



Update on Rollover Crash Research: Dummy Biofidelity Analysis

Jason R. Kerrigan

University of Virginia Center for Applied Biomechanics

UVA Rollover Research 2009-Present

Long-Term Research Goals:

- Identify and investigate injuries, mechanisms, and sources
- Evaluate and improve dummy biofidelity
- Investigate potential for repeatability
- Determine what can be learned about vehicle crashworthiness by a dynamic test
- Develop a suite of computational models for modeling crashes, vehicles, and occupants.

UVA Rollover Research 2009-Present

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GOAL

Evaluate How Well
Existing ATDs Mimic
Humans in Rollover
Crash Tests

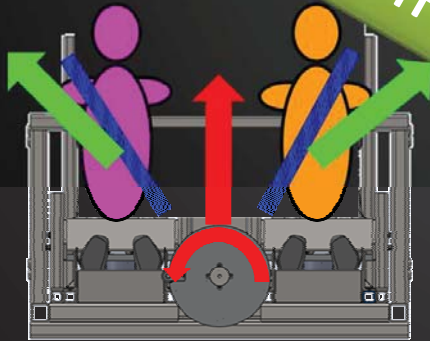
Rollover Dummy Biofidelity

Evaluate How Well Existing ATDs Mimic Humans in Rollover Crash Tests

PART 1: ATD vs. Cadaver

Step 1: Kinematics Response

- Evaluate rollover-like kinematics
- Example: Seat belt response



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Step 2: Impact/Deformation/Injury

- Rollover Impact Test
- PMHS (and Cause)



January 22, 2014

5

Kinematics: Six AM50 Dummies Evaluated

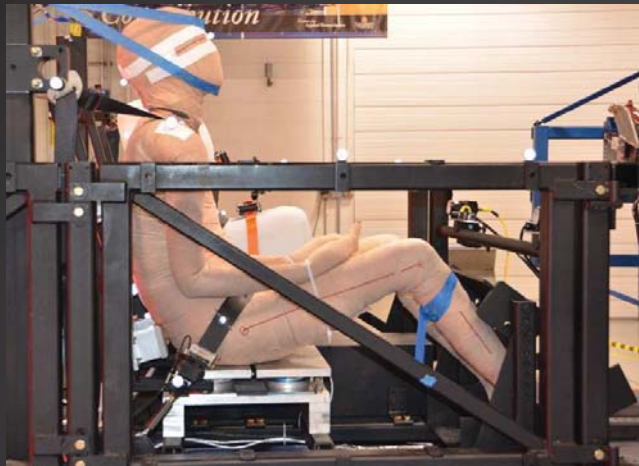


Kinematics: Six AM50 Dummies Evaluated



Four ~50th Male PMHS Tested

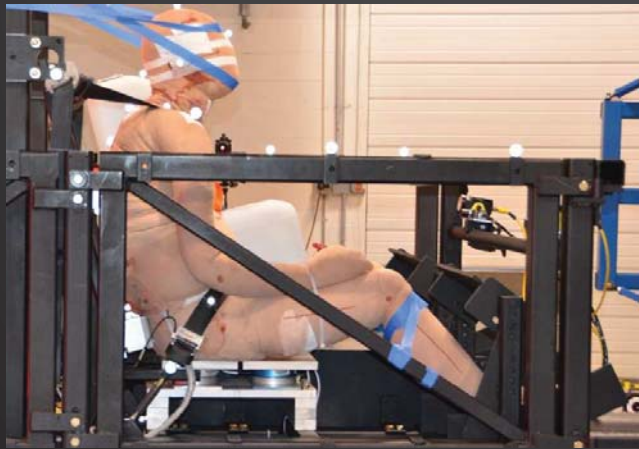
CAD 1-580M
51 Years
69.0 kg
191 cm



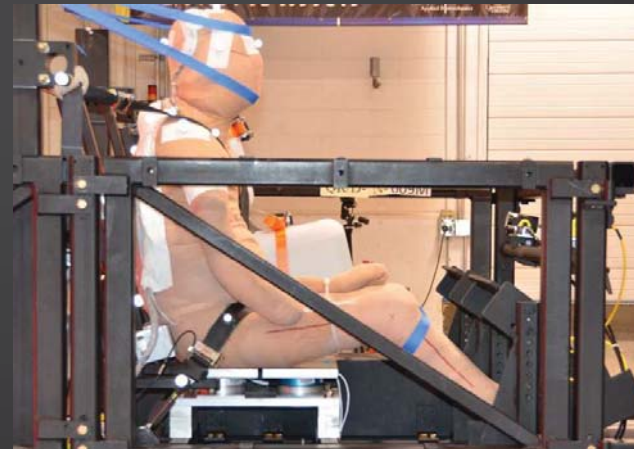
CAD 3-571M
58 Years
83.4 kg
175 cm



CAD 2-570M
59 Years
83.1 kg
175 cm

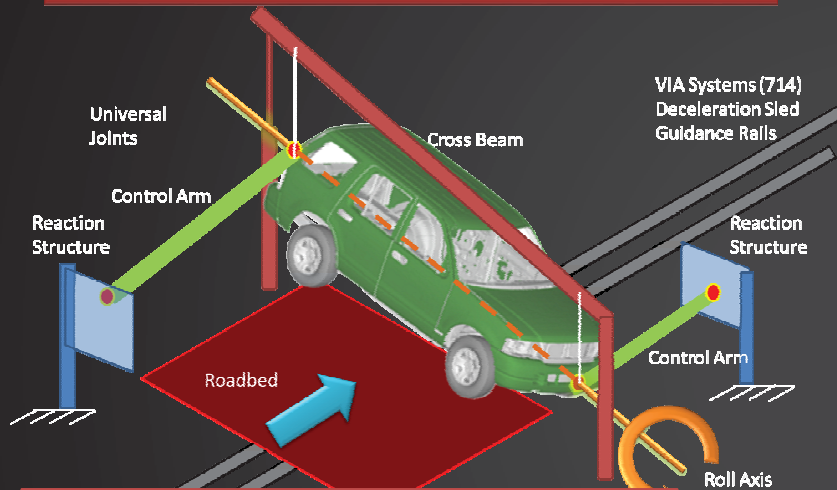


CAD 4-609M
58 Years
86.2 kg
180 cm



Test Fixture/Procedure

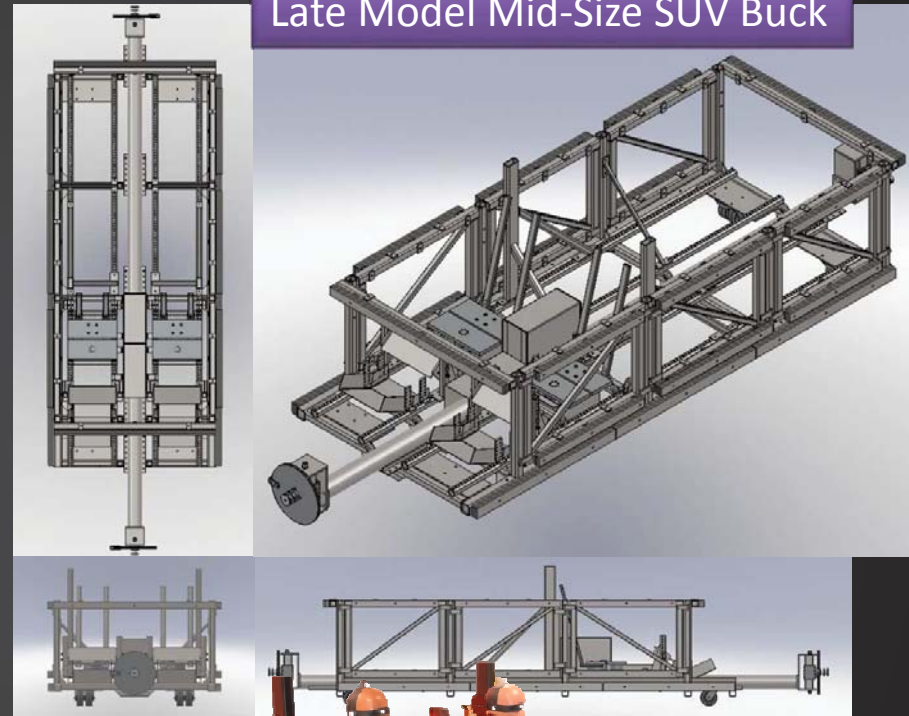
Dynamic Rollover Test System (DRoTS)



Kerrigan JR, et al. SAE 2011-01-1116.

Kerrigan JR, et al. SAE 2013-01-0468.

Late Model Mid-Size SUV Buck

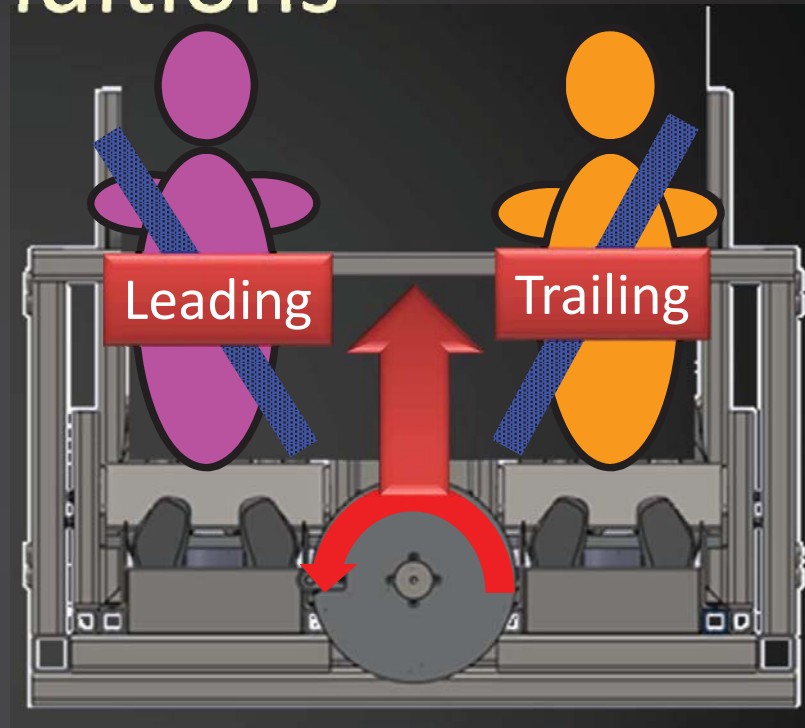


Foltz P, et al. (2011) ESV 11-0271.

Toczyski J, et al. (2013) ESV 13-0203

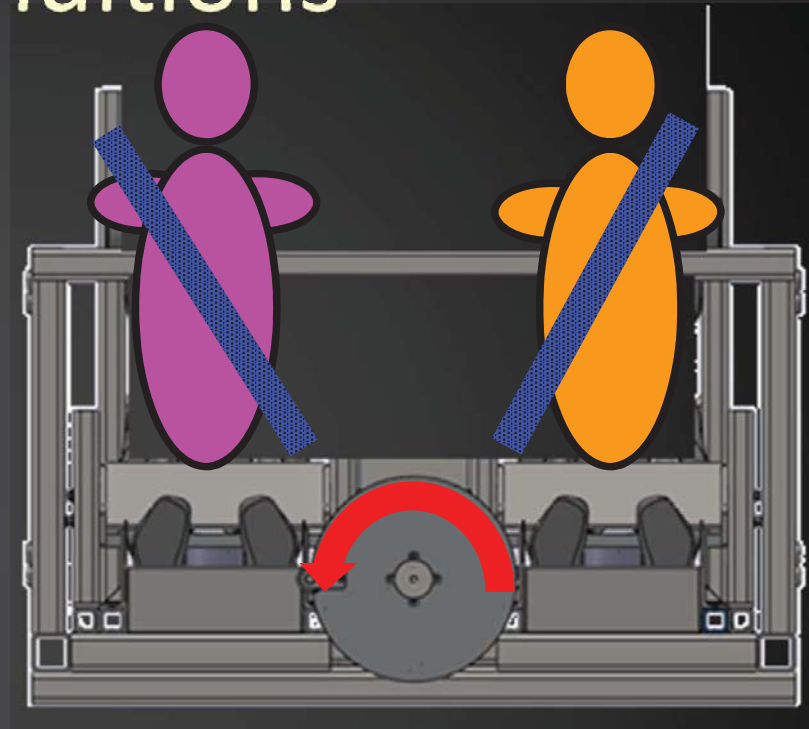
Test Conditions

- 2 Belt Tensions
 - Nominal
 - Pre-Tensioned
- 2 Seating Positions
 - Leading
 - Trailing
- 8 Test Conditions
 - Quasi-static Roll
 - Inverted Drop
 - Dynamic Roll (2 Conditions)
 - 180 deg/s
 - 360 deg/s
 - Roll + Drop (4 Conditions)
 - 180 AND 360 deg/s
 - Leading Side AND Trailing Side Drop



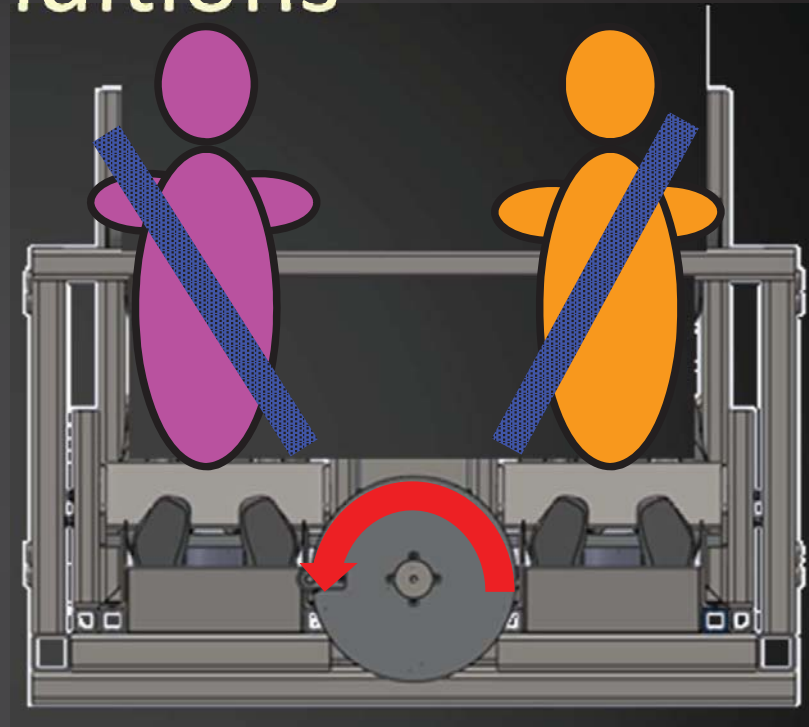
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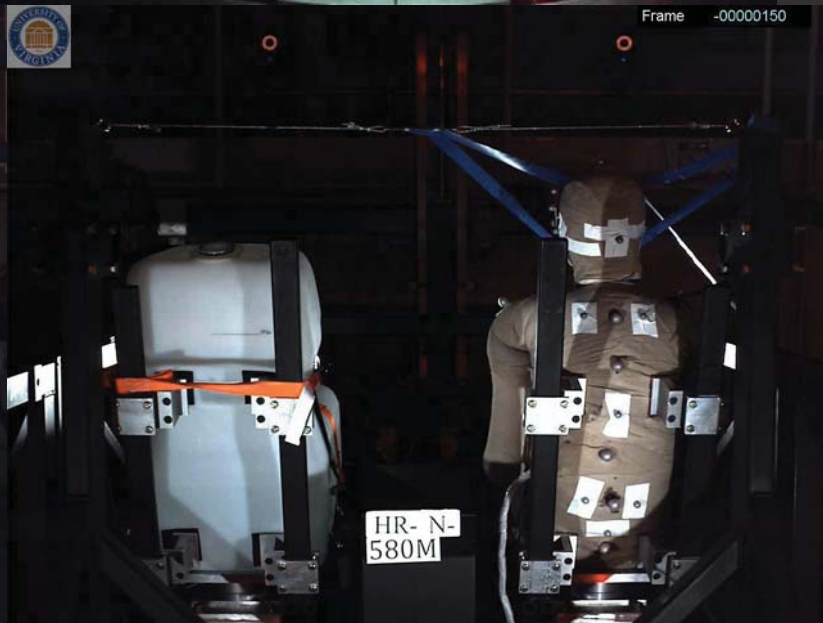
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No Vehicle/Road Impact
Kinematics Only

