LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

The THUMS User Community
Harmonisation of THUMS in Different Crash Codes

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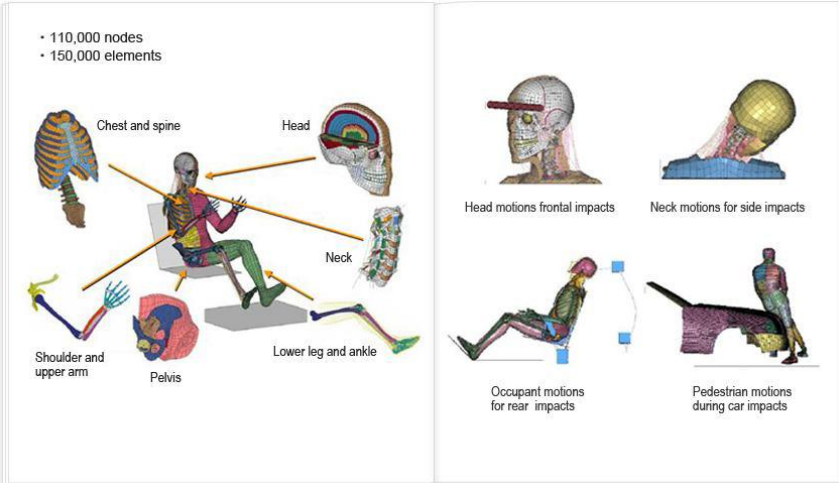
5th International Symposium on
Human Modeling and Simulation in Automotive Engineering

Agenda

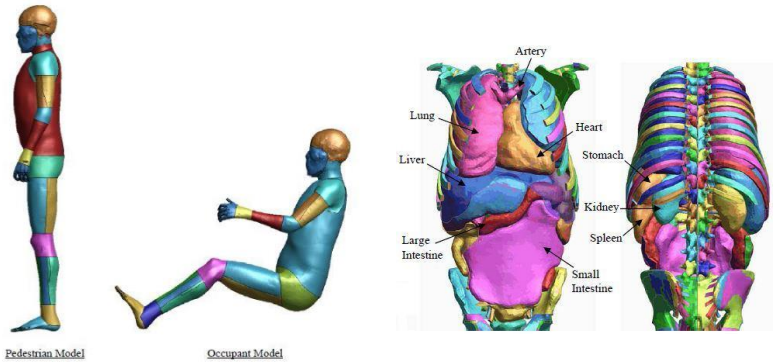
1. Introduction to the Project
   a. Challenges
   b. Motivation and Aims
2. Harmonisation of THUMS V3 in LS-Dyna, VPS and Abaqus: Process to THUMS TUC
   a. Identification of Modelling Guidelines
   b. Integration and Translation
   c. Multi-Stage Validation Catalogue
   d. Implementation of Harmonised Tracking Points
3. Status and Outlook

THUMS
Total HUman Model for Safety



THUMS version 3 (© JSOL Corporation)

- FE Human Model
- Developed by Toyota Motor Corporation and Toyota Central R&D Labs
- Human-like behaviour in crash
  - Human-like kinematics
  - Realistic loading representation in crash
- Representing American male body 50th percentile size (175cm, 77kg)
- Available in different versions



THUMS version 4 (© JSOL Corporation)

Injury Mode	Version 1	Version 3	Version 4
Fracture and Tendon rupture	Yes	Yes	Yes
Brain damage	No	Yes	Yes
Organ damage	No	No	Yes

Used within THUMS User Community

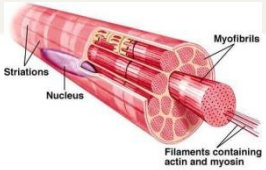
Finite Element Human Body Models: Challenges in General

