Occupant Response After Pre-Crash Vehicle Maneuvers

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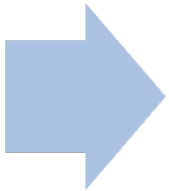
NHTSA

Research Purpose

The aim of this research is to use a finite element (FE) human body model to determine how a range of pre-crash occupant kinematics and seat positioning impacts occupant safety performance response.

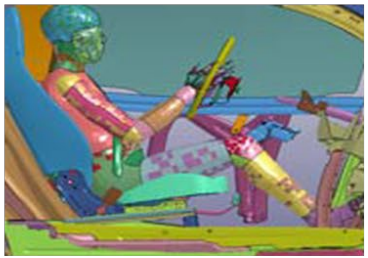
ADAS pre-crash systems (e.g., AEB) + occupant's muscle contraction



Occupant's posture, position, and velocity relative to the car interior and restraint systems

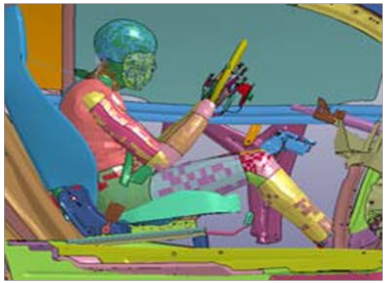
Technical Approach Overview

$t < t_a$ (t_a ~-1500/-2000 ms)



A pre-crash simulation with **Pre-Crash HBM**

t= 0 ms (crash starts)



A pre-crash simulation with **In-Crash HBM**

End of the crash
(***t_f ~ 150 ms***)

All simulations were run in the front passenger seat environment of a 2014 Honda Accord model (pictured left).

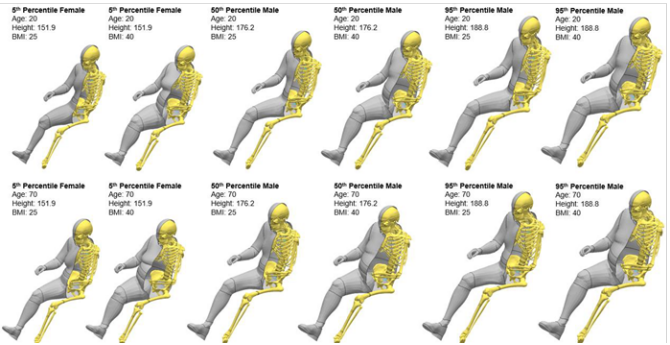
Design of Experiments (DOE)

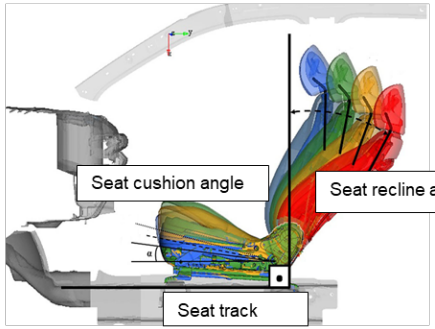
Design variables

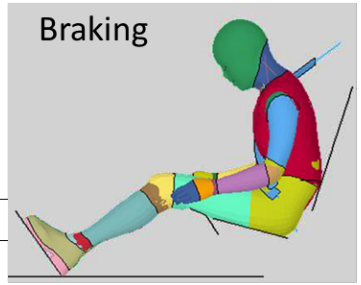
Occupant characteristics
1. Age
2. BMI
3. Stature
4. Sex

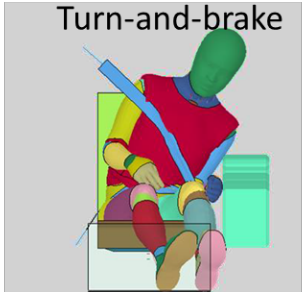
Seat positioning
1. Seat track
2. Seat Recline Angle
3. Seat Cushion Angle

