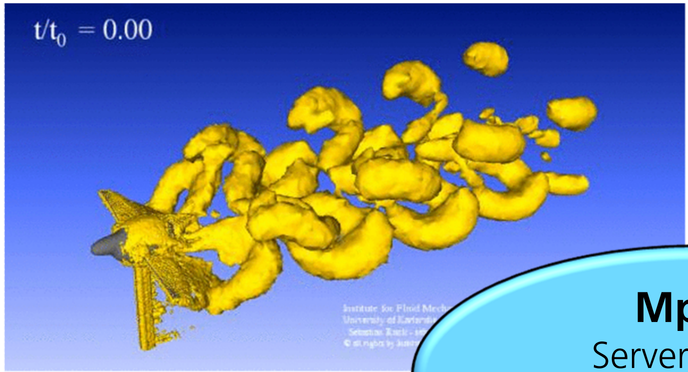
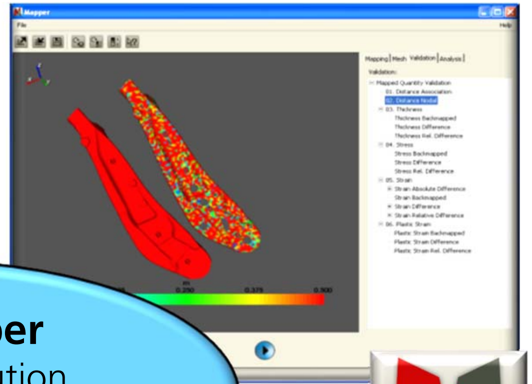
MpCCI – The Independent Code Coupling Interface

Dr. Carsten Brodbeck, Fraunhofer Institut SCAI

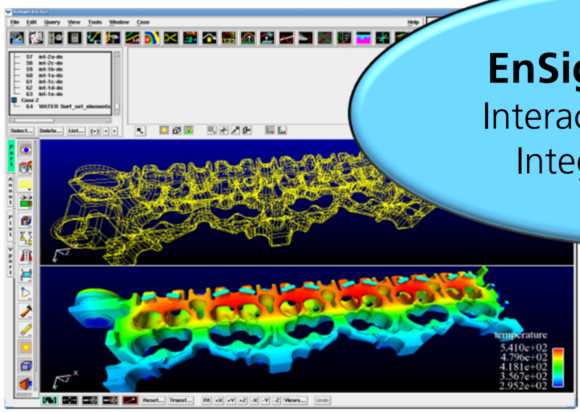
Fraunhofer SCAI – Multiphysics Solutions



MpCCI
Server Engine
Code Adapters
Runtime Environment

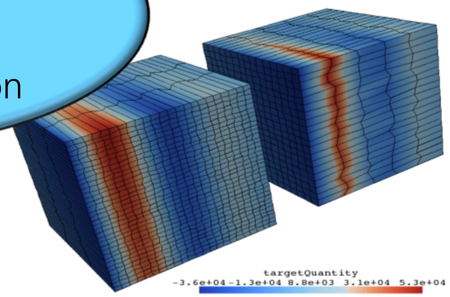


SCAIMapper
File Based Solution
Format IO
Interactive Mapping



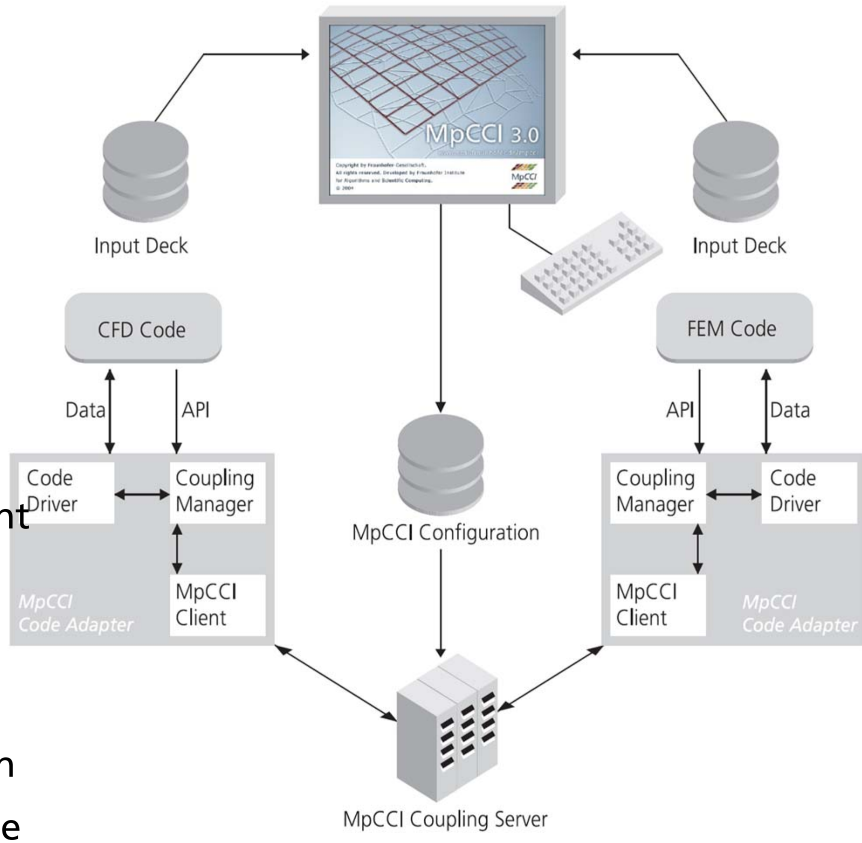
EnSight FSI-Plugin
Interactive FSI Mapping
Integrated Solution

MapLib
Neighborhood Search
Geometry Checks
Mapping & Extrapolation



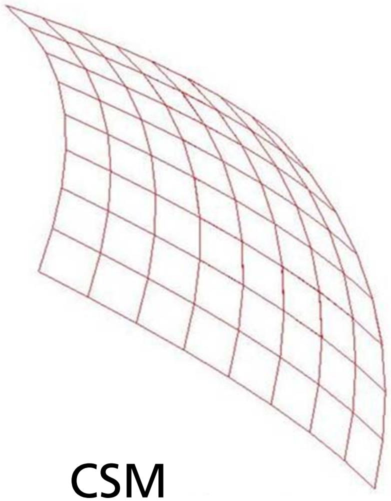
MpCCI – The Independent Code Coupling Interface

- Spatial Mapping
  - Flexible mapping workflows
  - Ramping and under-relaxation
  - Support for dynamic remeshing in code
  - Handling for orphaned nodes
- Coupling Schemes
  - Asynchronous buffered communication
  - Subcycling support
  - Explicit coupling, implicit coupling under development
- Coupled Simulations as Platform independent Computing
  - Coupling of parallel codes
  - Coupling of <n> codes and models in one application
  - Running on distributed and heterogeneous hardware
- Open interface through API



MpCCI - Data Transfer

3D surface coupling

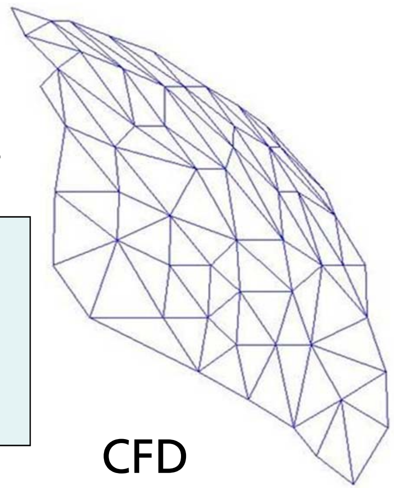


CSM

deformation →

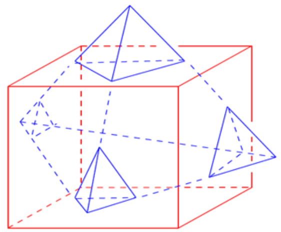
← forces

Mapping between non-matching Meshes

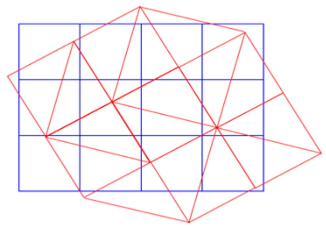


CFD

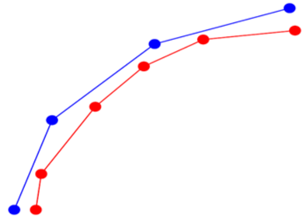
3D volume coupling



2D volume coupling



2D surface coupling



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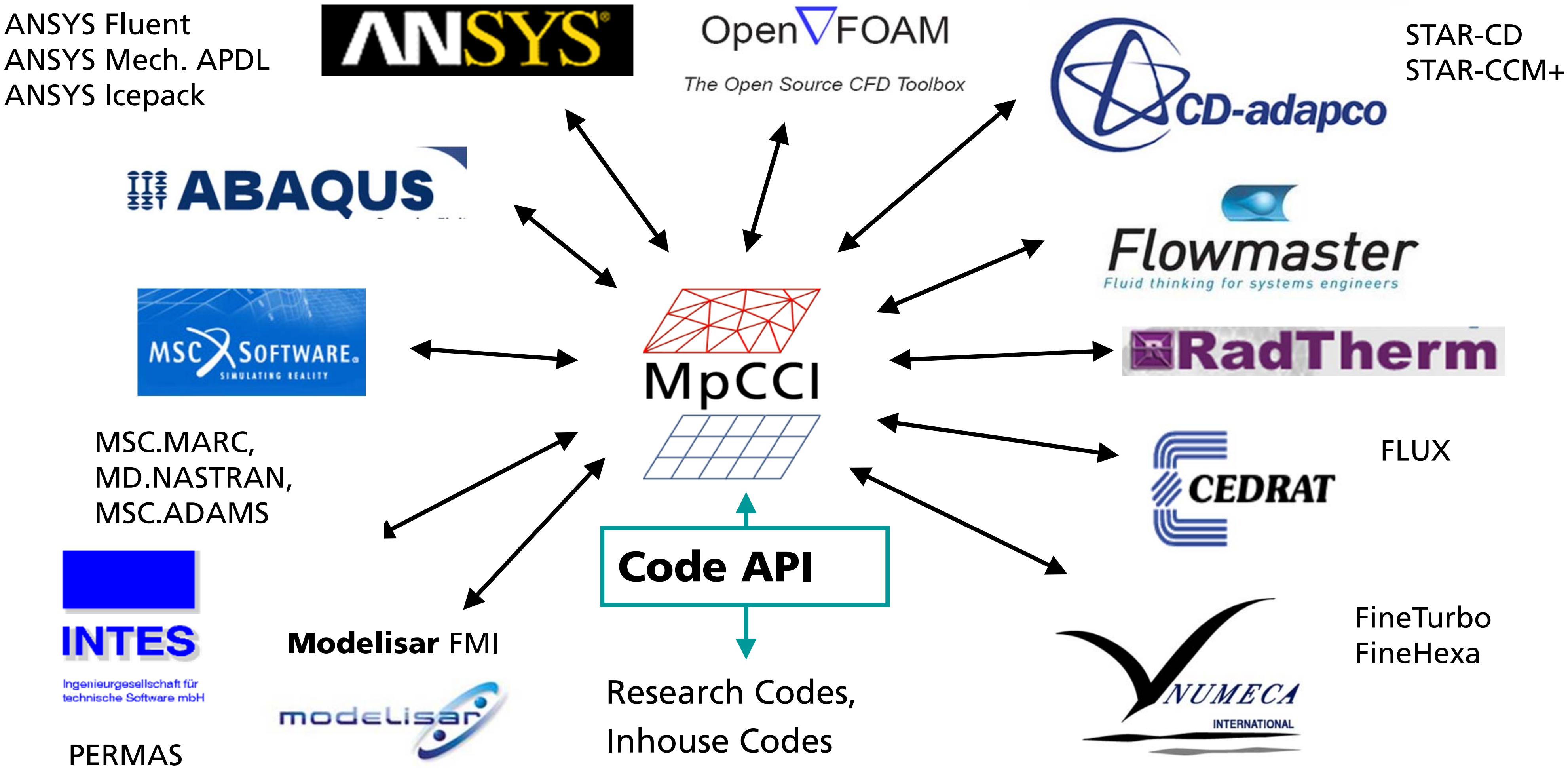
Supported Simulation Codes



