MP197HB Transport Application

Structural Analysis

Impact Limiter Analysis

Overview of Structural Analysis

- **Components**
  - **Impact limiter**
    - **Decelerations calculated to be used in subsequent analysis**
    - **Impact limiter crush depth obtained to make sure that the cask does not bottom out**
  - **Transport Cask**
  - **Canister Shell**
  - **Basket Assembly**
  - **Fuel**

MP197 Impact Limiter vs. MP197HB Impact Limiter

- Dimensions are similar
- Design is similar (No new design features)
- Materials are the same

Feature	MP197	MP197HB
Impact Limiter Material	Redwood and Balsa	Redwood and Balsa
Casing	¼" SST	¼" SST
Gussets	3/16" SST	3/16" SST
Limiter OD	122"	126"
Limiter ID	83.0"	85.5"
Total Package Weight	132.55 tons	149.5 tons

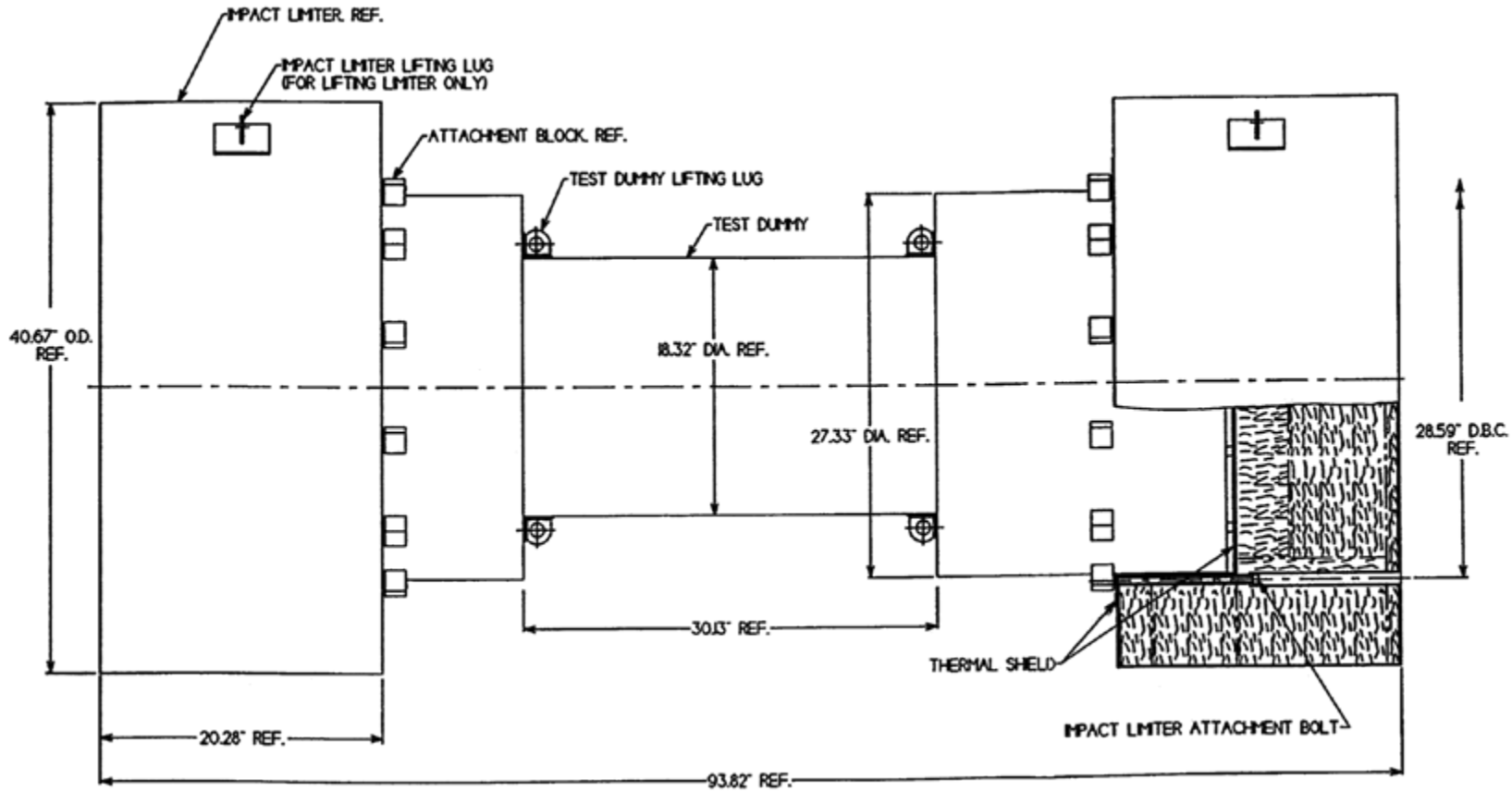
Impact Limiter Analysis Overview

