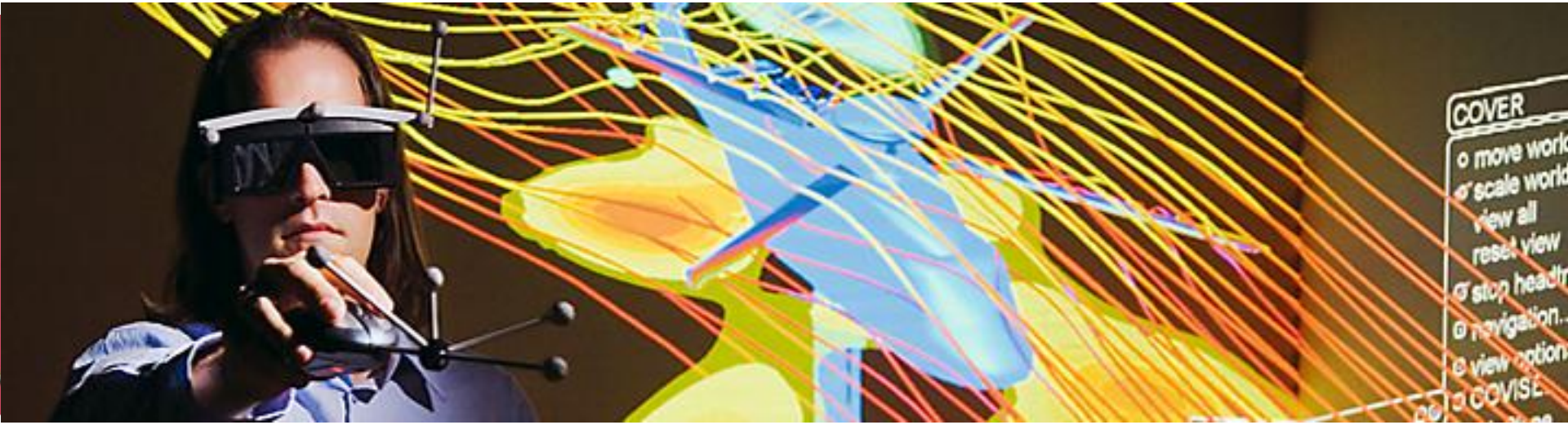
Using interactive Simulations, Virtual and Augmented Reality for intuitive Product optimization

Uwe Wössner, HLRS



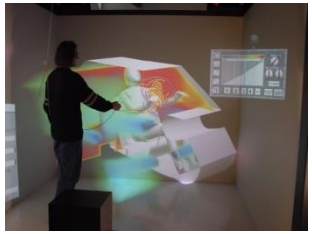
THE HLRS SYSTEMS

Hermit
Cray XE6(7000x16)

NEC SX-9 (156)

NEC SX-8 (576/~120)

NEC Asama
(64)



CAVE

DALCO Viz-Cluster
(8*4+32*2)

Fileserver

IBM HSM
> 2 PB

Ulm

Stuttgart

bwGRiD

SUN Fire 2900
(48x2)

IBM x3755
(144x2)

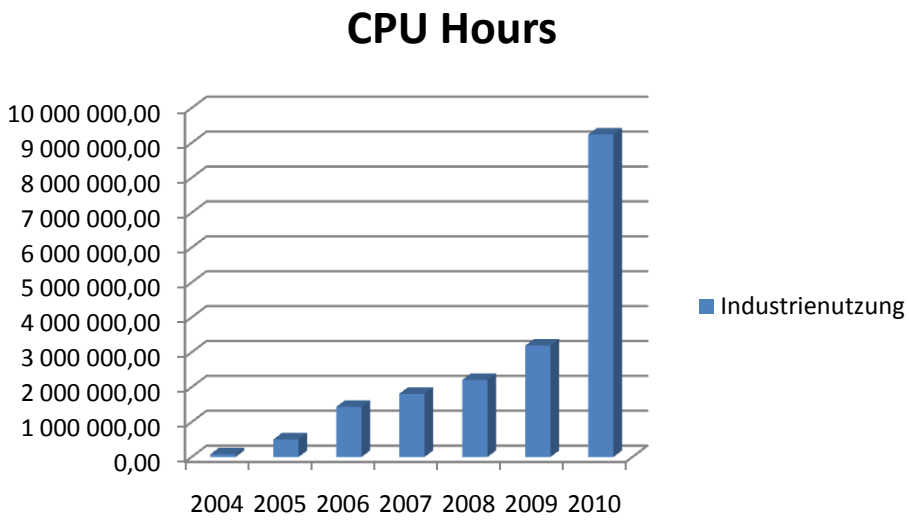
Cray XT5+XD1
(224*4+48)

NEC Nehalem
(1400x4)

IBM Cell

IBM
(2800x4)

INDUSTRIAL USAGE



- Bertrandt
- BTB
- Daimler
- Kärcher
- Mahle
- Porsche
- RECOM
- Transsolar
- Stellba

PRODUCT DEVELOPMENT PROCESS

3 Phases:

Planning → Development → Production

practical example (Daimler):

Definition | Design | Startup

Concept | Series development | Series production

Focus of this presentation:

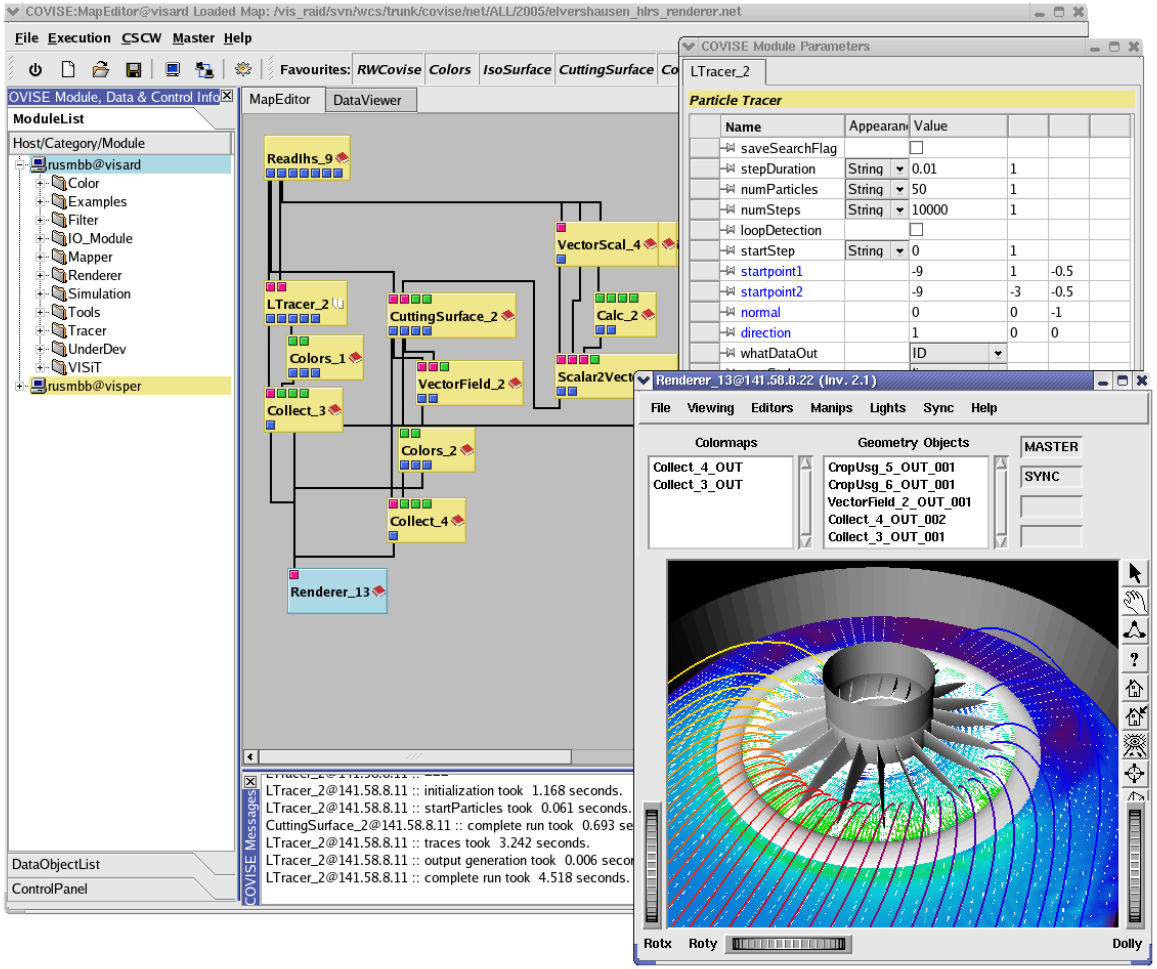
Hybrid Prototypes

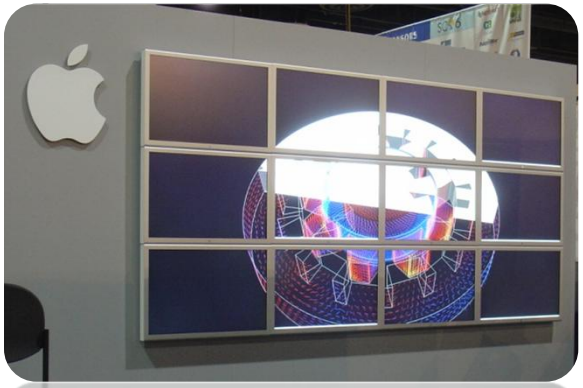
BUILDING BLOCKS OF A WORKSPACE

User Interface	VR Userinterface (VRUI)	Tablet-PC (TabletUI)	Tangible Interface	Multi Touch
Tools	Visualization	Simulation		
Workspace	Virtual Reality (VR)	Augmented Reality (AR)	Desktop	
	Hybrid Prototypes			

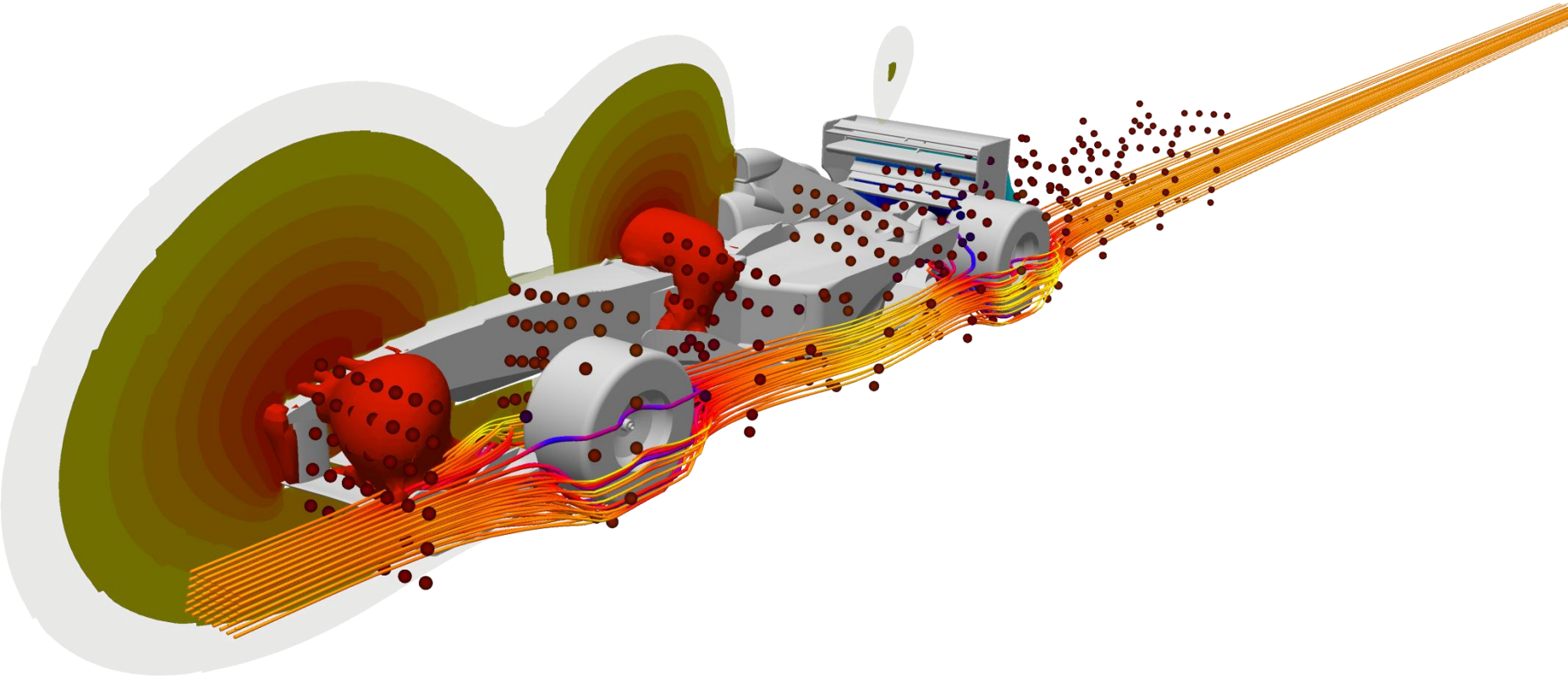
COVISE

COLLABORATIVE VISUALIZATION AND SIMULATION ENVIRONMENT





Virtual Reality

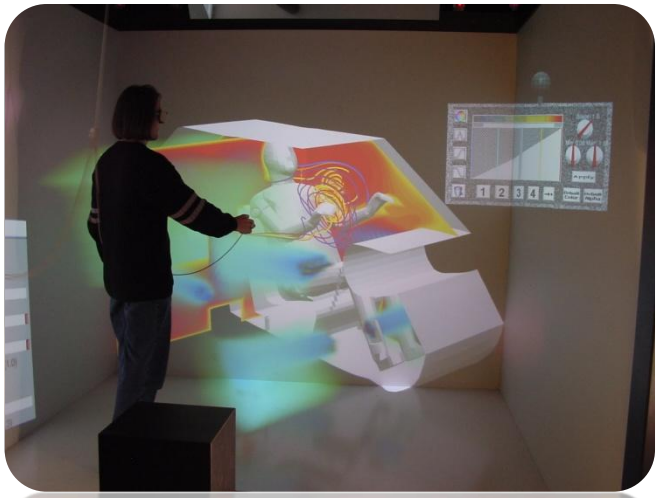


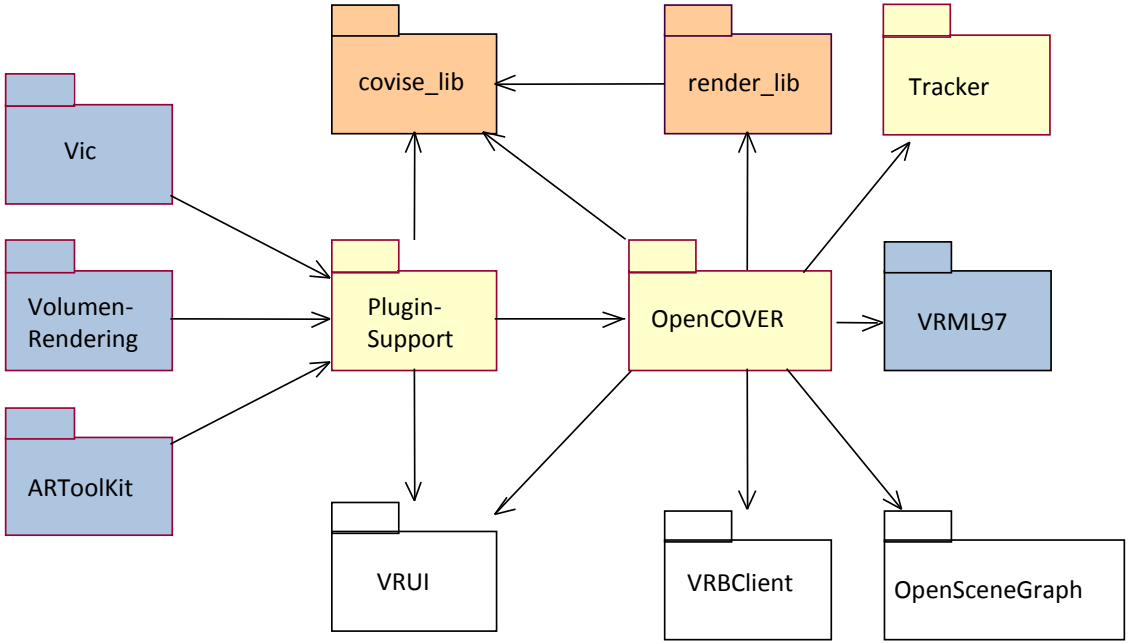
OPENCOVER

COVISE VIRTUAL ENVIRONMENT RENDERER

Features:

