

# Modifications to the THOR-50M for Improved Usability in Reclined Postures – Update and Preliminary Findings

NHTSA Contract No. DTNH2215D00022/693JJ919F000222

*Jason Forman<sup>1</sup>, Adrian Caudillo-Huerta<sup>1</sup>, Justin McMahon<sup>1</sup>, Matthew Panzer<sup>1</sup>, William Marshall<sup>2</sup>, Derek Winter<sup>2</sup>, Matthew Dyer<sup>2</sup>, Paul Lemmen<sup>2</sup>*

*<sup>1</sup>University of Virginia Center for Applied Biomechanics*

*<sup>2</sup>Cellbond*

*SAE Government Industry Meeting – Feb. 2021*

DISCLAIMER: The opinions, findings, and conclusions expressed in this presentation are those of the authors and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade or manufacturers' names are mentioned, it is only because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

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# THOR 50M in Reclined Postures

## ▶ Prasad et al. 2019 (GIM)

- Positioning / usability study with THOR, H3, other dummies
- 2012 Odyssey Driver's seat
- THOR was able to recline
- Concerns for gaps in abdomen, deformation in lumbar spine



## ▶ Goals for this study

- Expand positioning study to other seats
- Identify potential limitations / concerns
- Develop & prototype potential parts modifications to improve usability in recline
- Implement modifications in NHTSA's THOR FE model



# Positioning Study – Qualitative Analysis

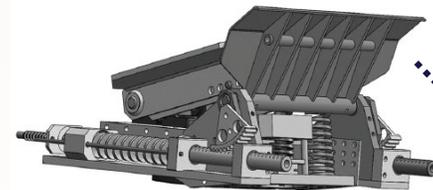
- ▶ 2018 Honda Odyssey 2<sup>nd</sup> row captain's chair
- ▶ Acura TLX Driver's Chair
- ▶ LAB seat with marionette positioning



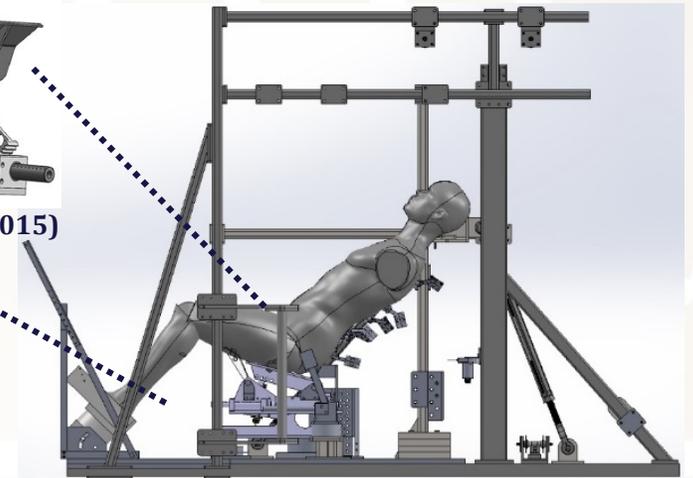
Honda Odyssey 2<sup>nd</sup> row captain's chair



Acura TLX Driver's Chair



LAB Seat (Uriot et al. 2015)



LAB Seat on HAV Gold Standard Buck

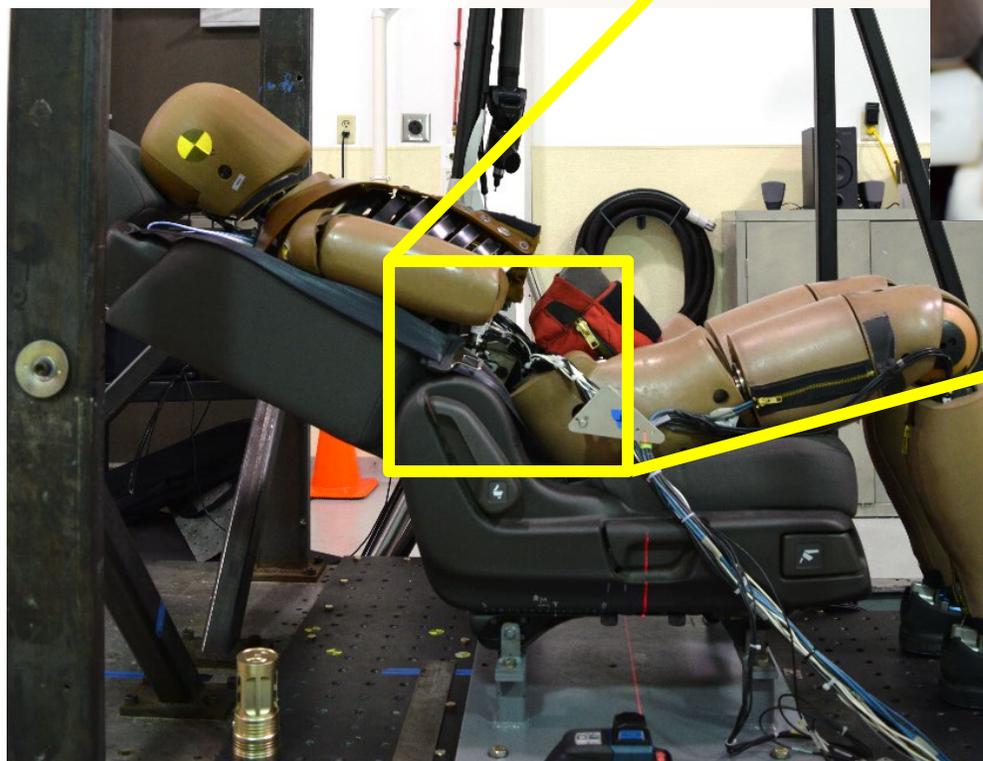


# Positioning Study – Key Findings

High Pivot Point

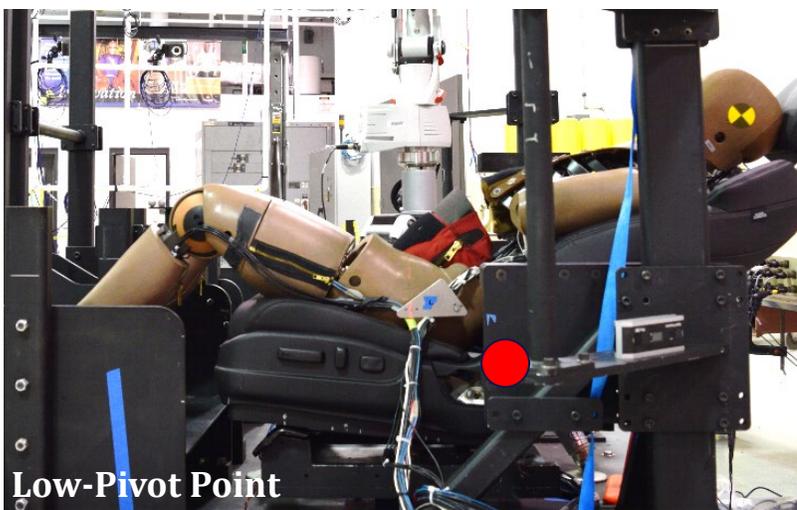


Lumbar flex joint pulls apart under extension



Amount of extension depends on seat geometry

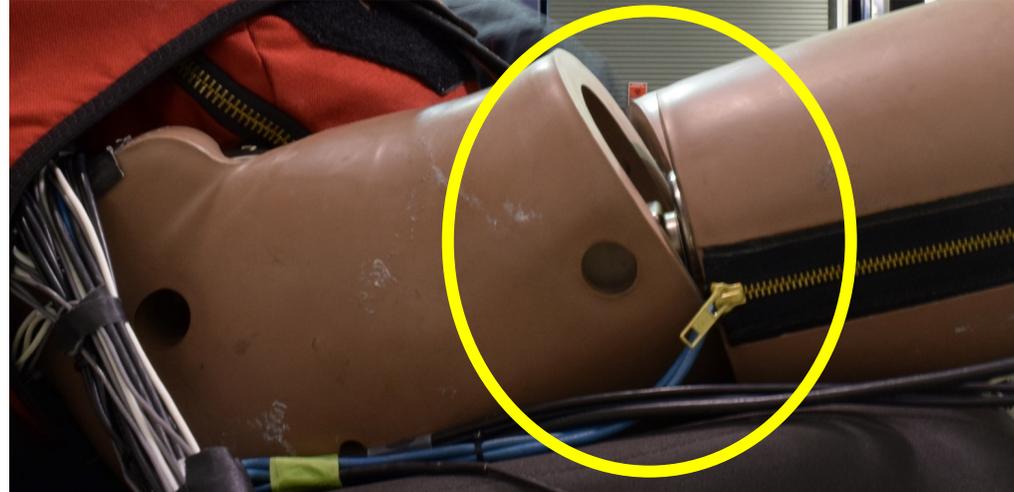
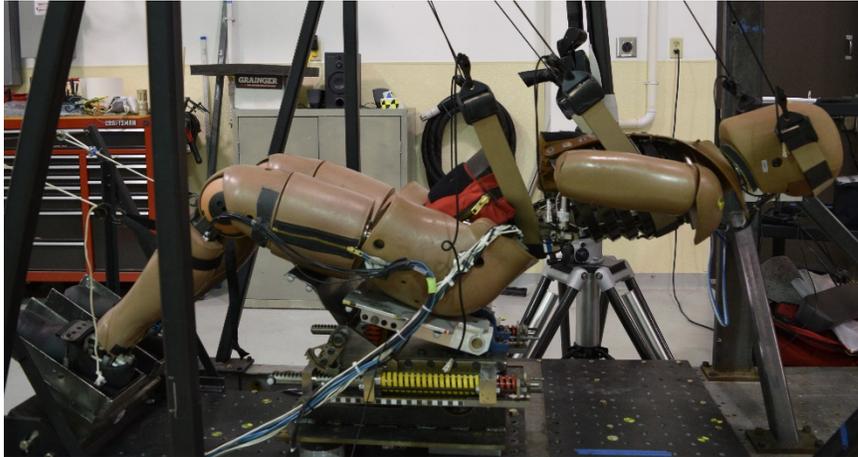
Low-Pivot Point



