SAND2017-9026PE

Surrogate Spent Nuclear Fuel International Multi-Modal Transportation Test

DOE:NE Transportation Core Group

Joint Tour of Transportation Technology Center, Inc. (TTCI) – Pueblo, Colorado

August 24, 2017

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Sandia National Laboratories, **Pacific Northwest National Laboratories

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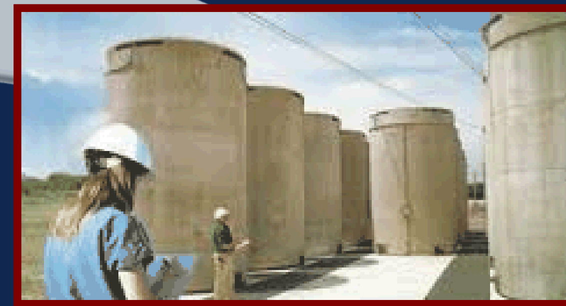

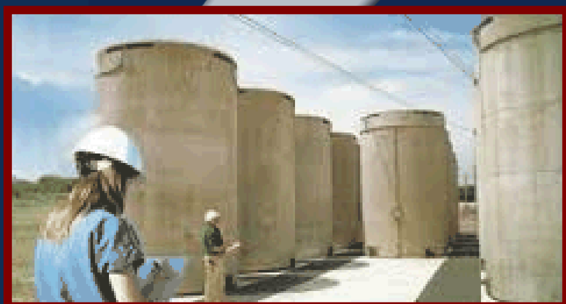

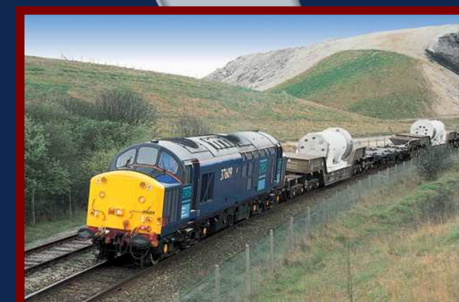

The Big Picture

PROJECT PARTICIPANTS

Equipos Nucleares S.A.

Korea Radioactive Waste Agency

Korea Atomic Energy Research Institute

US Department of Energy

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Why Are We Doing this Test?

- To validate our hypothesis that spent fuel will maintain integrity during normal conditions of transport.
  - We will be obtaining more realistic data for truck, barge, ship, and rail transport as well as the transfer between these modes of transportation.

Transporting Spent Nuclear Fuel

Sandia National Laboratories

- How do stresses on fuel during normal conditions of transport compare to failure limits?

- Could vibrations or shocks result in fatigue failure?

Based on previous tests, the stresses fuel rods experience due to vibration and shock during normal transportation are far below yield and fatigue limits for cladding.

- But previous tests are only simulations of the configuration of *actual* SNF transport modes.

Transporting Spent Nuclear Fuel:
How do Stresses on Fuel During Normal Conditions of Transport Compare to Yield?

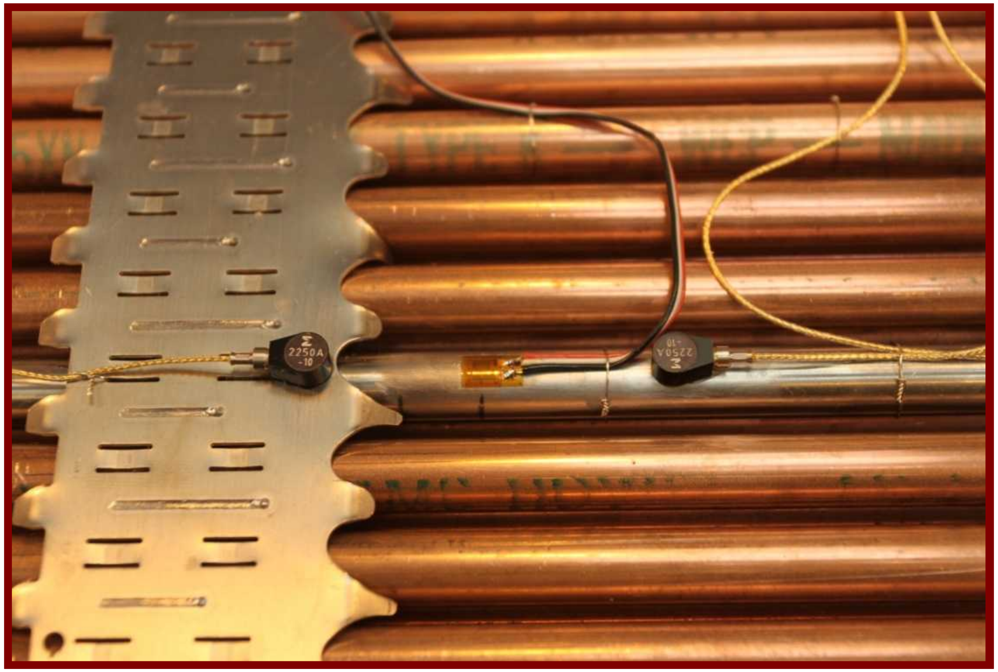
THREE SERIES OF TESTS USING SURROGATE PWR ASSEMBLY

1) ***Truck data on a vertical acceleration shaker table***
2) ***Over-the-road truck test***
3) ***Truck and rail data on a commercial seismic shaker with six degrees of freedom***

