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PROPOSED METHODOLOGY FOR FREESTANDING STACK-UP ANALYSIS

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Presentation to SFST Technical Exchange on Stack-Up Analysis

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Overview

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- Stack-Up Components
  - Pre-stressed vs. Non Pre-stressed
- Acceptance Criteria
- Dynamic Analysis Model
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  - Input Considerations
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Stack-Up Components

- "Stack-up" refers to the evolution during a dry storage loading campaign when a HI-TRAC transfer cask is vertically mounted on top of a HI-STORM storage cask
- Typical stack-up configurations consist of the following components:
  - HI-STORM storage cask (no lid)
  - Mating Device
  - HI-TRAC transfer cask
  - MPC
  - Low Profile Transporter (LPT) or alternate transport device
- Pre-stressed stack-up configuration is when bolts connecting HI-TRAC to mating device and mating device to HI-STORM are installed and preloaded to specified torque values; non pre-stressed stack-up configuration is when the mating device bolts are installed without any preload or replaced by alignment pins

Stack-Up Components (cont.)

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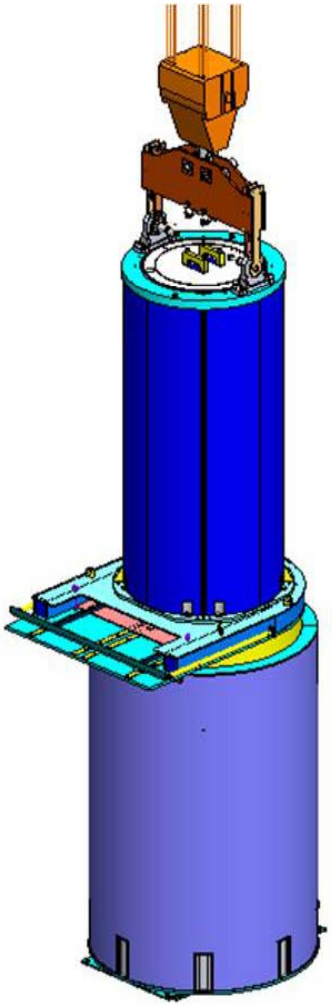

