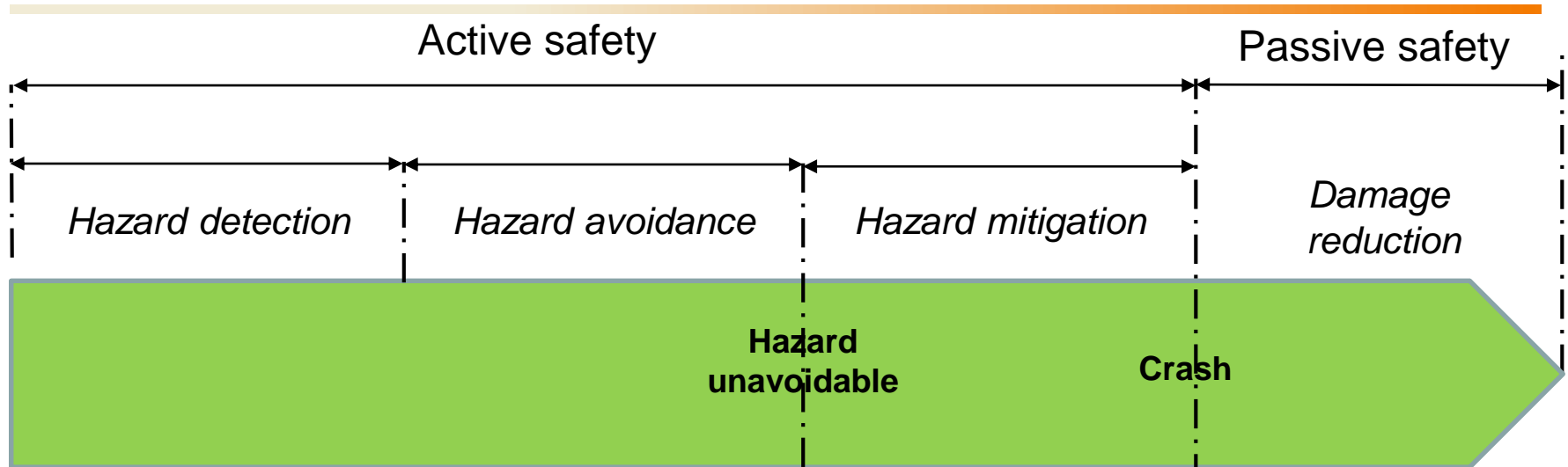


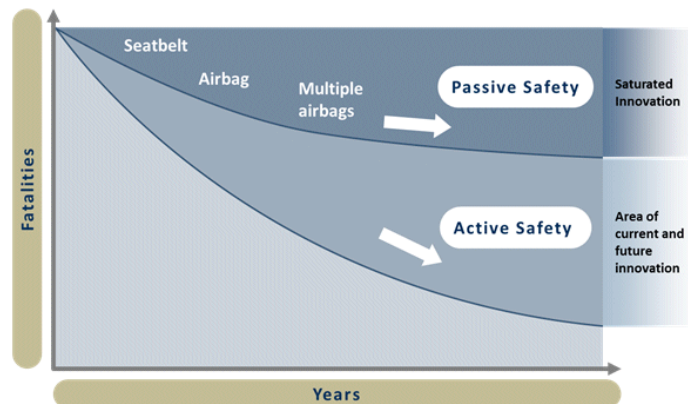
A workflow for simulating precrash-crash scenarios with Human Body Models

18.06.2018

Introduction



- Anti Braking Systems (ABS)
- Electronic Stability Control (ESC)
- Intelligent Speed Assistant (ISA)
- Autonomous cruise control
- Road sign detection
- Steering control
- Autonomous Emergency Braking
- Lane departure warning
- ...



