Assessing Rollover Crashworthiness in Dynamic vs. Static Testing

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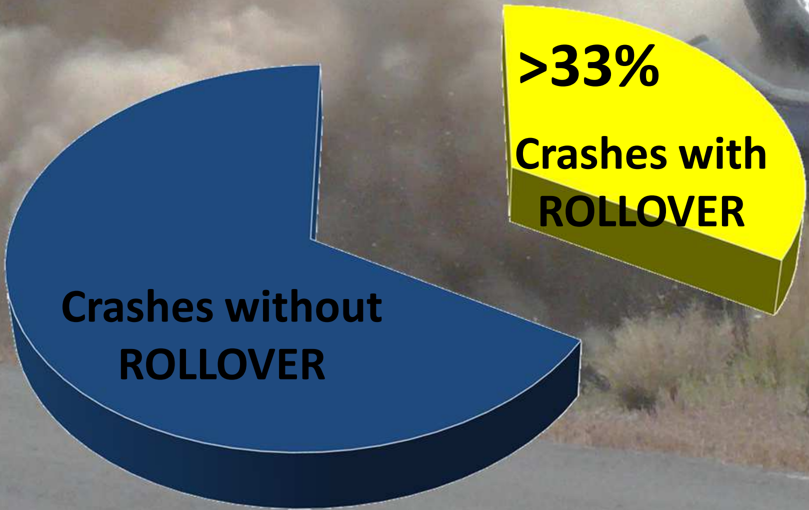
Problem: Rollover Crashes

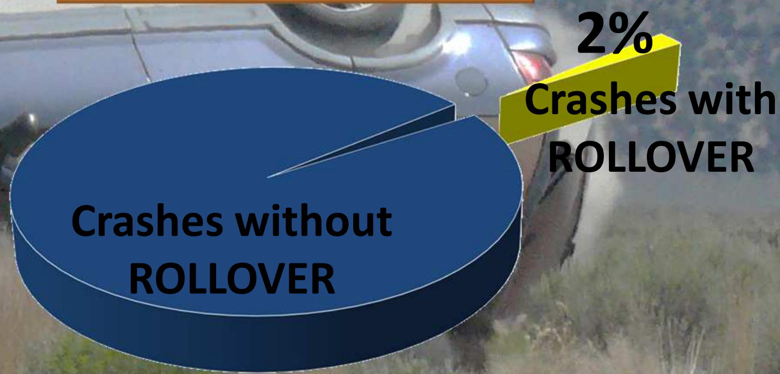
Since 2005:

Vehicle Occupant Fatalities

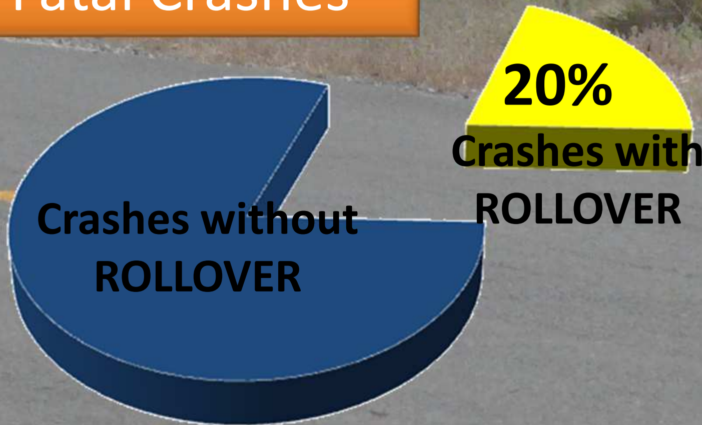


In 2010:

Vehicle Crashes



Fatal Crashes



2013:
-7017 People Killed (33.2% of Occ. Fat.)
-1.7% of Crashes

Source: NHTSA Traffic Safety Facts 2013, FINAL Edition

UVA Rollover Research 2009-Present

Long-Term Research Goals:

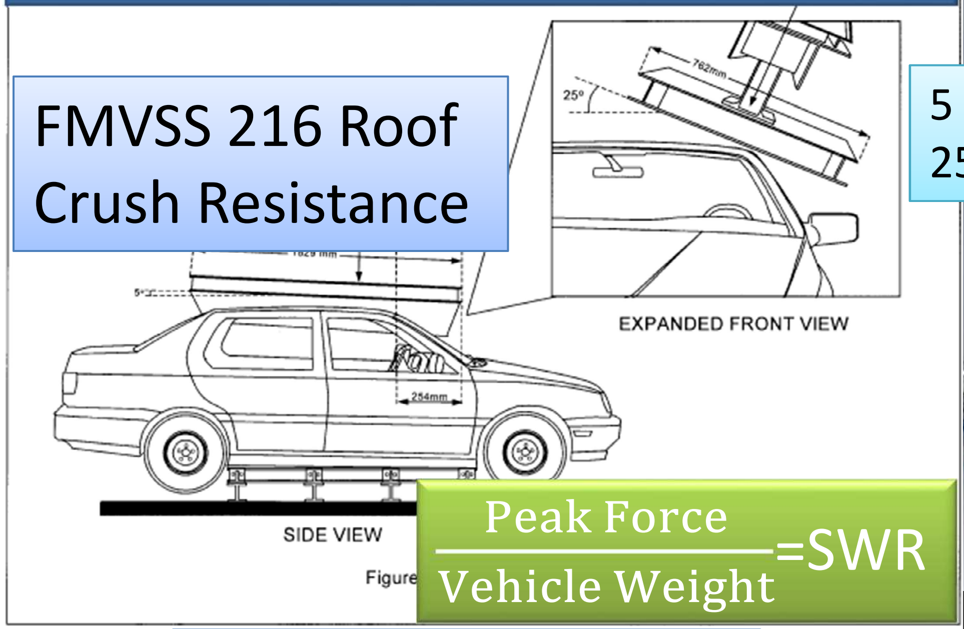
- Identify and investigate injuries, mechanisms, and sources
- Evaluate and improve dummy biofidelity
- Investigate potential for repeatability
- Determine what can be learned about vehicle crashworthiness by a dynamic test
- Develop a suite of computational models for modeling crashes, vehicles, and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


wer.com
ISUZU

Standardized Rollover Crashworthiness Evaluations

US Dept of Transportation (NHTSA)

FMVSS 216 Roof Crush Resistance



$$\frac{\text{Peak Force}}{\text{Vehicle Weight}} = \text{SWR}$$

Required: SWR ≥ 3.0

(Updated 2009)

Insurance Institute for Highway Safety

5 deg pitch
25 deg roll

IIHS Roof Strength

"Good" Rating: SWR ≥ 4.0

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IIHS 2008
Brumbelow et al. 2008
Brumbelow et al. 2009

Roof Strength:

Peak Strength to Weight Ratio

?

