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

NHTSA Contract No. DTNH2215D00022/693JJ919F000222

Jason Forman[1], Adrian Caudillo-Huerta[1], Justin McMahon[1], Matthew Panzer[1], William Marshall[2], Derek Winter[2], Matthew Seavers[2], Matthew Dyer[2], Paul Lemmen[2]

[1]University of Virginia Center for Applied Biomechanics

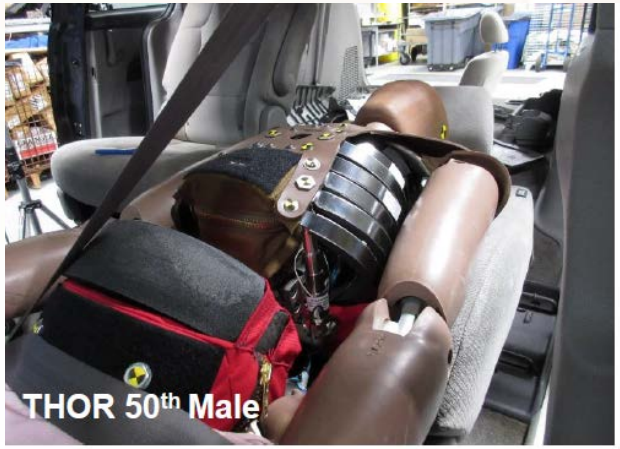
[2]Cellbond

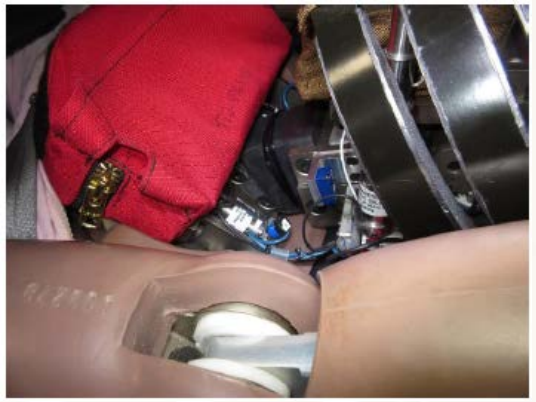
RCCADS Public Workshop – May 2021

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



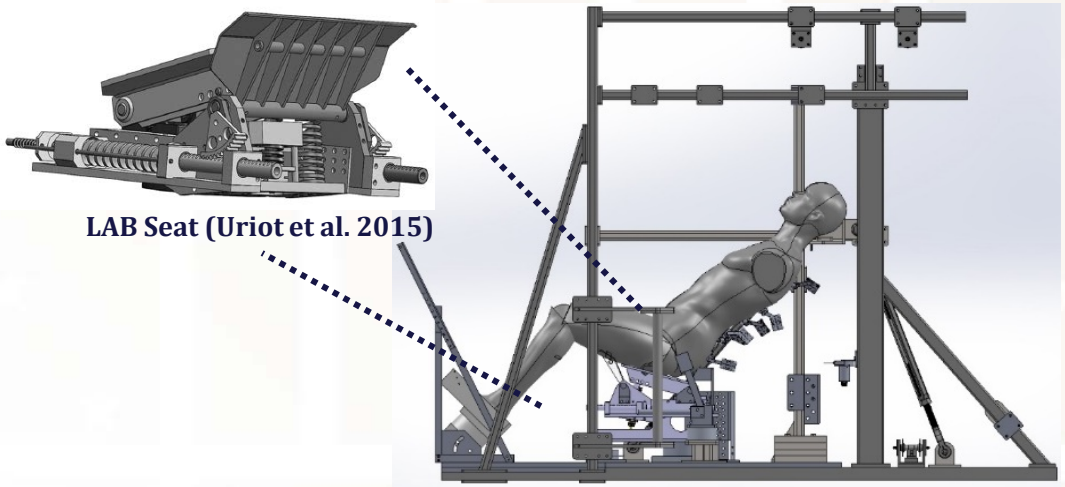


Positioning Study – Qualitative Analysis

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

Honda Odyssey 2nd row captain's chair

Acura TLX Driver's Chair

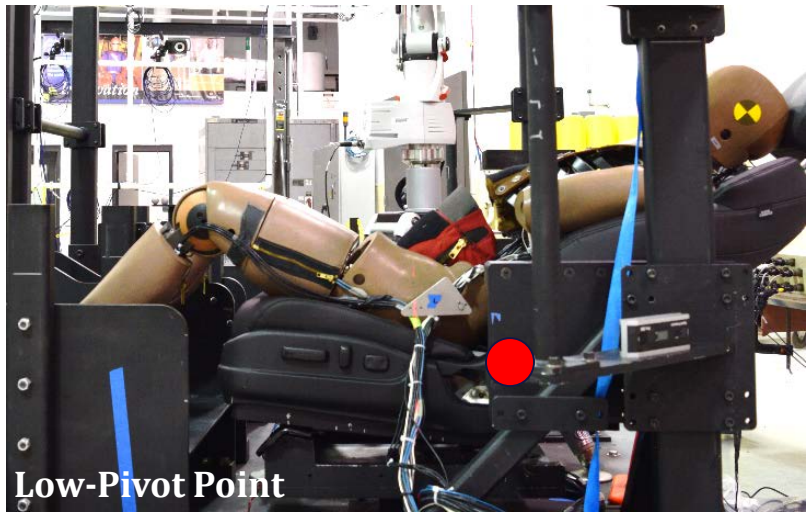


LAB Seat (Uriot et al. 2015)

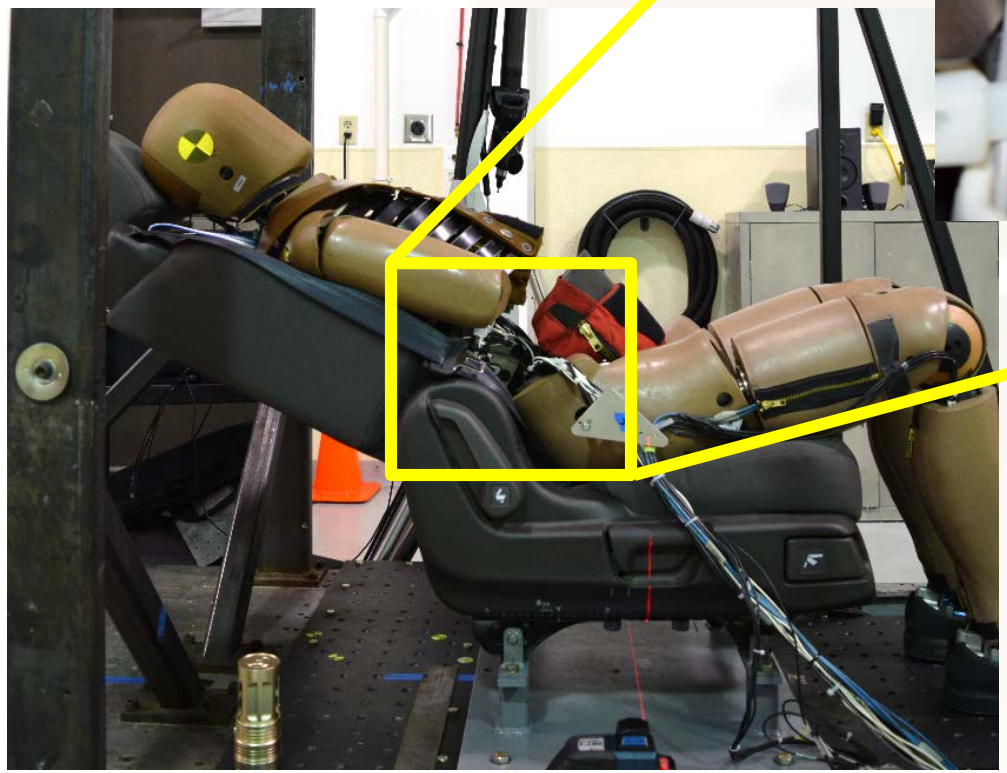
LAB Seat on HAV Gold Standard Buck

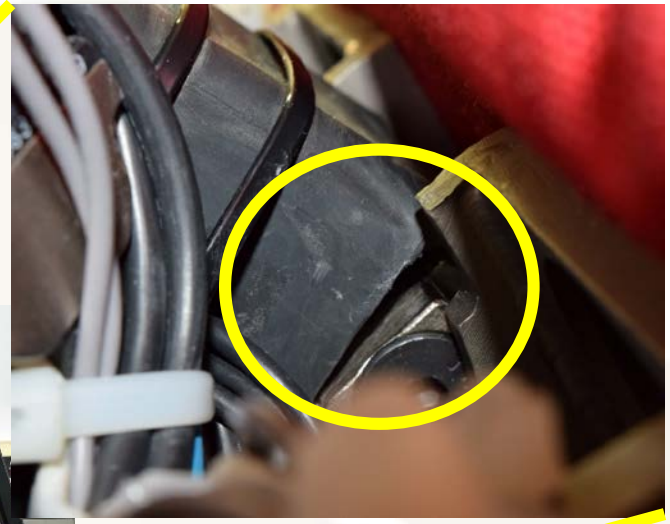
Positioning Study – Key Findings

High Pivot Point



Lumbar flex joint pulls apart under extension



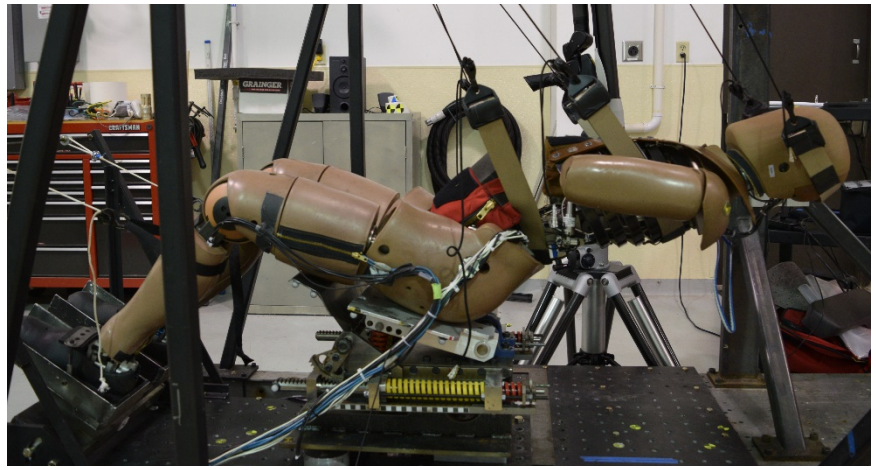


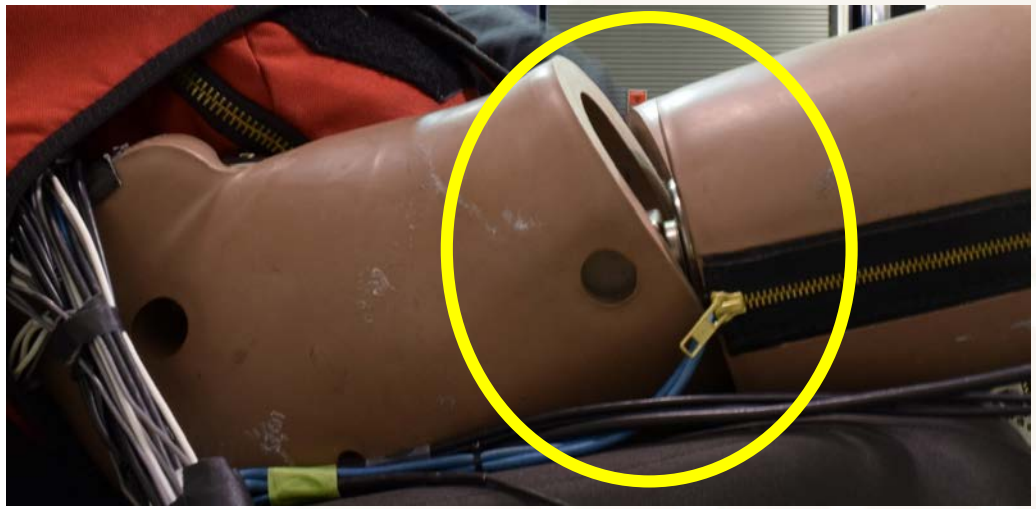
Amount of extension depends on seat geometry

