Aktuelle Anwendungen und Entwicklungen des THUMS-D
Status der Implementierung und Validierung aktiver Muskeln

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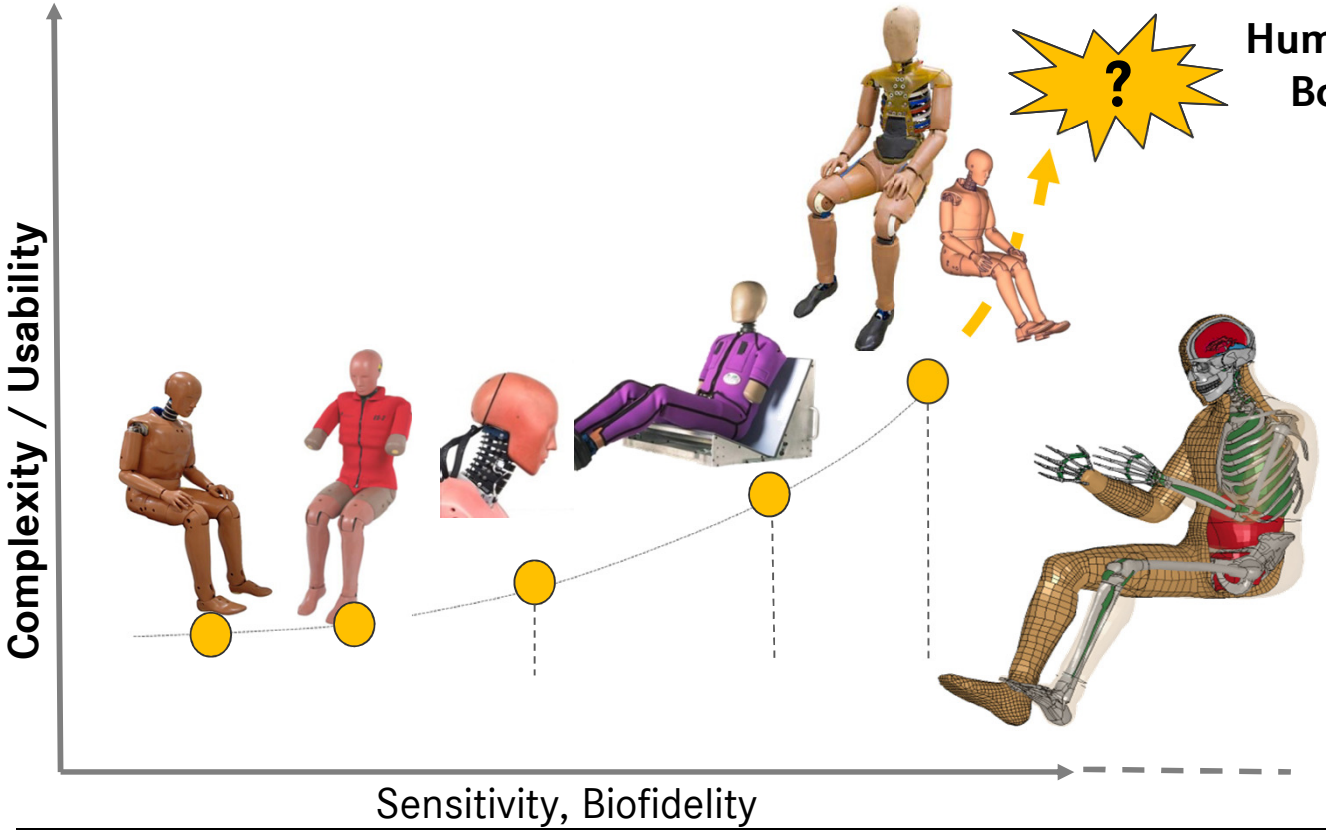
Dynamore Informationstag, Juni 2016
Menschmodelle – Überblick und Erweiterungsmöglichkeiten

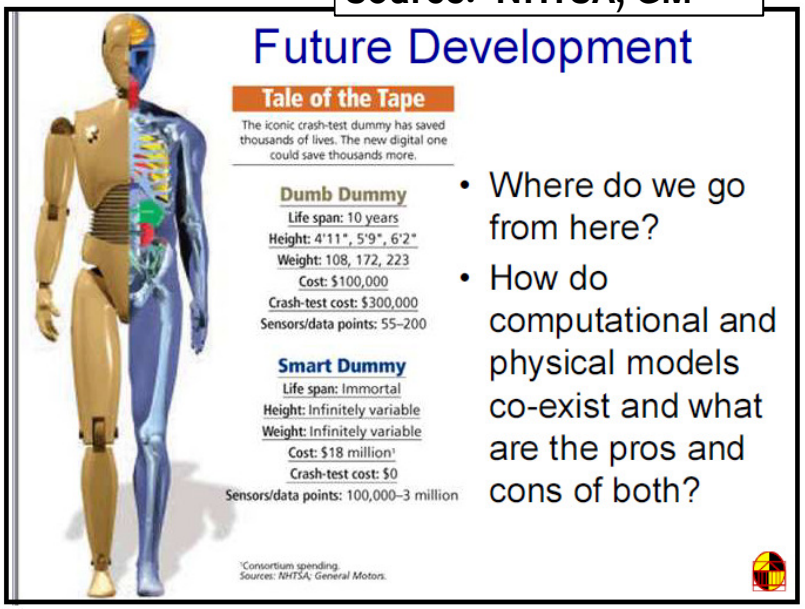
Mercedes-Benz
The best or nothing.

Passive Safety – Injury risk Assessment → an “Hybrid Approach”

Increasing demand for biofidelity & sensitivity (e.g.: age, gender, individual body shapes) will make conventional dummies highly complex and finally unmanageable

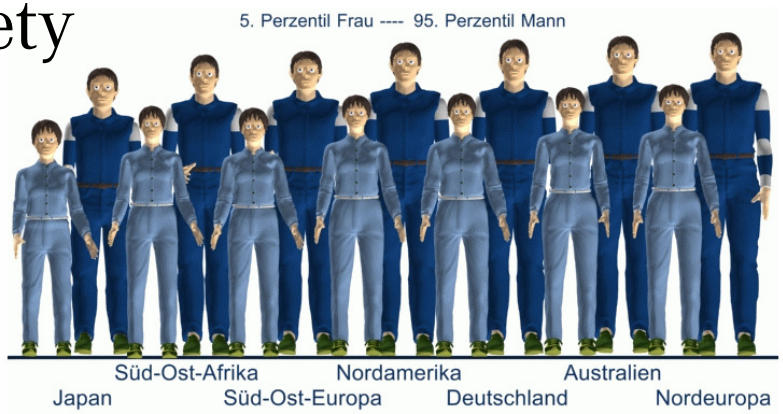


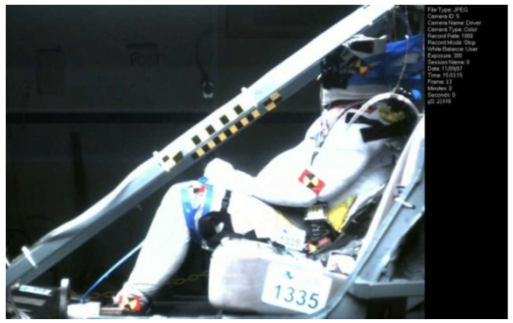
Injury Biomechanics
Jeff Crandal 2015
Source: NHTSA, GM

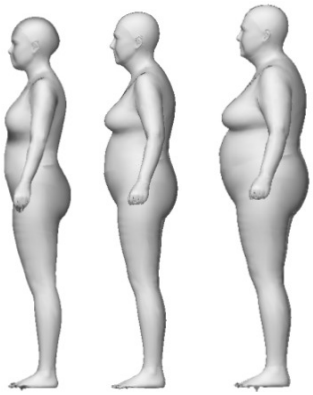


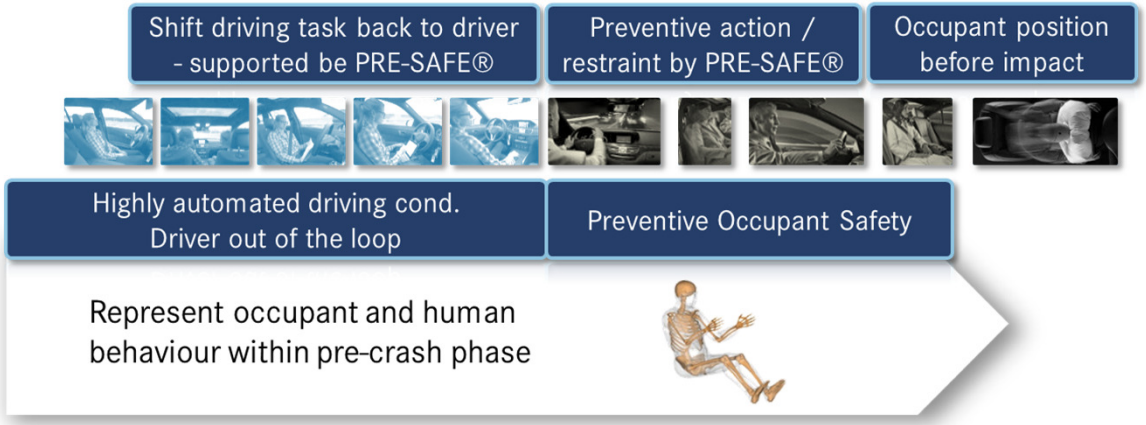
Key topics of Next Generation Passive Safety

Localization / Anthropometrie
Aging Society
Individual Body Shape
Automated Driving Cond.