Moffatt and Padmanaban 1995
Padmanaban et al. 2005
Padmanaban and Moffatt 2008

Injury Risk:

Head, Neck, Face, Spine

NHTSA:
TSF RN 2010
(DOT HS 811365)

Roof Deformation:

Intrusion

NHTSA:
Austin et al. 2005
Strashny 2007

- Retrospective Analyses
- Simplify Numerous Factors
- Statistical Correlation

Goal

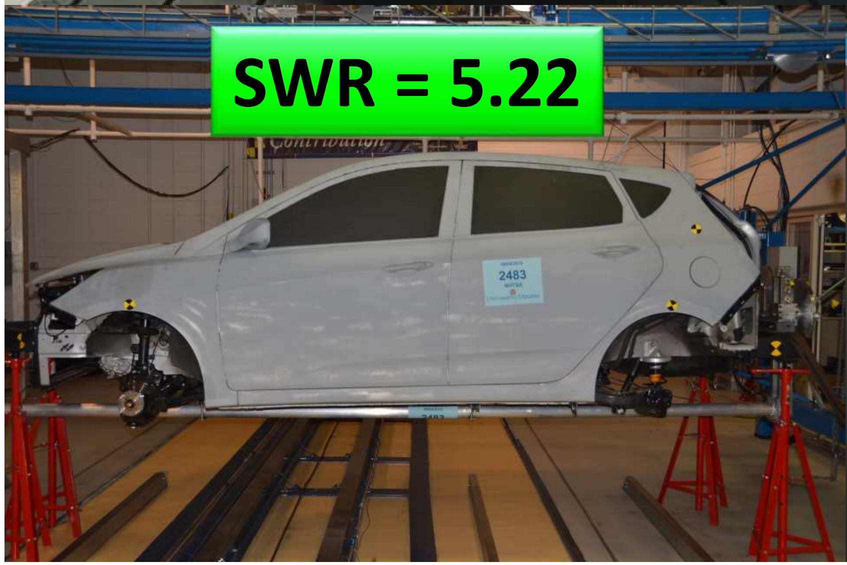
To examine the relationship between roof strength, roof intrusion, and injury risk by testing:

