Exelon Nuclear

Seismic Analysis of Unrestrained Stack-up at Byron Station

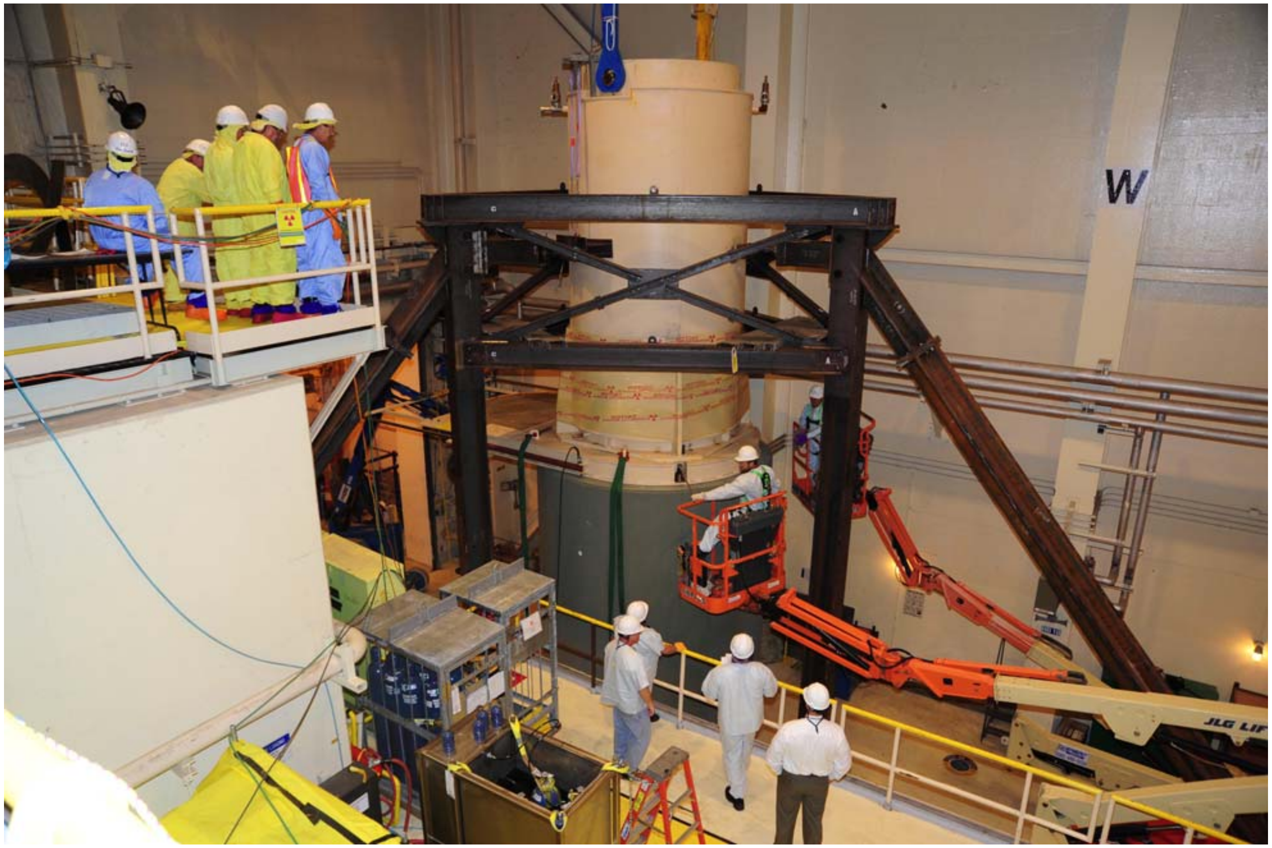
NRC Presentation

January 10, 2012

Exelon Goals for Meeting

- ✓ Describe in-progress seismic analysis of unrestrained stack-up at Byron, relative to information presented by NRC at November 1, 2011 Technical Exchange
- ✓ Present preliminary analytical results
- ✓ Communicate intended implementation at Byron
- ✓ Seek input from NRC regarding analysis, **understand** any NRC concerns, and respond to NRC questions

Operation with Restraints



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Expected Benefits of Restraint Removal

