DaimlerChrysler

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CFD as a Part of a CAE driven Development Process Experiences from the Automotive Industry

Walter Bauer, DaimlerChrysler, Stuttgart, Germany

Introduction of CAD into the vehicle development process about 15 years ago

First industrial CFD application in late 1980's

CAD is the basis of shorter turn around cycles of CAE applications, made development of powerful mesh generation tools possible

Increasing performance of computing hardware und software led to more and more complex applications

Idea of ***Virtual Vehicle Development***

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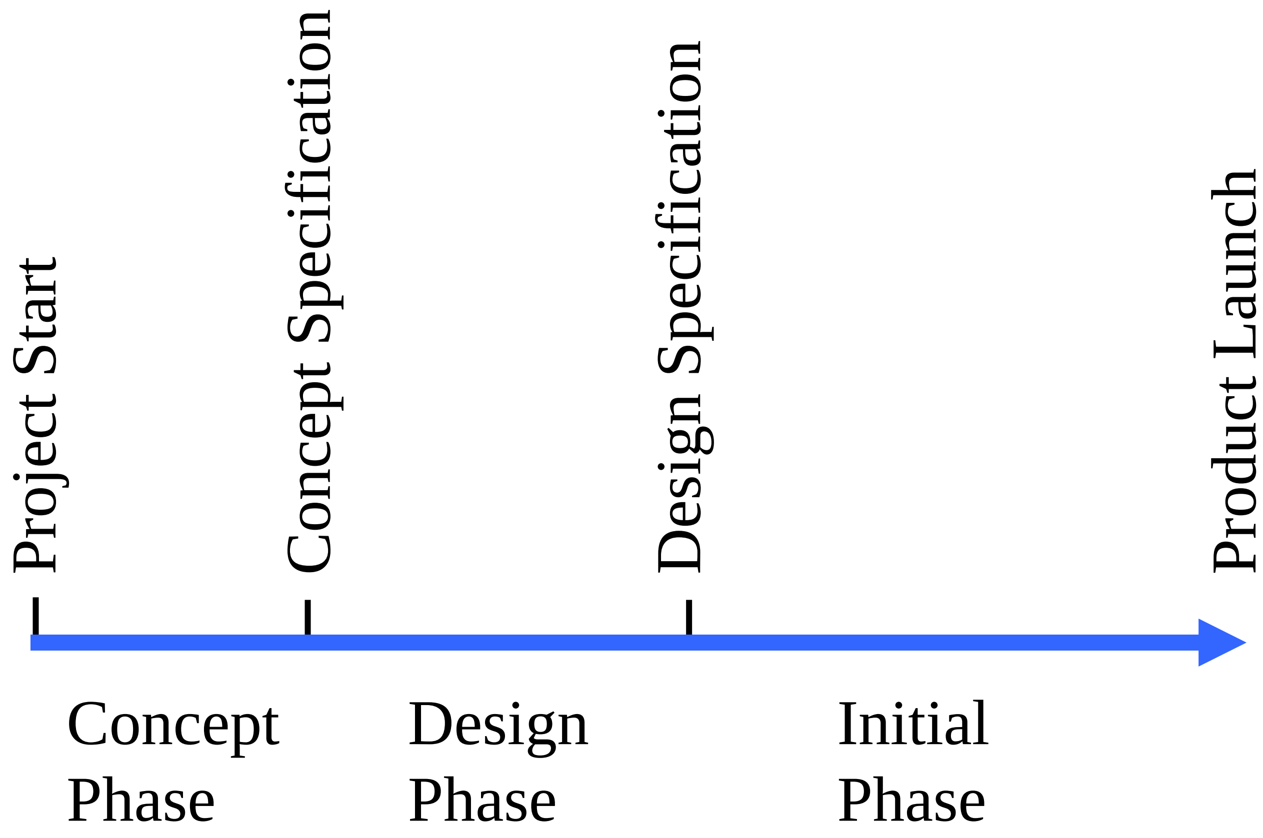

Mercedes-Benz Development System (MDS)

CFD of Full Vehicle Functions:

- **Underhood Flow Analysis/Vehicle Cooling**
- **Passenger Compartment Flow/Air Conditioning/Thermal Comfort**
- **Brake Cooling/Underhood Component Temperature Analysis**
- **External Flow/Vehicle Aerodynamic**

Computer Hardware:

IBM SP2	80 CPUs
SGI ORIGIN 2000	32 CPUs
Workstations	2 GB RAM each

Software:

CFD-Code	STAR-CD
Preprocessor	EZAero, EZUhood, pro*am, Medina, ICEM-Hexa
Postprocessor	pro*am, EnSight

Man Power:

Full vehicle functions:	25 PY/Y
Applied technique improvement:	2-3 PY/Y

Underhood Flow Analysis/Vehicle Cooling

First CFD simulations at Mercedes-Benz in 1990

Big effort was made for verification of results

CFD is applied for more than 15 model series

CFD is today a standard application at Mercedes-Benz

CFD is combined with one dimensional coolant flow simulation

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Sequence of a basic optimization loop for *Underhood Flow Analysis/Vehicle Cooling*

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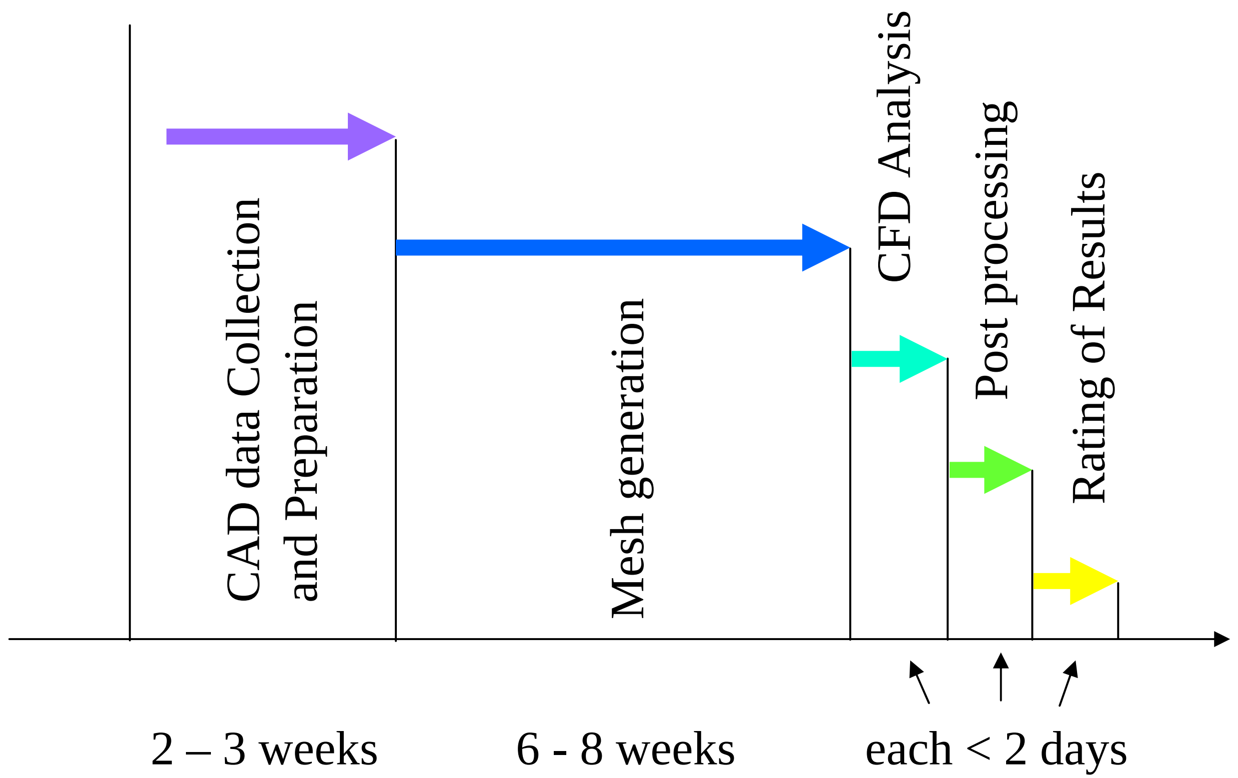

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Underhood Flow Analysis/Vehicle Cooling

Mesh generation:

Preprocessor:	EZUhood, pro*am, MEDINA
Mesh size:	3 – 5 Million cells
Mesh topology:	for all vehicle the same with a lot of special features, three fan models

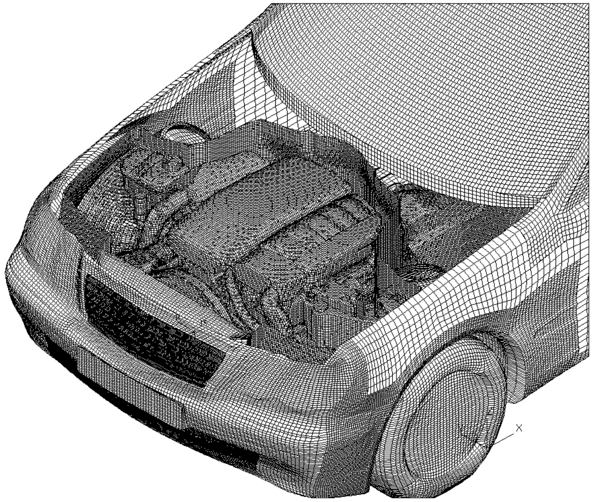
Underhood Flow Analysis/Vehicle Cooling

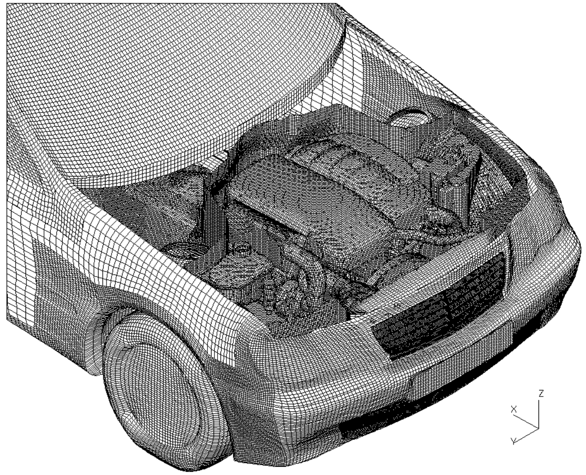
Load cases:

1. Vehicle driving with maximum speed and cooling fan off
2. Vehicle driving uphill with trailer towing and cooling fan on
3. Vehicle with no speed, engine idle, air-condition system full load, cooling fan on

Mesh structure

Underhood Flow Analysis/Vehicle Cooling





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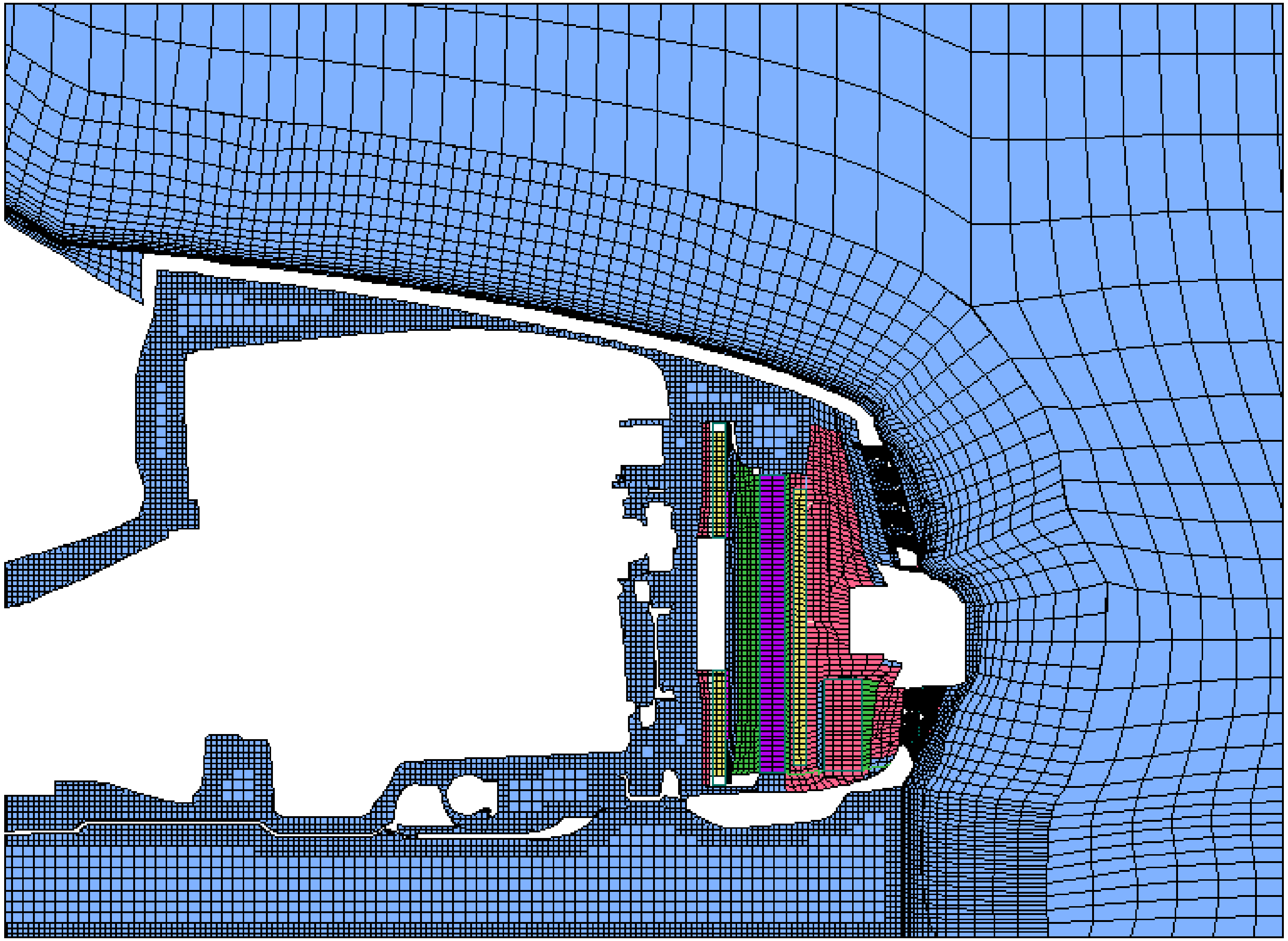
Mesh structure

Underhood Flow Analysis/Vehicle Cooling



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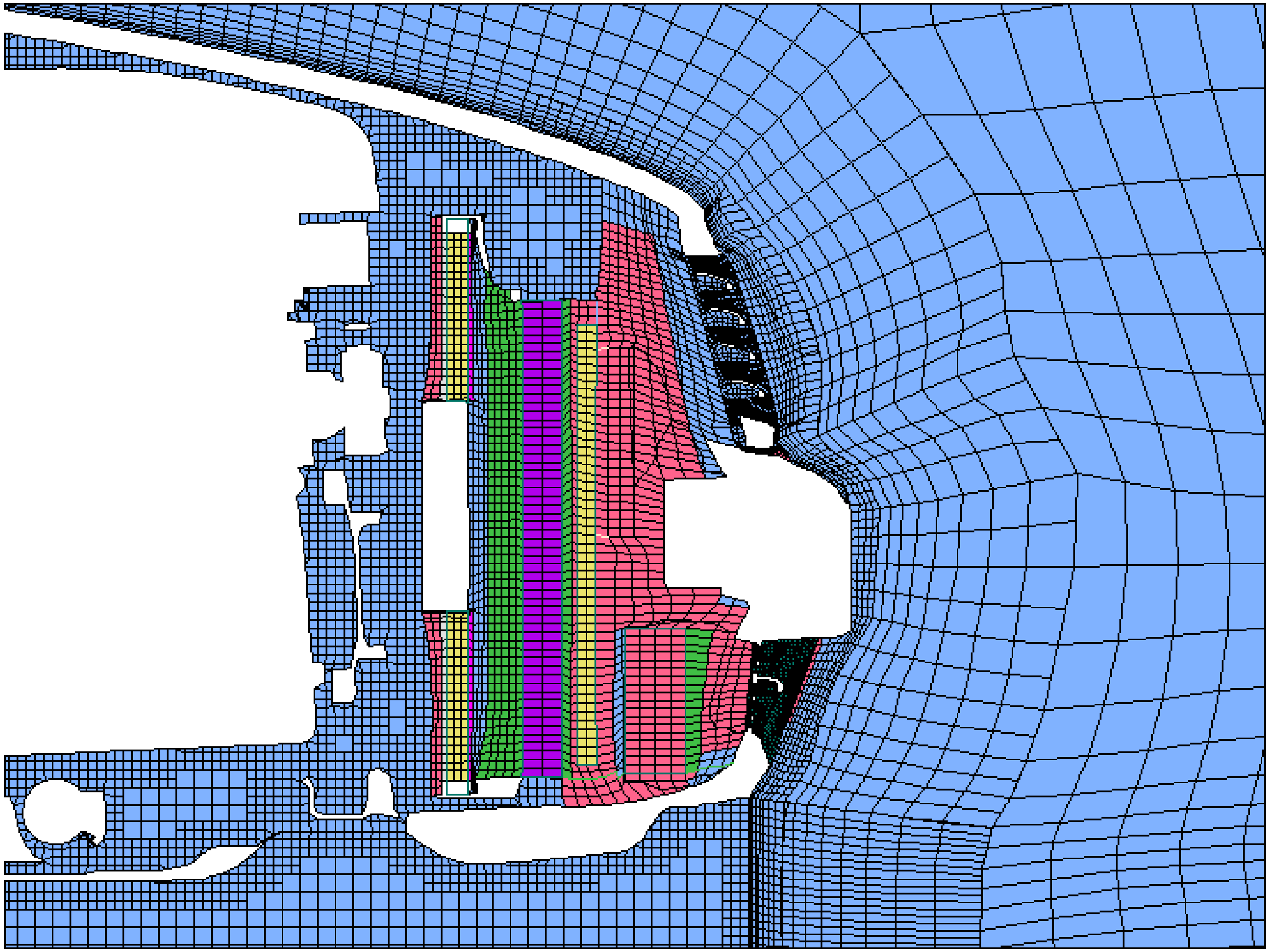

