crashtest-service

RESEARCH ACTIVITIES AT FRAUNHOFER INSTITUTE FOR HIGH-SPEED DYNAMICS

Fraunhofer
EMI

Marcin Jenerowicz

CONTENT

- BLAST EXPOSURES
- BONE SURROGATES
- WHEELCHARITY
- DYNAMIC X-RAY
- HUMAD

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EMI

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- BLAST EXPOSURES
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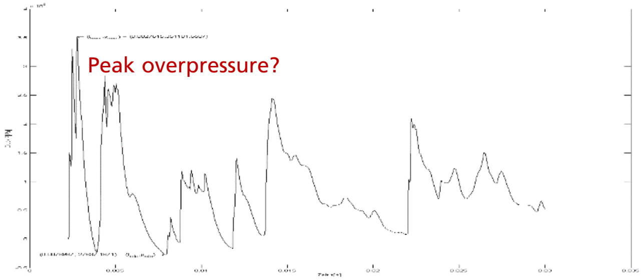
BLAST-STAR
BLAST-Security Test and Research Facility

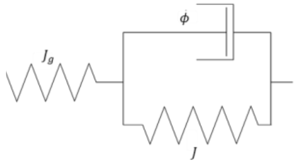
BLAST EXPOSURES - Development of dynamic lung injury models

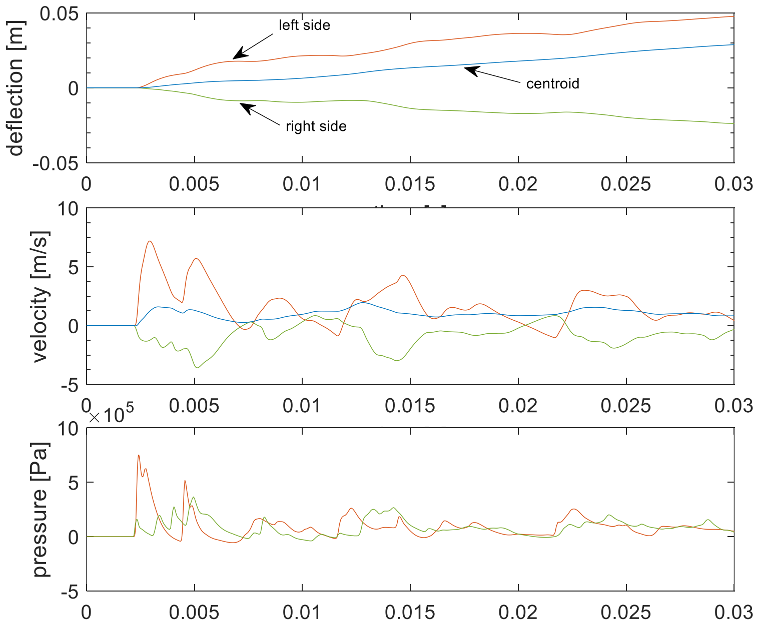
Risk Management and Protective Structures – Dr. Malte von Ramin

MOTIVATION

- Current approaches to model lung injury due to blast loads are not suitable for conditions different from free-field characteristics
- Dynamic lung injury models need to be able to represent: physical phenomena, material properties and medical condition
- Modification @ EMI exhibits retardation of strain, relaxation of stress







material model → viscoelastic behaviour of torso → correlation with degree of injury

BLAST EXPOSURES - Development of dynamic lung injury models

Risk Management and Protective Structures – Dr. Malte von Ramin

- EXPERIMENTAL SETUP
  - Single spanned masonry wall 1.8 x 1.5 m
  - Blast Star shock tube facility
    - 50-150 kPa
    - Blast resistant classifications (EPR1 – EPR3)

Shock wave loads resulting from explosives and gas explosions are simulated at the facility.

BLAST-STAR
BLAST-Security Test and Research Facility

Fraunhofer EMI

BLAST EXPOSURES - Development of dynamic lung injury models

Risk Management and Protective Structures – Dr. Malte von Ramin

- EXPERIMENTAL SETUP
  - CTS-Dummy preparation
  - Four pressure sensors each on the thorax and head
  - A total of five acceleration sensors on the thorax, the spine and one on the head

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BLAST EXPOSURES - Development of dynamic lung injury models

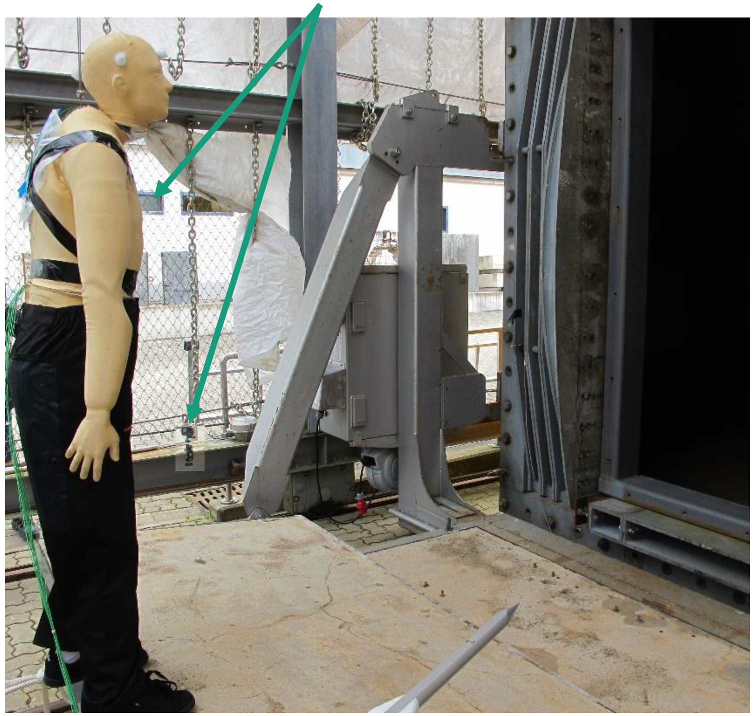
Risk Management and Protective Structures – Dr. Malte von Ramin

- PRE-TRIAL-TESTING No.3
  - ~ 68 kPa

BLAST EXPOSURES - Development of dynamic lung injury models

Risk Management and Protective Structures – Dr. Malte von Ramin

- EXPERIMENTAL SETUP
  - After pre-trial-test No.3, setup was modified



BLAST EXPOSURES - Development of dynamic lung injury models

Risk Management and Protective Structures – Dr. Malte von Ramin

- PRE-TRIAL-TESTING No.5
  - ~20 kPa
- PRE-TRIAL-TESTING No.6
  - ~40 kPa

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BLAST EXPOSURES - Development of dynamic lung injury models

Risk Management and Protective Structures – Dr. Malte von Ramin

- OUTLOOK
  - Based on first experience, further test series to complete the load ranges will be carried out.
  - Further chest wall acceleration values (around the thorax) and pressure values to validate corresponding models (lung injury models) are necessary.
  - Strictly speaking, in a first step we can only map the reaction of the chest wall to the pressure load and not the injury itself (medically).
  - We will then have to resort to empirical data on injury probabilities.

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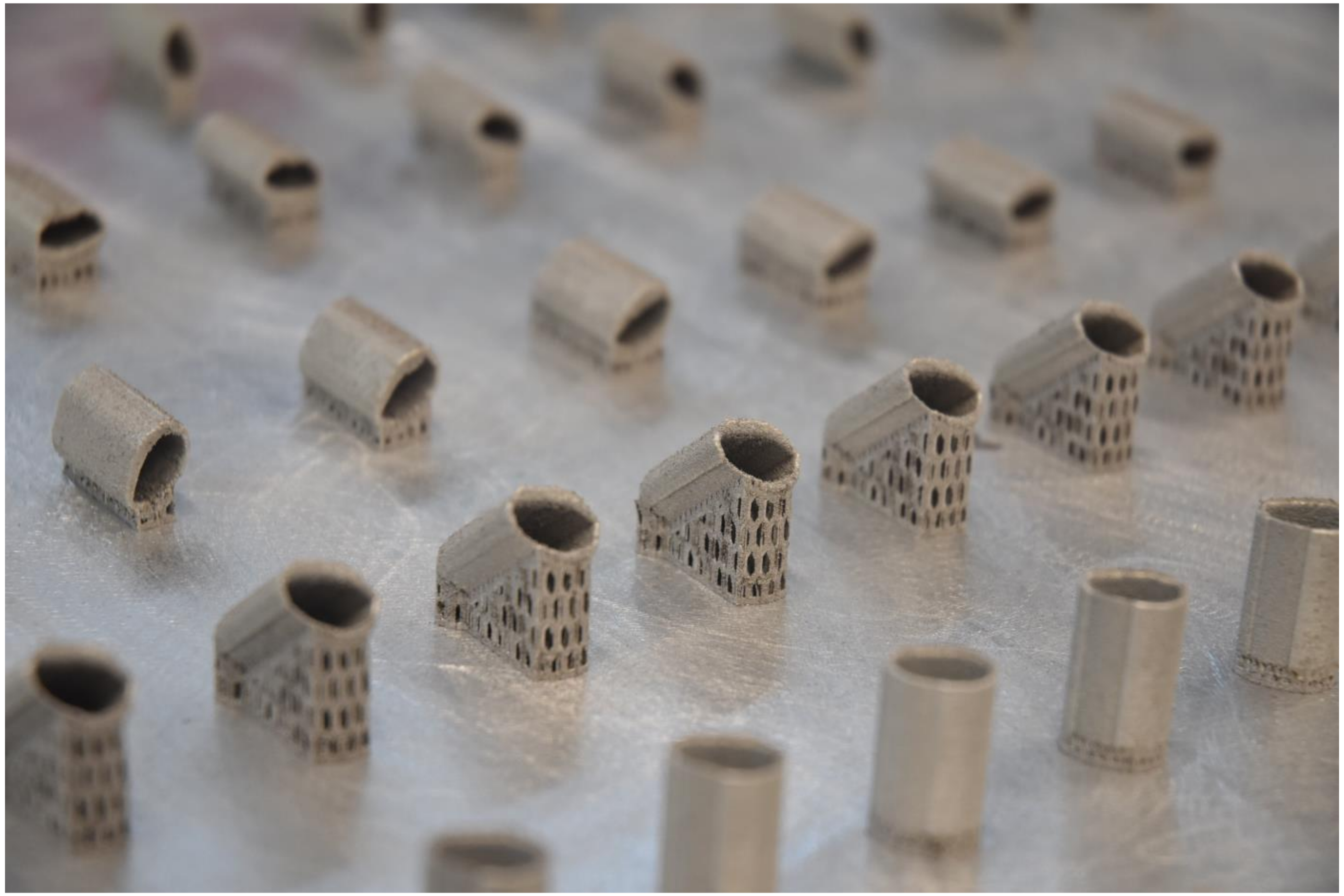

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BONE SURROGATES

Human Body Dynamics – Marcin Jenerowicz

MOTIVATION

- Innovative methods for body armour
  - Development of an FE model of a ballistic protective waistcoat with all components.
  - Transformation of the FE model from a 2D planar form into a 3D lay-up configuration (node mapping method DYNAskin)

