FIMCAR Frontal Impact Assessment Approach
• EC funded project ended September 2012
• Partners:
  – Car manufacturers: Daimler, FIAT, Opel, PSA, Renault, Volkswagen, Volvo
  – OEM associated: CRF
  – Research institutes test houses: BASt, Chalmers, IDIADA, TNO, TRL, TTAI, TUB, UTAC
  – Suppliers: HUMANETICS, IAT
• 2/3 majority required for decision making
FIMCAR definition of compatibility

- Compatibility consists of self and partner protection.
- Improved compatibility will decrease the injury risks for occupants in single and multiple vehicle accidents.
- Compatible vehicles will deform in a stable manner allowing the deformation zones to be exploited even when different vehicle sizes and masses are involved.
Accident analysis
Summary of findings

• Structural interaction still an issue
  – over/underriding
  – horizontal homogeneity (small overlap / fork effect)
• Compartment strength still an issue
  – seems to be independent from vehicle size
  – especially in crashes with HGV and objects
• High proportion of fatal and severely injured in large overlap accidents (even at relatively low speed)
• Large number of injuries are related to restraint loading without intrusion
• Higher injury risks for occupants in lighter car
FIMCAR priorities
Structural interaction

• Structural alignment
  – Common interaction zone defined based on US bumper zone

• Vertical load spreading
  – Load spreading in common interaction zone
  – Load spreading below interaction zone

Common Interaction Zone
Lower Area for Load Spreading

A = 180 mm  B = 406 mm  C = 508 mm
FIMCAR priorities

Structural interaction

- Structural alignment
  - Common interaction zone defined based on US bumper zone
- Vertical load spreading
  - Load spreading in common interaction zone
  - Load spreading below interaction zone
- Horizontal load spreading
  - Load spreading between longmembers
  - Load spreading outside longmembers
FIMCAR priorities
Test severity and self protection

• Test severity
  – current compartment strength requirements maintained
  – appropriate severity level for occupant protection (RS)
  – (address mass dependent injury risk)

• Pulse requirements
  – field relevant pulse
  – different pulses
FIMCAR assessment approach

• Full-width deformable barrier test
  – 50 km/h
  – LCW based metrics for alignment of crash structures

• Current ODB (ECE R94)
  – Additional a-pillar displacement limits
    • 50 mm max
Justification FWDB

• Accident analyses have shown the relevance of collisions with high overlap and high acceleration
• More representative loading of the front structures with the FWDB w.r.t. car-to-car tests and accidents
  – FWRB guarantees stable, ideal deformation of forward structures not observed in real accidents
  – FWDB tests produce more realistic deformation patterns compared to car-car tests
  – > more challenging for structural design
Justification FWDB
more representative deformation pattern

FWDB

FWRB
Justification FWDB
more representative deformation pattern
car-to-car 50% overlap
Justification FWDB

more representative deformation pattern
Justification FWDB

- Higher dummy loadings with the FWDB
- Acceleration pulse more comparable with car accident pulses
  - especially in the initial phase
  - > more representative w.r.t. restraint system triggering
  - Dainius Dalmotas reported that RS triggering time is much faster in FWRB than in accidents (EDR data) while FWDB is more realistic
- Maximum acceleration can be higher than in FWRB
Centered pole impact

Occupant starts to move

Airbag start to deploy

Airbag is loading the occupant

Justification FWDB

restraint system triggering

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Justification FWDB
restraint system triggering

Puls comparison to FWDB

Puls comparison to FWRB

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Justification FWDB

restraint system triggering

PAB starts to deploy

Occupant starts to move

FSP contacts deploying airbag

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40 km/h FWDB
Justification FWDB

restraint system triggering

![Airbag trigger time chart]

- Car 1
- Car 2
- Car 3
- Car 4

Airbag trigger time [ms]

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Justification FWDB
restraint system triggering

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Concept:

- Assess structural alignment from measurement of forces in rows 3 and 4

FWDB metrics

Height of load cell: 125 mm

Part 581 Zone; 16 to 20 inches (406 to 508 mm)

