

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

NHTSA Contract No. DTNH2215D00022/693JJ919F000222

Jason Forman¹, Adrian Caudillo-Huerta¹, Justin McMahon¹, Matthew Panzer¹, William Marshall², Derek Winter², Matthew Seavers², Matthew Dyer², Paul Lemmen²

¹University of Virginia Center for Applied Biomechanics

²Cellbond

RCCADS Public Workshop – May 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.

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

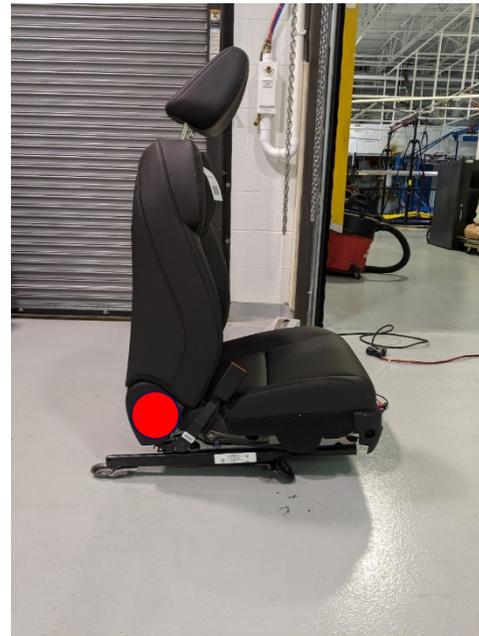


Positioning Study – Qualitative Analysis

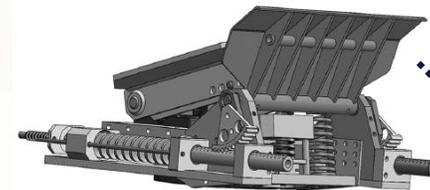
- ▶ 2018 Honda Odyssey 2nd row captain's chair
- ▶ Acura TLX Driver's Chair
- ▶ LAB seat with marionette positioning



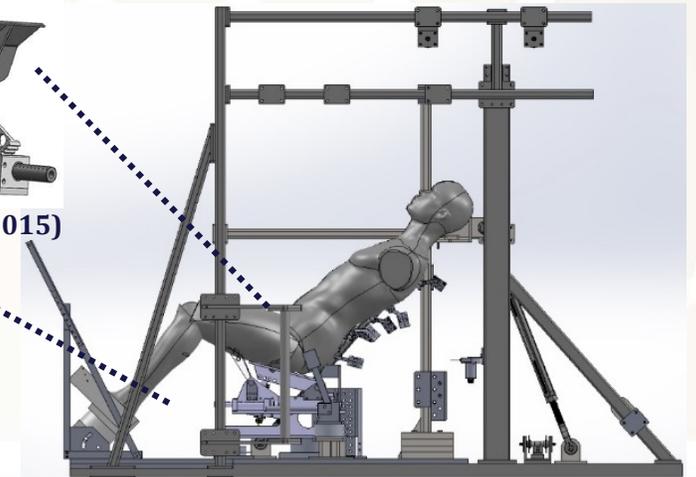
Honda Odyssey 2nd row captain's chair



Acura TLX Driver's Chair



LAB Seat (Uriot et al. 2015)



