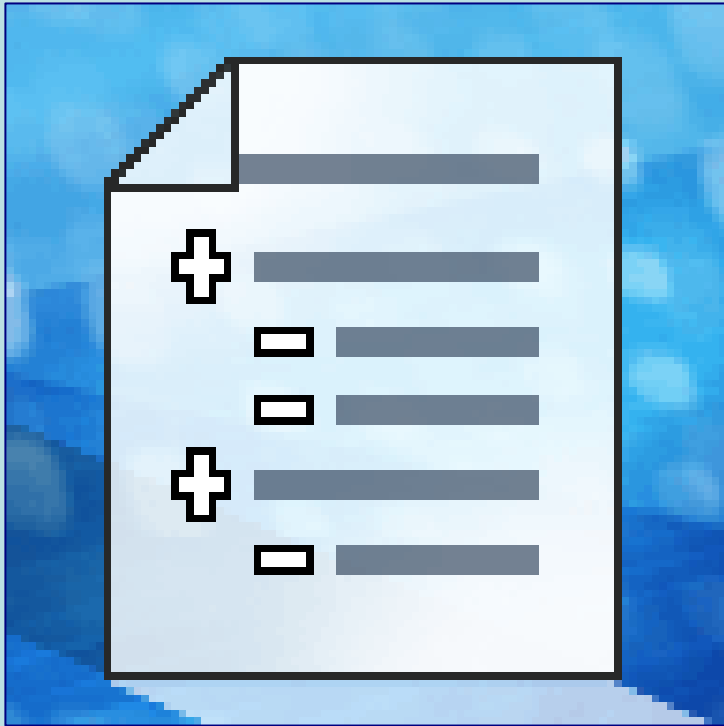


# Rollover Rates and Severity - Dynamic Testing Results

*Dr. Kennerly Digges*

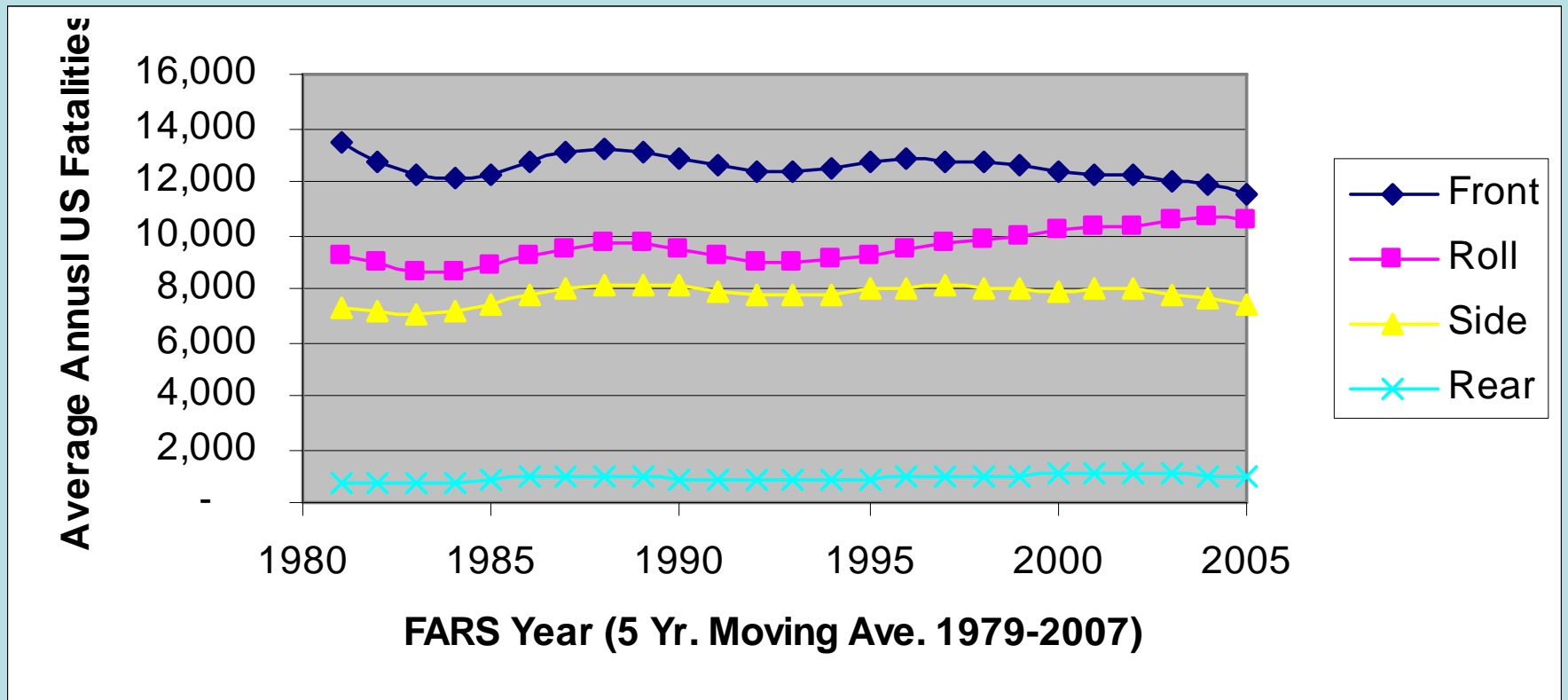
George Washington University  
Automotive Safety Research Institute (ASRI)

