

## STAR European Conference 2010

London, March 22<sup>nd</sup>, 2010

## Vehicle Thermal Reliability with STAR-CCM+

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Dr. Gerald Seider



# Vehicle Thermal Reliability

## Vehicle Thermal Management

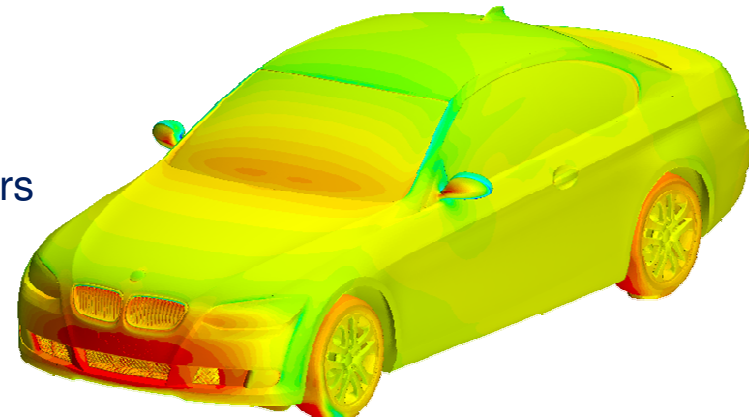
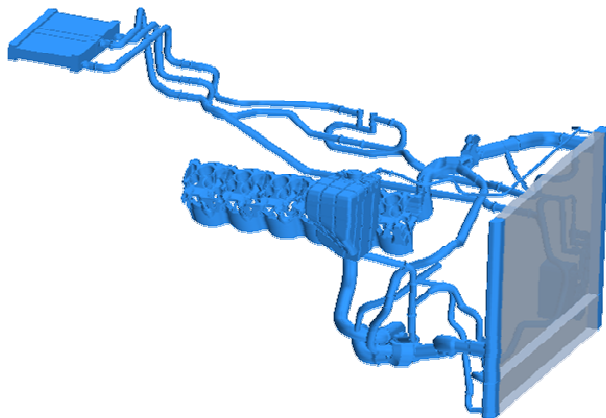
### Thermal Sources:

Engine  
Exhaust System  
Alternator, etc.



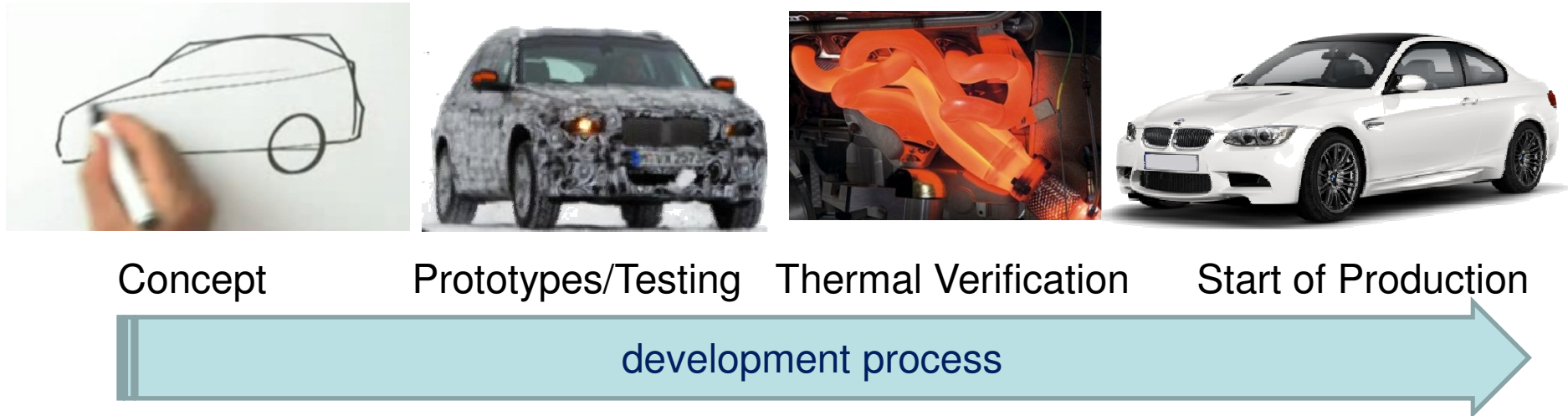
### Heat Release:

Heat Exchangers  
Convection  
Radiation



# Vehicle Thermal Reliability

## Design and Verification of Thermal Reliability



- ⇒ Verification of thermal reliability is carried out late in the development process.
- ⇒ Engine's safety applications for combustion must be released, which guarantee secure operation of the engine in the earlier development stages.
- ⇒ Thermal load imposed by the exhaust system to the underhood environment will become more critical as the engine matures.
- ⇒ Underhood thermal reliability is very dependent on the proper location of air ducting components, seals and heat shields which are settled late in the developing process.

**Therefore a simulation methodology is needed which can assess thermal reliability at a much earlier stage of the development process.**

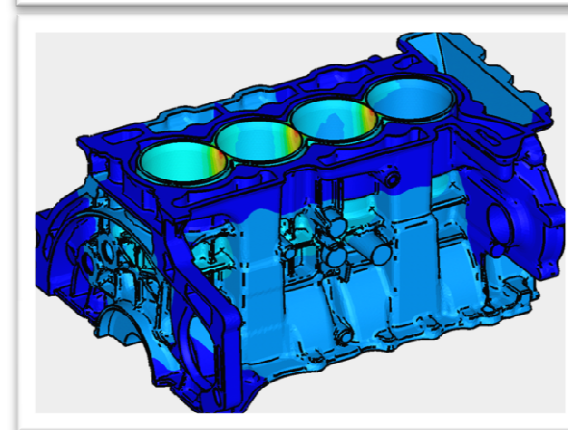
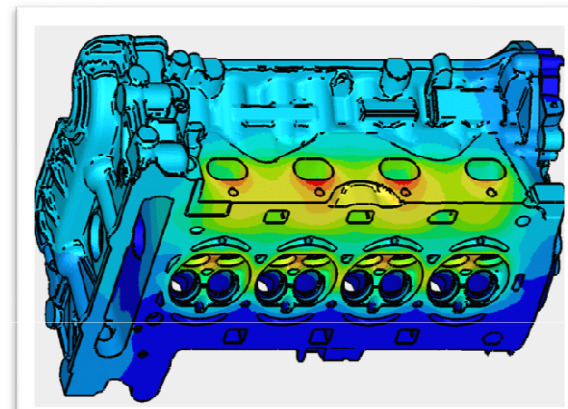
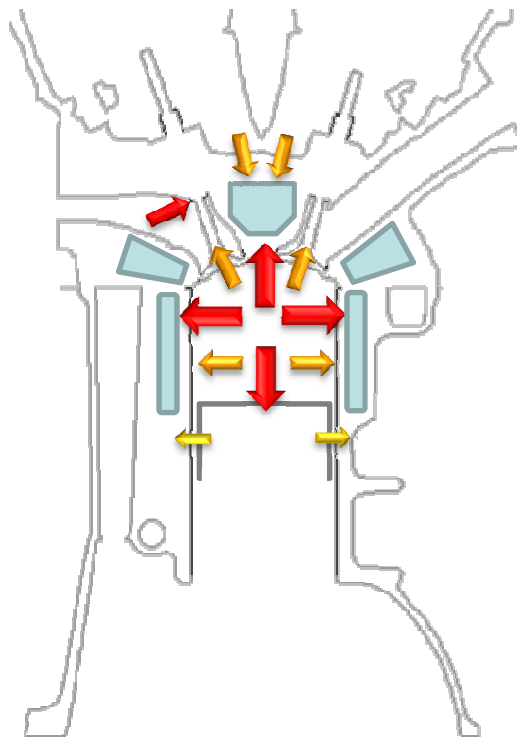
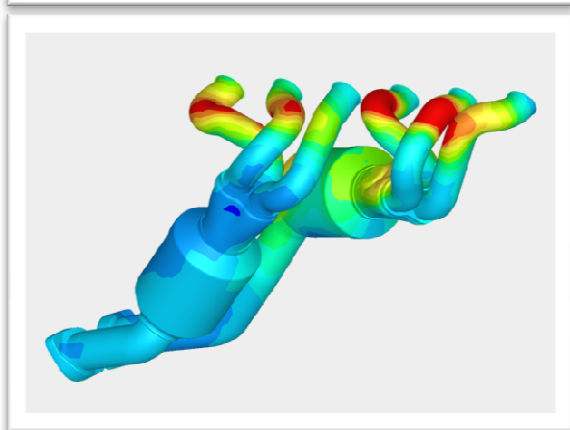
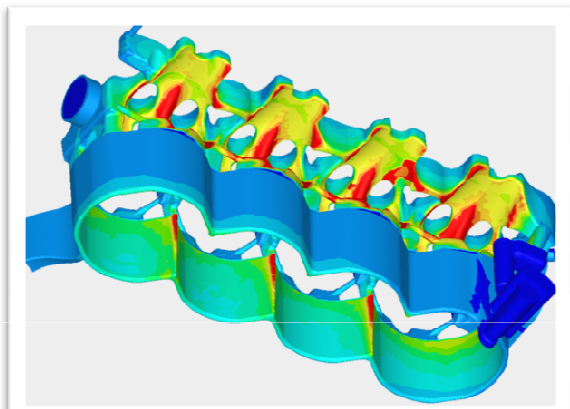
# Vehicle Thermal Reliability