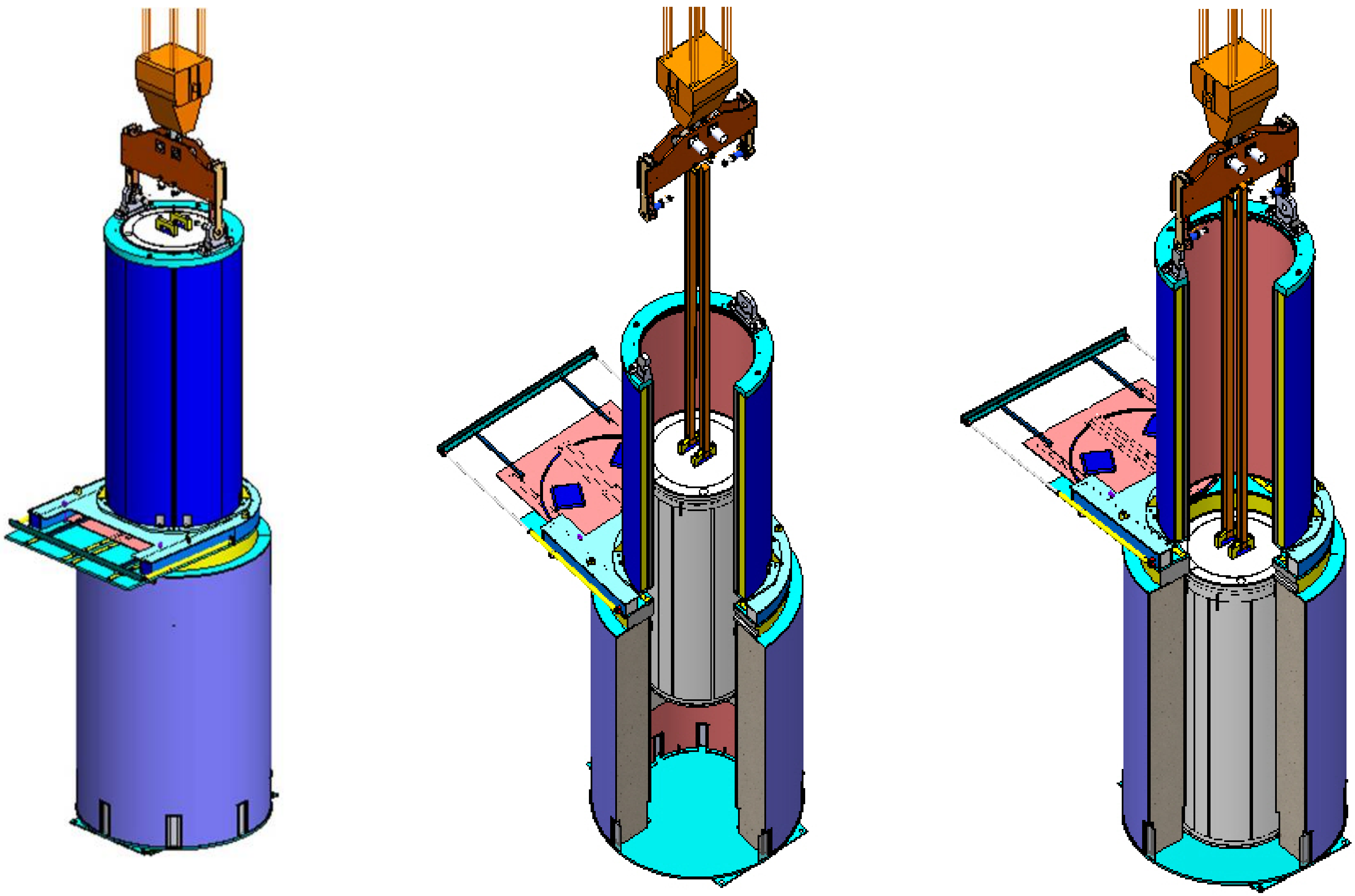
- ✓ **ALARA – will reduce dose per cask due to impact of restraints on processing activities**
- ✓ **Industrial Safety – will minimize potentially significant challenges leading to personnel injury during seismic restraint construction, operation, and removal**
- ✓ **Cost of Campaign – will reduce overall cost of campaign by approximately $600k for parts and labor for seismic restraint**
- ✓ **Efficient Use of Fuel Handling Building – seismic restraint significantly impacts accessibility of FHB, which can impact refueling outage preparations and parts support for other plants in refueling outages**
- ✓ **Radwaste Processing – seismic restraint equipment is contaminated, thereby requiring additional processing for storage and transport; fastener disposal an additional cost**

