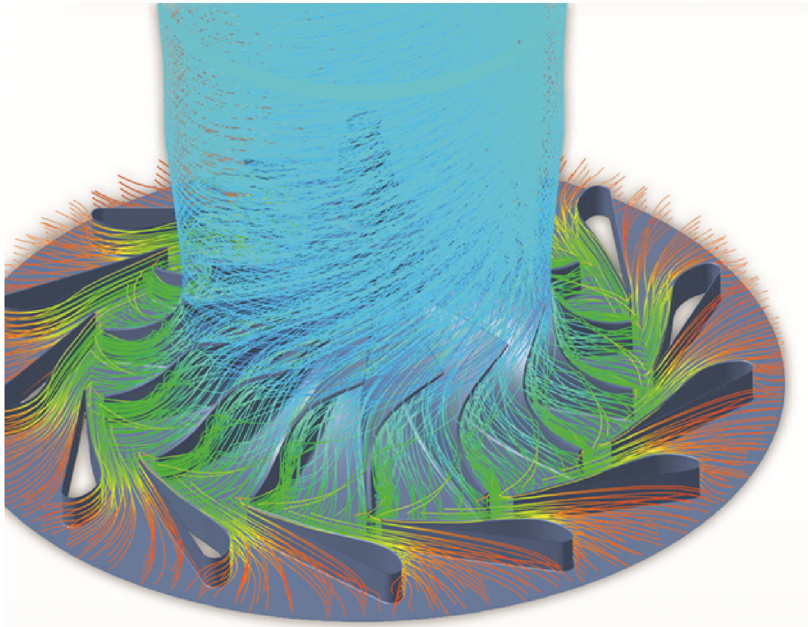
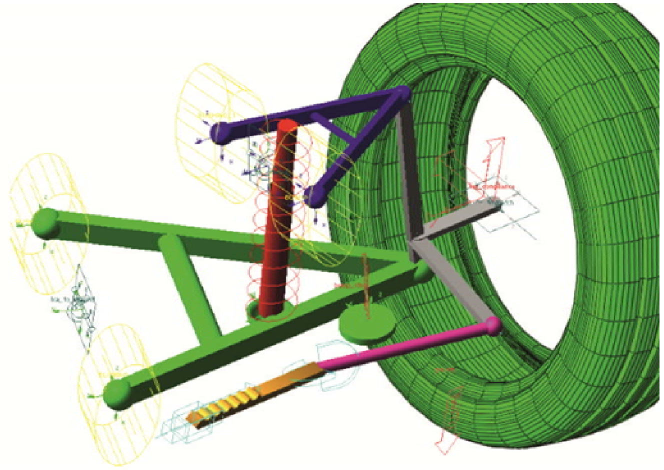
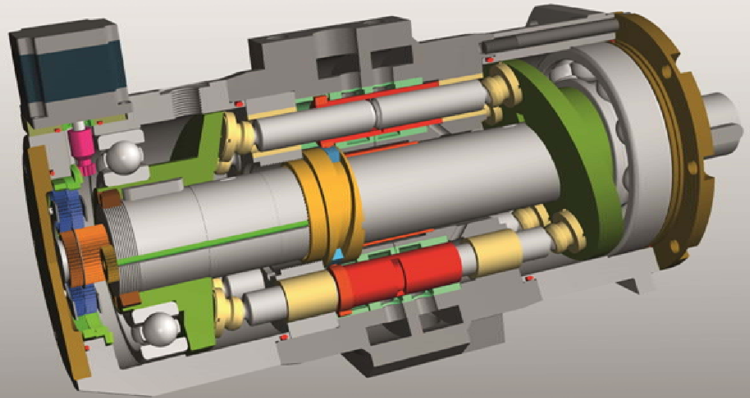
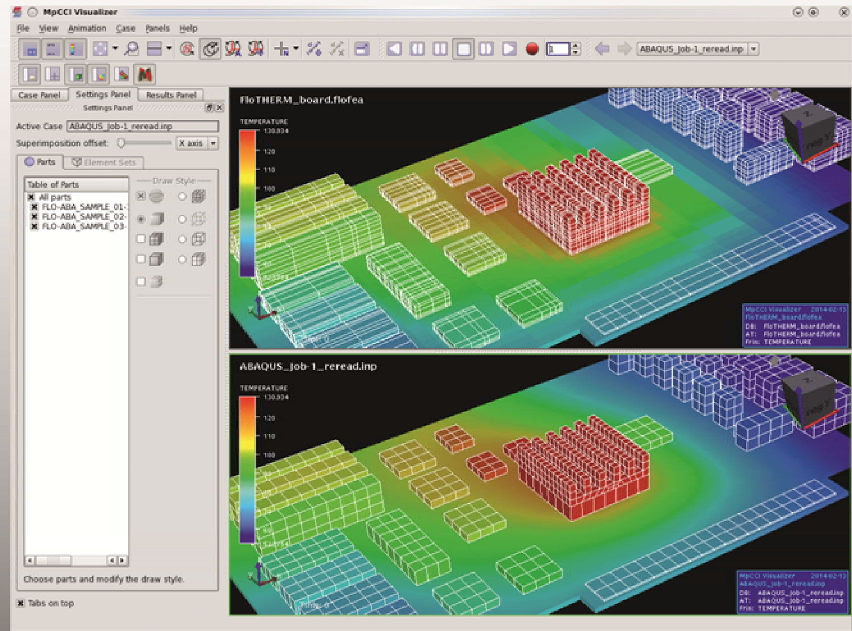




MpCCI

Multiphysics Interfaces





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Fraunhofer Institute for Algorithms and Scientfic Computing - SCAI

Multiphysics
Klaus Wolf , Johannes Linden

High Performance Computing
Dr. Thomas Soddemann, Johannes Linden

Optimization
Dr. Ralf Heckmann

Fast Solvers
Dr. Klaus Stüben

Bioinformatics
Prof. Dr. Martin Hofmann-Apitius, Dr. Marc Zimmermann (dp.)

High Performance Analytics
Dr. Tanja Clees

Virtual Material Design
Dr. Jan Hamaekers

Numerical Data-Driven Prediction
Prof. Dr. Jochen Garcke

Computational Finance
Prof. Dr. Thomas Gerstner

Meshfree Multiscale Methods
Prof. Dr. Marc Alexander Schweitzer

AUTO COMPACTOR automatic compact arrangement
AUTO NESTER-L automatic nesting
AUTO NESTER-T automatic marker making
CUT PLANNER automatic cut planning
PACK Assistant
MpCCI
SAMG Algebraic Multigrid Methods for Systems
SCAIVIEW
ProMiner Recognition and Normalization of Named Entities in Scientific Text
chemoCR chemical compound reconstruction
MYNTS
DesParO
TREMOLO X

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MpCCI - Multiphysics Tools by Fraunhofer SCAI

- **MpCCI Cosimulation**
  - Tool for code coupling for static or transient simulation setups, usually with a bi-directional data exchange on diversely discretized meshes (point, line, surface, volume).
  - Non-file based approach.
- **MpCCI FSI Mapper**
  - Tool for data mapping between diversely discretized meshes usually in one direction as a singular event.
  - Performs mesh alignment
  - File based approach.
  - Plugin for Ensight and as library for code integration available.
- **MpCCI Mapper**
  - Tool to pass data through different simulations in a process workflow.
  - Checks geometry compliance, combines and compares experimental and simulation results, performs mesh alignments and maps data on nodal-, element- or shell-layer based locations.
  - File based approach.

