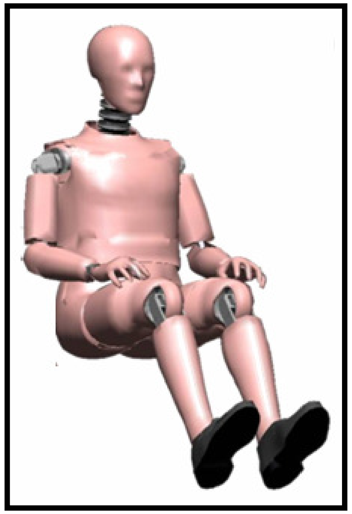


Hybrid III 50th Percentile Male

- Hong Zhou, Jim Rasico, Fuchun Zhu, Robert Kant

- First Technology Safety Systems, Inc.

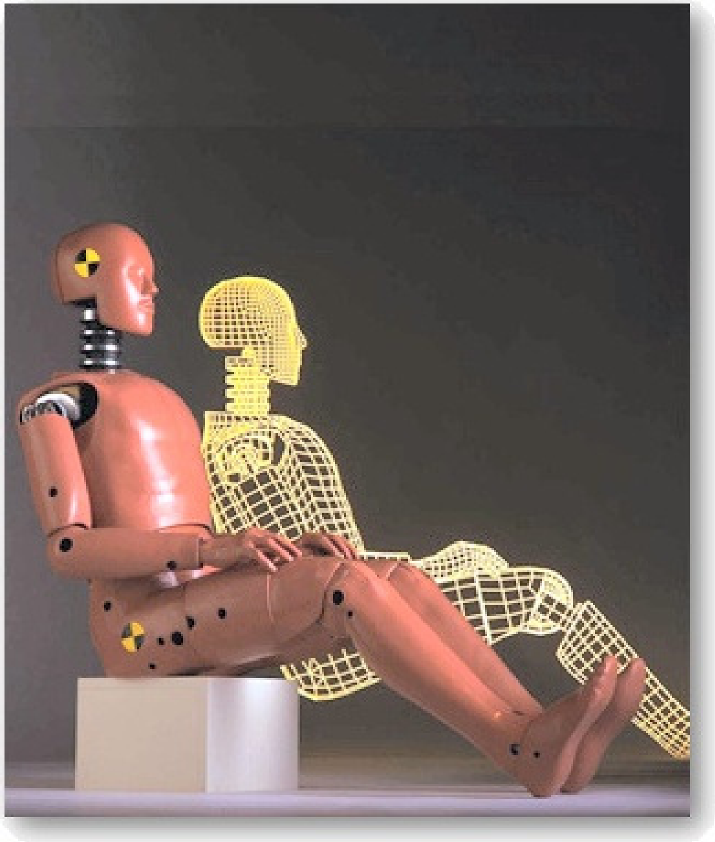
Contents

- Introduction
- Current Improvements (Based on PDB data)
- Upgrade Plan
  - Geometry Improvement
  - New Meshing
  - Material Tests
  - Component Tests
  - Sled Tests

Introduction

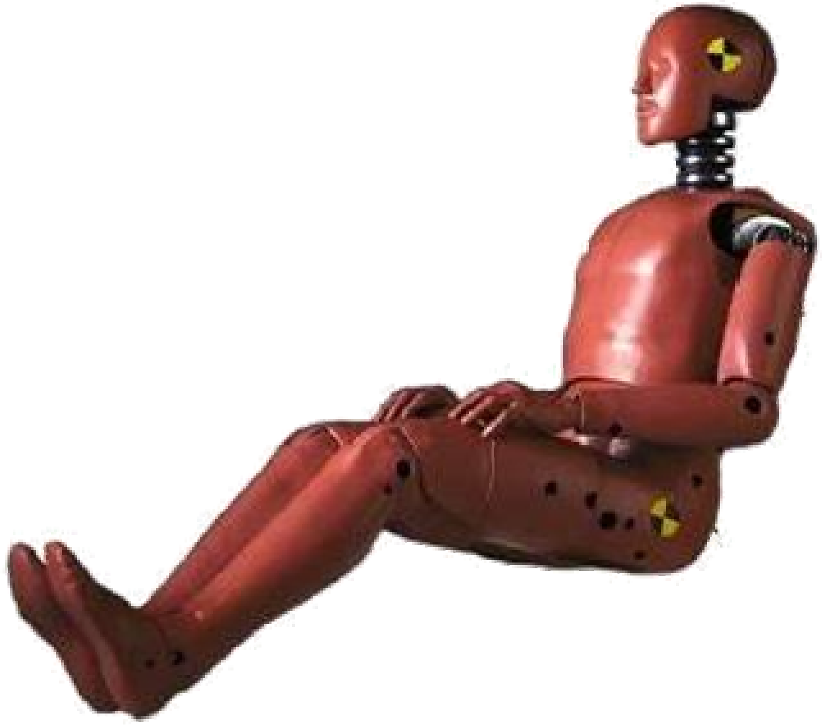
Crash Test Dummies: Hybrid-III

- Alderson Research and Sierra Engineering with GM creates first automotive crash test dummy, the Hybrid I, in 1971
- GM improves Hybrid I, developing the Hybrid II dummy
- Hybrid II dummy becomes the standard for frontal crash testing to comply with regulations governing restraint systems in 1972
- Between 1973-1977 the Hybrid III dummy is created
- In 1986 Hybrid III is accepted as an alternative test device for government compliance FMVSS 208 / NCAP
- In 1998, ECE R94 using H-III comes into effect



Current Improvements

- Head and Neck
- Thorax
- Legs
- Foot and Shoe



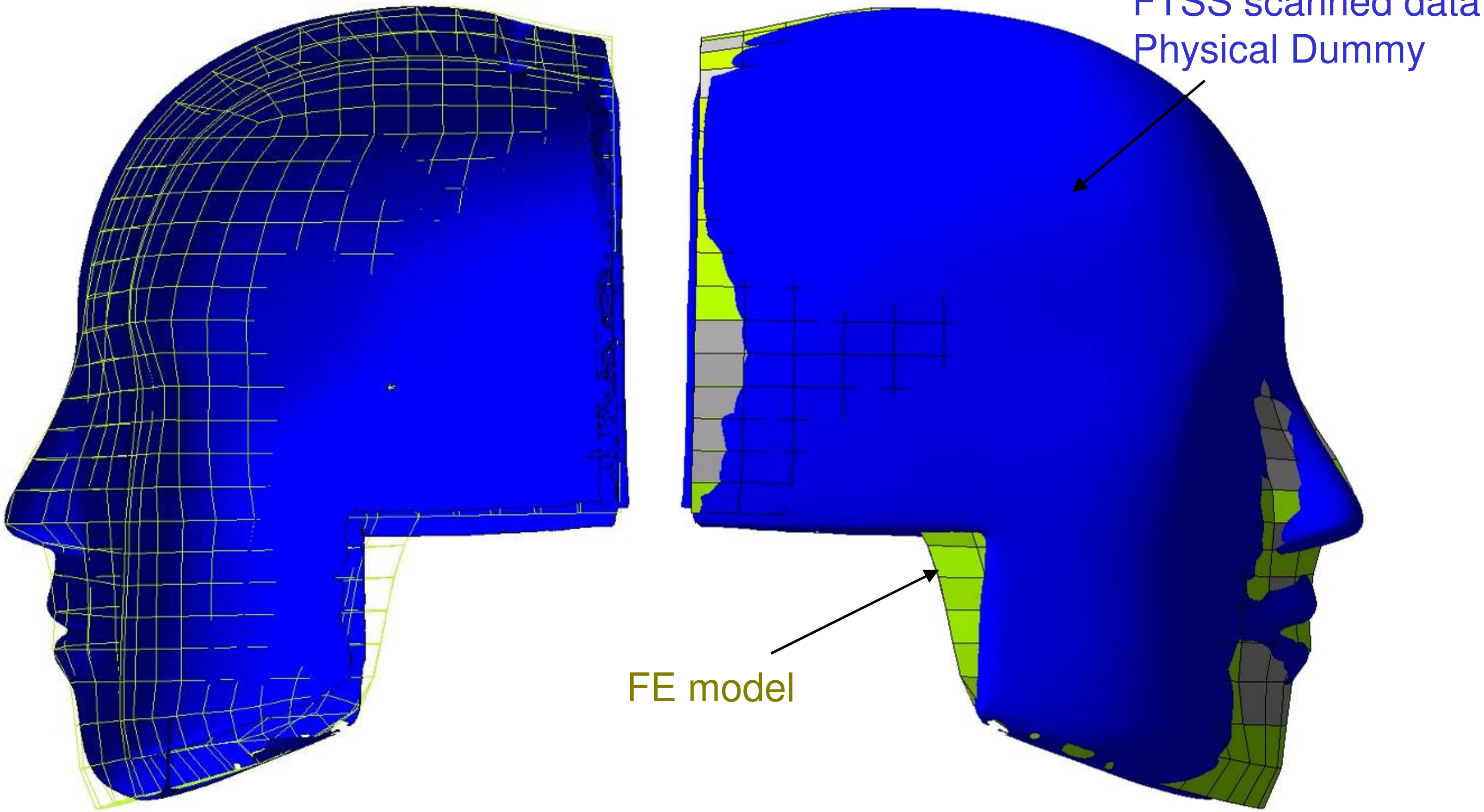
Head and Neck Model

- Head skin and skull geometry scanned and remodelled.
- Head assembly mass and inertia verified.
- Head vinyl skin material re-calibrated to meet standard head drop calibration tests.
- Updated neck cable modeling

Head and Neck Model

Head Geometry

- The H3-50 head was scanned at FTSS using a laser scanner



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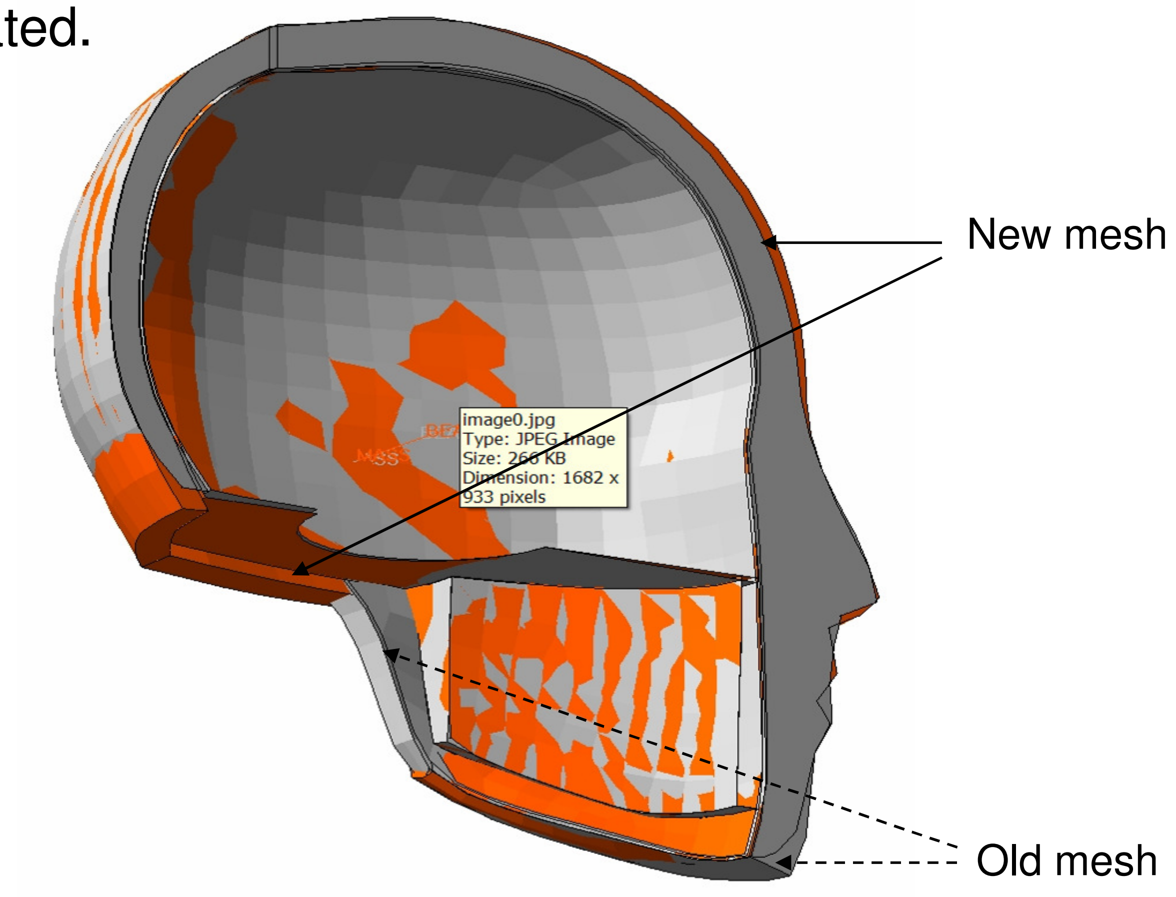
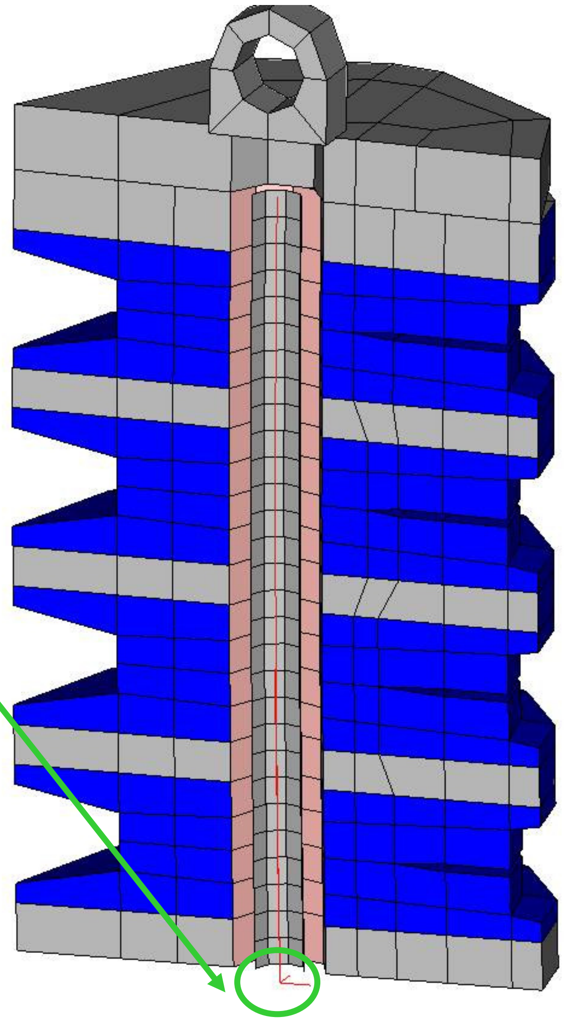
Head and Neck Model

- The H3-50 head was remodelled, with the skin and skull separated.



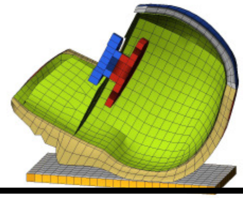
Head and Neck Model

- Updated neck cable modeling
  - – The cable slack translational spring was removed.
  - –LS-DYNA: A non-linear elastic stiffness curve is implemented for the neck cable beam elements and the stiffness curve optimized.