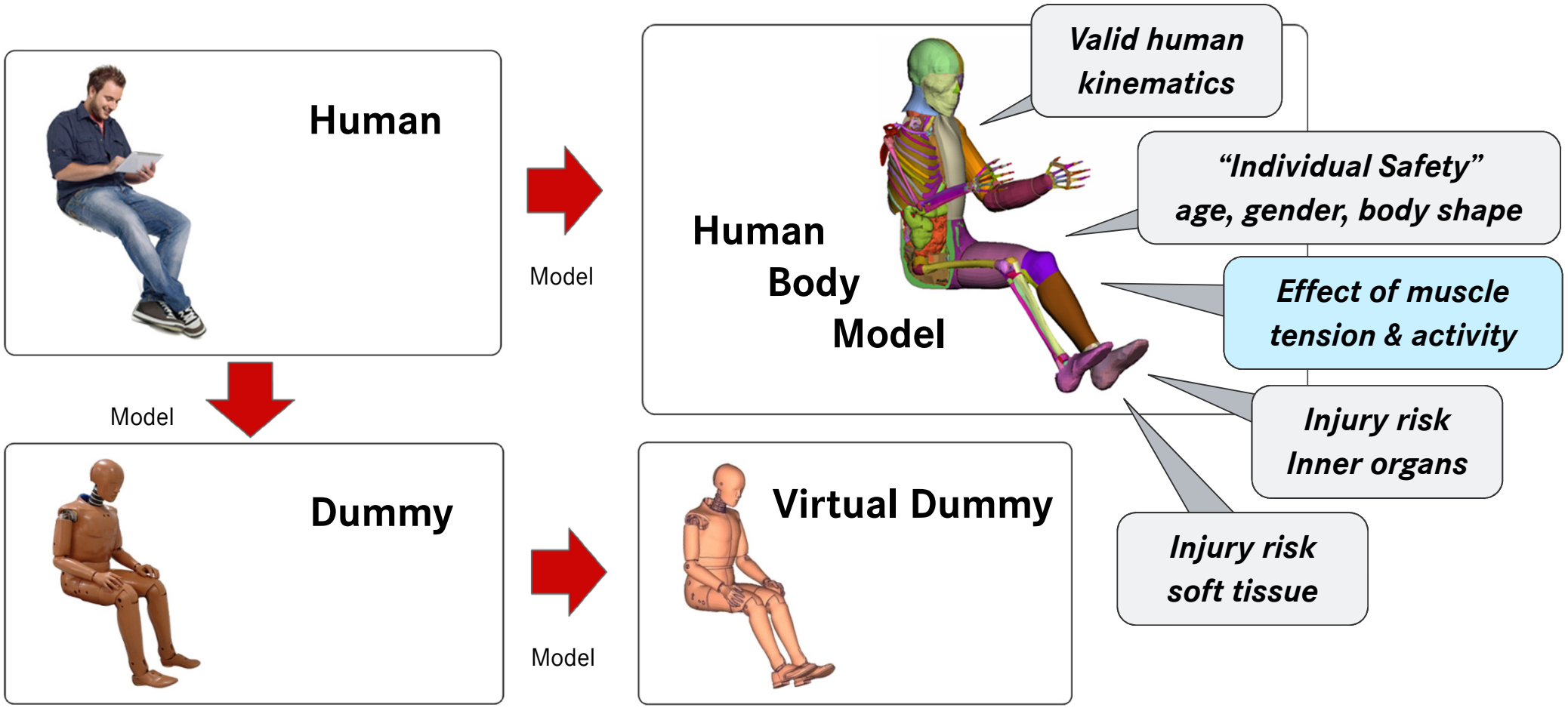






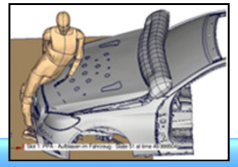


Modelling the Human for Vehicle Safety
- a step towards pure virtual tools & assessment



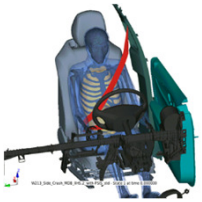
THUMS-D
Chronology of development & applications

Applications

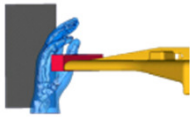


Pedestrian safety

Beltbag



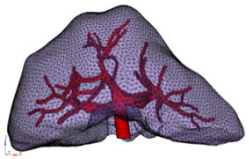
PSIS, HRI & Accident reconstruction



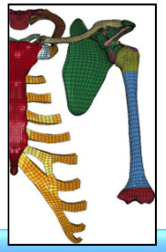
„Advanced safety systems“

Biomechanical development

Shoulder bones & ligaments



Internal organs

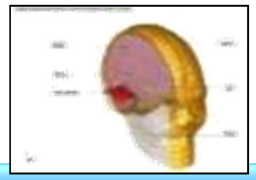


Shoulder complex

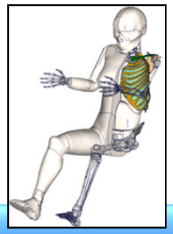
Knee ligaments

THUMS-D family:

Pedestrian family & coupling SUFEHM



HBM / Pedestrian accepted to be used within EuroNCAP protocol



5% Female

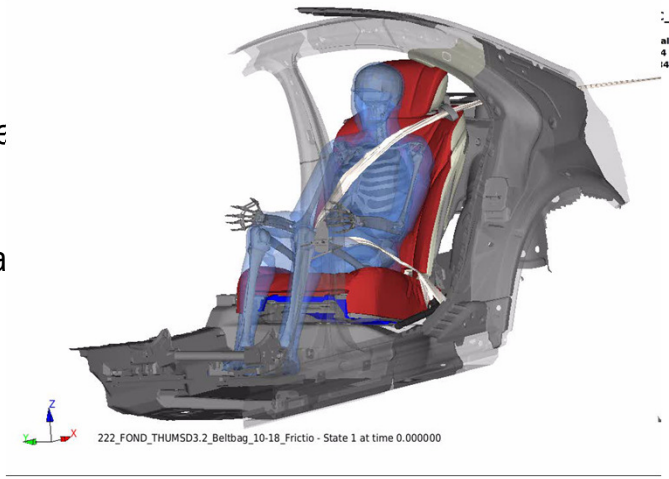
V 4.0 & Child

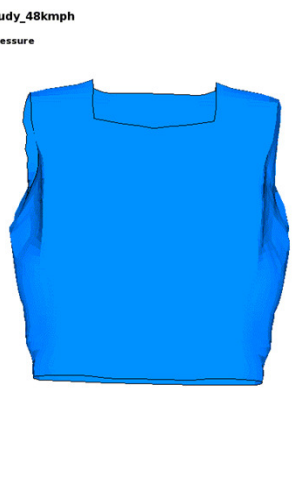
2003 2007 2009 2011 2013 2014 2015 2016 2020

THUMS-D: Applications / Product development

Beltbag:

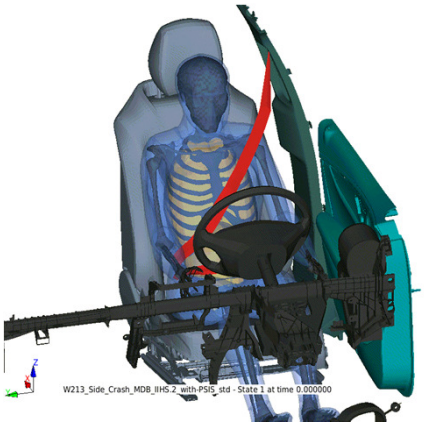
- Designed to improve safety of rear passe & demonstrated in ESF 2009
- System on the market in current S-&Ecla
- Optimization of system parameters was done using THUMS-D

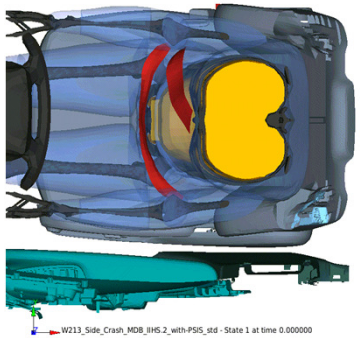




PSIS (PRE-SAFE® Impulse Side) :

- Designed to improve safety of front passenger is case of side impact
- **Pre-Crash triggered bag system**
- **System safeguarding & performance optimization using THUMS-D**





THUMS-D: Applications / PSIS development

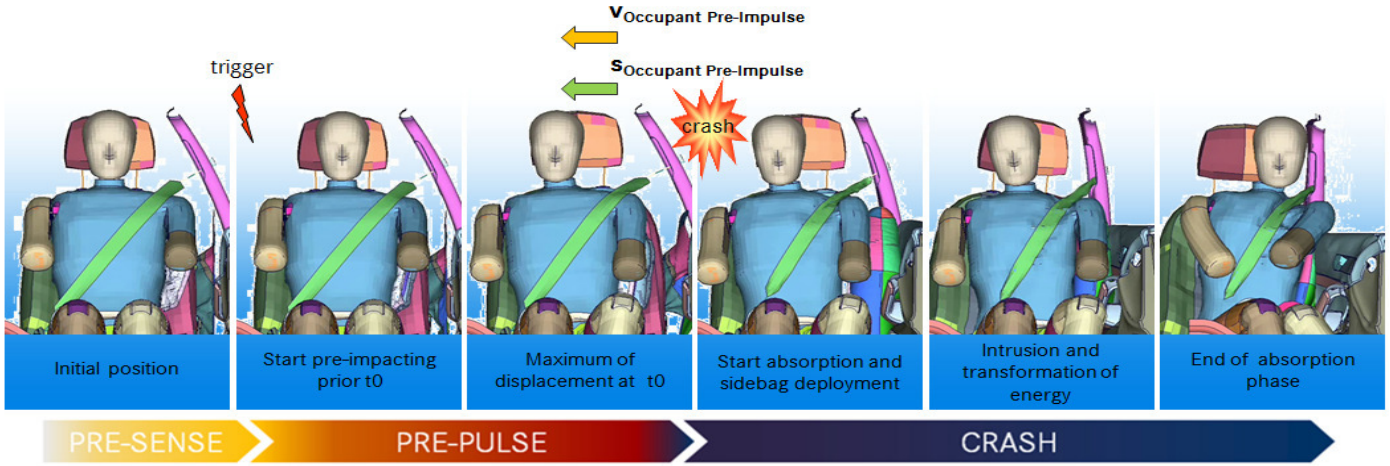
PSIS (PRE-SAFE® Impulse Side) :

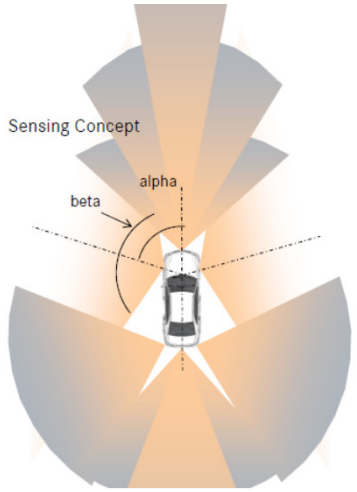
- System **pre-crash triggered** based on environmental sensor information (radar)
- Reduce Injury risk by pre-acceleration of the occupant
- -initiated by inflatable air-bladder

Application of THUMS-D:

- **Optimization** of system performance & parameters (Real Life Safety)
- **Due care** / system safeguarding (false trigger)

