# Occupant Simulation for the Mercedes-Benz S-Class

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# Occupant Simulation at Mercedes-Benz Cars
# Contents

Mercedes-Benz

# Occupant Simulation at Mercedes-Benz Cars
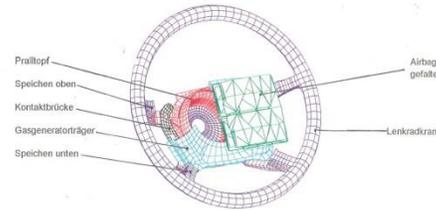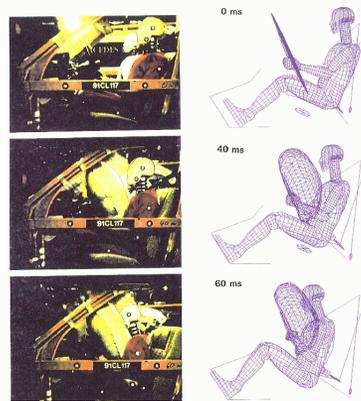# History Frontal Impact (1991-2009)

Start 1991:
MADYMO (Dummy)

1991-2009:     Madymo Models
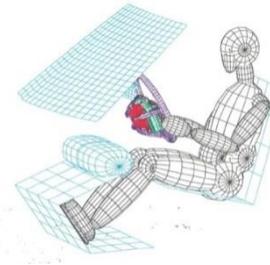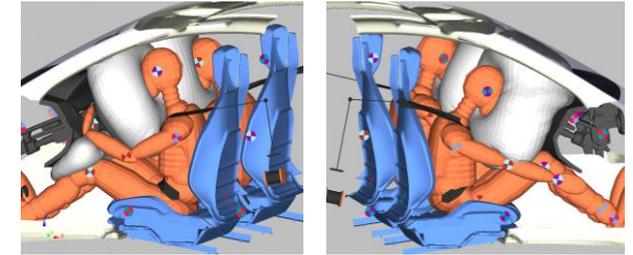Example W140, W220 and C207

1994:
dummy kinematic
investigations
for W140

1994: knee bolster
investigations
for W220
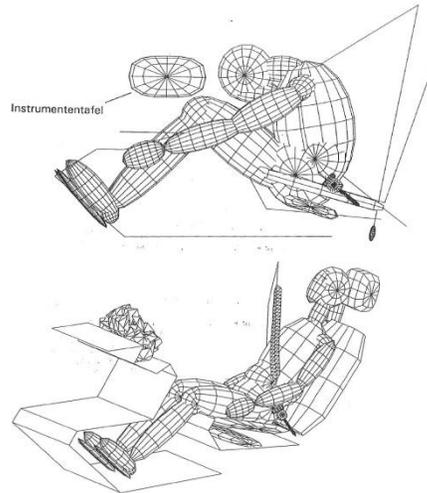
since 2004:
LS-Dyna-Models for Sled– and
integrated crash simulation
(Example W212)
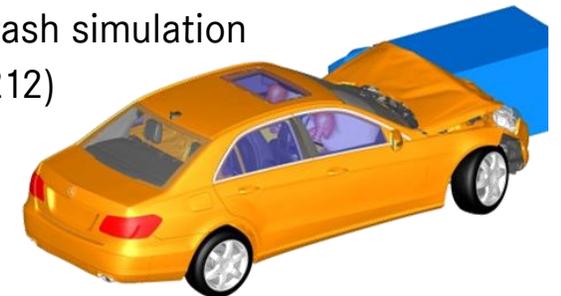
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# Occupant Simulation at Mercedes-Benz Cars
# Evolution of Side Impact Simulation:



5%-Sitzposition W210 bei t = 20ms nach t0, asym. Sidebag  50%-Sitzposition W210 bei t = 20ms nach t0, asym. Sidebag  95%-Sitzposition W210 bei t = 20ms nach t0, asym. Sidebag
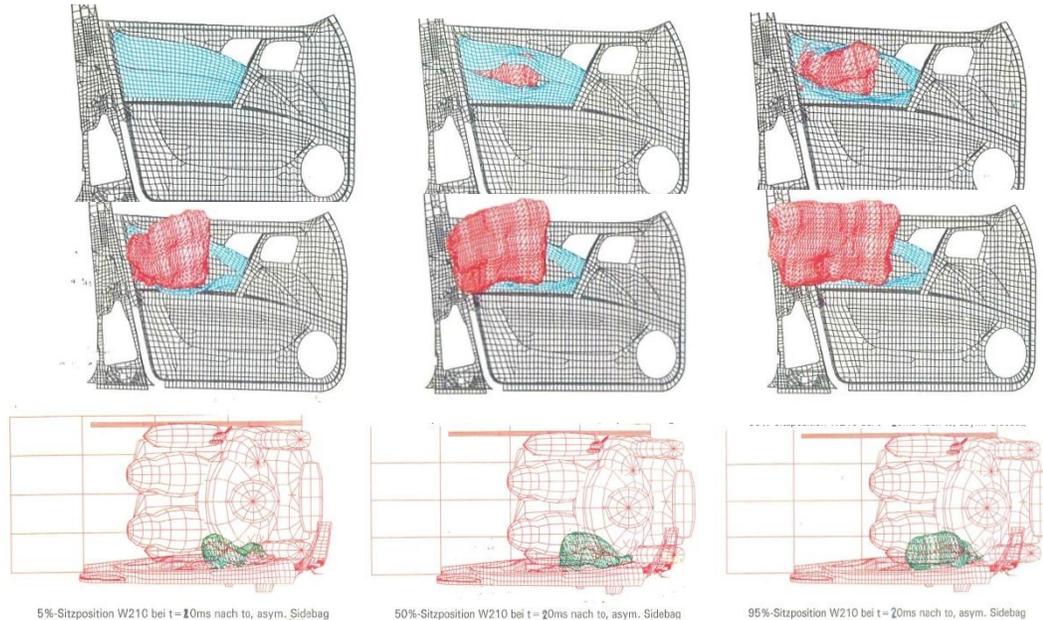
First airbag deployment simulations W210 (1994)

Continuous model optimization and refinement :

➔ increasing number of applications and investigations
   for virtual development of interior and restraint components



Side Impact Model BR222 (pole test)

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# Occupant Simulation at Mercedes-Benz Cars
# Status Digital Investigations – Interior / Occupant Safety

## Scope Levels

### Vehicle Level

- Crash Simulation with Front and Rear Occupants in Frontal + Side Impacts
- Child Safety
- Head Impact FMVSS201u
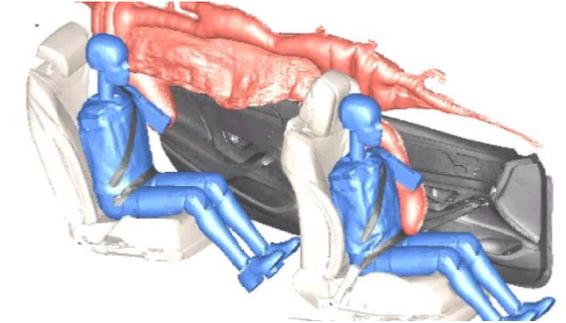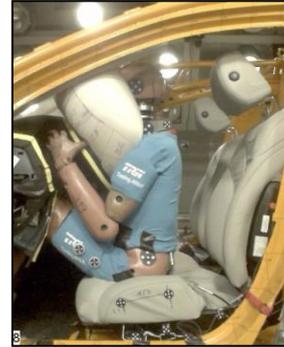
### Subsystem Level

- Whiplash (seats)
- Airbag Deployment (head liner, IP, seats)
- Airbag – out of position

### Component Level

- Fracture and Deformation behavior, Stiffness and Durability
- Safety related Functionality
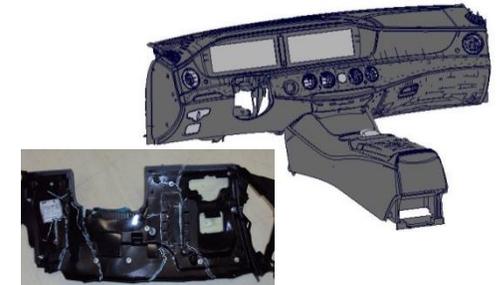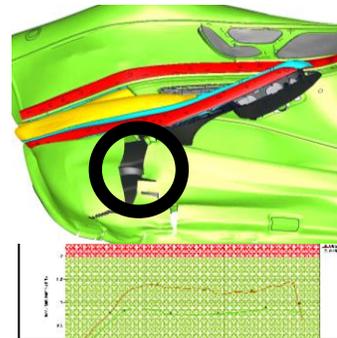
# Occupant Simulation at Mercedes-Benz Cars
## Integration into "Digital Prototype"

➢ Occupant simulation is part of the digital prototype development with assessments in all digital development phases.
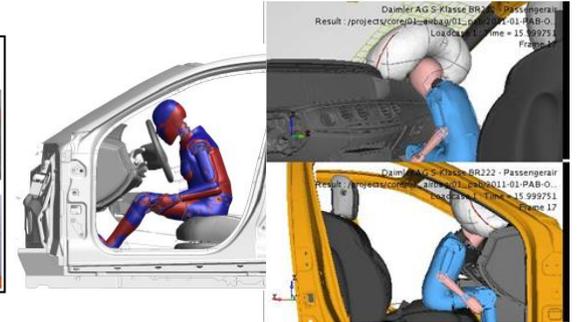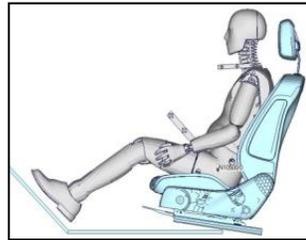
➢ Iterative component development / optimization between suppliers and occupant simulation.

➢ Increasingly parallel development between digital and hardware phases.

