Using the KULI Thermal Network in the Area of Convective Gearbox Cooling

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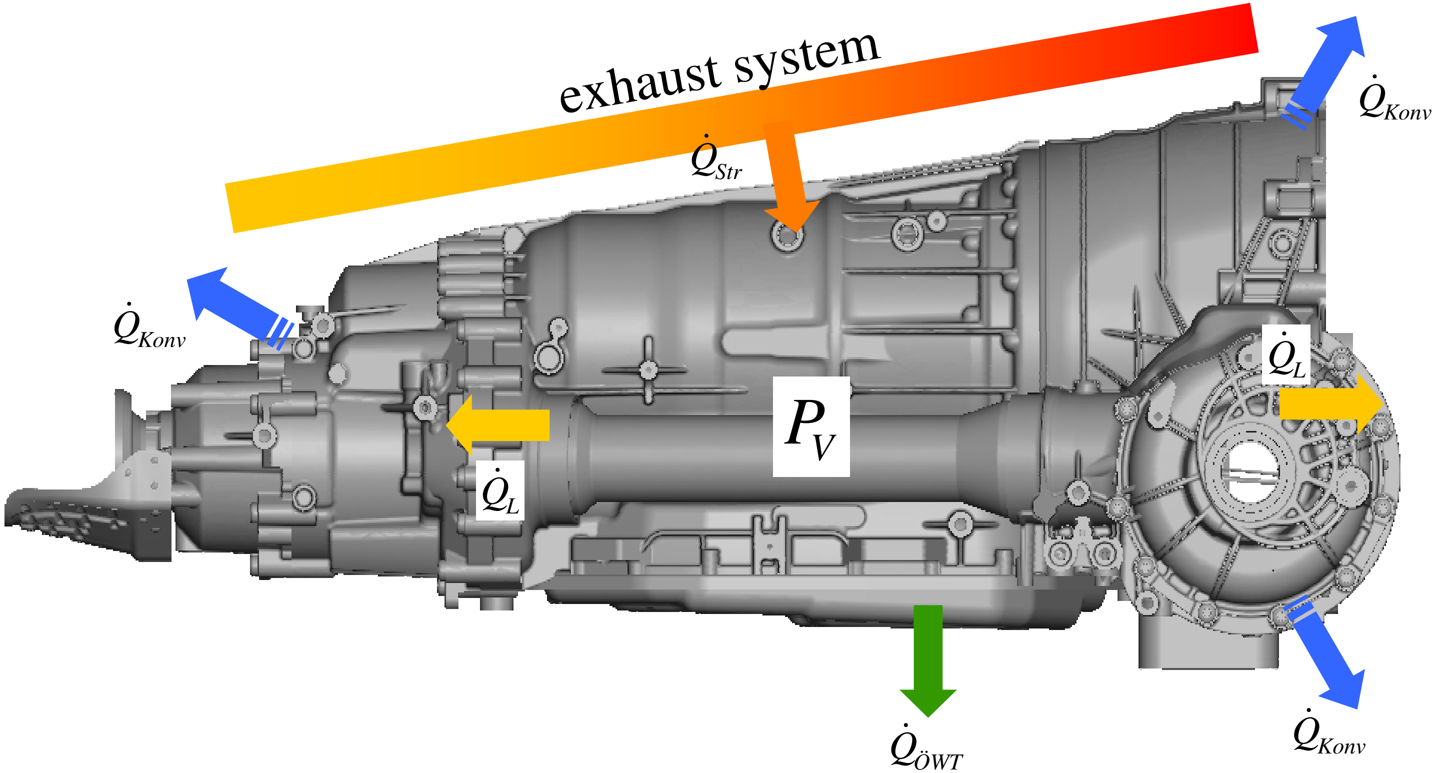
- Formulation of the problem, motivation
- Gearbox analysis, measurement method
- Modeling technique, intersection between 1D and 3D
- The KULI Thermal Network
- Application, examples
- Summary and outlook

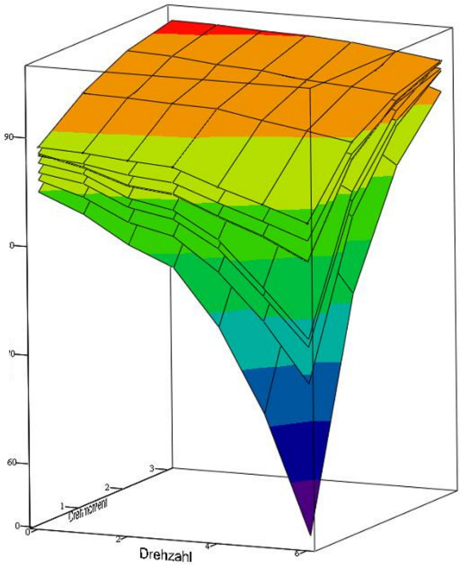
Influencing variables in the heat balance from a modern automatic transmission gearbox



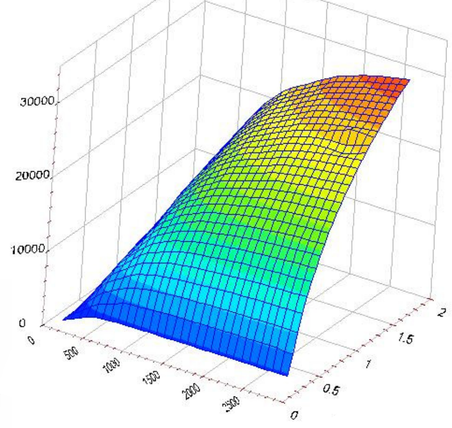
$$\dot{Q}_{Konvektion} = P_{Verlust} + \dot{Q}_{Str,AGA} - \dot{Q}_{ÖWT} - \dot{Q}_{Leitung}$$

