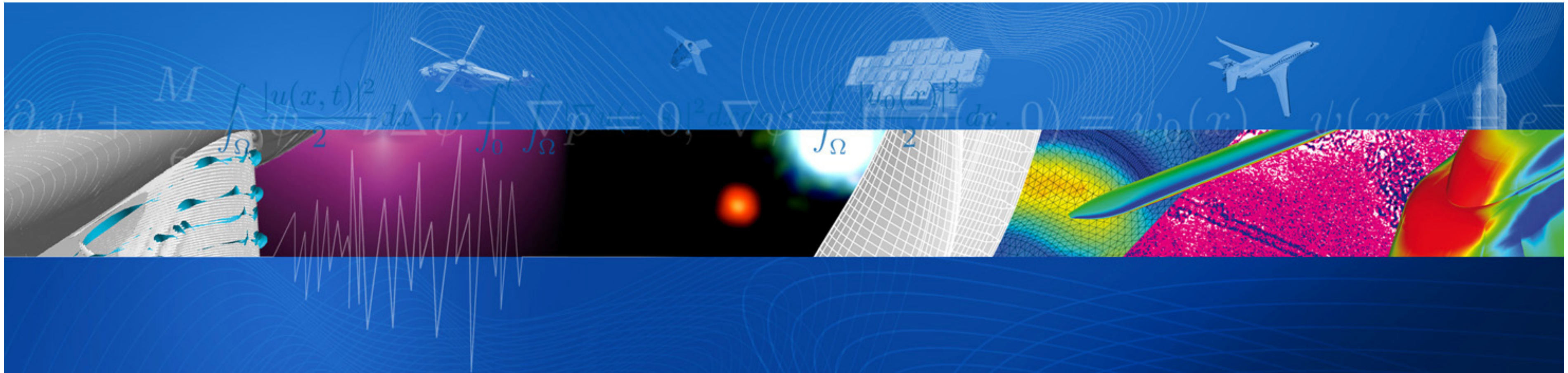

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Numerical Simulation of the NASA High-Lift Trap Wing with the *elsA* CFD Software

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30th AIAA Applied Aerodynamics Conference
26 June 2012, New Orleans, Louisiana

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Outline

- *elsA* CFD software
- Summary of ONERA results on the Workshop Test Cases[1]
- Evaluation of different grid generation approaches
- Off-body focus
- Conclusions

NASA Trap-Wing model

[1]Wiart and Meunier, AIAA-2011-0865, 49th ASM, Jan 2011, Orlando, FL

The *elsA* solver

CFD High Lift Prediction Workshop

RANS computations

- Cell-centered finite volume on structured multi-block meshes
- Time integration: Backward-Euler scheme with LU-SSOR relaxation
- Spatial discretization: Jameson’s second-order centered scheme
- V-cycle multigrid technique
- Low-speed preconditioning

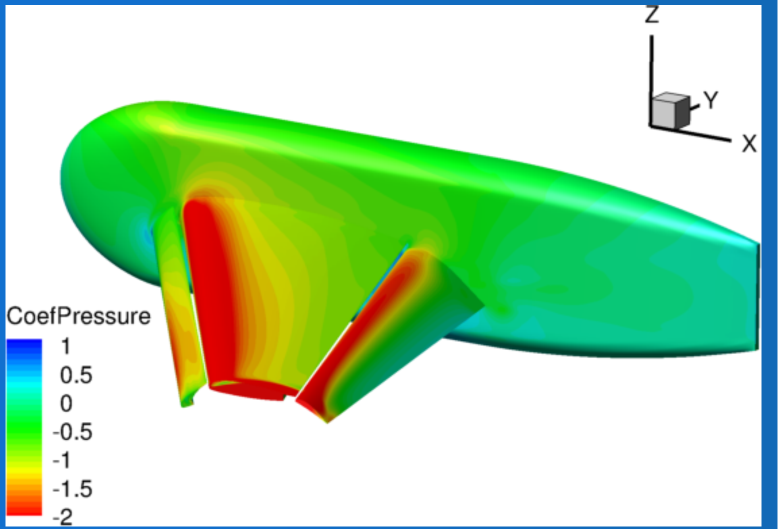
CGNS input and output format

Parallel mode (SGI Altix ICE 8200 EX)

Free-stream aerodynamic conditions:

• M=0.2

• Re=4.3M (based on MAC)



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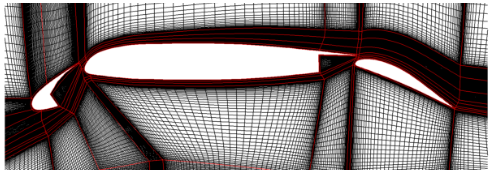
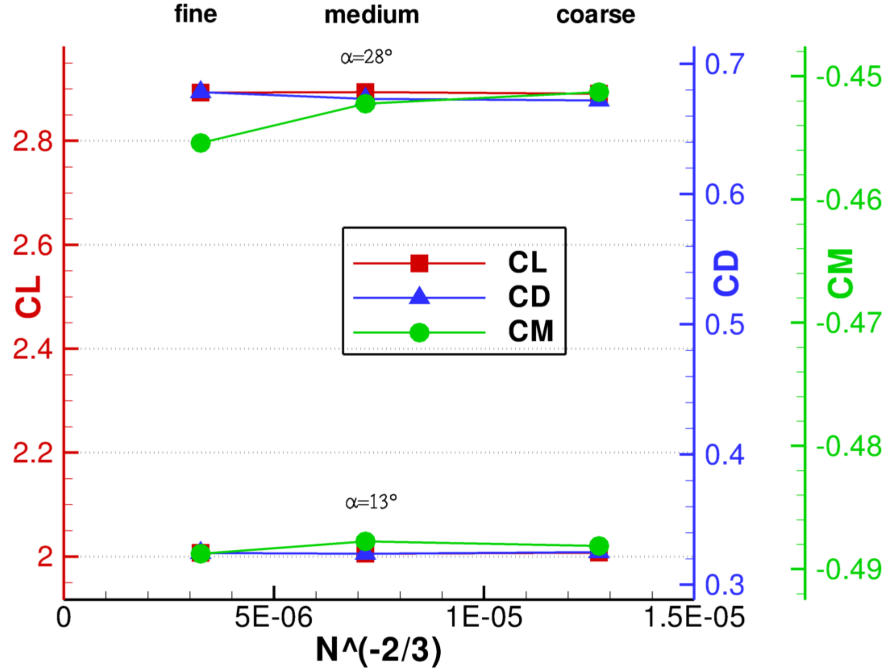
Summary of ONERA results on the workshop test cases

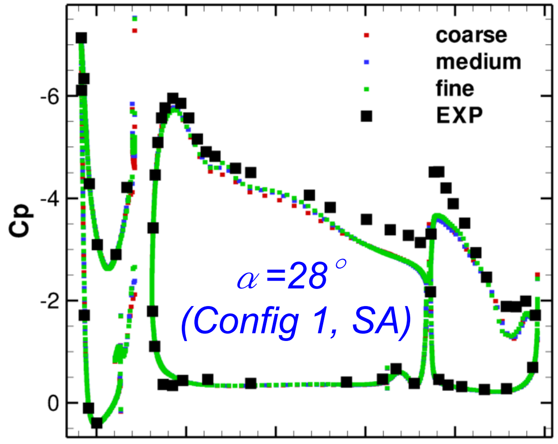
Grid convergence study

- Str-OnetoOne-A-v1 (supplied by HiLiftPW-1 Committee)
  - Coarse: $22x10^6$ nodes
  - Medium: $52x10^6$ nodes
  - Fine: $170x10^6$ nodes
- Small variations between the different grid levels

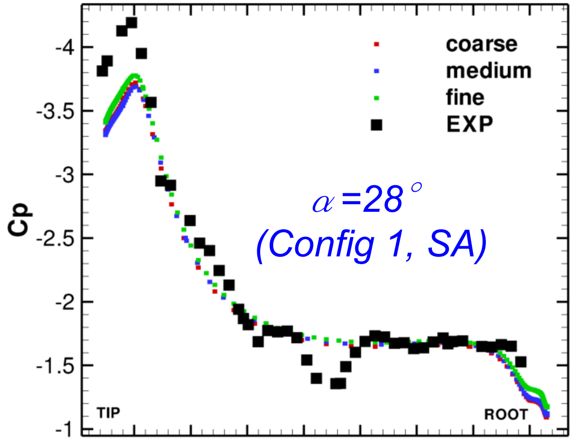




Influence of grid refinement on aerodynamic coefficients (Config 1, SA)



98% Span



Flap forward span (flap upper side)

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Flap deflection prediction study (1/3)

