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ENERGY

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Nuclear Energy

Full-scale Rail-Cask Tests with Surrogate PWR Assemblies

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Previous tests of a surrogate PWR assembly simulated normal conditions of transport to measure strains on fuel rods

**SNL Shaker
2013**



*Normal Conditions of Transport
Truck*

**Over-the-Road Truck
2014**



*Normal Conditions of Transport
Truck*

**DCL Multi-Axis Shaker
2015**



*Normal Conditions of Transport
Truck and Rail*

All tests used a surrogate PWR assembly which was placed within a surrogate truck-cask basket.

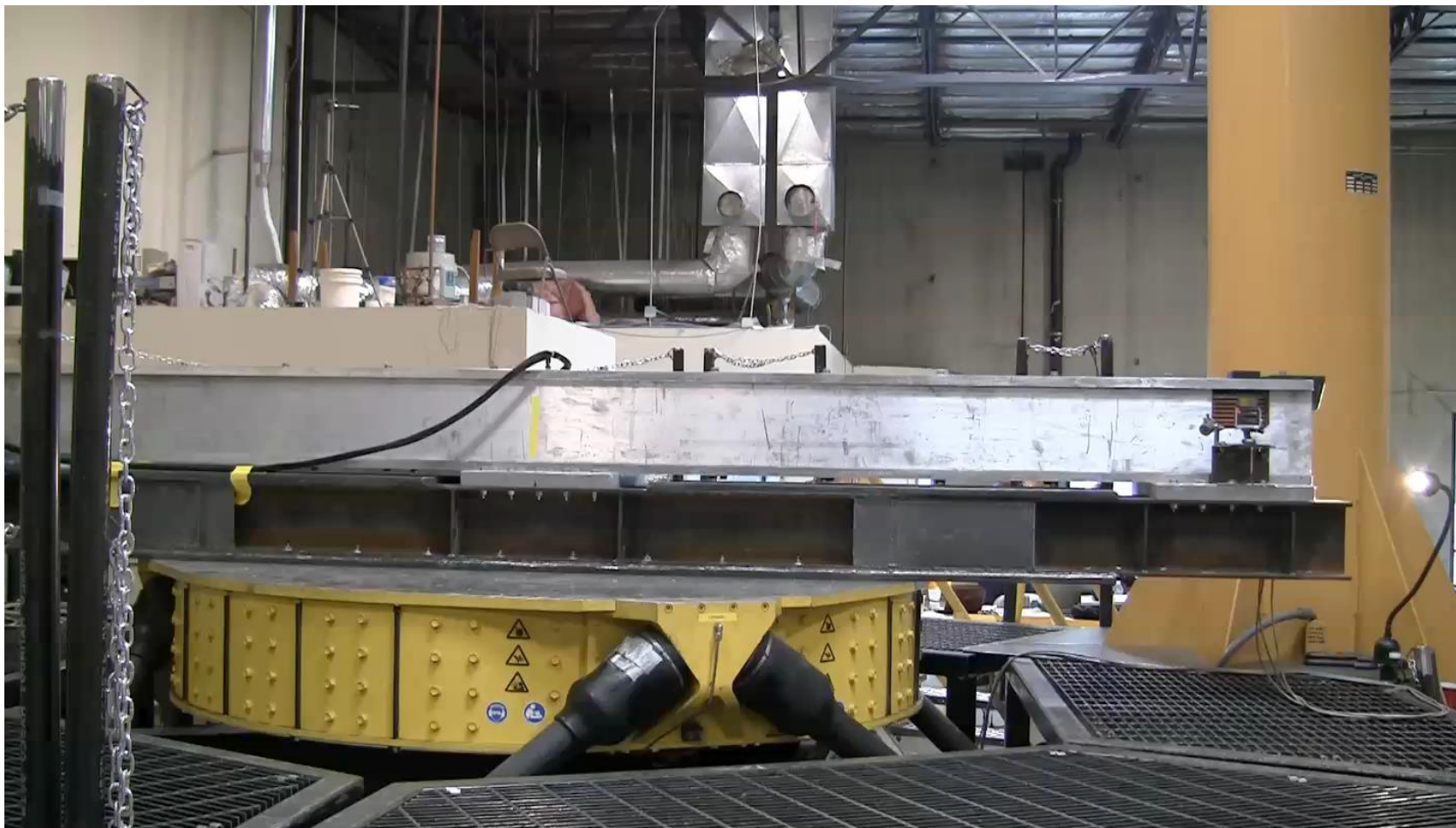
The assembly and rods were instrumented with strain gauges and accelerometers.