- **MP197 1/3 scale drop test performed for the CoC 9302 license application**
- **Impact analysis methods using LSDYNA code are benchmarked to the 1/3 scale drop test**
- **Same analysis methods using LSDYNA code are used for the analysis of the full scale MP197HB Transport Cask with Impact Limiters**

MP197 1/3 Scale Drop Test

- The drop tests accident conditions were as follows:
  - 30’ End Drop (-20 ºF)
  - 30’ Side Drop (Room Temperature)
  - 30’ 20º Slap Down (Room Temperature)
- Impact limiters consist of sections of redwood and balsa enclosed in a stainless steel shell
- Cask test model consists of a solid carbon steel body which matches the weight and moment of inertia of the MP197 Transport Cask

MP197 1/3 Scale Drop Test–Model



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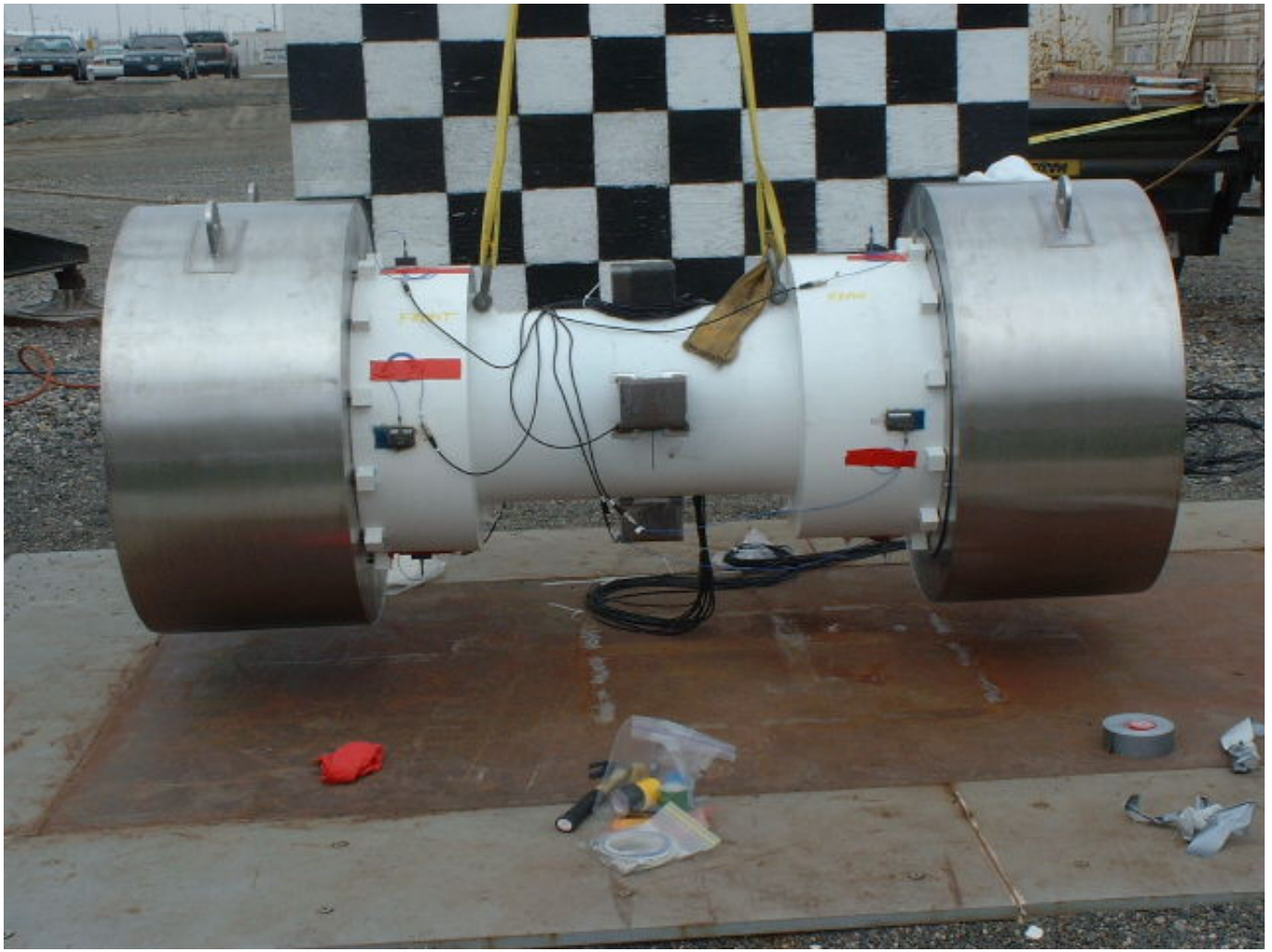
MP197 1/3 Scale Drop Test–Accelerometer Locations



