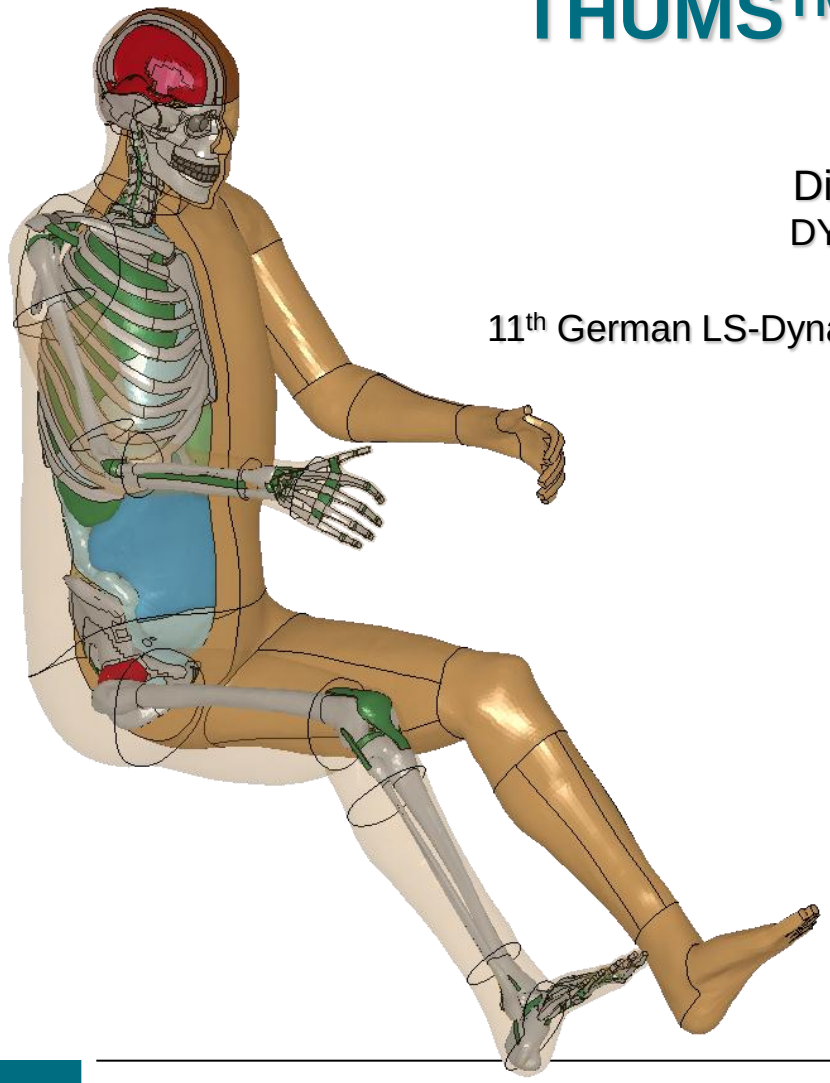
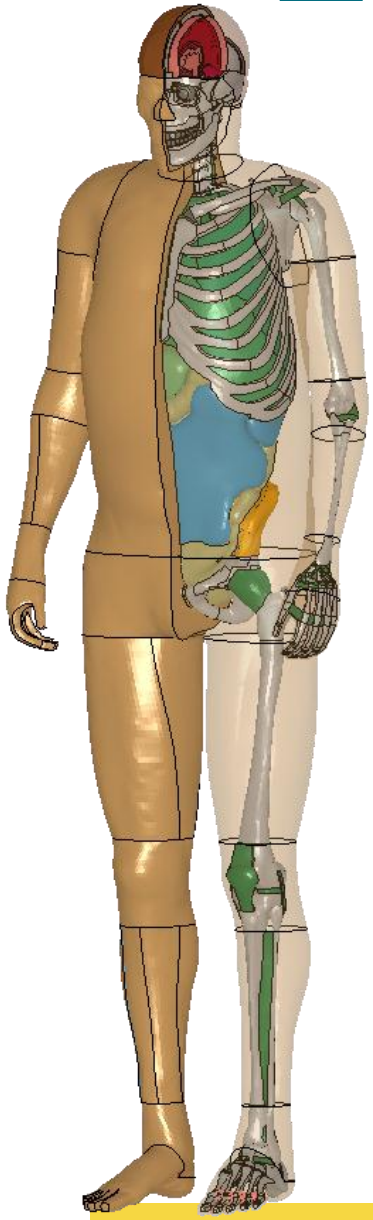
Vehicle Safety using the THUMS^{TM} Human Model





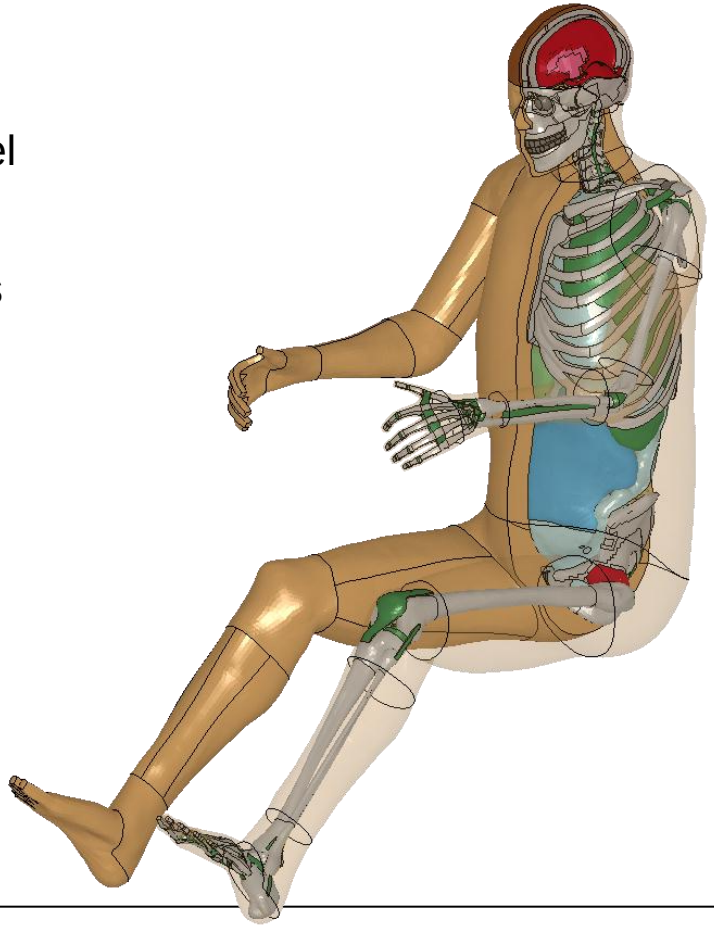
Dirk Fressmann
DYNAmore GmbH

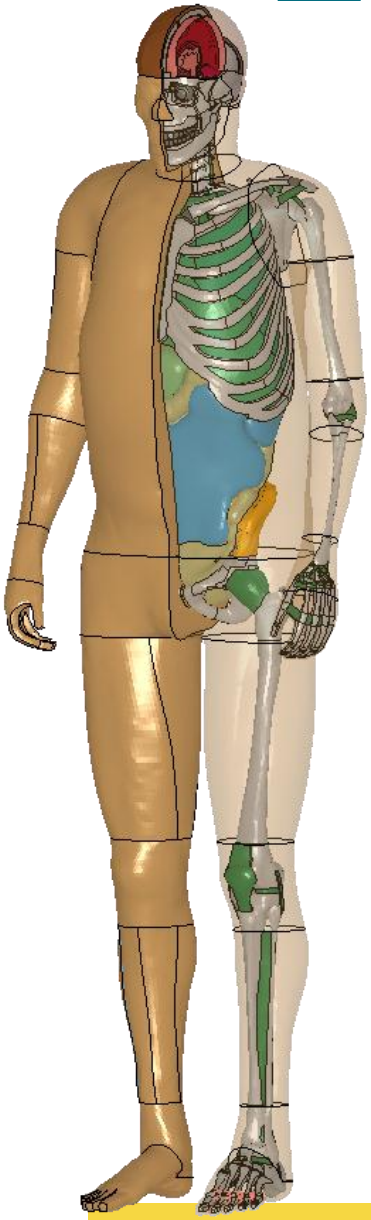
11th German LS-Dyna Forum 2012, October 9-10, 2012

Agenda

THUMS^{TM} – Total HUman Model for Safety

- model of the human body for application in automotive crash test scenarios



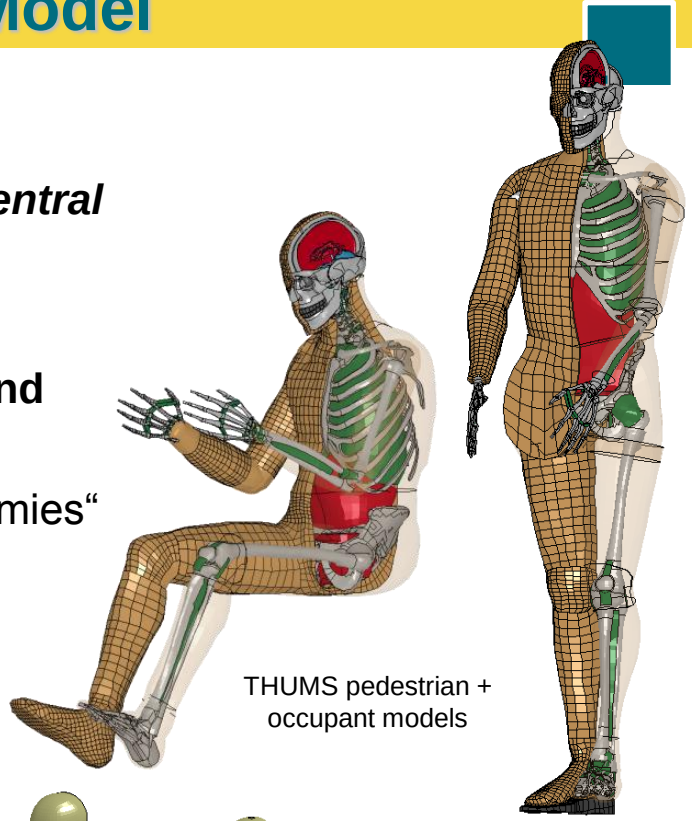


Agenda

1. Introduction – the THUMS Model
2. Model Variants & Versions
3. Geometric Details of the Models
4. Application Examples
   - Pedestrian Model
   - Occupant Model
5. Summary and Outlook

Introduction – The THUMS™ Human Model

- **THUMS™ – Total HUman Model for Safety**
- **developed by *Toyota Motor Corporation* and *Toyota Central R&D Labs.* Inc. since 2000**
  - additional research institutes involved (e.g. WSU)
- **represents an additional tool to evaluate injury risks and develop passive and active safety systems**
  - „vehicle optimisation w.r.t. to humans, rather than dummies“
- **reproduces anatomical geometry and biomechanical properties of the human body**
  - e.g. skeletal structure, joints, bone stiffness, skin flexibility, etc.