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Simulated rail shock





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Non-normal transport condition





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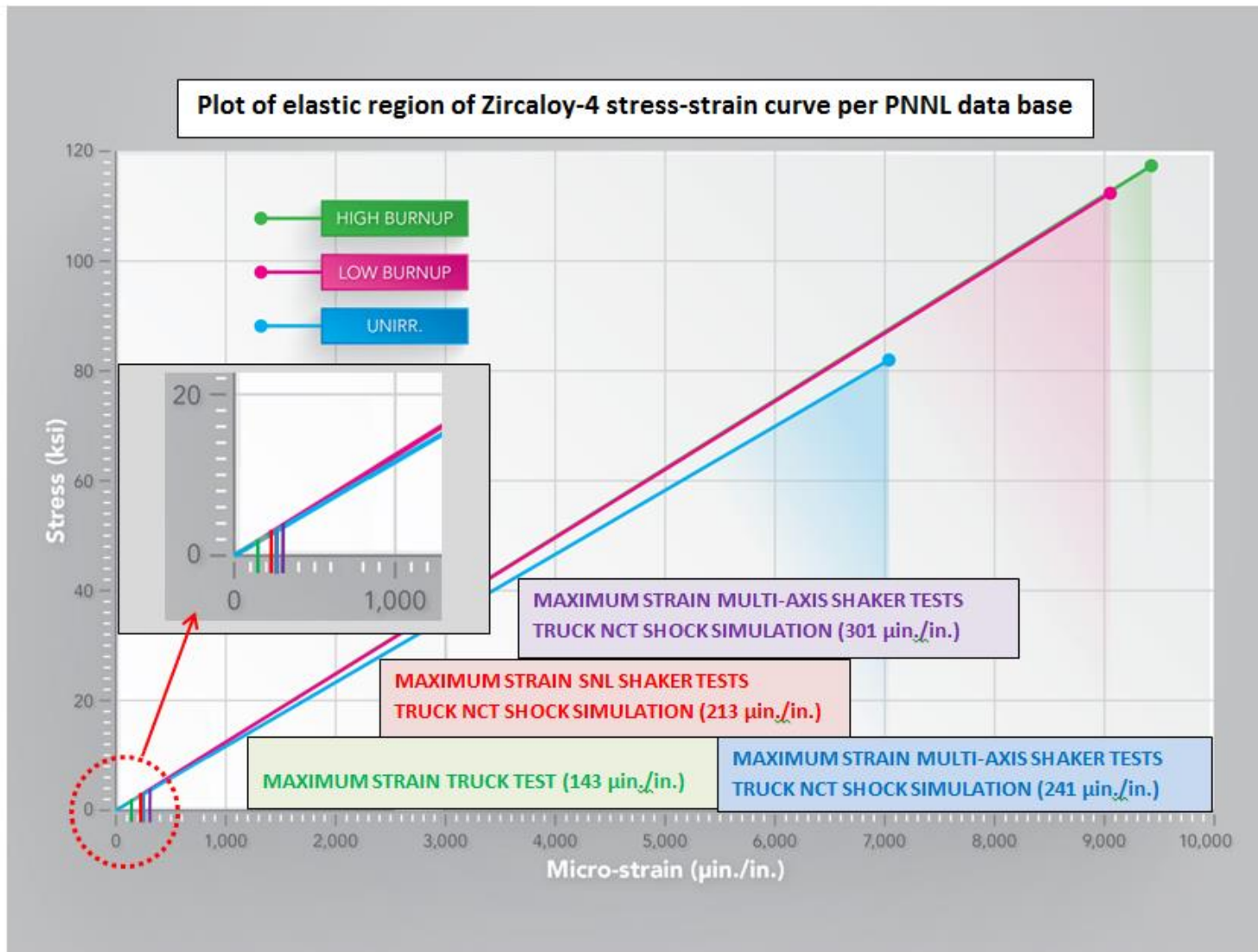
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Over-the-road truck test