Byron Stack-Up Components

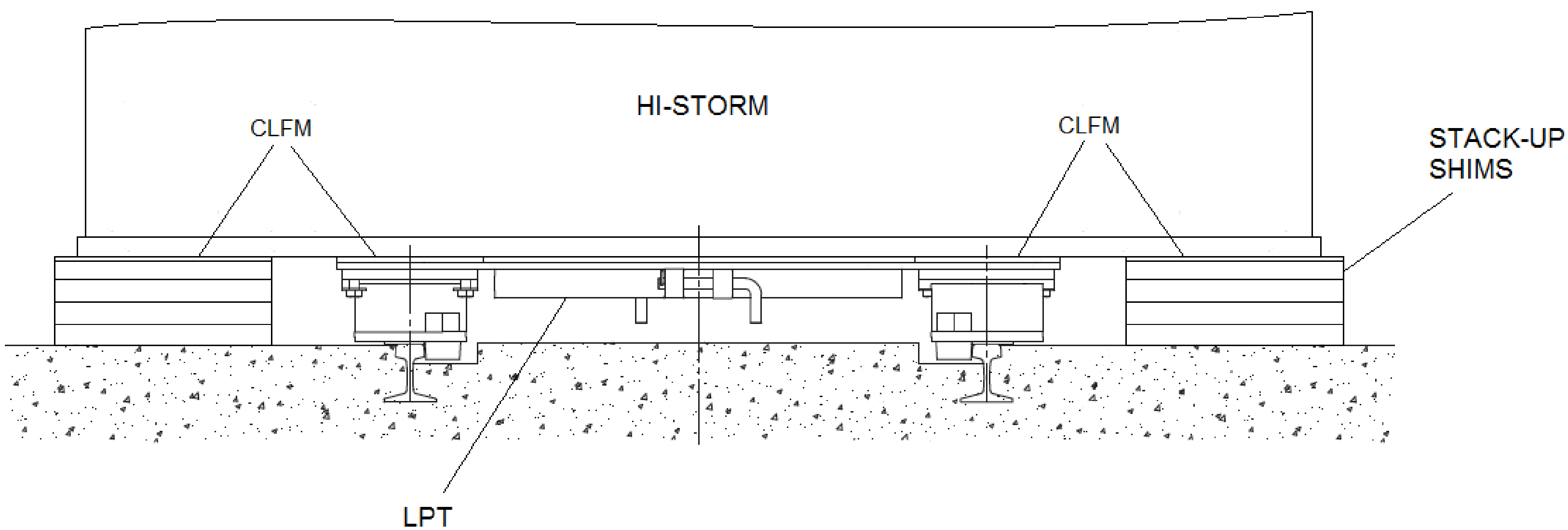
- ✓ "Stack-up" refers to the evolution during a dry storage loading campaign when a HI-TRAC transfer cask is vertically mounted on top of a HI-STORM storage cask for MPC transfer operations.

- ✓ Stack-up configuration consist of the following components:
  - – Low Profile Transporter (LPT) with HERMIT
  - – HI-STORM storage cask (no lid)
  - – Mating Device
  - – HI-TRAC transfer cask
  - – MPC
  - – Stack-up Shims

Byron Stack-Up Components (Cont.)



Dynamic Analysis Model for Byron (cont.)



