Donald Friedman
Susie Bozzini

Jordan Rollover System

CfIR
Center for Injury Research
Rollover frequency and AIS 3+ Injury

As much as 40% of these injuries occur in pre roll crash events, limiting the likelihood that ESC will be as effective as predicted, emphasizing occupant out of position concerns when the rollover commences.
Ejections are a Major Problem

<table>
<thead>
<tr>
<th></th>
<th>Rollover</th>
<th>Planar</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Ejection</td>
<td>3,295</td>
<td>1,516</td>
<td>4,812</td>
</tr>
<tr>
<td>Partial Ejection</td>
<td>1,476</td>
<td>1,348</td>
<td>2,824</td>
</tr>
<tr>
<td>Total</td>
<td>4,772</td>
<td>2,864</td>
<td>7,636</td>
</tr>
</tbody>
</table>
Basis for JRS Dynamic Repeatable Rollover Testing

- Malibu and Blazer Dolly Rollover Data
- NASS 500 Serious Injury Case Investigation Data
- Injury & Ejection Potential Measures
Reference Details

- “A Study of NASS Rollover Cases and the Implication for Federal Regulation” ESV 2005 publication
- “What NASS Rollover Cases Tell Us” ESV 2007 publication
- “A Rollover Human/Dummy Head/Neck Injury Criteria” ESV 2007 publication
- “Results From Two Sided Quasi-Static (m216) And Repeatable Dynamic Rollover Tests (JRS) Relative to FMVSS 216 Tests” ESV 2007 publication
- “Human/Dummy Rollover Falling (Excursion) Speeds” ESV 2007 publication
Jordan Rollover System (JRS)

- Design Criteria
- System Functionality
- Testing Results
Combining 50 years of Testing Experience

- Acen Jordan has designed, built, and implemented more than 30 test sleds to testing facilities and manufacturers around the world.

- Donald Friedman has designed and tested numerous vehicles, sleds and other measurement tools over his 50 years in automotive safety.
The results of their collaboration:

The Jordan Rollover System

- A standard pneumatic sled to be used as a road bed for the vehicle to drop on to.
- A spit - drop test rig to hold and rotate the vehicle
- Instrumentation to measure the loads on the inside of the vehicle and in the road bed.
- A control module to set testing parameters such as roll angle, roll rate and road bed speed.
Jordan Rollover System Fixture

Drop Towers

Road Bed Sled

Cradle under vehicle
JRS Sled Construction (road bed)

- Sled weighs 3600 pounds and is constructed of steel and aluminum.
- Impact surface is an eight inch thick wooden surface covered with a grit surface that approximates the coefficient of friction of asphalt.
- Using plywood surfaces for testing is common practice in automotive industry and testing facilities.
JRS Sled Construction (road bed)

- Sled is inertially matched to vehicle
- The sled provides the translational velocity that a vehicle has when rolling over in the field
- The sled slows down when the vehicle impacts it because a vehicle rolling in the field converts its translational velocity into rotational velocity when it contacts the ground
JRS Drop Tower Construction

- Towers are fixed, yet expandable to fit different vehicle sizes
- Towers fitted with vehicle cradle for rotation in impact event
- Towers have brakes to “catch” the vehicle after the impact event, so it maintains and isolates the test result deformation
Data Acquisition Systems

- Industry-standard data measurement and acquisition system is used to collect data from the sled and vehicle:
  - More than two dozen data channels are recorded from the sled, vehicle and Hybrid III dummy

- GMC uses the same data acquisition system at its rollover test facility
JRS Initial Impact Conditions Criteria
JRS Impact Conditions

- Derived directly from GM’s own reporting of roof-to-ground impact conditions in the Malibu test series
- Derived from extensive analysis of dolly rollover tests conducted by GMC in defense of litigation
- Derived and validated from detailed investigation of over 600 rollover accidents in litigation
- Validated by investigation and review of over 400 NASS cases
GM’s Malibu studies

- Conducted by litigation engineers and consultants
- Two series totaling 16 dolly rollovers
- Extensively instrumented and filmed
JRS Test Conditions – Road Bed Speed and Drop Height