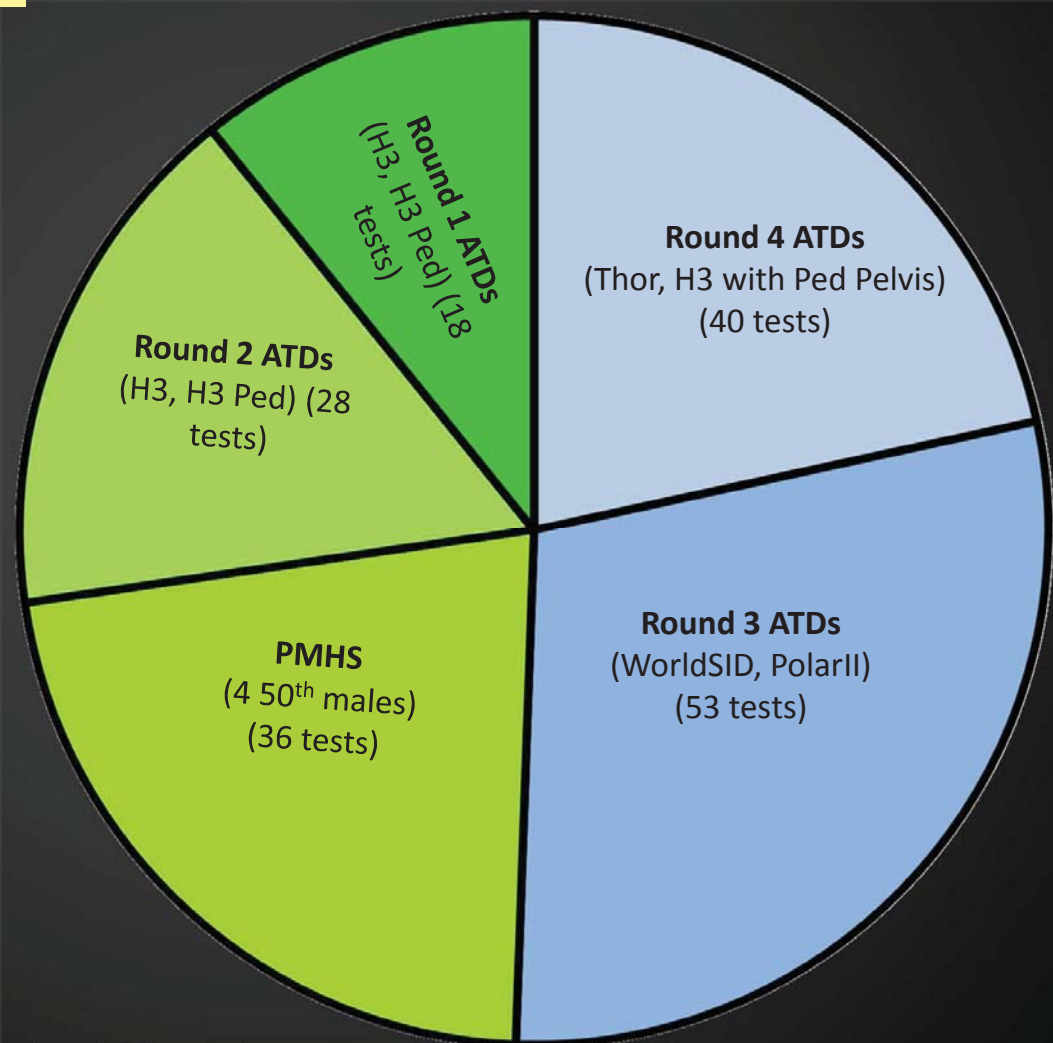
PMHS Test (Nominal Belt, Leading Side, 360 deg/s roll)



Rollover Kinematics Tests

175 Total Tests

- 6 Dummies
- 4 Cadavers

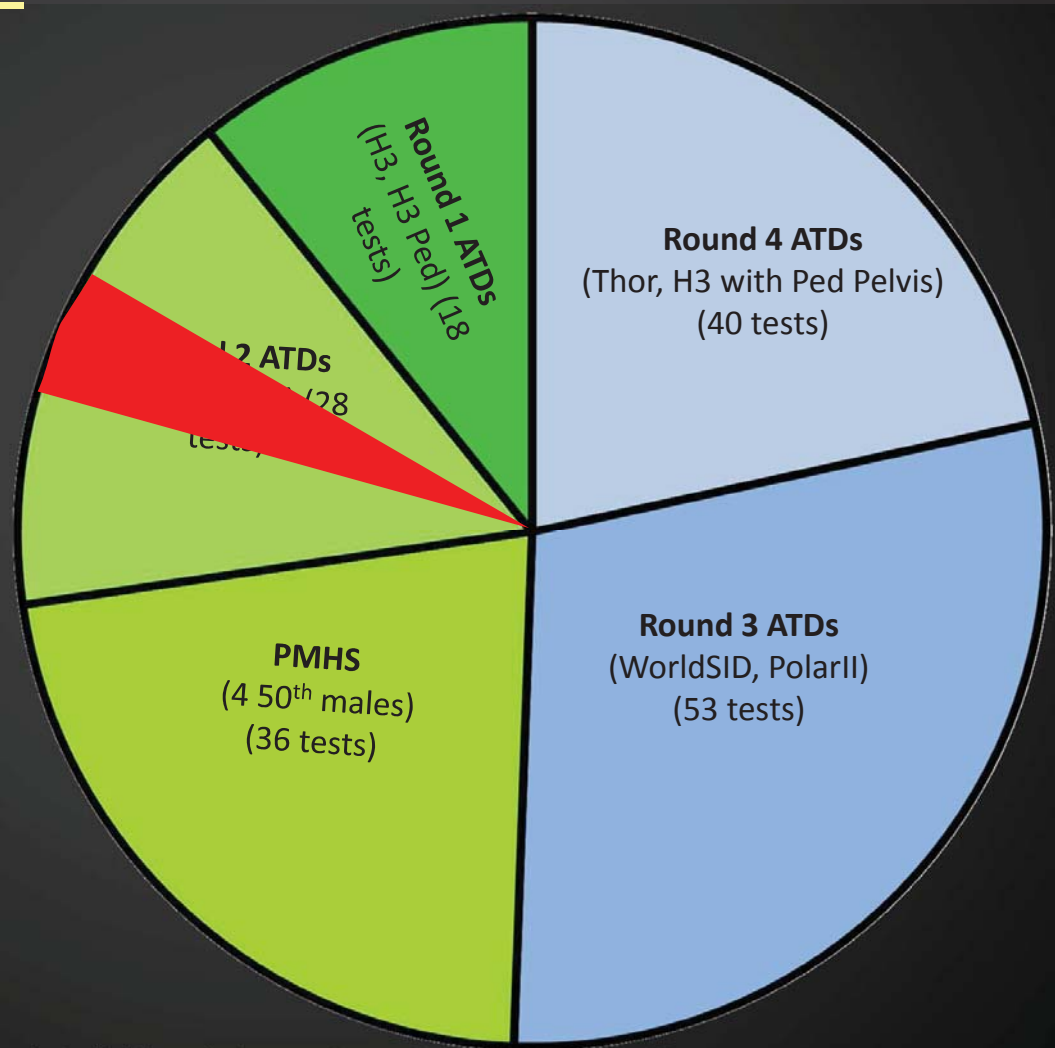


Rollover Kinematics Tests

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IRCOBI
(Zhang et al. 2013)



Vertical Excursion: Pelvis Effect

Hybrid III Pedestrian

Hybrid III

Vertical Excursion:
Hybrid III > Hybrid III Ped.

Hybrid III
Pedestrian Pelvis



Hybrid III Pelvis

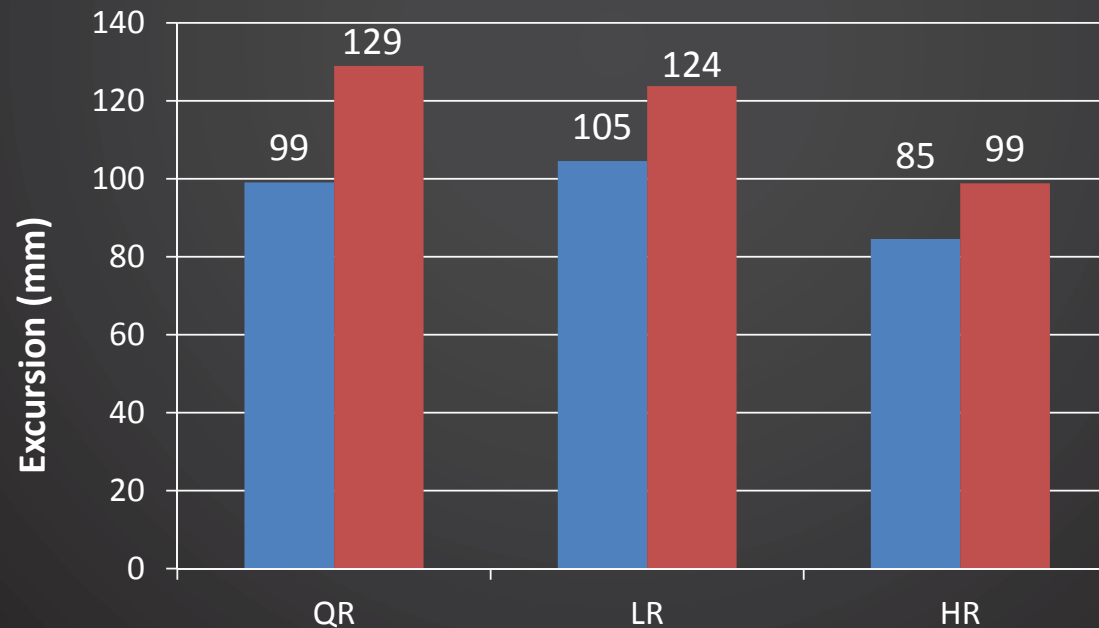


Lateral Excursion

- Hybrid III Pedestrian > Hybrid III

■ Hybrid III ■ Hybrid III Pedestrian

Head lateral excursion- Leading side

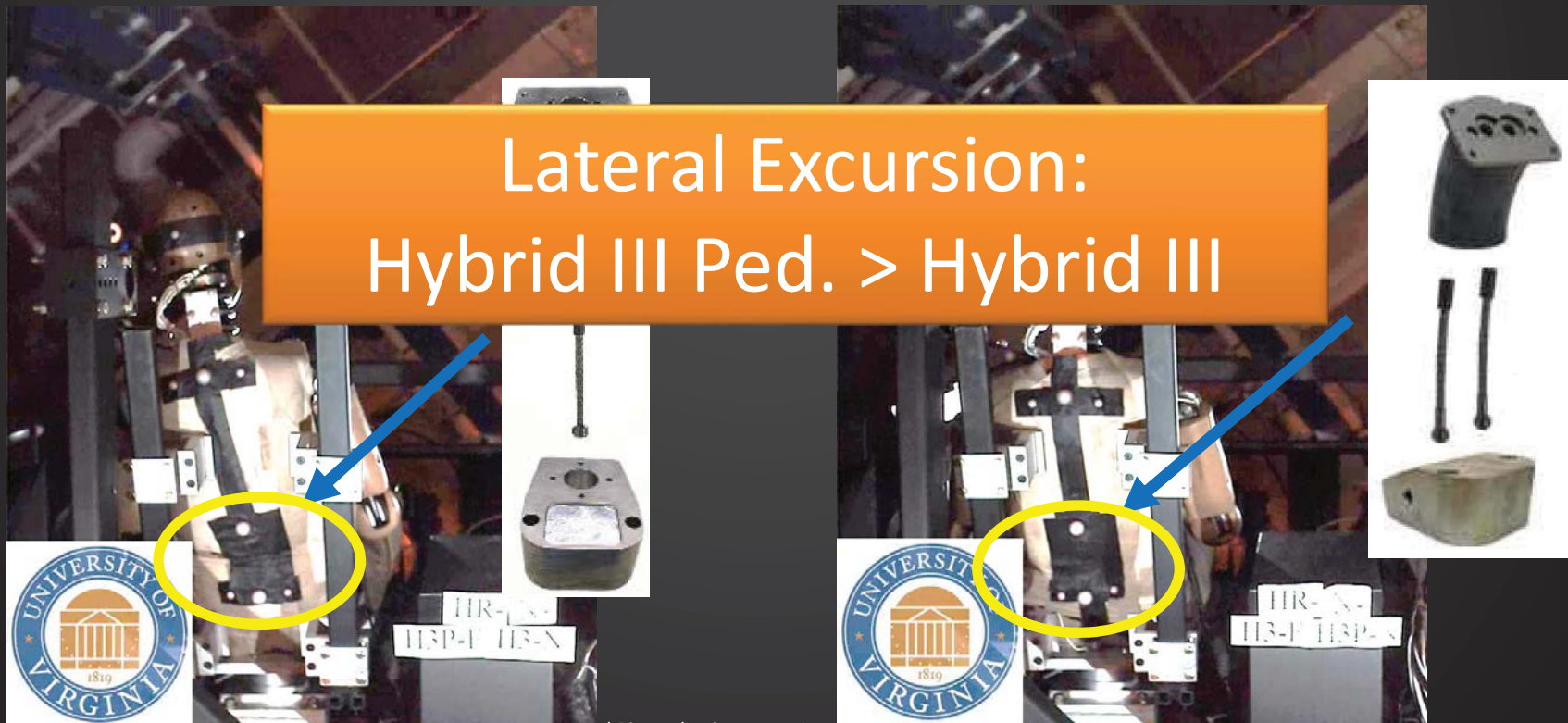


Lateral Excursion: Lumbar Effect

- @Roll angle 40 degree in trailing side in HR Tests

Hybrid III Pedestrian

Hybrid III



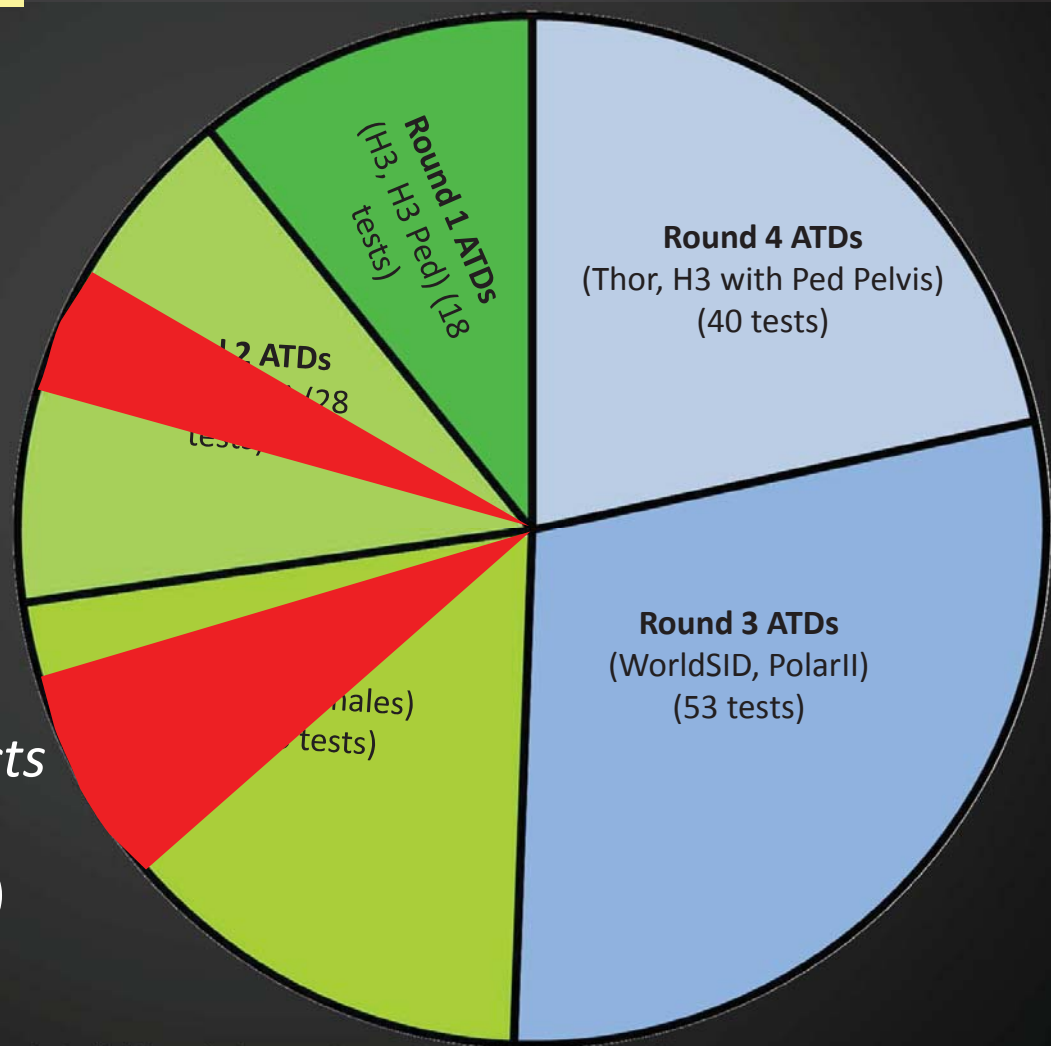
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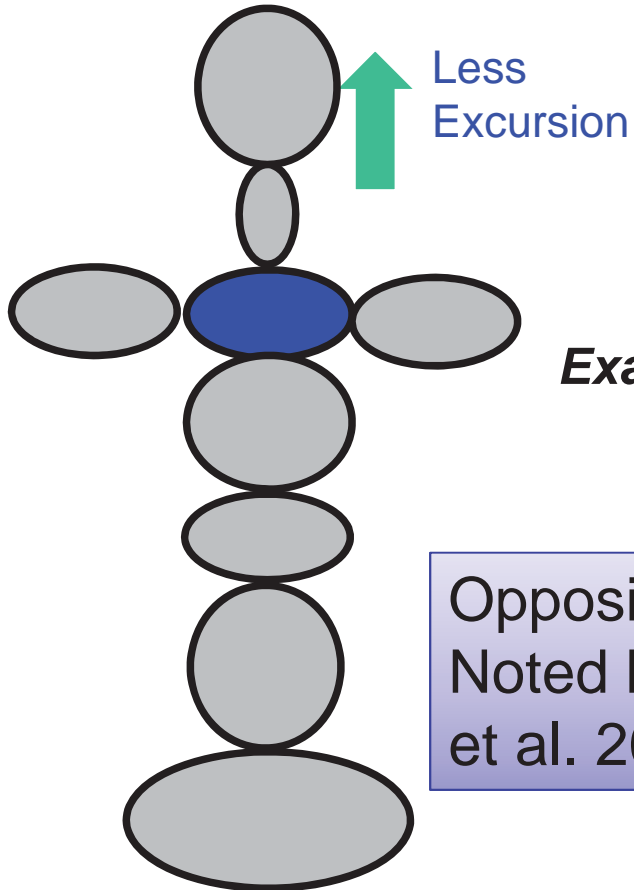
IRCOBI
(Zhang et al. 2013)