McConnell et al, 2016, SNL and PNNL

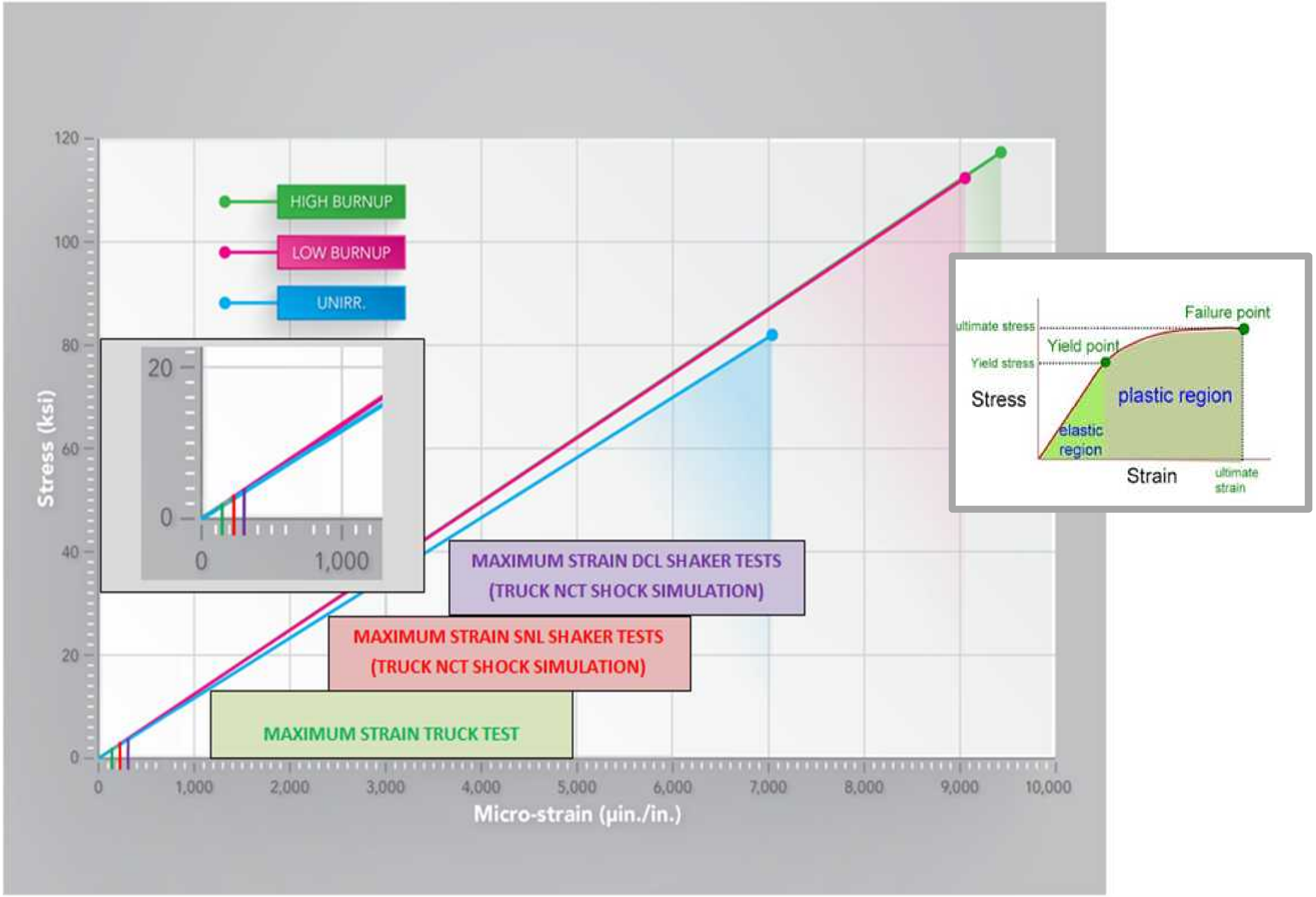
Getting Data Directly from the Fuel Rods.

A surrogate PWR assembly was assembled and instrumented at Sandia to measure strain and accelerations during Normal Conditions of Transport.



Transporting Spent Nuclear Fuel:

How Do Stresses on Fuel During Normal Conditions of Transport Compare to Yield Points?



McConnell et al, 2016, SNL and PNNL

However, these tests…

…are only simulations of the configuration of *actual* SNF transport mode.

So, We Are Performing a More Realistic Test

Sandia National Laboratories

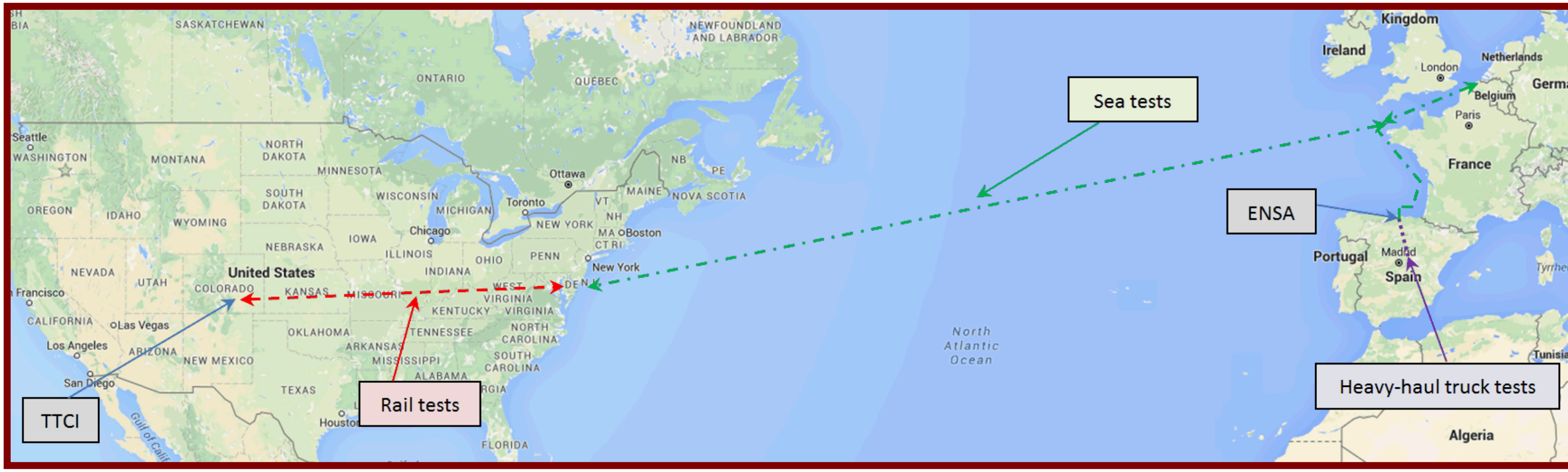
- Equipos Nucleares (ENSA) provided an ENUN 32P rail cask, basket, and cradle for international test program
  - ENUN 32P is similar to existing NRC-licensed cask currently in use in USA
- Three individual surrogate PWR assemblies are included in the test: SNL/ENRESA/Korea
- The other 29 basket cells are filled with dummy concrete assemblies to represent the mass of the loaded cask
- Tests significantly different than previous tests
  - Instrumented surrogate assemblies will be
    - within a rail-cask basket
    - within an actual rail cask on
      - ✓ *a heavy-haul truck*
      - ✓ *two different ships*
      - ✓ *a railcar*