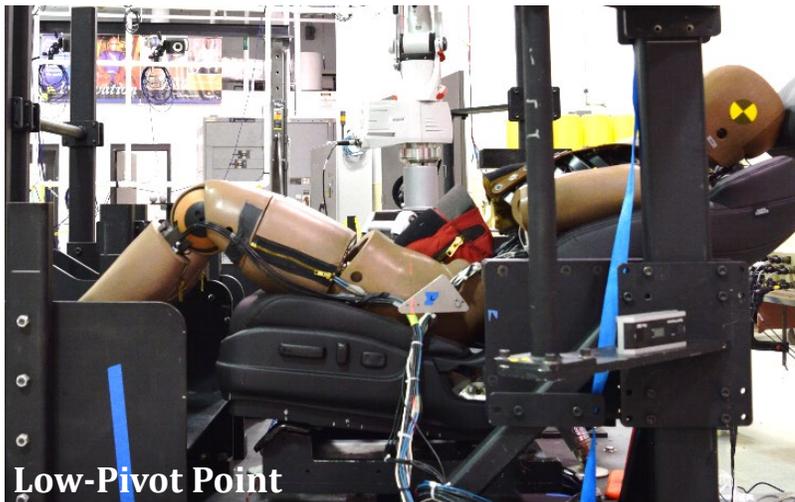
Report: NHTSA BioDB TSTNO 12990

# Positioning Study – Key Findings

Generic Seat



Pelvis Flesh  
Restricts Hip  
Extension

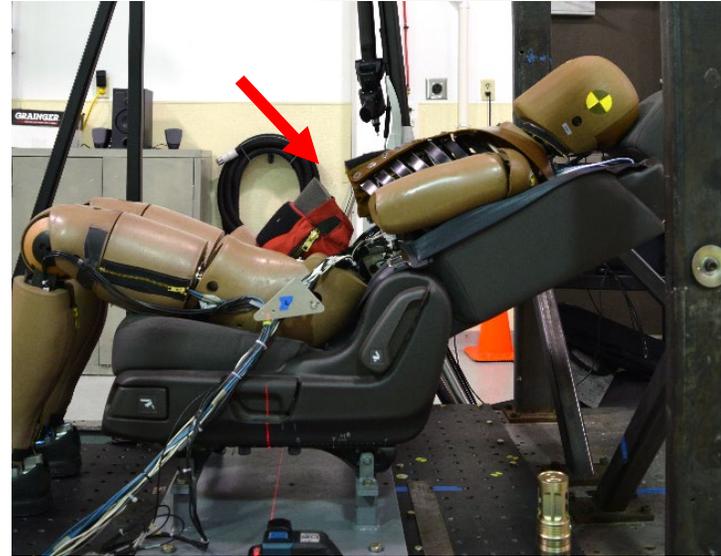
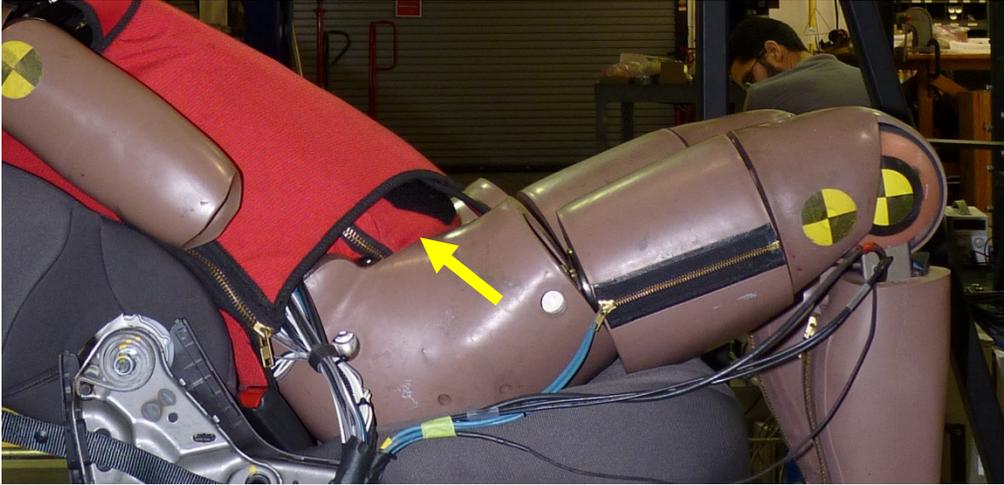


Low-Pivot Point

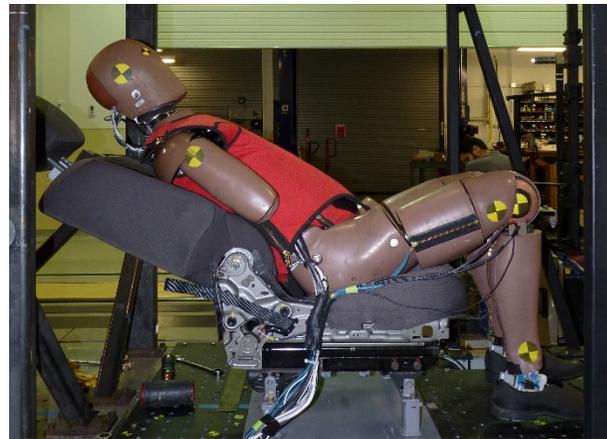


Lifts Thighs  
from Seats

# Positioning Study – Key Findings



Substantial Gaps in Jacket, Flesh, Abdomen

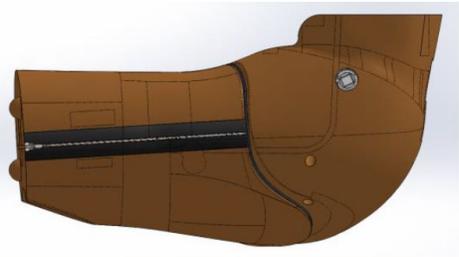


Jacket Limits Recline, Shunts Loads/Moments Around Spine

Report: NHTSA BioDB TSTNO 12990

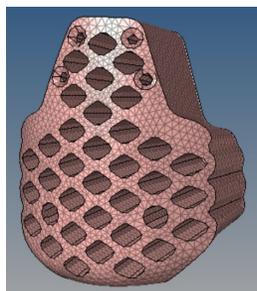
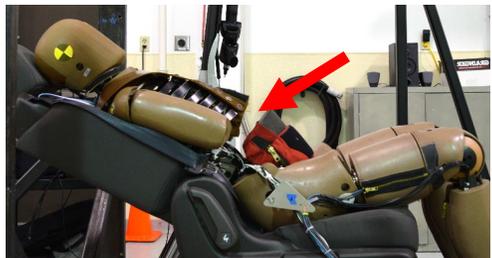
# Design Goals

Increase range of motion of hip extension

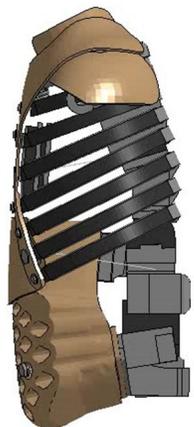


Modified hip & thigh flesh

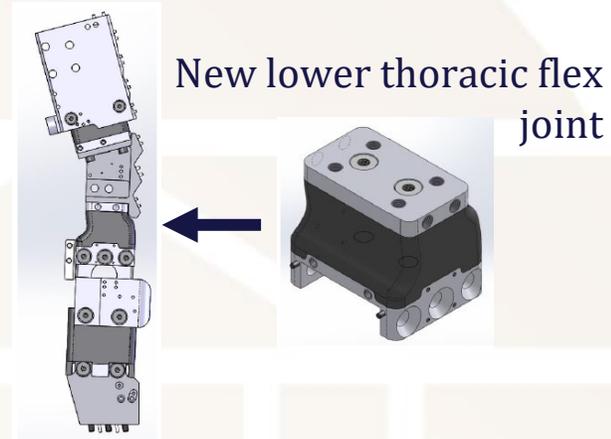
Minimize jacket/abdomen gaps throughout range of motion



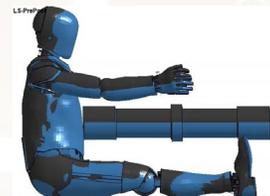
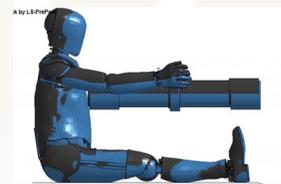
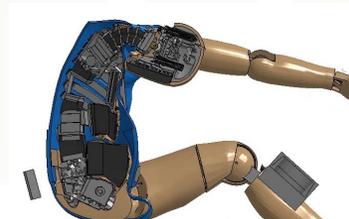
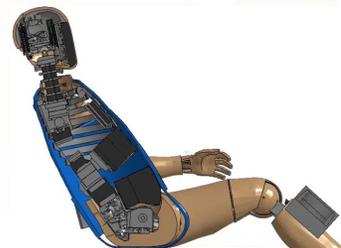
1-piece honeycomb abdomen  
Updated Jacket



Increase range of spine motion without damaging lumbar flex joint

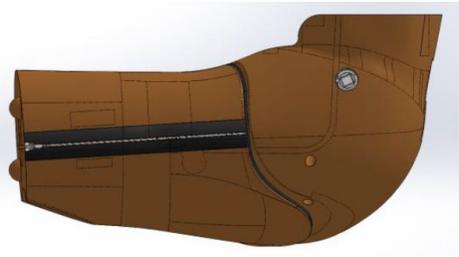


Do not adversely affect biofidelity in upright postures



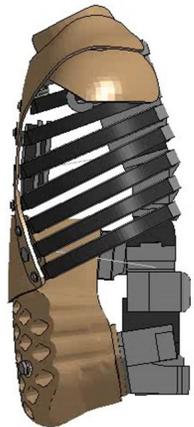
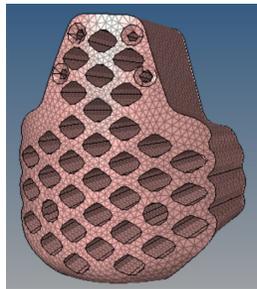
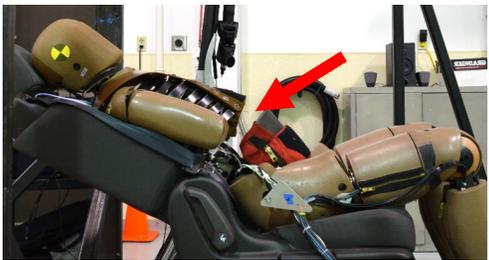
# Design Goals

Increase range of motion of hip extension



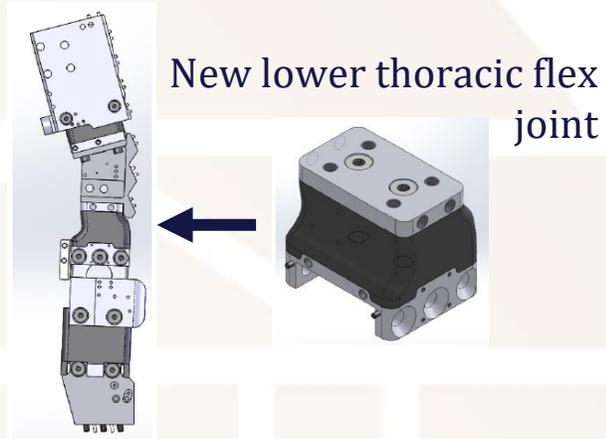
Modified hip & thigh flesh

Minimize jacket/abdomen gaps throughout range of motion

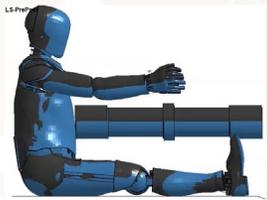
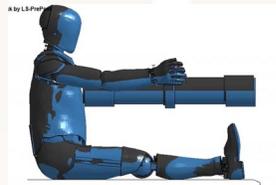
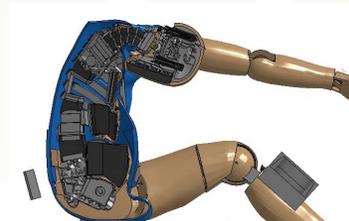
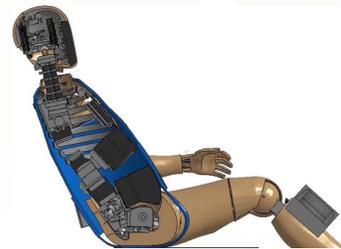


