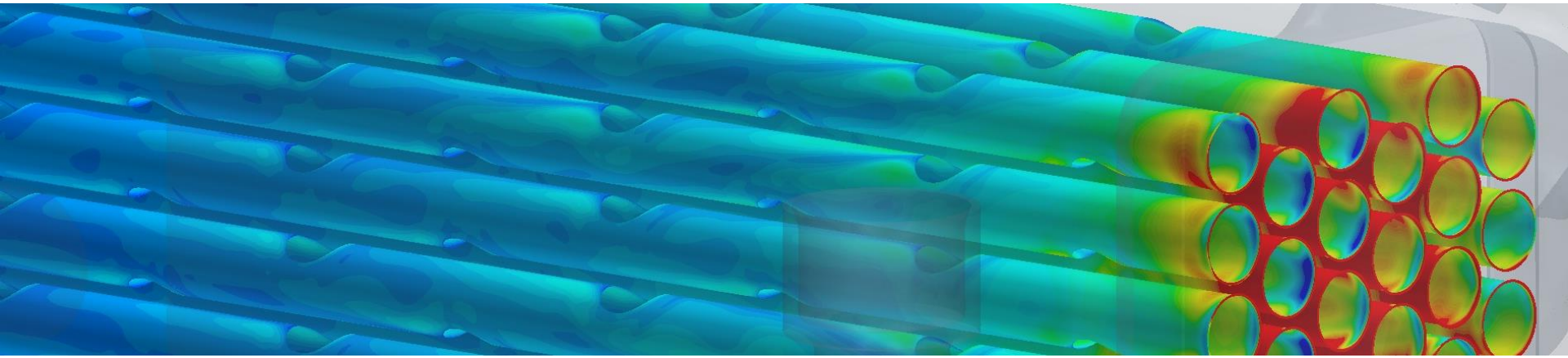
STAR Global Conference 2013 ORLANDO

INTEGRATED DESIGN ANALYSIS GmbH InDesA



Virtual Testing for Automotive Components and its Integration into the OEM´s Product Creation Process

Dr. Gerald Seider
Dr. Fabiano Bet

Orlando, 18 March, 2013

Company Profile

INTEGRATED DESIGN ANALYSIS GmbH **InDesA**

Consulting, Engineering Services & Virtual Test Center

- Simulation and Analysis of complex fluid flow and heat transfer systems for engineering and industrial applications
- Virtual Performance Testing for automotive accessory units

STAR-CCM+

3D CFD/CHT Analysis

GT-SUITE

1D System Analysis

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INTEGRATED DESIGN ANALYSIS

Virtual Testing for Automotive Components
Overview

1. The product creation process (PCP)
2. Motivation, concept and architecture of InDesA's Virtual Test Facilities
3. Test rig for an EGR cooler, data processing and feed back to PCP
4. Conclusion
5. Outlook to acoustic applications

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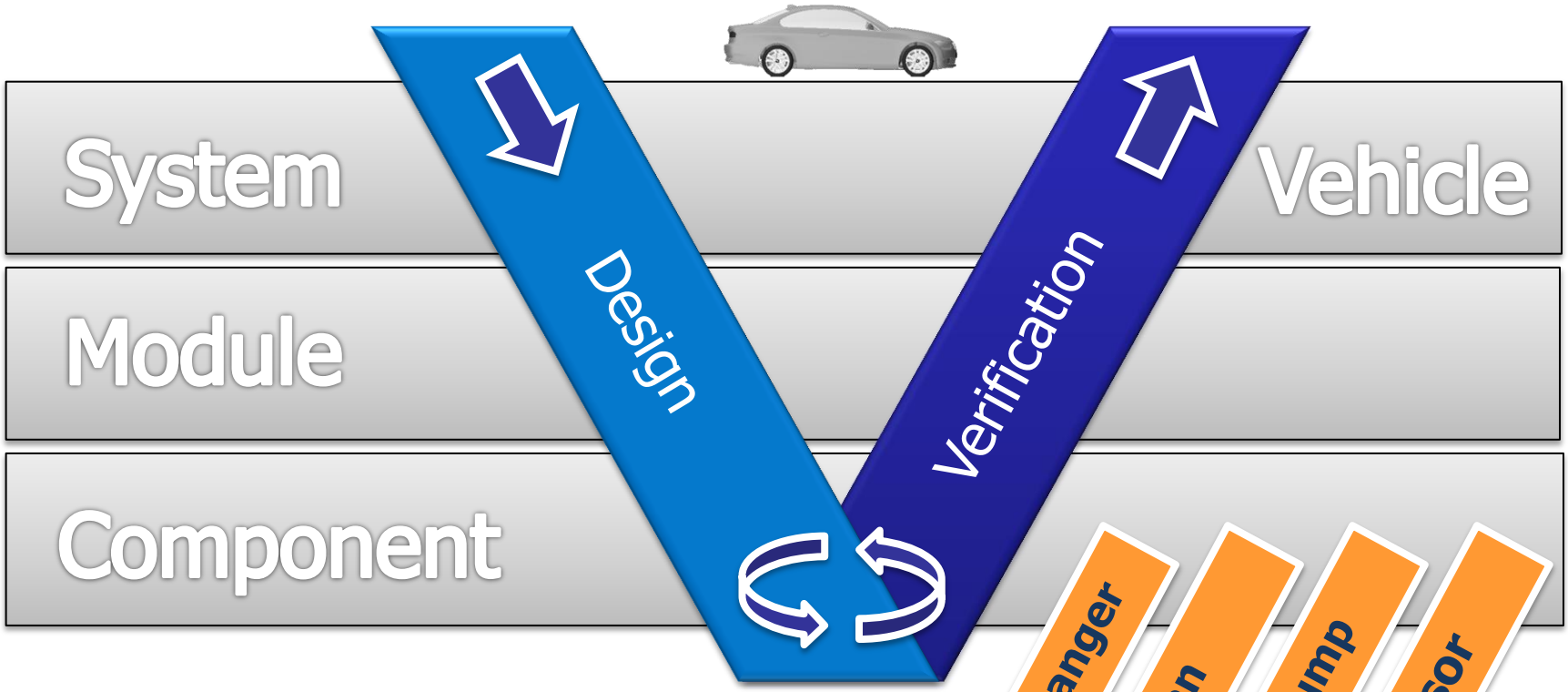
Virtual Testing for Automotive Components
The OEM's V-Type Development Process



supplier accessory units:

- Heat Exchanger
- Cooling Fan
- Coolant Pump
- Compressor
- ...

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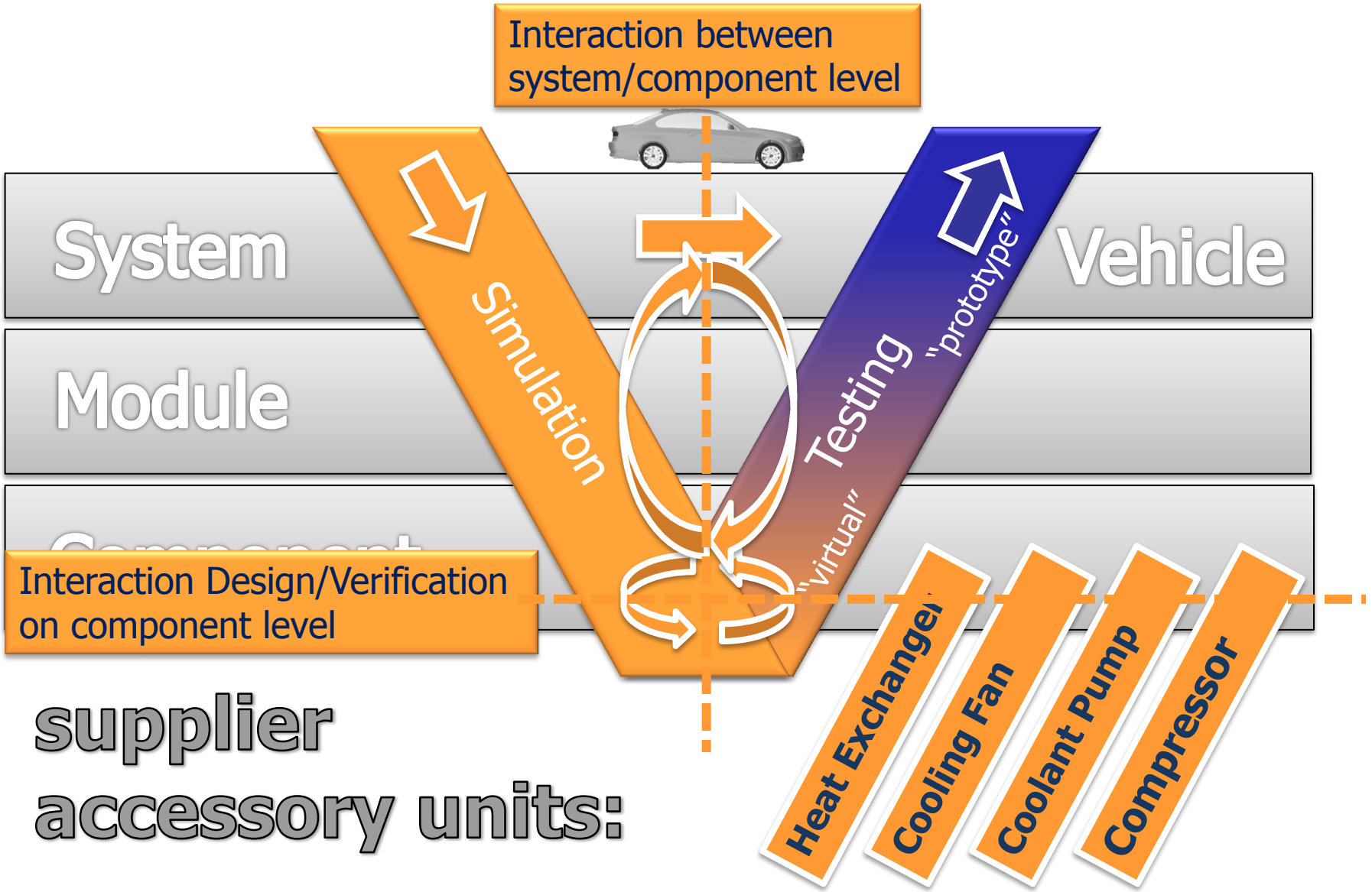
Virtual Testing for Automotive Components
The OEM's V-Type Development Process



