scapos

Simulation & Design of Complex Systems: techniques & applications developed at SCAI

Guy Lonsdale - CEO, scapos AG

TERATEC FORUM 2011
Workshop 2: Complex Systems Engineering
June 29th, 2011

Presentation Overview

- Intro to scapos & Fraunhofer SCAI
- Simulation-related aspects of complex systems design
- 3 SCAI technology & tool developments
  - Multi-physics = Multi-code coupling for complex simulations: MpCCI
  - Multi-code workflows: SCAI-Mapper
  - Analysis of complex processes in simulation: DIFF-CRASH
- Concluding Remarks

scapos AG

scapos AG offers Maketing & sales support for Research Insitutes and SMEs having a focus on software development.

Established: Januar 2009
No. staff: 7
Location: Schloss Birlinghoven, Sankt Augustin, Germany

scapos AG offers support for:

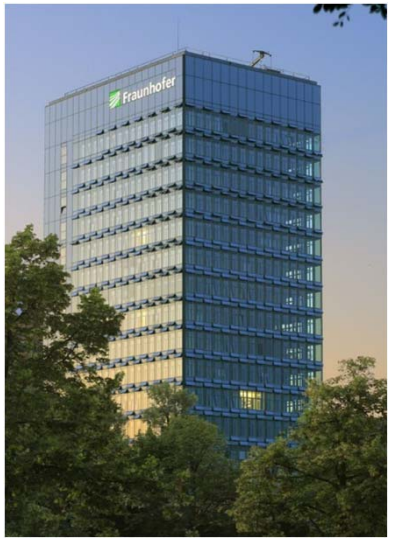
- Sales & Partnering
- Strategic Marketing
- Product Marketing

THE FRAUNHOFER-GESELLSCHAFT

The Fraunhofer-Gesellschaft undertakes applied research of direct utility to private and public enterprise and of wide benefit to society.

*Joseph von Fraunhofer (1787 – 1826) - Scientist Inventor and Entrepreneur

- More than 80 research institutions, including 60 Fraunhofer institutes
- More than 17,000 employees, the majority educated in the natural sciences or engineering
- An annual research volume of 1.7 billion euros, of which 1.4 billion euros is generated through contract research.
  - 2/3 of this research revenue derives from contracts with industry and from publicly financed research projects.
  - 1/3 is contributed by the German federal government and the *Länder* governments in the form of institutional financing.
- International collaboration through representative offices in Europe, the US, Asia and the Middle East



THE FRAUNHOFER-GESELLSCHAFT IN GERMANY

THE PROFILE OF THE FRAUNHOFER-GESELLSCHAFT

7 Groups:

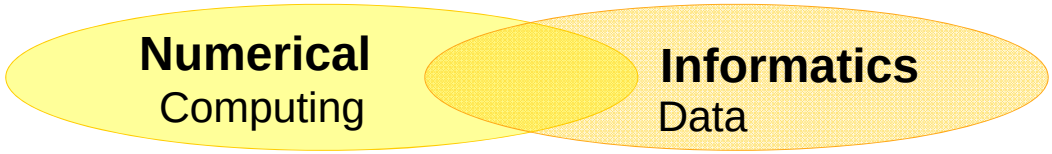
- Information and Communication Technology
- Life Sciences
- Microelectronics
- Light & Surfaces
- Production
- Materials and Components – MATERIALS
- Defense and Security

FRAUNHOFER INSTITUTE FOR ALGORITHMS AND SCIENTIFIC COMPUTING SCAI

Topics / Research Areas

- Numerical Simulation
- Optimization
- Bioinformatics

Synergy effects



Core Competences

- Computational Engineering
- Fast Solvers
- Data and Text Mining
- Cutting/ Packing
- Grid Computing
- …

Target groups / Industrial Sectors

- Engineering
- Automotive
- Textile
- Pharma, Bio
- Ship building
- …
- Software Houses

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Simulation-related aspects of complex systems design

- HPC: Scalability of software for the extreme requirements of multi-phenomena, multi-scale simulations of complex physical processes
- Environments to Integrate multi-scale simulations

- Coupling software components at a common scale for flexible multi-code, multi-physics simulations
- Transferring information between simulations in complex design workflows
- Understanding sources of variation arising in modelling and simulation in engineering design
- …….

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Multi-physics Simulation & MpCCI

Numerical Solutions for coupled systems comprising at least two different physical domains

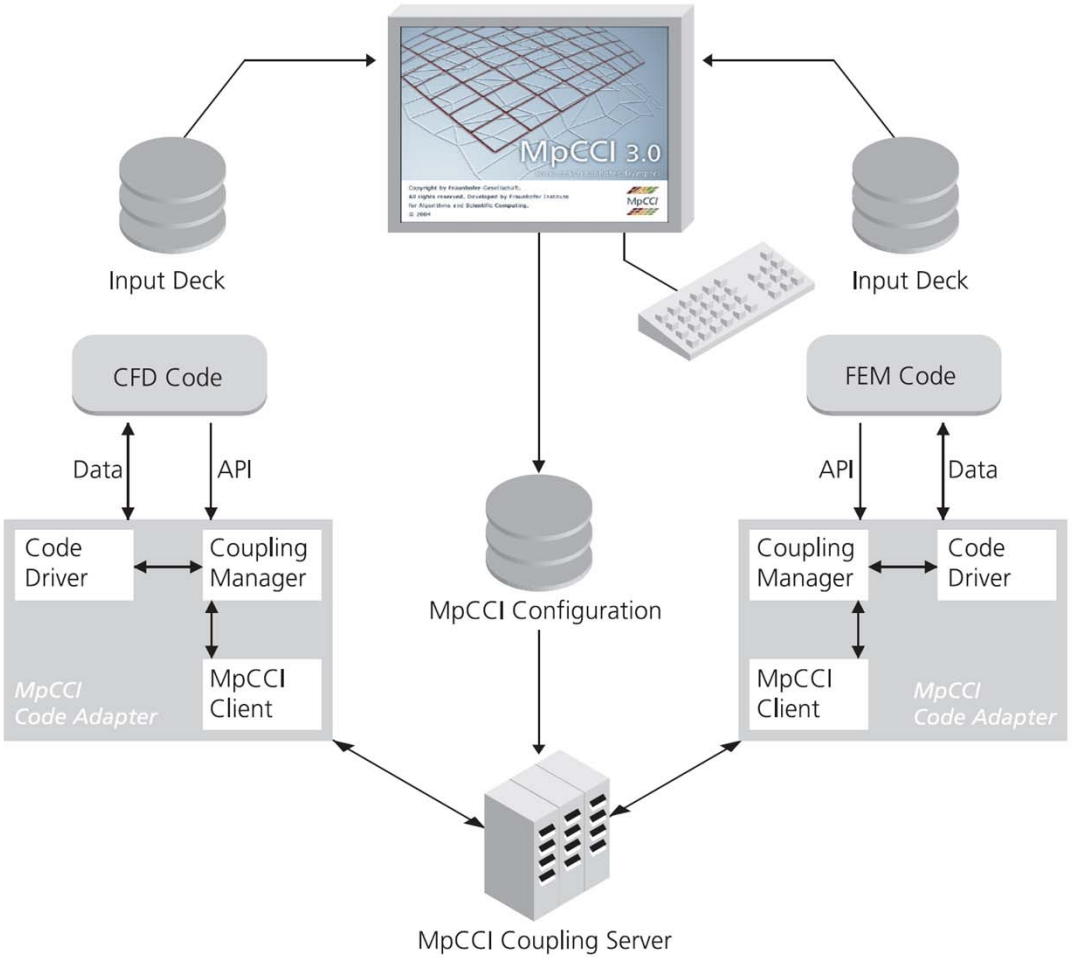
Coupled systems and formulations are those applicable to multiple domains and dependent variables which usually (but not always) describe different physical phenomena and in which

a) neither domain can be solved while separated from the other;

b) neither set of dependent variables can be explicitly eliminated at the differential equation level.

From: Zienkiewicz & Taylor. The Finite Element Method, Volume 1, The Basis. Butterworth Heinemann, Oxford, 2000

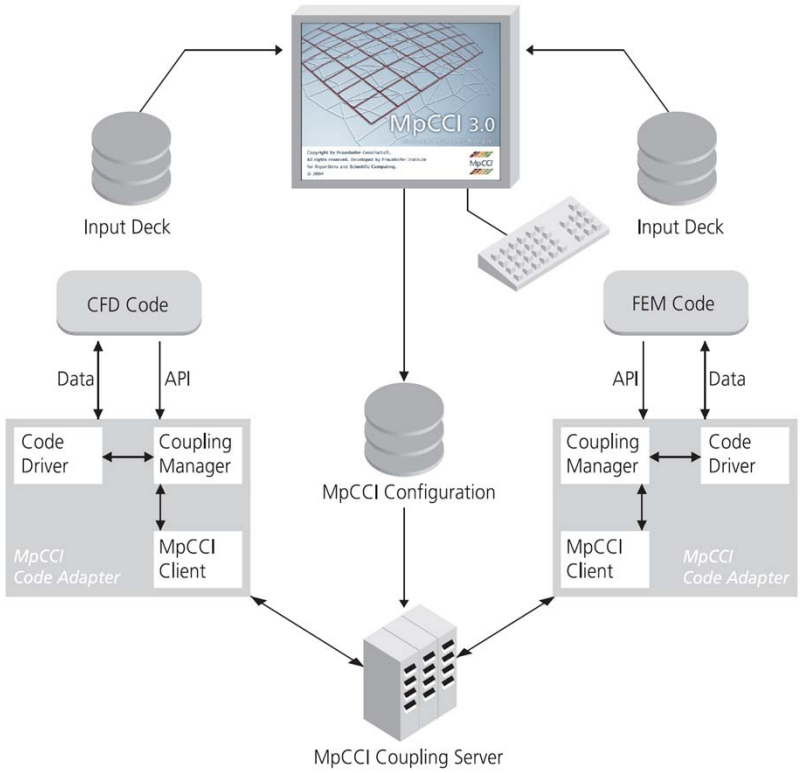
MpCCI – The Independent Code Coupling Interface



MpCCI – The Independent Code Coupling Interface

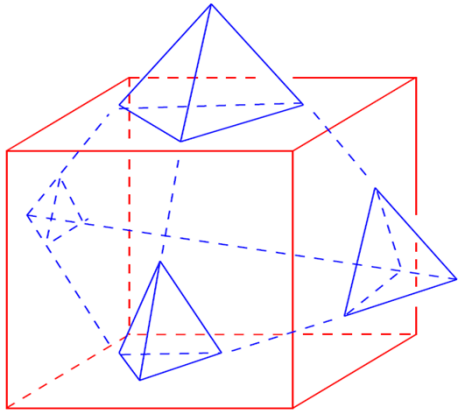
Open interface through API

- Generic coupling concept
  - Flexible mapping workflow:
  - Ramping and under-relaxation
  - Support for dynamic remeshing in code
  - Handling for orphaned nodes
- Flexible coupling schemes
  - Asynchronous buffered communication
  - Subcycling support
  - Coupling on demand
  - Support for ‘iterative explicit’ coupling
- 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

