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Parametric Evaluation of Seismic Behavior of Freestanding Spent Fuel Dry Cask Storage Systems

6860 Technical Seminar Series

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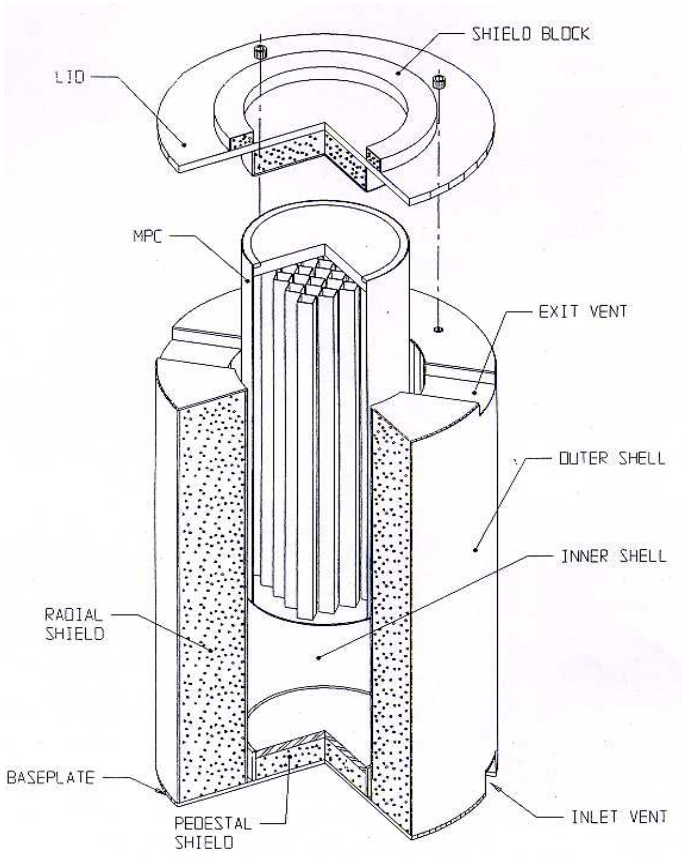
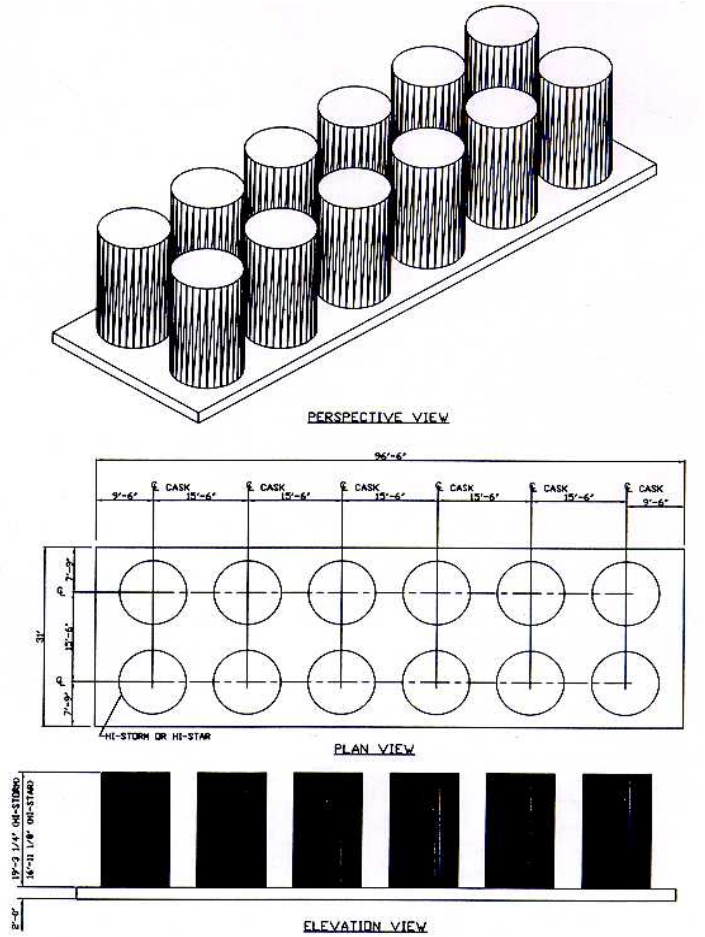
Presentation Outline

- **Background**
  - What are dry cask storage systems
  - Why are they needed
  - Are they widely used
  - Why freestanding
- **Project Scope**
  - Three site-specific analyses
  - Parametric evaluation
- **Coupled Analysis Methodology**
- **Parametric Evaluation**
  - Scope
  - Nomograms