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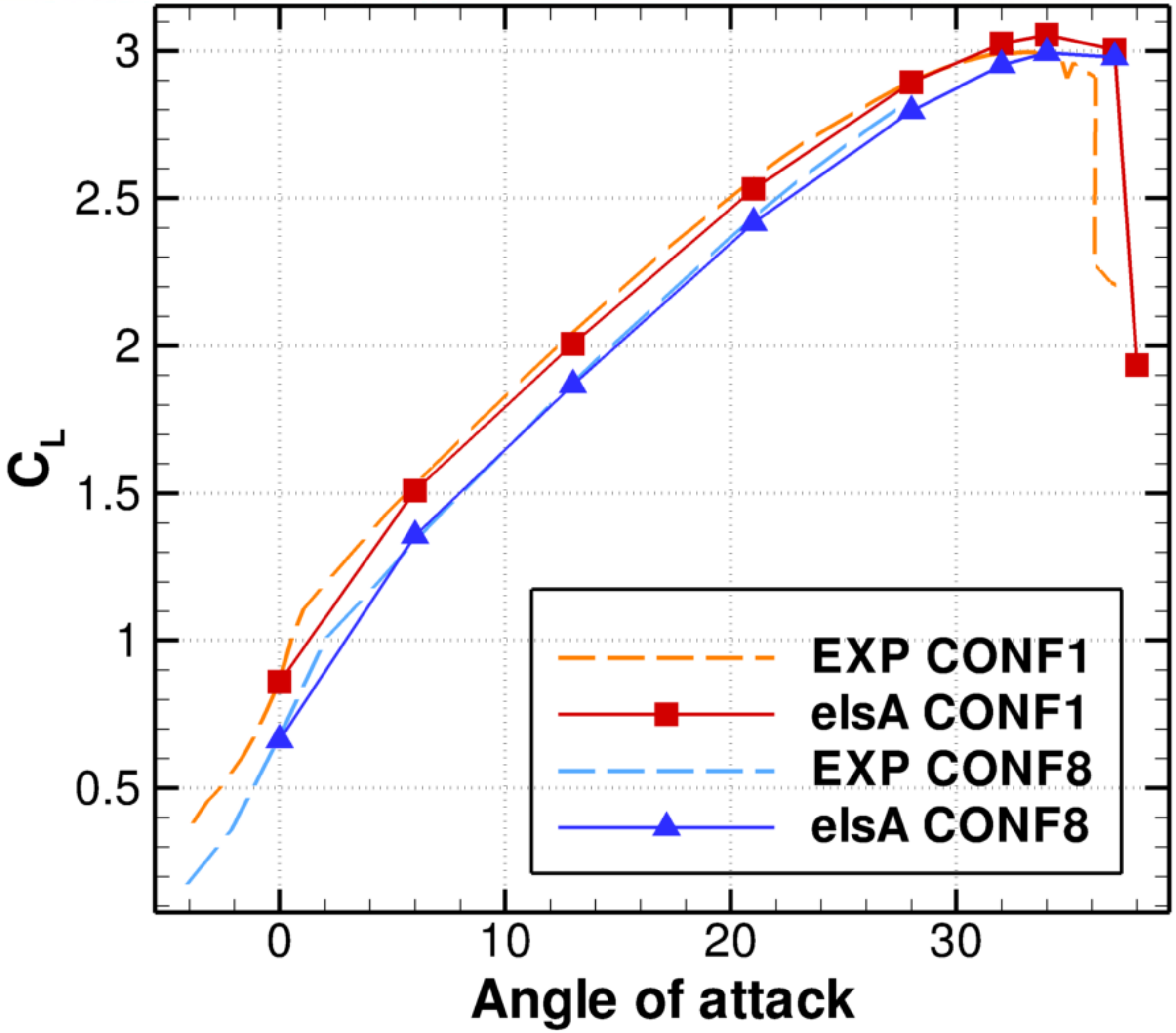


Config 1: flap 25 deg.

Config 8: flap 20 deg.

Config 1:

- *Exp*

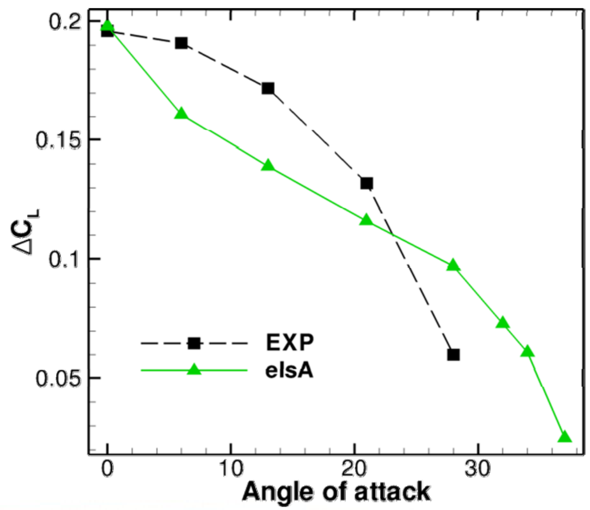
α_{max}=33 deg.

CL_{max}=2.995

- *elsA (SA)*

α_{max}=~34 deg.

CL_{max}=3.054



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Flap deflection prediction study (2/3)

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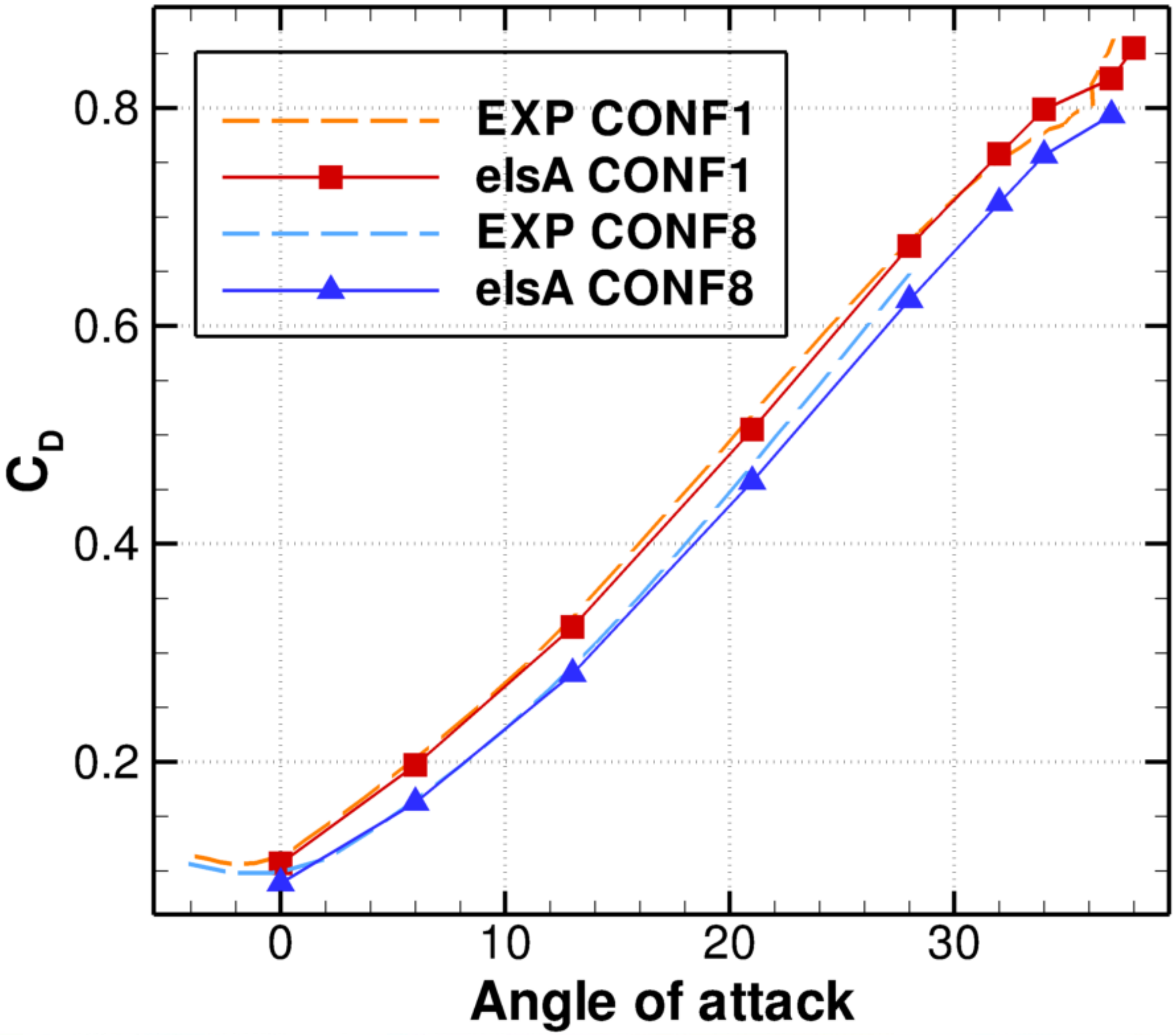
Config 1: flap 25 deg.

Config 8: flap 20 deg.



