

Development of Load Cases for Robustness Evaluation of HBMs

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Agenda

- 1. The THUMS User Community (TUC)**
- 2. TUC Validation Repository**
- 3. Development of Robustness Load Cases**

THUMS User Community

Core Partners



PORSCHE

DAIMLER



VOLKSWAGEN
AKTIENGESELLSCHAFT

Technical Advisor



Coordinator

LMU

Associated Partners

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Development Partners

DYNA
MORE

esi
get it right®

Collaborations (inter alia)



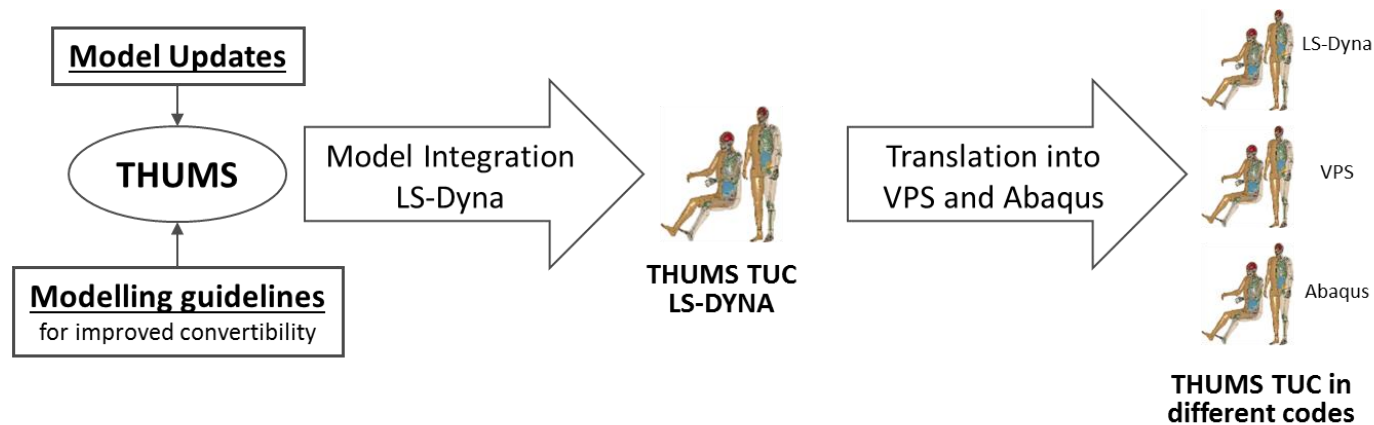
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Key Project Data

- **Duration** 3.5 years (Mar 2017 – Oct 2020)
- **Scientific Director** Prof. Dr. Steffen Peldschus
- **Project Coordinator** Dr. Therese Fuchs
Biomechanics and Accident Analysis Group, LMU
- **TUC founding members** Adam Opel AG, Audi AG, Autoliv, BMW AG, Daimler AG, LMU, Porsche AG, Toyota Motor Corporation, Volkswagen AG
- **Preceding project:** “TUC1”: Dec 2012 – May 2016