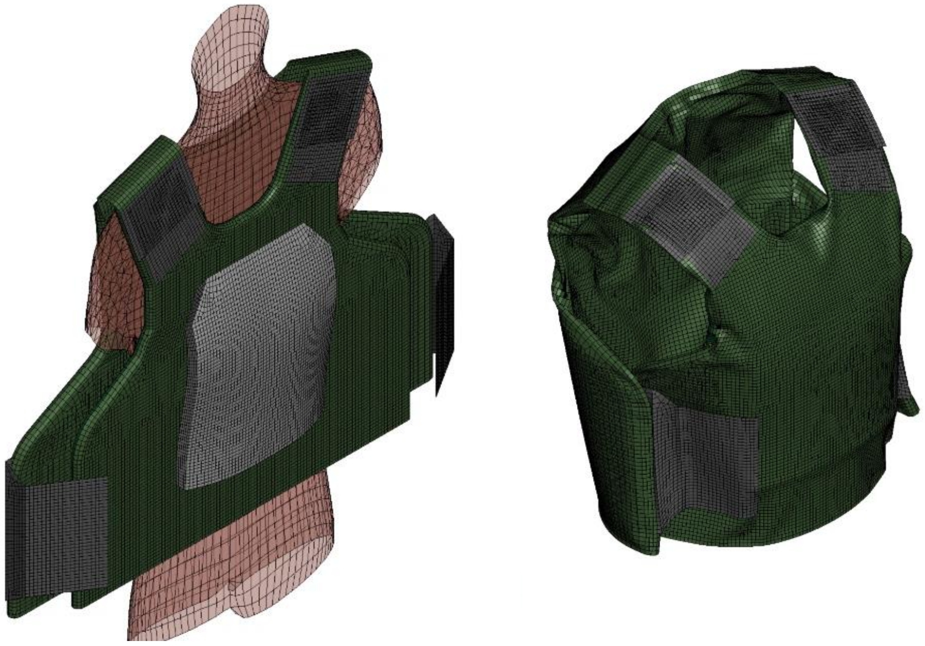
Wehrtechnische Dienststelle für Waffen und Munition– WTD 91

DSM

© Fraunhofer EMI 10 cm

© Fraunhofer EMI 10 cm

Referenz: Mehler Vario SK4 Weste, Aramid Soft Ballistik und SiC-Composit / Dyneema ® Hart Ballistik Platte



Expansion simulation of protective vest with DYNAskin

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BONE SURROGATES

Human Body Dynamics – Marcin Jenerowicz

- **MOTIVATION**
  - Working Group: Non-lethal Impact
  - Surrogate for the technical investigation of lethality limits
  - Investigation of bullet impact and BABT (Behind Armor Blunt Trauma).

Wehrtechnische Dienststelle für
Schutz- und Sondertechnik – WTD 52

HELMUT SCHMIDT UNIVERSITÄT
Universität der Bundeswehr Hamburg

LaFT
Laboratorium Fertigungstechnik

Fig.: CTS biofidel dummy with MVS protective vest

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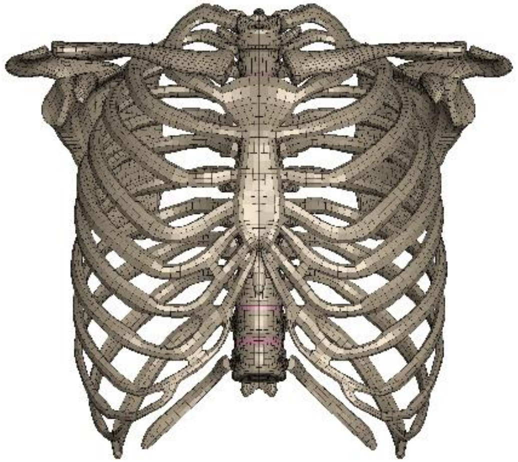
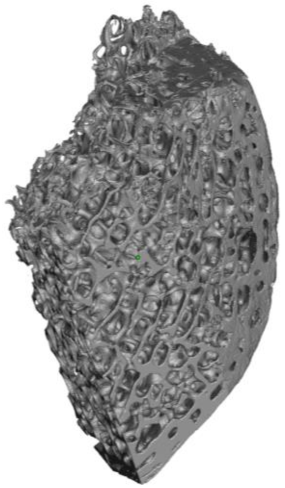
BONE SURROGATES

Human Body Dynamics – Marcin Jenerowicz

- APPROACH
  - 3D-printed bone surrogate structures for the fabrication of a more anatomically designed thorax



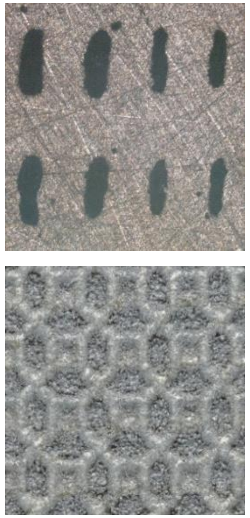
GHBMC-M50 Thorax



CT-Scan of real Bone structure

1 x 1 cm

3D printing from titanium of a human jaw bone on a scale of 1:1



Human rib in cross section

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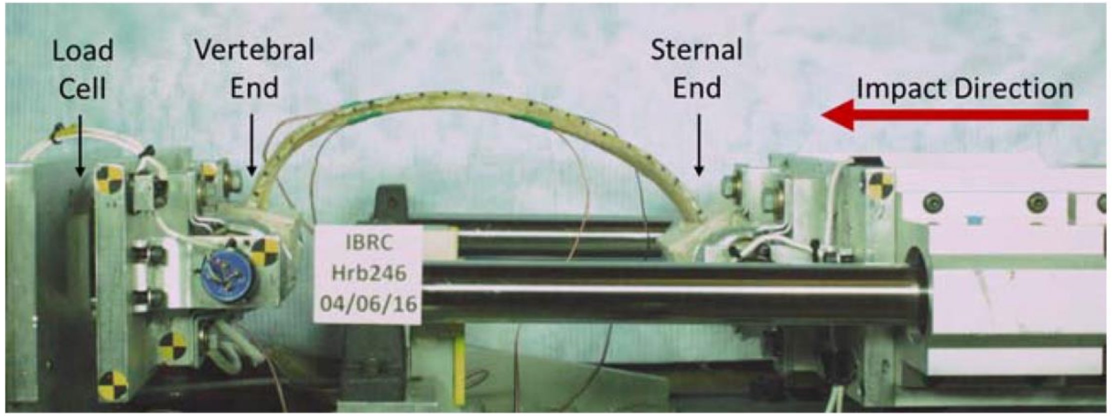
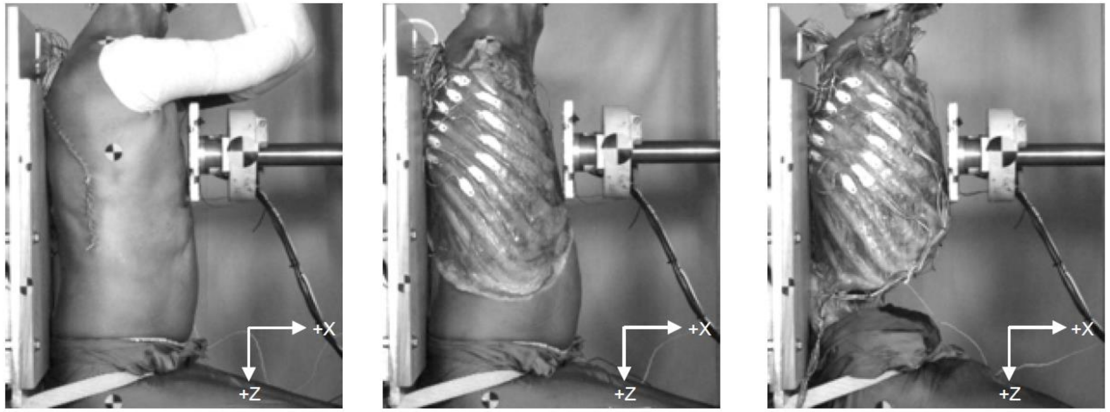
BONE SURROGATES

Human Body Dynamics – Marcin Jenerowicz

- EXPERIMENTAL SETUP
  - Extraction of the required structures from HBM
  - Test series from the automotive sector
  - Set-up / execution of the tests at EMI

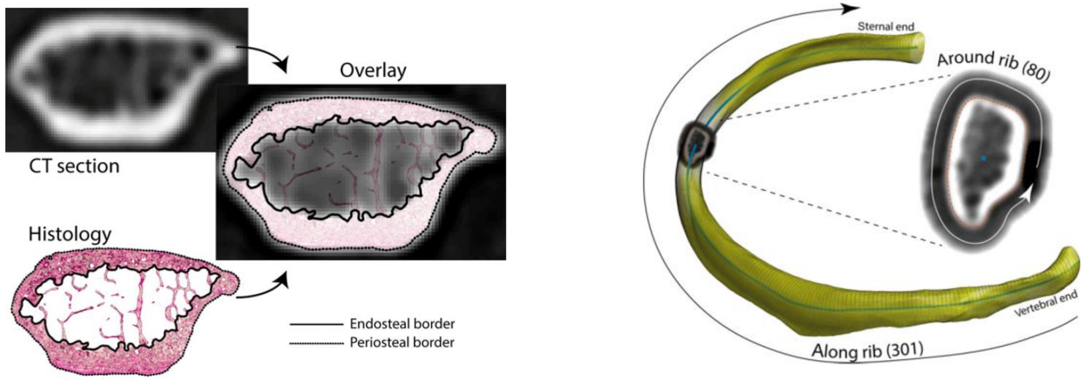


D. Albert et al., 2017: Dynamic rip bending test setup



a. Intact b. Denuded c. Eviscerated

A. Sreedhar et al., 2020: A hierarchical study of rib loading during dynamic frontal thoracic impacts



S. A. Holcombe et al., 2019: Regional cortical rib thickness map based on CT scans

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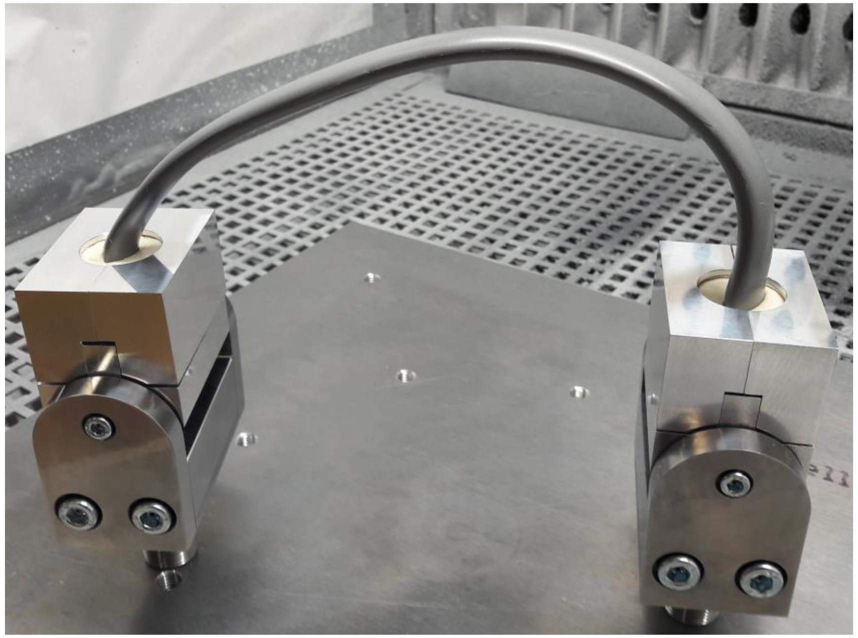
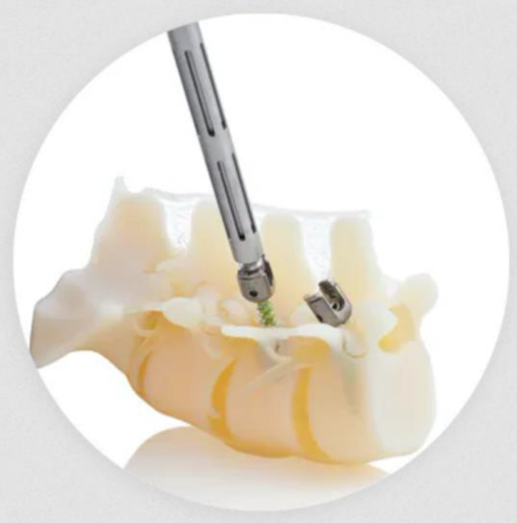
BONE SURROGATES

