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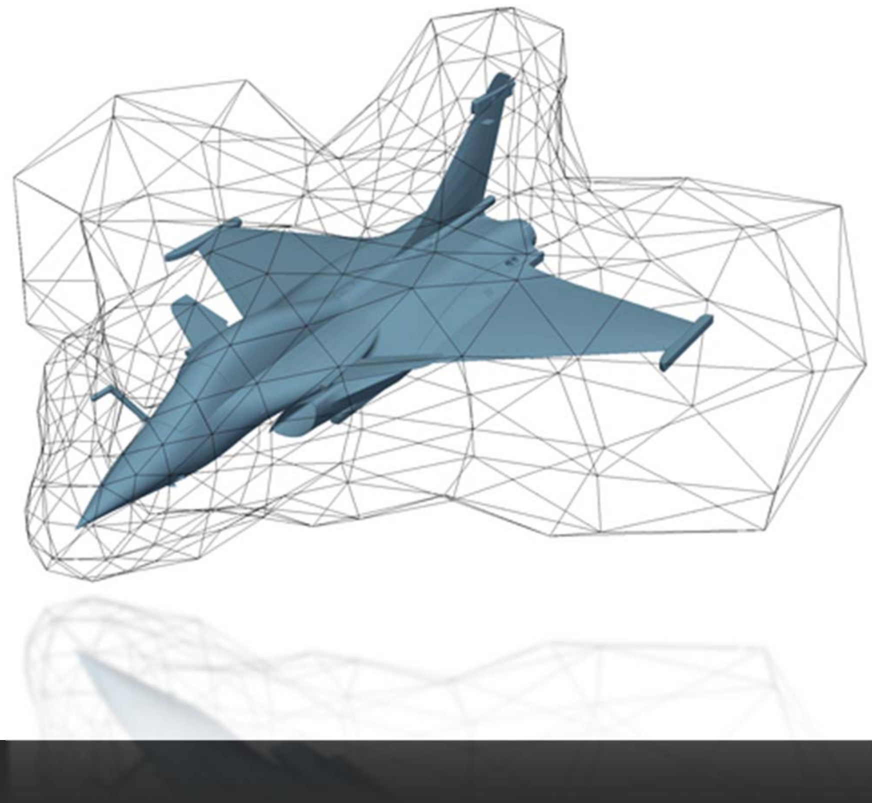
iconCFD - A MODULAR APPROACH TO SUPPORTING BUSINESS WITH CFD



J. Papper, D. Martineau, P. Nayyar,
B. Leroy, R. Devaradja, L. Gagliardi

Technology • Process • Consulting

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AGENDA

- Introduction
- iconCFD Process
- iconCFD Wrap
- iconCFD Mesh
- iconCFD Cold
- iconCFD Thermal
- iconCFD Optimize
- iconCFD VOF
- Conclusion

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iconCFD
INTRODUCTION

Modularized • Industrialized • Customized

iconCFD Process

iconCFD Wrap

iconCFD Mesh

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...

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iconCFD PROCESS
Graphical Interface

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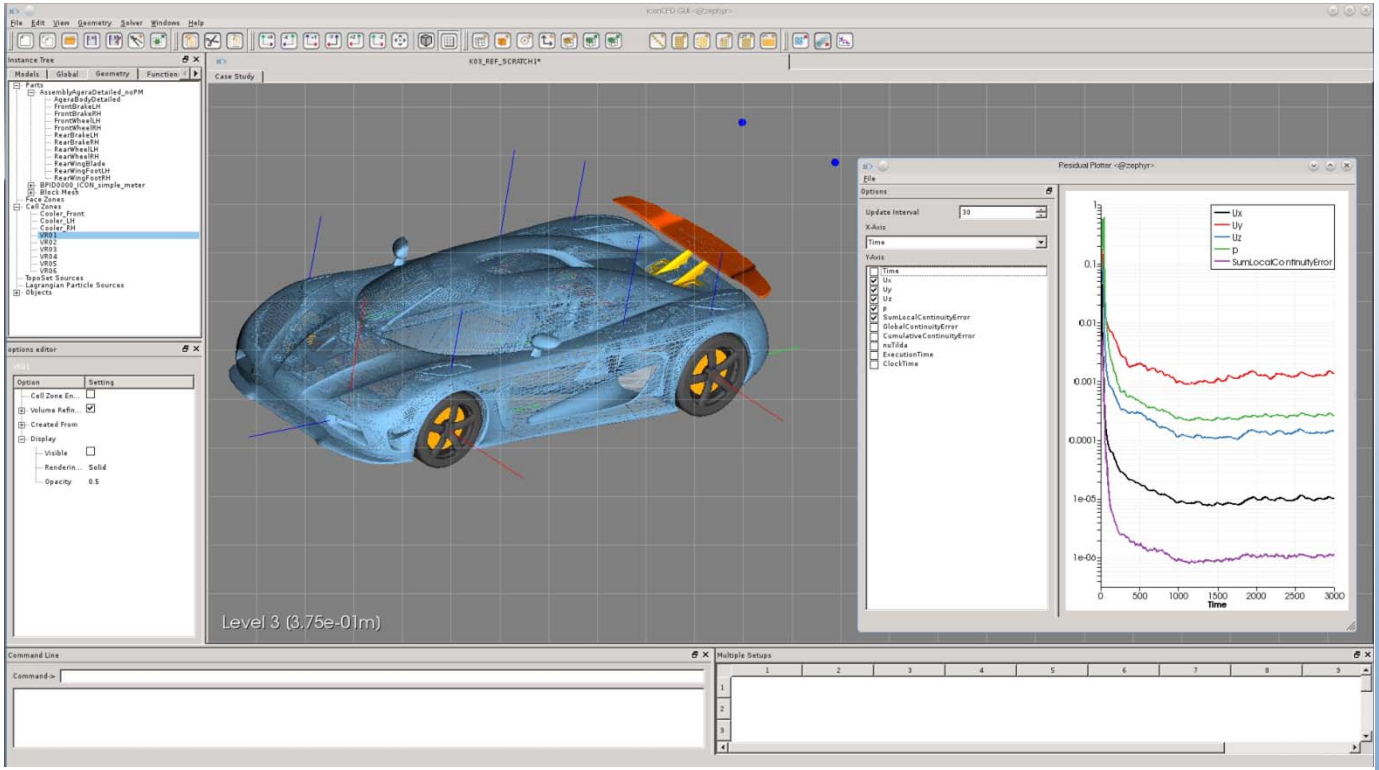

- **Graphical User Interface**
- **Support for all iconCFD Modules**
- MultiCase mode
  - Templates
  - Python interface
- Parts replacing & renaming
- Case template support
- Import mesh capability
- XML based customization
  - Material library
  - Boundary conditions
  - Choice of defaults
- Default & advanced modes
- **Run script output**
- **Flexible licensing (RLM)**
- **Embedded residual plotting tool**

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iconCFD PROCESS
Customization

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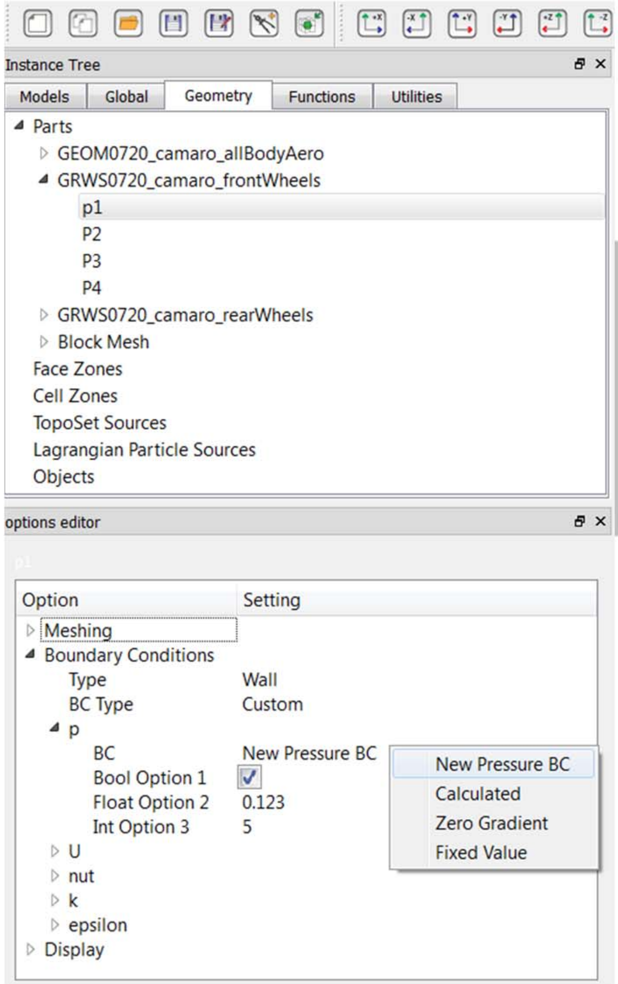


```
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{
  type zeroGradient;
}

GRWS0720_camaro_rearWheels_P6
{
  type newPressureBC;
  optionFloat1 0.123;
  optionInt2 5;
  optionBool3 yes;
}

GRWS0720_camaro_rearWheels_P7
{
  type zeroGradient;
}

GRWS0720_camaro_rearWheels_P8
{
  type zeroGradient;
}
```