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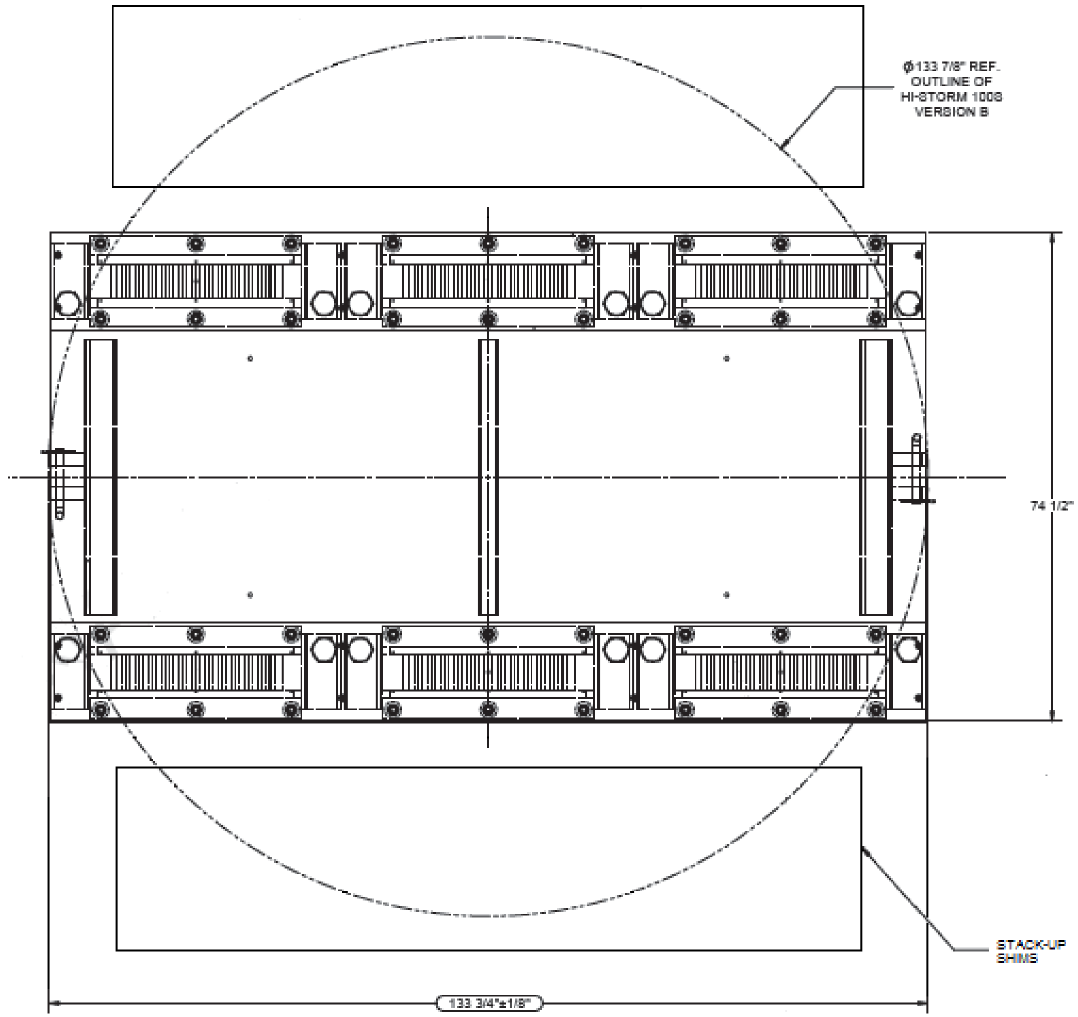
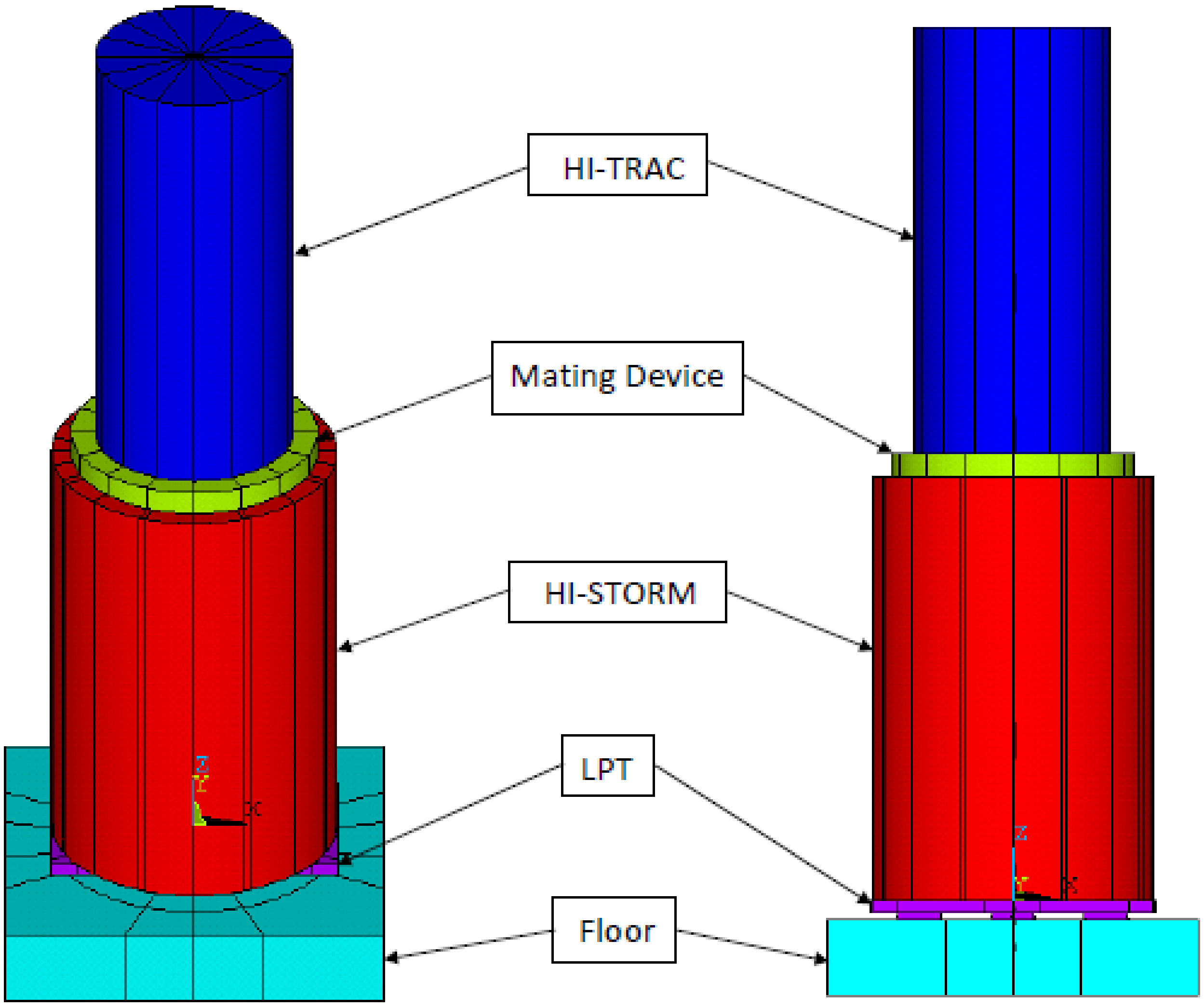
Dynamic Analysis Model for Byron (cont.)