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Mesh structure

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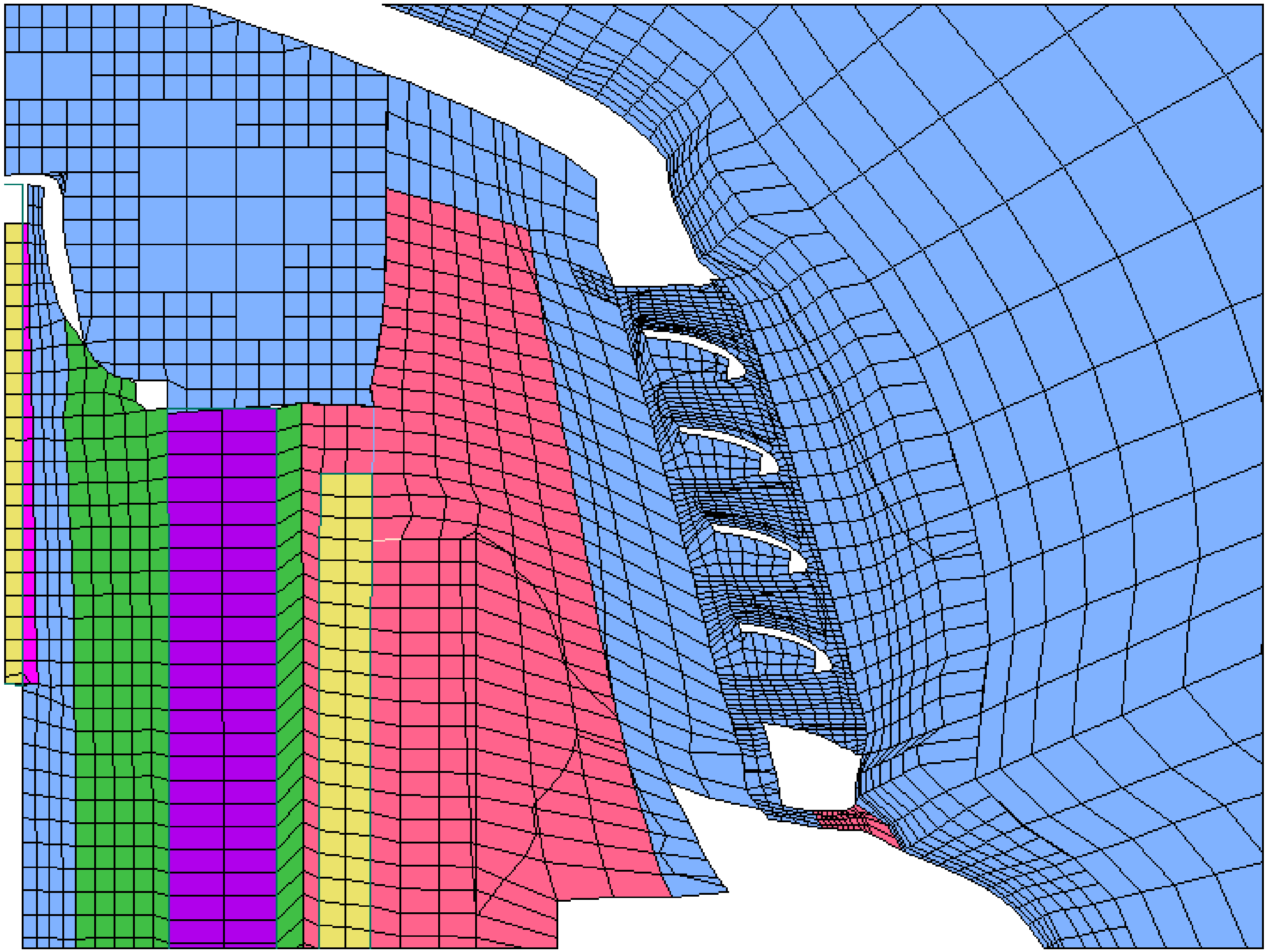

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Passenger Compartment Flow/Air Conditioning/Thermal Comfort

First application for Thermal Comfort in 1998

Big effort was made for verification of results

CFD for Thermal Comfort has been applied for more than 10 model series

CFD for air conditioning (ducts, HVAC-unit) is today a standard application at Mercedes-Benz

CFD is combined with two other simulation tools

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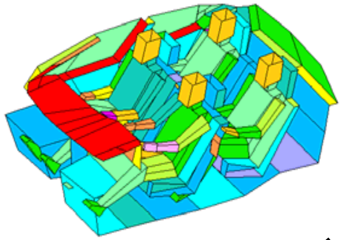
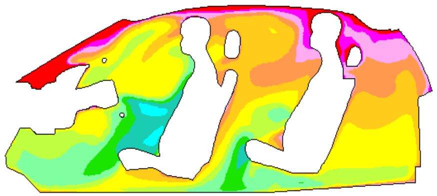
Thermal Comfort – Procedure (TEKOS)

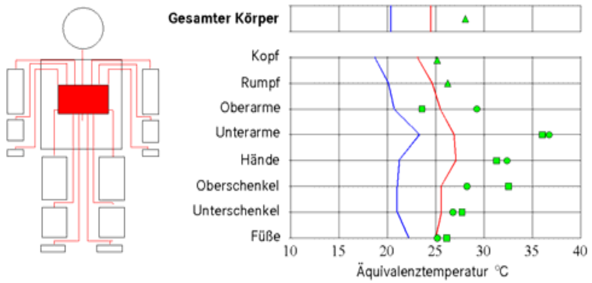


•Provision for solar and thermal radiation

STAR-CD

TIM





•Local flow and thermal conditions in the cabin

•Evaluation of the thermal comfort of the passengers

Sequence of a basic optimization loop for *Passenger Compartment Flow/Thermal Comfort*

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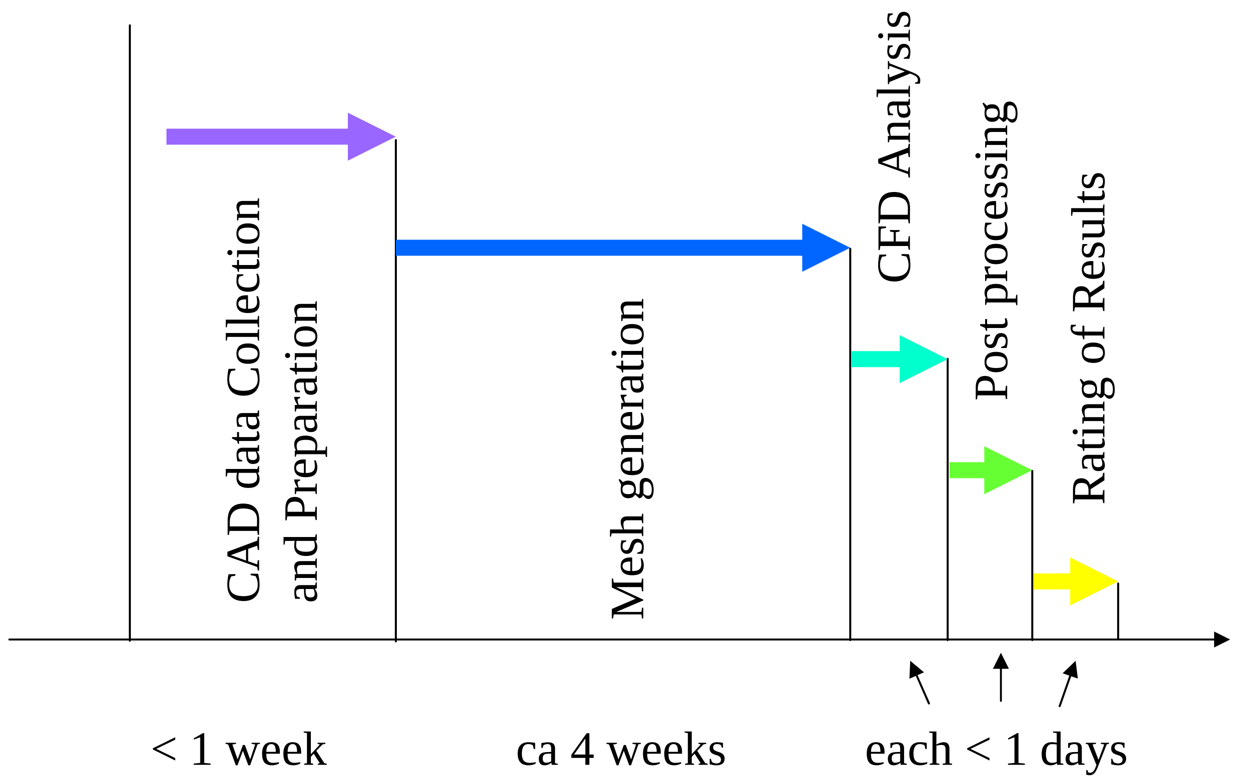

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Passenger Compartment Flow/Air Conditioning/Thermal Comfort

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Variation of surrounding properties

- Surrounding temperature
- Solar vector and intensity
- Diffusive solar radiation
- Speed of car

Variation of climate control system

- Air flow of every vent
- Air temperature at vent
- Shape, position and direction of air flow for vents

Modifications on the cabin

- Geometry variations
- Influence of different glass properties on thermal comfort
- Simulation of glass roof
- Influence of windshield angle

