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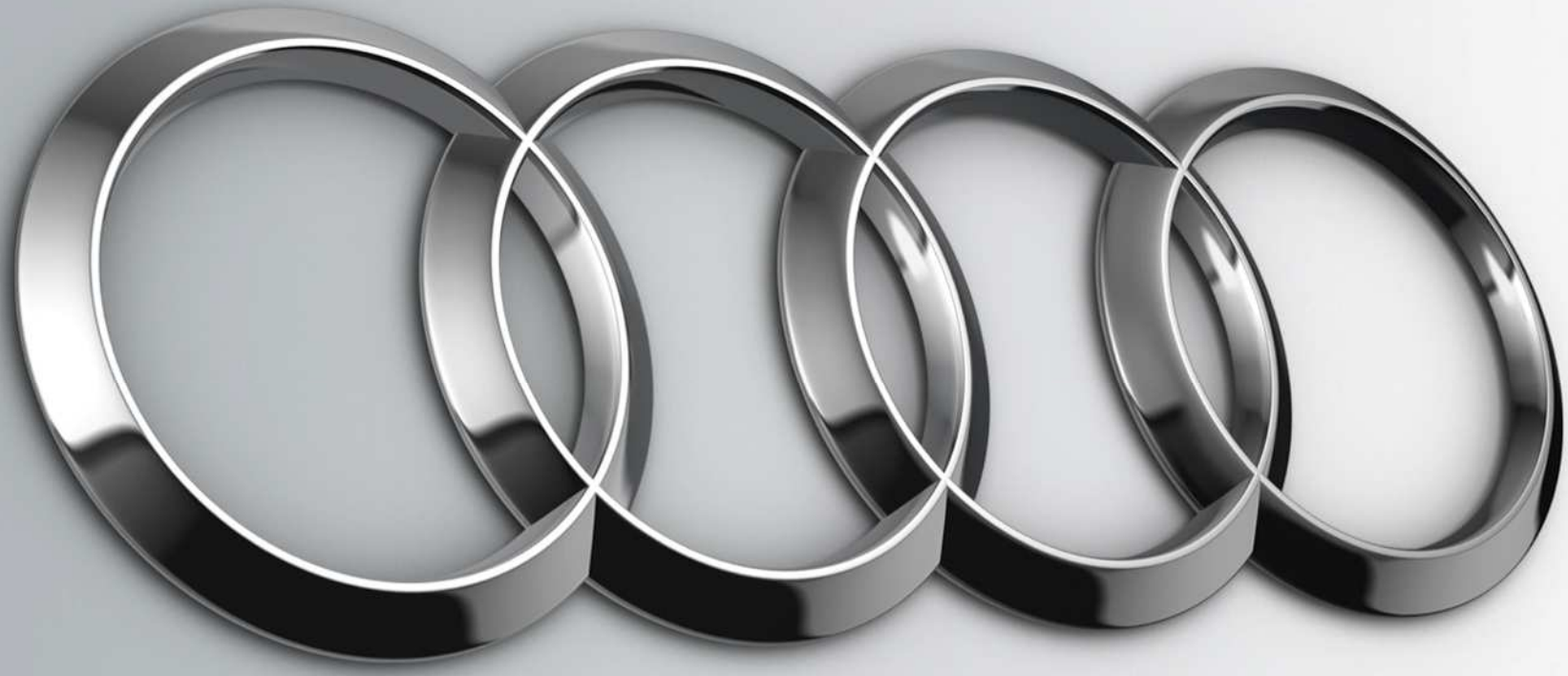

Pedestrian Protection and its Implications on Front-Ends

Dr. Dominic Seibert, Andreas Koukal

Agenda

1. Pedestrian Protection - *Motivation, State of the Art and Future Trends*
2. Front-Ends - *Scope and Design Conflicts*
3. Processes in Front-End Development
4. Virtual Testing - *State of the Art in Industry and Research, Future Trends*
5. Summary

Agenda

1. **Pedestrian Protection - *Motivation, State of the Art and Future Trends***
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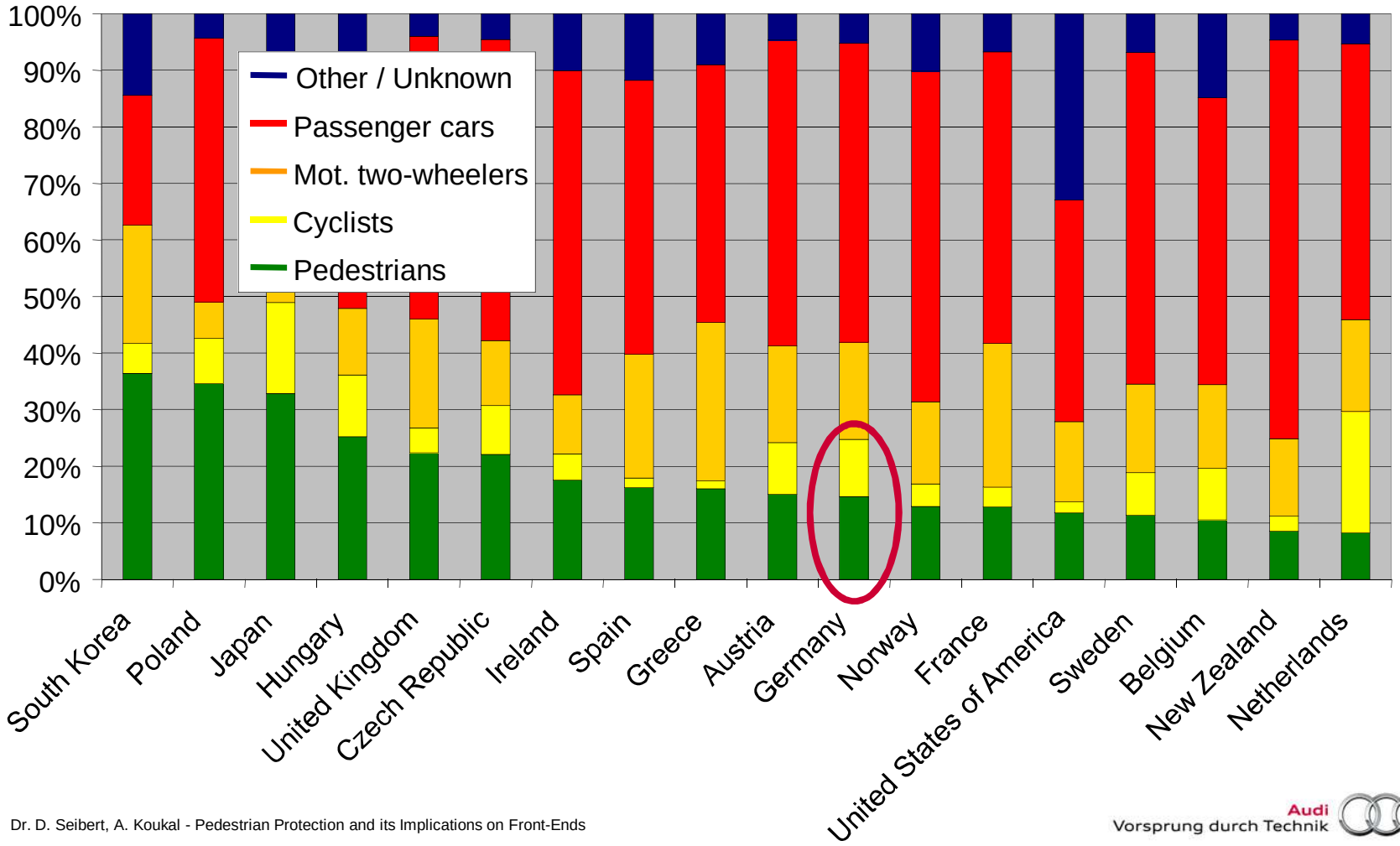
5. Summary

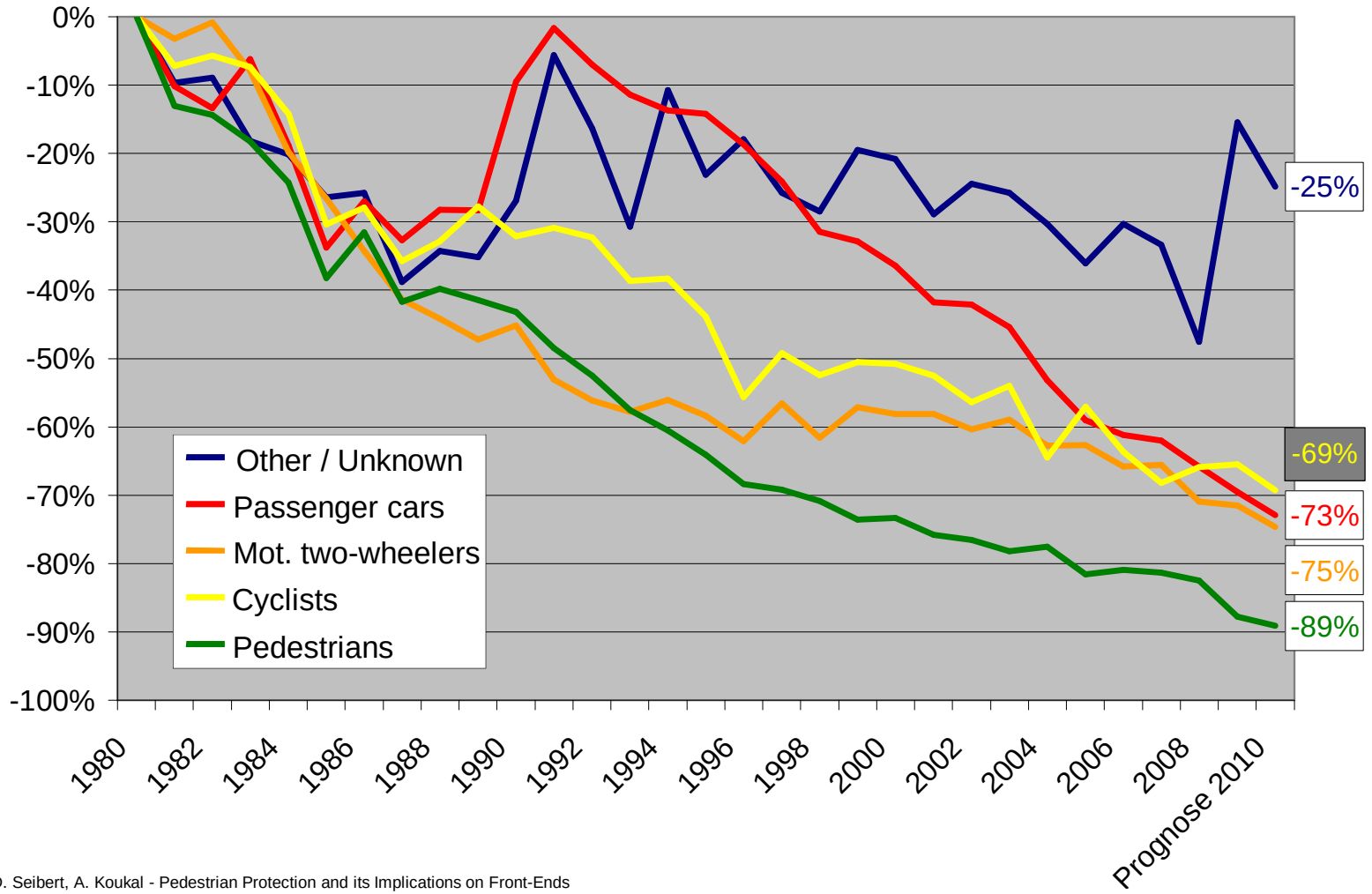
Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Motivation - Fatalities in Road Traffic in 2008 [IRTAD]