">

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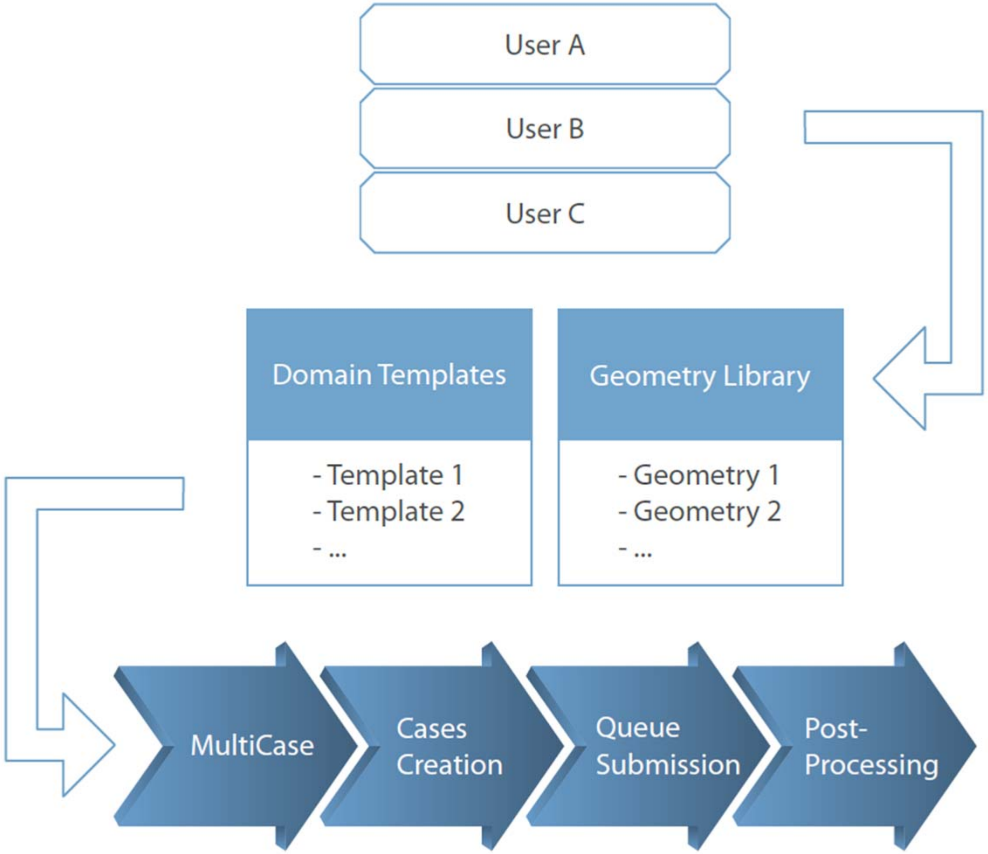
iconCFD PROCESS
MultiCase



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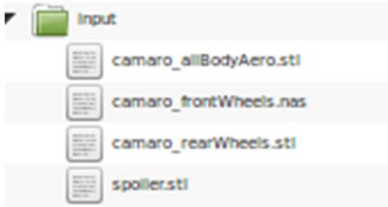
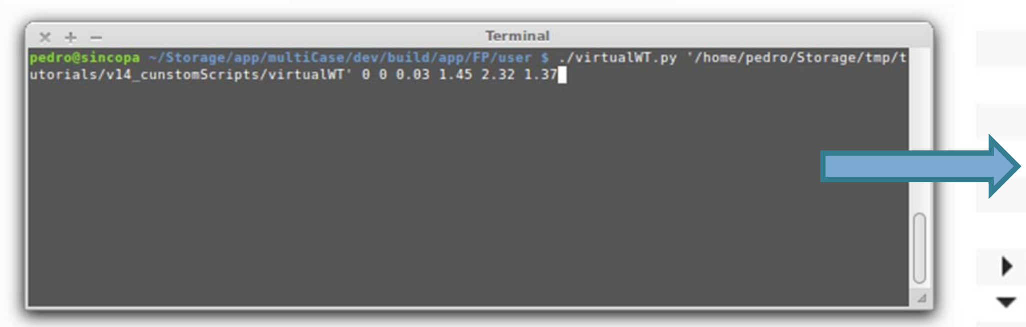
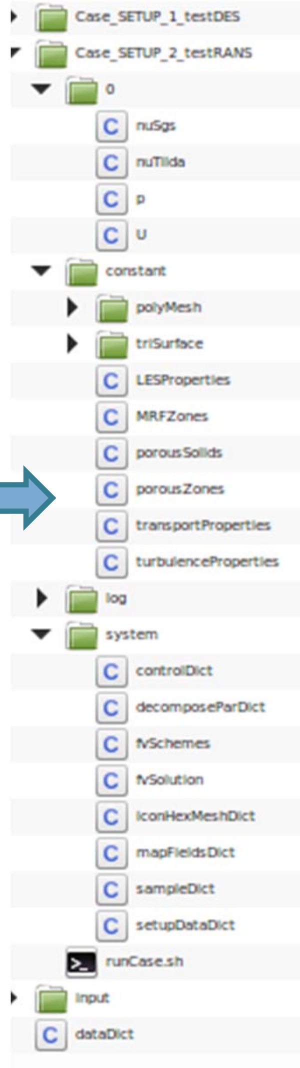
iconCFD PROCESS
MultiCase







<u>Custom "press button" setups</u>

This sample script only requires :

- Frontal area
- Reference point
- Wheel base
- Wheel track

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iconCFD WRAP

Objectives :

- Water-tight domains from huge assemblies
- No loss of accuracy (no de-featuring!)
- Remove isolated parts

Technology :

- Advancing front
- Coarse to fine
- MPI

- Internal wrap support
- External wrap support
- Multiple volumes wrapping
- Multiple keep spheres
- Multiple orphan spheres
- Front merging
- Front collapsing
- Feature line capturing
- Parallelized algorithm (MPI)
- Sag-based curv. refinement
- Handling of very large surface

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iconCFD WRAP

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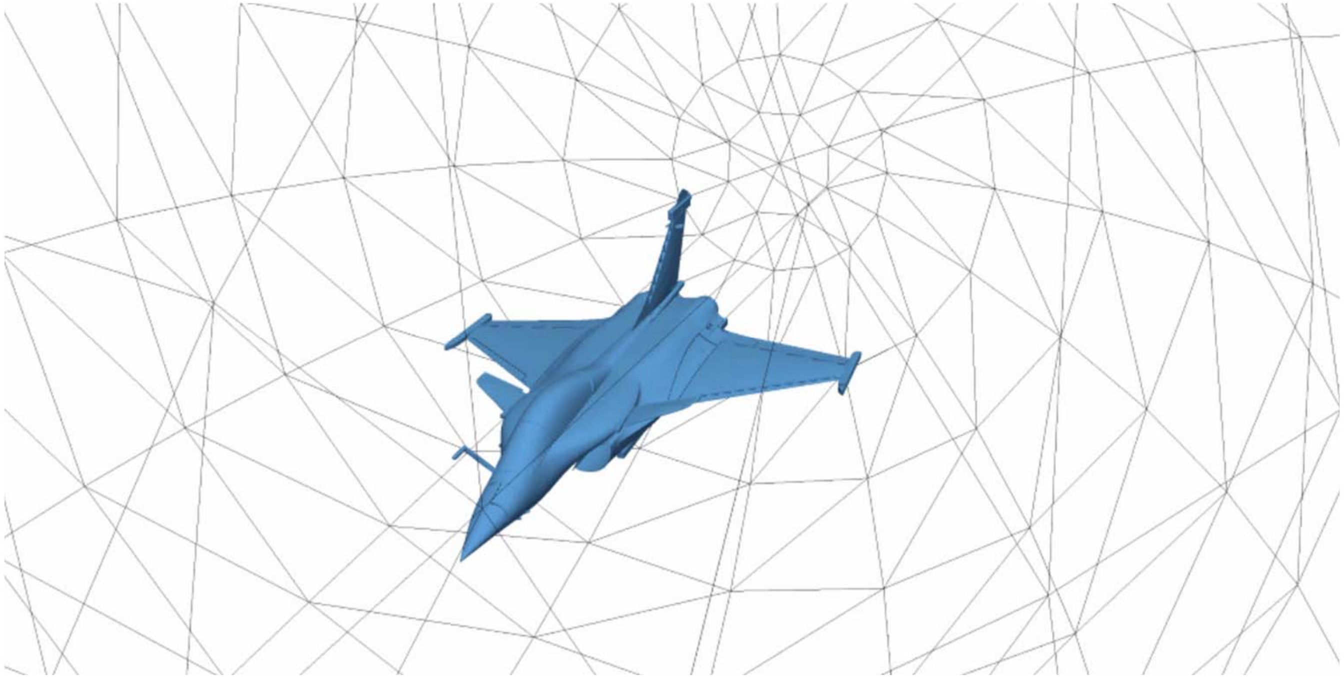

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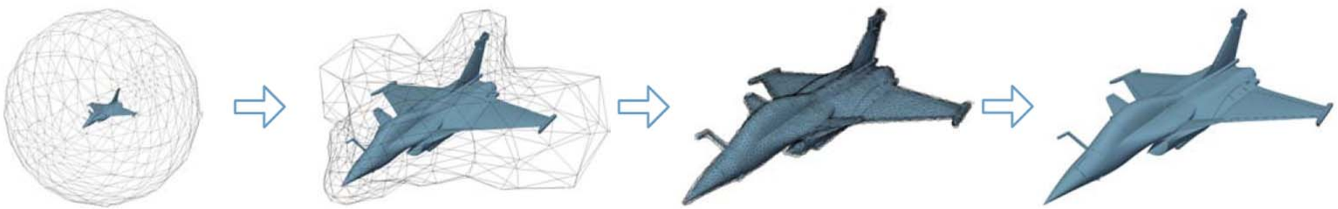
External Wrap Example