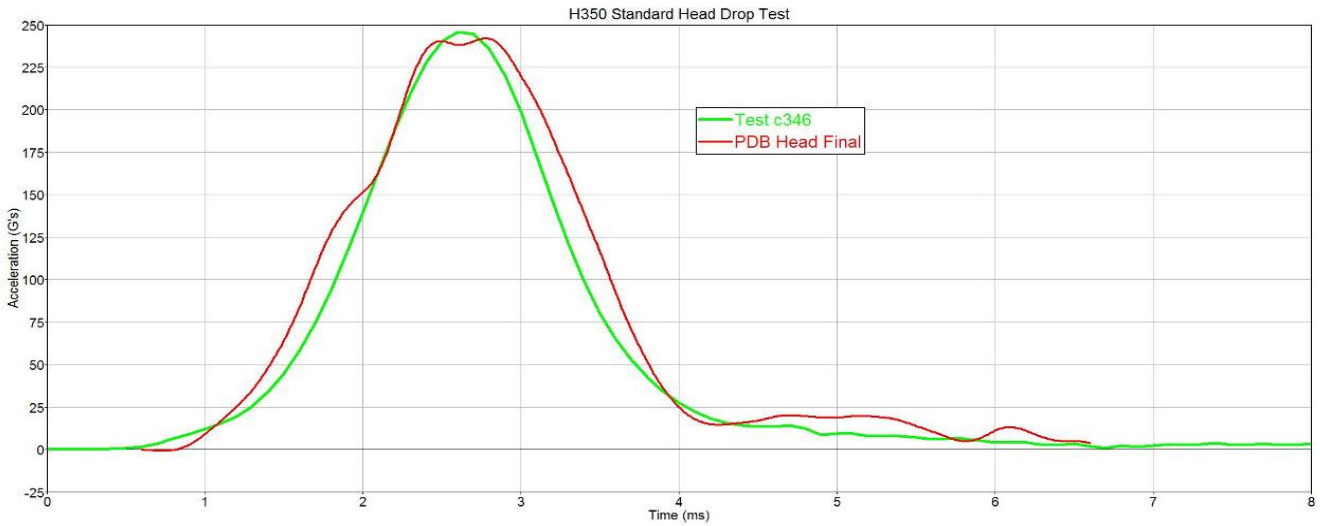


Head and Neck Model

- **Standard Head Drop Test**

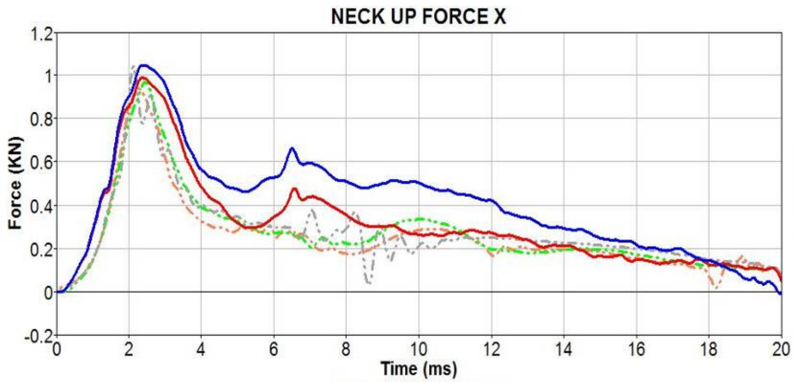


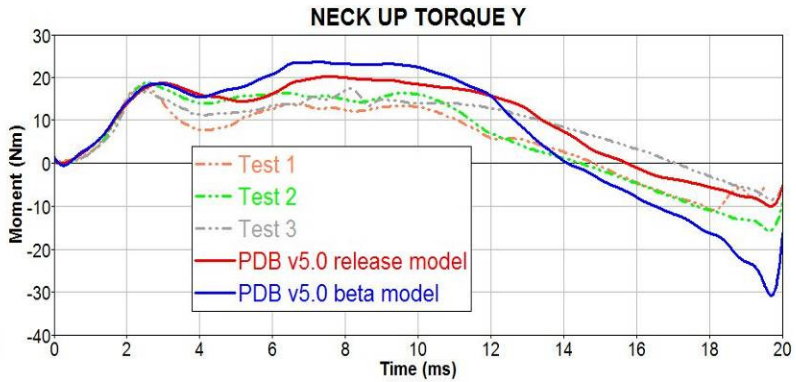
Head Performance Specifications	FTSS Model
Peak resultant acceleration between 225 and 275 g's (CFC1000)	241.9
Unimodal acceleration curve; Subsequent oscillations < 10% of peak resultant acceleration.	8.3%
Lateral acceleration <15g.	2.09

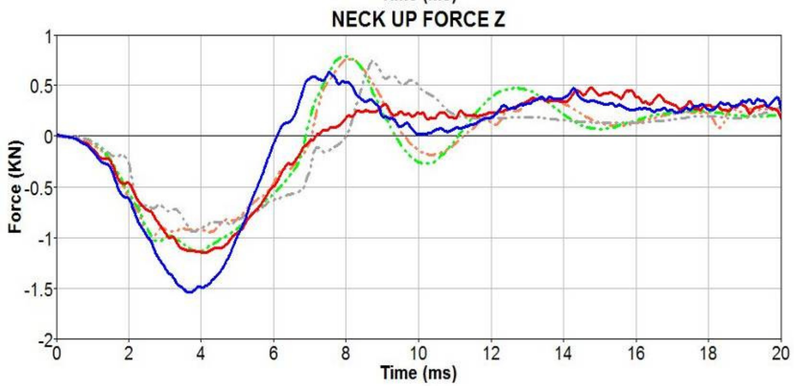


Head and Neck Model

- PDB Forehead test results





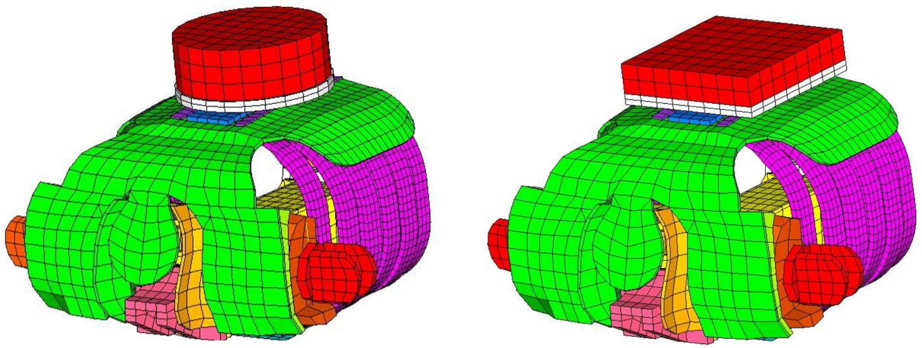


Thorax Model

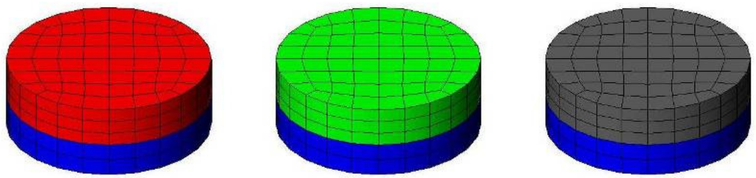
- Thorax Model Development
  - New rib damping material tests and ensolite foam tests helped achieve a better dummy material characterization for the thorax sternum impacts.
  - The revised H3-50 model based on the jacket and pad geometry measurements taken at Audi, VW and BMW achieves a good correlation to test.

Thorax Model

- Rib damping and Ensolite pad material development impact tests conducted at FTSS



- Ensolite material drop tests at 3 speeds were used to develop the jacket ensolite pad properties



Thorax Model

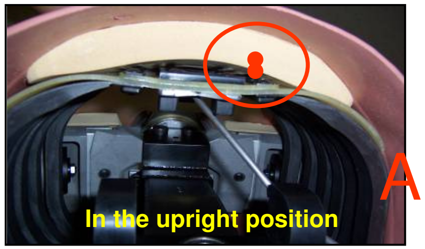
thorax jacket/pad measurements

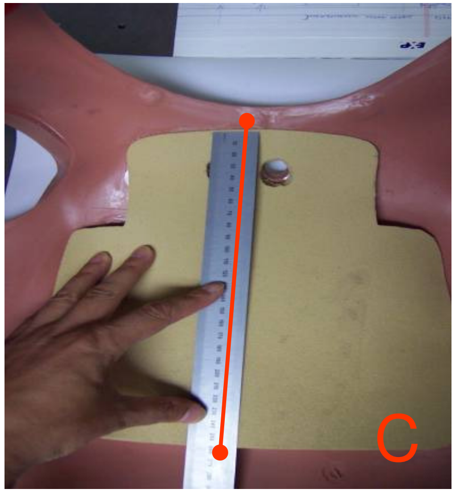
Summary of PDB Jacket and Ensolite Pad Measurements - 31st August 2005

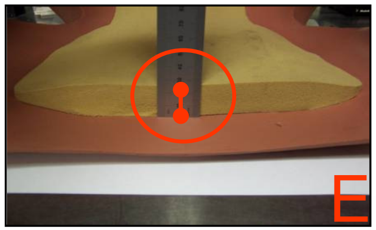
	AUDI	Volkswagen	BMW
H3-50 Test Dummy ID	D 0.12	ID 91	ID 307
Dummy manufacturer	FTSS	FTSS	Denton
Date of H3-50 purchase	?	?	Oct-96
Details of any H3-50 jacket spare parts purchased	?	?	?
Date measurements completed	30.08.2005	31.08.2005	30.08.2005

PDB geometry

Measurements	AUDI	Volkswagen	BMW	Average (all)	Average (FTSS)	% Deviation
A [mm]	3	10	9	7.3	6.5	-11%
B [mm]	27	29	40	32.0	28.0	-13%
C [mm]	247	245	250	247.3	246.0	-1%
D [mm]	67	66	79.5	70.8	66.5	-6%
E [mm]	25	21	25	23.7	23.0	-3%

