

# Update on Refinements to THOR to Improve Usability and Biofidelity in Diverse Seating Postures

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# THOR 50M in Reclined Postures

## ▶ Prasad et al. 2019 (SAE 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



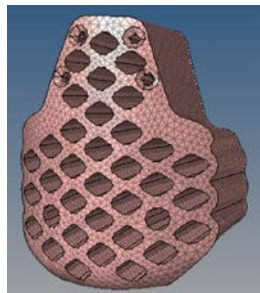
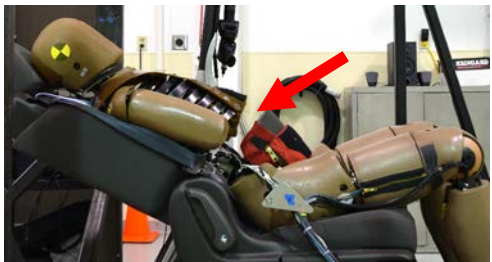
# Design Goals

Increase range of motion of hip extension

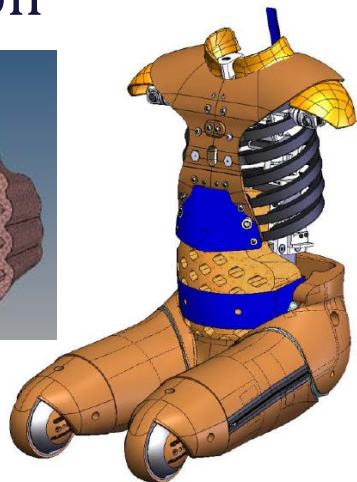


Modified hip & thigh flesh

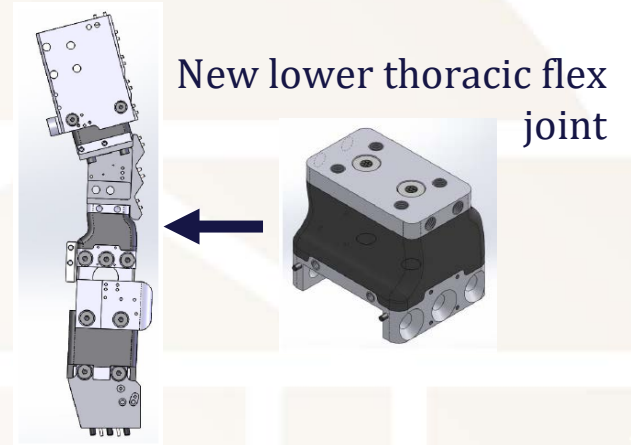
Minimize abdomen gaps throughout range of motion



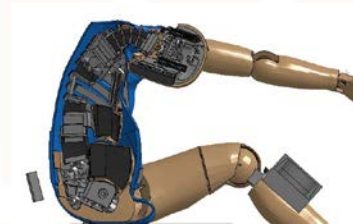
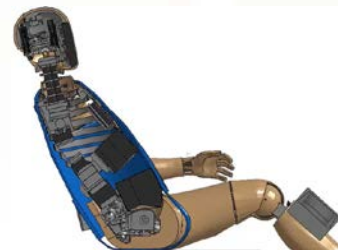
1-piece honeycomb abdomen



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 Pitch Adjuster

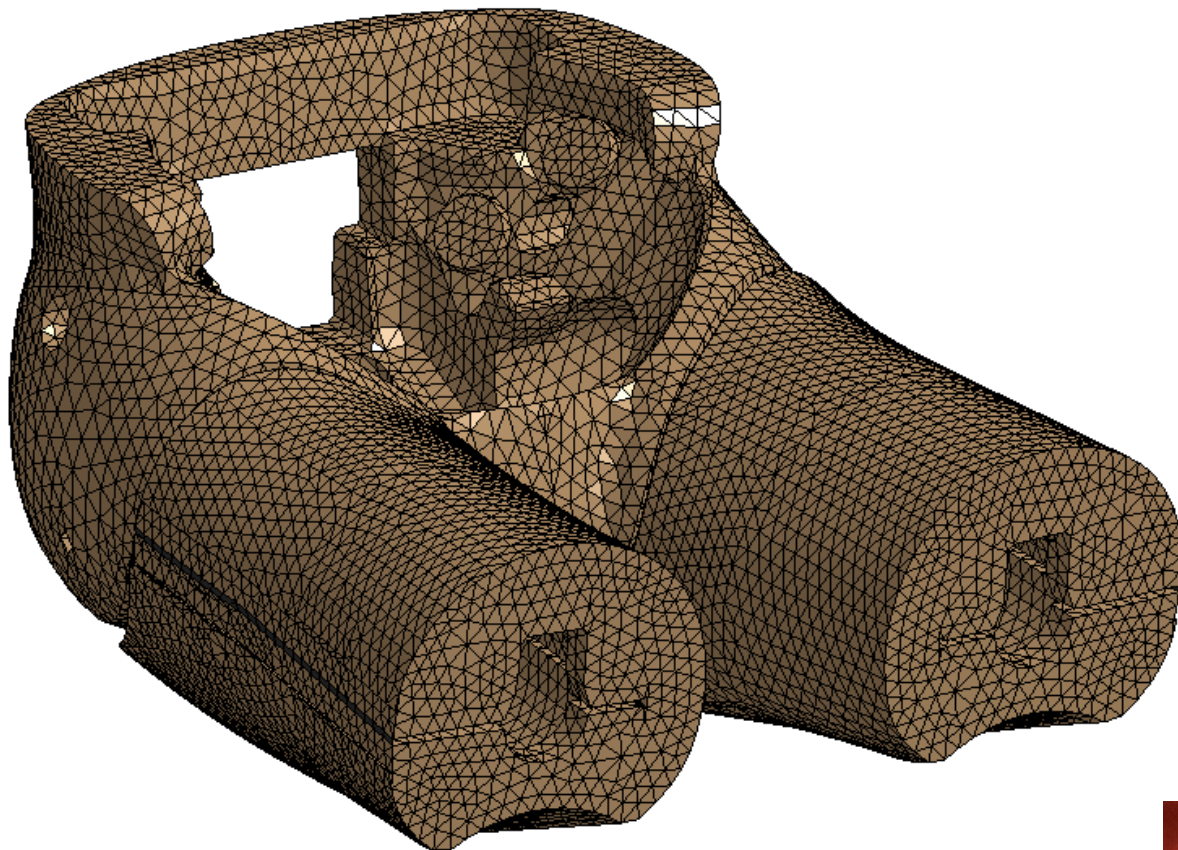
Stock Model

Modified Model

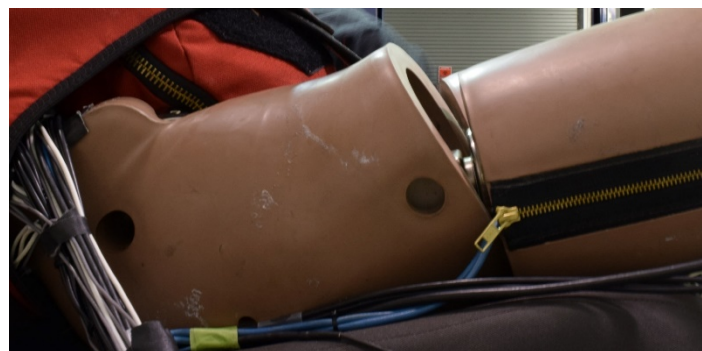
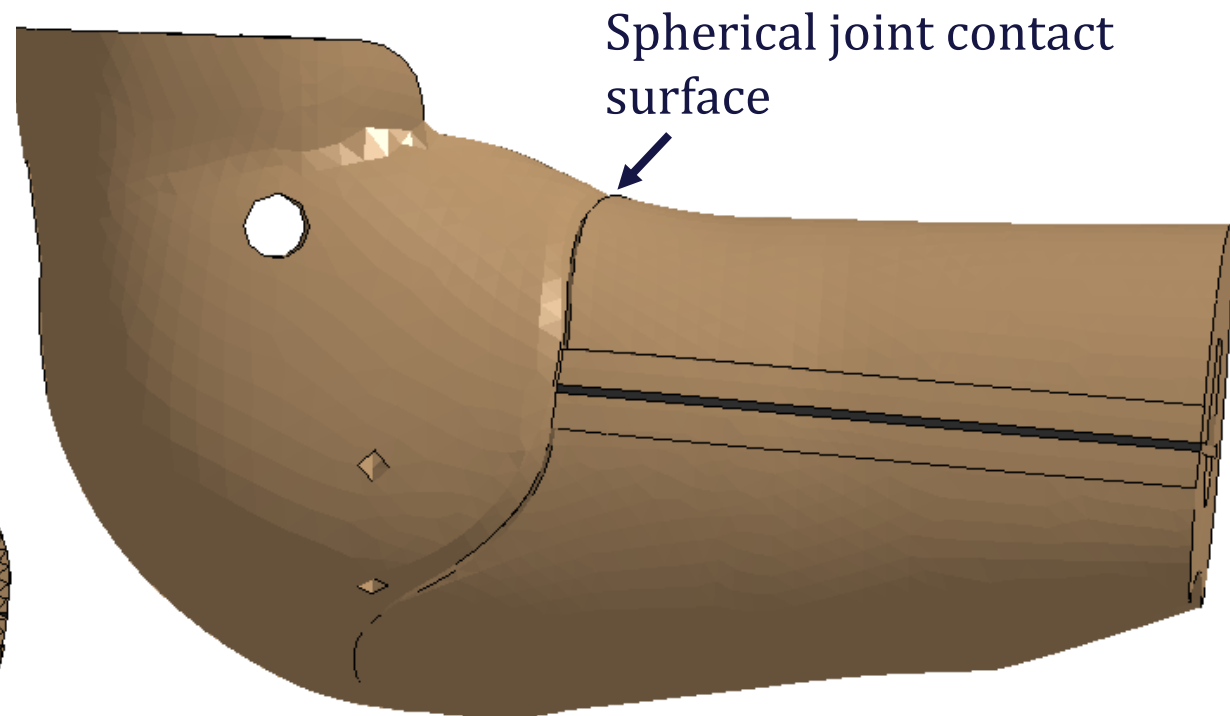
New Flex Joint