# Outline of Presentation

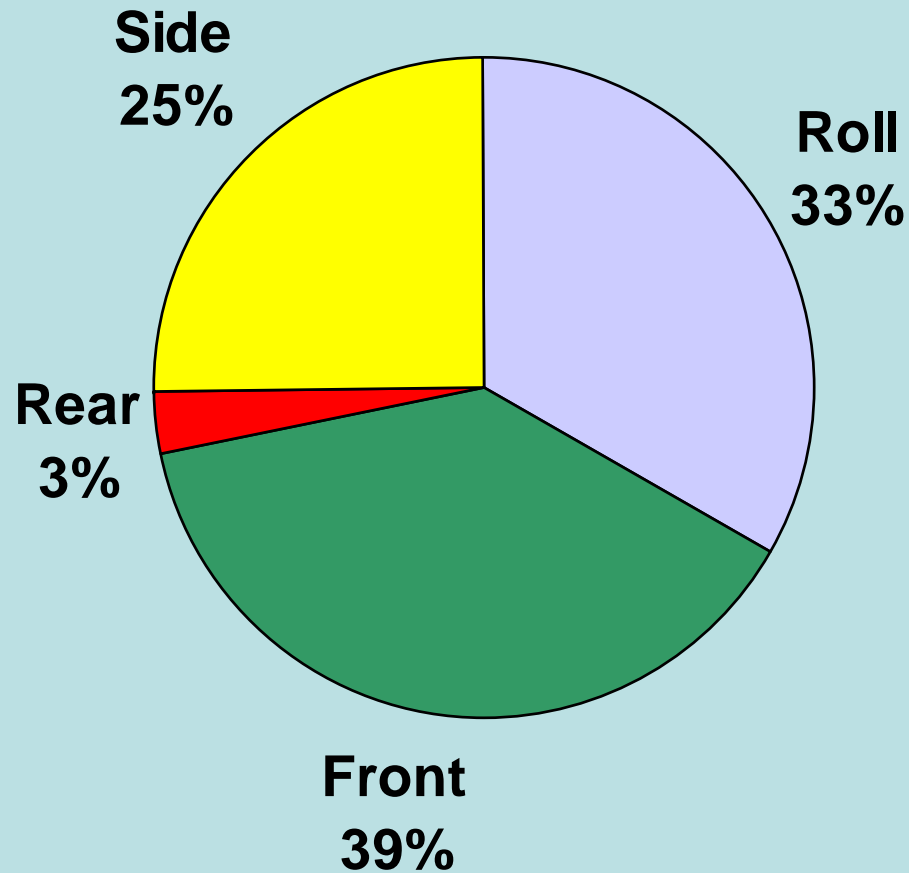


- FARS and NASS Data on Rollover
- Dynamic Test Results

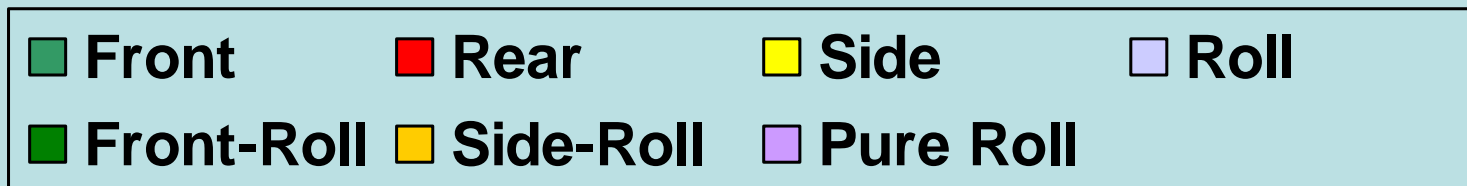
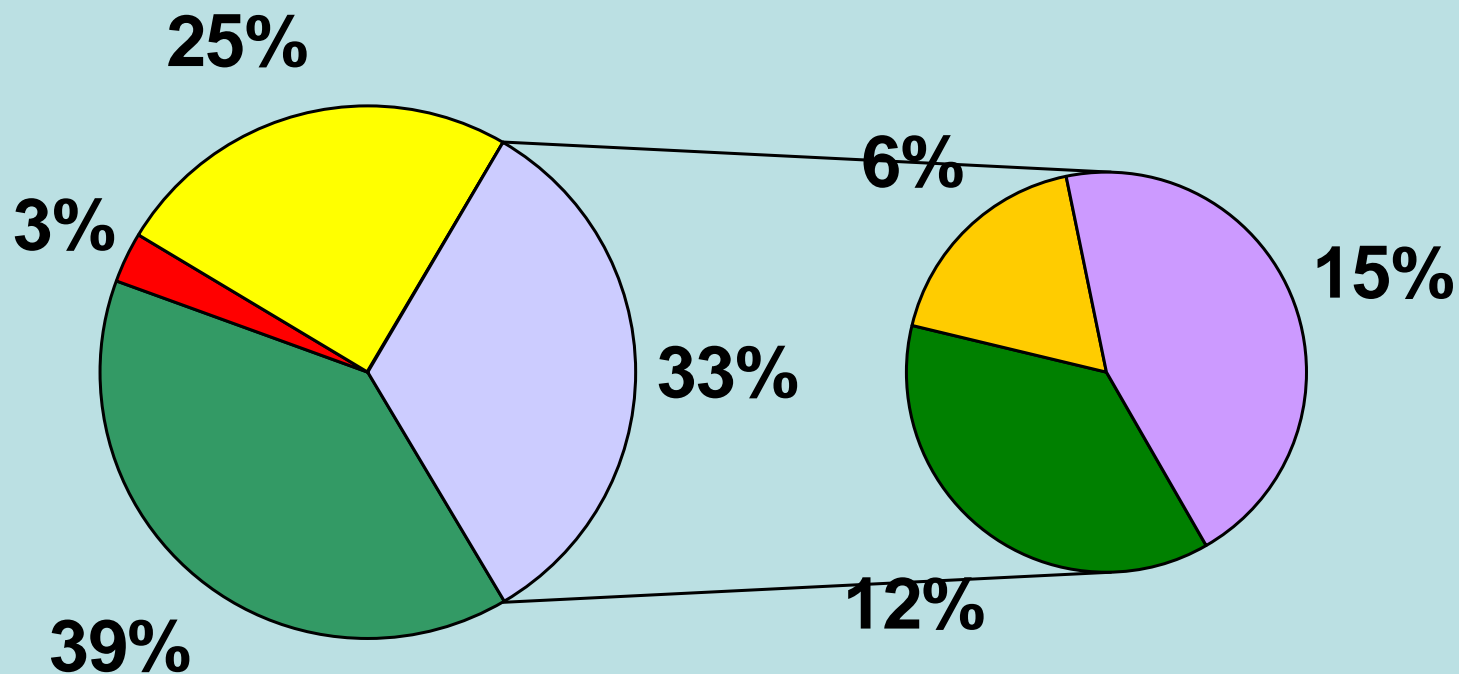
# Fatality Trends in US by Crash Type



# Distribution of Fatalities by Crash Direction – FARS 2001-2005



# Distribution of Fatalities by Crash Direction – FARS 2001-2005

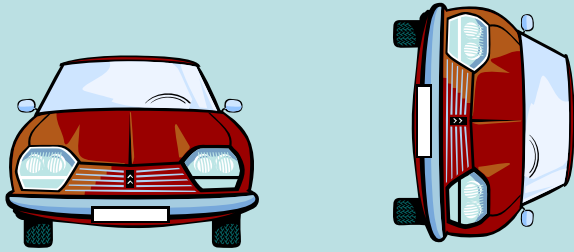


# Rollover Data from 2007 ESV

- Authors
  - Ana Eigen – NHTSA
  - Ken Digges – GWU
- Data Analysis
  - NASS/CDS 1995-2005 (NHTSA's Accident Data)
  - Belted front seat occupants in rollovers
- The Data to Follow
  - Single vehicle rollovers
  - Injured belted occupants