Pre-crash maneuvers
1. Braking
2. Turn-and-brake





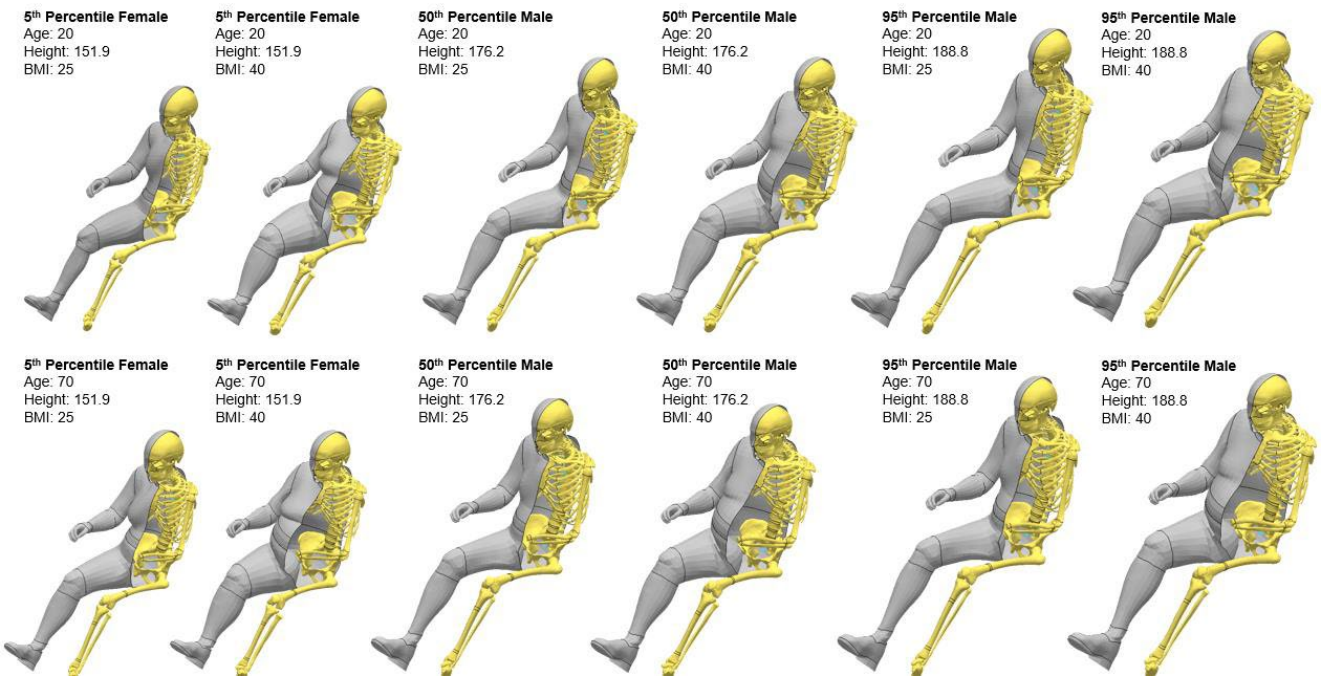




Pre-Crash Models: The GHBMCsi-pre[1]

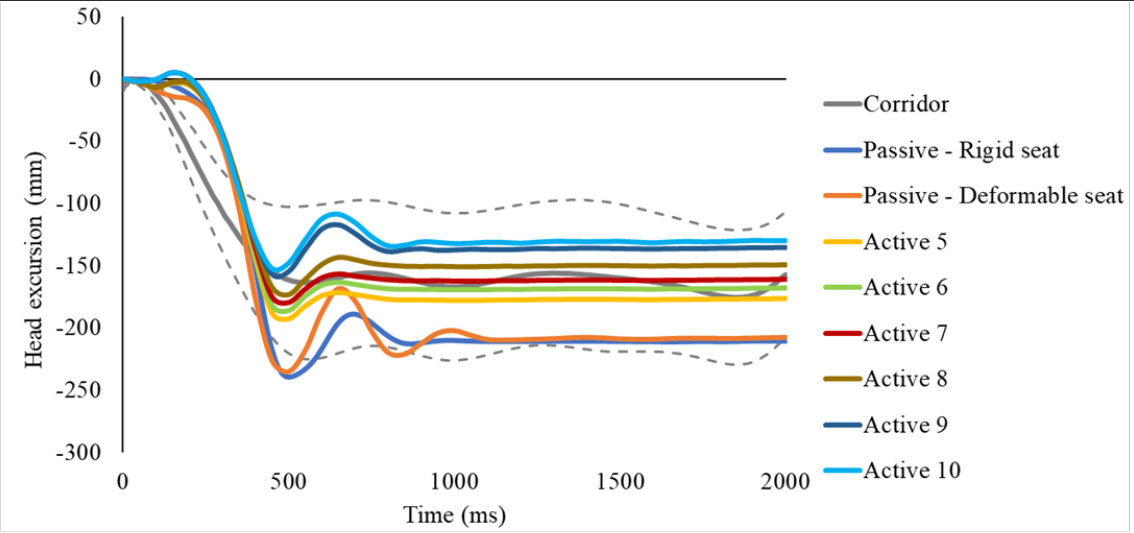
Run Pre-crash (with Optimized AL)

GHBMCsi-pre



[1] Hu, J., Reed, M., et al. (2019 SAE Government Industry Meeting) *Measuring and Modeling Occupant Responses During Abrupt Vehicle Maneuvers*. Transportation Research Institute, University of Michigan (UMTRI).

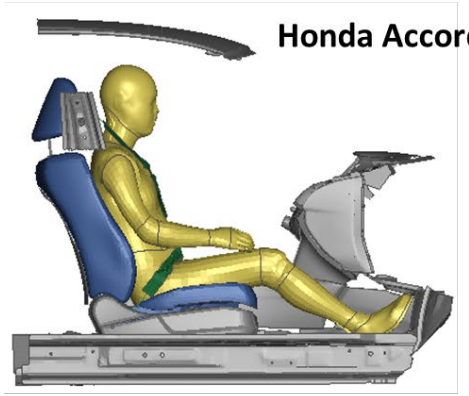
Optimizing GHBMCsi-pre Activation Levels



Head excursion of passive and active GHBMCsi-pre (Model No. 5) models in pre-crash simulations.

GHBMC information				Abrupt brake		Turn-and-brake	
Model No.	Size	Age	BMI	Active level	CORA	Active level	CORA
5	M50	20	25	AL7	0.975	AL11	0.836
6	M50	20	40	AL7	0.99	AL5	0.882
Average CORA score throughout the 12 models:							
				Brake		Turn-and-brake	
		Average CORA		0.967		0.863	

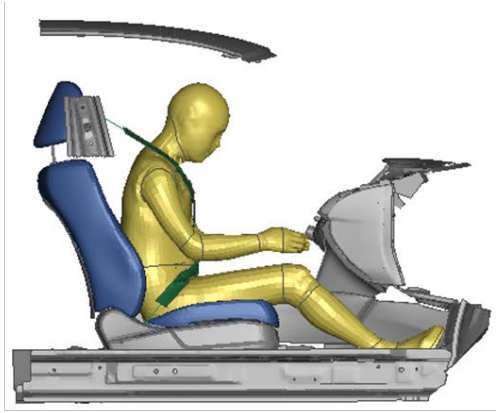
Pre-Crash Simulations w/ the GHBMCsi-pre



