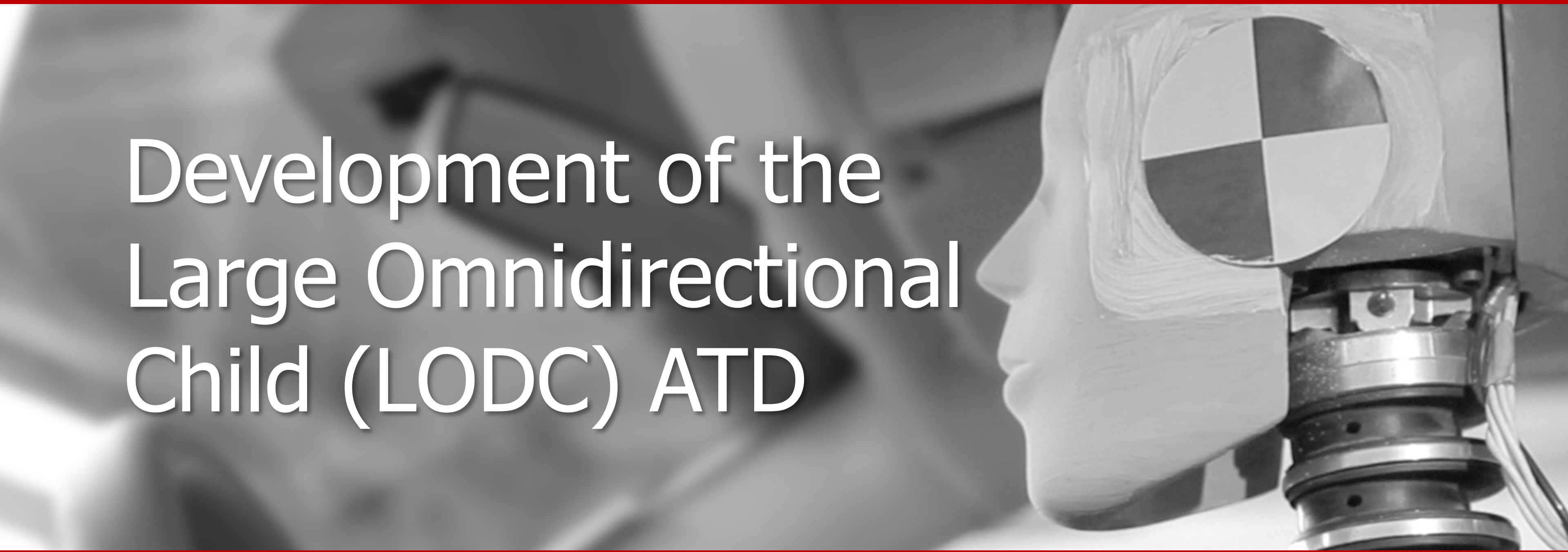
National Highway Traffic Safety Administration

Development of the Large Omnidirectional Child (LODC) ATD



Jason Stammen (NHTSA)
Brian Suntay (TRC)
Mike Carlson, Yun-Seok Kang (OSU)

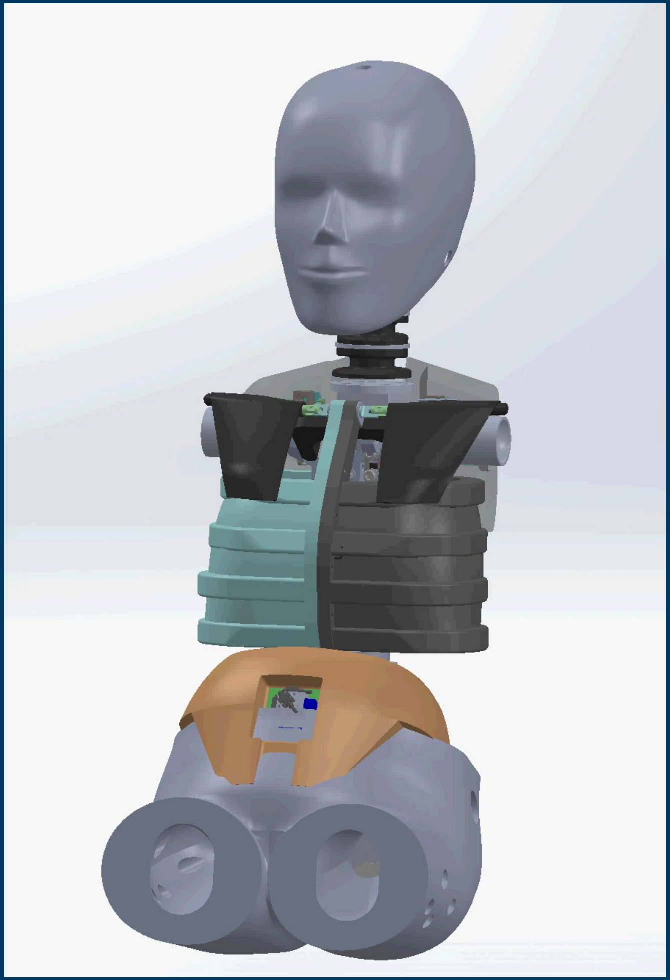
SAE Government/Industry Meeting
January 21, 2016

Motivation

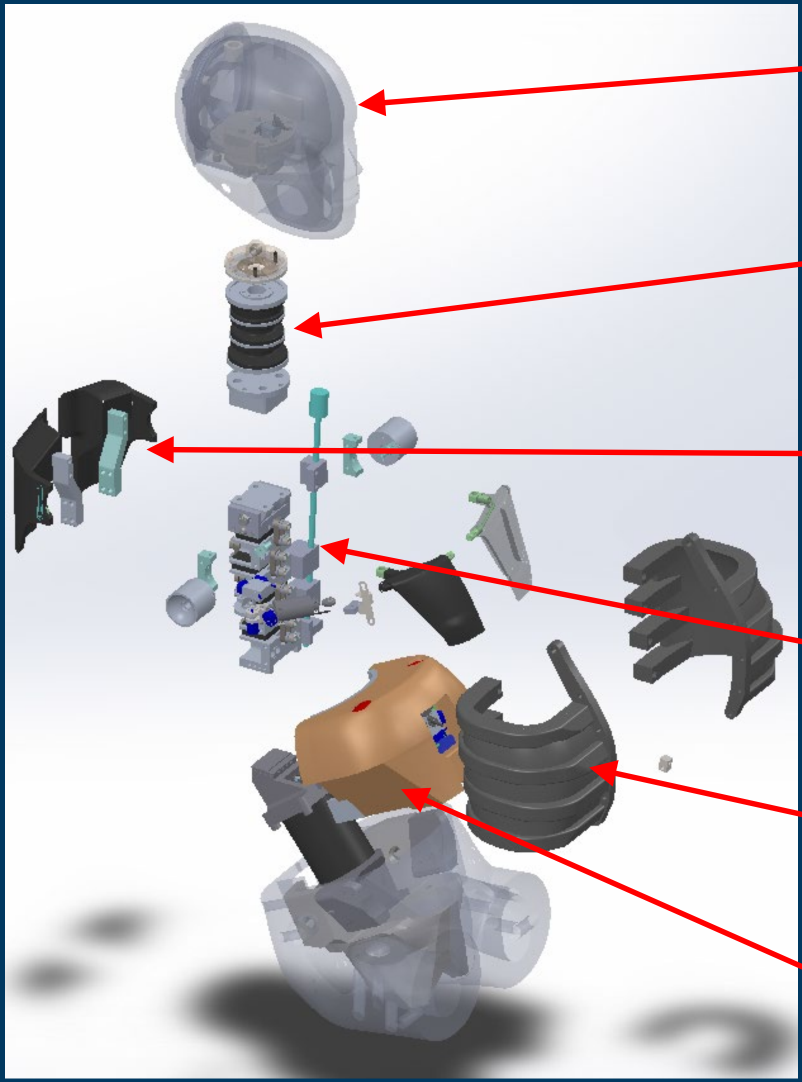
- Improvements to Hybrid III child ATD performance needed
  - Head kinematics & neck loads
  - Abdomen injury assessment
  - Belt interaction with thorax & shoulder