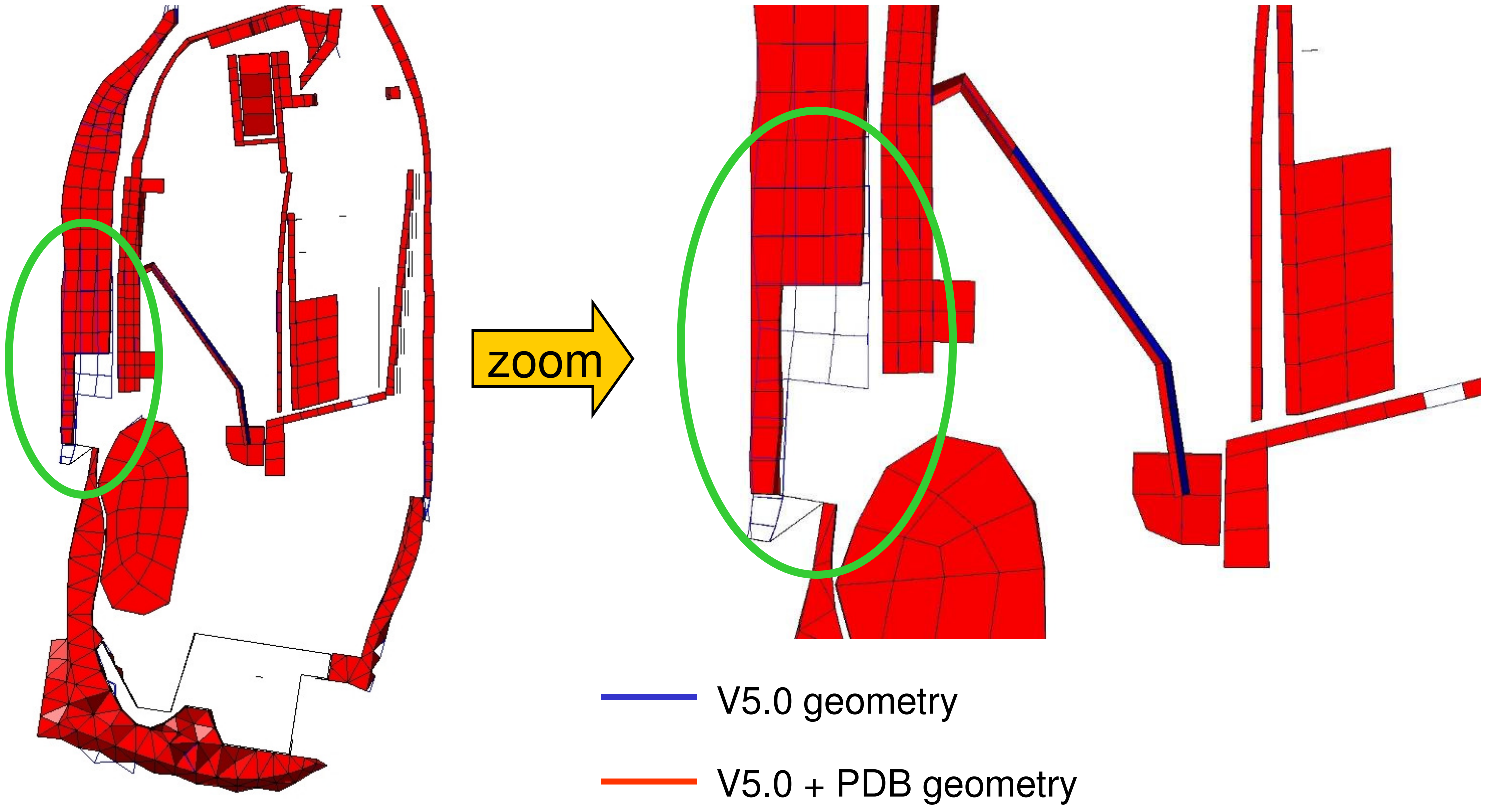






Thorax Model

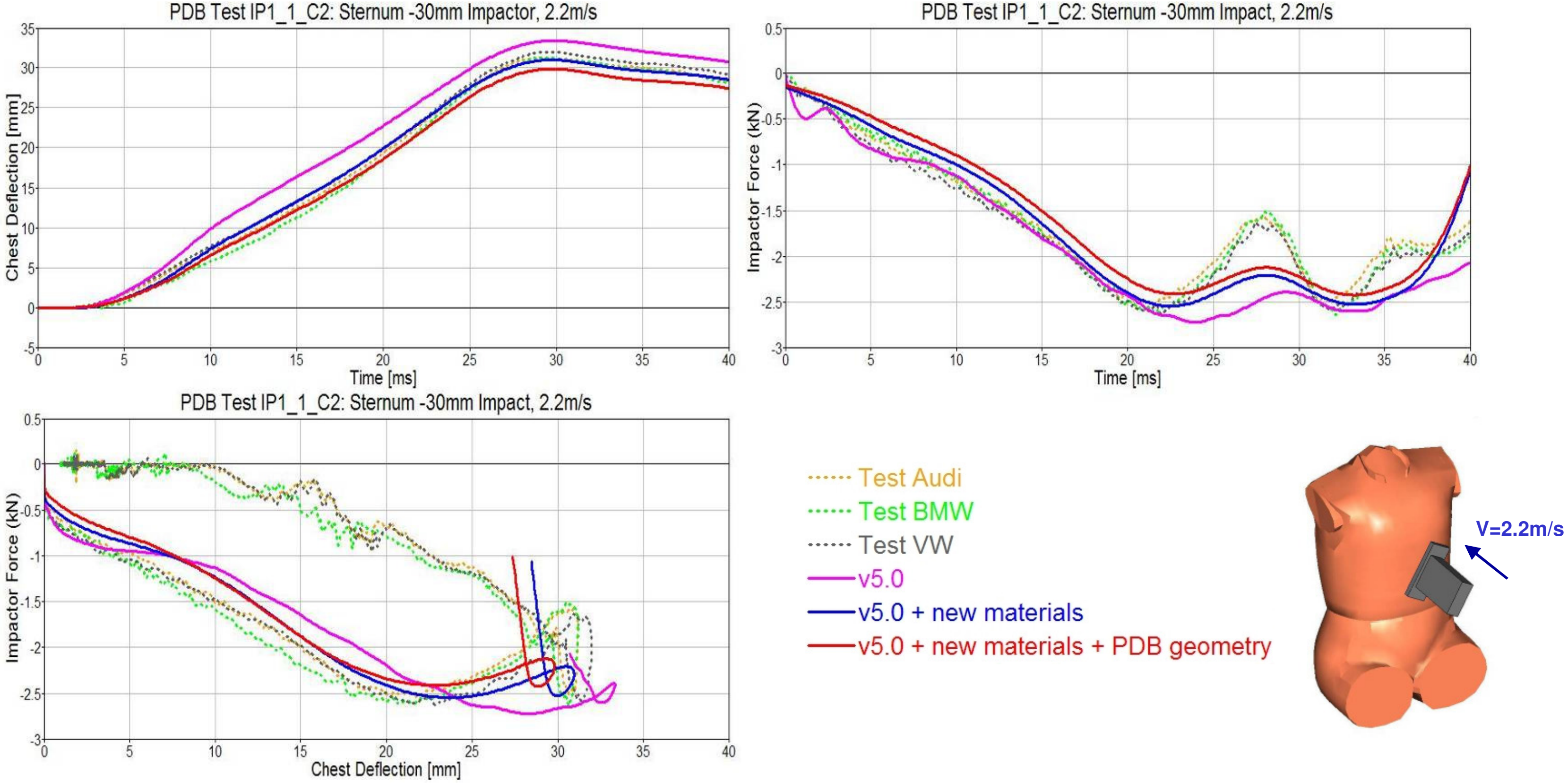
- Geometry Improvements



Thorax Model

Sternum -30mm Impact Test

Load case test ID: IP1_1_C2, Final Correlation



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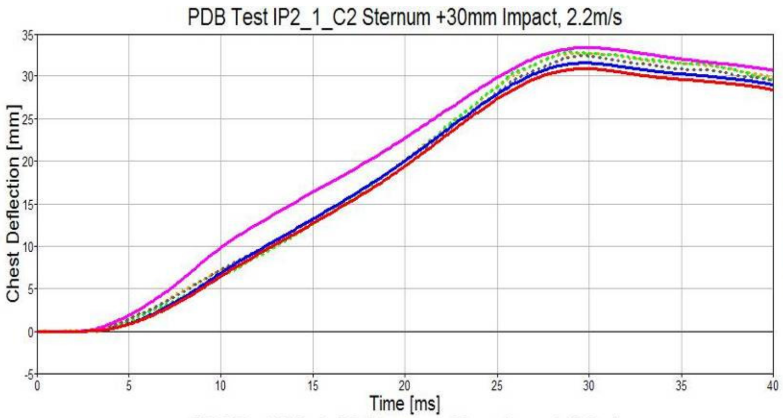
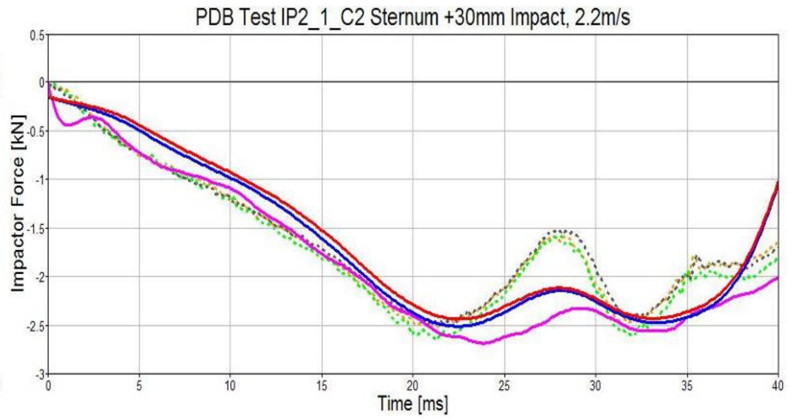
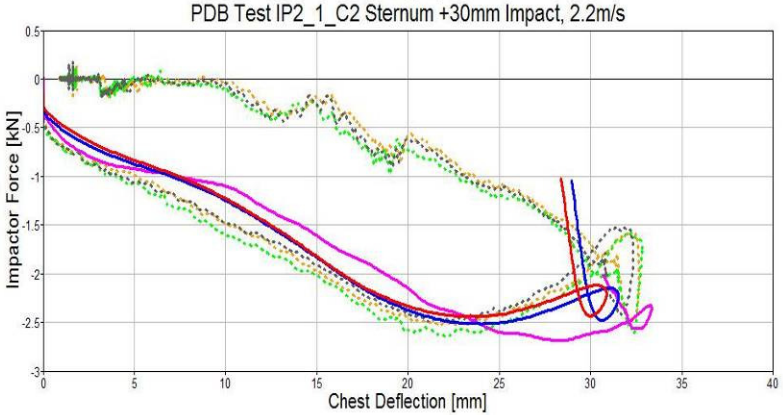
Thorax Model

Sternum +30mm Impact Test

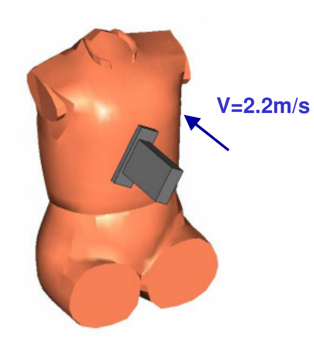
Load case test ID: IP2_1_C2, Final Correlation







Test Audi
Test BMW
Test VW
v5.0
v5.0 + new materials
v5.0 + new materials + PDB geometry



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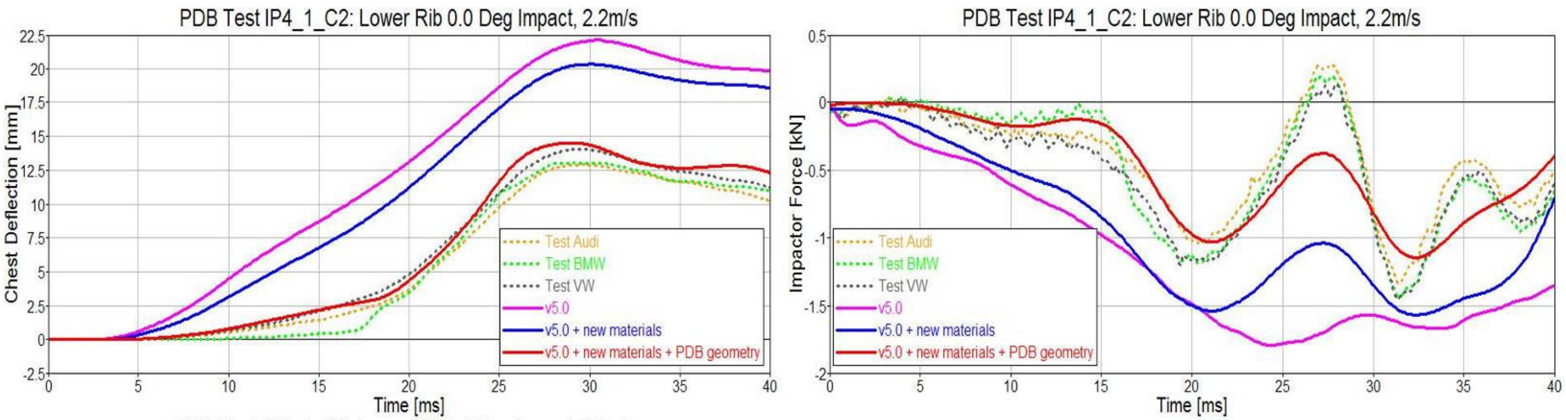
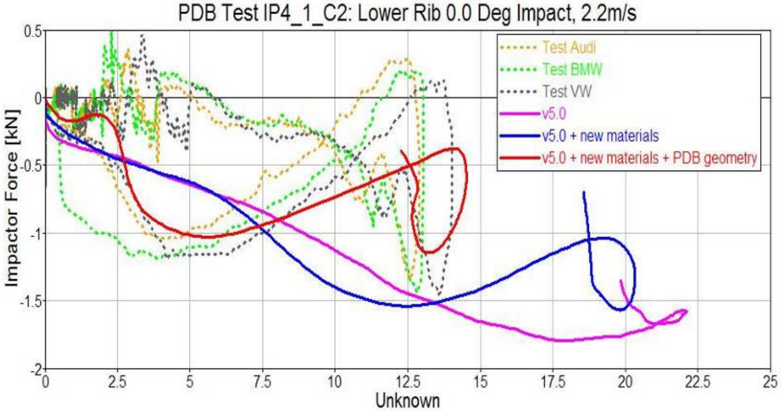
Thorax Model

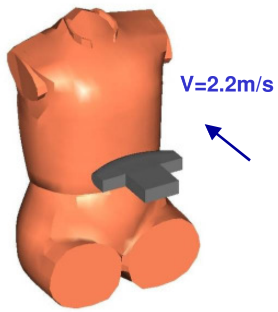
Lower Rib 0 Deg Impact Test

Load case test ID: IP4_1_C2, Final Correlation





Test Audi
Test BMW
Test VW
v5.0
v5.0 + new materials
v5.0 + new materials + PDB geometry



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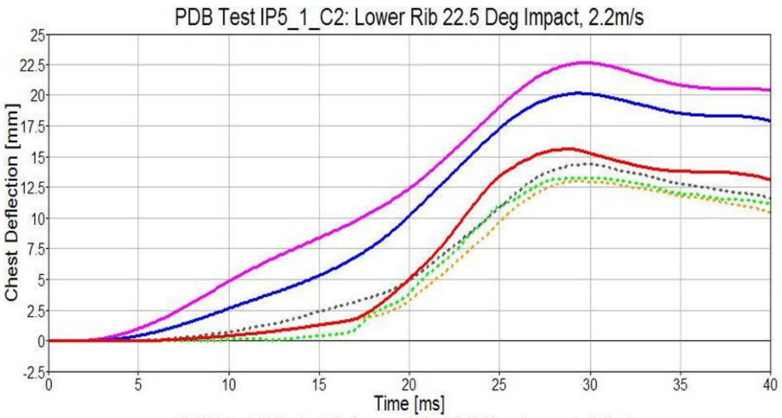
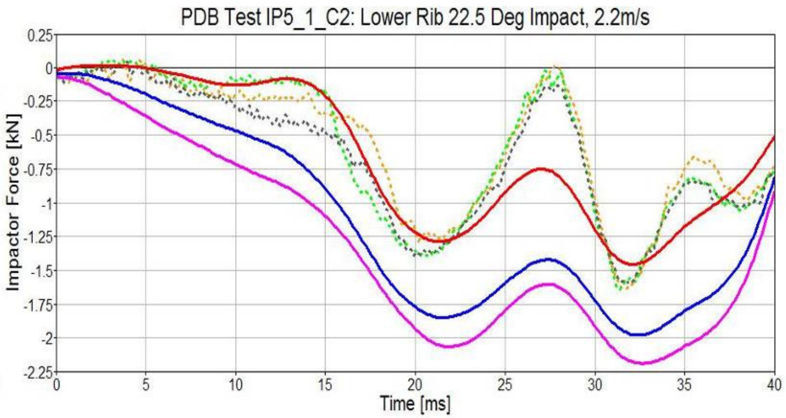
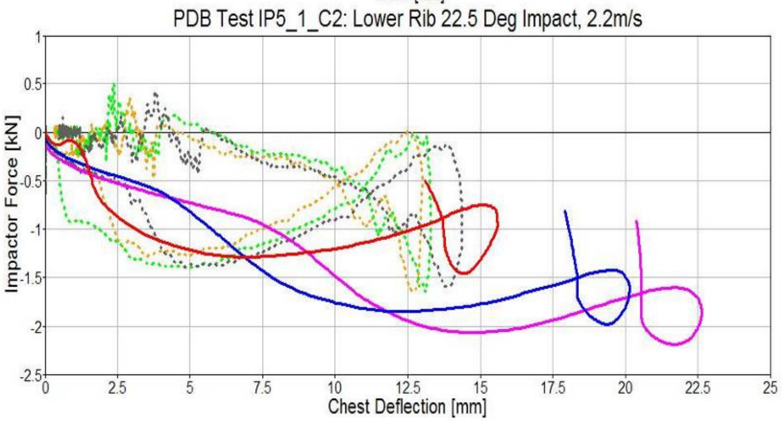
Thorax Model

Lower Rib 22.5 Deg Impact Test

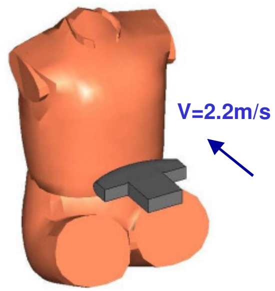
Load case test ID: IP5_1_C2, Final Correlation







Test Audi
Test BMW
Test VW
v5.0
v5.0 + new materials
v5.0 + new materials + PDB geometry



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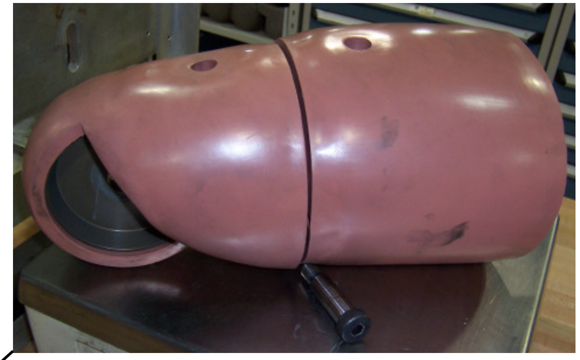
Upper Leg Model

- Modeling modification – mass distribution 1
  - re-calibration the upper leg and knee mass distribution in the FE model

Upper leg total mass: 6.05 kg



Knee foam: 0.6668 kg

Upper leg foam: 1.4197 kg

Knee cap (aluminum) + screw: 0.6758 kg.

Knee insert (rubber): 0.059 kg.

Knee shaft (solid steel): 0.6395 kg

Upper leg bone (steel) +2 screws: 2.59 kg

Lower Leg Model

- Modeling modification – mass distribution 2
  - re-calibration the lower leg mass distribution in the FE model

Lower leg and foot total mass: 5.41 kg

Foot vinyl + steel insert + ankle screw: 1.129 kg

Knee slider assembly + screw 0.4808 kg.

Ankle assembly +screw: 0.771 kg.

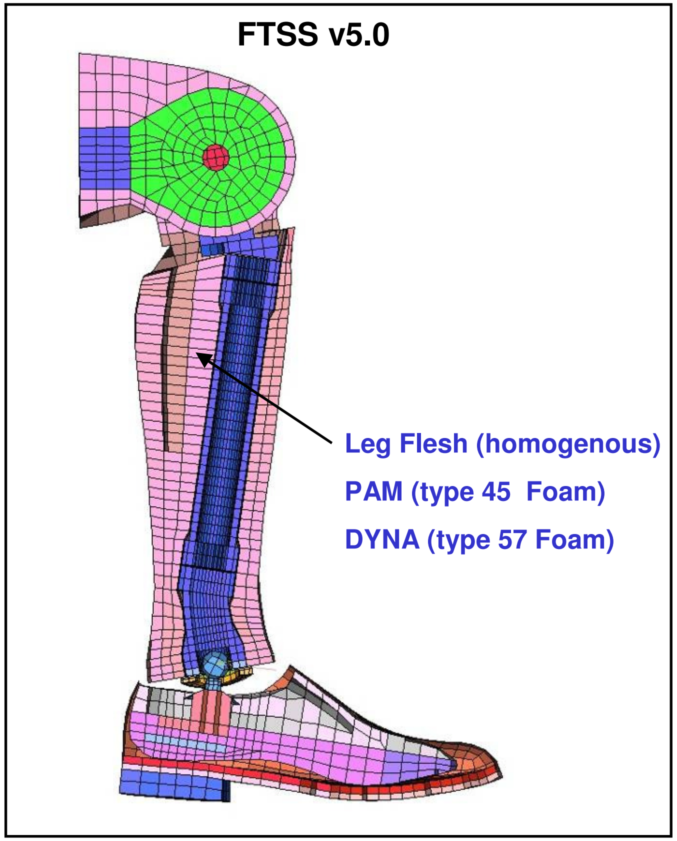
Lower leg bone (hollow inside) + screw 2.0048 kg.

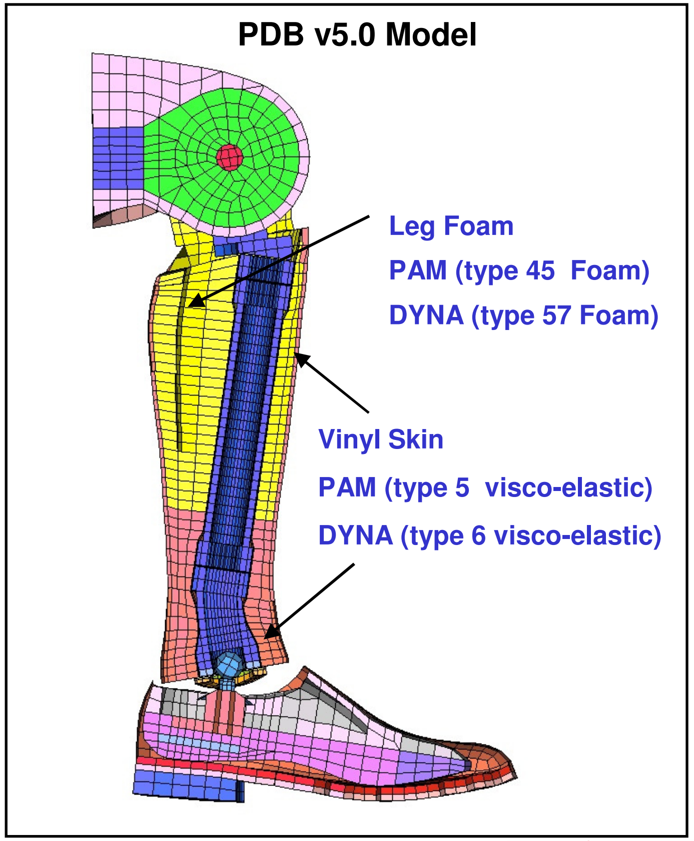
Lower leg foam: 1.0205 kg.