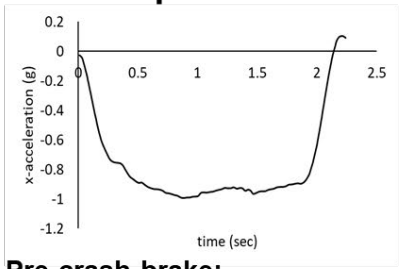
Honda Accord 2014 FE Model (NHTSA database)

Pre-crash Pulse

~2000-3000 ms

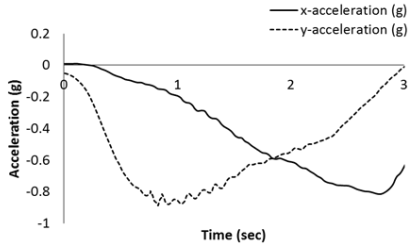


Abrupt brake



Pre-crash brake:
Drop in X - velocity ~ 16.02 m/s (57.67 km/h)
At the end of pre-crash brake: 56 km/h

Turn-and-brake



Pre-crash Turn-and-brake:
Drop in X - velocity ~ 15.4 m/s (55.44 km/h)
Drop in Y - velocity ~ 11.5 m/s (41.4 km/h)
At the end of pre-crash turn-and-brake: 56 km/h

Methods: Segmentation

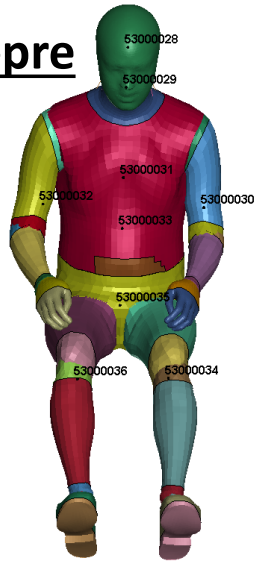
Run Pre-crash (with Optimized AL)

→

Save posture and kinematics from the GHBMCsi-pre

(**Segmentation Approach**)

GHBMCsi-pre



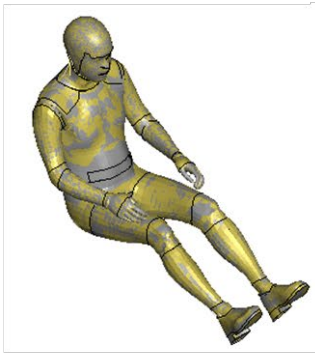
Body regions/segments
Head
Neck
Upper extremity - Left
Thorax - Axial
Upper extremity - Right
Abdomen
Lower extremity - Left
Pelvis
Lower extremity - Right