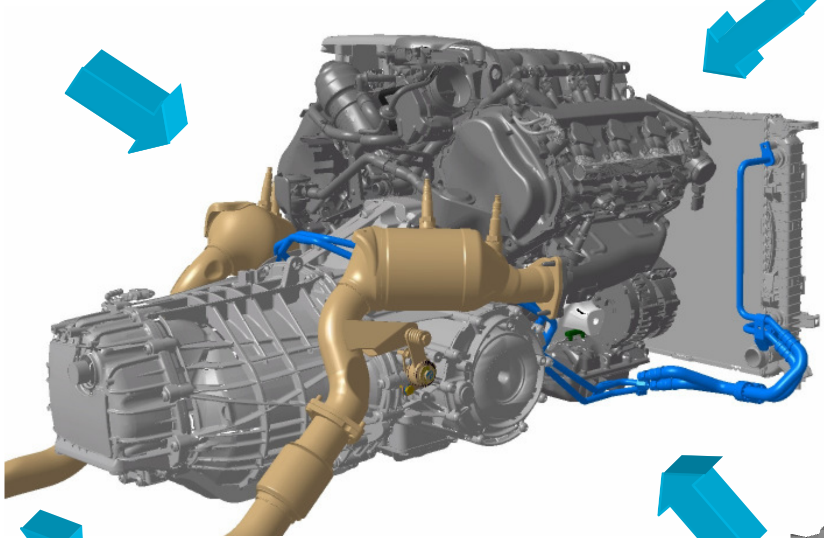
$$\dot{Q}_{Konvektion} = f\left(\bar{v}_{Kühlluft}, \bar{v}_{Öl}, T_{Kühlluft}, T_{Öl}, A\right)$$

Influencing variables in the heat balance from a modern automatic transmission gearbox

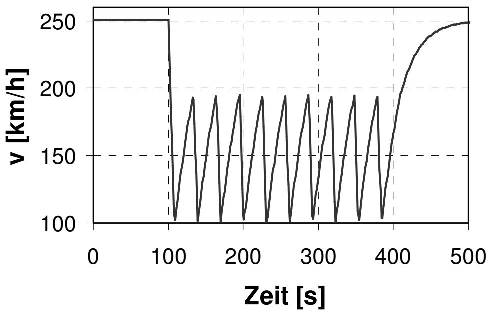


Efficiency of the gearbox, power loss over rotational speed and torque



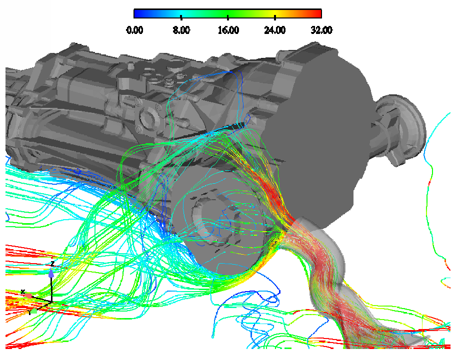


exposition from active cooling in dependence on cooling air mass flow and coolant volume flow



Exposition from exhaust system in dependence from driving conditions

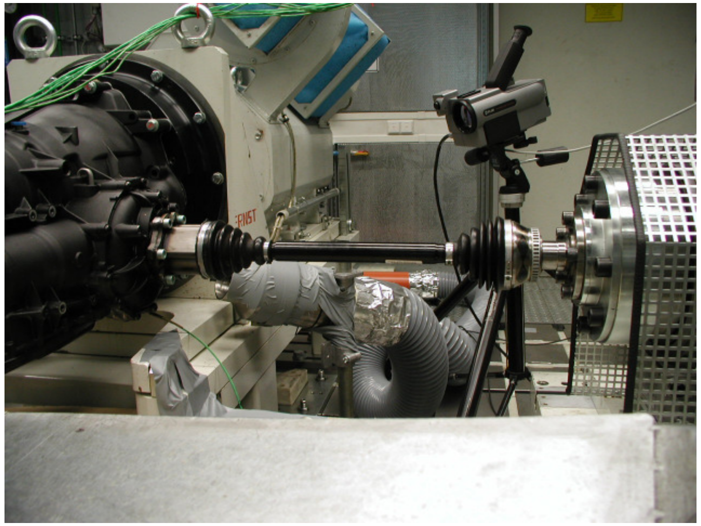
Exposition of convection in dependence of flow velocity and temperature

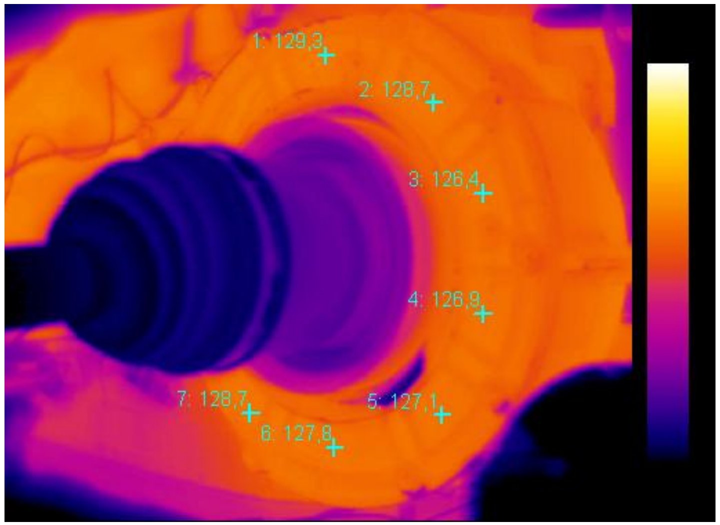


Analysis from gearbox power loss, media temperatures and surface temperatures

Requirements to test bench measurements

- Determination from the developing power loss
- Determination from all media temperatures, in particular oil temperatures
- Determination from surface temperatures on the gearbox
- Test bench conditions close to the real vehicle