ENUN 32P basket. Photo curtesy of ENSA

Barge from Spain to Belgium. Photo: McConnell, SNL

ENUN 32P Cask. Photo curtesy of ENSA

Routing of Cask

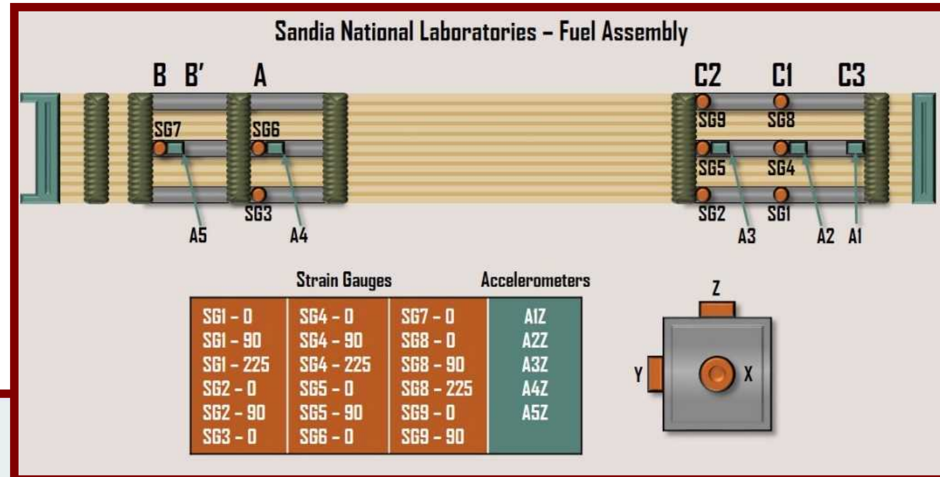


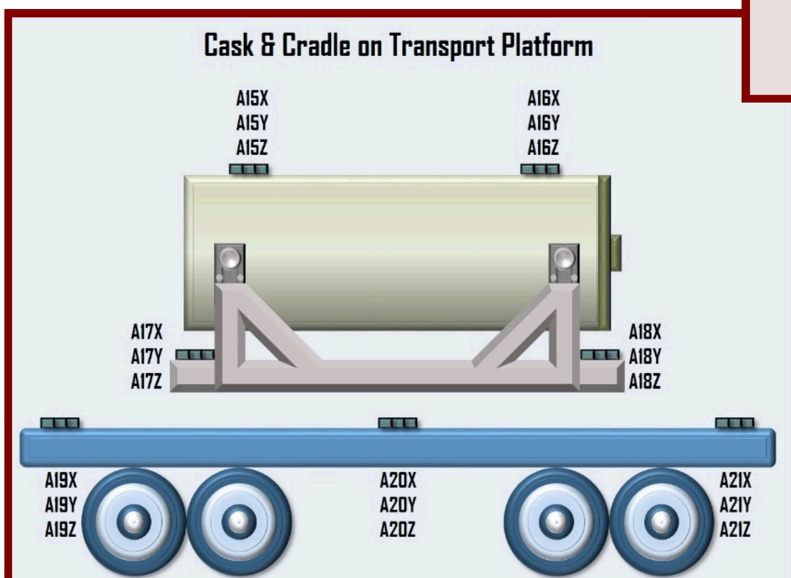
1) **Heavy-haul truck from within Spain** ~ June 2017
2) **Coastal sea shipment from Santander, Spain, to Zeebrugge, Belgium,** June 2017
3) **Ocean transport from Belgium to Baltimore**
4) **Commercial rail shipment from Baltimore to Pueblo, Colorado,** July-August 2017
5) **Testing at the Transportation Technology Center, Inc.** August 2017
6) **Return trip to ENSA will be the same**

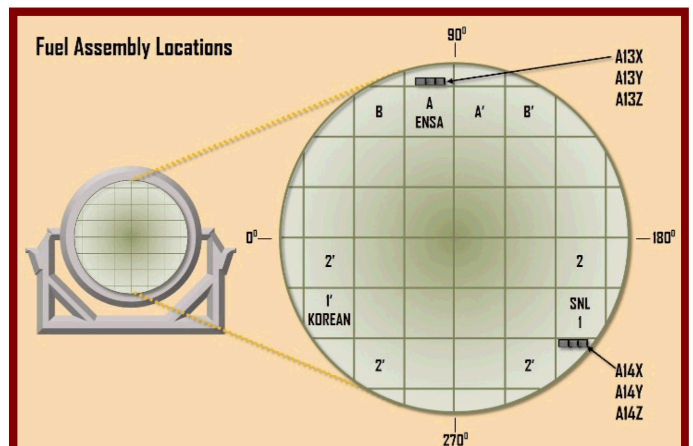
Data will be collected throughout all legs of the transport as well as the transfers between legs.

DOE Laboratories Team Instrumented Assemblies, Basket, Cask Body, Cradle, & Transport Platforms

- Sandia assembly instrumented February 2017 with strain gauges and uniaxial accelerometers.
- Triaxial accelerometers on cask, basket, cradle, and transport platforms.

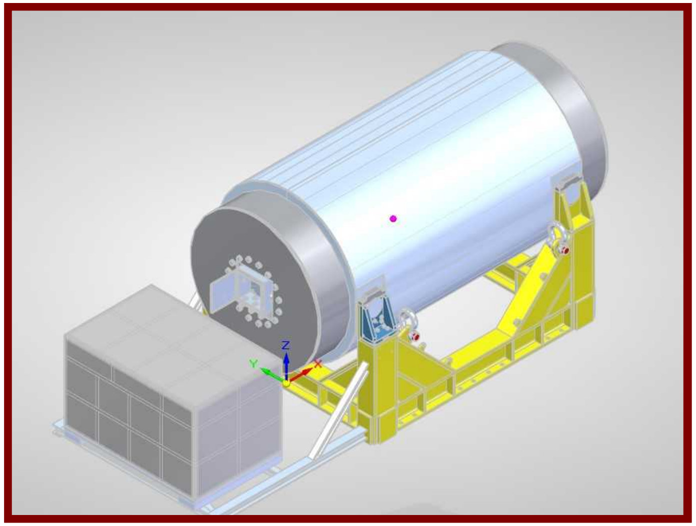






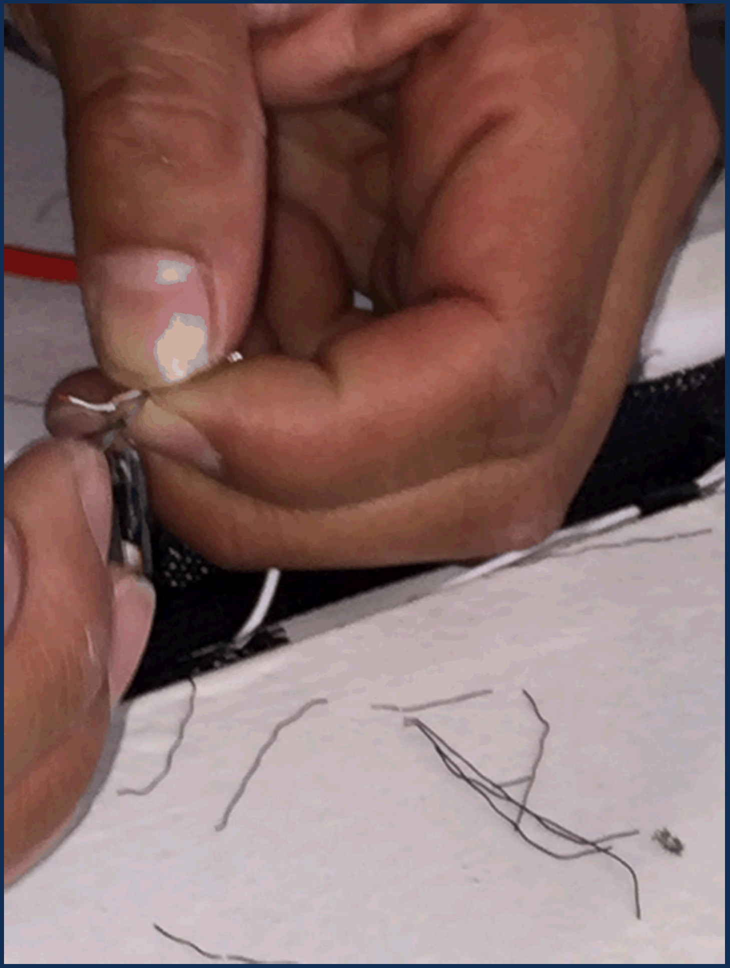
Instrumentation/Battery Box

Two 40-channel data acquisition systems, 20 batteries, 6160 feet (1.17 miles) of cable



The ENUN 32P holds 32 assemblies. We loaded it with three surrogate assemblies and 29 concrete masses. Carissa is adding the accelerometers to the baskets.