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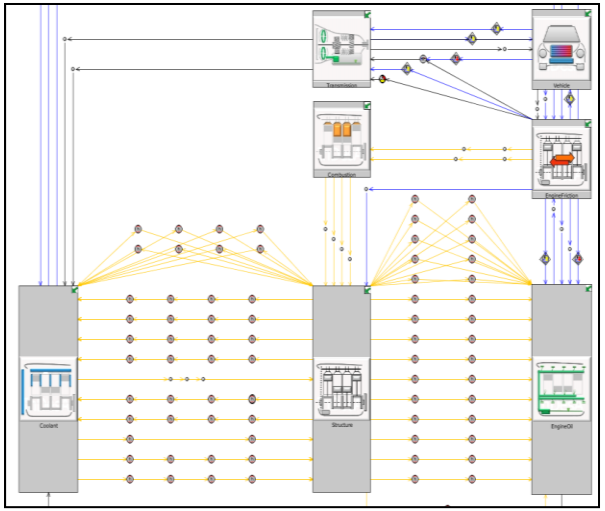
Virtual Testing for Automotive Components
Example for Multi-Physics System Application

System Level → **Vehicle**

Engine warm-up simulation is a typical OEM application on system level

- ❑ for the prediction of fuel consumption for warm-up drive cycles.
- ❑ for the assessment of thermal management and friction reduction techniques.



1D System Simulation (GT-SUITE)

⇨ **need for performance data for components from test bench**

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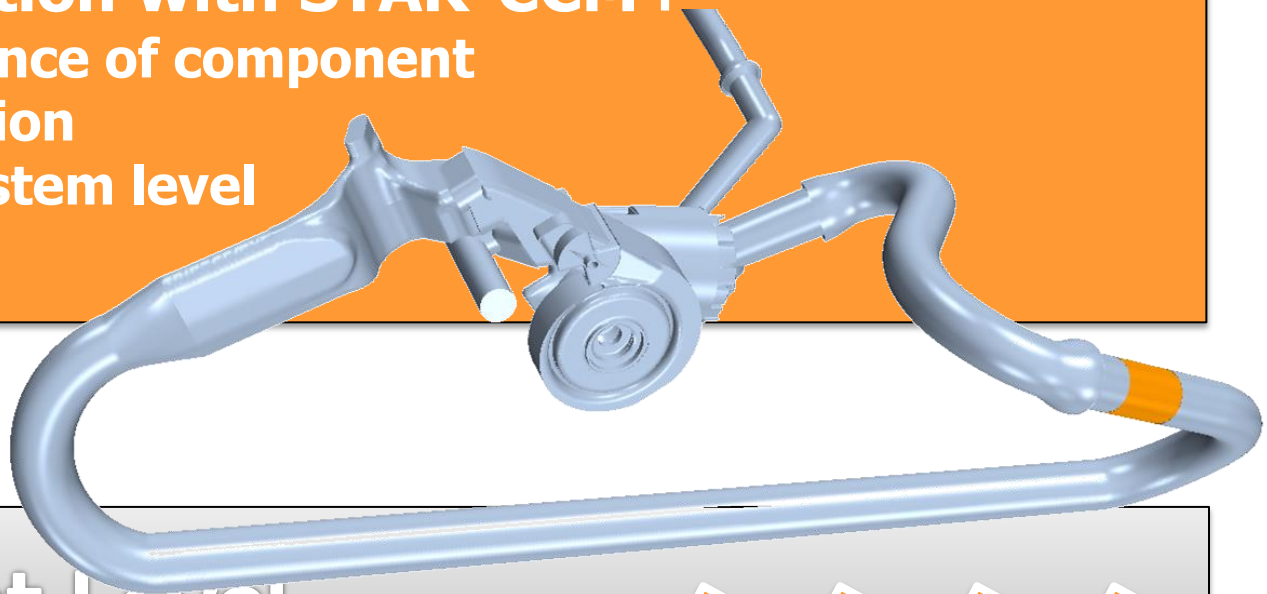
Virtual Testing for Automotive Components
Virtual Test Bench for a Coolant Pump

3D CFD Simulation with STAR-CCM+
predicts performance of component
⇨ design verification
⇨ feed back to system level



Component Level

supplier
accessory units:

- Heat Exchanger
- Cooling Fan
- Coolant Pump
- Compressor

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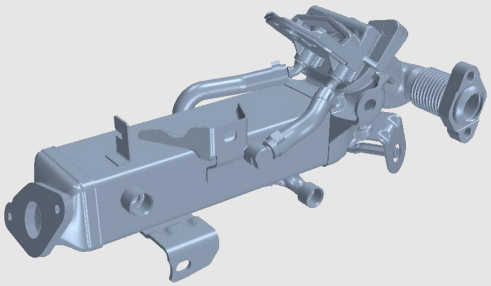
Virtual Testing for Automotive Components
InDesA's Virtual Test Bench Categories

Type A

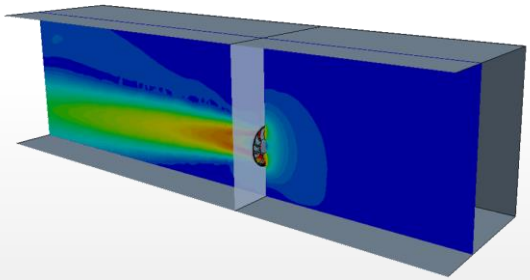


- isolated component in isolated test environment
- no interaction with other components

Example:
EGR cooler module

STAR-CCM+

Type B

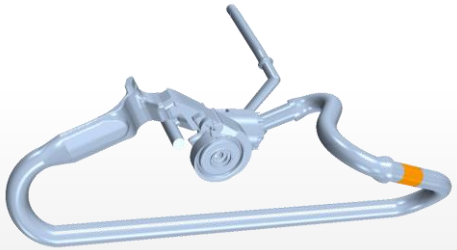


- standardized test environment
- interaction with other components

Example:
two-chamber test cell for cooling fans

STAR-CCM+

Type C



- unique test environment
- interaction with other components

Example:
Water pump assembly

STAR-CCM+

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Virtual Testing for Automotive Components

Interaction between Component and System Level

... for the example of a Heat Exchanger

Supplier
accessory component

"nice to have"

Heat Exchanger(HX)

"available"

CAD data

InDesA
Virtual Test Bench

... with ***STAR-CCM+*** and ***GT-SUITE*** Expertise

"rapid" Prototype

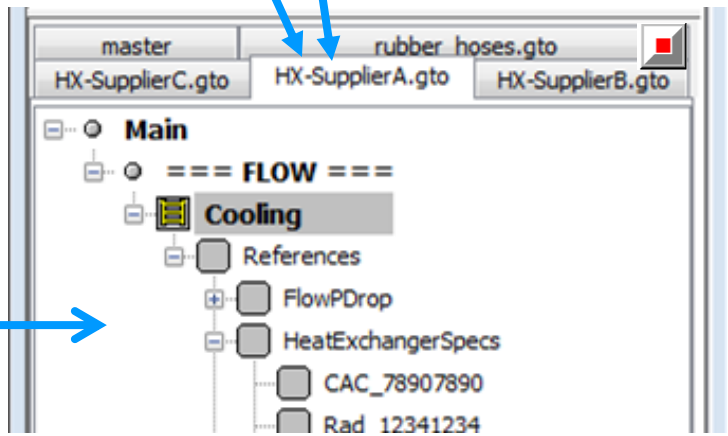
OEM's shared object libraries

physical test bench

test bench results

"common practice"