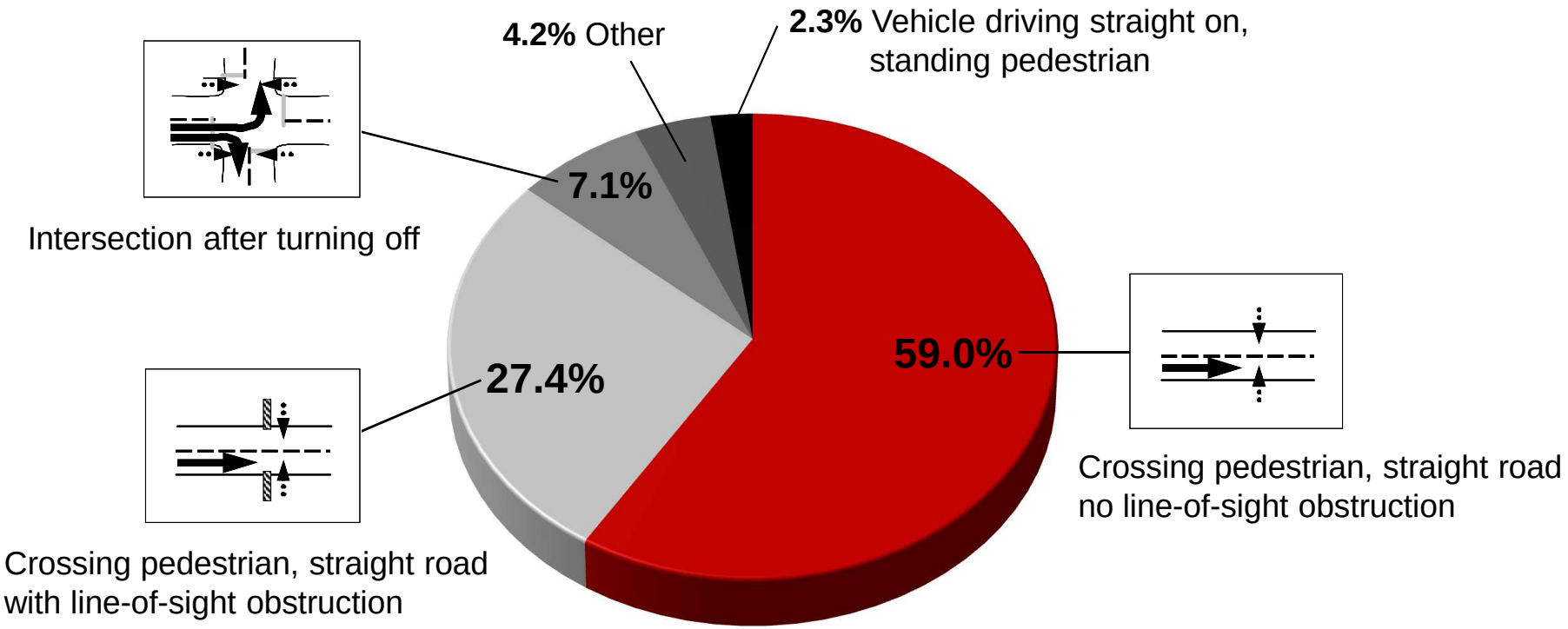
Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Motivation - Fatalities in Road Traffic in Germany from 1980 - 2008 (normalized) [IRTAD]



Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Pedestrian Protection - Accident Analysis [GIDAS, 2006]



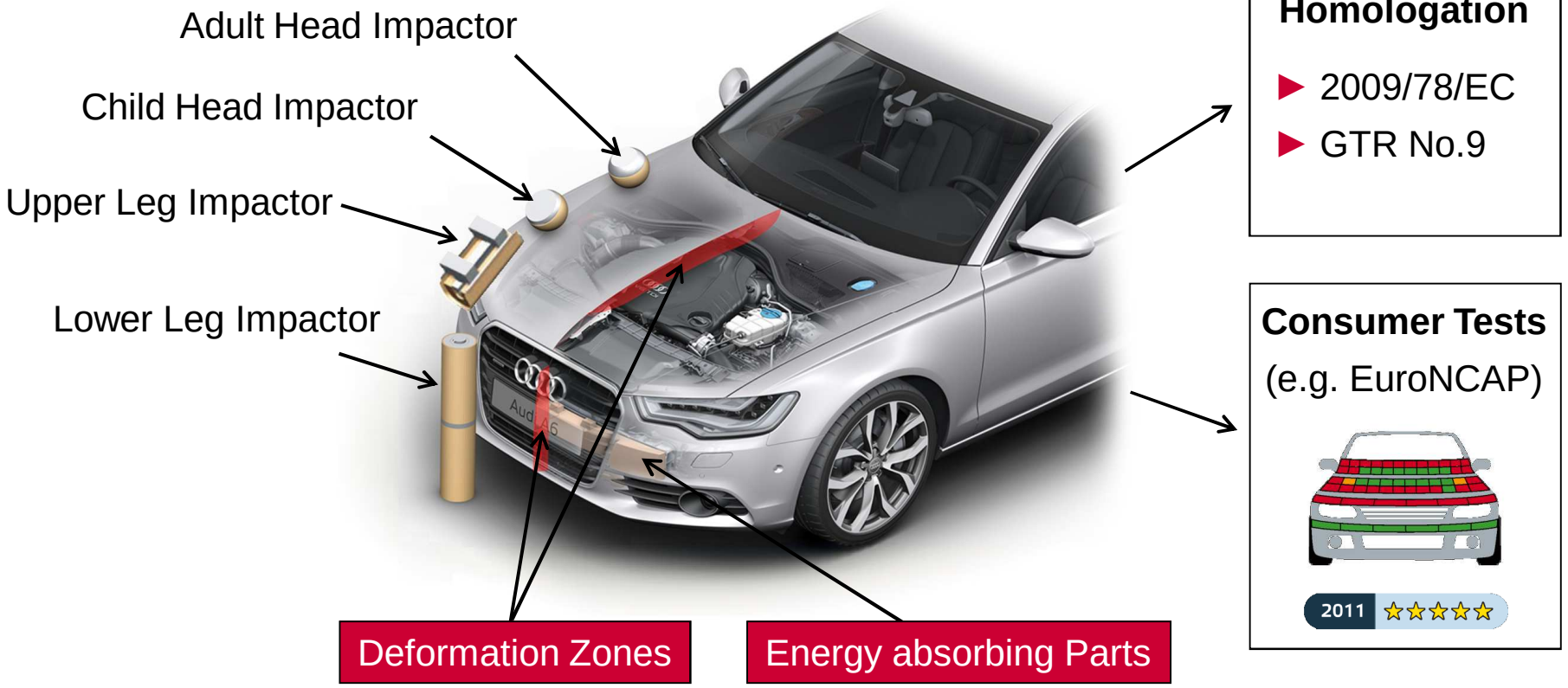
- **Important Result:** 86% of pedestrian accidents involve crossing pedestrians

Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Pedestrian Protection - Chronology of a Pedestrian Collision

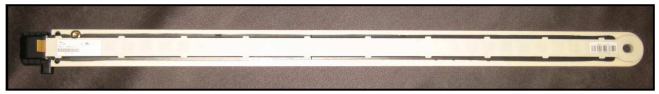
Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

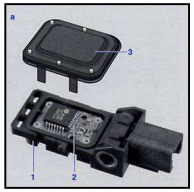
- Pedestrian Protection - State of the art



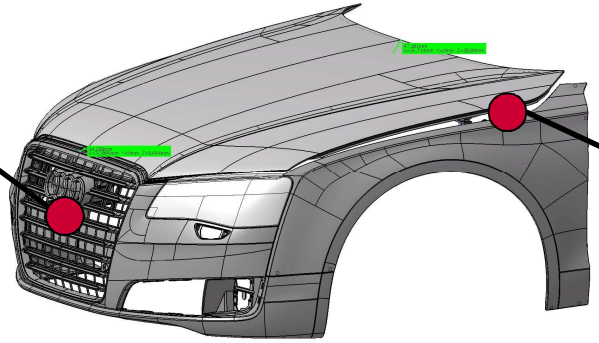
Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Future Trends - Active Bonnet