All instrumentation leads connect into this box.
It is very precise work.



The cask, cradle, and assemblies are very large, but the accelerometers, strain gauges, and leads are very small and require a careful and steady hand. Out of 78 connections, we only lost one.

The instrumentation box (the Hoffman Box) is the nexus for all the instrumentation leads and is mounted to the side of the cask.

On June 12, 2017, we completed cask handling tests performed by three different crane operators who are experienced in dry cask movement. Each crane operator performed 3 tests each.

Each handling test included a lift up, movement left or right, and then back to the ground.

Some tests were intentionally more aggressive or faster and some allowed for the cask to sway more than others.

The cask was then placed on the cradle.

You can see one of the two cask accelerometers on the left side of the cask.

Our three crane operators. They each performed three cask handing tests, so we got nine tests in all. Each cask operator has a different touch.

The trunnion was centered carefully in the cradle.
Data was collected during this entire placement.

Placing the cask carefully in the center of the cradle

The cask was then slowly tipped so it would rest horizontally in the cradle. We moved the top of the cask back and forth to initiate some more assembly movement.

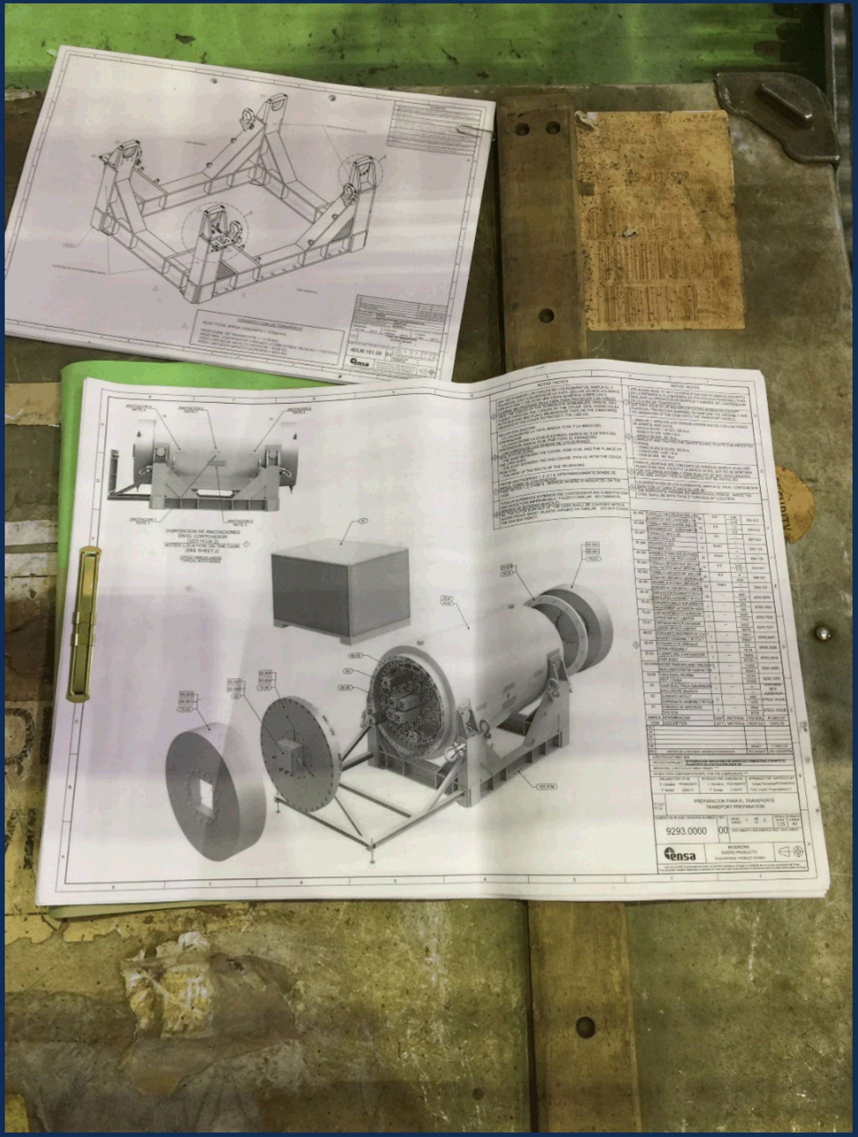
Our longer set of data acquisition cables can be seen hanging from the end of the cask.

Horizontal and yoke removed

The yoke

[redacted]

All work was performed per detailed drawings.



The two impact limiters go on next. A hole was manufactured into one to allow the data acquisition cables to pass through the lid.

The long cables are wrapped around the Hoffman Box and then led to the Data Acquisition Instruments located in the Battery Box.

Carissa Grey, Mike Arviso, and Doug Ammerman ensuring data quality before we cut off the long cables.

You can see the length of the cable needed for the handling test. The cables were then cut and shorter ones installed for the transportation tests.

Placing the impact limiter on the cask was difficult because all the bolt holes had to align perfectly.

ENSA told us, "This could take 5 minutes or 5 days." It took a few hours.

Positioning and gently moving.