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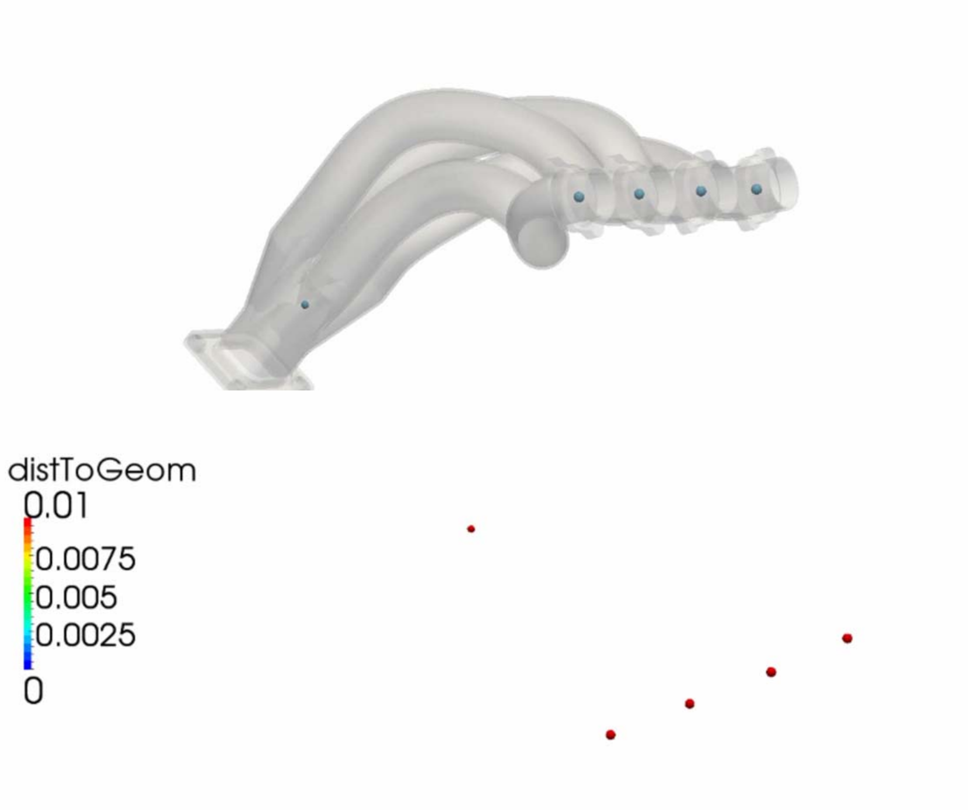
iconCFD WRAP



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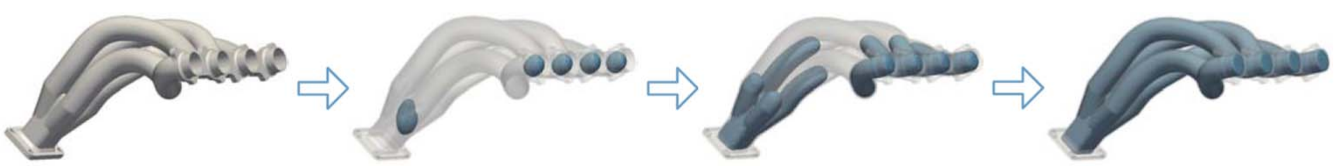
Internal Wrap Example



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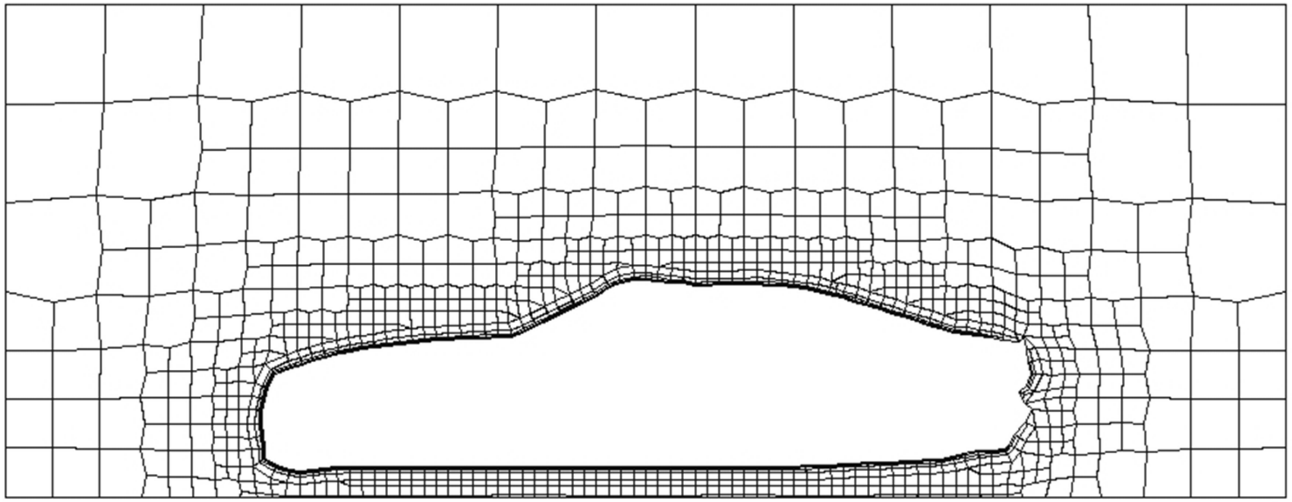
iconCFD MESH
OVERVIEW

Refinement → **Snapping** → **Layers**



- **Fully automatic**
- **Hexahedral-dominant**
- Parallelized & scalable (MPI)
  - Automatic surface distribution
  - Automatic mesh re-partitioning
- **Volumetric refinement**
  - **Distance based refinement**
  - **Surf. proximity based refinement**
  - **Volume shell refinement**
- **Surface based refinement**
  - **Curvature based refinement**
  - **Feature line refinement offset**
  - **Feature line proximity refinement**
- **Feature line snapping**
  - **Automatic detection of features**
  - **Feature line filtering**
  - **Automatic surface intersection**
- Boundary layer cells
  - First cell layer height control
  - Total layer thickness control
  - Number of layers control
  - Growth rate control
  - Multiple layering algorithms

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iconCFD MESH
PARALLELISATION

Aim:

- Scalable parallelization of the mesh generation process
- Generation of large meshes on complex geometries

Approaches:

- Can be categorized based on the degree of coupling

Decoupled	→	Tightly coupled
✓	simplicity	✗
✗	load-balancing	✓
✗	mesh quality	✓
✗	layer generation	✓

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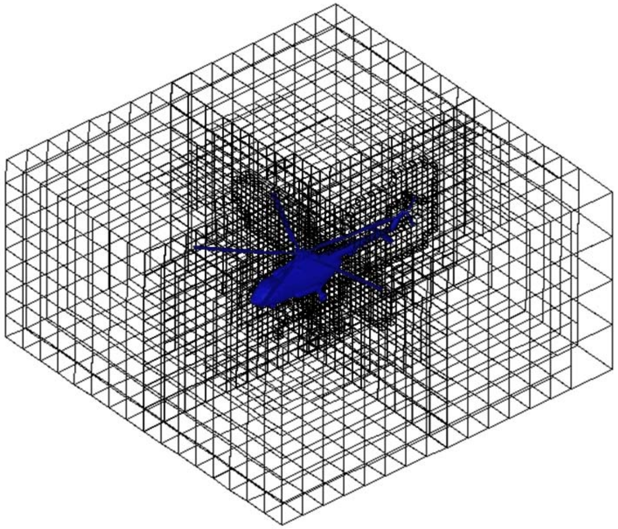
PARALLELISATION

Problem:

- Dynamic load-balancing vs. interface to geometry

Solution 1



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PARALLELISATION

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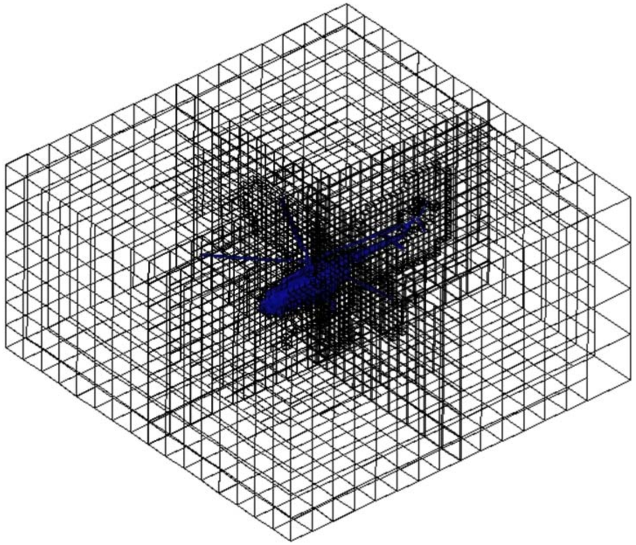
Problem:

- Dynamic load-balancing vs. interface to geometry

Solution 2



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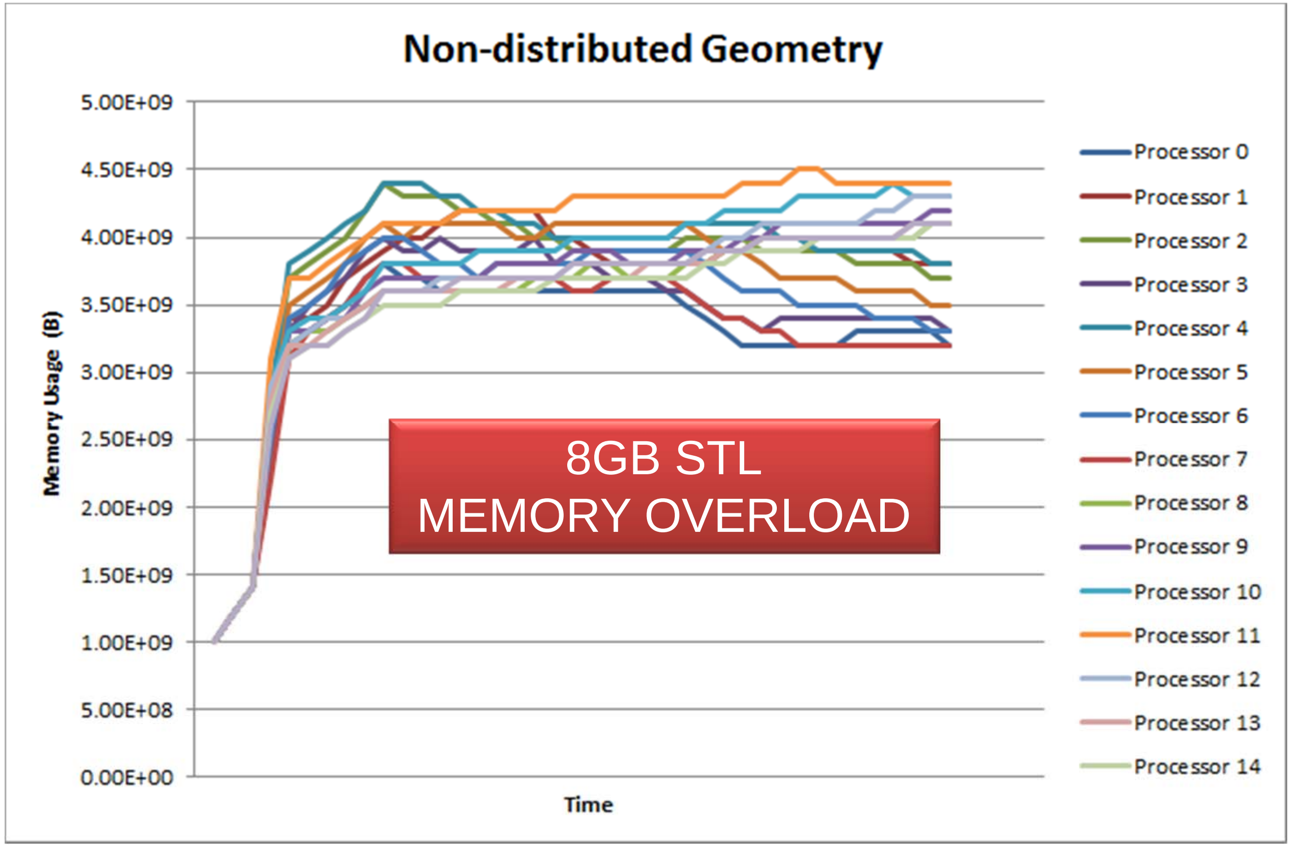

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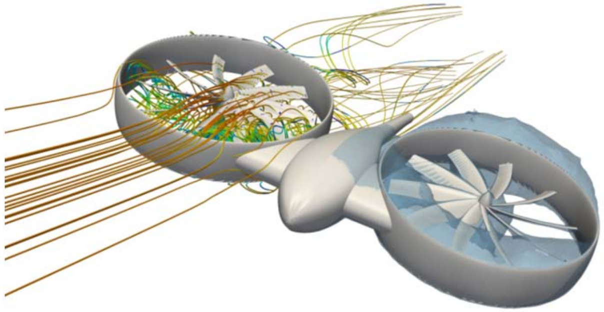
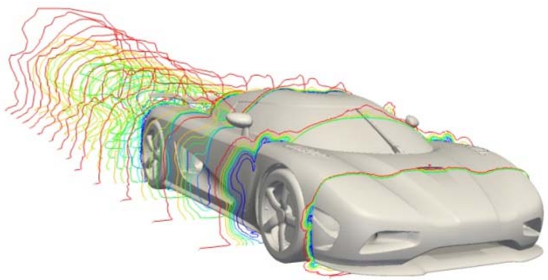
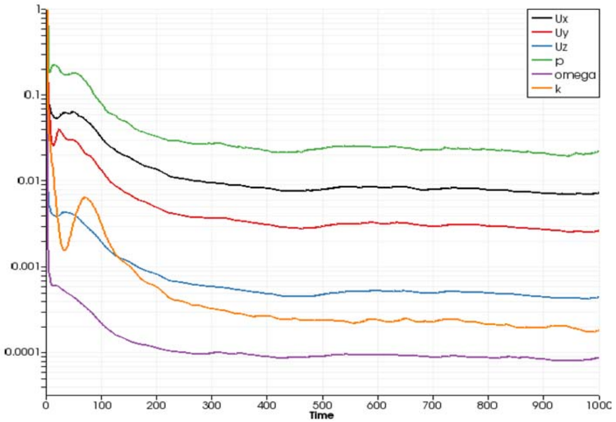
iconCFD COLD
ROBUSTNESS

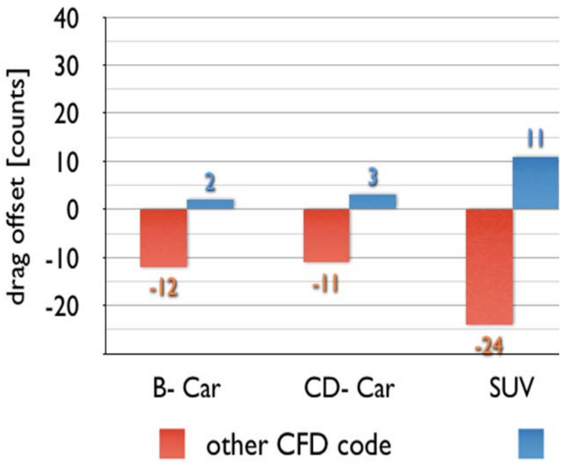


iconSimpleFoam



iconPisoFoam





- **Incompressible**
  - **Steady-state**
  - Pseudo-transient
  - **Full transient**
- **RANS** / **DES** / LES
- **MRF**
- Porous zone models
- Fan models
- Passive scalar transport
- Species transport
- Lagrangian Particle Tracking

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iconCFD COLD
ROBUSTNESS

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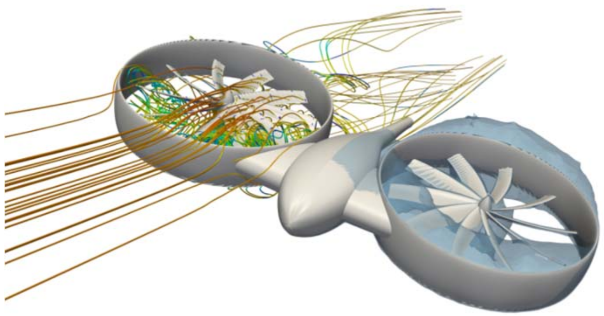
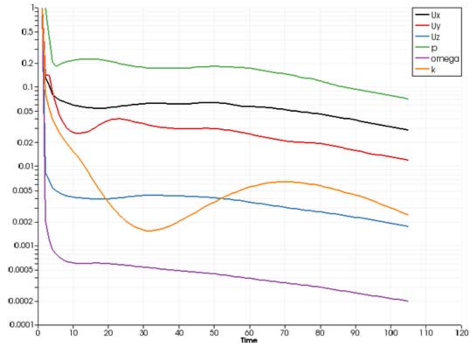
iconHexMesh – 8MCells



Using OpenFOAM®
“robust” bounded schemes



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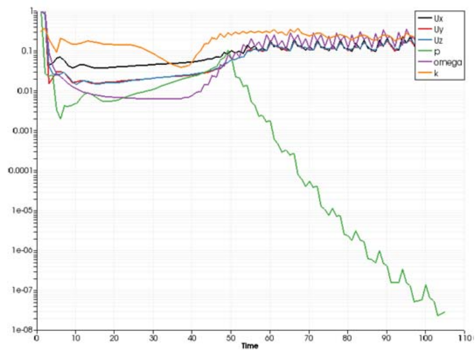

simpleFoam
OpenFOAM® 2.2.x

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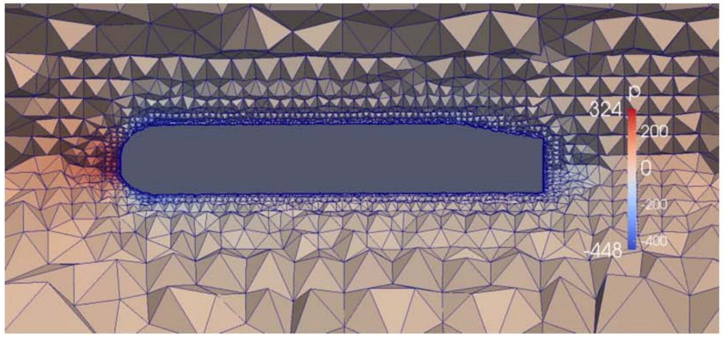
iconCFD COLD ROBUSTNESS

Third Party – 500 kCells
Full Tet Mesh



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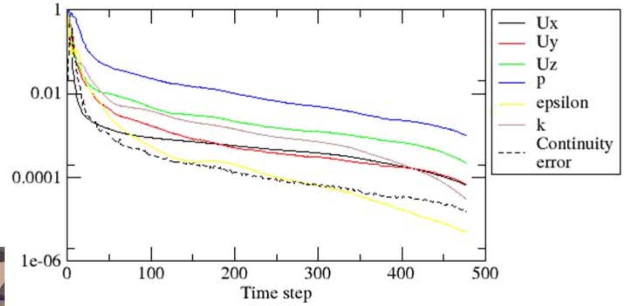