Human Body Dynamics – Marcin Jenerowicz

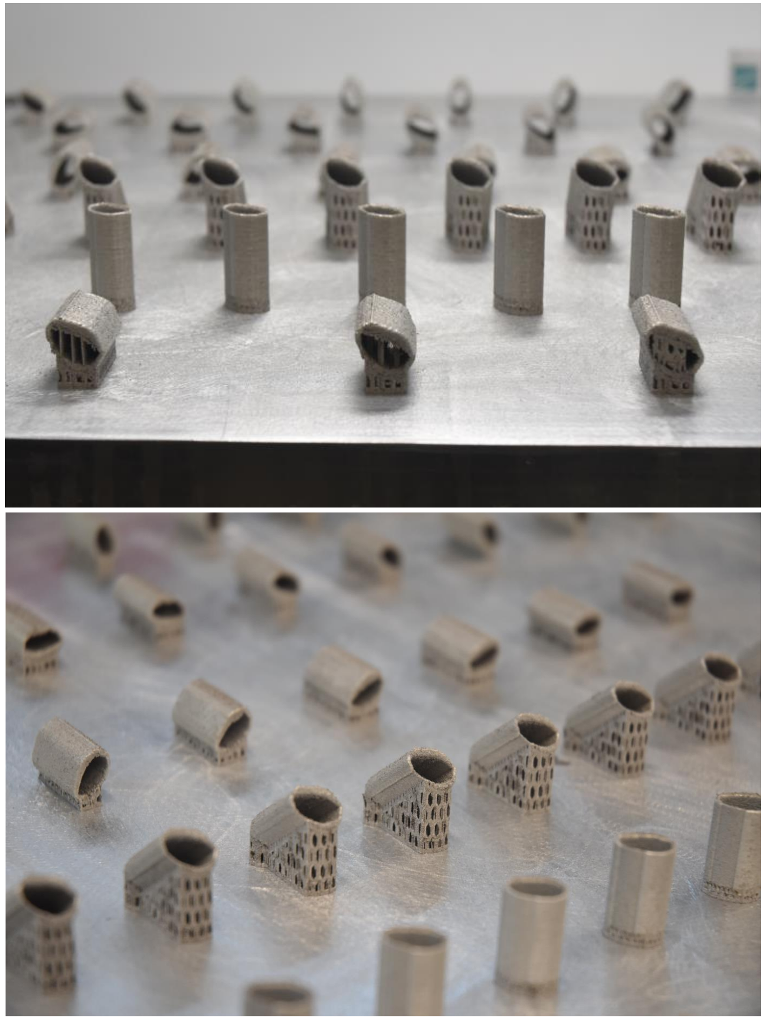
- OUTLOOK
  - Validation of the printed rib structures
  - Comparison to CTS Ribs and Stratasys BoneMatrix™



Dynamic rip bending test setup at EMI (1-500 mm/sec.)



©Stratasys BoneMatrix™



3D printed test specimen of real human ribs from Scalmalloy®

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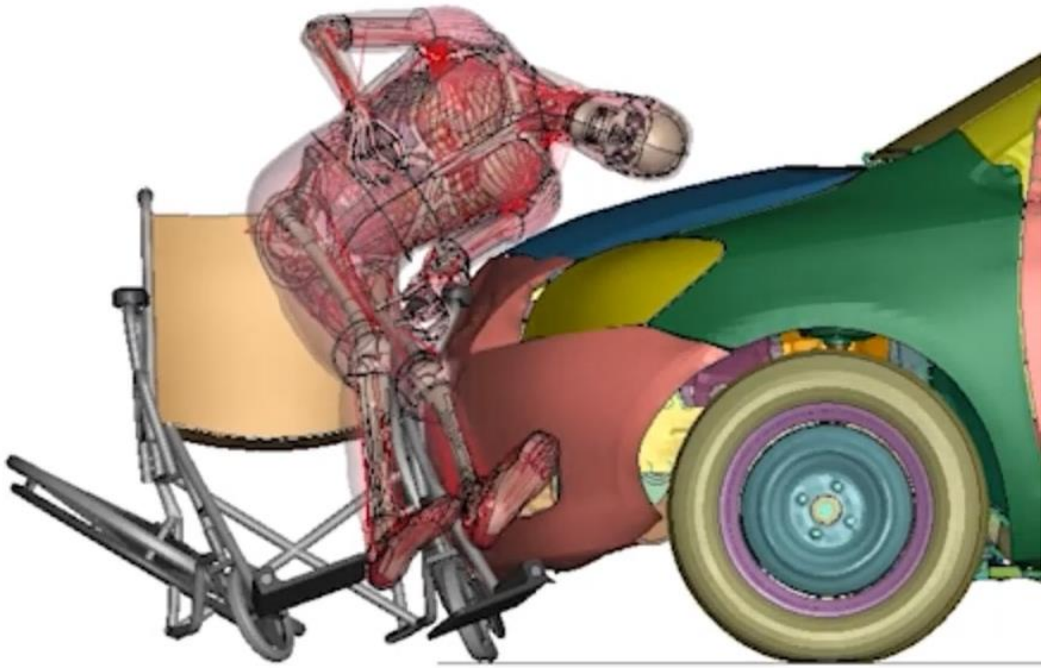
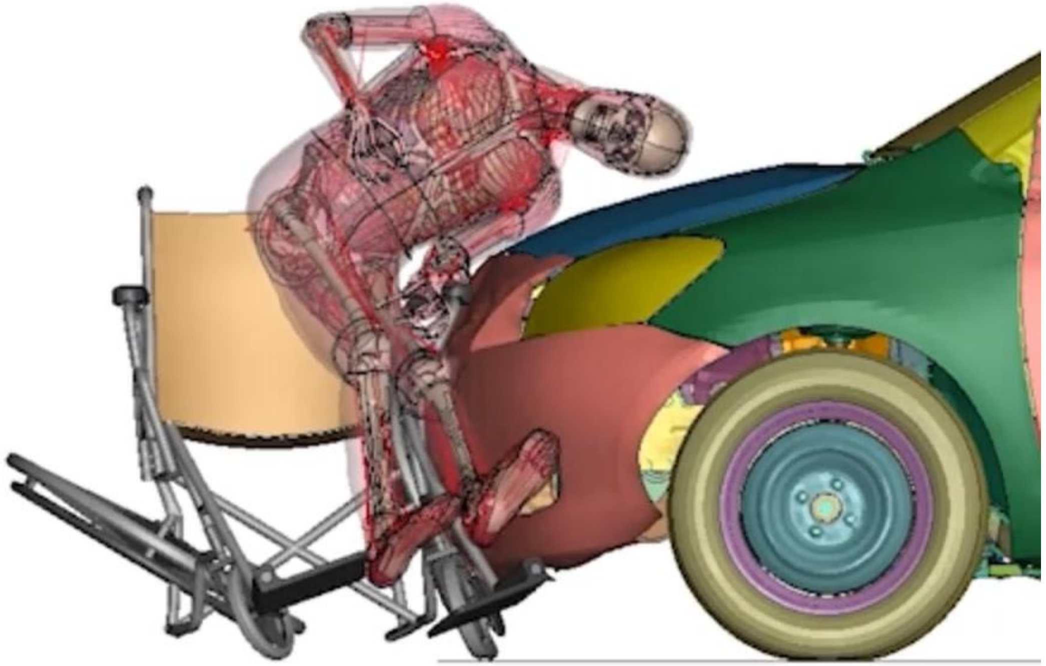


WHEELCHARITY – Road safety of wheelchair users

Human Body Dynamics – Niclas Trube

- MOTIVATION
  - Risk of death for wheelchair users (WCU) in traffic accidents is 36% higher than for pedestrians [Kraemer et al. 2015].
  - Safety analysis based on numerical simulation of WCU-vehicle collision and crash tests with Biofidel dummies, providing a more comprehensive picture on the kinematic behaviour of WCUs in traffic accidents.



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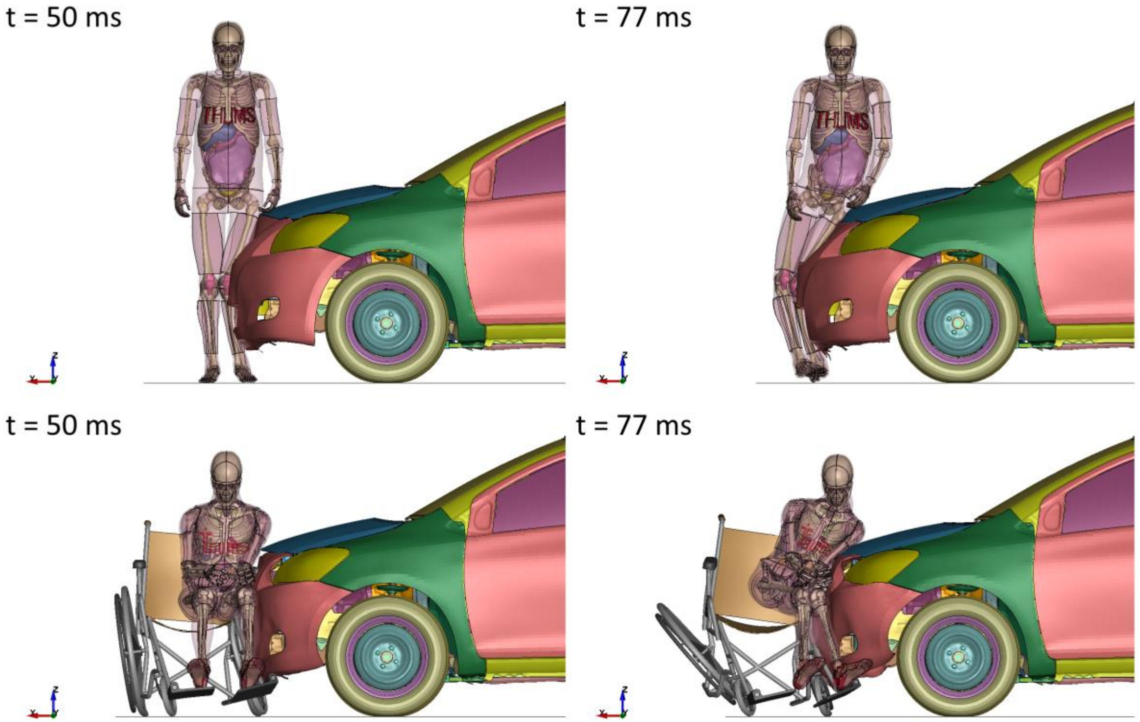
WHEELCHARITY – Road safety of wheelchair users

Human Body Dynamics – Niclas Trube

- SIMULATION SETUP
  - Human model: THUMS version 5.01 AM50 Occupant / THUMS version 4.02 AM50 Pedestrian.
  - Car model: Toyota Yaris course at 30 km/h.
  - Comparison: vehicle-to-WCU impact with vehicle-to-pedestrian impact based on numerical collision simulations using LS-DYNA.
  - Injuries were predicted based on the accumulation of effective plastic strain (over 290 ms) exceeding a threshold of 3 % in cortical bone elements results in fractures.



