



## **Central application of KULI- Engine Model in Engine Cooling and Air Conditioning**

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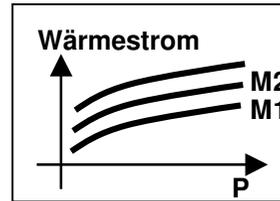


- Functional Layout for Engine Cooling Systems with Simulation at AUDI
- Position of KULI in the Development Prozess at AUDI
- Application of KULI Engine Model at AUDI
- Difficulties and Requirements at an Engine Model
- Summary and Outlook

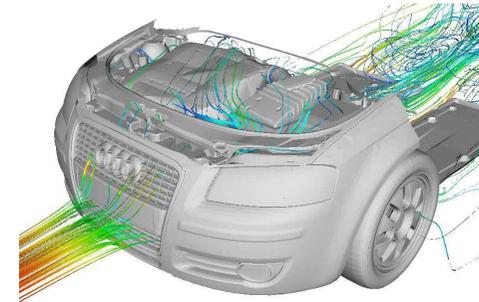
# Functional Layout for Engine Cooling Systems at AUDI



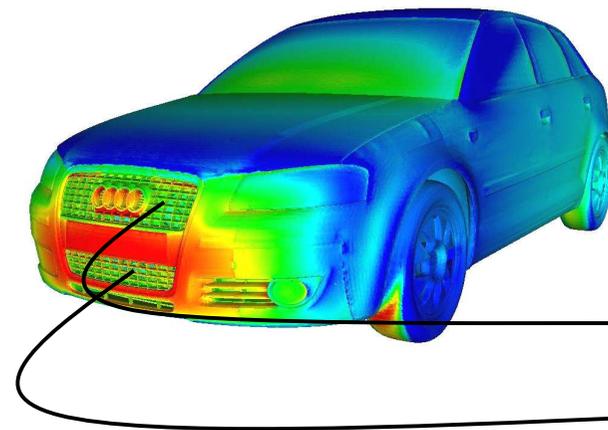
**Input Parameter for Generation of 1D Models for Evaluation of stationary Operating Points**



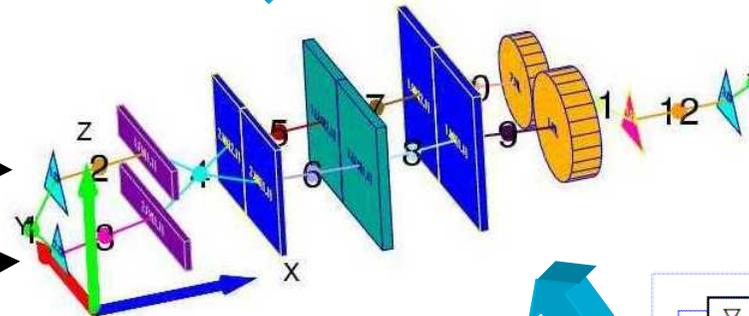
Engine Heat Flow from Test Bench or Vehicle Measurements



Cooling Air Flow and Air Resistance from 3D Underhood Air Flow Calculation

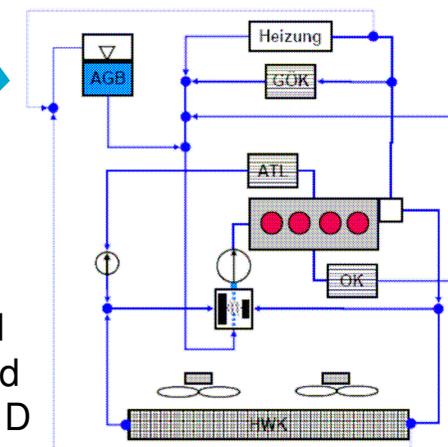


cp- Distribution from 3D Airflow Simulation, Exterior Aerodynamic



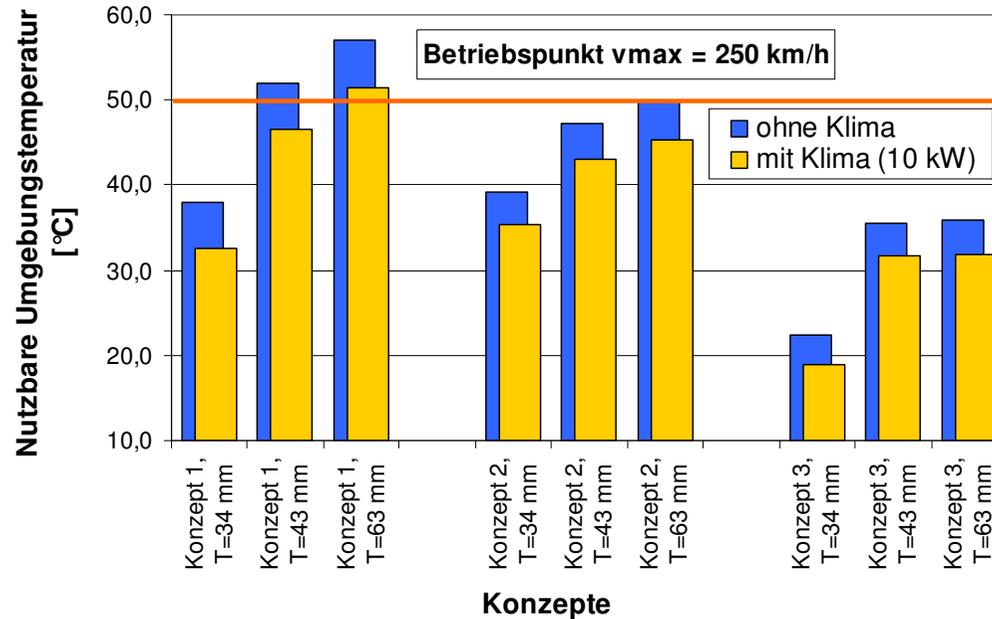
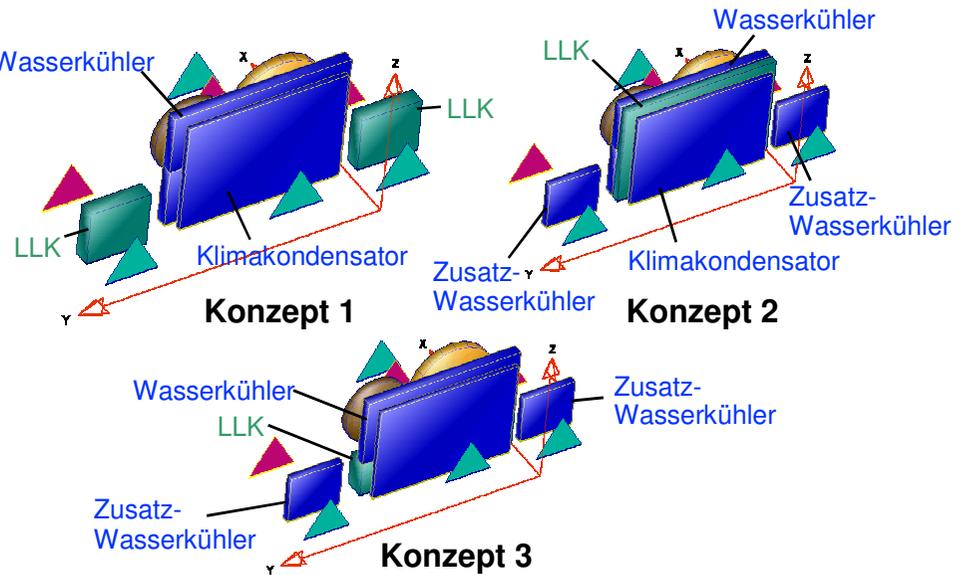
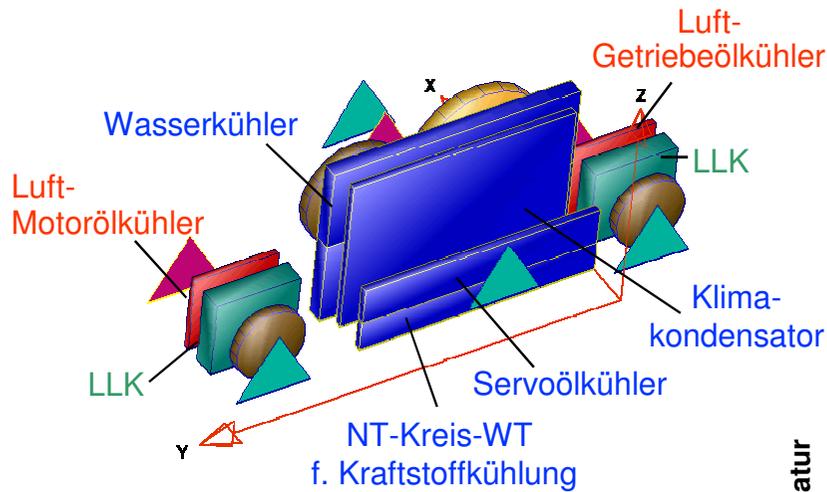
**1D Model from Cooling Circuit**