- 95% of rollovers are 2 rolls or less
- Typical speed at the initiation of the roll sequence is 20+ mph
- Decrease in rolling velocity due to friction
- CG falls approximately 4” to near side contact

The JRS can run at variable speeds. We run at 15 or 18 mph on most tests.
JRS Test Conditions – Roll Rate, Angle and Pitch

- In dolly rollover tests, the first near side roll contact occurs at 200º per sec. and 130+ degrees.
- Near side friction increases the roll rate to 300 degrees per sec. by far side impact.
- The pitch can be as little as 5 degrees in low severity rollovers.
JRS Test Conditions – NASS Data

10º of Pitch in Real World Rollovers

Damage was observed on the top of at least one front fender in more than 80 percent of the cases for which there were pictures, indicating that the vehicle was pitched at least 10 degrees during at least part of the time it was inverted. This is approximately the angle formed with the horizontal by a line between the top of the roof over the A pillar and the top of the front fender of virtually all contemporary production light vehicles.
Repeatable dynamic tests provide real world consumer information not obtainable with a static test. Data such as, the injury potential performance of:

- child seats,
- children and small adults in rear seats,
- roof racks,
- padding,
- belts,
- door latches and

Unregulated and voluntary safety features, like:

- rollover activated window curtain airbags,
- single and dual seat belt pre-tensioners,
- tempered and composite glazing and
- rollover activated canopy and head impact air bags.

Furthermore, such testing is consistent with NCAP dynamic tests to injury criteria in the frontal and side impact crash modes.
Technical Details and Results
GM Malibu I
Test 5
(All data from GM)

Near Side Contacts:
(Green Lines)
550 ms = 0.6 mph
1500 ms = 0.3 mph
2350 ms = 1.2 mph
3350 ms = 1.2 mph

Far Side Contacts:
(Red Lines)
790 ms = 0.6 mph
1677 ms = 0.4 mph
2662 ms = 1.2 mph
4330 ms = 0.7 mph
GM Malibu I
Test 6
(All data from GM)

Near Side Contacts:
(Green Lines)
575 ms = 2.2 mph
1500 ms = 2.5 mph

Far Side Contacts:
(Red Lines)
836 ms = 2.7 mph
1802 ms = 3.1 mph

Note: Similar data between vehicle types. The main difference is the rollcaged vehicle does not crush.
### ESV 2001 – Basis for JRS Initial Conditions

<table>
<thead>
<tr>
<th>PII</th>
<th>Neck Load (N)</th>
<th>Time between Roof Touchdown and Peak Load (ms)</th>
<th>Traveling Speed at Touchdown (mph)</th>
<th>Degrees of Revolution at Neck Load</th>
<th>Vehicle Pitch at Neck Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L2</td>
<td>10,900</td>
<td>28</td>
<td>22.1±2.2</td>
<td>210°</td>
<td>5°</td>
</tr>
<tr>
<td>3L3</td>
<td>12,000</td>
<td>30</td>
<td>20.0±2.1</td>
<td>1 roll+210°</td>
<td>7°</td>
</tr>
<tr>
<td>4L2</td>
<td>7,600</td>
<td>28</td>
<td>21.9±3.2</td>
<td>1 roll+225°</td>
<td>3°</td>
</tr>
<tr>
<td>7L4</td>
<td>13,200</td>
<td>5 + 12</td>
<td>6.7±8</td>
<td>3 rolls+190°</td>
<td>10°</td>
</tr>
</tbody>
</table>

Table 2. Vehicle circumstances at the time of each of the four injurious Malibu II head impacts.

Statistical Probability Analysis of Serious Injury suggests 7 mph Criteria

Figure 13: PMHS data on neck fracture versus impact force and impact velocity.
Rollover related Drop tests suggest 10 mph Head impact speed for **Severe to Fatal** injury

Onset of severe neck injury

4m/s=9mph, 4.5m/s=10mph

Figure 5: Impact Force as a Function of Impact Velocity for PMHS Drop Tests.
Probability of Injury as a function of Head Impact Speed

- Probability of Severe Injury or Death
- Probability of Serious Injury
Phase II JRS Low Severity Testing

We developed the JRS low severity test protocol to represent rollover crashes at 5° of pitch which are completed in two rolls. This protocol is intended to identify the poorest performing roof designs with high injury and ejection potential.