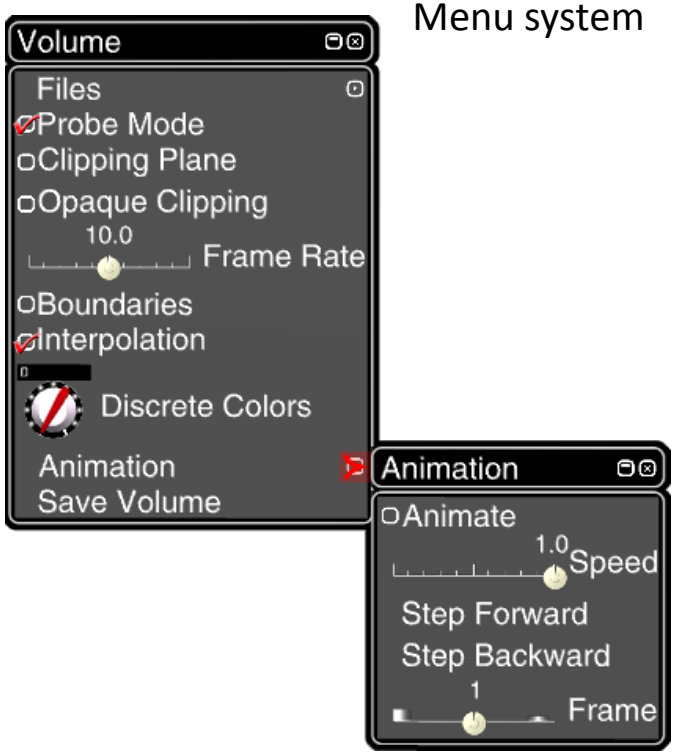
- Flexible plugin system
- Support for projection based VR, tiled Displays and HMDs
- Augmented Reality
- CSCW
- Volume rendering
- VRML97
- 3D VR GUI (VRUI)
- Parallel rendering



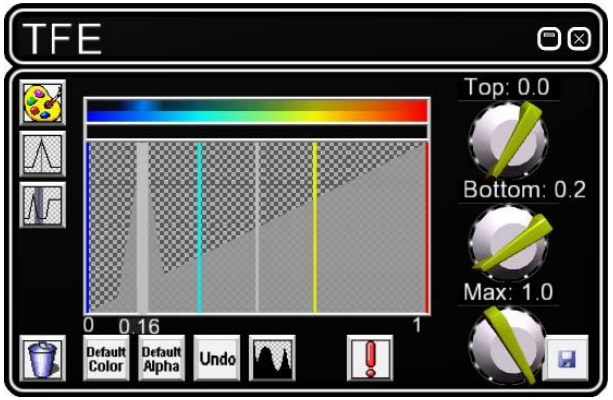


VRUI USERINTERFACE

- The API resembles that of QT, AWT,…
- Supports hierarchical menu systems.
- Supports concurrent interaction in collaborative VEs
  - Automatic synchronization of values
  - Kontext dependend GUIs for collaborative work
  - Locking to support concurrent interaction



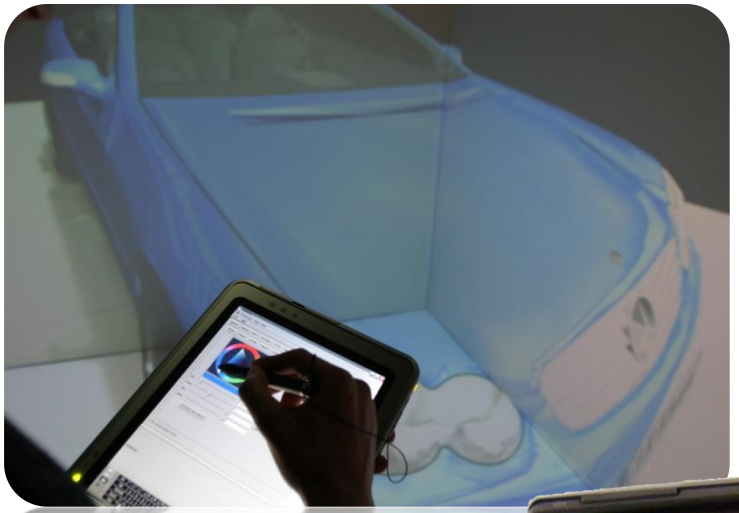
Menu system



Transferfunktionseditor

Toolbar

TABLET-PC USER INTERFACE



- Easy input of Text and numbers
- Precise interaction
- Independent of frame rate
- Development of optimized complex GUIs
  (Material editor, transfer funktion editor, scene graph browser)
- Scalable from smartbords over tablet PCs to mobile phones

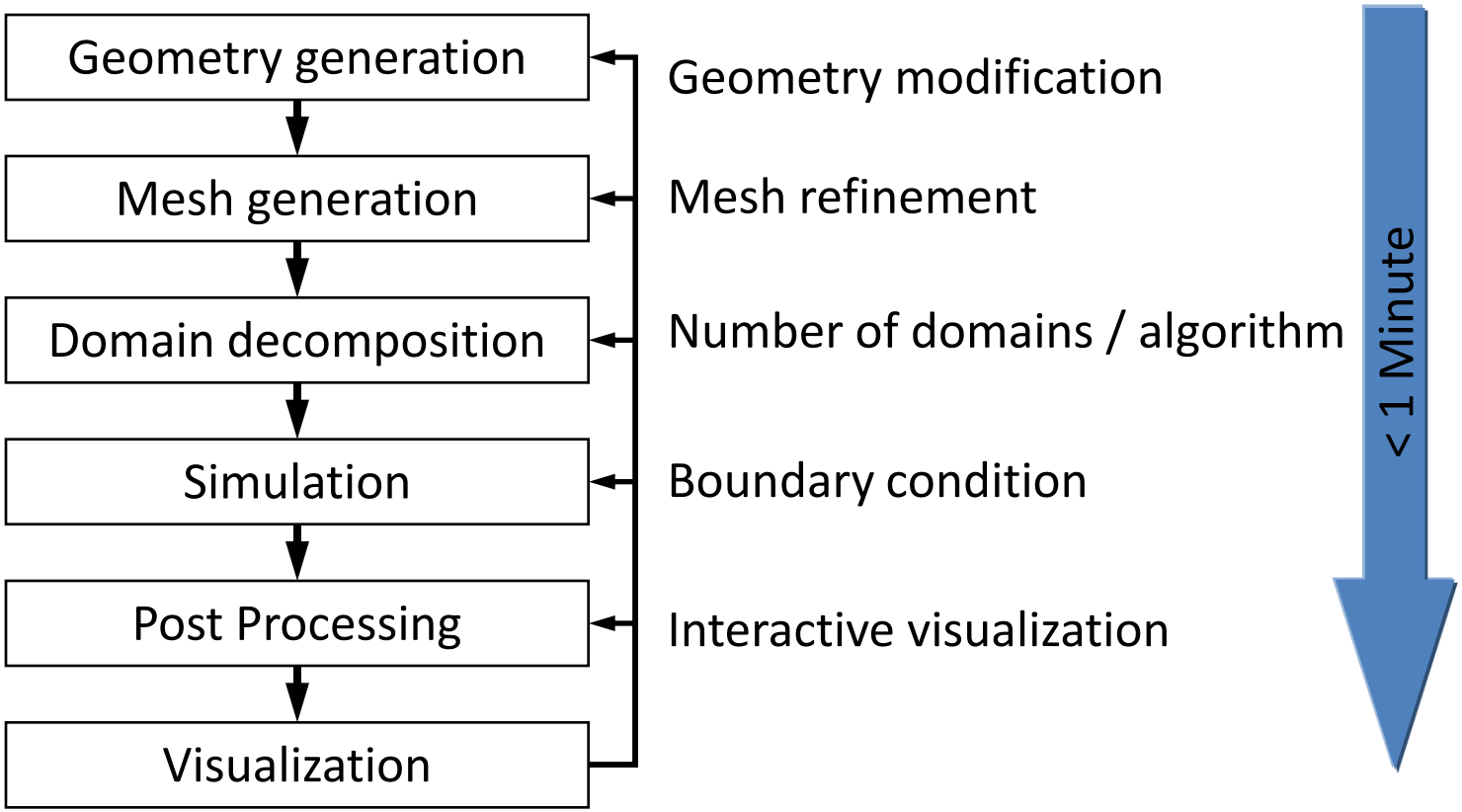
RECOM SERVICES
REaction & COmbustion Modelling

HLRS
High Performance Computing Center Stuttgart

Combustion Modelling
in Power Plants

RECOM Services

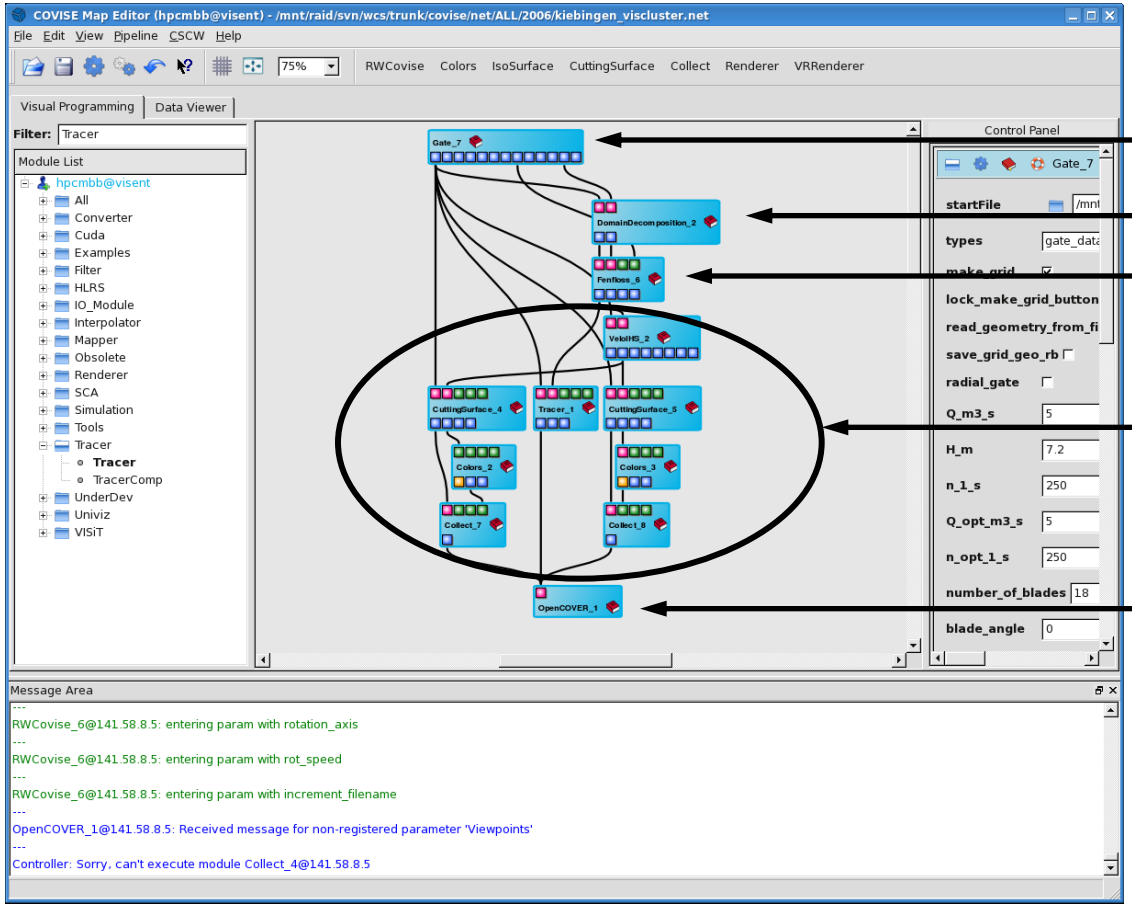
PROCESS INTEGRATION



SIMULATION COUPLING

Code	Type	Coupling mode
StarCD	CFD	SimLib, Fortran user subroutine, Loose
CFX	CFD	SimLib, Fortran user subroutine, Loose
Fluent	CFD	SimLib, C user subroutine, Loose
OpenFoam	CFD	SimLib, C++ user subroutine, Loose
Fidap	CFD	Script, Black-Box, Loose
Fenfloss	CFD	SimLib, C Plugin, Loose
Diablo	Diffusion in metal alloys	Script, Black-Box, Loose
Trans3D	Laser ablation	COVISE Modul C++, Tight
Uranus	CFD	Socket interface, coupling module, C++, Loose
SunFace	Radiation	COM/DCOM, coupling module, C++, Hybrid