1-piece honeycomb abdomen  
Updated Jacket

Increase range of spine motion without damaging lumbar flex joint



Do not adversely affect biofidelity in upright postures



# New Lower Thoracic Spine Flex Joint

New Lower Thoracic Spine Flex Joint

Stock Lumbar Flex Joint

Base: publicly-available NHTSA THOR FE Model

Stock Model

Stock Pitch Adjuster

Modified Model

New Flex Joint

Goal: Distribute flexibility within the spine

# New Lower Thoracic Spine Flex Joint

New Lower Thoracic Spine Flex Joint

Stock Lumbar Flex Joint

Base: publicly-available NHTSA THOR FE Model

Stock Pitch Adjuster

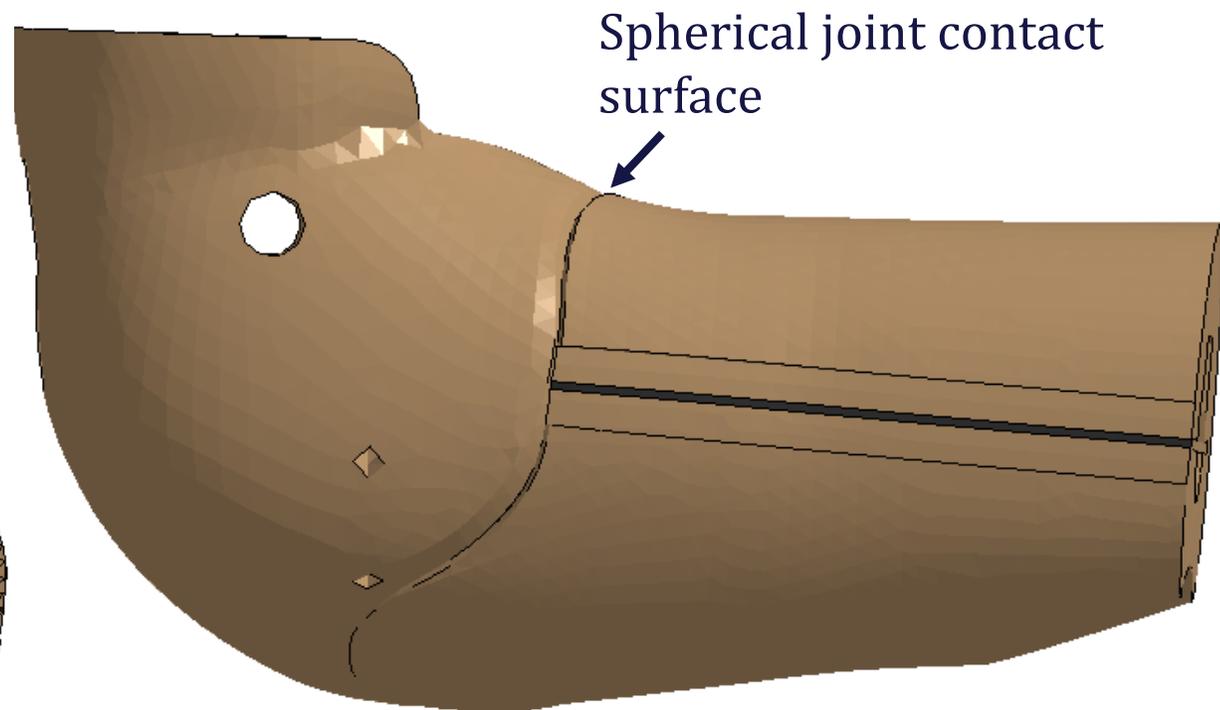
Stock Model

Modified Model

New Flex Joint

Goal: Distribute flexibility within the spine

# Modified Pelvis & Thigh Flesh



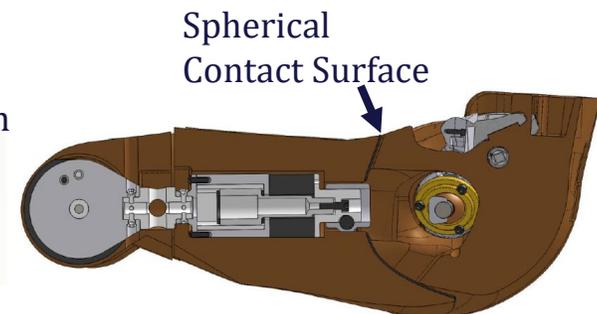
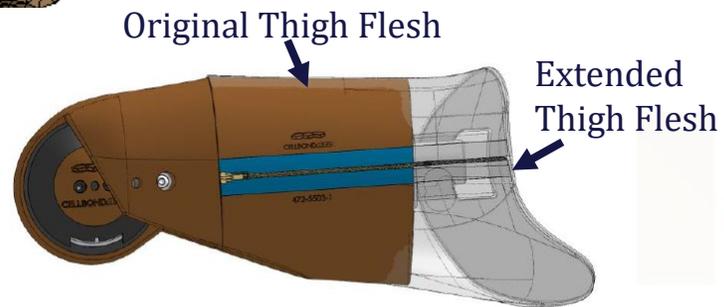
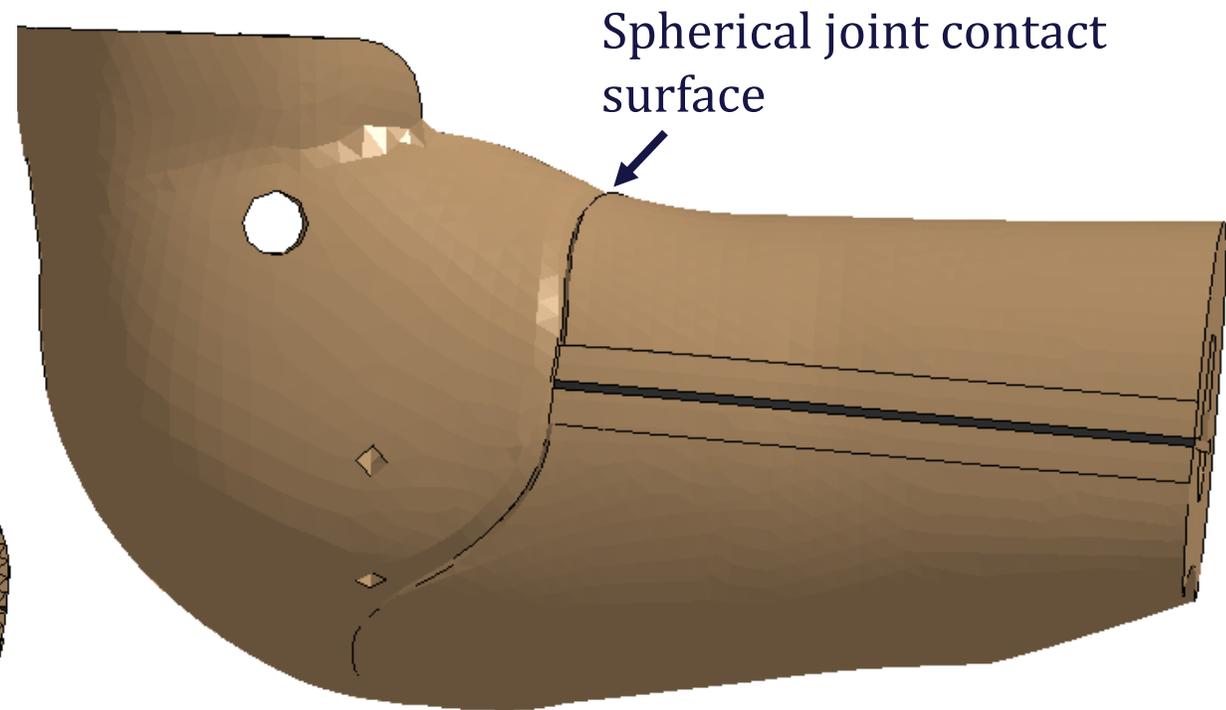
Goal: Greater range of hip extension



# Modified Pelvis & Thigh Flesh



Goal: Greater range of hip extension

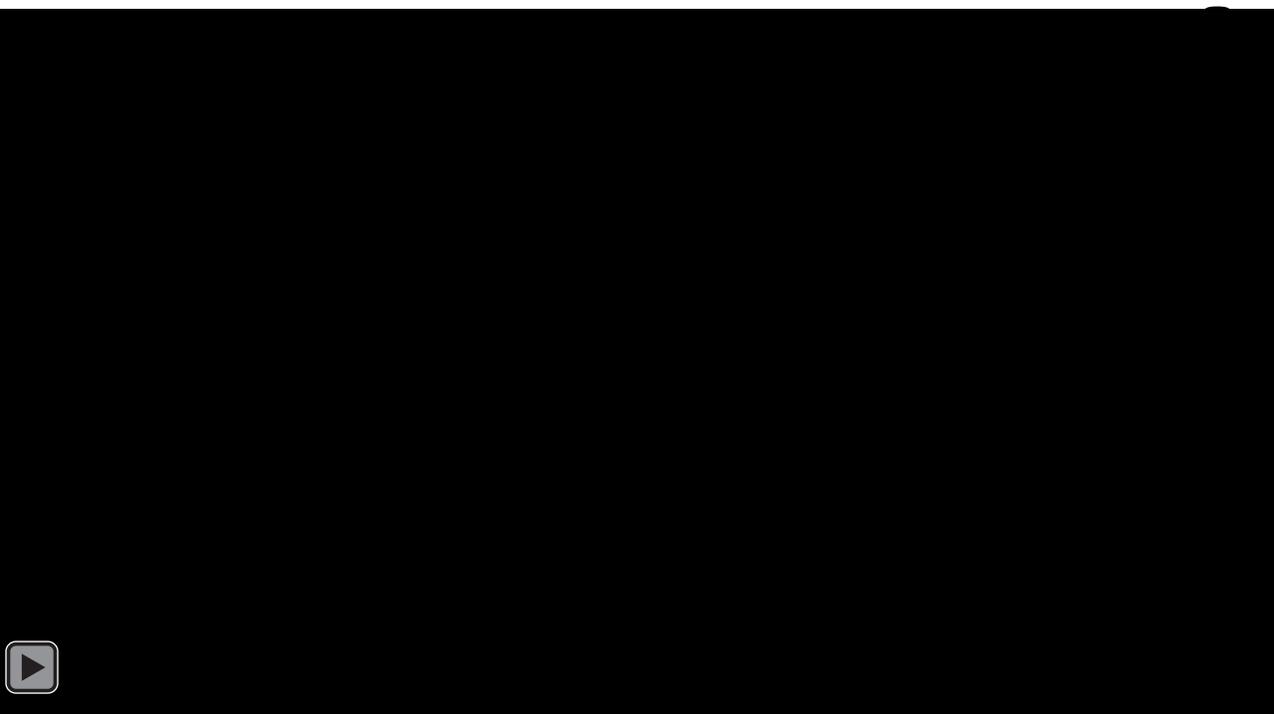


Side View

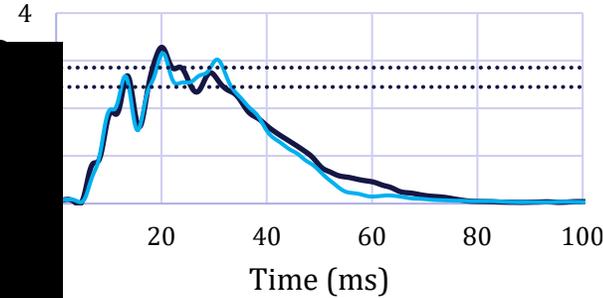


# Upper Thorax Impact

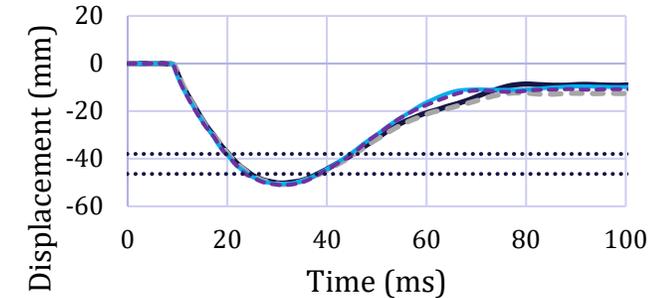
Stock THOR  
 Lower Thorax Flex Joint + New Pelvis Flesh