Goal: Distribute flexibility within the spine

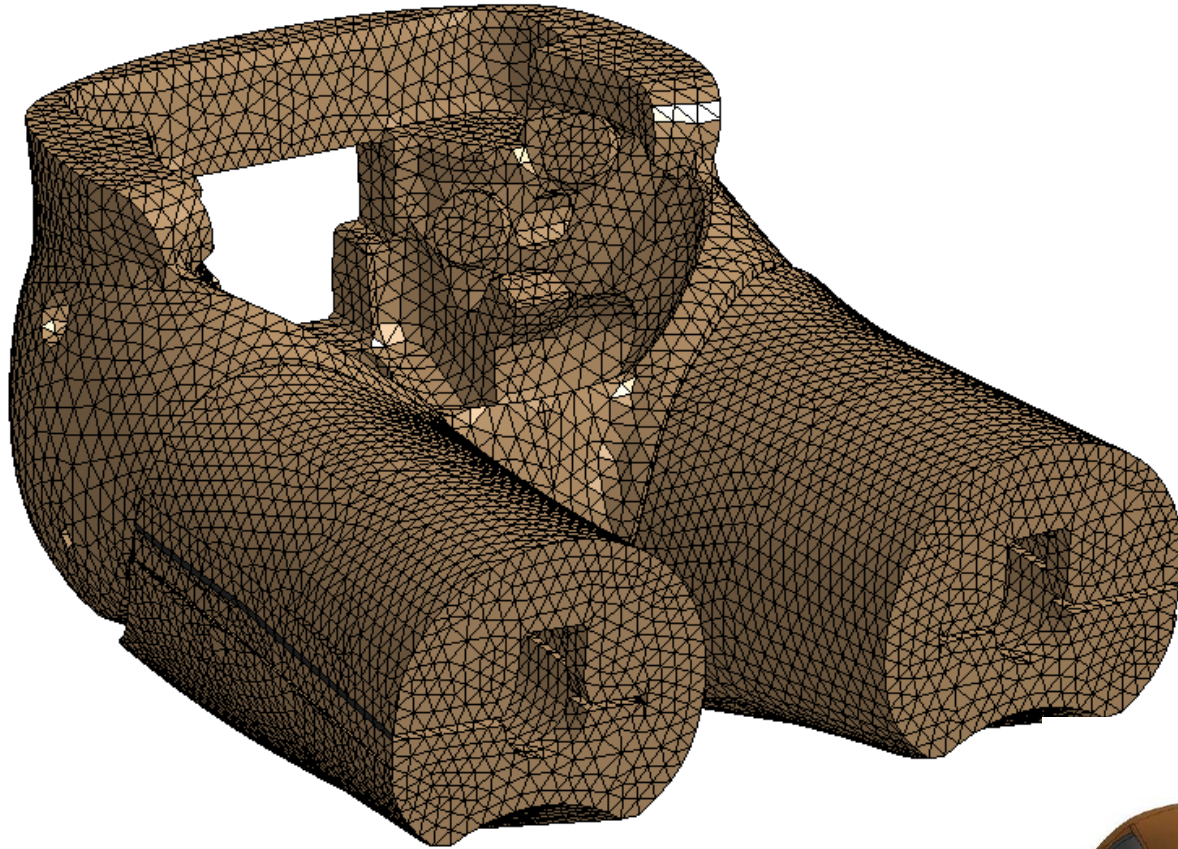
# Modified Pelvis & Thigh Flesh



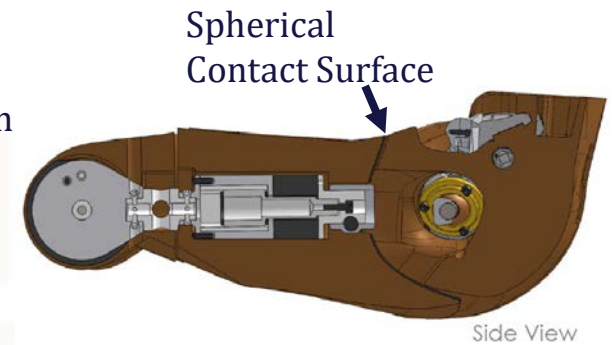
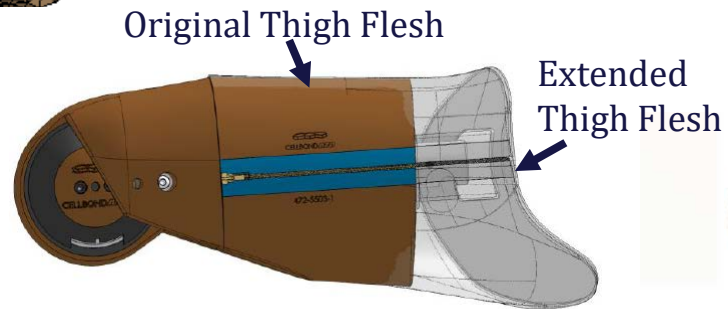
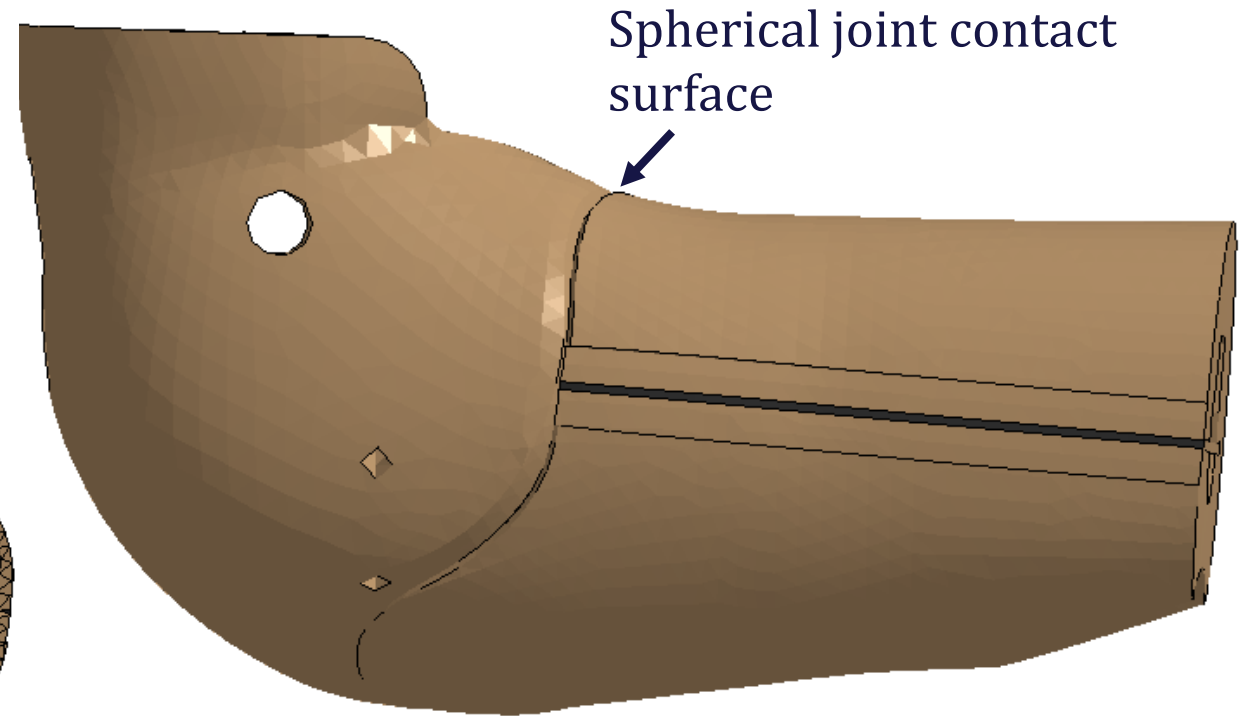
Goal: Greater range of hip extension



# Modified Pelvis & Thigh Flesh

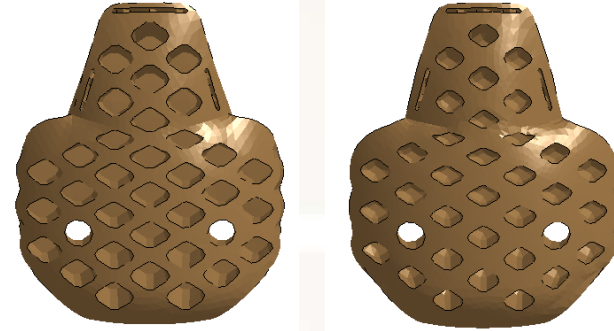
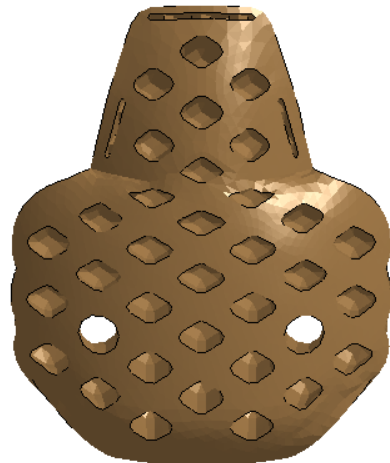
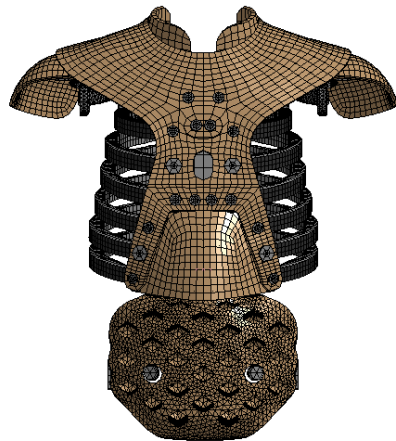
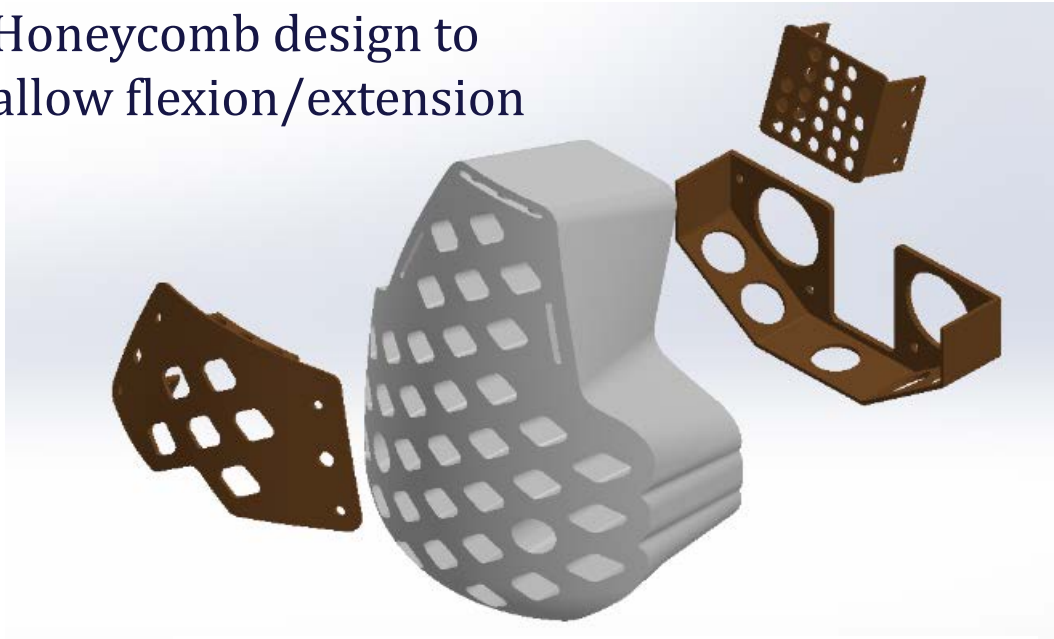


Goal: Greater range of hip extension



# Unified Foam Abdomen

Honeycomb design to allow flexion/extension

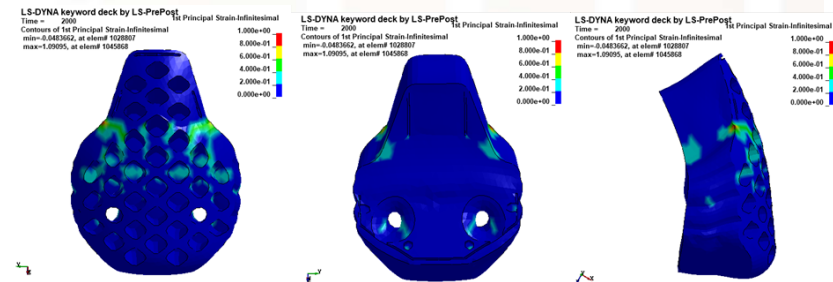


FE-Based Sensitivity Analysis

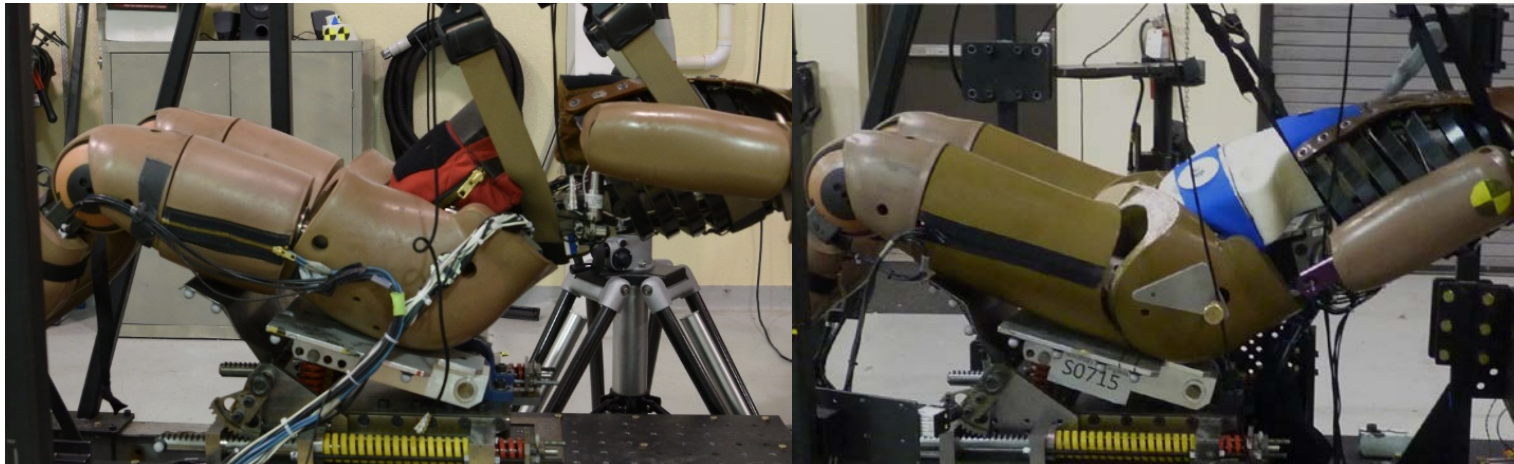
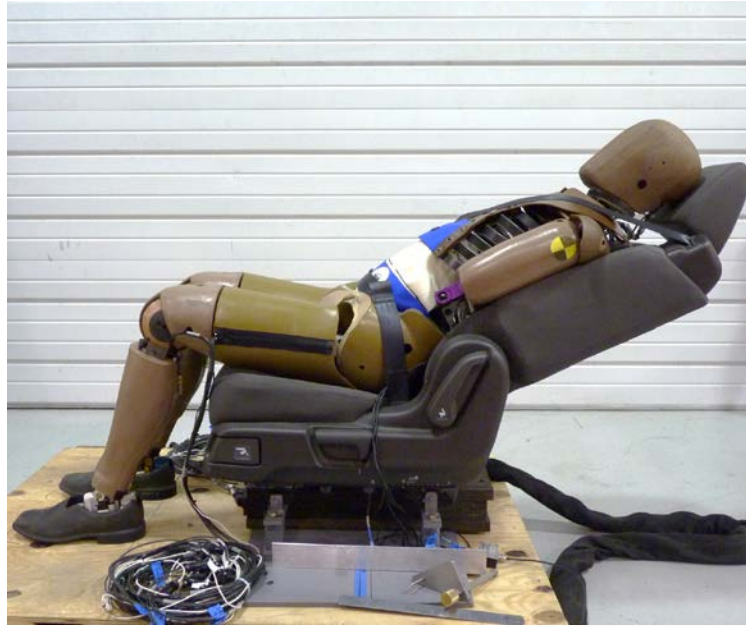
Different geometries

Different materials

Effects on dummy response in certification tests, sled tests, spine extension & flexion



