NRC & NAC 10 CFR Part 72 Inspection

Pre-Decisional Enforcement Conference

October 20, 2020

Kent Cole
President & CEO, NAC International

George Carver
Vice-President Engineering & Support Services

Wren Fowler
Director of Licensing

Marc Griswold
Senior Project Engineer

Ryan Bailey
Senior Project Manager

NAC INTERNATIONAL

The Skills and Experience to Deliver Nuclear Excellence

PURPOSE

- Demonstrate NAC used the existing FSAR design control measures for incorporating CC5 into the MAGNASTOR FSAR, relative to the tip-over evaluation.
- Demonstrate that the method of evaluation (MOE) used by NAC to incorporate CC5 into the FSAR was not a "departure" per the regulations, relative to the tip-over evaluation.

OUTLINE – PART 1

- Part 1 of the presentation will be conducted as follows:
  - Apparent Violations (AVs)
  - Non-Mechanistic Tip-Over Event
  - FSAR Non-Mechanistic Tip-Over Licensing Basis
  - FSAR Design Control Measures
  - 10 CFR 72.48 Design Control Process
  - 10 CFR 72.48 Determination for CC5
  - Summary

OUTLINE – PART 2

- Part 2 of the presentation will be conducted as follows:
  - MAGNASTOR Amendment 9
  - NAC Comments on the NRC Inspection Report
  - Palo Verde NRC Inspection vs. NAC NRC Inspection
  - NAC Corrective Actions Following the Palo Verde Inspection
  - NAC Actions Following AVs
  - Presentation Conclusion

Apparent Violations

- 10 CFR 72.146(c) – “Design control”
  - NRC’s Position (Reference: AV “A”, Enclosure 1, NRC Choice Letter)
    - “…NAC implemented a design change for the MAGNASTOR spent fuel cask without ensuring that design control measures were commensurate with those applied to the original design.”
    - “Specifically, NAC failed to use the nonlinear LS-DYNA computer model (identified in the MAGNASTOR FSAR Sections 3.7.3.7 and 3.10.4.4 as the method of evaluation for concrete cask tip-over analysis applied to the original design) for the assessment of acceleration values for a design basis tip-over accident of the MAGNASTOR CC5 spent fuel cask.”

APPARENT VIOLATIONS (CONT'D)

- 10 CFR 72.48(c)(2)(viii) – "Changes, tests, and experiments… departure from a method of evaluation…"
  - NRC's Position (Reference: AV "B", Enclosure 1, NRC Choice Letter)
    - "…NAC failed to obtain a CoC amendment from the NRC pursuant to 10 CFR 72.244 prior to implementing a design change for the MAGNASTOR CC5 spent fuel cask that resulted in a departure from a method of evaluation described in the MAGNASTOR FSAR."
    - "Specifically, NAC failed to utilize LS-DYNA, a non-linear analysis methodology that was described in the MAGASTOR FSAR Section 3.7.3.7, when implementing a design change for the MAGNASTOR CC5 spent fuel storage cask."

Non-Mechanistic Tip-Over Event

- The following is a detailed discussion about the non-mechanistic tip-over event and subsequent evaluations:
  - The tip-over event is a hypothetical accident condition in which the concrete cask tips-over onto an ISFSI pad.
  - In the absence of a credible hazard that induces tip-over, it is evaluated as a non-mechanistic event (i.e., an event with no identifiable cause).
  - During a non-mechanistic tip-over, the cask is postulated to rotate from a position with its center of gravity (CG) over its lowest corner to a horizontal orientation, which results in an impact with the ISFSI pad.
  - When the cask impacts the pad, kinetic energy is transferred to the pad and the cask experiences a rapid deceleration (measured in g-loads).
  - The cask's confinement boundary (canister) and internal basket structure are evaluated for the inertial loads experienced during this deceleration to confirm stress levels are below limits.

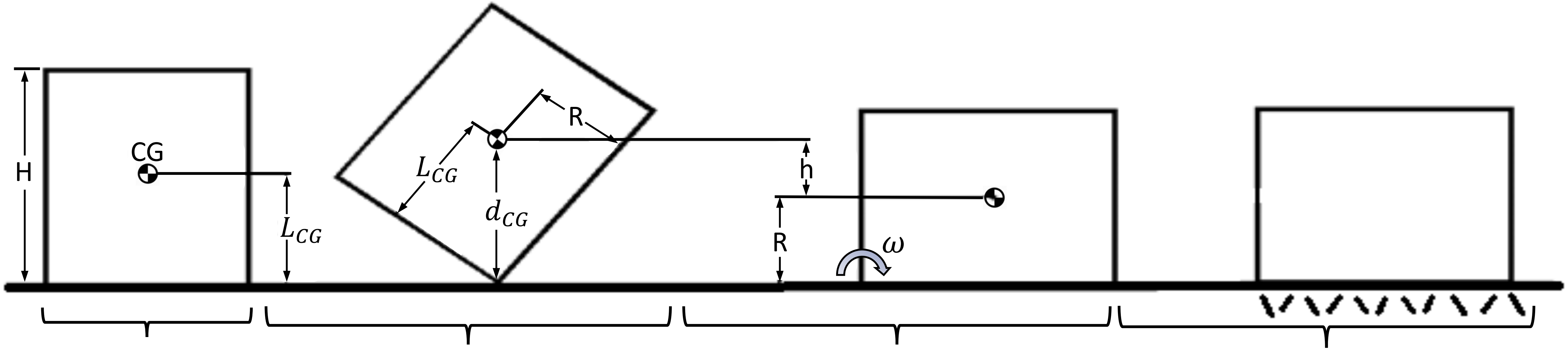
Non-Mechanistic Tip-Over Event (Cont'd)

Position A
Vertical Orientation
Normal Storage Condition

Position B
CG Over Corner
Zero Velocity

Position C
Horizontal Orientation
Prior to Impact

Position D
Horizontal Orientation
Impact/Deceleration



Cask at rest

Cask CG at its highest point (maximum potential energy)

Cask is completely tipped over, just prior to contact with the pad. The value "h" corresponds to a change in potential energy (PE) which is assumed to be completely transformed into rotational kinetic energy (KE). Using the law of conservation of energy, this relationship is expressed as:

$$mgh = \frac{I\omega^2}{2} \quad (EQ\ 1)$$

Cask has impacted the ISFSI Pad and is decelerating. Cask decelerations are governed by the structural characteristics of the cask, ISFSI pad, and underlying soil.

