Goals of 1D - simulation in the field Air Conditioning / Engine Cooling / Aerodynamics for the optimisation of vehicle thermal management

4th KULI User Meeting, T. Kobs, I/EK-41, 25.6.2003

Content

1. Simulation tools for “Development Air-Conditioning” at AUDI

2. Model of a combined “Air-conditioning / Engine Cooling / Aerodynamics” heat management simulation

3. Combined heat management simulation:
   Procedure - problems - benefits

4. Development of 1d-methods: Fields of work

5. Summary - Discussion

Air conditioning engineering process: Historical development

- Standard approach:
  functionality „climate comfort“ as main development goal is a very subjective target value - “rule”: comfort can only be assessed in the car!
  Therefore: only main target values defined!

- Today:
  Type variety and shortened development cycles lead to minimised prototype-testing times - consequence: engineering of function “air conditioning” has to be done more and more in component tests and simulations

- Problem:
  Component test-bench development as simulation need localised development targets derived from comfort values

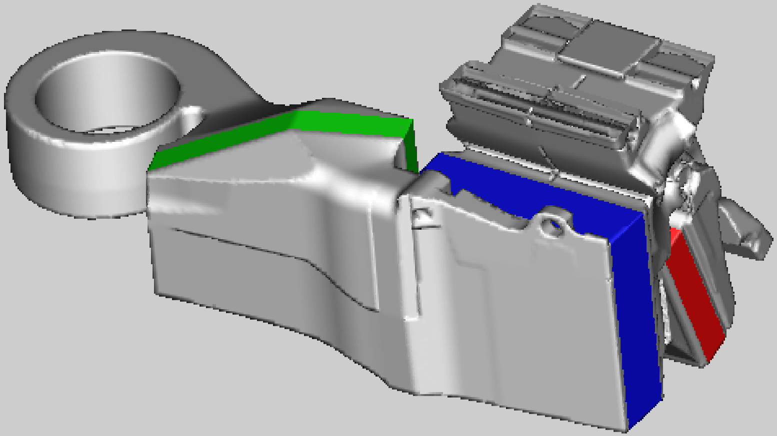
Air conditioning engineering process: Target values

- Advanced approach:
  AC-simulation- and test-engineers develop
  detailed functional target values for components and overall system, e. g.:
  - Heating output heater core & cooling performance evaporator
  - Pressure Loss = f(Re) for air ducts and vents
  - Standard operating points for evaluation:
    Heat-up & cool-down transient and stationary, bi-level with:
    -> Defined Boundary conditions (ambient temperature, humidity...)
    -> Maximum air mass flow
    -> Air mass flow- and temperature-distribution
    -> Temperature limits:
    e.g. average cabin temperature of 15ºC after 20min

Which simulation tools are capable of fulfilling these tasks?

Simulation methods

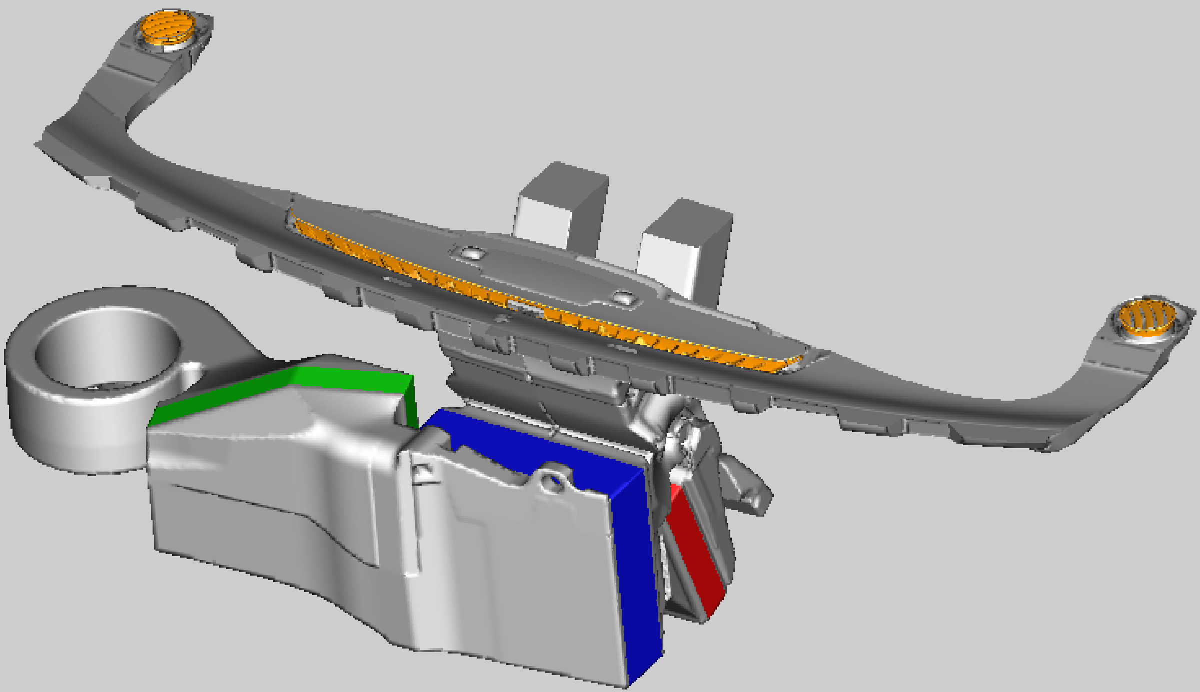
3d-CFD:



Scope: HVAC (blower-casing-heat exchangers)

Simulation methods

3d-CFD:



Scope: HVAC (blower-casing-heat exchangers) - Ducts & vents

Simulation methods

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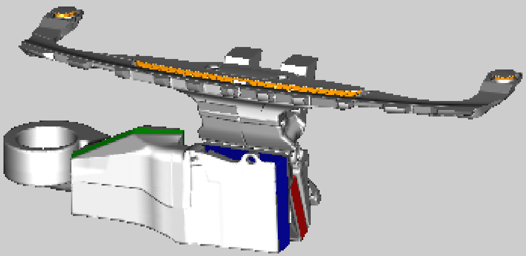