In-Crash Models: The GHBMCsi

F-05-BMI-25-Age-20

F-05-BMI-25-Age-70

M-50-BMI-25-Age-20

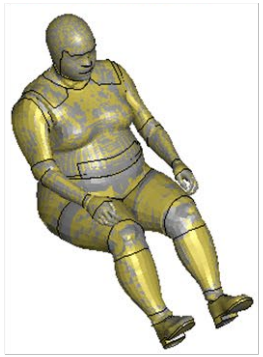


M-50-BMI-25-Age-70

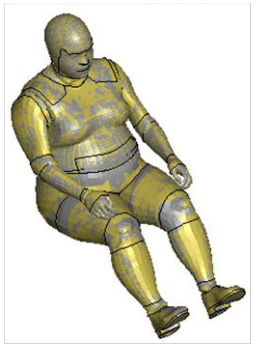
M-95-BMI-25-Age-20

M-95-BMI-25-Age-70

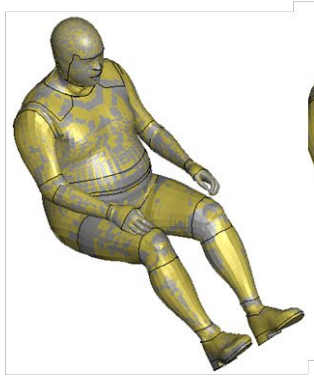
F-05-BMI-40-Age-20



F-05-BMI-40-Age-70

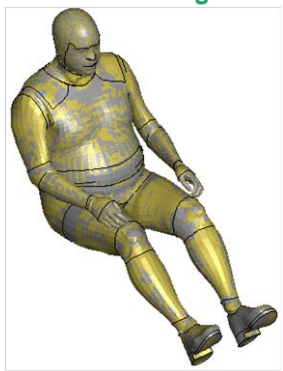


M-50-BMI-40-Age-20

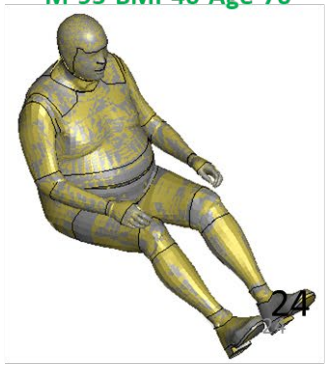


M-50-BMI-40-Age-70

M-95-BMI-40-Age-20



M-95-BMI-40-Age-70



Methods: GHBMCsi Positioning

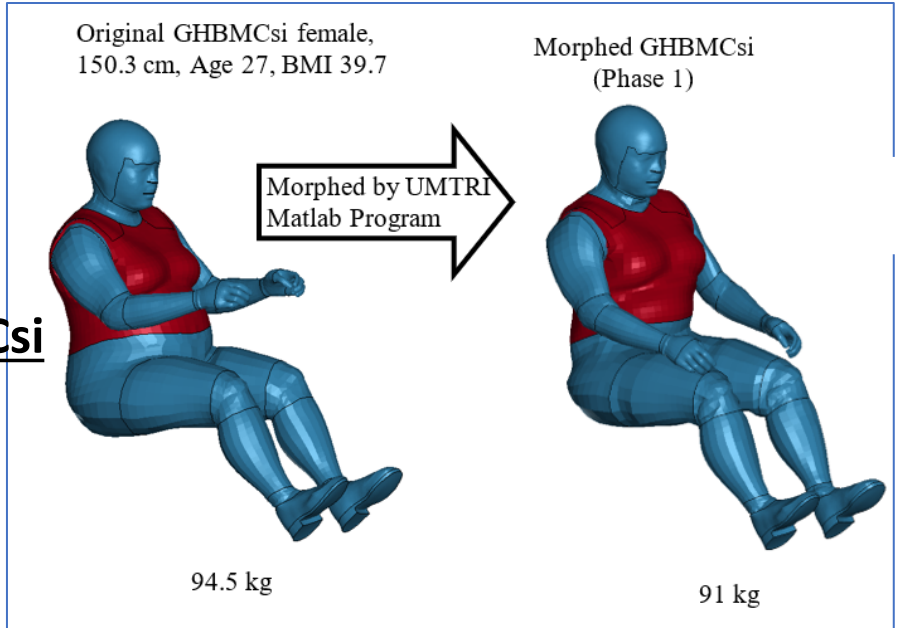
Run Pre-crash (with Optimized AL)

Save posture and kinematics from the GHBMCsi-pre

(**Segmentation Approach**)

Position **GHBMCsi** using UMTRI tool

GHBMCsi



Methods: GHBMCsi Morphing

Run Pre-crash (with Optimized AL)

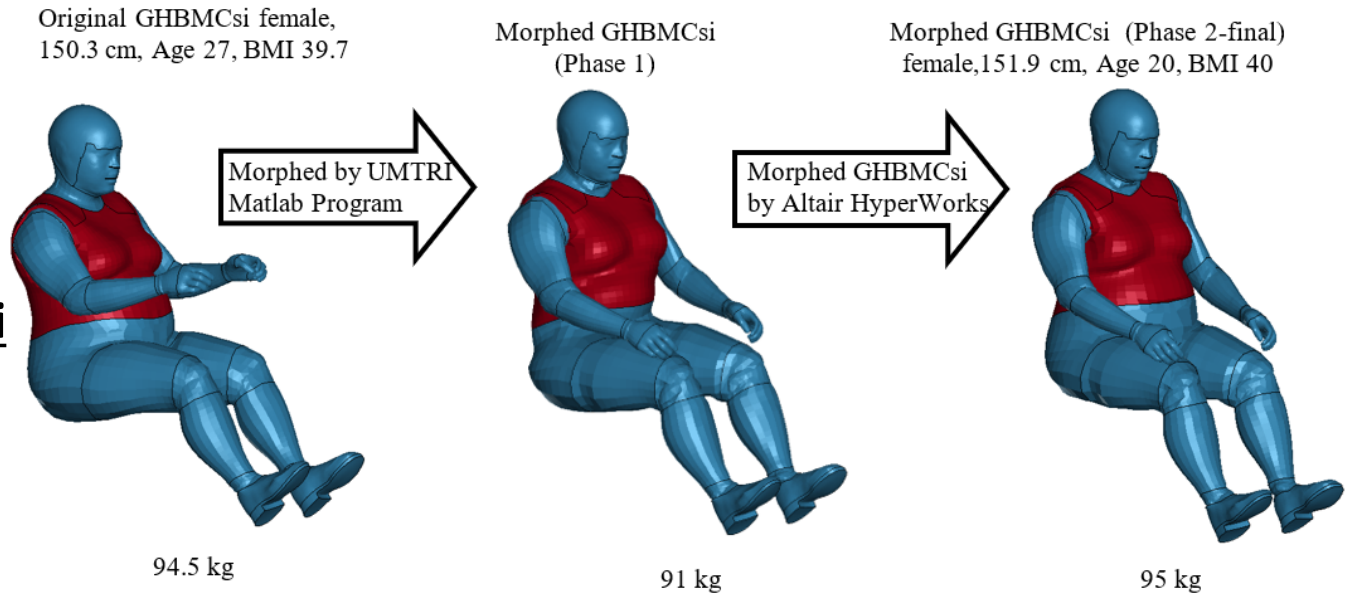
Save posture and kinematics from the GHBMCsi-pre

(**Segmentation Approach**)

Position GHBMCsi using UMTRI tool

Morphing using Altair HyperWorks

GHBMCsi



Methods: 'The Switch Algorithm'

Run Pre-crash (with Optimized AL)

→

Save posture and kinematics from the GHBMCsi-pre

(**Segmentation Approach**)

→

Position GHBMCsi using UMTRI tool

↓

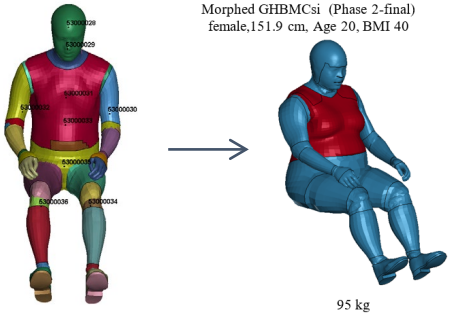
Morphing using Altair HyperWorks

→

Assign the pre-crash kinematics to GHBMC-si models

(**Switch Algorithm**)

GHBMCsi-pre



GHBMCsi

Methods: Run In-Crash Simulations with the GHBMCsi

Run Pre-crash (with Optimized AL)

→

Save posture and kinematics from the GHBMCsi-pre

(**Segmentation Approach**)