Lower Leg Model

- Model modification
  - The lower leg flesh is now sub-divided into 2 parts:

    1. Outer vinyl skin 2. Inner leg foam





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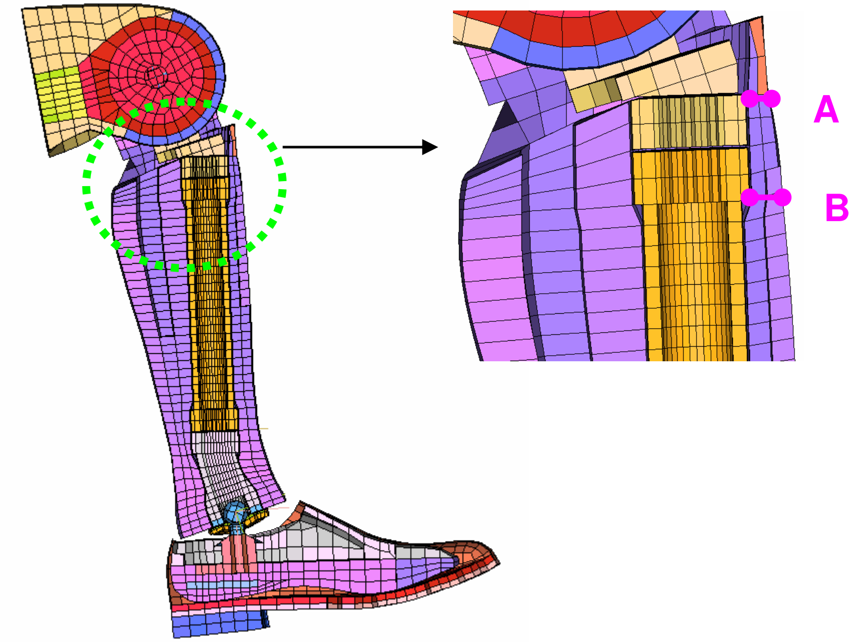
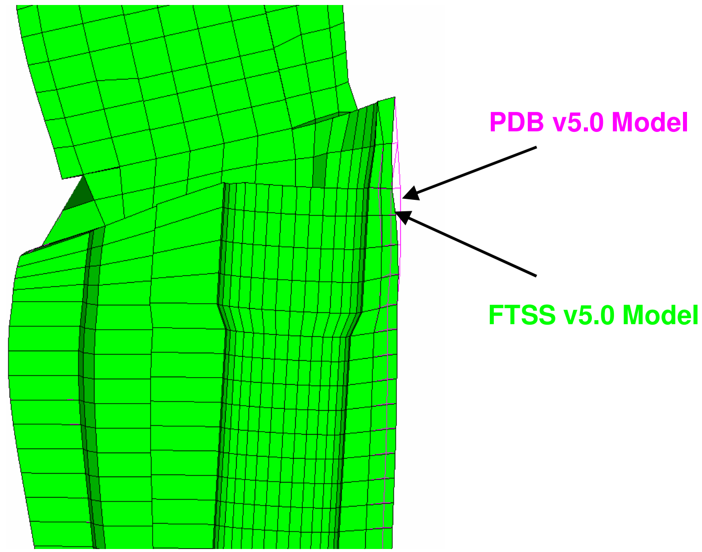
Lower Leg Model

- Geometry modifications
  - Measurements were taken in positions A and B of the standard un-instrumented H3-50 lower leg and the PDB model adjusted accordingly.



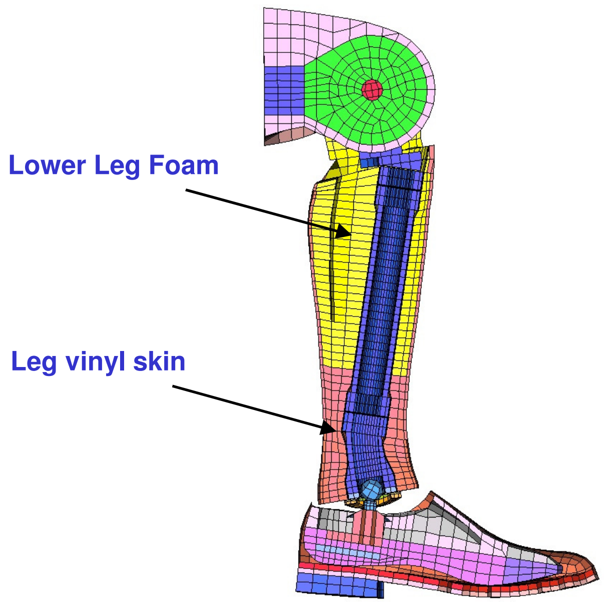


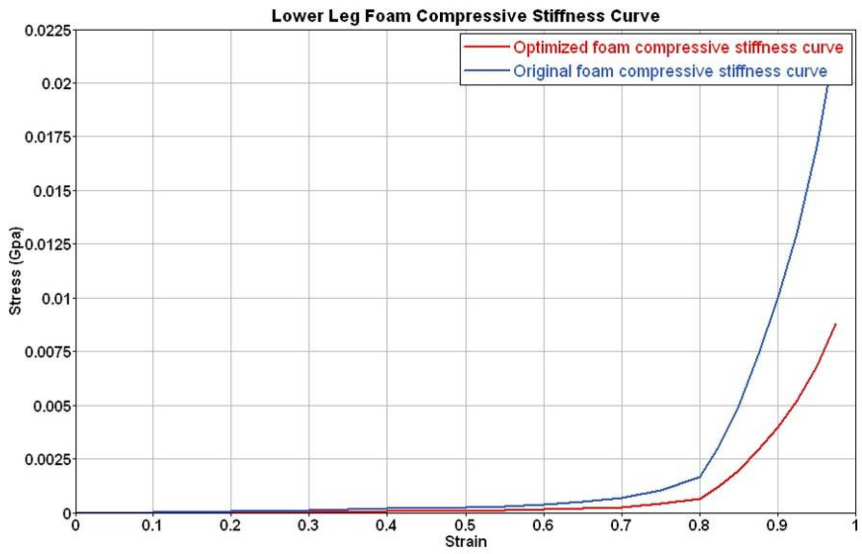
FE Model Cross Section
Overlay Comparison

Thickness at position A:	Thickness at position B:
Physical Dummy : 10.4	Physical Dummy: 11.75
PDB v5.0 Model : 10.38	PDB v5.0 Model : 11.8

Lower Leg Model

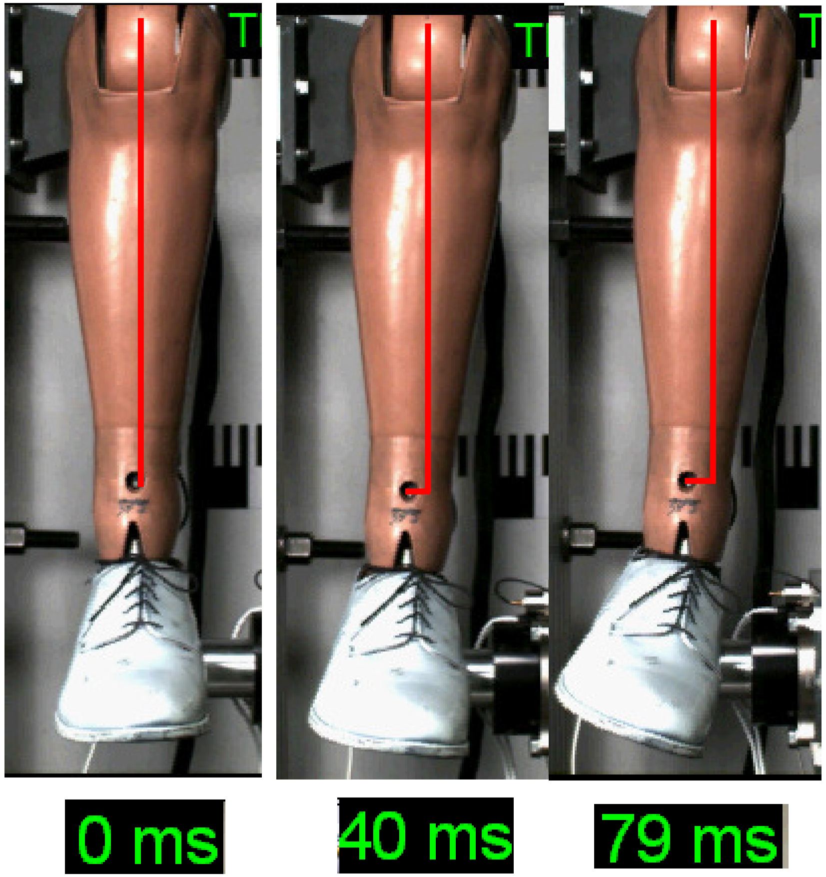
- Material optimization for lower leg vinyl skin
  - The vinyl skin properties are optimized using the Tibia_IP3a load case
- Material optimization for lower leg inner foam
  - The inner leg foam stiffness is optimized using the Tibia_IP2a load case





Knee Model

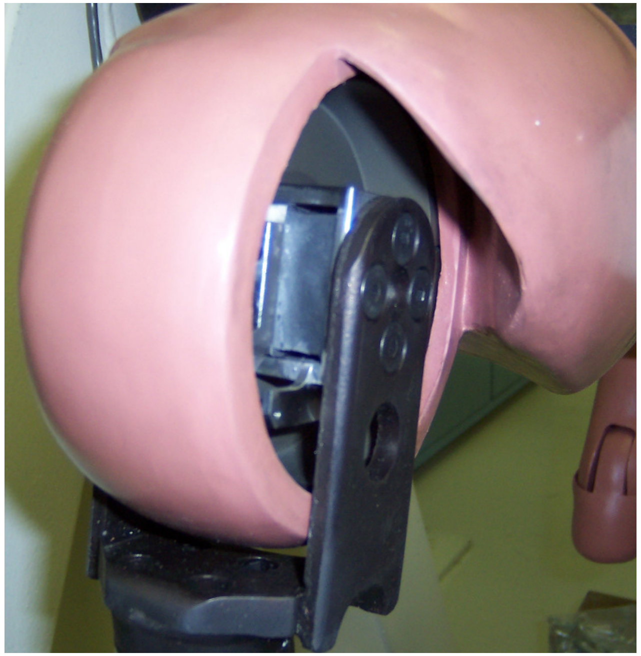
- The IP8, IP9, IP10 (Y-direction loading) test videos show the lower leg rotating relative the knee joint during the first phase of the impact.



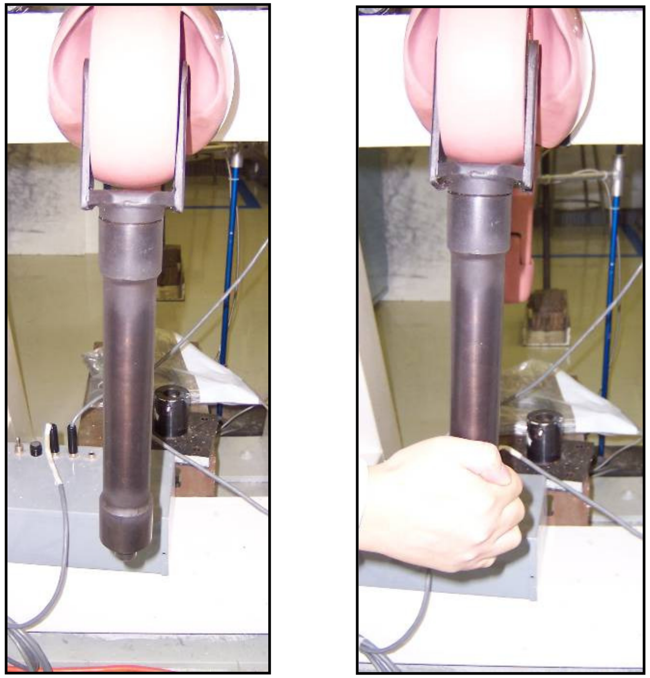
PDB test video (**IP8**) shows that lower leg rotates relative to the knee.

Knee Model

- Investigation in the FTSS lab shows that manual force can rotate the lower leg relative to the knee by 3-5 degrees quite easily.
- **Conclusion:** The clevis has some rotational compliance.



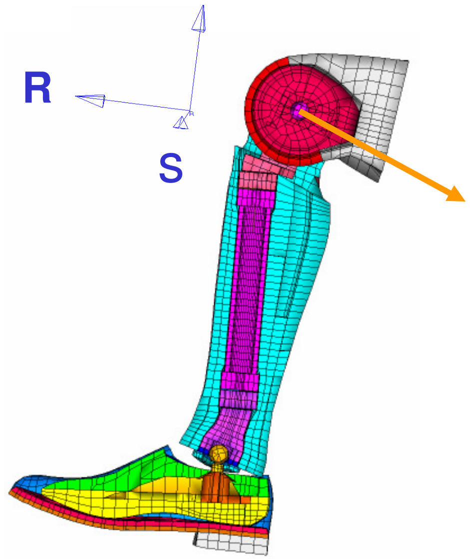
Knee Clevis

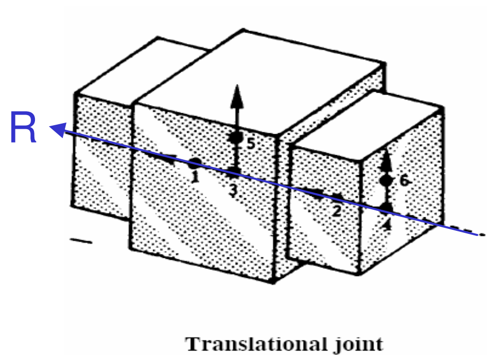


Investigation confirms that the clevis joint rotates.

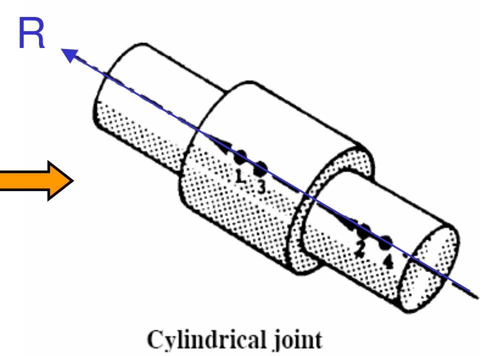
Knee Model

- Dyna specific modifications
  - The H350 v5.1 Dyna model clevis is represented by a translational joint with a knee clevis spring for clevis displacement.
  - In the new PDB v5.0 model, the translational joint is replaced by a cylindrical joint with a rotational spring (defined along the local R- axis of the joint) for rotational compliance.