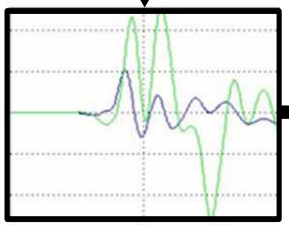




Sensors
- Acceleration
- Pressure



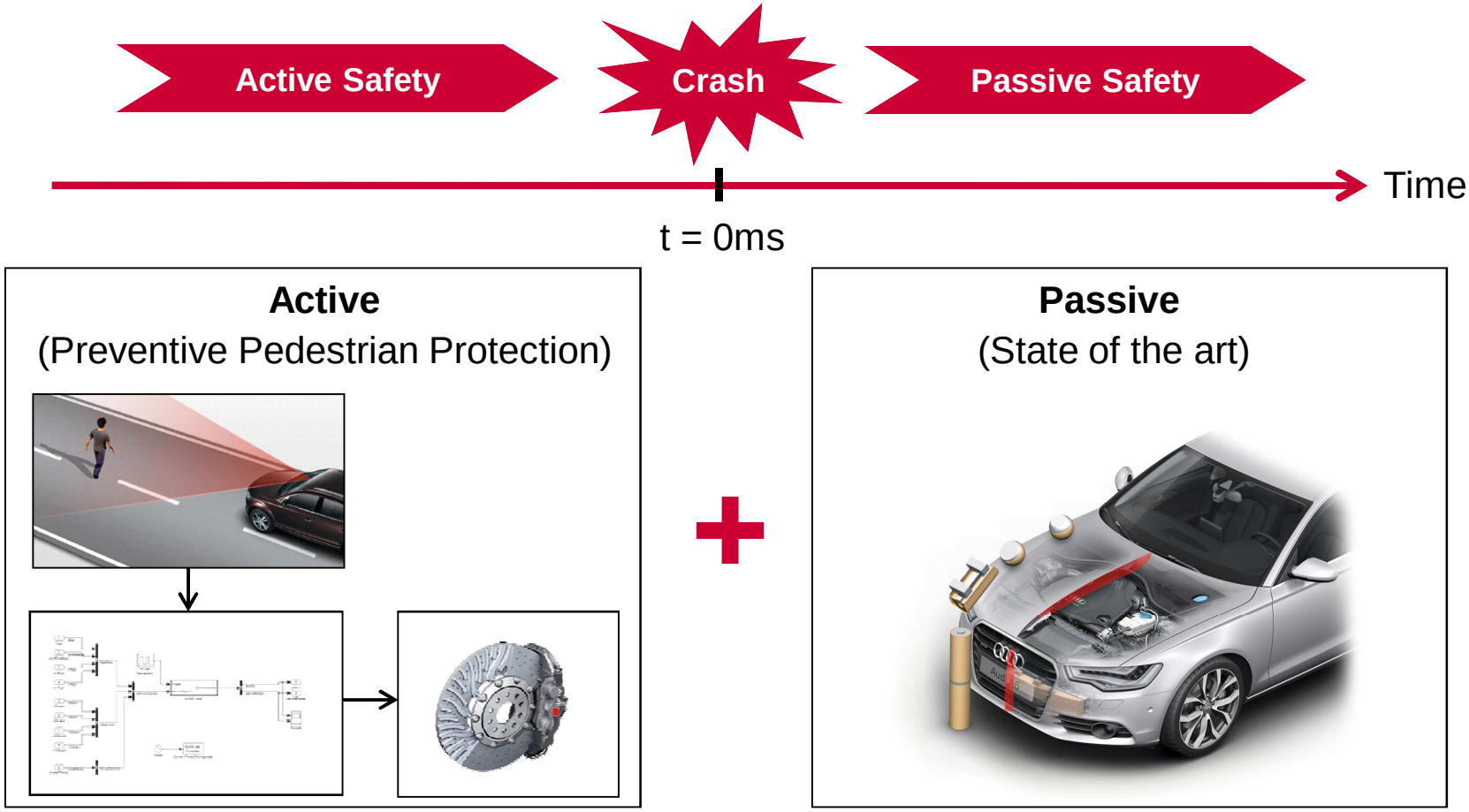
Actuator (Hinge)
- Mechanical (Spring)
- Pyrotechnic
- Pneumatic (Gas cartridge)



Signal processing
- Control unit with power electronics
- Algorithm

Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Future Trends - Integrated Safety



Pedestrian Protection *(Motivation, State of the Art and Future Trends)*

- Summary
  - Pedestrian Protection has been introduced to further reduce fatalities in Public Traffic. The OEMs are aware of their Social Responsibility and have invested in this field.
  - Pedestrian Protection is relevant for the homologation of a car.
  - Pedestrian Protection is developed and tested as an impactor method, for repeatability and reproducibility reasons.
  - The post crash passive pedestrian protection methods are tending towards saturation as far as field effectivity is concerned. (This could be shown studying the injury risk curves corresponding to these different levels)
  - **Active Protection** is the future, due to its higher Field Effectivity and will be the major focus of development in the next years.

Agenda

1. Pedestrian Protection - *Motivation, State of the Art and Future Trends*
2. **Front-Ends - *Scope and Design Conflicts***
3. Processes in Front-End Development
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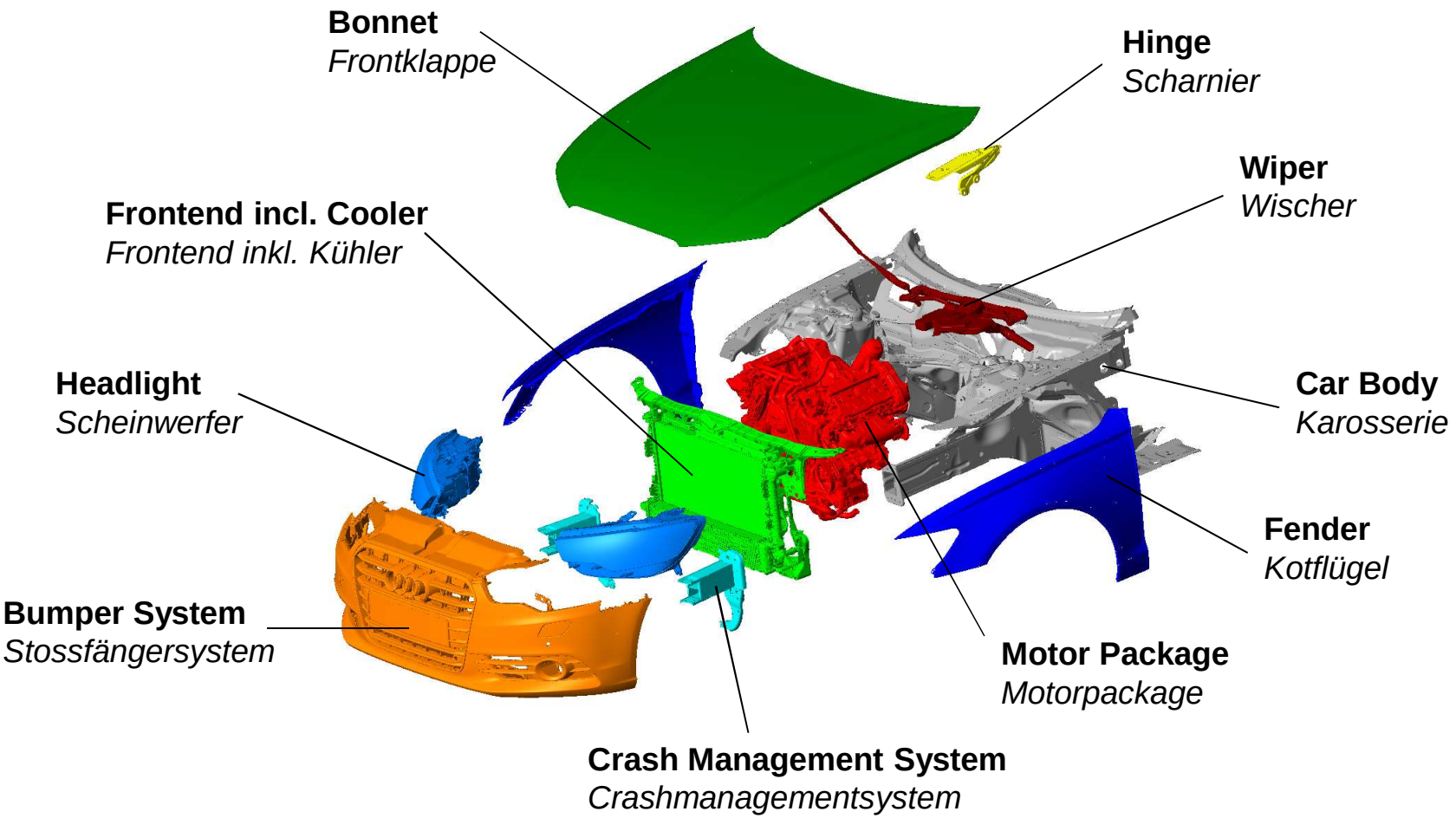
5. Summary