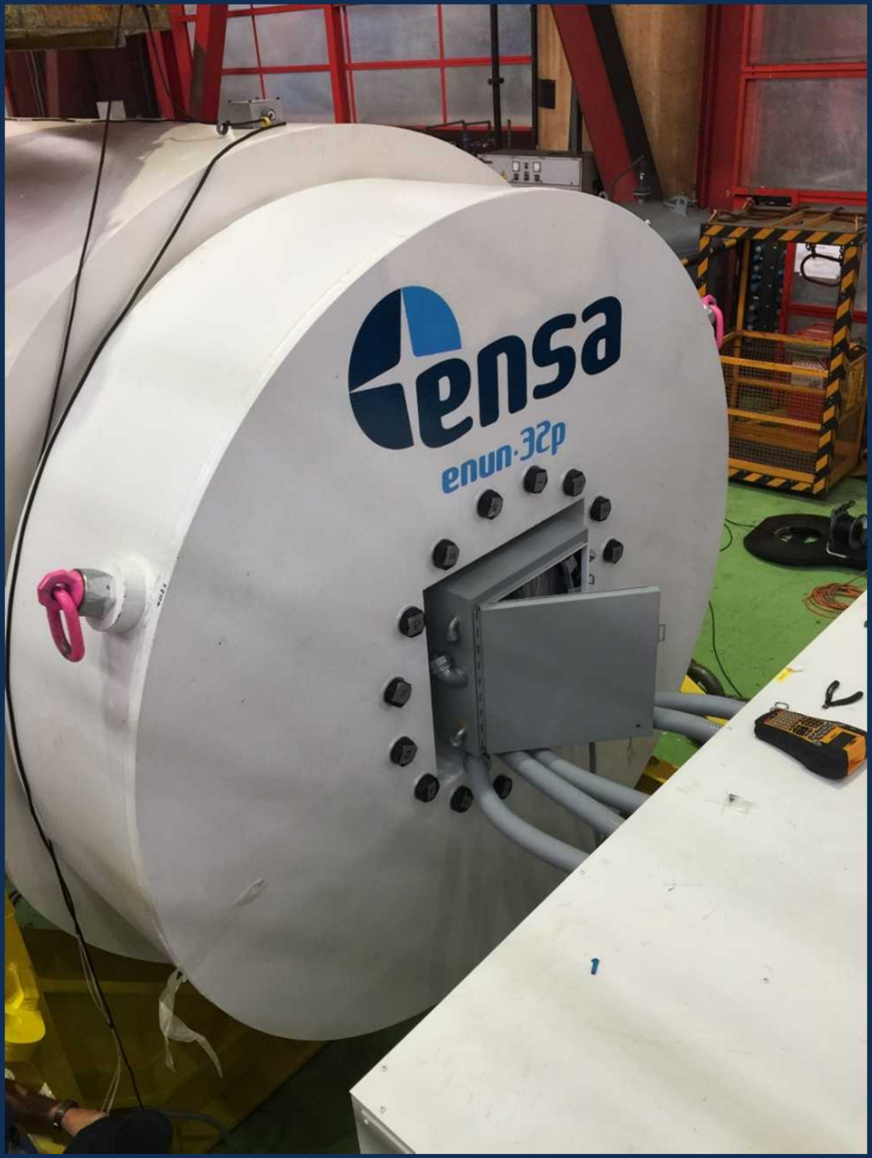
Getting the right alignment involved very small and precise crane movements.

Installing the bolts.

Success!

Placement of the battery and data acquisition box onto the cradle extension and the cask gets logos.

The short cables are now attached to the data acquisition box. Cables are run through waterproof conduit called "Liquid-tight."



Cables pulled through the liquid-tight housing.

The back impact limiter is installed and bolted.

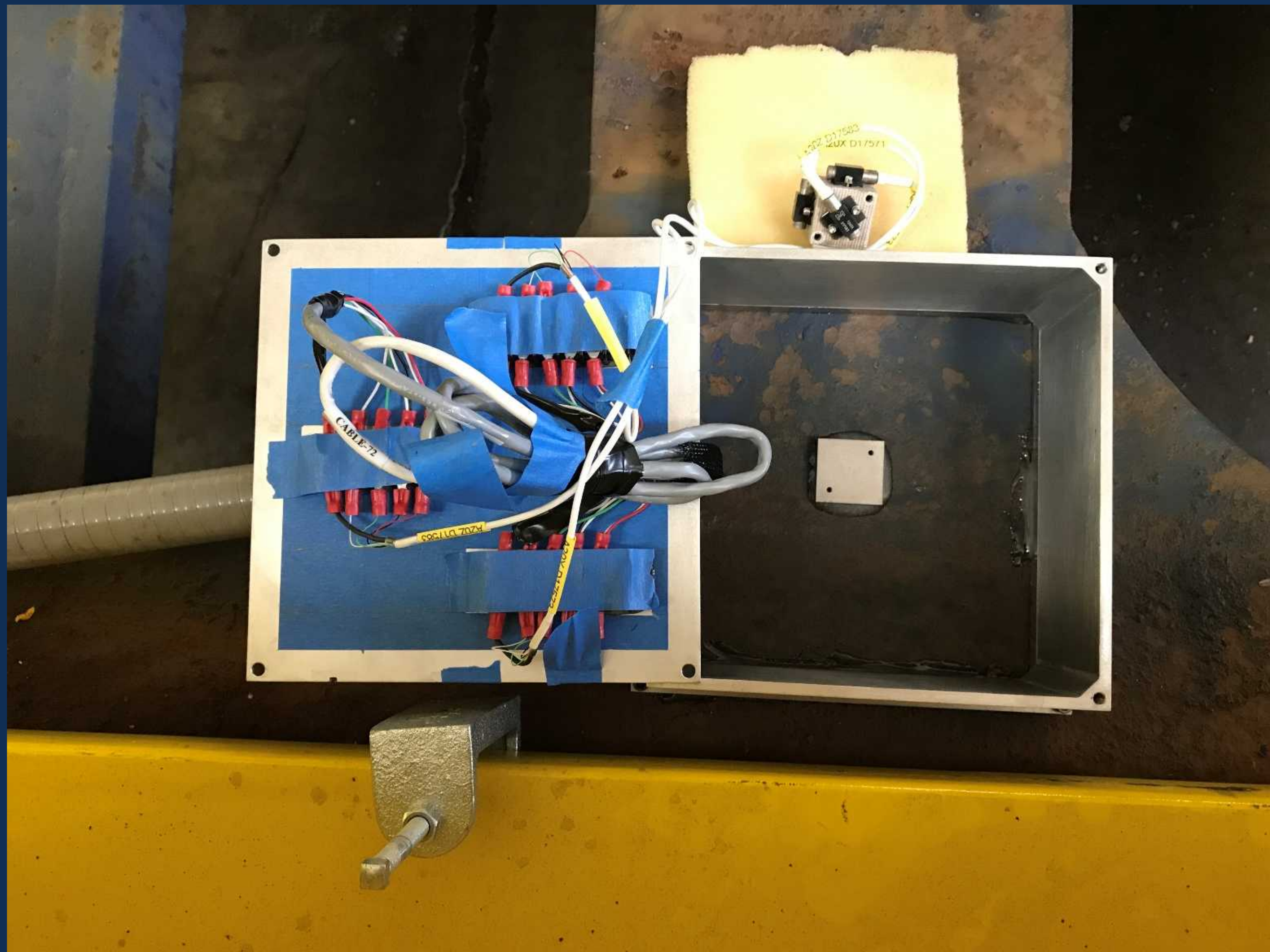
Cask accelerometer cables are placed in liquid-tight and attached to the top of the cask.

Cask accelerometers cables are connected to the Hoffman Box.

