CFD & Aerodynamics at Volvo Car Corporation

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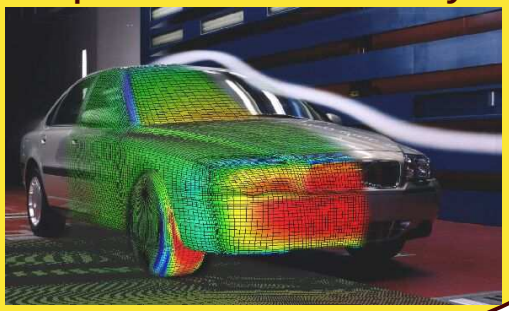
Outline

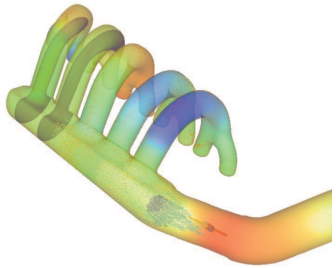
- Introduction
- Why work with CFD
- What kind of problems we look at
- Hands on the CFD process
- How we work in projects
- Exemples

CFD groups at VCC

Fluid Dynamics Centre,
Computational Fluid Dynamics

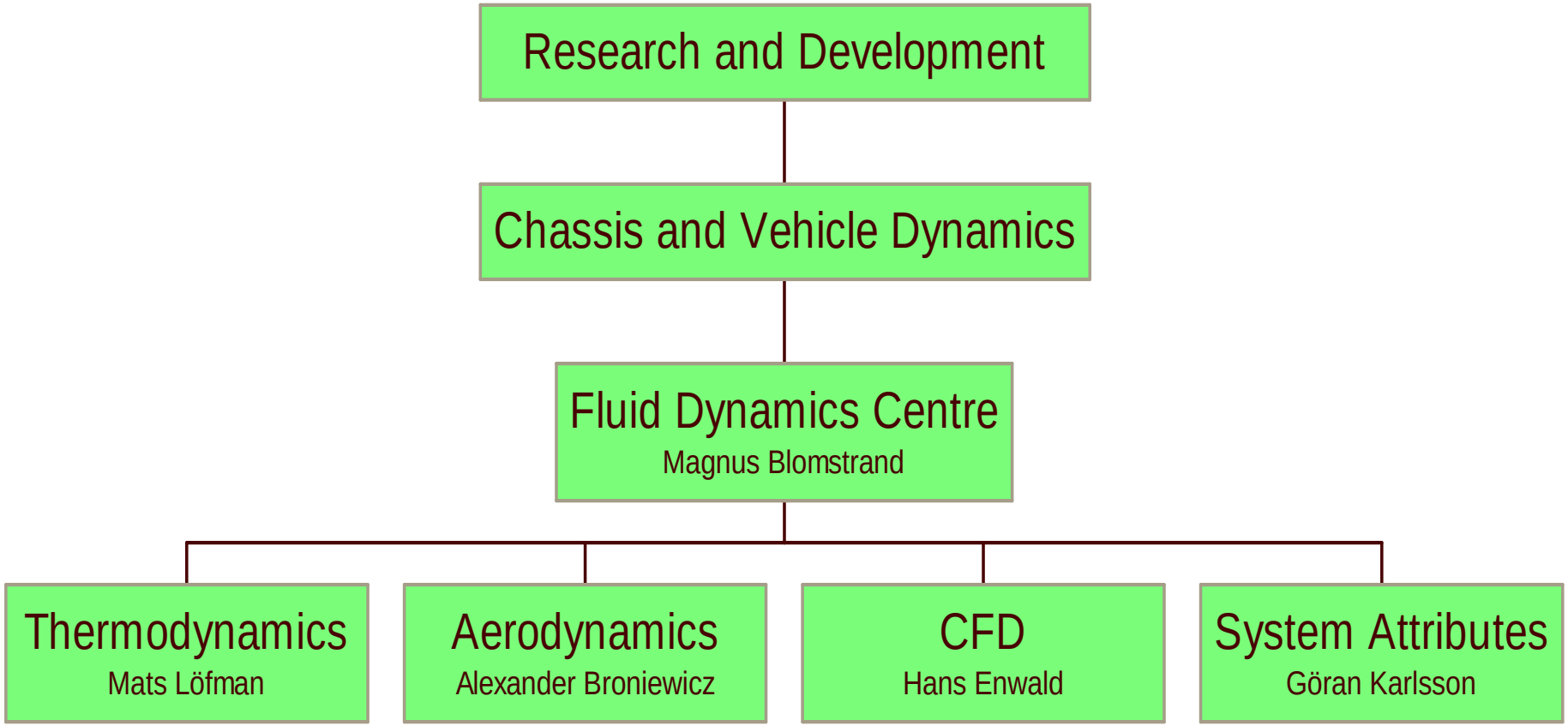


Powertrain,
Thermodynamics analysis



Powertrain,
Combustions systems

VCC Fluid Dynamics Centre



VCC Fluid Dynamics Centre

Thermodynamics	Aerodynamics	CFD	System Attrib.
Cooling Performance Thermal Environment: Engine bay Floor Air Intake / Intercooler 13 People: 3 Mechanics 2 B.Sc. 7 M.Sc. 1 Lic.	Drag Stability Dirt Deposition Water Tightness 11 People: 1 Mechanics 7 M.Sc. 1 Lic. 2 Ph.D	Aerodynamics Climatic Comfort Thermodynamics Dirt Deposition 15 People: 5 M.Sc. 1 Lic. 8 Ph.D	Aerodynamics Thermodynamics Dirt Deposition Water Tightness 13 People: 5 B.Sc. 7 M.Sc. 1 Lic.

Requirement specification, Customer requirements, Project management
Testing / System simulations, R&D / method development

- Plus 1 Aerodynamicist resident at the Design Studio

CFD Aerodynamics:

Magnus Ahl, Ms.C.

Jonas Ask, Ph.D. student

Andreas Borg, Ph.D.

Olga Roditcheva, Ph.D.

Simone Sebben,Ph.D.

Why work with CFD?

- UNDERSTANDING: complete picture of the flow field at any time
- COMPLEMENTS physical testing
- Show CONSEQUENCES of choices early on in project, balancing of requirements
- Meets the need for REDUCED LEAD TIME

Successful factors of our CFD group:

- Competent staff
- Computer environment
- Working process

Connection to Academic Research

Fundamental fluid mechanics & CFD research

Universities

CFD research work for future automotive applications

VCC Ph.D. projects

Development of computational procedures according to technology Strategies (help of ex-job work)

Method dev. projects

R&D and Vehicle projects

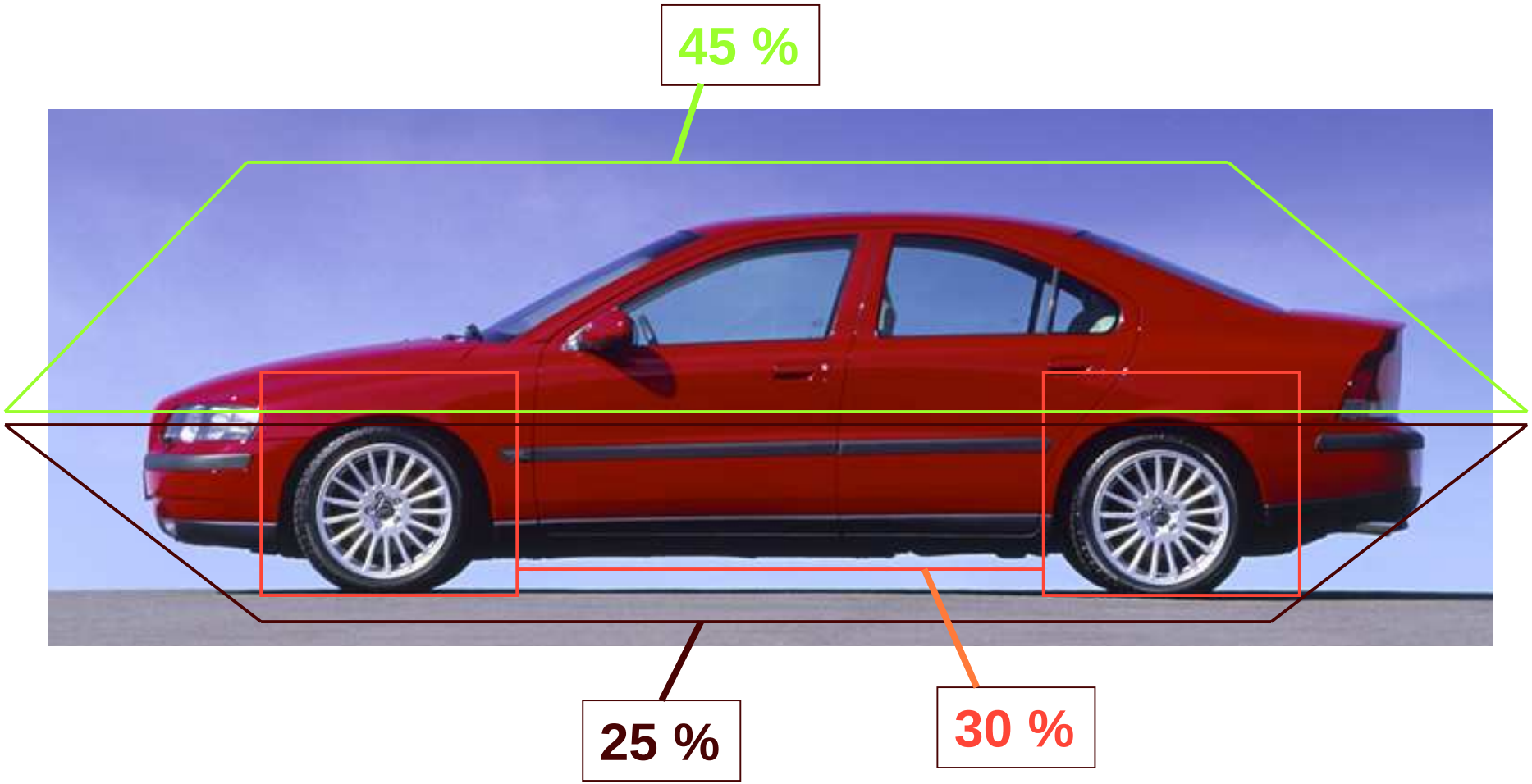
Computational Fluid Dynamics Group, 96630