OEM
with *GT-SUITE*
Expertise



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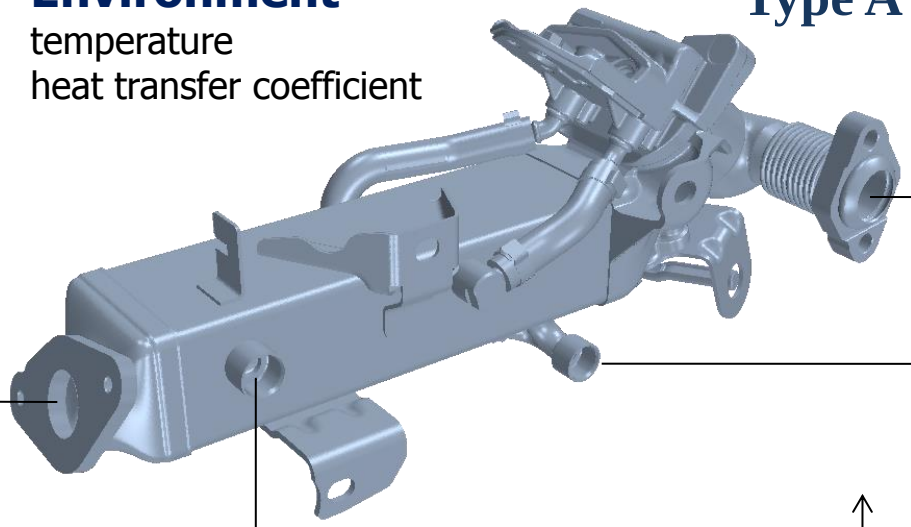
Virtual Testing for Automotive Components
Test Rig Set-Up for an EGR Cooler Module

Environment
temperature
heat transfer coefficient

Type A



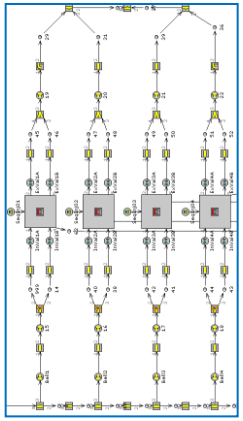
Exhaust

Coolant

Exhaust

Coolant

Flow Rates
optional from
GT-SUITE
engine model

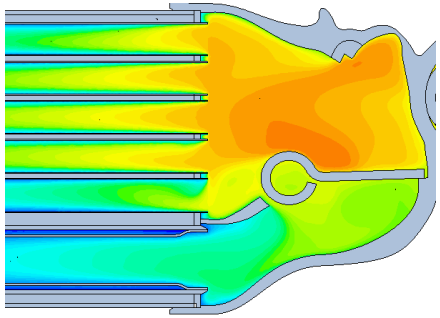


Model Set-Up with STAR-CCM+

- Thermal Fluid/Structure Coupling
- Full details of pipes or fin/plates
- EGR valve cooling and flow leakage at by-pass flap included

Additional Boundary Conditions

- Flap position for bypass-flow
- EGR valve position



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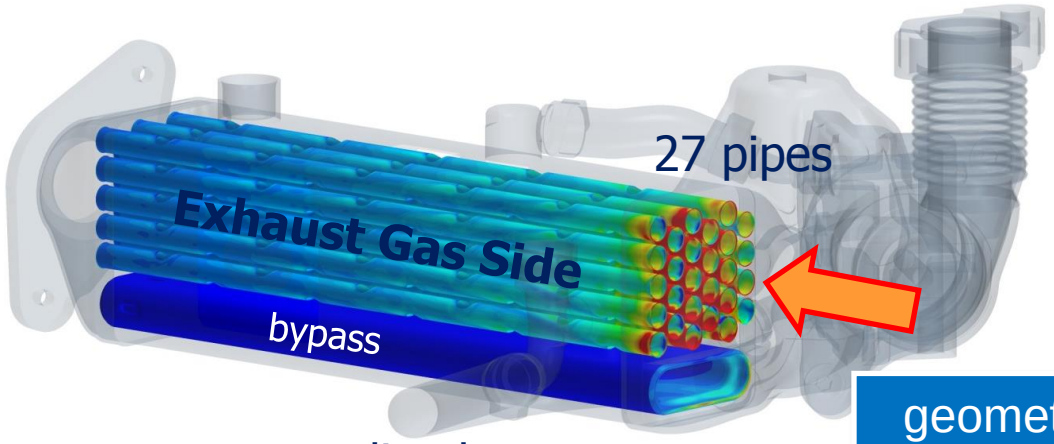
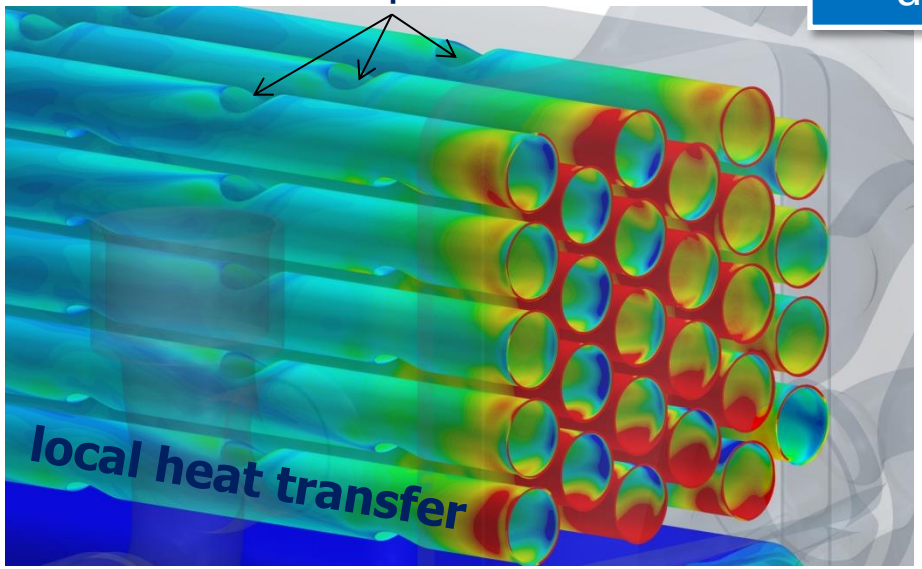
Virtual Testing for Automotive Components
Pipe Bundle EGR Cooler Module

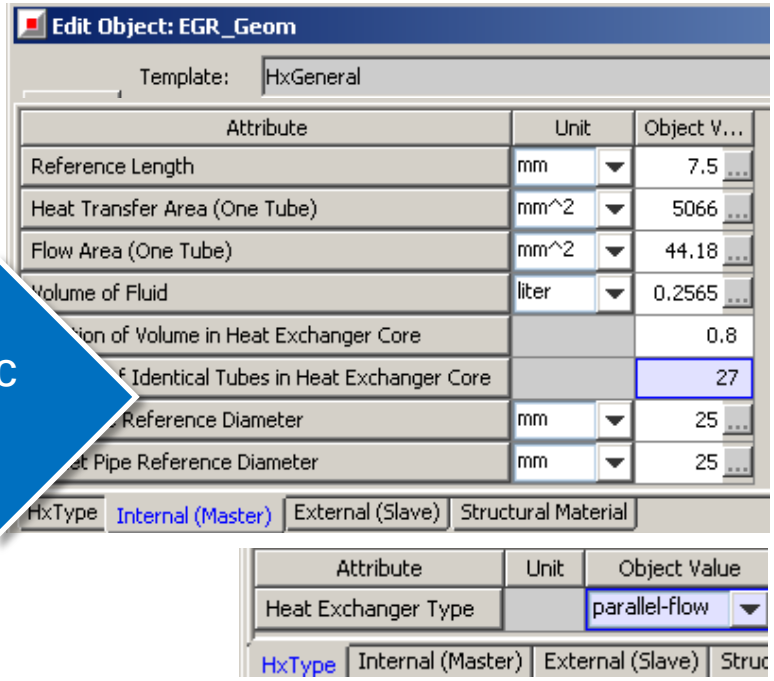
Component Level — STAR-CCM+ — System Level — GT-SUITE



dimples



geometric details



- dimple design by InDesA to enhance heat transfer through turbulence

⇨ only turbulent flow

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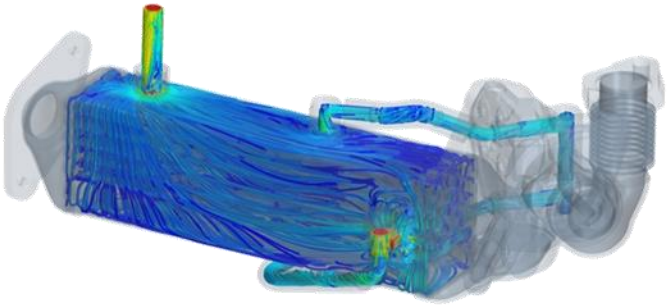
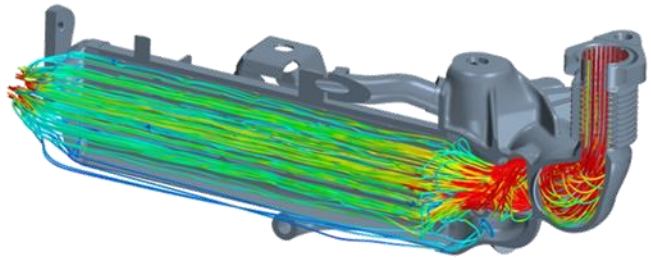
Virtual Testing for Automotive Components
Test Rig Results for an EGR Cooler