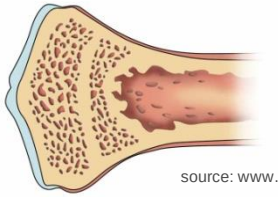
source: openwallpaper.info

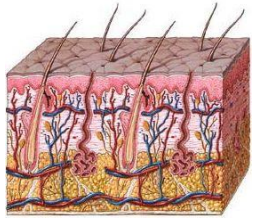
source: www.aokainc.com

Biological Materials

non-linear
viscoelastic
anisotropic





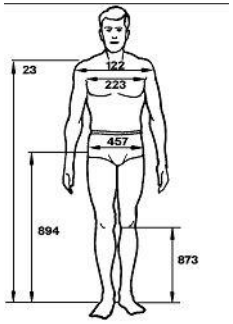


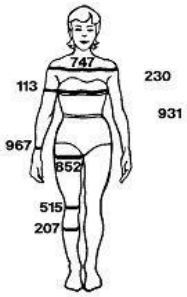
source: www.simple-health-secrets.com

Complex Geometries

Anthropometric Diversity

Children
Men/ Women
Elderly





source: www.msis.jsc.nasa.gov

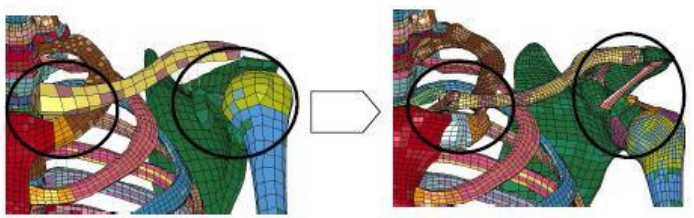
Different impact scenarios:

e.g. frontal/ lateral
Interaction between occupant and belt/ airbag

Motivation for the project

- Common motivation and interest of project partners to constantly improve vehicle and traffic safety
  - Implementation of HBMs as tool for the evaluation of passive safety systems

- Harmonisation, provision and maintenance of THUMS in 3 different codes (DYNA, VPS, Abaqus)
  - No uniform model available among project partners
    - THUMS was further developed by several project partners
      - Daimler: shoulder, improved mesh



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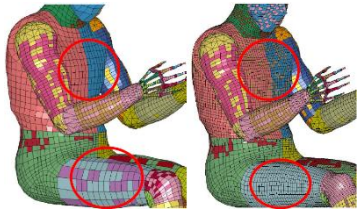

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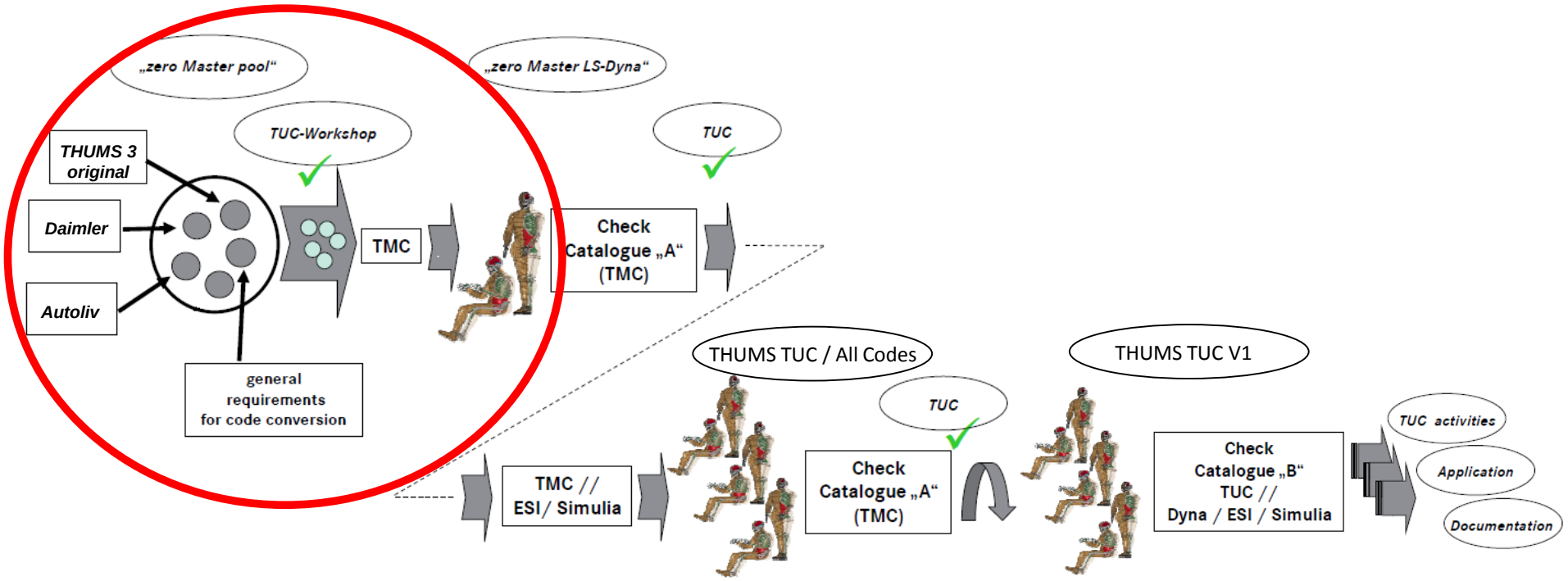
      - Autoliv: thorax, complete remeshing of ribs

