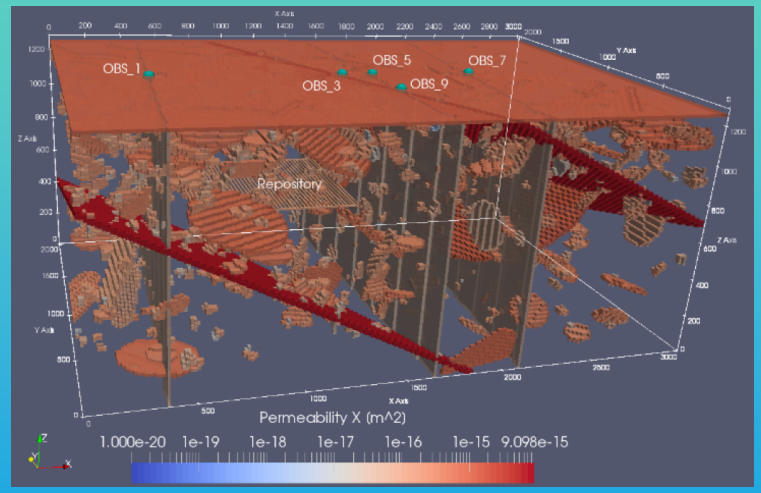
SAND2022-8947C

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Spent Fuel and Waste Science and Technology (SFWST)

Clean. Reliable. Nuclear.



PLANNING FOR SEISMIC SHAKE TABLE TEST OF A FULL-SCALE DRY STORAGE OF SPENT NUCLEAR FUEL

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Sandia National Laboratories
Presented by Elena Kalinina

SAND2022-XXXX

SMiRT-26
Berlin/Potsdam, Germany, July 10-15, 2022
Division IX

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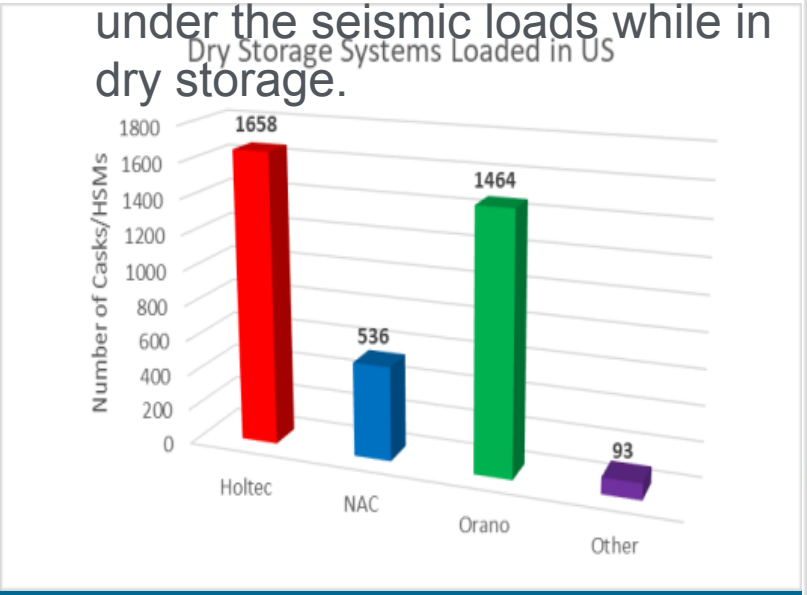
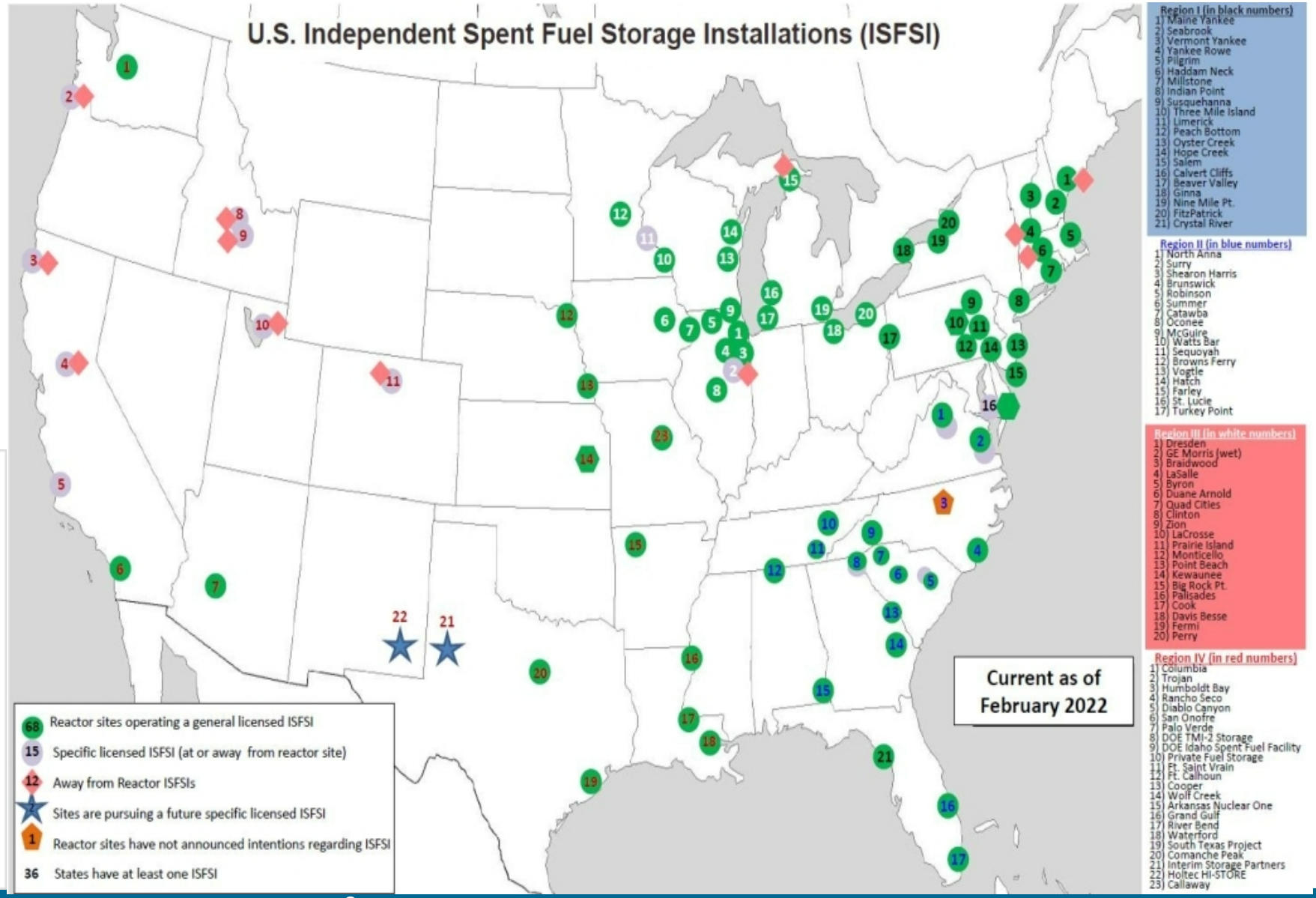
Motivation for the Seismic Shake Table Test