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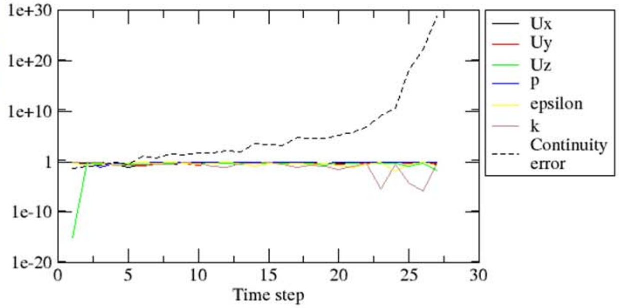

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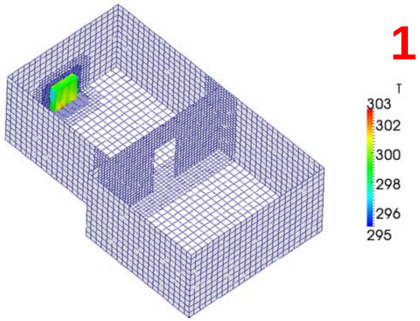
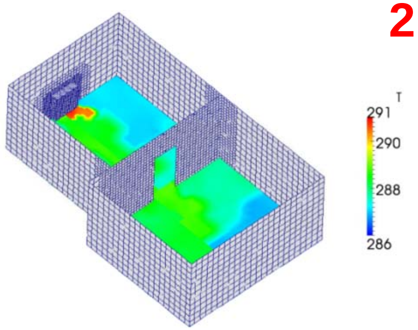
iconCFD THERMAL
RADIATION

1



- T — Convection, conduction and radiation
  - iconHeatFluxTemperature 1
  - iconOuterWallTemperature 2
  - iconBaffleTemperature 3
  - iconChtCoupledTemperature

2



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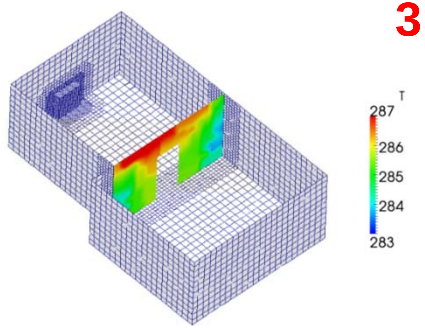

- **Incompressible / Compressible**
- Optional Buoyancy
- Humidity
- Conjugate Heat Transfer
- **Radiation**
  - **Surface to surface**
  - **Fast view factors calculation**
- Heat exchanger models
  - Single stream
  - Dual stream
  - Porous solid
- Thermal boundary conditions
  - Thermal wall functions
  - **Thin wall conduction**
  - **Radiation aware boundaries**
- Thermal function objects
  - Heat balance
  - Solar radiation
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iconCFD THERMAL RADIATION

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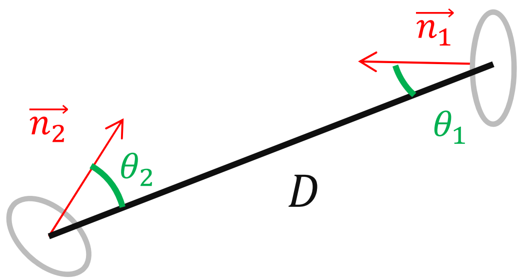
"Surface to surface" method:



The view factor $F_{1\to2}$ is the fraction of radiation leaving 1 and reaching 2. It is calculated as:

$$F_{1\to2} = \frac{\cos(\theta_1)\cos(\theta_2)dS_2}{\pi D^2}$$

Summation of view factors :

$$\sum_{i\neq j} F_{i\to j} = 1$$

Reciprocity theorem:

$$dS_1\ F_{1\to2} = dS_2\ F_{2\to1}$$

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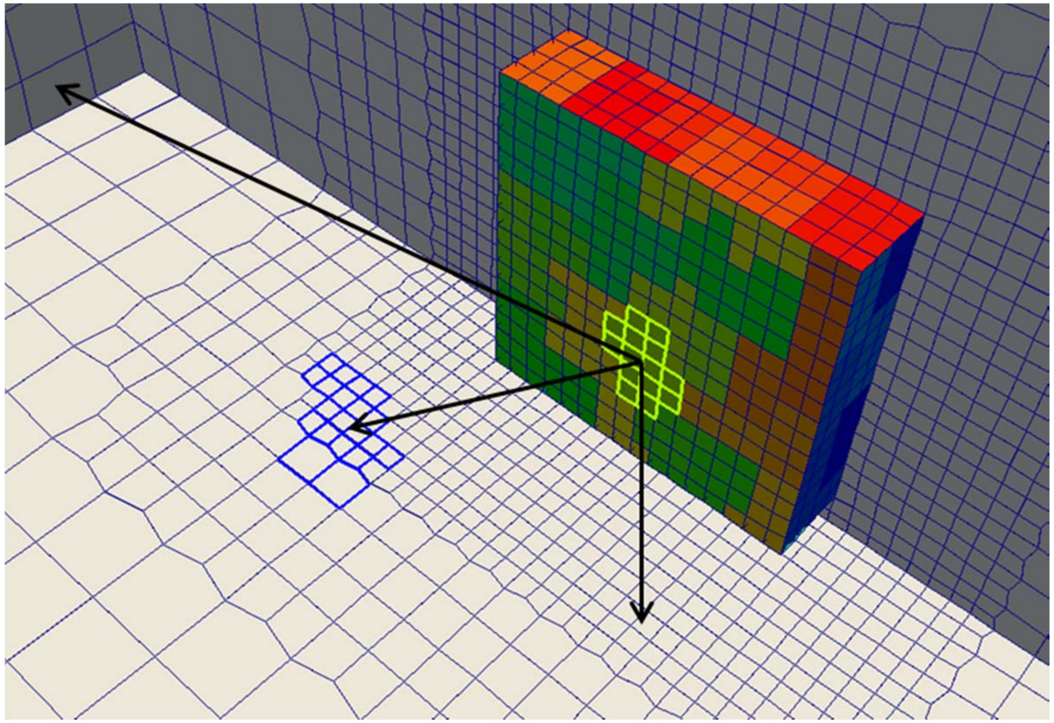
iconCFD THERMAL
RADIATION



Fully parallelised view factor calculation ~ 15 times faster
Robust Face agglomeration algorithm.

- **Incompressible / Compressible**
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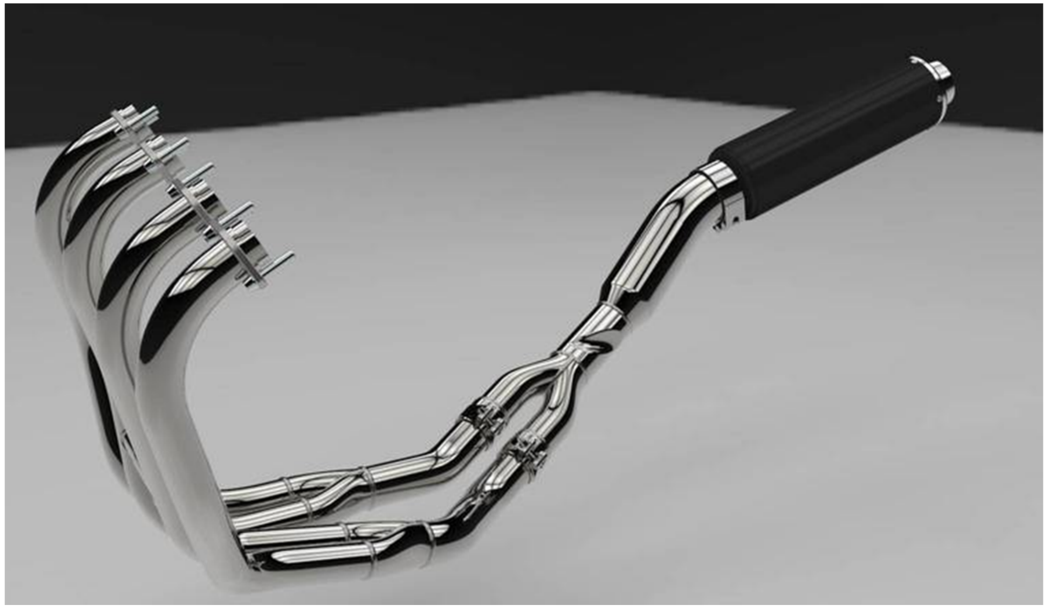
iconCFD THERMAL EXHAUST

Difficult case :

- High speeds
- High compressibility
- Pressure waves
- Time varying temperature and velocity inlets



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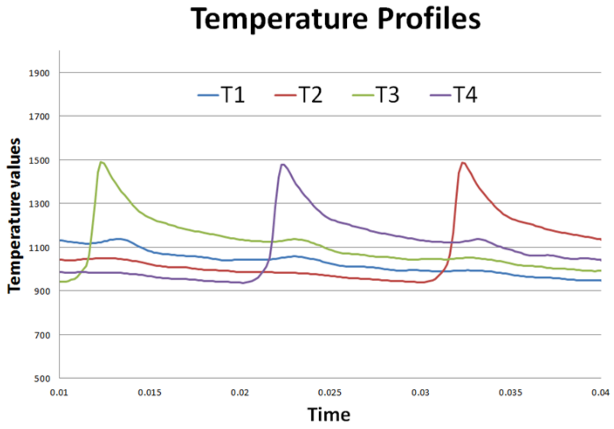