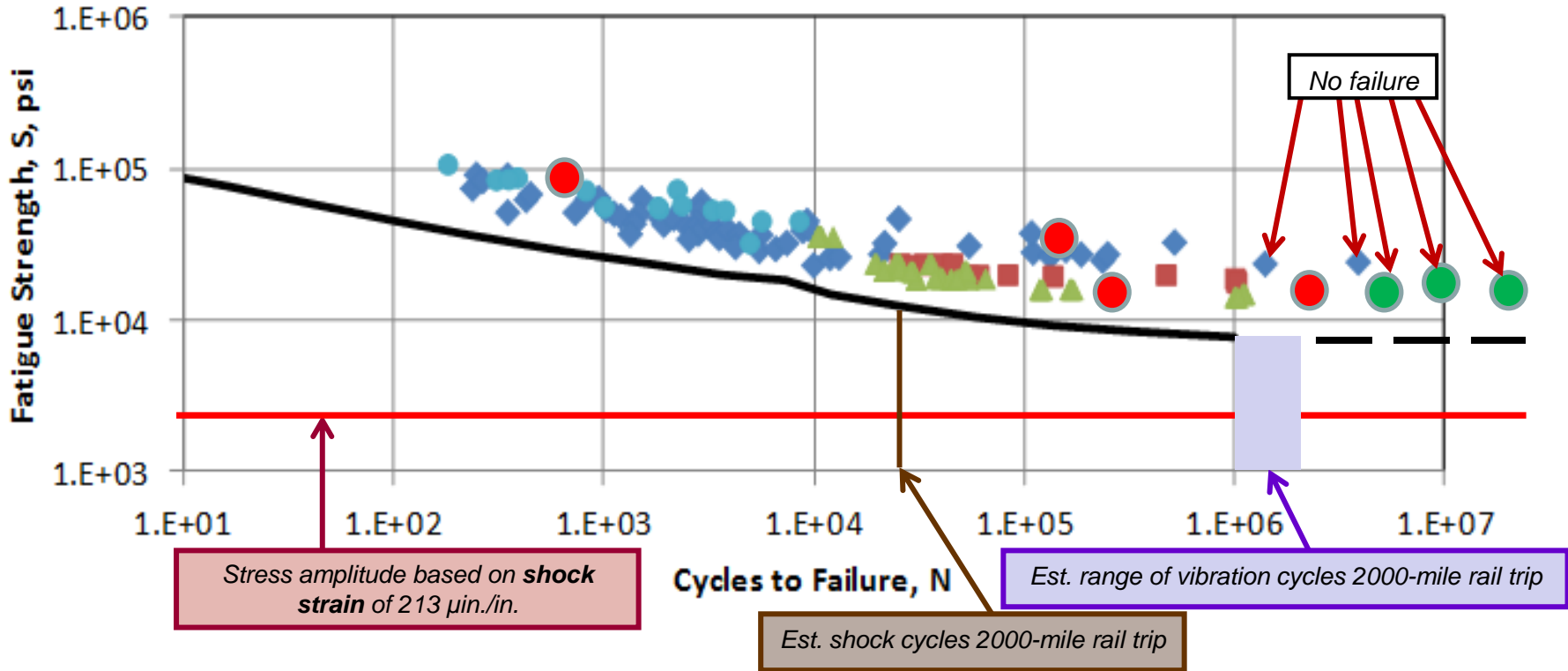


Strains on Zircaloy-4 rods were very low





NCT vibrations unlikely to result in fatigue failure



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

This curve and the data points were generated with irradiated Zircaloy with circumferential hydrides. It is also considered valid for irradiated Zircaloy with radial hydrides if the material is above the DBTT.

The large circles are ORNL HBR data.

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 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.**



However,

these tests...