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Flap deflection prediction study (3/3)

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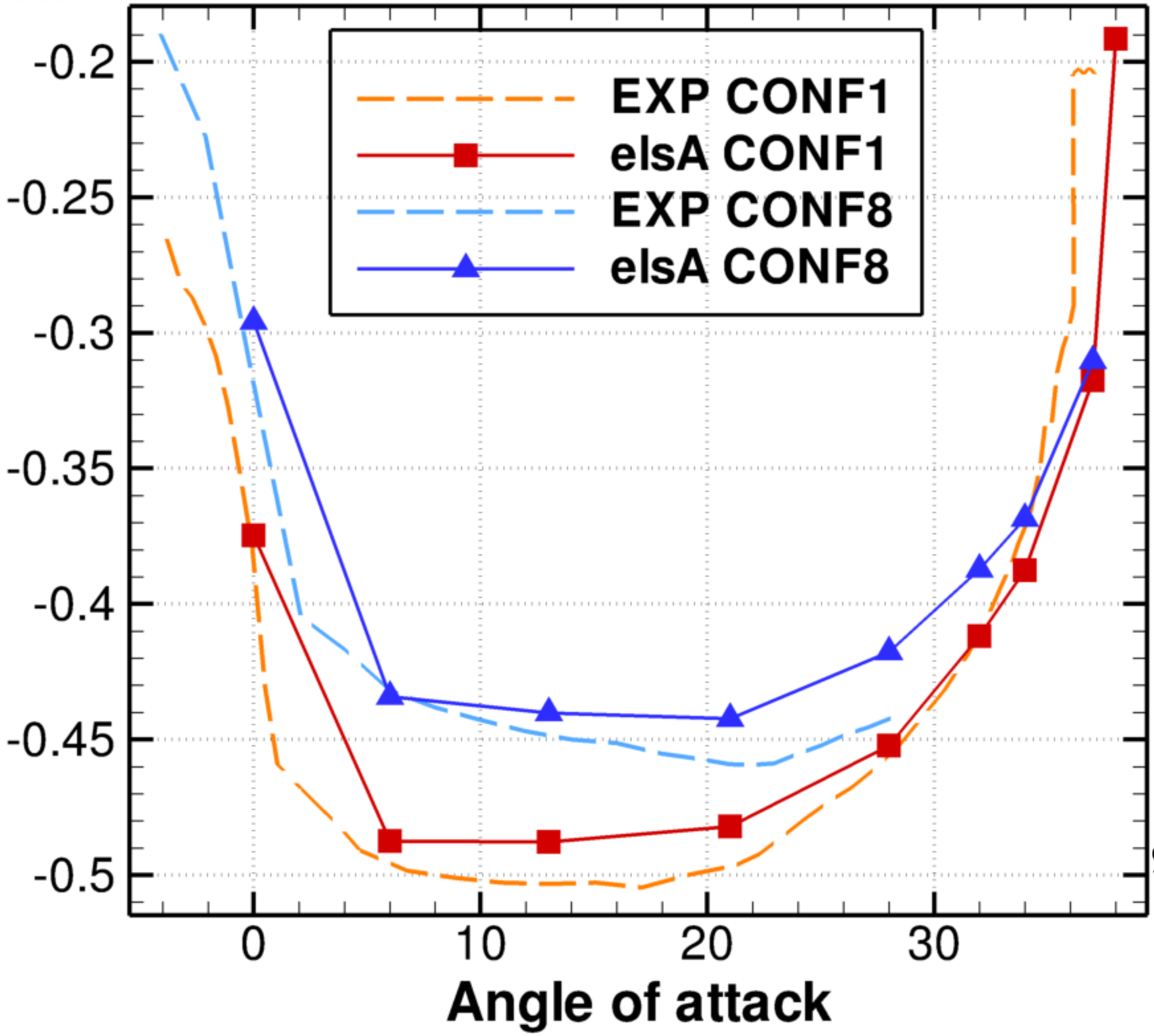
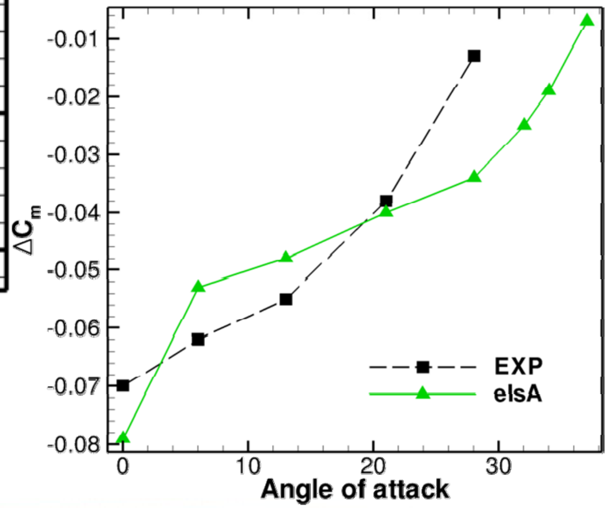


Config 1: flap 25 deg.

Config 8: flap 20 deg.



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Other investigated points of interest

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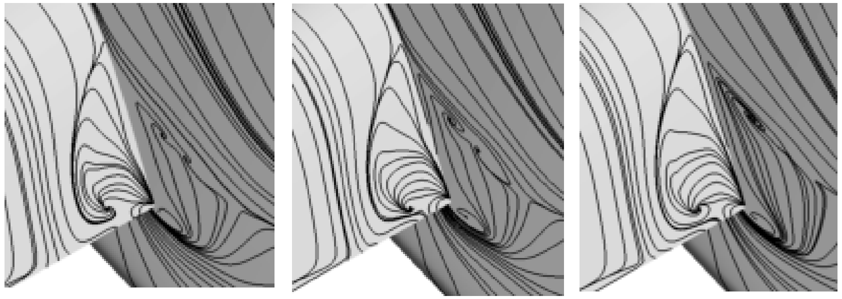
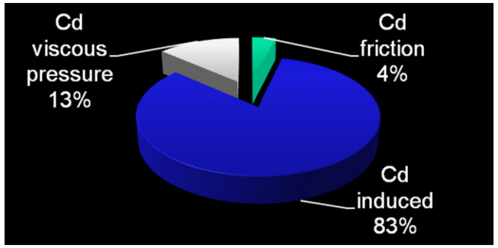
- Computation strategy
  - Initialization from previous AoA necessary to avoid early lift break-down
- Turbulence modeling
  - SA, SA with rotation correction, *k-ω* SST (Menter, Kok, Wilcox) → SA
- Flap/SOB separation
  - Little influence of grid refinement



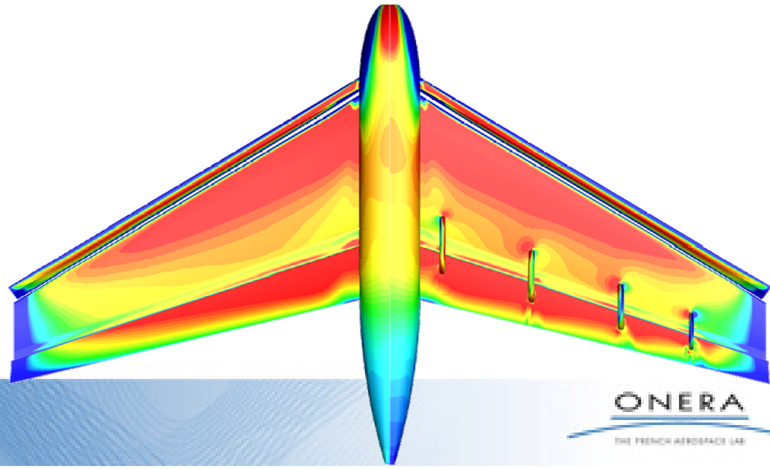
Coarse *Medium* *Fine*

- Far-field analysis (ffd72 software)
  - Drag breakdown

α =13 deg.