Vertical Cylindrical Cask





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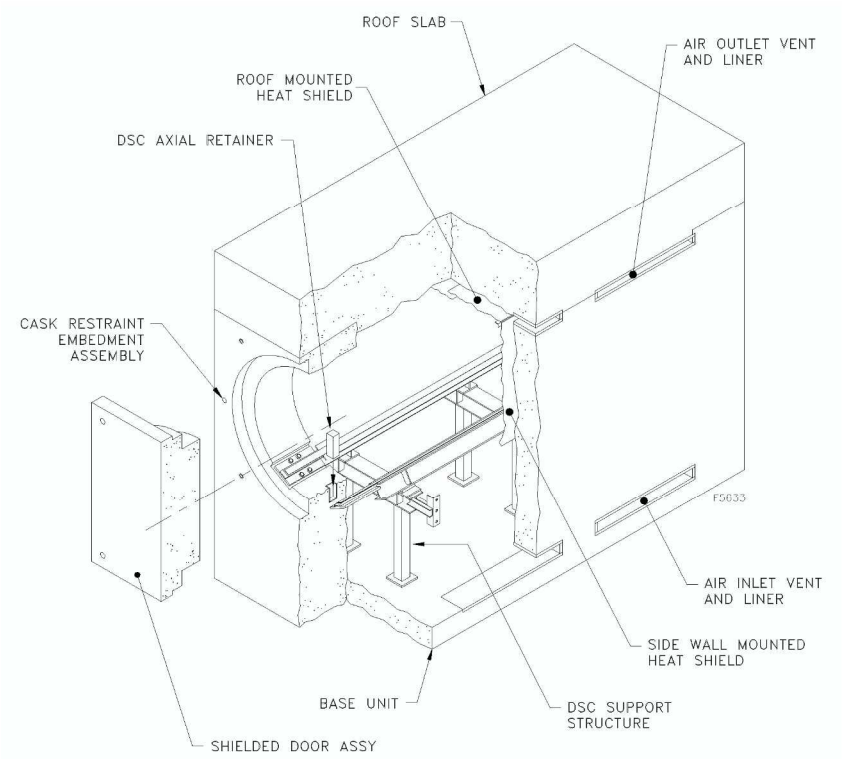
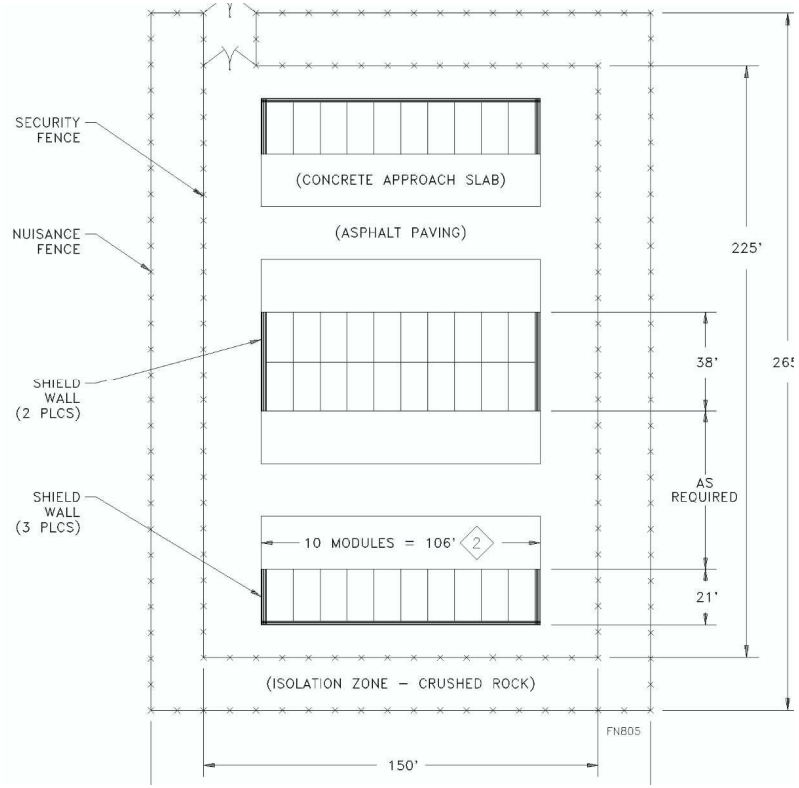
Horizontal Rectangular Module





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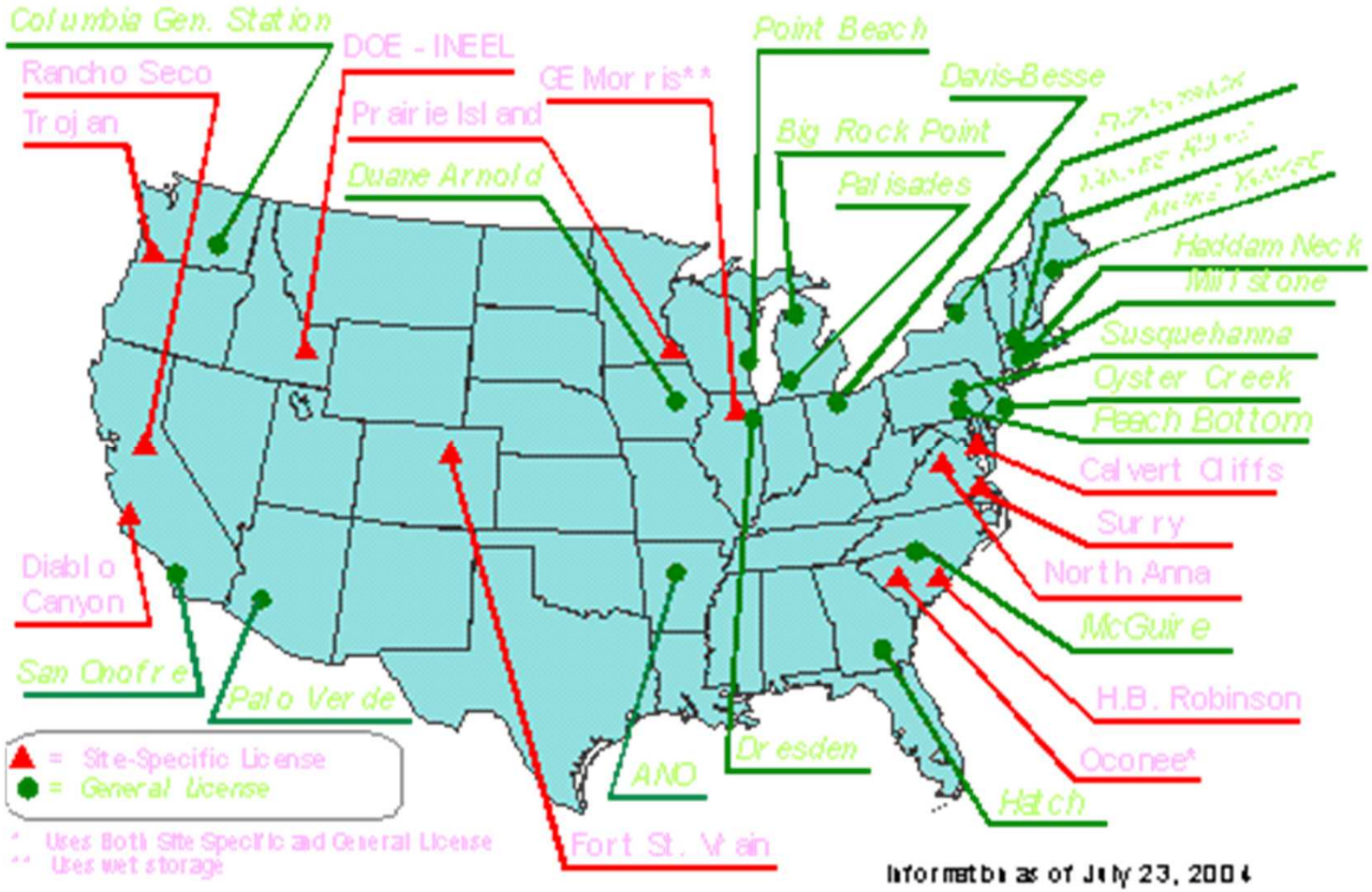
Why Are DCSS Needed