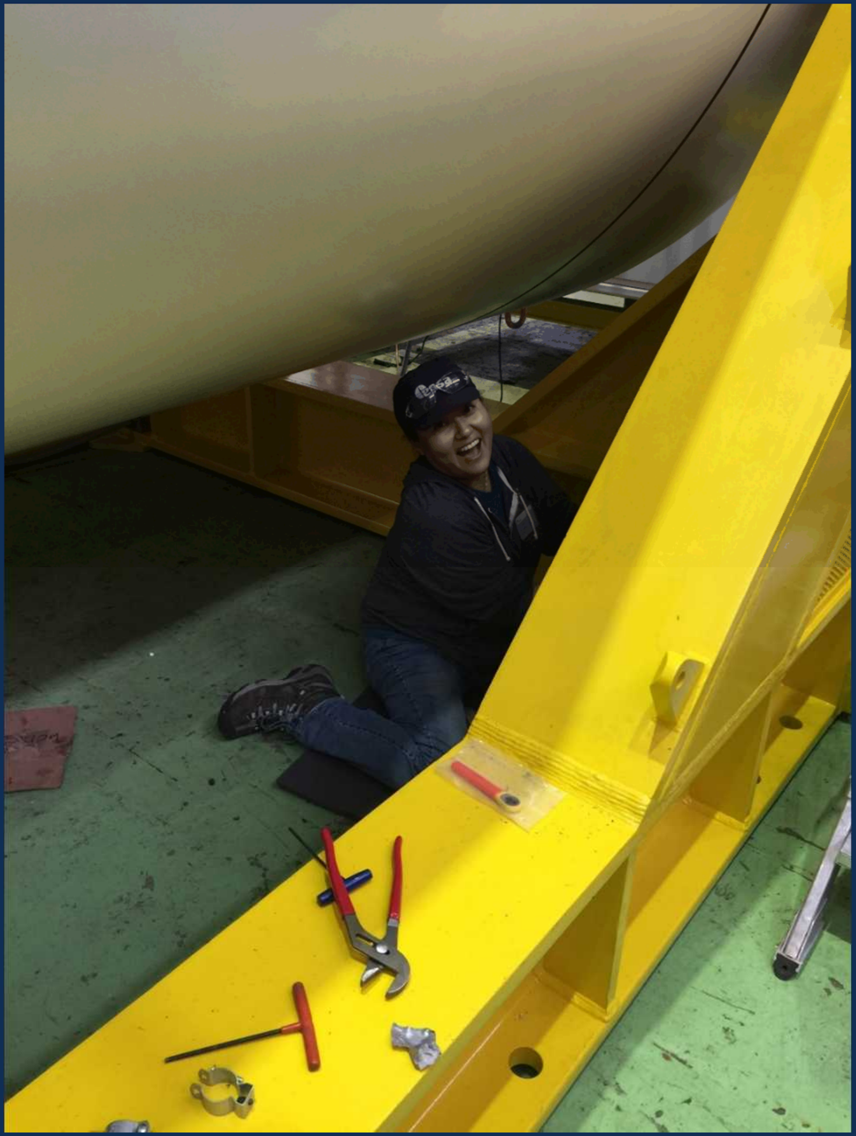
Cradle accelerometers are attached inside the corners of the cradle.

Cabling is protected with Liquid-Tight

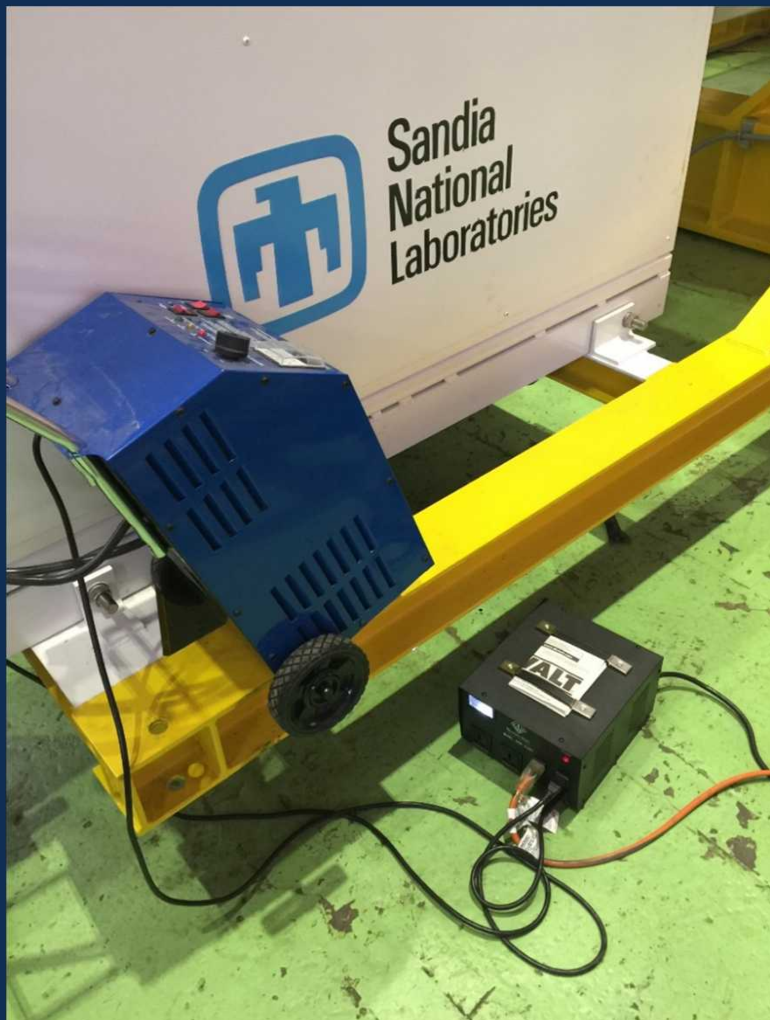


Picture of conveyance accelerometer with the cover off showing the accelerometer and inside of the box.

Carissa worked in very tight quarters for the entire project.



Charging the Batteries



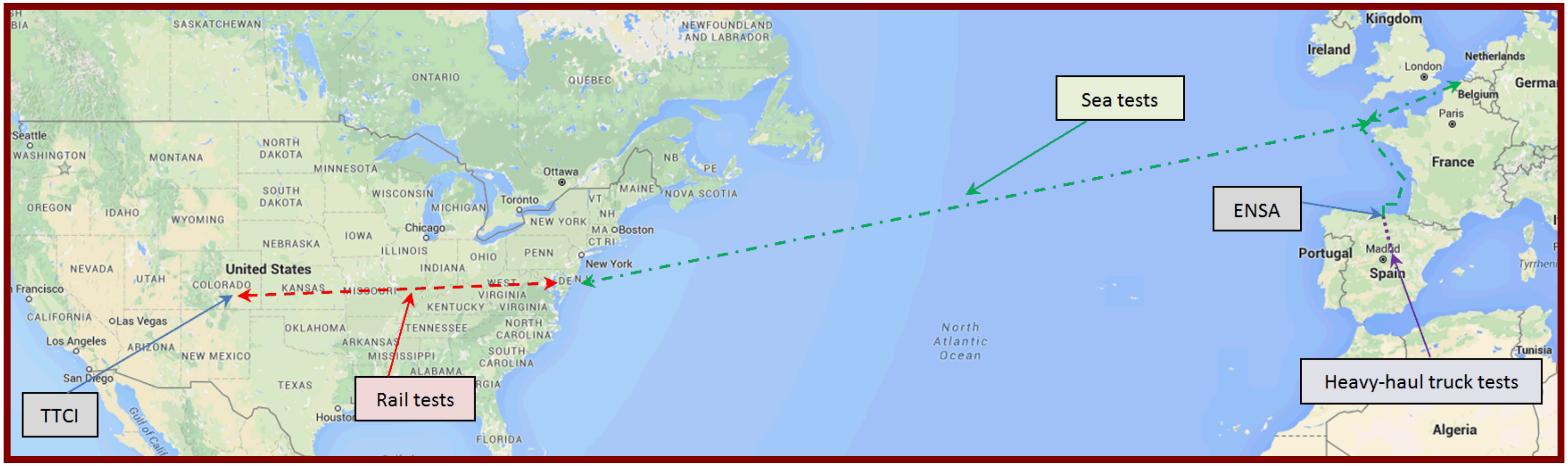
Everything coming together.