- Large Omnidirectional Child (LODC)
  - 10YO size

- Prototype development activities done in-house



LODC: Design Overview



Head mass properties adjusted to Duke human head data

Neck assembly tuned to Duke pediatric model response

Shoulder will carry shoulder belt loads in a humanlike way

Flexible thoracic spine tuned to human data

Ribcage tuned to 10 year old corridor

Abdomen instrumentation to measure injury risk

Head: Design

LODC head should have proper mass properties & respond correctly in impact

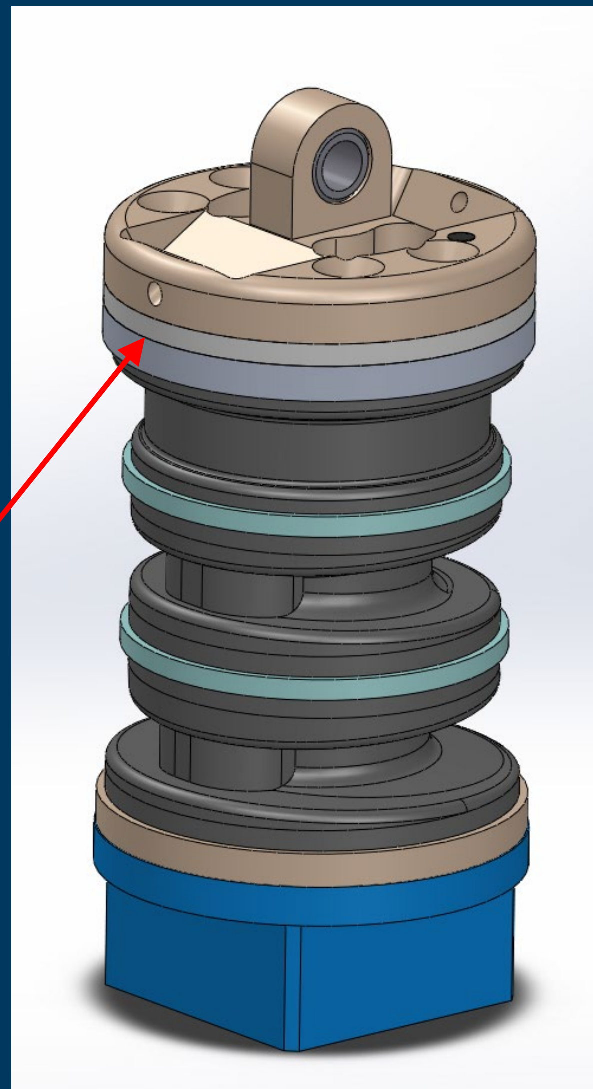
Measurement	10YO Human	LODC	Hybrid III 10YO
Mass (kg)	**3.56**	**3.56**	**3.73**
CG to OC (x, mm)*	17.8	18.6	20.1
CG to OC (z, mm)	**52.8**	**52.5**	**44.8**
Ixx (mm^4)	0.0121 ± 0.0014	0.0118	0.0120
Iyy (mm^4)	0.0150 ± 0.0014	0.0153	0.0160
Izz (mm^4)	0.0112 ± 0.0008	0.0118	0.0130

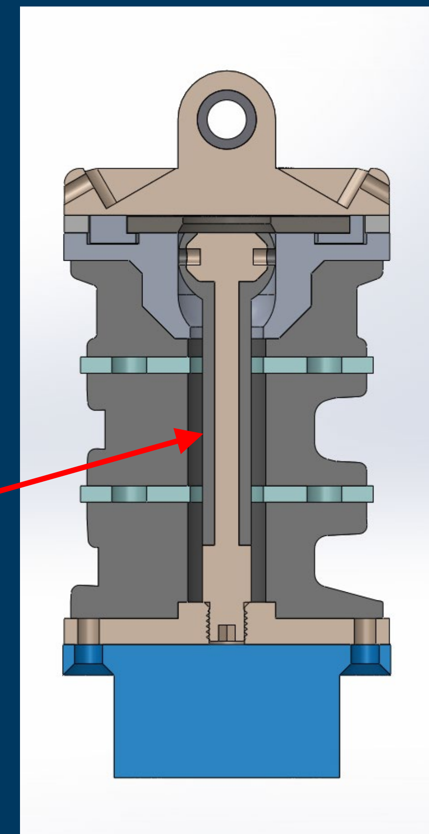
Human properties from Loyd et al. (Stapp 2009)
***CG-OC(x) was weakly correlated with characteristic length, so linear interpolation alone between 9-16YO specimens was used for human target**

- Secondary focus: revise head skin to match head drop response targets from Loyd et al (2009)

Neck: Design

20 degrees free range of motion in Z-axis

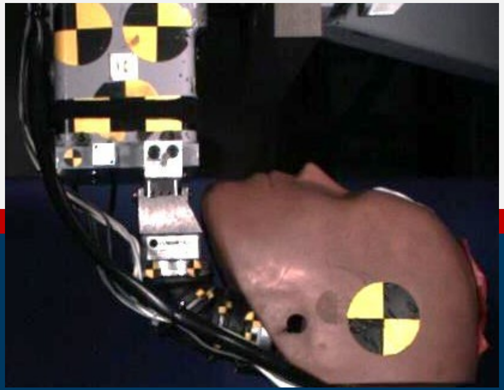




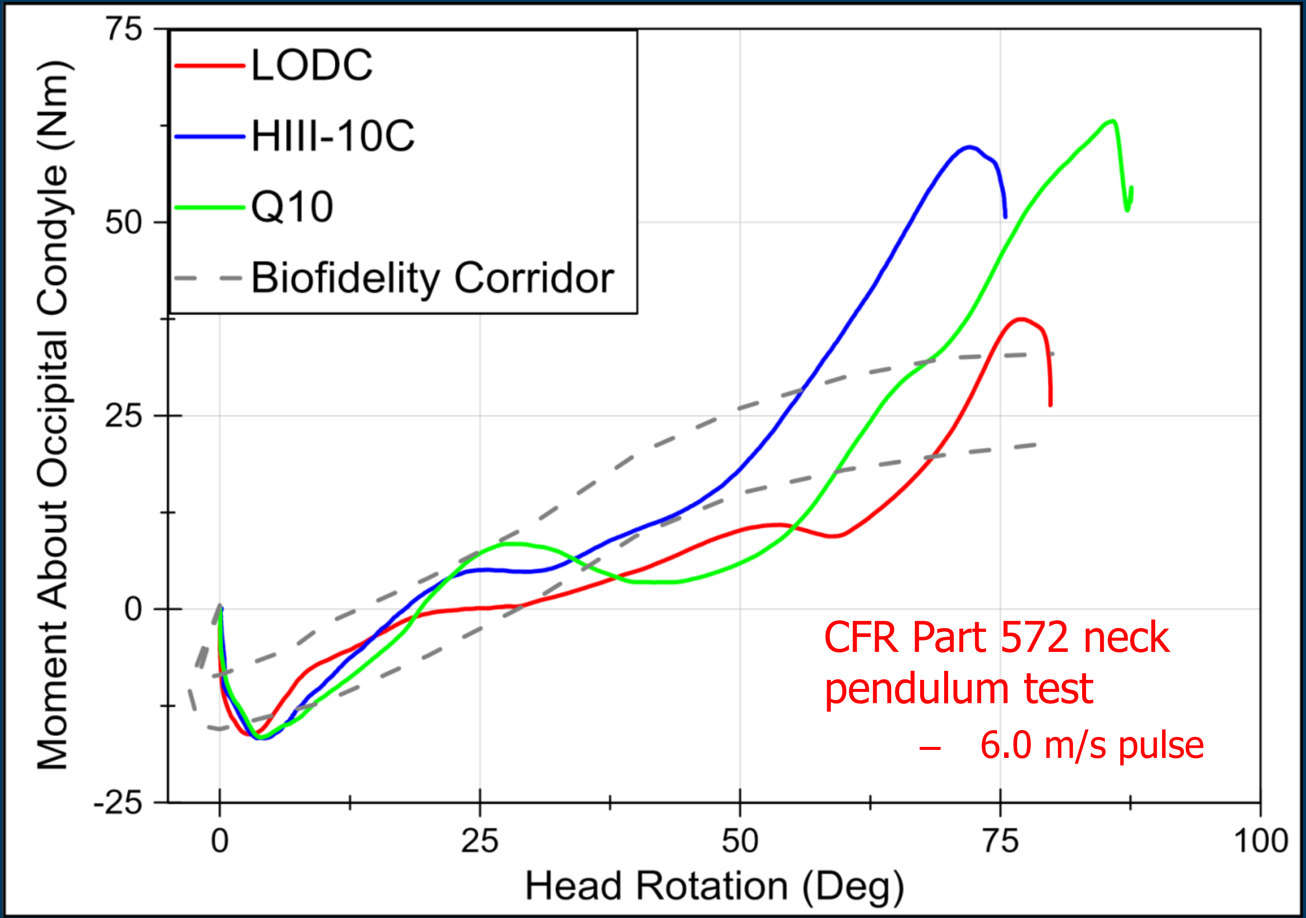
C2 twist mechanism for more humanlike off-axis ROM

Over-molded central cable that allows some elongation without fasteners, reducing risk of interference & noise

Neck: Response



Biofidelity Target From Dibb et al (ESV 2013)



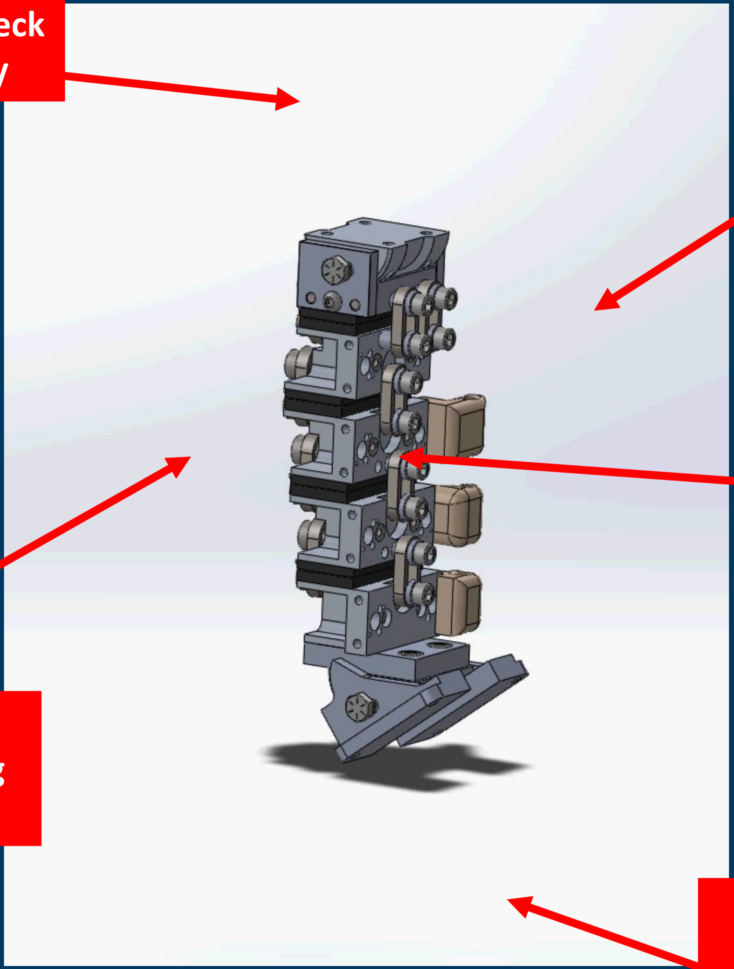
CFR Part 572 neck pendulum test
- 6.0 m/s pulse