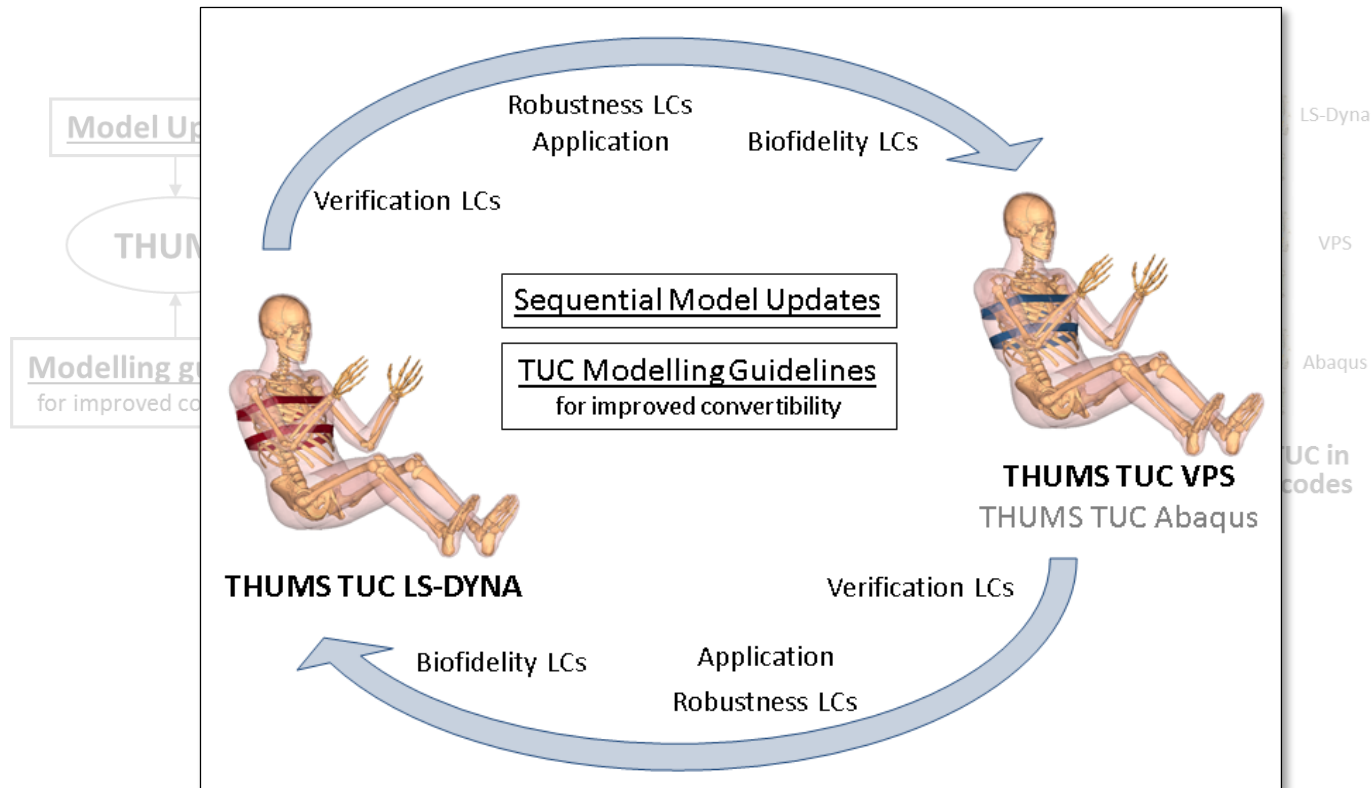
Aims and Objectives

- Harmonisation, provision and maintenance of a FE Human Body Model (THUMS™) in the three crash codes LS-DYNA, VPS and Abaqus
- Old Process:



Aims and Objectives

- Harmonisation, provision and maintenance of a FE Human Body Model (THUMS™) in the three crash codes LS-DYNA, VPS and Abaqus
- Updated Process:

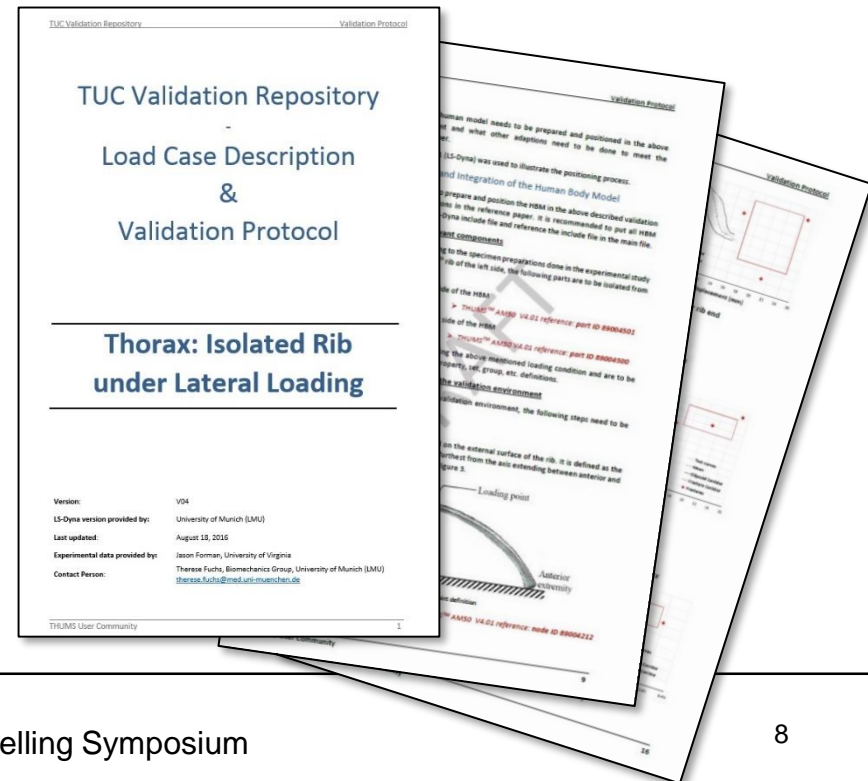


Aims and Objectives

- Harmonisation, provision and maintenance of a FE Human Body Model (THUMS™) in the three crash codes LS-DYNA, VPS and Abaqus
- Development of agreed procedures for the use of Human Body Models in terms of...
 1. ... an improved model convertibility between codes
 2. ... defining validation procedures
 3. ... defining pre- and post-processing methods

