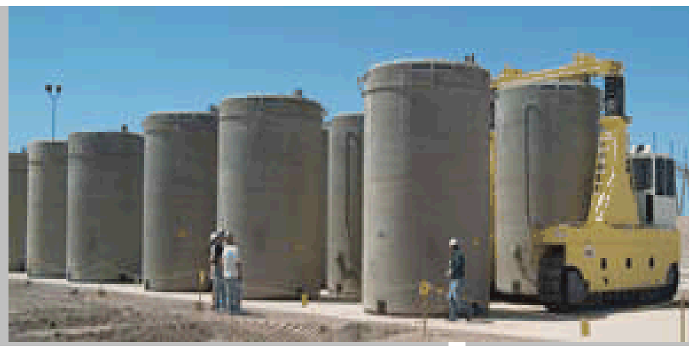
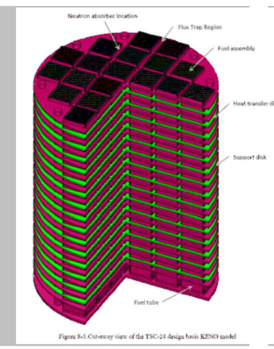
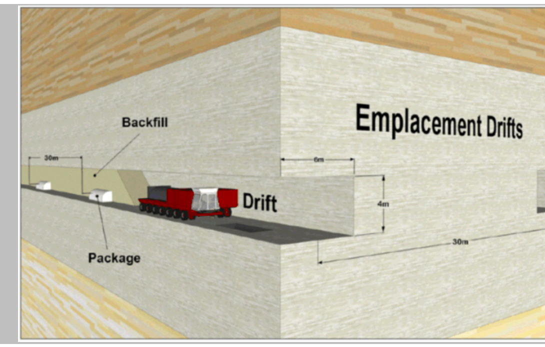
SAND2017-7183PE







Multi Modal Transportation Test Set-Up and Handling Test

June 12-14, 2017

Tito Bonano, Robert MacKinnon, Kevin McMahon, Sylvia Saltzstein, Ken Sorenson, Peter Swift

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SAND Number: SAND2017-XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Transporting Spent Nuclear Fuel:

How do Stresses on Fuel During Normal Conditions of Transport Compare to Failure Limits?

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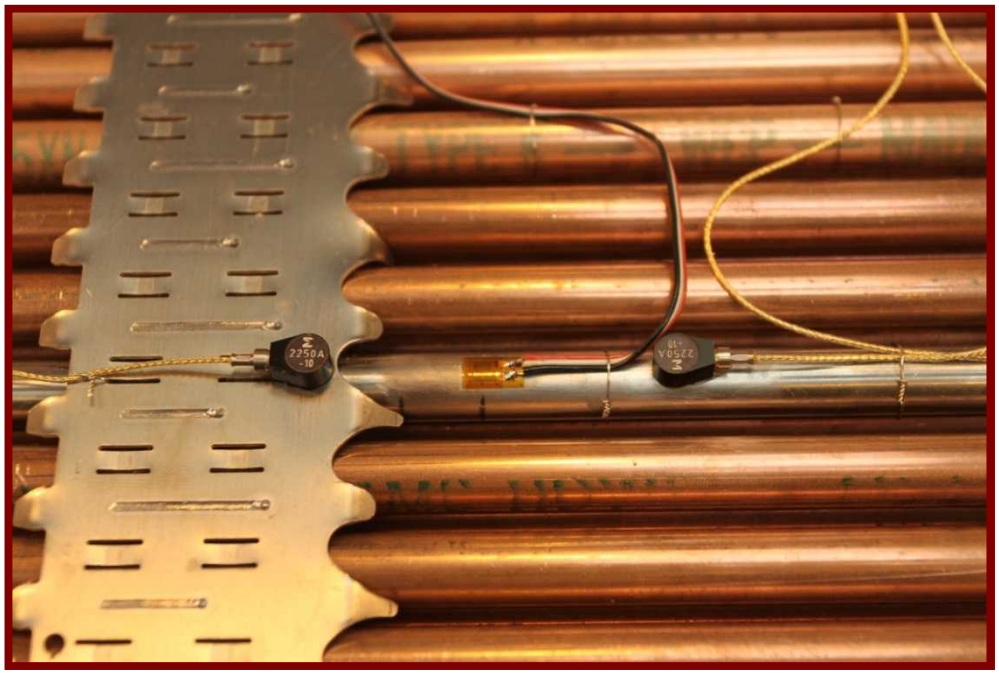
THREE SERIES OF TESTS USING SURROGATE PWR ASSEMBLY