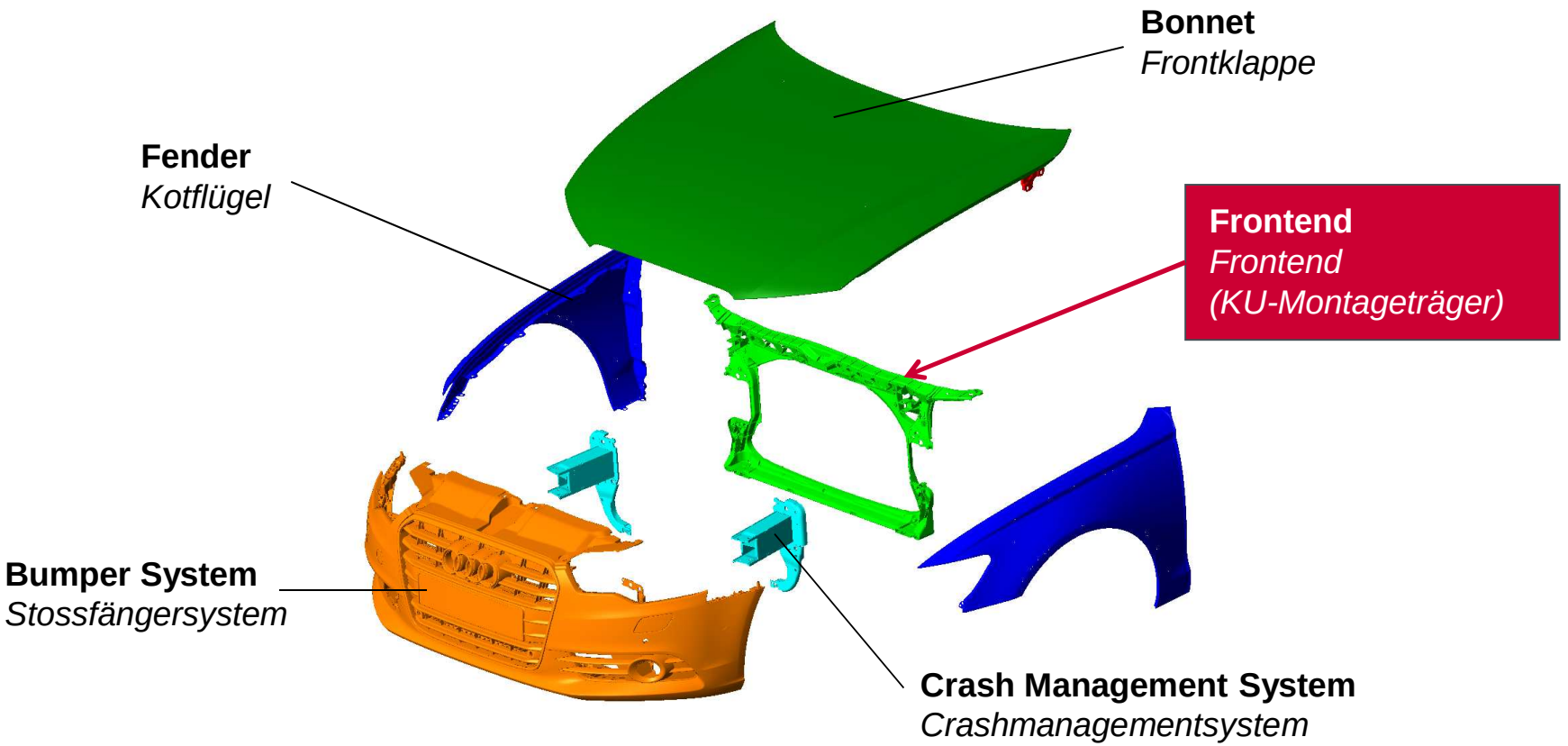
Front-Ends *(Scope and Design Conflicts)*

- Scope - Assemblies of the Front Vehicle



Front-Ends *(Scope and Design Conflicts)*

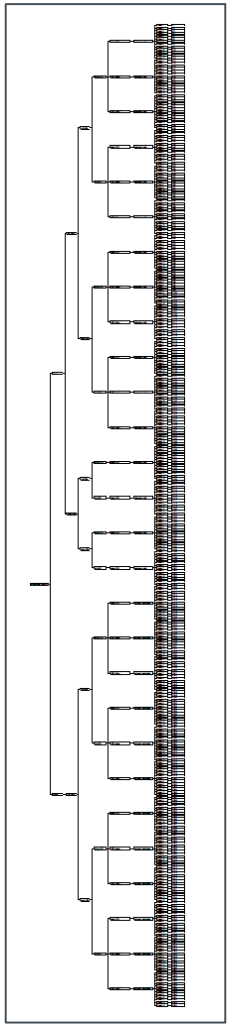
- Scope - Terminology “Front-End”



Front-Ends *(Scope and Design Conflicts)*

- Complexity of the Bumper System for a given Audi car

Equipment	Options	Variants
Bumper System	Standard : S-Line	2
Fog Light	with : with out	3
Headlight Cleaning System	with : with out	6
Audi Parking System	with : with out	12
Licence Plate Cover / Front Grill	with out : Japan : China	28
Colour	13 Colours	**364**



Front-Ends *(Scope and Design Conflicts)*

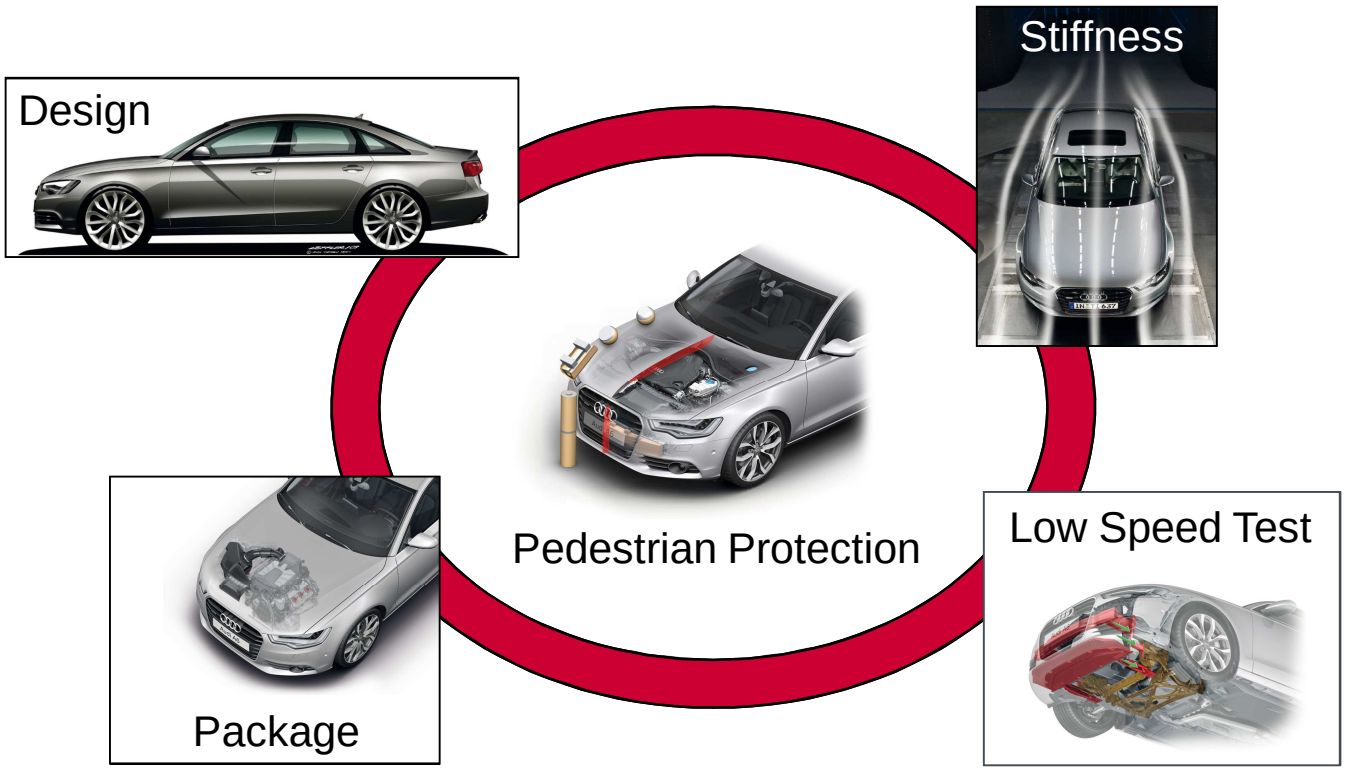
- Future Trend - “**Soft Nose**”

Other Brands

VW Group

Front-Ends *(Scope and Design Conflicts)*

- Design Conflicts
  - Pedestrian Protection vs. Design
  - Pedestrian Protection vs. Bonnet Stiffness
  - Pedestrian Protection vs. Low Speed Test (Insurance Classification)
  - Pedestrian Protection vs. Front Vehicle Package



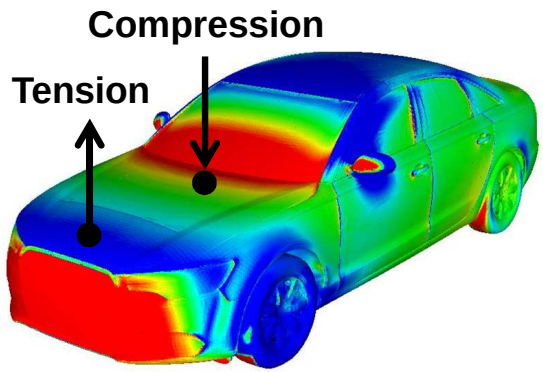
Front-Ends *(Scope and Design Conflicts)*

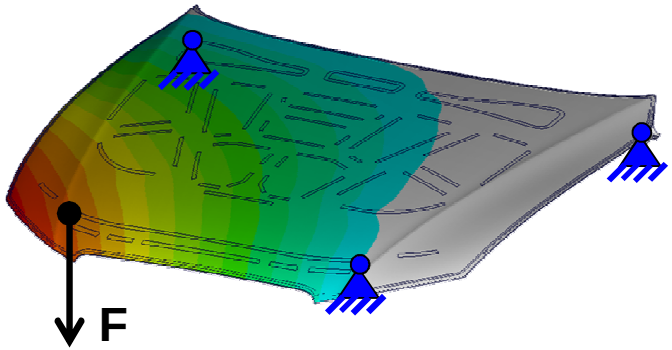
- Pedestrian Protection vs. Design
  - Short Front Overhang
  - Flat Contour

  } Dynamic and Sportive Exterior

Front-Ends *(Scope and Design Conflicts)*

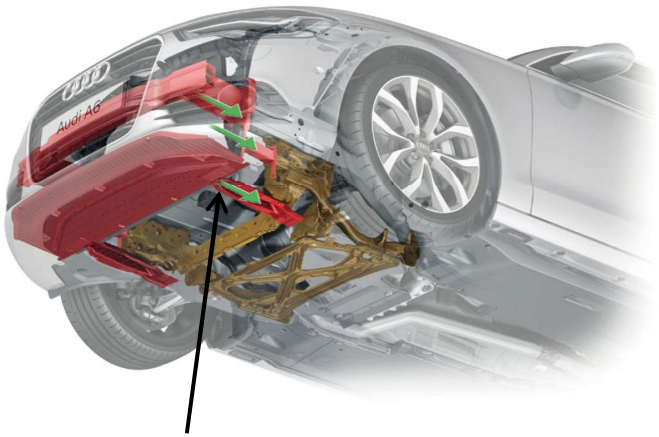
- Pedestrian Protection vs. Bonnet Stiffness
  - Wind Load
  - Tension at the Lock
  - “Special Load Cases”