Coolant Volume Flow Rate and Pressure in the System from Cold Running Measurement Tests or 1D Simulation



## Concept Decision for

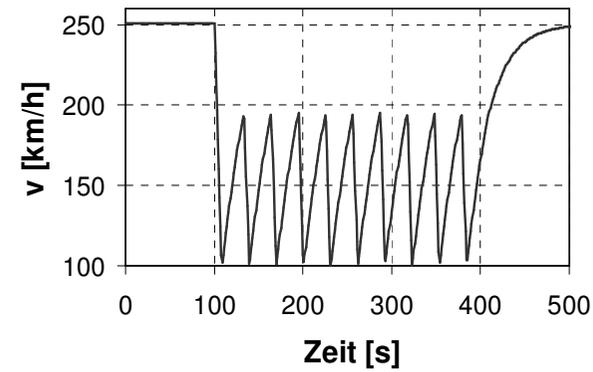
- Media-Air-Heat Exchanger-Arrangement
- Media-Air-Heat Exchanger-Geometries
- Fan Systems



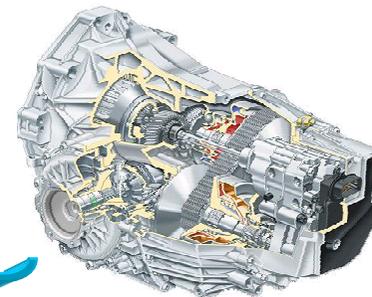
# Application of KULI Engine Model in the Development Process



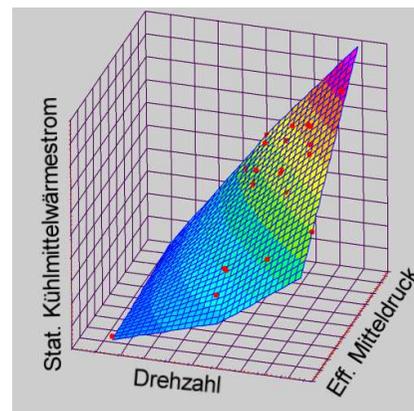
**Driving Profile**  
Velocity / Time  
Road High Altitude



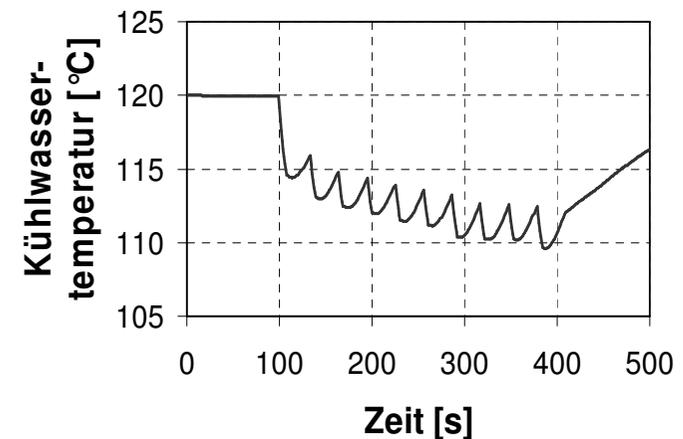
**Vehicle**  
Mass  
Road Resittance  
Inertia Moment



**Gearbox**  
Transmission Ratio,  
Efficiency,  
Gear Shift Strategy

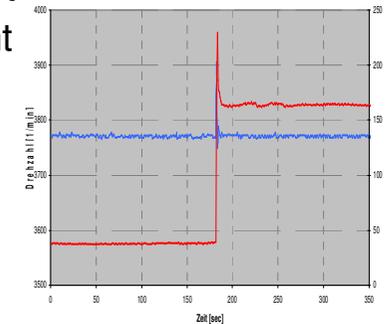
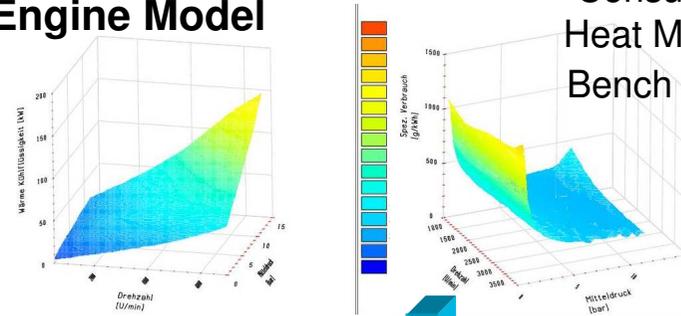