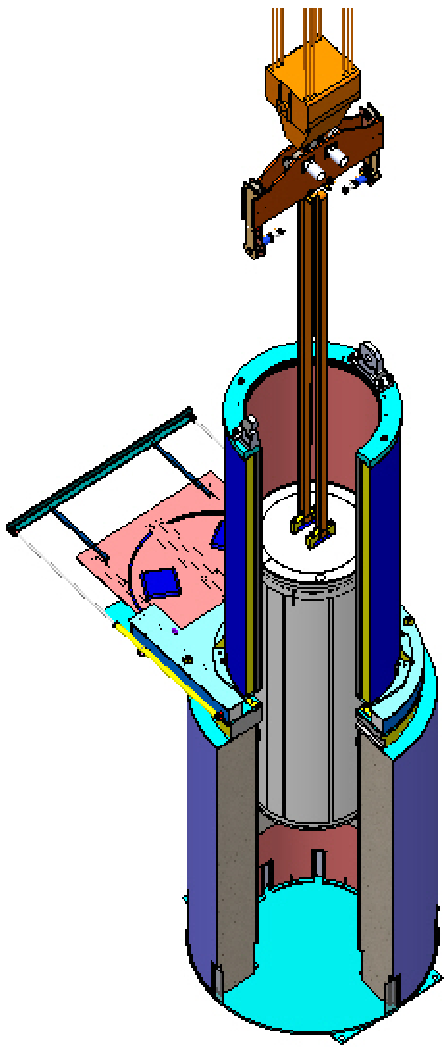

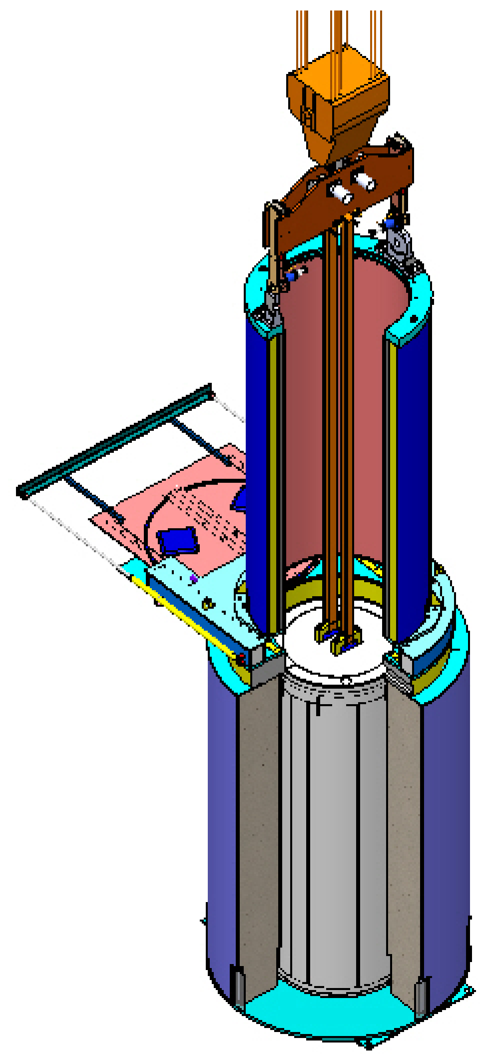

Acceptance Criteria

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- Stack-up configuration must remain stable during and after design basis earthquake “with an extremely high level of certainty”
  - Appendix D of SRP 3.8.4 requires a minimum safety factor (SF) of 1.1 against overturning for spent fuel racks under SSE conditions
  - ASCE 43-05 requires a minimum SF of at least 2 against overturning
  - Minimum SF of 1.93 against overturning ruled acceptable during ASLB hearings for the 4,000 cask ISFSI pad installation at Skull Valley
  - Holtec proposes a minimum SF of 2 against overturning for stack-up configuration (i.e., maximum predicted rotation angle from all time history simulations must be less than 50% of the rotation angle at the balance point)

Acceptance Criteria (cont.)

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- Stack-up components must be capable of resisting seismic loads
  - Stresses must be less than the applicable design basis stress limits for each component (e.g., ASME Subsection NF stress limits)
  - This condition is generally not limiting for the HI-STORM and MPC since these components have been designed to withstand much higher impact loads resulting from drop accidents and non-mechanistic tip over
- Underlying floor system must have sufficient capacity to withstand loads transmitted by stack-up
  - Forces and moments induced by the stack-up must comply with existing design basis code for the Part 50 structure

Dynamic Analysis Model

Computer Code Used

- Dynamic analysis model of freestanding stack-up is developed using the finite element code ANSYS
- ANSYS has been independently validated by Holtec under the company's QA program
- ANSYS has been used previously by Holtec to perform structural analyses for the HI-STORM 100 System and it is explicitly referenced in the HI-STORM FSAR
- NRC Staff has identified ANSYS in its response to the Perry TAR as a finite element program that provides a "high level of transparency"

Dynamic Analysis Model (cont.)

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<u>Input Considerations</u>

- Multiple synthetic time histories (5 sets) are used as input since dynamic analysis model is non-linear due to contact elements at HI-STORM /LPT interface and possibly HI-TRAC/Mating Device interface (for non pre-stressed configuration)
  - Use of 5 sets complies with SRP 3.7.1, ASCE 4-98, and ASCE 43-05
  - Time histories generated in accordance with SRP 3.7.1 requirements
- Upper and lower bound coefficients of friction (COF) of 0.8 and 0.2 are considered at steel-to-steel and concrete-to-steel interfaces
  - Bounds range of COF values specified in ASCE 43-05 and NUREG/CR-6865
- Coefficients of restitution at contact interfaces are determined from a series of numerical tests using LS-DYNA or based on Reference B-9 in ASCE 43-05

Dynamic Analysis Model (cont.)

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Modeling Assumptions

- MPC is considered to be at its highest elevation inside the HI-TRAC in order to maximize center of gravity (CG) height of stack-up
- Mass of MPC is lumped together with the HI-TRAC mass causing them to respond in unison as a single rigid body
  - Single rigid body assumption is justified based on small radial gap (3/16”) between MPC shell and HI-TRAC inner shell
  - Energy dissipation due to MPC rattling is conservatively neglected
- LPT is bonded to the floor and its width is conservatively set equal to the center to center spacing between LPT rails to allow the stack to rock about the rail centerlines

Dynamic Analysis Model (cont.)

