

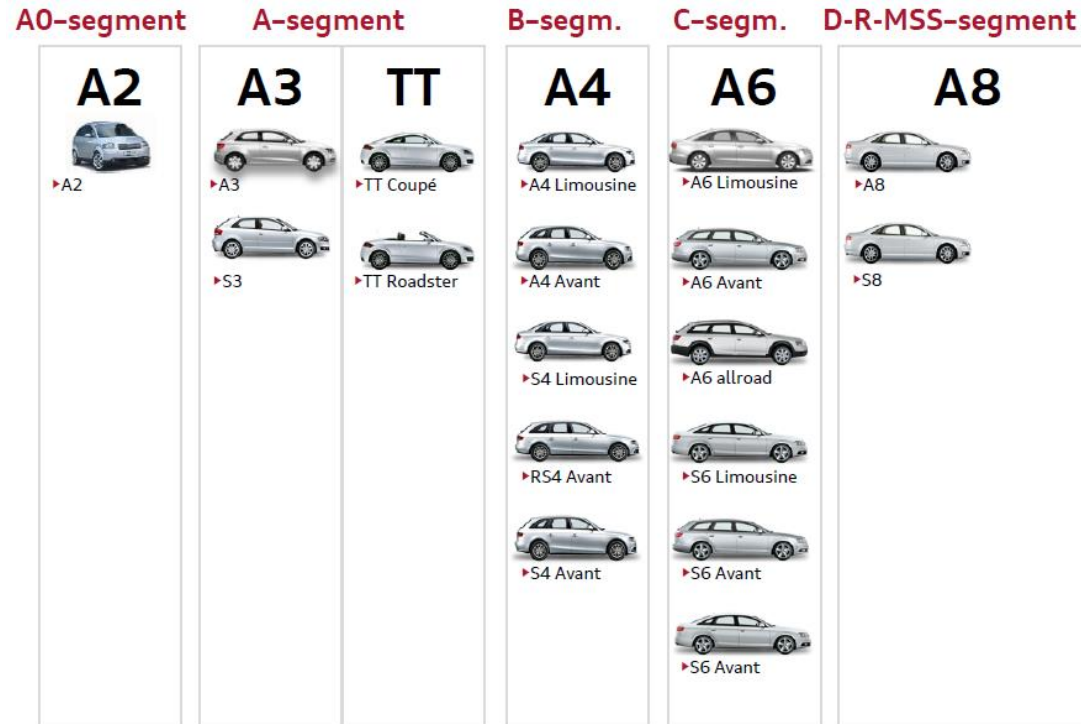
CFD Simulation of Water Management of a Vehicle under Realistic Driving Conditions

Dr. Dirk Bäder, Audi AG

























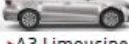










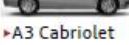





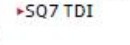















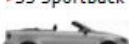








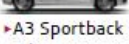

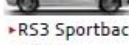

Agenda

- › Challenge
- › Investigation of the Influence of the Windscreen Wiper Movement
- › Investigation of the Influence of the Airflow Field
- › Investigation of the Influence of Acceleration Forces
- › Summary and Outlook

Overview over vehicles of the Audi AG in the year 2000








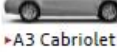
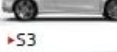




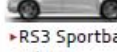












































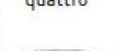












Overview over vehicles of the Audi AG in the year 2015

A0-segment	A-segment			B-segment			C-segment			D-segment	MSS
A1	A3	TT	Q2	A4	A5	Q5/Q	A6	A7	Q7	A8	R8
 A1	 A3	 TT Coupé	 Q2	 A4 Limousine	 A5 Coupé	 Q5	 A6 Limousine	 A7 Sportback	 Q7	 A8	 R8 Coupé
 A1 Sportback	 A3 Sportback	 TT Roadster		 A4 Avant	 A5 Sportback	 SQ5 TDI	 A6 Avant	 S7 Sportback	 Q7 e-tron quattro	 A8 hybrid	 R8 Spyder
 S1	 A3 Limousine	 TTS Coupé		 A4 allroad quattro	 A5 Cabriolet	 Q5 hybrid quattro	 A6 hybrid	 RS7 Sportback	 S7 Sportback quattro	 S8	 R8 e-tron
 S1 Sportback	 A3 Cabriolet	 TTS Roadster	Q3	 S4 Limousine	 S5 Coupé		 A6 allroad quattro	 RS7 Sportback performance	 SQ7 TDI	 A8 L	
	 S3	 TT RS Coupé	 Q3	 S4 Avant	 S5 Sportback		 S6 Limousine			 A8 L hybrid	
	 S3 Limousine	 TT RS Roadster	 RS Q3	 RS4 Avant	 S5 Cabriolet		 S6 Avant			 A8 L W12	
	 S3 Sportback		 RS Q3 performance	 A4 L	 RS5 Coupé		 RS6 Avant			 S8 plus	
	 S3 Cabriolet				 RS5 Cabriolet		 RS5 Avant performance				
	 RS3 Sportback						 A6 L				
	 A3 Sportback e-tron										
	 RS3 Sportback g-tron										

Bildquelle: Vortrag D. Bäder: Berechnung der Lufttemperaturen im Motorraum eines Fahrzeugs, NAFEMS-Konferenz, November 2017 sowie R. Borris: Customized developments for AUDI's OpenFOAM process, October 11, 2016, OpenFOAM-Conference 2016

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 ▶A1  ▶A1 Sportback  ▶S1  ▶S1 Sportback	 ▶A3  ▶A3 Sportback  ▶A3 Limousine  ▶A3 Cabriolet  ▶S3  ▶S3 Limousine  ▶S3 Sportback  ▶S3 Cabriolet  ▶S3 Sportback  ▶A3 Sportback e-tron  ▶RS3 Sportback g-tron	 ▶TT Coupé  ▶TT Roadster  ▶TTS Coupé  ▶TTS Roadster  ▶TT RS Coupé  ▶TT RS Roadster	 ▶Q2 Q3  ▶Q3  ▶RS Q3  ▶RS Q3 performance	 ▶A4 Limousine  ▶A4 Avant  ▶A4 allroad quattro  ▶S4 Limousine  ▶S4 Avant  ▶RS4 Avant  ▶A4 L	 ▶A5 Coupé  ▶A5 Sportback  ▶A5 Cabriolet  ▶S5 Coupé  ▶S5 Sportback  ▶S5 Cabriolet  ▶RS5 Coupé  ▶RS5 Cabriolet	 ▶Q5  ▶SQ5 TDI  ▶Q5 hybrid quattro	 ▶A6 Limousine  ▶A6 Avant  ▶A6 hybrid  ▶A6 allroad quattro  ▶S6 Limousine  ▶S6 Avant  ▶RS6 Avant  ▶RS6 Avant performance  ▶A6 L	 ▶A7 Sportback  ▶S7 Sportback  ▶RS7 Sportback  ▶RS7 Sportback performance	 ▶Q7  ▶Q7 e-tron quattro  ▶SQ7 TDI	 ▶A8  ▶A8 hybrid  ▶S8  ▶A8 L  ▶A8 L hybrid  ▶A8 L W12  ▶S8 plus	 ▶R8 Coupé  ▶R8 Spyder  ▶R8 e-tron