**Engine Model**  
Rotational Speed, Mean Pressure,  
specific Consumption



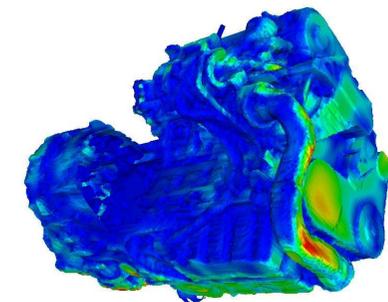
## Buildup the Engine Model, Influencing Variable and Balancing of the Engine Model

## Consumption- and Heat Map from Test Bench Measurement

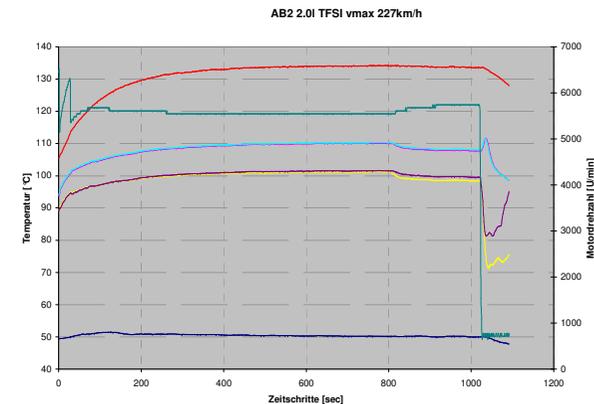
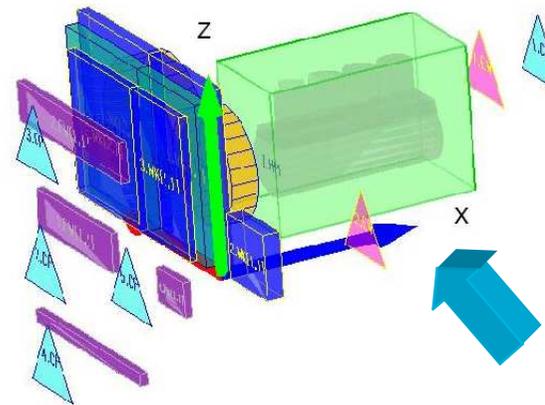


Change in Load for the Determination of the engine internal Heat Transmission Coefficient

Balanced 1D KULI- Modell based on stationary Operating Points



Velocity Distribution on the Engine and the Oil Pan from 3D CFD- Calculation



Wind Tunnel or Test Bench Measurement for Balancing and Calibration of the Engine Model

## Methodical and Development accompanying Application of the KULI Engine Modell in the Field of Engine Cooling

### ➤ A3 Sportback 2.0l R4 TFSI 147kW

Calculation from Heat up of the Engine Oil and Coolant for the Operating Point  $v_{\max}$ , Balancing with Test Bench Measurement and Comparison of the Calculation with Wind Tunnel Measurements



### ➤ A6 Limousine 3.0l V6 TDI 165kW

Simulation of Uphill Driving at the Großglockner with decreasing Ambient Temperature and Air Pressure, Comparison with Reality from Test Drive at the Großglockner



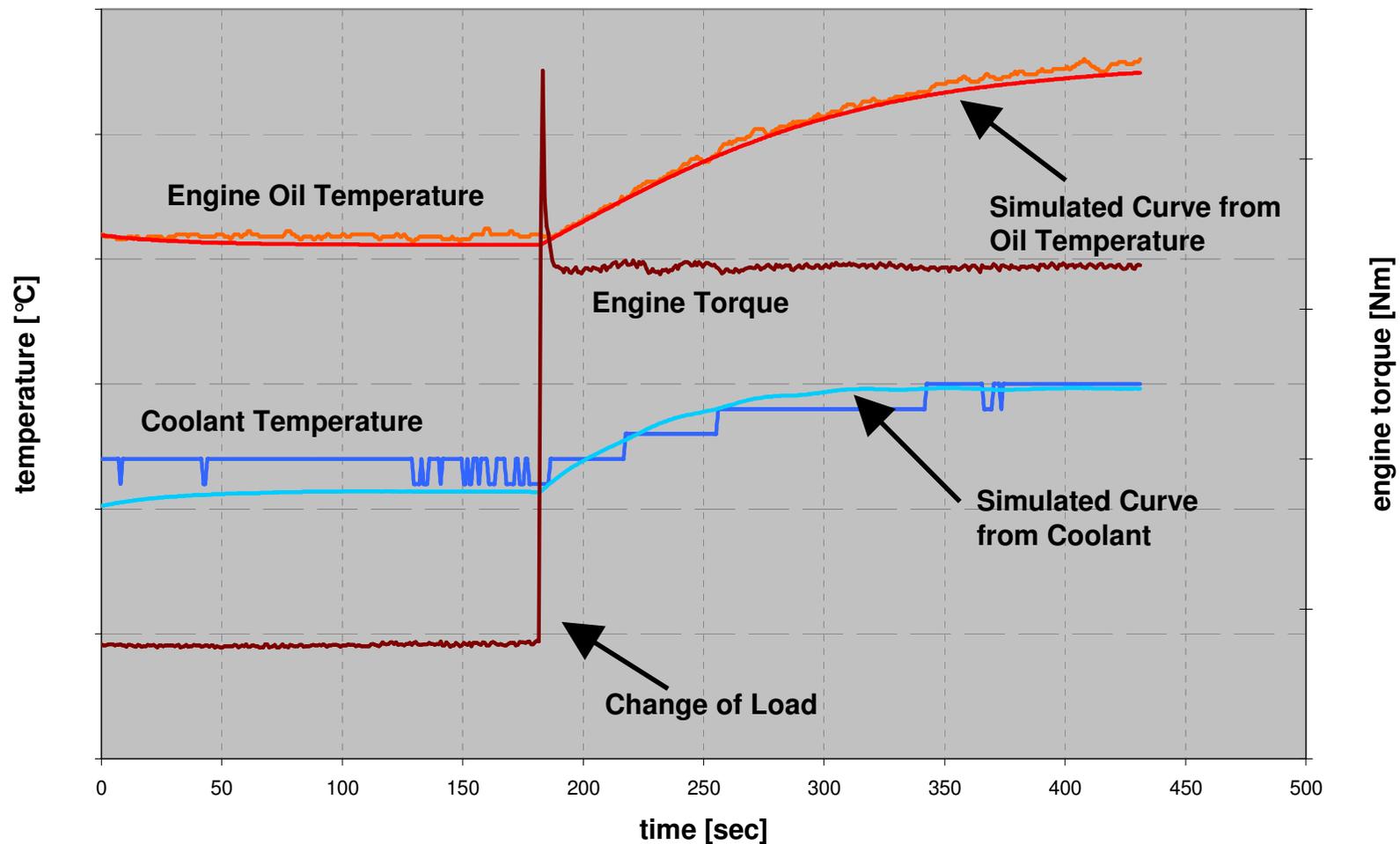
### ➤ A8 Limousine 6.0l W12 MPI 330kW

Simulation of a High Speed Circuit in Combination with a Handling Course, Calculation from Coolant- and Engine Oil Temperature, Comparison with Reality from Test Drive