## Engine Thermal Analysis - „State of the Art“

Cooling  $\Rightarrow$  Distortion  $\Rightarrow$  Stress  $\Rightarrow$  Endurance



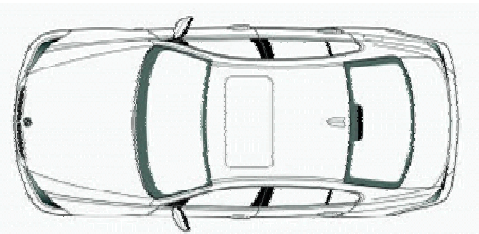
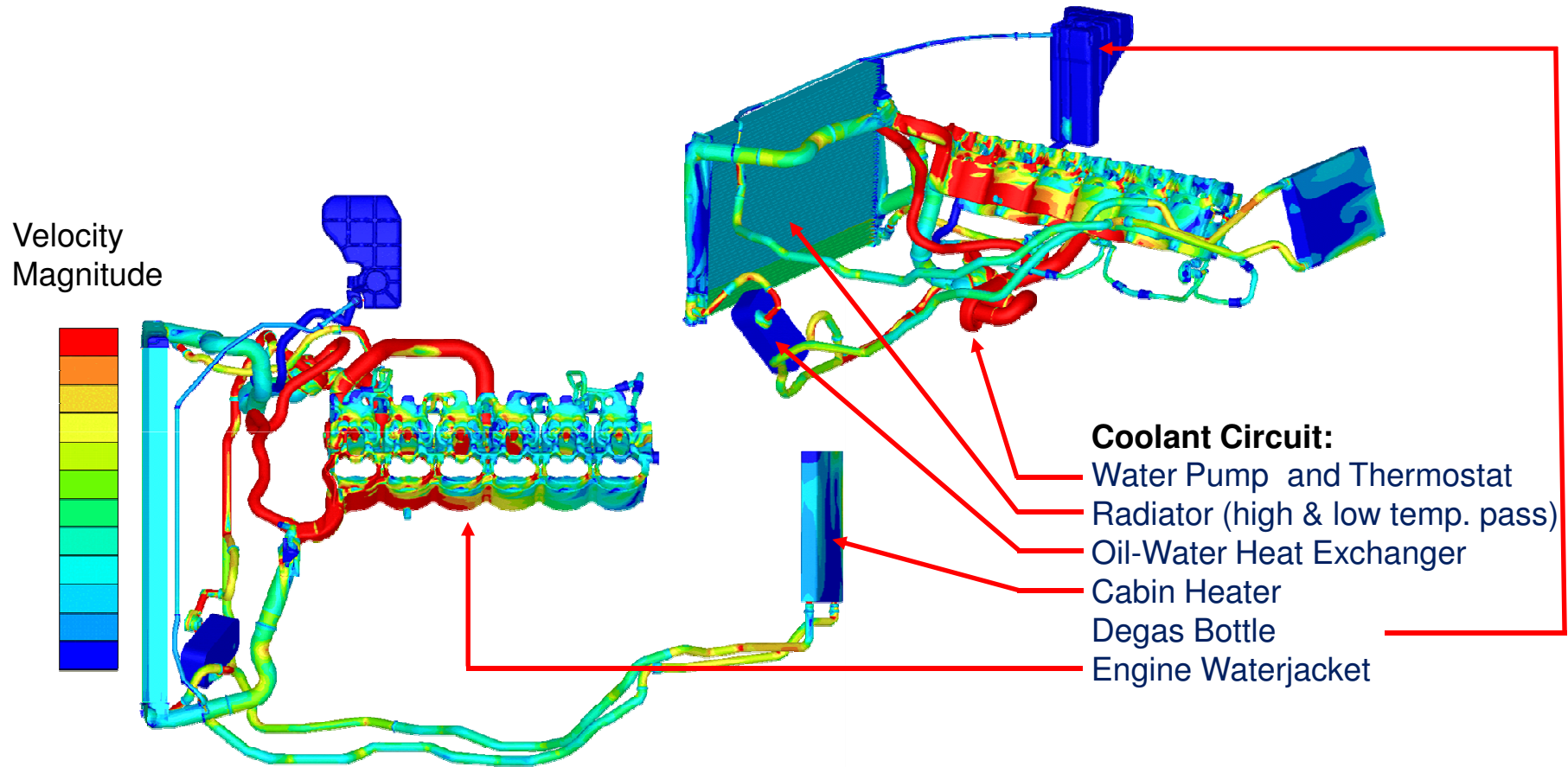
Thermal Management





# Vehicle Thermal Reliability

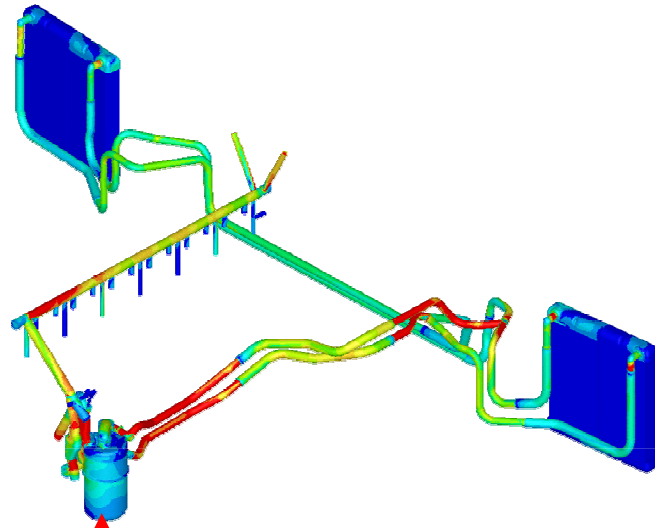
## Analysis of Coolant Circuits - „State of the Art“



- ➔ Simulation decoupled from thermal analysis.
- ➔ constant temperature of coolant.
- ➔ analysis of volume flow rates
- ➔ analysis of pressure losses in components
- ➔ verification/Input data for 1D system analysis

# Vehicle Thermal Reliability

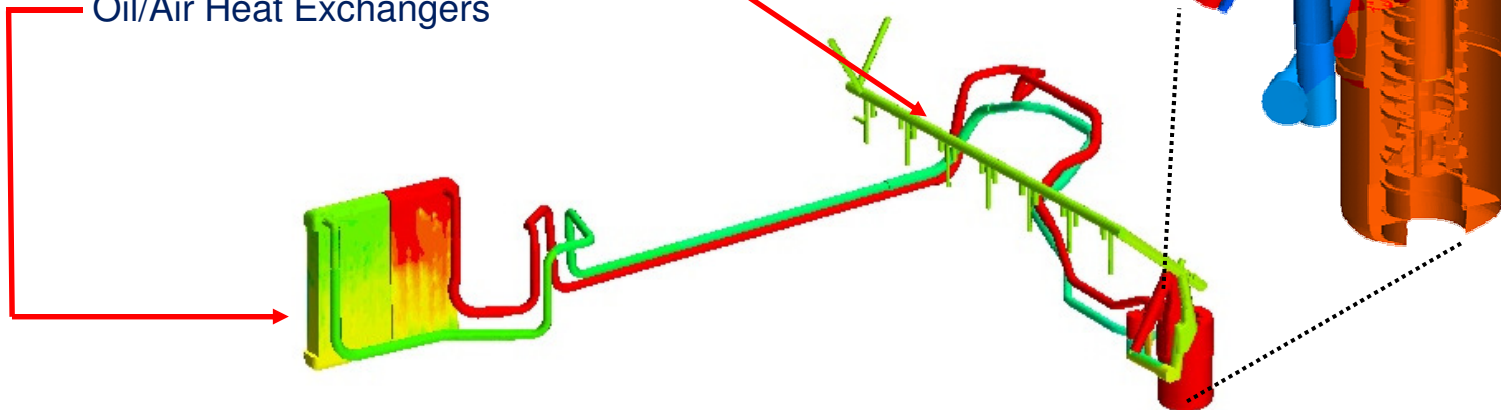
## Analysis of Engine Oil Supply - „State of the Art“



- simulation decoupled from thermal analysis.
- fluid properties temperature dependent.
- analysis of volume flow rates (e.g. bypass)
- analysis of pressure losses in components
- verification/Input data for 1D system analysis