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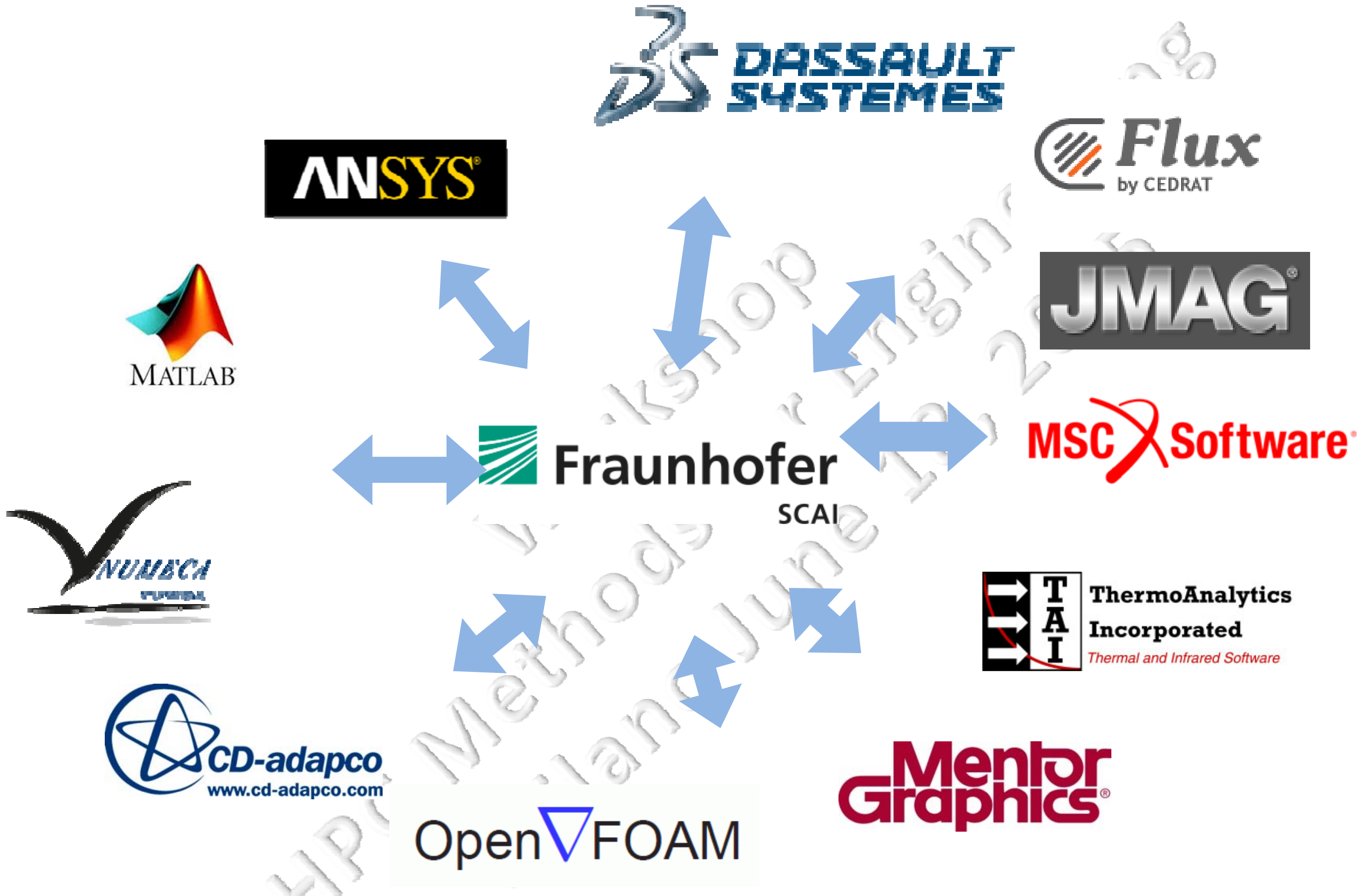
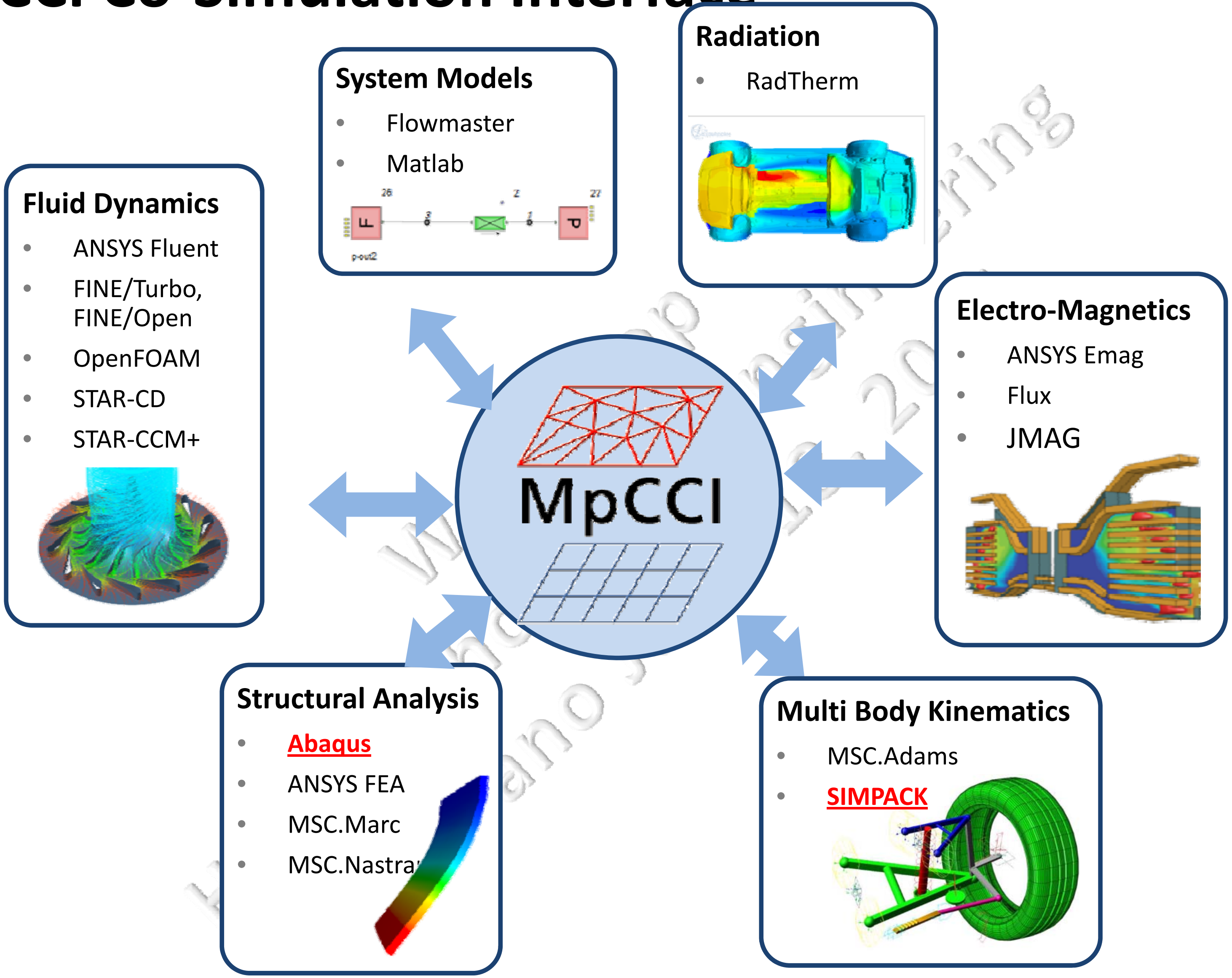
MpCCI - Multiphysics Interfaces by Fraunhofer



MpCCI Co-Simulation Interface

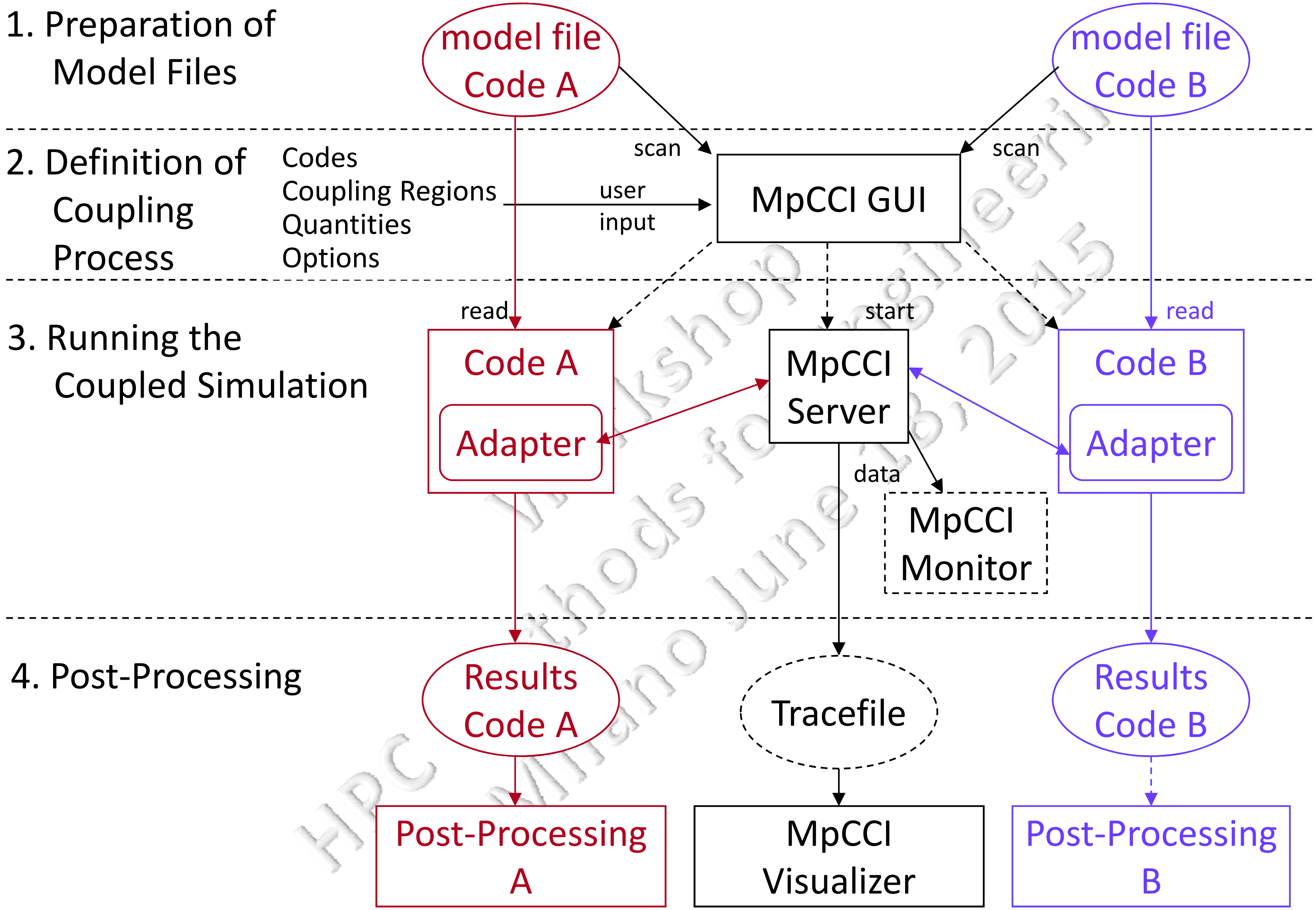
MpCCI Co-Simulation Interface



MpCCI Cosimulation Interface – General Features

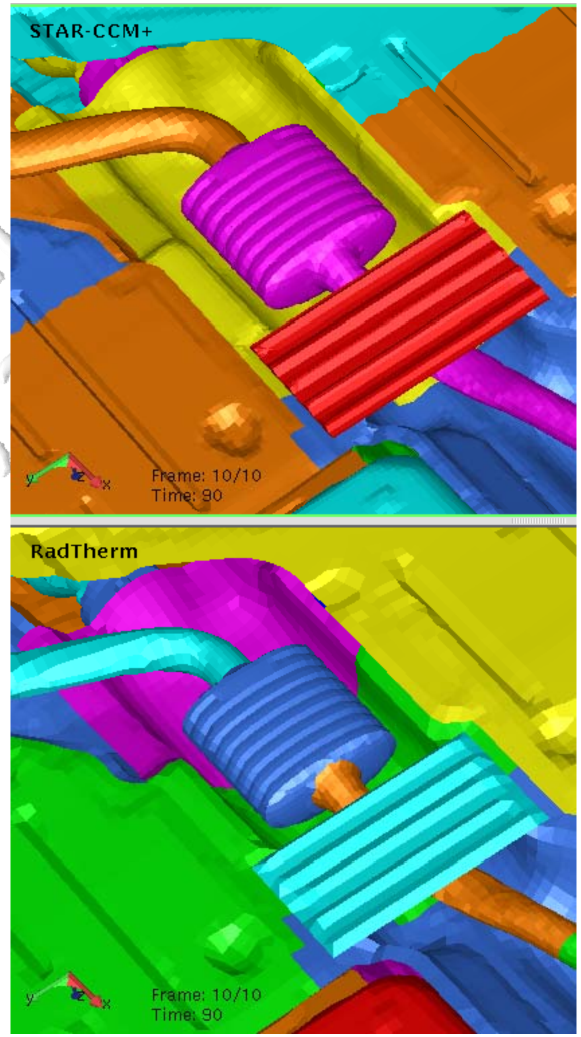
- Graphical user interface, runtime monitoring and visualization tool
- Coupling quantities
  - Pressure, Force, Deformation, Temperature, Heat Flux, Heat Transfer Coefficient, Film Temperature, Electrical Conductivity, Joule Heat, Global Quantities, and more…
  - Complex pressures (e.g. in turbomachinery NLH analysis to harmonic structural analysis)
  - Ramping in time, under and over relaxation with constant or variable factor
  - Handling of orphaned regions (e.g. orphan filling through extrapolation)
- Mapping Schemes
  - Shape-function based interpolation
  - Coupling of periodic models (e.g. average over rotation-axis etc.)
- Coupling for static, transient or mixed problems
- Time marching algorithms
  - Constant coupling time, master-slave mode for time control
  - Interpolation in time through MpCCI server
  - Synchronous or asynchronous data exchange
- Iterative FSI
  - In combination with ANSYS Fluent, OpenFOAM, Abaqus, MSC Nastran, more codes in preparation.