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*

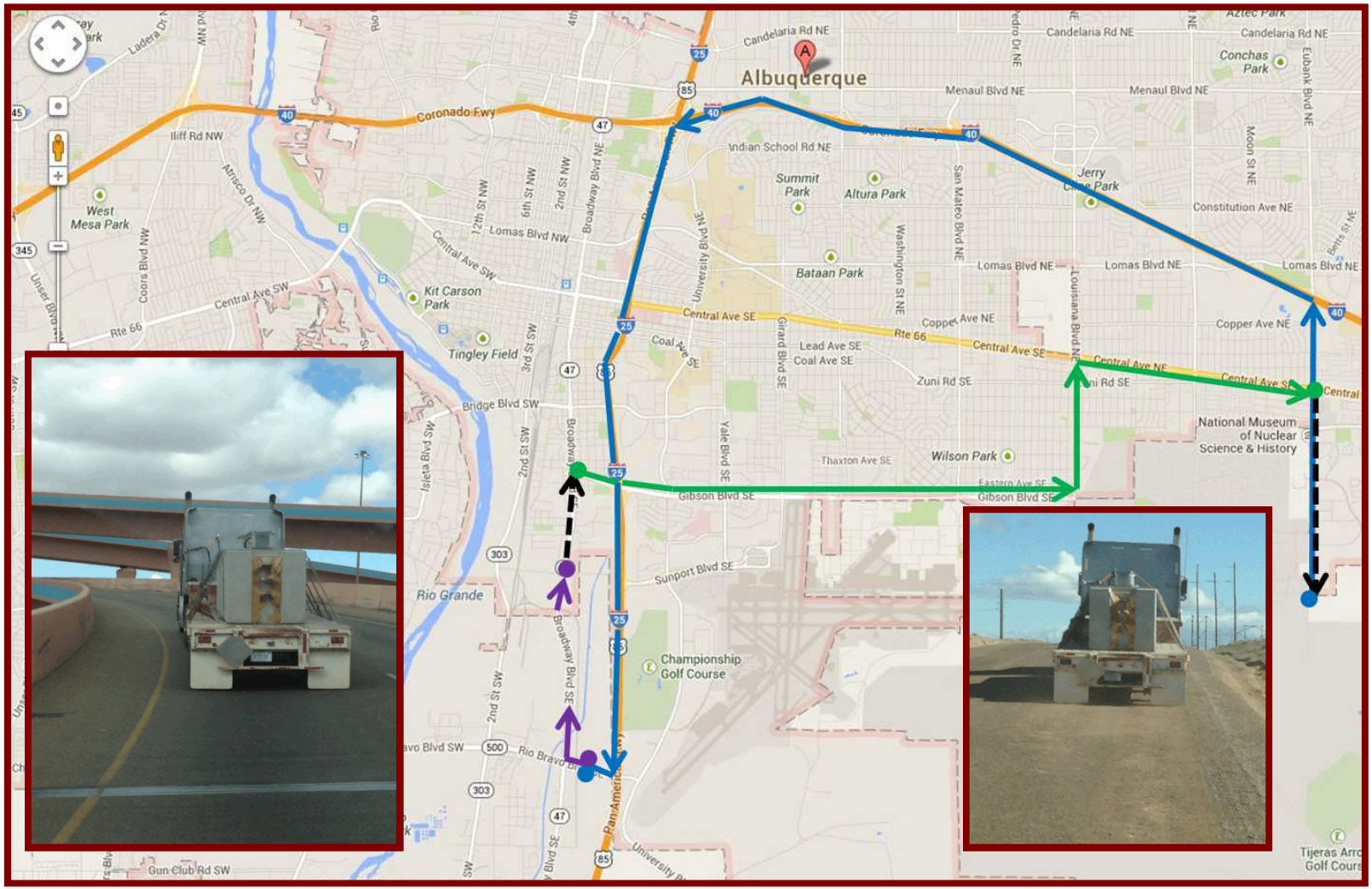
McConnell et al, 2016, SNL and PNNL

Surrogate Assembly

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

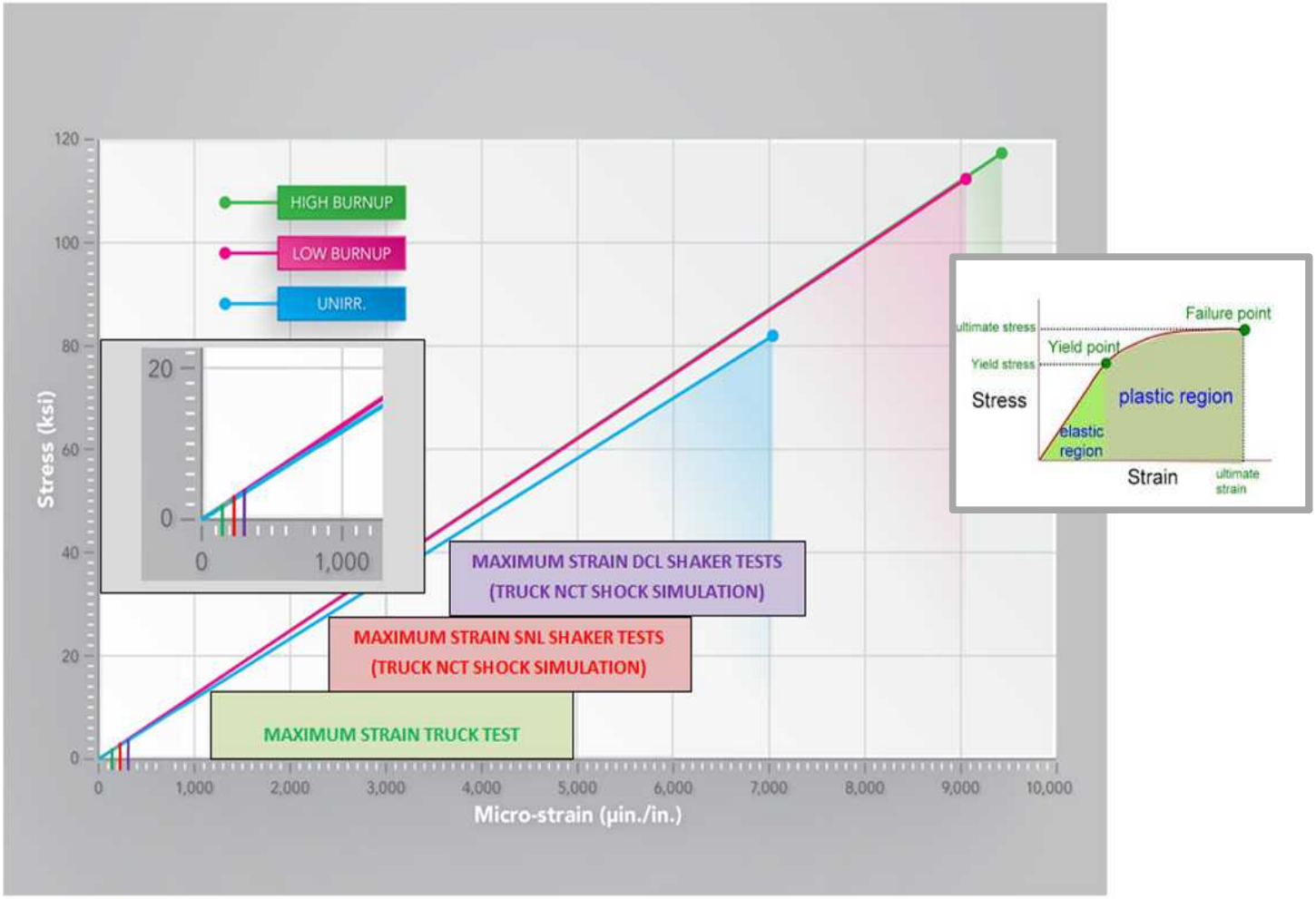


Driven 40 miles Over Range of Road Conditions (ABQ)



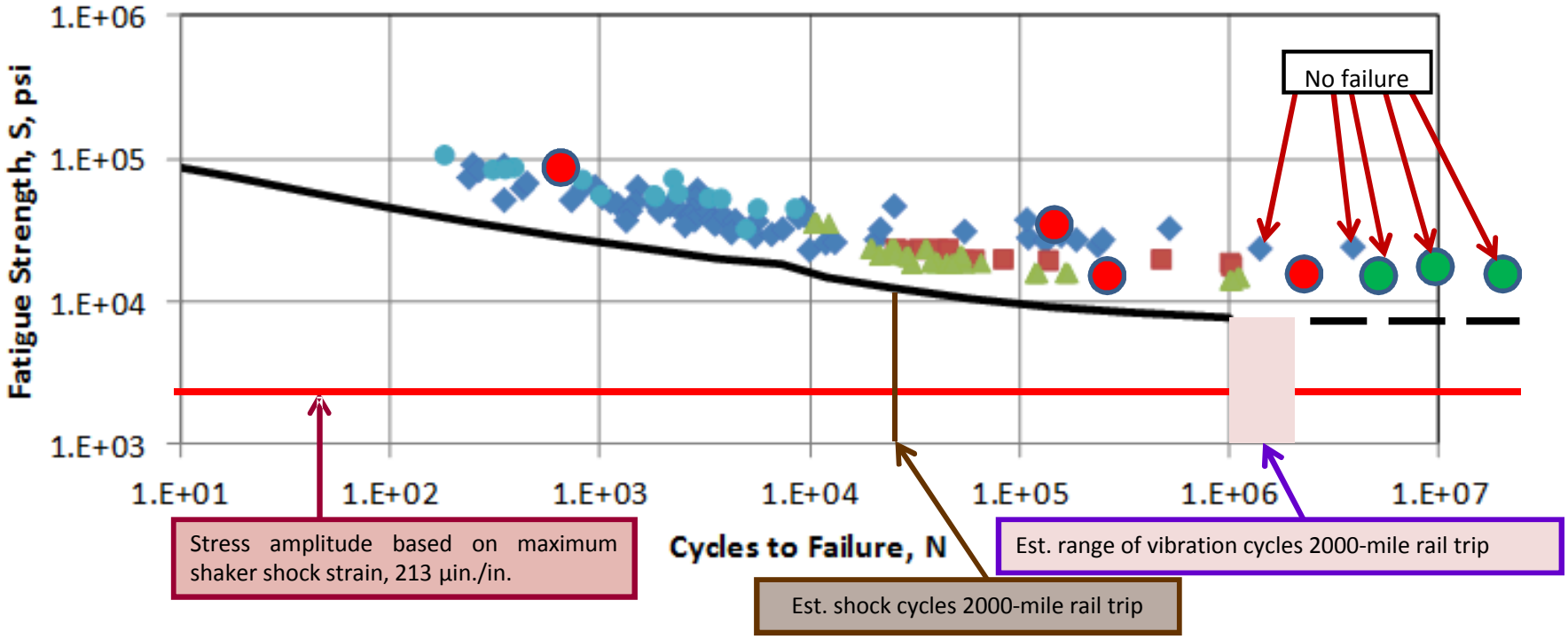
Transporting Spent Nuclear Fuel:

How do Stresses on Fuel During Normal Conditions of Transport Compare to Elastic Failure Limits?