Report: NHTSA BioDB TSTNO 12990

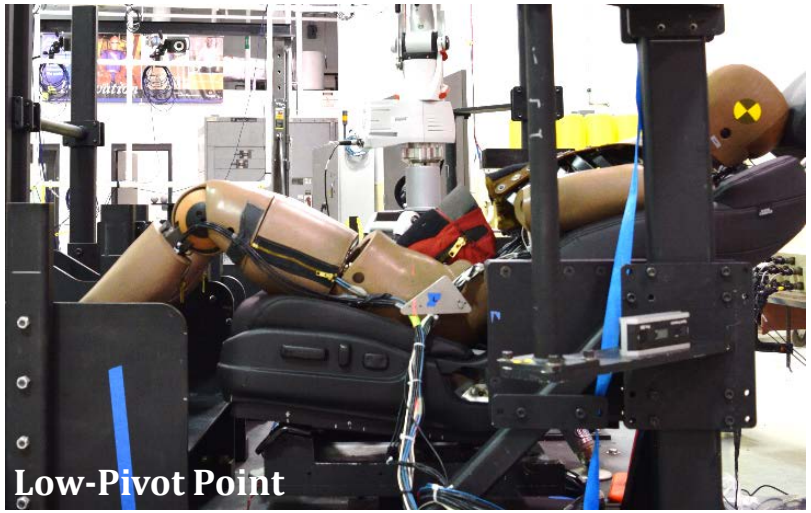
Positioning Study – Key Findings

Generic Seat

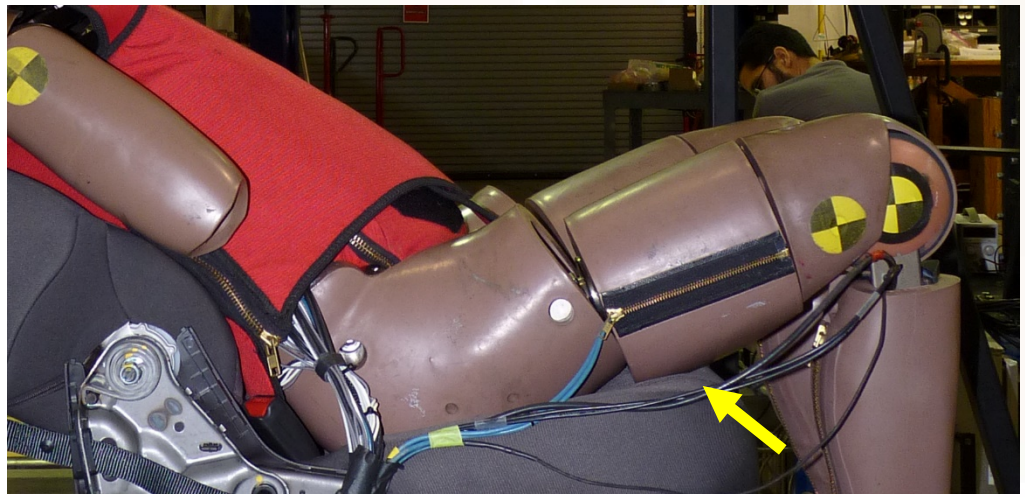




Pelvis Flesh Restricts Hip Extension



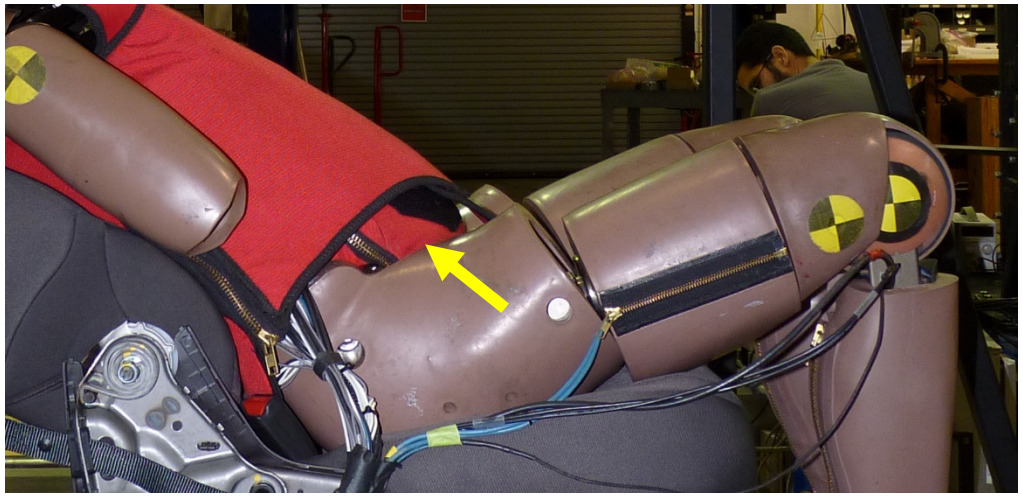
Low-Pivot Point

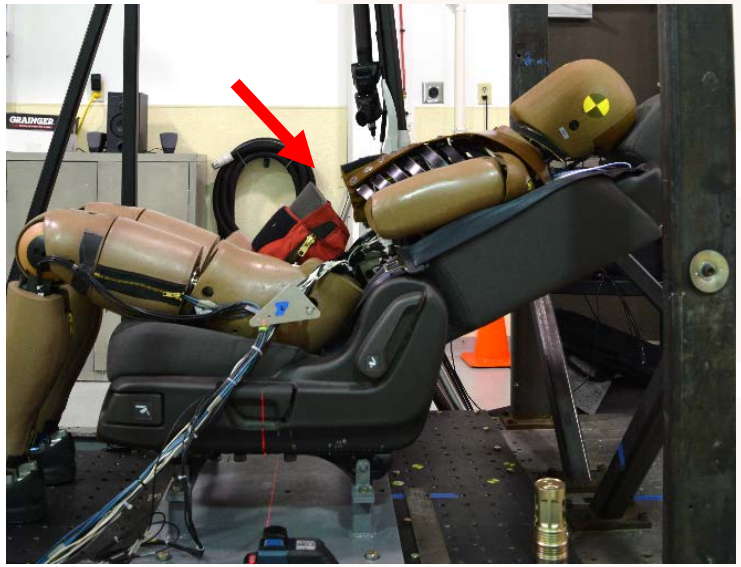


Lifts Thighs from Seats

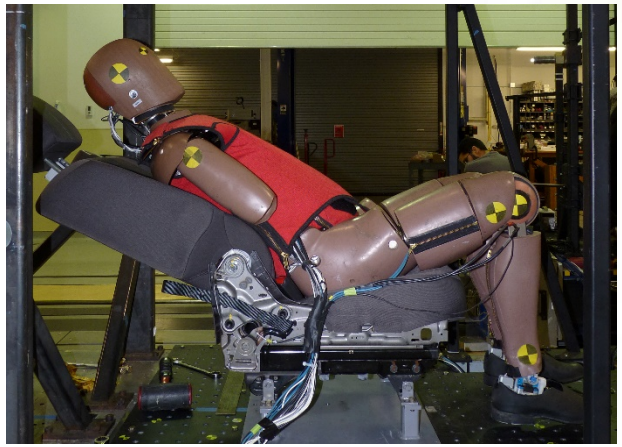
Report: NHTSA BioDB TSTNO 12990

Positioning Study – Key Findings





Substantial Gaps in Jacket, Flesh, Abdomen



Jacket Limits Recline, Shunts Loads/Moments Around Spine

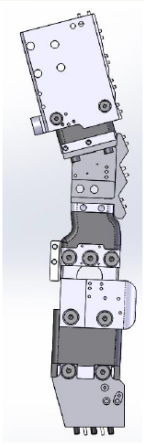
Report: NHTSA BioDB TSTNO 12990

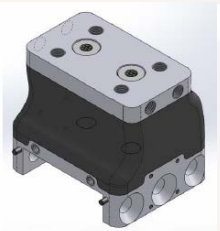
Design Goals

Increase range of motion of hip extension

Modified hip & thigh flesh

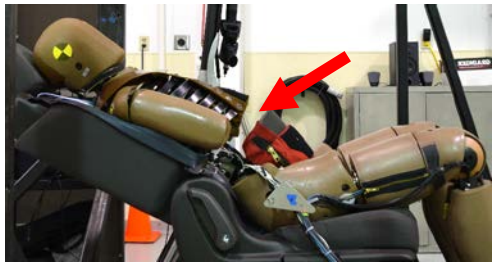
Increase range of spine motion without damaging lumbar flex joint