CG – center of gravity
L_{CG} – CG height from cask bottom
d_{CG} – CG height at Position B
h – change in CG height $\left(\sqrt{R^2 + L_{CG}{}^2} - R\right)$
m – cask mass
I – mass moment of inertia
R – cask radius
H – cask height
g – acceleration of gravity
ω – angular velocity

FSAR Non-Mechanistic Tip-Over Licensing Basis

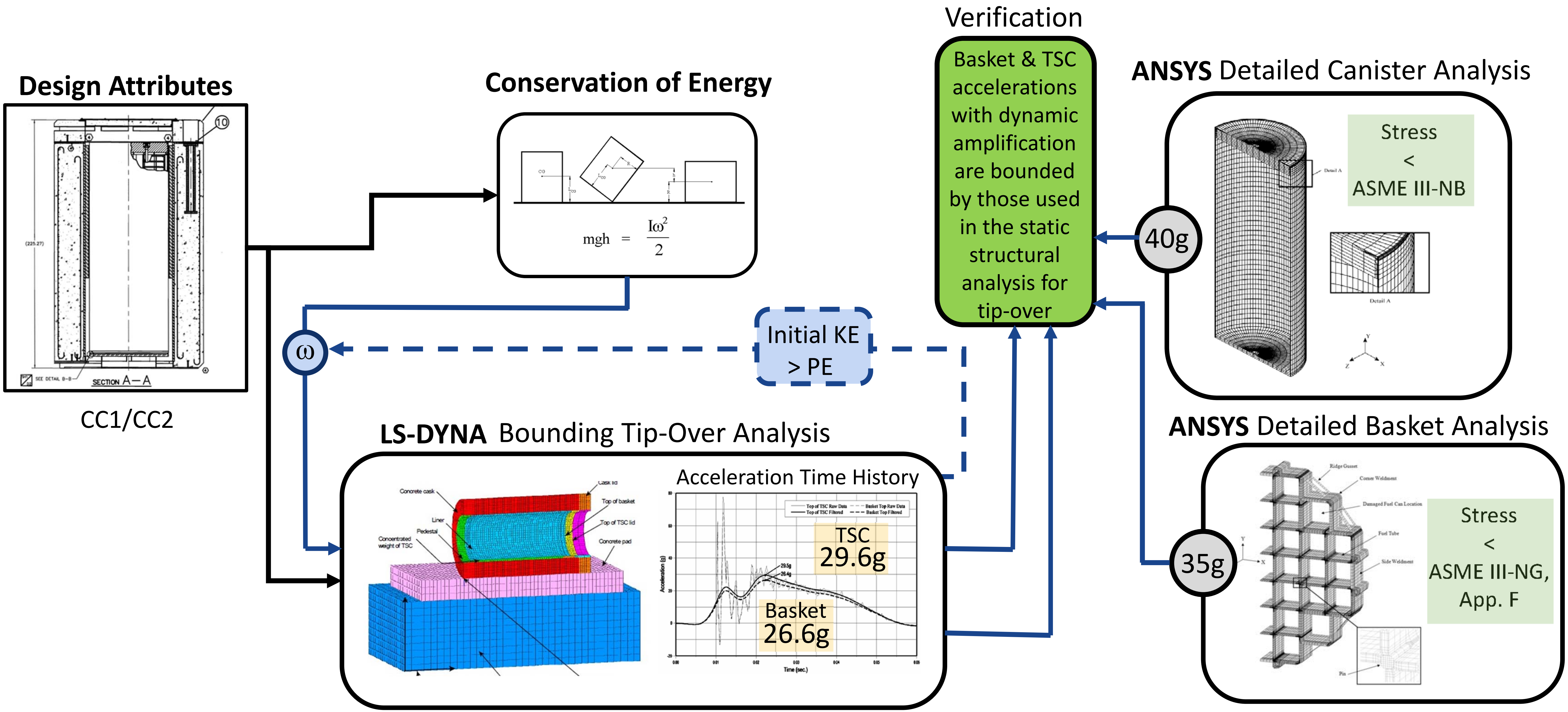
- The FSAR (Section 3.7.3.7) uses a computer code known as LS-DYNA in the original licensing of MAGNASTOR to calculate the cask content g-loads (i.e., decelerations at the top of the canister lid and top of the fuel basket).
- The tip-over is simulated in LS-DYNA by applying an initial angular velocity "ω" to the entire cask as described in the FSAR (Section 3.10.4.4).
  - Note that the simulation starts with the cask on its side on the generic ISFSI pad.
- The method of evaluation (MOE) used in the FSAR (Section 3.10.4.4) for determining the angular velocity input for LS-DYNA (and checking the LS-DYNA output kinetic energy) is the following classical mechanics equation which relates the cask's potential energy at CG over corner to the kinetic energy (angular velocity) at impact on the storage pad.
  - Where "m" is the mass of the system; "g" is the acceleration due to gravity; "h" is the CG height change; "I" is the cask's moment of inertia; and "ω" is the resulting angular velocity at impact.
  - The potential energy needs to match the kinetic energy and vice versa to ensure the LS-DYNA results for g-load accelerations are accurate.
  - The key variable is the angular velocity, which is the energy being imparted to the cask during impact.

$$mgh = \frac{I\omega^2}{2}$$

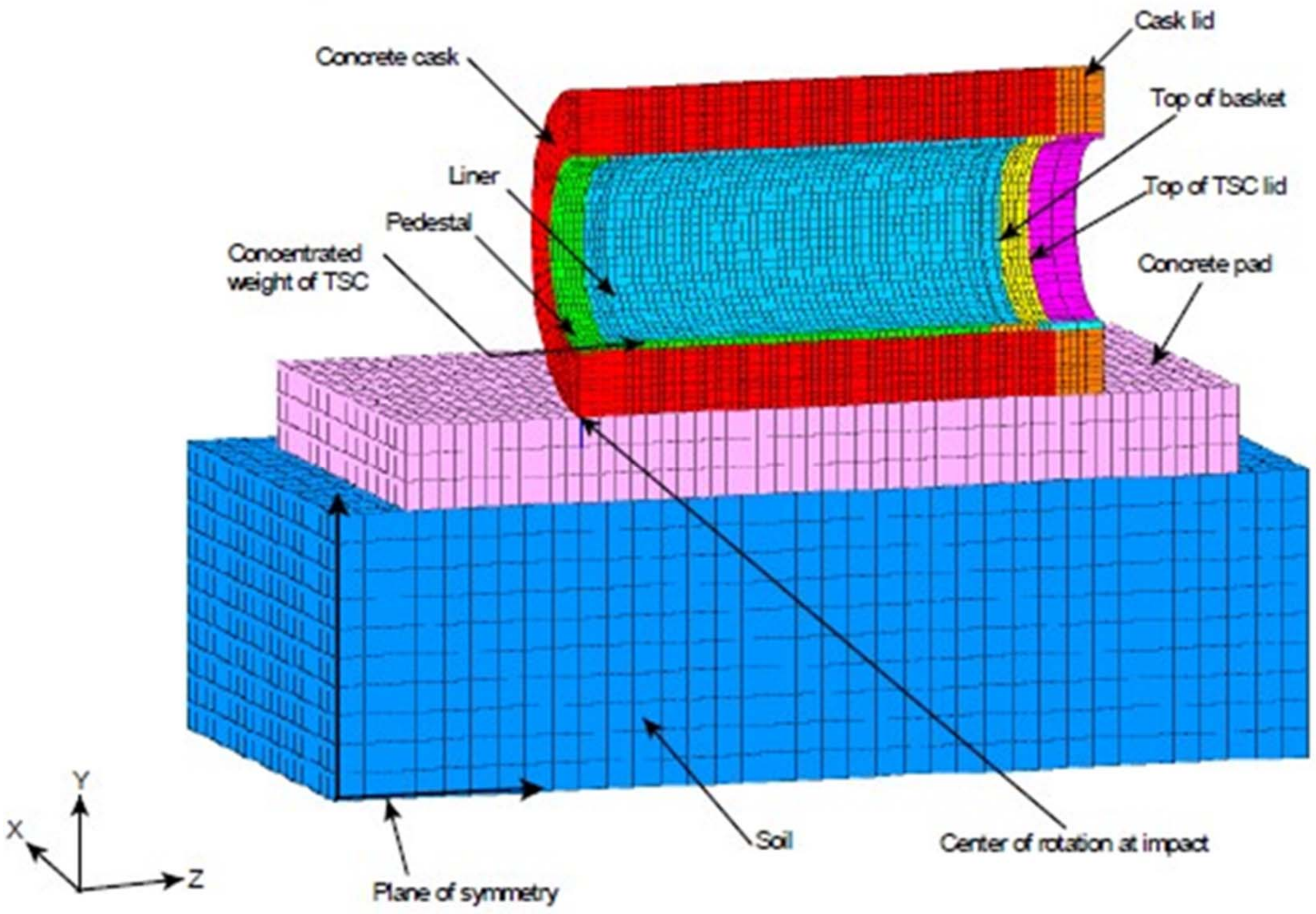
FSAR Non-Mechanistic Tip-Over Licensing Basis (Cont'd)

