
AREVA

Benchmarking of Analytical Methods and Analysis Software Used for Transportation Package Drop Analysis

Peter Shih

Looking to the future PATRAM 2010

AREVA

- Introduction
- Transport Cask Design Compliance
  - Design Criteria Based on 10CFR Part 71, NUREG, and ASME Code
  - Analysis
  - Acceptance Testing (Fabrication)
- MP197 Impact Limiter Drop Testing
  - Test Article Description
  - 1/3 Scale Model Impact Limiter Testing
- Benchmark of the Testing Using LS-DYNA
  - Finite Element Model
  - Material Properties
- Conclusion

Introduction

Over Thirty Years Experience in Storage and Transportation of Spent Fuel, Radioactive Waste and Other Radioactive Material.

Experience Includes:

- **Design**
- **Analysis**
- **Testing**
- **Certification**
- **Fabrication**
- **Operation**

Transport Cask Design Criteria

Design Basis:

- 10CFR Part 71
- Regulatory Guide 7.6
- Regulatory Guide 7.8
- ASME Section III, Subsection NB and NG

MP197 Impact Limiter Drop Testing

- **Validate the Acceleration Values Used for the Structural Analysis**
- **Demonstrate that Crush Depths are Acceptable**
- **Demonstrate the Adequacy of the Impact Limiter Enclosure**
- **Demonstrate the Adequacy of the Impact Limiter Attachment Design**
- **Evaluate the Effect of Low Temperature (-20^{o}F) on the Crush Strength**

