

# Consideration of Head/Face Trauma, Intruding Door Velocity, and Spine Flexibility for Children in Side Impact

Lilly Nix, Paul Scullion, Richard M. Morgan, Pradeep Mohan, Vinay Nagabhushana, Leyu Wang, Vishal Sangade, Kennerly H. Digges, and Cing-Dao Kan

– *George Washington University*

Tony M. Lamb – *Johnson Controls Inc.*



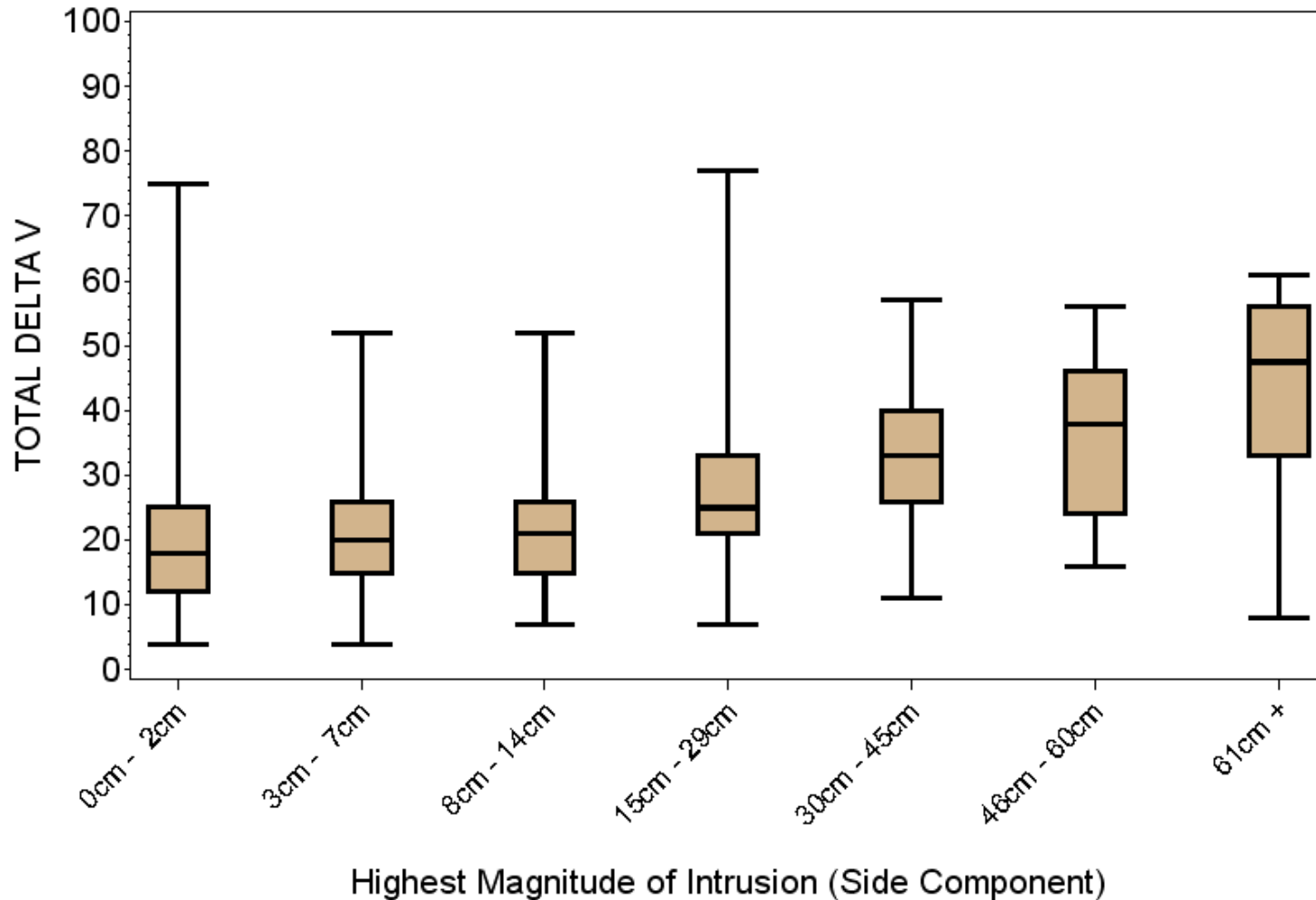
# Outline of Presentation

- Risk of head and face Harm to children in struck-side impact based on **field data**
- Influence of interior door velocity on HIC for the struck-side 6-year-old child
- Kinematics comparison of both a rigid-spine and a flexible-spine ATD for the struck-side 6-year-old child

# Field Data - NASS/CDS Case Selection Criteria

- NASS/CDS years 1993-2008
- Passenger Cars or Minivans
- General Area of Damage to Left or Right Side
- Vehicle did not Rollover during collision
- Occupants aged 1 to 13 years old.
- Occupants seated in the rear row(s) and adjacent to the struck side of the vehicle.
- Occupants were not ejected from vehicle.
- Occupants had known injury severity.