NHTSA Human Subjects
Workshop
(Lessley et al. 2013)

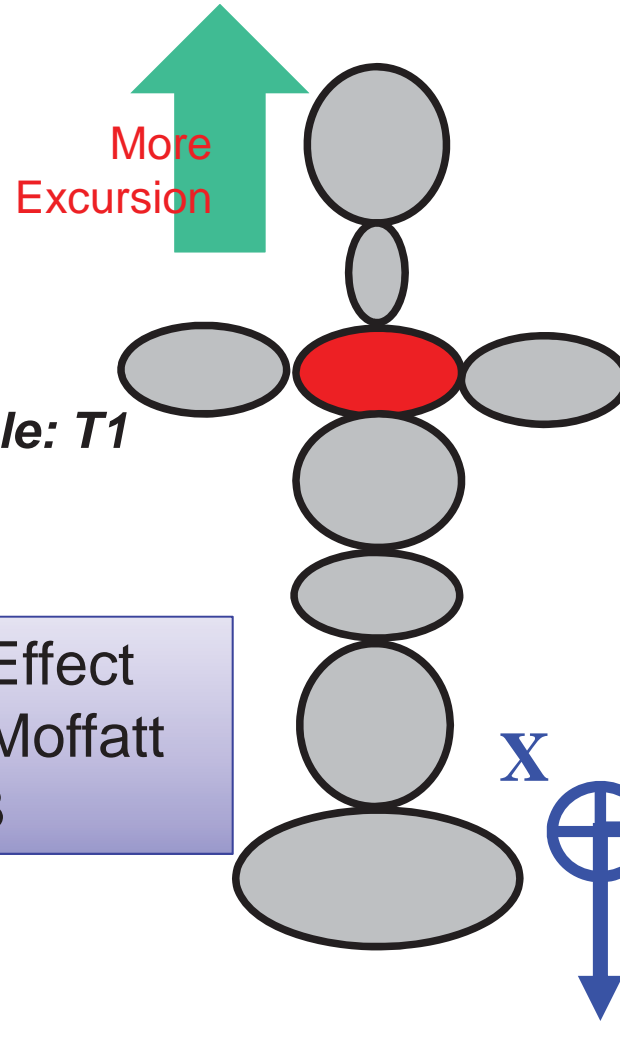


Displacement Comparison

Trailing-Side Position



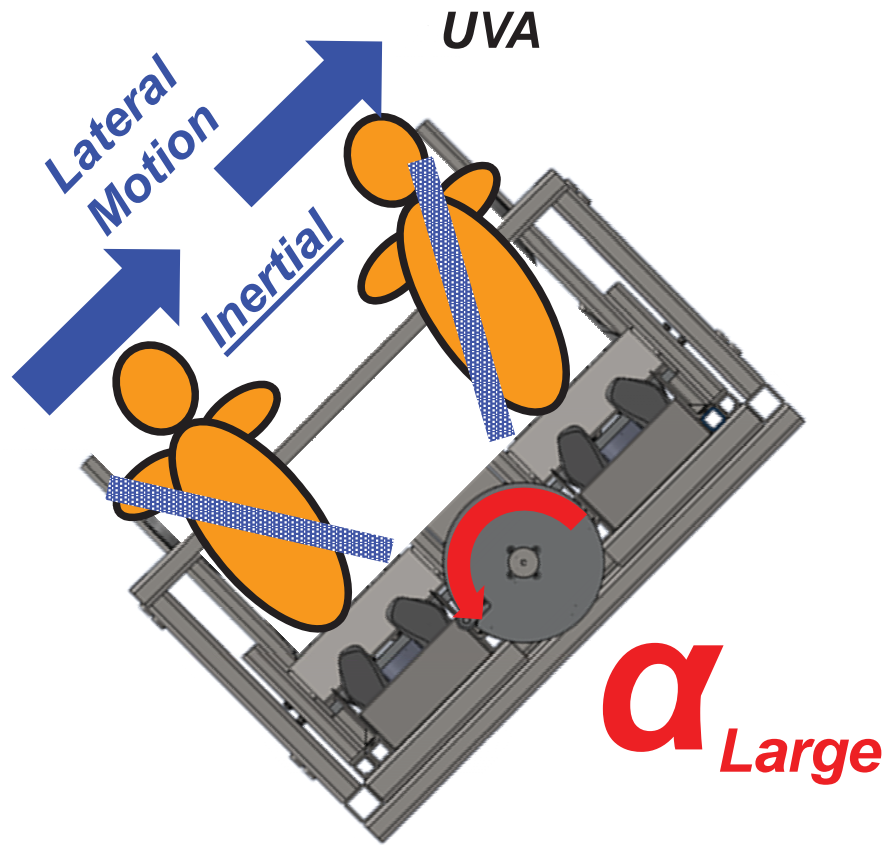
Leading Side



Example: T1

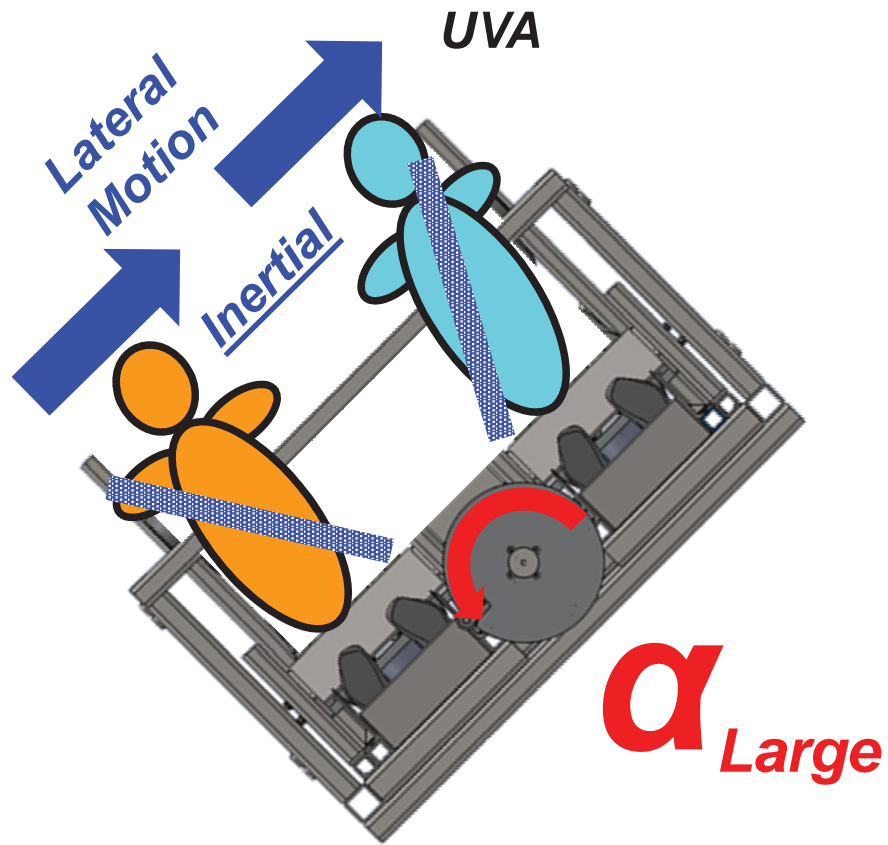
Opposite Effect
Noted by Moffatt
et al. 2003

Effect of Rotational Acceleration



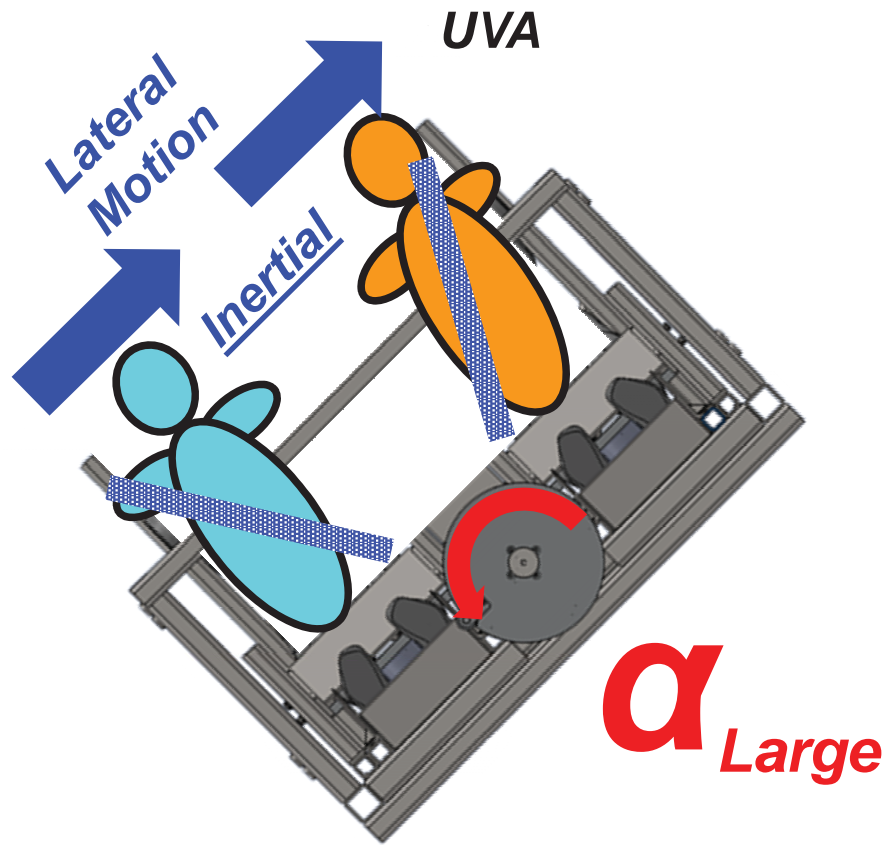
**Rotational acceleration
dominates**

Effect of Rotational Acceleration



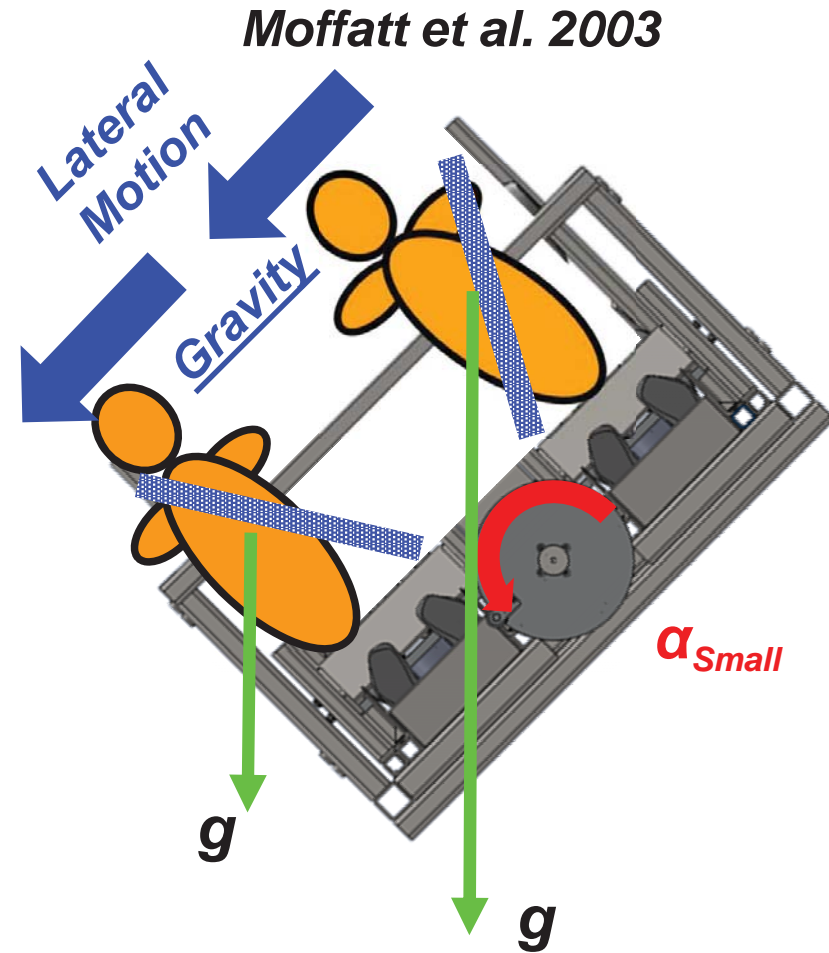
Trailing side: Toward belt, toward door

Effect of Rotational Acceleration



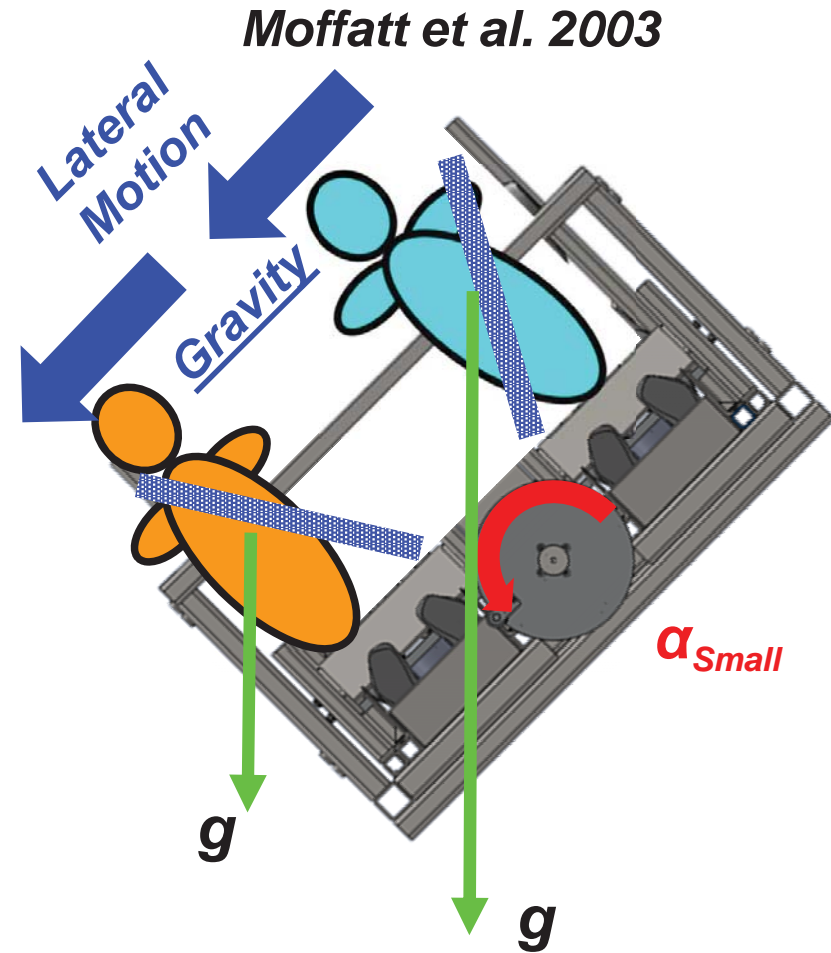
Leading side: Away from belt,
away from door

