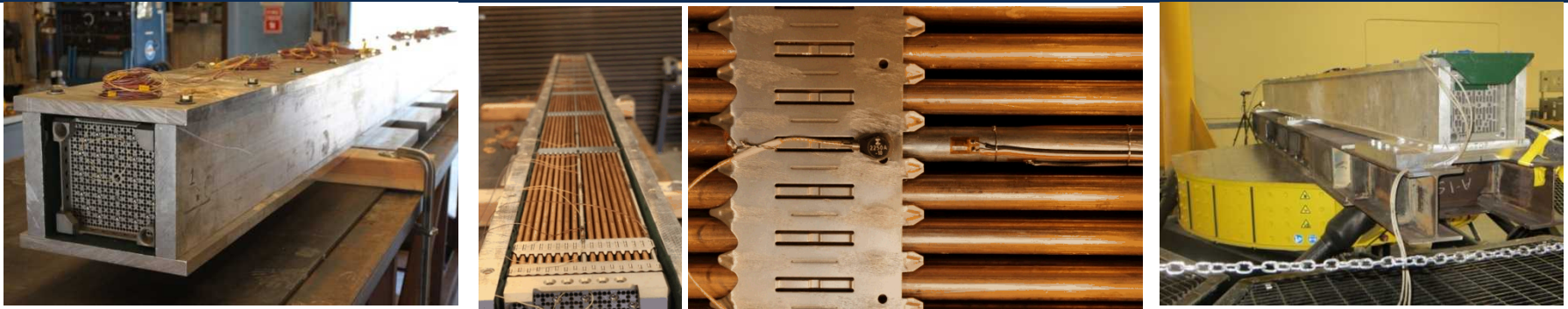


Exceptional service in the national interest



Transportation R&D Activities

PWR Assembly Tests Simulating Normal Conditions of Transport

Paul McConnell



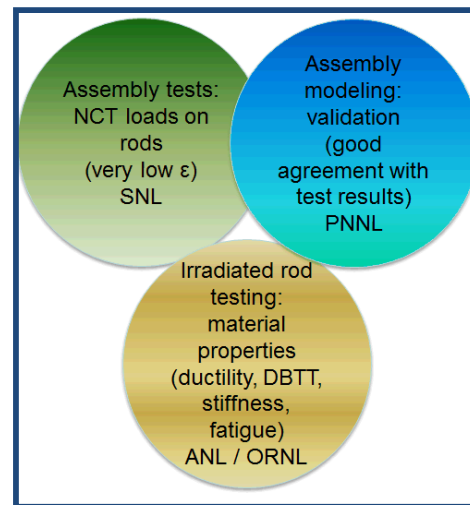
Nuclear Energy



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Rationale for fuel assembly testing

- NRC, DOE, and industry concerns regarding transportation of high burnup UNF: Possible failure of rods during Normal Transport
- Until now, there was absolutely no data on the strains imposed on UNF rods during Normal Conditions of Transport
- The assembly tests compliment UFD-funded material property tests of high burnup Zircaloy at ANL and ORNL