- The g-loads from LS-DYNA are used to justify the acceptance of the values used in the subsequent structural evaluations in the FSAR, which are performed using ANSYS.
  - LS-DYNA is not the licensing basis program used to structurally evaluate the cask system. It is a simplistic model used to validate that the g-loads (used in ANSYS) bound the loads seen during the event.
  - The ANSYS evaluations can be found in FSAR Sections 3.7.1, 3.7.2, and 12.2.12.4.

FSAR Non-Mechanistic Tip-Over Licensing Basis (Cont'd)



FSAR Non-Mechanistic Tip-Over Licensing Basis (Cont'd)



CC1/CC2 LS-DYNA Cask & Pad Model

- The cask is simplistically modeled as two concentric right circular cylinders - An inner steel liner surrounded by concrete.
- Discrete volumes of the cask model are assigned appropriate densities to represent the mass and relative distribution (i.e., CG) of all cask components.
- Fine design details such as the rebar, vents, pedestal, lid, canister, etc. are not explicitly modeled.
- The liner is modeled as a rigid body.
- The loaded canister is represented by including its mass in a strip of elements at the ID of the cask.
- Cask is in the horizontal orientation above the pad and soil.
- An initial angular velocity "ω" is applied to the entire cask about the point of rotation.

FSAR Design Control Measures

- For the tip-over evaluation, the following are the design control measures:
  - Simplistic LS-DYNA model of a cask and a generic pad & soil.
  - Application of an initial angular velocity on the cask.
  - An evaluation that ensures the conservation of energy is preserved in LS-DYNA.
  - Verification that the resulting LS-DYNA g-loads are bounded by the g-loads used in the subsequent ANSYS structural evaluations.

10 CFR 72.48 Change Control Process

- 10 CFR 72.48 allows the cask designer to make changes to their licensing basis design, provided certain conditions are met.
  - Per the regulation (72.48(c)(2)(viii)) a certificate holder shall obtain a CoC amendment for a proposed change that would "(viii) Result in a departure from a method of evaluation described in the FSAR (as updated) used in establishing the design bases or in the safety analyses."
  - A "departure" from an MOE is defined in 72.48(a)(2), and a cask designer can change any of the elements of an MOE (72.48 (a)(2)(i)) or change to another MOE (72.48(a)(2)(ii)) - provided certain conditions are met.

10 CFR 72.48 Change Control Process (Cont'd)

- The most recently published (September 22, 2020) NRC guidance is Regulatory Guide 3.72, Revision 1, "Guidance for Implementation of 10 CFR 72.48,"Changes, Tests, And Experiments." Page 3 of RG 3.72 Rev. 1 states that:
  - "The statement of considerations (SOC) for the final rule states that a departure from an MOE as described in the FSAR (as updated) used in establishing the design bases or in the safety analyses means (1) changing any of the elements of the method described in the FSAR (as updated) unless the results of the analysis are conservative or essentially the same or (2) changing from a method described in the FSAR to another method unless that method has been approved by the NRC for the intended application."
- Regulatory Guide 3.72, Rev. 1 formally endorses NEI 12-04, Rev. 2.

10 CFR 72.48 Determination for CC5

- To incorporate CC5 into the FSAR, NAC evaluated the new cask via the 72.48 process to determine if prior NRC approval was needed.
- NAC confirmed that:
  - The FSAR contains a licensing basis MOE (a simplistic LS-DYNA cask model) used to justify ANSYS g-loads.
  - The FSAR also contains a licensing basis MOE for determining the angular velocity input for LS-DYNA (and checking the LS-DYNA output kinetic energy).

10 CFR 72.48 Determination for CC5 (Cont'd)

- NAC used the licensing basis MOE for determining the angular velocity input for LS-DYNA.
- As previously discussed, this can be found in the FSAR (Section 3.10.4.4) and is shown below:
  - Where "m" is the mass of the system; "g" is the acceleration due to gravity; "h" is the CG height change; "I" is the cask's moment of inertia; and "ω" is the resulting angular velocity at impact.

$$mgh = \frac{I\omega^2}{2}$$

10 CFR 72.48 Determination for CC5 (Cont'd)

- By taking the licensing basis MOE equation for determining the angular velocity input for LS-DYNA (and checking the LS-DYNA output kinetic energy), the terms can be rearranged to solve for the angular velocity.
- The angular velocity for CC5 can then be compared to CC1 by solving for their ratio to determine the extent that they are different.

$$\frac{\omega_2}{\omega_1} = \left[\frac{\left(d_{CG_2} - R\right)\left(\frac{1}{4}R^2 + \frac{1}{3}H_1^2 + d_{CG_1}^2\right)}{\left(d_{CG_1} - R\right)\left(\frac{1}{4}R^2 + \frac{1}{3}H_2^2 + d_{CG_2}^2\right)}\right]^{1/2}$$

10 CFR 72.48 Determination for CC5 (Cont'd)

- Thus, the relative difference in angular velocity between CC5 and CC1 was determined.
- The difference in angular velocity between CC5 and CC1 is less than 1%.
- In this case, the licensing basis LS-DYNA model angular velocity input was verified to be applicable to CC5.