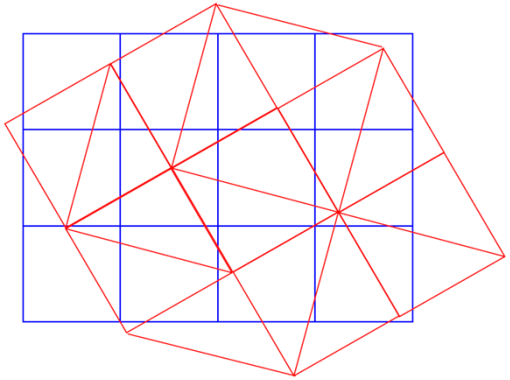


MpCCI – Coupling

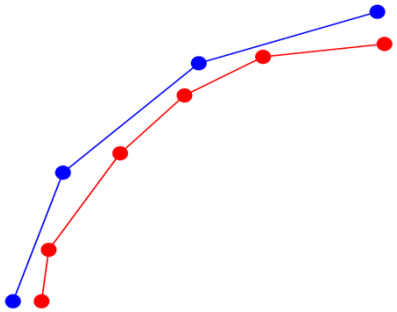
Volume



Surface



Line



MpCCI – Applications

Automotive

- Thermal management
- Engine cooling jackets

Energy

- Elastic Wind Turbine Blades
- Vibrations and Thermal Stresses in Turbines

Consumer Area

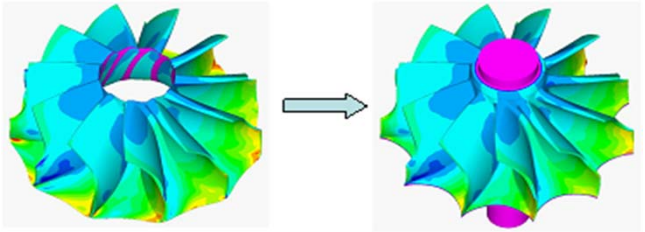
- Joints and Gaskets

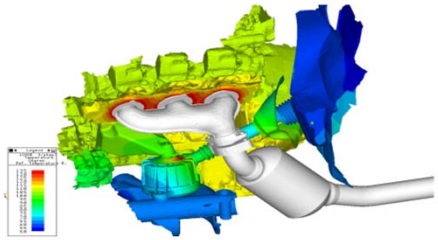
Space and Aircraft

- Aero-Elasticity
- Thermal Effects and ECS

Bio-Medical Area

- Elastic Vasculature





MpCCI – The Independent Code Coupling Interface

MpCCI	v3.1 (March 2009)	V4.0.1 (Q2 2010)	V4.1 (Q1 2011)
Abaqus	6.8,6.9	6.10	6.10
Ansys	9, 10, 11, 12	11, 12	11, 12, 13
Elmer	-	-	5.5
Flowmaster	7,5, 7.6	7.6	7.6, 7.7
Fluent	6.3.26, 12.0.16	6.3.26 12.0.16 12.1.2 12.1.4	6.3.26, 12.x, 13
Flux	10.2, 10.3beta	10.x	10.2, 10.3
Icepak	4.4.6, 4.4.8	4.4.x	4.4.x, 13
MD.Nastran		2010	2010
MSC Adams			Prototype, MpCCI 4.2
MSC.Marc	2005r3, 2007r1, 2008r1	2007r1, 2008r1	2007r1, 2008r1, 2010
Numeca	Fine/Hexa 2.7	-	Fine/Hexa 2.11, Fine/Turbo 8.9
OpenFoam	-	-	1.5, 1.6, 1.7
RadTherm	9.0.1, 9.1.0, 9.1.2, 9.2	9.1.0, 9.1.2, 9.2	9.1, 9.2, 9.3, 10
Permas	12	-	-
Samcef	Samv130 (prototype)	-	-
STAR-CD	4.04, 4.06, 4.08	4.06, 4.08, 4.10, 4.12	4.06, 4.08, 4.00, 4.12
STAR-CCM+		4.04, 4.06, 5.02	4.06, 5.02, 5.04
Adapter API	Available	Available	Available
Modelisar FMI API			Prototype, MpCCI 4.2

Application Examples

- Complex, multi-equation and component coupling for the analysis of electric arcs in switches
- New development: coupling network (0D) and 3D Mechanics simulations
- Coupling for functional mock-up design

Simulation of electric arcs in switches - Overview

- Complex coupled application
- Solution of MHD-Equations
- Application: Switching electric arc in electromagnetic switches
- Cooperation with Eaton Industries (formally Moeller)

Industrial

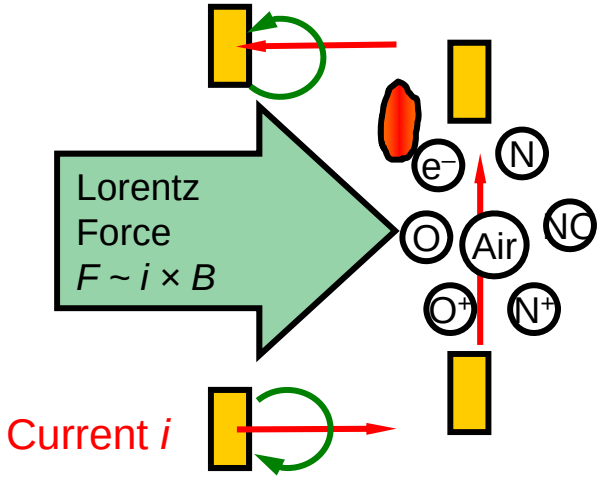
Circuit-breaker

Household

Fuse boxes

Electric arc between contacts

magnetic Flux density



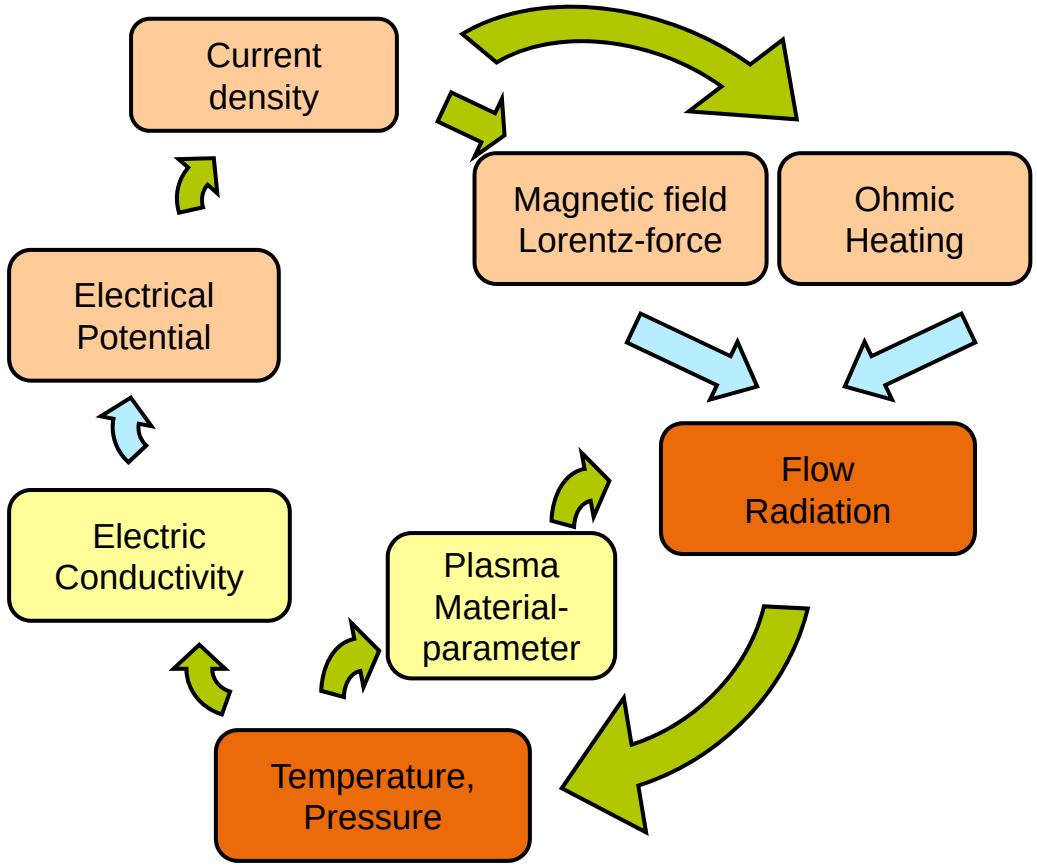
Electric Arc Simulation– Physics

- Complex processes in both fluid- mechanics and electromagnetics
- Plasma handled/modelled as fluid