An excerpt of wheels of the Audi A4

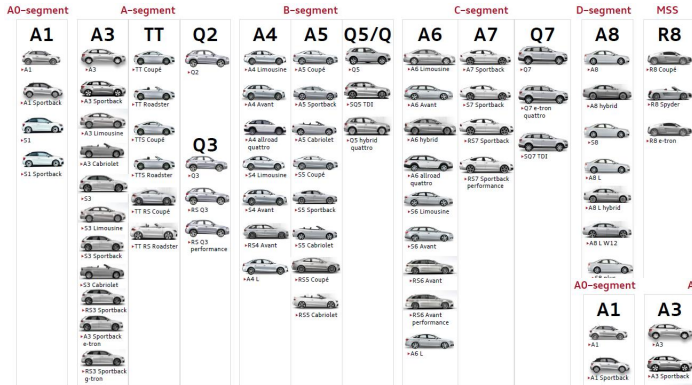


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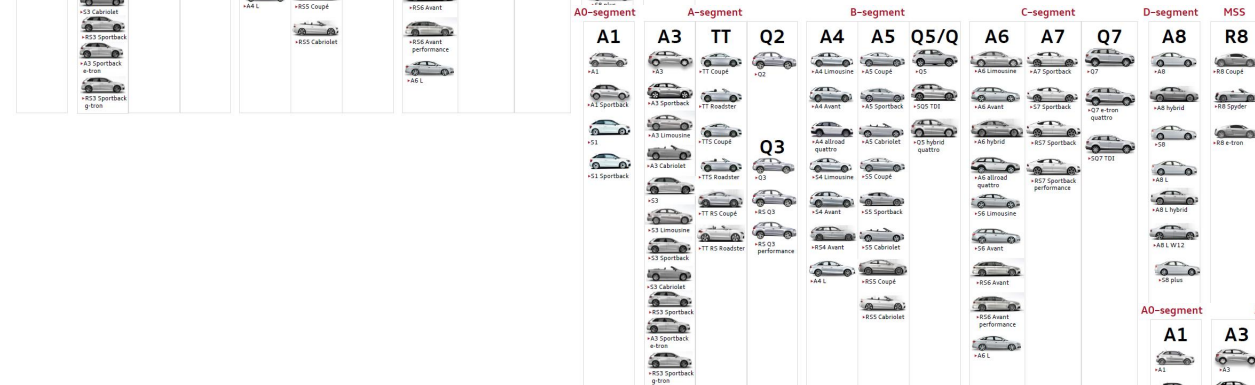
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What does the future bring?

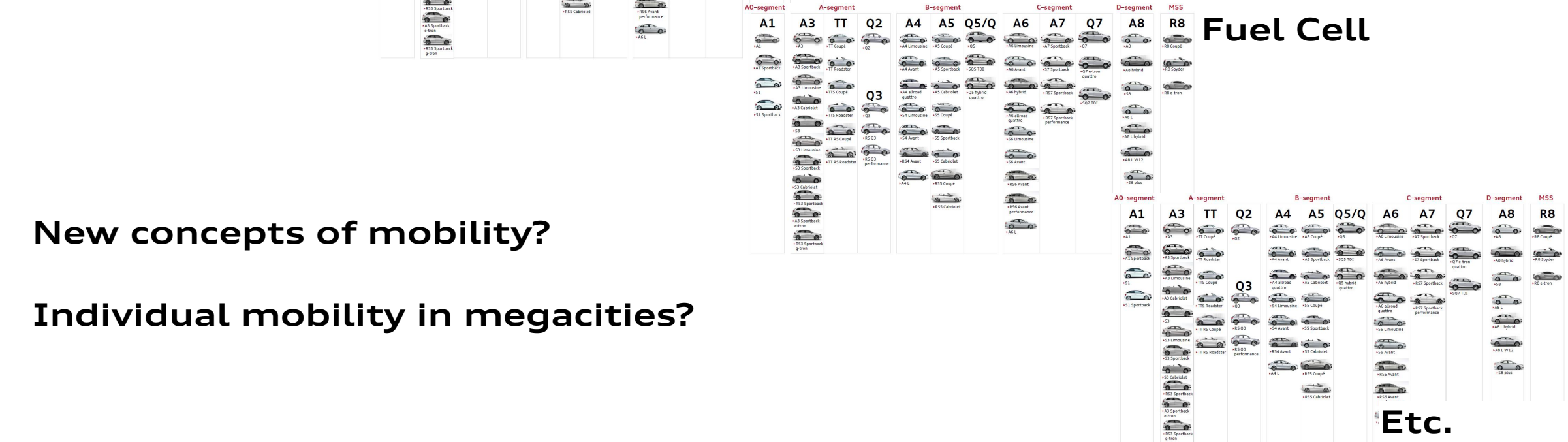
Conventional drive units (Otto + Diesel) with conventional and e-fuels



Electrical drive units (BEV, HEV, etc.)



Fuel Cell



New concepts of mobility?

Individual mobility in megacities?