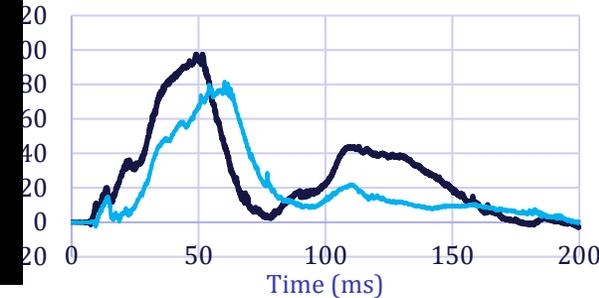
Impactor Force



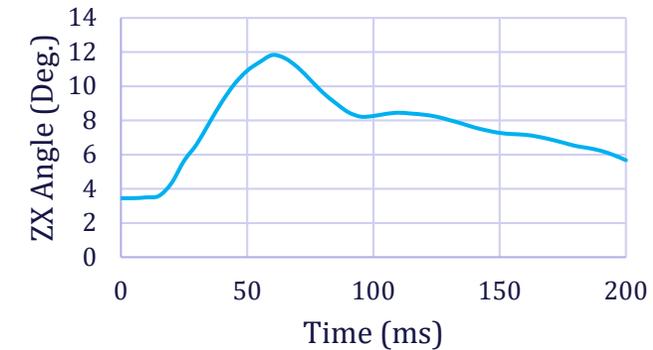
Rib X-Displacement



Lumbar LC Y-Moment



Lower Thorax Flex Joint Angle



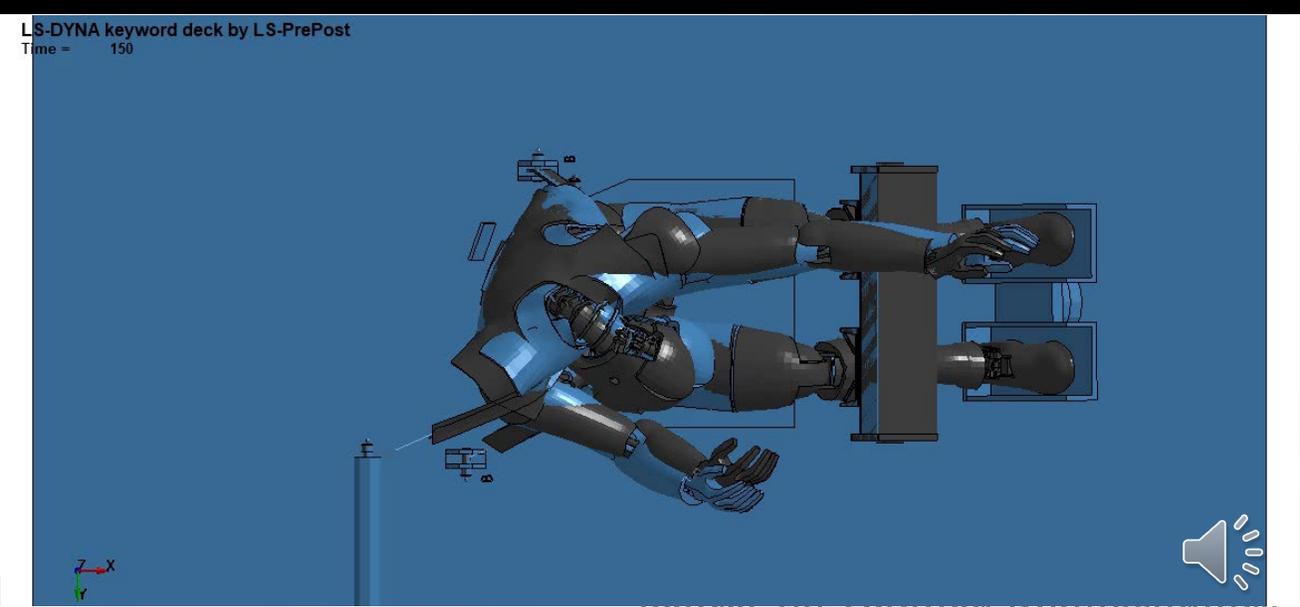
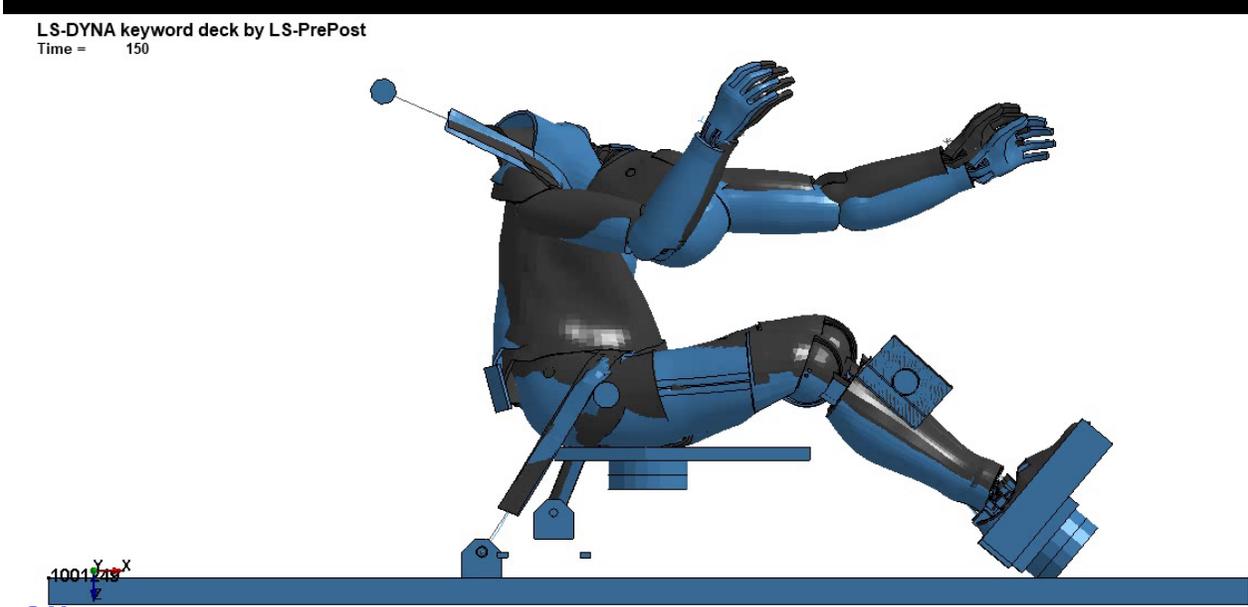
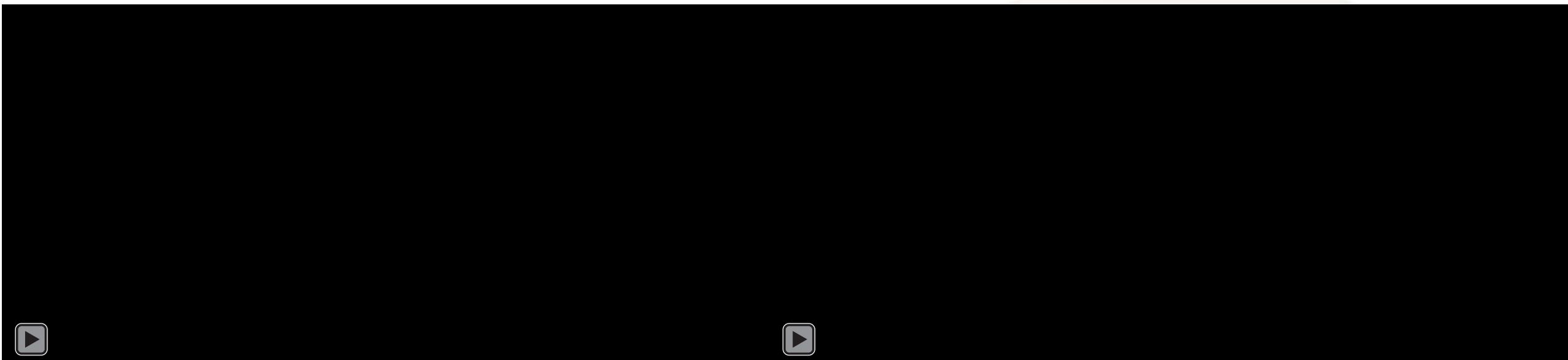
A positive angle indicates forward flexion

Slight difference in initial positioning due to bending of the new upper lumbar flex joint during gravity settling. NHTSA certification corridors provided where applicable.