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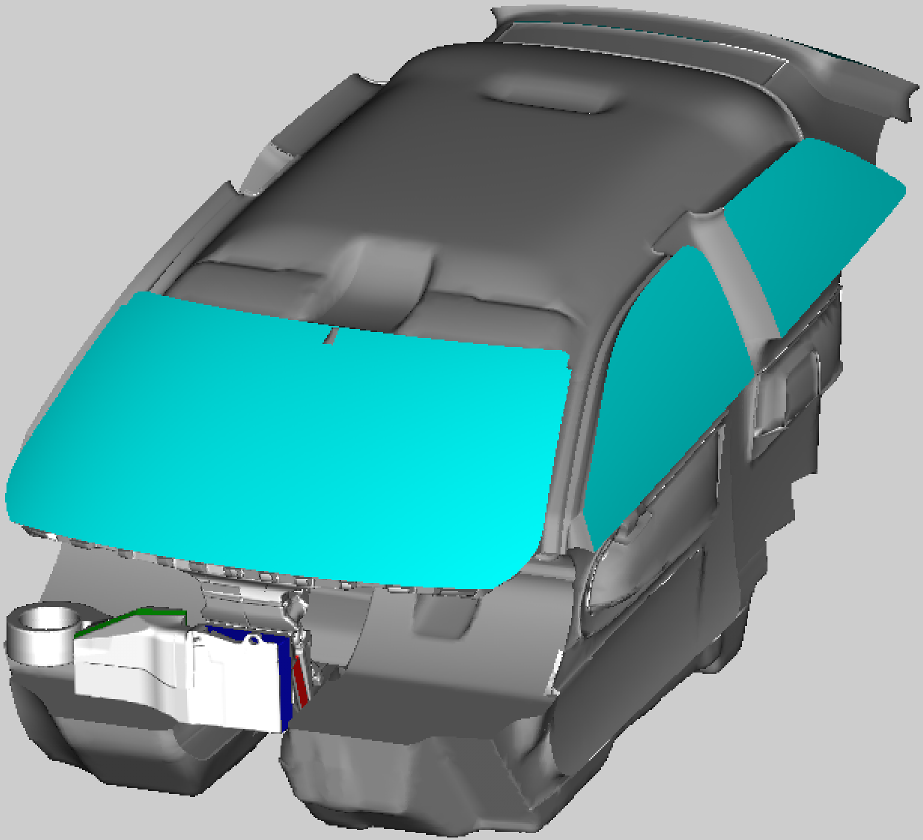
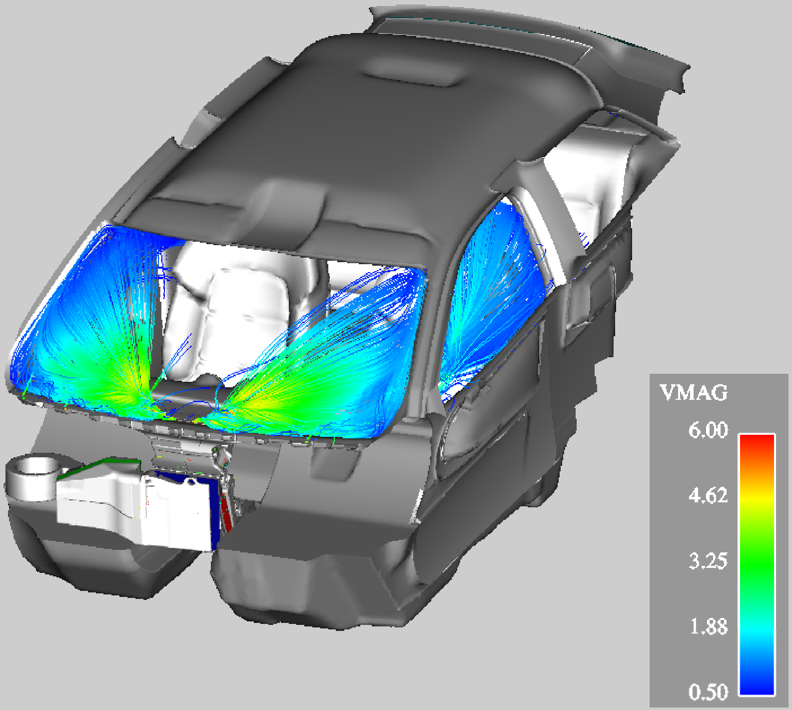


Scope: HVAC (blower-casing-heat exchangers) - Ducts & vents - cabin

Simulation methods

3d-CFD:



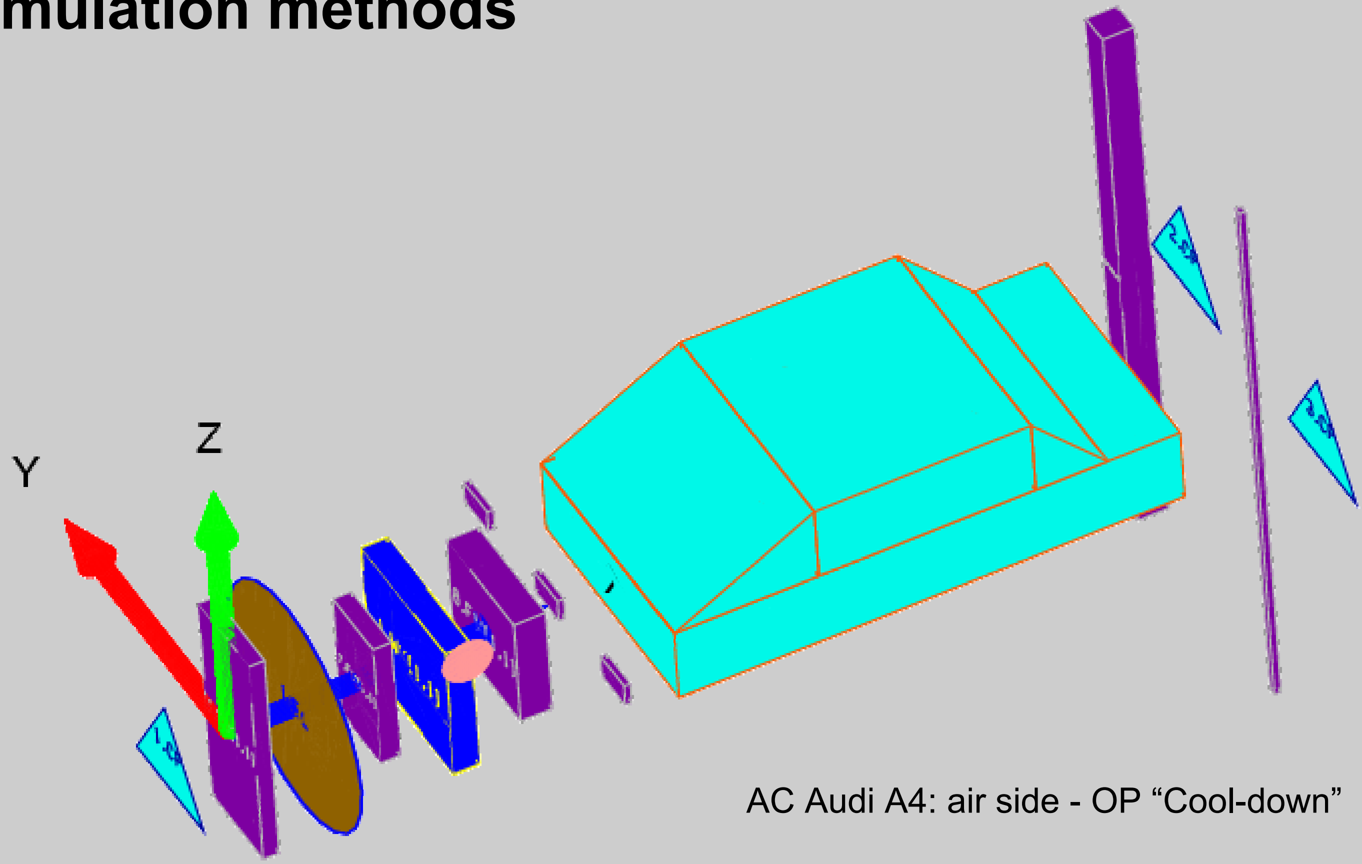
Defrost Audi A3
Streamlines coloured by air velocity