Finite Volume solution of equations for conservation and radiation

FEM for Maxwell-equations for electrical and magnetic fields

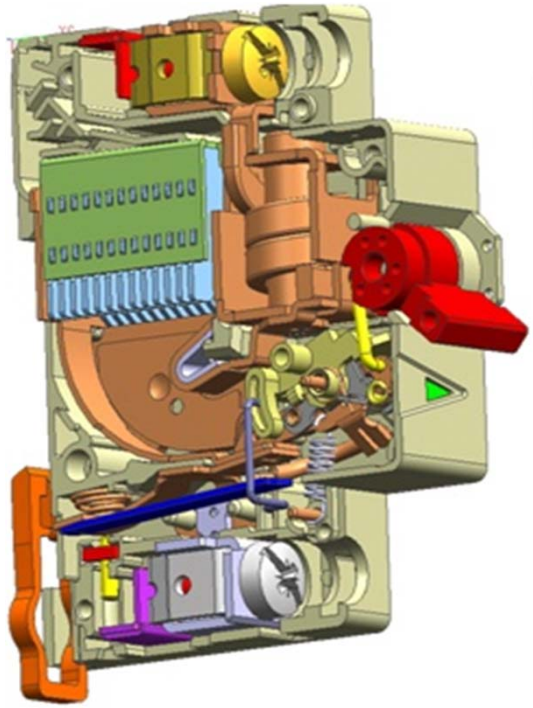
Coupling via MpCCI



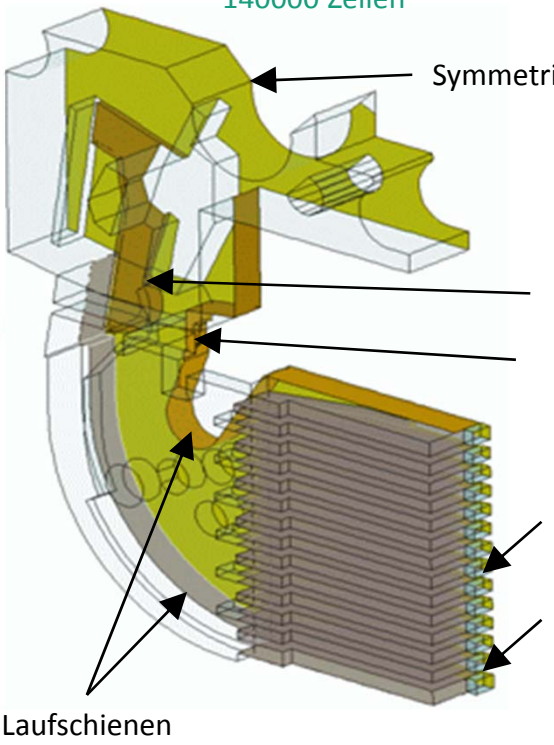
Electric arc simulation

Circuit Breaker PLSM

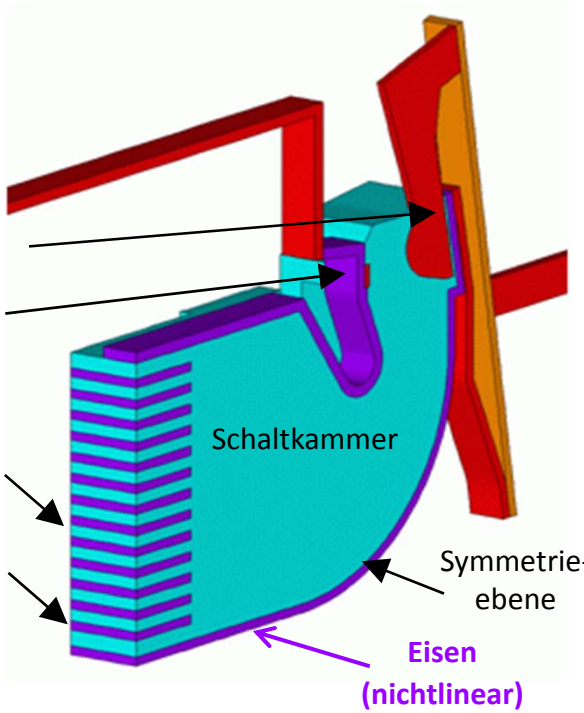
- Calculation performed by A. Zacharias, Eaton



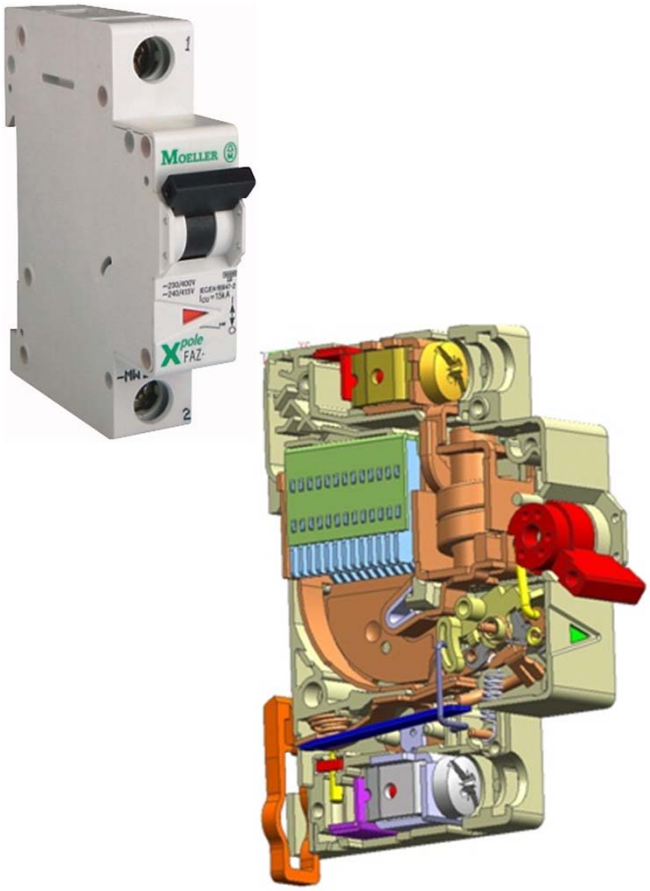
Fluent
140000 Zellen

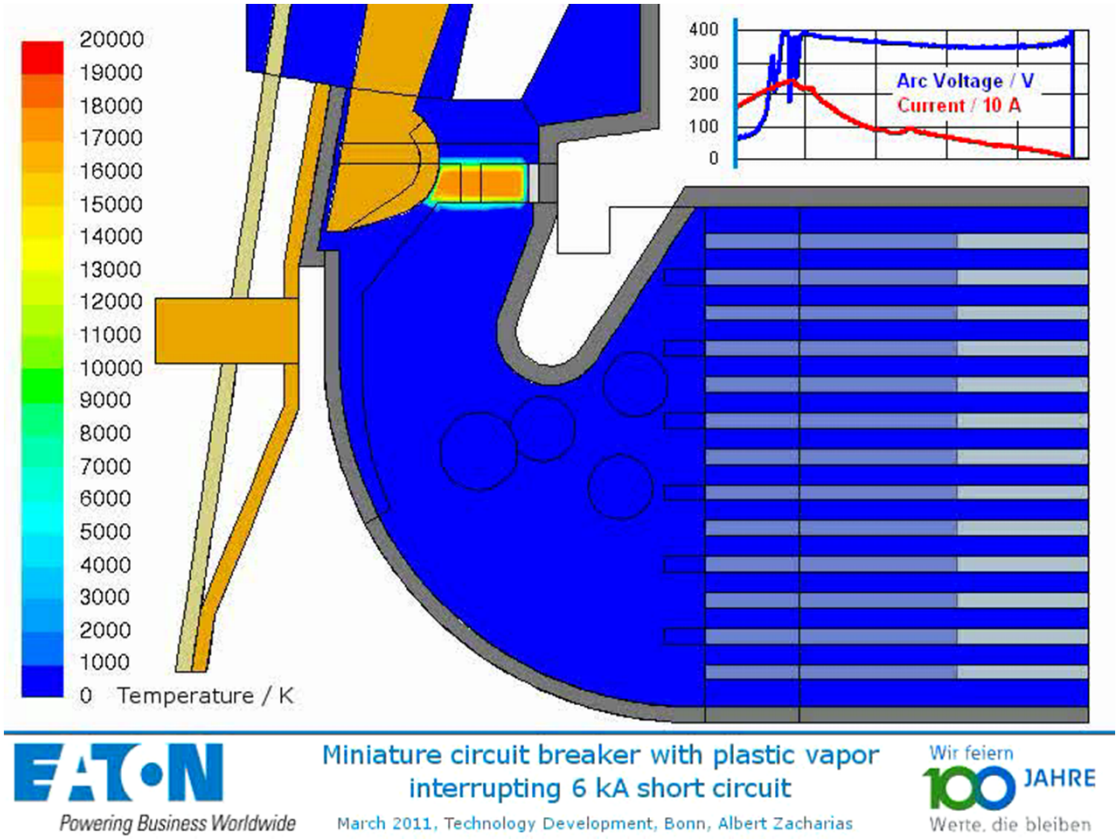


Ansys
99000 Elemente



Electric arc simulation – plastic vapour

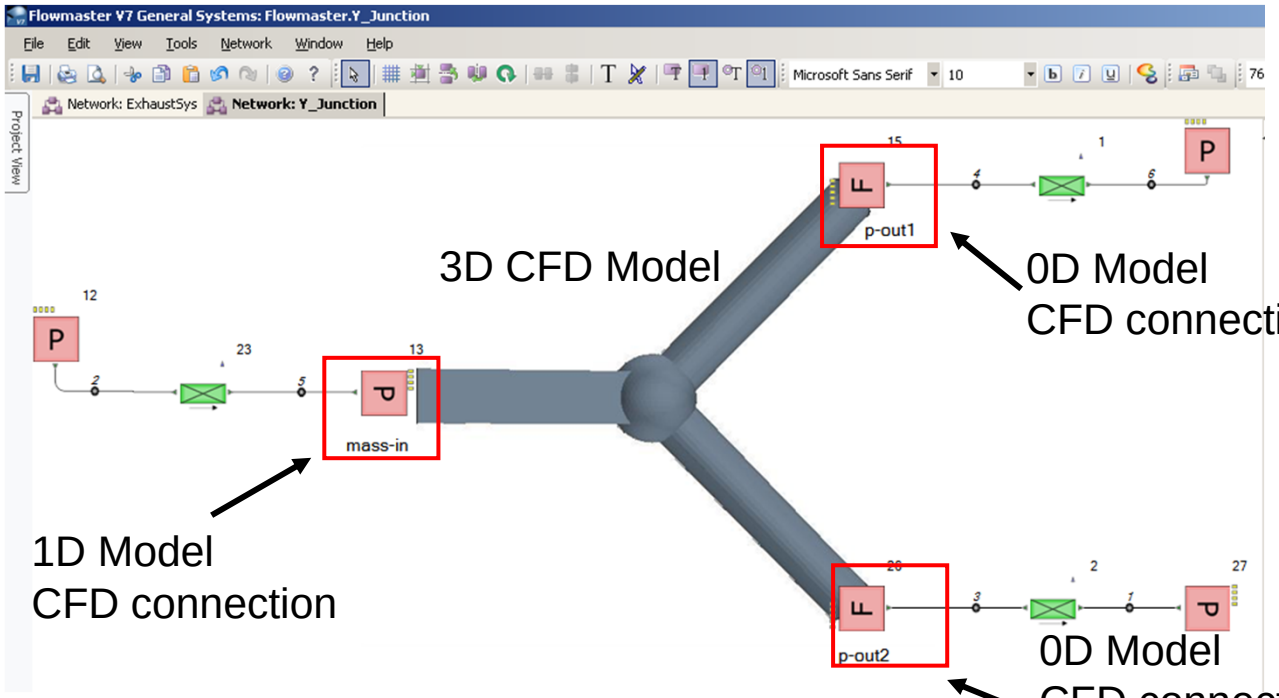




MpCCI – 0D-3D CFD-Applications

Co-simulation is the coupling between

- A network (0D) model component (integration point)
- a surface of the 3D CFD application