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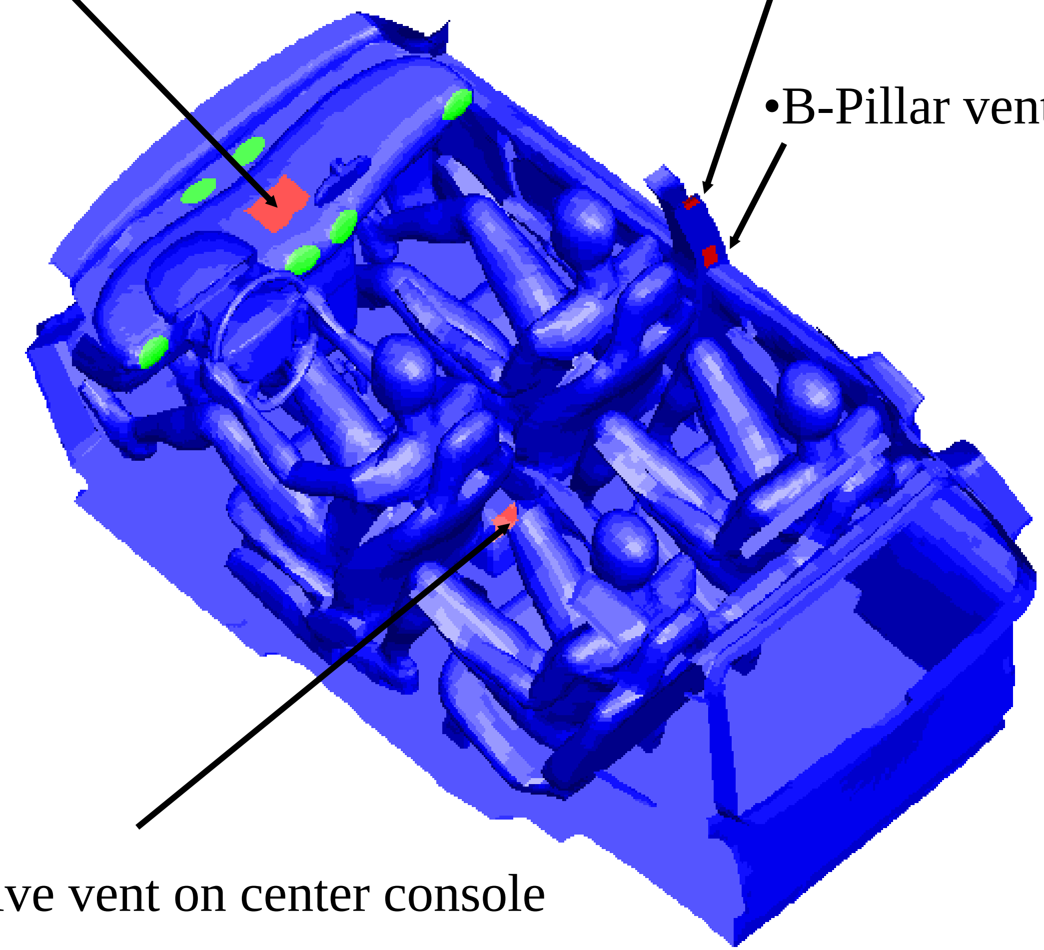

Passenger Compartment Flow/Air Conditioning/Thermal Comfort

Mesh generation:

Preprocessor:	ICEM-Hexa, pro*am
Mesh size:	1.5 - 3.5 Million cells
Mesh topology:	for all vehicle the same

Passenger Compartment Flow/Air Conditioning/Thermal Comfort

Load cases:

1. Winter Cases: Steady state and transient (heat up)
2. Summer cases: Steady State and transient (cool down)
3. Windshield deicing
4. Defogging

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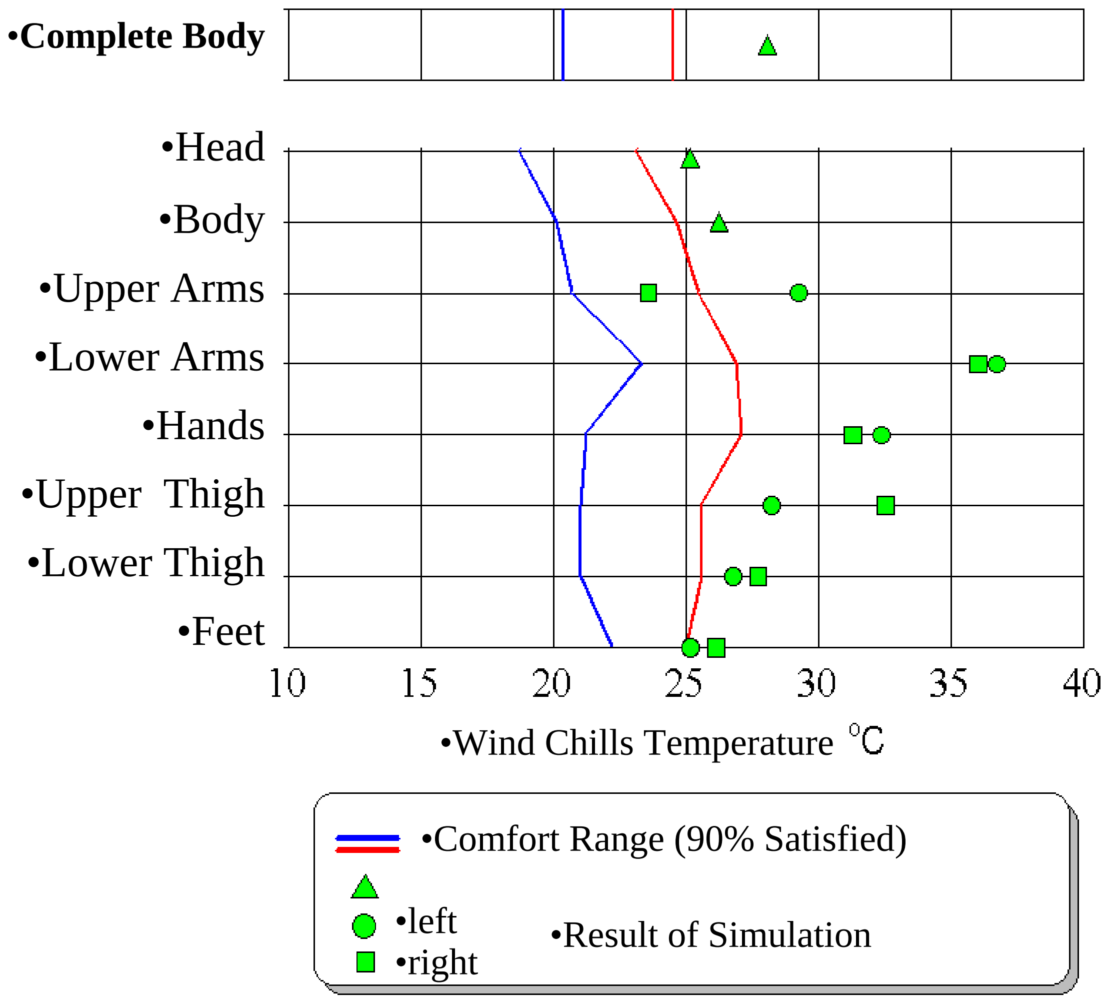
- **Thermal Comfort diagram for the passengers (Steady State Analysis)**



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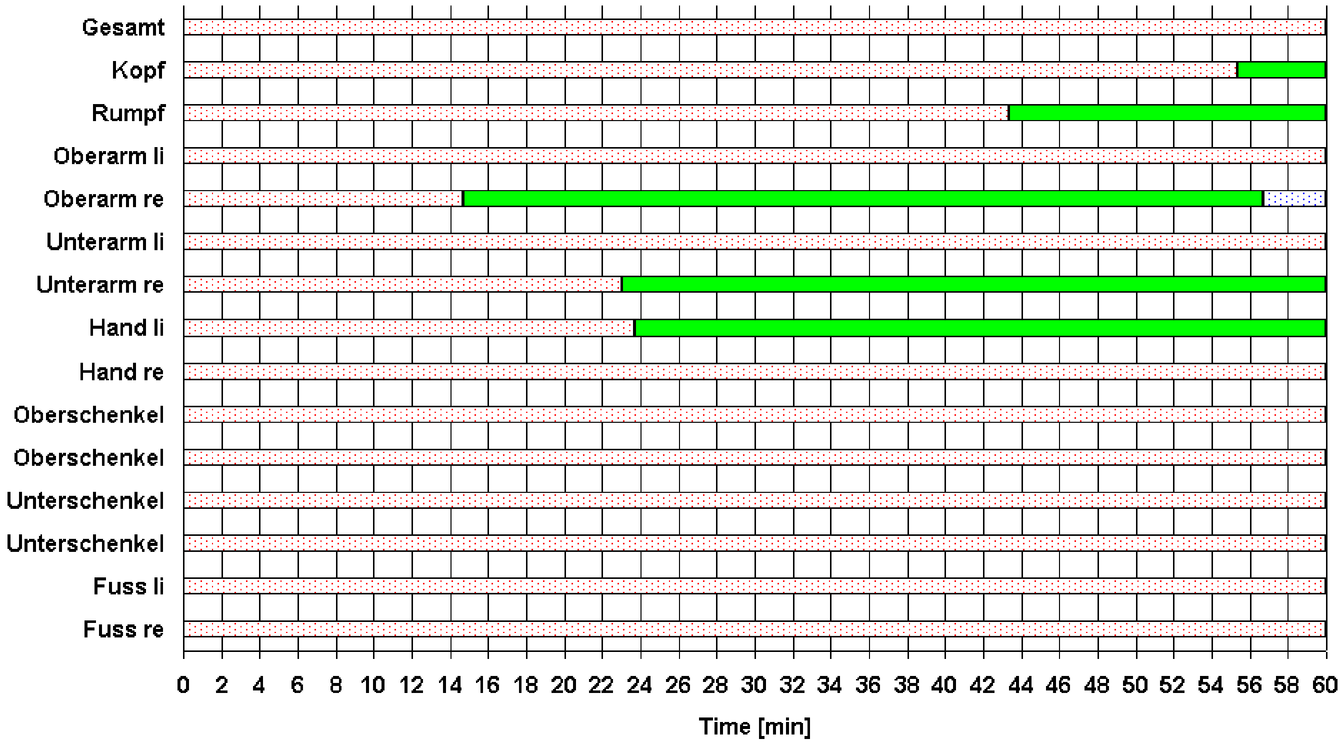
- **Thermal Comfort diagram for the passengers (Transient Analysis)**