Goals: -> Optimisation part geometry (pressure loss, air distribution)
-> Layout part performance (blower, heat exchangers)
-> Preparation type approval (Defrost)
-> Comfort assessment cabin interior (air velocity)

Usage: concept and series development

Simulation methods

1d:



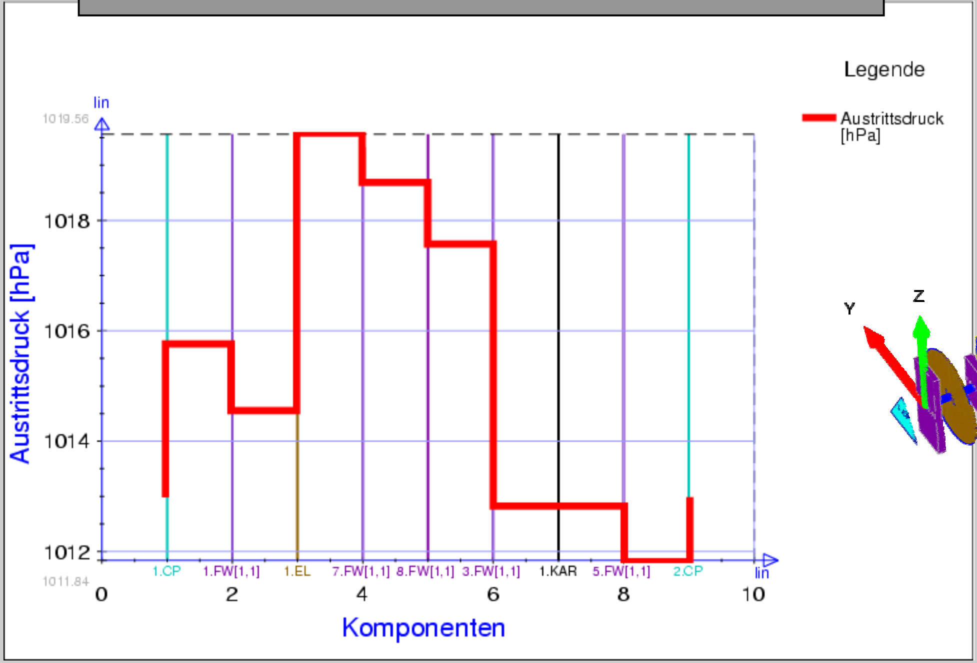
AC Audi A4: air side - OP “Cool-down”

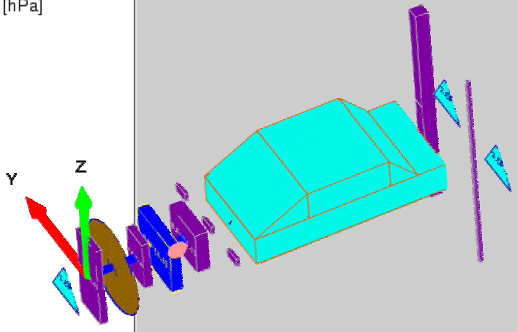
Scope: AC-air side - Inlet - HVAC - duct & vents - leakage - outlet

Simulation methods

1d:

Audi A4 - OP “Cool-down” - 160km/h - 88%PWM





AC Audi A4: air side

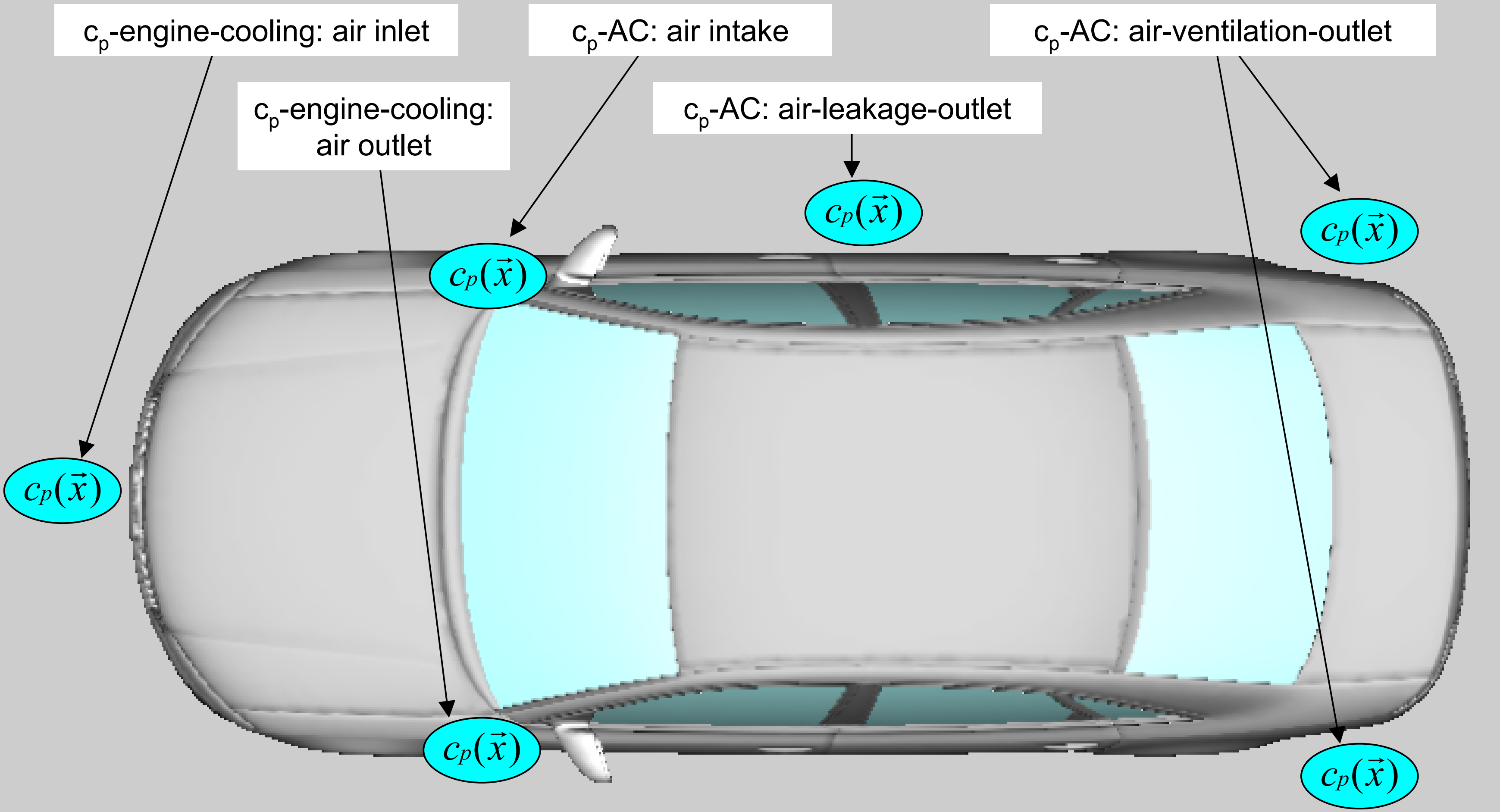
Goals: -> Layout part performance (blower, heat exchangers)

-> Optimisation part geometry (pressure loss, air distribution)