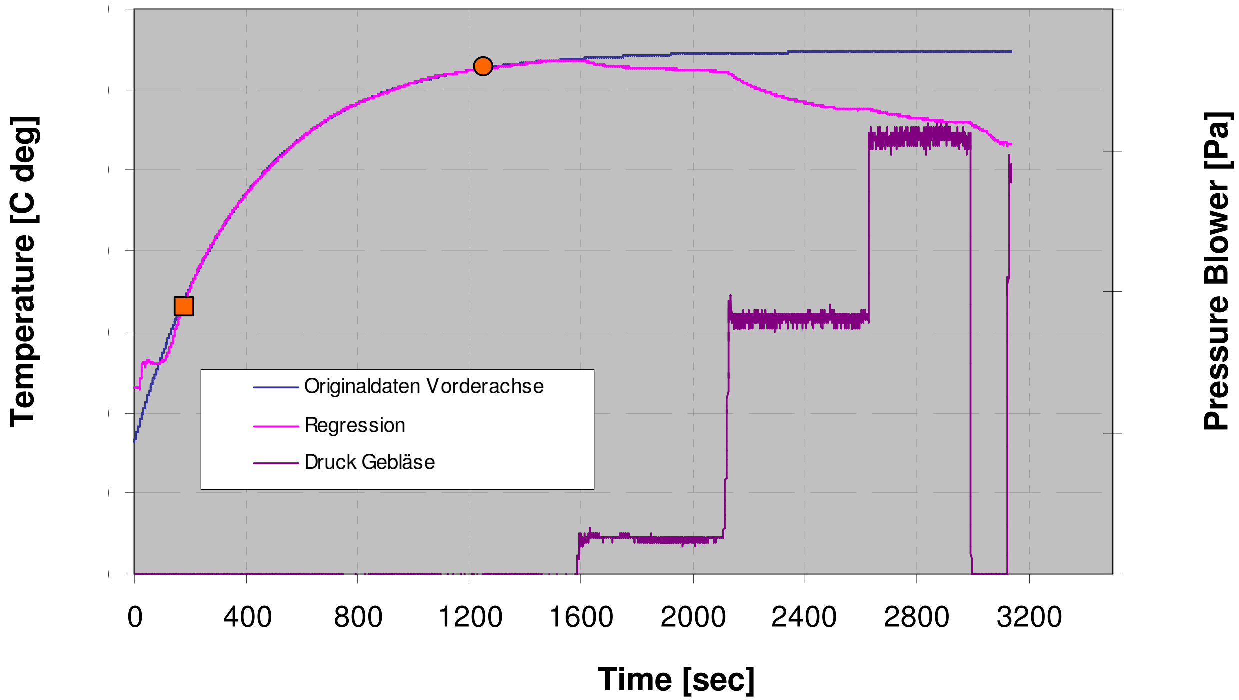




Analysis from gearbox power loss, media temperatures and surface temperatures

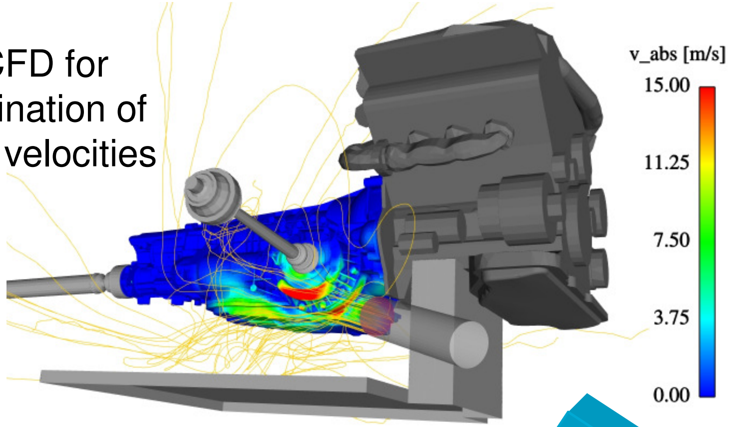
Necessary measurements and simulations

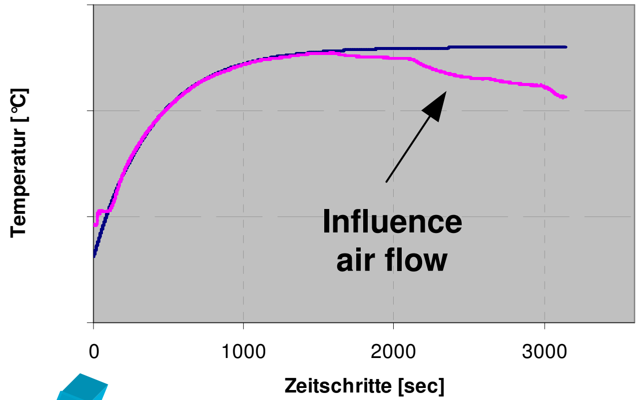
- Heat up behavior from cooling media and surfaces
- Cool down behavior from cooling medias and surfaces in dependence on flow velocity



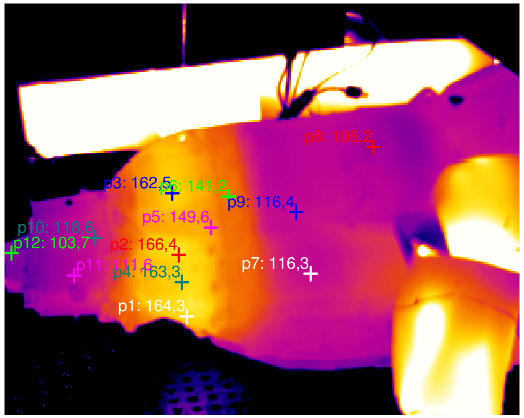
Translation of test bench conditions in a 1D model