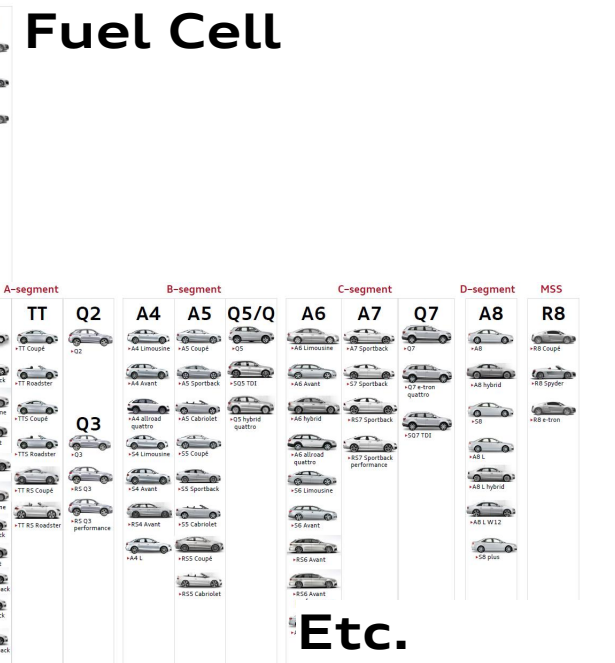
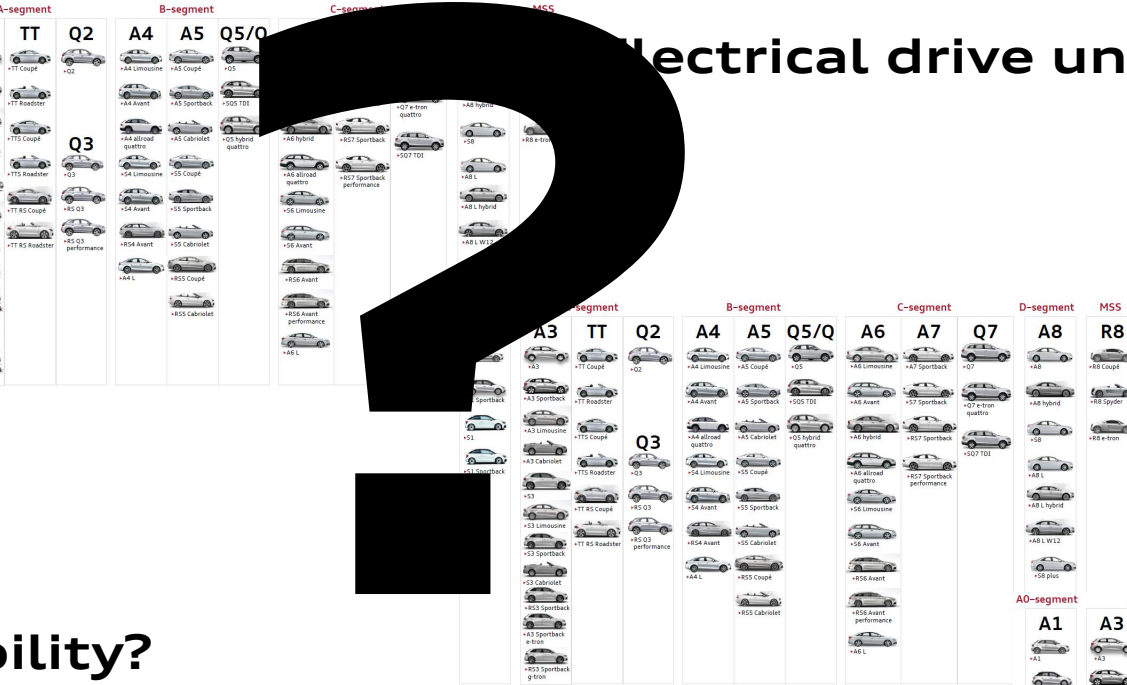
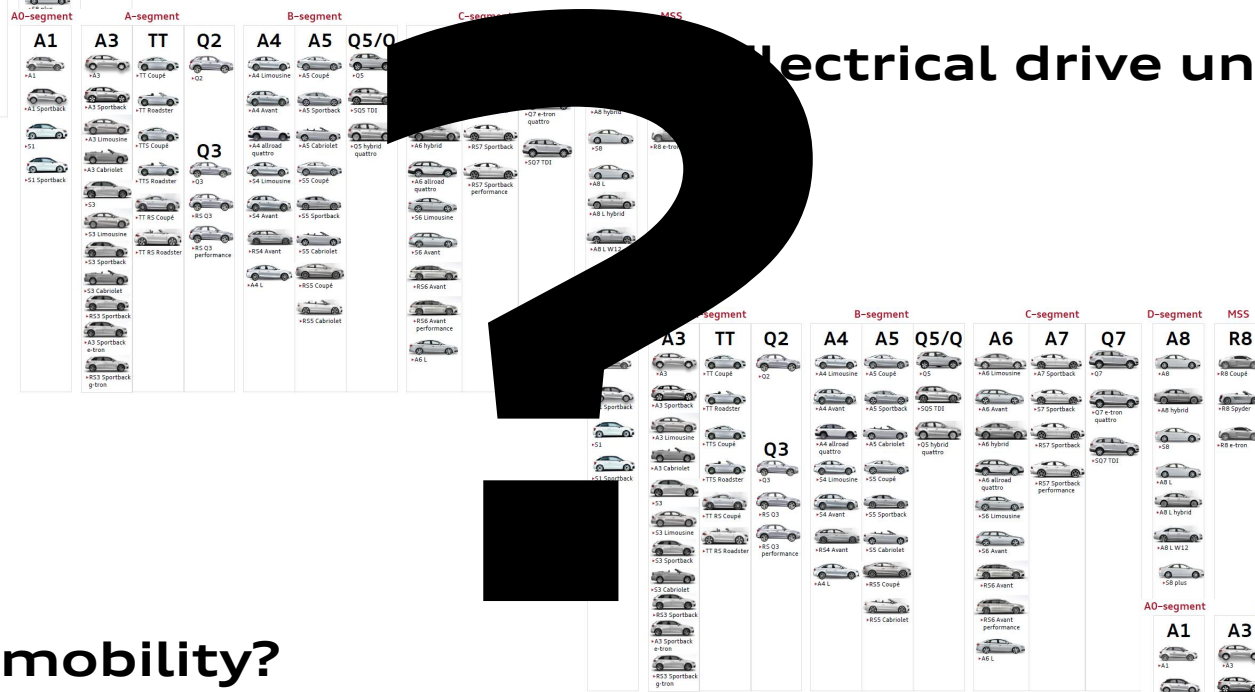
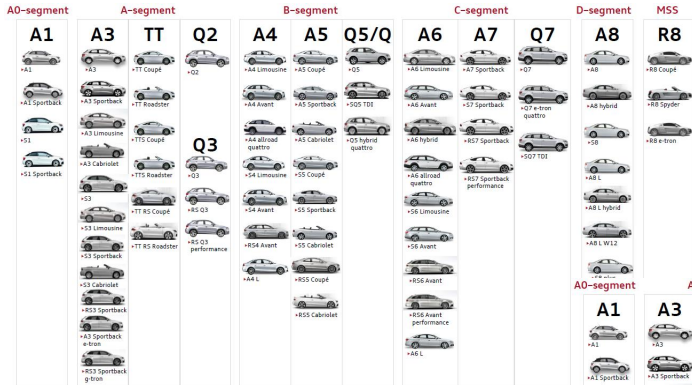
Etc.

