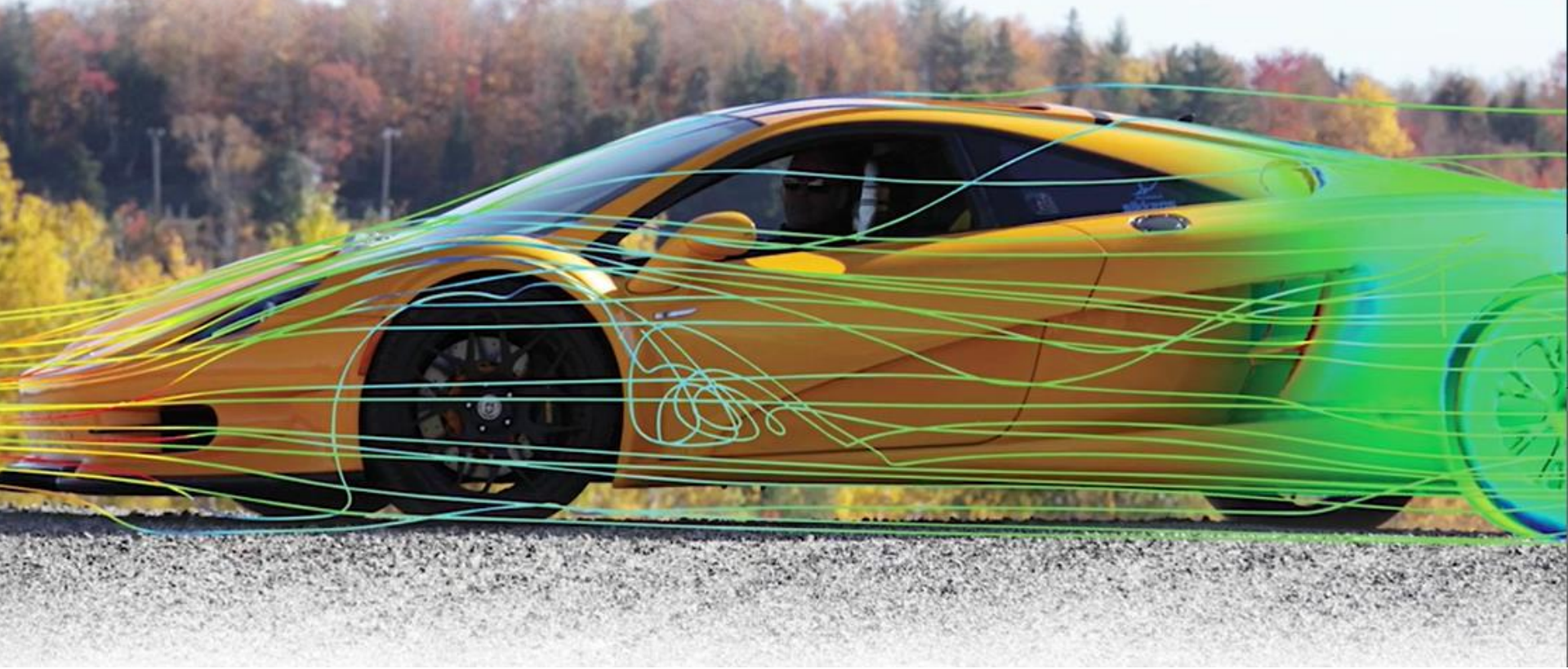
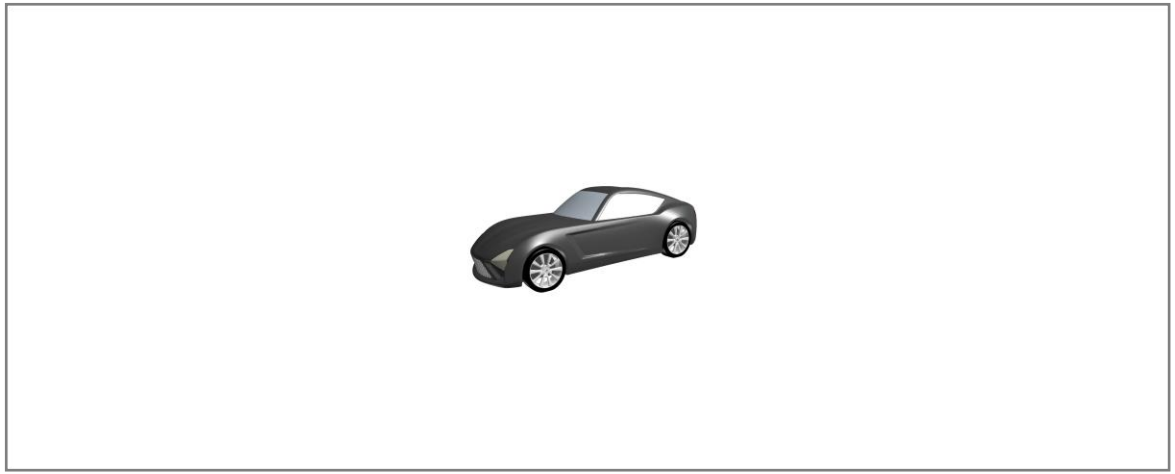


VIRTUAL WIND TUNNEL FOR EXTERNAL AERODYNAMIC ANALYSIS

Kory Soukup - 2/20/2021

Agenda



- Overview external aerodynamics
- VWT Workflow and Demo
- Tips, Tricks, and Post Processing Results

About Me

- University of Minnesota
  - Aerospace Engineering, 2019

- “Rayces”
  - **FSGP / ASC** 2016, 2018,
  - **WSC** 2015, 2017

Joined Altair Engineering in 2019

- Structural FEA
- Composite Design & Optimization

ALTAIR

Importance of External Aerodynamics *(automotive)*

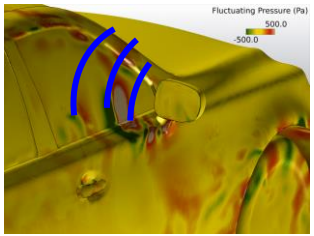
Visibility
- Dirt (soiling)
- Splash/spray
- Wiper lift off

Comfort
- Ventilation
- Heating
- Air conditioning
- Wind noise

Stability
- Directional
- Cross wind sensitivity

Cooling
- Engine
- Transmission
- Brakes
- Condenser

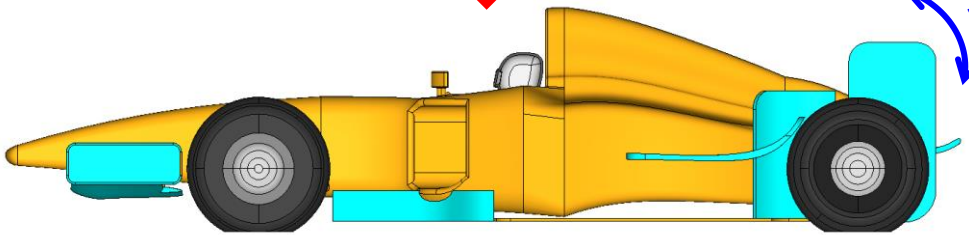
Performance
- Fuel economy
- Emission
- Max. speed
- Acceleration



Aero acoustics (CAA)