→

Position GHBMCsi using UMTRI tool

↓

Morphing using Altair HyperWorks

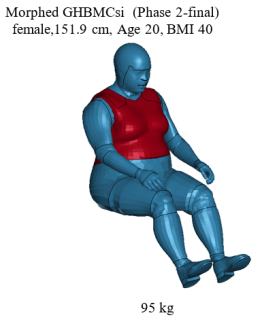
→

Assign the pre-crash kinematics to GHBMC-si models

(**Switch Algorithm**)

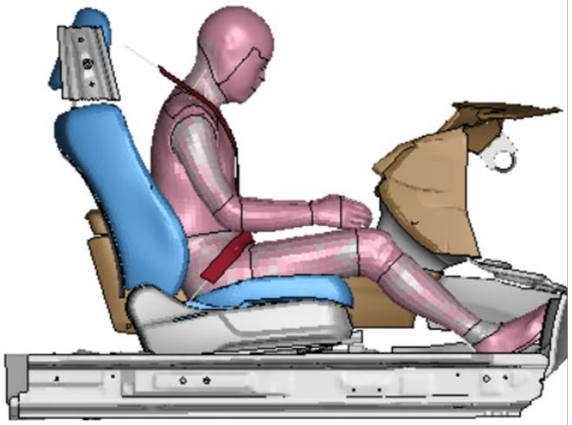
→

Run In-crash: Input ready in the desired posture



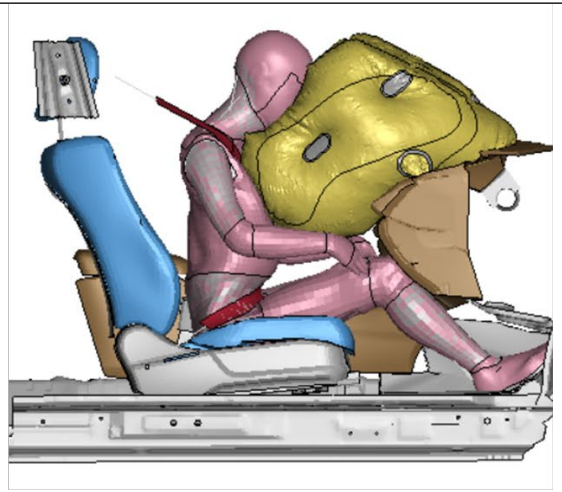
GHBMCsi

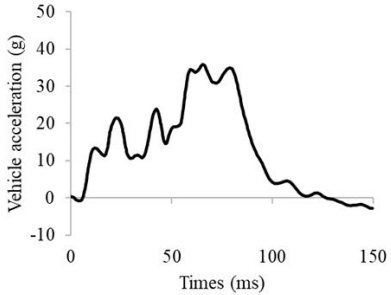
Methods: In-Crash Simulations



Crash Pulse

~150 ms

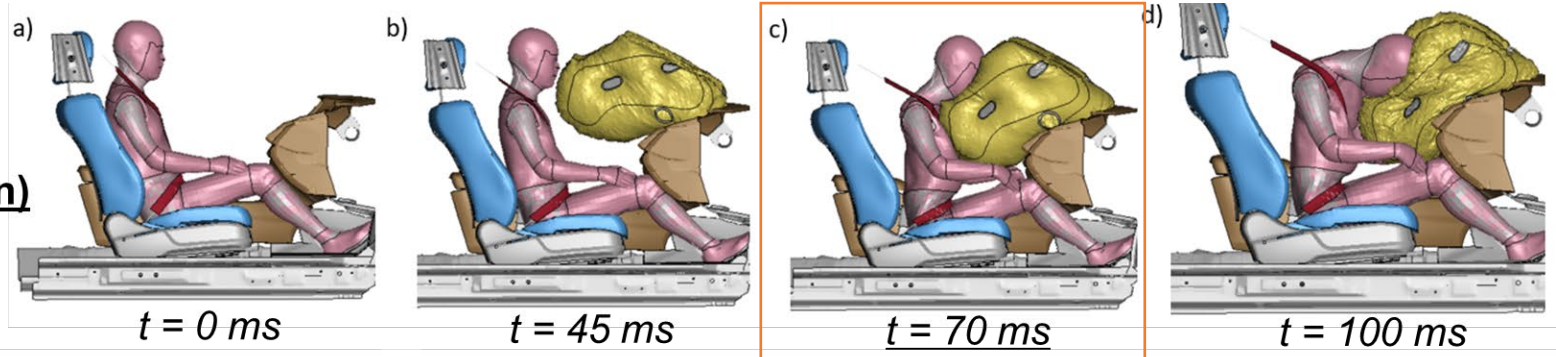




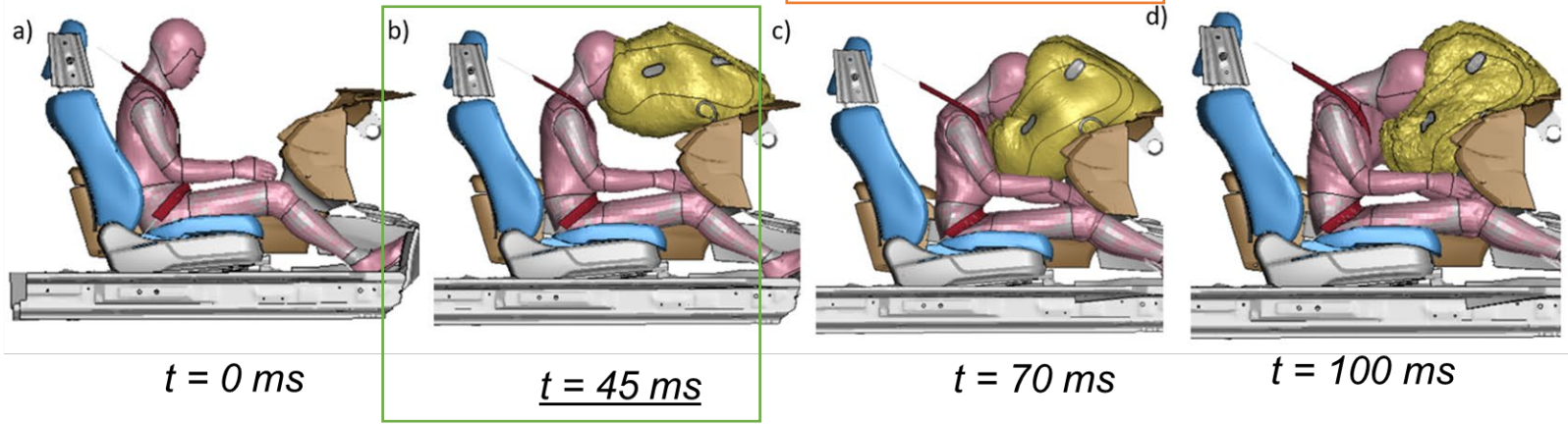
Acceleration pulse for in-crash simulations (56 km/h)