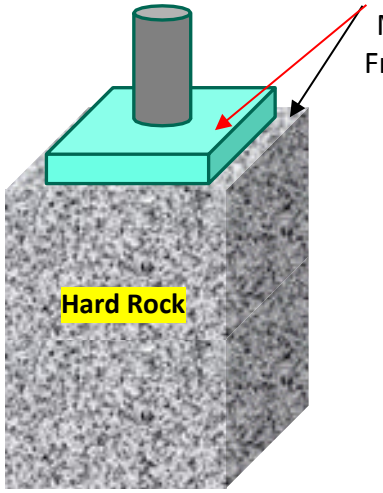
- Spent nuclear fuel (SNF) is in dry storage at 73 ISFSIs .
- **3,751** dry storage systems were currently loaded in the US.
- SNF will be in dry storage for extended time and will experience earthquakes of different magnitudes.
- The test will close the gap regarding the fuel integrity under the seismic loads while in dry storage.



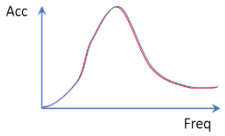


Main Challenge – Representative Ground Motions

Hard Rock Sites



Shake Table Motion Same as Free-Field Ground Motion

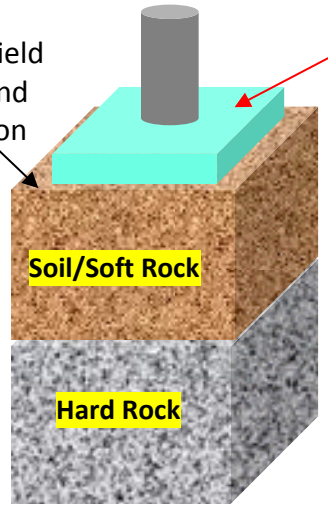


24 Sites in CEUS

Soil and Soft Rock Sites

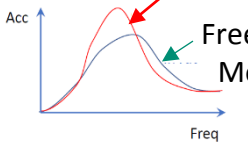
Free-Field Ground Motion

Shake Table Motion with Account for Soil-Structure Interaction



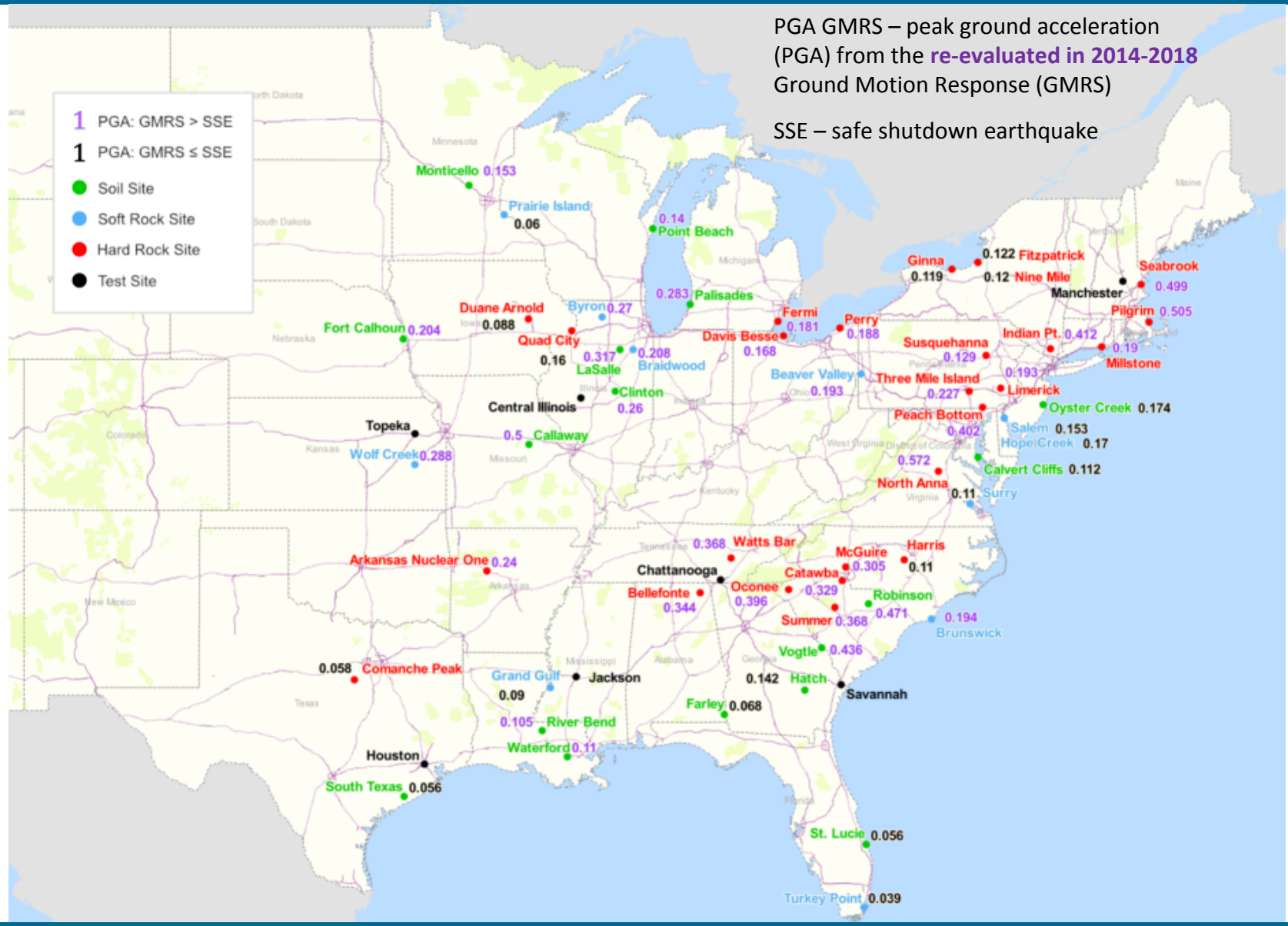
Shake Table Motion

Free-Field Motion



16 Soil Sites

11 Soft Rock Sites



PGA GMRS – peak ground acceleration (PGA) from the **re-evaluated in 2014-2018** Ground Motion Response (GMRS)