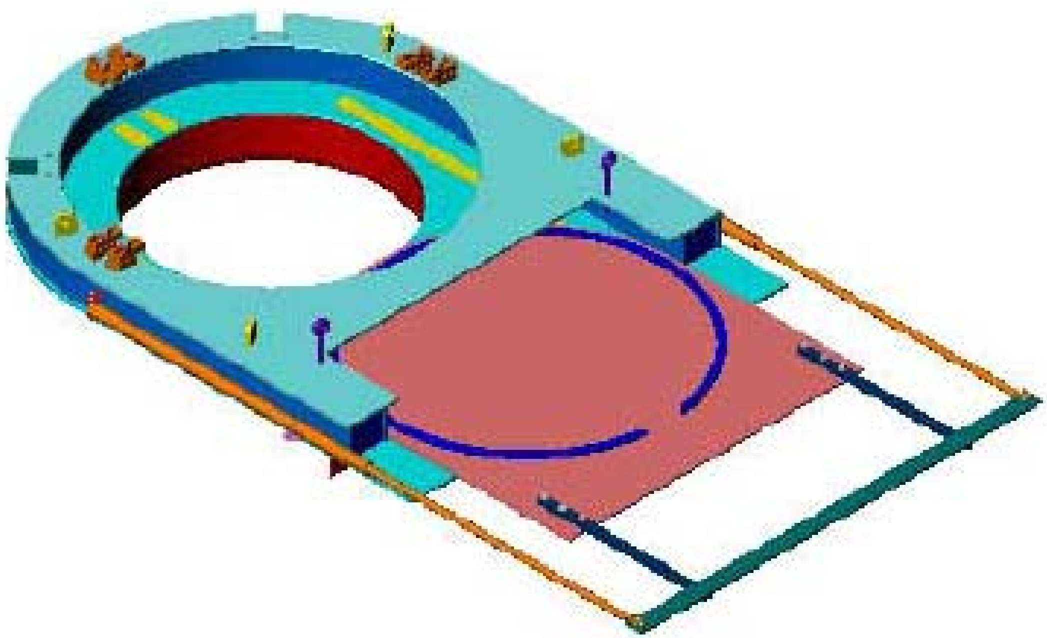
Byron Free-standing Stack-up Analytical Configuration

- ✓ HI-TRAC, Mating Device, and HI-STORM are modeled as solid cylinders.
- ✓ Nodes on the HI-TRAC cylinder and the Mating Device cylinder are merged at the HI-TRAC/Mating Device interface; nodes are also merged at Mating Device/HI-STORM interface.
  - ✓ Bolted joints are assumed to be inflexible in the dynamic analysis.
  - ✓ Analysis will determine the extent of pre-stress in the bolts required to validate the inflexible joint assumption.
- ✓ Low Profile Transporter (LPT) is modeled as rectangular solid fixed to floor; HI-STORM-to-LPT interface is simulated in ANSYS using discrete point-to-point contact elements with frictional capabilities.
- ✓ Additional point-to-point contact elements (i.e., shims) are inserted between the HI-STORM base and the floor (outboard of the LPT)
- ✓ Top surface of LPT and stack-up shims are equipped with Calibrated Low Friction Material (CLFM)

Dynamic Analysis Model for Byron (cont.)



Dynamic Analysis Model for Byron (cont.)