McConnell et al, 2016, SNL and PNNL

Transporting Spent Nuclear Fuel:
Could Vibrations or Shocks Result in Fatigue Failure?



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

Data plot courtesy of Ken Geelhood, PNNL
The large circles are ORNL HBR data

CONCLUSIONS

The realistic stresses fuel experiences due to vibration and shock during normal transportation are far below yield and fatigue limits for cladding. We only have limited rail data, which most likely will be the prevailing transportation mode.

However, these tests…

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

So, We Are Performing a More Realistic Test

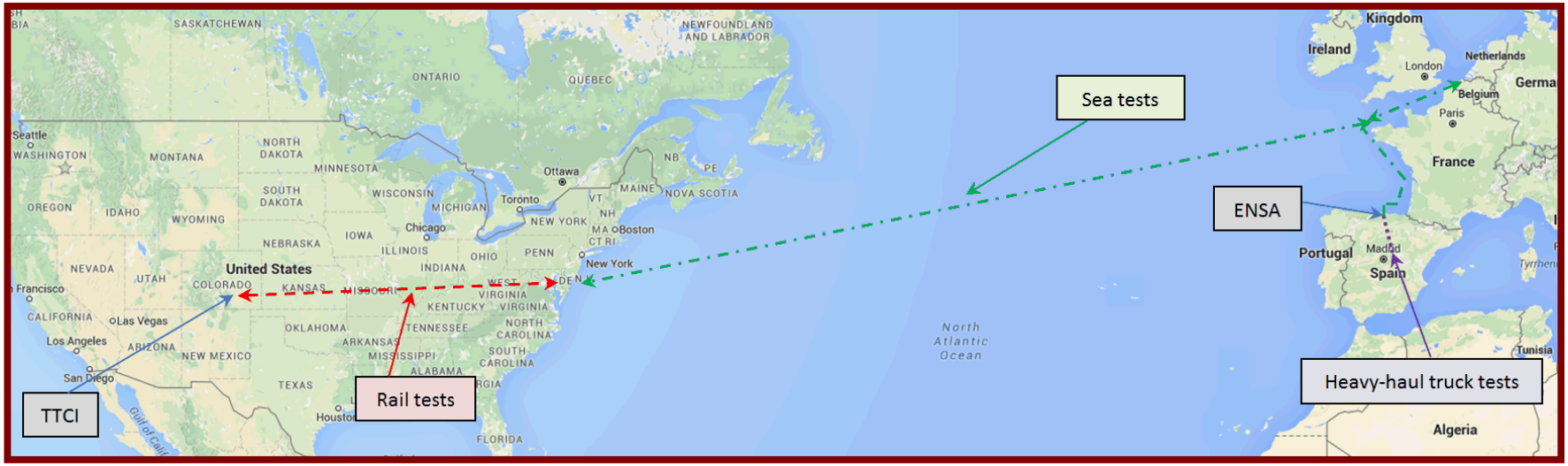
- Equipos Nucleares (ENSA) provided an ENUN 32P rail cask, basket, and cradle for international test program
  - ENUN 32P is similar to existing NRC-licensed cask currently in use in USA
- Three individual surrogate PWR assemblies are included in the test: SNL/ENRESA/Korea
- The other 29 basket cells 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 14, 2017
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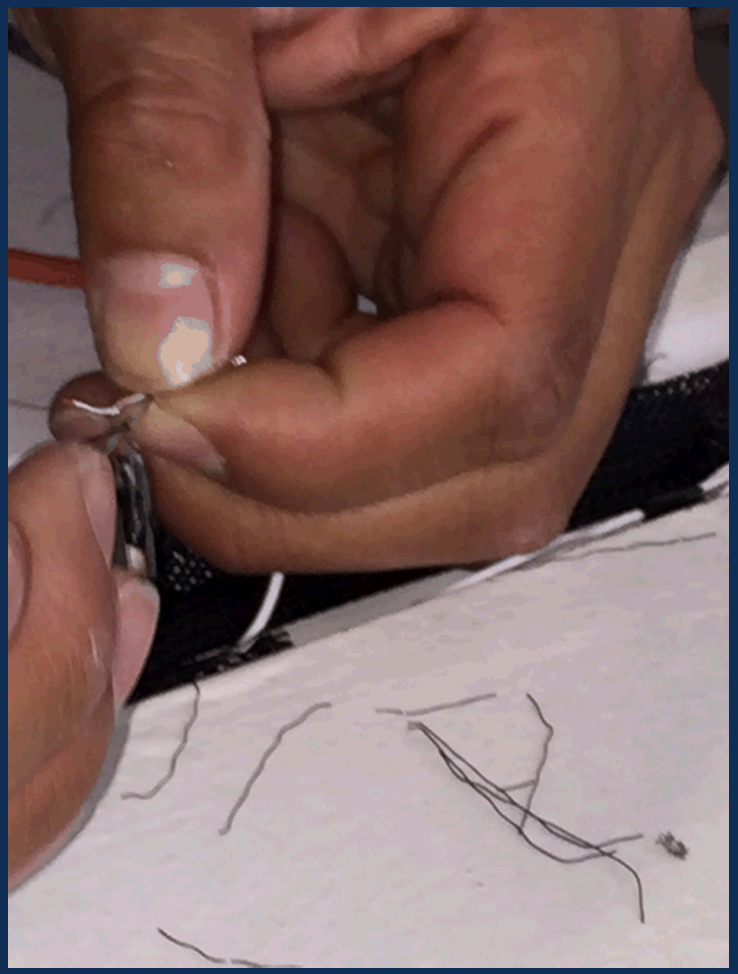
5) Testing at the Transportation Technology Center, Inc.
6) Return trip to ENSA will be the same

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

The ENUN 32P holds 32 assemblies. We loaded it with three surrogate assemblies and 29 concrete masses. Here, 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. For two years before this date, this team had been involved in very detailed planning so that everything would work perfectly. Each day has brought a new challenge, but all the planning has paid off.

Each handling test included a lift up, movement left or right, and then back to the ground. This was performed nine times by three different crane operators.

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.

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.

Cask positioned at about 45 degrees.