3D CFD for determination of surface velocities

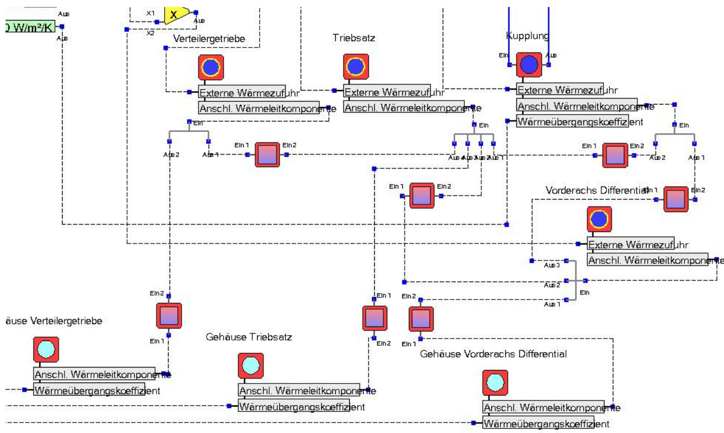




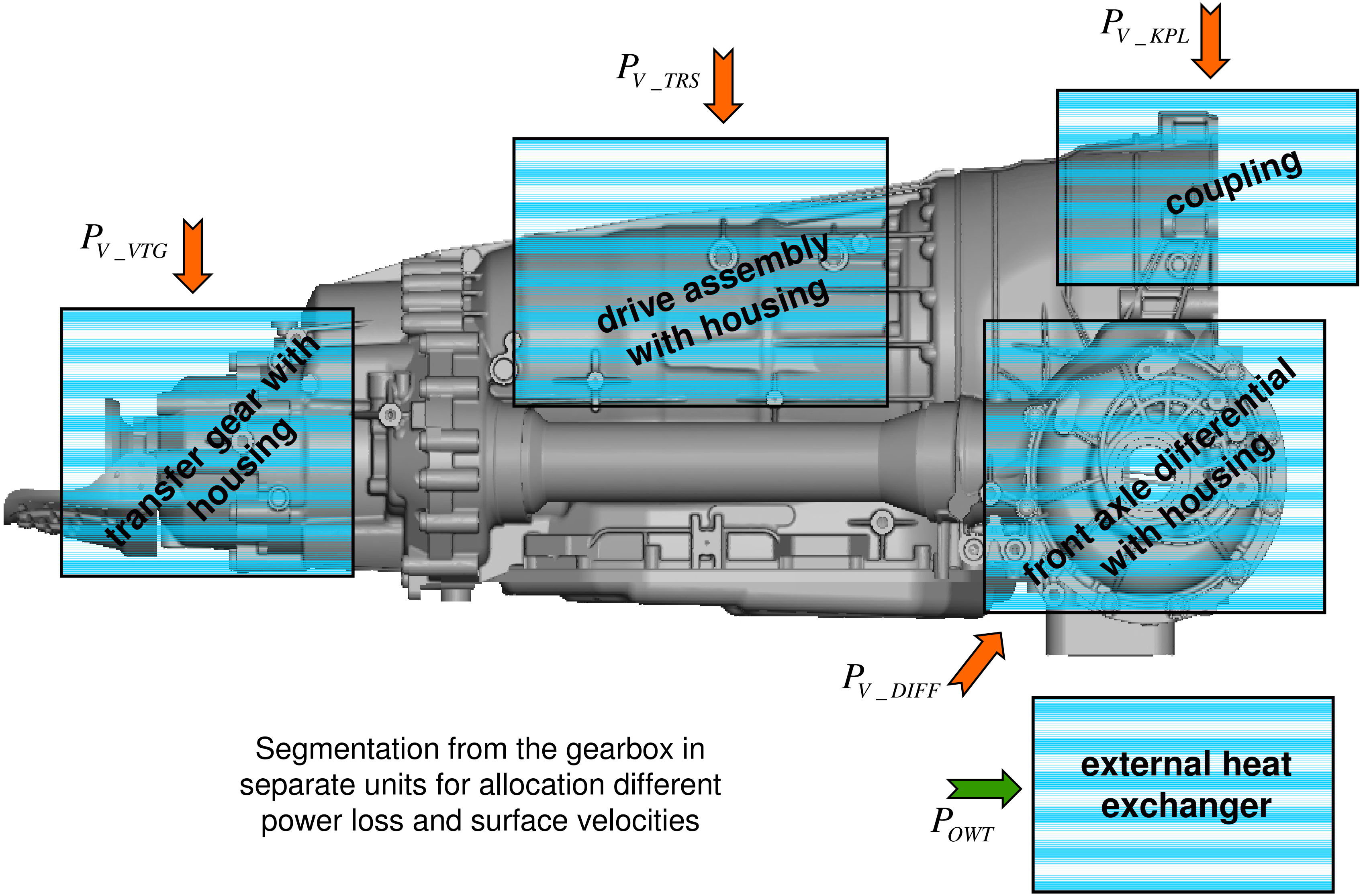
Measurement of the media temperatures in dependence on surface velocities