10 CFR 72.48 Determination for CC5 (Cont'd)

- Before building any new LS-DYNA model, NAC determined whether the previous model was relevant to CC5.
- Since the generic FSAR pad and soil remained unchanged and the casks are similar in design and materials, the licensing basis LS-DYNA model for CC1 is applicable to CC5 after confirming that the angular velocities are essentially the same.
- A substantial difference in angular velocity would preclude the ability to use the previous LS-DYNA results for CC5. In that case, a CC5 specific LS-DYNA model would need to be built and run to ensure the subsequent ANSYS structural evaluations were bounding.
- This is the licensing basis design control process.

10 CFR 72.48 Determination for CC5 (Cont'd)

- The FSAR licensing basis MOE for determining the angular velocity input for LS-DYNA contains both "input parameters" and "elements".
- Industry guidance on these key terms is provided in NEI 12-04, which is endorsed by Reg. Guide 3.72, Rev. 1 as follows:
  - The "input parameters" are the physical dimensions of the system and constants of nature (i.e., the mass, gravity, and center of gravity for the system).
  - The "elements" are the moment of inertia and the angular velocity.
- In order to verify the licensing basis LS-DYNA model was applicable to CC5, NAC followed the licensing basis design control process and determined the relative difference in angular velocity between CC5 and CC1.
- For the moment of inertia, NAC elected to derive the moment of inertia via a hand calculation instead of using LS-DYNA, which is the method described in the FSAR.

10 CFR 72.48 Determination for CC5 (Cont'd)

- NAC recognizes that calculating the moment of inertia by hand rather than using LS-DYNA is a new method.
- However, NAC can do this provided it is not a "departure".
- The regulation allows NAC to change to another method provided the method has been previously approved by the NRC for the intended application.
- NAC previously received NRC acceptance to use hand calculations for deriving the moment of inertia for a cask in the tip-over evaluation.
  - The NAC-MPC (72-1025 - FSAR Section 11.2.12.2.1) and NAC-UMS (72-1015 – FSAR Section 11.2.12.3.1) systems are licensed by the NRC this way.
  - This is consistent with the regulation and the NRC's guidance (Reg. Guide 3.72, Rev. 1), which endorsed NEI 12-04, Rev. 2.
- Therefore, a "departure" has not occurred, and NAC is allowed to use hand calculations in lieu of LS-DYNA.

SUMMARY

- NAC used the licensing basis design control measures in the FSAR.
- NAC used the licensing basis methods of evaluation in the FSAR except for the moment of inertia for CC5.
  - NAC did change the way the moment of inertia was derived but it did not constitute a “departure” because the method had been previously approved by the NRC for the intended application.

Outline – Part 2

- Part 2 of the presentation will be conducted as follows:
  - MAGNASTOR Amendment 9
  - NAC Comments on the NRC Inspection Report
  - Palo Verde NRC Inspection vs. NAC NRC Inspection
  - NAC Corrective Actions Following the Palo Verde Inspection
  - NAC Actions Following AVs
  - Presentation Conclusion

MAGNASTOR AMENDMENT 9

- Contrary to the IR, the NRC staff has substantiated and approved the adequacy of the 72.48 tip-over approach taken.
- The NRC IR states that NAC's 72.48 approach "…would likely not be approved by the technical staff…" (see Choice Letter Enclosure 2 Page #15, 3rd paragraph). However, the NRC through the MAGNASTOR Amd. 9 Safety Evaluation Report (SER) concludes the approach is acceptable to the NRC (see SER Pages 7 and 8)
  - Amd. 9 included an alternative cask known as CC6.
  - NAC could have incorporated it via the 72.48 process, but elected to include all cask design changes in a comprehensive amendment for a specific project.
  - This cask was evaluated by NAC for tip-over in the same manner as CC5.
  - The Amd. 9 SER has already been approved by the NRC Staff.

- The following is from the SER (Page 8, last paragraph; emphasis added)
  - "However, despite having not performed a more in-depth tip-over analysis, the staff has concluded that no additional non-mechanistic tip-over analysis of the CC6 is needed, in this instance, because there is reasonable assurance that the CC6 will perform its intended safety functions under a non-mechanistic tip-over event. This is due to conservatism and similarity of the CC6 to other applicant's concrete casks as shown in Table 3.3 of this SER below. Specifically: (i) CC1 was designed with an additional 50% margin with the g-loads calculated by LS-DYNA tip-over analysis (i.e., design-basis of 35.0g and 40.0g at the top of the fuel basket and cask, respectively, compared to calculated g-loads); (ii) both the CC1 and CC6 are evaluated on the same pad; (iii) the CC1 and CC6 are of similar construction; (iv) the CC6 is shorter and has a slightly shorter center of gravity as compared to the CC1, therefore it is more stable; and (v) the initial angular velocity of CC6 is within 2% of the CC1."

Table 3.3 – g-load at Top of the Fuel Basket and Cask

Cask Type	Method	Fuel Basket (Design Basis = 35g)	Cask Design Basis = 40g
CC1	LS-DYNA	26.4g	29.5g

MAGNASTOR AMENDMENT 9 (CONT'D)

- There are several important takeaways from this SER:
  - A LS-DYNA model for CC6 was not built and run.
  - The NAC cask tip-over approach for CC3, CC4, CC5 and CC6 are the same.
  - The NRC SER concludes CC6 is similar to the applicant's other concrete cask, CC1.
  - The NRC SER paragraph on the previous slide presents the basis of the NRC's acceptance of CC6; the following presents how CC5 compares to the same NRC's criteria:
    i. *Significant design margin exists in the licensing basis (CC1).*
    ii. *Same ISFSI pad and soil.*
    iii. *Similar construction and materials.*
    iv. *CC5 is not shorter than CC1 (like CC6) but is essentially the same (<0.3%)*
    v. *The angular velocity relative to CC1 is acceptable (<2% difference)*
        - *Note, CC5 is <1% different than CC1*

NRC staff approved the approach NAC used for CC5 when it approved Amendment 9 demonstrating it as an acceptable technical basis without the need to reperform LS-DYNA

NAC Comments on the NRC Inspection Report

- The NRC staff represents in the IR that LS-DYNA is the MOE for tip-over evaluation.
- However, the MOE for tip-over also includes:
  - The predecessor calculation of potential energy and angular velocity prior to impact. These are inputs to the LS-DYNA model that can be developed from classical formulas through application of the conservation of energy equation and basic cask physical parameters and are “elements” of the MOE in NAC’s licensing basis.
  - LS-DYNA is used to perform dynamic analysis of structures, but it does not calculate initial potential energy, or angular velocities resulting from a tip-over.
- The NRC IR did not acknowledge significant conservatism in g-load inputs into the subsequent ANSYS stress evaluations for determining whether the canister and basket stresses resulting from the tip-over g-loads are within applicable stress limits.
  - G-Loads resulting from a tip-over calculated by LS-DYNA are NOT subject to specified regulatory limits or criteria.
  - NAC utilized bounding acceleration values of 35g (basket) and 40g (canister) in its downstream ANSYS structural evaluations.
- NRC staff asserts that NAC changed its MOE for tip-over from LS-DYNA to “linear scaling”, but it is clear from NAC’s 72.48 evaluation and supporting calculations that NAC did not estimate any g-loads for CC5.
  - Any MOE that replaces LS-DYNA for dynamic analysis of tip-over events would, like LS-DYNA, need to produce g-load outputs.