➢ Need of "on-time" delivery of adequate simulation models and material data by all process participants to meet DPT timelines and targets.
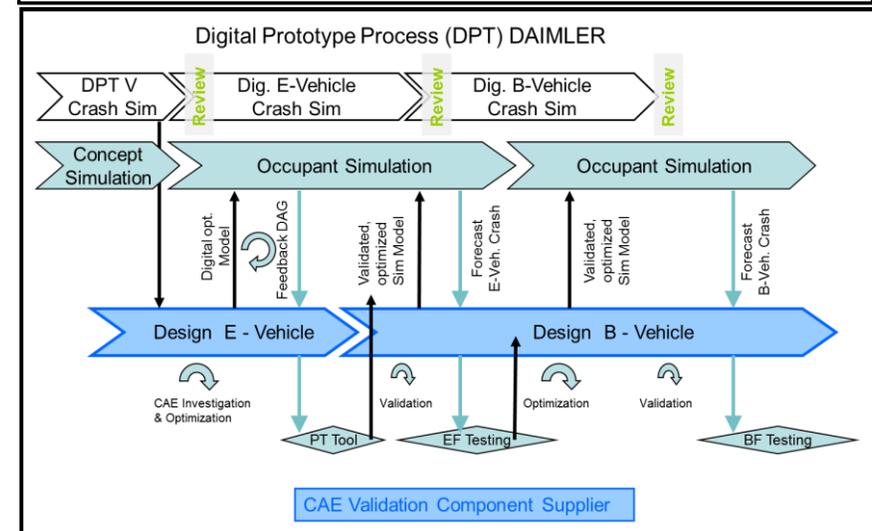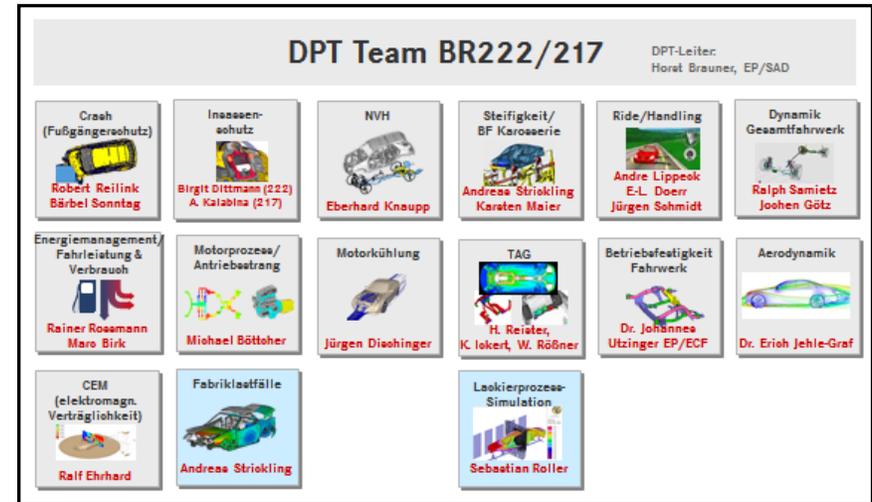
# Occupant Simulation for the New S Class
# Involved Objectives within Frontal Occupant Simulation



Airbag Systems

Dummies

Belt Systems

Steering

Floor room, Pedals

Structure Input

Instrument Panel with knee bolster

Seat

Mercedes-Benz
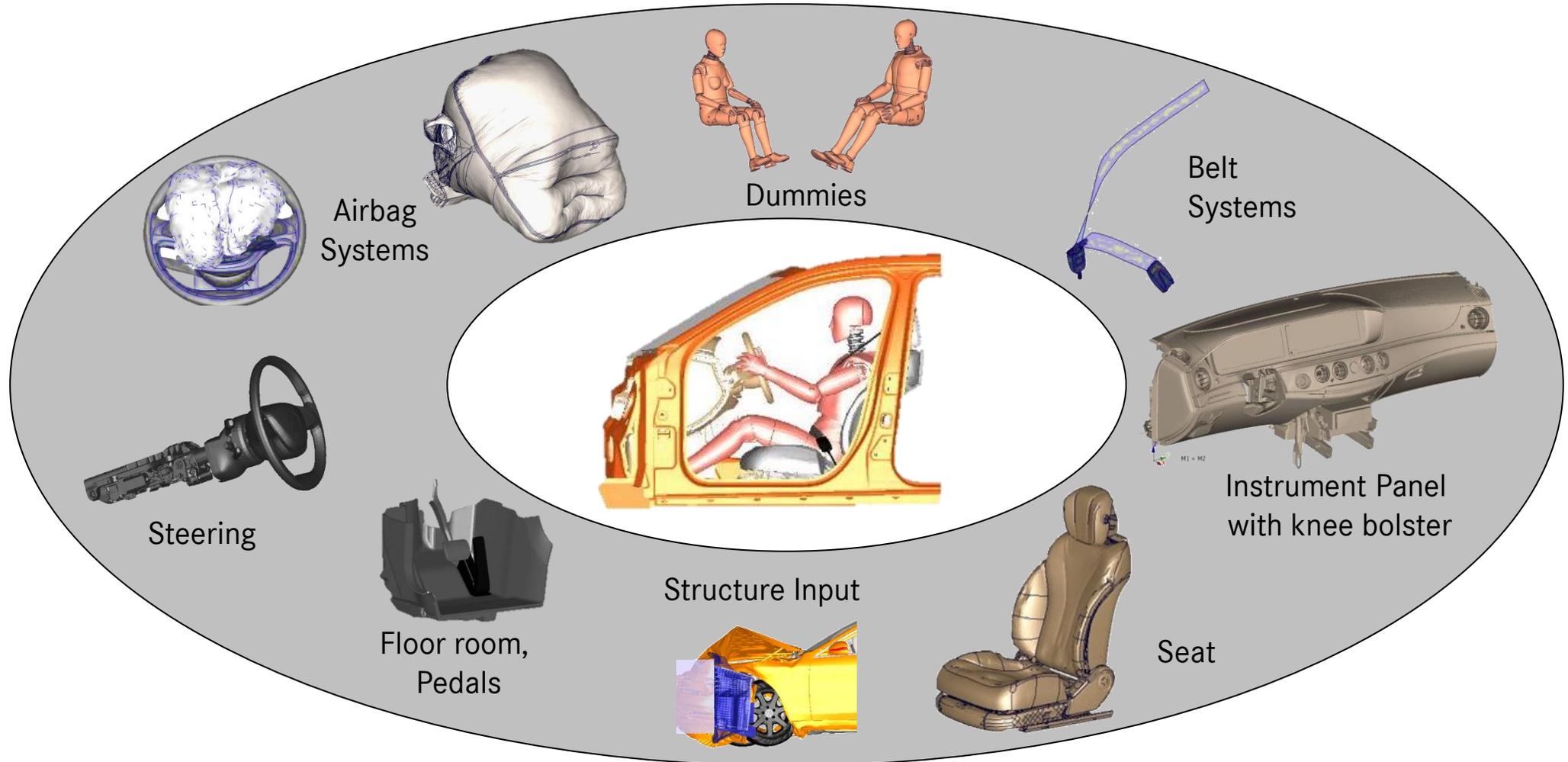
# Occupant Simulation for the New S Class
# Modell Abstraction Frontal Impact – 40% Offset Barrier Test

I: Integrated structure- and occupant simulation

Full Integrated Model : 6 Mio. elements (shells/solids)
Computing time:   30h  (150ms on 192 CPUs)

II: Model reduction to occupant cell (sled) model
with vehicle movement

Sled Model :        2 Mio. elements (shells/solids)
Computing time:   6 - 8h  (150ms on 96 CPUs)

# Occupant Simulation for the New S Class
# Model content frontal impact Driver and Passenger
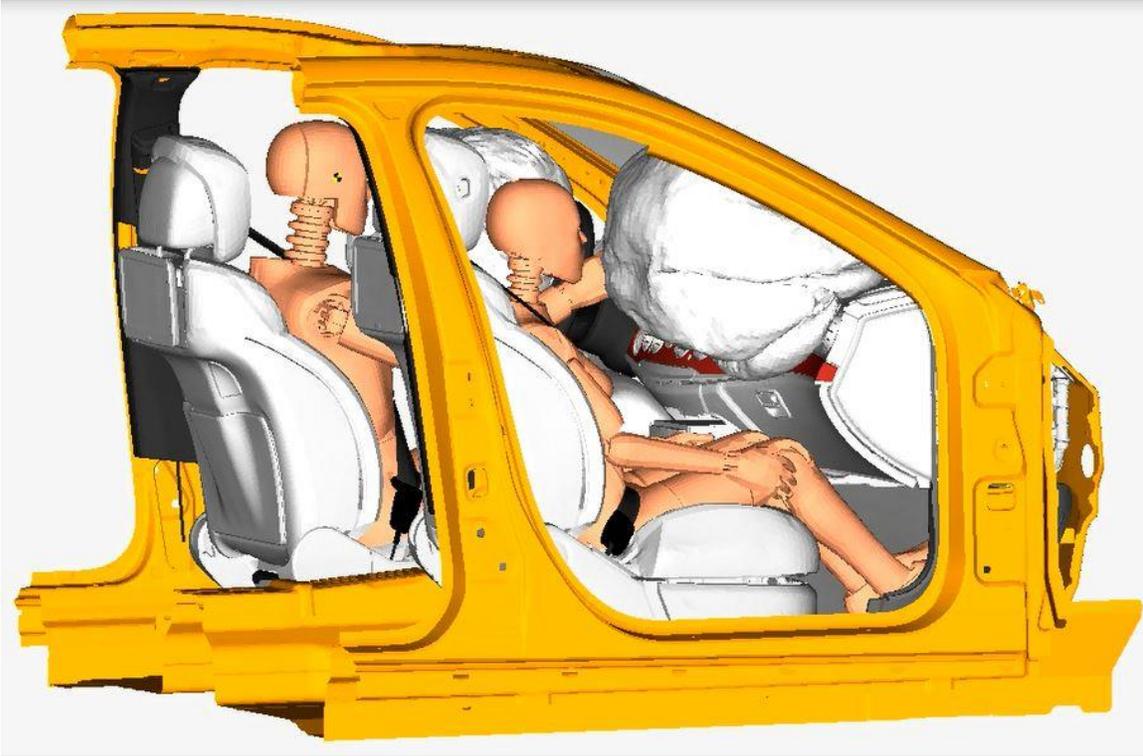


**Sim-Model with FEM subsystems of:**

- Vehicle structure (stiff or dynamic)
- FEM dummy 5% , 50% and 95% occupant
- Driver airbag
- Kneebag (US-Version) with CPM
- Passenger airbag
- Steering wheel and steering column
- Instrument panel assembly including:
  IP w. airbag door, cross car beam, glove box, knee bolster, HVAC, control units, ...
- Seat (structure and cushion assembly) incl. Primer® adjustment kinematics
- Floor room incl. carpet, support brackets, padding and pedals

Model size:          (1,3  -) 2 Mio. elements
Computing time:      6 - 8h  (150ms on 96 CPUs)