Height of Ground: 80 mm

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FWDB Metric

• Up to time of 40 msec
  – \( F4 + F3 \geq [\text{MIN}(200, 0.4F_{T40}) \text{kN} \)
  – \( F4 \geq [\text{MIN}(100, 0.2F_{T40}) \text{kN} \)
  – \( F3 \geq [\text{MIN}((100-LR), (0.2F_{T40}-LR))] \text{kN} \)
  – where:
    • \( F_{T40} \) = Maximum of total LCW force up to time of 40 msec
    • Limit Reduction (LR) = \([F2-70]\text{kN and } 0 \text{kN} \leq LR \leq 50 \text{kN} \)
  – Note: metric was developed based on FWDB 56 km/h tests, metric needs to be adjusted to proposed impact velocity of 50 km/h (especially LR)
FWDB Metric
SEAS detection

• FWRB would require stage 2 approach for correct assessment of cars applying SEAS in common interaction zone
  – Likely additional test
• Discussion whether or not FWDB is able to correctly detect SEAS structures
FWDB Metric
SEAS detection

• Q1: How far back can FWDB detect subframes and similar lower structures
• Q2: Can FWDB detect structures that are beneficial for car-car crashes?
FWDB Metric
SEAS detection

Question 1 SEAS Position

- The Public NCAC* Ford Taurus vehicle FE model was modified with three subframe positions
- FWDB simulations run with the Taurus variants in a raised position

* National Crash Analysis Centre, George Washington University
FWDB Metric
SEAS detection
Results Question 1 SEAS Position

- FWDB detects structures up to 350-400 mm back
- Car car simulations with the three variants showed that the most forward subframe provided best performance relative to baseline model
- Most rear variant was worse than baseline variant
- FWDB detecting differences in subframe performance
Question 2: Beneficial SEAS

- The TUB PCM models were used in 2 simulation series to investigate car-to-car and FWDB performance of different architectures
- Simulations conducted in normal ride height (baseline) and raised vehicles
Series 1 – Adjust Subframe Length

- Vertical offset for misalignment
Simulation results – FWDB

- LFC raised by 70mm against FWDB
- All subframe configurations failed FWDB

<table>
<thead>
<tr>
<th>Modification</th>
<th>time [ms]</th>
<th>SumForce [kN]</th>
<th>$0.2 F_{T40}$ [kN]</th>
<th>F1 [kN]</th>
<th>F2 [kN]</th>
<th>F3 [kN]</th>
<th>F4 [kN]</th>
<th>pass/fail</th>
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<tbody>
<tr>
<td>LFC_70mm</td>
<td>40</td>
<td>499</td>
<td>100</td>
<td>5</td>
<td>34</td>
<td>51</td>
<td>96</td>
<td>fail</td>
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</table>
**Simulation results – car-to-car**

- **Analysis of intrusions**
  - Maximum dynamic intrusion measured on firewall

<table>
<thead>
<tr>
<th>Baseline runs</th>
<th>LFC</th>
<th>SM</th>
<th>LFC</th>
<th>LFC</th>
<th>LFC</th>
<th>EXE</th>
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<tr>
<td></td>
<td>86</td>
<td>334</td>
<td>163</td>
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<table>
<thead>
<tr>
<th>Extended Subframe</th>
<th>LFC_D250</th>
<th>SM</th>
<th>LFC_D250</th>
<th>LFC</th>
<th>LFC_D250</th>
<th>EXE</th>
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<tr>
<td></td>
<td>112</td>
<td>347</td>
<td>239</td>
<td>158</td>
<td>284</td>
<td>88</td>
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</table>

<table>
<thead>
<tr>
<th>Standard Subframe</th>
<th>LFC_basis</th>
<th>SM</th>
<th>LFC_basis</th>
<th>LFC</th>
<th>LFC_basis</th>
<th>EXE</th>
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<tr>
<td></td>
<td>89</td>
<td>343</td>
<td>error</td>
<td></td>
<td>205</td>
<td>89</td>
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</table>

<table>
<thead>
<tr>
<th>Shorter Subframe</th>
<th>LFC_D400</th>
<th>SM</th>
<th>LFC_D400</th>
<th>LFC</th>
<th>LFC_D400</th>
<th>EXE</th>
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<tbody>
<tr>
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<td>125</td>
<td>334</td>
<td>222</td>
<td>164</td>
<td>277</td>
<td>88</td>
</tr>
</tbody>
</table>

- Misalignment causes higher intrusions on overridden car
- No clear trend of cars with different sub frame positions
FWDB Metric
SEAS detection