Effect of Rotational Acceleration



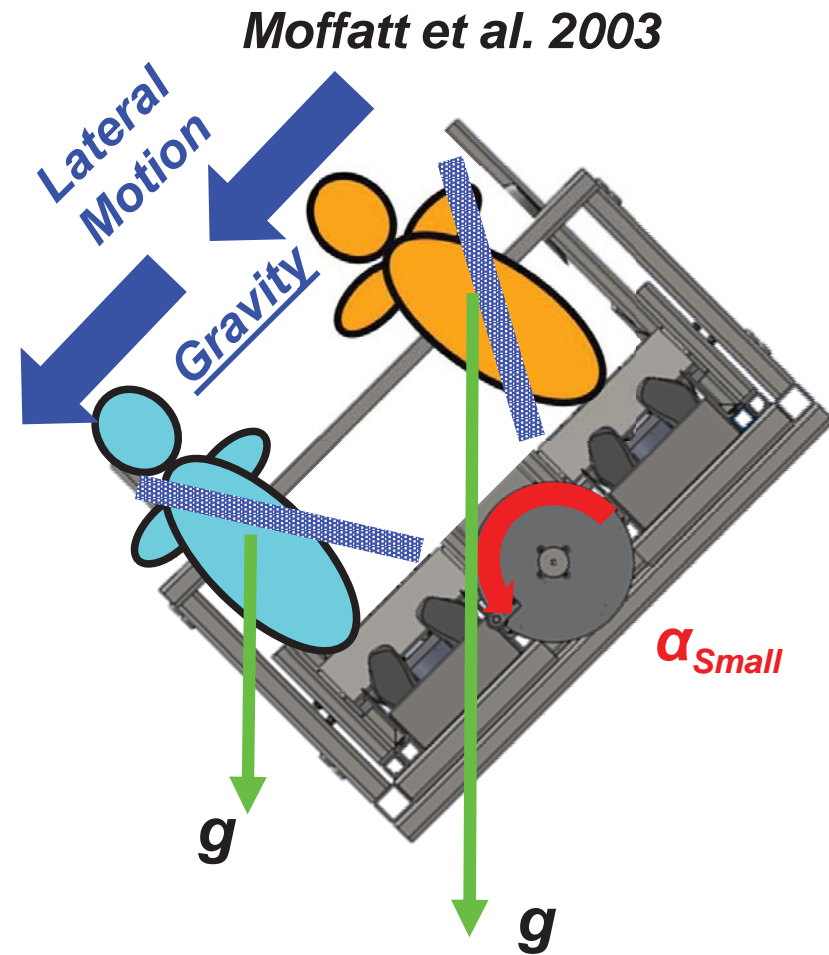
Acceleration of gravity dominates

Effect of Rotational Acceleration



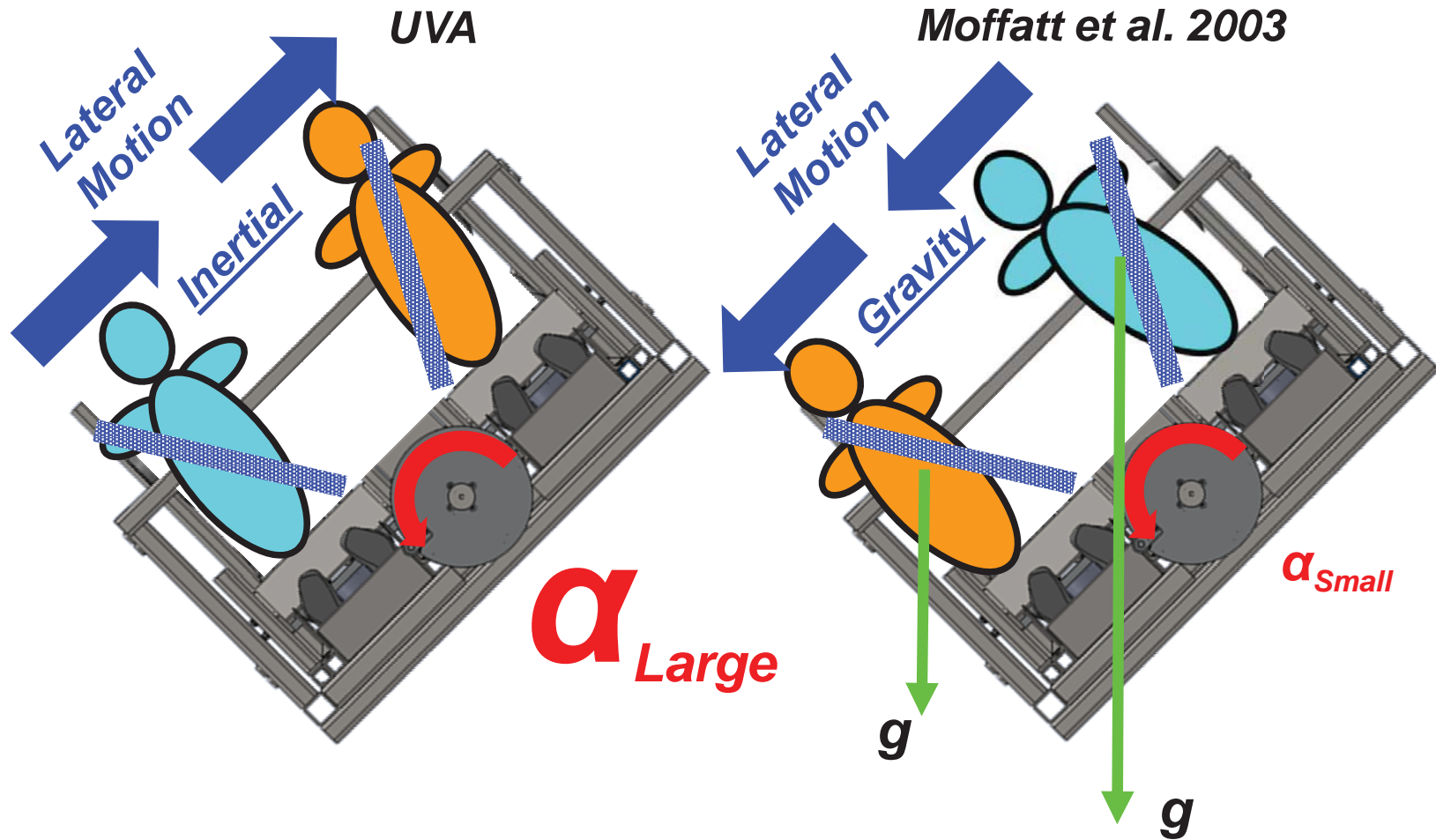
Trailing side: Away from belt, away from door

Effect of Rotational Acceleration



Leading side: Toward belt, toward door

Effect of Rotational Acceleration



**Leading side: Away from belt,
away from door**

**Trailing side: Away from belt,
away from door**

Rollover Kinematics Tests

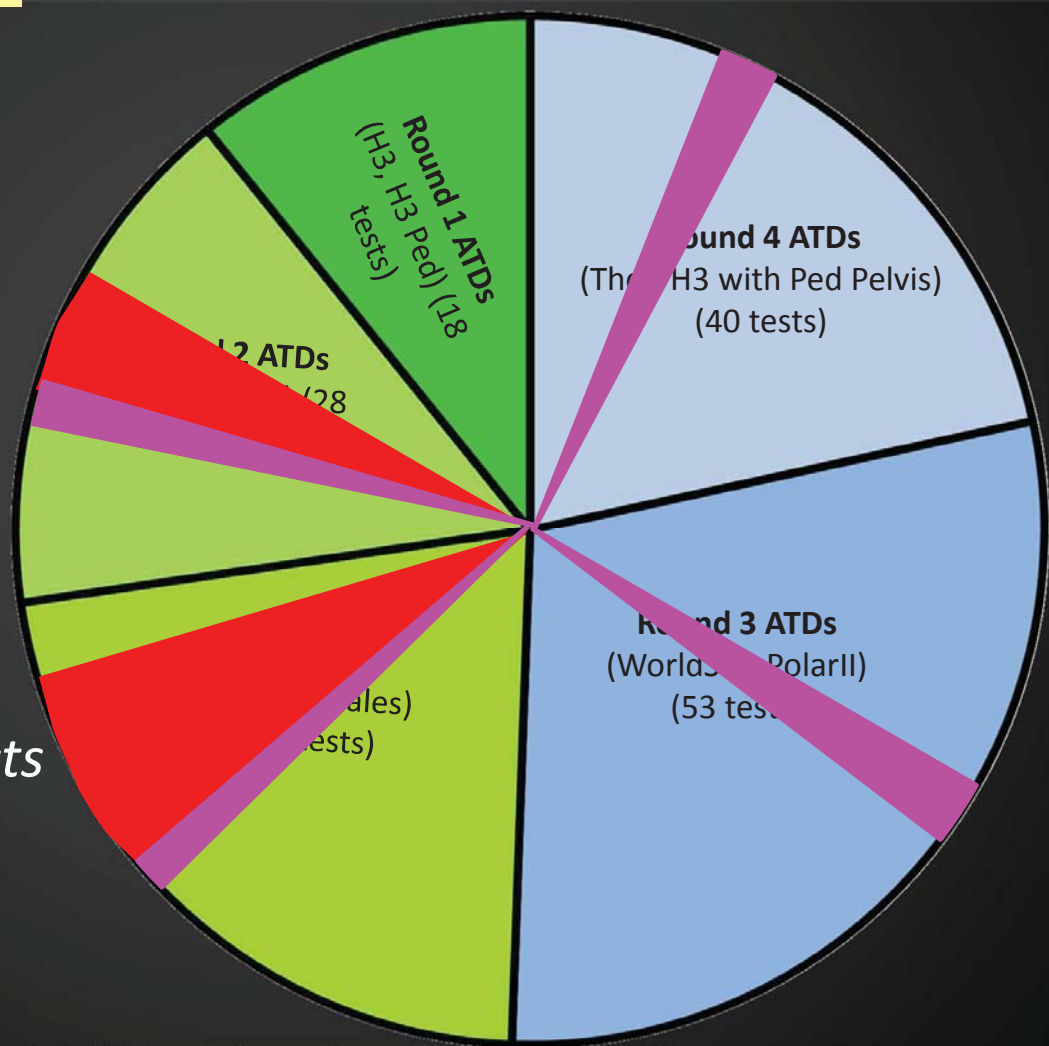
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IRCOBI
(Zhang et al. 2013)

**SAE Government/
Industry**
(Kerrigan 2014)

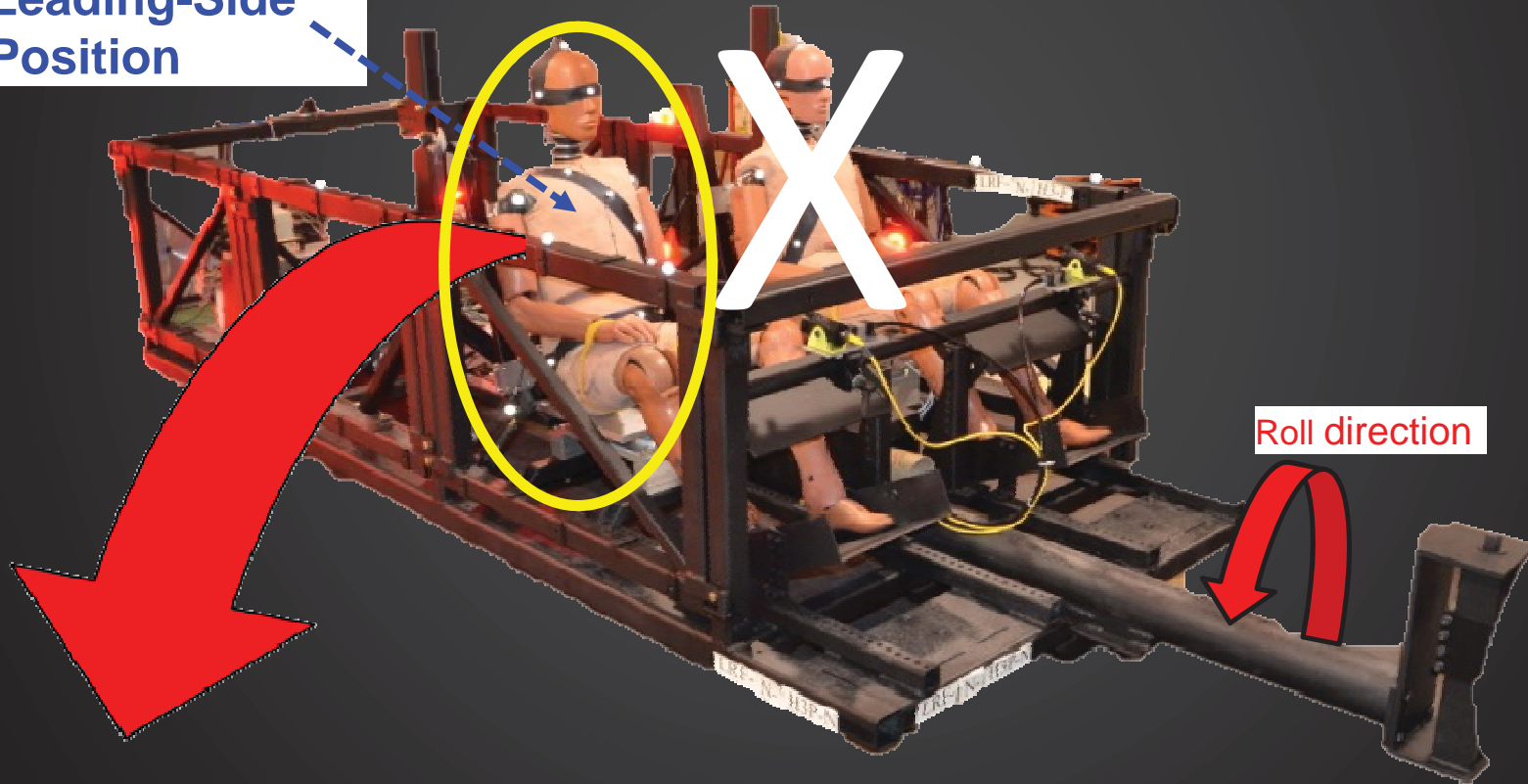
NHTSA Human Subjects
Workshop
(Lessley et al. 2013)



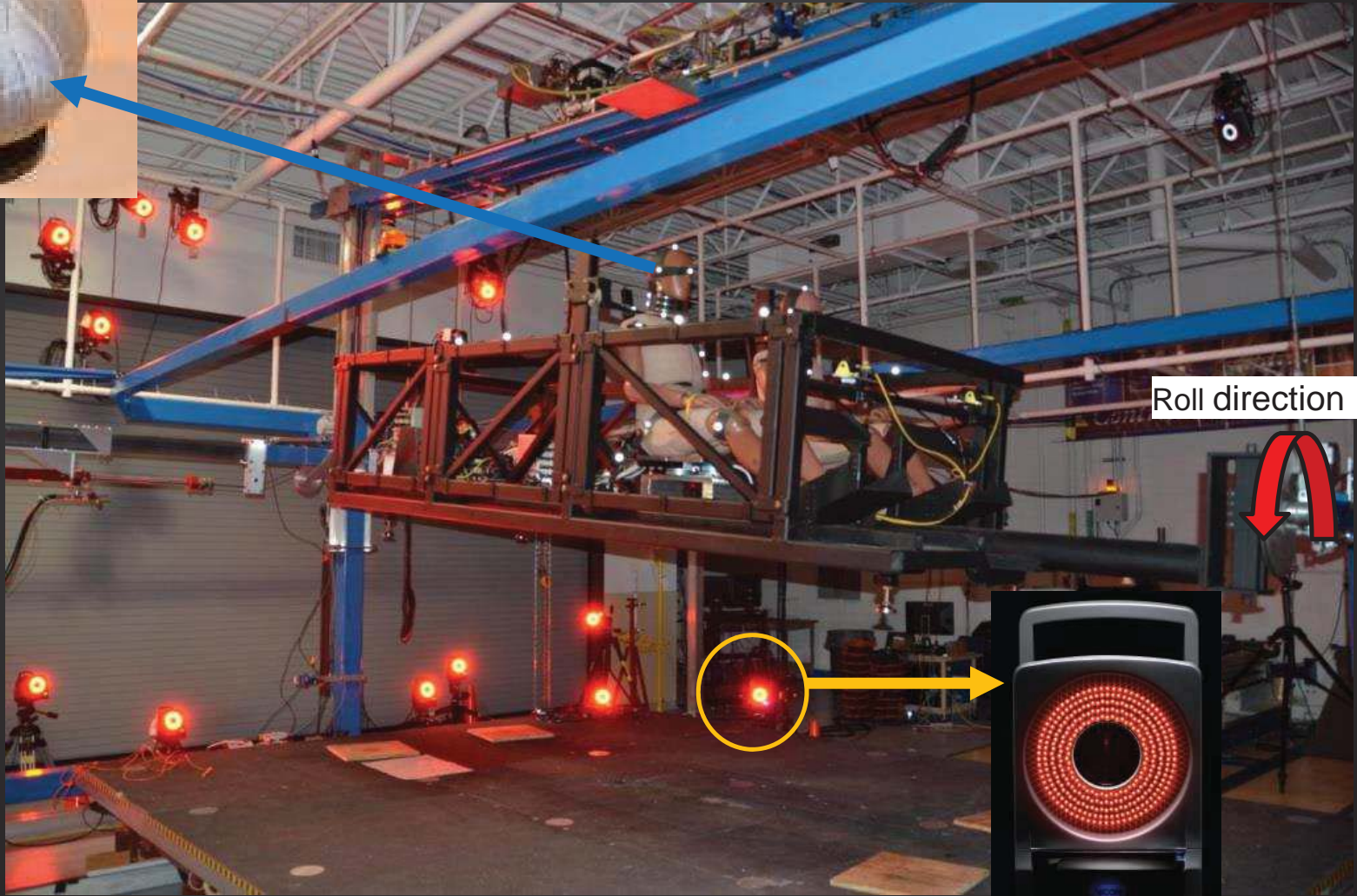
Example: ATD vs PMHS Displacements

ONE CASE: Leading-Side Seating Position, Nominal Belt Tension, 360 deg/sec roll rate