Thermal imaging for determination of the surface temperatures



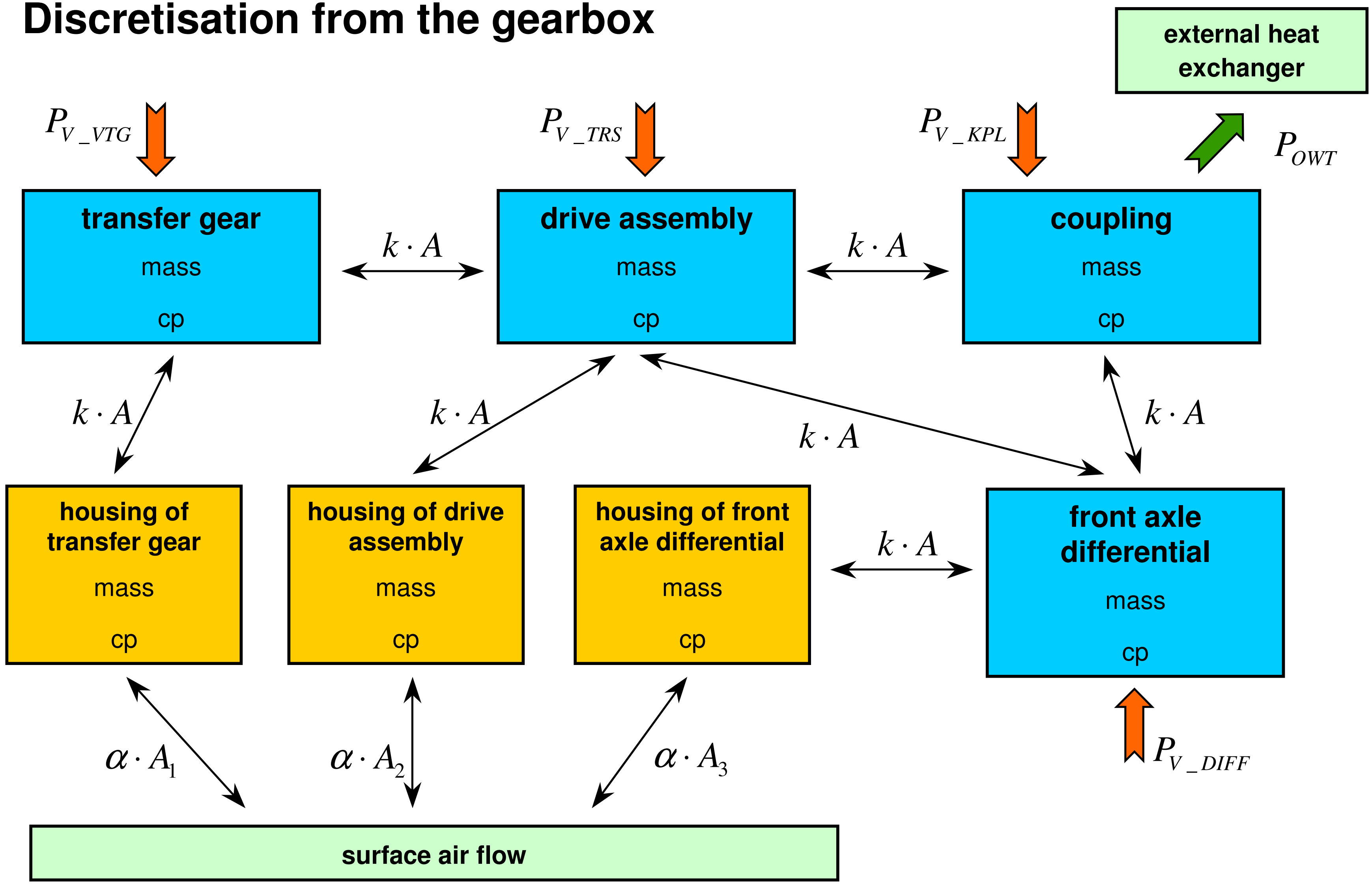
Discretisation from the Gearbox



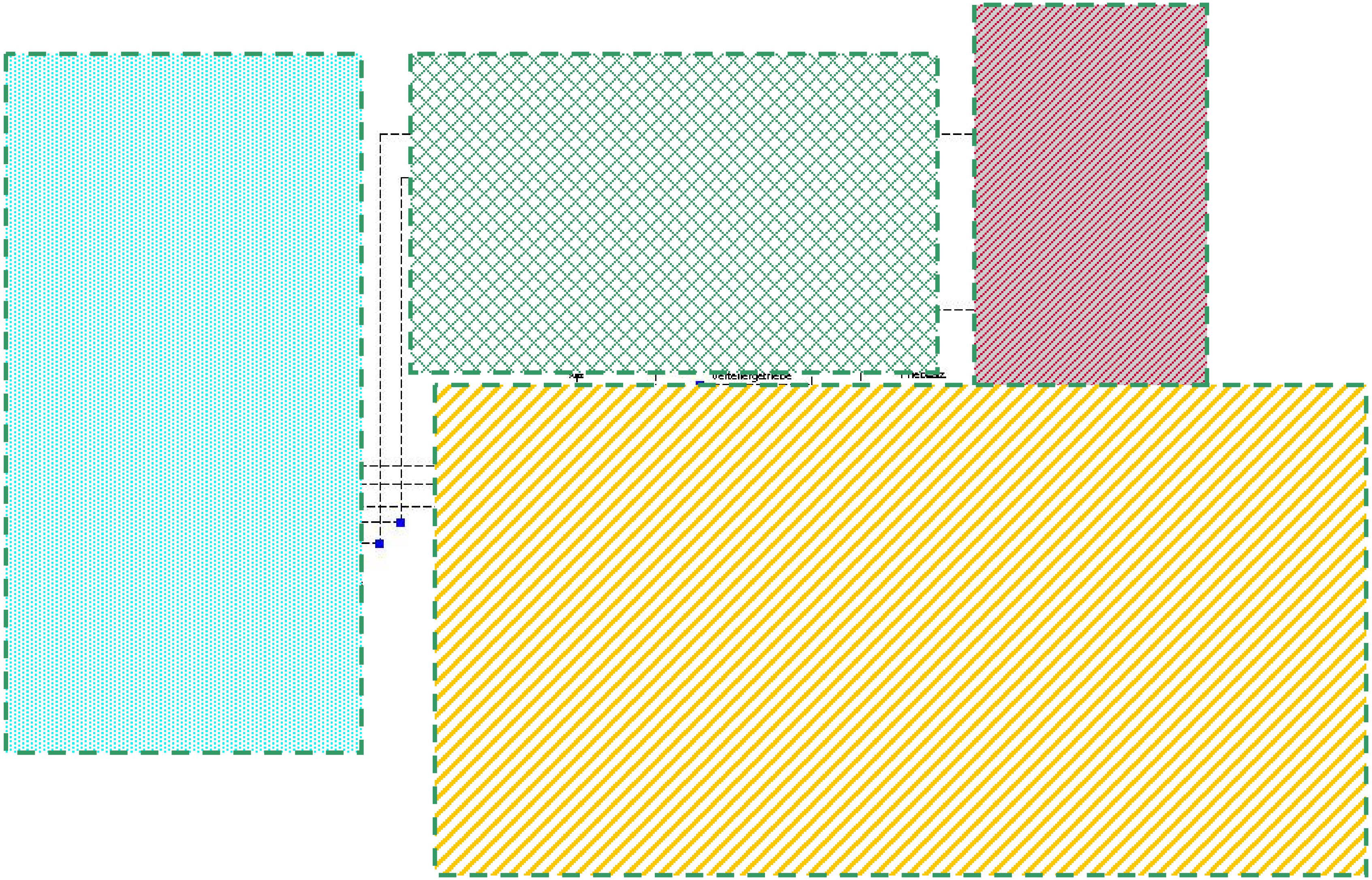
Segmentation from the gearbox in separate units for allocation different power loss and surface velocities