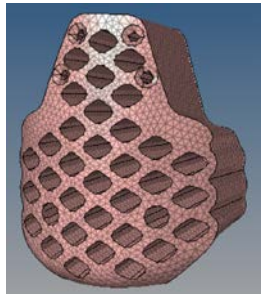


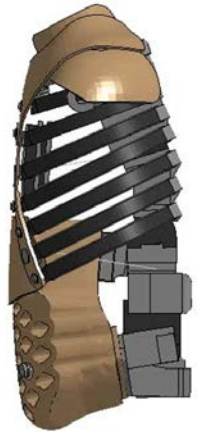
New lower thoracic flex joint

Minimize jacket/abdomen gaps throughout range of motion



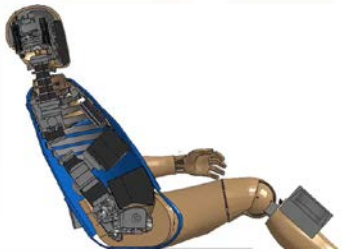
1-piece honeycomb abdomen

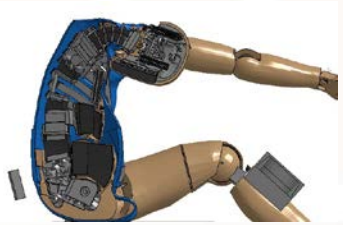


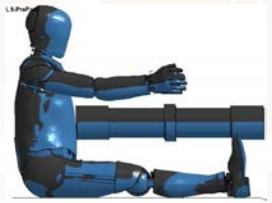


Updated Jacket

Do not adversely affect biofidelity in upright postures



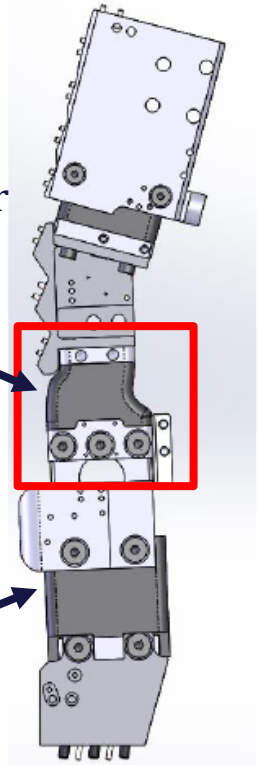


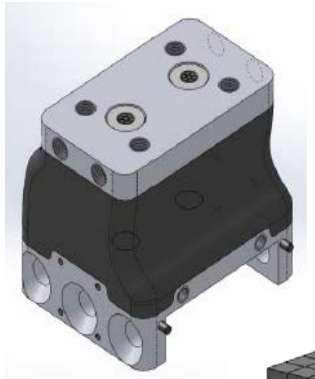


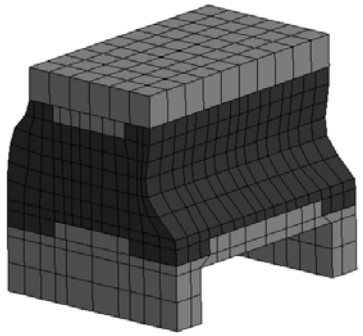
New Lower Thoracic Spine Flex Joint

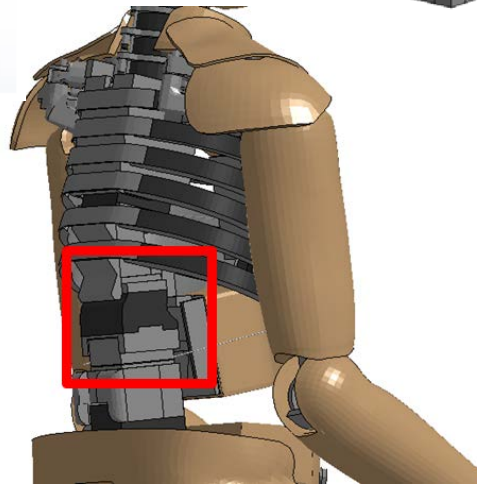
New Lower Thoracic Spine Flex Joint

Stock Lumbar Flex Joint





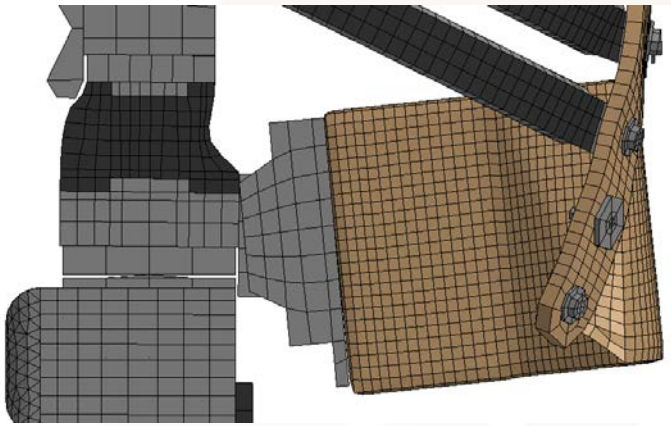




Base: publicly-available NHTSA THOR FE Model

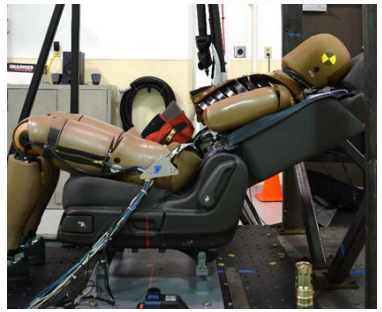