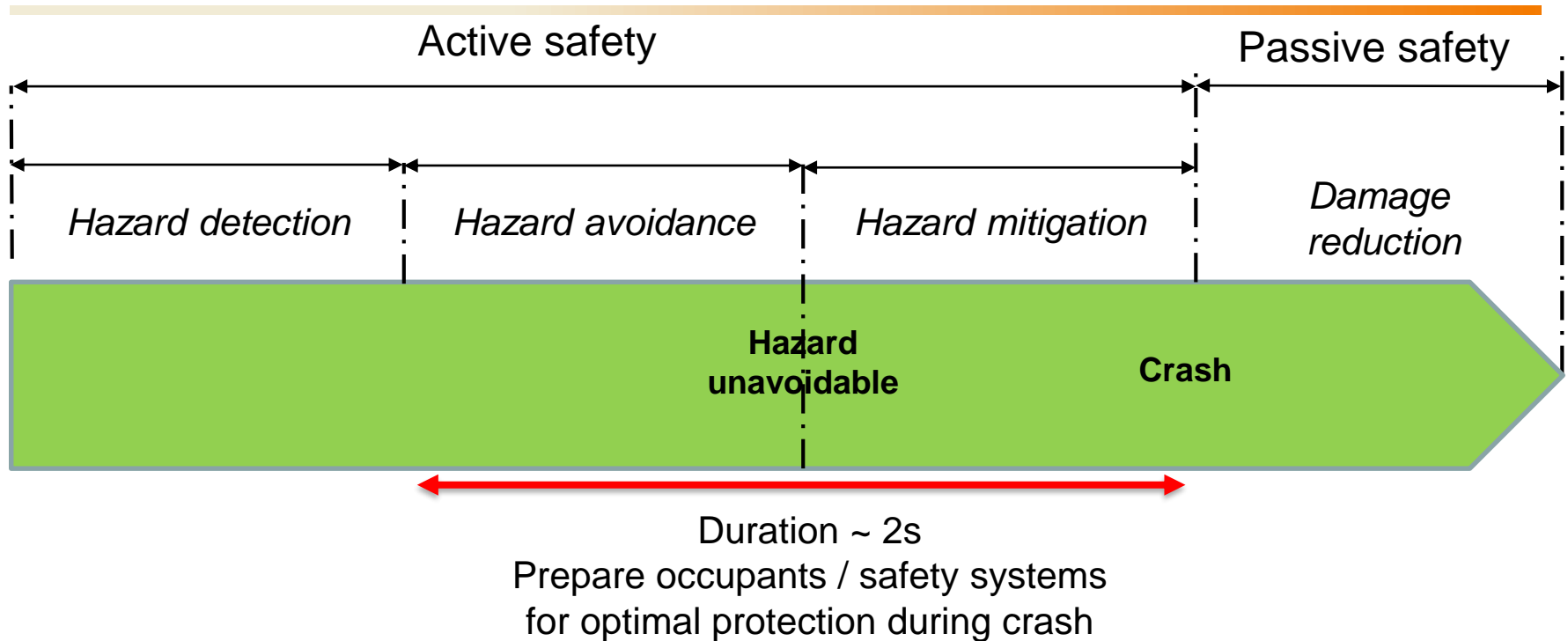
Source: Frost and Sullivan analysis

- Body structure
- Retractable steering column
- Belt
- Airbags
- Head restraint
- Anti submarining
- ...

- Integrated safety
 - Crashes are the result of unusual events
 - Occupant position can be altered before the crash
 - Occupant position has a significant influence on injury severity
 - Antona et al. 2011, Bose et al. 2010
 - Passive safety systems are optimised for standard occupant positions

Passive safety systems should be designed considering effect of pre-crash

Introduction



-Reversible belt
pretensioner
(Audi)



-PRE-SAFE®
Impulse Side
pyrotechnical
bladder (Daimler)



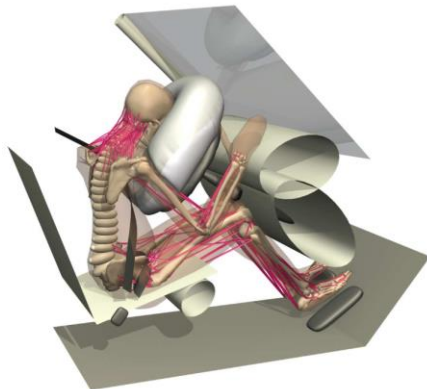
Introduction

- Occupant surrogates

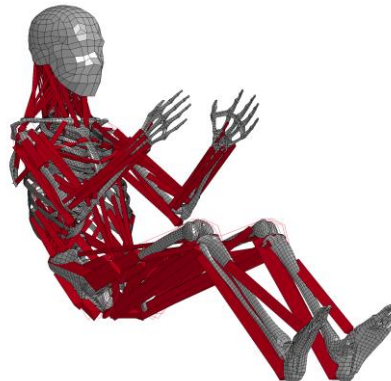
	Crash dummies	Post Mortem Human Subjects	Human Body Models
Repeatability	+	-	+
Reproducibility	+	-	+
Durability	+	-	+
Biofidelity	-	+	+
Cost	-	-	+
Personalizability	-	+	+
Muscular activation	-	-	+

- Active Human Body Models (AHBM)s

- Validity for low g (Pre-crash)
- Validity for high g (Crash)
- Stability
- Numerical efficiency (event duration ~ 2-3 s)



Madymo AHM (TASS
International)