# Delta V versus Intrusion of Side Interior

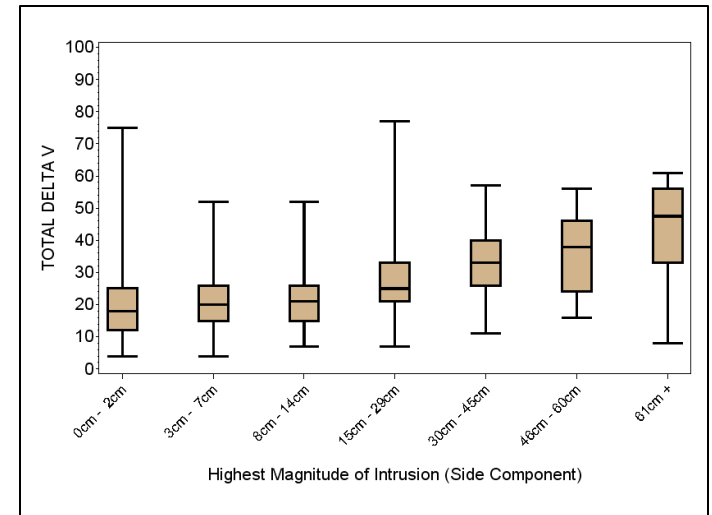


ANOVA: f-value 40.42 (Pr <0.0001) R<sup>2</sup> 0.173165

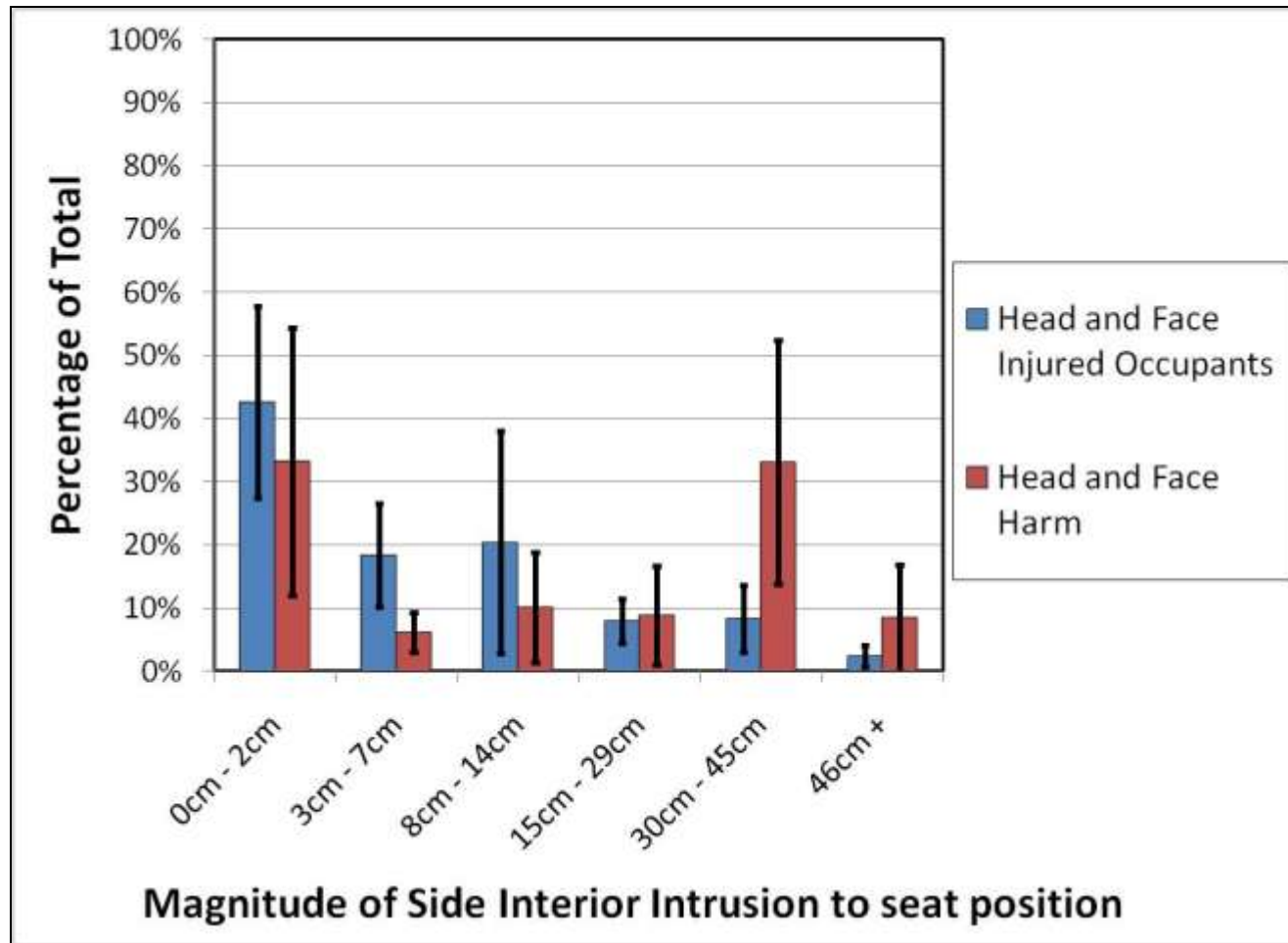
\*non-weighted

# Delta V - Intrusion of Side Interior

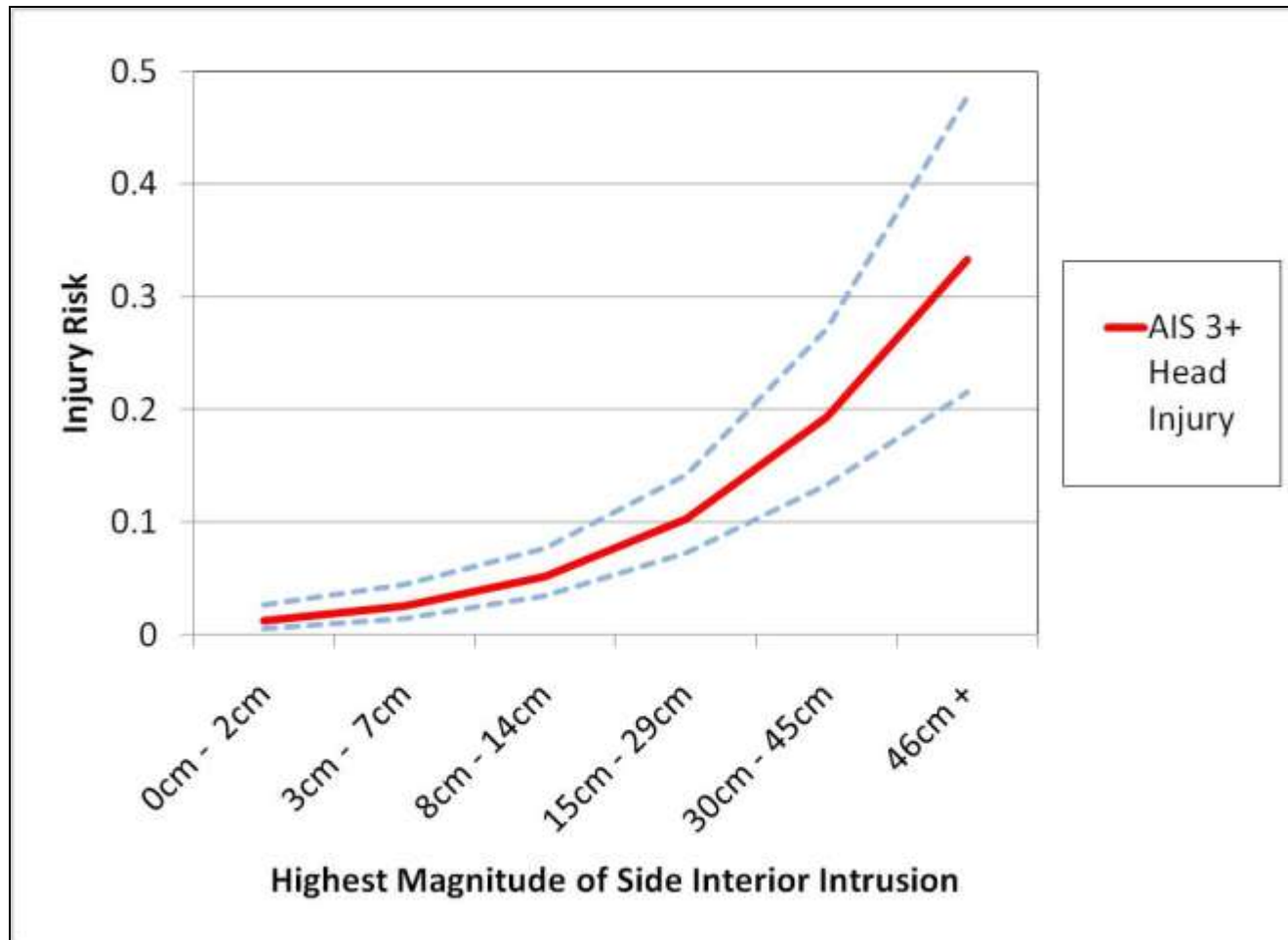
- $\Delta V$  might not be the only important crash severity parameter for struck-side lateral impact
- Interior door panel may reach max value and hit occupant before max  $\Delta V$  of vehicle
- Relative velocity of door may be more related to closing speed between vehicles than  $\Delta V$  of struck vehicle



# Intrusion of Side Interior Head & Face Injuries and Harm – Ages 1 – 13 YO



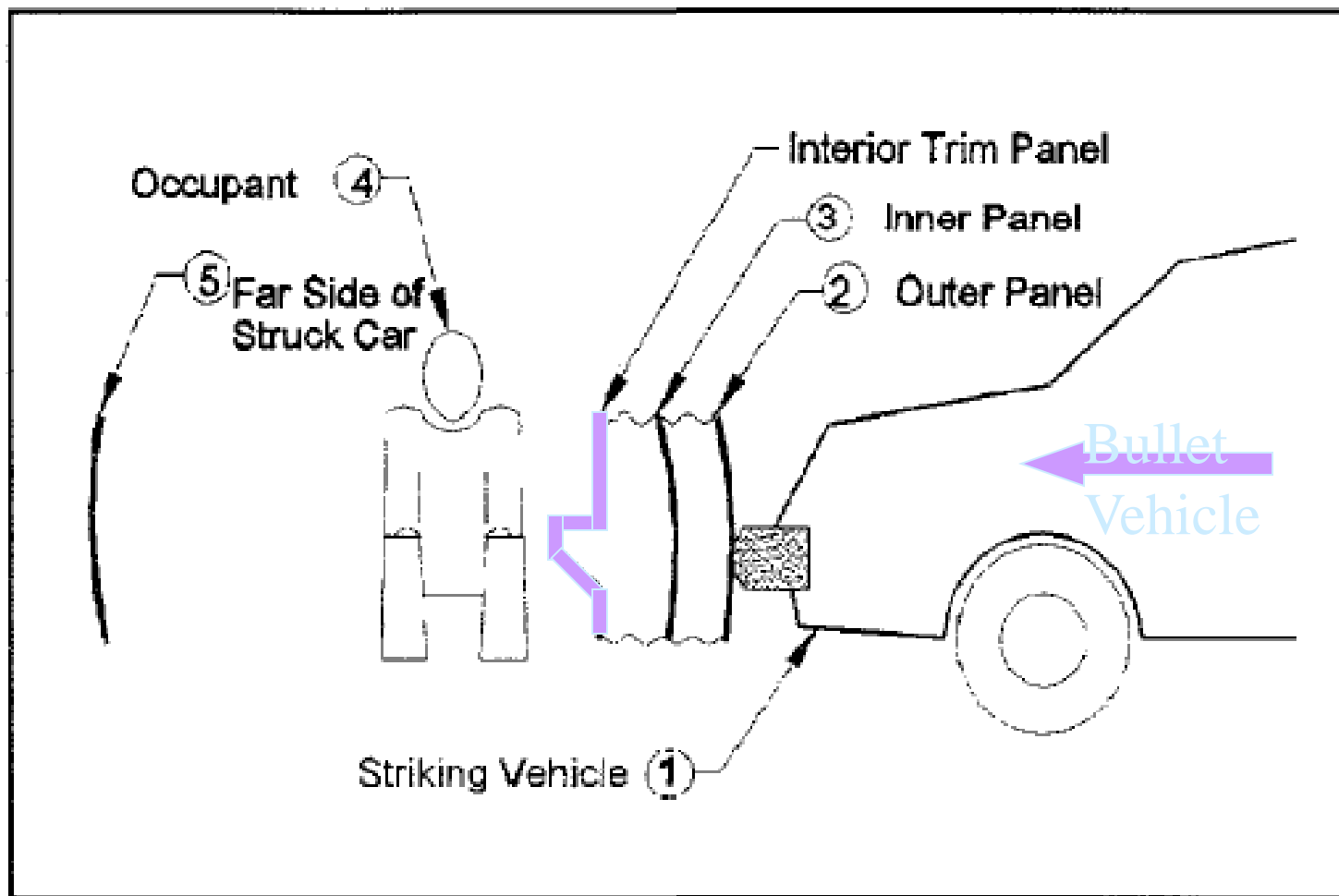
# Child Head Injury Risk & 95% Confidence Limits for Intrusion of Side Interior



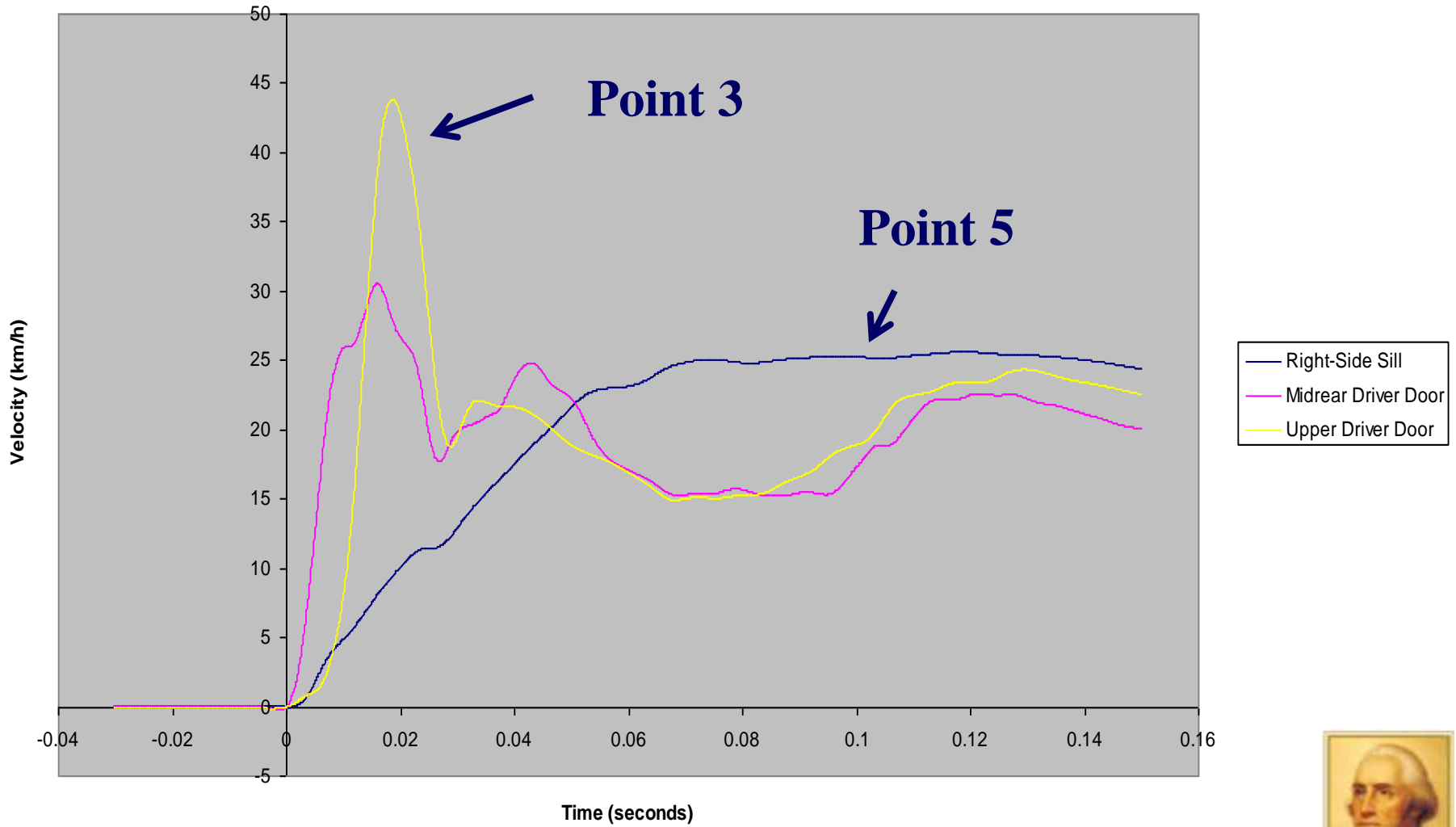
# Outline of Presentation

- Risk of head and face Harm to children in struck-side impact based on field data
- INFLUENCE OF INTERIOR DOOR VELOCITY ON HIC FOR THE STRUCK-SIDE 6-YEAR-OLD CHILD
- Kinematics comparison of both a rigid-spine and a flexible-spine ATD for the struck-side 6-year-old child

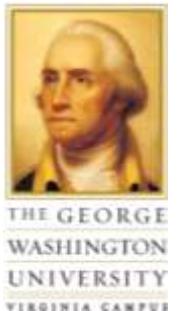
# IDEALIZED Interior Door Velocity - Door and Essential Locations for a Velocity-versus-Time Diagram of an Idealized Side Impact