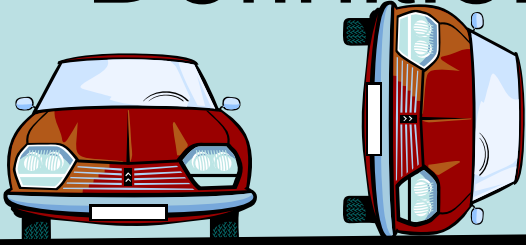
# Definition of Vehicle Inversions

No roof contact

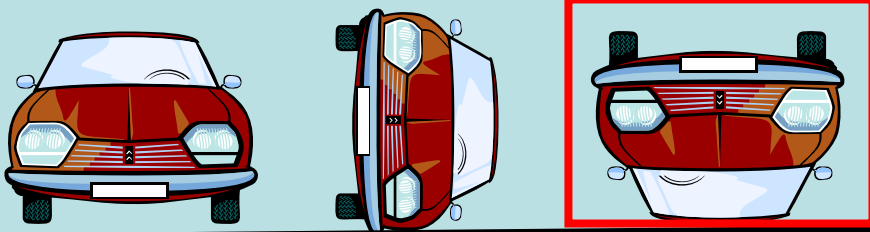


0 Inversions – 1 Quarter-turn

# Definition of Vehicle Inversions

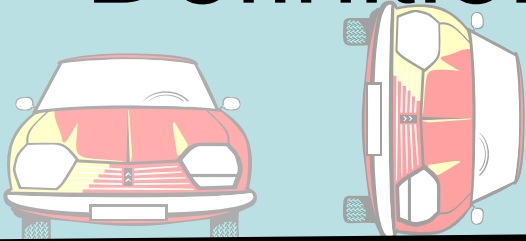


0 Inversions – 1 Quarter-turn

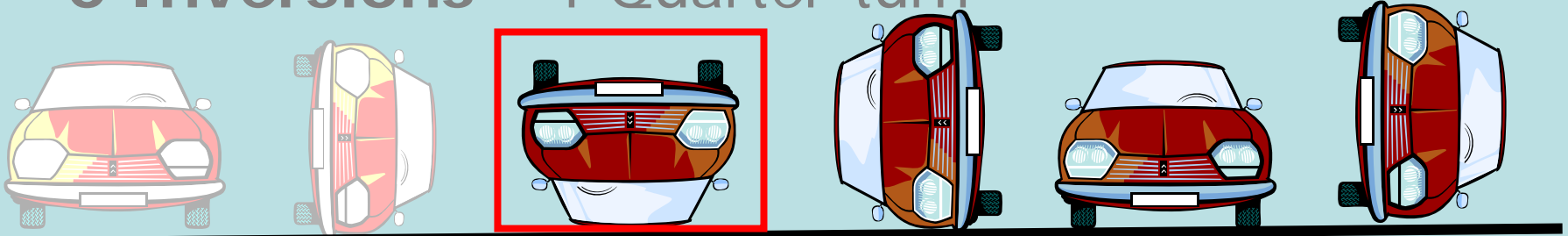


1<sup>st</sup> Inversion – 2 Quarter-turn = 1st Upside-down

# Definition of Vehicle Inversions



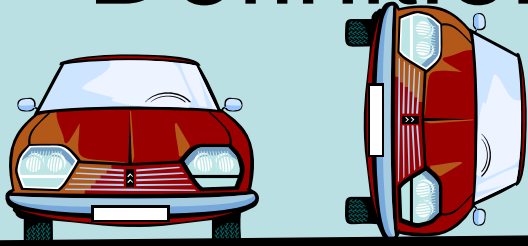
0 Inversions – 1 Quarter-turn



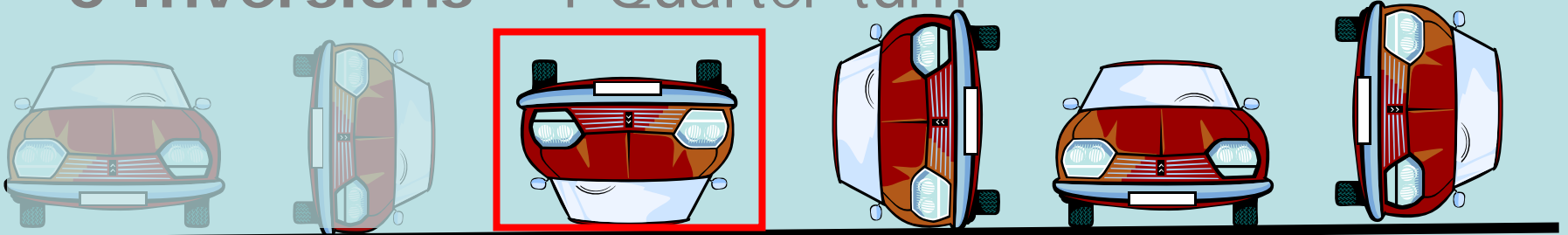
1 Inversion – 1st Upside-down + next 3 Quarter-turns