- Flap brackets effect



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Evaluation of different grid generation approaches (Config 1, SA)

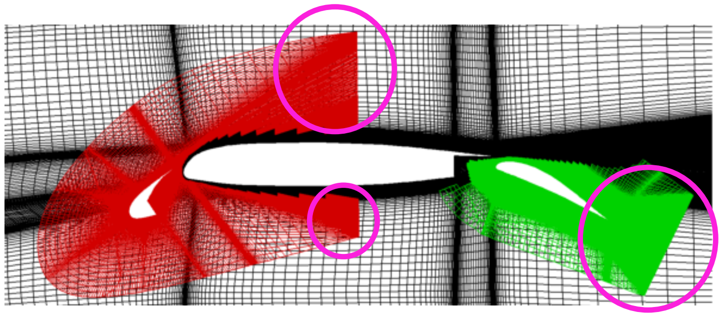
Overset approach

- Study limited to structured grids (although new capabilities from *elsA* version 3.4.03 include unstructured and hybrid grids consideration)

- Generation of 1-to-1 abutting structured grids considered too time consuming for 3D high lift configurations

- Need to evaluate and improve our overset methods

- "Classic" overset approach: insert slat and flap C-meshes in the glider grid



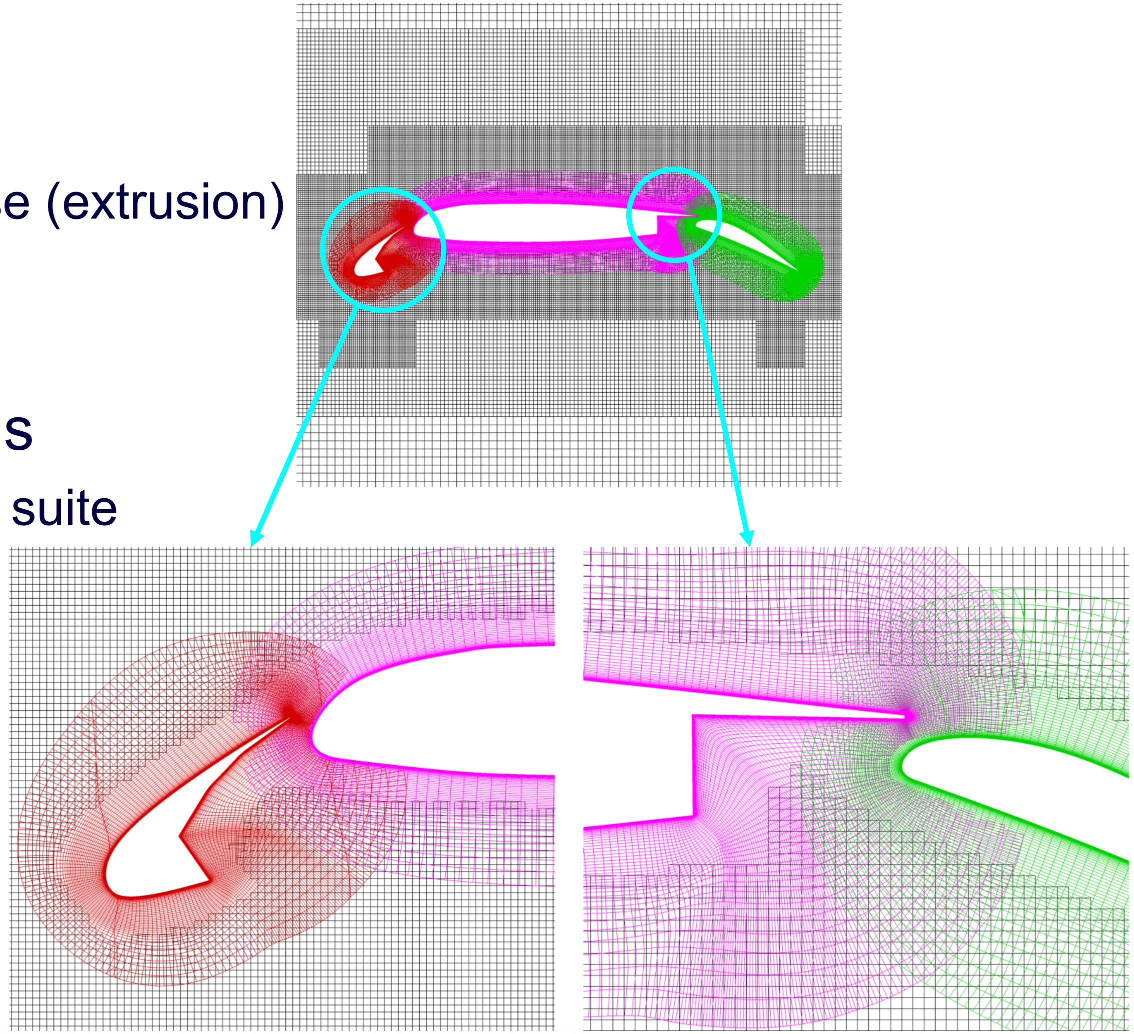
- Limitations:
  - important cell size discrepancies in the interpolation regions

Overset/Cartesian approach

- Near-body/off-body mesh partitioning approach

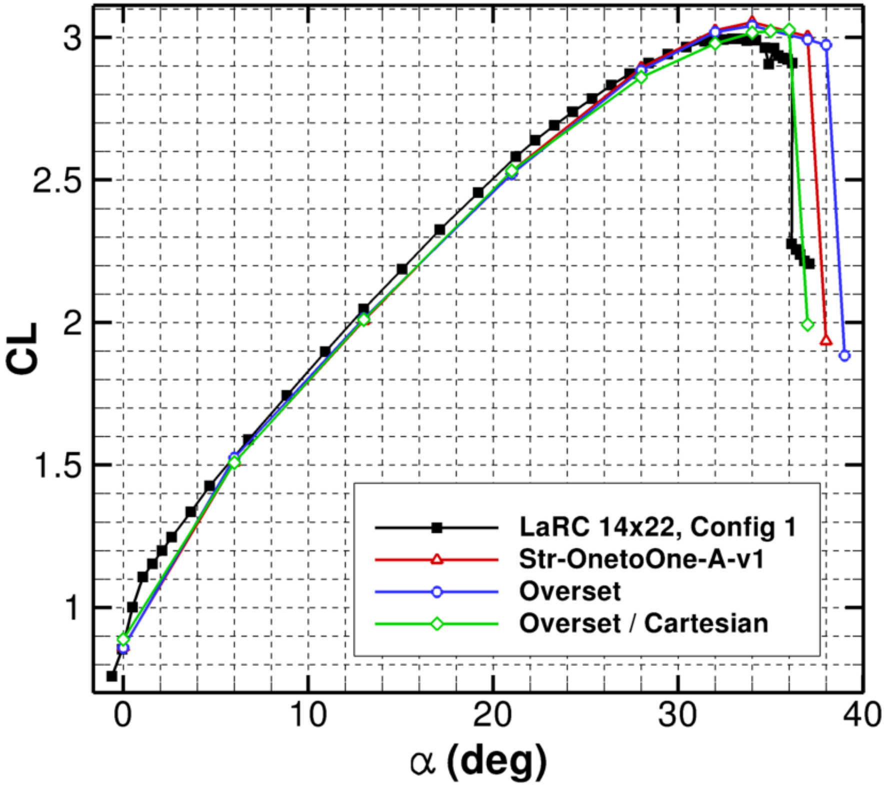
- Near-body O-grids
  - Generated with Pointwise (extrusion)
  - 18M points

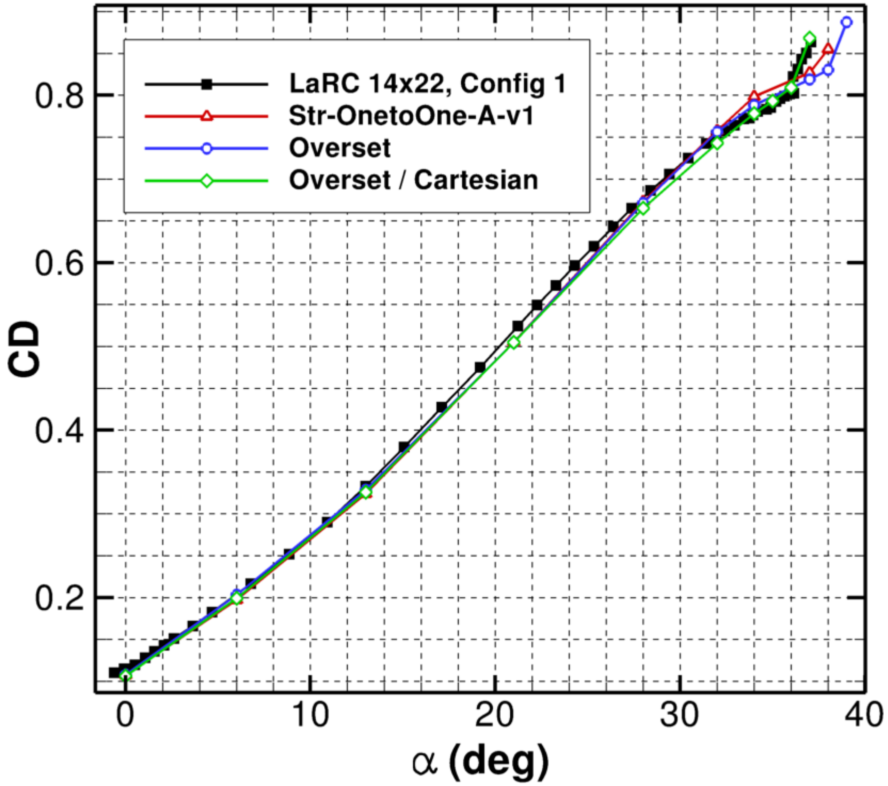
- Off-body Cartesian grids
  - Generated with the *elsA* suite
  - Octree-based
  - Patch grid BCs
  - Adaptation capabilities
  - 36M points



Force and moment comparisons (1/2)