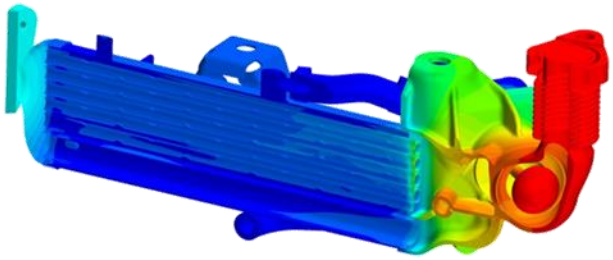
Component Level

System Level

GT-SUITE



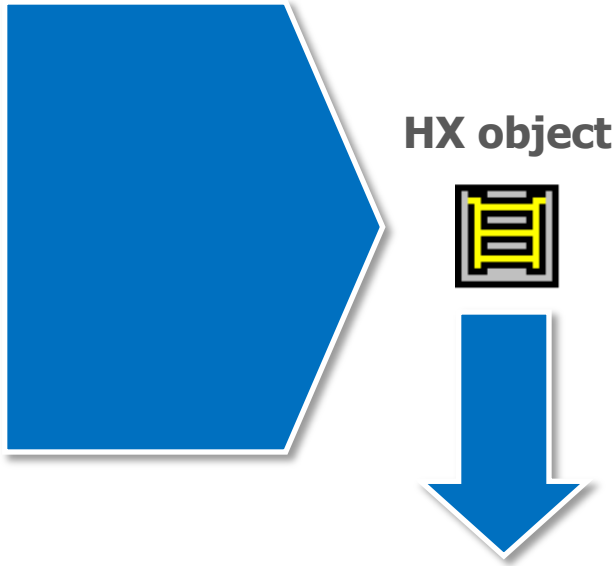




Coolant
- temperatures
- pressure loss
- onset of boiling
- volume flow rates
- flow uniformity

Exhaust
- outlet temperature
- pressure loss
- force on flap
- flow leakage

Structure
- temperatures
  esp. valve seat
- heat transfer



Nusselt Correlation
Nu = f (Re,Pr)

⇨ heat transfer for arbitrary operating conditions

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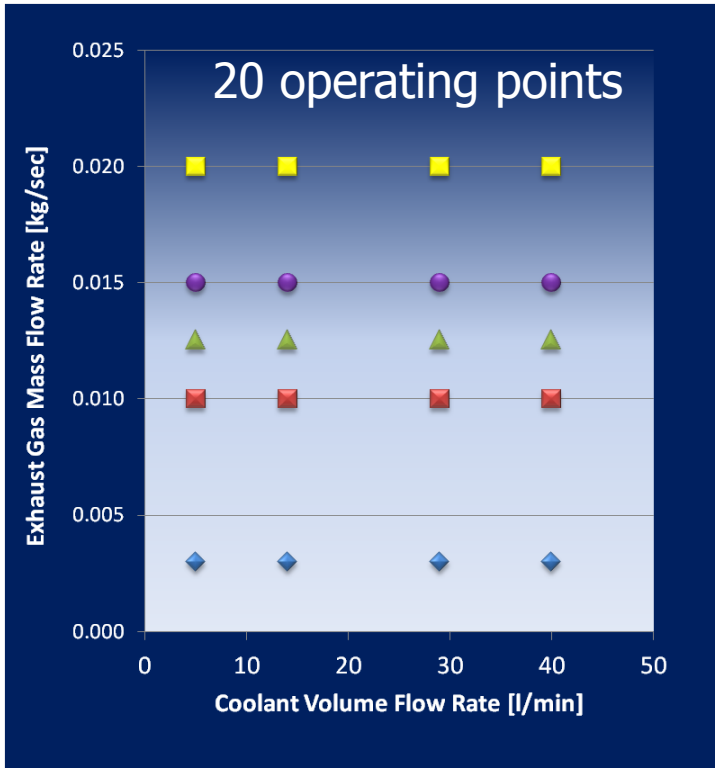
Virtual Testing for Automotive Components
The InDesA Virtual Test Rig

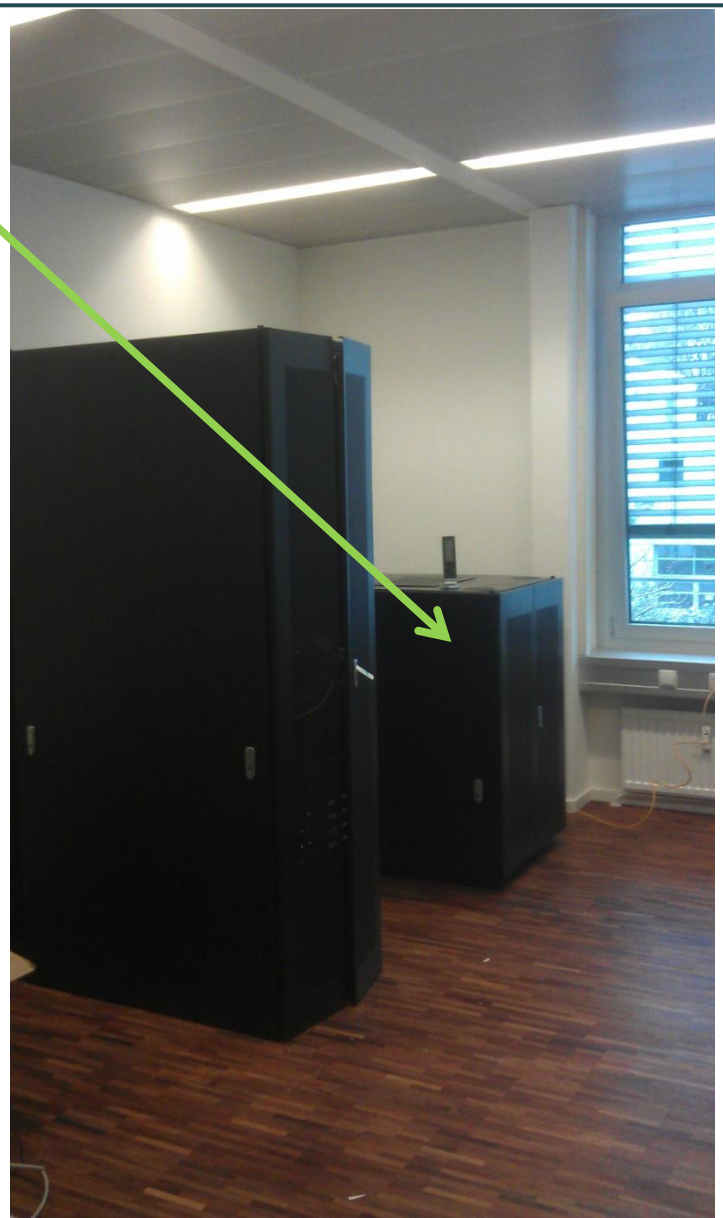
Parallel Cluster with 112 Nodes

(14 Blades, each with 2 Intel Xeon/Nehalem Quad-Core Prozessors and InfiniBand Switch, Integrated Storage Area Network)

- compute time: 1 day for
  14 steady flow operating points *)



*) for STAR-CCM+ model with 14 million cells



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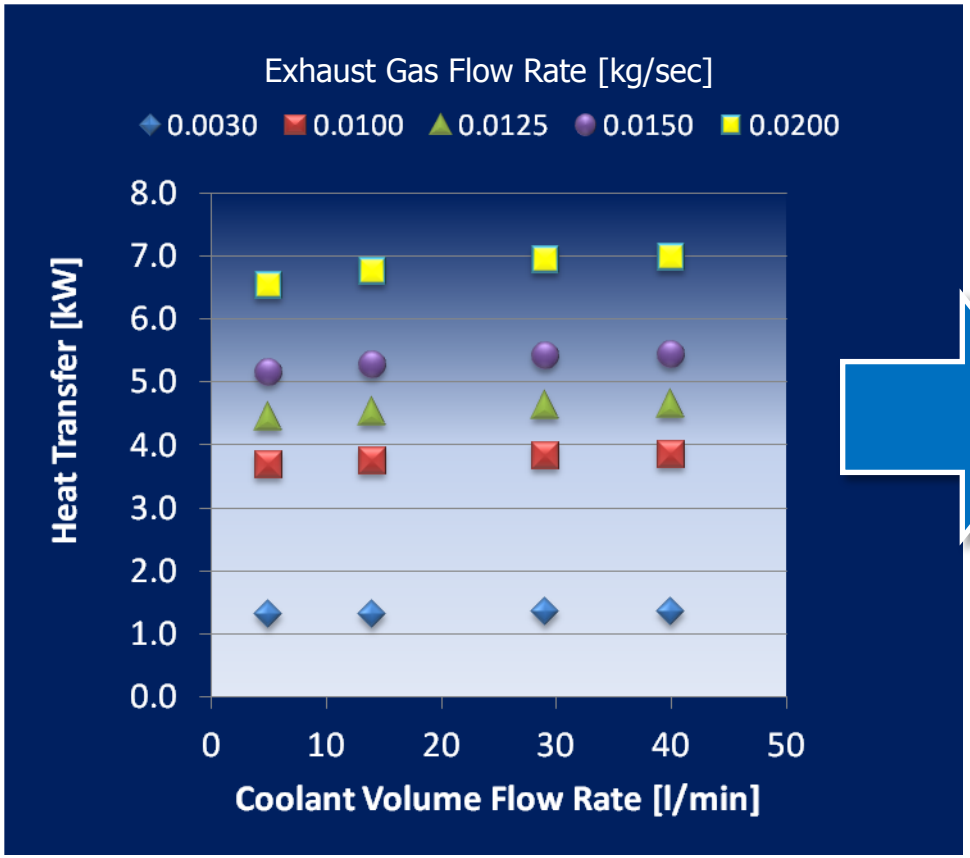
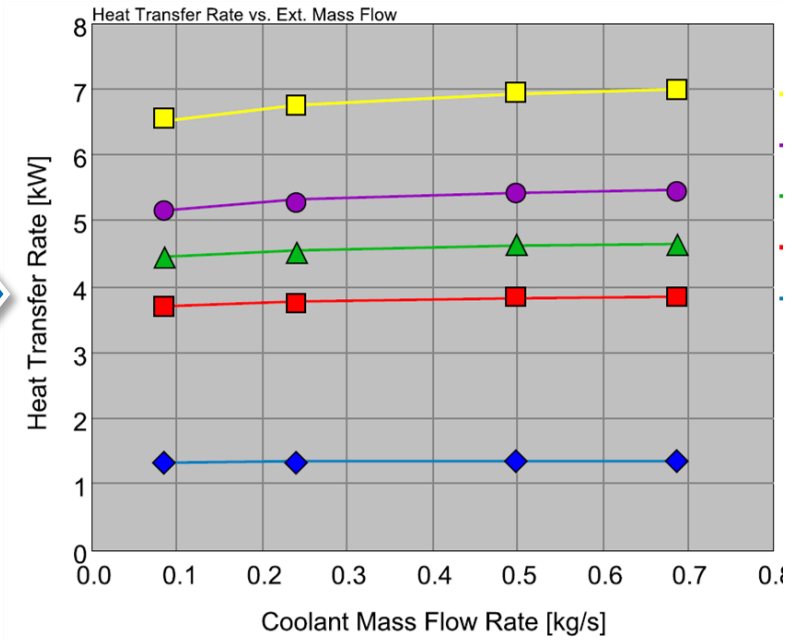
Virtual Testing for Automotive Components
Virtual Test Rig Results & Transfer to GT-SUITE



