CFX Simulations for 3rd AIAA Drag Prediction Workshop

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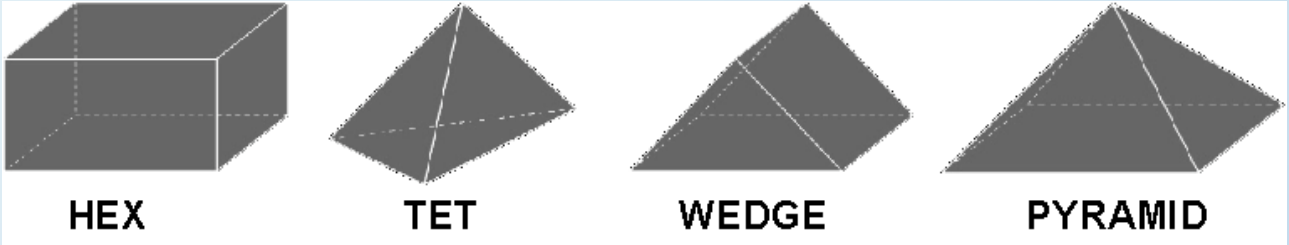
Outline

- CFX-10 solver technology
- CFX-10 mesh strategy
- Results 3rd AIAA DPW

CFX-10

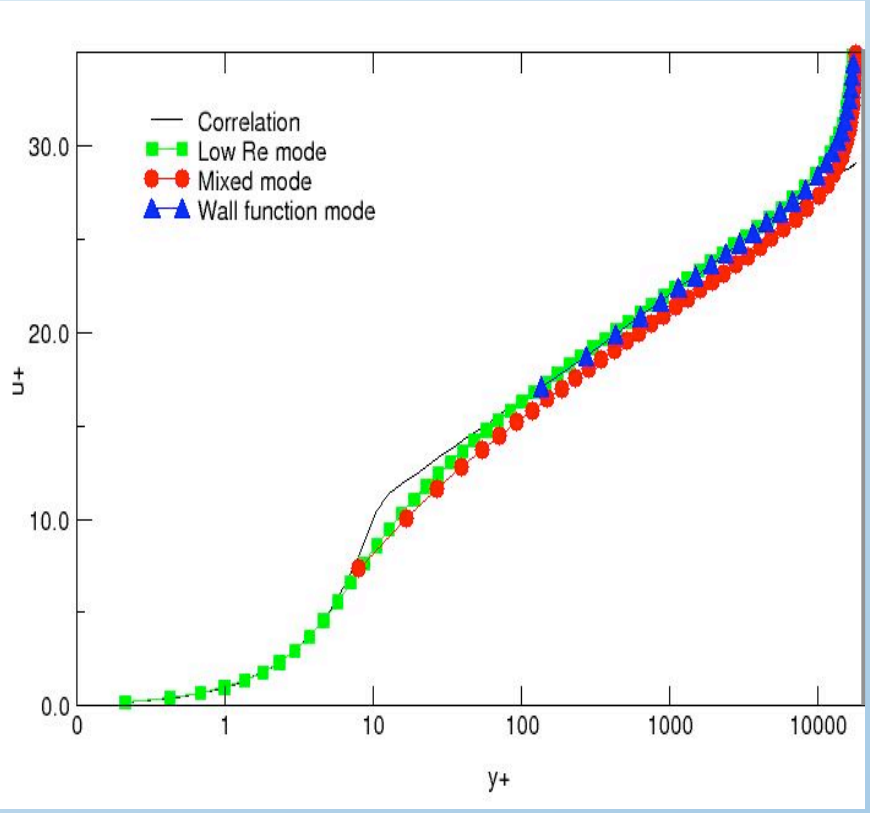


- Finite volume method for mixed unstructured meshes
- Fully conservative vertex based discretisation
- Co-located variable arrangement (pressure based)
- Rhie & Chow velocity-pressure coupling
- Fully coupled equation system (mass and momentum coupling)
- Implicit formulation – 1st and 2nd order backward Euler
- Algebraic multigrid solver
- Scalable parallelisation
- Second order time- and space discretisation
- Entire Re and Mach number range

Turbulence Models

- Wide range of turbulence models
  - One-equation KE1E
  - Two-equation (k-ε, k-ω, SST ..)
  - RSM (LRR, SSG, SMC-ω,…)
  - LES, DES, SAS
- AIAA drag prediction based on SST model:
  - Reliable separation prediction
  - high accuracy near walls (automatic wall treatment) – heat transfer validation
  - Robustness