MpCCI – Supported Codes

MpCCI	v3.1 (March 2009)	V4.1 (Q1 2011)	V4.2 (Q4 2011)
Abaqus	6.8,6.9	6.10	6.11
Ansys	9, 10, 11, 12	11, 12, 13	11, 12, 13
Elmer	-		5.5
Flowmaster	7,5, 7.6	7.6, 7.7	7.6, 7.7
Fluent	6.3.26, 12.0.16	6.3.26, 12.x, 13	6.3.26, 12.x, 13
Flux	10.2, 10.3beta	10.2, 10.3	10.2, 10.3
Icepak	4.4.6, 4.4.8	4.4.x, 13	4.4.x, 13
MatLab	-	-	Aktuelle Version
MD.Nastran		2010	2011
MSC Adams			2011
MSC.Marc	2005r3, 2007r1, 2008r1	2007r1, 2008r1, 2010	2007r1, 2008r1, 2010
Numeca	Fine/Hexa 2.7	Fine/Hexa 2.11, Fine/Turbo 8.9	Fine/Hexa 2.11, Fine/Turbo 8.9
OpenFoam	-	1.5, 1.6, 1.7	1.5, 1.6, 1.7, 2.0
RadTherm	9.0.1, 9.1.0, 9.1.2, 9.2	9.1, 9.2, 9.3, 10	9.1, 9.2, 9.3, 10.1
Permas	12	-	-
STAR-CD	4.04, 4.06, 4.08	4.06, 4.08, 4.00, 4.12	4.06, 4.08, 4.12, 4.14, 4.16
STAR-CCM+		4.06, 5.02, 5.04	4.06, 5.02, 5.04, 6.02
Adapter API	Available	Available	Available
Modelisar FMI			Internal Prototype

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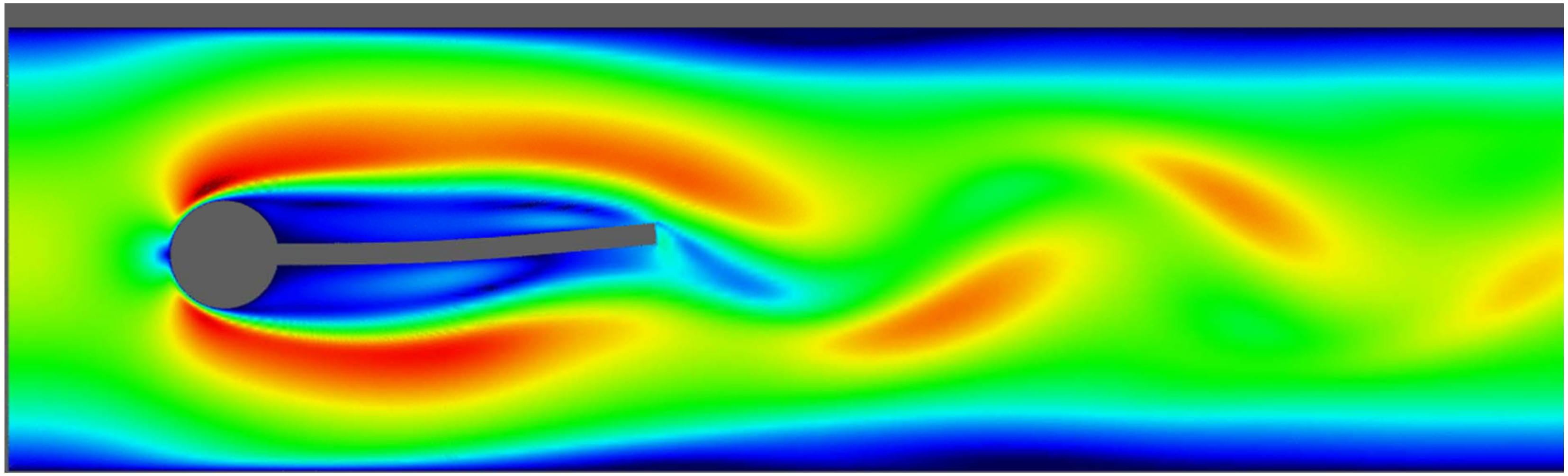
MpCCI Selected Applications

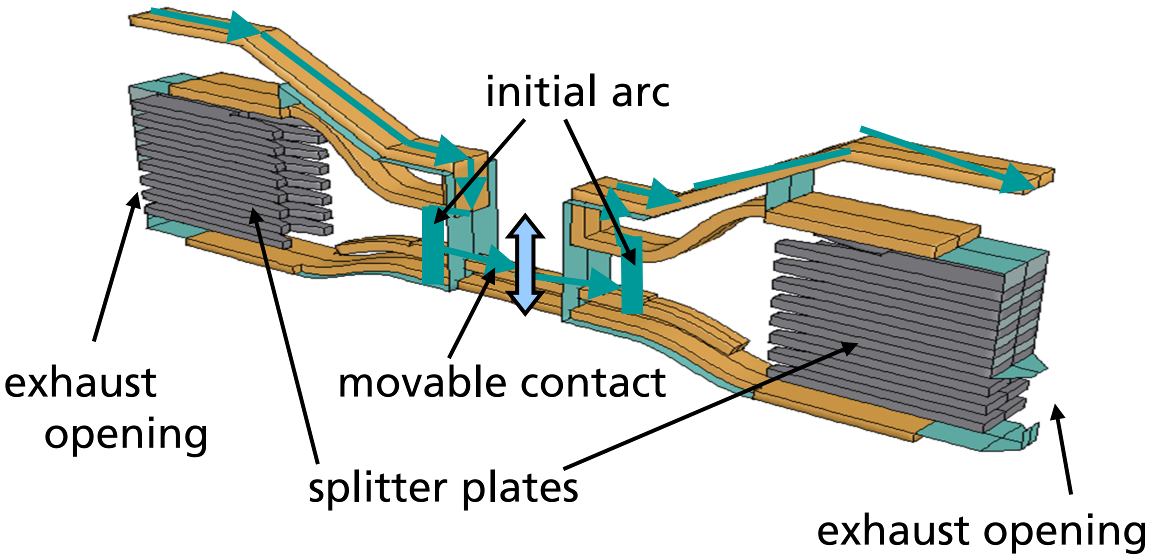


Electromagnetics

Electric Arc Simulation

Christian Rümpler, Fraunhofer Institute SCAI
Albert Zacharias, Moeller GmbH, Bonn