Nusselt Correlation



- excellent agreement of CFD data points with GT regression for Nu-correlation from low to high mass flow rates.

Prediction Fidelity:
InDesA has computed over 30 different EGR coolers of various designs.
Prediction accuracy has been checked and approved by supplier,
e.g. at the Automotive Research Experiment Station / Michigan State University.
Accuracy of simulation lies within test bench accuracy of 2-3 % for the heat transfer rate.

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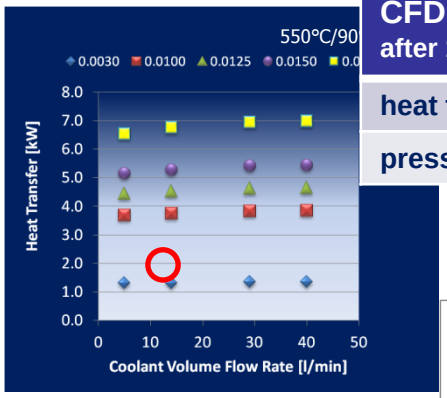
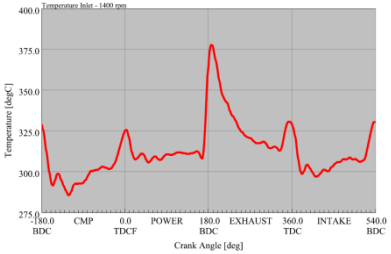
Virtual Testing for Automotive Components
Transient Simulation with Pulsating Flow



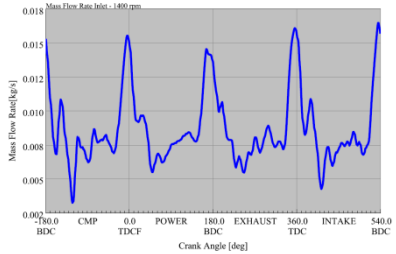
CFD Results after 10 cycles	stationary simulation	transient simulation	enhancement factor
heat transfer rate	1.82 kW	1.96 kW	1.08
pressure loss	534 Pa	841 Pa	1.57

transient b.c.
from GT-POWER analysis:

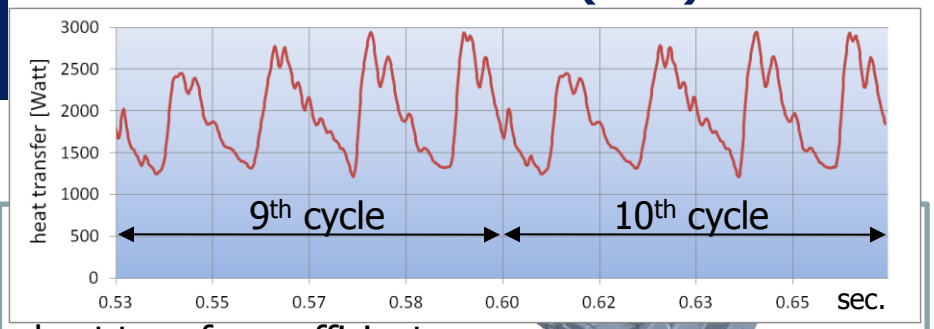
temperature



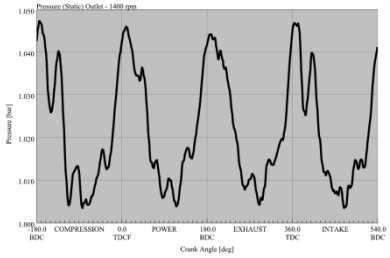
mass flow rate



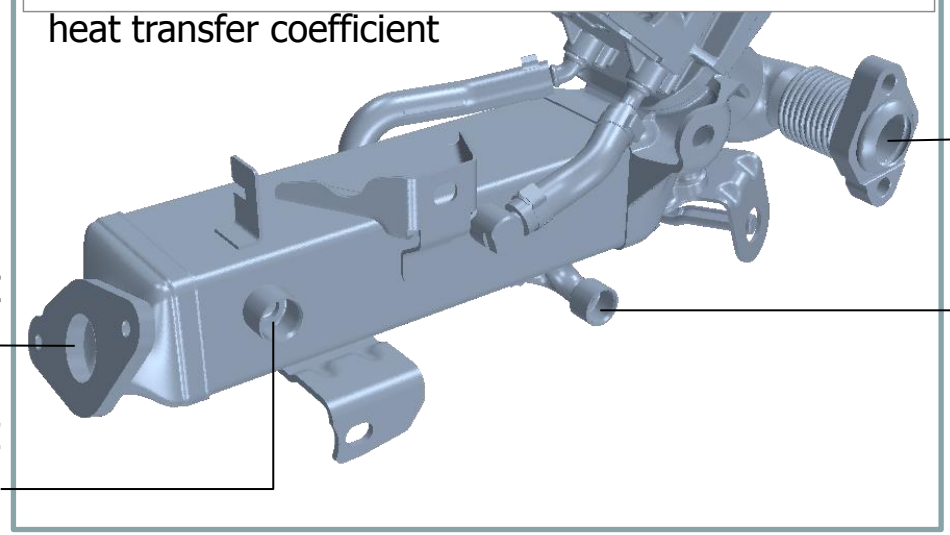
heat transfer (CFD)



pressure



heat transfer coefficient



Exhaust
transient

Coolant

Exhaust

Coolant

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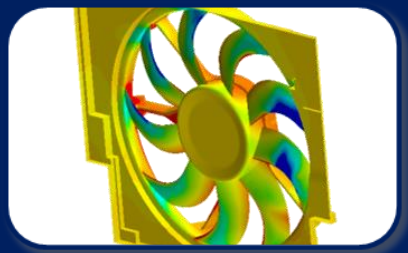
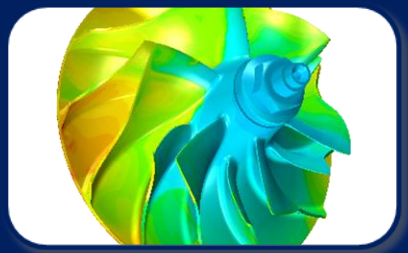
Virtual Testing for Automotive Components
Concept of InDesA's Test Facility Center

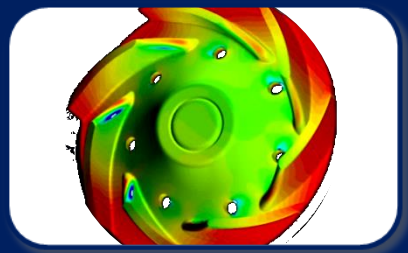
Cooling Fan



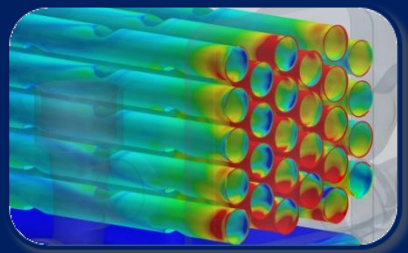
Compressor

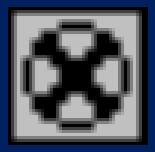


Coolant Pump



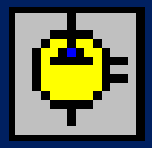
Heat Exchanger





OEM Library

1D Objects



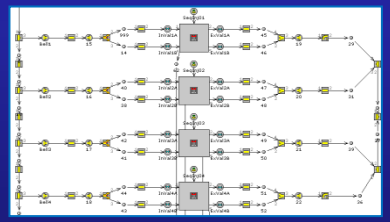
OEM Library

Computing Cluster

STAR-CCM+

Facility Supply

GT-SUITE



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Virtual Testing for Automotive Components
Conclusion and Outlook

InDesA's standardized Virtual Bench Testing for Accessory Components

… significantly speeds up the virtual creation process between supplier and OEM at lower costs.