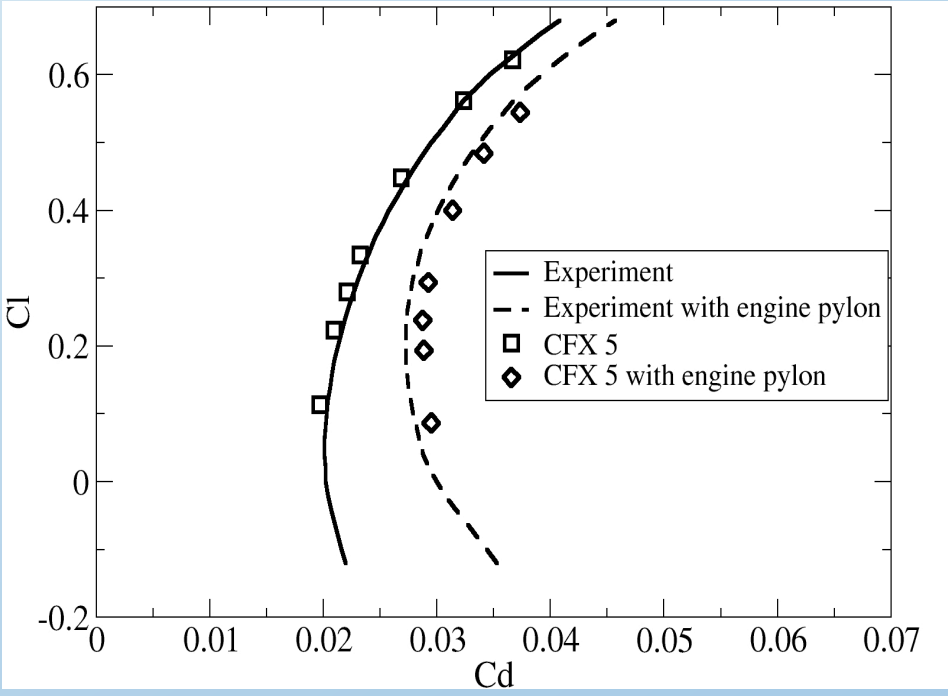
Automatic Wall Treatment



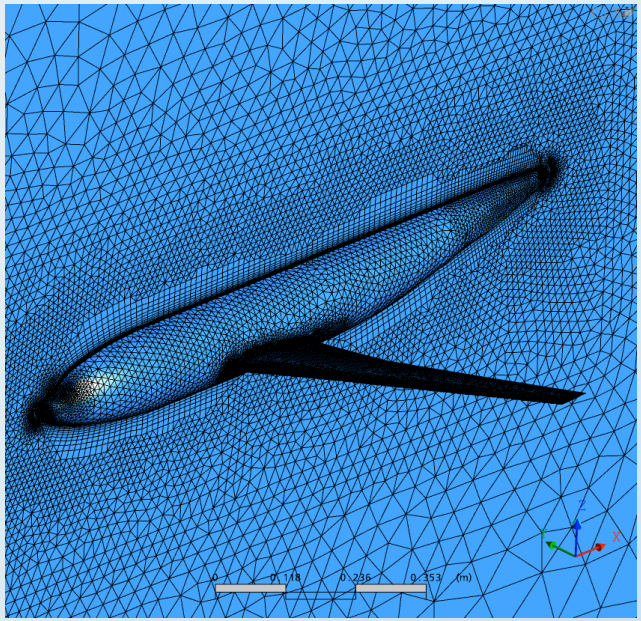
Goals

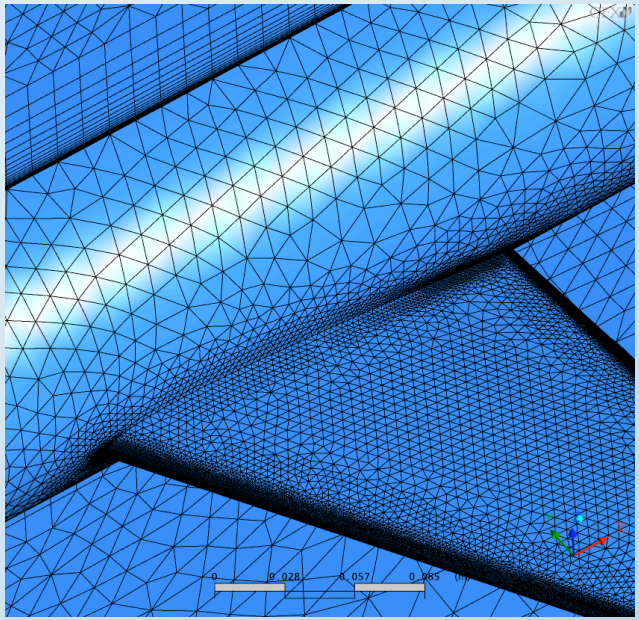
- Good results were obtained for the 2nd Drag Prediction Workshop using purely Hexahedral grids
- Goal of the present work was to investigate the accuracy and required grid sizes for unstructured tet/prism grids.

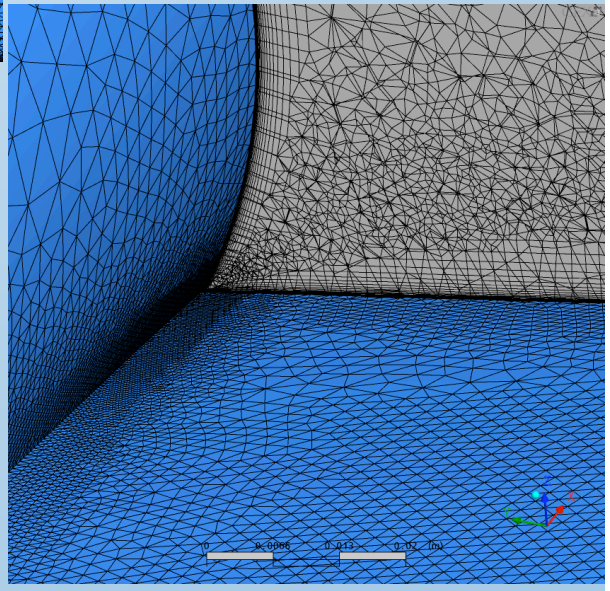
Drag Polar from the 2nd DPW using purely Hexahedral grids



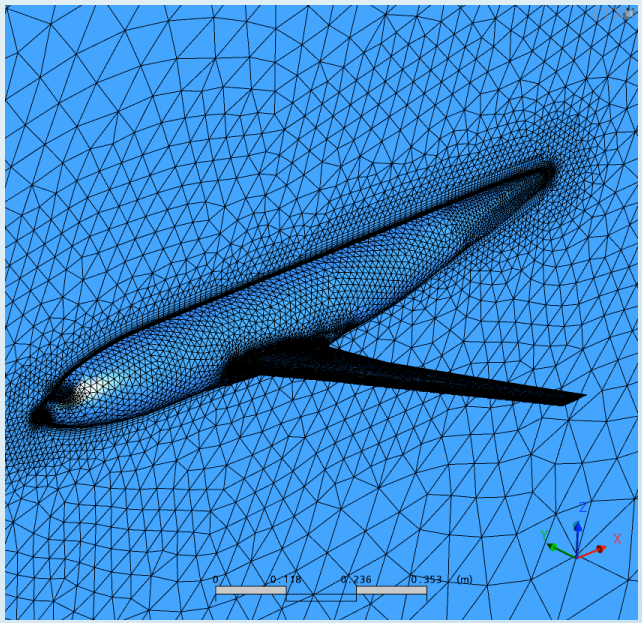
Grid CFX-Mesh (Tet/Prism) with out Fairing