Aims and Objectives

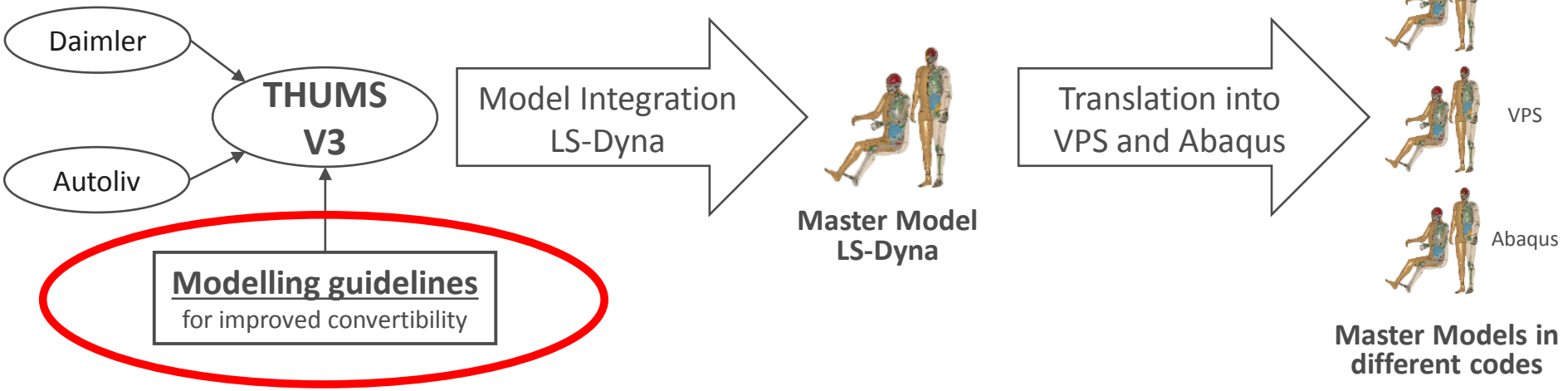
Harmonisation, provision and maintenance of a FE – Human Body Model for vehicle and traffic safety application

- ✓ Safeguarding effective and robust usability of THUMS by implementation of a dedicated tool management, support and documentation.
- ✓ Set up a platform to share and exchange pre-competitive know-how and experience with the application of THUMS.
- ✓ Discuss and formulate framework requirements to establish a permanent institution by the end of this project to continue this platform approach.
- ✓ Exchange and documentation of research results and initiation of further research activities
- ✓ Gain new members contributing to the project

Process to THUMS TUC



Harmonisation of THUMS V3 in LS-Dyna, VPS and Abaqus



Finite Element Human Body Models: Challenges in Using Different Crash Codes

Solver dependent…

…numbering systems,

mesh requirements,

contact algorithms,

material modelling…

} … cause solver dependent simulation results!

Identification of Modelling Guidelines

Definition of **modelling guidelines** to ensure an **improved convertibility** between the solvers LS-Dyna, VPS and Abaqus concerning…

…numbering systems,

mesh requirements,

contact algorithms,

material modelling…

Identification of Modelling Guidelines

Definition of **modelling guidelines** to ensure an **improved convertibility** between the solvers LS-Dyna, VPS and Abaqus concerning…

…numbering systems,

mesh requirements,

contact algorithms,

material modelling…

Requirements for improved convertibility

- Unique numbering of elements / parts / nodes

Identification of Modelling Guidelines

Definition of **modelling guidelines** to ensure an **improved convertibility** between the solvers LS-Dyna, VPS and Abaqus concerning…

…numbering systems,

mesh requirements,

contact algorithms,

material modelling…

Requirements for improved mesh

- Elements might be accepted by one solver but not by the other ones
- Definition of minimum mesh quality / element criteria

Identification of Modelling Guidelines

Definition of **modelling guidelines** to ensure an **improved convertibility** between the solvers LS-Dyna, VPS and Abaqus concerning…

…numbering systems,

mesh requirements,

contact algorithms,

material modelling…

Requirements for contact definitions

- Avoidance of segment sets in LS-Dyna
- Removal of initial penetrations as far as possible

Identification of Modelling Guidelines

Definition of **modelling guidelines** to ensure an **improved convertibility** between the solvers LS-Dyna, VPS and Abaqus concerning…