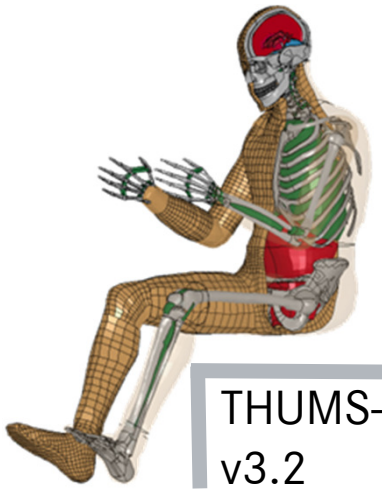
→ **Dedicated biomechanical improvement of THUMS-D by implementation of rib material representing elder population**



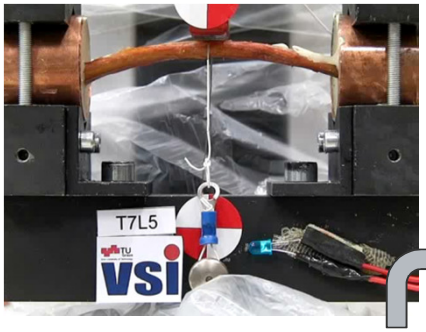


THUMS-D: Applications / PSIS development

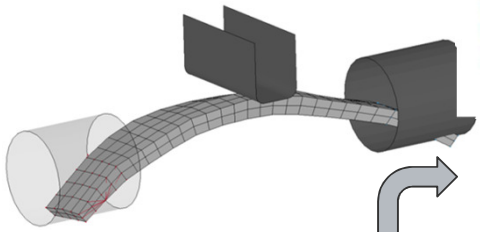
- **Experimental work and validation steps**
- Specific focus on material properties and characteristics of human ribs representing young & elderly population.
- Failure modelling of rib fracture



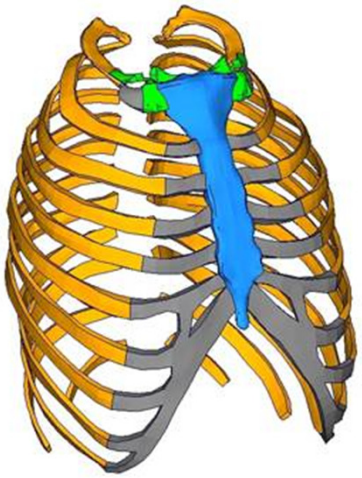
THUMS-D v3.2



Tests of rib bones by TU Graz



Definition of material cards by DYNAmore



Integrating new material properties in THUMS-D v3.2

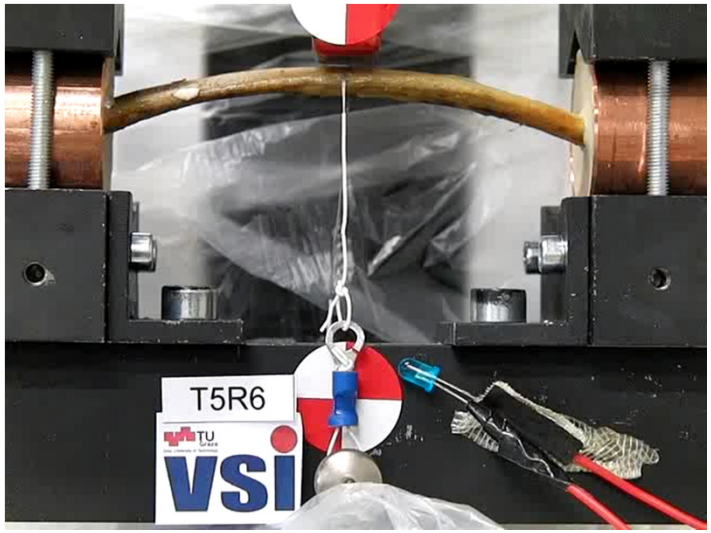
Validation of updated thorax

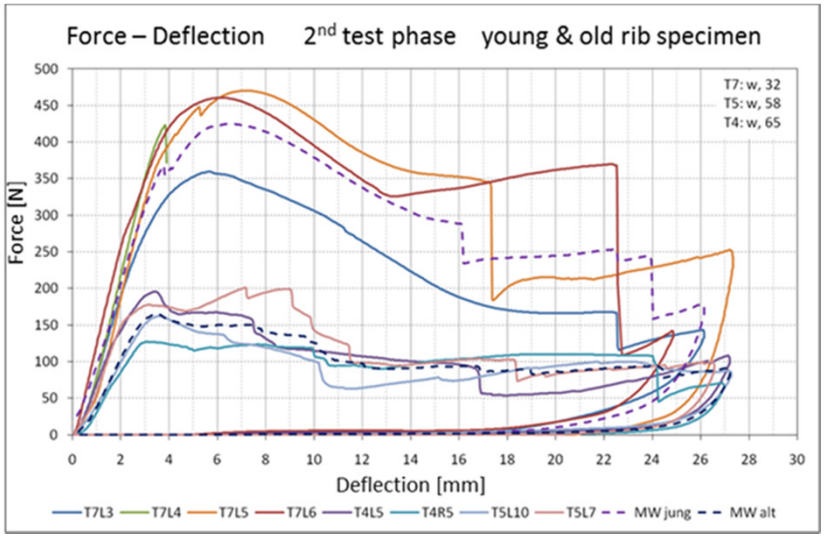
THUMS-D: Applications / PSIS development

- **Experimental work (TU Graz)** (2nd test phase: female 32 years old & female 58-65 years old – 28 rib specimen)

3-Point Bending Test

(58 yo)



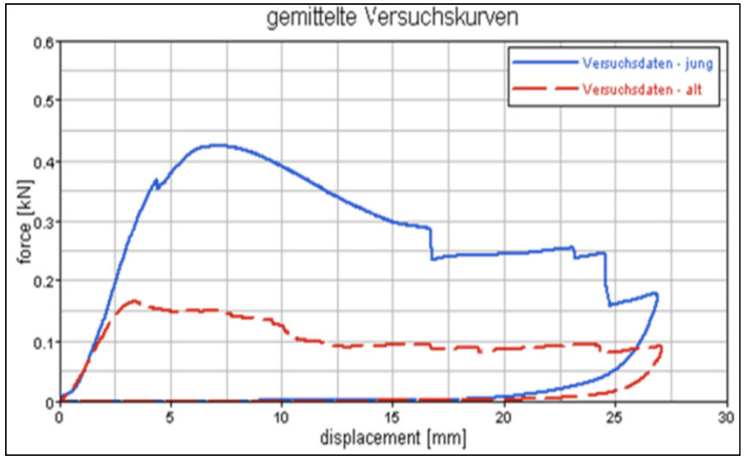


- **Rib samples from young PMHS withstand approx. two to three times higher loads compared to rib samples from elderly.**
- **Stiffness (elastic curve section) of younger ribs is significantly higher.**
- **All rib specimen (young and elderly) with similar dimensions showing comparable post-cracking behavior.**

Tomasch E., Sinz W., Kirschbichler S., Steffan H., Darok M., Patsch J., Dimai H.P., "Korrelation von Knochendichte u. Rippenfrakturen"; EVU 2011-8 ; 20th EVU Conference, 2011, Graz.
Mayer C. ,Kirschbichler S., Tomasch E, Sinz W., Fressmann D. , Mayer F. Untersuchung des Bruchverhaltens älterer und jüngerer menschlicher Rippen - Definition eines Materialmodells und Implementierung in ein FE Human Model, TIM Symposium - Traumabiomechanik des älteren Verkehrsteilnehmers, 12. Februar 2014.

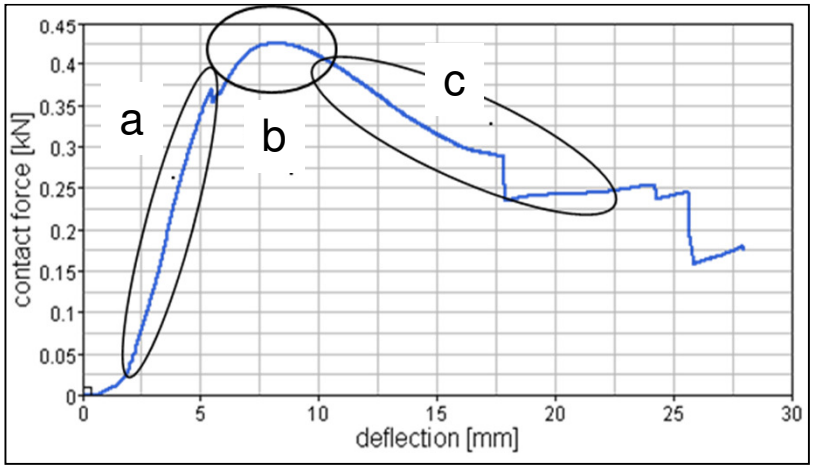
THUMS-D: Applications / PSIS development

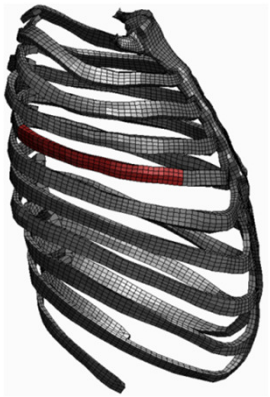
- **Rib material model and failure modelling of rib fracture**

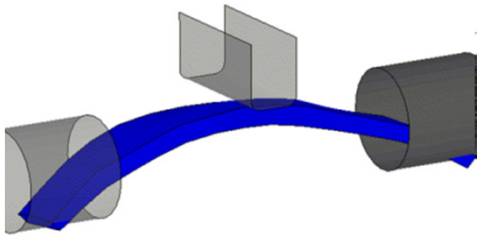


Mean of **young ribs**
Mean of **elderly ribs**

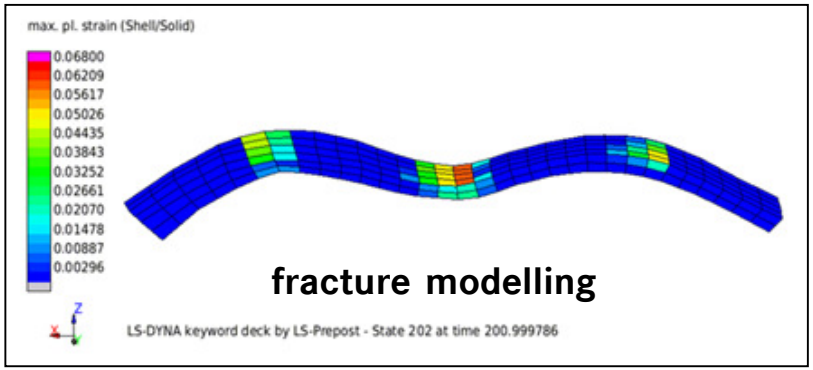
Material characterization of test curve segments
(a) elastic
(b) elastic-plastic/hardening
(c) elastic plastic/softening