JRS testing is at a roadbed speed of 15 mph, a roll rate of 200°/second, with 5° of pitch, ~140° roll angle, 10° yaw angle and a drop height of 4 inches to the near side.
CfIR
Center for Injury Research

1995 - 2001 Ford Explorer
2003 - 2006 Volvo XC90

Dynamic Rollover Test Comparison

CfIR
Center for Injury Research
<table>
<thead>
<tr>
<th>Location</th>
<th>2000 Ford Explorer 4dr Roll 1</th>
<th>2000 Ford Explorer 4dr Roll 2</th>
<th>2004 Volvo XC90 Roll 1</th>
<th>2004 Volvo XC90 Roll 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crush (in)</td>
<td>Crush (in)</td>
<td>Crush (in)</td>
<td>Crush (in)</td>
</tr>
<tr>
<td>A-Pillar</td>
<td>-8.7</td>
<td>-9.2</td>
<td>-1.0</td>
<td>-1.9</td>
</tr>
<tr>
<td>Mid Point Between A and B Pillar</td>
<td>-9.1</td>
<td>-9.9</td>
<td>-1.5</td>
<td>-2.6</td>
</tr>
<tr>
<td>B-Pillar</td>
<td>-6.7</td>
<td>-9.9</td>
<td>-1.2</td>
<td>-2.6</td>
</tr>
<tr>
<td>Inboard of A-Pillar</td>
<td>-7.0</td>
<td>-6.3</td>
<td>-0.6</td>
<td>-1.2</td>
</tr>
<tr>
<td>Inboard of Roof Rail Midpoint</td>
<td>-11.5</td>
<td>-6.3</td>
<td>-0.3</td>
<td>-0.9</td>
</tr>
<tr>
<td>Center of Roof</td>
<td>-8.2</td>
<td>-6.2</td>
<td>-0.4</td>
<td>-0.9</td>
</tr>
<tr>
<td>Near Side A-Pillar</td>
<td>-4.2</td>
<td>-6.2</td>
<td>-1.2</td>
<td>-0.9</td>
</tr>
</tbody>
</table>

**2000 Ford Explorer 2 Roll JRS Test Series**

Peak Dynamic Crush – 11.5 inches

Peak Cumulative Crush – 14.5 inches

Peak Crush Speed – 12.1 mph

**2004 Volvo XC90 2 Roll JRS Test Series**

Peak Dynamic Crush* – 2.6 inches

Peak Cumulative Crush* – 1.1 inches

Peak Crush Speed* – 3.0 mph

* Far side only
15 mph Equal Severity JRS Rollover Test Results: Injury Potential on Far Side Roof Crush Speed vs. FMVSS 216 SWR

Ford Explorer

- Peak Far Side Crush Speed
- Probability of Severe Injury or Death
- Probability of Serious Injury

Other Vehicles Tested

Volvo XC90

Crush Speed (mph)

SWR (Ratio of FMVSS 216 Peak Load v. Test Weight)
### JRS 15 mph Low Severity Dynamic Rolls Ordered by Max. Roof Crush Speed at any Point for Injury Potential Evaluation