Compare the dynamic response to rollover of two vehicles with the same SWR

2014 Hyundai Accent Hatchback Compact

2014 Volvo XC60 SUV

SWR = 5.22



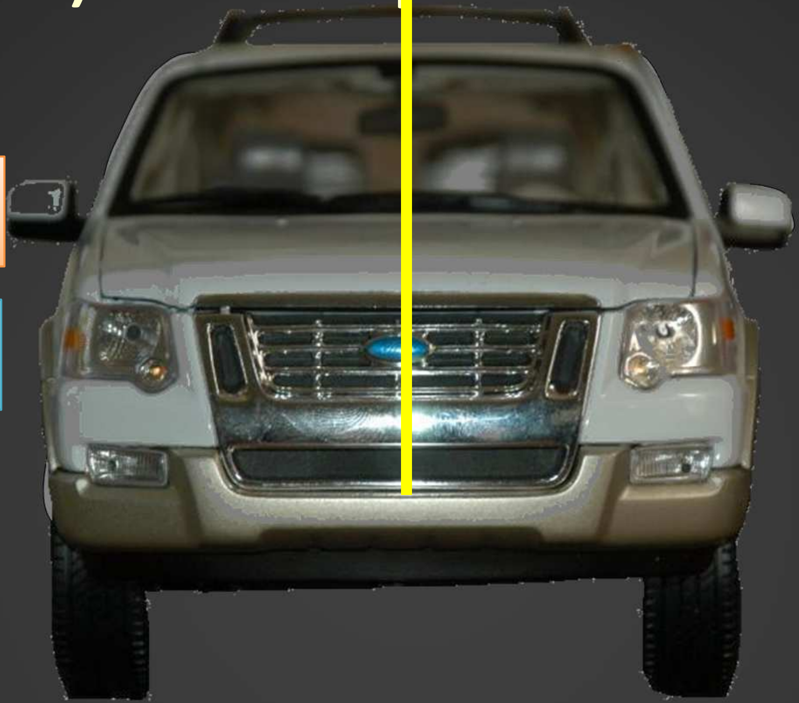
SWR = 5.23

Dynamic Rollover Test System (DRoTS) Concept

PRE-TEST

TEST PHASE

POST-TEST



1) Rotated to Test Velocity and Test Angle

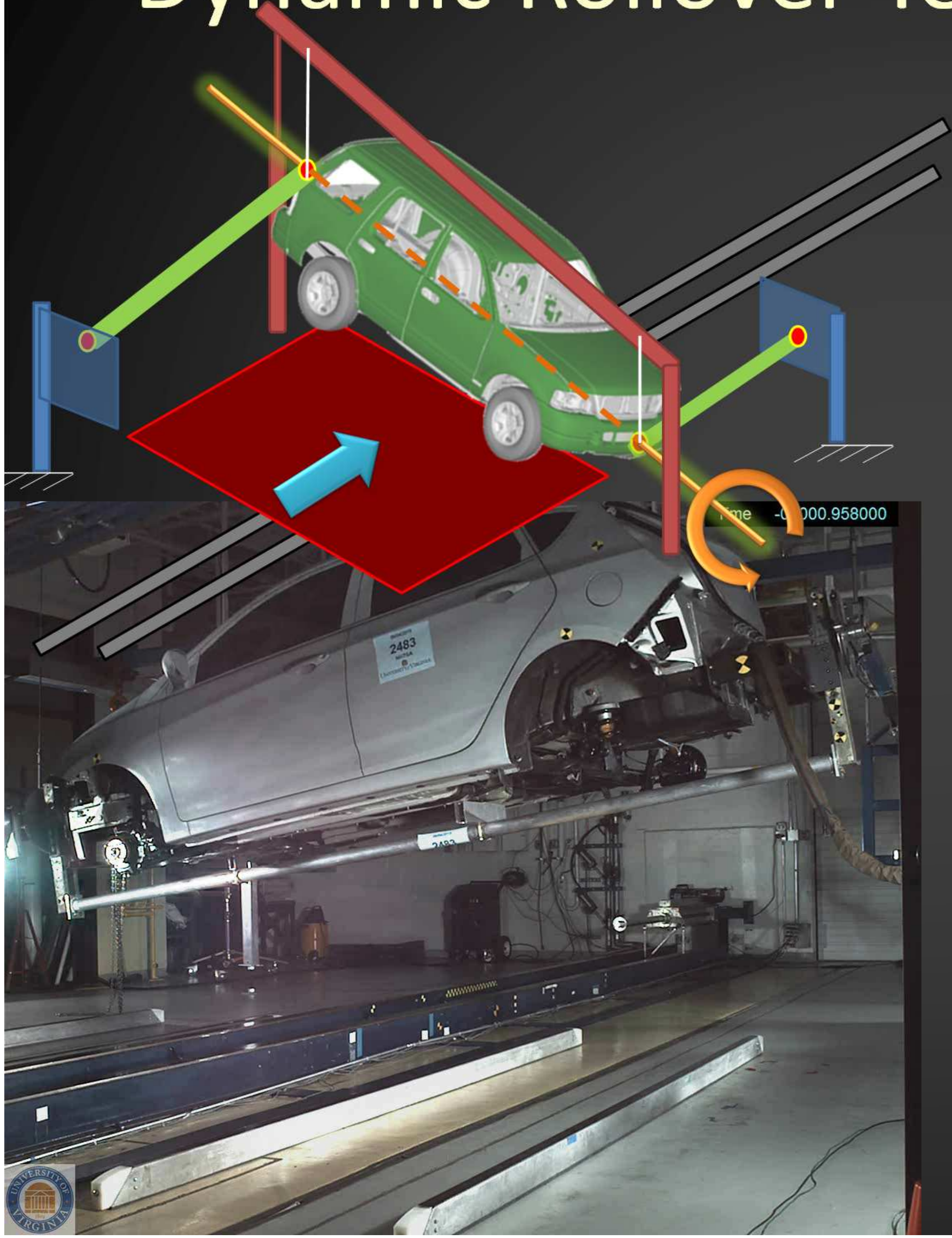
2) Dropped onto Moving Road Surface

3) Rolls Across Moving Road Surface

4) Vertical Motion Is Arrested

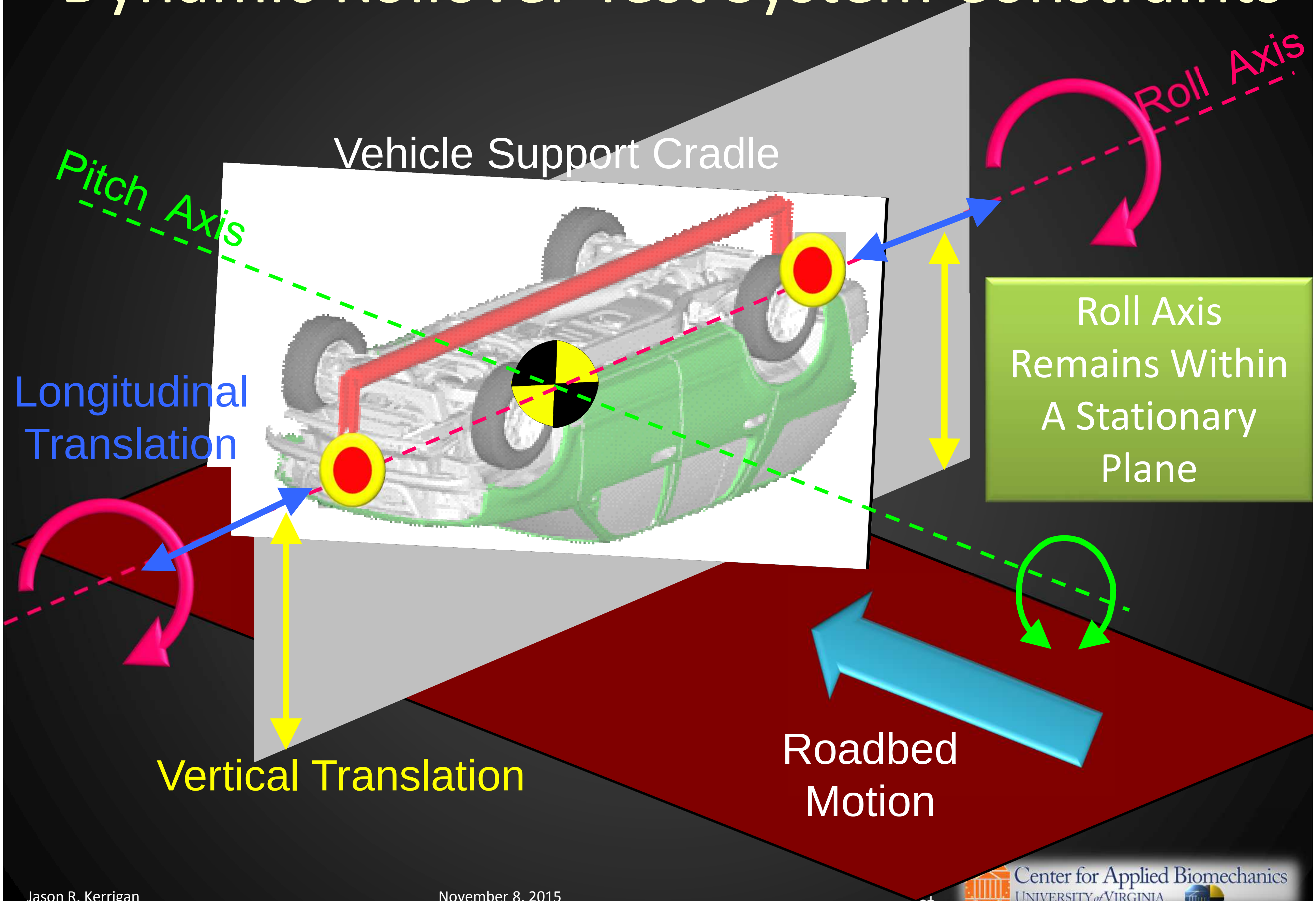
5) Rotational Motion is Arrested

Dynamic Rollover Test System (DRoTS)

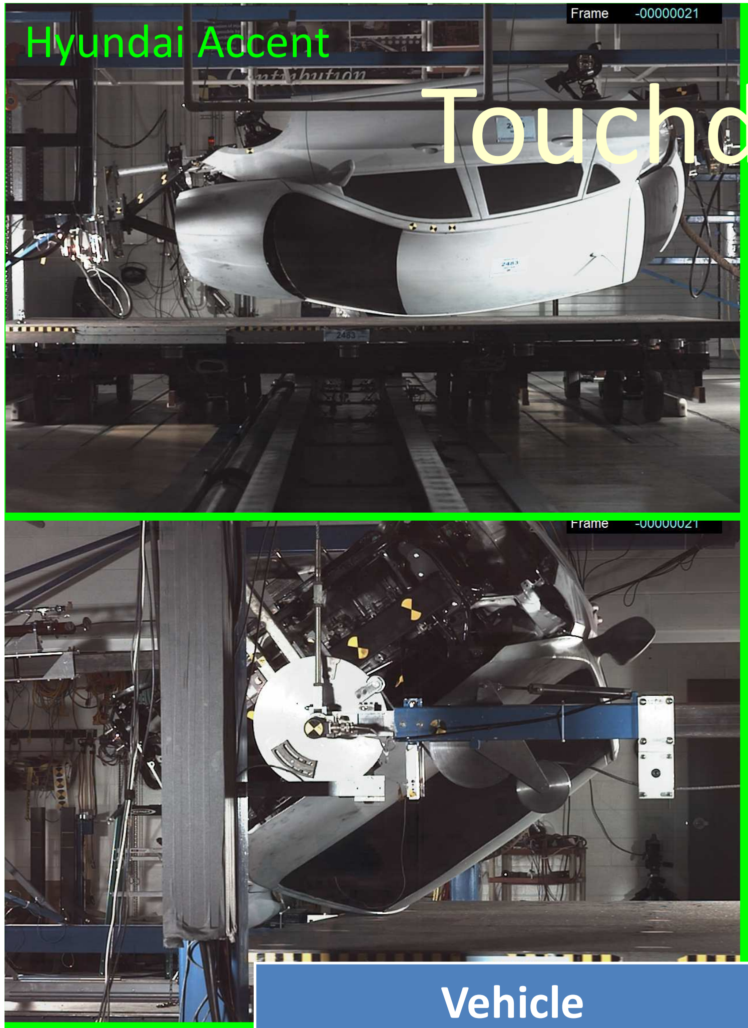


- Research Tool
  - Repeatability
  - Dummy Biofidelity
  - Injury Risk
  - Dynamic vs. Static
- Development
  - Kerrigan et al. 2011
- Operation/Performance
  - Kerrigan et al. 2013
- Dummy Biofidelity
  - Zhang et al. 2013/2014
  - Lessley et al. 2014
- Repeatability
  - Seppi et al. 2015
  - Roberts et al. 2015
- Crash Fidelity
  - Kerrigan et al. 2015
  - Roberts et al. 2016

