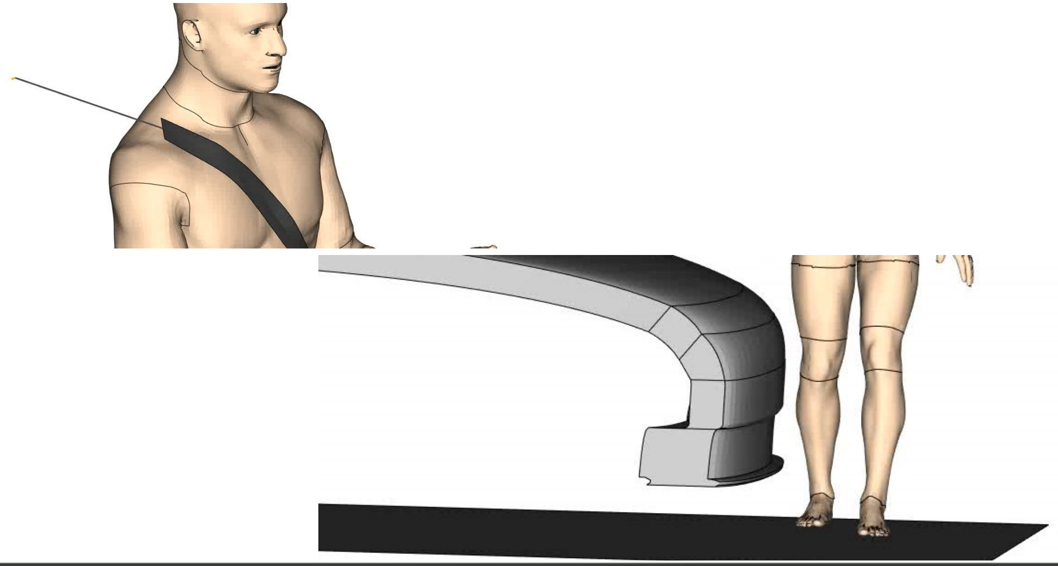
This is Hans

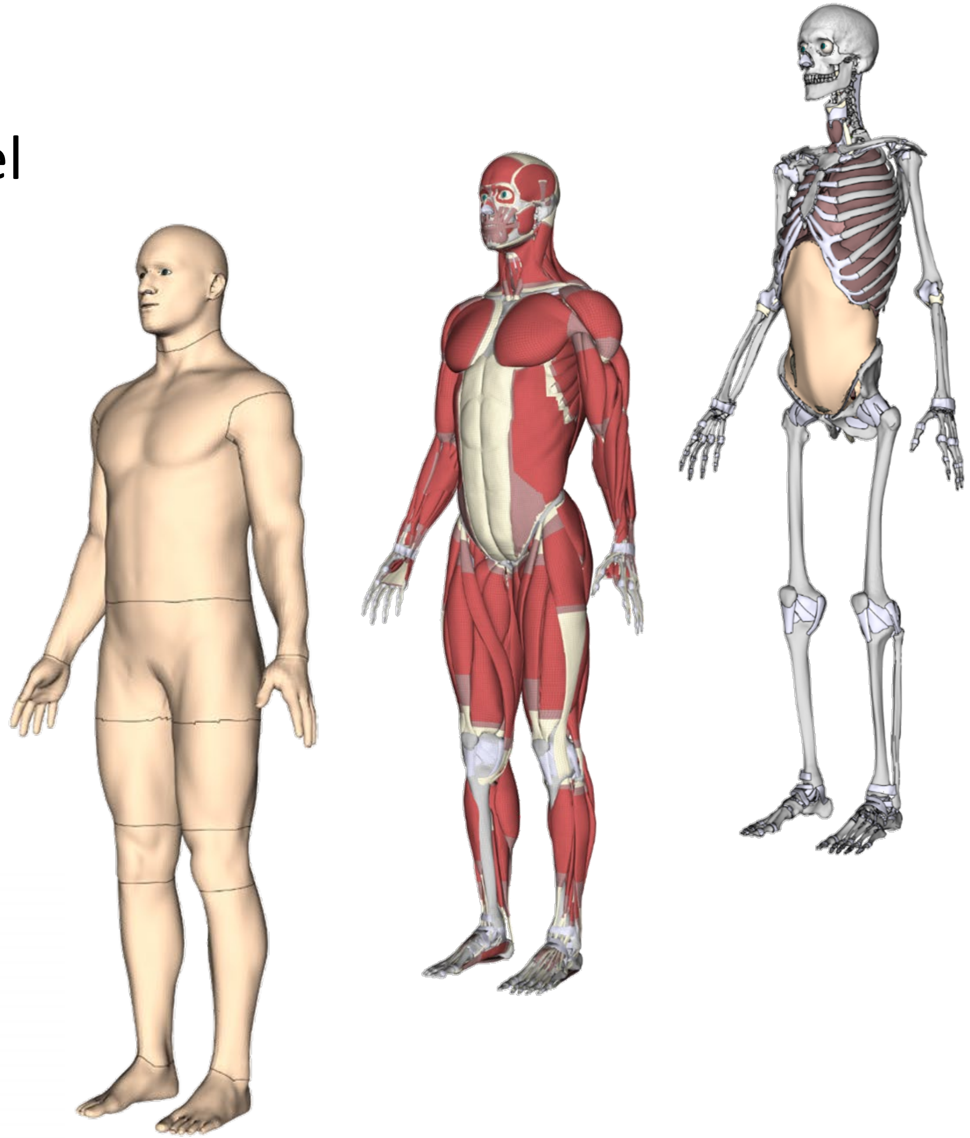
Alex Gromer, Dirk Fressmann, Skylar Sible,
Silvia Mandel, Li Högberg, Torbjörn Johansen,
Fabian Koch

Ansys

What – or better – Who is Hans?

- Hans is a high-fidelity LS-DYNA human body model
- Hans represents an average male person – AM50
- Our Vision:
  HBM to support advanced product development in multiple industries





Motivation and targeted customer benefits

- In the second half of the decade, we expect virtual certification in the automotive industry for occupant and pedestrian safety
  - EuroNCAP, IIHS, C-NCAP are actively working on such protocols
  - DYNAmore/ANSYS is involved in the EuroNCAP activities
- Automotive:
  - Increased # of HBM analyses for next gen restraint systems/autonomous driving positions and to prepare for homologation
  - Occupant/Pedestrian safety
  - Comfort/ergonomics simulations
- Consumer Products: Helmets, body armor, ...
- Medical industry: Implants, medical devices, patient specific health care
- Defense

Benefits of our Hans HBM:

- **High biofidelity/accurate results**
- **deep insights**

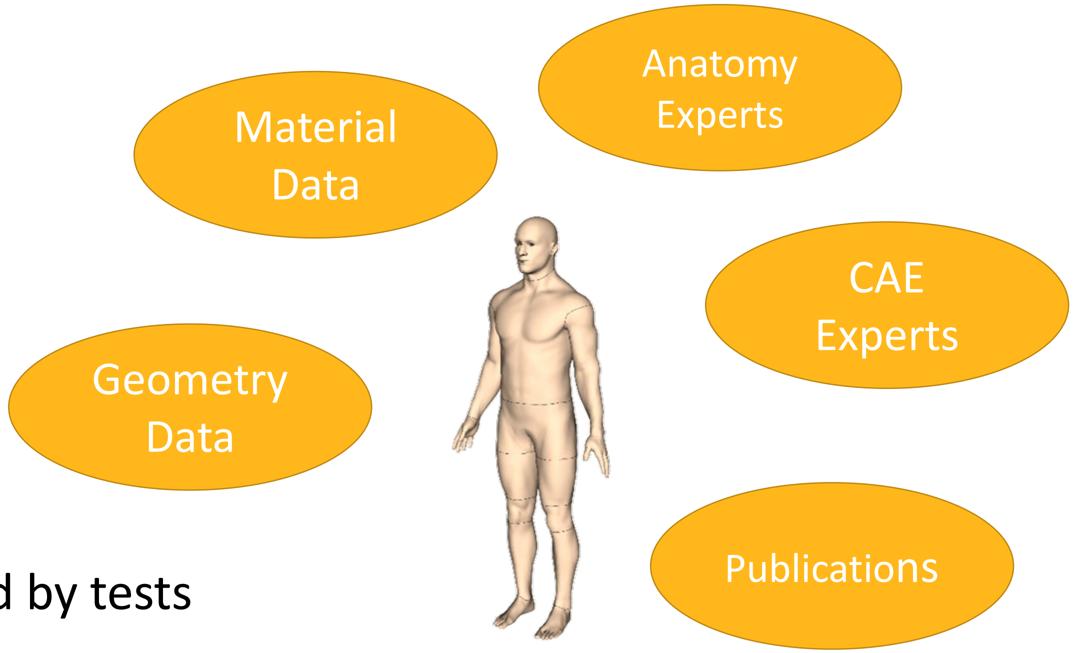
- **best possible user experience/expert support**
- **constant maintenance**
- **road map for future needs**