<table>
<thead>
<tr>
<th>Model Years</th>
<th>Make/Models</th>
<th>216 SWR</th>
<th>Max Crush (Inches)</th>
<th>Maximum Speed (MPH)</th>
<th>Injury Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002-2006</td>
<td>Volvo XC90 SUV</td>
<td>4.6</td>
<td>3.2</td>
<td>3.7</td>
<td>Best</td>
</tr>
<tr>
<td>1999-2005</td>
<td>Hyundai Sonata Sedan</td>
<td>2.8</td>
<td>6.4</td>
<td>8.0</td>
<td>Fair</td>
</tr>
<tr>
<td>2003-2006</td>
<td>Kia Sorrento SUV</td>
<td>1.9</td>
<td>6.9</td>
<td>9.0</td>
<td>Poor</td>
</tr>
<tr>
<td>1995-1999</td>
<td>Nissan Sentra Sedan</td>
<td>3.2</td>
<td>9.1</td>
<td>9.6</td>
<td>Poor</td>
</tr>
<tr>
<td>1995-2001</td>
<td>GMC Jimmy SUV</td>
<td>2.4</td>
<td>6.7</td>
<td>9.8</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>1995-2005</td>
<td>Chevy Blazer SUV</td>
<td>2.4</td>
<td>9.6</td>
<td>10.1</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>1999-2001</td>
<td>Isuzu VehiCross SUV</td>
<td>NA</td>
<td>6.8</td>
<td>11.1</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>2001-2006</td>
<td>C2500 HD Reg Cab Pickup</td>
<td>2.2</td>
<td>9.9</td>
<td>11.2</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>1995-2001</td>
<td>Ford Explorer SUV</td>
<td>1.6</td>
<td>11.5</td>
<td>12.1</td>
<td>Not Acceptable</td>
</tr>
<tr>
<td>1994-1999</td>
<td>Mitsubishi Eclipse</td>
<td>2.5</td>
<td>7.6</td>
<td>12.1</td>
<td>Not Acceptable</td>
</tr>
</tbody>
</table>

(Criteria: Best = < 6mph and no ejection portals; Good = < 6 mph; Fair = < 8 mph; Poor = < 10 mph; Not Acceptable = > 10mph)
JRS Real World Severity Testing

We developed the Phase III JRS real world test protocol to represent 95% of the rollovers, which are in two rolls, where 95% of the serious to fatal injuries occur.

Real world JRS testing is at a roadbed speed of 18 mph, a roll rate of 240°/second, with 10° of pitch, 145° roll angle, 10° yaw angle and a drop height of 4 inches to the near side.
JRS 1998 Reinforced Blazer Tests
JRS 1993 Cherokee Tests
JRS 2001 Suburban Test
JRS 1998 Mercedes ML320 Test
A Jordan Rollover System Test
1999 Jeep Grand Cherokee

STI

Proprietary Test Data Property of Safety Testing International
JRS 18 mph, 10° Pitch, 1998 ML320 Test
Peak Neck Load \( v. \) Peak Crush Speed

\[
y = 673.02x + 1573.6 \\
R^2 = 0.7808
\]
Neck Injury Criteria (Nij) v. Peak Crush Speed

\[ y = 0.1777x + 0.338 \]
\[ R^2 = 0.8523 \]
Calculated Head Contact v. Measured Peak Crush Speed

\[ y = 0.622x + 1.4543 \]

\[ R^2 = 0.7808 \]
Load as Measured on the Road Bed
Measured Intrusion and Speed Adjacent to Dummy

<table>
<thead>
<tr>
<th>Location</th>
<th>Intrusion (in)</th>
<th>Peak</th>
<th>End of Test</th>
<th>Peak Intrusion Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998 Mercedes ML</td>
<td>Intrusion (in)</td>
<td>Peak</td>
<td>End of Test</td>
<td>Peak Intrusion Velocity</td>
</tr>
<tr>
<td>A-Pillar</td>
<td>-7.7</td>
<td>-5.3</td>
<td></td>
<td>-11.2</td>
</tr>
<tr>
<td>B-Pillar</td>
<td>-5.4</td>
<td>-2.8</td>
<td></td>
<td>-7.9</td>
</tr>
<tr>
<td>Roof Header</td>
<td>-7.6</td>
<td>-5.4</td>
<td></td>
<td>-11.5</td>
</tr>
<tr>
<td>Near Side A-Pillar</td>
<td>-0.9</td>
<td>0.6</td>
<td></td>
<td>-3.0</td>
</tr>
</tbody>
</table>
Far Side HIII Dummy Motion as Measured with an Under Seat String Potentiometer Compared with Neck Load and Adjacent Roof Motion

- Peak Neck Load of 4,647 N at 185°
- Near Side Contact at 145°
- Far Side Contact over at 230°