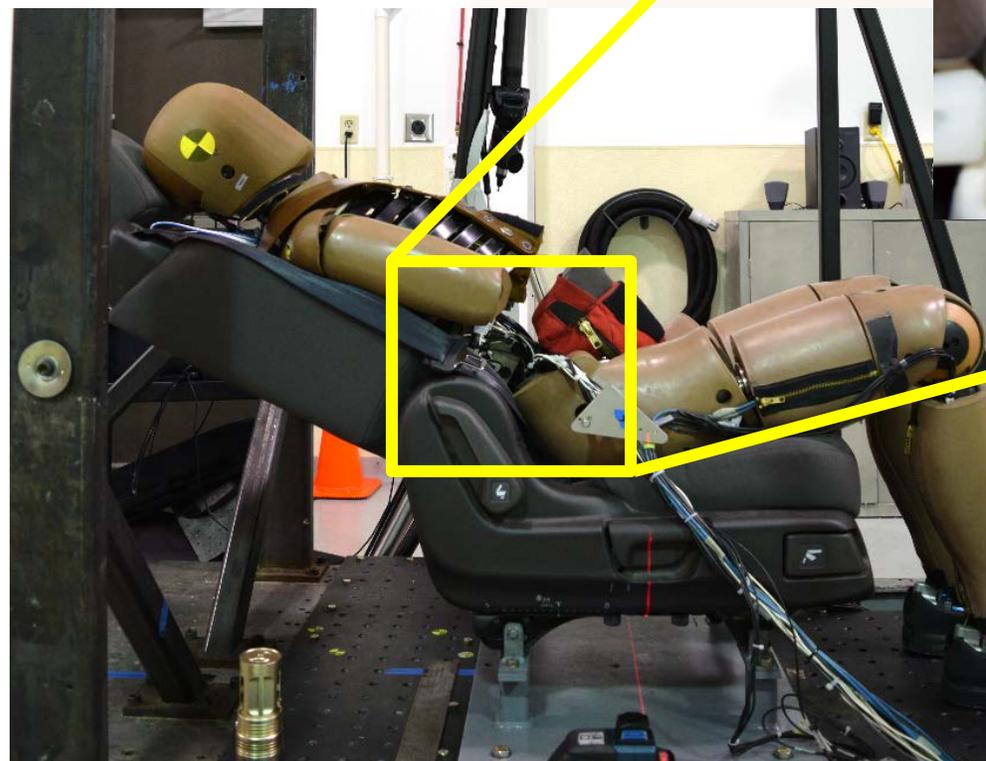
LAB Seat on HAV Gold Standard Buck

Positioning Study – Key Findings

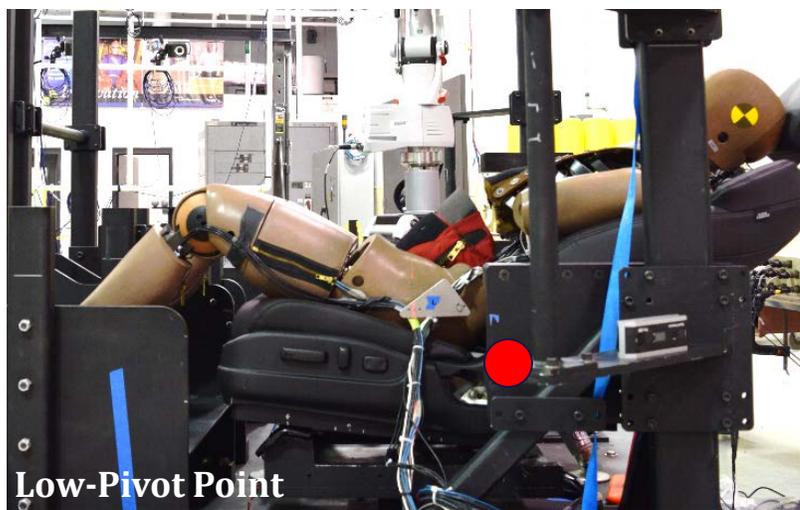
High Pivot Point



Lumbar flex joint pulls apart under extension



Amount of extension depends on seat geometry

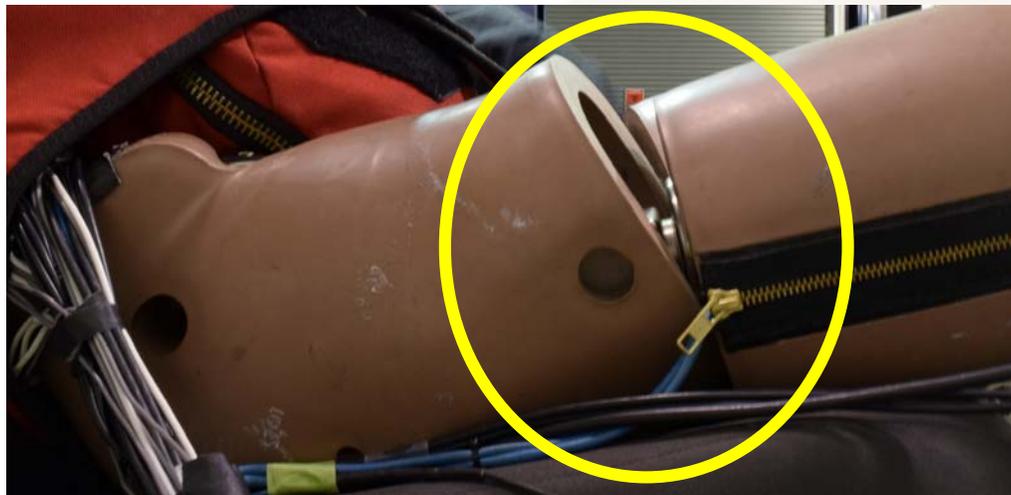
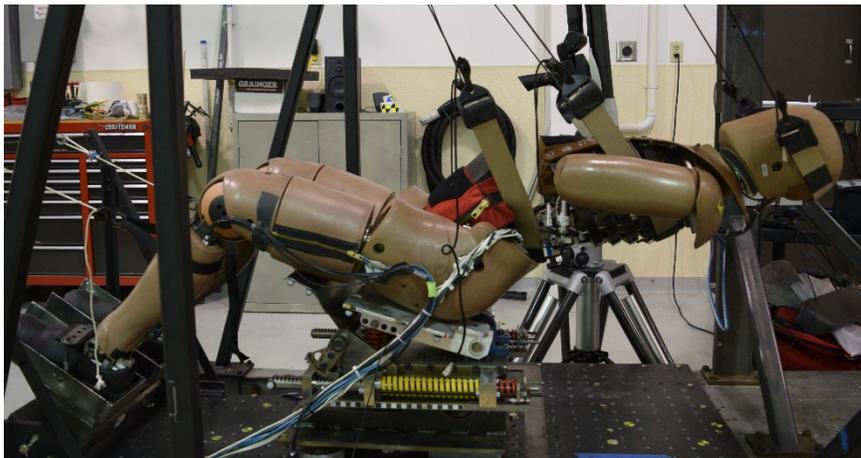


Low-Pivot Point

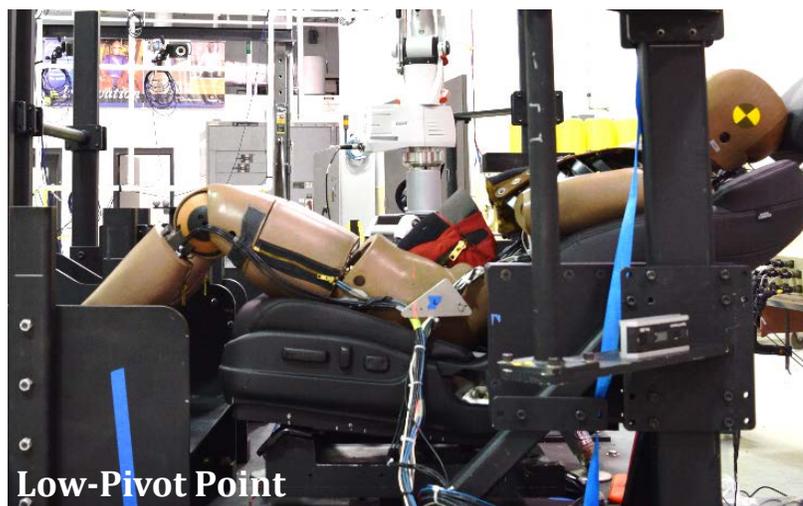
Report: NHTSA BioDB TSTNO 12990

Positioning Study – Key Findings

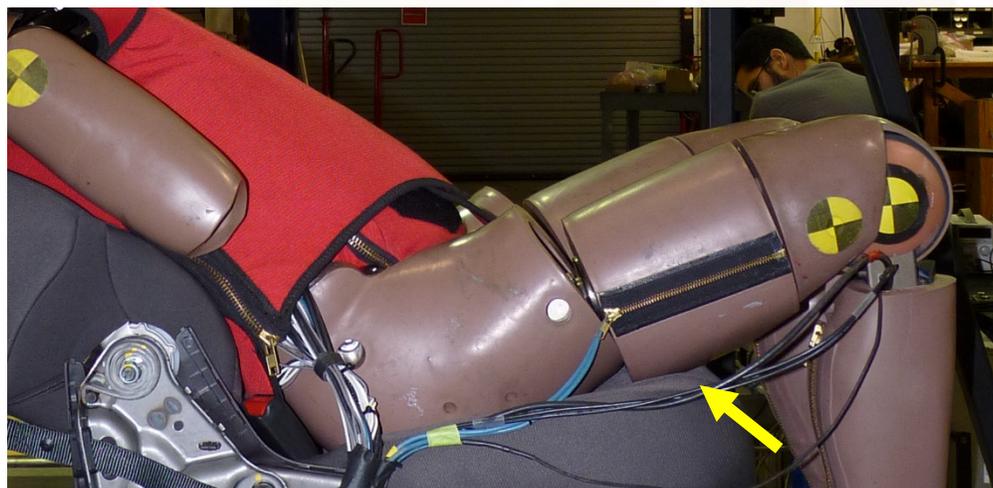
Generic Seat



Pelvis Flesh
Restricts Hip
Extension

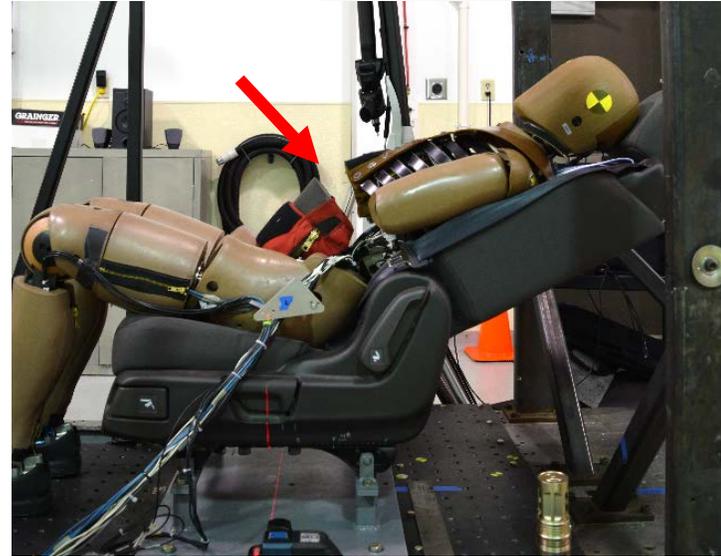
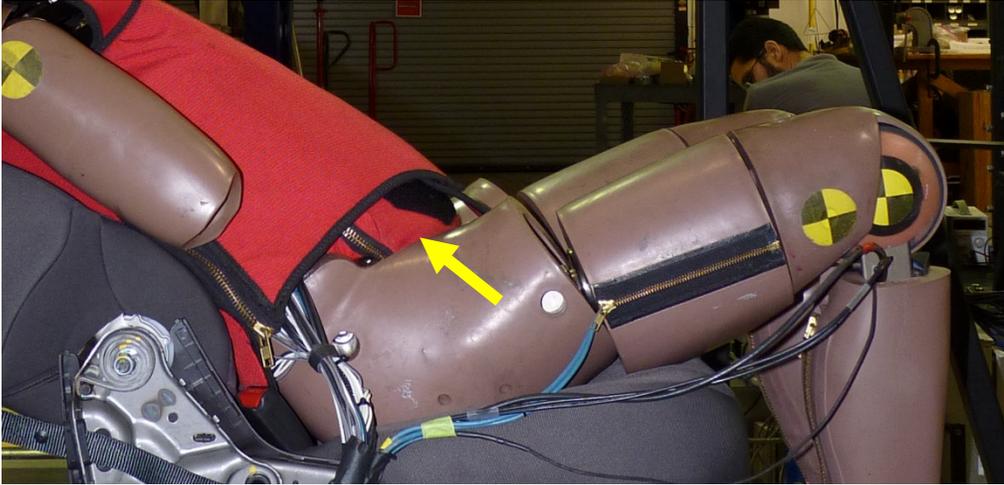