MpCCI Cosimulation Interface - Workflow Overview



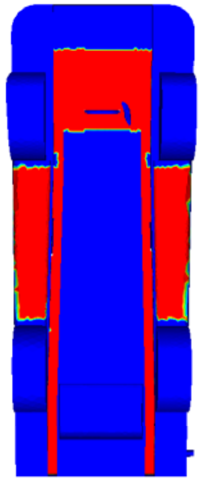
MpCCI Cosimulation - Geometry Deviations

- **<u>Possibility 1: Search Radius</u>**
- Increase the search radius (Multiplicity Factor) to catch geometry deviations.
Caution: For nearby parts in one coupling mesh wrong associations might be possible.
- **<u>Possibility 2: Default Values</u>**
- Orphaned regions will be impressed with default values, e.g. HTCoeff = 0.0 = adiabatic.
Caution: What is a good default value for temperatures?
- **<u>Possibility 3: Mean Values</u>**
- Orphaned regions will be impressed with mean values from the region.
- **<u>Possibility 4: Extrapolation</u>**
- The orphaned regions are filled by extra- and interpolation from neighboring non-orphaned parts
- Caution: Large orphaned regions might be filled not as desired.

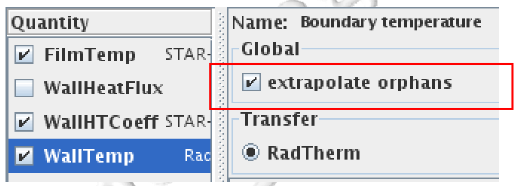


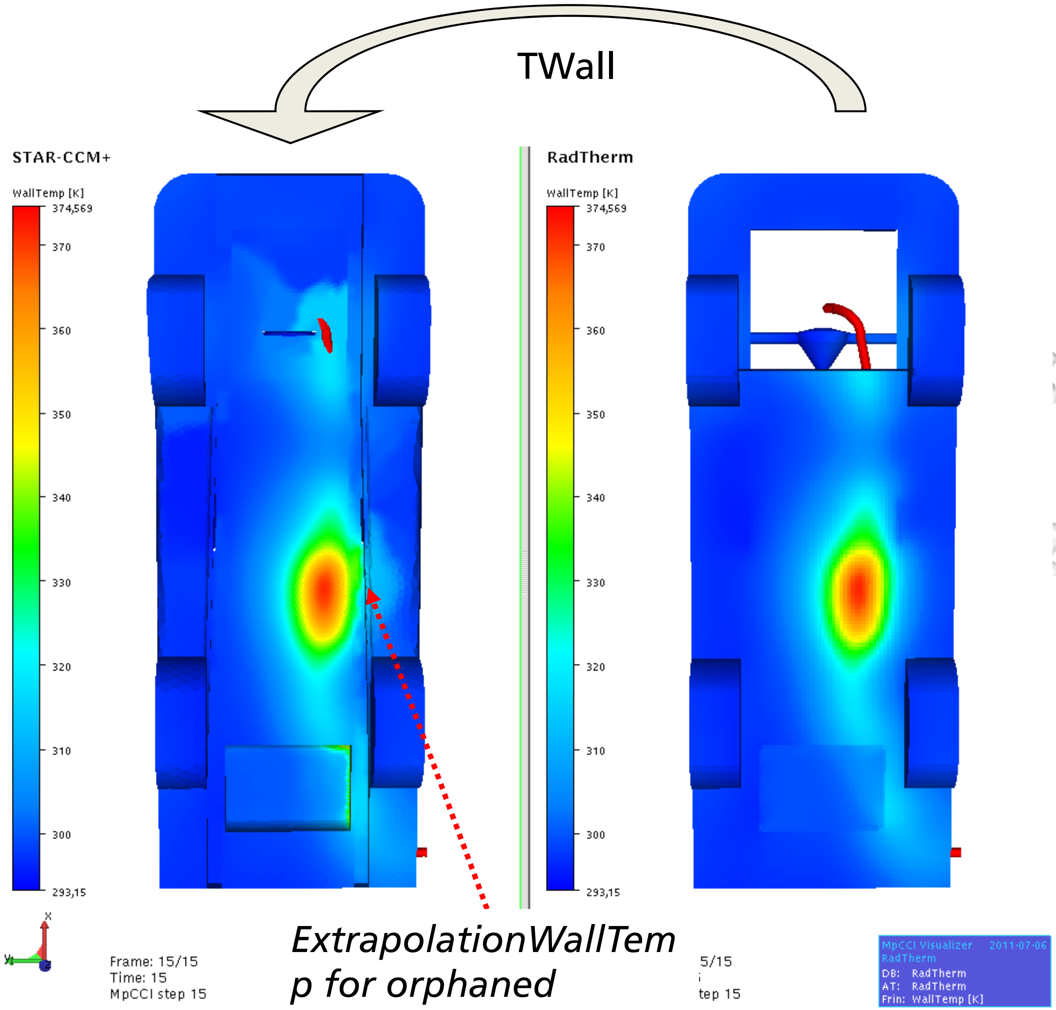
MpCCI Cosimulation – Orphans Extrapolation

Orphan Regions



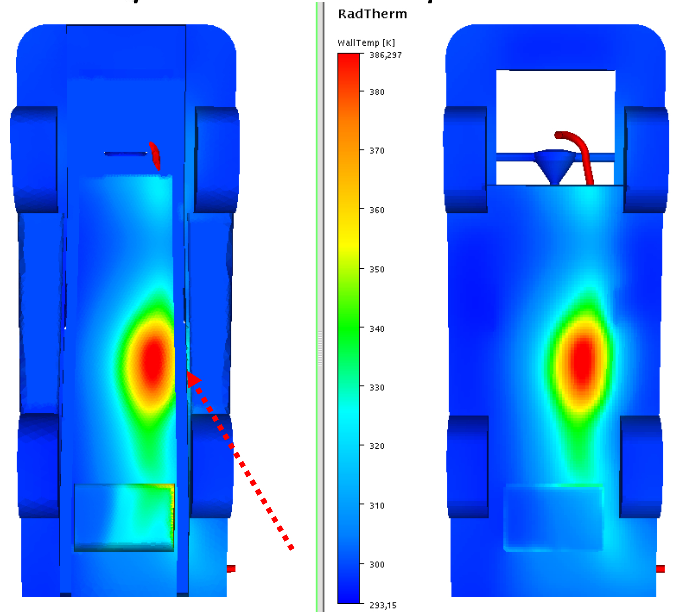
MpCCI GUI





ExtrapolationWallTemp for orphaned regions

For comparsion: no extrapolation



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Fluid-Structure Interaction

Fluid-Structure Interaction / Cosimulation

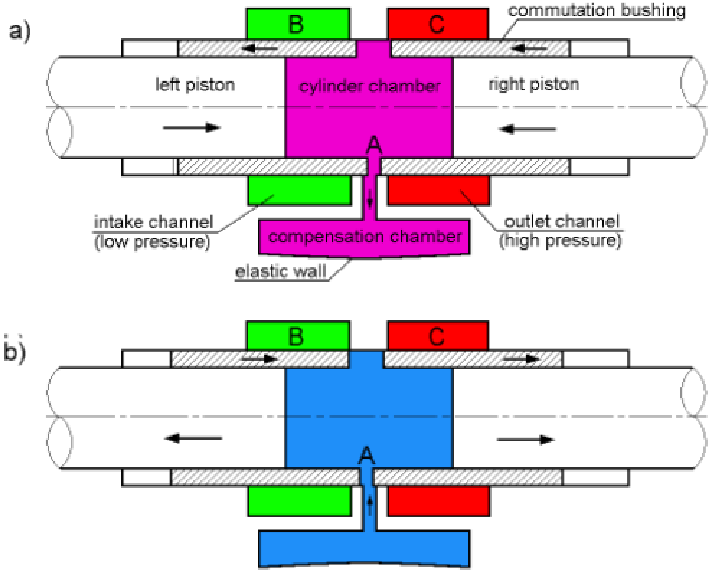
- General Features
  - Coupling quantities
    - Pressure, Force
    - Temperature, Heat Flux, Heat Transfer Coefficient, Film Temperature
  - Quantity exchange
    - Ramping
    - Under and over relaxation with constant or variable factor
    - Handling of orphaned regions
  - Mapping Schemes
    - Standard nearest-neighbour or shape-function based interpolation (most CFD tools to Abaqus static or transient analysis)
    - Average over rotation-axis (e.g. Fluent ‘frozen rotor’ to Abaqus)
    - Complex pressures (from FINE/Turbo harmonic analysis ’NLH’ to harmonic structural analysis in Abaqus)

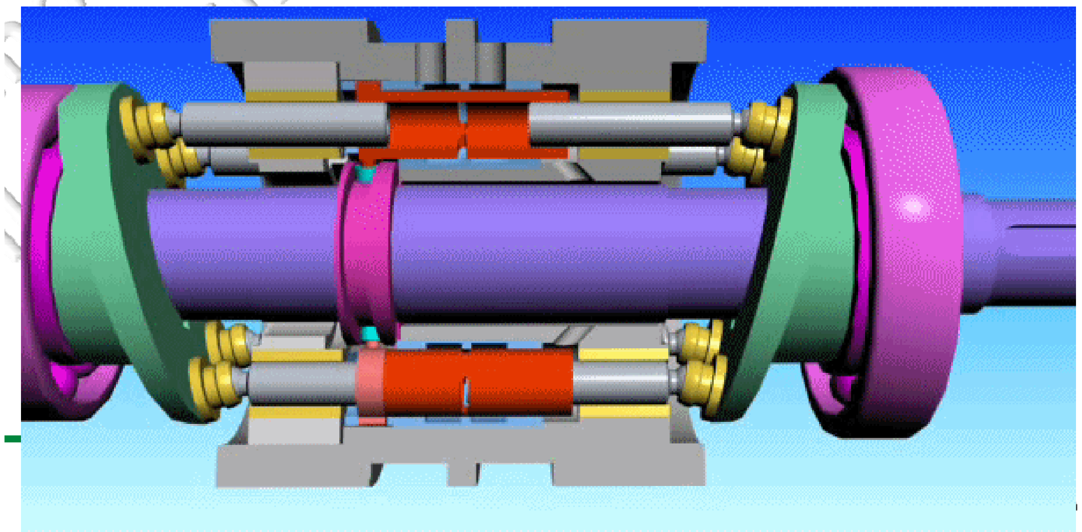
Fluid-Structure Interaction / FSIMapper

- General Features
  - Coupling for static problems
  - Coupling transient CFD with static or dynamic Abaqus
  - Time marching algorithms
    - Constant coupling time
    - Master-slave mode for time control
    - Interpolation in time through MpCCI server
    - Synchronous or asynchronous data exchange
  - Iterative FSI
    - In combination with ANSYS Fluent or OpenFOAM
    - Iterative extension for STAR-CCM+ under development

Fluid-Structure Interaction – Hydraulic Pump

- PWK-pump with a cam-driven commutation unit
  - Problem: pump model generated noise and vibration
  - Reason: pressure peaks during opening and closing of inlet channels
  - Solution: introduction of a compensation chamber connected to all cylinders
  - FSI: using Abaqus – MpCCI –Fluent
  - Validation: very good compliance with experimental data – significantly better than CFD stand-alone





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Fluid-Structure Interaction – Spoiler Design

- Automotive Spoiler for High Speed Driving Modes
  - Problem: spoiler design needs to be adjusted to changing F1 rules
  - FSI models (static and transient)
    - FSIMapper to do first ‘pressure’ checks
    - using Abaqus – MpCCI – OpenFOAM (~100 Mio cells)
    - fully automated workflow for decomposed OF meshes
    - local mesh morphing around spoiler area
    - running on 500 Linux cores
    - batch support