Dynamic Rollover Test System Constraints



Touchdown Conditions



Vehicle	GOAL	Volvo	Hyundai
Pitch Angle (deg)	-7.6	-8.1	-8.6
Roll Angle (deg)	-143	-142	-144
Roll Rate (deg/s)	-245	-247	-246
Road Speed (m/s)	7.5	7.4	7.4
Vertical Velocity (m/s)	1.55	1.53	1.51

Exterior Video

Volvo XC60

Hyundai Accent

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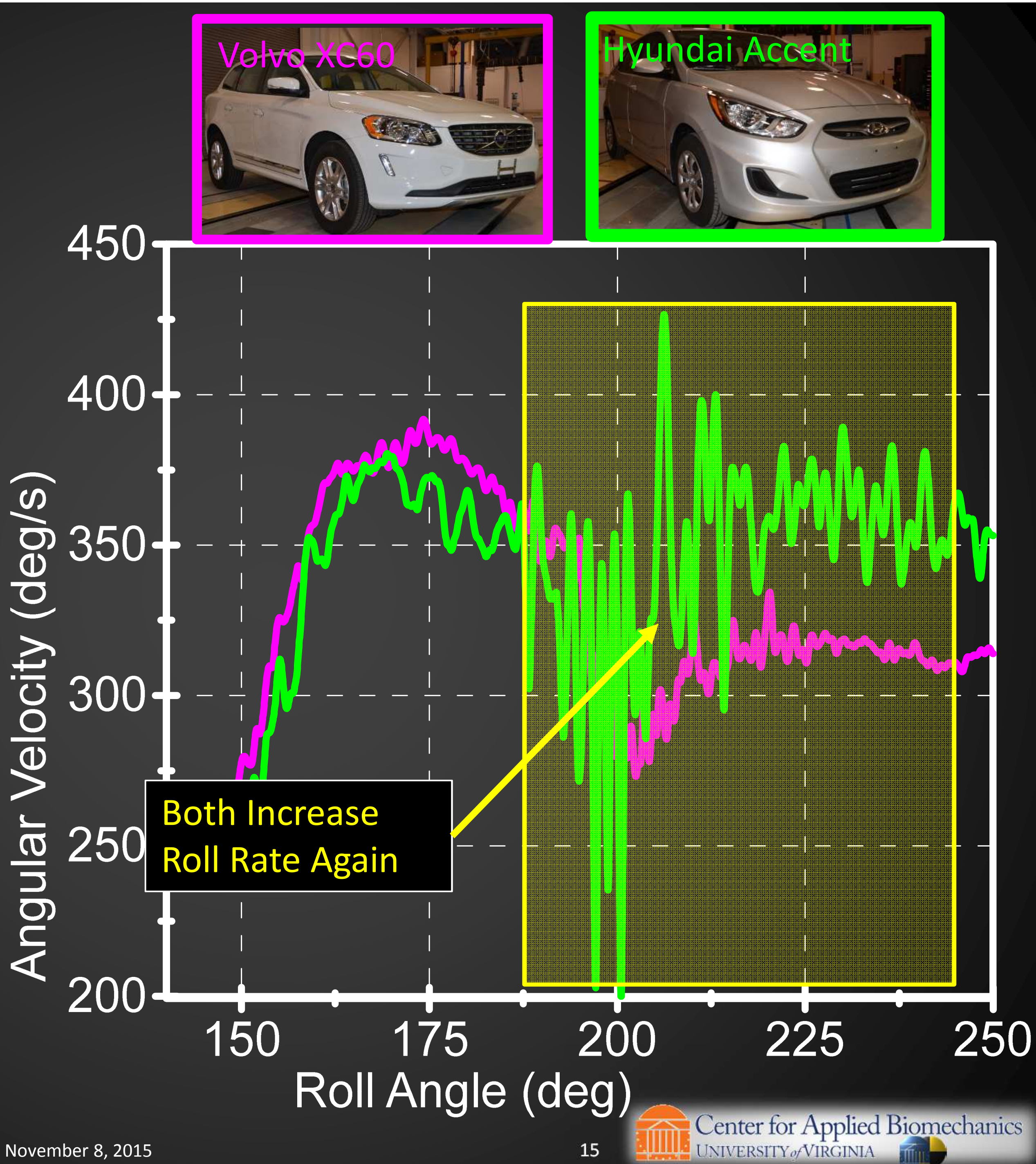
Roll Rate
Roll Angle

Leading Side Impact


Roll Rate
Roll Angle
Trailing Side Impact


Volvo XC60
Hyundai Accent
450
400
350
300
250
200
150
175
200
225
250
Angular Velocity (deg/s)
Roll Angle (deg)
Both Increase
Roll Rate Again
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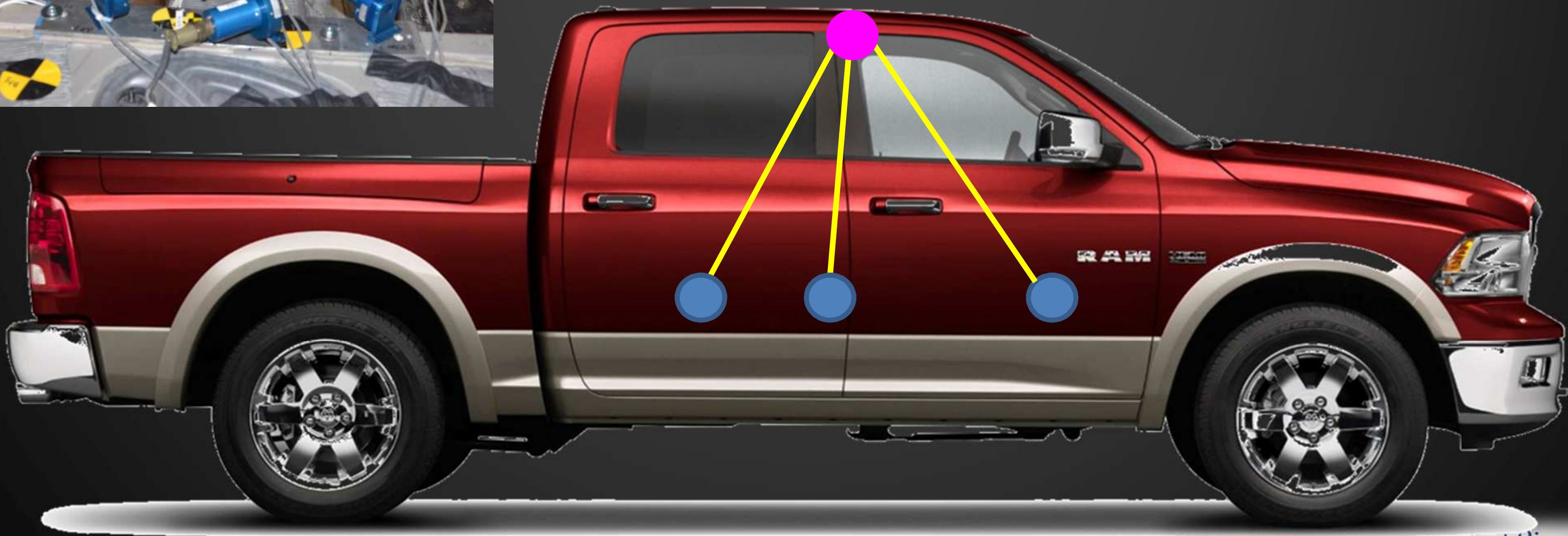
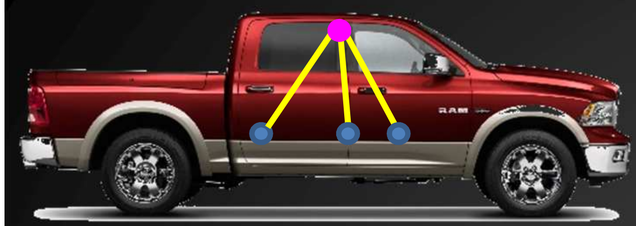
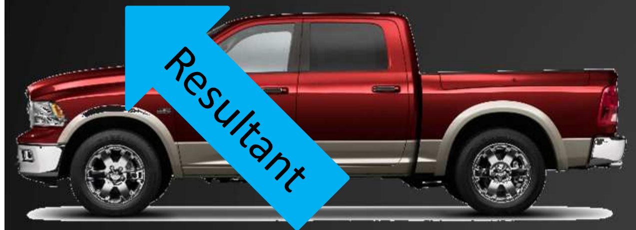
Deformation Measurement