Low-Pivot Point

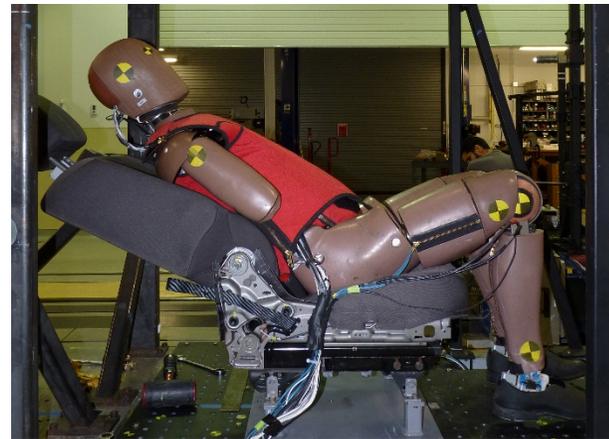


Lifts Thighs
from Seats

Positioning Study – Key Findings



Substantial Gaps in Jacket, Flesh, Abdomen



Jacket Limits Recline, Shunts Loads/Moments Around Spine

Report: NHTSA BioDB TSTNO 12990

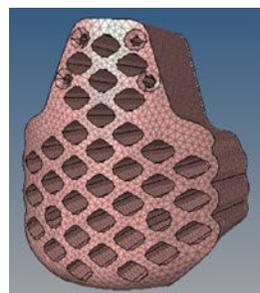
Design Goals

Increase range of motion of hip extension

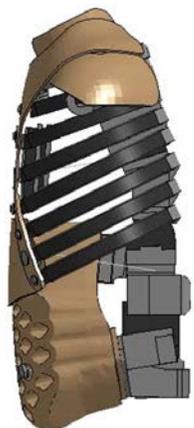


Modified hip & thigh flesh

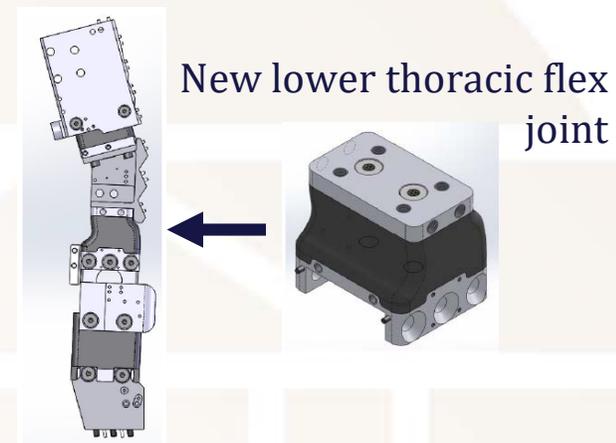
Minimize jacket/abdomen gaps throughout range of motion



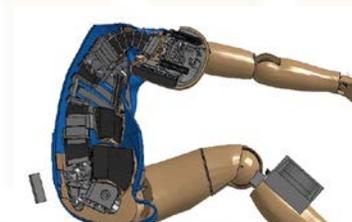
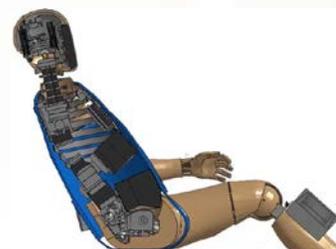
1-piece honeycomb abdomen
Updated Jacket



Increase range of spine motion without damaging lumbar flex joint



Do not adversely affect biofidelity in upright postures



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

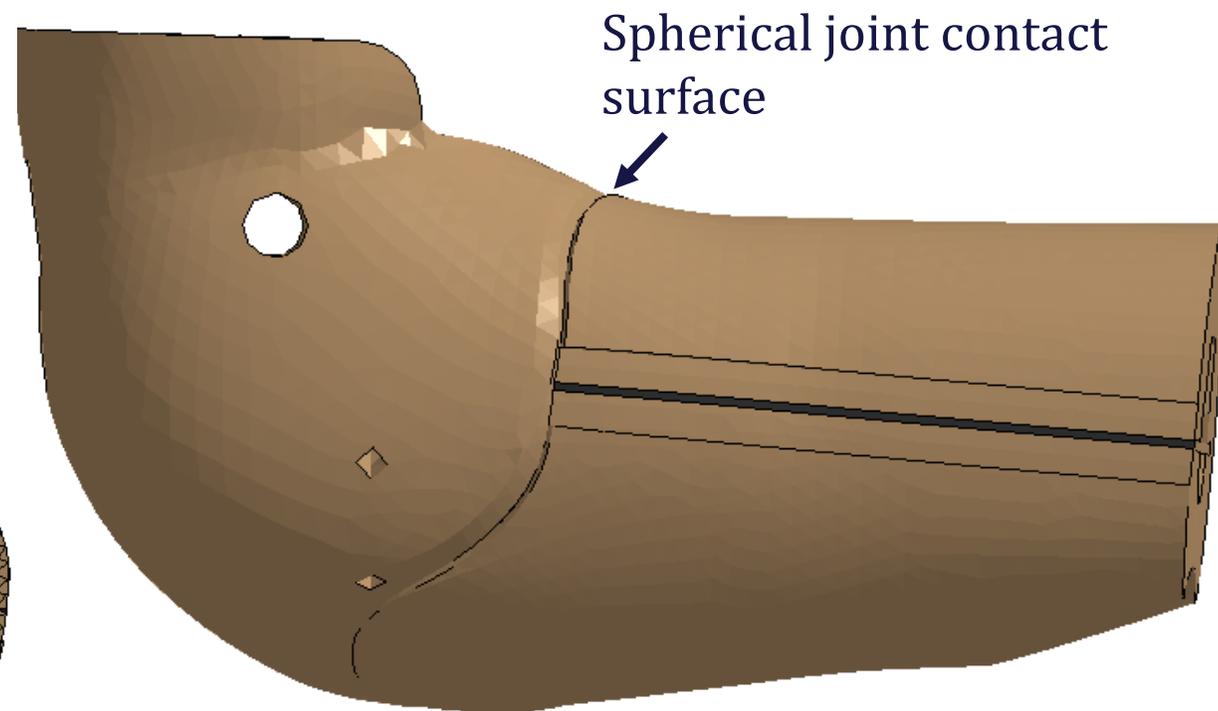
Goal: Distribute flexibility within the spine