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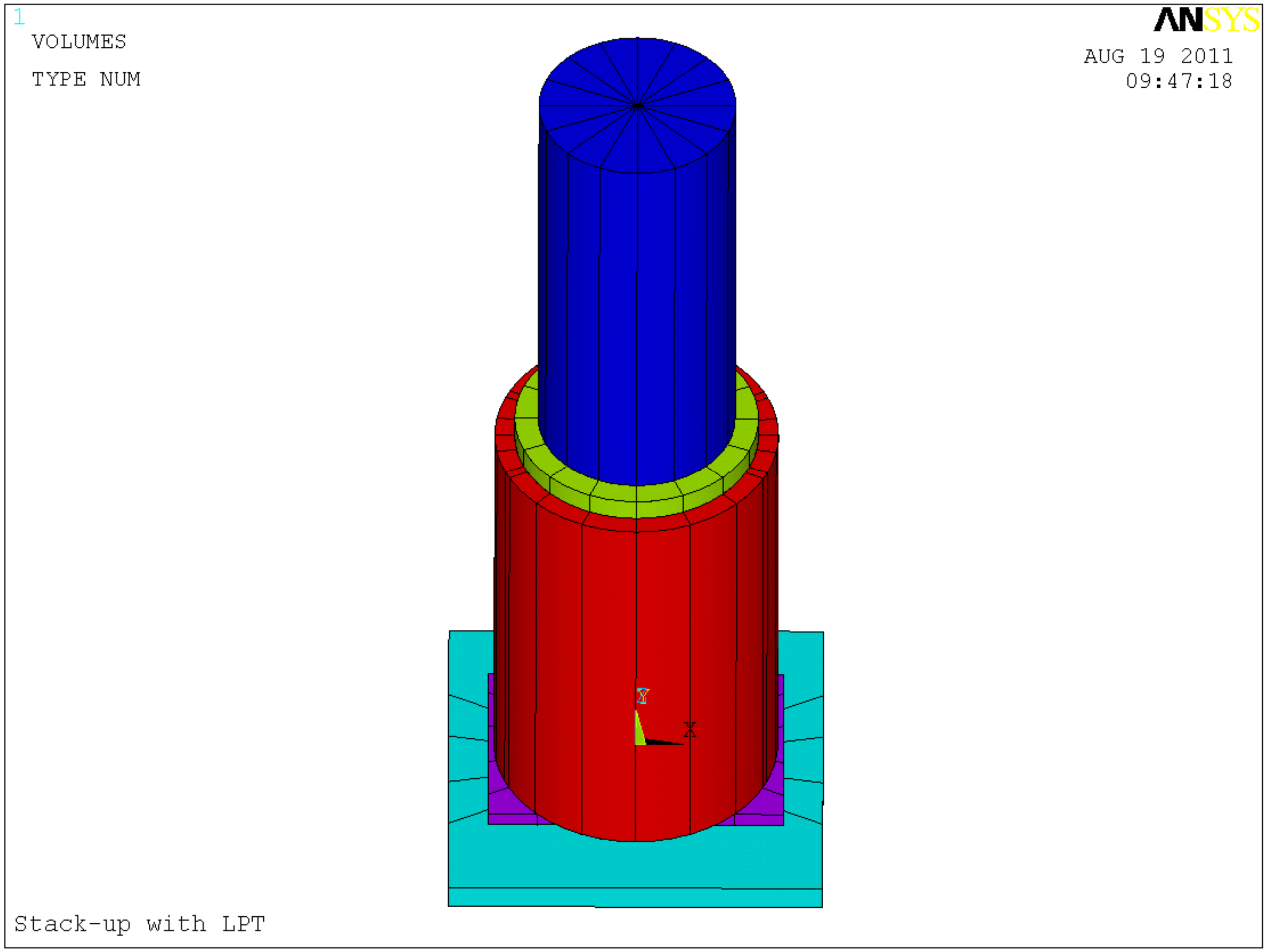