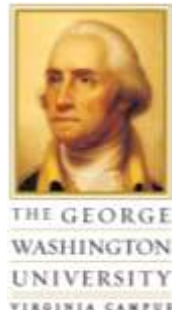
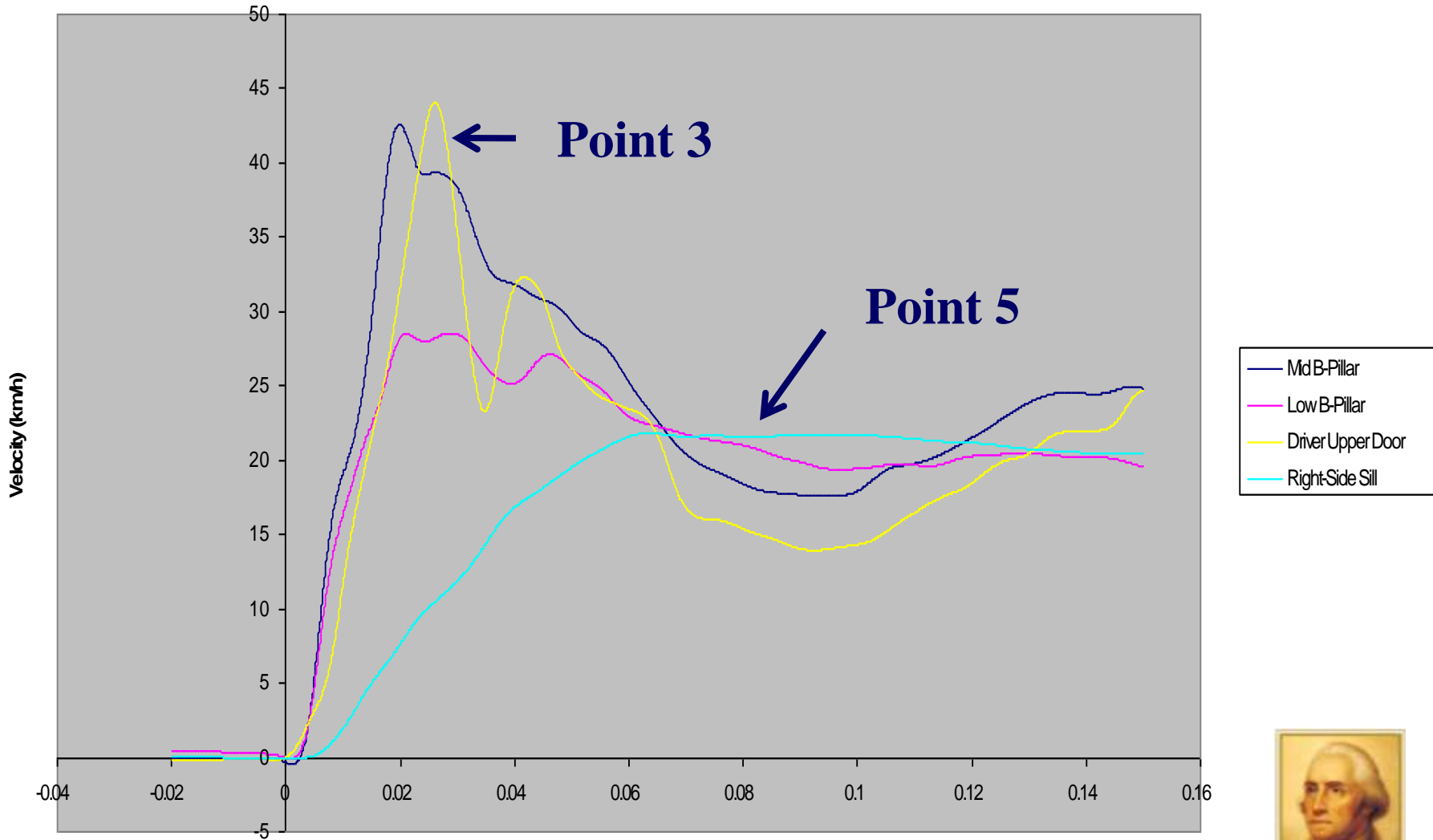
# NCAP Side Impact of Model Year 2001 Mitsubishi Galant



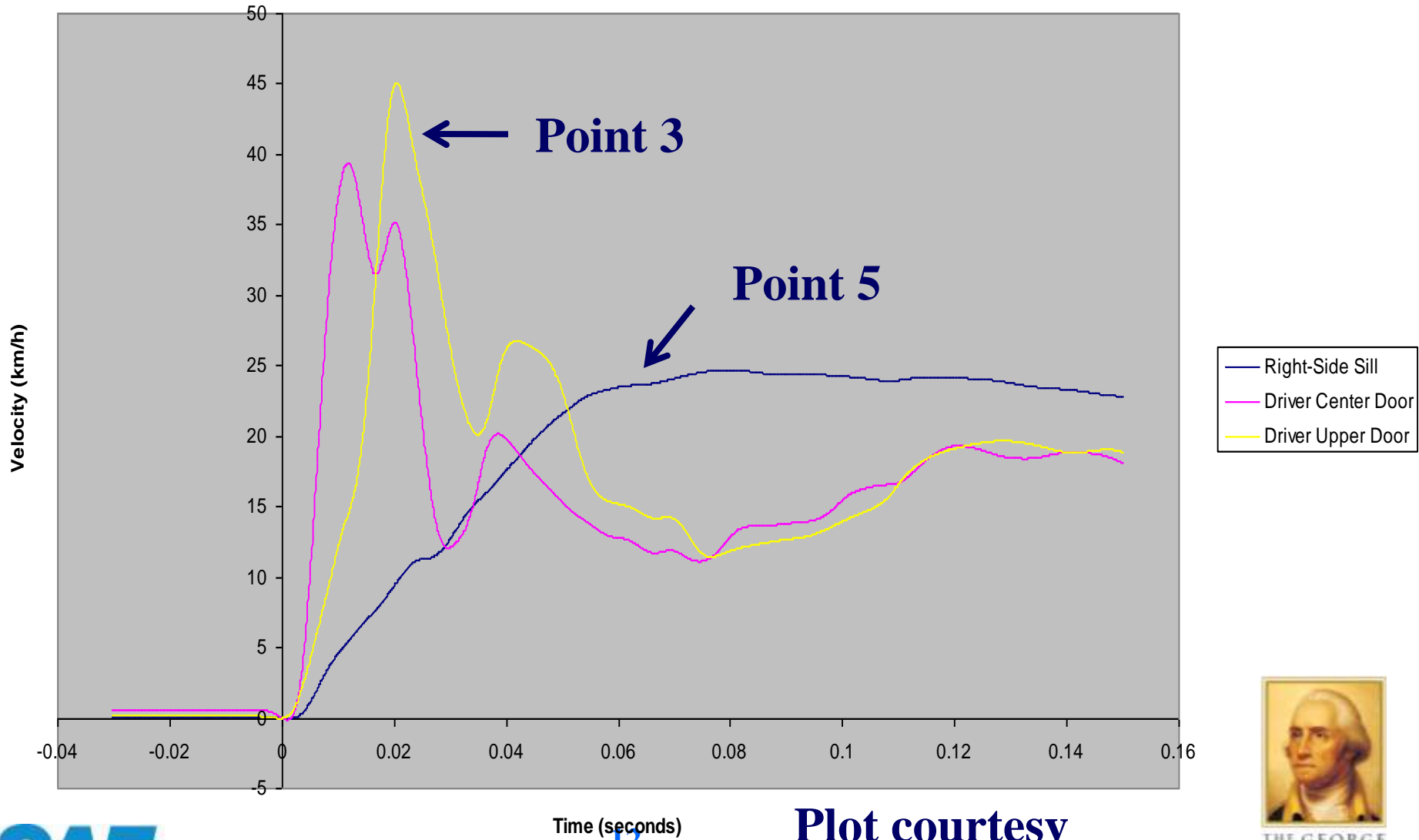
Plot courtesy  
Cristina Echemendia



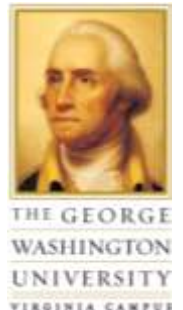
NCAP Side Impact Test of Model Year 1999 Dodge Intrepid