Leading-Side
Position



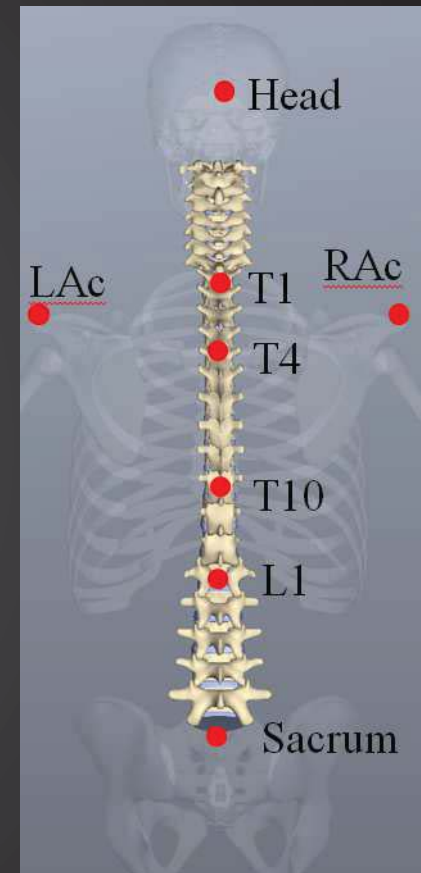
3D Motion Capture



Roll direction

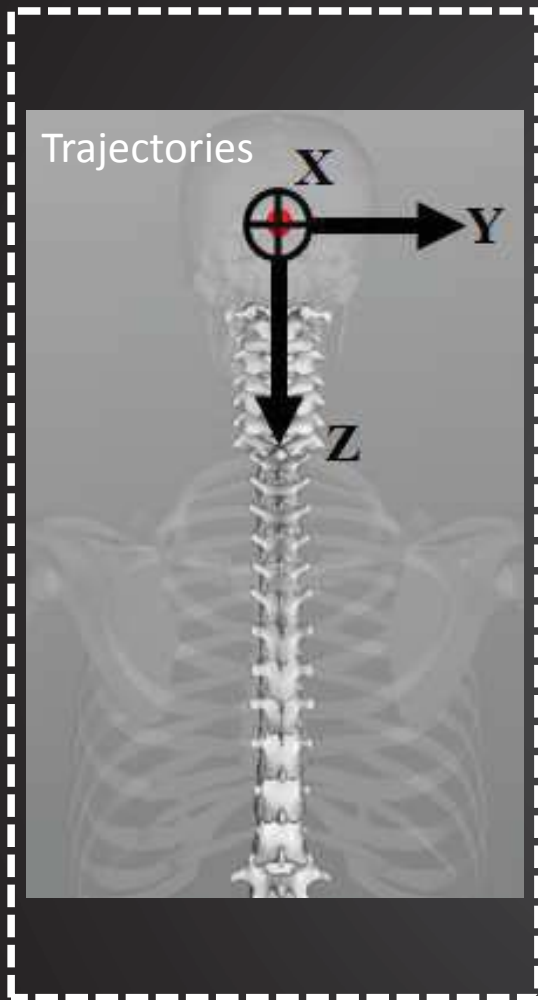
Rollover Tests with PMHS

Kinematic Measurement Locations

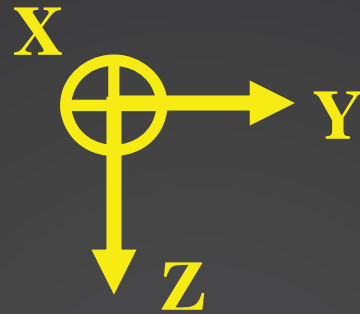


Kinematic
Measurement
Locations

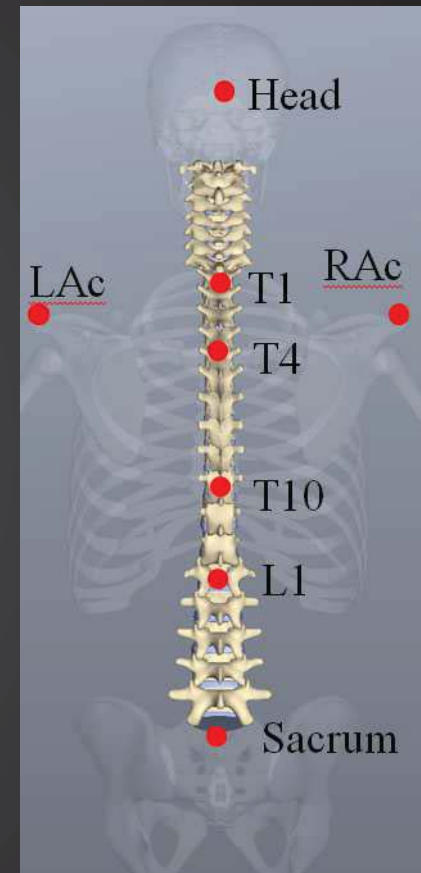
Kinematic Analysis



**3D Displacements
Relative to Vehicle**

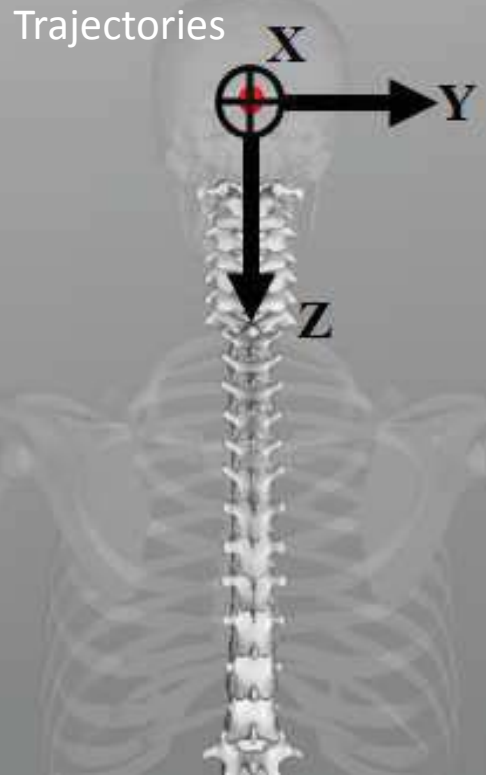


**Vehicle-based SAE
coordinate system**

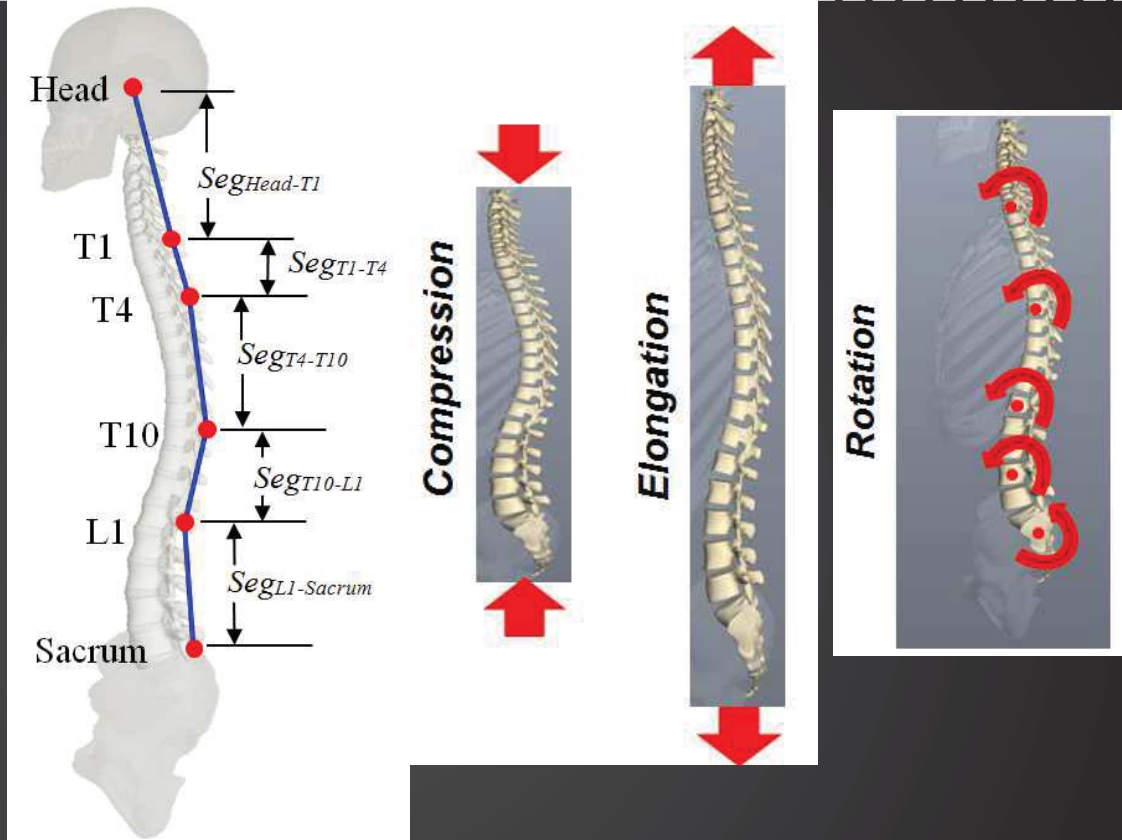


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Kinematic Analysis

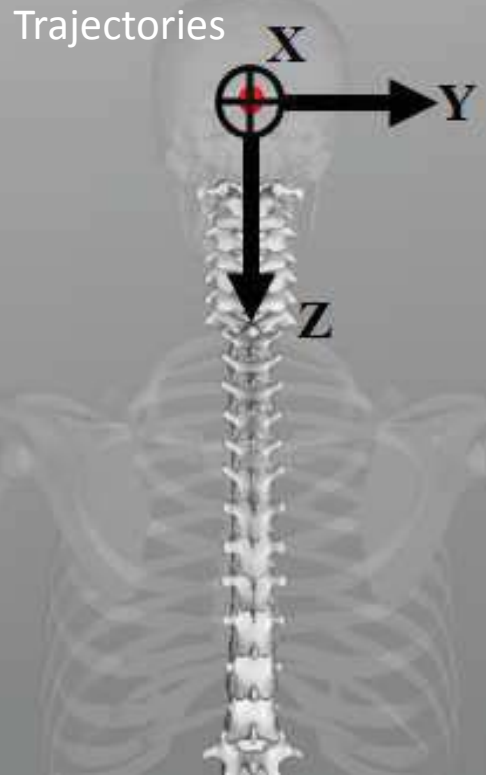


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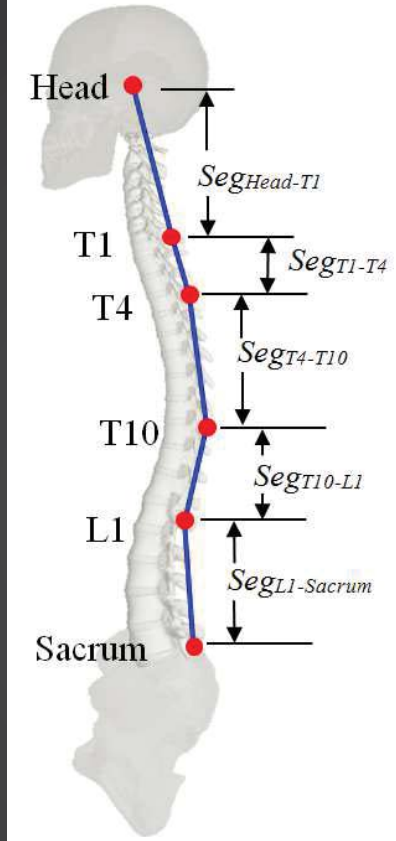


**Compression, Elongation, and Rotation of Spine
Segments**

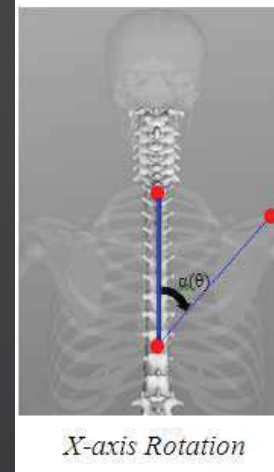
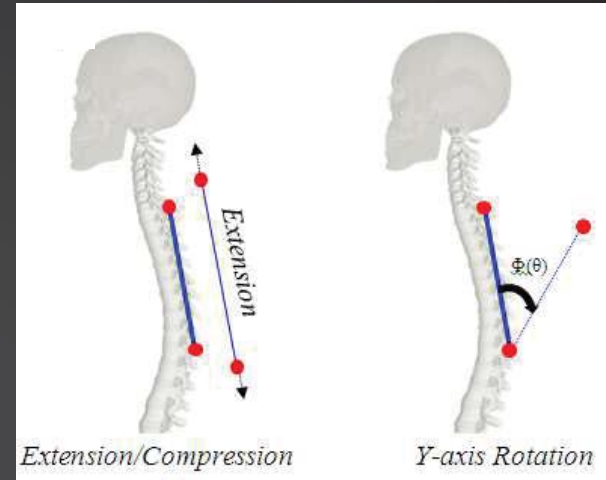
Kinematic Analysis: Spine Segments