Thoracic Spine: Design

Flexible, stable, and repeatable

Angle adjustment at lower neck adds positioning versatility

Top thoracic joint has two anterior links for added stability during seating



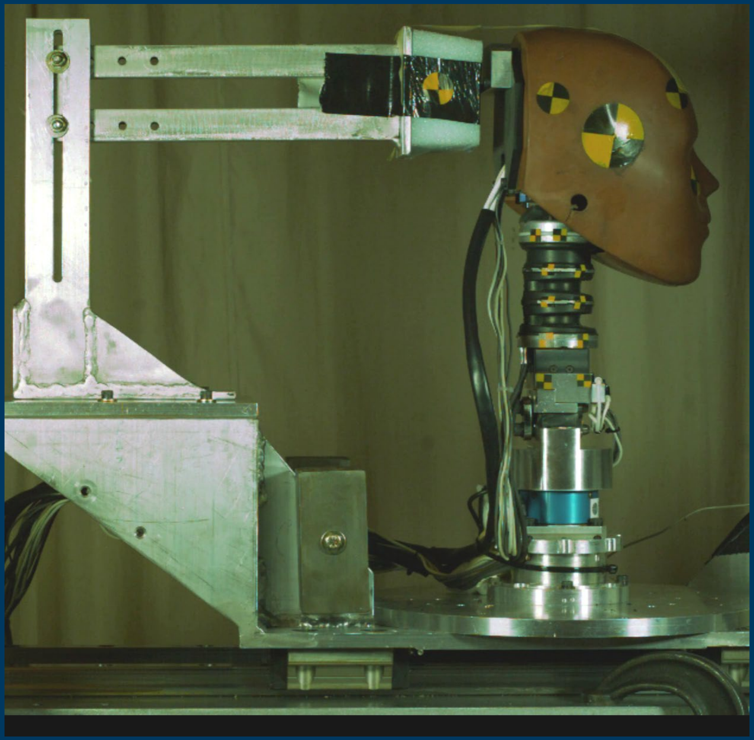
Thoracic mounts provide posterior rib and shoulder attachment, and mounting locations for motion blocks to measure spine motion

Bi-layer rubber elements provide flexibility while being stabilized by connecting links

Lumbar bracket is adjustable within the range of normal child seated postures

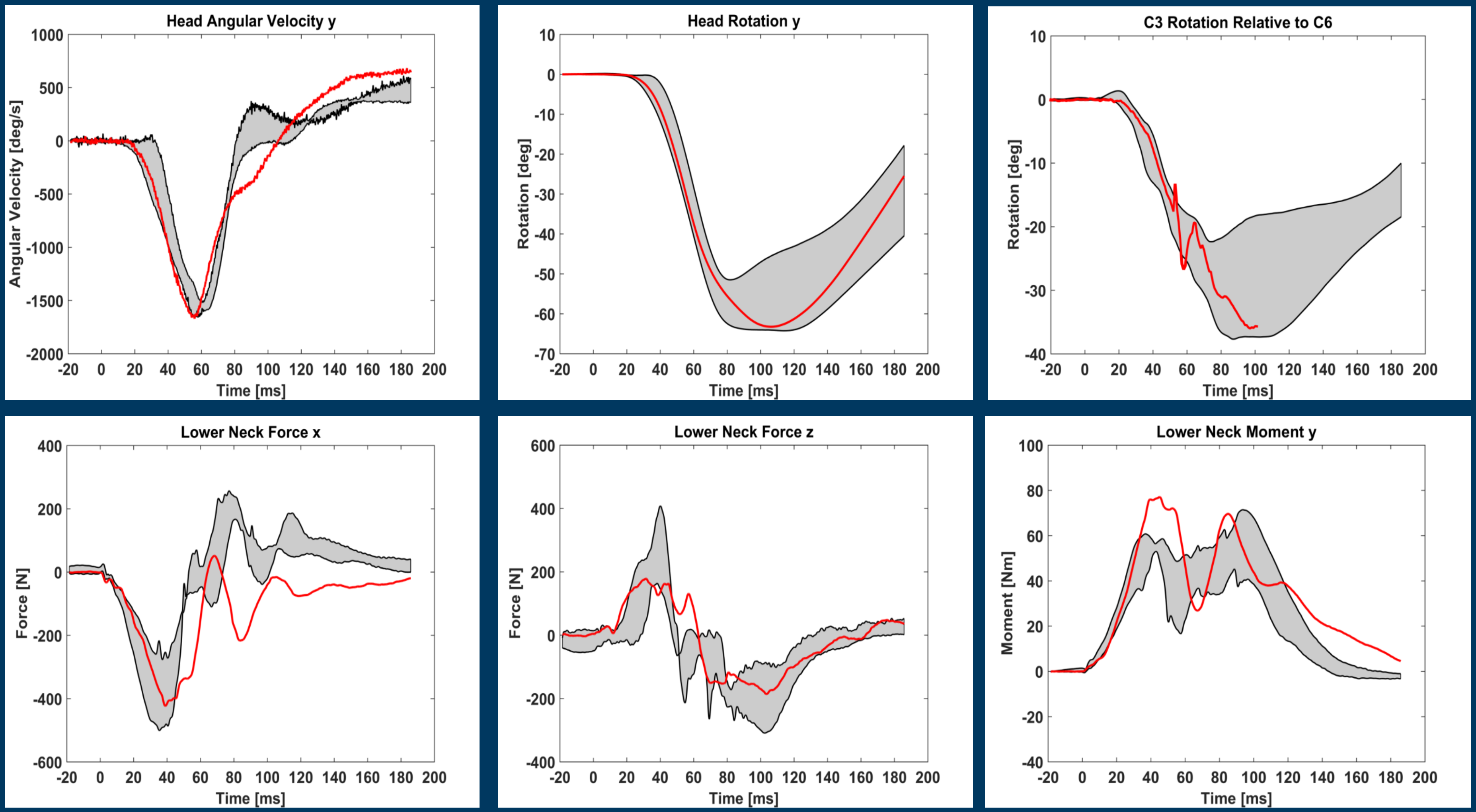
Cervicothoracic Spine: Test Setup

- **Goal:** Exercise neck and upper spine together in flexion
- **Pulse:** 12 G, 4 m/s (based on T1 X acceleration data from a FMVSS No. 213 sled test)
- **Biomechanical reference:** Adult PMHS scaled to LODC size (Kang et al 2016, in progress)



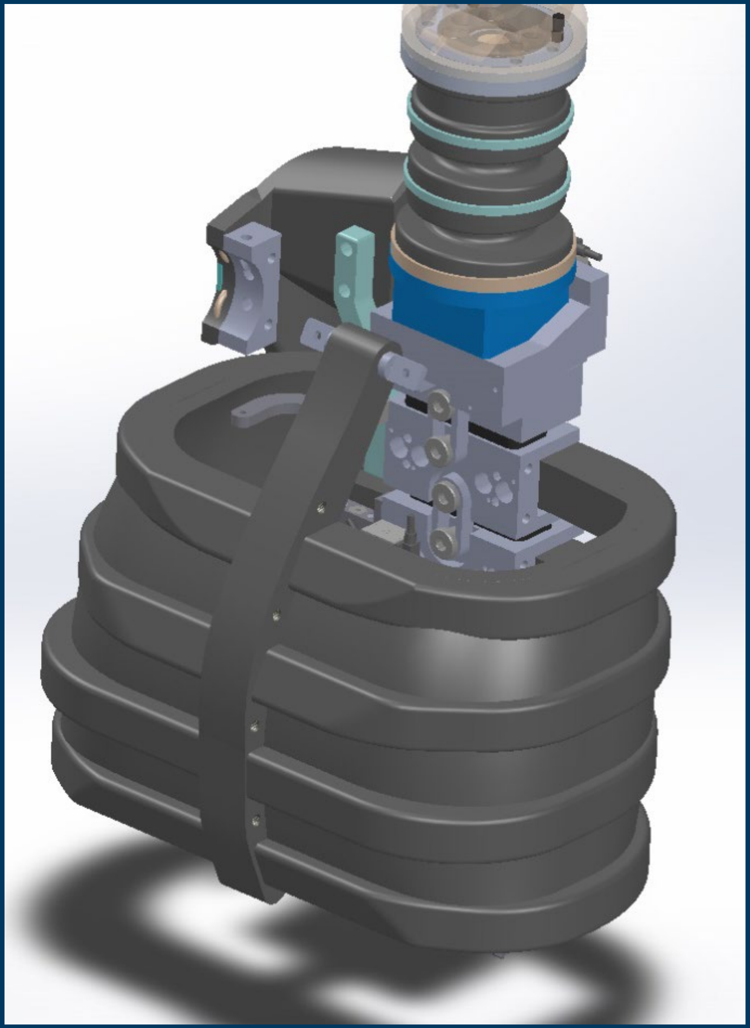
Thoracic Spine: Response

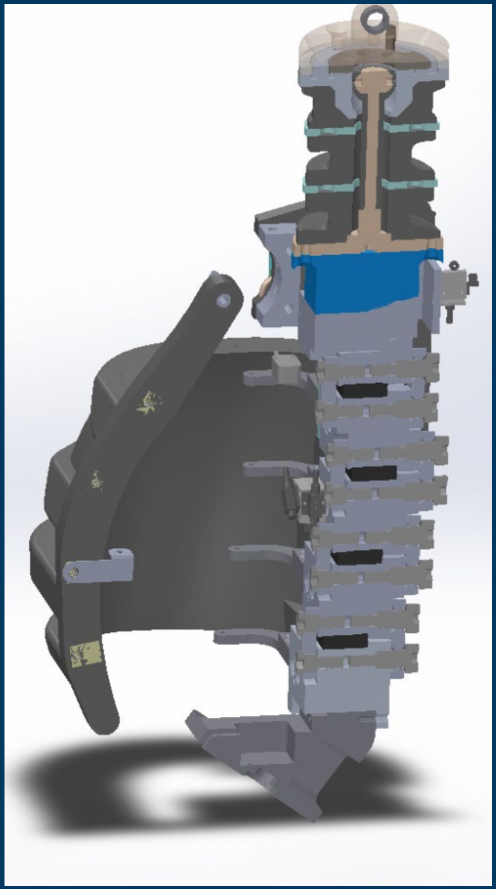
LODC should display proper head kinematics and neck loads