- **Dry storage of spent fuel above ground has become an accepted "repository" alternative by installing DCSS at Independent Spent Fuel Storage Installations (ISFSI).**

Are DCSS Widely Used
Operating ISFSI Locations



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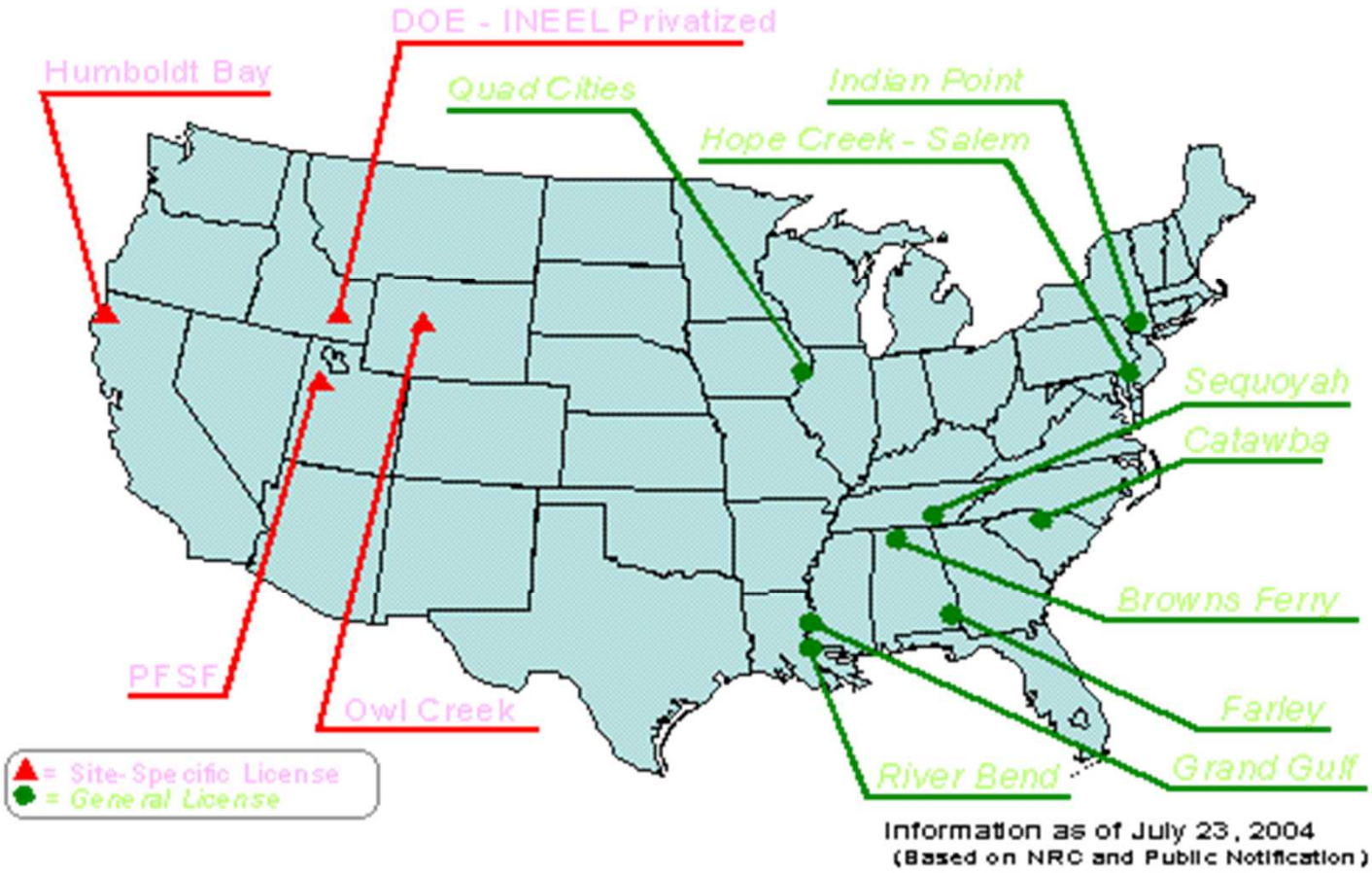
Are DCSS Widely Used (cont'd)
Potential Near-Term, New ISFSI Sites



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Why Are DCSS Freestanding

- It has financial benefit in the form of a reduced implementation and future decommissioning costs.
- It reduces a significant amount of regulatory requirements and associated paperwork.
- Consequence:
  - Cask stability concerns of probable tipping-over and collision of neighboring casks in an earthquake event