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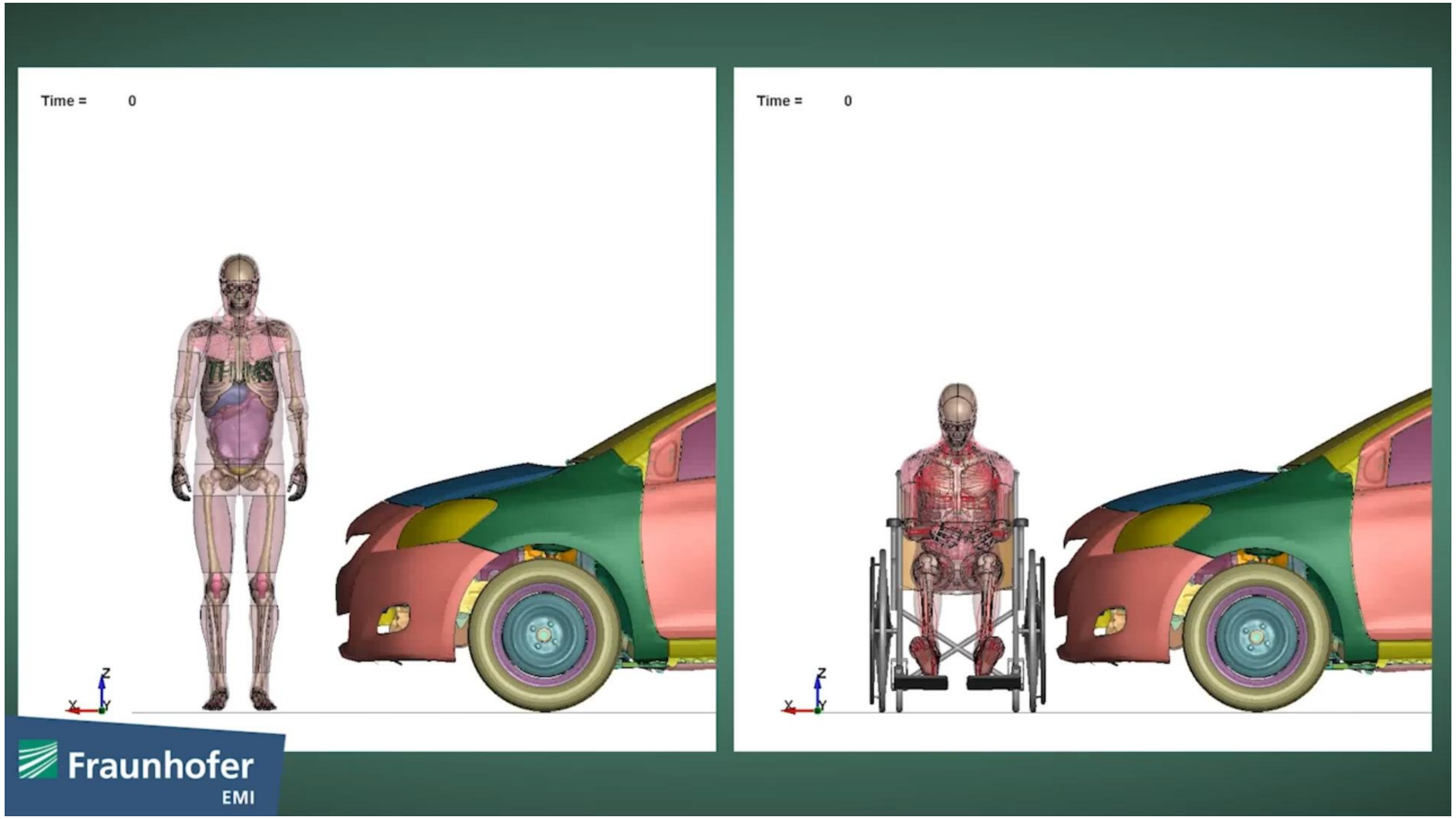
WHEELCHARITY – Road safety of wheelchair users

Human Body Dynamics – Niclas Trube

- SIMULATION RESULTS
  - Body kinematics shows that the pedestrian is rather smoothly bending around the bodywork, while the WCU kinematics seem more abrupt due to vehicle impact. Head impact occurs at different points in time and locations for the pedestrian (185 ms, windshield) and the WCU (147 ms, hood).



Trube N., Matt P., Boljen M.: A Numerical Study on Pedestrian and Wheelchair User Safety in VRU-Vehicle Collisions. In: Proceedings of the IRCOBI Conference 2020

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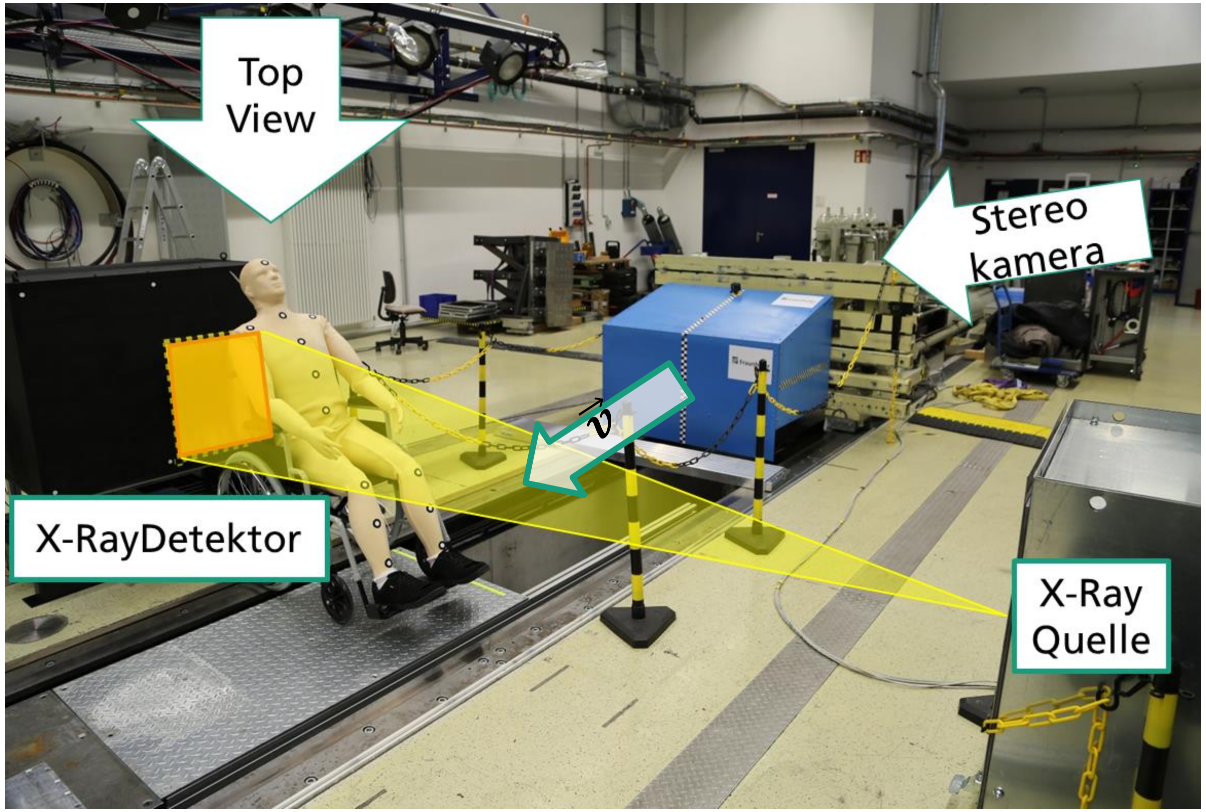
WHEELCHARITY – Road safety of wheelchair users

Crash Center – Philipp Bösl

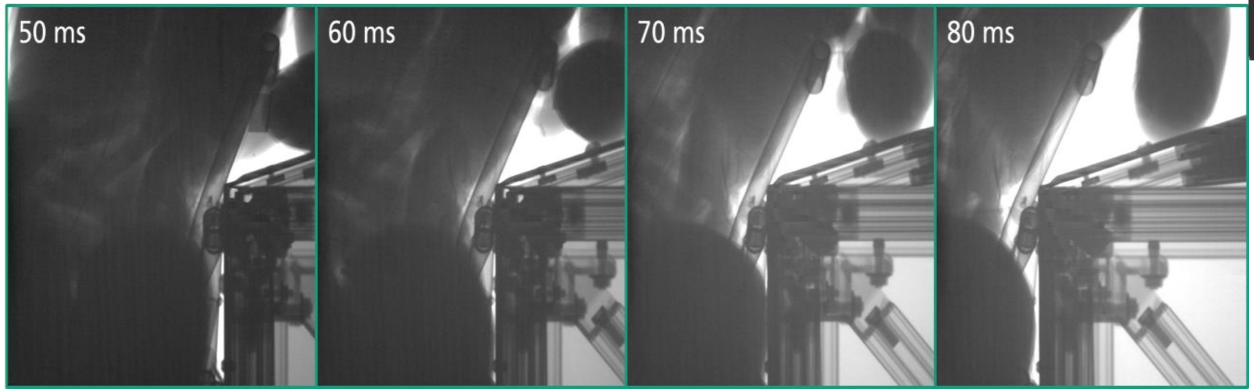
- EXPERIMENTAL SETUP
  - Simplified vehicle front
  - Impact speed v=20 km/h
  - Biofidel dummy
  - Commercially available wheelchair
  - 4 high-speed cameras with 5 kfps
  - 3D point tracking with stereo camera system
  - X-ray flash technology (4 flashes)
  - Path measurement via impactor slide



WHEELCHARITY – Road safety of wheelchair users

Crash Center – Philipp Bösl

- EXPERIMENTAL RESULTS
  - Image detail: hip impact
  - Contrast range not sufficient to recognize internal structures of dummy during impact



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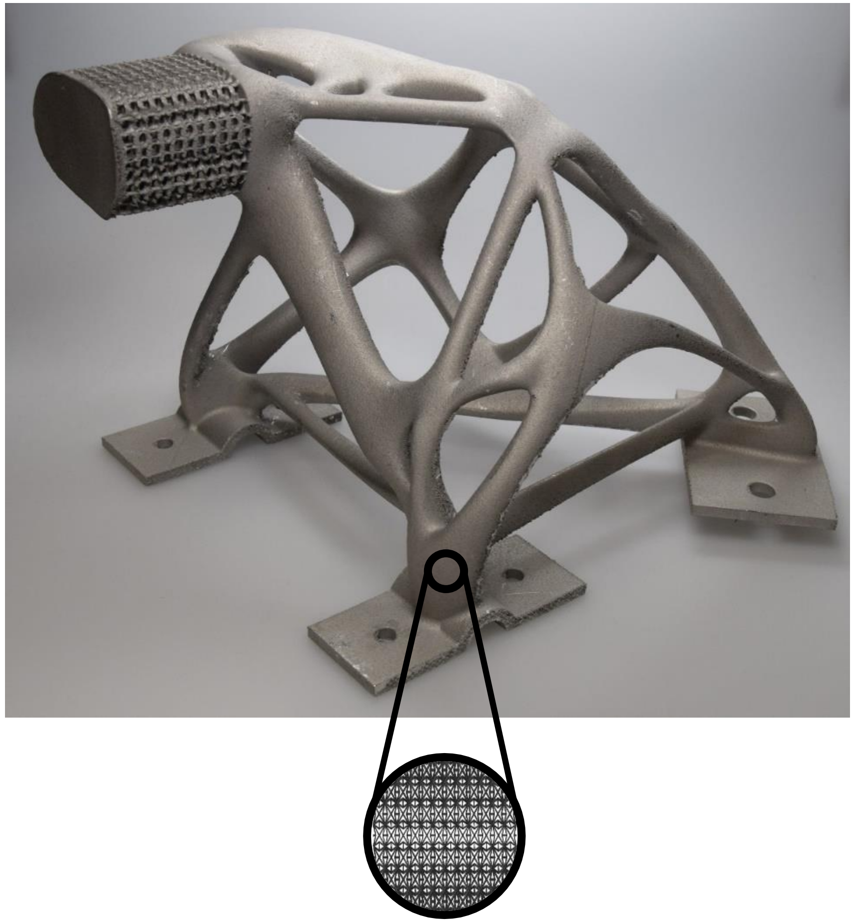
WHEELCHARITY – Road safety of wheelchair users

Human Body Dynamics – Niclas Trube

- OUTLOOK
  - Changed trajectory due to force redirection
    - Maximization of head position
  - Reduction of forces acting on the wheelchair user by applying grid structures
  - Combined crash absorber and deflector