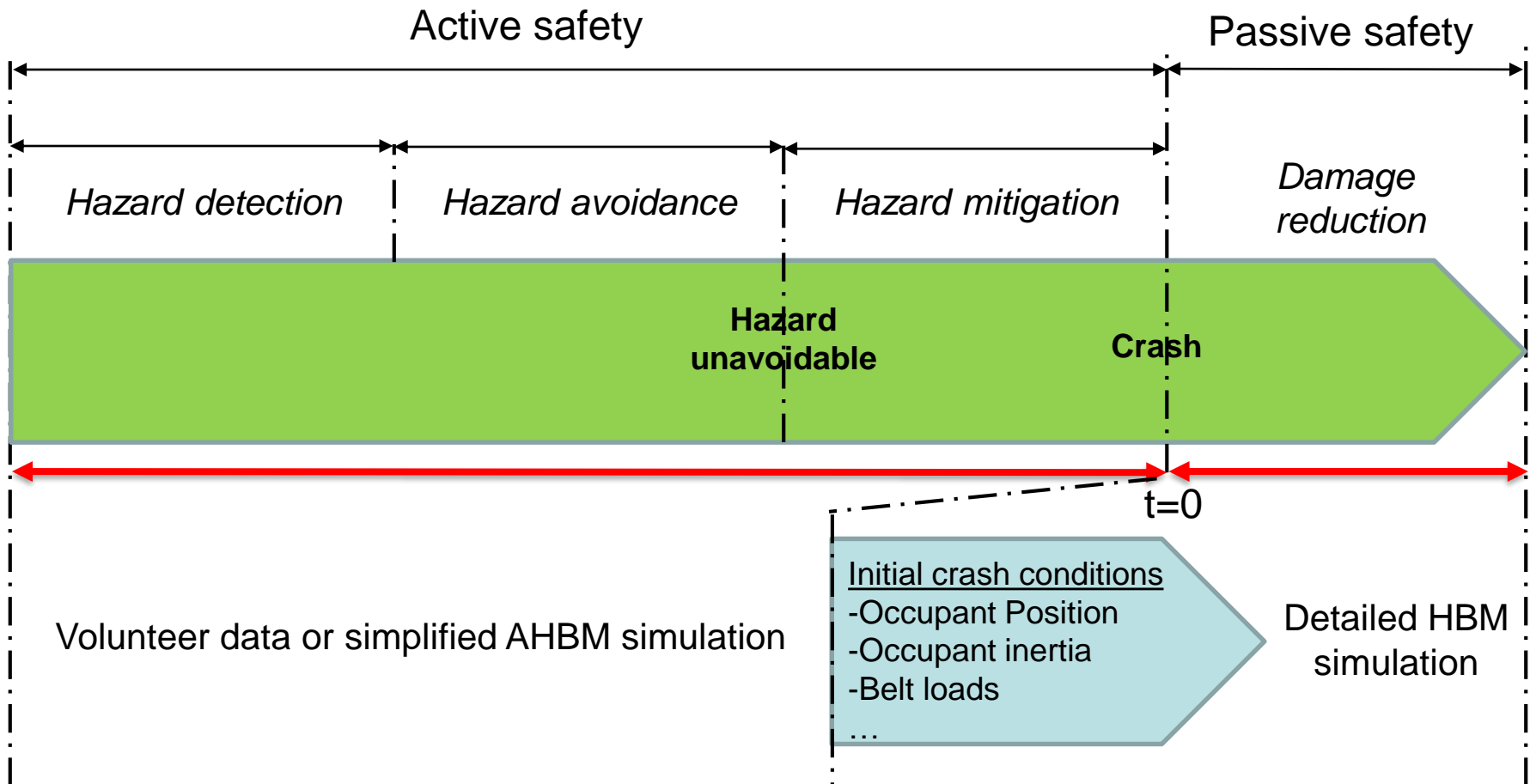
Safer AHBM (Chalmers)
Based on THUMS version 1



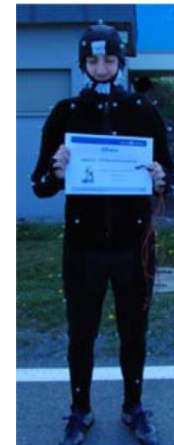
THUMS v5 (Toyota)

Methods

- Split pre-crash and crash event

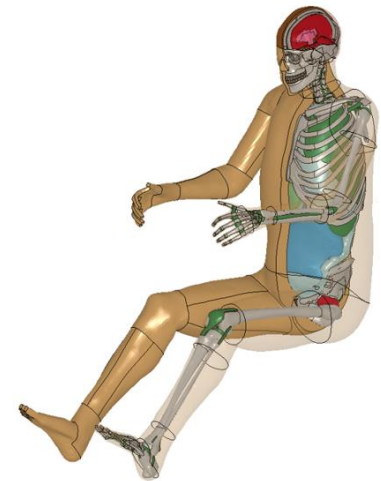


- Pre-crash data from volunteer testing
 - Occupant Model for Integrated Safety (O4MIS)
 - Huber 2013, 2015; Kirschbichler 2014
 - Volunteer occupant motion during pre-crash manoeuvres
 - Vicon recording system
 - Tracking of optical markers
 - Focus on front occupant passenger motion