SSE – safe shutdown earthquake

Seismic Shake Table Test Roadmap

New Methodology to Define Representative Free-Field GMs

GM – ground motion

Free-Field GM Spectra and Amplitudes

TH – time history

Free-Field THs

TH for Hard Rock Sites

TH Simulation on the Shake Table

Final Set of the Test THs

SSI and Pad Flexibility Analyses

SSI – soil-structure interaction

TH for Soft Rock and Soil Sites

Dummy Assemblies

Surrogate Assemblies

Canister

Dry Storage Overpack(s)

Test Unit

Final Test Plan

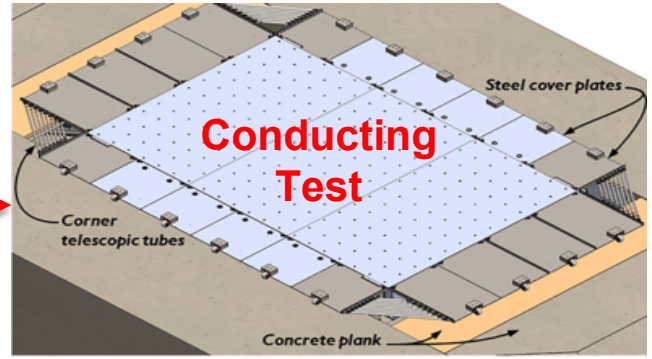
Pre-Test Modeling

ISFSI Pad Concrete Formulations

Concrete Layer on the Shake Table

Instrumentation

Final Instrumentation Procedure

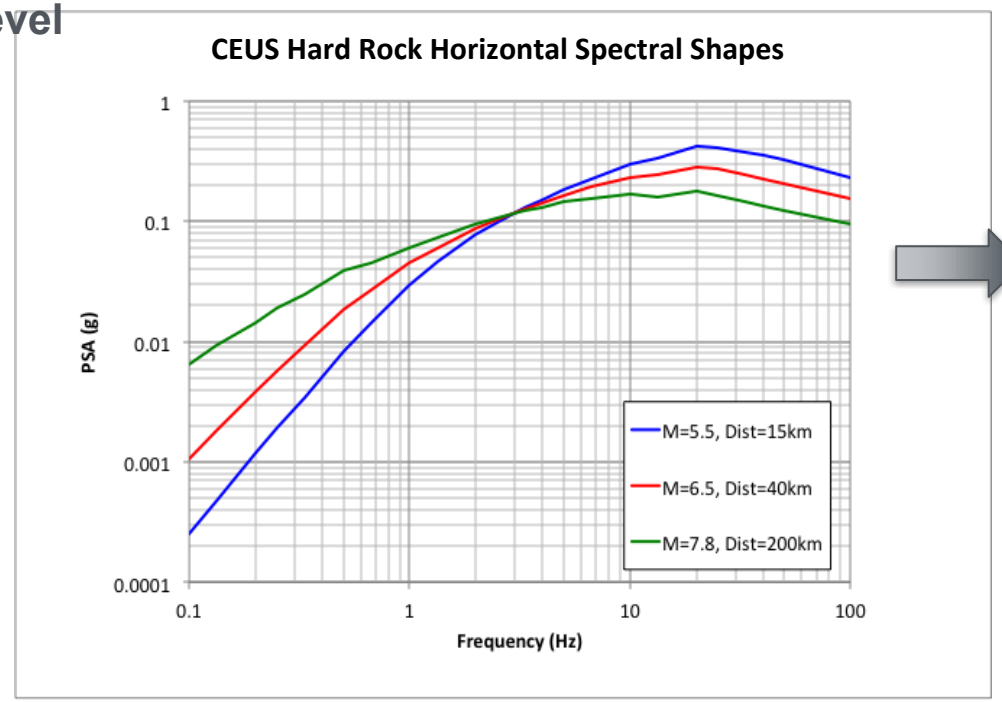


New Methodology to Define Representative Free-Field Ground Motions for Hard Rock, Soil, and Soft Rock Sites in CEUS and WUS

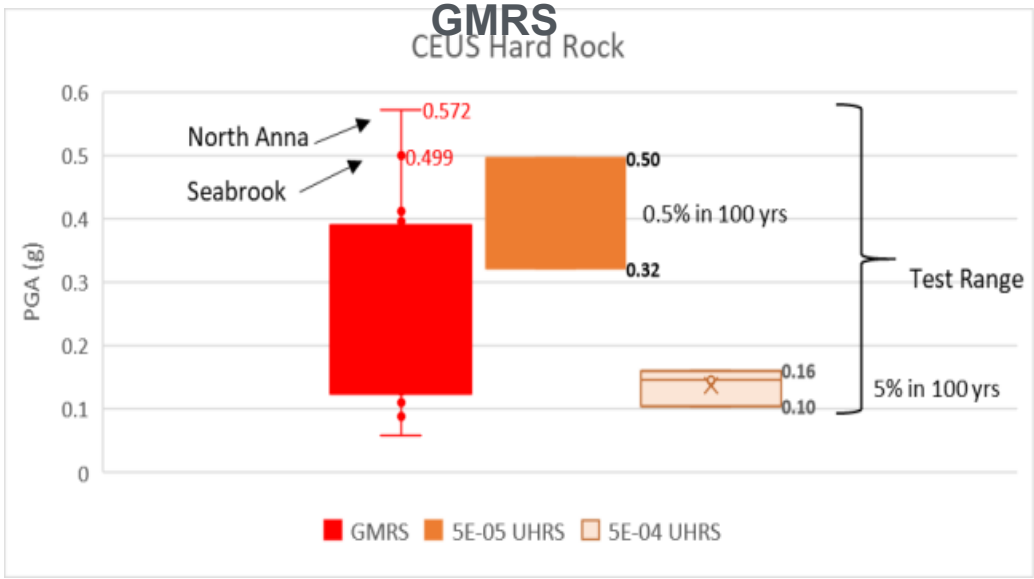
New methodology was developed by Dr. Abrahamson (SC Solutions).

- The representative earthquake scenarios were selected based on the de-aggregation of USGS and NPP screening reports data.
- These scenarios represent the controlling events for any site in the CEUS or WUS and are not specifically meant to replicate the results for a given NPP site.