Series 2: Adjust subframe connections and vertical section

Misaligned

Option 1

Option 2
Simulation matrix

- FWDB_50
  - Large Family Car
    1. Height of basic configuration increased to align PEAS with row 4 (+60mm) ➔ misaligned
    2. Sub frame and vertical connection (longitudinal - sub frame) moved forward ➔ option 1
    3. Cross section of sub frame cross beam increased ➔ option 2

- Car – to – car
  - baseline* vs. option 1
  - baseline* vs. option 2

*baseline model passes all metrics
## FWDB Metric results

### Limit Reduction Metric

<table>
<thead>
<tr>
<th></th>
<th>Misaligned (aligned row 4)</th>
<th>Option 1 (subframe and vertical connection far forward)</th>
<th>Option 2 (subframe cross section increased and vertical connection far forward)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{\text{sum}}$ [kN]</td>
<td>458</td>
<td>427</td>
<td>467</td>
</tr>
<tr>
<td>$F_4$ [kN]</td>
<td>190</td>
<td>146</td>
<td>155</td>
</tr>
<tr>
<td>$F_3$ [kN]</td>
<td>61</td>
<td>66</td>
<td>81</td>
</tr>
<tr>
<td>$F_3 + F_4$ [kN]</td>
<td>251</td>
<td>212</td>
<td>236</td>
</tr>
<tr>
<td>$0.4F_{\text{sum @ 40ms}}$ [kN]</td>
<td>183,2</td>
<td>170,8</td>
<td>186,8</td>
</tr>
<tr>
<td>$0.2F_{\text{sum @ 40ms}}$ [kN]</td>
<td>91,6</td>
<td>85,4</td>
<td>93,4</td>
</tr>
<tr>
<td>$F_2$ [kN]</td>
<td>32</td>
<td>46</td>
<td>63</td>
</tr>
<tr>
<td>LR [kN]</td>
<td>(-38 ⇒ 0)</td>
<td>(-24 ⇒ 0)</td>
<td>(-7 ⇒ 0)</td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td>October 11th 2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Author</strong></td>
<td>Heiko Johannsen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FWDB Metric**

**SEAS detection**
**Car – to – car**

- **Intrusions**
  - Maximum dynamic intrusions measured at the same location in all 4 vehicles

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Modified car</th>
</tr>
</thead>
<tbody>
<tr>
<td>baseline - misaligned</td>
<td>-125mm</td>
<td>-220mm</td>
</tr>
<tr>
<td>baseline - option 2</td>
<td>-98mm</td>
<td>-122mm</td>
</tr>
<tr>
<td><strong>Reference</strong></td>
<td><strong>Baseline</strong></td>
<td><strong>Baseline</strong></td>
</tr>
<tr>
<td>Baseline - Baseline</td>
<td>-163mm</td>
<td>-167mm</td>
</tr>
</tbody>
</table>
Series 2: Summary – car-to-car

- Intrusions decreased clearly in configuration with improved sub frame loads measured in the FWDB compared to misaligned PEAS configuration
- Option 2 produced improved intrusions from the reference of unmodified, aligned, baseline vehicles
- Higher deceleration of crashed vehicles with improved sub frame as a result of the improved structural interaction
- Rows 2 & 3 are detecting the improved performance of a subframe that also provides benefit in car-car impact
Conclusion

Q1: How far back can FWDB detect subframes and similar lower structures
• Ford Taurus simulation show that FWDB can detect up to about 350 mm behind bumper cross beam for structures that affect car-car performance

Q2: Can FWDB detect structures that are beneficial for car-to-car crashes?
• The PCM and Taurus simulations show that the FWDB is detecting structures in Rows 2 and 3 that detect car-to-car crash performance
• Simulations indicate that the following sub frame characteristics can have a positive influence in car-to-car crashes:
  – Far forward position of the sub frames cross beam to catch the
  – Far forward vertical connection between SEAS and PEAS
  – Large cross section to provide enough support for penetrating structures
Limitations

- The PCM models do not represent a real vehicle and thus a vehicle with the Option 2 architecture specifically designed for the metric should pass the metric with modest redesign efforts (balancing upper and lower load path)
SEAS Design – ORB

- ORB

Original test configuration (ORB aligned with Part 581 zone (16” to 20”)) was adjusted to measure loads produced by SEAS

