FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

FIMCAR Frontal Impact Assessment Approach

FIMCAR
frontal impact and compatibility assessment research

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FIMCAR

- 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

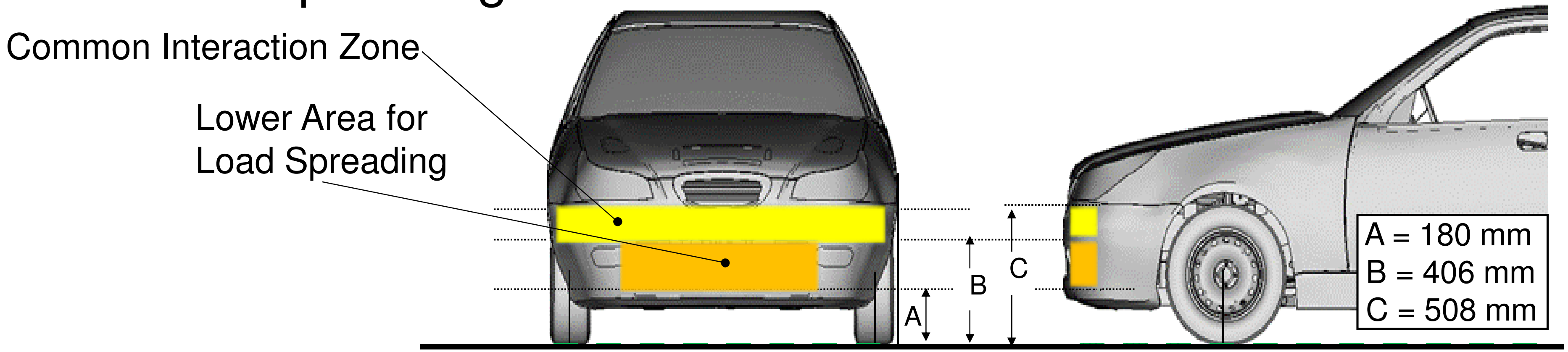
Summary of findings

- 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



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