# NCAP Side Impact Test of Model Year 2001 Dodge Stratus

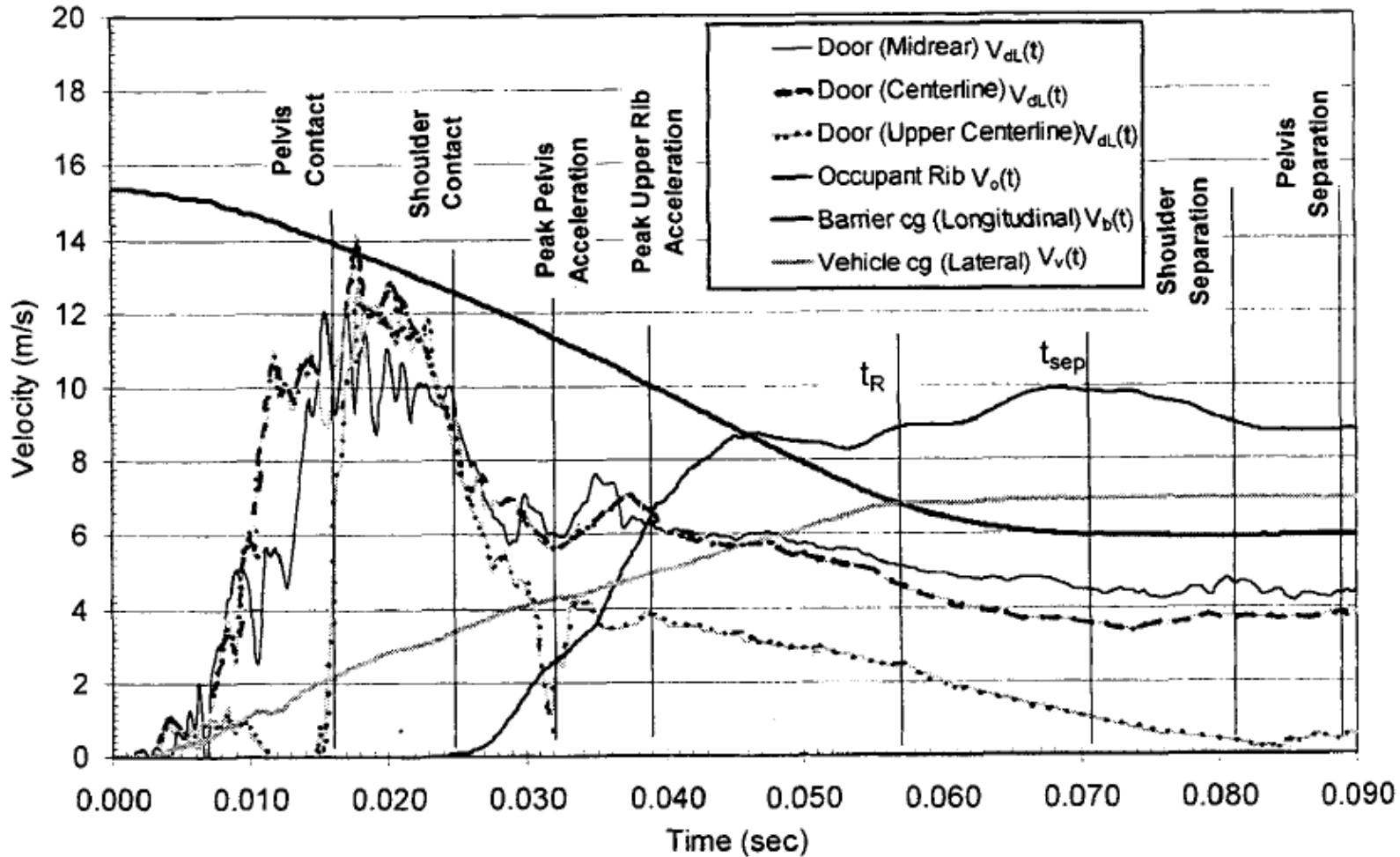


Plot courtesy  
Cristina Echemendia

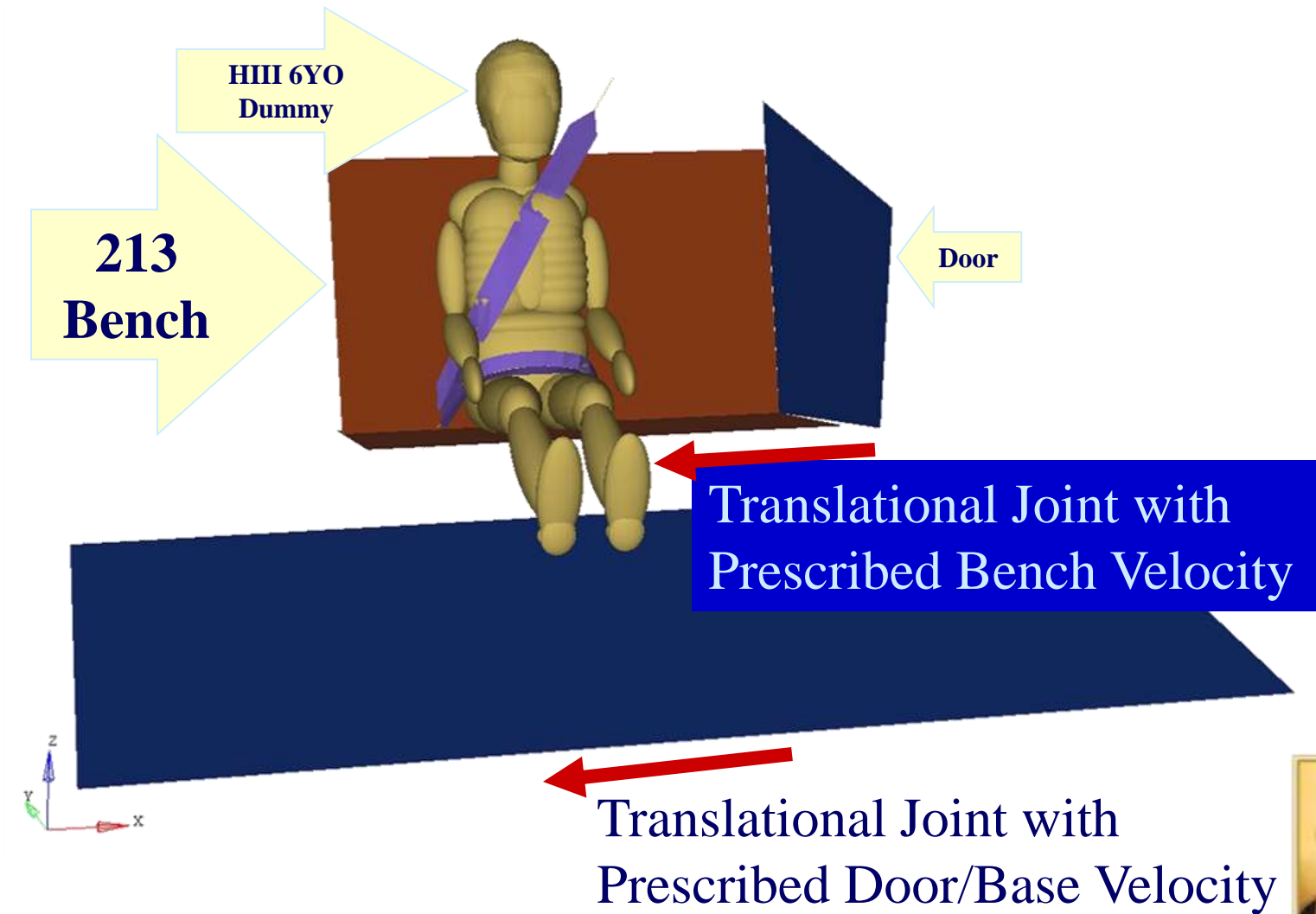


# Kent and Crandall, 2000

NHTSA Test Number 2970 - 1999 Honda Accord SINCAP



# MADYMO Side Sled Design with Intruding Door used for 6-year-old Child Simulations



# Simulations at 4 Different Intrusions

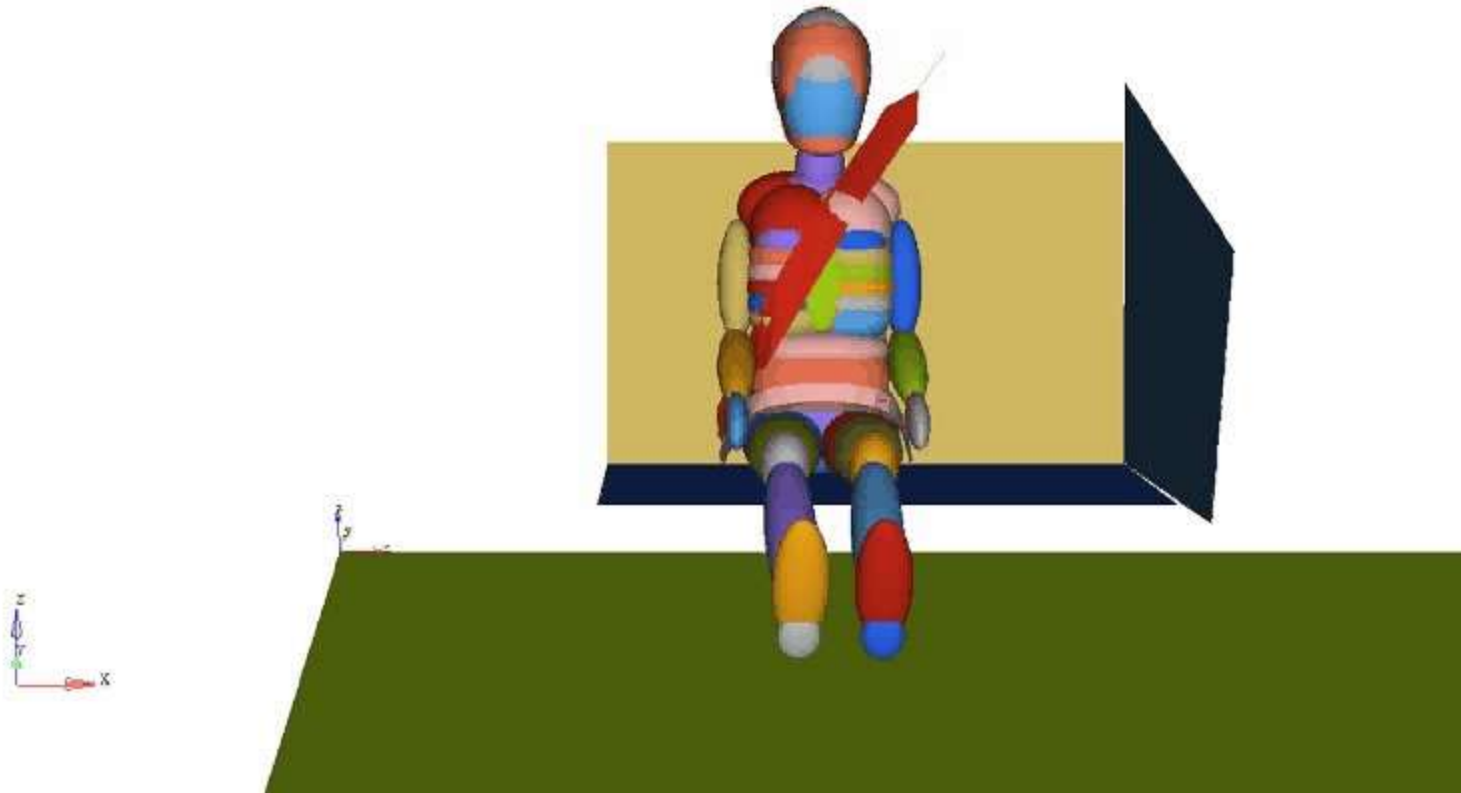
- Simulations conducted for 0, 100, 200, and 300-mm of intrusion
- Velocity versus time histories used for simulations were *idealized approximation* of actual crash data
- In these simulations, as intrusion increases, the speed of the inner door increases.
- In all simulations, the final speed of vehicle set at 33-km/h

# Example of Idealized Velocity - Time Input used in Simulation at 200-mm



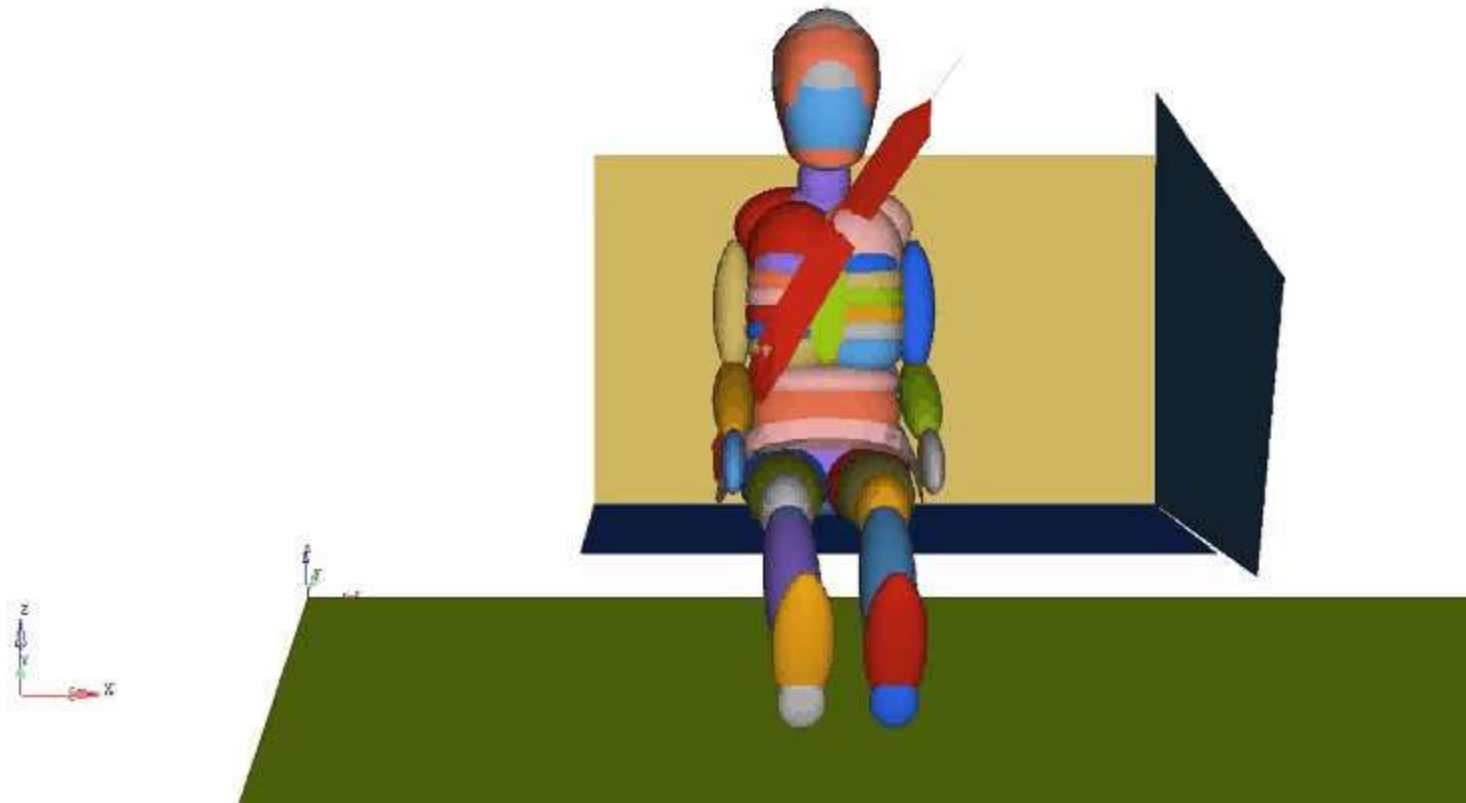
# Simulation – Zero Intrusion of Interior Door – 6-year-old child Hybrid III

