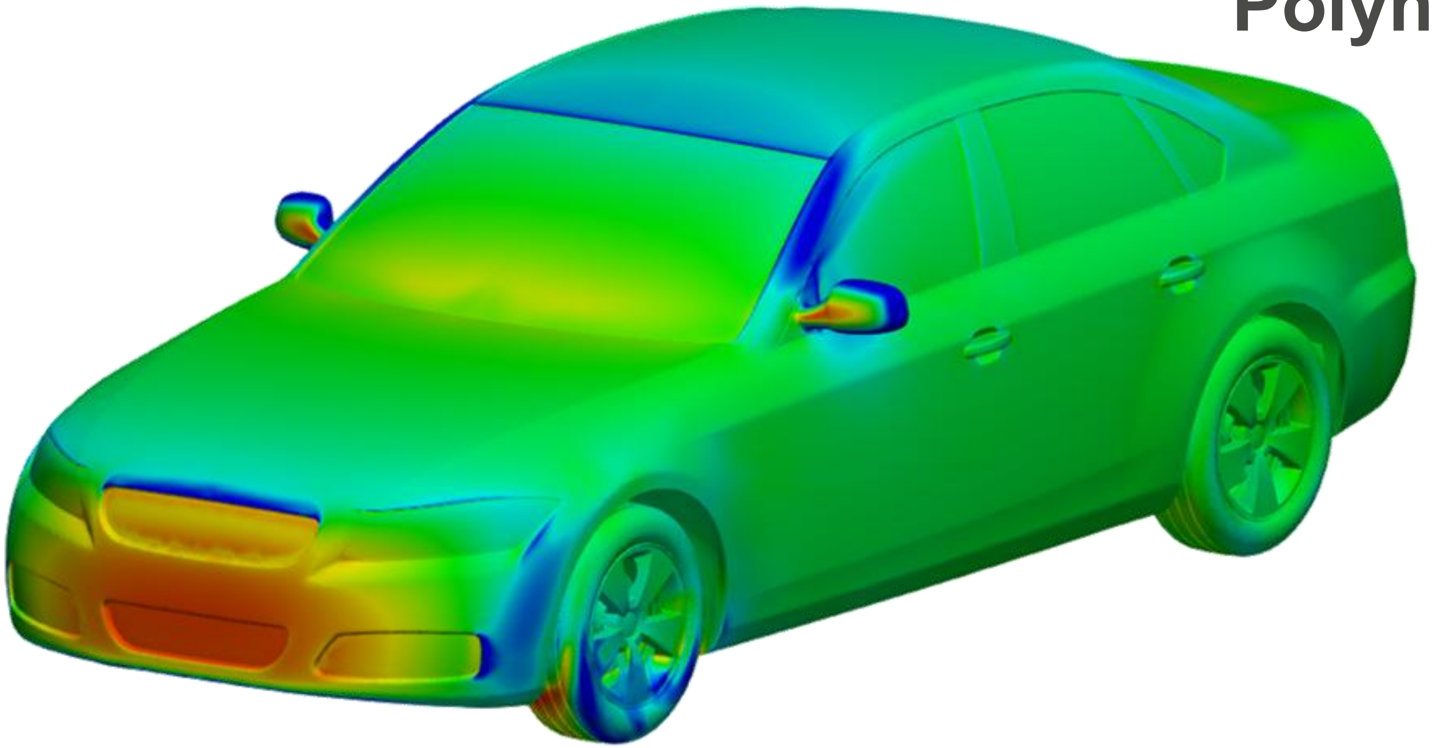
Optimizing Automotive CFD

Ennova's Role in Comparing Polyhedral and Hex-Core Meshes Using OpenFOAM



Ennova Technologies Inc

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Confidential

Outline

- Abstract
- Introduction & Benefits of Ennova
- Advantage of Polyhedral mesh
- Ennova workflow
- Case 2a
  - Mesh
  - Simulation Setup
  - Post Processing and result comparison

Abstract

- **To investigate** the performance of polyhedral meshes in comparison to hex-core meshes for the AutoCFD 4 Benchmark 2.0 and 2.1, utilizing the OpenFOAM RANS solver.
- Polyhedral meshes, characterized by their isotropic nature and 14 connections at a node, offer a more spherical approximation around vertices compared to the directional preference of hex-core meshes, which have six connections per node.
- **We aim** to determine the polyhedral mesh density required to achieve similar integrated aerodynamic quantities as those obtained with hex-core meshes, which have half the number of cells due to their uniform cubic structure.
- **Our methodology** includes assembling a NURBS-based model by integrating geometry from AutoCFD 2, 3, and 4 benchmarks. This approach facilitates varying the mesh size independently of the given STL tessellation, providing greater flexibility in mesh generation. By conducting a series of simulations with progressively refined meshes, we aim to achieve a mesh-independent solution, validating the convergence of aerodynamic quantities.
- **The analysis** focuses on mesh generation time, cell count, mesh quality, and solver performance metrics such as convergence rate and computational efficiency. Preliminary results indicate that polyhedral meshes, despite requiring more cells to match the accuracy of hex-core meshes, provide superior solver stability and capture turbulent flows more effectively. However, achieving mesh independence for integrated aerodynamic quantities with polyhedral meshes demands careful density adjustments.
- This comparative study offers insights into the trade-offs between polyhedral and hex-core meshes, guiding the selection of appropriate meshing strategies for complex automotive CFD applications in OpenFOAM.
- **Ennova can streamline the entire process from CAD to simulation removing unnecessary manual steps including any geometry cleanup**. Detailed results, including intermediate solutions and convergence proofs, are presented to demonstrate the efficacy of polyhedral meshes in achieving high-fidelity simulations.

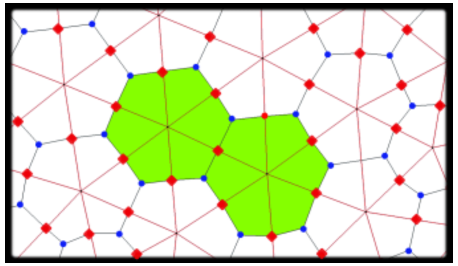
Ennova CFD – For faster and accurate analysis

- Industry relevant pre-processor with parallel polyhedral mesh generation
  - The polyhedral meshes cell count is approximately 1/6th of the tetrahedral mesh
- Automatic Pre-processor with minimal manual CAD cleanup
  - Topology based automatic CAD repair
  - Shrinkwrap – wrapping tool which does not require any of the CAD repair steps to be executed
- Hassle free Case setup for OpenFOAM
  - Even naive CFD user can easily setup the openFOAM case which is otherwise requires through understanding of OpenFOAM disctionary and is only terminal based
  - Not just case setup but, OpenFOAM based post-processing utilities can be set with Ennova-CFD
- Ennova-CFD provides CFD solutions
  - With highly experience team (20+ years) headed by founder and core developer of ICEM CFD Dr. Hohmeyer
  - Has off-the-shelf as well as customized processes for CFD

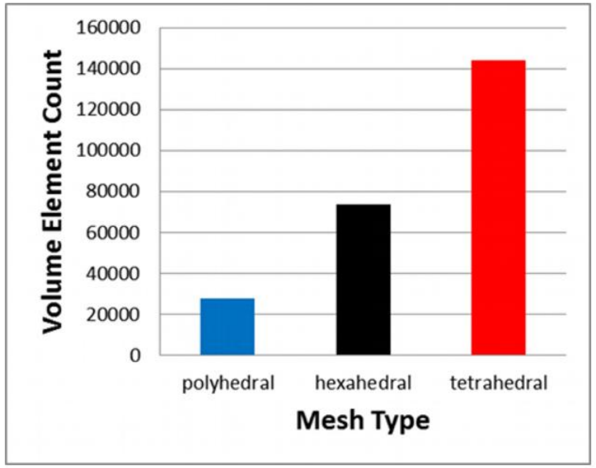
EnnovaCFD

- **At Ennova our goal is simple**
  - **To enable the CFD engineer to build models in hours that previously took months (or in minutes that took hours) without sacrificing quality or accuracy.**
- EnnovaCFD™ for OpenFOAM® is a complete CFD solution based on the open source industry standard OpenFOAM® and Ennova's pre- and post- processing capabilities.
- The CAD repair algorithms are carefully tuned to provide the right balance between being automatic to process 99% of the model without manual input and being flexible with a suite of CAD cleanup tools which can be applied manually for specialist use.
- Ennova mesh schemes include, topology-based meshing , Octree, Tetra, Cut-mesh, and Shrink-wrap for use depending on solver and model requirements.
- Ennova uses a proprietary parallel architecture that utilizes modern multi-core CPU's to speed up CAD import, CAD cleanup and mesh generation by factors of 10x or 100x.