…numbering systems,

mesh requirements,

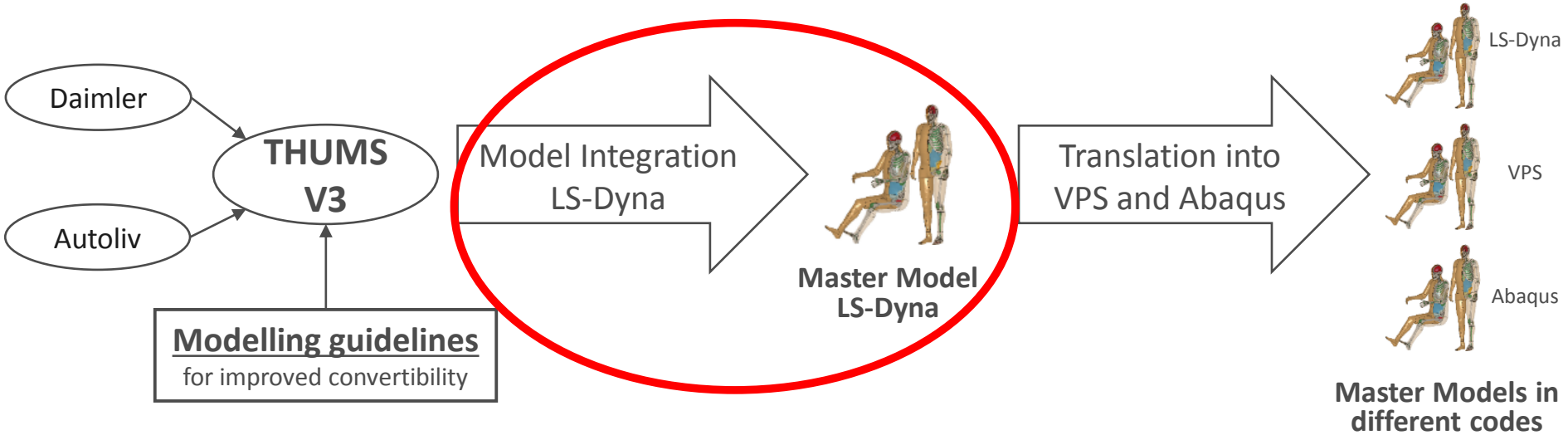
contact algorithms,

material modelling…

Requirements for material modelling

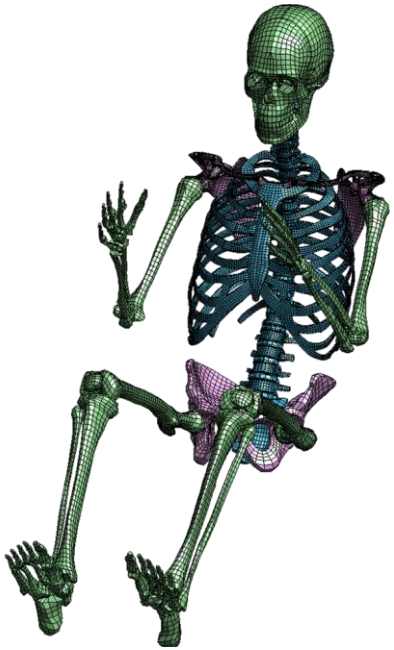
- Prefer material which is directly translatable
- Etc.

Harmonisation of THUMS V3 in LS-Dyna, VPS and Abaqus



Model Integration (TMC)

- ✓ TUC 1st Master Model was developed integrating Daimler Pedestrian and Occupant Models and Autoliv Occupant Model.