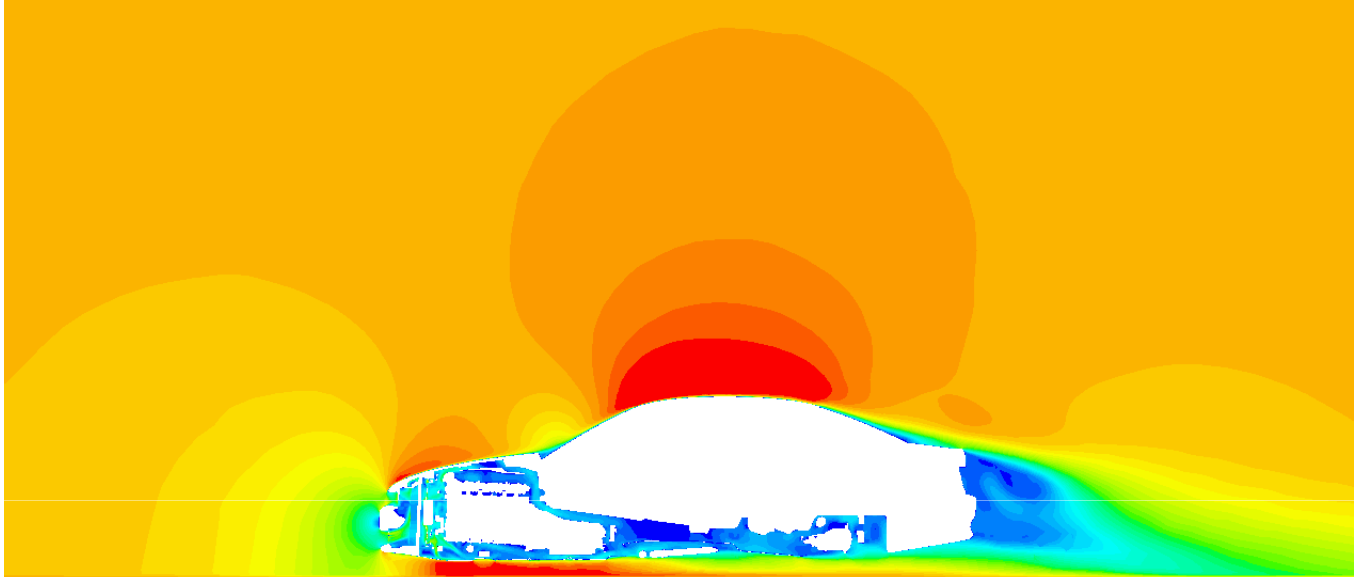
### Oil supply with heat exchangers (pressure side):

Thermostat and Filter  
Oil Main Gallery Crankcase  
Oil/Air Heat Exchangers

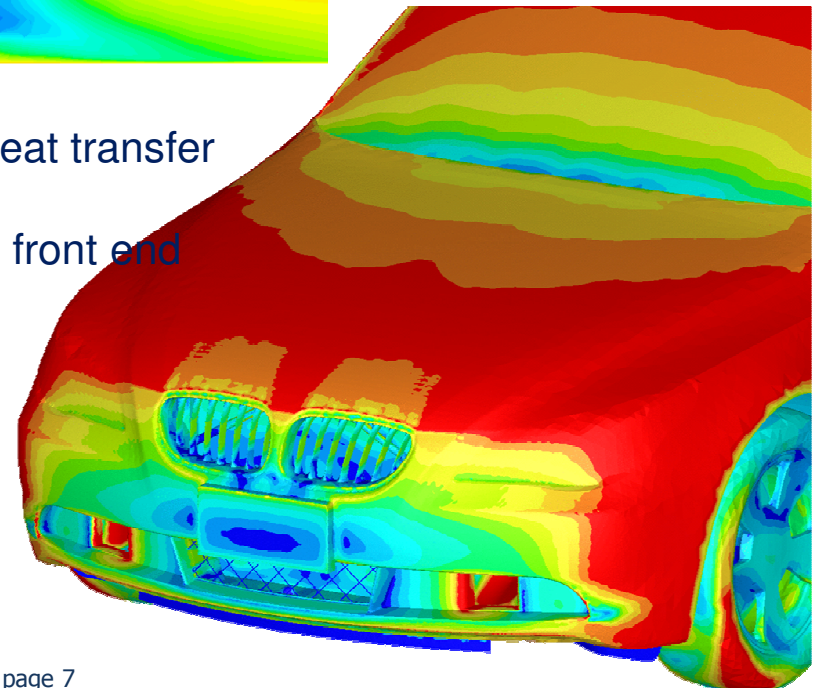


# Vehicle Thermal Reliability

## Underhood Analysis - „State of the Art“

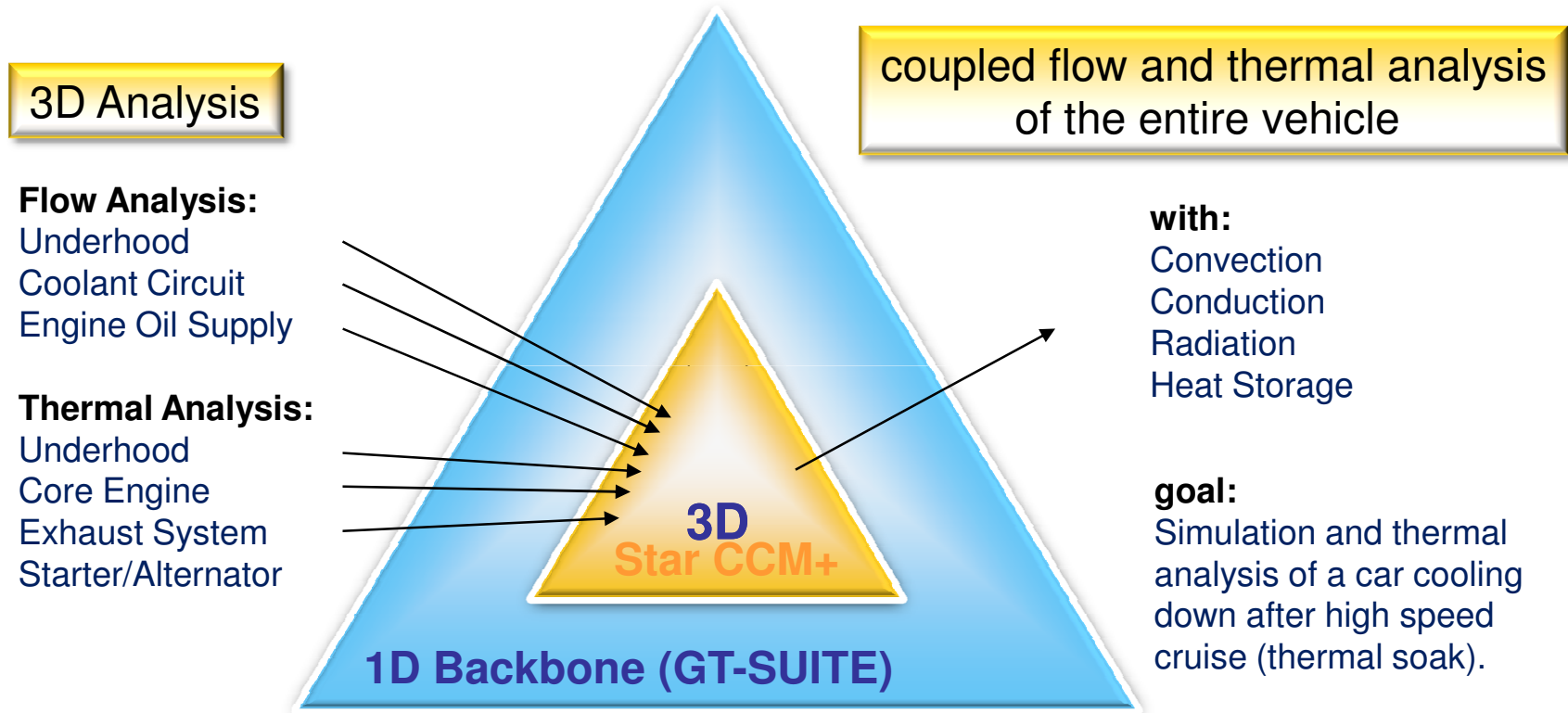


- simulation includes heat exchanger package with heat transfer
- fluid properties temperature dependent.
- analysis of flow rates through heat exchangers and front end
- analysis of heat transfer in heat exchangers
- verification/Input data for 1D system analysis



# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis

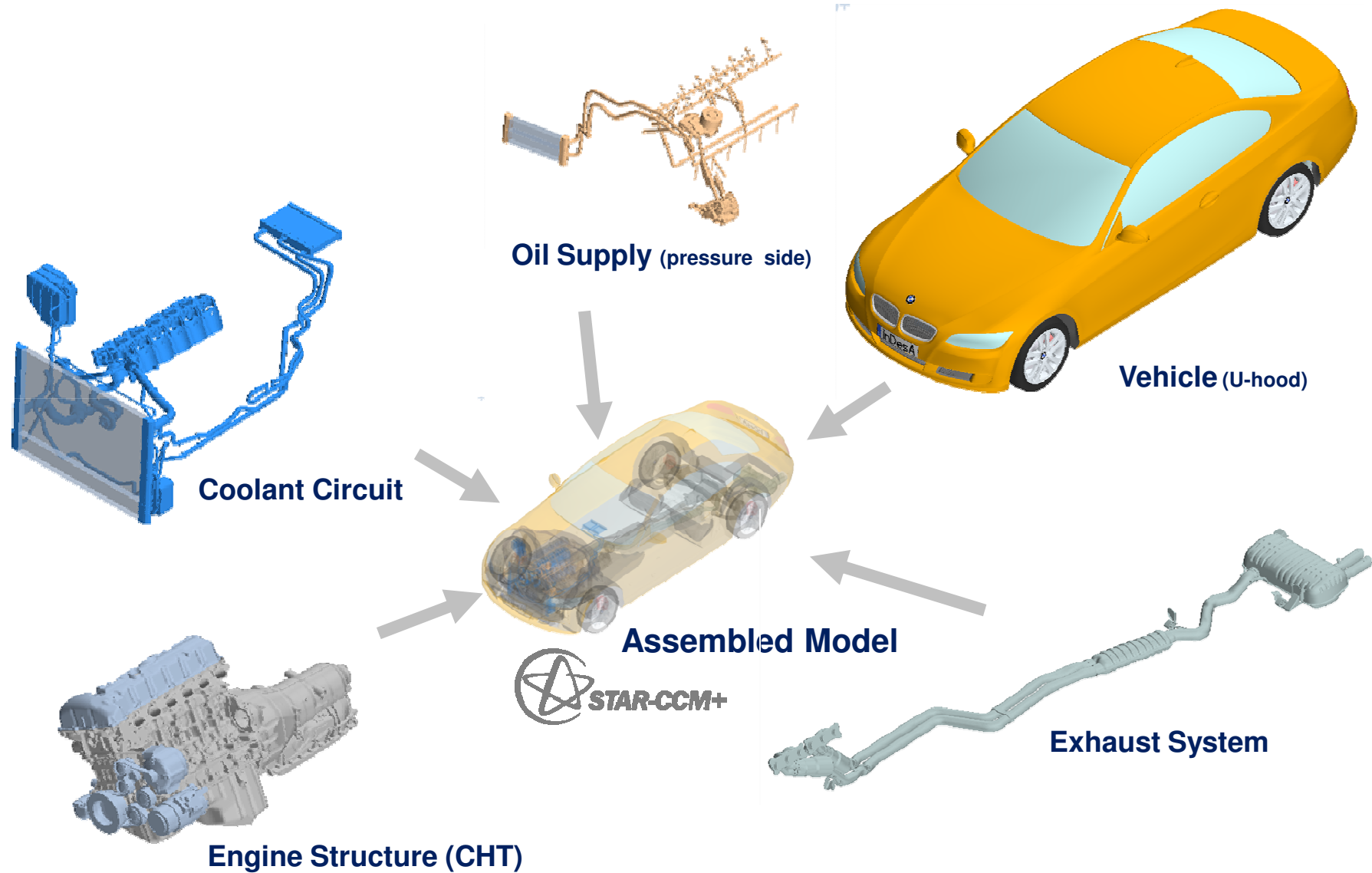


### Challenge:

1. Handling of CFD/CHT Mega Simulation Models
2. Providing of Synchronized Sub-Models and Boundary Conditions

# Vehicle Thermal Reliability

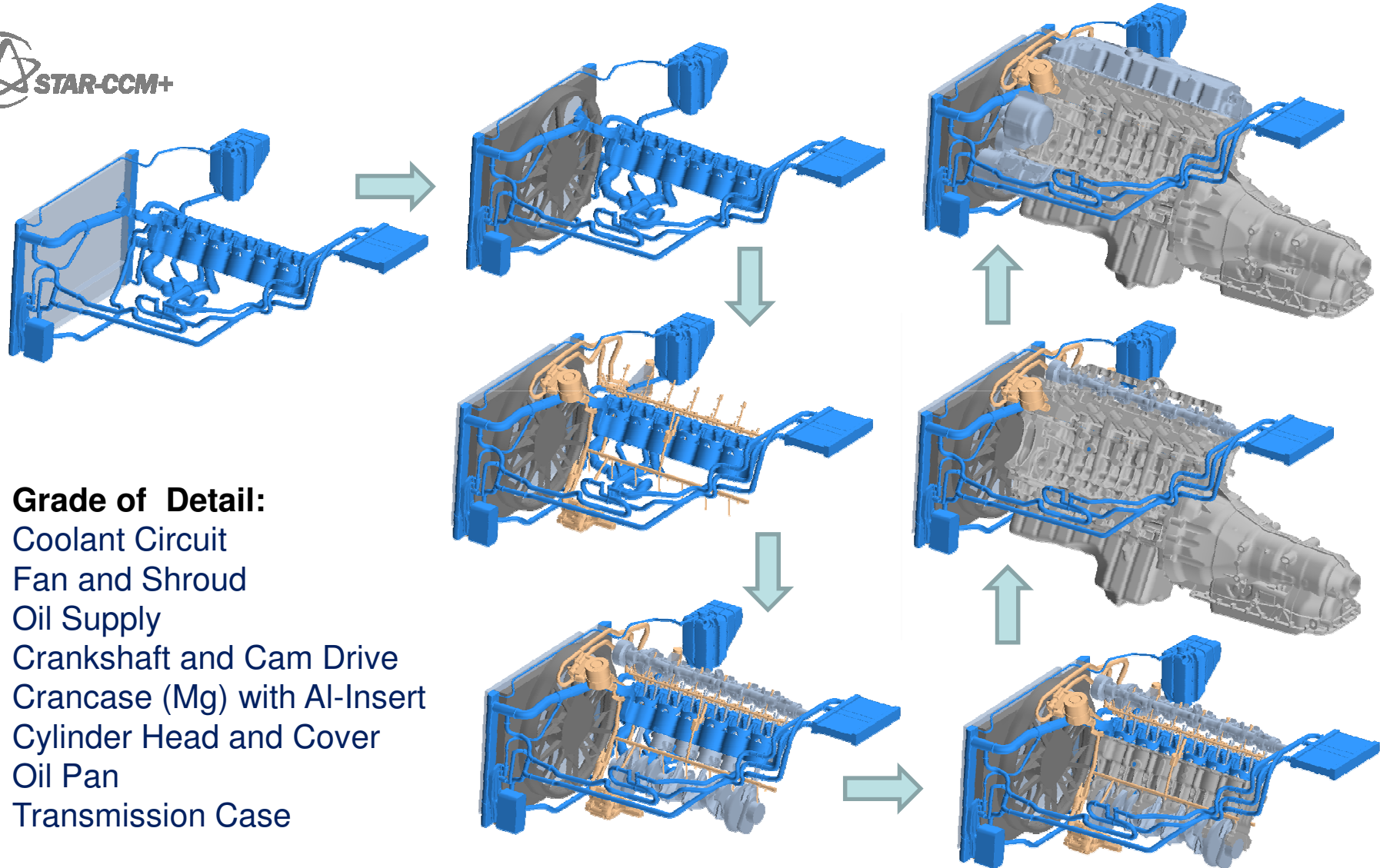
## Thermal Coupling of Simulation Models