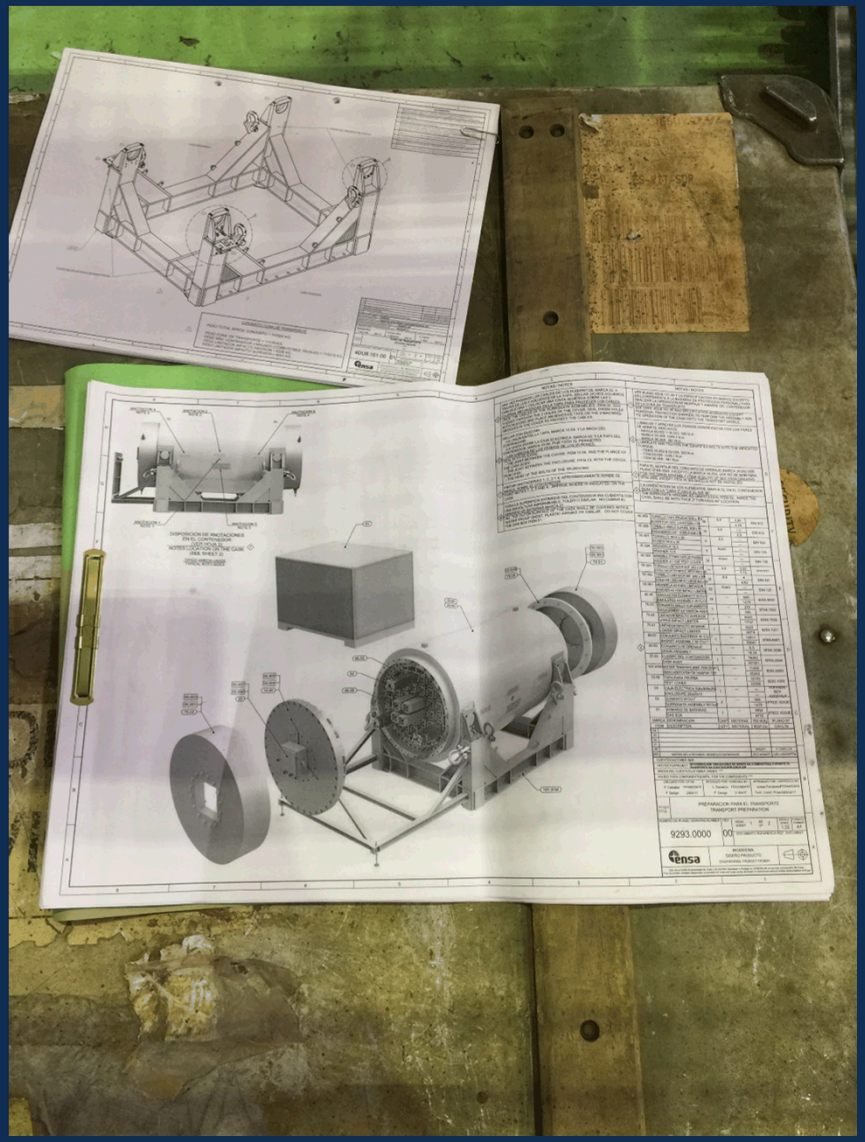
Our longer set of data acquisition cables can be seen hanging from the end of the cask.

Horizontal and yoke removed

Horizontal

The yoke

All work was performed per detailed drawings.



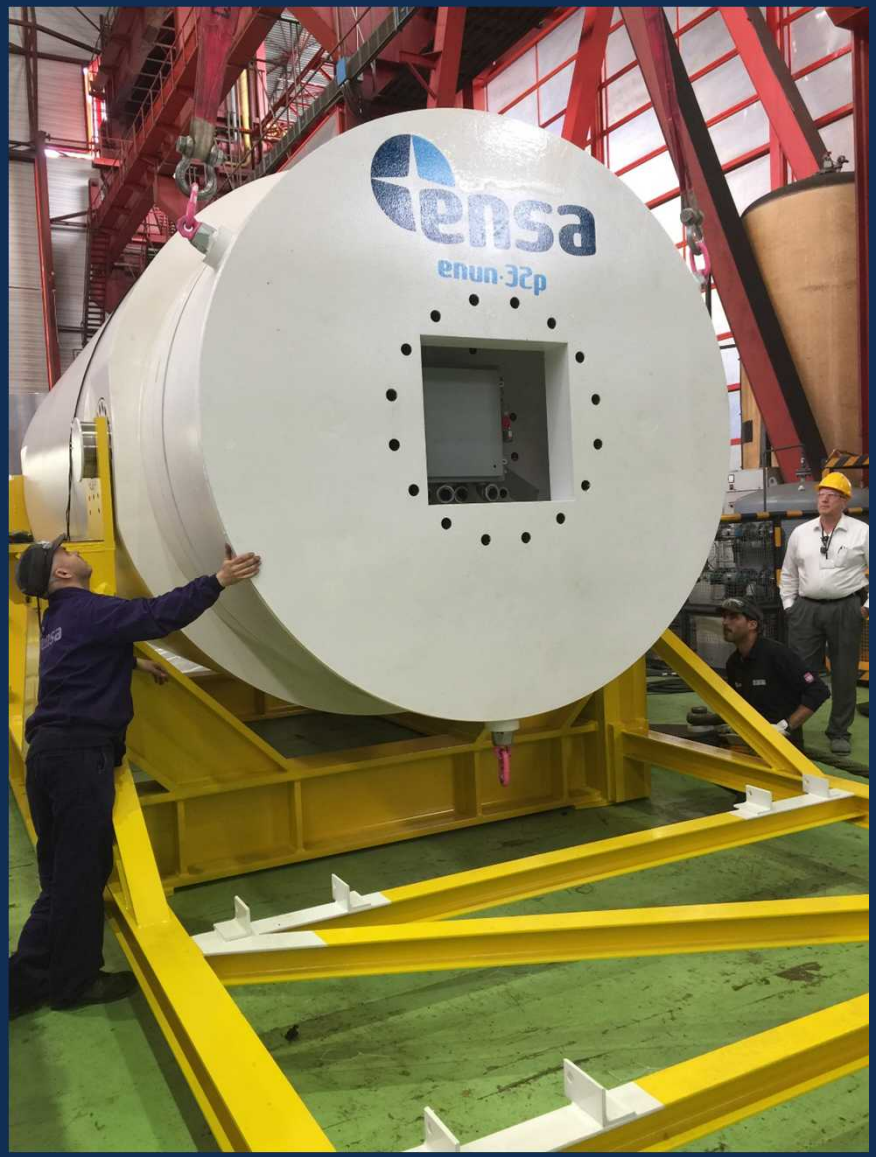
The two impact limiters go on next. A hole was manufactured into one to allow the data acquisition cables to pass through the lid.

The long cables are wrapped around the Hoffman Box and then lead 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.