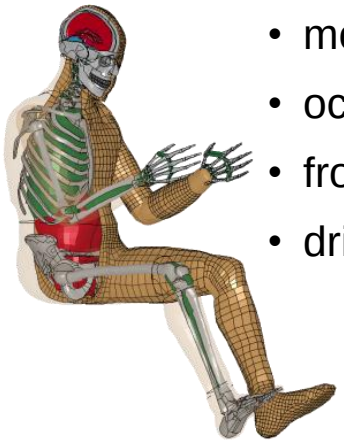


THUMS pedestrian + occupant models

- **applications in crash, ergonomics, sport sciences, etc.**
  - simulation of the kinematics of the human body
  - poss. stress- and strain evaluations in bones and joints
  - newer models (version 4) may also allow deeper analysis of injury mechanisms

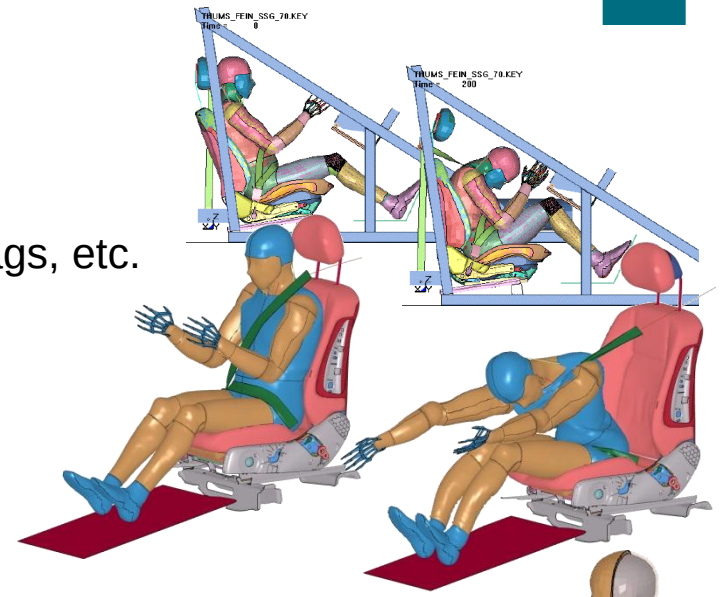
Comparison WorldSID, Hybrid III, THUMS V3, THUMS V4

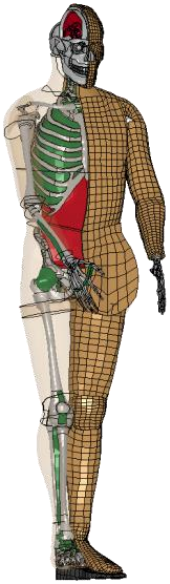
Introduction – Model Variants and Versions



THUMS Occupant Model

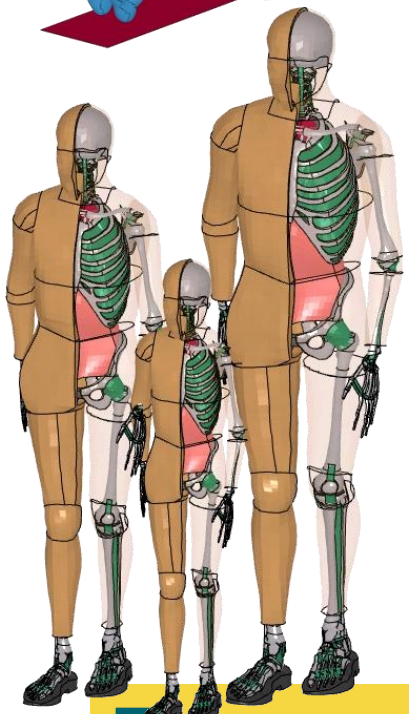
- model of a seated 50%ile Adult Male (AM50)
- occupant simulations, belt development, airbags, etc.
- front/side/rear crash situations
- driver & co-driver postures





THUMS Pedestrian Model

- model of a standing 50%ile Adult Male (AM50)
- pedestrian safety simulations (head impact time and location)
- variation of posture, stance or model size
- additional interest in „THUMS Family“
  (different model sizes - AM50, AF05, 6YO, ...)



- basically same modelling techniques for occupant and pedestrian with slight modifications (e.g. internal organs, shoulder, material properties + failure behaviour)

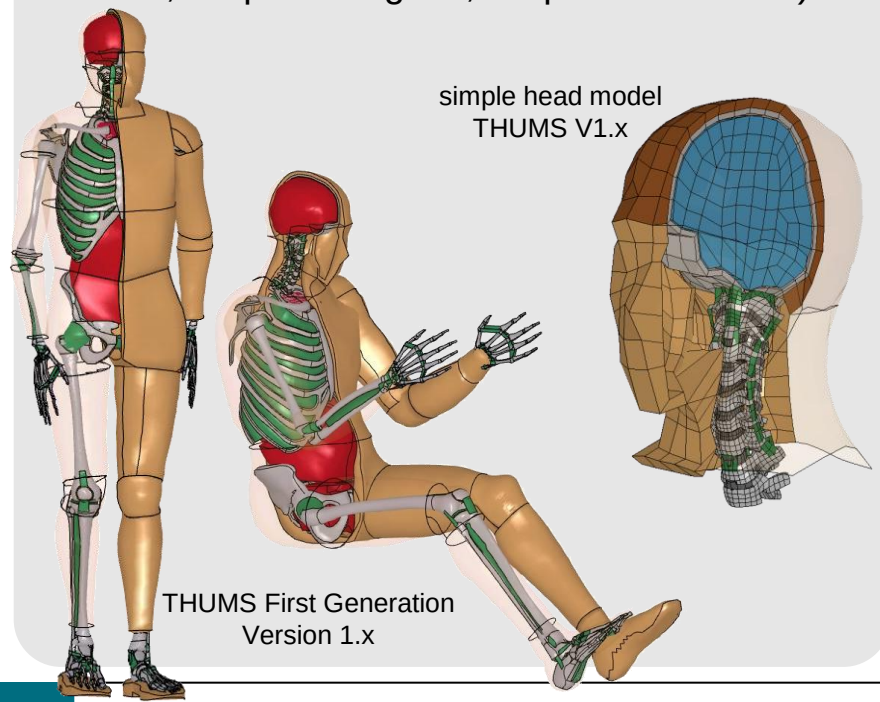
Introduction – Model Variants and Versions

THUMS Model Versions 1.x and 3.0

- mostly based on literature data (geometry and material properties)
- simple materials (mostly elastic, elastic-plastic, viscoelastic)
- AM50 model size, comparable to size of corresponding dummy models
- exclusively used for kinematical evaluations

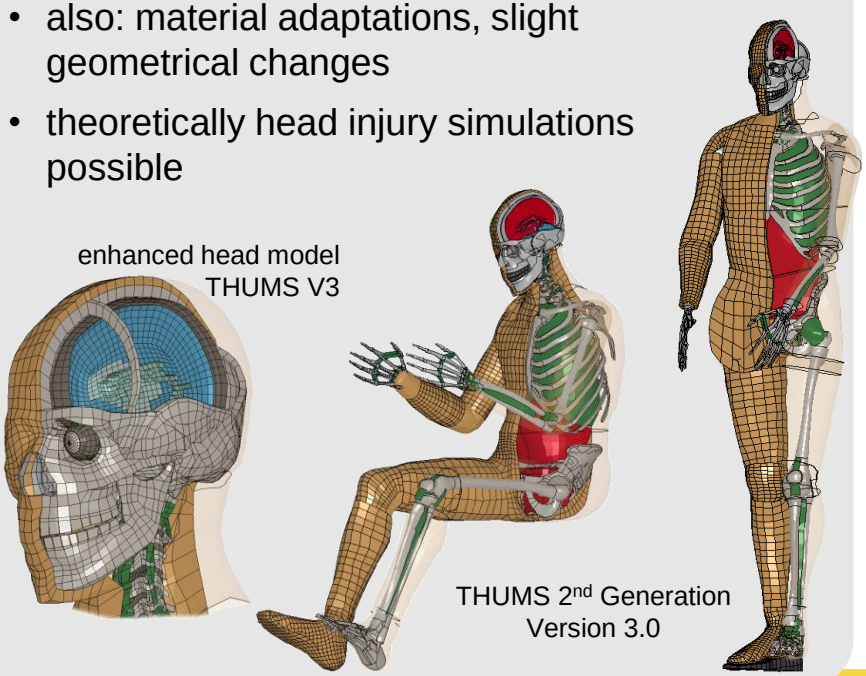
Versions 1.4/1.6 (ca. 2004-06)

- kinematical model (skeletal structure, joints, flesh, simplified organs, simple head model)



Version 3.0 (beginning of 2008)

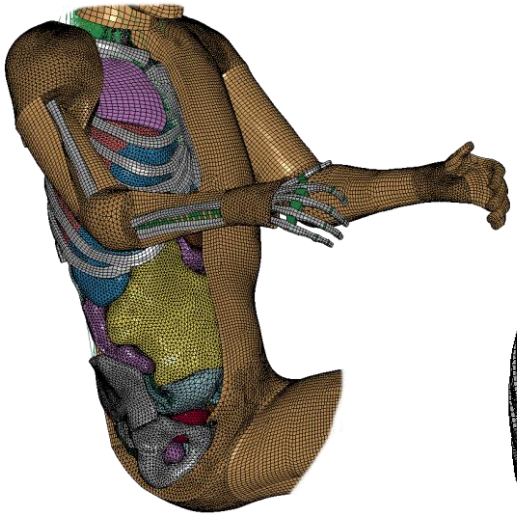
- refined head model (based on CT-scans)
- also: material adaptations, slight geometrical changes
- theoretically head injury simulations possible