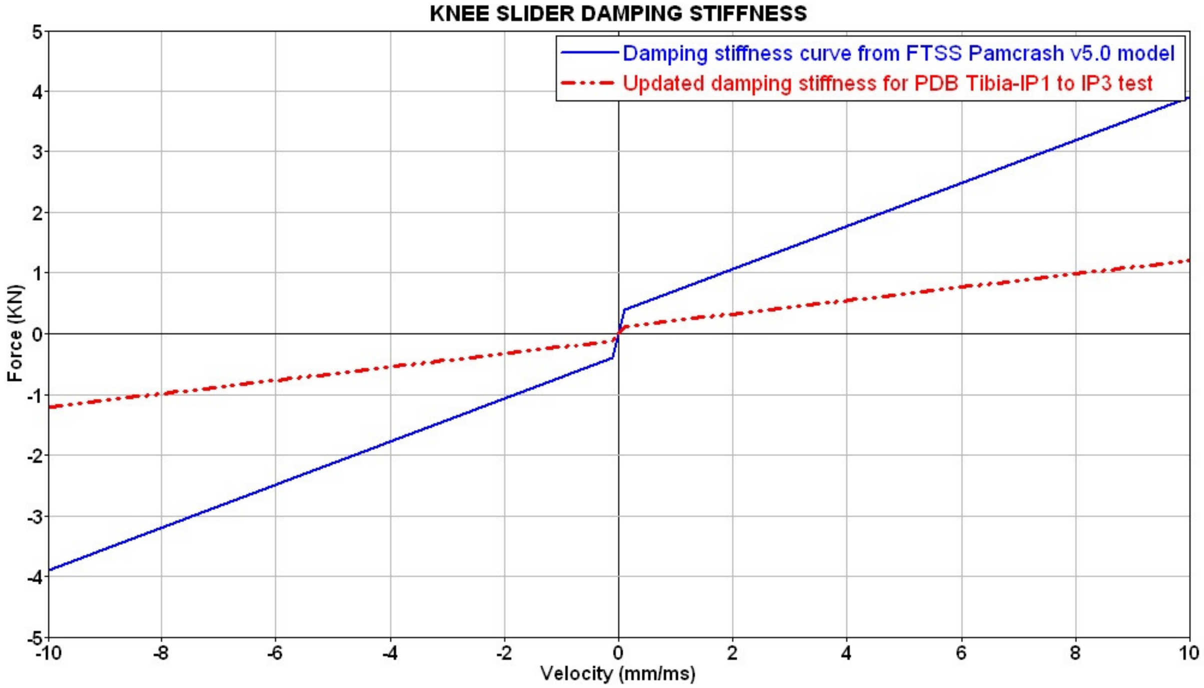
H350 v5.1 Dyna



PDB v5.0 Dyna

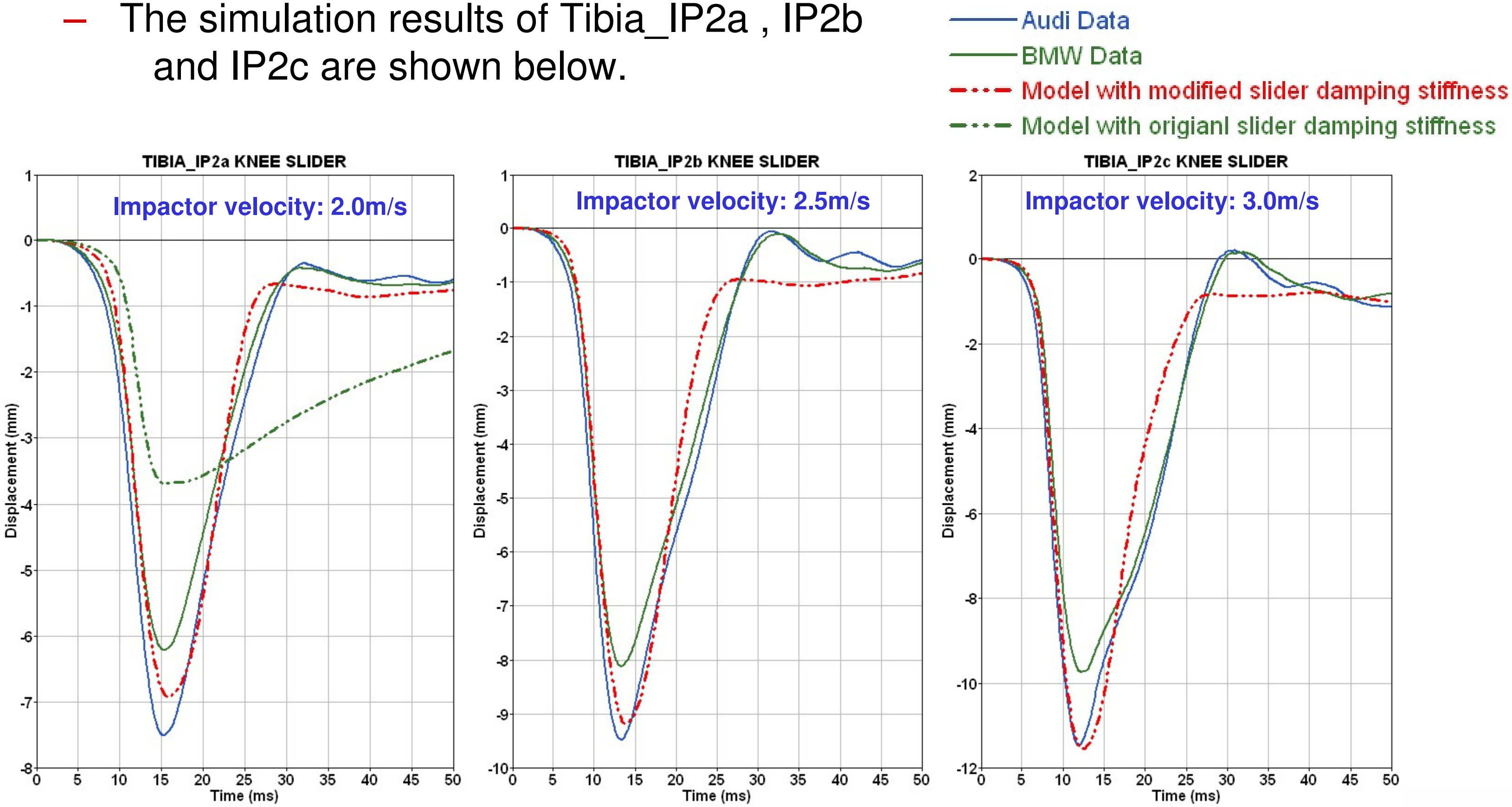
Lower Leg Model

- Knee slider modification
  - The knee slider damping stiffness curve shown below in the red dotted line is optimized for improved knee slider and upper tibia behavior.
  - The original characteristic is shown in blue. now use the knee slider damping characteristic shown in red dotted line.



Knee Model

- Knee slider modification
  - The knee slider damping characteristic is optimized using the IP2 load case. Relates to three different impact velocities.
  - The simulation results of Tibia_IP2a , IP2b and IP2c are shown below.



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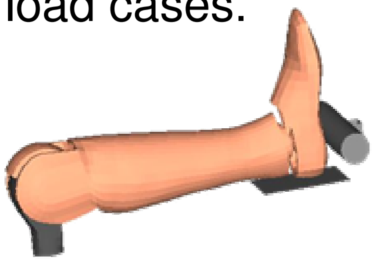
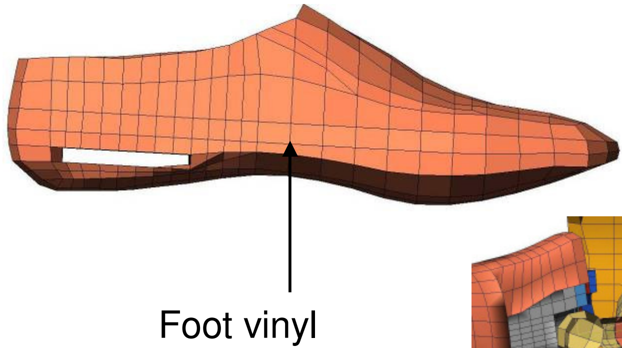
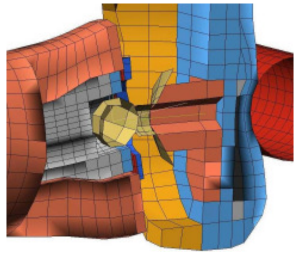
Foot and Shoe Model

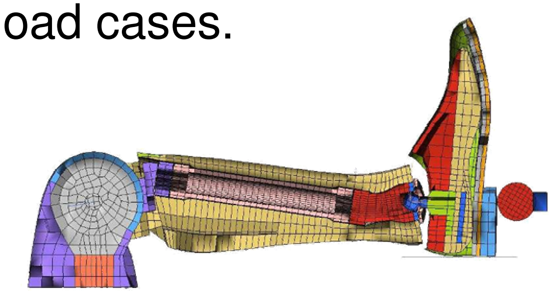
- The foot vinyl material properties are optimised using the IP4_No_a (no shoe) impact load cases.

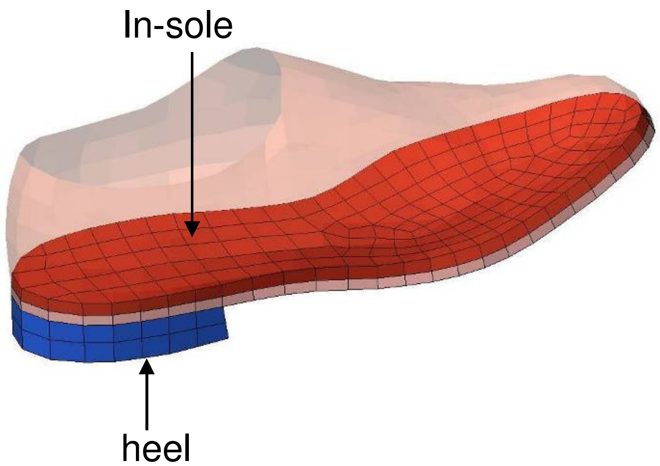






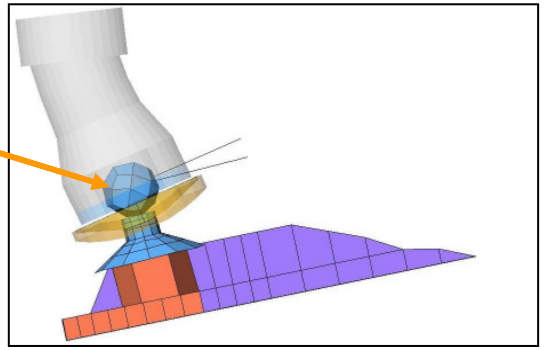
- The shoe in-sole and heel properties are optimised using the IP4_Ba/Su (with shoe) load cases.



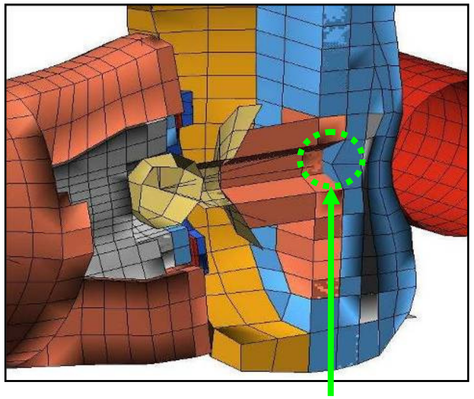


Foot and Shoe Model

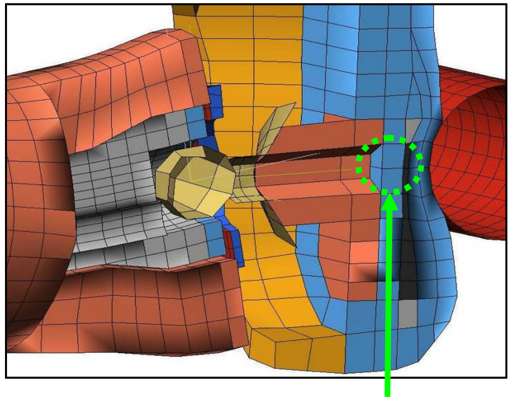
- Ankle stop angles defined for X, Y, Z axis
- Ankle joint orientation co-ordinate system now defined relative to foot ankle ball, instead of lower leg as in v5.0 model.



- A foot vinyl node was incorrectly attached to the foot bone. This is fixed.



This node was not constrained to the foot bone.



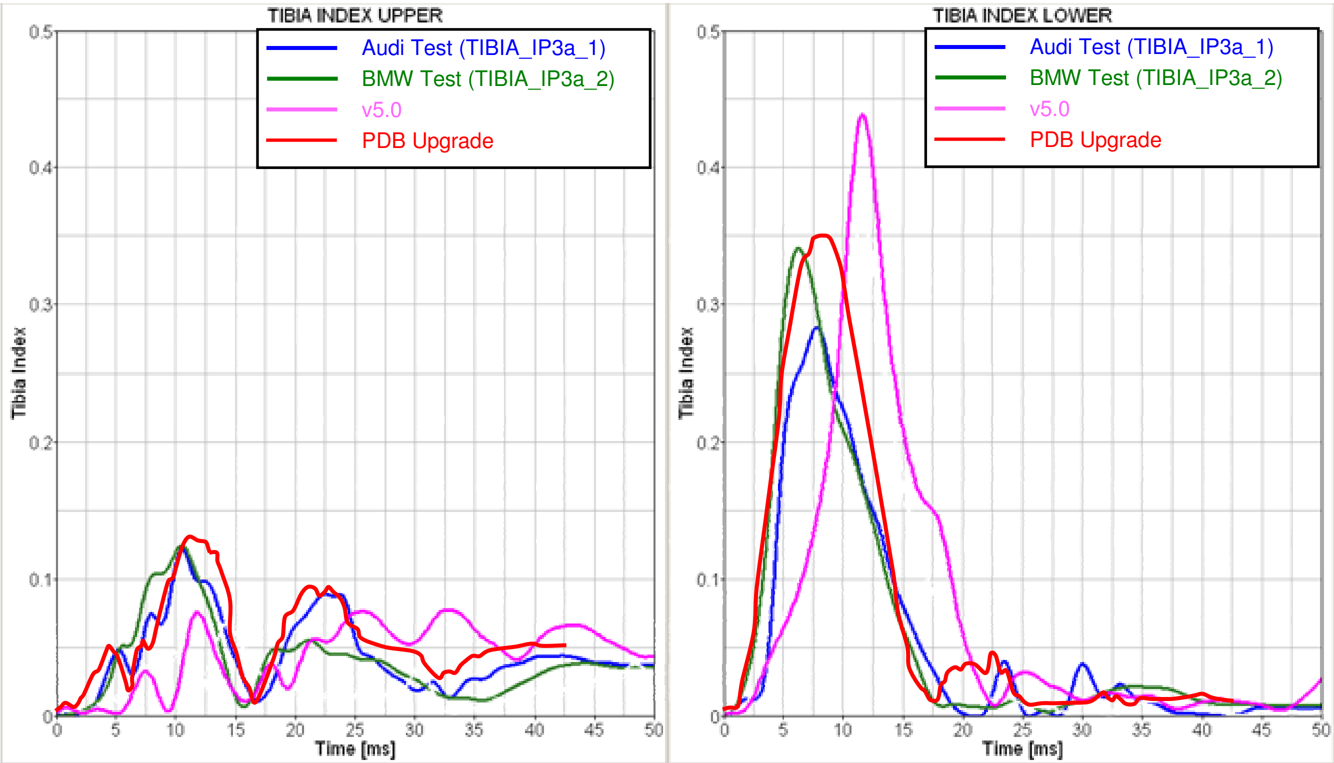
Fixed in the new model

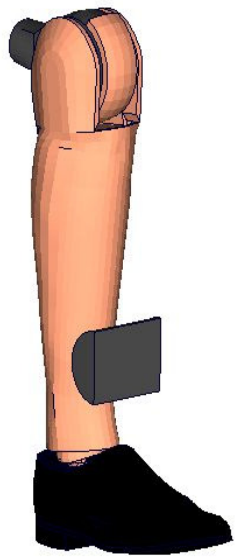
Lower Leg Model

Lower Leg TIBIA_IP3a

Tibia Index Upper and Lower

$TI = |M_R / (M_R)_C| + |F_Z / (F_Z)_C|$
$(M_R)_C = 225\ Nm$
$(F_Z)_C = 35.9\ kN$





Lower Leg Model

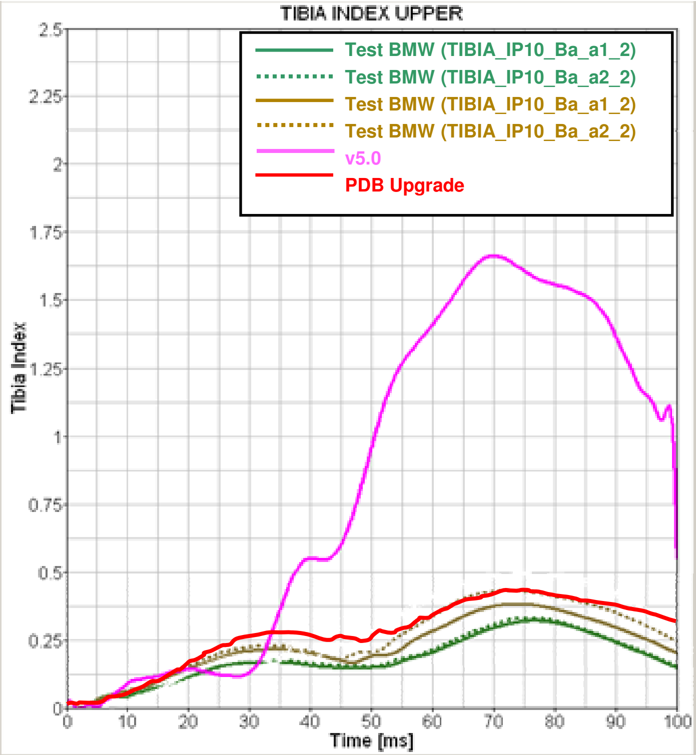
TIBIA_IP10_Bates Shoe

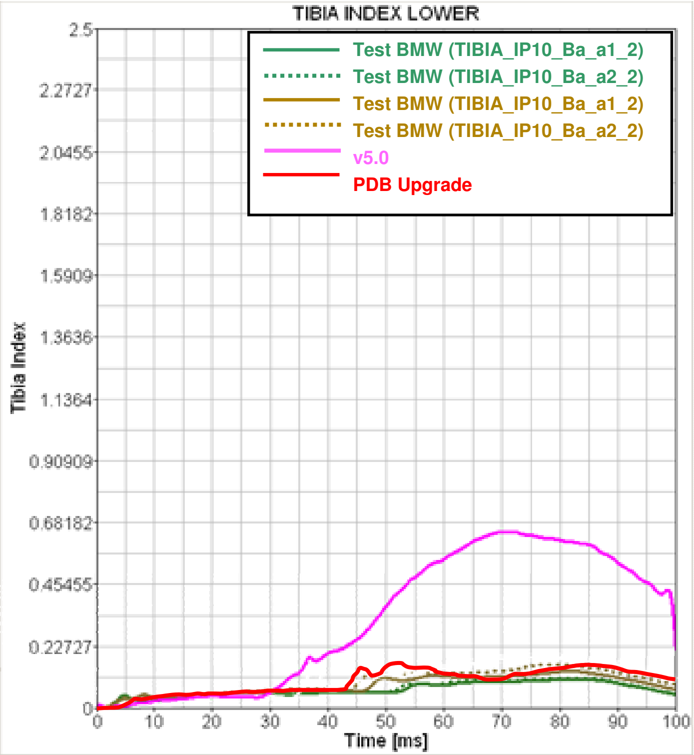
Tibia Index Upper and Lower

$TI = |M_R / (M_R)_C| + |F_Z / (F_Z)_C|$

$(M_R)_C = 225\ Nm$

$(F_Z)_C = 35.9\ kN$





H3-50th Upgrade Plan

- H3-50 G-2 model upgrade project
  - Local/global geometry verification/update;
    - Global geometry check
    - Pelvis,abdomen and Jacket – vinyl and foam separated
    - Stability
  - New material models
    - Vinyl
    - Foam
    - Rubber
    - Rib Damping
  - New component testing
    - Oblique and Orthogonal
      - Lumbar
      - Neck
      - Ribs
    - PDB Thorax Impactor – Airbag