Basic: **THUMS-D** v3.2 rib



THUMS-D: Applications / PSIS development

- **Rib material model and failure modelling of rib fracture**

Young rib material

- **Elastic range**

  cortical bone (MAT 24)
  E_{co} = 3.5 kN/mm2
  trabecular bone (MAT 1)
  E_{tra} = 0.04 kN/mm2

- **elastic-plastic/hardening**
  σ_y = 0.109 kN/mm2

- **elastic plastic/softening**
  → „failure flag“
  εpl = 0.05
  → element deletion/damage
  dam 50, 0.05-0.1

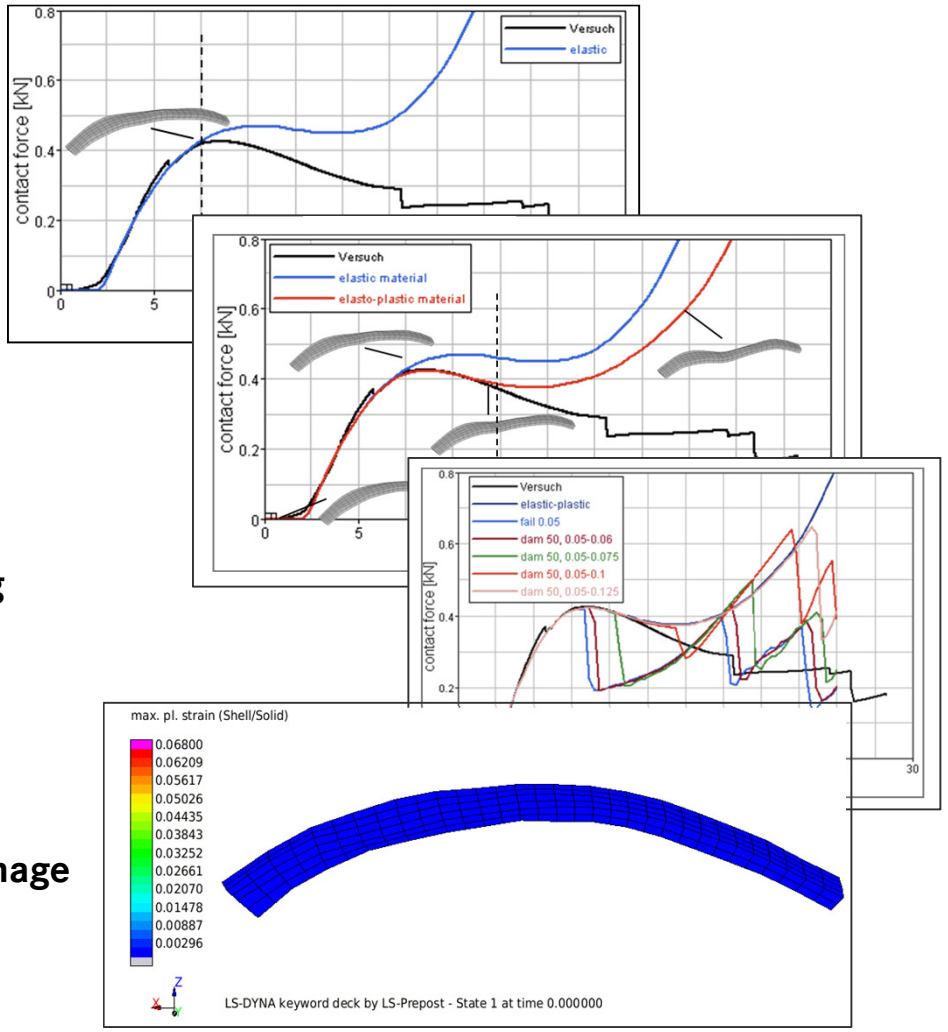
Old rib material

- **Elastic range**

  cortical bone (MAT 24)
  E_{co} = 1.5 kN/mm2
  trabecular bone (MAT 1)
  E_{tra} = 0.04 kN/mm2

- **elastic-plastic/hardening**
  σ_y = 0.026 kN/mm2

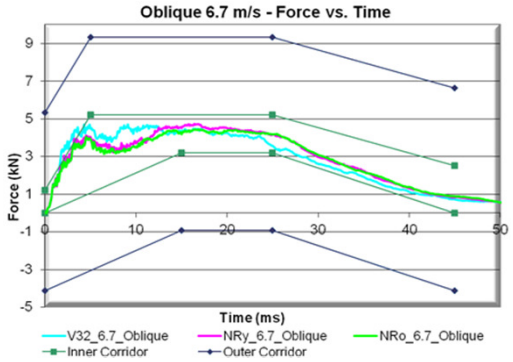
- **elastic plastic/softening**
  → „failure flag“
  εpl = 0.068
  → element deletion/damage
  dam 50, 0.05-0.1

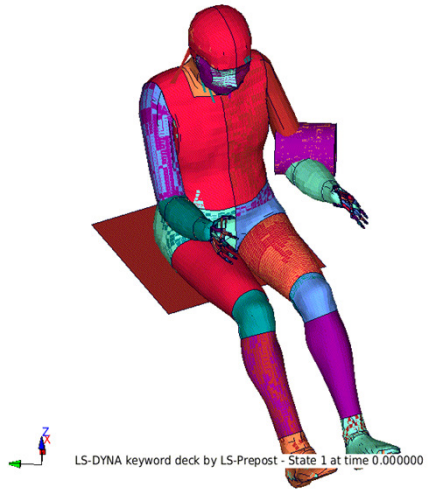


THUMS-D: Applications / PSIS development

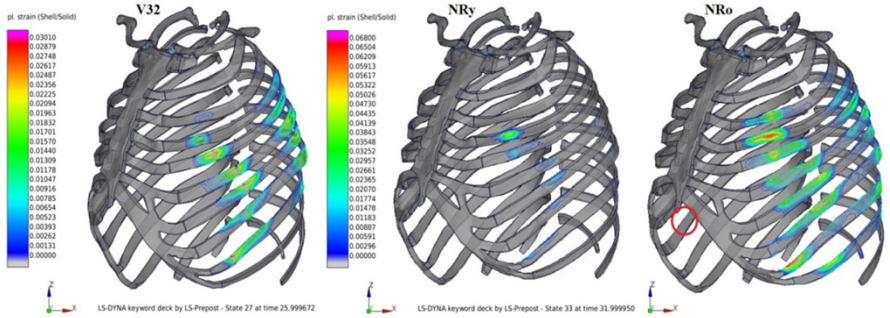
- **Validation according to ISO TR9790**

  Oblique-lateral pendulum impact test





  - Oblique-Lateral 6.7 m/s



- ***V32***:
  L4-9 (high)
- ***NRy***:
  L5-9 (low)
  L4 (medium)
- ***NRo:***
  L3, L6-8, L10 (medium)
  L4-5, L9 (high)
  R8 (low)

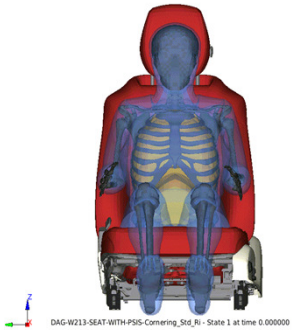
Test No.	Cadaver Data: Body Mass (kg)	Cadaver Data: Chest Breadth (mm)	Cadaver Data: No. of Rib Fractures L	Cadaver Data: No. of Rib Fractures R	Test Conditions: Impactor Velocity (m/s)
17	70,3	300	0	0	5,50
29	53,1	285	0	0	5,20
36	67,6	305	0	0	4,00
40	75,8	335	0	2	3,62
41	75,8	335	0	0	3,80
4	69,9	280	7	0	5,99
5	56,3	290	3	0	6,48
7	56,3	270	5	1	6,73
9	61,7	280	2	3	6,71
11	76,2	295	5	0	6,71

(ISO/TR 9790:1999, Table C.1)

→ **Rib fractures predicted from simulation shows good correlation to rib fractures observed in PMHS tests (documented in ISO/TR 9790)**