Three series of tests were conducted using a PWR assembly

1. Tests on a SNL shaker

- Vertical accelerations only
- Truck NCT simulations



2. Over-the-road truck test



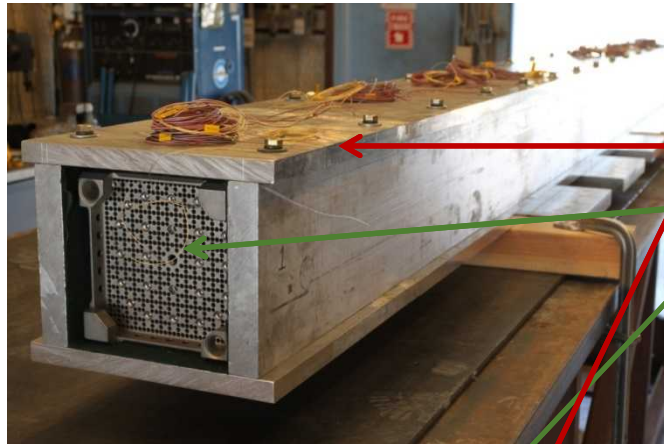
3. Test on commercial seismic shaker

- 6-degrees of motion
- Rail and truck NCT simulations

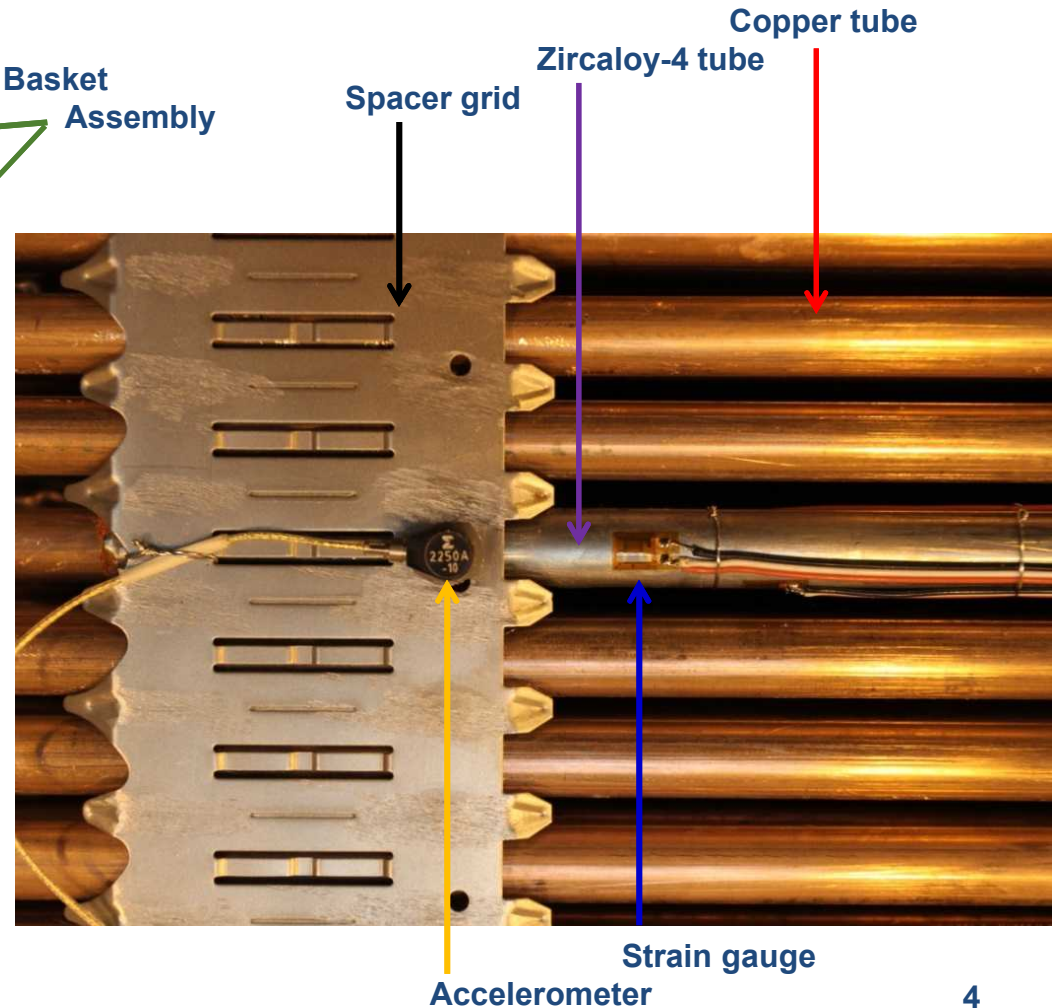
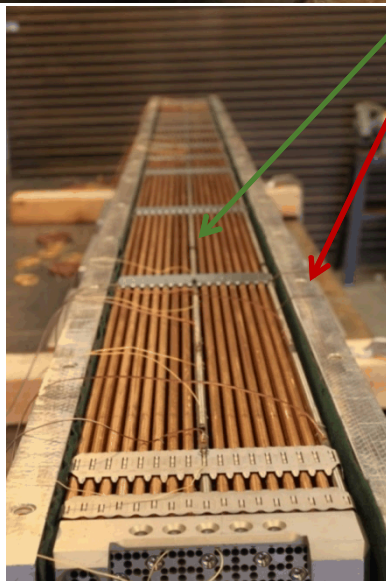


- Inputs to the shakers simulated Normal Conditions of Truck and Rail Transport (vibrations and shocks).
- Zircaloy-4 rods on the PWR assembly were instrumented with strain gauges and accelerometers.