PKZM0: Motor-protective circuit-breaker



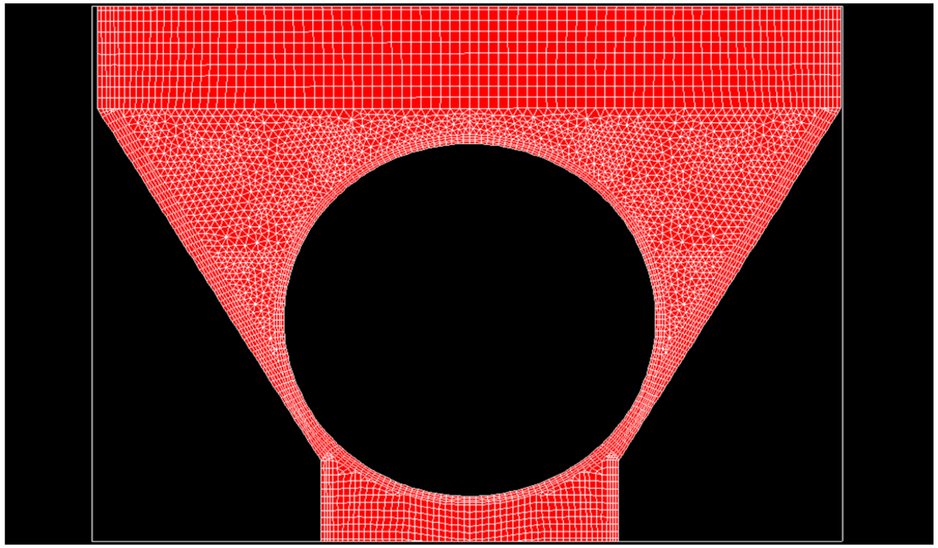
Contact geometry

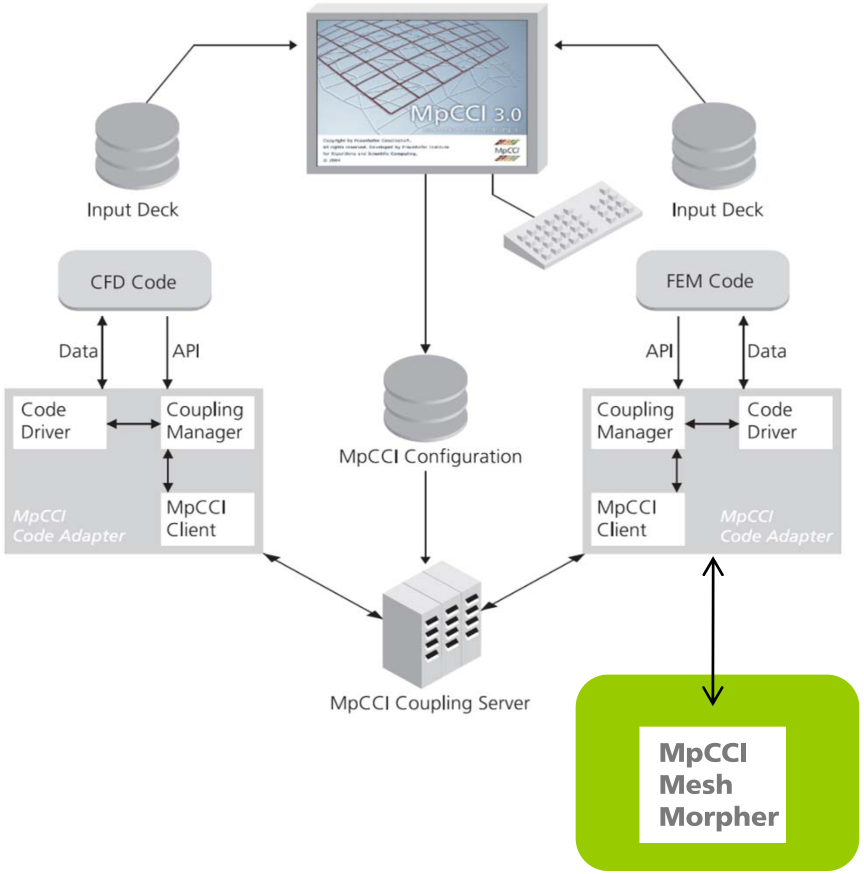
Fluid-Structure Interaction

MpCCI Mesh Morpher

MpCCI provides an automatic and fast mesh morphing tool for FSI

Communicates via sockets with CFD code





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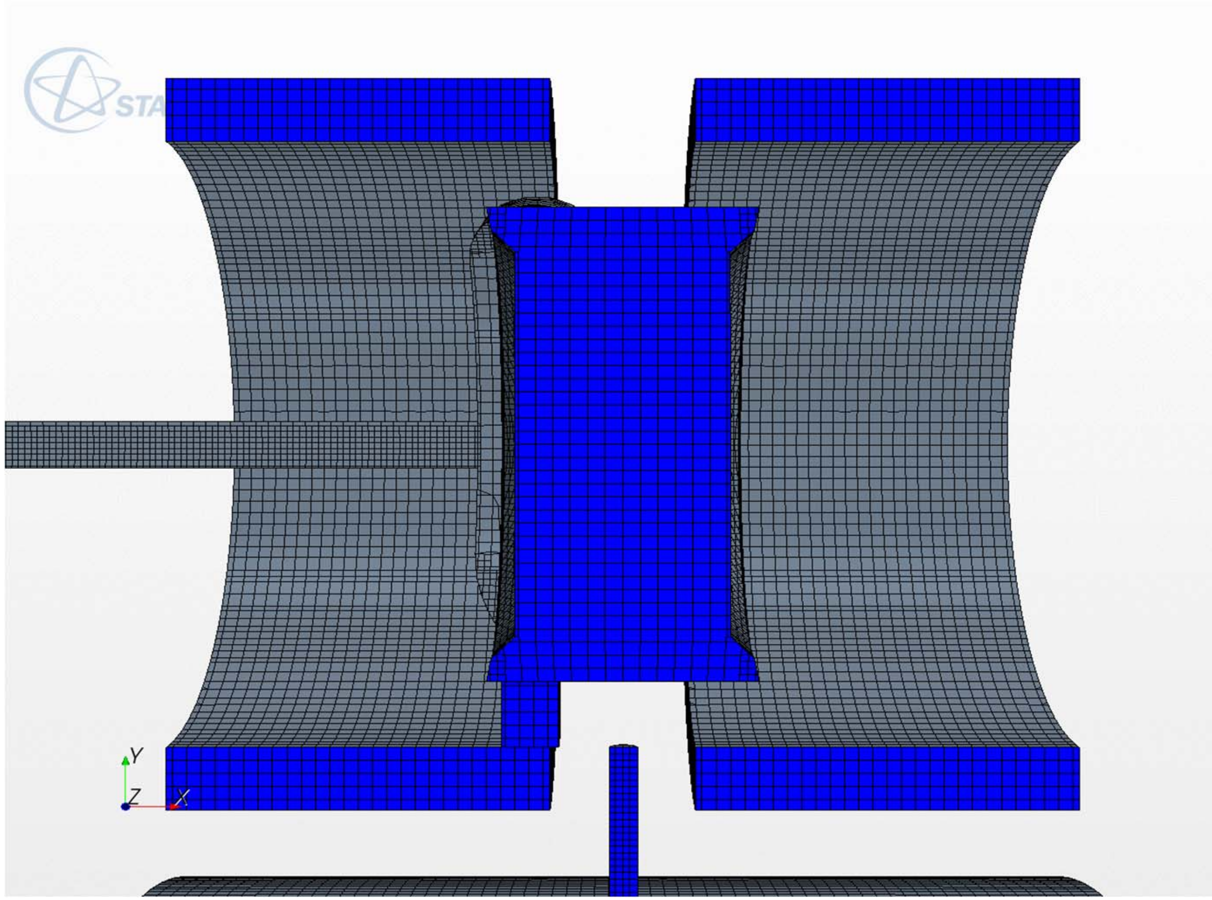
MpCCI - STAR-CCM+ Remeshing Module

Activation in MpCCI GUI

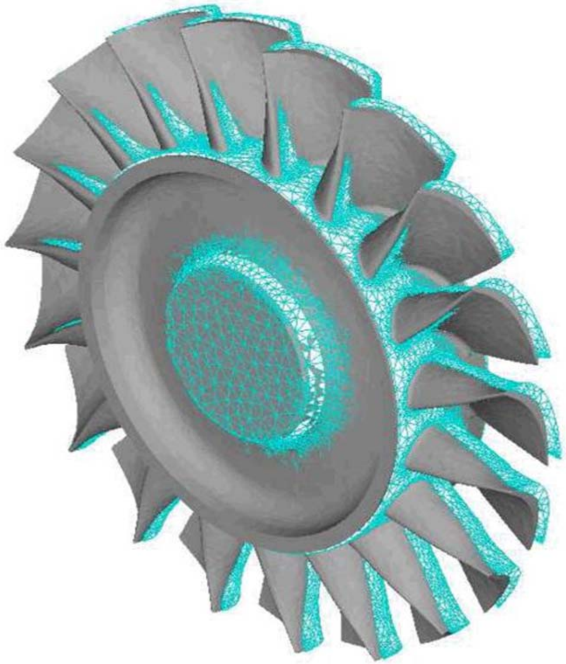
Example: Pump

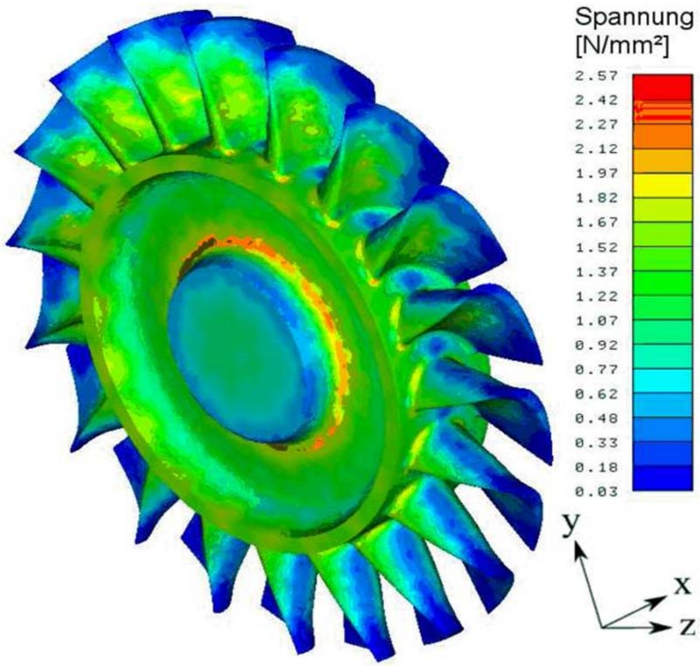


Example FSI: Turbine Rotor

Simulation of deformation of turbine rotor TWT-GmbH:

- Star-CD
- Permas



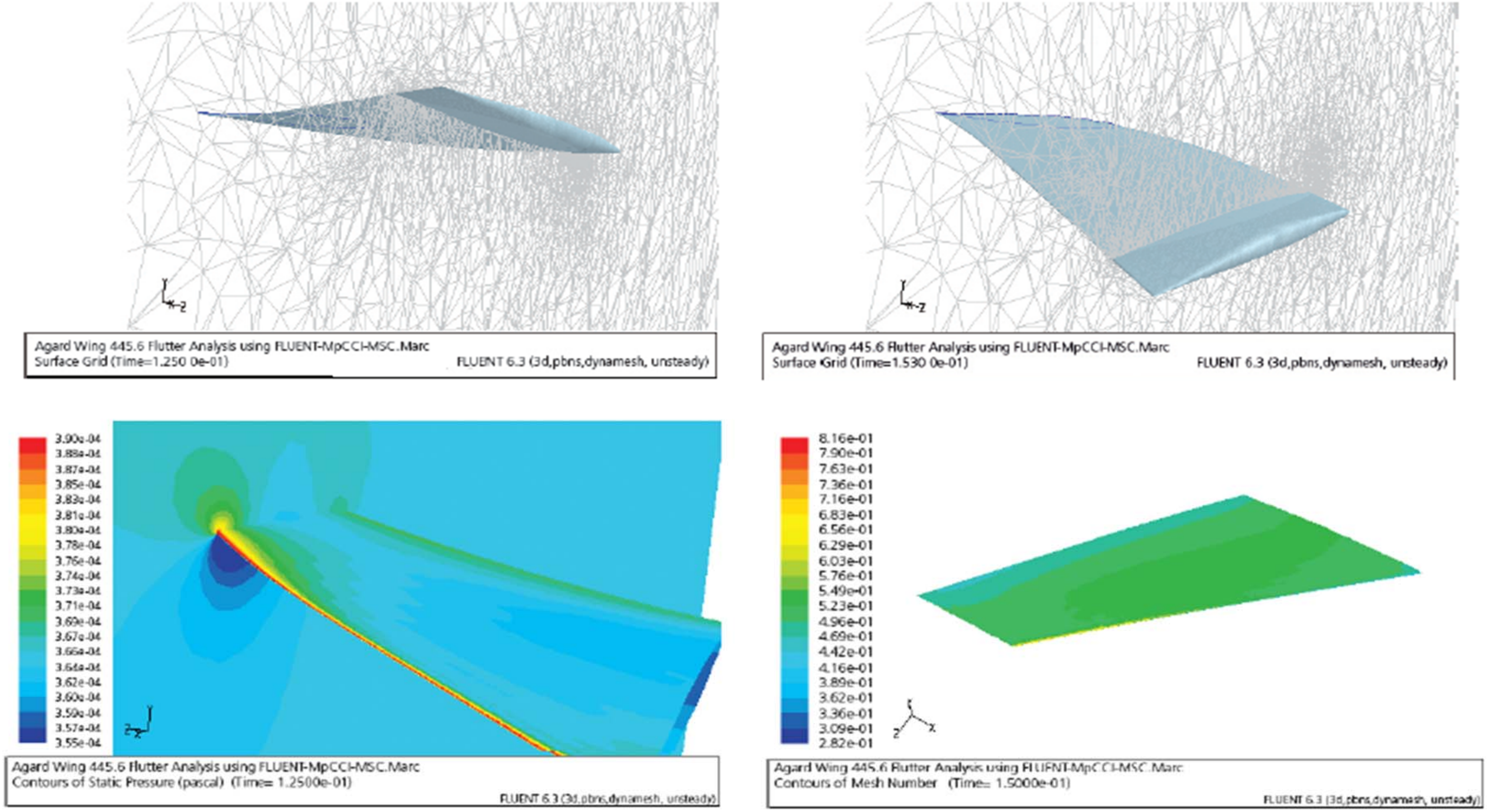


Example FSI: Flutter Analysis of Wing

Simulation of the fluttering of a Agard wing 445.6H by Tekno Tasarim Inc., Tu

© Tekno Tasarim, Turkey

- Fluent
- MSC.Marc



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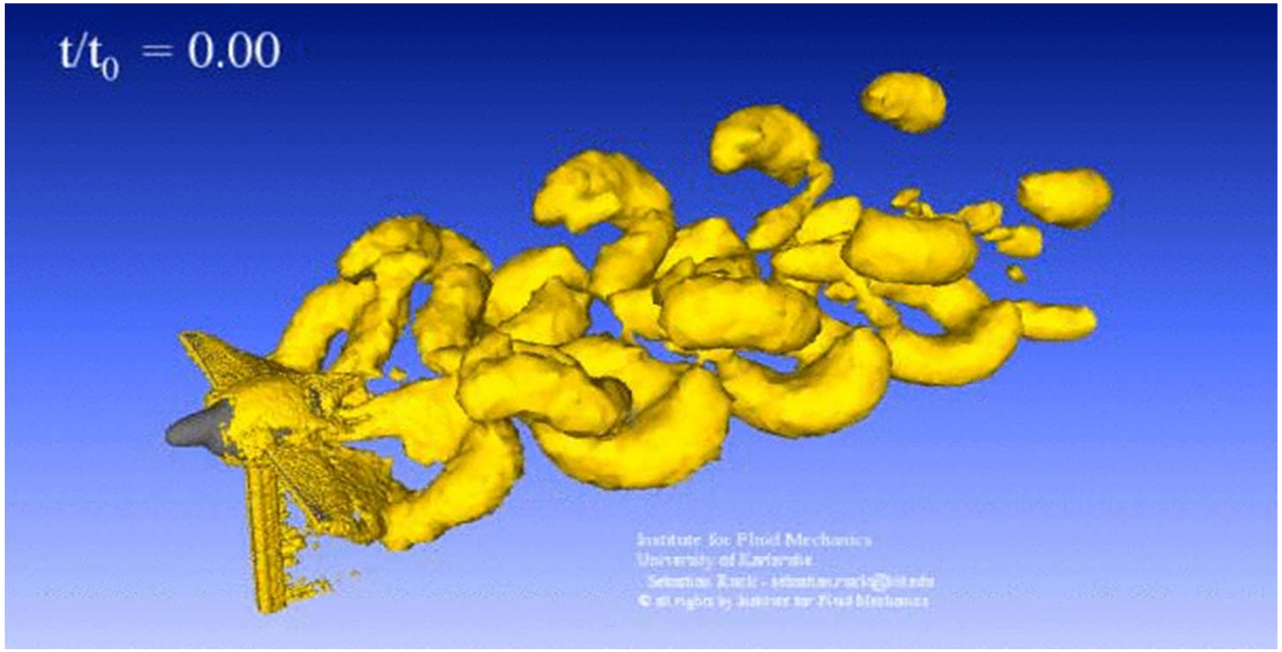
Example: Bird Flight

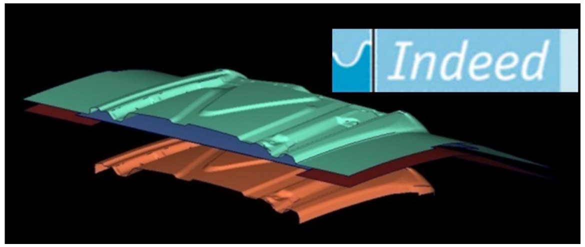
- **Institute of Fluid Dynamics, University of Karlsruhe**

Bird flight with wing-beat kinematics as FSI

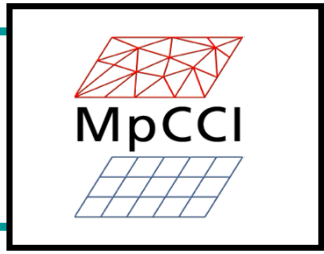


IMAUF – Blechumformung mit elastischem Werkzeug

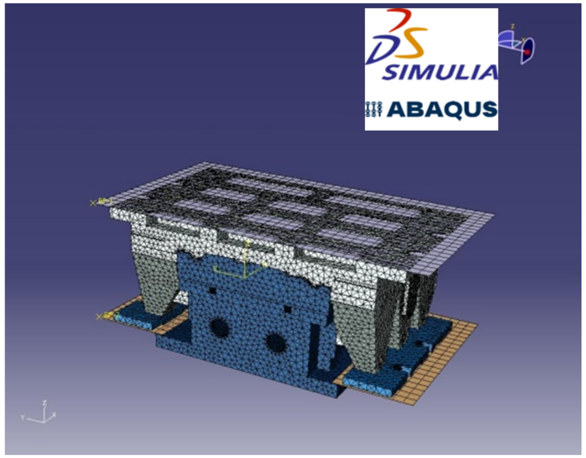
Umformsimulation | Datentransfer | Werkzeugverformung

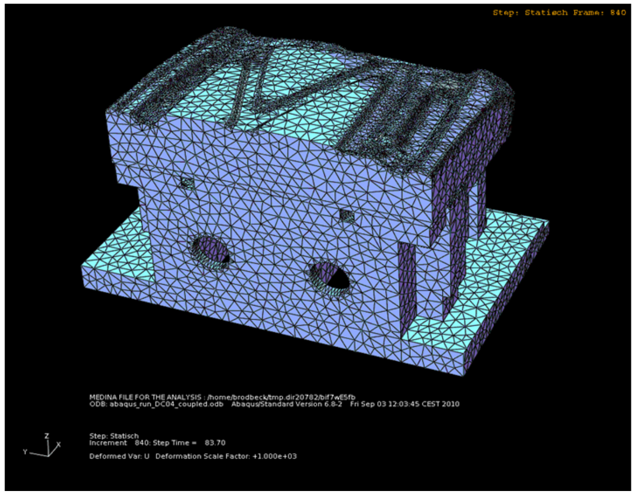


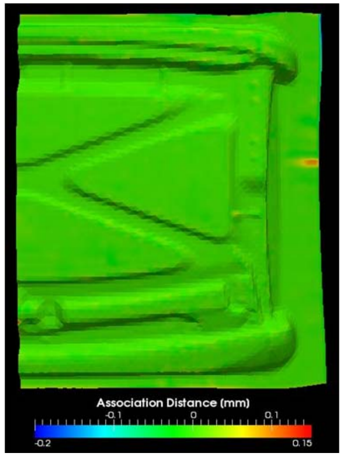
Kräfte



Verformung





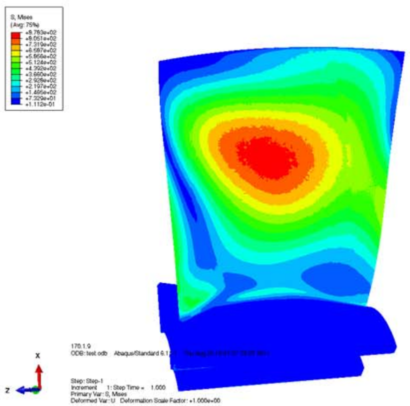


Formabweichung Platine DC04
Vergleich gekoppelt - ungekoppelt

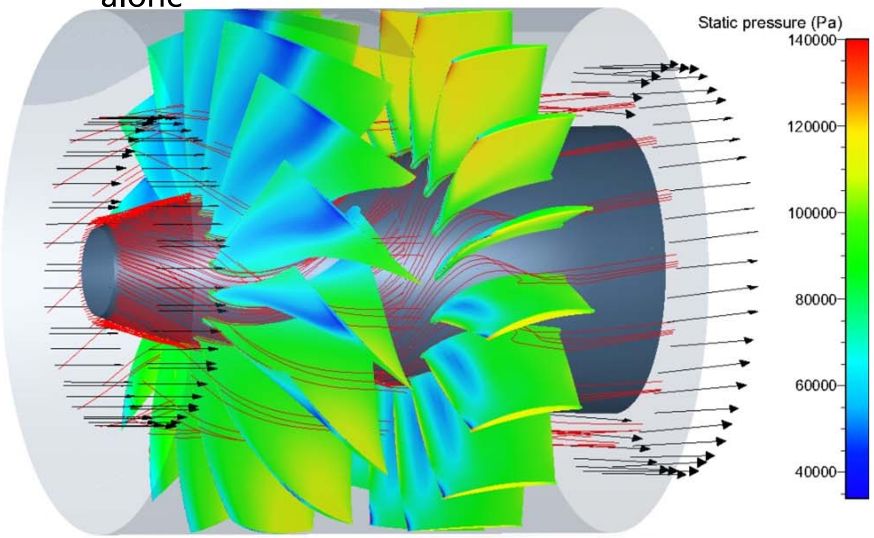
Coupled Simulation of a small scale transonic fan using Abaqus and FineTurbo