Sample Analysis

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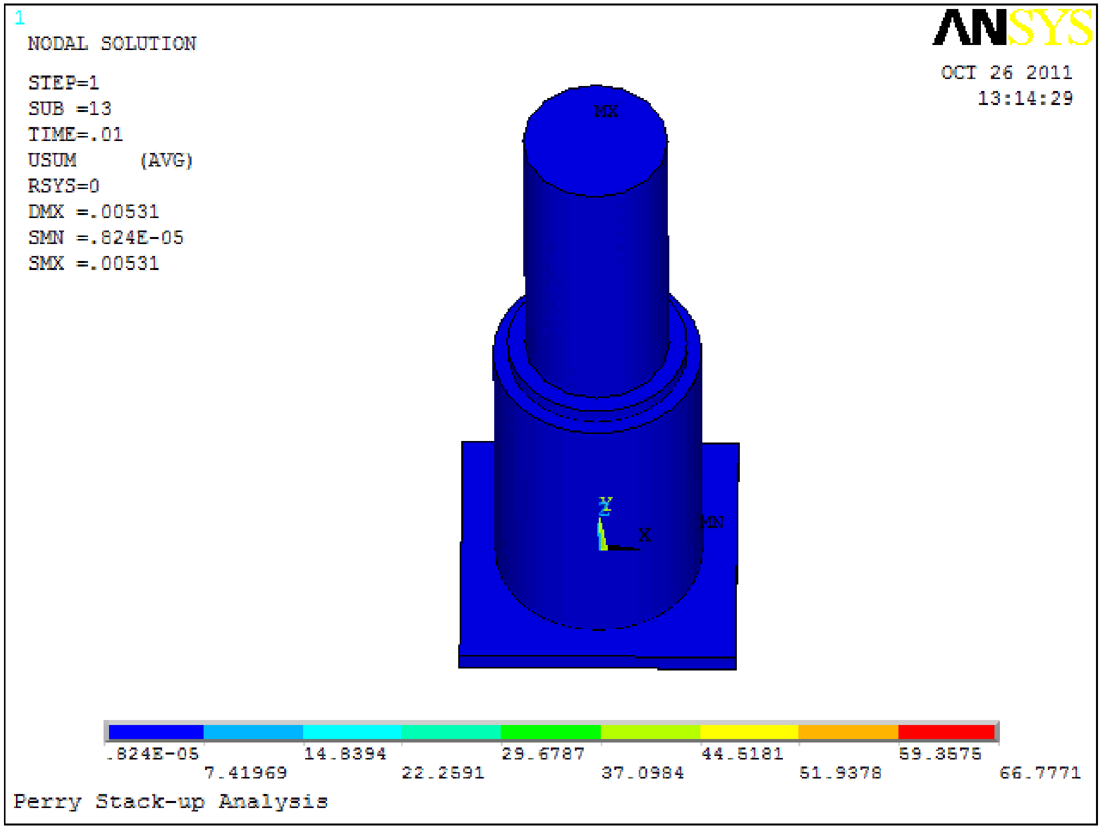

- Pre-stressed stack-up, 3-D earthquake simulation, 30 second duration, ZPA values of 0.325g EW, 0.225g NS, 0.2g Vert, COF = 0.8

Sample Analysis (cont.)

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- Peak lateral displacement at top of HI-TRAC (relative to HI-STORM base) is 11.6" (or 1.62º) based on 5 time history sets and 2 COF values
  - Top of HI-TRAC disp. corresponding to balance point is 137" (or 18.5º)
  - SF against overturning is 18.5 / 1.62 = 11.4 >> 2
- Maximum instantaneous shear forces and moments at HI-TRAC-to-Mating Device and HI-STORM-to-Mating Device interfaces are extracted from ANSYS to evaluate components in the structural load path (e.g., Mating Device bolts)
- Peak vertical load on truck bay floor from all simulations is 1,281 kips
  - Total dead weight of stack-up is 491 kips
- Per ASCE 43-05, if five or more time history sets are used, the mean of the calculated maximum responses may be used in making strength capacity checks

Concluding Remarks

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- Proposed methodology for stability analysis of freestanding stack-up follows the applicable guidance from ASCE 4-98, ASCE 43-05, SRP 3.7.1, and the NRC's response to the Perry TAR
- Methodology is also valid for other freestanding cask configurations (e.g., HI-TRAC in cask pit)