Hybrid III 6YO  
No Intrusion  
Time = 0.000000

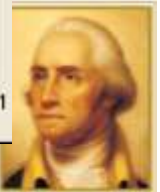
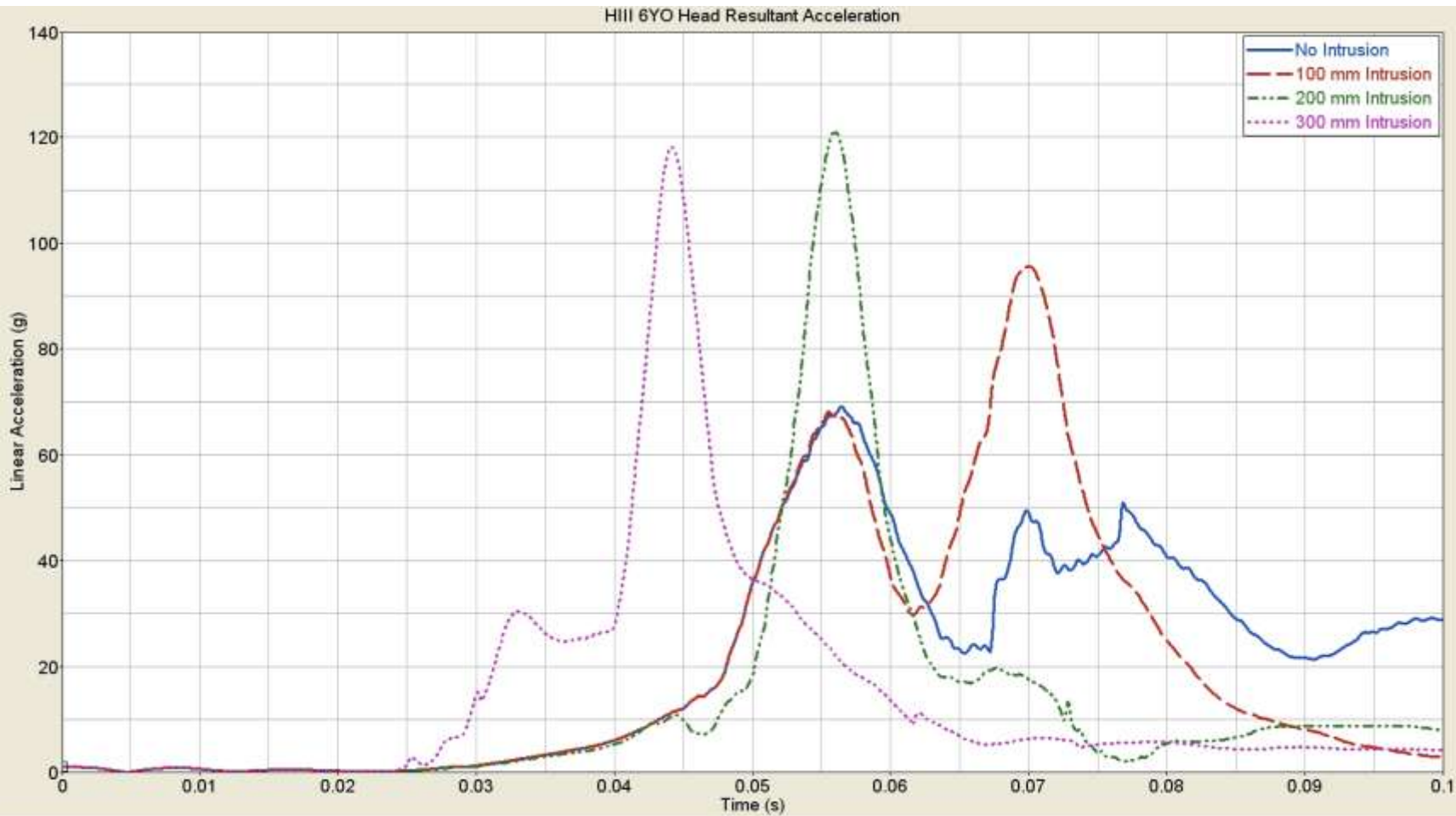


# Simulation – 100-mm Intrusion of Interior Door – 6-year-old child Hybrid III

Hybrid III 6YO  
100 mm Intrusion  
Time = 0.000000



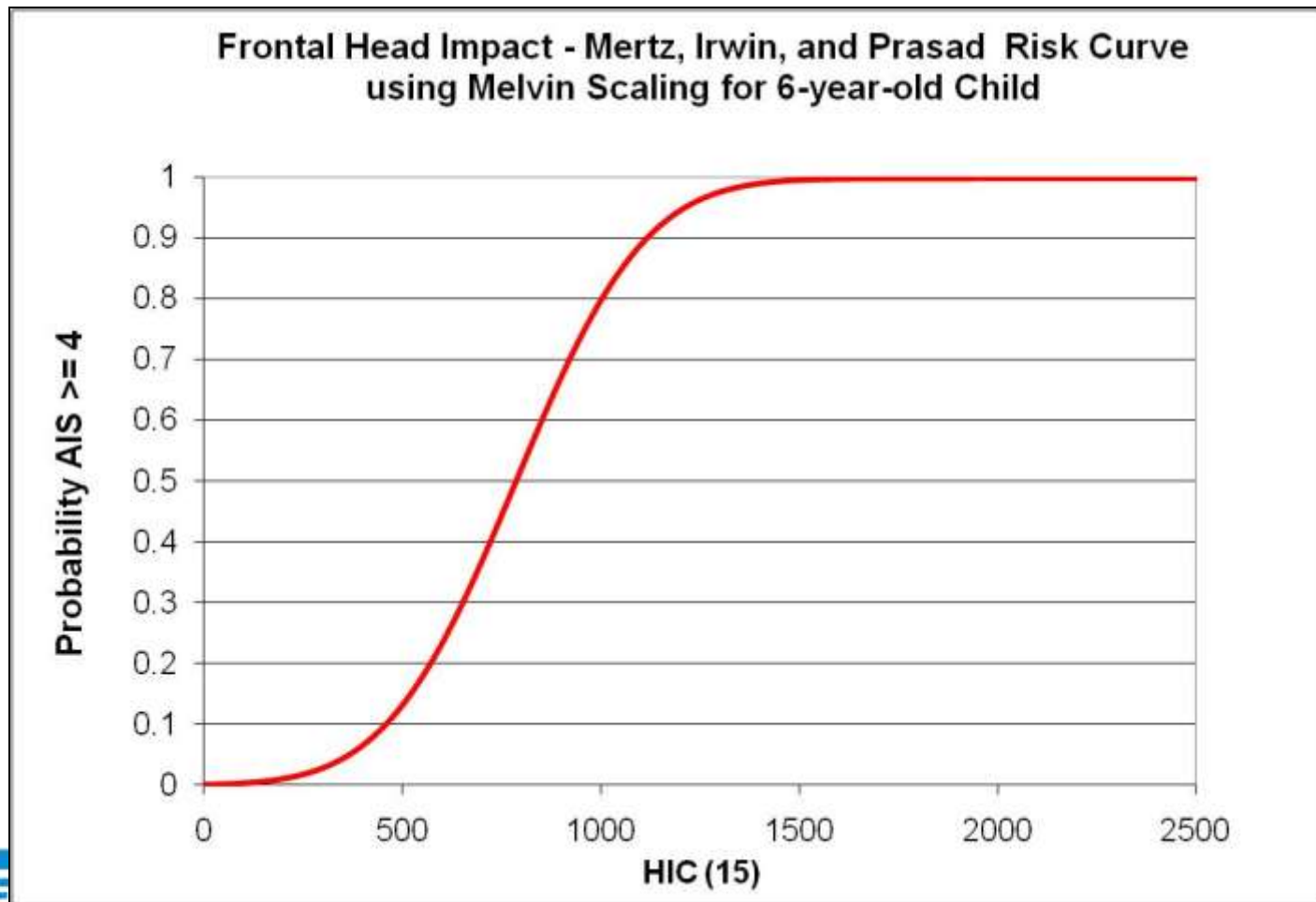
# Simulation Results – Head Accelerations for 4 Intrusions – 6-year-old child Hybrid III



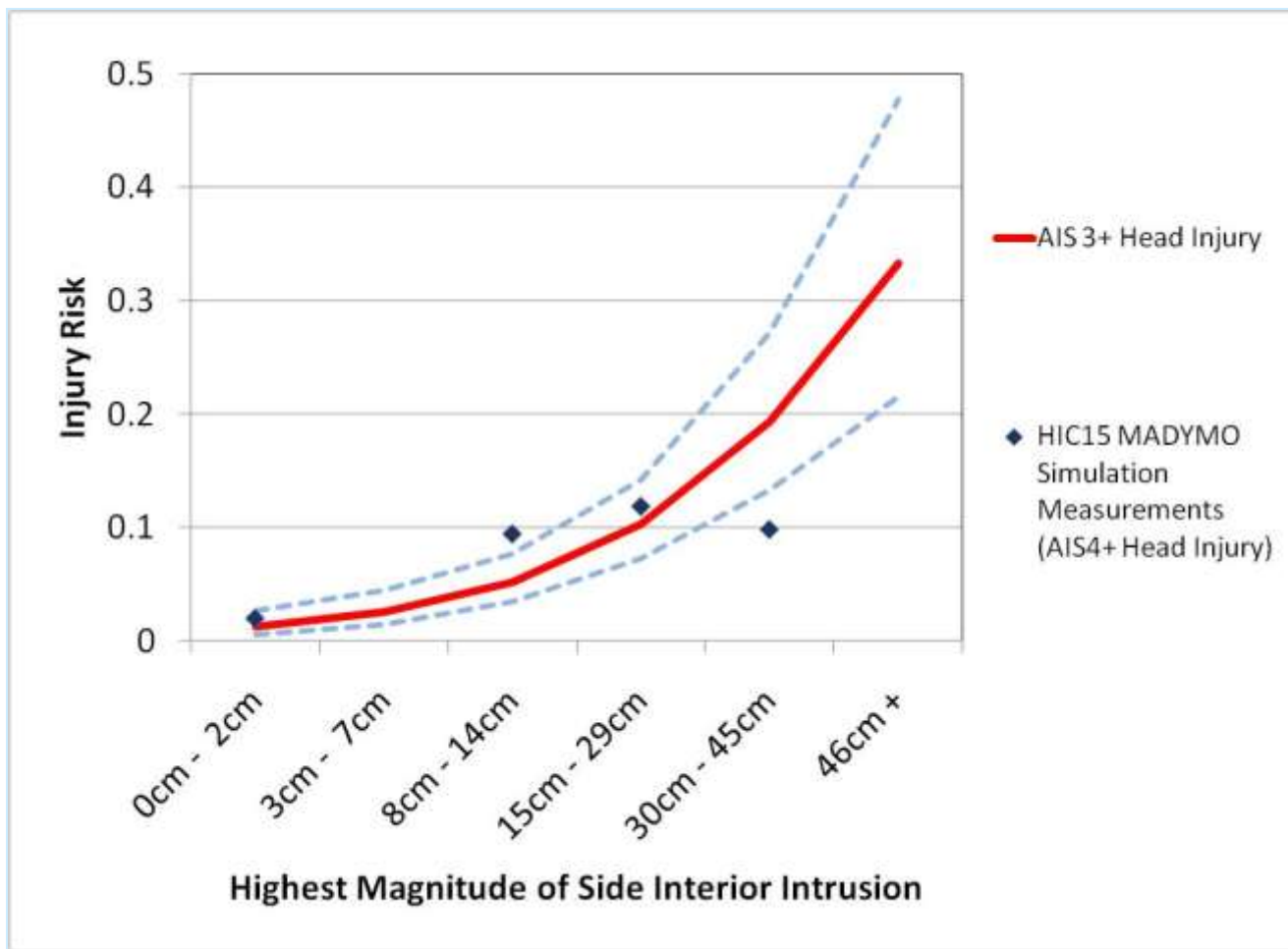
# Simulation Results for 4 Intrusions – 6-year-old Child Hybrid III

Intrusion (mm)	Peak Door Velocity (km/h)	HIC15
0	N/A	265
100	24	451
200	38	561
300	53	457

# Risk curve for the Head of 6-year-old Child (Mertz, Irwin, Prasad 2003, Melvin 1995, and Eppinger 2000)



# Head Injury Risk & 95% Confidence Limits for Intrusion of Side Interior – Risk by Intrusion-Type Simulation



# Outline of Presentation

- Risk of head and face Harm to children in struck-side impact based on field data
- Influence of interior door velocity on HIC for the struck-side 6-year-old child
- KINEMATICS COMPARISON OF BOTH A RIGID-SPINE AND A FLEXIBLE-SPINE ATD FOR THE STRUCK-SIDE 6-YEAR-OLD CHILD