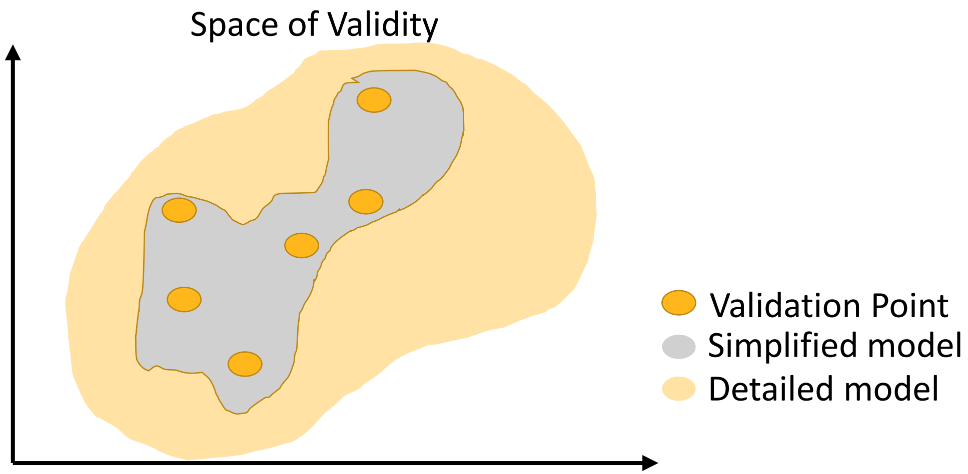
Modeling Fundamentals: Hans V1.0

- **Passive model** targeted for any kind of impact simulation
- **Modeling the physics**:
  - Model the human body with a high level of detail
  - Avoiding abstraction and substitute approaches
    - Geometry and materials are modeled **as is**

    → **Less tweaking** needed to correlate to test data

    → **Better confidence** in load cases that are not covered by tests
- Focus on the musculoskeletal system at first
- **Following** the modeling approaches of the successful **DYNAmore Dummy models**





Hans Ingredients: Geometry

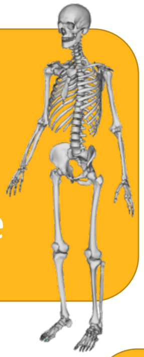
- High resolution/quality CAD aquired from partner company
  - CAD data based on high resolution MRI and CT-Scans of **one** individual
  - Scan in recumbend position – corrections applied for upright standing posture
- All mechanically relevant parts are discretizied
- Body Specs of Individual at time of scan
  - 79 kg – 176 cm – BMI 25.5
  - 21 years old
  - Athlete body shape

ZYGOTE

Hans Ingredients: Materials

- Materials taken from literature for major body parts, divided into functional layers

Layer 1
Cortical & trabecular bone

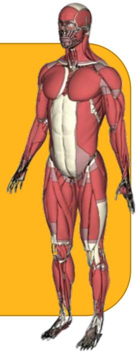


- Elastic Plastic Material Models
- Optional: Strain based failure
- Future Release: Damage based failure

Layer 2
Ligaments & cartilage

- Fabric Models (shells)
- Ogden-based (solids)
- Rate dependent

Layer 3
Muscle, tendon, myotendinous junction



- Ogden-based
- Rate dependent

Layer 4
Organs, blood filling, brain

- Ogden-based
- Rate dependent
- Visco-elastic
- Airbags
- Fluids: EOS

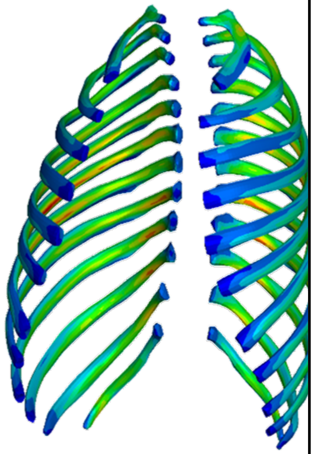
Layer 5
Skin & adipose tissue

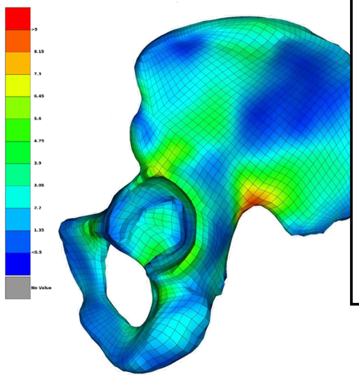
- Ogden-based
- Rate dependent
- Fabric

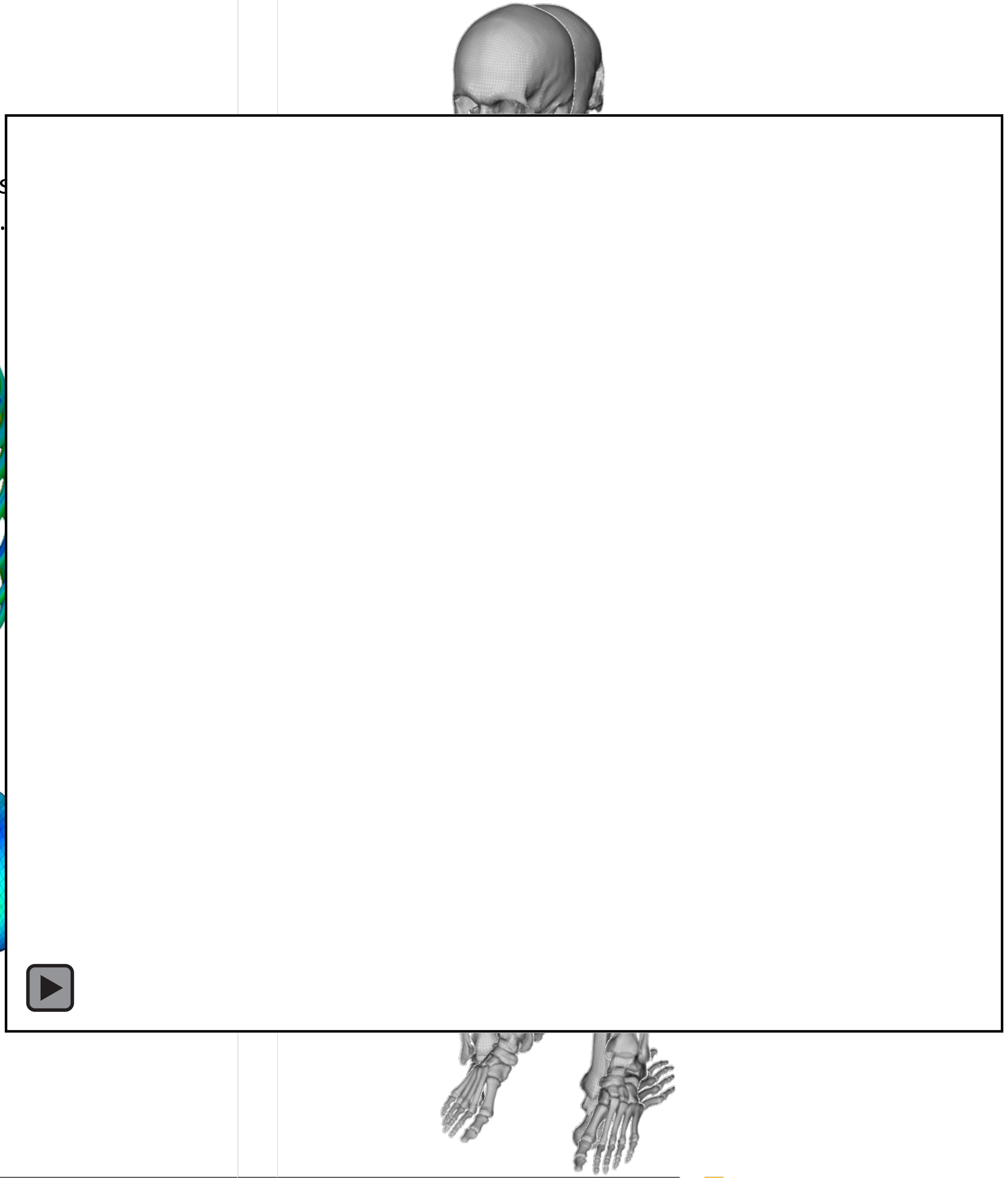
Muskuloskeletal System: Skeleton

- cortical bones
  - hard outer bone layer
  - mostly shell elements, partly solid elements
  - Partly reflect thickness distribution
- trabecular bone
  - Weak and porous structure
  - Solid elements

Cortical Bone thickness
average male (Holcombe et.