Stock Model

Stock Pitch Adjuster



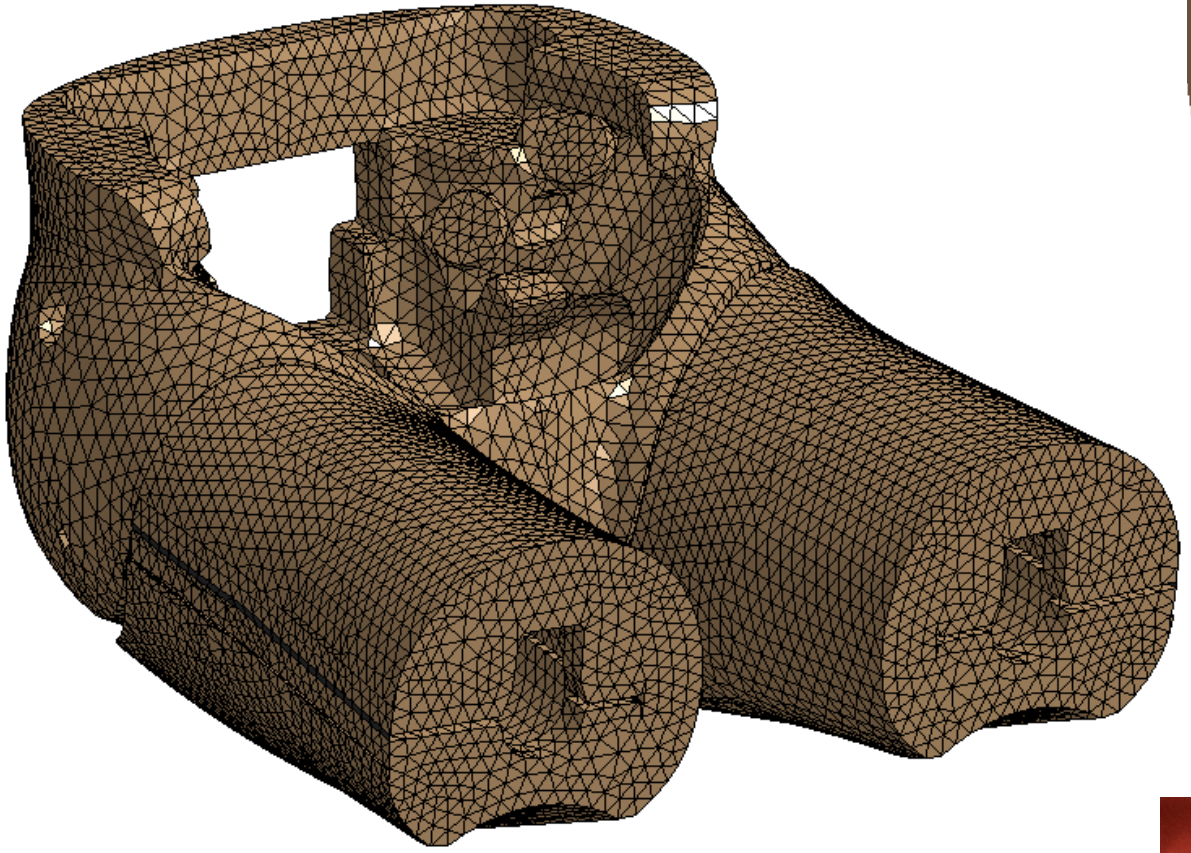
Modified Model

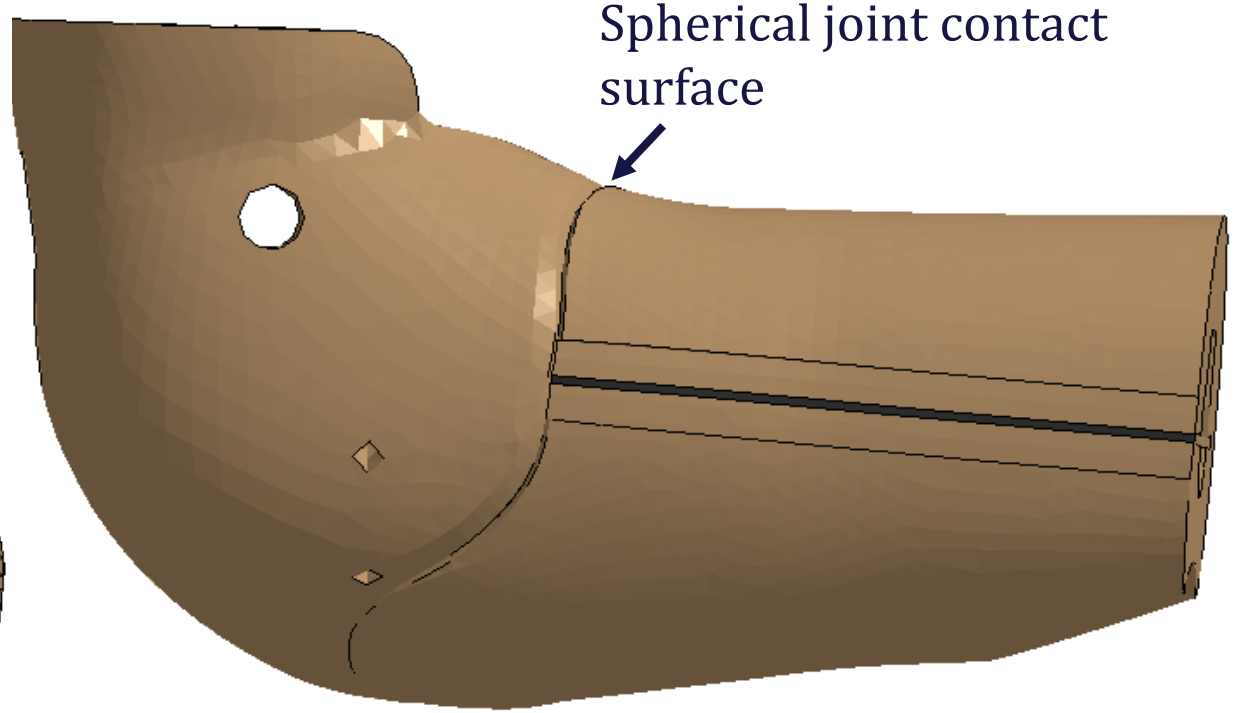
New Flex Joint



Goal: Distribute flexibility within the spine

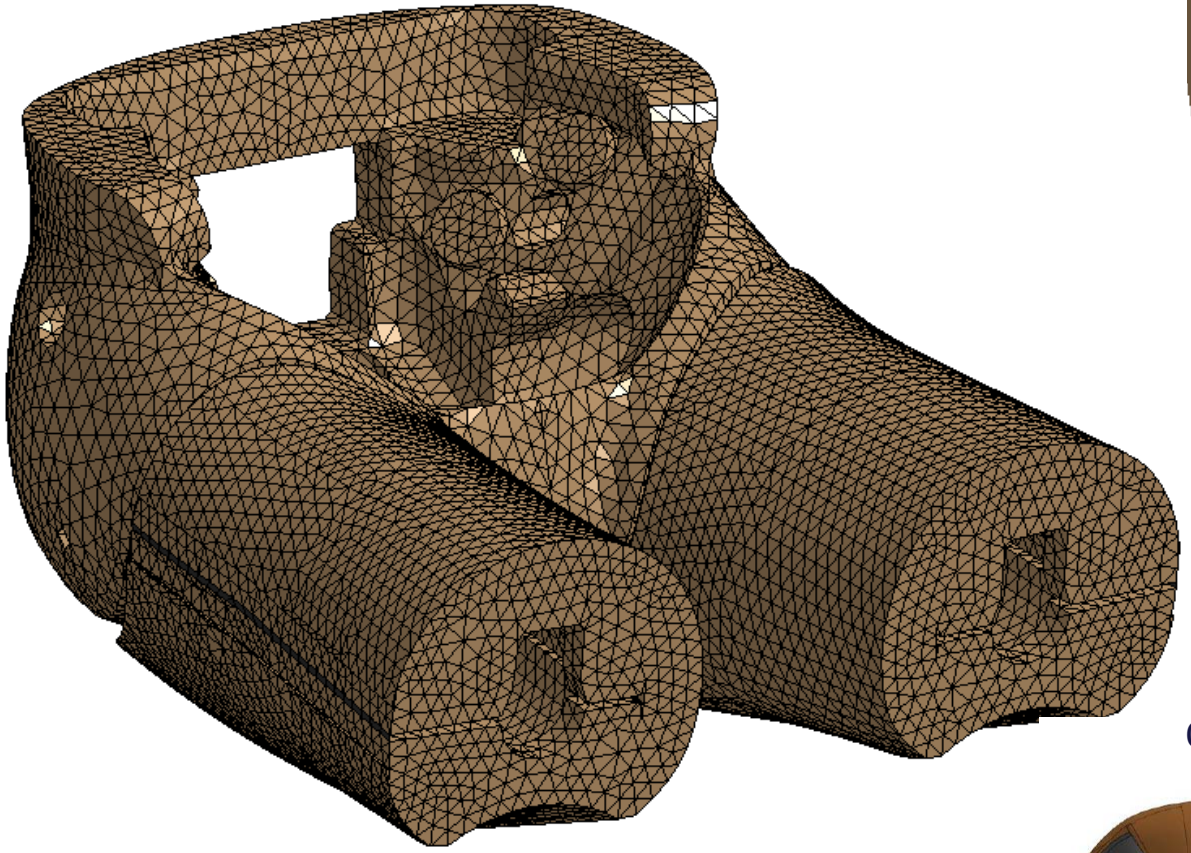
Modified Pelvis & Thigh Flesh

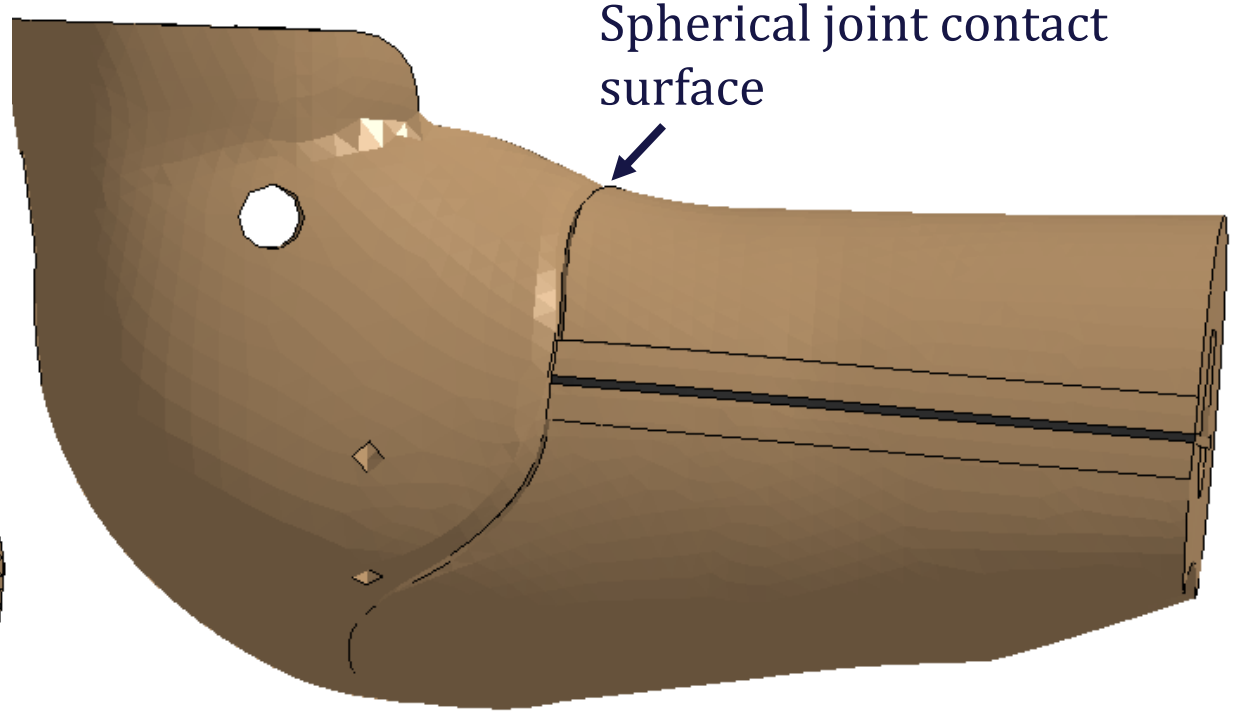


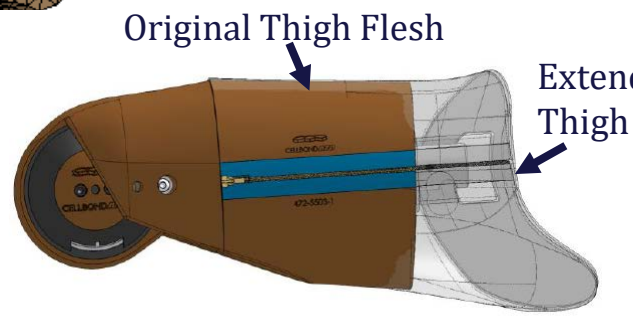


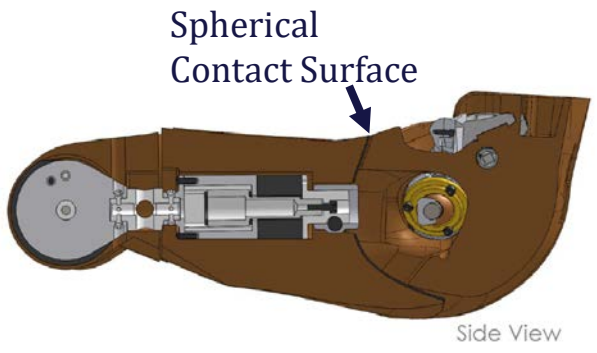
Goal: Greater range of hip extension

Modified Pelvis & Thigh Flesh





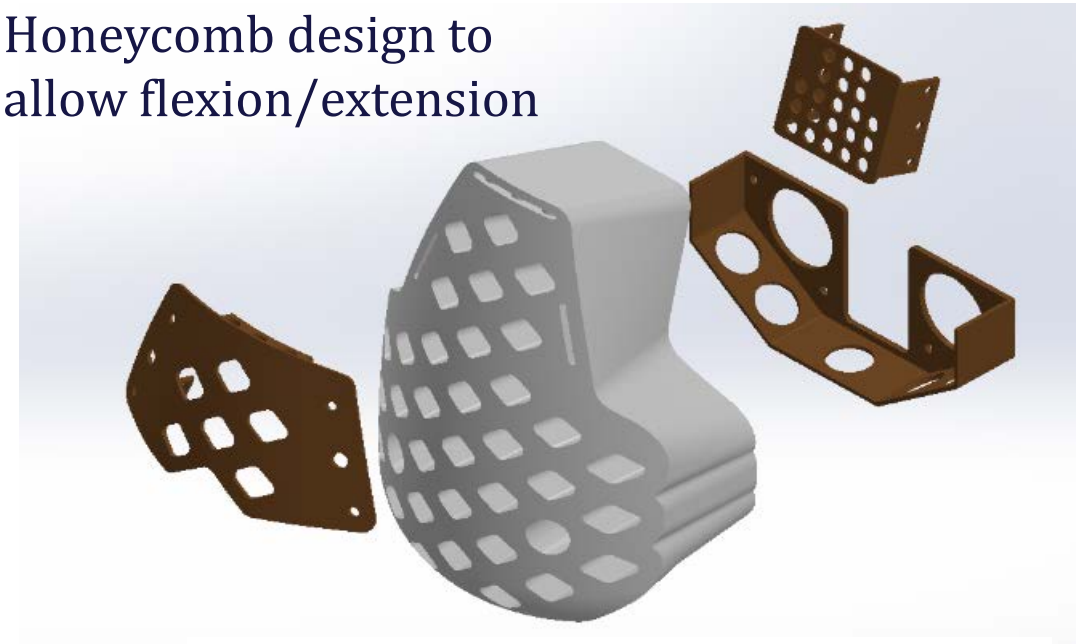


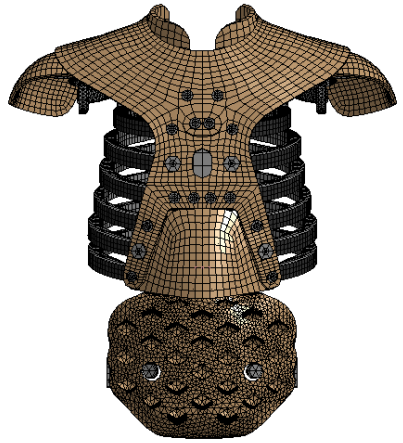


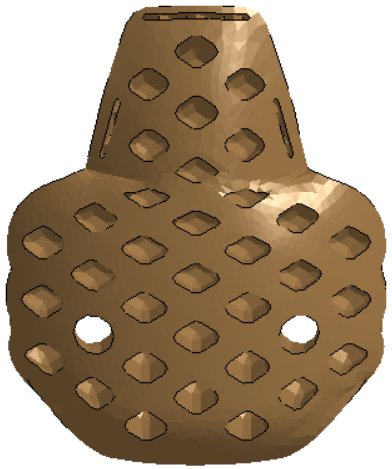
Goal: Greater range of hip extension

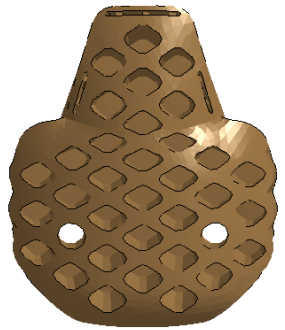
Unified Foam Abdomen

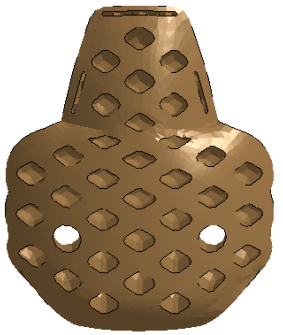
Honeycomb design to allow flexion/extension