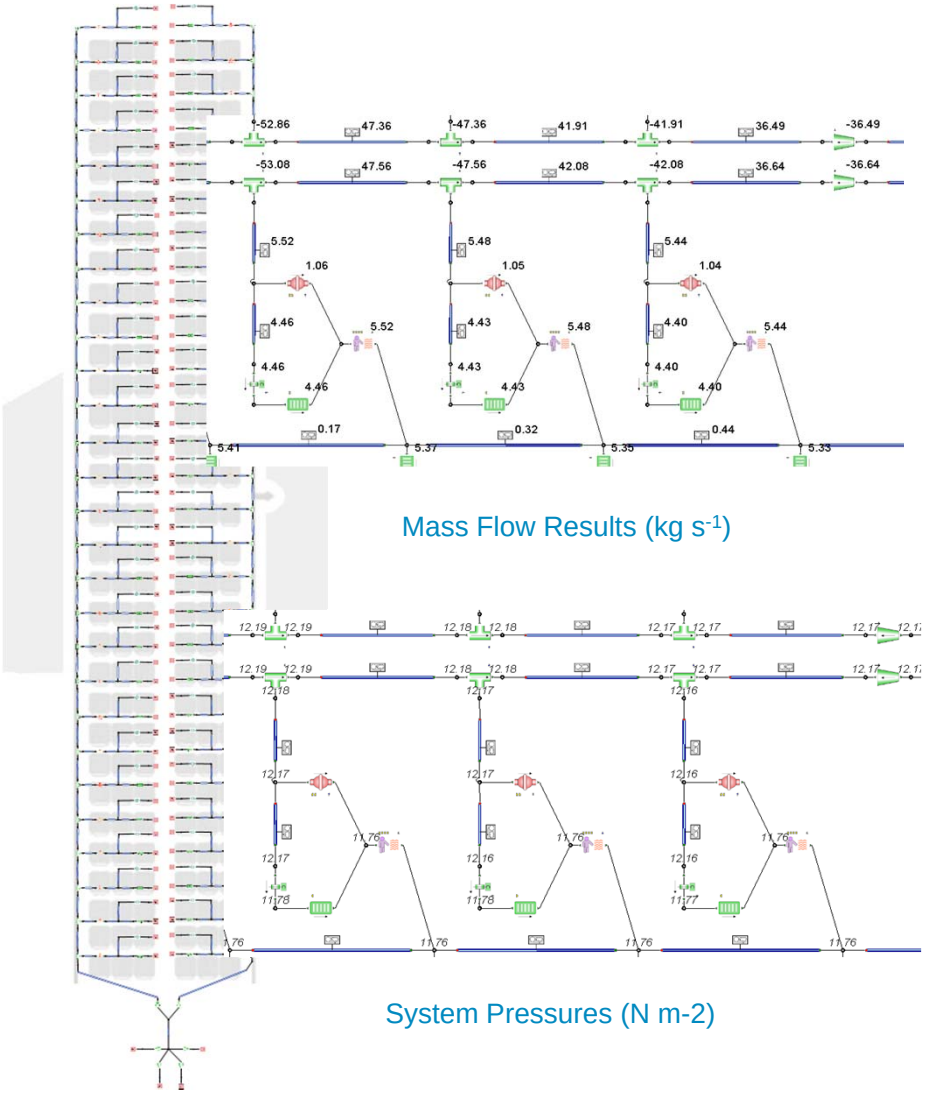
MpCCI – 0D-3D CFD-Applications

0D – 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 to set up and very quick to analyze

Enabling

- Understand system interactions
- Help meet passenger flow rate requirements
- Help guarantee proper temperature and pressure



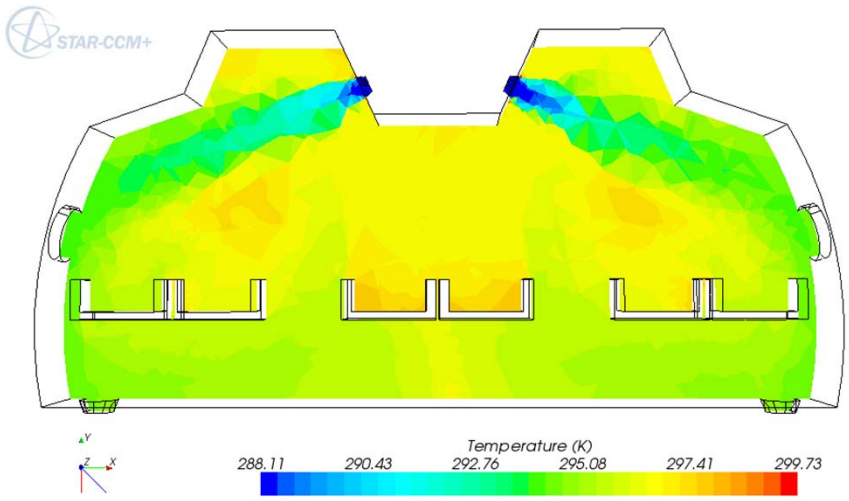
Mass Flow Results (kg s^{-1})

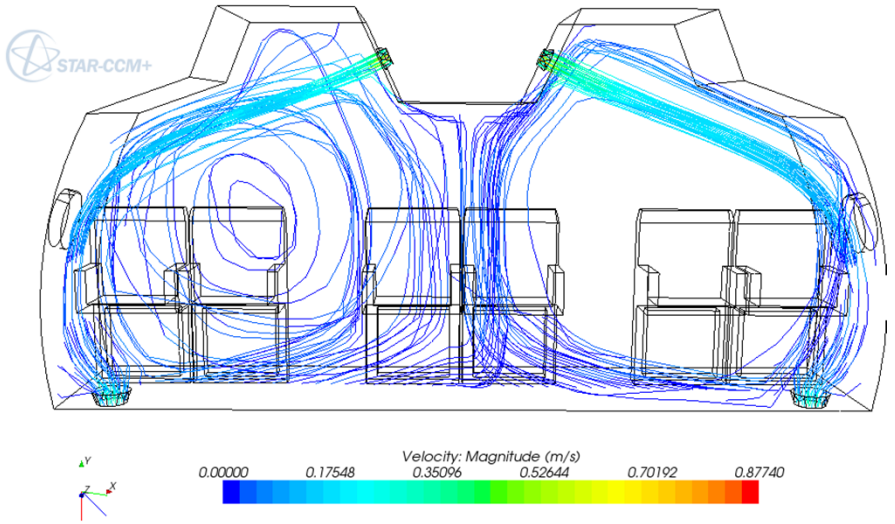
System Pressures (N m-2)

MpCCI – 0D-3D CFD-Applications

3D CFD

- Better technique for modeling larger ‘open’ volumes with complex flows.
- Gives better appreciation of factors affecting passenger comfort