# Positioning Assessment – Initial Design

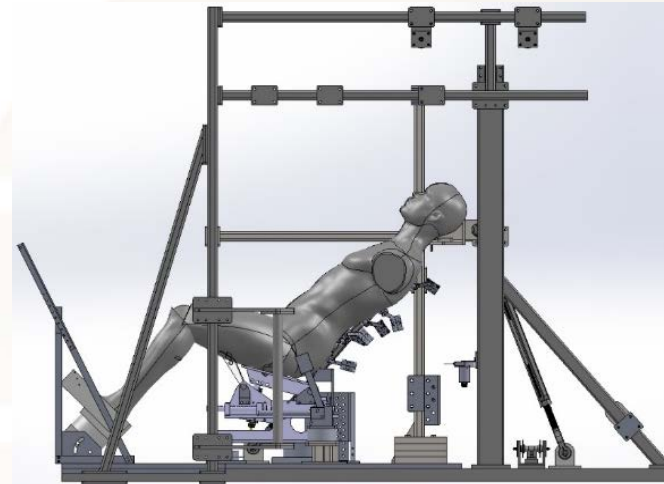


Successfully addressed  
positioning goals



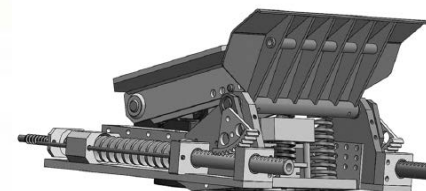
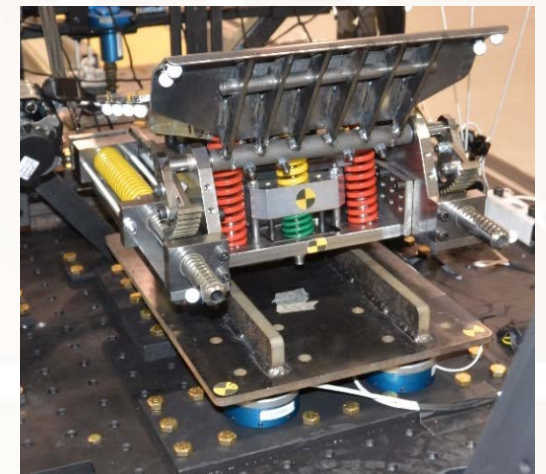
# Recline – UVA PMHS Tests

Richardson et al. 2019 ESV, 2020 Stapp  
Supported by Autoliv Research



50 km/h  
x3 Pretensioners  
Kinematic &  
Dynamic  
Corridors

Uriot 2015 Seat



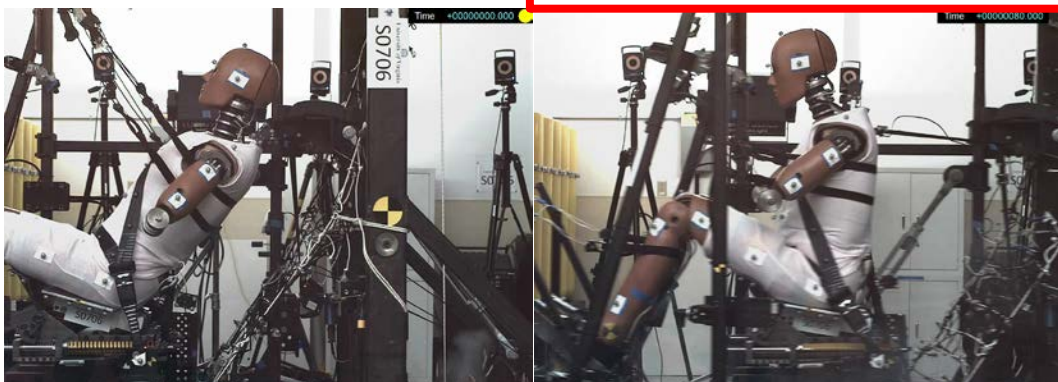
Caution: PMHS Images

# THOR Pelvis Motion

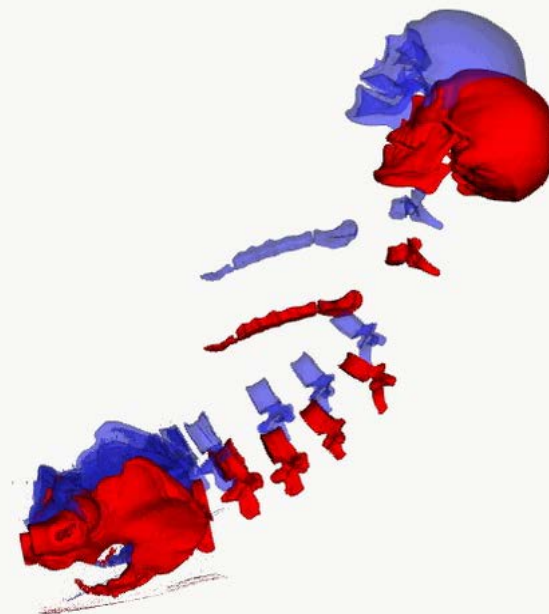
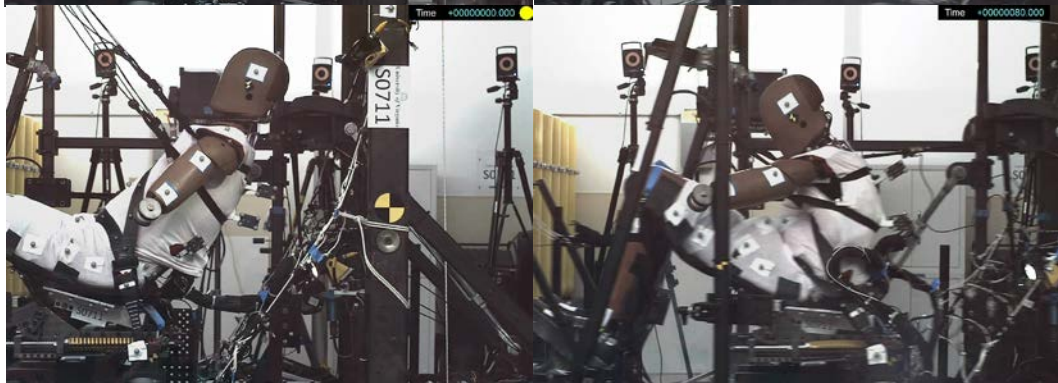
PMHS



Hybrid III



THOR



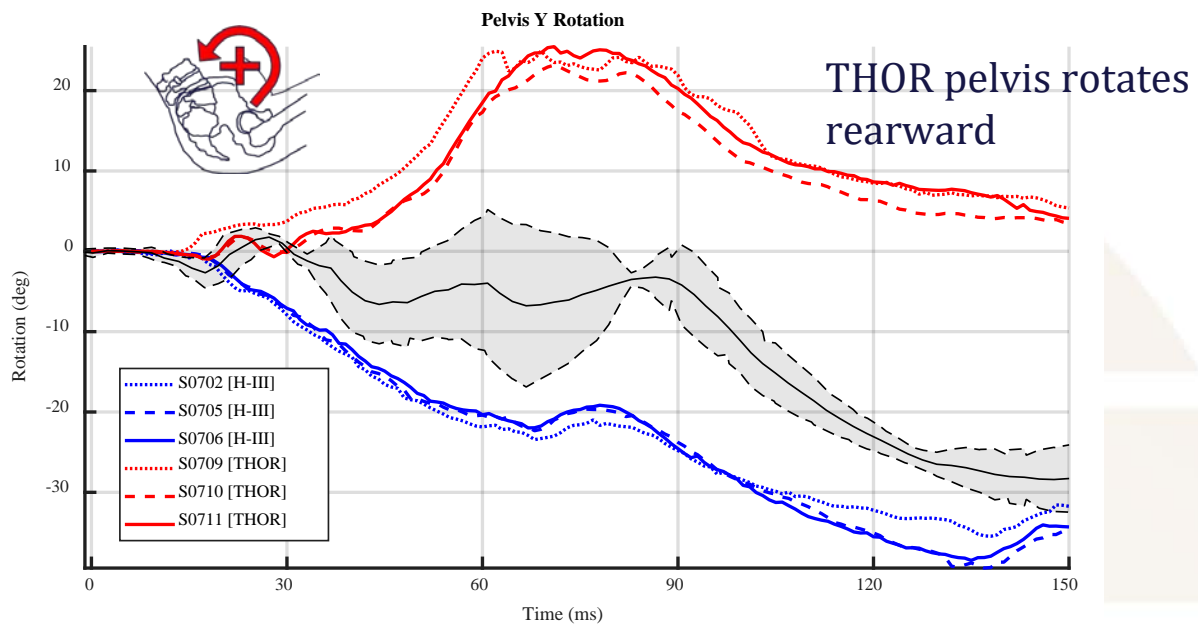
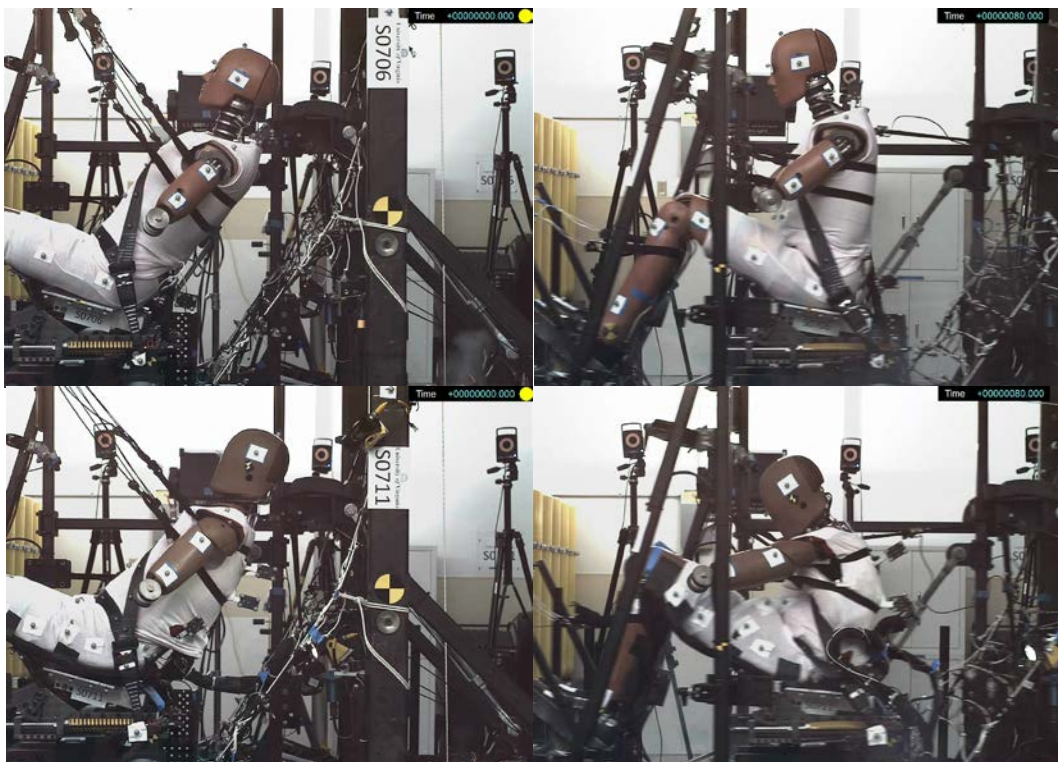
PMHS pelvis's rotated forward into the belt

# THOR Pelvis Motion

PMHS

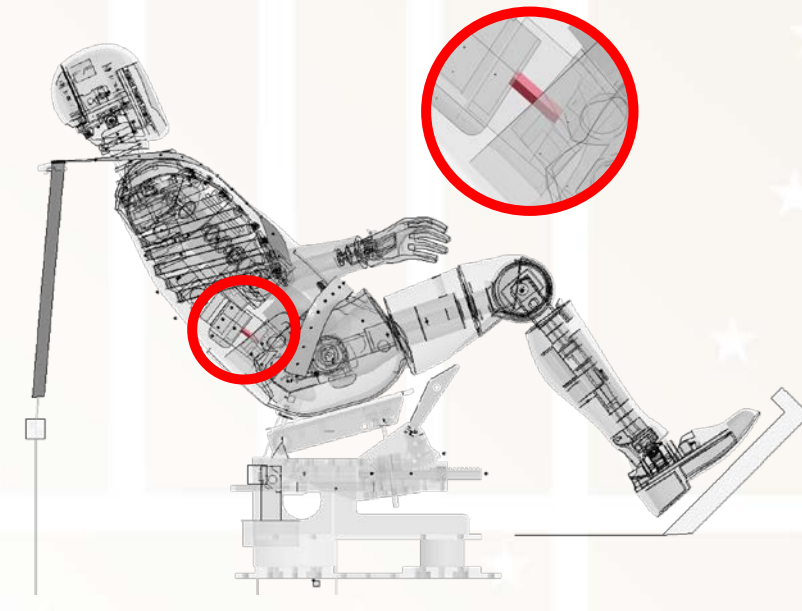
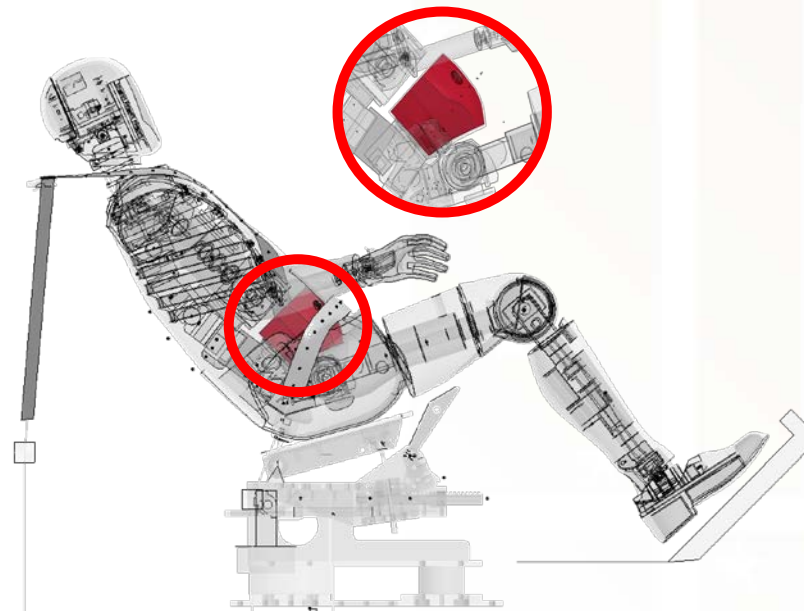
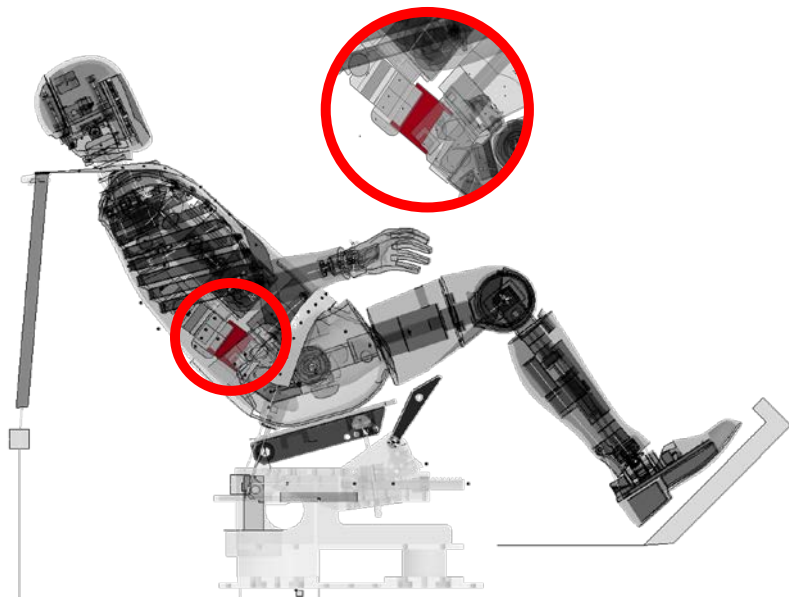
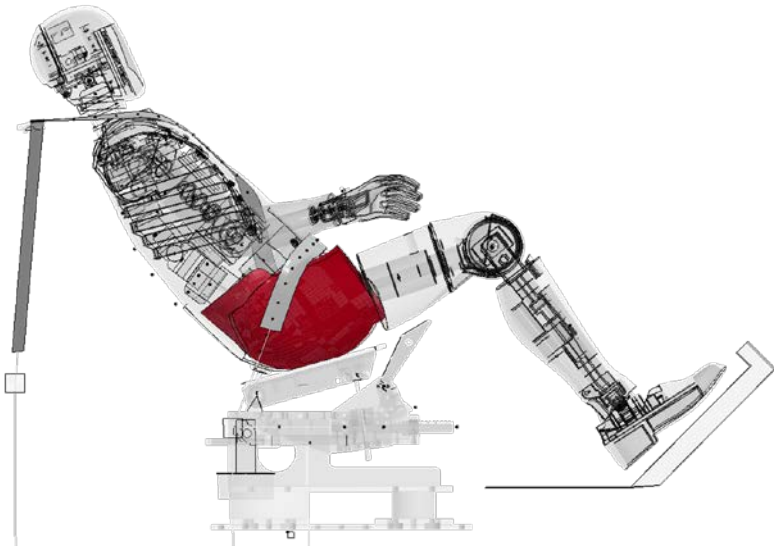
Hybrid III