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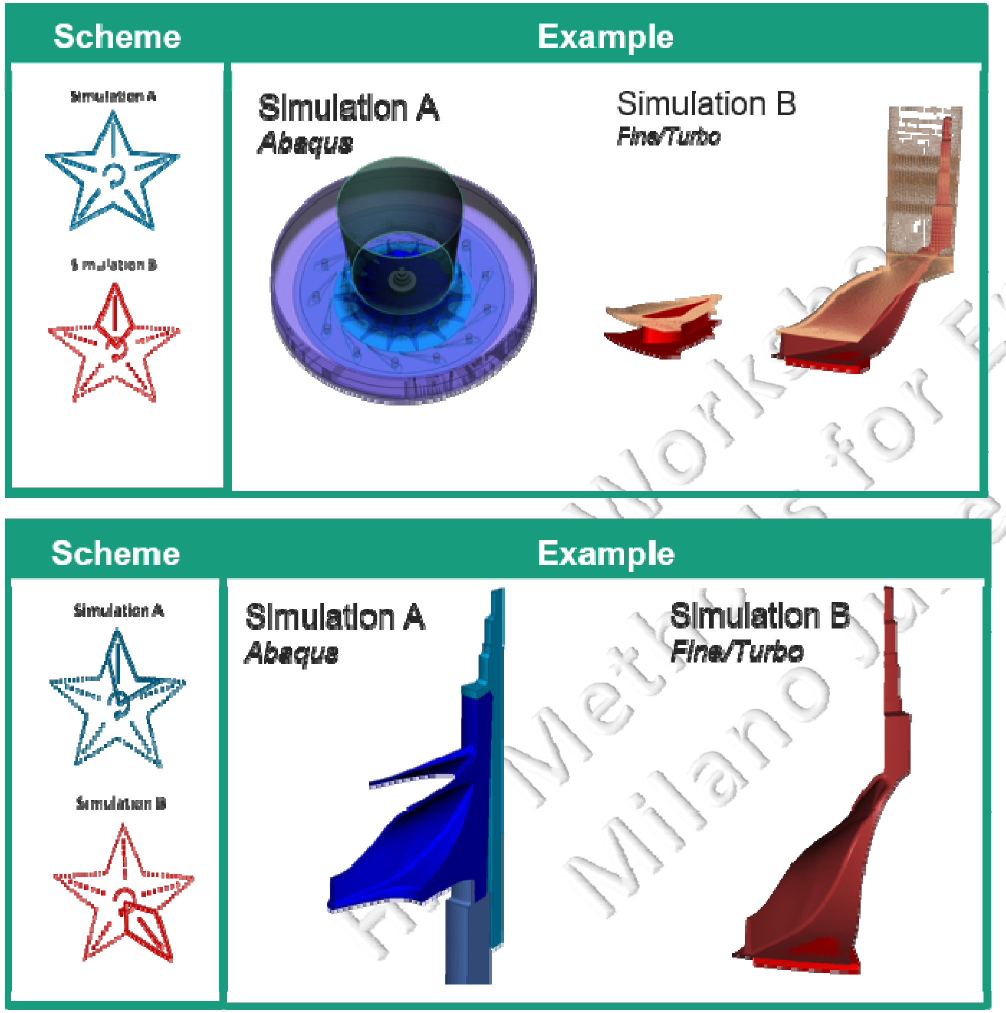
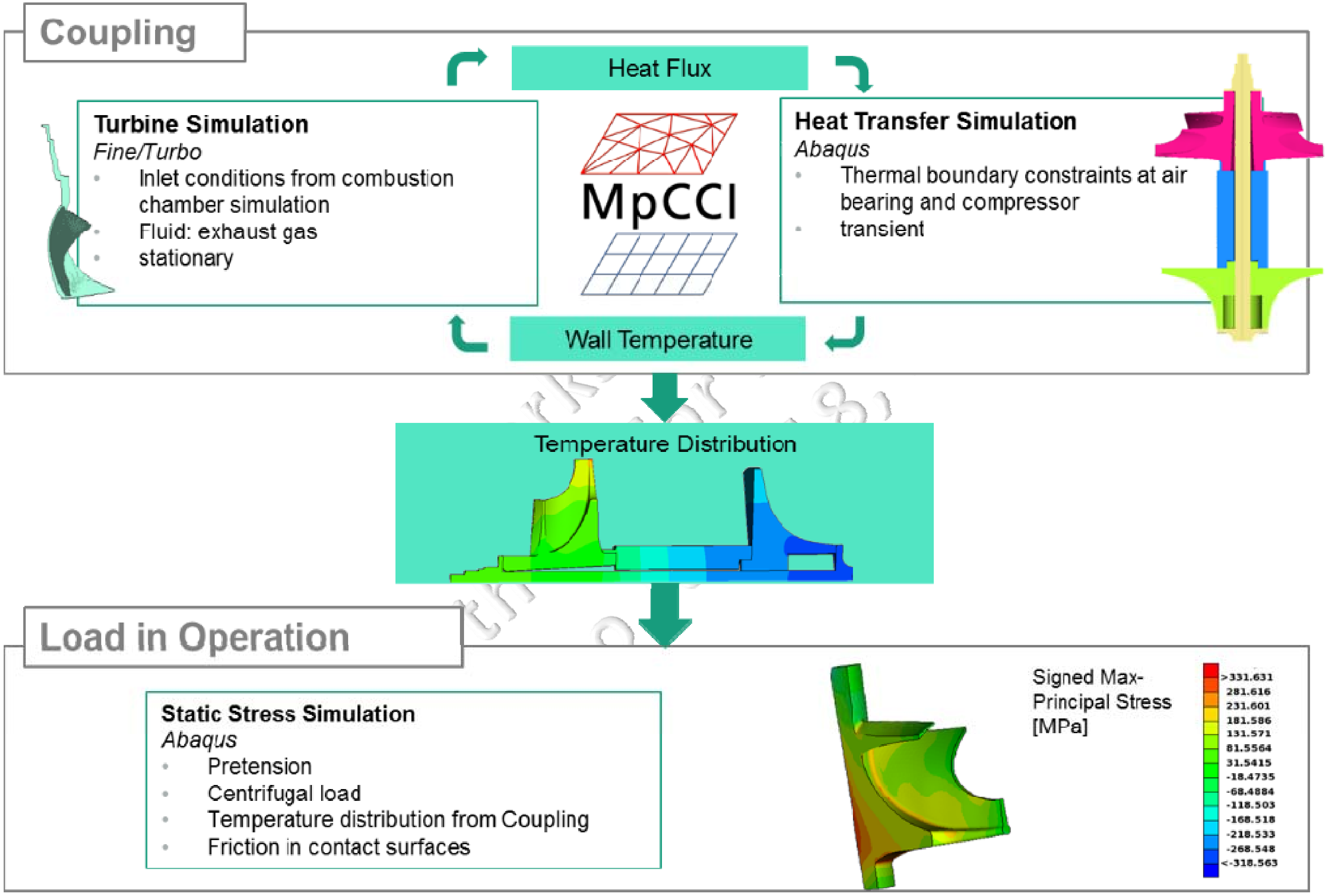
Fluid-Structure Interaction – Turbo Machinery



Coupling Periodic Models with Different Section Shapes and Positions

➡ **Saves Modelling and Computation Time**

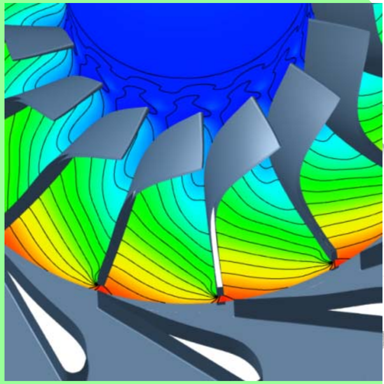
Fluid-Structure Interaction – Turbo Machinery



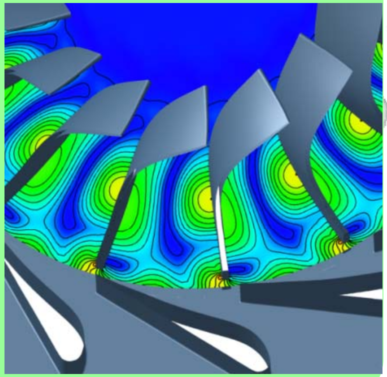
Fluid-Structure Interaction – Turbo Machinery

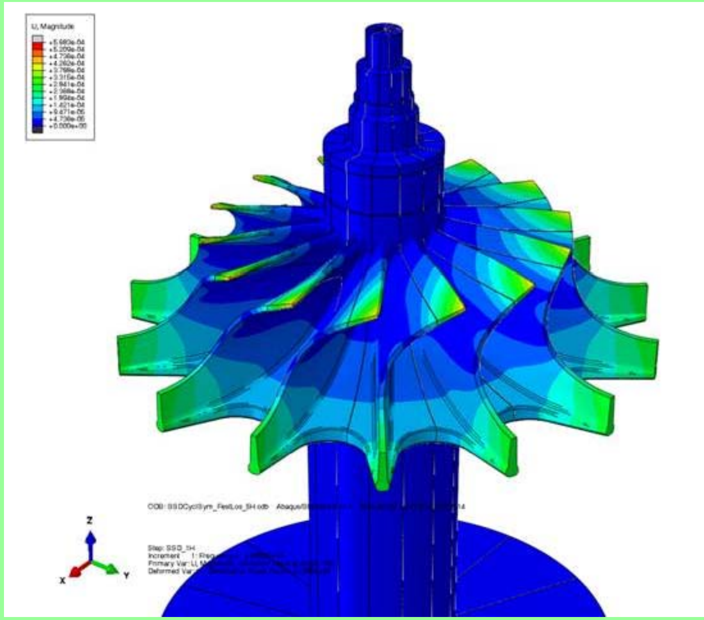
Average pressure
Complex pressure amplitudes