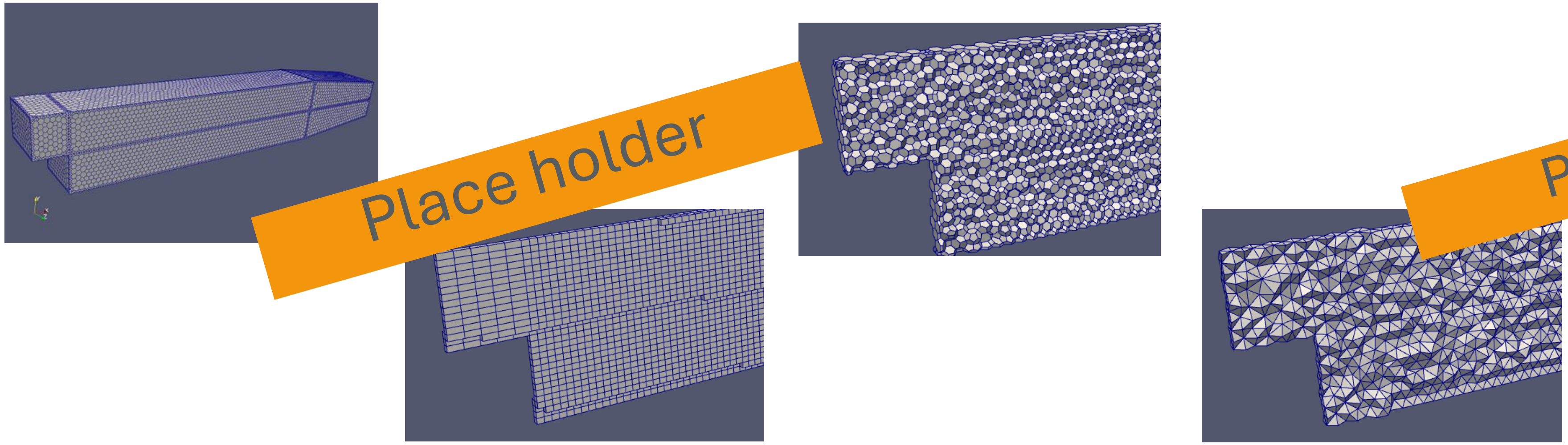
Polyhedral Mesh

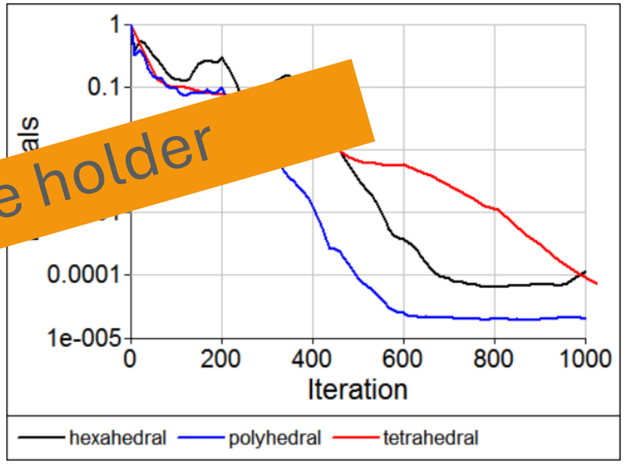


- It is well known that for high quality aerodynamic solutions, structured grids or multi-block structured grids preform well in most solvers.
- However, structured or multi-block structured grids are not easy or fast to make on anything but the simplest conceptual geometry, and they often require hours of manual input to make a grid.
- Polyhedral meshes have been in use for long now but limited to proprietary software. Hence, introducing polyhedral meshes generated using Ennova liberates user not only in terms of fast meshing but monitory benefits too.
- Polyhedral meshes reduces cell counts to the considerable extents yet gives similar results to that of heavy structured or tetrahedral meshes.



Volume Element Counts

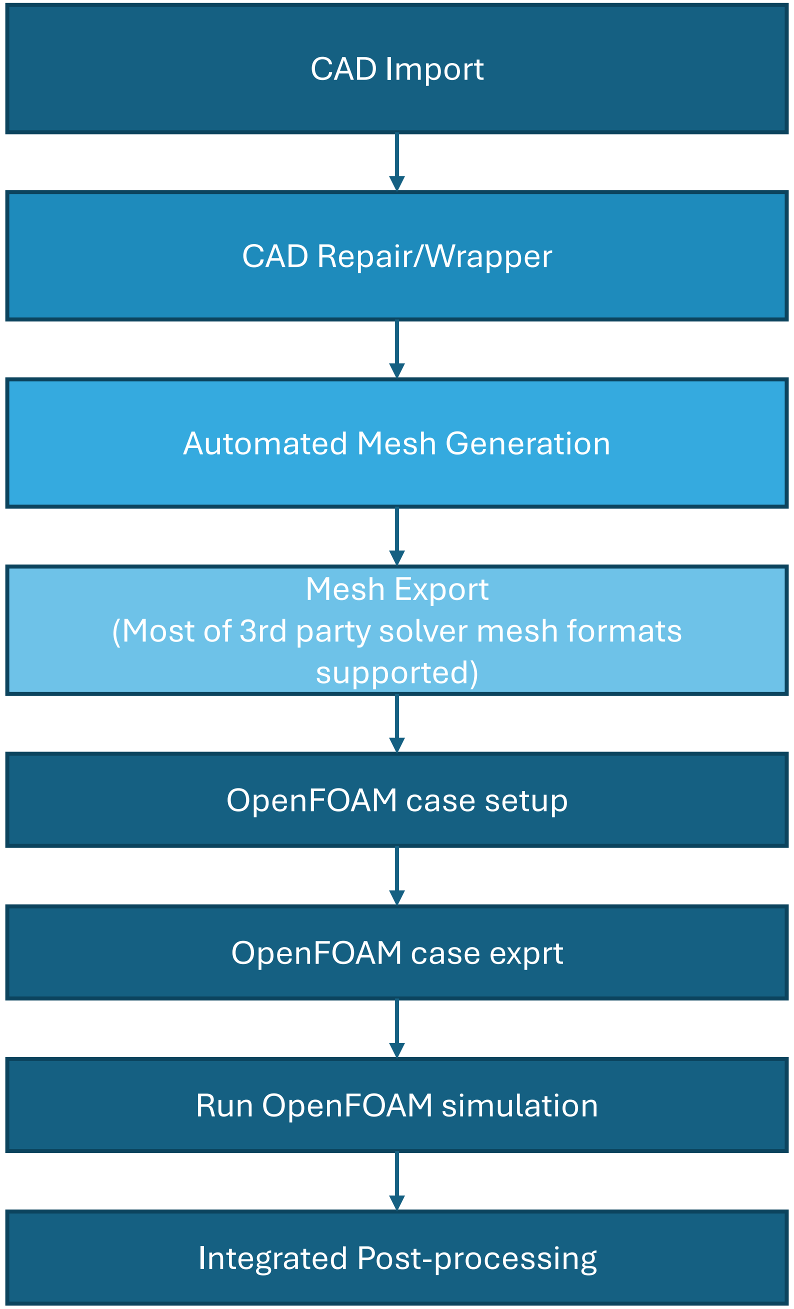




Pressure Residuals Monitor

Ennova For OpenFOAM

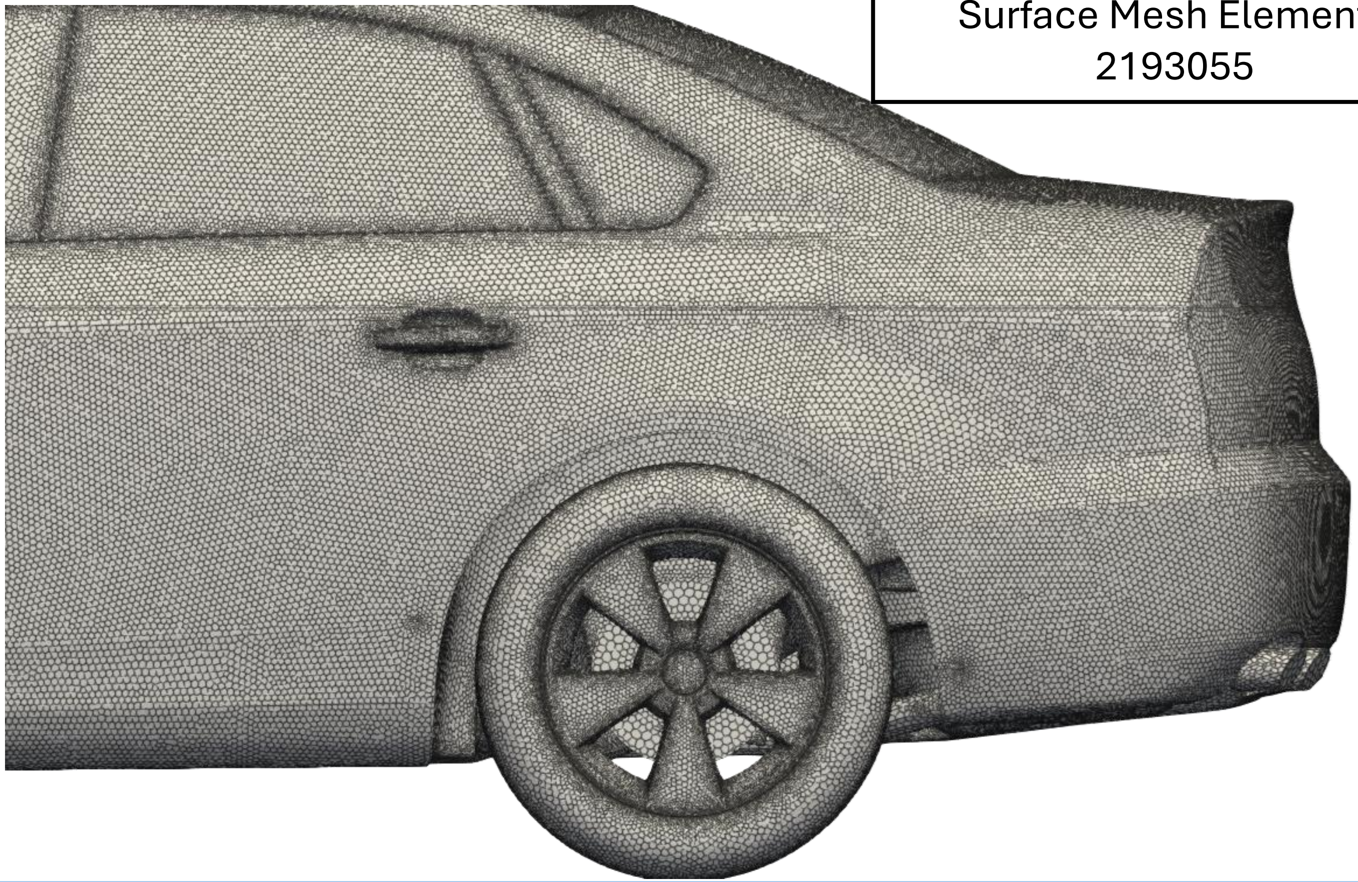
- Ennova supports a range of CAD exchange formats.
- The imported CAD can be modified, and any defects can be corrected using the graphical interface eliminating need to revisit the original CAD tool.
- A surface wrapper tool is available to handle imperfect geometries as well as to reduce manual efforts
- The software includes a Tetra-Polyhedral volume meshing tool that uses the Delaunay method. It can generate boundary layers even for most complex geometries.
- Once the mesh is created, it can be exported to most third-party CFD solvers, supporting a variety of major formats.
- To ease out case setup process which is otherwise tiresome for OpenFOAM® users, easy-to-use GUI for setting up the case is available within Ennova.