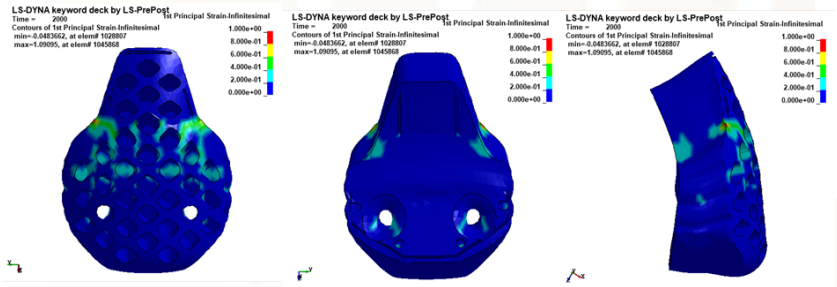


FE-Based Sensitivity Analysis

Different geometries

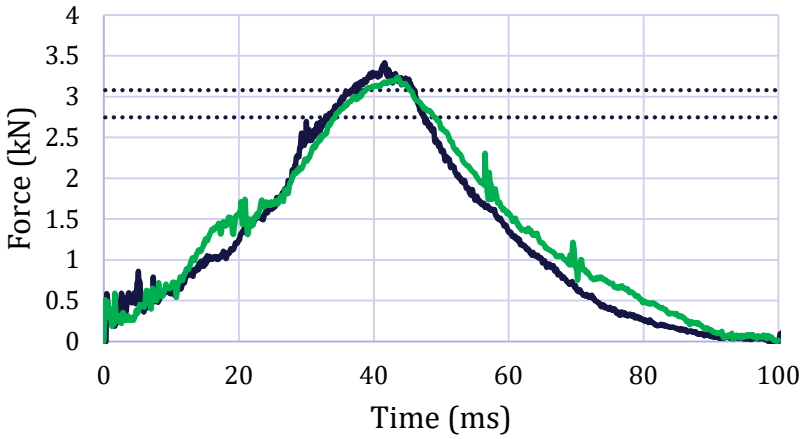
Different materials

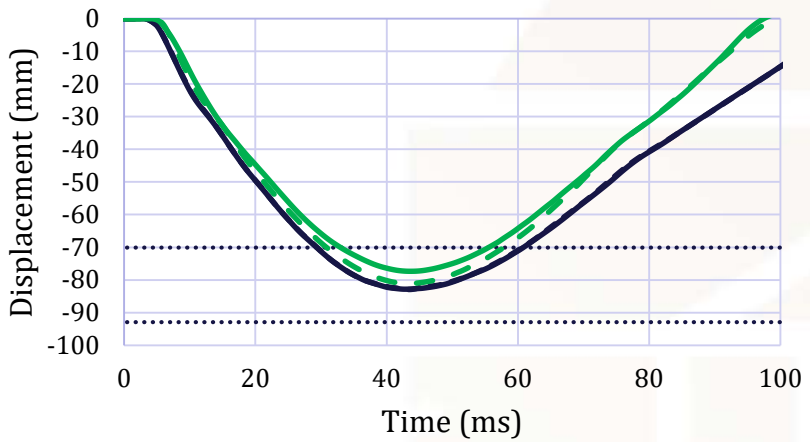
Effects on dummy response in certification tests, sled tests, spine extension & flexion



Abdomen & Lower Thorax Certification Simulations

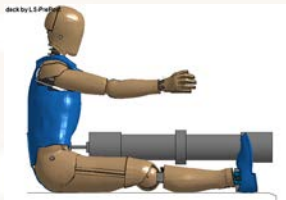
Abdomen Bar Impact

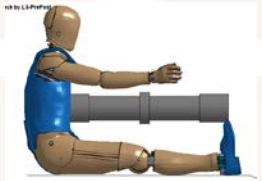




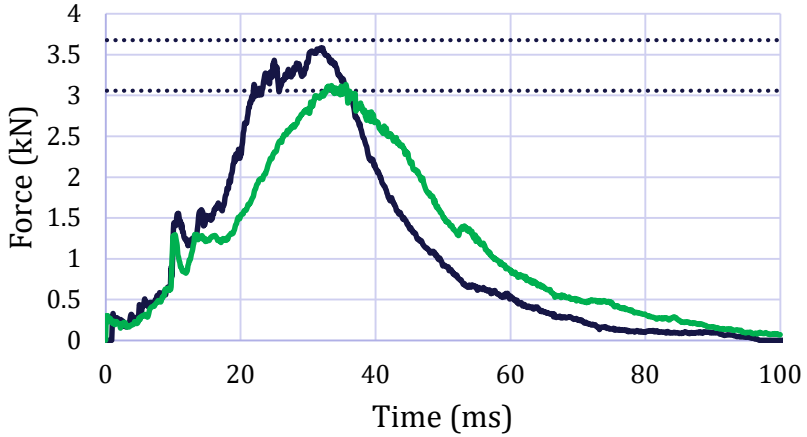
Stock THOR

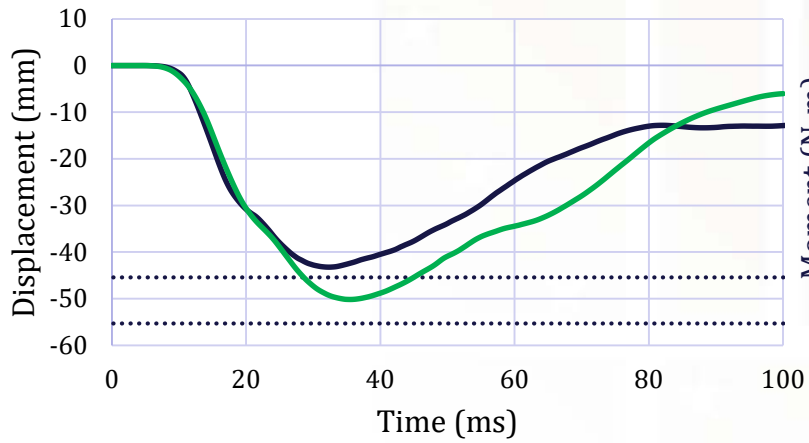
Current Design Mods.