Thorax: Design

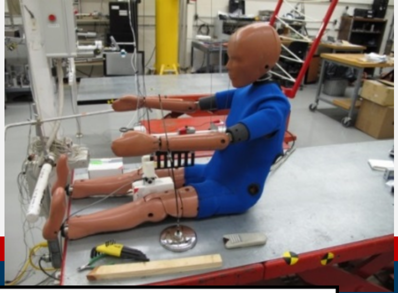
Two hemispheres with continuous interior surface to maintain rib alignment

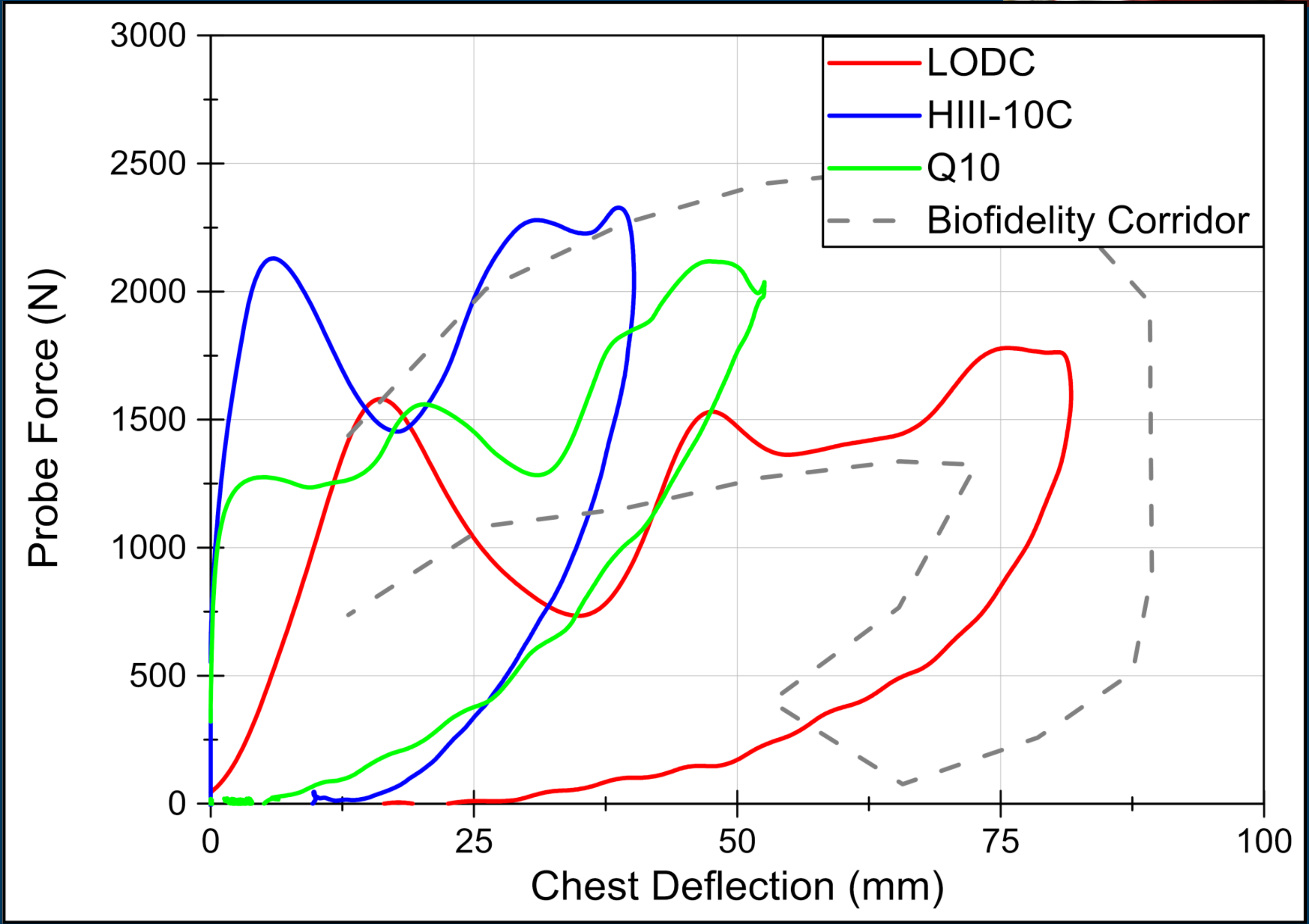




Thorax: Response

Tune LODC thorax stiffness to reflect human response

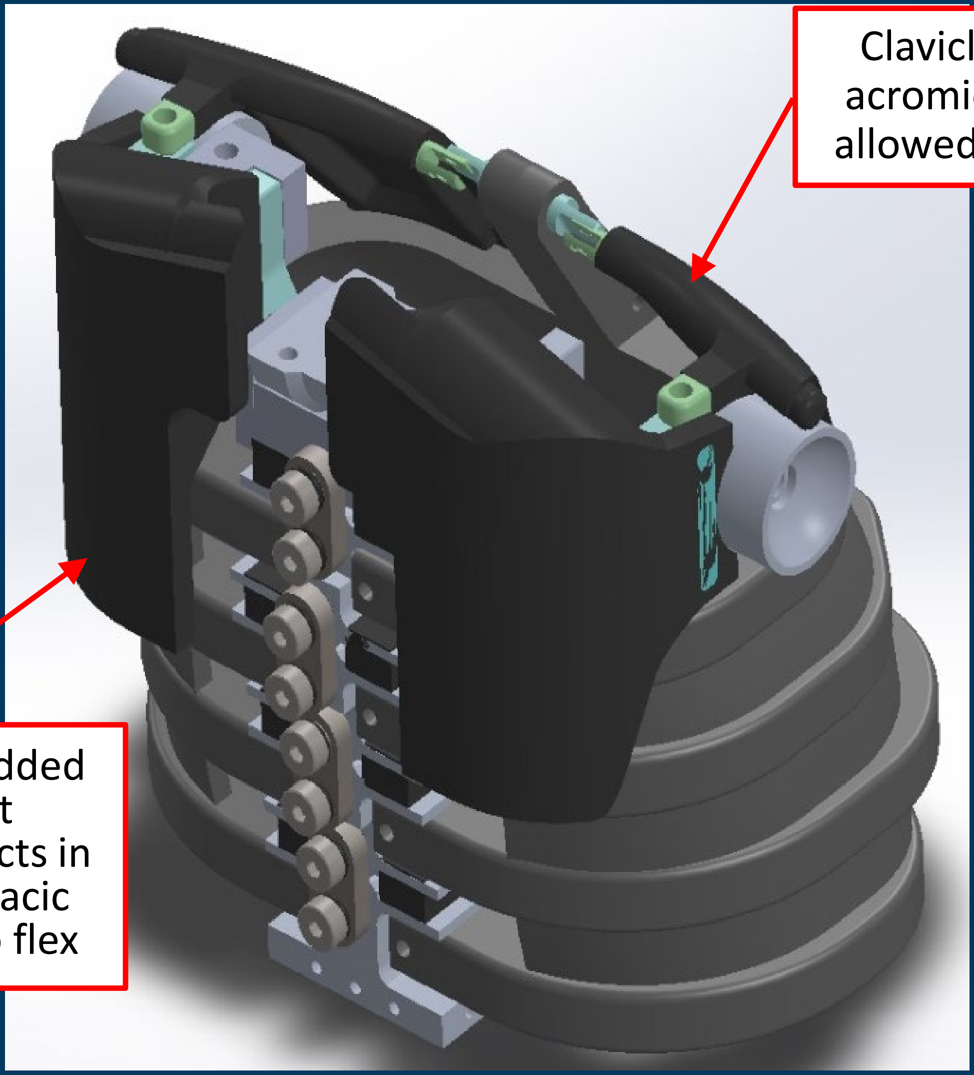




Biofidelity Target derived by Parent et al (2010) from Ouyang et al (2006) data

Shoulder: Design

Humanlike construction with clavicle-acromion-scapula load path to the spine

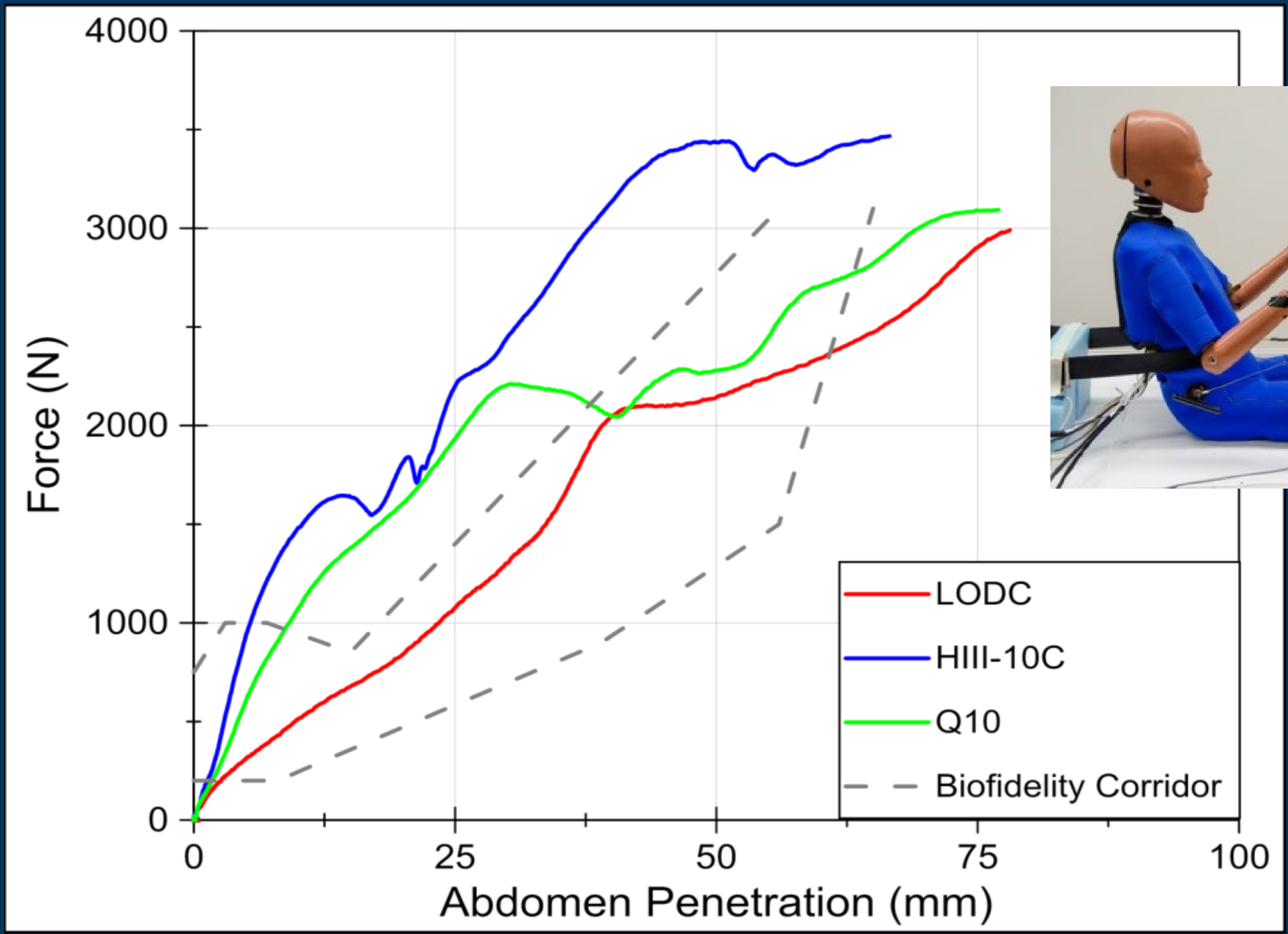


Clavicle connects sternum to acromion with relative motion allowed at SC and AC joint ends

Scapula provides added support for belt resistance & connects in a way so that thoracic spine is still free to flex

Abdomen: Response

Same geometry as Hybrid III 10YO but heavier and softer; pelvis same as Hybrid III



Biofidelity Targets From Kent et al (Stapp 2008)

Full Dummy Evaluation

Compare with Hybrid III 10YO in FMVSS No. 213 condition. Does LODC:

- Replicate the head kinematic trajectory characteristics of previously conducted pediatric PMHS/volunteer testing?
- Eliminate chin-chest induced head acceleration spikes?
- Reduce neck loads to levels more suitable for neck injury risk assessment?
- Provide added sensitivity for distinguishing between restraint conditions?
- Identify the potential for submarining and measure abdominal injury risk?

Full Dummy Evaluation

Visual comparison with Hybrid III 10C ATD

5-PT HARNESS

Hybrid III 10YO

LODCrev2

BACKLESS BOOSTER

Hybrid III 10YO

LODCrev2

HIGHBACK BOOSTER

Hybrid III 10YO

LODCrev2

NO CRS

Hybrid III 10YO

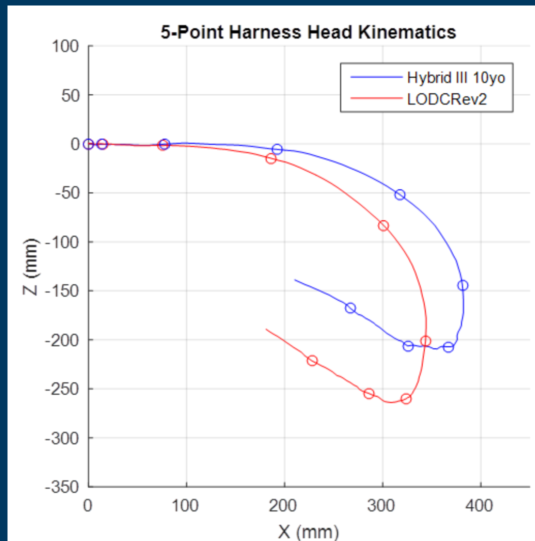
LODCrev2

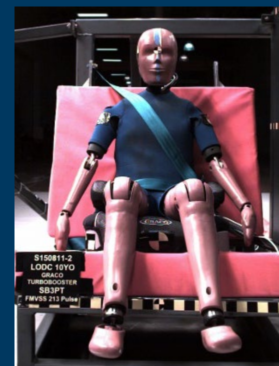
***For more details on the upgraded 213 bench, see NHTSA-2013-0055-0002**

Full Dummy Evaluation

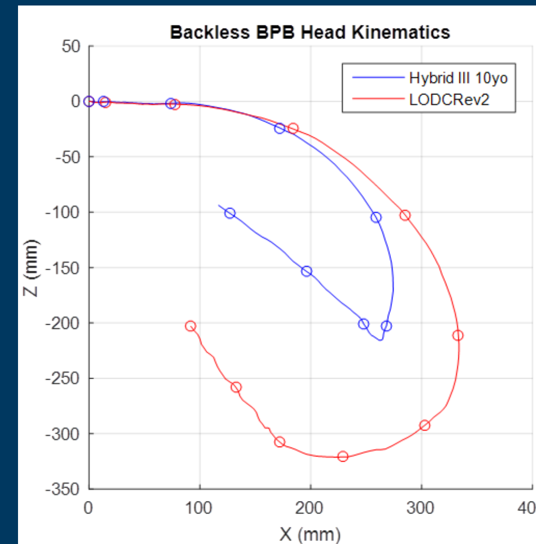
Head/spine trajectories more reflective of human data (more X & Z translation)