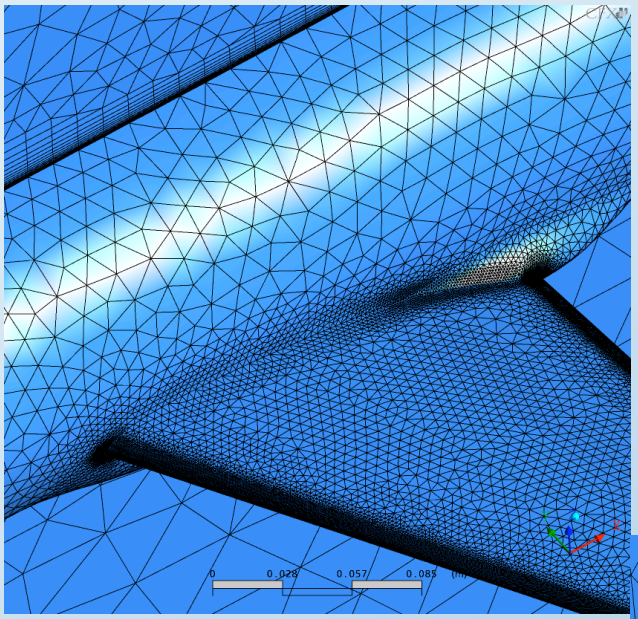


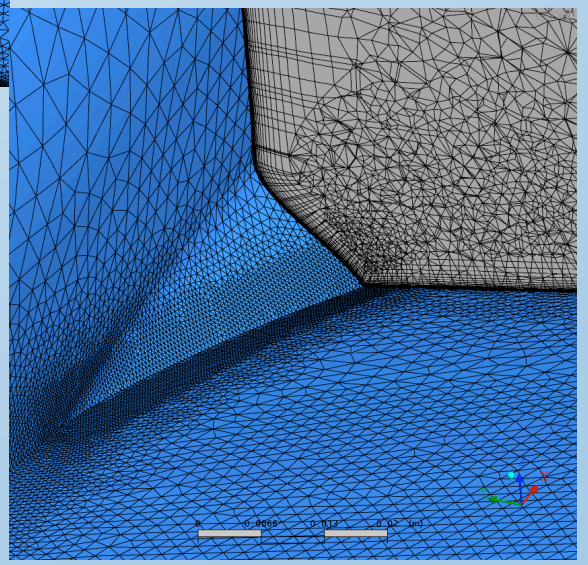




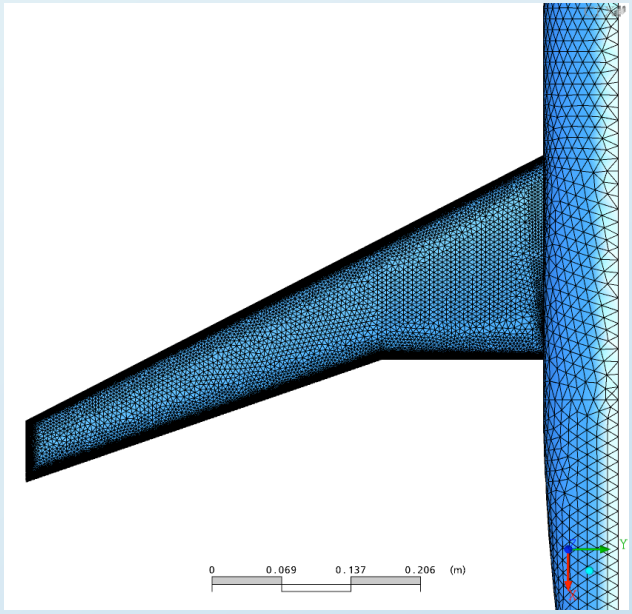
Grid CFX-Mesh (Tet/Prism) with Fairing



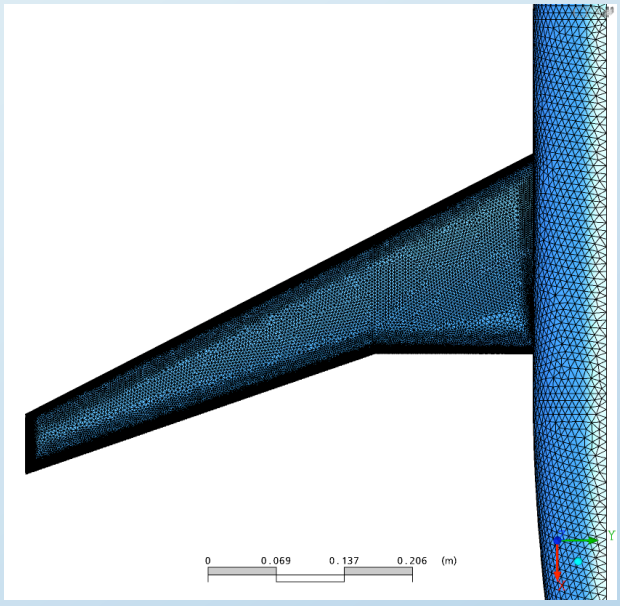




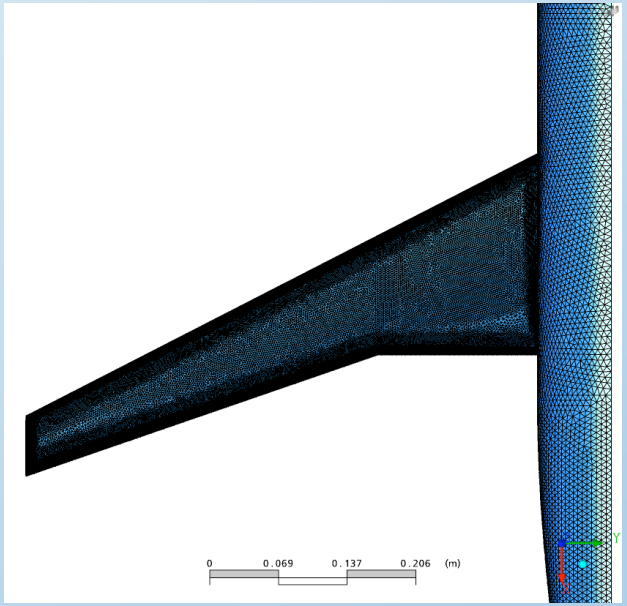
Grid CFX-Mesh (Tet/Prism) without Fairing