Quarter-turns 3,4, and 5 do not have a higher injury risk than quarter-turn 2

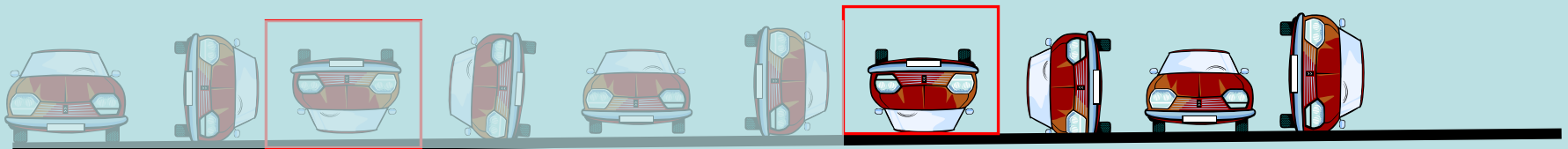
# Definition of Vehicle Inversions



0 Inversions – 1 Quarter-turn

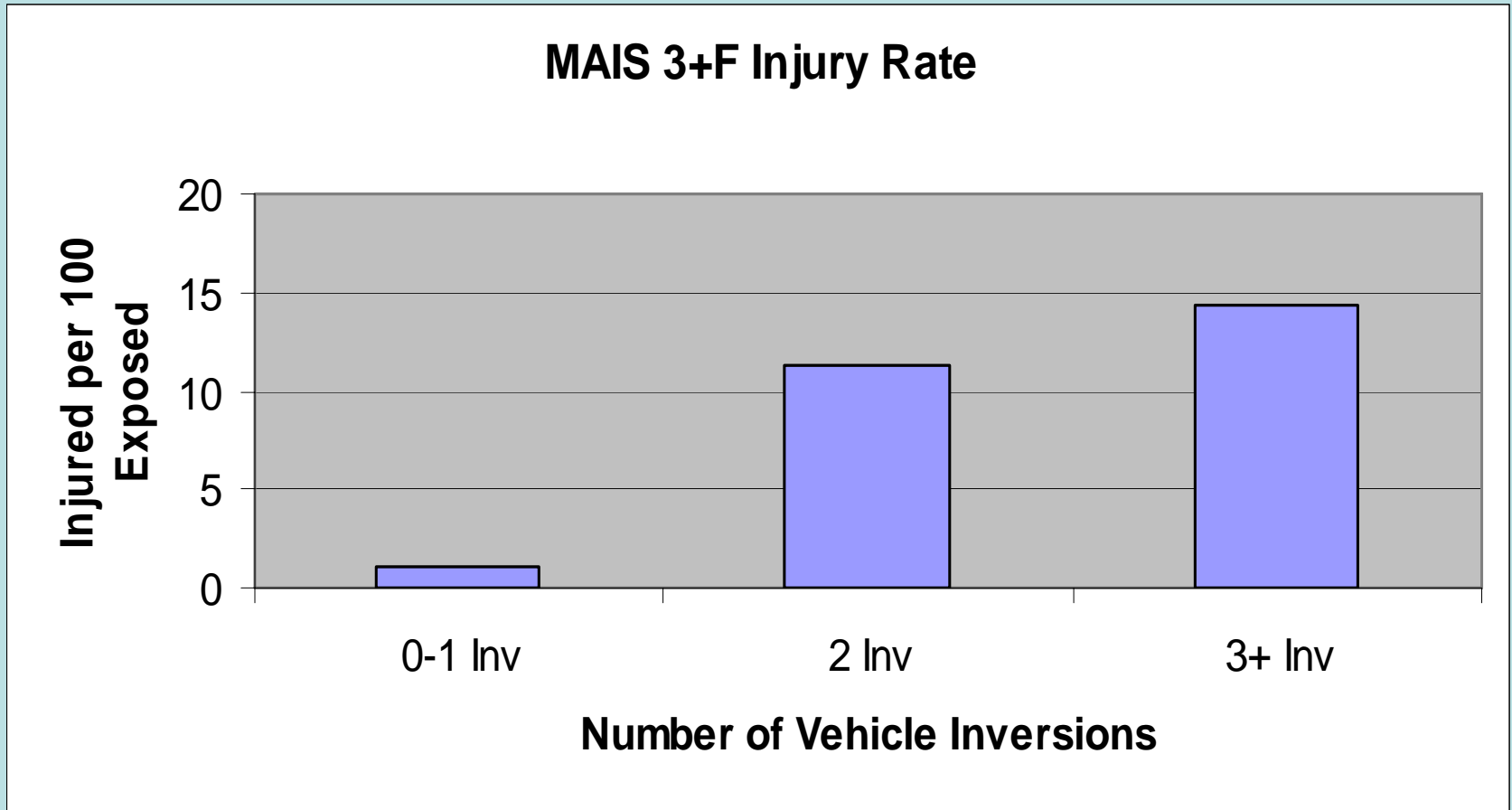


1 Inversion – 2 thru 5 Quarter-turns



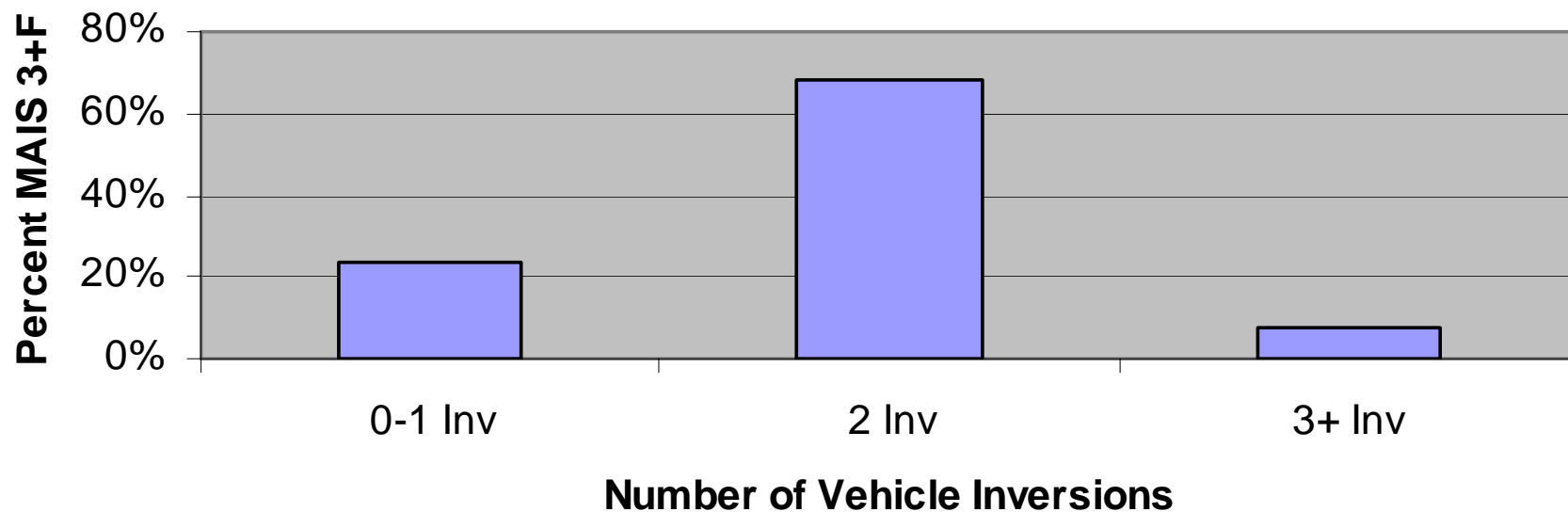
2 Inversions – 6 thru 9 Quarter-turns

# Injury Rate in Rollovers by Crash Severity



# Rollover MAIS 3+F by Crash Severity

**MAIS 3+F in Single Vehicle Rollovers**



# Observations

- *Number of Vehicle Inversions* is a good severity metric
- *Two Inversions* account for more than 60% of the MAIS 3+F among belted front occupants in single vehicle rollovers