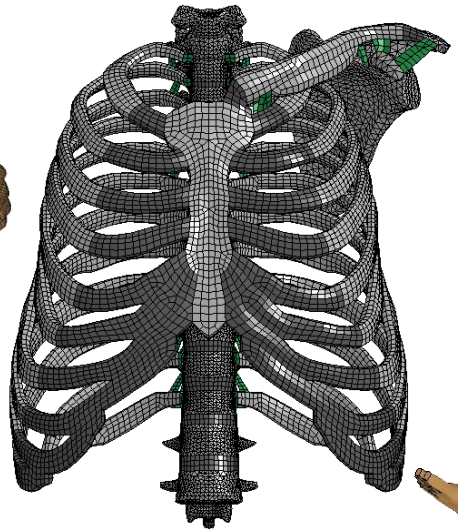
Introduction – Model Variants and Versions

THUMS Model Version 4 (since end 2010)

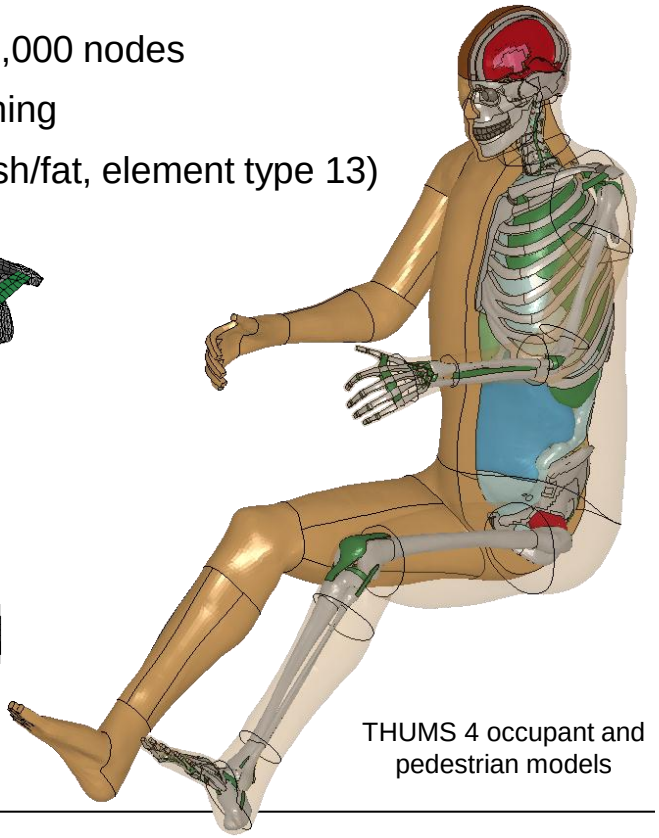
- no model update → completely new model
- geometry obtained from medical CT scans
  - basis: 39 year-old male (173cm, 77.3kg, BMI 25.8)
  - scaled to AM50 model (178.6cm, 74.3kg) → realistic geometry
  - very high detailing of joints, internal organs, head, …
- model parameters
  - element size 3-5mm, 1.8Mio elements, 630,000 nodes
  - mainly solid elements and some shell meshing
  - hexa- and tetrahedral meshing (organs, flesh/fat, element type 13)