Graph showing:
- Under the Seat String Pot: Displacement
- Under the Seat String Pot: Velocity
- Roof Header: Displacement
- Roof Header: Velocity
- Neck Load, Fz
Road Bed Contact at 140° accelerates roll rate
Road Speed v. Roll Angle

Accelerating roll rate reduces road speed after energy transfer
Minus motion of driver dummy towards passenger side
String Potentiometer: Head Longitudinal Movement

Time (sec)
Inches

Minus driver head motion is in flexion
Mercedes 2007 C-Class HSS Structure
C-Class HSS Roof Rail/A-pillar/Header Joint
C-Class Window Curtain Air Bag
Table 1. NHTSA Roof Strength to Weight Ratio (SWR) vs. Platen Displacement Related to JRS Testing

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>FMVSS 216</th>
<th>Year Range</th>
<th>SWR</th>
<th>N216</th>
<th>JRS Test</th>
<th>Injury Measure</th>
<th>JRS Test</th>
<th>Injury Measure</th>
<th>Comments</th>
<th>JRS Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subaru</td>
<td>Forester</td>
<td>2001-2006</td>
<td>5.0 @ 3&quot;</td>
<td>1.26</td>
<td>10 MPH, 10°</td>
<td>7.0 MPH</td>
<td>12 MPH, 10°</td>
<td>0.5 MPH</td>
<td>Sequence of two tests. Second with dummy.</td>
<td>Acceptable with retained glazing</td>
<td></td>
</tr>
<tr>
<td>Toyota</td>
<td>Corolla</td>
<td>2002-2008</td>
<td>4.3 @ 3.4&quot;</td>
<td>1.26</td>
<td>15 MPH, 6°</td>
<td>4.0 MPH</td>
<td>15 MPH, 6°</td>
<td>0.4 MPH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toyota</td>
<td>Corolla</td>
<td>2002-2008</td>
<td>4.3 @ 3.4&quot;</td>
<td>1.26</td>
<td>15 MPH, 10°</td>
<td>7 MPH</td>
<td>20 MPH, 10°</td>
<td>0.4 MPH</td>
<td>After 2 JRS tests at 5°.</td>
<td>Unacceptable at 10° Pitch</td>
<td></td>
</tr>
<tr>
<td>Toyota</td>
<td>Corolla</td>
<td>1994</td>
<td>2.5 @ 3.5&quot;</td>
<td>1.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td>Xterra</td>
<td>2004-2008</td>
<td>3.0 @ 2.6&quot;</td>
<td>0.98</td>
<td>15 MPH, 10°</td>
<td>10.4 MPH</td>
<td>15 MPH, 10°</td>
<td>0.2 MPH</td>
<td>Buck without roof rack; After M216, JRS at SWR = 3.2</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Volvo</td>
<td>XC90</td>
<td>2007-2003</td>
<td>3.5 @ 3&quot;</td>
<td>2.13</td>
<td>15 MPH, 5°</td>
<td>3.8 MPH</td>
<td>15 MPH, 5°</td>
<td>4.1 MPH</td>
<td>Black; After M216 Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volvo</td>
<td>XC90</td>
<td>2007-2003</td>
<td>3.5 @ 3&quot;</td>
<td>2.13</td>
<td>15 MPH, 5°</td>
<td>2.3 MPH</td>
<td>15 MPH, 5°</td>
<td>3.0 MPH</td>
<td>White</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volvo</td>
<td>XC90</td>
<td>2007-2003</td>
<td>3.5 @ 3&quot;</td>
<td>2.13</td>
<td>15 MPH, 10°</td>
<td>6.9 MPH</td>
<td></td>
<td></td>
<td>White; After 2 JRS tests at 5°.</td>
<td>Acceptable</td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td>Sentra 2 Door</td>
<td>1998-1999</td>
<td>2.8 @ 3.1&quot;</td>
<td>1.17</td>
<td>15 MPH, 5°</td>
<td>9.6 MPH</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Hyundai</td>
<td>Sonata</td>
<td>2005-1999</td>
