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Transient Simulation of a Cooling System for Sports Cars with KULI

Development of the Cooling System for the Boxster S

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Introduction

The Cooling System of the Porsche Boxster S

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Development of Porsche Cooling Systems

Requirement: Thermodynamic Fluid Temperatures must not exceed given Limits at several Test Conditions, e.g.:

V_{max}- test

Most severe for gearbox

Simulation parameters nearly constant

Steady temperature conditions achieved

↓

Time-averaged simulation sufficient

Race track

Most severe for coolant and oil temperatures

Simulation parameters highly time dependent

Steady temperature conditions not achieved

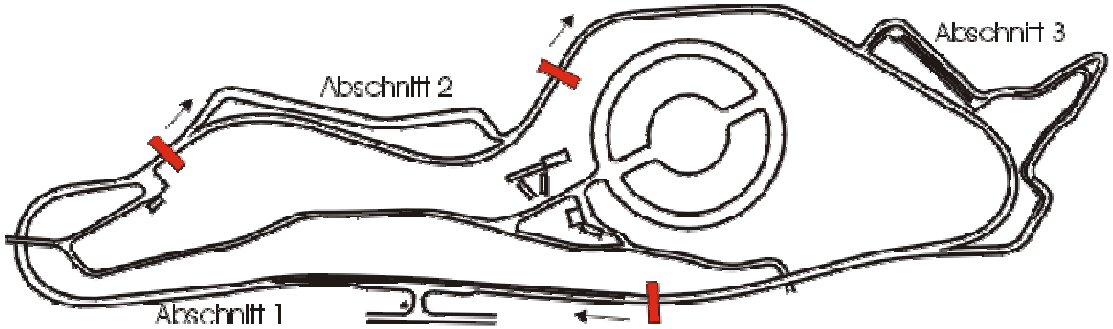
↓

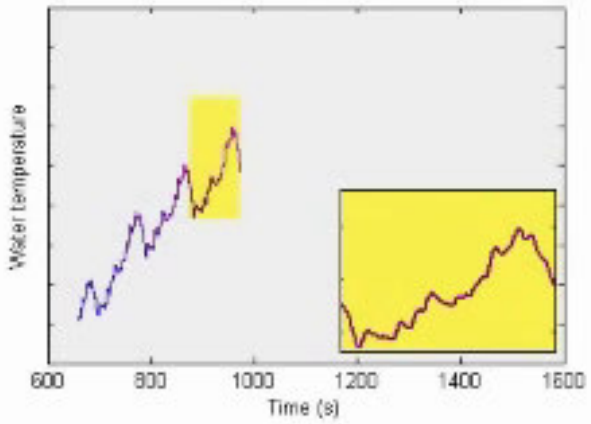
Fully transient simulation required

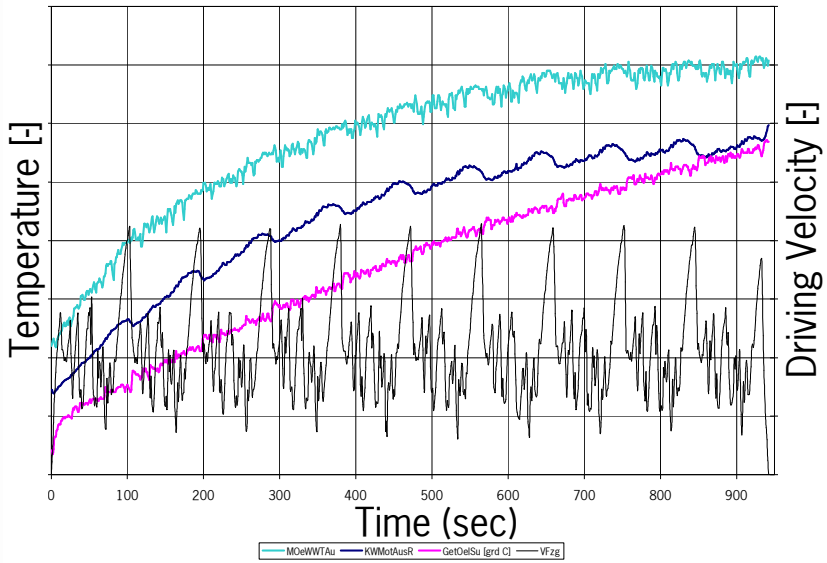
↓

Much more difficult to simulate

Test Conditions: Test Track, Typical Temperature Curves





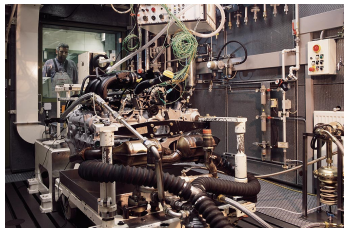


Steps of Thermal Management Simulation

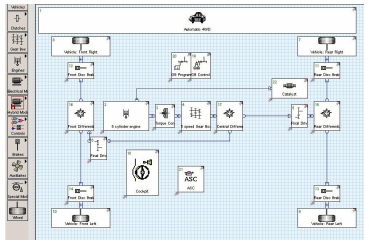
- Provision of required data
- Build-up of the KULI model
- Calibration
- Variation simulations / parameter studies