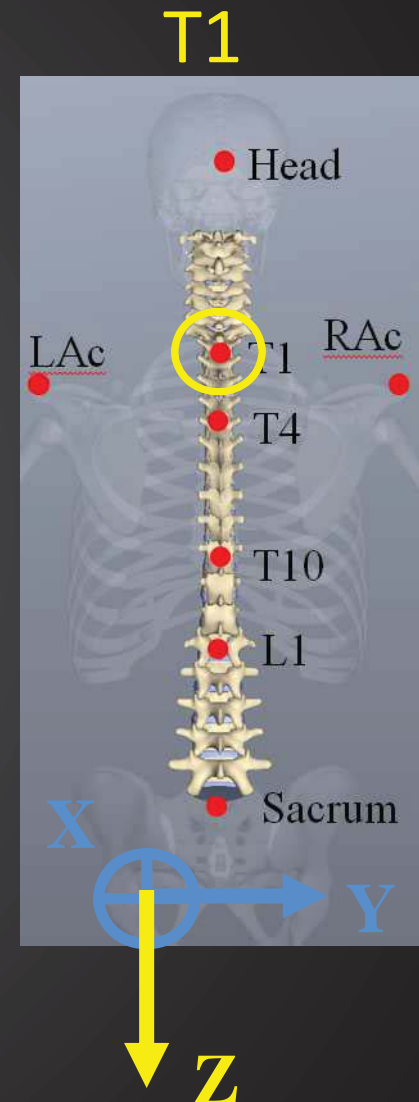
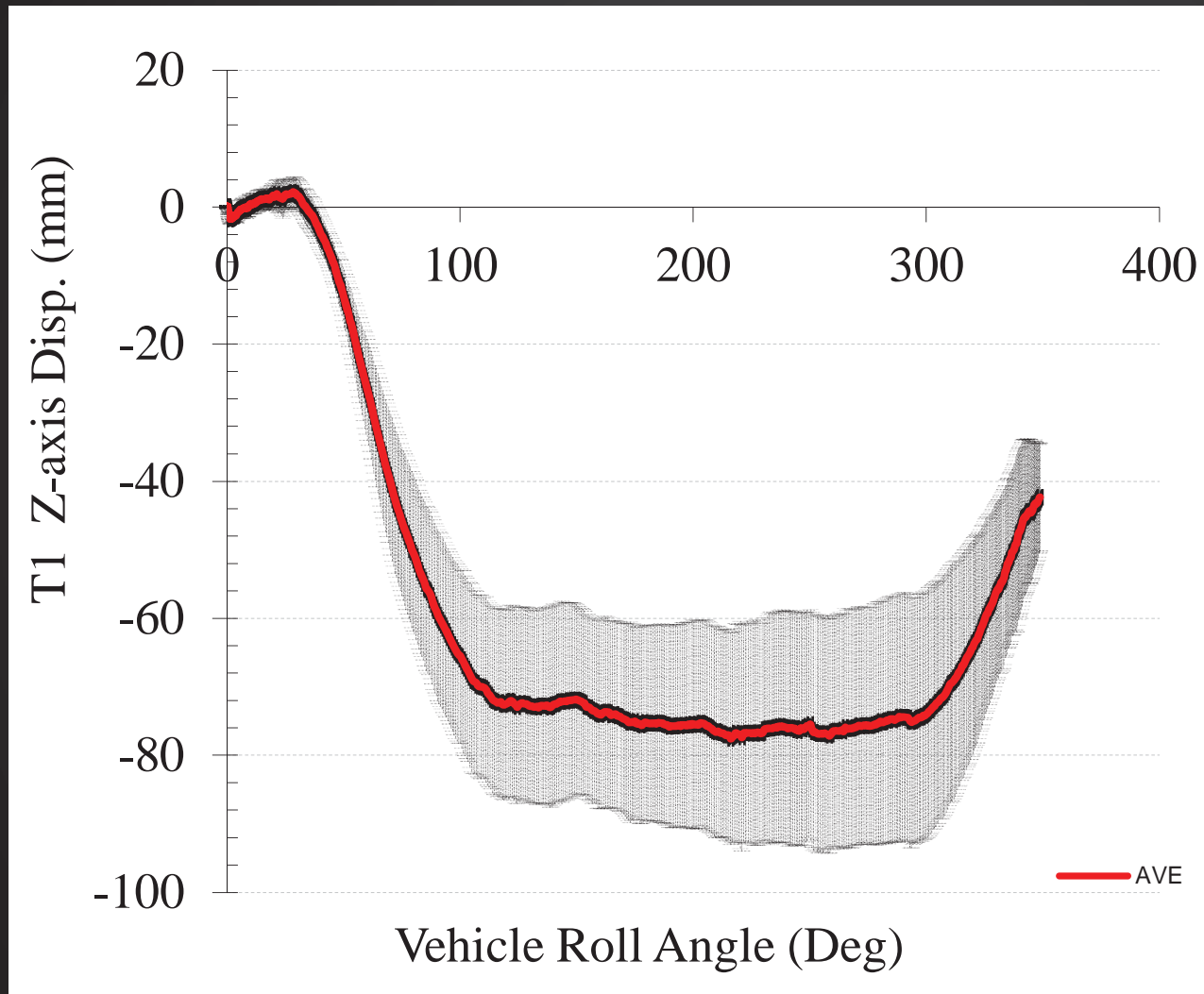
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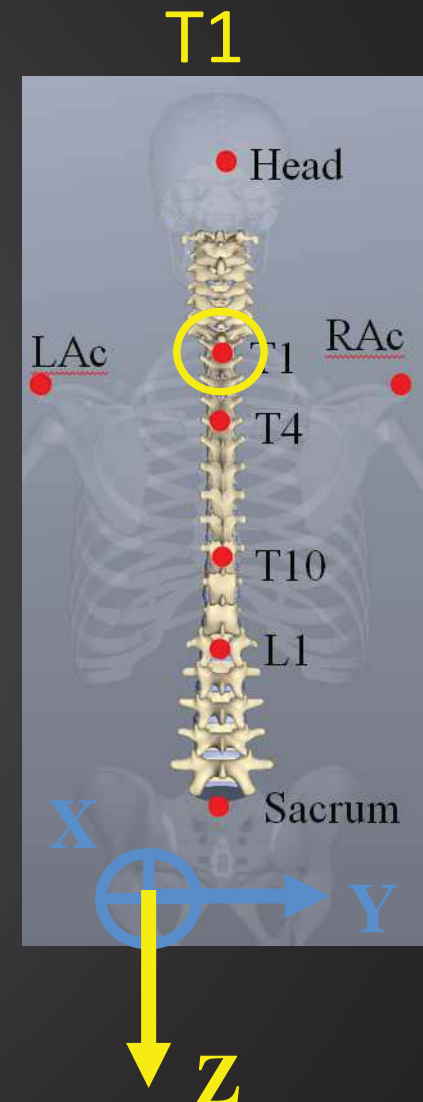
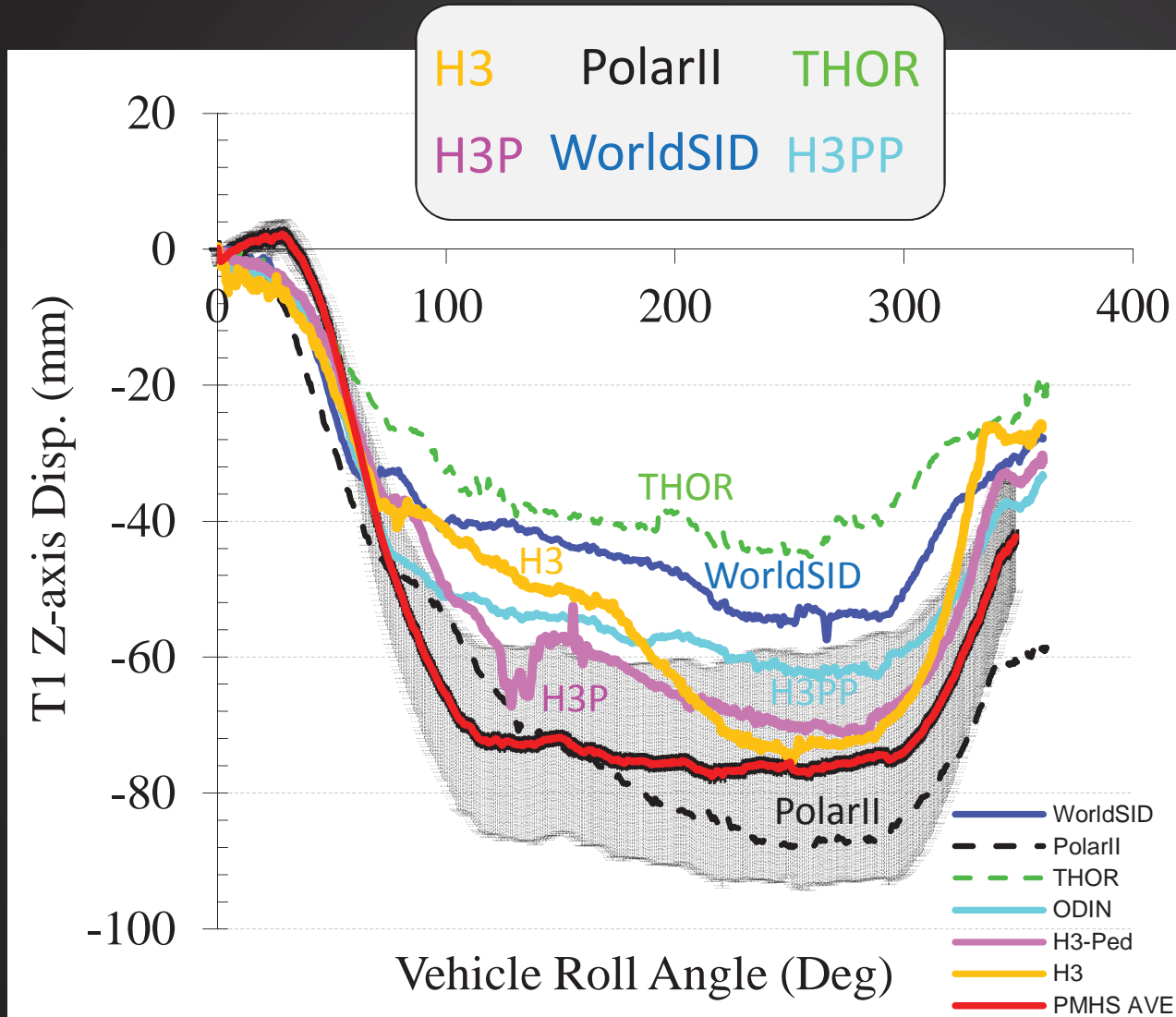
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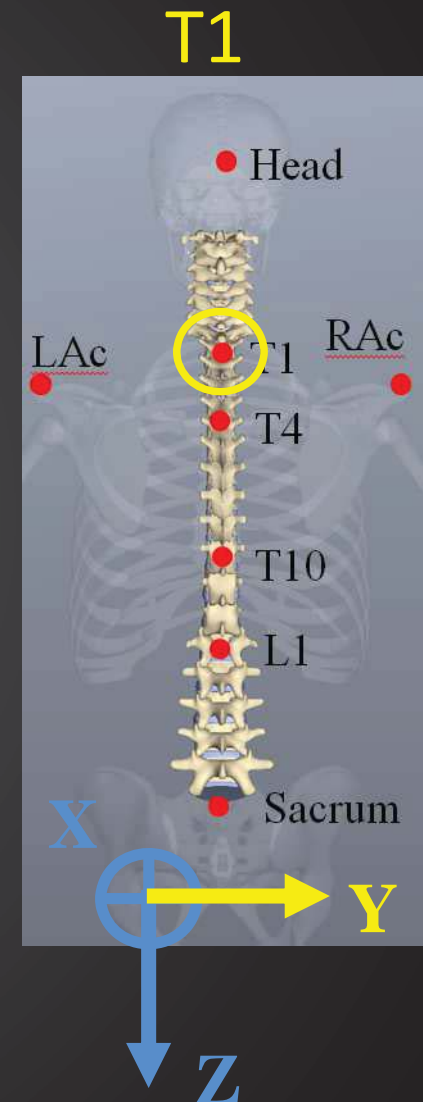
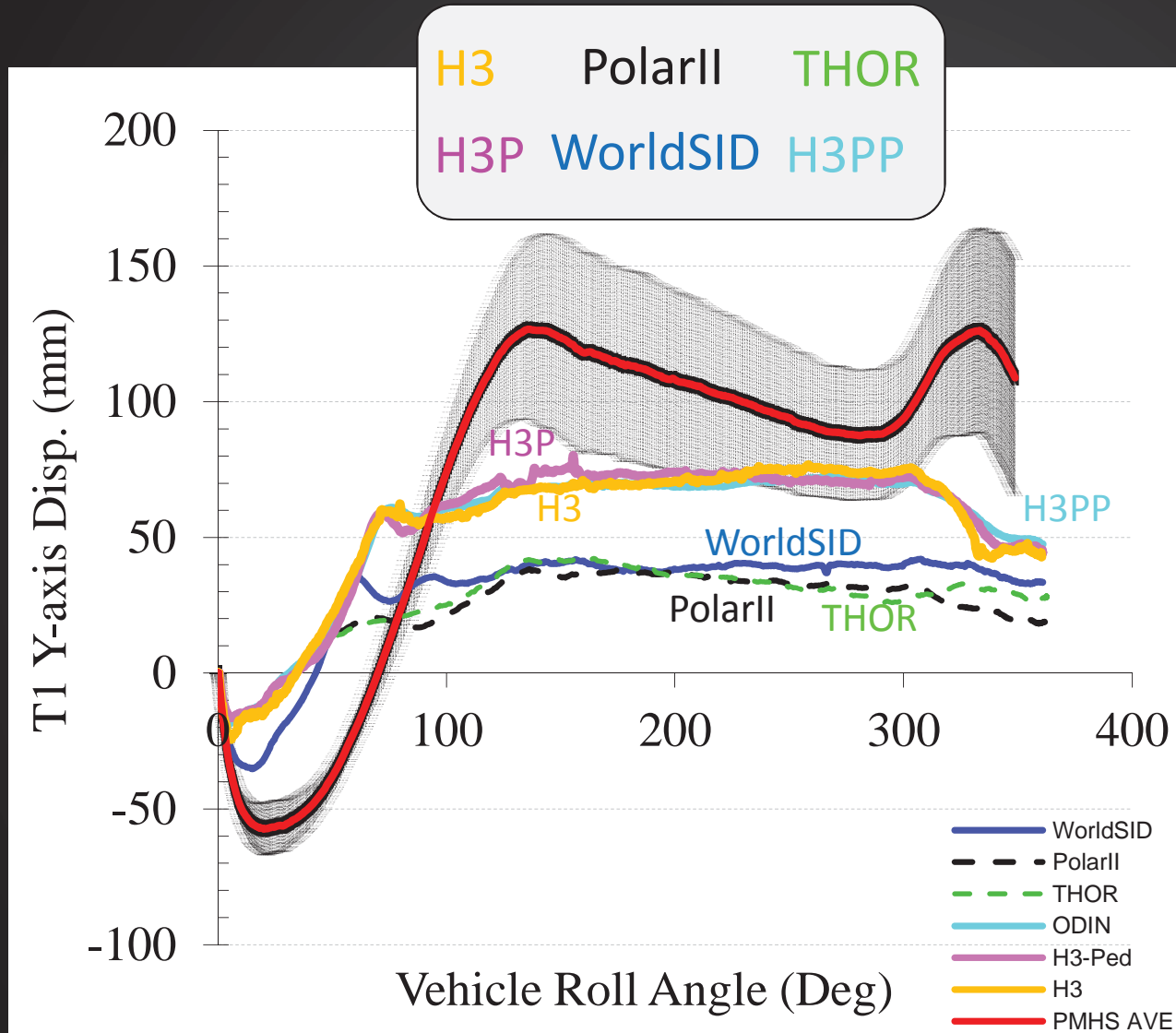
Kinematics: Dummies vs. PMHS