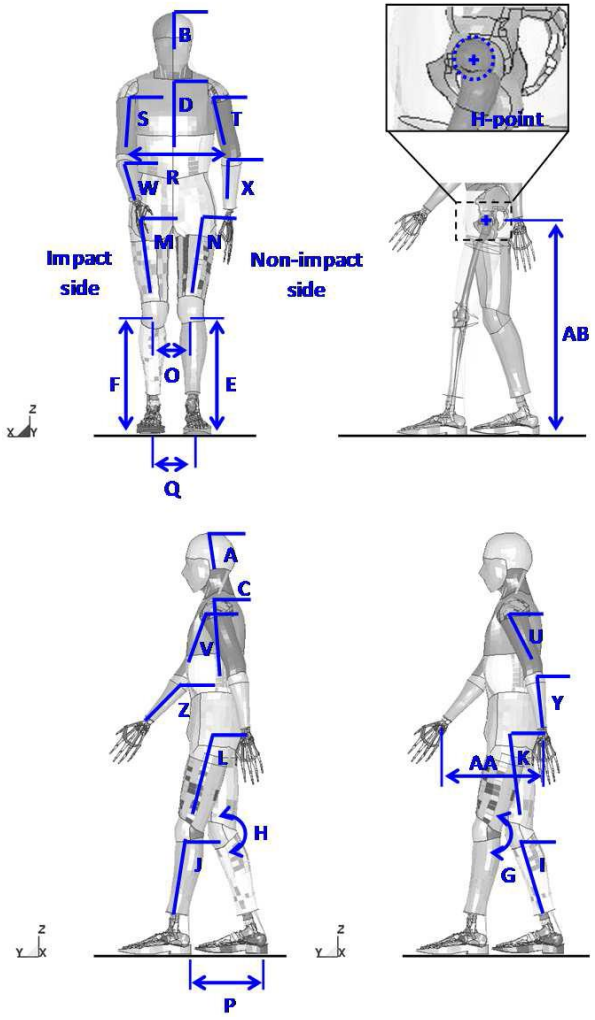
- Daimler Pedestrian
- Daimler Occupant
- Autoliv Occupant

Model Specification

Elements:	227,744
Nodes:	165,993
Parts:	1,576
Time Step:	2.77E-1

Body Region	Daimler Pedestrian	Daimler Occupant	Autoliv Occupant
Head			
Neck			X
Thorax		X	X
Abdomen			X
Pelvis		X	X
Extremities	X		

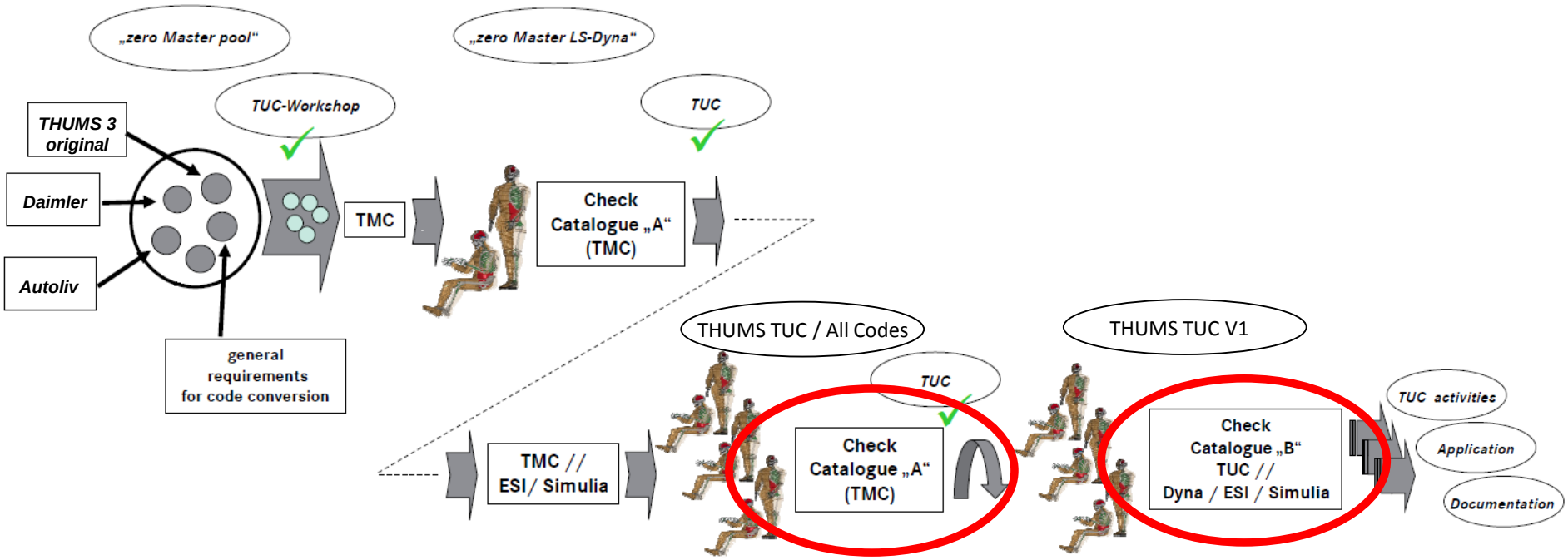
Positioning for Pedestrian



- ✓ THUMS TUC pedestrian obtained by positioning the occupant model
- ✓ Positioned to SAE J2782 (EuroNCAP T/P V7 compatible)