Results: Without Pre-Crash Maneuver vs. With Pre-Crash Maneuver

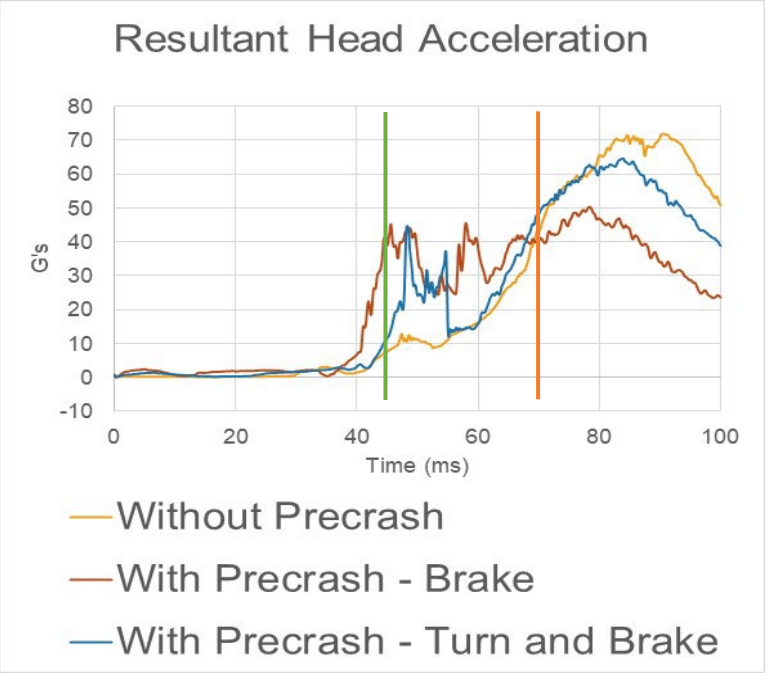
Without Precrash (Standard position)



With Precrash (After braking)



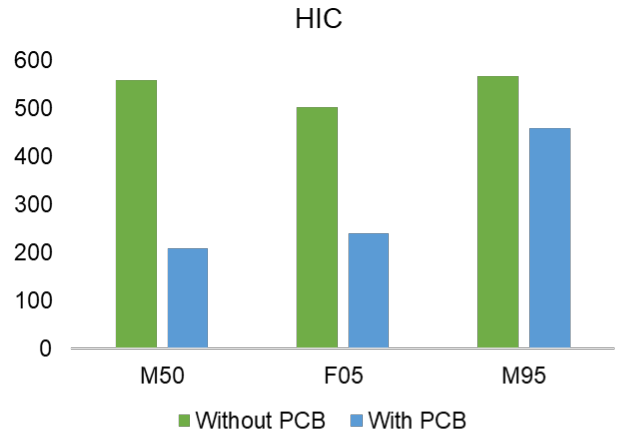
Results: Without Pre-Crash Maneuver vs. With Pre-Crash Maneuver

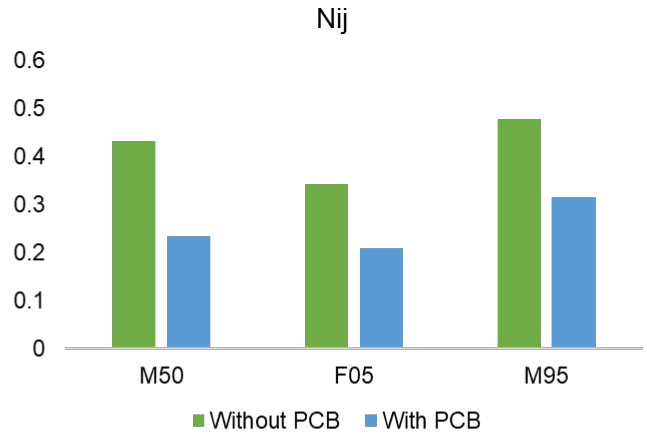


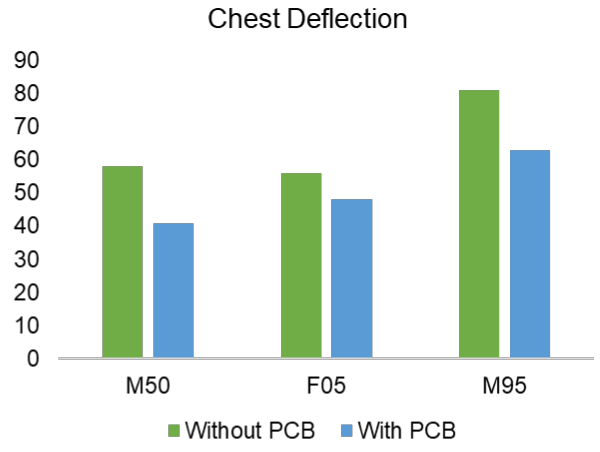
Crash Scenario	Injury Metrics				
	HIC15	BrIC	Nij	Chest Deflection (mm)	Femur Force (N)
Without Precrash	559	0.58	0.43	58	2696
With Precrash - Brake	208	0.52	0.23	41	1724
With Precrash - Turn and Brake	431	0.52	0.36	57	1947

With precrash braking, head velocity relative to the buck at the time of impact is lower (0.95 m/s) compared to without precrash (4.86 m/s).