- Two main sources of differences between CFD and WT:
  - The slat and flap brackets are not included in the CFD
  - Fully turbulent calculations whereas the transition was not triggered in WT





- Good agreement for CL_{max} prediction
- Different stall behavior

Force and moment comparisons (2/2)

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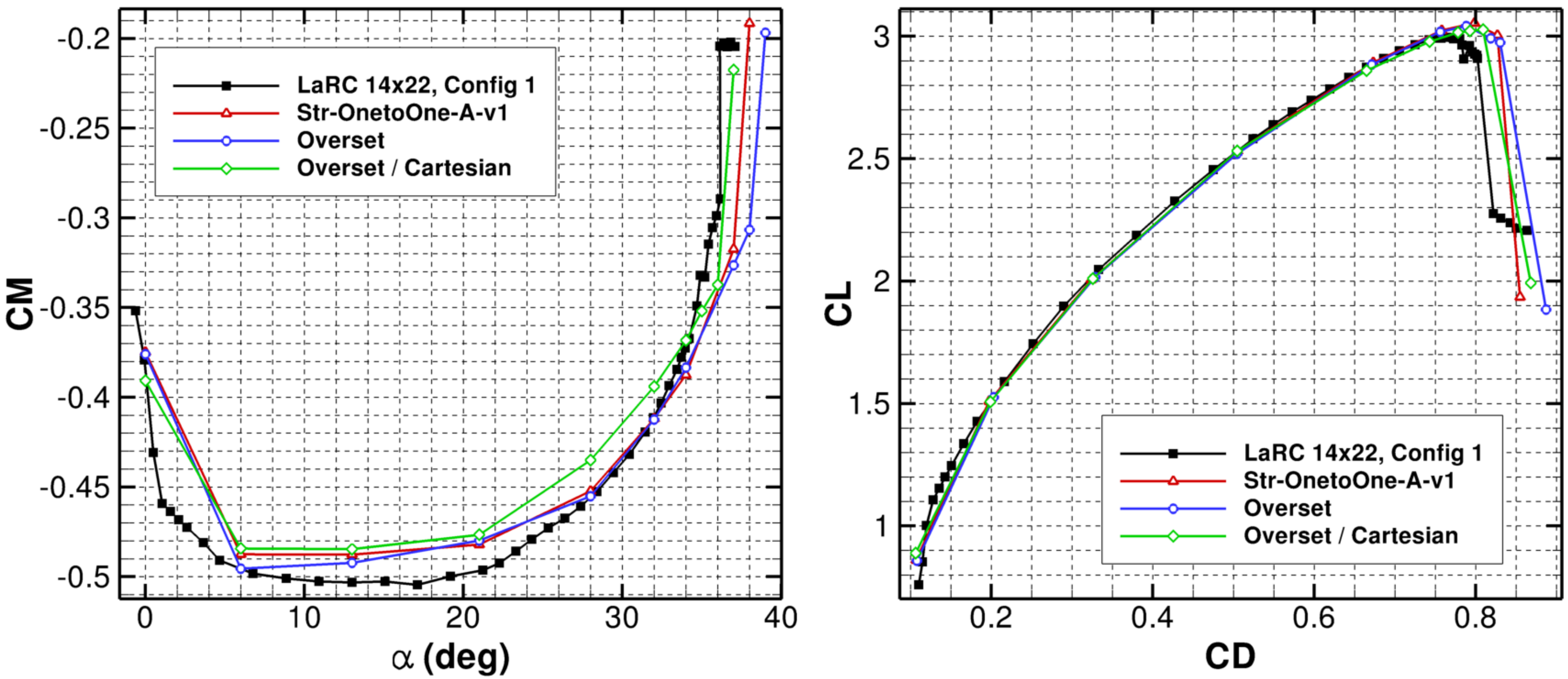
- Pitching moment prediction is the most challenging but probably the most subject to brackets/transition effects too



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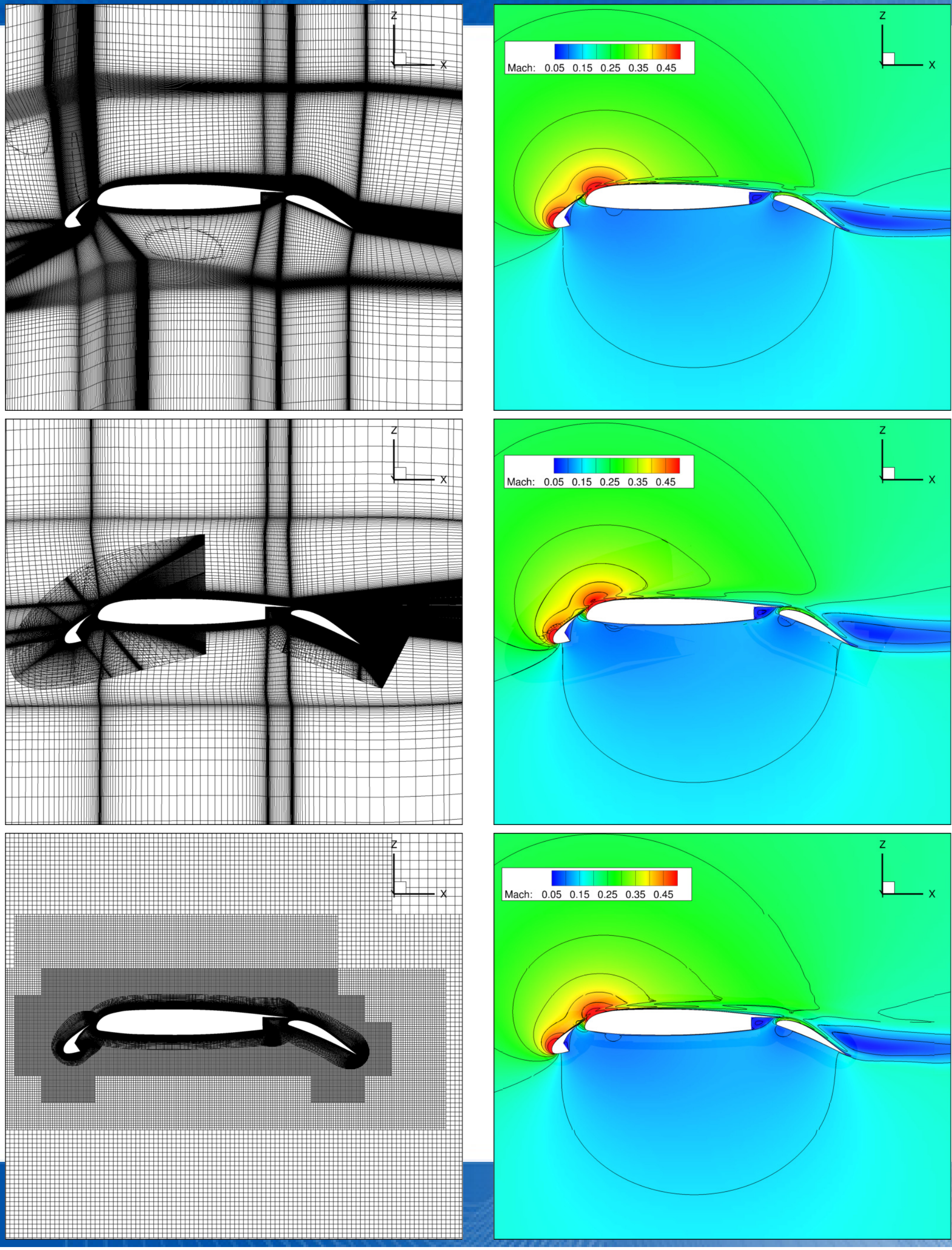
"Medium" grids and corresponding Mach number field (α=28°, η=50%)



- Str-OnetoOne-A-v1
  - 52M points
- Overset
  - 32M points
- Overset/Cartesian
  - 54M points

Skin pressure comparison (η=50%)

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- Excellent agreement between all CFD results
- Good overall agreement with WT data