Center for Applied Biomechanics

Modified Pelvis & Thigh Flesh



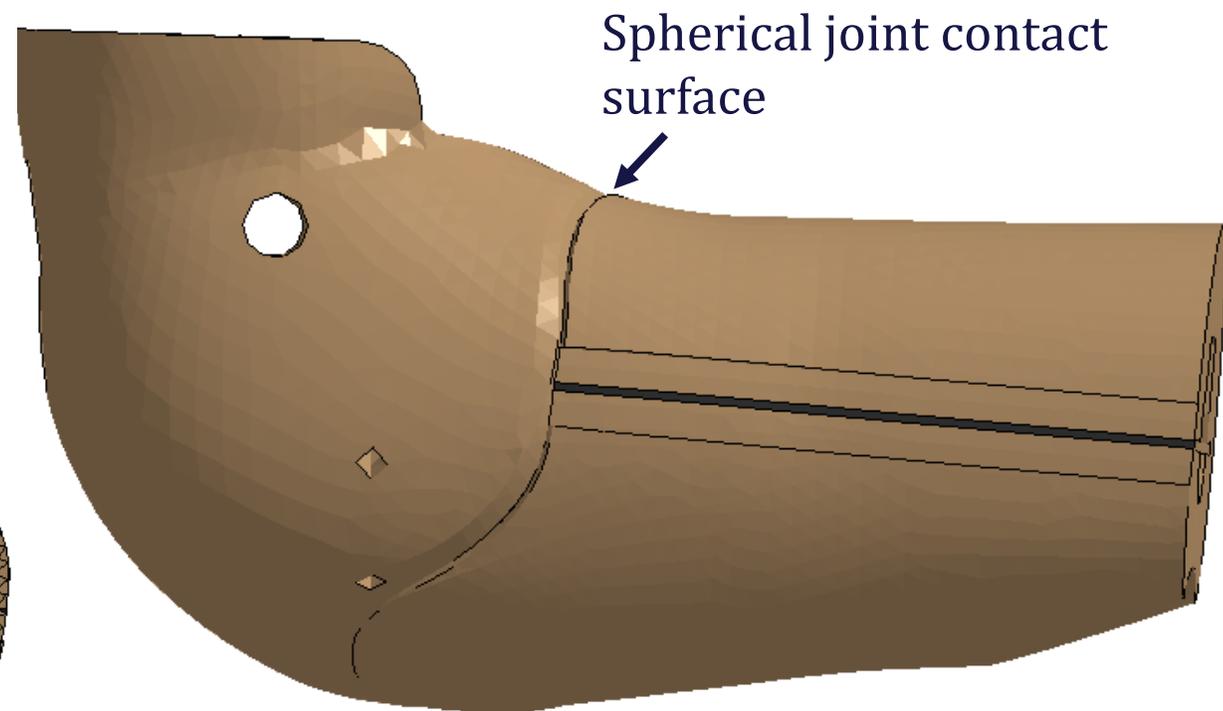
Goal: Greater range of hip extension



Modified Pelvis & Thigh Flesh

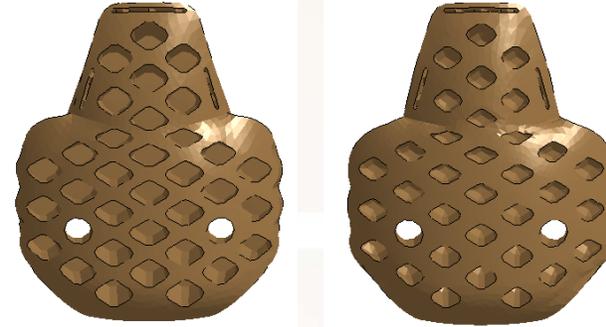
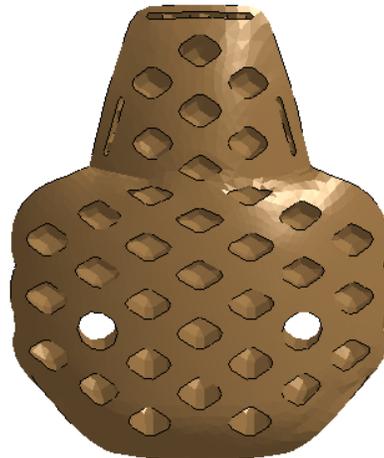
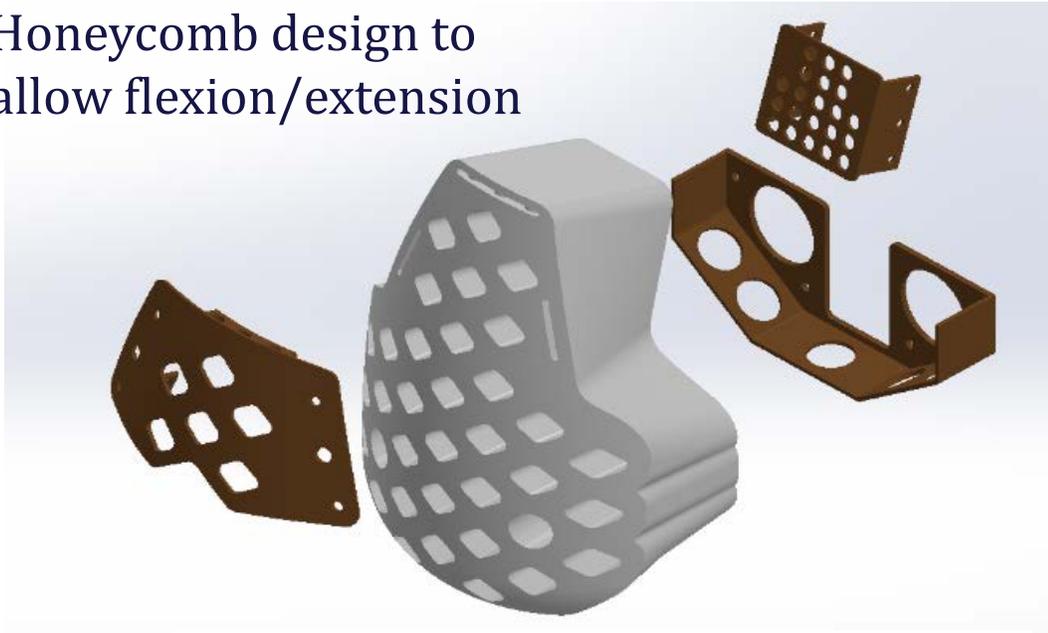


Goal: Greater range of hip extension



Unified Foam Abdomen

Honeycomb design to allow flexion/extension

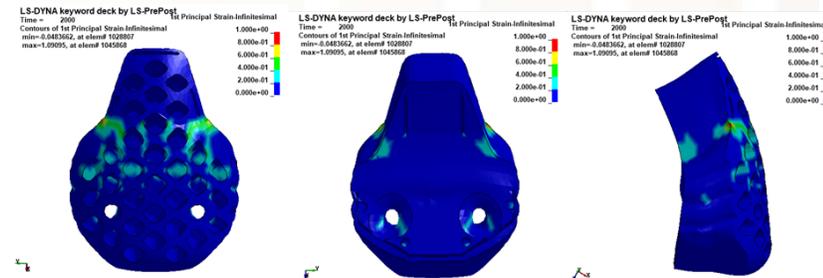


FE-Based Sensitivity Analysis

Different geometries

Different materials

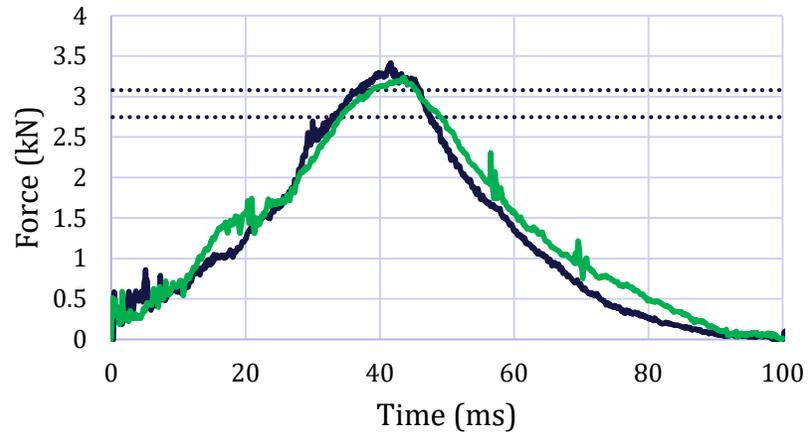
Effects on dummy response in certification tests, sled tests, spine extension & flexion



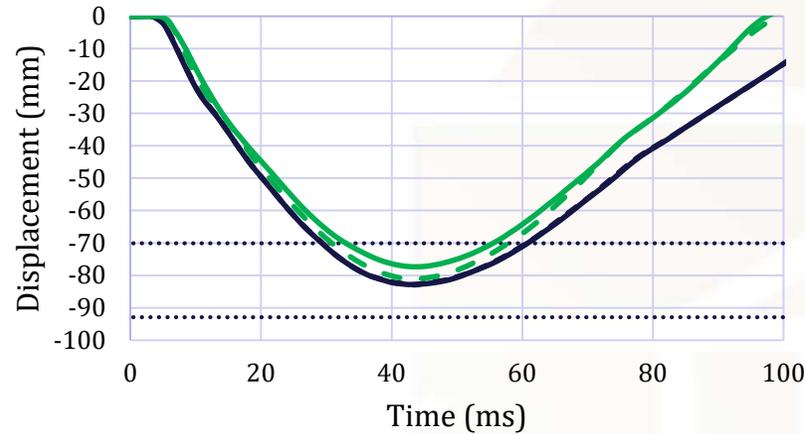
Abdomen & Lower Thorax Certification Simulations

Abdomen Bar Impact

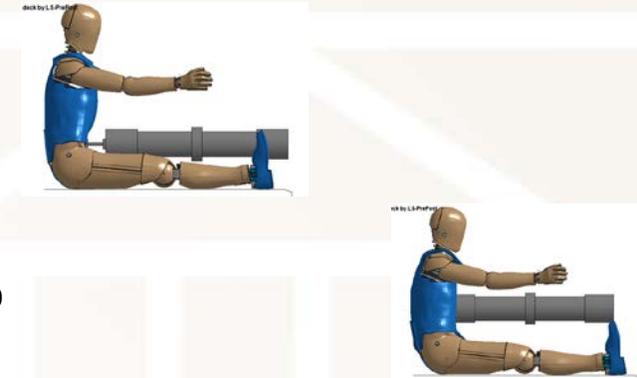
Impactor Force



Abdomen IR-TRACC Displacement

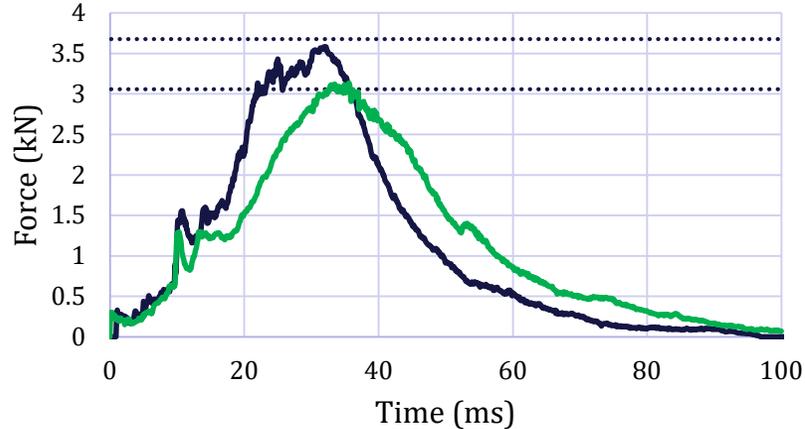


Stock THOR
Current Design Mods.