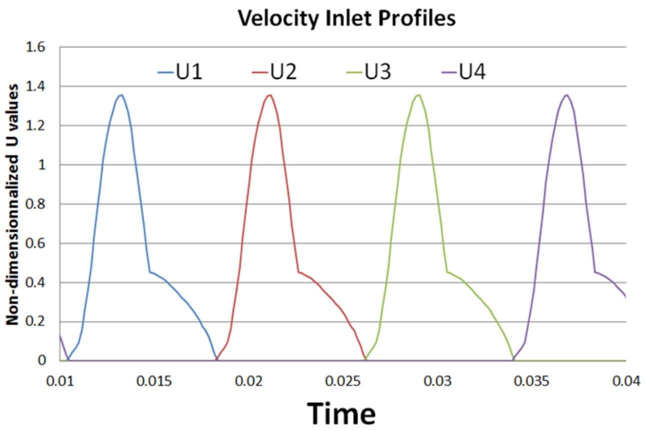

iconHexMesh

- 100kCells
- 3 layers on boundary

iconHotRhoPisoFoam

- 12 cores
- 0.2s of simulation
- 55min
- Time step 5.0e-5s

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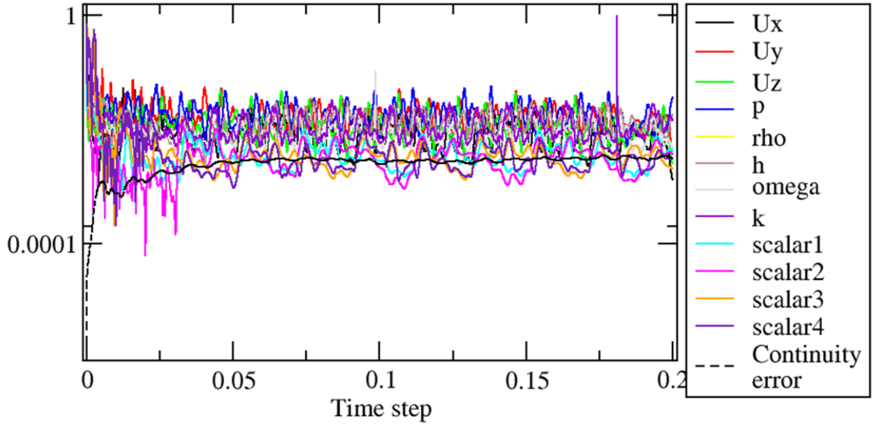

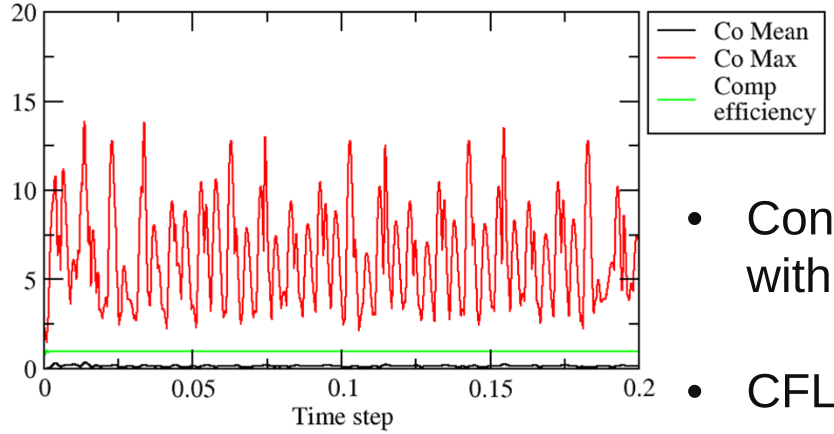

- Convergence reached within each PISO loop.
- CFL varies below 15

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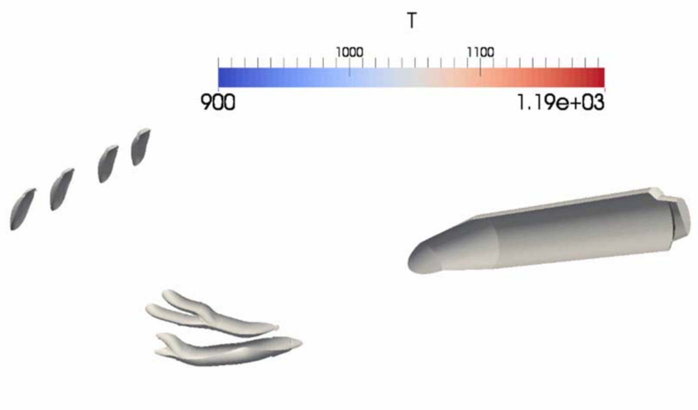

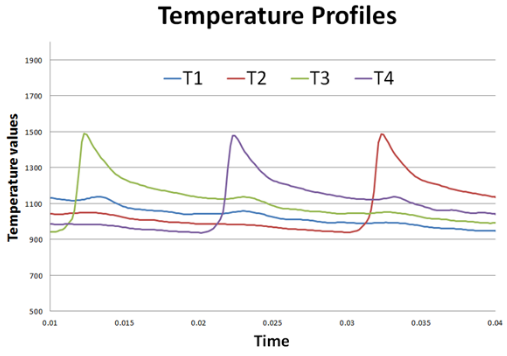

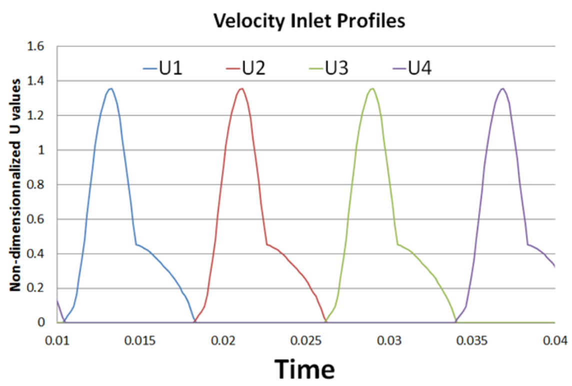

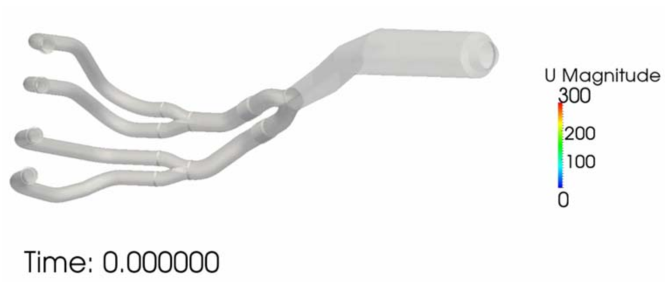

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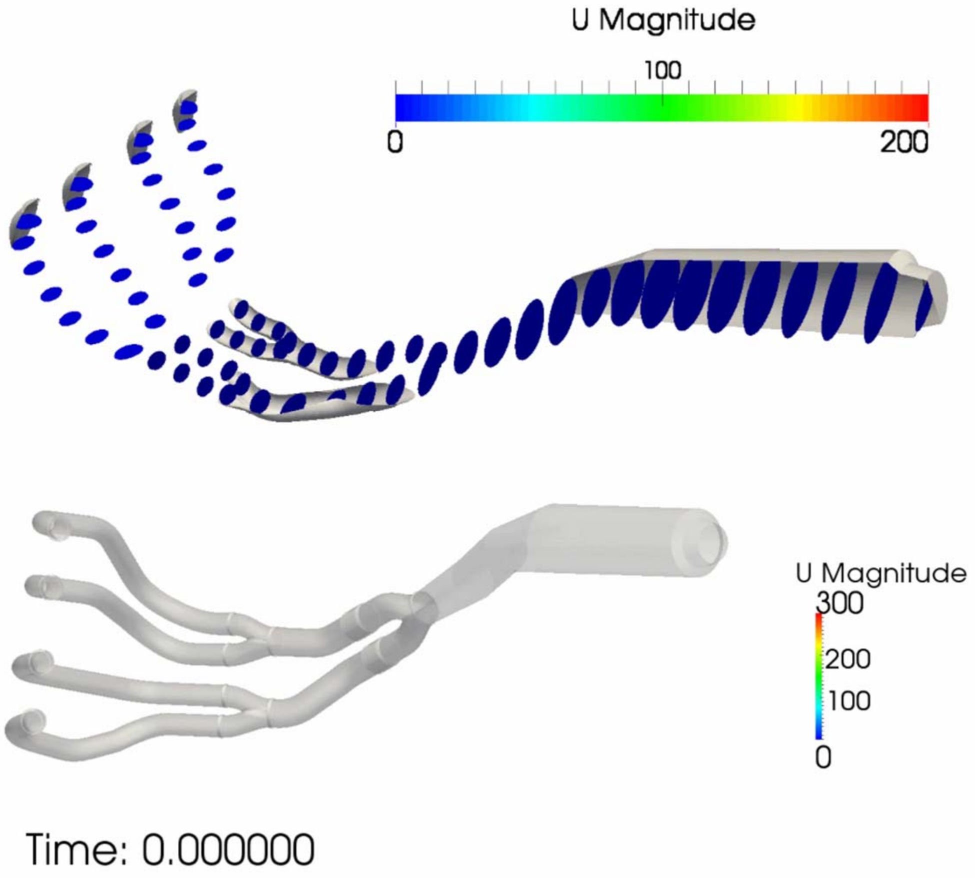