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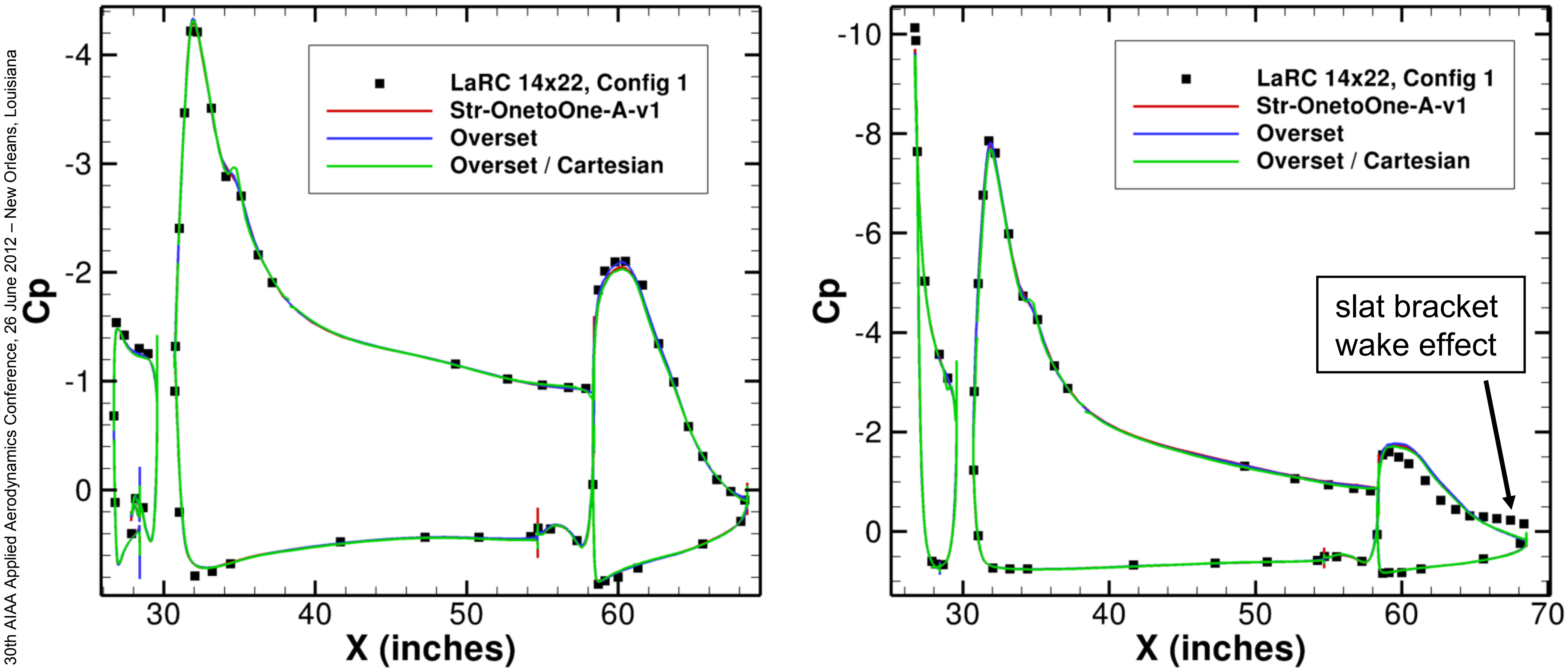

α=13° α=28°

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Skin pressure comparison (η=95%)

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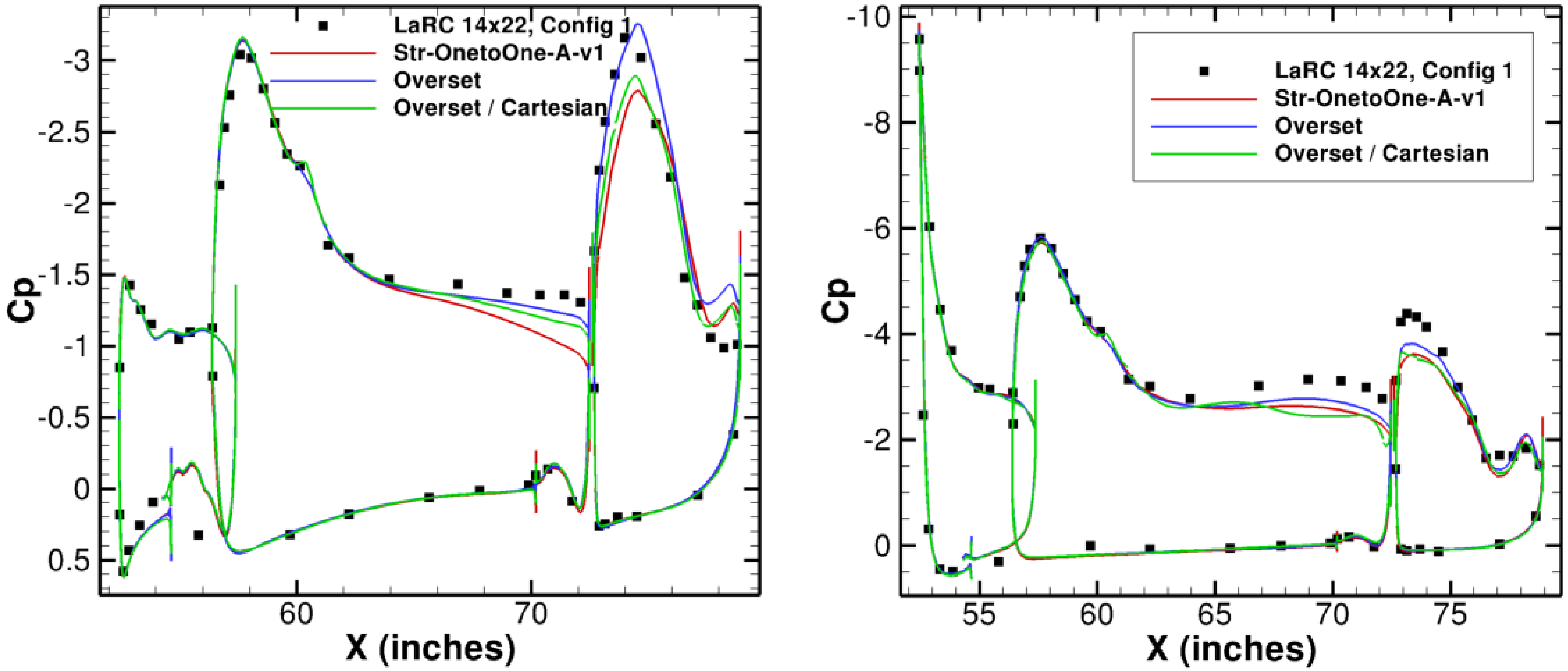
- Tip pressure prediction more challenging than at mid-span



$\alpha = 13^\circ$ $\alpha = 28^\circ$

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Skin pressure comparison (η=98%)

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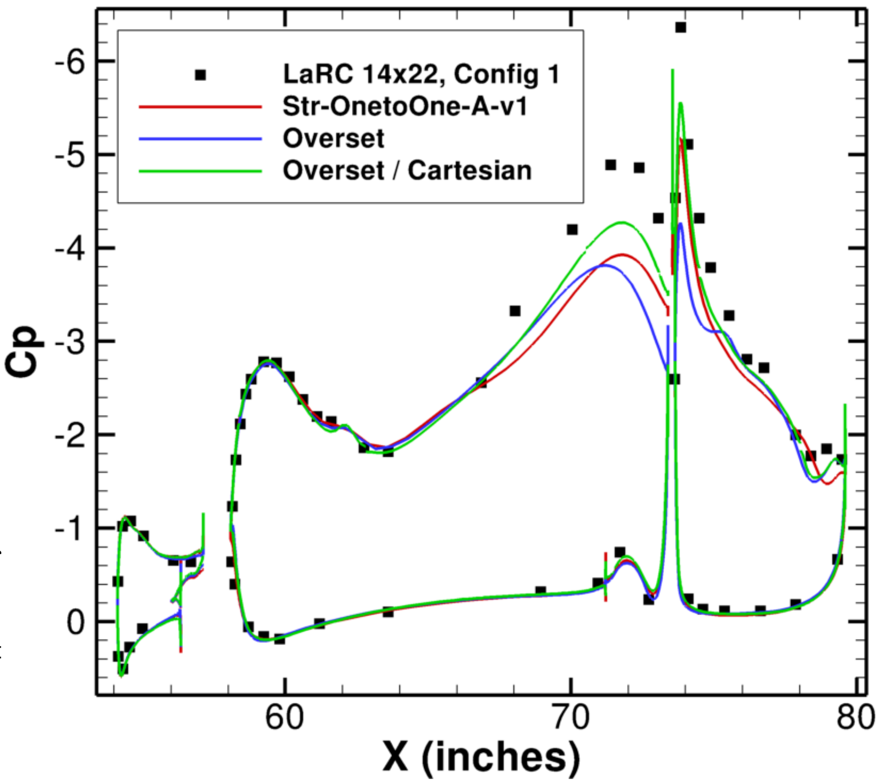
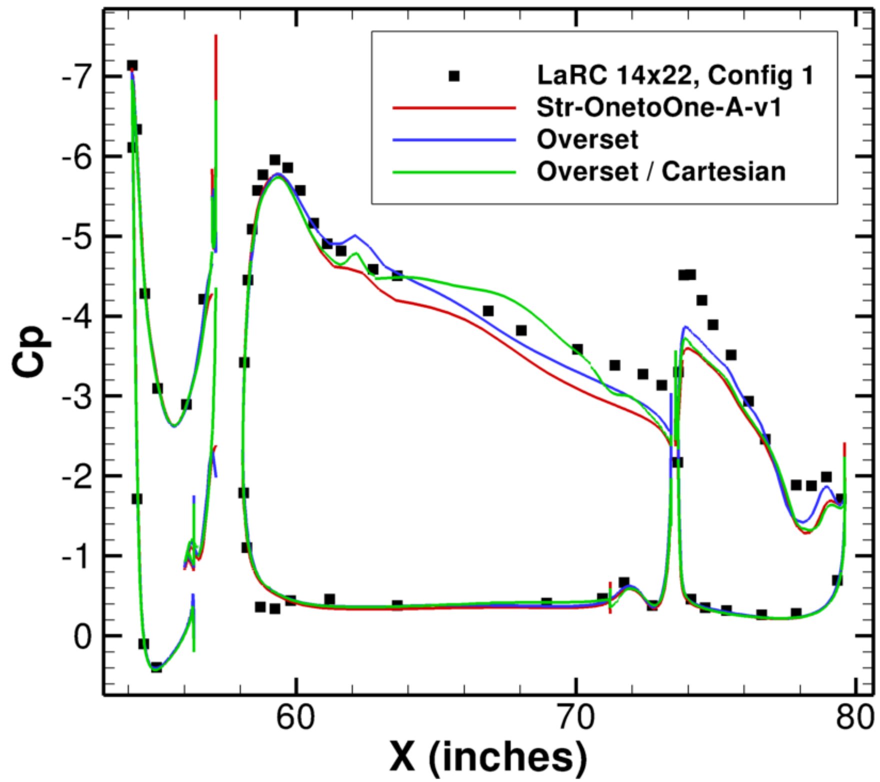
- The Overset/Cartesian approach performs great at α=13°, more mitigated results at α=28°