# Rollover Testing



Static Test



Dynamic Test

# FMVSS 216 Roof Crush Test

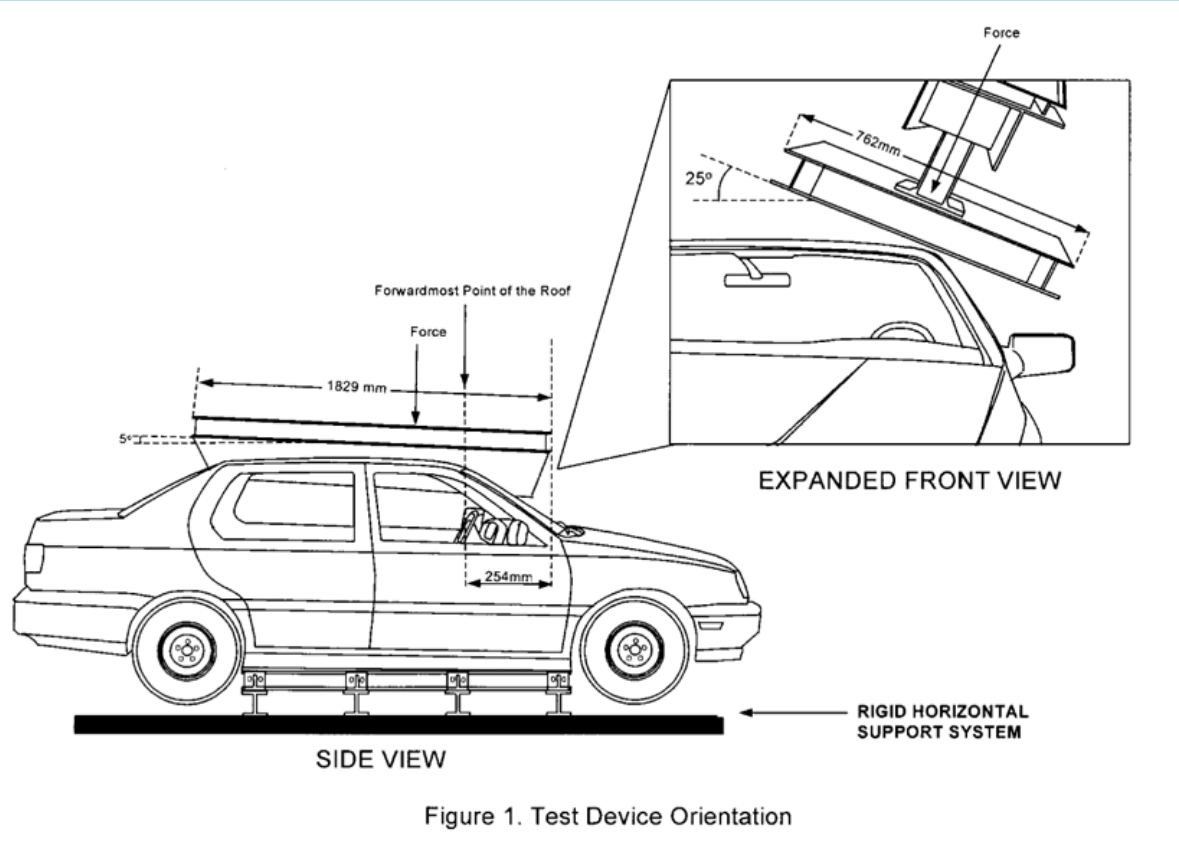


Figure 1. Test Device Orientation

Must support X times vehicle weight within 127 mm (5 in.) of deflection

Old 216 X=1.5

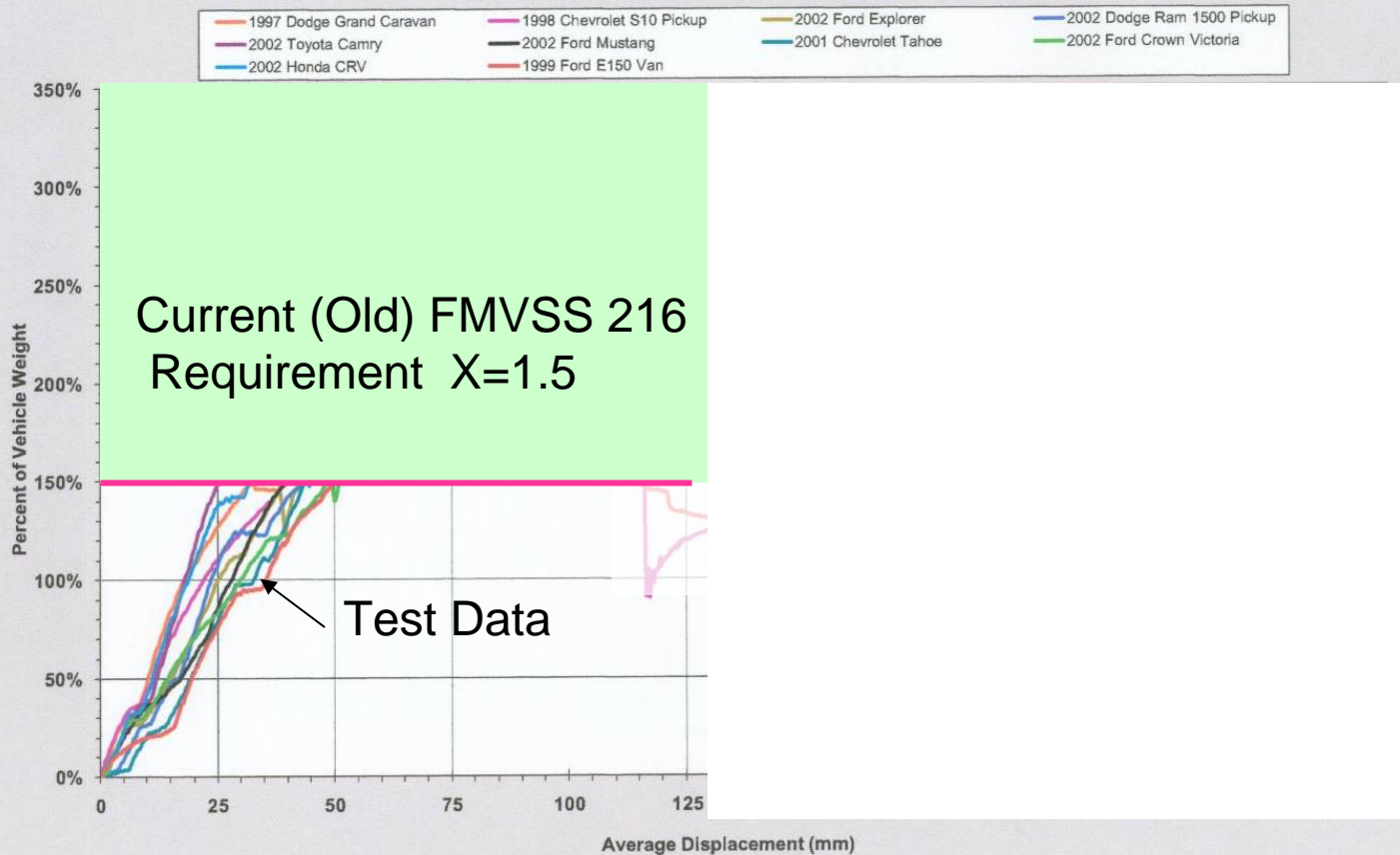
New 216 X=3.0

IIHS Test X=4.0