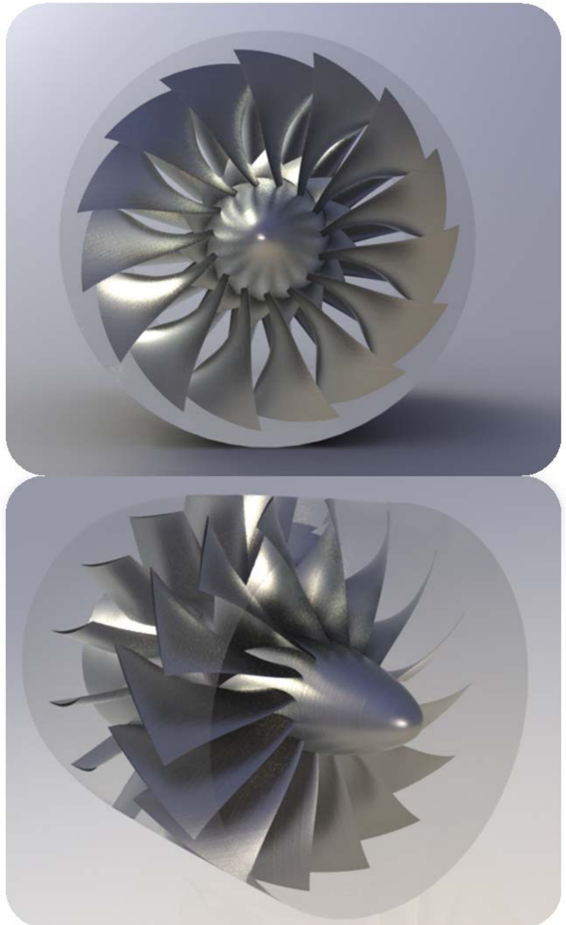
- Coupling Pressure – Deformation
- Cooperation with TU Dresden

Abaqus stand-alone



FineTurbo stand-alone





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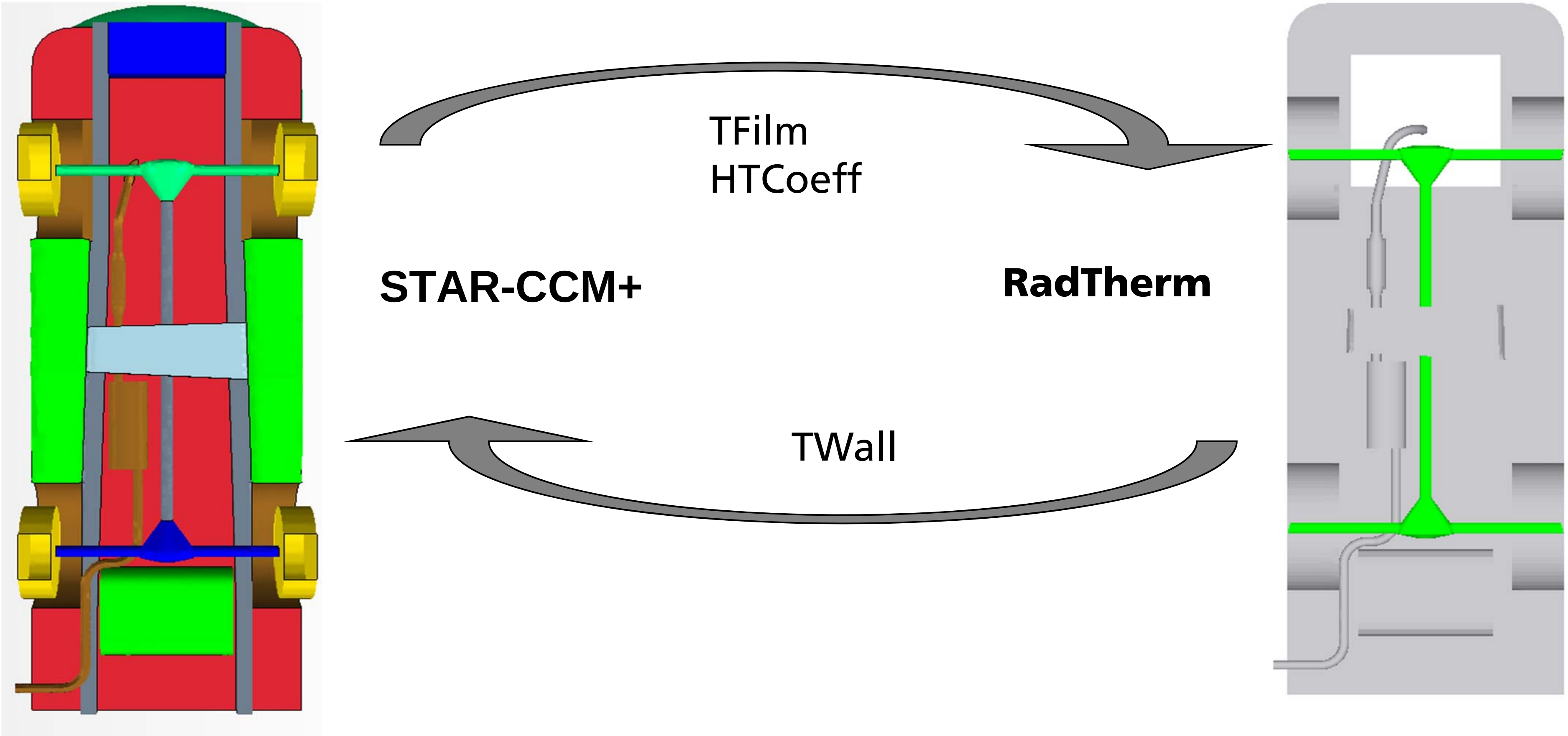
Thermal simulations

Automotive Thermal Management – STAR-CCM+ & RadTherm



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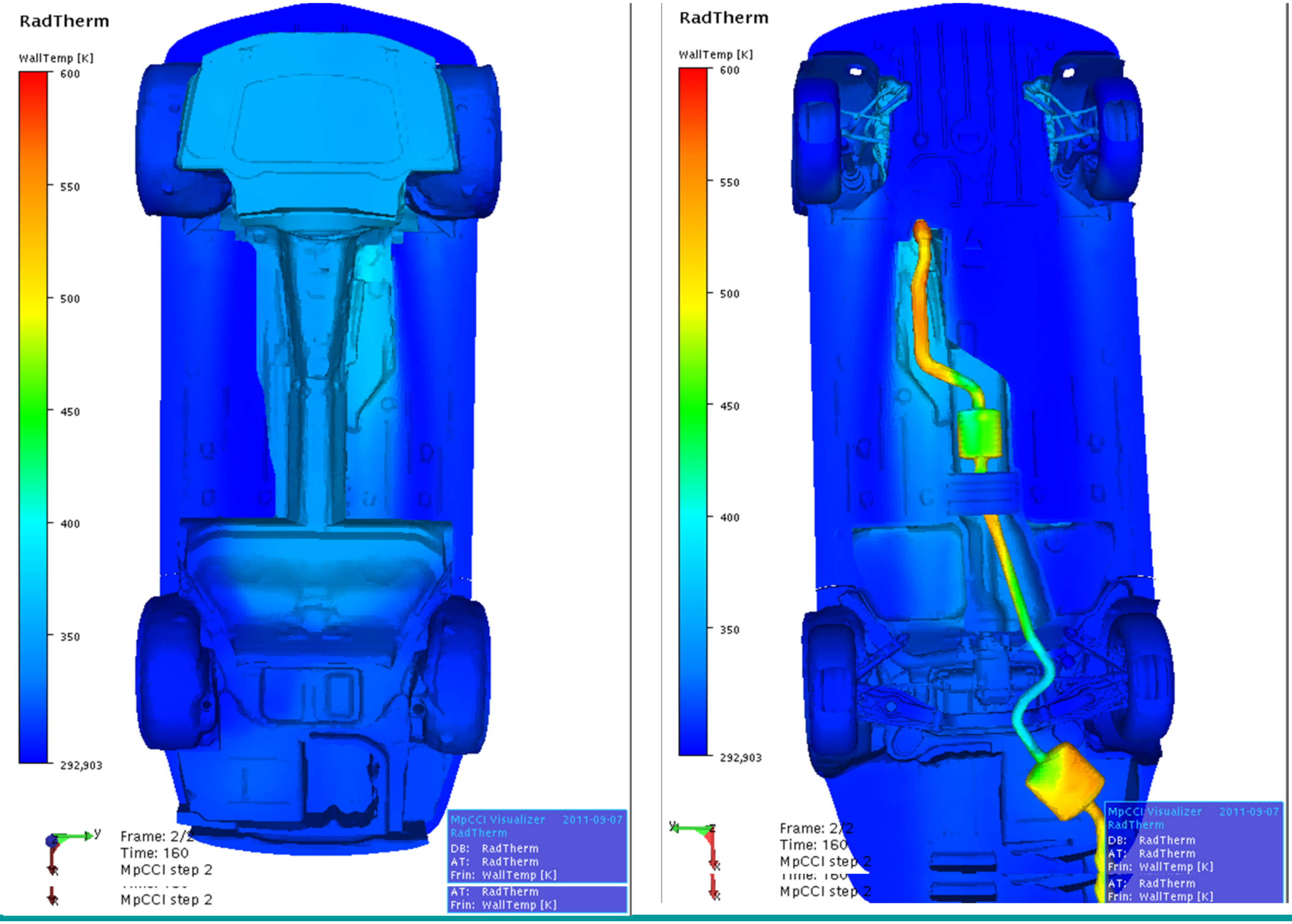
Automotive Thermal Management – STAR-CCM+ & RadTherm

Full Vehicle Coupling (BMW)