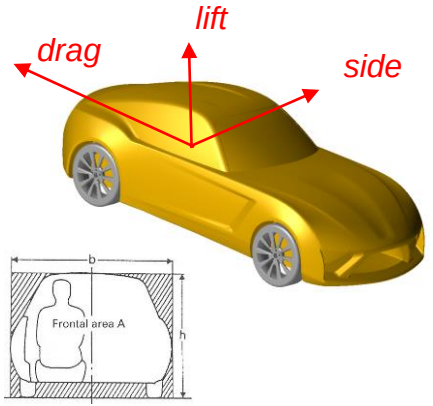
downforce

Spoiler oscillation, FSI



dragforce

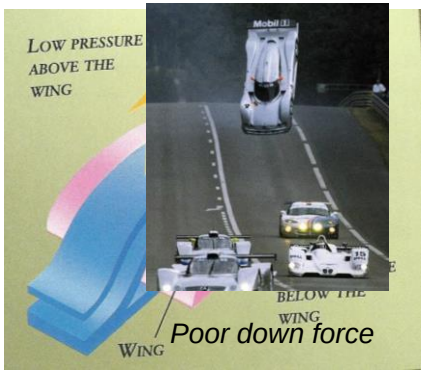
Aerodynamic forces



- Drag force
  - Accounts for 75% of the car's resistance (100km/h)
  - Computation: $F_D = \frac{1}{2}\rho v^2 C_D A$

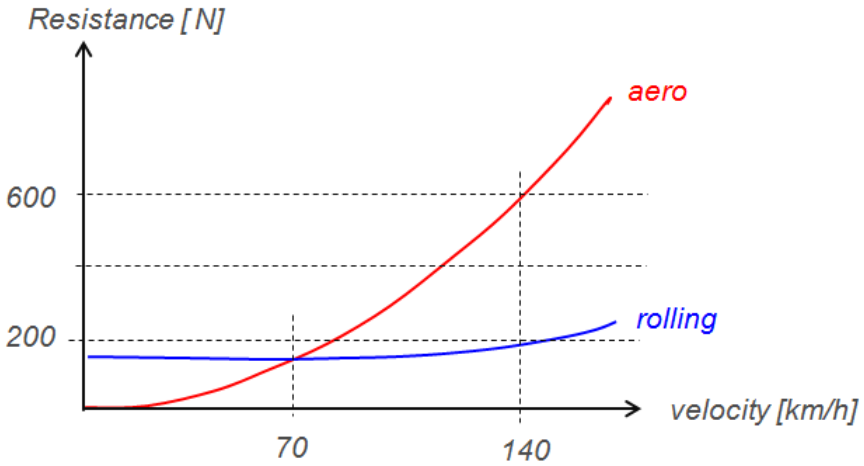
    Car shape *Frontal area*
  - Drag reduction by minimizing C_D → shape optimization

- Lift force
  - Impacts steering behavior
  - For race cars, down force important *(more grip)*



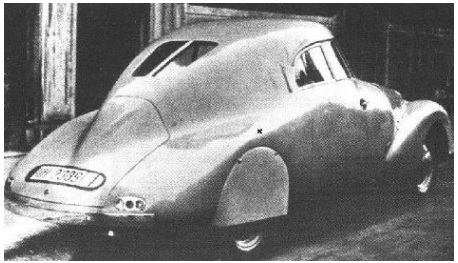
Drag force

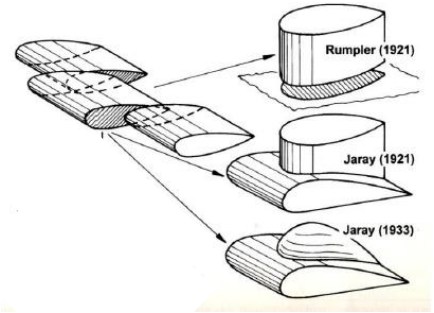
- Drag resistance vs. rolling resistance
  - From ~ 70km/h, the aero resistance is dominant



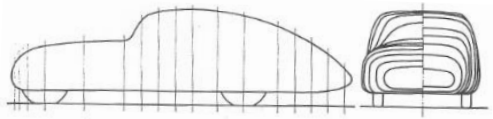
Early shape optimization

- Jaray *(1933)*





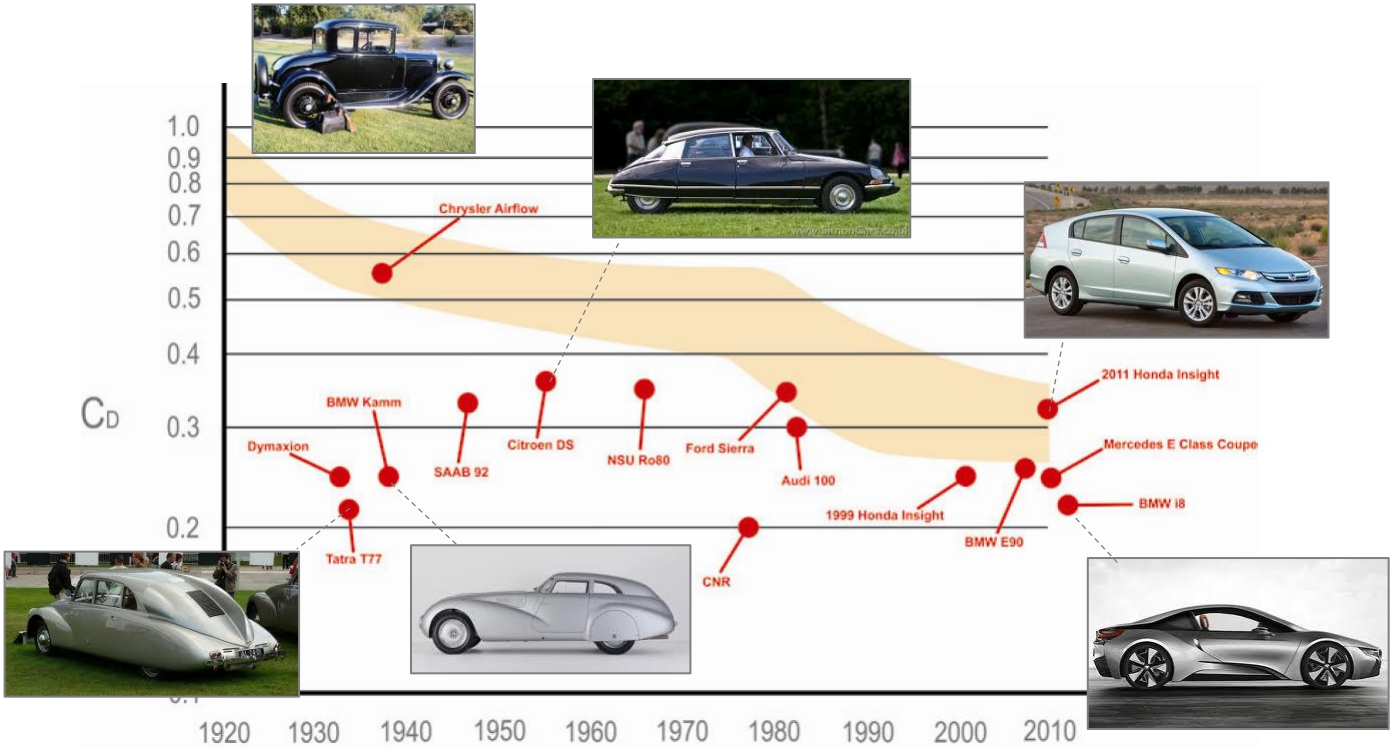
- Lange/Prandtl *(1937)*
  - Combine two airfoils, common trailing edge



C_D=0.16

C_D=0.33
(Porsche 911, 1995)

History of aerodynamic drag (Cd)



