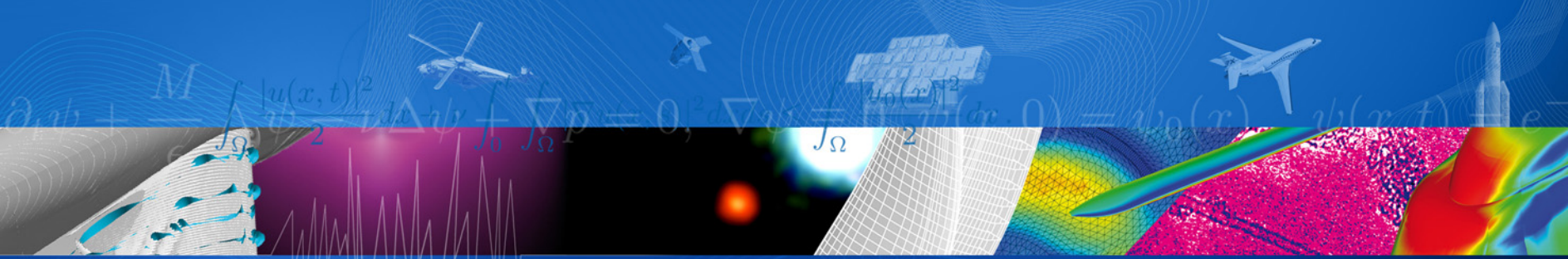

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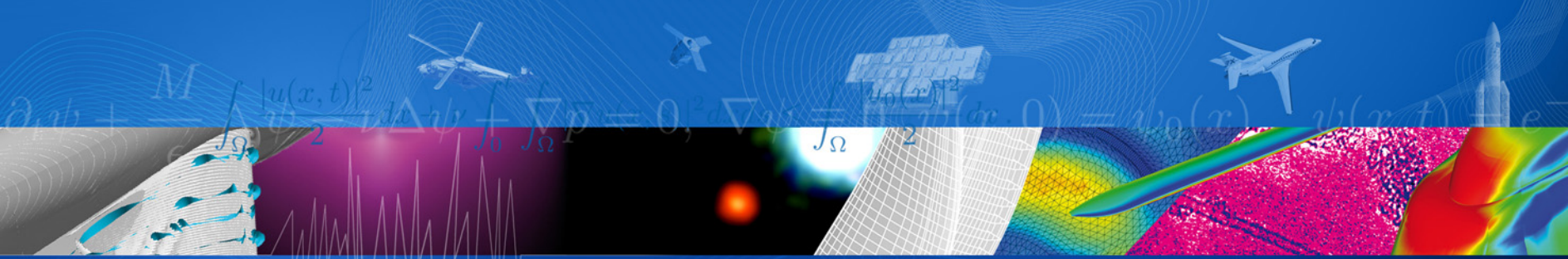

ONERA Contribution to HiLiftPW-2

L. Wiart
Aerospace Engineer, Civil Aircraft Unit, Applied Aerodynamics Department

2nd AIAA CFD High Lift Prediction Workshop
22-23 June 2013, San Diego, California

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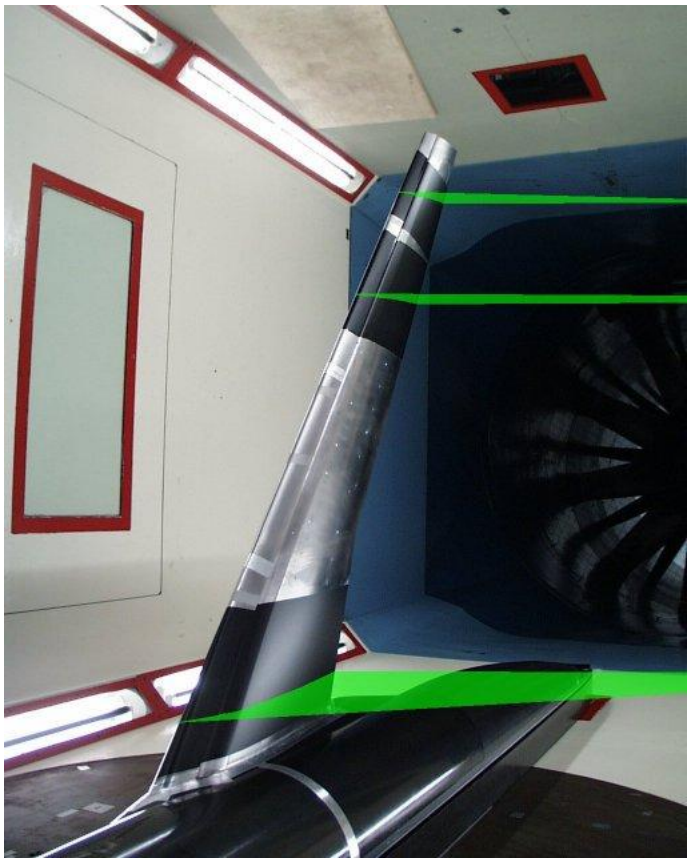
Outline

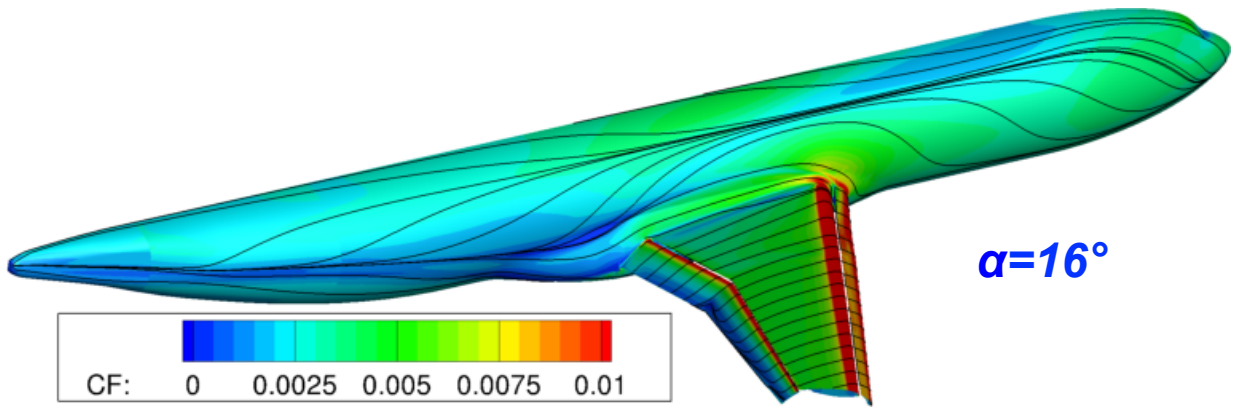
- *elsA* CFD software
- Grid convergence study
- Point-matched VS overset grids
- Conclusions
- Future work