STAR-CCM+ and RadTherm



Coupling of 3D-Codes with System Codes

Environment Control Systems in Large Aircraft Cabins

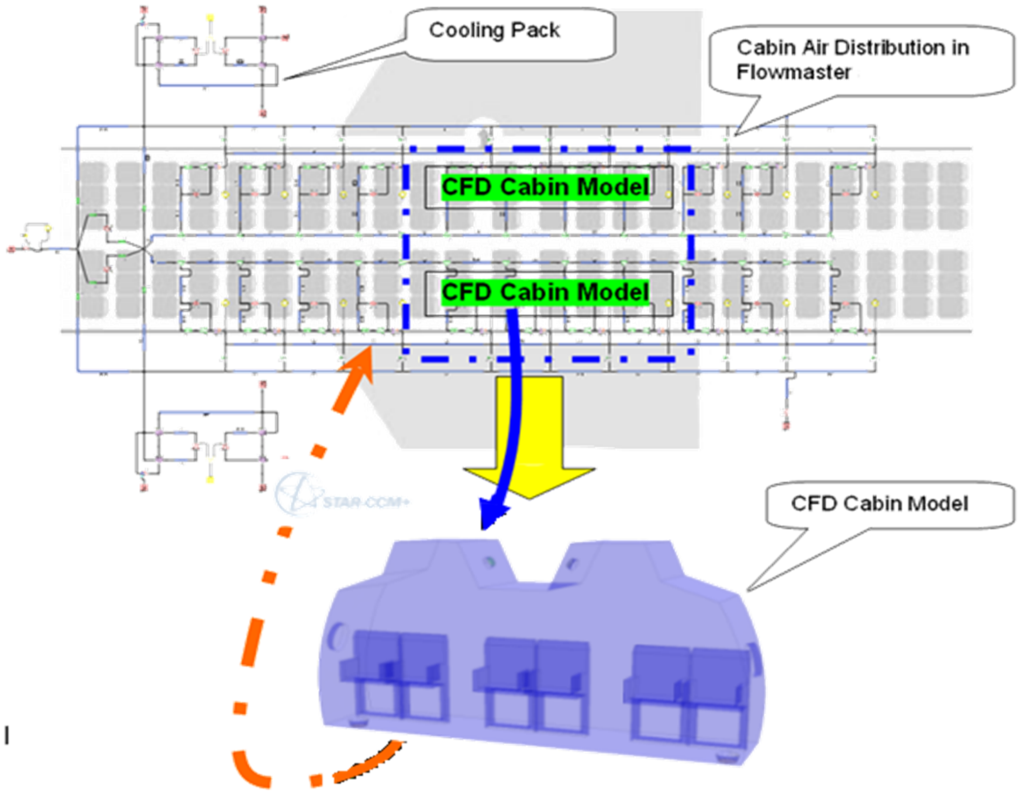
1D – Air Distribution System Modeling

- Analyze large aircraft air distribution
- Evaluate duct re-routing scenarios
- Study mixing of fresh and re-circulated air
- Conduct “what if” scenarios on duct sizing
- Fast set up and very quick to analyze

CoSimulation Method

- Partial CFD Model of Cabin
  - STAR-CCM+
  - Fluent
  - OpenFOAM
  - Other CFD codes
- Full ECS system model in Flowmaster v7
- MpCCI 4 Code Coupling Interface

Large Aircraft Cabin ECS System in Flowmaster V7



Partial CFD Model of Cabin in STAR-CCM+

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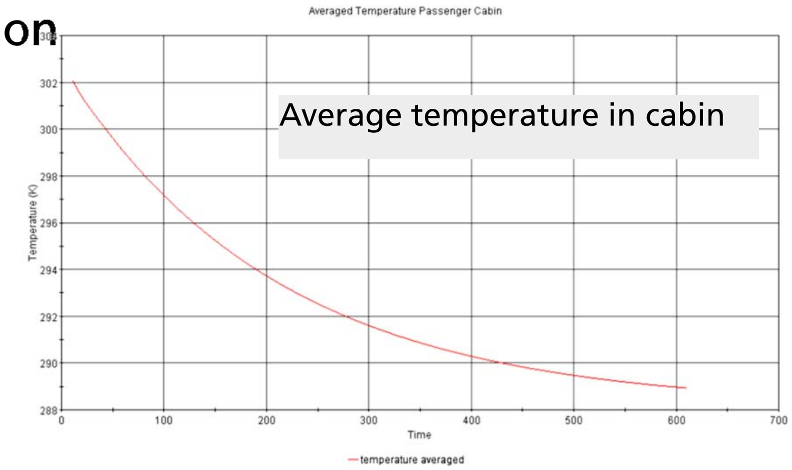
Environment Control Systems in Large Aircraft Cabins

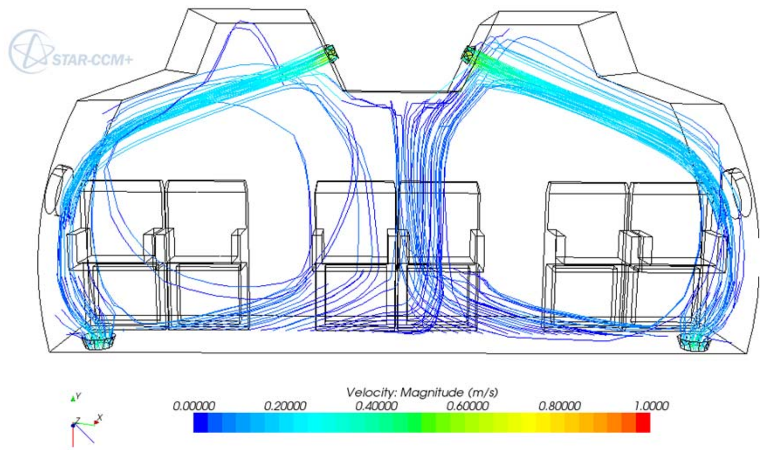
Combine Both Models for a Cool-Down Simulation

- Transient Heat Transfer Simulation
- Cooling Pack Temperature set to 282.65°K
- Time step 1s
- Cool-Down Period 600s



Co-Simulation Quantities

- Inlets:
  - Flowmaster: Temperature and Pressure
  - STAR-CCM+: Mass Flow Rate
- Outlets:
  - Flowmaster: Pressure
  - STAR-CCM+: Mass Flow Rate and Temperature



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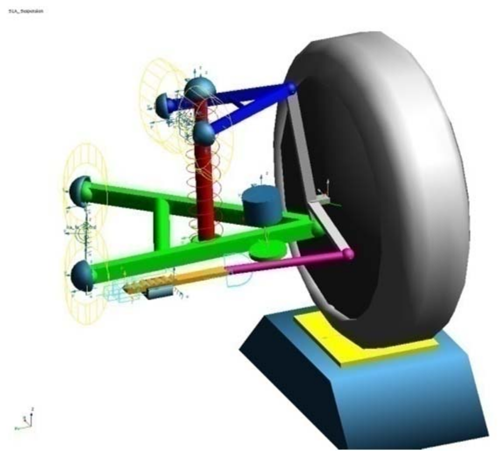
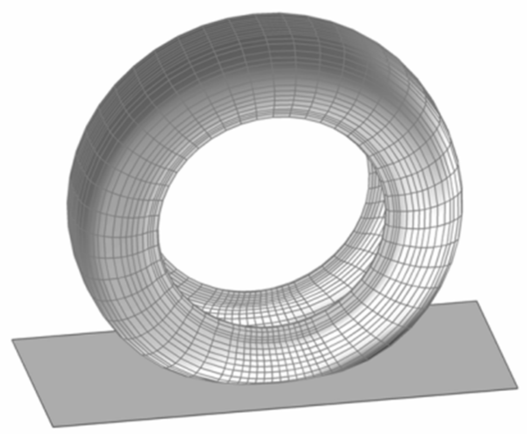
Multi-Scale CoSimulation for Automotive Applications MpCCI 4.2

Tire rolling over Road Curbs

(in collaboration with Fraunhofer ITWM)

- MBS model for suspension (MSC.Adams, other MBS codes planned)
- Detailed CSD models for the tire deformation during contact
- MBS-standalone needs to calculate all load conditions initially
- Then contact and deformations will be co-simulated with FEM
- Relevant Quantities for Coupling: Force, Torque, Position, Angle and Derivatives





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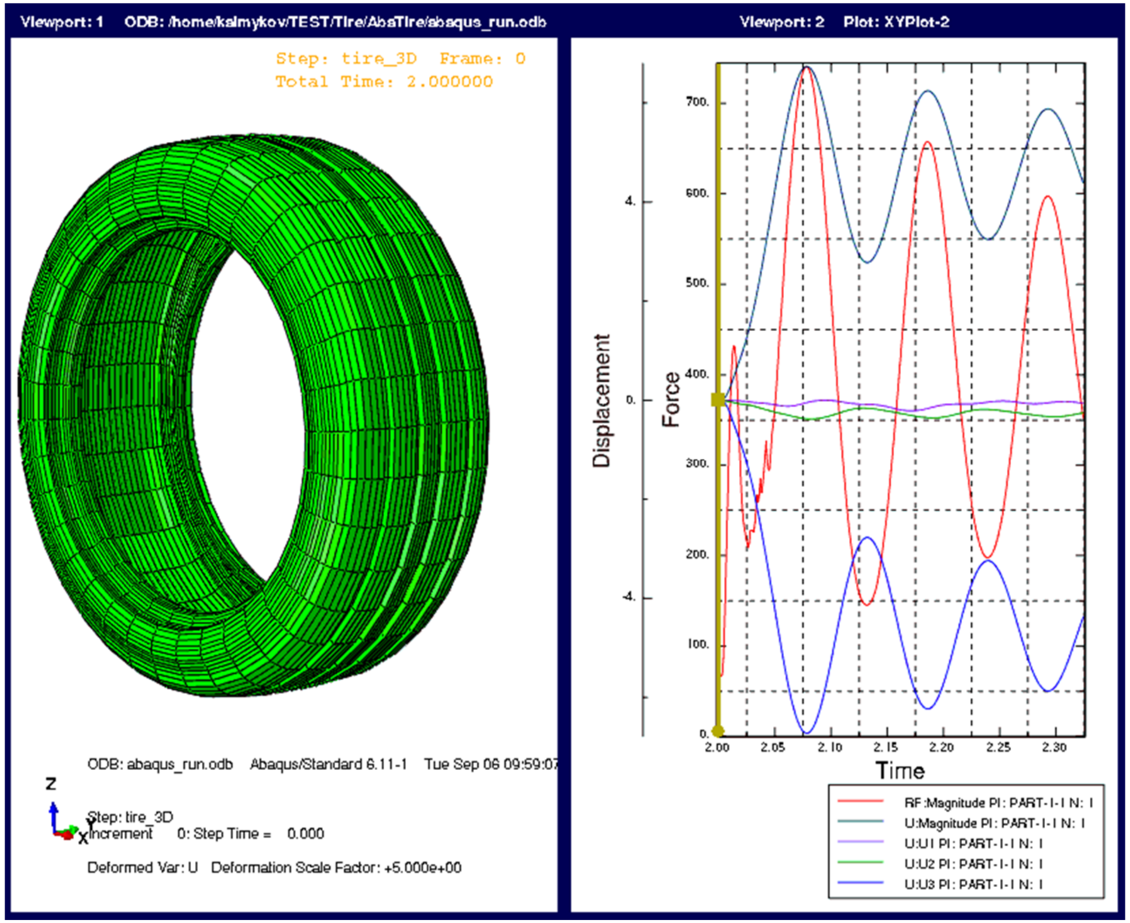
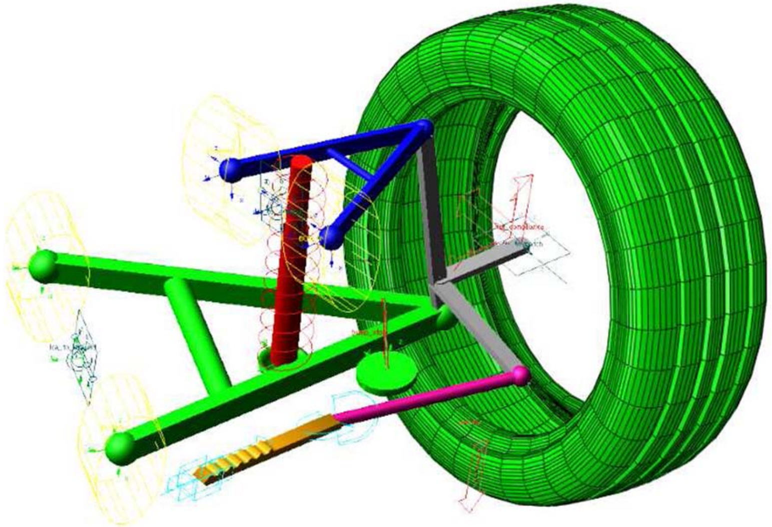
Multi-Scale CoSimulation for Automotive Applications
MpCCI 4.2 - Example