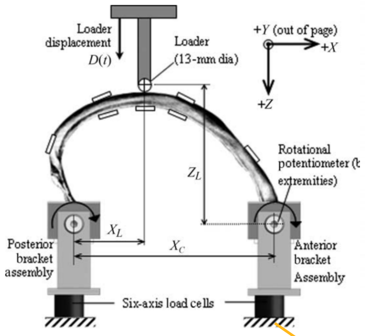


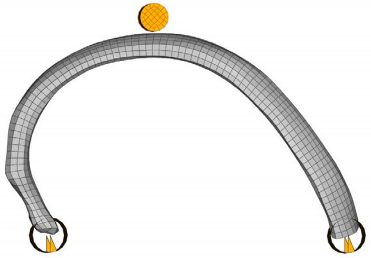


Example: Rib cage correlation

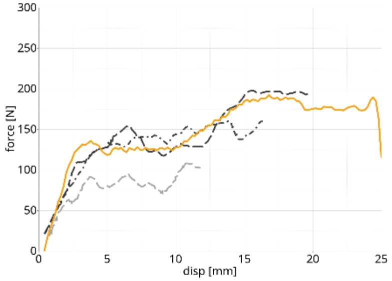
Step 1: Part level correlation – Rib 3

Local impact on single ribs 3-7

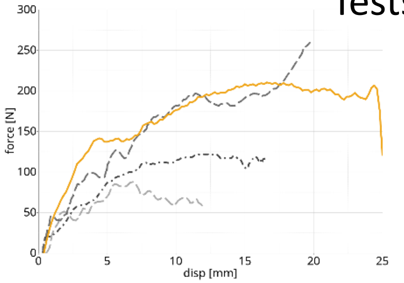




Posterior Res Force



Anterior Res Force

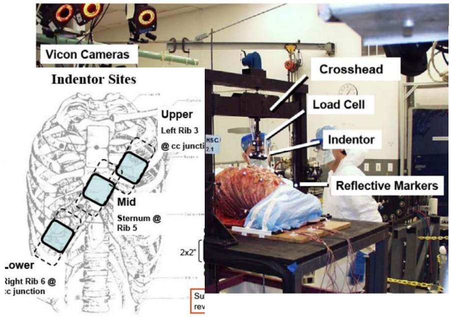


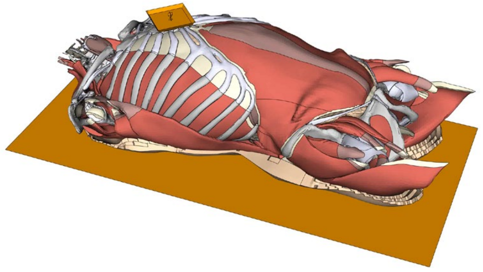
Hans Tests

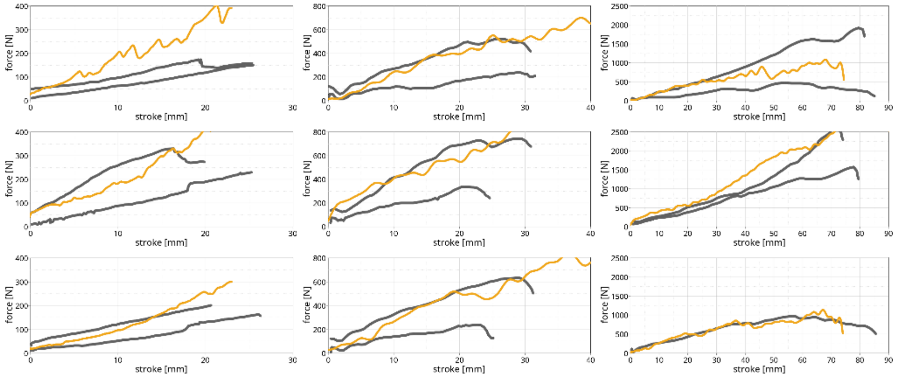
Del Pozo et. al – Structural response and strain patterns of isolated ribs under lateral loading, 2011

Step 2: Component level correlation

Impact on thorax along belt line

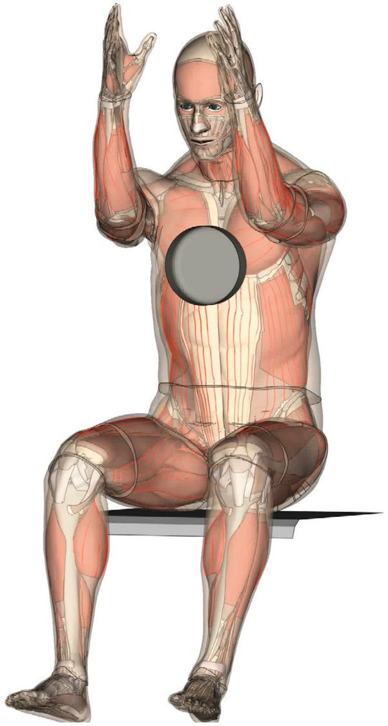






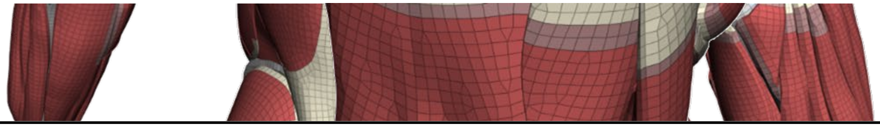
Shaw et. al – quasi-static and dynamic thoracic loading tests: Cadaveric Torsos, 2007

Step 3: Full Body correlation

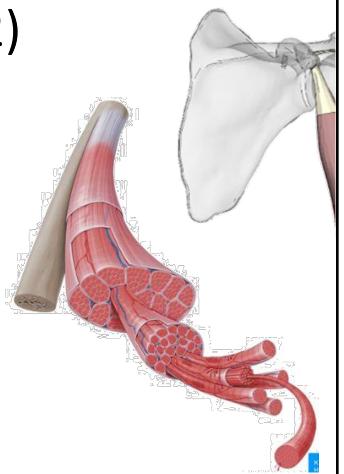


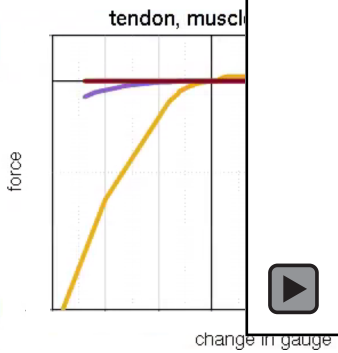
Kroell et. al – Impact tolerance and response of the human thorax, 1971

Musculoskeletal System: Muscles



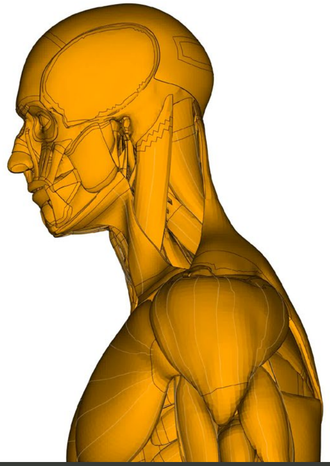
- For most accurate kinematics, almost all muscles are modeled as individual parts
- Muscle fibers (Takaza, 2012)
  - very soft contractile tissue
- Tendons (Maganaris, 1999)
  - connect muscles to bones, approx. 300x stiffer
- Myotendinous junction
  - transition between muscles and tendons to transmit muscle forces
  - averaged material stiffness