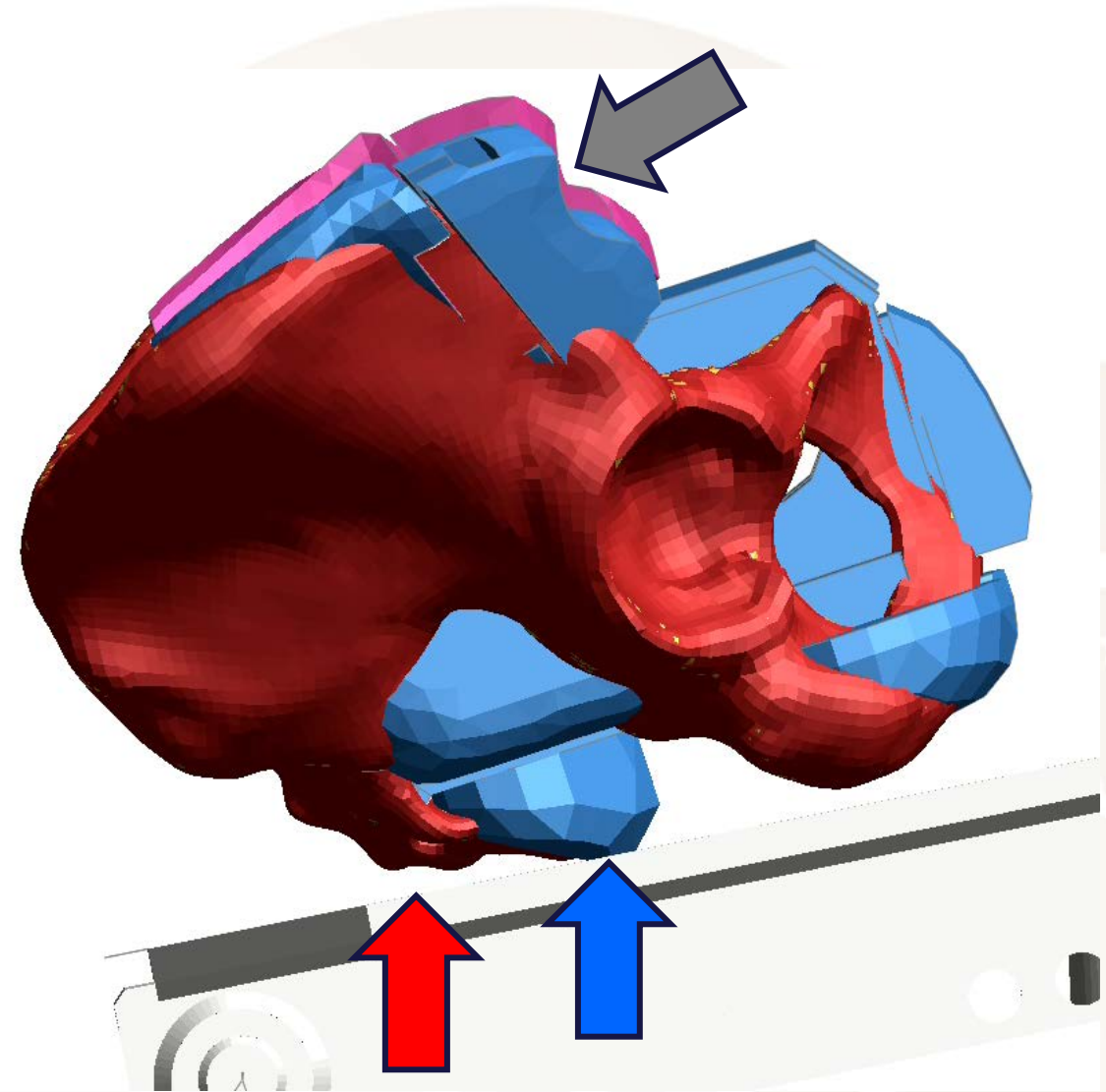
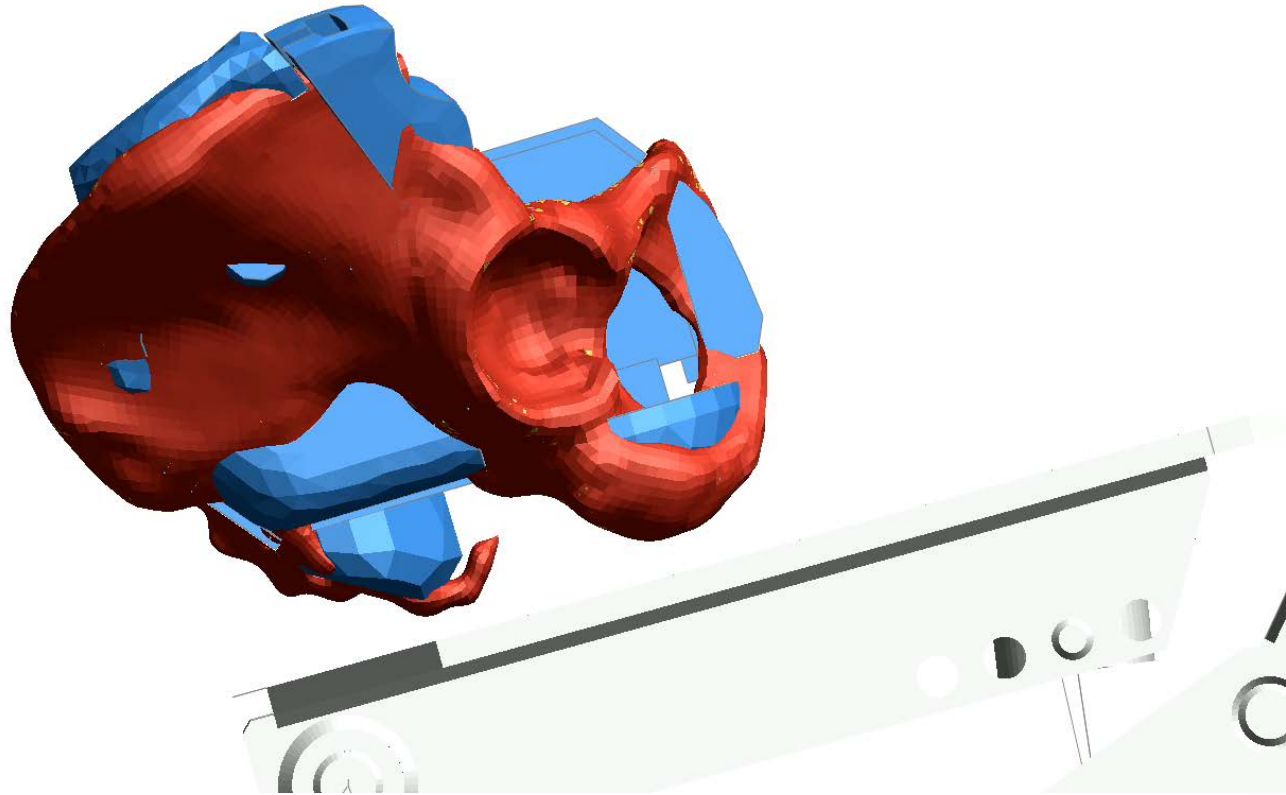
THOR



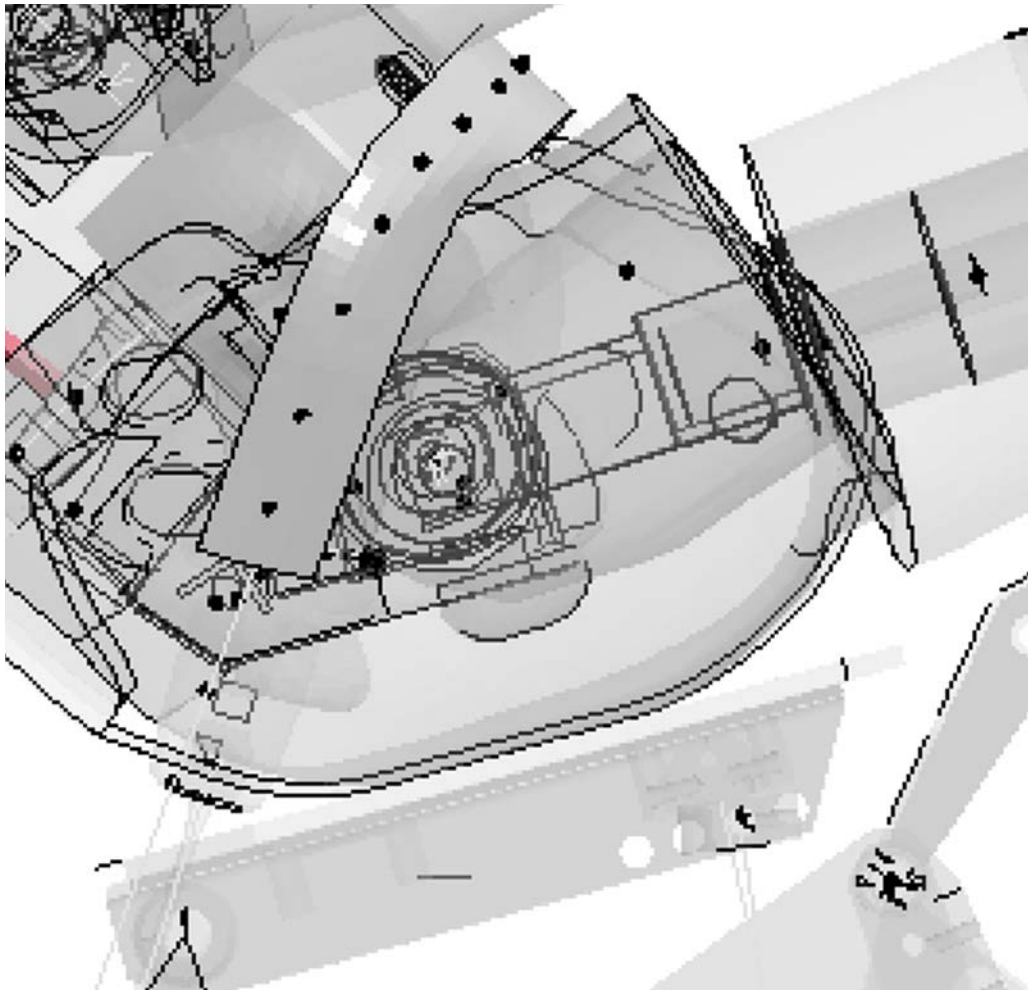
## Parameters Considered

- Pelvis Flesh Stiffness
- Lumbar Stiffness
- Abdominal Insert Stiffness
- Lumbar Cable Stiffness
- Seated Height/x-position
- Sacrum Shape