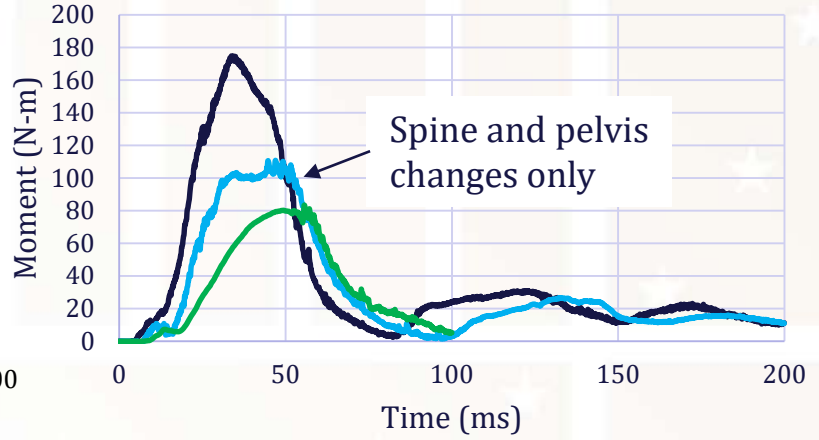




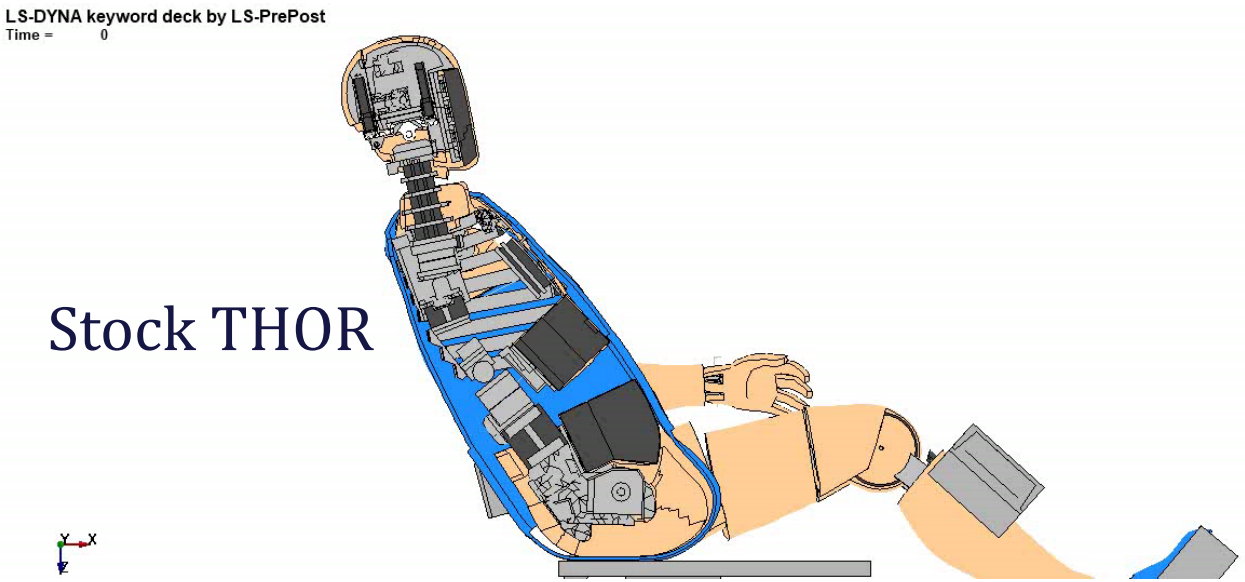
Lower Thorax Impact



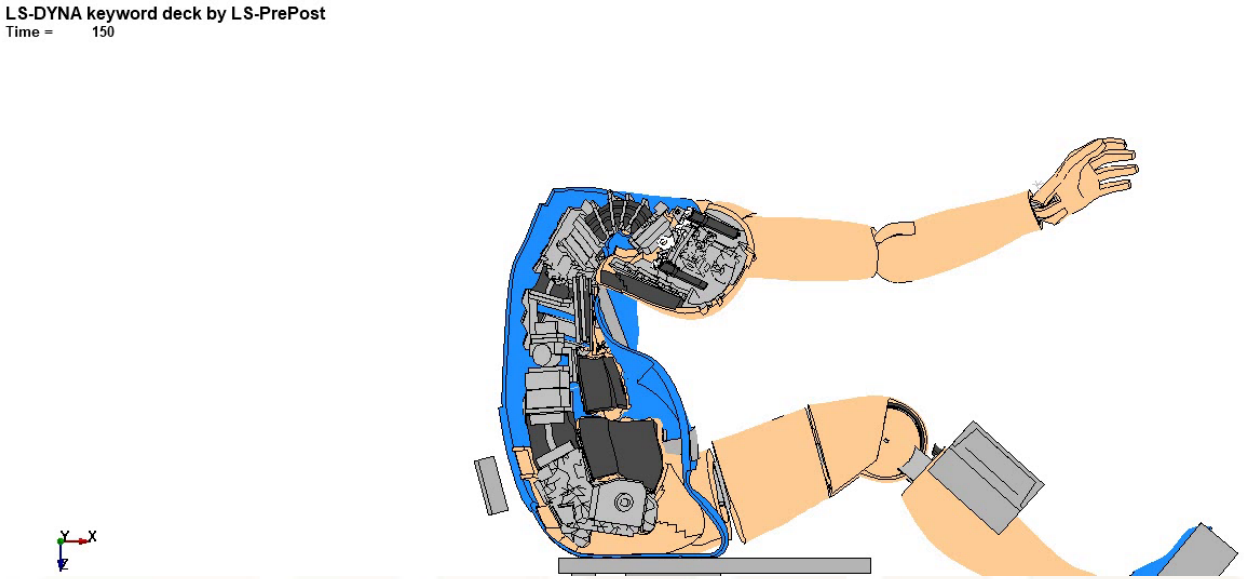


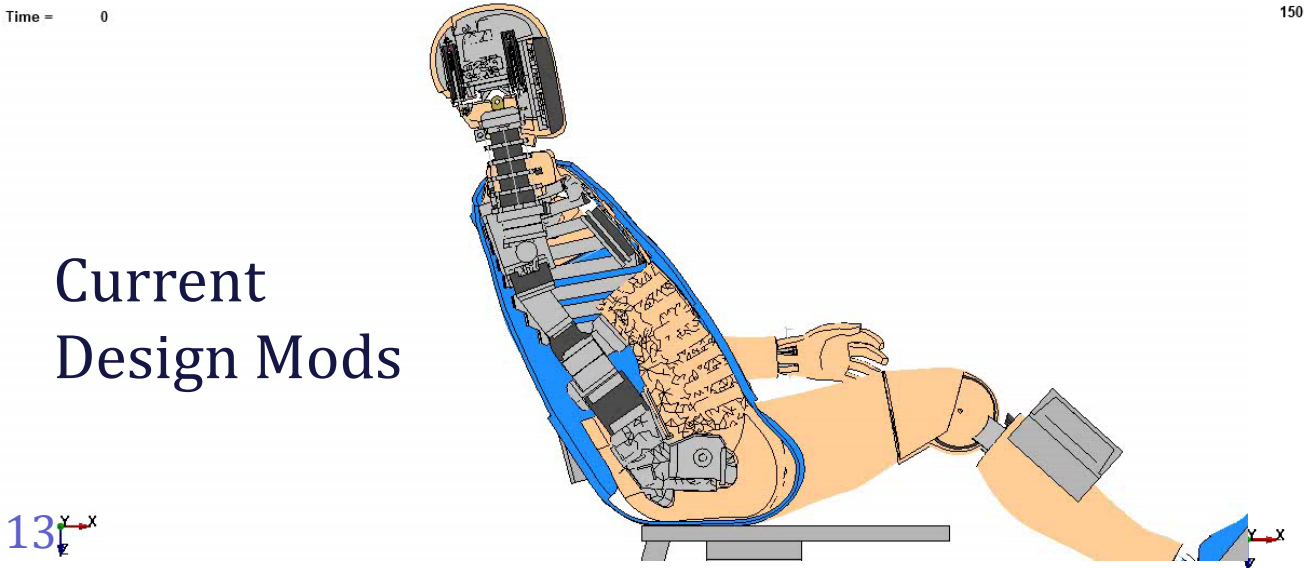


Gold Standard 1: 40 km/h, No Force Limiter

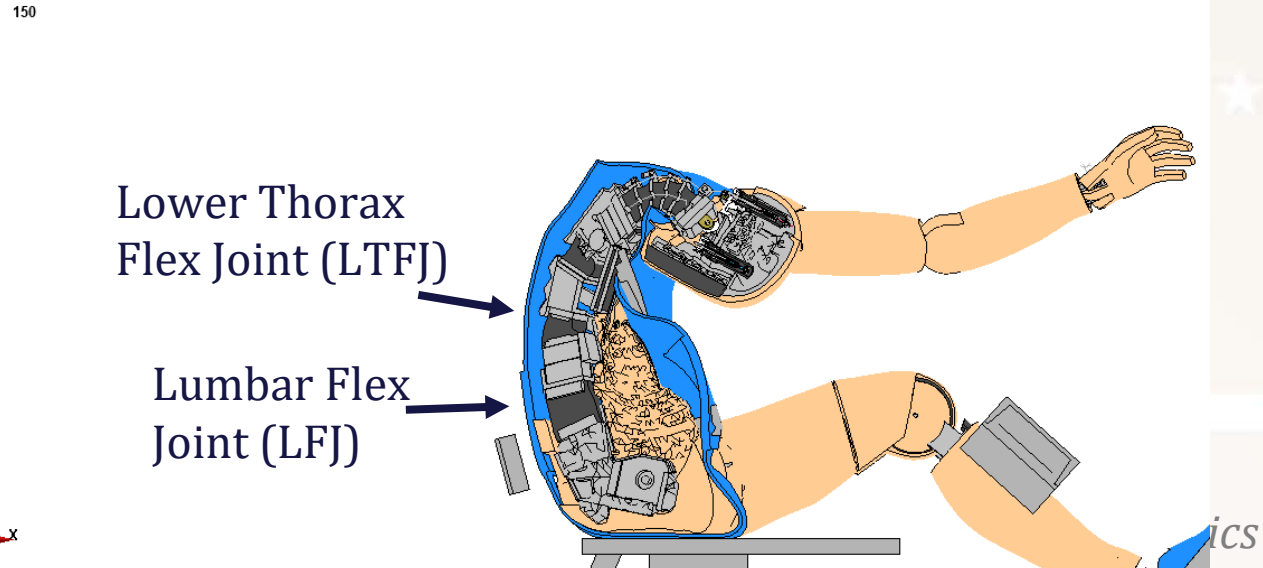


Stock THOR





Current Design Mods



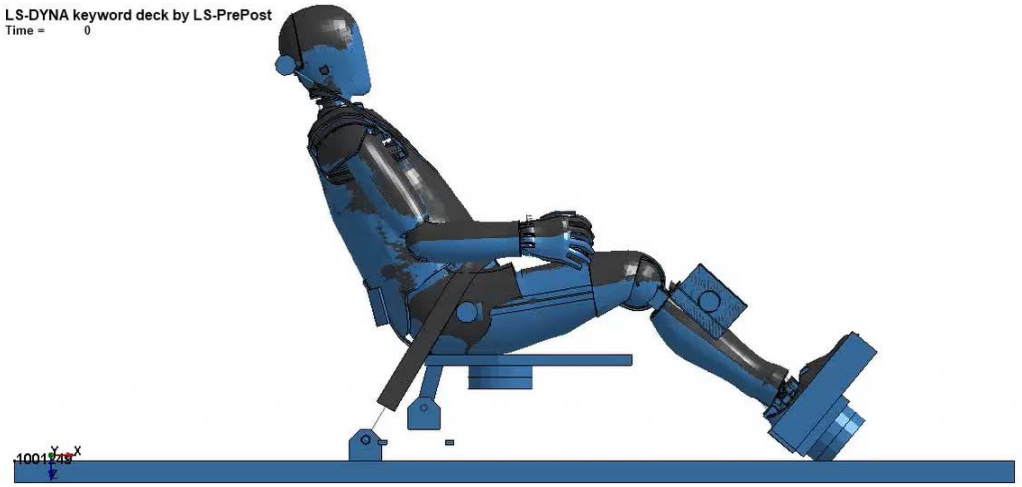
Lower Thorax Flex Joint (LTFJ)

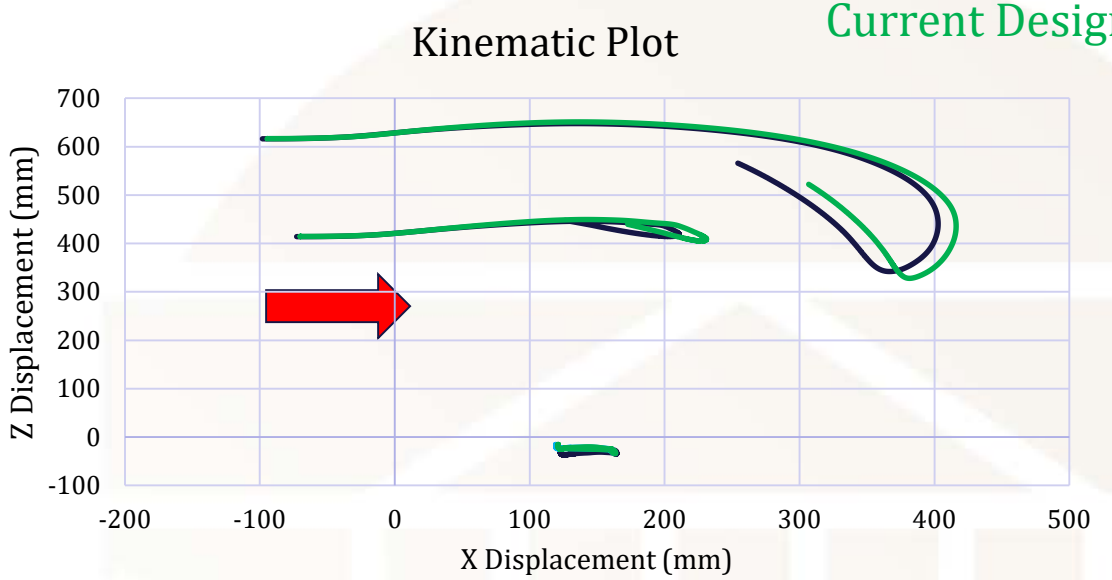
Lumbar Flex Joint (LFJ)

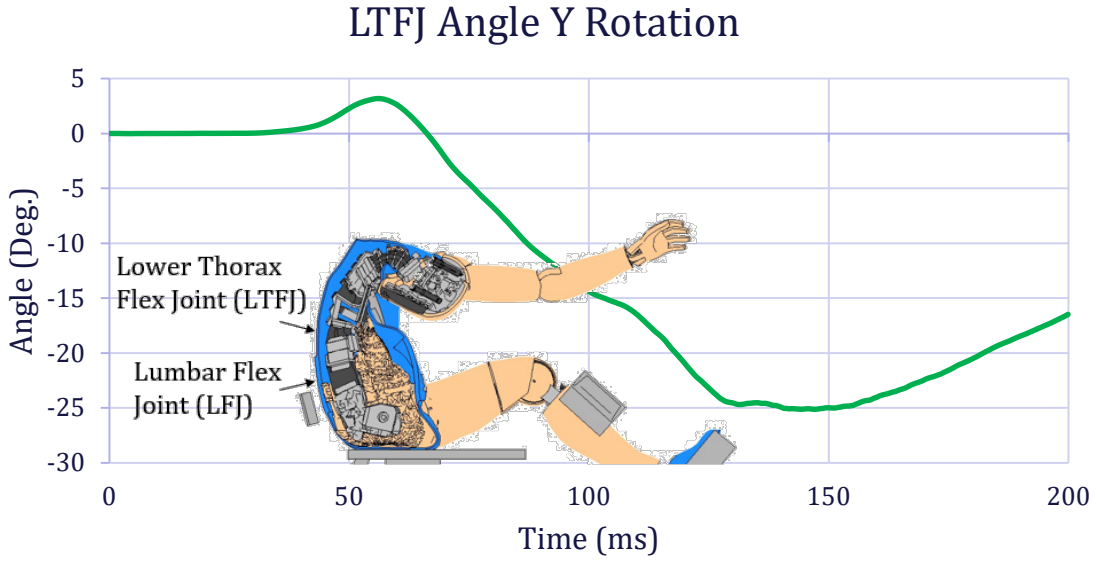
Gold Standard 1: 40 km/h, No Force Limiter

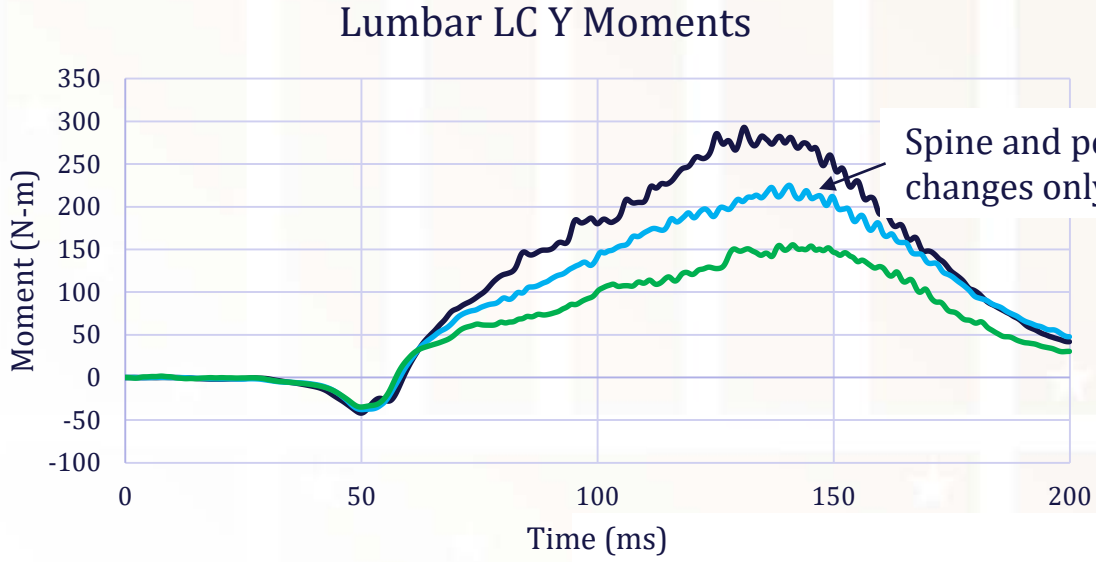
Stock THOR

Current Design Mods.