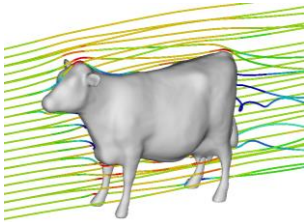
Non-automotive drag values

- Boeing 747: $C_D = 0.031$

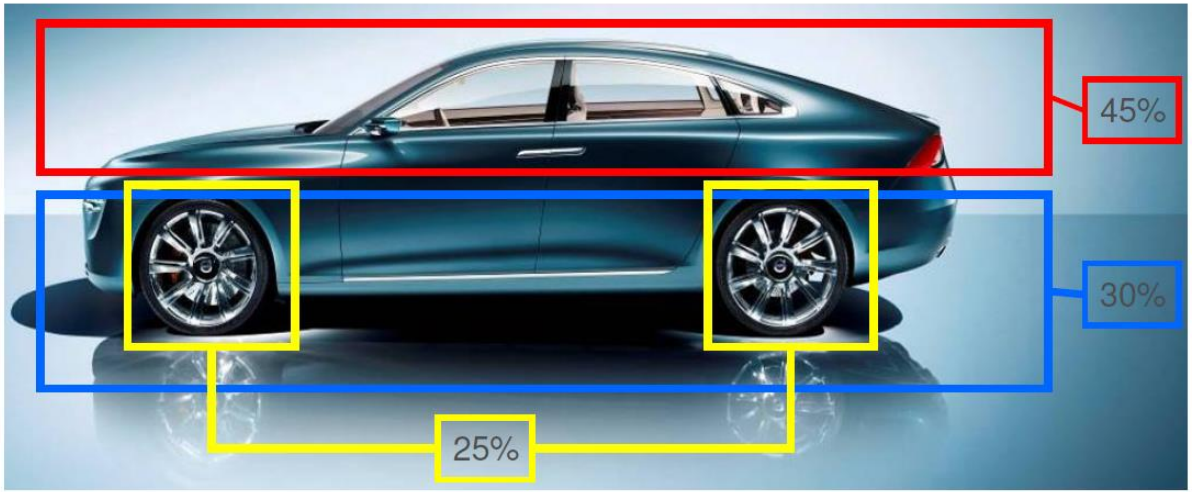
- Eiffel Tower $C_D = 1.8 – 2.0$

- Man (upright position) $C_D = 1.0 – 1.3$

- Cow Standing Upright $C_D = 0.2$

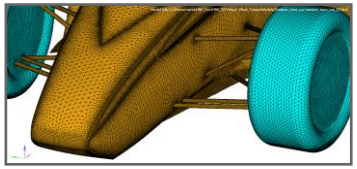


Source of drag on a modern passenger car

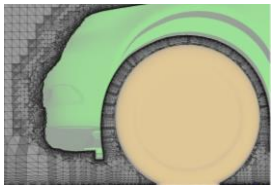


Determining the drag force *(CFD)*

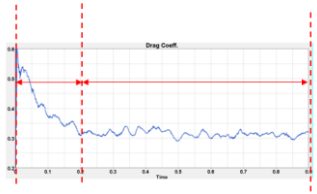
Altair



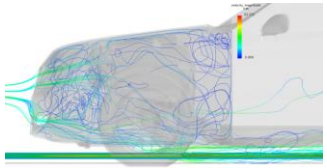
- Preparation
  - up to 4 weeks *(clean-up / surface meshing)*
  - Shell mesh ~ 4-7Mio trias

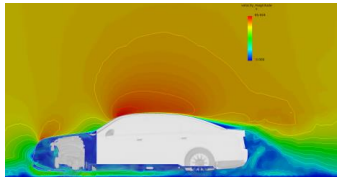


- Model
  - Volume mesh ~ 70-150M *(mixed elems, 1-6h meshing time)*
  - 1st layer height ~ 1e-4m *(y+ ~ 10)*
  - 5-10 boundary layers



- CFD run
  - 100-400 cores *(formula 1 teams use up to 3000 cores)*
  - Transient: 48h or more *(physical time 1-6 sec)*
  - Steady: over night ~ 10h

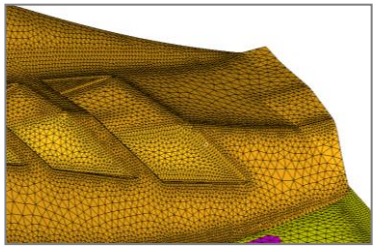


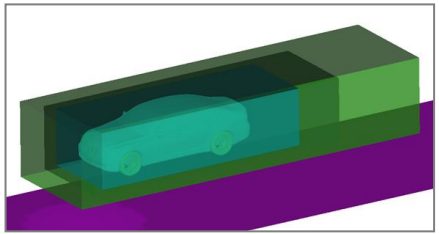


- Post-processing
  - Data size up 100GB and more
  - Batch process

Modeling aspects

- Wind tunnel dimensions
  - ~3 car length in the front,~7 car length to the rear
  - Blockage of ~2% *(ratio between WT inflow area and frontal area of car*
- Surface mesh
  - Triangle elements,
  - Variable element size, in general 2-10mm
- Volume mesh
  - Refinement zone(s) around the car
  - ½ car length to front, side and top
  - At least 1 car length downstream
- Boundary layer
  - y+ ~ 10 *(e.g. 1st layer height ~ 1e-4…1e-5)*
  - BL on wind tunnel floor, upper body, windows, wheels, rims, parts of underbody

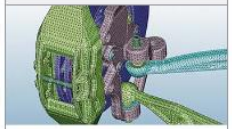




Showing results for CFD

Sort by Most Popular

SimLab
Latest Version: 2021

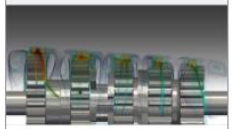


Process-oriented multidisciplinary simulation environment to accurately analyze the performance of complex assemblies.

Compose Personal Edit...
Latest Version: 2021

General purpose numerical computing environment that allows customers to easily develop and perform custom mathematical...

nanoFluidX
Latest Version: 2021



nanoFluidX is a SPH-based fluid dynamics simulation tool which predicts flow in complex geometries exposed to complex motion.

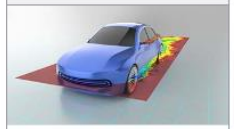
AcuSolve
Latest Version: 2021

Leading general-purpose Computational Fluid Dynamics (CFD) solver that is capable of solving the most demanding...

Compose
Latest Version: 2021

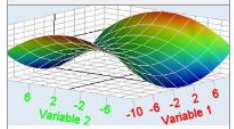
General purpose numerical computing environment that allows customers to easily develop and perform custom mathematical...

ultraFluidX
Latest Version: 2021



ultraFluidX is a simulation tool for ultra-fast prediction of the aerodynamic properties of passenger and heavy-duty vehicle...

HyperStudy
Latest Version: 2021

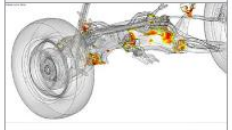


HyperStudy is a multi-disciplinary design study software that enables exploration and optimization of design performance and...

Virtual Wind Tunnel
Latest Version: 2021

A solution designed to provide better wind tunnel simulation and user experience. Altair's HyperWorks VWT is able to more...

HyperView
Latest Version: 2021



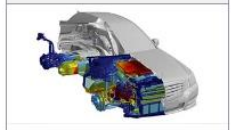
Post-processing and visualization environment for finite element analysis, multi-body system simulation, CFD results and digital...

Alsim PAINT SHOP
Latest Version: 1.10.2

Alsim PAINT SHOP allows full control over paint shop processes in the automotive industry. It includes simulation modules for air bubble...

Partner

FieldView Express
Latest Version: 16.1



FieldView Express is a CFD post-processor that engineers choose when they must deliver accurate results in ever-faster design cycles.

Partner

AVL CRUISE™ M
Latest Version: 2018.1

AVL CRUISE™ M is a multi-disciplinary system simulation solution that supports model-based development using high quality...

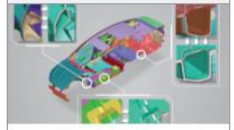
Partner

Flow Simulator
Latest Version: 20.1

Flow Simulator is an integrated flow, heat transfer, and combustion design software that enables mixed fidelity simulations to optimize...

Partner

Alsim MERGE
Latest Version: 2.1.4



Alsim MERGE is a is a data cleaning software that processes 3D input data of various formats. With Alsim MERGE, the user only has to impo...