INTERACTIVE SIMULATION IN COVISE



Grid generation

Domain decomposition

Simulation

Post processing

Rendering

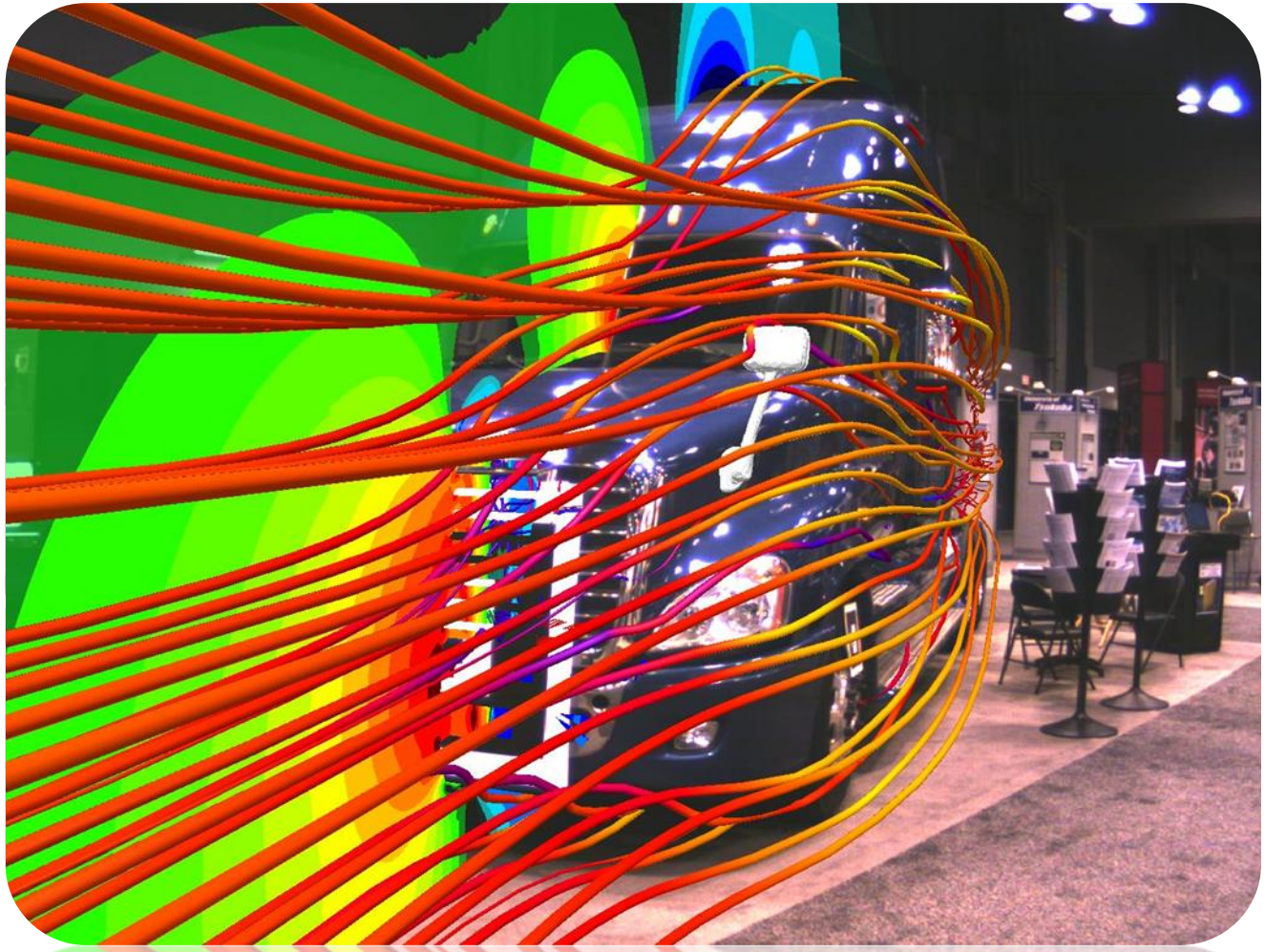
VIRTUAL WATER TURBINE TEST-BED

Simulation of the river power station Kiebingen, Neckar

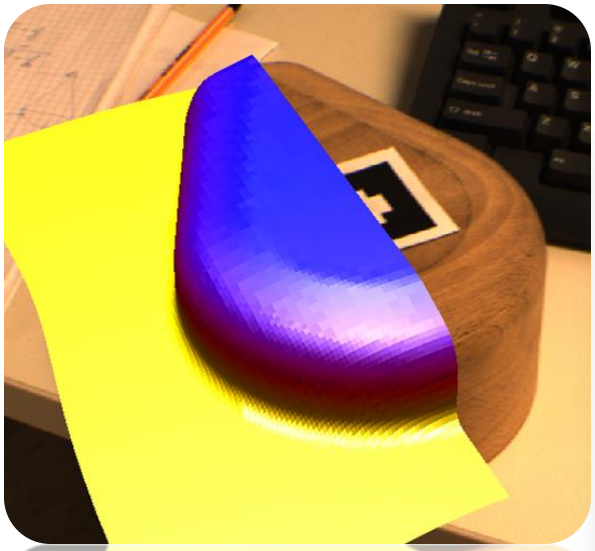
Through interactive simulation, the output could be increased by 30%, simply by substituting runner and wicked gate

VIRTUAL TURBINE TEST-BED

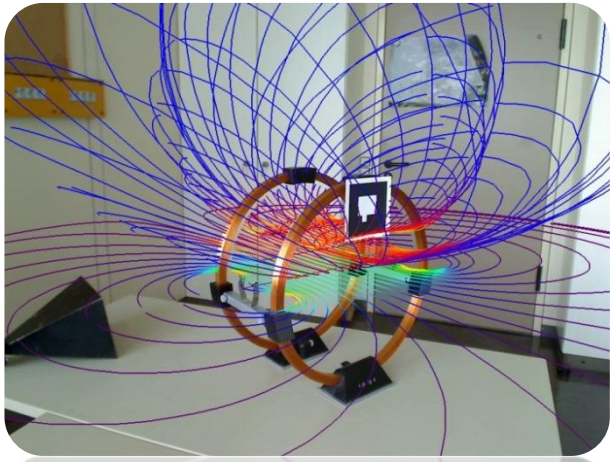
AUGMENTED REALITY

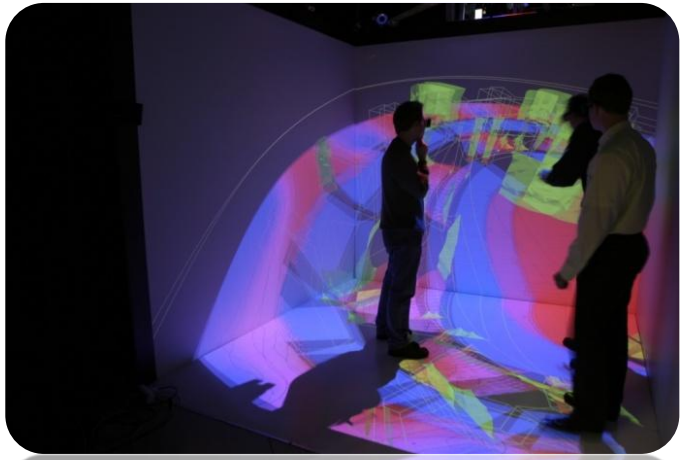


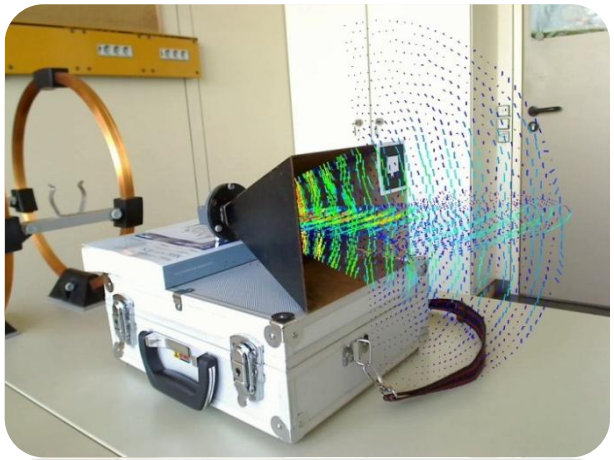
DEEP DRAWING OF A CUP

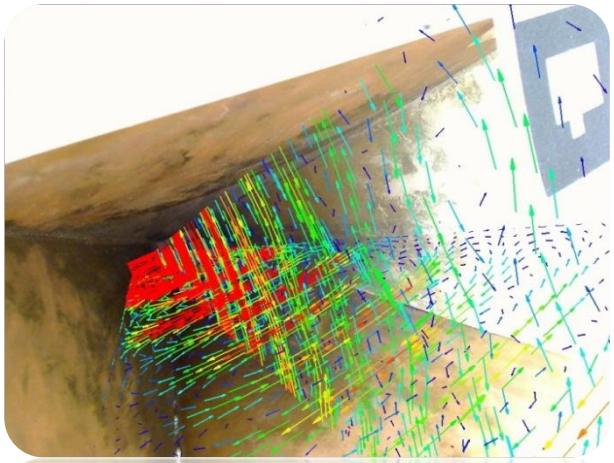


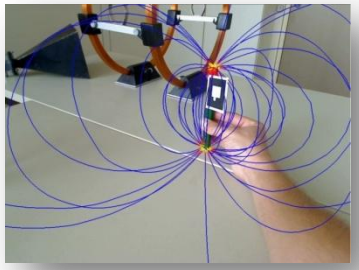
COMPUTATIONAL ELECTRODYNAMICS



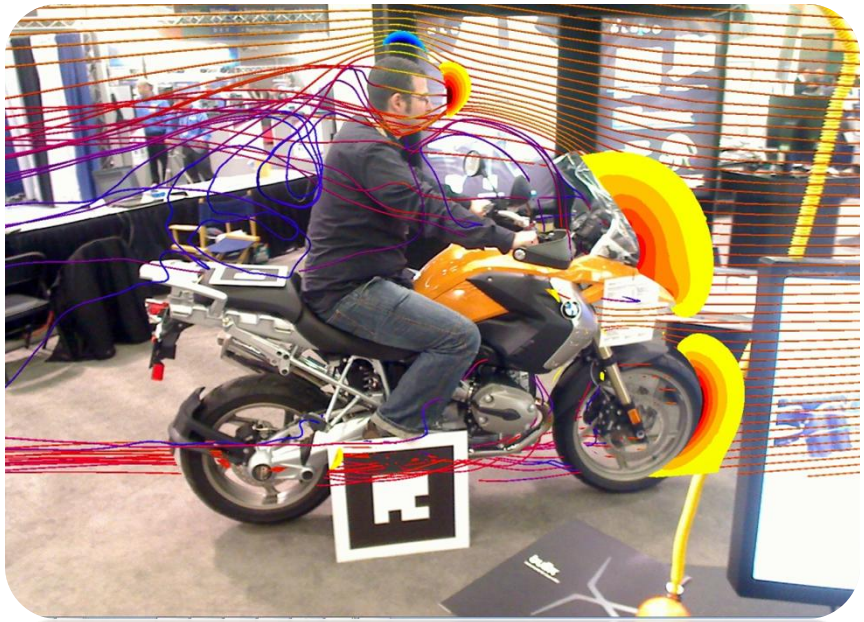






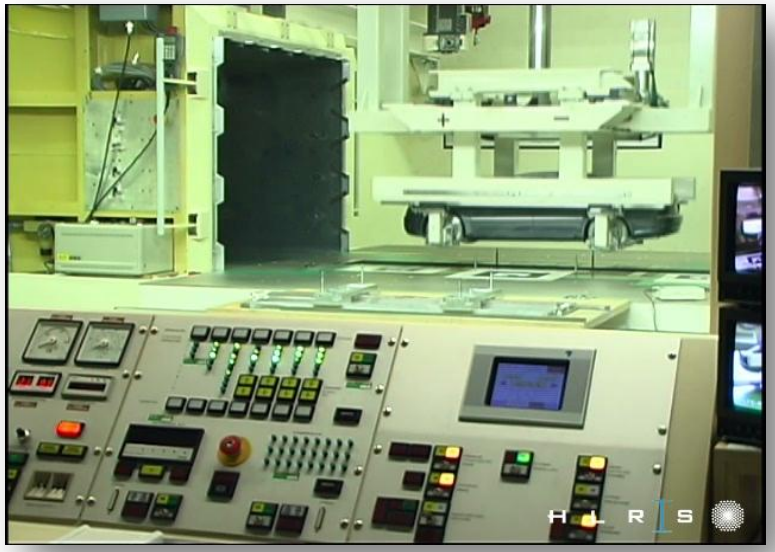


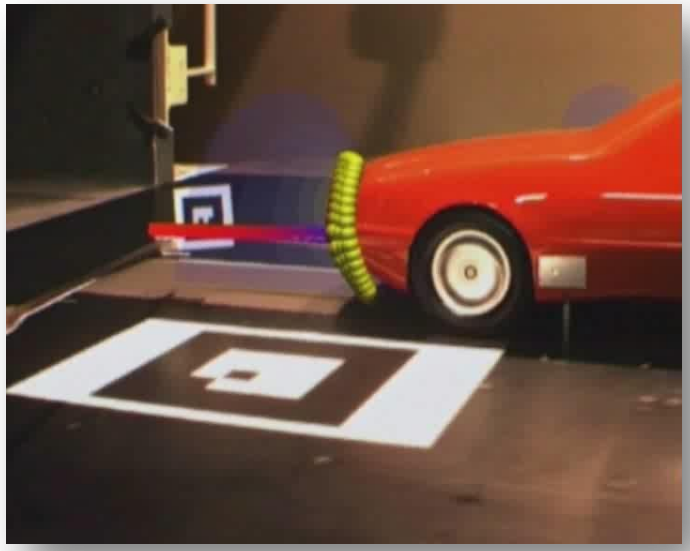
MINI / RS 1200 GS (SC 09)