THUMS-D: Applications / PSIS development

- **Safeguarding: Static deployment**



→ No plastic strain

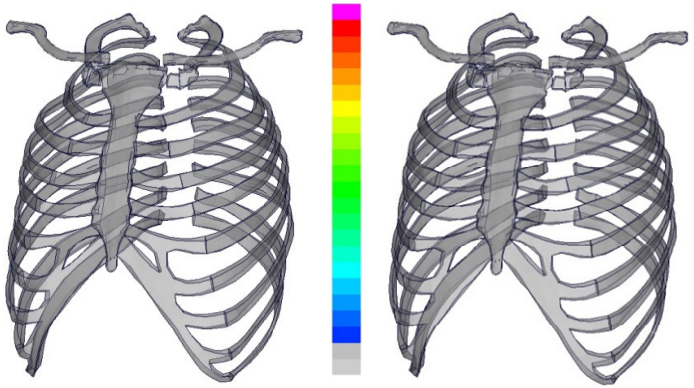
→ Only minor elastic strain

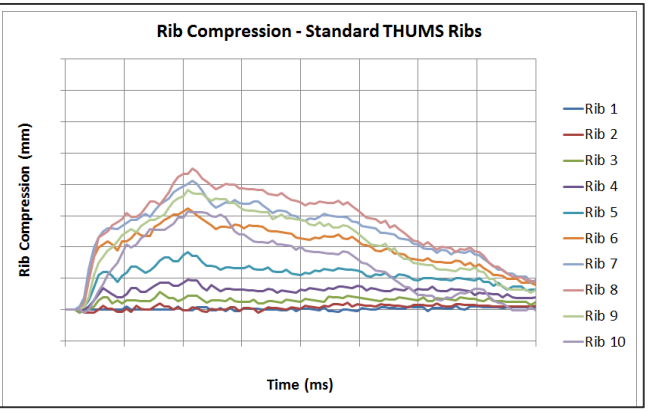
Plastic Strain Fringe Plots

True Strain Fringe Plots

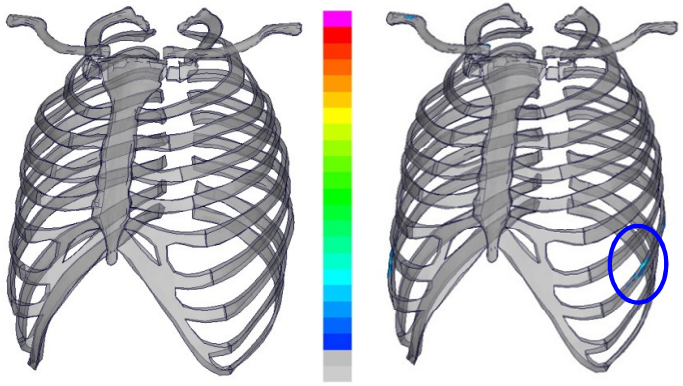
Rib Compression

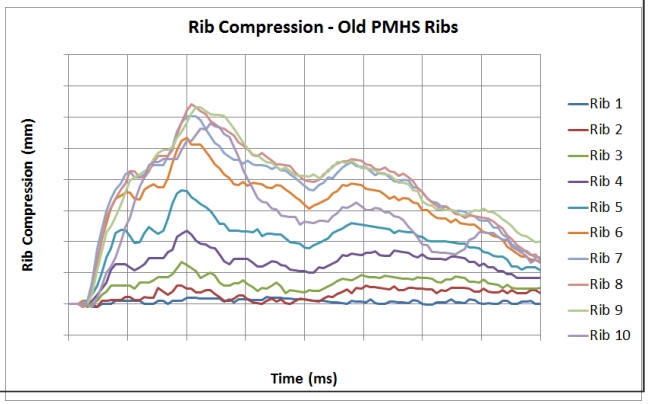
THUMS Standard Rib





Elderly Rib





THUMS-D: Applications / PSIS development

- **System performance:**

  Dynamic results

  → Old rib material

  IIHS Barrier Test

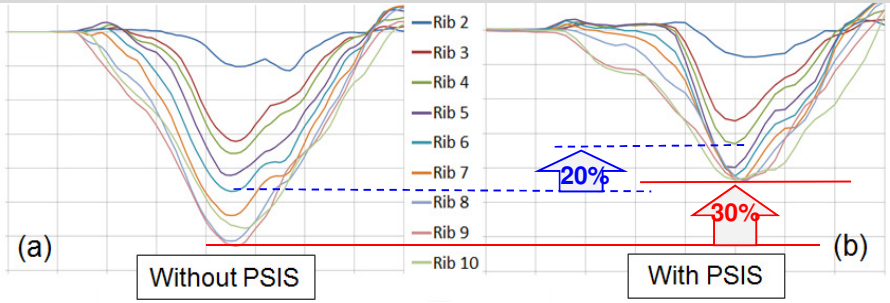
  50 kph

- **System optimization**

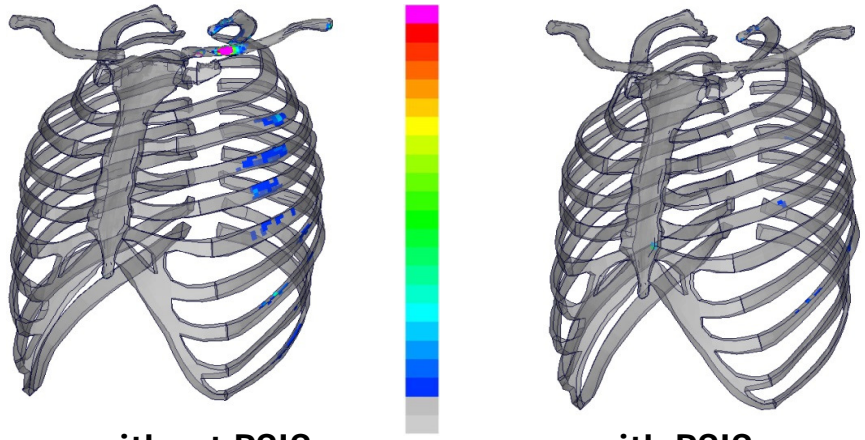
  → pre-crash trigger time

→ With PSIS significant decrease of rib fracture risk and rib compression

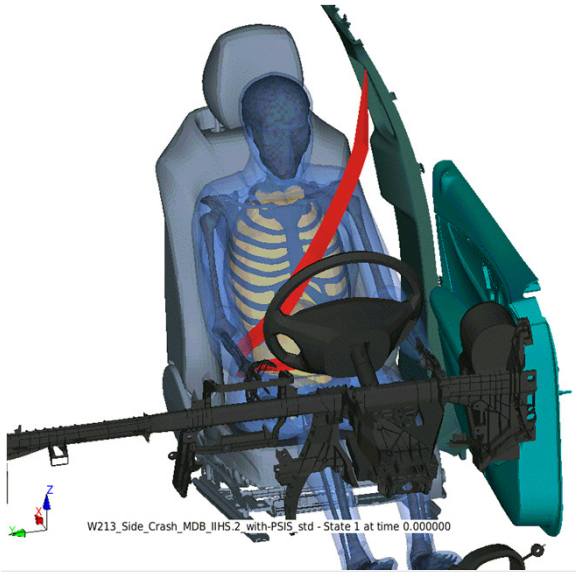
Rib Compression

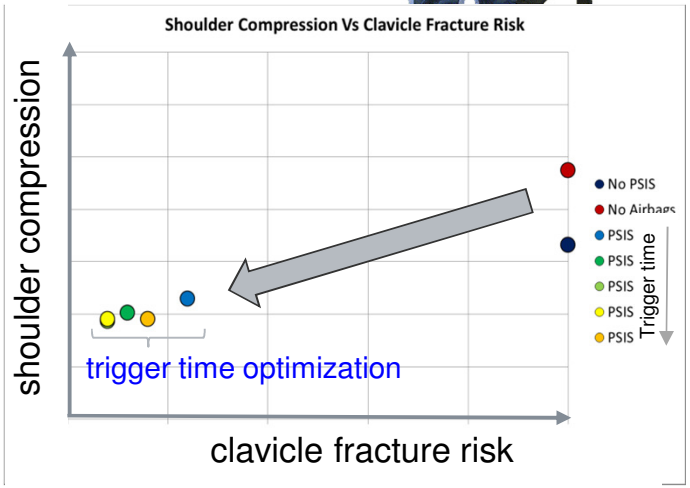


Fringe Plots



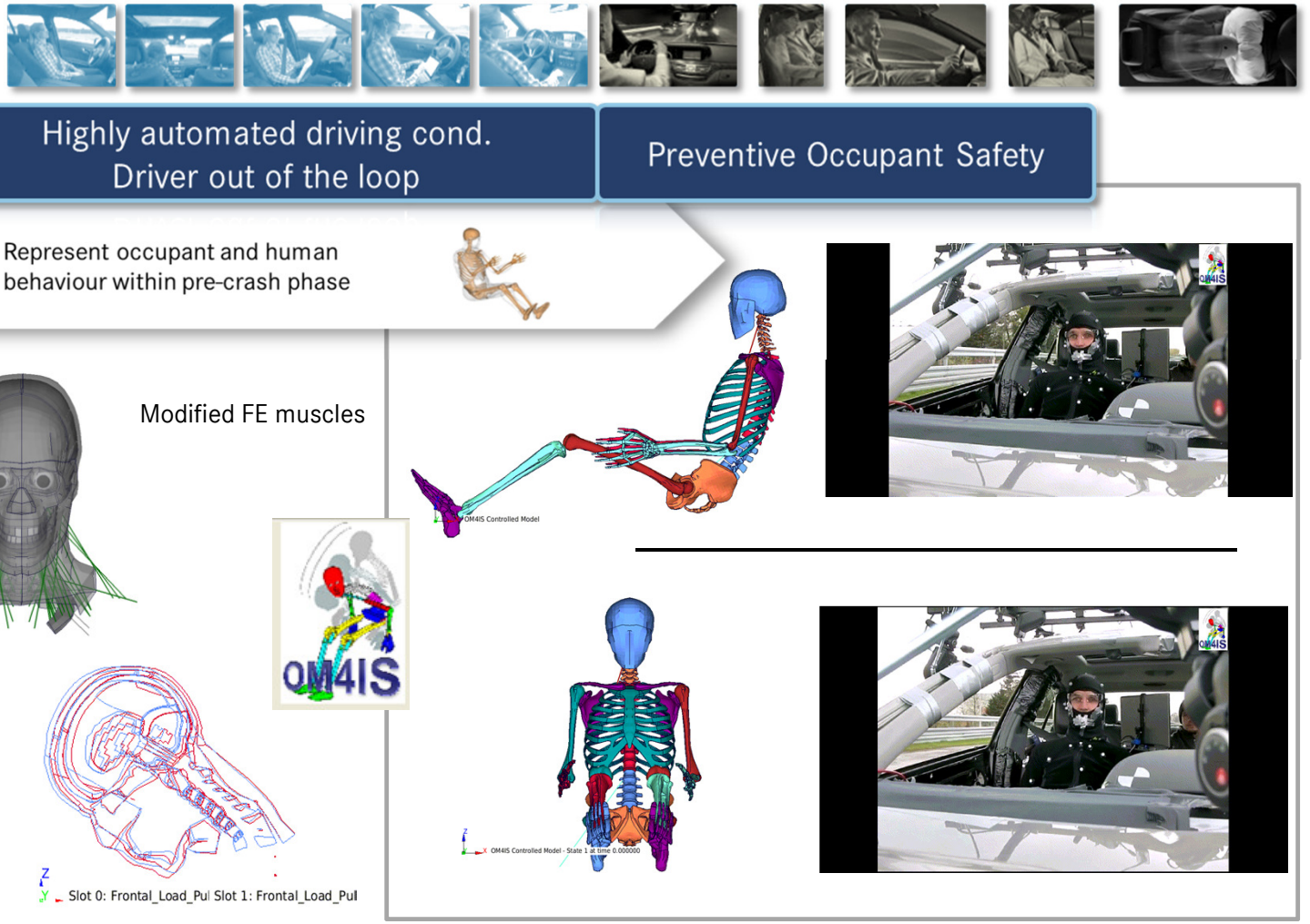
without PSIS **with PSIS**





THUMS-D: Development - Active HBM

- Todays PRE-SAFE systems **already addressing "preventive action" of passive safety – but this timeline will be extended much more with autonomous driving.**
- Active HBMs, take into account muscle activity and human behavior, will be capable of predicting occupant pre-crash positions and kinematics.
- Still in research stage, these HBM's will supplement the existing toolchain in predictive engineering – CAE.