Segment	Aspect	Units	Axis	SAE J2782	TUC AM50
Head angle		deg	About X	83 ±5	83
		deg	About Y	90 ±5	90
Torso angle		deg	About X	83 ±5	85
		deg	About Y	90 ±5	90
Knee height	Non-impact side	mm	Z	505 ±10	505
	Impact side	mm	Z	520 ±10	493
Knee bend angle	Non-impact side	deg	Angle in YZ plane	171 ±5	182
	Impact side	deg	Angle in YZ plane	164 ±5	182
Tibia angle	Impact side	deg	About X	73 ±5	79
	Non-impact side	deg	About X	98 ±5	100
Femur angle	Impact side	deg	About X	89 ±5	78
	Non-impact side	deg	About X	107 ±5	97
	Impact side	deg	About Y	87 ±5	84
	Non-impact side	deg	About Y	94 ±5	96
Knee to knee width		mm	X	280 ±10	171
Heel to heel distance		mm	Y	310 ±10	311
		mm	X	280 ±10	97
Elbow to elbow width		mm	X	420 ±10	436
Upper arm angle	Impact side	deg	About Y	-	95
	Non-impact side	deg	About Y	-	78
	Non-impact side	deg	About X	-	65
	Impact side	deg	About X	-	111
Lower arm angle	Impact side	deg	About Y	-	82
	Non-impact side	deg	About Y	-	269
	Non-impact side	deg	About X	-	-89
	Impact side	deg	About X	-	136
wrist to wrist distance		mm	Y	-	410
H-point		mm	Z	-	949

Process to THUMS TUC



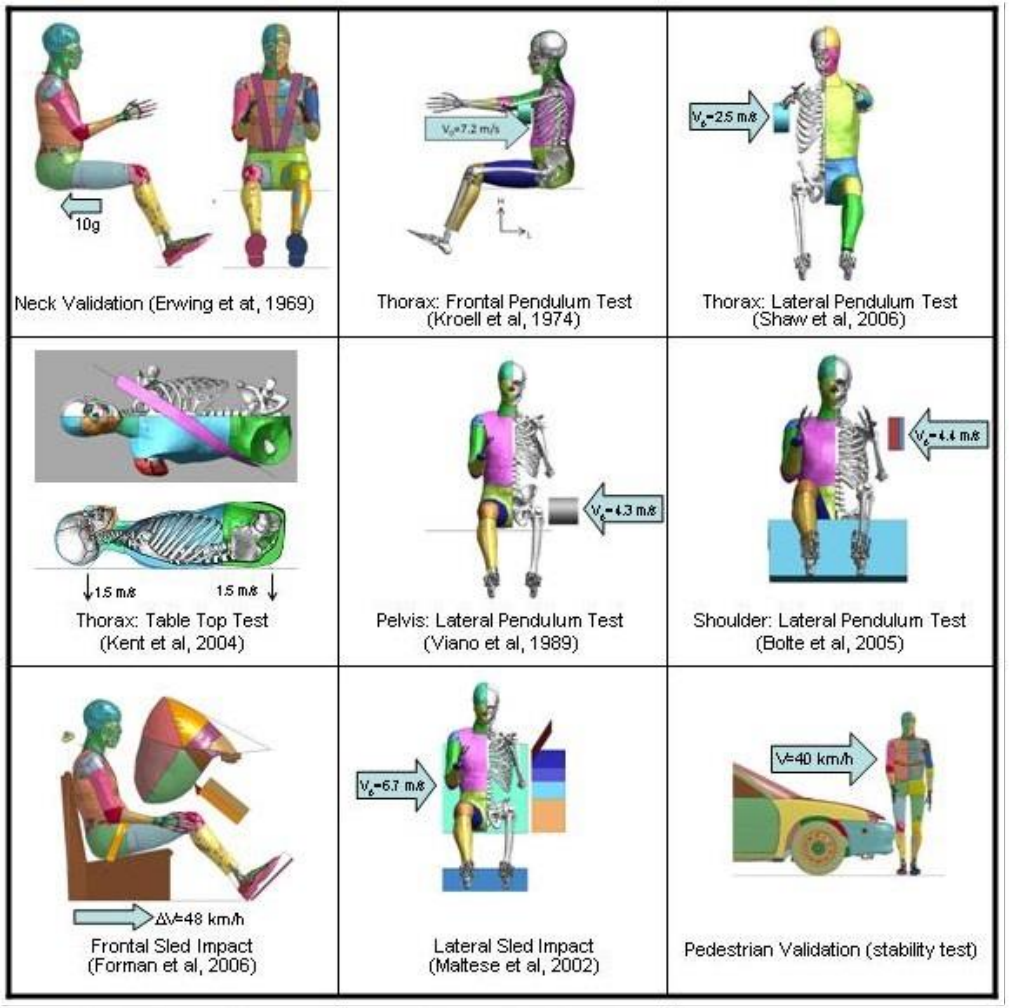
Multi-Stage Validation Catalogue

Validation Catalogue A		
Comparability of models	Robustness check	9 load cases

Validation Catalogue B			
Comparability of models	Robustness	Biomechanical quality	Approx. 30 load cases

