BioRID II
Preliminary
Repeatability Assessment
&
Biofidelity Assessment

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NHTSA
Repeatability Objective

• **Assess in a realistic repeatable mode**
  • “Yielding” seatback, 30° rotation
  • Two exposures
    • Low speed – 16.7 kph, 8.5 Gs
    • Mid speed – 24 kph, 10.5 Gs

• **Three dummies**
  • BioRID II
  • HIII
  • RID 3D
Biofidelity Objective

• **Assess biofidelity**
  - Two exposures: low & mid
  - Six PMHS at each speed
  - Low then Mid-speed
  - Internal biofidelity
  - External biofidelity

• **Analyze vertebral kinematics**
  - 6 DOF per vertebra
Injury Criteria Objective

- **Identify injurious kinematics**
  - Compare with values of non-injurious physiologic ROM
    - Flexion and extension rotations
    - Shear and axial displacements
  - Determine likelihood and mode of injury at each vertebral level
- **Compare to various injury criteria and look for best predictor**
  - IV-NIC
  - NIC, $N_{ij}$, $N_{km}$, $N_{te}$, ND criterion, LNL index
  - Head-to-Torso rotation, upper & lower extension moment
  - Other??
Pulses: Low & Mid-speed
Rear Impact Sled Seat

Head restraint
- Diameter: 17 mm
- Mass: 5.5 kg

Seat
- Mass: 30 kg
- Padding/cushions/seat cover of 1999 Toyota Camry seat

Damper
- One-way damper \( \times 2 \)

Angular rate sensor

Spring
- Stiffness: 13500 N/m \( \times 2 \)
# Repeatability Test Matrix

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Test Speed</th>
<th>Driver Side Dummy</th>
<th>Passenger Side Dummy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
<td>BioRID II</td>
</tr>
<tr>
<td>2</td>
<td>L</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
<td>BioRID II</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
<td>RID3D</td>
<td>BioRID II</td>
</tr>
<tr>
<td>4</td>
<td>L</td>
<td>RID3D</td>
<td>BioRID II</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>RID3D</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>RID3D</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>RID3D</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>RID3D</td>
<td>BioRID II</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>RID3D</td>
<td>BioRID II</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>Hybrid III 50&lt;sup&gt;th&lt;/sup&gt;</td>
<td>BioRID II</td>
</tr>
</tbody>
</table>

L = Low Speed (8.5 g, 16.7 kph FMVSS 202)
M = Moderate Speed (10.5 g, 24 kph)
**Repeatability Methodology**

- **Peak analysis** (Rhule 2005)
  - Coefficient of variation

- **Time based analysis**
  - Upper 80% only
  - Repeatability (J. Shaw 2006)
    - Cumulative C.V.
    - Confidence interval

- **Reproducibility** (J. Shaw 2006)
  - Repeatability established
  - Hypothesis testing
  - t-statistic at 10% cum. C.V.

<table>
<thead>
<tr>
<th>R&amp;R rating</th>
<th>C.V. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>0 to 5</td>
</tr>
<tr>
<td>Good</td>
<td>&gt;5 to 8</td>
</tr>
<tr>
<td>Acceptable</td>
<td>&gt;8 to 10</td>
</tr>
<tr>
<td>Poor</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>
EEVC Biofidelity Test Criteria

- Availability of data
- Quality of set-up, instrumentation, subject quality
- Reproducibility
- Relevance of test conditions, loading conditions, $\Delta V$
- Distribution of subject anthropometry, gender, age
- Number of tests and subjects

Biofidelity Analysis

• Qualitative analysis
  • Overplots
  • “Eyeball” assessment

• Quantitative analysis
  • BioRank?
  • Objective Rating Method?
  • CORA?
  • Phase, Magnitude, Shape?
## Biofidelity Test Matrix

<table>
<thead>
<tr>
<th>Test</th>
<th>24 kph</th>
<th>17 kph</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
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<td>5*</td>
<td>5*</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Tested 10-9-2010
Internal Biofidelity Parameters