3 String Potentiometers +
Trilateration Algorithm =
Local Frame X, Y, Z, Displacements





Trailing (Passenger) B-Pillar



<u>Hyundai Accent</u>

Max: 126 mm (207 deg)

Residual: 70 mm

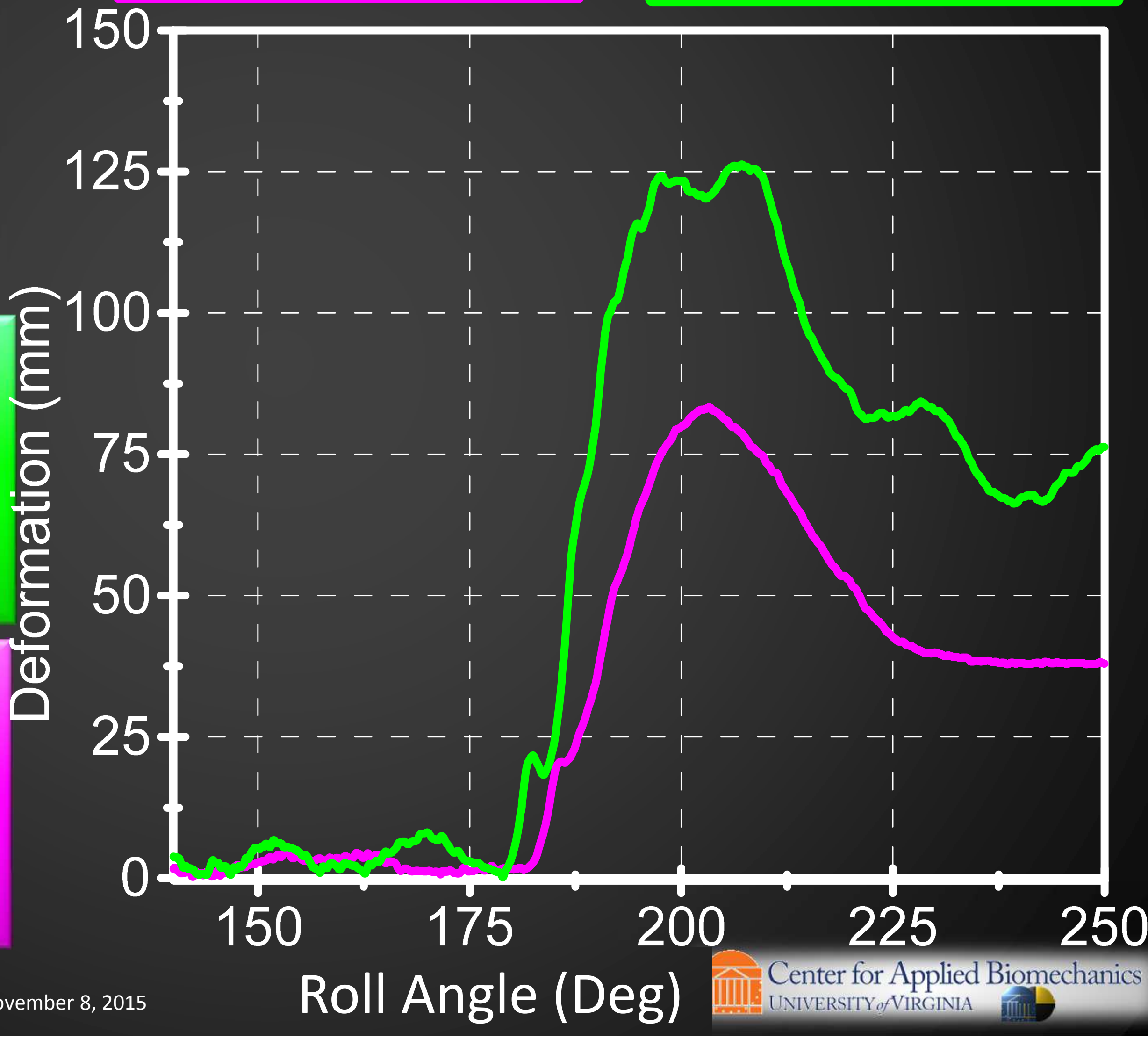
(45% Reduction)

<u>Volvo XC60</u>

Max: 83 mm (203 deg)

Residual: 38 mm

(55% Reduction)



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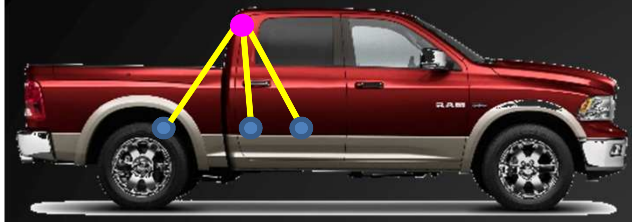
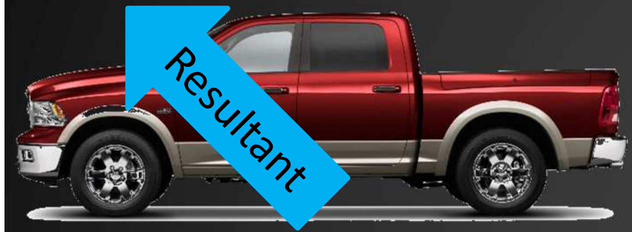


Trailing (Passenger) C-Pillar



<u>Hyundai Compact</u>

Max: 90 mm (197 deg)