Provision of required Data

Wind Tunnel Tests

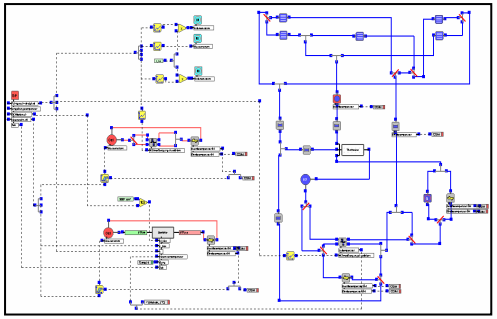


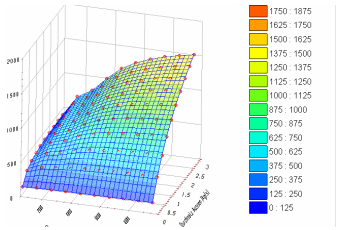
Engine Heat Balance



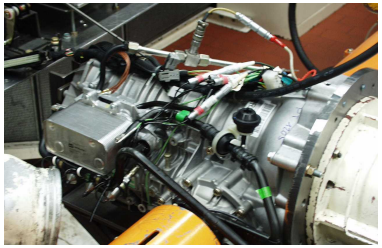
Driving Simulation

Test Track

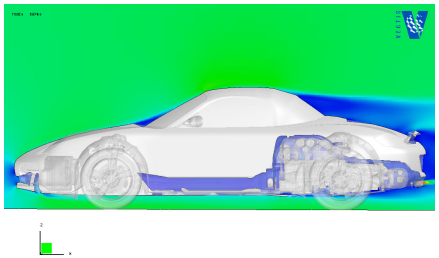




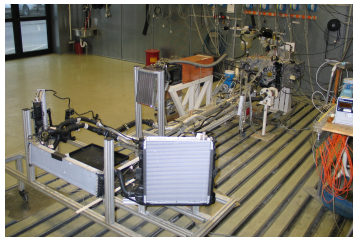
Component Data



Gearbox Test Bench

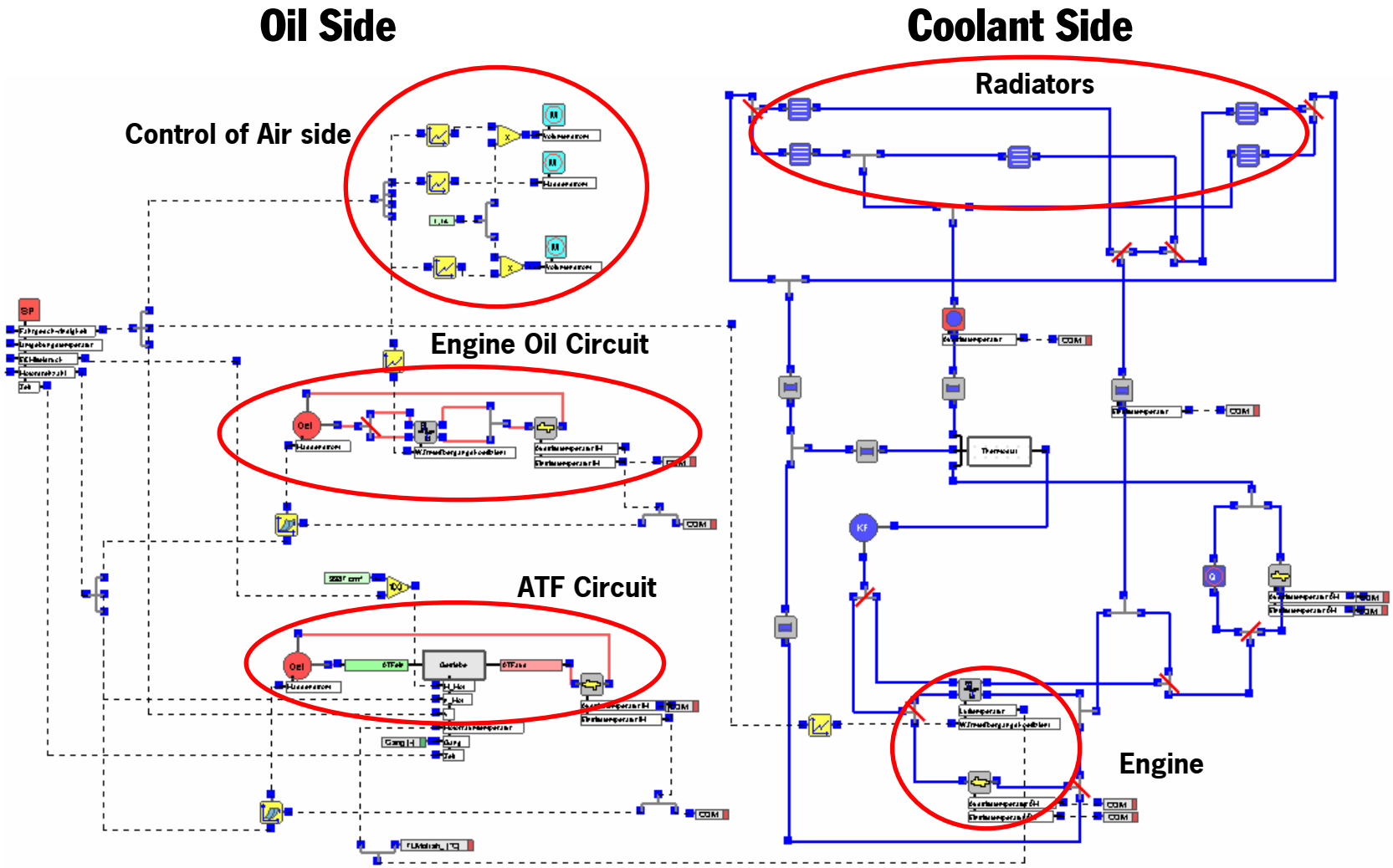


CFD Calculation



Flow Lab/Flowmaster

Kuli Model of the Boxster S Tiptronic



Kuli Model