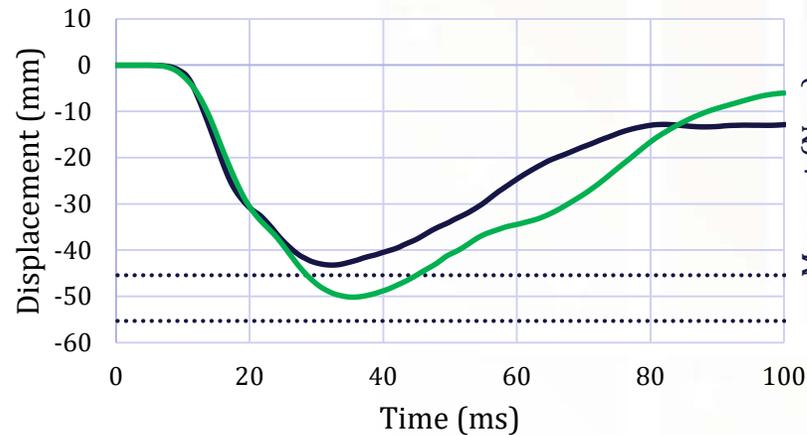


Lower Thorax Impact

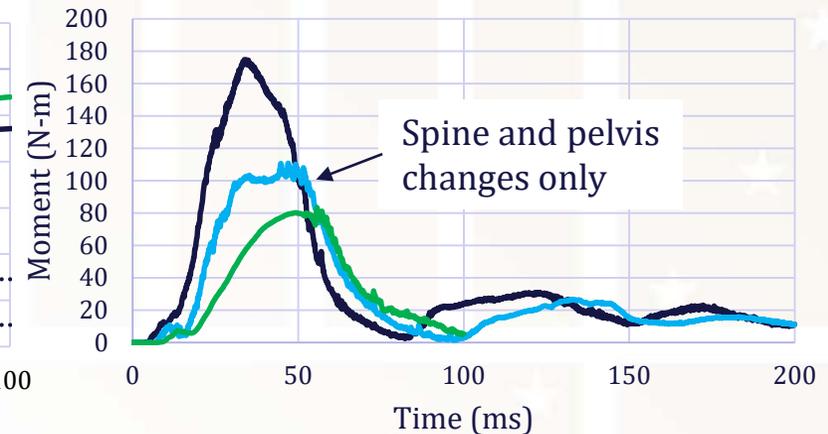
Impactor Force



Rib X-Displacement



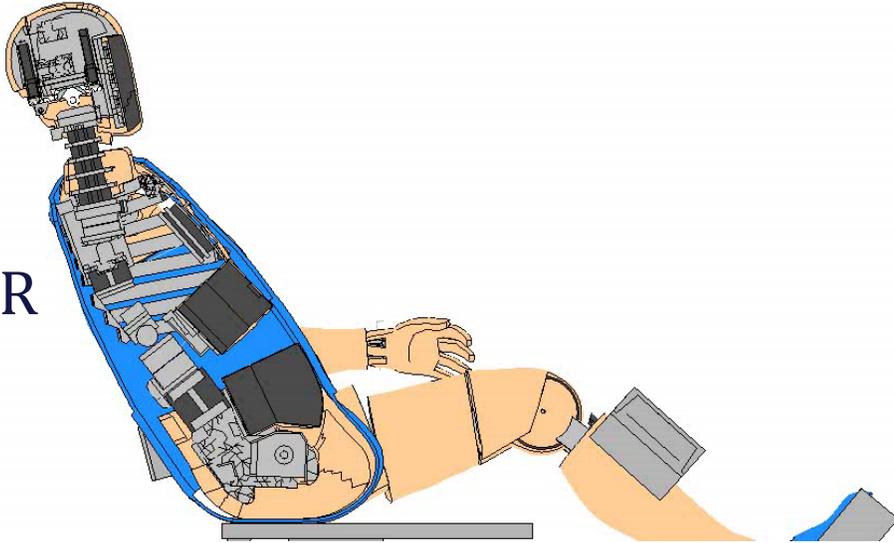
Lumbar LC Y-Moment



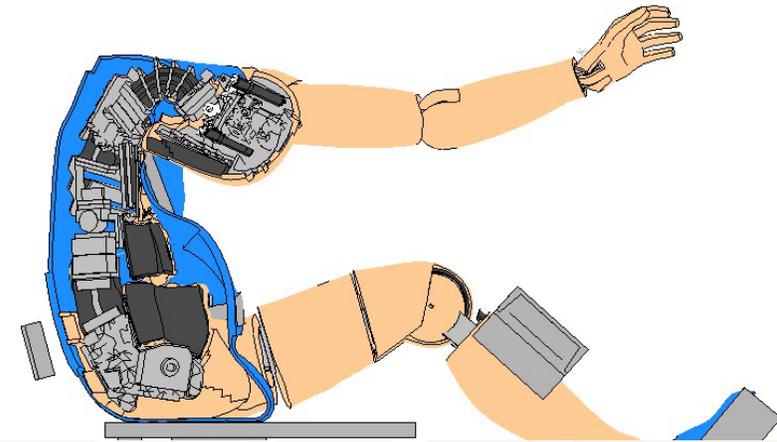
Gold Standard 1: 40 km/h, No Force Limiter

LS-DYNA keyword deck by LS-PrePost
Time = 0

Stock THOR

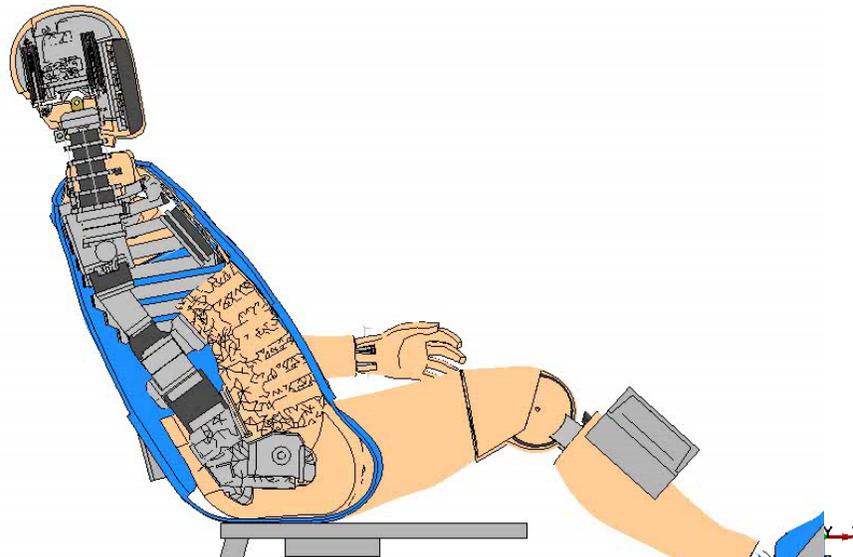


LS-DYNA keyword deck by LS-PrePost
Time = 150



Time = 0

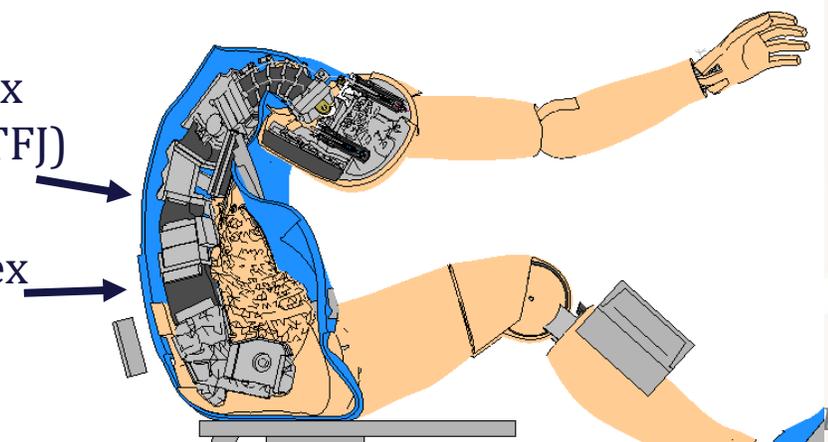
Current Design Mods



150

Lower Thorax Flex Joint (LTFJ)