**Kirschbichler et
al Ircobi 2014**

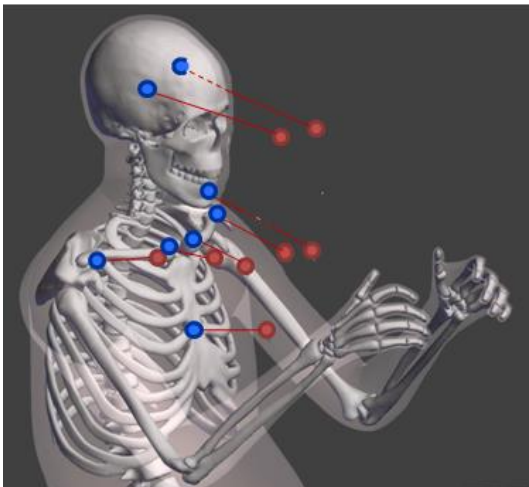
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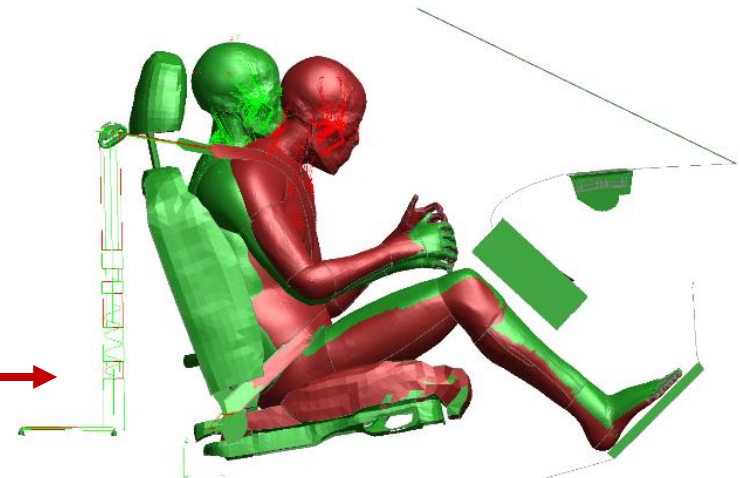
Simbio-M Conference, Stratford upon avon, 18-19 June 2018.
Jeremie Peres, Partnership for Dummy Technology and Biomechanics (PDB)
Email:Jeremie.peres@pdb-org.com Tel: +49 (0)841-89 436 83

- Human Body Model positioning for crash simulation
 - Piper software
 - European project
 - Open source tools for positioning / personalizing HBMs
 - Positioning using simplified physics module
 - Interactive pre-positioning
 - Simplified simulation → reduced number of degree of freedoms
 - Model smoothing
 - Improving mesh quality after transformation
 - Transformation smoothing using kriging algorithm
 - THUMS Model preparation
 - Creation of piper metadata file for THUMS v4.02 occupant
 - Contains: Anatomical entities, joints, landmarks, contacts, ...
 - Available for model licensees through JSOL

- Human Body Model positioning
 - Targets
 - Feet positioned on the footrest
 - Hands close to the thigh
 - 3 dimensional coordinates of volunteer markers
 - At time of maximum head excursion
 - Corresponding landmarks defined in THUMS Piper metadata



- THUMS Landmarks
- OM4IS target markers position



- Injury criterion

Traumatic Brain Injuries: Brain Injury Criteria (BrIC)

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xc}}\right)^2 + \left(\frac{\omega_y}{\omega_{yc}}\right)^2 + \left(\frac{\omega_z}{\omega_{zc}}\right)^2}$$

Takhounts 2013

Skull fracture:

Head Injury Criteria (HIC36)

$$HIC_{36} = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} (t_2 - t_1)$$

U.S. NCAP

Neck injuries:

Neck Injury Criteria (Nij)

$$Nij = \frac{F_z}{F_{zc}} + \frac{M_{ocy}}{M_{yc}}$$

Eppinger 1998

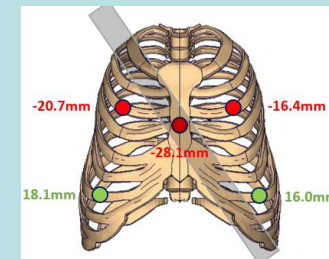
Thoracic Injuries:

-Maximum deflection

D_{max}

U.S. NCAP

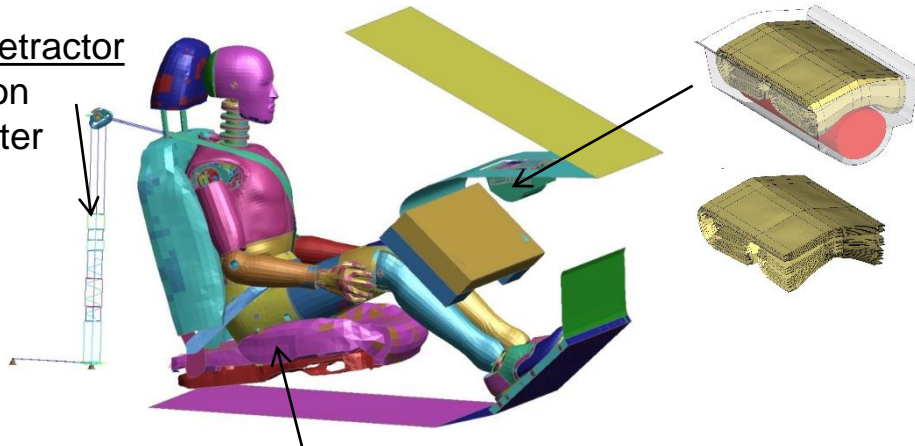
-Chest deformation profile



- Crash environment
 - Dimensions representative of a sedan interior
 - Validated using Hybrid 3 simulations
 - Against USNCAP crash test results
 - Behaviour representative of an average sedan car