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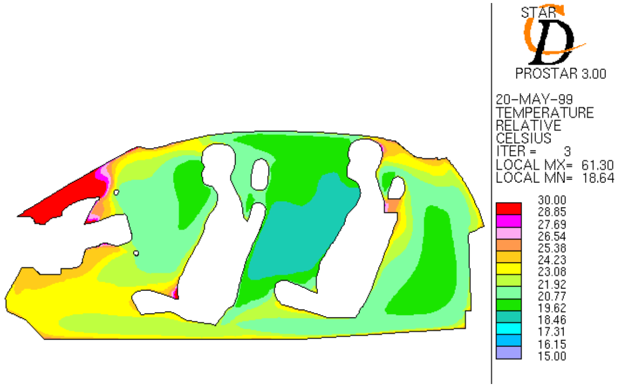
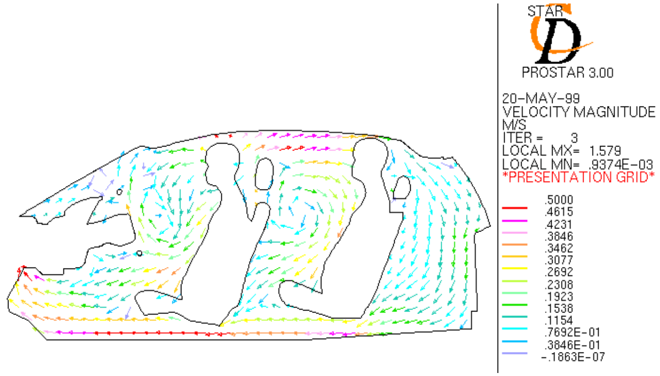
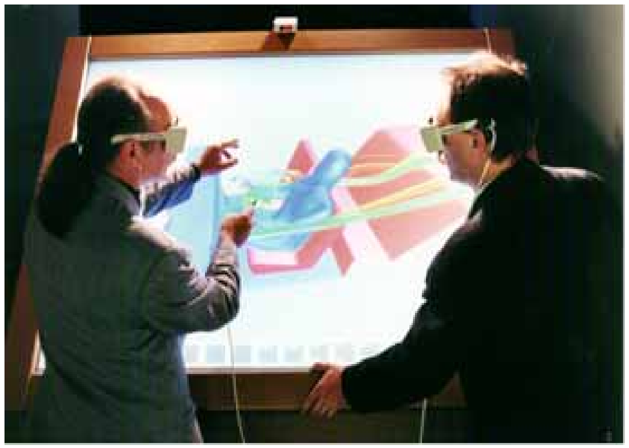
•Temperature and Flow section plots through the cabin

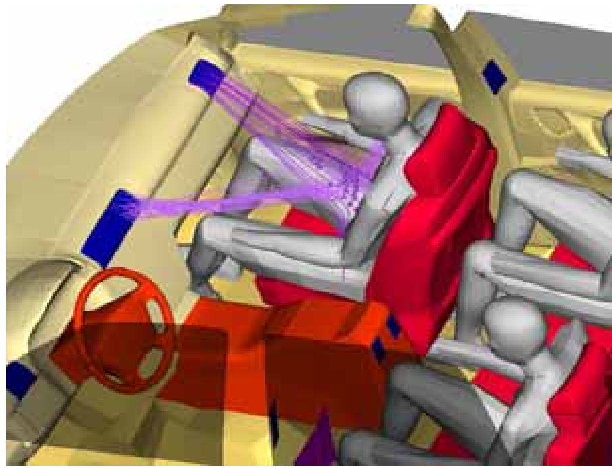




Virtual Reality Arbeitsplatz / CAVE / Powerwall

EnSight Movies





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Brake Cooling/Underhood Component Temperature Analysis

First application for Brake Cooling in 1992

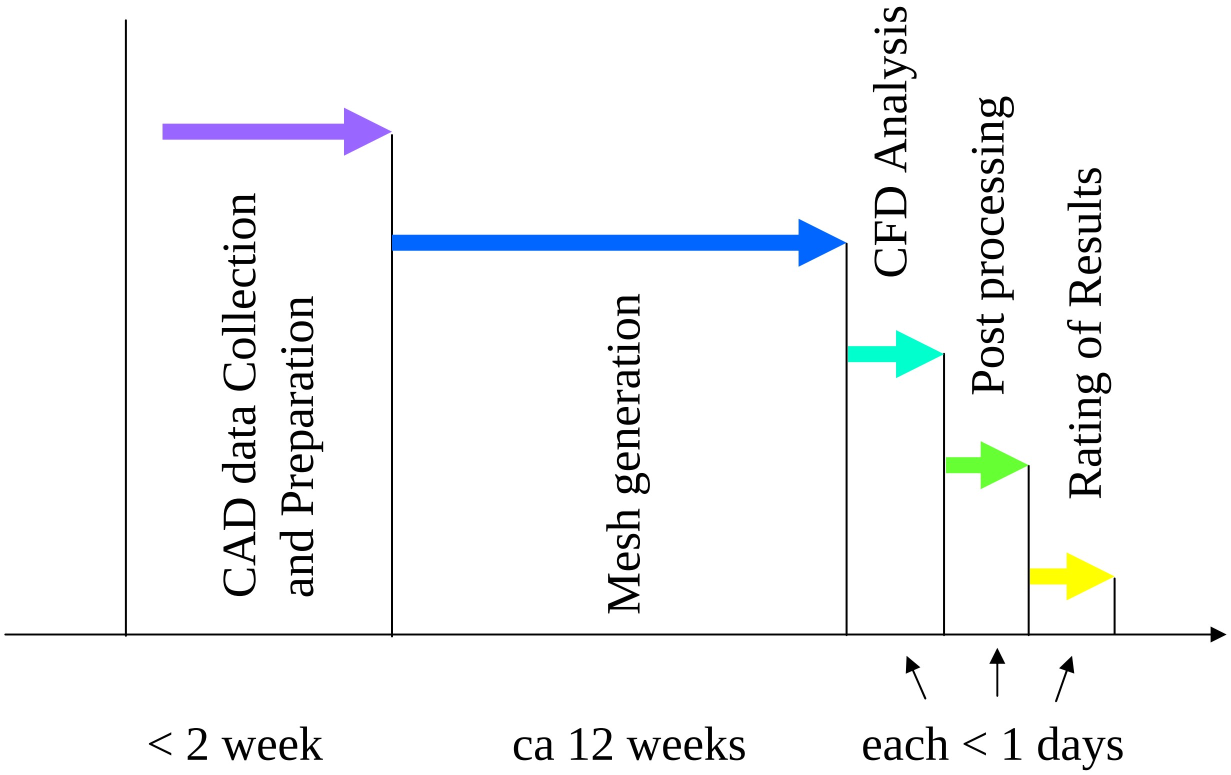
Big effort was made for verification of results

CFD for Brake Cooling has been applied for more than 7 model series

CFD for Brake Cooling is today a standard application at Mercedes-Benz

CFD is combined with a FEM program by a procedure called ALABASTA

Sequence of a basic optimization loop for *Brake Cooling*



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- **Numerical Simulation of Brake Disk Cooling**
- Solution:

CFD-Simulation of the wheel arch flow

(STAR-CD)

↓

Calculation of the heat transfer coefficients **a**

↓

Temperature calculation of the brake components

(ABAQUS)

- **ALABASTA-Process** by DaimlerChrysler started 1992
  - (**AL**PHAS for **ABA**QUS from **STA**R-CD)

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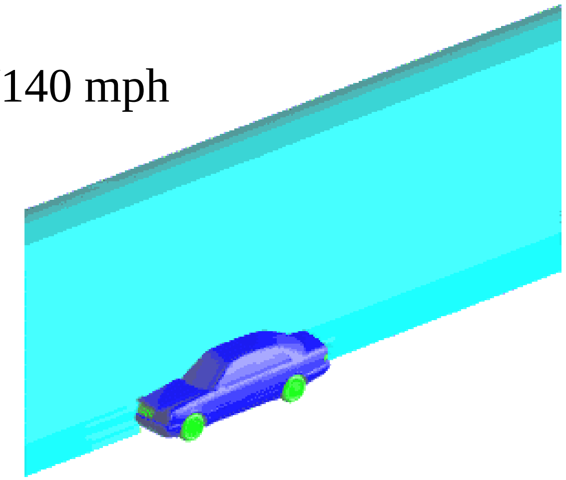
CFD-Simulation of the Wheel Arch Flow

STAR-CD (Finite Volume Method)

- Full wheel arch model: 3D
- Rotating components with Multiple Ref. Frame Analysis
- Global–local analysis:
  - Vehicle/underhood/underbody flow simulation with coarser mesh of the wheel arch region
  - Afterwards: more detailed model of the wheel arch
  - Mapping of boundary conditions
- Constant vehicle speed
  - ➔ Steady-state solution at 25/50/80/140 mph
- Results:
  - ➔ Velocities, pressures
  - ➔ Heat transfer coefficients **a**