PWR Assembly/Basket Test Unit



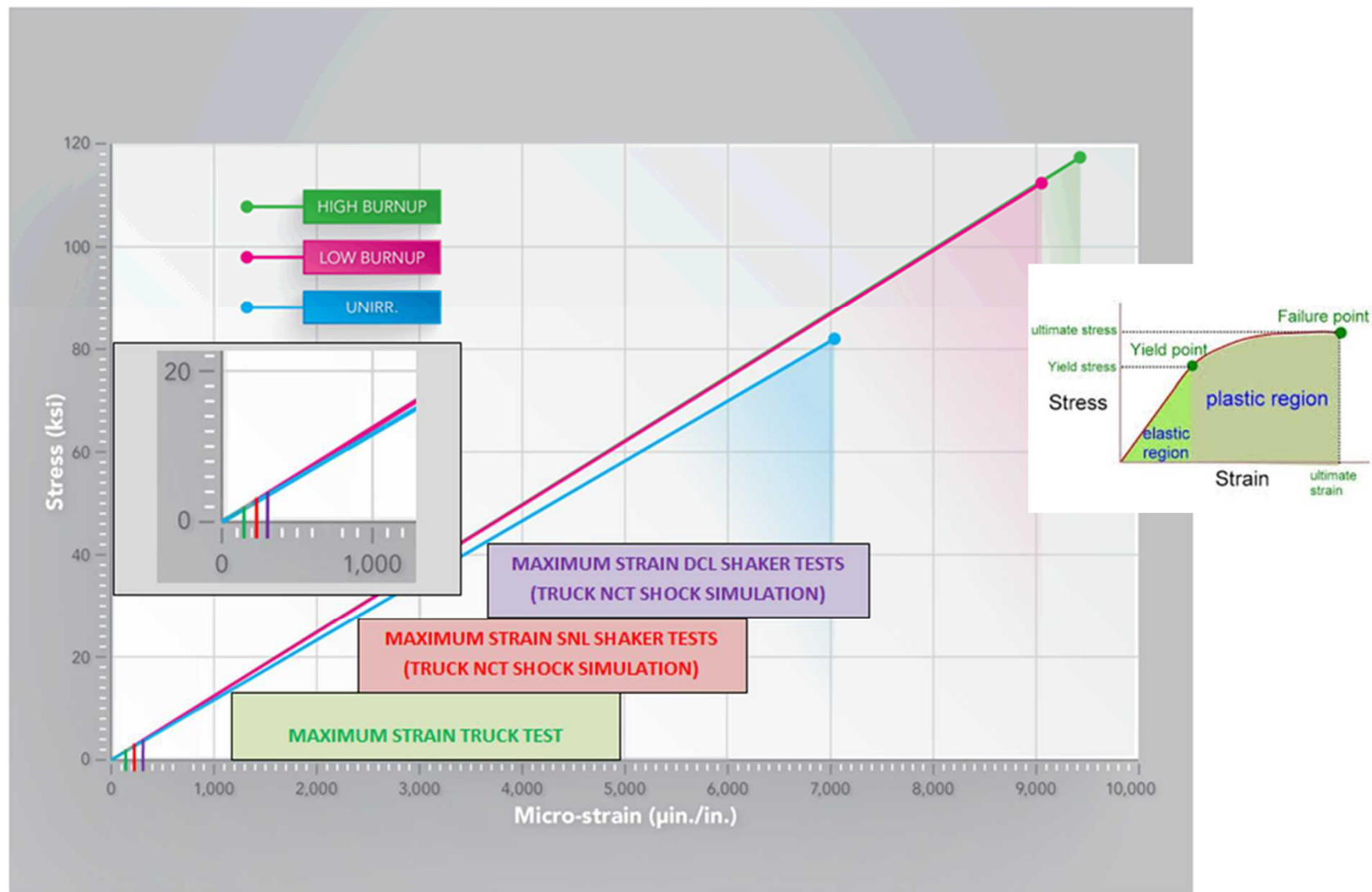
Basket
Assembly



Maximum strains measured in all three test series were extremely low

Strain Gauge / Surrogate UO ₂ Material within Zircaloy-4 Tube	Rod Location within Assembly (Axial Location on Assembly: Adjacent to First Spacer Grid, Middle Span) Same Axial Location for all Strain Gauges	Sandia Shaker Truck Shock Test Maximum Micro-Strain ($\mu\text{in./in.}$)	Truck Test Maximum Micro-Strain ($\mu\text{in./in.}$)	DCL Shaker Truck Shock Test Maximum Micro-Strain ($\mu\text{in./in.}$)
S3 - 0° Pb "rope"	Middle Rod		143	
TMR-G-S5-0° Pb "rope"	Middle Rod	119		
S3 - 0° Pb pellets	Right-edge Rod			160
S7 - 0° Mo pellets	Middle Rod			214
S8 - 0° Pb "rope"	Left-edge Rod			301

How low were the strains?