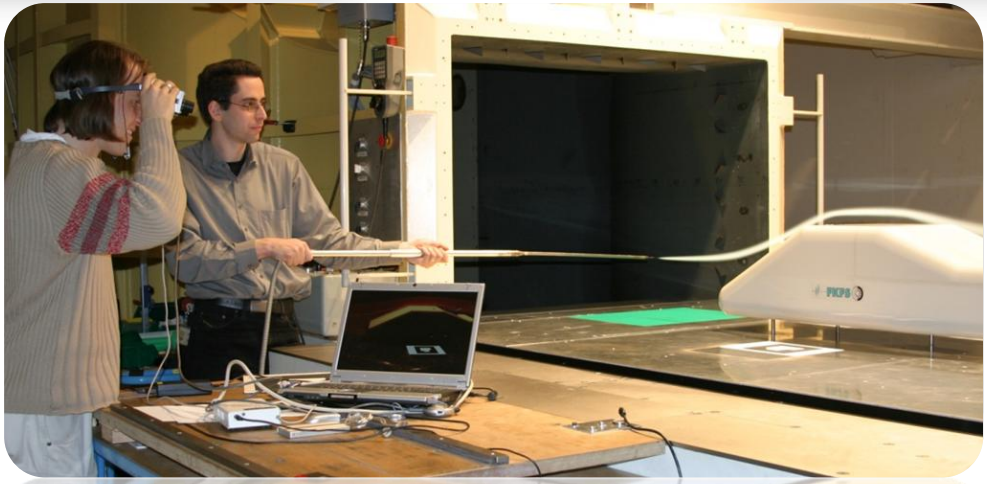


PANAMERA (SC 10)