Coarse: 3 Million Nodes

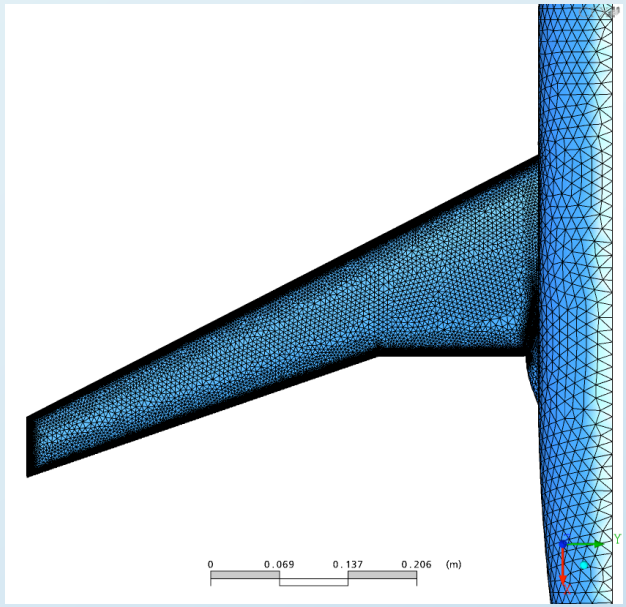


Medium: 8 Million Nodes

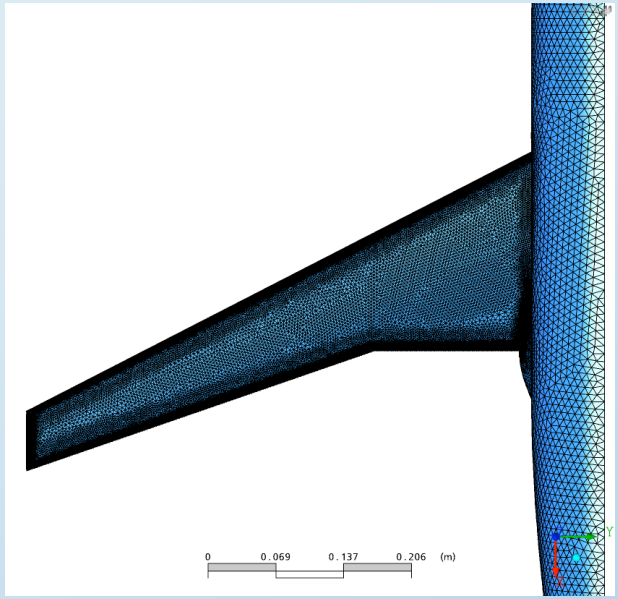


Fine: 18 Million Nodes

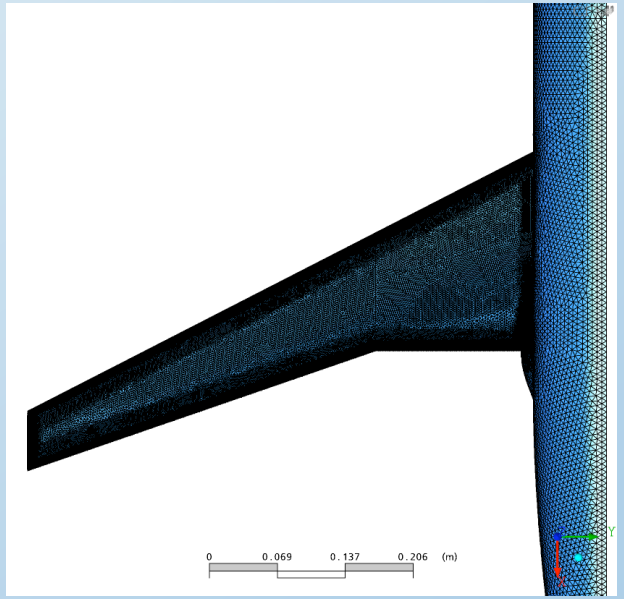
Grid CFX-Mesh (Tet/Prism) with Fairing



Coarse: 3.2 Million Nodes

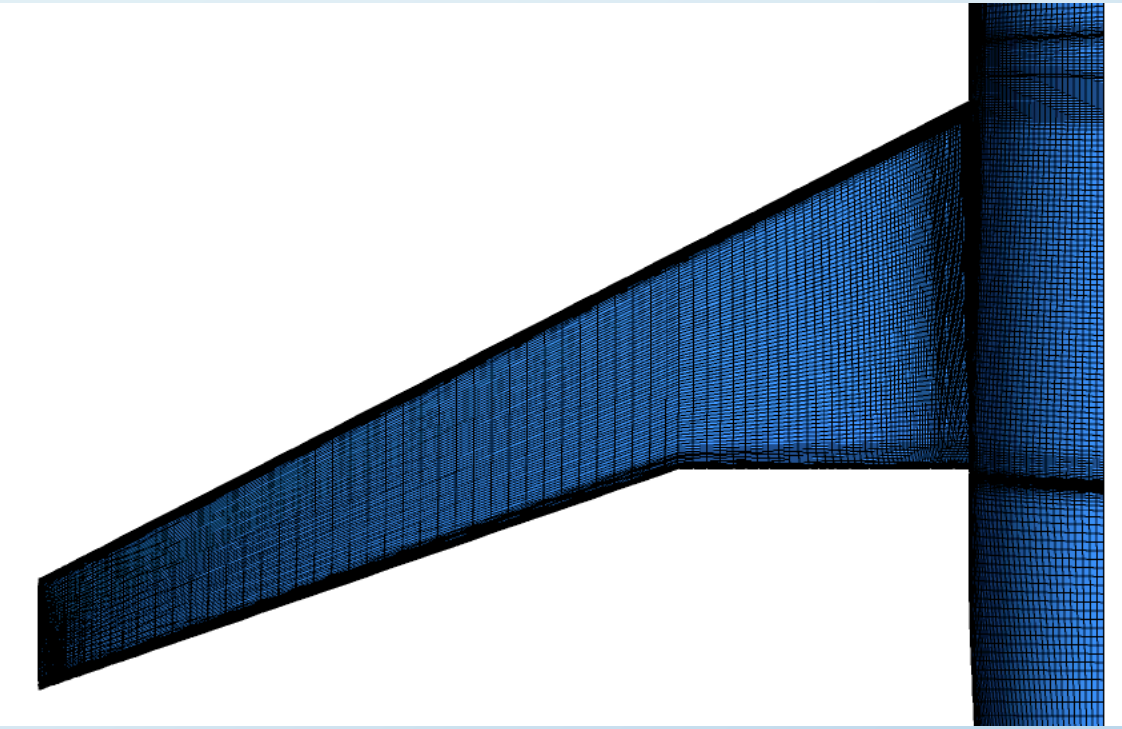


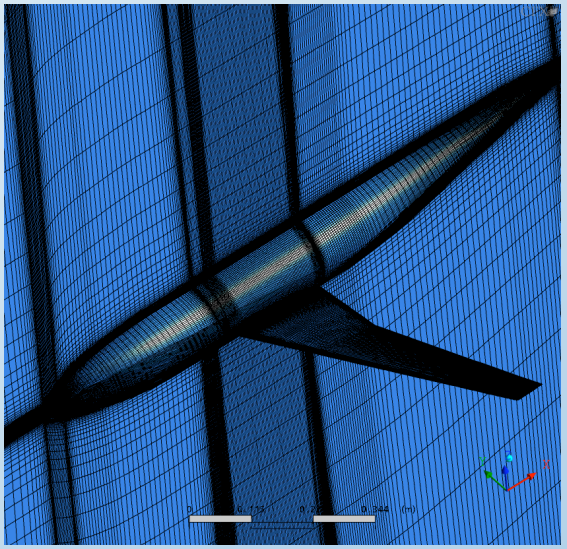
Medium: 8.3 Million Nodes

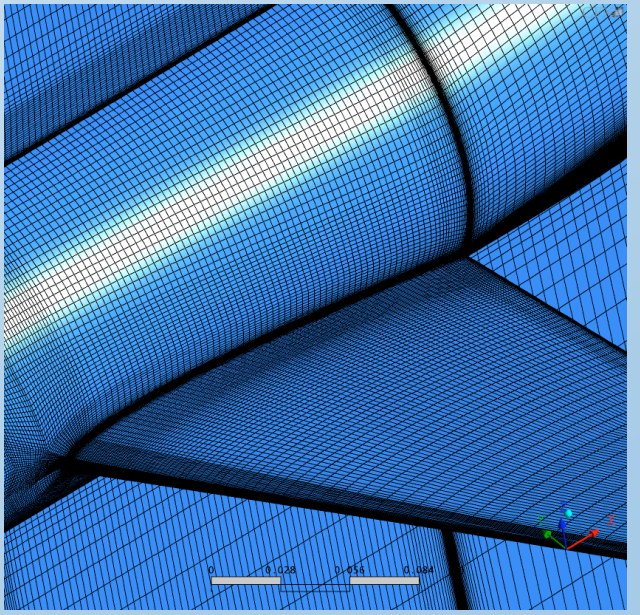


Fine: 20.5 Million Nodes

Grid Hexahedral Mesh



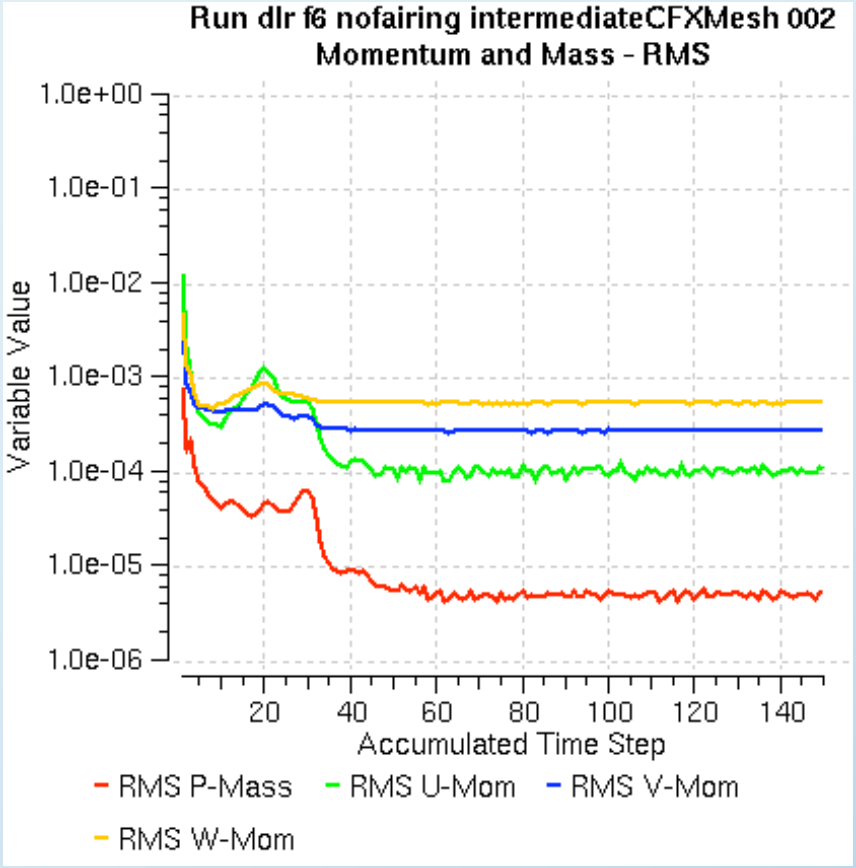


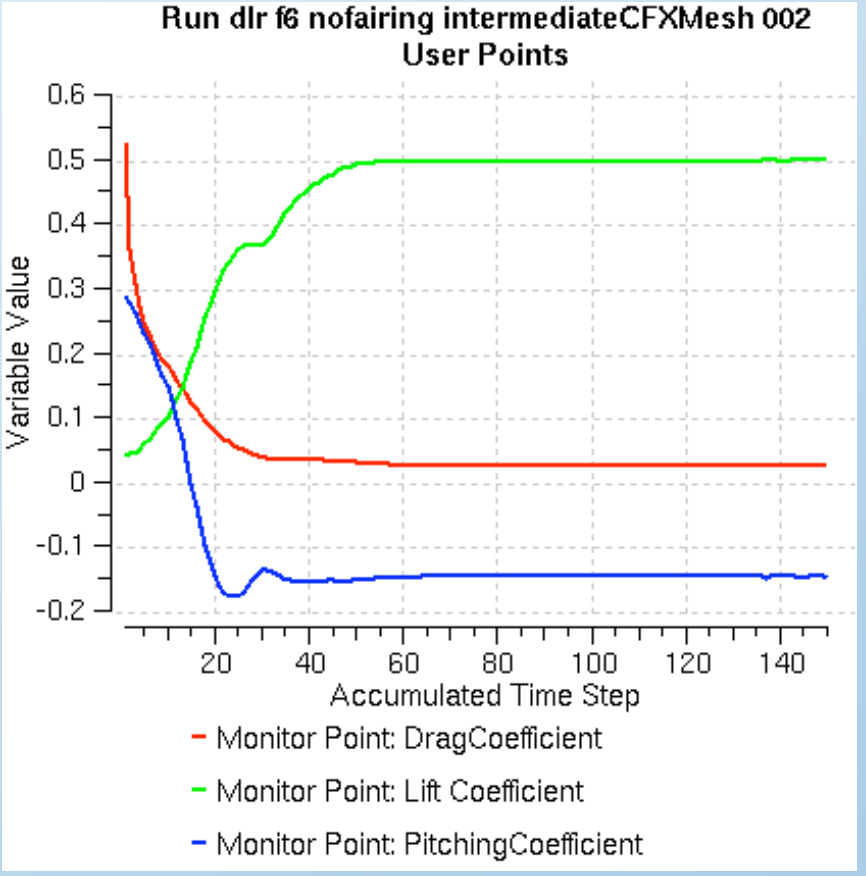


Time Integration

- For small time steps ($\Delta t \sim 1.x10^{-5}$) unsteady oscillations observed at wing-body separated zone (no fairing case).
- Computations carried out in unsteady mode
  - 3 coefficient loops
  - Start with a small time step ($\Delta t \sim 1.x10^{-5}$) and slowly ramp up to a large time step ($\Delta t = 2.x10^{-4}$) to damp unsteadiness
- Convergence reached in ~80-150 time steps
- Computing times ~20-40h
  - 20 million nodes (45 GB memory)
  - 21 Dual Core Nodes 2.4GHz Opteron HP Proliant Linux cluster.
- Note that steady state simulations are factor 3 faster (no coefficient loops).