# Flexibility of Spine in Standard Belt-

## Sherwood et al. (2002)

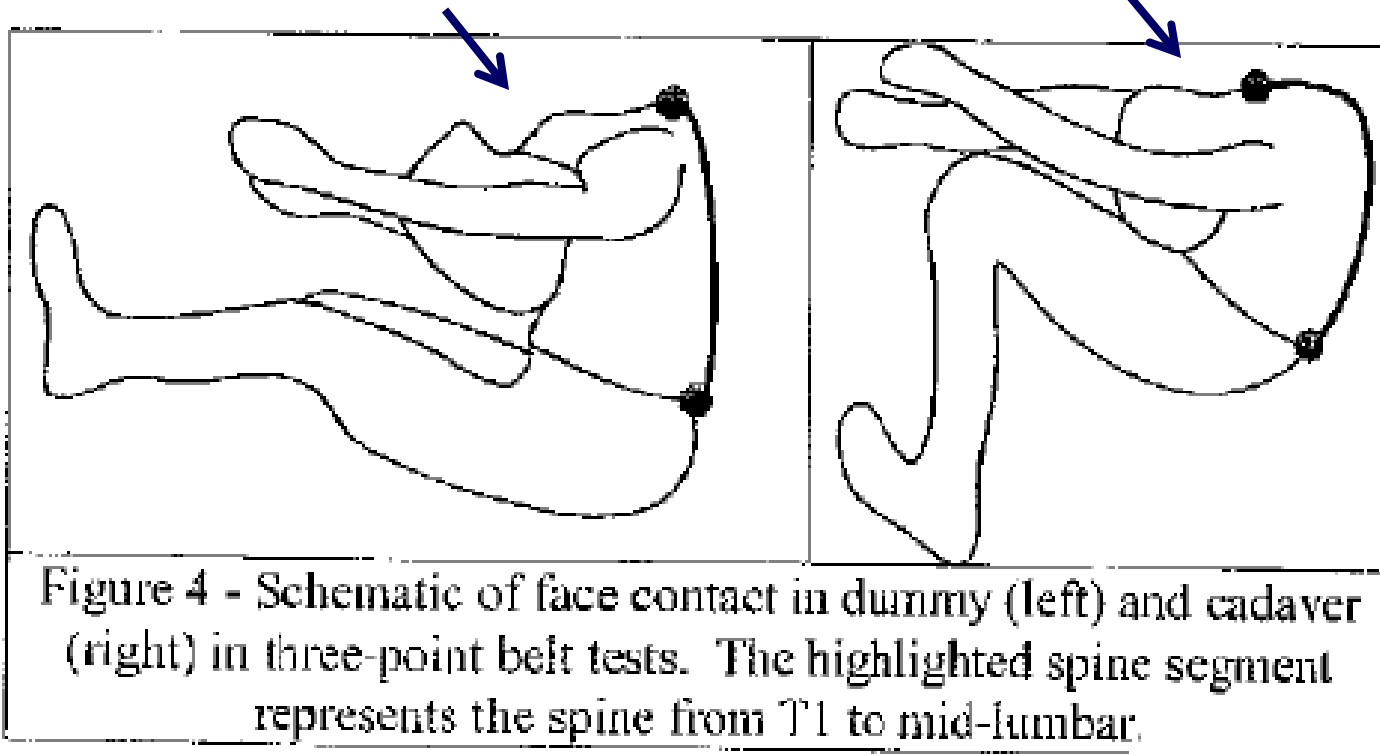
- Sled tested the 6-year-old child Hybrid III dummy and a 12-year-old child post mortem human surrogate (PMHS) both restrained by a 3-point belt system and high-back booster.
- For the Hybrid III, significant cervical spine flexion with minimal thoracic and lumbar flexion.
- In contrast, the PMHS's head flexion was the result of bending along the entire spine.

# Flexibility of Spine in Standard Belt-

## Sherwood et al. (2002)

6YO Child Hybrid III

12YO PMHS

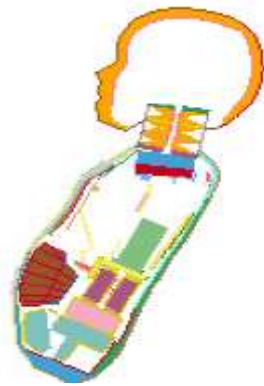


# Flexibility of Spine in Forward Facing CRS – Zhang et al. 2007

- Zhang et al. (2007) compared the kinematics of a finite element model of the human 3-year-old child (THUMS) with a finite element model of the 3YO Hybrid III dummy.
- Test setup was a frontal sled test at 48-km/h.
- Higher flexion of the upper torso and the neck was observed for the human child model.

# Flexibility of Spine in Forward Facing CRS – Zhang et al. 2007

**3YO Child  
Hybrid III**



0 ms



40 ms



80 ms



120 ms

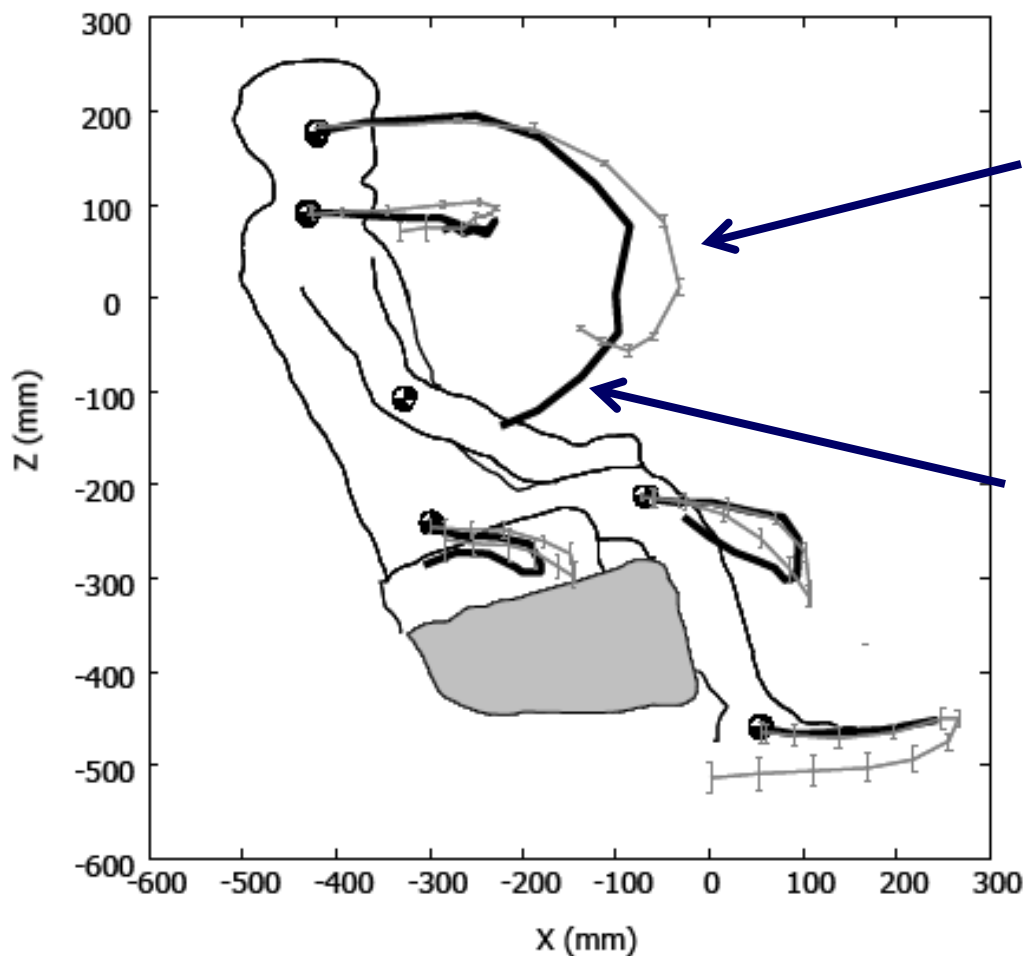
**3YO THUMS  
Human Child**



# Flexibility of Spine in Standard Belt – Lopez-Valdes et al. 2009

- Lopez-Valdes (2009) compared the kinematics of a 6YO child Hybrid III with child-size adult PMHS.
- Both Hybrid III and PMHS were positioned on booster seat with a standard 3-point belt in a frontal 48-km/h sled test.

# Flexibility of Spine in Standard Belt – Lopez-Valdes et al. 2009



Trajectory of head of  
6YO child Hybrid III

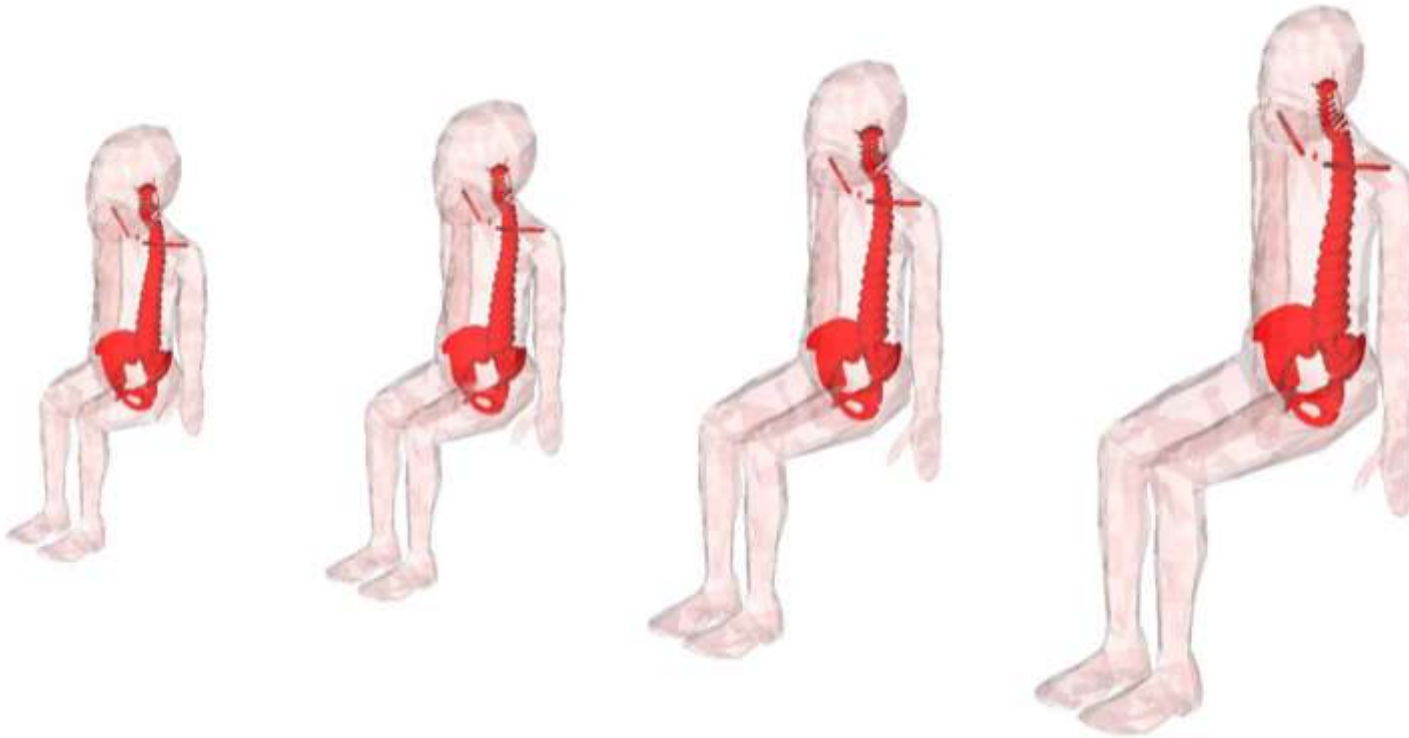
Trajectory of head of  
PMHS scaled to size of  
6YO

# Flexibility of Spine in Far-Side Impact

## – Alonso et al. (2007)

- Alonso et al. found motion of existing ATD was different from the motion of PMHS in oblique impacts and perpendicular side impact.
- Alonso suggested that the motion of PMHS can satisfactorily be reproduced by the human facet model (in MADYMO).