Computer Codes Used for Byron Stack-up Analysis

- ✓ Dynamic analysis model of freestanding stack-up is developed using the finite element code ANSYS Version 13
- ✓ Damping at HI-STORM/LPT and HI-STORM/stack-up shim interfaces are based on a LS-DYNA analysis.
- ✓ Seismic loads are input to ANSYS in the form of velocity time histories simultaneously applied to the floor section in three orthogonal directions
- ✓ ANSYS and LS-DYNA have been independently validated by Holtec under the company's QA program

November 2011 Technical Exchange

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 26:** Nonlinear time history analysis methods shall be used if incipient tipping is expected.
  - ✓ **Incipient tipping is expected. Therefore, nonlinear time history analysis is being performed using ANSYS**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 27:** "The transfer cask shall be attached to the mating device and the mating device shall be attached to the storage overpack by positive mechanical connections. The connections and mating device shall be designed to resist DL, LL and SSE without exceeding the Level D Stress Limits of the ASME B&PV Code Section III, Division 1, Subsection NF."
  - ✓ **Mating Device is bolted to the top of the HI-STORM cylinder; HI-TRAC is bolted to top of Mating Device cylinder**
  - ✓ **Bolted joints are assumed to be inflexible in the dynamic analysis**
  - ✓ **Analysis will determine the extent of pre-stress in the bolts required to validate the inflexible joint assumption without exceeding ASME Subsection NF stress limits**
  - ✓ **Mating Device structure will also be evaluated based on demand loads from dynamic analysis to ensure compliance with Code allowables**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 28:** "To determine the rotational stiffness of the mating device a detailed finite element model incorporating the effects of prying action may be required." "….analyses shall be performed using both stiffnesses" (i.e., about a horizontal axis in both directions)."
  - ✓ **Mating Device body's lowest natural frequency is greater than the frequency corresponding to the ZPA of the floor spectra**
  - ✓ **Mating Device bolts will be pre-loaded such that the HI-TRAC/Mating Device and HI-STORM/Mating Device interfaces remain in compression during a seismic event (i.e., no separation of bolted joints)**
  - ✓ **As a result, detailed finite element analysis of Mating Device is not required to determine rotational stiffness**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 30:** "…multiple sets of floor motion time histories should be used to represent the floor motion. Each set of floor motion time histories shall be selected from real recorded ground motions. The staff suggests that the five ground motion time histories used to envelope the RG 1.60 ground spectrum in NUREG/CR-6865 be used."
  - ✓ **Dynamic analysis will be performed using five sets of floor motion time histories**
  - ✓ **Real recorded ground motions from PEER database and are modified to match the applicable Byron floor spectra**
    - ✓ **Ground motions are selected based on their spectral shape and total time duration (> 20 sec)**
    - ✓ **Preliminary analysis results are based on the following real recorded event:**
      - ✓ **Point Mugu, PTMUGU 02/21/73 1445, PORT HUENEME**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 30 (cont.):** "…multiple sets of floor motion time histories should be used to represent the floor motion. Each set of floor motion time histories shall be selected from real recorded ground motions. The staff suggests that the five ground motion time histories used to envelope the RG 1.60 ground spectrum in NUREG/CR-6865 be used."
  - ✓ **Ground motion amplitudes are scaled in the frequency domain to improve spectral match while preserving the phasing of the Fourier components**
  - ✓ **Average of the computed response spectra for each direction envelopes the corresponding target floor spectrum in accordance with SRP 3.7.1**
  - ✓ **Each set of three modified real recorded time histories is statistically independent (i.e., correlation coefficients are less than 0.16)**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 31:** "When the nominal radial gap between the canister and transfer cask is small (<1/2") the canister and transfer cask may be considered to respond together as a rigid body."
  - ✓ **The nominal radial gap between the MPC and the HI-TRAC is 3/16"**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 19:** "Distribution of the Coefficient of Friction (CoF) between Steel and Concrete"
  - ✓ **Top surface of LPT and stack-up shims are equipped with Calibrated Low Friction Material (CLFM) (also referred to as HERMIT) to attenuate rocking motion of stack-up**
    - ✓ **HERMIT technology has been used successfully to carry out dry storage loading campaigns at several nuclear plants**
  - ✓ **Modeled CoF values for CLFM were based upon real QA-validated test results. Actual values will be confirmed by QA-validated test upon receipt of material by Holtec**
  - ✓ **Lower and upper bound CoF values of 0.08 and 0.25 were used in dynamic analysis**

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November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 33:** "The supporting structure shall be designed to support the concentrated load of the stack-up configuration in a slightly tipped condition. The flexibility of the supporting structure shall be modeled in the dynamic analysis."
  - ✓ **Dynamic analysis model considers the supporting structure to be rigid since the truck bay floor at Byron is 6-foot thick reinforced concrete founded on bedrock**
  - ✓ **Floor loading from ANSYS output will be evaluated, and verified to comply with Code allowables**

November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

- ✓ **Technical Exchange - Slide 30:** "The mean plus one standard deviation of calculated responses shall be an estimate of the maximum rocking angle. The estimate multiplied by a safety factor of 2.0 shall not exceed the critical angle for tip-over.
  - ✓ **A minimum safety factor of 2.0, based on the mean plus one standard deviation of the peak displacements from all simulations, is being used as the acceptance criterion for stability**