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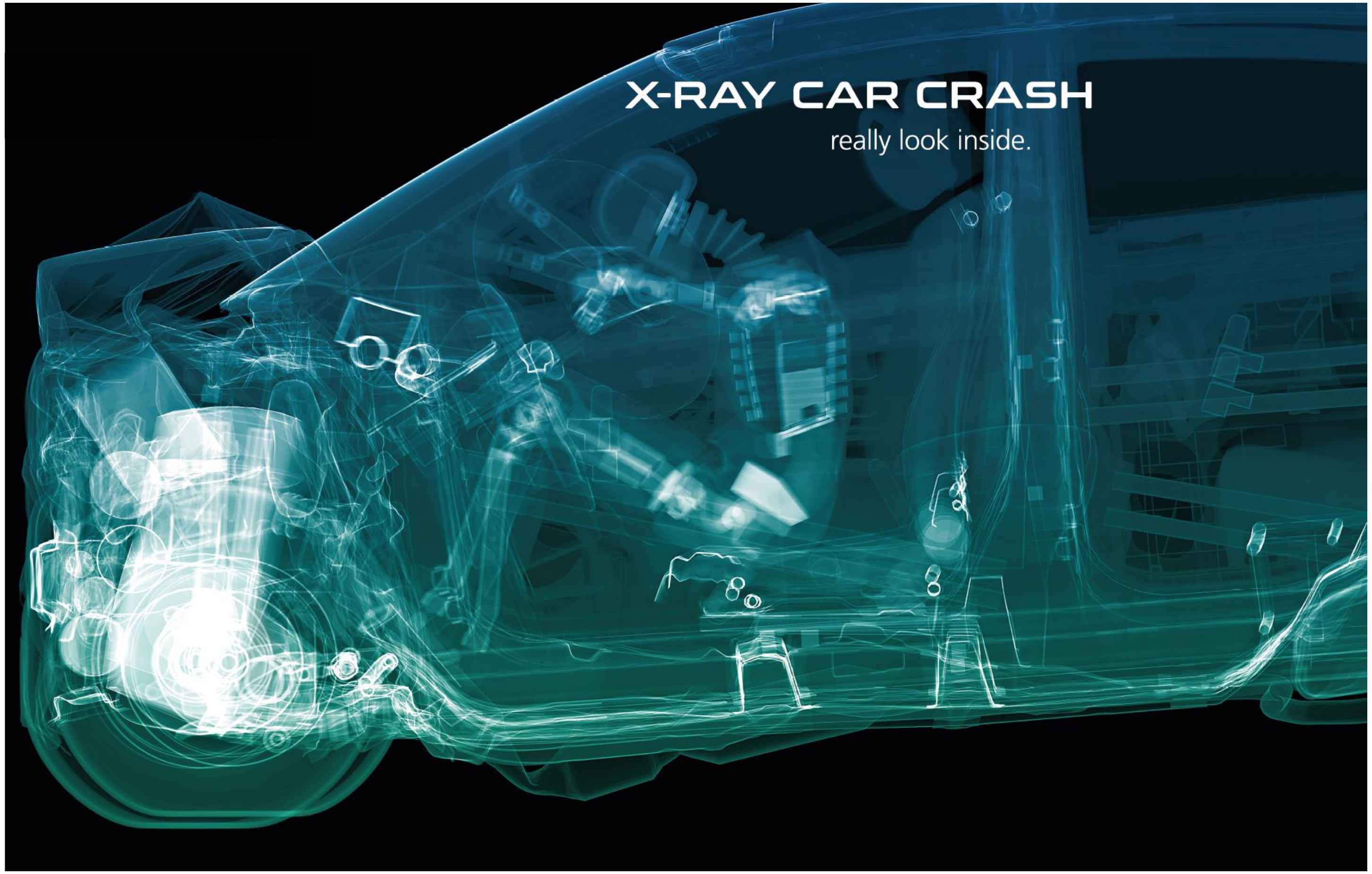


DYNAMIC X-RAY – CRASH TEST FACILITY

Crash Center – Dr. Malte Kurfiß

- **Acceleration facility** HyperG 220
- Flexible modular test setup
  - Customized to project requirements
  - Frontal, side, rear, pole impact
- Testing of restraint systems
  - Dynamic testing of restraint systems
  - Predefined acceleration profiles
- Maximum acceleration 70 g
- Maximum speed 22 m/s
- Maximum payload 3000 kg

DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

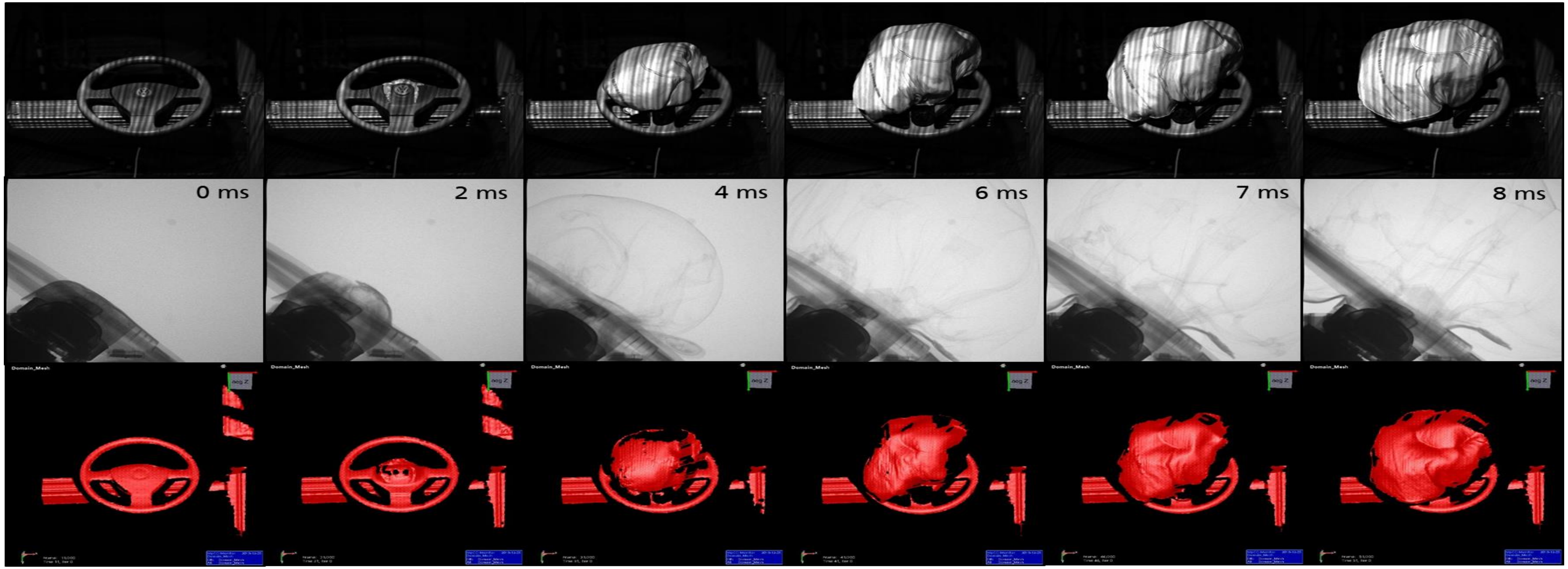
- MOTIVATION
  - Constantly new requirements for vehicle safety
  - More information from each crash test
  - Information about crash-relevant structures inside the vehicle
  - View individual relevant components in isolation
  - Freely selectable observation perspective
  - Good, intuitive comparability with simulation

X-ray flash unit with 450 kV, 6 individual flashes, 8 images

DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

- PROJECT EXAMPLE – Airbag
  - Airbag triggering: X-ray flash unit with 450 kV and 6 individual flashes, detector area 400 x 400 mm
  - Synchronization X-ray and 3D scan



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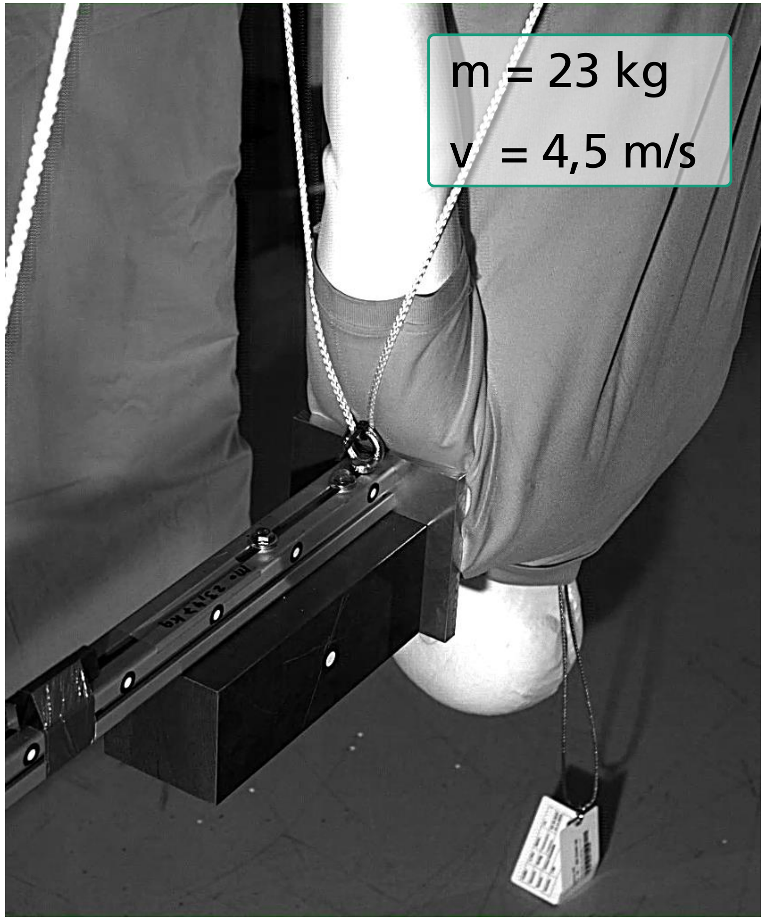
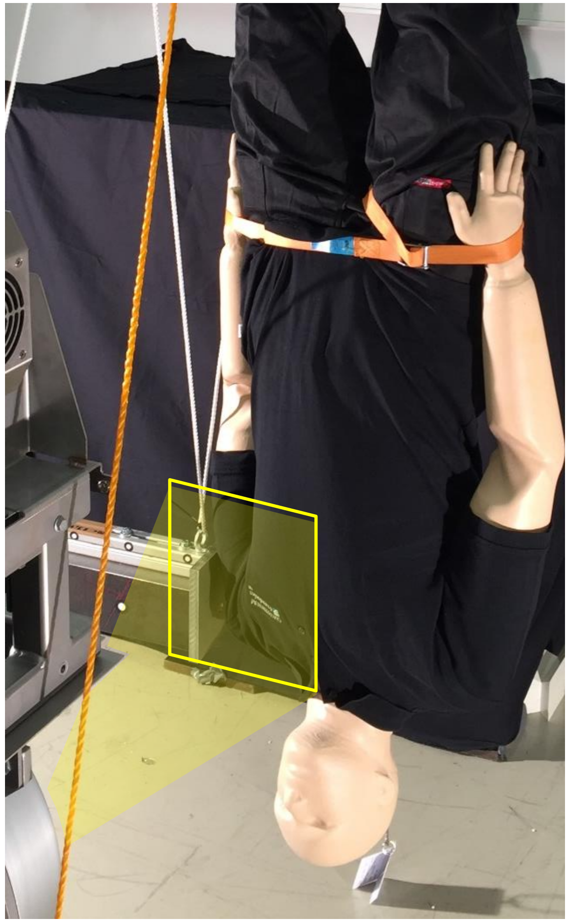
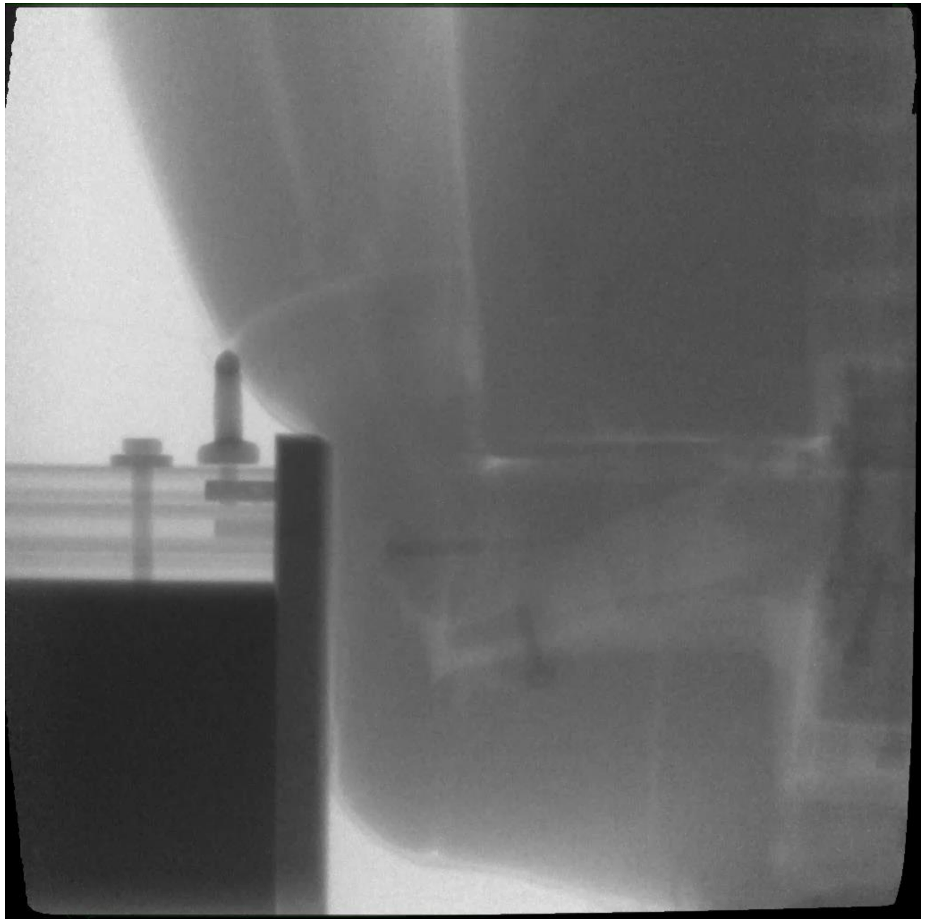
DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