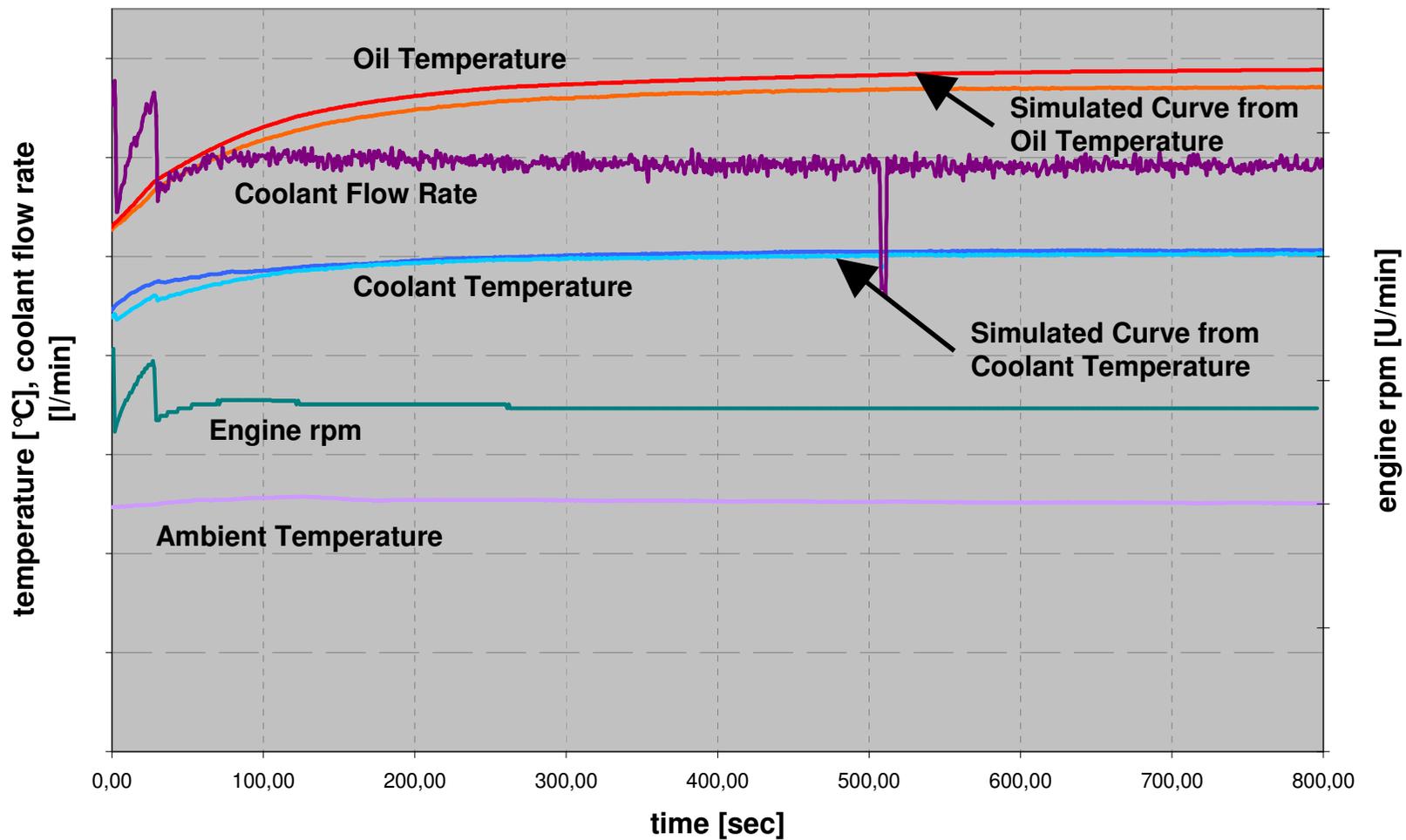
## A3 Sportback 2.0l R4 TFSI 147kW

Calculation of the Heat Up from Engine Oil and Coolant after a defined Change of Load realized on an Engine Test Bench



## A3 Sportback 2.0l R4 TFSI 147kW

Calculation of the Heat Up of Engine Oil and Coolant during a Wind Tunnel Measurement for the Operating Point  $v_{\max}$