MP197 1/3 Scale Benchmark LSDYNA Analysis

- **The analyzed drop were same as test:**
  - **30’ End Drop (-20 ºF)**
  - **30’ Side Drop (Room Temperature)**
  - **30’ 20º Slap Down (Room Temperature)**
- **Calculated decelerations, wood crush, and impact duration compared to the drop test**

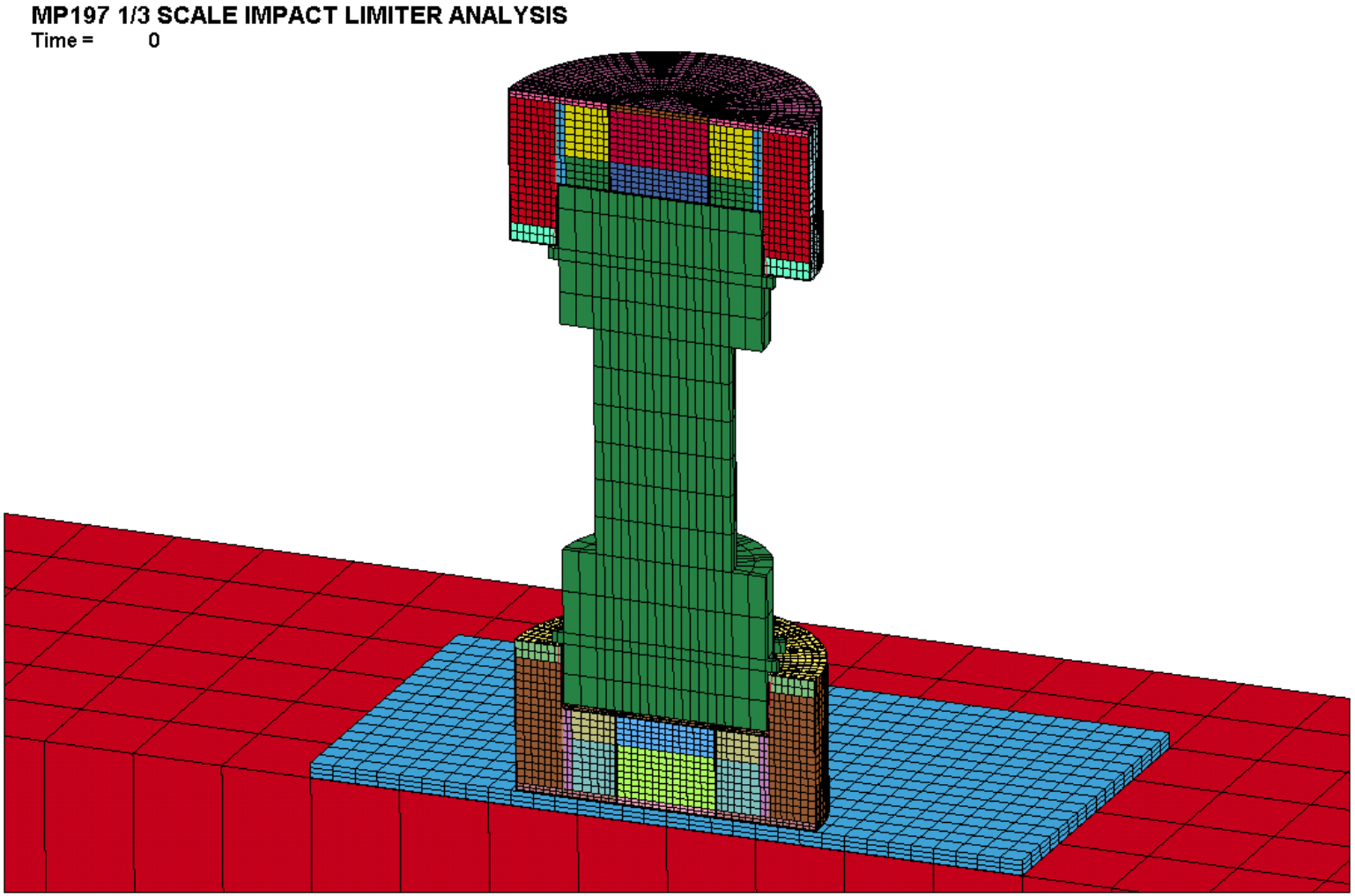
MP197 1/3 Scale Benchmark LSDYNA Analysis