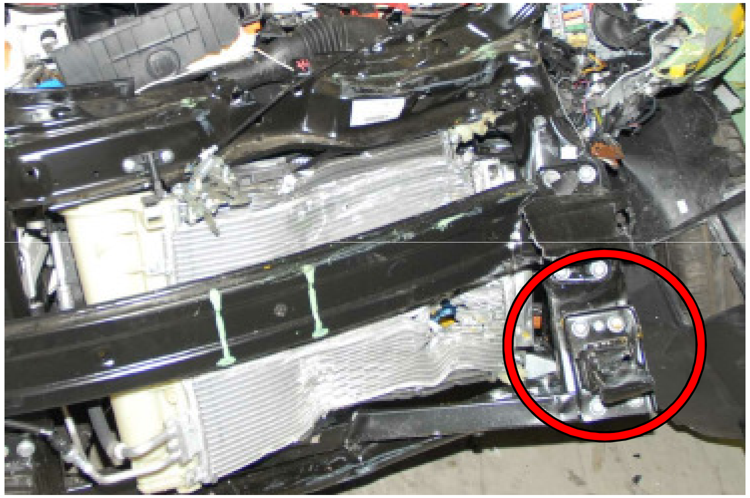
FWRB

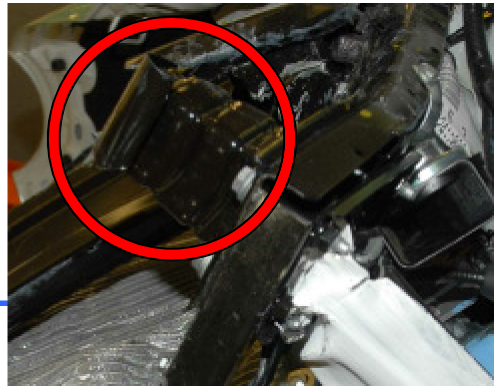
Justification FWDB

more representative deformation pattern

FWDB

car-to-car 50% overlap

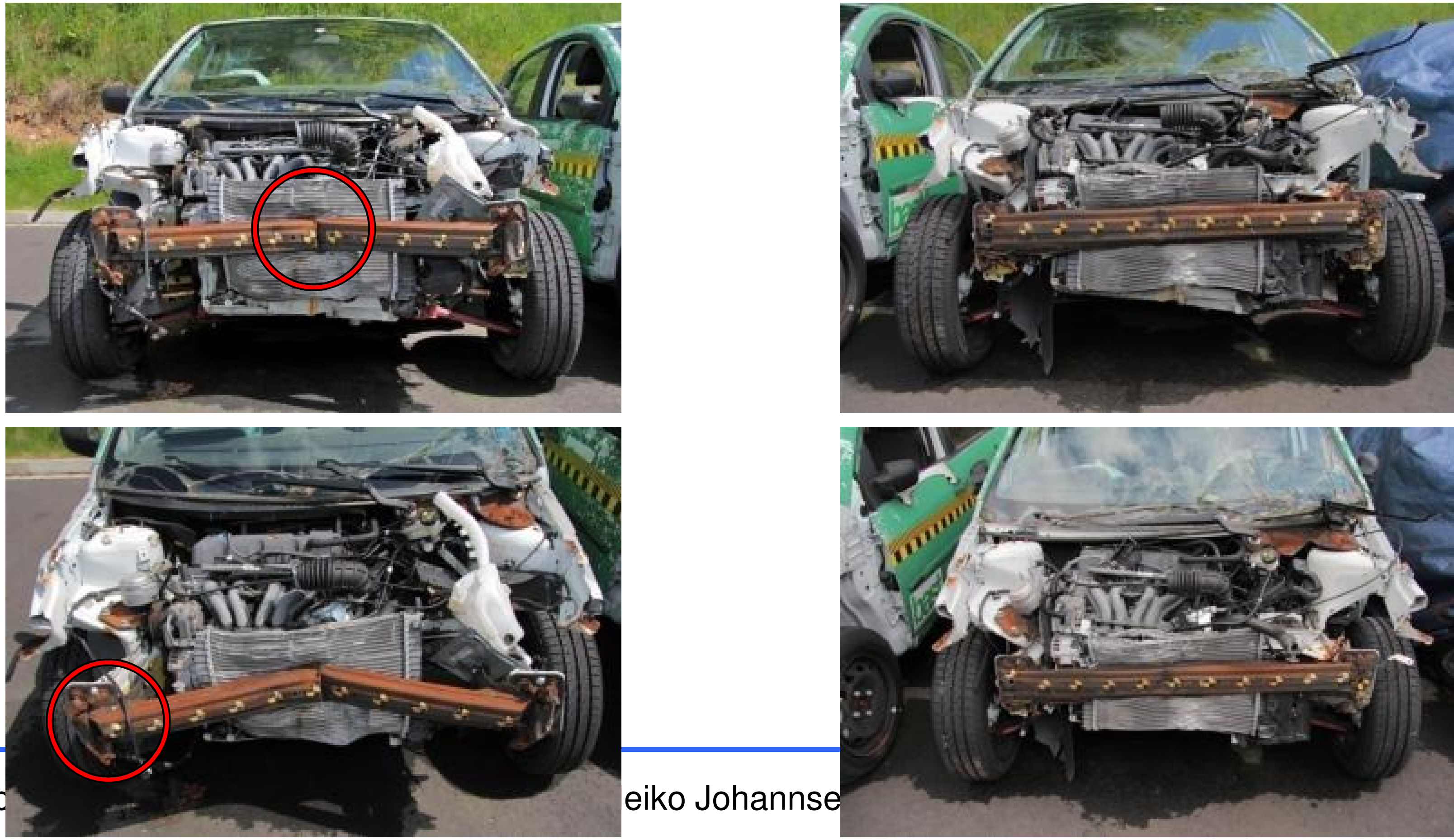




Justification FWDB

more representative deformation pattern

FWDB FWRB



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

Justification FWDB

restraint system triggering

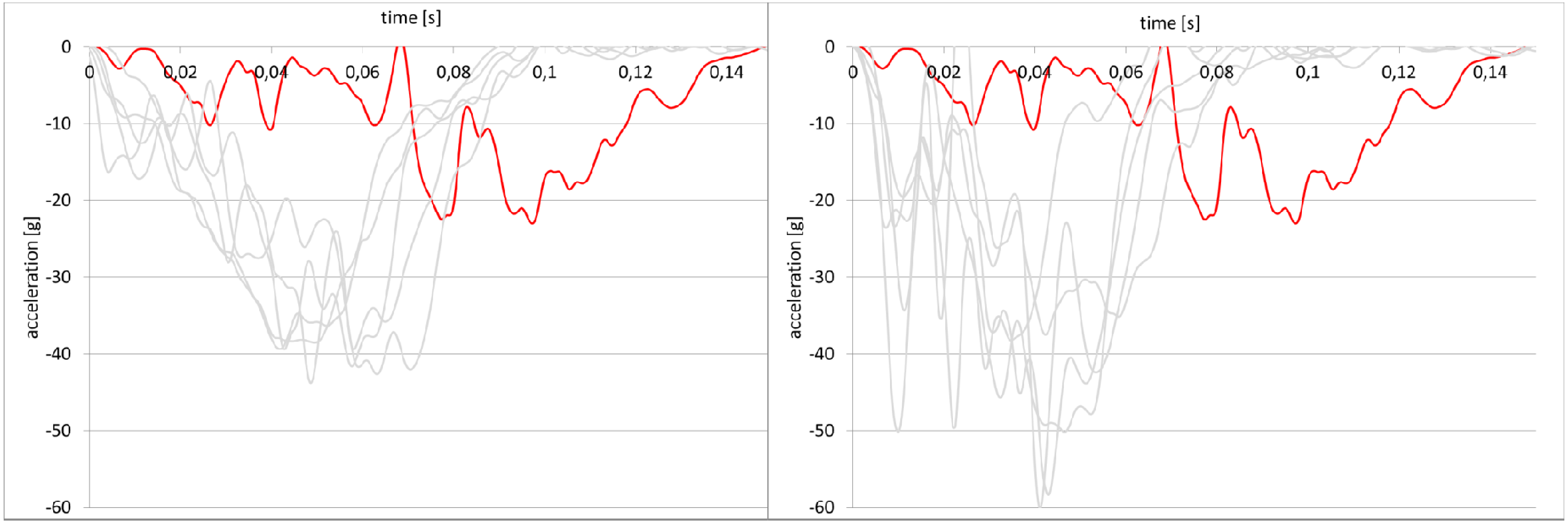
Centered pole impact