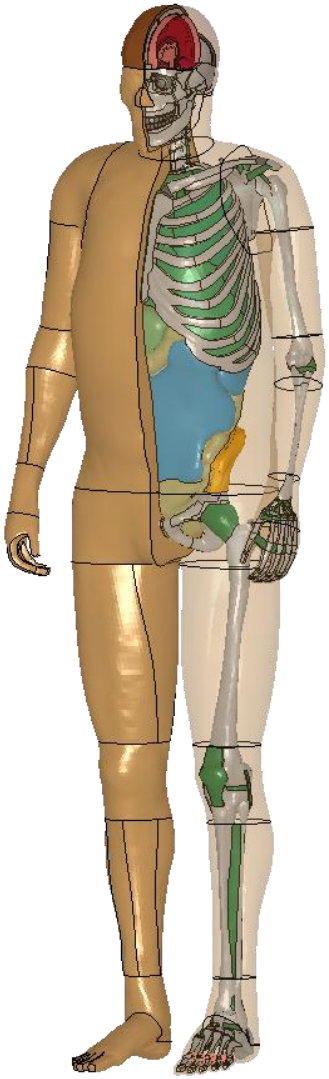


occupant upper body



pedestrian thorax





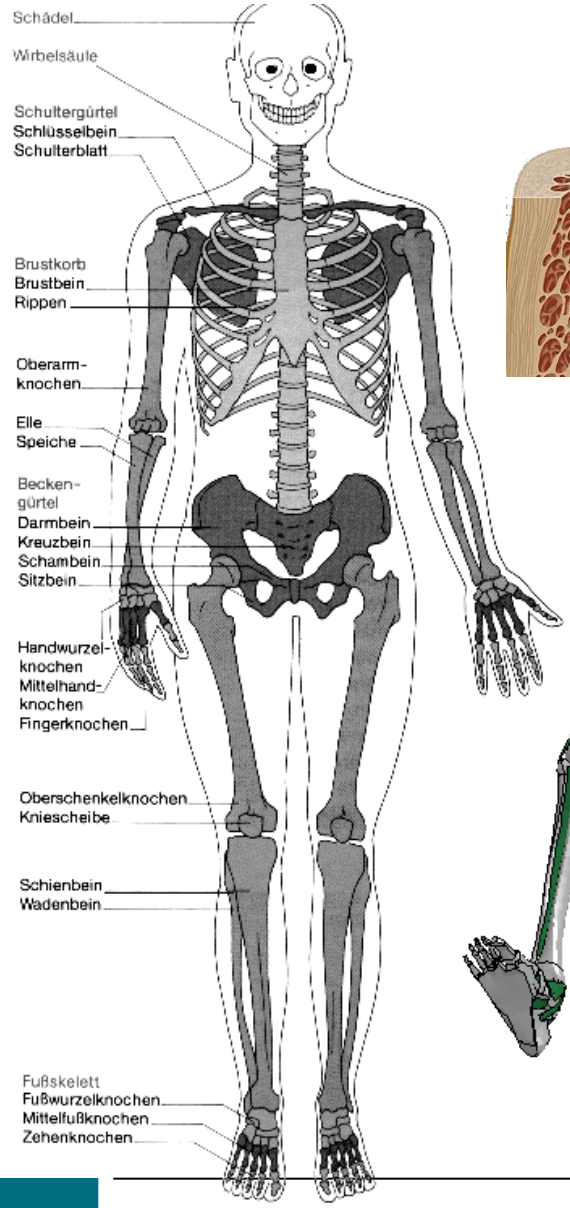
THUMS 4 occupant and pedestrian models

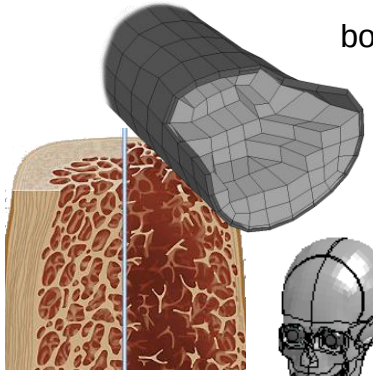
THUMS Geometric Details

Comparison between THUMS Version 3 and Version 4

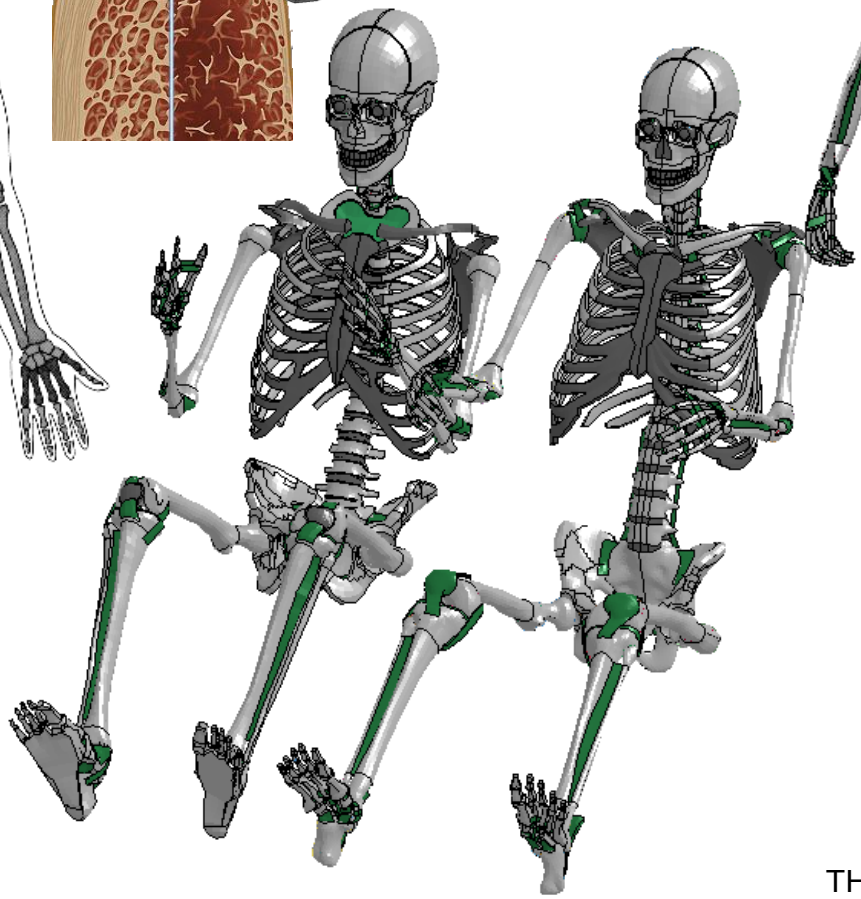
The THUMS Models – Geometric Details

Geometric Details: Skeletal Structure

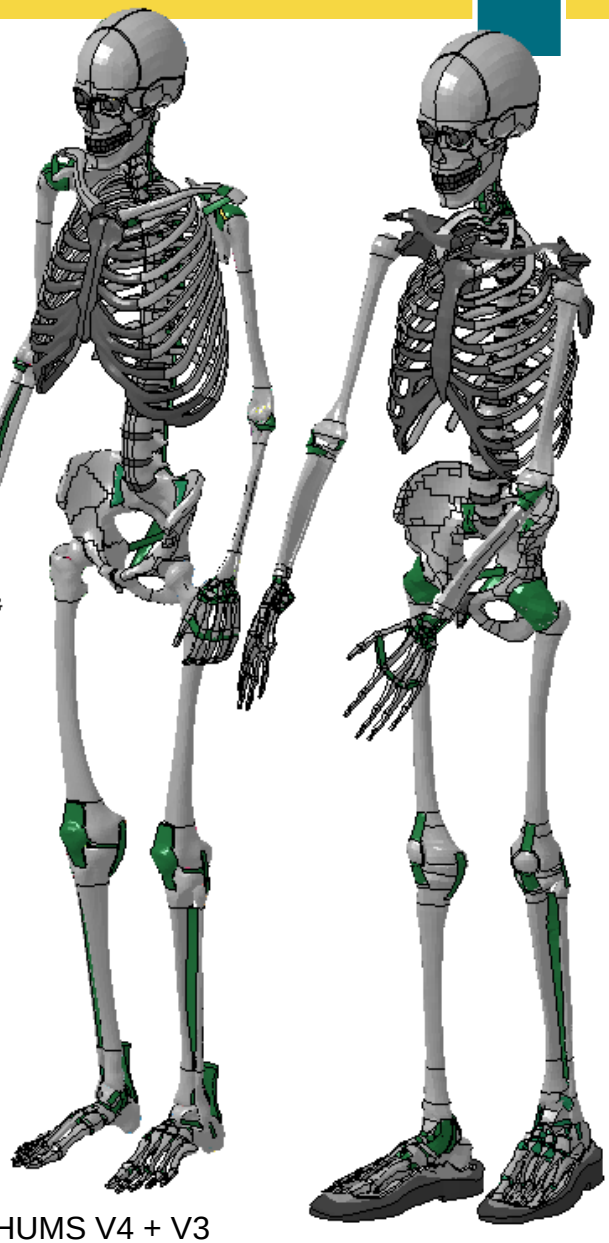




bone structure
- trabecular bones (solids)
- cortical bones (shells)