TUC Validation Repository

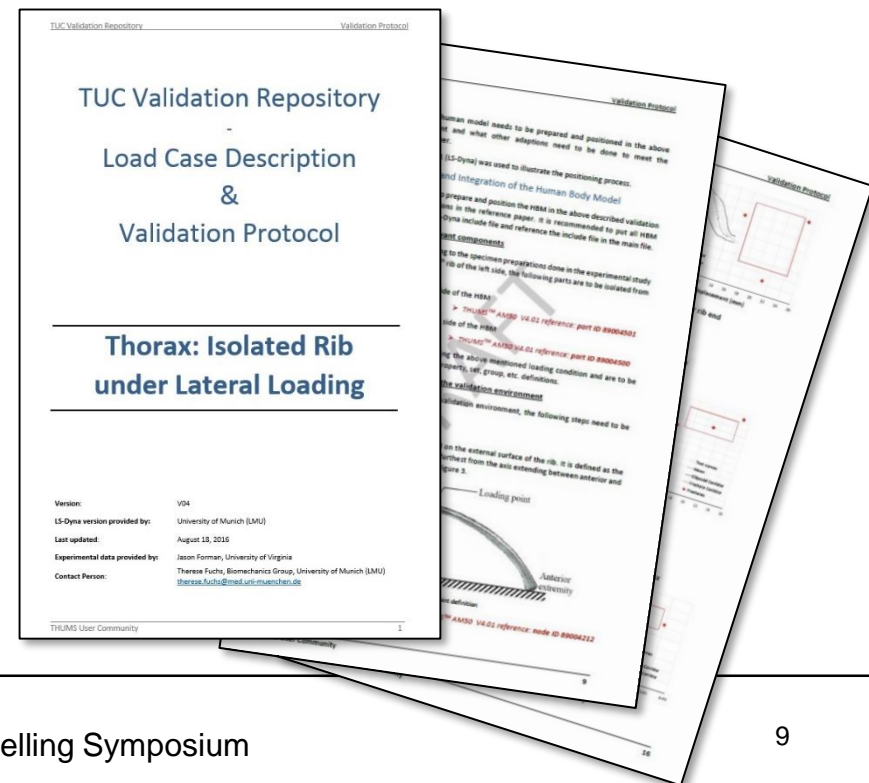
www.tuc-project.org/validation-repository



TUC Validation Repository

- Database with FE models of validation setups of state-of-the-art load cases for validating HBMs
- Precise documentation for a consistent application when evaluating HBMs
- Experimental data / validation parameters provided by institutions where testing was conducted
- Available in different crash codes (Abaqus, LS-Dyna, Radioss, VPS)
- Numerical check by Development Partners (DYNAmore, ESI)

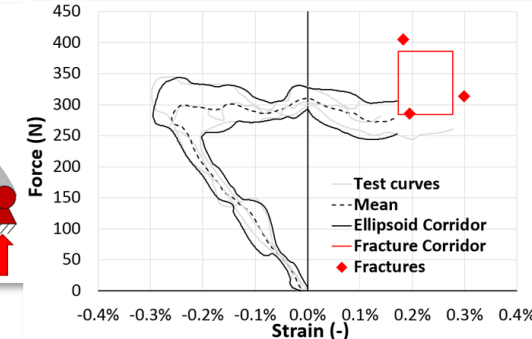
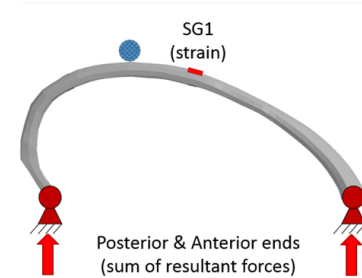
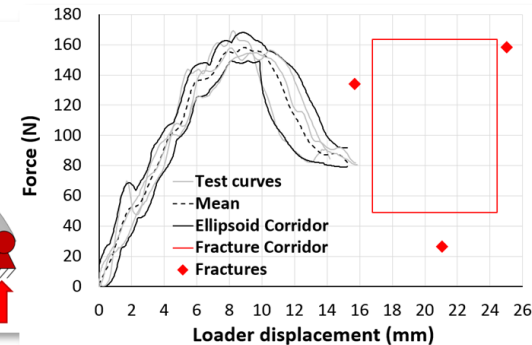
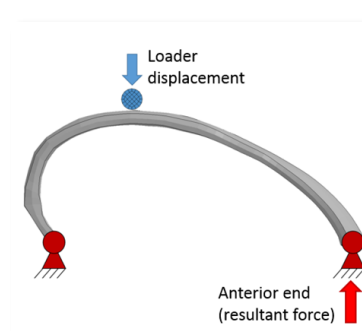
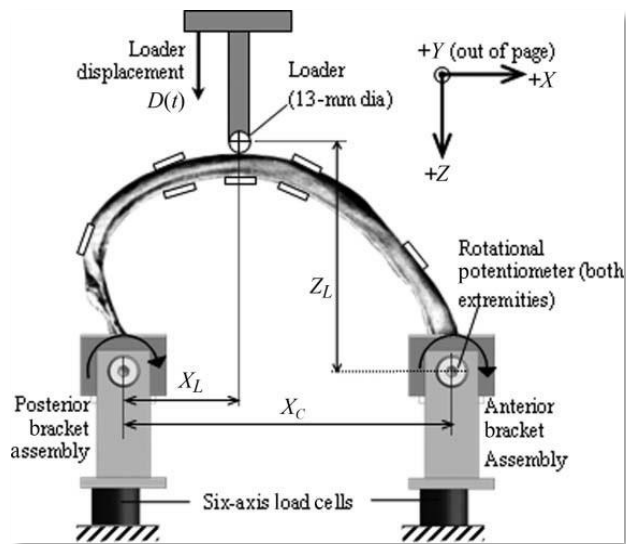
www.tuc-project.org/validation-repository