# Gold Standard 1

Stock THOR  
Lower Thorax Flex Joint + New Pelvis Flesh

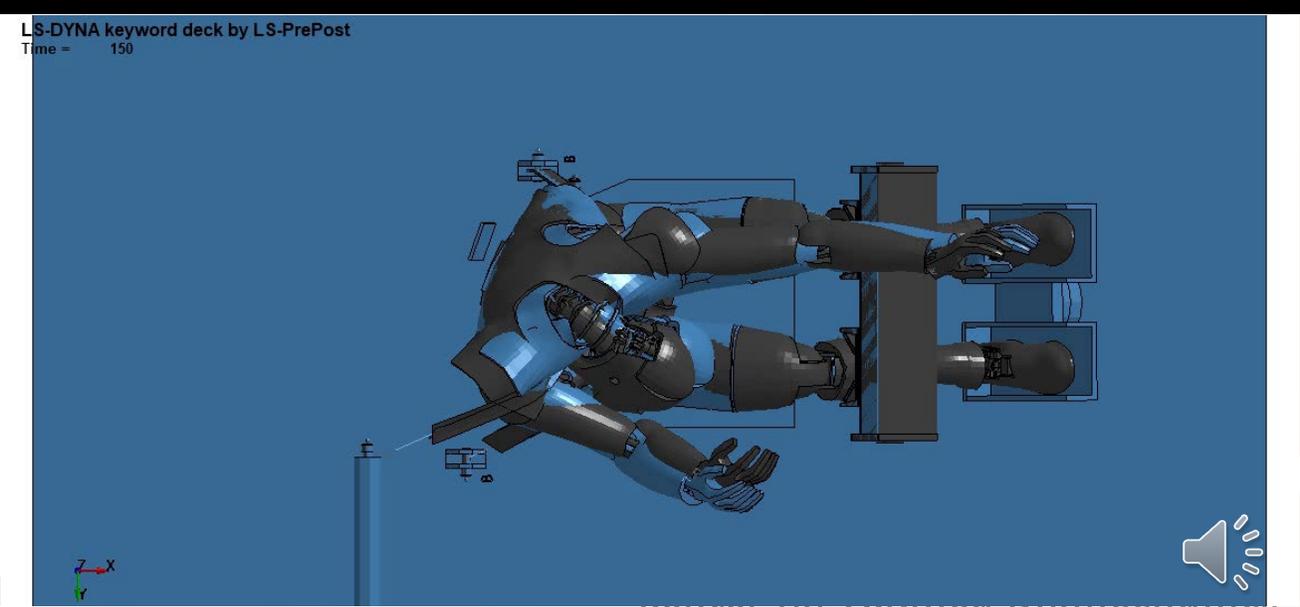
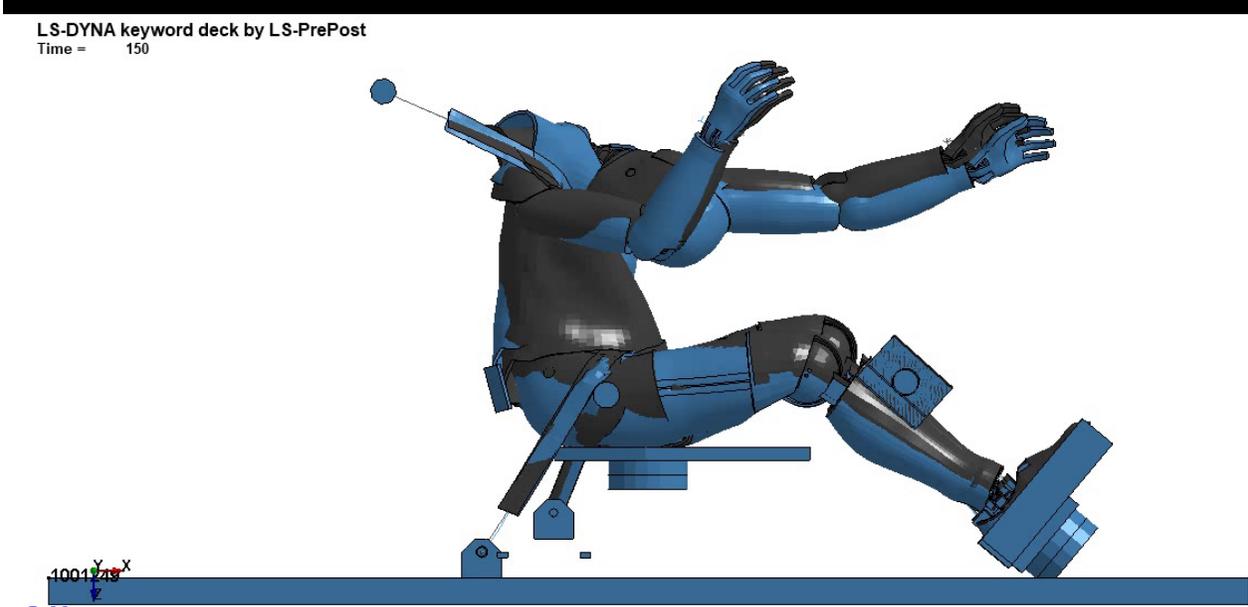
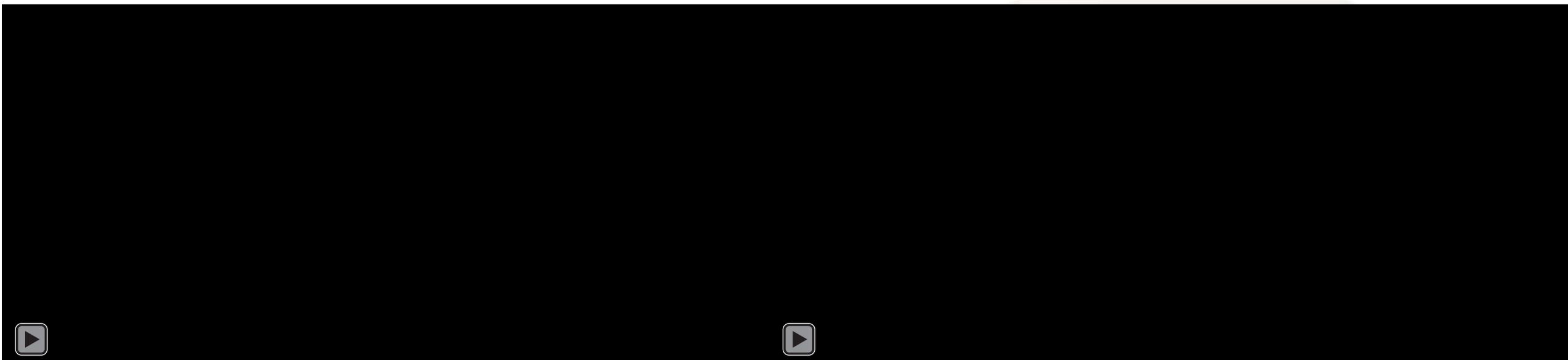
40 km/h, No Force Limiter



# Gold Standard 1

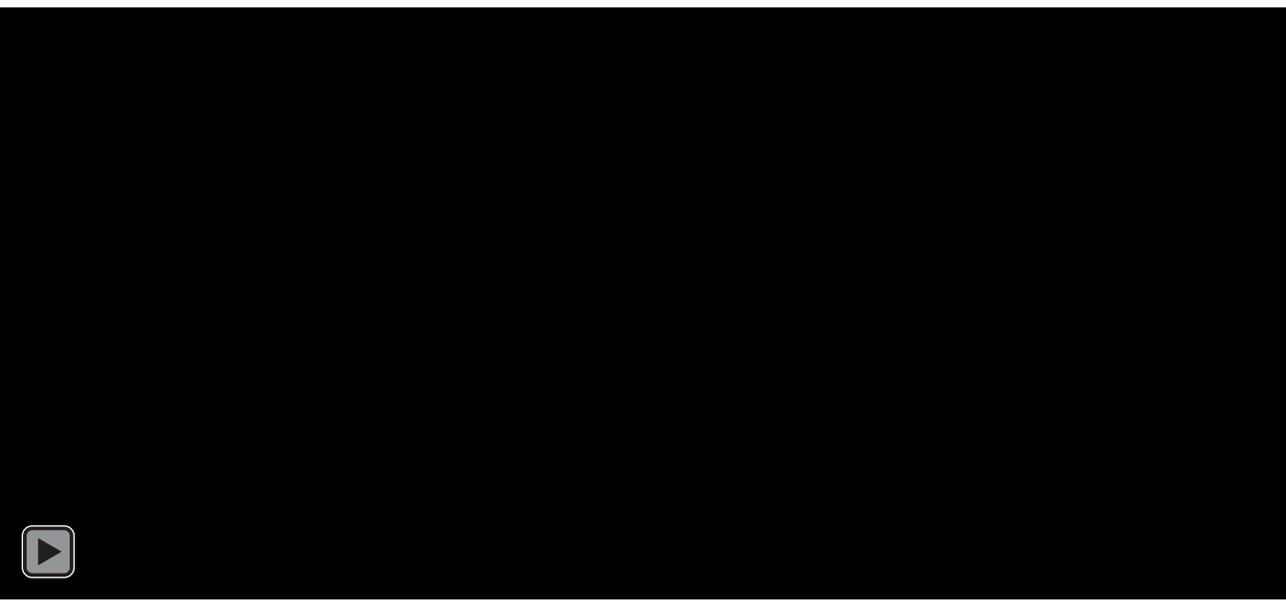
Stock THOR  
Lower Thorax Flex Joint + New Pelvis Flesh

40 km/h, No Force Limiter

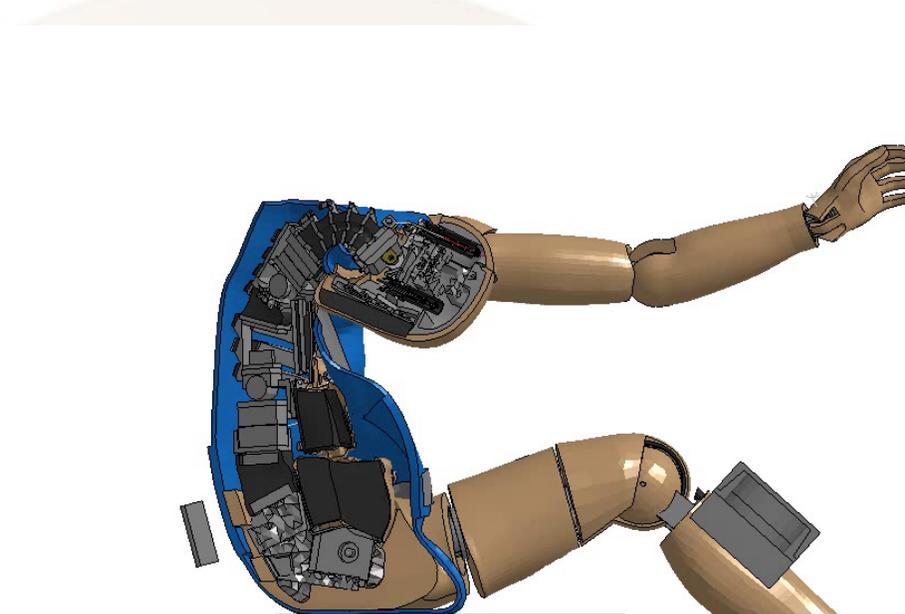


# Gold Standard 1 Cut View

40 km/h, No Force Limiter



DYNA keyword deck by LS-PrePost  
e = 150

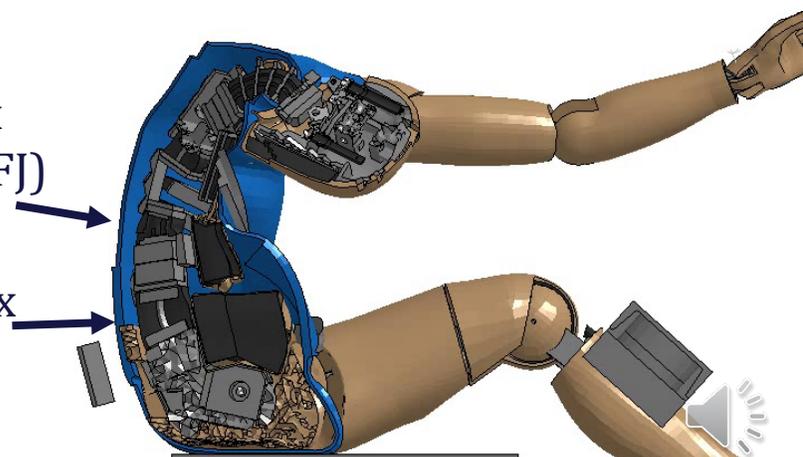


DYNA keyword deck by LS-PrePost  
e = 150



Lower Thorax  
Flex Joint (LTFJ)