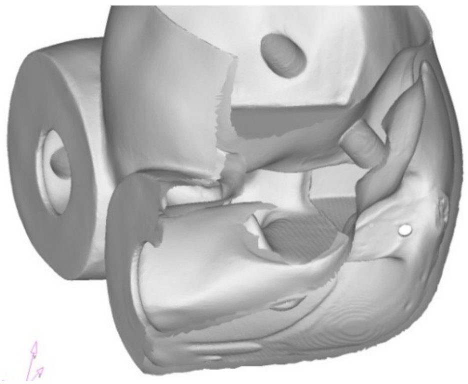
H3-50th Upgrade Plan

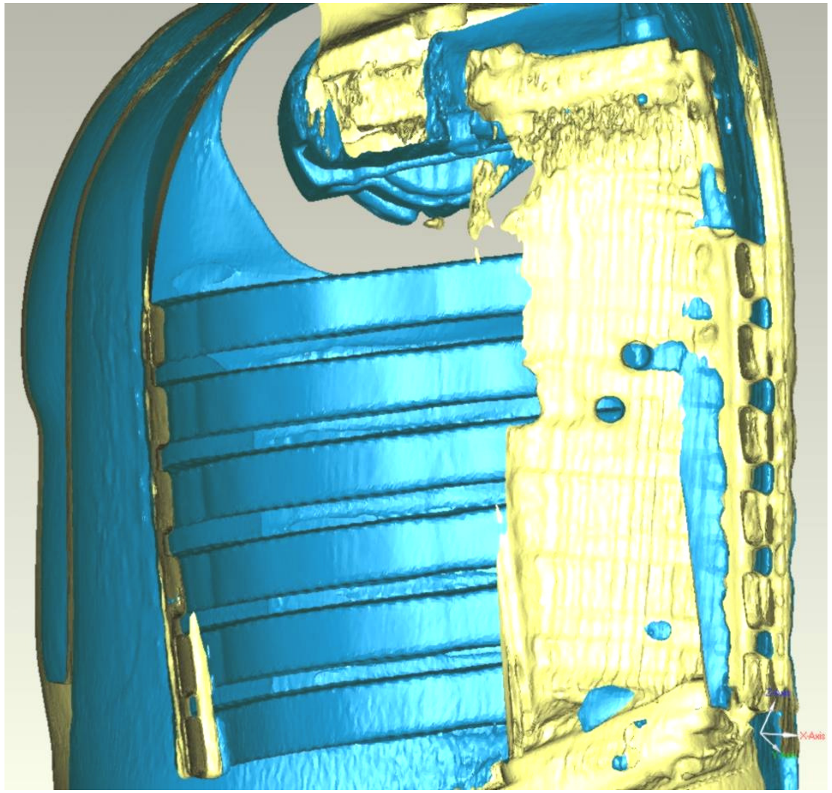
- H3-50 G-2 model upgrade project
  - PDB Sled Testing
  - More Optional instrumentation output channels modeled
  - Model available for Beta testing by PDB members at end of October
  - Production release v6.0 by early January

Geometry Improvements

Geometry Improvements

X-Ray Scanning





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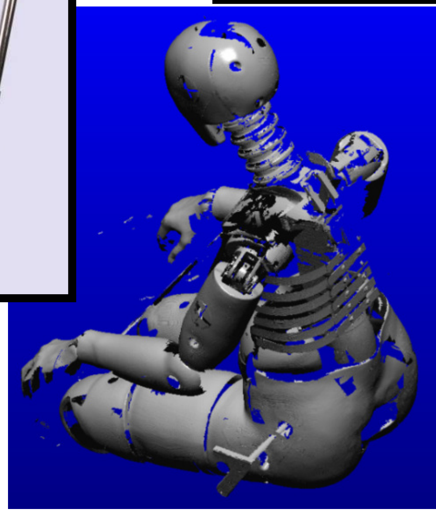
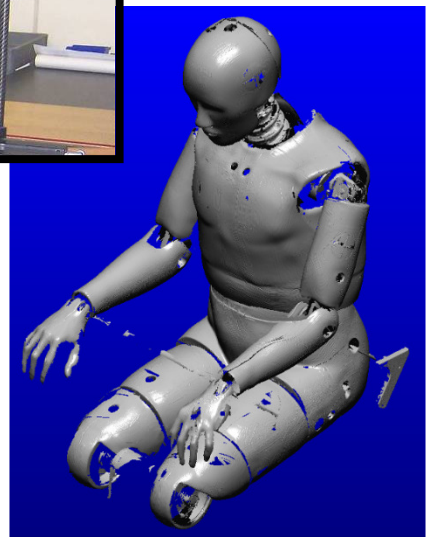
Geometry Improvements

Laser Scanning with Fixture

Laser Scanner

Dimensional Fixture



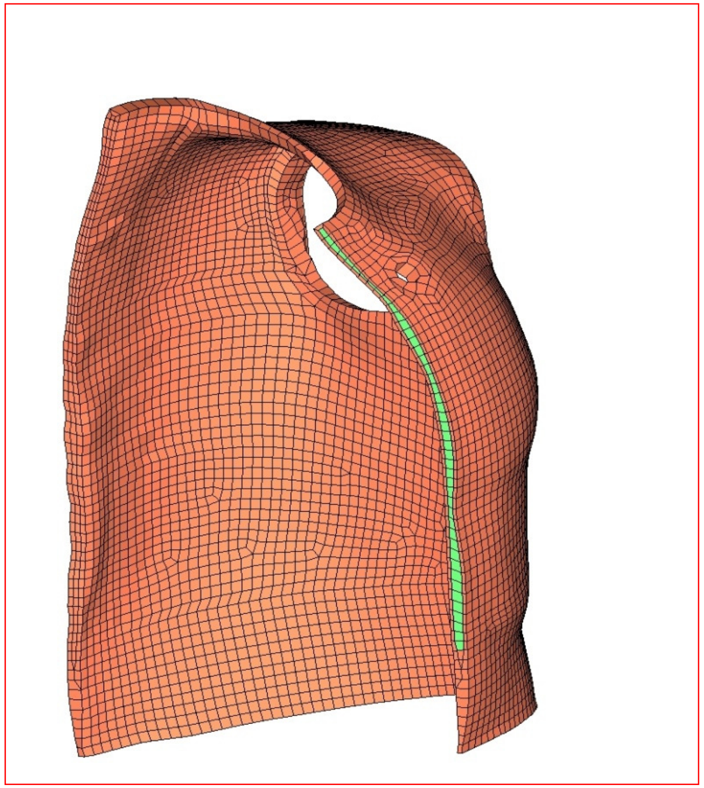


Measuring overall dimension, interference fit, aging and gravity effects

New Meshing

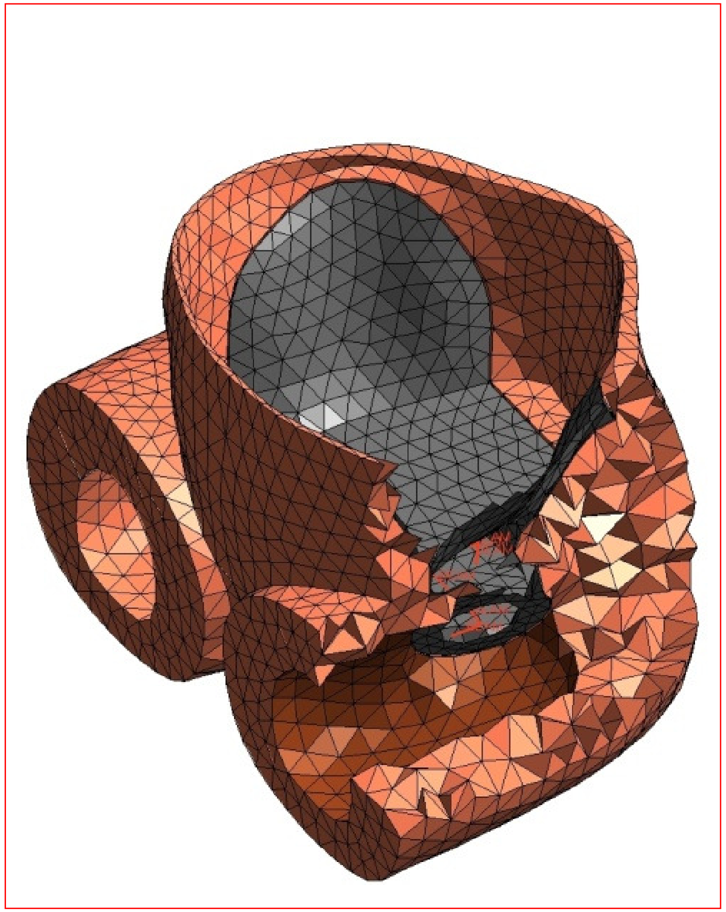
New Meshing

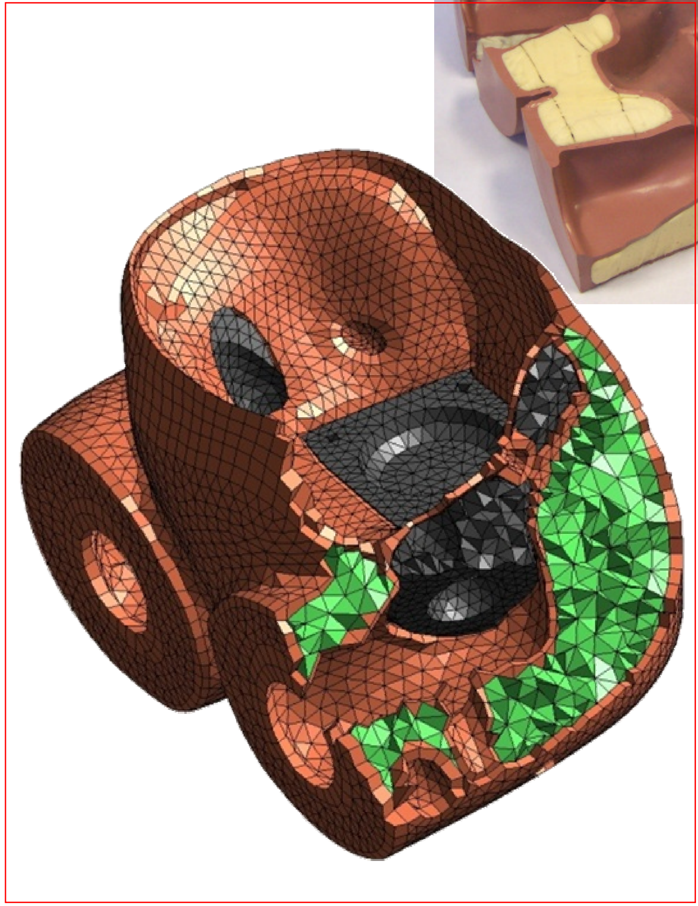
Jacket

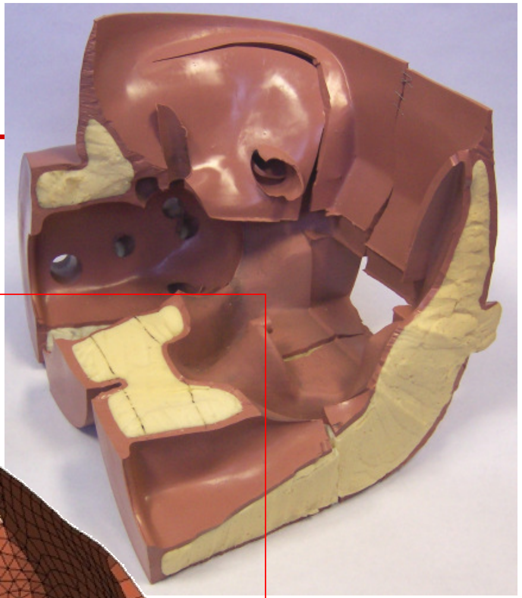


New Meshing

Pelvis

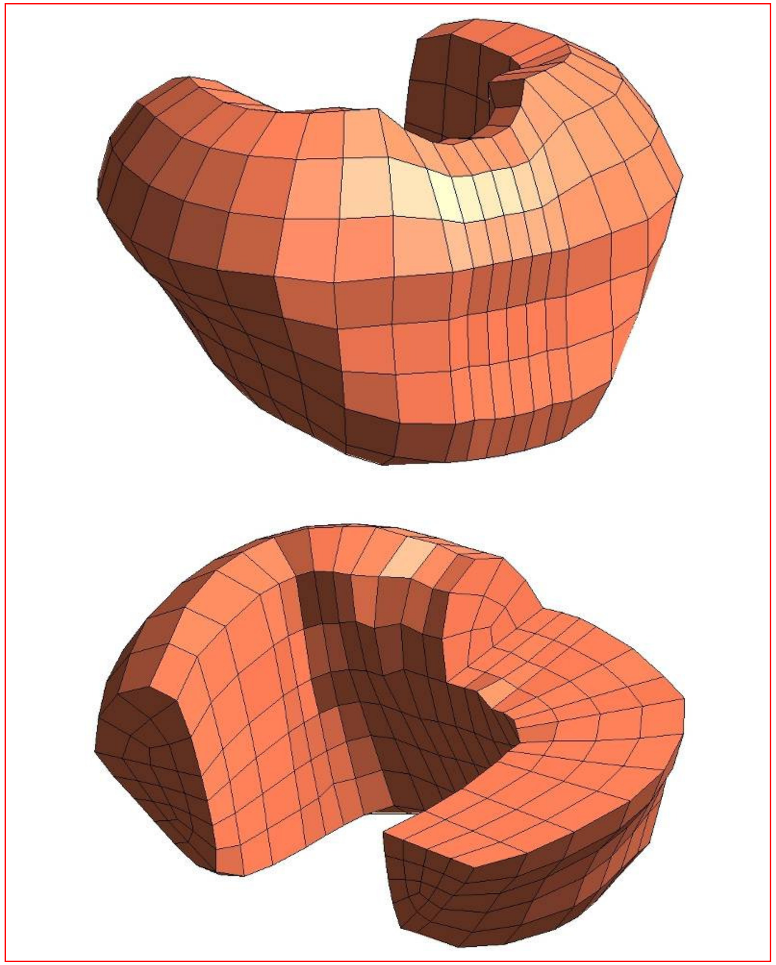


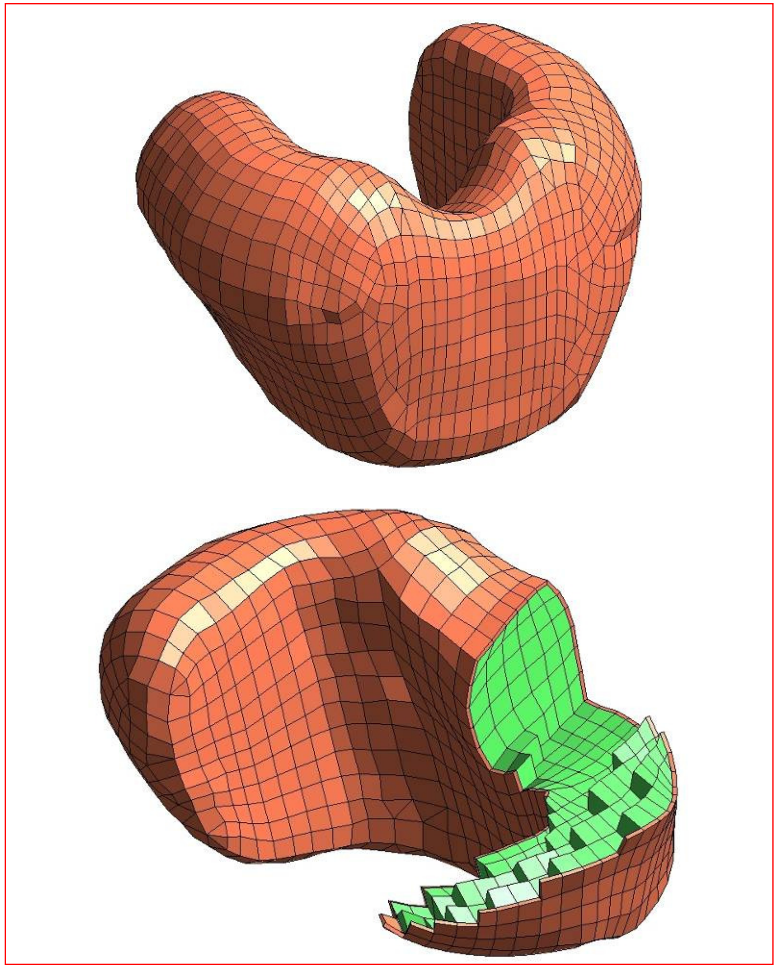




New Meshing

Abdomen





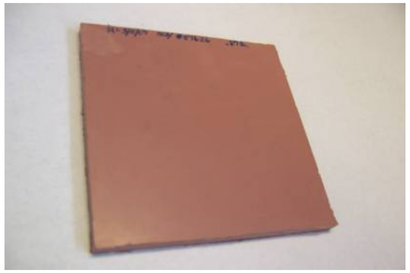
Material Tests

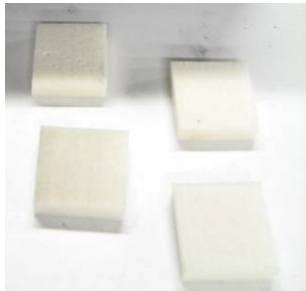
Material Tests

Material	Strain Rate	Test Type
Vinyl 2 Grades	4 rates	Compression Volumetric Compression Stress Relaxation
Butyl Rubber 3 Grades	4 rates	Compression Tension Stress Relaxation Volumetric Compression
Foam 3 Grades	4 rates	Compression
Ensolite Foam	4 rates	Same as above
Rib Damping Material	4 rates	Compression Stress Relaxation Poison’s Ratio