Justification FWDB

restraint system triggering

Puls comparison to FWDB

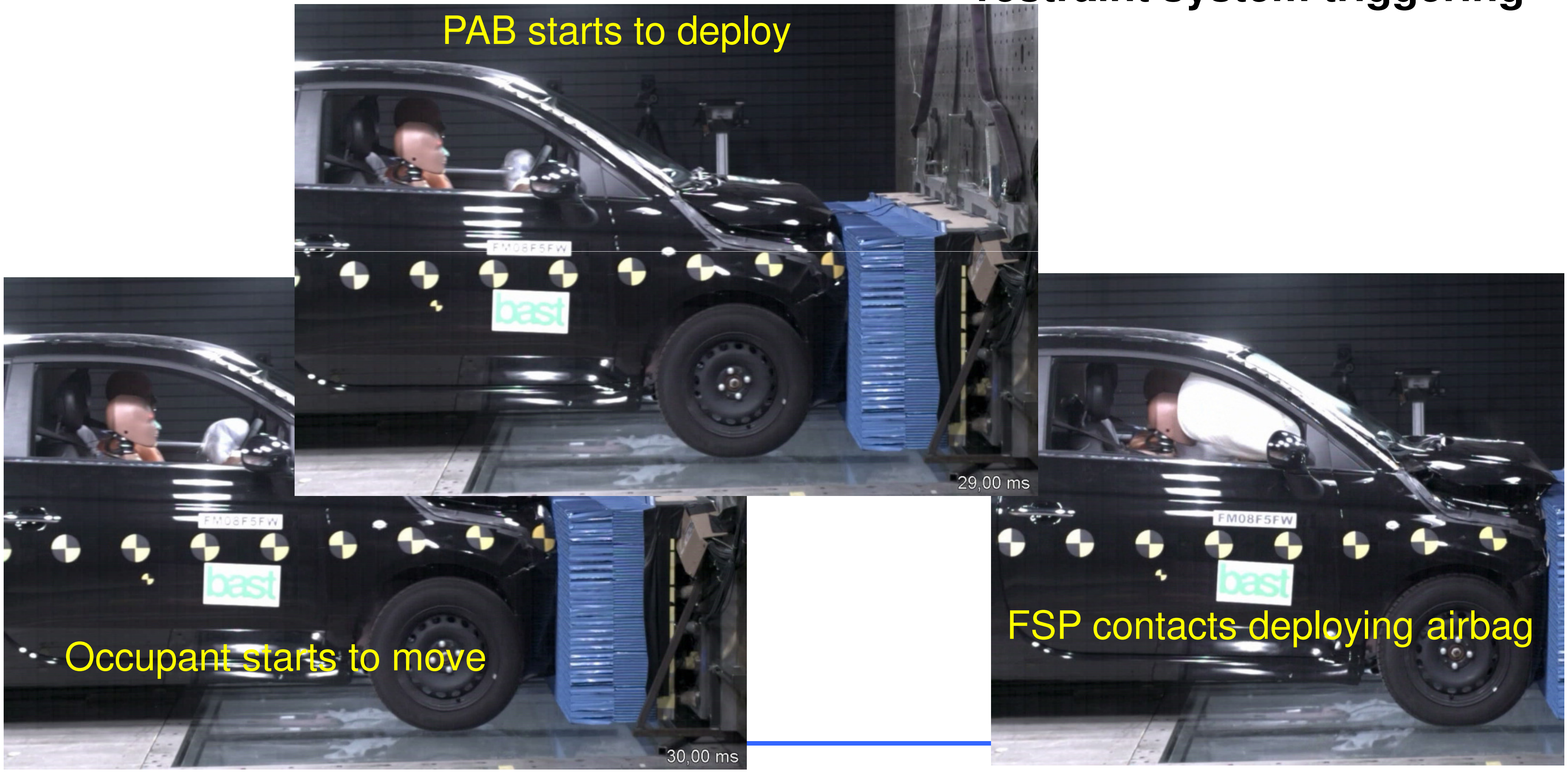
Puls comparison to FWRB



Justification FWDB

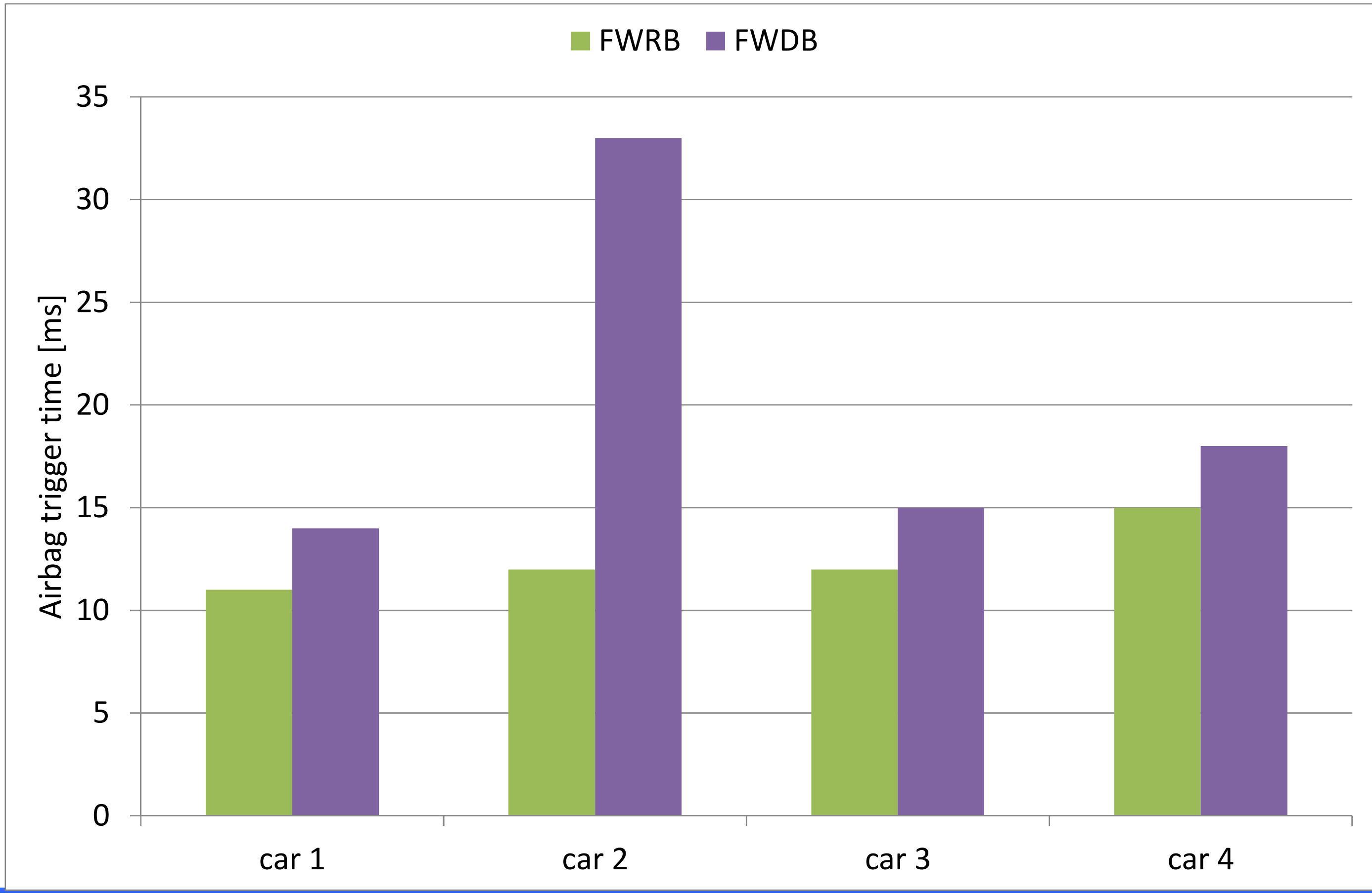
restraint system triggering

40 km/h FWDB



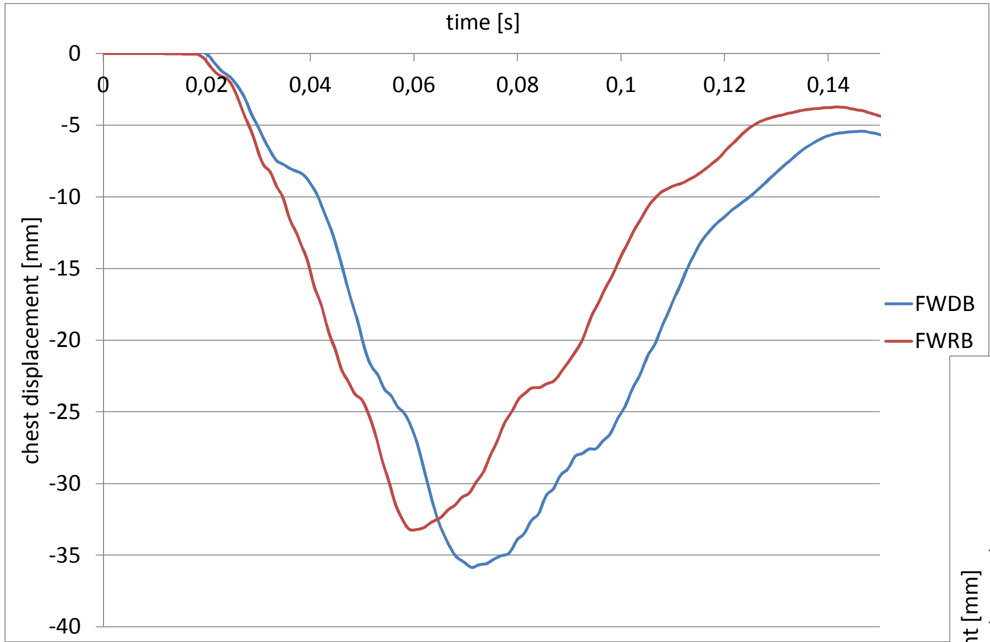
Justification FWDB

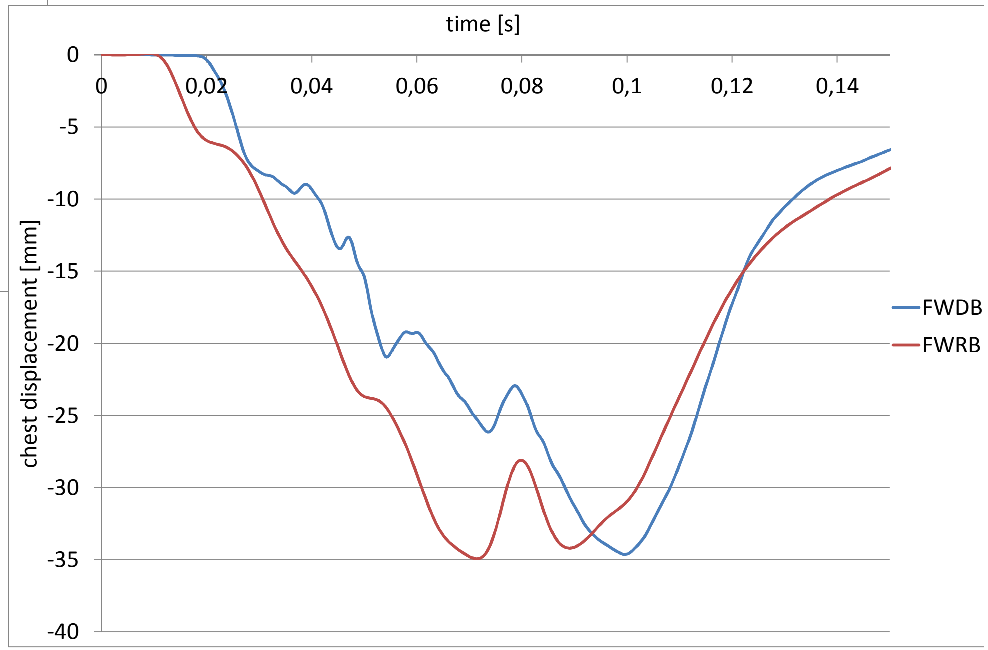
restraint system triggering



Justification FWDB

restraint system triggering

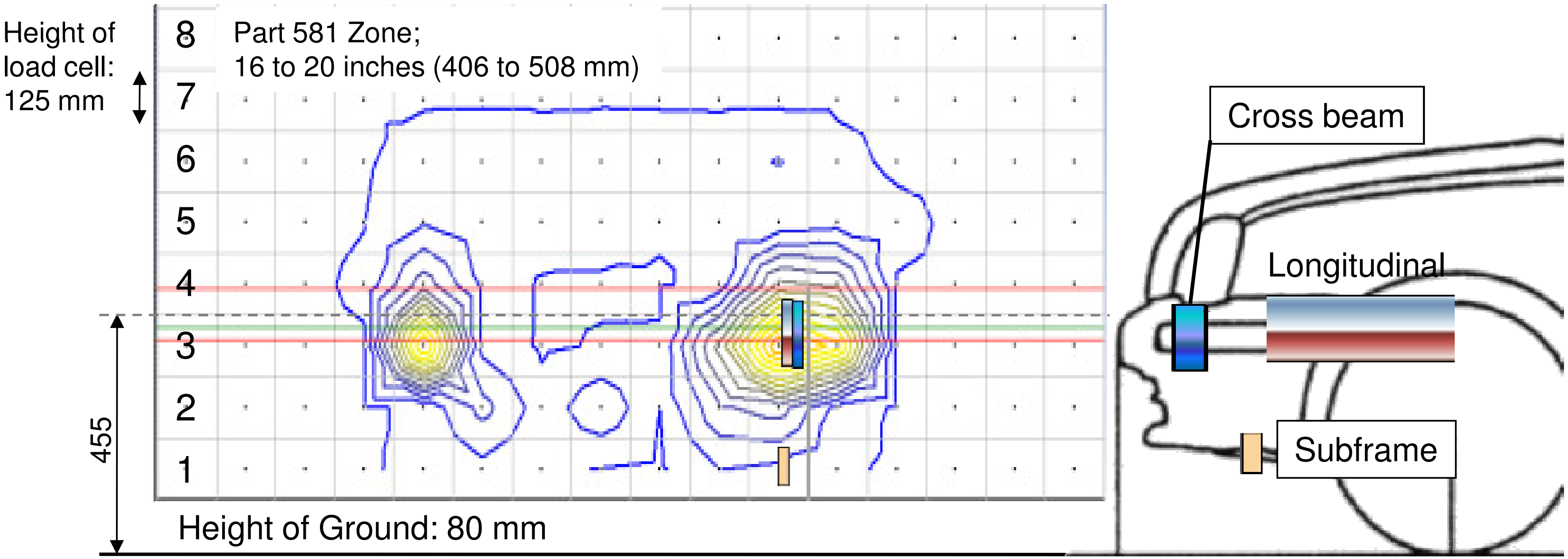




FWDB metrics

Concept:

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



FWDB Metric

- Up to time of 40 msec
  - $F4 + F3 \geq [MIN(200, 0.4F_{T40})$ kN
  - $F4 \geq [MIN(100, 0.2F_{T40})$ kN
  - $F3 \geq [MIN((100\text{-}LR), (0.2F_{T40}\text{-}LR))$, kN
  - where:
    - F_{T40} = Maximum of total LCW force up to time of 40 msec
    - Limit Reduction (LR) = [F2-70] kN and 0 kN ≤ LR ≤ 50 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