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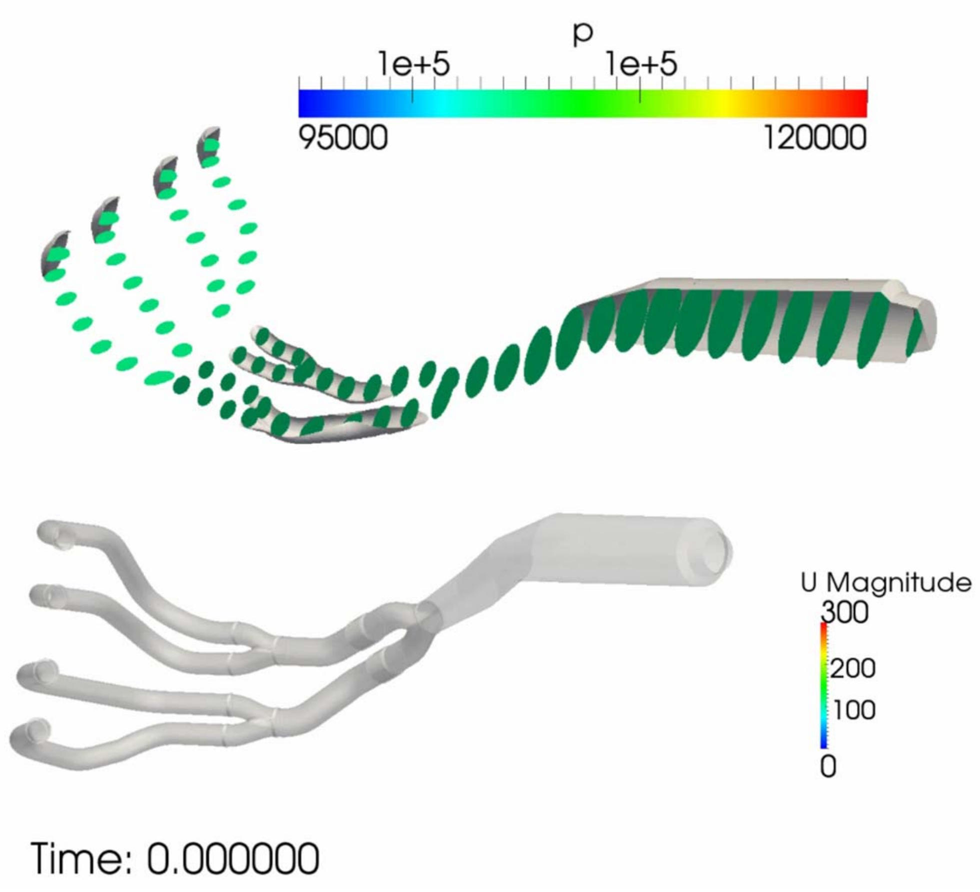

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iconCFD THERMAL
UNDER-HOOD VALIDITY

Case :

- Car under-hood
  - primary & secondary fans
  - dual stream heat exchanger

Objective :

- Validate iconCFD Thermal
- Compare performance and accuracy with leading commercial tool
- Compare with experimental measurements

- Incompressible / **Compressible**
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iconCFD THERMAL
UNDER-HOOD VALIDITY

- Solver used : iconHotRhoPisoFoam
- Fan models : Polynomial (baffle)
- Heat exchanger : liquidCoolerSimple
  - Uses interpolation in specifications table
- Boundary Conditions :
  - Fixed Temperatures on bonnet and transmission

5000 it / 36 cores	iconCFD	Code X	Experiment
Heat Dissipation (heat exchanger)	41.9kW	35.9kW	45.7 kW
Cells (Million)	30.2	28.3	N/A
Time	88h	89.3h	N/A

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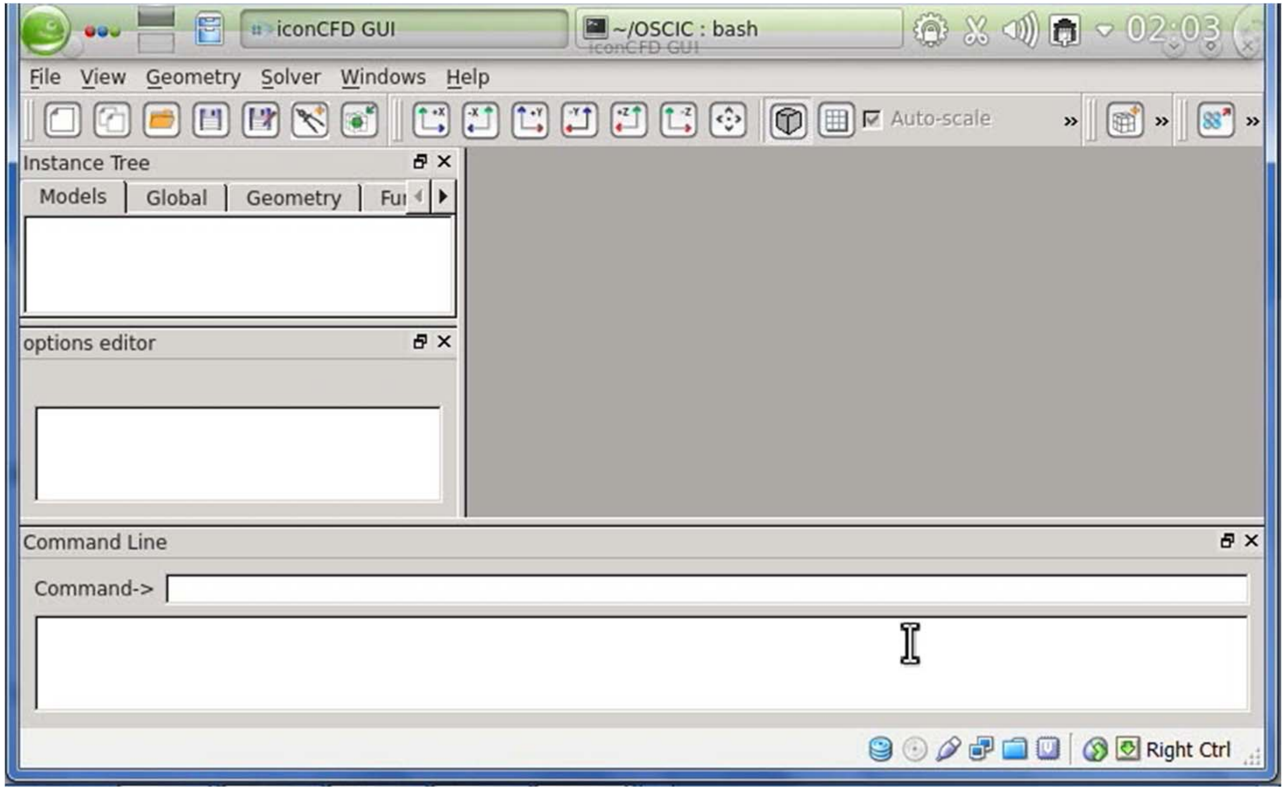
iconCFD OPTIMIZE



- Adjoint optimization solvers
  - Shape optimization
  - Topology optimization
- Adjoint turbulent models
  - Spalart-Allmaras
  - k-Epsilon
- DES primal support
- Sub-case capability
  - Local optimization
- Cost functions
  - Lift / Drag control
  - Power dissipation
  - Flow uniformity
  - Mass-flow rate
  - Swirl

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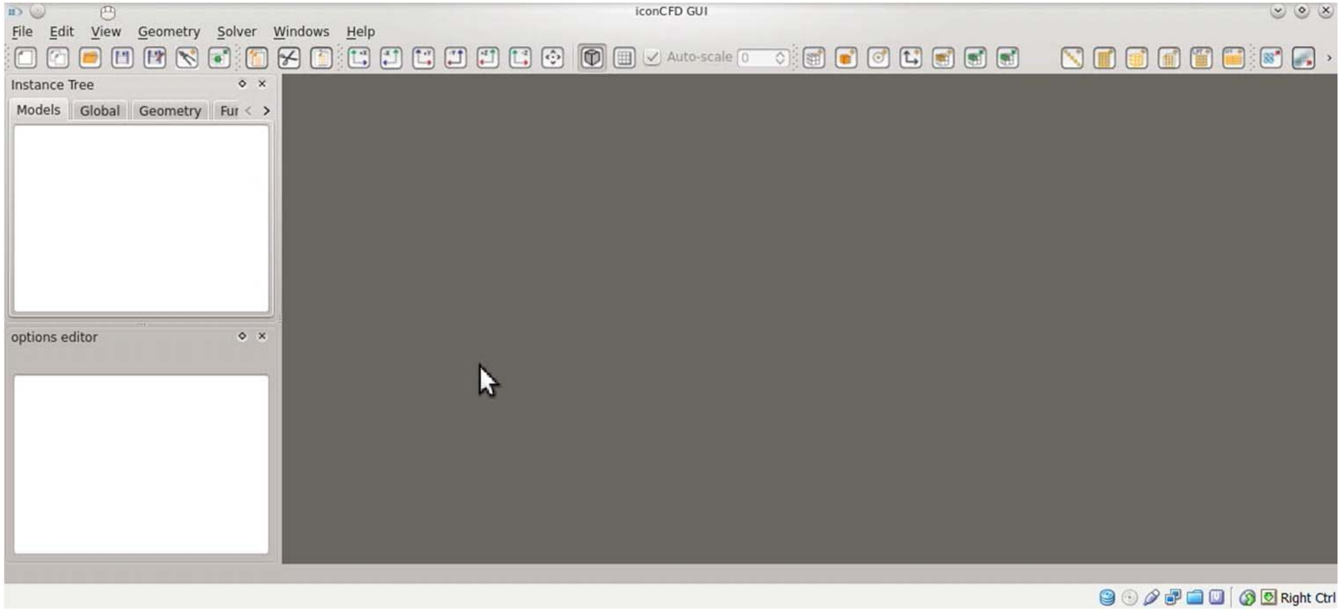