Approximate: resource allocation	10 %	20 %	70 %

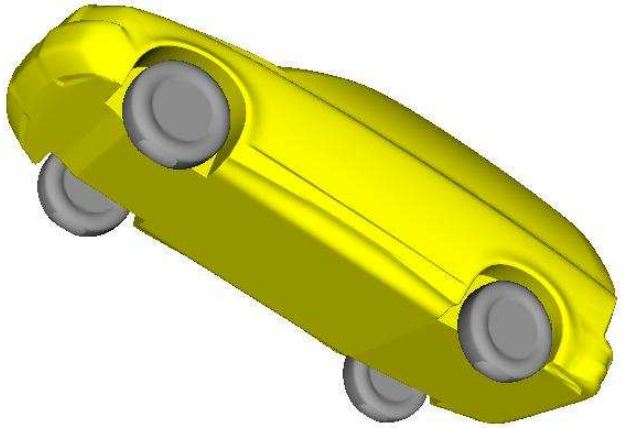
Aerodynamic issues

- Drag (fuel consumption, top speed, acceleration)
- High-speed stability (lift)
- Cross-wind stability (side force and yawing moment)
- Passenger comfort (cabriolets)
- Dirt deposition (visibility)
- Aero acoustics (limiting the strength of sources)
- Body deformation (Door frames etc)

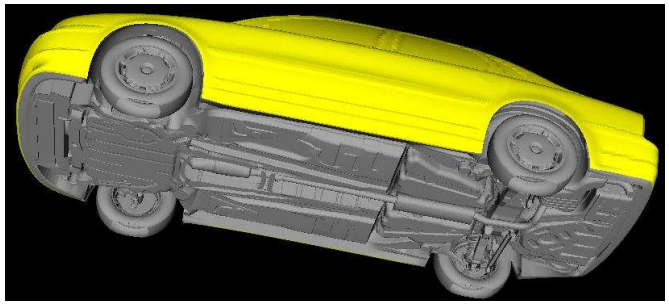
Sources of drag on a modern car



What we do:

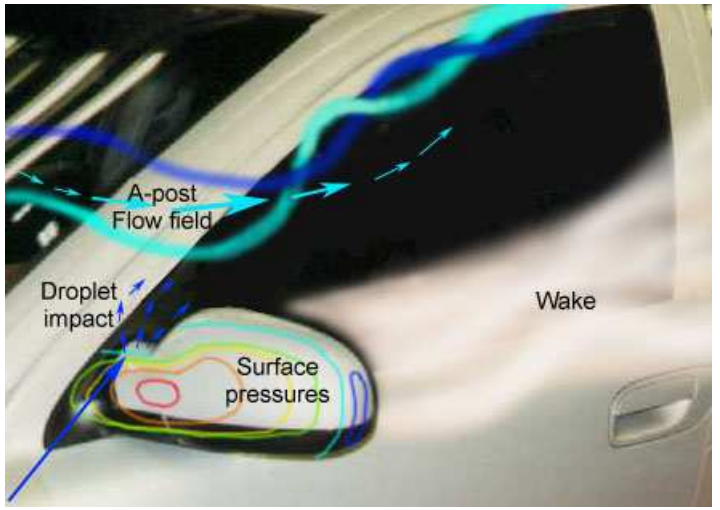


- Flat underbody imulations

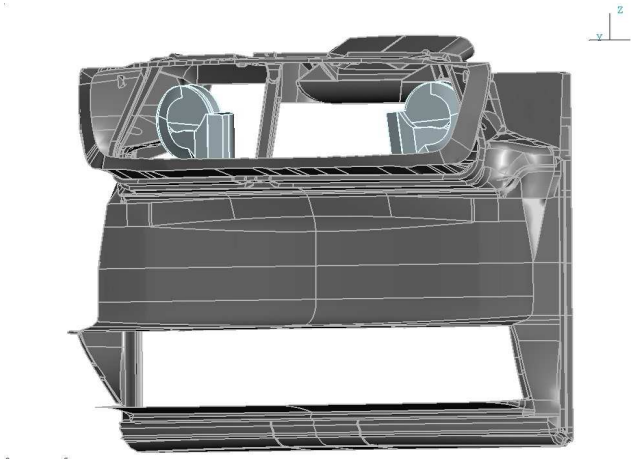


- Detailed underbody simulations

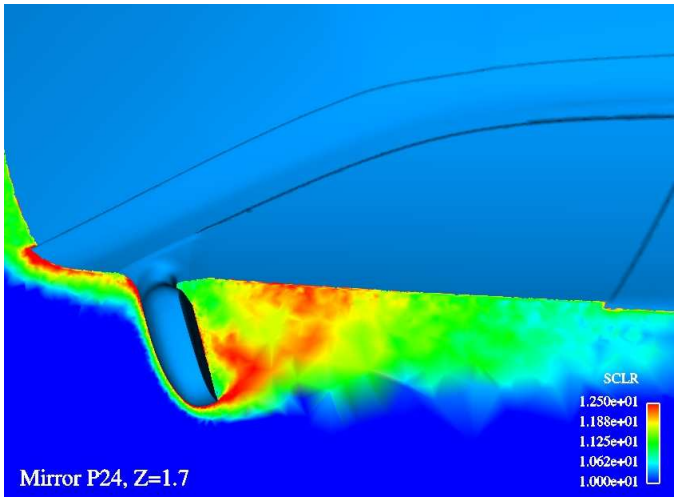
- Dirt deposition / underbody contamination



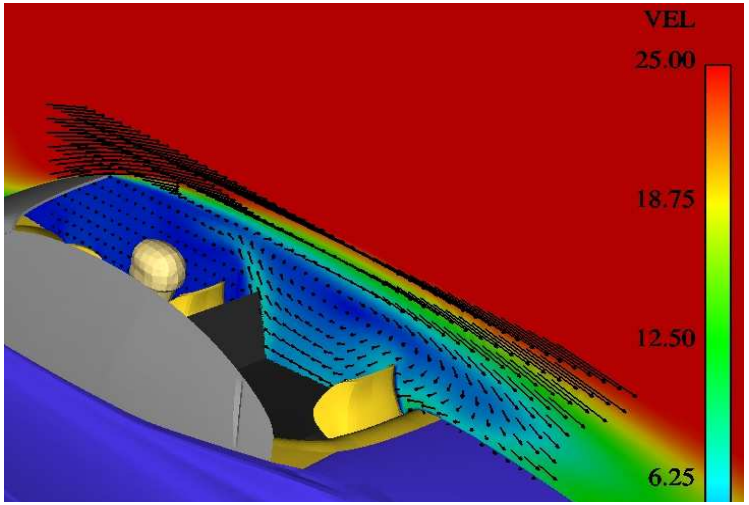
- Snow ingress analysis based on models from thermal analysis