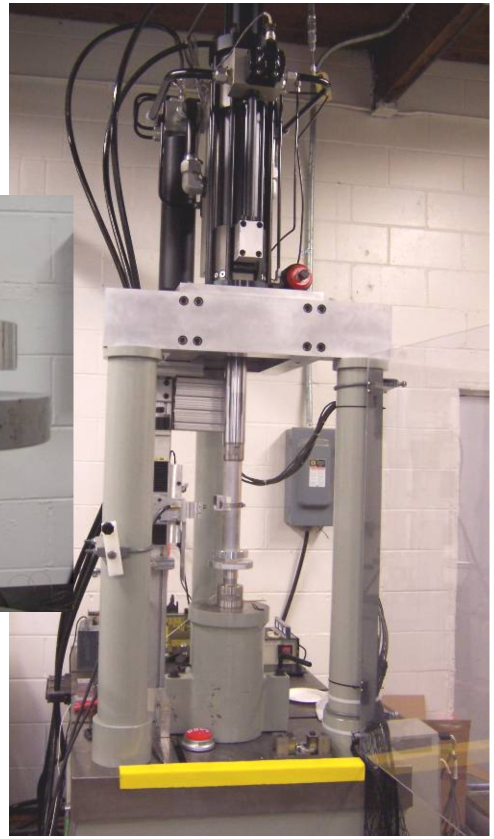
Total: 148 tests

Material Tests



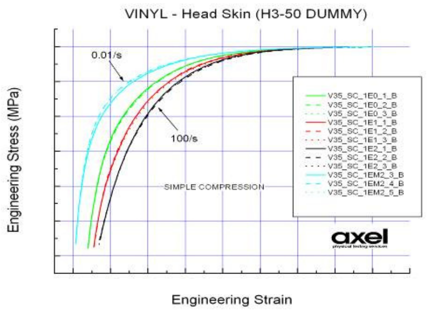


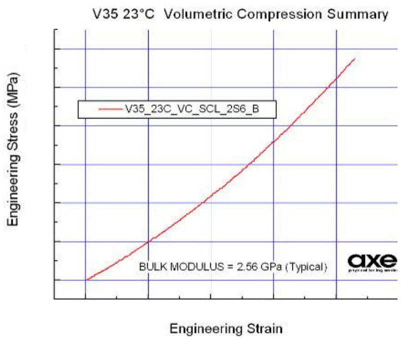
Axel Products, Inc.

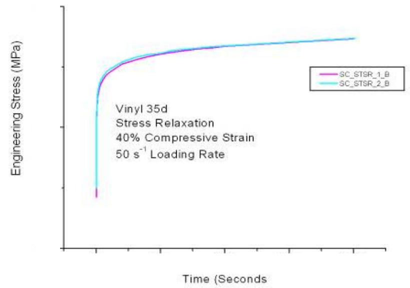


Material Tests - Vinyl

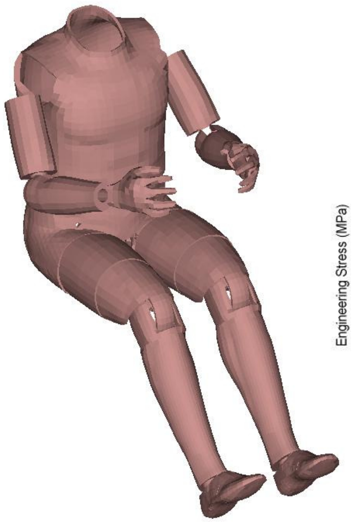
Head Skin

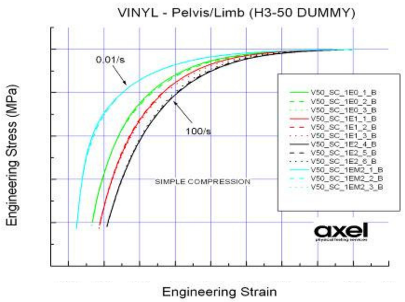


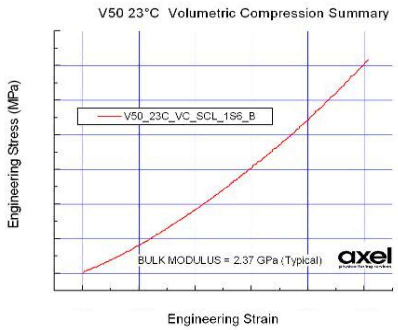


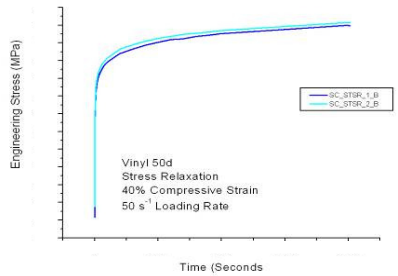


General

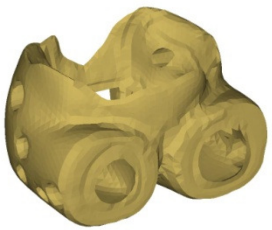


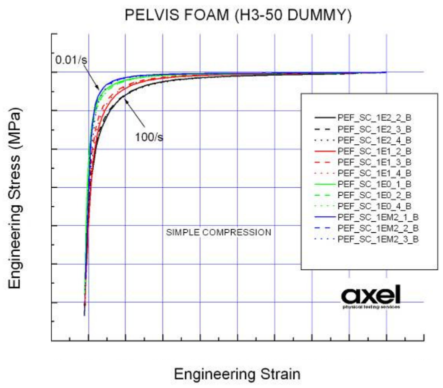


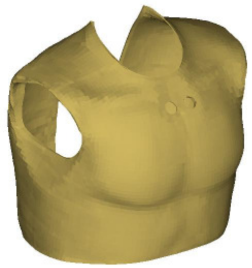


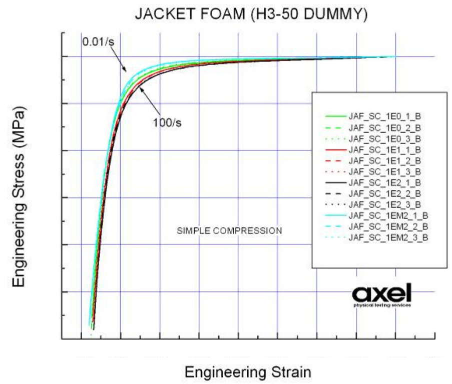


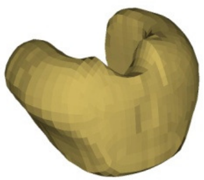
Material Tests - Foam

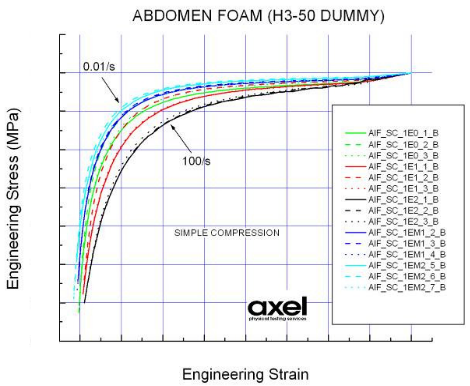


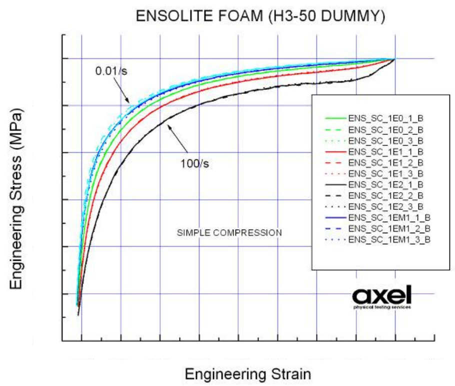




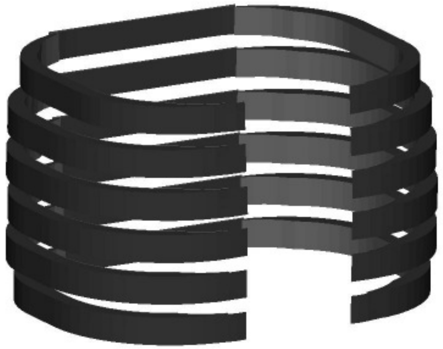


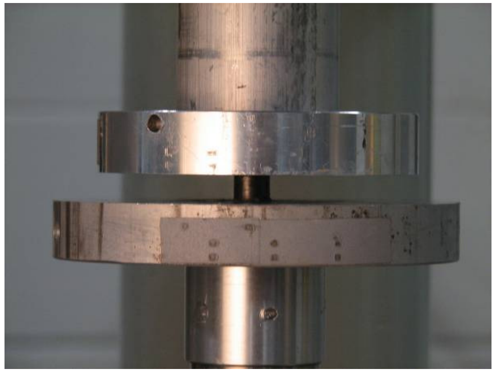


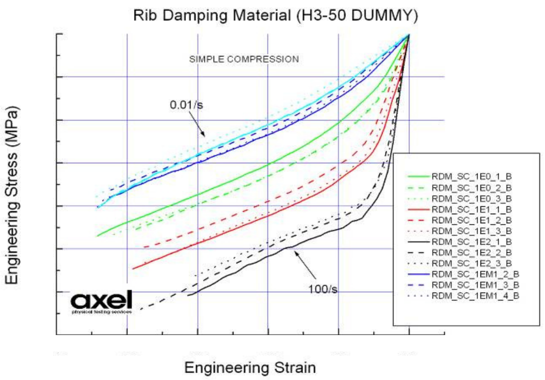


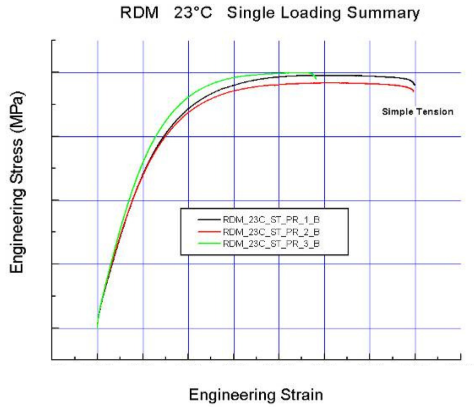


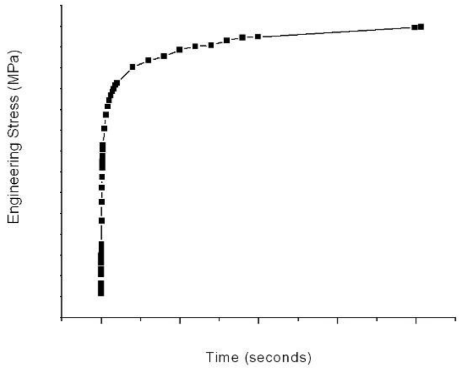
Material Tests - Rib Damping





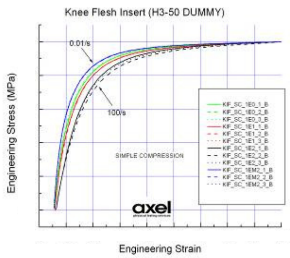


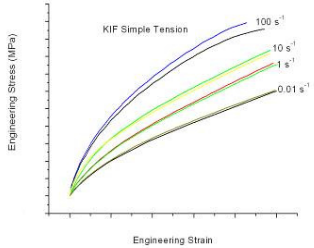


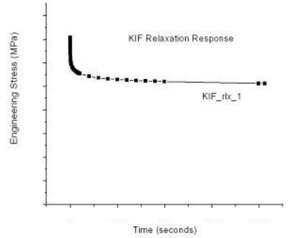


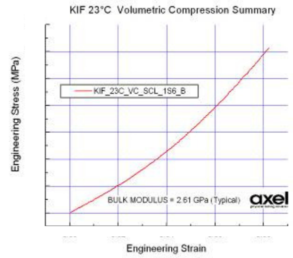
Material Tests - Rubber

Knee Insert

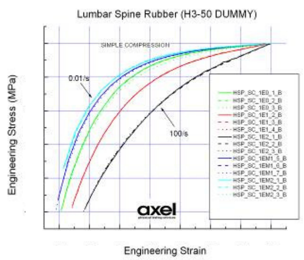


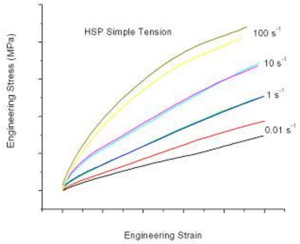


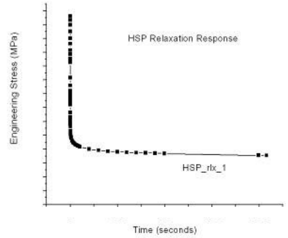


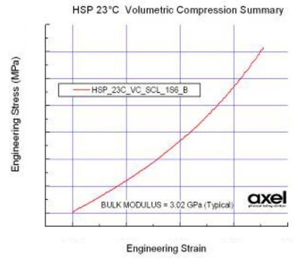


Lumbar Spine

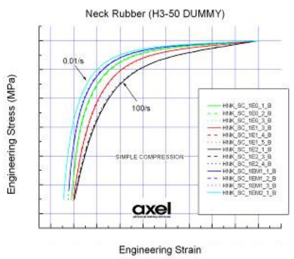


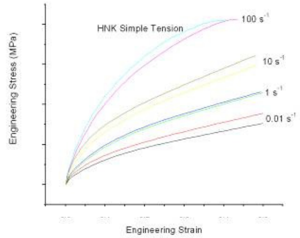


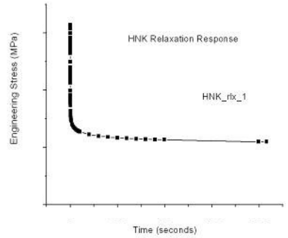


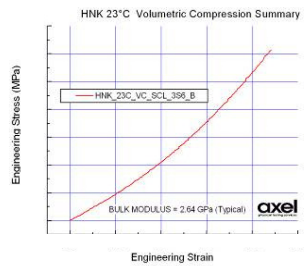


Neck







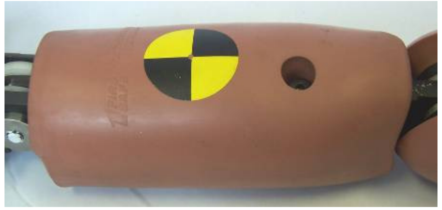


Component Tests

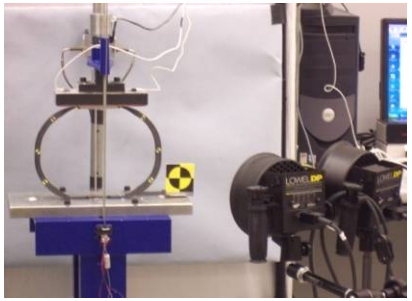
Component Tests

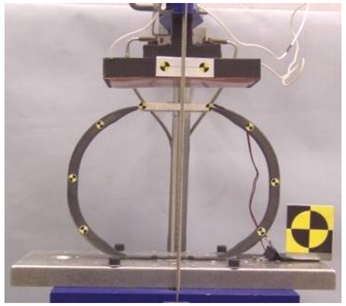
Dynamic impacts on components;