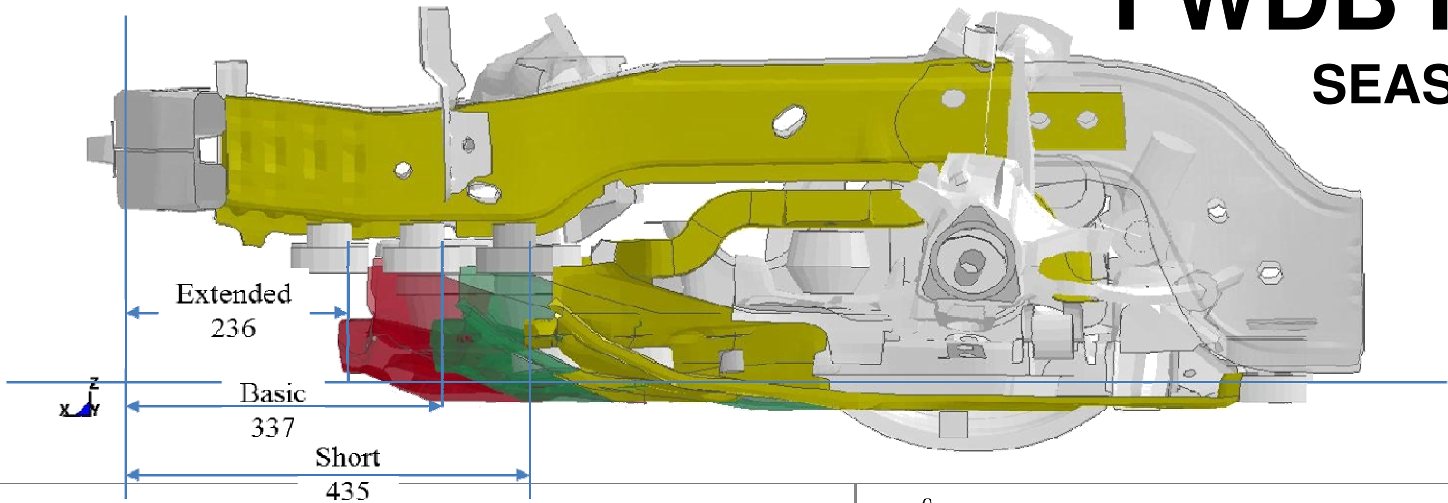
Question 1 SEAS Position

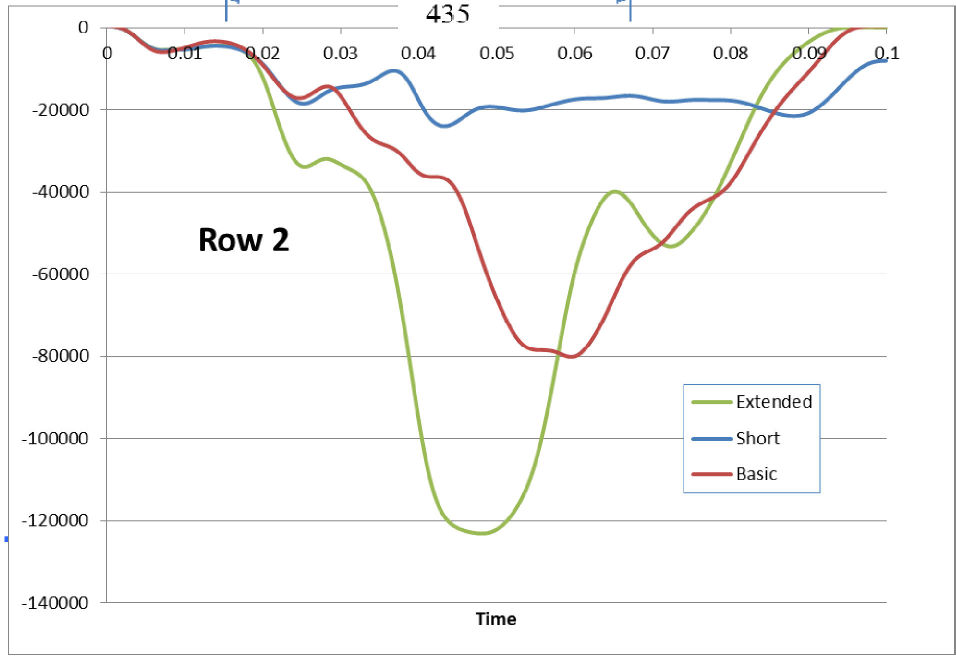
- The Public NCAC* Ford Taurus vehicle FE model was modified with three subframe positions
- FWDB simulations run with the Taurus variants in a raised position

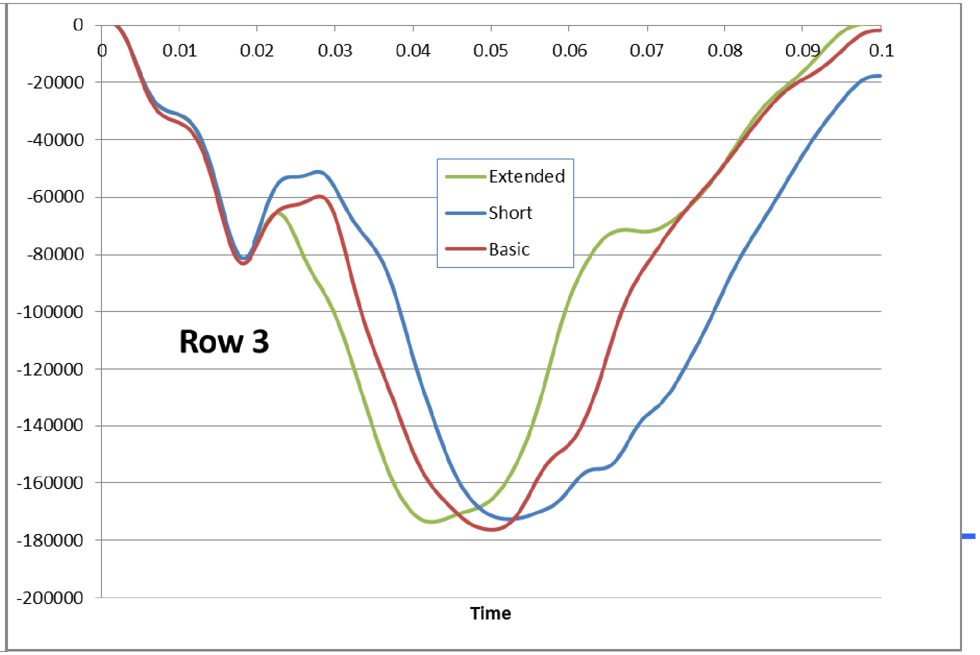
* National Crash Analysis Centre, George Washington University

FWDB Metric

SEAS detection







FWDB Metric

SEAS detection

Results Question 1 SEAS Position

- FWDB detects structures upto 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

FWDB Metric

SEAS detection

Question 2: Beneficial SEAS

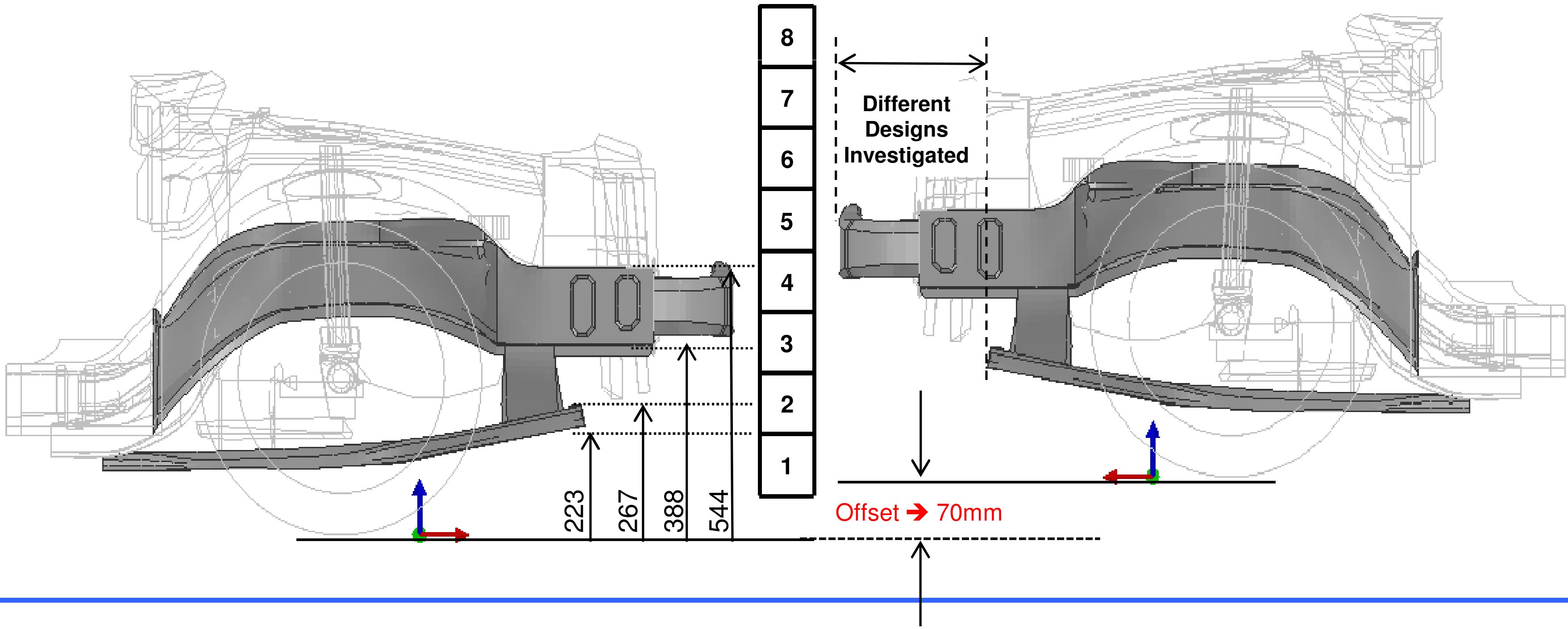
- The TUB PCM models were used in 2 simulation series to investigate car-to-car and FWDB perfance of different architectures
- Simulations conducted in normal ride height (baseline) and raised vehicles