TUC Validation Repository

➤ Available in three crash codes:

- Isolated Rib under Lateral Loading
- Experiments published by Del Pozo et al. (2011)
- Validation Setup developed in cooperation with University of Virginia (UVA)
- Experimental data / corridors provided by UVA

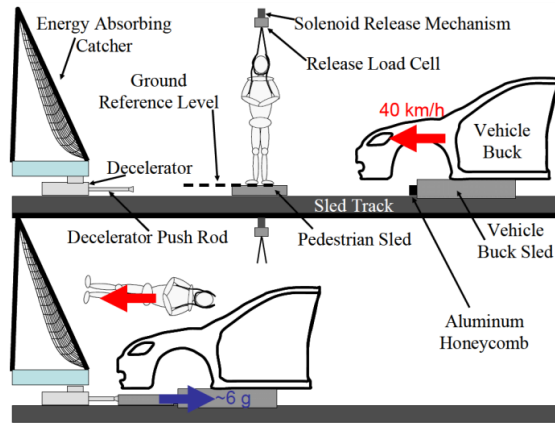


Del Pozo et al. (2011)
Toczynski et al. (2016)

TUC Validation Repository

➤ Available as beta-model

- Whole-Body Pedestrian Impact with a Generic Buck
- Experiments published by Forman et al. (2015)
- Generic buck model agreed SAE standard (SAE 3093)
- Validation Setup developed in cooperation with Autoliv



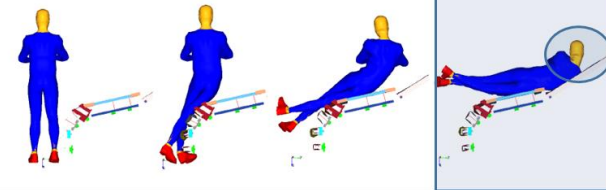
PMHS
[1]



THUMS V4.02
[6]



GHBMCS



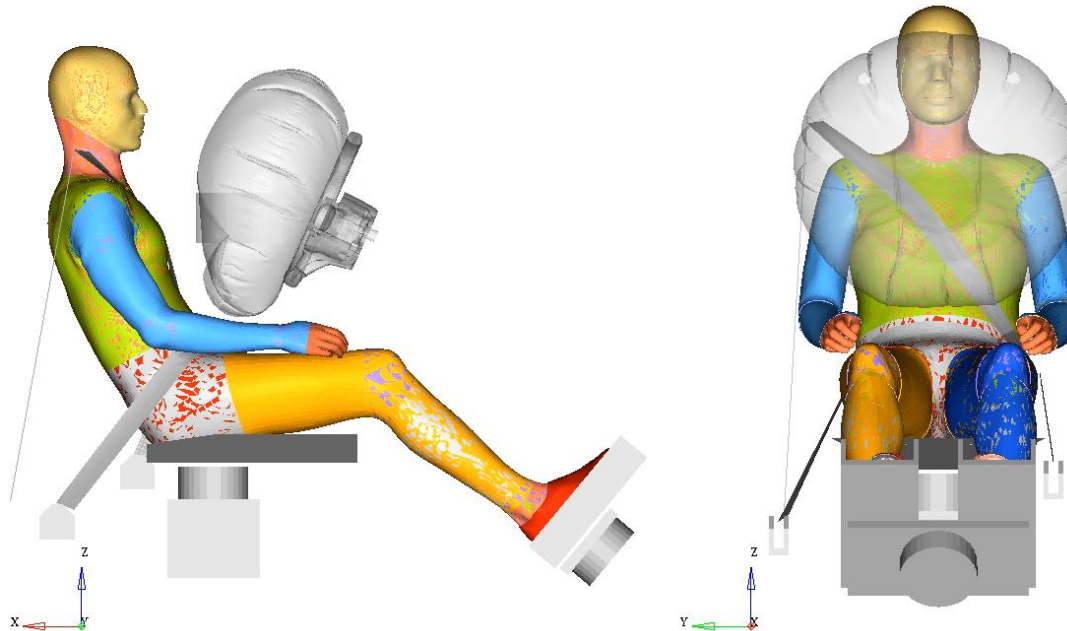
Kerrigan et al. (2005)
Forman et al. (2015)
Pipkorn et al. (2015)
Steinert et al. (2018)



TUC Validation Repository

➤ **Work in progress**

- Frontal sled using a generic test rig
- Experiments conducted within SENIORS EU project
- Experimental data published by Francisco J. Lopez-Valdes
- Validation Setup developed in cooperation with SENIORS