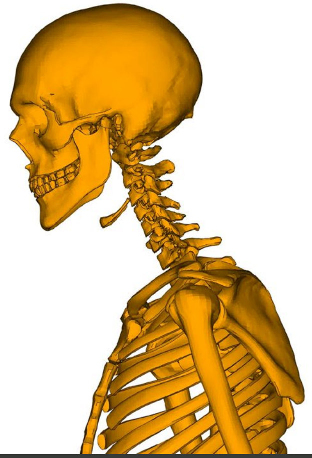


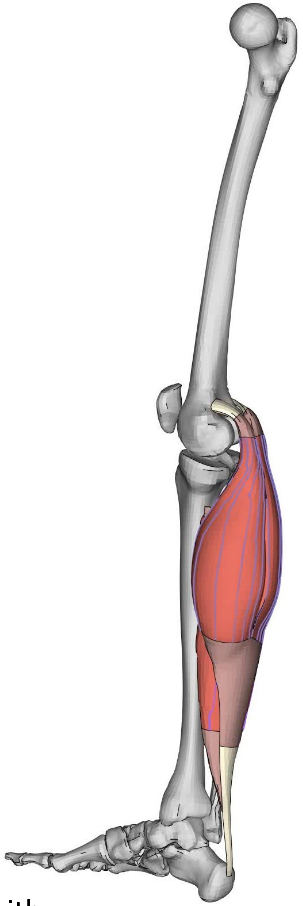


Macro Fiber Technology - MFT

- Assumption: muscles only act in the tensile regime
- During a guided motion in a passive model compression forces in muscles can occur
- Adding discrete Hill-type muscle elements (“fibers”) and use LS-Dyna’s PID controller to prevent compressive forces within muscles → no user interaction required
- MFT can improve kinematics during load case analyses



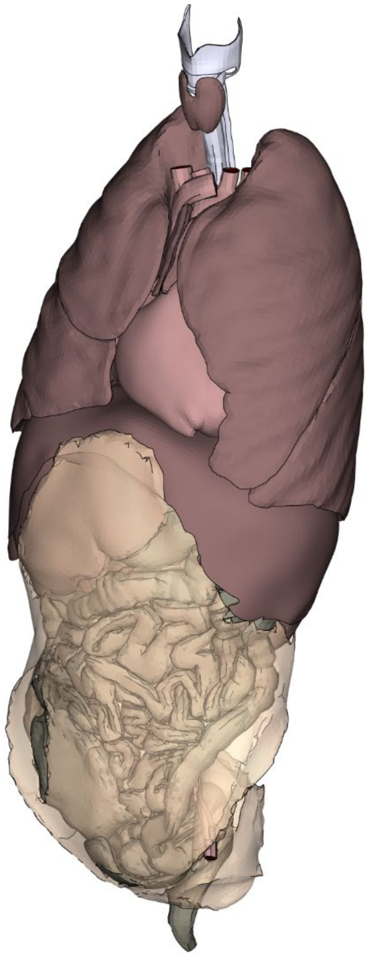




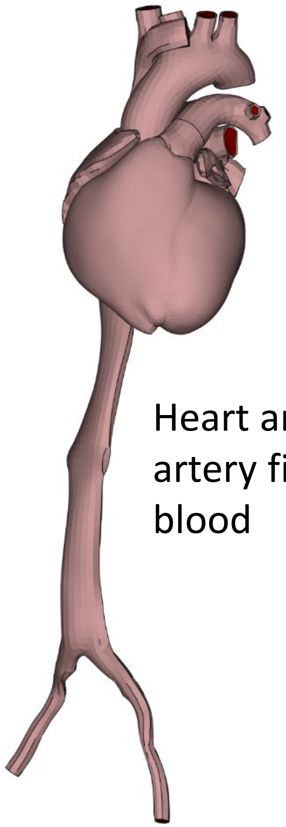
Calve muscles with MFT

Inner Organs

- All inner organs are individually discretized
- Main purpose for Hans V1.0:
  - Provide mass
  - Provide the correct stack up during torso or abdominal compression
- Materials
  - Literature based
  - derived from muscle material
  - Stomach, colon, bladder modeled as airbags
- For the initial release: little fine tuning on the organs → further tuning in a later release

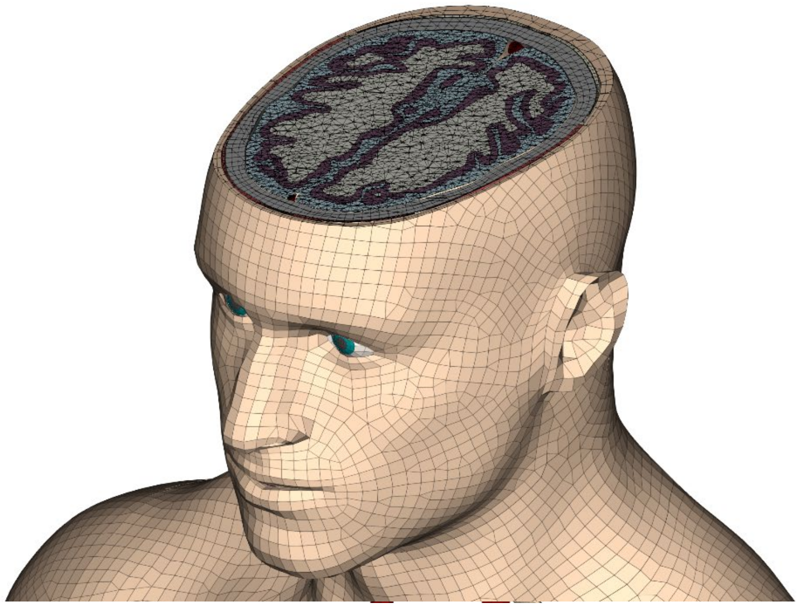


Internal organs enveloped in visceral fat

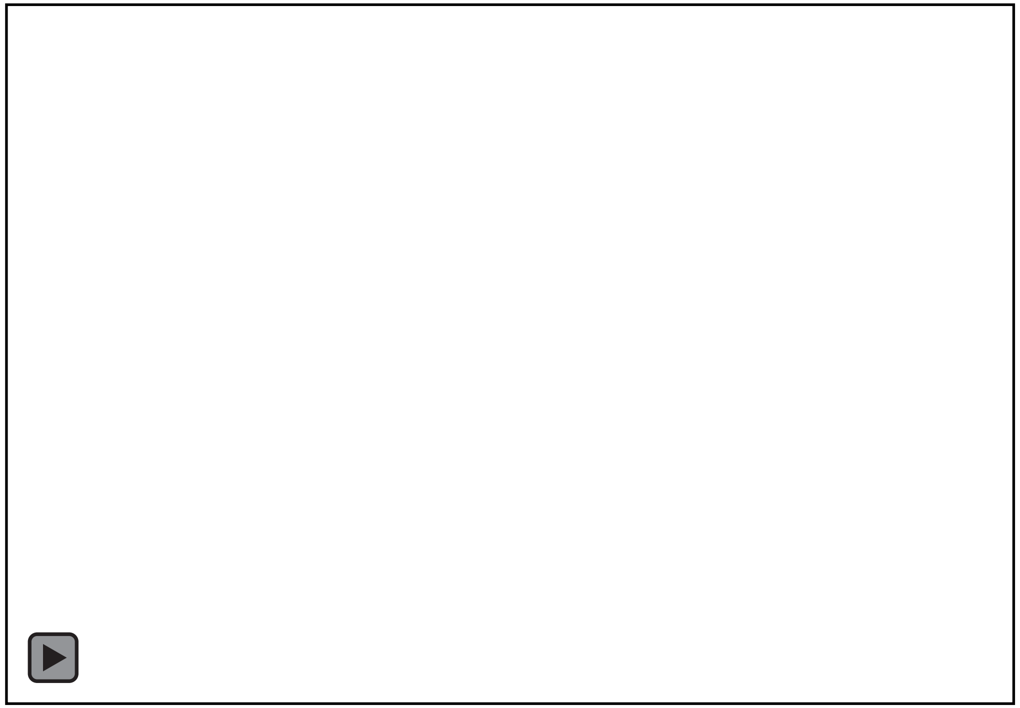


Heart and abdominal artery filled with blood

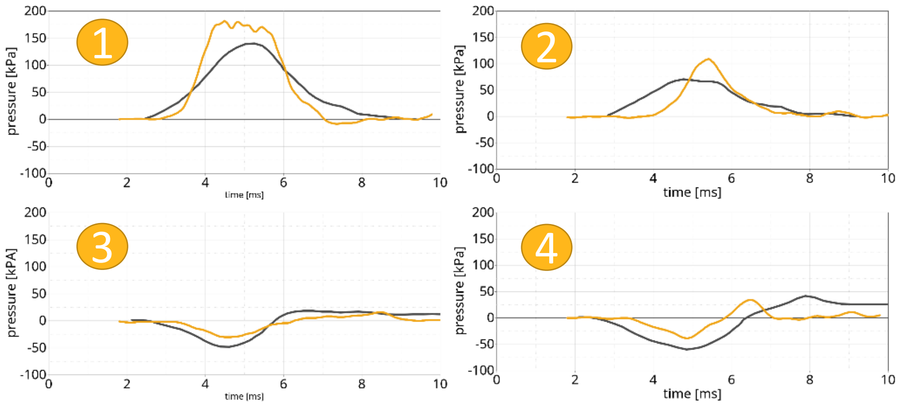
Head and Brain Model



- Skin
- Soft tissue
- Skull with
  inner and outer cortical table
- Arachnoid Skin and subdural fluid
- Head and bridging veins
- Gray matter
- White matter