<td>2.6 @ 3&quot;</td>
<td>1.17</td>
<td>15 MPH, 5°</td>
<td>6.1 MPH</td>
<td>15 MPH, 5°</td>
<td>0.8 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>Eclipse</td>
<td>1994-1999</td>
<td>2.5 @ 3&quot;</td>
<td>1.17</td>
<td>15 MPH, 5°</td>
<td>12.1 MPH</td>
<td></td>
<td></td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Kia</td>
<td>Sorento</td>
<td>2007-2003</td>
<td>1.9 @ 3&quot;</td>
<td>1.17</td>
<td>15 MPH, 5°</td>
<td>9 MPH</td>
<td>15 MPH, 5°</td>
<td>0.9 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Jeep</td>
<td>Grand Cherokee</td>
<td>2004-1999</td>
<td>1.7 @ 3.8&quot;</td>
<td>0.98</td>
<td>18 MPH, 10°</td>
<td>12.9 MPH</td>
<td>12 MPH, 10°</td>
<td>N/A</td>
<td>Second with dummy</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Jeep</td>
<td>Grand Cherokee</td>
<td>1998-1993</td>
<td>2.3 @ 3.8&quot;</td>
<td>0.98</td>
<td>12 MPH, 5°</td>
<td>4.7 MPH</td>
<td>14 MPH, 5°</td>
<td>8 MPH</td>
<td>Buck; After M216, JRS at SWR = 3.4. Then at 2.5</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td>Explorer</td>
<td>2001-1995</td>
<td>1.9 @ 3&quot;</td>
<td>0.72</td>
<td>15 MPH, 5°</td>
<td>12.1 MPH</td>
<td>15 MPH, 5°</td>
<td>0.9 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Isuzu</td>
<td>VehCROSS</td>
<td>2001-1999</td>
<td>1.5 @ 3&quot;</td>
<td>1.15</td>
<td>15 MPH, 5°</td>
<td>11.1 MPH</td>
<td>15 MPH, 5°</td>
<td>8.8 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Isuzu</td>
<td>Rodeo</td>
<td>1997-1991</td>
<td>1.9 @ 5&quot;</td>
<td>1.15</td>
<td>15 MPH, 5°</td>
<td>10.4 MPH</td>
<td>15 MPH, 5°</td>
<td>9.7 MPH</td>
<td>Buck; After M216, first JRS at SWR = 1.6, Then, at 1.6 again</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>GMC</td>
<td>Jimmy</td>
<td>2001-1995</td>
<td>1.5 @ 5&quot;</td>
<td>0.69</td>
<td>15 MPH, 5°</td>
<td>9.8 MPH</td>
<td>15 MPH, 5°</td>
<td>8.3 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Chevy</td>
<td>S-10 Blazer</td>
<td>2005-1995</td>
<td>1.5 @ 5&quot;</td>
<td>0.76</td>
<td>15 MPH, 5°</td>
<td>10.1 MPH</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Chevy</td>
<td>Suburban</td>
<td>2003-2000</td>
<td>1.6 @ 3.2&quot;</td>
<td>0.76</td>
<td>15 MPH, 10°</td>
<td>7.7 MPH</td>
<td></td>
<td></td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Land Rover</td>
<td>Discovery</td>
<td>2004-1999</td>
<td>1.7 @ 3&quot;</td>
<td>1.00</td>
<td>10 MPH, 5°</td>
<td>9.3 MPH</td>
<td>15 MPH, 5°</td>
<td>8.5 MPH</td>
<td>Rear seat 5th percentile dummy</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Chevy</td>
<td>Suburban</td>
<td>1999-1992</td>
<td>1.0 @ 4.0&quot;</td>
<td>0.60</td>
<td>15 MPH, 6°</td>
<td>10.8 MPH</td>
<td>N/A</td>
<td>N/A</td>
<td>Buck; JRS at SWR = 2.1</td>
<td>Unacceptable</td>
<td></td>
</tr>
<tr>
<td>Chevy</td>
<td>Silverado 2500 HD</td>
<td>2007-1989</td>
<td>2.5 @ 5&quot;</td>
<td>1.02</td>
<td>15 MPH, 5°</td>
<td>8.4 MPH</td>
<td>15 MPH, 5°</td>
<td>8.3 MPH</td>
<td></td>
<td>Unacceptable</td>
<td></td>
</tr>
</tbody>
</table>