DLR F11 model

elsA CFD software

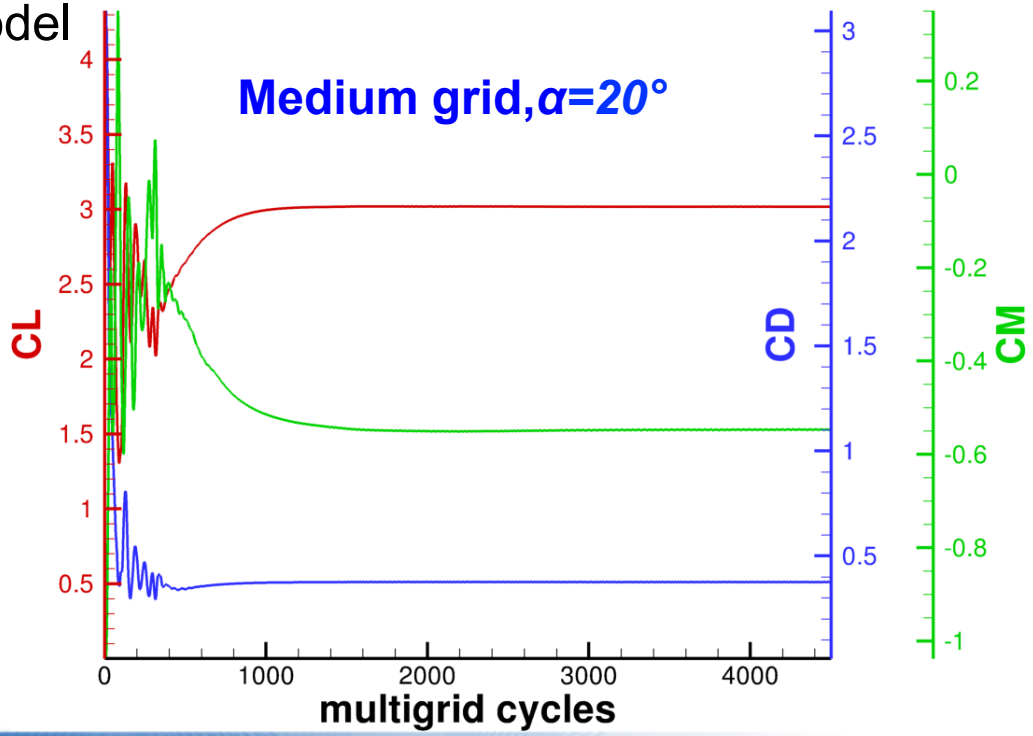
- Developed by ONERA, wide industrial use (Airbus, Snecma, Eurocopter…)
- Cell-centered finite volume on structured multi-block meshes
- CGNS input and output format
- Built-in Chimera capabilities
- Additional tools available in the Cassiopée package (blanking …)
- Hybrid capabilities currently under development



Grid convergence study

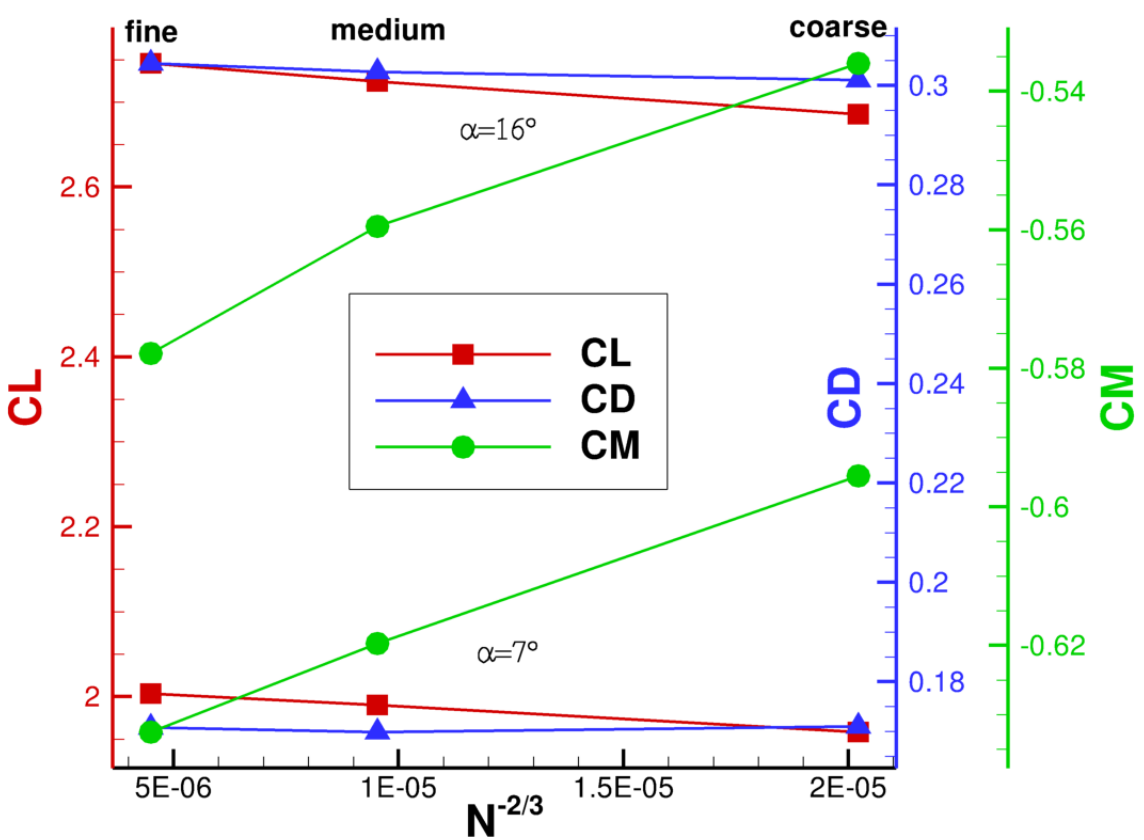
CFD settings

- *elsA* settings
  - Full Navier-Stokes equations
  - Time integration: Backward-Euler scheme with LU-SSOR relaxation
  - Spatial discretization: Jameson's second-order centered scheme
  - Fully-turbulent calculations
  - Spalart-Allmaras turbulence model
  - Low-speed preconditioning
  - V-cycle multigrid technique
  - Local time-stepping, CFL=20
  - All calculations from scratch
- Aerodynamic conditions
  - Re=15.1M based on MAC
  - M=0.175

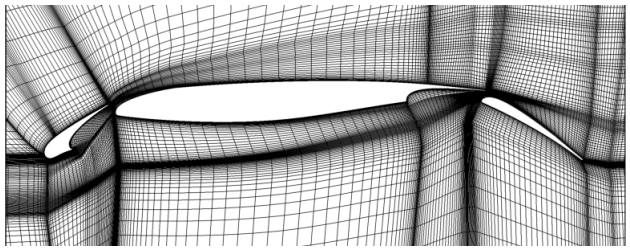


Effect of grid refinement

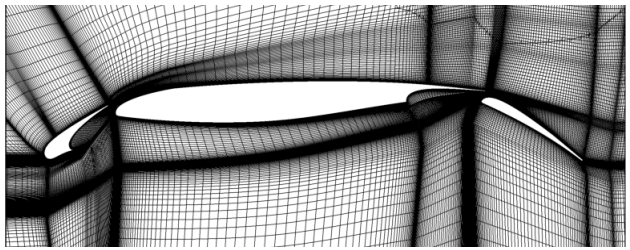
- A series point-matched structured grids (committee provided)
- Grid refinement leads to higher lift and drag and more negative pitching moment
- Maximum variations: 2.3% on CL, 1.1% on CD and 7.8% on CM



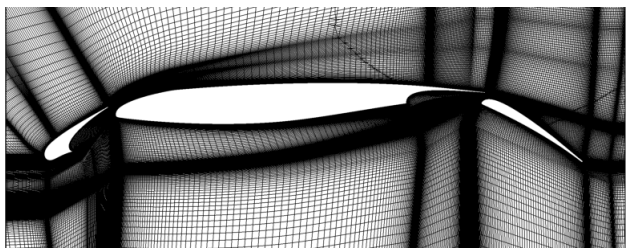
Influence of grid refinement on aerodynamic coefficients



