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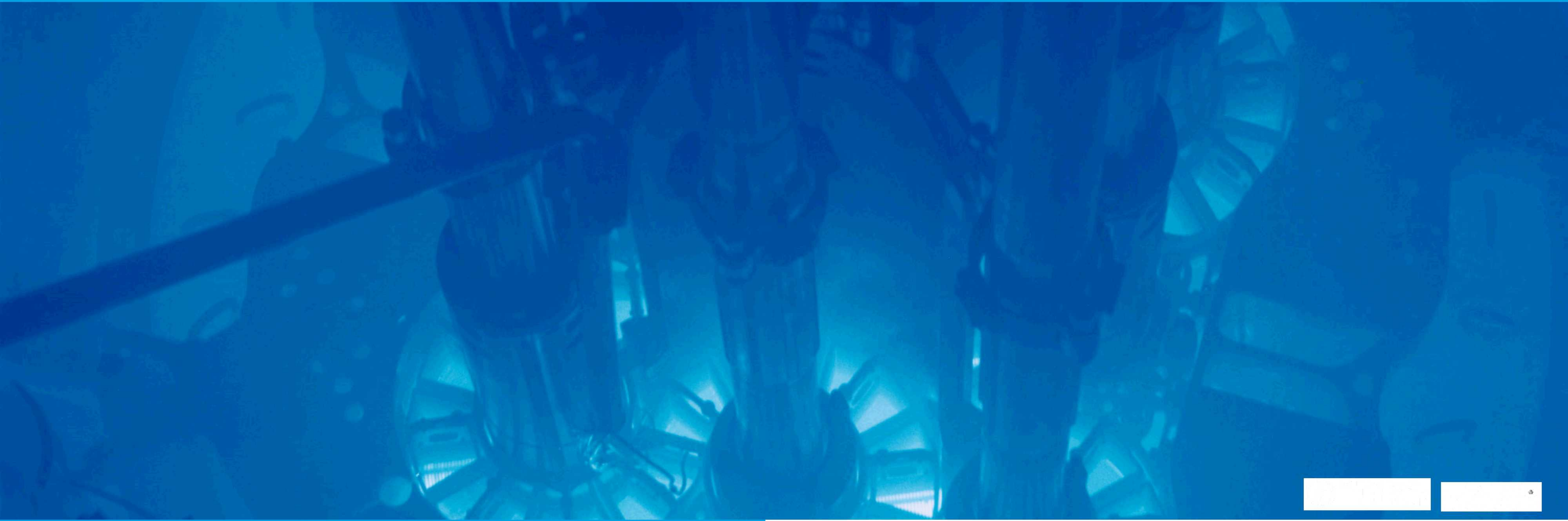
SAND2019-4282PE



30 cm Horizontal Drop of ENSA ENUN 32P 1/3 Scale Cask

Presenters: Elena Kalinina – Sandia National Laboratories
Alejandro Palacio – ENSA

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

EXTENDED STORAGE COLLABORATION PROGRAM

West palm Beach // May 6, 2019

Project Participants

Sponsored by Ned Larson

In collaboration with…

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TEST DESIGN & INSTRUMENTATION

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PRE-TEST MODELING PREDICTIONS
TRANSPORTATION LOGISTICS

BAM
Bundesanstalt für Materialforschung und -prüfung

F. Wille, T. Quercetti

TEST FACILITY & DATA ACQUISITION

ensa
Equipos Nucleares, S.A S.M.E.

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1/3 SCALE RAIL DUAL PURPOSE CASK, IMPACT LIMITERS, & MODIFIED LID

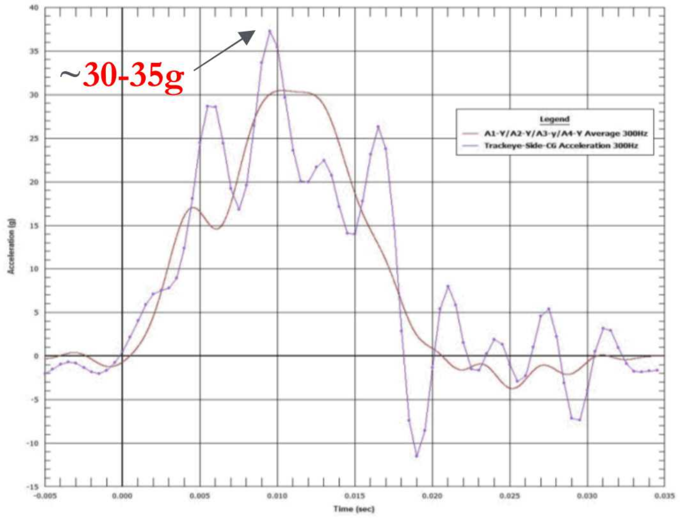
December 2018, BAM Indoor Test Facility, Berlin

30 cm Drop Test Purpose & Goals

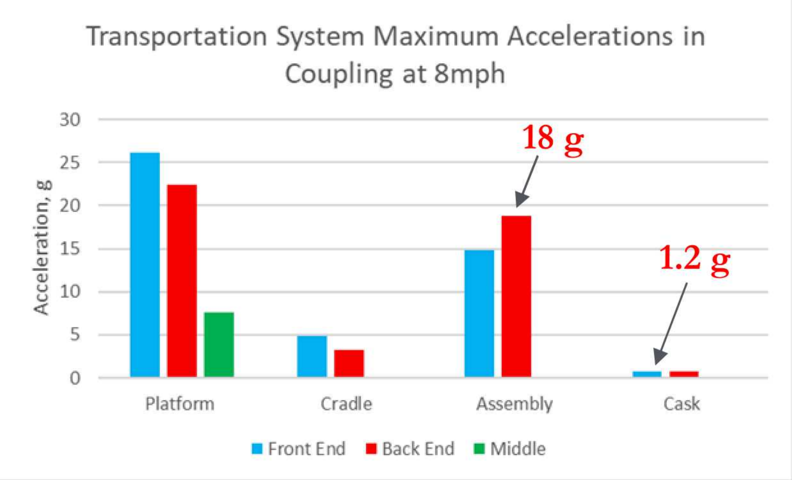
PURPOSE: MEASURE ACCELERATIONS ON THE DUMMY ASSEMBLIES

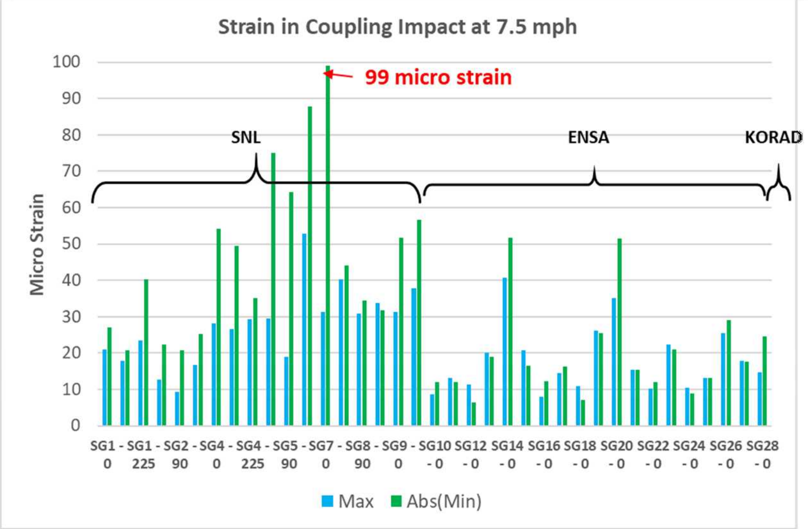
- These data do not exist for 30 cm drop
- Tests in 2010 provided accelerations on the cask only
- Expected acceleration on full scale cask is ~ 12g
- Max acceleration on the cask in MMTT was 1.2 g (coupling at 8 mph)

Acceleration Pulse on 1/3 Scale Cask in 30 cm Drop Test



Maximum Accelerations and Strains Measured in Multi-Modal Transportation test (MMTT)



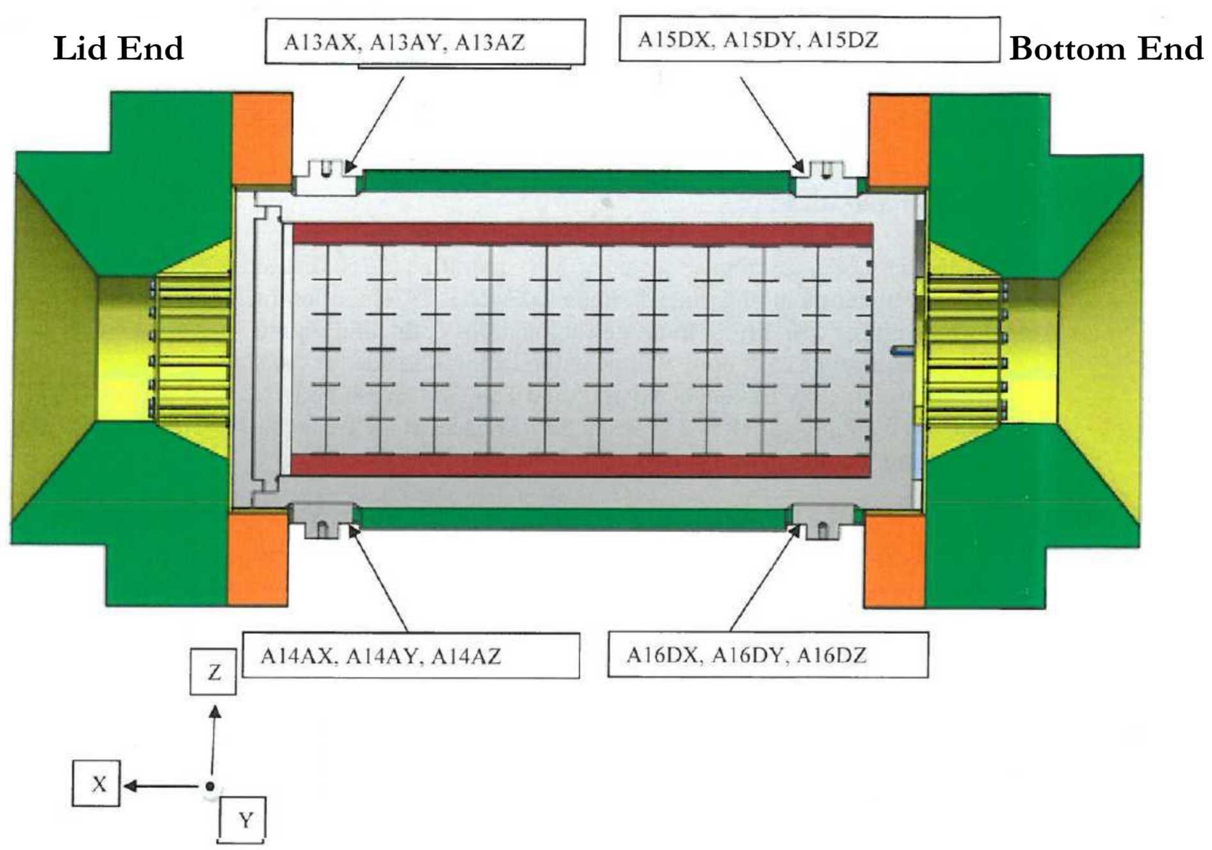


GOALS

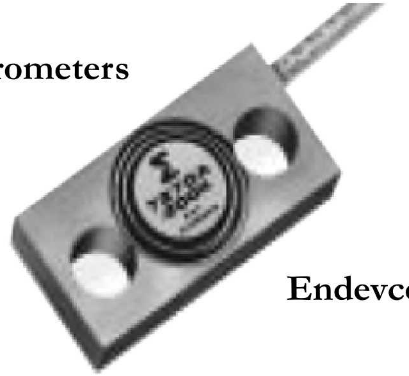
- Complete the NCT mechanical testing environment
- Better understand the potential implications of handling incidents
- Define transfer function from the cask to the fuel for more severe impacts