Average
pressure field



Amplitudes of
1. harmonic





Blade vibrations due to pressure
fluctuations from 1. harmonic

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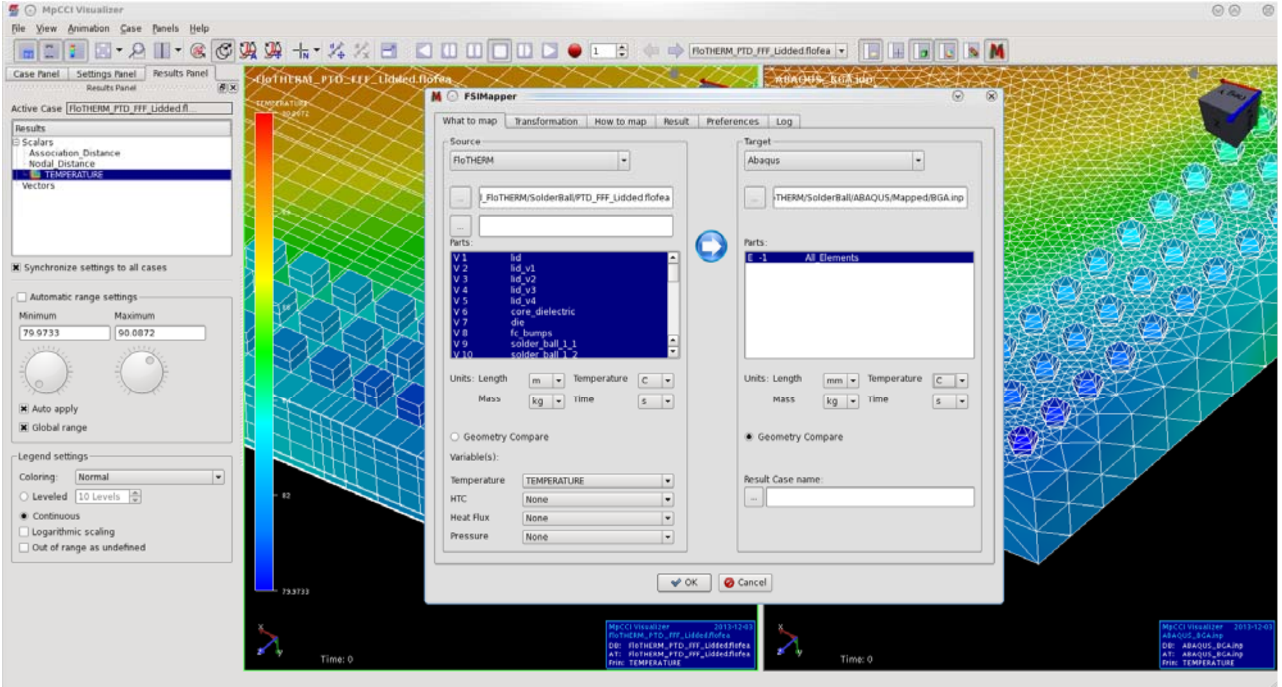
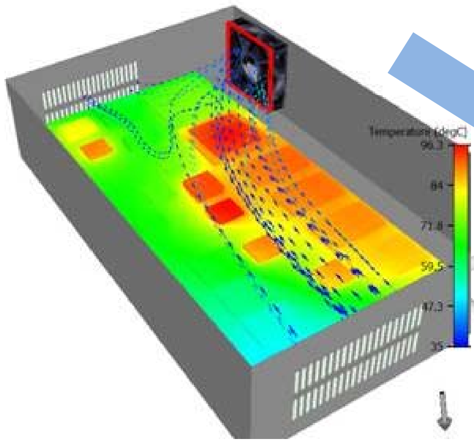
MpCCI FSIMapper



Results from CFD

- FloEFD 13
- FloTHERM 10
- ANSYS/Fluent
- EnSight Gold Format
  - Ansys/CFX
  - Converge
  - STAR-CCM+
  - AVL Fire
  - …



MpCCI

External Loads for FEA

- Abaqus
- Ansys
- Nastran

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Vehicle Dynamics – FEA and MBS

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Vehicle Dynamics – FEA and MBS

- General Features
  - Non-linear or plastic deformation in single components (Abaqus model)
  - Detailed analysis of the dynamic of the vehicle (MBS model)
  - Multiple connection points between MBS and FEA
  - Quasi-iterative coupling scheme
  - Abaqus
    - Rigid body
    - REFERENCE NODE as interface
  - MSC.Adams
    - Additional GFORCE element
    - IMARKER as interface

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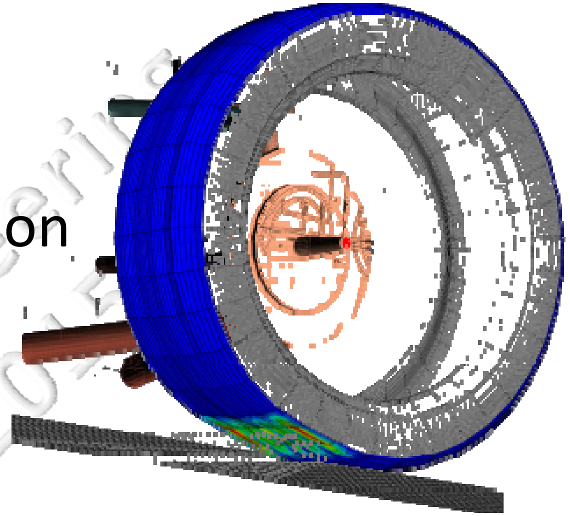
Vehicle Dynamics – Driving over Obstacles



- Non-Linear Tire Deformations and Suspension
- Co-Simulation is more realistic
- Reuse of existing models
- Coupling Quantities
  - Position of the wheel hub is send by MSC.Adams and received by Abaqus
  - Reaction Force on the wheel hub is send by FEA and received by MSC.Adams
- Currently evaluated by EDAG/BMW and other OEMs
  - Recent car geometries
  - Standard driving cycles

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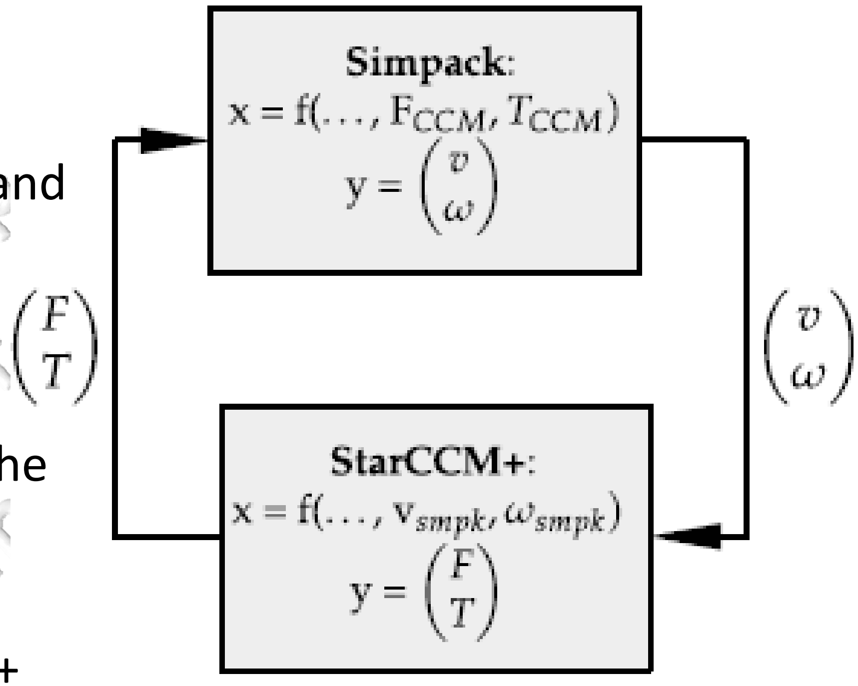
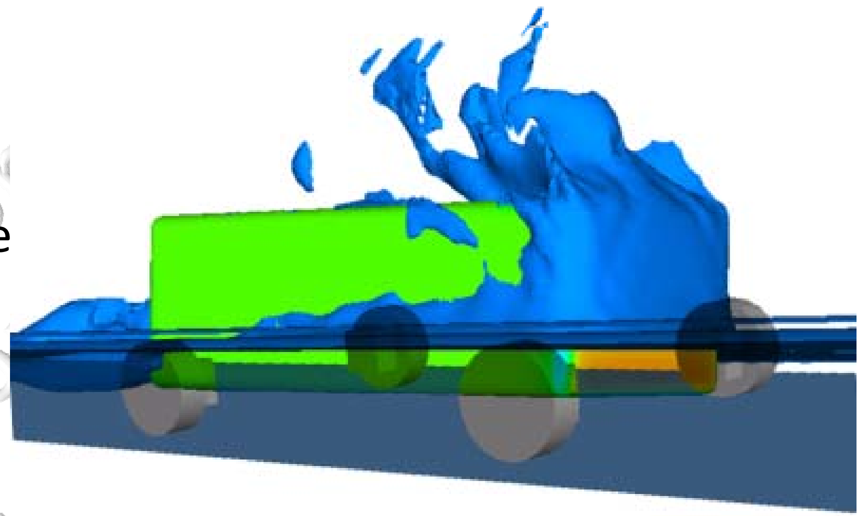
Vehicle Dynamics – CFD and MBS

- General Features
  - Analyzing interaction between fluid and the rigid body system
  - Velocity and angular velocity from SIMPACK to STARCCM+
  - Kinematic quantities are applied to the motion element in STARCCM+
  - Force and torque are calculated as resultants over surfaces in STARCCM+
  - Force and torque from STARCCM+ to SIMPACK



Vehicle Dynamics – CFD and MBS

- Automotive Cases
  - Deep water wading of a car
  - Side wind effects on trucks or busse



Deep Water Wading Simulation of Automotive Vehicles – JaguarLandrover & Fraunhofer SCAI Presentation NAFEMS WC 2015

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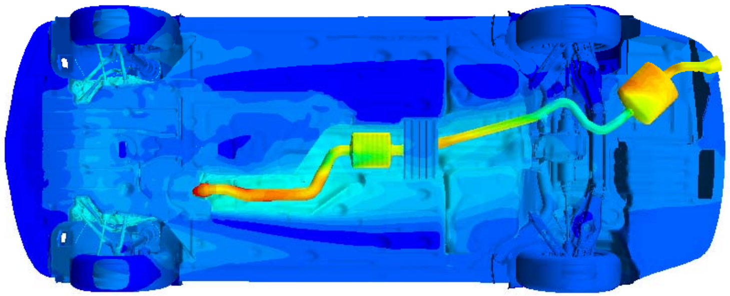
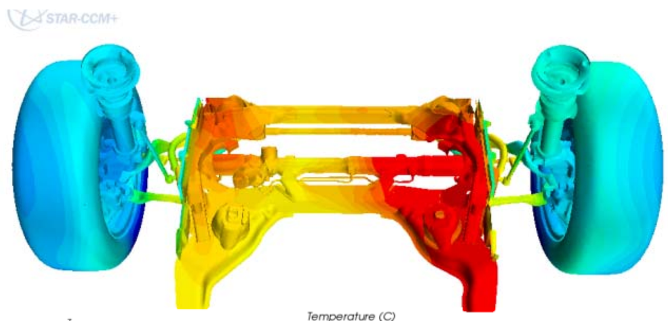
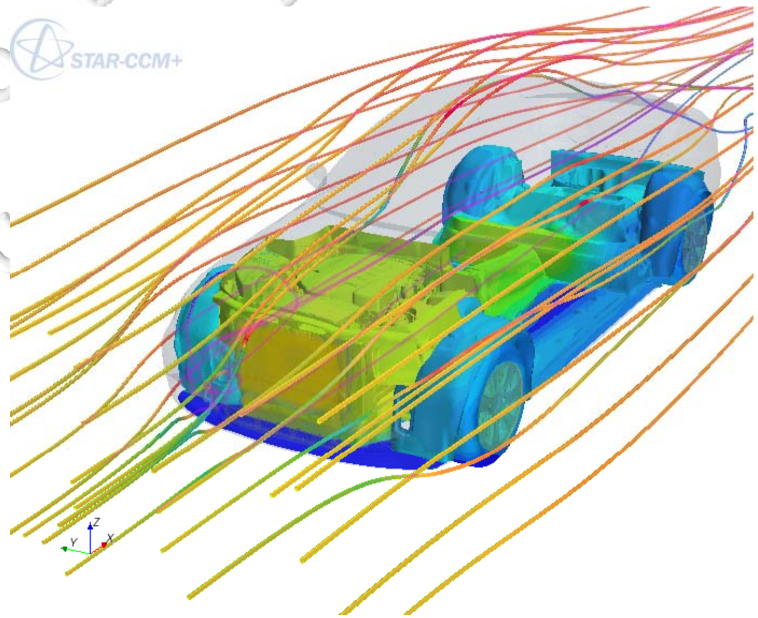
Full Vehicle Thermal Management