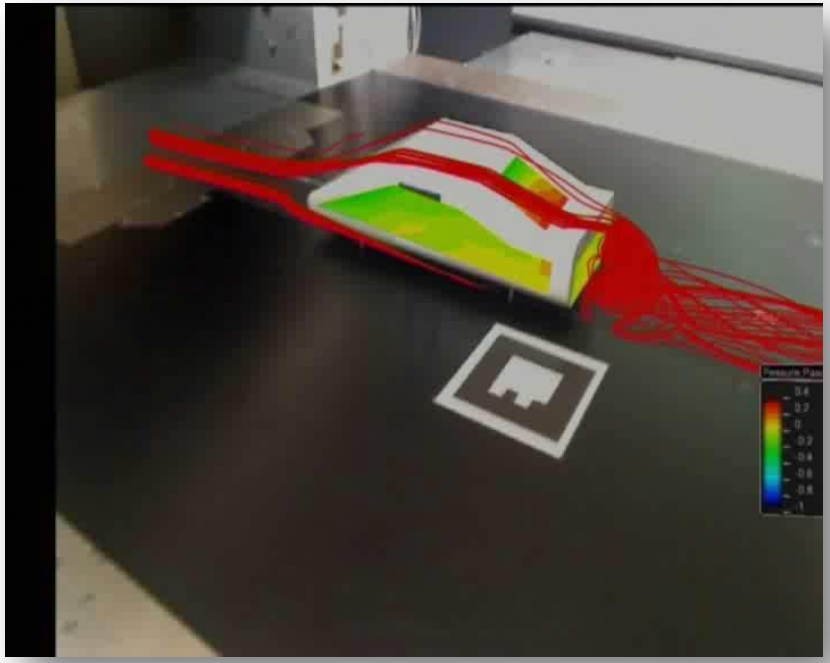
MODELL WIND TUNNEL AT THE FKFS

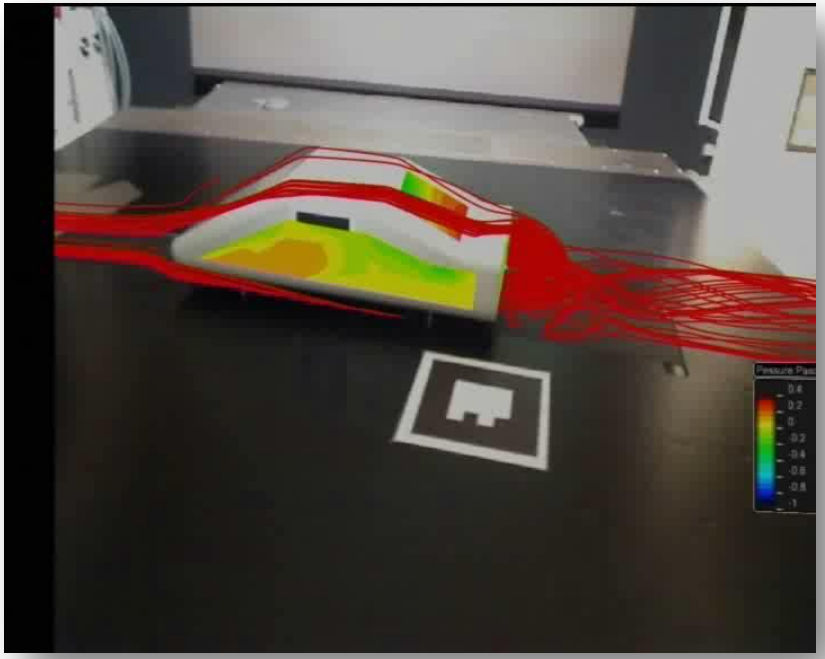


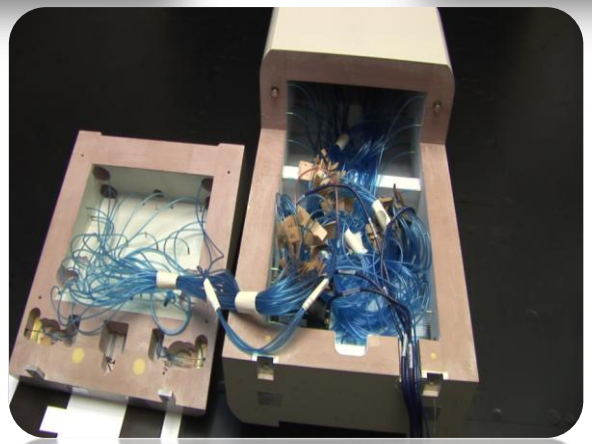




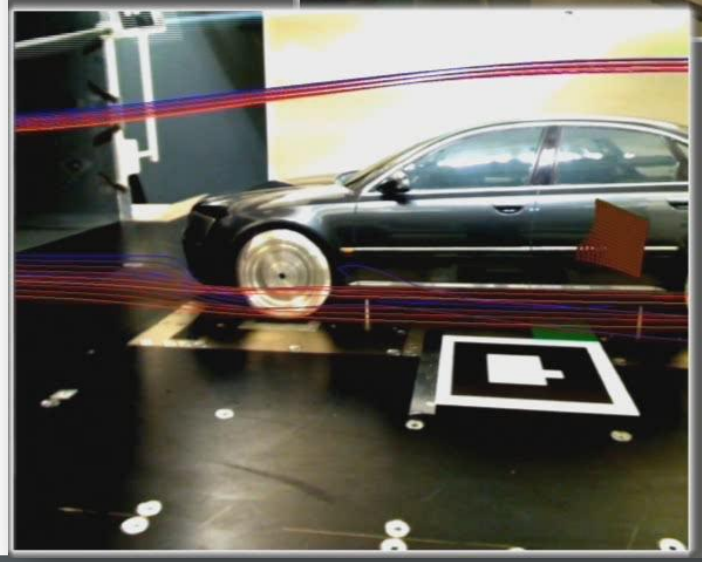
WIND TUNNEL AT FKFS







COLLABORATIVE WIND TUNNEL



Interactive Simulation in Architecture

ARCHITEKTUR UND RAUMPLANUNG

Supercomputer Education

2009

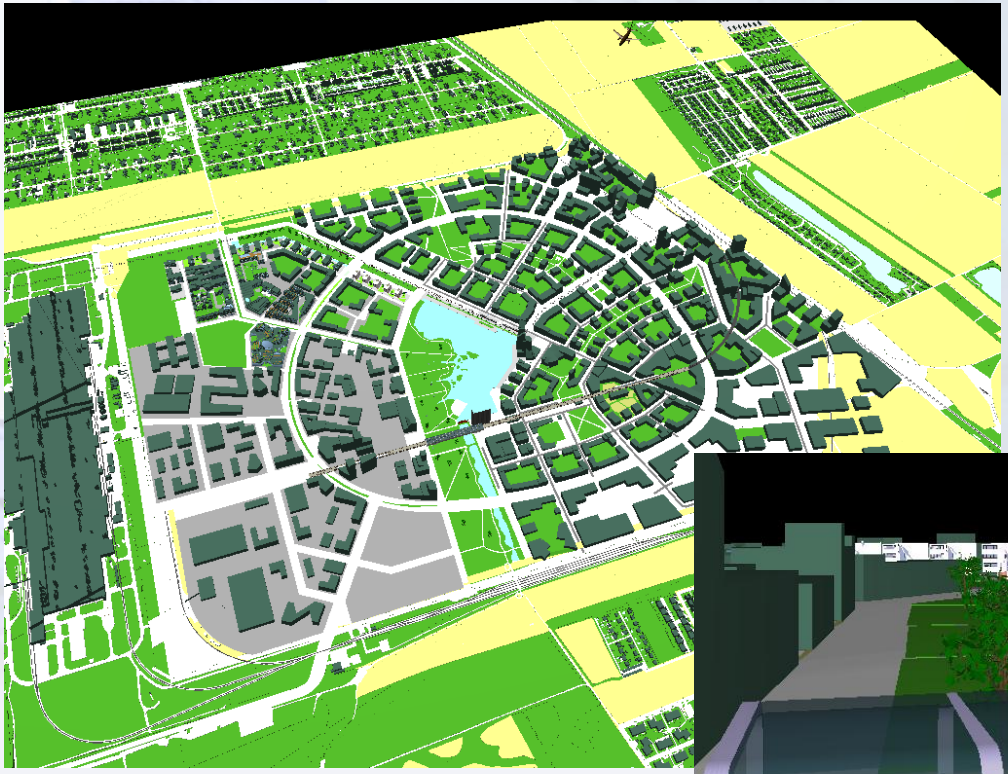
Stadtraumlabor TU-Wien

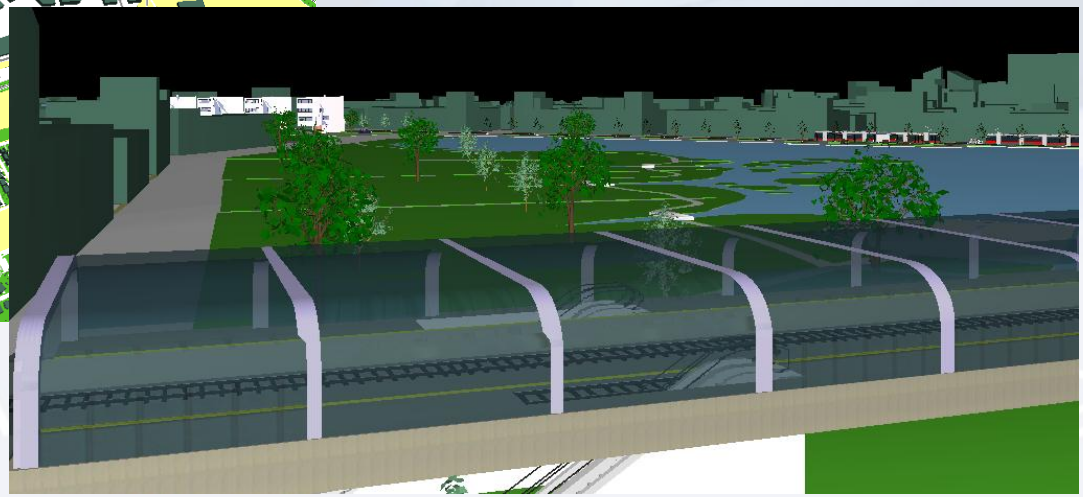
TAG 28. Mai 2009

ARCHITEKTUR UND RAUMPLANUNG

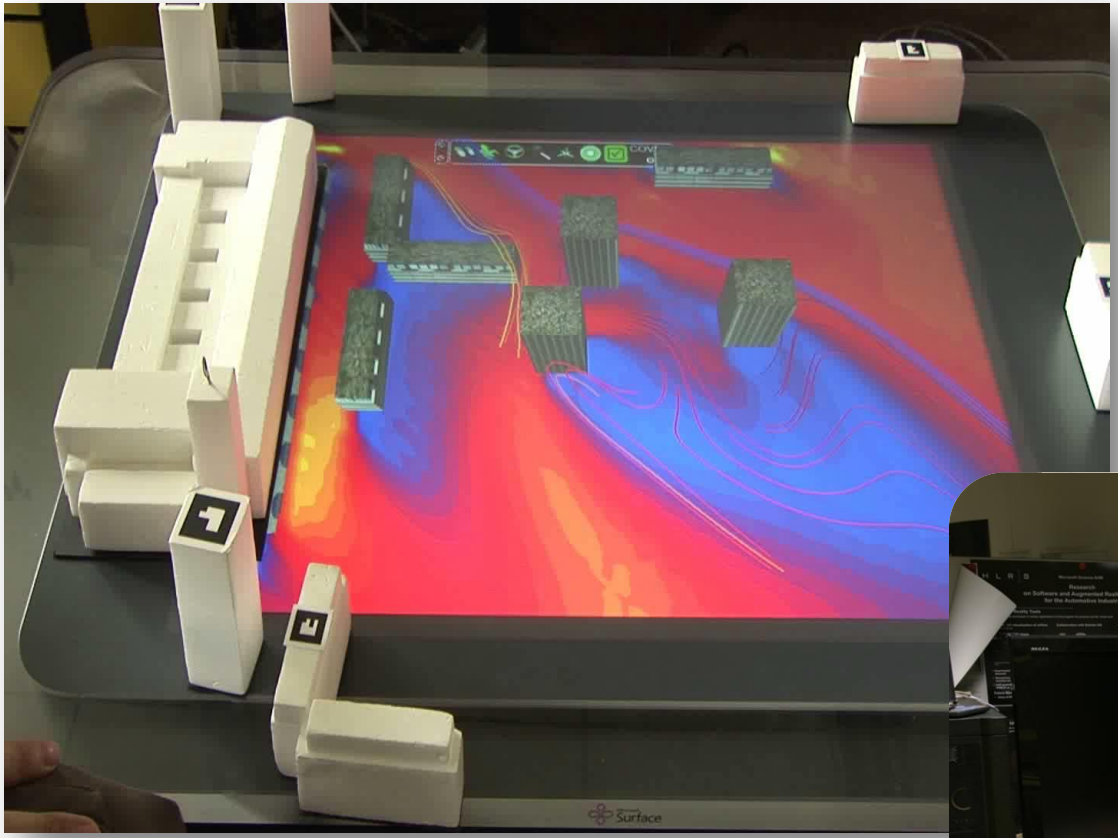
Supercomputer Education

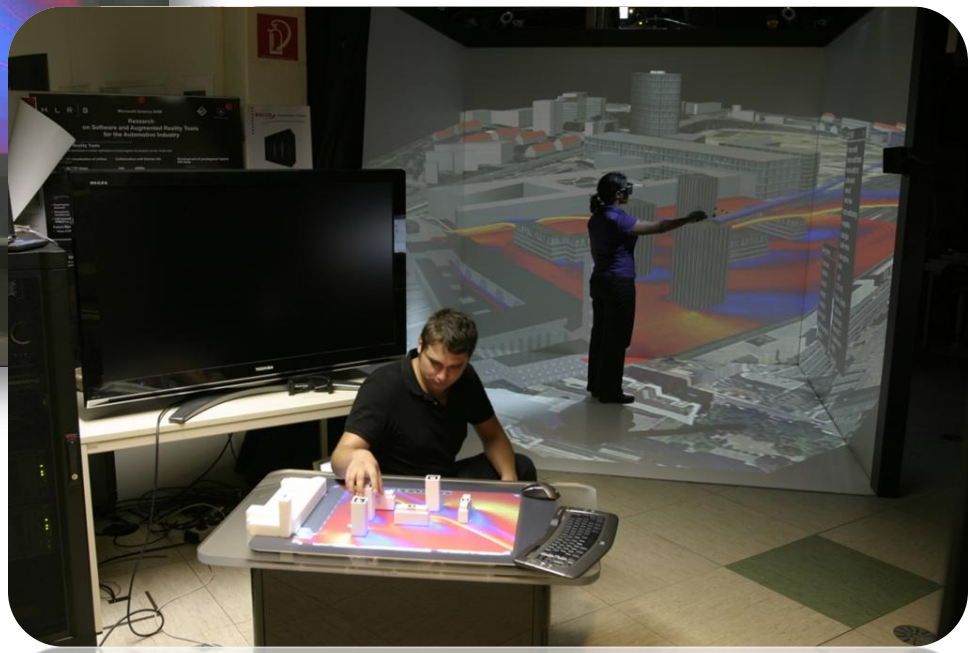
Masterplan Seestadt Aspern





INTERACTIVE SIMULATION IN ARCHITECTURE

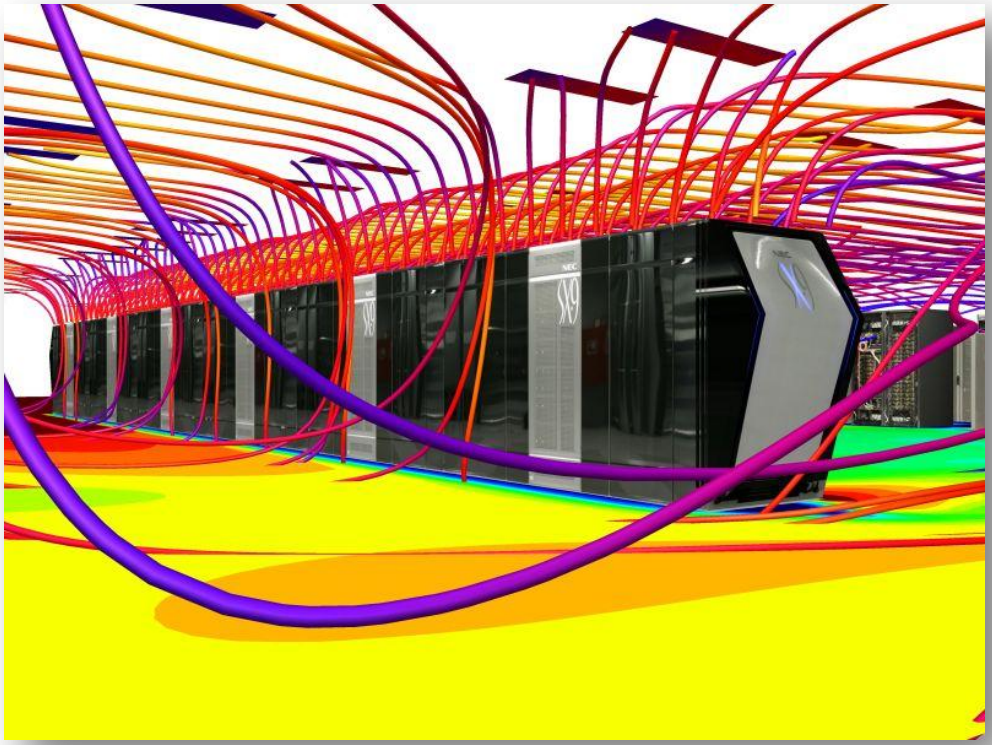




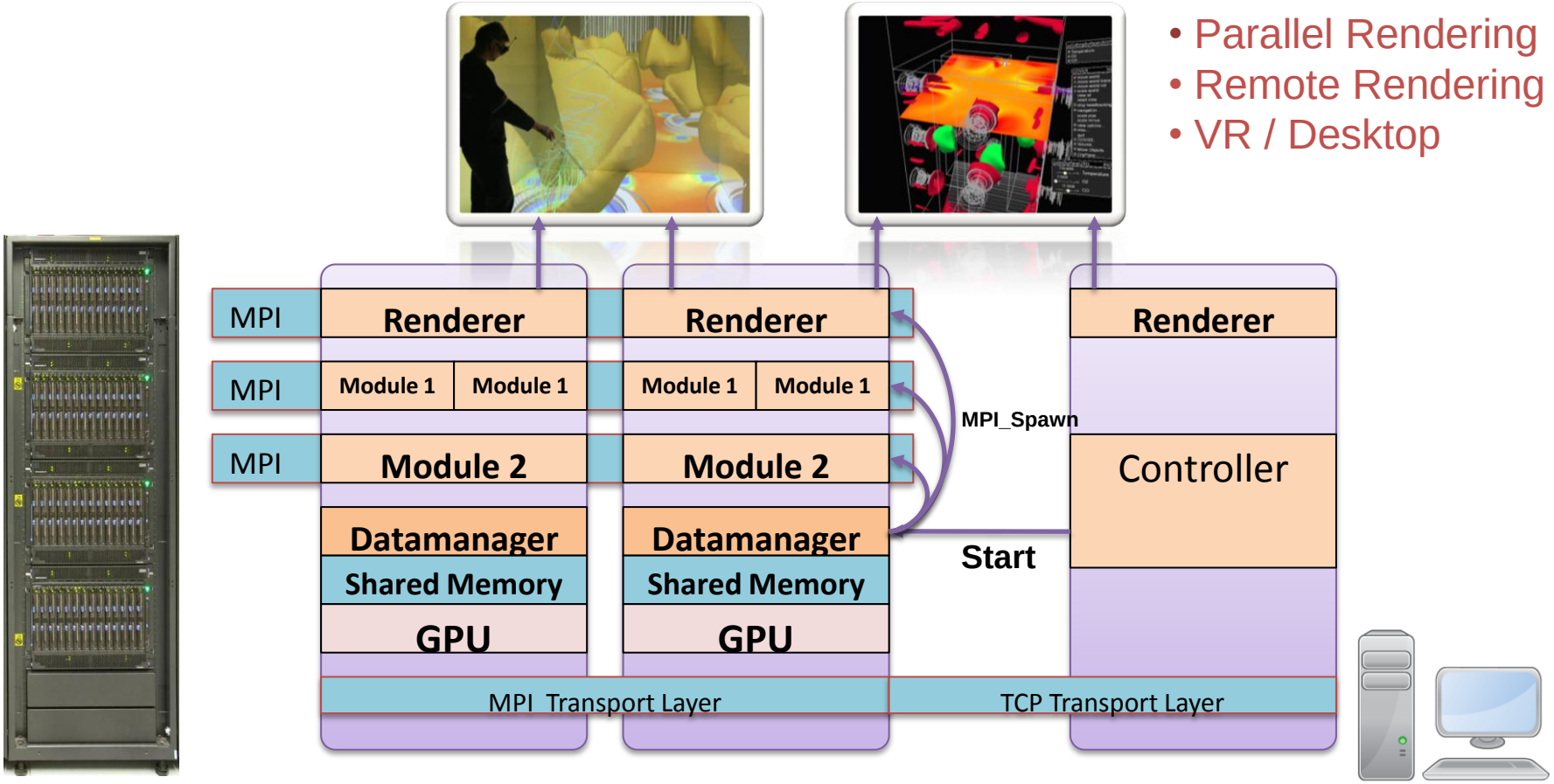
AIR CONDITIONING

Simulation of Racks in the HLRS server room
- 5MW of Power
- 1.5MW cooled by air
- Temperature distribution has to be optimized
- Simulation using Ansys CFX

Tangible interface on a Microsoft Surface



PARALLEL POST PROCESSING



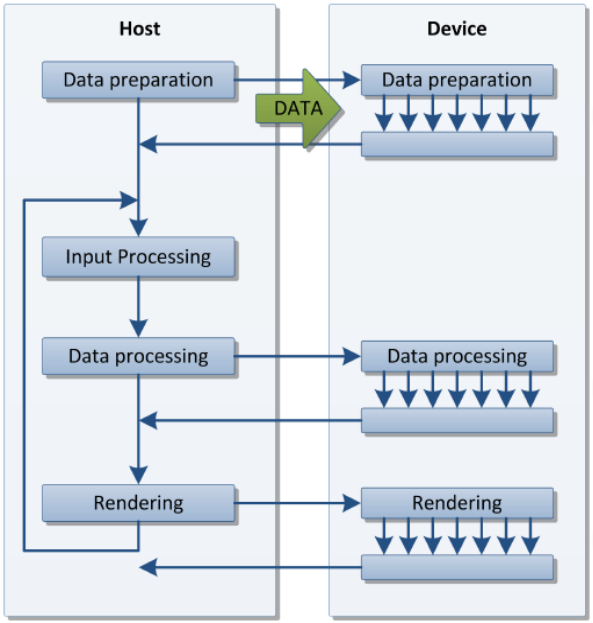
- Parallel Rendering
- Remote Rendering
- VR / Desktop

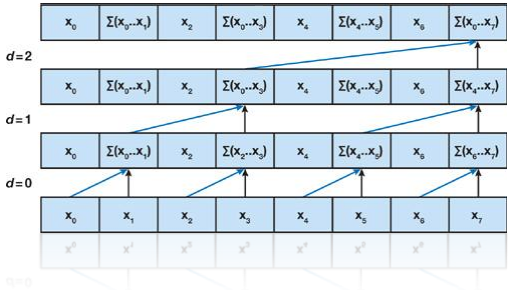
GP-GPU POST PROCESSING

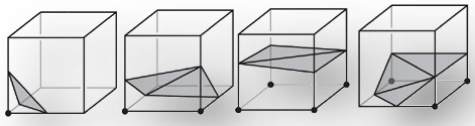
Visualization Cluster
- Multiple Nodes
- Multiple CPUs / Node
- highly parallel GPUs

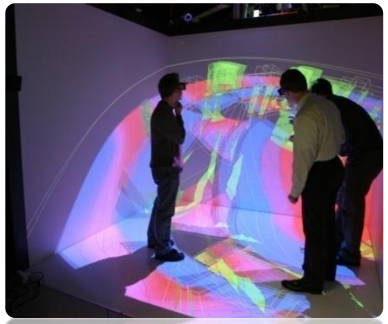
Data Processing on GPUs
- Preparation
- Processing
- Rendering / Readback

Datamanager stores (partial) data objects
- Host memory
- Device memory



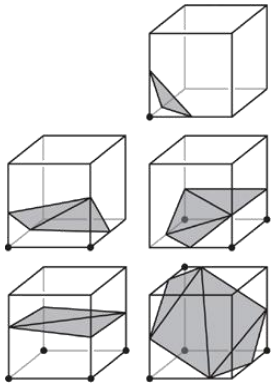






CUDA ISO/CUTTINGSURFACE COMPUTATION

- Classify Elements / number of vertices (TLT)
  - Tetrahedron, Hexahedron, Prism



- ***Exclusive Prefix Sum (scan)***

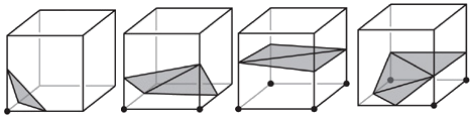
3	0	6	0	0	0	0	12	0	0	9	0
1	0	1	0	0	0	0	1	0	0	1	0

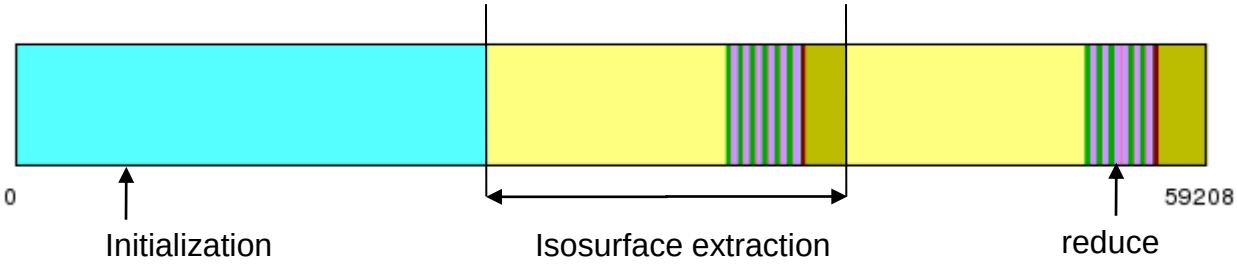
- ***Reduce (scatter)***

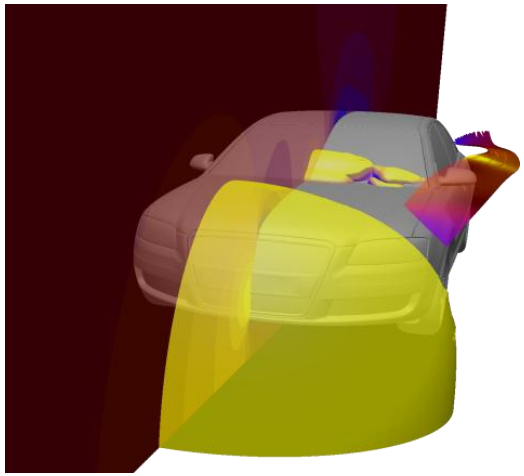
0	3	3	9	9	9	9	9	21	21	21	30
0	1	1	2	2	2	2	2	3	3	3	4