$\alpha=13^{\circ}$



$\alpha=28^{\circ}$

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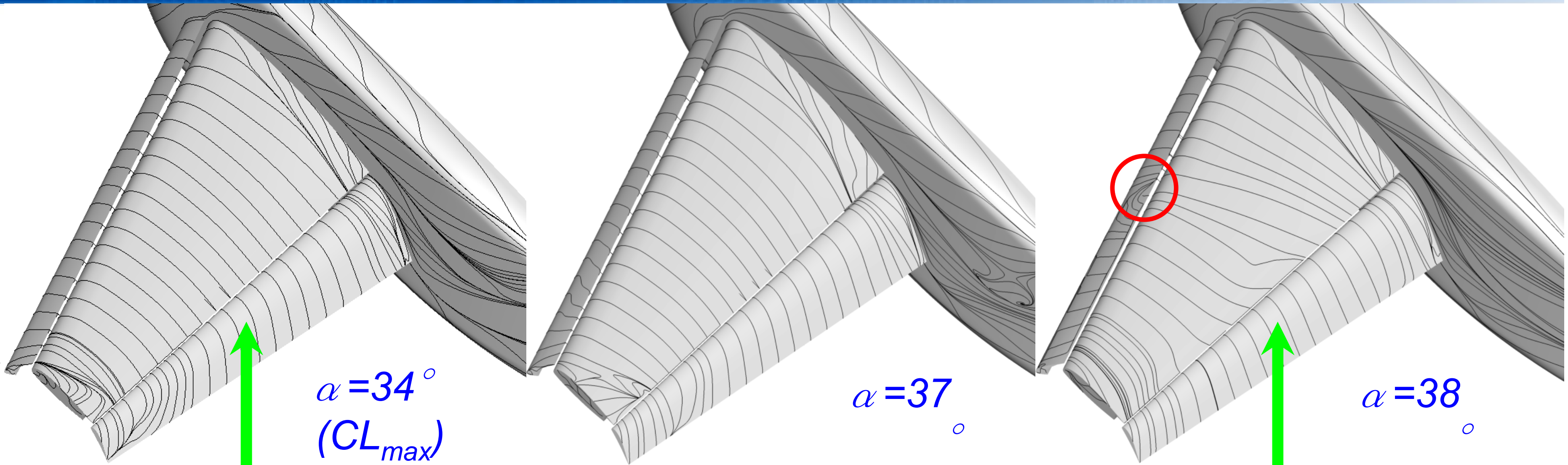
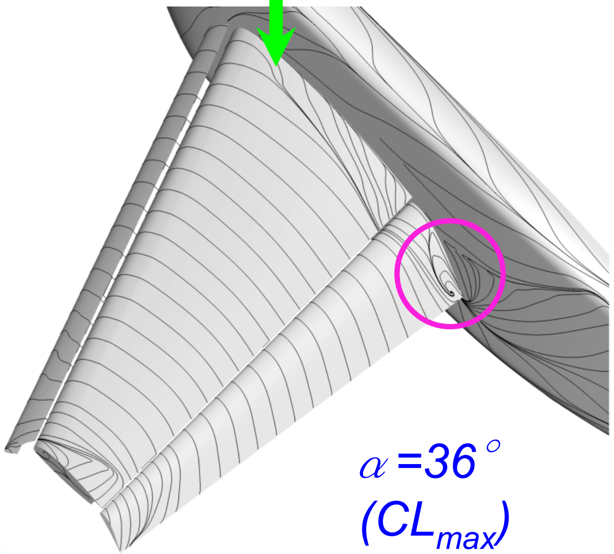
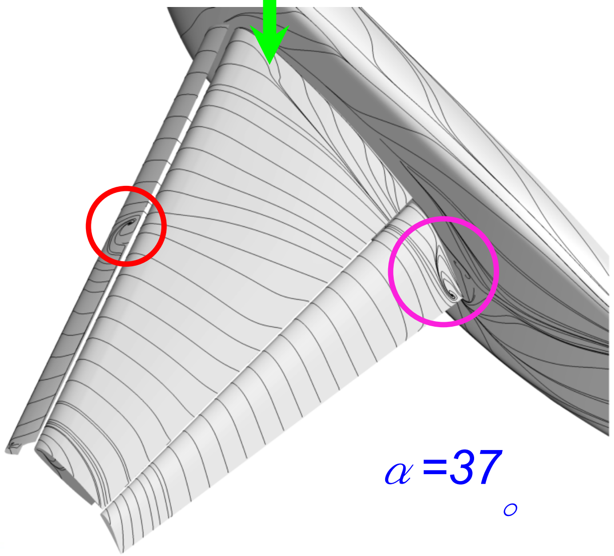
Stall mechanism



-------------------------------- Str-OnetoOne-A-v1 --------------------------------



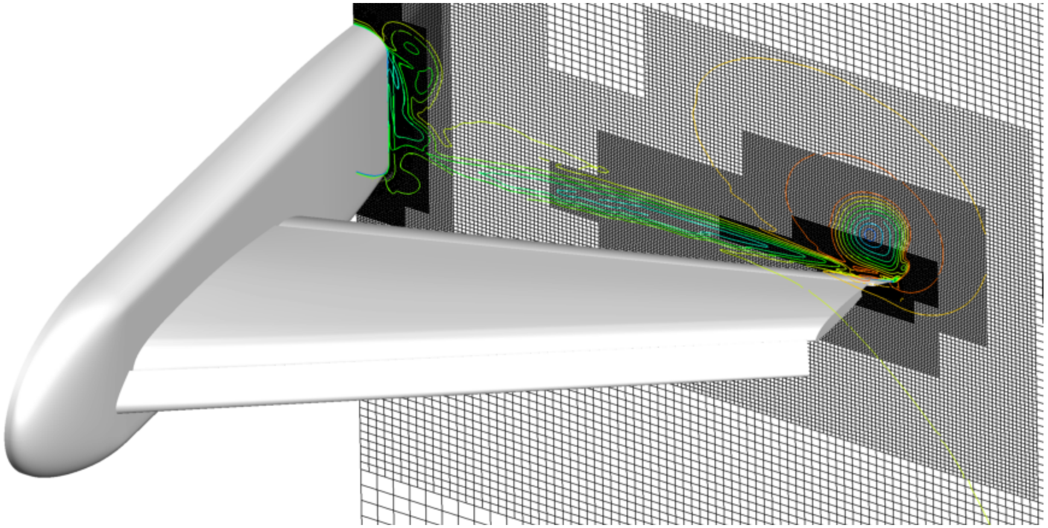
- Similar flow patterns
- Lift breakdown origin
- Flap/SOB separation