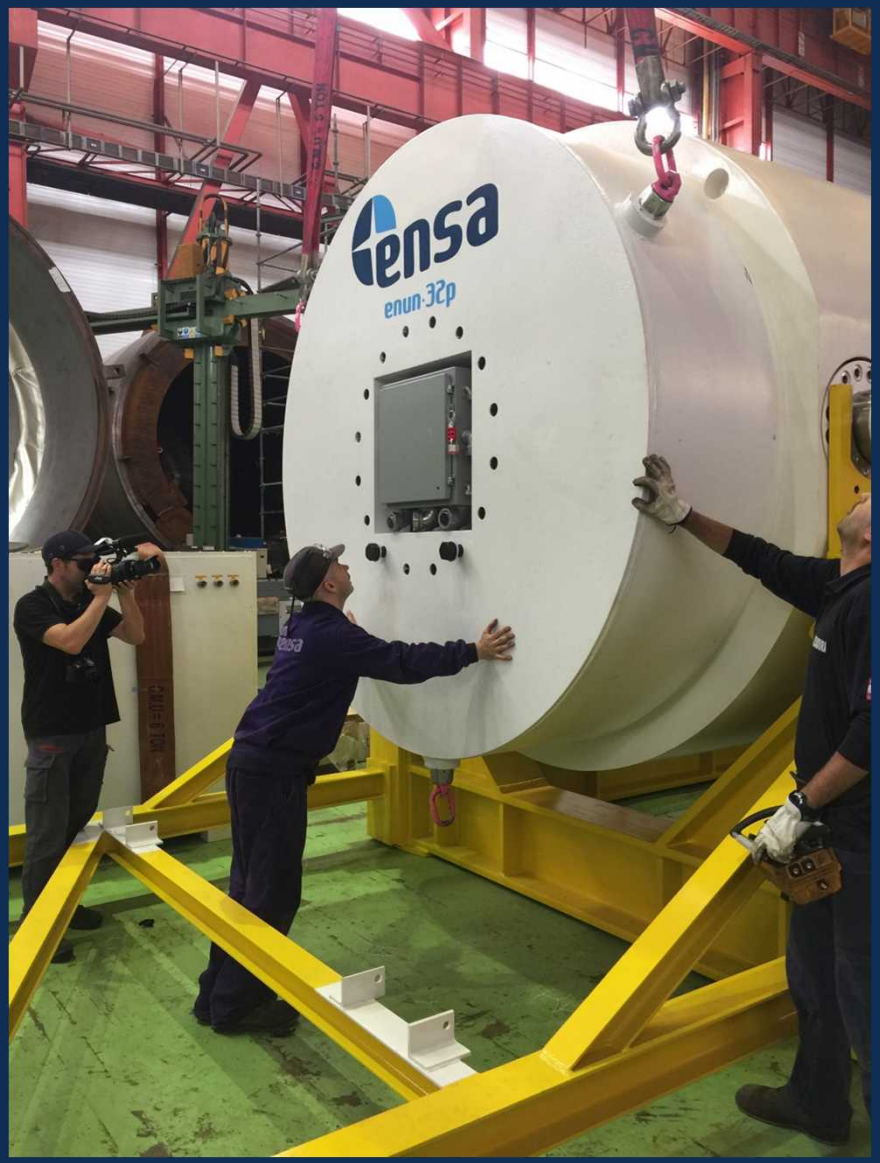


Positioning and gently moving.

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

Installing the bolts that hold the impact limiter to the cask.

More tiny crane movements to allow the bolts to go in.



Installing the bolts.

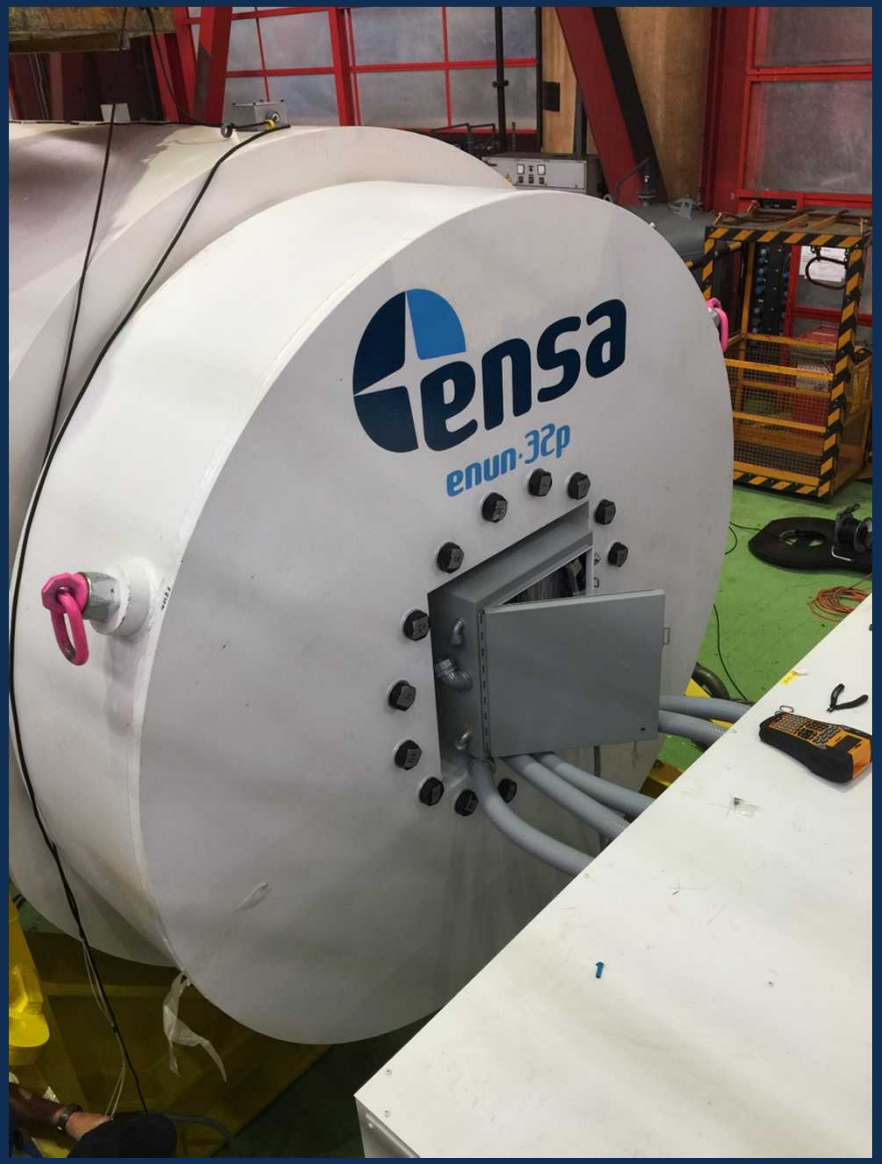
Success!

Tightening the bolts.

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

Earlier at SNL, 20 batteries, 2 data acquisition boxes, and lots of cabling were placed in the box.

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

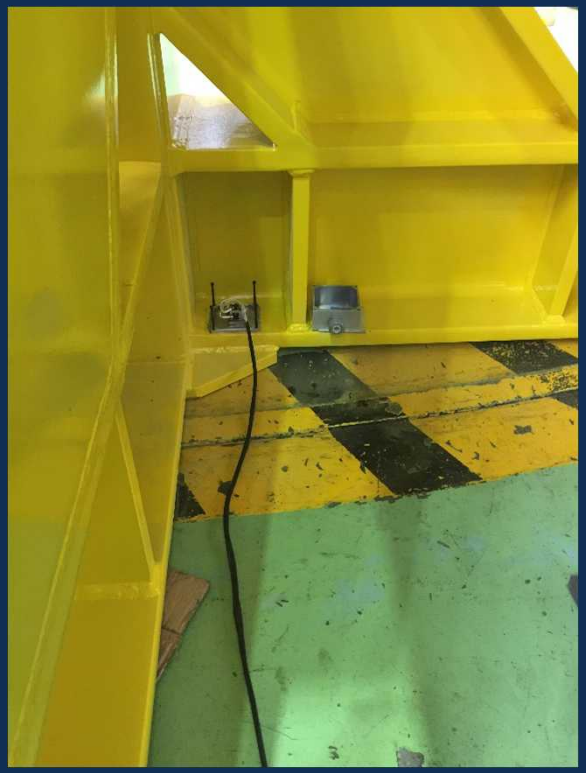


Cables pulled through the liquid-tight housing.