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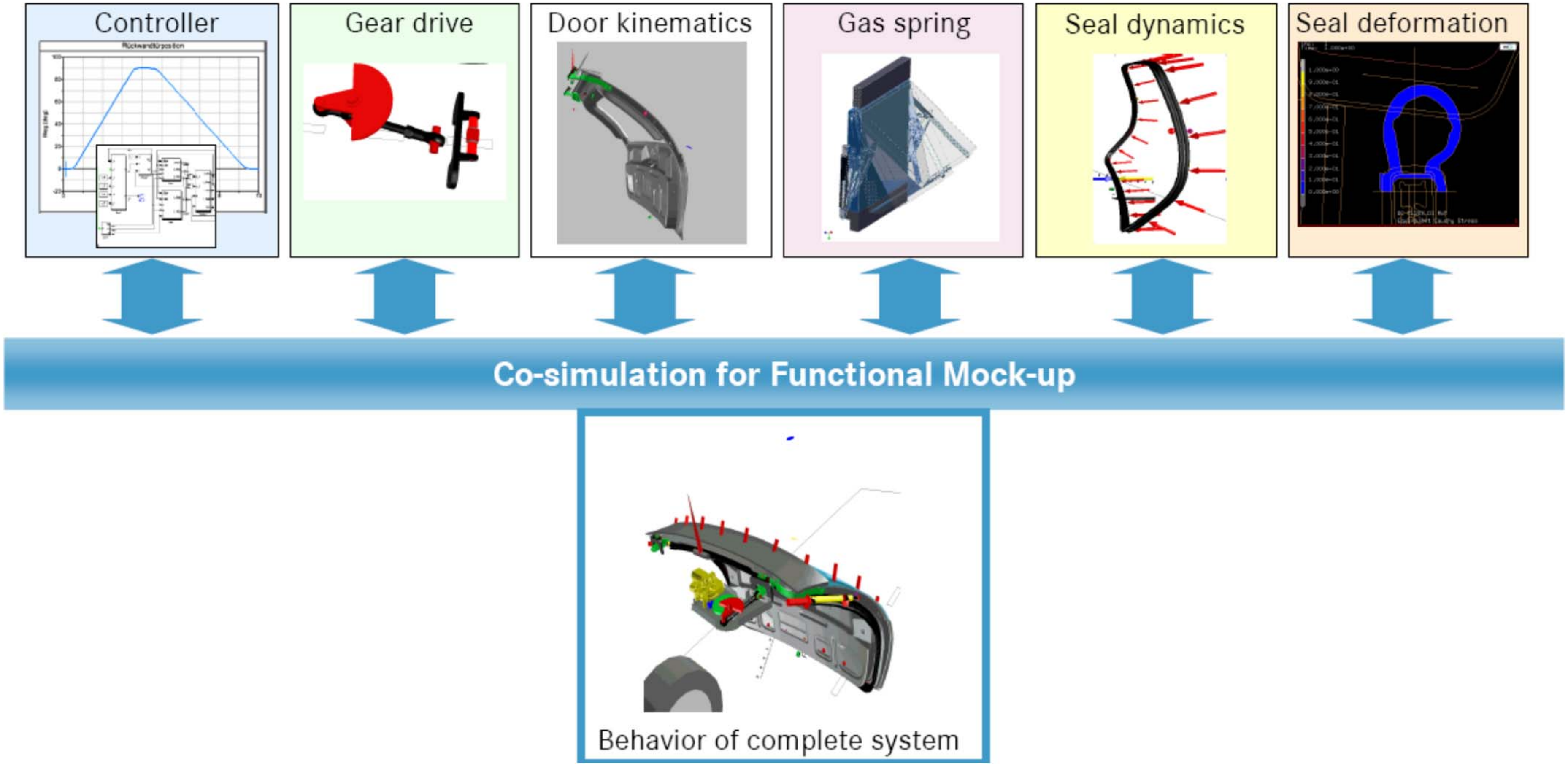
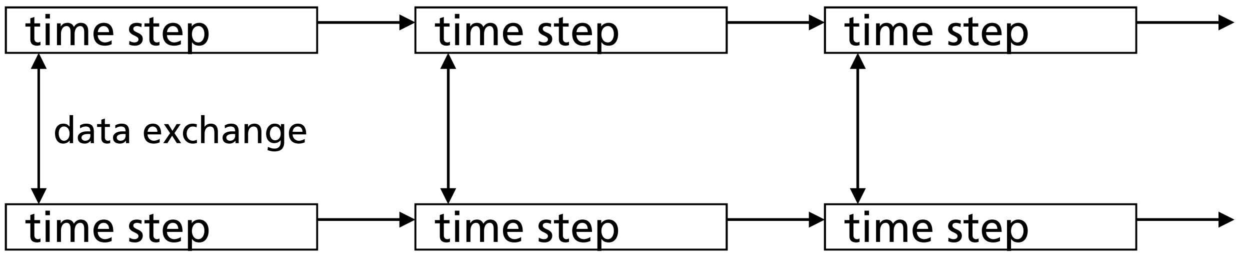
The Functional Mockup Vision
Modelisar FMI Standard for CoSimulation



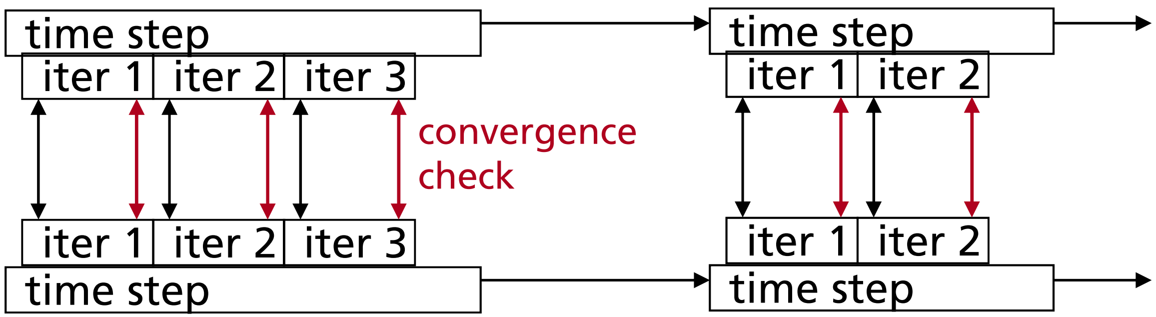
Implicit Coupling in MpCCI 4.2

Weak and Strong Coupling

Weak coupling (explicit coupling):



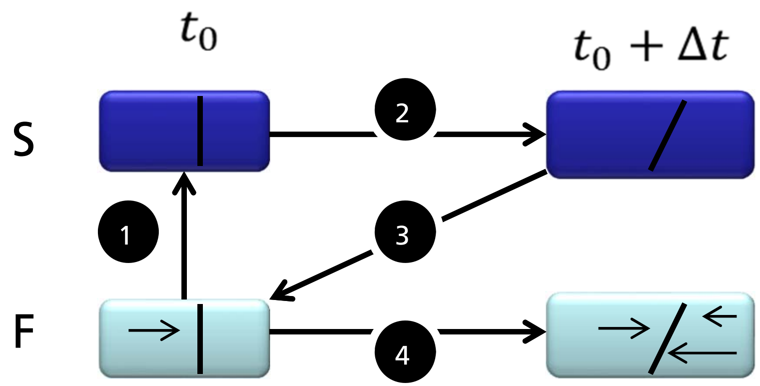
Strong coupling (implicit) coupling:



New Feature in MpCCI 4.2
Implicit Coupling – Problem Description

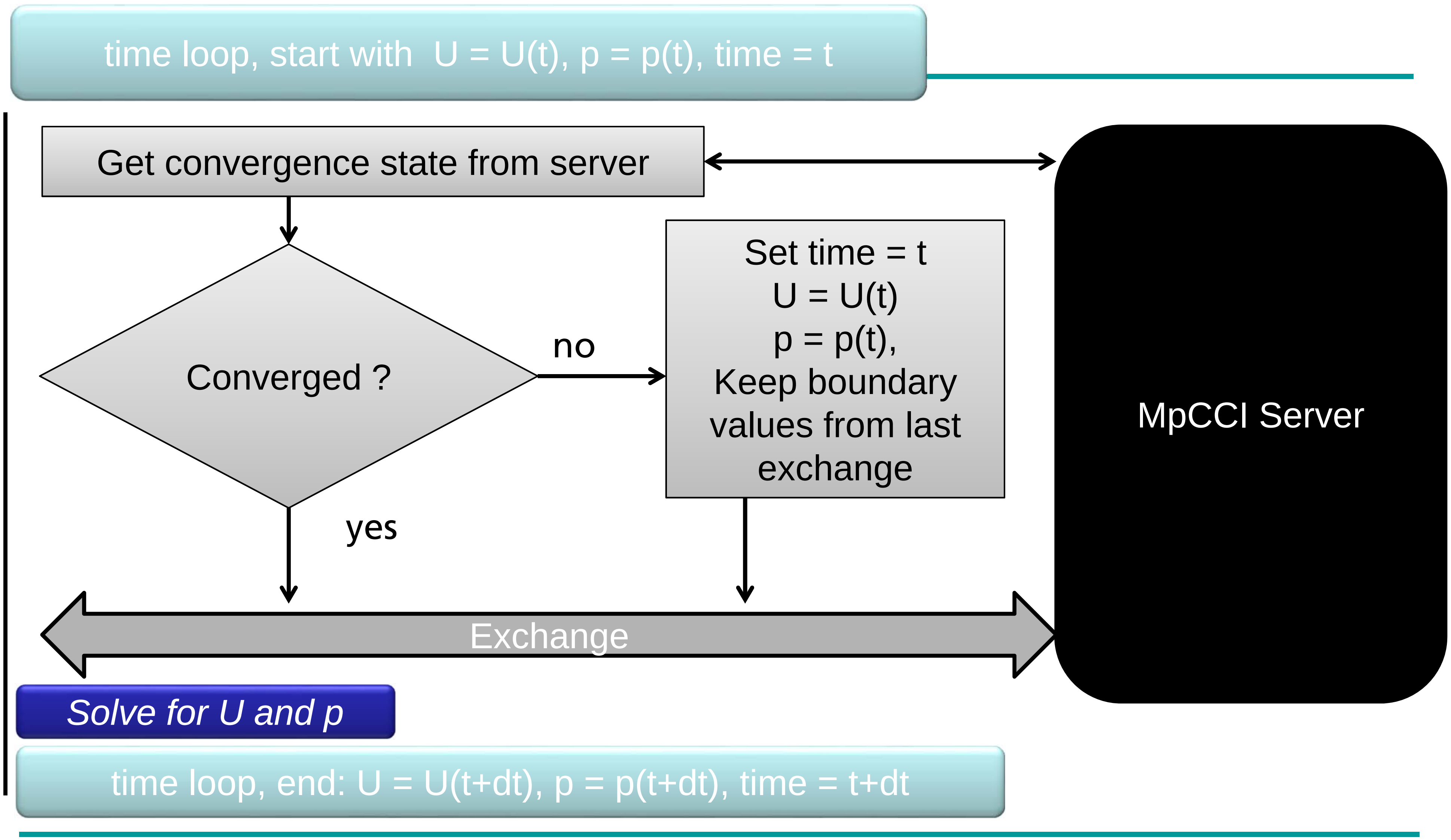
- essentially in fluid structure interaction with incompressible media
- extremely high pressure near moving walls
- severe oscillations of moving parts with explicit coupling
- each individual solution (CFD/FEM) converges to a stable solution with implicit coupling -> kinematic (displacements, velocities, accelerations) and dynamic (loads, forces, stress) coupling conditions must be fulfilled

Solution scheme of explicit coupling



1. F submits actual loads to FEM (dynamic. coupling conditions hold).
2. S performs one time-step to obtain new deformation without any knowledge about the inertia of the fluid. The new strucure's position is overestimated.
3. S submits new positions to F (kinematic coupling conditions hold, dynamic coupling conditions do not).
4. F performs one time-step to obtain new flow field after having performed mesh adaption.
   High fluid inertial forces act on structure resulting in a „reversed" pressure force.

Details of implicit coupling scheme (OpenFOAM)



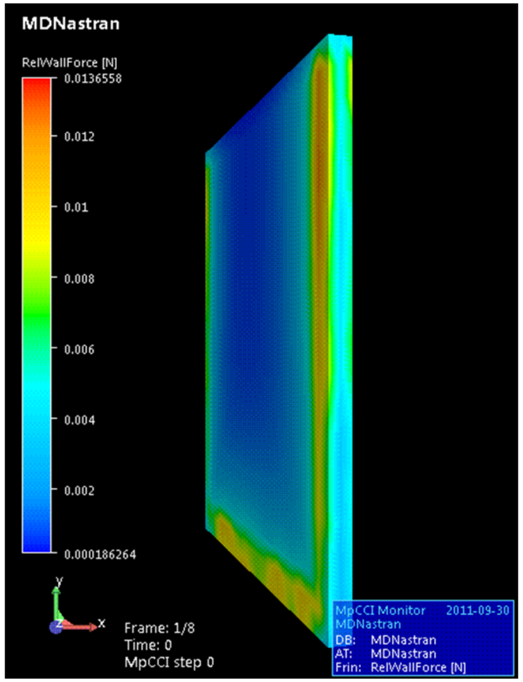
Problems of Implicit Coupling Schemes

- Iteration in a time step until convergence while not advancing in time.
- Do some under-relaxation to avoid instabilities within iterations, choice of good relaxation factors is a balance between convergence speed and stability
- Observe convergence, convergence of sub-problems measured by codes and convergence of coupling conditions measured by MpCCI. What is a good criterion for convergence, dynamic and kinematic tolerance?
- Remeshing will invalidate buffered data.
- Codes have to support implicit coupling, i.e. access to inner iterations and advancing back in time, modification of relaxation factors, dynamic abortion of iteration and immediate advancement in time.
- Implicit coupling is more time consuming

Implicit Coupling
MpCCI 4.2

Non-linear FSI for an Elastic Flap in a Duct with water

OpenFOAM 🡐 🡒 MD.Nastran



Explicit Coupling

ImpStableAni

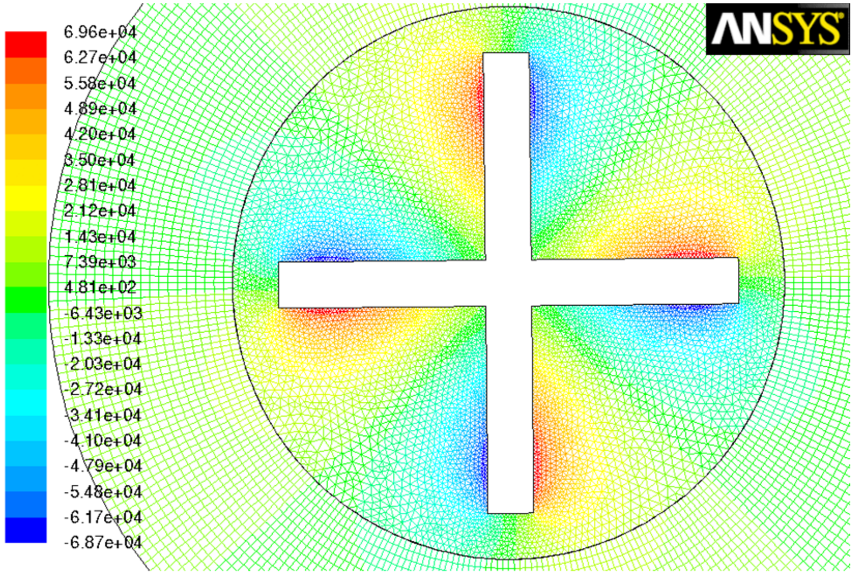
Rotating Systems in MpCCI 4.2

Mesh Motion and Moving Reference Frames Supported in MpCCI 4.2

Problem Description

- Parts of the model in CFD and FEM may rotate and/or translate either in a inertial coordinate system or in a moving reference frame
- Some exchanged quantities have to run through transformation
- Force vectors have to follow the rotation (Piola-Kirchhoff) in FEM
- Rotational velocity might be part of the solution (not in MpCCI 4.2)
- For not constant rotations sophisticated mesh smoothing and remeshing is needed in CFD

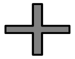
Example Ansys Fluent Sliding Mesh

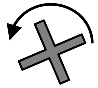


Contours of Static Pressure (pascal) (Time=1.0000e-04) Jul 20, 2011
ANSYS FLUENT 12.1 (2d, dp, pbns, dynamesh, skw, transient)

Mesh Motion and Moving Reference Frames Supported in MpCCI 4.2

Possible combinations:

 = rotation in moving reference frame

 = rotation in stationary reference frame

CFD CSM

e.g. steady state deformation with centrifugal loads and fluid forces

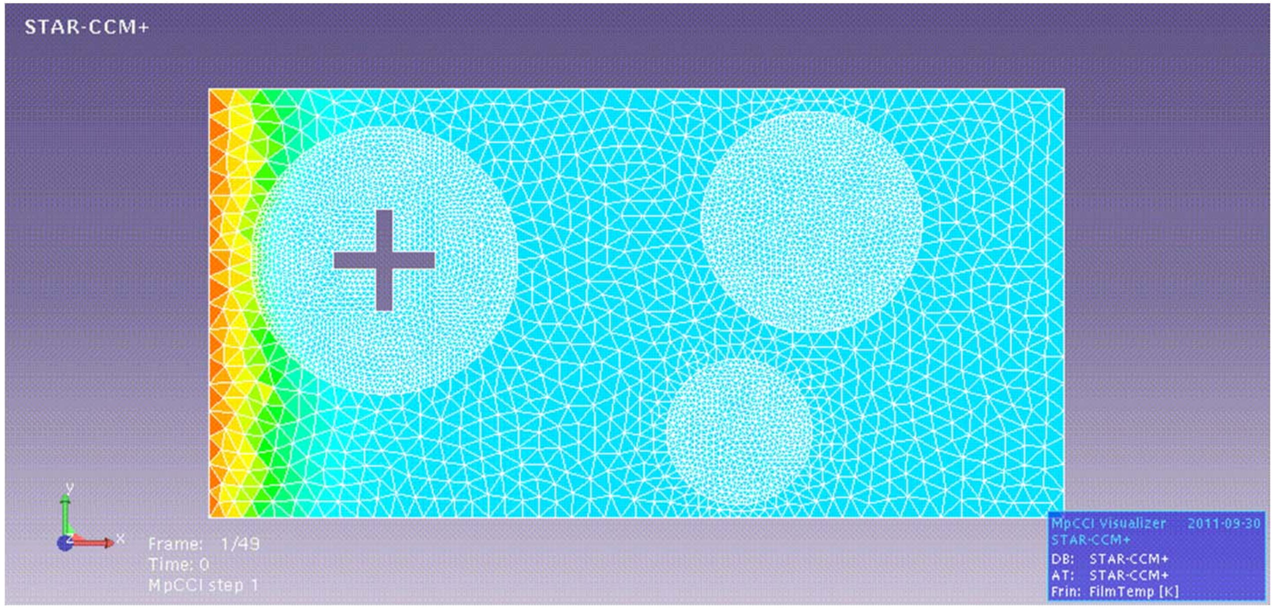
e.g. strong stator – rotor interaction, constant rotation, transient

e.g. non-constant rotation velocity, strong rotor – stator interaction , accelerating rotation, transient

Mesh Motion and Moving Reference Frames Supported in MpCCI 4.2

Possible Applications:

- Pumps, turbines, rotors, stirrers
- Gas turbine propulsion
- Marine propeller
- Clutches, brakes



Contact

Thanks for your attention!

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