- Aeroacoustic analysis based on modelled acoustic source terms



- Confort in convertibles



Geometry data

Hands on CFD process

VPM/CATIA

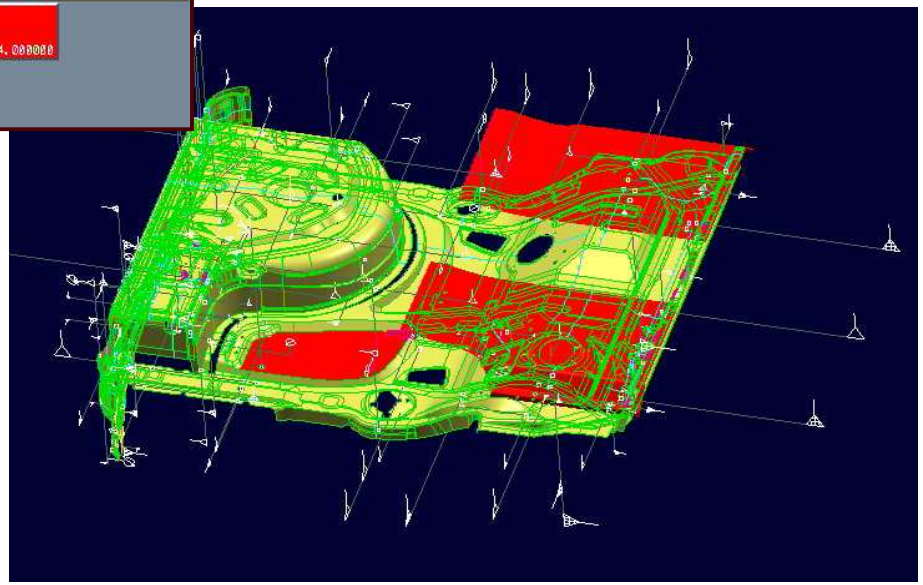
ANSA

Icem-CFD/ TGrid

Star -CD

Ensight

VPM: Data base of VS



Hands on CFD process

Clean up CAD and generate surface mesh

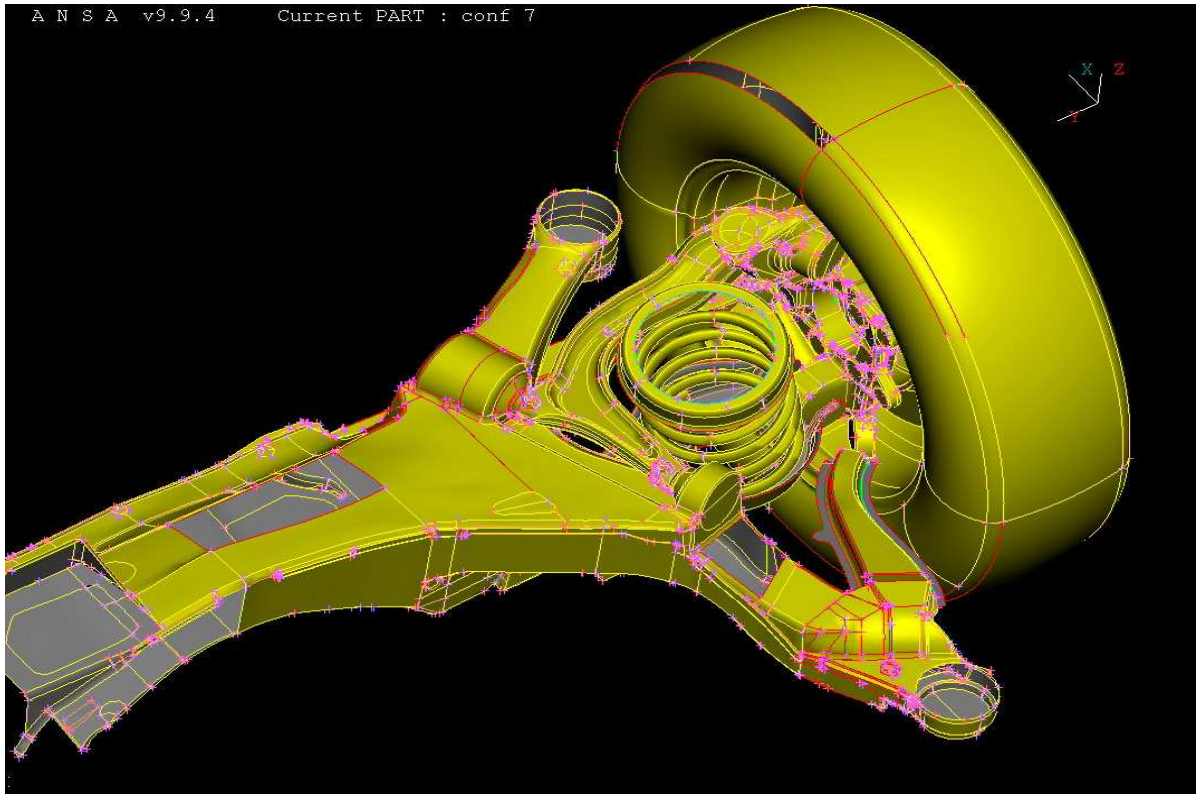
VPM/CATIA

ANSA

Icem-CFD/
TGrid

Star -CD

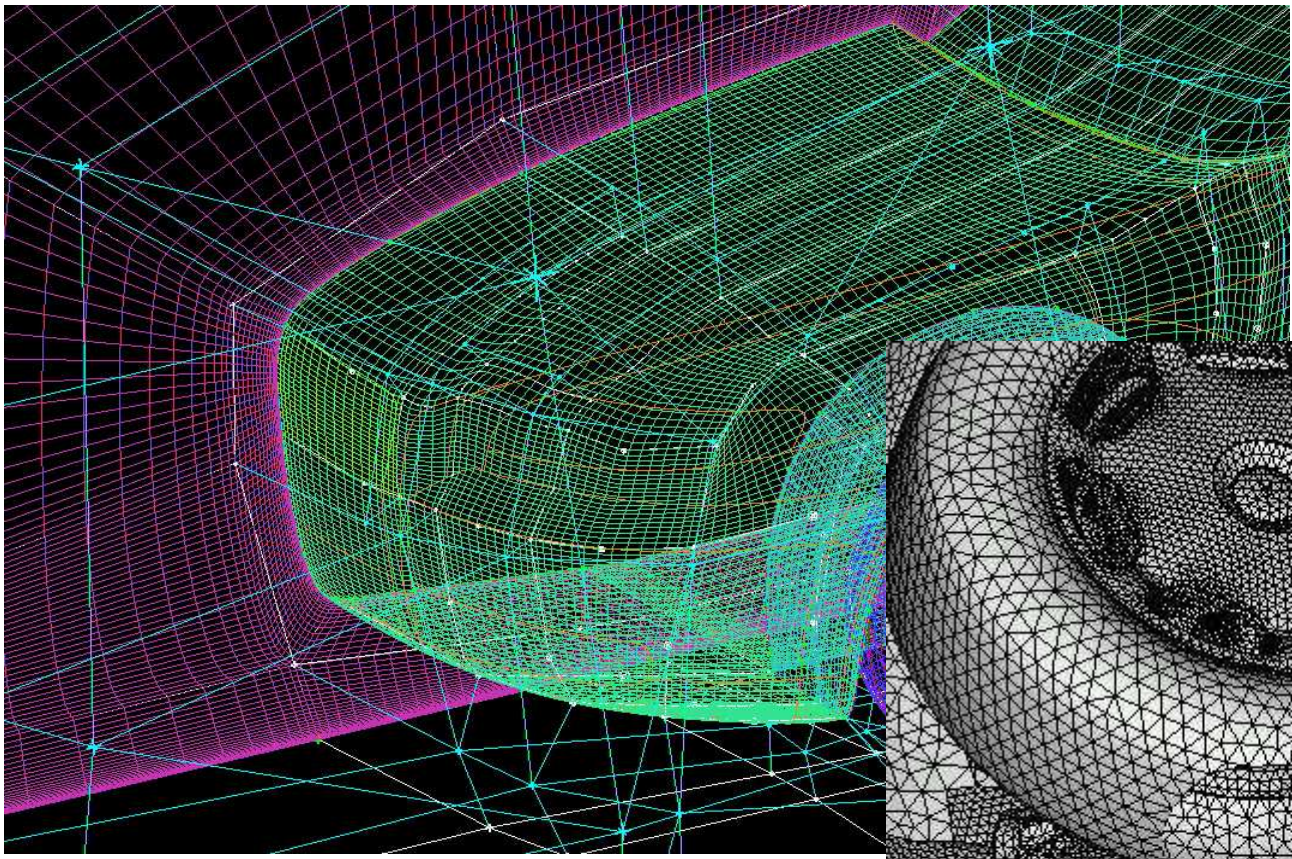
Ensight

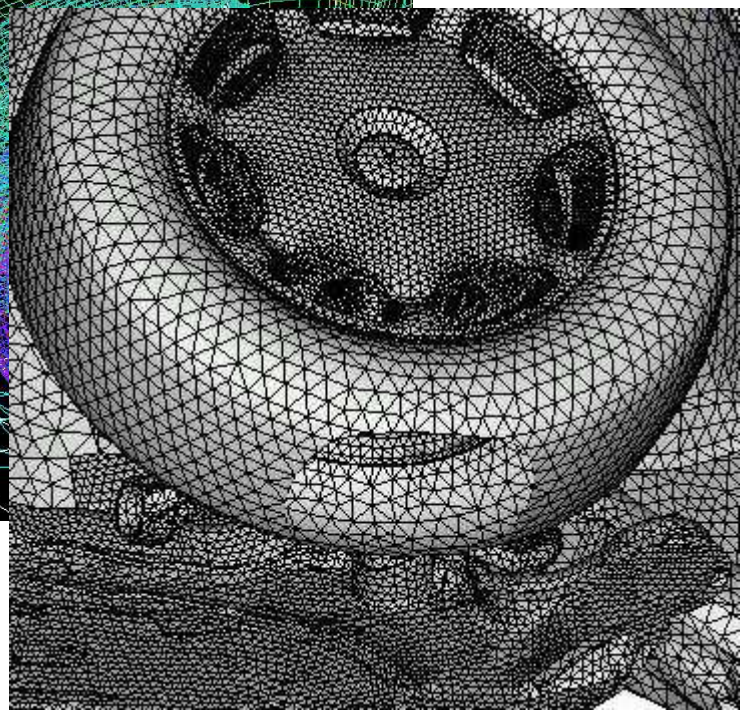


Hands on CFD process

Generate volume mesh

- VPM/CATIA
- ANSA
- Icem-CFD/ TGrid
- Star -CD
- Ensight

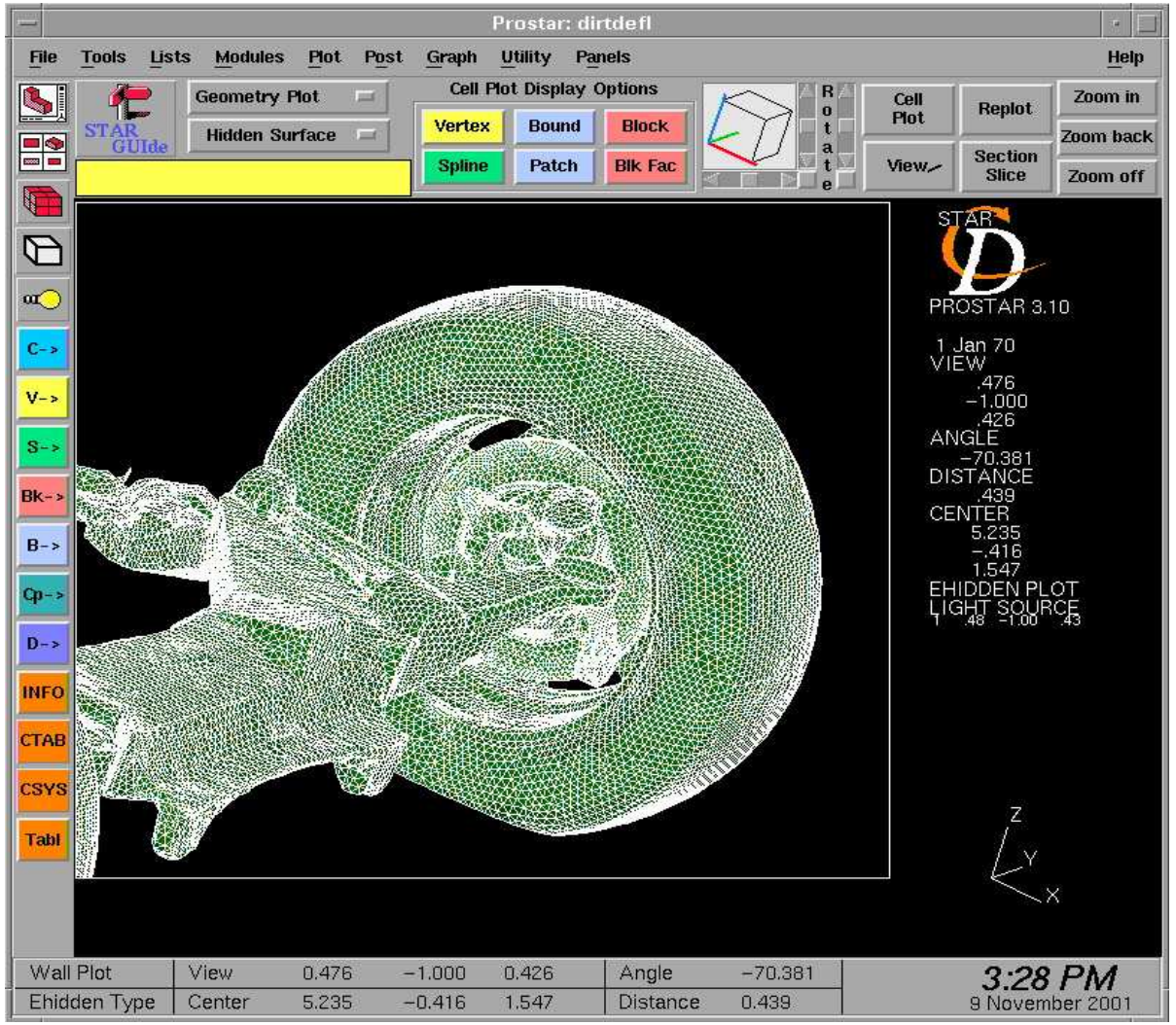




Hands on CFD process

Set-up case & solver

- VPM/CATIA
- ANSA
- Icem-CFD/ TGrid
- Star -CD
- Ensight



Hands on CFD process

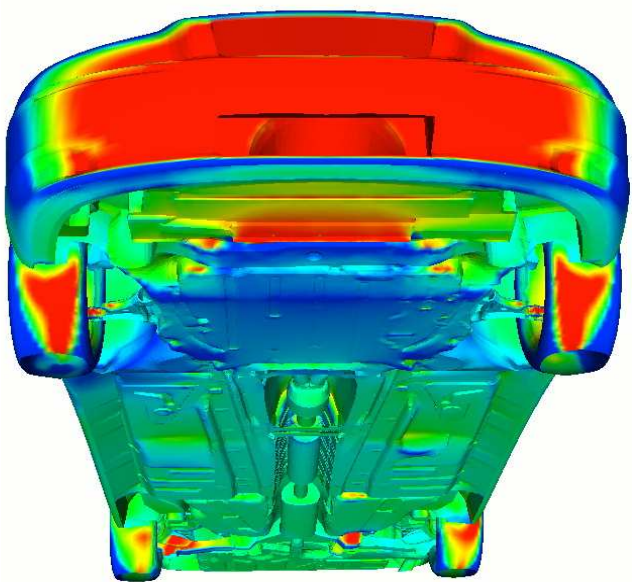
VPM/CATIA

ANSA

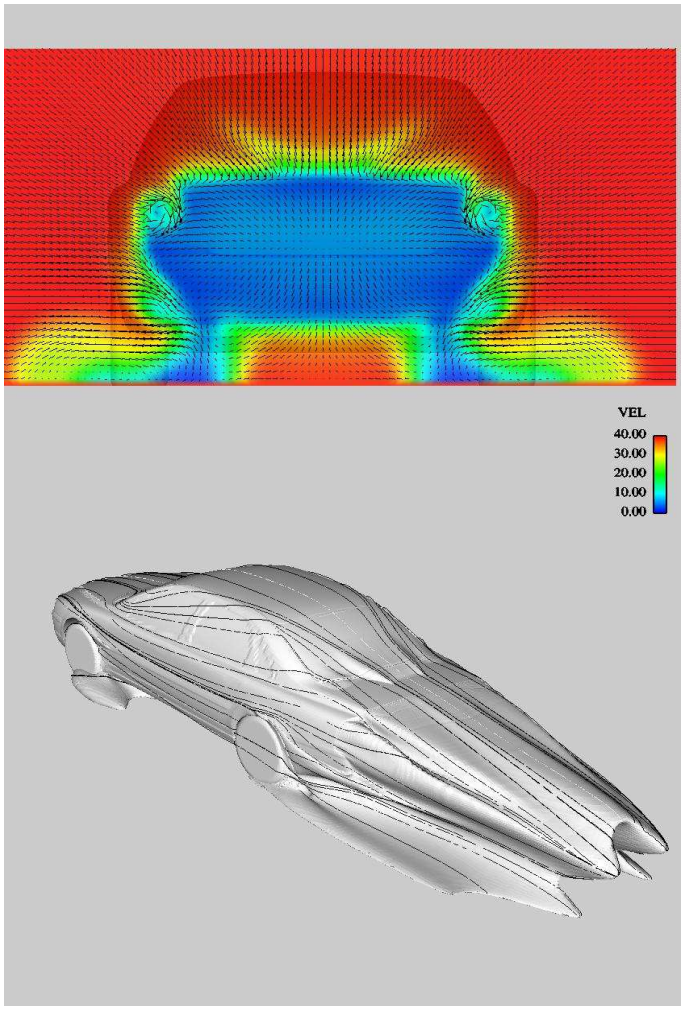
Icem-CFD/ TGrid