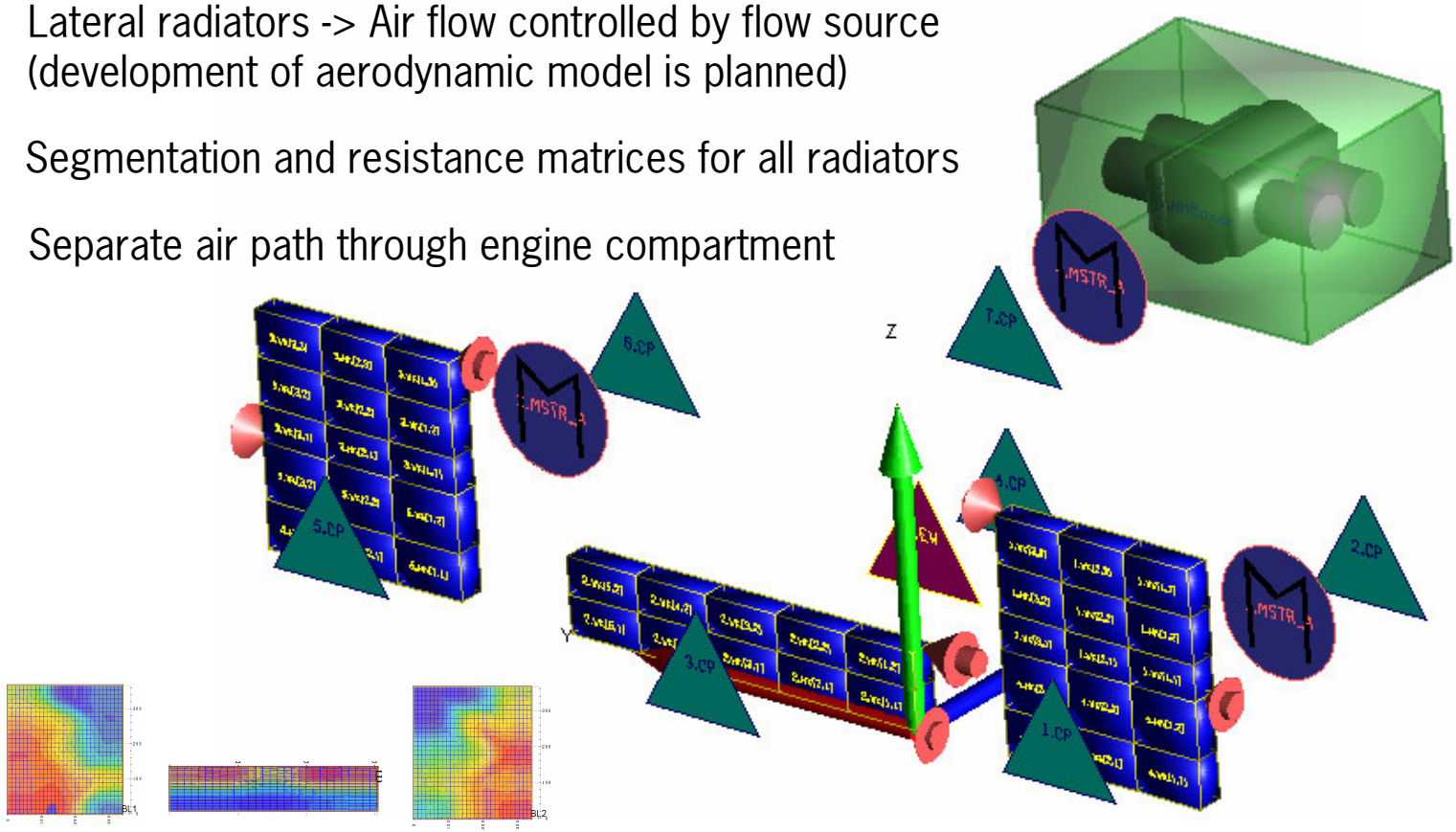
Air Side

Central radiator -> Air flow calibrated with CP and BiR

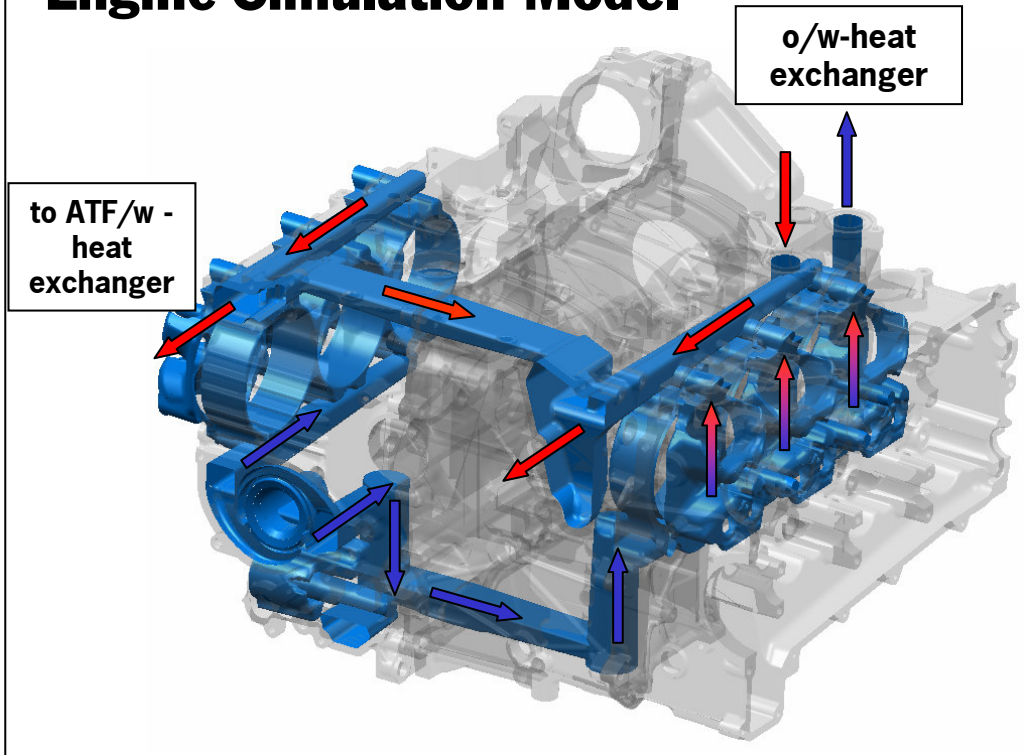
Lateral radiators -> Air flow controlled by flow source (development of aerodynamic model is planned)