...are only simulations of the configuration of actual UNF transport modes:





International multi-transportation mode tests with a rail cask

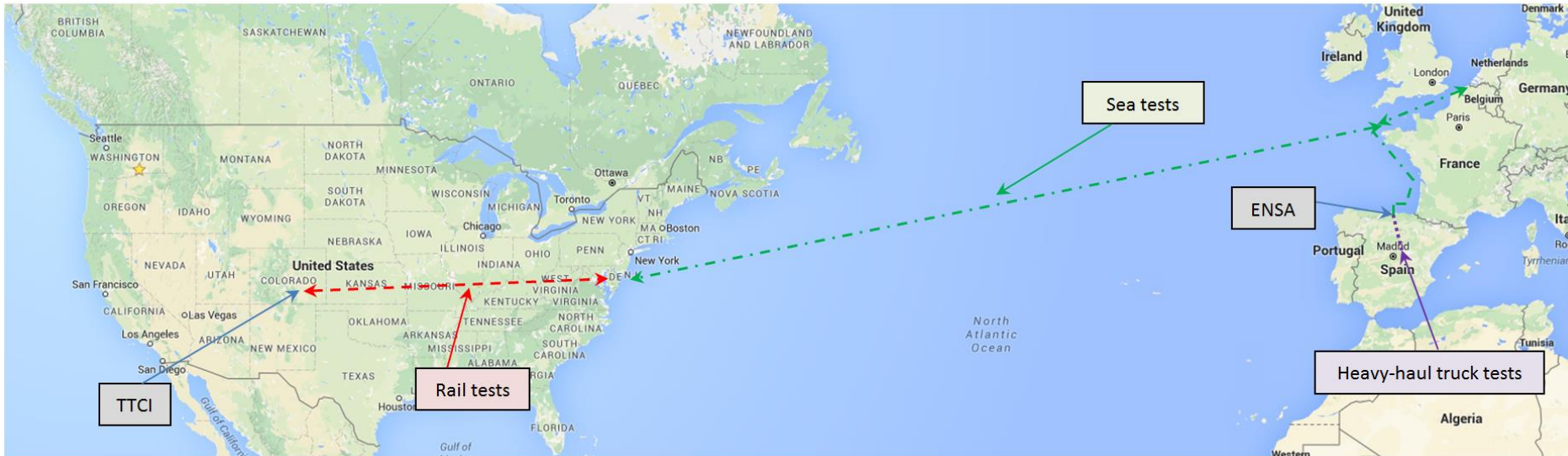
- ***Equipos Nucleares (ENSA)*** will provide an ENUN 32P rail cask, basket, and cradle for an international test program
 - The ENUN 32P is similar to an existing NRC-licensed cask currently in use in the USA
- **Testing to be conducted by DOE laboratories**
- **These tests are significantly different than the previous tests:**
 - instrumented surrogate assemblies will be...
 - within a rail-cask basket...
 - within an actual rail cask which will be on...
 - 1) a heavy-haul truck, then
 - 2) two different ships, and then
 - 3) a railcar

We have a unique opportunity to conduct these tests the Summer of 2017





Proposed routing of the cask



1. Heavy-haul truck from within Spain.
2. Coastal sea shipment from Santander to a large northern European port.
3. Ocean transport from Europe to an eastern U.S. port (e.g., Baltimore).
3. Commercial rail shipment from East Coast to Pueblo.
4. Testing at the Transportation Technology Center, Inc.
5. Return trip to ENSA will be the same.

Data will be collected throughout all legs of the transport of the cask & assembly

Collaboration of UFD ST R&D activities with ENSA

DOE UFD will manage the technical aspects of the rail-cask tests.

- **Send the SNL surrogate assembly to ENSA in Santander, Spain**
- **Instrument the assembly and the cask and cradle to obtain load data (strain, acceleration, # of cycles, etc.)**
- **Send the data acquisition system to Spain**
- **Responsible for all data acquisition during heavy haul, sea transport, and rail transport to TTCI with ENSA support**
- **Responsible for all testing at TTCI**
- **Responsible for all data reduction and analysis**
- **NFST has expressed interest in collaborating on this project**
- **Korean Atomic Energy Research Institute has expressed interest in supporting the sea transport**





Specifics of Modal Tests (cont'd)