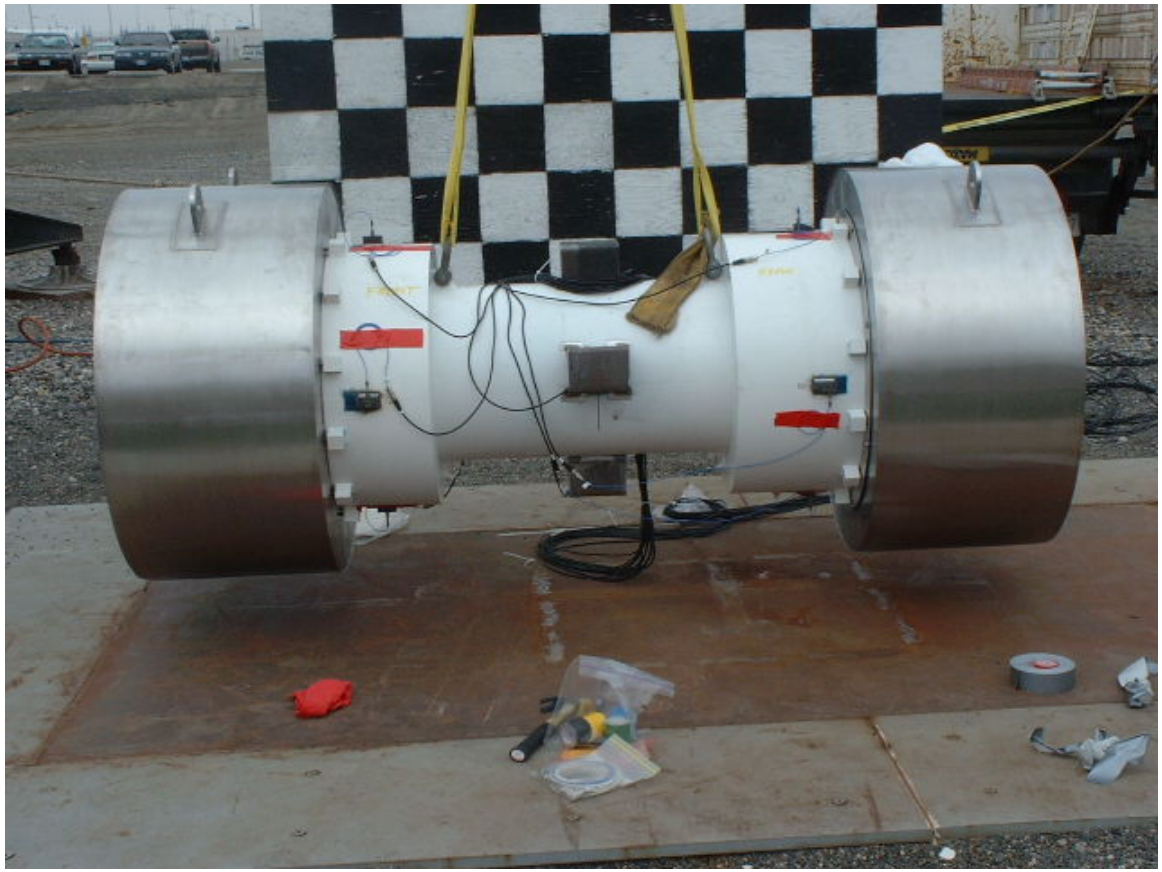
Test Model Description

	Full Size Package	1/3 Scale Model
Weight of Package	266,300 lbs (121 metric tons)	9,750 lbs (4.43 metric tons)
Overall Length of Package	208.00 in. (5283 mm)	69.33 in. (1761 mm)
Outside Diameter of Impact Limiter	122.00 in. (3099 mm)	40.67 in. (1033 mm)
Overall Package CG Location	102.85 in. (2612 mm)	34.38 in. (873 mm)

Drop Orientations

Test Number	Drop Orientation	Drop Height	Impact Limiter Number	Location of Impact Limiter	Comments
1	0° Side Drop	30 feet (9m)	1	Top	
			2	Bottom	
2	20° Slap Down	30 feet (9m)	3	Top (2^{nd} Impact)	Impact Limiter #1 was removed and replaced with limiter #3, entire test article rotates 180°.
			2	Bottom (1^{st} Impact)	
3	90° End Drop	30 feet (9m)	3	Top	Impact Limiter #2 was removed and replaced with limiter #4. Impact Limiter #4 chilled at –20° F for 48 hours before installed to the test body.
			4	Bottom (Impact End)	