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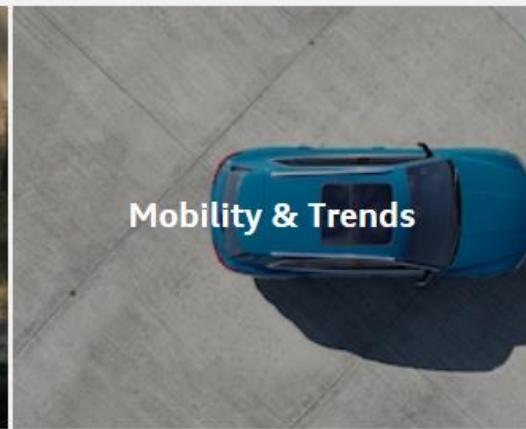


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Etc.

The World Changes – Audi Strategy

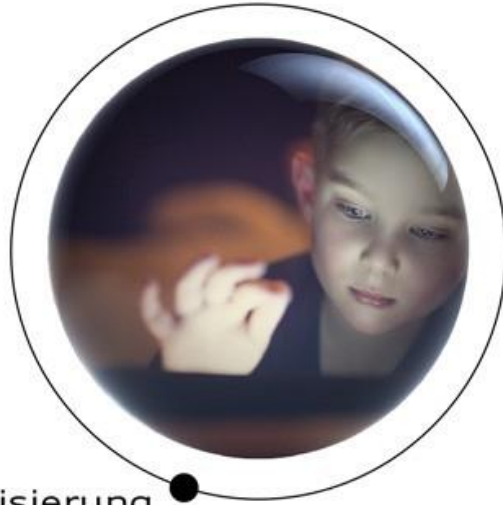


Digitalization – Audi Strategy:

Digitization offers great opportunities for Audi: Vehicles can be personalized and made safer, the driving public protected and the flow of traffic made more efficient. **We aim to systematically digitize our processes** and use digital services to open up new business models and sales potential – in retail, in the vehicle and for mobility offers beyond the vehicle.

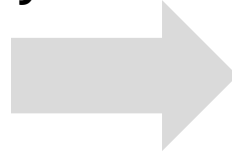


Digitalization – Audi Strategy



Digitalisierung

Development of new Simulation Methods are necessary



► thermal management



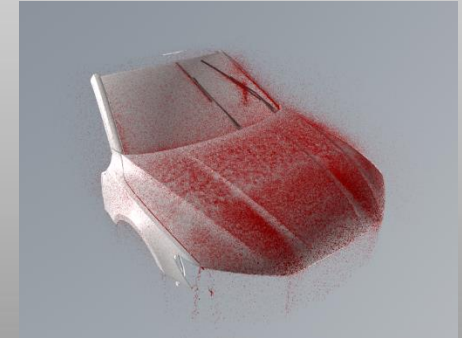
► aerodynamics/aeroacoustics



► cabin HVAC



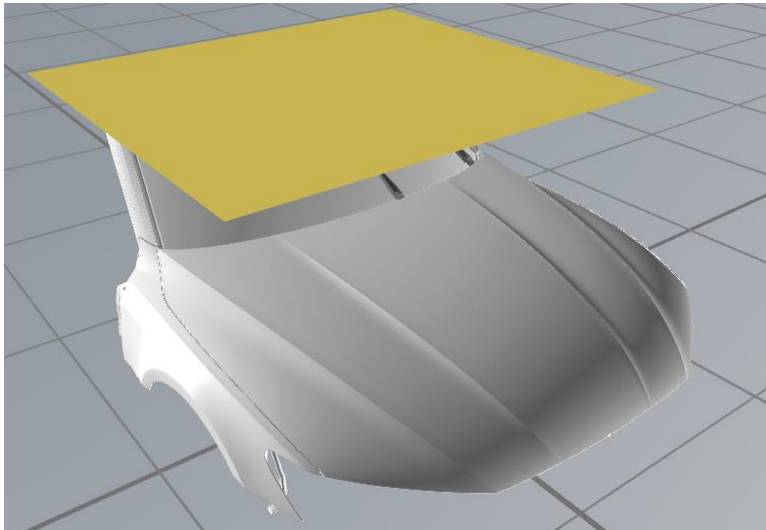
► water management



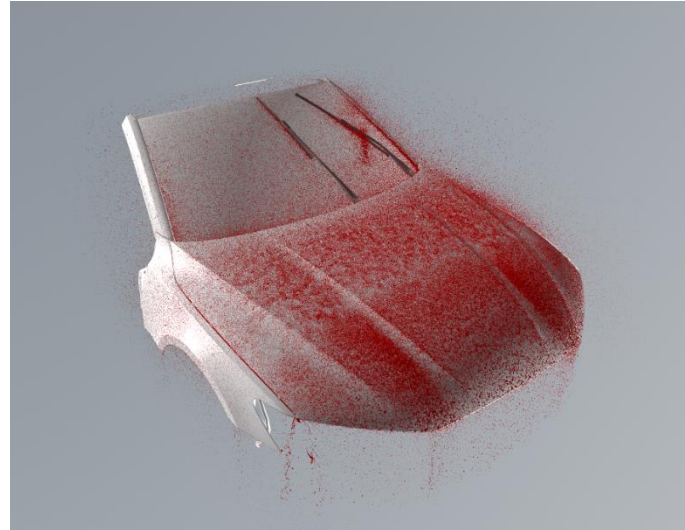
Water Management Simulations

- › Using simulation techniques that have never been used before at Audi, at least when looking back 5 to 10 years
- › Water Management Simulations are of huge interest in order to predict water pathes
- › In the following, the simulation of the water path around the front part of the vehicle is investigated
 - › Wetting of the air intake for HVAC
 - › Wetting of components, in particular metallic components, in the water box located under to root of the front window