# Vehicle Thermal Reliability

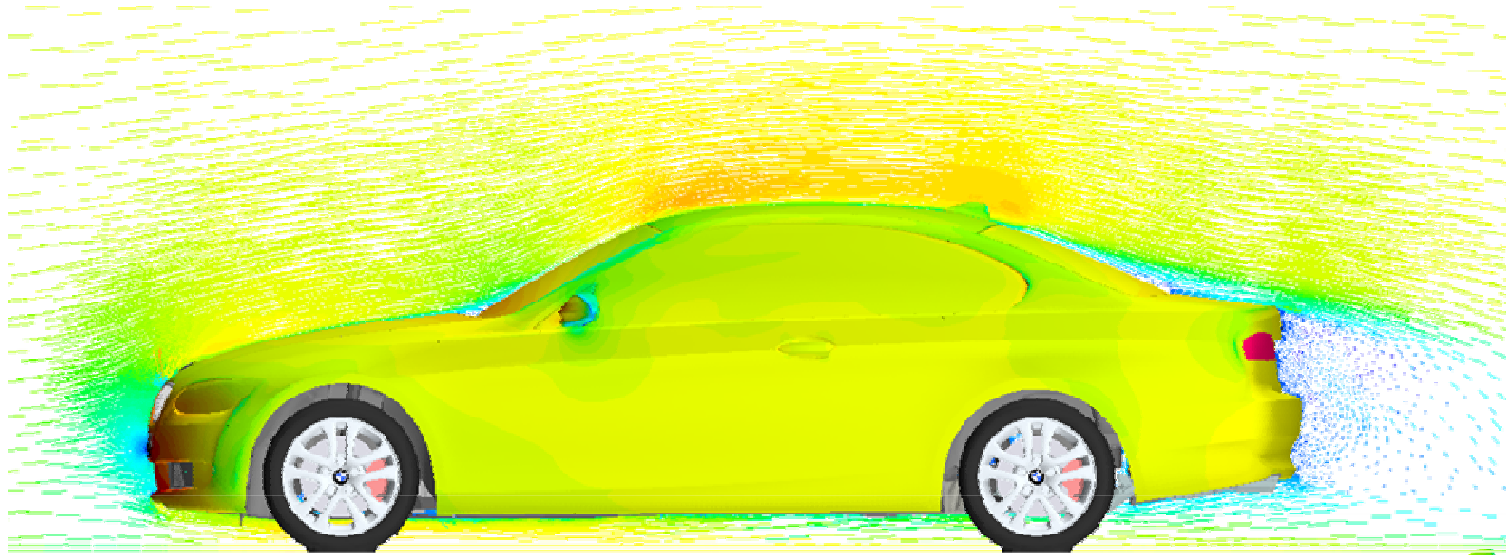
## Assembling of Simulation Models





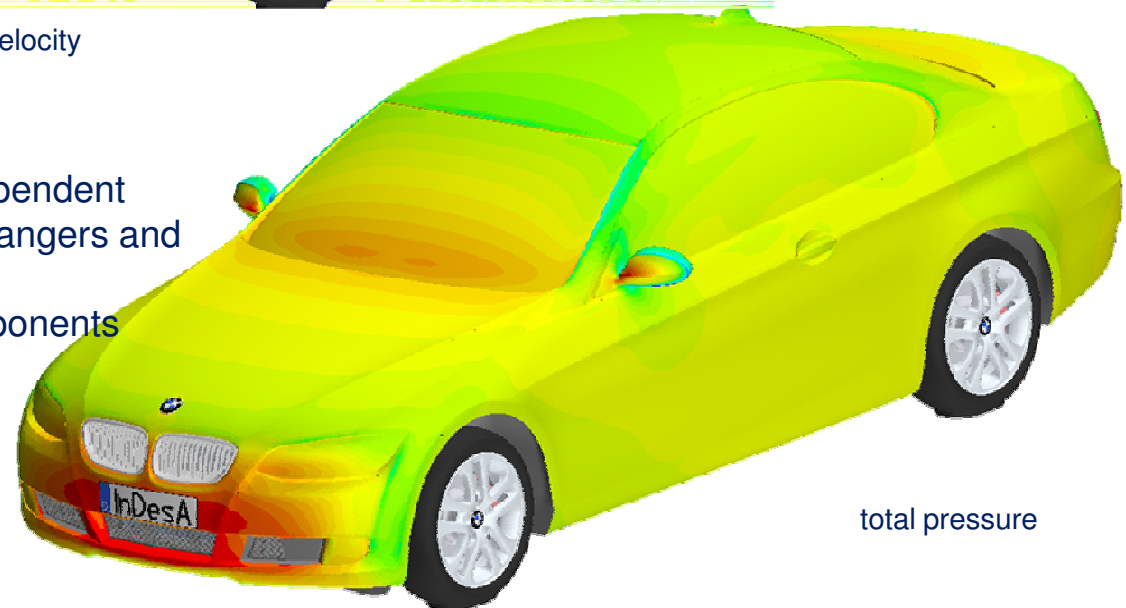
# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis



total pressure and velocity

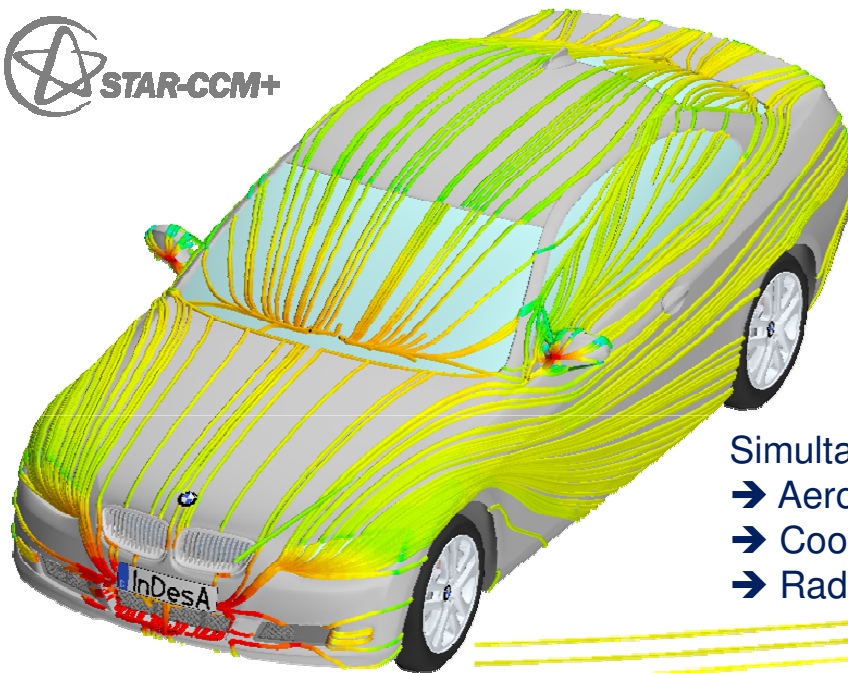
- fully coupled thermal analysis
- fluid/material properties temperature dependent
- analysis of flow rates through heat exchangers and front end inlets
- thermal interaction of all fluids and components



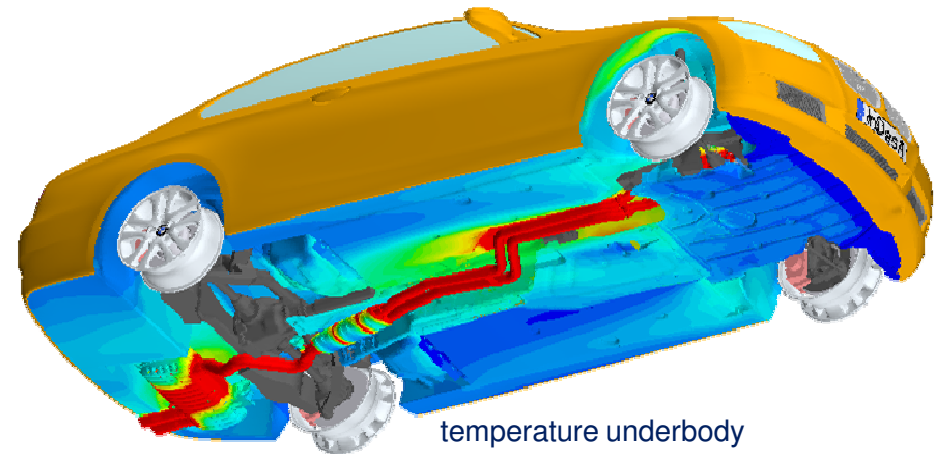
total pressure

# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis



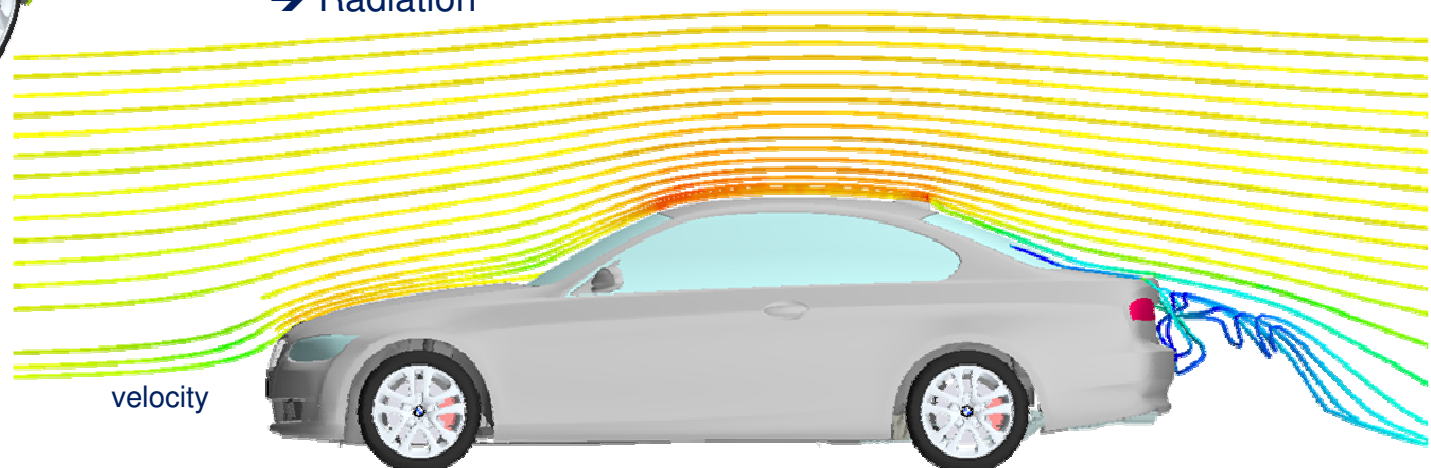
total pressure



temperature underbody

Simultaneous Simulation of:

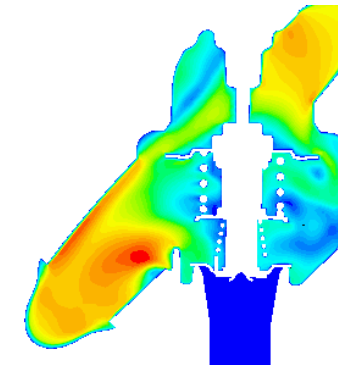
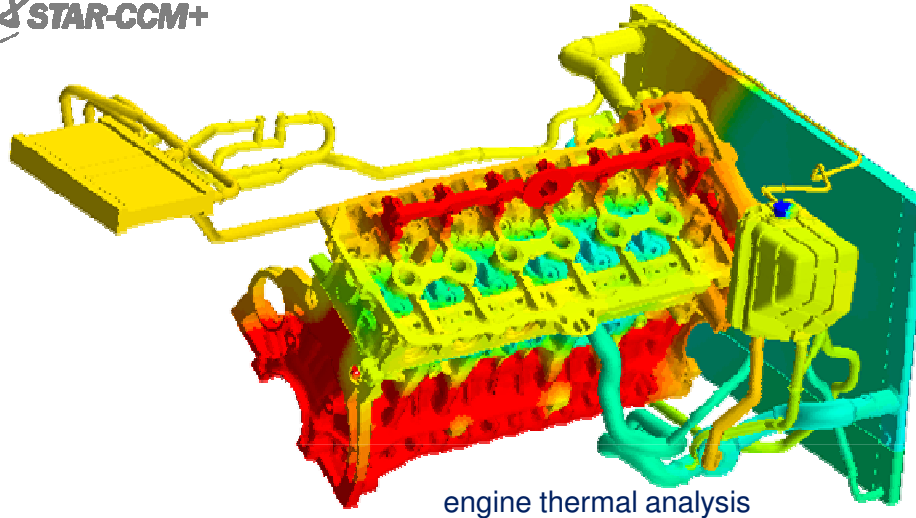
- ➔ Aerodynamics
- ➔ Cooling and Temperature Fields
- ➔ Radiation



velocity

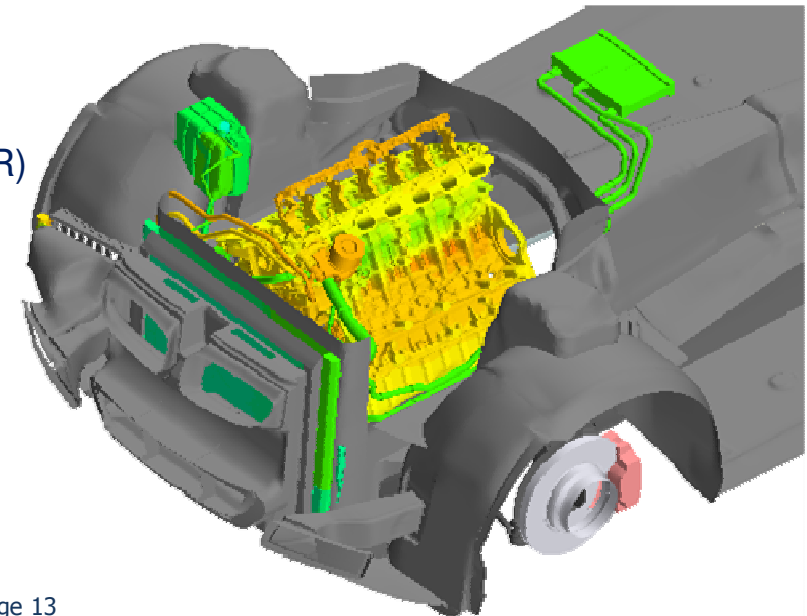
# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis



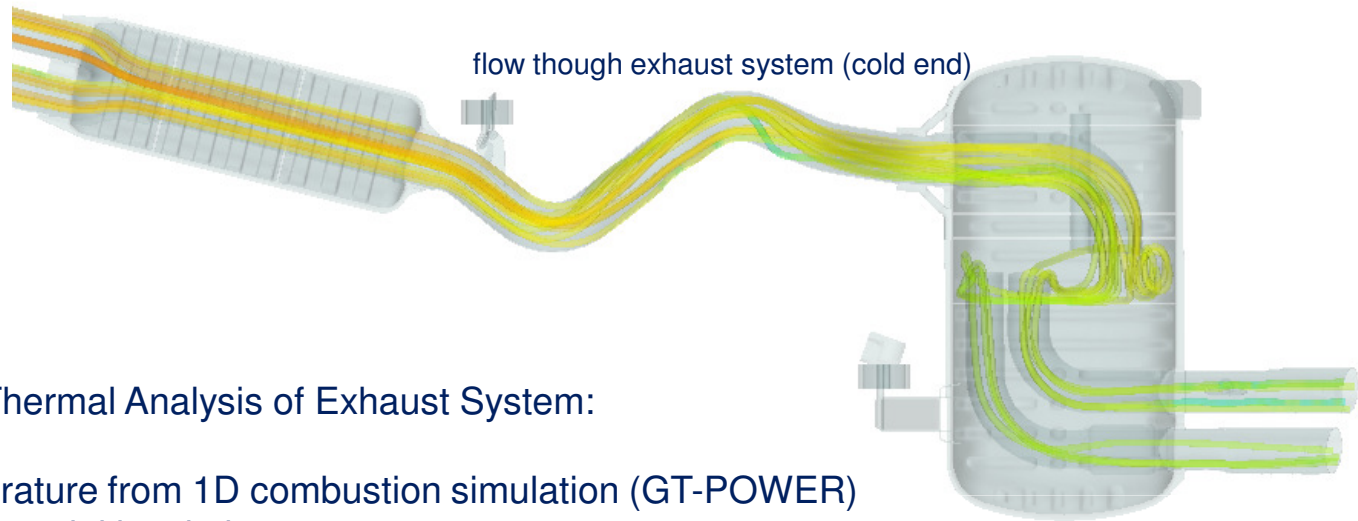
Coupled Thermal Analysis:

- thermal load e.g. from 1D combustion simulation (GT-POWER)
- conduction through engine structure
- convective transport through coolant
- heat release through heat exchangers (dual-stream)
- convective transport through engine oil



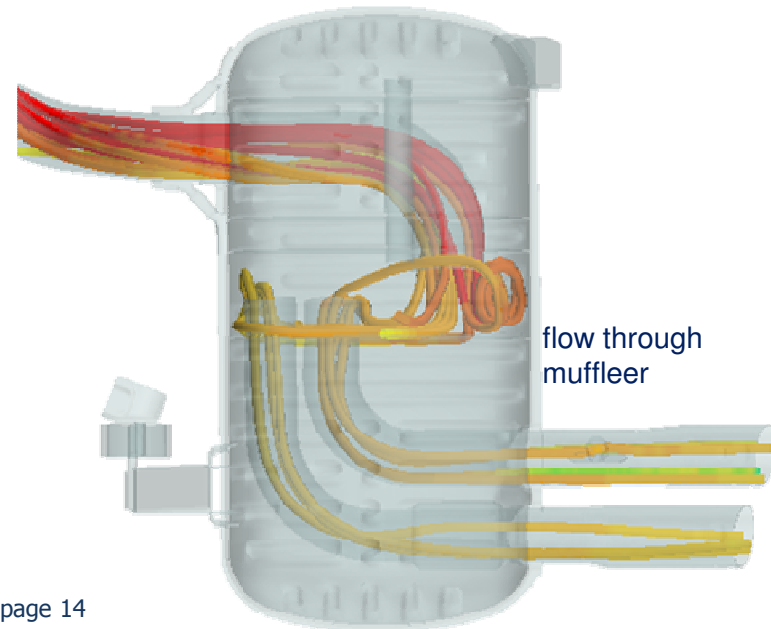
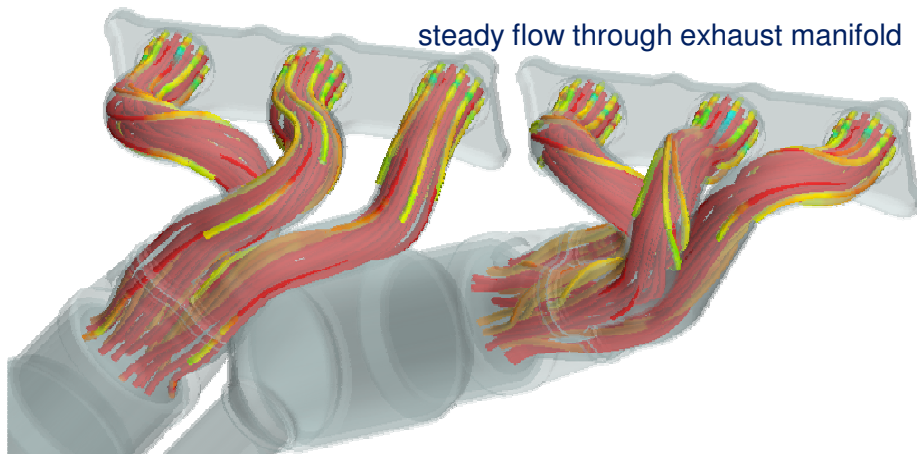
# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis