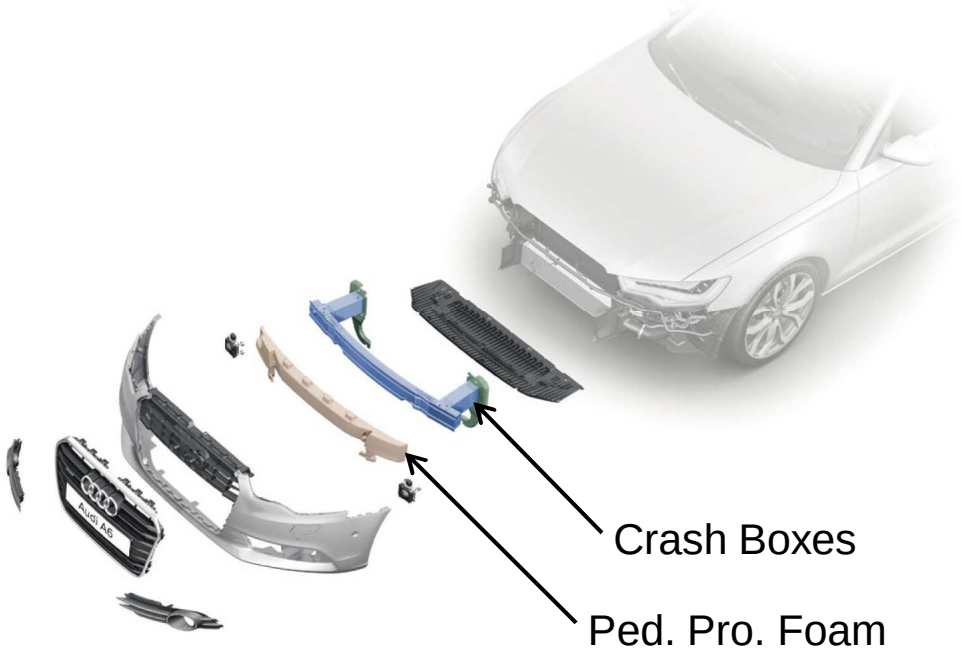




Front-Ends *(Scope and Design Conflicts)*

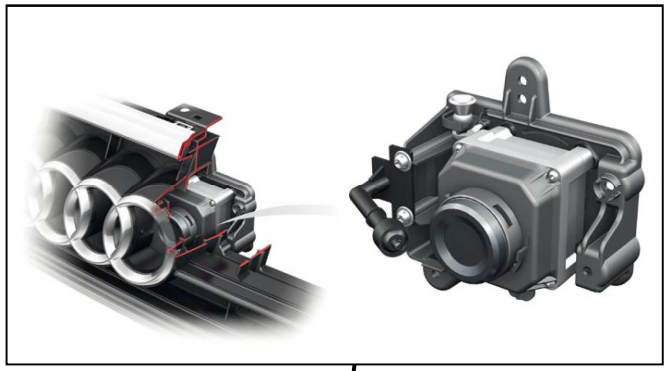
- Pedestrian Protection vs. Low Speed Test (Insurance Classification)
  - No Damage to the Frontend and Cooler → Lower Load Path has to be “opened”
  - Large Crash Boxes → Less space for Pedestrian Protection Foam

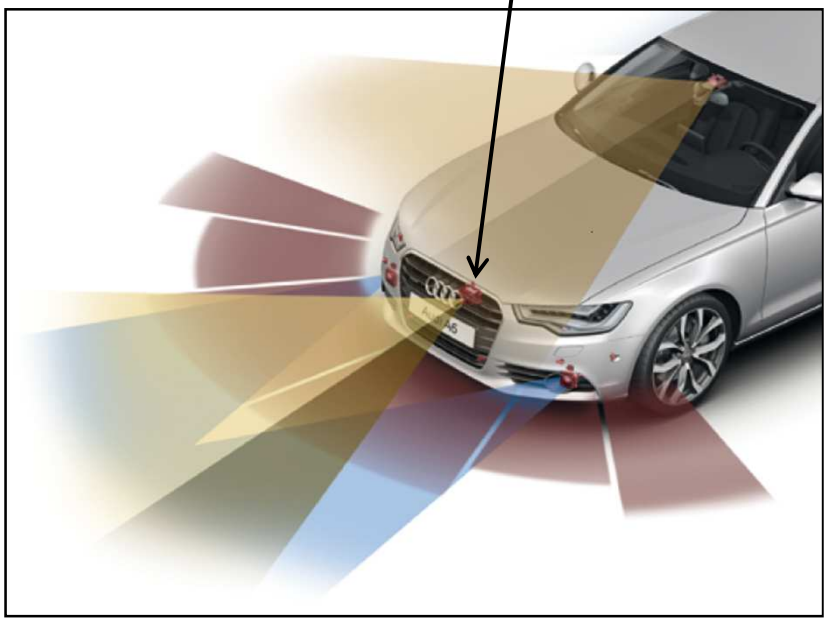




Front-Ends *(Scope and Design Conflicts)*

- Pedestrian Protection vs. Front Vehicle Package
  - Conflict with Air Intake
  - Sensors for Driver Assistance Systems





Front-Ends *(Scope and Design Conflicts)*

- Summary
  - Terminology “Front-End” has been clarified in the English and German context.
  - The Complexity of Front-Ends (in terms of numbers of variants) is quite significant and constitutes a major burden in development, quality assurance, production and logistics both for the OEM and the Suppliers.
  - Given the limited package space in a car, Pedestrian Protection generates many Design Conflicts
  - Observation of market trends shows a tendency to an increased use of the “Soft Nose” - Technology in the Front-End, with advantages especially for Pedestrian Protection and Low Speed Insurance Test.

Agenda

1. Pedestrian Protection - *Motivation, State of the Art and Future Trends*
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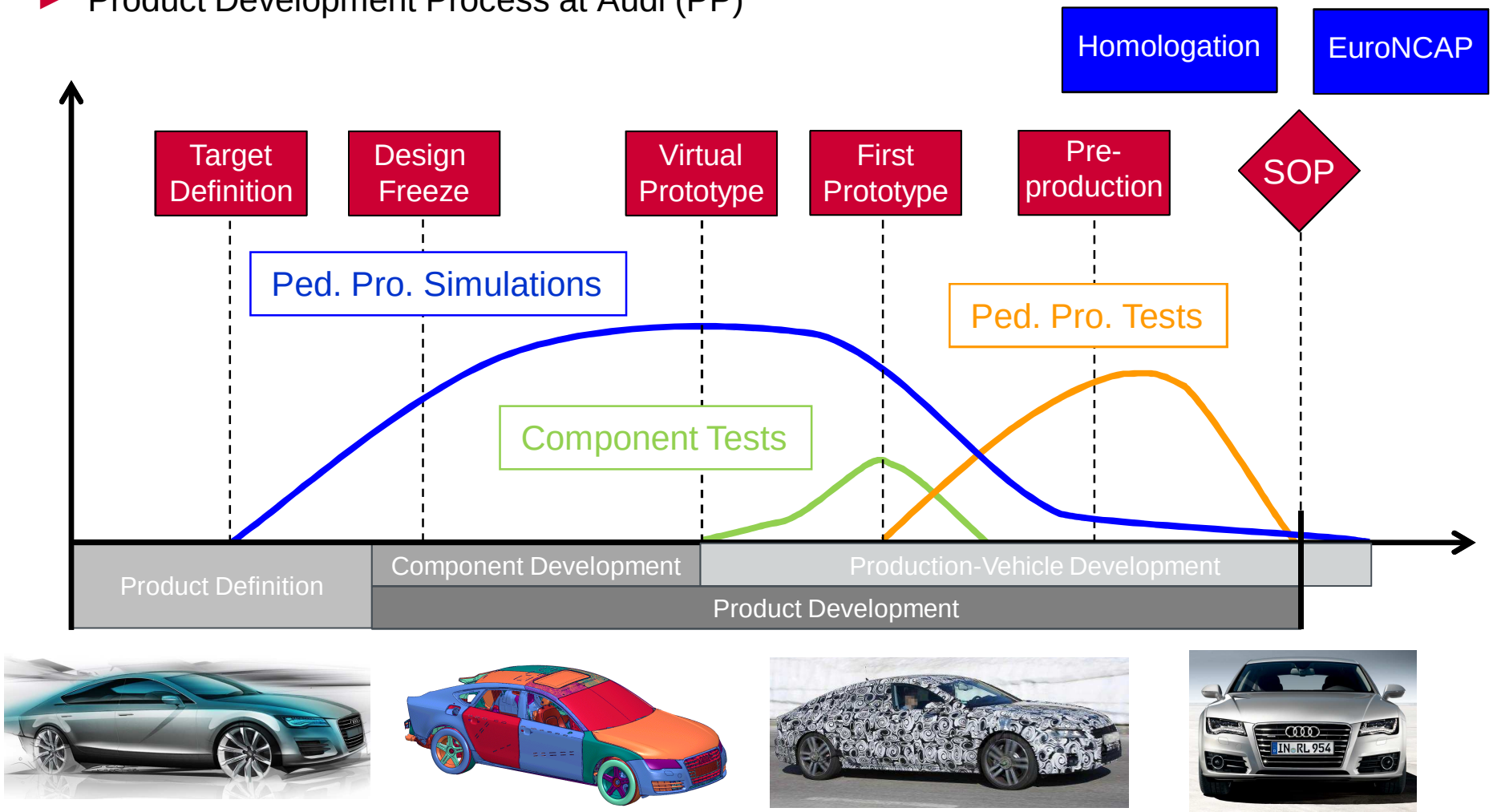
3. **Processes in Front-End Development**
4. Virtual Testing - *State of the Art in Industry and Research, Future Trends*
5. Summary