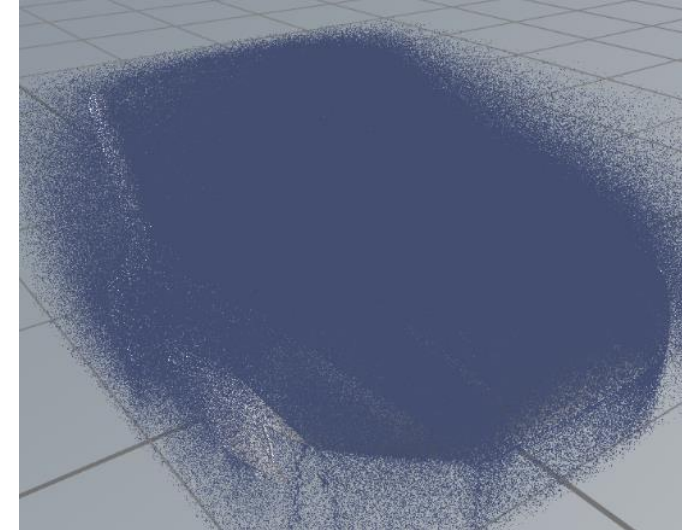
Rain Source



Rain – Mainly visible the wetted surface



Rain – Mainly visible the rain in space



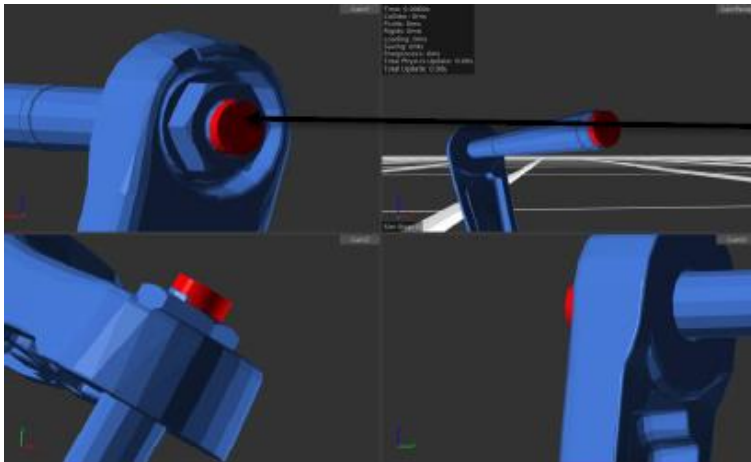
Bildquelle: D. Bäder, F. Paur, M. Ehlen: Simulation of the air intake of the air conditioning unit of a vehicle in heavy rain, NAFEMS 2018

Modeling of the Movement of the Windscreen Wipers

Definition of the movement:

- Very complex movements can be modeled
- Different rotational velocities around different pivots can be defined
- The real movement of the pivots can be defined
- A challenge is the bending of the wiper itself