Shaker test video simulating NCT rail shock



Shaker test video simulating rail coupling shock **NOT** a Normal Condition of Transport simulation



Rail coupling shock shaker test, GoPro® side view of rods (**NOT** NCT)



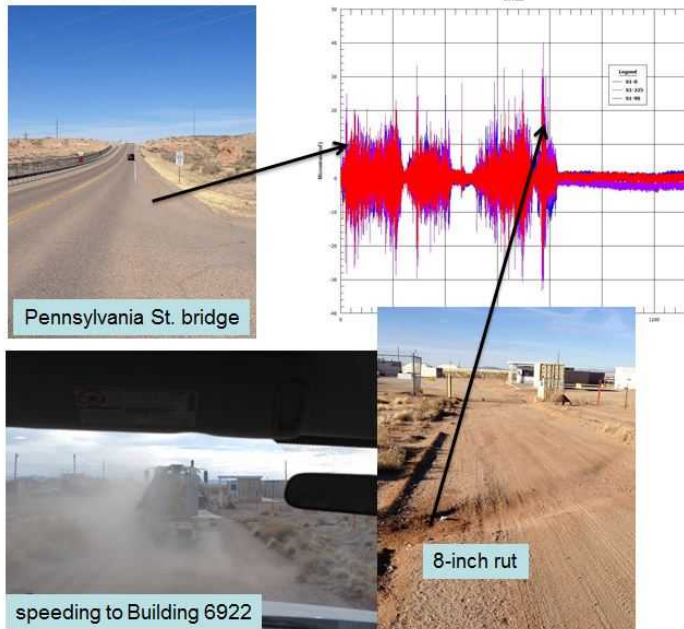
Test Unit on Trailer for Over-the-Road Test



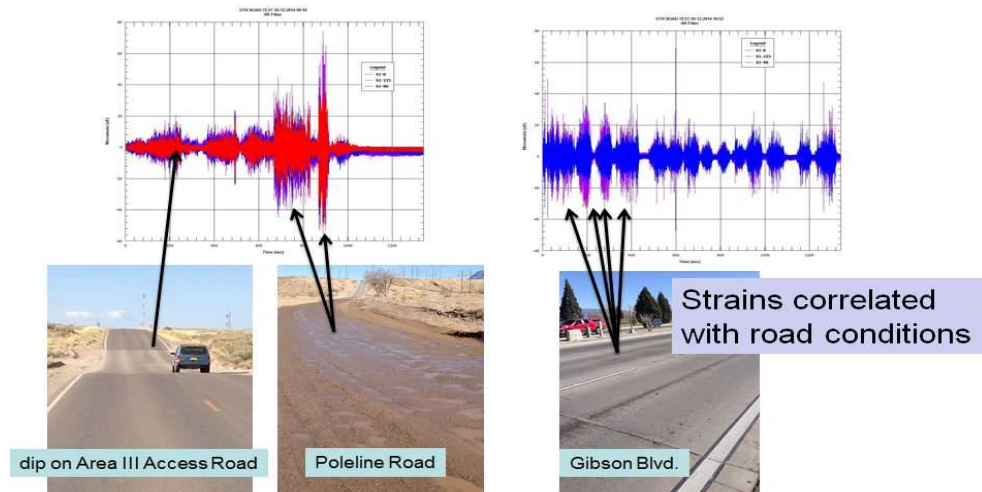
Video of Assembly during the Truck Test rough asphalt and dirt road