- ***Interpolate /***
- ***Generate Triangles***

0	3	9	21
0	1	2	3



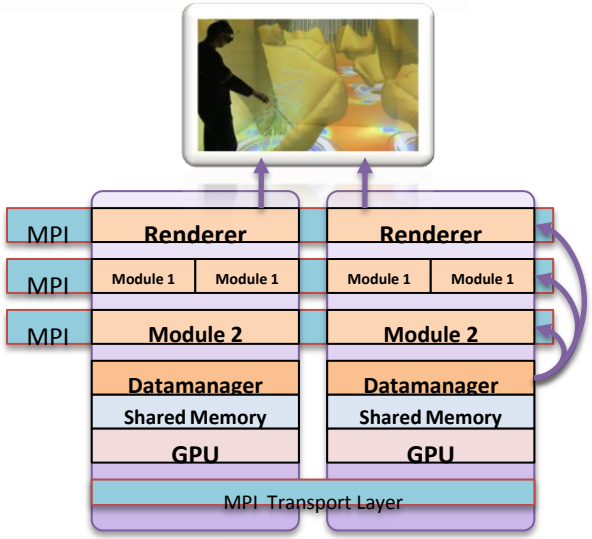


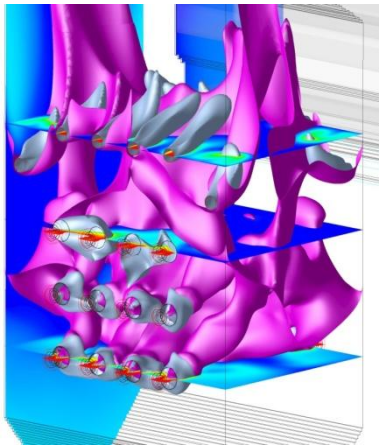


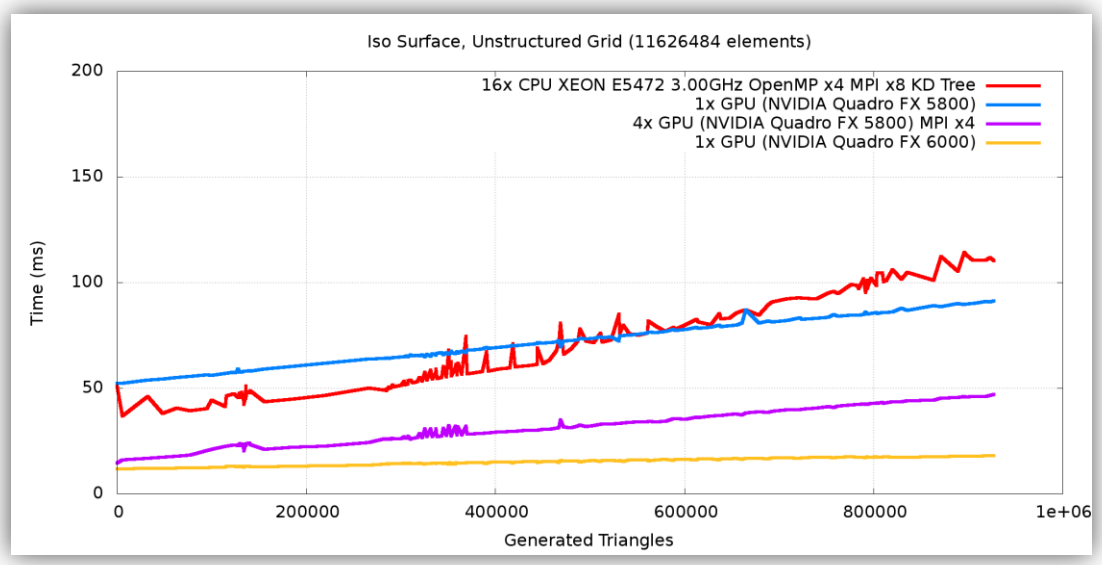
PARALLEL SURFACE EXTRACTION (GPU)

Parallelization of iso-/cutting surface extraction for interactive post-processing on unstructured grids

- NVIDIA Quadro 6000 (Fermi):
  >5x faster than 16 Xeon E5472





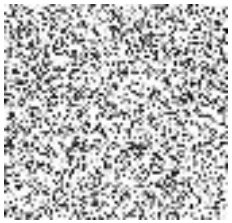


INTERACTIVE TEXTURE BASED FLOW VISUALIZATION

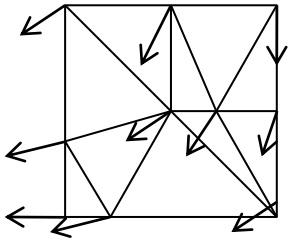
Line **I**ntegral **C**onvolution

- Convolute a noise texture alongside a flow field
- Vector field tracing (Euler/Runge-Kutta)
- Pixels along field lines show strong correlation
- Pixels orthogonal to the field lines are uncorrelated

-> ***Qualitative*** view of a slice of the flow field



Noise



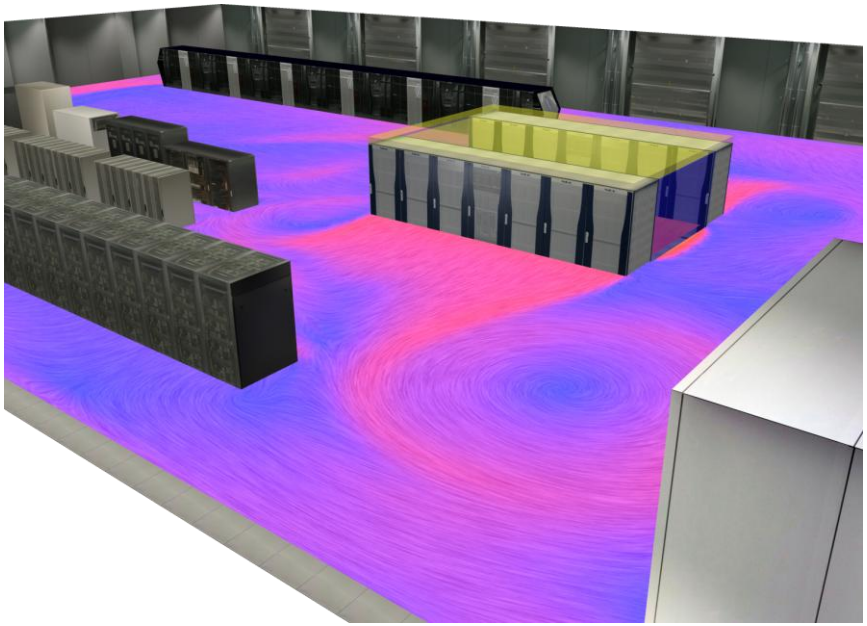
Flow field on extracted surface

LIC result

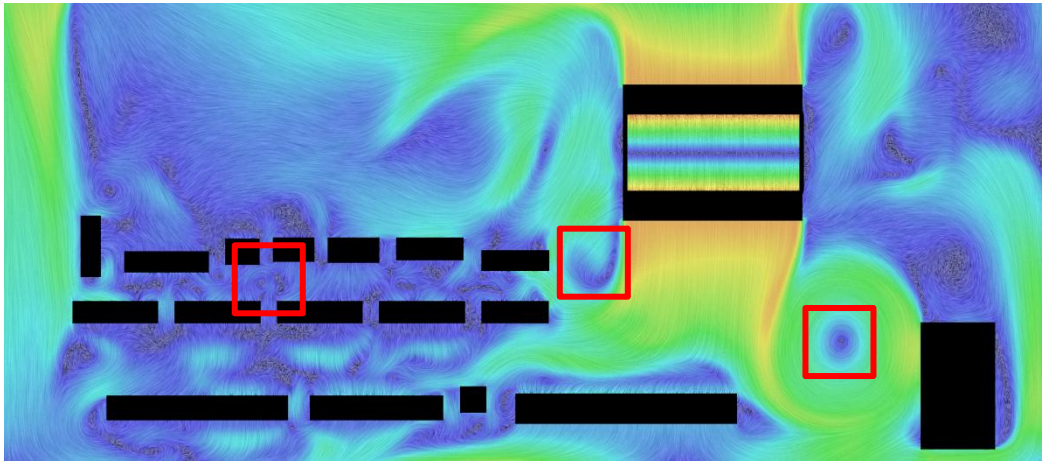
Interactive speeds through

- Flow field as per-vertex attribute in fragment shader (obtained from CUDA cutting-surface kernel)
- Evaluating the flow-field ***once*** per fragment
- Convoluting the noise texture along interpolated vector

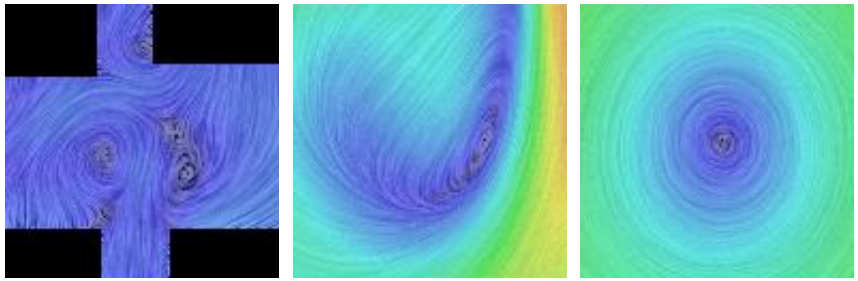
High gradient in the flow field -> wrong vectors (esp. far away from fragment position)