- PROJECT EXAMPLE – Pendulum Side Impact Biofidel Dummy







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DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

- PROJECT EXAMPLE – MPDB crash test with in-situ X-ray

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DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

- PROJECT EXAMPLE – MPDB crash test with in-situ X-ray

Image 3/8

@110 ms

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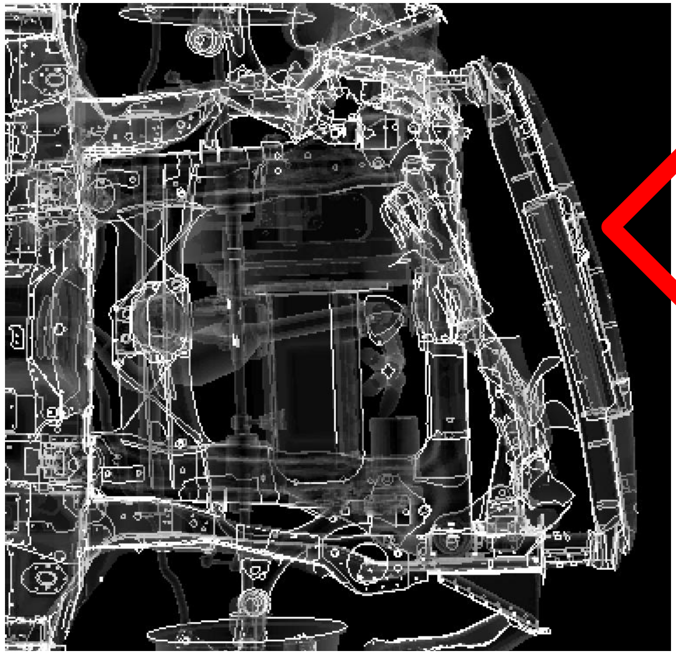
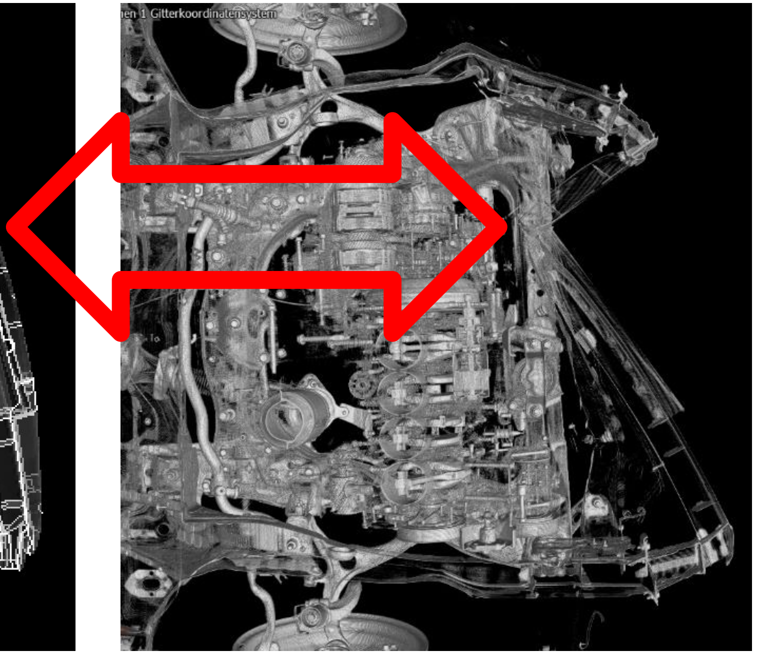
DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

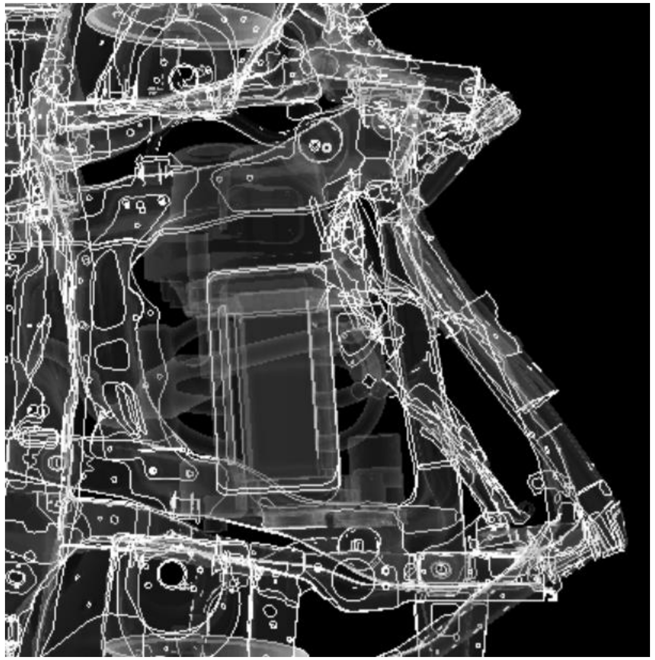
- PROJECT EXAMPLE – MPDB crash test with in-situ X-ray



Simulation NHTSA Modell



Post Crash CT-Scan
Fraunhofer EZRT, M. Salamon



EMI optimized simulation

- Primary goal of observing detachment from the barrier achieved!
- Continuous recordings could clarify the buckling of the crossbeam.

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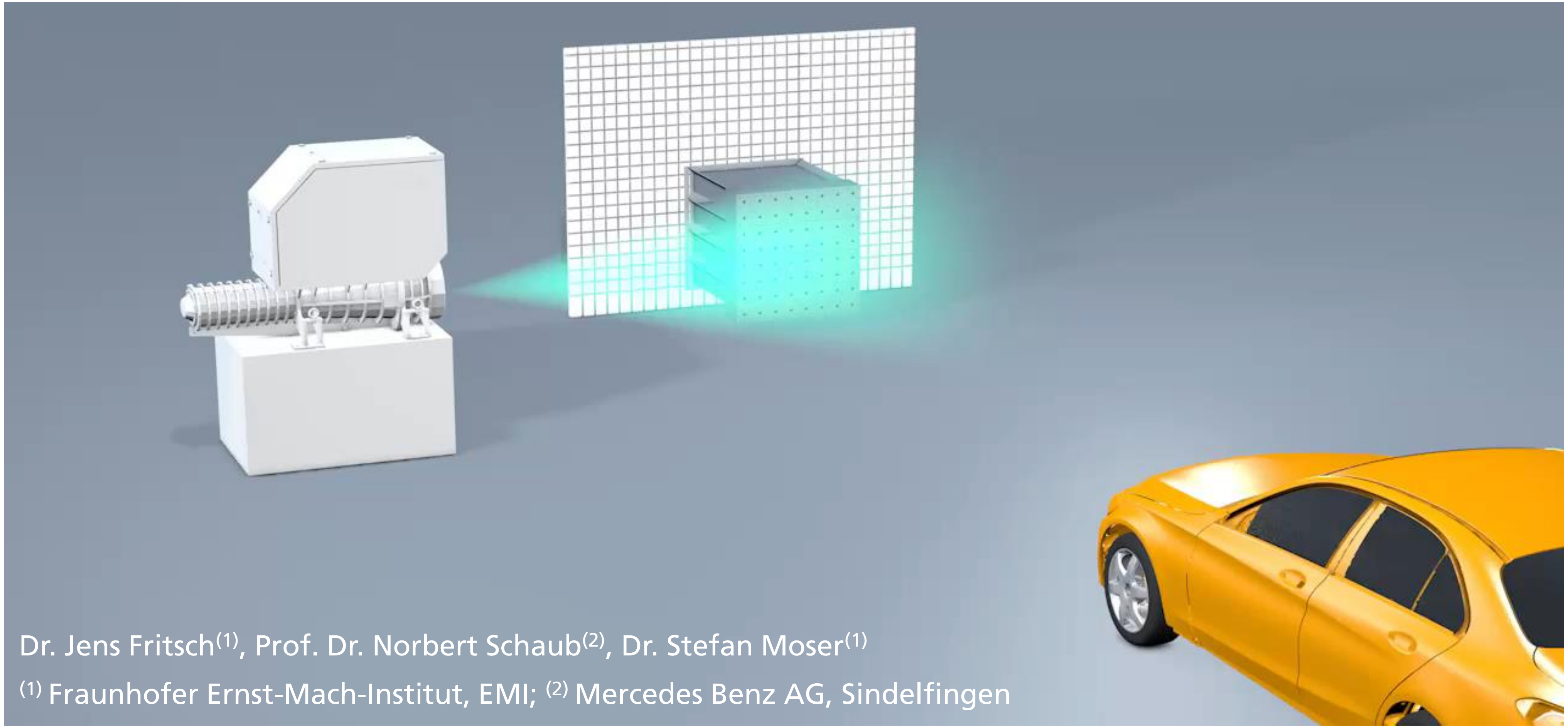
DYNAMIC X-RAY