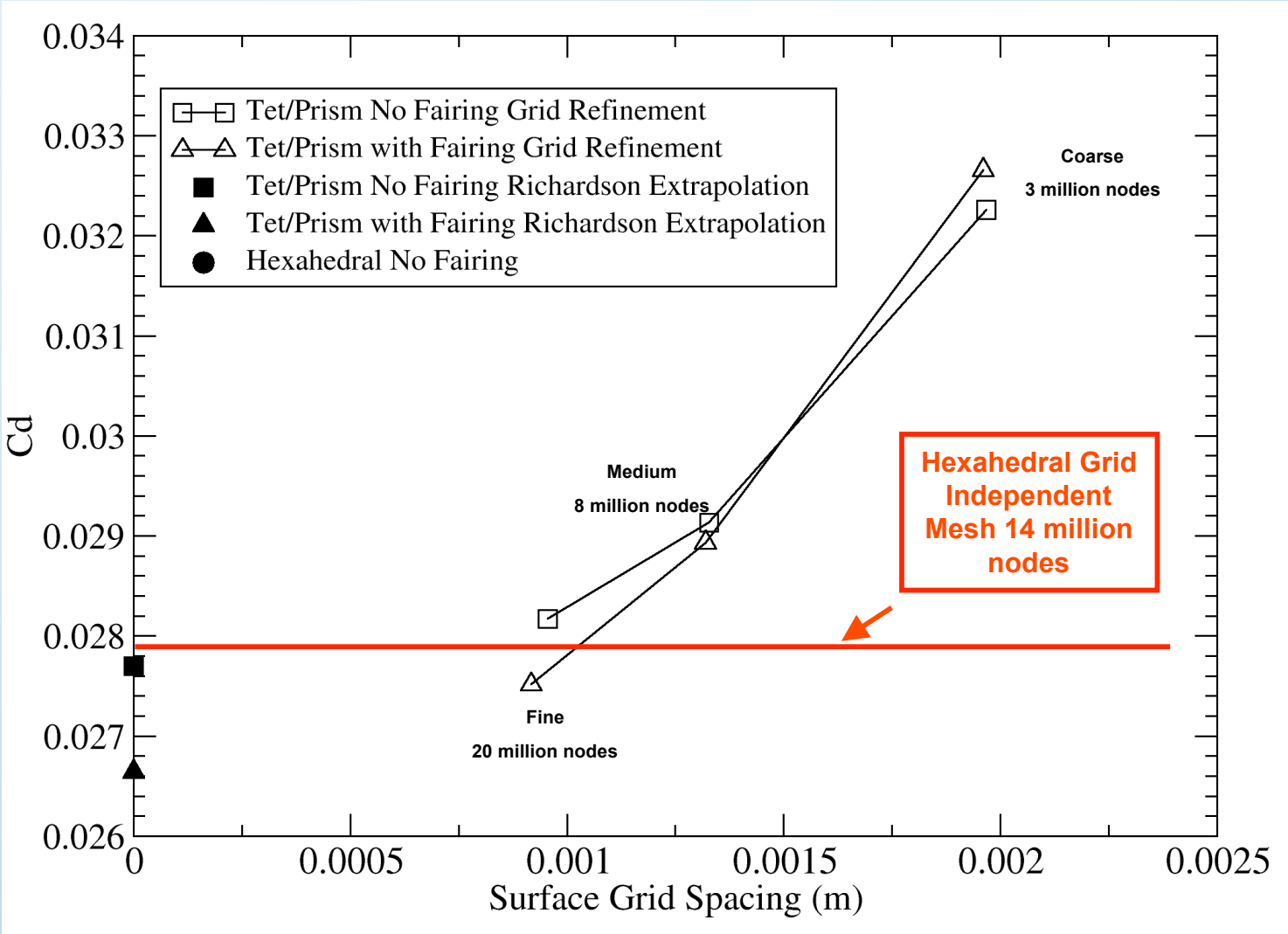
Convergence History



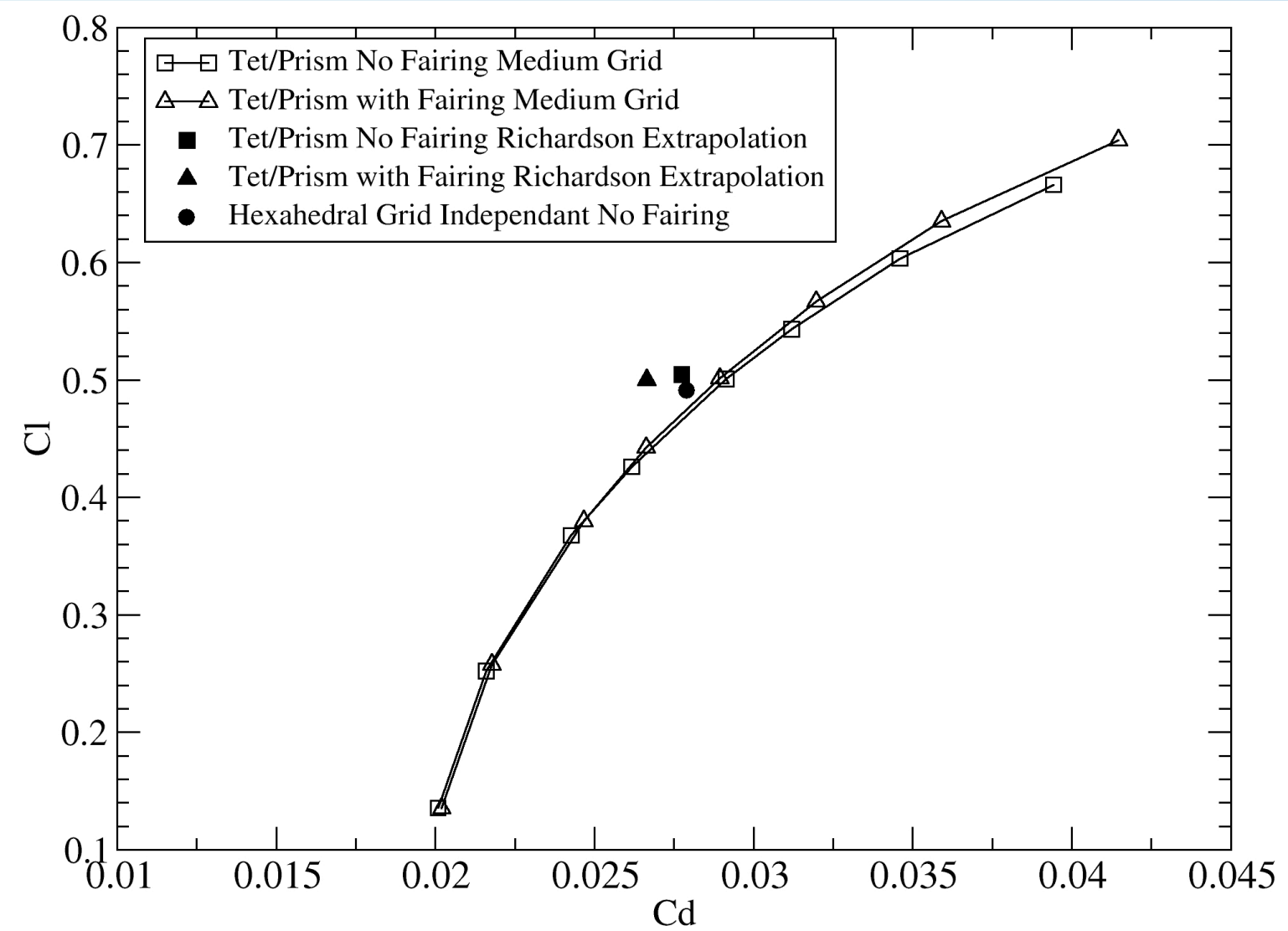


- **Unsteadiness damped by large time step $\Delta t=2x10^{-4}$ s**
- **Good convergence in forces after 75-150 time steps**

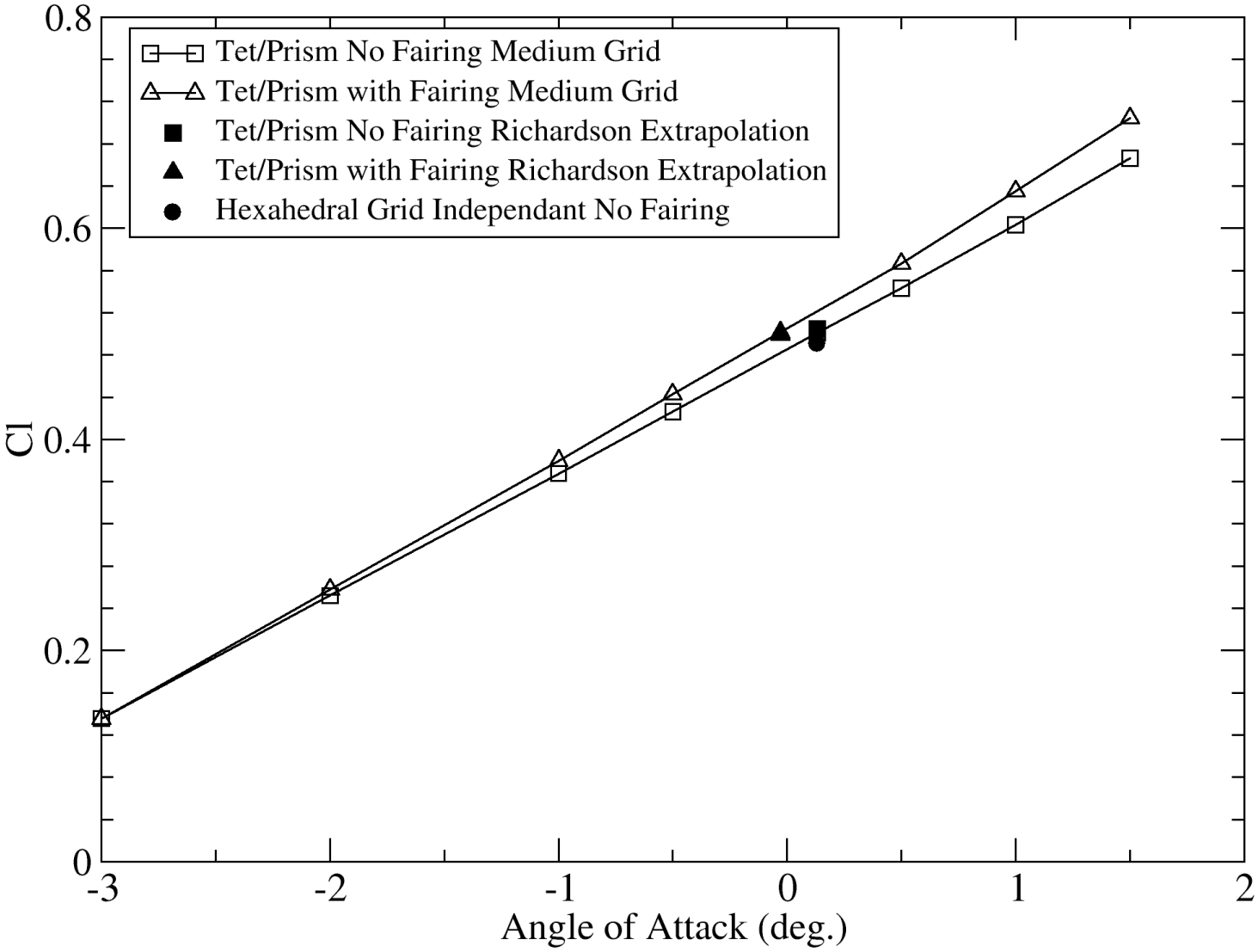
Grid Convergence/Richardson Extrapolation