# Occupant Simulation for the New S Class
# Scope of investigations frontal impact driver and passenger
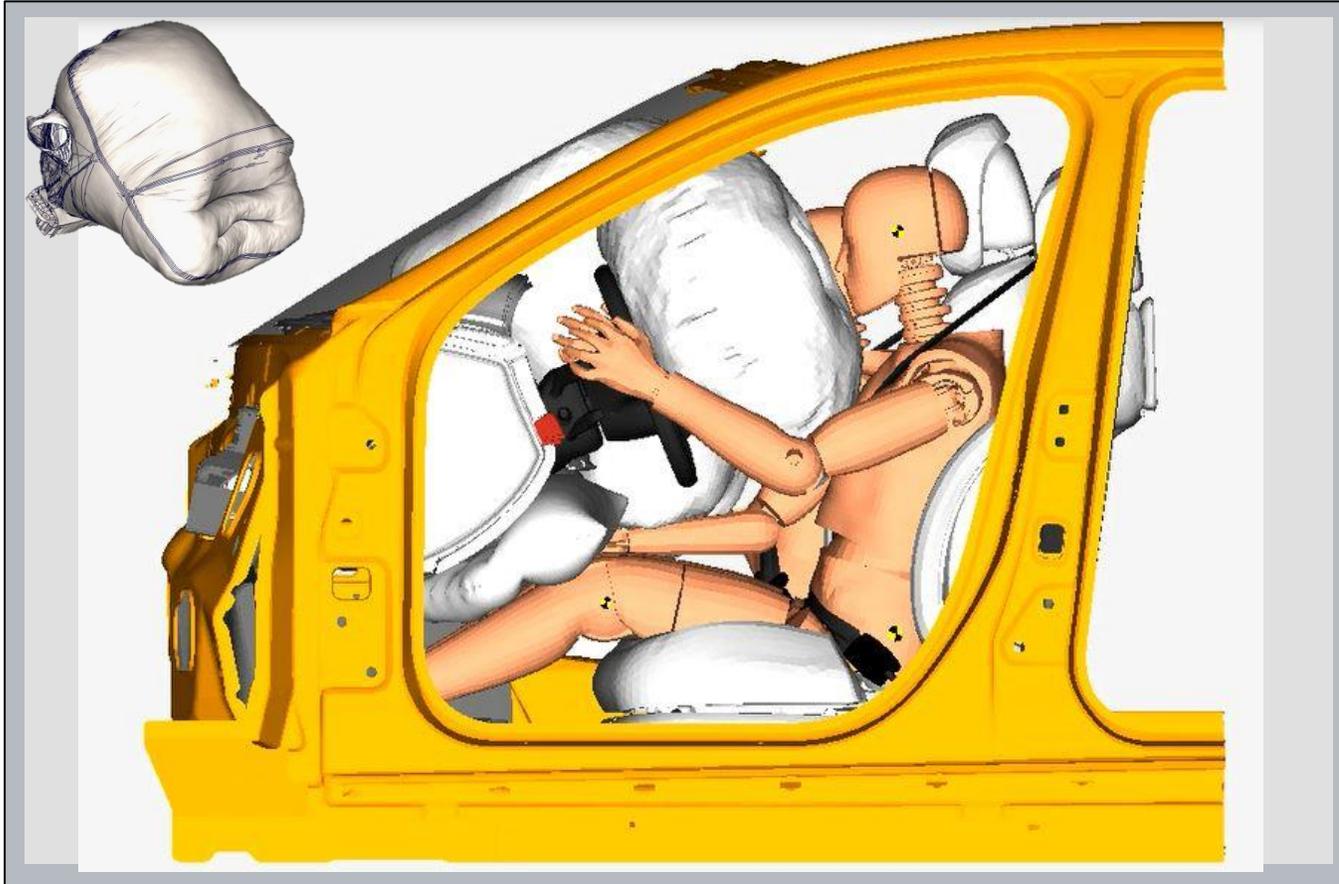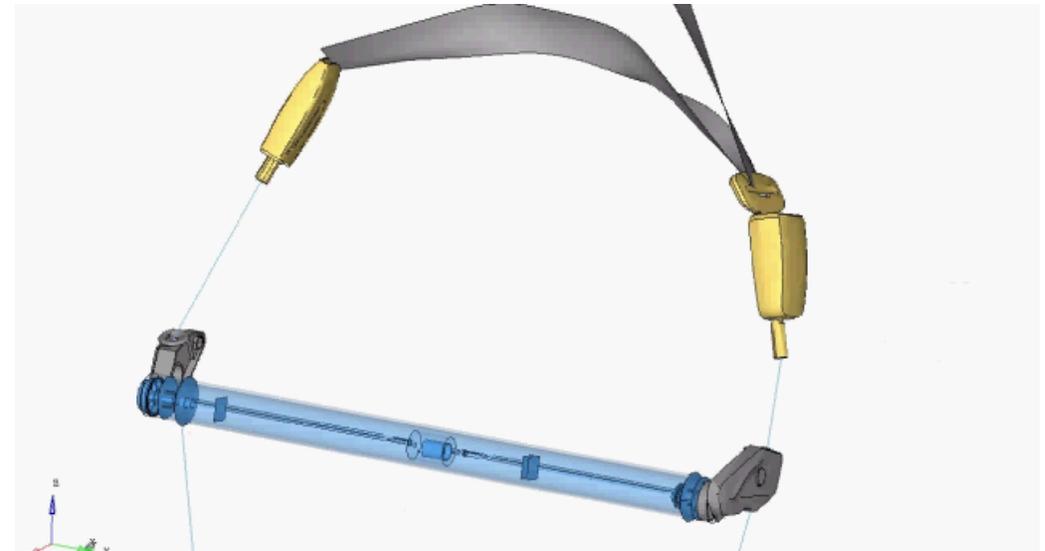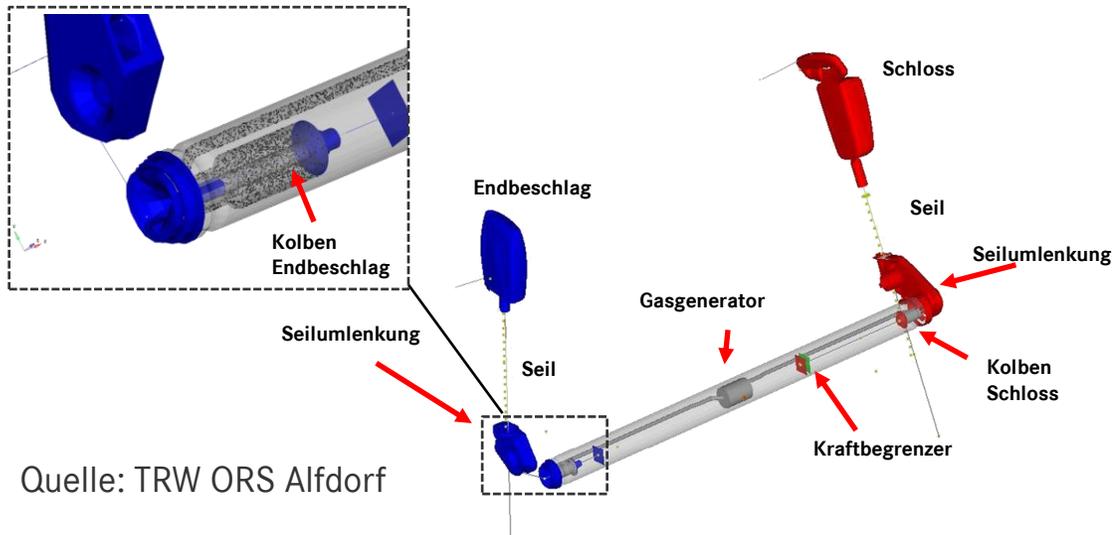
**Contents BR222:**

- Airbag geometry / performance (incl. static and adaptive vents)

- Secure cushion deployment (head, chest and knee contacts)

- Belt retractor with pre-tensioning and force limitation.

- Innovative PRE-SAFE_ Impulse anchor and buckle pre-tensioner with force limitation.

- Analysis und optimization of several crash load cases

# Occupant Simulation for the New S Class
# FEM-Models of Innovative Components



## Impulse Pre-Tensioner:

Problem: No feasible function of integrated double pre-tensioner by using the conventional model definition (forces/distances by time). Piping reactions influence forces and travels.

Task: Implementation of a simulation model adapted to physical results

Solution: Implementation of the airbag-related CPM method also for belt component



Kolben Endbeschlag

Seilumlenkung

Endbeschlag

Seil

Gasgenerator

Schloss

Seil

Seilumlenkung

Kolben Schloss

Kraftbegrenzer

Quelle: TRW ORS Alfdorf

Mercedes-Benz

# Occupant Simulation for the New S Class
# Scope of investigations frontal impact driver and passenger
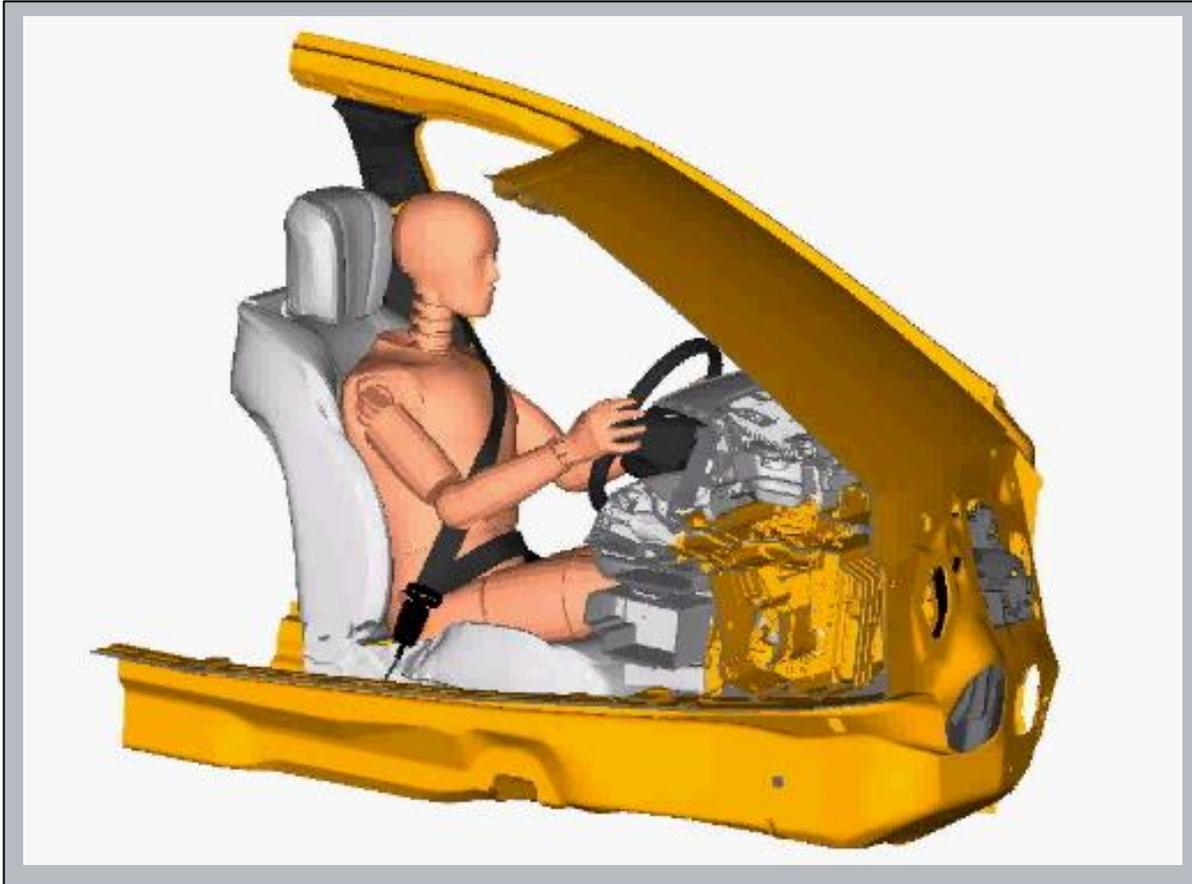
**Contents BR222:**