Star -CD

Ensight



Post processing



CFD - Hardware

Workstations	Servers
15 HP FX6-10 Graphics, 3 –8 GB 3 SGI Octane, 4 GB	2 IBM Linux cluster: 3x12 CPU: Intel 3.06GHz Xeon 2x8 CPU: Intel 2.2GHz Pentium 4

Project work

- Requirements specification
- Tests / Computations
- Analyses
- Recommendations & design guidelines
- Information and implementation

Product development phases

Concept study

- Generic shape studies
- Evaluate styling proposals
- Define underfloor concepts

Prestudy

- Develop frozen design
- Develop underfloor solutions

Project

- Detail optimization
- Verification

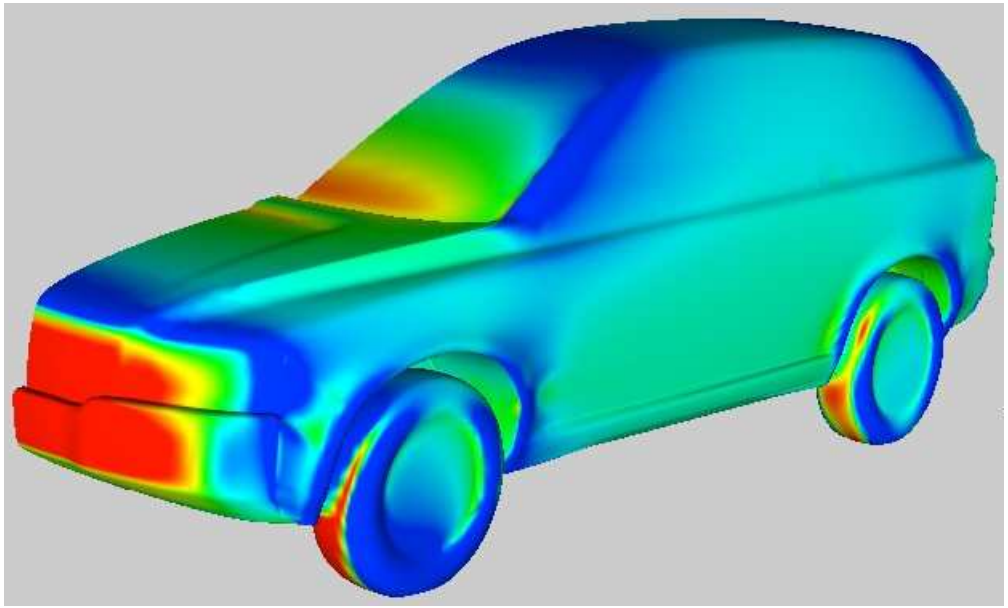
Exemples:

- Flat underbody simulations
  - Detailed and quick analysis of the flow field
  - Recommendations on exterior body shape
  - Used at very early stages of the project
  - Used for Cd/dCd comparisons among models
  - Lead-time: 1 to 2 weeks