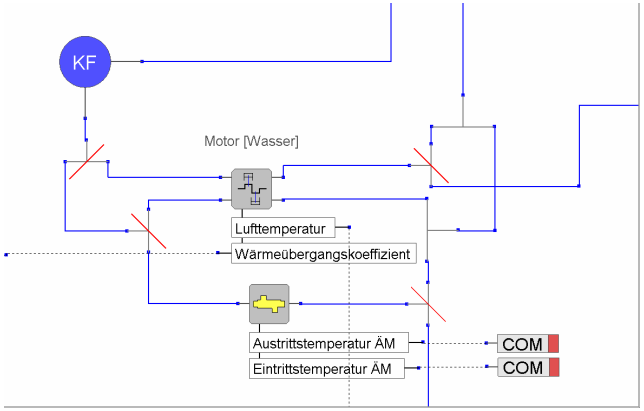
Segmentation and resistance matrices for all radiators

Separate air path through engine compartment



Engine Simulation Model





Newly developed KULI Component “Boxer Engine” required due to:

→ coolant side of oil/coolant heat exchanger is parallel to cylinder bank 4-6

→ coolant side of ATF/coolant heat exchanger fed by cylinder bank 1-3

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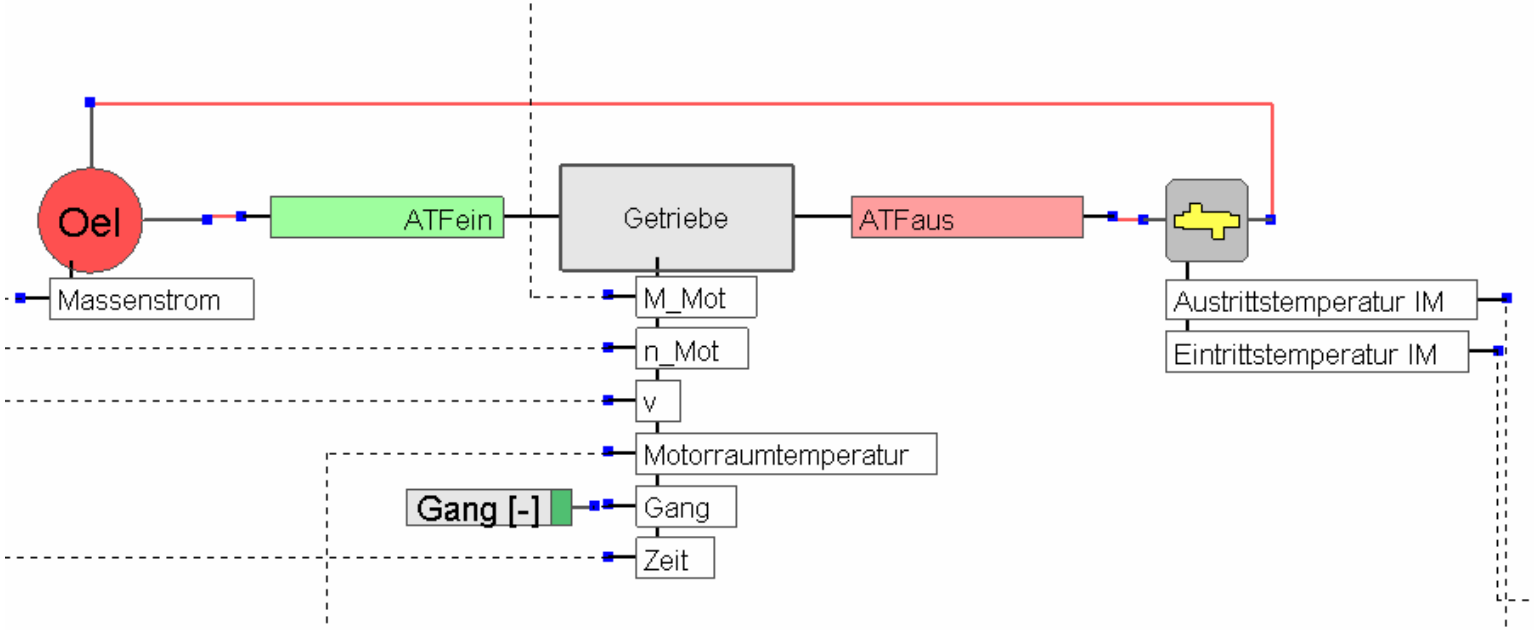
Gearbox Thermal Model