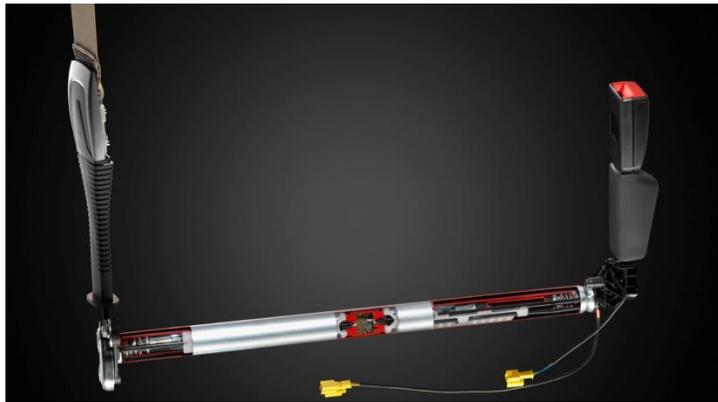- Analysis und optimization of several crash load cases

- Effect of intrusions:
  fire wall, floor structure and steering system

- Dynamic interior behavior (seat, knee bolster, floor room)

- Euro-NCAP knee-mapping

# Occupant Simulation for the New S Class
# Involved Objectives within Side Impact Occupant Simulation
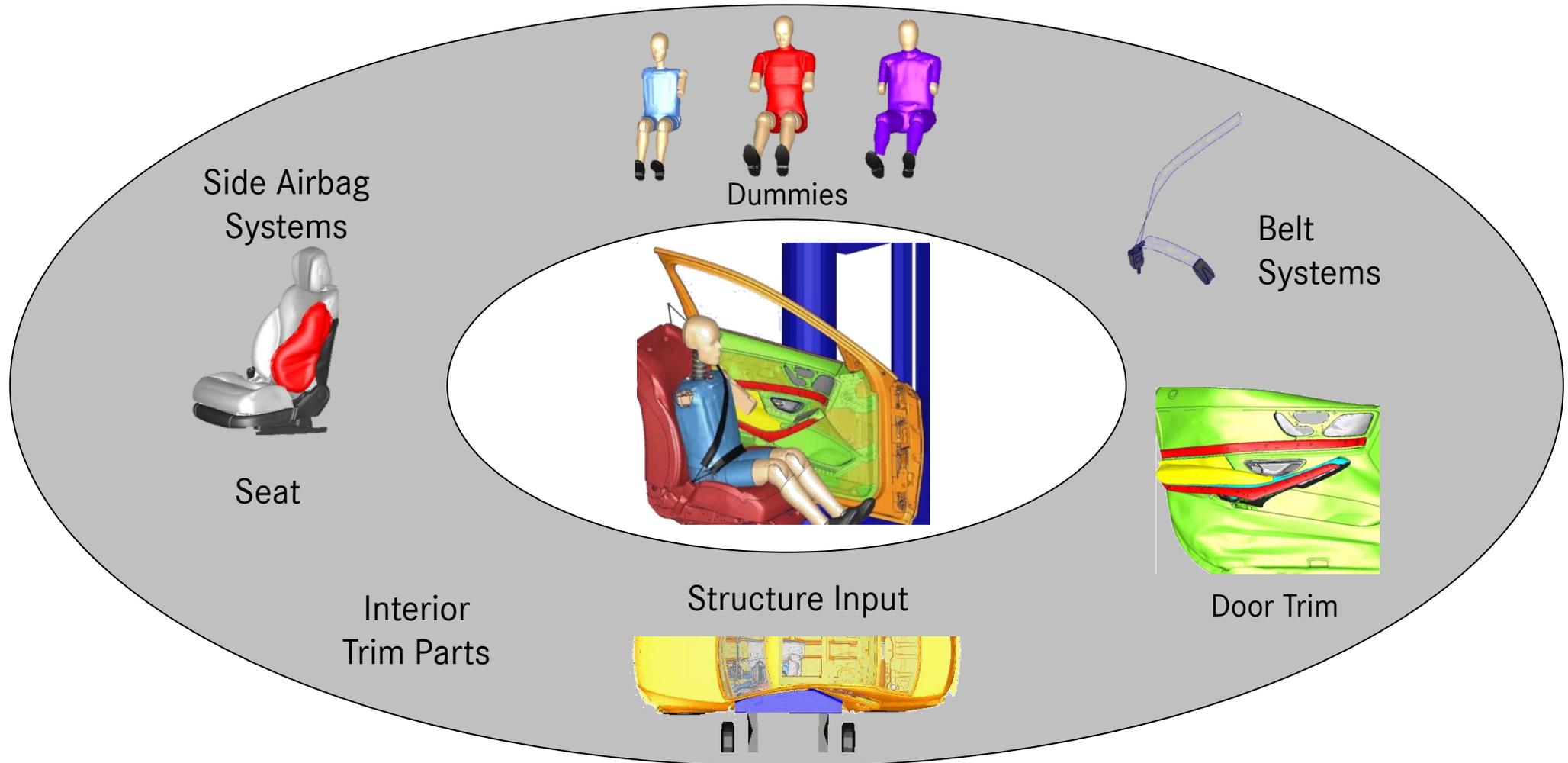
Side Airbag
Systems

Dummies

Belt
Systems

Seat

Door Trim

Interior
Trim Parts

Structure Input

# Occupant Simulation for the New S Class
# Side Impact:  IIHS – Barrier  (5% SID-IIs Occupant)

**IIHS Barrier Test**

**50 km/h 2x SID IIs (5% Dummy)**
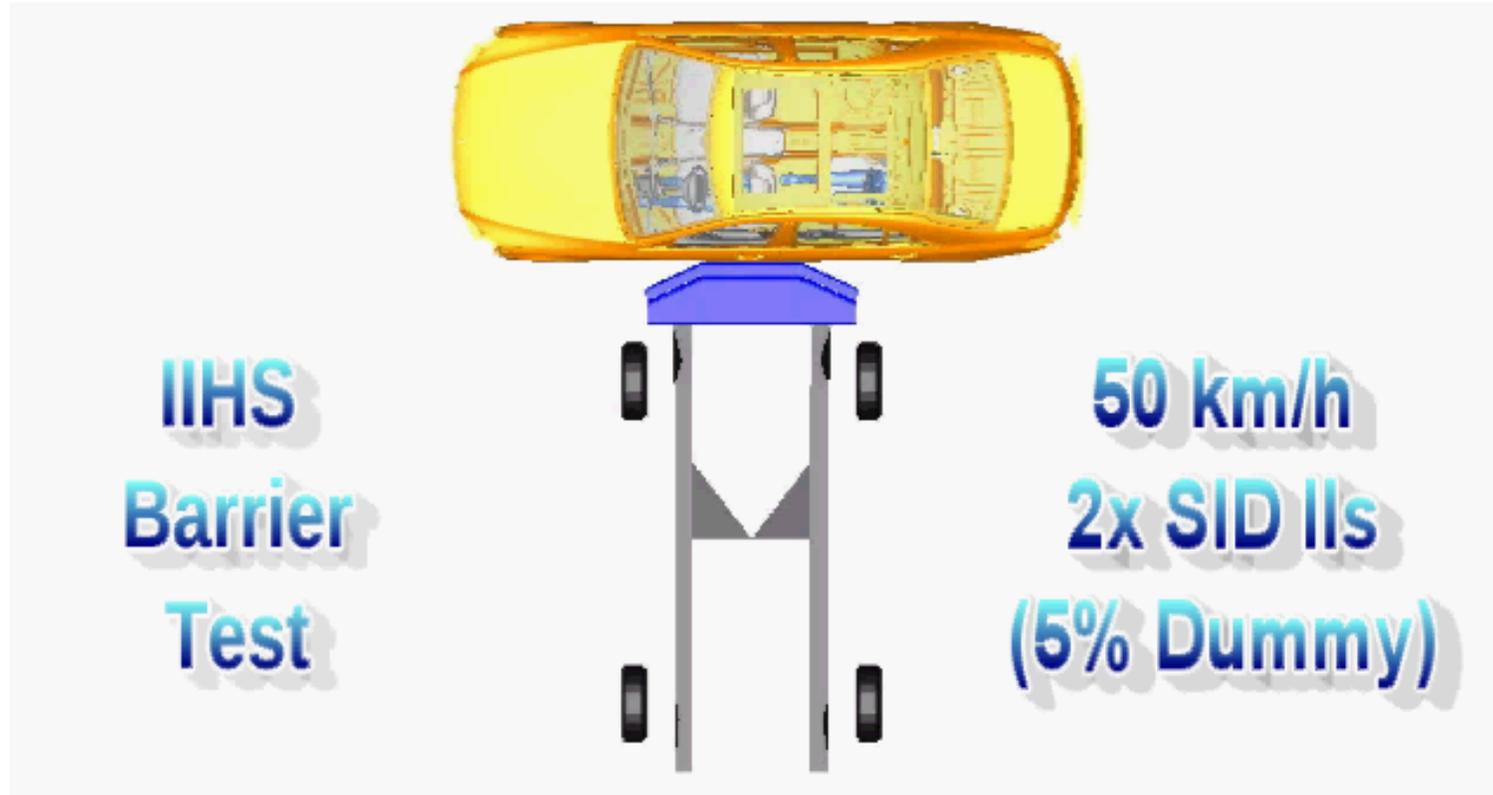
Model size:          6-7 Mio. elements
Computing time:      20 h  (150ms on 192 CPUs)

# Occupant Simulation for the New S Class
# Side Impact:  IIHS – Barrier  (5% SID-IIs Occupant)

- All occupant simulations are running completely integrated into the structure model (no subsystem)

# Occupant Simulation for the New S Class
# Side Impact:  IIHS – Barrier  (5% SID-IIs Occupant)

- Focus on analyzing the crash interaction and design setup of side airbag systems, door trim (arm rest, pelvis support), seat assembly (esp. backrest), side trims and belt tensioning