Cask Instrumentation

Accelerometer Locations



Accelerometers



Endevco Model 7270A

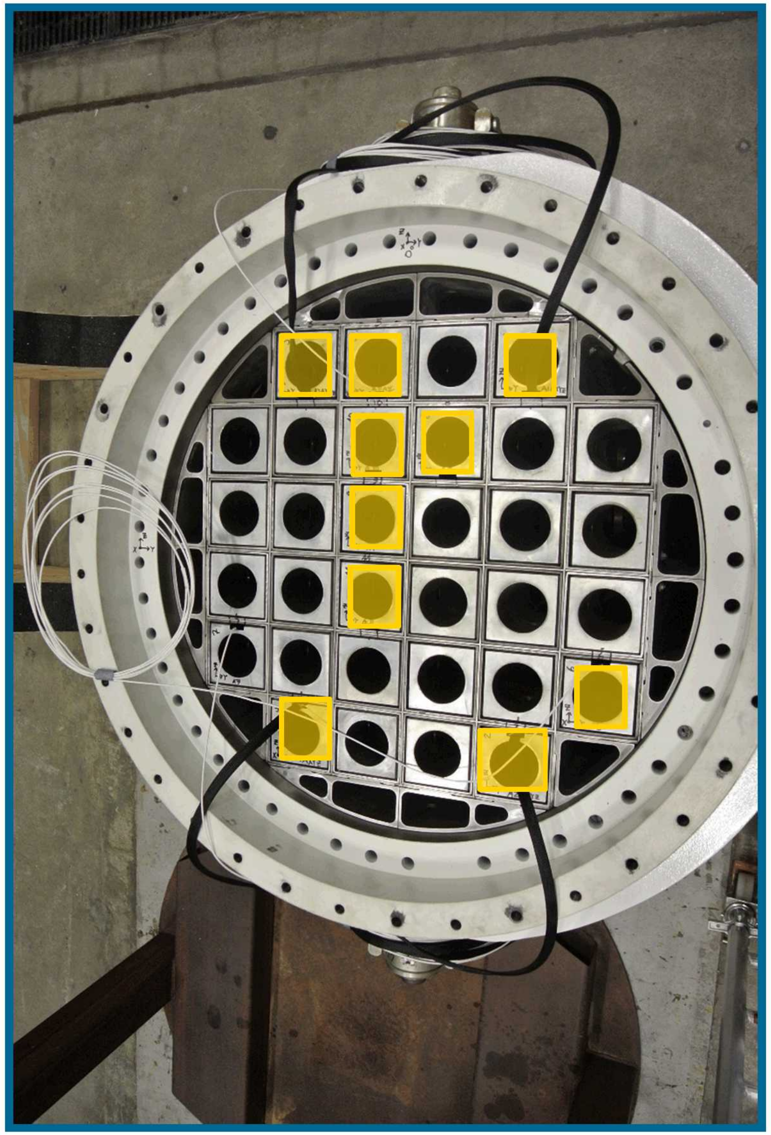
INSTRUMENTATION

- 12 of model 7270A accelerometers
- Two tri-axial accelerometer blocks on the cask top
- Two tri-axial accelerometer blocks on the cask bottom

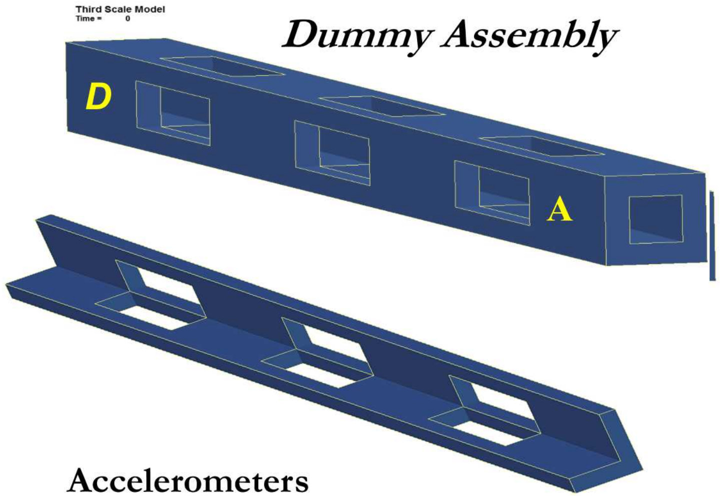
Cask Instrumentation was the same as in 2010 series of tests

Dummy Assembly & Basket Instrumentation

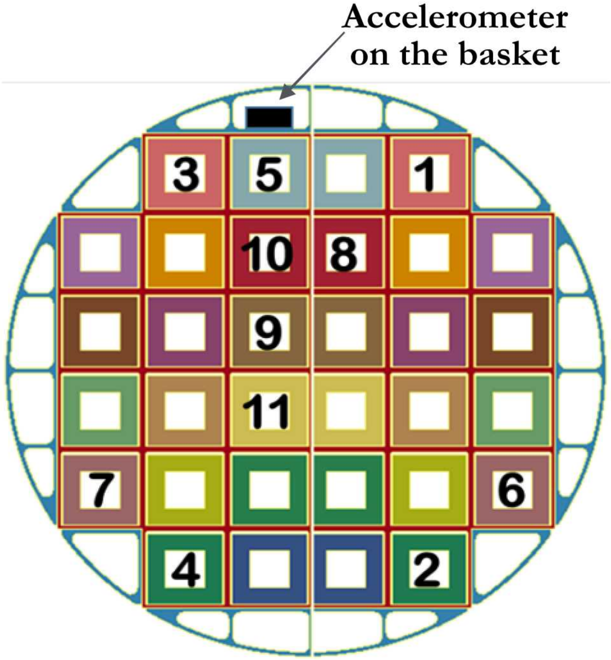
Implementation



Dummy Assembly



Instrumented Assembly Locations



Accelerometers

Endevco Model 727-2K

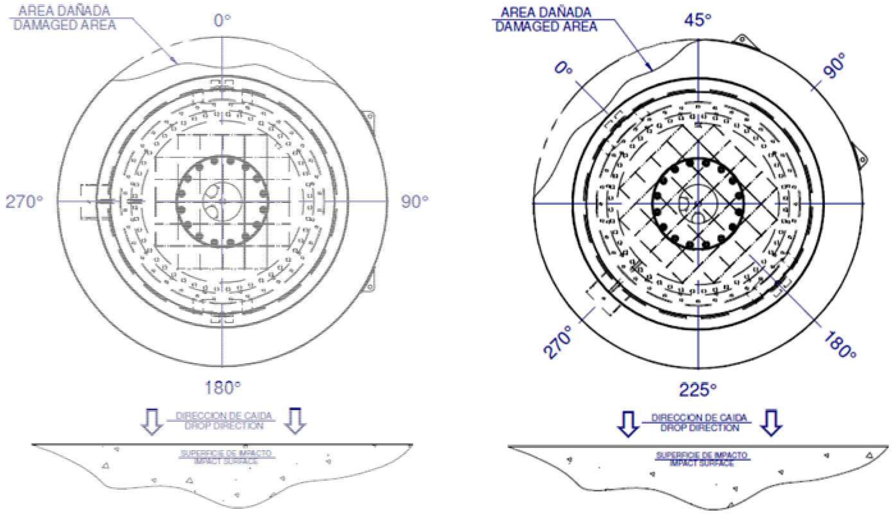
Endevco Model 7265A

INSTRUMENTATION

- **11 instrumented assemblies on A (lid) side: tri-axial accelerometers in locations 1-4, uniaxial (vertical). accelerometers in locations 5-11**
- **7 instrumented dummy assemblies on D (bottom) side: tri-axial accelerometers in locations 1-4, uniaxial (vertical). accelerometers in locations 5-7**
- **One tri-axial accelerometer on basket**

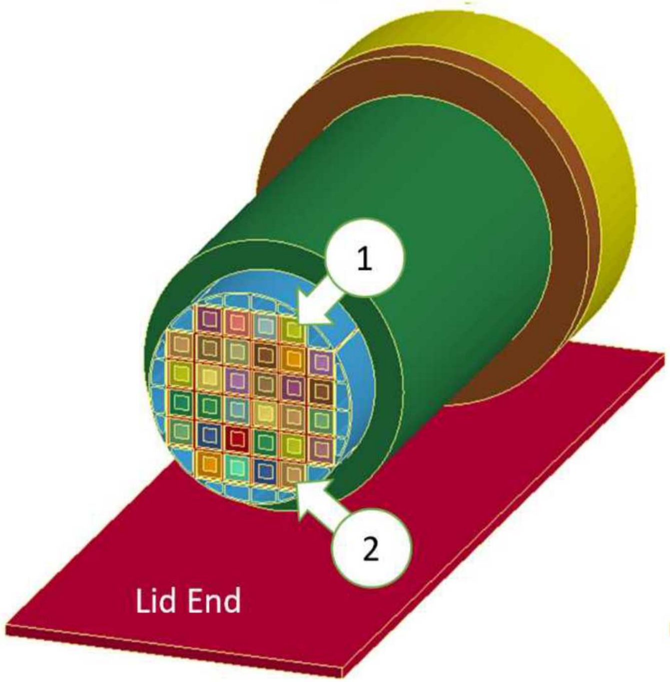
Test Configurations

Impact Limiter Configurations in Two Drop Tests



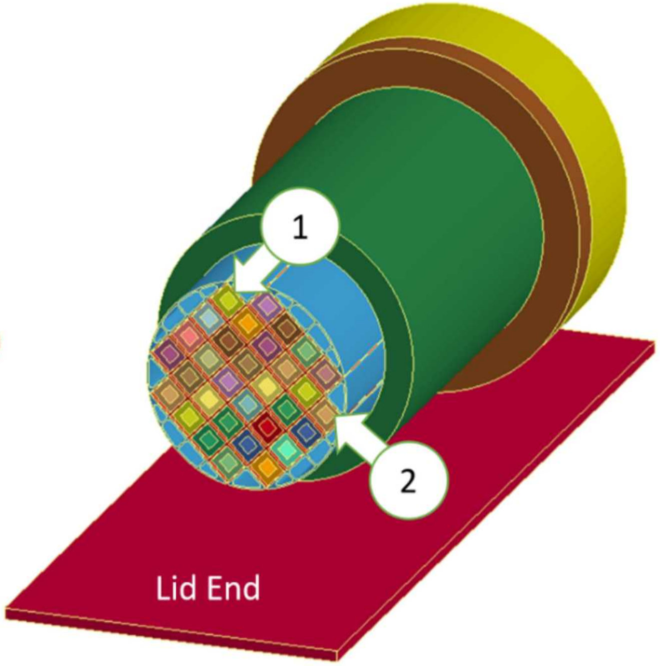
The purpose of Drop Test 2 is to quantify the variation of fuel assembly impact response due to a change in basket orientation.