👍 no need for prototypes and physical bench testing

… enhancing development quality by feeding populated and tested objects for 1D system simulation directly to OEM.

👍 through complementary use of 3D CFD and 1D system analysis

Outlook:

☞ **move the concept of virtual bench testing to module level**

☞ **develop virtual testing for acoustic applications**

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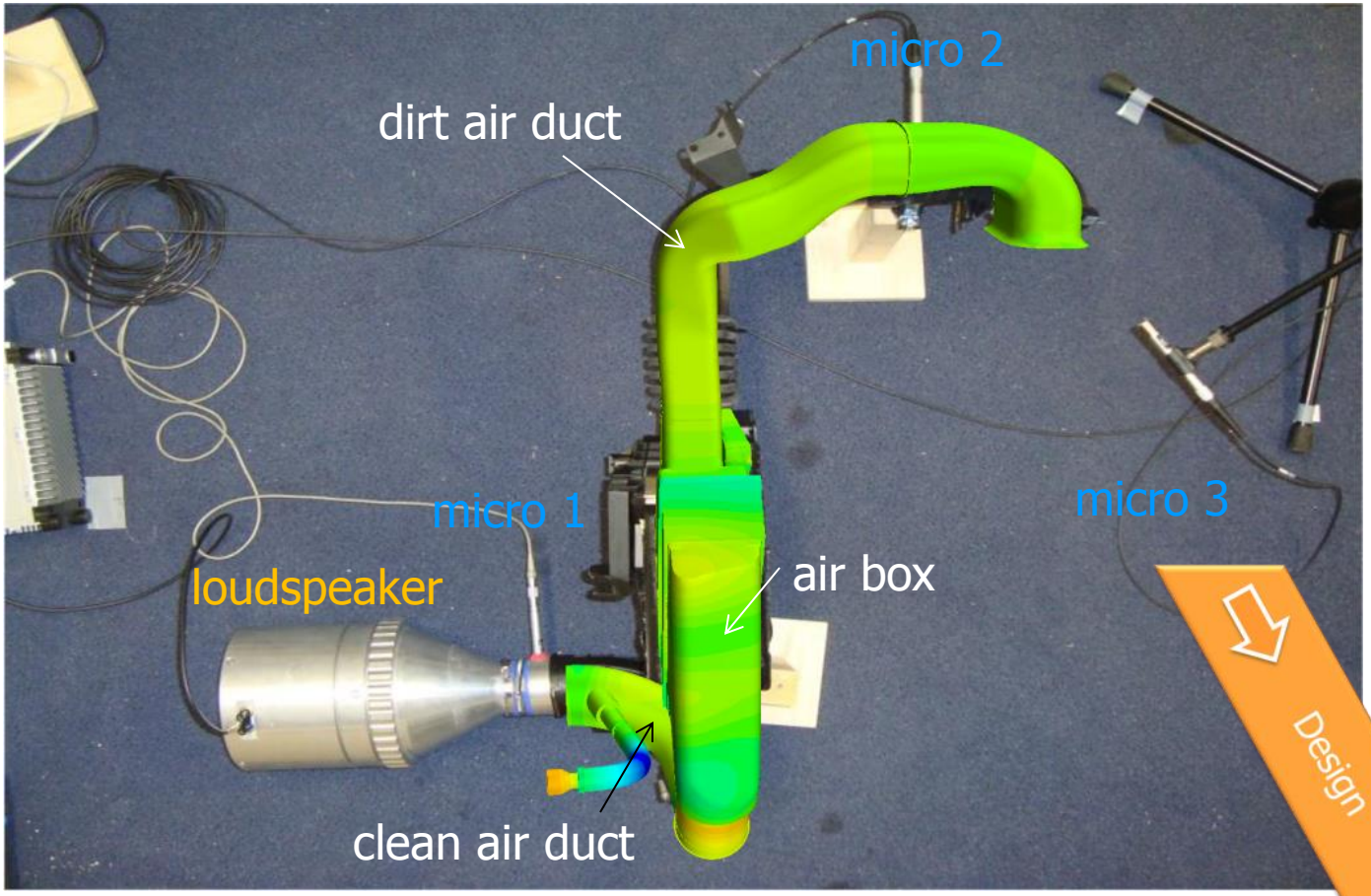
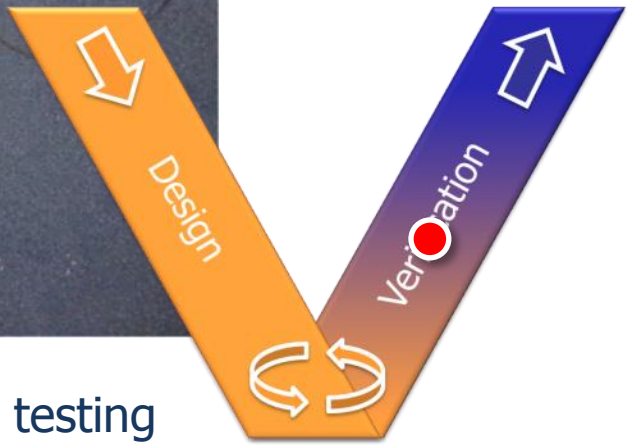
Virtual Testing for Automotive Components
Outlook on Virtual Testing at InDesA / Acoustics

Test bench to predict noise reduction for an Air Intake System





Objective: … test bench to be substituted by virtual testing

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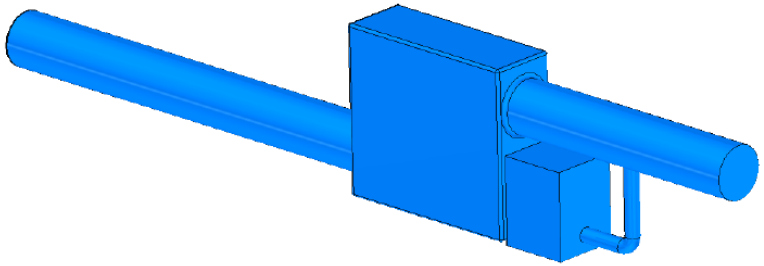
Virtual Testing for Automotive Components
Test Bench Setup for an Air Intake System



STAR-CCM+

to compressor

air box
w/o filter

clean air

air intake (open, echoic)

dirt air duct

HHR

white noise*)
loudspeaker

pressure sensors

Helmholtz resonator
(~ 60 Hz)

GT-SUITE

signal analyzer

- FFT
- transmission loss
- noise reduction
- insertion loss

*) random signal with constant power spectral density (intensity)

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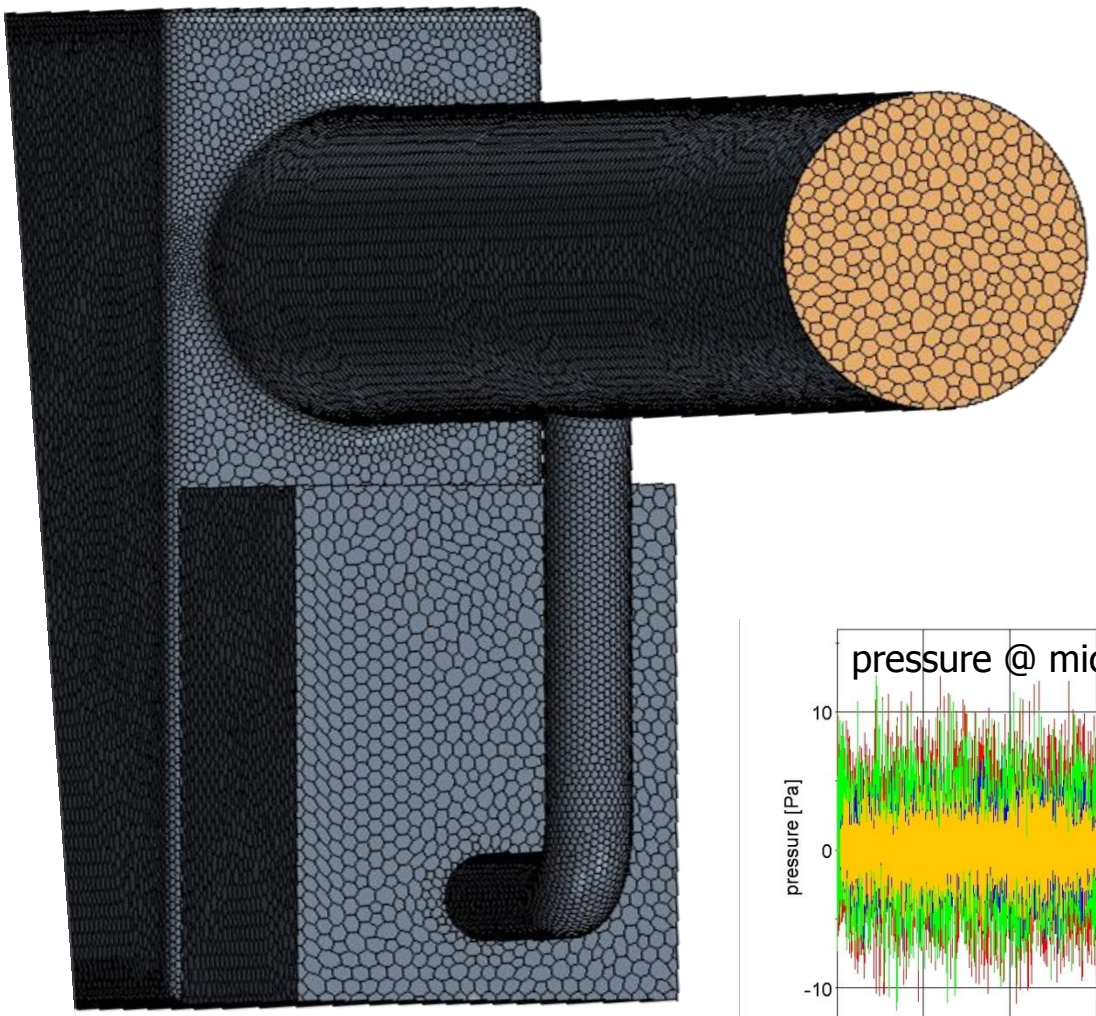
Virtual Testing for Automotive Components
Air Intake System – Setup Parameters