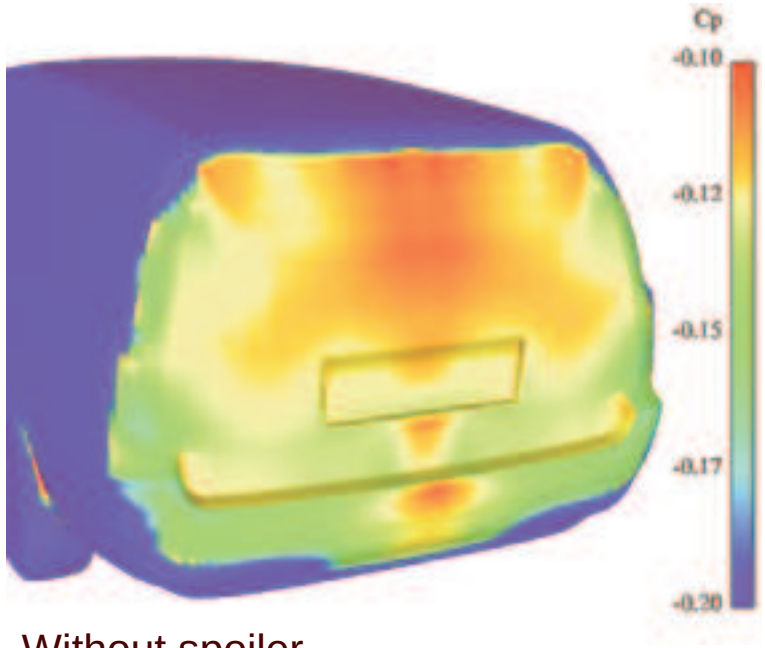
Surface restricted streamlines

Visualization of the wake

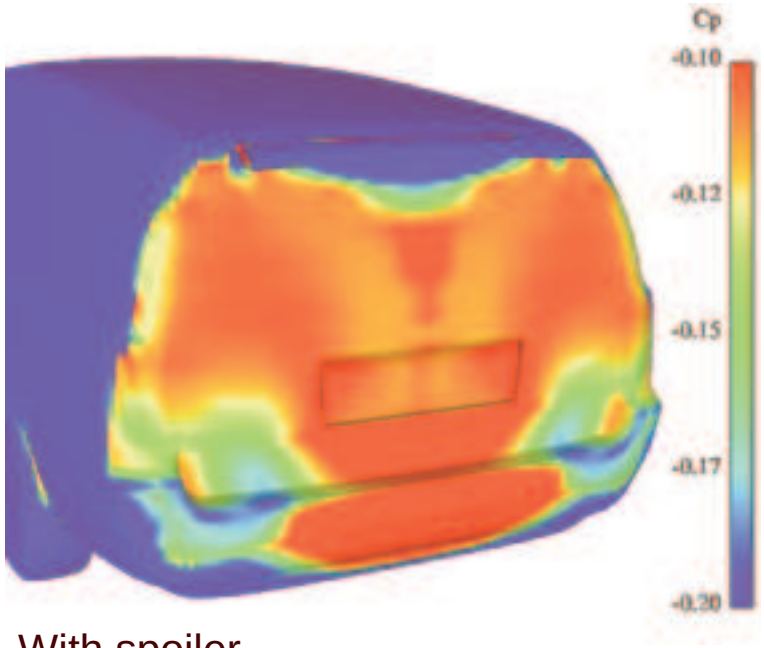
Pressure distribution on the car



Effect of tailgate spoiler on base pressure



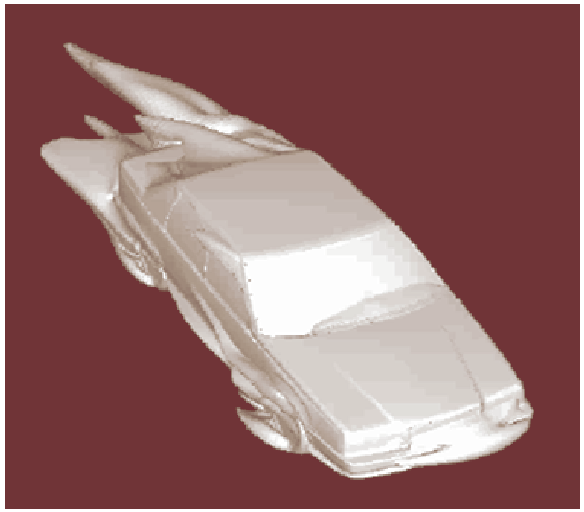
Without spoiler



With spoiler

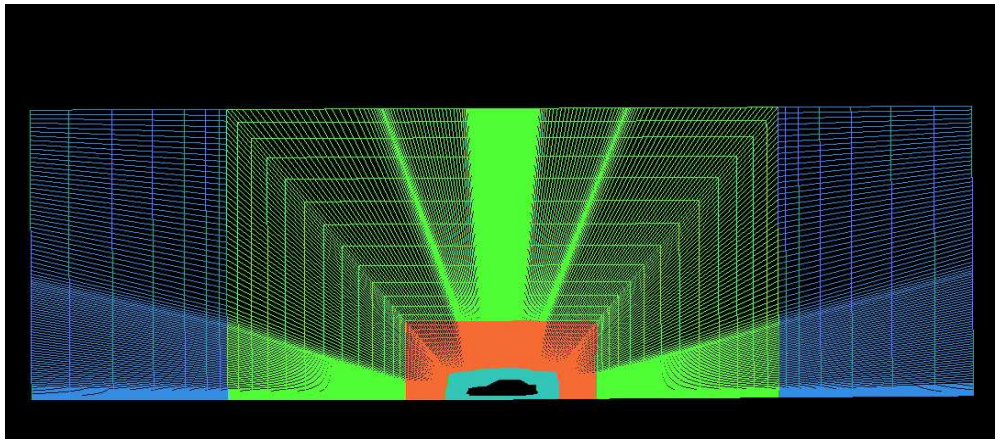
Side wind simulations

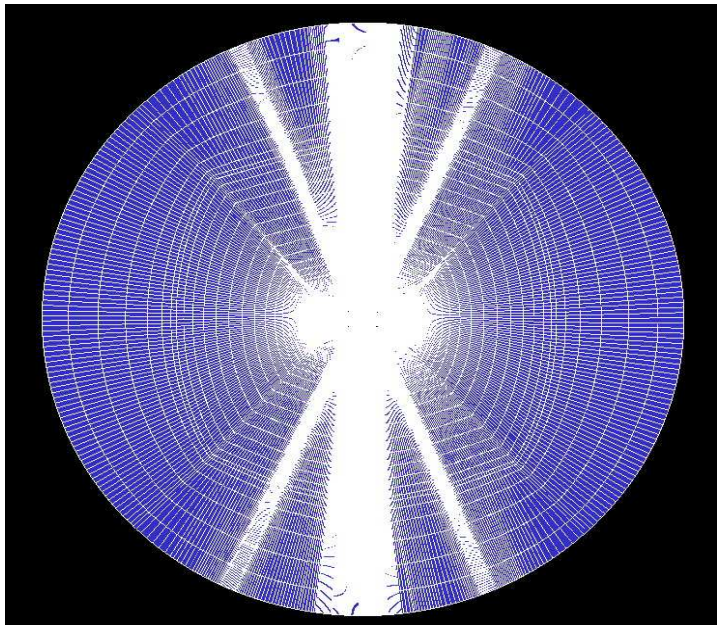
- Detailed and quick analysis of the flow field
- Recommendations on exterior body shape
- Used for analysing effects of side forces
- Effect on handling
- Lead-time: 1 to 2 weeks



Representation of the wake with
yaw = 10 degrees

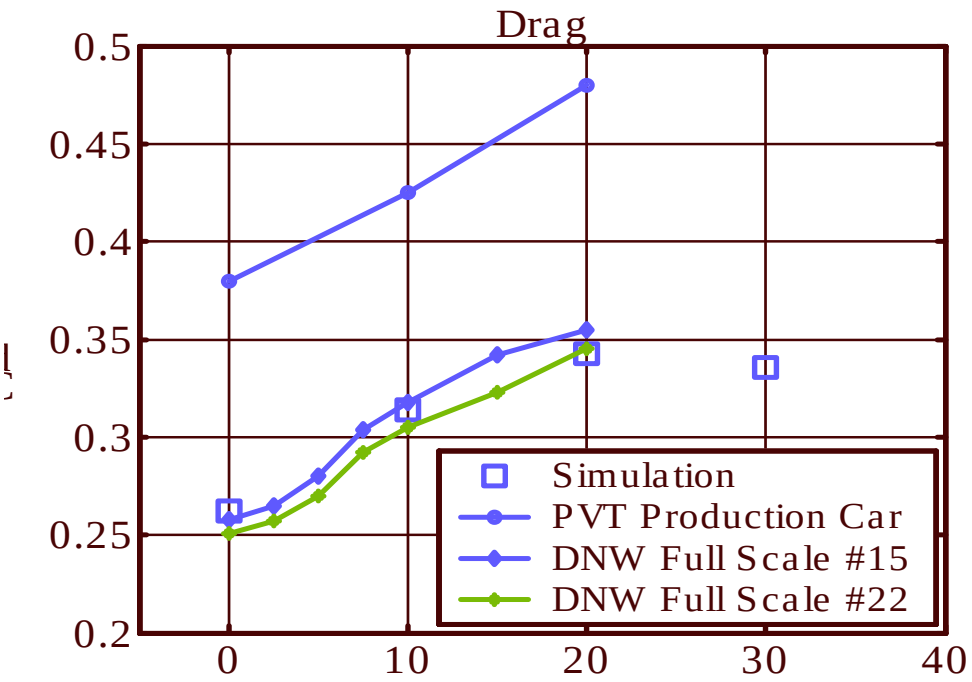
Representation of the wake with
yaw = 30 degrees





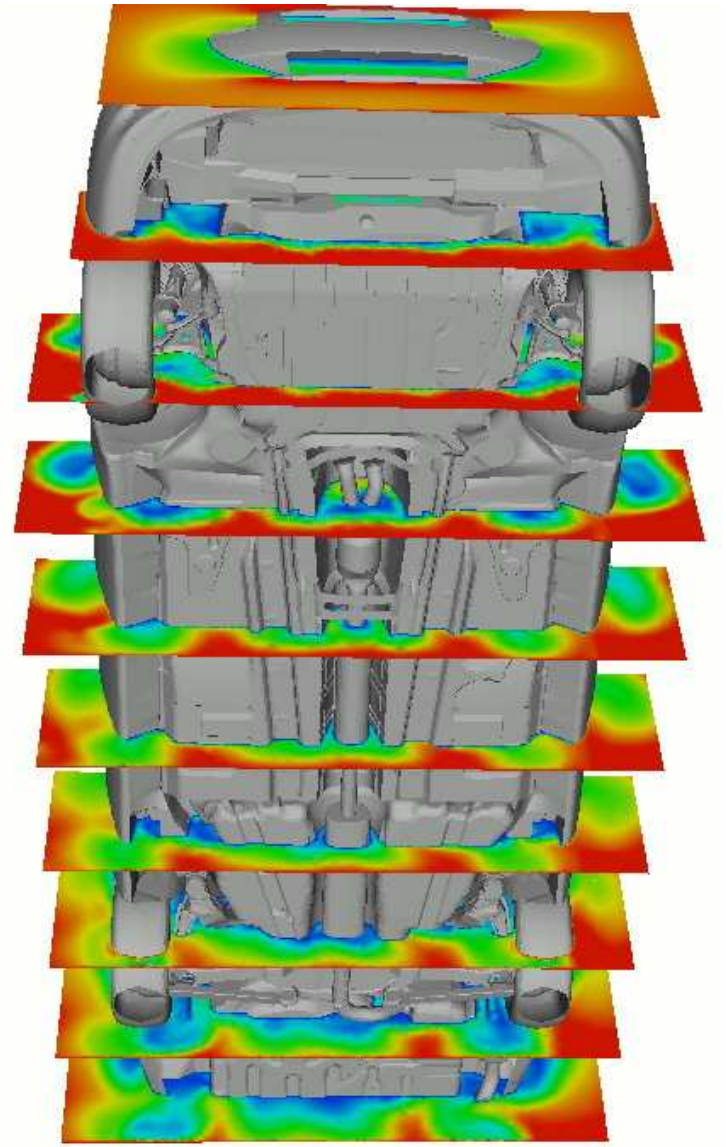
- Cylindrical windtunnel
- One mesh for different angles
- BC control the wind angle