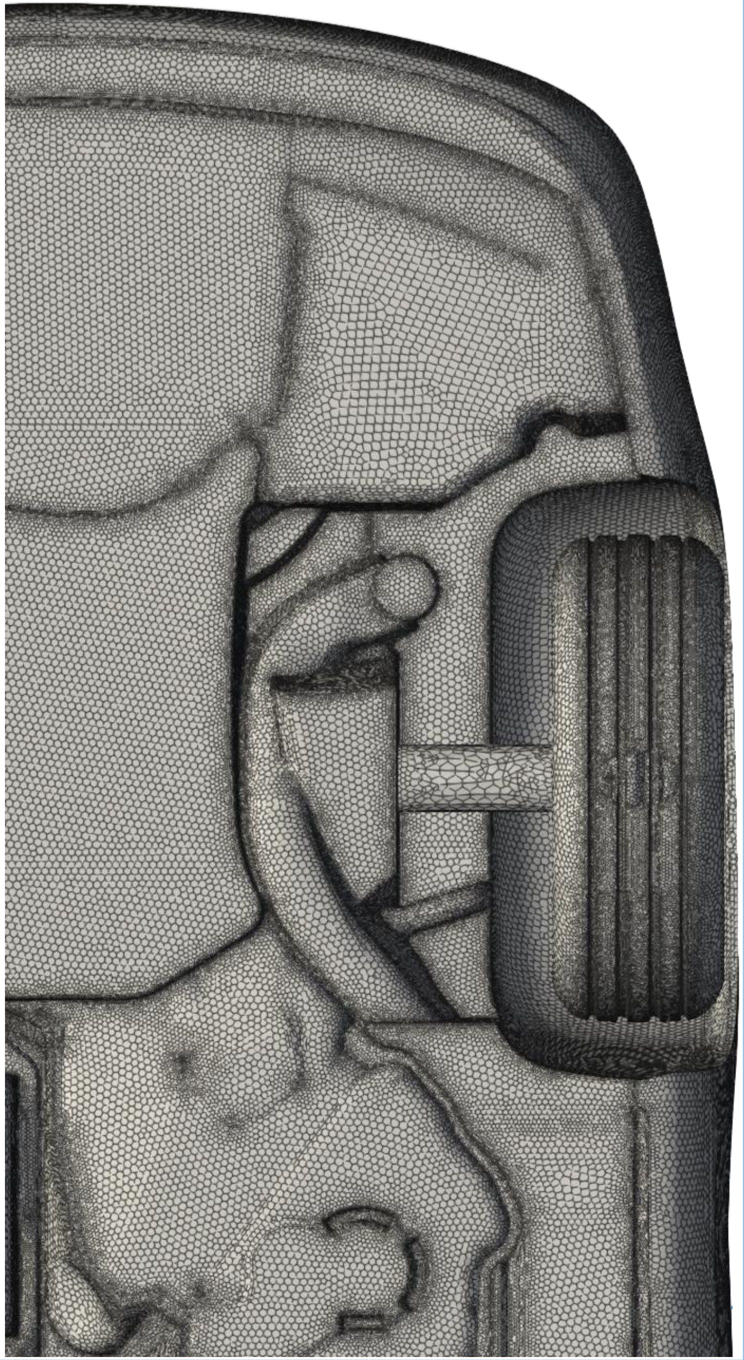


Case 2a
DrivAer Notchback

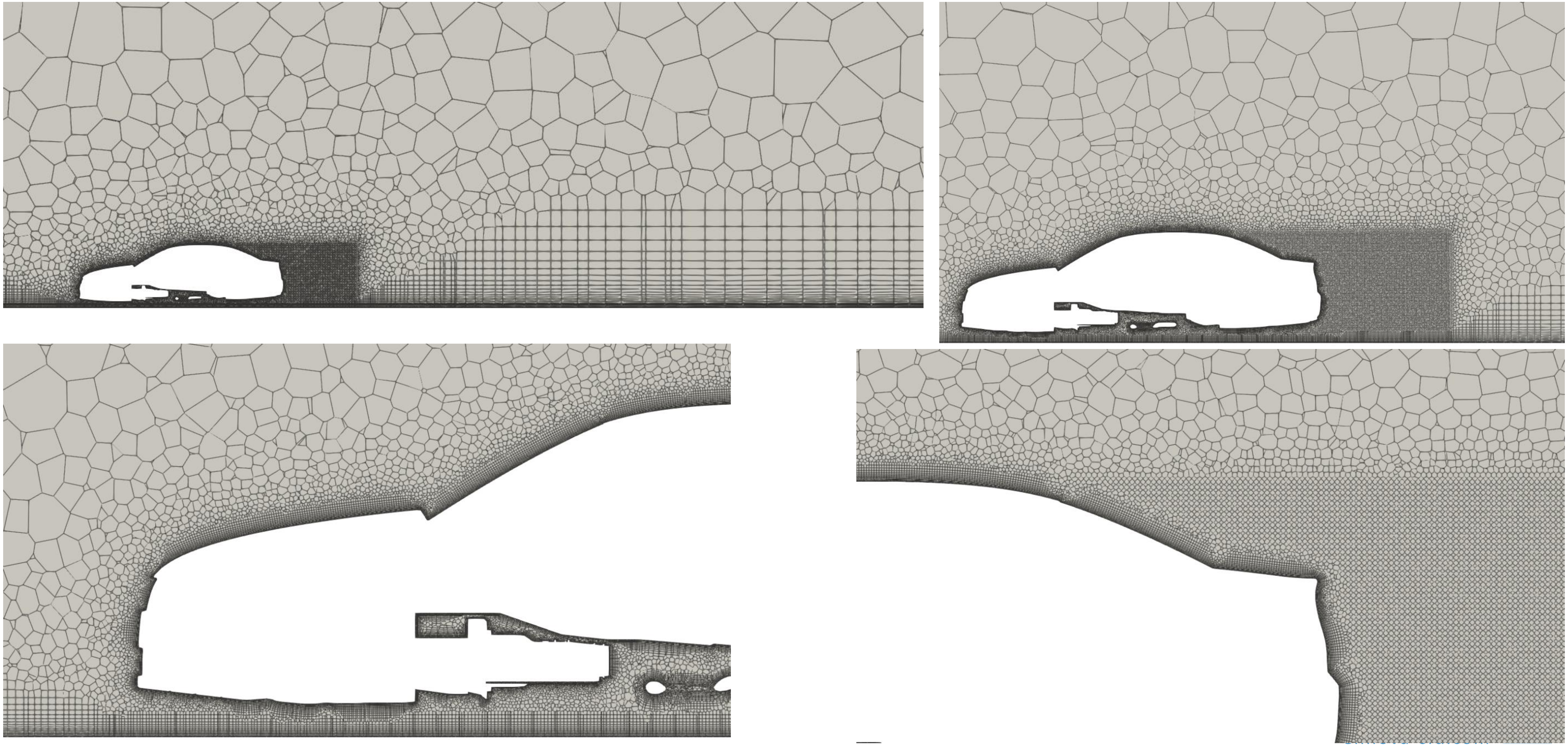
Surface Mesh : Mesh 20M

Surface Mesh Elements
2193055





Volume Mesh Cutplane : Mesh 20M

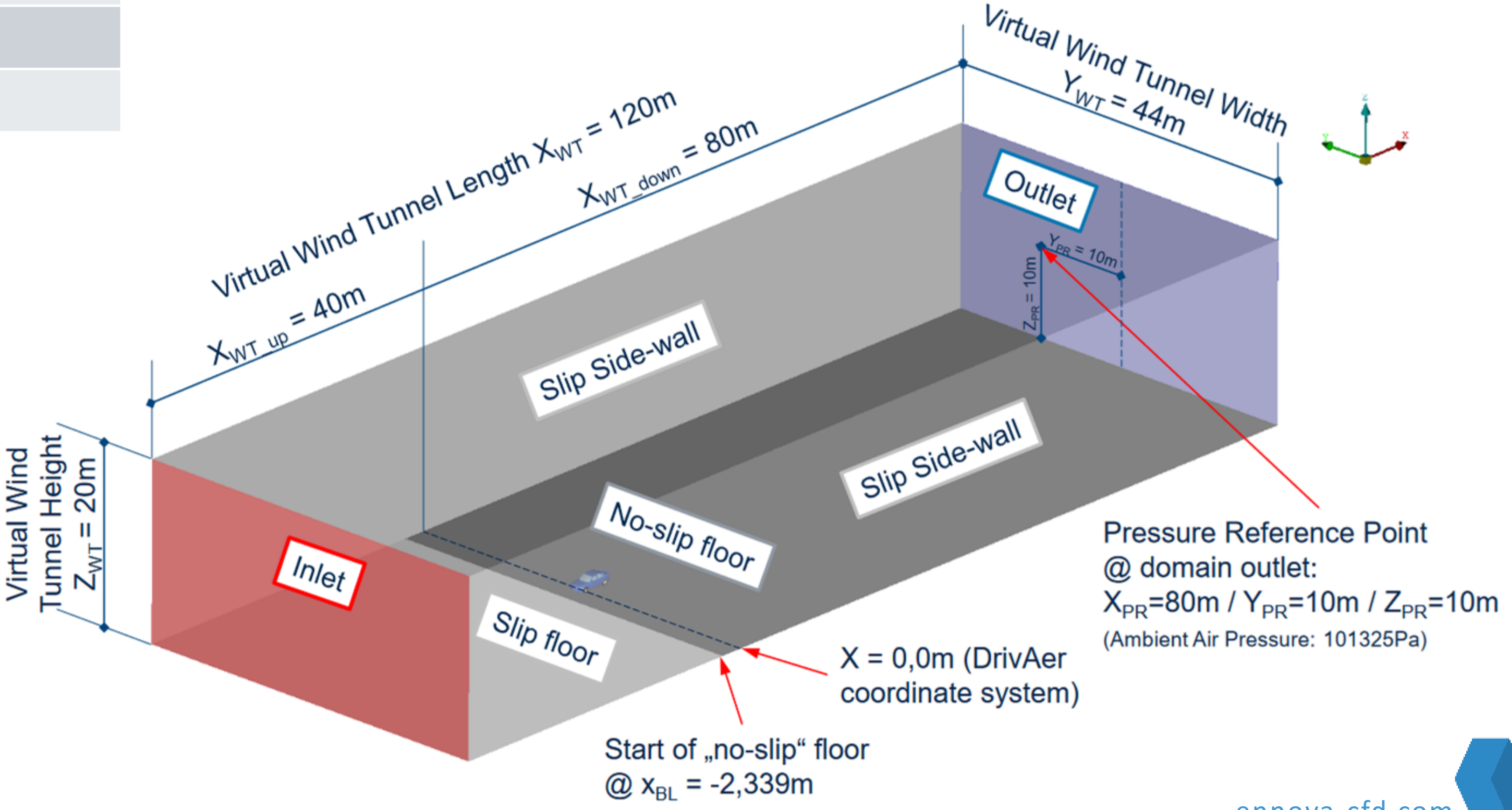


Case Setup

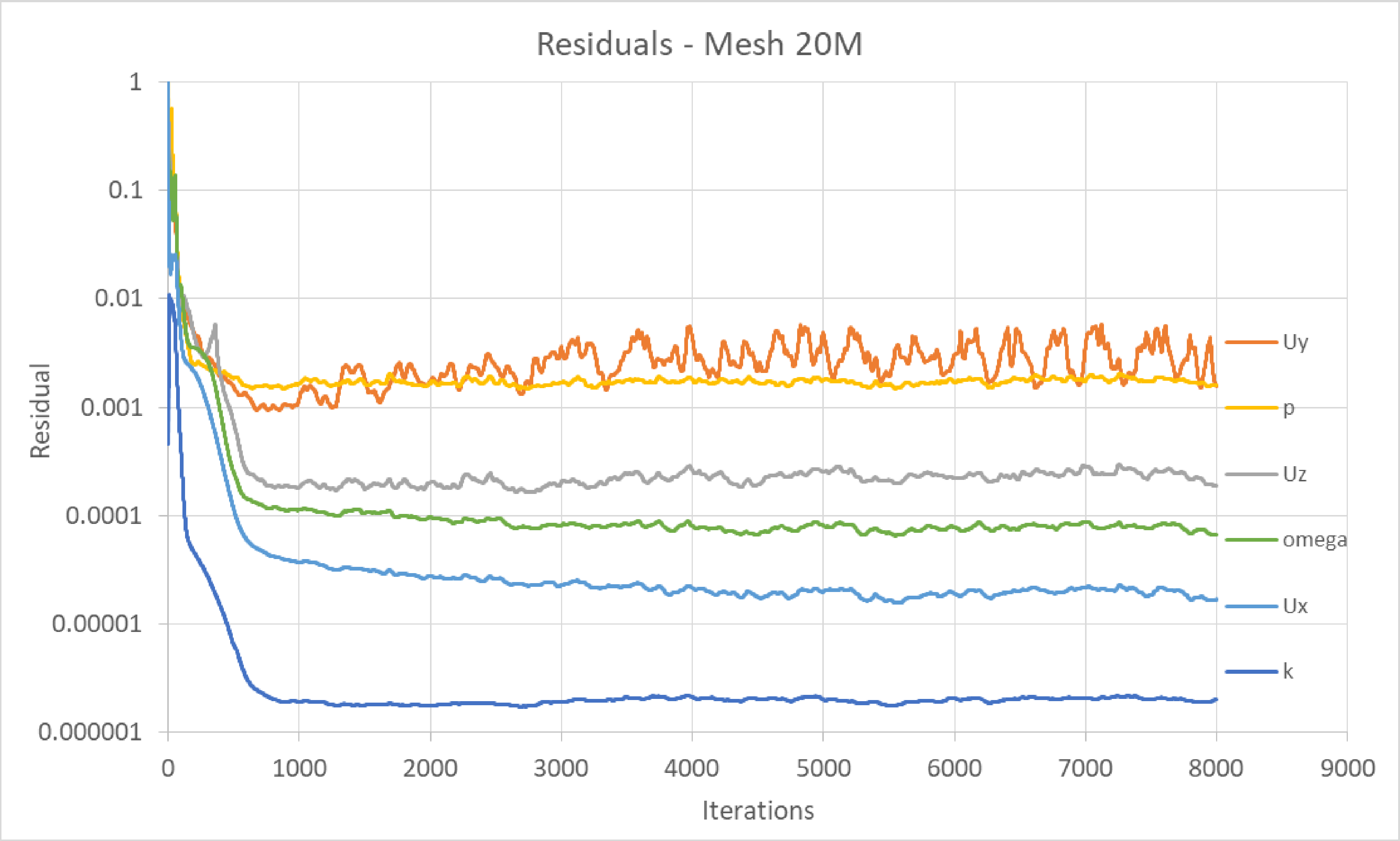
Field Parameters	
Vehicle Velocity	140 km/hr (38.889 m/s)
Yaw Angle	0
Ground effect	Off (Floor and wheels stationary)
Ambient Air Pressure	101325 Pa