- **Wood Material**
  - **Modified_Honeycomb (MAT 126) material model used for the wood to model anisotropic behavior–this is consistent with technical papers**
  - **Density, Shear Modulus perpendicular and parallel to grain, Bulk Modulus perpendicular and parallel to grain, and strain failure properties used**
  - **Wood modeled with hexahedron elements**
  - **Material Properties taken from test performed by TN and from "Wood Handbook: Wood as an Engineering Material, Forest Products Laboratory" reference**
  - **To address the -20 °F temperature drop, material strength and stiffness were increased by 20%–this was verified by comparing the analysis results with the drop test data**

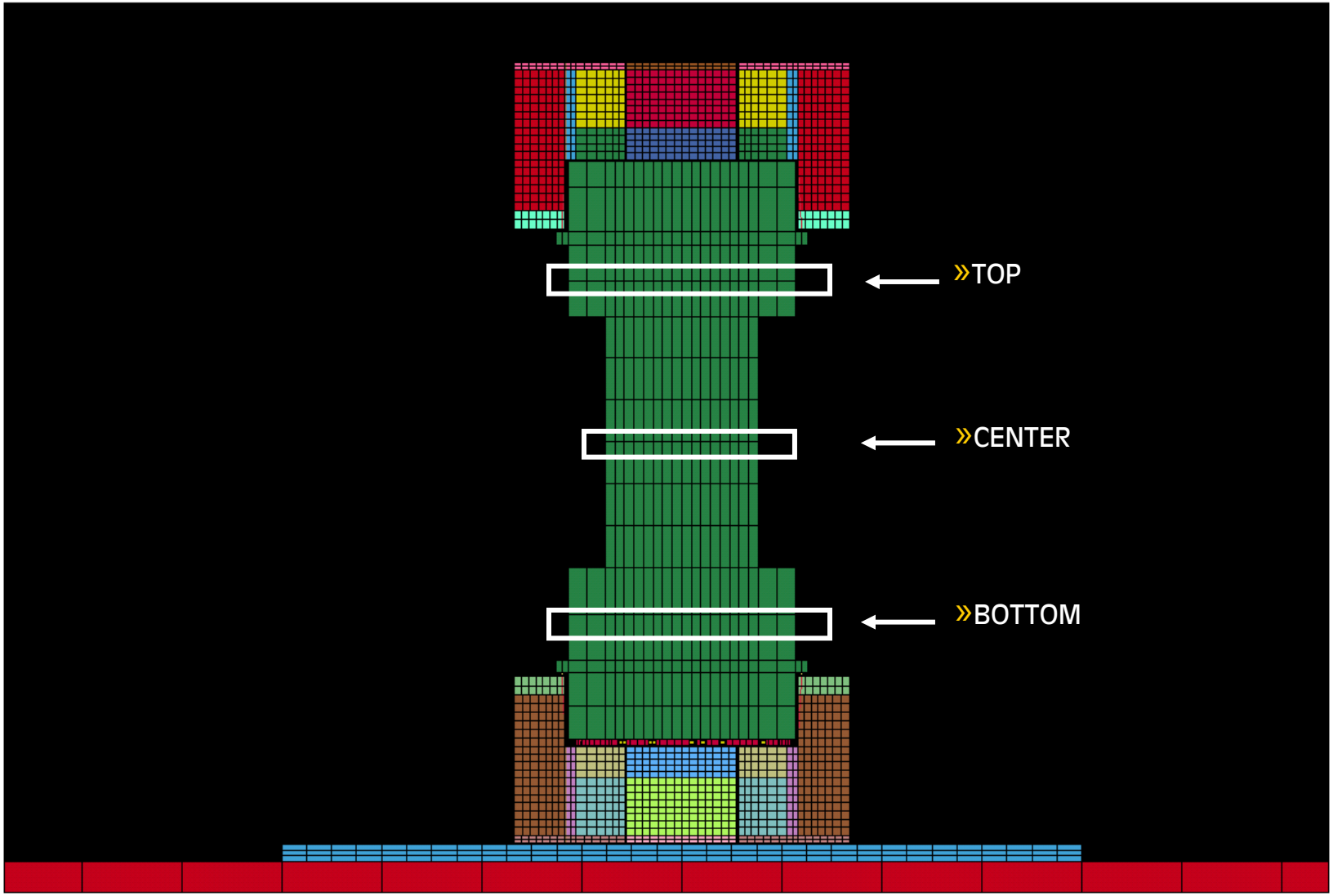
MP197 1/3 Scale Benchmark LSDYNA Analysis