# Occupant Simulation for the New S Class
# Side Impact:  IIHS – Barrier  (5% SID-IIs Occupant)
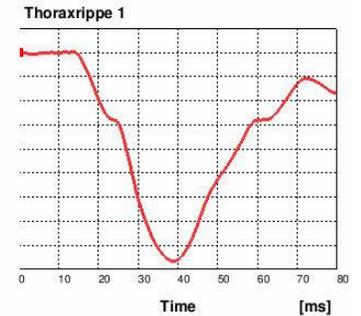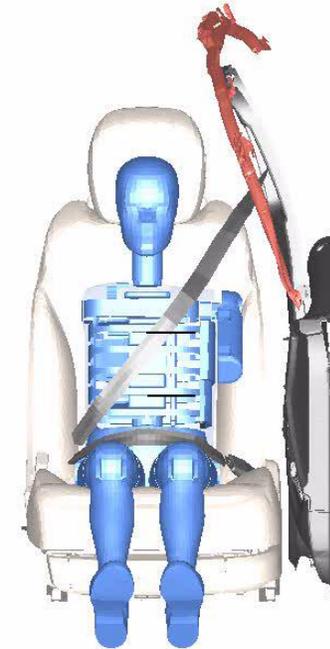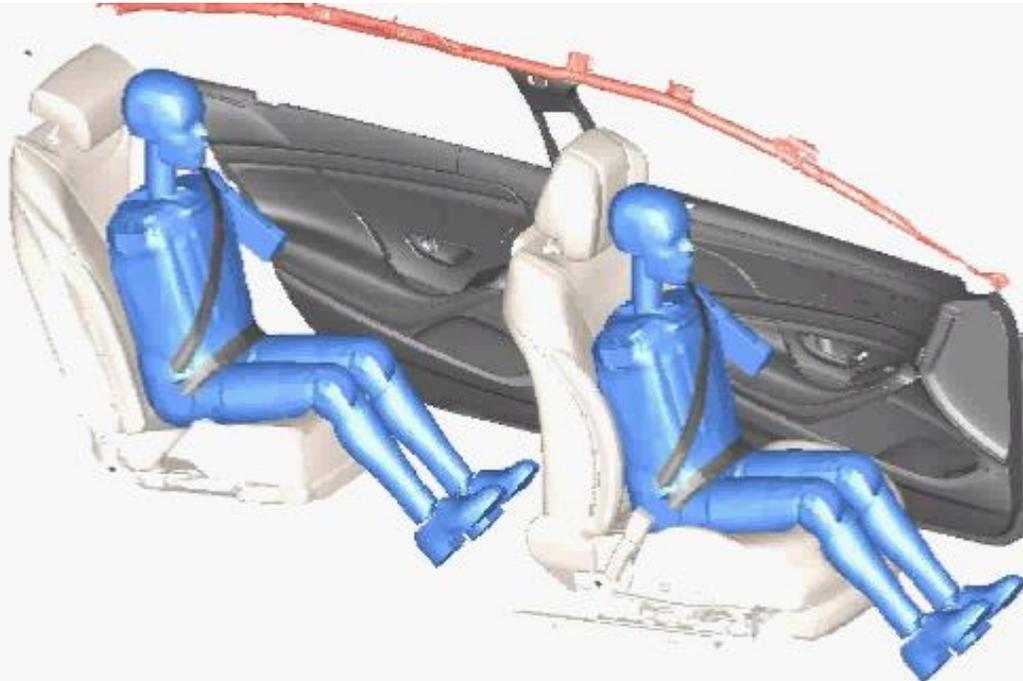


- Focus on analyzing the crash interaction and design setup of side airbag systems, door trim (arm rest, pelvis support), seat assembly (esp. backrest), side trims and belt tensioning
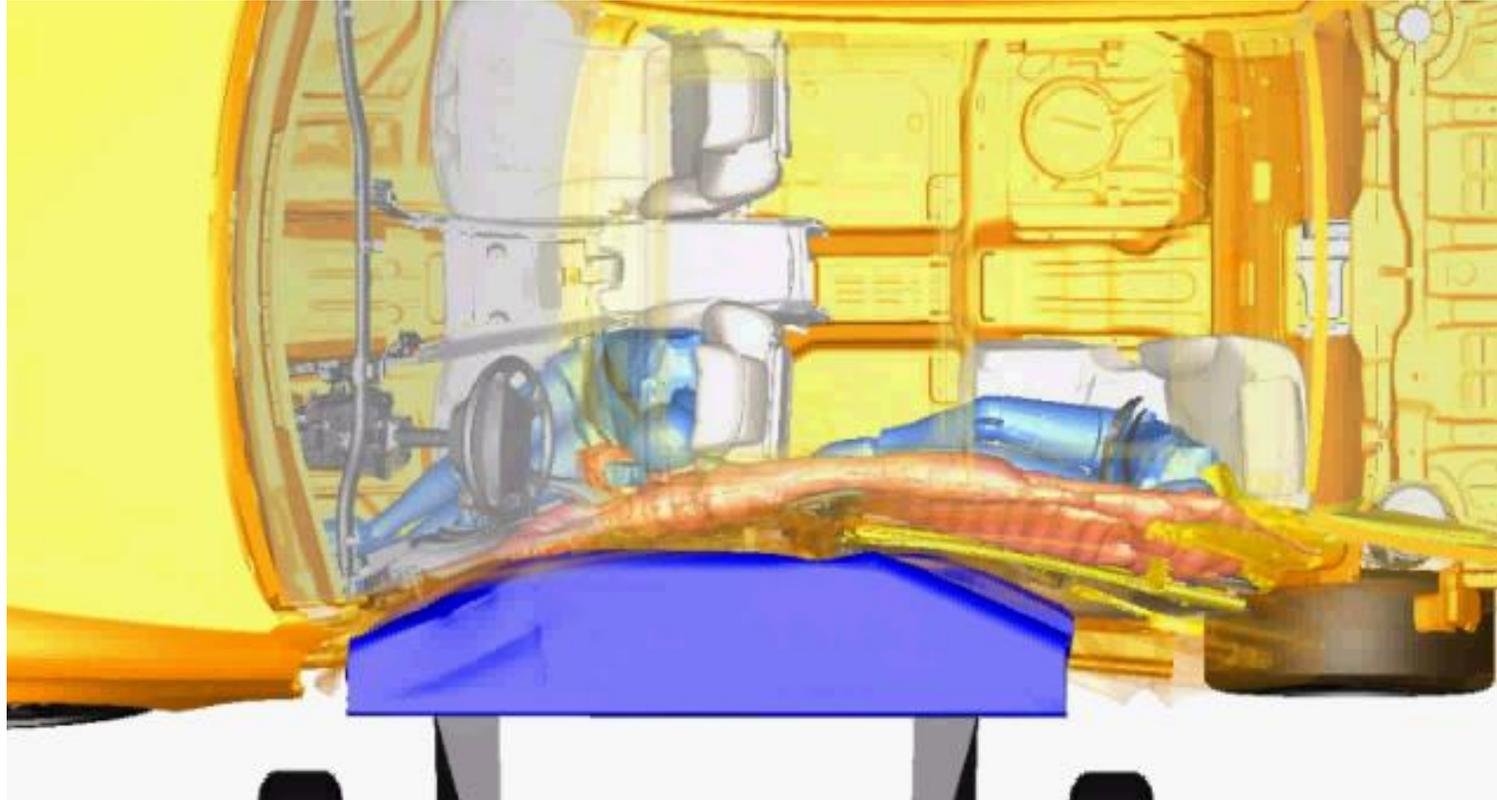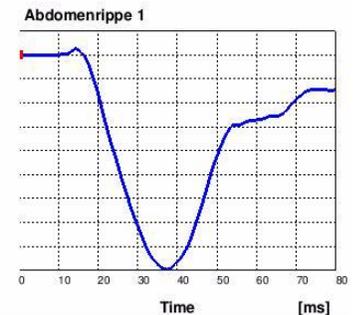
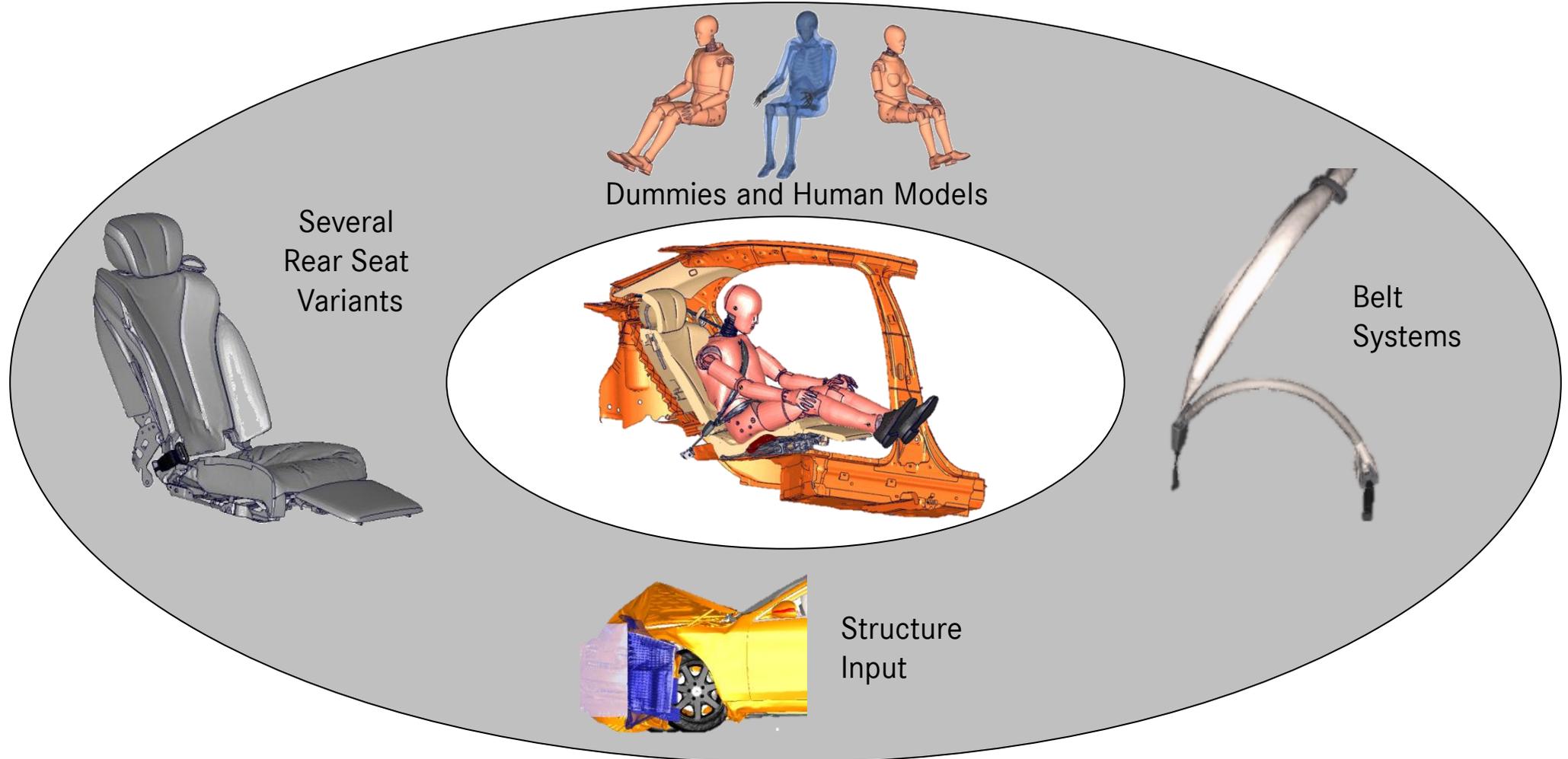# Occupant Simulation for the New S Class
# Involved Objectives within Rear Occupant Simulation