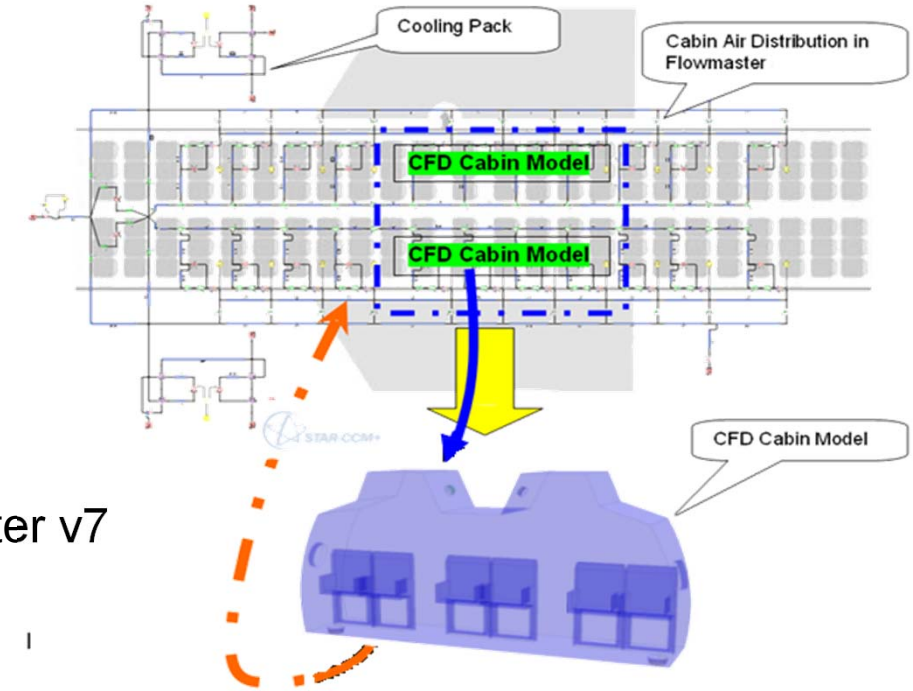


MpCCI – 0D-3D CFD-Applications

Large Aircraft Cabin ECS System in Flowmaster V7

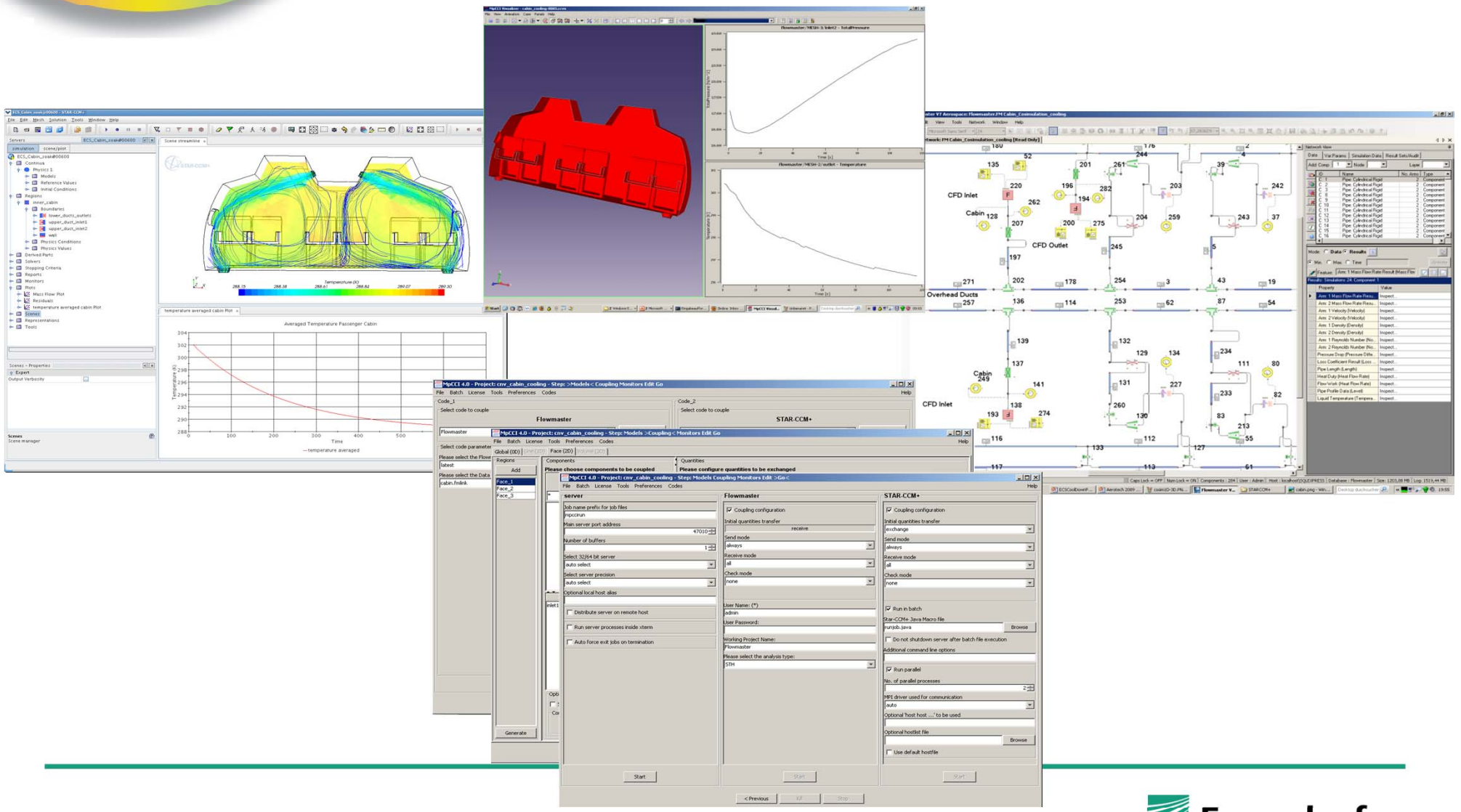
CoSimulation Method

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



Partial CFD Model of Cabin in STAR-CCM+

MpCCI – 0D-3D CFD-Applications



Functional Mockup CoSimulation

MODELISAR Characteristics

International consortium with focus on IT and technology partners

ITEA 2
INFORMATION TECHNOLOGY FOR EUROPEAN ADVANCEMENT

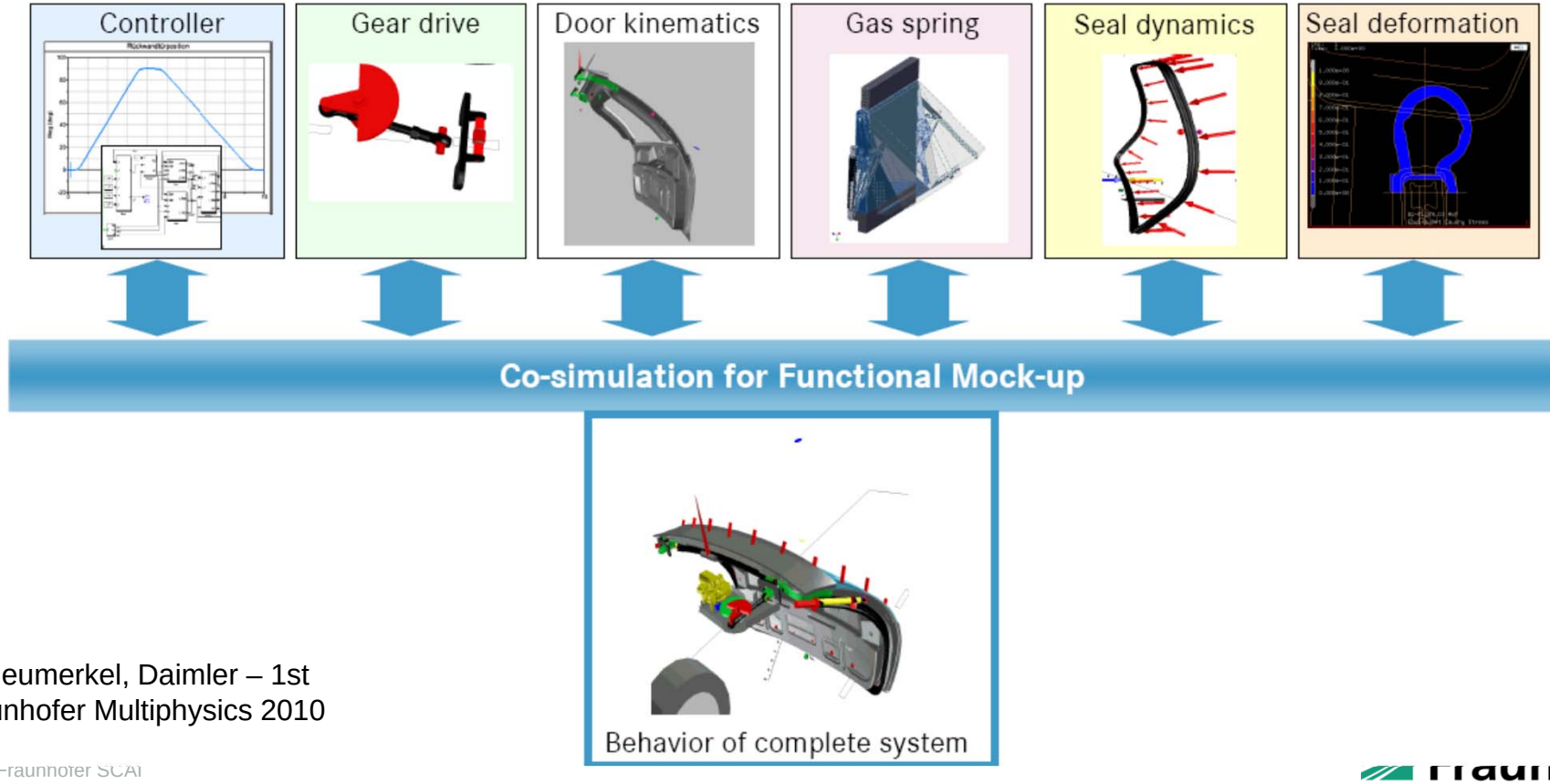
- Project Duration (ITEA)
  - 3 years
  - July 2008 – June 2011
- Project Partners
  - 29 partners from 5 countries
    - Austria
    - Belgium
    - France
    - Germany
    - Sweden
- Coordinators
  - Dassault Systèmes
  - Daimler AG
- Budget / Funding
  - 30M€ / 10M€

D. Neumerkel, Daimler – 1st Fraunhofer Multiphysics 2010

Functional Mockup CoSimulation

The Functional Mockup Vision

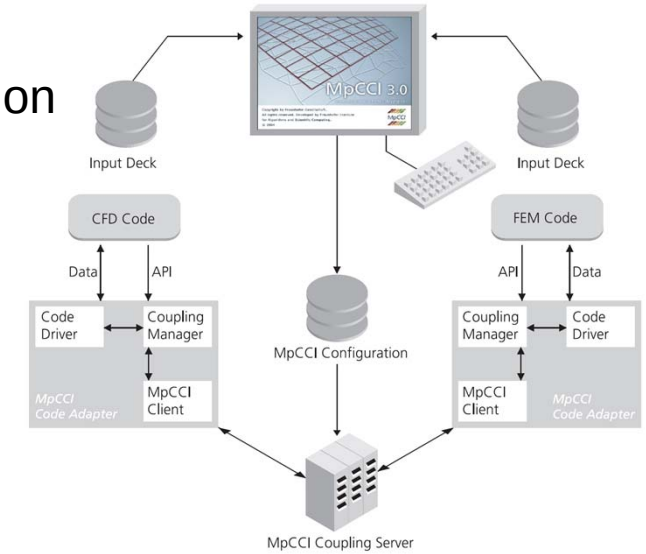
Robust system simulation with "plug and play"
integration of models from different domains and tools



D. Neumerkel, Daimler – 1st Fraunhofer Multiphysics 2010

Functional Mockup CoSimulation using MpCCI

Modules and Communication



FMI master

MpCCI FMI library
(contained in FMU)

Code(s) with MpCCI adapter

MpCCI FMI proxy code

MpCCI server

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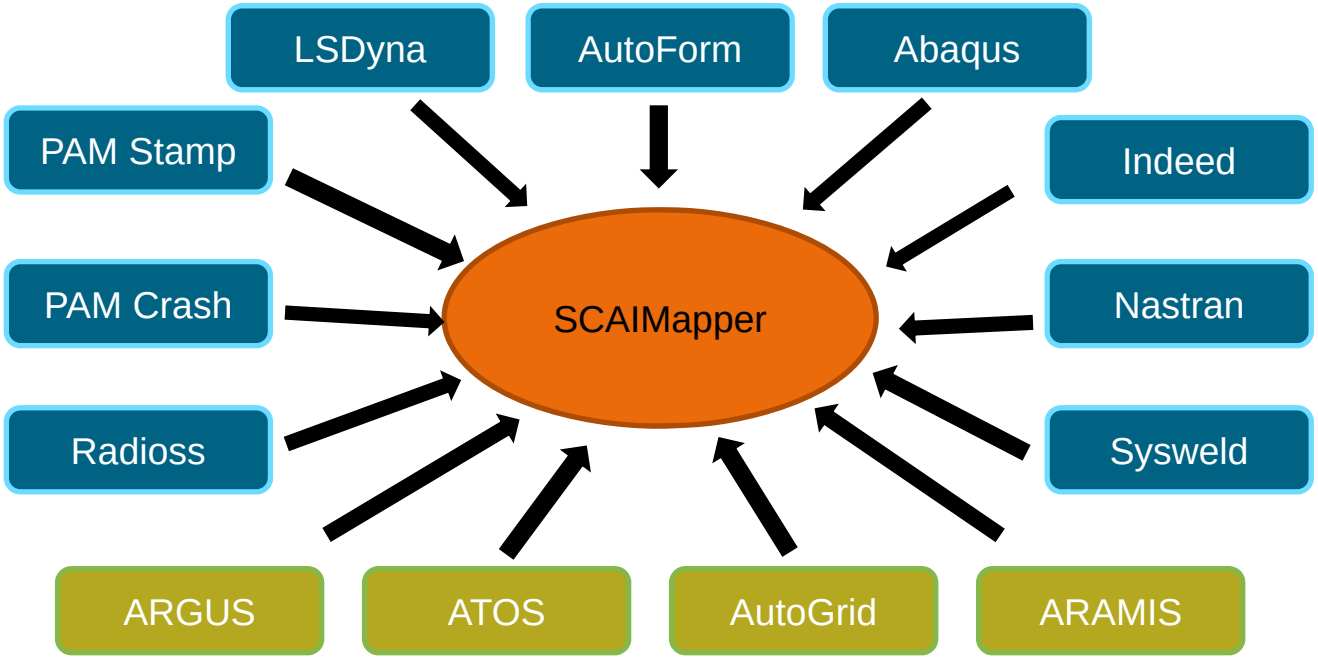
SCAIMapper: Mapping Solutions