HBM : Future
Active HBM

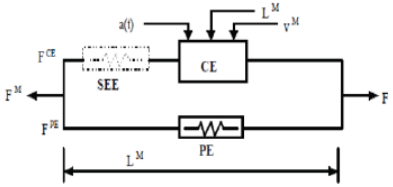
- Latest improvements
- Muscle modelling
- Relaxed

Highly automated driving cond.
Driver out of the loop

Preventive Occupant Safety

Represent occupant and human behaviour within pre-crash phase

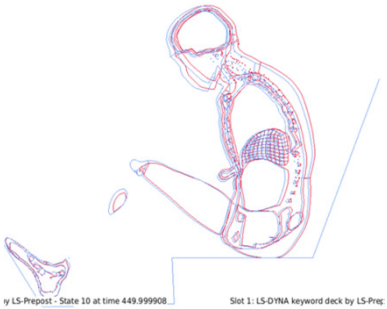
Hill type muscle (MAT_156)



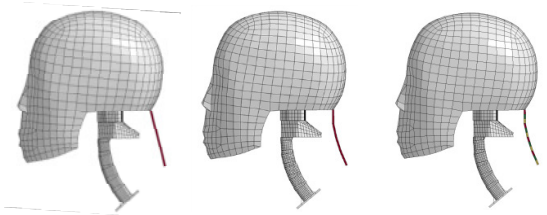
Improvement through

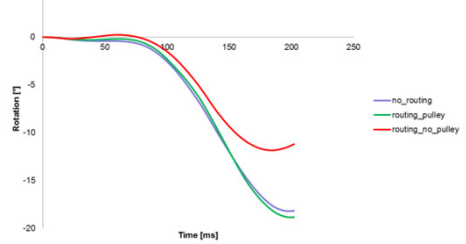
muscle routing

at element level

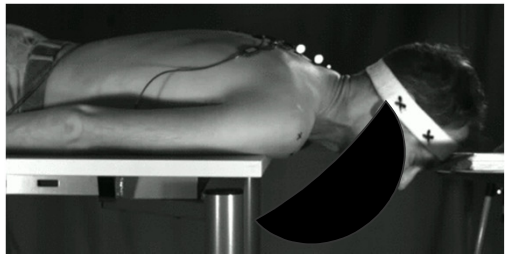


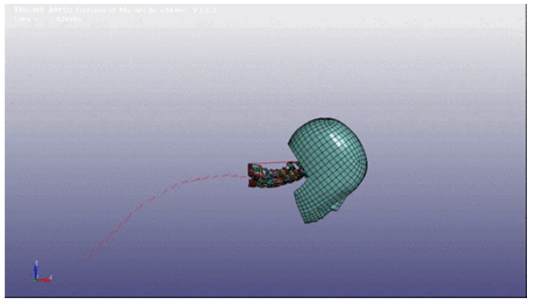
Switching from element level to full HBM model



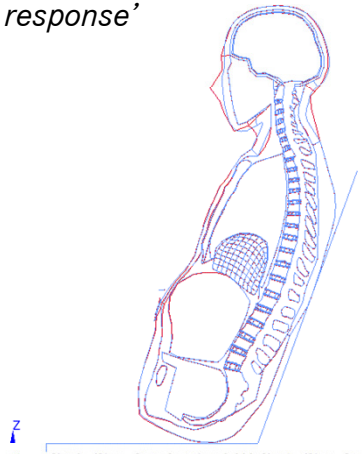


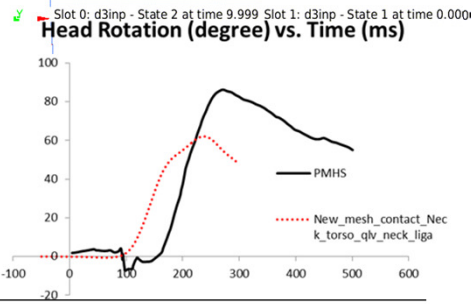
Experimental tests for relaxed state response