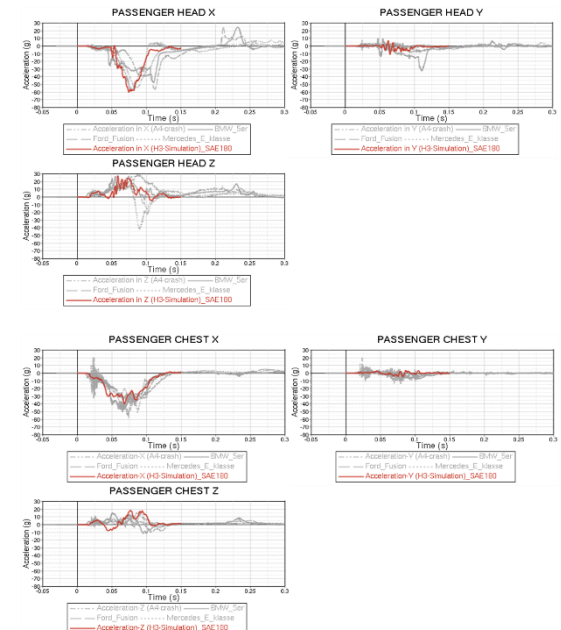
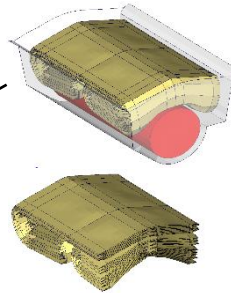
Seatbelt retractor