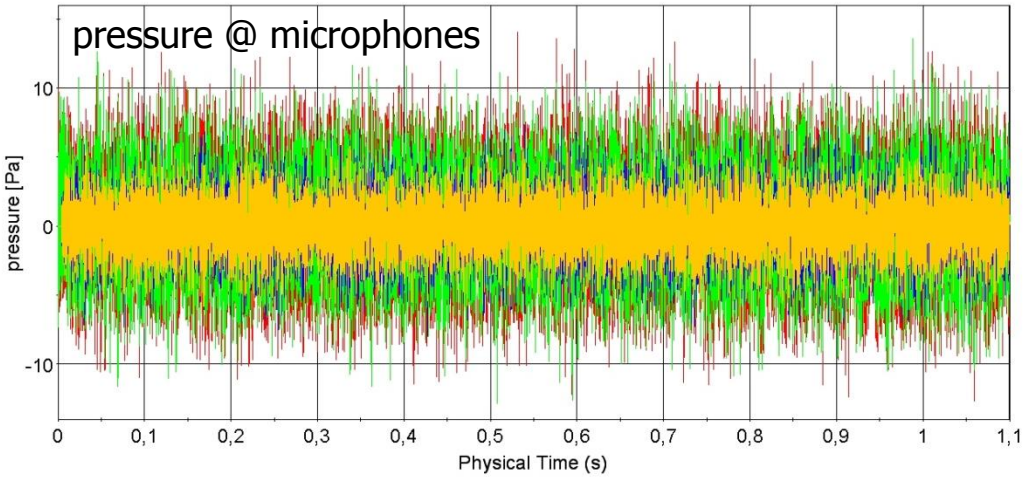


mesh:
230.000 polyhedral cells
base size: 5mm

discretization accuracy:
2nd order in space and time

time step:
1.0 E-5 sec

simulation time:
5 days on 16 CPU´s
physical time 1.1 sec



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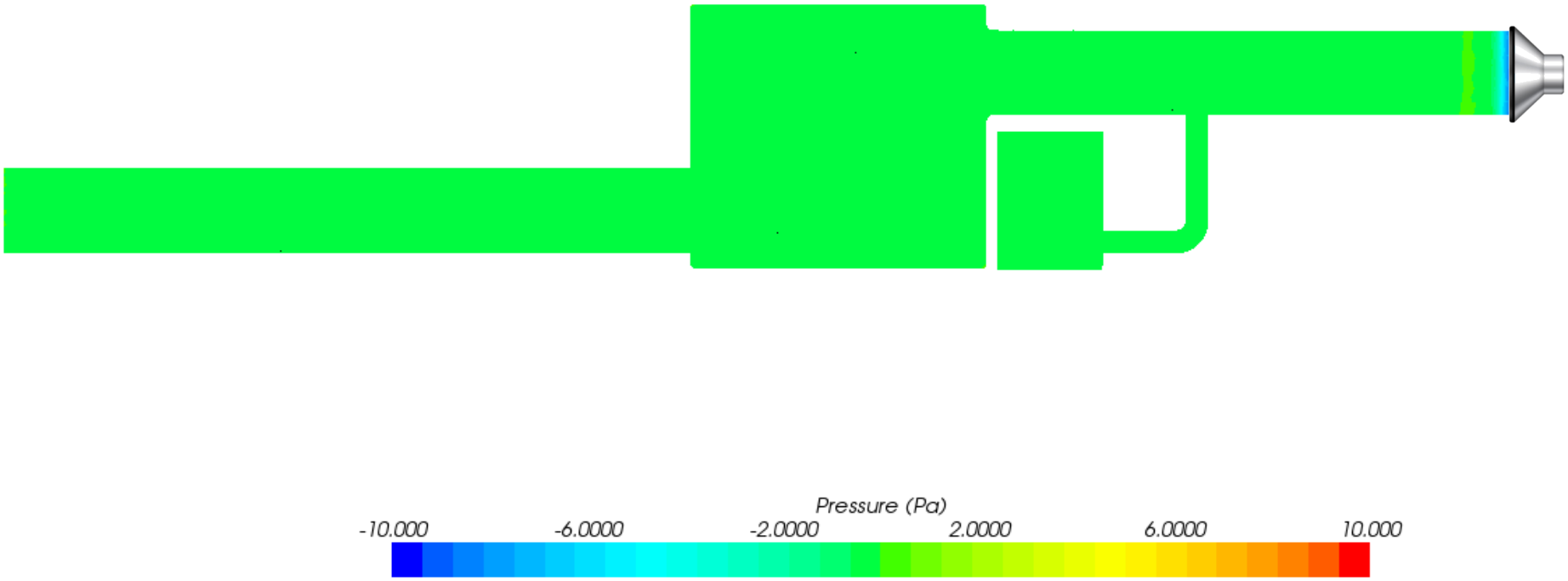
Virtual Testing for Automotive Components

Air Intake System – Pressure Waves



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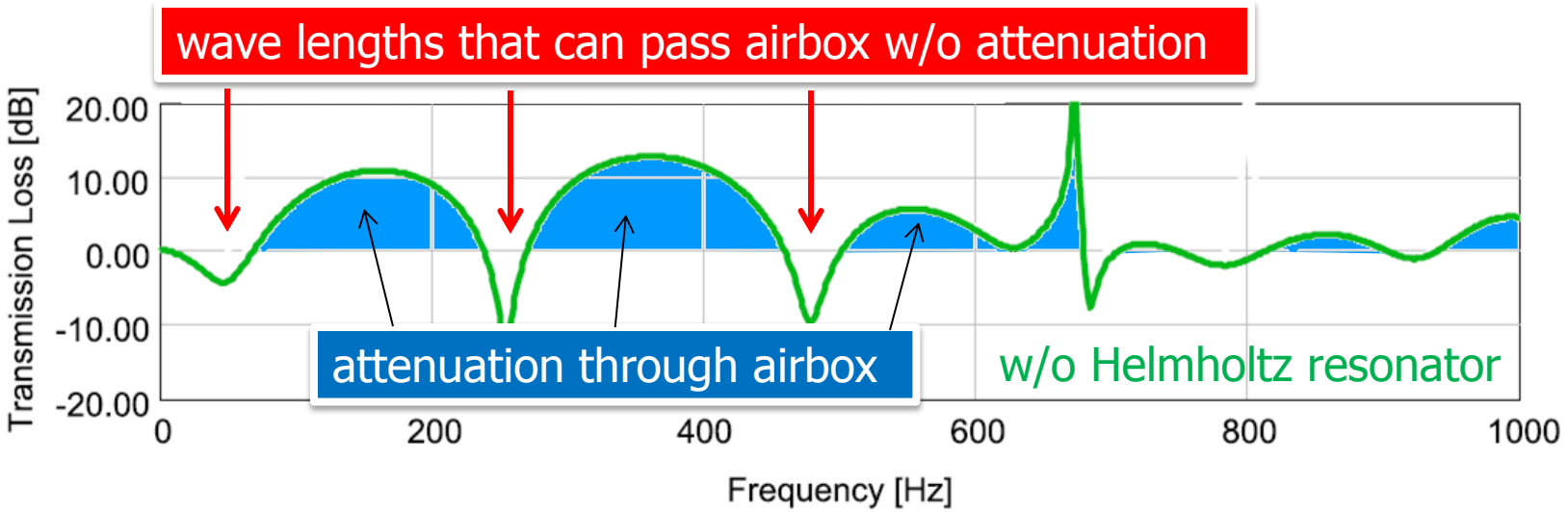
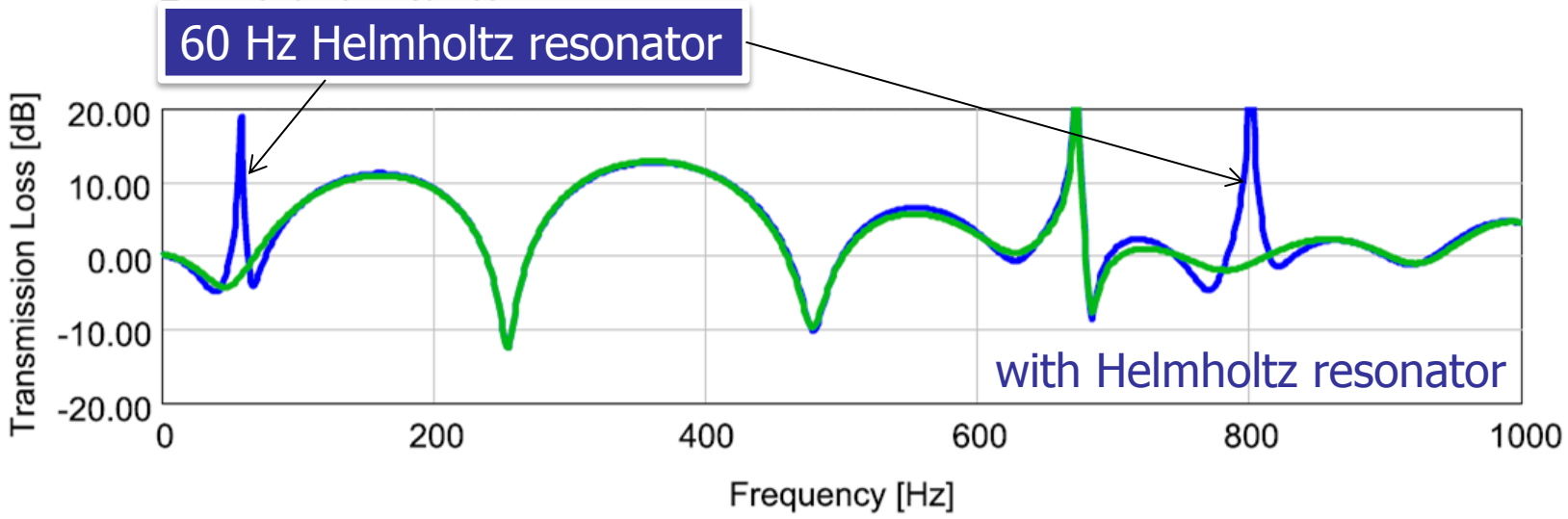
Virtual Testing for Automotive Components
Transmission Loss from 1D *GT-POWER* analysis