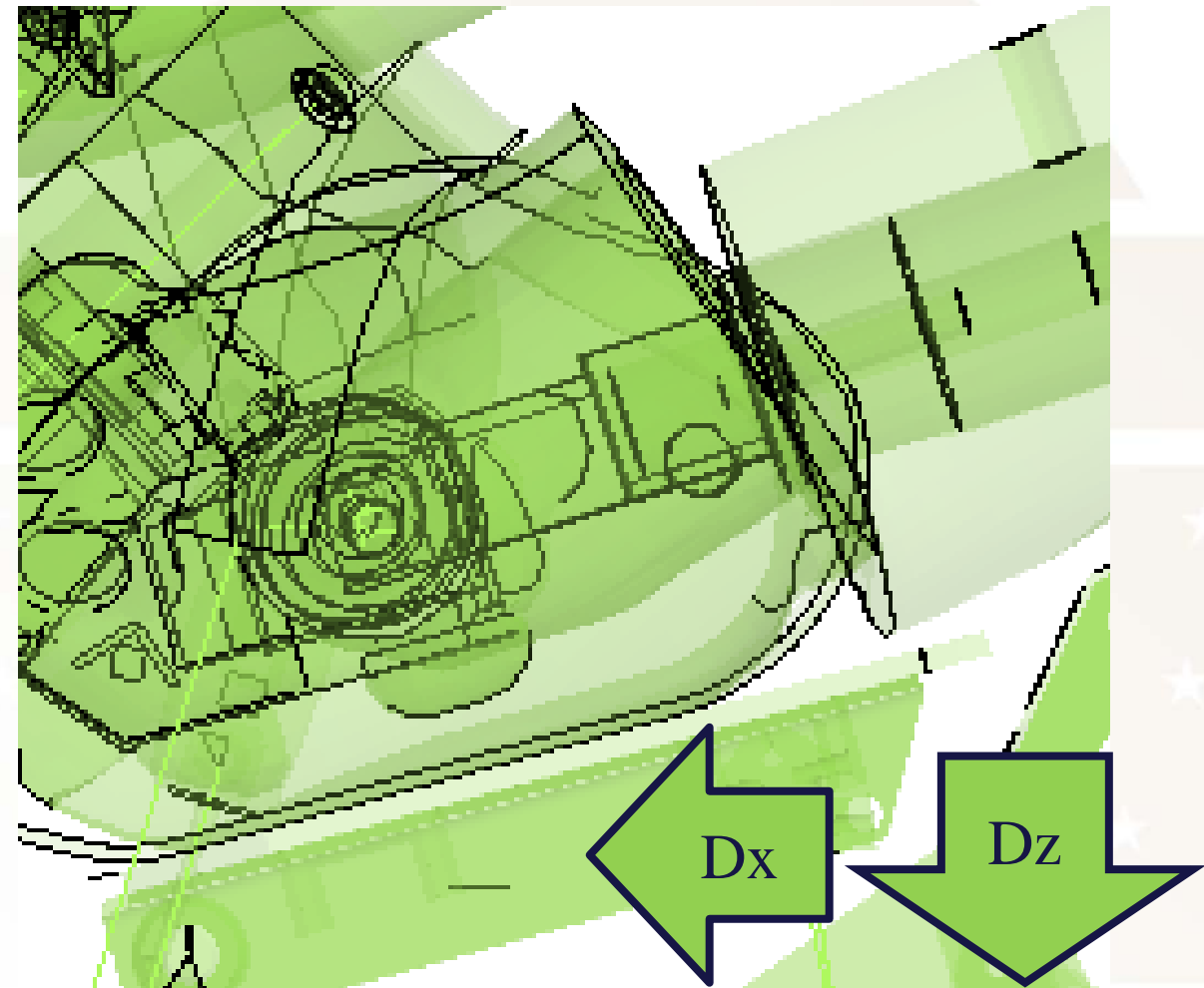




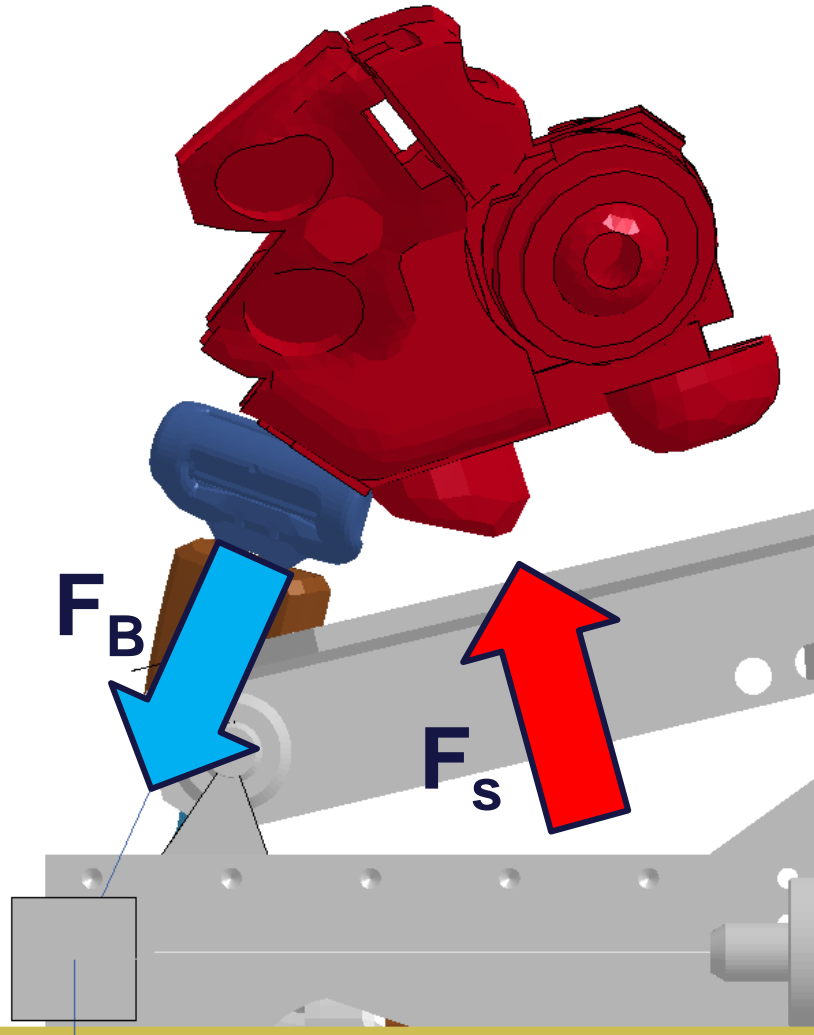
# Nominal



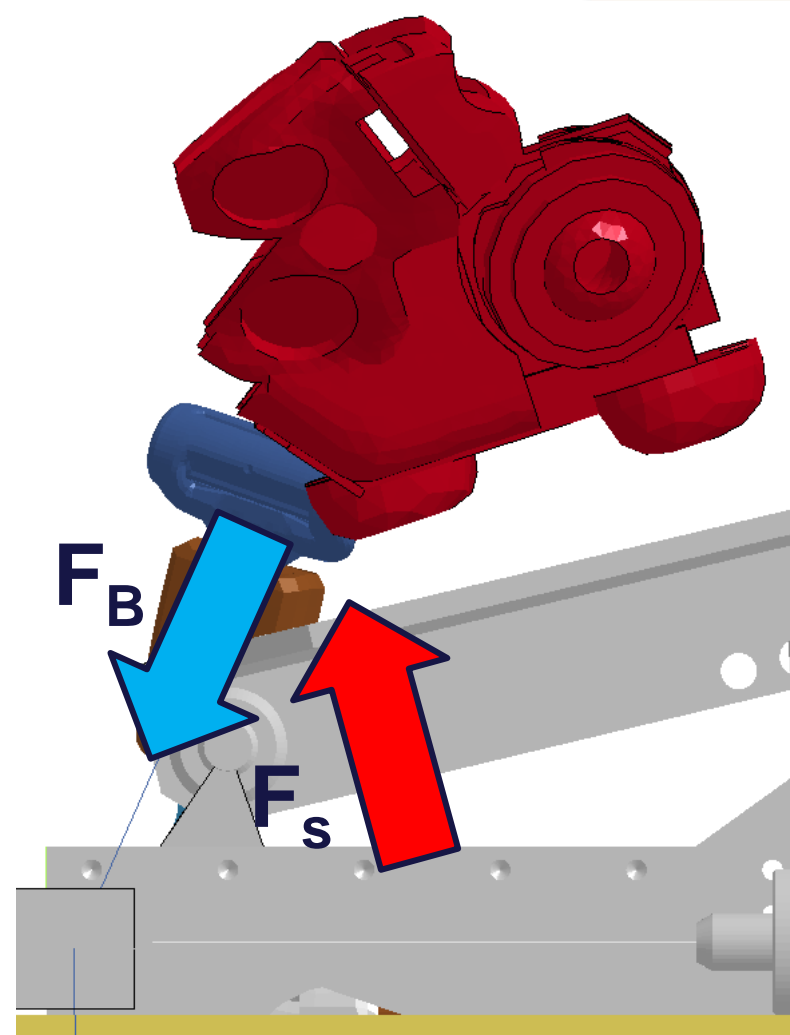
# Dx Dz



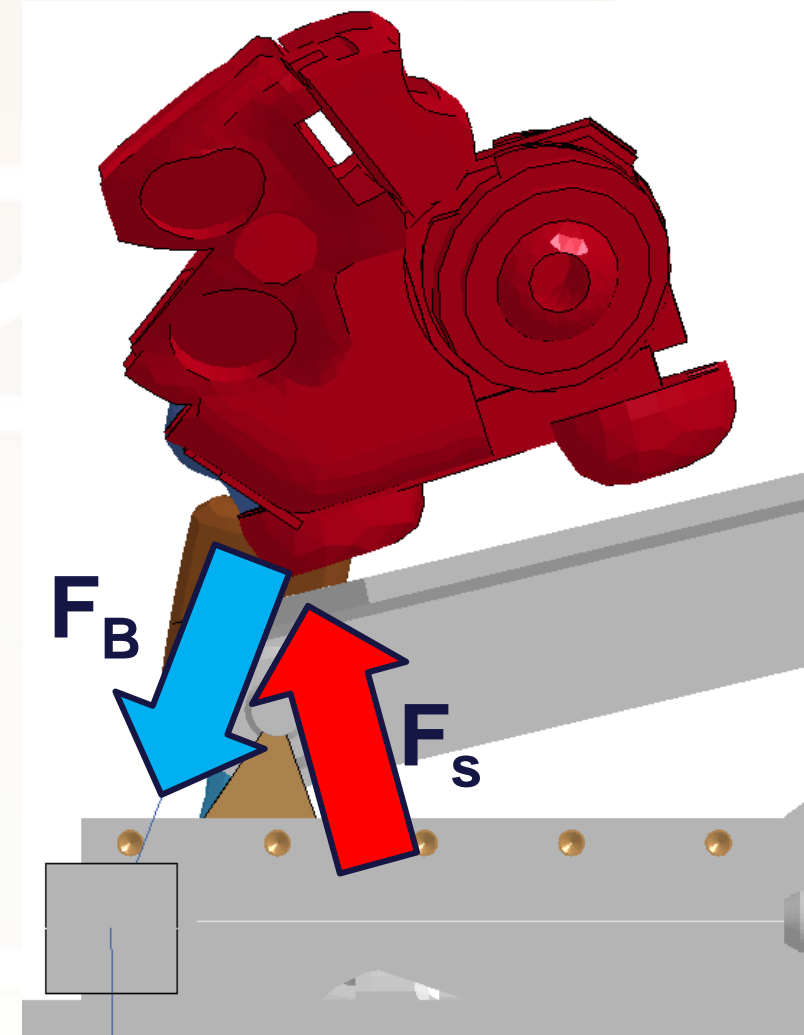
# Nominal



# Sacrum



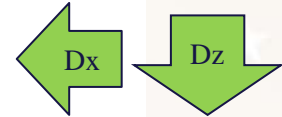
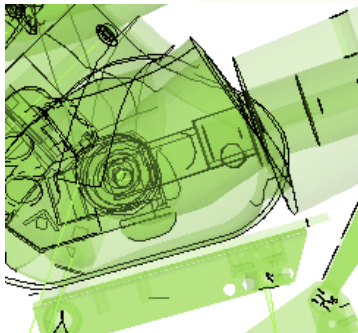
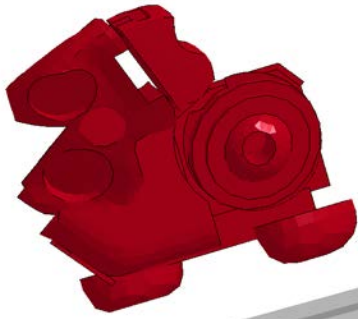
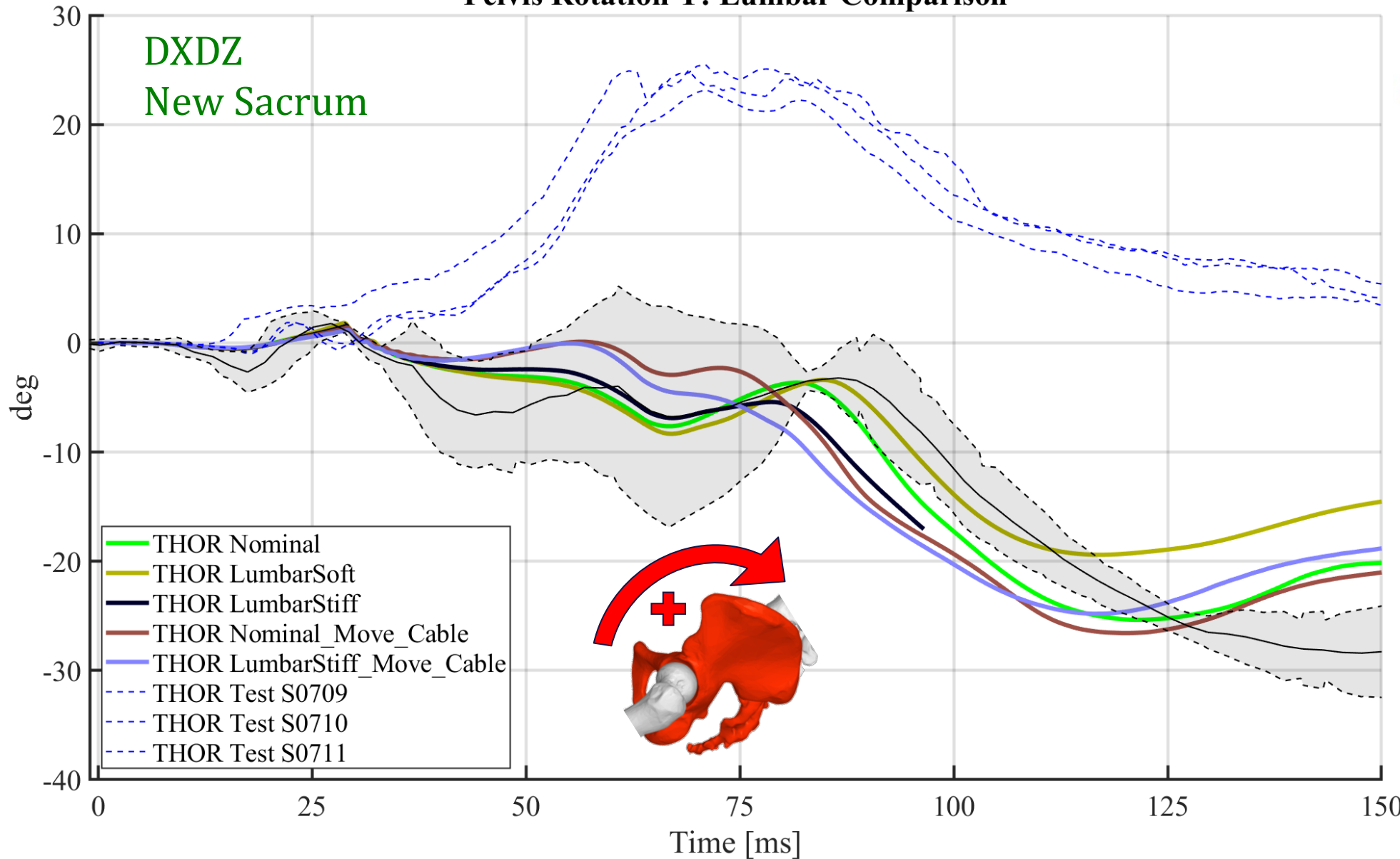
# Sacrum dx dz