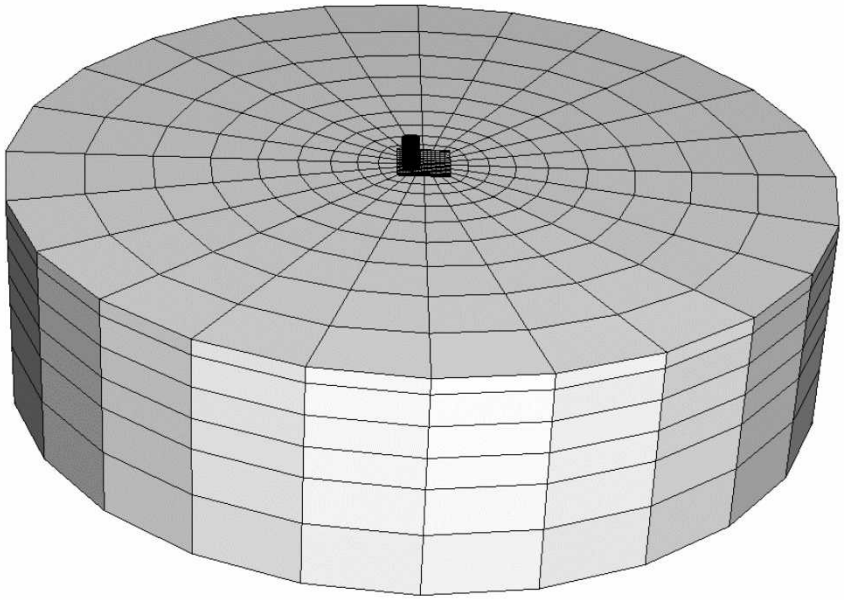
Project Scope

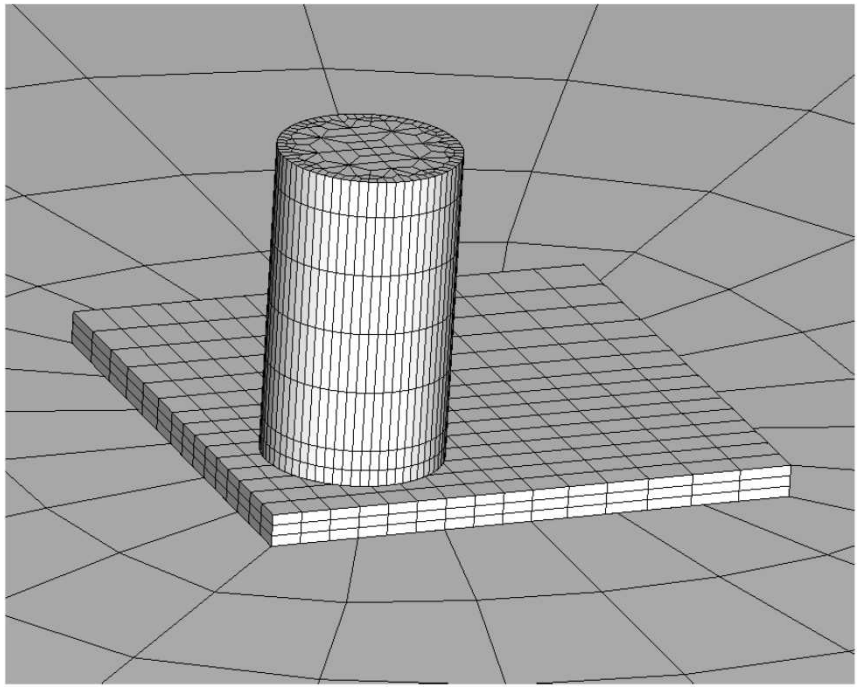
- **Three site-specific analyses**
  - **Three-module rectangular Transnuclear West module/cask at San Onofre Nuclear Generating Station**
  - **HI-STORM 100 casks at Hatch Nuclear Power Station, and**
  - **HI-STORM 100 casks at Private Fuel Storage Facility**
- **Parametric evaluation**
  - **The main objective is to characterize the sensitivity of the cask response to a number of important input parameters:**
    - **Cask designs**
    - **Coefficient of friction at cask/pad interface**
    - **Foundation types**
    - **Spectral shapes**
    - **Earthquake ground motions**

Coupled Analysis Methodology

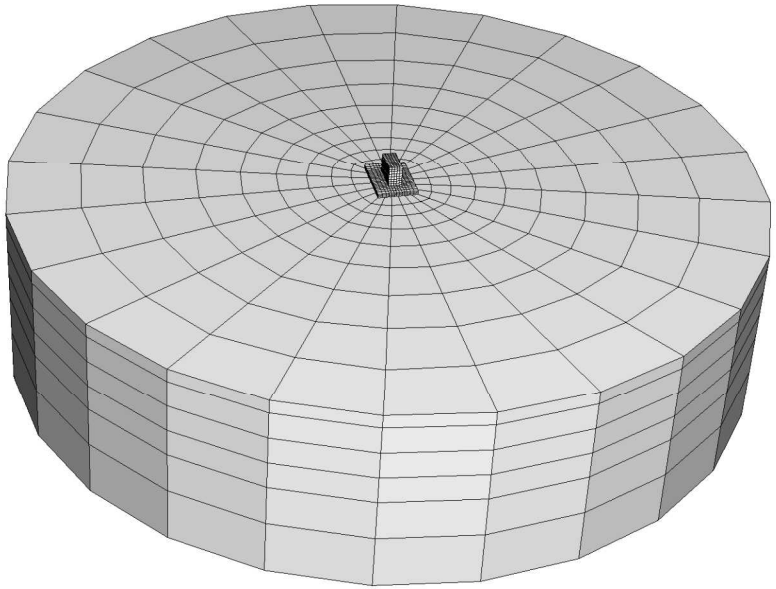
- **Modeling goal:**
  - **To model the full nonlinear behavior of the freestanding cask system as realistically as possible in a seismic event.**
- **Unique modeling features:**
  - **Coupled finite element models, using ABAQUS/Explicit, were developed consisting of freestanding cask, pad, and foundation simulated as independent bodies, each capable of experiencing large independent movements relative to one another.**
  - **Contact constraints are used to realistically model the interactions between these bodies.**

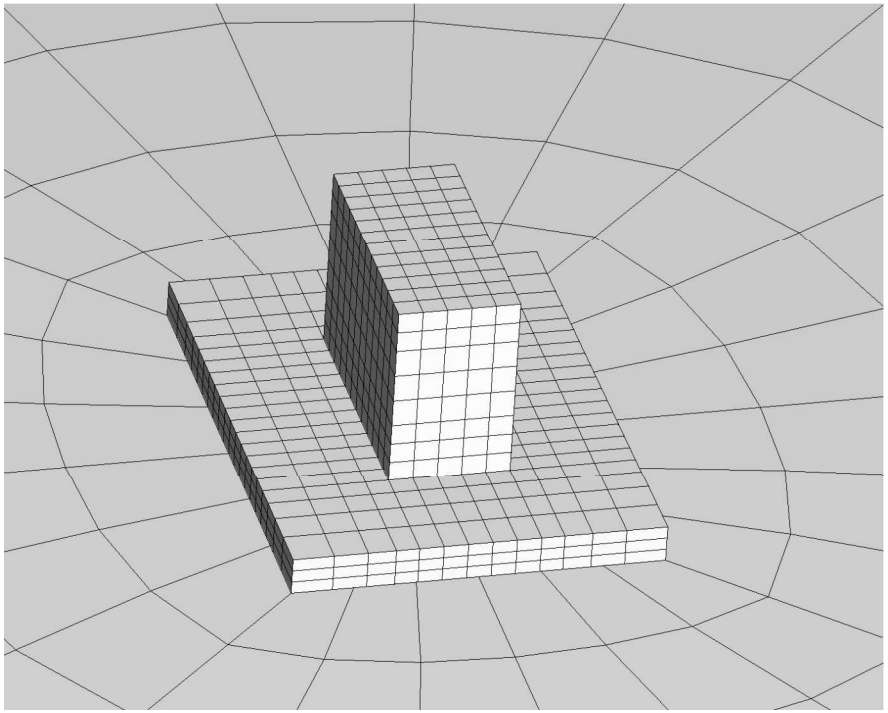
Coupled Finite Element Model for Cylindrical HI-STORM 100 Cask