Test Model and Accelerometer Locations



0° Side Drop Test Setup

Cask Test Model After 0° Side Drop

20° Slap Down Test Setup

Cask Test Model After 20° Slap Down Drop

90° End Drop Test Setup

Cask Test Model After 90° End Drop

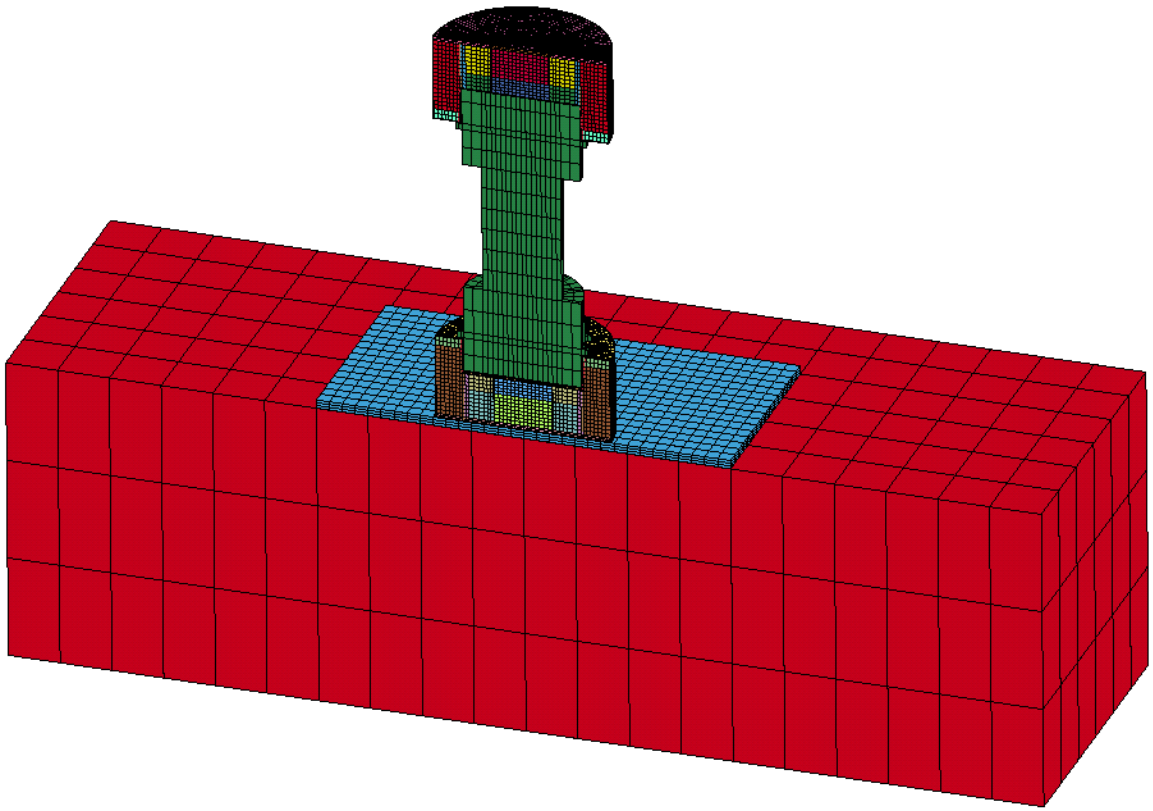
Benchmark of the Testing Using LS-DYNA

- **The finite element analysis model is a representation of the 1/3 scale MP197 cask used for the actual drop tests with an impact limiter installed on each end of the cask. The model includes:**
  - **Cask model**
  - **Impact Limiters**
    - Redwood
    - Balsa
    - Stainless steel shell and covers
  - **Impact Limiter Attachment Bolts**
  - **Impact Surface**
    - Steel plate
    - Concrete Pad

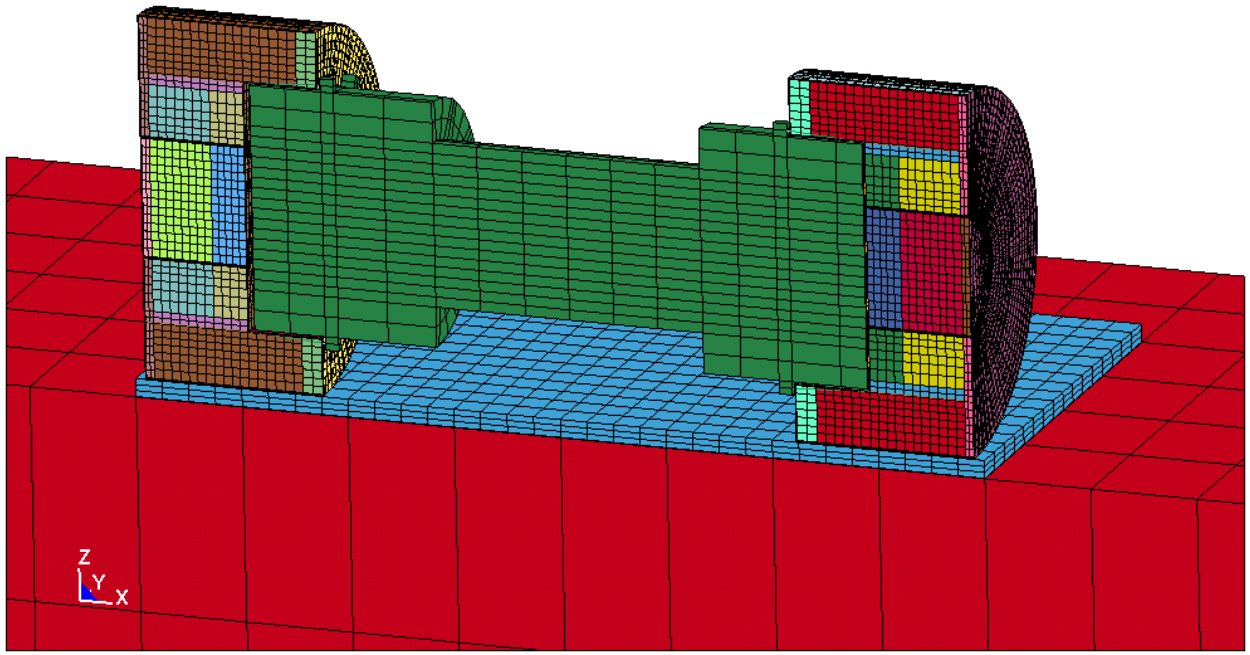
Finite Element Model

- **The impact limiter wood sections, the concrete pad, the steel plate, and the cask model are modeled with the default LS-DYNA constant stress solid element. The impact limiter shell is modeled with a fully-integrated shell element.**
  - **Cask model material**
    - A-36 steel with elastic-plastic properties
  - **Impact limiter shell material**
    - SA-240 Type 304 SST with elastic-plastic properties
  - **Impact limiter wood segment material**
    - Using Mat_Modified_Honeycomb material model in LS-DYNA (material type 126), which models crushable material with anisotropic behavior
  - **Concrete material**
    - Modeled using material law 16 in LS-DYNA, which was developed specifically for granular type material
  - **Steel plate material**
    - A-36 steel with elastic-plastic properties