- Coarse: 11×10^6 points



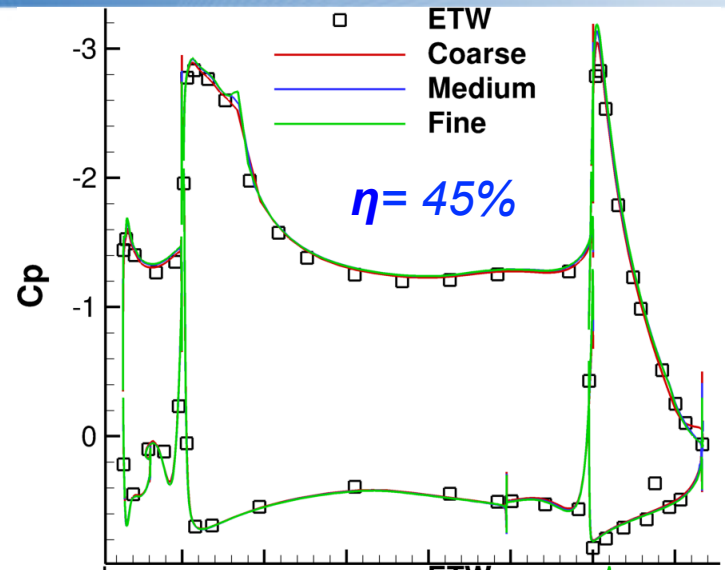
- Medium: 34×10^6 points

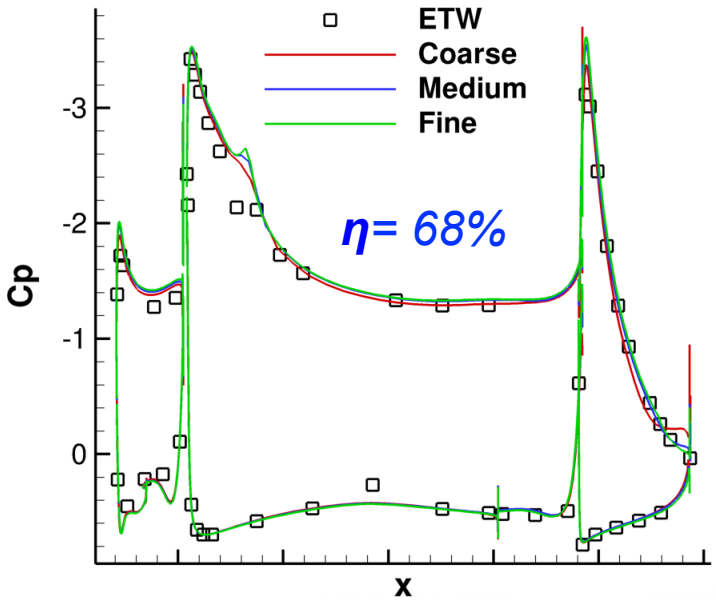


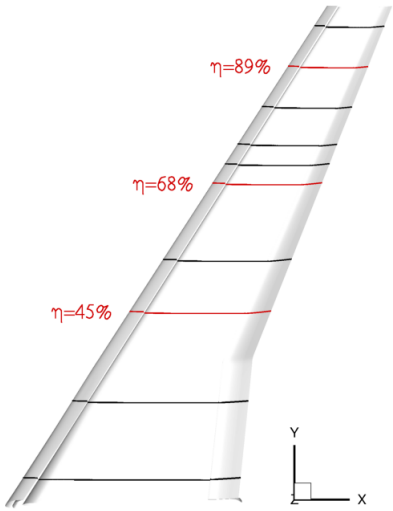
- Fine: 105×10^6 points

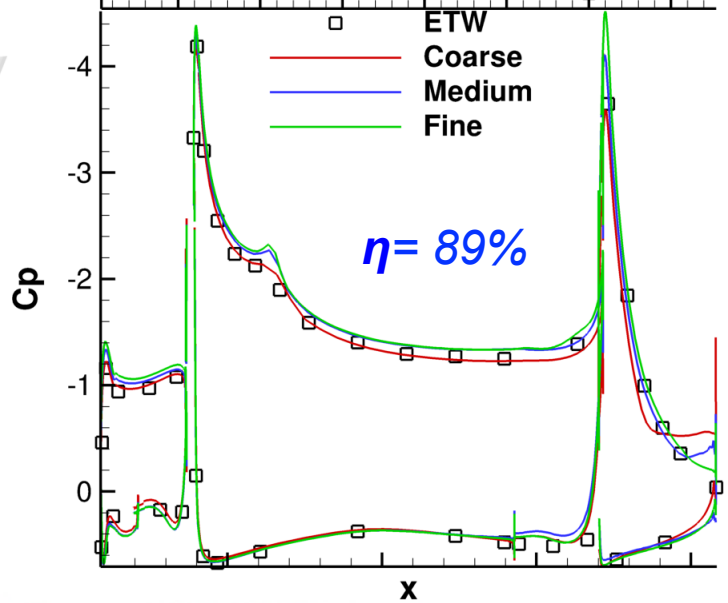
Cp distribution (α=7°)

- Effects of grid refinement visible mainly in the outboard part of the span
- Most visible difference on flap separation prediction, impacting all the two upstream wing elements as a consequence



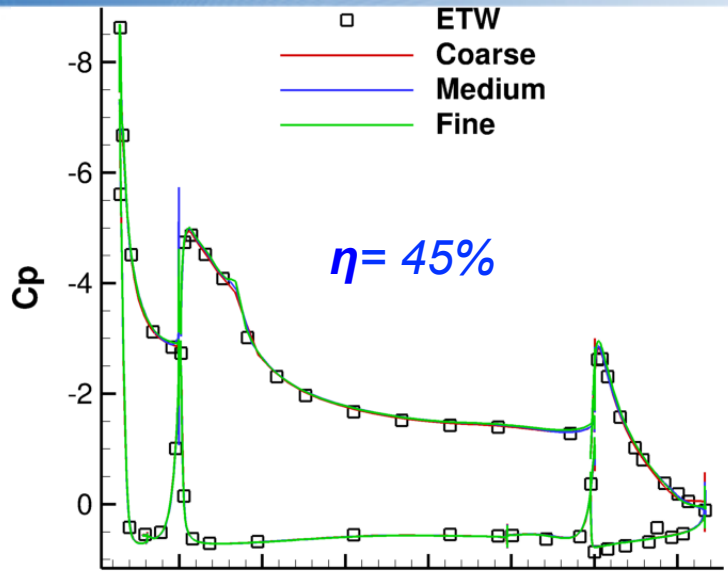


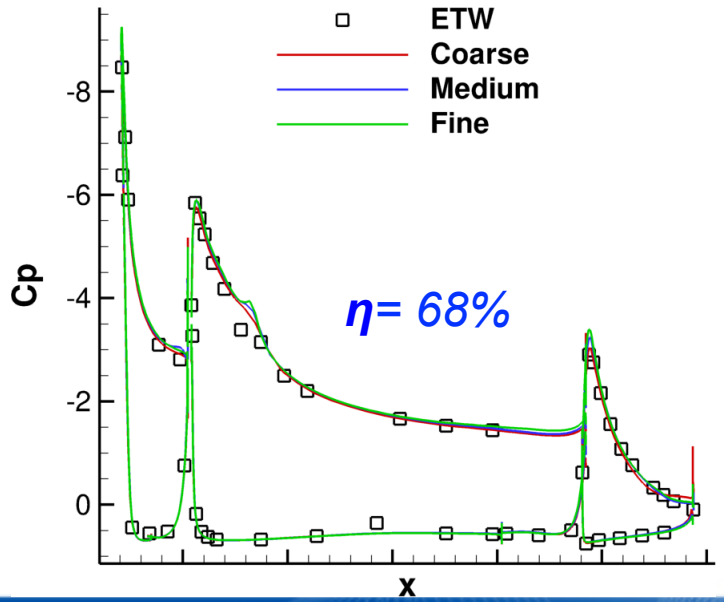


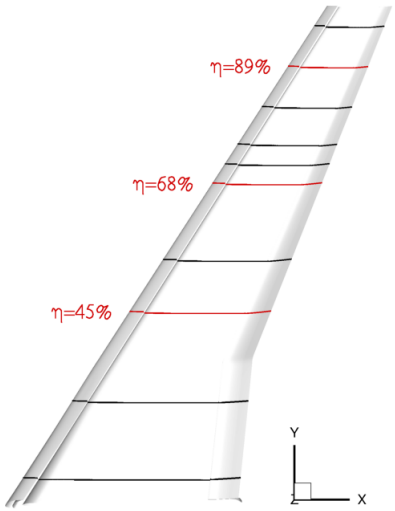


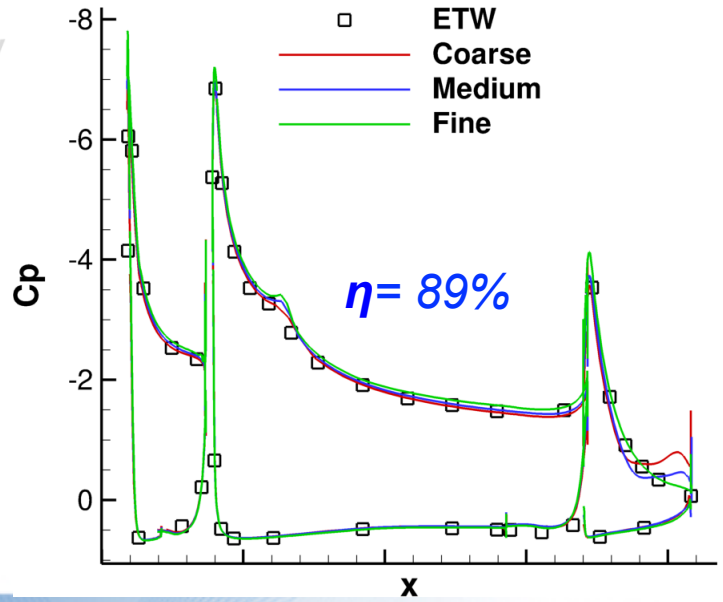
Cp distribution (α=16°)