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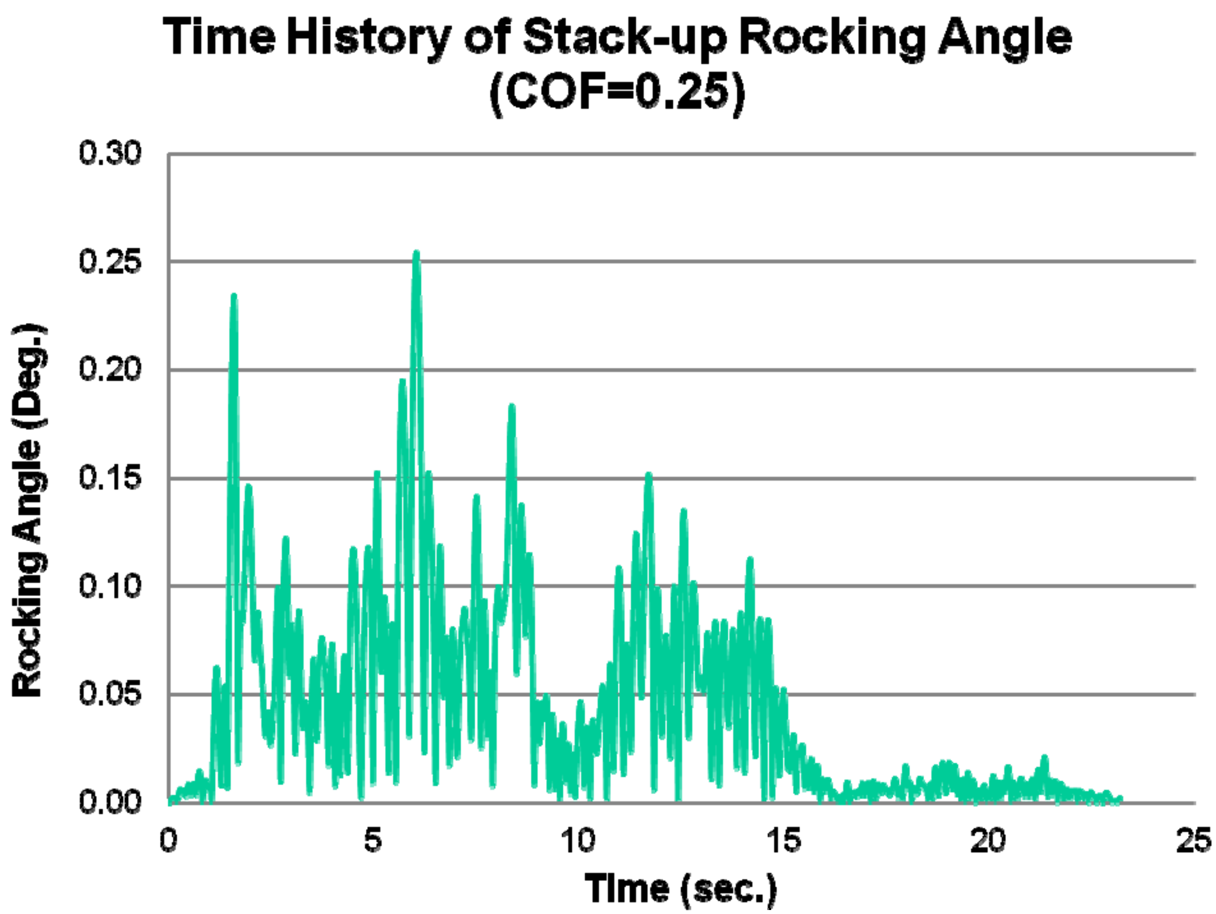
November 2011 Technical Exchange (cont.)

Methodologies Acceptable to the Staff for Performing Seismic Stability Analyses of a Stack-up Configuration within a 10 CFR Part 50 Facility