Drop Orientation 1
Baseplate End



Normal Position

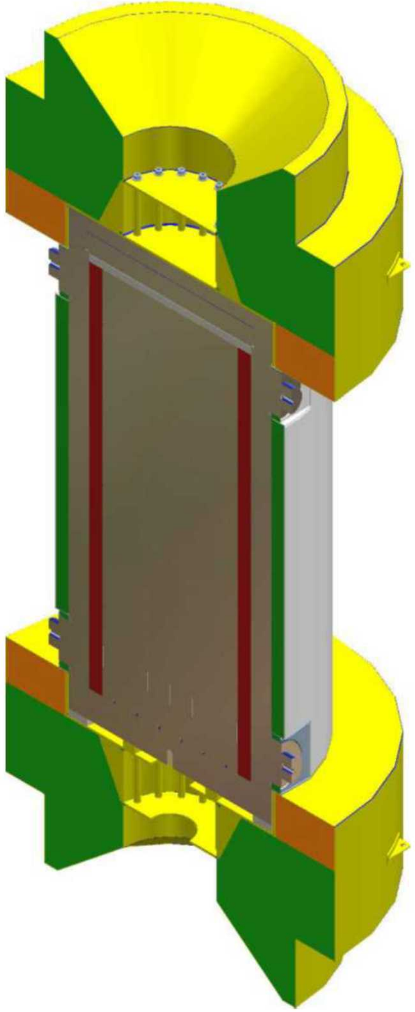
Drop Orientation 2
Baseplate End



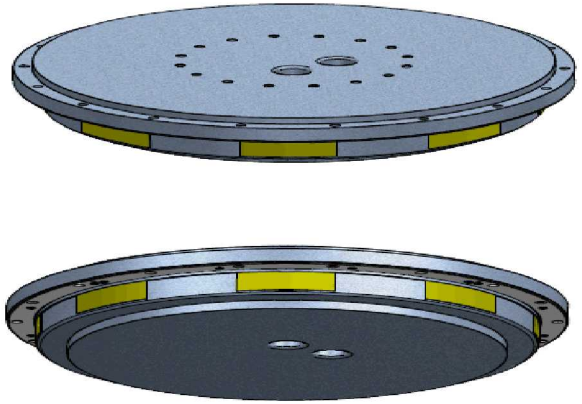
45° Degree Axial Rotation

Hardware Provided by ENSA

1/3 Scale ENUN 32P Rail Dual Purpose Cask With 32 Dummy Assemblies

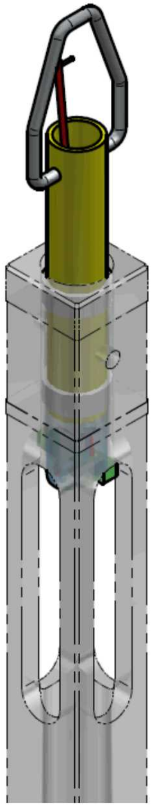


Modified Lid with 2 Holes for Instrumentation

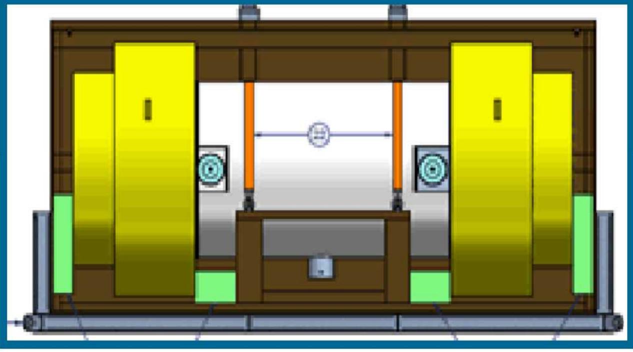


Two Used Impact Limiters from 2010 Tests (bottom one is shown)

Tool for Loading/ Unloading Dummy Assemblies

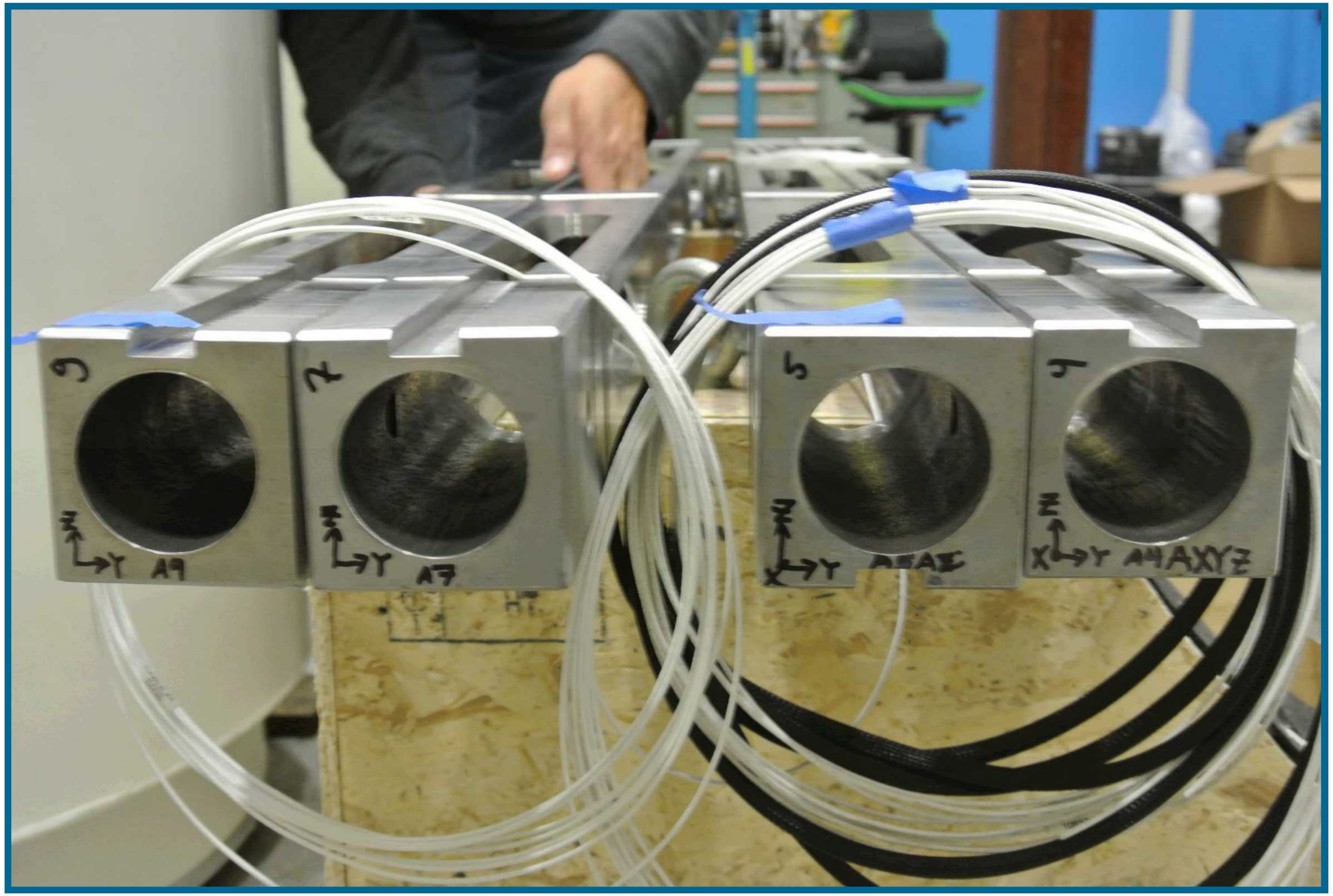


Cask Arrives at BAM



11 Dummy Assemblies Unloaded for Instrumentation

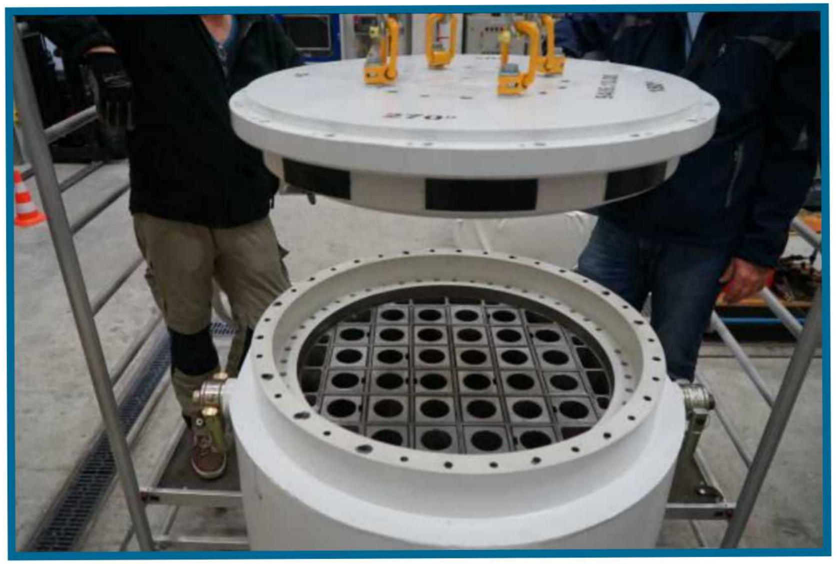
Dummy Assemblies Instrumented with Accelerometers



