Compatibility Research Plan

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Objective and Scope

- Objective: To lay the basis for a decision on near term rulemaking.
- Scope: Offset and compatibility research programs support one another, compatibility is focused on full frontal.
  - An offset test for occupant compartment stiffness to reduce lower extremity injuries.
  - A Compatibility test for matching frontal structure stiffness and height of forces to reduce all injuries. Good design for full frontal is good design for offset compatibility.
The Metrics of Compatibility

- **Initial stiffness, \( K_s \)**
  - Initial slope of the force-deflection curve from NCAP tests over about 200 mm of crush (Kahane, 2003)

- **Work stiffness, \( K_w \)**
  - Area under the force-deflection curve from NCAP tests, hence work or energy absorbed.
  - More reliable, less design restrictive than \( K_s \).
  - \( K_w^{400} = \) during first 400 mm of crush.

- **Average Height of Force**
  - Height of force averaged over the crush.
  - \( \text{AHOF}^{400} = \) during first 400 mm of crush.
Height of Force versus Weight for MY 00-05

Part 581

<table>
<thead>
<tr>
<th>AHOF400 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact</td>
</tr>
<tr>
<td>Midsize</td>
</tr>
<tr>
<td>Large</td>
</tr>
<tr>
<td>Minivan</td>
</tr>
<tr>
<td>Pickup</td>
</tr>
<tr>
<td>SUV</td>
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</tbody>
</table>

Weight (Kg)
## Preliminary AHOF400 & Kw400 Matching in CDS

(Combined offset and full frontal, belted car drivers only)

<table>
<thead>
<tr>
<th>Car AHOF</th>
<th>Other AHOF</th>
<th>Car Stiffness</th>
<th>Other Stiffness</th>
<th>AIS 3+ Prob. Inj.</th>
<th>AIS 2+ Prob. Inj.</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Med.</td>
<td>Med.</td>
<td>Low</td>
<td>Low</td>
<td>1.1%</td>
<td>2.4%</td>
<td>31</td>
</tr>
<tr>
<td>Med.</td>
<td>Med.</td>
<td>Low</td>
<td>Med.</td>
<td>9.2%</td>
<td>19.4%</td>
<td>23</td>
</tr>
<tr>
<td>Med.</td>
<td>Med.</td>
<td>Med.</td>
<td>Low</td>
<td>16.5%</td>
<td>18.9%</td>
<td>12</td>
</tr>
<tr>
<td>Med.</td>
<td>Med.</td>
<td>Med.</td>
<td>Med.</td>
<td>1.9%</td>
<td>6.8%</td>
<td>12</td>
</tr>
<tr>
<td>Med.</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>4.0%</td>
<td>74.2%</td>
<td>11</td>
</tr>
</tbody>
</table>
Cars Before and After the IIHS Offset Test
LTVs Before and After the IIHS Offset Test

![Graph showing LTVs before and after the IIHS Offset Test.](image-url)
Next Steps in Analytical Work

- Additional analyses of CDS data to better understand injury outcomes for Kw and AHOF.
- Analyses of FARS data to better understand fatality outcomes for Kw and AHOF.
- Analyses of crashes with objects for Kw and AHOF.
- Optimization study to select Kw limits.
- CDS case study and CIREN analyses to better understand injury patterns.
Vehicle Testing Approach

Full Frontal Collinear

1. IPT test series called for in the IPT Report, 6/03.
   - Initial stiffness, $K_s$, matched pairs.
   - Work stiffness, $K_w$, matched pairs to match energy absorption.

2. Begin to compare various frontal constructions
   - Option 1 LTVs – Body on frame, Advanced Compatibility Engineering (ACE), and Unibody structures.
   - Option 2 LTVs – Secondary Energy Absorbing Structure (SEAS) to engage cars.