Modeling technique, intersection between 1D and 3D

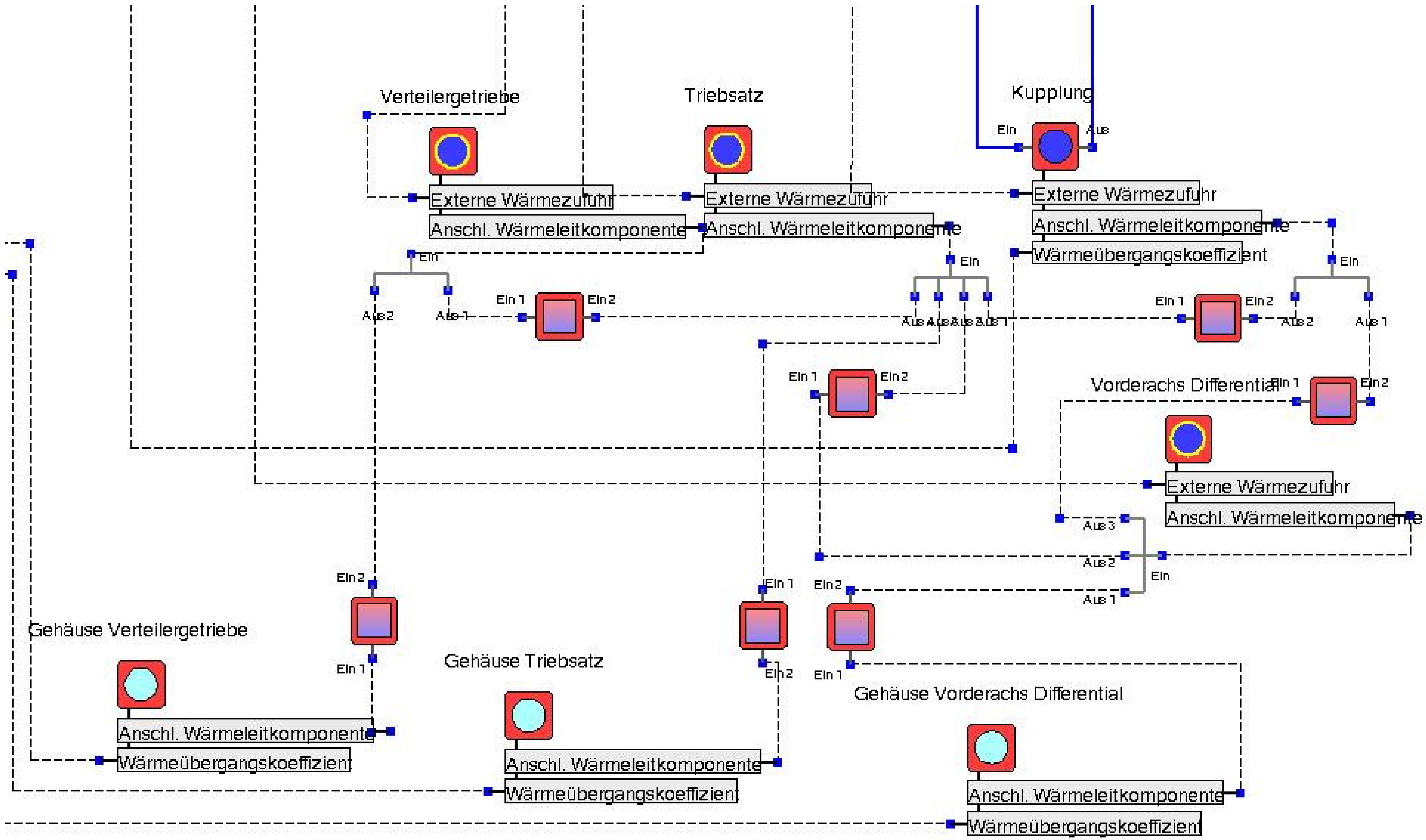
Discretisation from the gearbox



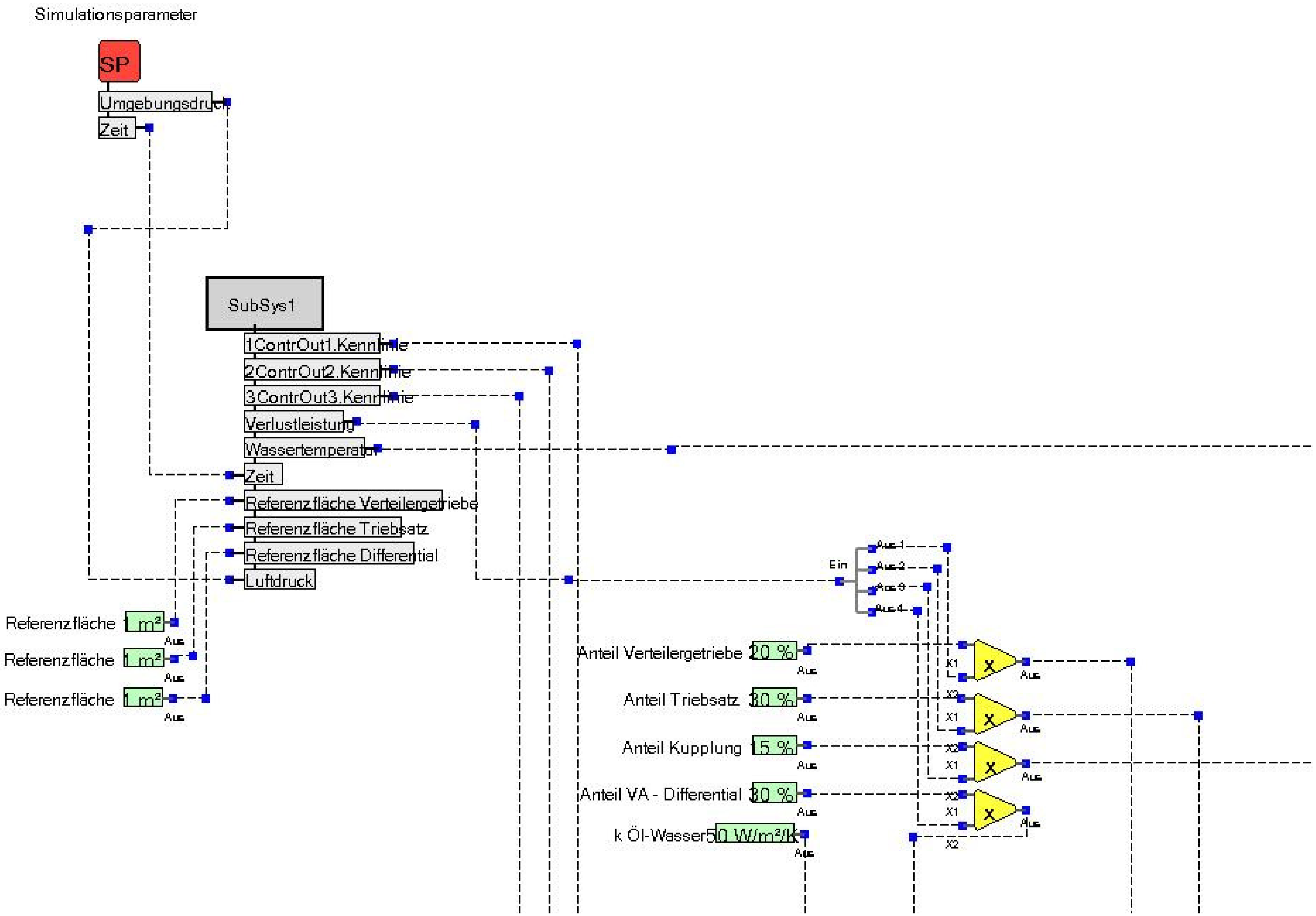
Presentation of the discrete gearbox in the KULI- Thermal Network