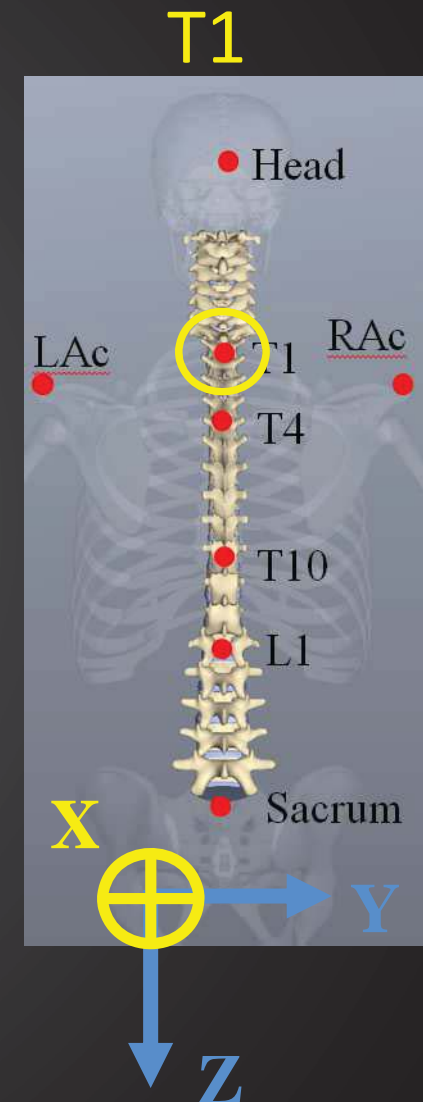
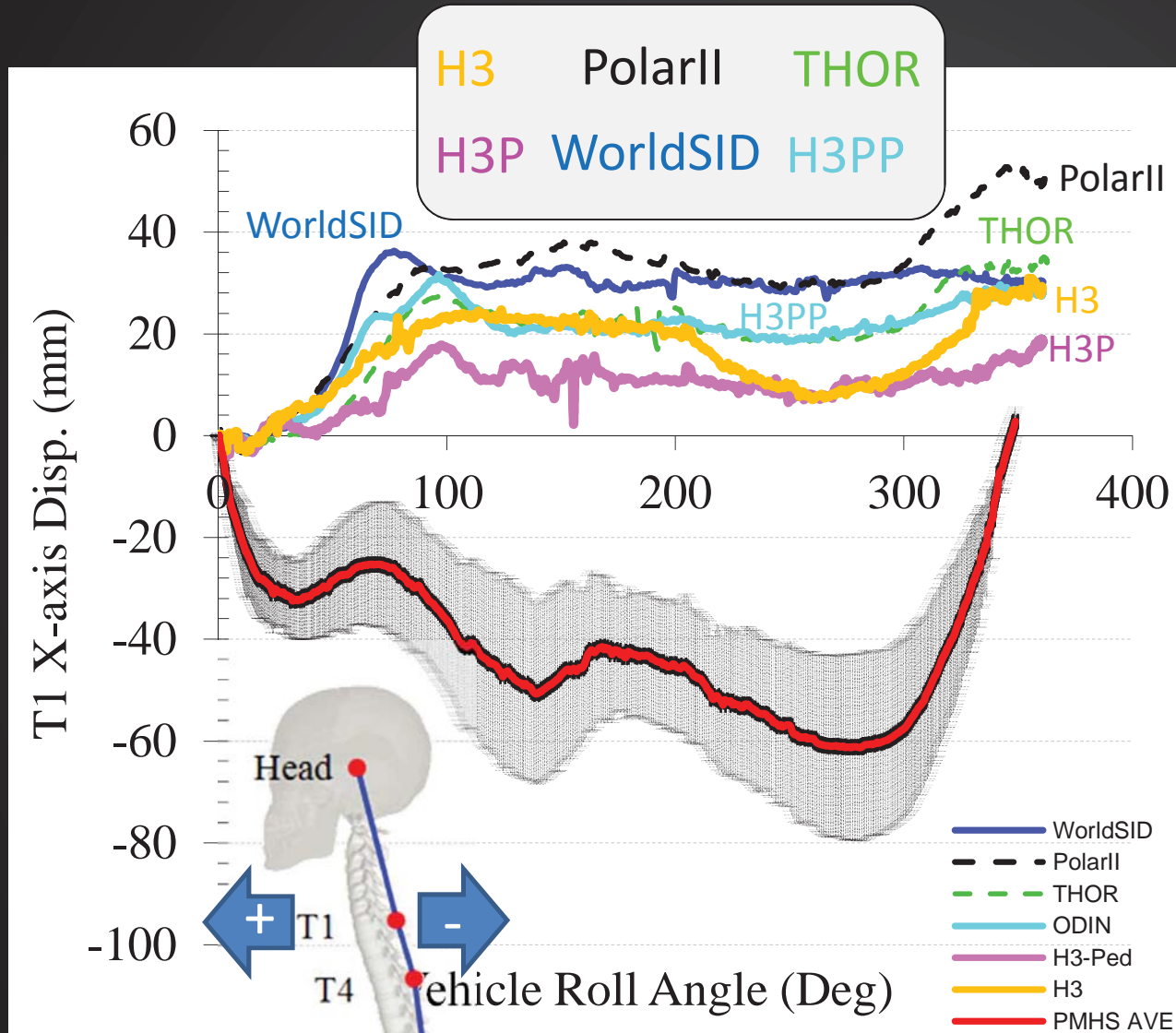
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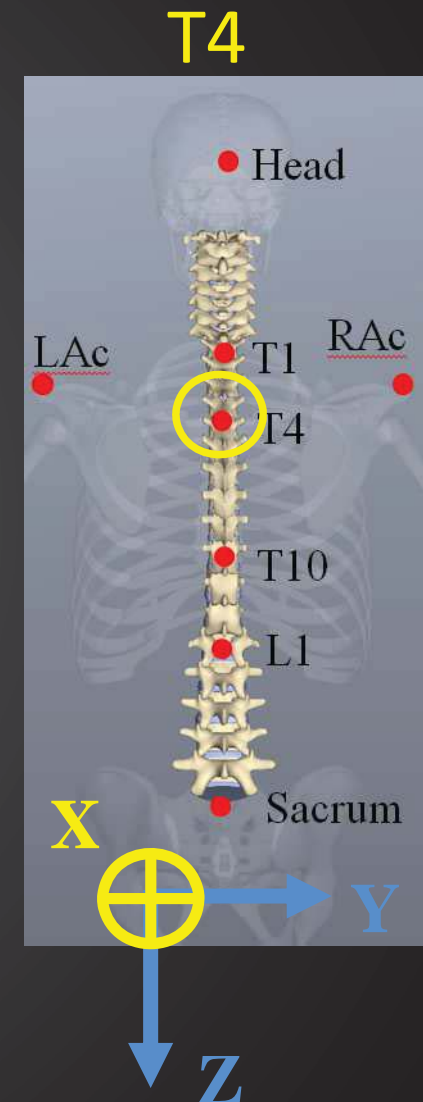
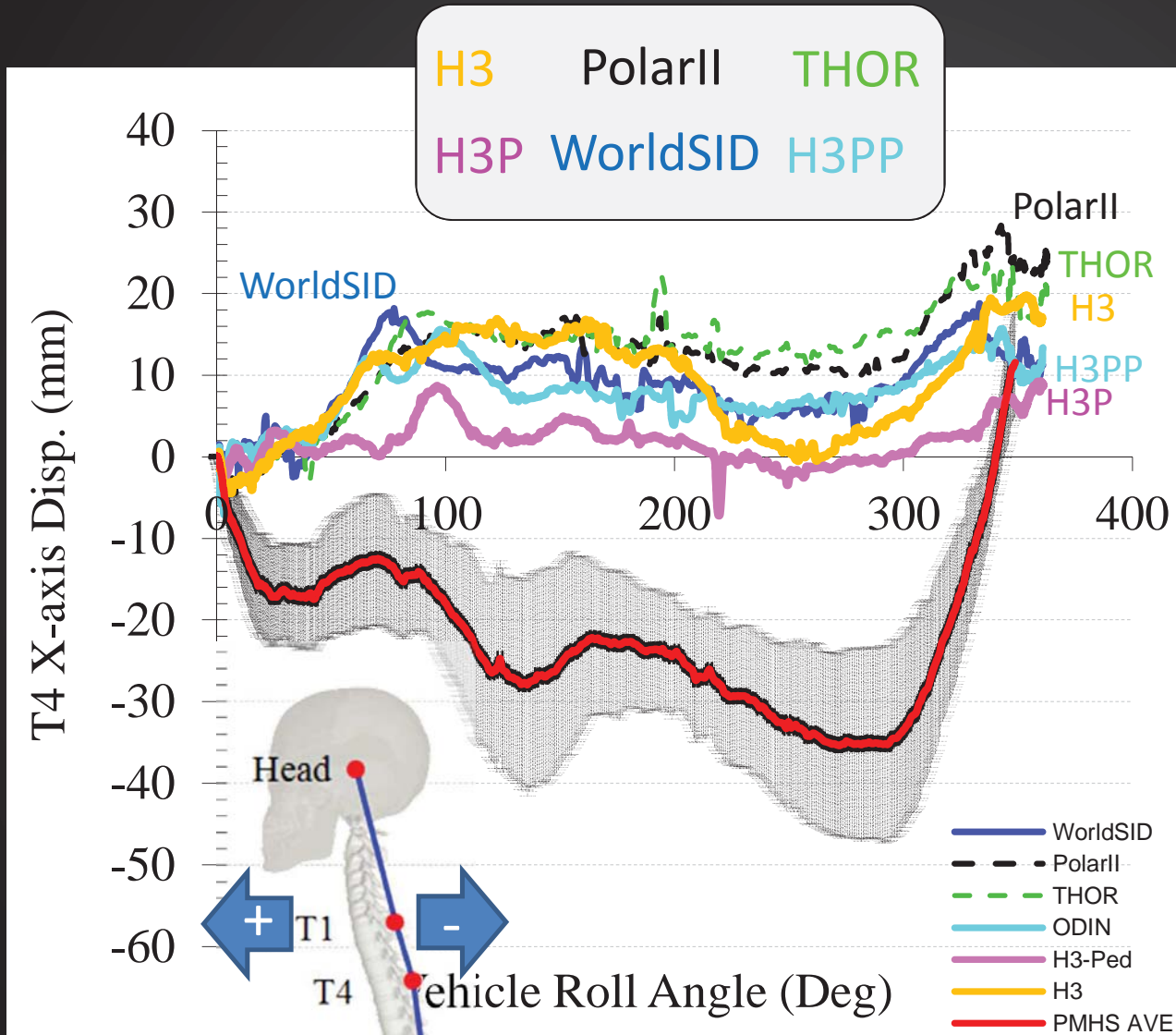
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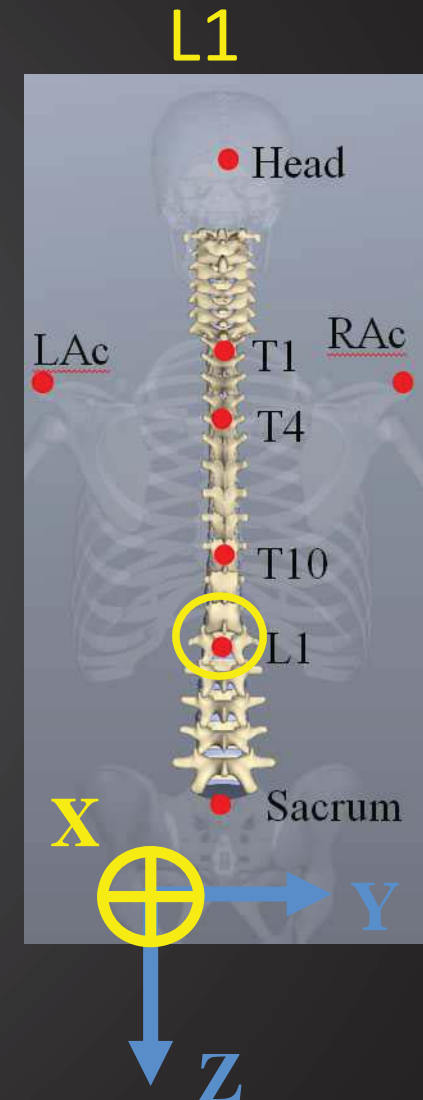
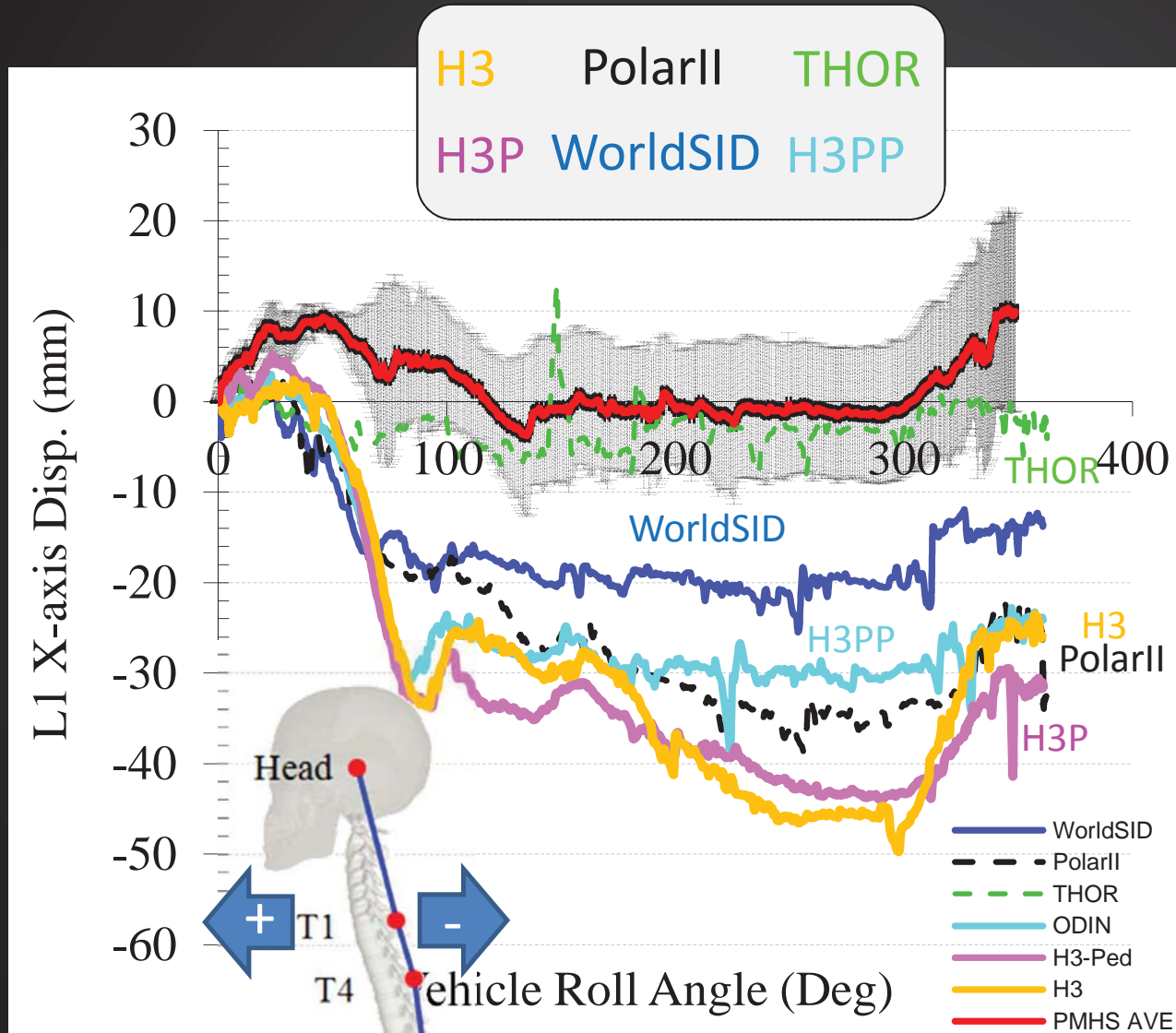
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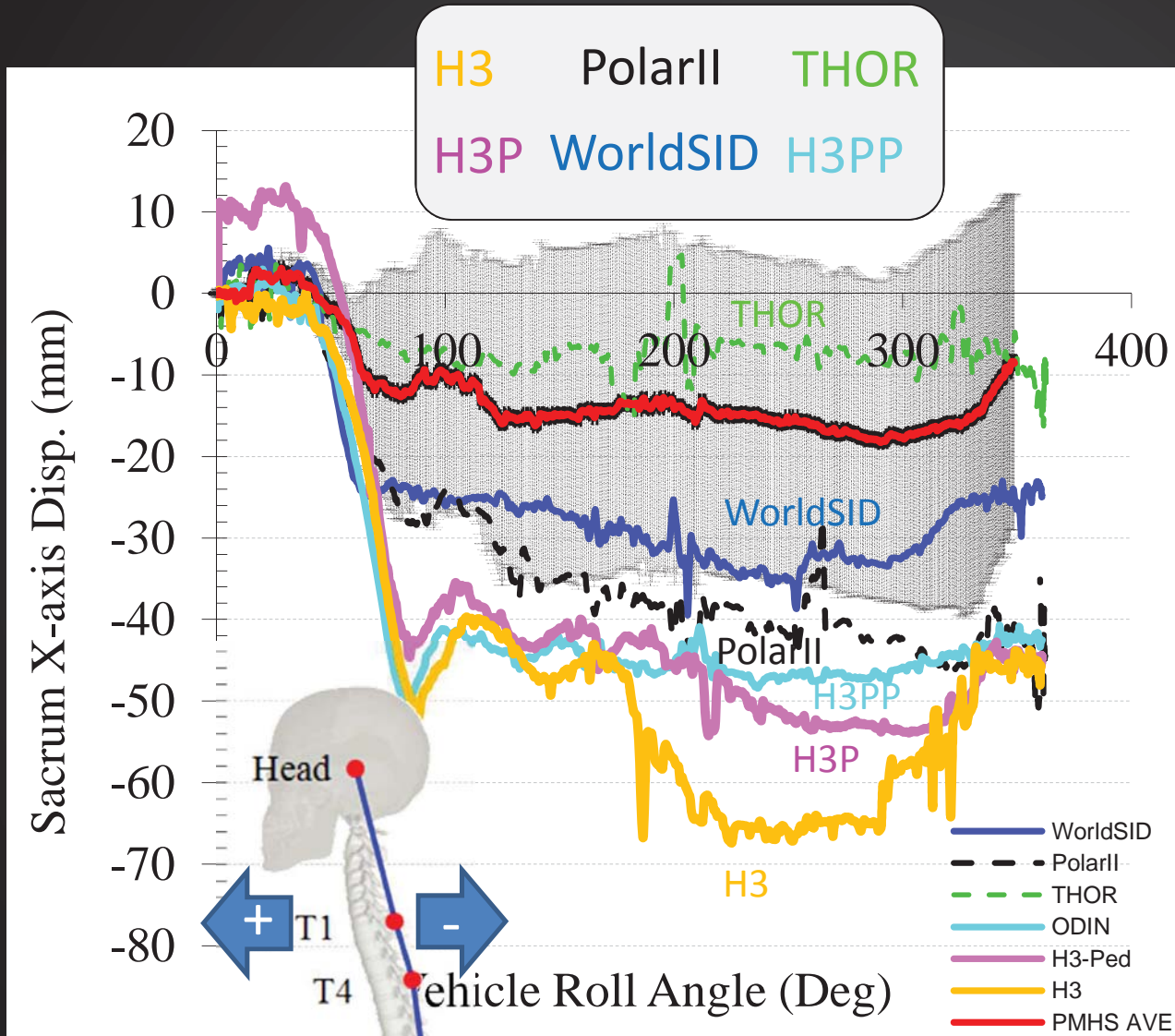
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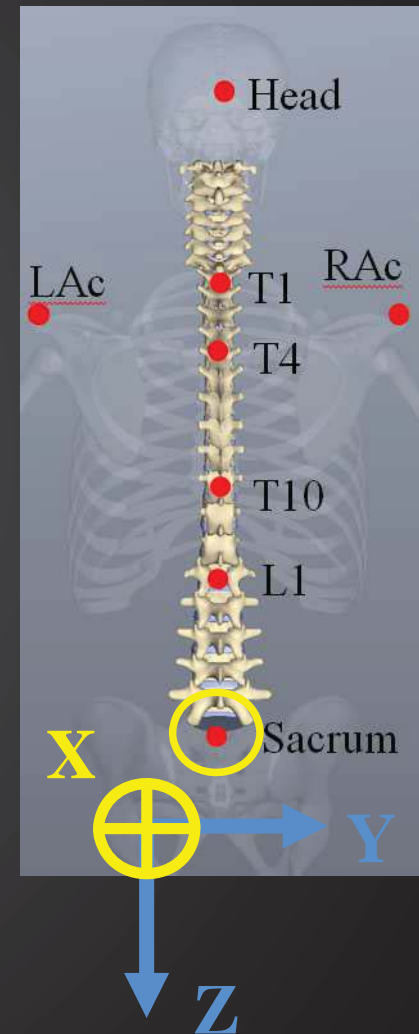
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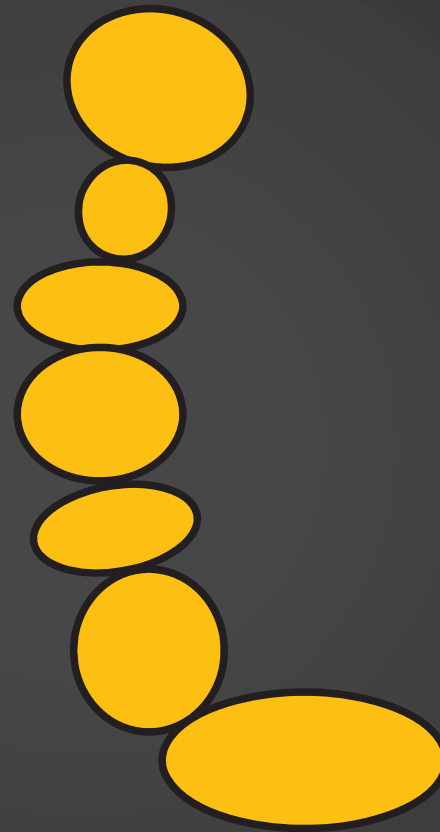