# Human Facet Model has a flexible spine by modeling each vertebra with individual rigid bodies



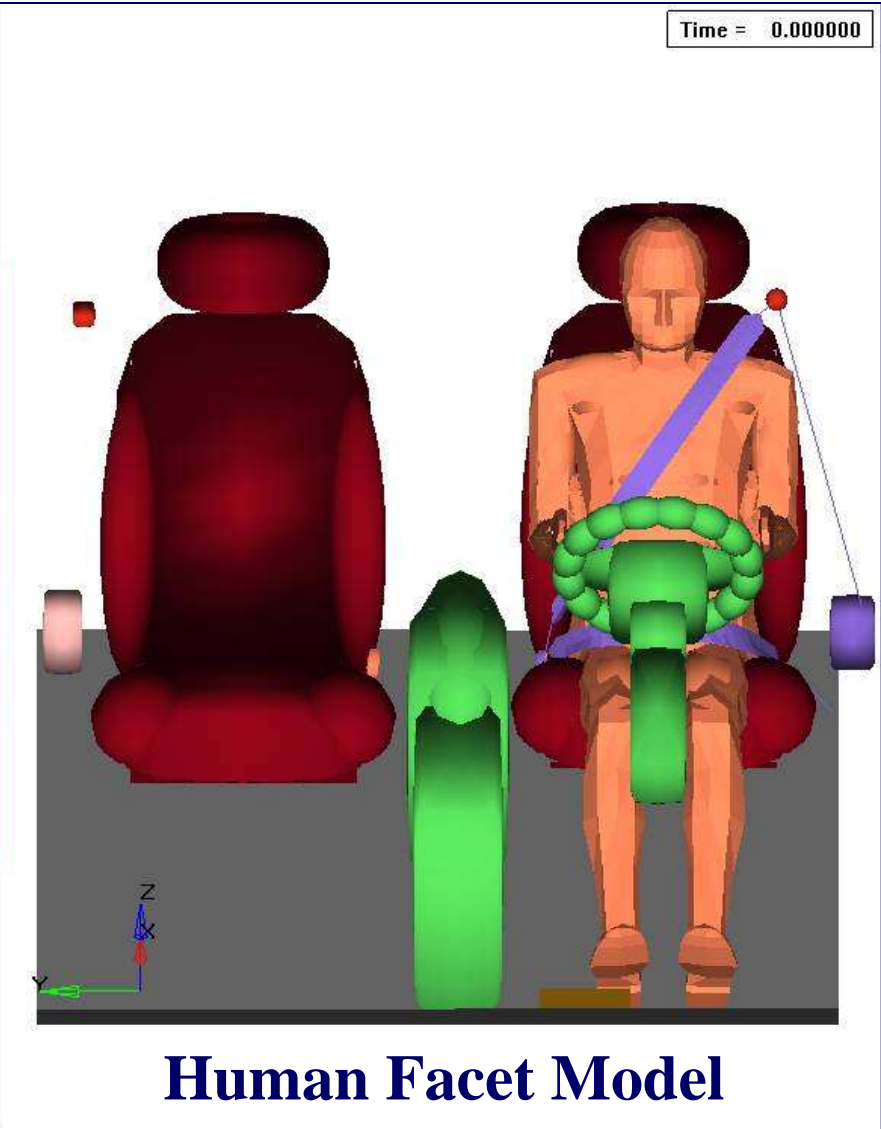
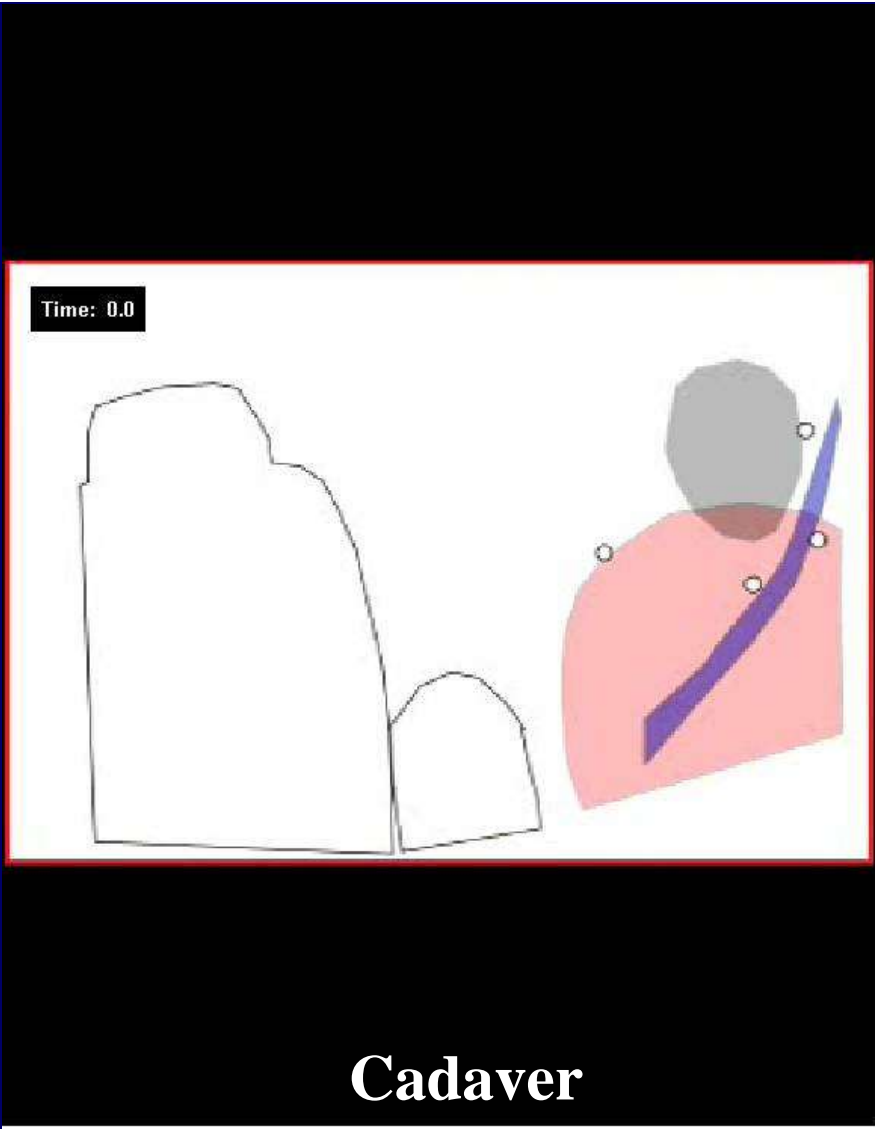
1.5yo

3yo

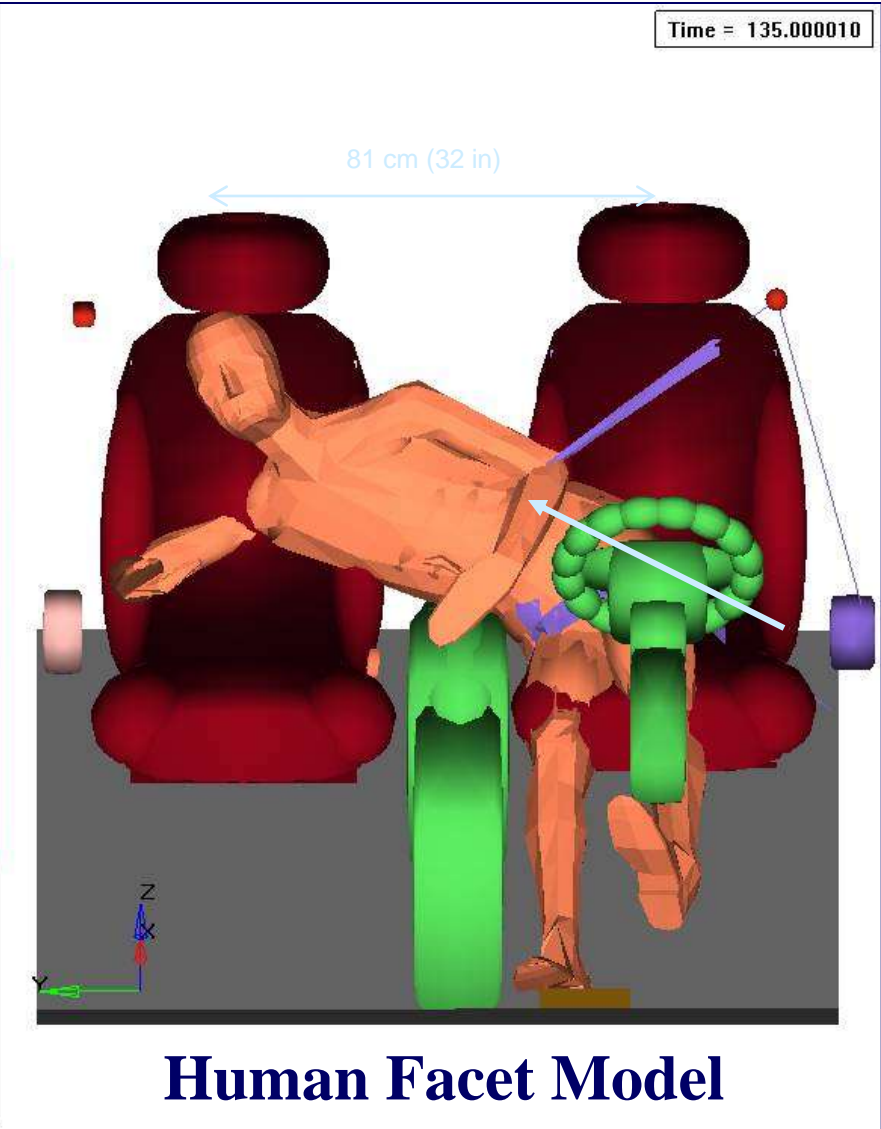
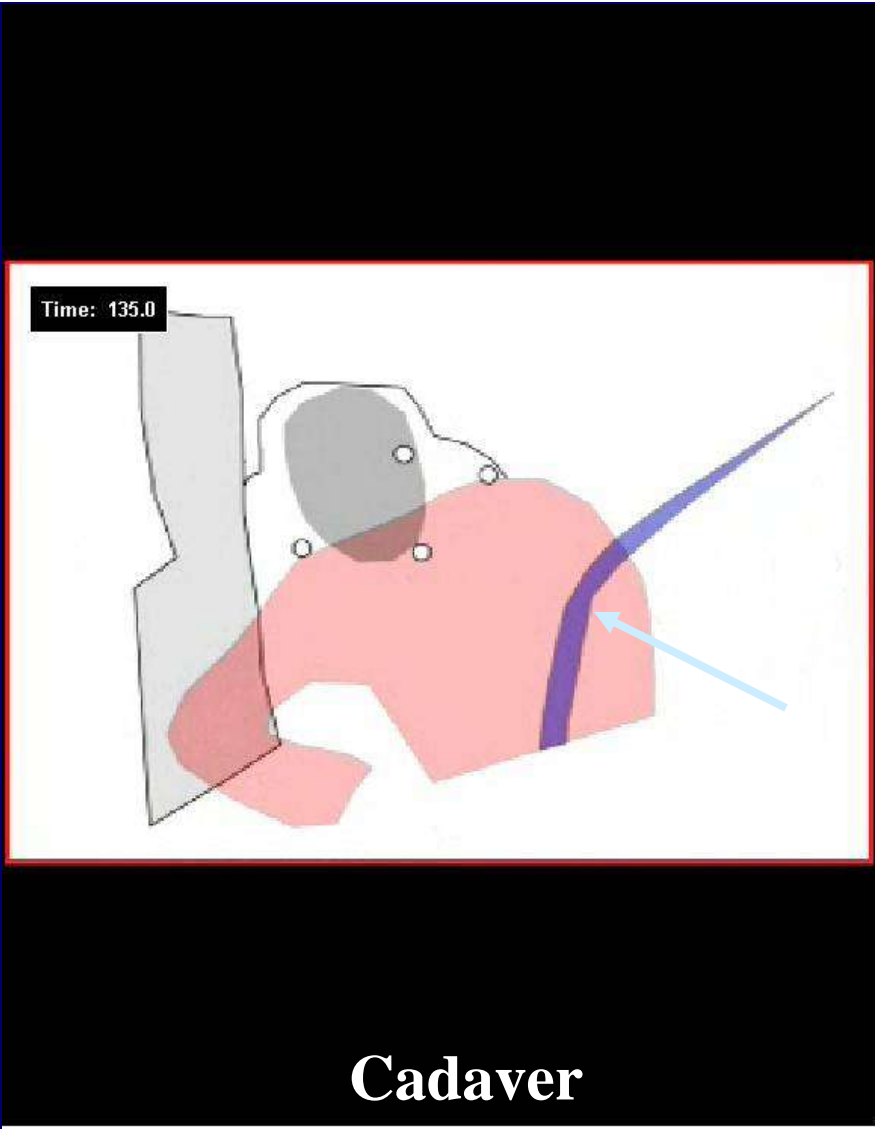
6yo