HBM ***relaxation*** *to achieve 'relaxed response'*





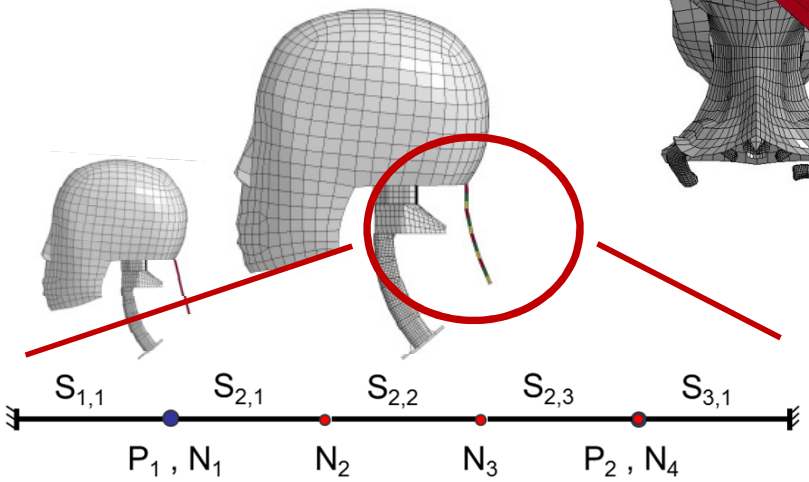
Mercedes-Benz

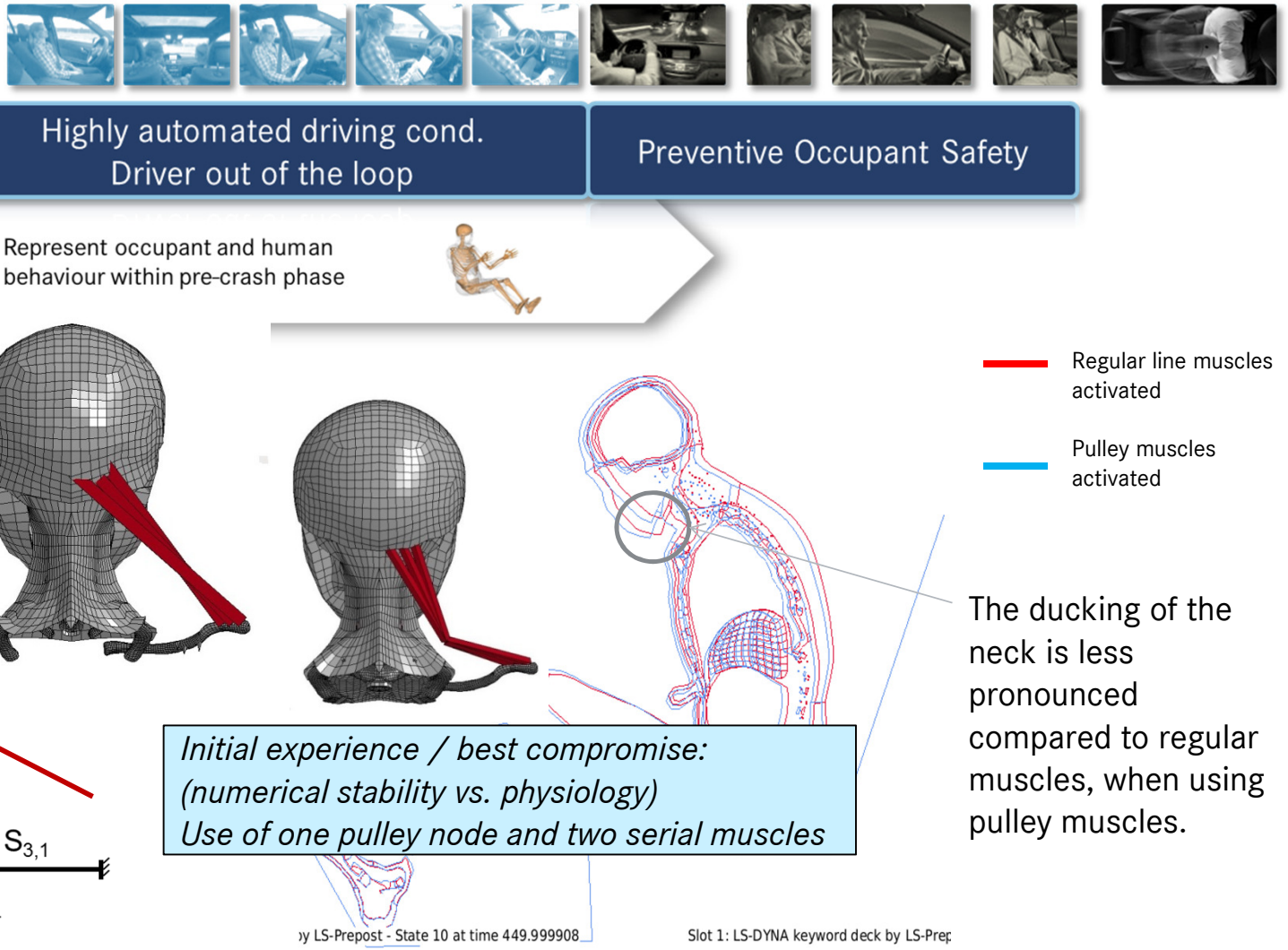
HBM : Future Active HBM

- Muscle routing

One beam element generates unphysiolocical situation

Pulley mechanism created by splitting into pully beams and pulley nodes



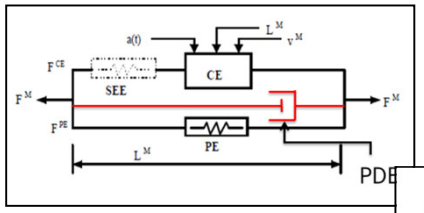


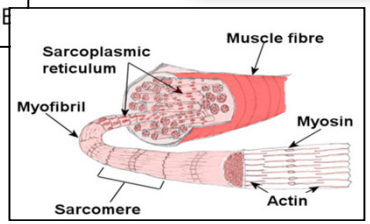
HBM : Future
Active HBM

Highly automated driving cond.
Driver out of the loop

Preventive Occupant Safety

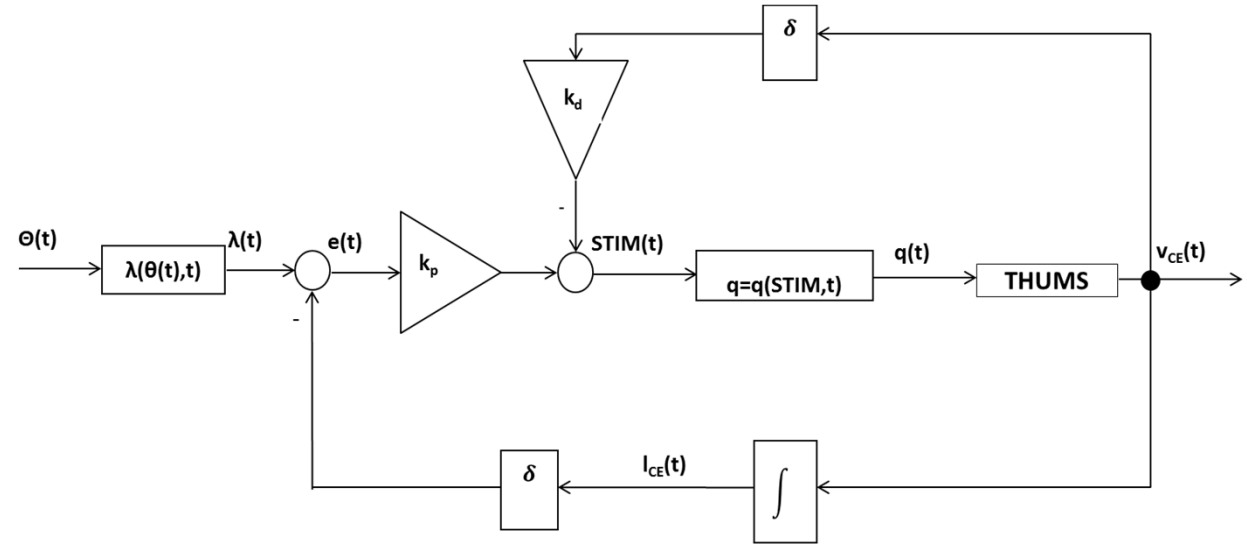
Represent occupant and human behaviour within pre-crash phase





- Latest improvements /outlook:

Implementation of physiological ***activation dynamic and Lambda-control***



Regelkreis der λ-Kontrolle, nach (Kistemaker, Van Soest, & Bobbert, 2006)

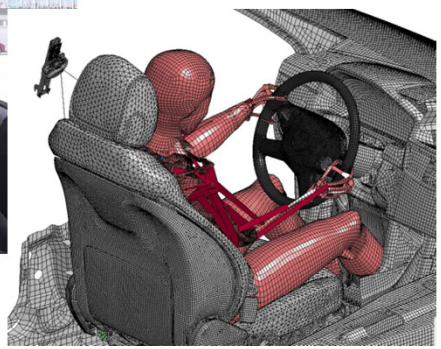
*DEFINE_CURVE_FUNCTION, *DEFINE_CURVE

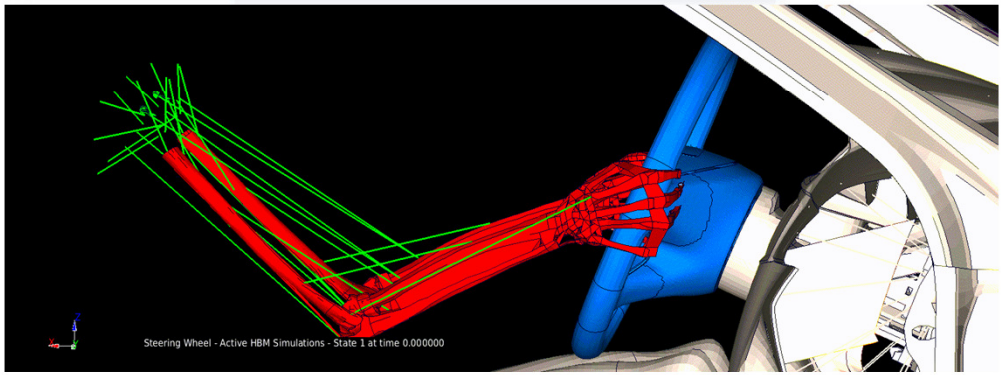
& *DEFINE_FUNCTION keywords

HBM : Future
Active HBM

Highly automated driving cond.
Driver out of the loop

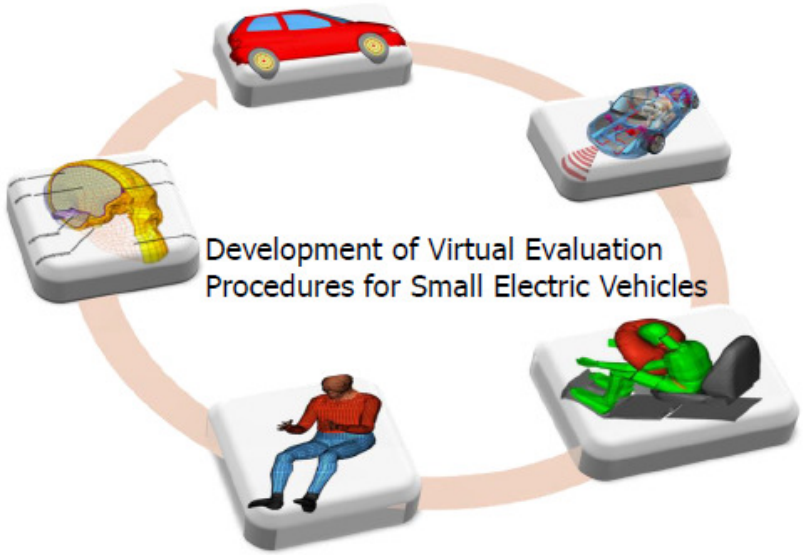
Preventive Occupant Safety





Collaboration

- **European research project - SafeEV**



Safe small Electric Vehicles through advanced simulation methodologies

- **Provide the methods, criteria and advanced active and passive safety evaluation tools needed for pedestrian & occupant protection and increased compatibility**
- **Deliver key building blocks that are required for virtual certification of small electric vehicles**

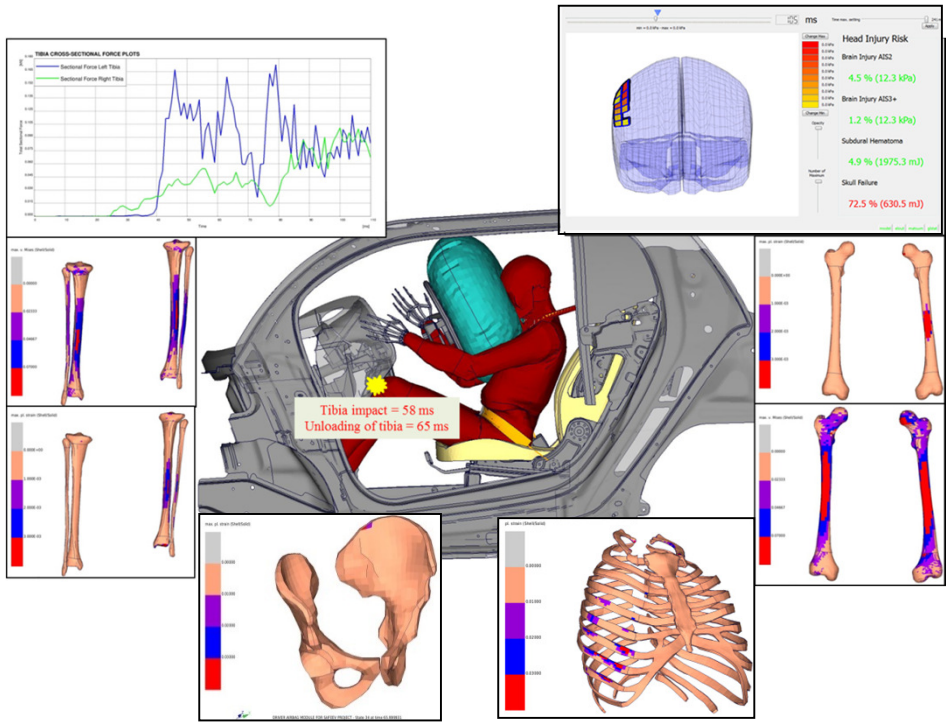
www.project-safeev.eu

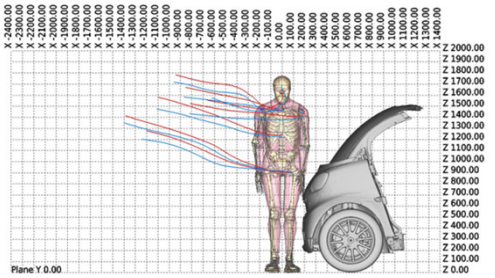
Final event Sept. 25th

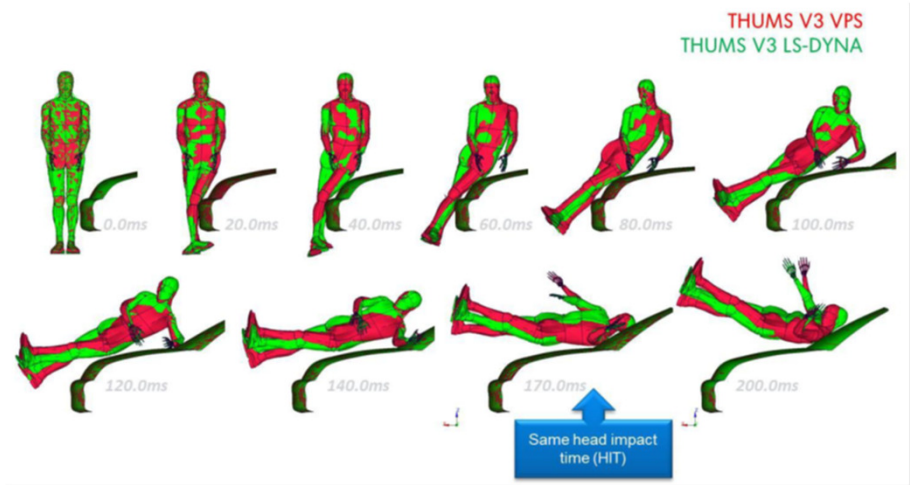
Collaboration

- **“Key building blocks…”**

Post processing →
Injury predictors → Criteria
Post processing tools (SUFEHM/IRA ; “DYNASAUR”)