- Same conclusions concerning the grid refinement effect as for α=7°
- Running the extra-fine grid would be interesting to see if that flap separation issue has indeed settled down





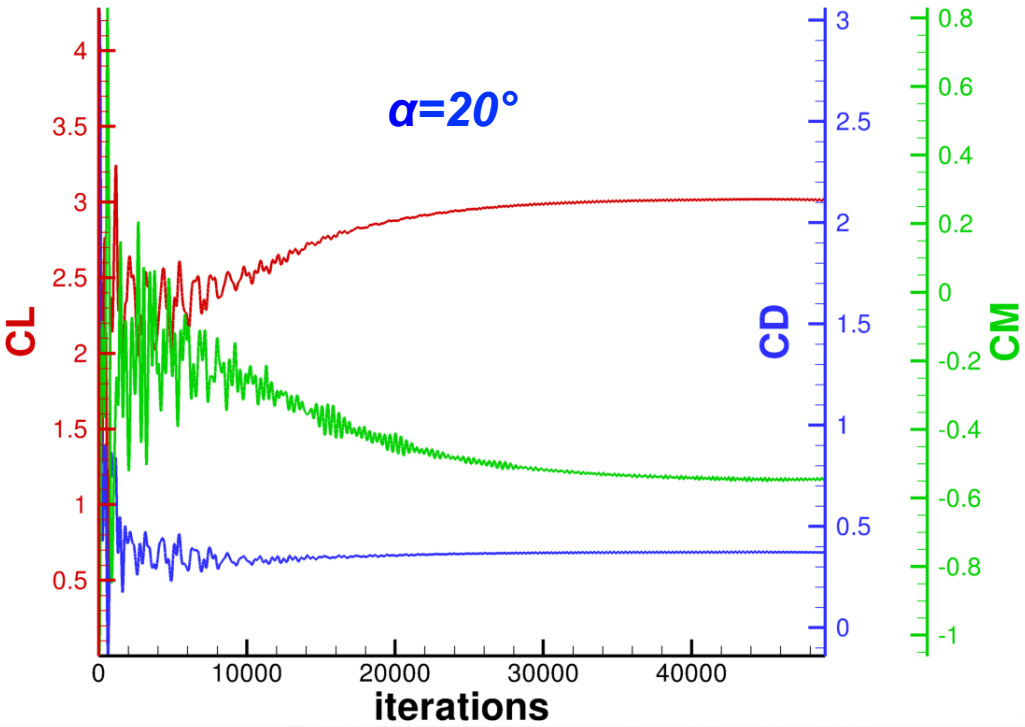


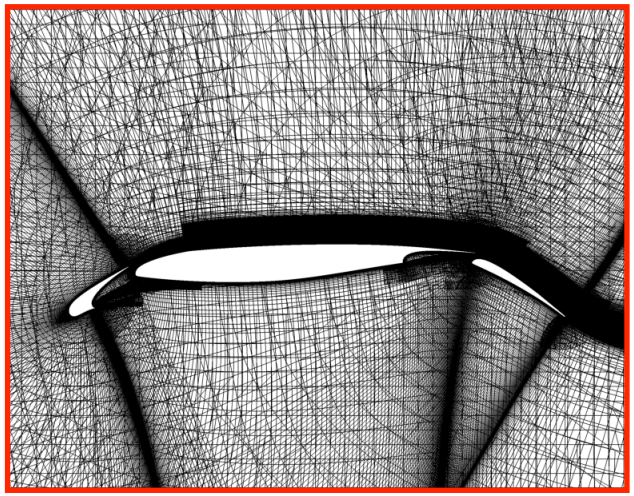


Point-matched VS overset grids

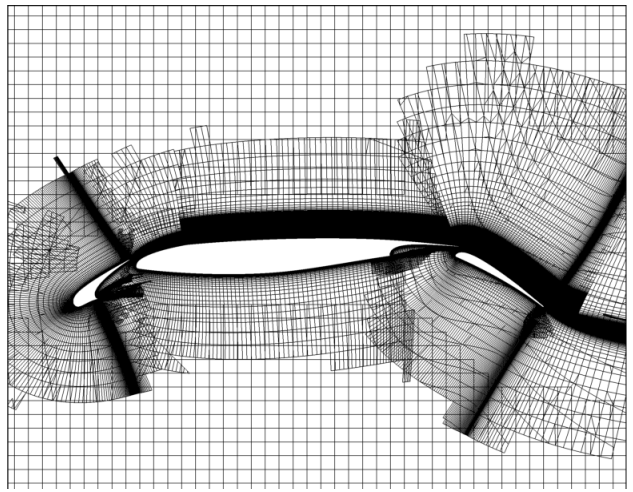
CFD settings

- E medium overset grid (committee provided)
- Body blanking / no overlap optimization
- *elsA* settings (same as before except):
  - no multigrid (provided grids do not allow it)
  - CFL=1 for robustness issues