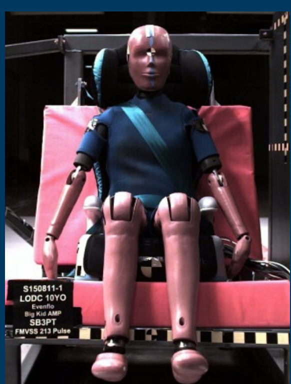
5-PT HARNESS



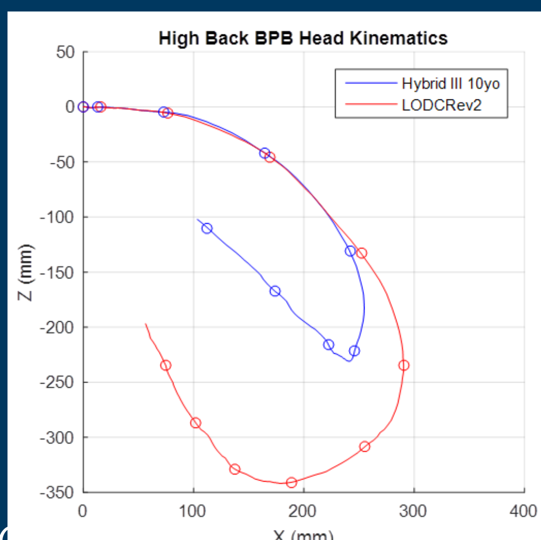


BACKLESS BOOSTER

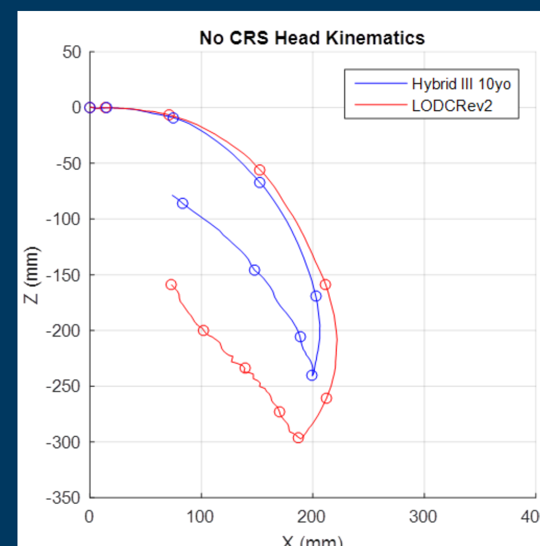




HIGHBACK BOOSTER

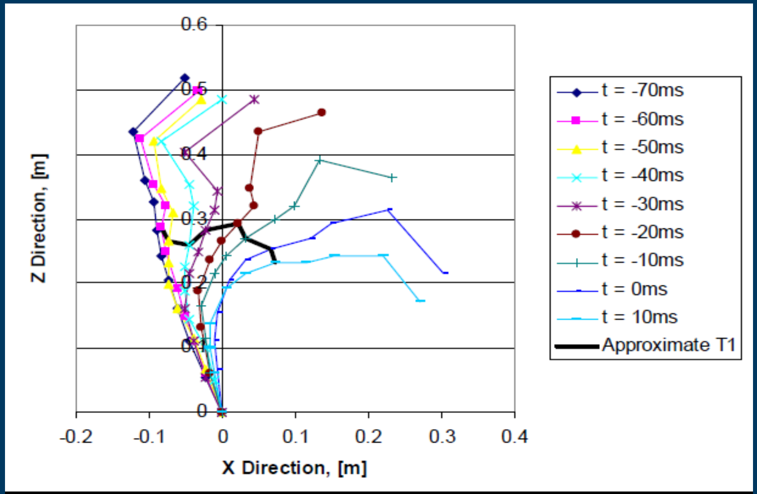


NO CRS

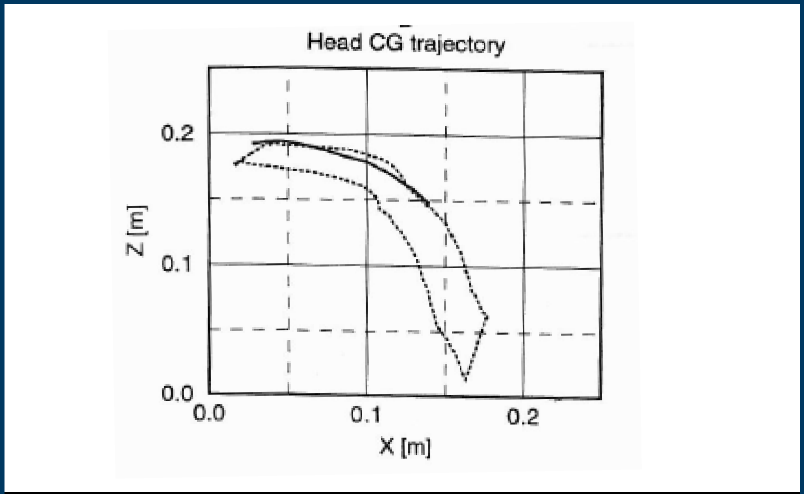


Full Dummy Evaluation

Head/spine trajectories more reflective of human data (ratio of Z to X peak displacement)



Ash et al 2009: Re-analyzed 13YO PMHS data from Kallieris et al 1976 showed roughly 1:1 ratio of peak X/peak Z head CG displacement

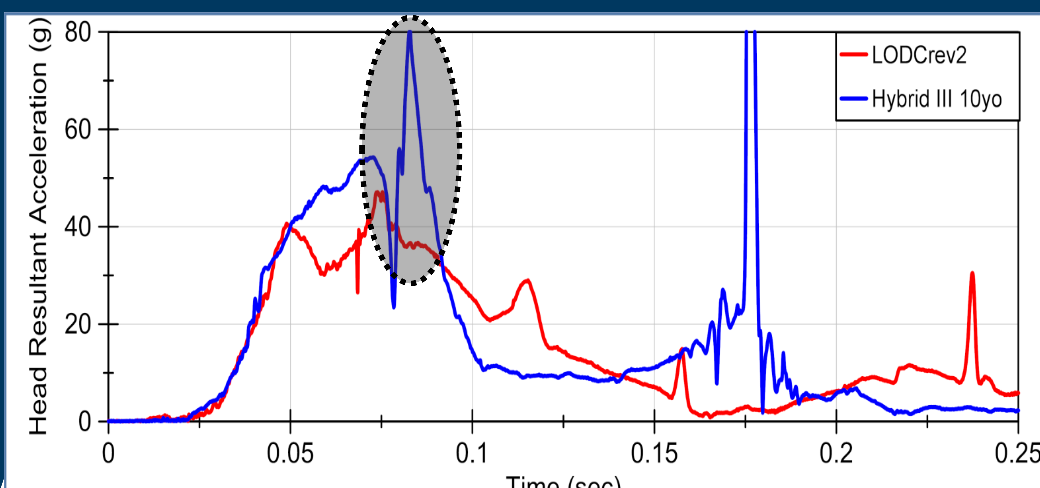


Thunnissen et al 1995: adult volunteers had significantly greater Z (vertical) displacement for head CG than Hybrid III 50th ATD did

Restraint	Z_{peak} / X_{peak} (Hybrid III 10YO)	Z_{peak} / X_{peak} (LODC)
5 Pt Harness	0.54	0.77
Highback BPB	0.88	1.17
Backless BPB	0.77	0.98
No CRS	1.20	1.34

Full Dummy Evaluation

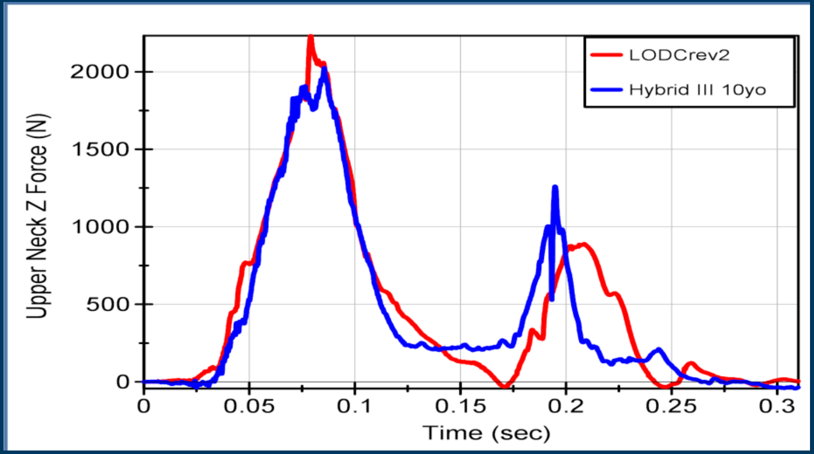
Eliminates head acceleration spikes (& high HIC) induced from chin-chest contact



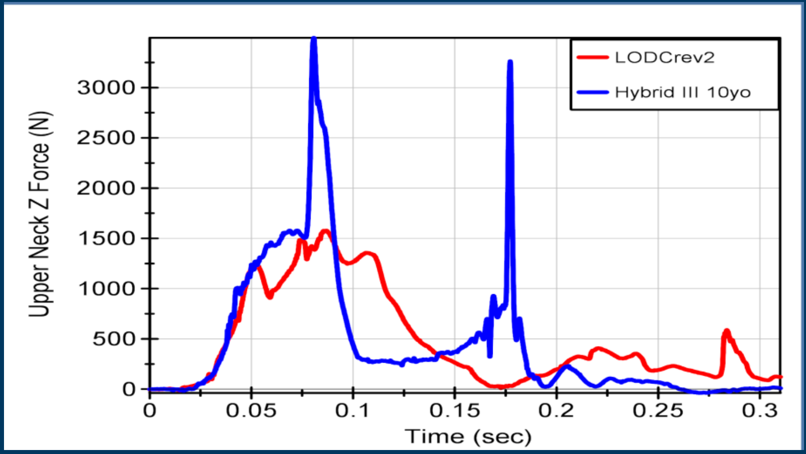
CRS	ATD	HIC36
5-pt Harness	LODC	481
	H3	497
High Back	LODC	214
	H3	531
Backless	LODC	306
	H3	1956
No CRS	LODC	271
	H3	637

Full Dummy Evaluation

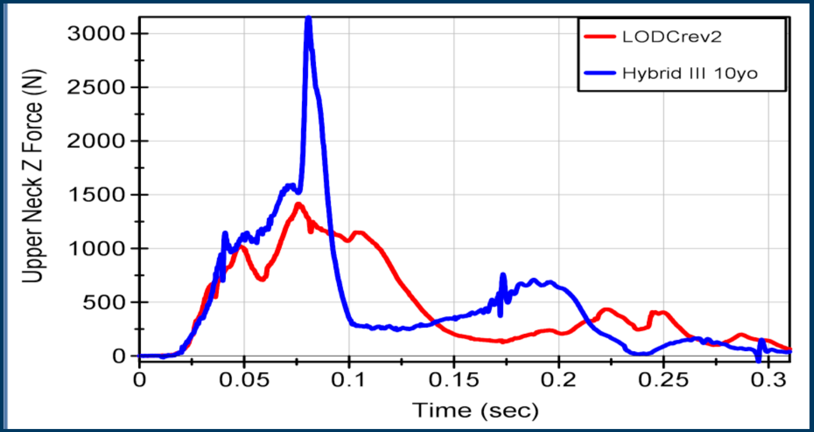
Reduced neck tensions to levels more appropriate for neck injury assessment