Usage: advanced and concept development

2. Concept for heat management simulation: schematic model

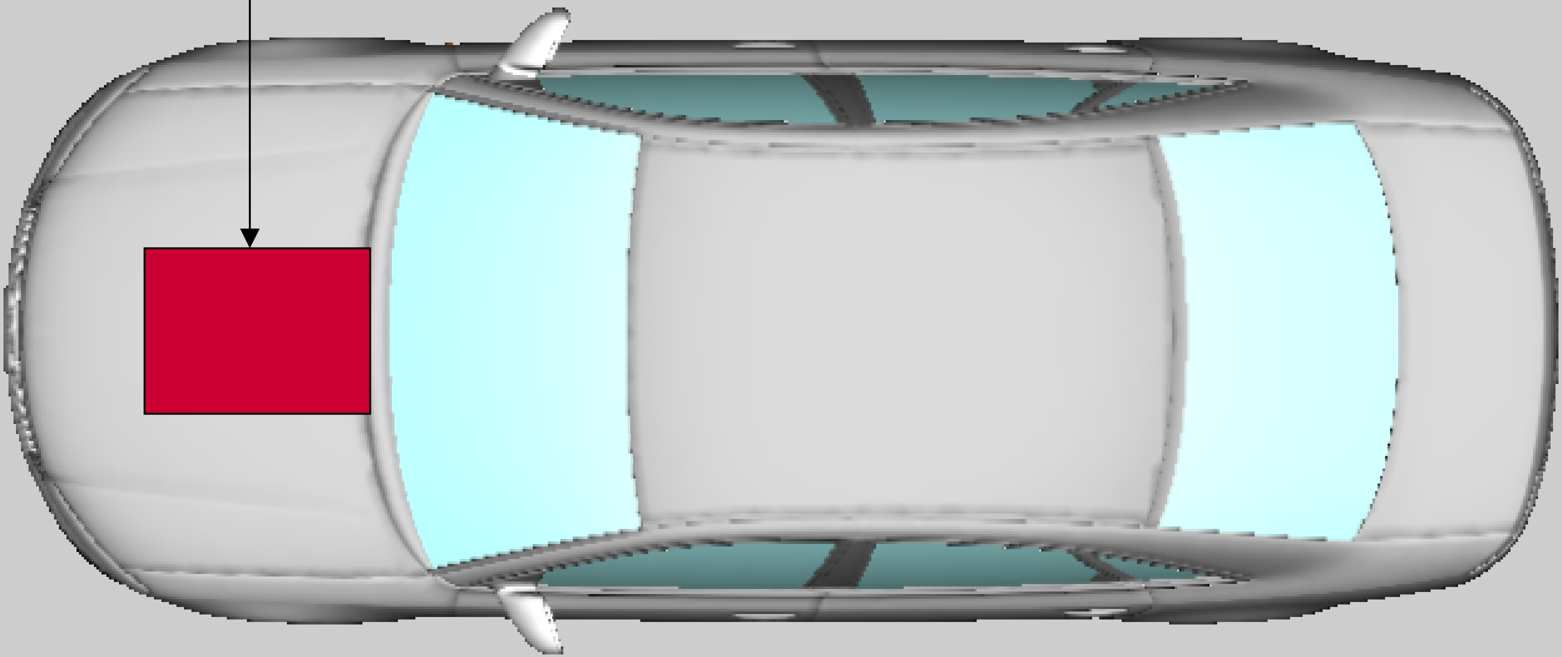
Submodel 1



Aerodynamics

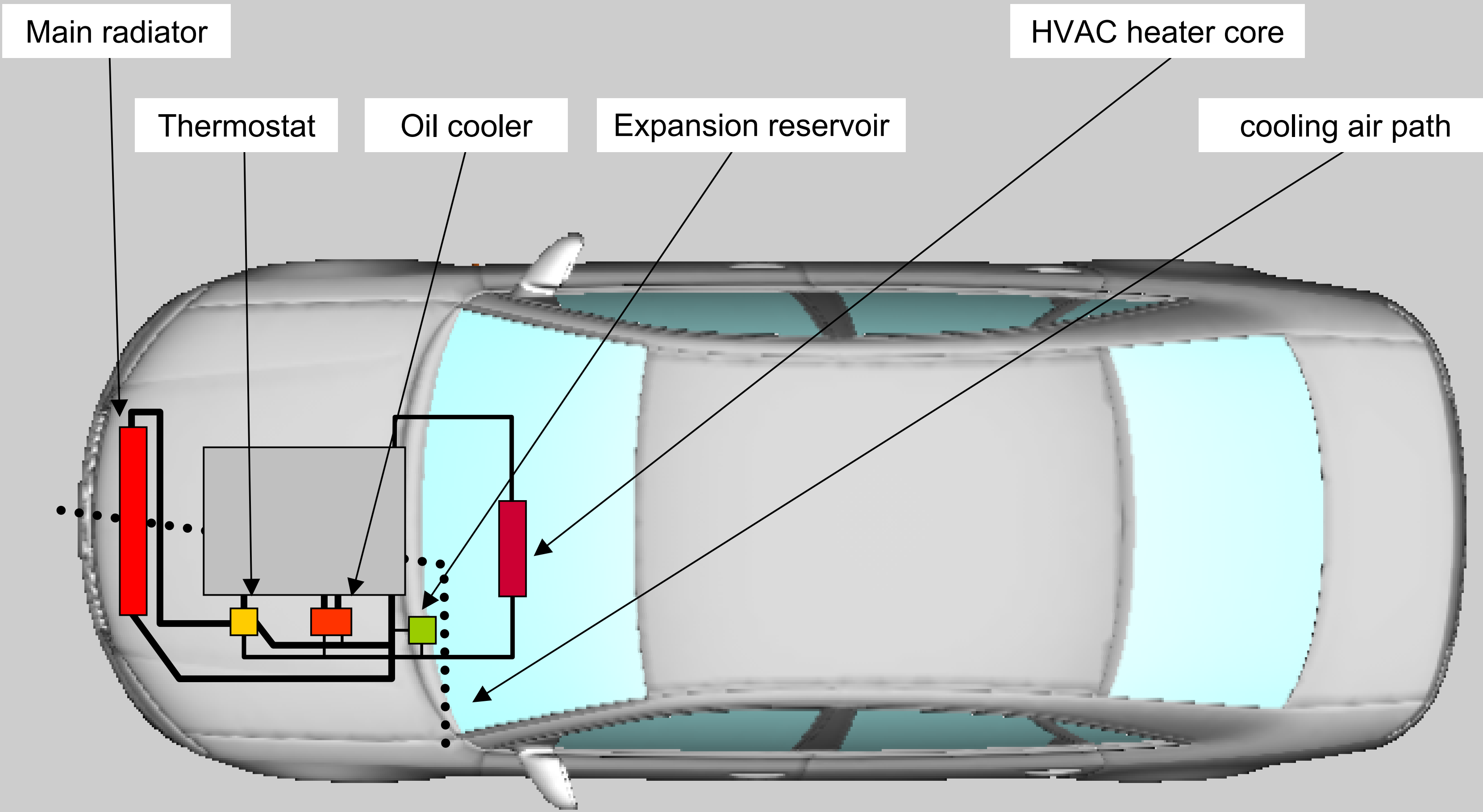
Submodel 2

Engine model: Enthalpy source - transient and capacitive behaviour



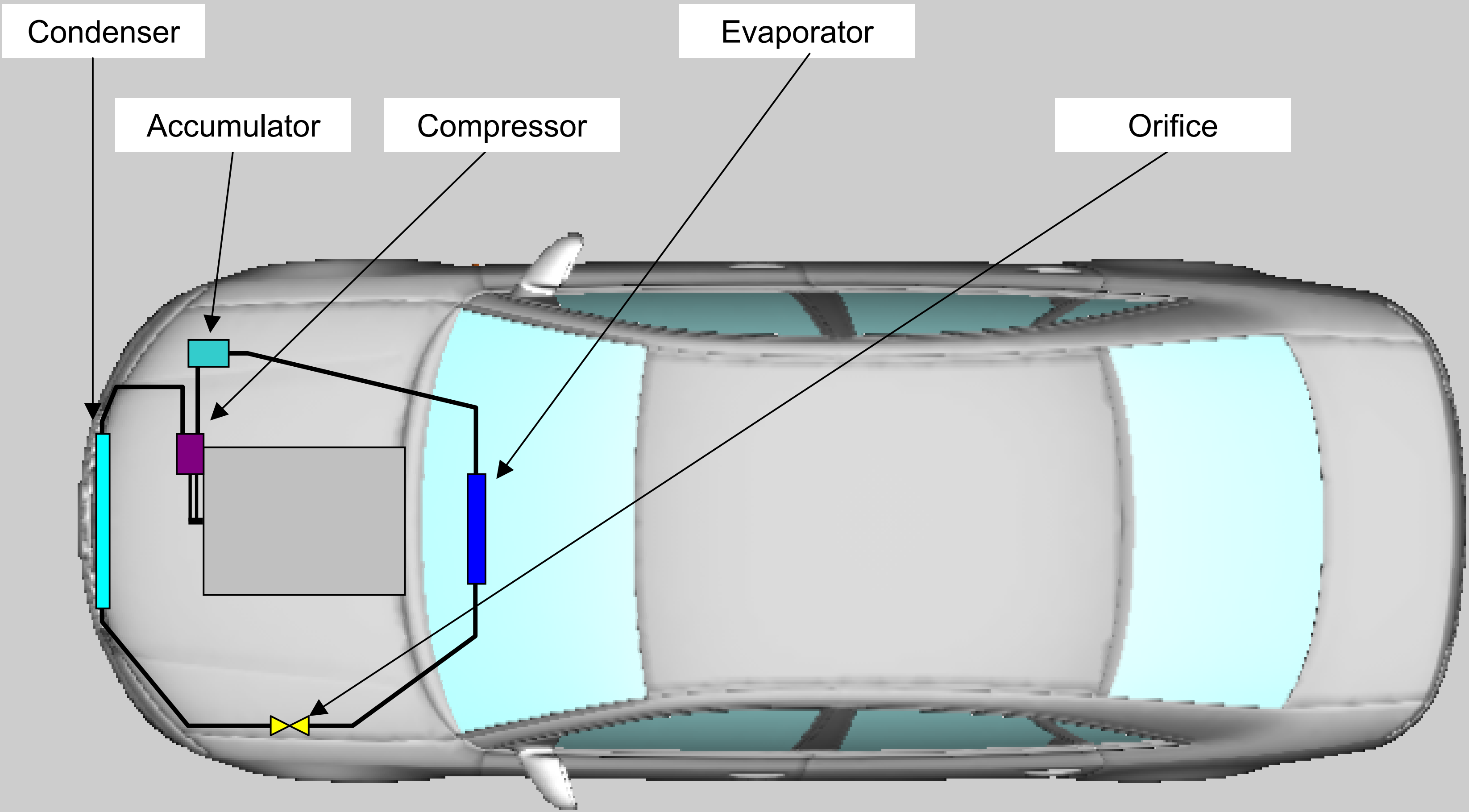
2. Concept for heat management simulation: schematic model