Dummy Assemblies from Locations 4, 5, 7, and 9

Tri-Axial Accelerometer Block
A2DX, A2DY, and A2DZ

Loading Instrumented Assemblies & Closing Lid



Installing Impact Limiters

Experimental Setup for 1st Drop

1st Drop Fast Camera Video

Time History of Vertical Accelerations on Cask Filtered to 300 Hz

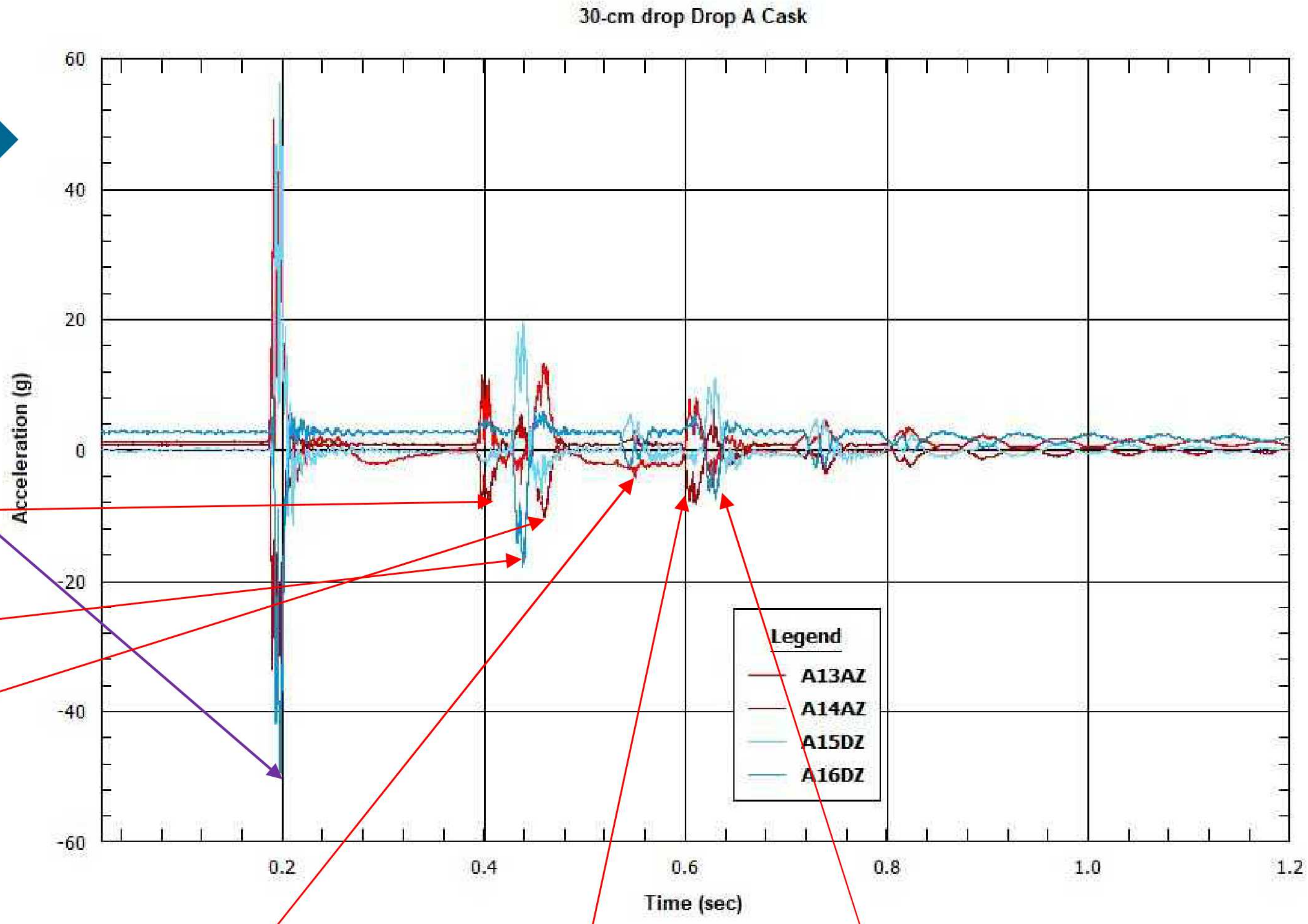
Seven impacts as seen in the video

1st Impact: At approximately the same time Front end hit ~2 millisec earlier than the back end

2nd Impact: Front end

3rd Impact: Back end

4th Impact: Front end



5th Impact: Small, Back end

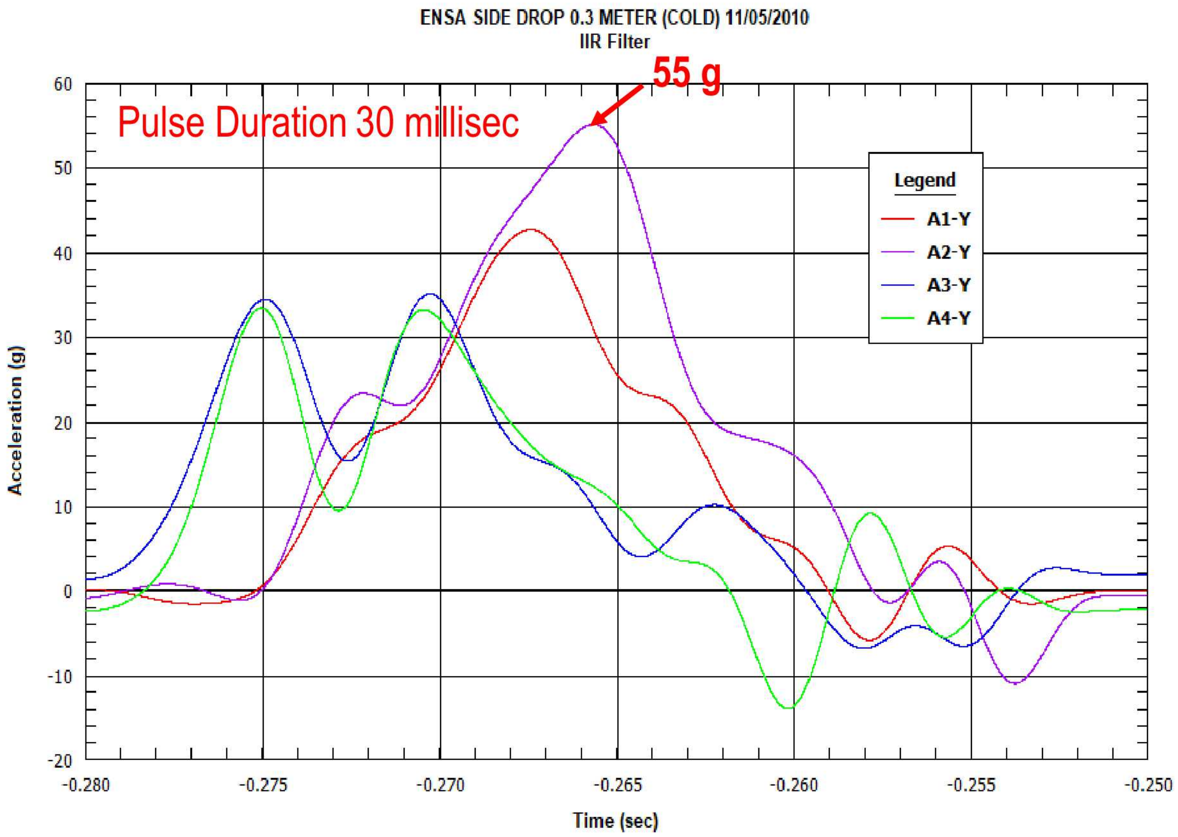
6th Impact: Front end

7th Impact: Back end

Vertical Accelerations on Cask in 2010 & 2018 Tests

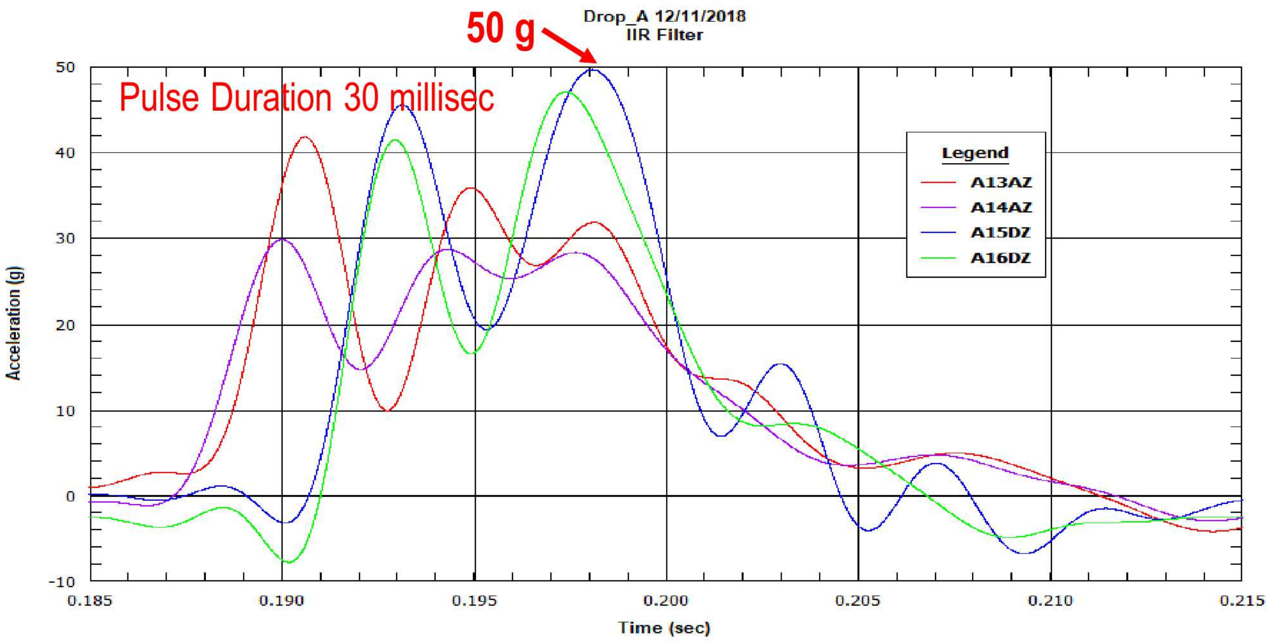
2010 Test

First Impact Time History Filtered to 300 Hz



2018 Test

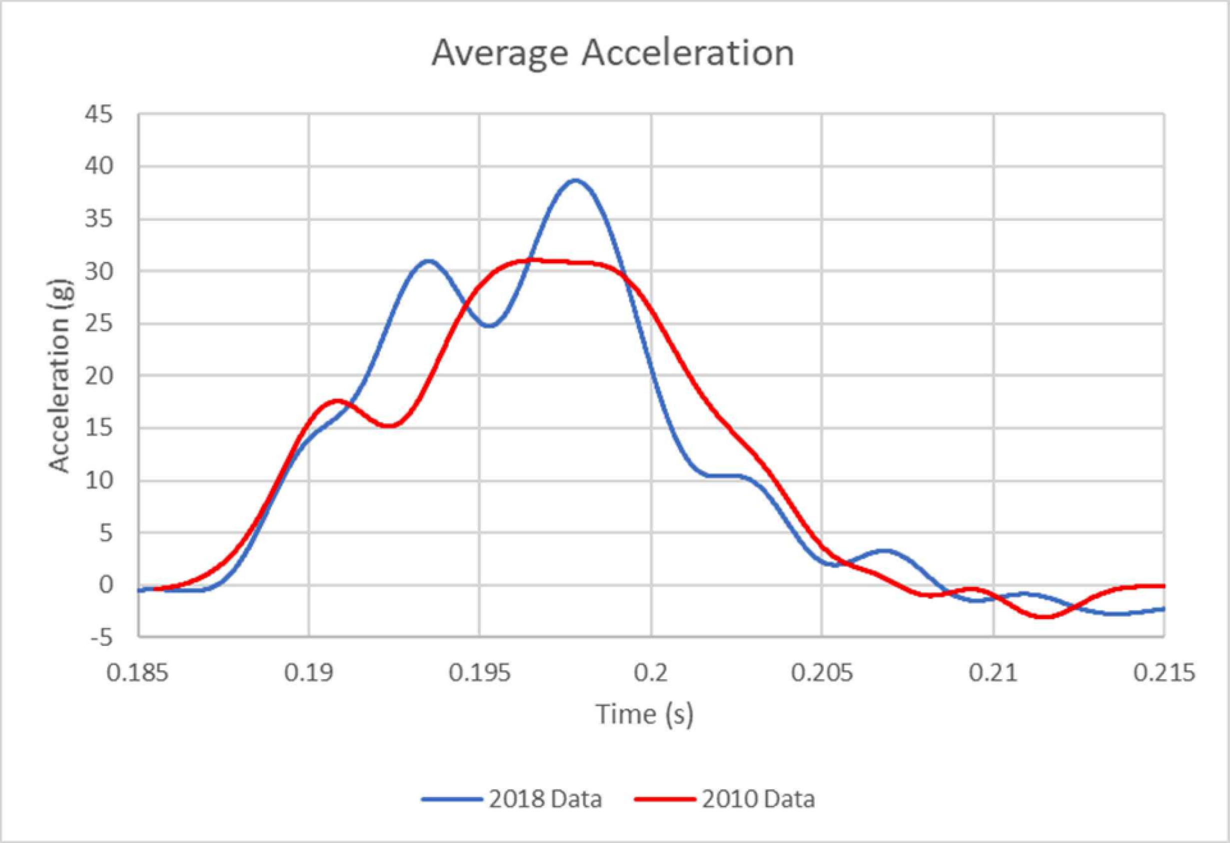
First Impact Time History Filtered to 300 Hz