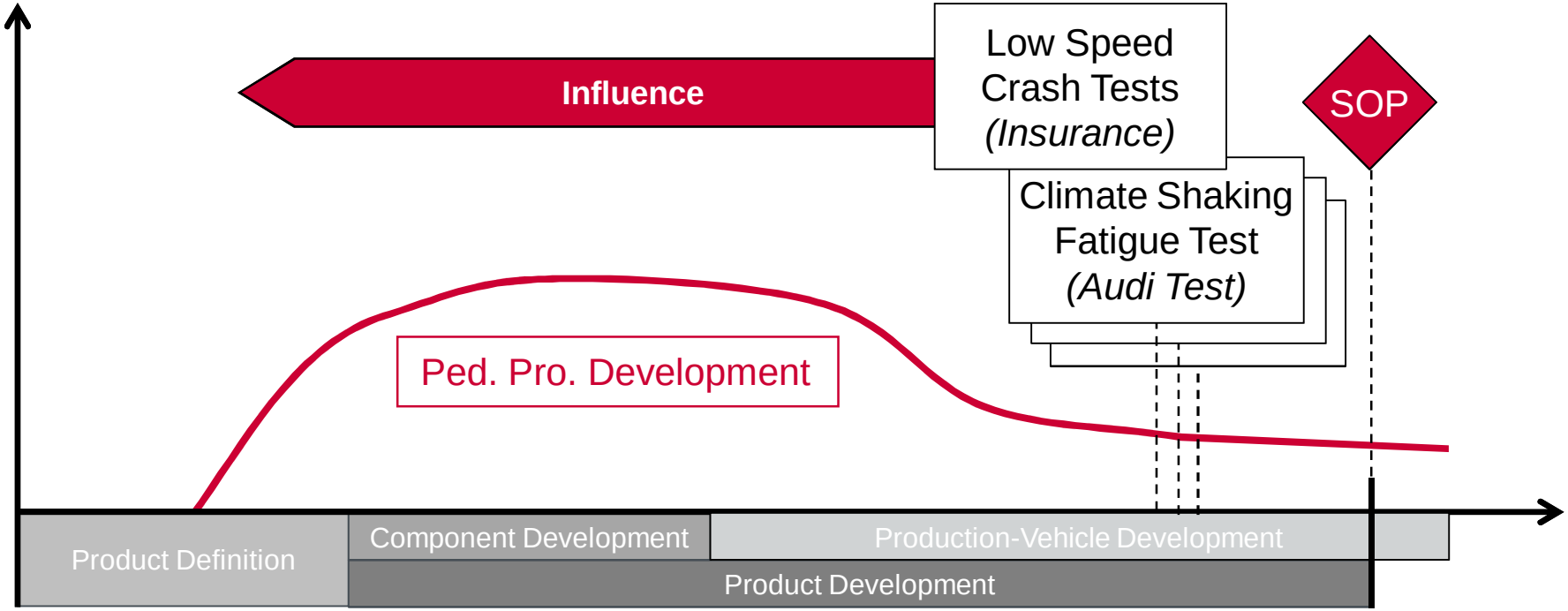
Processes in Front-End Development

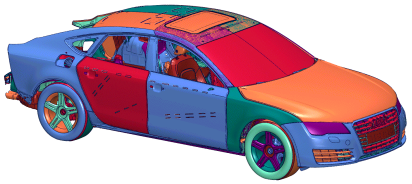
- Product Development Process at Audi (PP)



Processes in Front-End Development

- Other Functions influencing Pedestrian Protection





Processes in Front-End Development

- Summary
  - Given the typical Product Development Process of a car, Front-End development marks the very beginning and the very end of the design cycle, for its concept relevance and the complexity of the testing requirements, respectively.
  - Component Tests will gain importance as they bridge the gap between the virtually driven concept phase and the availability of first physical prototypes or preproduction cars.
  - As the understanding of the component requirements grows, suppliers will be more and more able to pre-optimize their components without the need of a full vehicle.
  - The key to a stable Front-End development process lies in the quality of virtual methods that represent the physical tests relevant for the release towards the end of the development cycle.

Agenda

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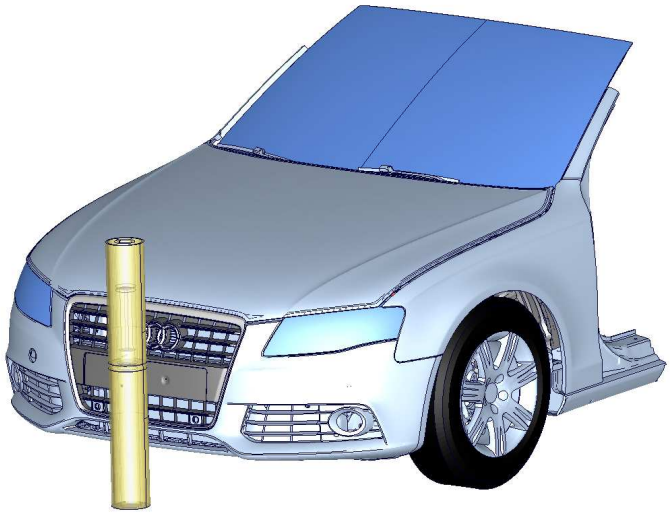
5. Summary

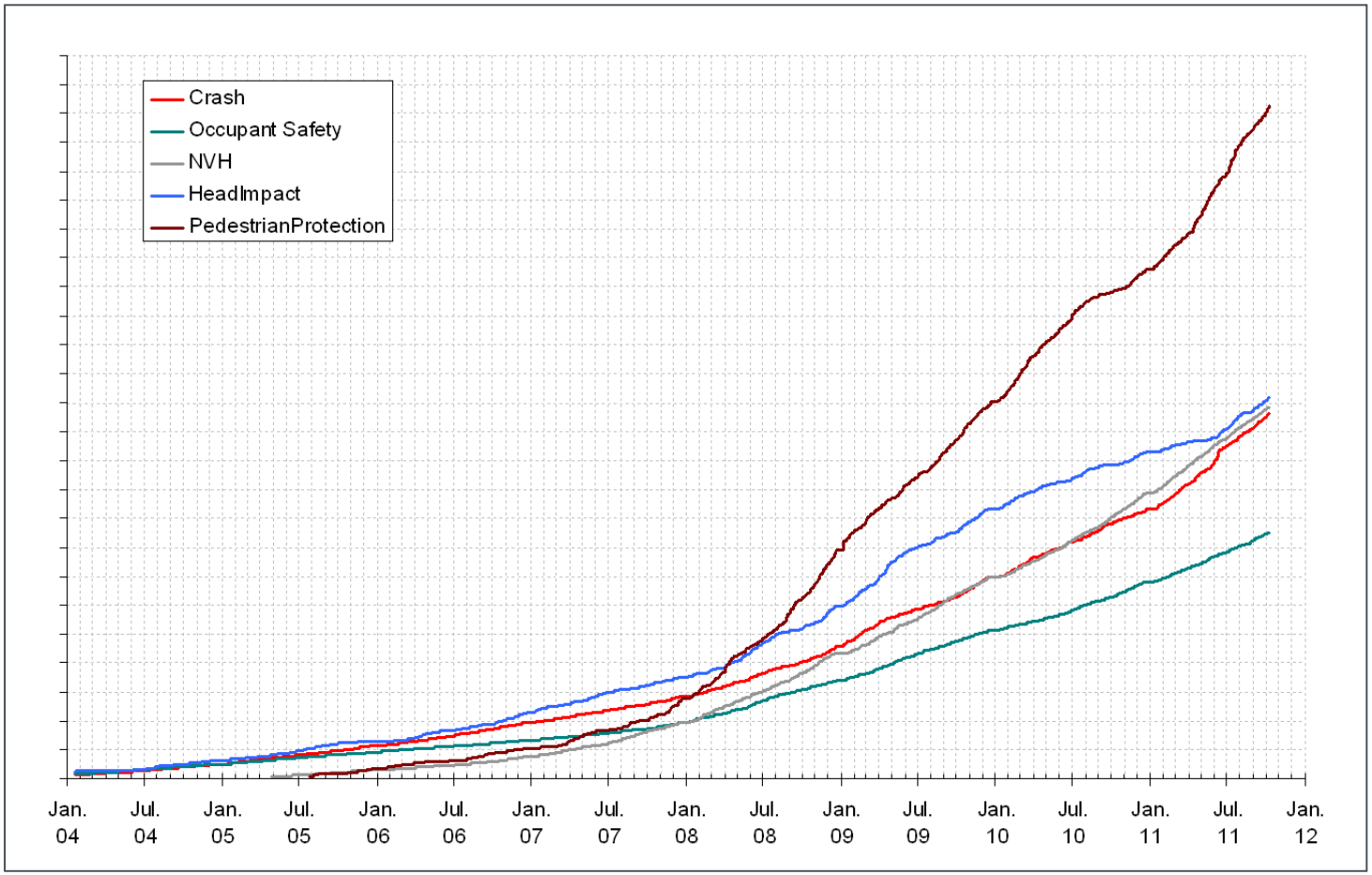
Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Motivation for Virtual Testing
  - Experiments are **Cost** and **Time** consuming
  - **No Prototypes** in early stages of the Development Process
  - Simulation offers much more **Information**



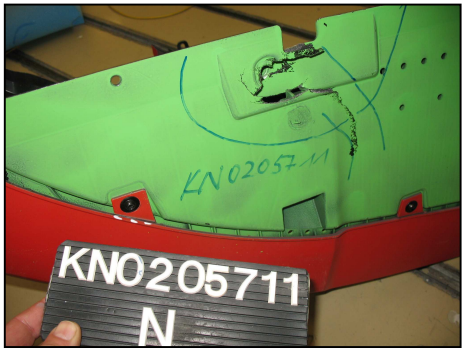
Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