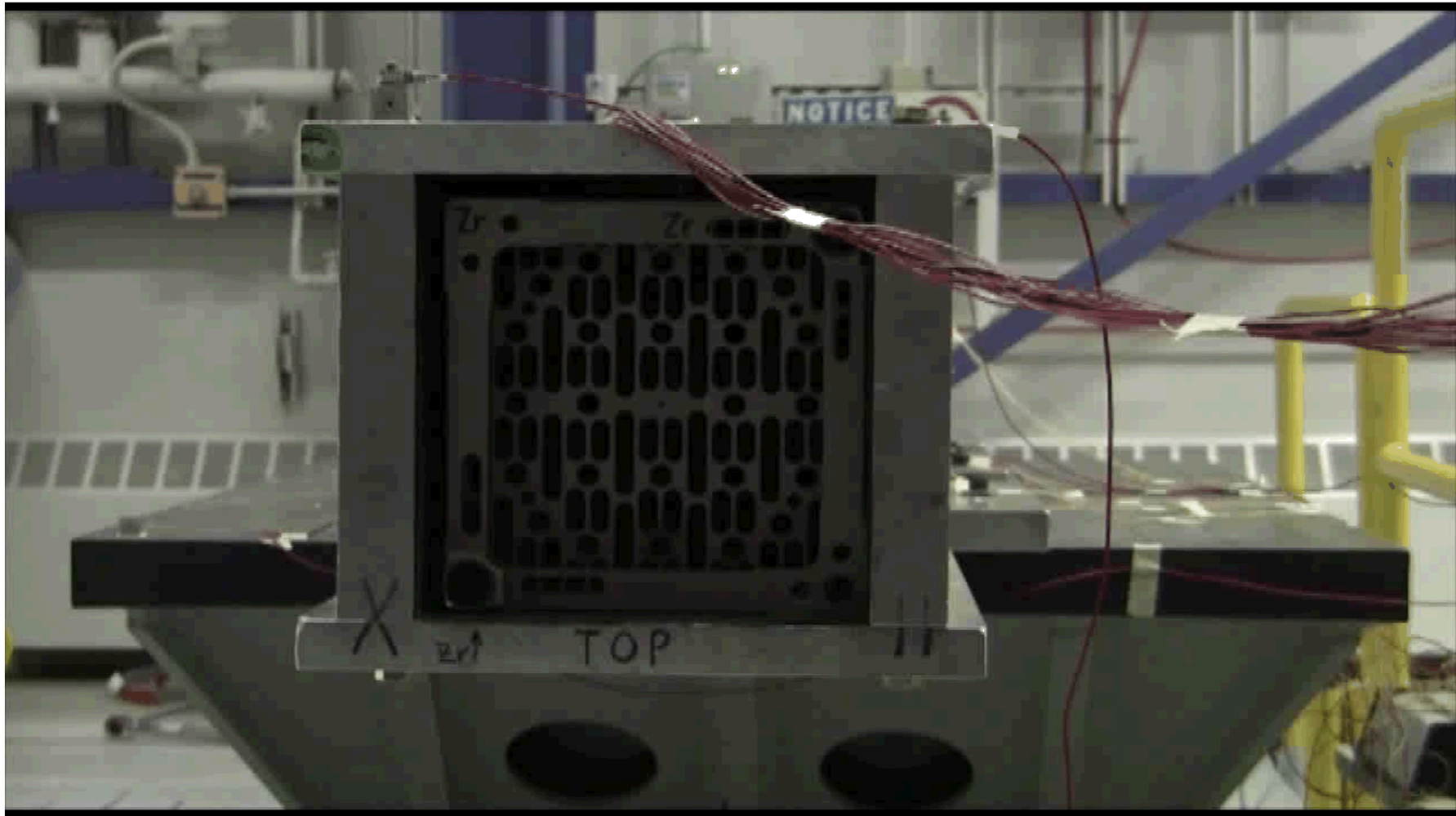
Strain data from over-the-road truck test



- Very low strains
- Strains correlated with road features



SNL Shaker Shock Test Video



Comparison of strains from all three test series at same location on assembly

Strain Gauge ID	Location on Assembly: Adjacent to first spacer grid, Span 5	Sandia Shaker Truck Shock Test Maximum Strain Absolute Value ($\mu\text{in/in}$)	Truck Test Maximum Strain Absolute Value ($\mu\text{in/in}$)	DCL Shaker Truck Shock Test Maximum Strain Absolute Value ($\mu\text{in/in}$)
S3 - 0° Pb “rope”	Middle rod		143	
TMR-G-S5-2 (0°) Pb “rope”	Middle rod	119		
S3 - 0° Pb pellets	Right-edge rod		160	
S7 - 0° Mo pellets	Middle rod		214	
S8 - 0° Pb “rope”	Left-edge rod		301	

At each strain gauge location (denoted "S") there are three (3) gauges circumferentially positioned at 0, 90, and 225 degrees (0 degrees is top of rod)

All strain gauges on Span 5 STRADDLE a SINGLE 0.6" PELLET

What these tests tell us

- The strains measured on the rods during the NCT test simulations were in the micro-strain levels – well below the elastic limit for either unirradiated or irradiated Zircaloy-4
- Based upon the test results, which simulated normal vibration and shock conditions of truck and rail transport, failure of fuel rods during normal transport seems unlikely
- Fatigue during transport does not appear to be an issue
- These results have received positive feedback from the NRC, NWTRB, and the technical community
- These results correlate with the used nuclear fuel transportation experience of Areva in France, i.e.: no rod failures during NCT

Plans for completing this work

- Prepare detailed Test Plan (FY16) for tests of PWR assemblies configured:
 - Within a rail-cask basket which is...
 - within an actual rail cask which is...
 - on a rail car which will be...
 - transported.
- Performance of rail cask tests of the assembly (FY17) using a gratis cask from Ensa
 - Over commercial rail lines, and
 - at the AAR Transportation Technology Center, Inc.



These rail tests will:

- eliminate questions re the simulated tests,
- support future licensing and transport of UNF,
- support public acceptance of rail transport.