Pivots

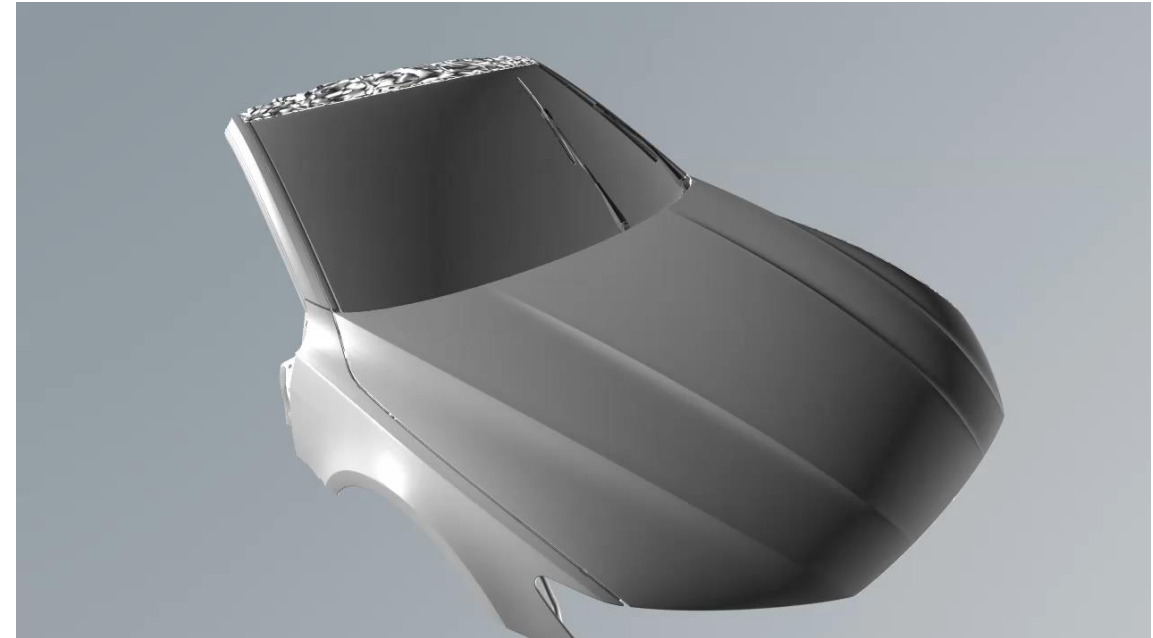


Wiper rods



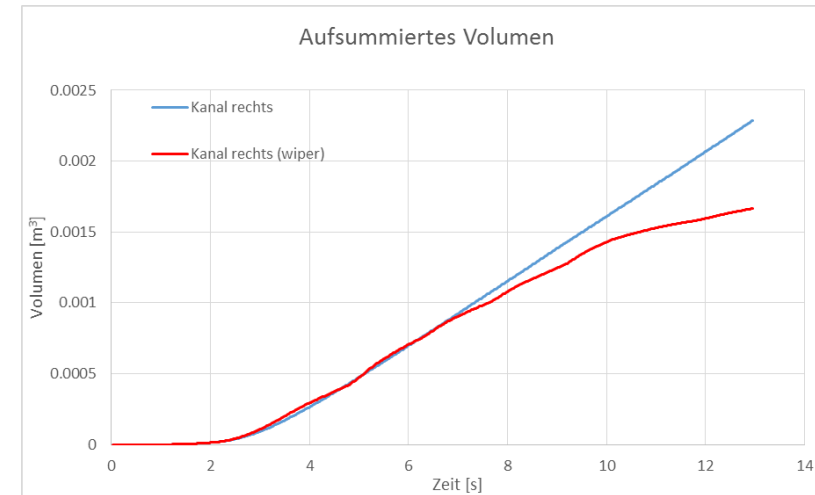
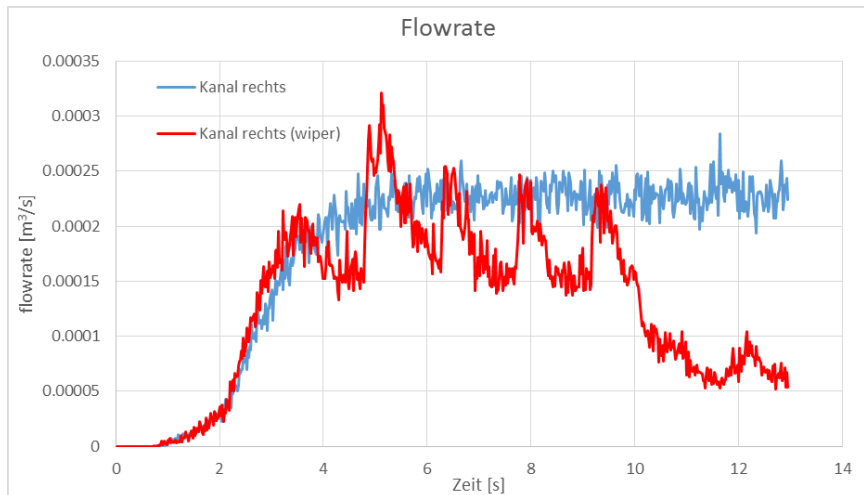
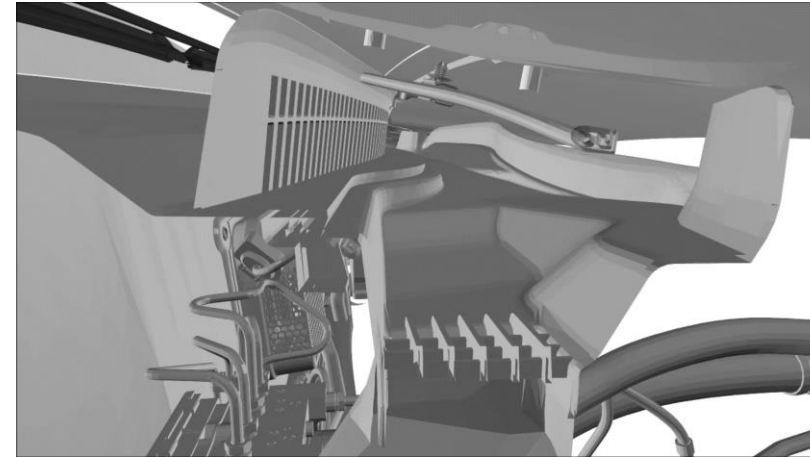
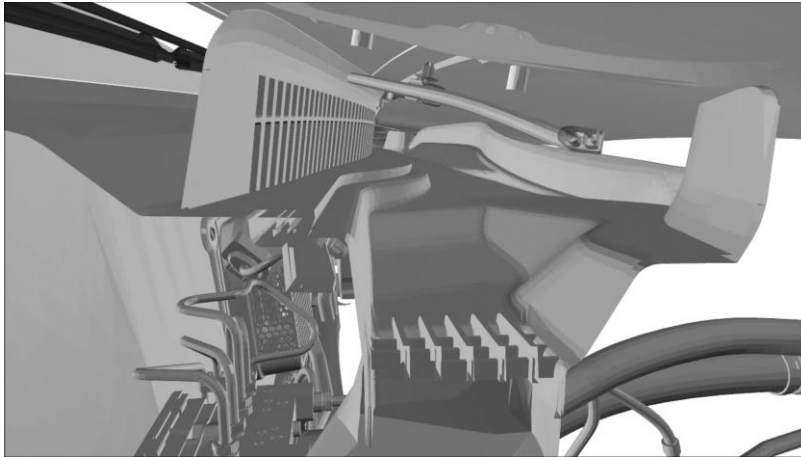
Visualization of the wiper movement:

- Audi A6
- Only front part of the geometry is used



Bildquelle: D. Bäder, F. Paur, M. Ehlen:
Simulation of the air intake of the air
conditioning unit of a vehicle in heavy
rain , NAFEMS 2018