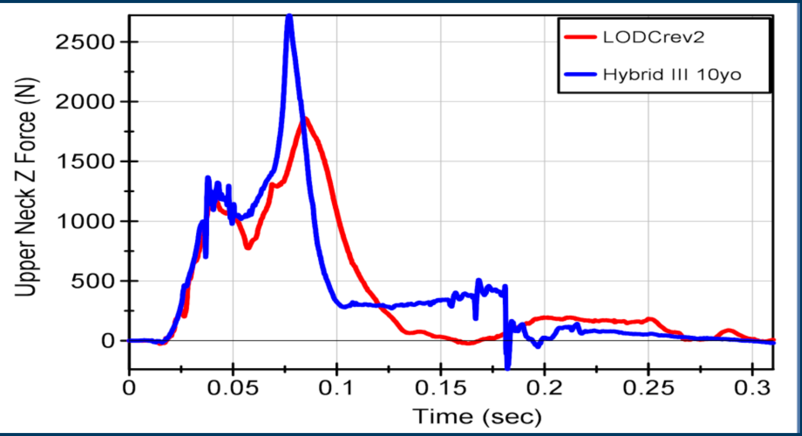
5-Point Harness



Backless Booster



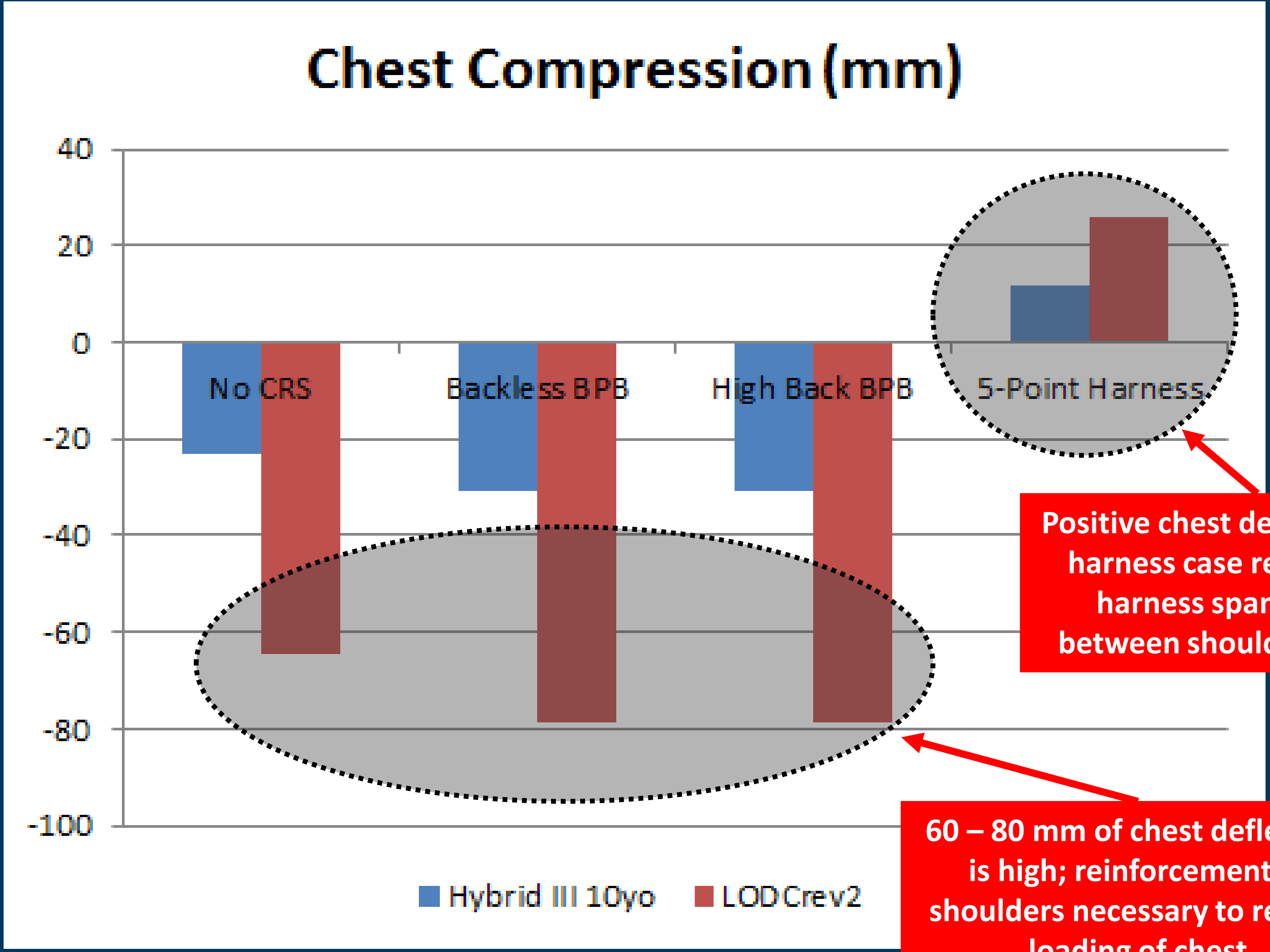
Highback Booster



No CRS

Full Dummy Evaluation

Large chest compressions?

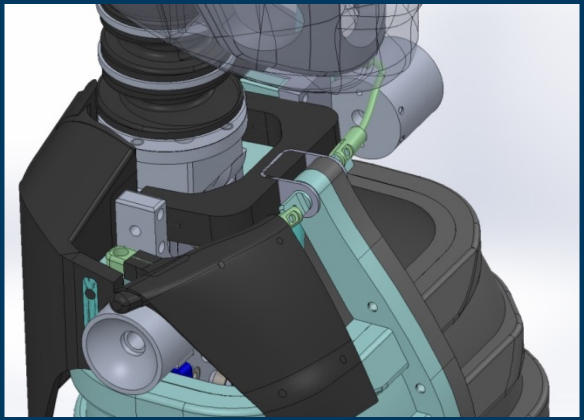


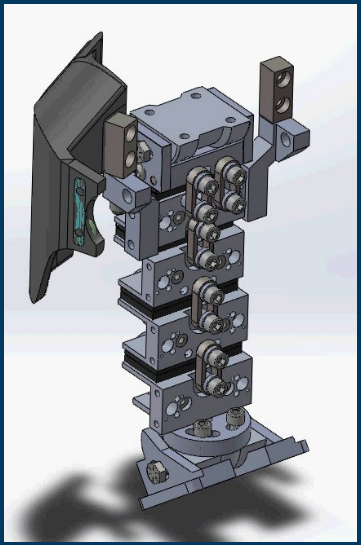
Positive chest deflection in 5 pt harness case resulting from harness spanning chest between shoulder and pelvis

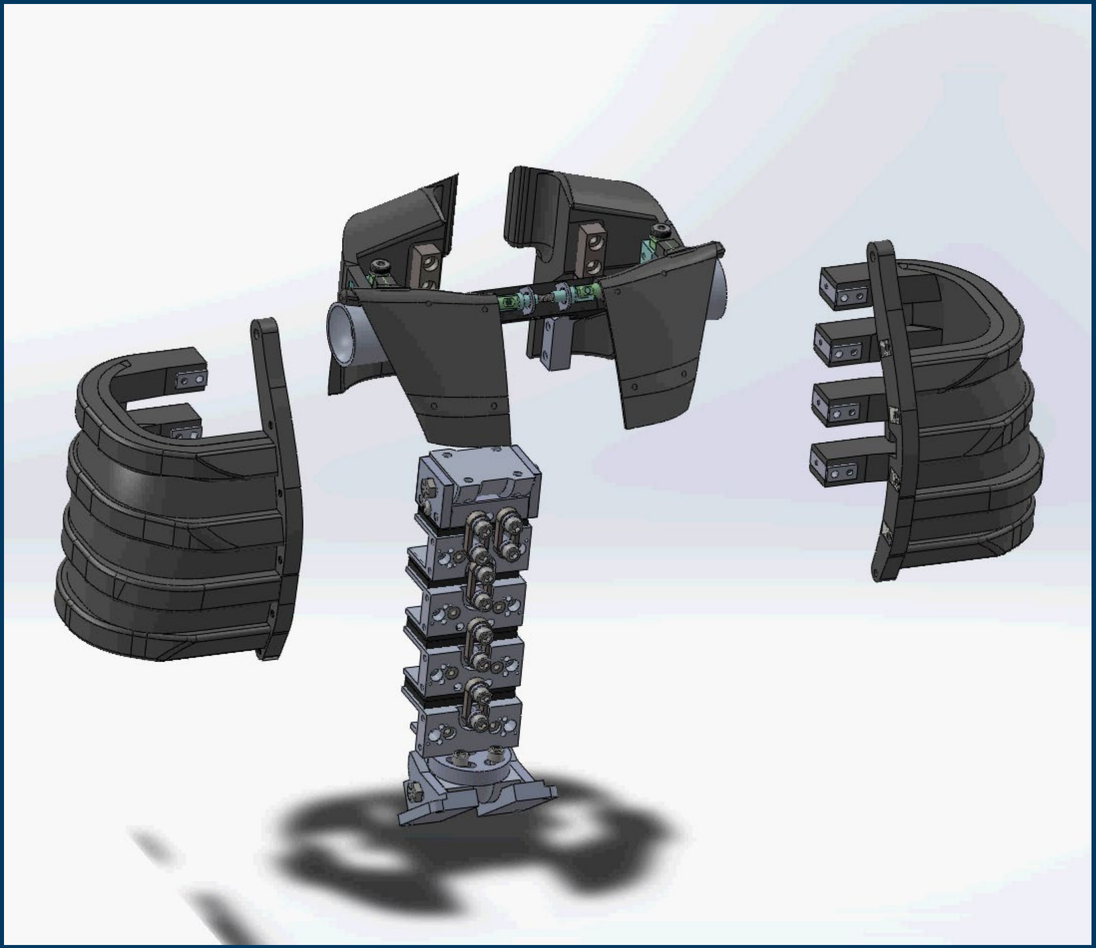
60 – 80 mm of chest deflection is high; reinforcement of shoulders necessary to reduce loading of chest