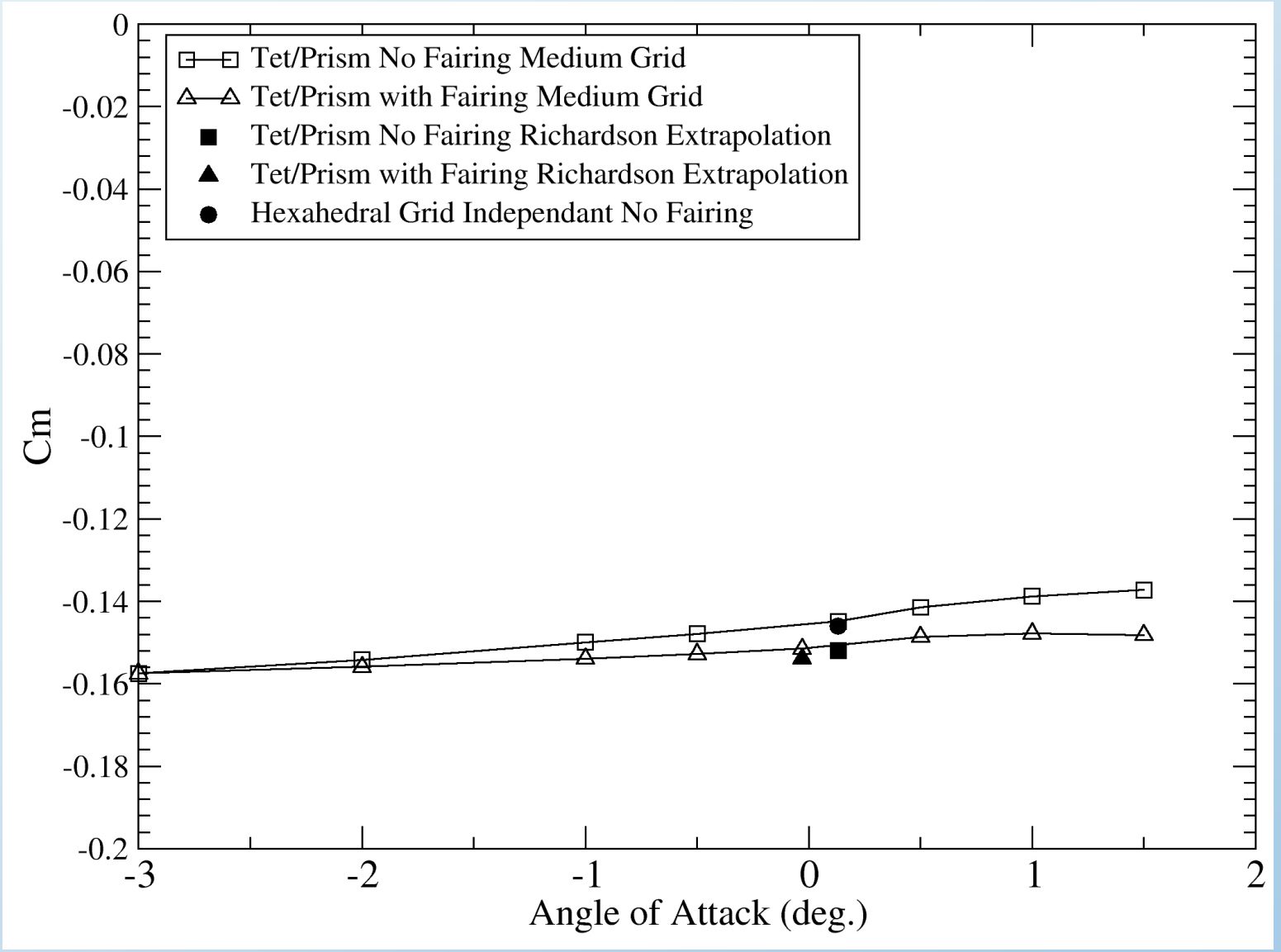
Drag Polar



Lift Curve

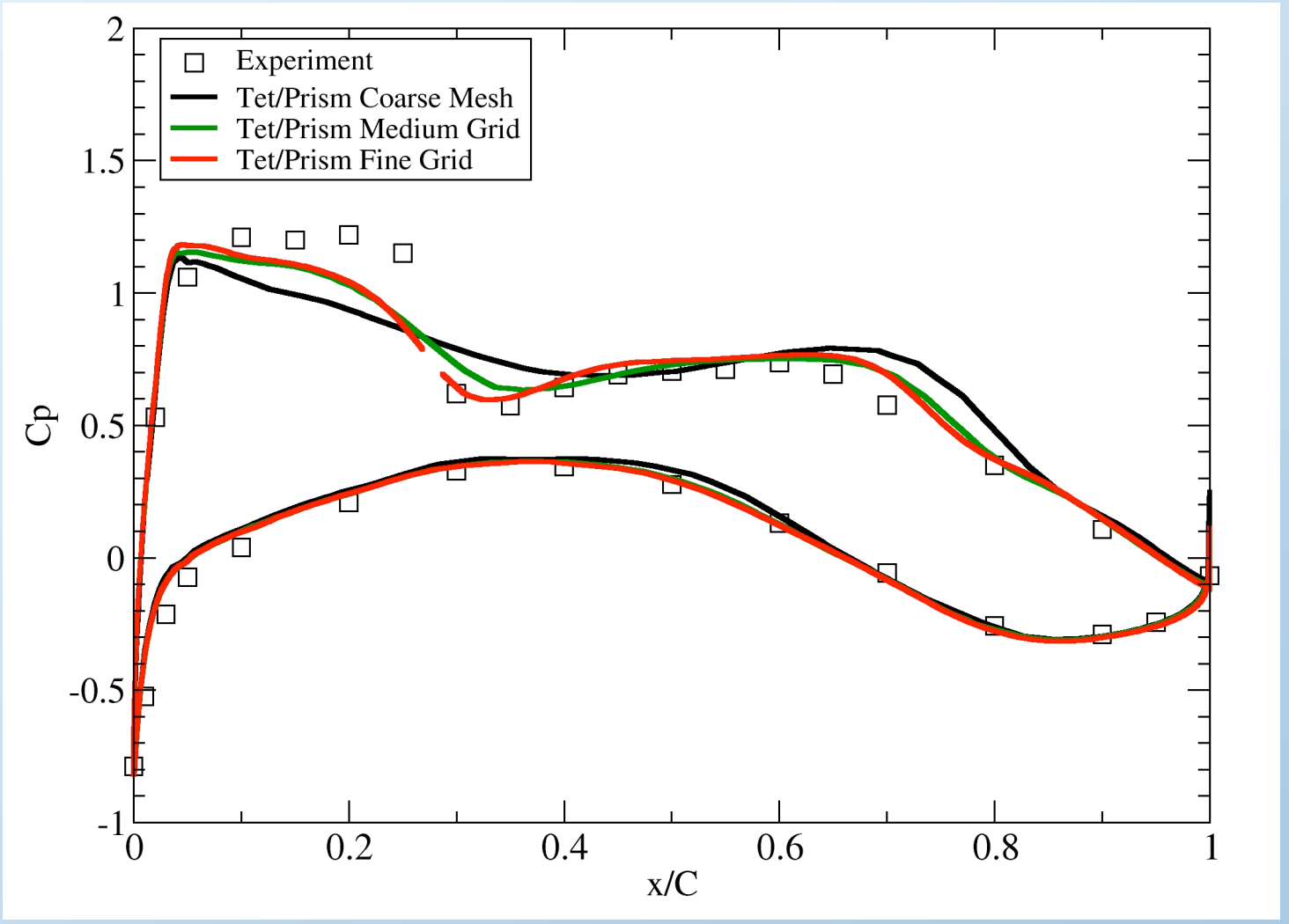


Lift Curve

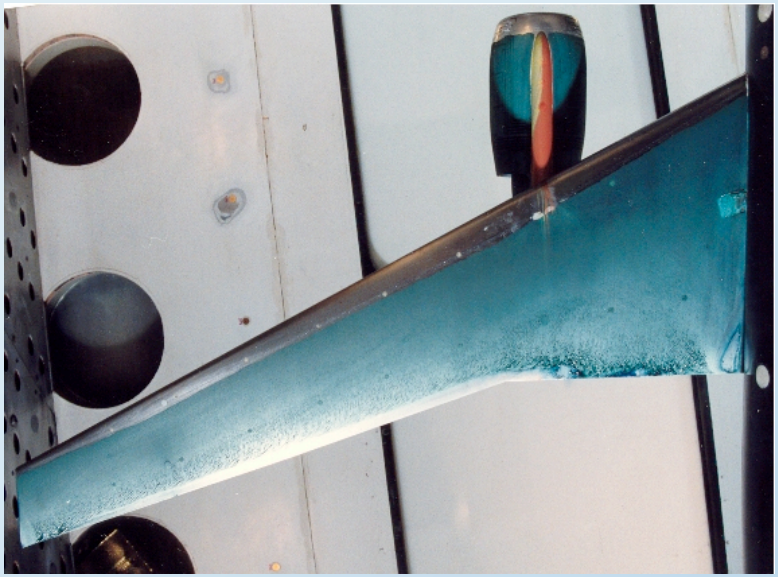


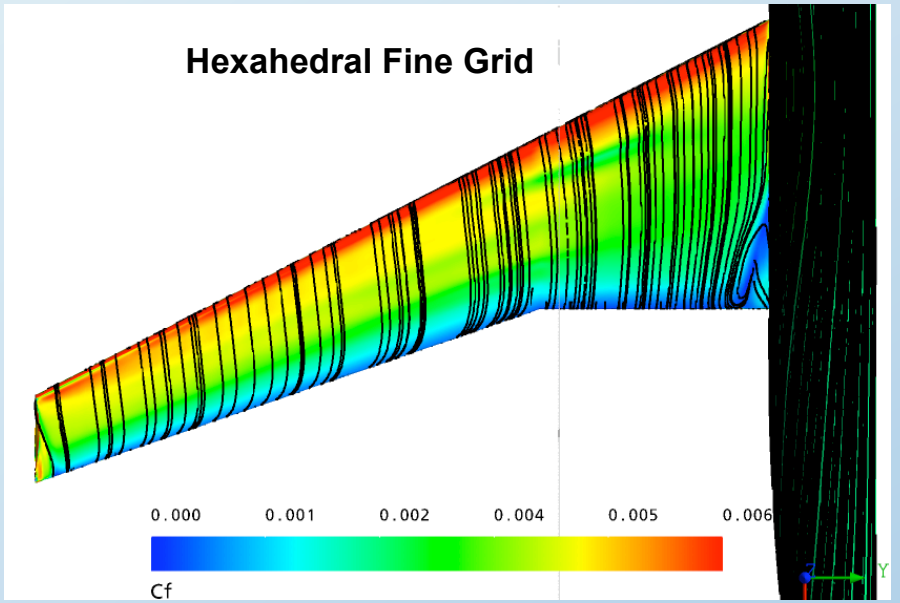
Cp Distributions WB no Fairing
Effect of Grid Refinement