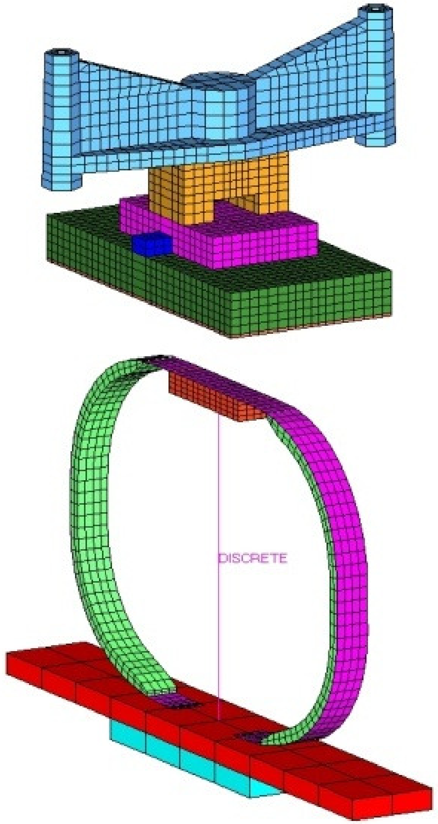
Quasi-static tests for joints



Component Tests



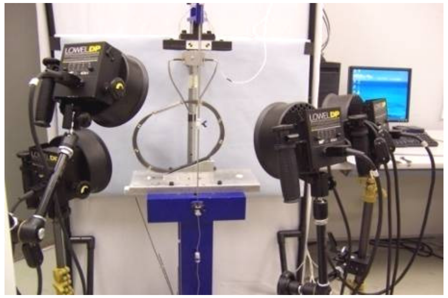


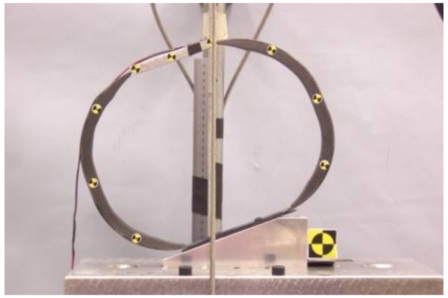


Single Rib Drop Test - Orthogonal

- 5 speeds
- Rib deflection ranges from 20mm to 73mm.
- High speed video used for tracking motion of multiple target points.

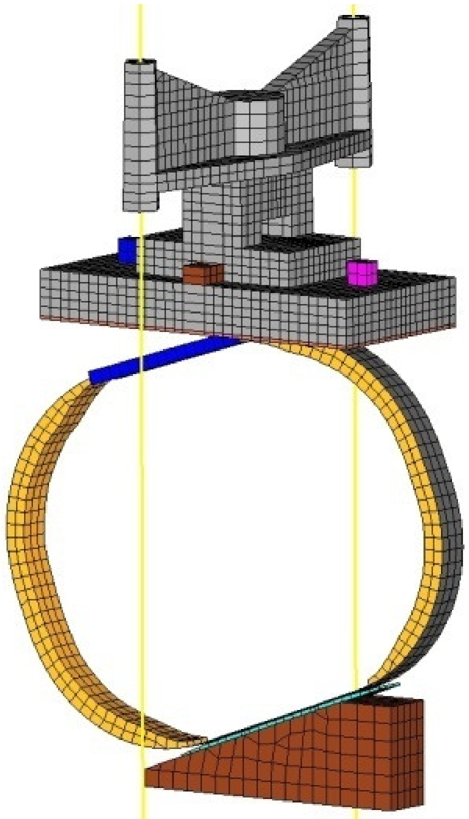
Component Tests



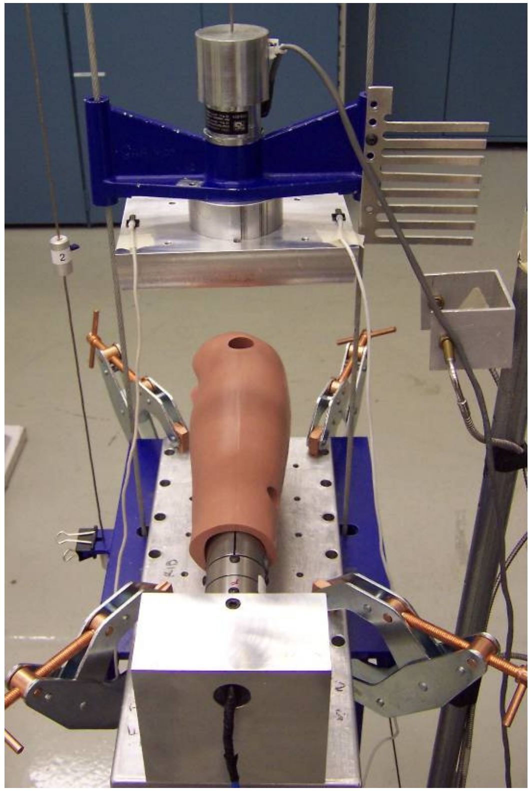


Single Rib Drop Test - Oblique

- 3 speeds
- Rib deflection ranges from 20mm to 40mm.
- High speed video used for tracking motion of multiple target points.

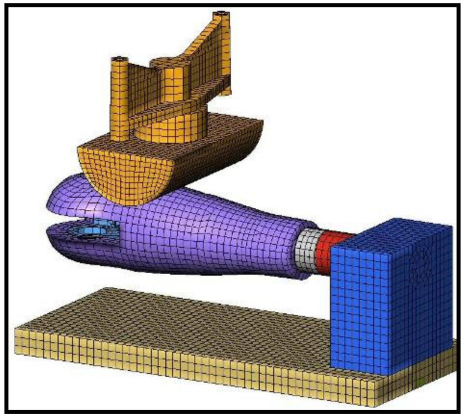


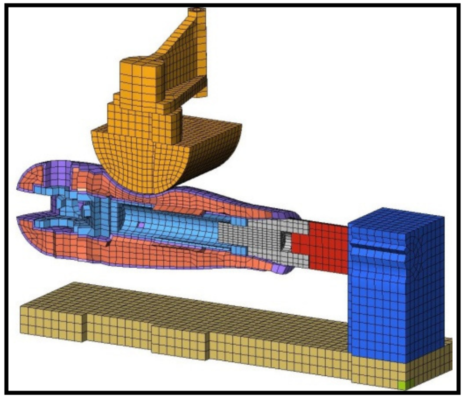
Component Tests



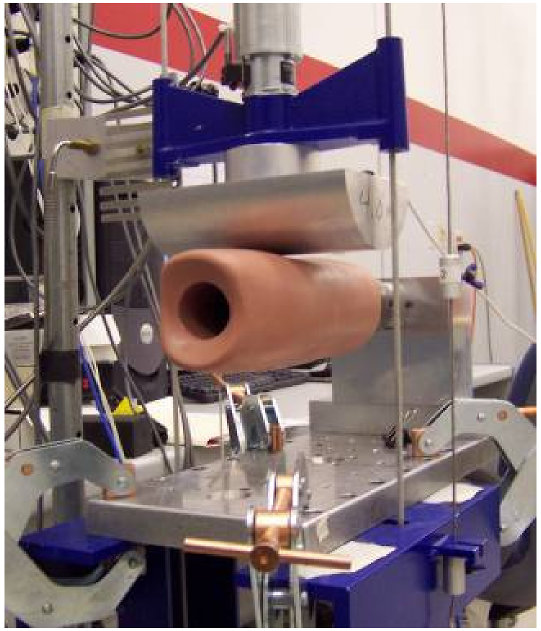
Lower Arm Drop Tests

- 6 speeds
- Drop head accelerations, force, and moment tracked.



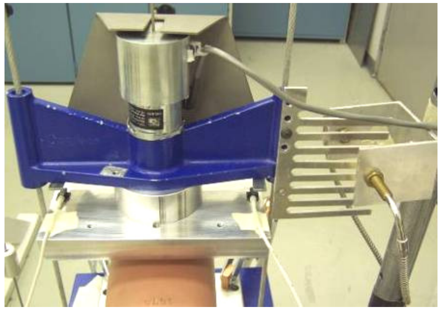


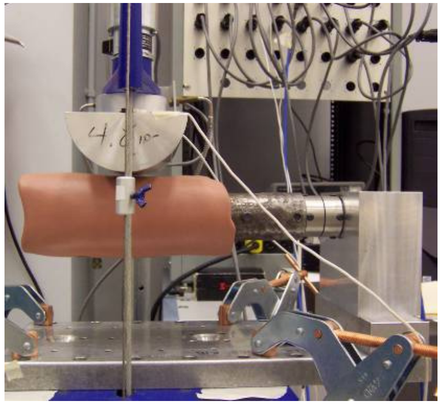
Component Tests



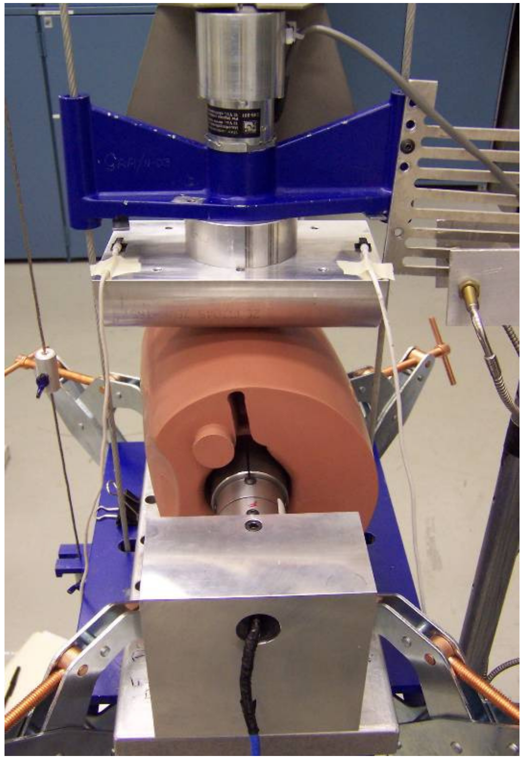
Upper Arm Drop Tests

- 3 speeds
- Drop head accelerations, force, and moment tracked.



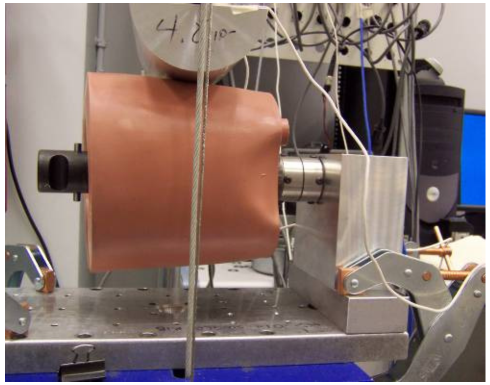


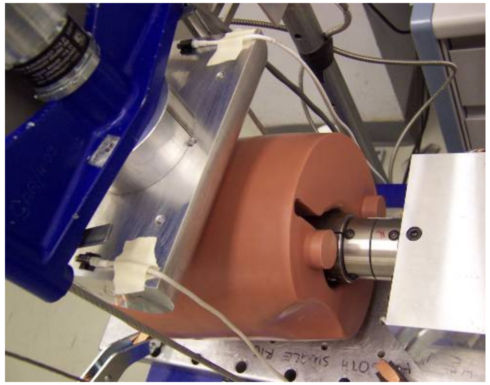
Component Tests



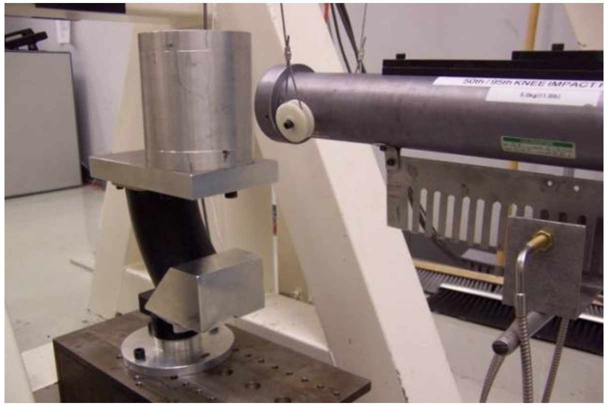
Upper Leg Drop Tests

- 6 speeds
- Drop head accelerations, force, and moment tracked.





Component Tests



Lumbar Spine Pendulum Impact

- 4 speeds
- Drop head accelerations, force, and moment tracked.

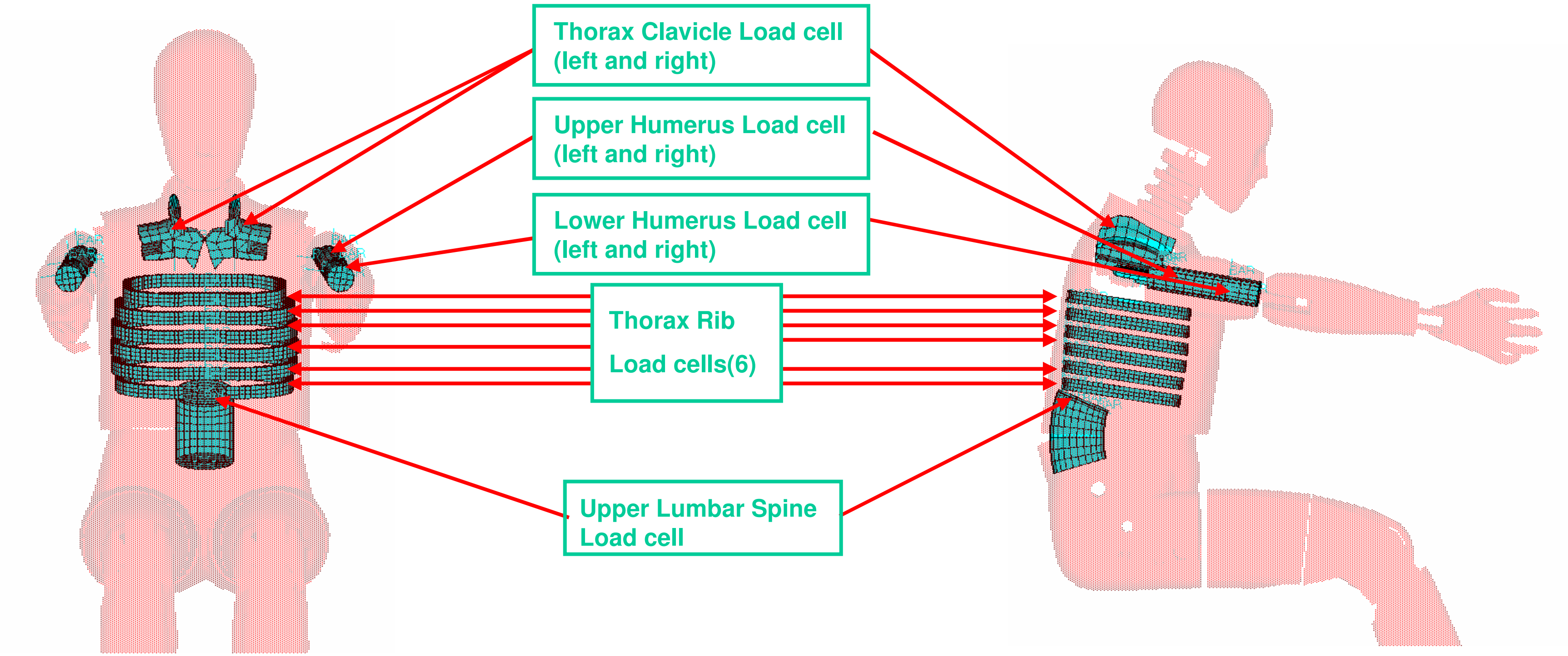
Component Tests

Pelvis – INSTRON Compression

Joint stiffness (nodding)

More optional load cells added

– Effective restraint design through a better understanding of the load path and energy flow through the dummy model



More new Load cells optional in PDB H350 v5.3 Model

First Technology Innovative Solutions

Sled Tests

- PDB Test Data
- Dummy model performance verification in user load case
  - Energy levels
  - Deformation modes
- Potential stability issues identify and addressed before production release

Thank You!