Crash Center – Dr. Malte Kurfiß

- OUTLOOK – LINAC 1 kHz frame rate



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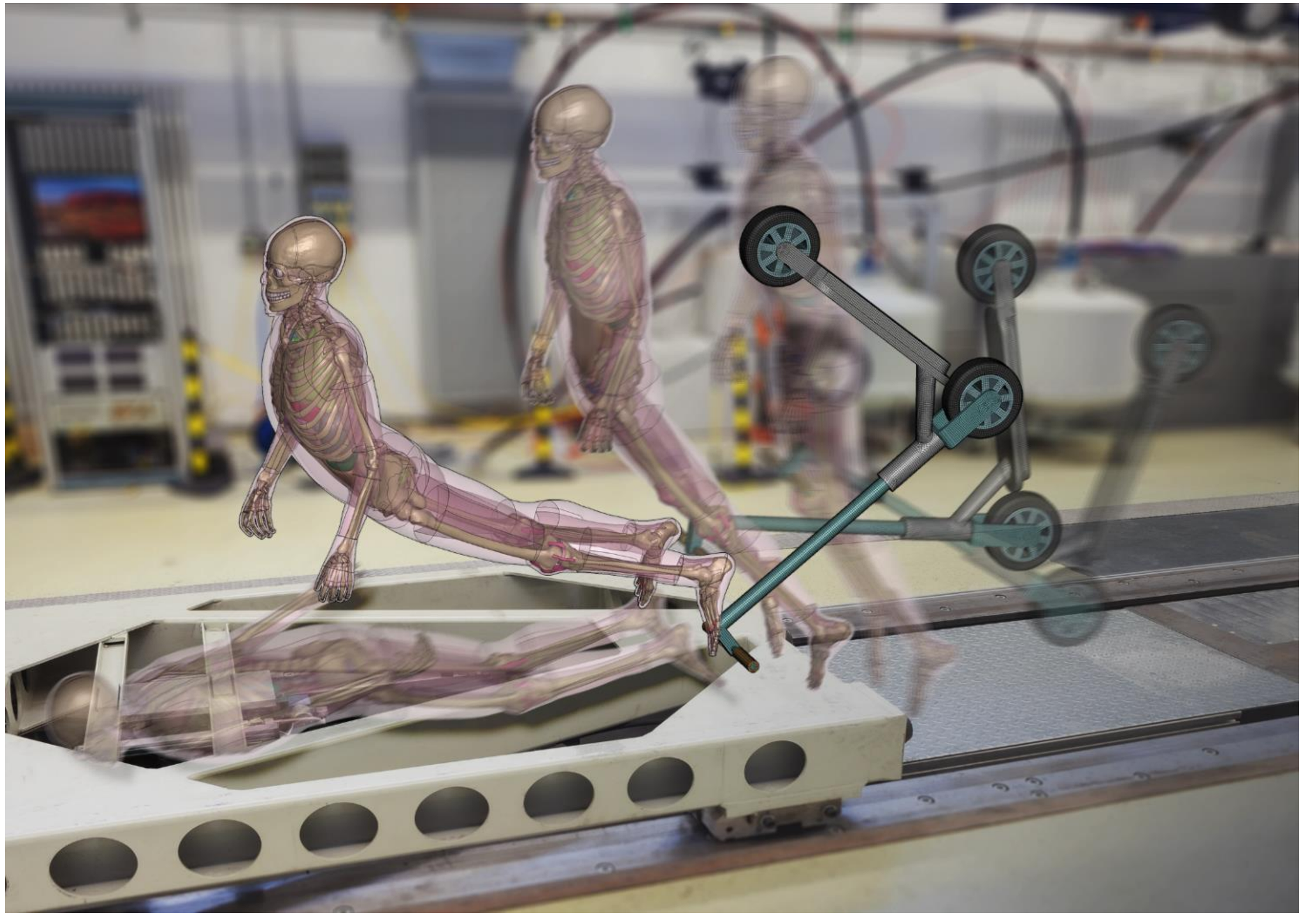

HUMAD

Fraunhofer EMI – Dr. Matthias Boljen / Fraunhofer IWM – Dr. Jörg Lienhard

MOTIVATION

Accident statistics of E-Scooters 2021

- 2155 personal injury accidents in Germany, thereof 5 killed und 386 seriously injured. More than 80% of the injured people were driving an e-scooter.
- 918 accidents were single-vehicle accidents (42%). 1170 accidents (54%) were collisions with 1 other vehicle (thereof 693 were driving a car).
- The drivers of the E-scooters were blamed for responsibility in 1553 cases (72%).
- The police registered inappropriate behavior for personal injury accidents involving e-scooter drivers in 2355 cases.
  - Driving under the influence of alcohol (18%)
  - Wrong road use (16%)
  - Speeding (8%)

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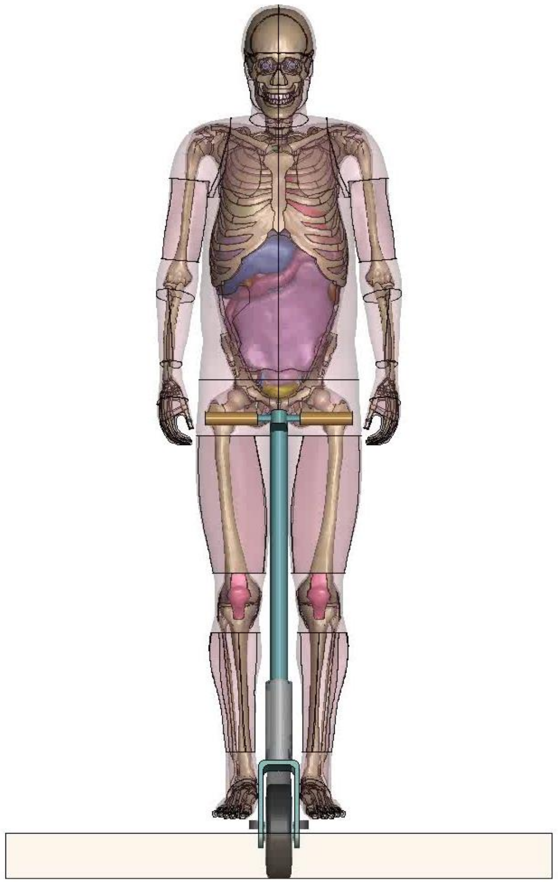
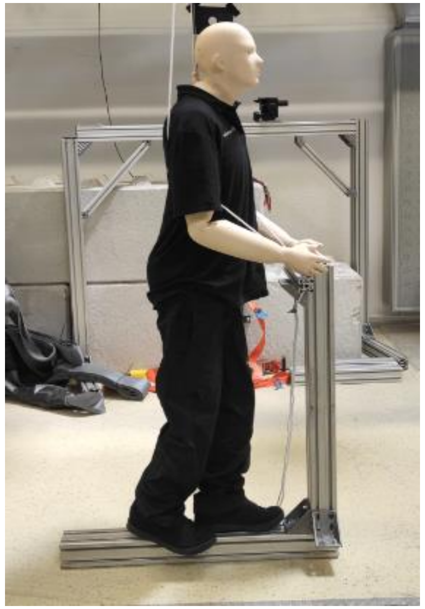
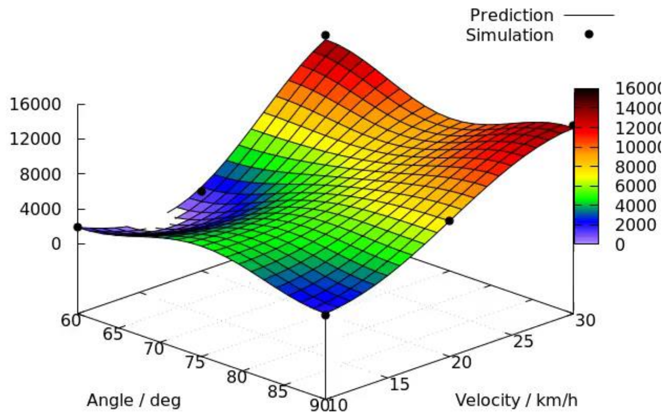
FEASIBILITY STUDY AND FRAMEWORK



- Combining virtual HBM and crash test dummies addressing VRU safety in urban traffic
  - Single-accident of E-Scooter driver at curb
  - Different velocities: 10, 20, 30 km/h
  - Different curb angles: 60, 90 deg
  - Influence of helmet and knee protectors
  - Use CTS biofidelic dummy “Primus”
  - Evaluate 3D acceleration for head + knee
  - Check injury criteria and interpolate

- THUMS V4.02 M50 pedestrian
- E-Scooter Xiaomi Mi M365





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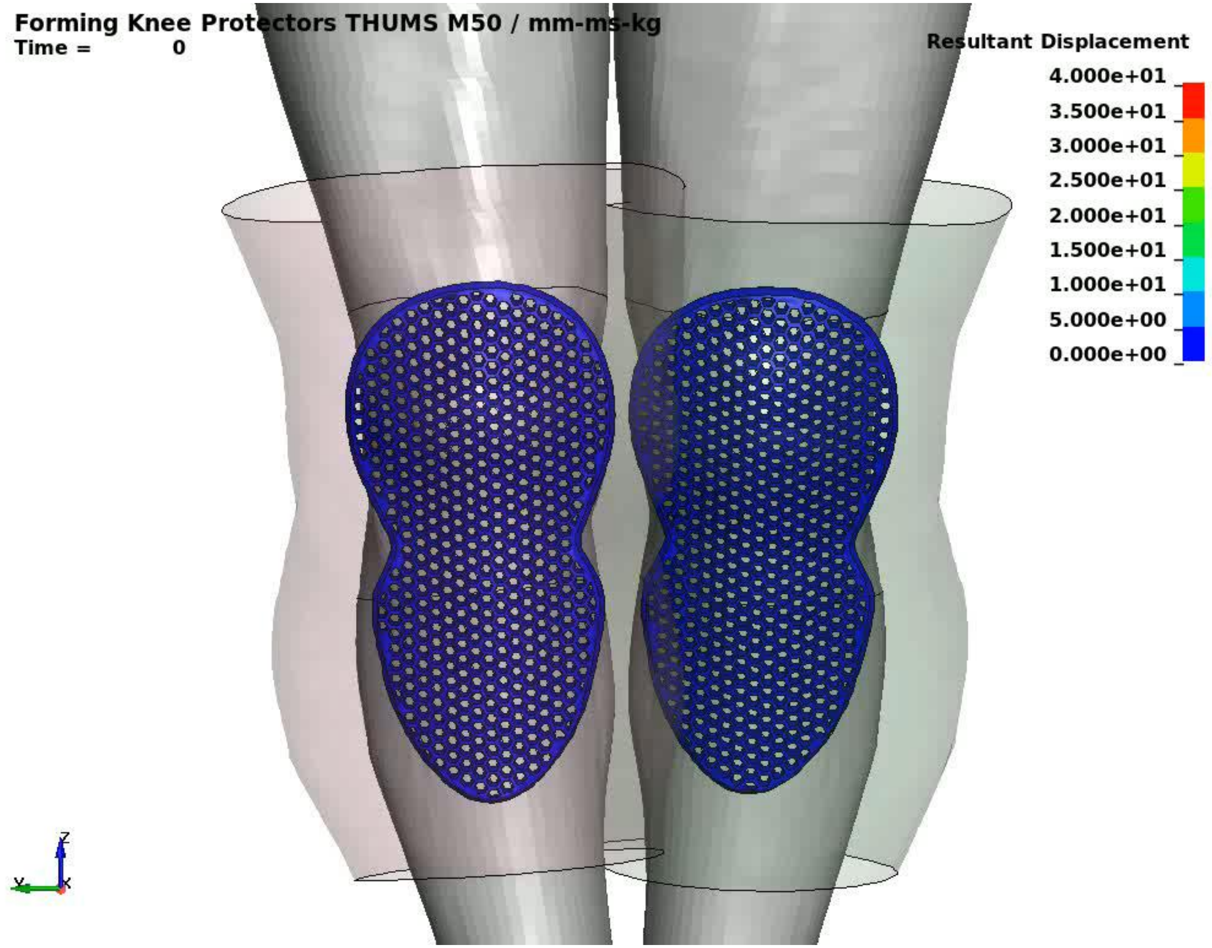
DONNING KNEE PROTECTORS TO HBM