155 tons being loaded onto the truck.

The cask system was meticulously placed on the truck bed. The Heavy Haul Handling Test was successful. It collected 4.3GB of data on one hour.

Loading on the 16-axle, 110 foot-long truck. The truck had 3 sets of tri-axial accelerometers on the bed.

Routing of Cask



1) Heavy-haul truck from within Spain ~ June 2017
2) Coastal sea shipment from Santander, Spain, to Zeebrugge, Belgium, June 2017
3) Ocean transport from Belgium to Baltimore
4) Commercial rail shipment from Baltimore to Pueblo, Colorado, July-August 2017
5) Testing at the Transportation Technology Center, Inc. August 2017
6) Return trip to ENSA will be the same

Data will be collected throughout all legs of the transport as well as the transfers between legs.

The cradle is chained to the truck bed at 12 places.

Starting the 2-day heavy-haul leg of the test.

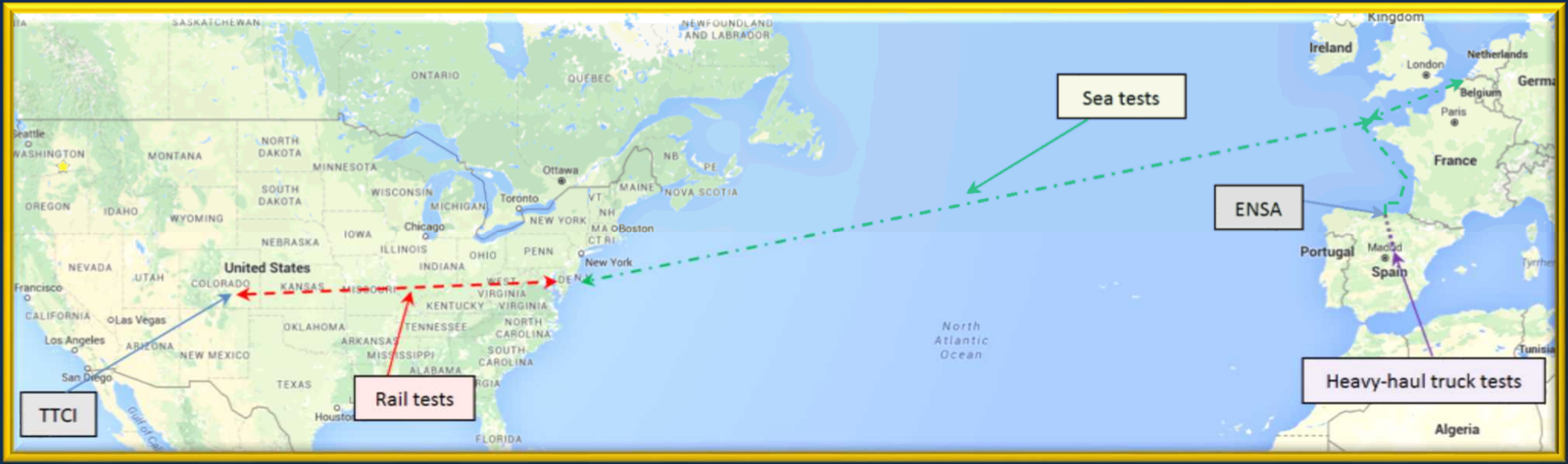
There is a 900 meter grade in which a smaller truck (seen in the back) must push up the larger truck.

The truck needed to push our truck.

Oops! Can you make a U-Turn at the light ahead?
(just kidding)

Addressing a minor hydraulic leak along the way.

Routing of Cask



1) Heavy-haul truck from within Spain ~ June 14, 2017
2) Coastal sea shipment from Santander to large northern European port ~ June 27, 2017
3) Ocean transport from Europe to eastern U.S. port (e.g., Baltimore)
4) Commercial rail shipment from East Coast to Pueblo, Colorado ~ July 12, 2017
5) Testing at the Transportation Technology Center, Inc.
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Awaiting transfer of the ENSA cask on the Samson trailer onto the ship (TARAGO) at the Port of Zeebrugge.

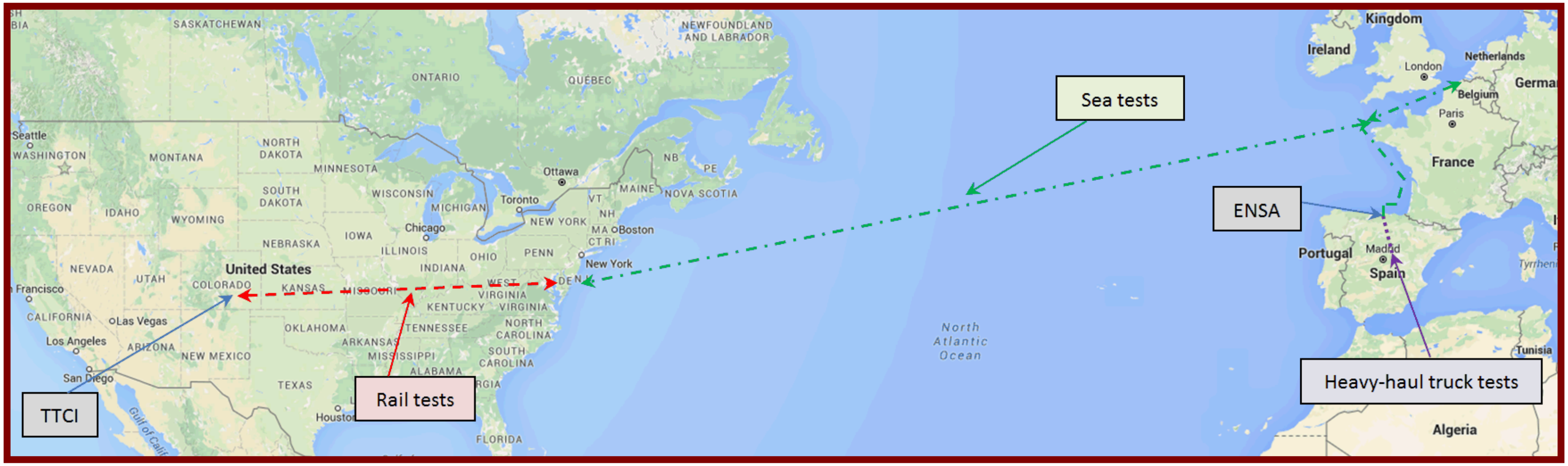
Loading the system onto the ship in Belgium to go to the US.