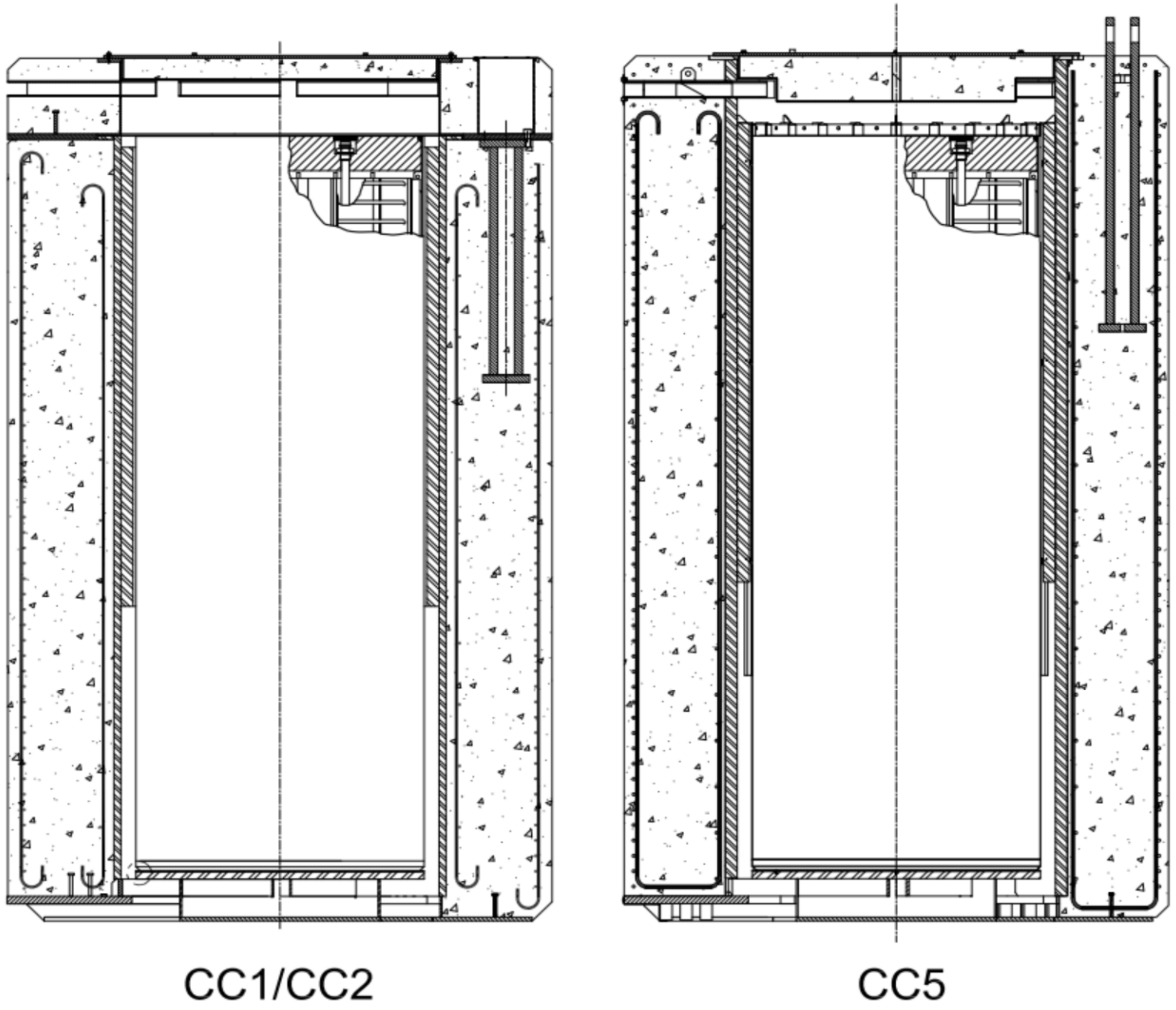
NAC Comments on the NRC Inspection Report (Cont'd)

- The NRC IR[i] has presented concerns over the non-linear behavior of the tip-over model parameters and inputs, specifically with respect to the storage pad and underlying soil.
  - NAC used identical pad & soil (these have not changed in the FSAR since CC1/CC2) properties in the 72.48 evaluation.
- The NRC IR indicated a scaling method resulted in "errant determination that each cask had a uniform density cylinder".
  - The use of an approximation of the casks moment of inertia using a hand calculation for a uniform density cylinder is appropriate for the evaluation of the cask's relative angular velocity.
- The NRC IR indicated many differences in cask designs.
  - There are no significant differences in CC1/CC2 and CC5 cask designs.
    - *General geometry, materials and design of both casks are very similar. Weight is slightly higher, but the general effect on the tip-over is a reduction of decelerations with a similar angular velocity.*

i. The NRC's Choice Letter considers the pad and soil properties have changed with the incorporation of CC5 (see Choice Letter Enclosure 2 Page #15)

Similarities of CC5 to CC1/2

- There are substantial similarities that will control the casks behavior in a tip-over event.*
- All Materials of cask construction are the same.
- Concrete Cask outside and inside diameter are the same.
- Cask height is essentially the same – 0.6" - 0.3%.
- Cask center of gravity is essentially the same – 2.1" - <2%.
- Shielding enhancements - Loaded cask weight increased by ~17,500 lbs., this is less than 6% and is largely comprised of distributed masses with little impact on the CG of the system including:
  - Rebar spacing of the outer cage is slightly denser but distributed (~900 lbs. – 0.3%).
  - Cask liner is 1.25" thicker and, although a more significant contributor to the system weight increase (14,900lbs - ~4%), is distributed.
  - Cask lid thickness (1,630lbs) and inlet vent steel bars (580 lbs.), are more local masses but contribute a very small percentage (0.7%) to the system weight.