- T1 angle w/r to sled
- T1 X-acceleration w/r sled
- Head angular displacement w/r to sled
- Head CG X-displacement w/r to sled
- Head angular displacement w/r to T1
- $HIC_{15}$
T1 angle w/r to sled-17 kph

Repeatability (Peak CV):
Hybrid III: 4.5%
RID3D: 5.5%
BioRID: 1.2%
T1 angle w/r to sled-17 kph

Rotation [deg] vs Time [msec]

- HybridIII
- RID3D
- BioRIDII
- PMHS
**T1 X-acceleration w/r sled 17 kph**

Repeatability (Peak CV):
- Hybrid III: 3.8%
- RID3D: 5.1%
- BioRID: 7.5%
T1 X-acceleration w/r sled
17 kph
Head angular displacement w/r to sled – low speed

Repeatability (Peak CV):
- Hybrid III: 4.1%
- RID3D: 5.2%
- BioRID: 4.8%
Head angular displacement w/r to sled – 17 kph
Head CG X displacement w/r to sled – 17 kph

Repeatability (Peak CV):
Hybrid III: 2.2%
RID3D: 2.1%
BioRID: 2.3%
Head CG X displacement w/r to sled – 17 kph
Head angular displacement w/r to T1 – 17 kph

- Hybrid III: 5.4%
- RID3D: 1.2%
- BioRID: 11.7%
Head angular displacement w/r to T1 – 17 kph
## Table 1 HIC15 – Hybrid III

<table>
<thead>
<tr>
<th></th>
<th>HIC15</th>
<th>Begin [ms]</th>
<th>End [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test #1</td>
<td>176.5</td>
<td>117.1</td>
<td>120.1</td>
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<tr>
<td>Test #2</td>
<td>183.3</td>
<td>119.7</td>
<td>122.6</td>
</tr>
<tr>
<td>Test #3</td>
<td>163.3</td>
<td>121.9</td>
<td>125.0</td>
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</tbody>
</table>

## Table 2 HIC15 – RID3D

<table>
<thead>
<tr>
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<th>HIC15</th>
<th>Begin [ms]</th>
<th>End [ms]</th>
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</thead>
<tbody>
<tr>
<td>Test #1</td>
<td>175.6</td>
<td>130.1</td>
<td>132.8</td>
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<tr>
<td>Test #2</td>
<td>137.8</td>
<td>131.8</td>
<td>135.3</td>
</tr>
<tr>
<td>Test #3</td>
<td>281.7</td>
<td>134.8</td>
<td>137.4</td>
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</table>

## Table 3 HIC15 – BioRIDII

<table>
<thead>
<tr>
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<th>Begin [ms]</th>
<th>End [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test #1</td>
<td>136.3</td>
<td>123.3</td>
<td>126.9</td>
</tr>
<tr>
<td>Test #2</td>
<td>164.6</td>
<td>126.8</td>
<td>129.9</td>
</tr>
<tr>
<td>Test #3</td>
<td>177.8</td>
<td>128.4</td>
<td>131.3</td>
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</table>

## Table 4 HIC15 – PMHS

<table>
<thead>
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<th>Begin [ms]</th>
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<tbody>
<tr>
<td>Test #1</td>
<td>58.1</td>
<td>129.8</td>
<td>159.6</td>
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<tr>
<td>Test #2</td>
<td>37.4</td>
<td>126.2</td>
<td>162.2</td>
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<tr>
<td>Test #3</td>
<td>36.1</td>
<td>128.6</td>
<td>164.6</td>
</tr>
</tbody>
</table>
T1 angle w/r to sled-24 kph

Repeatability (Peak CV):
- Hybrid III: 3.7%
- RID3D: 3.0%
- BioRID: 1.2%
T1 angle w/r to sled-24 kph
T1 X-acceleration w/r sled
24 kph

Repeatability (Peak CV):
Hybrid III: 5.6%
RID3D: 13.9%
BioRID: 17.4%
T1 X-acceleration w/r sled
24 kph
Head angular displacement w/r to sled – 24 kph