Ambient Air Density	1.204 kg/m3
Dynamic Viscosity	1.8138E-5Pa*s

Simulation Type	
Simulation Type	Steady-State
Turbulence Model	k Omega SST
Turbulence Parameter	Intensity : 0.03 Length scale : 0.01m
Iterations	8000

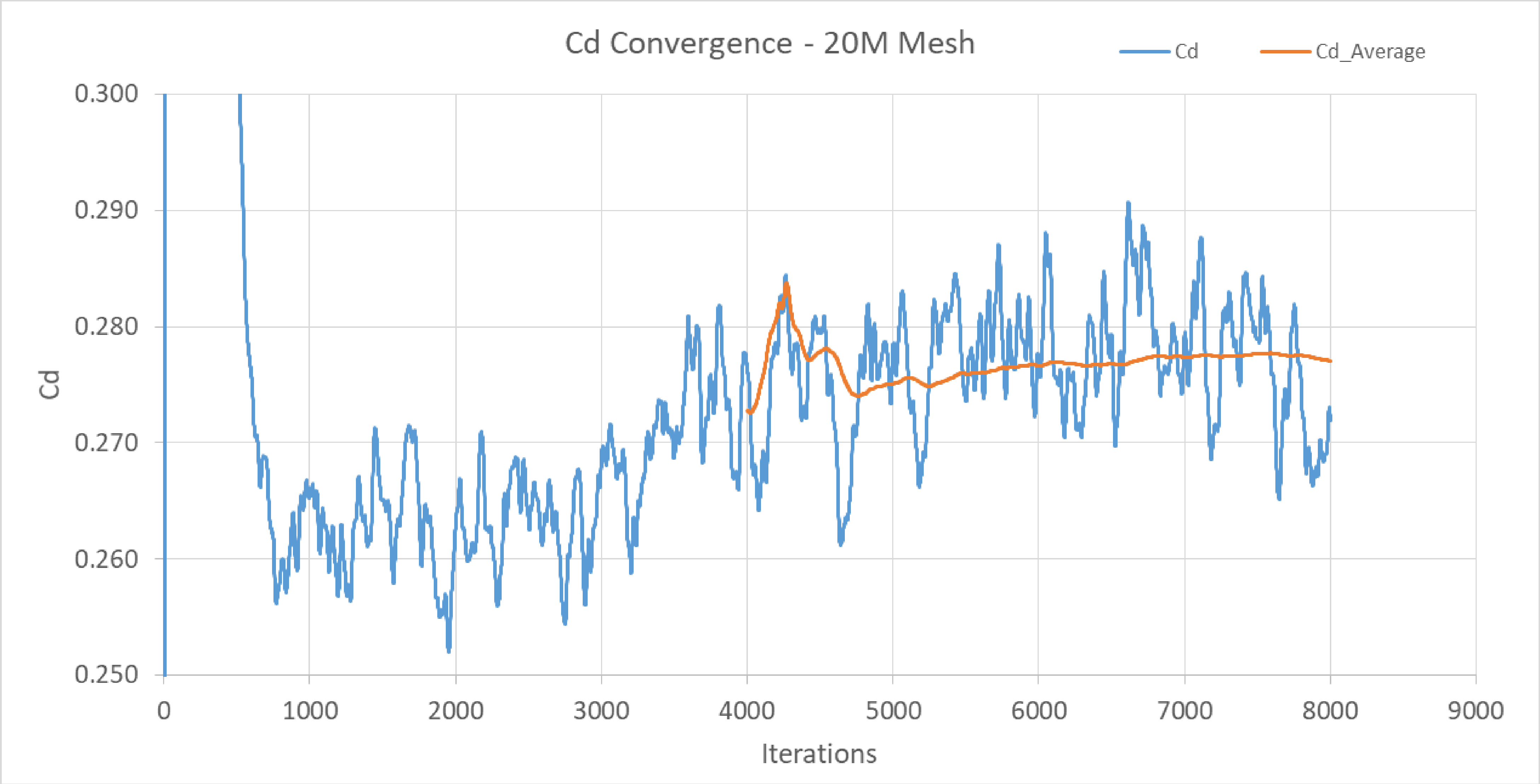
Machine Detail	
Processor Type	AMD Opteron(tm) Processor 6380
RAM	512GB
Number of cores Used/Available	48/64
Time taken for simulation	107 hrs for 8000 iterations