- **Impact limiter attachment bolts modeled as circular cross section beams**
- **Cask test model and impact limiter shell modeled with hexahedron and shell elements, respectively**

MP197 1/3 Scale Benchmark LSDYNA Analysis– Model



MP197 1/3 Scale Benchmark LSDYNA Analysis– Location of Nodes for Average Acceleration



MP197 1/3 Scale Benchmark LSDYNA Analysis–Results

Test Conditions	Parameter	Drop Test Results	LS-DYNA Analysis Results
90º End Drop (-20 ºF)	Acceleration	65g	65.1g
	Impact Duration	0.010 sec.	0.012 sec.
	Wood Crush Depth	2.5”	2.8”
0° Side Drop (Room Temperature)	Acceleration	61g	65.6g
	Impact Duration	0.012 sec.	0.013 sec.
	Wood Crush Depth	2.69”-2.75”	2.7”-2.9”
20° Slap Down 1st Impact (Room Temperature)	Acceleration at Center of Cask	17g	20.8g
	Acceleration at Bottom of Cask	36g	40.1g
	Impact Duration	0.016 sec.	0.018 sec.
	Wood Crush Depth Bottom Limiter	4.92”	4.9”
20° Slap Down 2nd Impact (Room Temperature)	Acceleration at Center of Cask	32g	36.3g
	Acceleration at Top of Cask	73g	72.2g
	Impact Duration	0.009 sec.	0.010 sec.
	Wood Crush Depth Upper Limiter	4.72”	2.8”