Results: Injury Metrics



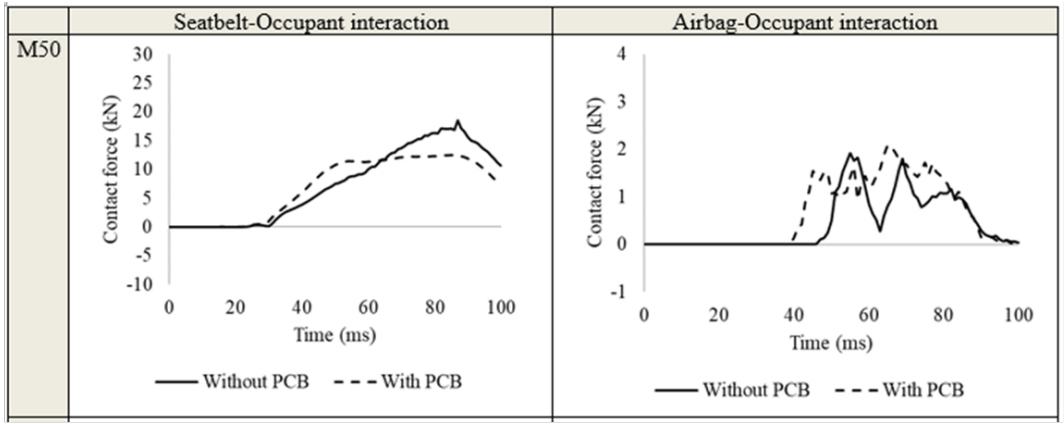




Male 50th

Crash Scenario	Injury Metrics					
	HIC_{15}	BrIC	N_{ij}	Chest Deflection (mm)	VC_max	Femur Force (N)
Without Precrash	559	0.58	0.43	58	0.00	2696
With Precrash - Brake	208	0.52	0.23	41	0.00	1724

Results: Restraint Systems

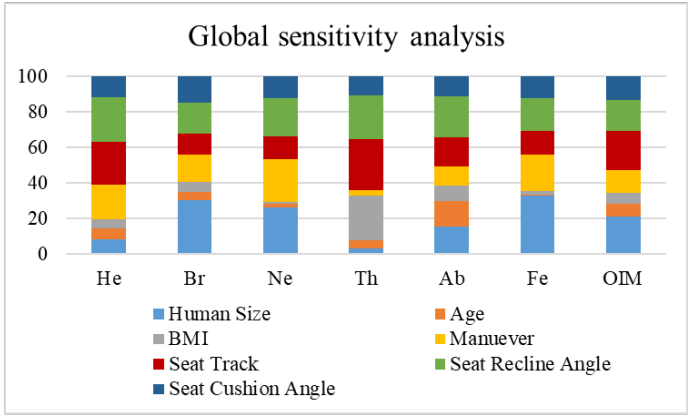


The seatbelt contact forces are higher for the case 'Without PCB' as compared to the case 'With PCB'.

- During PCB, the HBM moves forward towards the dashboard, hence the airbag is contacted much earlier with PCB leading to kinetic energy being distributed to the seatbelt and airbag.
- This leads to smaller seatbelt contact forces and larger airbag contact forces.
- Whereas in the case 'Without PCB', most of the kinetic energy is restrained by the seatbelt leading to larger seatbelt contact forces and smaller airbag contact forces.

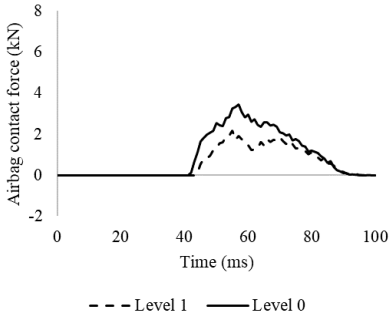
Results: Global Sensitivity Analysis

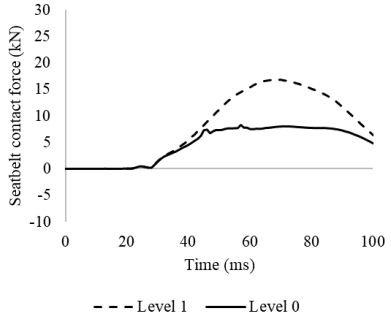
- **Head** most sensitive to Seat Track position and Seat Recline Angle.
- **Brain** most sensitive to Human size and Seat Track position.
- **Neck** highly sensitive to Maneuver type and Seat Recline Angle.
- **Thorax** significantly sensitive to BMI and Seat Track position.
- **Abdomen** risks were negligible but most sensitive to Human Size
- Larger risks associated with Seat Recline Angle, Seat Track position, Human Size, and Maneuver type
- Seat Cushion Angle had smallest influence



Results: Effect of Seat Track Position and Recline Angle

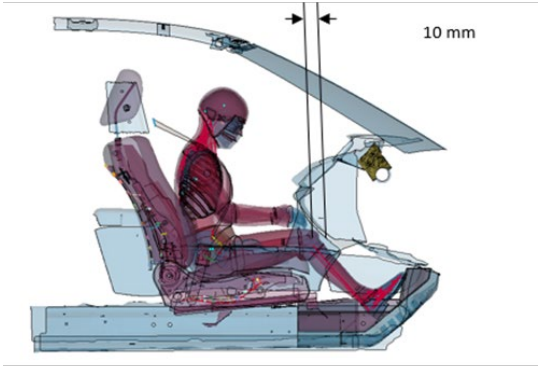
- Contact forces with the airbag and seatbelt were compared for two seat track levels with GHBMCsi-F05.
- When GHBMCsi-F05 is seated at level 0 (closer to the dash), airbag interaction occurs earlier than at level 1 (farther from the dash), leading to smaller belt forces and larger airbag forces.