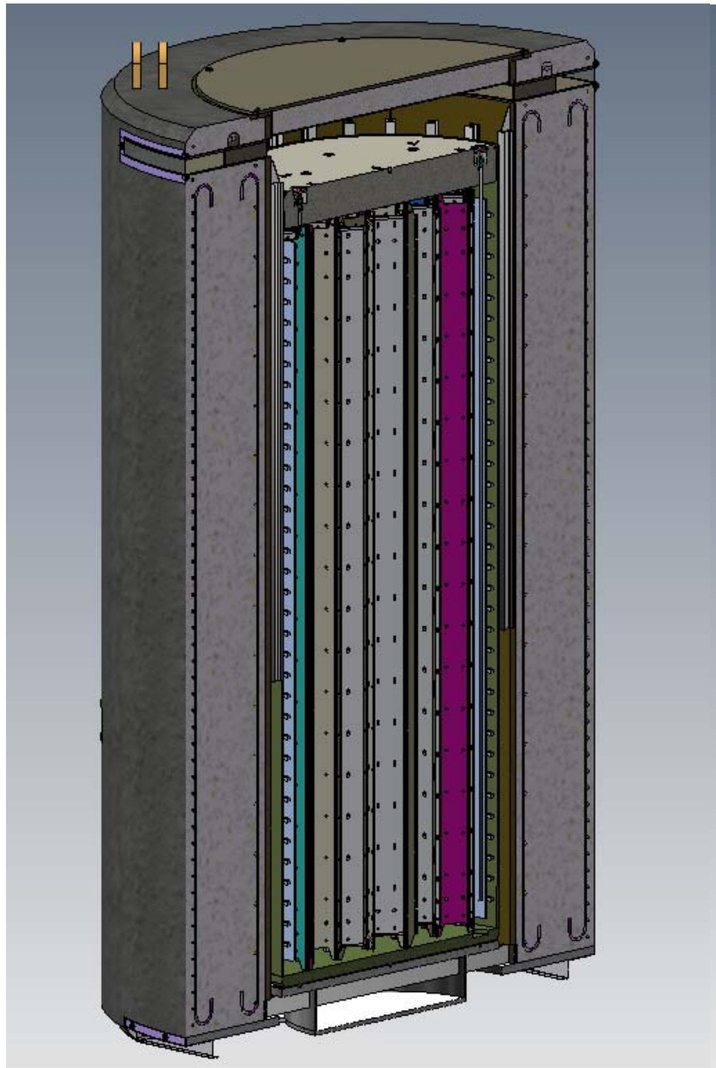


CC1/CC2	CC5	Characteristic
225.27	225.90	Concrete Cask Height H (in)
1.75	3.00	Concrete Cask Liner Thickness (in)
26.50	25.25	Concrete Thickness (in)
136.00	136.00	Concrete Cask Outside Diameter (in)
130.079	132.14	Concrete Cask CG to Rotation Point d_{cg}

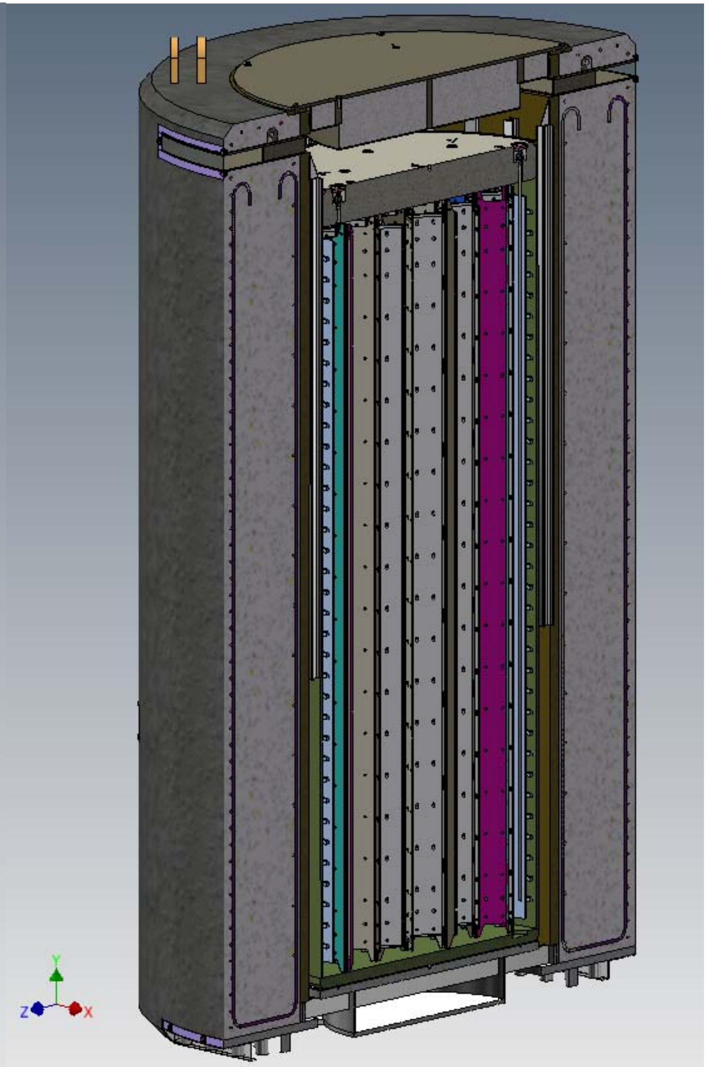
*The NRC Choice Letter states many characteristics are different (see Choice Letter Enclosure 2 Page #12, 2nd Paragraph)

Uniform Density Cylinder Approximation

- The mass moment of inertia calculation is only used in calculating the relative difference of the cask system's response to motion in the determination of relative angular velocities.
- The approximation for mass moment of inertia for the uniform density representation results in a CC5 to CC1 ratio of 1.073.
- To demonstrate the suitability of simplified uniform density representation, which the IR described as "errant", NAC subsequently developed highly detailed 3D design models of the CC5 and CC1 casks to obtain inertial properties to a high level of accuracy. The 3D models result in a CC5 to CC1 ratio of 1.062.
- The small difference in these two ratios demonstrates the suitability of the uniform density cylinder representation of a moment of inertia.