# Roof Crush Phase 2 - Results

# Vehicle Tests

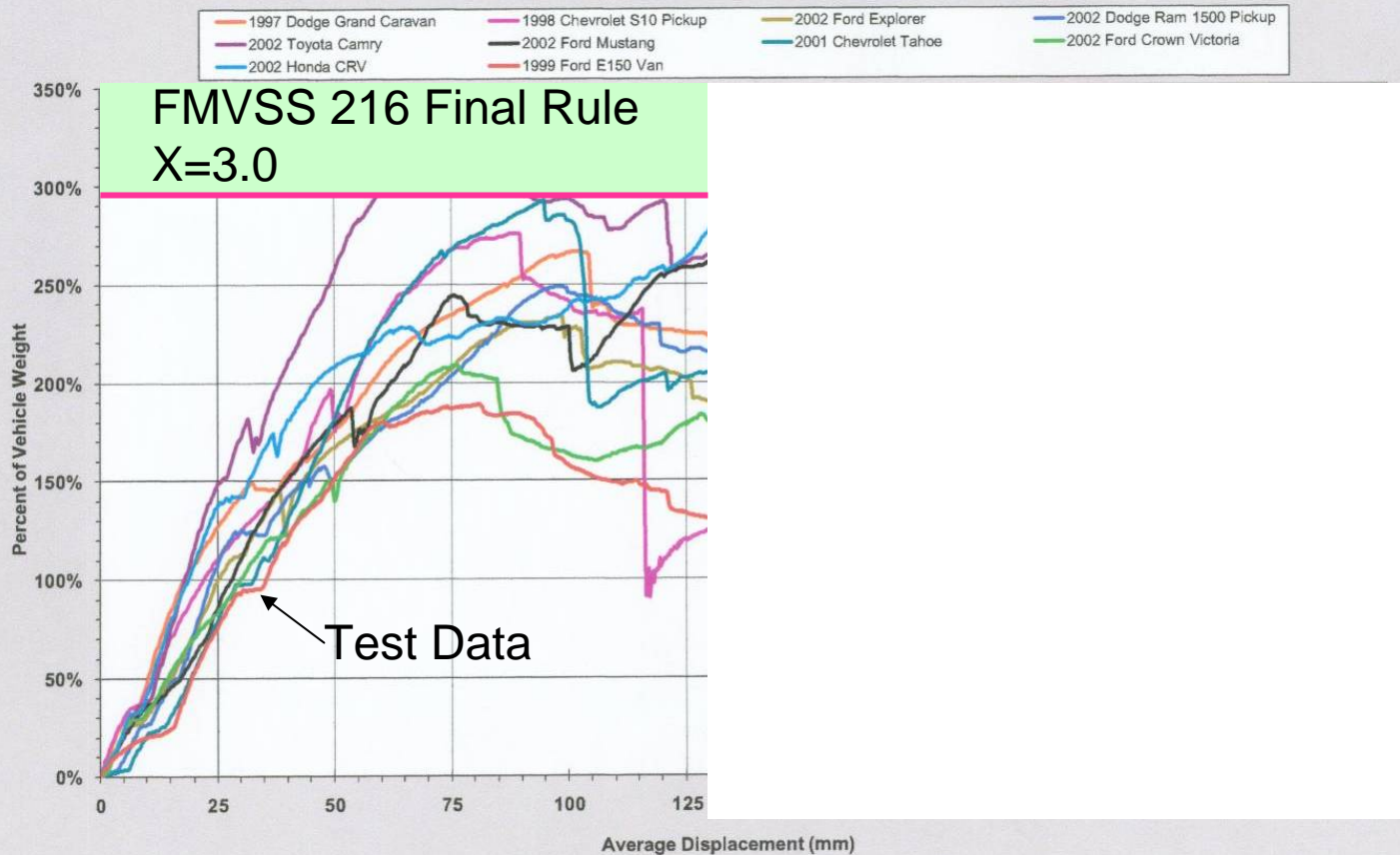
Percent of Vehicle Weight vs. Displacement  
To 254 mm Load Plate Displacement



# Roof Crush Phase 2 - Results

# Vehicle Tests

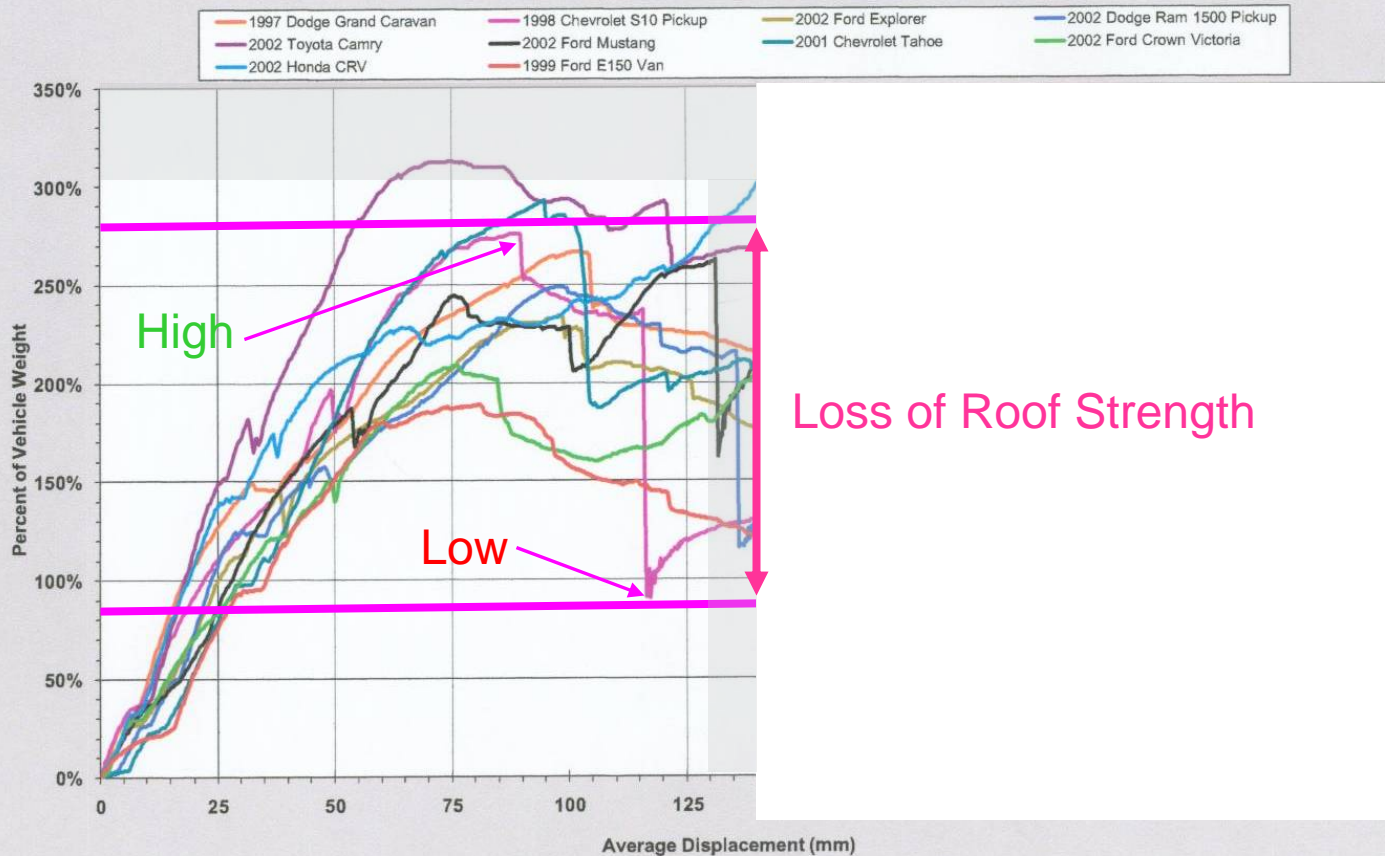
Percent of Vehicle Weight vs. Displacement  
To 254 mm Load Plate Displacement