Results – Residuals

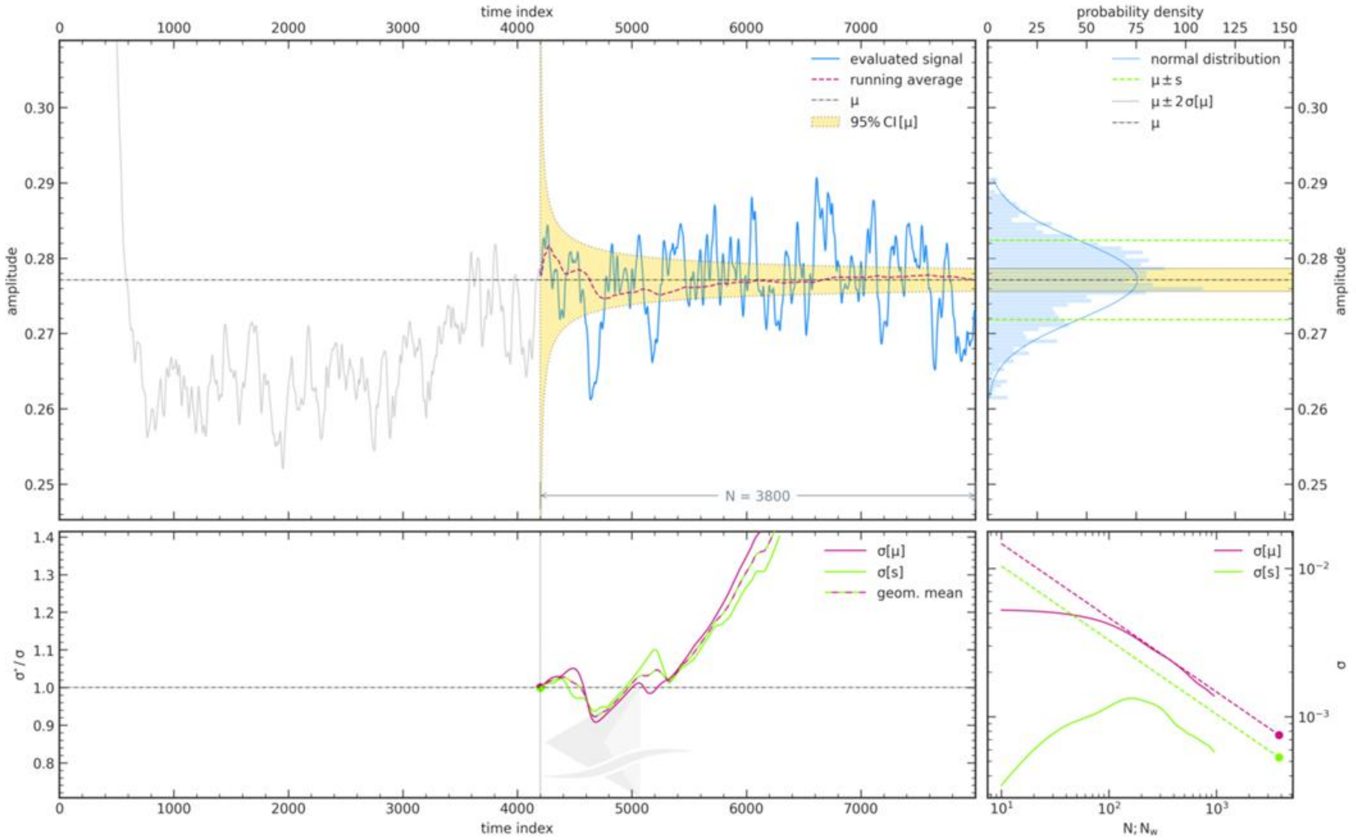


Results – Cd Convergence



Results – Cd Convergence

(meancalc – by upstream CFD)