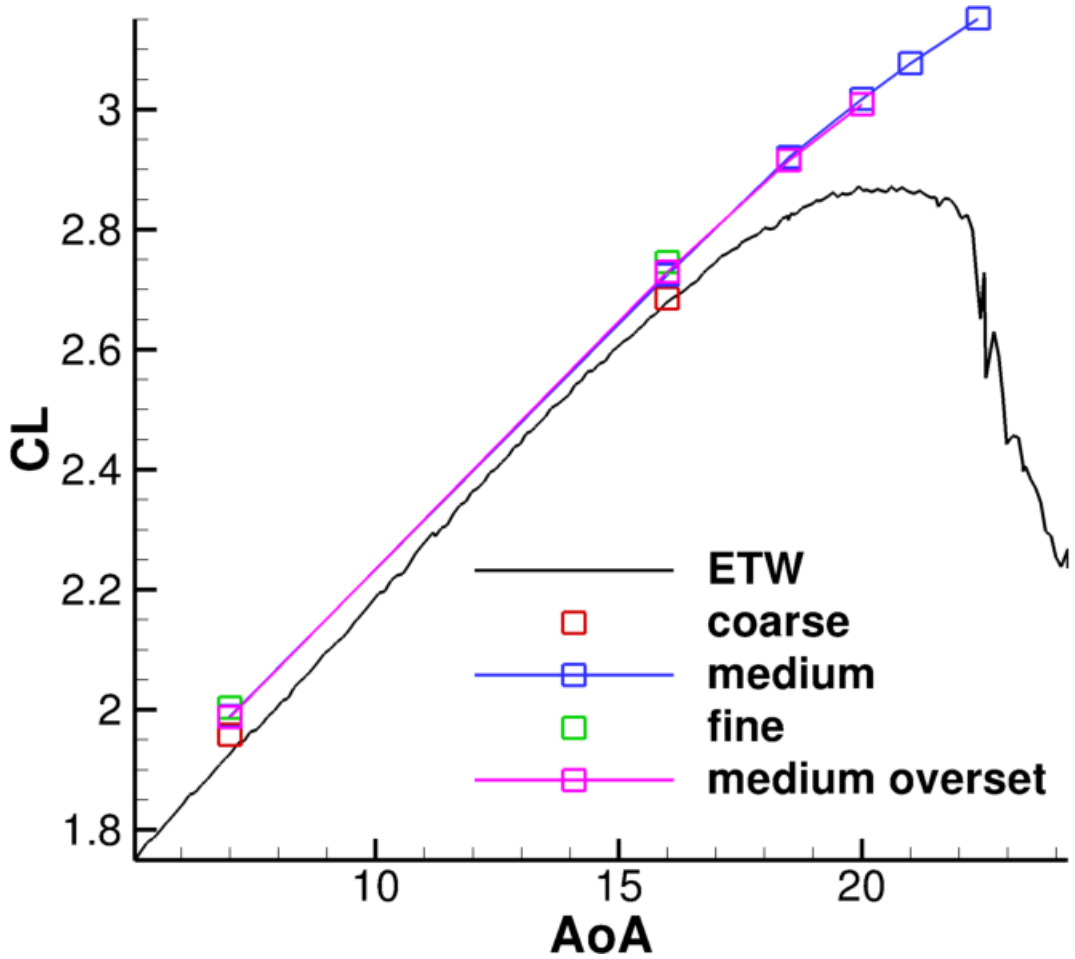
without overlap optimization



optimization performed by Boeing

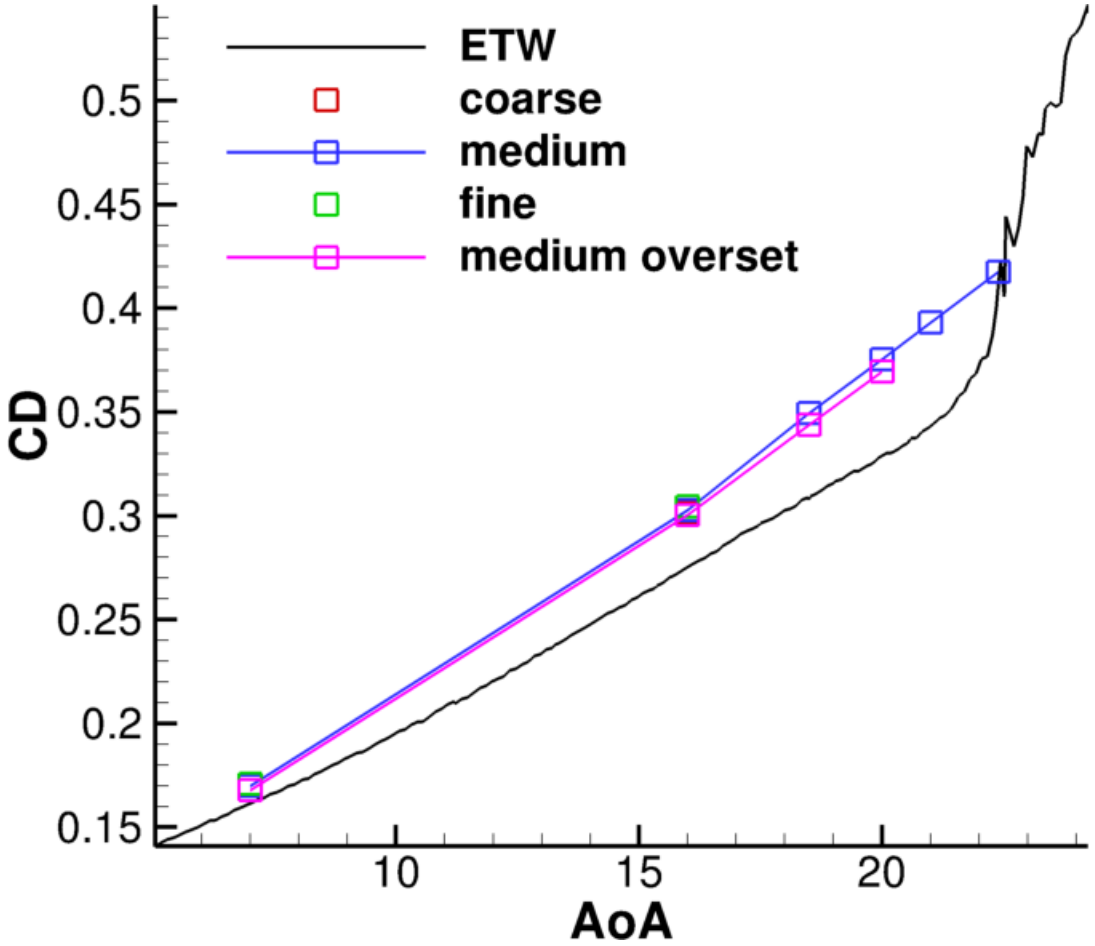
Lift

- Excellent agreement between point-matched and overset medium grids
- Overpredicted lift level. This was expected (no tracks)
- Neither predicts the CL_{max} region accurately
- Fully turbulent flow seems a reasonable hypothesis at that Re_c
- Most of the discrepancies with the tests are then probably related to slat/flap tracks, driving the lift breakdown



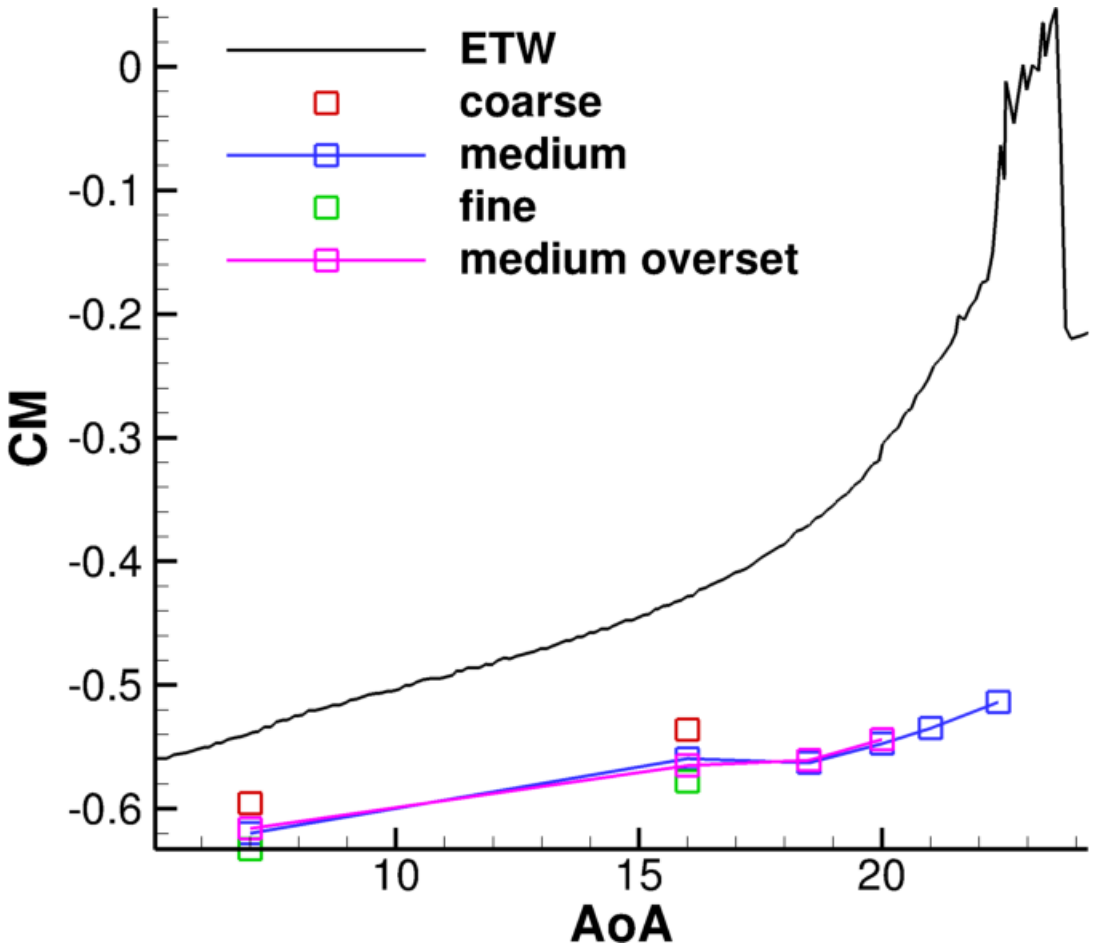
Drag

- Excellent agreement between point-matched and overset medium grids
- Overpredicted drag level. This is logical since lift induced drag is clearly dominating is such landing configuration and its proportion increasing with AoA
- Including the slat/flap tracks should decrease lift and consequently the drag level as well