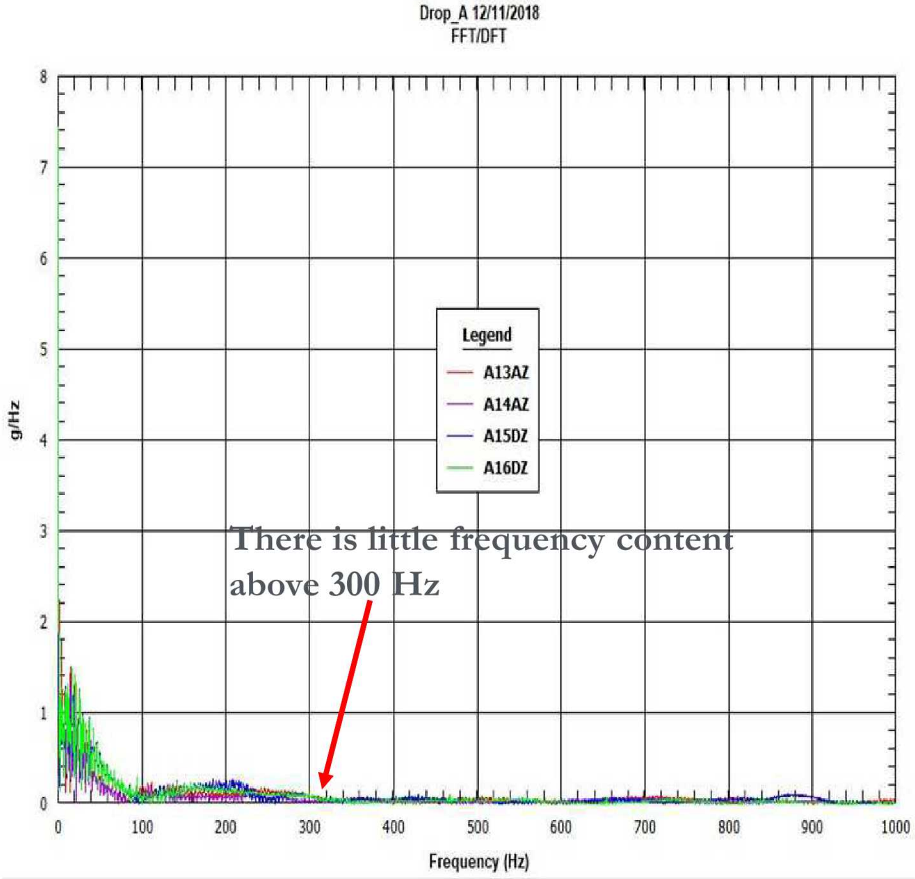
- ***Some differences are due to the fact that the drops are never perfectly horizontal.***

Averaged Vertical Acceleration on Cask in 2010 & 2018 Tests

Averaged Time History Filtered to 300 Hz



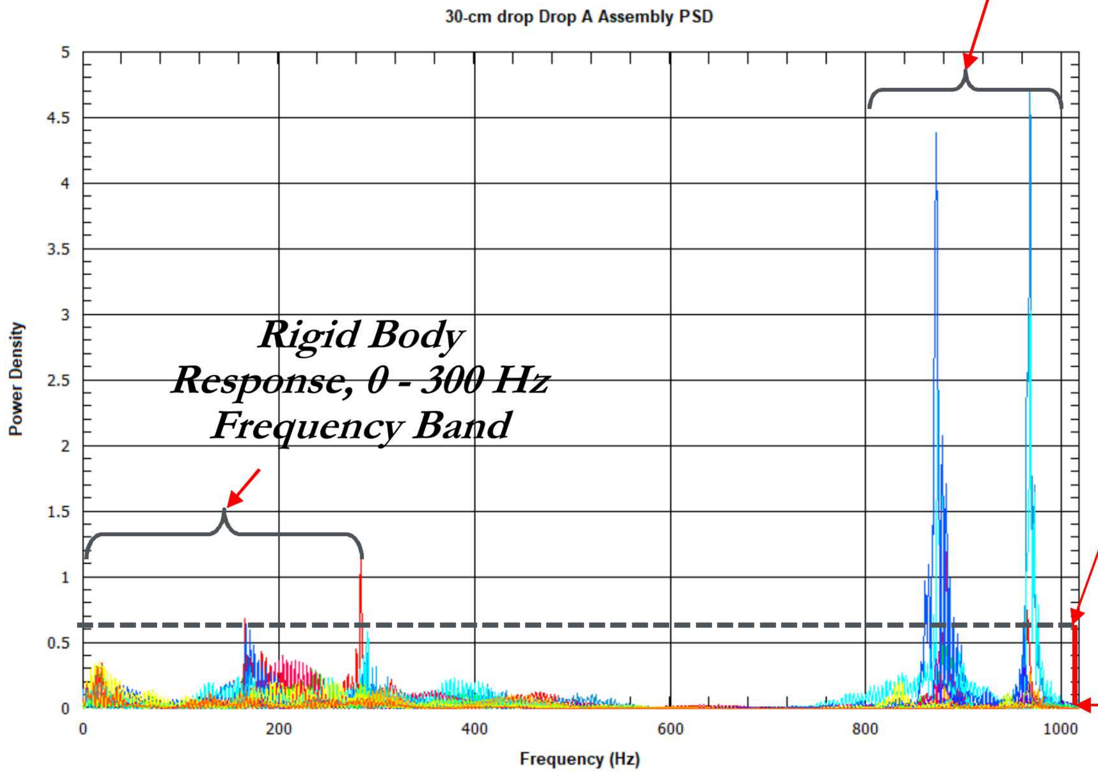
FFT of Cask Acceleration Time Histories (2018 Test)



- ***The cask accelerations measured in 2018 are very similar to the ones measured in 2010.***

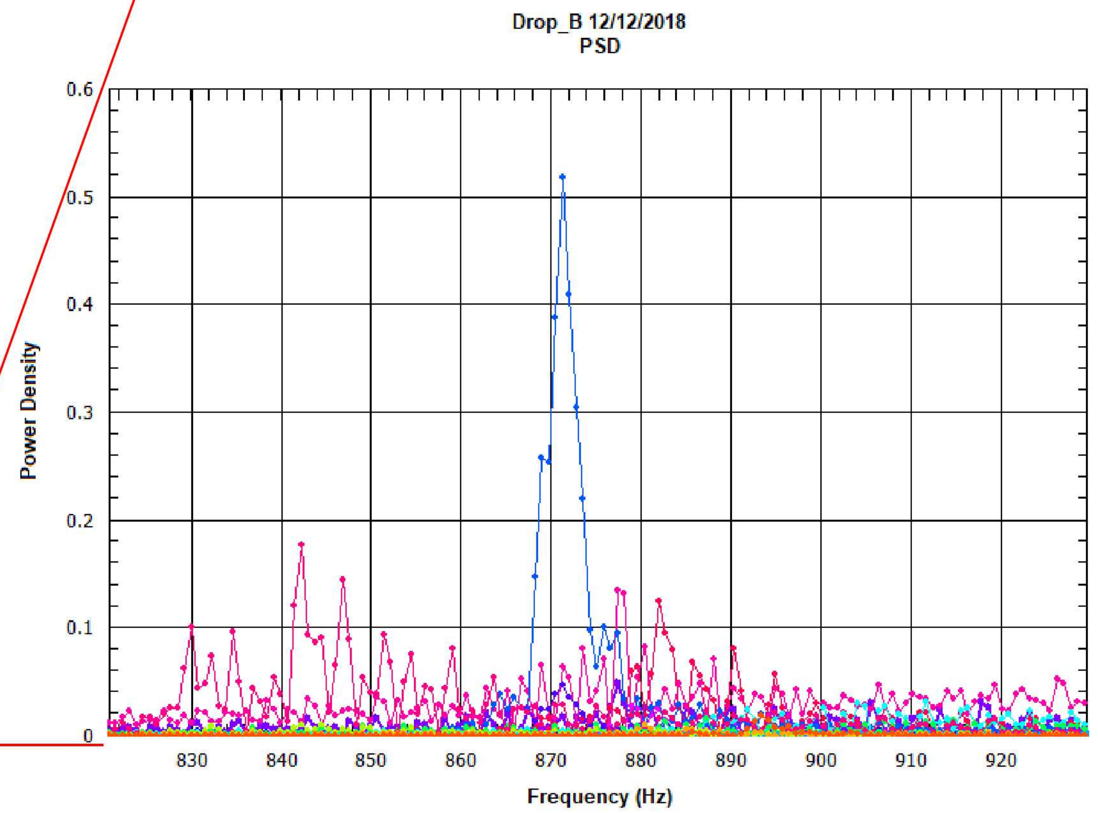
Dummy Assembly Frequency Content During 1st Impact