Submodel 3



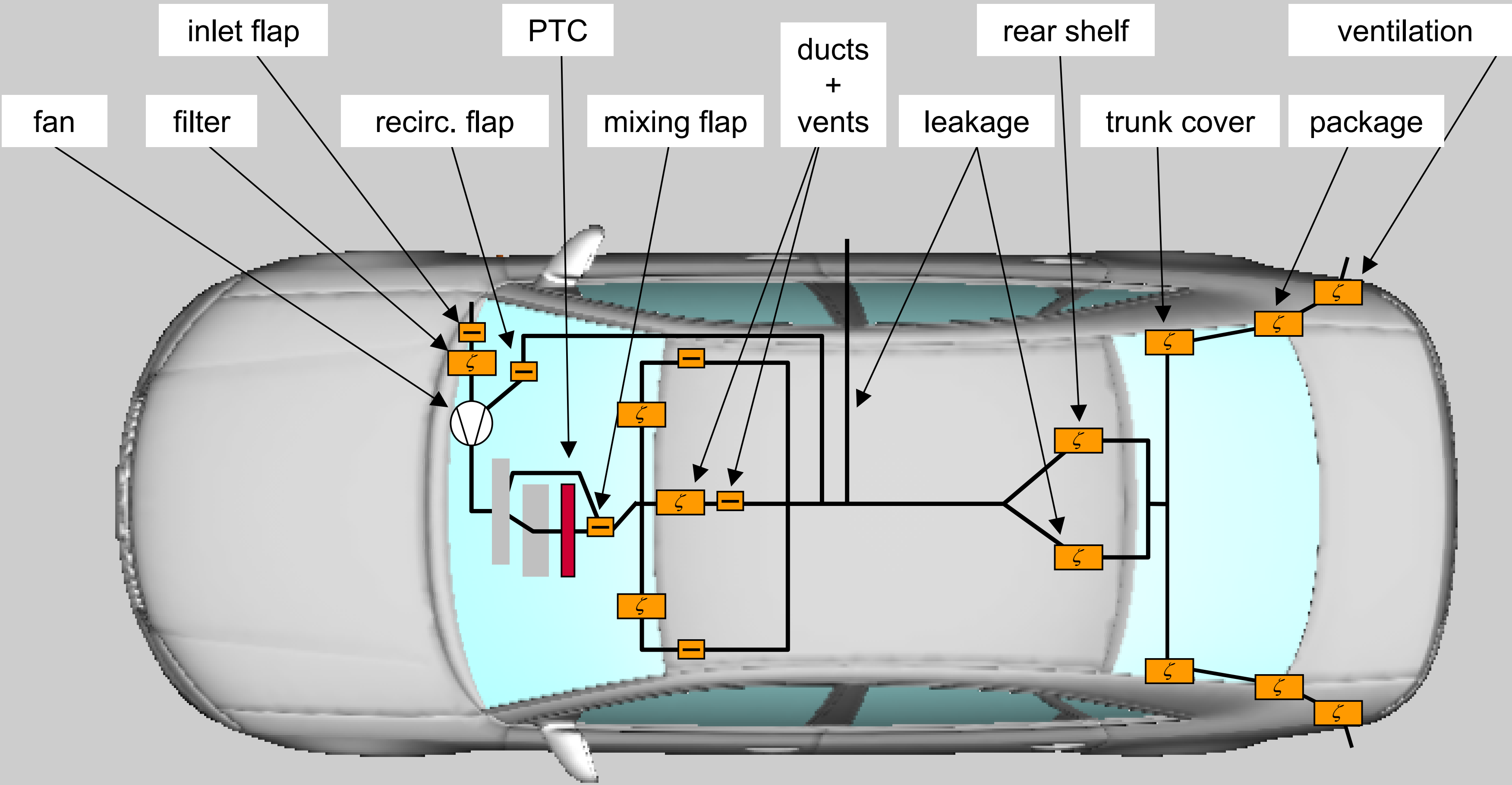
2. Concept for heat management simulation: schematic model