Lopez-Valdez et al. (2017)

TUC Validation Repository

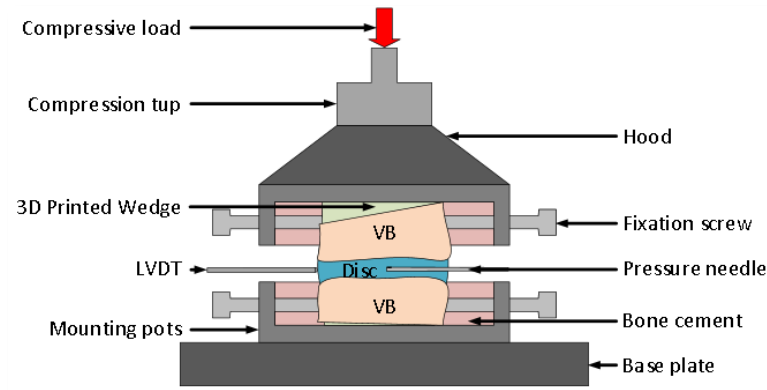
➤ Work in progress (cont'd)

1. Frontal sled (Gold Standard/Shaw, 2009) in cooperation with BASt and UVa
2. Dynamic bending of femur acc. to Forman et al. (2011)
3. Intervertebral disc under axial compression acc. to Newell et al. (2017) in cooperation with Imperial College London

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UNIVERSITY
of VIRGINIA
CENTER FOR APPLIED
BIOMECHANICS

**Imperial College
London**



Newell et al. (2017)

Shaw et al. (2009)
Forman et al. (2011)
Draper et al. (2018)

Agenda

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- 3. Development of Robustness Load Cases**

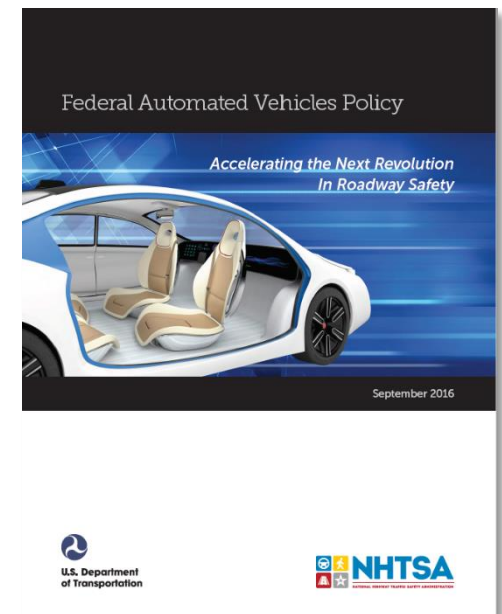
Robustness Evaluation of HBMs

➤ Motivation

- FE Human Body Models to complement conventional dummy models and expected to become method of choice to evaluate active and passive safety systems, especially w.r.t. to future driving modes
- Robust models necessary in industrial processes when developing and optimizing safety systems
- Trade-off between biofidelity and robustness?



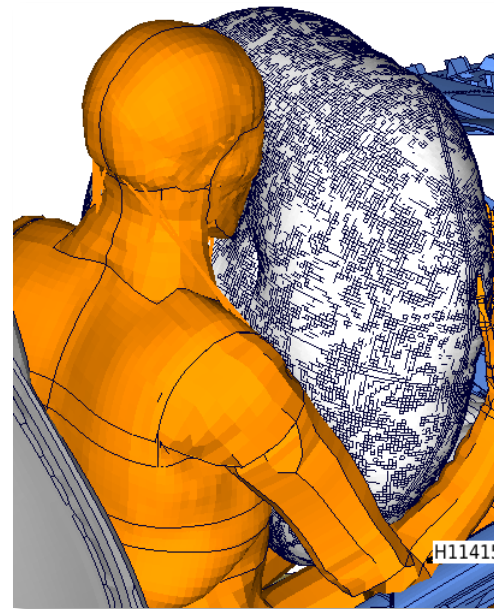
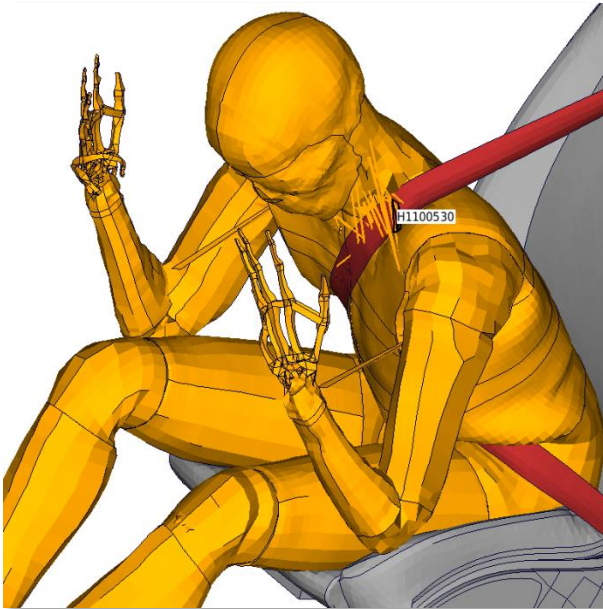
Genfer Autosalon 2014: Rinspeed XchangeE