Brain Fluid Pressure



Hans
Tests

Nahum et. al – Intracranial Pressure Dynamics During Head Impact, 1977

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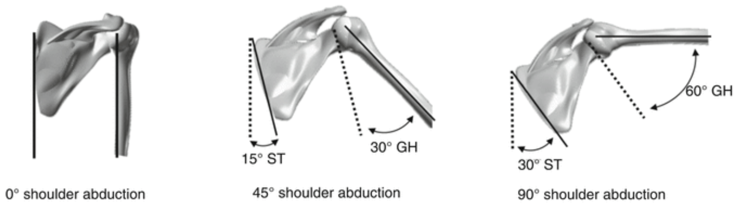
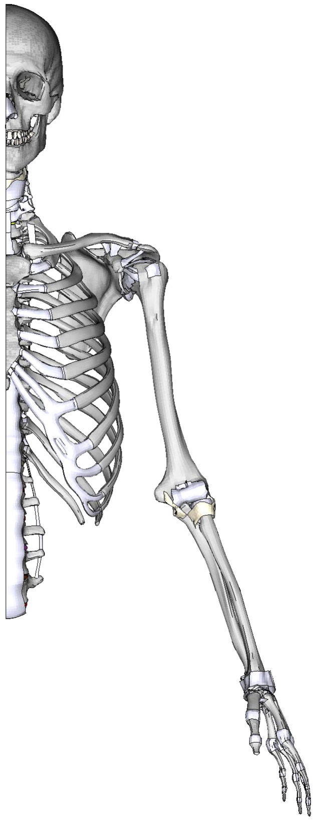
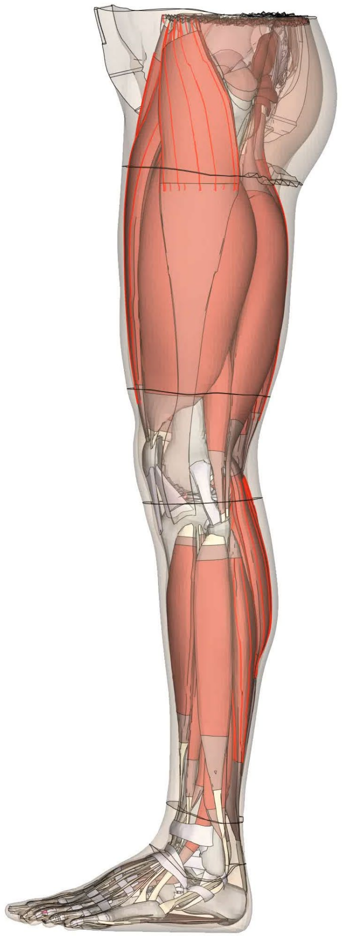
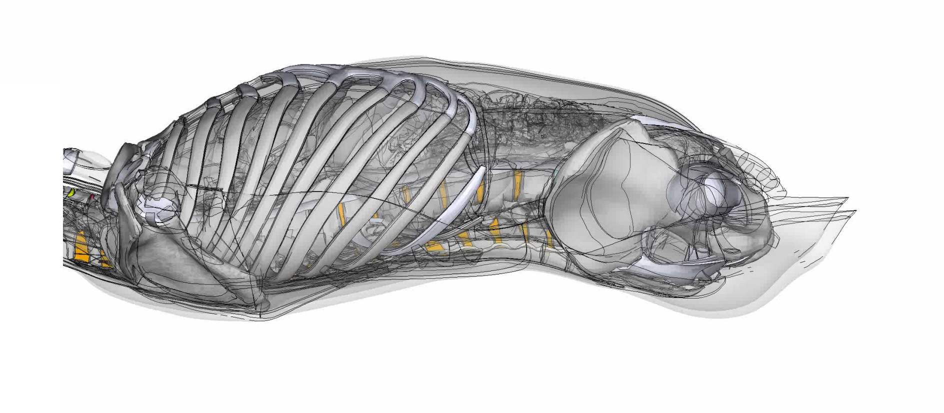
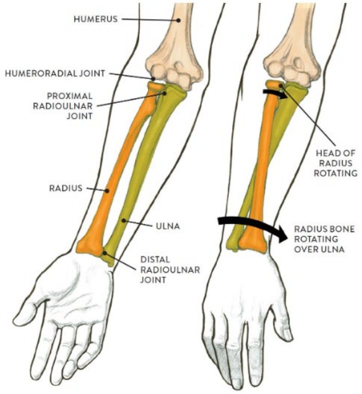
Basic Kinematic Checks

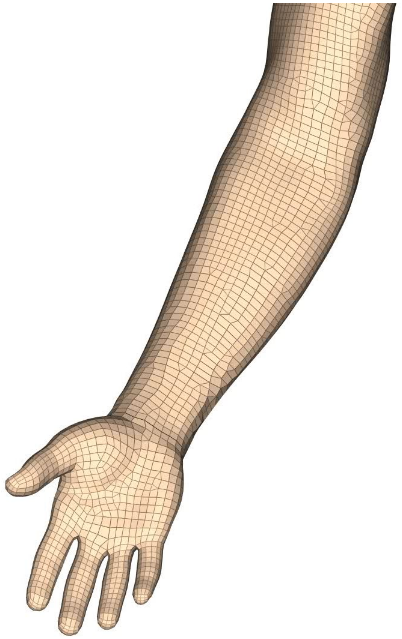






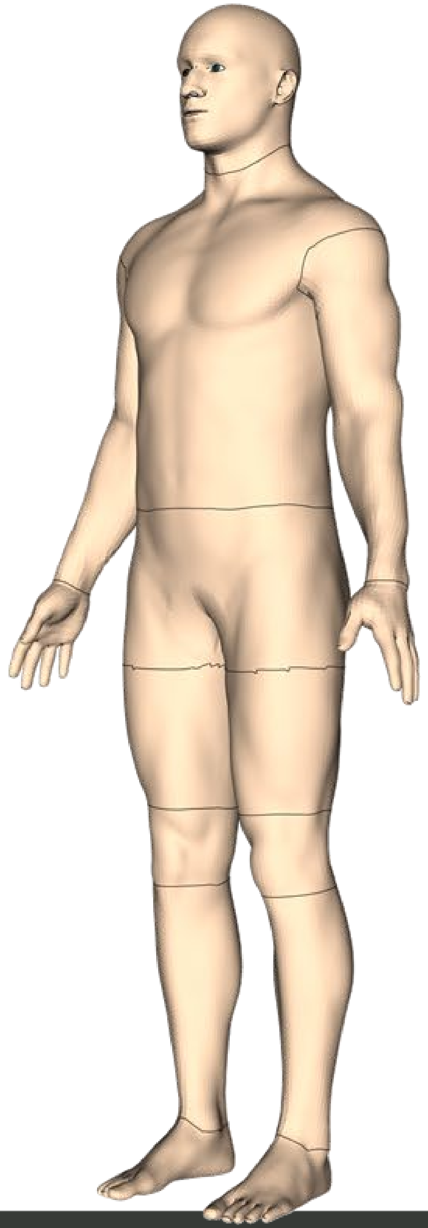






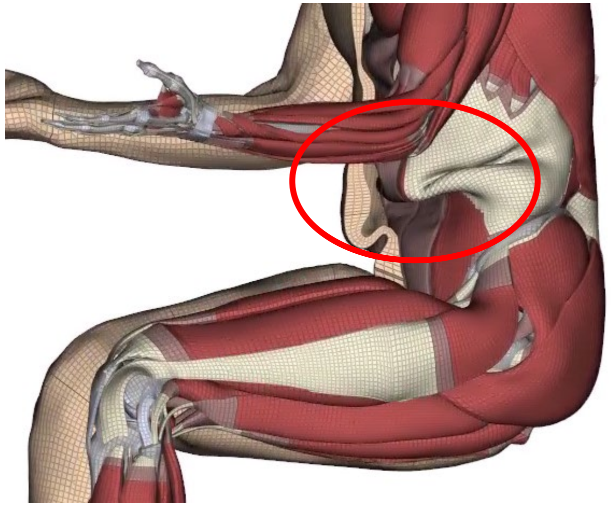
Hans Model Stats

- Body Specs: ~77kg, 176cm, BMI 24.9, Age 30-40
- Model size
  - Number of nodes: ~1.6Mio
  - Number of elements: ~1.9Mio
  - Number of parts: 1,978
  - Macro Fiber Parts (keep adding): 138
- Contacts
  - 1 single surface contact
  - 5 tied contacts to attach soft tissue
- Recommended time step: 0.5µsec