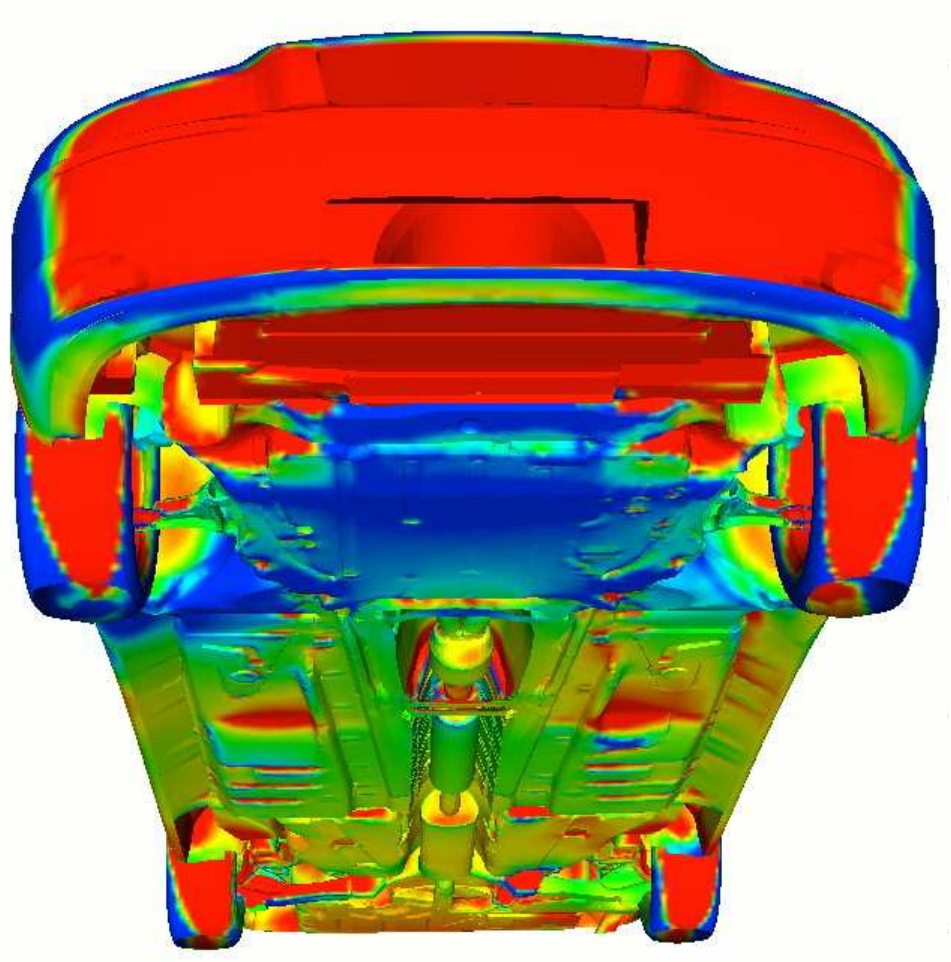
- Good results on squarish shapes.



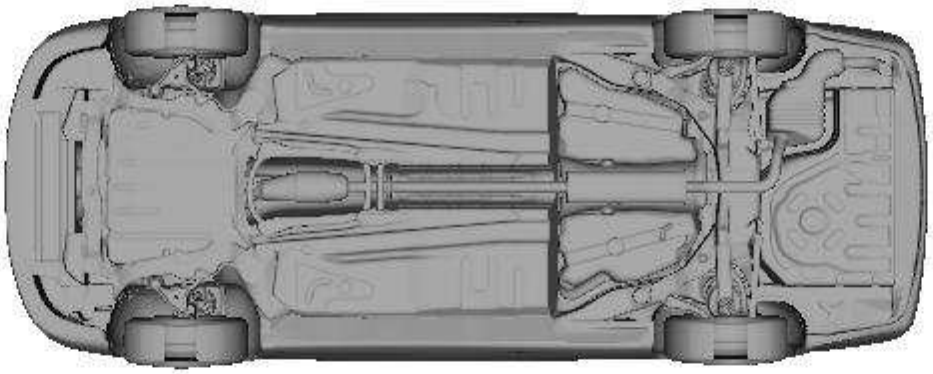
Detailed underbody simulations

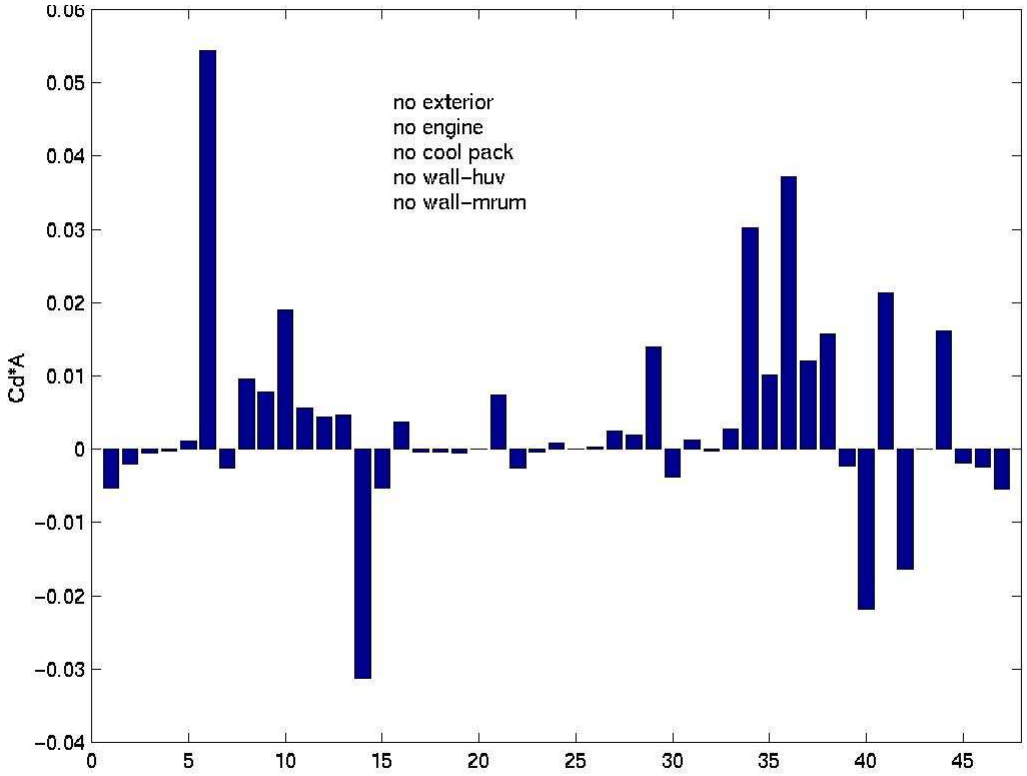
- Detailed analysis of the flow field
- Recommendations on underbody parts (deflectors,pannels)
- Used at any stage of the project
- Used for Cd / dCd comparisons among configurations / models
- Large models, hybrid meshes of 7 - 10 million cells
- Lead-time: 5 to 7 weeks for a completely new model
  3 days for configurations





Velocity planes and pressure distribution





Contribution of the individual parts of the underbody to Cd*A. Easy to identify problematic areas or zones of improvement due to aditional parts (ex. deflectors, rear pannel)

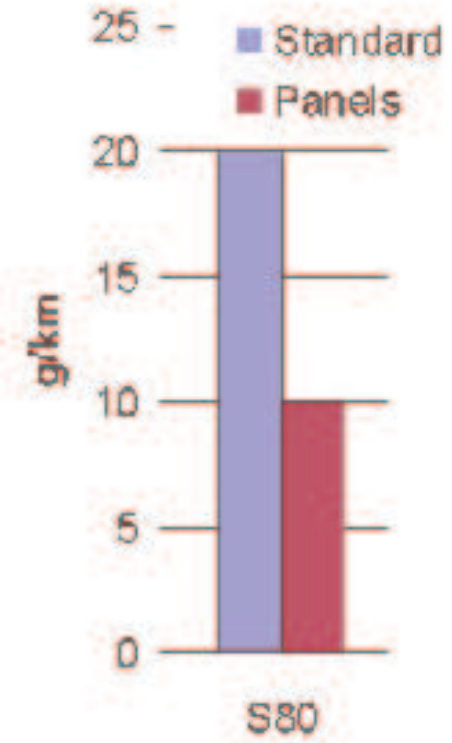
Underbody contamination

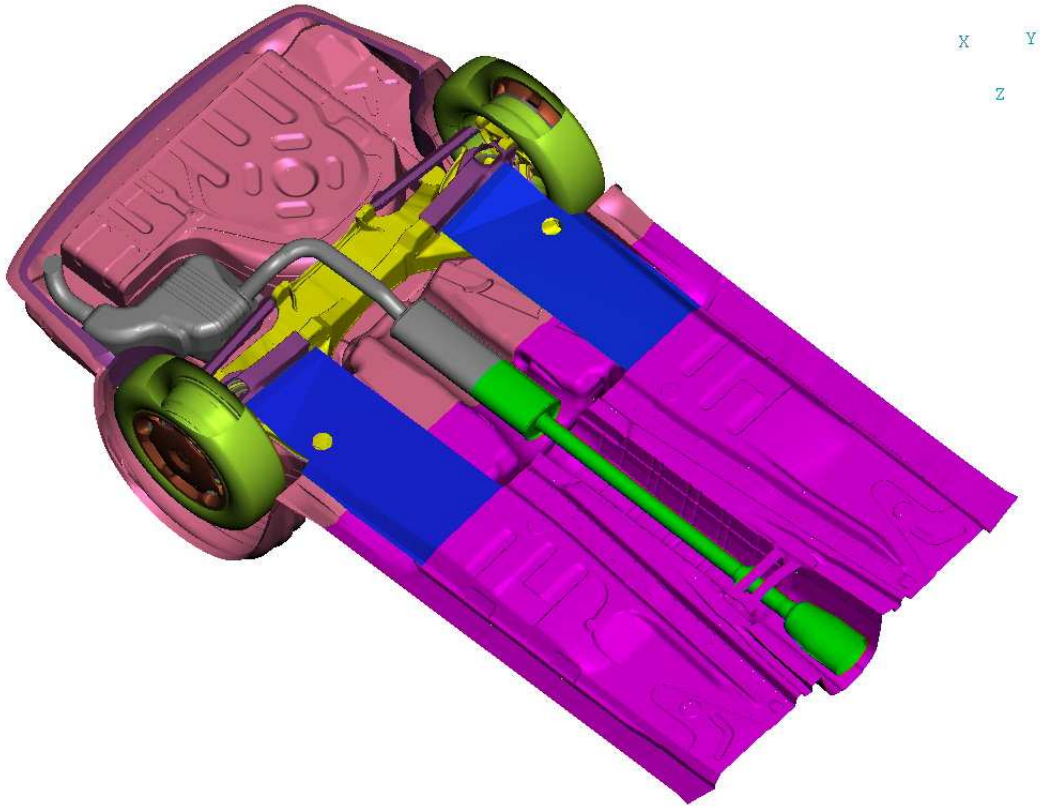
- Water mist contaminated with dirt particles is entering the rear rims causing unbalance

- The water mist is generated from the front wheels

- The biggest factor to affect the dirt deposition in the rims is the underbody air flow.

The effect of underbody deflectors and body plates to reduce dirt depostion in rear rims.