Dummies and Human Models

Several
Rear Seat
Variants

Belt
Systems

Structure
Input

Mercedes-Benz

# Occupant Simulation for the New S Class
# System Development Rear Occupants – Scope of Investigations

BR222 T-11131930 FC 48kmh H350 BB Liege - State 1 at time 0.000000
Video0 frame 50 at time 0

Time: 0.000
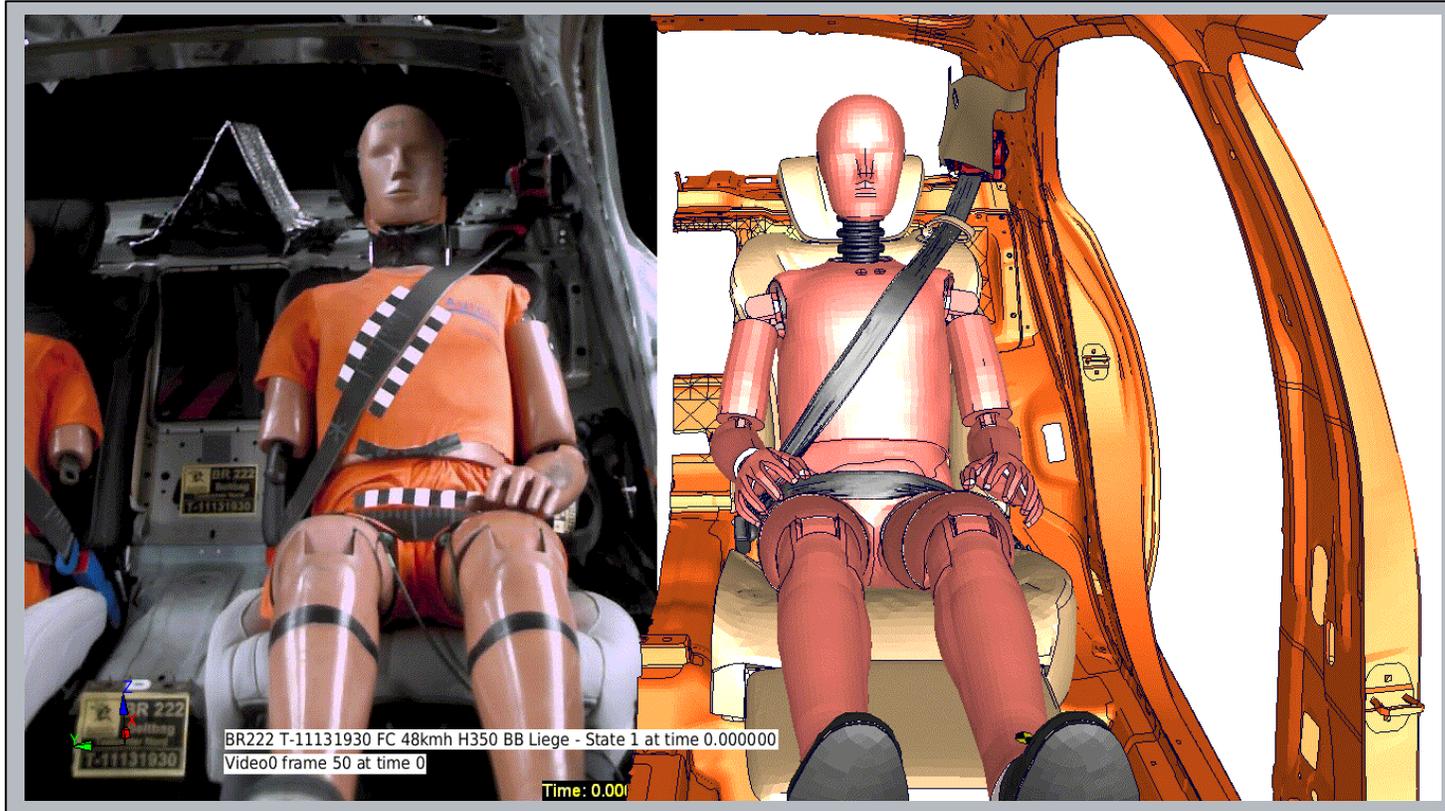
- Belt Fit Analysis
  (standard belt / Beltbag)

- Beltbag System Design:
  deployment characteristic,
  bag filling and pressure,
  consideration of belt buckle lifter

  - Detailed filling process
    (+ pyro. belt tensioning)

  - Beltbag geometry

  - Deployment strategy

- Optimization of details:

  - Belt tongue geometry for
    optimized Beltbag filling

  - Belt guide / deflection

- Validation of multiple seat
  variants and backrest angles

# Occupant Simulation for the New S Class
# FEM-Models of Innovative Components



**Beltbag:**

Problem:  Assessment of Beltbag filling and deployment as well as analysis of interaction to the occupant needs a belt simulation model with deployment same as for an airbag

Task:  Implementation of a physical adapted simulation model adapted to physical results for the innovation "Beltbag"
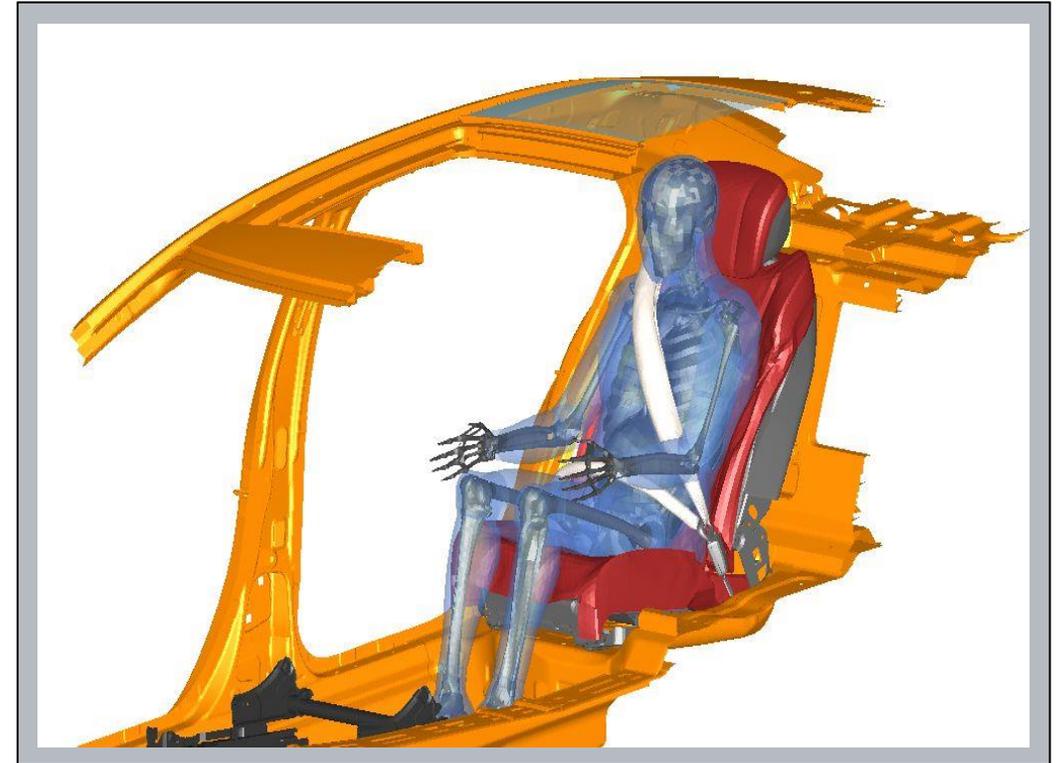
Solution:  Implementation of the airbag related CPM method also for the Beltbag component

# Occupant Simulation for the New S Class
# System Development Rear Occupants in Frontal Impacts
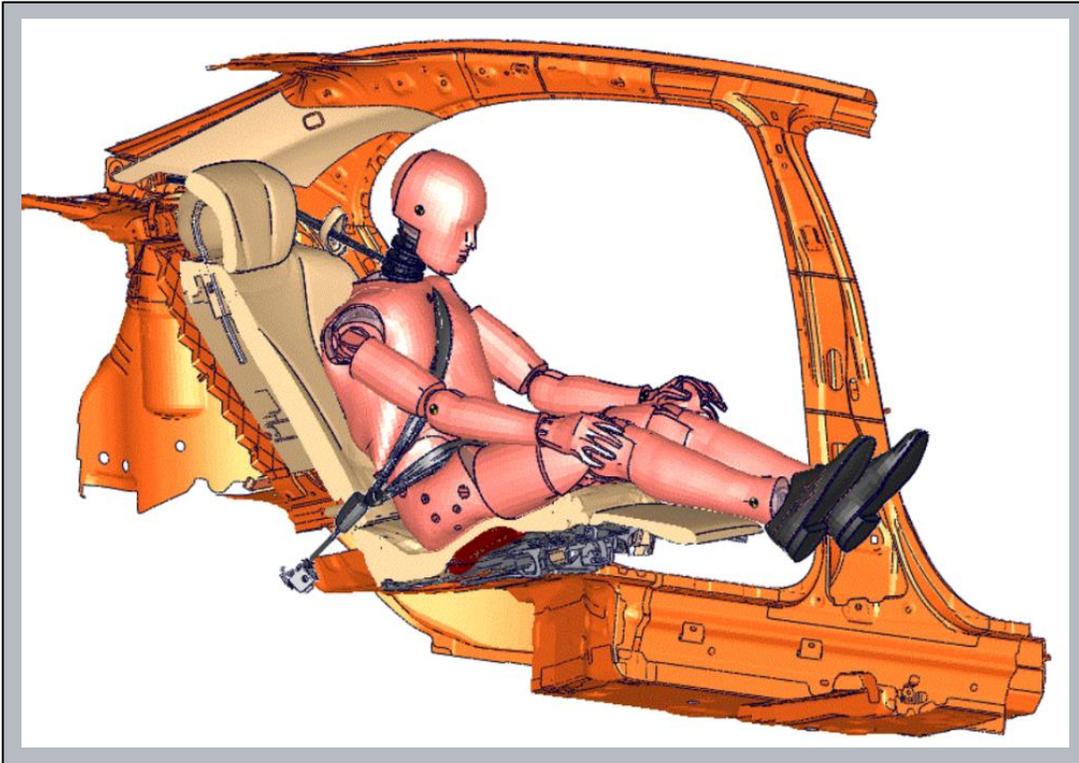
**Dummy**