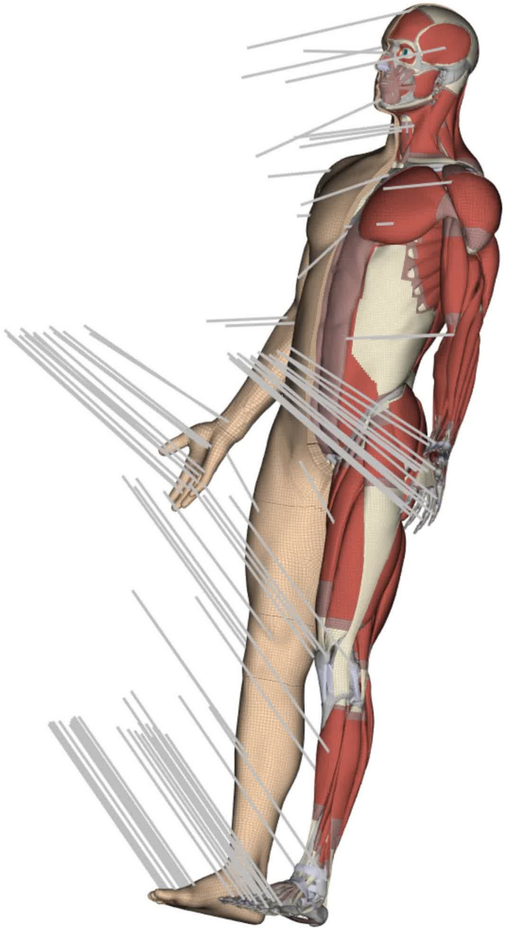


Positioning

- simulation-based positioning using marionette technique
  - Supported pre-processors: ANSA PRE PROCESSOR, LSP, Oasys PRIMER
  - Tree-File included
- Due to the level of detail in the muscles, straight forward posing does not deliver acceptable results

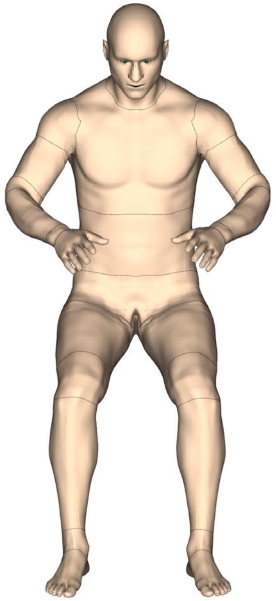


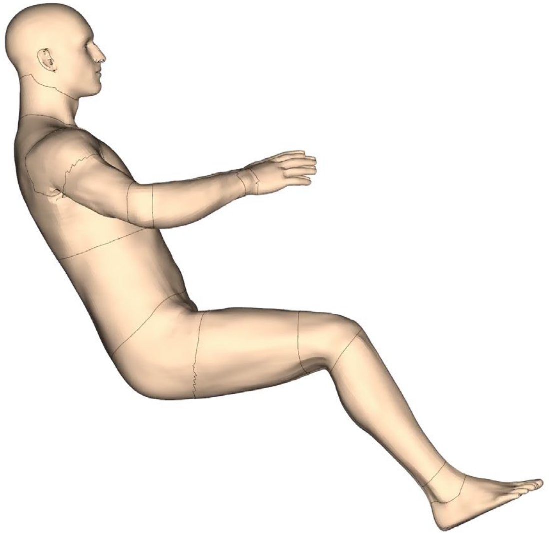
Folding of muscles and skin layers

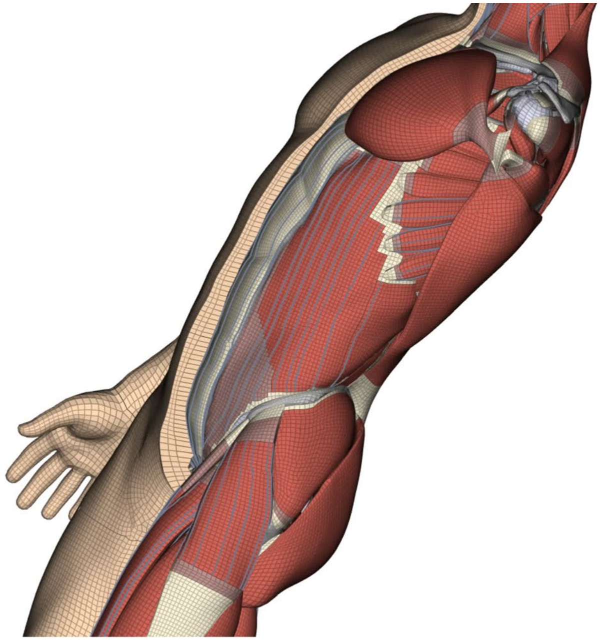


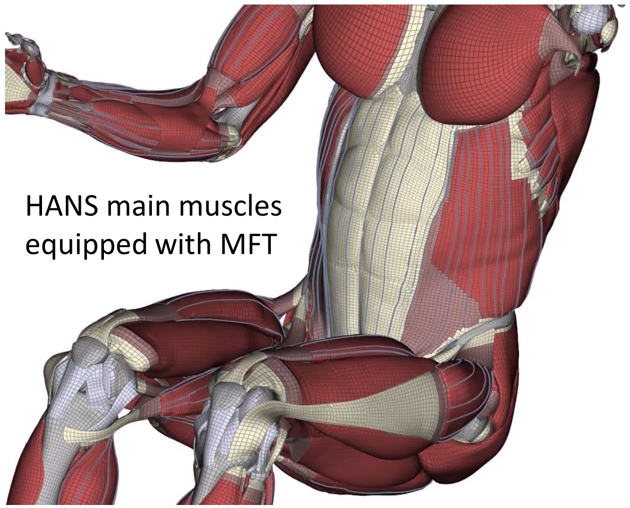
Positioning cont'd

- Applying the MFTs to the positioning process delivers realistic deformations in the body
- Best/fastest results can be achieved when changes are small
- Jack of all trades: Zero-G position





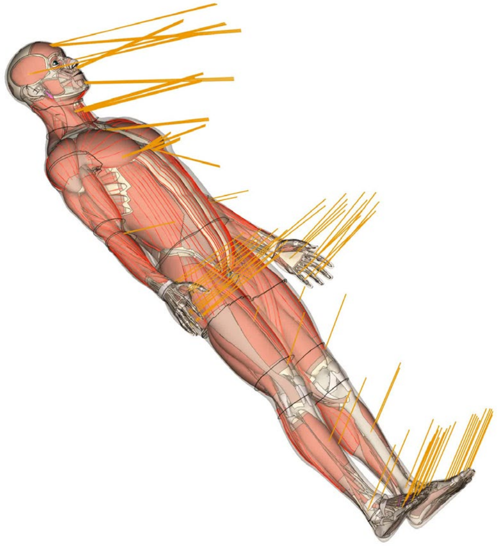




HANS main muscles equipped with MFT

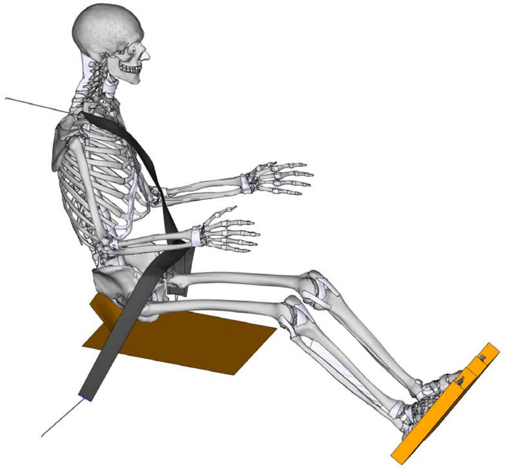
Occupant Load Case Examples

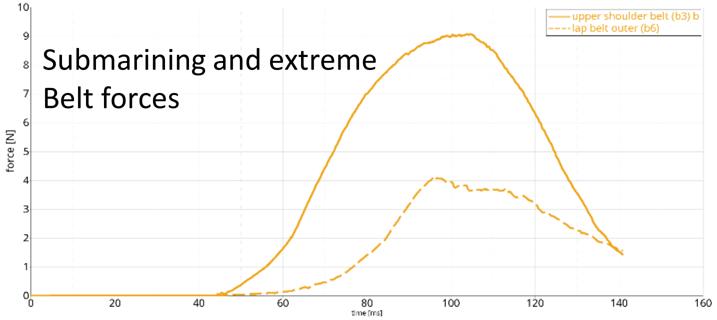
Step 1: Positioning	Load Case: Sled Test	Load Case: Submarining Check