Repeatability (Peak CV):
Hybrid III: 8.2
RID3D: 7.5%
BioRID: 3.8%
Head angular displacement w/r to sled – 24 kph
Head CG X displacement w/r to sled – 24 kph

Repeatability (Peak CV):
Hybrid III: 2.3%
RID3D: 0.7%
BioRID: 0.8%
Head CG X displacement w/r to sled – 24 kph
Head angular displacement w/r to T1 – 24 kph

Repeatability (Peak CV)
- Hybrid III: 12.2%
- RID3D: 25.1%
- BioRID: 5.9%
Head angular displacement w/r to T1 – 24 kph
<table>
<thead>
<tr>
<th></th>
<th>HIC15</th>
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<tbody>
<tr>
<td>Test #1</td>
<td>239.2</td>
<td>115.5</td>
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### Table 6 HIC15 – RID3D

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### Table 7 HIC15 – BioRIDII

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<thead>
<tr>
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<tbody>
<tr>
<td>Test #1</td>
<td>193.9</td>
<td>126.8</td>
<td>129.5</td>
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<tr>
<td>Test #2</td>
<td>183.7</td>
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<td>129.4</td>
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<tr>
<td>Test #3</td>
<td>139.3</td>
<td>126.2</td>
<td>129.4</td>
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### Table 8 HIC15– PMHS

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<tbody>
<tr>
<td>Test #1</td>
<td>77.0</td>
<td>141.4</td>
<td>154.6</td>
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<tr>
<td>Test #2</td>
<td>95.4</td>
<td>145.3</td>
<td>181.3</td>
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<tr>
<td>Test #3</td>
<td>90.7</td>
<td>148.2</td>
<td>184.2</td>
</tr>
</tbody>
</table>
External Biofidelity

- Seat back loads
  - Sum
  - Top
  - Middle
  - Lower
- Head restraint loads
  - Front
  - Top
17 kph - Seatback Load

Repeatability (Peak CV):
Hybrid III: 0.6%
RID3D: 3.5%
BioRID: 5.8%
17 kph - Seatback Load

The graph shows the force (in Newtons, N) versus time (in milliseconds, msec) for different models: HybridIII, RID3D, BioRIDII, and PMHS. The data is presented for two different conditions: 17 kph - Seatback Load.
17 kph - Seatback Load

Top Level

Force [N]

Time [msec]
17 kph - Seatback Load

![Graph showing force vs. time for different scenarios.](image)

**Middle Level**

- HybridIII
- RID3D
- BioRIDII
- PMHS
17 kph - Seatback Load

Bottom Level

Time [msec]

Force [N]

HybridIII
RID3D
BioRIDII
PMHS
17 kph – Head Restraint Load

Repeatability (Peak CV):
Hybrid III: 1.4%
RID3D: 15.0%
BioRID: 4.4%
17 kph – Head Restraint Load
17 kph – Head Restraint Load
24 kph - Seatback Load

Repeatability (Peak CV):
- Hybrid III: 2.1%
- RID3D: 4.9%
- BioRID: 6.5%

Diagram showing force versus time for different systems.
24 kph- Seatback Load

- HybridIII
- RID3D
- BioRIDII
- PMHS

Sum

Force [N]

Time [msec]

-10000
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000
10000
24 kph - Seatback Load

Top Level

HybridIII
RID3D
BioRIDII
PMHS
24 kph - Seatback Load

Middle Level

Force [N]

Time [msec]
24 kph - Seatback Load

Bottom Level

- HybridIII
- RID3D
- BioRIDII
- PMHS

Force [N] vs. Time [msec]
24 kph – Head Restraint Load

Repeatability (Peak CV):
Hybrid III: 11.2%
RID3D: 16.2%
BioRID: 4.4%
24 kph – Head Restraint Load

![Graph showing head restraint load over time for different models: HybridIII, RID3D, BioRIDII, PMHS. The graph plots force [N] against time [msec].]
24 kph – Head Restraint Load

- HybridIII
- RID3D
- BioRIDII
- PMHS

Force [N] vs Time [msec]