Mapping: one-time data exchange

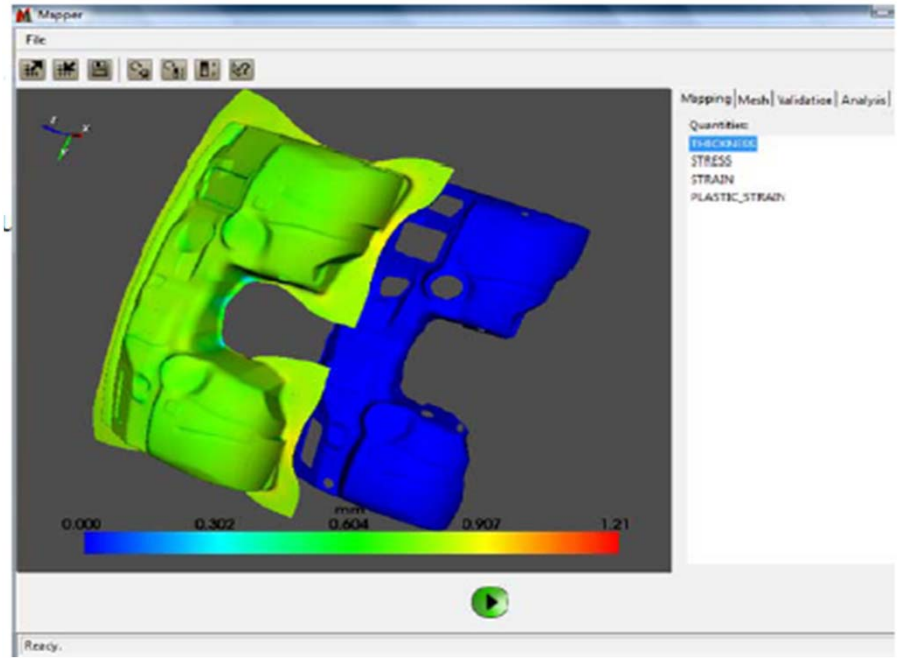
- Supports various CAE data formats
- Automatic mesh-orientation
- Robust algorithms for interpolation



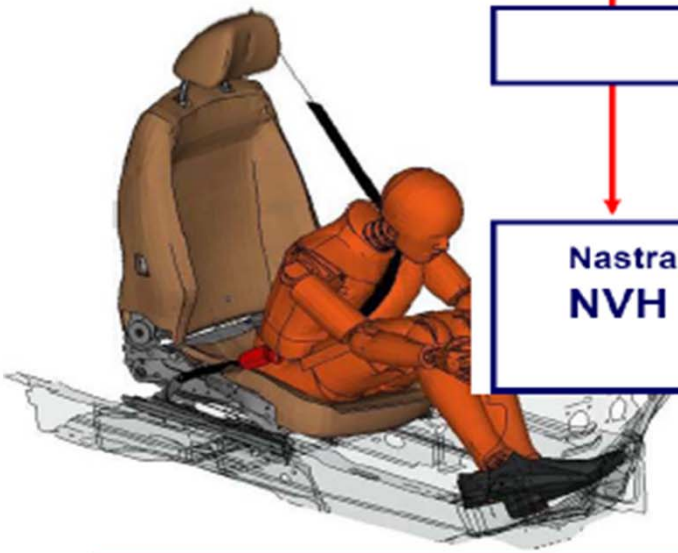
SCAIMapper for Metal-Forming Workflows

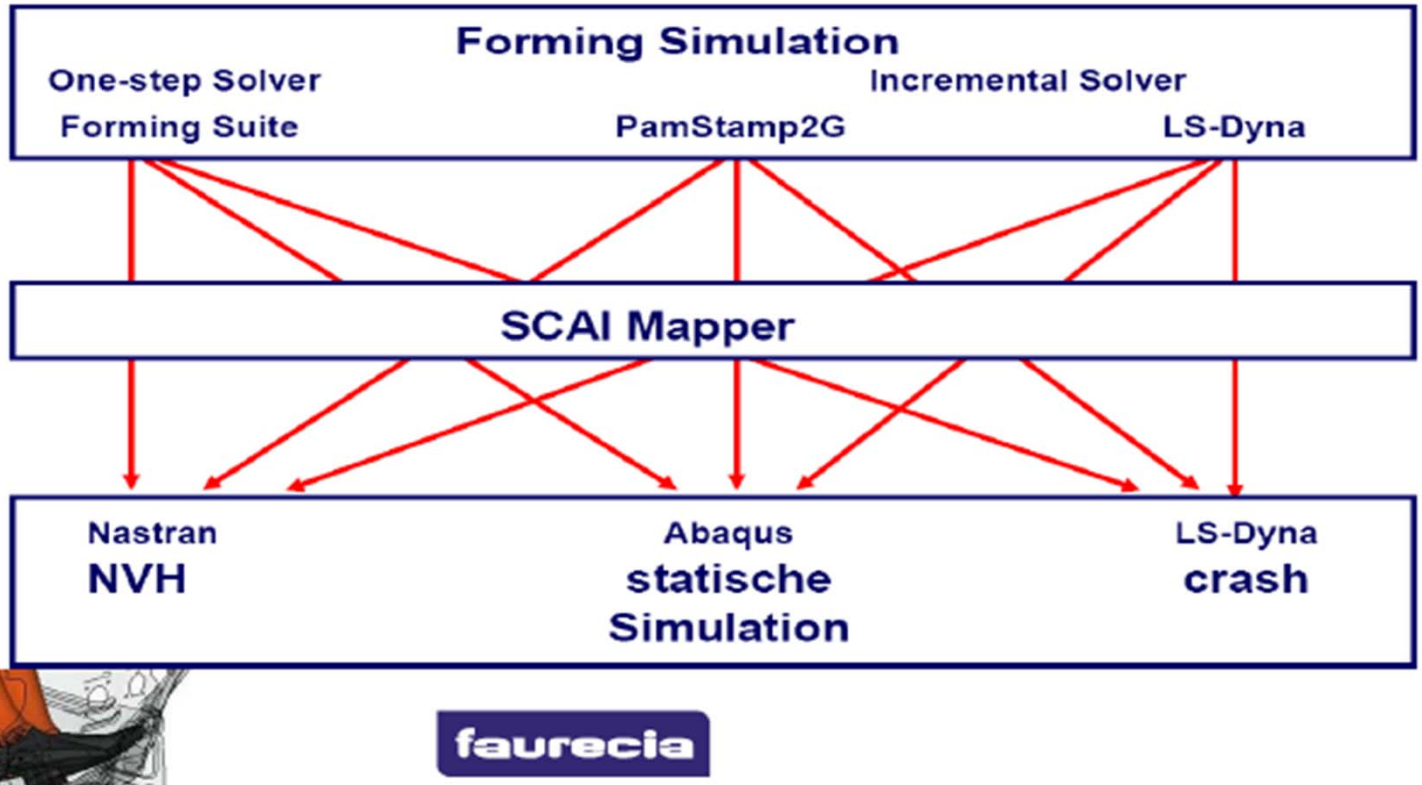
Basic Features

- Supports various native CAE file formats
- Automatic and interactive mesh alignment
- Robust algorithms for mapping of various element type and quantities
- Validation of mapping results and local comparison of quantities



SCAIMapper for Metal-Forming Workflows





faurecia

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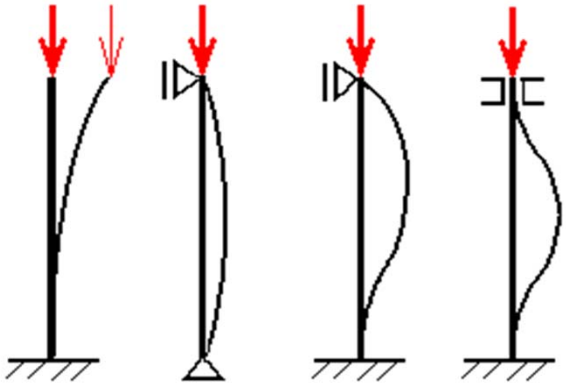
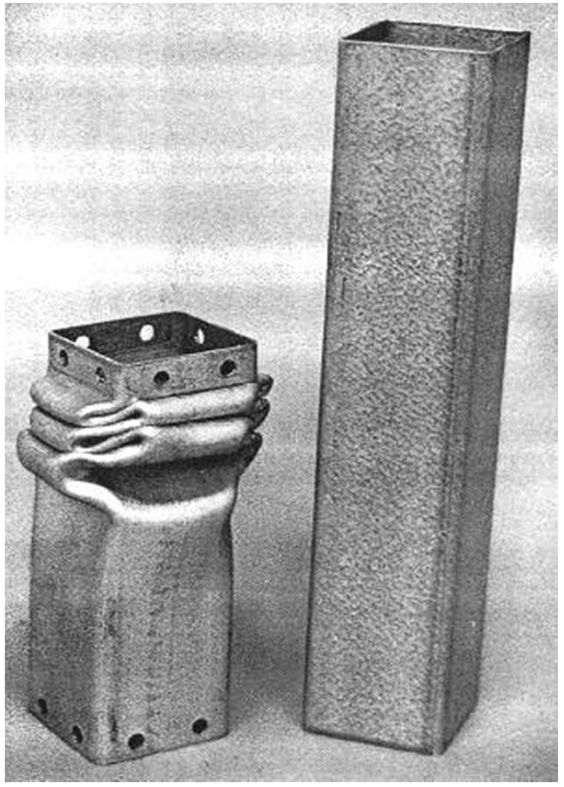
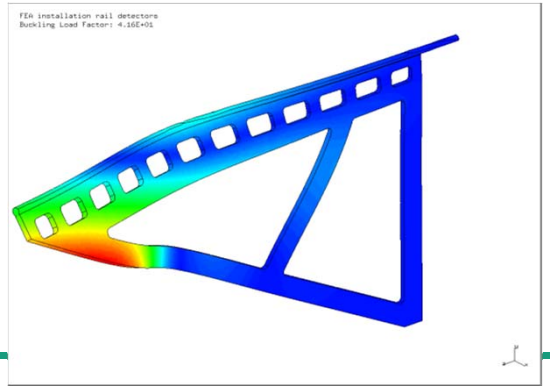
Buckling: example of variation in engineering structures