Simulation based positioning
Created by a commonly used pre-processor

Shaw et. al – Sled test





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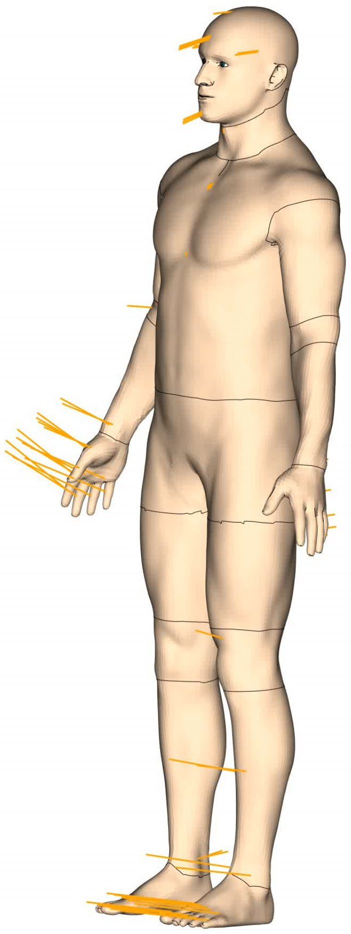
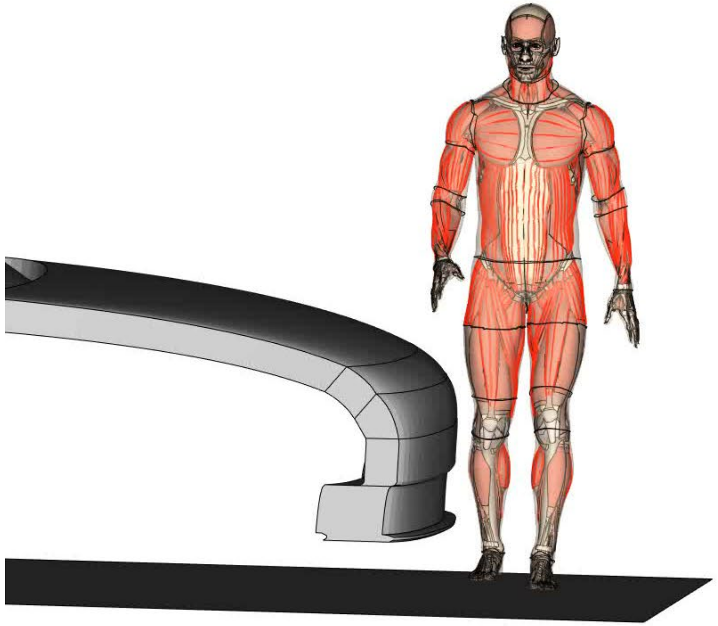
Pedestrian Load Case Example EuroNCAP TB024

Step 1: Positioning



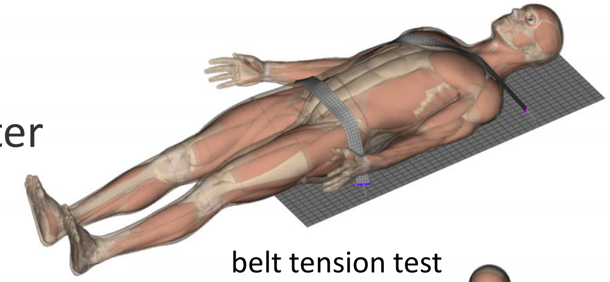
Load Case: FCR 30kph



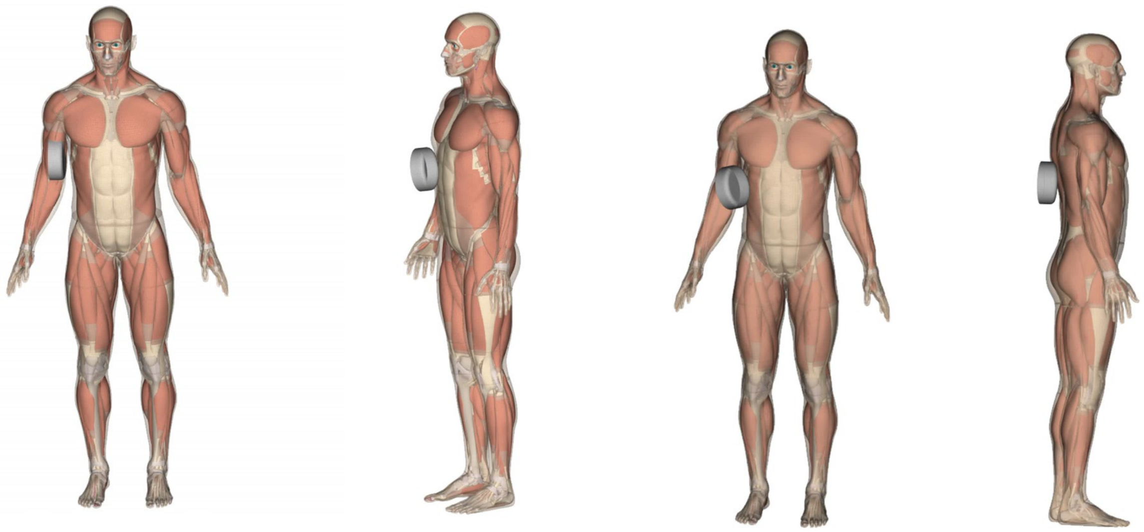
Load Case: RDS 40kph

Robustness

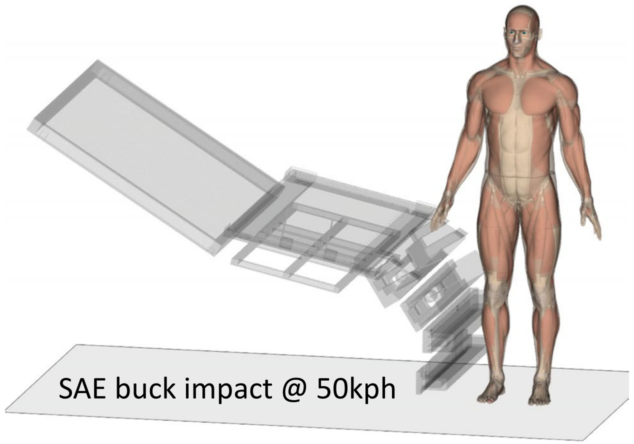
- High robustness through
  - Best possible element/mesh quality
  - material models
  - Contact parameter