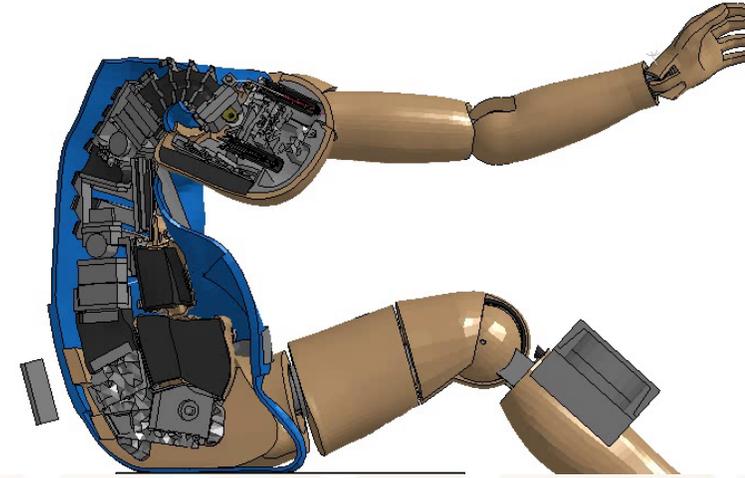
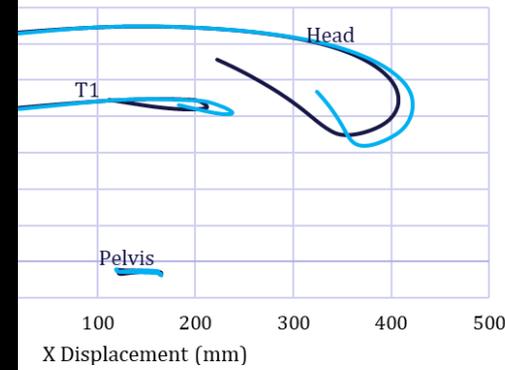
Lumbar Flex  
Joint (LFJ)



# Gold Standard 1 Cut View

40 km/h, No Force Limiter

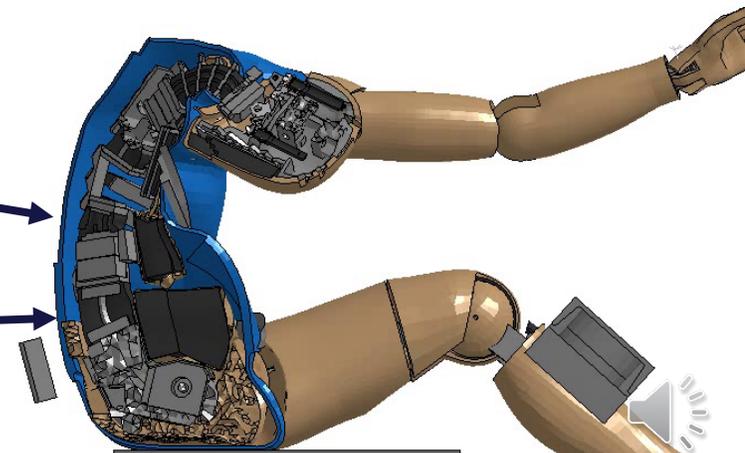
Kinematic Plot



DYNA keyword deck by LS-PrePost  
e = 150

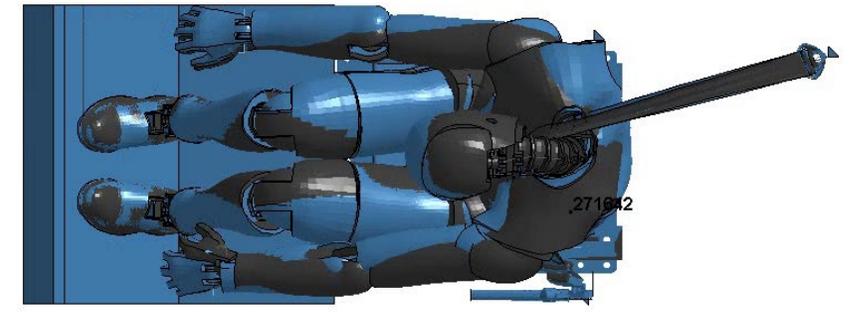
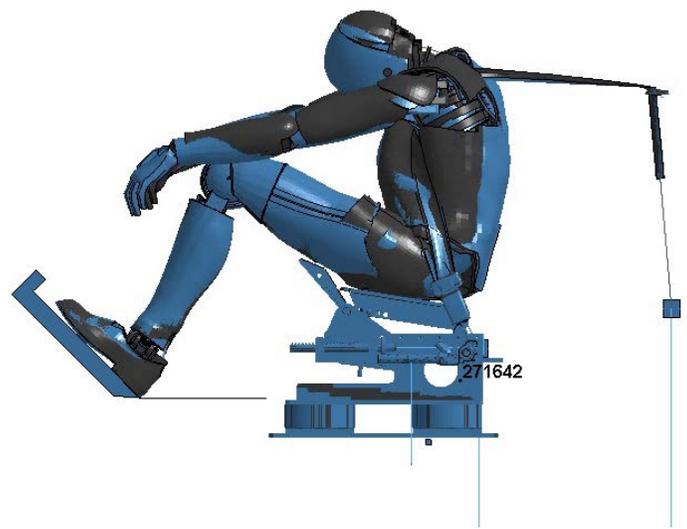
Lower Thorax  
Flex Joint (LTFJ)

Lumbar Flex  
Joint (LFJ)



# Reclined

Test Environment: Richardson et al.  
2019 ESW, 2020 Stapp



Stock THOR

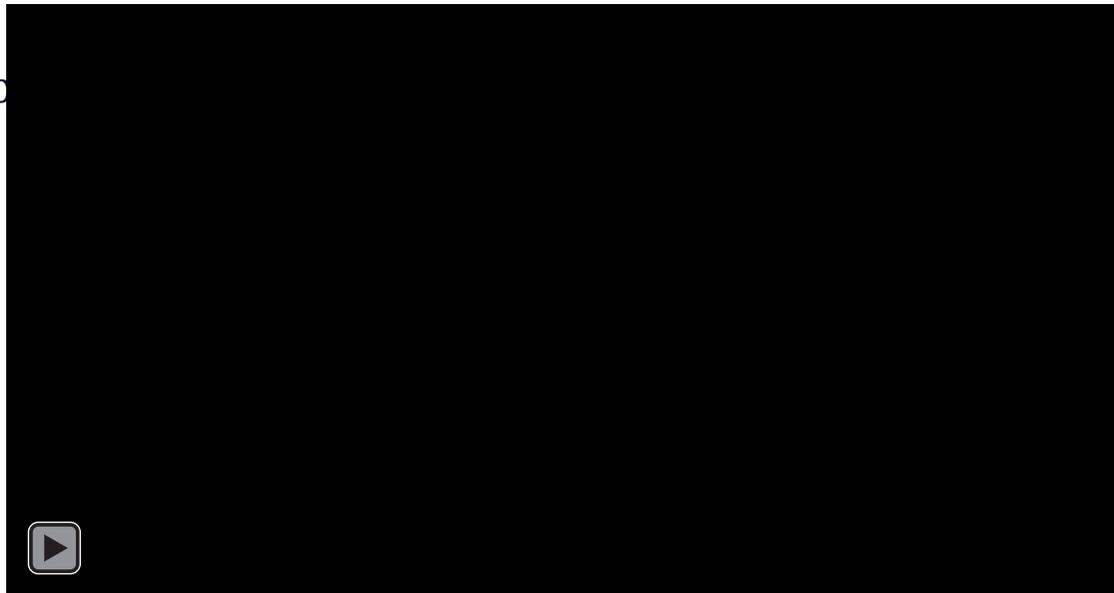
Lower Thorax Flex Joint + New Pelvis Flesh