3. High Resolution Rigid Barrier (HRRB) Tests
Ks Matching Results

- Vehicles matched AHOF. LTV weights were ballasted to match.
  - 03 Silverado, $K_s = 2541 \text{ N/mm}$, aggressive.
  - 05 Town&Country, $K_s = 1244 \text{ N/mm}$, compatible.
  - 02 Focus, $K_s = 1304 \text{ N/mm}$.
- High test speeds were chosen to show relation of injury to structural matches, Focus delta$V = 45 \text{ mph}$.
- Crash tests showed a significant improvement (10 – 20%) in the risk of serious injury with matched height and low initial stiffness.
- Improvement was seen in both the LTV and passenger car.
Kw Matching Approach

- Same test conditions as the Ks series to compare results.

<table>
<thead>
<tr>
<th></th>
<th>$K_w400$ Work Stiffness</th>
<th>AHOF400 Height of Force</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>03 Silverado</td>
<td>2019 N/mm</td>
<td>470 mm</td>
<td>2359 Kg</td>
</tr>
<tr>
<td>05 T&amp;C</td>
<td>1469 N/mm</td>
<td>477 mm</td>
<td>2229 Kg (Ballast to Silverado 2359)</td>
</tr>
<tr>
<td>01 Civic 2 Dr Coupe</td>
<td>1433 N/mm</td>
<td>415 mm</td>
<td>1335 Kg (Ballast to Focus 1410 kg)</td>
</tr>
</tbody>
</table>
Begin to Compare Frontal Constructions, vehicle-vehicle tests

- Same test conditions as previously (mass, speed, target) and compare injury outcomes.
- ACE structure – MY03/05 Honda Odyssey before and after ACE against 02 Focus.
- Unibody structure – MY05 Honda Ridgeline against 02 Focus.
- SEAS structure – MY06 F-250 with and without SEAS against 02 Focus.
Begin to Compare Frontal Structures – High Resolution Rigid Barrier (HRRB) Tests

To get more accurate data for the test design metrics and better understand the vehicle-vehicle crash test results

- 02 Focus
- 01 Civic 2 Dr coupe
- 03 Silverado
- 05 Town and Country
- 03 Odyssey (without ACE)
- 05 Odyssey (with ACE)
- 05 Ridgeline
- 06 F-250 (with SEAS)
Perform a Progressive Deformable Barrier (PDB) Test Series

Memo of Cooperation with the French signed in 2004.

- Tests now being co-designed with the French, and co-funded.
- Selected LTVs to match our vehicle-vehicle IPT test series, 03 Silverado and 05 Town and Country.
- Evaluate how well the barrier distinguishes between the two frontal structures - one aggressive, the other compatible.
Dynamic Test Approach

• Rigid barrier 208 approach is the best near term option.
  – Self protection comes from 208 and NCAP.
  – Partner protection comes from Kw400 and AHOF400 measured during 208 tests at 35 mph. (cases of concern car-car, Opt.1 LTV-car, LTV-LTV)
  – Barrier instrumentation will be designed using an 04 earmark to GWU/NCAC and finite element analysis.

• A new rigid barrier will be needed for the new Option 2 LTVs to ensure SEAS compatibility with passenger cars.
  – Alliance override rigid barrier (ORB)
ORB Tests and the SEAS

• The Alliance override rigid barrier extends out from the rigid wall about 1.2 m and upward to engage the SEAS.
  – Force height and energy absorption need to be evaluated to ensure car compatibility.

• An override barrier will be fabricated at VRTC for test and evaluation.
  – Load cell dimensions and metrics will be developed.
  – Tests on the Ridgeline and F-250 will be conducted.
**Advanced Technology for Compatibility**

- Investigate crash mitigation systems.
  - Perhaps automatic braking to bleed LTV energy, real-time ride height adjustments, real-time stiffness adjustments, belt and bag preparations, others.
  - Identify the most promising protection system(s) and prototype them.
  - Develop objective tests and preliminary benefits.

- Parallel research with Volpe to develop a preliminary benefits methodology that can bridge the gap between these crashworthiness systems and crash avoidance benefits.
Summary

• All work will be started in FY2006.
• Some work will extend beyond FY2006.
  – The GWU 2004 earmark joint with FHWA on F-250 modeling and SEAS virtual testing extends into 2007.
  – The advanced technology research goes till 2009.
• More research may be needed if the results show continued promise.
• A milestone in Q4 of FY2006 exists to brief the results of this plan. A new plan will be proposed at that time, if needed.