Residual: 48 mm

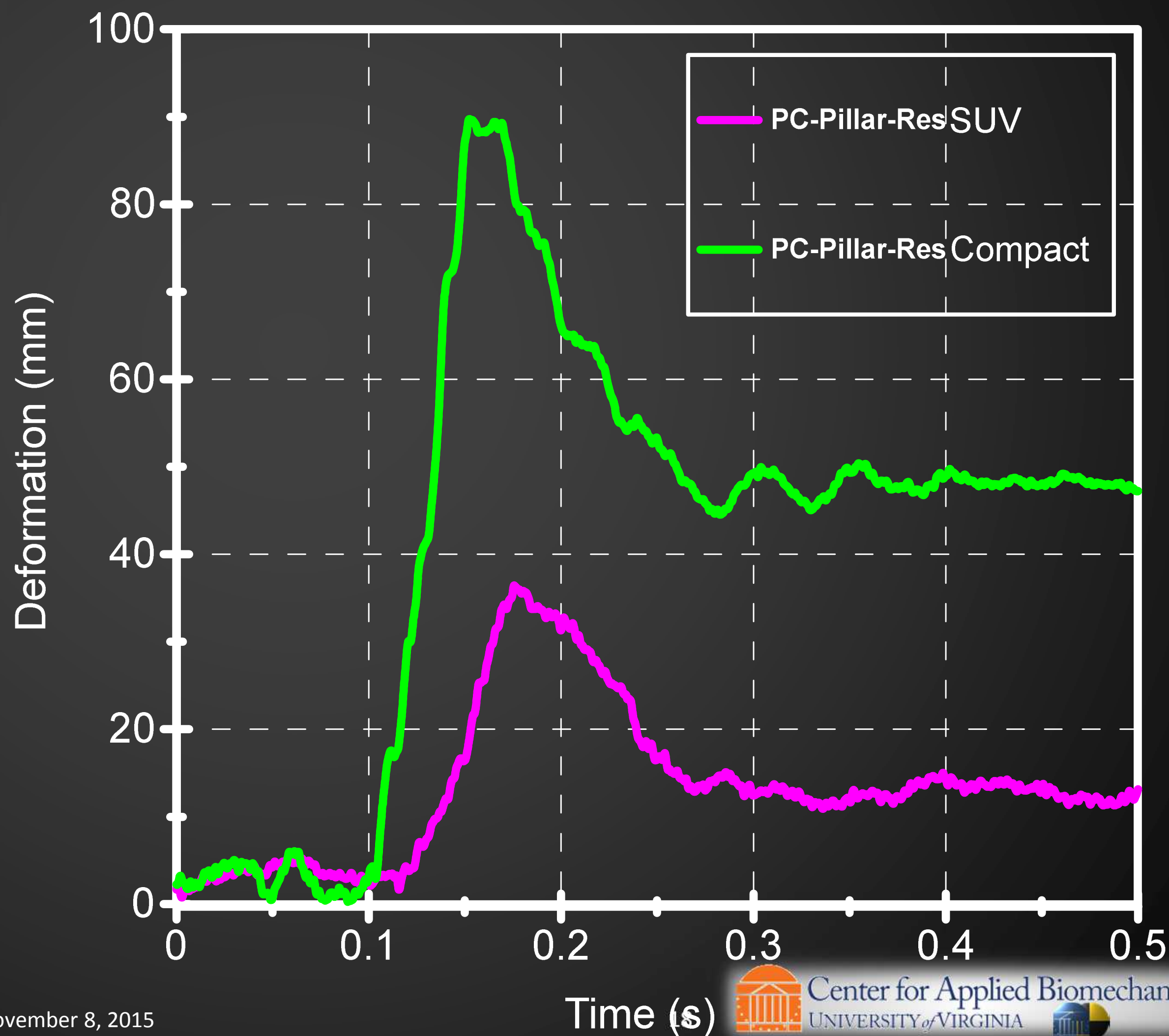
(47% Reduction)

<u>Volvo SUV</u>

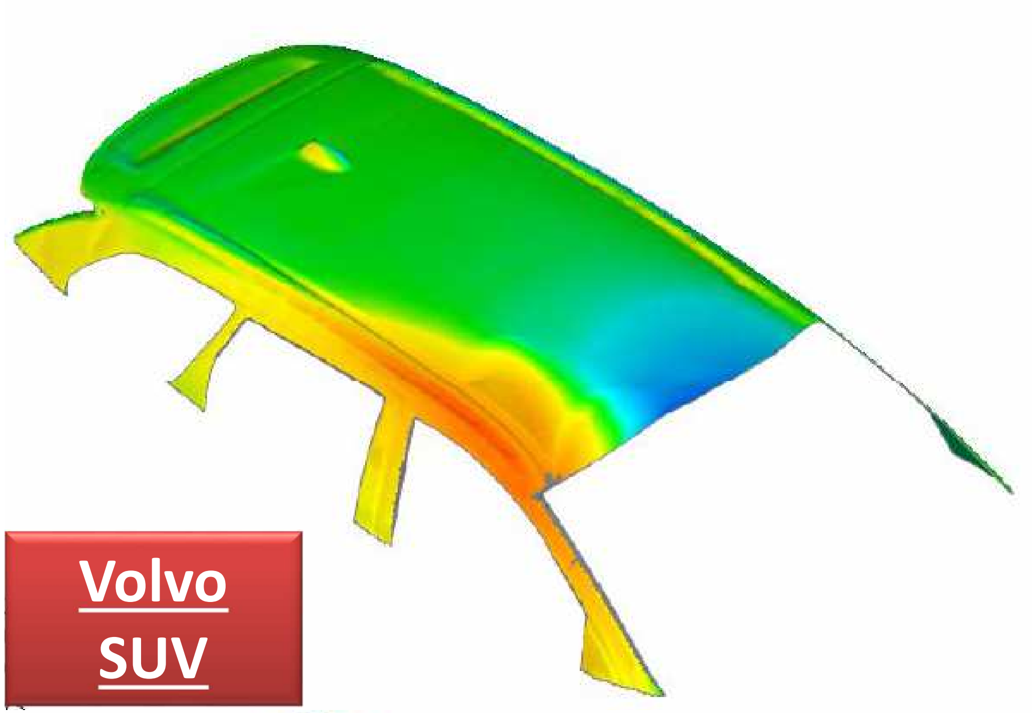
Max: 36 mm (203 deg)