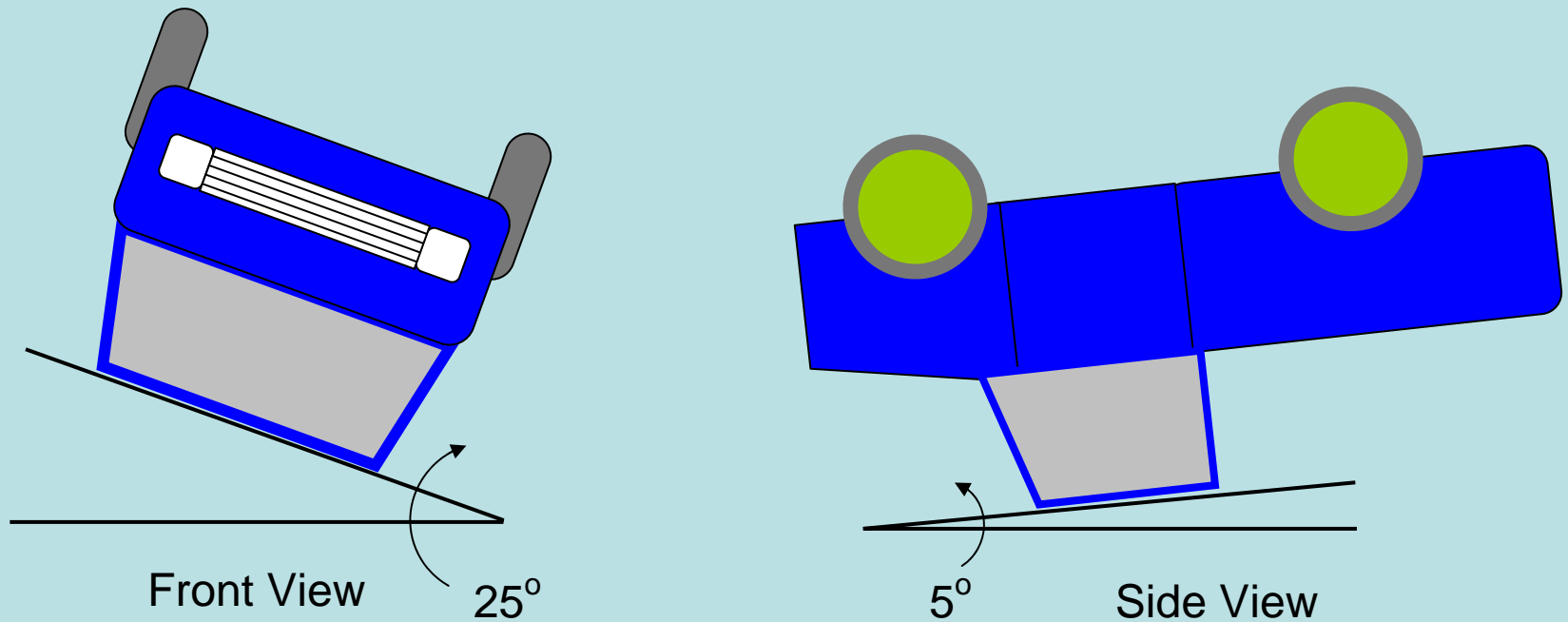
# Roof Crush Phase 2 - Results

# Vehicle Tests

Percent of Vehicle Weight vs. Displacement  
To 254 mm Load Plate Displacement



# NCAC Research Tests for Roof Crush



**Drop Height = 6" (152mm)**

# Pickup Roof Drop from 6"



**1<sup>st</sup> Roof Impact**



**2<sup>nd</sup> Roof Impact**

# 1<sup>st</sup> and 2<sup>nd</sup> Drop Comparison

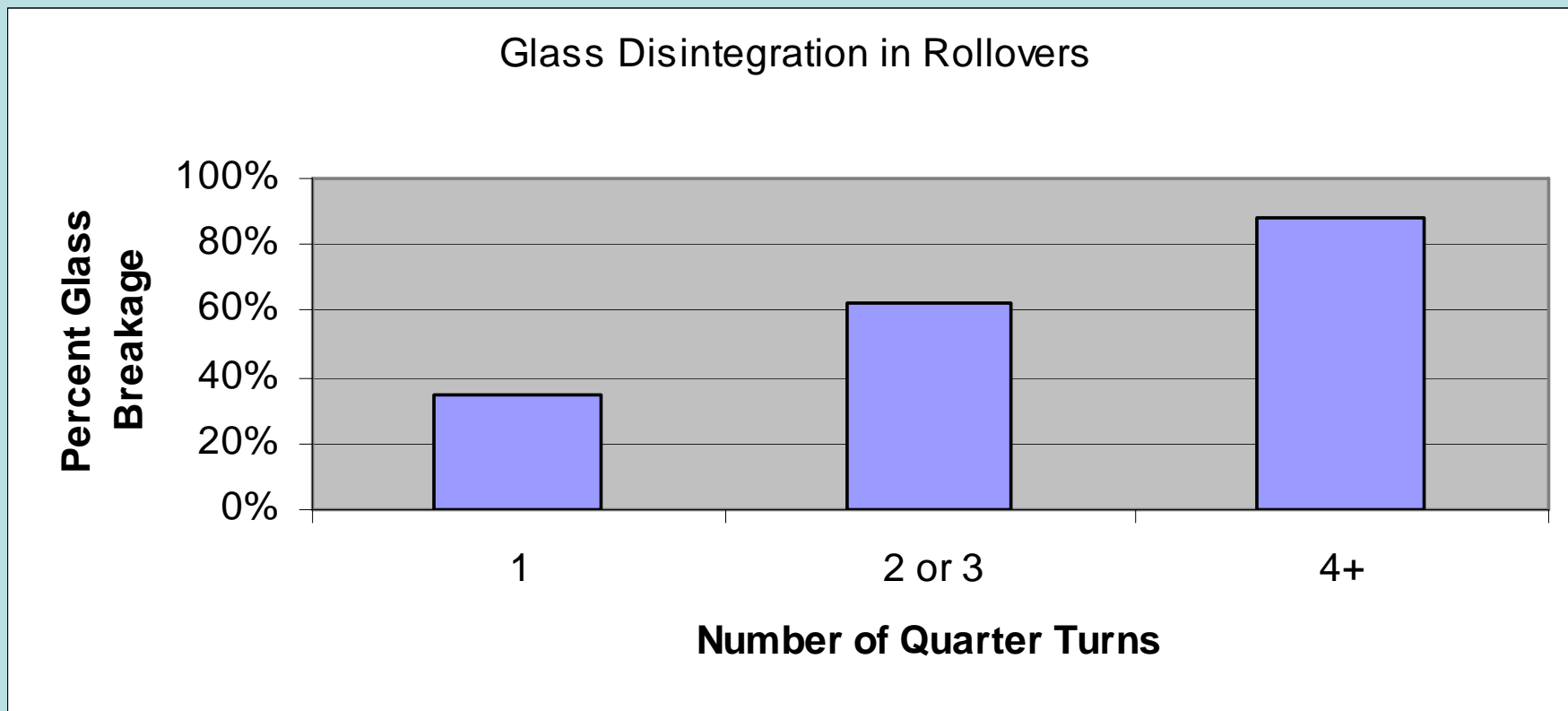


1<sup>st</sup> Drop Maximum Roof Crush



2<sup>nd</sup> Drop Maximum Roof Crush

# Loss of Glass Integrity in Rollovers

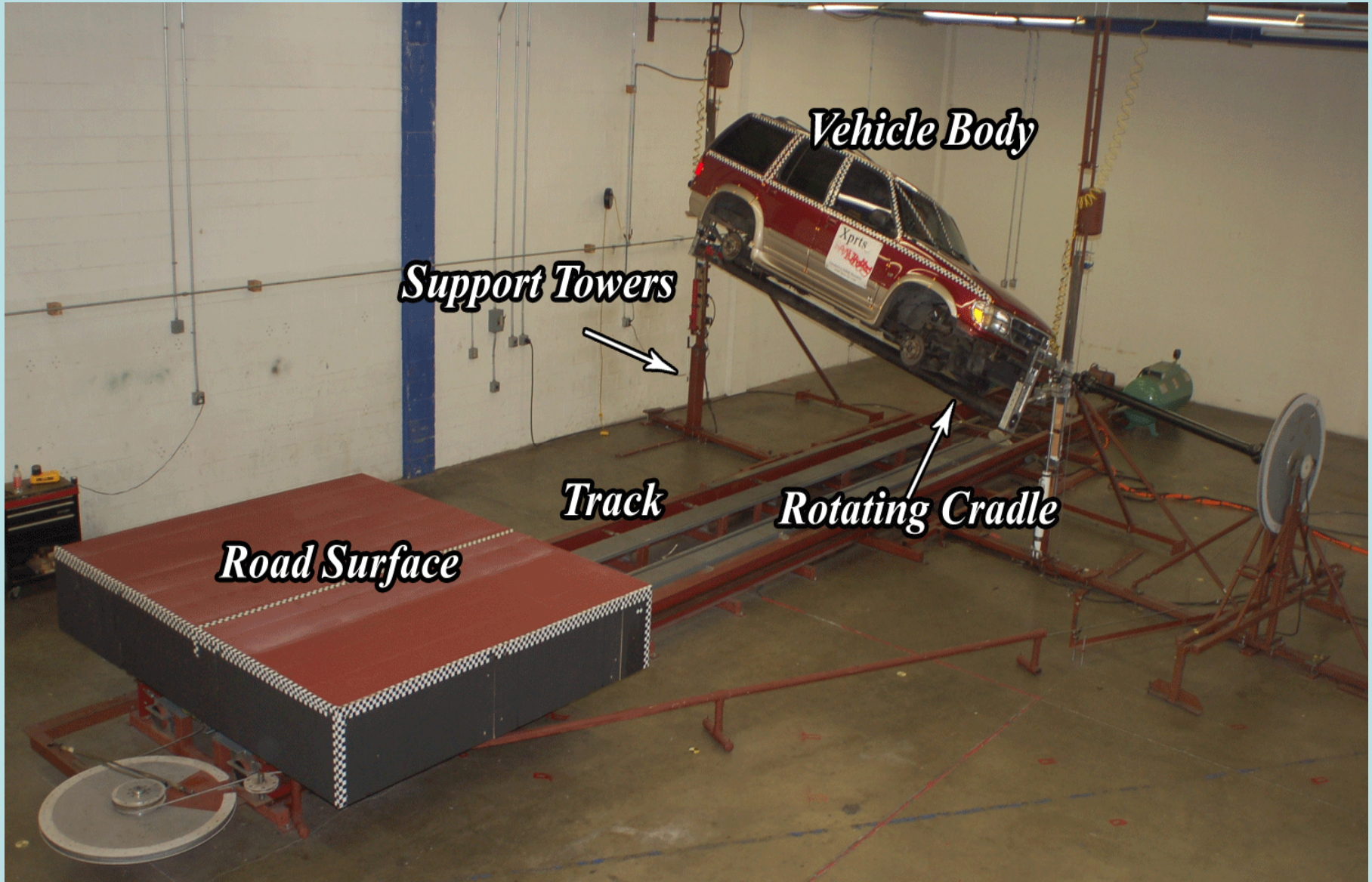


NASS Analysis by Malliaris, ESV 1991

# Observations

- Glass breakage can influence roof strength and ejection potential
- Research testing should include two vehicle inversions

# Jordan Dynamic Rollover System (JRS)



# Rollover Safety Measurements

- Without Dummies
  - Visual Inspection
  - Residual Headroom
  - Max Crush
  - Max Crush Velocity



# Rollover Safety Measurements

- With Dummies
  - Visual Inspection
  - Existing Injury Criteria
  - New Injury Criteria

# Initial Conditions for Dynamic Rollover Tests

- |                     |   |
|---------------------|---|
| <b>Road Speed</b>   | <ul style="list-style-type: none"><li>• <b>24 k/hr</b></li></ul>  |
| <b>Roll Rate</b>    | <ul style="list-style-type: none"><li>• <b>190 deg/sec</b></li></ul>  |
| <b>Pitch</b>        | <ul style="list-style-type: none"><li>• <b>5° (1<sup>st</sup> Roll);</b></li><li>• <b>10° (2<sup>nd</sup> Roll)</b></li></ul> |
| <b>Impact Angle</b> | <ul style="list-style-type: none"><li>• <b>145°</b></li></ul>   |