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.

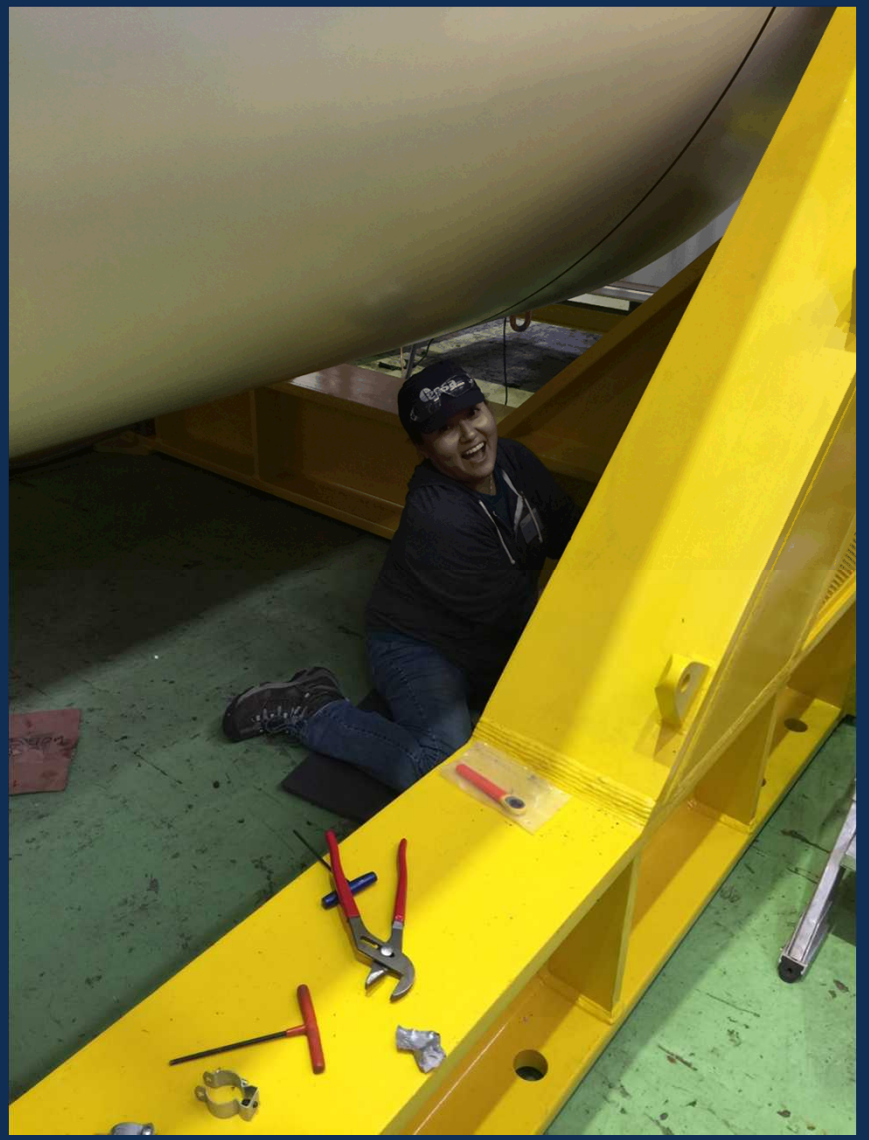


Cradle accelerometers are attached inside the corners of the cradle.

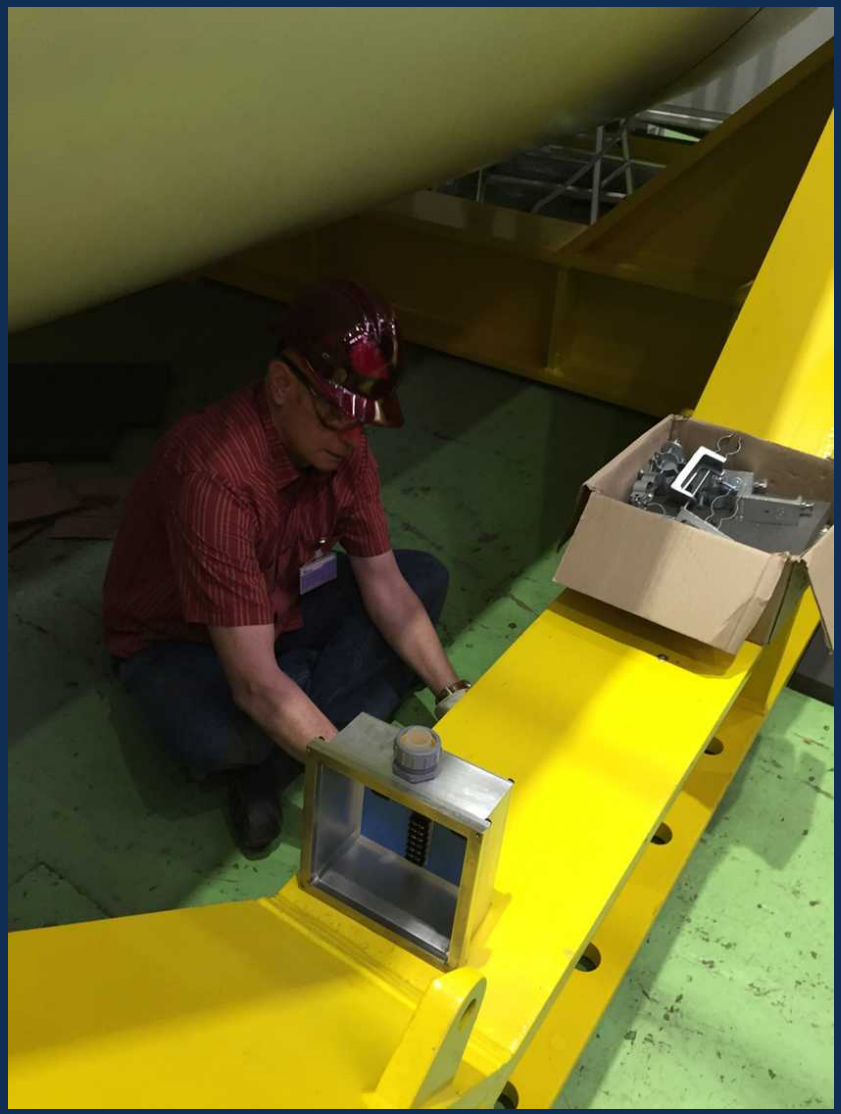
Cabling is protected with Liquid-Tight

Cask accelerometer cabling is attached to the cask with nylon belt.