10yo

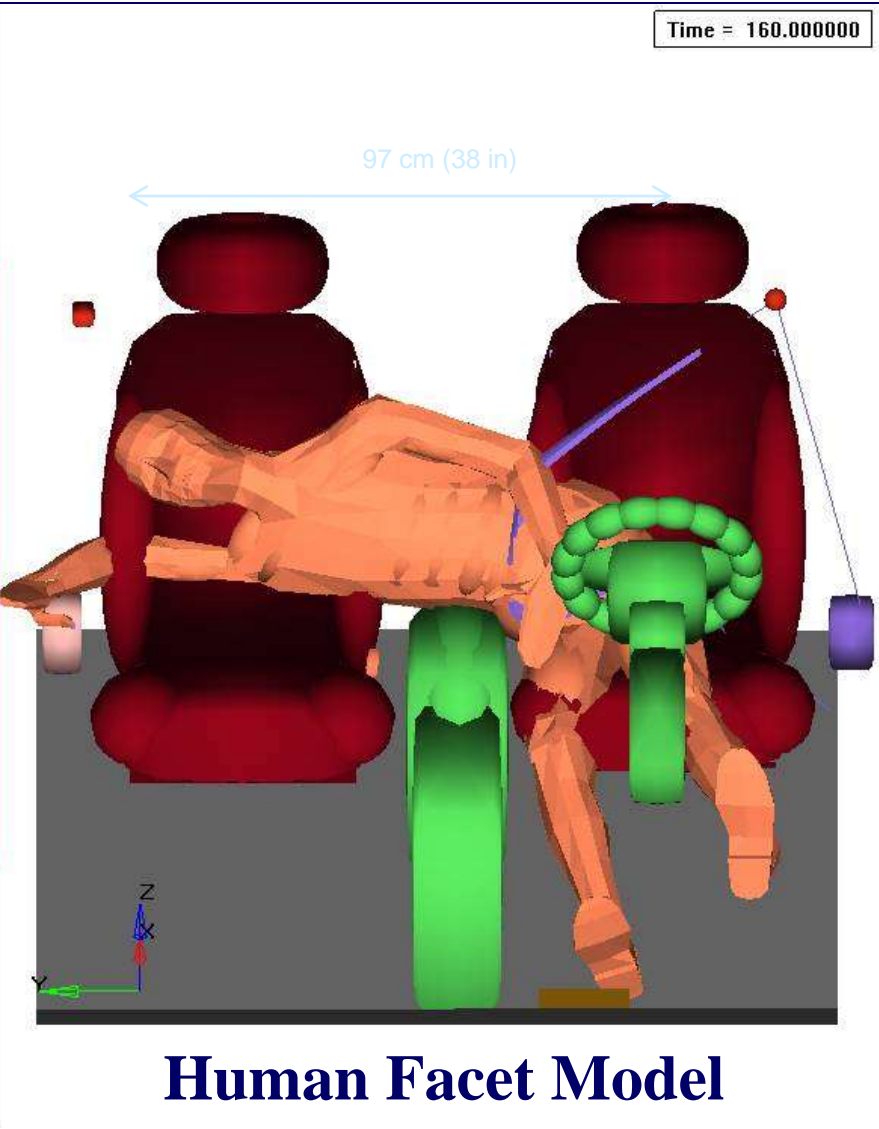
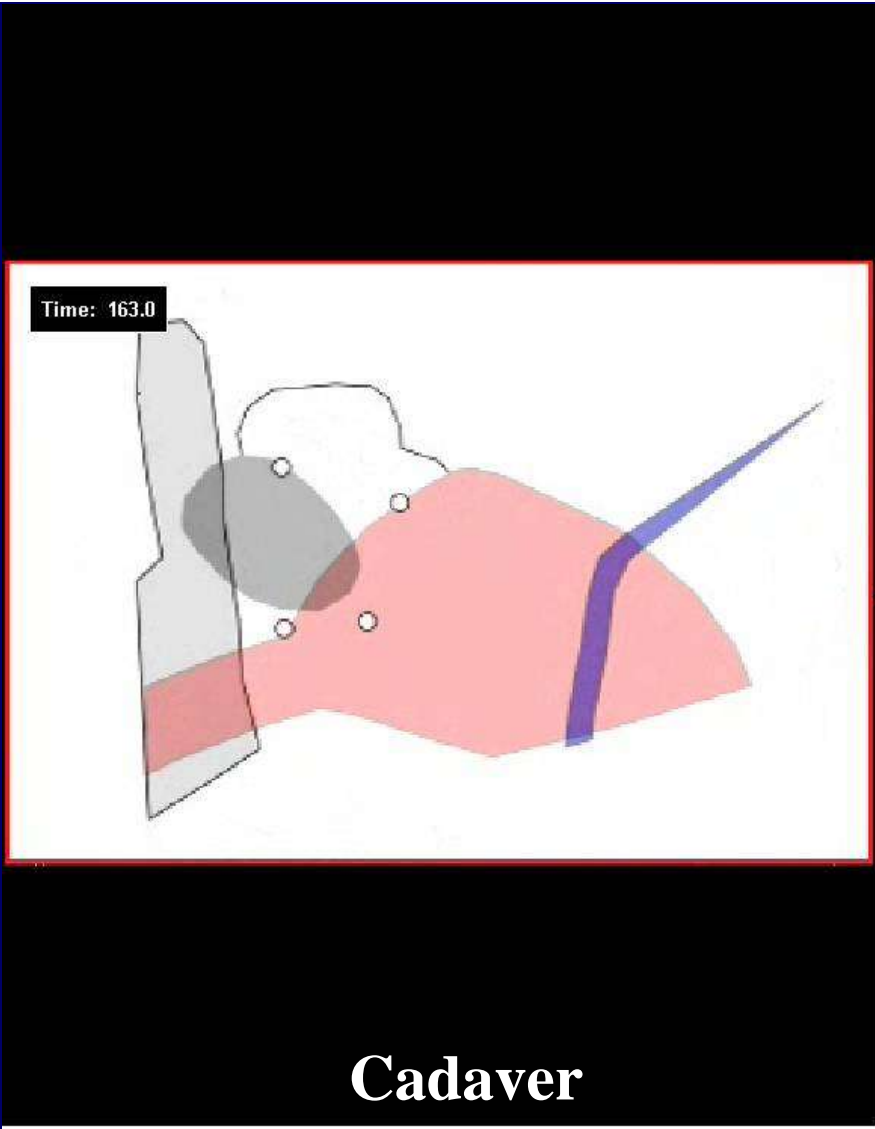
# PMHS vs. MADYMO Human Facet Model



# PMHS vs. MADYMO Human Facet Model



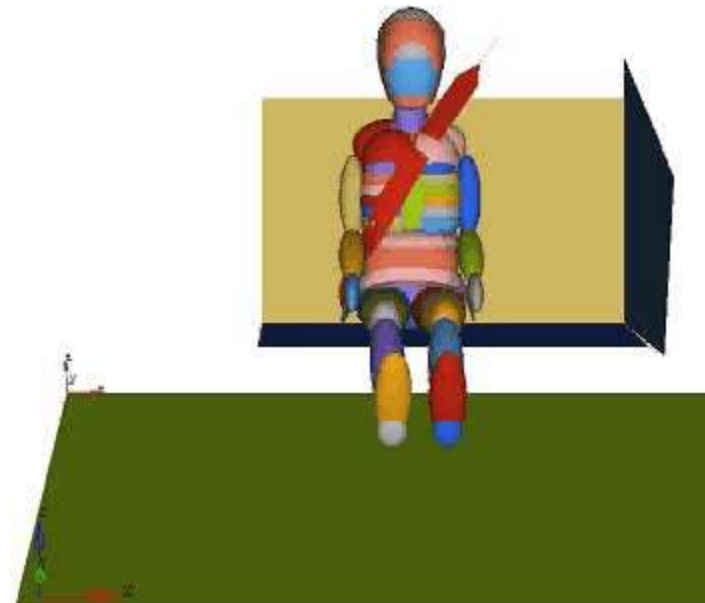
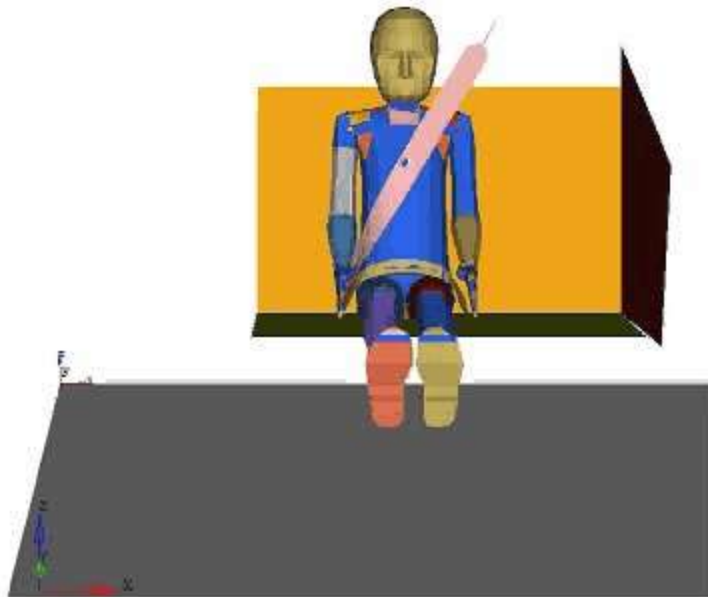
# PMHS vs. MADYMO Human Facet Model



# Simulations of Kinematics: Flexible-Spine vs. Rigid-Spine ATD

6YO Human Facet Model  
300 mm Intrusion  
Time = 0.000000

Hybrid III 6YO  
300 mm Intrusion  
Time = 0.000000



**Findings → Kinematics Appear Similar**

# CONCLUSIONS

- Side impact field data suggests that Harm to child on the struck side increases as interior door intrusion increases.
- While  $\Delta V$  of the struck vehicle is an important variable for safety, intrusion of the interior door seems to complement the  $\Delta V$  variable.
- Test data from side crashes in the laboratory suggest that the interior door may reach high velocity in the first 0 to 30-msec.

# CONCLUSIONS

- As MADYMO simulations increased the interior-door intruding velocity, the HIC 15 of the 6-year-old child increased into a risk of 20% and beyond. As the simulation predictions are near the 95% confidence limits of field data, the simulations need further progress to match the field data.
- Simulations combined with field data suggest that some crash scenarios may result in severe head/face trauma if 6-year-old child's head contacts the door during a higher-velocity phase of intrusion.

# CONCLUSIONS

- The kinematics of the occupant in some crash configurations depends significantly on the flexibility of the spine. These simulations suggest that the flexibility of the spine—in and of itself—does not appear to affect the kinematics of the 6-year-old child occupant on the struck side in a side impact.

# Thank You for Your Attention