NHTSA 2016

Robustness Evaluation of HBMs

- **Compilation of critical interactions between HBMs and vehicle interior / safety systems within TUC project partners**

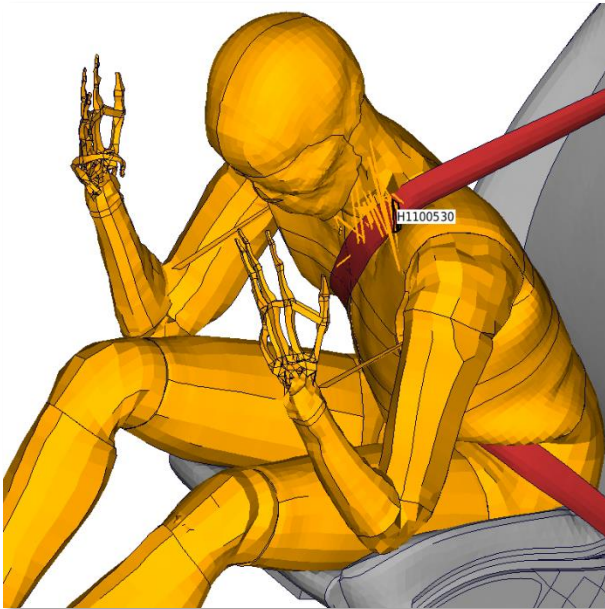


Images: Courtesy of Porsche AG

→ **Development of reference robustness load cases**

Robustness Evaluation of HBMs

➤ Example 01:



Images: Courtesy of Porsche AG

➤ Reported by Porsche AG:

- Error termination due to instable soft tissue in in-house application case

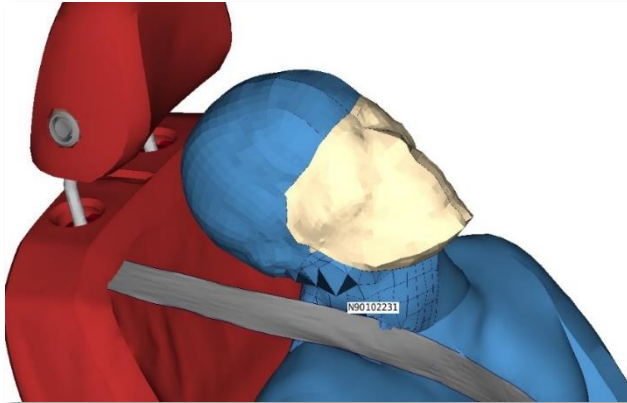


➤ Derivation of robustness load case

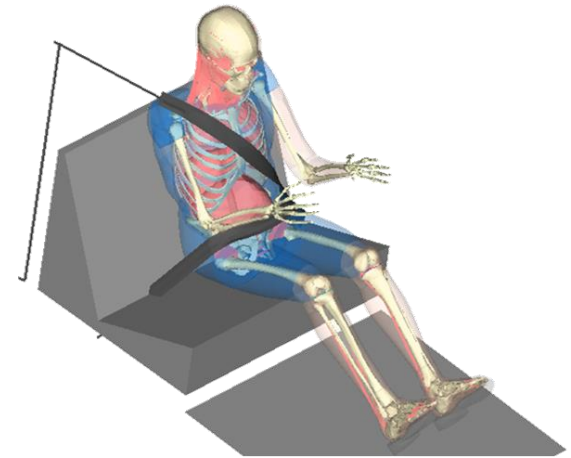
- Frontal sled based on Gold Standard 1 (Shaw et al., 2009): no load limiting, no belt-pre-tensioning
- Modified pulse: small vehicle pulse in a 56km/h FWRB, downscaled

Robustness Evaluation of HBMs

➤ Example 02:



Images: Courtesy of Volkswagen AG



➤ Reported by Volkswagen AG:

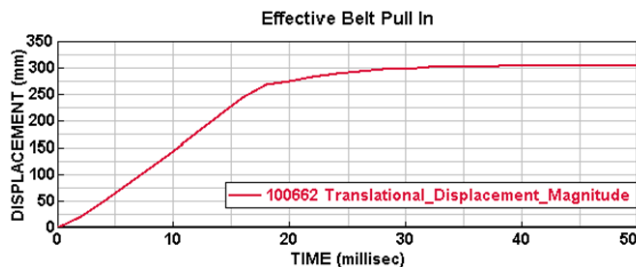
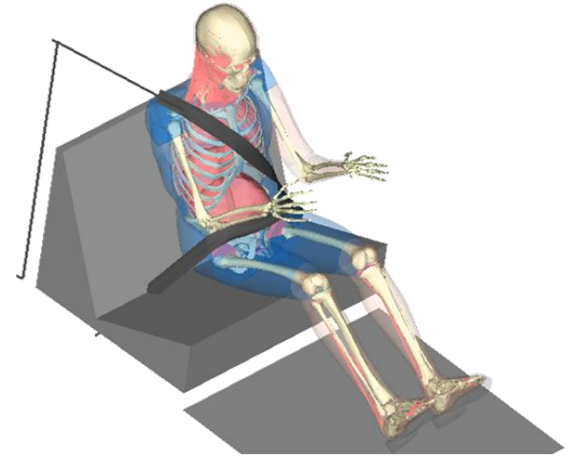
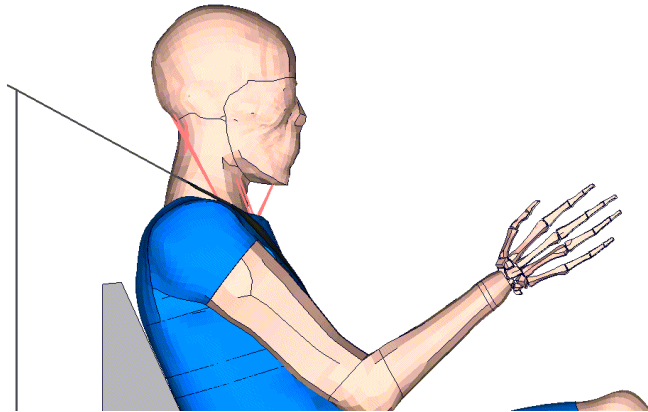
- US NCAP frontcrash with initial pre-crash braking
- HBM: THUMS TUC reactive VW (Code VPS)
- Belt with load limiter and pretensioner
- Instable soft tissue

➤ Derivation of additional robustness load case

- Instantaneous pretensioning of shoulder belt
- No pulse

Robustness Evaluation of HBMs

➤ Robustness Load Case 02:

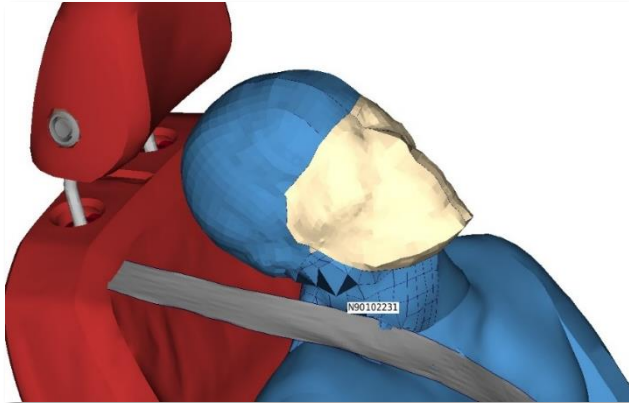


➤ Derivation of additional robustness load case

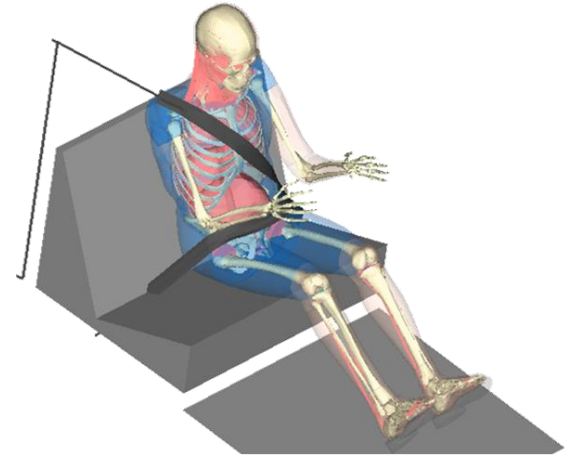
- Instantaneous pretensioning of shoulder belt
- No pulse