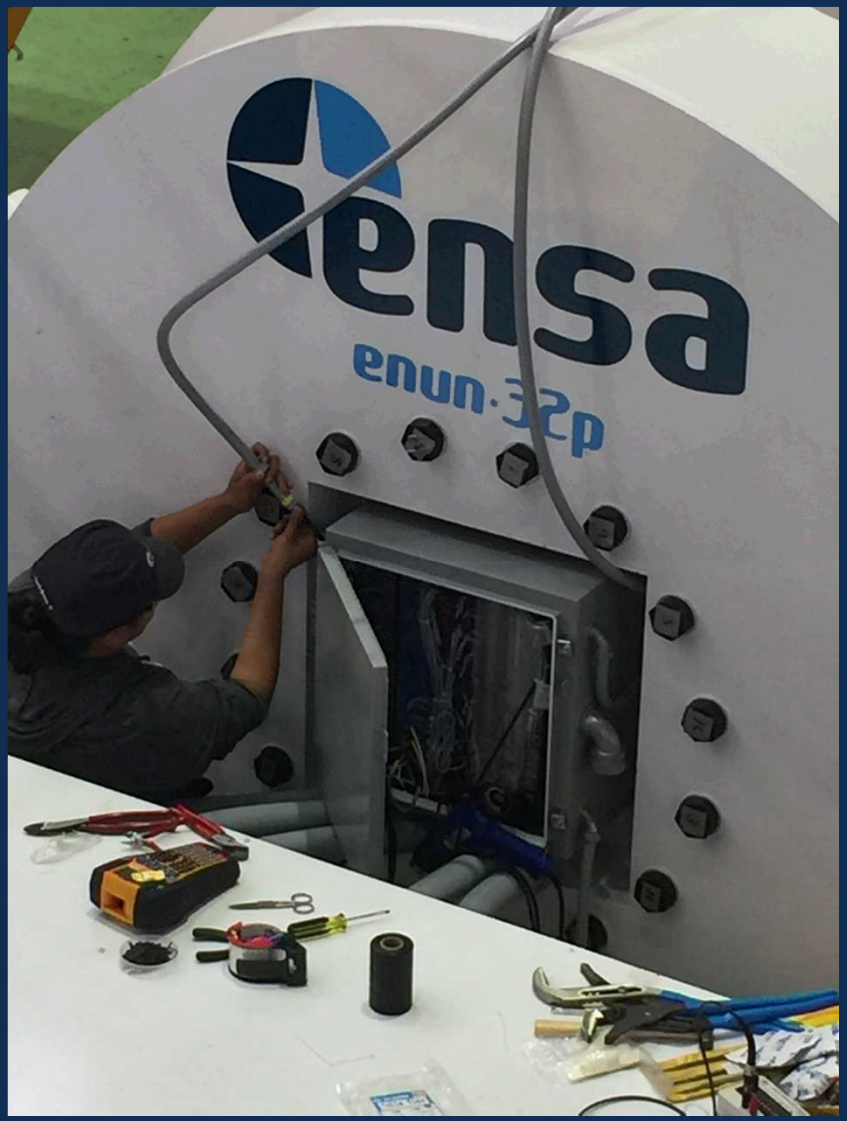
Carissa worked in very tight quarters for the entire project.



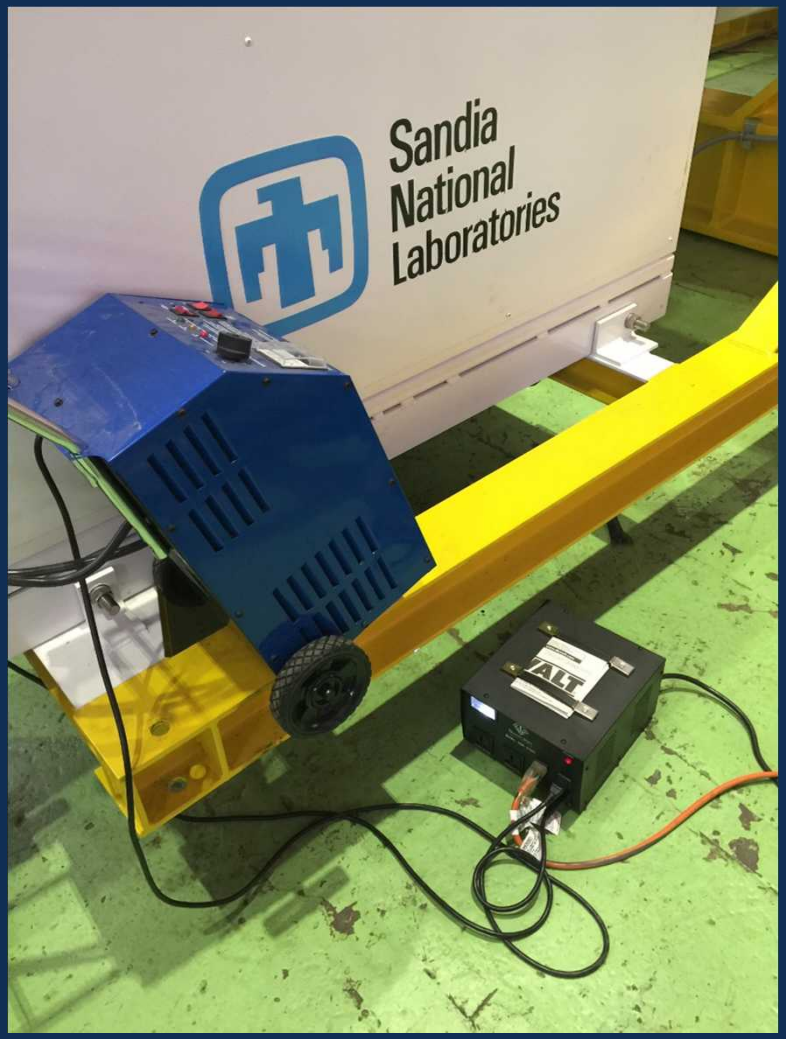
Hours of detailed work was accomplished by all.



Installing cask accelerometers to the Hoffman Box.



Charging the Batteries



Everything coming together.

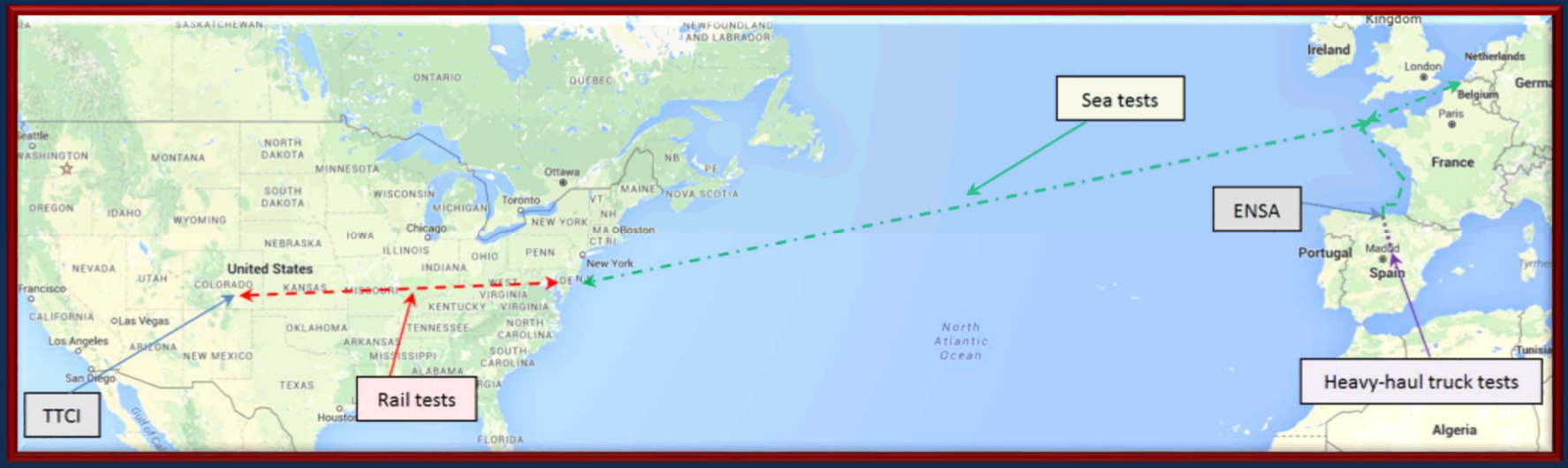

ensa
Sandia National Laboratories

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 will have 3 sets of tri-axial accelerometers on the bed.