⇒ Row 1 and 2 of FWB LCW were used (80mm to 330mm)
Simulation results – barriers

- ORB – reinforced sub frame passed ORB test except when subframe placed 400mm behind bumper crossbeam

<table>
<thead>
<tr>
<th>Modification</th>
<th>s @ F_{max} [mm]</th>
<th>F_{max} [kN]</th>
<th>Distance to front [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>D200</td>
<td>288</td>
<td>457</td>
<td>262</td>
</tr>
<tr>
<td>D250</td>
<td>338</td>
<td>468</td>
<td>312</td>
</tr>
<tr>
<td>D300</td>
<td>388</td>
<td>446</td>
<td>362</td>
</tr>
<tr>
<td>Basis</td>
<td>400</td>
<td>257</td>
<td>400</td>
</tr>
<tr>
<td>D350</td>
<td>400</td>
<td>183</td>
<td>412</td>
</tr>
<tr>
<td>D400</td>
<td>331</td>
<td>25</td>
<td>462</td>
</tr>
</tbody>
</table>
Overall Conclusions SEAS Detection

• Separate “Stage 2” testing options are not recommended to allow vehicles which do not meet FWDB metrics
  – FIMCAR and NHTSA results identify vehicles with acceptable ORB test results for SEAS designs that do not improve car-to-car crash performance (false positives)
Advantages and disadvantages ODB

+ ODB guarantees that current level of compartment strength will be maintained for all vehicles
+ Used in legislated and consumer tests in many countries
+ Provides a softer pulse compared to the full width test
+ Harmonization potential
  - Load spreading not covered
Justification ODB Modification

– Additional compartment strength requirement will likely not affect recent cars
  • They are Euro NCAP driven are designed for more challenging requirements

– Legal requirement required to ensure minimum safety levels even if cars are not designed for good ratings

– FIMCAR to maintain compartment strength at least at level of today requires compulsory target
Achievement of FIMCAR priorities

• Structural alignment
  – Addressed with FWDB metric

• Vertical load spreading
  – Addressed at basic level
    – Requirements for row 3 and 4
    – Limit reduction on Row 3 for load spreading down to row 2
    – Minimum section size required for SEAS to be detectable

• Horizontal load spreading
  – Not addressed

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Achievement of FIMCAR priorities

- Current compartment strength requirements maintained
  - Addressed by definition

- Appropriate severity level for occupant protection (RS)
  - Addressed (metrics are expected to be consistent even at lower speeds, dummy performance?)

- Pulse requirements
  - Addressed
Benefit Analysis

• Assumptions
  • Occupants suffering from high acceleration injuries would benefit from the introduction of FWB
  • Occupants suffering from under/override accidents caused by structural misalignment would benefit from the introduction of FWB
Benefit Analysis

• Assumptions (continued)
  • Occupants suffering force mismatch issues would benefit from additional introduction of PDB
  • Occupants suffering from fork effect issues would benefit from additional introduction of PDB
  • Occupants suffering from low overlap would benefit from additional introduction of PDB
Benefit Analysis

• Target Population GB

- All KSI: 314 (100.0%)
  - No issue: 177 (56%)
    - No issue (High severity): 16 (5%)
    - No issue (Large vehicle underride): 76 (24%)
  - Compatibility issue: 94 (30%)
    - Structural Interaction: 82 (26%)
    - Frontal Force / Compartment Strength: 12 (4%)
  - Deceleration: 43 (14%)

- Override: 17 (5%)
- Fork effect: 38 (12%)
- Low overlap: 27 (9%)

Full width Test
PDB Test

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Benefit Analysis

**Target Population D**

- **KSI (MAIS 2+)**
  - 195 (100%)

- **No issues**
  - 90 (46%)

- **Compatibility issue**
  - 24 (13%)
    - **Frontal Force Mismatch**
      - 1
    - **Structural interaction**
      - 23

- **Deceleration**
  - 80 (41%)
    - **Fork Effect**
      - 0
    - **Low Overlap**
      - 14
    - **Underride**
      - 9

- **Full width Test**
- **PDB Test**

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Benefit Analysis

- Estimation of break even costs per car scaled for Europe
  - For introduction of FWB with compatibility metrics
    - 104 – 294 Euro
  - For introduction of FWB with compatibility metrics and PDB with compatibility metrics
    - 158 – 415 Euro