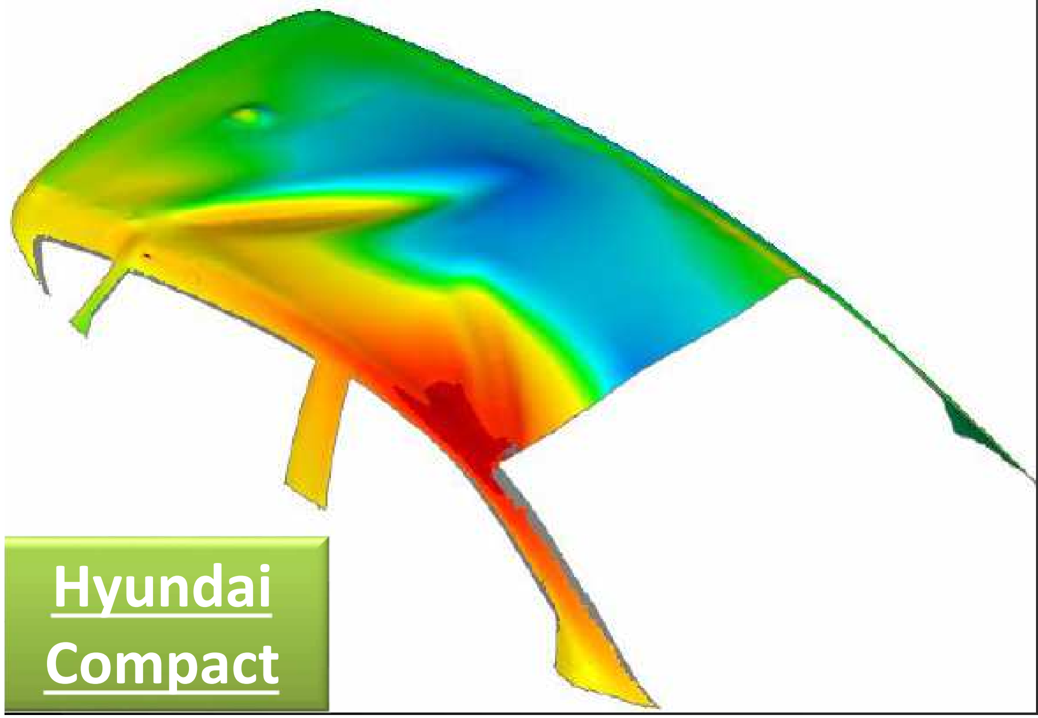
Residual: 14 mm

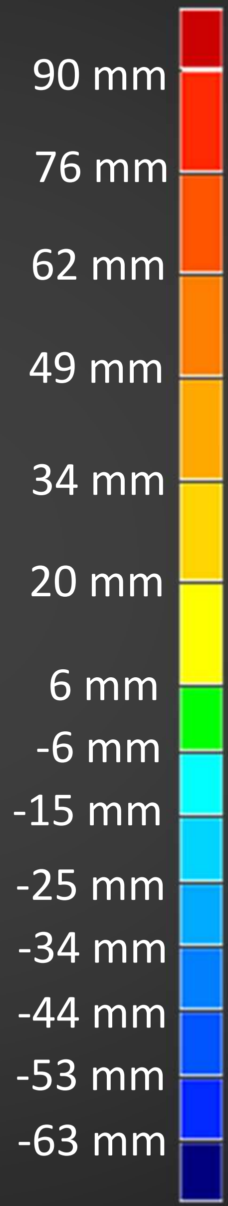
(61% Reduction)



Roof Deformations







VOLVO

Avg. Deformation:

14 mm

-6 mm

HYUNDAI

Avg. Deformation:

27 mm

-14 mm

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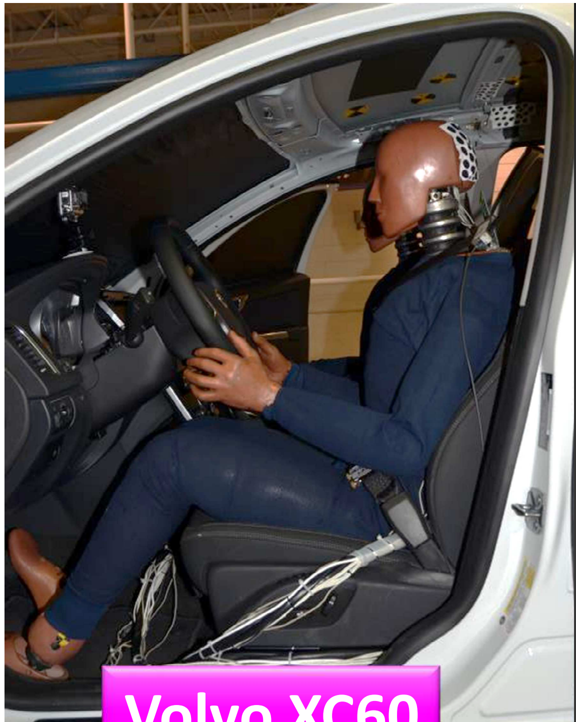
Two Hybrid-III ATDs in Each Vehicle