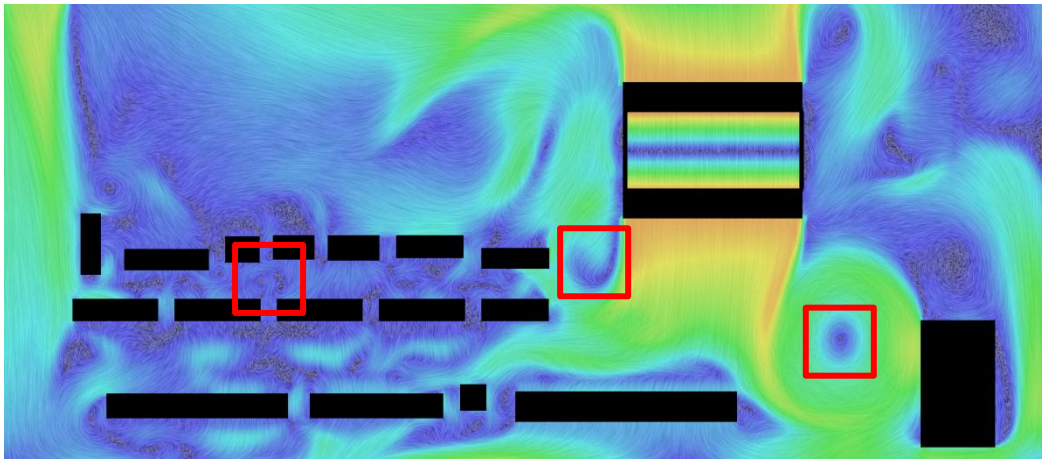


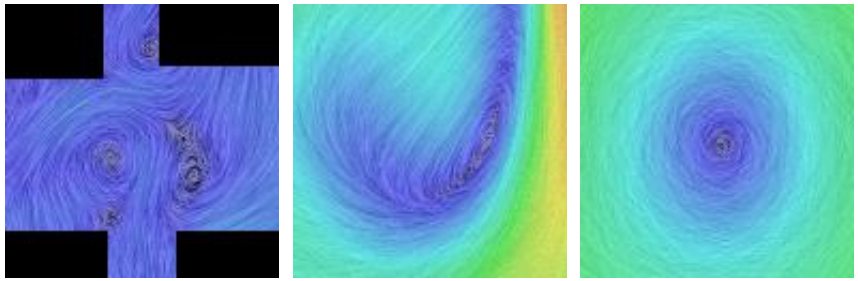
INTERACTIVE LIC COMPARISON



64 vector field evaluations

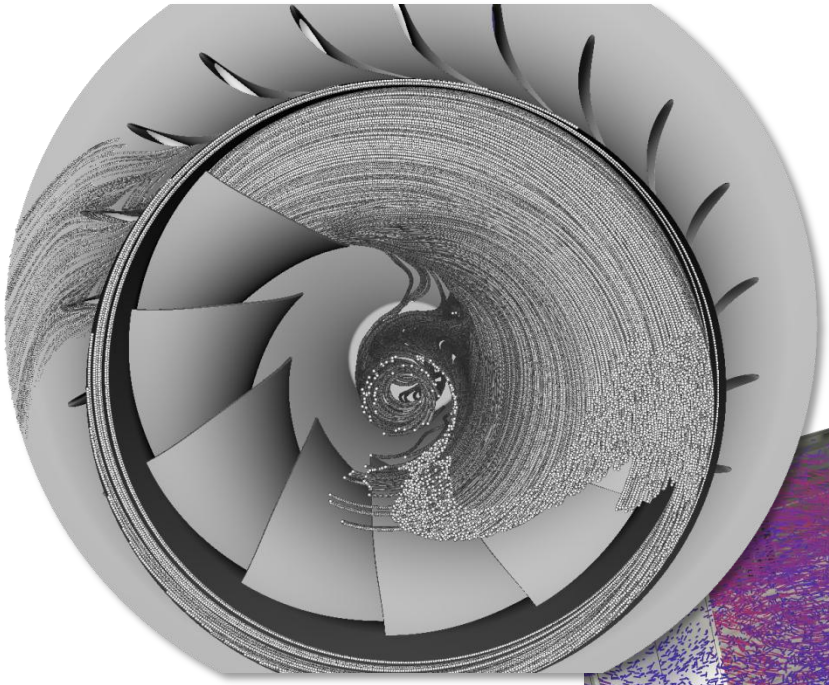


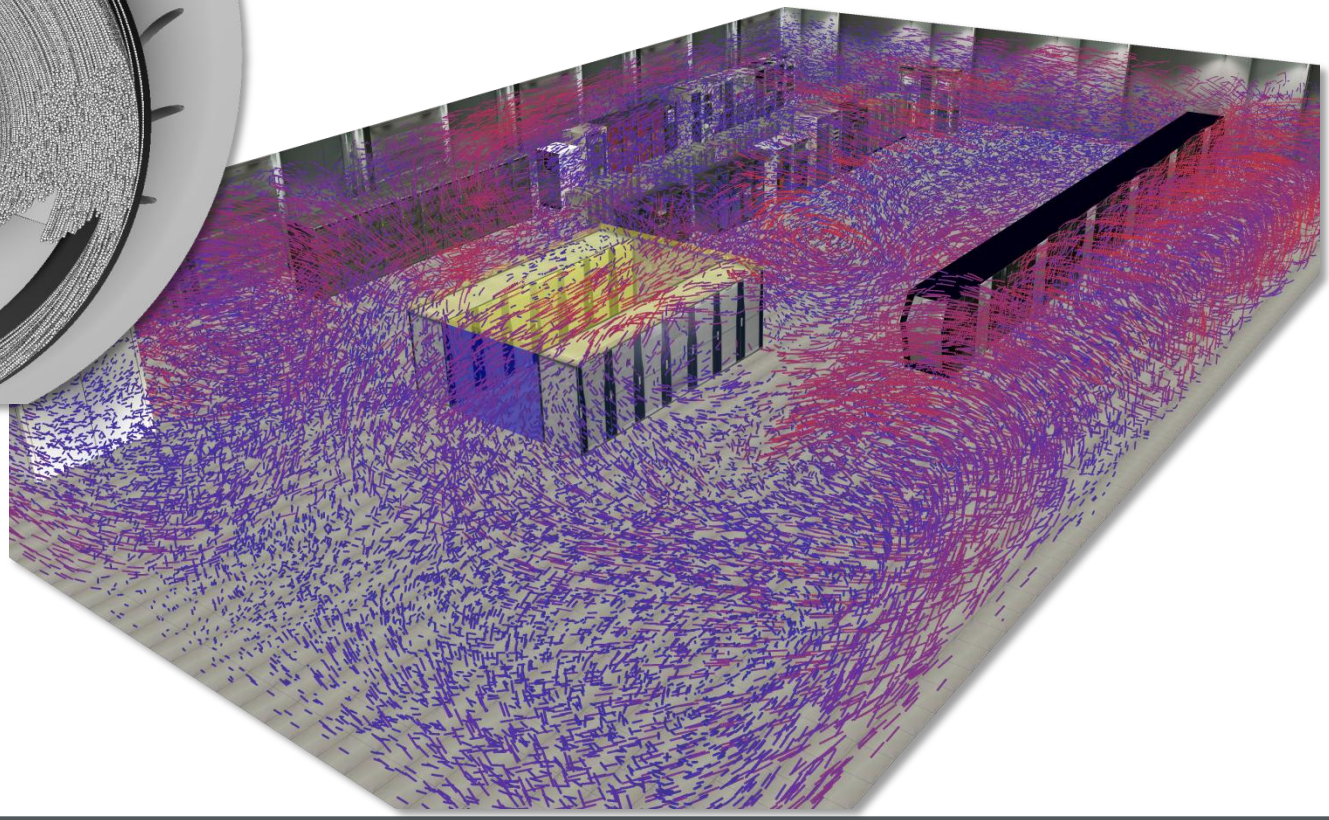




1 vector field evaluation

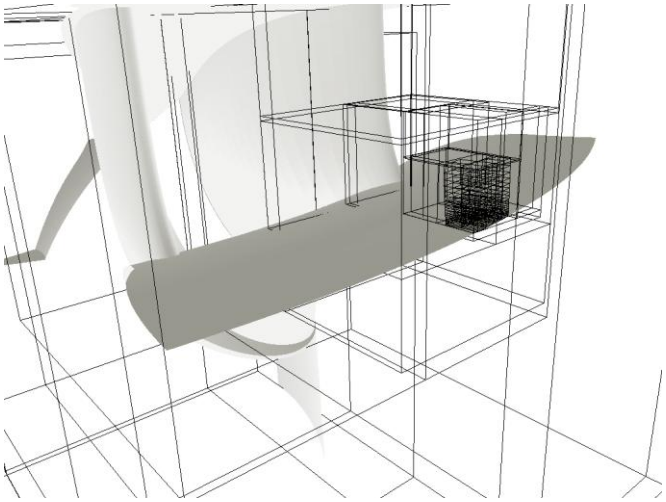
PARALLEL PARTICLE TRACING

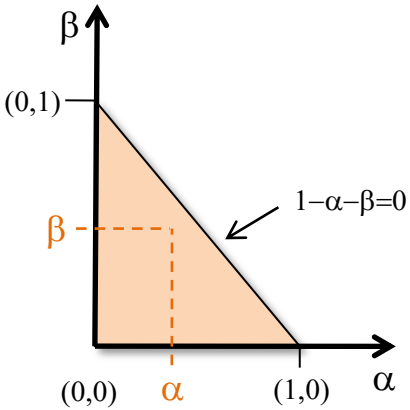


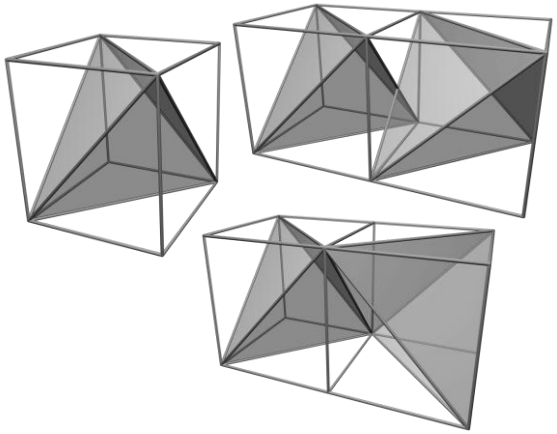


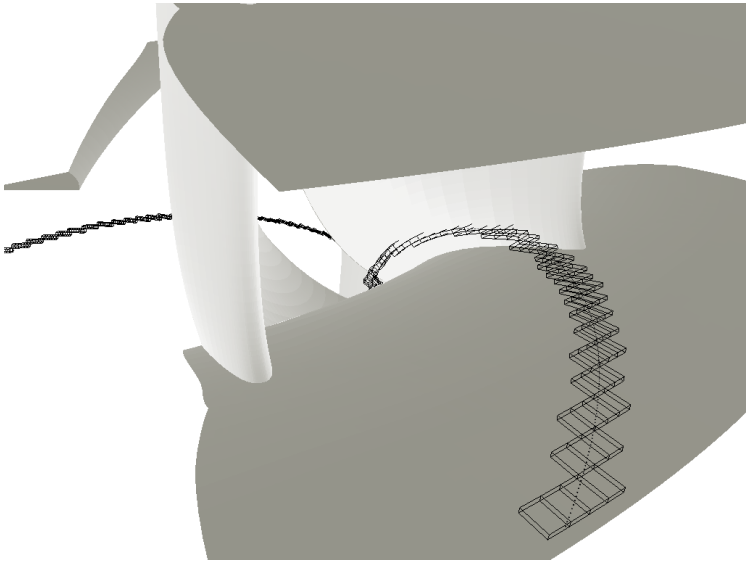
INITIAL CELL LOCATION / NEIGHBOR SEARCH

- KD-Tree
- Walk to neighboring element
- On-the-fly decomposition to tetrahedra
- Interpolation in tetrahedra
- Runge-Kutta(4)





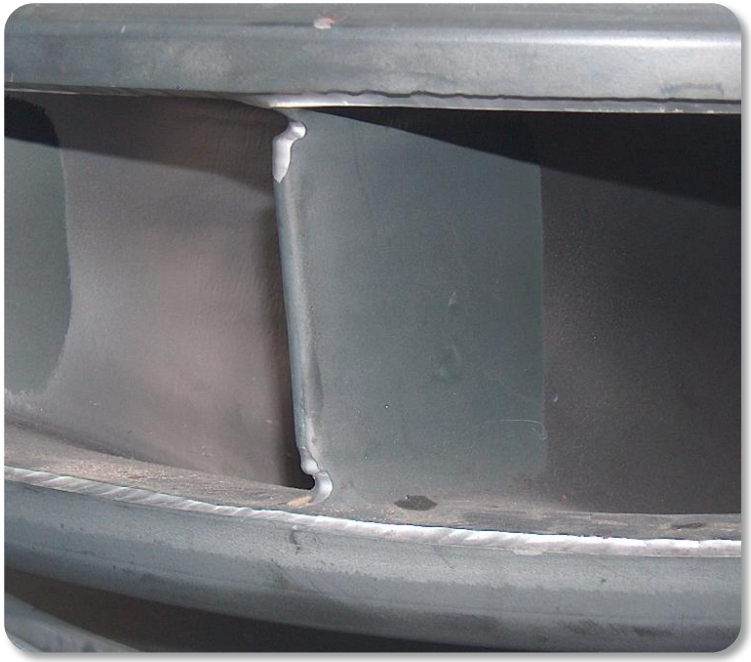




MASSIVE PARTICLE TRACING

Simulation of erosion in a turbine runner

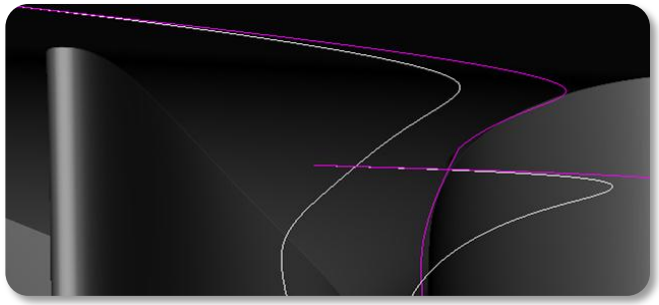
- In postprocessing on a hybrid many-core CPU/GPU cluster



MASSIVE PARTICLES

Assumptions:

- Spherical, monomorphic particles
- Particles do not influence fluid and walls
- No interaction between particles

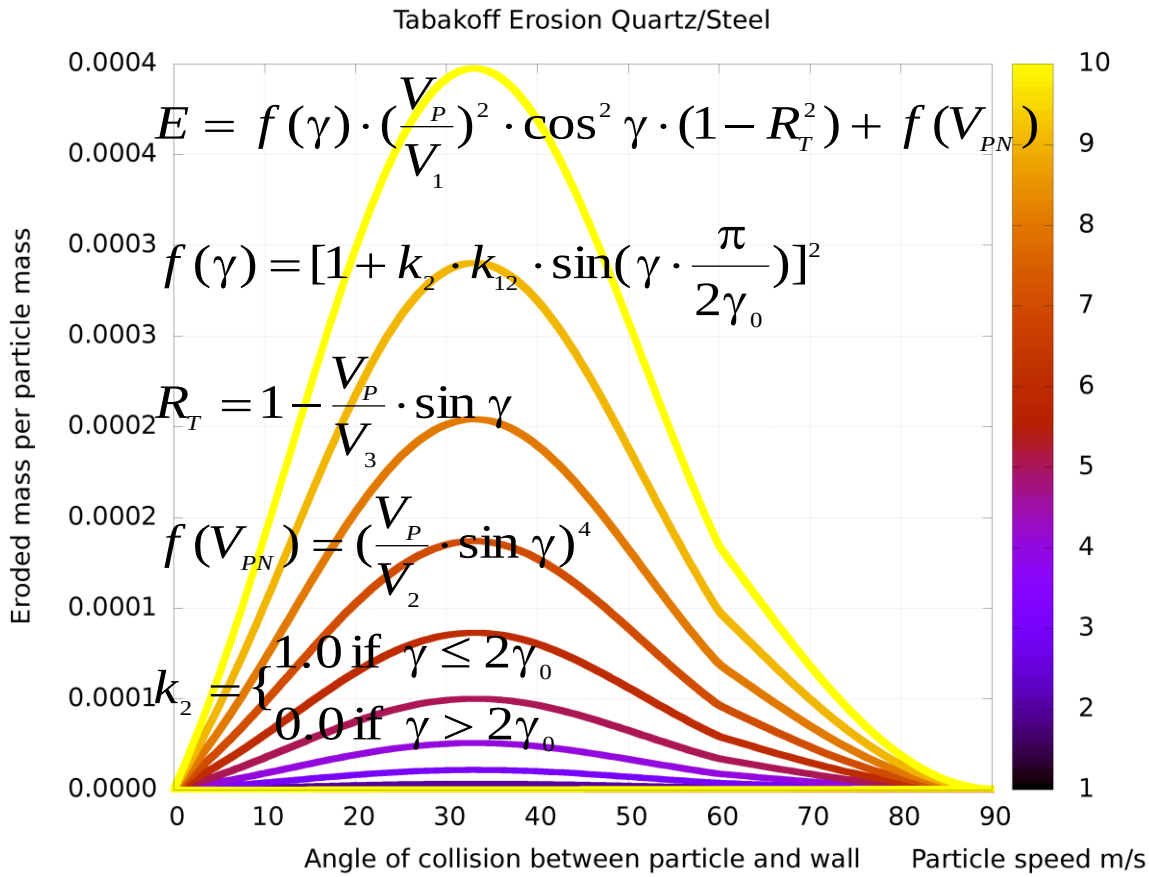


$$\frac{dU_P}{dt} = \frac{F_D + F_B + F_{VM} + F_P}{m_P}$$

$$F_D = \frac{1}{2} \cdot C_D \cdot \rho_F \cdot A_F \cdot |U_F - U_P| \cdot (U_F - U_P)$$