Full Vehicle Thermal Management

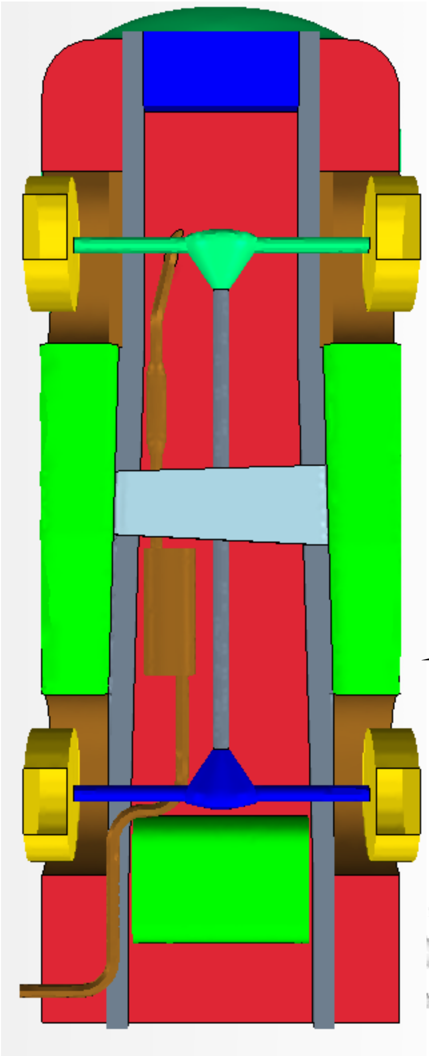
- Coupling CFD code and other thermal codes e.g. for radiation
- Fast and robust mapping even for geometrical deviations (e.g. extrapolation)
- Shell parts supported
- STAR-CCM+ sending heat coefficient and film temperature, RadTherm sending wall temperature







Full Vehicle Thermal Management - Concept

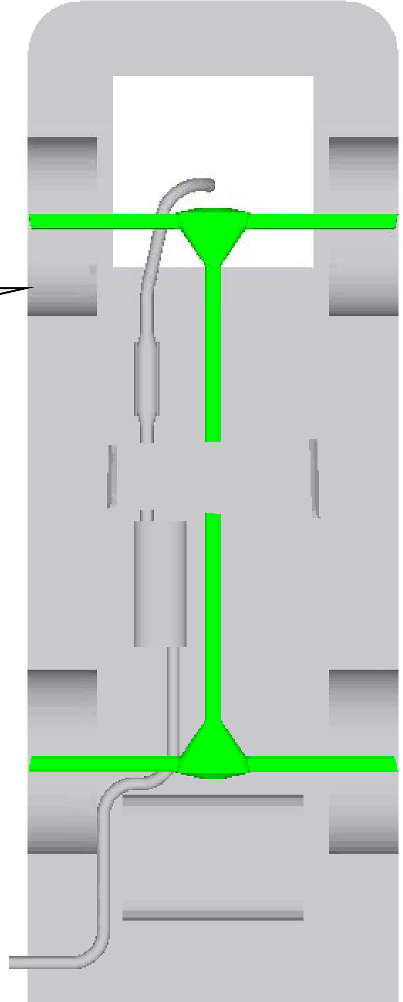


TFilm
HTCoeff

•**STAR-CCM+**

RadTherm

TWall

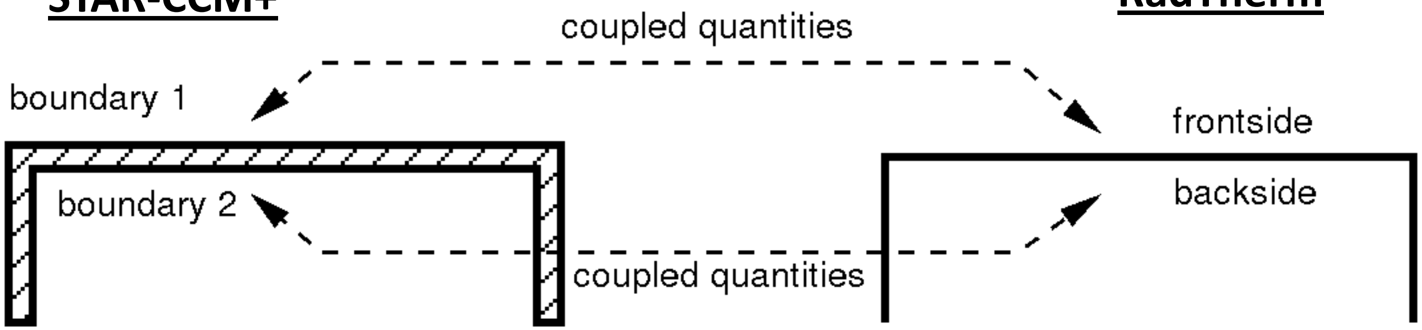


Start with uncoupled flow, use estimated wall temperatures Tw=const.

Start with uncoupled heat, use estimated convective conditions

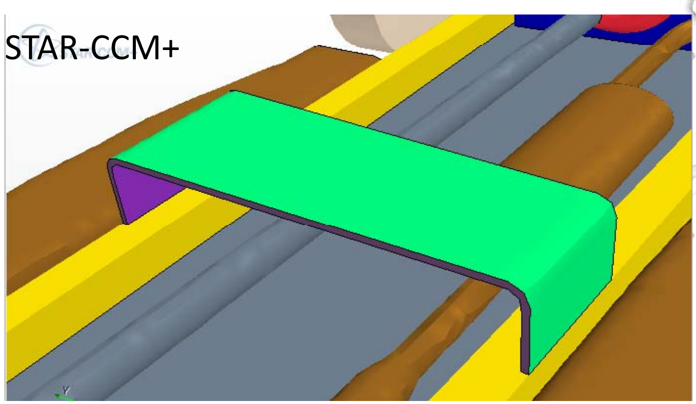
Full Vehicle Thermal Management – Detailed Geometry

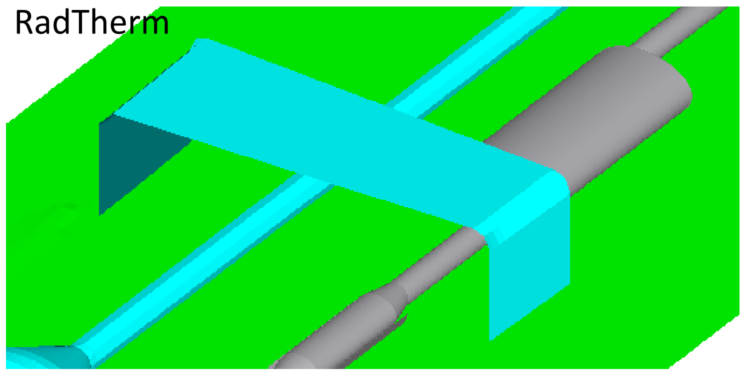
STAR-CCM+ | **RadTherm**



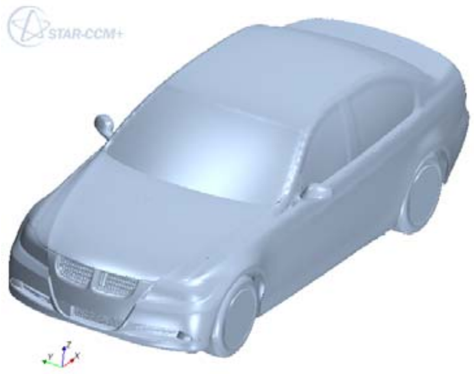
Coupling region 1	Coupling region 2
boundary 1, frontside	boundary 2, backside

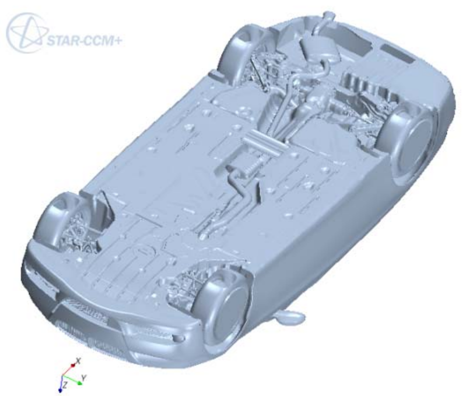
Example:





Full Vehicle Thermal Management – Validation Model





STAR-CCM+

approx. 45 mio cells

15 cell regions

525 boundary regions

MRF for fans and wheels

Porous regions for heat exchanger and cooling devices

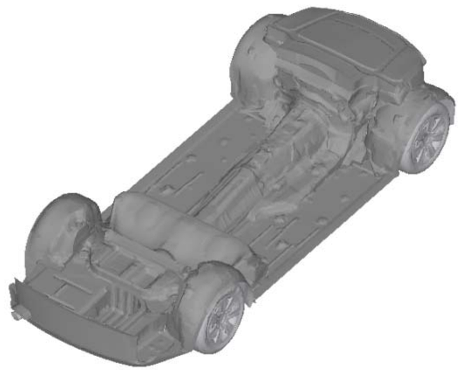
Wall rotation for shafts and axles

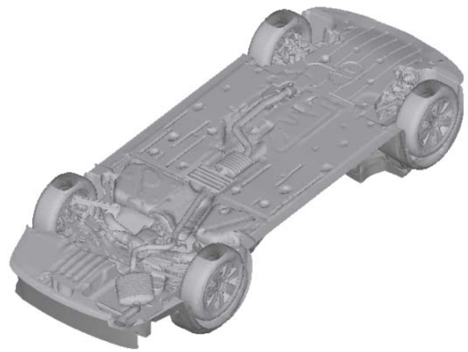
RadTherm

approx. 1 mio cells

323 shell parts

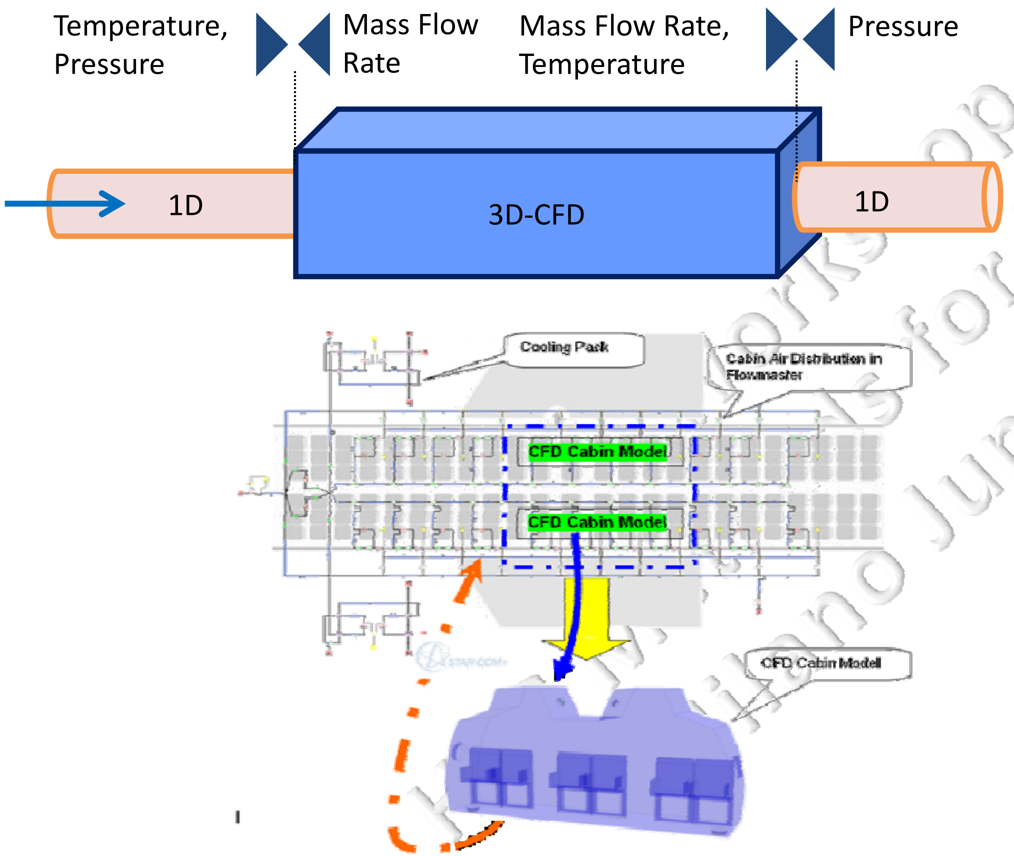
13 fluid parts for exhaust system

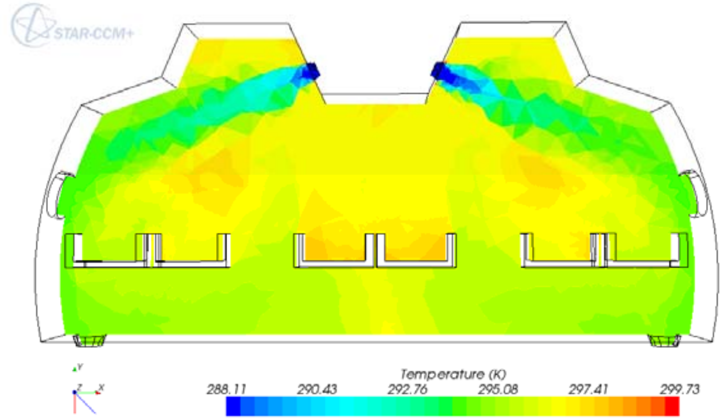


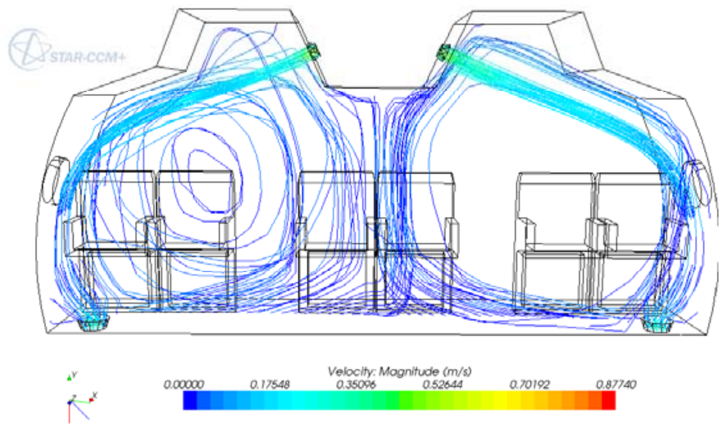


Comfort Analysis in Cabin

– Couple 1D-Flow Simulation (Flowmaster) with detailed CFD (STAR-CCM+) for Environmental Control in Aircraft Cabin

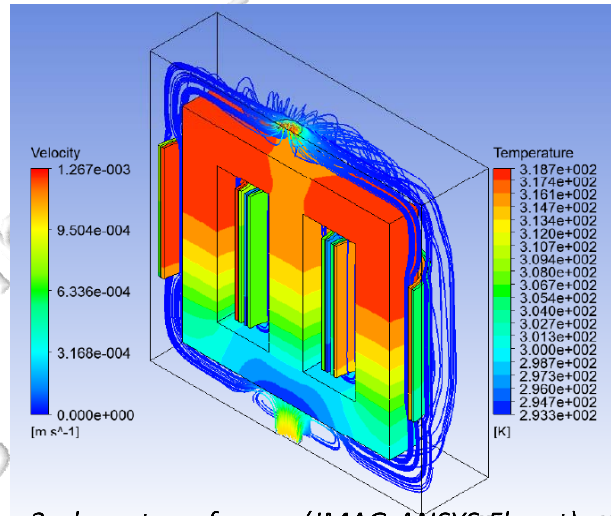




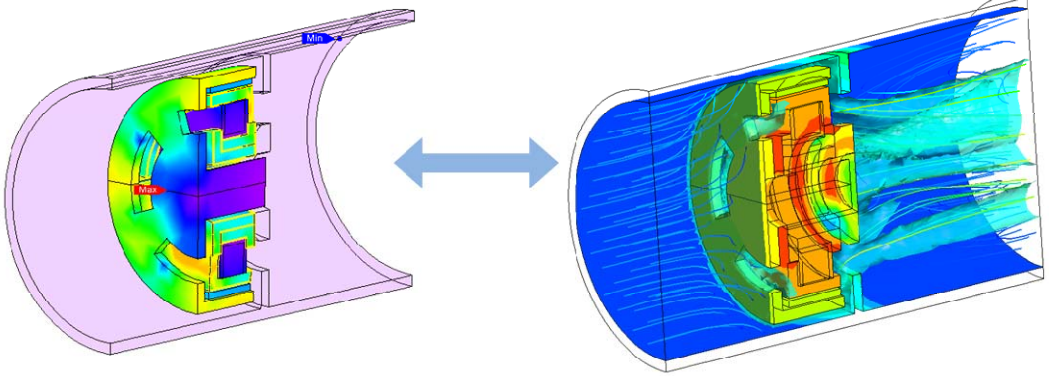


Electrical Systems

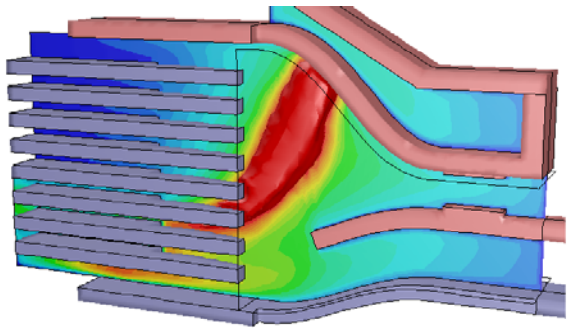
- Electric arc simulations in switching devices
- Magneto-thermal design of electrical systems like engines or transformers
- Magnetic valves
- Typical exchanged quantities i.a. are Electrical Conductivity, Lorentz forces, Joule Heat, Temperature.



3-phase transformer (JMAG-ANSYS Fluent)



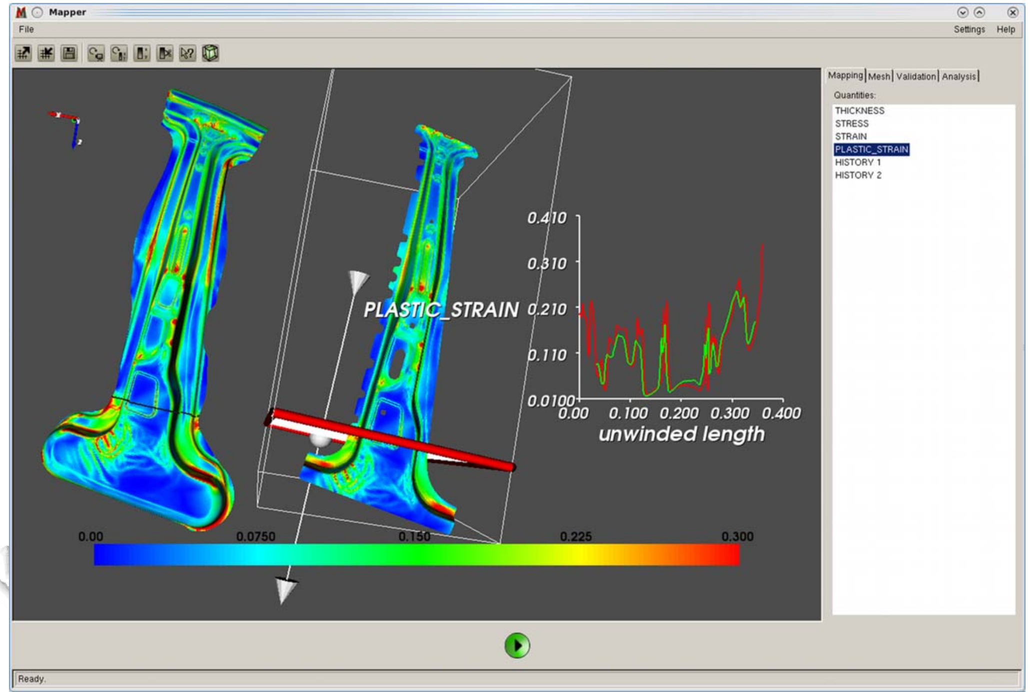
Electric motor (JMAG-ANSYS Fluent)



Circuit breaker (ANSYS Emag-ANSYS Fluent)

MpCCI Mapper

MpCCI Mapper

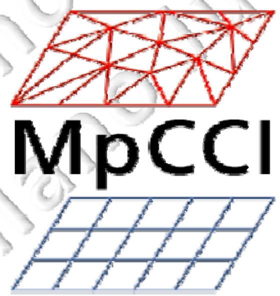


Manufacturing Simulation

- AutoForm *.af
- INDEED *.gns
- LS-Dyna *.key, *.dyn
- PAM-Stamp *_M00 - M99
- SYSWELD *.acs

Measurement Data

- AutoGrid *.dat
- Argus / Aramis *.txt
- Atos *.ply



Manufacturing History in FEA Models

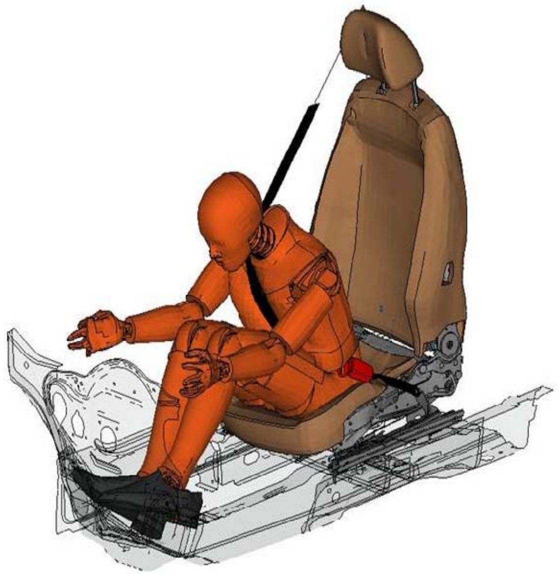
- Abaqus *.inp
- Ansys *cdb
- LSDyna *.key, *.dyn
- Nastran *nas
- PAM Crash *.pc, *.ps
- Radioss *D00