Detailed 3D Model of CC1



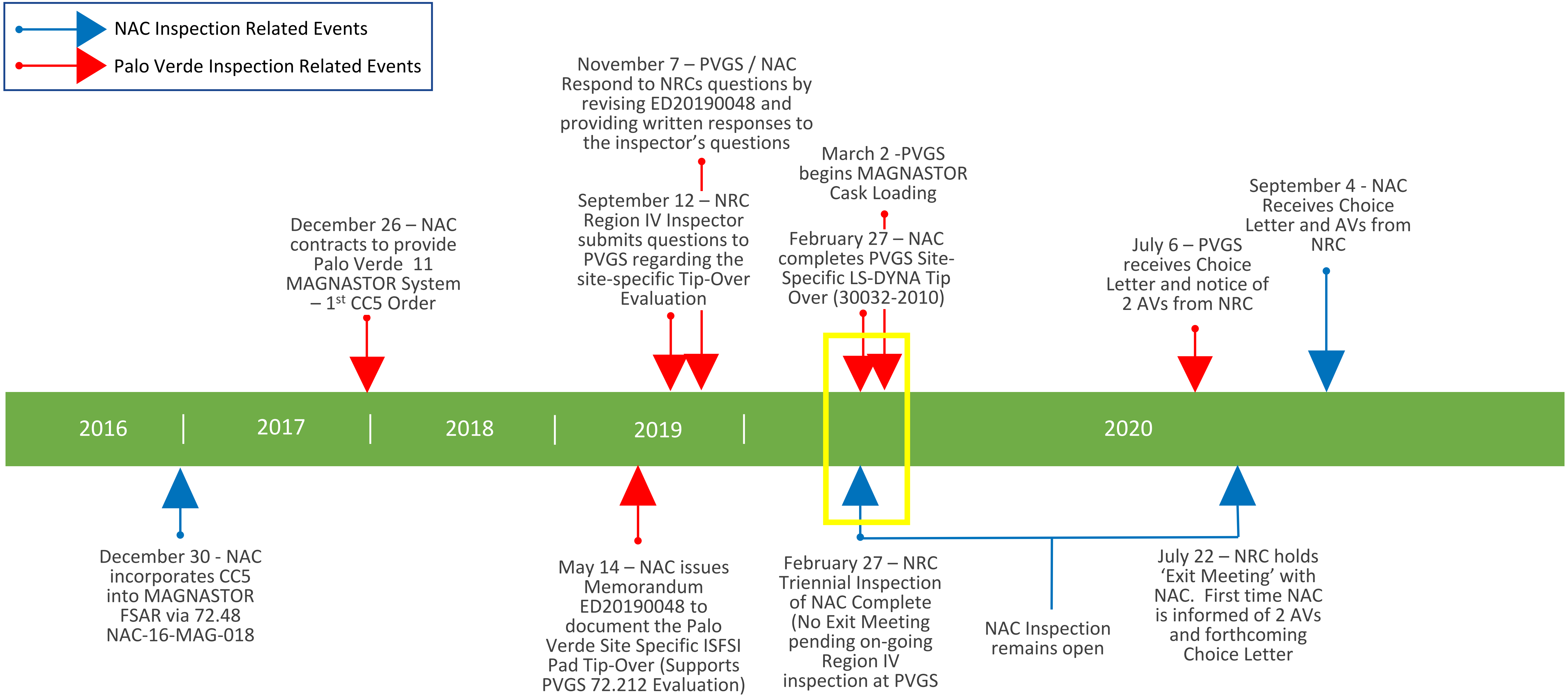
Detailed 3D Model of CC5

Palo Verde NRC Inspection vs. NAC NRC Inspection

- Palo Verde (PVGS) Transition from NAC UMS to MAGNASTOR
  - First customer to utilize the CC5 Concrete Cask Design
- The NRC Inspection at Palo Verde was on-going during the scheduled triennial NAC February 2020 inspection.
- In September 2019, Region IV Inspectors had concerns related to the "linear scaling" of g-loads for the site-specific condition.
- Prior to the loading of the first MAGNASTOR system at Palo Verde, NAC performed a site-specific LS-DYNA evaluation (30032-2010) which resolved the Inspection Team's questions .
  - Results were in-line with our previous calculational results.
- Why is the PVGS Inspection relevant to today's conference? Because the IR commingles facts between the NAC Inspection and the PVGS Inspection. For example:
  - IR states that NAC compared "hand calculated acceleration results to the previous non-linear LS-DYNA acceleration results" [i]
  - IR states that "linear scaling or ratioing would likely not be approved by the technical staff because so many variables such as the concrete and soil material properties, pad and soil configurations (e.g., compressive strength) can change" [ii]
- These PVGS 72.212 support activities were completely separate from, and long after NAC's licensing efforts which incorporated CC5 into our FSAR.

i. NRC Choice Letter Enclosure 2 Page #13, 3rd Paragraph
ii. NRC Choice Letter Enclosure 2 Page #15, 3rd Paragraph

Timeline of Significant Events



Palo Verde NRC Inspection vs. NAC NRC Inspection (Cont'd)

CC5 Incorporation into FSAR via 72.48 (2016)

- NAC initiates the 72.48 process to determine if incorporation of CC5 into the FSAR requires prior NRC approval.
- NAC performed a screening and subsequent evaluation, per the regulation.
- NAC determined that CC5 was acceptable without obtaining prior NRC approval.
- NAC did not use “linear scaling”.

CC5 Acceptance on the Palo Verde ISFSI Pad via 72.212 (2019 – 2020)

- 10 CFR 72.212 requires Palo Verde to review the FSAR generic ISFSI pad and identify / justify differences.
- Palo Verde provided these ISFSI pad differences to NAC via a specification.
- NAC provided a report (ED20190048) which ratioed prior LS-DYNA tip-over evaluation results to estimate g-loads that would be expected with CC5 on the Palo Verde ISFSI pad.
- Palo Verde then performed a 72.48 determination, referencing the NAC report to justify the pad was acceptable for CC5 tip-over.
- NRC Region IV raised questions on the MOE used in the evaluation.
- NAC promptly developed a site-specific LS-DYNA model and calculation (30032-2010) to support the PVGS MAGNASTOR CC5 tip-over and resolve the Region IV concerns.
- APS revised their 72.212 report prior to cask loading to include 30032-2010.
- Through subsequent dialog with Palo Verde and Region IV, NAC understands the NRC’s position. NAC acknowledges this ratioing (or “linear scaling”) approach when applied to multiple parameter differences with non-linear behavior (i.e. those between the generic FSAR pad and the PVGS pad) was an over-reliance on ratioing. The site-specific LS-DYNA model and calculation was the appropriate choice of analysis.

NAC Corrective Actions Following Palo Verde Inspection

- Following the APS Inspection, NAC issued CAR 20-01 with respect to NAC's decision not to initially perform a site-specific LS-DYNA run.
- CAR 20-01 Corrective Actions:
  - Evaluation of the ability of the components to perform intended safety function (reportability).
  - Extent of condition review:
    - *Design Control Methods*
    - *Other Customer's site-specific tip-over analyses*
  - Root Cause Analysis.
  - Review NAC calculation process and procedure for weakness related to the specific issue.
  - Review NAC project management planning procedure for weakness related to design deliverables.
  - Employee training – including emphasis on compliance with licensing basis MOE.
- Participated in the Palo Verde corrective action process.
- NAC is in the process of updating our 72.48 training program to include Reg Guide 3.72 Rev. 1 and NEI 12-04 now that it has been endorsed by the NRC.