- Pretension
- Load limiter



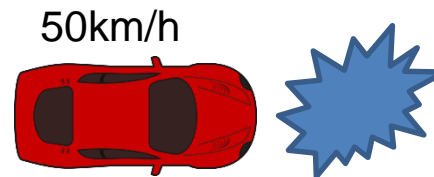
Seat from NCAC Taurus model

Folded airbag

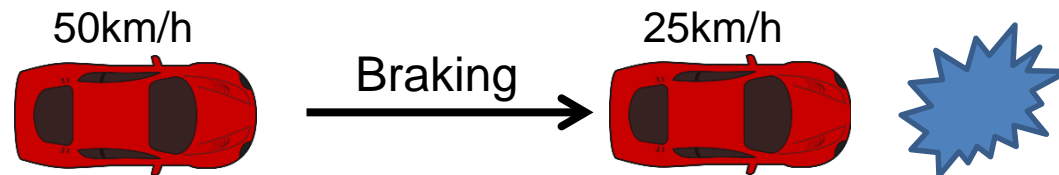


- Crash Scenarios

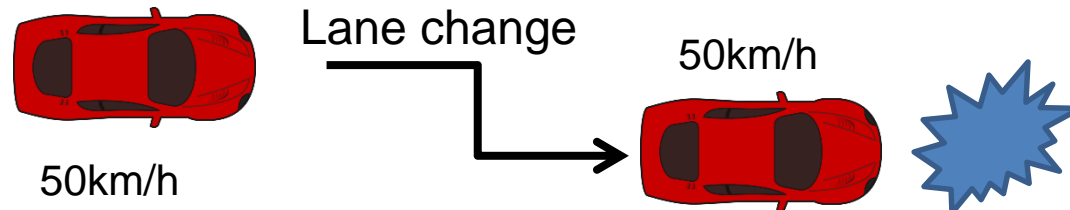
- 1 Normal driving position 50km/h



- 2 Autonomous Emergency Braking 50→25km/h



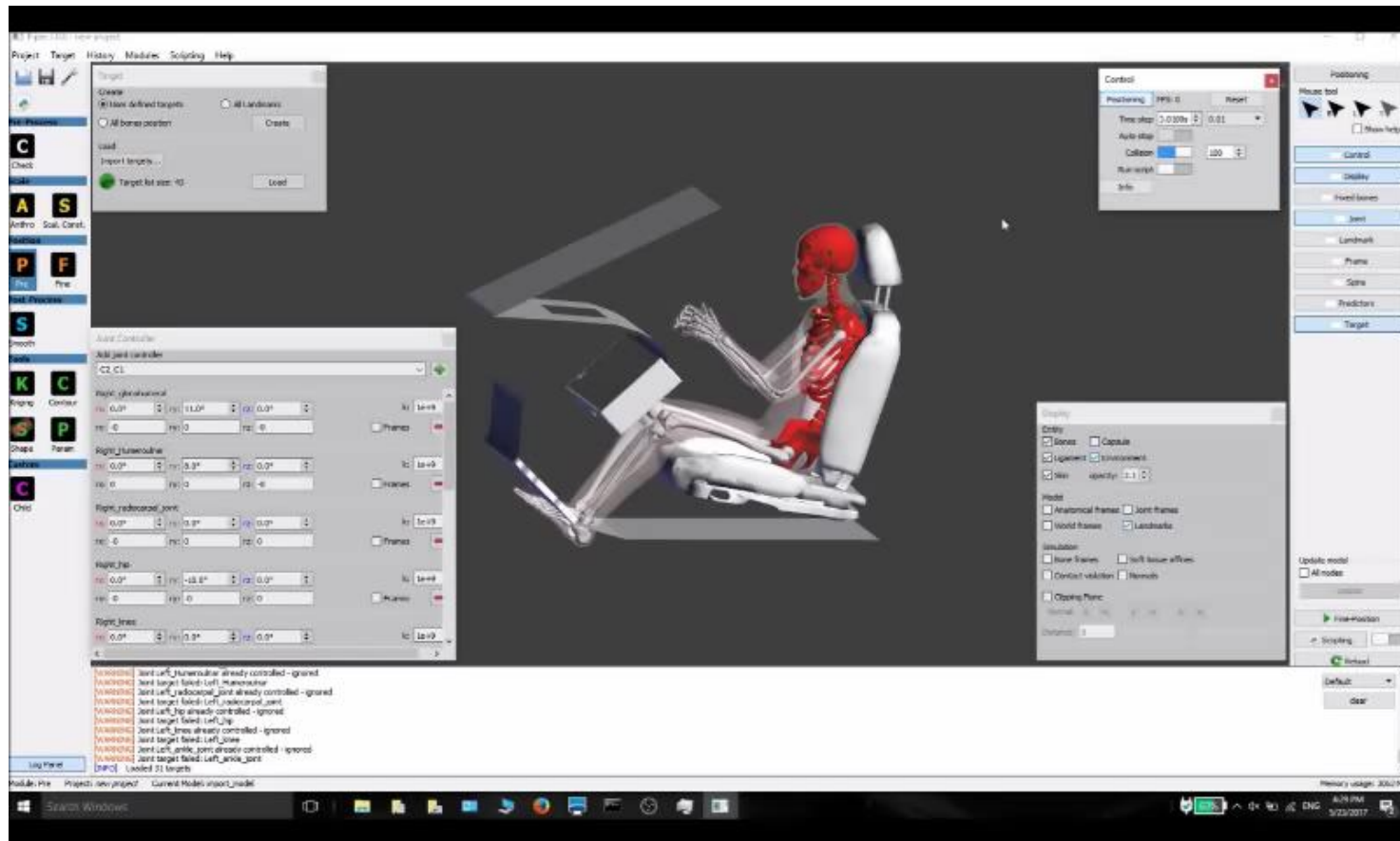
- 3 Lane change 50km/h



Results

Results

- Positioning



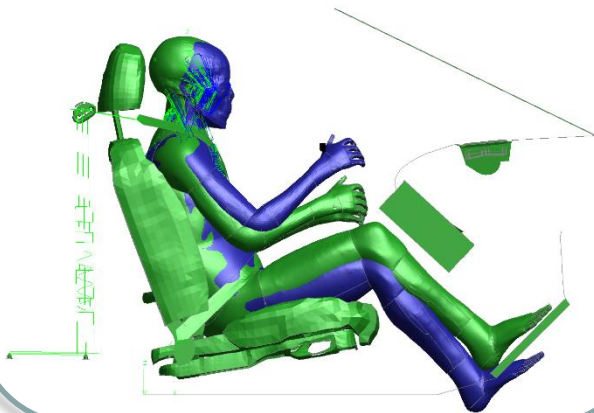
Results

- Positioning

Normal driving 50km/h (ND50)

-Original THUMS position

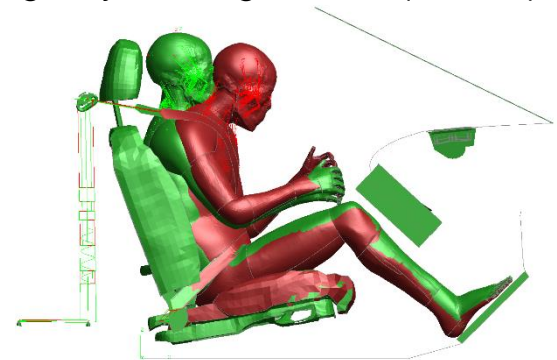
-Normal driving position (ND50)



Autonomous Emergency Braking 25km/h (AEB25)

-ND50 position

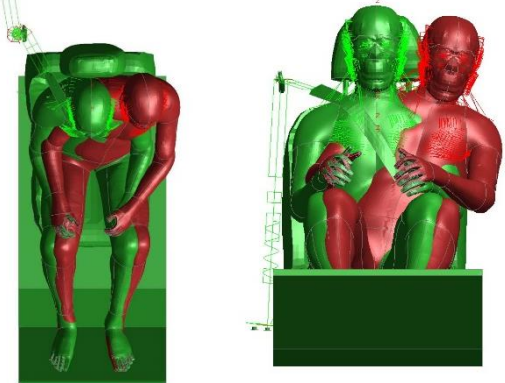
-AEB25 position



Lane change right 50km/h (LC50)