Volvo XC60

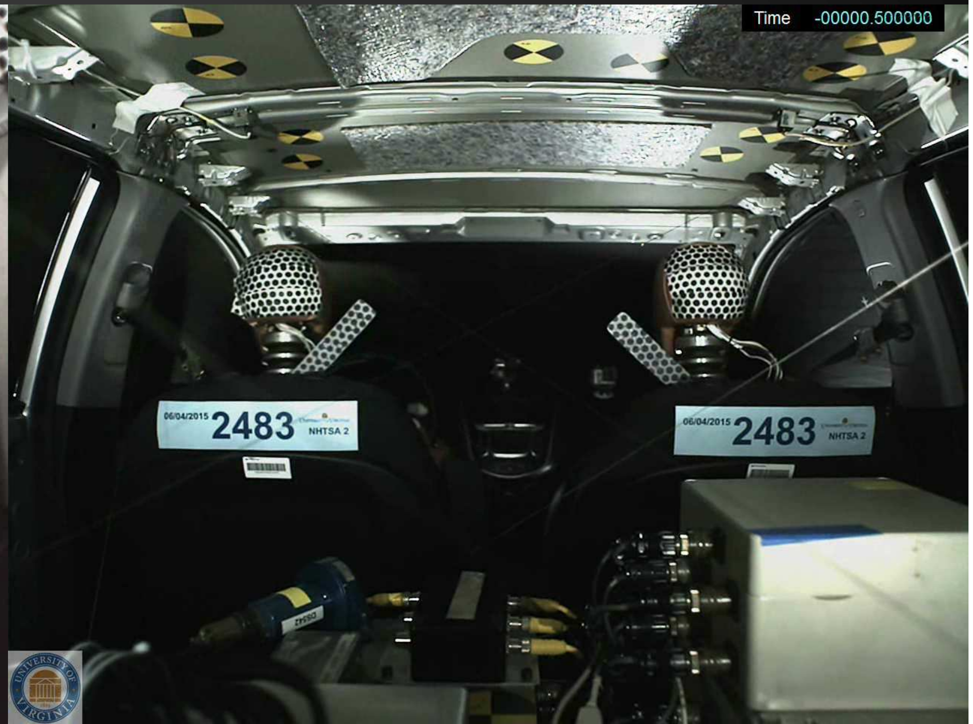
No Curtain Airbags Deployed

No Seatbelt Pretensioners Deployed

NCAP Seating

Hyundai Accent

Interior Videos



Volvo XC60

Hyundai Accent

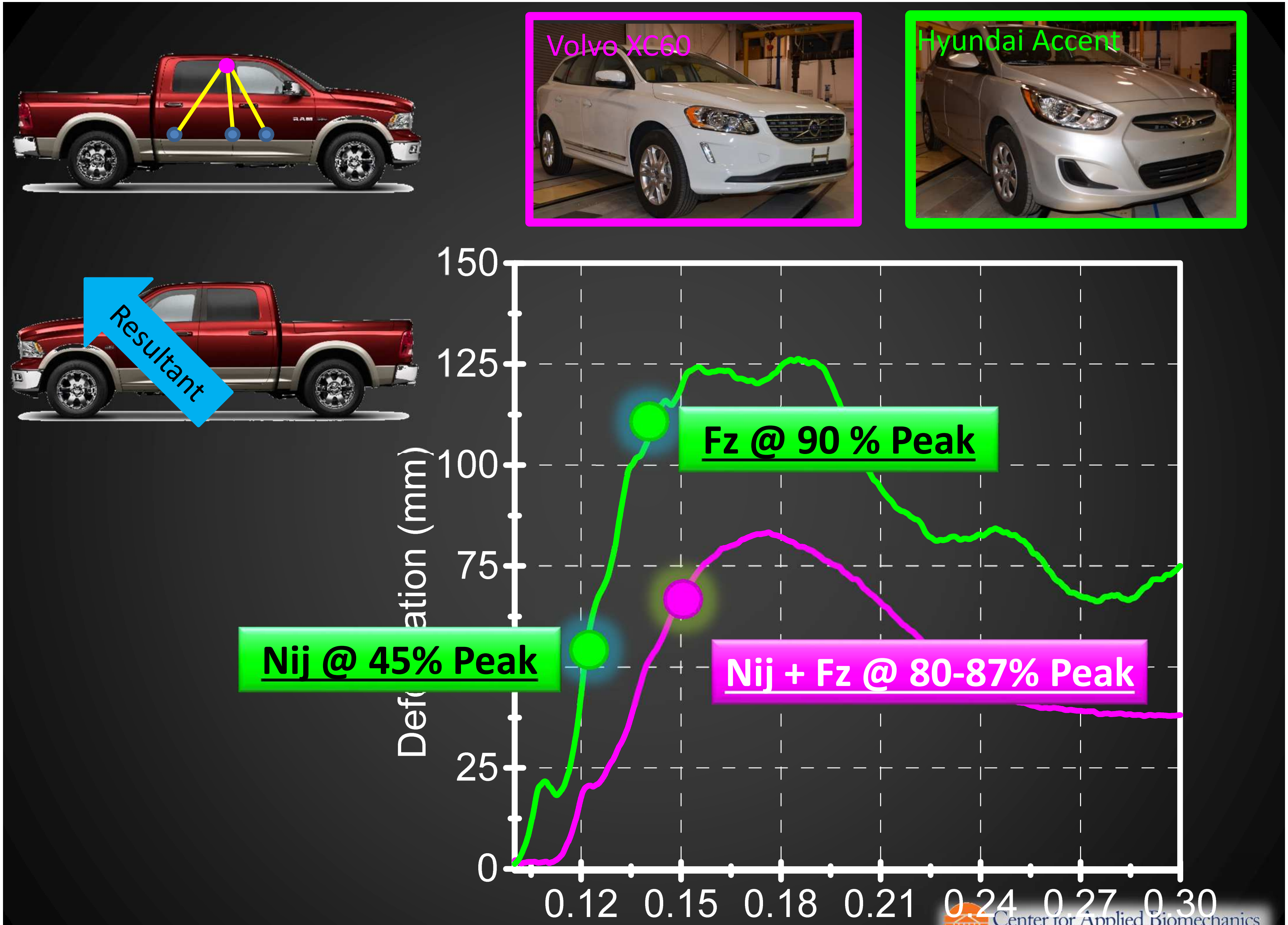
Injury Risk

Volvo XC60

Nij (CE) = 1.25 @ 154 ms
Compression Force: 6220 N @ 149 ms
HIC15: 363 (135-139 ms)

Hyundai Accent

Nij (CE) = 1.55 (@ 122 ms)
Compression Force: 6022N @ 143 ms
HIC15: 51 (108-123 ms)


Volvo XC60
Hyundai Accent
Resultant
150
125
100
75
25
0
0.12
0.15
0.18
0.21
0.24
0.27
0.30
Time (s)
Fz @ 90 % Peak
Nij @ 45% Peak
Nij + Fz @ 80-87% Peak
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Roof Strength:
Peak Strength to Weight Ratio

IIHS Predicted?

Same SWR
Similar Injury
Risk Prediction

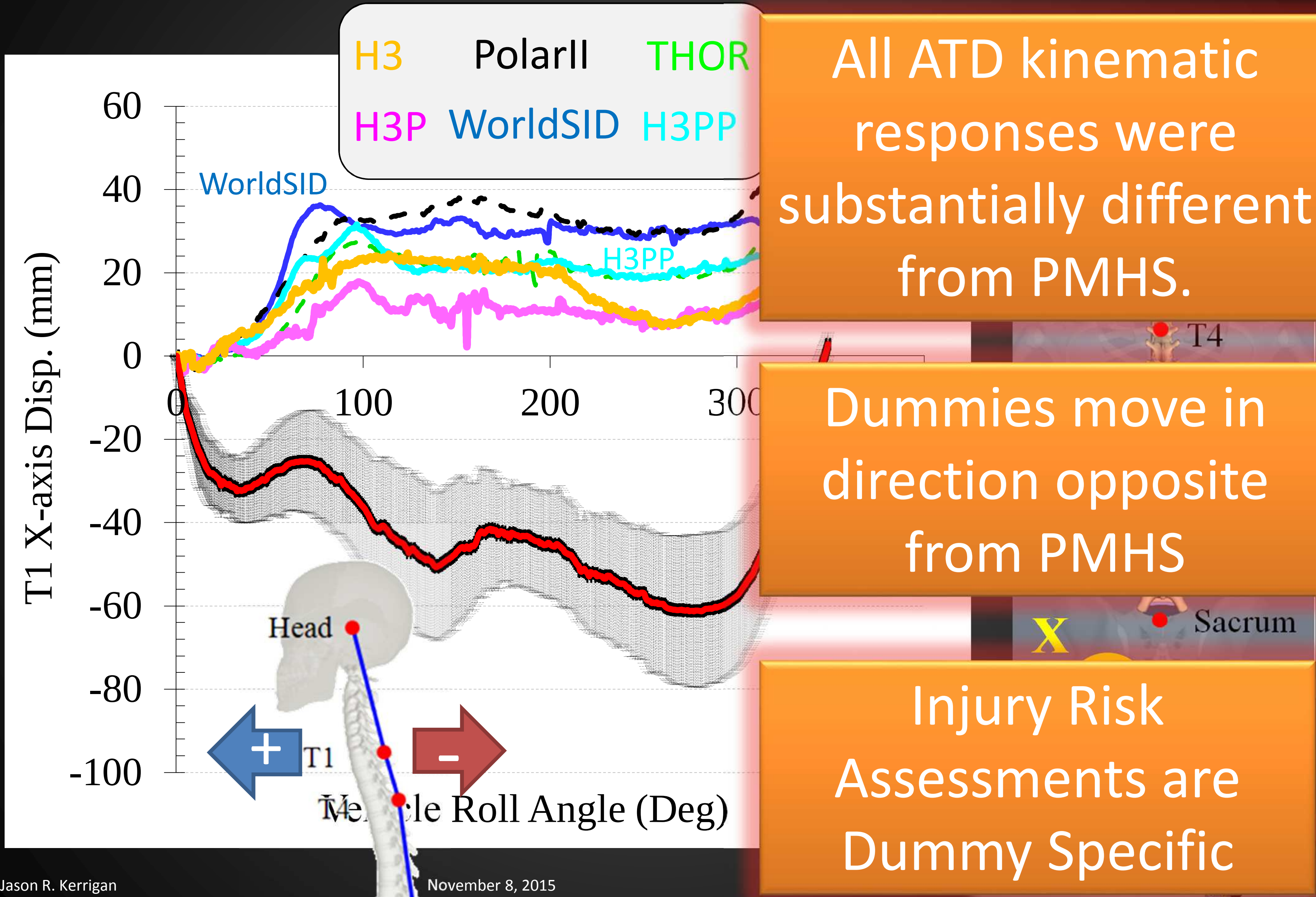
Injury Risk:
Head, Neck, Face, Spine

Roof Deformation:
Intrusion

Same SWR
50%-250%
more
deformation

Similar Injury
Risk Prediction
50%-250% more
deformation

2014 STAPP Conference: Zhang et al., Lessley et al.



All ATD kinematic responses were substantially different from PMHS.

Dummies move in direction opposite from PMHS

Injury Risk Assessments are Dummy Specific

Conclusions

- Despite similar kinematics, vehicles had vastly different deformations
- Static Roof Crush Resistance (SWR)→
  - Does not correlate with Dynamic or Final (Plastic) Deformation
  - Roofs unload to 45-61% of peak deformation
- Using the Hybrid III→
  - Similar injury risk for vastly different deformations
- For these two vehicles, in this one condition:
  - Should consider other vehicles and conditions

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