Coupled Finite Element Model for Rectangular NUHOMS HSM Module/Cask





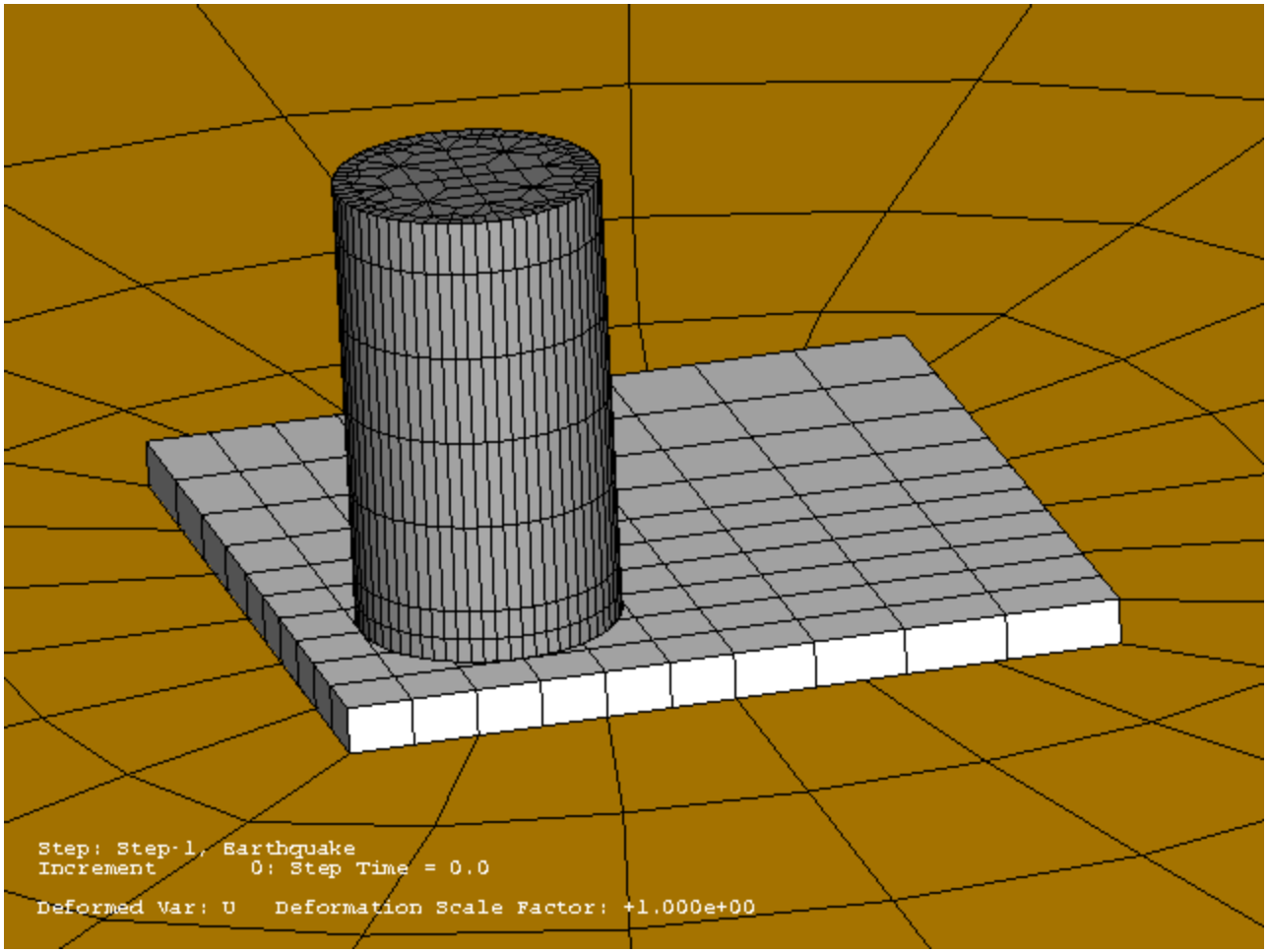
Modeling Issues

- **Explicit formulation was chosen in order to arrive at a converged solution set for the highly nonlinear problem.**
- **A significant modeling effort is focused on developing a reasonably fine, yet practical, mesh configuration to allow for executing all parametric cases.**
- **The friction model at the cask/pad interface**
- **A finite foundation model to represent a semi-infinite foundation**
- **Deconvolution analyses of surface-defined ground motions were performed by preserving their dynamic characteristics of amplitudes and frequency contents prior to applying them at base of foundation model.**
- **Selection of a limited set of earthquake records as inputs of ground motions in parametric study.**

Scope of Parametric Analyses

Input Parameter	Description	Details
Coupled finite element models	2 Cask designs	Cylindrical HI-STORM 100 cask and rectangular NUHOMS HSM module
	3 Foundation types	Soft soil, stiff soil, and rock
	3 Coefficients of friction at cask/pad interface	0.20, 0.55, and 0.80
Seismic ground motions	3 Spectral curve shapes	NUREG/CR-0098 Regulatory Guide 1.60 NUREG/CR-6728
	5 Selected earthquake records	NUREG/CR-0098 and Regulatory Guide 1.60: 1) 1978 Iran Tabas 2) 1999 Taiwan Chi-Chi 3) 1992 Landers Joshua Tree 4) 1994 Northridge Jensen Filtration Plant 5) 1979 Imperial Valley Calexico Fire Station
		NUREG/CR-6728: A) 1985 Nihanni B) 1988 Saquenay C) 1979 Imperial Valley D) 1989 Loma Prieta E) 1994 Northridge
	4 PGA (Peak Ground Acceleration) levels	0.25, 0.60, 1.00, and 1.25 g