THUMS V3 + V4 occupant model

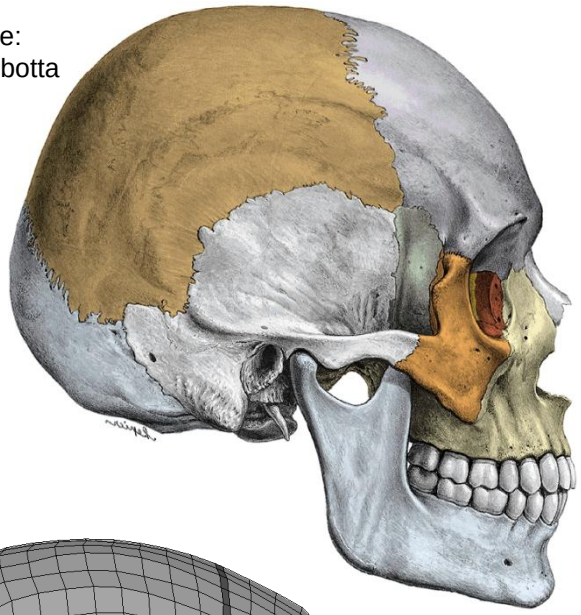


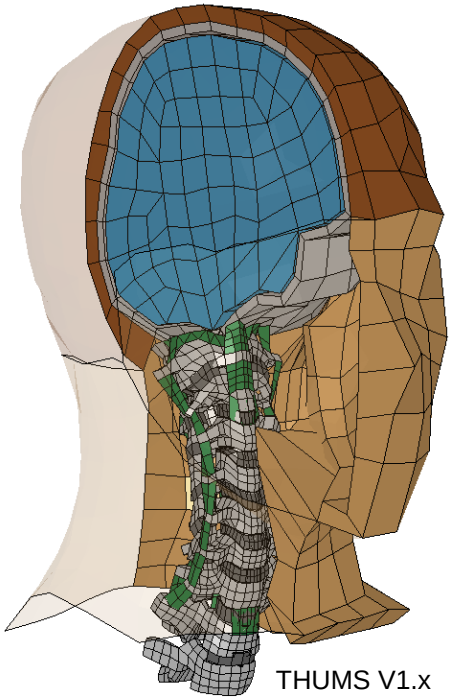
THUMS V4 + V3
pedestrian models

The THUMS Models – Geometric Details

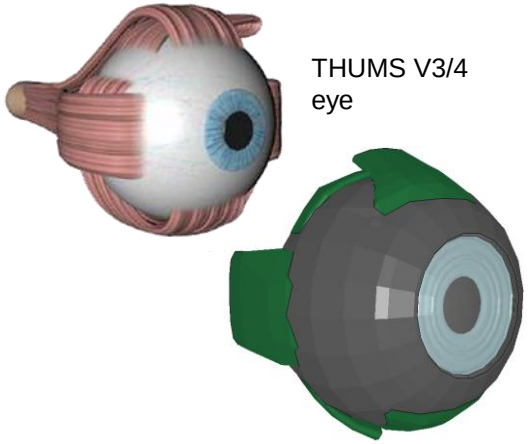
Geometric Details: Head & Skull

Source:
Sobotta

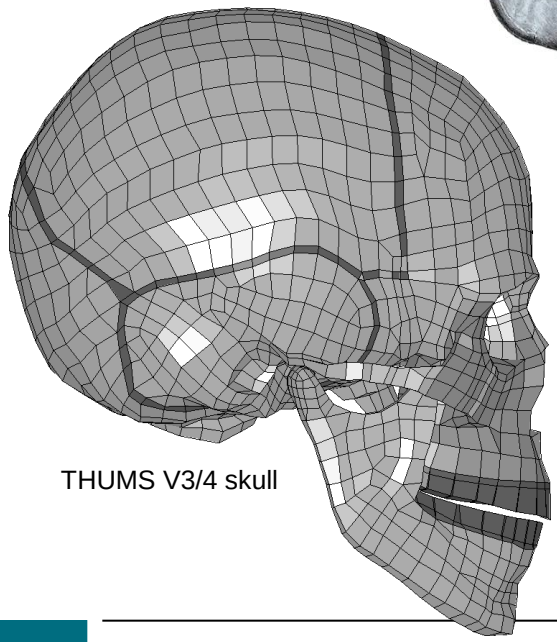




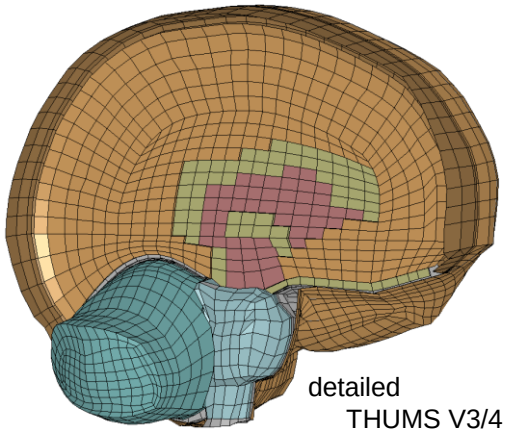
THUMS V1.x
head model



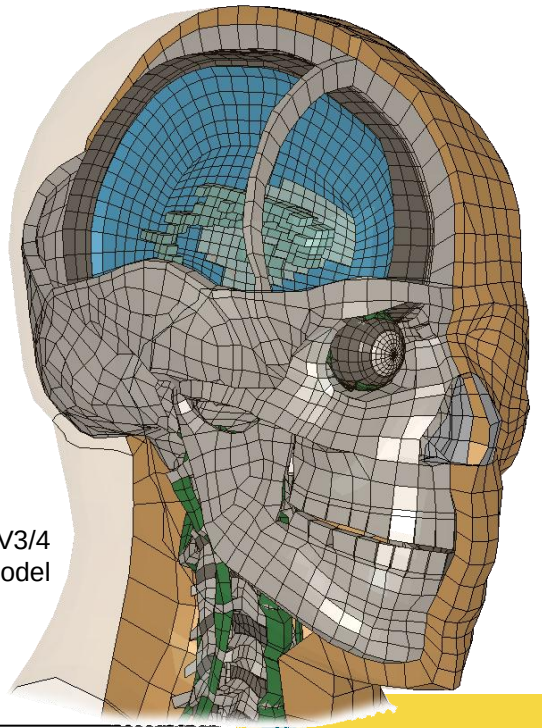
THUMS V3/4
eye



THUMS V3/4 skull



detailed
THUMS V3/4 brain

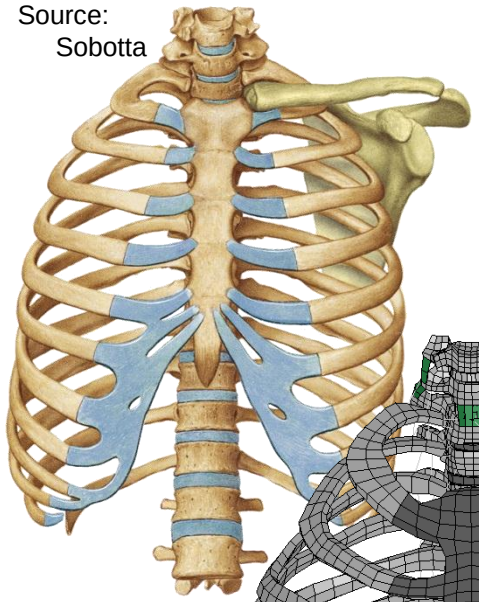


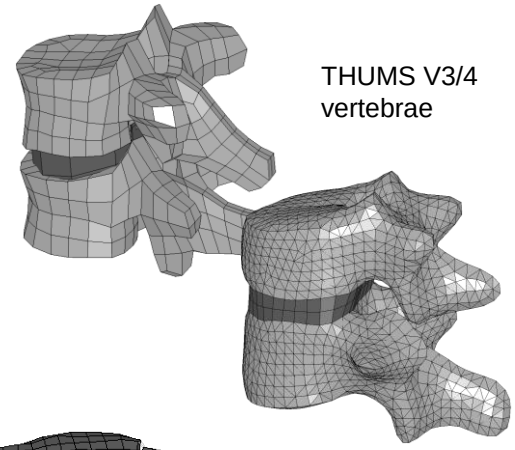
THUMS V3/4
head model

The THUMS Models – Geometric Details

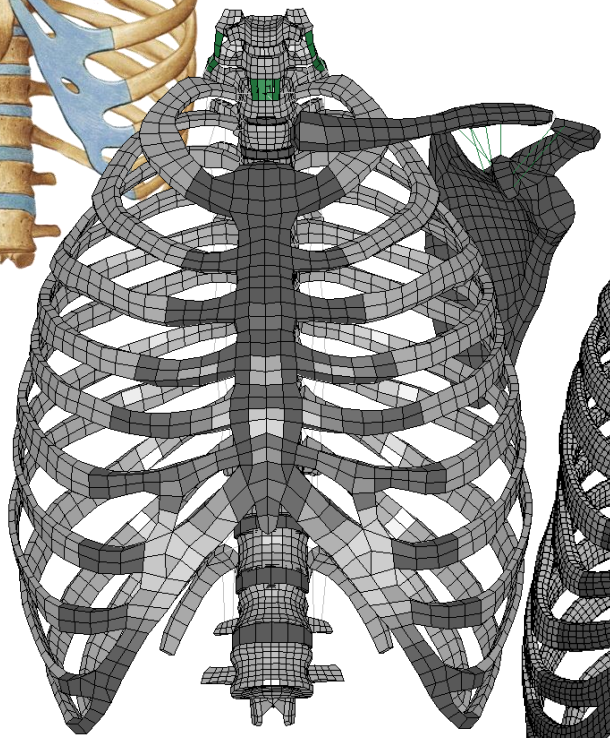
Geometric Details: Thorax & Spine

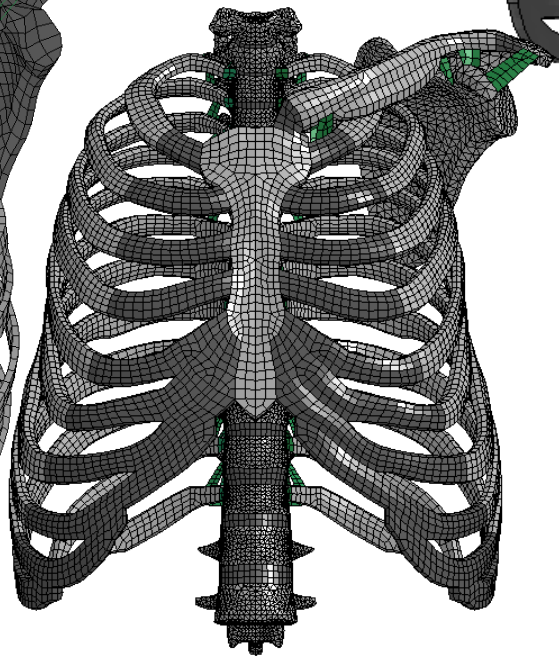