4. Commercial rail shipment from East Coast to Pueblo

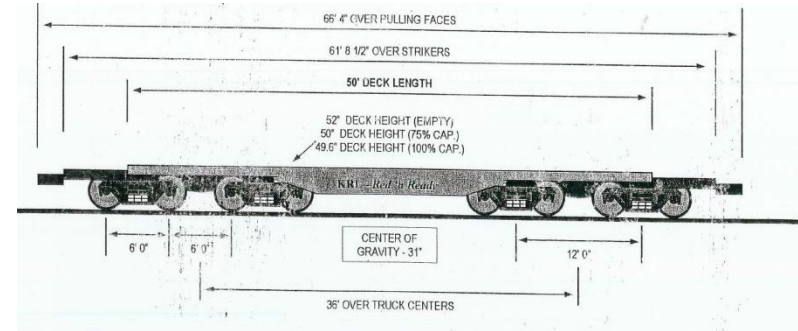
- Transit time ~ 3 weeks
- Data collection during transit
- Rail car will be instrumented

5. Testing at TTCI

- ~ 2 weeks for all testing
- Specific tests being considered include:
 - Instrumented wheel set
 - Dynamic curving test
 - Hunting test

6. Return trip

- Data collection for the entire return trip is being considered (the same route will have different track, weather conditions, etc.)
- Sandia assembly will be removed at ENSA and shipped back to Sandia



Typical commercial flat deck rail car



PFS 2043 rail car with mass loading @ TTCI

Collect data also during the truck-to-barge, barge-to-ship, ship-to-rail transfers. No other testing mechanism will capture these is real situations.



Programmatic Considerations

How does this align into the UFD ST R&D objectives?

Gap ^a	Updated Prioritization	Original Prioritization
Thermal Profiles	1	1
Stress Profiles	1	1
Monitoring - External	2	2
Welded Canister – Atmospheric Corrosion	2	2
Drying Issues	3	6
Monitoring - Internal	4	4



1. Stress profiles are a #1 priority in our up-dated 2014 technical gap priority assessment.
 - Truck NCT loadings have been completed
 - Rail NCT loadings have not been fully addressed.
 - Most commercial shipments will be made by rail.
 - This is a critical component in closing out the cladding data gap
 - Will provide vital input to sister pin testing



2. The DOE/Industry data confirmation project is a priority for NE-53.
 - The ENUP-32P is very close in design and performance characteristics to the TN-32B
 - Having rail shock/vibration data from the ENUP-32P should help the NRC transportation licensing review for the TN-32B when the DOE gets ready to ship the demo cask.



Benefits of multi-transportation mode rail cask tests

The ENSA rail-cask tests would:

- **provide data for all transport modes**
 - Heavy-haul truck
 - Coastal shipment (e.g., barge)
 - Open ocean transport
 - Normal rail
 - Inter-modal transfers
- **add to the library of NCT rail and truck loadings**
- **reduce uncertainty in the existing data by testing under more real-life conditions**
- **support future licensing and transport of high burnup UNF**
 - e.g., demo cask
- **eliminate many of the compromises inherent to the previous tests**

Why now????

Arguments have been made that this test would best be done later using the 2043 rail car when it is ready and when the DOE is closer to actually shipping commercial spent fuel.

We feel the time is right to do this test project now:

- The ENUP-32P will not be available in later years.
- ENSA may not be willing to co-fund such a program in the future...this truly is a window of opportunity.
- This set of rail shock and vibration data will support licensing of the DOE/EPRI Confirmatory Data Project demo cask for transportation.

Why now????

- This set of rail data could support the public consent process when DOE actually starts talking to stakeholders concerning CIS siting. Questions will come early about transportation.
- Ruben Peña of the TTCI has stated his belief that the ride quality using the 2043 will be superior to a standard rail car. We believe that using a standard rail car will provide data that will bound loads using the 2043.

Why now????

- The 2043 Standard requires that buffer cars and an escort car be tested along with the cask car. Planning for procuring and testing the buffer cars and the escort cars has not begun. It is expected that, along with the 2043 cask car, these have long lead times.
- It is not unreasonable to expect that some of the DOE rail shipments may be done without the 2043 (e.g., short spur transfers, etc.). This will provide the data to support these types of shipments.

Why now????

- The data will be used to benchmark our computer codes, thus making it possible to analytically extend our assessments to many types of rail cars.
- Getting this data sooner may help to inform future test plans (e.g., the 2043 rail car).
- An incident tomorrow might make the timeline much tighter for the rail movement of commercial UNF. The most recent values for railroad loads are ~38 years old and are obsolete. It is in DOE's best interest to get up to date realistic loading of NCT rail transport.