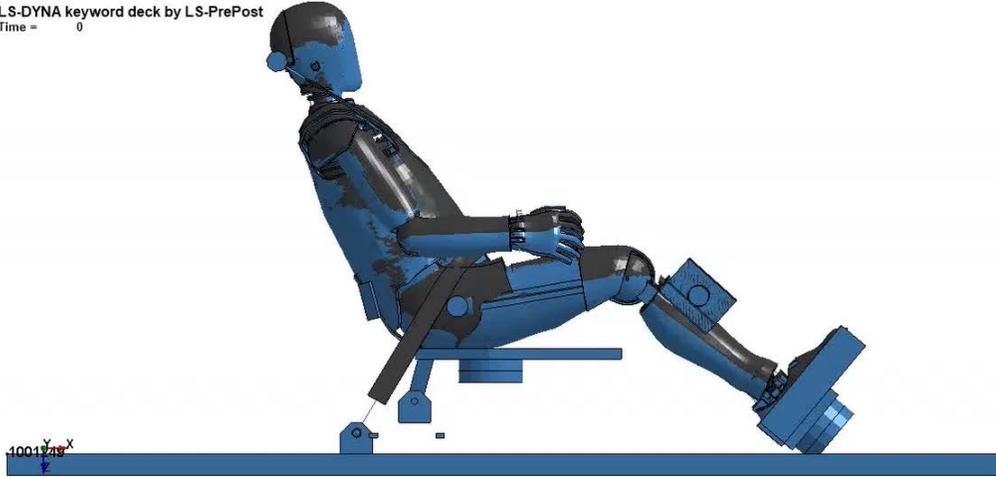
Lumbar Flex Joint (LFJ)



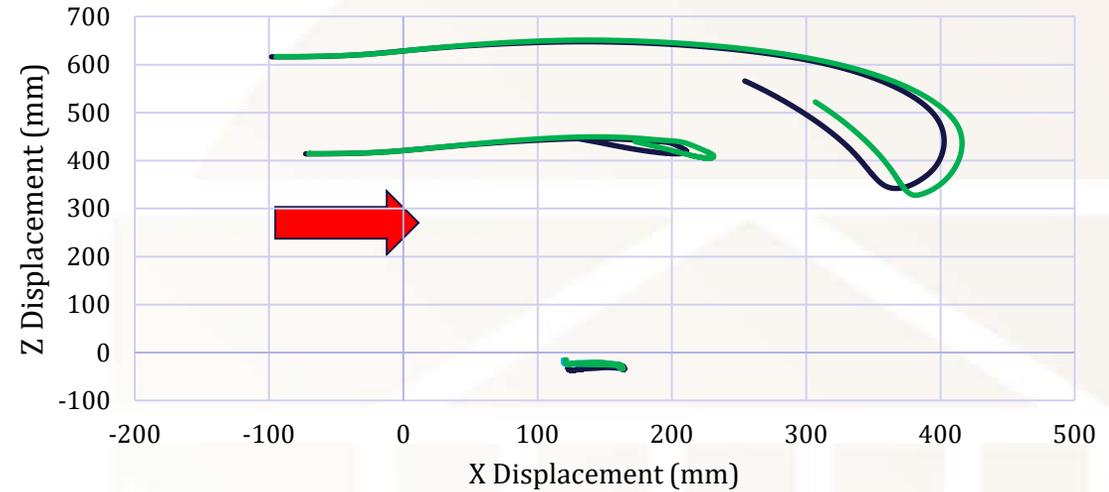
Gold Standard 1: 40 km/h, No Force Limiter

Stock THOR
Current Design Mods.

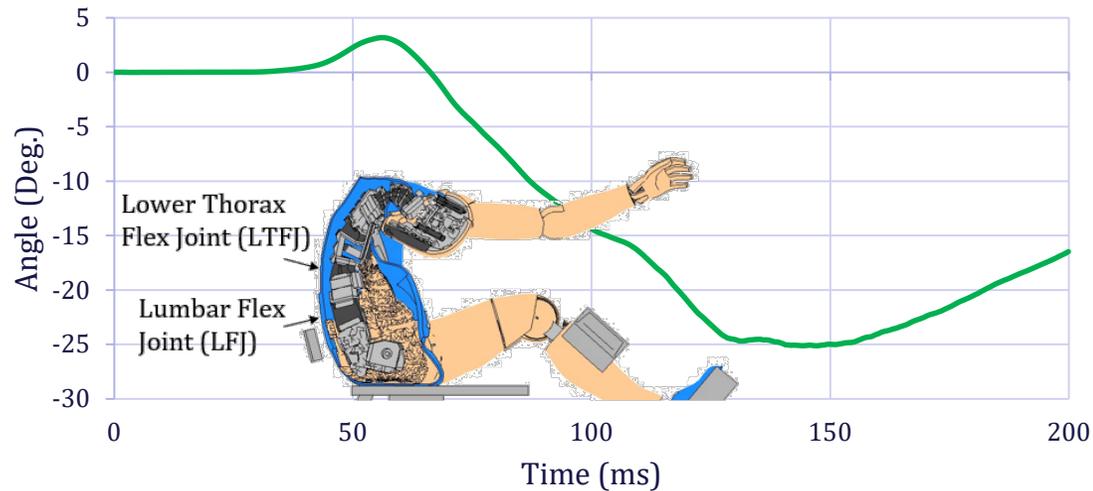
LS-DYNA keyword deck by LS-PrePost
Time = 0



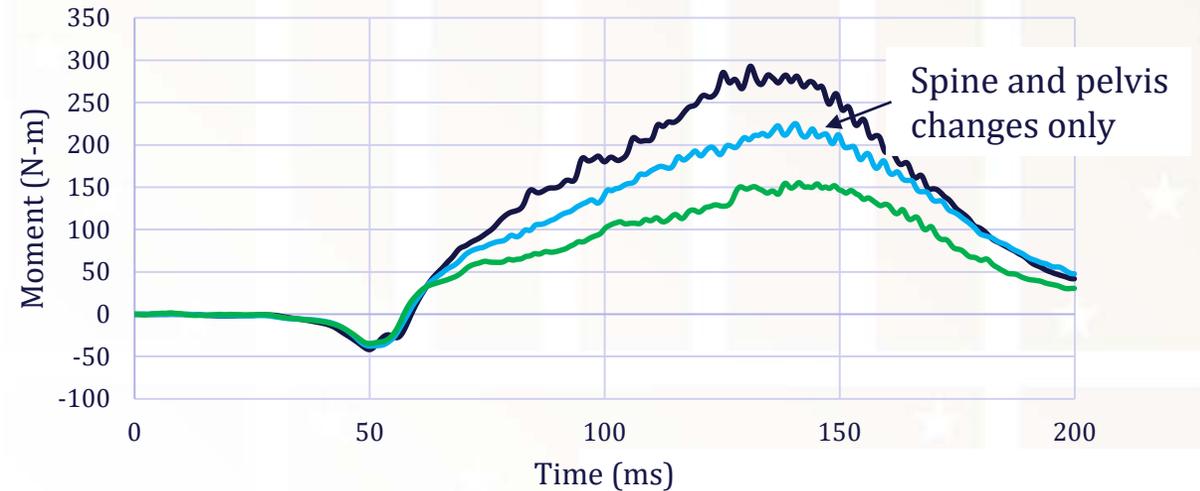
Kinematic Plot



LTFJ Angle Y Rotation



Lumbar LC Y Moments

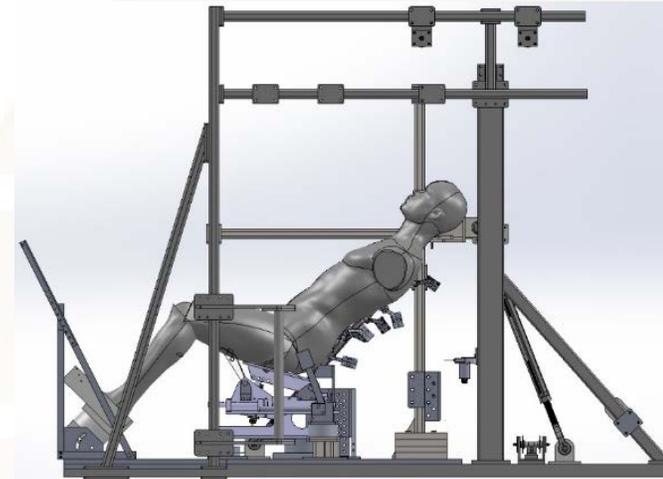


Recline – Matched UVA PMHS Tests

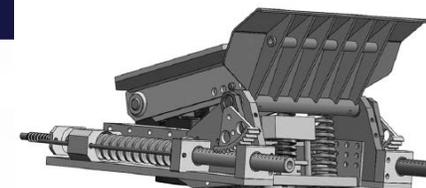
Richardson et al. 2019 ESV, 2020 Stapp
Supported by Autoliv Research