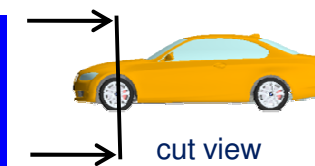
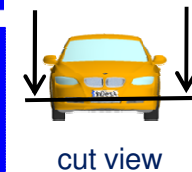
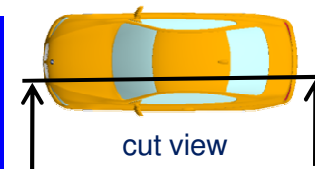
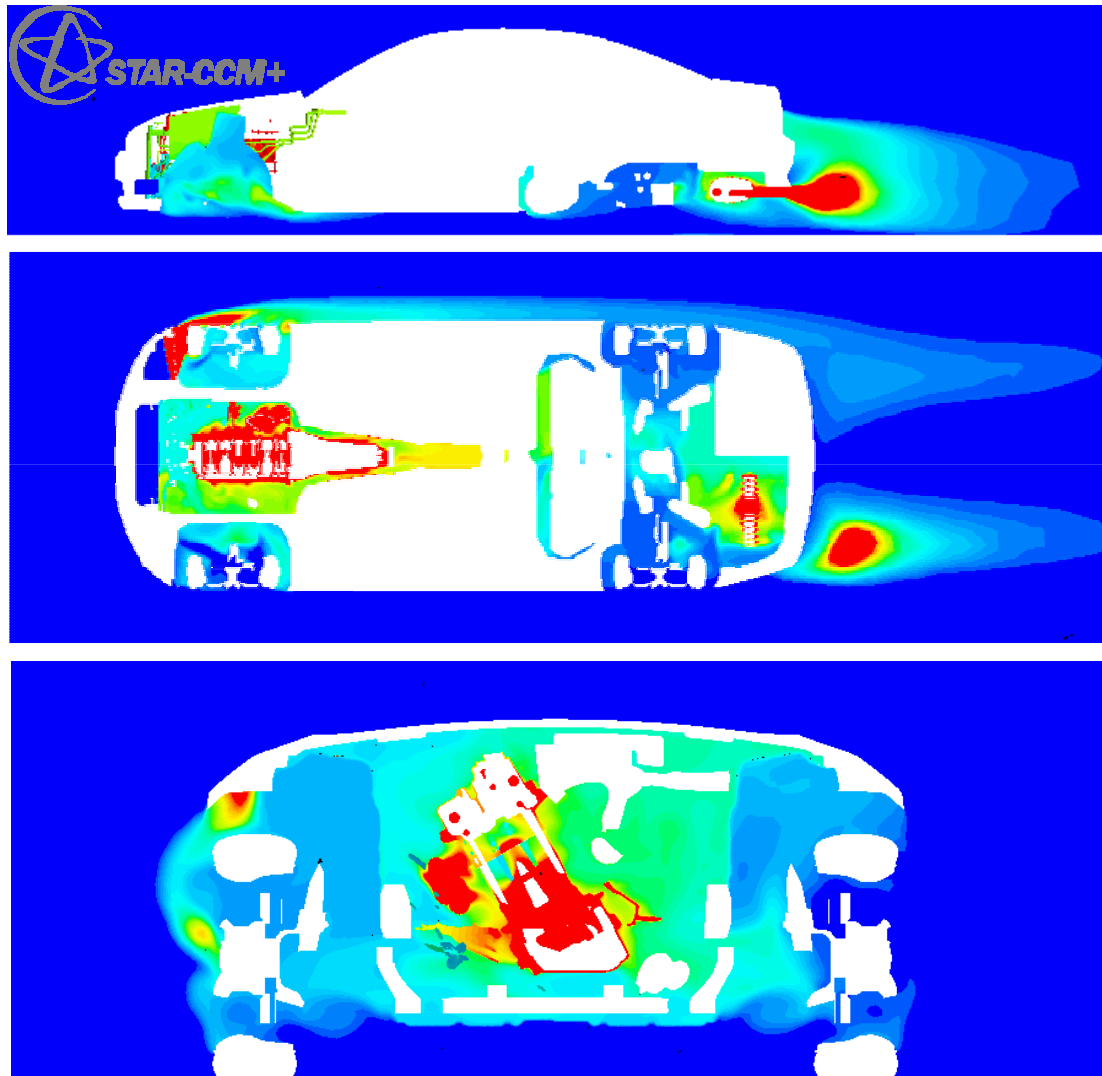
Coupled Thermal Flow and Thermal Analysis of Exhaust System:

- mass flow rate and temperature from 1D combustion simulation (GT-POWER)
- conduction through walls; partial insulation
- temperature fields and heat release through radiation
- addition of heat sources in catalysts