Robustness Evaluation of HBMs

- **Summary of approach:**



Images: Courtesy of Volkswagen AG



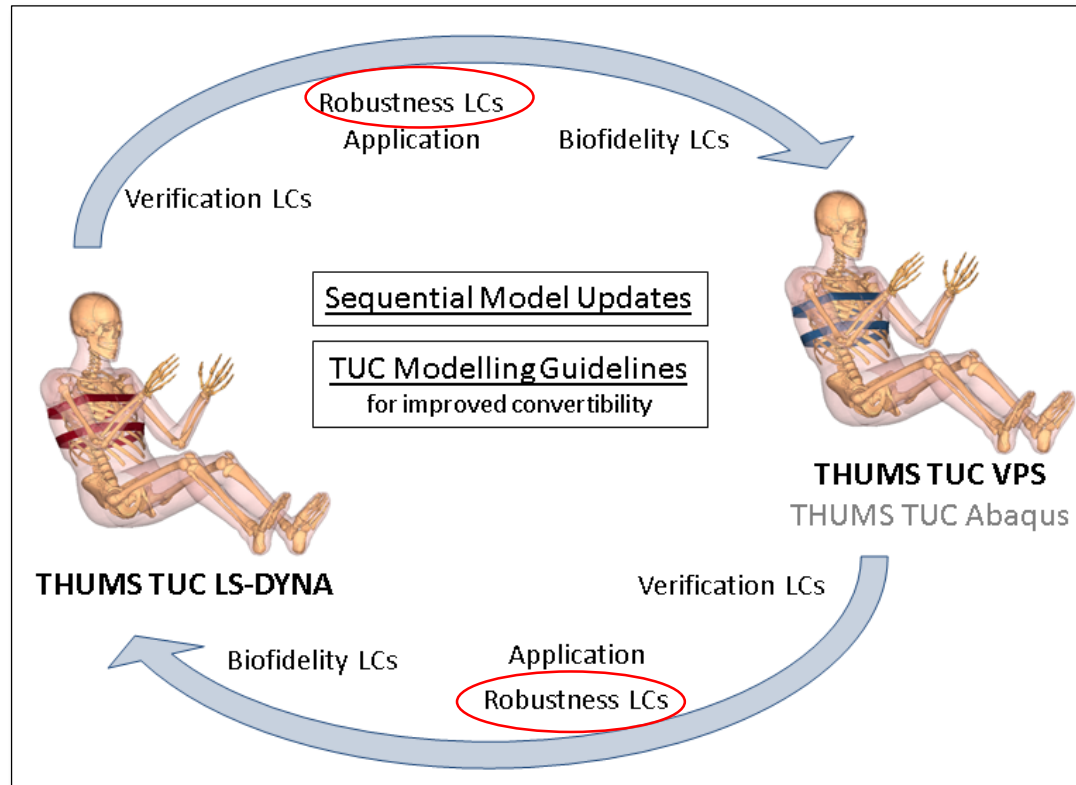
- **Reported issues in applications**

- **Derivation of robustness load cases**

Verify how robustness LC could have detected/prevented instability

Robustness Evaluation of HBMs

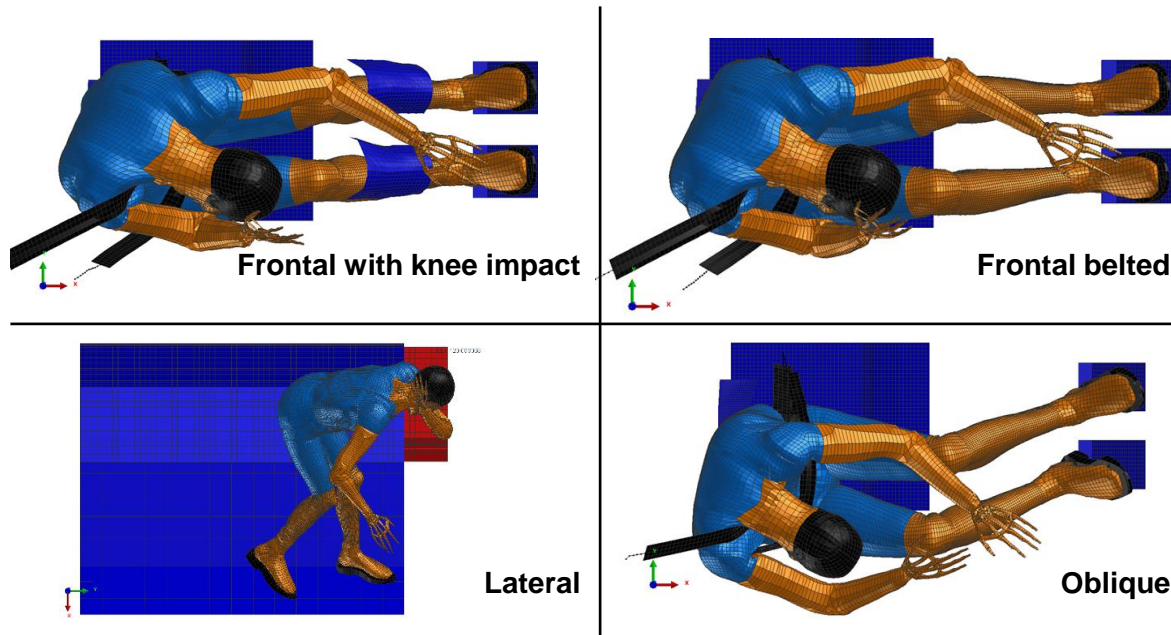
➤ Use of Robustness Load Cases:



Robustness Evaluation of HBMs

➤ Outlook

- Large rotation errors as well as negative volume errors are typical problems for largely deformed soft tissue together with unstable material definition. Robustness load cases could reveal those problems earlier.
- Exploring the limits of the models' predictive capability
- Complete analysis on crucial load case details (model positioning, belt position,...)
- Addressing the development of further robustness load cases representing reported application scenarios



- Upon completion: Make Robustness Load Cases publically available

THANK YOU



HUMAN MODELING
AND SIMULATION
IN AUTOMOTIVE ENGINEERING