High Frequency Chattering, 800 - 1,100 Hz



1st Drop

Noise in High-frequency Band

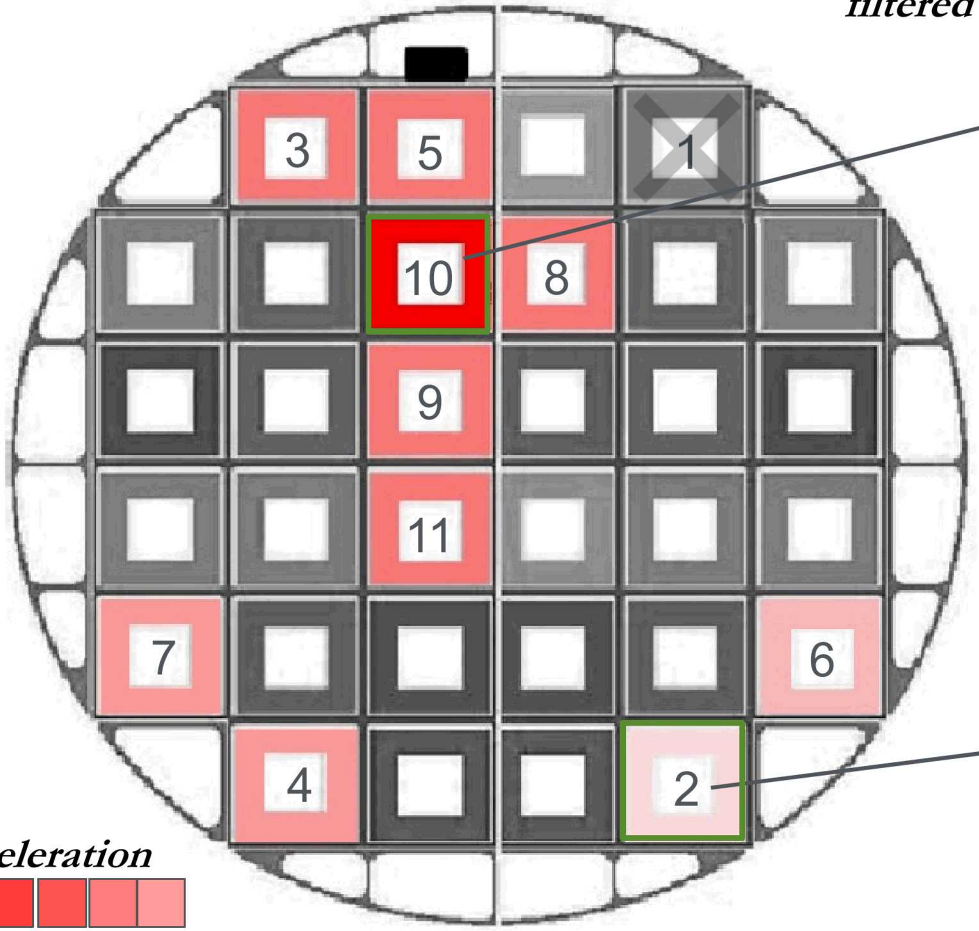


2nd Drop with 45° Degree Axial Rotation

- ***The high-frequency response was only observed in the 1st drop and was attributed to the dummy assembly vibration inside the basket tube. The vibration was limited when the basket was rotated.***

Side A *(Lid)* Maximum Accelerations on Instrumented Assemblies

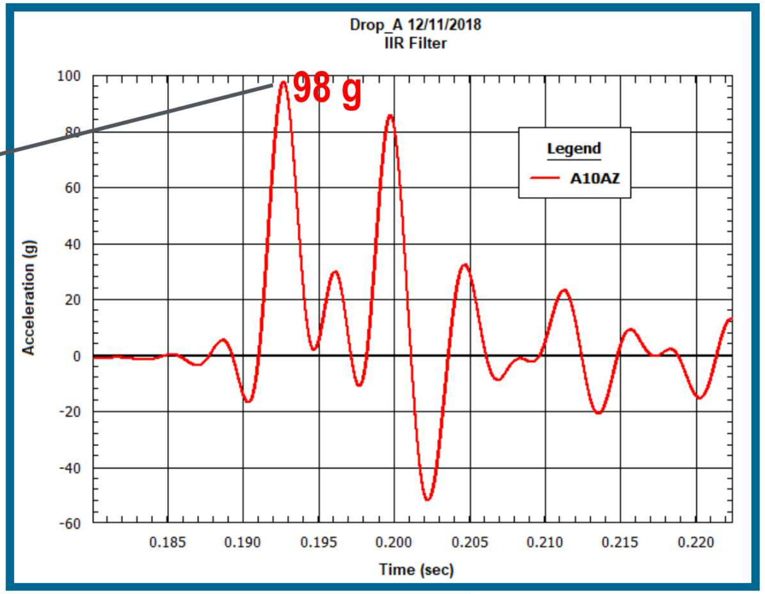
Acceleration Color Map



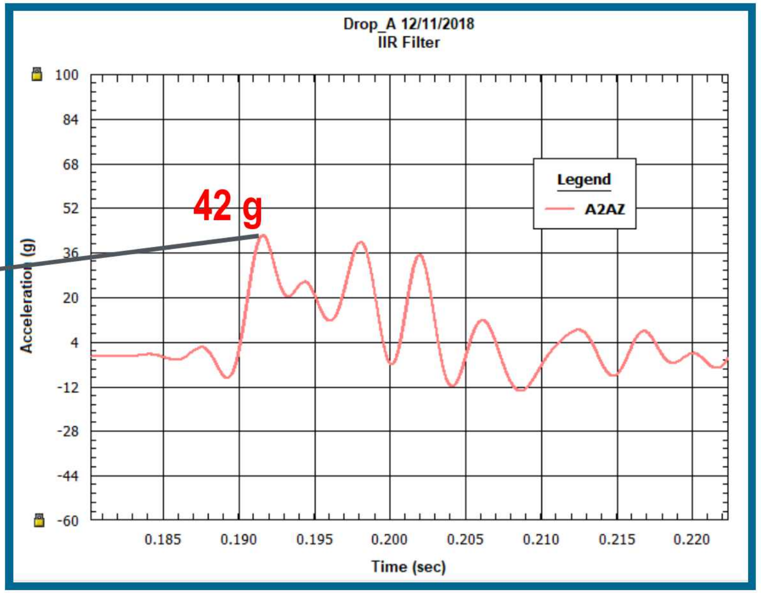
Acceleration

Increasing Acceleration

Assembly #10 time history filtered to 300 Hz

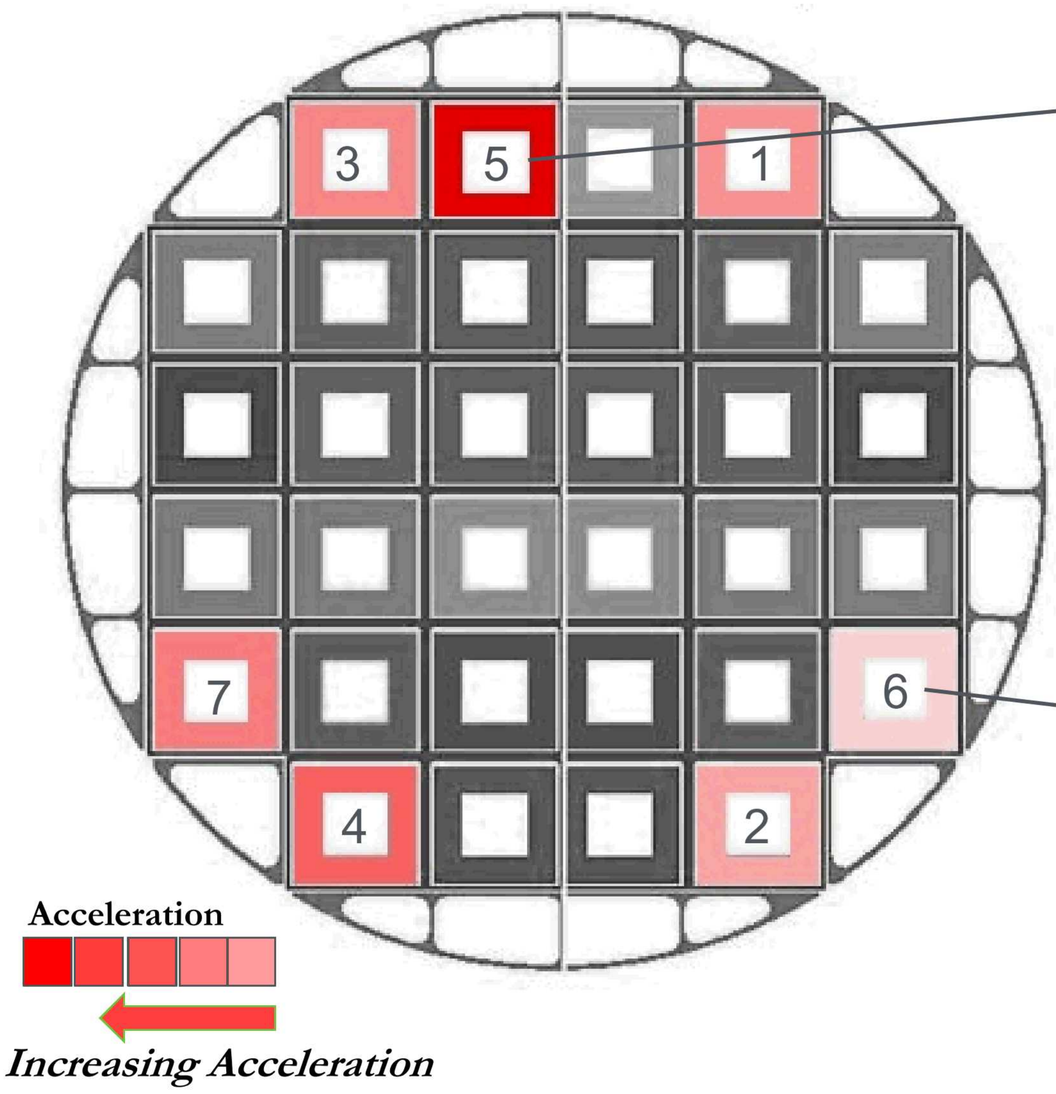


Assembly #2 time history filtered to 300 Hz

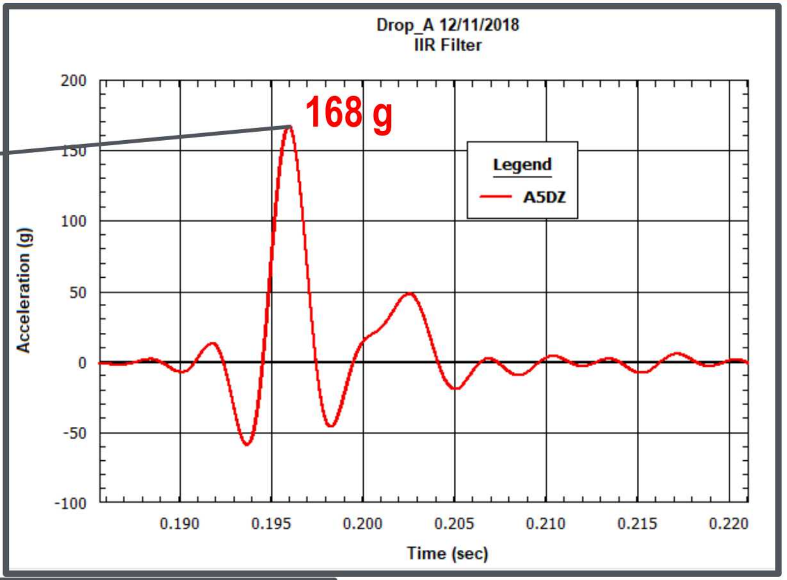


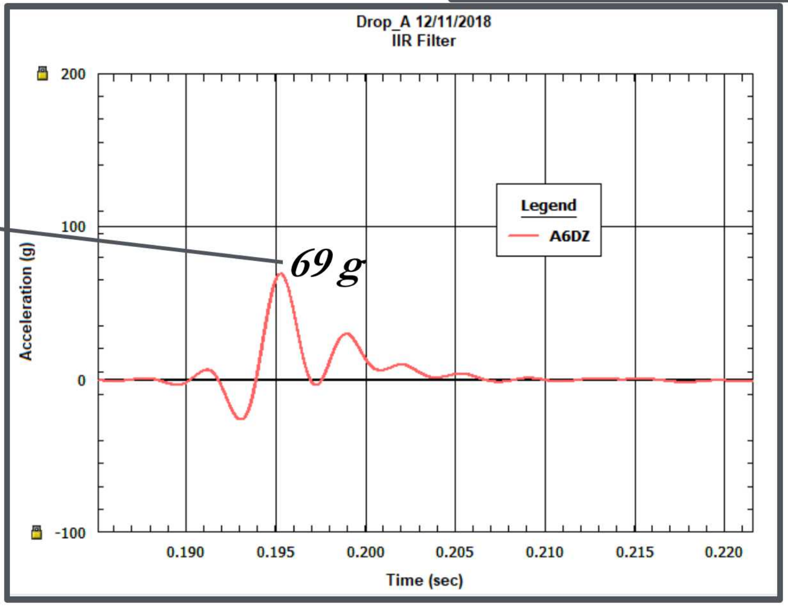
Side D *(Bottom)* Maximum Accelerations on Instrumented Assemblies