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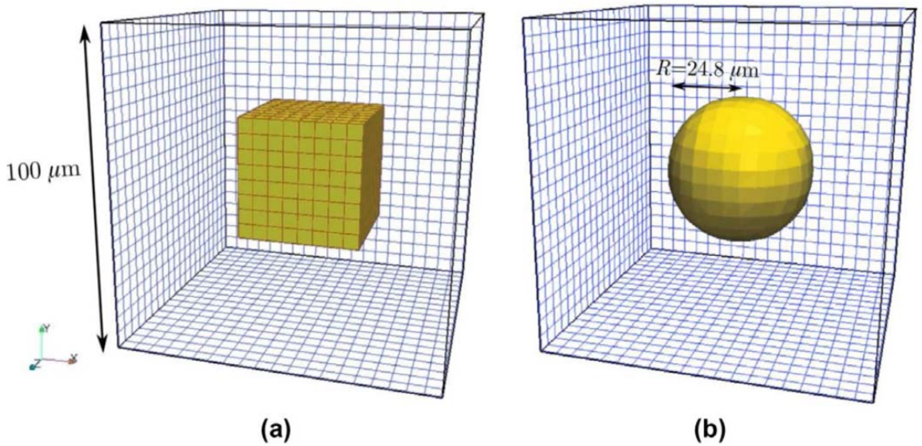
iconCFD VOF
STATIONARY DROPLET

Focus of developments:

- Allow larger time steps for large scale simulations.
- Solve the "micro" problems first.



Testcase description :
Modelling two-phase flow in porous media at the pore scale using the volume-of-fluid method – Journal of Computational Physics 231 (2012) - Ali Q. Raeini […]

- **Validated multi-phase flow**
- **Transient** / Pseudo-transient
- **Newtonian fluids**
- Non-Newtonian fluids
- Sloshing models (time varying)
- MRF
- **Parasitic currents reduction**
- Automatic interface refinement with load balancing
- Advanced boundary conditions
  - Dynamic contact angle
  - Fixed contact angle

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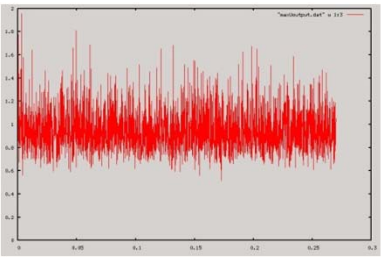
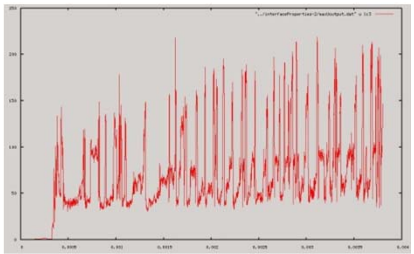
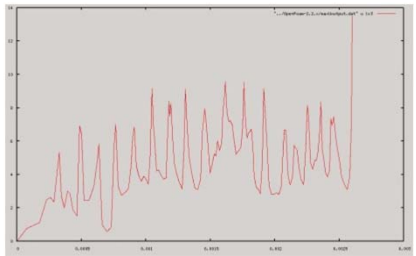
iconCFD VOF
STATIONARY DROPLET

Comparison of 3 solvers:

- **1 iconInterPisoFoam** (iconCFD 3.0)
- **2 interPisoFoam** (iconCFD 3.0 without improved interface numerics & corrections)
- **3 interFoam** (OpenFOAM® 2.2.x)







iconInterPisoFoam	interPisoFoam	interFoam
0.6 < max(U) < 1.4	max(U) > 50	diverges (10+)

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iconCFD VOF
STATIONARY DROPLET

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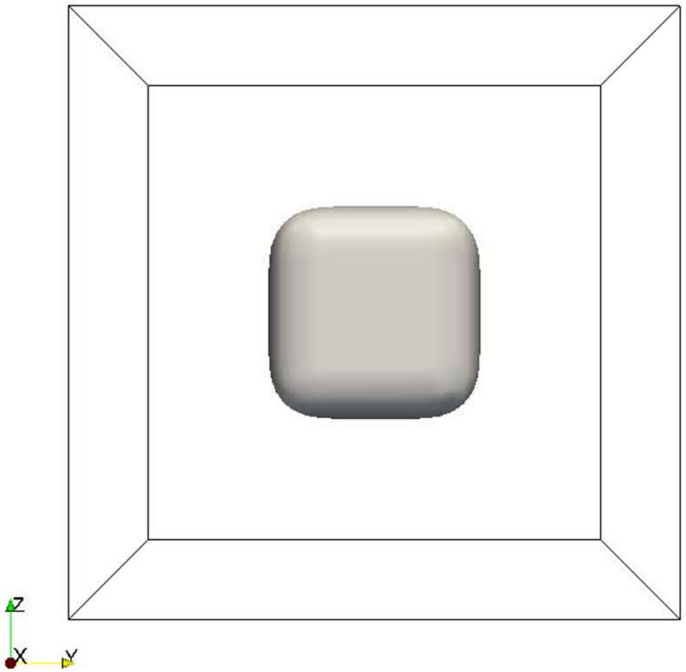
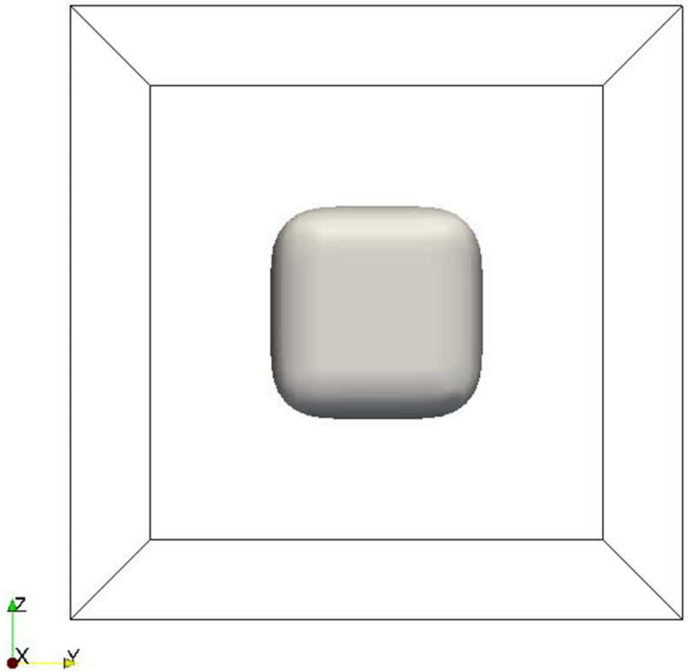
Time: 0.000000



iconInterPisoFoam



interPisoFoam

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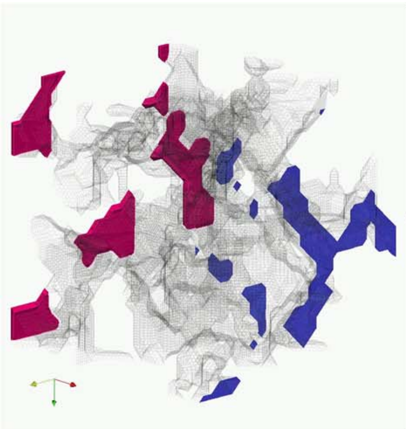
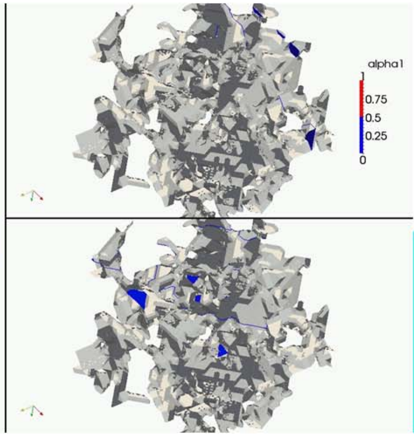
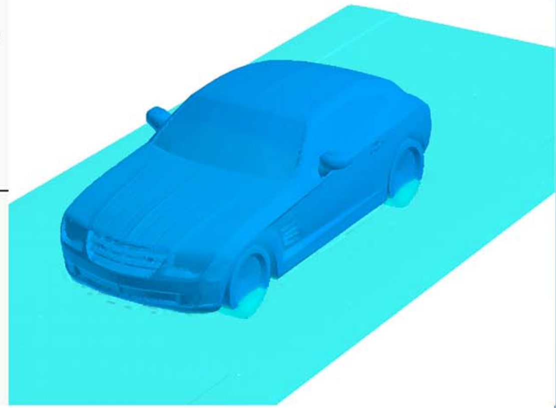
iconCFD VOF
STATIONARY DROPLET

Solver	Solution Time Step [s]	deltaT [s]	Execution Time [s]
iconInterPisoFoam	0.001000486	5e-7	**148.7**
interPisoFoam	0.001000006	7.4e-9	7438.09
interFoam	0.001000085	9.1e-8	387.36







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Technology • Process • Consulting

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iconCFD 3.X
OUTLOOK

- Foundations set for the next 3 years :
  - **iconCFD Transonic**
  - **iconCFD Waves**
  - **iconCFD React**
  - **iconCFD Move**
  - **iconCFD …**

- **iconCFD Transonic**
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