Progress achieved in Gearbox Modelling:

- Switch from SIMULINK controller to KULI subsystem

  → No restrictions in the amount of input and output parameters

- Heat generation during gear shifting is also considered
- Gearbox is now modelled with the new thermal network components in KULI 6.0

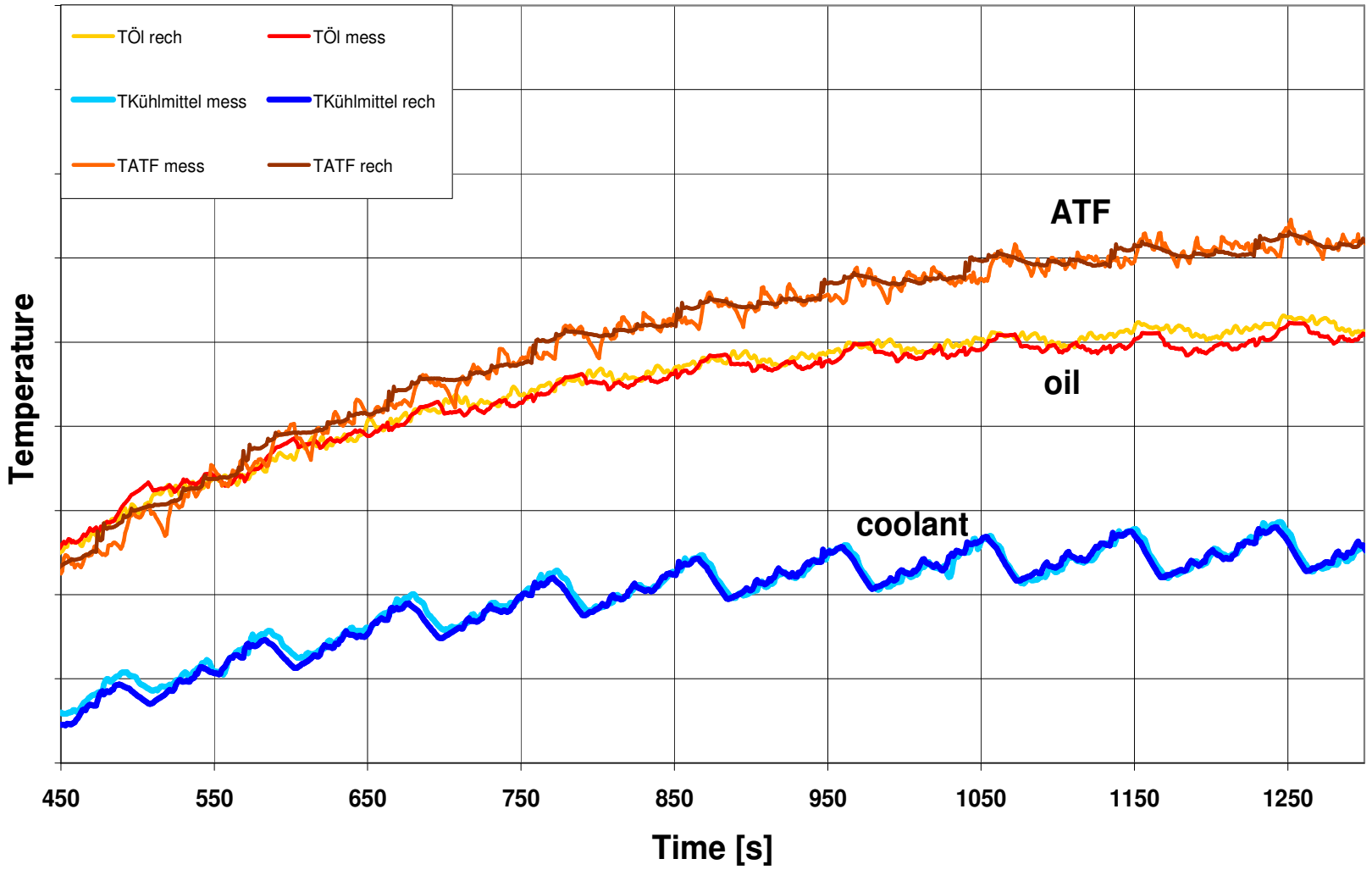
Calibration

Calibration: Process of Determination of unknown System Variables by means of the Parameter Identification Method