# Vehicle Thermal Reliability

## Coupled Flow & Thermal Analysis

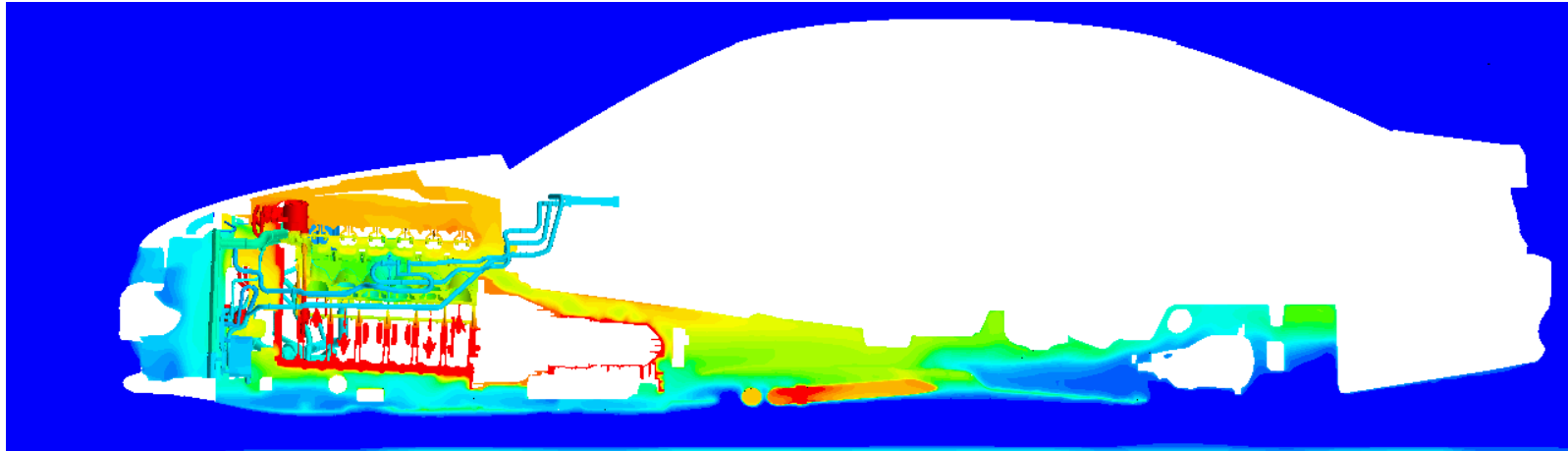


Temperature Distribution

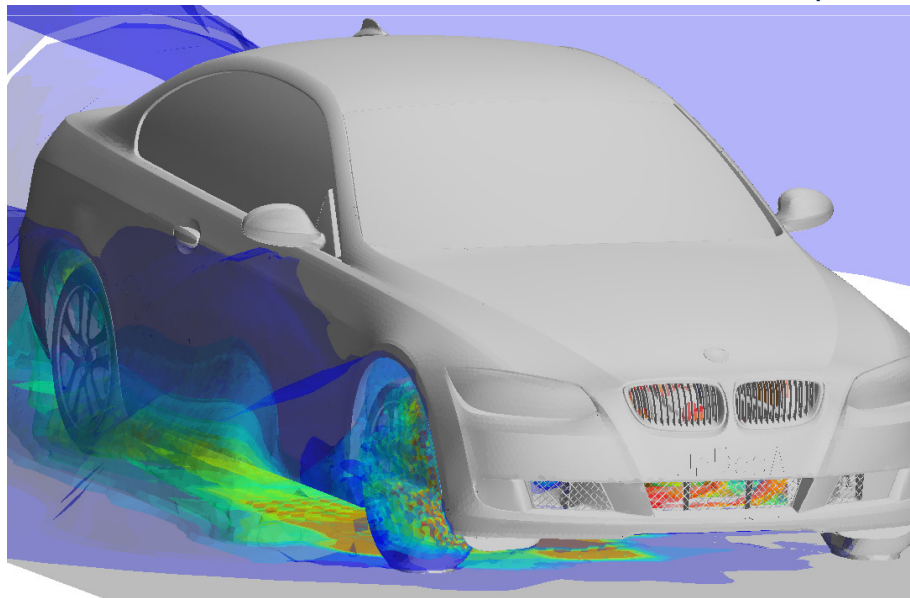


# Vehicle Thermal Reliability

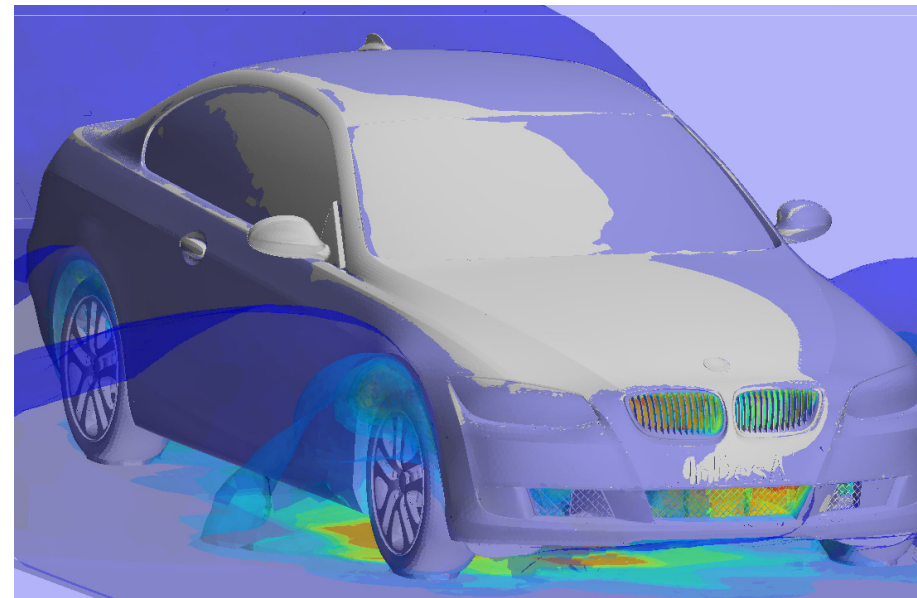
## Thermal Soak Analysis



temperature ditribution



t = 0 s



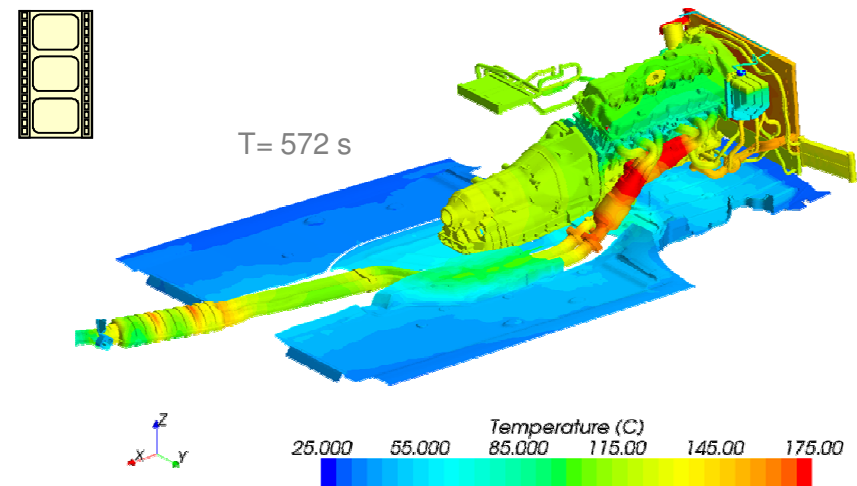
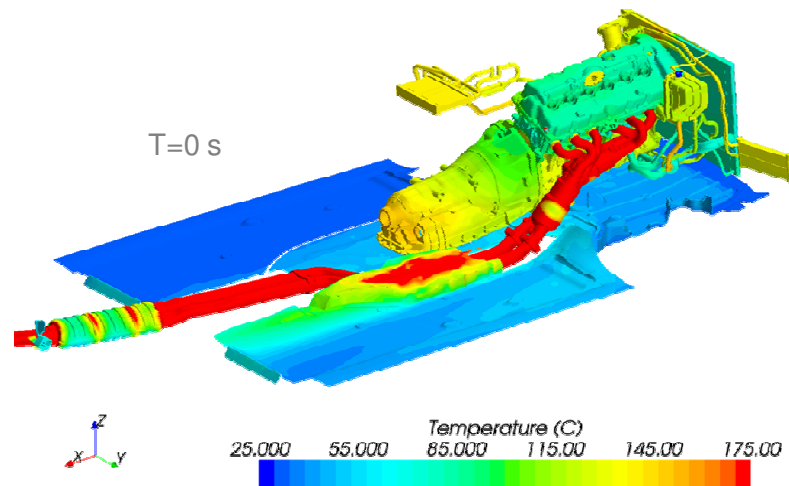
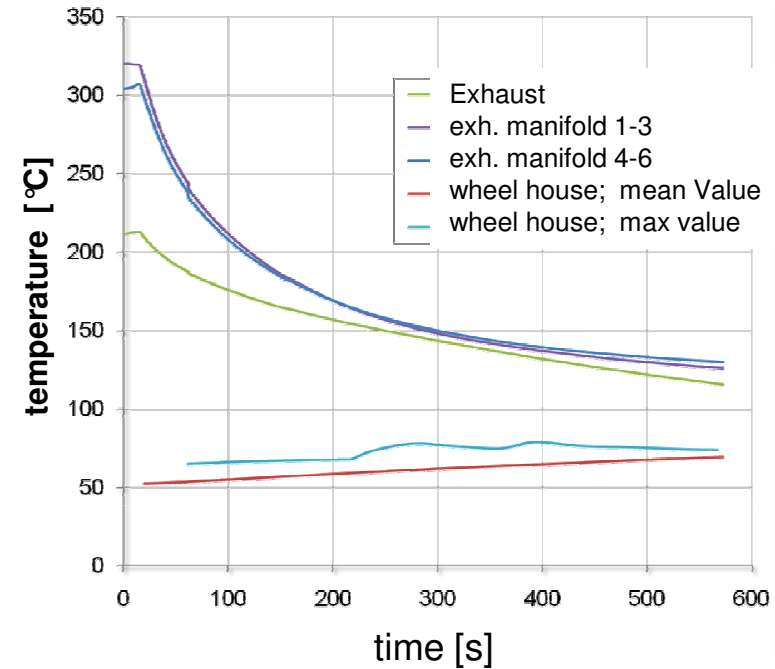
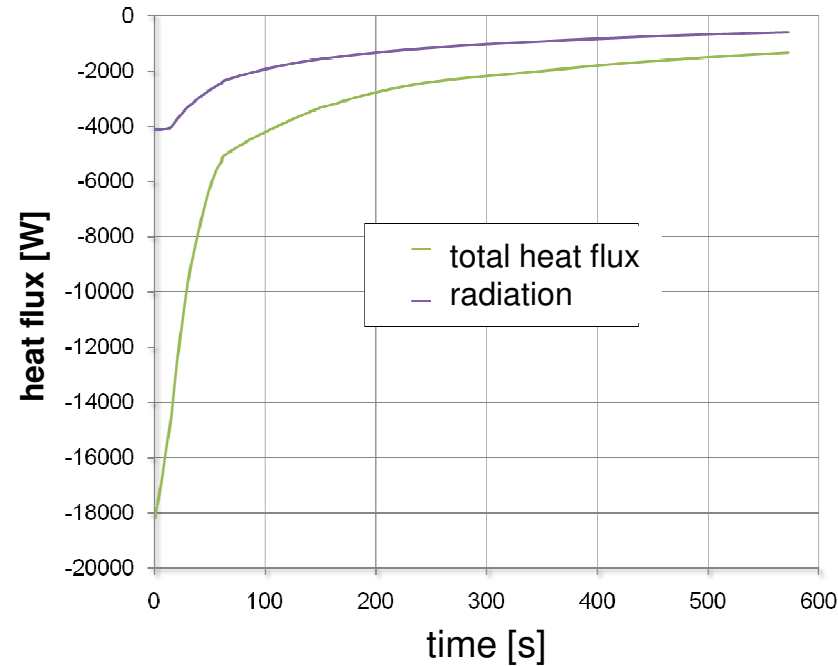
t = 572 s

temperature iso-surfaces



# Vehicle Thermal Reliability

## Thermal Soak Analysis



# Vehicle Thermal Reliability

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**Thank you for your attention !**