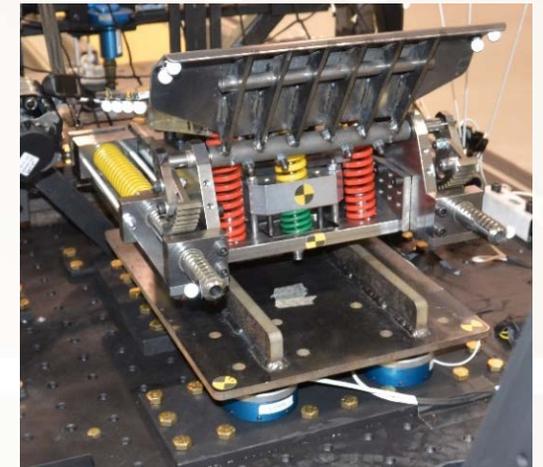
Caution: PMHS Images



50 km/h
x3 Pretensioners
Kinematic &
Dynamic
Corridors



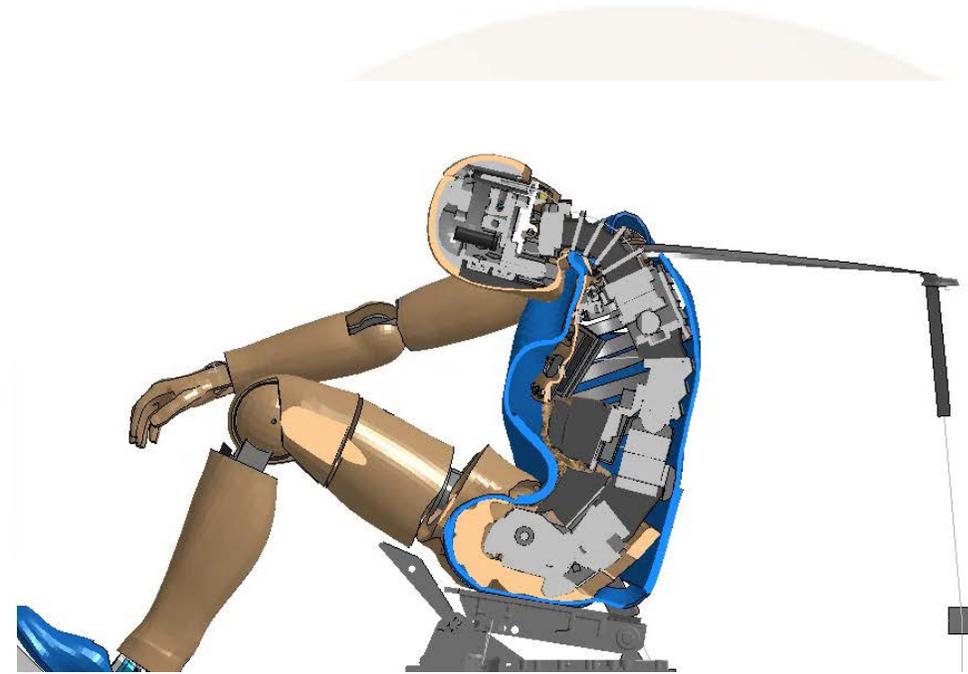
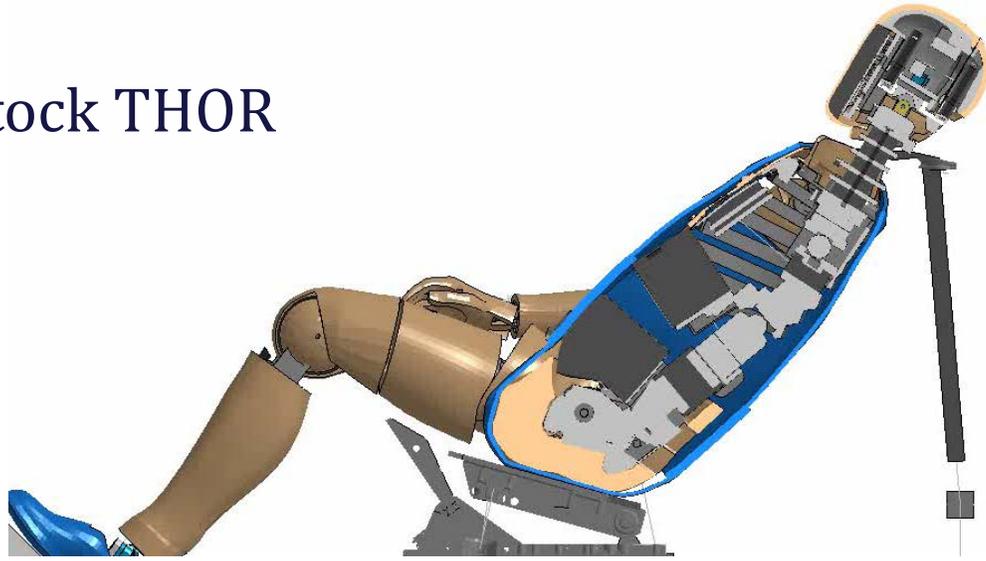
Uriot 2015 Seat



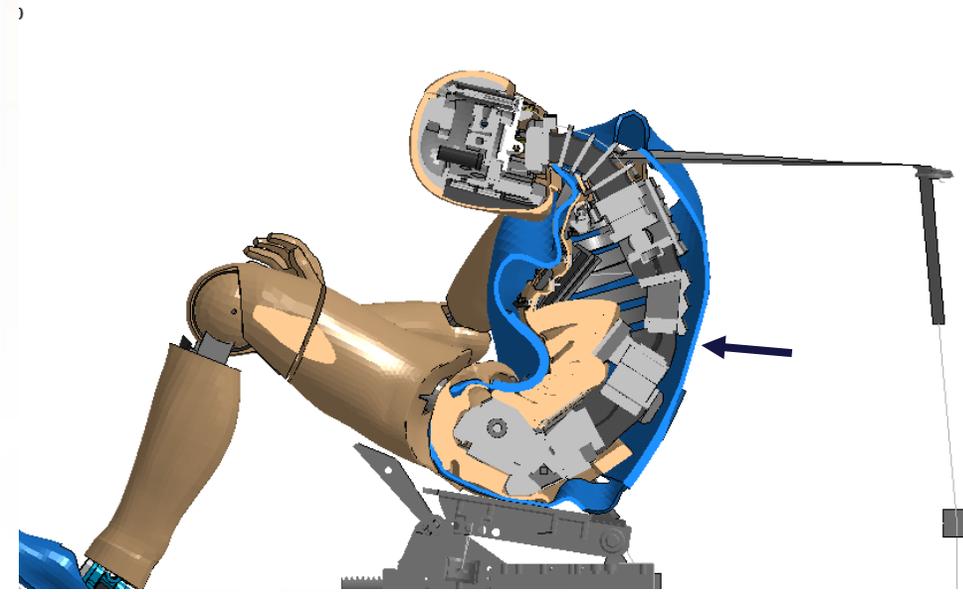
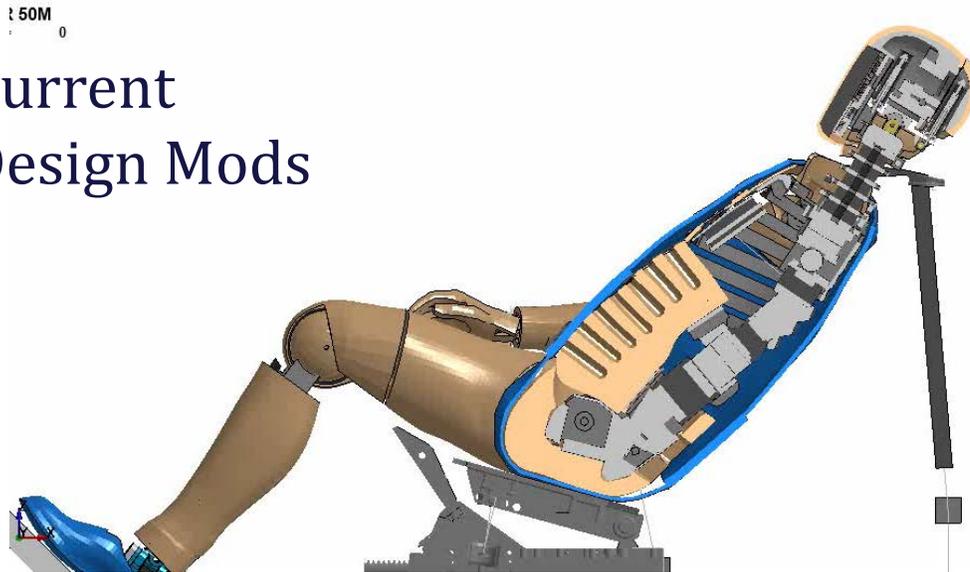
Center for Applied Biomechanics