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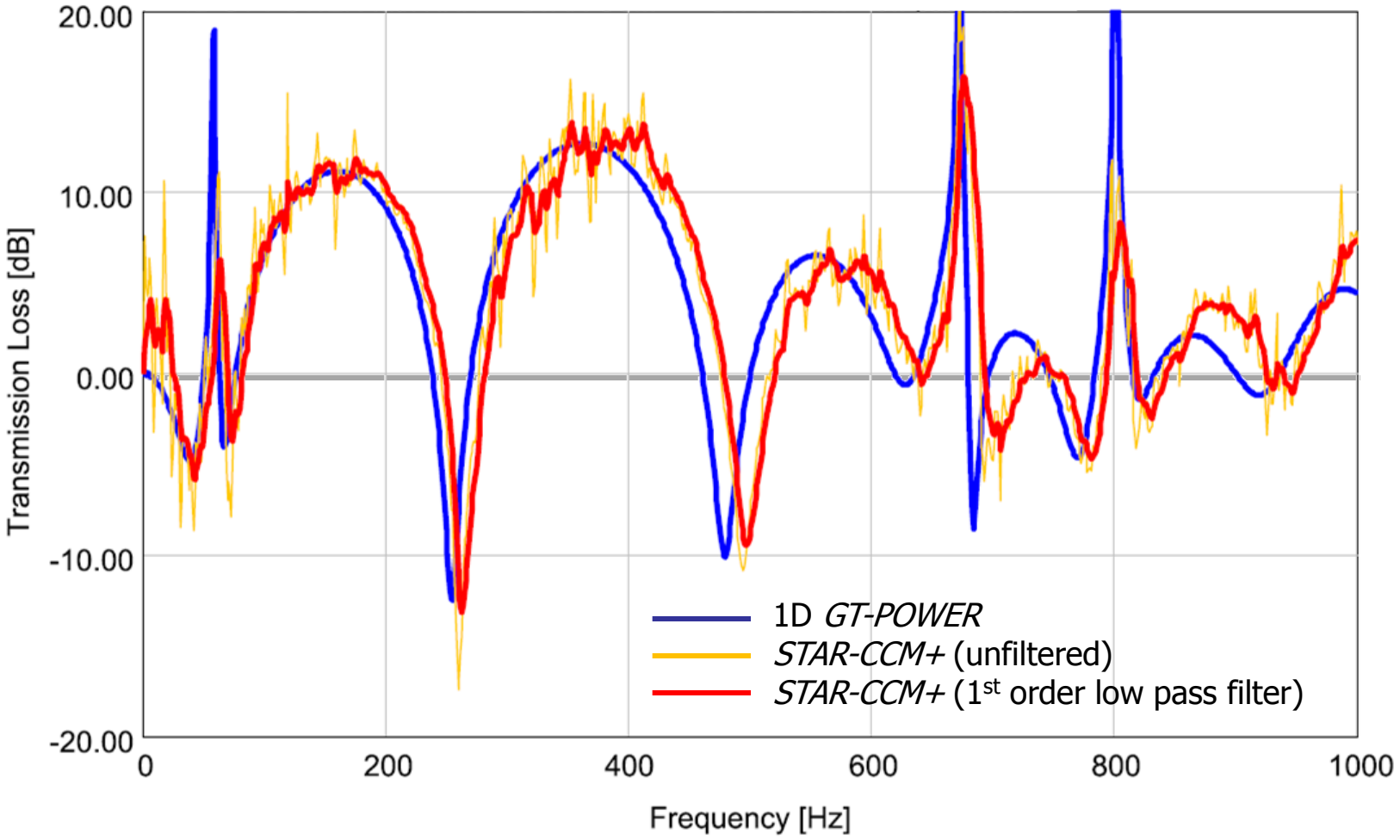
Virtual Testing for Automotive Components

Transmission Loss – Comparison 1D vs 3D

- excellent agreement for response of Helmholtz resonator
- good agreement of TL up to 700 Hz
- 3D predicts higher attenuation for frequencies > 850 Hz



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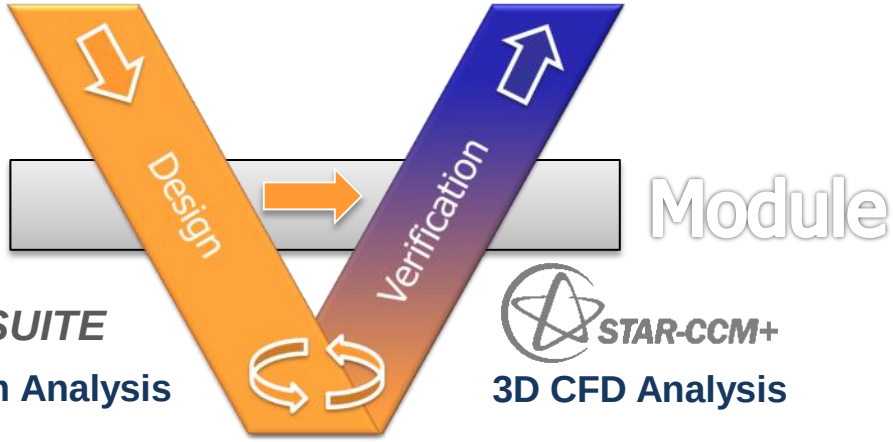
Virtual Testing for Automotive Components
Conclusion for the Future

the concept works

- for the module level
- for acoustic applications

the concept is consistent with respect to the virtual creation process:



fast design tool
for lay out of acoustic systems

to be developed for verification and substitution of physical bench testing

STAR Global Conference 2013 ORLANDO

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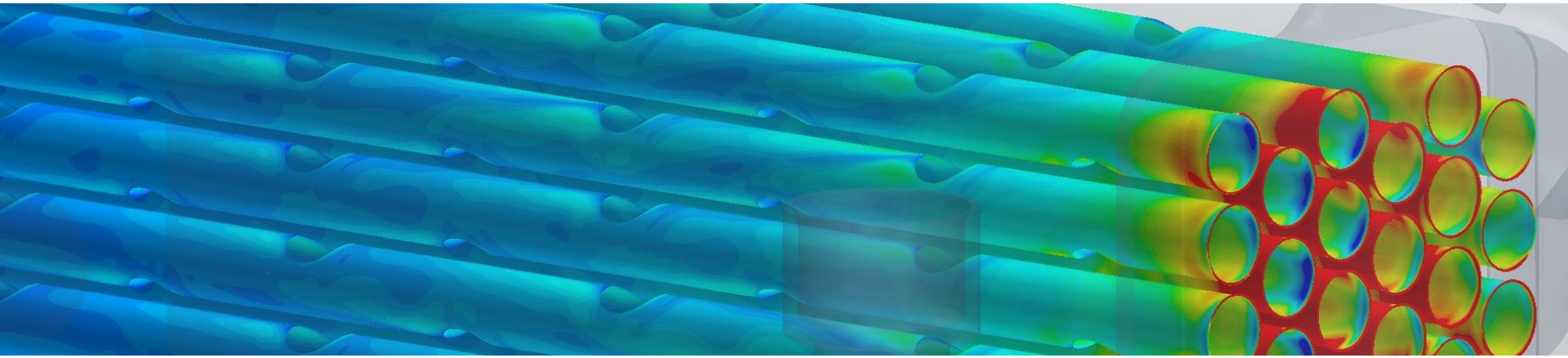

Thank you for your attention.

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