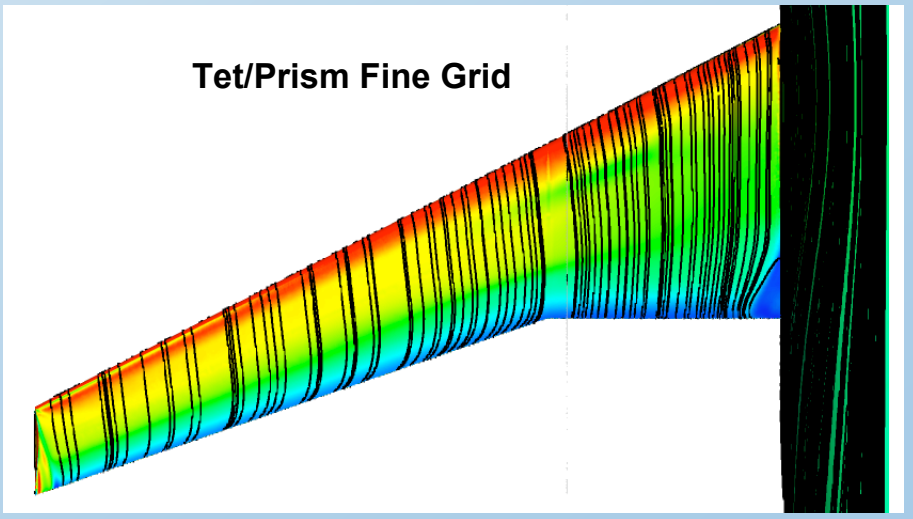
0.377 Span



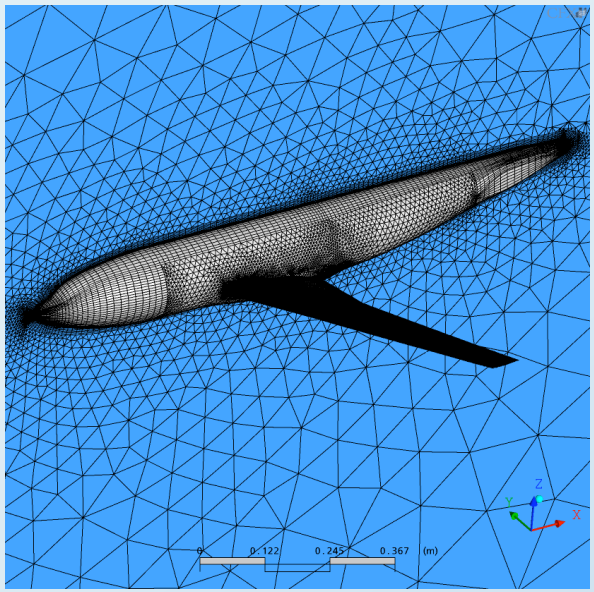
Upper Surface Flow Vis.

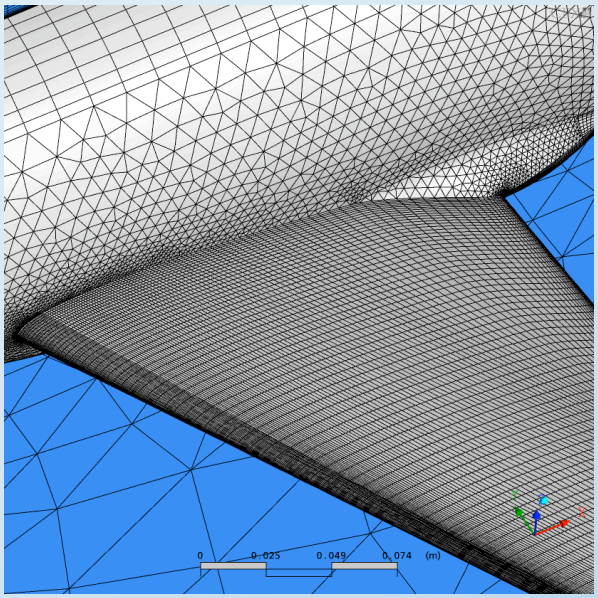


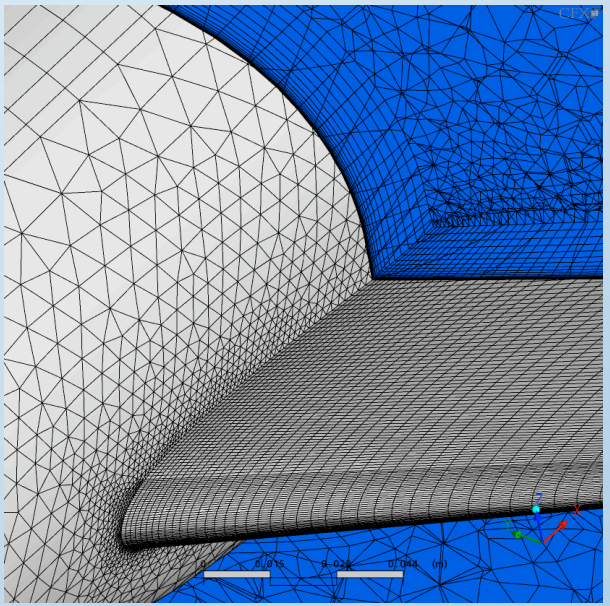


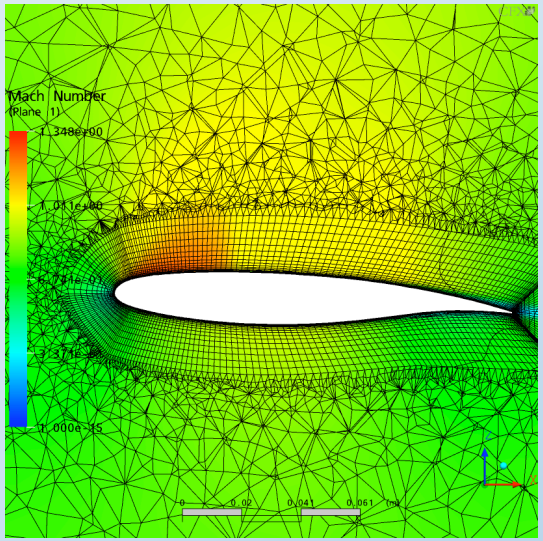


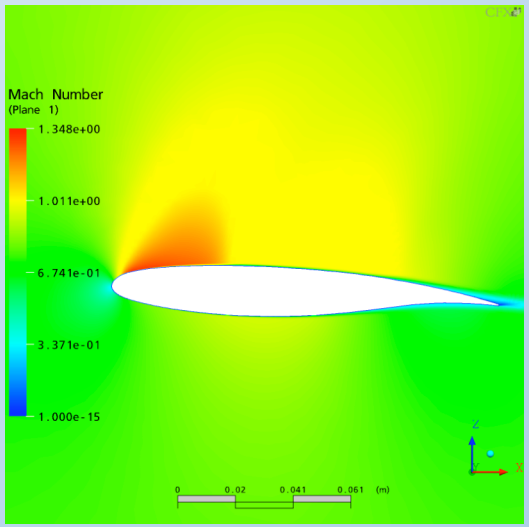
New ICEM Hybrid Meshing Approach











Summary

- High grid requirements for tet/prism mesh
  - Grid independence not achieved for 20 million nodes
- Richardson extrapolation performed Proper grid refinement achieved?
- Hexahedral grid independent at approx. 12 million nodes(?)
- Future goal: Hybrid approach using hexahedral in BL, tetrahedral every where else (see next slide)