Routing of Cask



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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.

Ready for the 2-day heavy-haul leg of the test.

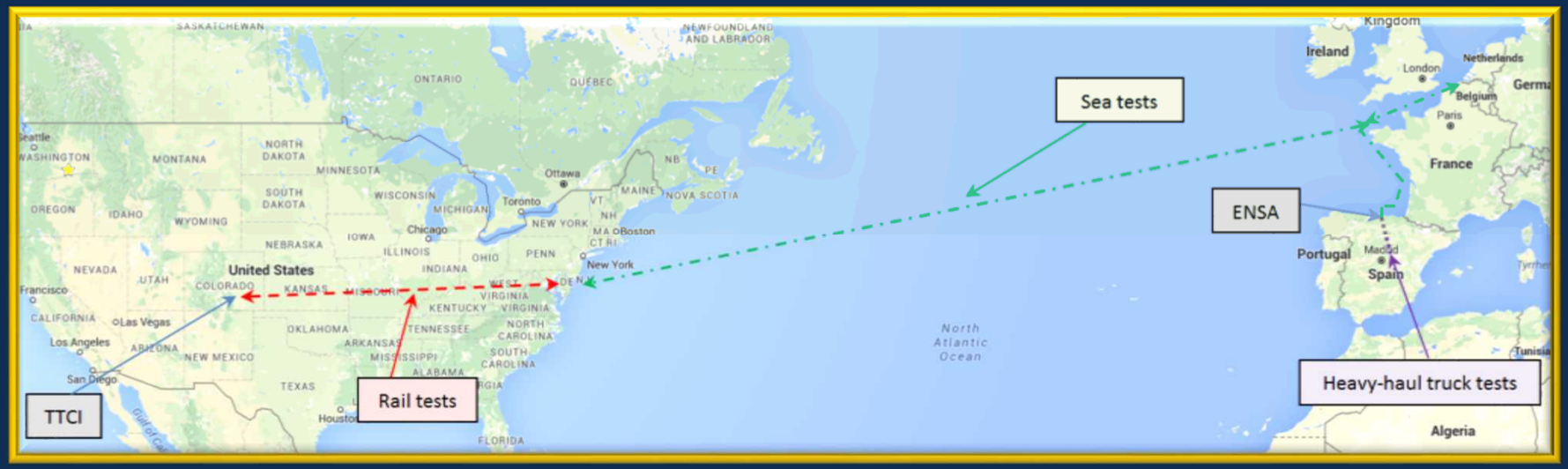
There is a 900 meter grade in which a smaller truck (seen in the back) will push up the larger truck.

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



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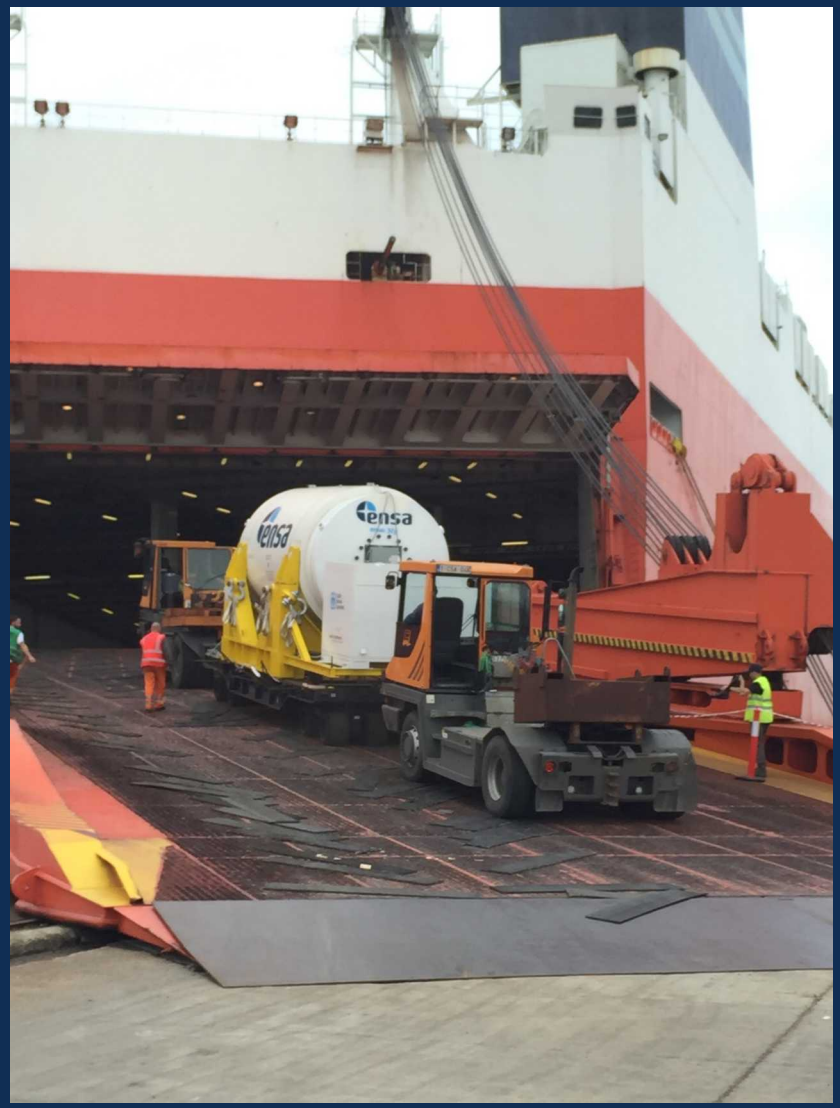
The system is being loaded onto the ship in Belgium to go to the US.

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



Inside the ship

Thank you.

(Left to Right) Paul McConnell (SNL), Ismael Fernandez Perez (ENSA), Rafael Gonzalez Garmendia (ENSA)

(Left to Right) Marco, Roberto, Paul McConnell, Sylvia Saltzstein, Ismael Fernandez Perez, Doug Ammerman, Mike Arviso, Carissa Grey. We are missing Steve Ross, Guillermo Calleja and Rafael Gonzalez.

Mike Arviso, SNL Instrumentation Expert, and Rafael Gonzalez Garmendia, ENSA Project Lead.

We all signed the battery box.

(Top Left to Right) Ismael Perez (ENSA), Mike Arviso (SNL), Carissa Grey (SNL), Rafael Gonzalez (ENSA).

(Bottom lLeft to Right) Doug Ammerman (SNL), Roberto (ENSA), Marco (ENSA), Paul McConnell (SNL). Not pictured Steve Ross and Sylvia Saltzstein.

We owe enormous thanks to Ned Larson 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!

Beautiful Spanish Tapas