Influence of Wiper Movement

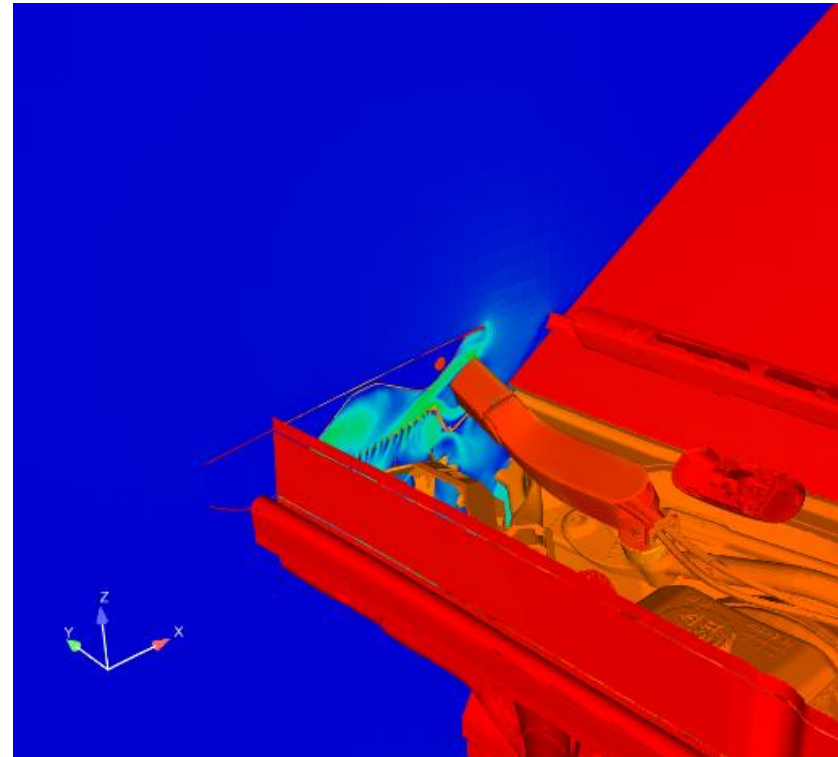


Bildquelle: M. Ehlen:
Juni 2017

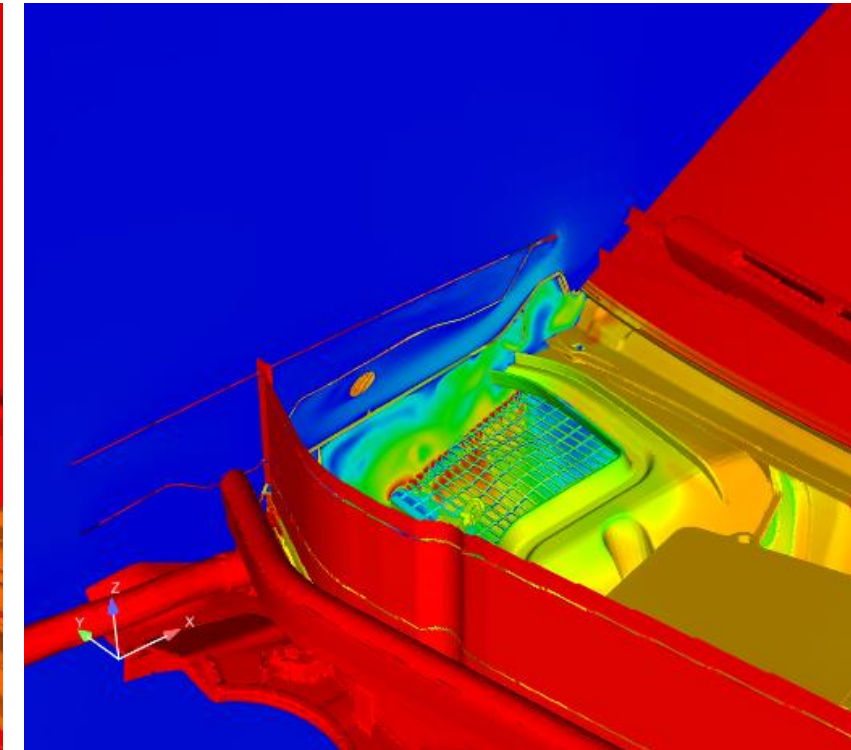
Simulation of the Influence of the Airflow Field

- › Simulation of the Airflowfield using FV-Methods, in this case with OpenFOAM®
- › Standard-RANS simulation seem to be good enough, averaged DES or LES seem to be too computationally too expensive

Cut through $y = 0$ m



Cut through air inflow



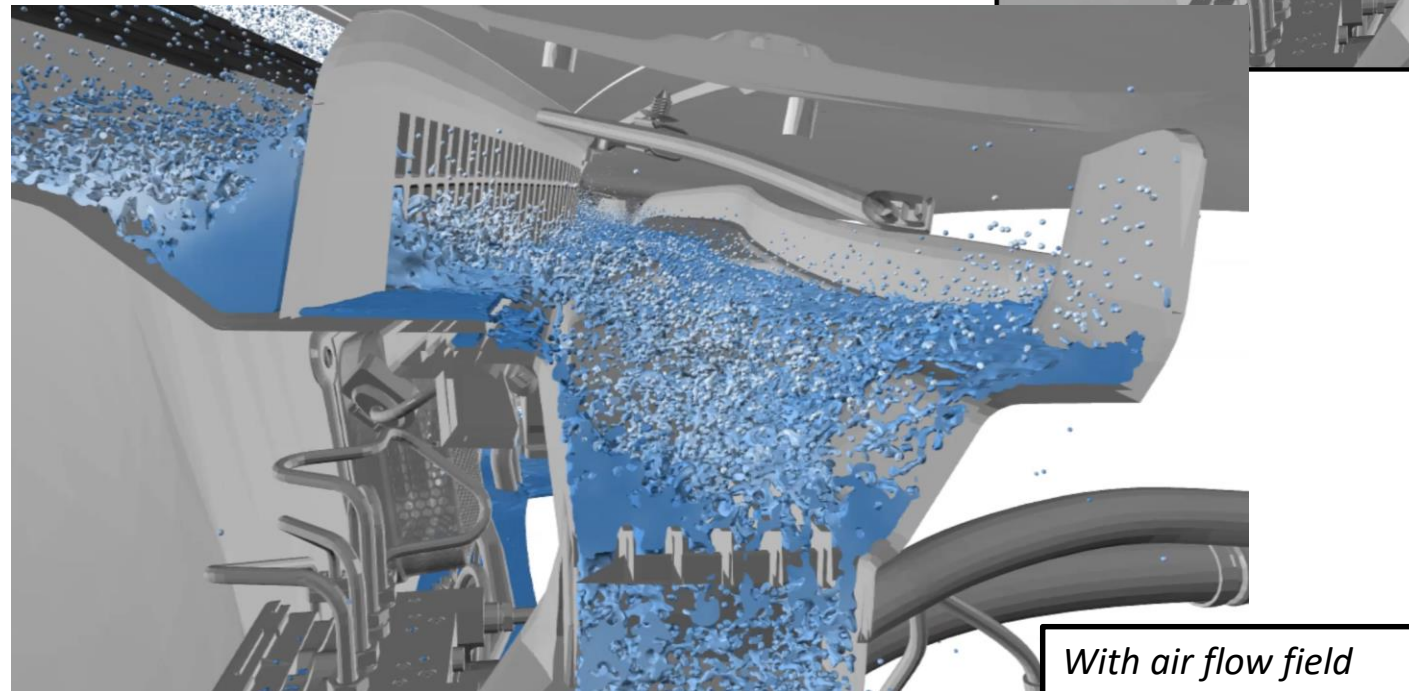
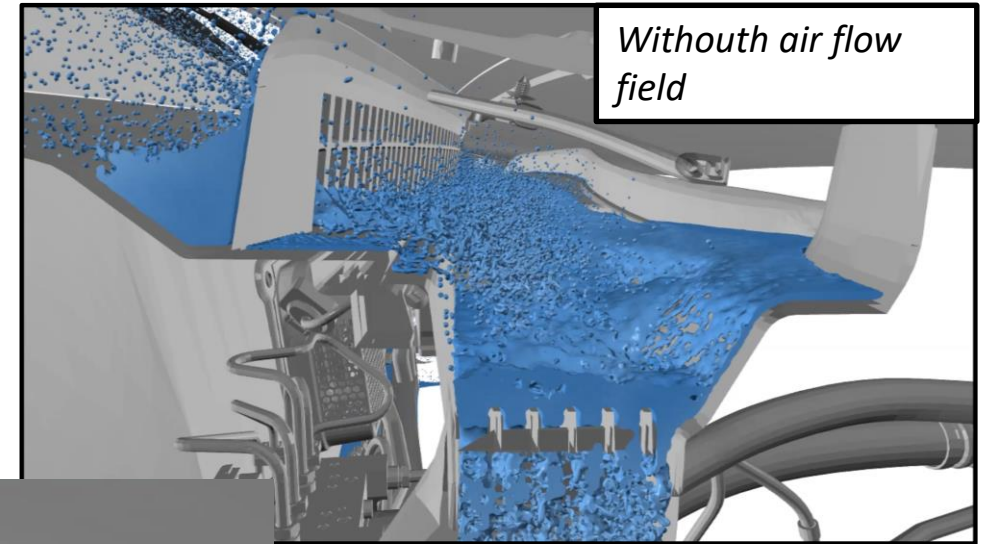
On the surface: The pressure is visualized (red = high pressure, blue = low pressure)