FWDB Metric

SEAS detection

Series 1 – Adjust Subframe Length

- Vertical offset for misalignment



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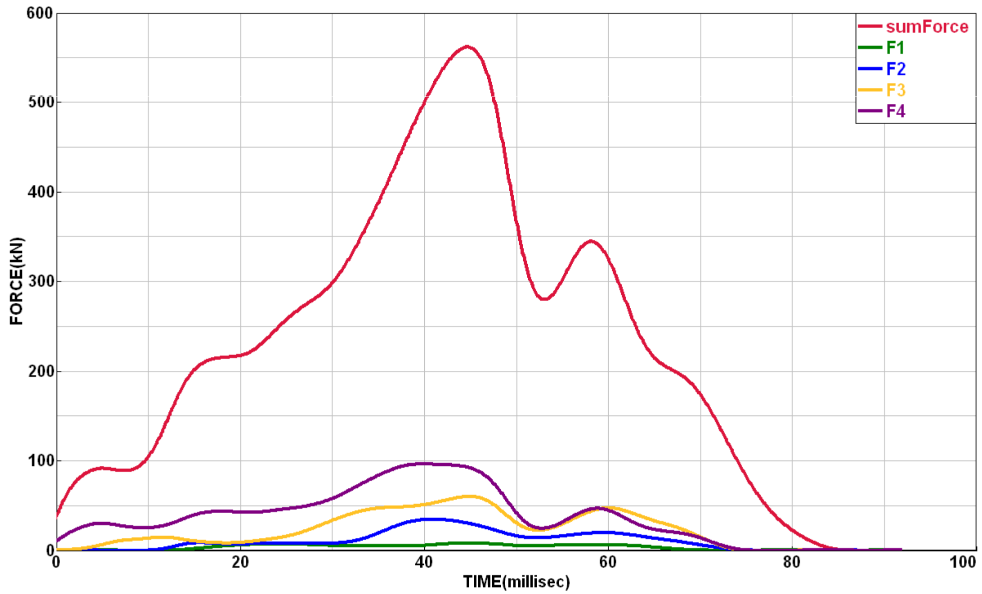
FWDB Metric

SEAS detection

Simulation results – FWDB

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



Modification	time [ms]	SumForce [kN]	$0.2F_{T40}$ [kN]	F1 [kN]	F2 [kN]	F3 [kN]	F4 [kN]	pass/fail
LFC_70mm	40	499	100	5	34	51	96	fail

FWDB Metric

SEAS detection

Simulation results – car-to-car

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

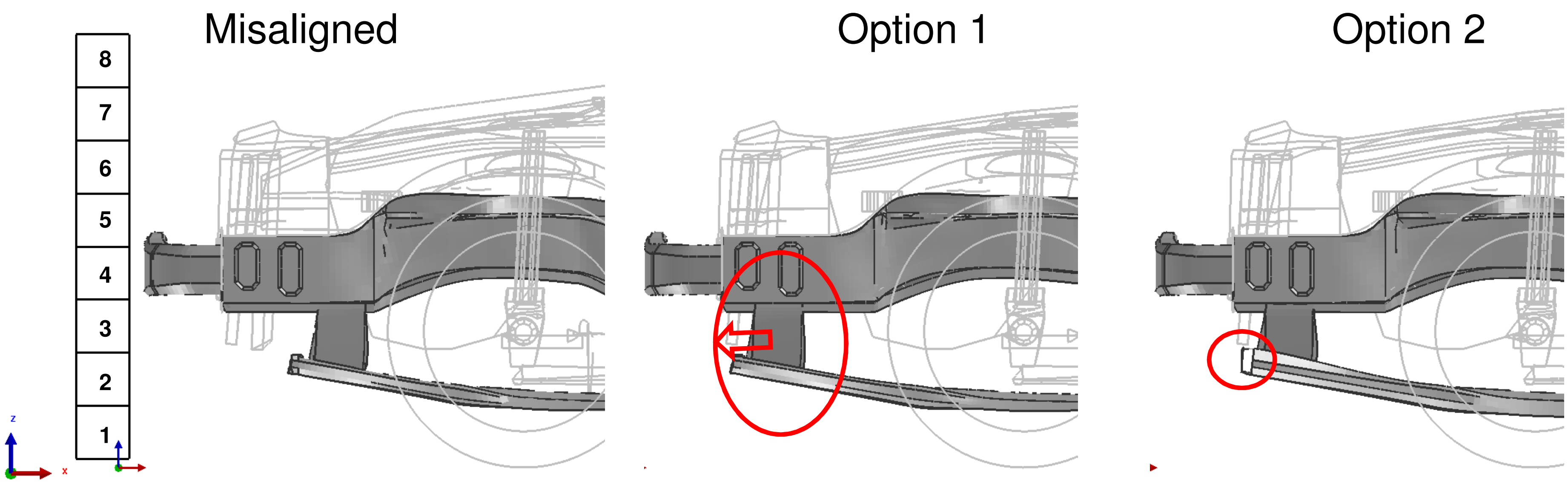
Baseline runs	LFC	SM	LFC	LFC	LFC	EXE
	86	334	163	167	187	77
Extended Subframe	LFC_D250	SM	LFC_D250	LFC	LFC_D250	EXE
	112	347	239	158	284	88
Standard Subframe	LFC_basis	SM	LFC_basis	LFC	LFC_basis	EXE
	89	343	error		205	89
Shorter Subframe	LFC_D400	SM	LFC_D400	LFC	LFC_D400	EXE
	125	334	222	164	277	88