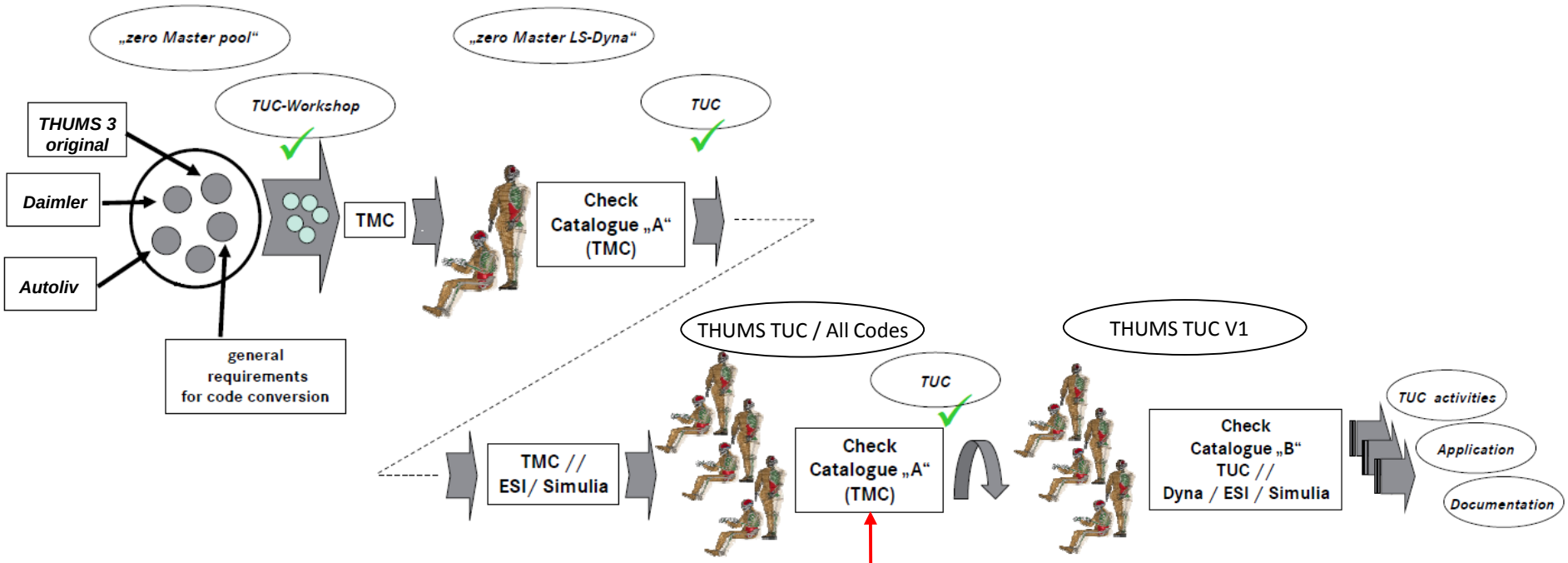
Validation Catalogue C	
Advanced biomechanical assessment	Load cases to be defined

Validation Catalogue A



- ✓ 9 validation cases on neck, thorax, pelvis, shoulder, whole body (occupant and pedestrian)
- ✓ Basic validation checks
- ✓ Robustness checks
- ✓ Comparability between codes
- ✓ Cases defined for occupant and pedestrian validation independently