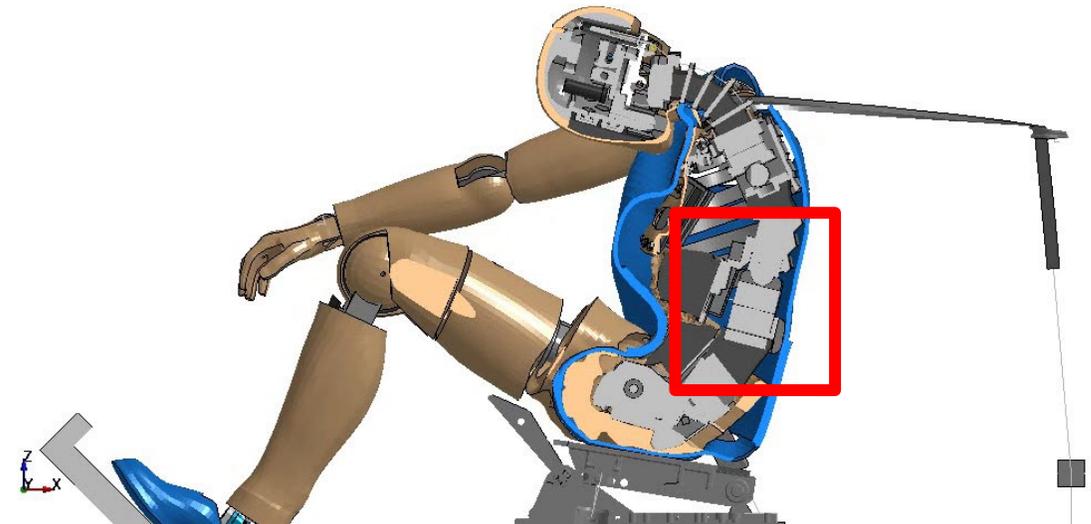
# Reclined Cut View

Test Environment: Richardson et al.  
2019 ESV, 2020 Stapp

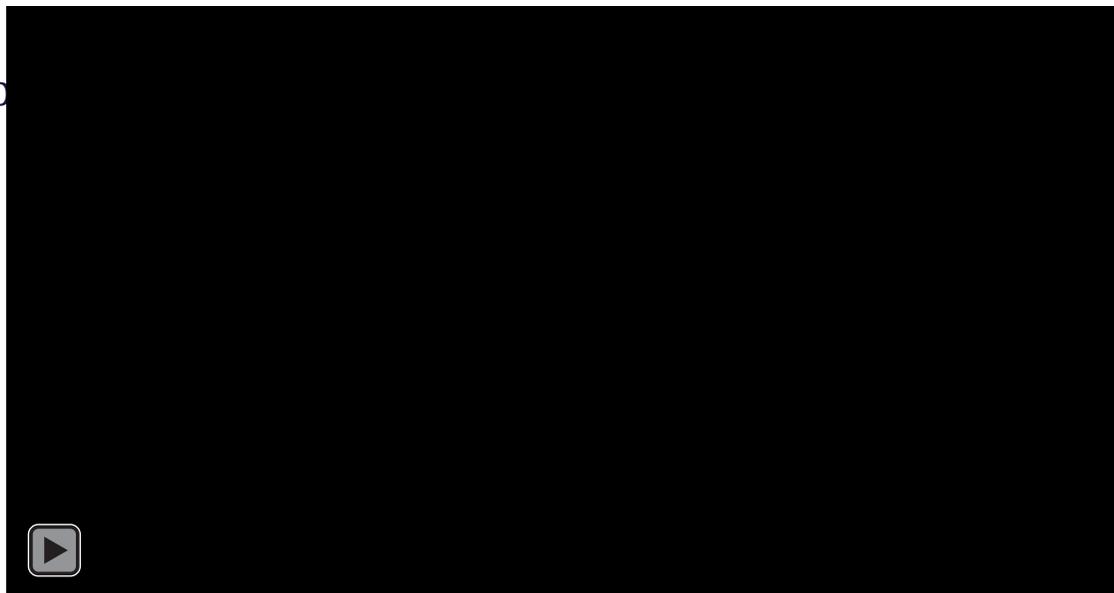
Sto



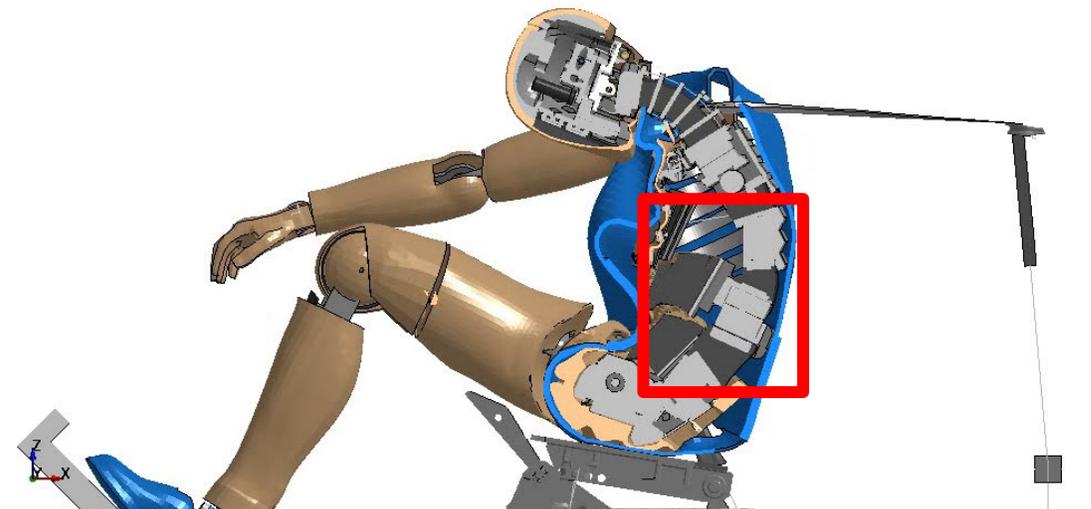
THOR 50M  
Time = 100



Mo



THOR 50M  
Time = 100

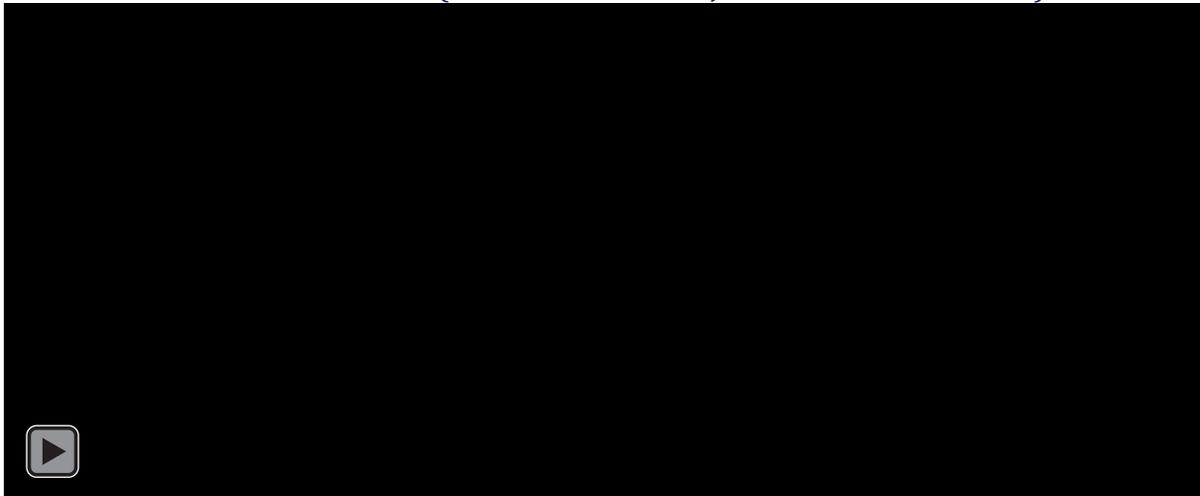


# Pelvis Motion

Stock THOR

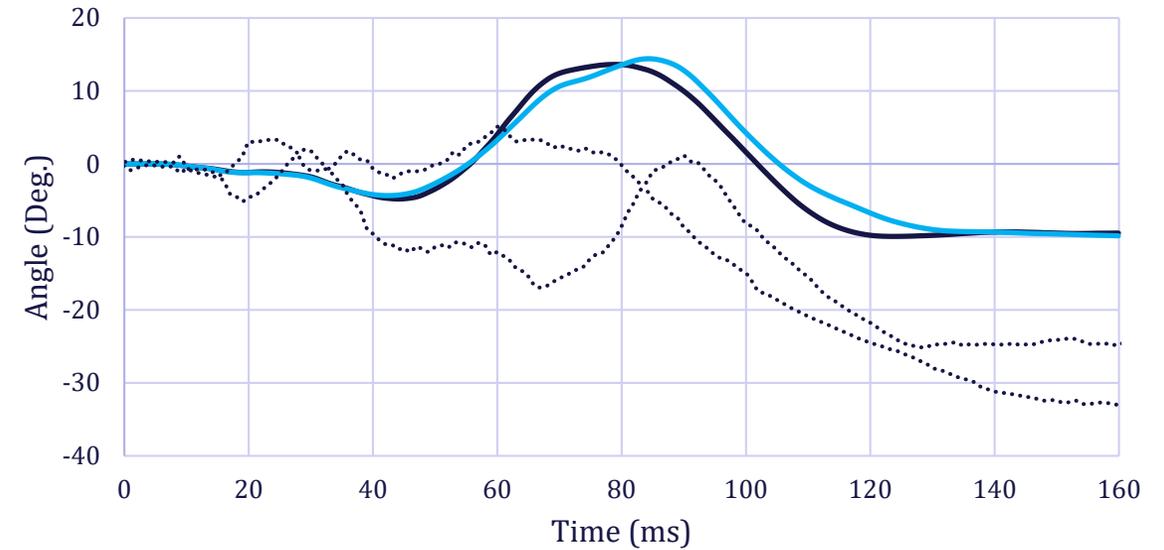


Modified THOR (Lower Thorax Flex Joint + New Pelvis Flesh)

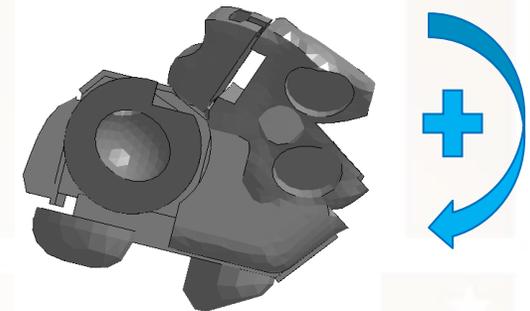


Stock THOR  
Lower Thorax Flex Joint + New Pelvis Flesh

Pelvis Rotation



Dashed Lines: PMHS corridors from Richardson et al. 2020 Stapp.

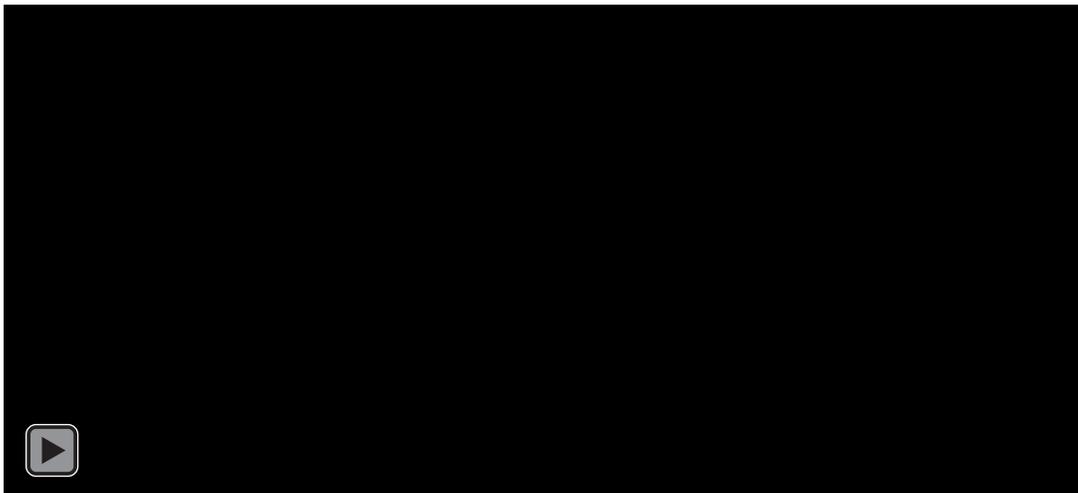


# Pelvis Sensitivity Study

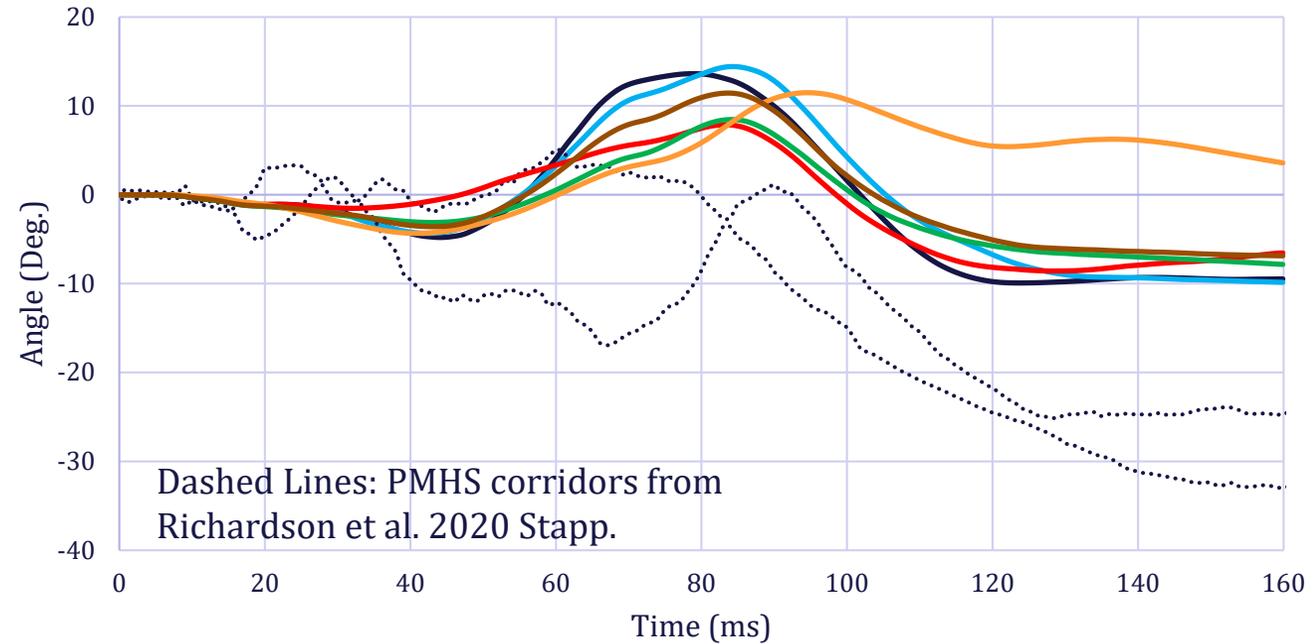
Lower Thorax Flex Joint + New Pelvis Flesh