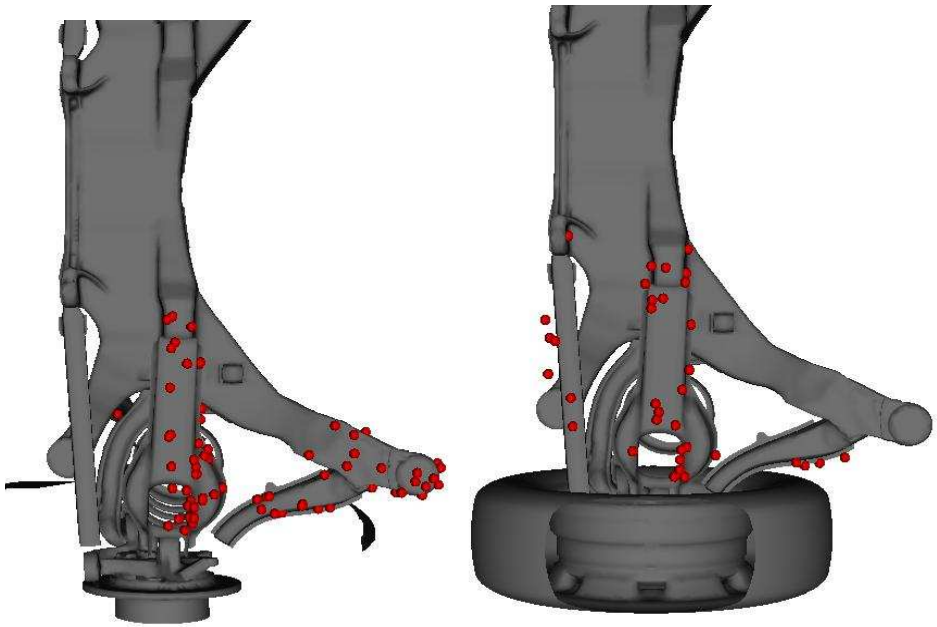


Dirt deposition in rear rim

hits on rear-susp. parts and wheels

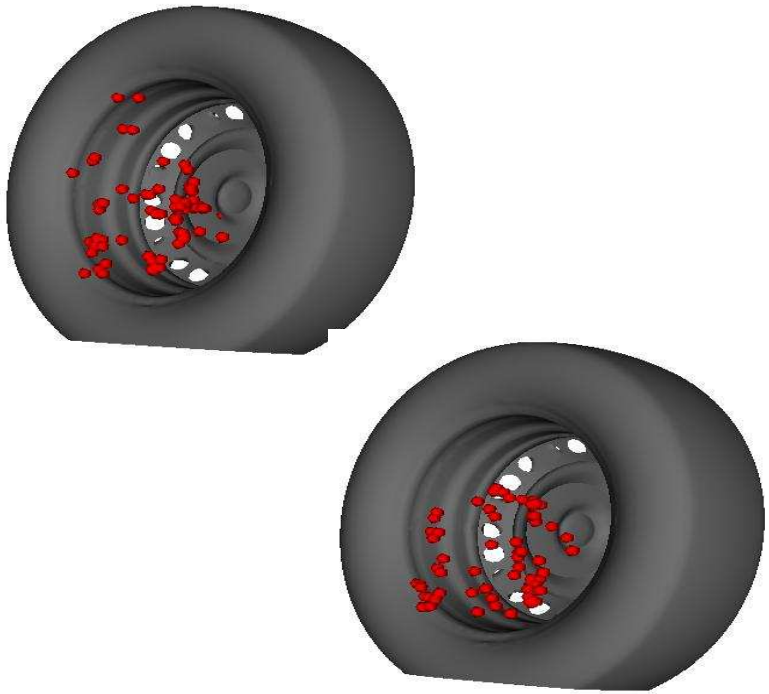
No deflector 79 of 1045, 7.5 %

Deflector 38 of 1045, 3.6 %



No deflector, 6 % of released nr

Deflector 4.3 % of released nr

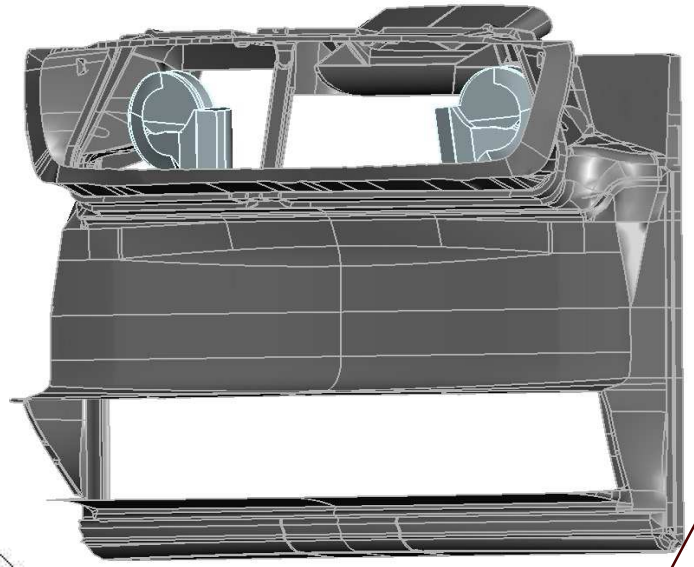


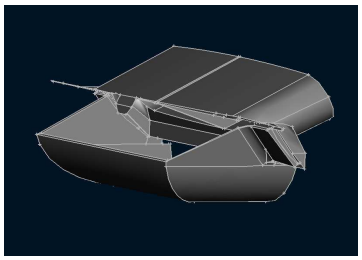
- SNOW DUST, ENGINE AIR FILTER INSTALLATION

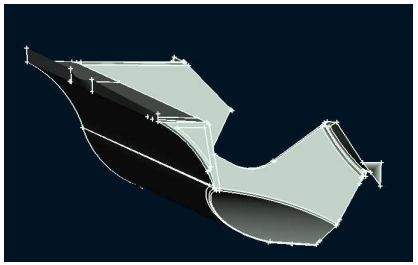
CFD: Method to approximately predict the intake of snow into the air filter

(understanding mechanisms)