Submodel 4



Aerodynamics - Engine - Engine cooling - AC cooling circuit

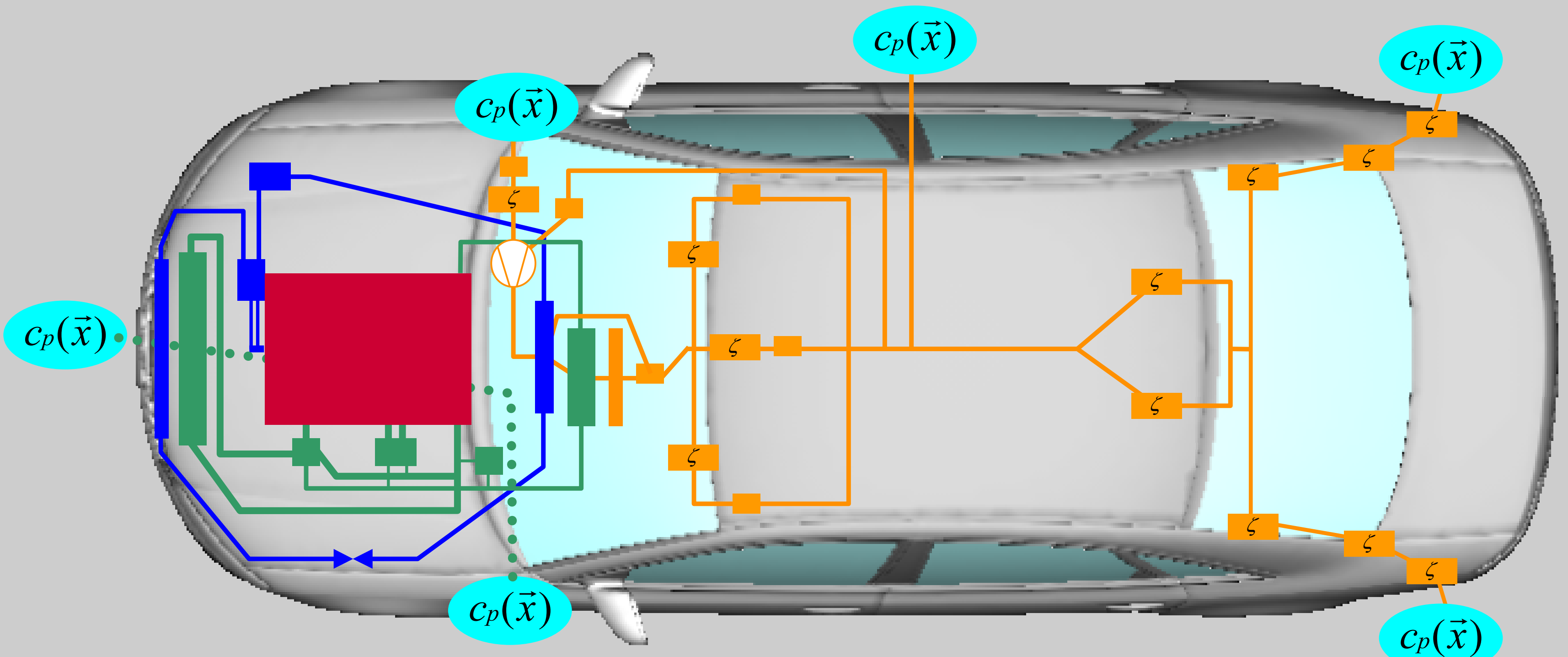
Submodel 5



Aerodynamics - Engine - Engine cooling - AC cooling circuit - AC air side

Overall model

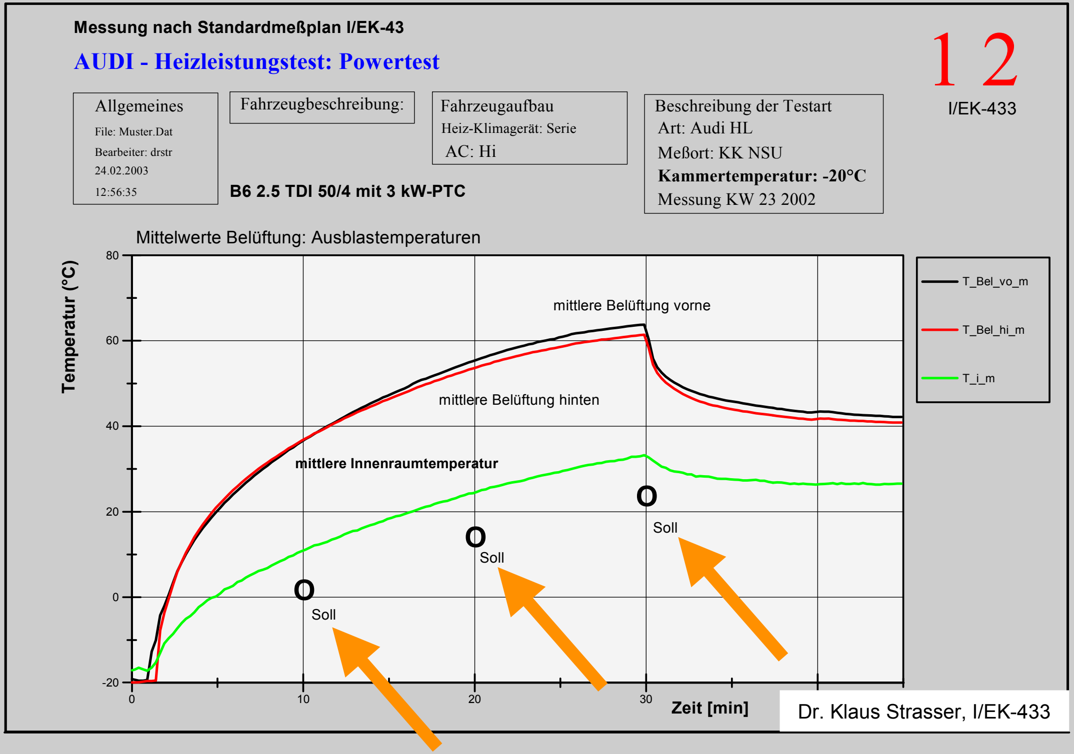
Combination of 5 stand-alone submodels for transient overall system simulation in KULI



Aerodynamics - Engine - Engine cooling - AC cooling circuit - AC air side

Example: AC operating point „Heat-Up transient“

Engineering problem: Sufficient heater output for a typical winter environment?
Boundary conditions: $T_{ambient}$ = -20°C; driving speed 50km/h; 4th gear
Target value:



Other operating points for simulation: Cool-down stationary / transient, bi-level(s)

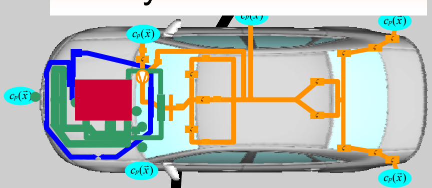
Example: Simulation „Heat-Up transient“: Procedure

<u>Goal:</u> Simulate average cabin temperature

Combined heat management simulation

1. Acquire measurement data and build components

2. Build “KULI overall system model”

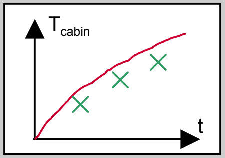


3. Prescribe and implement control strategy (“manually”, SIMULINK)

4. Prescribe boundary conditions (50 km/h; 4th gear; -20ºC)

5. Run KULI

6. Evaluate results



7. Target values reached? (e. g. 15ºC after 20min)

NO → **8.** Modify components (blower, heater core ...)