Movie
Cylindrical Cask - HI-STORM 100



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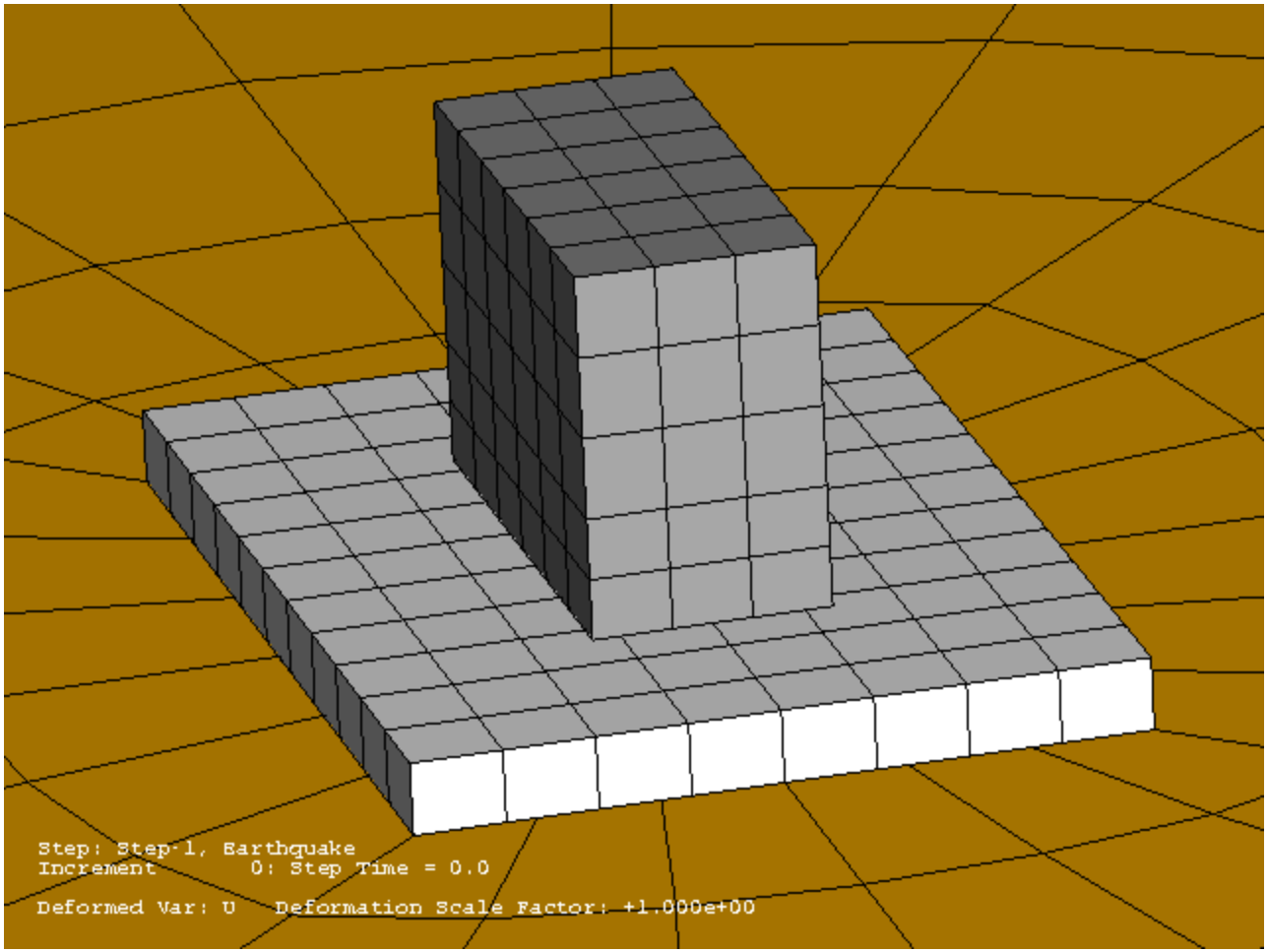
Movie
Rectangular Module - NUHOMS HSM



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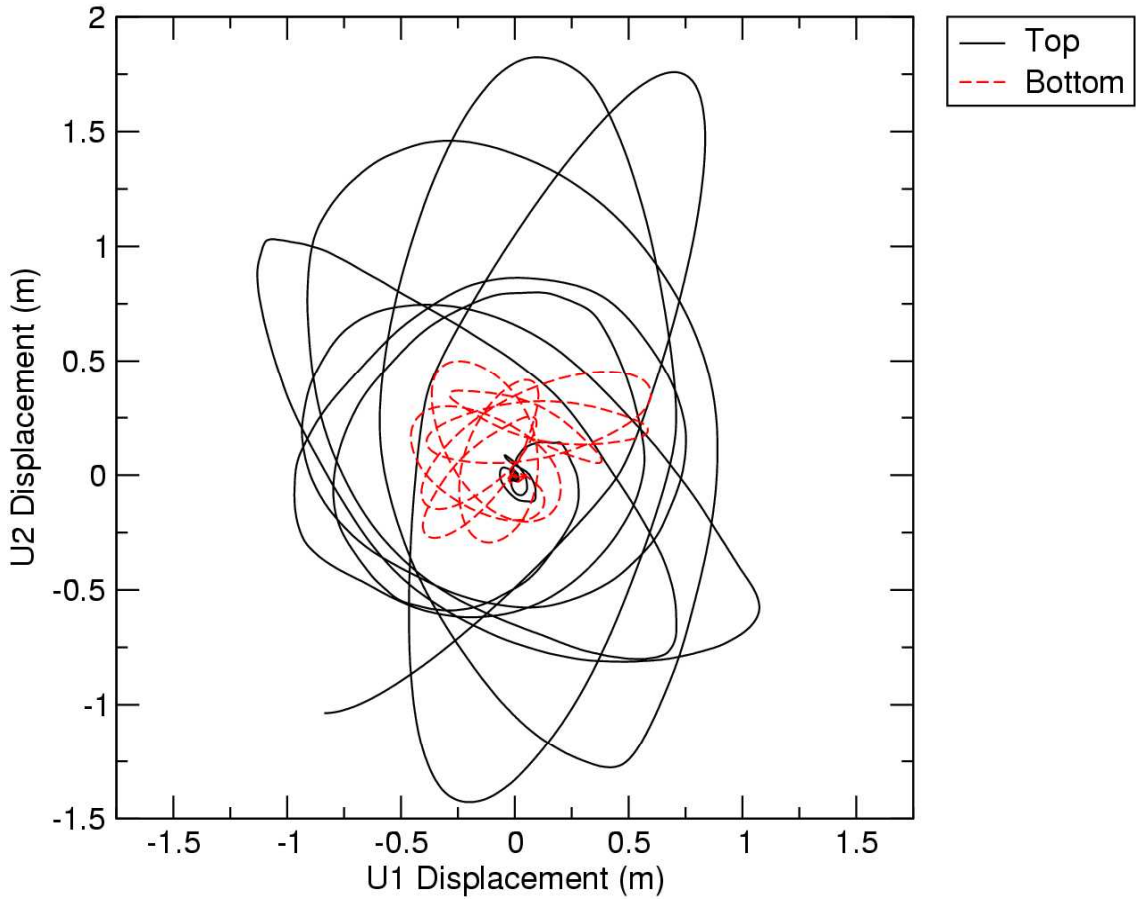
Lateral Displacement Trajectory Plots
Cylindrical Cask