Pelvis Rotation Y: Lumbar Comparison

Dx, Dz

New Sacrum

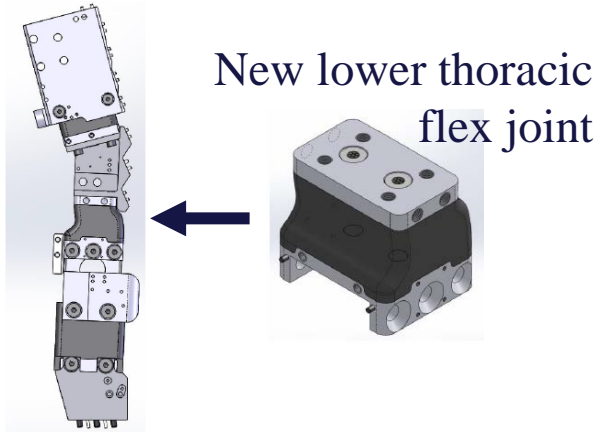




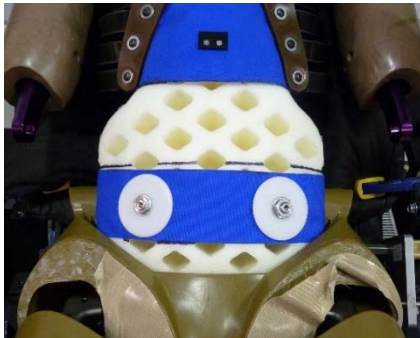
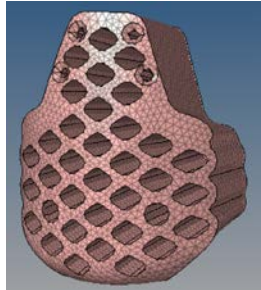
# 2022-2023: Integrate Pelvis Changes into Design



Modified hip & thigh flesh

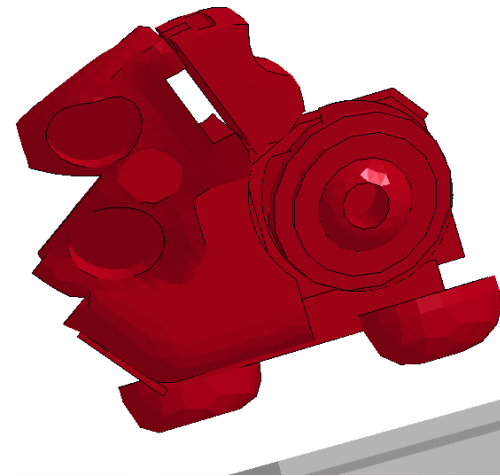
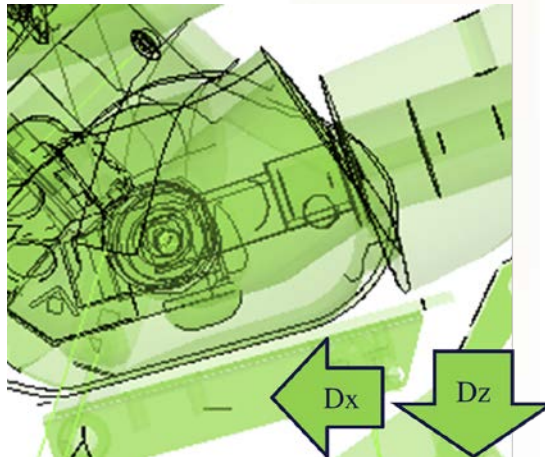


Design & prototype iteration:  
implement pelvis flesh thickness,  
sacrum geometry changes

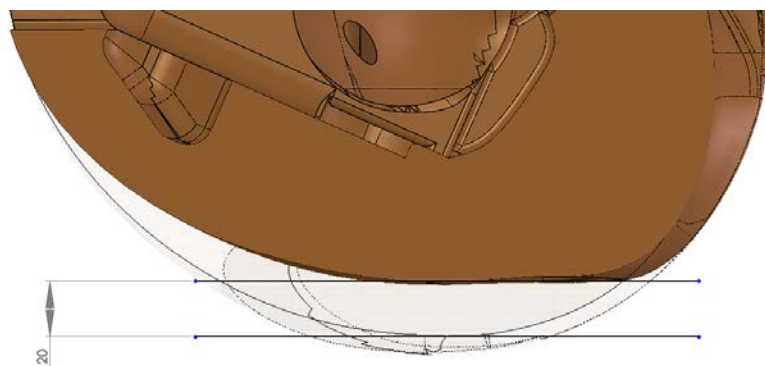
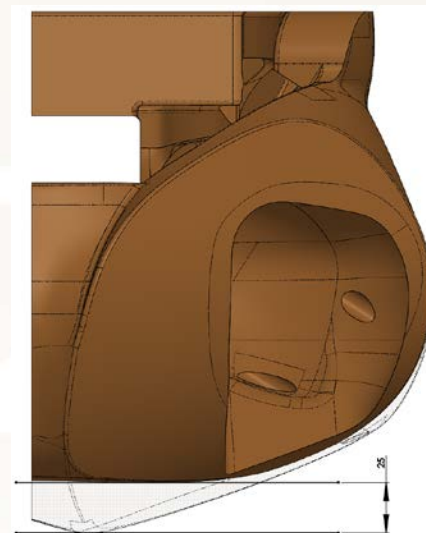
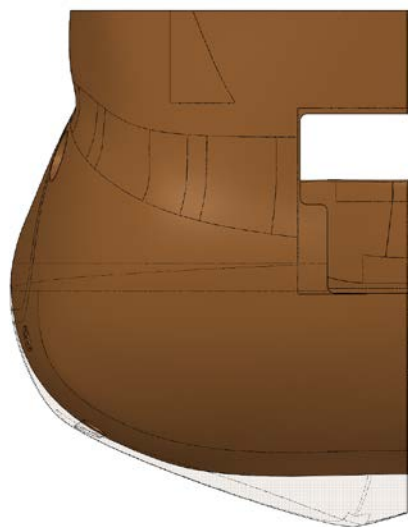
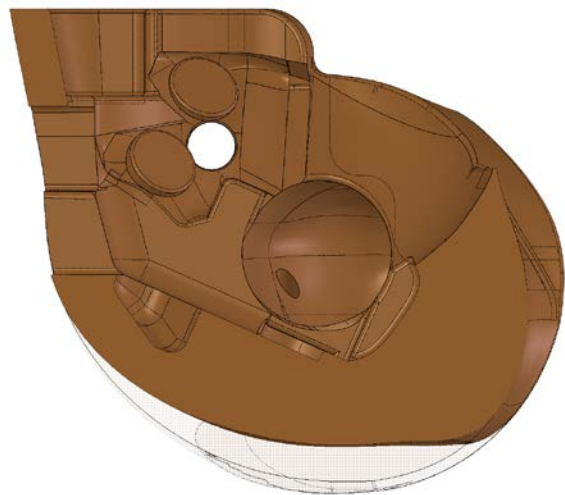


1-piece honeycomb abdomen

+



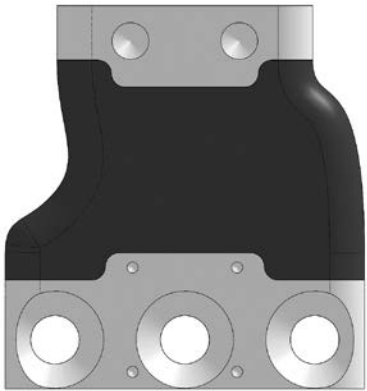
# Design Refinement



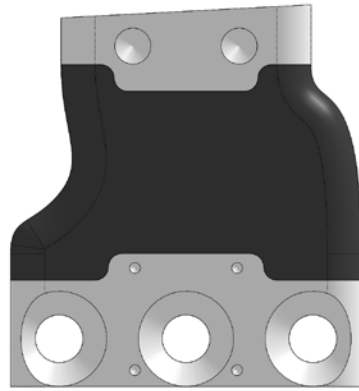
Pelvis flesh  
thickness reduction  
(preliminary – not final drawings)

# Design Refinement

## Thorax Flex Joint Angle

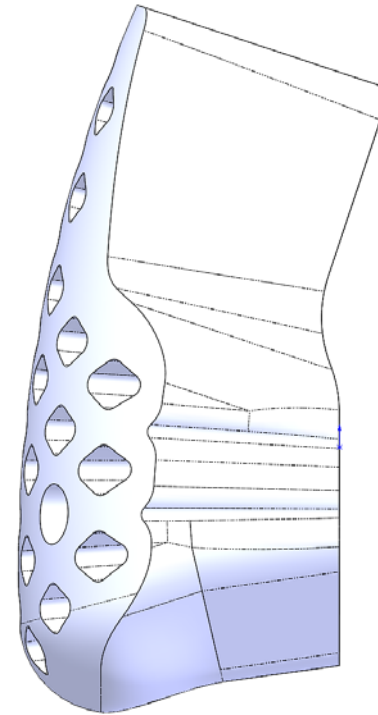


Original  
(erect)

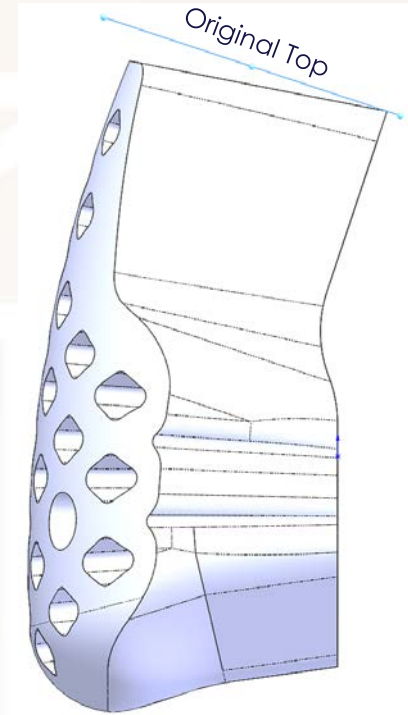


Modified  
(between erect  
and slouched)

## Unified Abdomen Shape



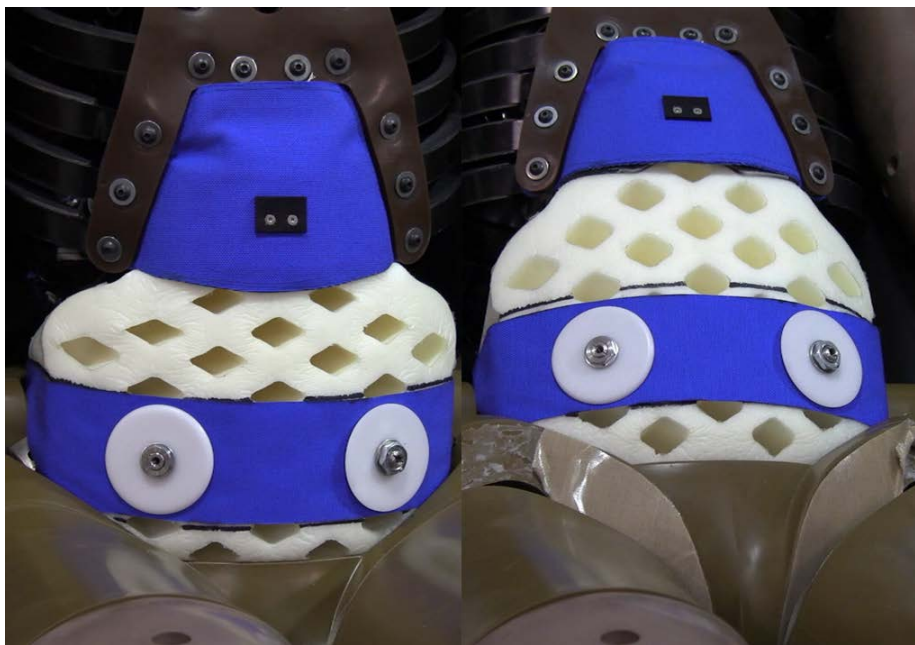
Original



Modified  
(mitigate interference,  
change in flex joint angle)