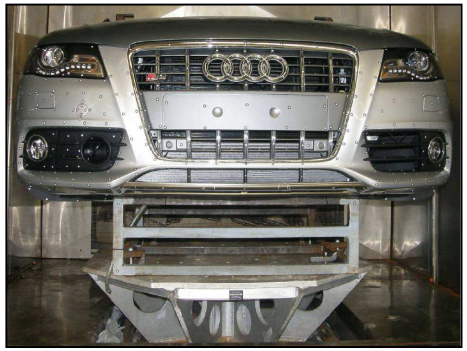
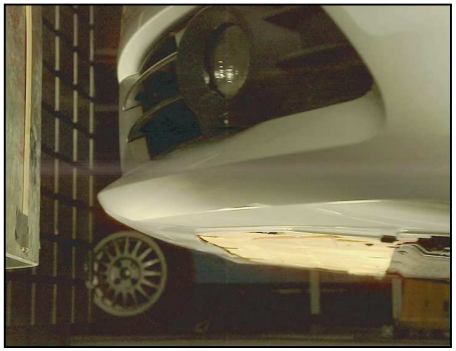
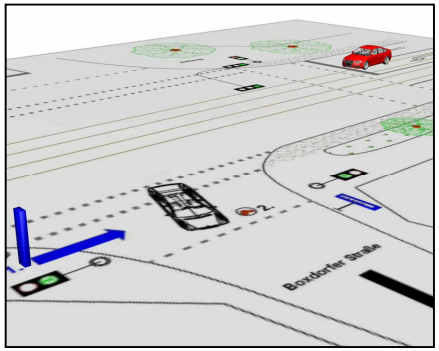
- Quantity of Virtual Testing at Audi (cumulated)



Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

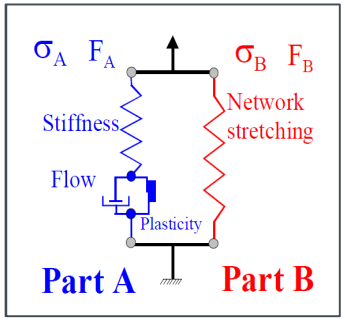
- Some Challenges in Virtual Testing for Pedestrian Protection
  - Crash and Fracture Behaviour of Polymers
  - Climate Shaking Fatigue Test
  - Low Speed Crash
  - Evaluation of the Field Effectivity



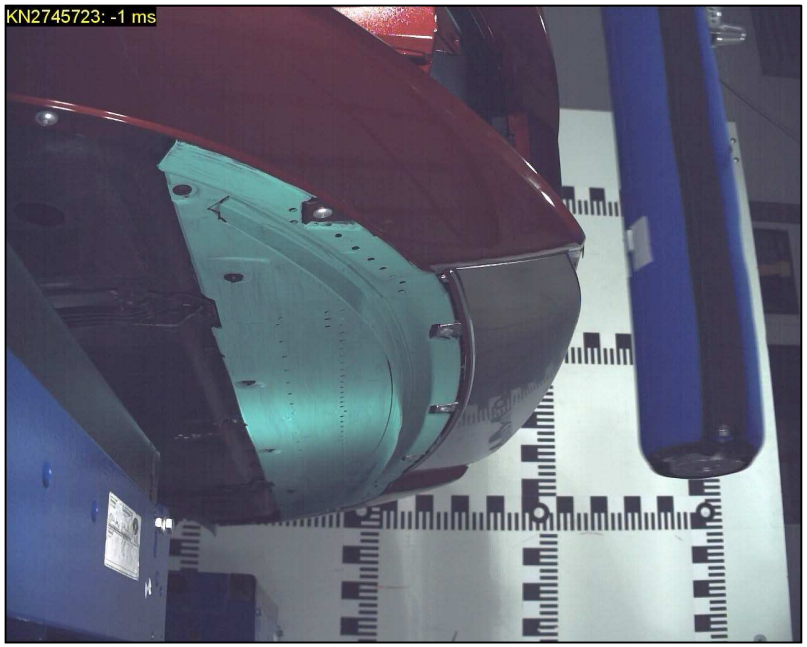




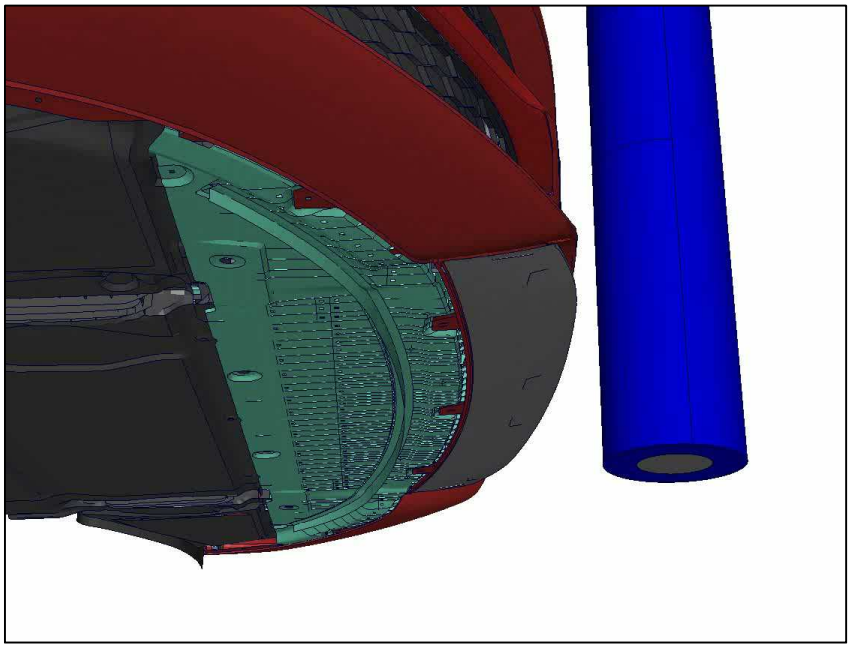
Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Crash and Fracture Behaviour of Polymers - Challenges
  - Complex Material Behaviour → New Material Models
  - Influence of Manufacturing Process (e.g. Fibre Orientation)
  - Complex Fracture Behaviour



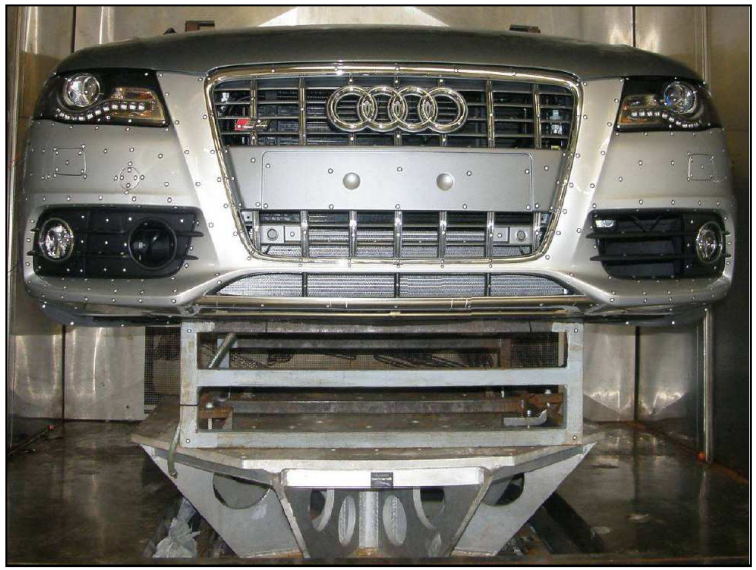
[SIMLab]

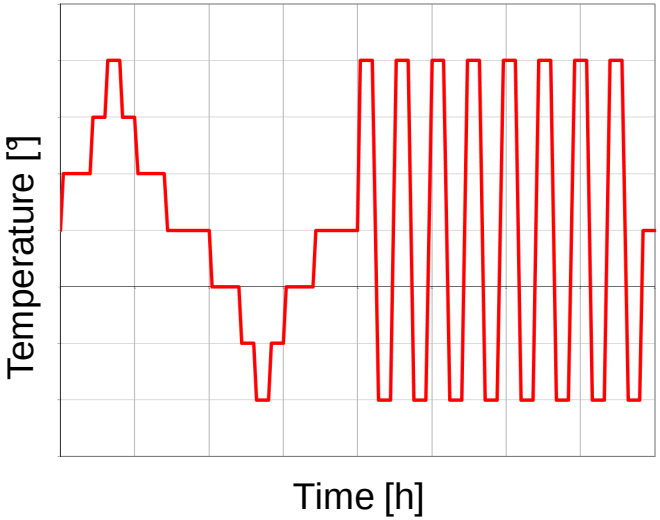


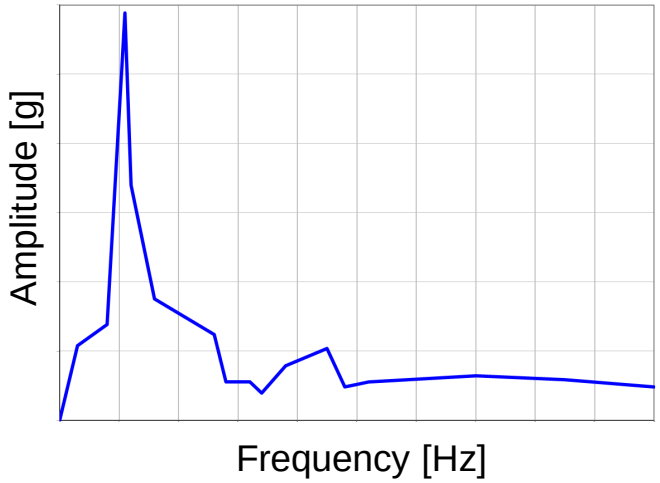


Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Climate Shaking Fatigue Test - Challenges
  - Material Behaviour (Creep, Temperature, Fatigue)
  - Simulation -
    Coupling of thermal and mechanical Behaviour