- 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



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

SEAS detection

FWDB Metric results

Limit Reduction Metric			
	Misaligned (aligned row 4)	**Option 1** (subframe and vertical connection far forward)	**Option 2** (subframe cross section increased and vertical connection far forward)
F_{sum} [kN]	458	427	467
F_4 [kN]	190	146	155
F_3 [kN]	61	66	81
$F_3 + F_4$ [kN]	251	212	236
$0.4F_{sum\_@\_40ms}$ [kN]	183,2	170,8	186,8
$0.2F_{sum\_@\_40ms}$ [kN]	91,6	85,4	93,4
F_2 [kN]	32	46	63
LR [kN]	(-38 → 0)	(-24 → 0)	(-7 → 0)
	fail	fail	fail

FWDB Metric

SEAS detection

Car – to – car

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

	Baseline	Modified car
baseline - misaligned	-125mm	-220mm
baseline - option 2	-98mm	-122mm
Reference	**Baseline**	**Baseline**
Baseline - Baseline	-163mm	-167mm

FWDB Metric

SEAS detection

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**

FWDB Metric

SEAS detection

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

FWDB Metric

SEAS detection

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)

FWDB Metric

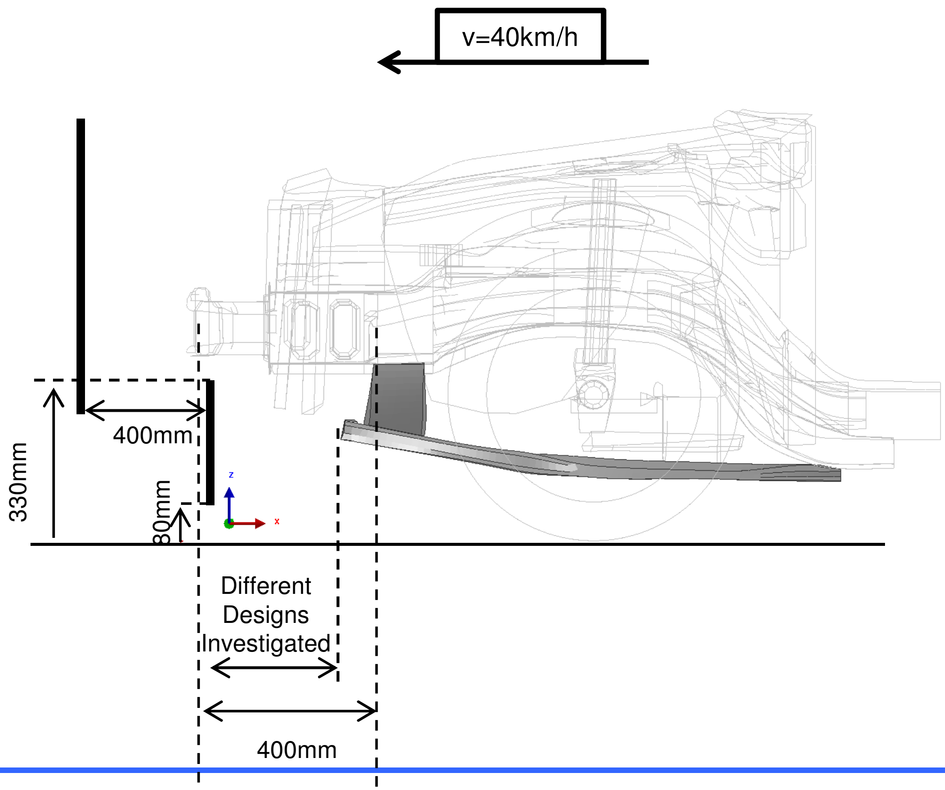
SEAS detection

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)

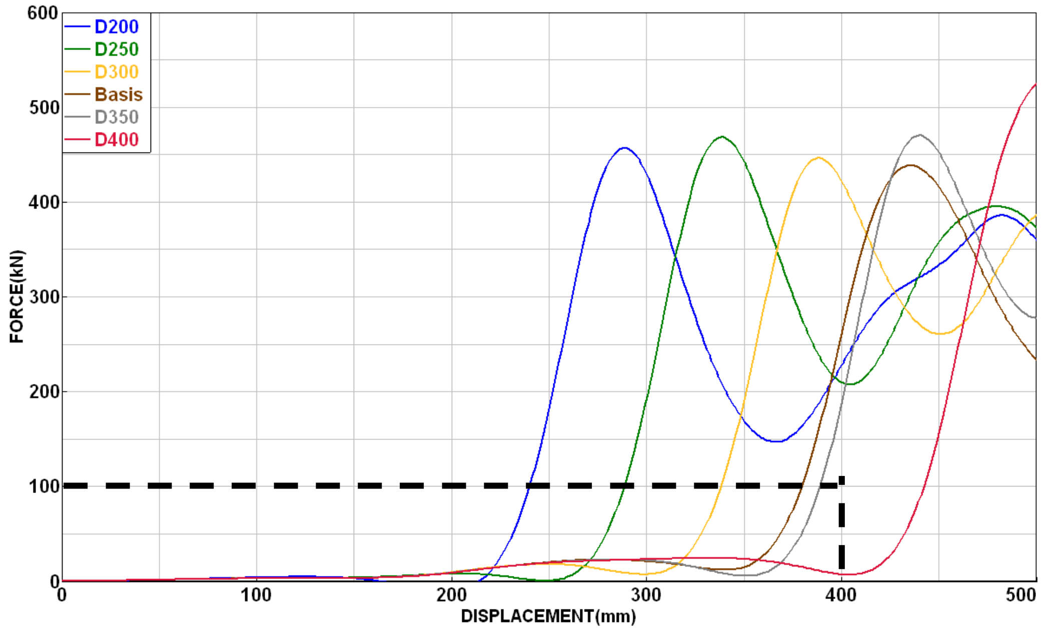


FWDB Metric

SEAS detection

Simulation results – barriers

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



Modification	s @ F_{max} [mm]	F_{max} [kN]	Distance to front [mm]
D200	288	457	262
D250	338	468	312
D300	388	446	362
Basis	400	257	400
D350	400	183	412
D400	331	25	462