Reclined Test Configuration

Stock THOR

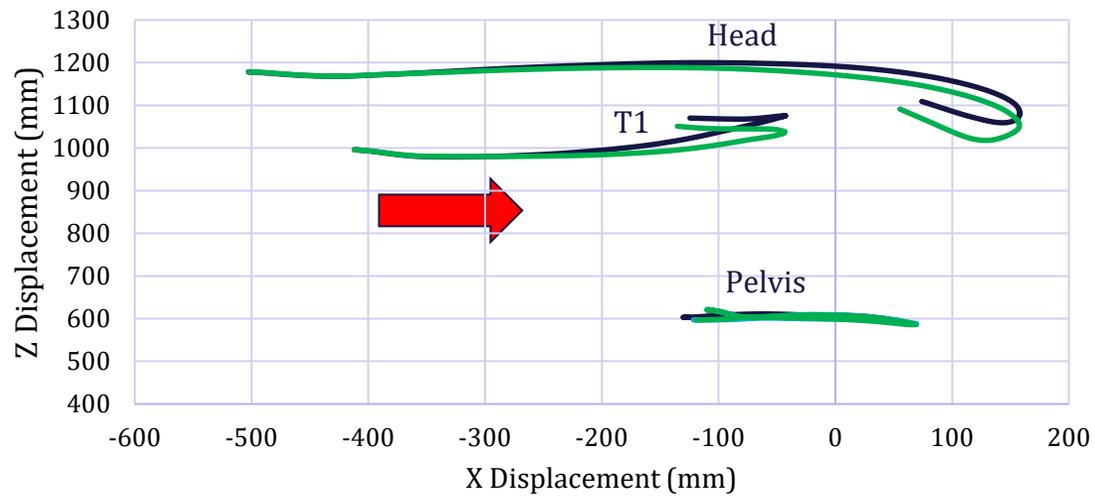


Current Design Mods

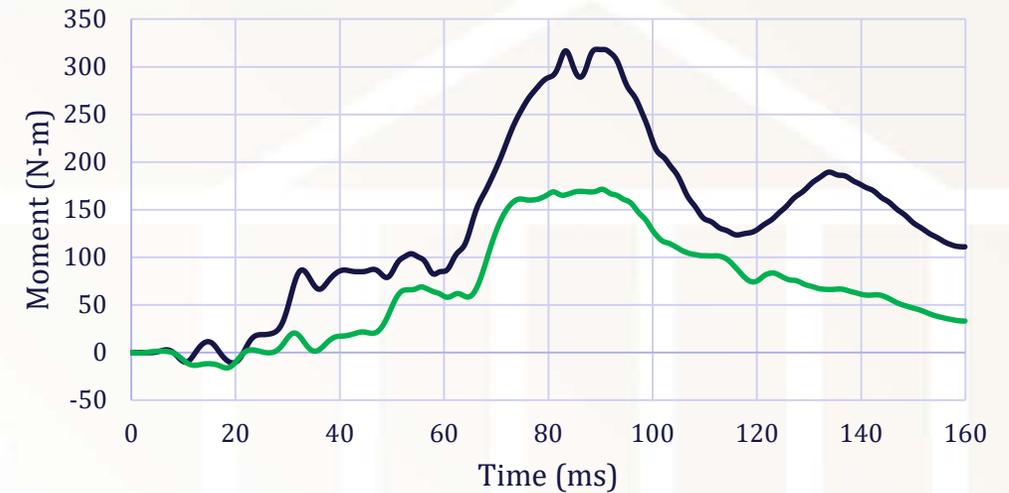


Reclined Test Configuration

Kinematic Plot



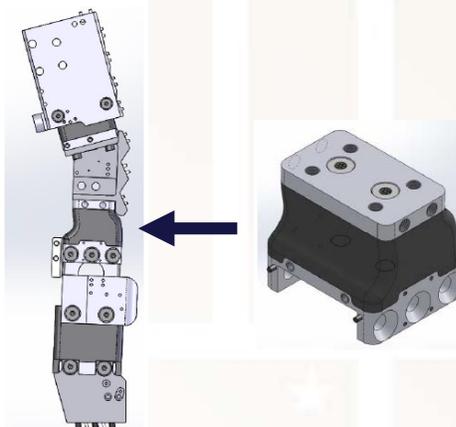
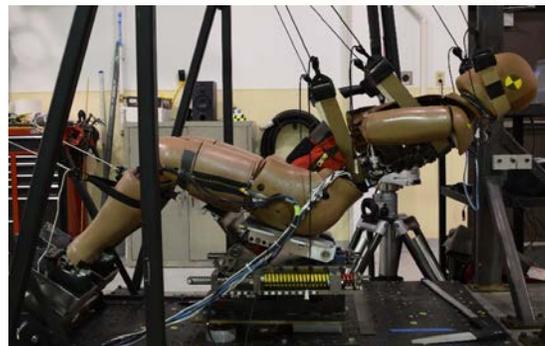
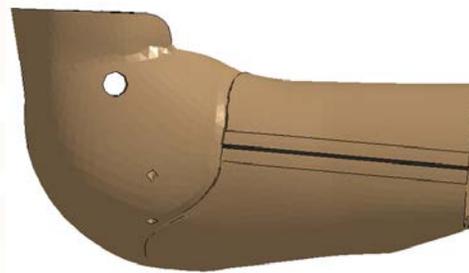
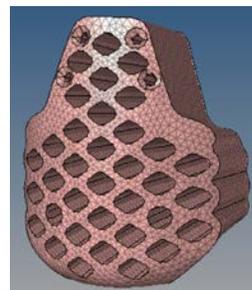
Lumbar LC Y Moment



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

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

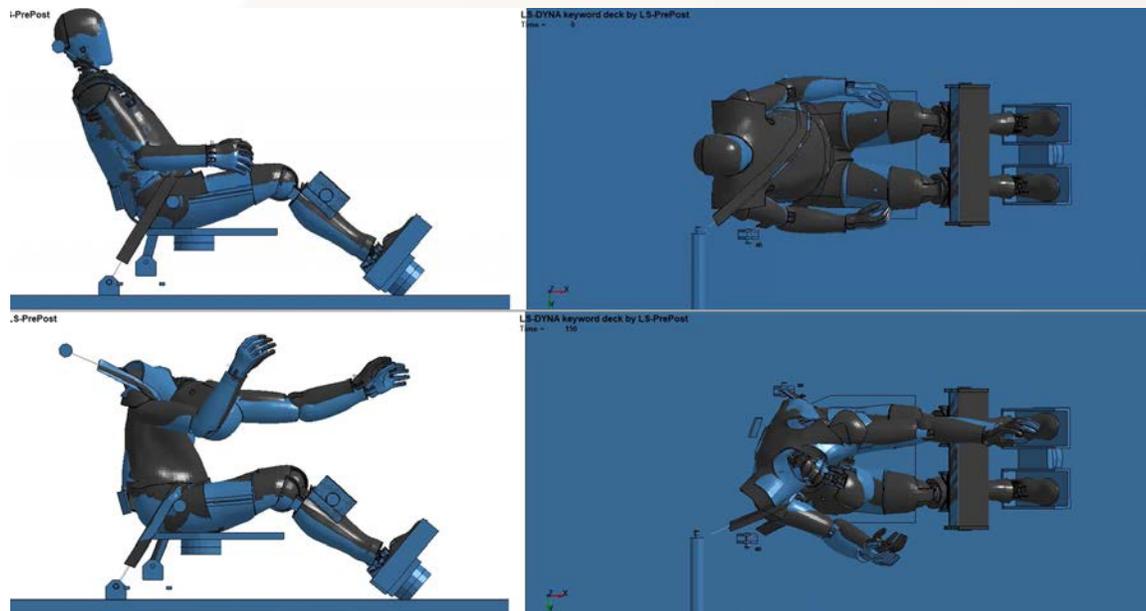
UVA/Autoliv Reclined Test Setup

Richardson et al.
2020

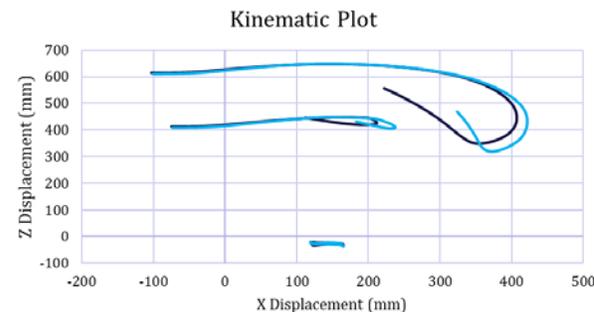
50 km/h
3x Pretensioner
Shoulder Belt FL

LAB Semi-Rigid Seat

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



Gold Standard 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