CEUS Hard Rock Earthquake Scenarios, 1E-04 Hazard Level

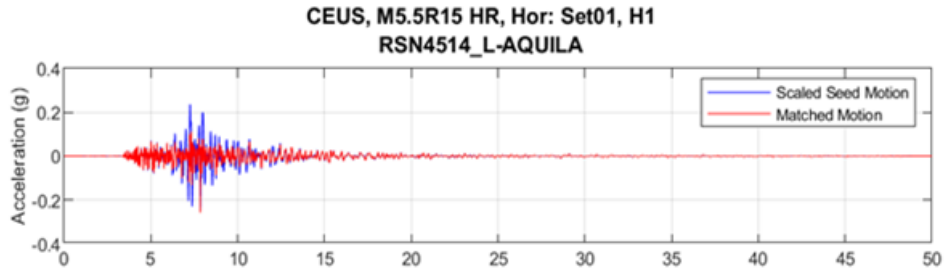


CEUS Hard Rock PGAs from Representative Earthquake Scenarios Compared to Site-Specific GMRS



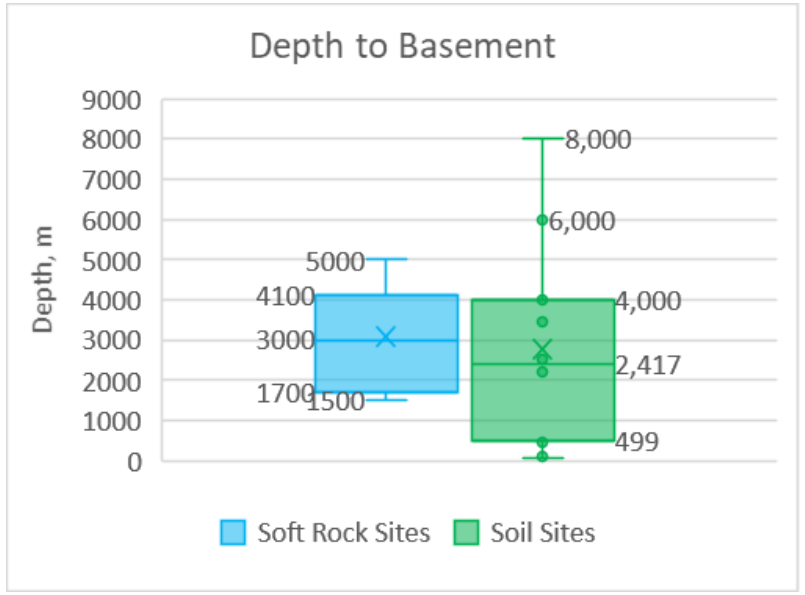
- Select candidate seed time histories consistent with the scenario.
- Modify time histories (5 per seed) to be spectrum compatible.
- Apply developed hazard . .

Free-Field Time Histories



Conditions at the Soil and Soft Rock Sites in CEUS

Depth to Hard Rock

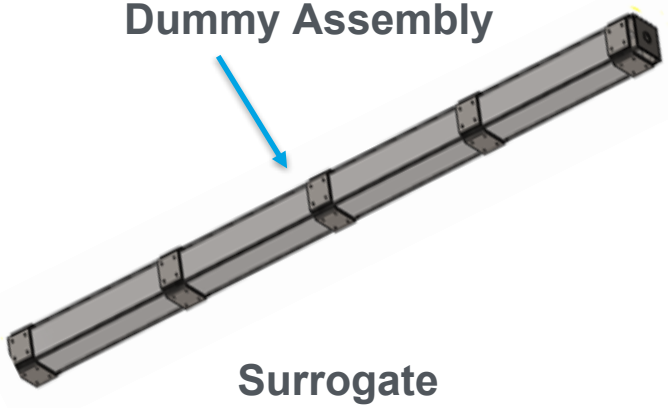


- **Most sites have deep soil or soft rock > than 500 m.**

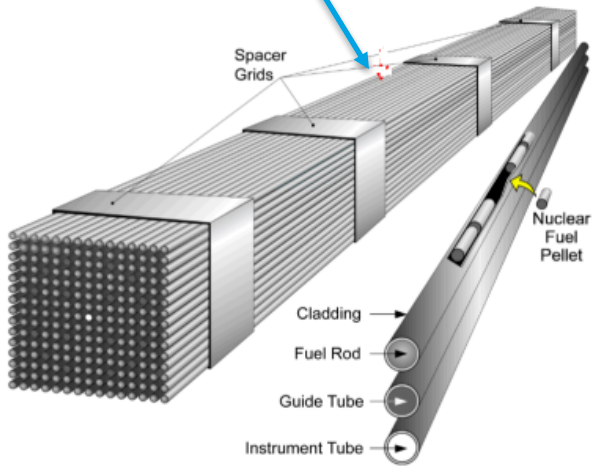
Depth to Hard Rock (shear wave velocity = 3000 m/s)