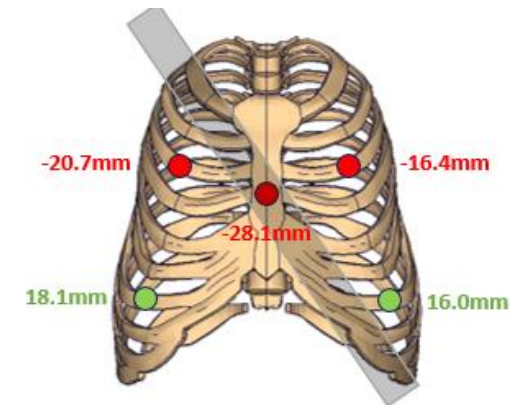
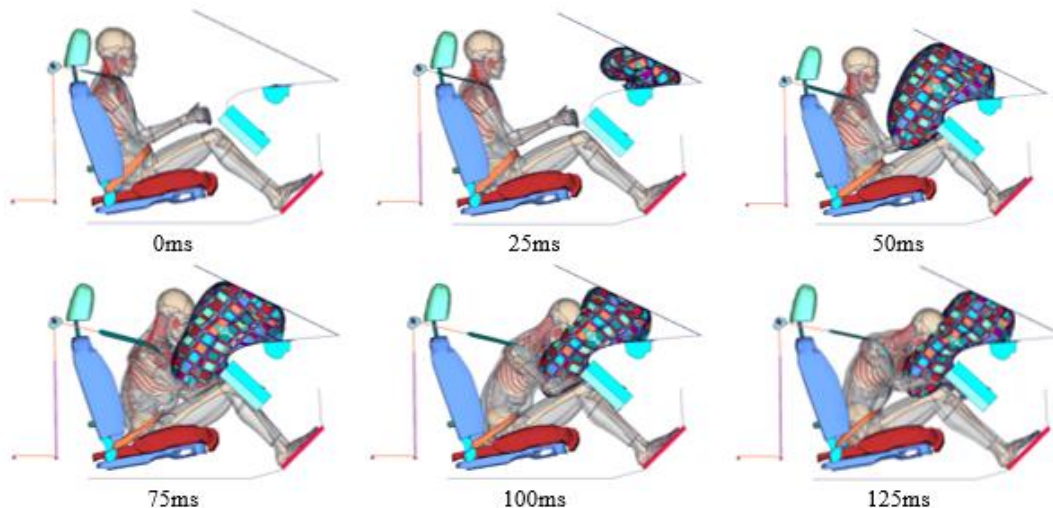
-ND50 position

-LC50 position



Results

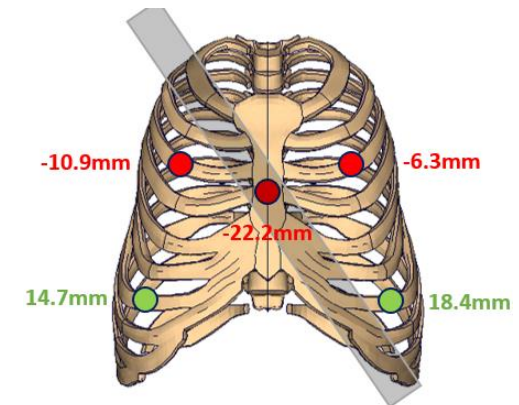
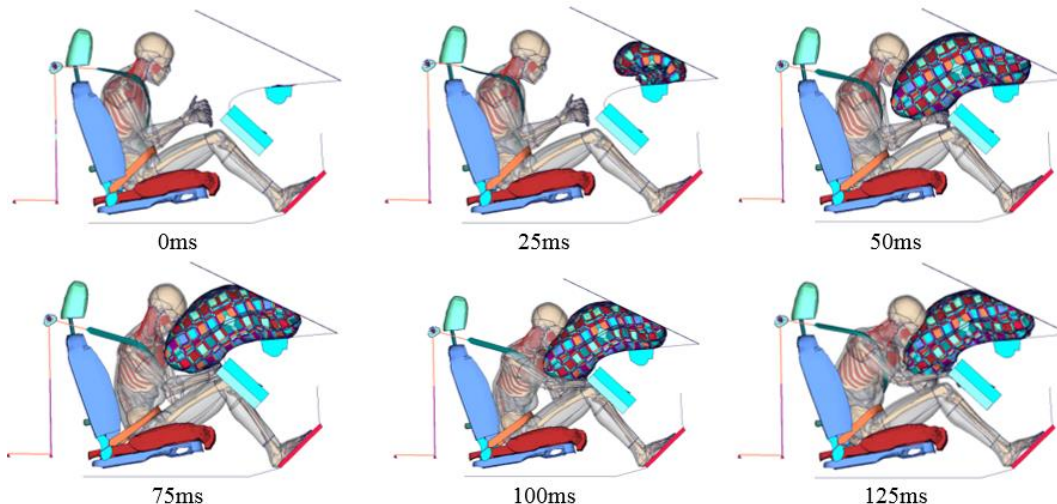
- Crash simulation: Normal driving 50km/h



Criteria	HIC36	Bric		Nij	Dmax
		MPS based	CSDM based		
Value	153.6	0.58	0.53	0.64	28.0mm
AIS 3+ risk (%)	0.1	19.4	0.0	12.3	3.7