NAC Actions Following AVs

- NAC has issued a Self-Identification Report (SIR) to document the AVs for potential escalation into NAC's Corrective Action Program (CAP) including extent of condition review pending outcome of the PEC.
- NAC has performed LS-DYNA analyses explicitly for CC3, CC4, CC5 and CC6 via NAC calculation 71160-2024
  - Resulting accelerations are essentially the same as FSAR CC1/CC2
- NAC verified LS-DYNA was used for all sub-contracted site-specific MAGNASTOR implementations.
- NAC has reviewed earlier cask system designs (i.e., NAC-MPC and NAC-UMS) and found FSAR tip-over analyses to be consistent with the current MAGNASTOR licensing basis.
- NAC has performed an inspection of our 72.48 activities with respect to linear scaling or ratioing dispositions.

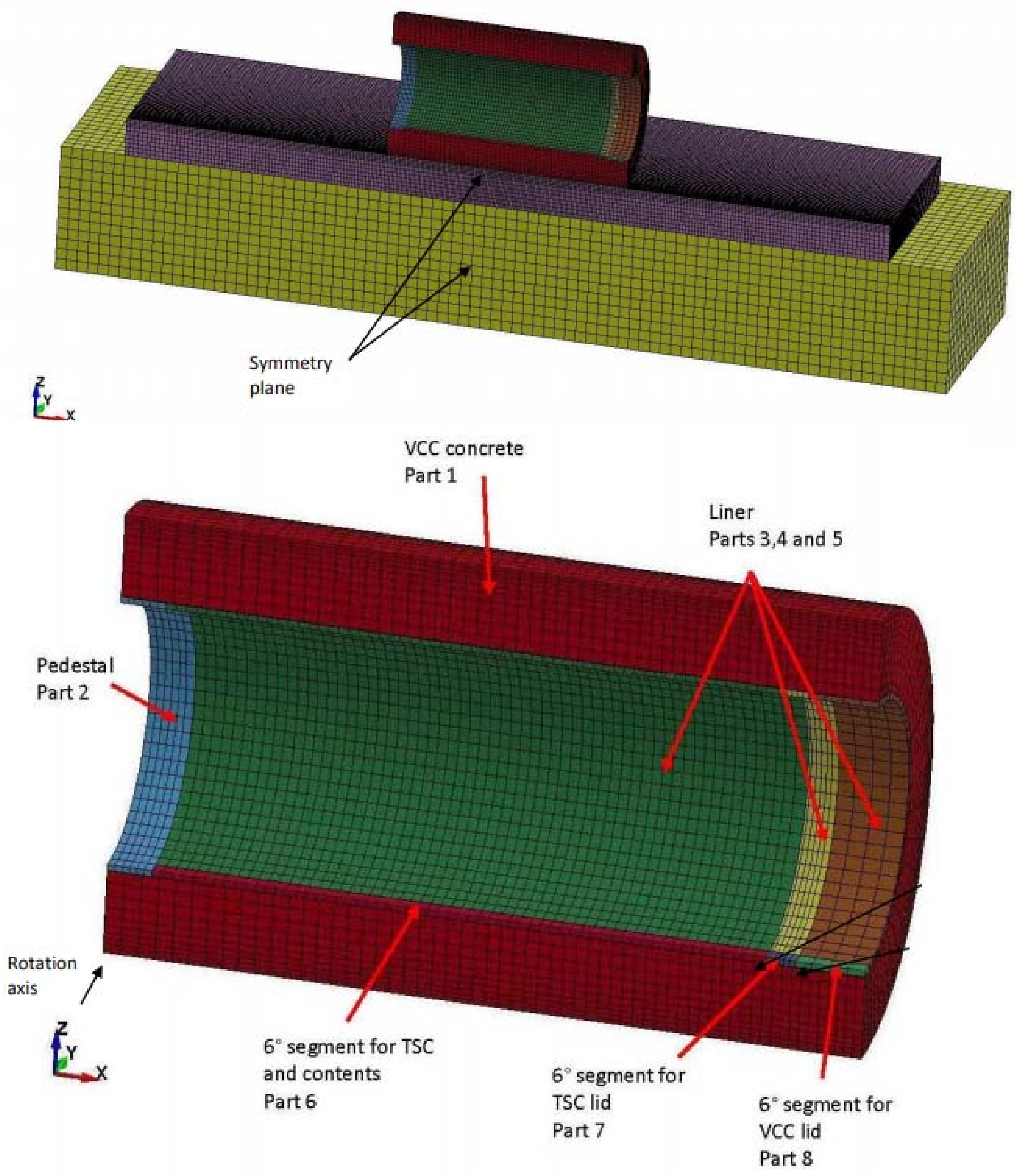
NAC Actions Following AVs (Cont'd)

In preparation for this PEC, NAC has used LS-DYNA to explicitly evaluate the CC5 cask for the non-mechanistic tip-over impact onto the FSAR pad & soil.

- The CC5 cask was modeled in LS-DYNA using an approach consistent with the licensing basis analysis described previously.
  - The cask model reflects the minor physical differences in the CC5 cask design (taller, thicker lid, thicker liner, inlet bars, and outer cage rebar spacing).
  - The ISFSI pad and underlying soil are represented with the same material models considered in the licensing basis analysis.
- Results show that the LS-DYNA produced accelerations for CC5 are lower than the licensing basis analysis accelerations.
- The relative difference in "I" for these CC5 and CC1 cask models is 1.064 which is consistent with the uniform density cylinder approximation presented earlier.
- These results further support the conclusion NAC made in the CC5 72.48 determination, that no additional tip-over analysis was required as the existing licensing basis analysis is applicable to the CC5 cask design.

	CC1/CC2 (1)	CC5(2)
Basket peak acceleration, g	26.6	25.8
TSC peak acceleration, g	29.6	28.9

1) NAC Calculation 71160-2005, Rev. 0, "Newgen VCC Tip-Over Analysis", 2004
2) NAC Calculation 71160-2034, Rev. 0, "LS-DYNA Tip-Over Analysis for CC1 and CC5 Concrete Casks", 2020



CC5 LS-DYNA Cask & Pad Model

Presentation Conclusion

- The 72.48 evaluation performed for CC5 FSAR non-mechanistic tip-over did not result in a "departure" from the existing MOE in the licensing basis.
- The CC1/CC2 FSAR LS-DYNA licensing basis was reasonably determined to be applicable to CC5.
- CC5 meets the same criteria NRC used to approve CC6 in the Amendment 9 SER.
- There is low regulatory significance and low safety significance associated with the AVs, since no FSAR limits or criteria are based on the LS-DYNA results.
- NAC's supplemental LS-DYNA calculation confirmed the adequacy of the design.
- NAC believes neither a 72.48 nor a design control violation has occurred.
- NAC takes nuclear safety and regulatory compliance seriously and hopes this presentation helps clarify any misunderstandings the NRC may have with regards to the underlying facts.

NAC INTERNATIONAL

NAC International Inc.
3930 East Jones Bridge Road, Suite 200
Peachtree Corners, GA 30092 USA
www.nacintl.com