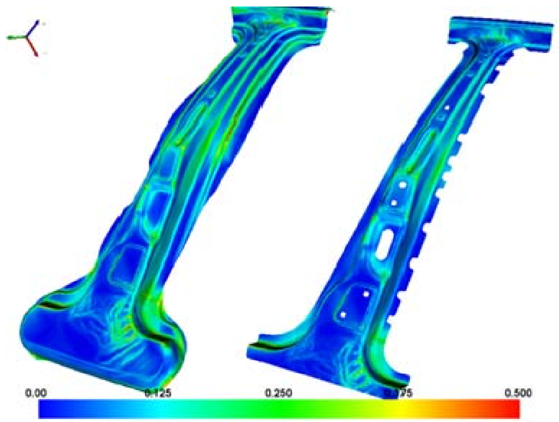
MpCCI Mapper - Simulation Workflows

- General Features of MpCCI Mapper
  - Automatic mesh alignment
  - Fast mapping algorithms
  - Shell-to-shell
  - Shell-to-volume
  - Volume-to-shell
  - Validation of mapping quality
  - Interactive and batch-processing

Mapper Example – Passive Safety

- Seat Systems – from Massive Forming to Crash
  - Local thickness reduction, stresses, plastic strain or material properties from single manufacturing steps may have critical influence on seat behavior.
- Virtual Painting Workflows – from Stamping over Painting to Crash
  - Transfer of mechanical parameters along the process chain stamping, welding and painting to analyze final product properties in crash simulation.
- Validation of Crash Models - Morphing Geometries between Simulation and Experiment
  - Validation of crash models by comparison of experimental data and simulation results. A GeoMorpher module morphs non-matching geometries onto each other

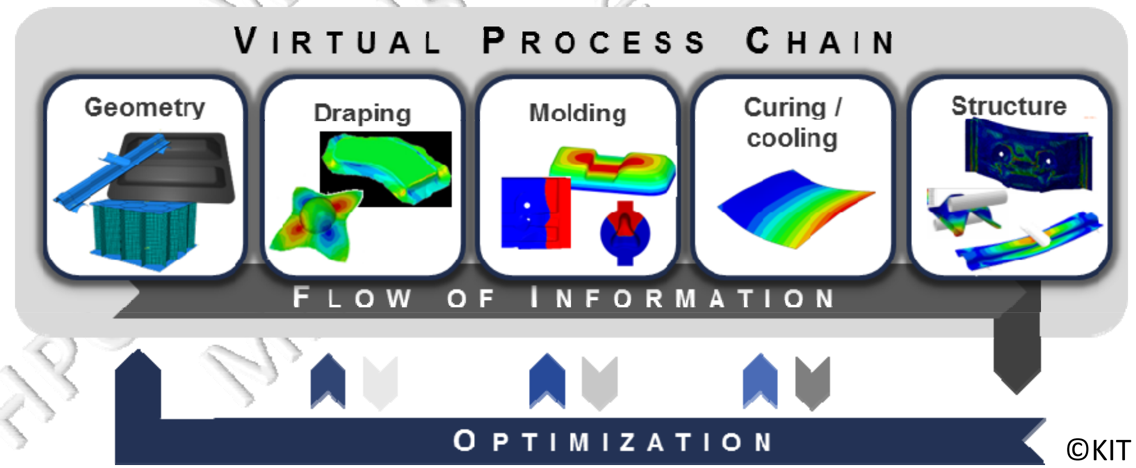




Mapper Example – Composites and Plastic Components

- CFRP* workflows – from Draping over Molding and Curing to Structural Analysis
  - Development of high-performance composite structures
  - KIT Karlsruhe used MpCCI Mapper for process workflow from “draping” over “molding” and “curing” to “structural analysis”.
- Structural Integrity of Blow Molded Plastic
  - Transfer local material properties and orientations from blow molding simulation to structural analysis (e.g. plastic bottles or fuel tanks).

* Carbon Fiber Reinforced Plastic



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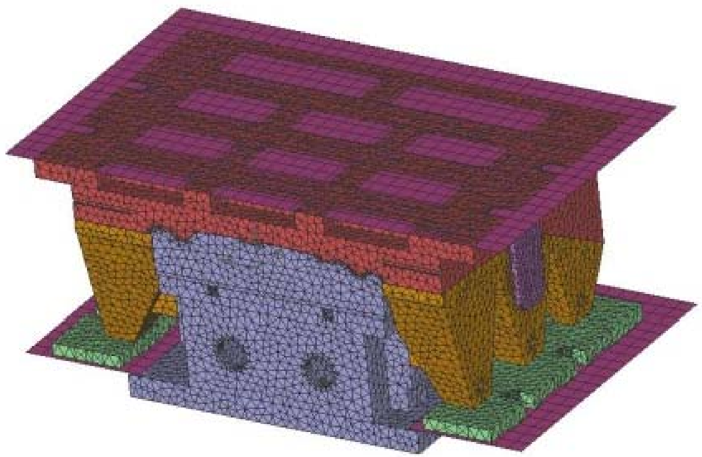
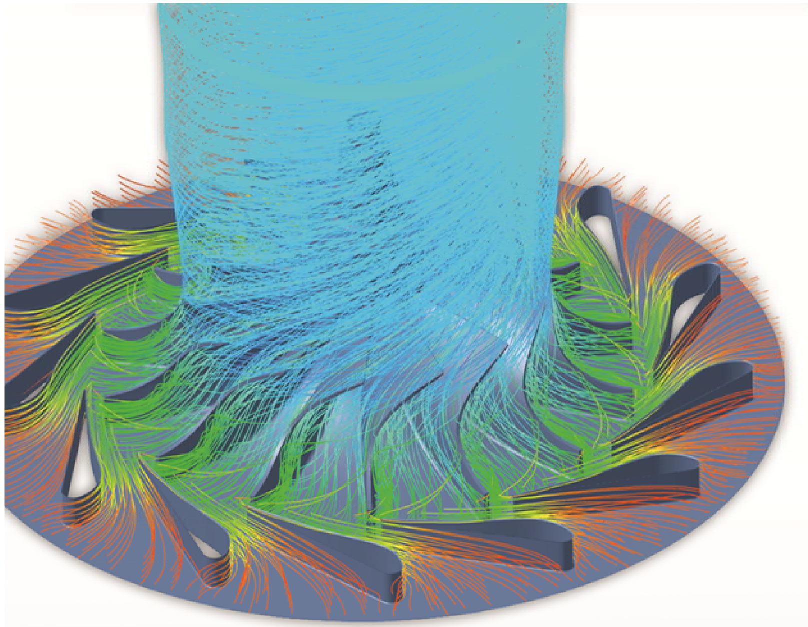
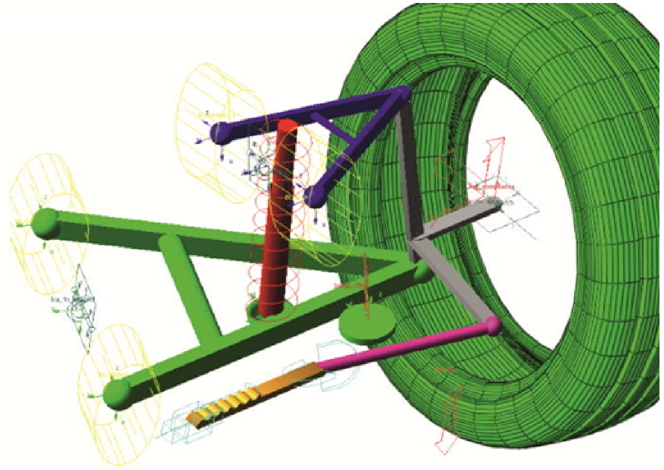
Mapper Example – Forming Tools and Material Properties

- Lighter Stamping Tools – use Forming Loads in Structural Optimization
  - Pressure loads from stamping simulation mapped on structural optimization
  - Improved designs with less total mass but same stability
- Validation of Material Model Parameters – compare Forming Results and Experimental Data
  - MpCCI Mapper used to compare experiment and simulation.

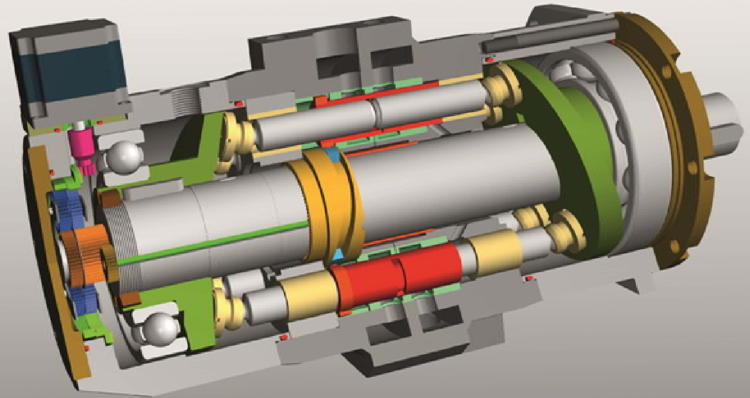


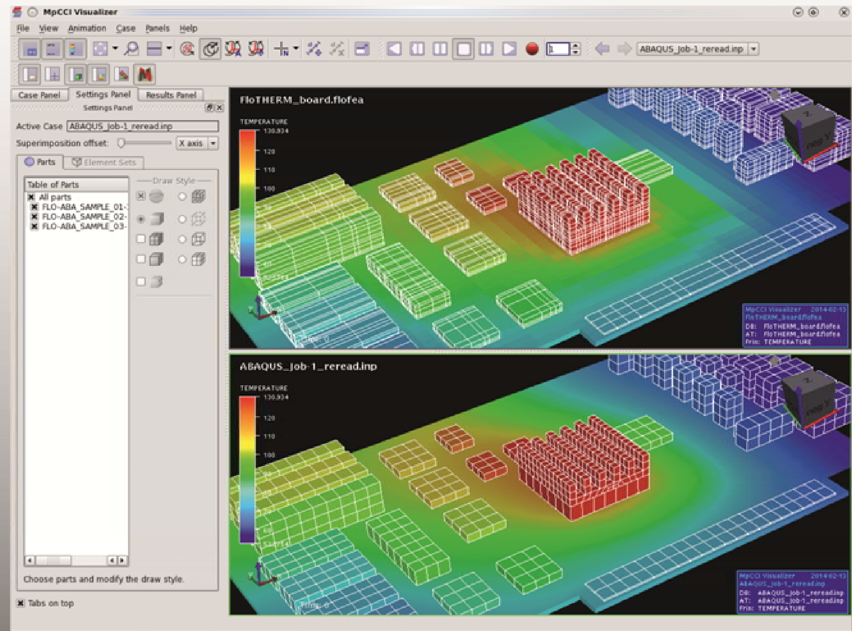




MpCCI

Thank You!





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