„Knickstab“



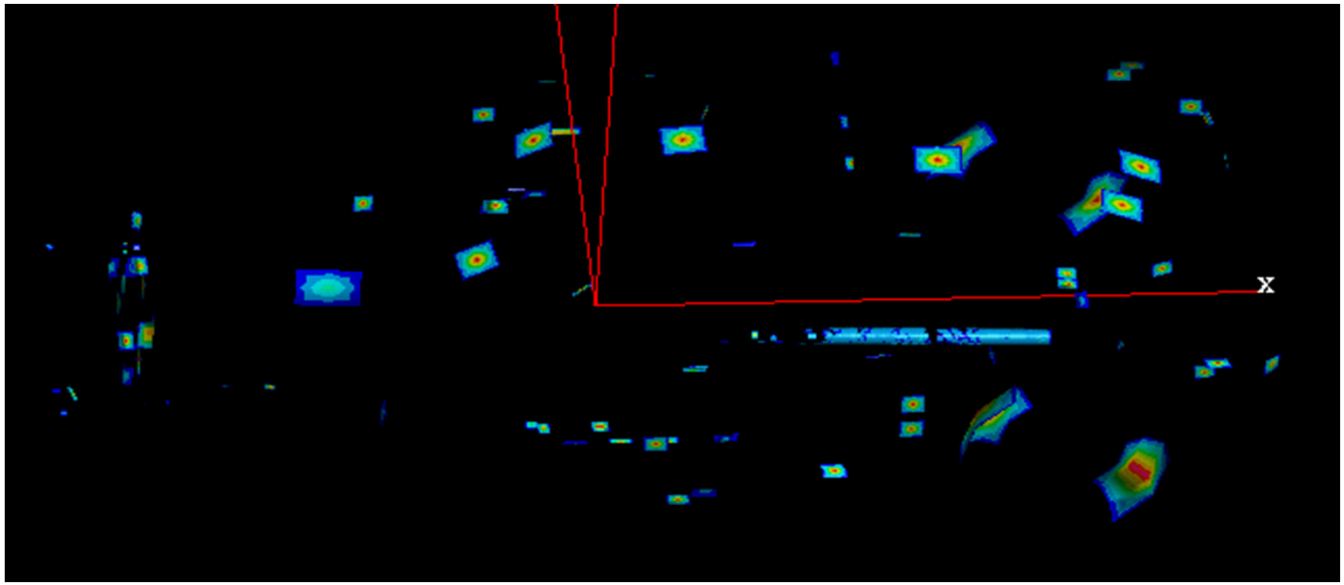
Tubes





Buckling mode as result of linear structural analysis

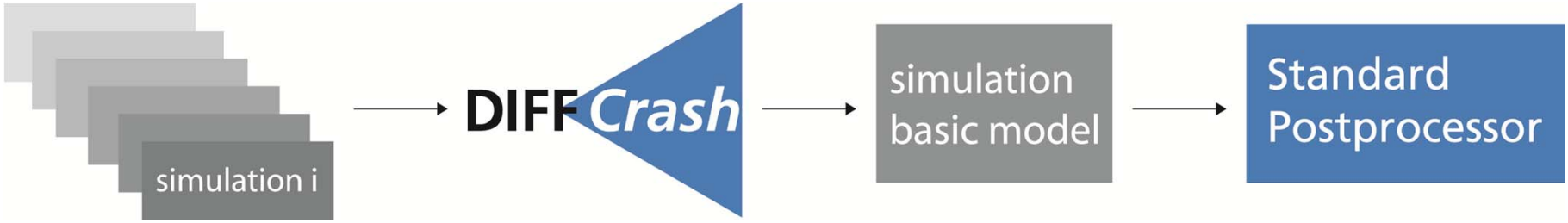
Buckling candidates in full automobiles



Model provided by BMW during the AUTOBENCH Project
Forge indicator as color coding computed by DIFFCRASH

DIFF-CRASH : Stability analysis

- Postprocessing tool

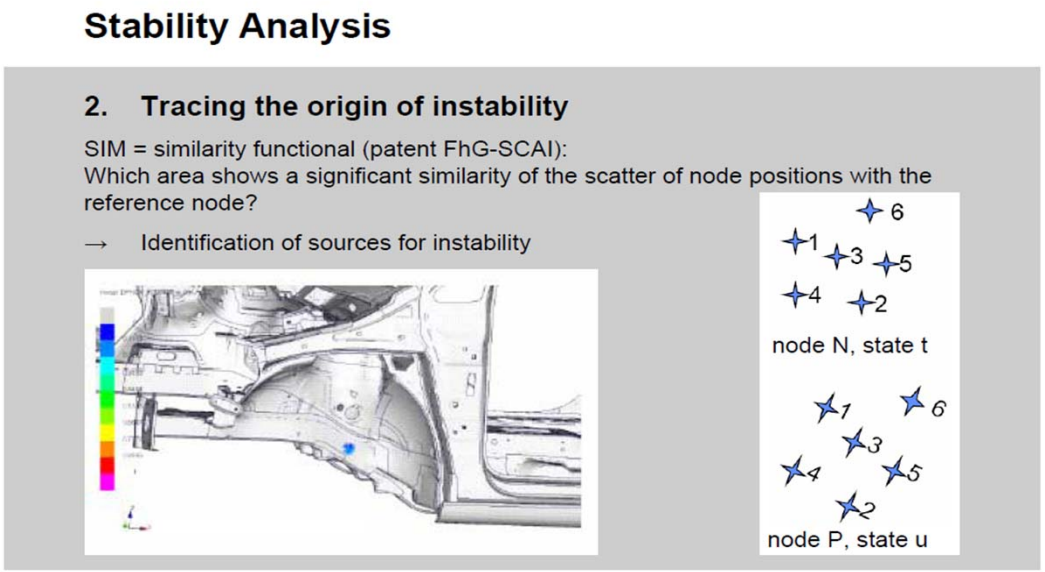


- Statistical Analysis of full simulation models

- New: Difference Mode Analysis

DIFFCRASH Aim:

- DIFFCRASH: Identification of sources of scatter: location and time
- DIFFCRASH 5: Separation of multiple sources
- Mathematical methods:
  - Correlation analysis
  - New: Elimination of a detected source from the set of results (Orthogonalprojection)
  - New: Decomposition of scatter into modes with physical meaning

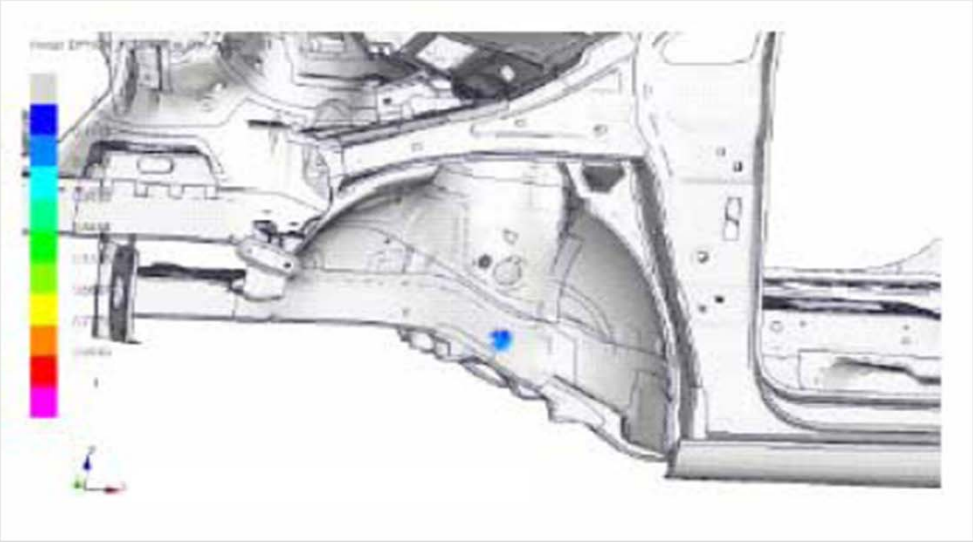


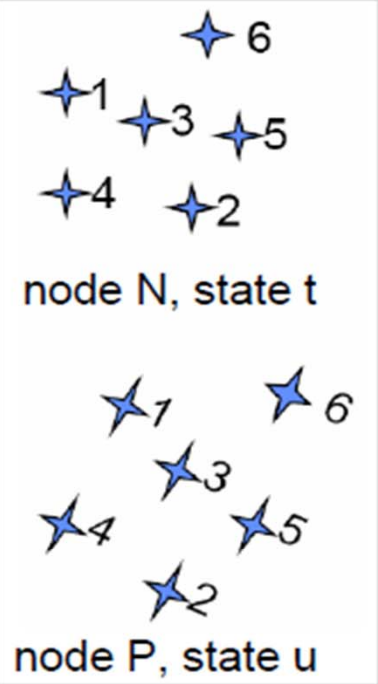
Stability Analysis

2. Tracing the origin of instability

SIM = similarity functional (patent FhG-SCAI):
Which area shows a significant similarity of the scatter of node positions with the reference node?