Test Unit – Full-Scale Dry Storage System

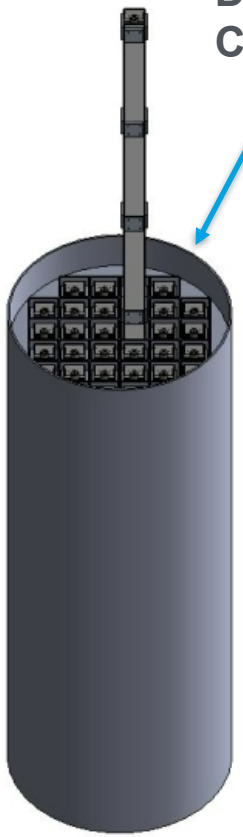
Dummy Assembly



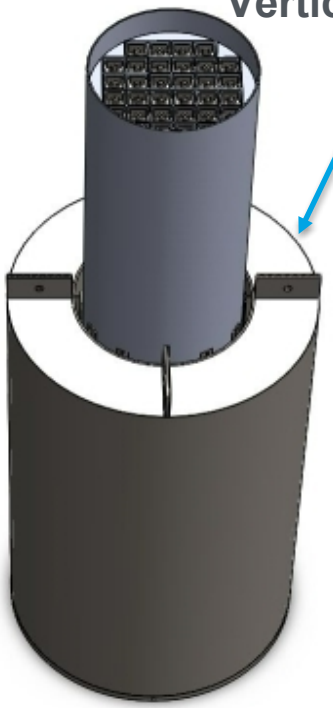
Surrogate Assembly



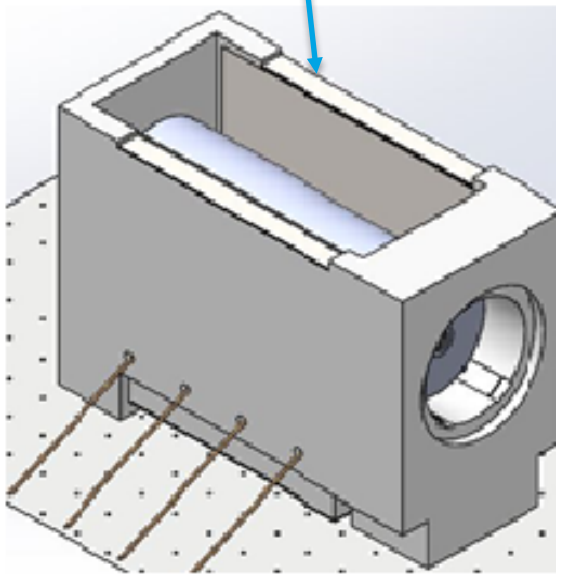
Dry Storage Canister



Vertical Cask

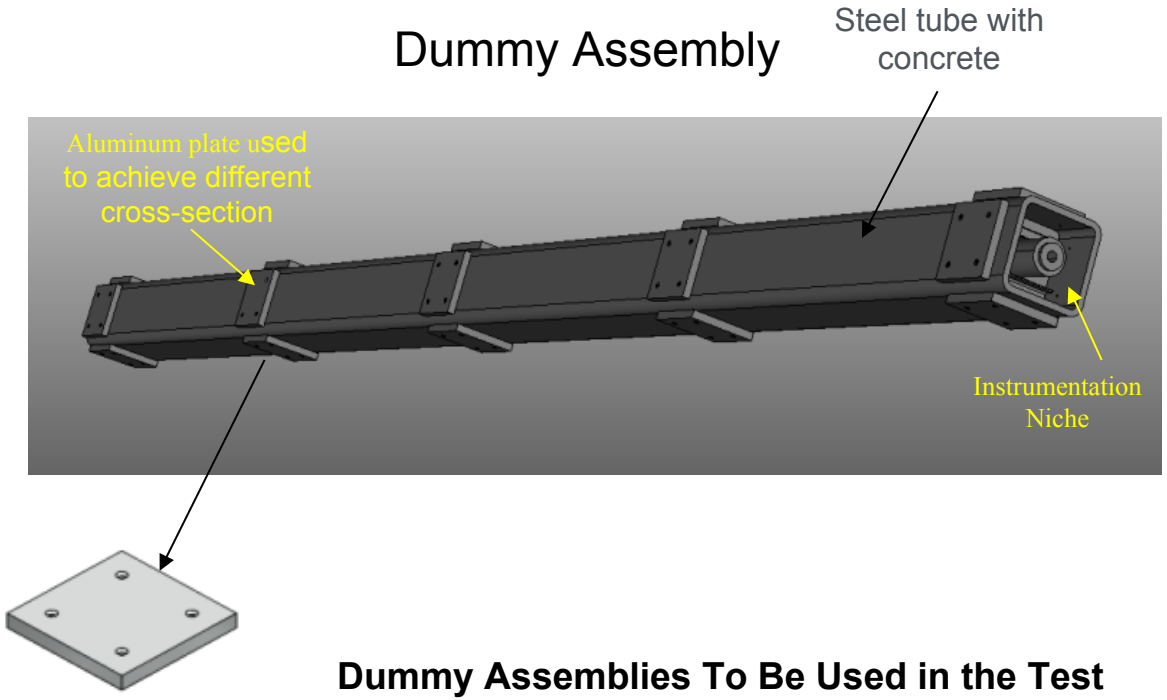


Horizontal Storage Module (HSM)



Dummy and Surrogate Assemblies

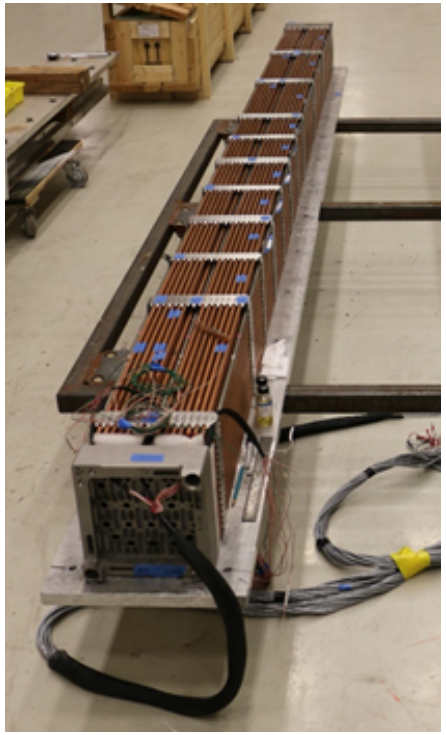
Dummy Assembly



Dummy Assemblies To Be Used in the Test

Width (mm)	Weight (lbs)	Number
207	1410	26
210	1414	1
214	1419	1

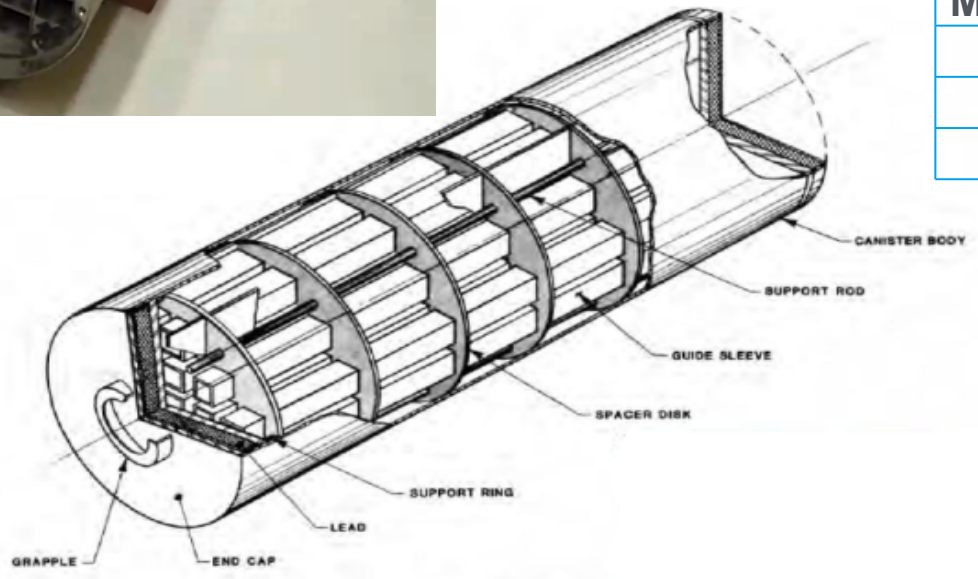
17x17 Westinghouse Surrogate Assembly (slightly damaged)