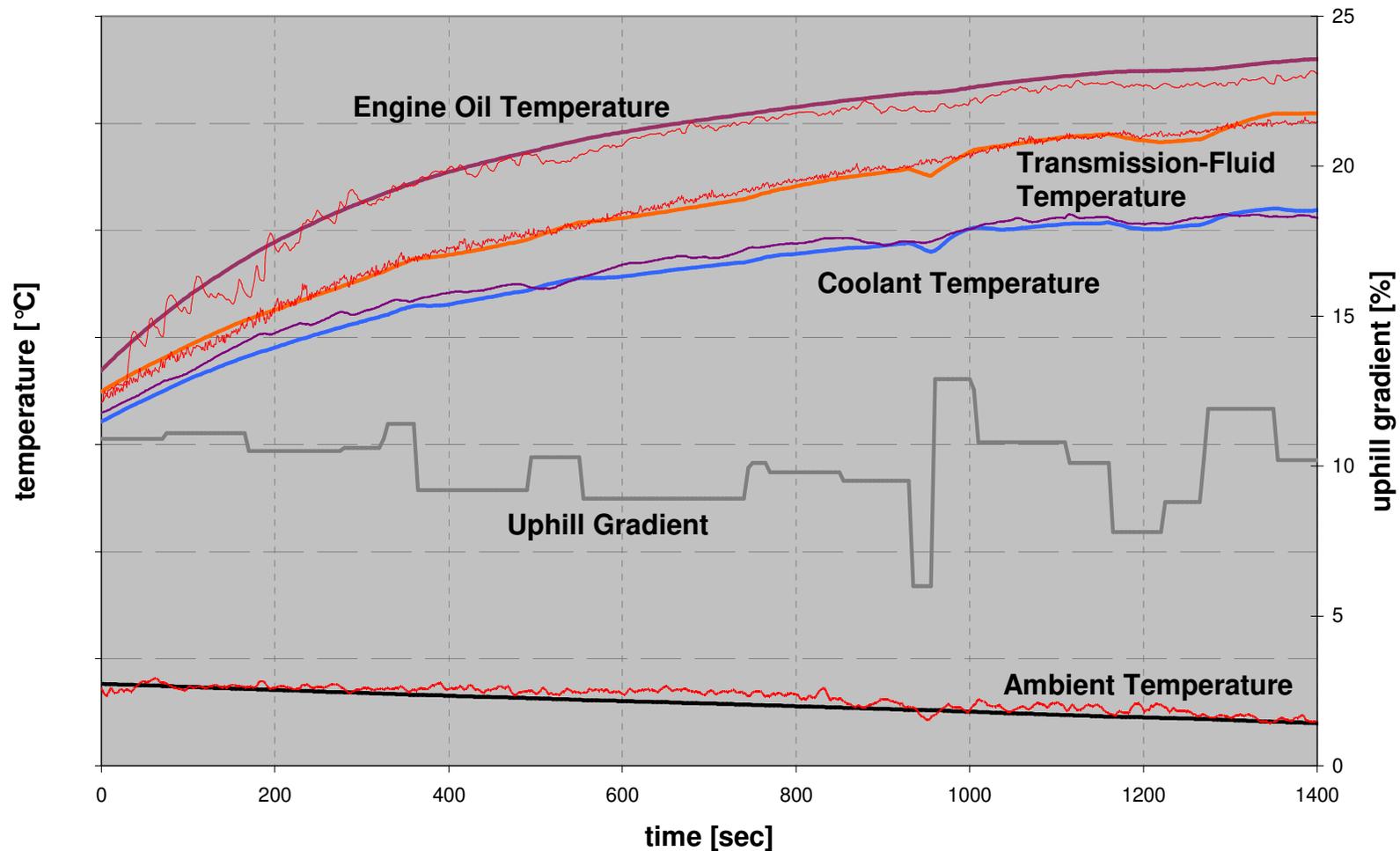


# Application of KULI Engine Model in the Development Process



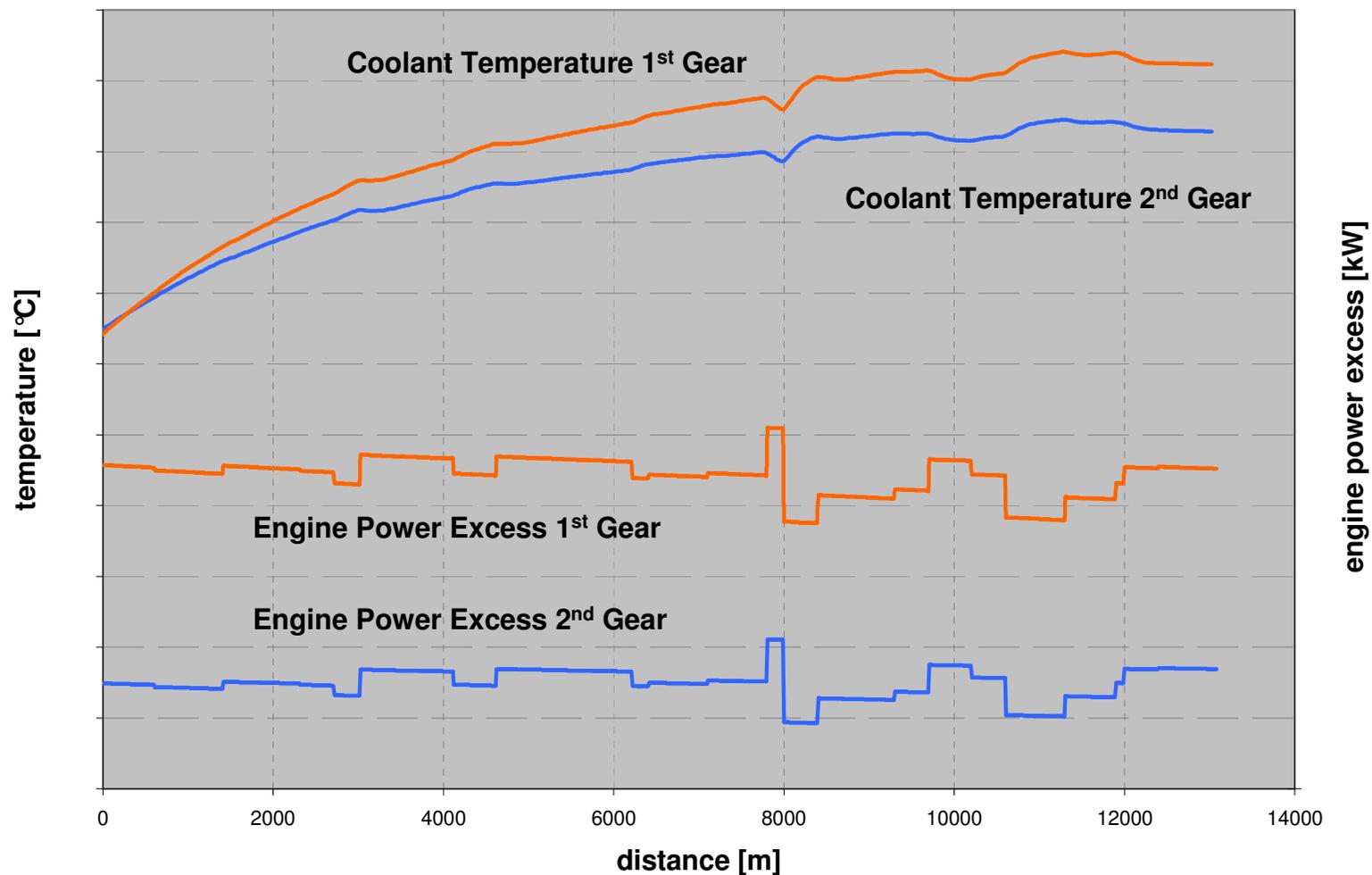
## A6 Limousine 3.0l V6 TDI 165kW

Simulation of Uphill Driving at the Großglockner with decreasing Ambient Temperature and Air Pressure