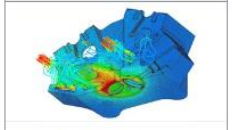
Partner

LOGEresearch
Latest Version: 1.08

LOGEresearch performs combusion and chemical kinetics simulations for all reactive systems.

Partner

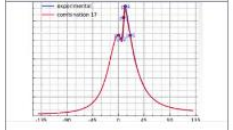
AVL FIRE™ M
Latest Version: 2018.1



AVL FIRE™ M is a multi-domain simulation software solving non-reacting, single phase fluid flows, heat transfer and solid...

Partner

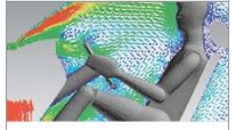
LOGEengine
Latest Version: 3



LOGEengine contains an intelligent tool for automatic simulation tuning.

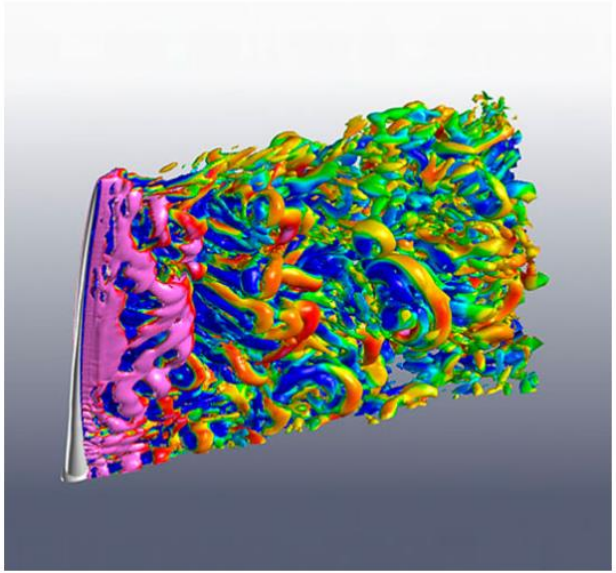
Partner

AcuNexus
Latest Version: 1.6.8

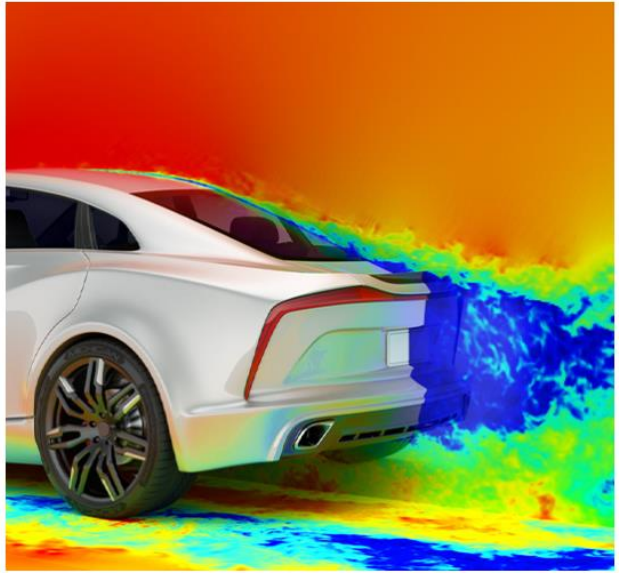


AcuNexus is a novel CFD pre-processor intended to facilitate efficient, automated simulation based design (SBD) processes...

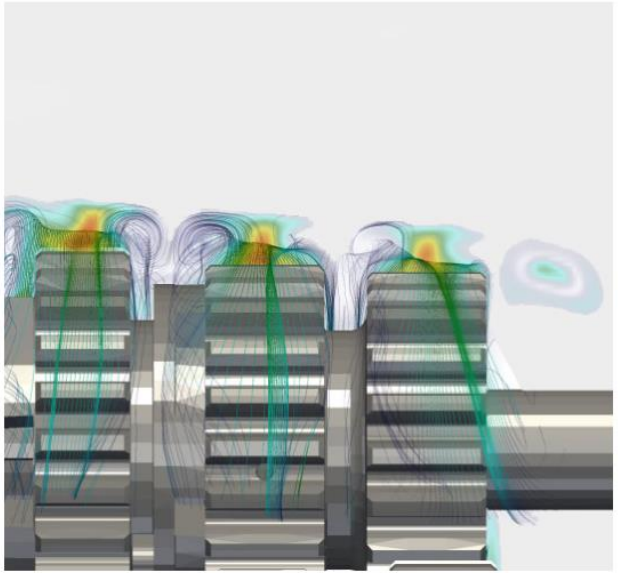
Partner



General Purpose CFD



External Aerodynamics

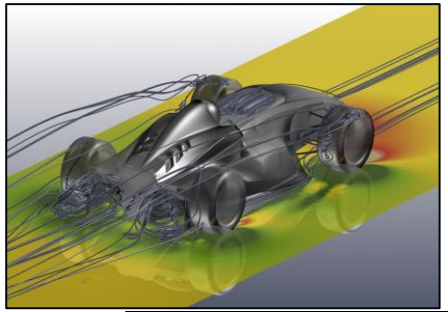


Particle-based Fluid Dynamics

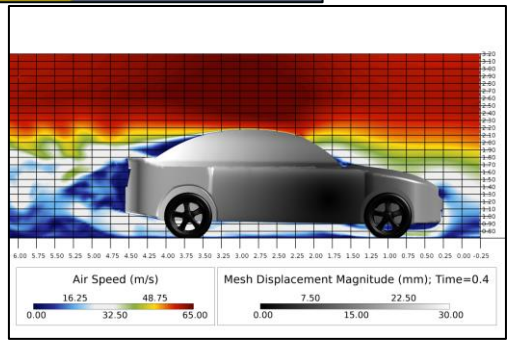
ALTAIR

AcuSolve - Overview

- *AcuSolve* Key Points
  - General purpose, 3-dimensional, unstructured flow solver
- **Based on finite element method**
  - Started at Stanford University in 80's and 90's
  - Rich history in academia
  - Further refined by Altair Engineering for industrial applications



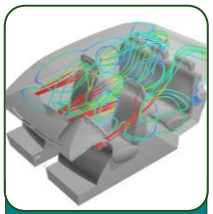
- Differentiation
  - Robustness
    - Most problems solved on first attempt, no parameter tuning/knob turning required!
    - Almost no Element quality requirements
  - Speed
    - Architected for massively parallel applications, with efficient time stepping
  - Accuracy
    - Highly accurate in space and time
    - 2nd order for **all** problems

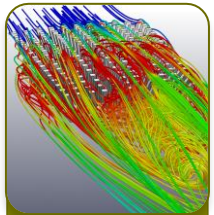


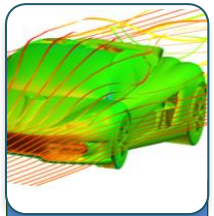
AcuSolve – Better Technology, Better Solution