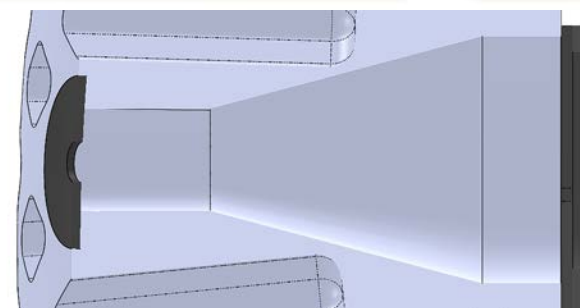
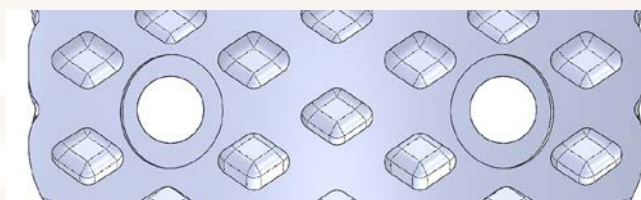
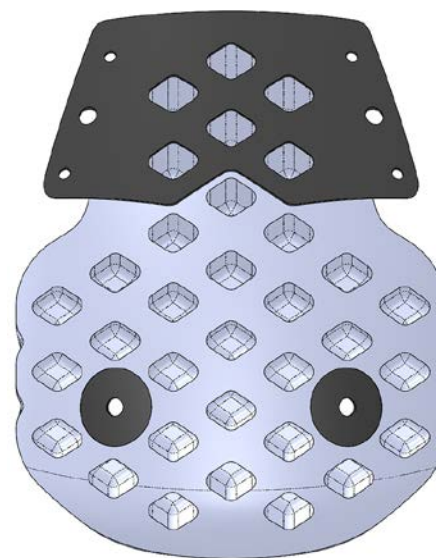
# Design Refinement

## Abdomen IR-TRACC Attachment



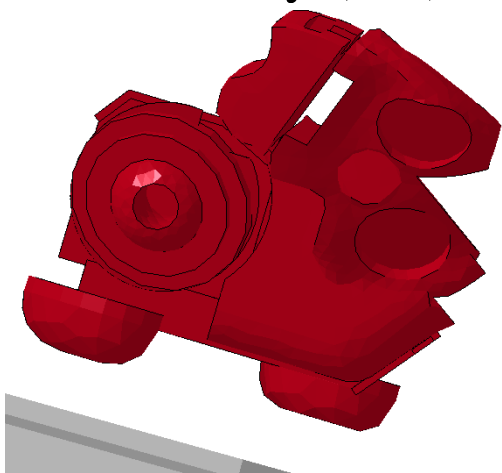
Preliminary

## Molded Anterior Attachment



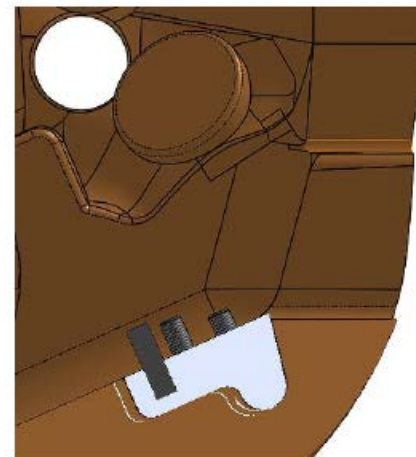
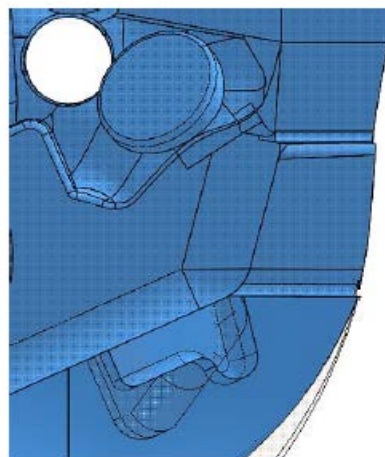
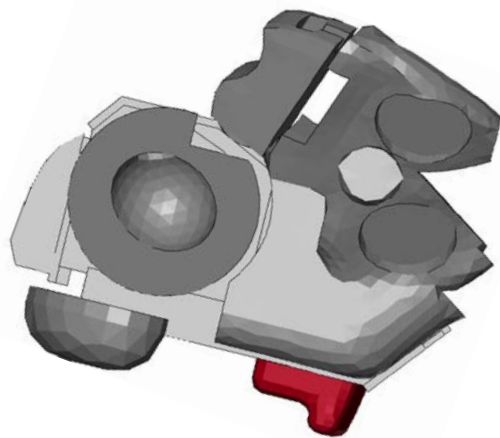
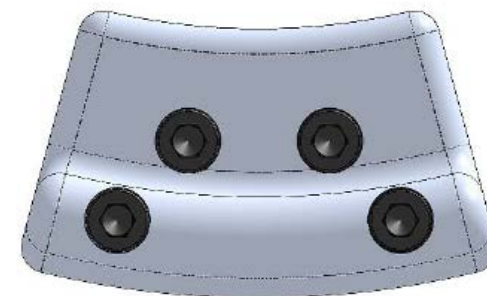
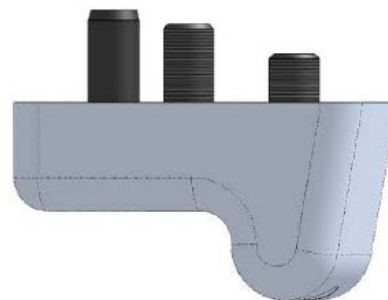
# Design Refinement - Sacrum

Preliminary (flat)



Avoid extending  
beyond edge of the  
pelvis

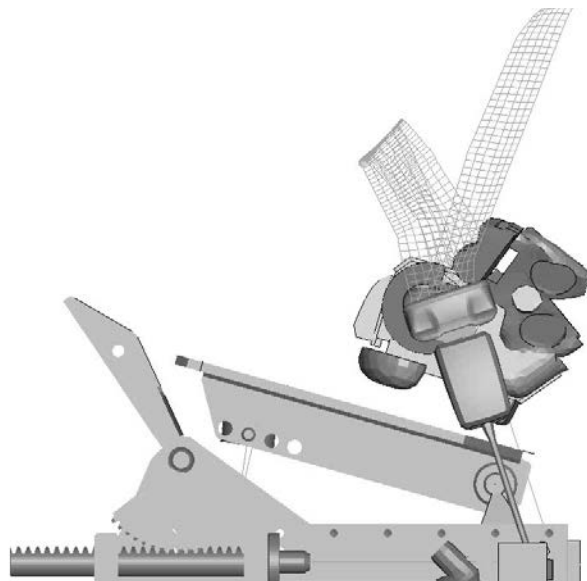
Current Design (contoured)



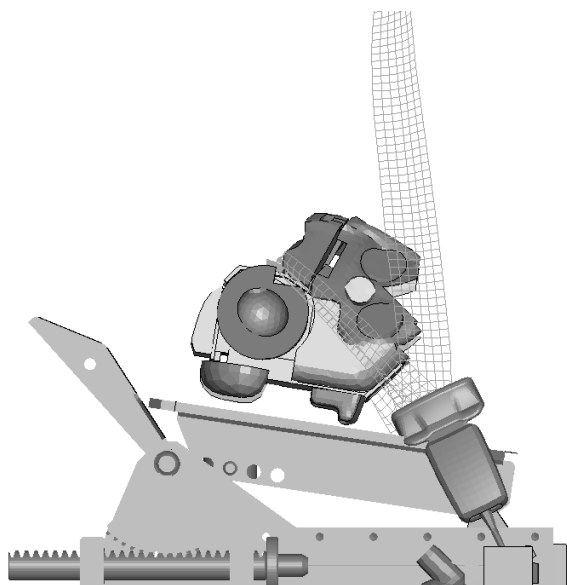
Keep  
engagement  
point rearward

# Pelvis Behavior

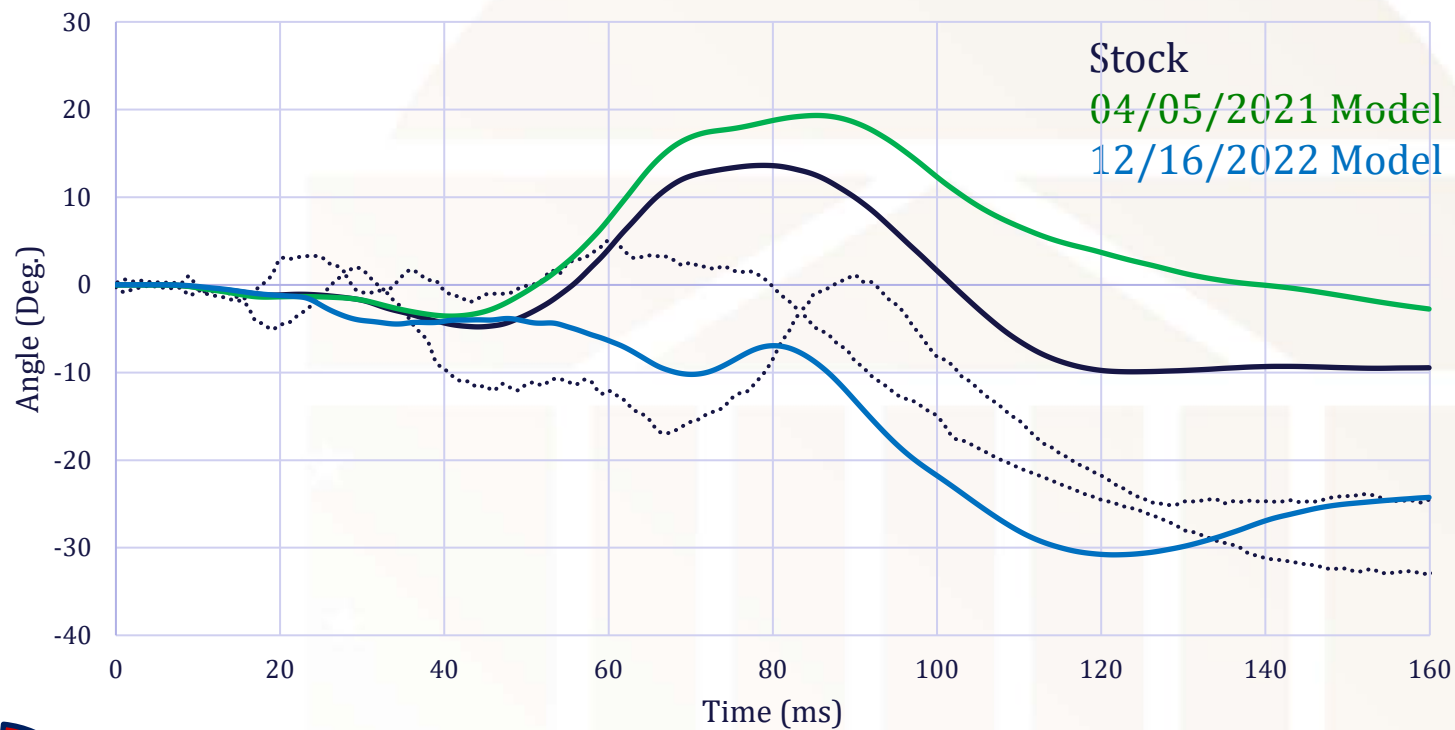
THOR 50M  
Time = 0



THOR 50M  
Time = 80



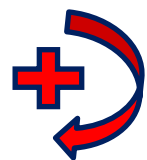
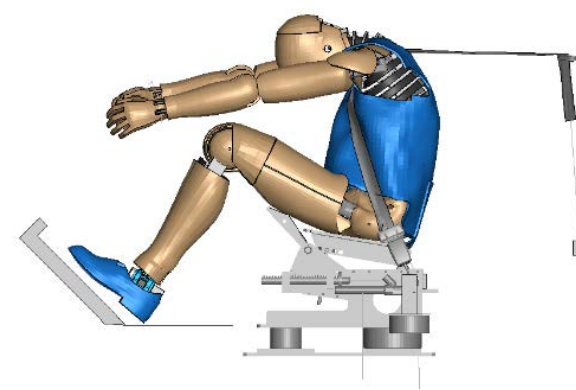
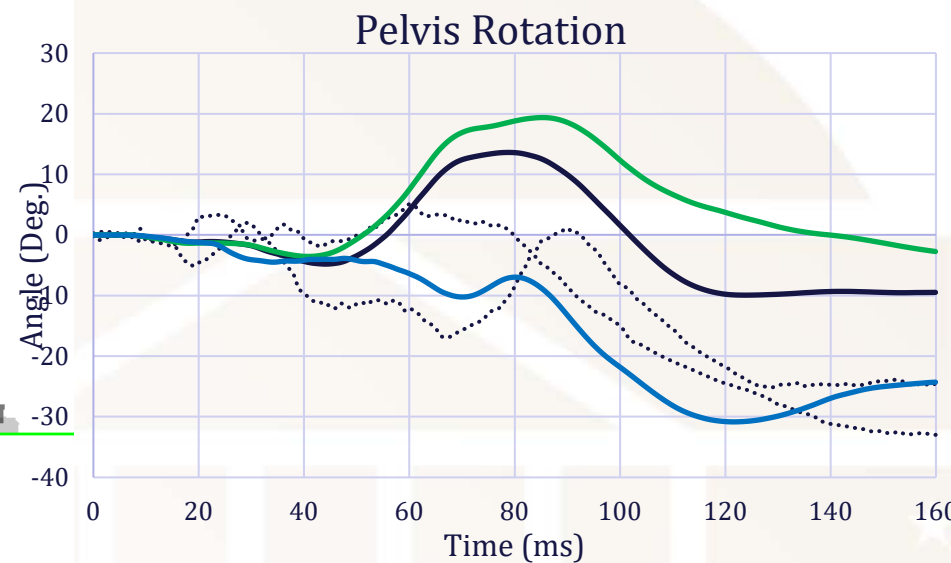
Pelvis Rotation