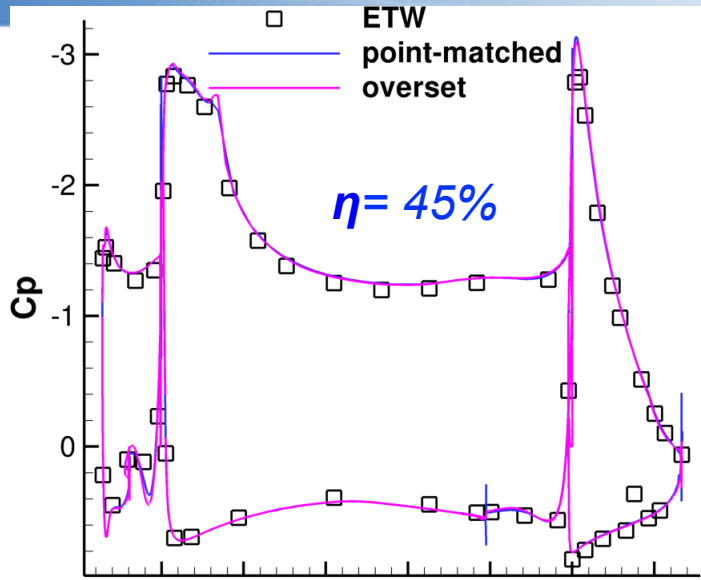
Pitching moment

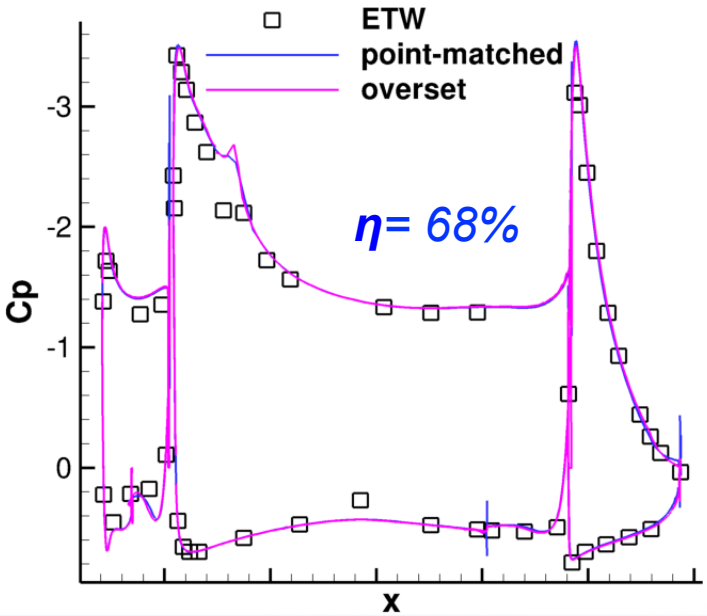
- Excellent agreement between point-matched and overset medium grids
- This coefficient is likely to be largely influenced by the flap track fairings that are expected to reduce the lift generated by the flap in large portions of it

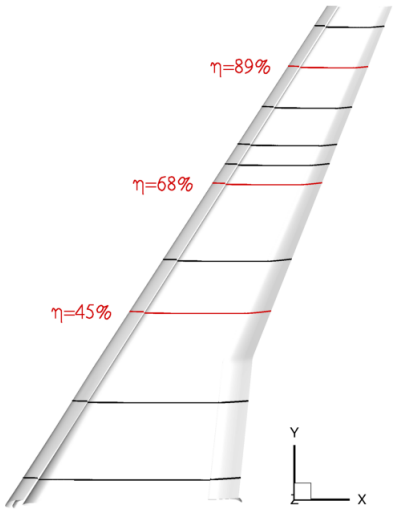


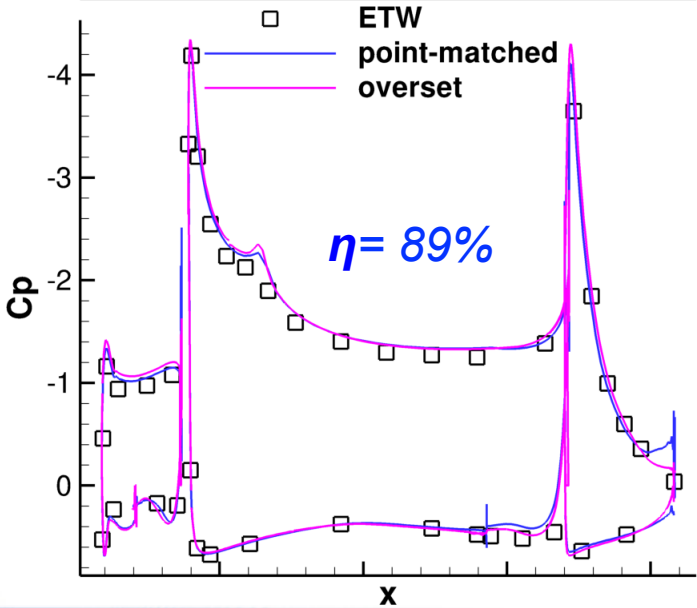
Cp distribution (α=7°)

- Good agreement between pressure levels obtained on point-matched and overset medium grids
- Only differences appear outboard on the flap where the medium overset behaves more like the fine point-matched grid