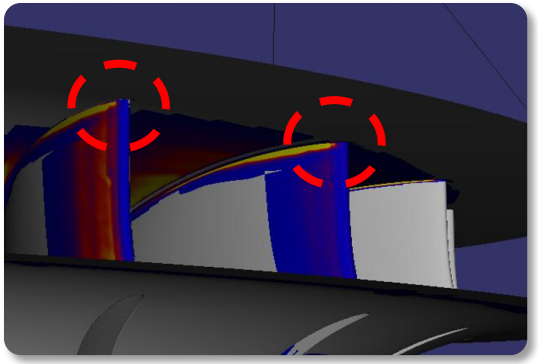
$$F_B = (m_P - m_F) \cdot g$$

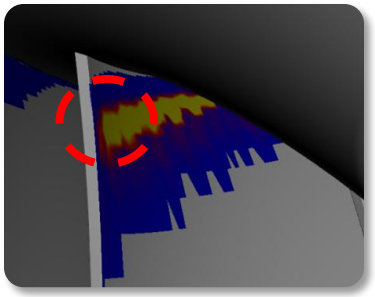
TABAKOFF MODEL OF EROSION

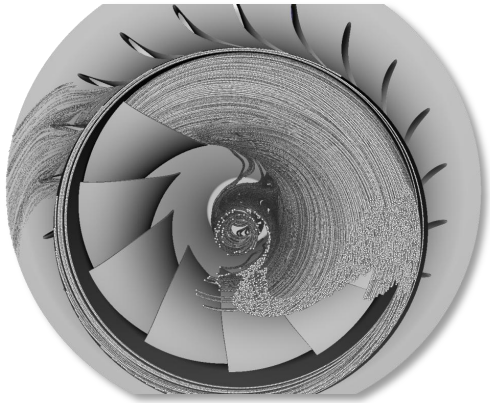


EROSION IN TURBINE RUNNERS

Tracing of massive sand particles

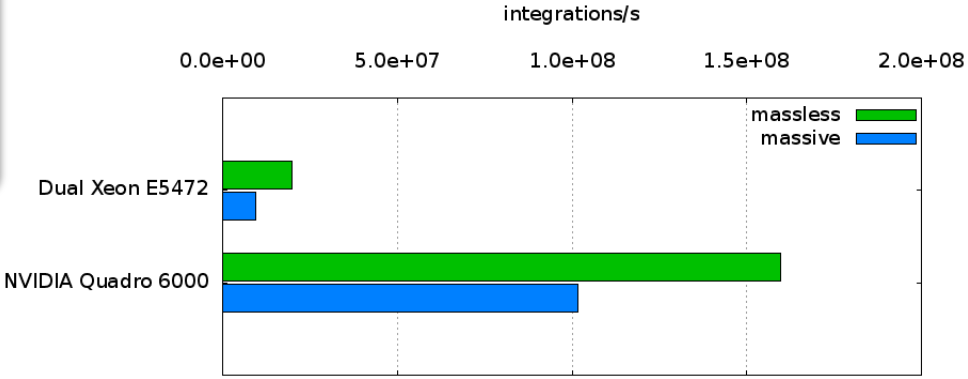






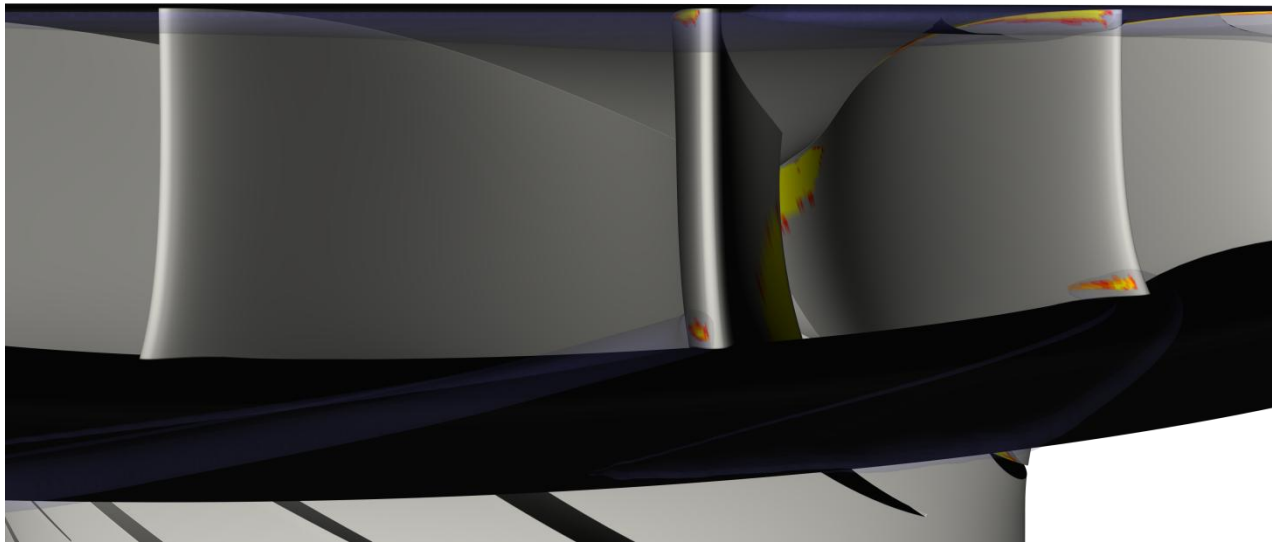
CFD Simulation: Ansys CFX

15.215.488 hexahedral elements



GP-GPU POST-PROCESSING

- Post-processing of numerical simulation data at interactive speeds on the visualization cluster using GPGPU
  - immediate rendering of VBOs
  - asynchronous / overlapping streaming memcpy of transient data
- Interactive qualitative visualization of vector data (LIC)
- Integrates with parallel rendering (sort last)



VALIDATE

Virtual Automotive Lab for Integrated Digital Automation Technologies

Driving Simulation at University of Stuttgart

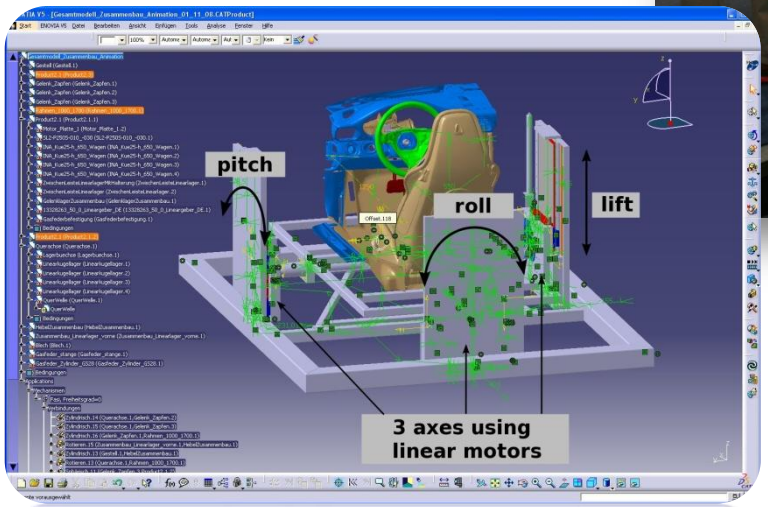
GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

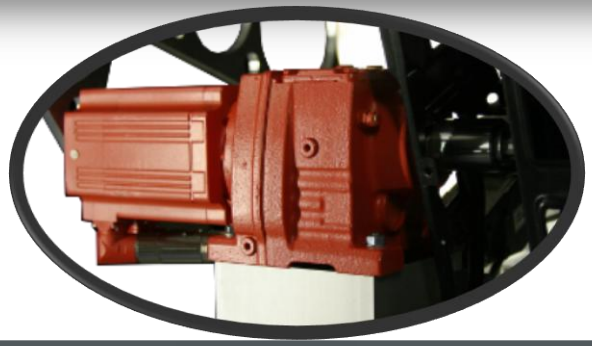
PORSCHE 997 TURBO (BEFORE)

AFTER

VALIDATE

- 3 degrees of freedom
- 3 linear motors
- a-max 2g
- V-max 1m/s
- Force feedback steering wheel
- Active gas pedal (Conti)
- Active brake pedal

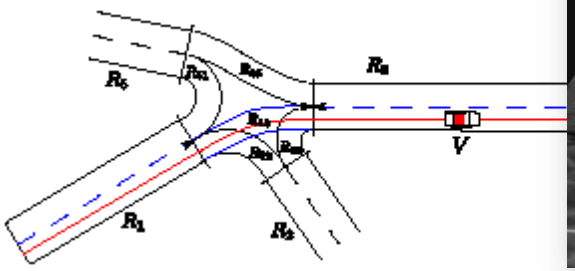


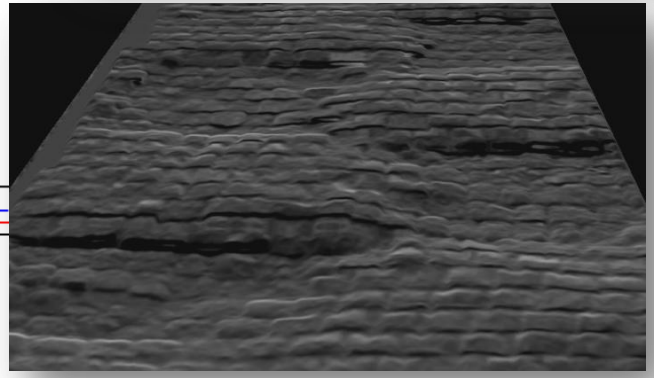


HAPTIC SIMULATOR

COMPONENTS OF THE DRIVING SIMULATOR

- Hardware
- Restbus Simulation
- Vehicle dynamics





- Road surface
- Street logic
- Third party vehicle simulation

- Landscape
- Buildings
- Traffic signs
- Side rails
- Trees

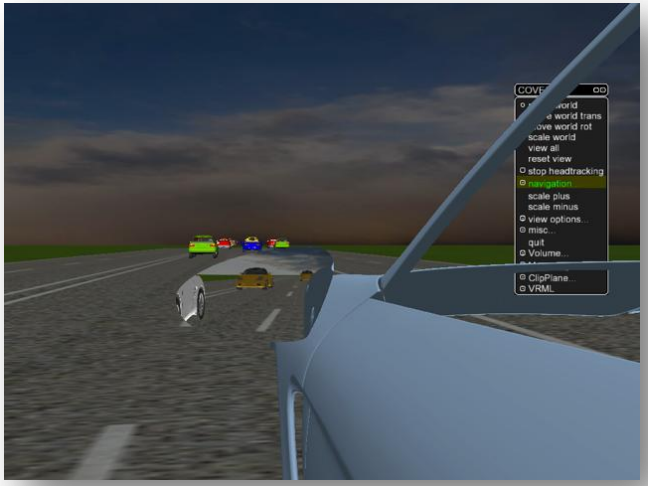
THIRD PARTY VEHICLE SIMULATION

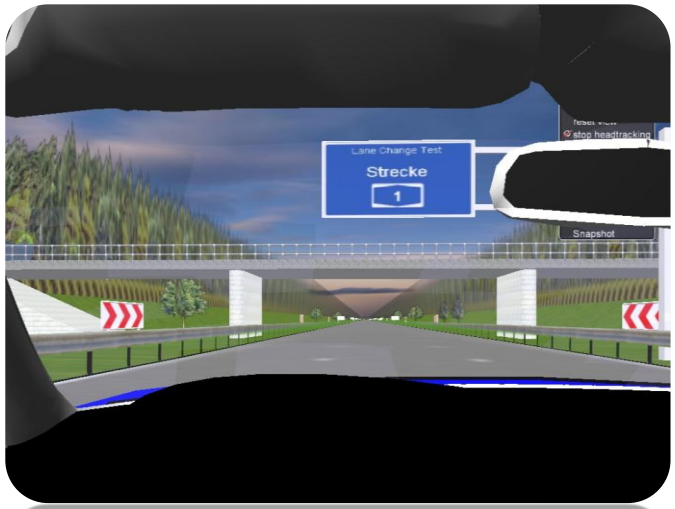
- Realistic behavior
- Respecting traffic rules
- Car to car / car to infrastructure communication

APPLICATIONS

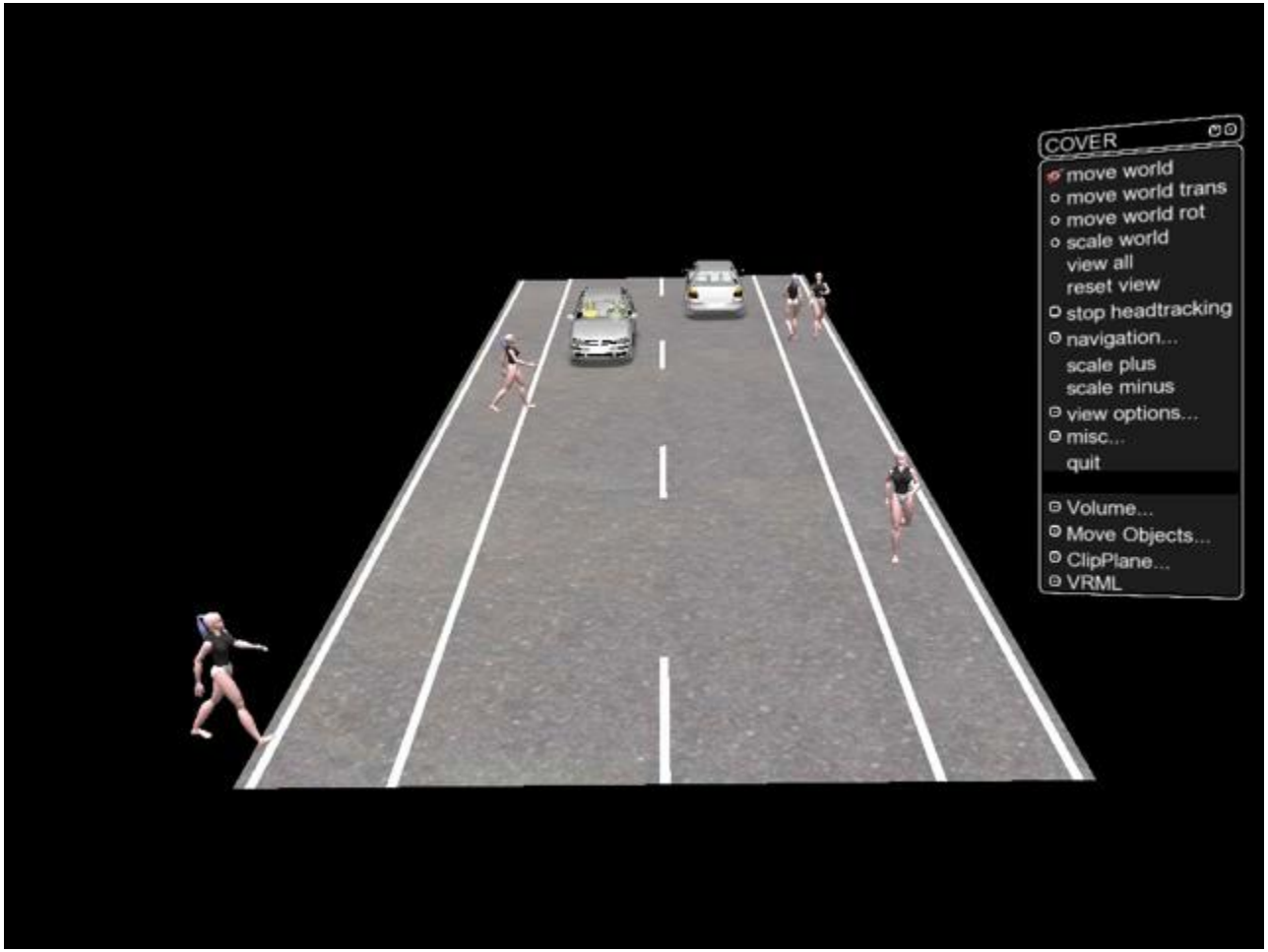
- Standard tests, e.g. lane change test
- Evaluation of driver assistance systems
- Test of new HMI concepts
  Entertainment, GPS, Telephone, air conditioning
- Driver reaction in critical situations
- Visibility studies
- Evaluation of rear view mirrors

Lane Change Test





PEDESTRIANS



THE HLRS VIS-TEAM

- Blasius Czink
  - (SCALB)
- Andreas Gottlieb
  - Automatic optimization (Daimler CFD)
- Andreas Kopecki
  - Parallel Rendering;Collaborative Working (VisPME/VISIONAIR)
- Florian Niebling
  - Parallel Visualization; Grid;Infiniband; (VisPME)
- Jutta Sauer
  - Video streaming; Video Conferencing; COVISE Dev.; 3D Modeling
- Florian Seybold
  - Driving Simulator; interactive vehicle dynamics (VALIDATE); GP-GPU SPH
- Uwe Zimmat
  - Video service
- N.N.
  - Parallel and Remote Visualization (CRESTA)
- N.N.
  - Interactive Simulation (Cool-Em-All)
- N.N.
  - Virtual Reality(VISIONAIR)

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