All SWR data @ unloaded vehicle weight (SWR). Maximum UWW (NUVW) reduces the SWR by 20% and increases injury potential accordingly.
Injury potential measures of less than 7 MPH have a low probability of serious injury.
Injury potential measures of more than 7 MPH and less than 10 MPH have a high probability of serious injury.
Injury potential measures of more than 10 MPH have a high probability of severe to fatal injury.
## Population Effected

<table>
<thead>
<tr>
<th>Population Affected</th>
<th>PRIA Serious</th>
<th>PRIA Fatal</th>
<th>Revised Assessment Serious</th>
<th>Revised Assessment Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fixed collision on top</td>
<td>19,000</td>
<td>7,426</td>
<td>19,000</td>
<td>7,426</td>
</tr>
<tr>
<td>Not totally ejected</td>
<td>13,000</td>
<td>3,559</td>
<td>18,000</td>
<td>6,500*</td>
</tr>
<tr>
<td>Using safety restraint</td>
<td>9,600</td>
<td>2,026</td>
<td>17,000</td>
<td>6,100†</td>
</tr>
<tr>
<td>Front outboard seats</td>
<td>9,000</td>
<td>1,780</td>
<td>16,000</td>
<td>5,900</td>
</tr>
<tr>
<td>Not 12 years or older</td>
<td>9,000</td>
<td>1,764</td>
<td>16,000</td>
<td>5,900‡</td>
</tr>
<tr>
<td>Roof Component Intrusion</td>
<td>7,100</td>
<td>1,030</td>
<td>14,000</td>
<td>4,700§</td>
</tr>
<tr>
<td>Head/neck/face Injury from intruding</td>
<td>2,400</td>
<td>751</td>
<td>14,000</td>
<td>4,700</td>
</tr>
<tr>
<td>Sole MAIS Injury</td>
<td>800</td>
<td>225^</td>
<td>14,000</td>
<td>4,700</td>
</tr>
</tbody>
</table>

Note: Occupants who have the potential to benefit from a strong roof are shown in bold type.

Table 1. Revised estimates of the population affected in comparison with the NPRM by improved roof crush resistance based on the PRIA Table IV-2.
5th Percentile Adult (10yr old child) Dummy in Rear Seat

High Speed: Interior View

Xprts, LLC
Produced for Use Only in Luckey v. Land Rover North America Inc.
JRS Insights to Occupant Protection

Near side Window Curtain Airbag

Far side 10° Pitch Intrusion w/ buckled header
Conclusion
The JRS can compare the injury and ejection potential of vehicles and occupant protection devices in rollovers and can definitively test vehicle safety components and their causal relationship to decreasing death and injury in crashes or tests.
NHTSA-CFIR Activities

- 2001 – NHTSA legislatively directed to evaluate dynamic rollover testing
- 2005 – NHTSA dynamic rollover evaluation incomplete and requests additional data. CFIR submits 6 additional comments to NHTSA 2005-22143 Docket.
- CFIR briefs NHTSA on December 8, 2006 in Washington, DC (and submits confidential detailed electronic data on 10 production vehicles to NHTSA)
- December 9, 2006 – CFIR briefs United States House and Senate Congressional committees with NHTSA oversight
- December 11, 2006 – CFIR briefs Insurance Institute for Highway Safety (IIHS)
- February 23, 2007 CFIR briefs NHTSA in Santa Barbara, California on detailed responses to NHTSA concerns
NHTSA-CFIR Activities - Continued

- March 8, 2007 CFIR briefs NHTSA at NCAP hearing in Washington, DC. Indications are that timing for dynamic legislative response is too tight, research will take too long, increased Strength to Weight Ratio (SWR) static compliance will continue.


- June 8, 2007 – CFIR submits correlation of intrusion speed and dummy Nij injury measures, comparison of FMVSS 216 compliance versus JRS dynamic injury and ejection potential acceptability for 17 production vehicles, recommends that JRS or finite element dynamic tests establish the static criteria for compliance, as well as four ESV papers summarizing results of JRS Testing