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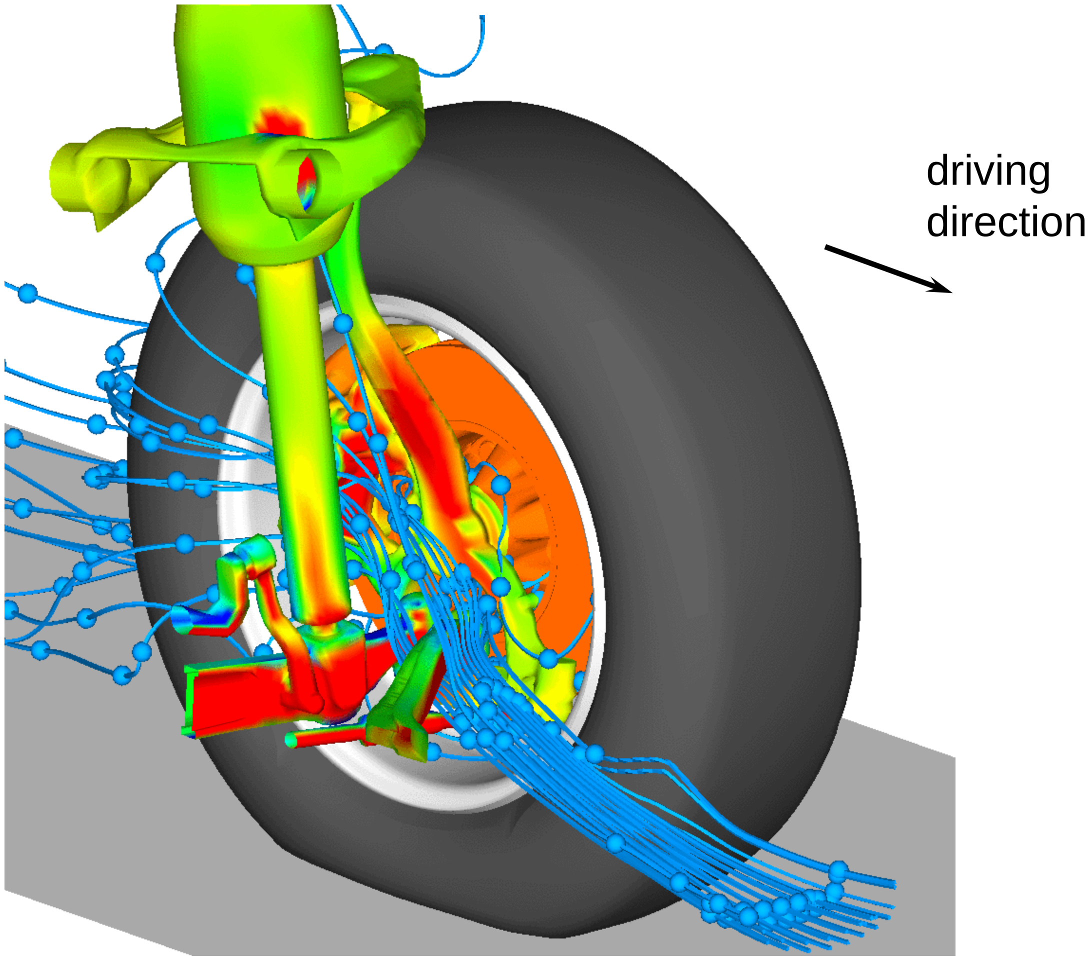
Analysis and optimization of brake disk cooling (wheel arch flow)



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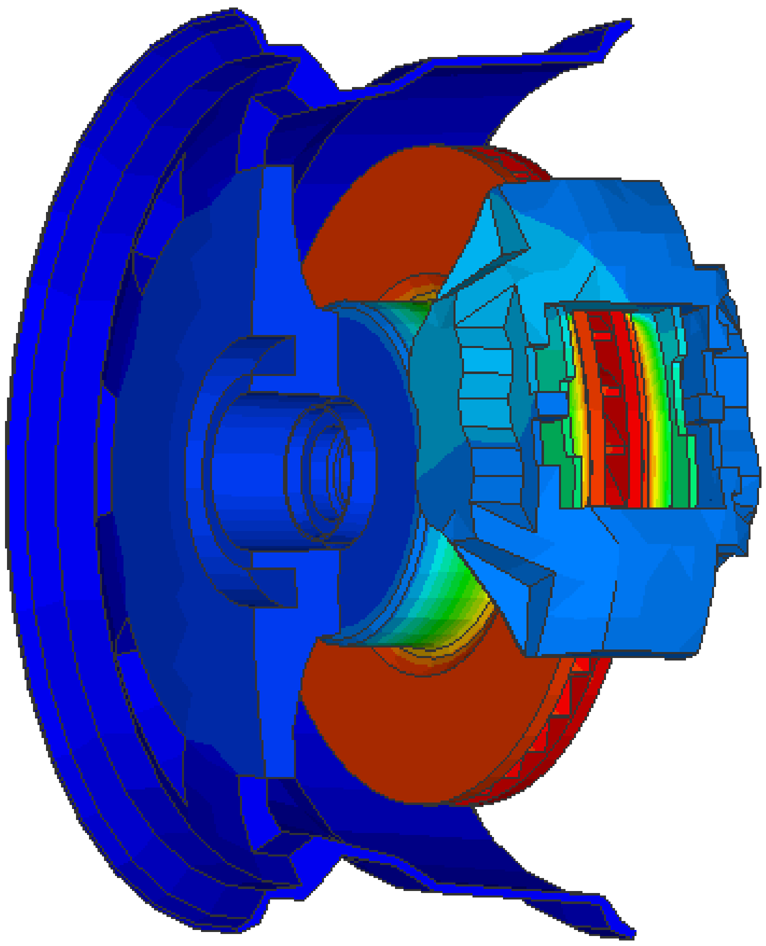
Temperature distribution after 26 minutes downhill braking



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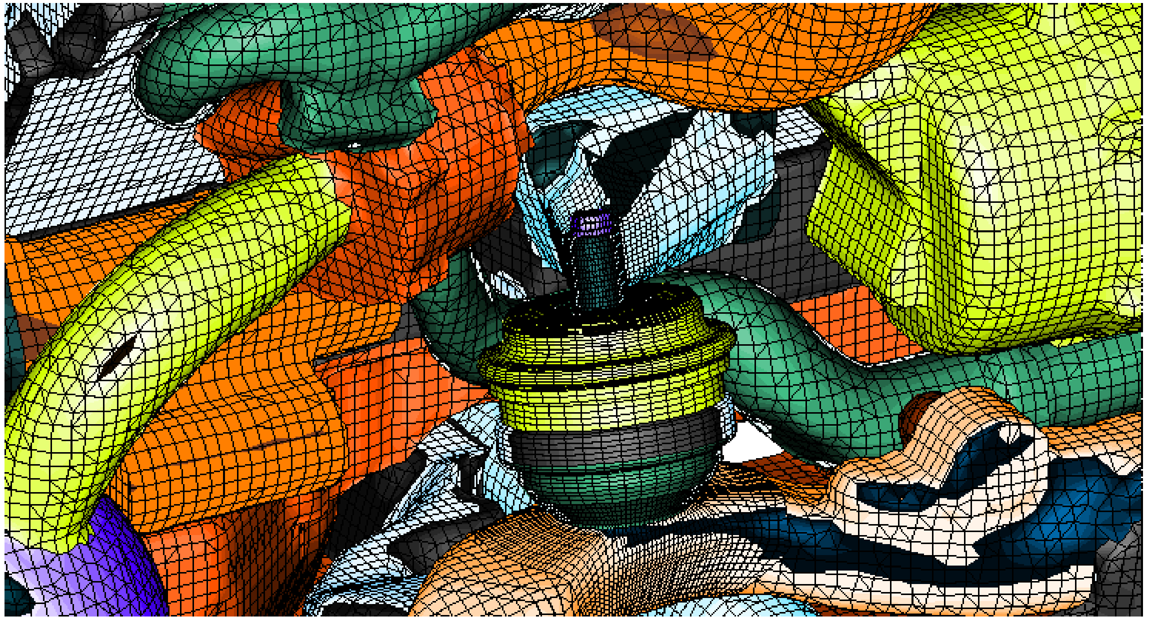
Heat Transfer Analysis of engine components

Problem:

- High temperatures (e.g. **engine mount**)
- significant radiation heat transfer from exhaust system, turbocharger and catalyst

Objective:

- Prediction of temperatures
- Analysis and optimization of cooling flow
- Further cooling improvements e.g. by radiation shield



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Heat Transfer Analysis of engine mount