It was the first cargo loaded onto the ship, so it was positioned in the bottom of the ship.

Inside the ship

Lashing of the ENSA cask onto the Samson trailer and onto the deck of the ship in Zeebrugge on the TARAGO.

Routing of Cask



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Cask being lifted by crane; placed on 12-axle railcar.

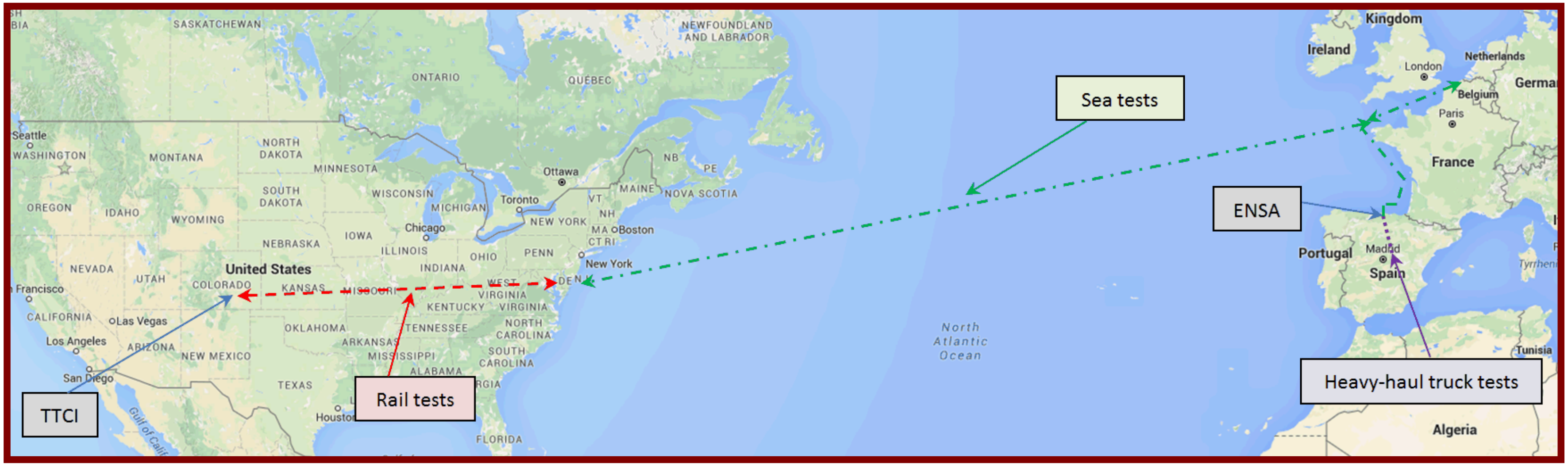
Cask on Railcar

ENSA Cask after being transferred by crane from Samson trailer to Kasgro 12-axle railcar. This picture is prior to lashing (welding) and reconnection of instrumentation system.

ENSA Cask after been placed on 12-axle railcar. DOE and NRC observers observing SNL instrumentation system.

The Rail portion of the trip.

Routing of Cask



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Accelerometer on Rail Car

TTCI Instrumented Wheel Set

Rail Tests at TTCI

August 14-25, 2017

1) **Crossing Diamond Tests –**subject the vehicle to typical vertical impacts resulting from the wheels traversing gaps in the rails where tracks intersect.

2) **Twist & Roll Test –**determine the car's ability to negotiate oscillatory cross-level perturbations.

3) **Pitch & Bounce Test –**determine the car's ability to negotiate parallel vertical rail perturbations.

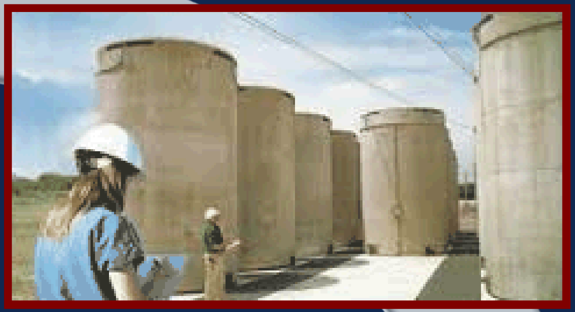
4) **Dynamic Curving Test –**determine the cars ability to negotiate curving over jointed track with a combination of lateral misalignment at the outer rail joints and cross-level due to low joints on the staggered rails.

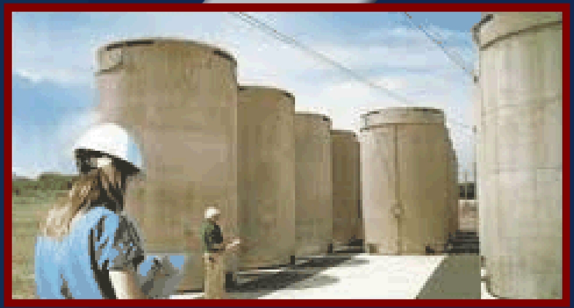
5) **Tests at Pueblo Chemical Depot –**runs over FRA Class-2 railroad track and tests through No. 8 turnout and No. 8 crossovers.

6) **Coupling Impact Test –**provide longitudinal inputs from coupling at higher than normal speeds.

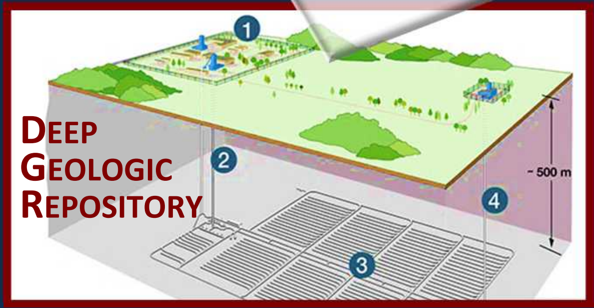
7) **Loaded Hunting Test –**determine the vehicle's lateral stability at higher speeds.

8) **Single Bump Test –** This test is intended to represent a grade crossing. The test zone consists of a 1" bump on tangent track. The bump is a flat topped ramp that rises up over 7', has a steady elevation over 20', and drops back down over 7'. Test speeds are 40-75 mph in 5 mph increments. Railroad industry experience is that vertical dynamic response at grade crossings is a significant source of large vertical accelerations and shock and vibration in freight cars.





THE BIG PICTURE



We owe enormous thanks to Ned Larson at the Department of Energy who saw the value in this project, funded it, and kept looking for money for us at every turn.

We owe equal thanks to ENSA, who initiated the brainstorming, provided the hardware and the operational excellence to get this done.

Thank you!