Presentation of the discrete gearbox in the KULI- Thermal Network

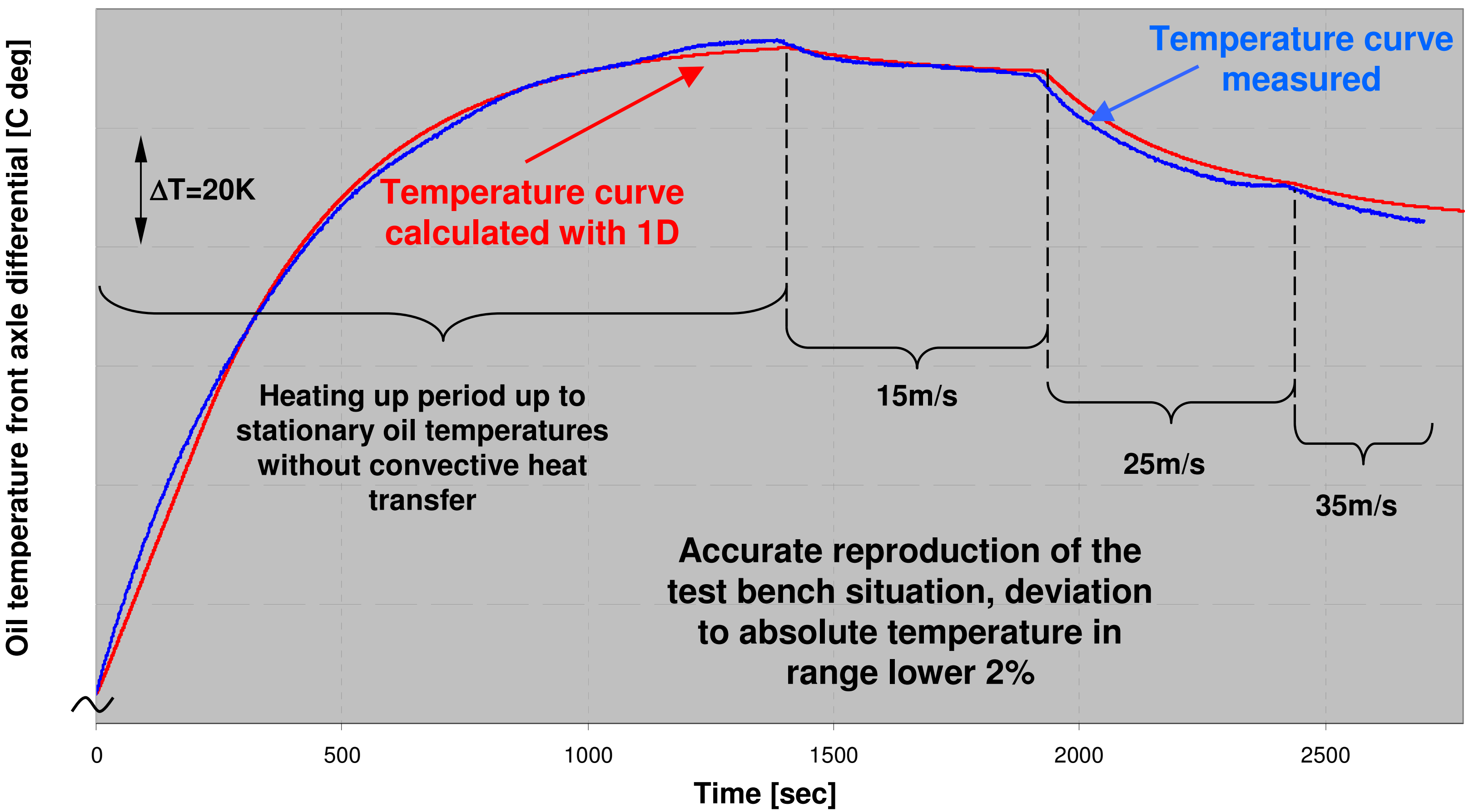


Presentation of the discrete Gearbox in the KULI- Thermal Network



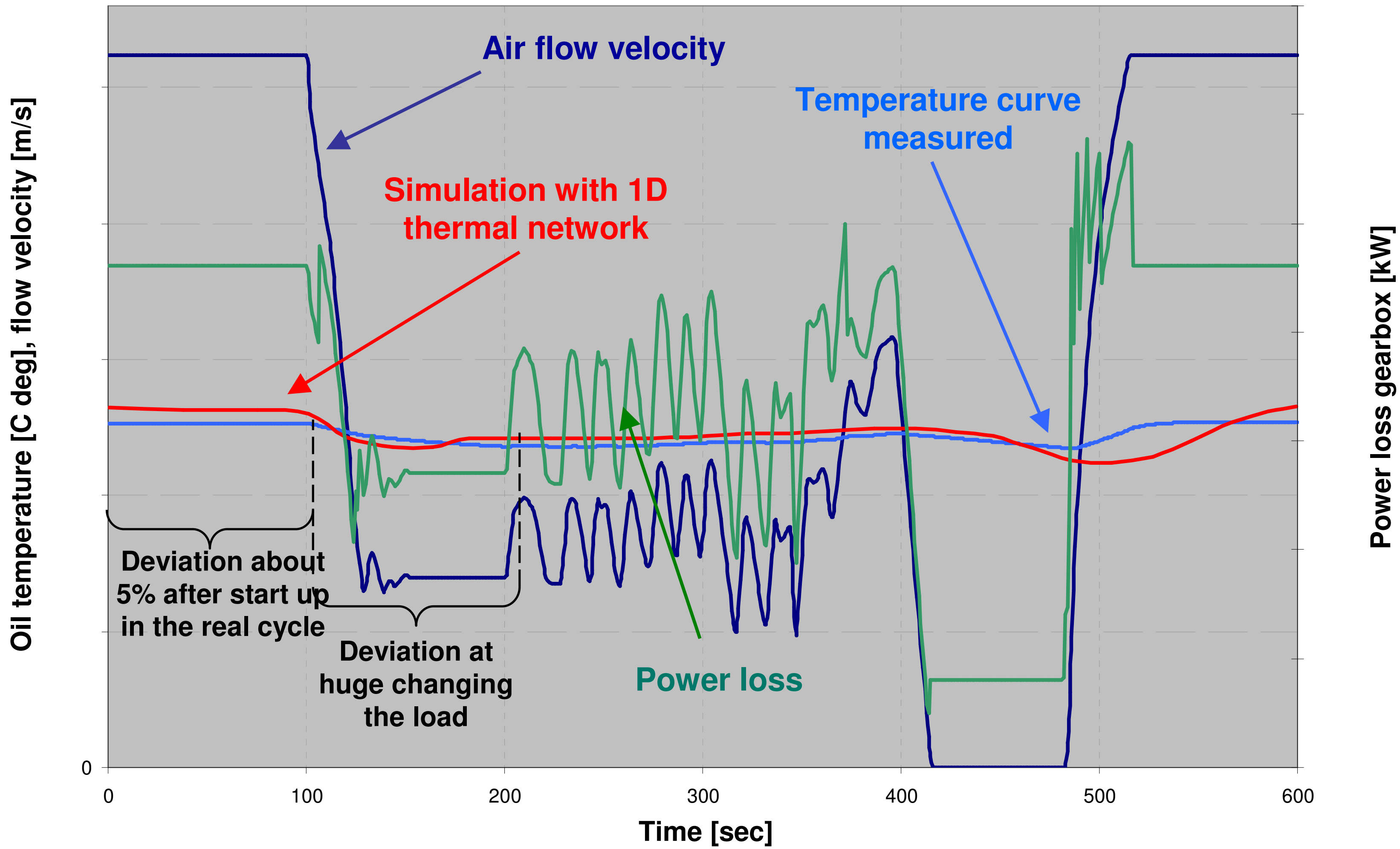
Application on a test bench cycle

- Run up to maximum power, equal vmax- loading while driving
- Cooling down behavior in dependence on different air flow velocities



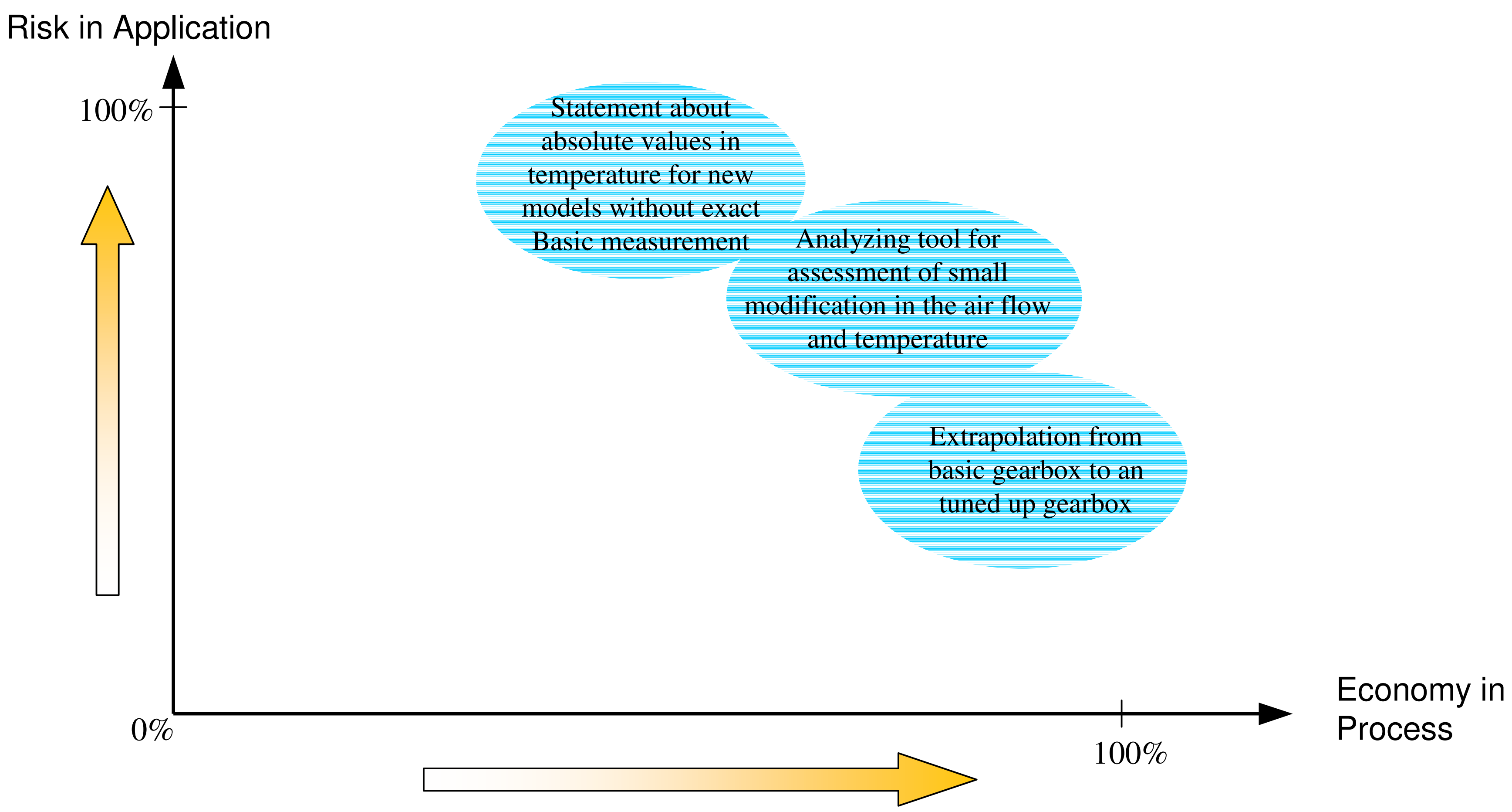
Application on a Driving Cycle

➢ View of a driving cycle on a real vehicle



Views and requirements to a thermal network

Risk and economic views of the actually and future applications



Summary and outlook

Current field of application of the thermal network at AUDI

- Analyzing tool for a fast assessment of small modification regarding gear step, gearbox- or rear axle reduction ratio on base of a complete balanced thermal network
- Generating of reference results and Δ- Values on base of balanced models

Necessities for extended application, current questions and requirements for process- stable 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

Summary and outlook

- Standardization of Generating a gearbox model with clear results at different users
- How will be a modification of the power loss during different operating points realized?
- Which differences do arise by balance between vehicle and test bench?
- How do different air flow velocities on the gear box influence the convective heat dissipation in the thermal network?
- How clear will be changes like performance tuning or gear box effectiveness forecasted?
- Knowledge of the remaining risk because of 1D modeling of high complex 3D flow conditions

Thank you for your Attention

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