Principal comparability of codes →
Metrix for comparison
Validation / set-up
Model settings
Tracking- / Reference Points

Collaboration

- **“Active HBM” – Evaluation Pre-Crash System**

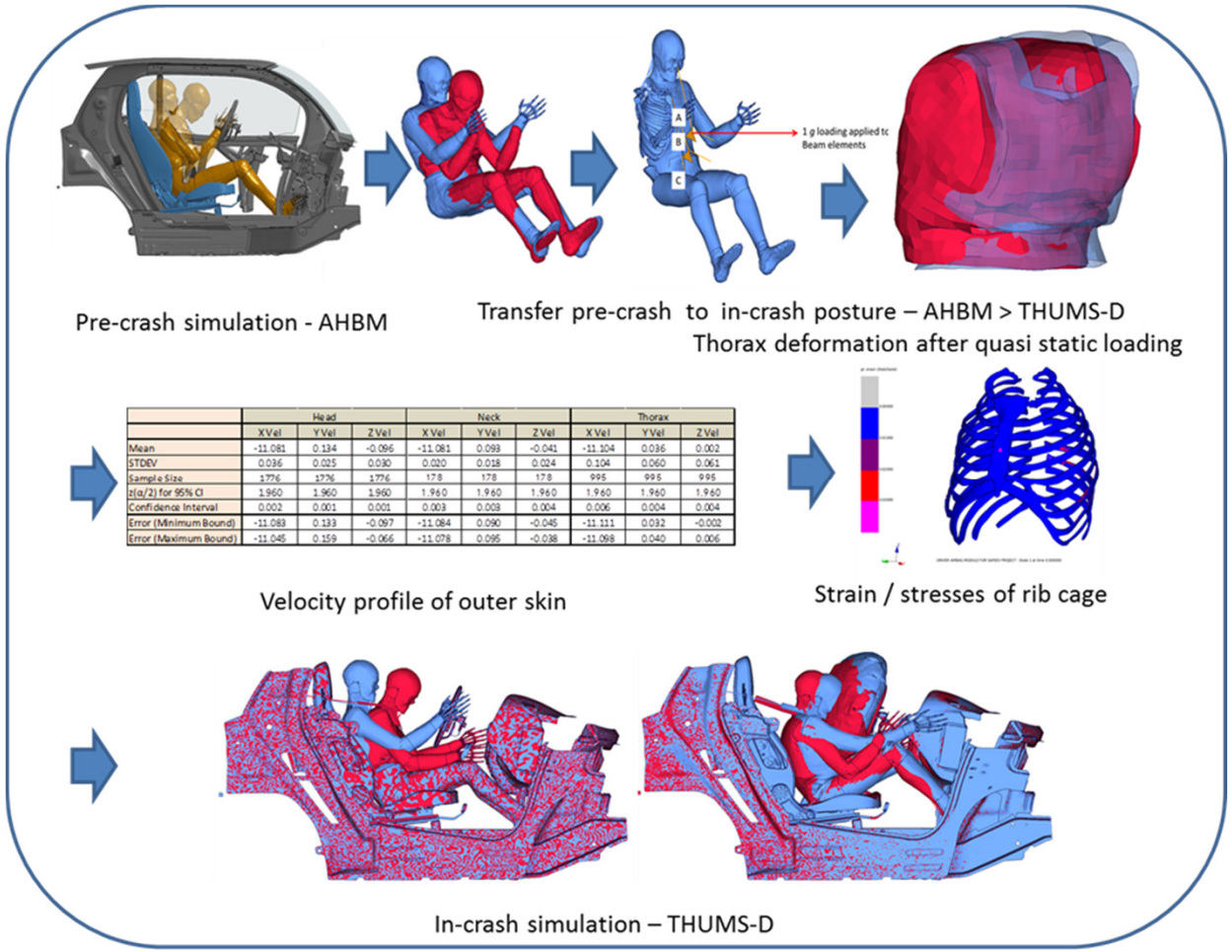
Approach / Method for data transfer between pre-crash and crash phase:

Applying an active HBM validated for pre-crash simulation (AHBM; carhs 2014; K.Brolin, J.Östh)

in Pre-Crash scenario (in this case: AEB).

Transfer of physical and dynamic data to

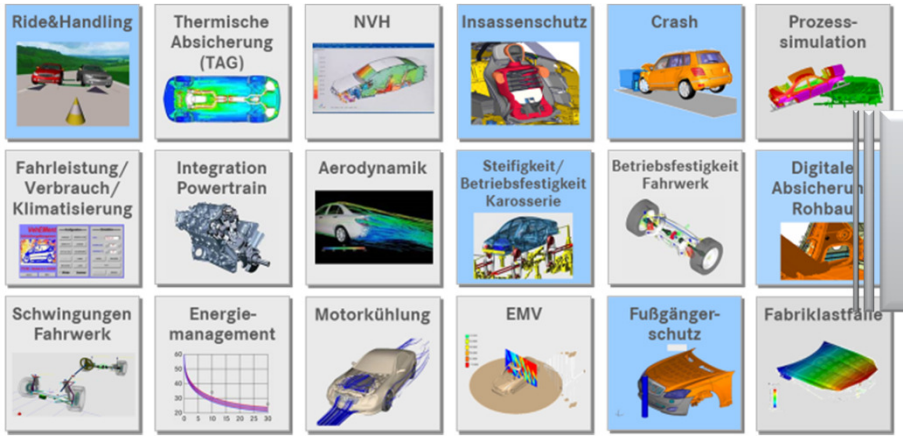
HBM (THUMS-D), validated for in-crash simulation and injury risk evaluation.

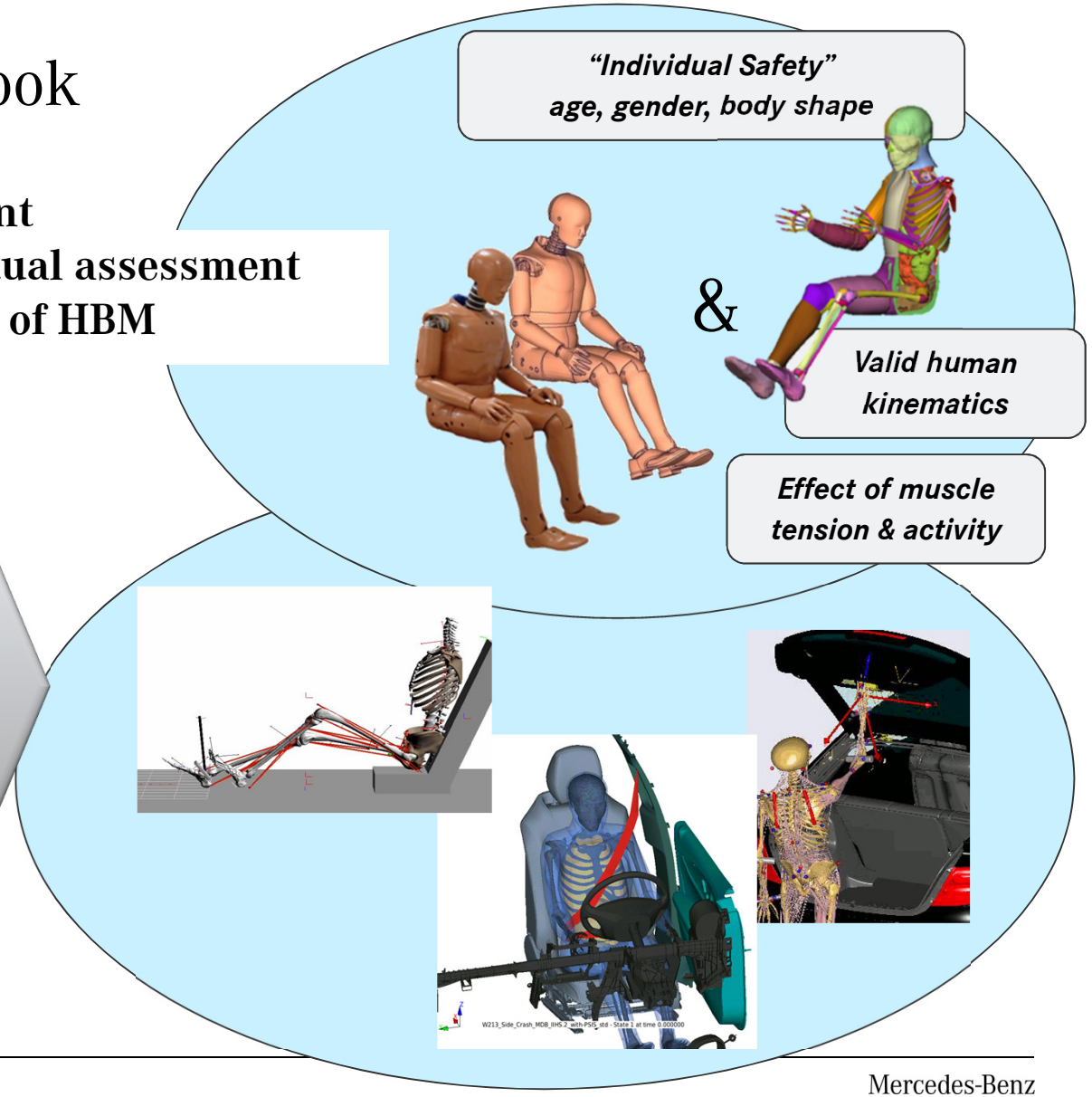


	Head			Neck			Thorax		
	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel	X Vel	Y Vel	Z Vel
Mean	-11.081	0.134	-0.096	-11.081	0.093	-0.041	-11.104	0.036	0.002
STDEV	0.036	0.025	0.030	0.020	0.018	0.024	0.104	0.060	0.061
Sample Size	1776	1776	1776	178	178	178	995	995	995
z(a/2) for 95% CI	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960	1.960
Confidence Interval	0.002	0.001	0.001	0.003	0.003	0.004	0.006	0.004	0.004
Error (Minimum Bound)	-11.083	0.133	-0.097	-11.084	0.090	-0.045	-11.111	0.032	-0.002
Error (Maximum Bound)	-11.045	0.159	-0.066	-11.078	0.095	-0.038	-11.098	0.040	0.006

HBM: Strategic Aspects & Outlook

- **Supplementary tool in safety development**
- **Tool Fusion within a supplementary virtual assessment**
- **Tool Fusion with other application areas of HBM**





Acknowledgement

Collaborations & Scientific partners