| <b>Drop Height</b>  | <ul style="list-style-type: none"><li>• <b>10 centimeters</b></li></ul>   |
| <b>Yaw</b>          | <ul style="list-style-type: none"><li>• <b>10°</b></li></ul>  |

# Variations in Vehicle Shape and Roof Strength



2007 Honda CRV  
SWR 2.4



2008 Scion XB  
SWR 6.8

# Residual Roof Crush after Two Dynamic Rolls



2007 Honda CRV  
SWR 2.4



2007 Scion XB  
SWR 6.8

# New Vehicle vs. Residual Crush After 2 Rolls



No Side Window Breakage

2007 Camry Hybrid  
Vehicle tested had  
strengthened header



C-pillar Deformation  
Rear Window Breakage

# Tests of Laminated Glass Side Windows



New 2008 Chevy Malibu  
with Laminated Glass



Glass Remained Intact

# Observations – Dynamic Testing

- Vehicle shape can influence test results – static vs. dynamic tests
- Hybrid vehicles may load the roof differently from conventional vehicles
- Laminated glass may provide ejection benefits even after severe roof distortion

# Conclusions

- Number of vehicle inversions is a good measure of rollover severity for belted occupants
- 60% of MAIS 3+F belted in rollovers without pre-roll impacts involve 2+ vehicle inversions
- Dynamic testing provides added insights into vehicle performance in rollover
- JRS provides a repeatable test that permits exposing vehicles to 2 inversions
  - Loads both sides of the roof
  - Allows a wide range of initial conditions
  - Encourages designs that resist the forces of real world rollovers

Reports on present and future rollover research may be found on website:

[autosafetyresearch.com/reports](http://autosafetyresearch.com/reports)

Click on: rollover and/or farside

Questions?