Iran Tabas Earthquake, NUREG/CR-0098, PGA=1.0g, Stiff Soil Profile, μ=0.55



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Lateral Displacement Trajectory Plots
Rectangular Module

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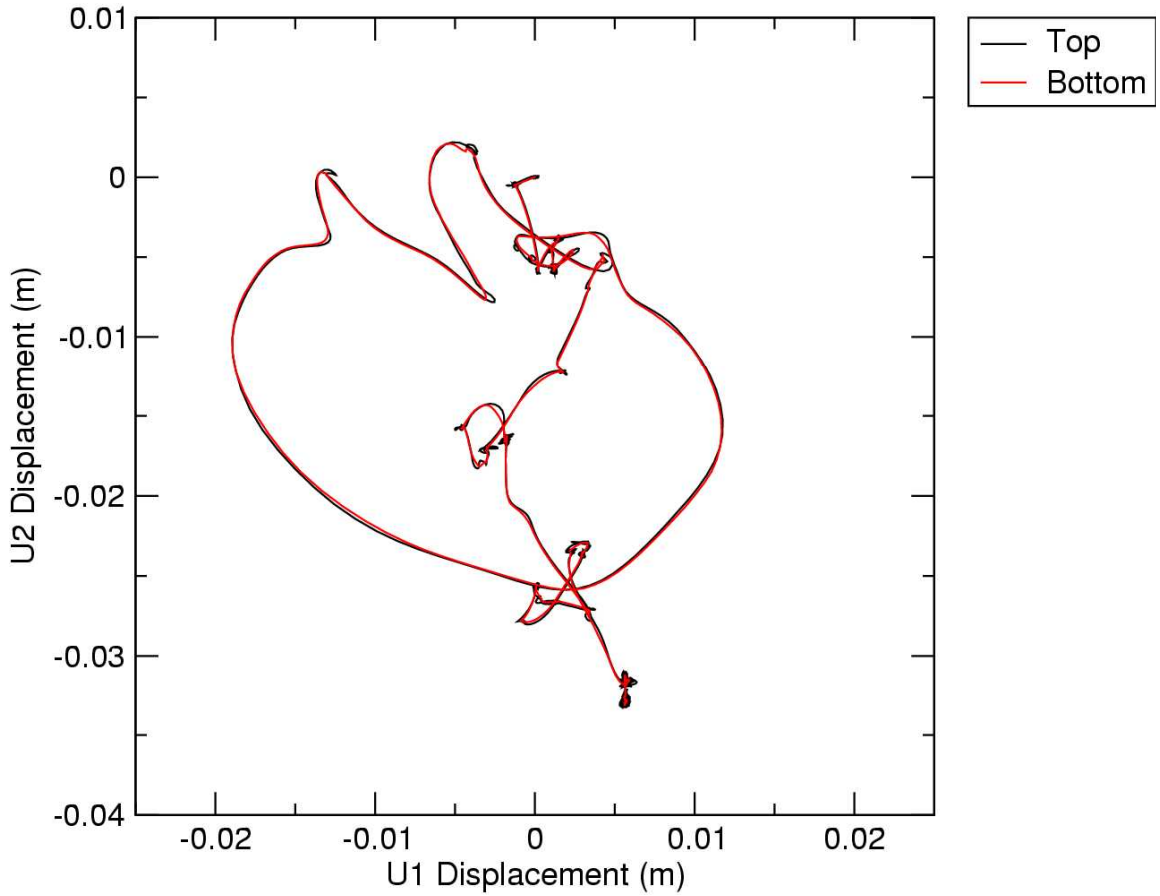

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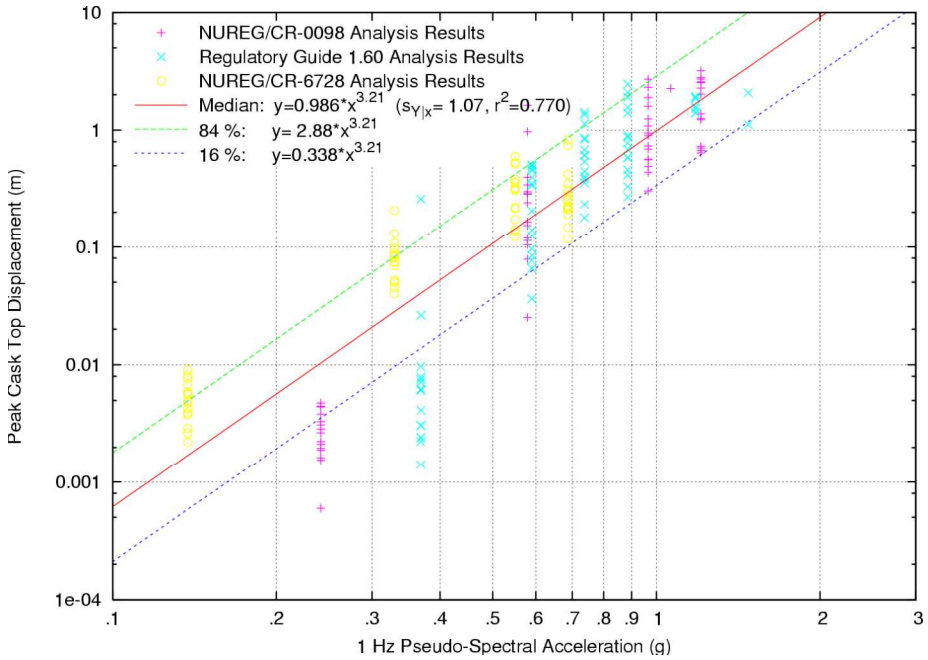
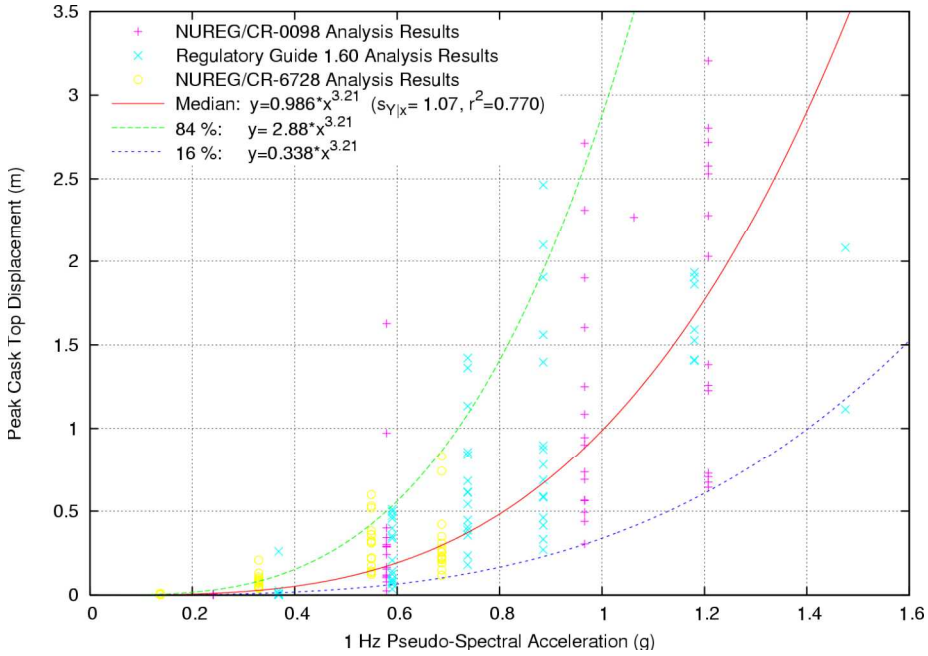
Parametric Analysis Results in Nomograms