chk = 0: sufficient data, non-suspicious

chk = 1/2/3: stationarity hypothesis rejected at 95/97.5/99 % confidence level

chk > 3: insufficient data, fundamental assumptions violated

μ: mean value

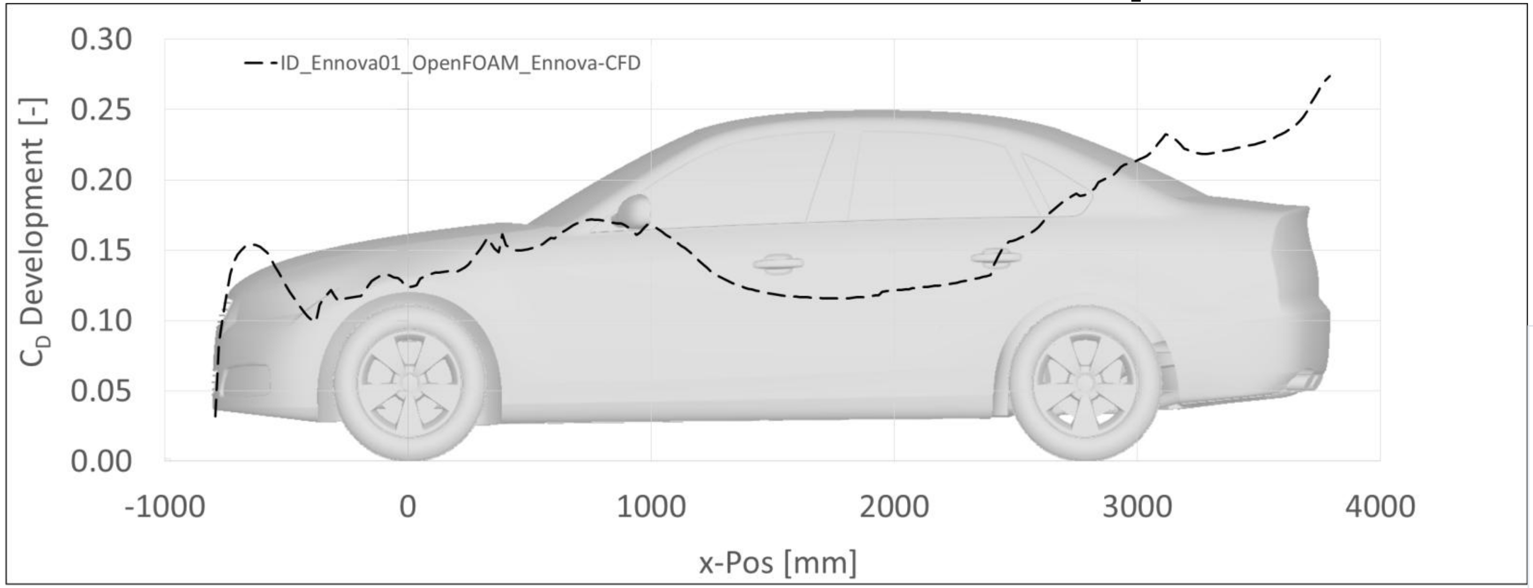
s: standard deviation

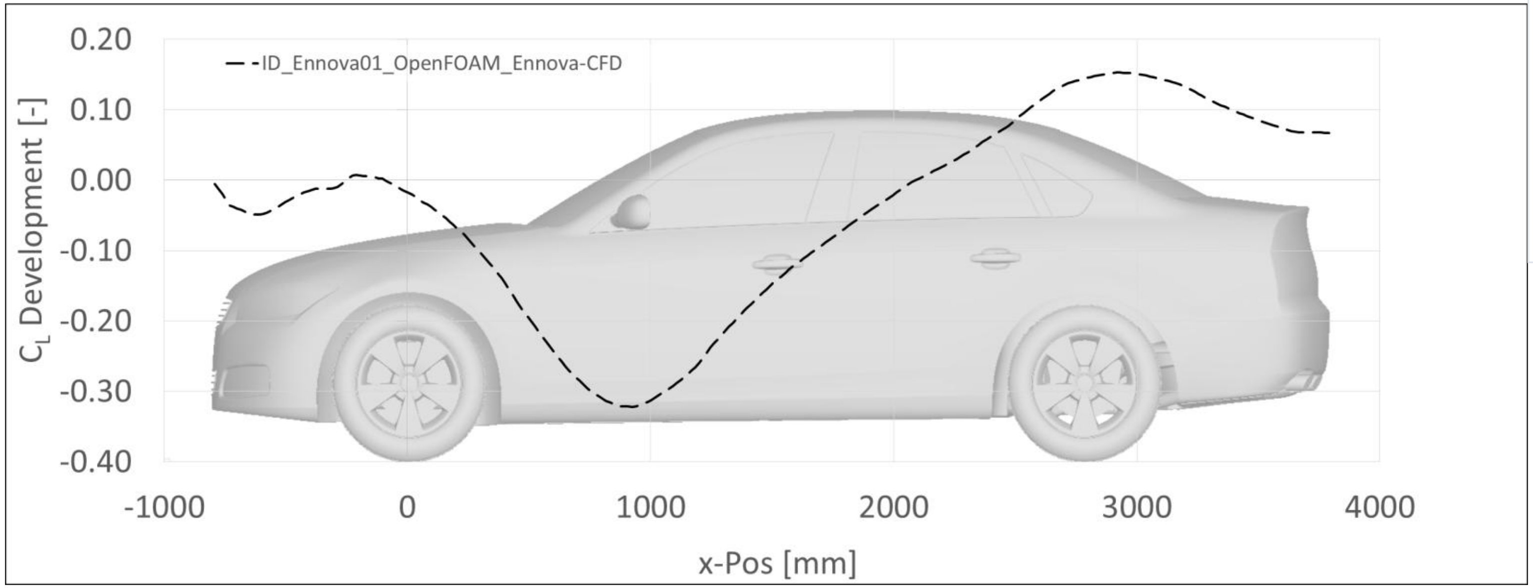
σ: random error

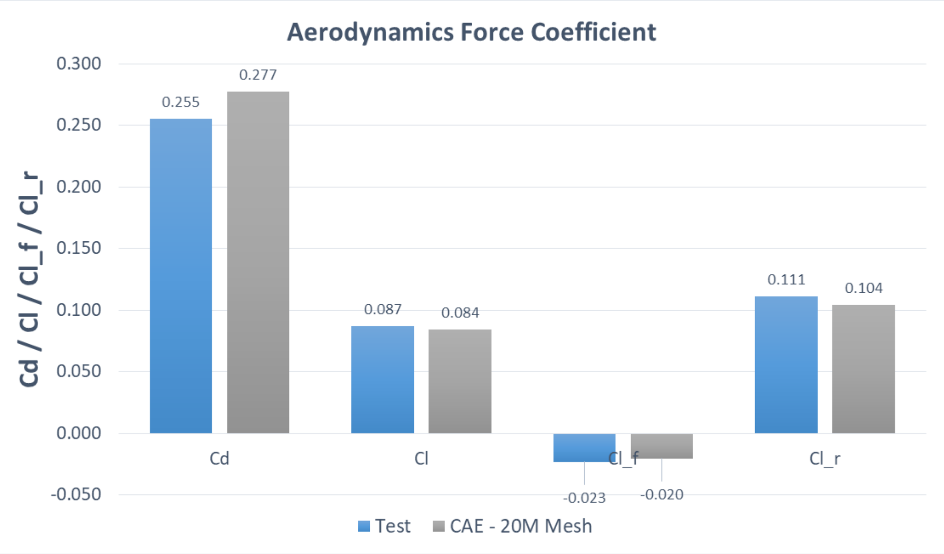
Averaging Starts at 4201

	file	column	nread	nskip	nused	chk	μ	σ(μ)	s	σ(s)
0	cd_convergence.dat	1	8000	4200	3800	0	2.771161e-01	7.531333e-04	5.263007e-03	5.325457e-04

Results – Force development Plot







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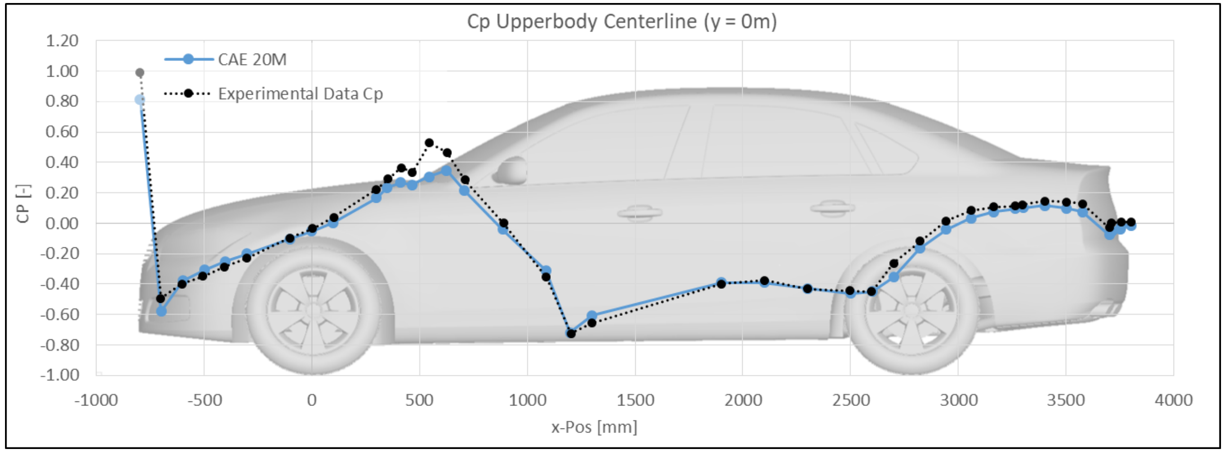
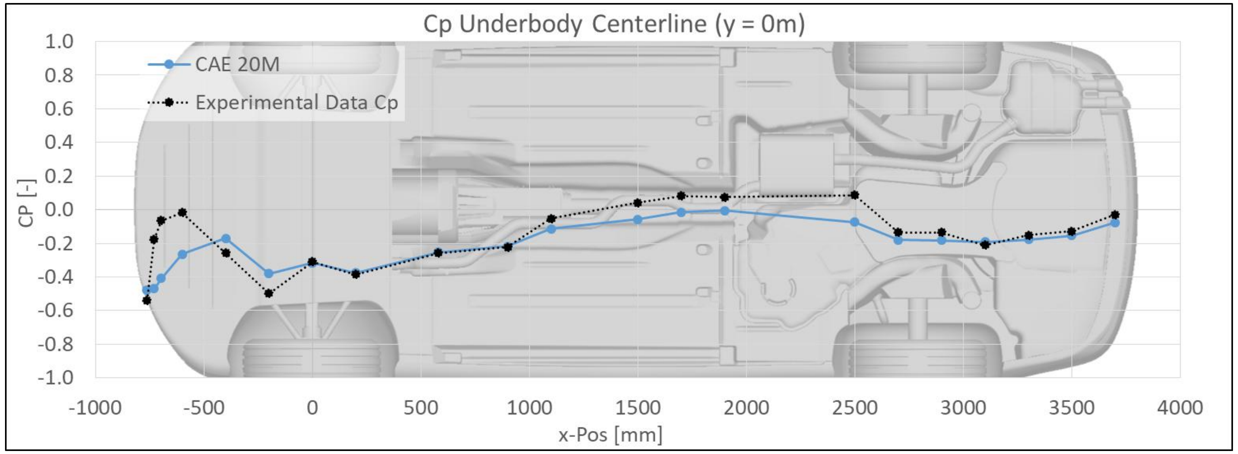
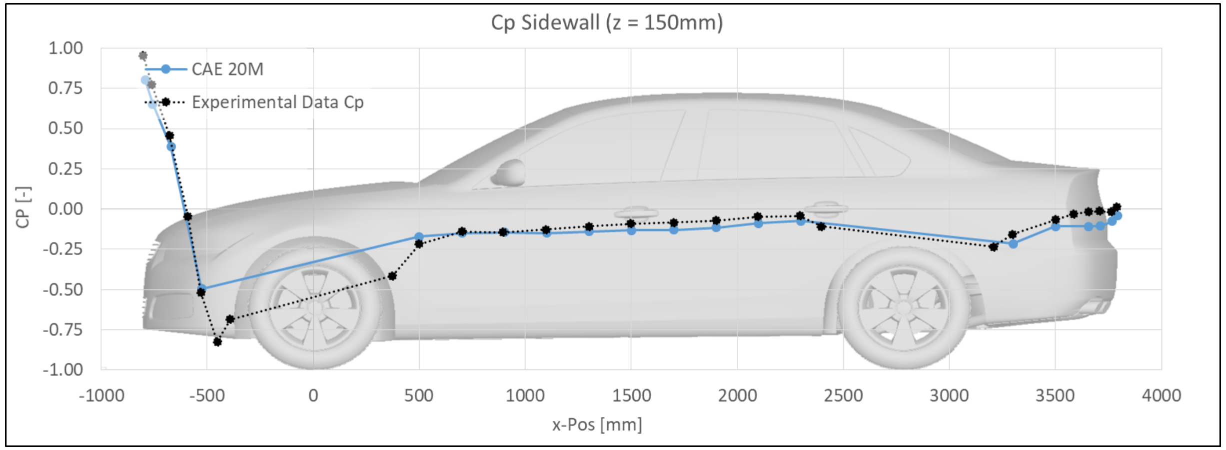
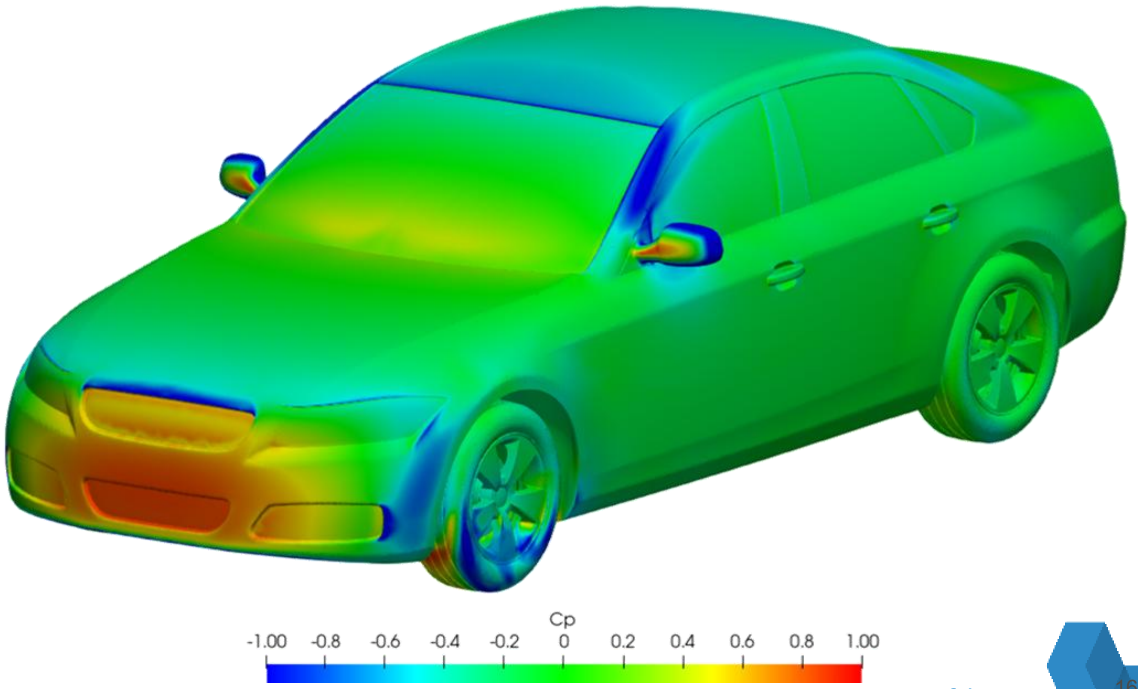
Results – Probe Points Cp