Coxal Bone Material Replaced with Soft Material



### Pelvis Rotation



Stock THOR

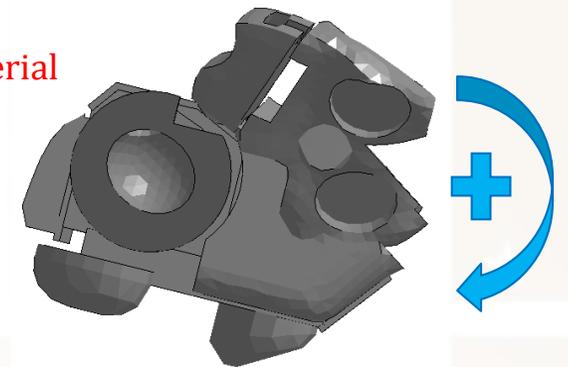
Modified

Coxal Bone Mat. Replaced with Soft Material

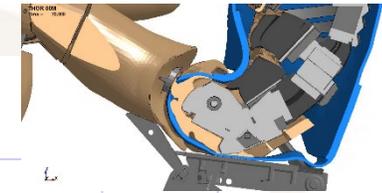
Pelvis Stiffness x5

Pelvis Stiffness x10

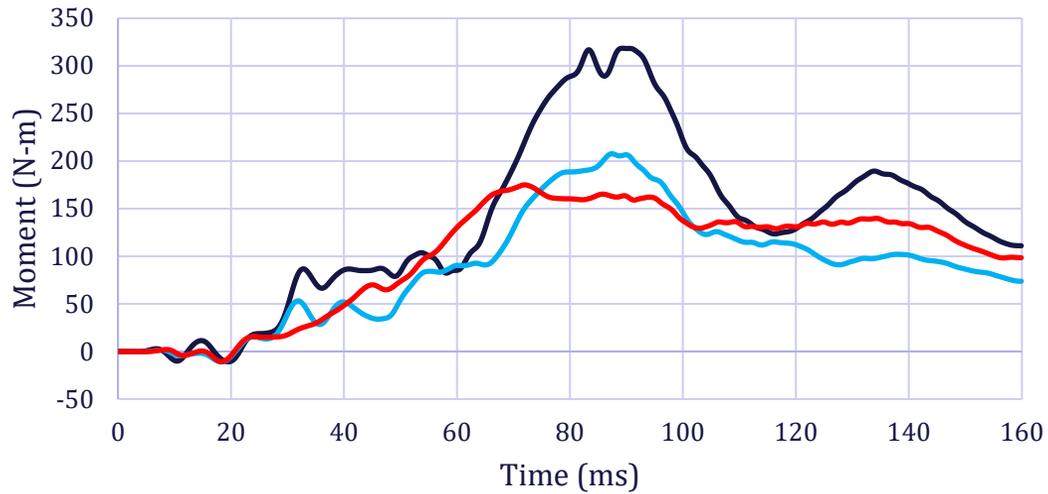
Pelvis Stiffness x100



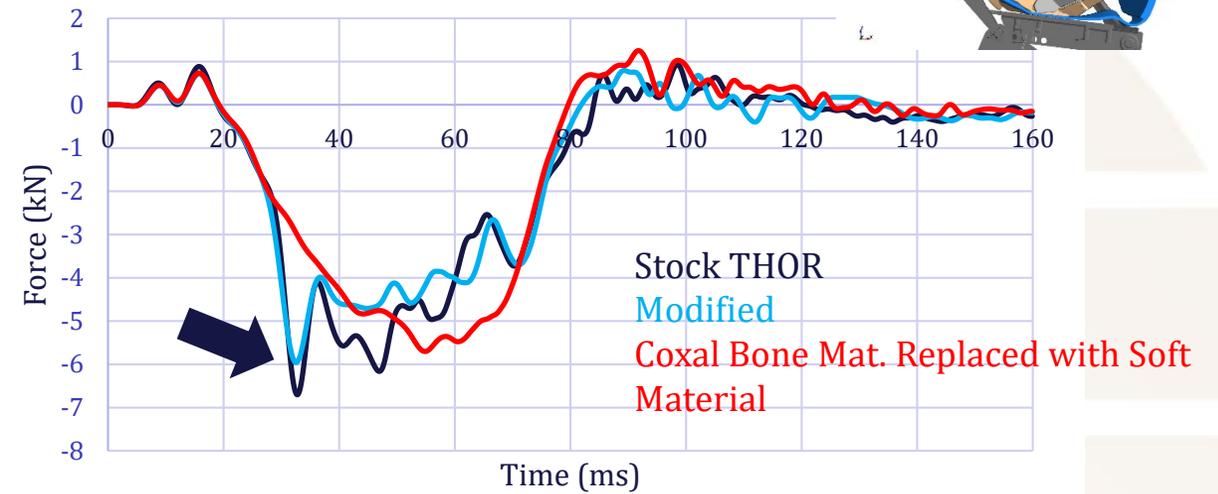
# Pelvis Sensitivity Study: Lumbar LC



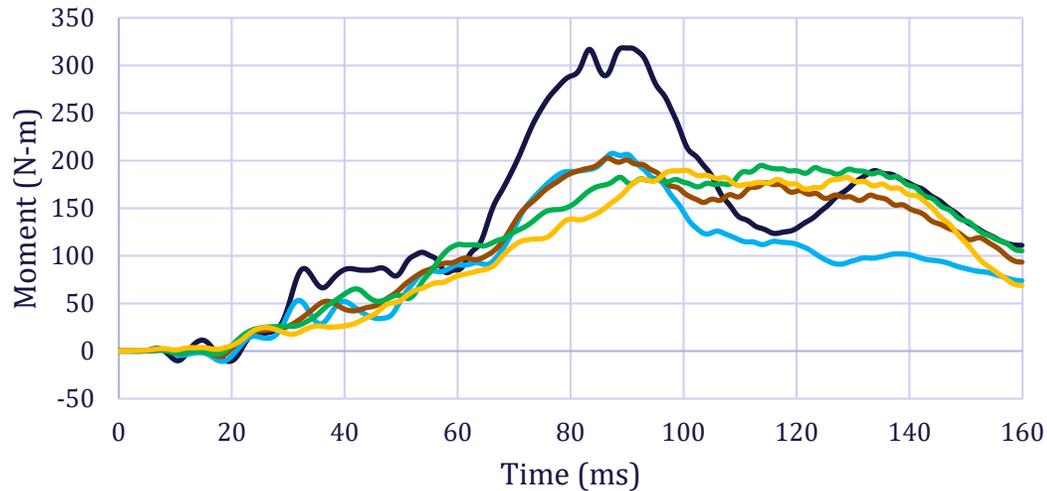
### Lumbar LC Y Moments



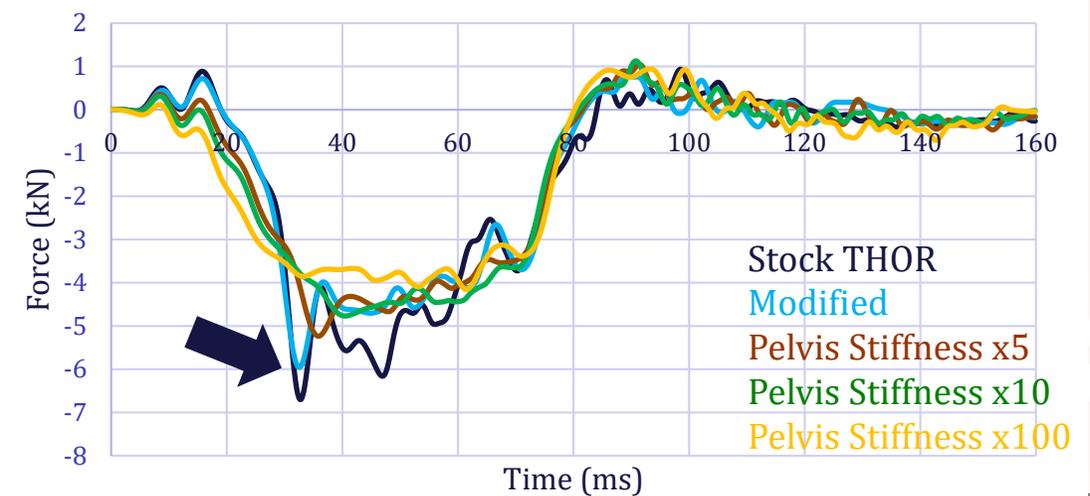
### Lumbar LC Z Force



### Lumbar LC Y Moments

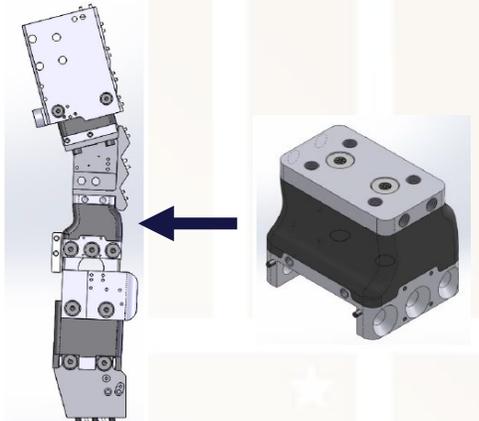
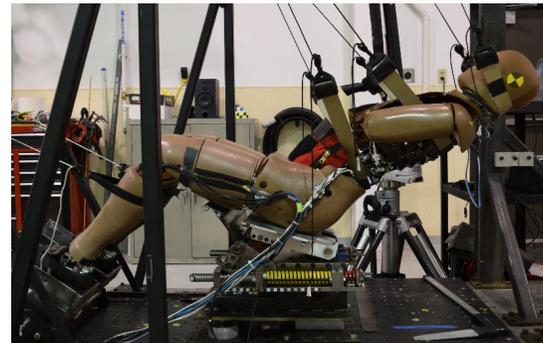
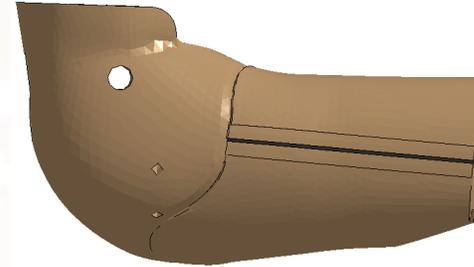
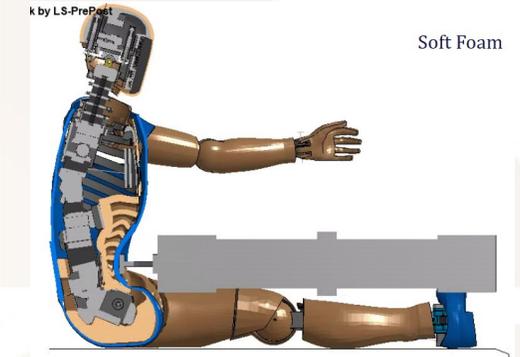
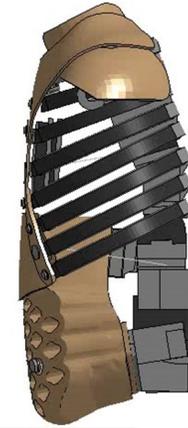
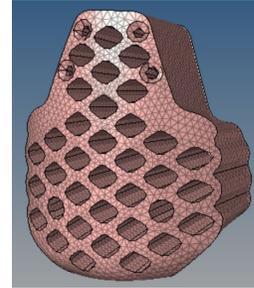


### Lumbar LC Z Force



# Next Steps

- ▶ Unified abdomen design & modeling
- ▶ Prototype fabrication
  - Lower thorax flex joint
  - New pelvis & thigh flesh
  - Unified abdomen
  - Modified jacket
- ▶ Certification testing
- ▶ Final positioning assessment



# Modifications to the THOR-50M for Improved Usability in Reclined Postures – Update and Preliminary Findings

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Questions?

Email: [jlf3m@virginia.edu](mailto:jlf3m@virginia.edu)

**Thank You!**

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