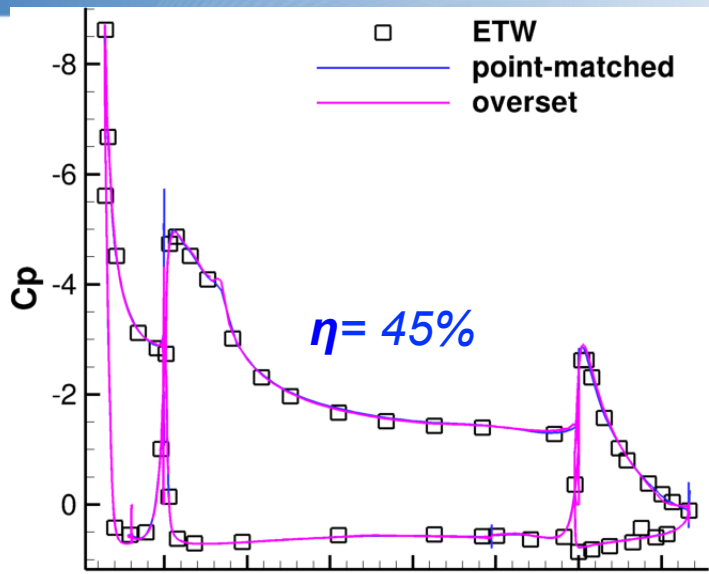


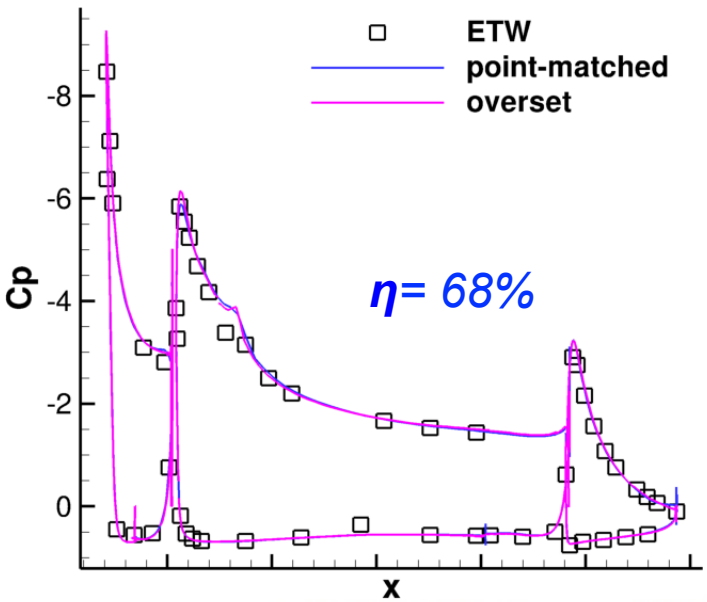


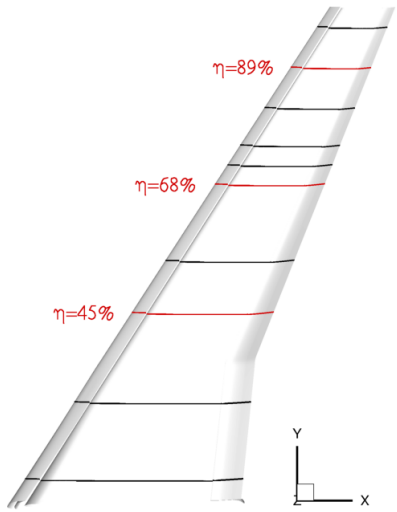


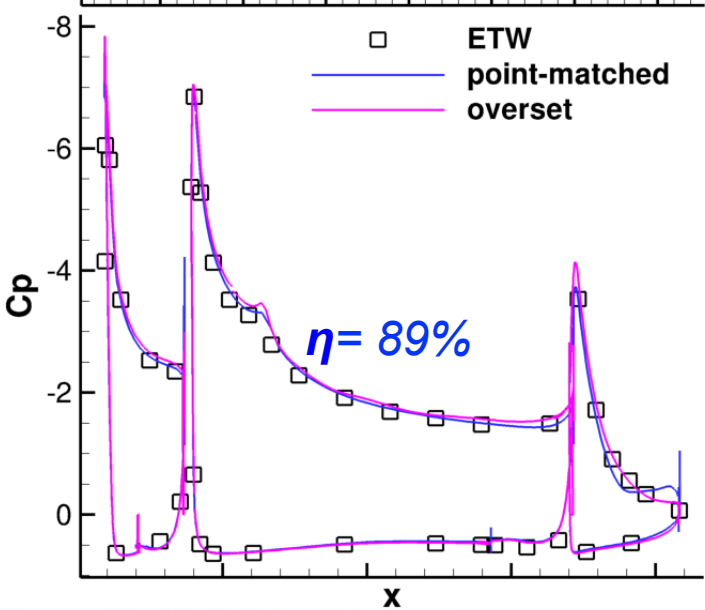
Cp distribution (α=16°)

- Same conclusions as for AoA=7°
- The agreement with WT data is excellent in those regions that are not influenced by the slat/flap tracks or their wakes



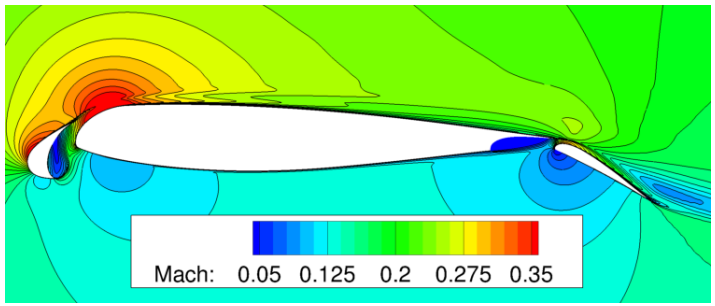




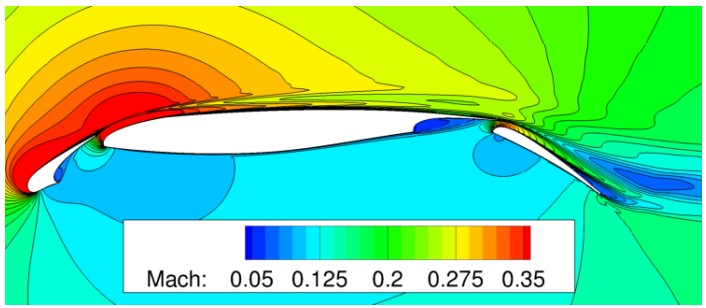


Mach number field (α=16°)