Surrogate Assemblies To Be Used in the Test

- 16x16 CE PLUS7
- 17x17 Westinghouse Intact
- 17x17 Westinghouse slightly damaged
- 16x16 – to be determined

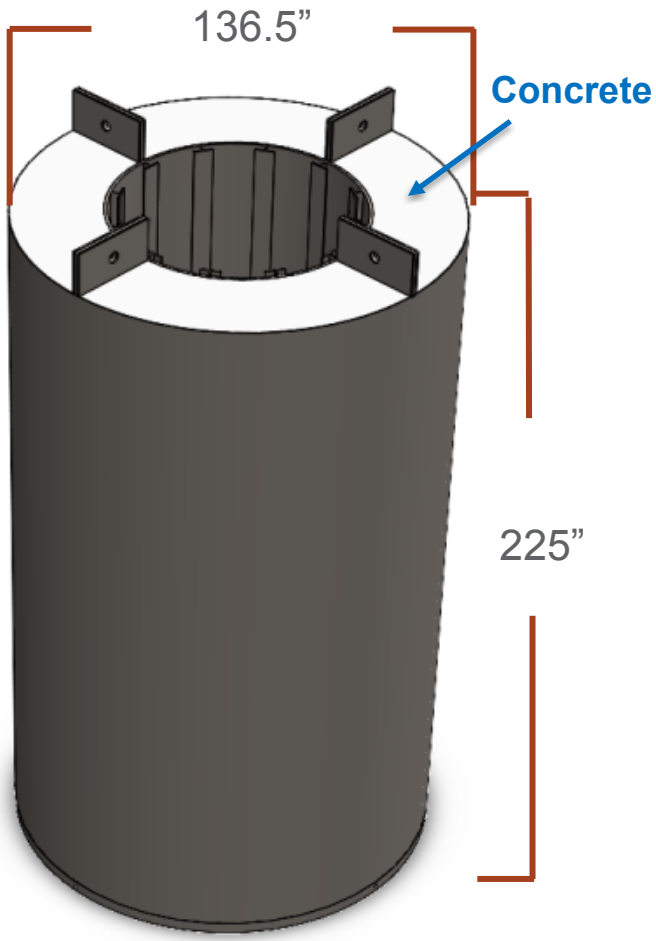
Dry Storage Canister – NUHOM 32 PTH2



Attribute	Sprcification	
Capacity	32 PWR	
Weight	lbs	kg
Empty	58.000	26,310
Loaded	108.850	49,370
Dimensions	in	mm
Overall Length	193.0	4802.2
Cross Section	69.75	1771.65
Cavity Length	171.63	4359.4
Wall Thickness	0.5	12.7
Materials of Construction		
Canister Body	SS	
Basket	SS/B-Al/Boral/MMC	
Shield Plugs	Steel	