## A6 Limousine 3.0l V6 TDI 165kW

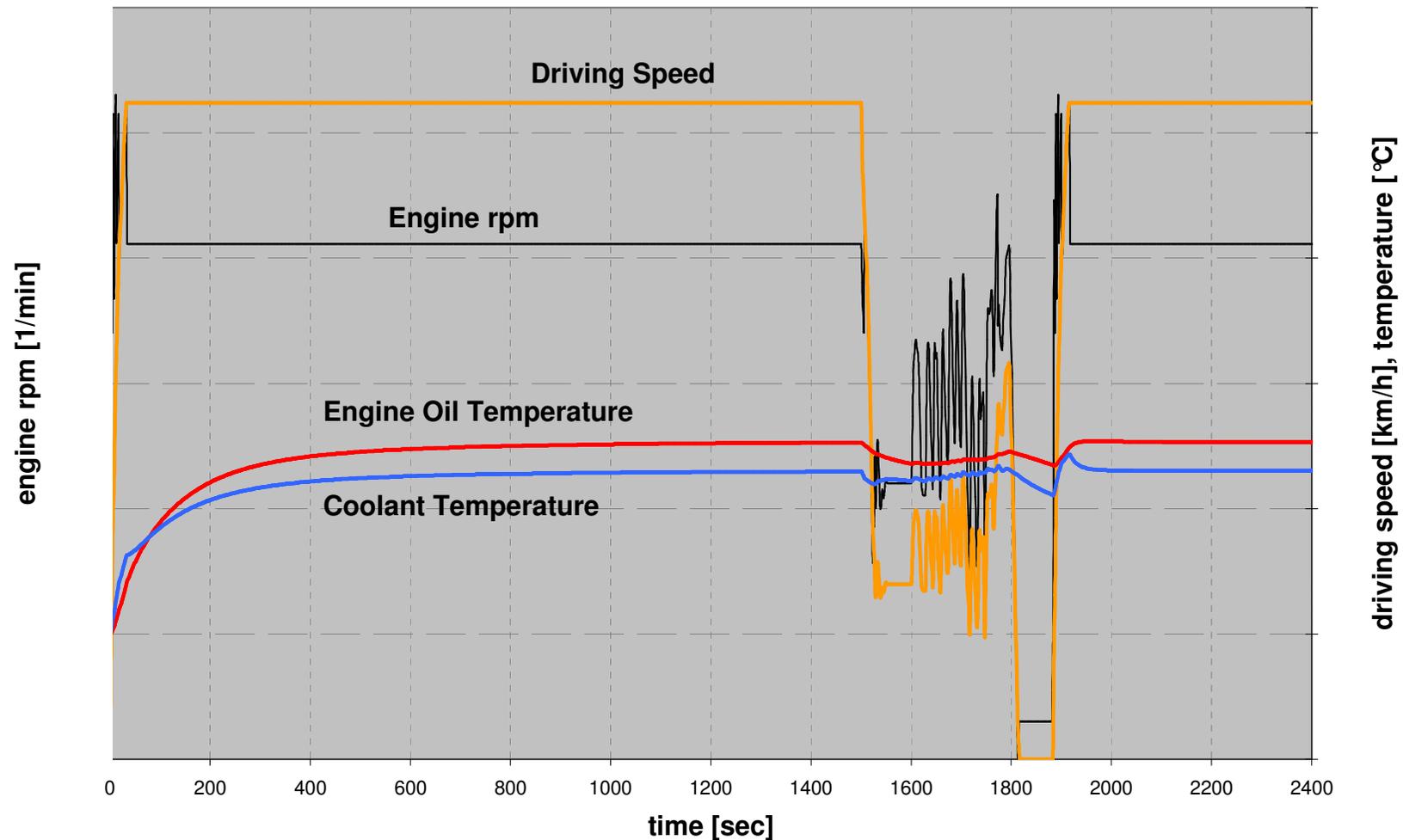
Simulation of Uphill Driving at the Großglockner with different Driving Positions and the Impact on Coolant Temperature