Source:
Sobotta



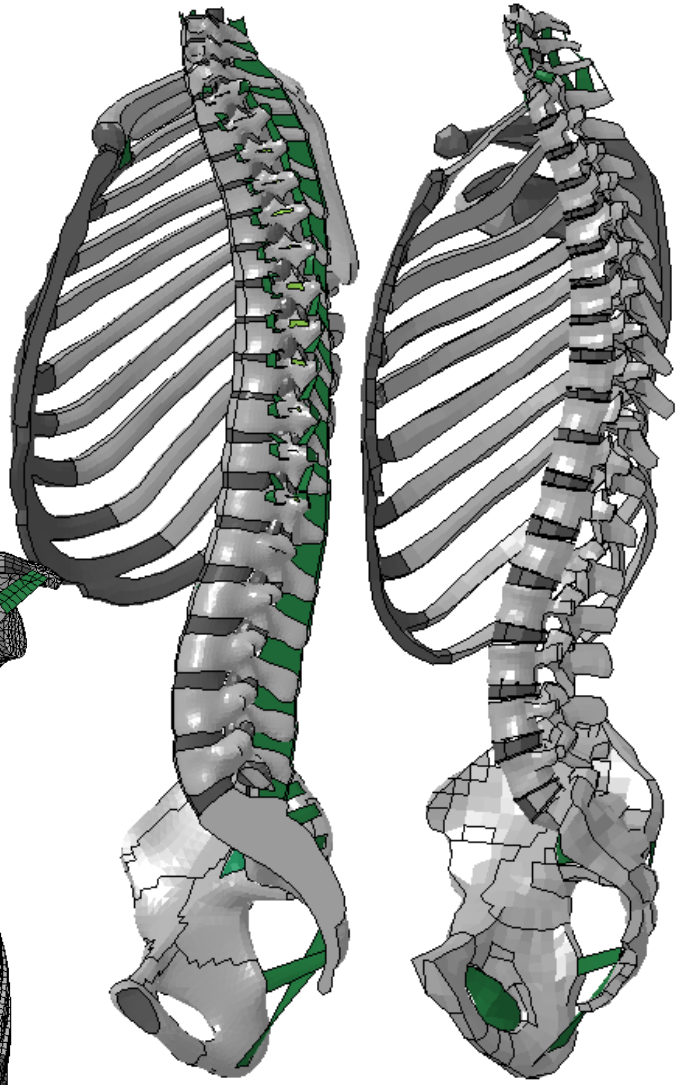


THUMS V3/4
vertebrae





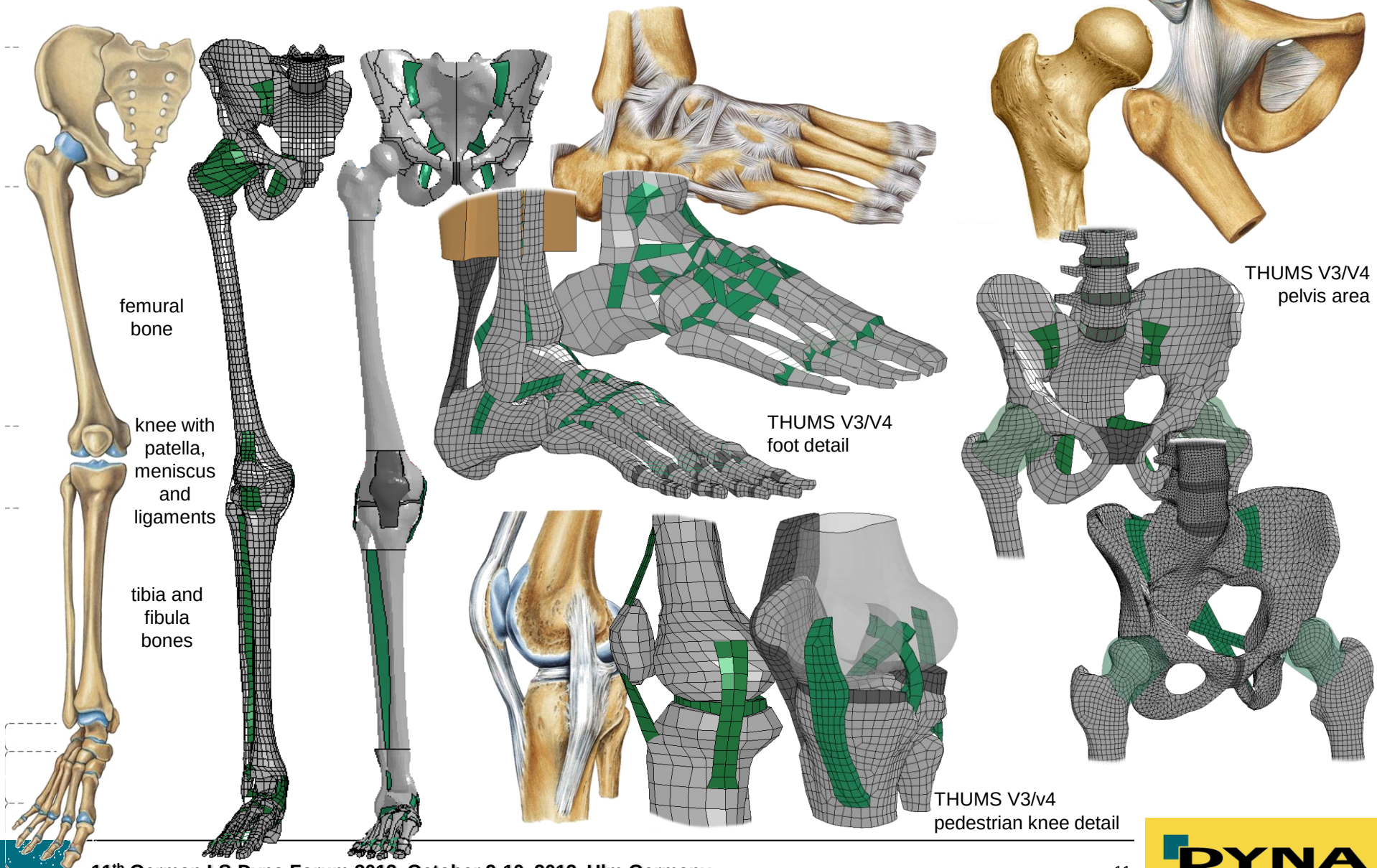
THUMS V3/V4
pedestrian thorax



THUMS V3 + V4 pedestrian
spine + thorax

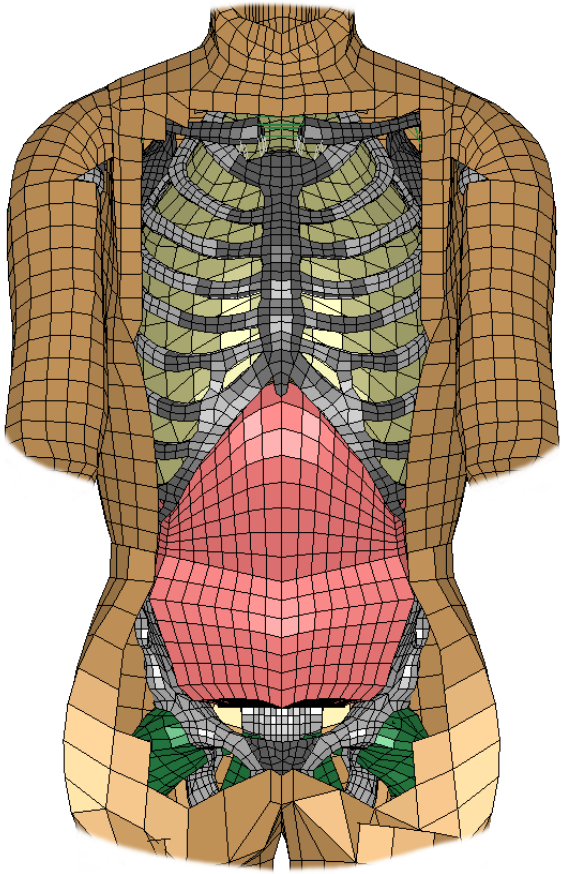
The THUMS Models – Geometric Details

Geometric Details: Lower Extremities

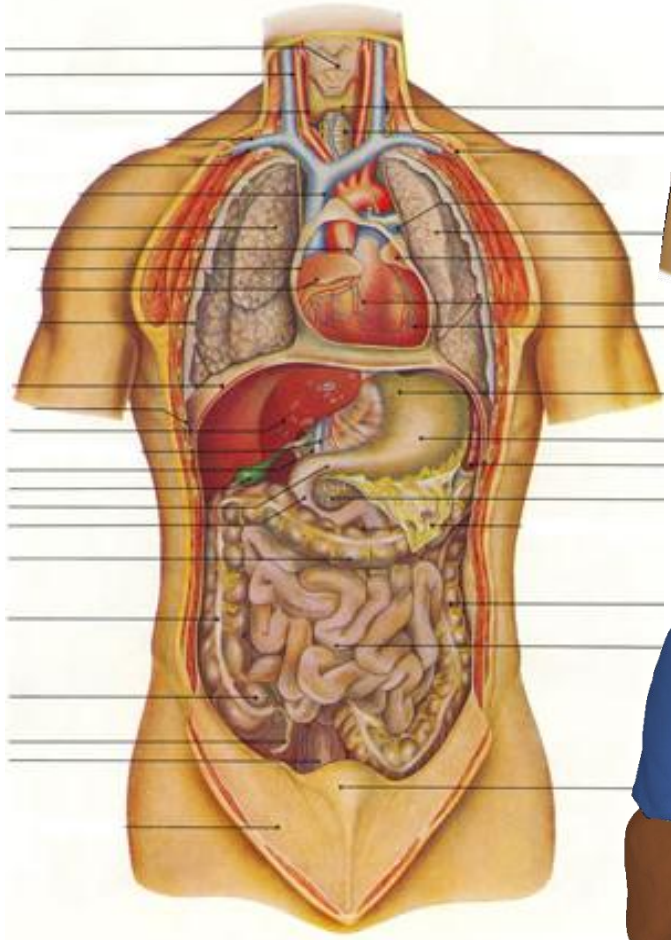


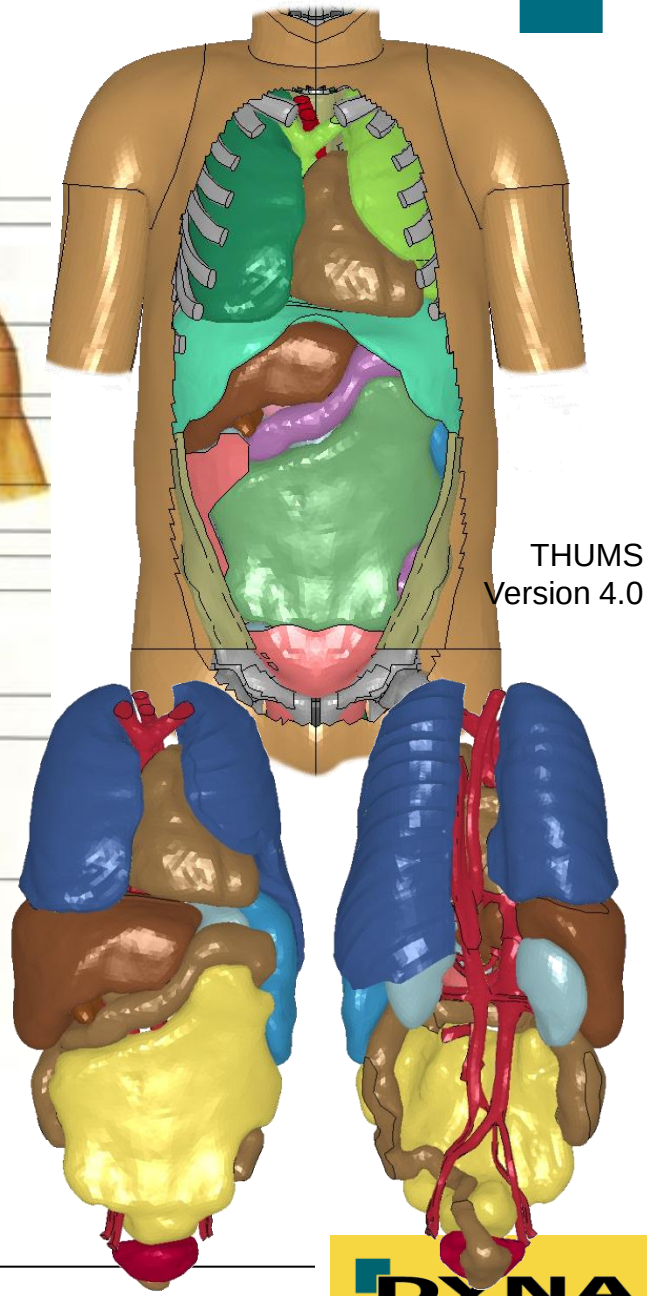
The THUMS Models – Geometric Details

Geometric Details: Internal Organs



THUMS Version 1.x/3.0



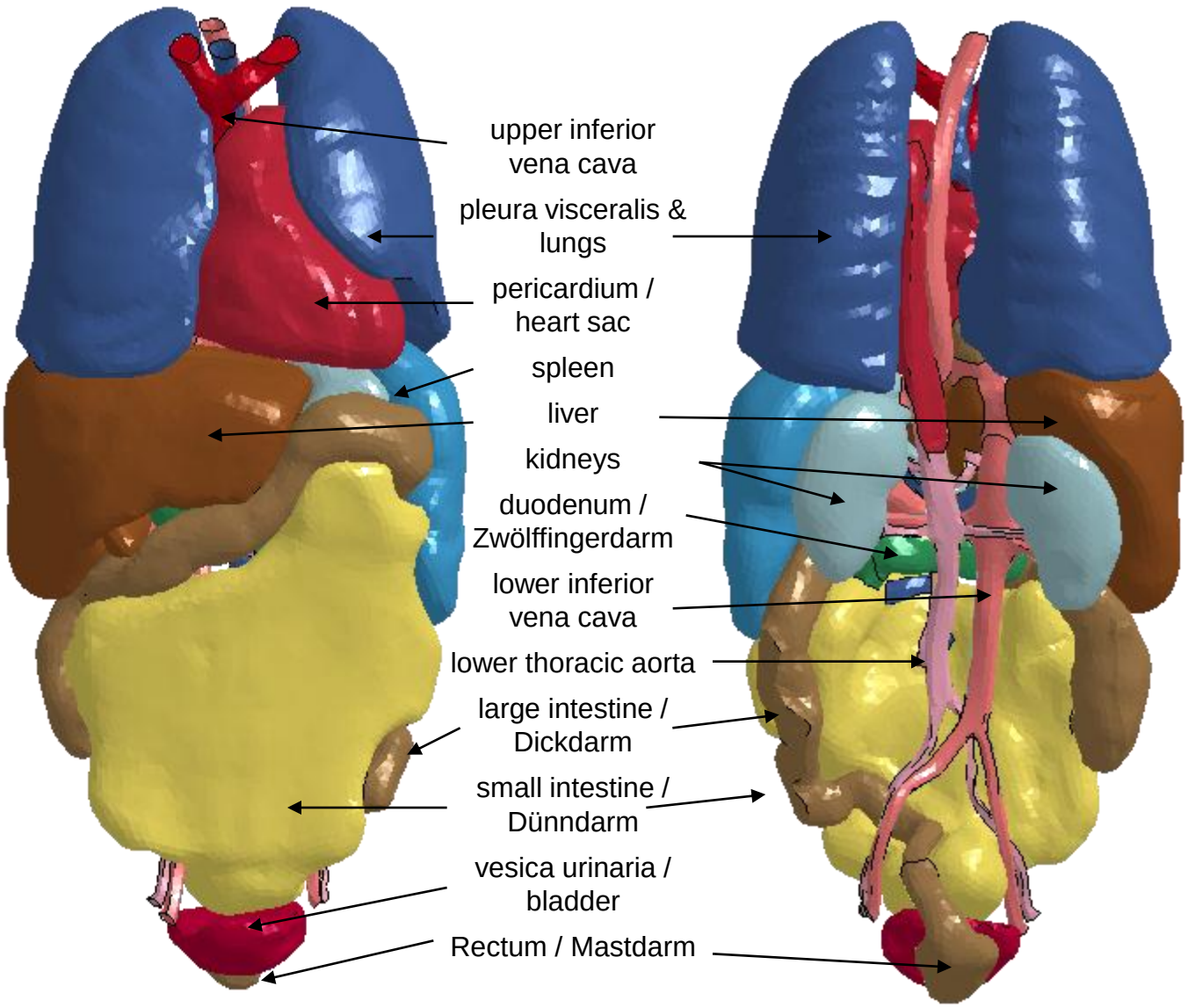


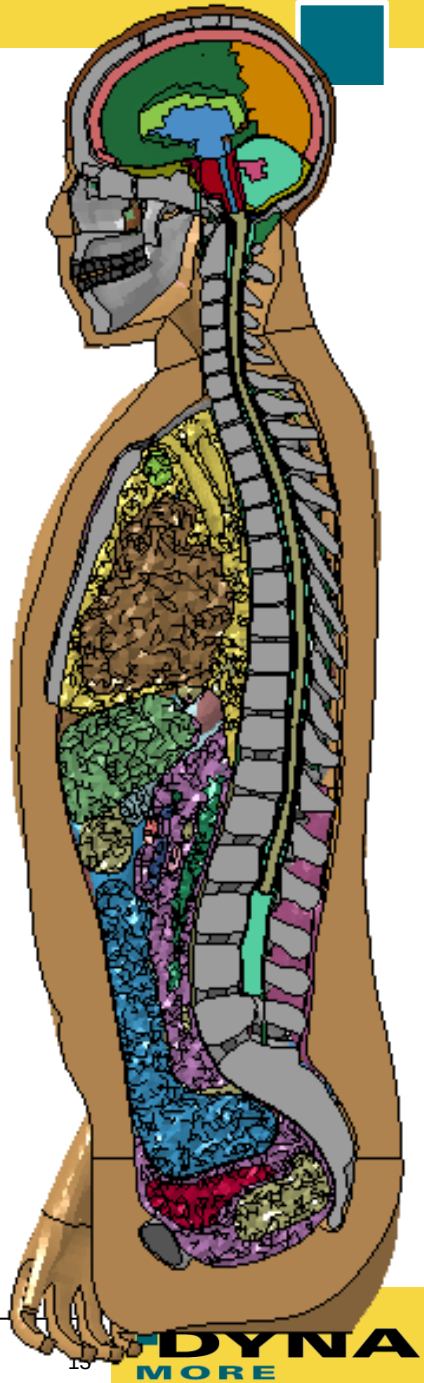
THUMS Version 4.0

- coarse organ modelling in THUMS v1.x-3.0
  - due to coarse meshing and required model stability
- (fine) organ modelling in THUMS version 4.0