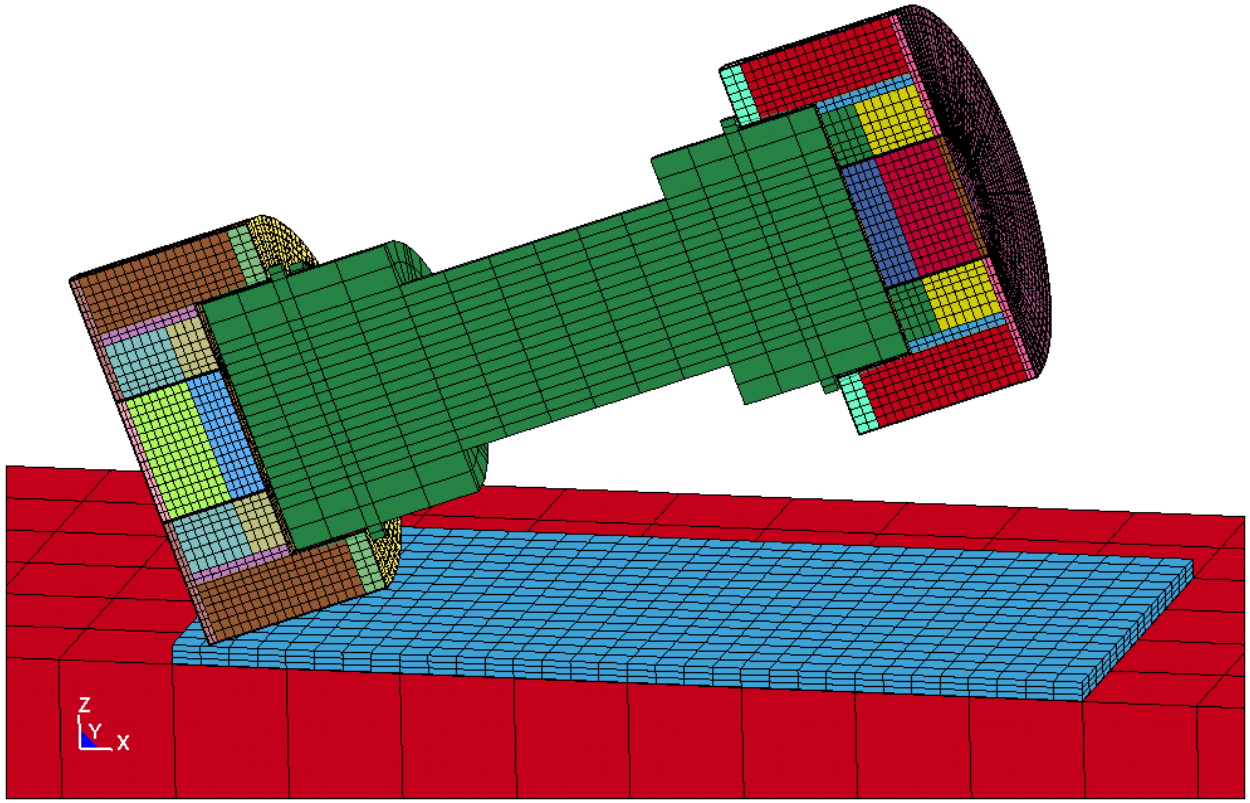
1/3 Scale Finite Element Model Overview



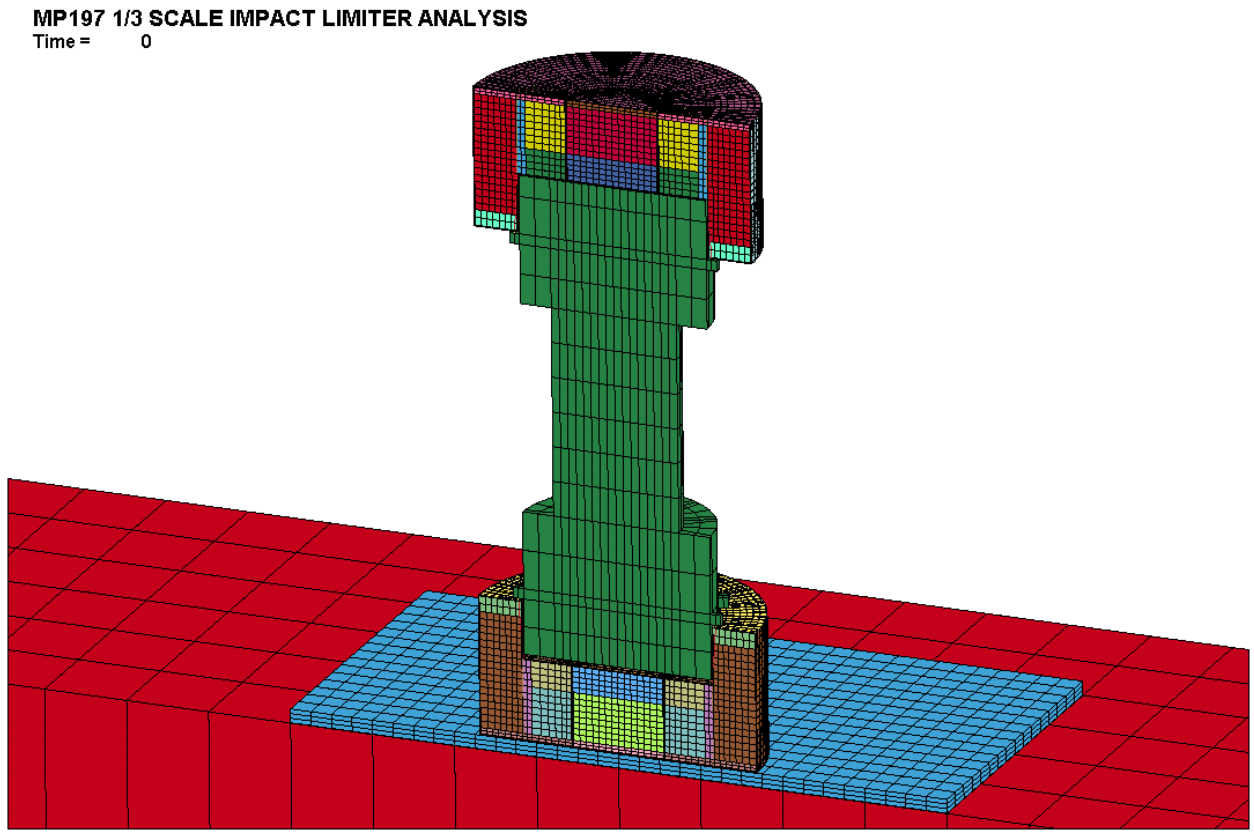
1/3 Scale Finite Element Model for Side Drop