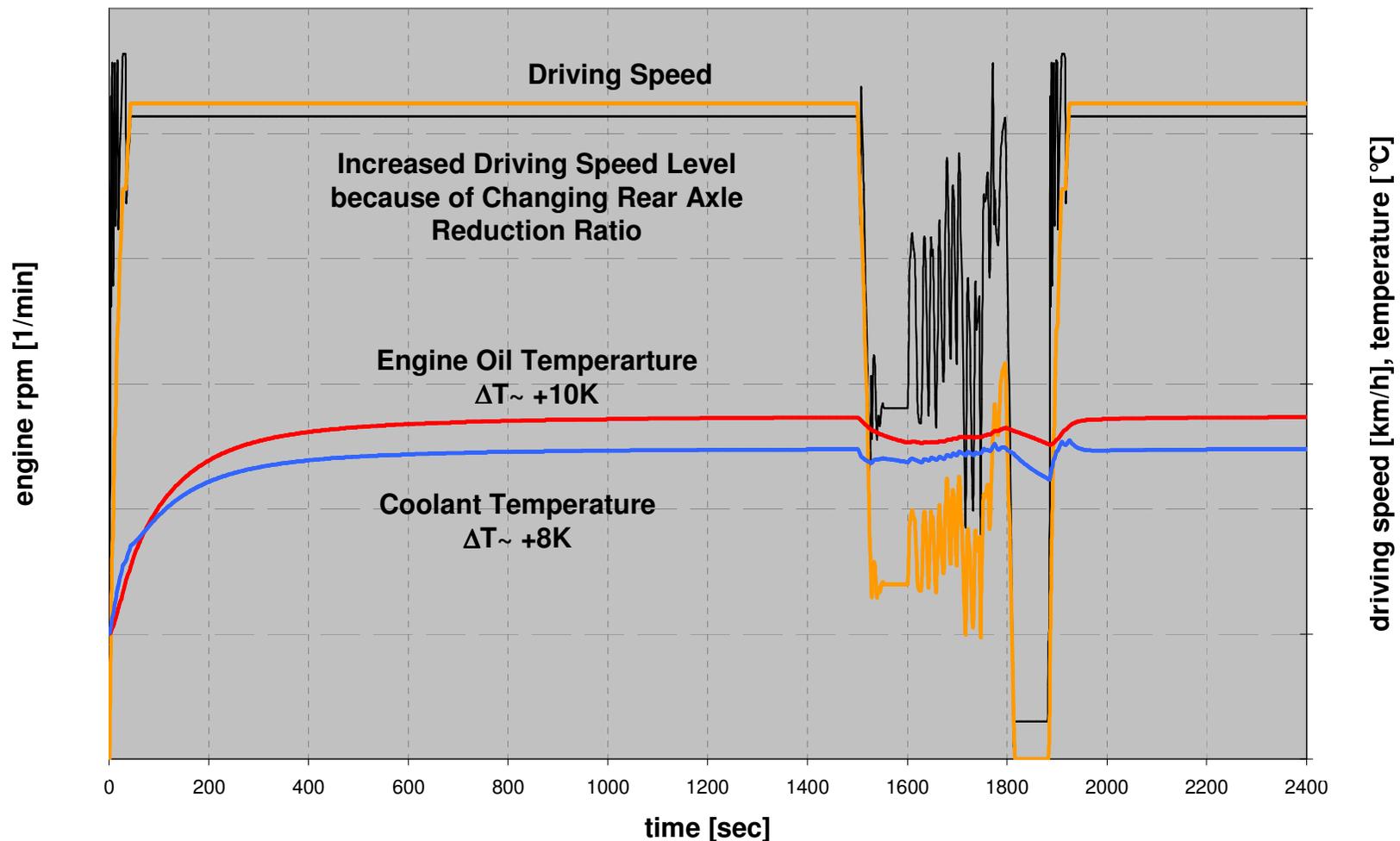
## A8 Limousine 6.0I W12 MPI 330kW

Simulation of a High Speed Circuit in Combination with a Handling Course, Calculation of Coolant- und Engine Oil Temperature, Rear Axle Reduction Ratio 1, Balancing of the Simulation with Engine Measurements



## A8 Limousine 6.0I W12 MPI 330kW

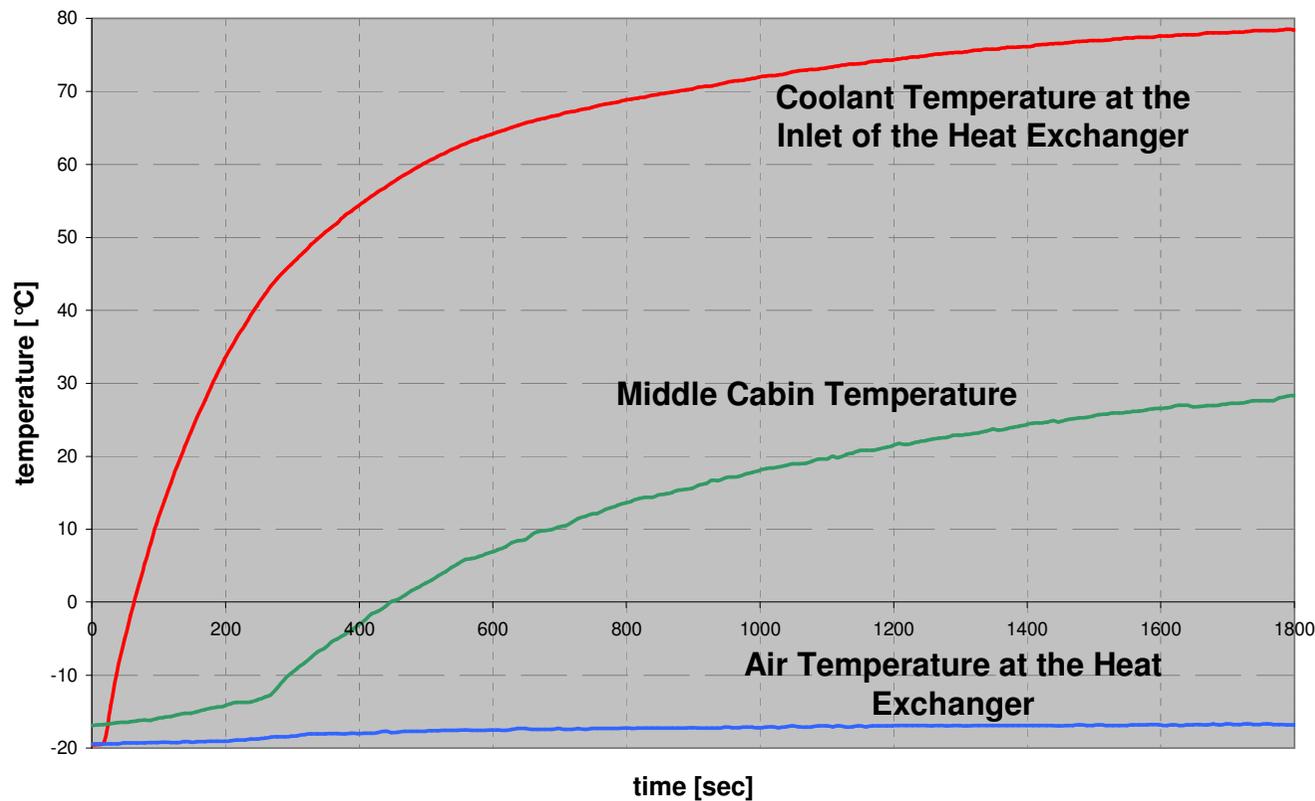
Simulation of a High Speed Circuit in Combination with a Handling Course, Calculation of Coolant- und Engine Oil Temperature, Rear Axle Reduction Ratio 2, Calculation of the changed Coolant and Engine Oil Temperatures



## Prospective Application of the Engine Model in the Vehicle Climatisation

➤ Operating Point: Heating Output Test

Vehicle will be operated with 50km/h in the 4<sup>th</sup> Gear at  $T_{\text{ambeint}}$  of -20°C for 30 Minutes. It will be determined the Funtion of the Passenger Cabin Temperature above the Time,  $T_{\text{cabin}}(t)=?$