System development rear occupants
with HIII 5% und 50% dummies



**Human**

Potential analysis and system performance
investigations with Human Body Model
(THUMS 5% und 50%)

# Occupant Simulation for the New S Class
# System Development Rear Occupants – "Human" Assessment

- Additional investigations of Beltbag System with virtual Human Body Model (THUMS) for 5% und 50% occupants:

  ➔ Advanced analysis and confirmation of potentials and benefits for real life safety

- Inspection of human occupant kinematics

- Belt fit investigations
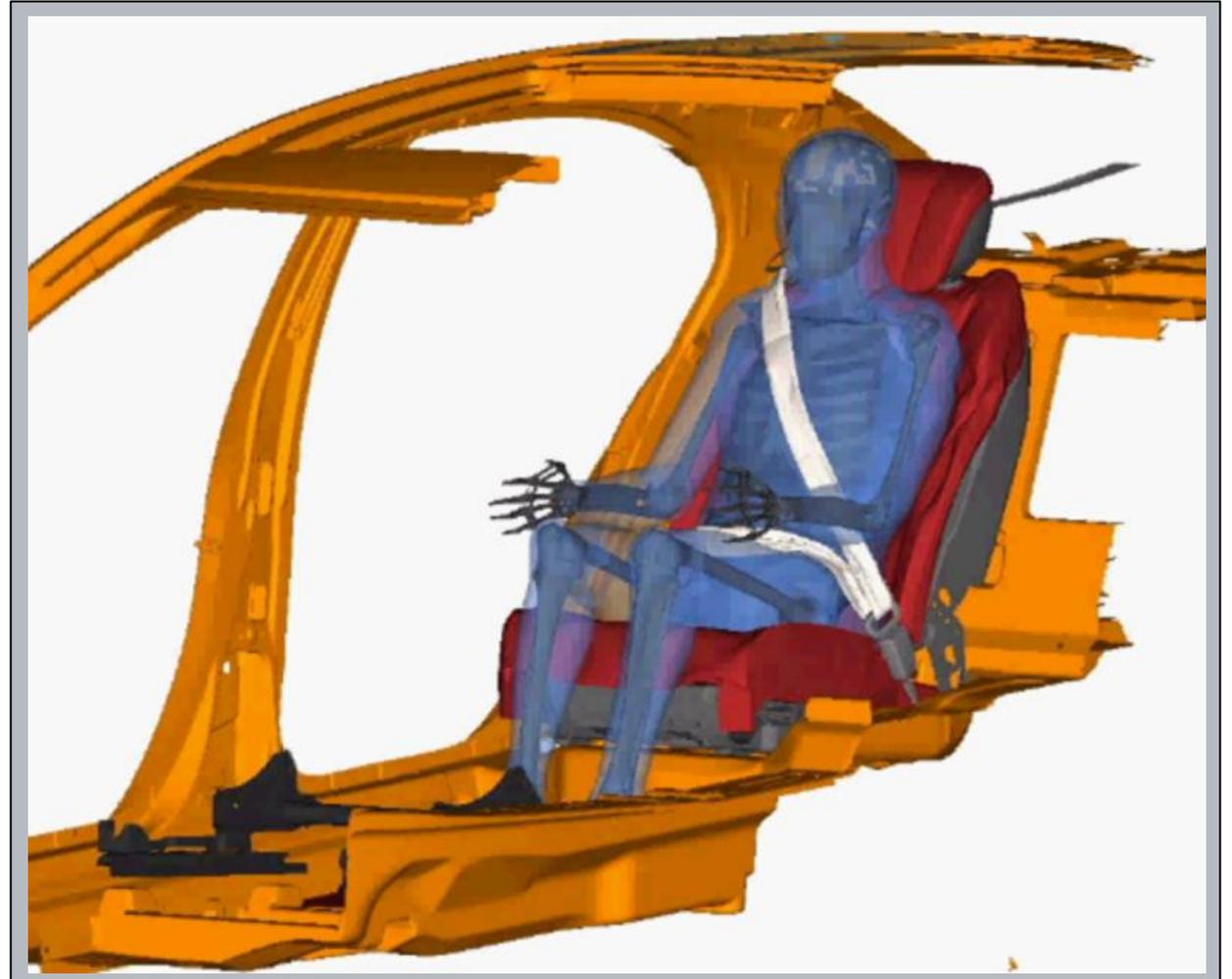
Model size:           1 Mio. elements
Computing time:       9 h  (120ms on 192 CPUs)

# Occupant Simulation for the New S Class
# System Development Rear Occupants – "Human" Assessment
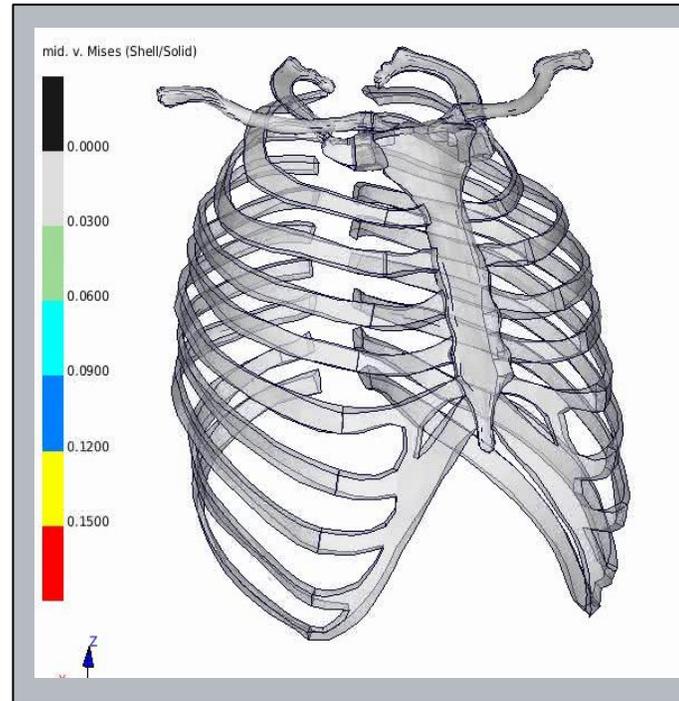


**Beltbag System**       **Conventional Belt System**
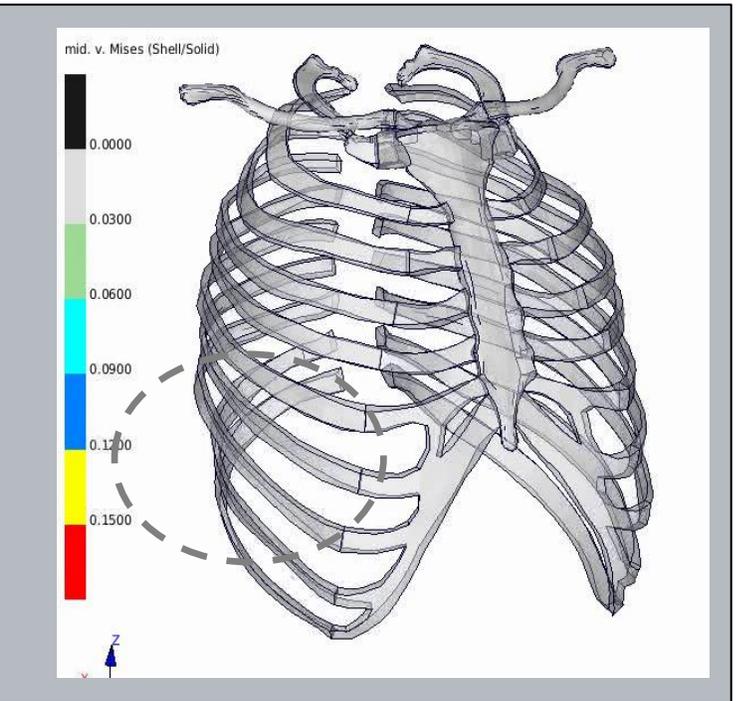
Investigations of occupant loads
with human body model:

Local rip deflection incl. display of "van Mises" equivalent strain

# Occupant Simulation for the New S Class
# In Development – Out-of-Position Simulation



Airbag
Systems

Seat

Instrument Panel
with airbag door

Dummies

# Occupant Simulation for the New S Class
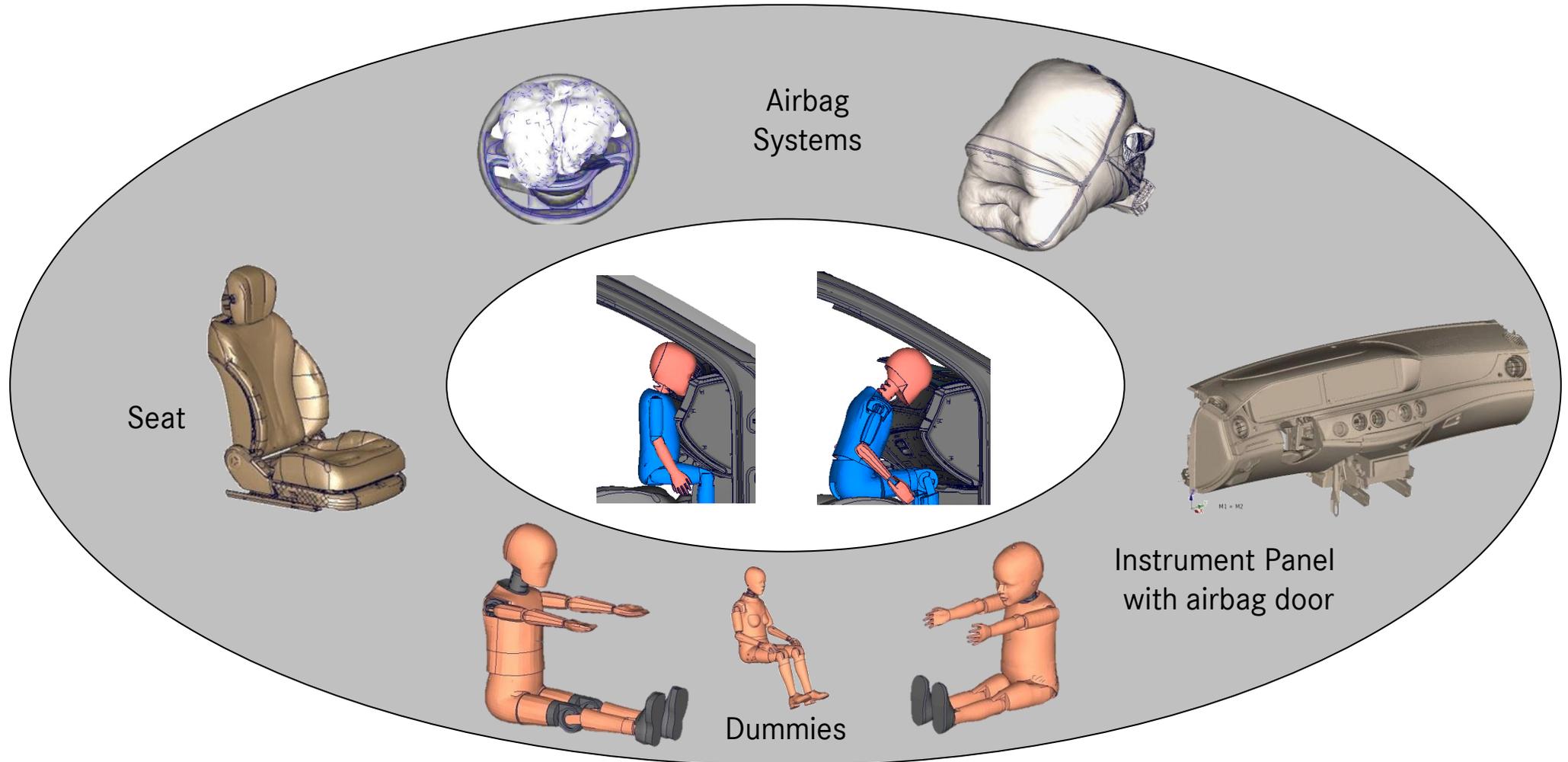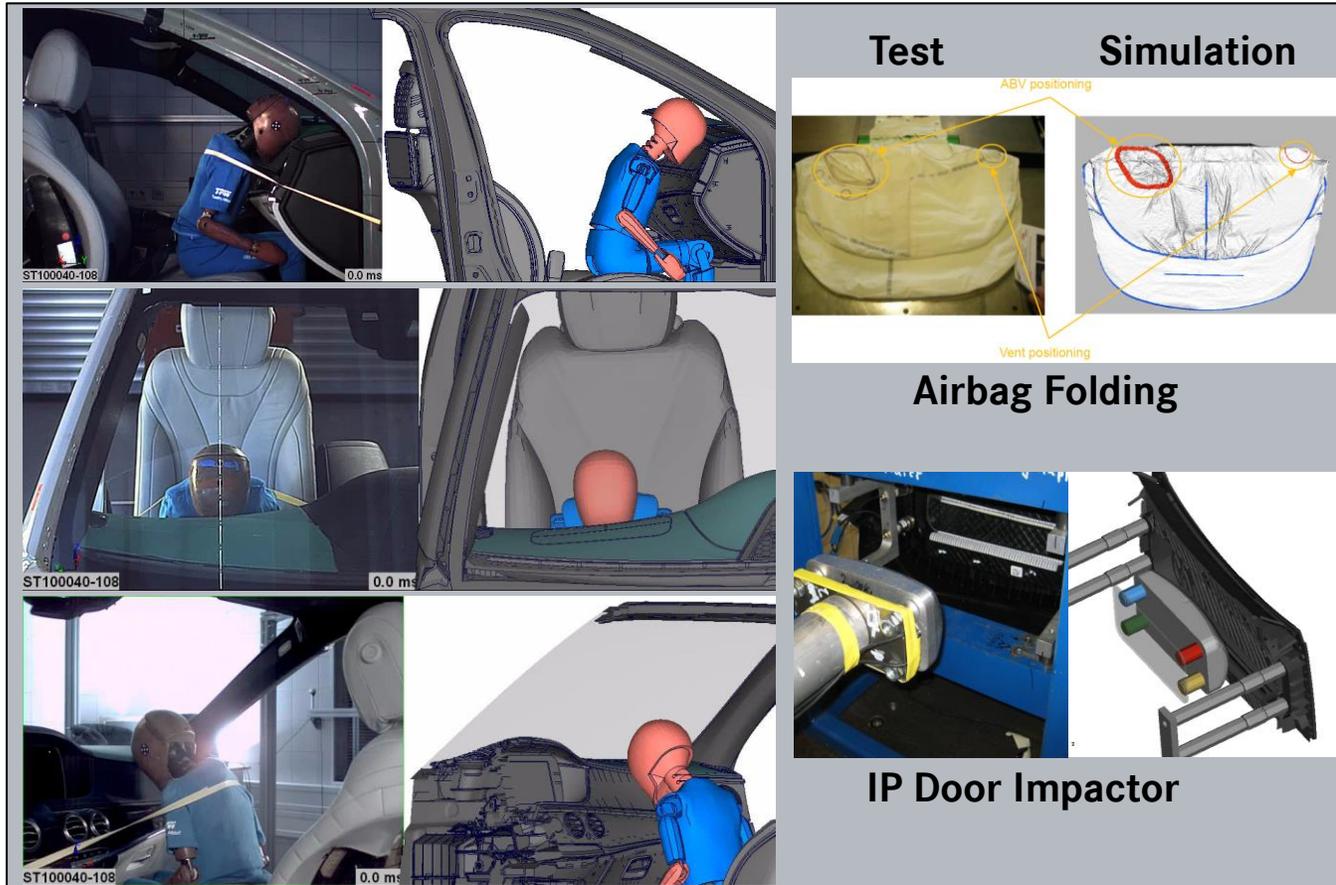# In Development - OOP simulation passenger side

**Test**  **Simulation**

**Airbag Folding**

**IP Door Impactor**

## Summary

- Deployment kinematics and dummy interaction captured
- Trends in injury values captured, absolute values partially captured
- High quality FE models of airbag module, dummy, IP required

## Lessons learned:

- Capture physical airbag parameters (folding, shape, leakage, etc.)
- Initial dummy positions w/o pre-stress
- IP: numerically robust behavior, proper material & failure definitions
- Valid seat / car geometry

# Occupant Simulation at Mercedes-Benz Cars
# Challenges – Material Modeling and new Dummies



Airbag Systems

Belt Systems

Seat

Door Trim

Interior Trim Parts

Dummies
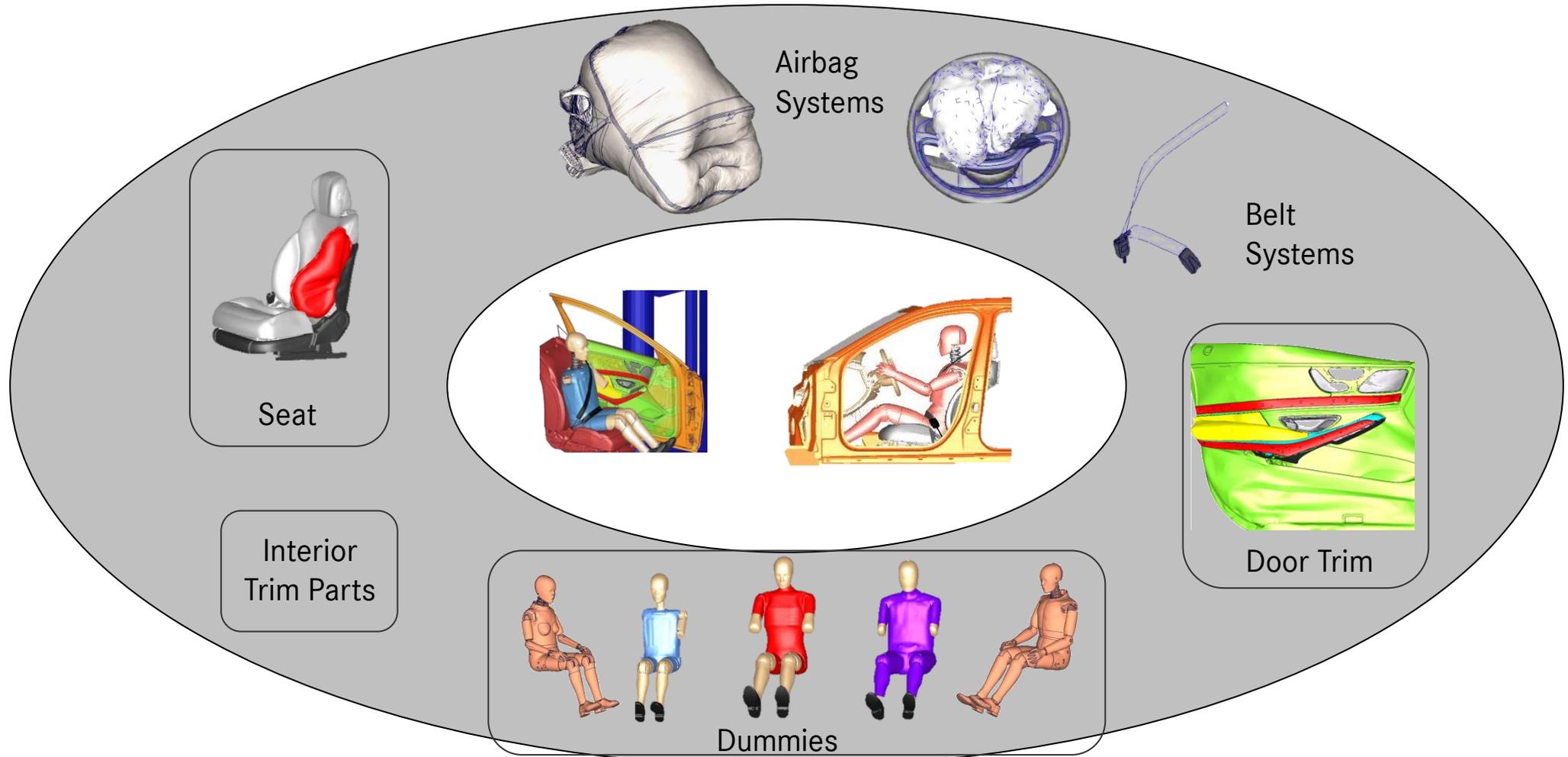
# Occupant Simulation at Mercedes-Benz Cars
# Challenges for proper material modeling of innovative materials



**Performance properties
of new materials especially
for interior parts:
(non-linear behavior)**

- Plastics
- Foams
- Fibers (natural and glass)
- Fracture behavior (plastics)
- Gas and fluid dynamics

**Joining technique**

- Clips, Rivets, Screws
- Plastic welding
- Plastic glueing
- Seams (fabric, leather)

**Failure modes:**

- Plastics
- Composite materials (plastics / fiber)

# Occupant Simulation at Mercedes-Benz Cars
# Conclusions

➢ Occupant simulation is a required and established development process for designing, optimizing and analyzing the function of the restraint systems as well as the crash performance for all interior components

➢ Increasing contribution to ensure the level of maturity and the value of hardware testing

➢ Proper component and material models for all parts and components are required to set up reliable simulations and virtual analysis

➢ Occupant simulation allows quick reactions based on first test results and enables investigation of constructive optimization measures

    ➢ influence analysis

    ➢ answers conflicts of goals

    ➢ definition of optimal system components or best material usage

# Occupant Simulation at Mercedes-Benz Cars

Thank you very much for your interest and attention !

Your questions are very welcome.