Acceleration Color Map



Assembly #5 time history filtered to 300 Hz

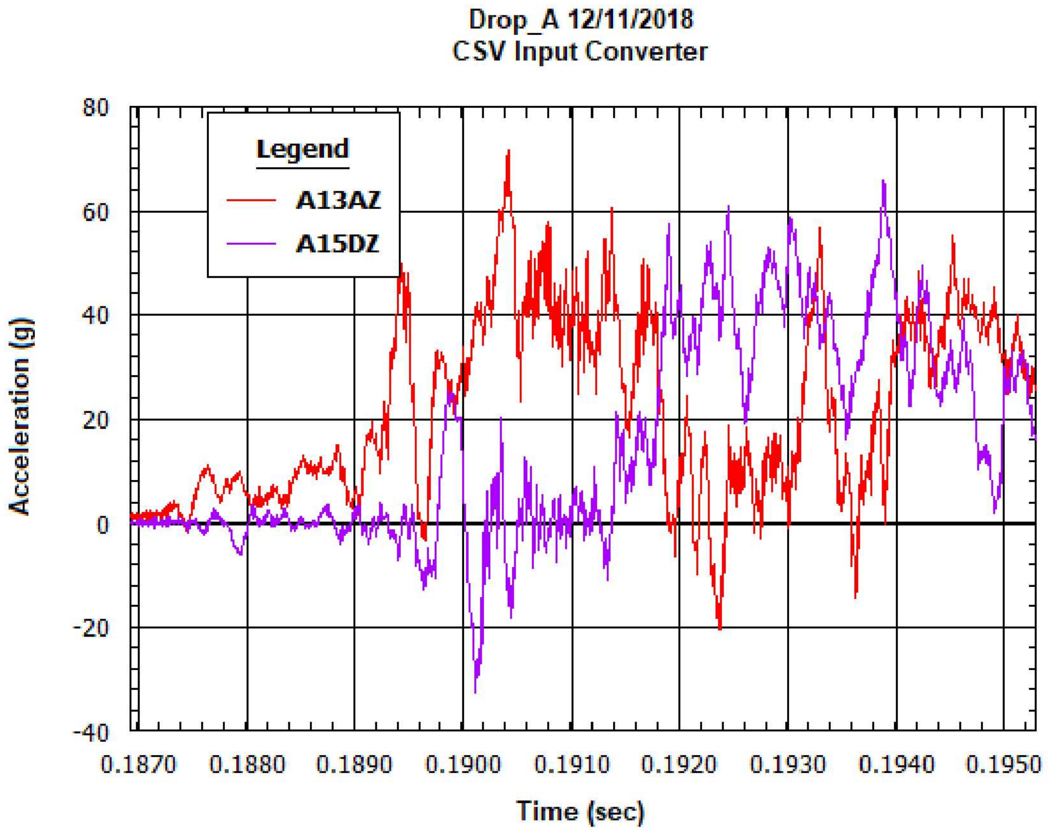




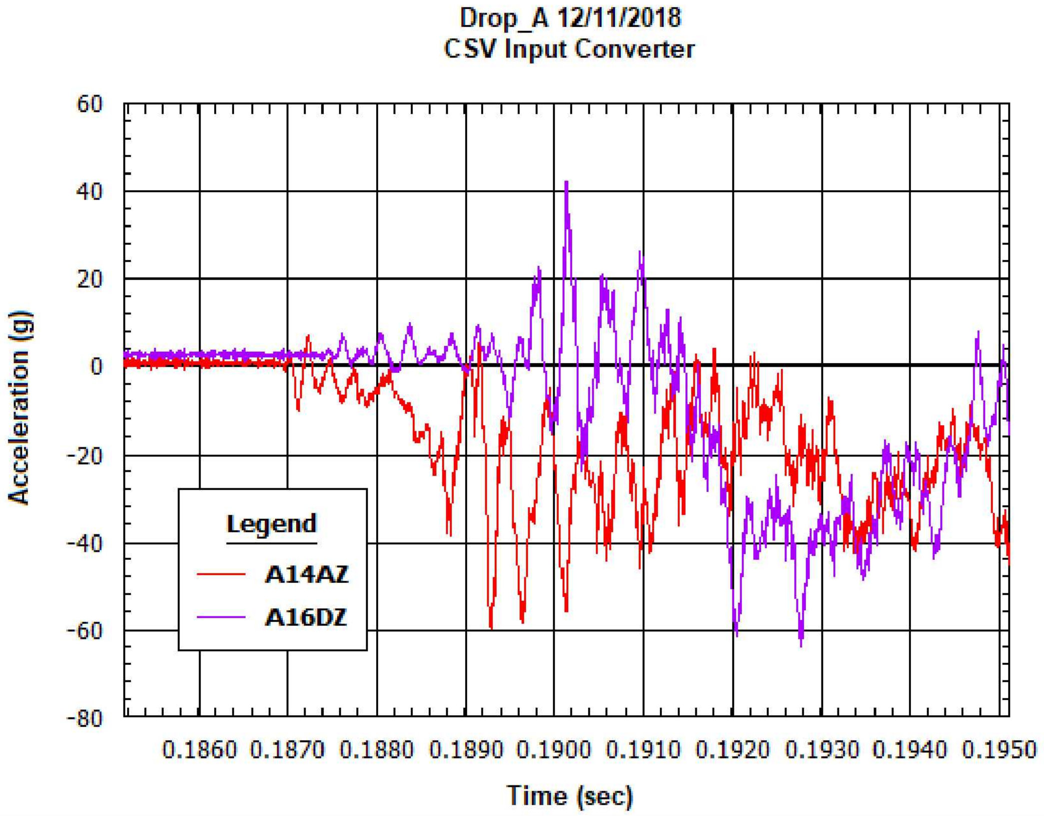
Assembly #6 time history filtered to 300 Hz

Accelerations on Lid Side versus Bottom Side of Cask

Lid versus Bottom on the Upper Cask Surface



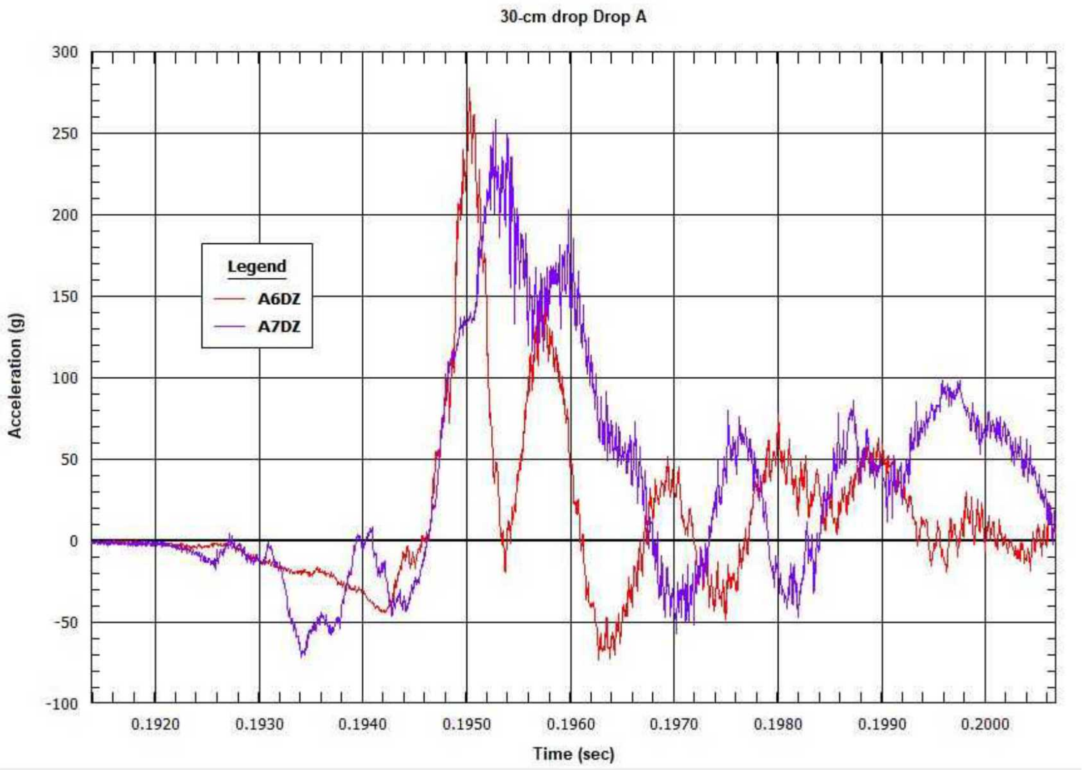
Lid versus Bottom on the Lower Cask Surface



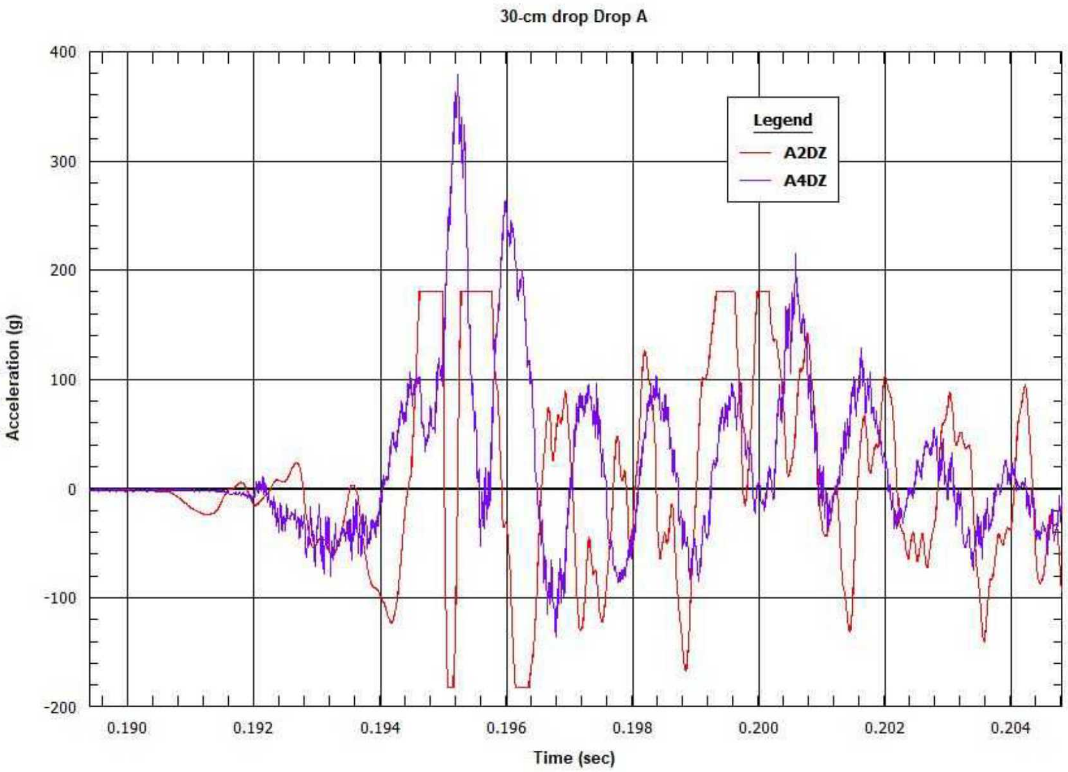
- ***The lid side (A) hits before the bottom side (D) with a time delay of ~ 0.44 ms***