→ Identification of sources for instability

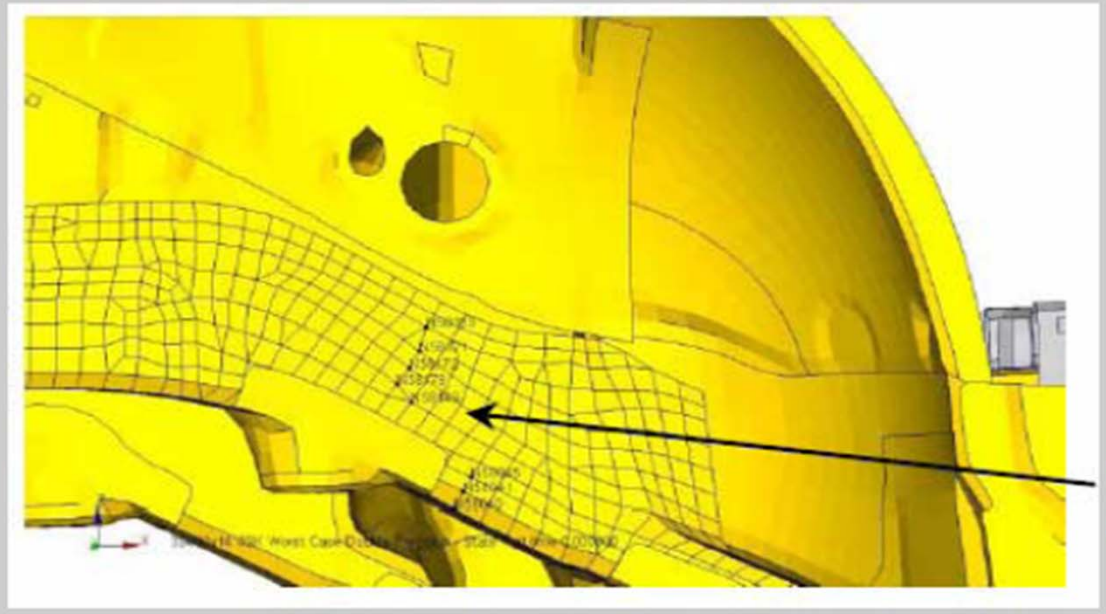




Stability Analysis

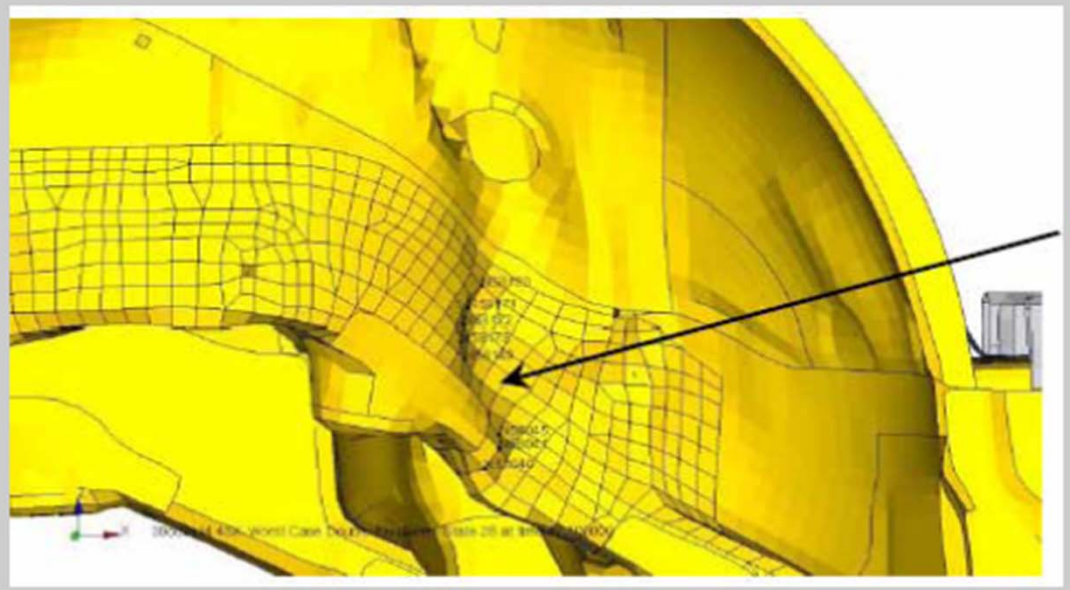
3. Development of measures to improve stability

→ adequate modification of the model / design that results in stable crash behaviour (similar to the crash behaviour of the best run)



Stability Analysis

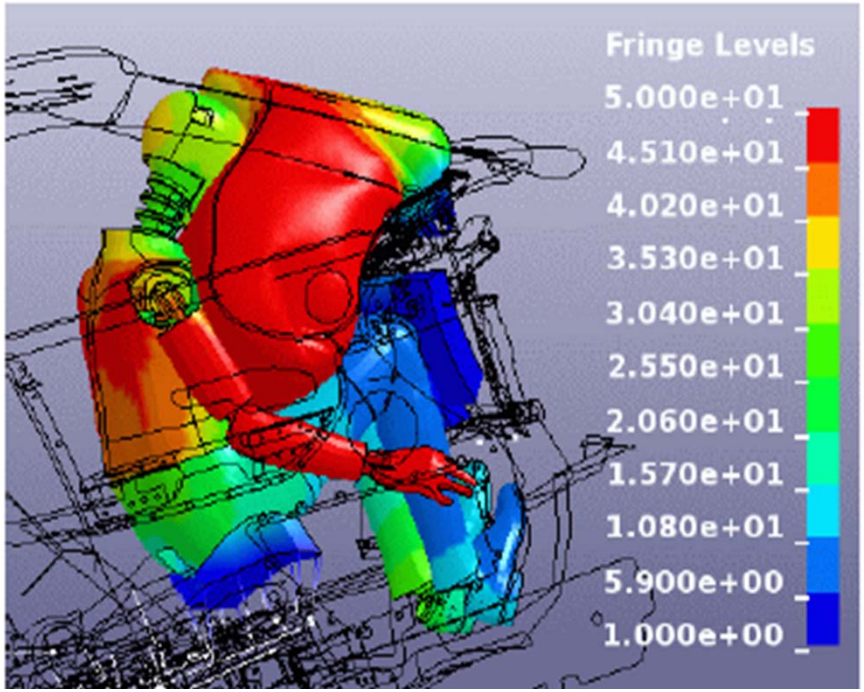
3. Development of measures to improve stability



Scatter of the firewall intrusions < 3mm

→ **Stability adequate!**

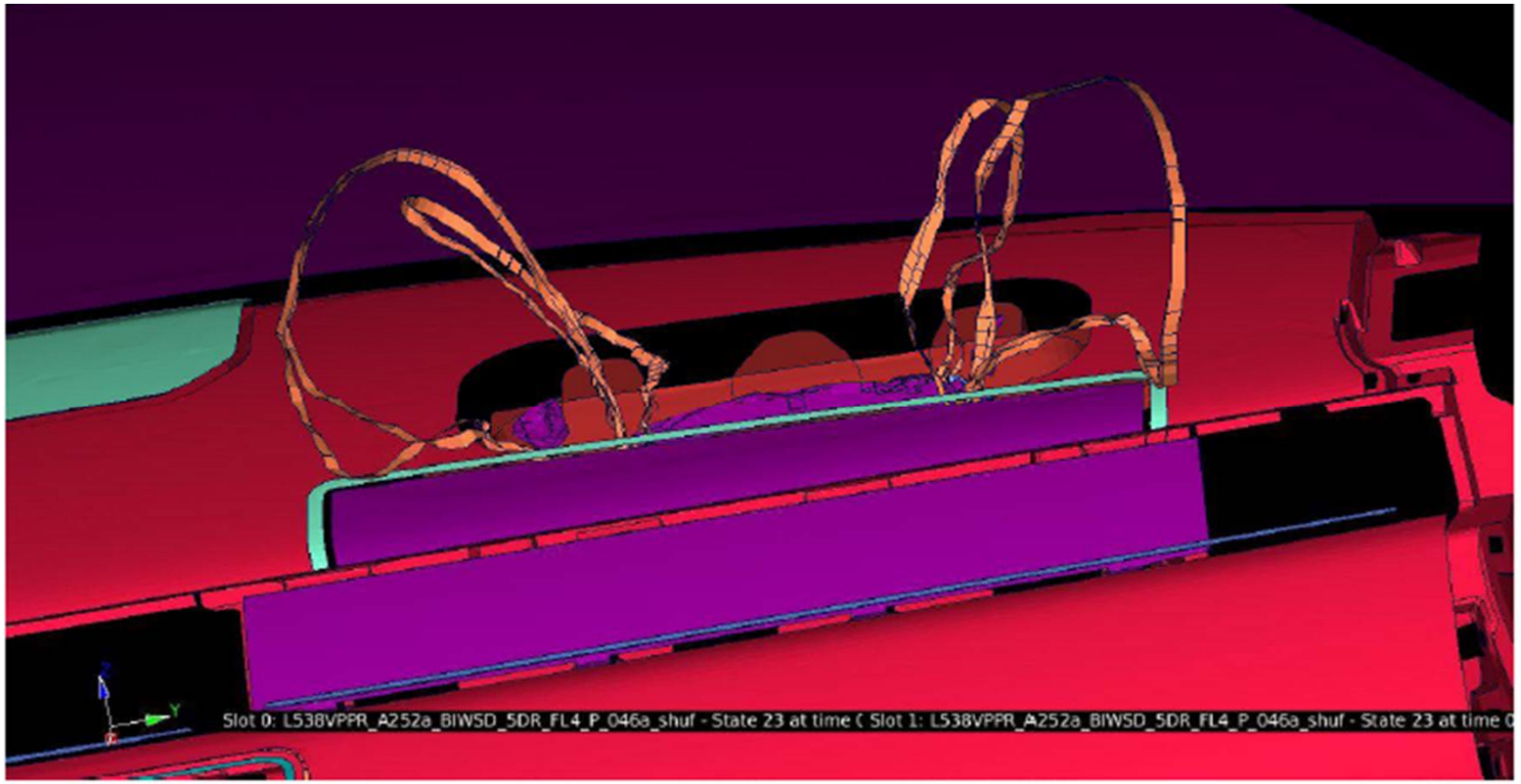
Simulation Variations in the air-bag – passenger-dummy impact



Maximal Scatter (mm) of simulation results at time step 50 shown as fringe plot

Courtesy of Land Rover

Extreme cases of the positioning of the air-bag ribbon depending on the interaction with the dashboard



State 23

Courtesy of Land Rover

Presentation Overview

- Intro to scapos & Fraunhofer SCAI
- Simulation-related aspects of complex systems design
- 3 SCAI technology & tool developments
  - Multi-physics = Multi-code coupling for complex simulations: MpCCI
  - Multi-code workflows: SCAI-Mapper
  - Analysis of complex processes in simulation: DIFF-CRASH
- Concluding Remarks

Simulation-related aspects of complex systems design

- **HPC: Scalability of software for the extreme requirements of multi-phenomena, multi-scale simulations of complex physical processes**
- **Environments to Integrate multi-scale simulations**
- Coupling software components at a common scale for flexible multi-code, multi-physics simulations
- Transferring information between simulations in complex design workflows
- Understanding sources of variation arising in modelling and simulation in engineering design
- …….

Summary: supported products

CAE Products

MpCCI

DIFFCrash

FEMZIP

DesParO

Fraunhofer SCAI

Optimisation & Logistics

AUTO NESTER-T automatic marker making

PACK Assistant

AUTO NESTER-L automatic nesting

LOGISTIK SIMULATION

HPC

GPI

Fraunhofer ITWM

Parallel Software

SAMG Algebraic Multigrid Methods for Systems

Tremolo-X

Bio-Informatics / Life Sciences

ProMiner

SCAIVIEW

chemoCR chemical compound reconstruction

Fin

– Merci pour votre Attention !