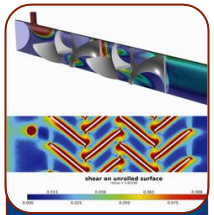
Altair


Fluid-Structure Interaction

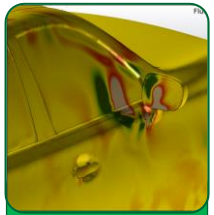

Thermal Management


Electronic Cooling


Aerodynamics



Non-Newtonian Flow Simulation


Computational Aero-acoustics

Multiphysics Analysis and Optimization

- Global footprint with diverse applications
- Integrated with HyperWorks

ultraFluidX by FluiDyna®

Altair

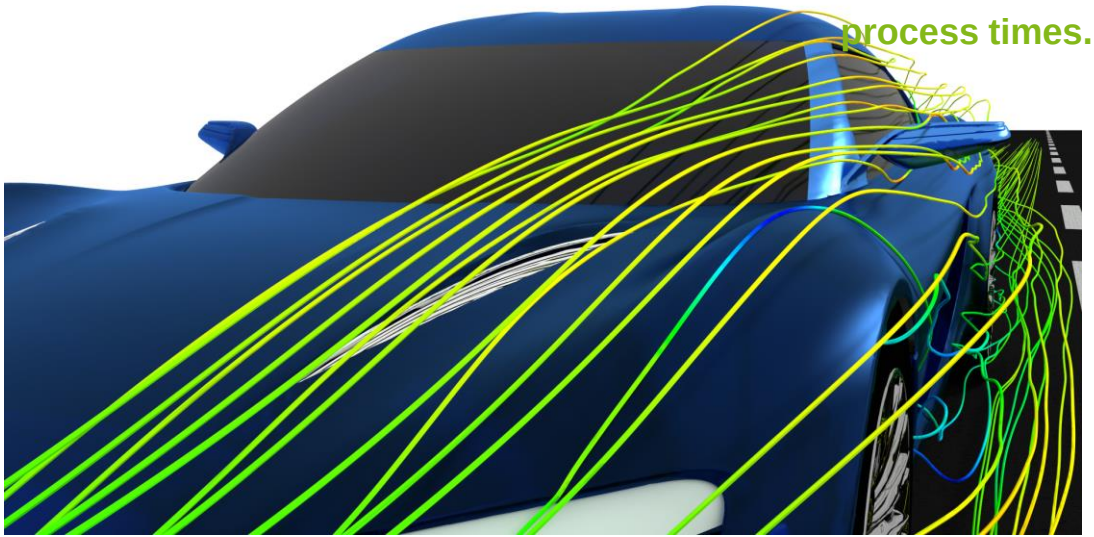
ultra-fast CFD for Ground Transportation Aerodynamics

Fast GPU-based LBM solver

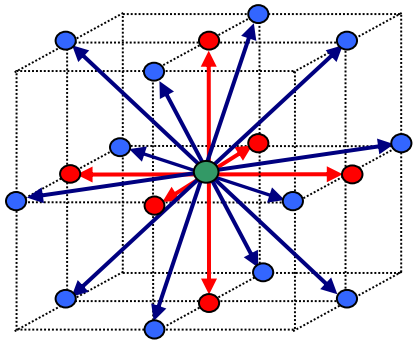
for transient external aerodynamics

with low surface mesh requirements

yielding short overall process times.

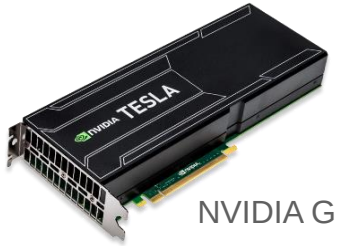


- Lattice Boltzmann Method
  - Based on kinetic gas theory (Boltzmann, Maxwell)
  - Discretization of space, time AND velocities
  - Statistical description of flow through particle velocity distribution functions
  - Inherently transient and weakly compressible



D3Q19

- Designed for GPGPUs
  - Computational algorithm well suited for extreme parallelization
  - GPGPUs deliver superior performance



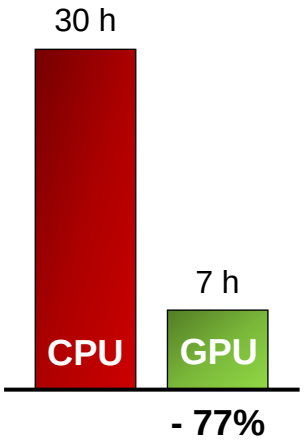
NVIDIA GPGPU

ultraFluidX

Customer Benefits

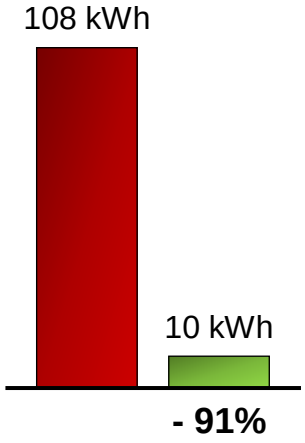
Altair

Time-to-solution



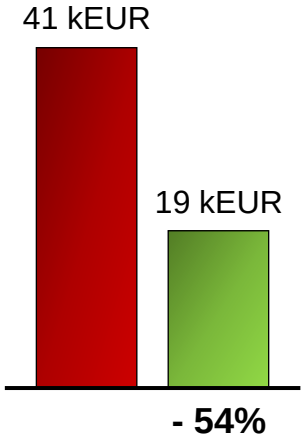
- 77%

Energy-to-solution



- 91%

Investment costs

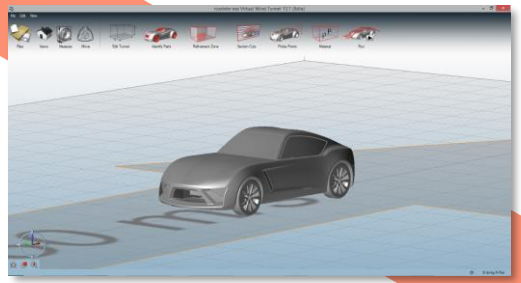


- 54%

- **Transient external aerodynamics case:**
  Passenger car, 70M voxels, 2sec physical time
- **ultraFluidX saves time, cost and energy against established commercial Lattice-Boltzmann solution**

Work Flow

Virtual Wind Tunnel



Pre-Processing

Surface Mesh Import

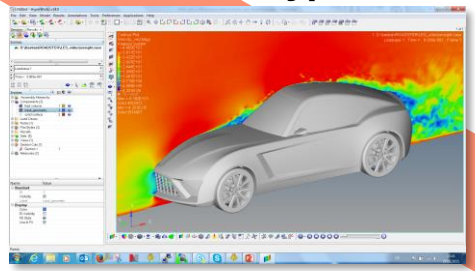
Definition of
- Domain
- Boundary Conditions
- Refinement Regions
- Run Parameters

HyperView

Post-Processing

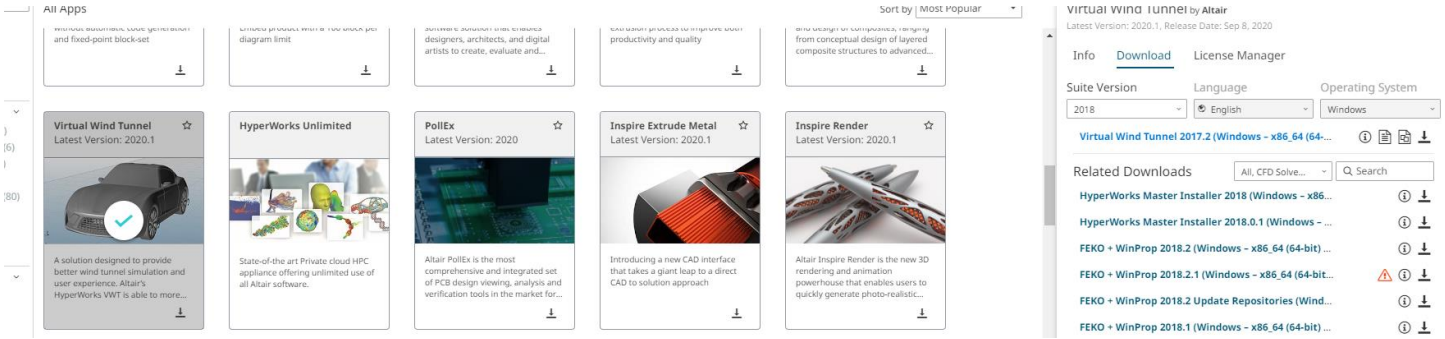
Visualization of
- Cutting Planes
- Isosurfaces
- Probes

Forces in **VWT**



Virtual Wind Tunnel 2017.2

- https://altairone.com/Marketplace
- Download Virtual Wind Tunnel 2017.2 for Acusolve.