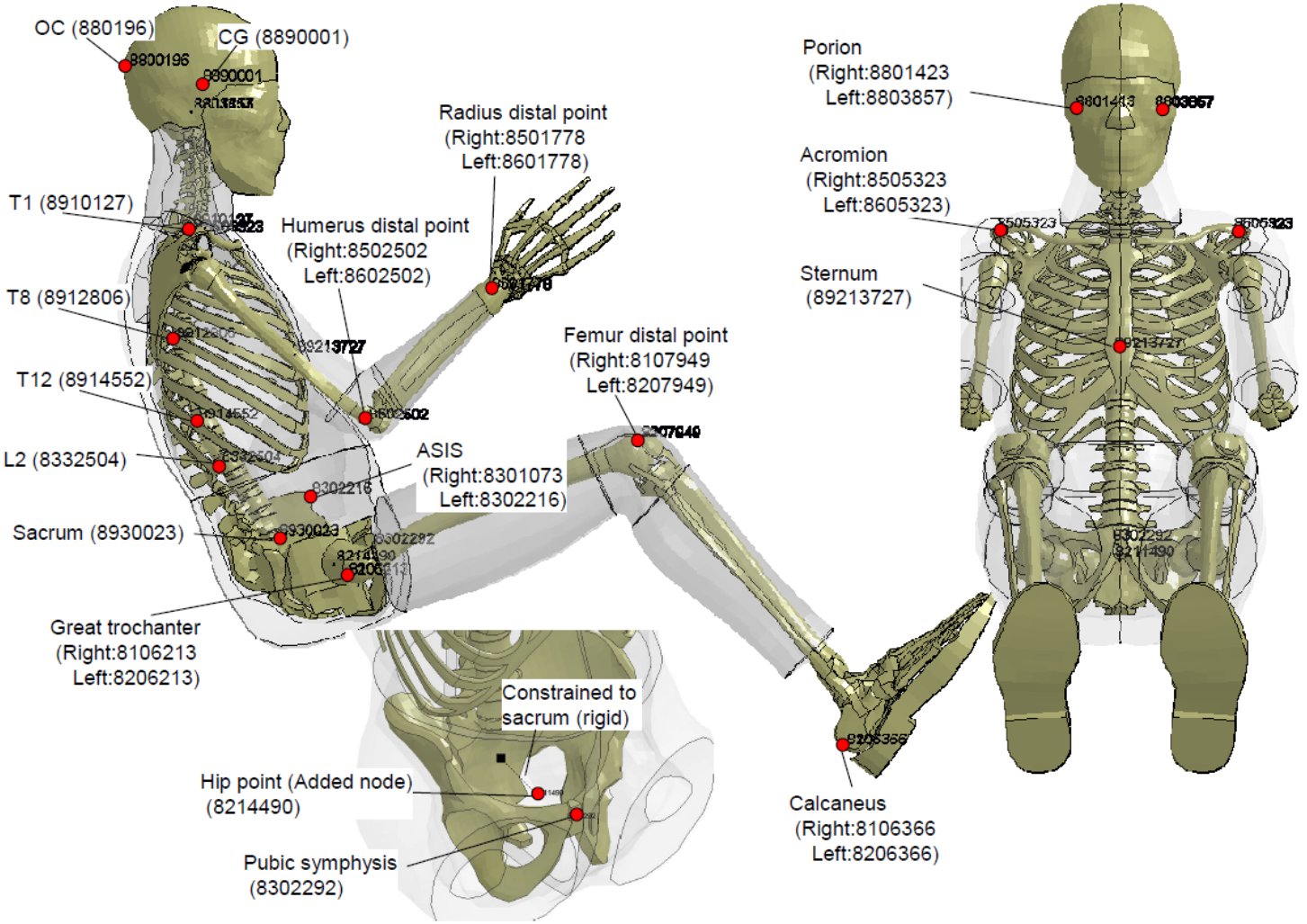
Process to THUMS TUC



TUC Tracking Points

✓Basic tracking of the occupant’s kinematics

Comparability of Simulation Results



Status

Work already conducted

- ✓ Identification of *Modelling Guidelines*
- ✓ Creation of harmonised Master Models in LS-Dyna, VPS and Abaqus
- ✓ Validation Catalogue A
- ✓ Identifying load cases for Validation Catalogue B, specifying boundary conditions
- ✓ Establishment of a platform for general and model-specific documentation and exchange

Outlook

Outlook

- ✓ Running Validation Catalogue B
- ✓ Foster discussion with external partners on state-of-the-art validation catalogue
- ✓ Providing database of simulation setups for validation (tuc-project.org)
- ✓ Development of harmonised pre-processing methods for the application of HBMs (positioning and scaling)
- ✓ Post-processing: Development of objective criteria for the evaluation of the performance of HBMs, including improved tracking/reference points

Web link: www.TUC-project.org

THANK YOU!

Acknowledgment:

The work presented has been conducted by **THUMS User Community**, a project of LMU in cooperation with Adam Opel AG, AUDI AG, Autoliv, BMW AG, Daimler AG, Dr. Ing. h.c.F. Porsche AG, Toyota Motor Corporation and Volkswagen Aktiengesellschaft.