Left Side of Cask versus Right Side *(when looking at lid end)*

Left Side (A7DZ) versus Right Side (A6DZ)



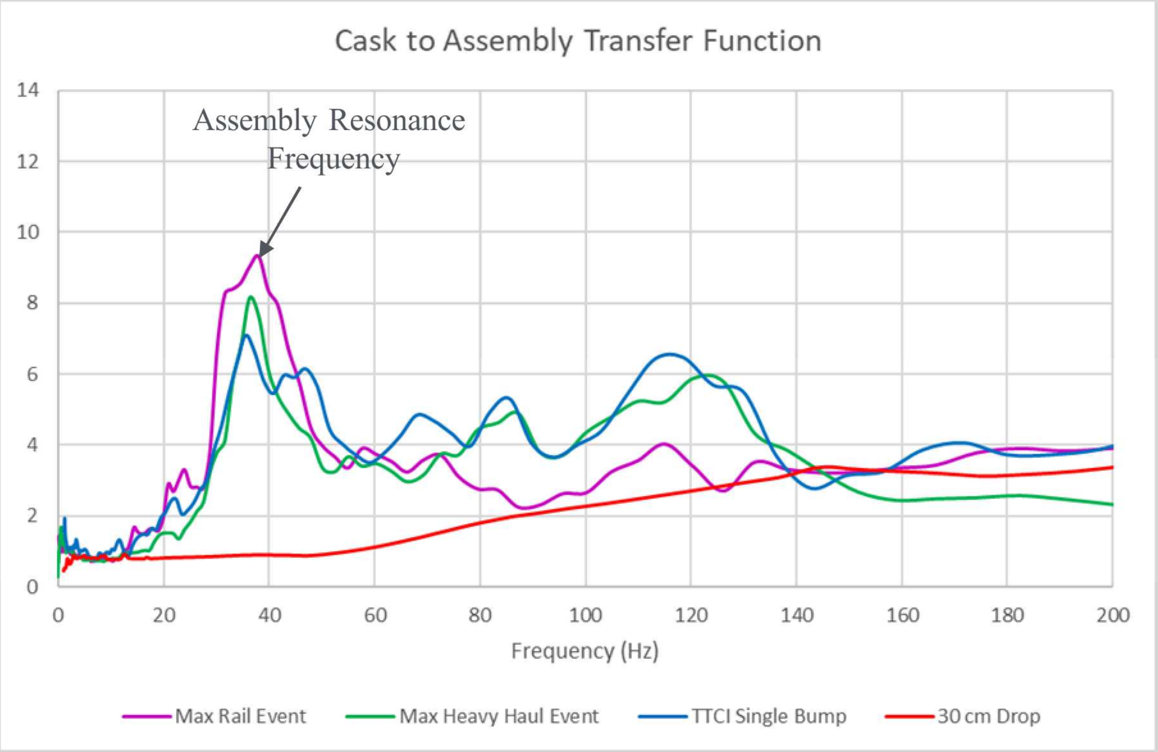
Left Side (A4DZ) versus Right Side (A2DZ)



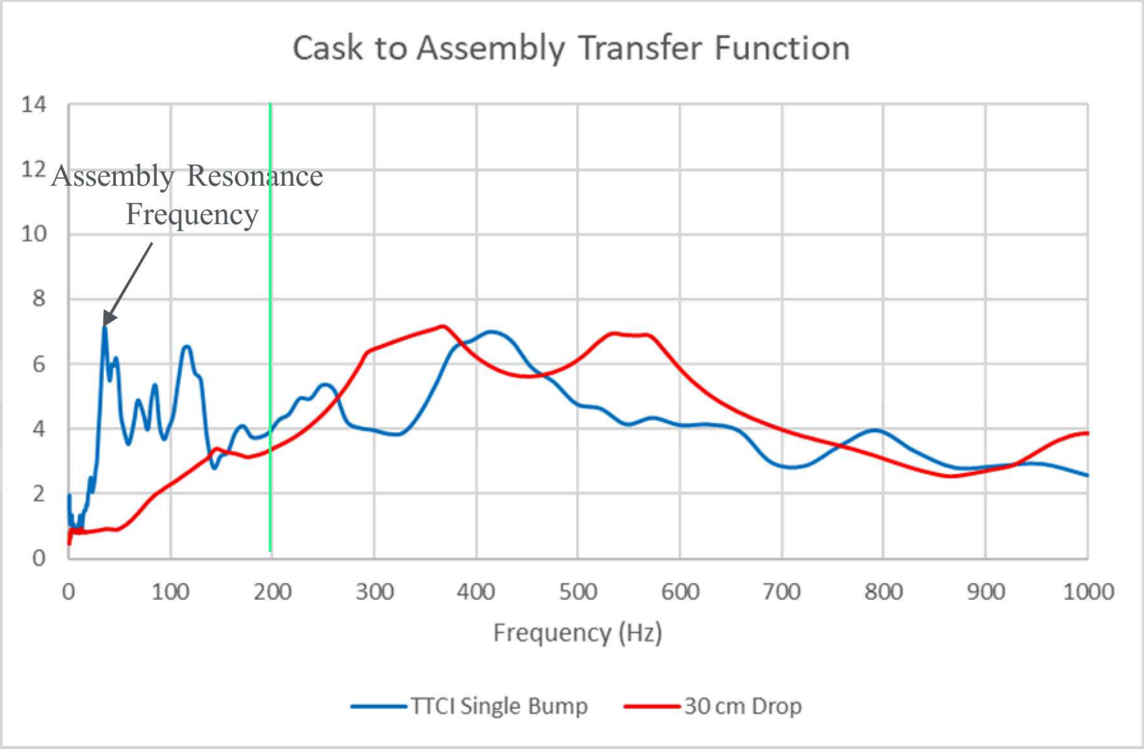
- ***In all cases (A6/A7 and A2/A4) the accelerometer on the right side responded before the accelerometer on the left side – the basket is slightly rotated inside the cask.***

Cask to Assembly Transfer Functions in MMTT & 30 cm Drop

0 to 200 Hz Frequency Band



0 to 1,000 Hz Frequency Band



- ***In the low frequency band the major differences between the dummy and surrogate assemblies are due to the surrogate assembly resonance frequency around 40 Hz.***

- ***In the high band frequency the differences between the surrogate and dummy assemblies are relatively small.***

Questions?

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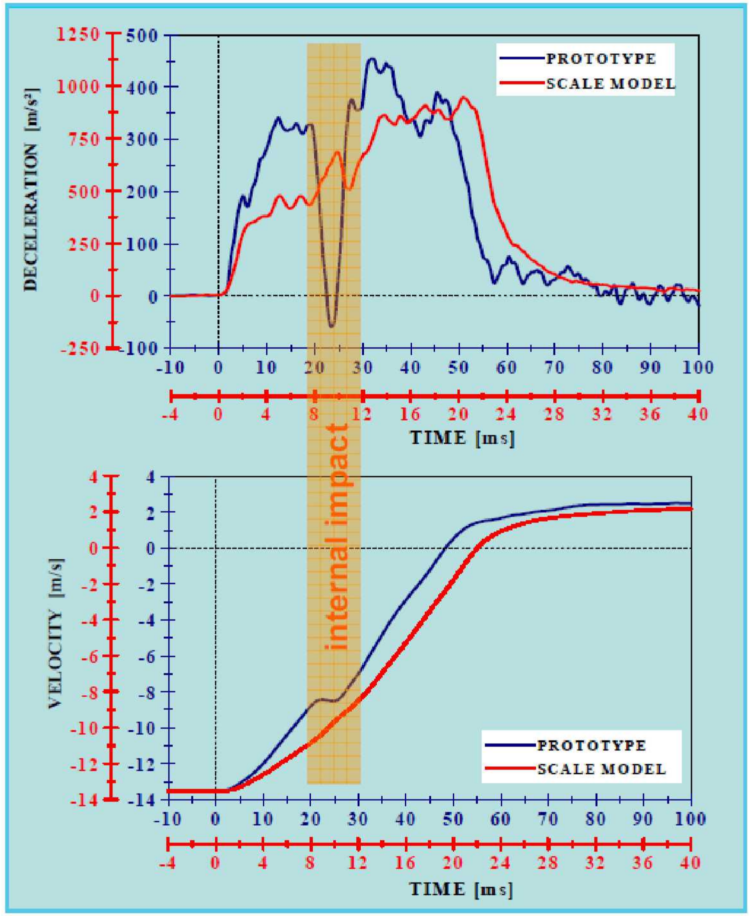
Scale Versus Prototype Cask Results in 9 m Vertical Drop Tests

Deceleration and Velocity



Prototype

Scale Model

From "Comparison of Experimental Results from Drop Testing of a Spent Fuel Package Design Using a Full-Scale Prototype Model and a Reduced-Scale Model", Quercetti et al, 2007.

Implications for the 30 cm Drop Test

Rigid body impact response of the scaled model	
▪ Maximum tranlation ↑+9 % ▪ Impact duration ↑+24 % ▪ Maximum and average deceleration ↓-17 %	The scaled model tends to represent the impact of the prototype model as softer

Structural impact response of scaled model	
▪ cask body axial strain ↓-26 % ▪ primary lid bending strain ↓-80 % ▪ primary lid bolt axial strain ↓-94 %	The scaled model undervalues the response of the prototype

Why Are There Differences?

- ❑ **Impact limiter material grain size is not scaled.**
- ❑ **Scale model should be tested in a scaled acceleration field.**
- ❑ **Compressed time in the scale model means that timing of secondary impacts is incorrect (the larger the gaps in the model, the more significant this difference is).**

How This Affects the 30 cm Drop of 1/3 Scale Model

- ➢ **1/3-scale drop test will not provide cladding strains.**
- ➢ **This can be obtained by dropping an instrumented full-scale assembly onto programming material to provide the same shock pulse as the dummy assemblies experienced in the 1/3-scale cask drop test ➡ June 2019, SNL.**