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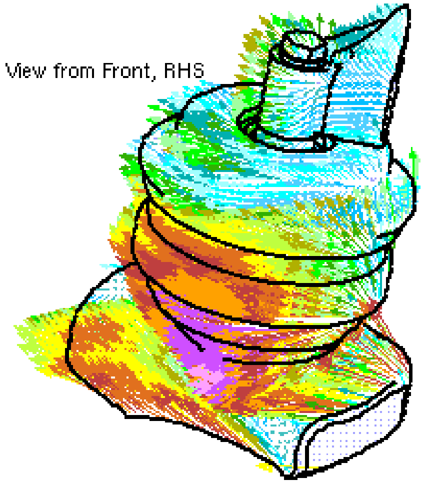
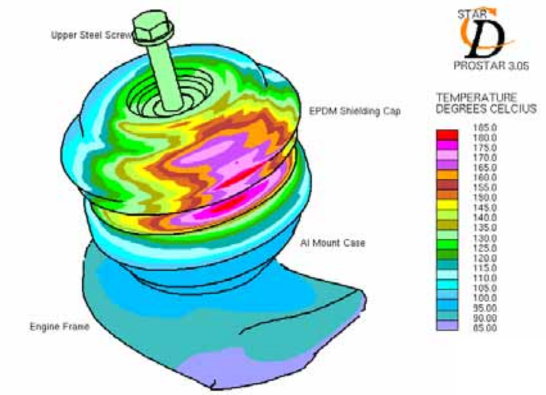


velocity distribution around the engine mount

Temperature distribution



External Flow/Vehicle Aerodynamics

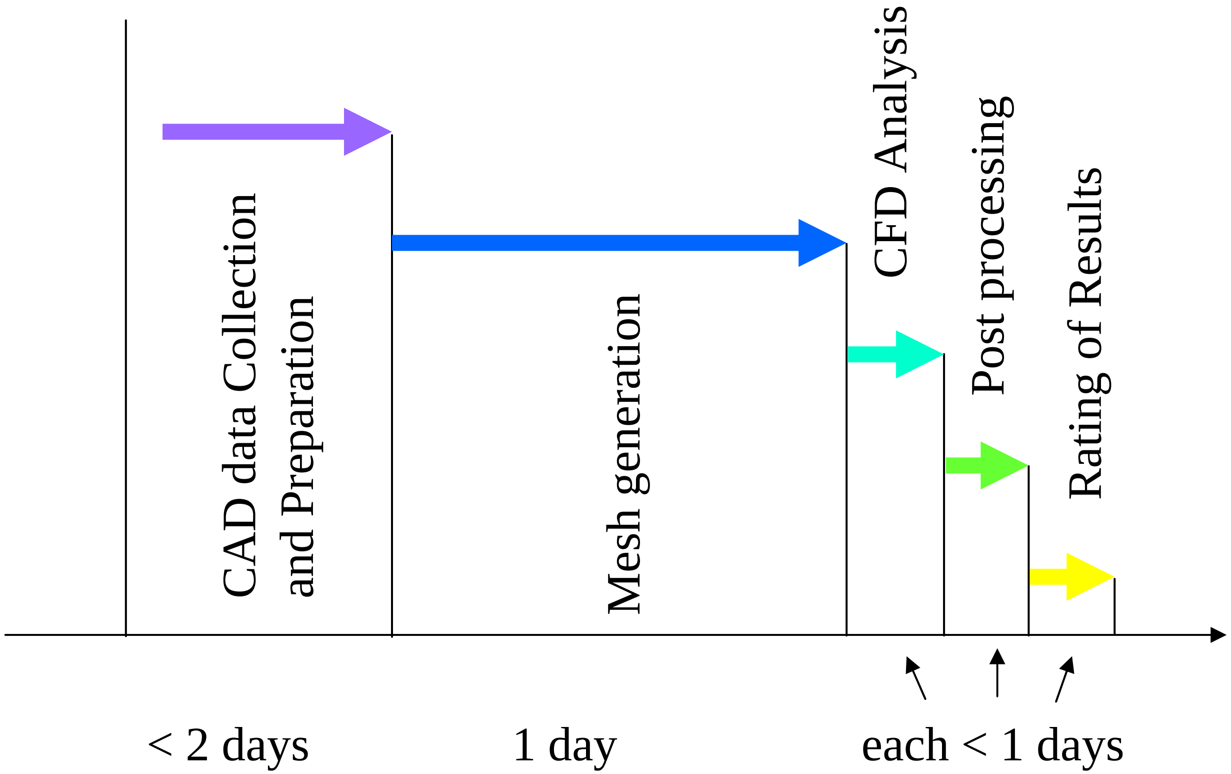
First applications for External Flow

Big effort was made and is still necessary for verification of results

CFD for External Flow has been applied for all major car shapes (smooth underbody)

CFD for External Flow is today not a standard application at Mercedes-Benz

Sequence of a basic optimization loop for *External Flow/Aerodynamics (smooth underbody)*



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External Flow/Vehicle Aerodynamics

Mesh generation:

Preprocessor:	EZAero, pro*am, MEDINA
Mesh size:	4 - 6 Million cells
Mesh topology:	for all vehicle the same with a lot of special features

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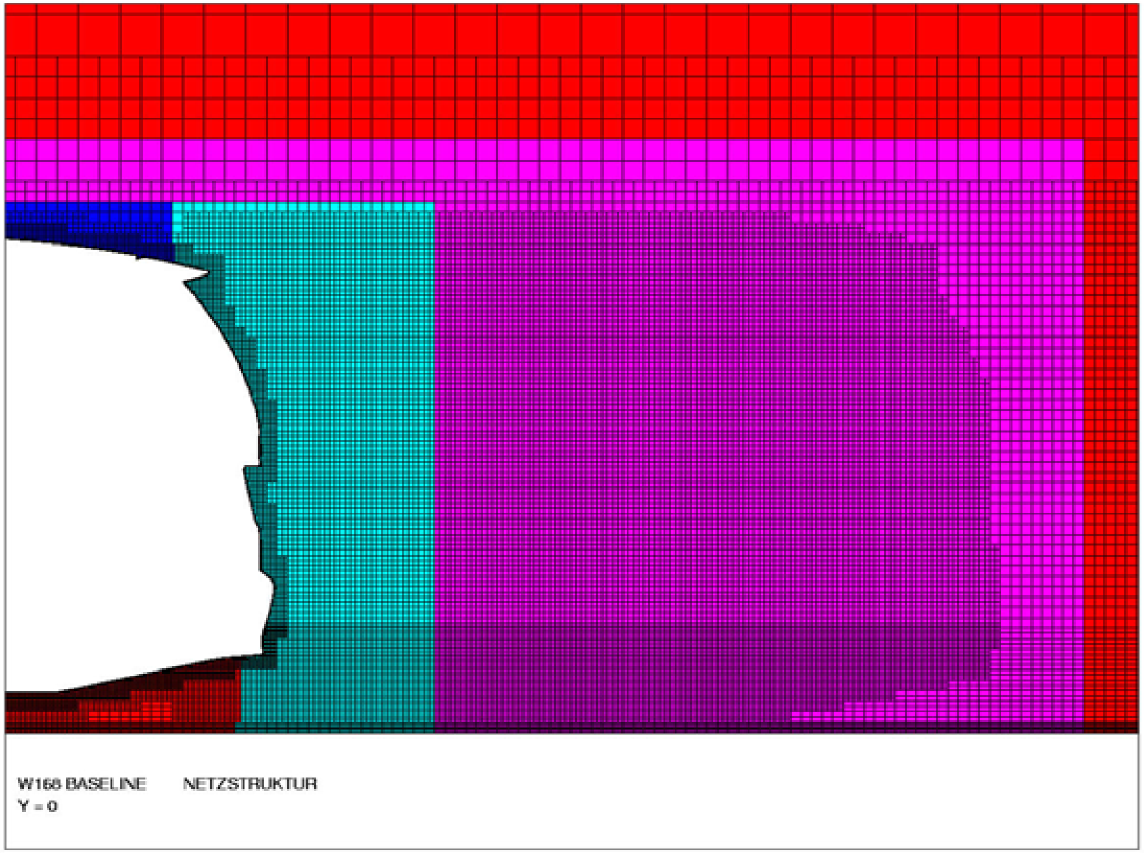
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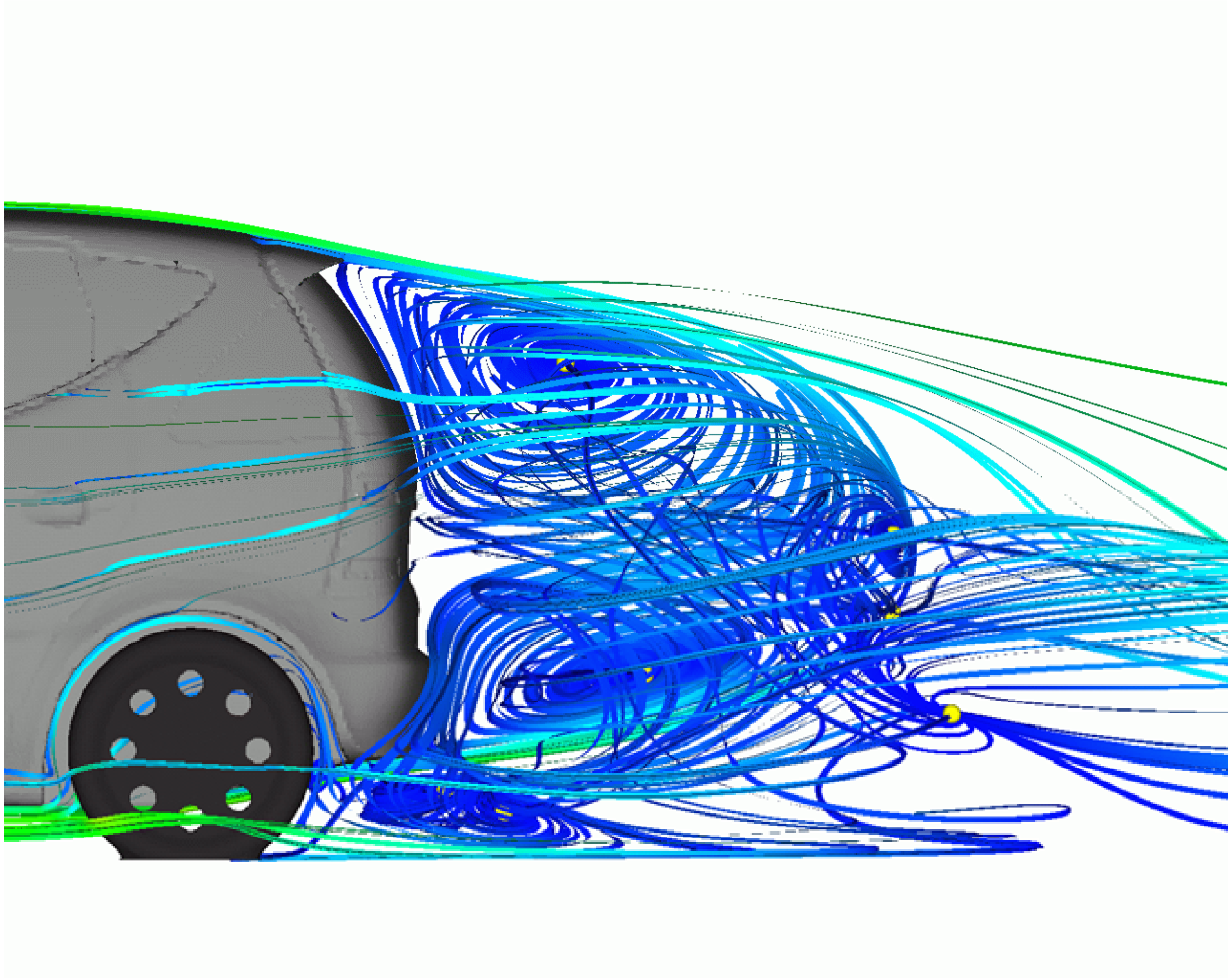