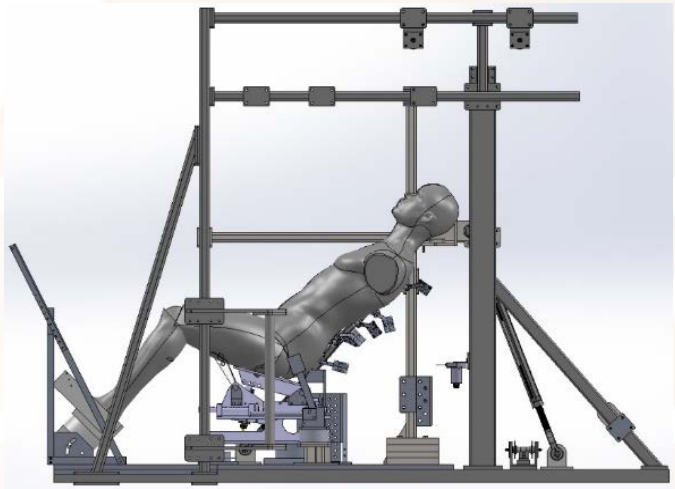




Recline – Matched UVA PMHS Tests

Richardson et al. 2019 ESV, 2020 Stapp

Supported by Autoliv Research

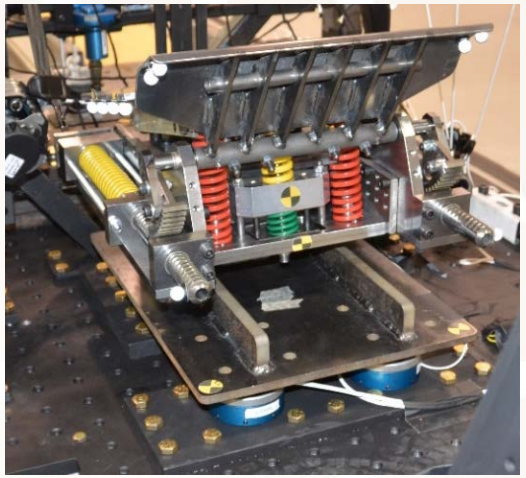


50 km/h

x3 Pretensioners

Kinematic & Dynamic Corridors

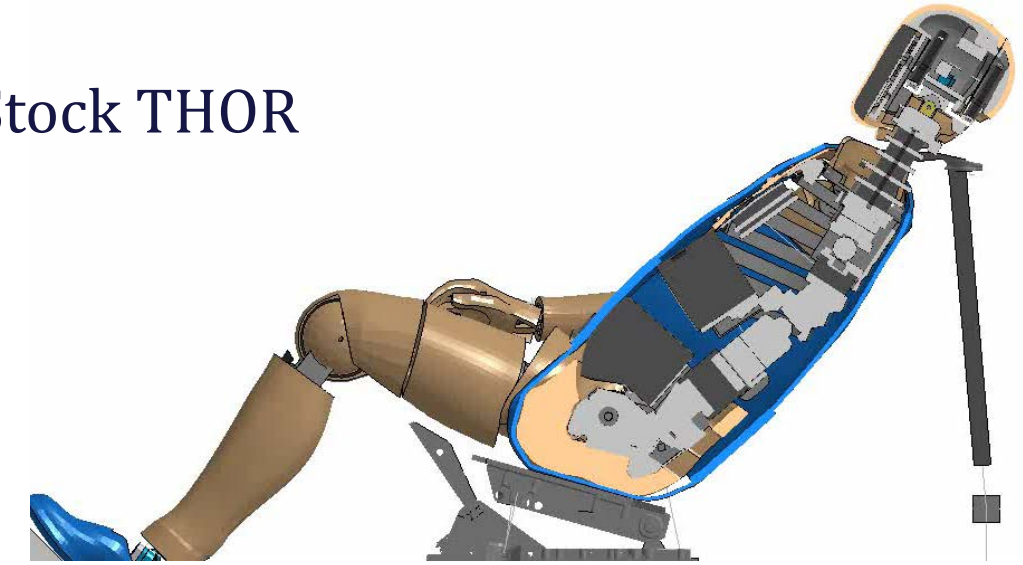
Uriot 2015 Seat

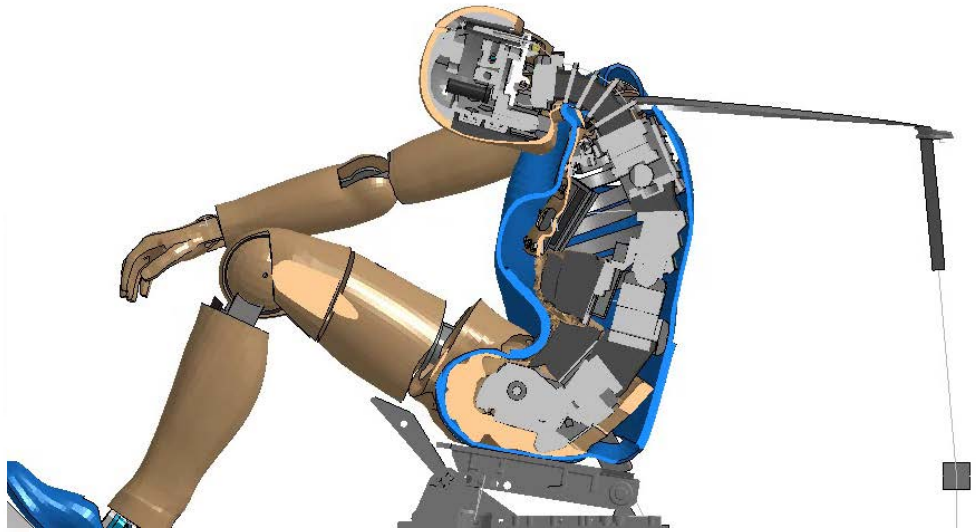


Caution: PMHS Images

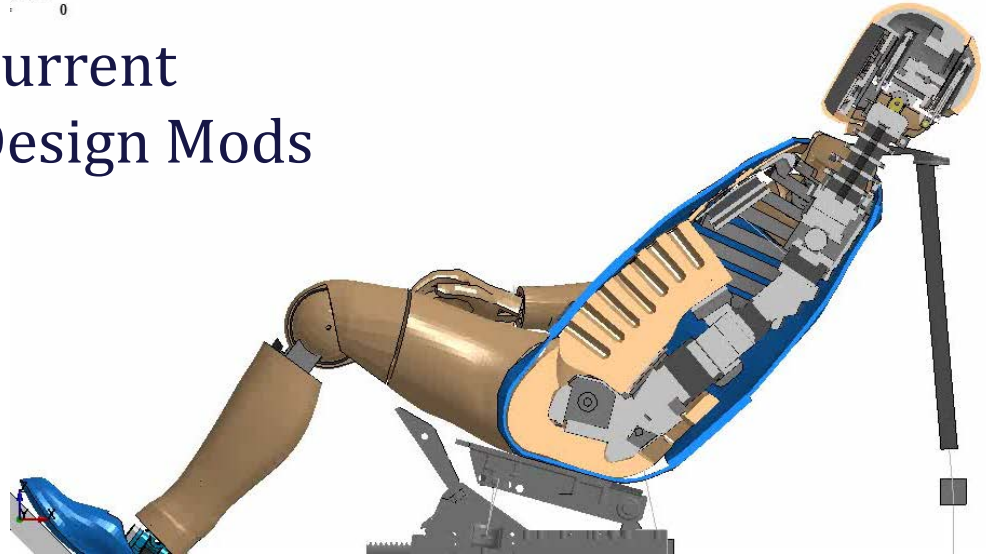
Reclined Test Configuration

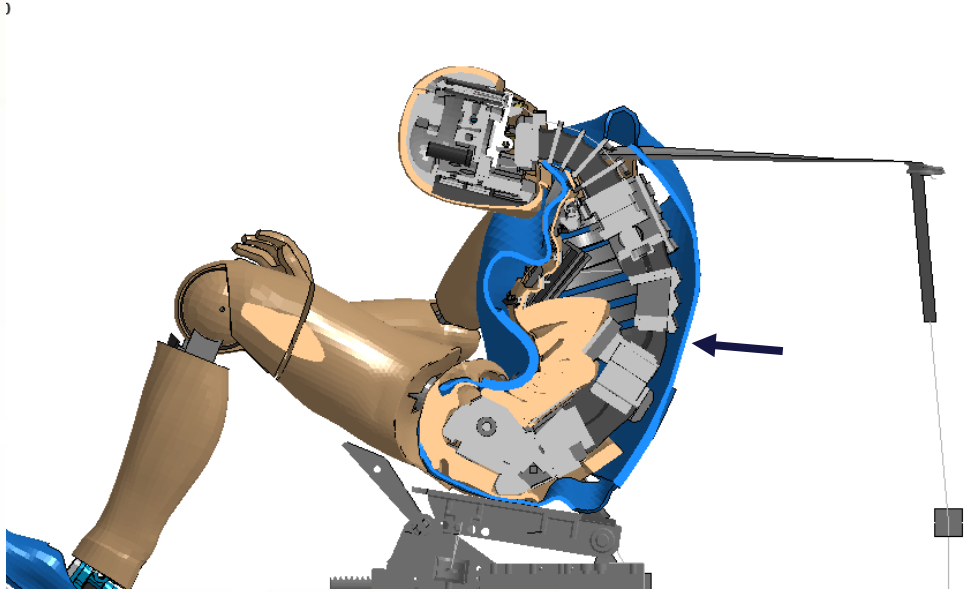
Stock THOR



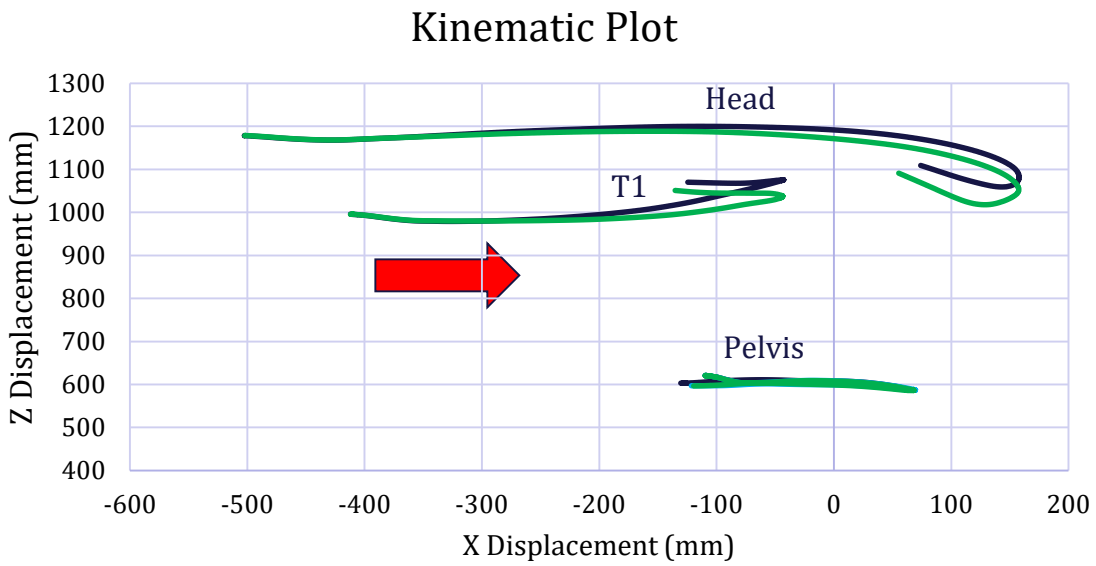


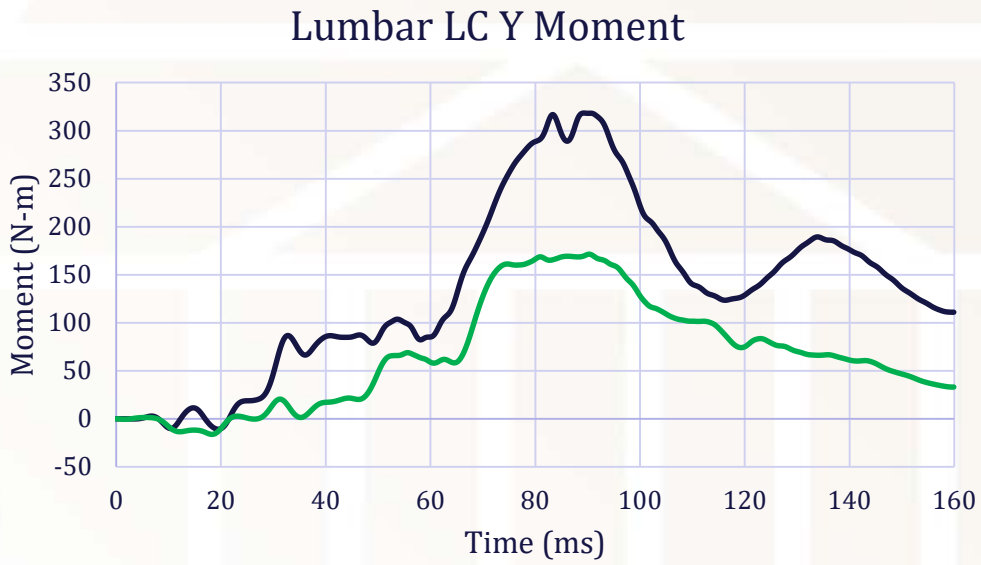
Current
Design Mods





Reclined Test Configuration



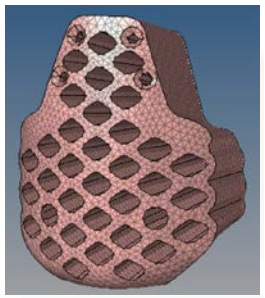


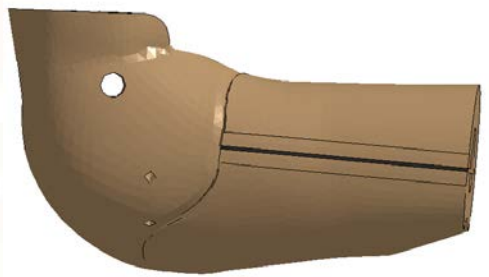
Stock THOR

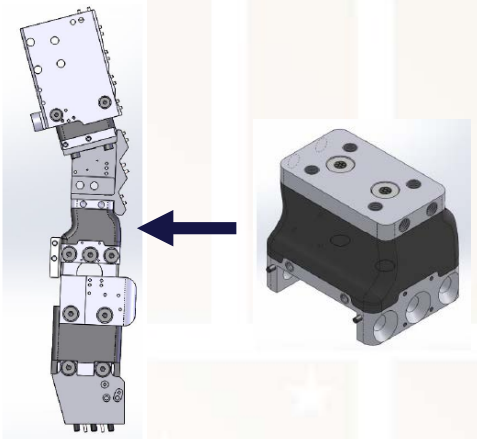
Current Design Mods.

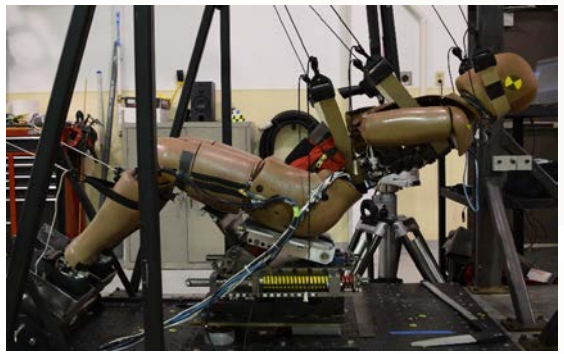
Next Steps

- Modified Jacket
- Prototype fabrication
  - Lower thorax flex joint
  - New pelvis & thigh flesh