On the plane: The velocity is visualized (red = high velocity, blue = low velocity)

Evaluation of the rain simulation

Cut through the right drain channel

- Influence of the Air-Flow field is recognizable
- Influence of the Wiper Movement
- Investigation of the flow through the drain channel



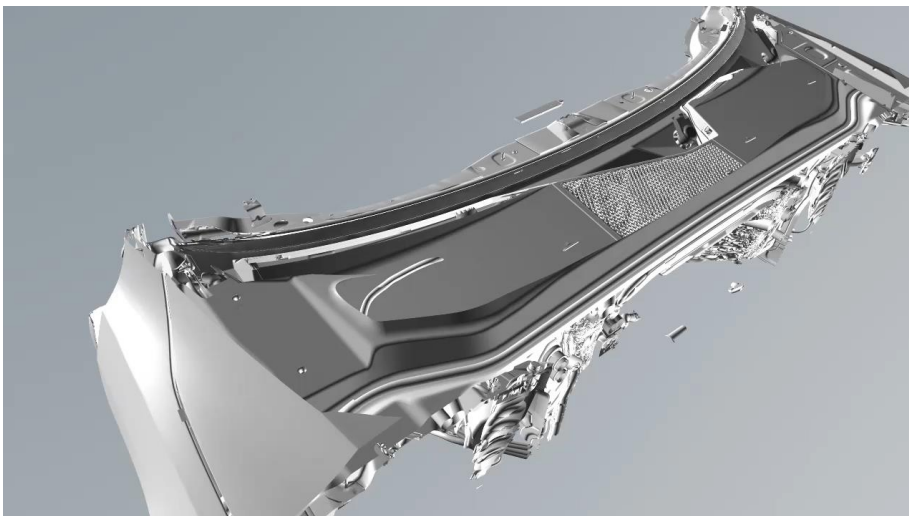
Bildquelle: M. Ehlen:
Juni 2017

Results Wiper Movement + Airflowfield

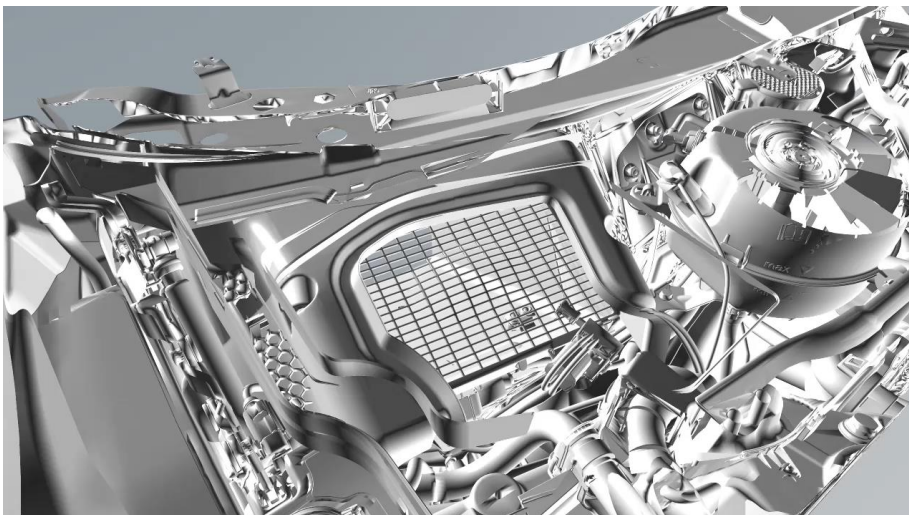
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Movies

Overview

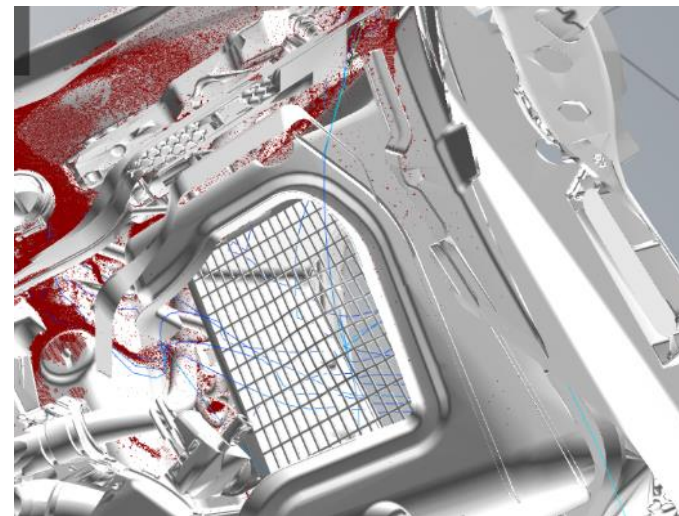


Detail around air suction

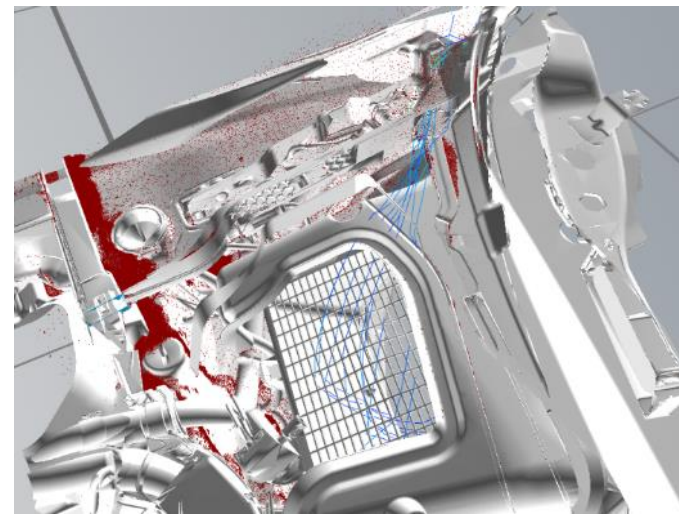


Static Pictures

Variant A
with intentional
leakage



Variant B
without leakage, but
inclined vehicle (17°)



Summary and Outlook

Summary

- › Challenging times need new simulation methods
- › Simulation of water management of a real vehicle is established in the development process
- › Necessary boundary conditions, depending on the type and the position of the part that needs to be investigated:
 - › Wiper movement
 - › Air flow field
 - › Force field from real driving conditions

Outlook

- › Better modeling of the bending of the rubber of the windscreen wipers
- › Coupling of the unsteady air flow field due to different vehicle velocities and different driving directions with the water simulation
- › Validation of complex simulation including wiper movement, air flow field and acceleration forces