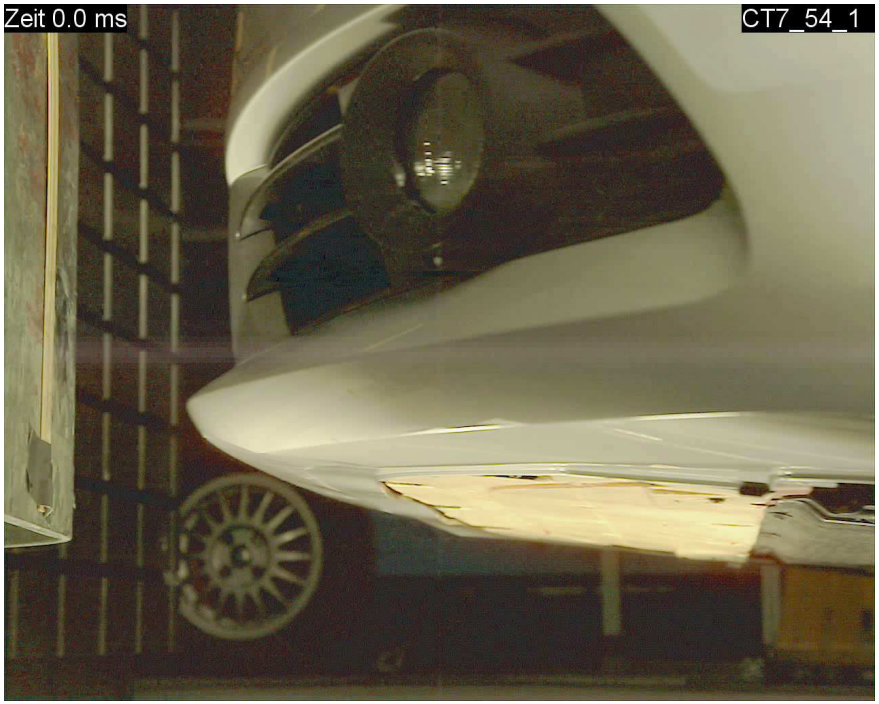


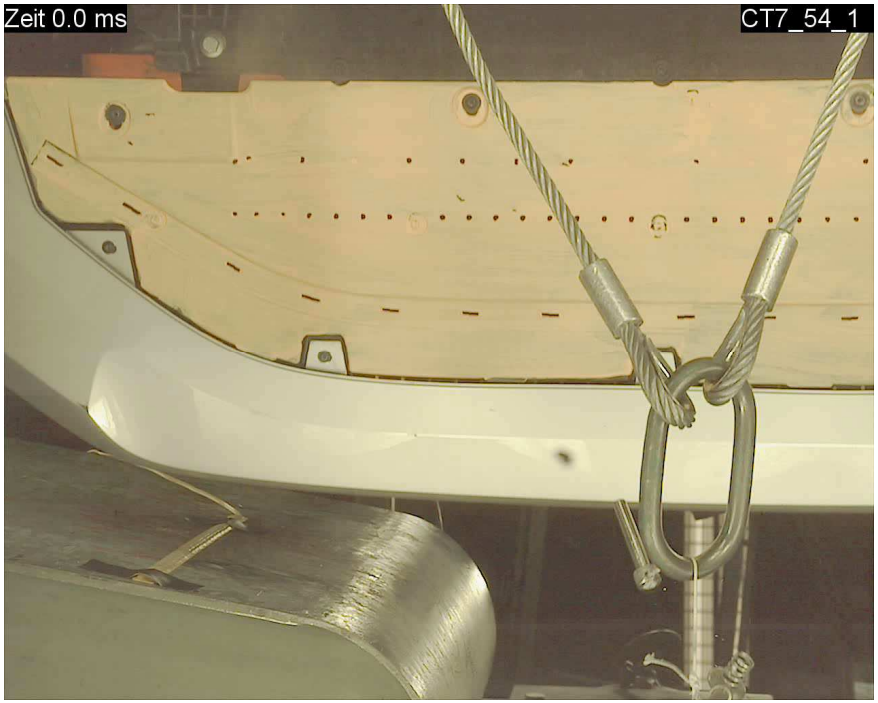




Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Low Speed Crash - Challenges
  - Crash- and Fracture Behaviour of Polymers
  - Joints and Connectors



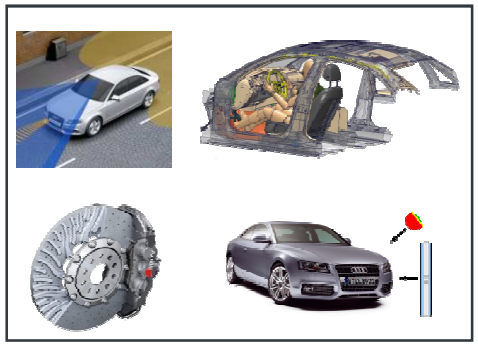


(AZT Insurance Test, 16 km/h, 10°)

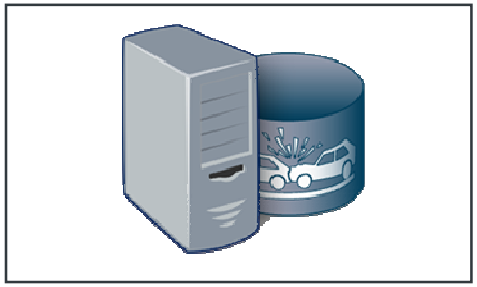
Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Evaluation of the Field Effectivity

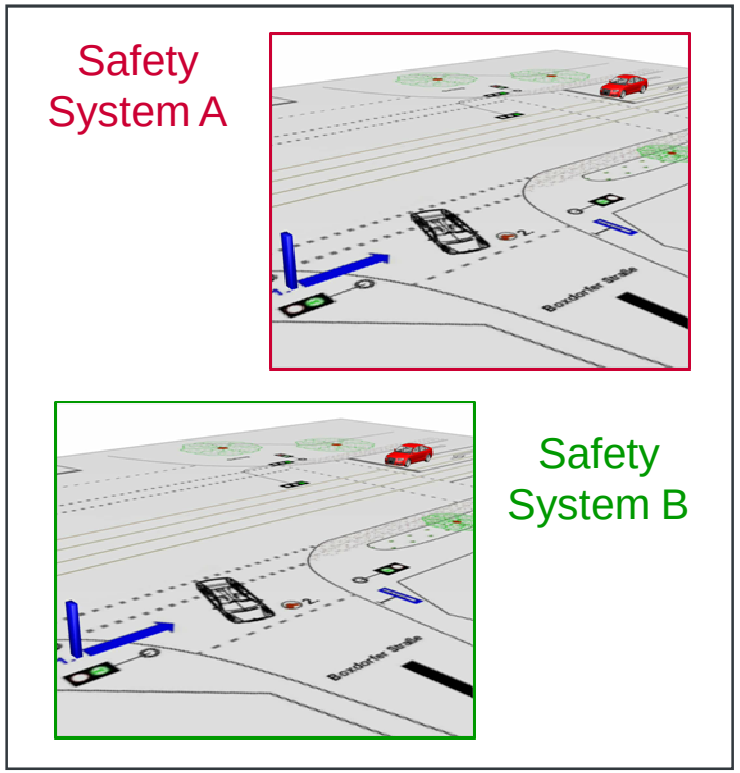
System Specification



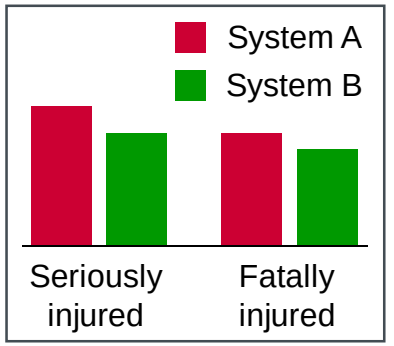
Real World in-depth Accident Data (GIDAS)



System Simulation



Real World Benefit of different Systems



Virtual Testing *(State of the Art in Industry and Research, Future Trends)*

- Summary
  - Virtual Testing is the key to successfully manage the challenges in automotive Front-End development in a cost efficient manner.
  - Simulation gets more and more important in Pedestrian Protection Development, yet accuracy needs further improvement, especially for the polymer components in the presence of unexpected fracture. Coupling of process simulation with structural simulation constitutes an important element to ensure seamless collaboration between Supplier and OEM.
  - Other disciplines affecting Front-End design, such as the simulation of Low Speed Crash and Climate Shaking Fatigue Test also need improvement.
  - Simulation methods are continuously being developed both by OEMs and Suppliers. Given the limitations of simulation and the relevance of experimental testing in the launching phase, each company has to find its way to optimize the interaction between virtual and physical testing methods.

Agenda

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5. **Summary**

Summary
Pedestrian Protection and its Implications on Front-Ends

- It is well known that Pedestrian Protection has significantly changed the manner to develop Front-Ends, in many cases leading to a new design language. Front-Ends which do not satisfy Pedestrian Protection may not be sold in many important markets.
- The post crash passive pedestrian protection methods are tending towards saturation as far as Field Effectivity is concerned.
- Given the limited package space in a car, Pedestrian Protection generates many Design Conflicts.
- Component Tests will gain importance as they bridge the gap between the virtually driven concept phase and the availability of first physical prototypes or preproduction cars.
- Virtual Testing is the key to successfully manage the challenges in automotive Front-End development in a cost efficient manner.
- Active Protection is the future, due to its higher Field Effectivity and will be the major focus of development in the next years.

Audi
Vorsprung durch Technik

Thank you.

References

[IRTAD] Data Source: IRTAD (International Road Traffic and Accident Database)
http://internationaltransportforum.org/irtadpublic/index.html

[GIDAS] VW-GIDAS Accident database 2006
(Basis: 649 Frontal collisions between pedestrians and cars/MPV, MAIS 2+,
no multiple collision, no skidding vehicles)

[SIMLab] Polanco-Loria Mario, A.H. Clausen, T. Berstad, O.S. Hopperstad (2011),
Constitutive model for thermoplastics with structural applications,
International Journal of Impact Engineering 37, 12, 1207-1219