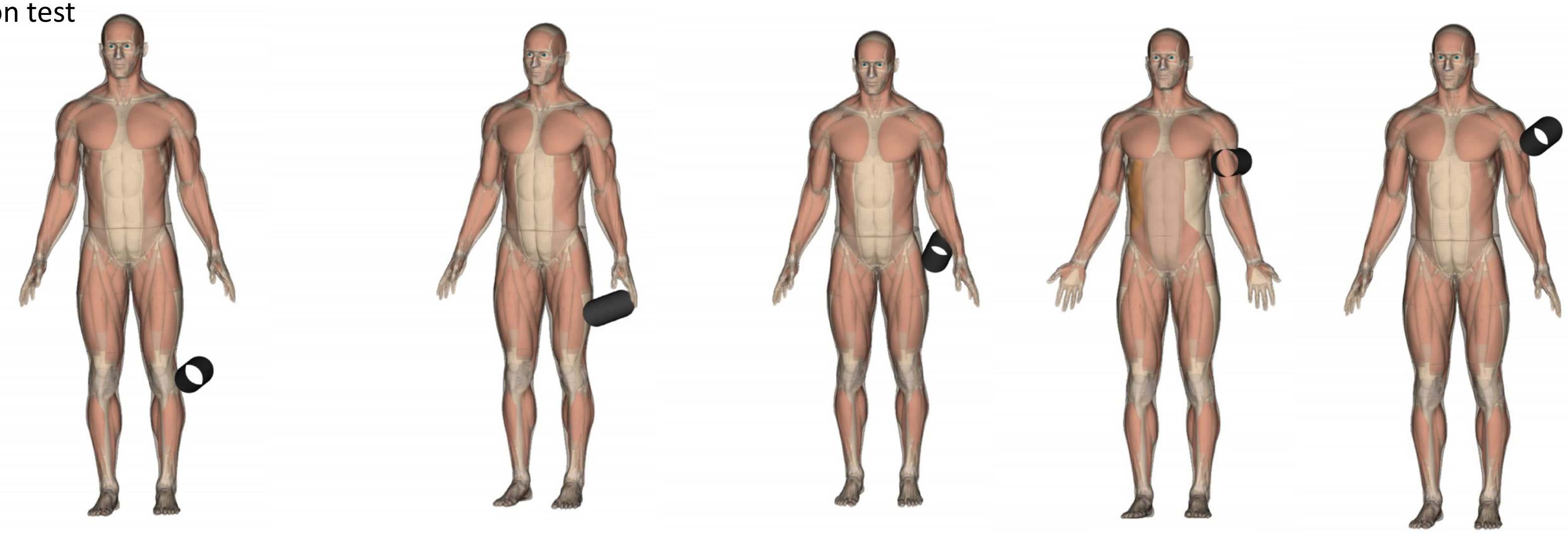
belt tension test



impactor tests with initial velocity (v_0=35kph)



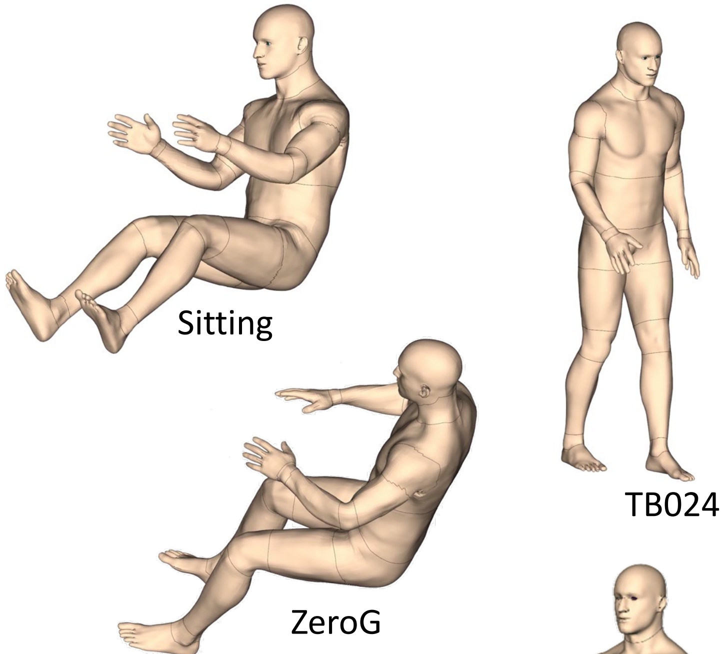
SAE buck impact @ 50kph

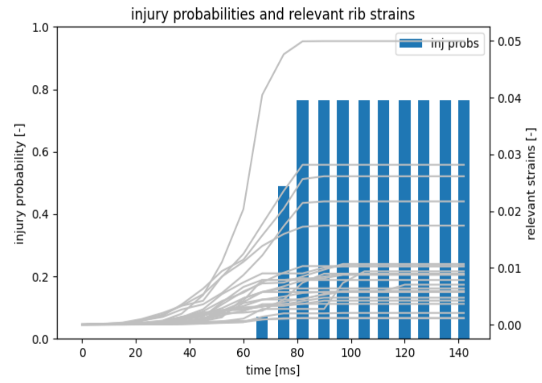


impactor tests with constant velocity (v=30kph)

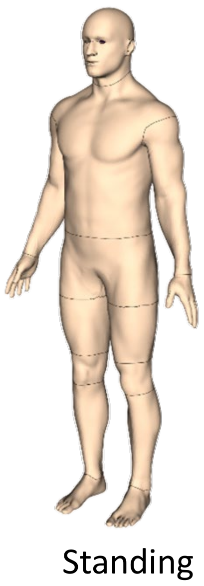
Hans V1.0 Release

- **R12.2** is the model development version and required to use Hans
- Release will be cross-checked with newer versions
- Human Body Model in three unit-systems
  - kg, m, sec, N (SI) // ton, mm, sec, N // kg, mm, ms, kN
- Delivery model in standing and sitting postures – **One Model**
- Accessoires like shoes, ...
- **Treefile for positioning** of the model in the commonly used pre-processing tools
- Injury extraction capabilities
- Documentation/Correlation report
- **1st class expert support**



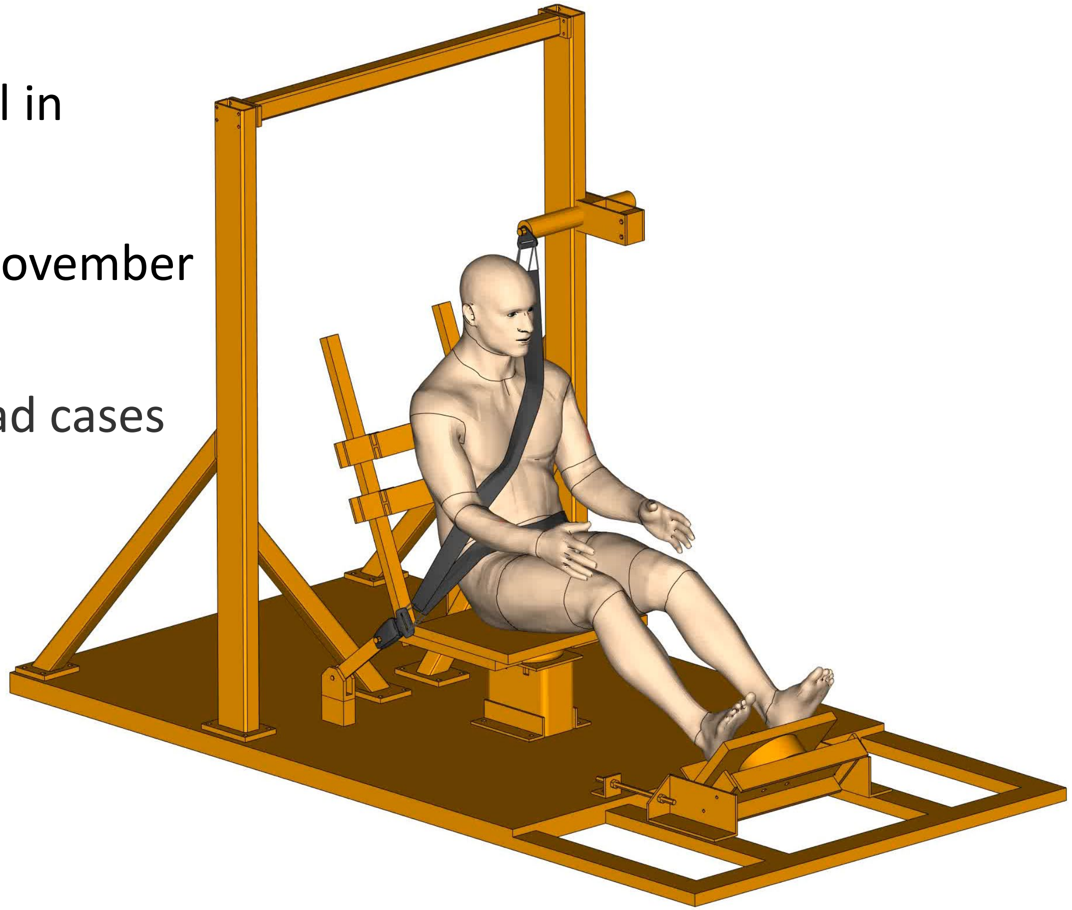


rib injury probability AIS2+ for a 25yo and relevant rib strains (probabilistic rib injury criterion, Forman 2012)



Current Status and Outlook

Forman et. al – Farside Sled, 2007



- Hans model build has been finalized
- Full body correlation work for automotive applications still in progress
- Release Candidate rollout for pilot customers starting in November 2023
  - Testing in foreign environments and actual customer load cases
  - First valuable customer feedback
- V1.0 release to a wider customer base in H1 2024

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