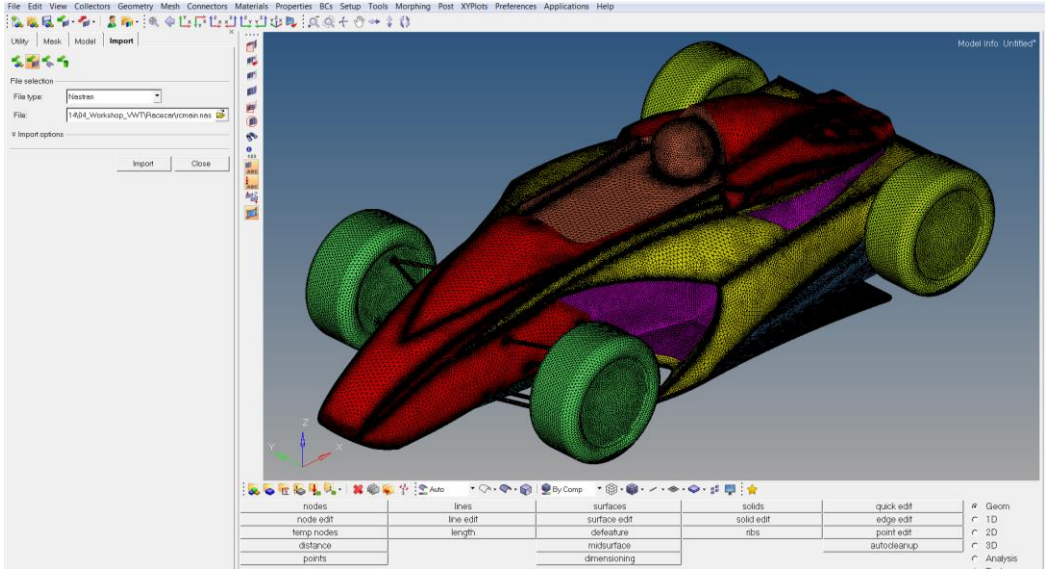


Virtual Wind Tunnel *(mesh)*

Virtual Wind Tunnel requires a good quality surface (2D mesh). The CFD surface mesh needs to be:

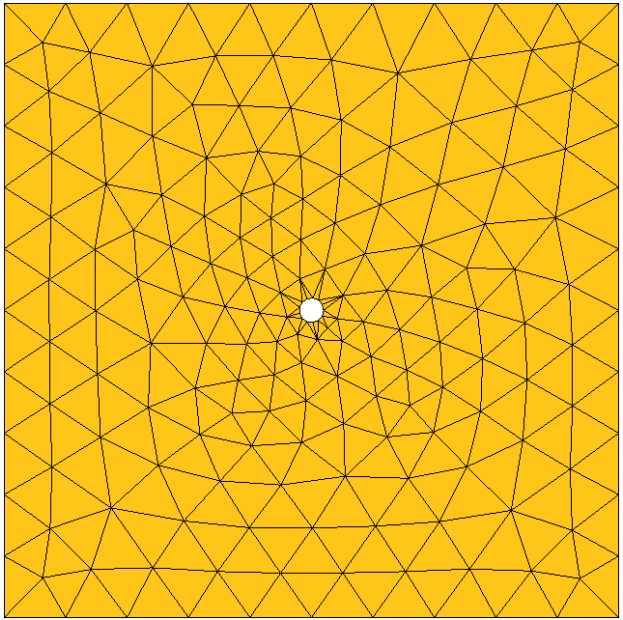
- Enclosed / Connected without holes or internal T-Connections
- No duplicate / double elements
- Good element quality, pay special attention to features like radius etc.

Meshing and Checks are usually done in HyperMesh:

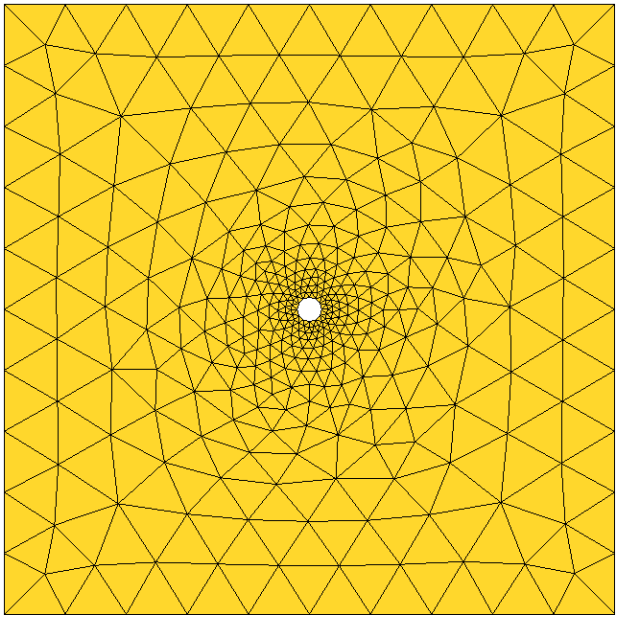


Possible situation

Size and bias

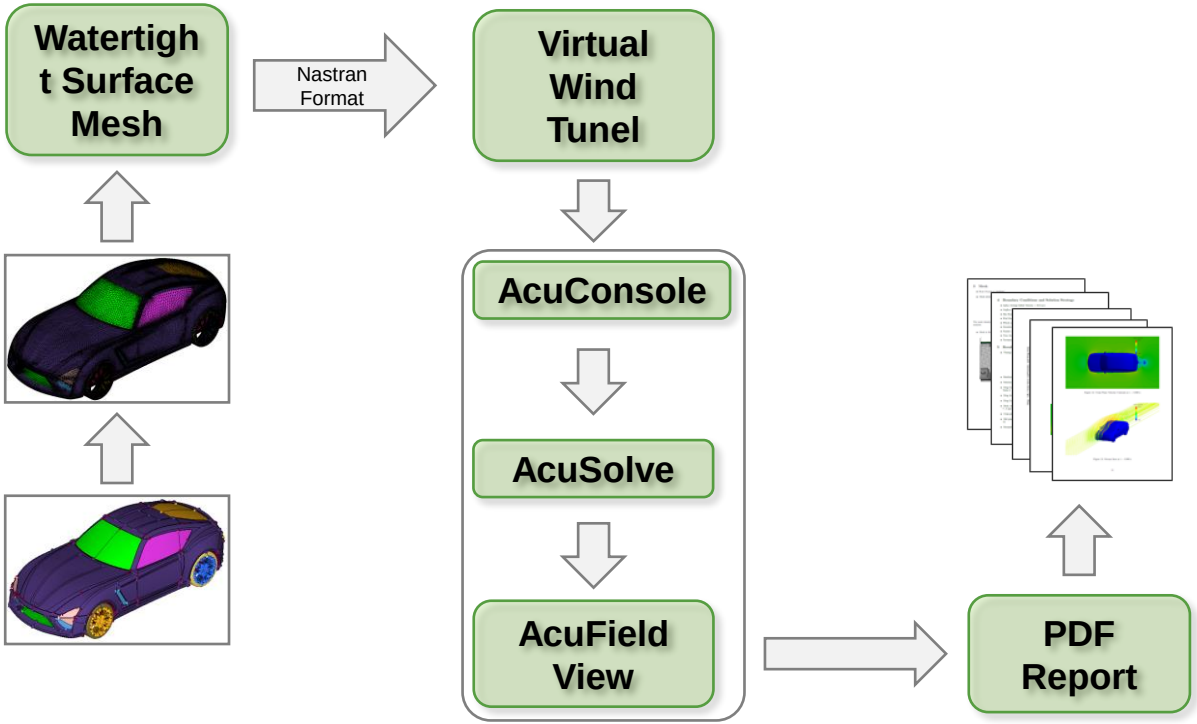


Surface deviation



Working with VWT

- Process Overview



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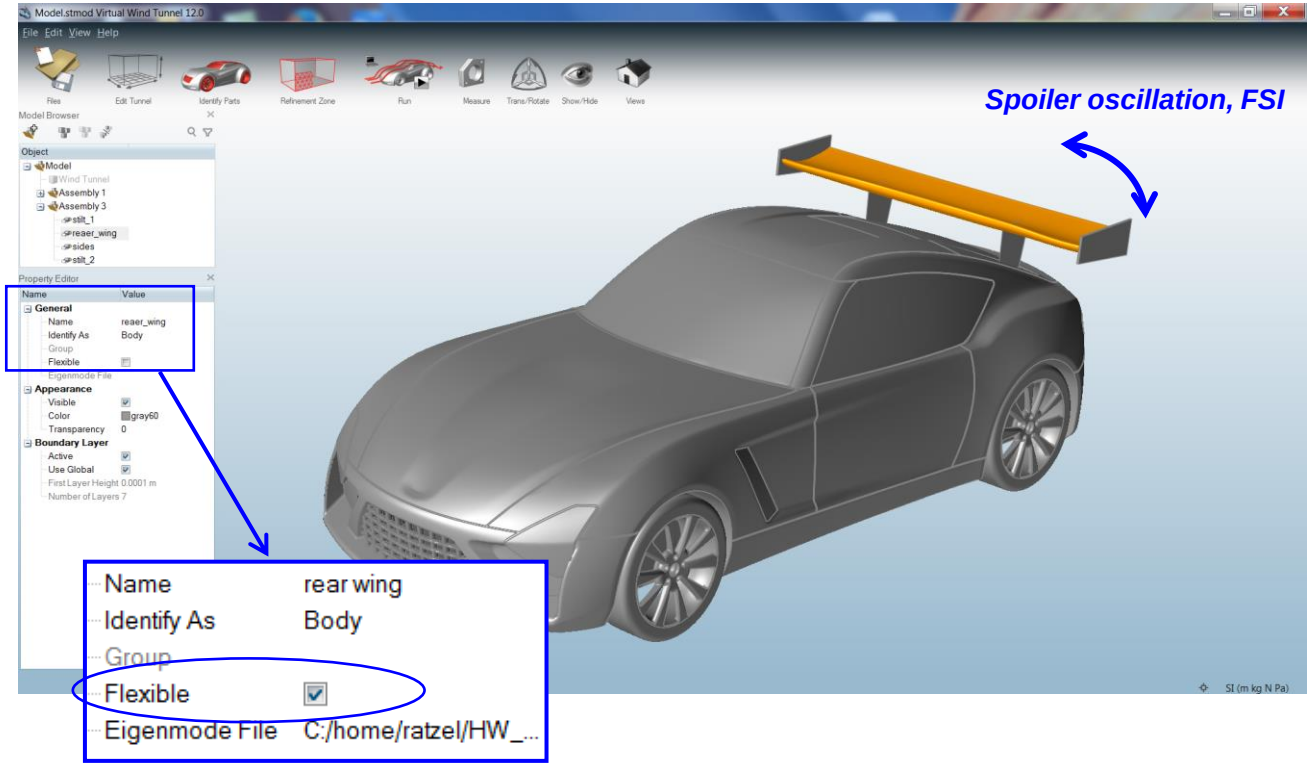
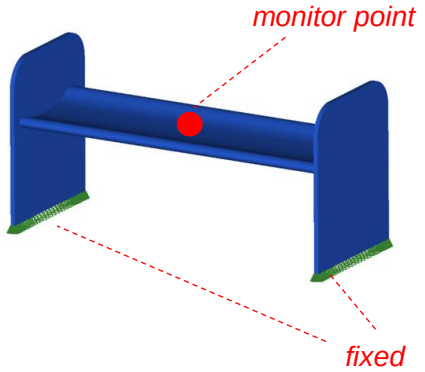
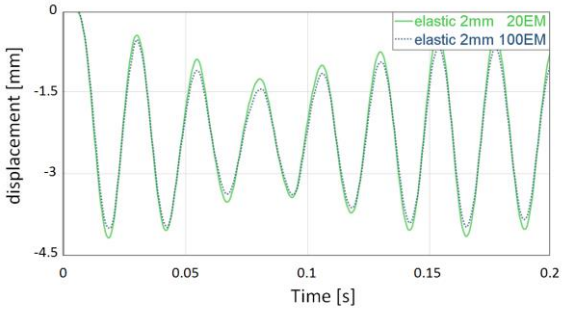
Advanced: Fluid-Structure-Interaction



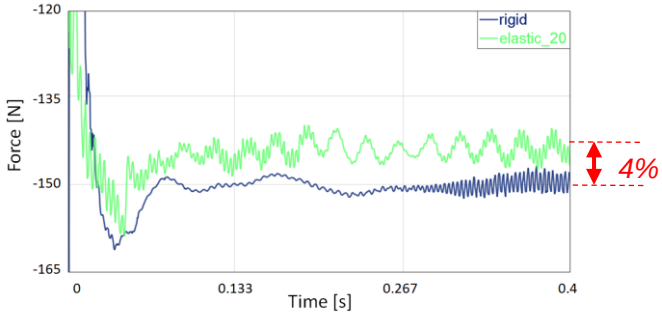
Advanced: Fluid-Structure-interaction of a rear wing

- FSI analysis
  - Generic model of an automotive rear wing
  - Soft plastic material, thickness of 2mm
  - 20 & 100 eigenmodes computed with OptiStruct





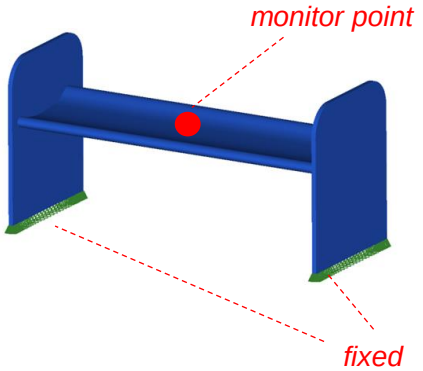
Displacement of monitor point (20 & 100 eigenmodes)

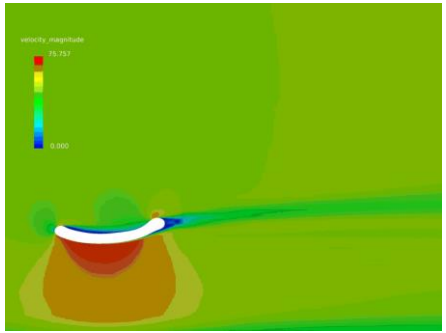


Down force for rigid and elastic

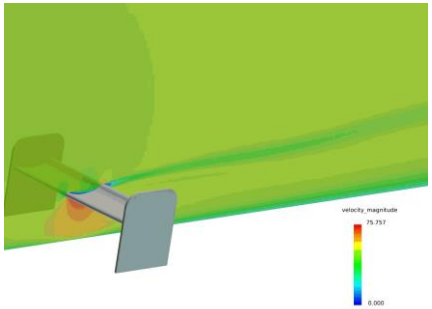
Advanced: Fluid-Structure-interaction for rear wing

- FSI analysis
  - Generic model of an automotive rear wing
  - Soft plastic material, thickness of 2mm
  - 20 & 100 eigenmodes computed with OptiStruct





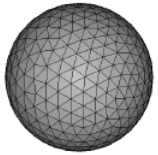
Structural deformation (vel. contour)



Structural deformation (vel. contour)

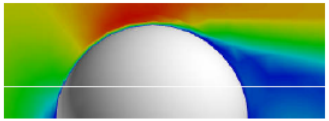
Extras: Morphing , Validation

- **HyperMesh**
  - Surface meshing of sphere (d=0.1m, elem size=0.01m)
  - Export “Nastran(Fluent)”