The THUMS Models – Geometric Details

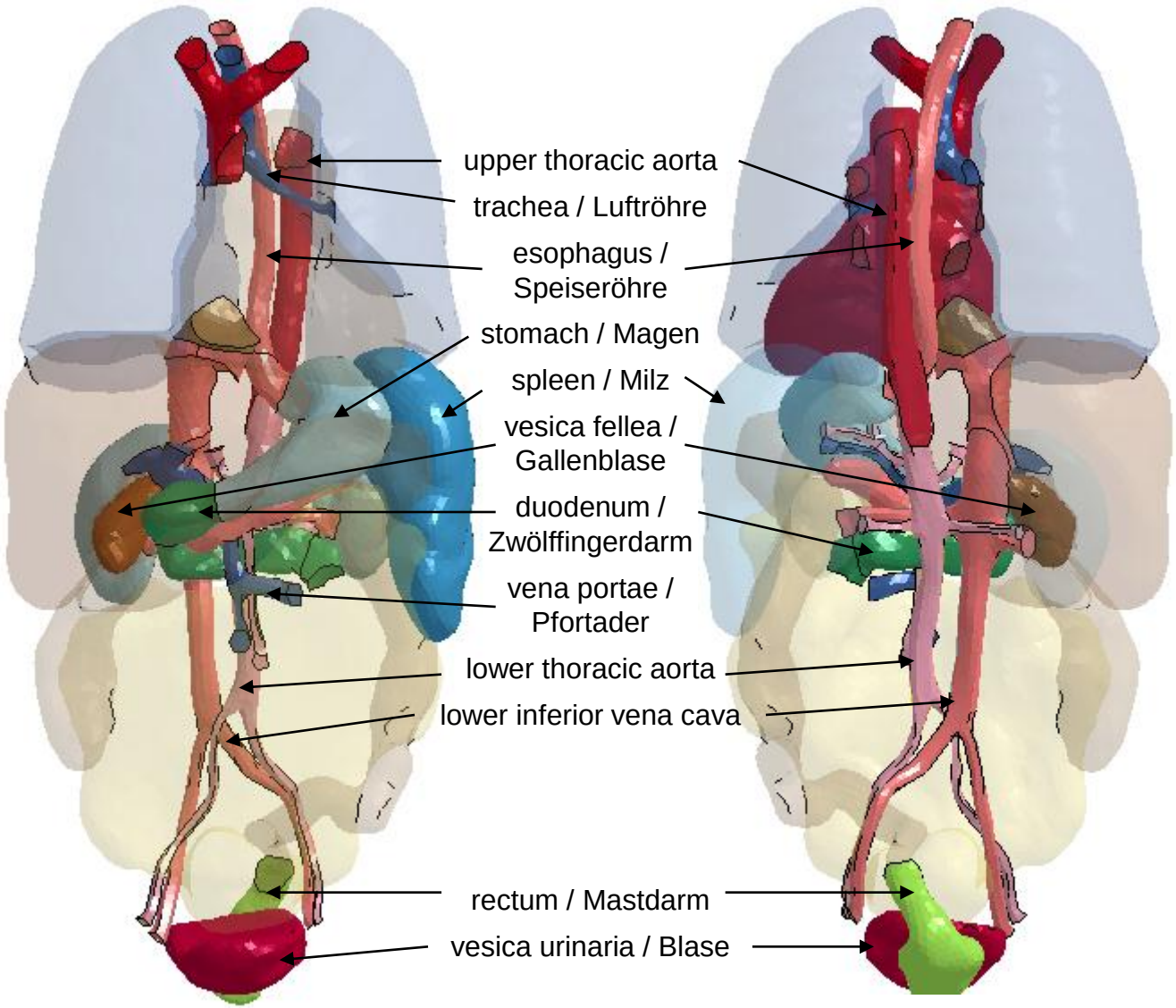
Geometric Details: Internal Organs (outer)

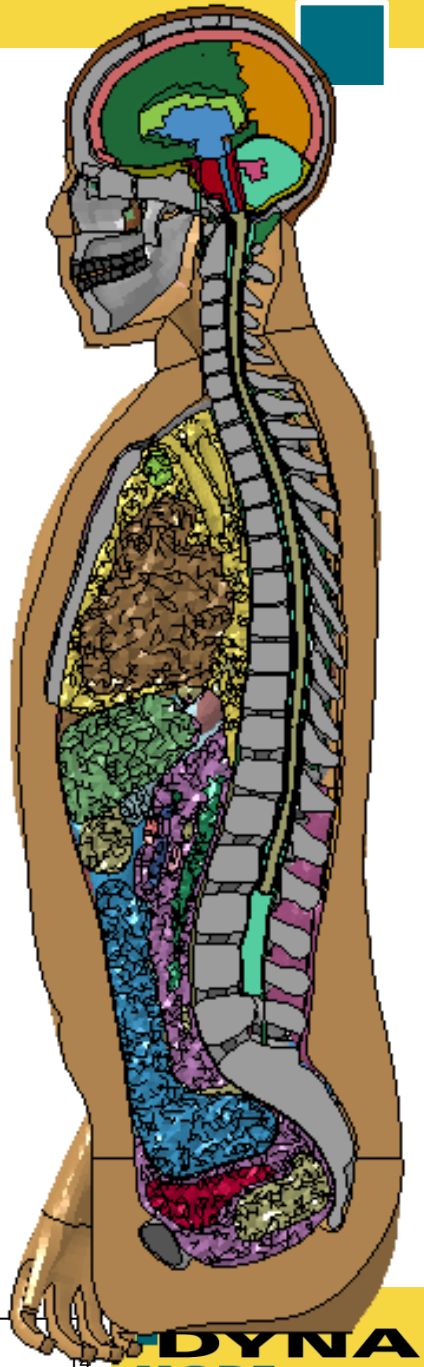




The THUMS Models – Geometric Details

Geometric Details: Internal Organs (internal)





Application Examples

Pedestrian and Occupant Impact Examples

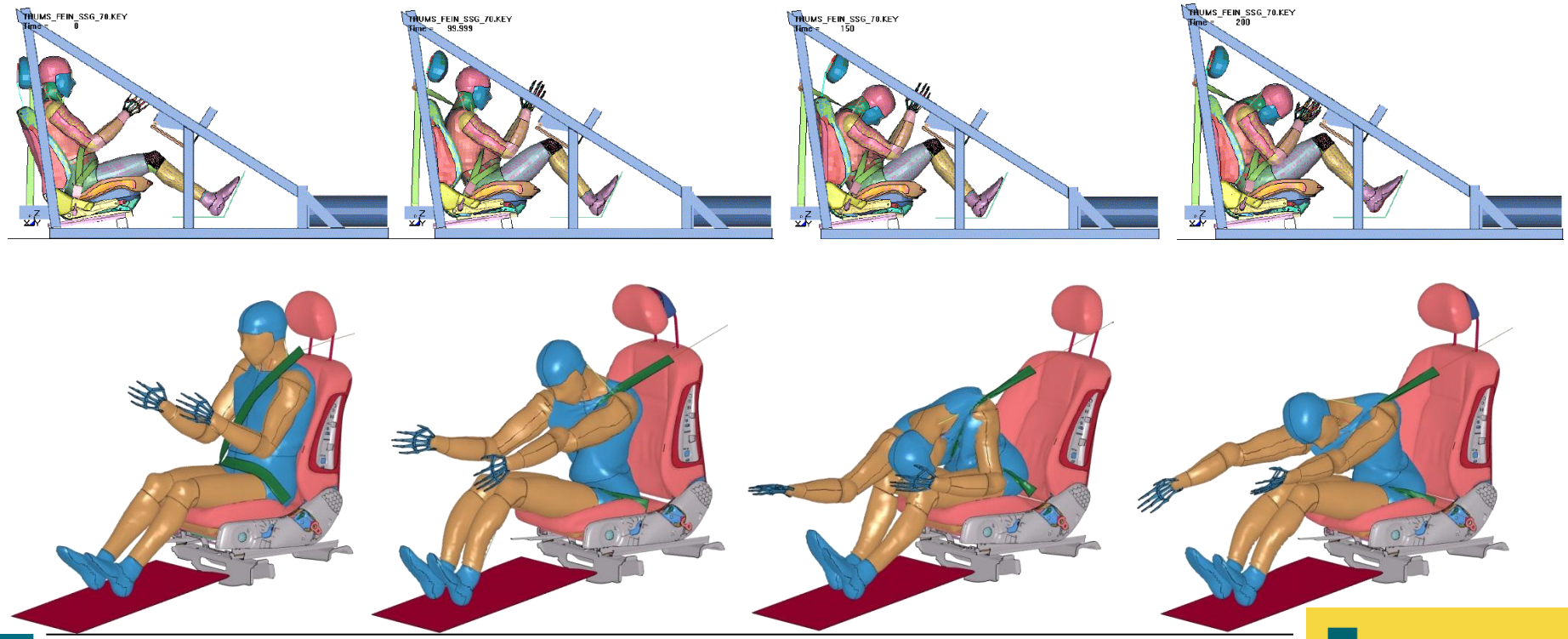
Application Example – Occupant Simulations

Applications THUMS Occupant Models

- dummy models available for frontal, rear and side impact situations
- get new insights from HBM (human body modelling) crash tests
  - improved biofidelity → reliable results in other crash scenarios