HI-STORM 100 Cask, μ=0.55, Scaled to 1 Hz PSA



log scale



linear scale

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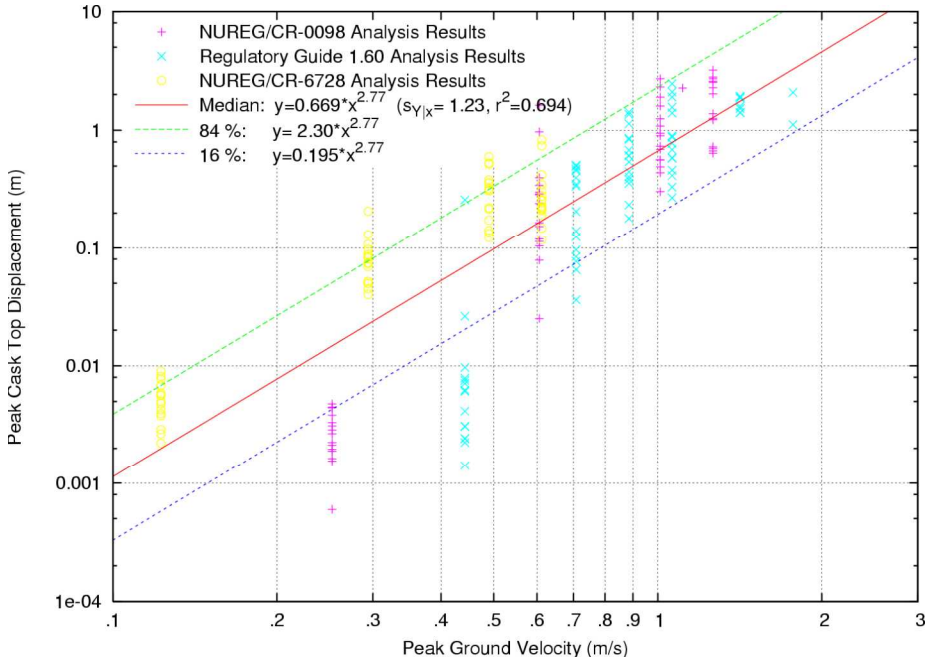
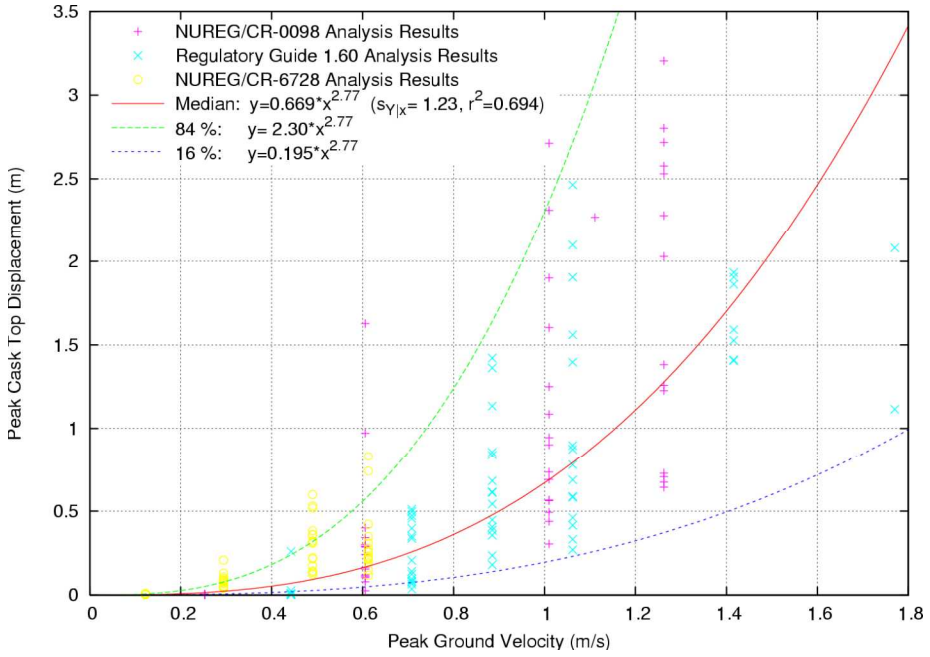
Parametric Analysis Results in Nomograms

HI-STORM 100 Cask, μ=0.55, Scaled to PGV



log scale



linear scale

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