FWDB Metric

SEAS detection

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

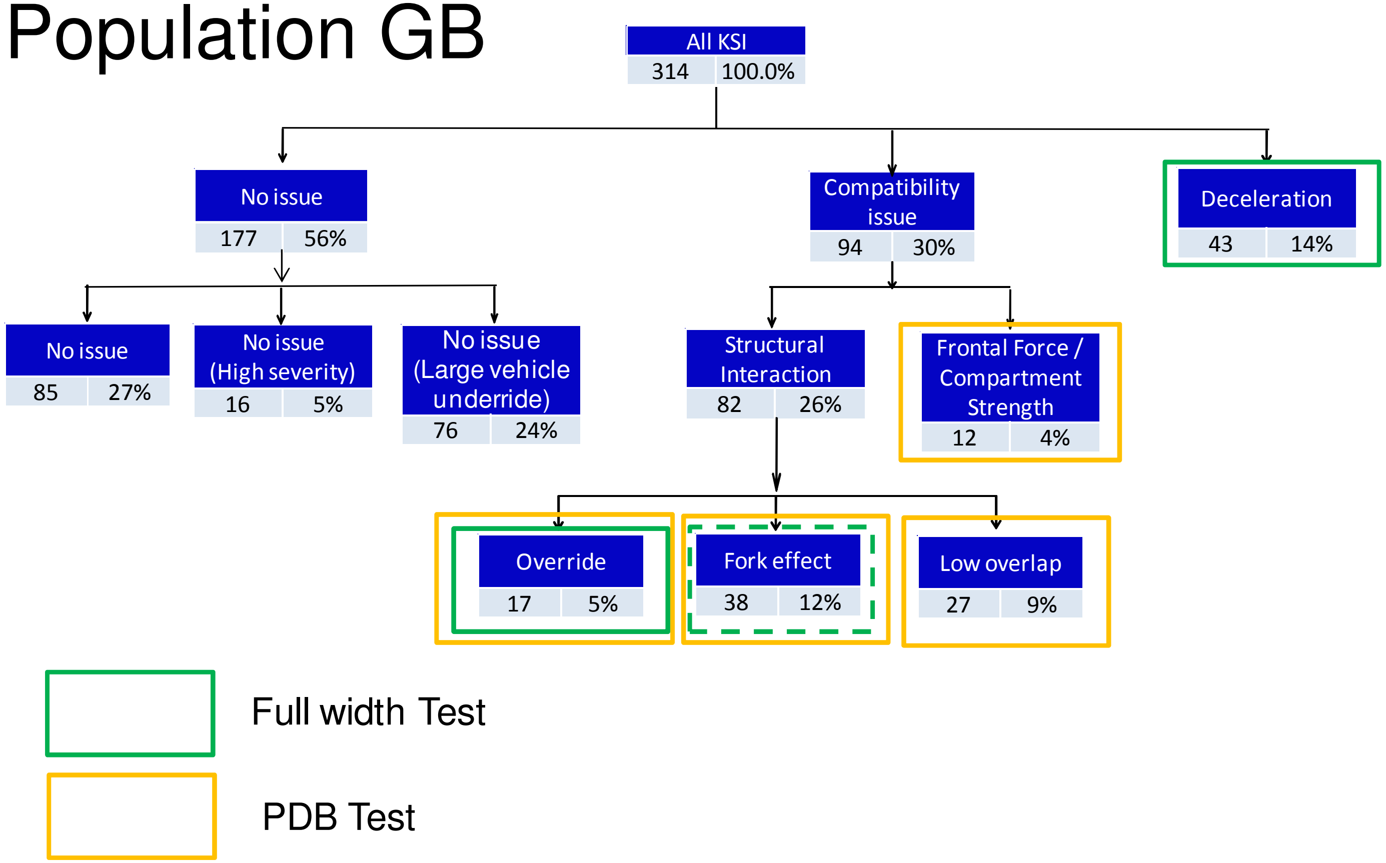
- Assumptions
  - Occupants suffering from high acceleration injuries would benefit from the introduction of FWB
  - Occupants suffering from under/override accidents caused by structural misalignment would benefit from the introduction of FWB

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

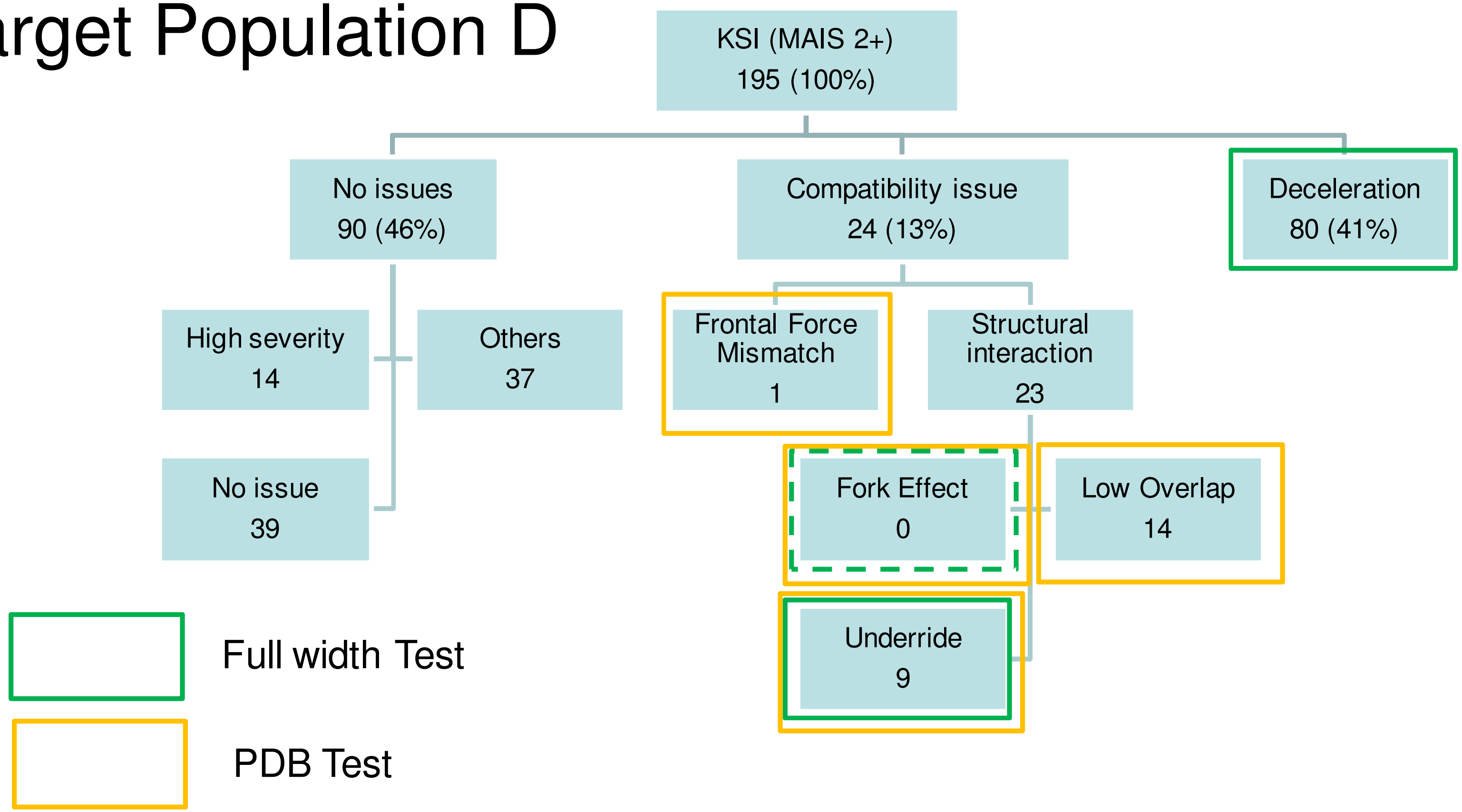
Benefit Analysis

- Target Population GB



Benefit Analysis

- Target Population D



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