YES → **Development finished**

Comments

- 1d methods are used in very early stages of product development - Therefore: components are either
  -> taken over from preceding projects
  -> only described by their target functions or values
  -> seldom geometrical models (not available)
- KULI model set-up mostly straightforward - crucial:
  -> component data collecting
  -> specification (thermal) boundary conditions
  -> subsystem understanding
  -> model / result sensitivity to underlying test results
- Accuracy of transient cabin temperature simulation using 1d methods is not satisfying: 3d methods have to be used additionally (in combination with KULI 1d)

Fields of work

- Audi: establish process for component / submodel / overall vehicle simulation: test data collecting, model-generation and -testing during development process
- Audi: Implementation AC-control strategies using SIMULINK
- Audi: Implementation power management
- "KULI": Combined interactive KULI - 3d-CFD simulation process must be established: calculation procedure (exchange during simulation), programming and maintaining software interfaces
- "KULI": Validation / improvement engine model, AC circuits, modelling of HVAC distribution box

Audi: Next steps for subsystems in 2003

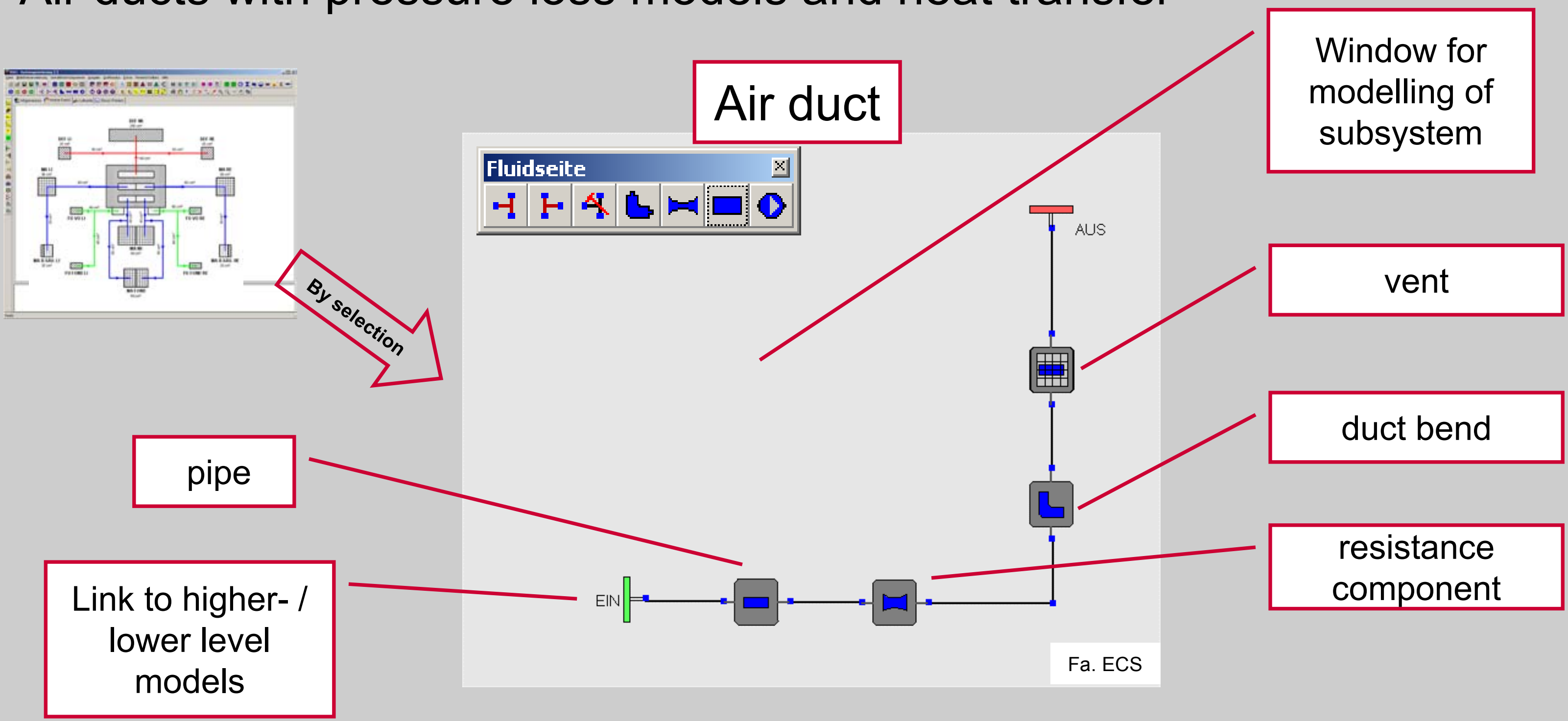
- KULI-AC: Software validation for R134a-circuit by simulation of Audi test bench and Audi A4; development "virtual compressor" (with Fa. ECS): inlet- / outlet-pressure specification instead of characteristic curves

- Engine: Measurement and validation 1,9l TDI and W12

- KULI-AC-Air Side:
  Development of new functions (with Fa. ECS) for a more detailed representation and transient simulation:
  -> Vents with alternating flap positions
  -> Model for the HVAC distribution chamber
  -> Interactive 1d - 3d interface
  -> Implementation of climate control functions using SIMULINK

Audi: Next steps for subsystems in 2003

- Example KULI-AC-Air Side:
  Air ducts with pressure loss models and heat transfer



Audi: Next steps for overall system

- Simulation Audi A4 1,9l TDI 100PS

  -> Component measurements: 08/2003

  -> Overall system measurements ($T(\vec{x}), \vec{v}(\vec{x})$ for different operating points, air-mass flow and -distribution): 10/2003

  -> Creation KULI-components and -submodels and verifying: 11/2003

  -> Overall system simulation and validation: spring 2004

5. Summary

- Engineering process air conditioning (target values, simulation methods)
- Concept for a combined aerodynamics - engine cooling - air conditioning model for overall vehicle simulation (e. g.operating point “Heat up”)
- Heat management simulation:
  procedure, problems (necessity for 1d-3d coupling!)
- Coming Audi activities with focus on air conditioning

Thank you!