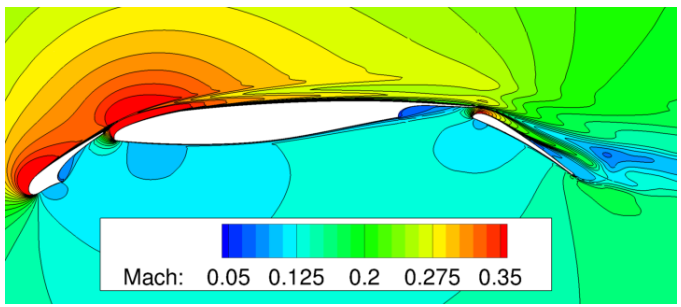
Point-matched grid



Plane 1

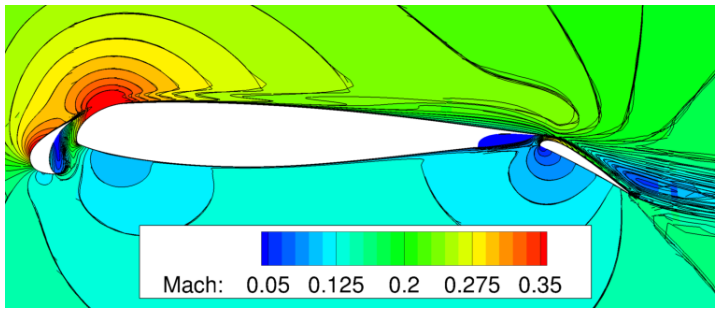


Plane 2

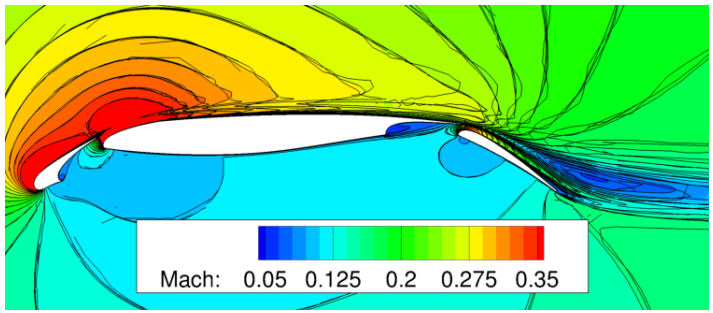


Plane 3

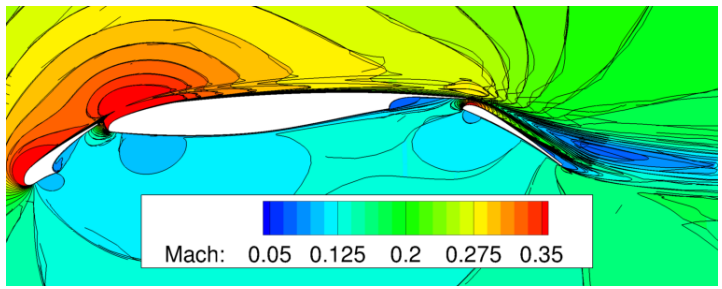
Overset grid



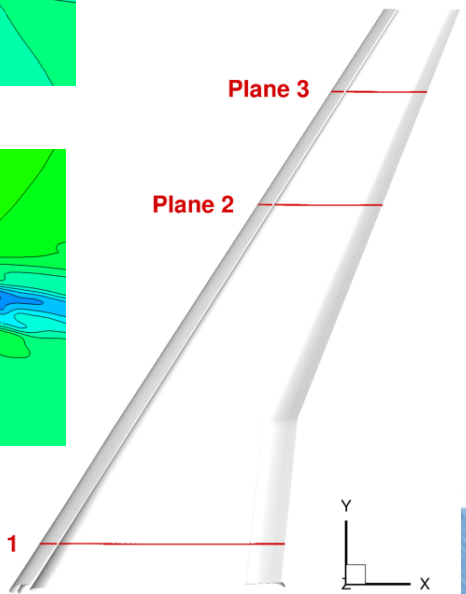
Plane 1



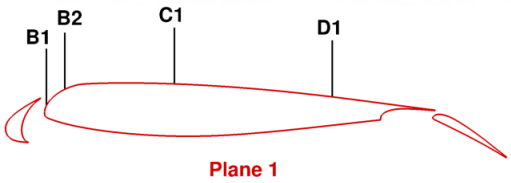
Plane 2

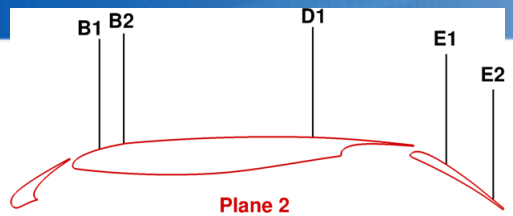


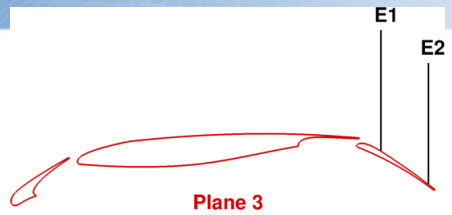
Plane 3

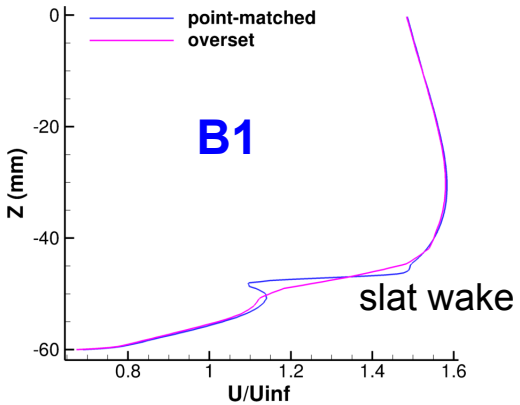


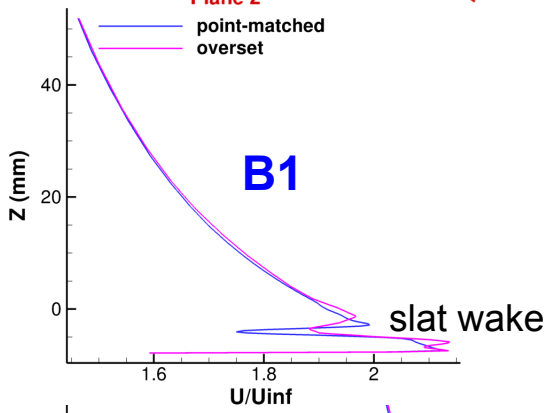
Velocity probes (α=16°)

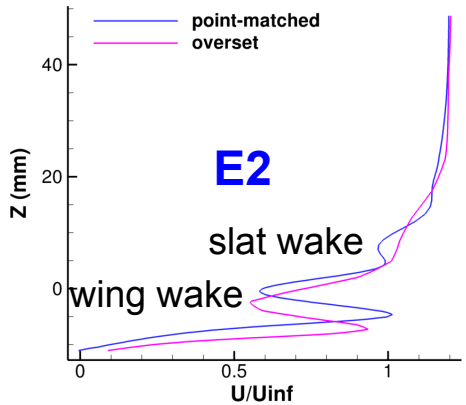


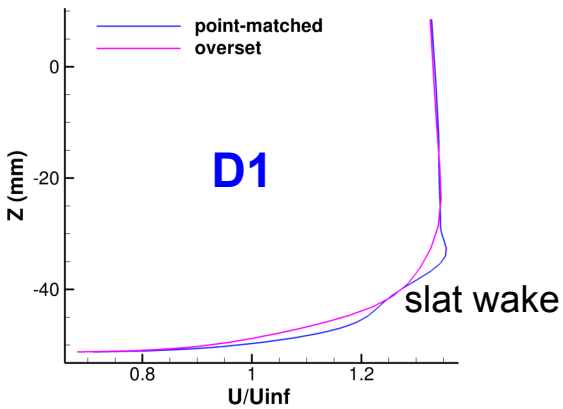


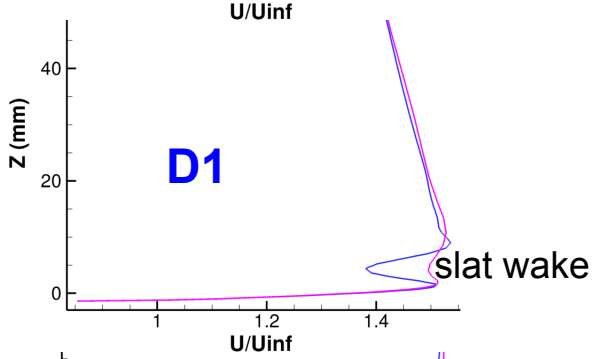


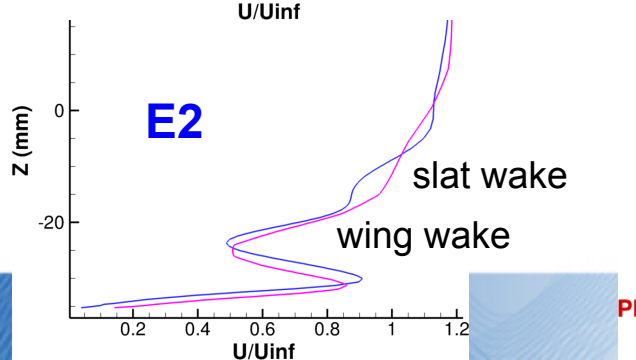


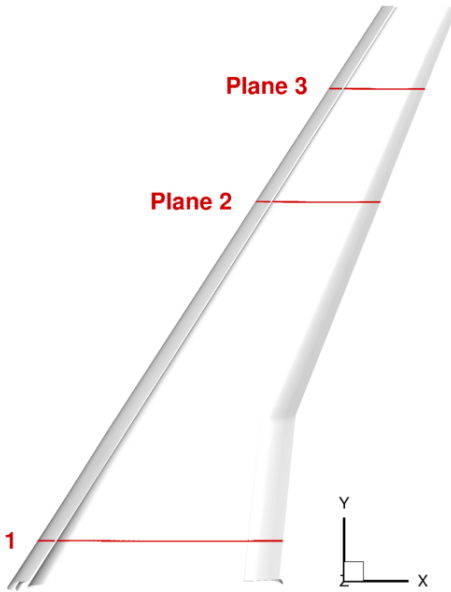












L. Wiart, 2nd AIAA CFD High Lift Prediction Workshop, 22-23 June 2013 – San Diego, CA

Conclusions for Case 1

- The grid convergence study demonstrated a strong impact of grid refinement on aerodynamic forces and moments
- This is due to overpredicted flow separation over the flap for this landing configuration with the coarse and medium point-matched structured grids using the SA turbulence model
- The results obtained on the point-matched and overset structured grids are in excellent agreement in terms of aerodynamic coefficients and Cp distribution, even without overlap optimization
- Although the predicted skin pressures are in excellent agreement with the WT data in the linear region, the slat/flap tracks need to be taken into account in the CFD when focusing on global aerodynamic forces and moments and to improve CL_{max} prediction

Future work

- Blanking was completed on the Case 2 medium overset grid but an issue appeared in the wall projection process for interpolations search due to the rather “brutal” approach (44 overset grids for Case 1, 163 overset grids for Case 2) compared to our usual in-house overset meshing practices

- We intend to have Case 2 calculations for next summer paper

- Remarks on the provided overset grids:
  - Case 1 and Case 2 grids contain negative volume cells
  - They are not multigrid compliant !
  - "Weird" gridding approach between the slat upper side and lower side blocks should be arranged somehow to fit a classic boundary condition

- Thank you for your attention !
- Any questions?