- Purposive variation of several system variables in the KULI model, which cannot be directly obtained from test bench results
- Possibly adjustable variables: thermal inertias, heat transfer behaviour, …
- Difficulties due to transient simulation:
  - Considerable number of time-consuming runs (calculation time)
  - Reproduction of time-dependent temperature behaviour in detail

→ Result: KULI model for an existing prototype

Result of Calibration



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Variation Simulations / Parameter Studies

By means of this KULI model it is possible to support the cooling system development of vehicle upgrades already at an early stage, before testing hardware is available.

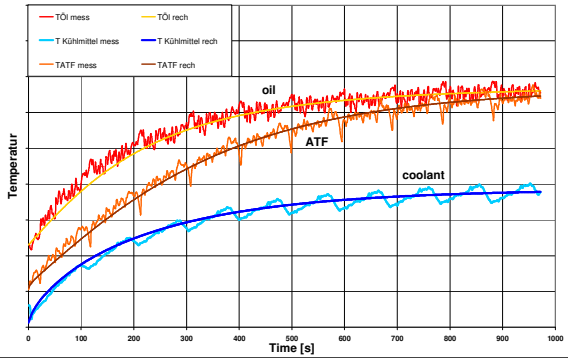
Numerous variations of the cooling system can be examined, e.g.

- Engine power increase
- Varied cooling system configuration
- New heat exchanger components
- Varied air flow rates at different styling concepts
- New gearbox concepts

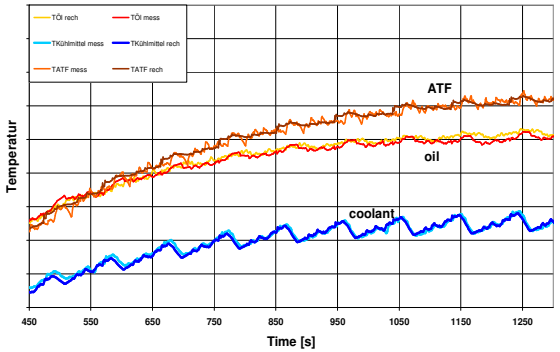
Conclusion

Important changes in KULI Simulation at Porsche over the last two years

Time-averaged Simulation



Fully-transient Simulation



Many Calibration Parameters

- heat into coolant and oil
- calibrated gearbox efficiency
- calibrated HTC

More measured and calculated Input Data

engine heat balance

measured gearbox efficiency

HTC from CFD calculation

Conclusion / Experience

High Calibration Effort:

Due to the various calibration factors and targets the process is difficult and time consuming → more experience with new method will reduce this effort

Large Amount of required Data:

The transition from calibrated parameters to measured data has lead to an increasing amount of required input data. Sometimes these data are not available.
→ Measurement methods have to be extended

Bi-directional Validation:

KULI Model is validated by use of measured data and input parameters.
Simulation results can be used to validate both measured data from the test track and input parameters in the KULI model.

Process Integration:

KULI simulations are getting more and more integrated into the development process of cooling systems at Porsche, especially in the early stages.
This integration is essential for the efficient use of any thermal simulation.

Outlook

Automation of the Calibration Process:

Further experience will show the most efficient method to calibrate a transient KULI model of a Porsche Cooling System. As a next step an automated calibration process is planned.

More detailed Modelling of Lateral Air Paths:

The actual state of the model for the lateral air paths with flow sources is rather simple. The development of an aerodynamic model considering the behaviour of the electric and the blow-by flaps is planned.

Conversion of Testing Results to different Test Drivers:

Individual driving styles of the test drivers can lead to slightly different measurement results from the test track. The successful simulation of this effect would give us the possibility to eliminate the driver influence with the help of the KULI model.

Conversion of Testing Results to different Test Tracks:

As a next step we have planned the conversion of measured temperatures from test tracks with comparable characteristics.

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