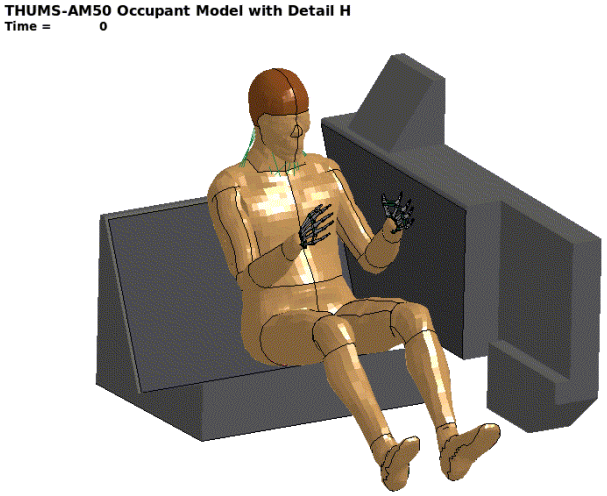
➢ evaluation of kinematics and possible injuries/injury criteria

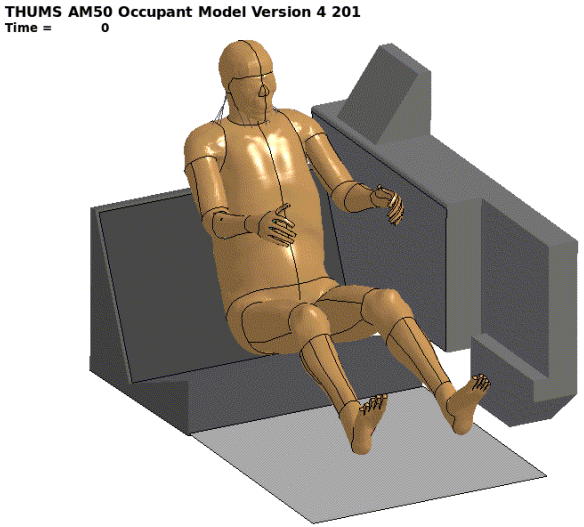
- knee impact simulation (Ipek et al. 2004 – Daimler AG)
- belt dimensioning / testing of alternative belt systems (Daimler AG)

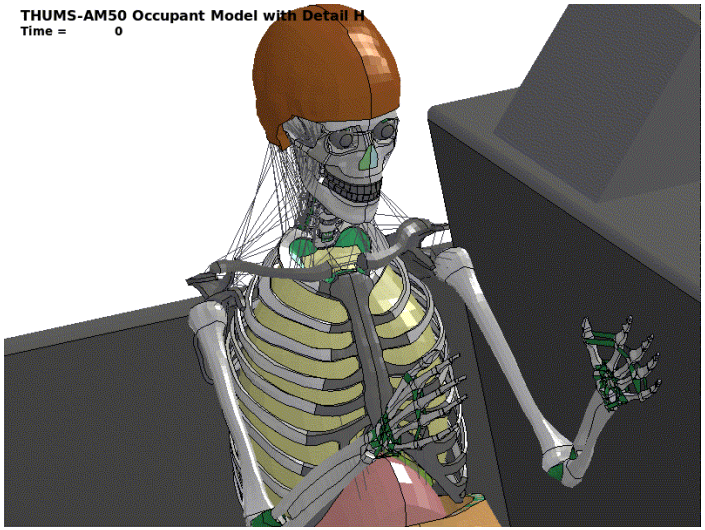


Application Example – Occupant Simulations

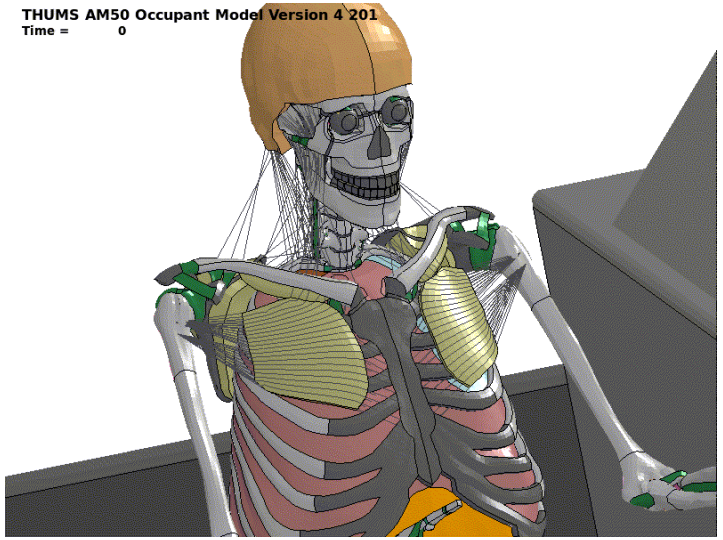
Occupant Barrier Impact







THUMS V3 impact from left total model and zoom on shoulder belt



THUMS V4 impact from left total model and zoom on shoulder belt

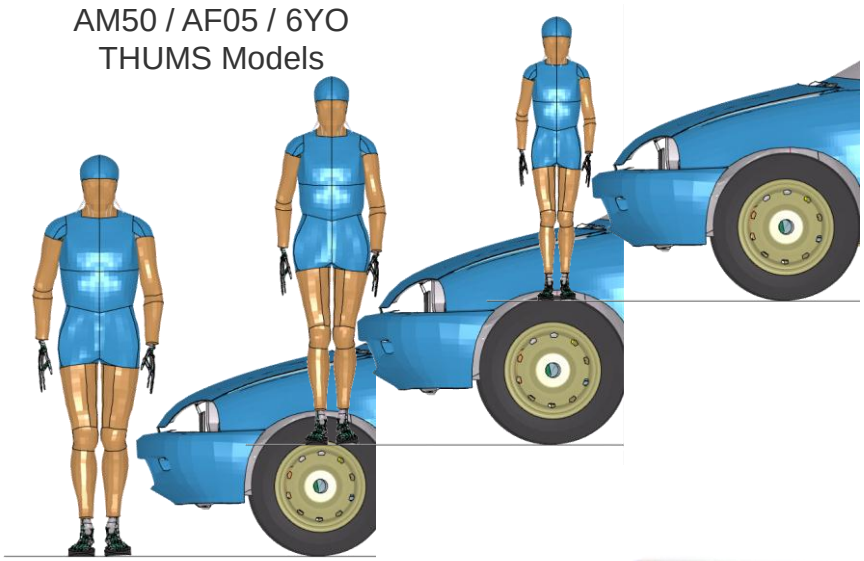
Application Example – Pedestrian Simulations

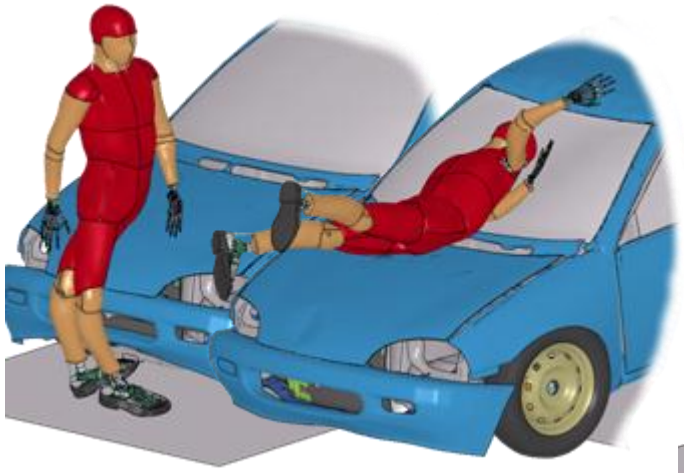
Pedestrian Frontal Impact

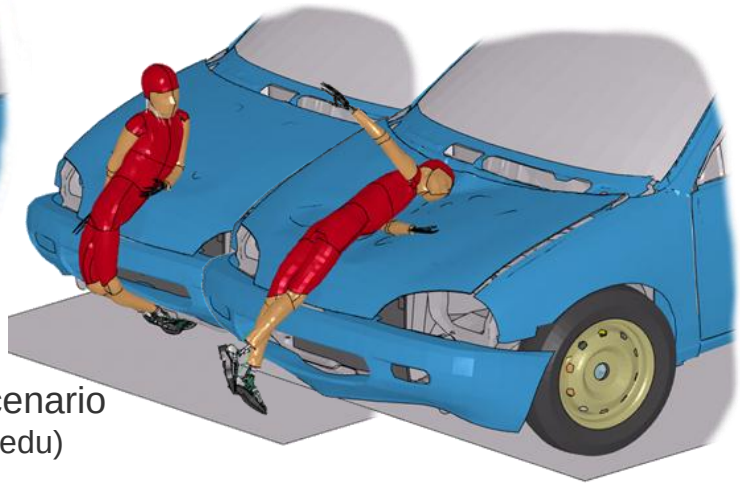
- no real pedestrian dummies available
- frontal impact using THUMS-Models
- evaluation: kinematical behaviour on bonnet; head impact location and time

➢ e.g. dimensioning of passive/active safety systems

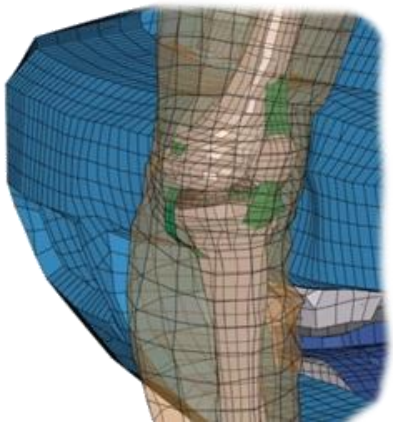
AM50 / AF05 / 6YO
THUMS Models







Kinematics for AM50 and 6YO impact scenario
(*Geo Metro* vehicle model – www.ncac.gwu.edu)



possible injury
simulation of bones

Remarks & Outlook

Some Remarks

- dramatically risen interest in human body modelling in automotive industry
- currently exclusive use of THUMS V3.0
  - primary concern: model kinematics in various crash situations → THUMS4 too detailed (expensive)
  - THUMS 3 model is easier to handle (numerically and biomechanically, validation issue)
  - validation only w.r.t. crash situations, rather than biomechanical injury mechanisms
- no injury criteria yet available for THUMS model(s)
  - direct simulation of injuries desirable, but difficult to realize (injury mechanisms, model validation)

➢ *we are still at the beginning of human body modelling in automotive applications !!!*

Outlook

- increase validation database for all body regions
- increase biomechanical (user) knowledge required for result extraction
- first step: establishment of a THUMS Users Community (TUC)
  - join forces in THUMS development, gather biomechanical knowledge and develop/establish useable injury criteria

The End …

Thank you for your Attention