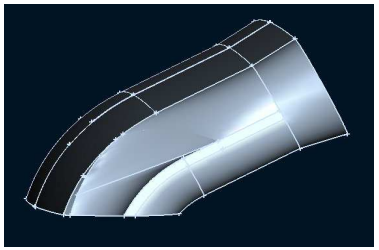
Geometry of the air intake

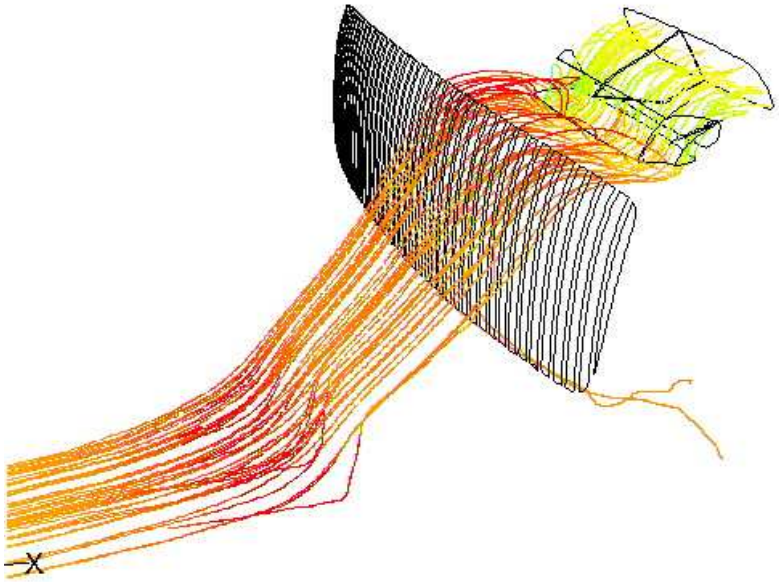


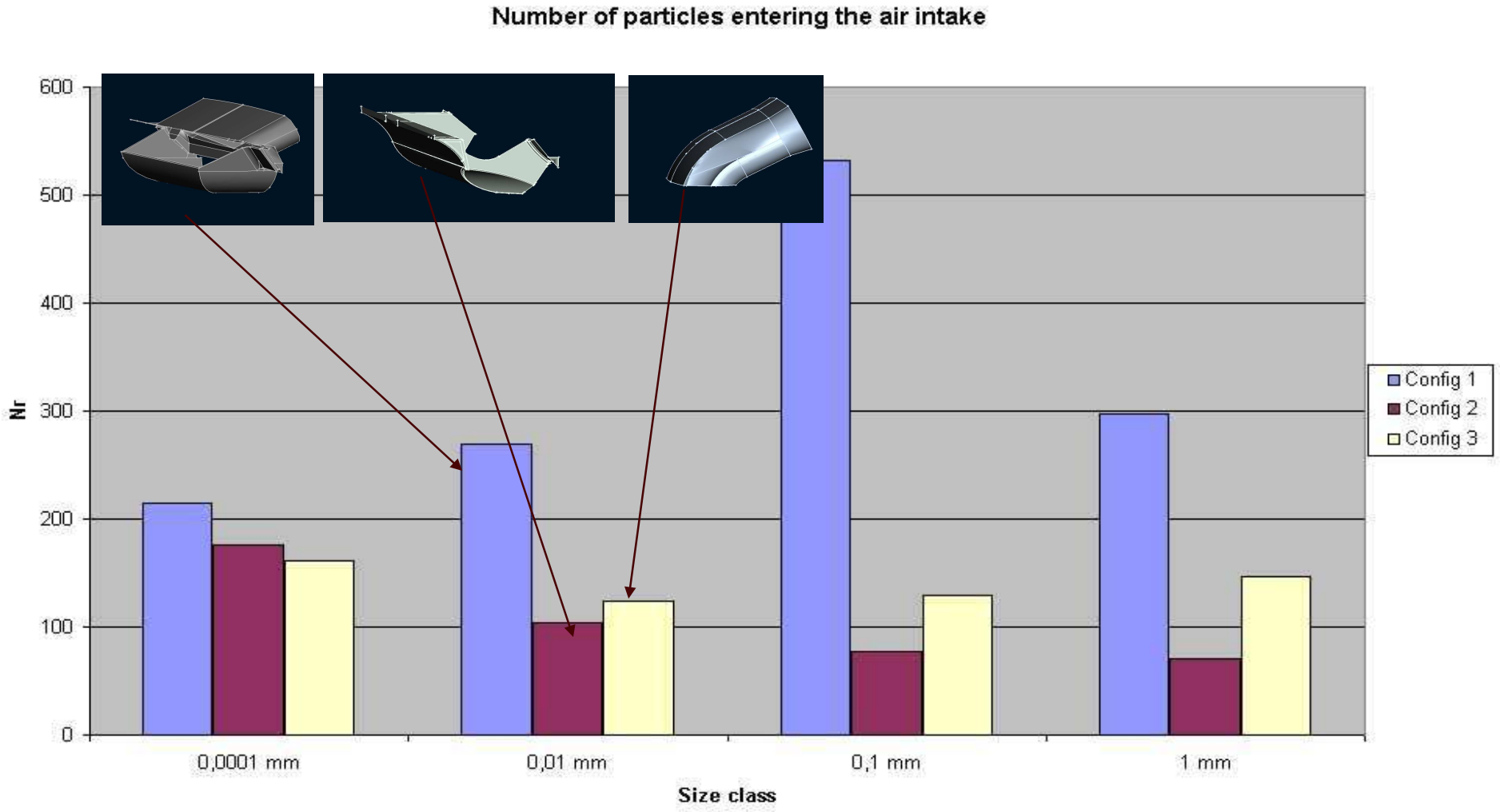




New ideas

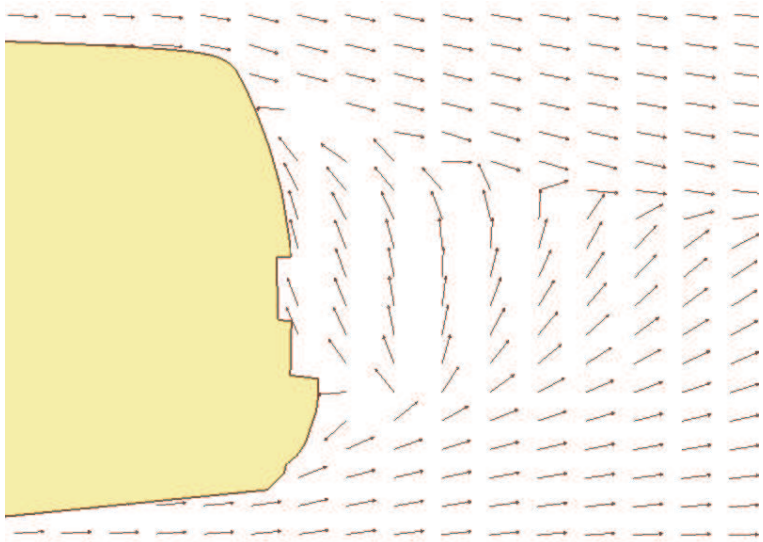






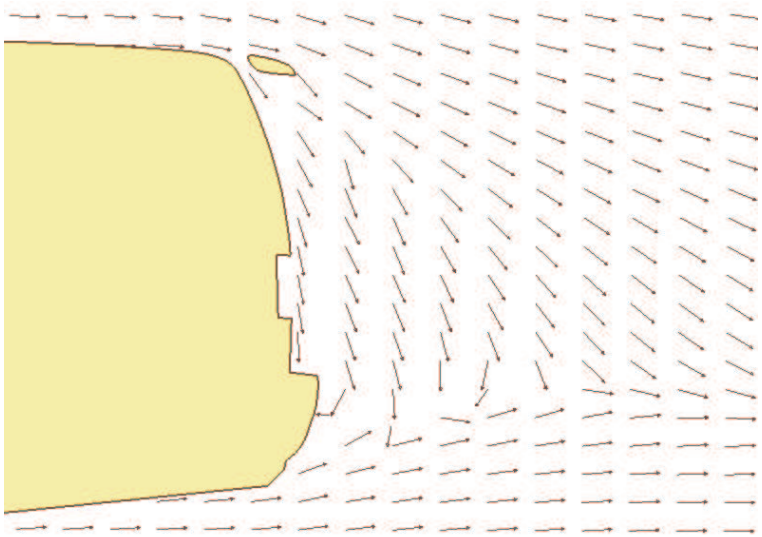
Total no of particles=40 000

Dirt deposition on the rear screen



Without rear tailgate spoiler

- Counterclockwise flow



With rear tailgate spoiler

- Clockwise flow

Without wing

With wing

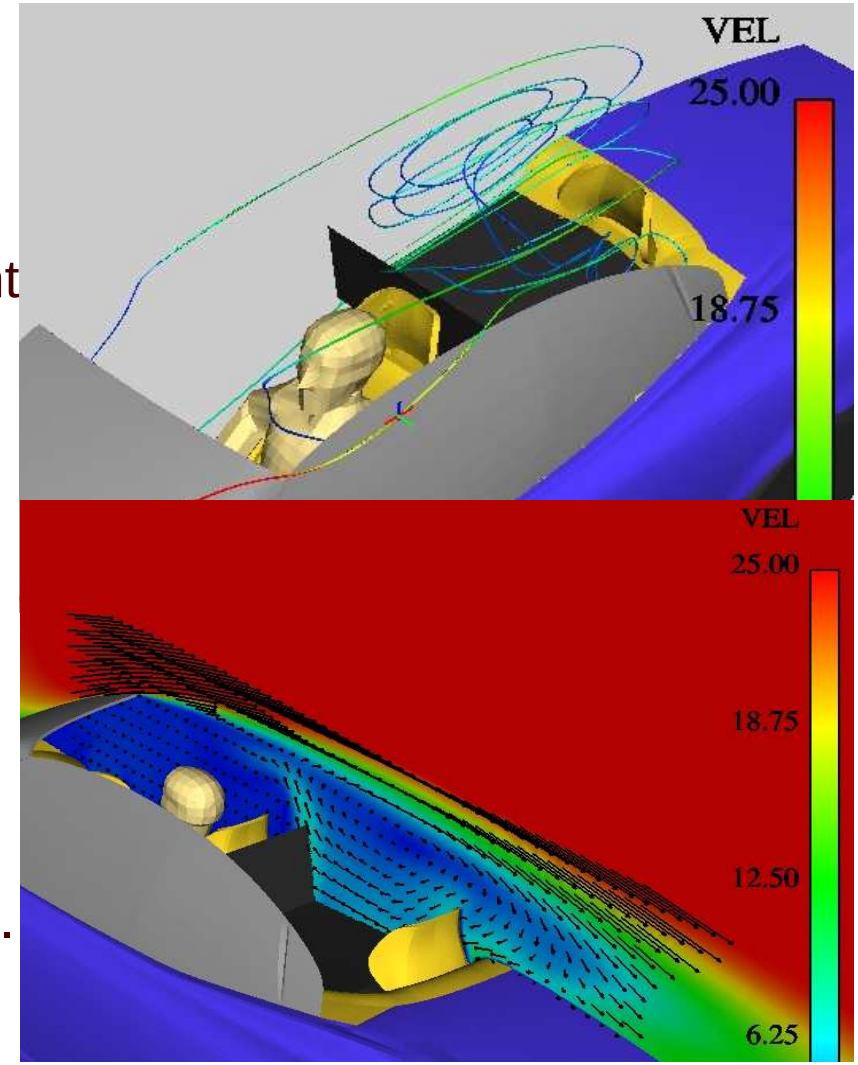
Smoke visualisation

Comfort in convertibles - C70

- Driving a convertible roof-down at high-way speeds is by no means comfortable.
- The recirculating air entering the compartment reaches ~15 m/s when driving 90 km/h.

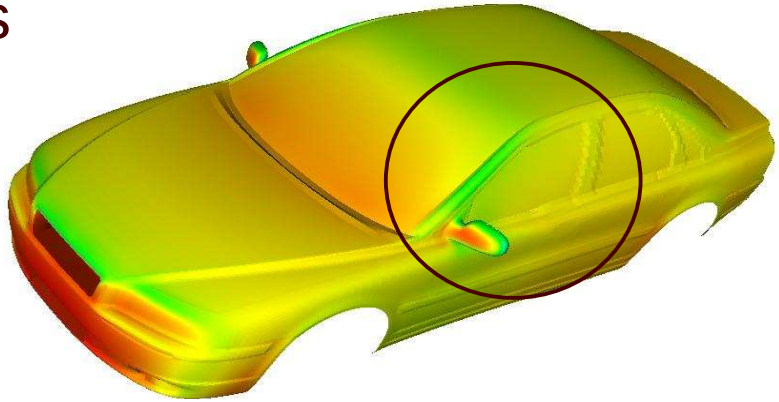
- Introducing a windblocker keeps the recirculation bubble above the rear seat.
- Flow speed is kept below 2 m/s in the front seat when driving 90 km/h.
- The windblocker is modelled as a permeable surface with a prescribed pressure drop.

- A windblocker is sold as an accessory to C70.

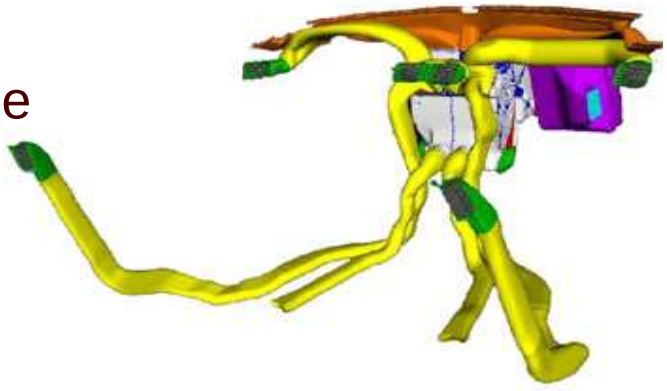


Ph.D. project & RD project on Aeroacoustics

- Increase knowledge about aeroacoustics
- Develop engineering tool for analysis



- Initial focus - rearview mirror and A-pillar
- Later on - underbody and climate system noise



Want coupled analysis - e.g. drag, dirt, noise

Aero Concept Car

Cd = 0,20

ACC Final Design 1999

Important parameters - drag of basic shape

- Stationwagon
  - Sweeping of roof
  - Boat-tailing
- Sportswagon
  - Angle of rear tailgate
  - Boat-tailing
- Sedan
  - Angle of rear window
  - Length, height and angle of boot-lid
- Hatchback
  - Angle of tailgate
  - Radius where roof meets tailgate
  - C-post
- Front end (common for all variants above)
  - Orientation and size of stagnation region surface.
  - Radius from front to hood
  - Incline of hood
  - Rake of windscreen

Aerodynamics, CFD and Volvo

- Heading for different areas of interest
  - Aeroacoustics
  - Dirt-deposition (water, sand, snow)
  - Handling