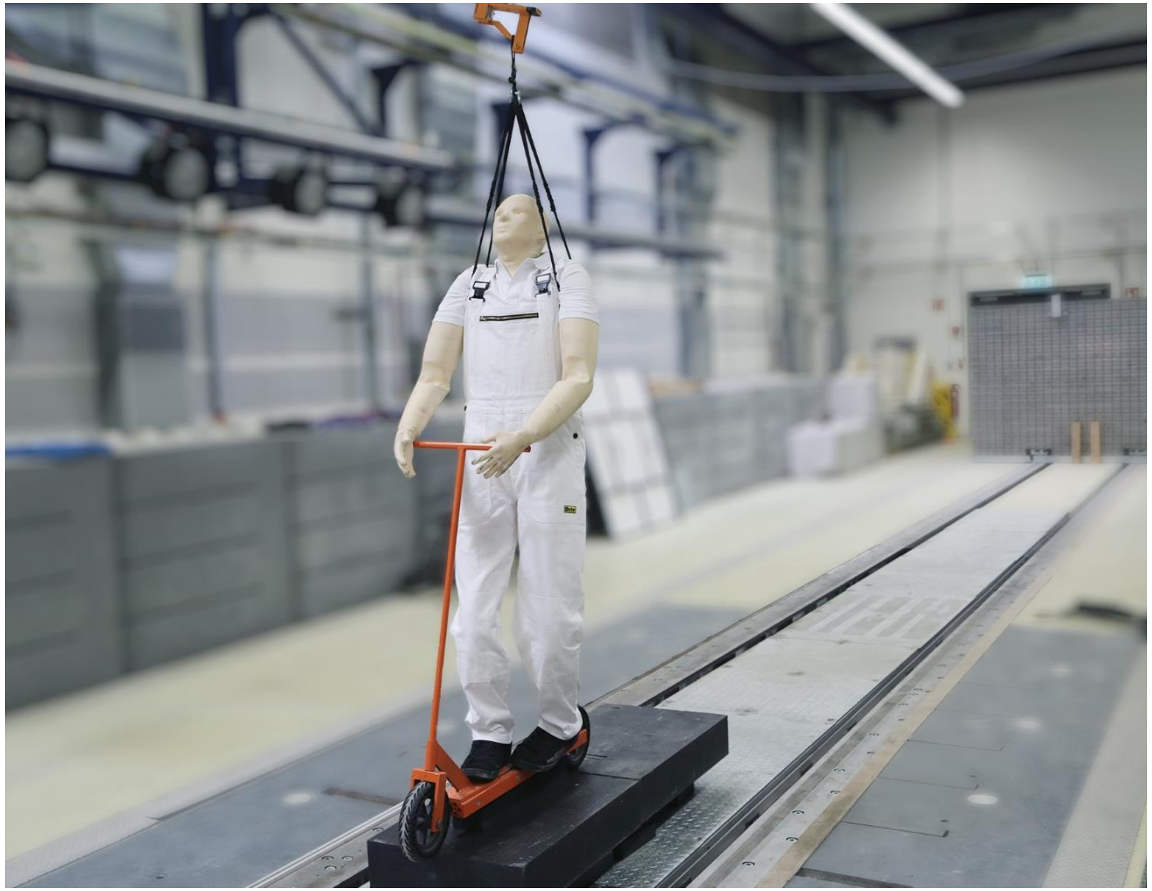
How to apply flexible knee protectors to an individual HBM and posture?

- Use 2D hull geometry of the body surface as stamp geometry for an a-priori forming simulation #3
- Scale stamp geometry and apply prescribed boundary conditions for each and every individual node to return to its original position (or near to it)
- Include protector model and apply appropriate contact definitions

HUMAD

Crash Center – Dr. Malte Kurfiß

■ EXPERIMENTAL SETUP



Test Setup

- Inverse impact with 10, 20, and 30 km/h:
  Moving curb is hitting an E-Scooter
- High speed cameras
  - Side view
  - Impact view
- High speed optical 3D scanner
- Accelerometers inside the dummy

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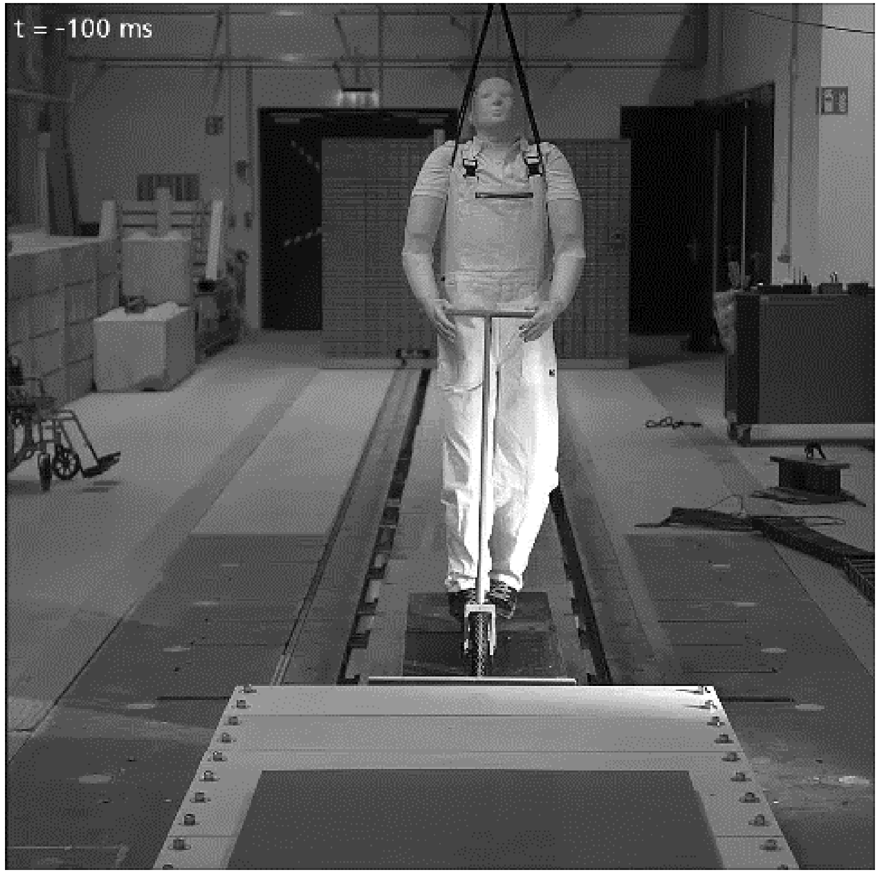
Crash Center – Dr. Malte Kurfiß

- EXPERIMENTAL RESULT - Pre-trial „gentle“ impact 10 km/h



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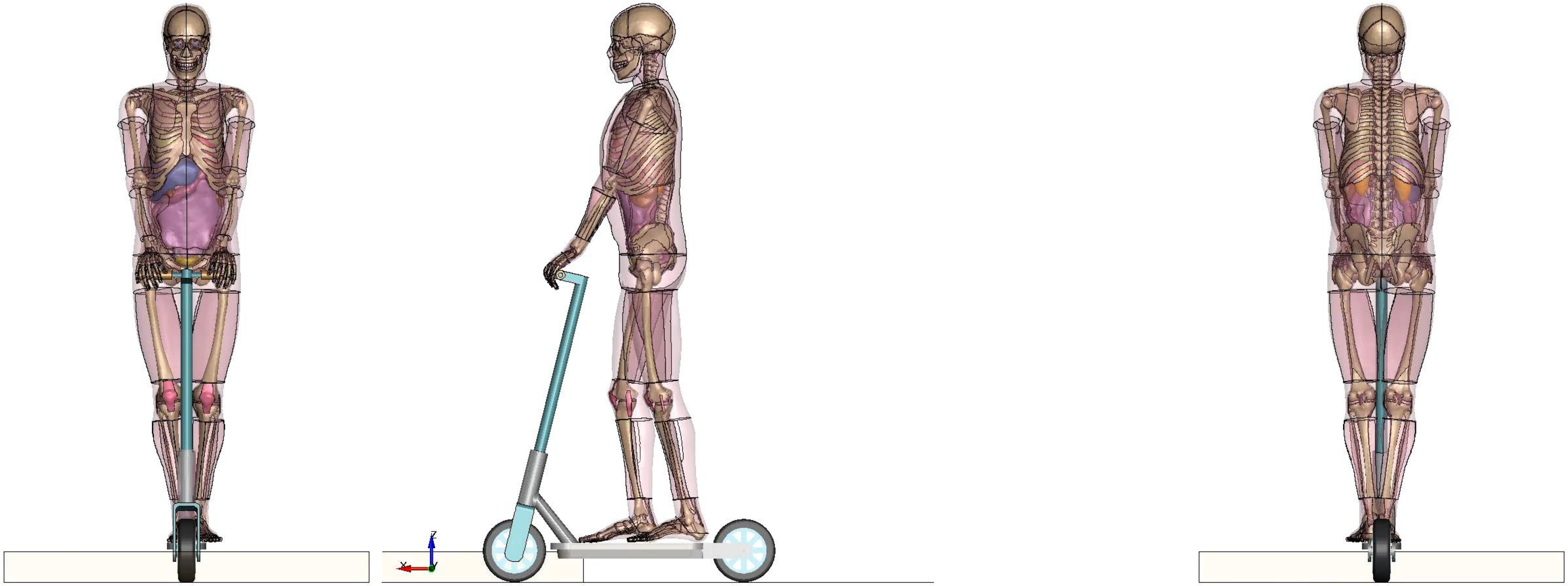
- SIMULATION RESULTS – THUMS V30 A60



Front view Left view Back view

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HUMAD

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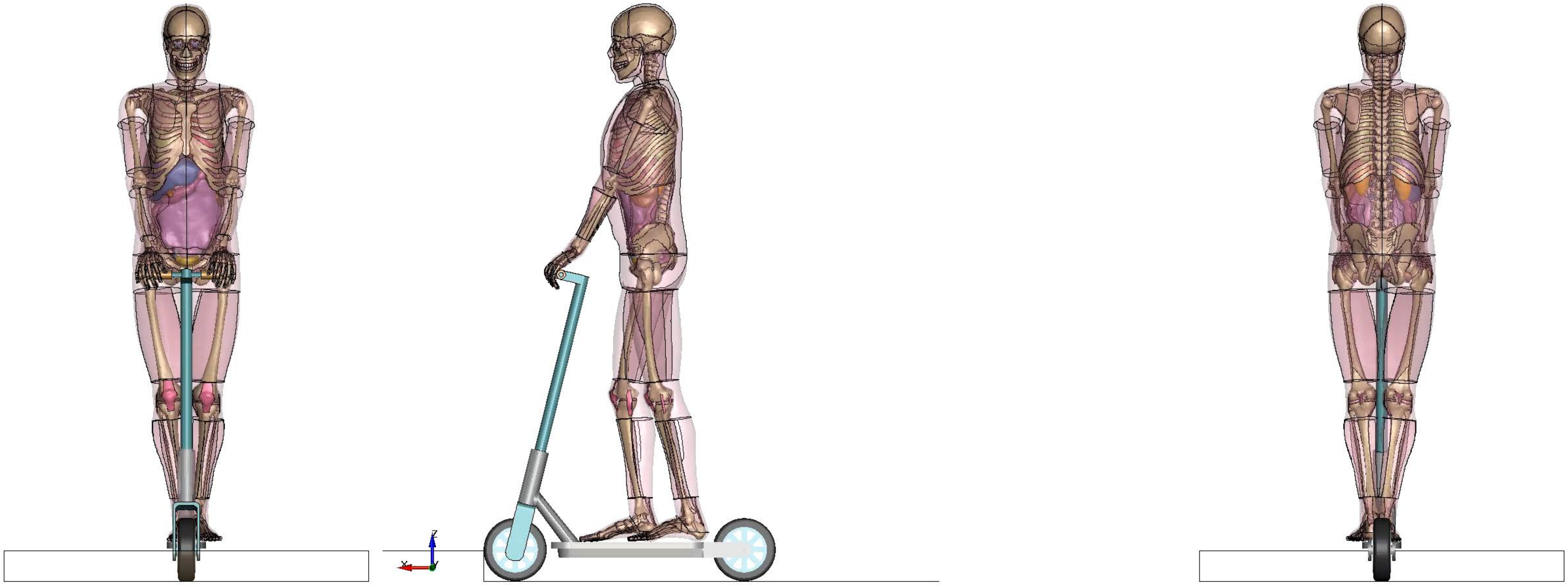
- SIMULATION RESULTS – THUMS V30 A90



Front view Left view Back view

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