Vertical Cask Mokeup

Vertical Cask Mockup: Steel-Concrete-Steel

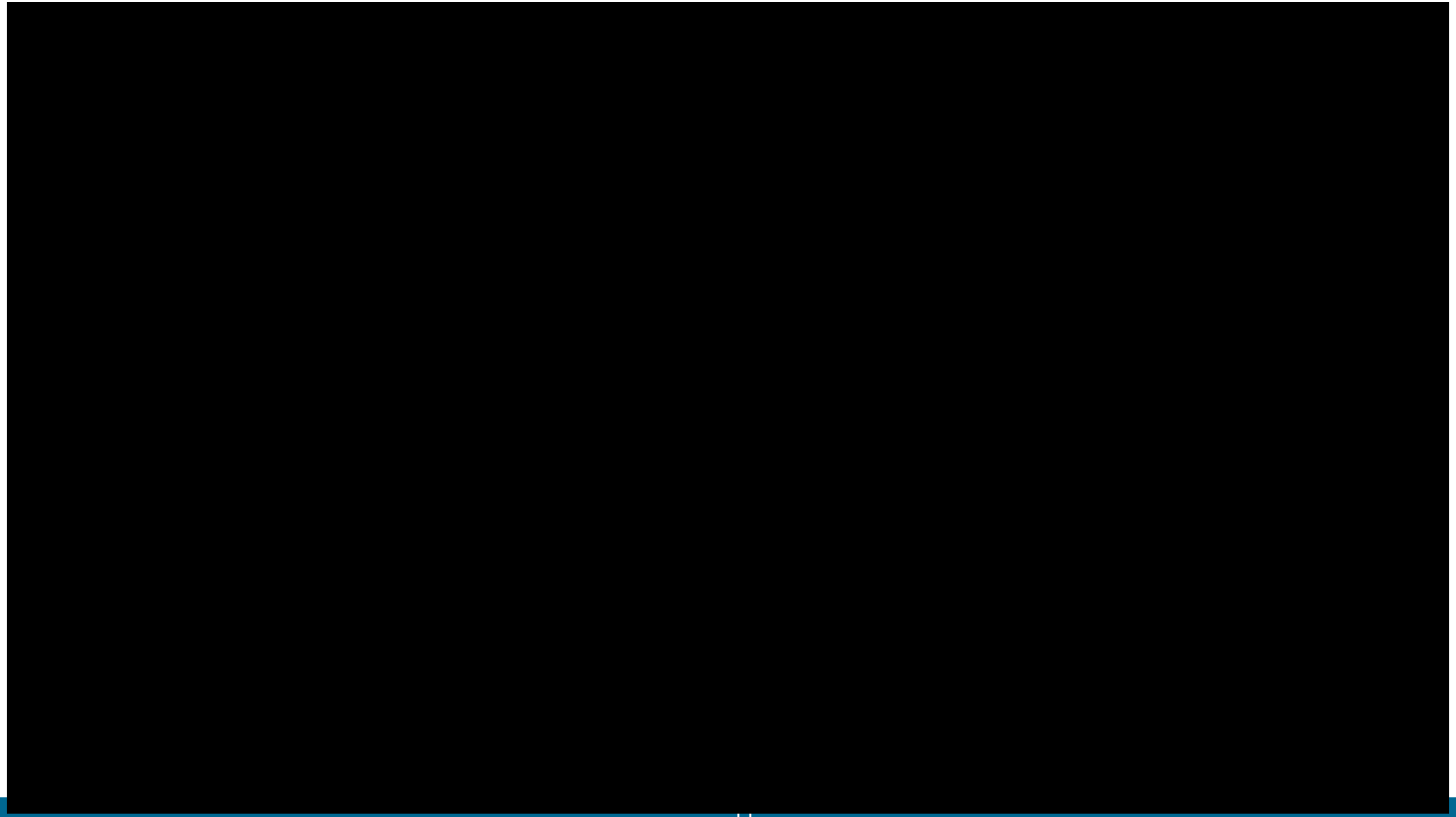


Empty Weight: 234,700 lbs
Loaded Weight: 335,952 lbs

Vertical Cask Carcass at the Manufacturing Facility

Inner Shell of the Cask Carcass

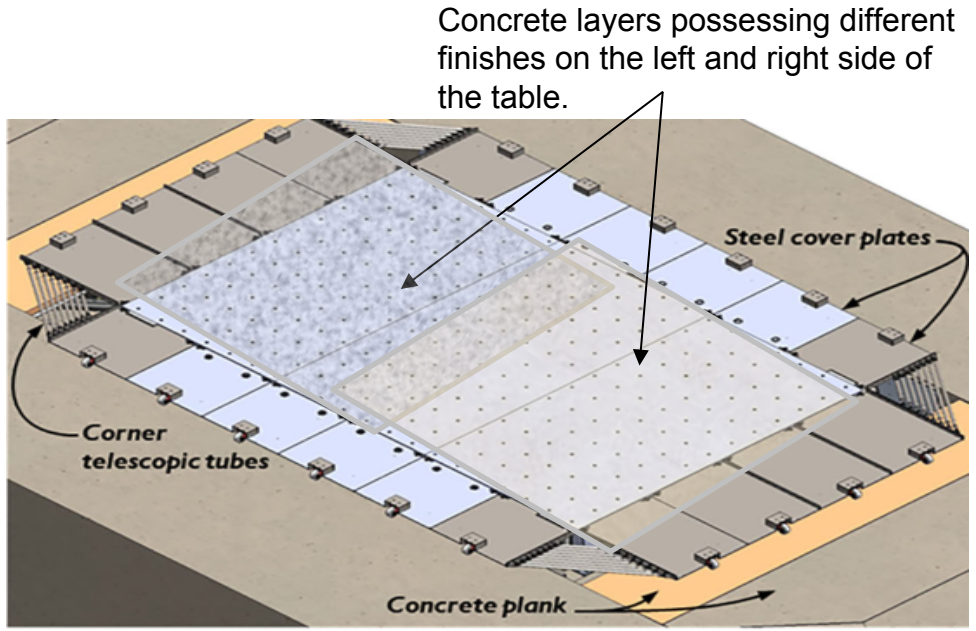
Pouring Concrete in the Vertical Cask at LHPOST6 (UCSD)



Simulating Representative ISFSI Pad Conditions

LHPOST6 Facility at UCSD (San Diego, California)

Closeup View of the Shake Table



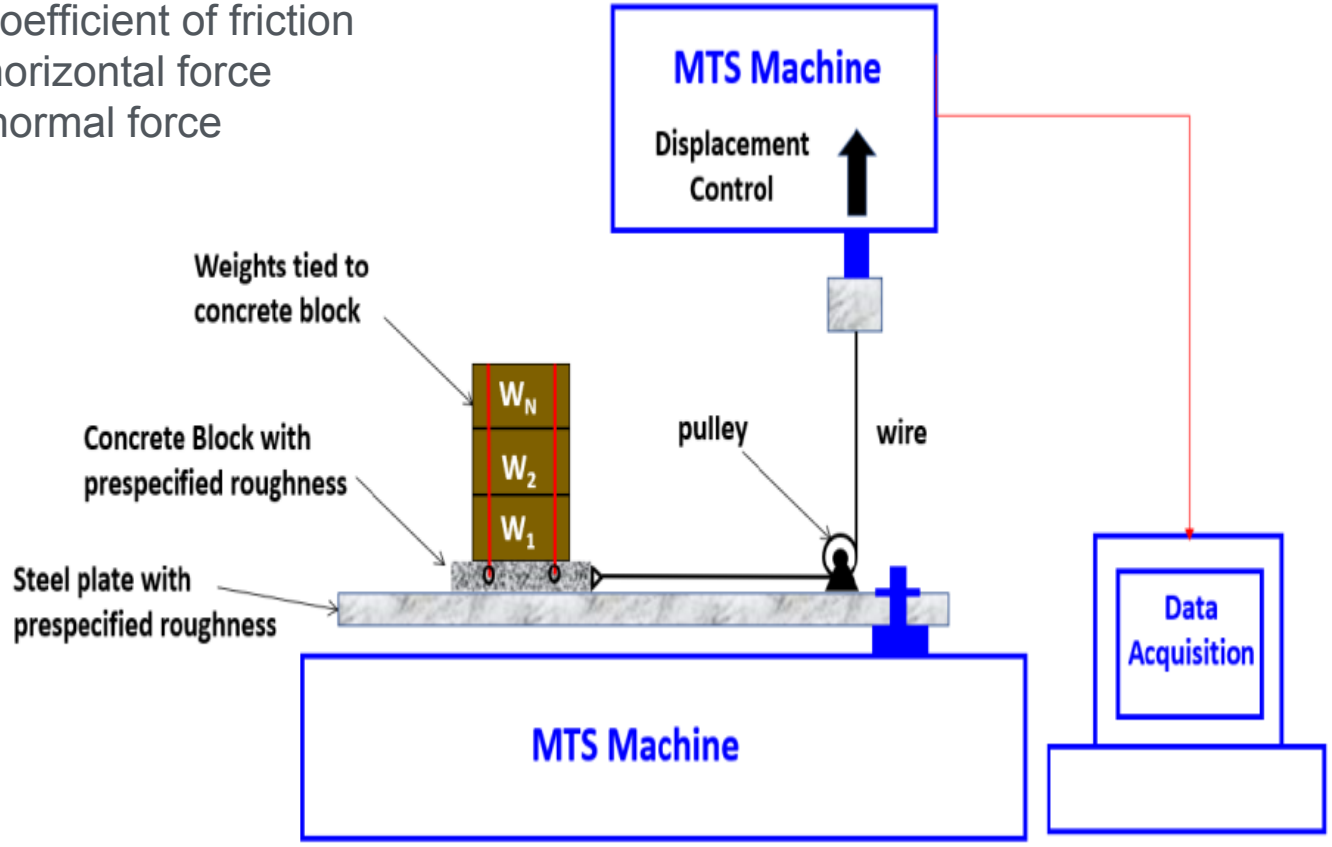
- The concrete finish on the left and right side of the table will be different to represent different ISFSI pad conditions.