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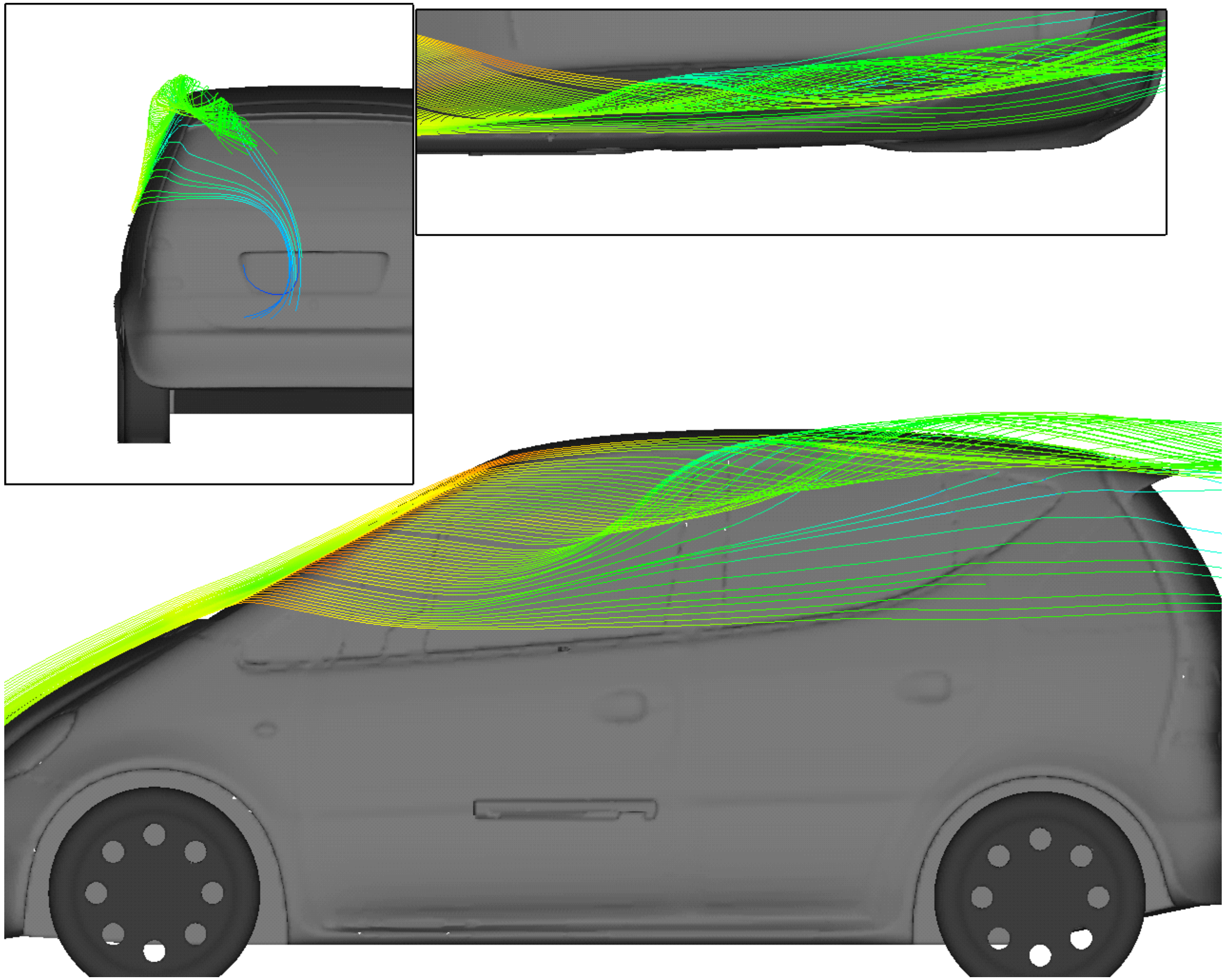

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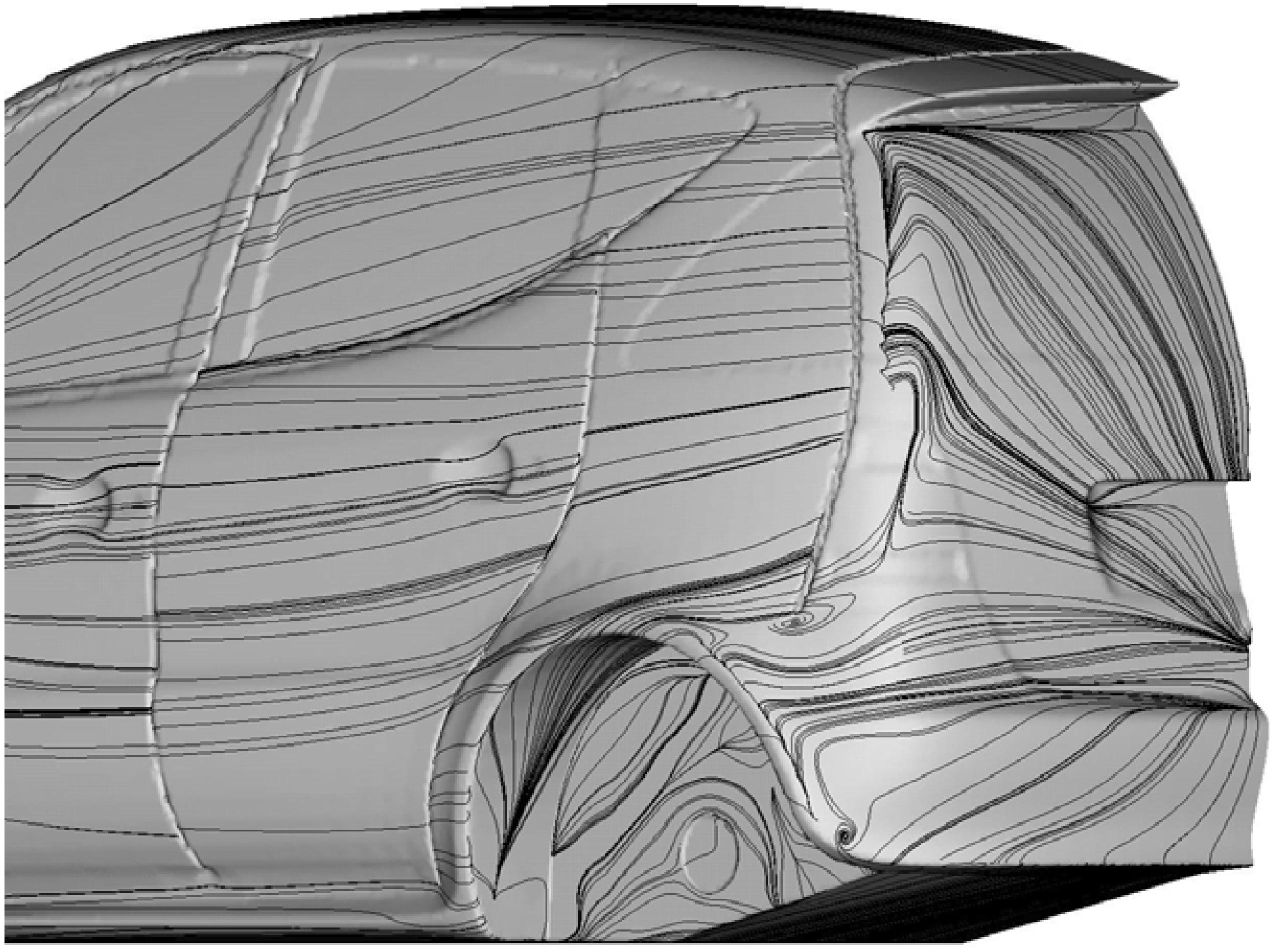

A-Klasse Baseline: Wandstromlinien

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CFD is for most applications embedded in a procedure with other tools

CFD results (except external flow) alone does not fulfill the MDS requirements

The optimization loops can only be shortened significantly if the meshing phase is shortened dramatically

The turn around time of the CFD analysis must be shortened therefore the robustness and convergence rate of the code must be improved

More complex CFD applications require suitable turbulence models