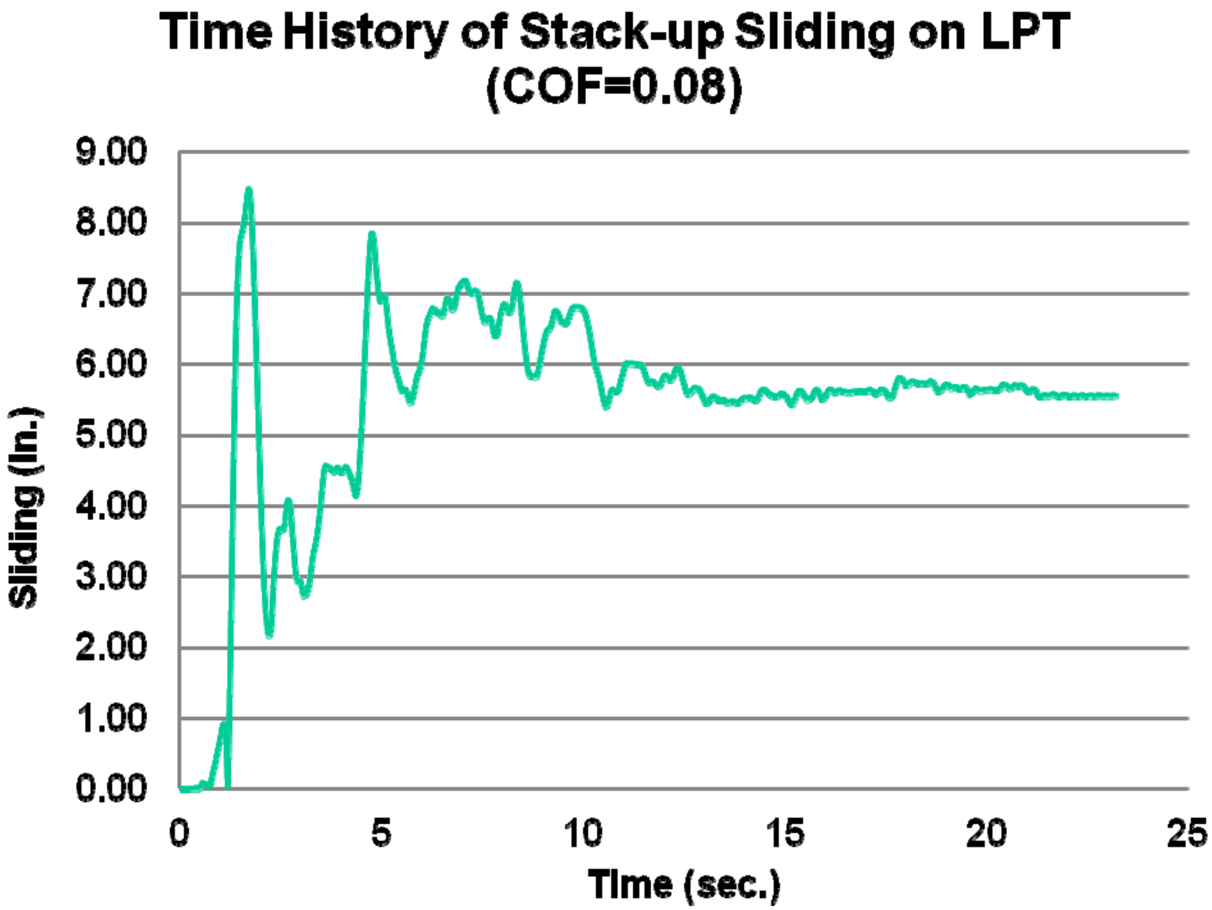
- ✓ **Technical Exchange - Slide 32:** "Only material damping shall be used in the time history rocking analysis, since impact damping is already accounted for in the rocking of a rigid body."
  - ✓ **Revised letter from Holtec to NRC-SFST dated November 21, 2011 summarizes Holtec's position relative to the use of impact damping**
  - ✓ **Impact damping at HI-STORM/LPT and HI-STORM/stack-up shim interfaces are established based on a LS-DYNA study of the rocking motion of the stack-up to determine the coefficient of restitution (COR); final COR value is converted to an equivalent viscous damping percentage and assigned to the point-to-point contact elements in ANSYS**
  - ✓ **Zero material (internal) damping is assigned to the ANSYS stack-up model**

Preliminary Results for Byron



Max. Rocking Angle = 0.254 deg.
Critical Rocking Angle = 14.865 deg.
SF Against Overturning = 14.865/0.254 = 58.5

Preliminary Results for Byron (cont.)



Max. Sliding Distance = 8.48”
Allowable Sliding Distance = 29.75” (50% of the centerline-to-centerline rail distance; no credit taken for stack-up shims)
SF Against Sliding Failure = 29.75/8.48 = 3.51

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Implementation of Analysis

- ✓ Upon completion of analysis (i.e., subsequent to owner acceptance review and assuming acceptable safety factor):
  - ✓ **Develop and complete 10 CFR 50.59 and 10 CFR 72.48 screenings/evaluations that justify use of unrestrained stack-up during 2012 Byron campaign (i.e., currently scheduled to start 20-Feb-2012)**
  - ✓ **Provide completed analysis, 50.59 and 72.48 screenings/evaluations to Region III prior to start of campaign**