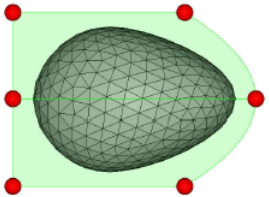
Cd=0.36

- **Virtual Wind Tunnel**
  - Import surface mesh
  - Setup: see next slide for details
  - Run & check report for Cd

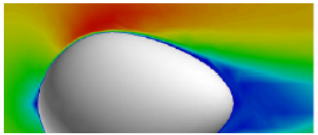


- **HyperMesh**
  - Morph initial surface mesh
  - Export “Nastran(Fluent)”

Cd=0.28

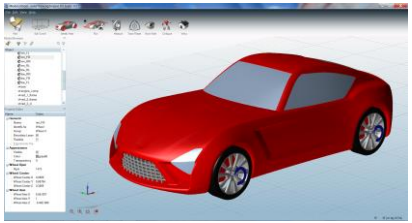


- **Virtual Wind Tunnel**
  - Import morphed surface mesh
  - Position at location of sphere
  - Run & check report for Cd

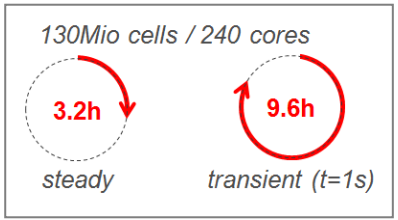


Summary – Altair's Virtual Wind Tunnel

- Virtual Wind Tunnel
  - Environment for external CFD analyses
  - Reduces user input to minimum
- Strength
  - Transient and steady state
  - Efficient workflow
- CFD solver AcuSolve
  - General purpose CFD solver
  - Accurate / robust / scalable

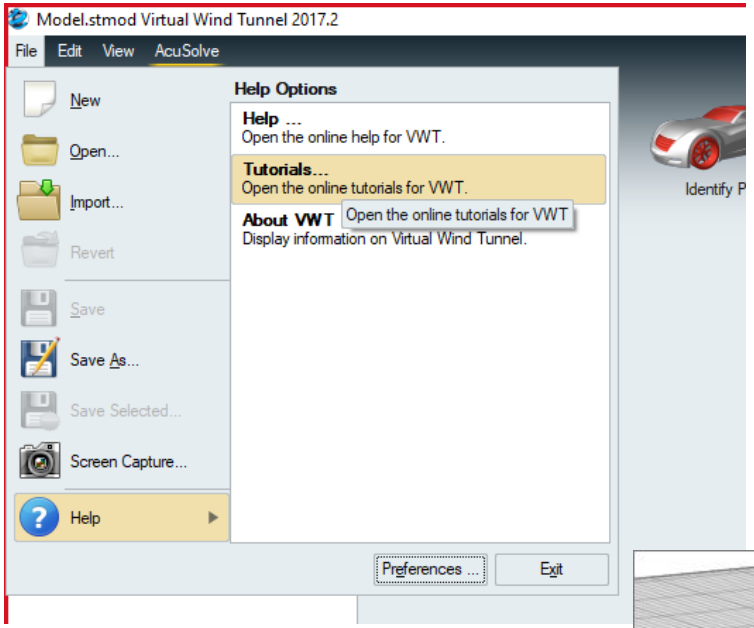


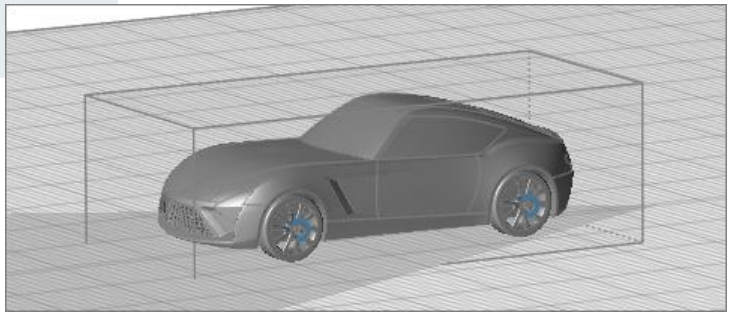
Virtual Wind Tunnel



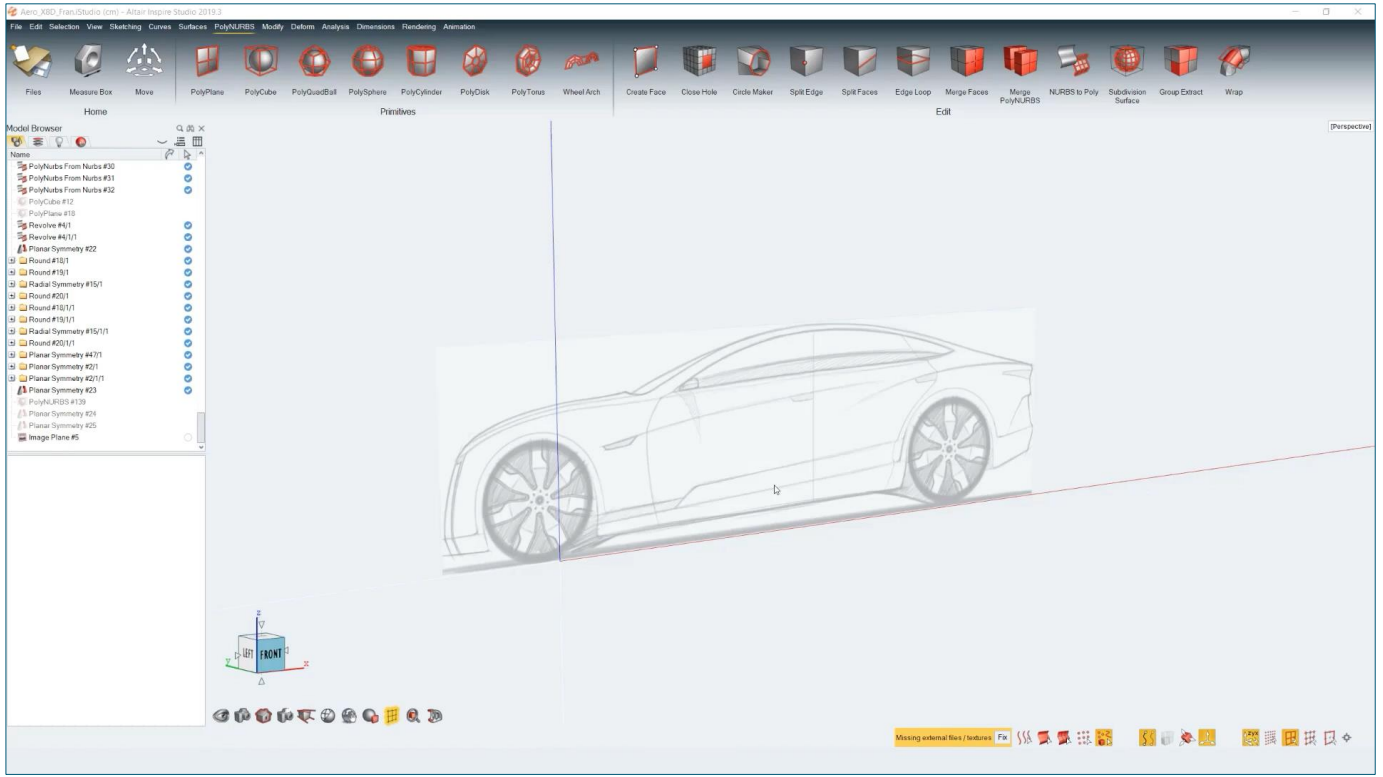
Xeon processors, 2.53GHz

Additional VWT Tutorial





Inspire Studio – Freeform Design



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