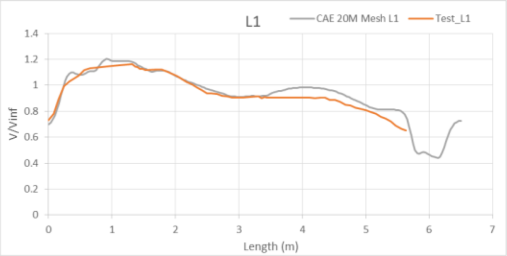


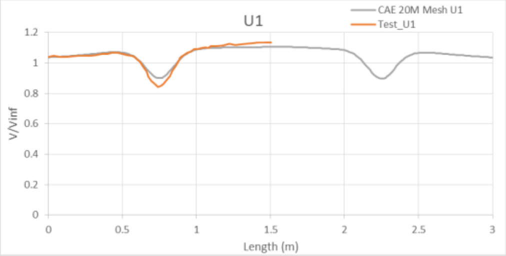


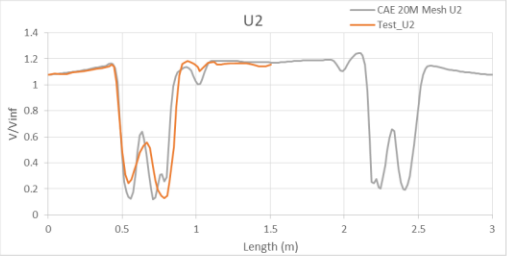


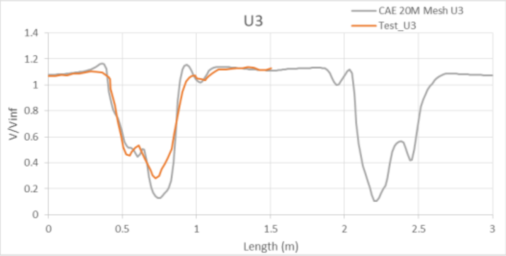


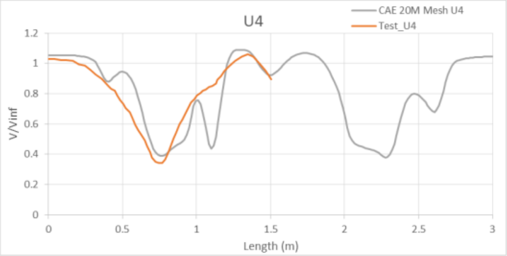
Results – Probe Points V/V∞

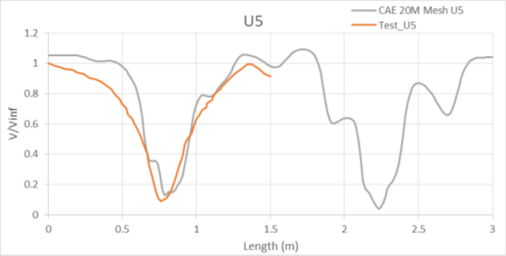


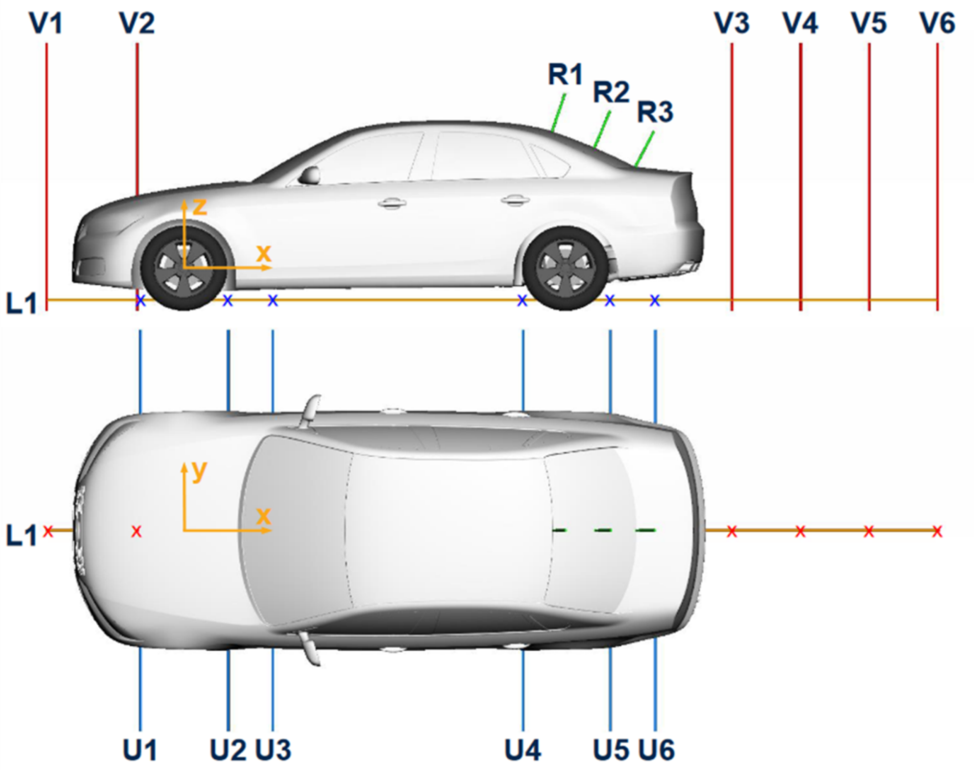


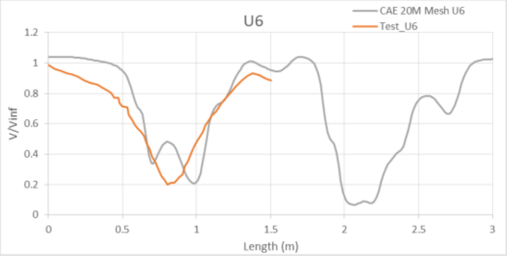


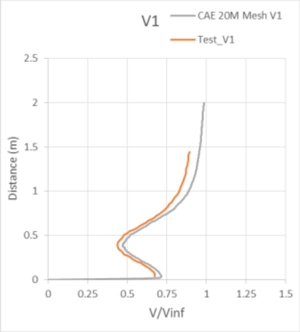