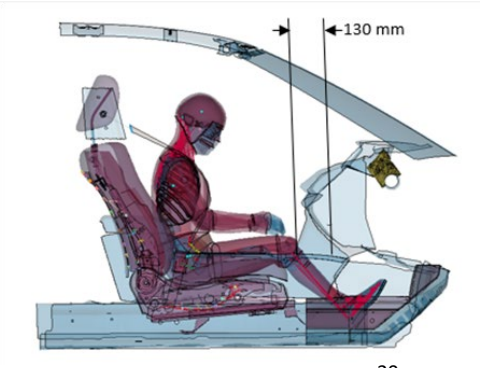


Crash Scenario	Injury Metrics					
	HIC15	BrIC	N_{ij}	Chest Deflection (mm)	VC_max	Femur Force (N)
Level 0	228	0.58	0.33	32	0.00	1907
Level 1	237	0.72	0.37	47	0.00	1444

Level 0



Level 1



Conclusion

- When pre-crash maneuvers are considered, the head and thorax contact the airbag earlier compared to simulations starting from a standard seating position (without a pre-crash maneuver).

- In general, lower injury values are observed when pre-crash maneuvers are considered.

- Higher injury values are observed with pre-crash braking compared to pre-crash turning and braking due to the lateral momentum gained during turning.

Contact Info

Thank you!

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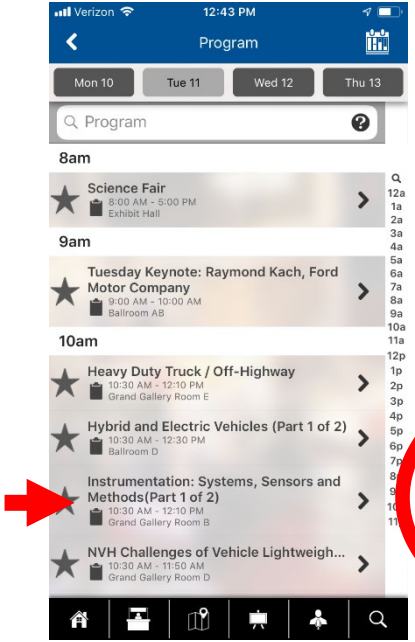
Rate My Talk in the App (if applicable)



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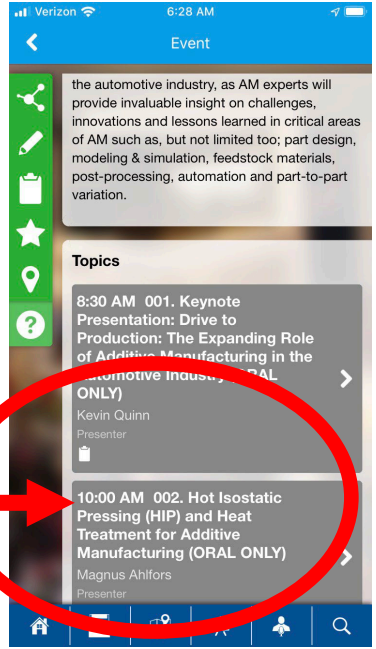
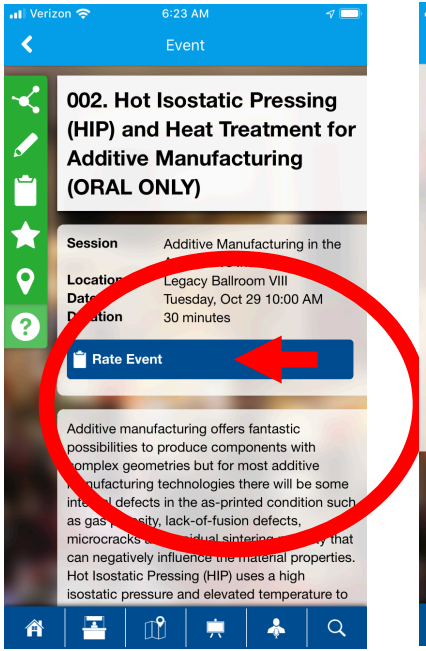
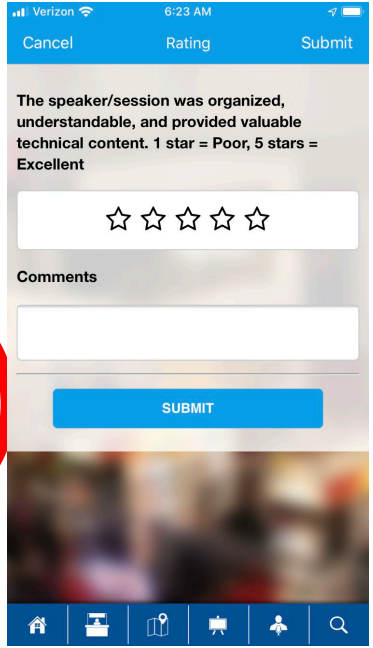


2. Click on individual presentation



3. Click on “Rate Event” button



4. Rate speaker