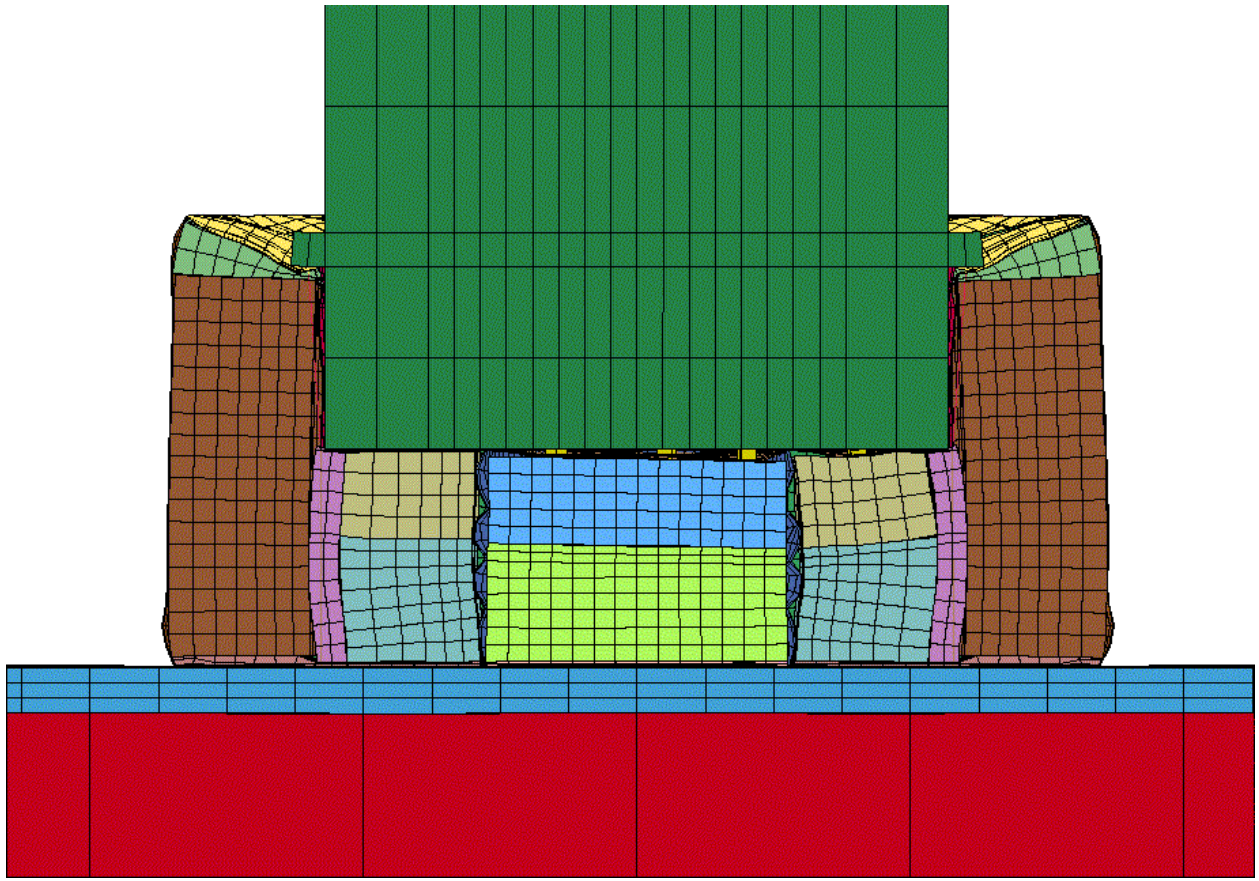
1/3 Scale Finite Element Model for 20° Slap Down Drop



1/3 Scale Finite Element Model for End Drop



Plot of Maximum Deformation for 1/3 Scale End Drop



Result From Test vs. From LS-DYNA Analysis

		Test Results	LS-DYNA Model
End Drop (-20ºF)	Acceleration	65g	65.8g
	Impact Duration	0.010 sec	0.012 sec
	Wood Crush Depth	2.5”	2.5”
Side Drop	Acceleration	61g	61.5g
	Impact Duration	0.012 sec	0.014 sec
	Wood Crush Depth	2.75”	2.75”
20° Slap Down 1st Impact	Acceleration at Center of Cask	17g	18.2g
	Acceleration at Bottom of Cask	36g	34.9g
	Impact Duration	0.016 sec	0.023 sec
	Wood Crush Depth Bottom Limiter	4.92”	5.5”
20° Slap Down 2nd Impact	Acceleration at Center of Cask	32g	41.1g
	Acceleration at Top of Cask	73g	78.4g
	Impact Duration	0.009 sec	0.012 sec
	Wood Crush Depth Upper Limiter	2.42”	3.0”

Conclusion

- **The LS-DYNA Analysis Results Correspond Well With the Measured Impact Limiter Drop Test Results**
  - **Decelerations**
  - **Impact time Durations**
  - **Impact Limiter Crush Depths**
- **The LS-DYNA code can be used to accurately evaluate the impact of a cask with impact limiters**
- **Mesh refinement and the correct characterization of wood is crucial**
- **Test is limited by the available resources (schedule, drop orientation, temperature, etc) while the analyses can be performed for all necessary conditions**