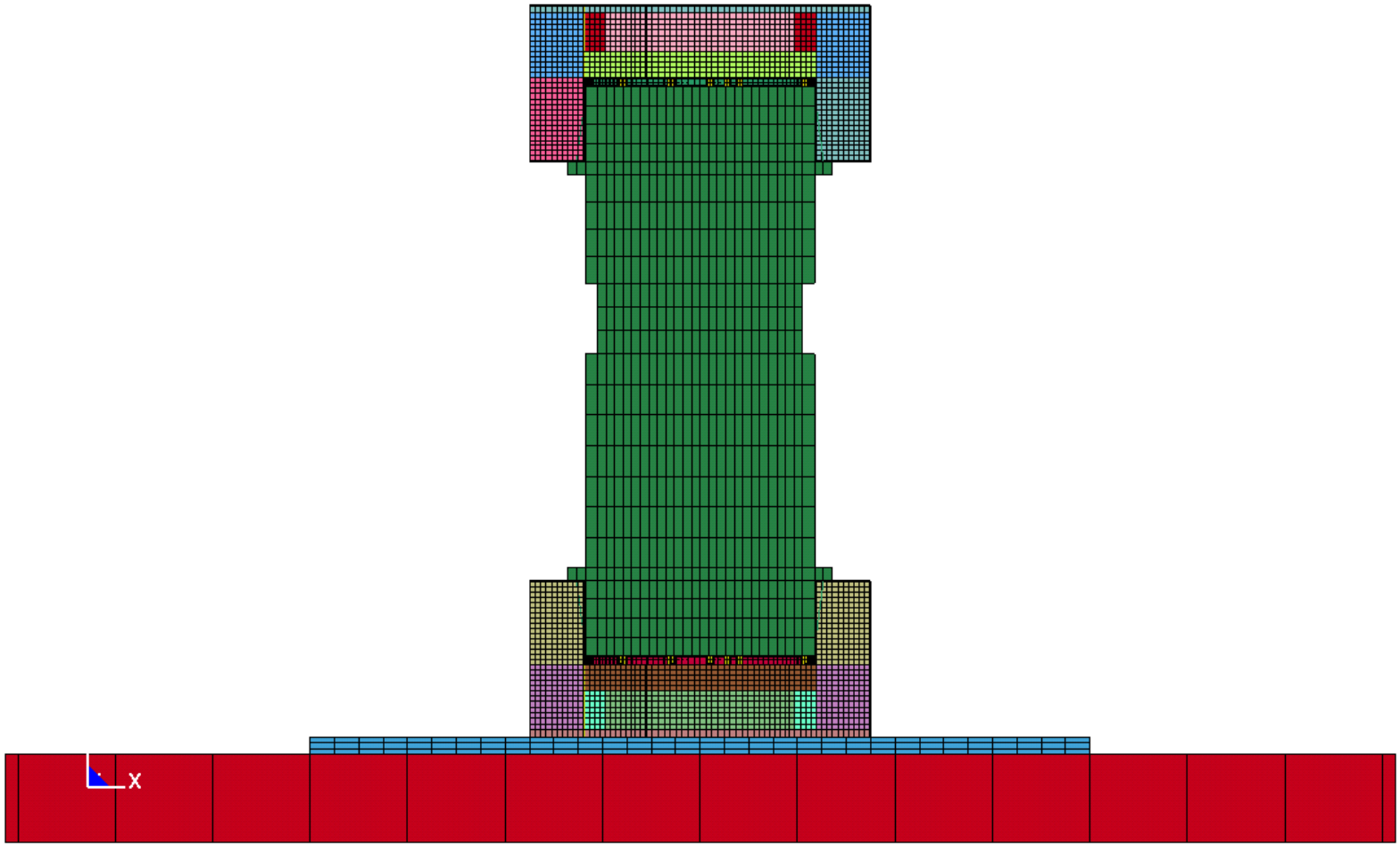
MP197 1/3 Scale Benchmark LSDYNA Analysis– Results

- **Calculated decelerations (max value and time duration) are close to or bound the measured drop test decelerations**
- **The methodology, material models, and material properties are benchmarked**

MP197HB Full Scale LSDYNA Analysis

- Full scale model
- Same methodology, material models, and material properties as the MP197 1/3 scale LSDYNA analyses
- To address the -40 °F temperature drop, material strength and stiffness were increased by 30%–"Wood Handbook: Wood as an Engineering Material, Forest Products Laboratory"
- The following analyses were performed for the MP197HB:
  - 30' End Drop (room temperature)
  - 30' End Drop (-20 ºF)
  - 30' End Drop (-40 ºF)
  - 30' Side Drop (room temperature)
  - 30' 20° Slap Down (room temperature)
  - 30' 10° Slap Down (room temperature)
  - 30' CG Over Corner Drop (room temperature)
  - 1' Normal Condition End Drop (room temperature)
  - 1' Normal Condition Side Drop (room temperature)

MP197HB Full Scale LSDYNA Analysis–Model



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MP197HB Full Scale LSDYNA Analysis–Results

- Rigid body decelerations are calculated for the cask and are used in subsequent analyses
- Cold temperature effect
  - Decelerations increase by 14% for the -20 °F temperature analysis vs. RT analysis
  - Decelerations increase by 20% for the -40 °F temperature analysis vs. RT analysis
  - Baseline decelerations, used in subsequent analyses, are calculated from room temperature analyses and increased by 20% to account for cold temperature

MP197HB Full Scale LSDYNA Analysis

- **Sensitivity studies performed to address the current NRC expectations**
  - **Mesh sensitivity study–Wood elements doubled–g-load changed by -0.65%; no change in crush**
  - **Bolts removed–g-load changed by -6.8%; crush changed by +4.3%**
- **Impact limiter bolts are qualified using two different methods**
  - **Forces from the LSDYNA analysis**
  - **G-loads from the LSDYNA analysis–similar method as the TN40 Transport Application**