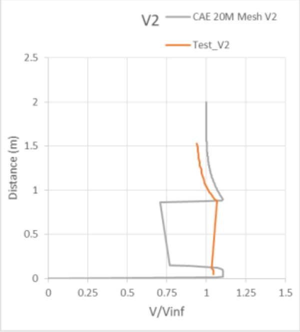


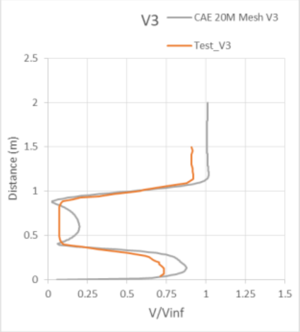


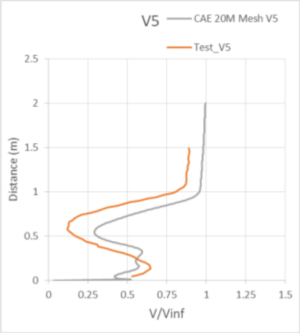




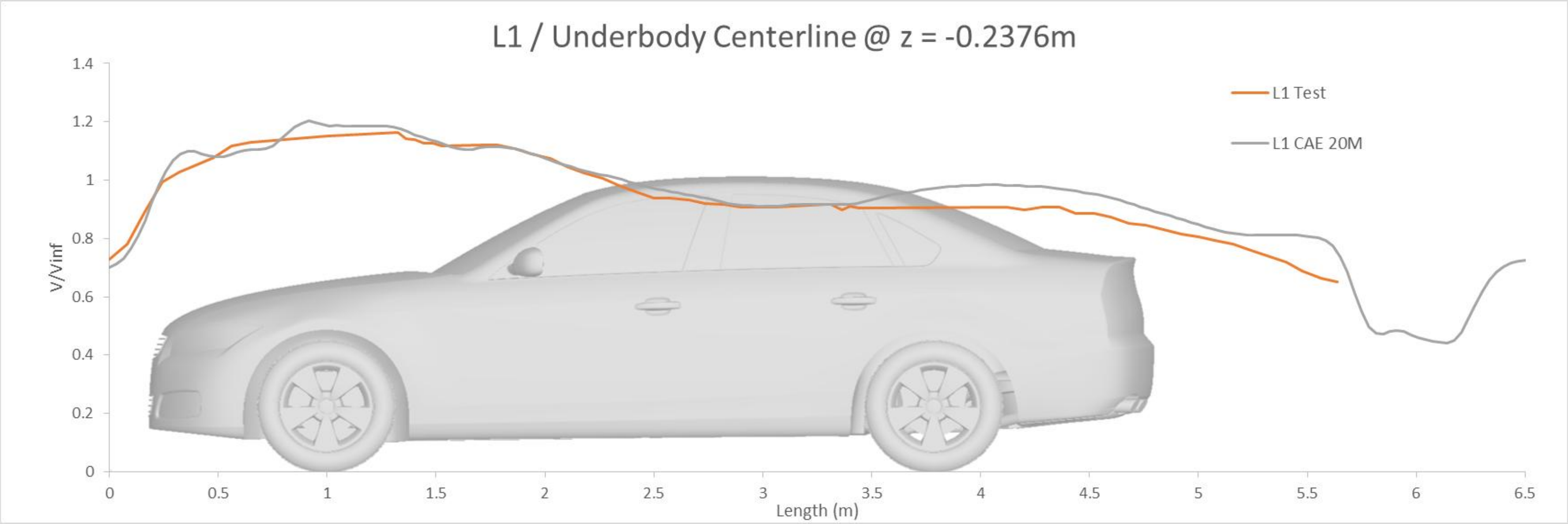




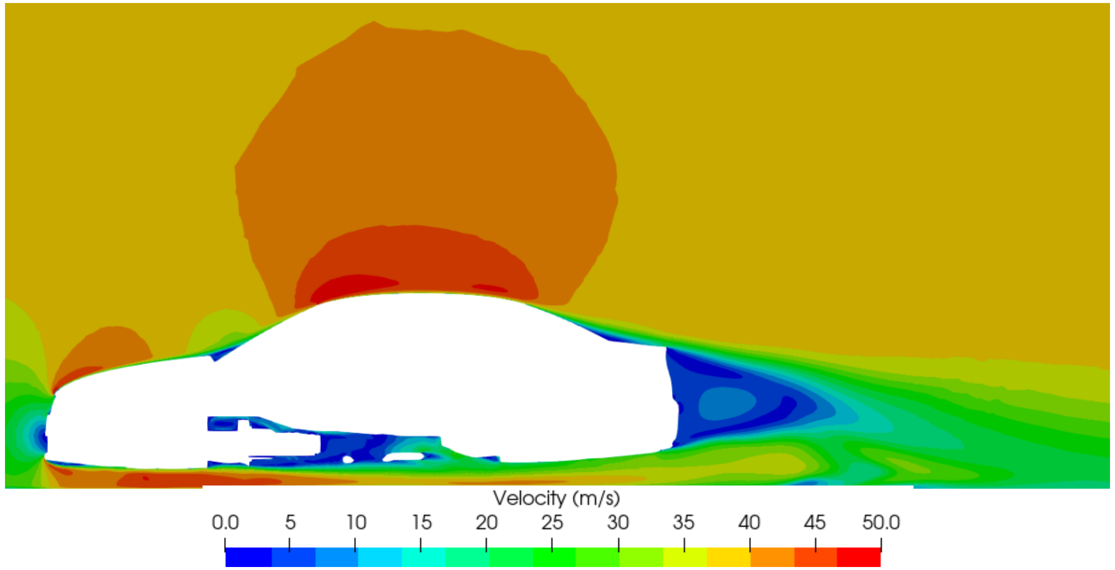




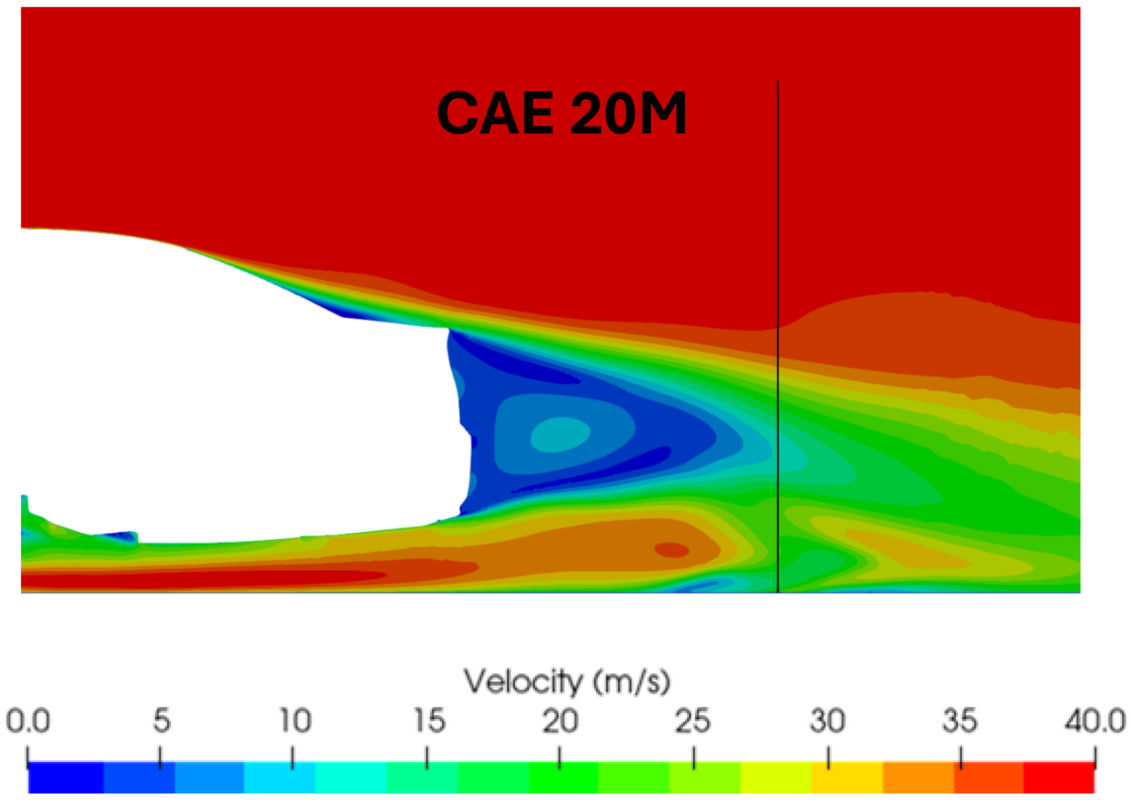
Results – Velocity at Centerline

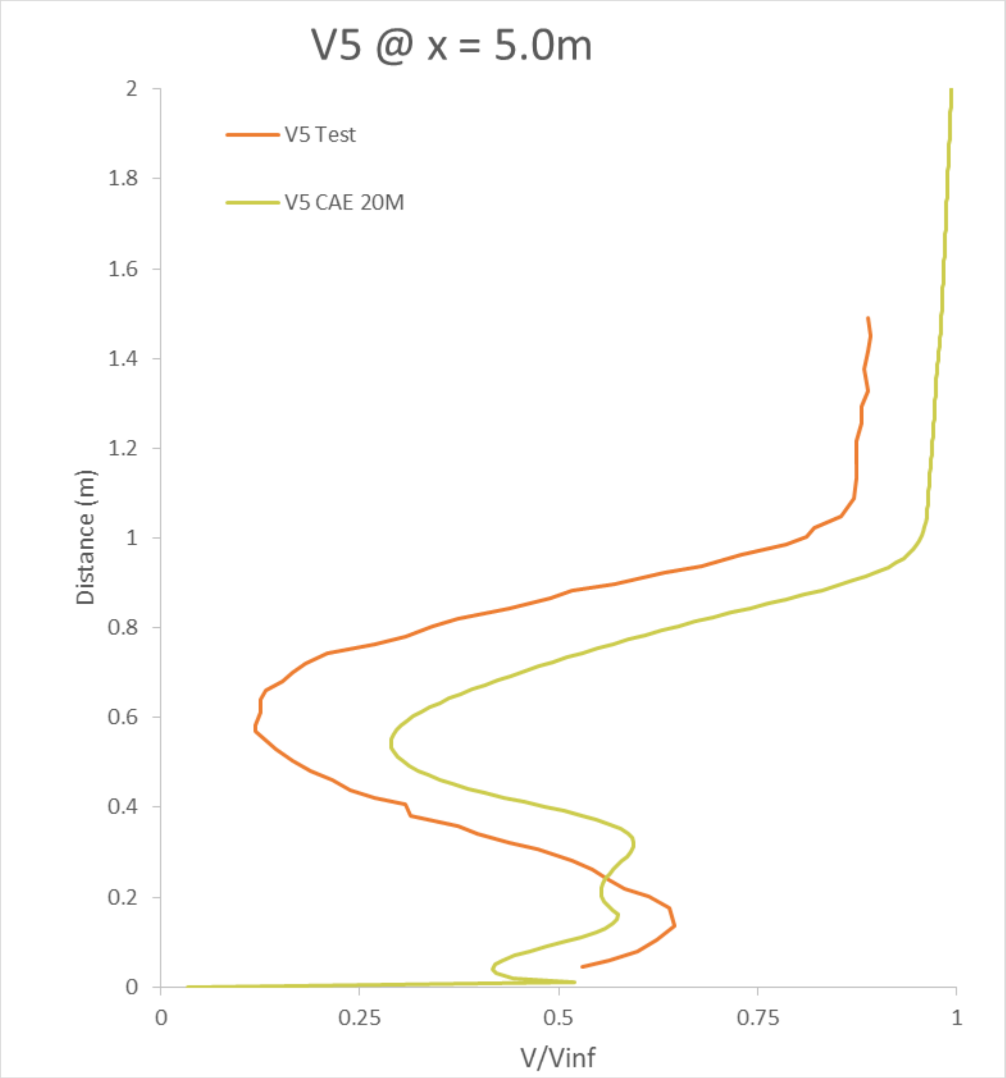


CAE 20M



Results – Velocity Wake Region





Thank you!

Questions?