## Prospective Application of the Engine Model in the Vehicle Climatisation

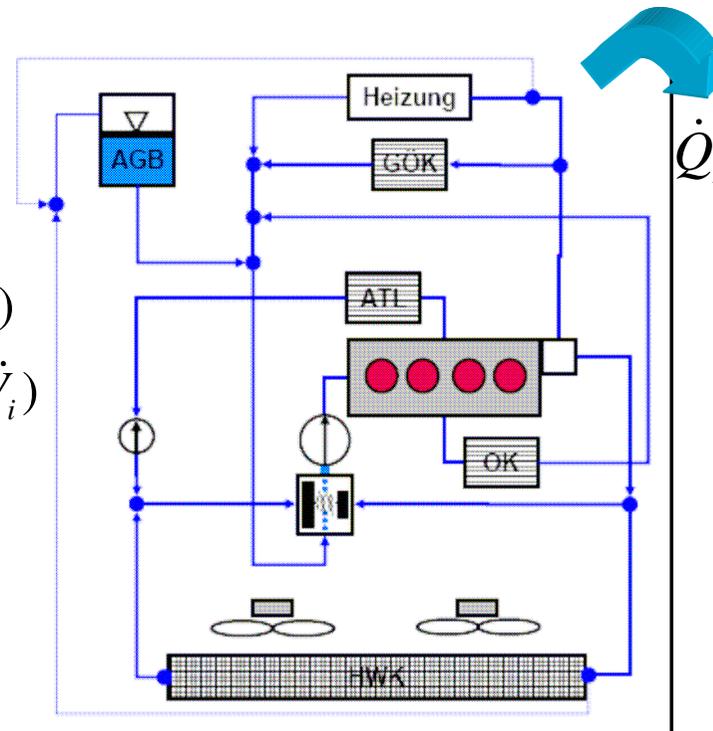
➤ Operating Point: Heating Output Test

In the Past Simulationmodels based on Input Data (Heat Flow) from Vehicle Measurements

Input Data in Cooling Simulation Modell

$$\dot{V}_{HWT} = f(\text{Engine rpm})$$

$$\dot{Q}_{HWT} = f(\dot{Q}_{Coolant}(t), \dot{V}_i)$$



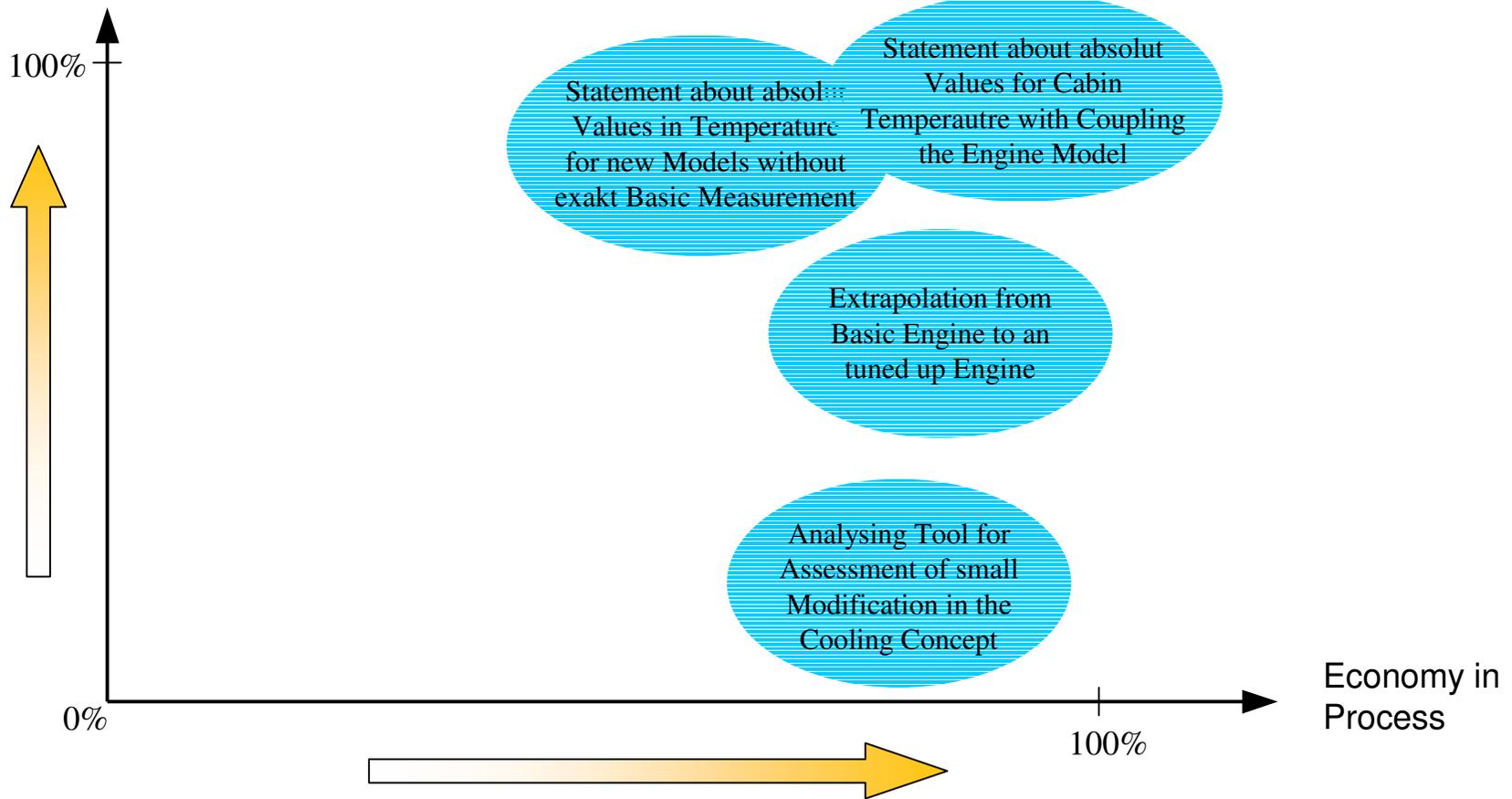
$\dot{Q}_{HWT} \Rightarrow$  Source for Cabin Heat Up

Future Target: Simulation of the Engine Heat Flow for different Operating Points with an Engine Model to generate the Input Data for the Heat Exchanger



## Risk and economic Views of the actually and future Applications

Risk in Application



### **Current Problems und Questions, Approach and Requirements for process- stable Application**

- Standardization of Generating an Engine Model with clear Results at different Users
- How can increase a variable  $k \cdot A$  over different Rotational Speeds the Quality of results
- How will be a modification of the combustion during different Operating Points realize?
- Which Differences do arise by balance between Vehicle and Test Bench?
- How do different Air Flow Velocities on the Engine influence the Convective Heat Dissipation in the Engine Model?
- How clear will be Changes like Performance Tuning or Capacity Enlargement forecast



### **Current Field of Application of the Engine Model at AUDI**

- Analysing Tool for a fast Assessment small Modification regarding Gear Step, Gearbox- or Rear Axle Reduction Ratio on Base of a complete balanced Engine Model
- Generating of Reference Results and  $\Delta$ - Values on Base of balanced Models

### **Necessities for extended Application**

- Documentation of the Approach for Generation and Balance, Lighting the physical Background
- Sensitivity and Failure Analysis of Input Parameters and Map Data
- High Quality of Forecast in the early Concept Stadium (without Test Bench Measurement) for Saving Development Time and Reduction of Iterations



**Thank you for your Attention**

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