Results

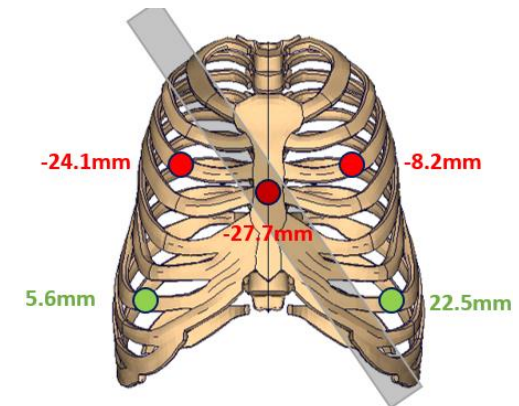
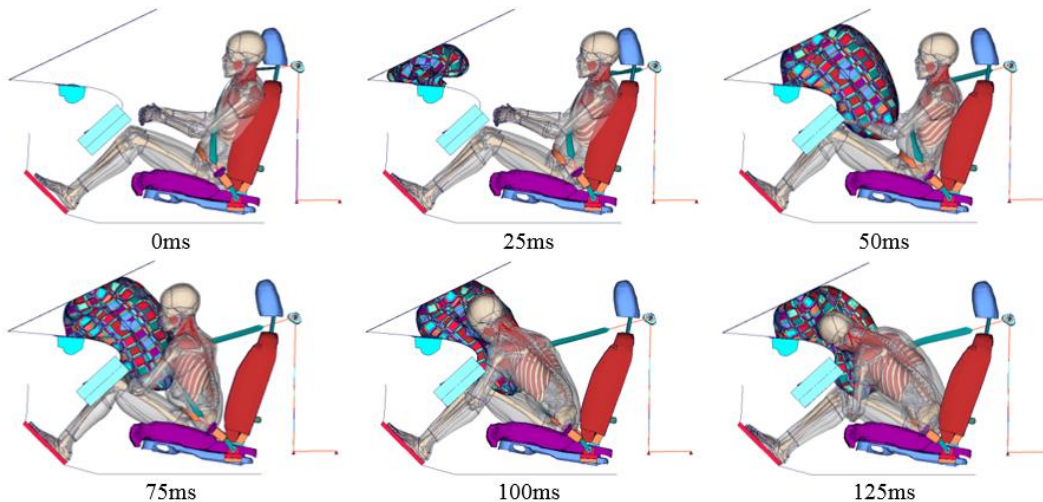
- Crash simulation: Autonomous Emergency Braking 25km/h



Criteria	HIC36	Bric		Nij	Dmax
		MPS based	CSDM based		
Value	7.8	0.26	0.25	0.52	22.2mm
AIS 3+ risk (%)	0.0	2.3	0.0	9.9	1.8

Results

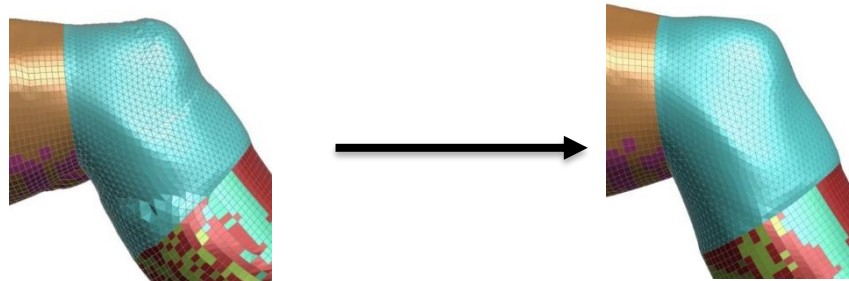
- Crash simulation: Lane change right 50km/h



Criteria	HIC36		Bric		Nij	Dmax
		MPS based		CSDM based		
Value	1963.2	0.86		0.81	0.59	27.9mm
AIS 3+ risk (%)	57	49.5		27.5	11.3	3.7

Discussion

- Positioning
 - Smoothing is a crucial step after positioning
 - Example: knee smoothing



- After smoothing some negative volumes can remain:
 - Manual mesh correction is then needed

Position	Normal driving	AEB25	LC50
Nr of negative volume	0	5	15

- Limitations
 - Crash environment
 - Simplified geometry
 - Dashboard modeled using rigid materials
 - Overestimation of HIC values
 - Airbag modeling
 - No access to real airbag geometry
 - 13 liters, 2 stage inflator, Particular method
 - No information was available on pelvis / lower limbs motion
 - THUMS geometry was not scaled to the subject anthropometry

Scenario	Normal driving	AEB25	LC50
Gender	M	M	M
Height (cm)	175	175	173
Weight (kg)	75	75	77

- Conclusion
 - Workflow using Piper for integrated safety successfully implemented
 - Stable crash simulations
 - Restraint systems might not work properly for large pre-crash motions
- Perspective
 - More variability should be simulated → Anthropometry / positions
 - Piper software improvements needed to ease / improve process