Rev3: Shoulder Modifications

Shoulder stiffener to reduce chest compressions; scapula can rotate in Z axis as well

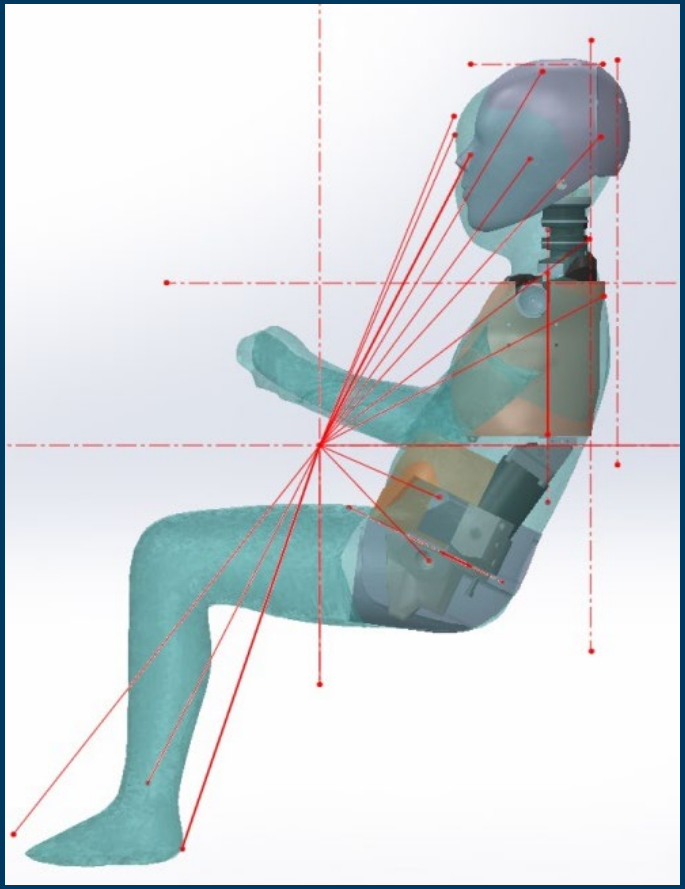




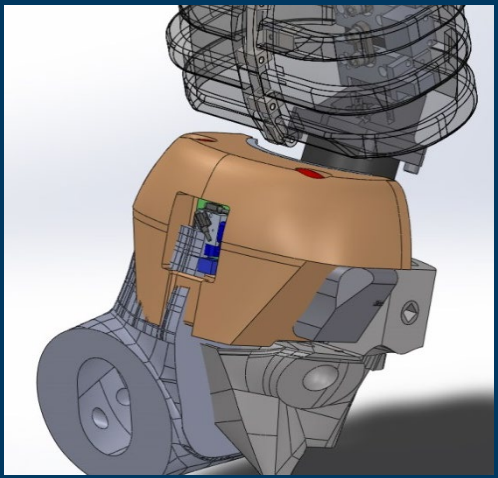


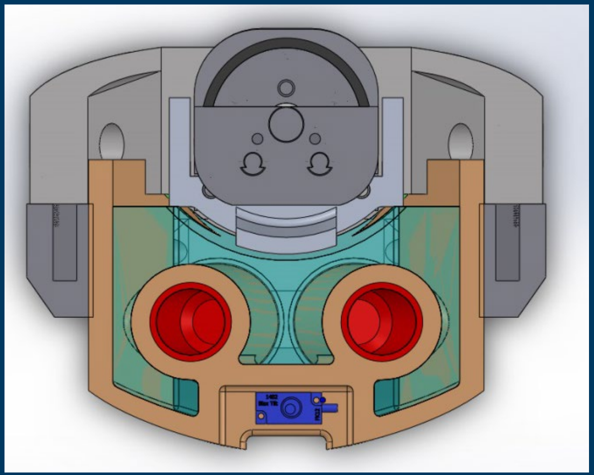
Rev3: Abdomen & Pelvis Modifications

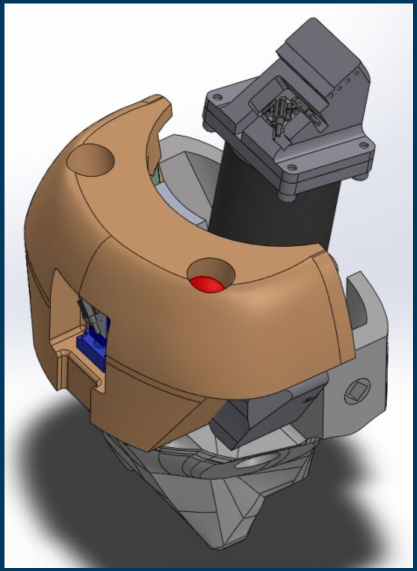
Added instrumentation & match UMTRI anthropometry

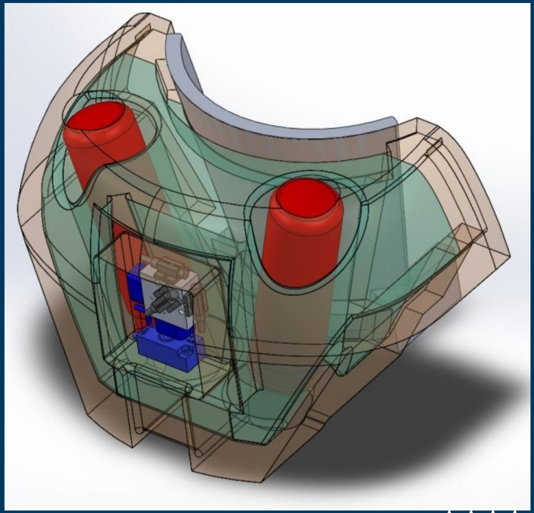


Anthropometry targets from www.childshape.org (UMTRI)





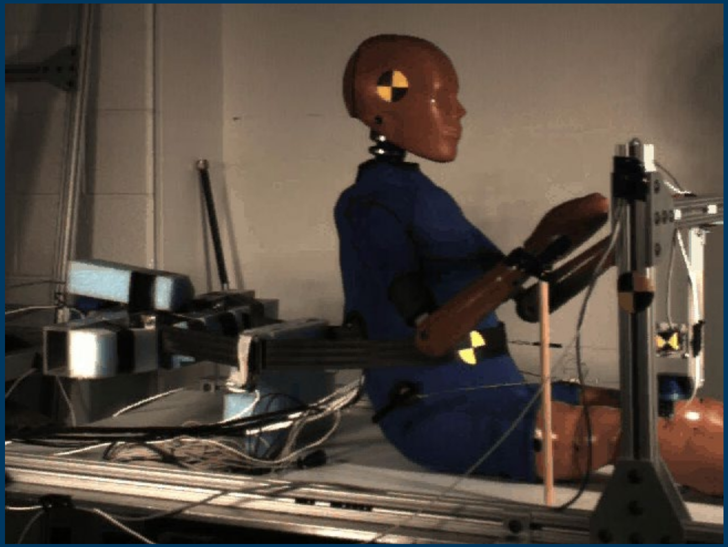


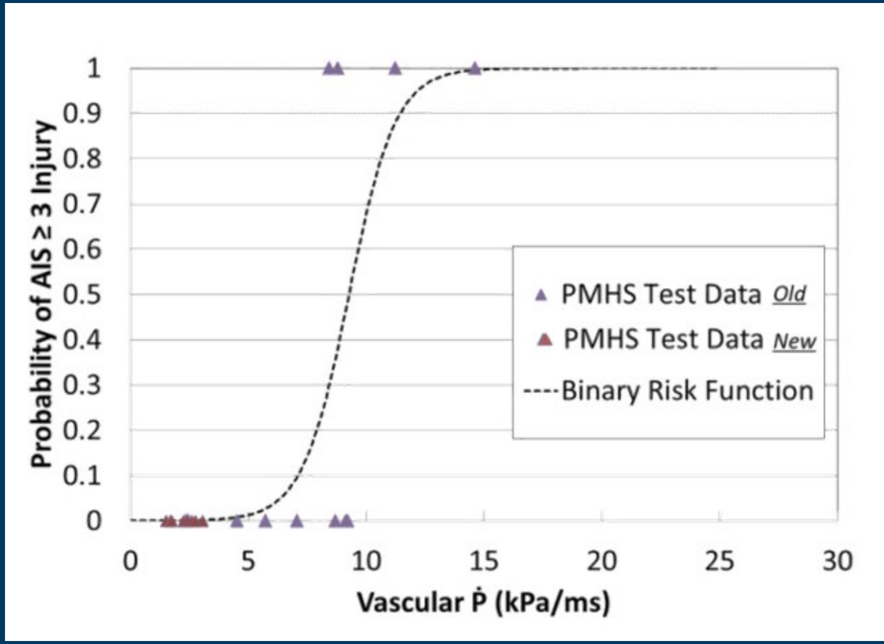


Rev3: Abdomen Injury Assessment

Paired testing

- **When F vs. d response biofidelity is sufficient, pressure and/or penetration based injury criteria can be derived for the LODC through paired testing with adult PMHS**





Injury risk functions from Kent et al (for penetration, Stapp 2008) and Kremer et al (for pressure rate, Stapp 2011)

Summary

- Component responses match recent pediatric biomechanical data
- Improved head kinematics & reduced neck loads in FMVSS 213 environment
- High chest compressions require modifications to shoulder-ribcage interface
- Instrumented abdomen, humanlike pelvis geometry, and injury criteria will allow abdomen injury monitoring