Steel on Concrete Static and Dynamic Coefficients of Friction Experiment

$$\mu = \frac{F}{N}$$

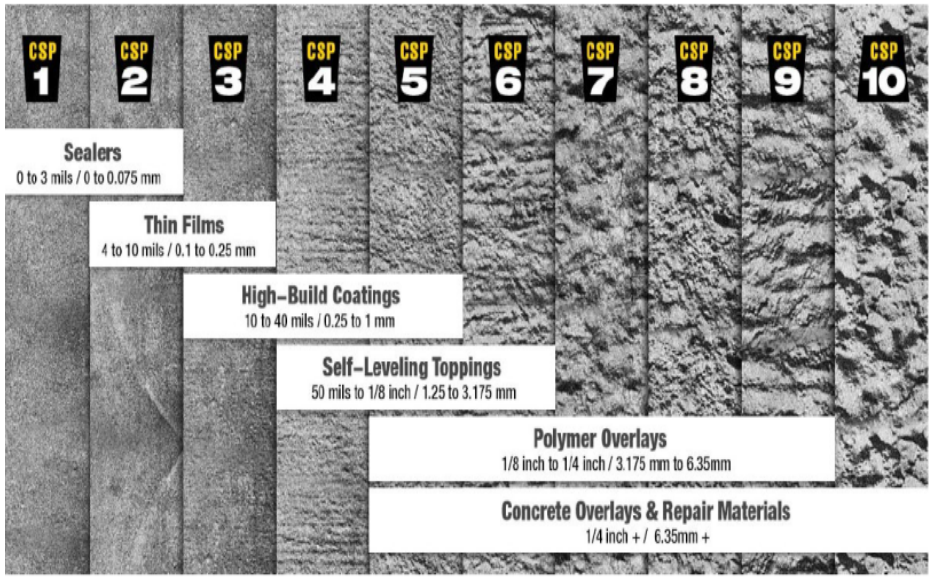
μ - coefficient of friction
F - horizontal force
N - normal force

Test Setup



The motion of the concrete block will be monitored with a digital image correlation (DIC) camera system and by measuring the displacement of the crosshead of the MTS machine.

Prescribed Concrete Roughness as determined by



Concrete blocks with 5 roughness levels will be produced for the test.

Static and dynamic coefficient of friction of concrete with different surface roughness with steel.

Proposed Instrumentation

Accelerometers

Instrumented Element	Location	NN of Triaxial	NN of Uniaxial
Dummy Assemblies (28)	top	28	
Surrogate Assemblies (4)	tie plate	4	
Surrogate Assemblies (4)	rods		32
Canister	top	2	
Canister	bottom	2	
Cask	top	2	
Cask	bottom	2	
Basket	top		2
Total		**40**	**34**

Strain Gauges

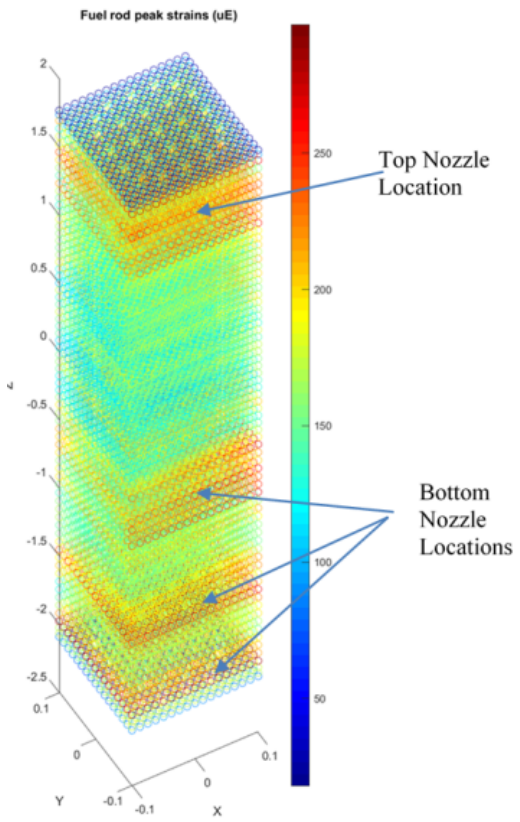
Instrumented Element	Location	NN
Surrogate Assembly (4)	rods	128

Accelerometer

Instrumented Element	Location	NN
Canister	Top	2
Cask	Top	2
Shake table	top	2
Total		6

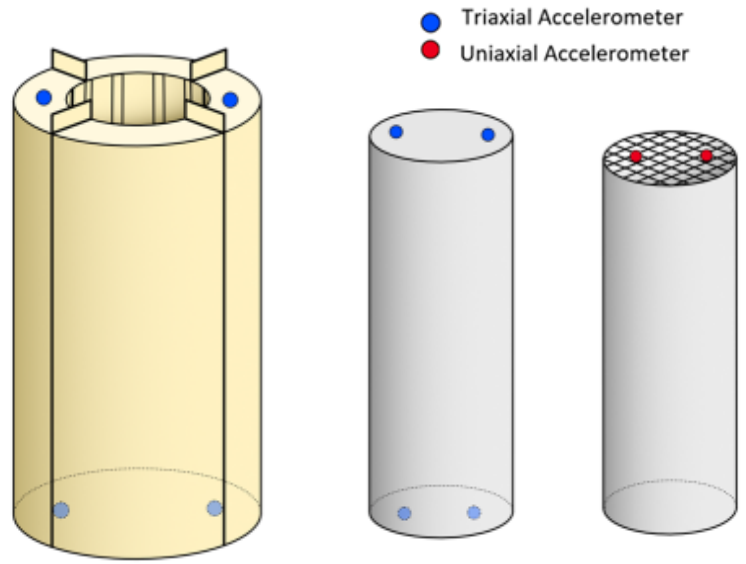
➢ **Proposed instrumentation will need ≈ 300 Channels**

Surrogate Assembly Instrumentation



Pre-Test Modeling Results from Klymyshyn, SMiRT26

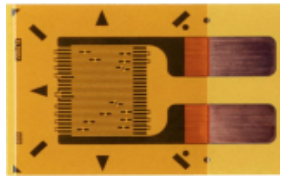
Cask, Canister, and Basket Instrumenta



Sensors

Endevco Model 727

CEA-03-062UW-350



Questions?