  - Unified abdomen
  - Modified jacket
- Certification testing
- Positioning Usability Assessment
- Sled testing









Anticipated Sled Testing

UVA/Autoliv Reclined Test Setup

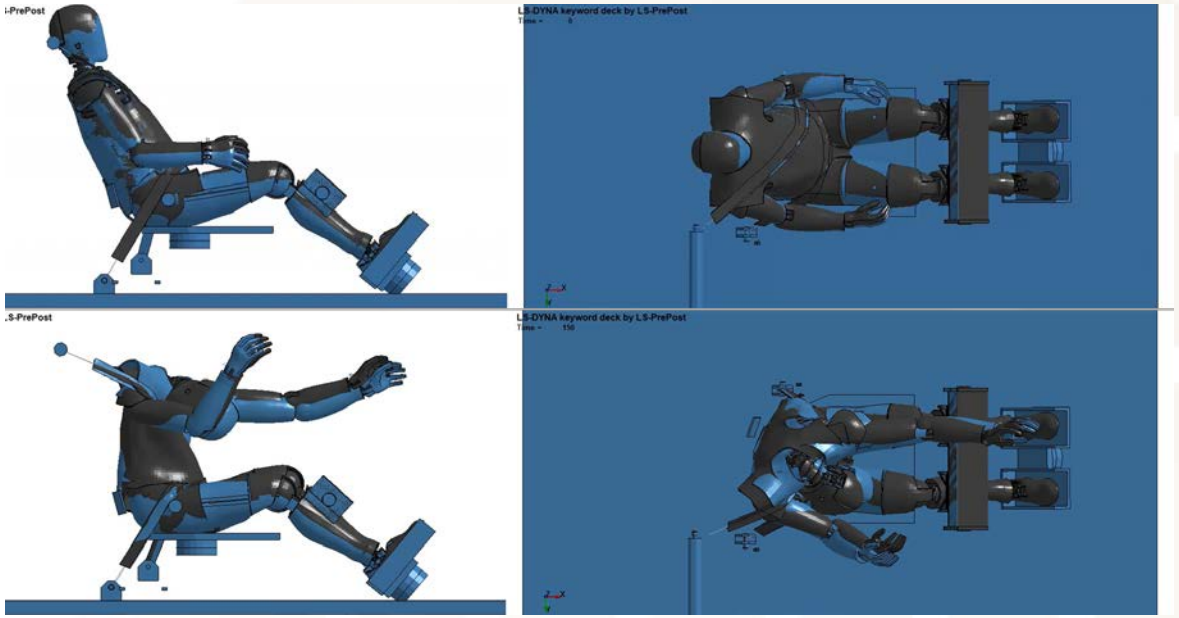
Richardson et al. 2020

50 km/h
3x Pretensioner
Shoulder Belt FL

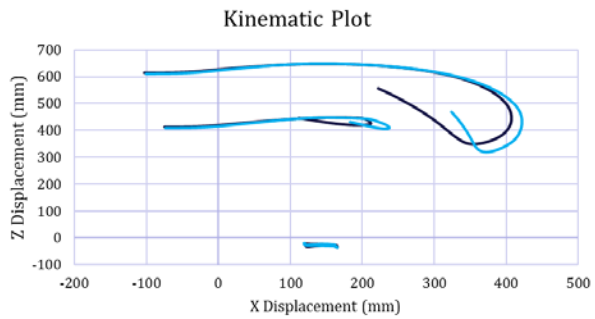
LAB Semi-Rigid Seat

PMHS Corridors with 6 d.o.f. Spinal, Pelvis Kinematics

Gold Standard 1 – 40 km/h, No Force Limiter

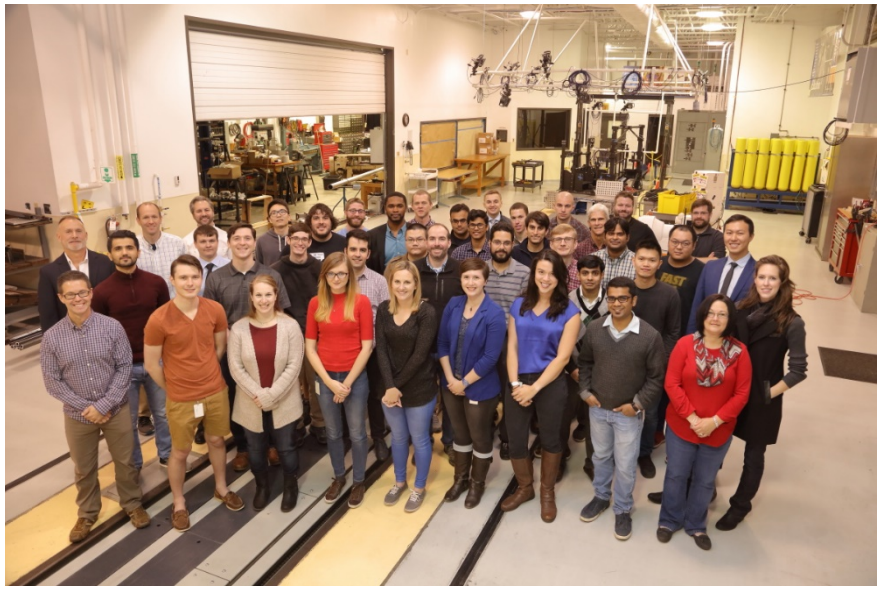


Gold Standard 2
30 km/h, 3 kN
Force Limiter



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

NHTSA Contract No. DTNH2215D00022/693JJ919F000222



Questions?

Email: jlf3m@virginia.edu

Thank You!

Jason Forman, Adrian Caudillo-Huerta, Justin McMahon, Matthew Panzer, William Marshall, Derek Winter, Matthew Dyer, Matthew Seavers, Paul Lemmen

University of Virginia Center for Applied Biomechanics & Cellbond

RCCADS Public Workshop – May 2021