Sacrum

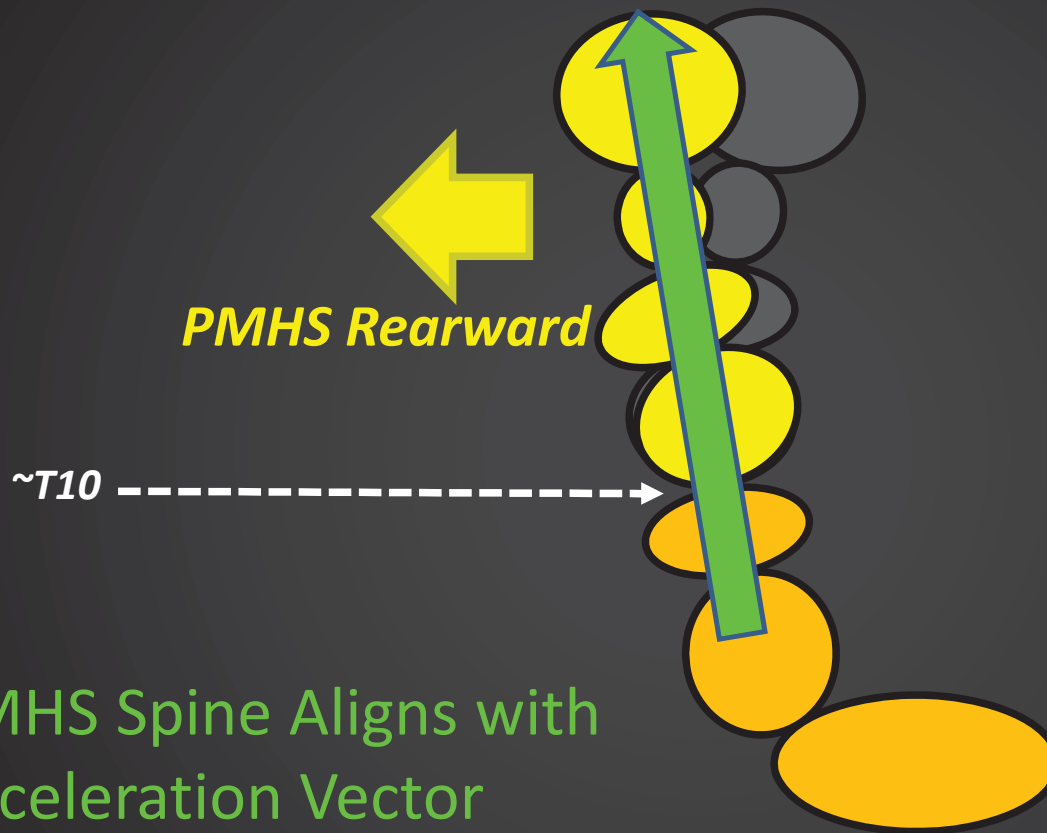




Lateral View

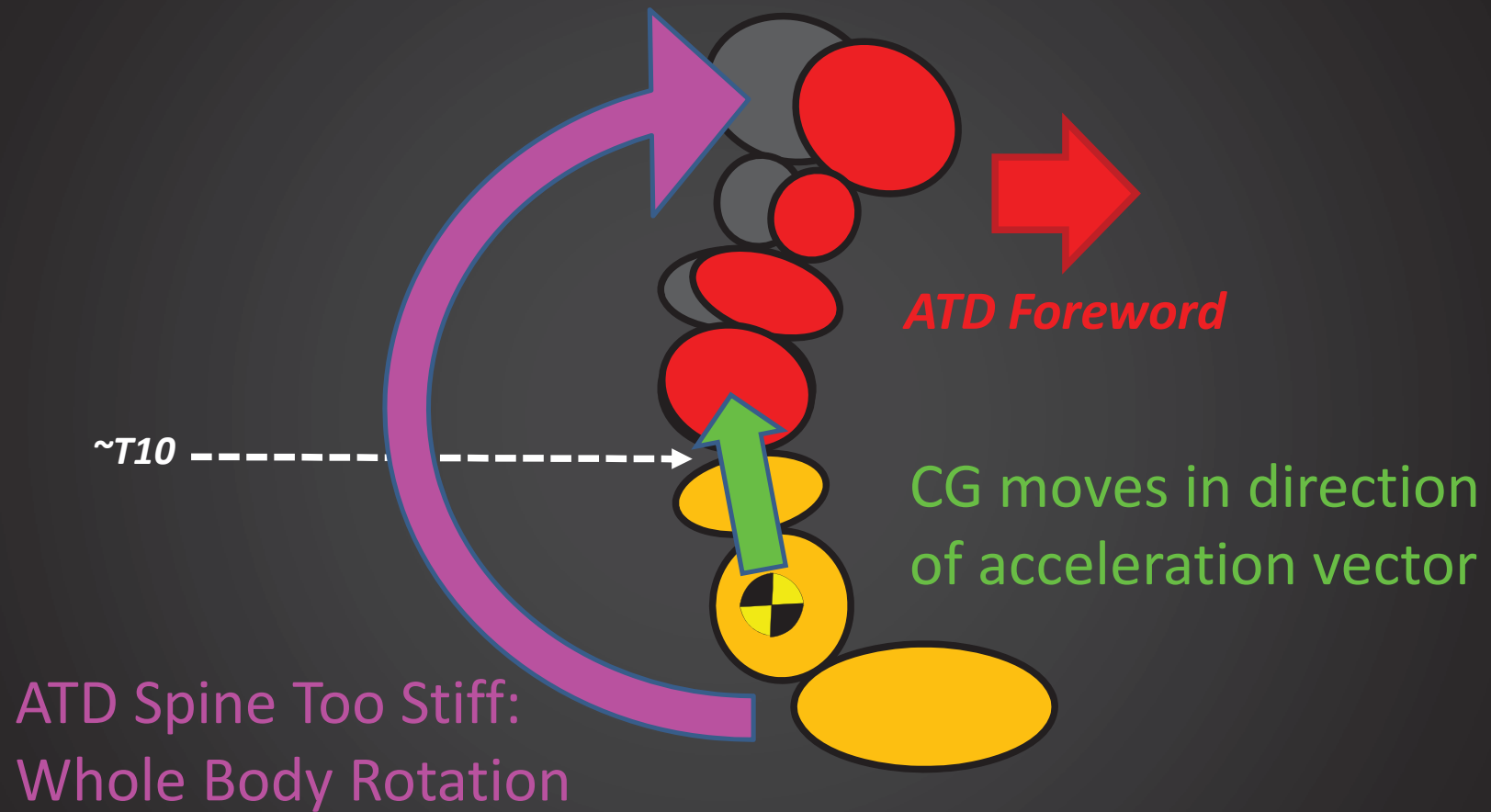


Lateral View

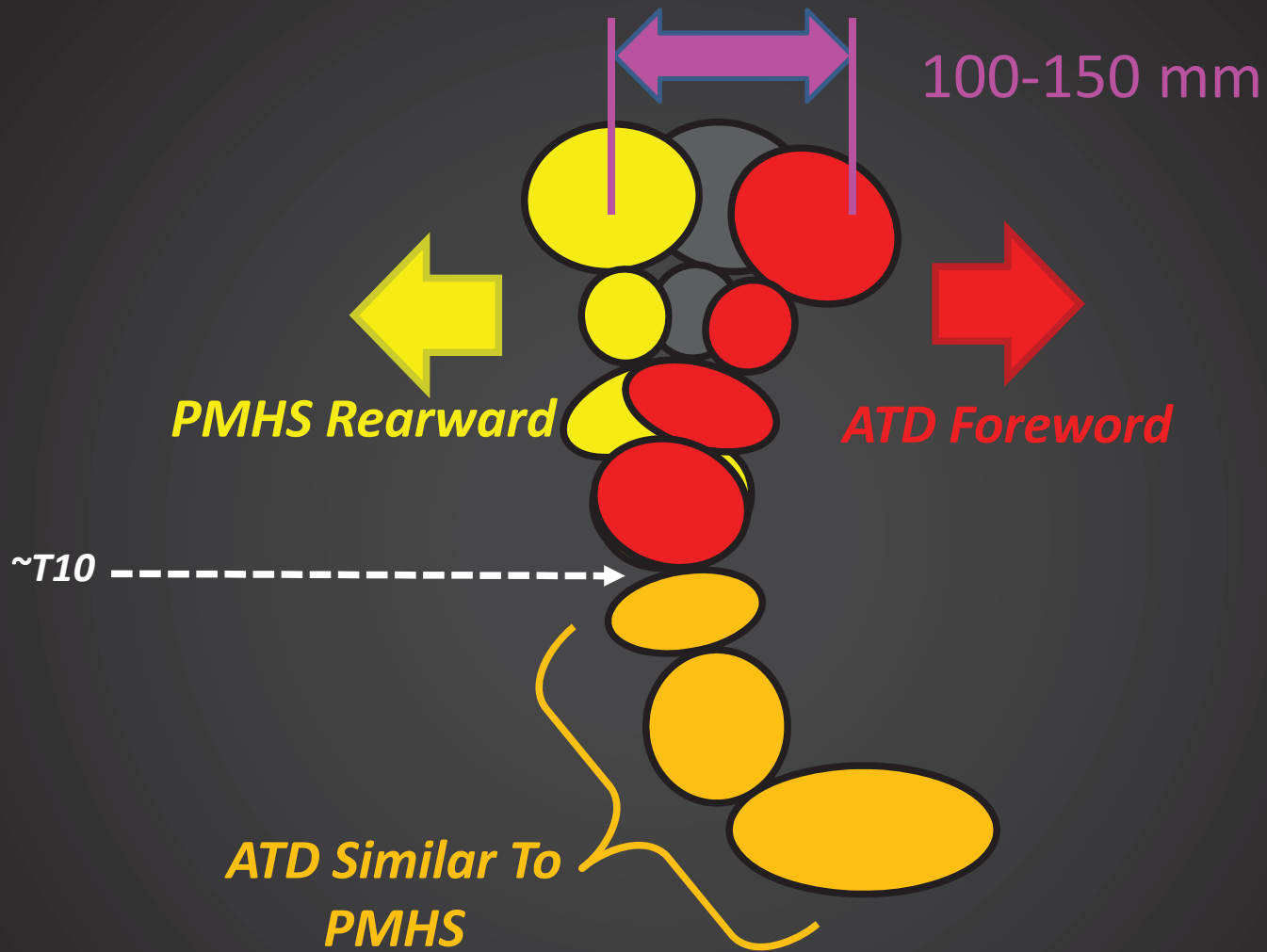


PMHS Spine Aligns with
Acceleration Vector
(Centrifugal + Gravity)

Lateral View

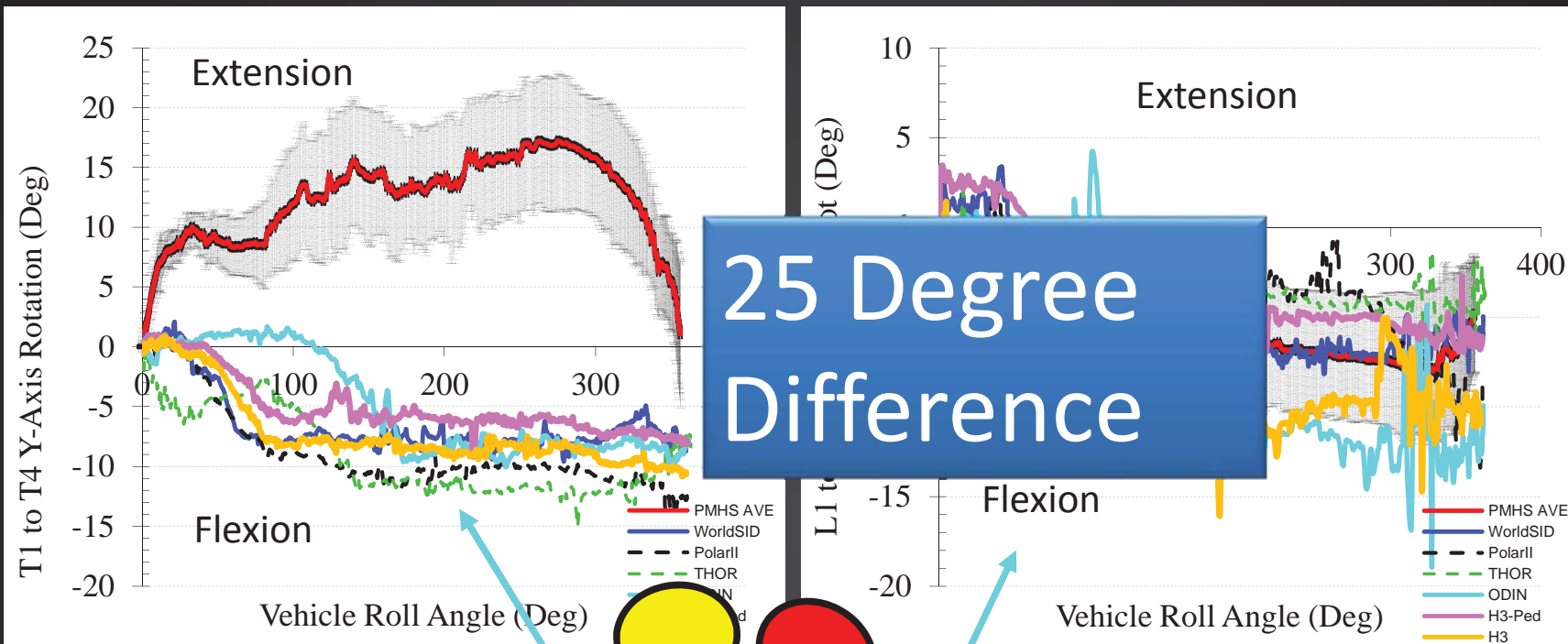


Lateral View



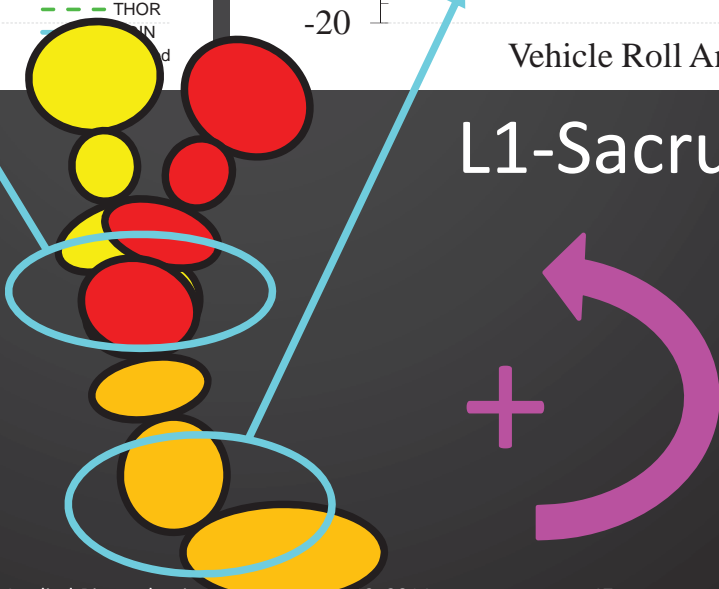
Lateral View

Spine Segment Y-axis Rotations



T1-T4 Rotation

L1-Sacrum Rotation





Funding/Technical Support: NHTSA

Jason R. Kerrigan

Kerrigan@virginia.edu

University of Virginia Center for Applied Biomechanics

Next Steps: Part 2- Injury

Pitch: -1.5 deg
Roll Angle: 155 deg
Roll Rate: 248 deg/s
Vertical Velocity: 1.1 m/s

- Replicate Rollover Impact Tests with Buck Roof
- 4 PMHS (AM50)
- 6 ATD (same)