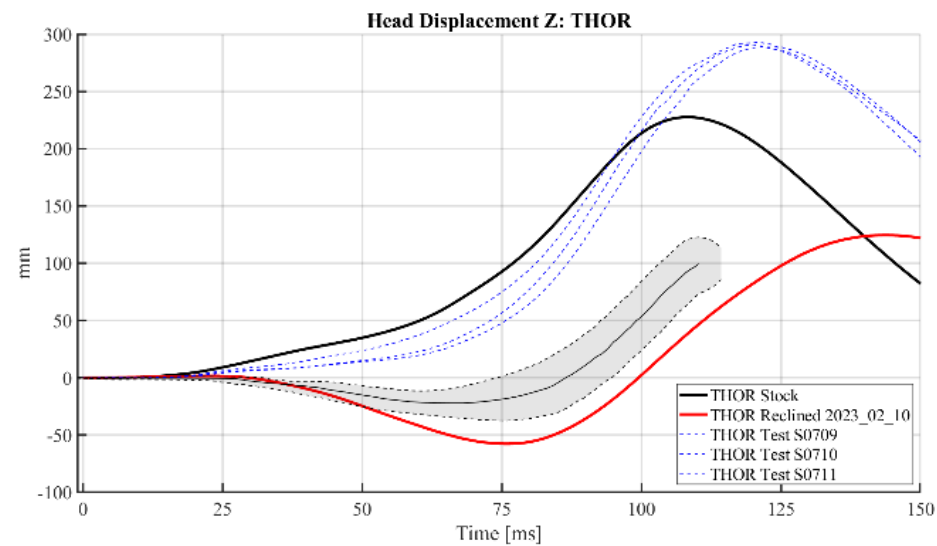
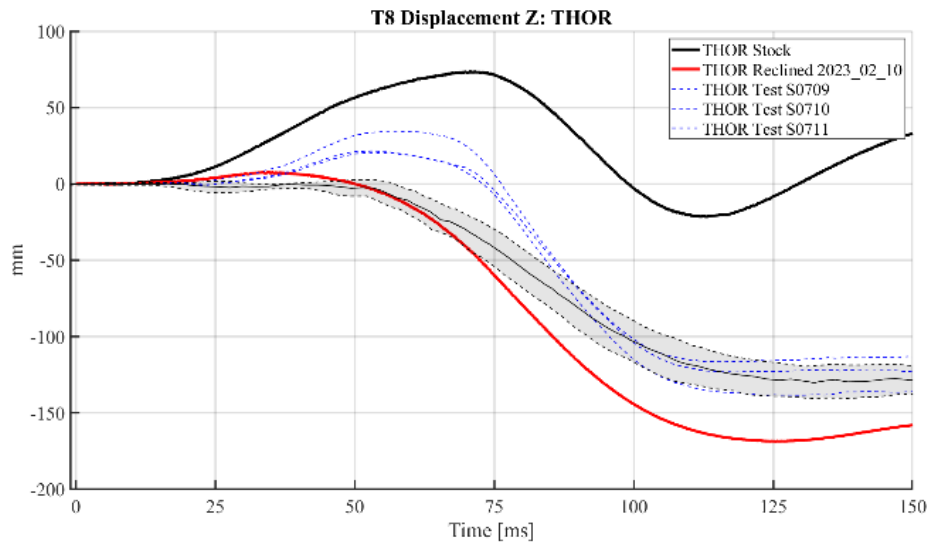
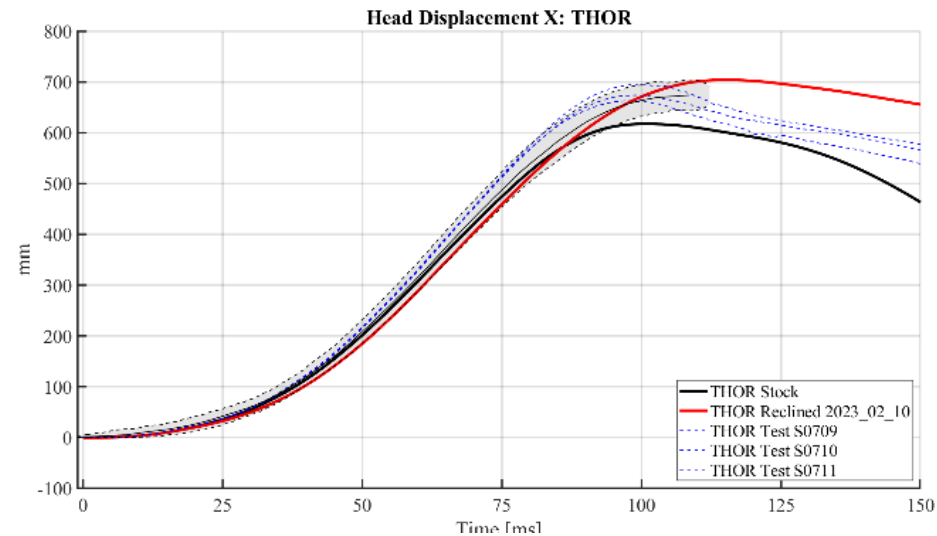
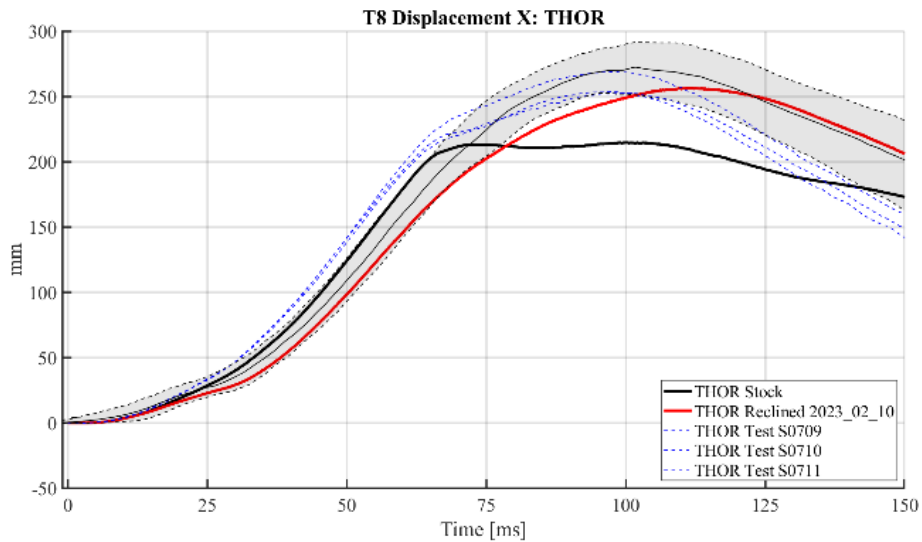
# Pelvis Behavior

04/05/2021

12/16/2022



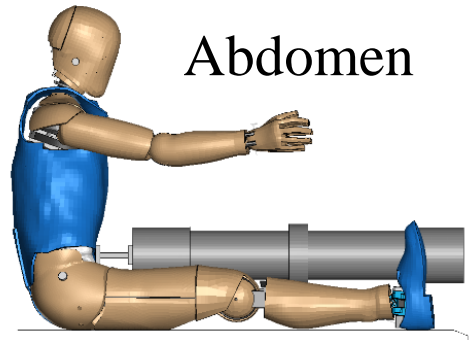
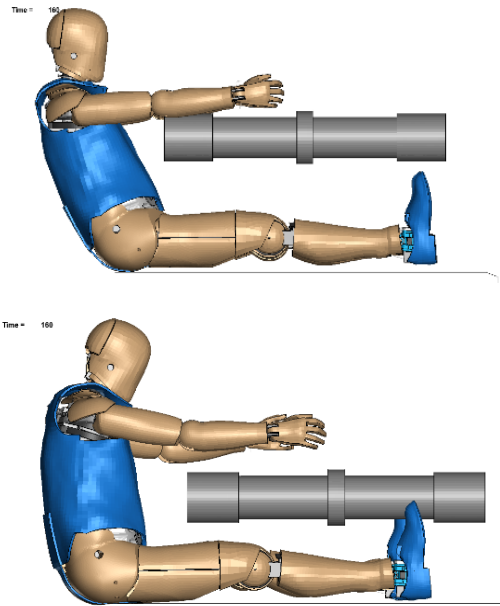
# Effect on Kinematics



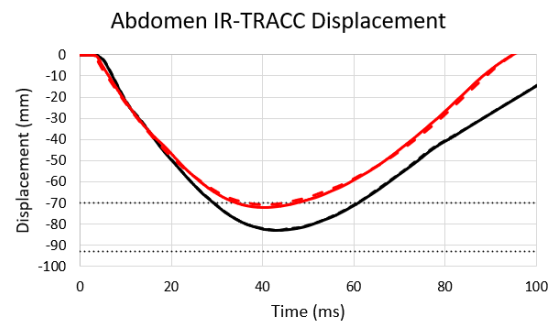
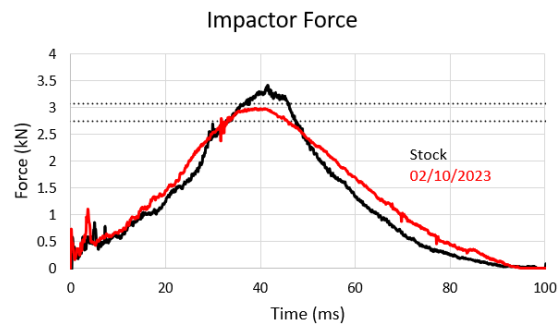


# Certification & Upright Simulations

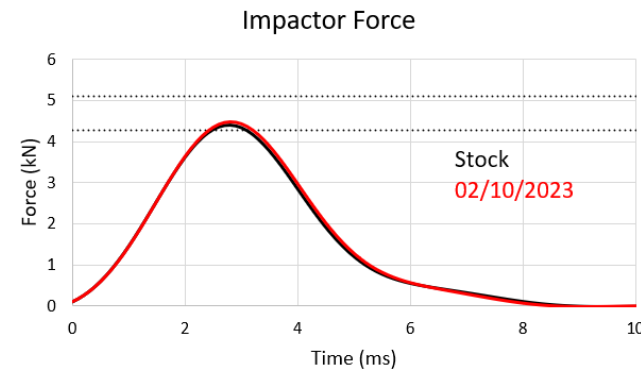
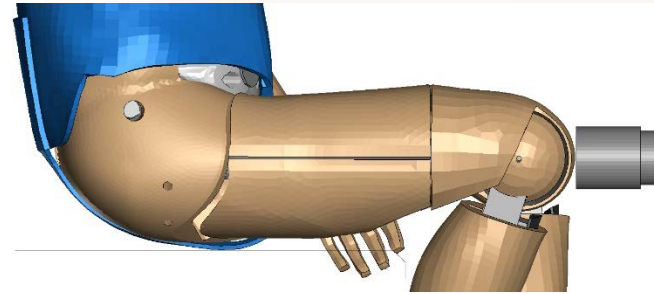
## Upper & Lower Thorax



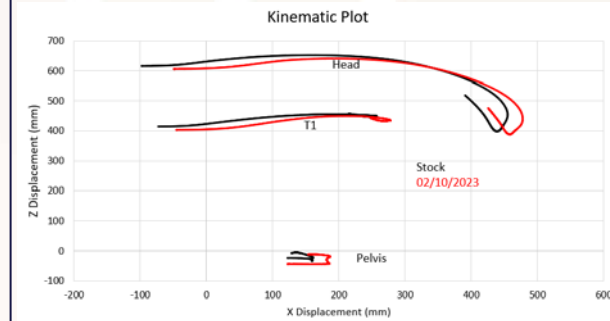
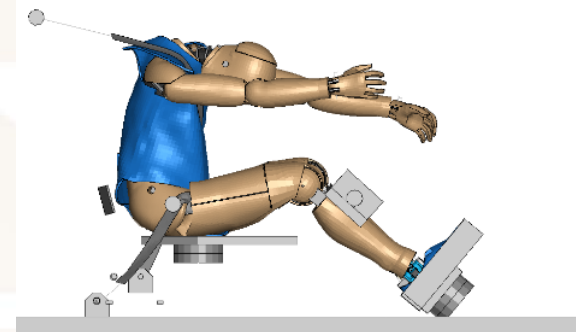
## Abdomen



## Knee Impact



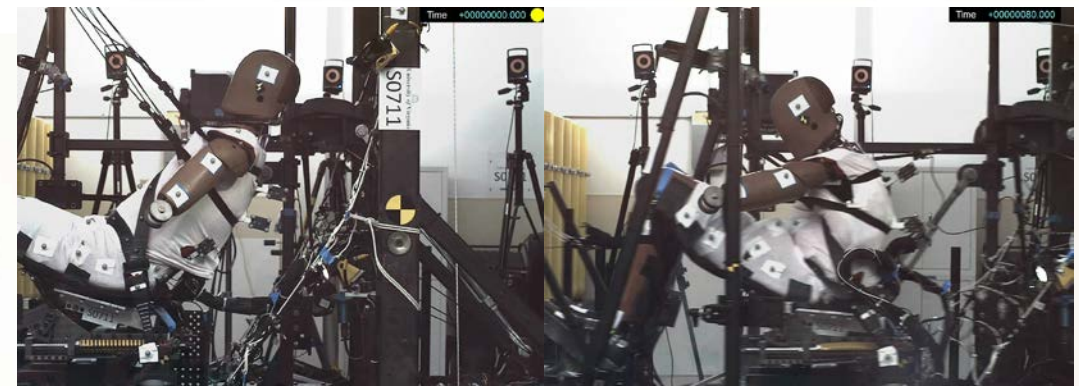
## Gold Standard 1, 2, & 3



Similar responses as the stock THOR

## Next Steps (Currently Underway)

- ▶ Positioning assessment with updated design
- ▶ Reclined sled testing with updated design (RCCADS 2022-2023 project)
- ▶ Production of additional sets of prototype parts



Initial design

# Update on Refinements to THOR to Improve Usability and Biofidelity in Diverse Seating Postures

NHTSA Contract No. DTNH2215D00022/693JJ919F000222



Questions?

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**Thank You!**

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RCCADS Public Workshop – May 2023*