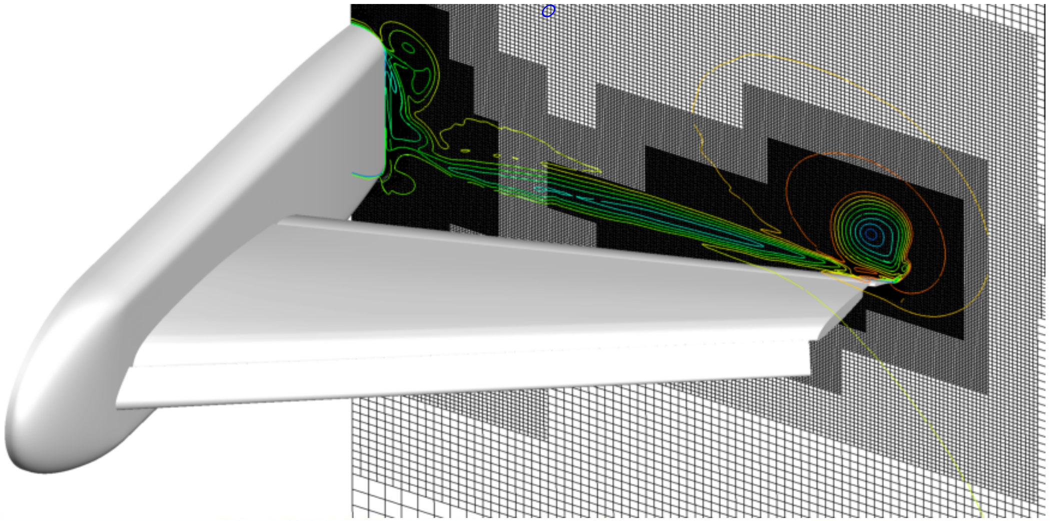
------------------------------Overset/Cartesian ------------------------------

Off-body Focus

Grid adaptation



$\alpha = 28^{\circ}$



- Baseline Overset/Cartesian grid
  - 54M points
- Level 0 Cartesian grids adaptation based on eddy viscosity criterion
  - 69M points

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Off-body velocity probe (1/2)

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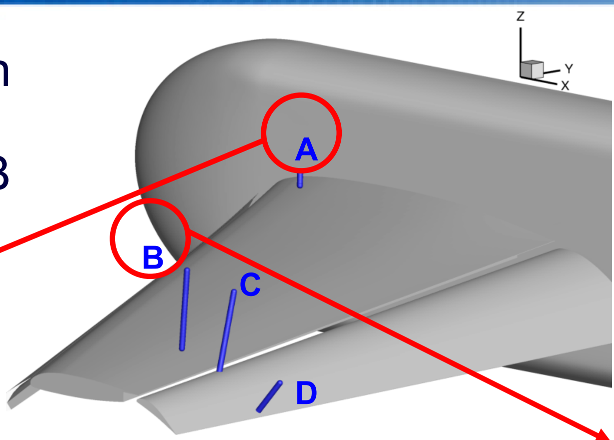
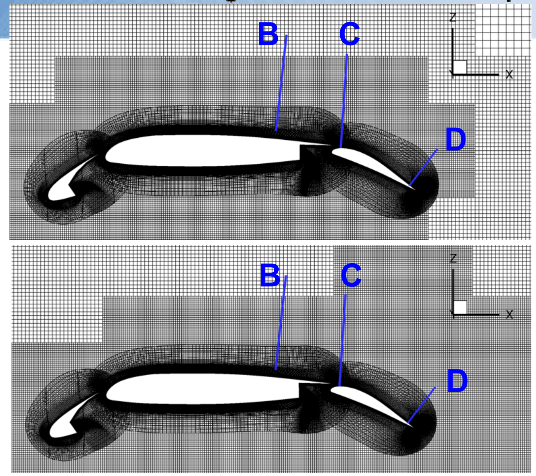
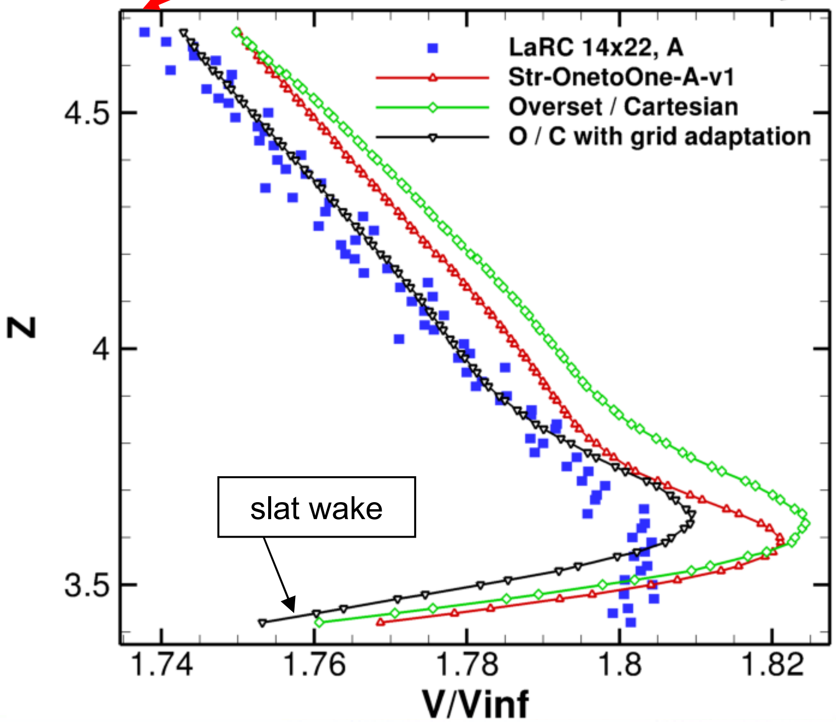
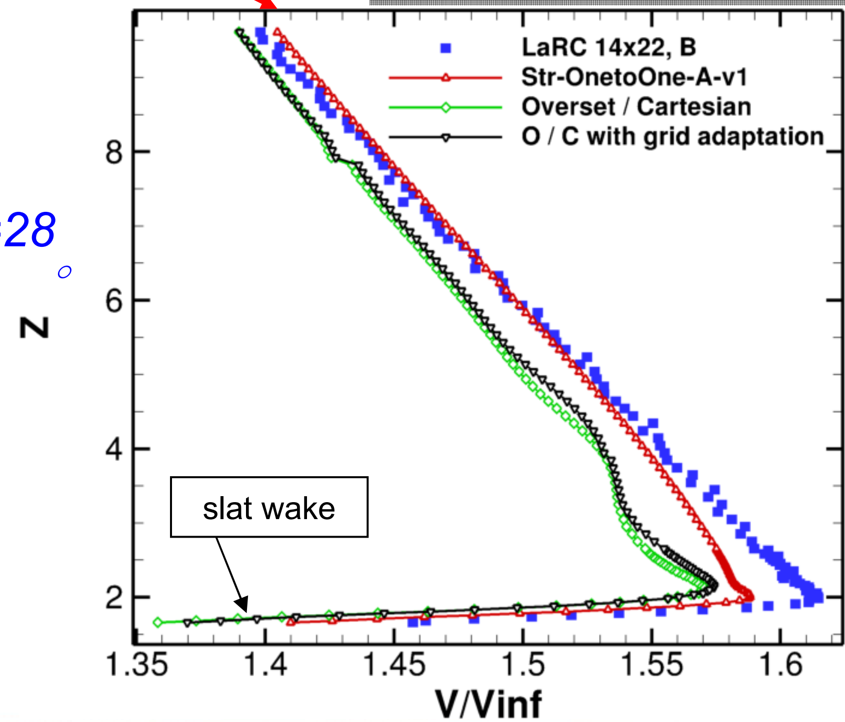
- Off-body grid adaptation very effective in A but does not help much in B







$\alpha = 28^{o}$



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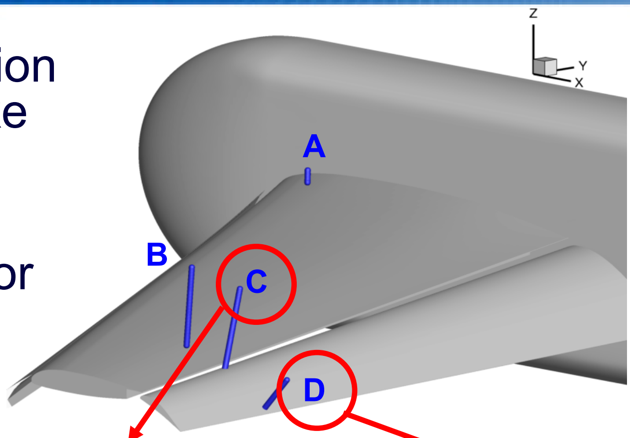
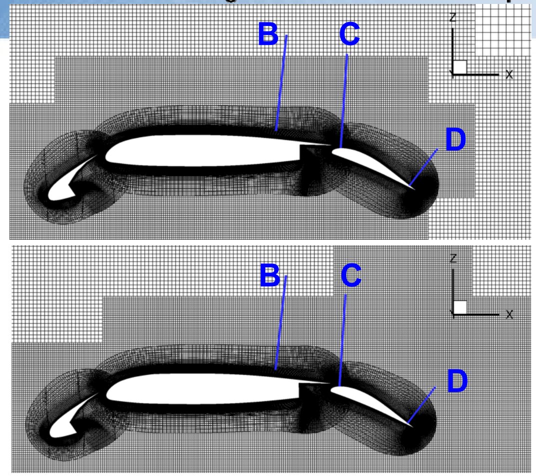
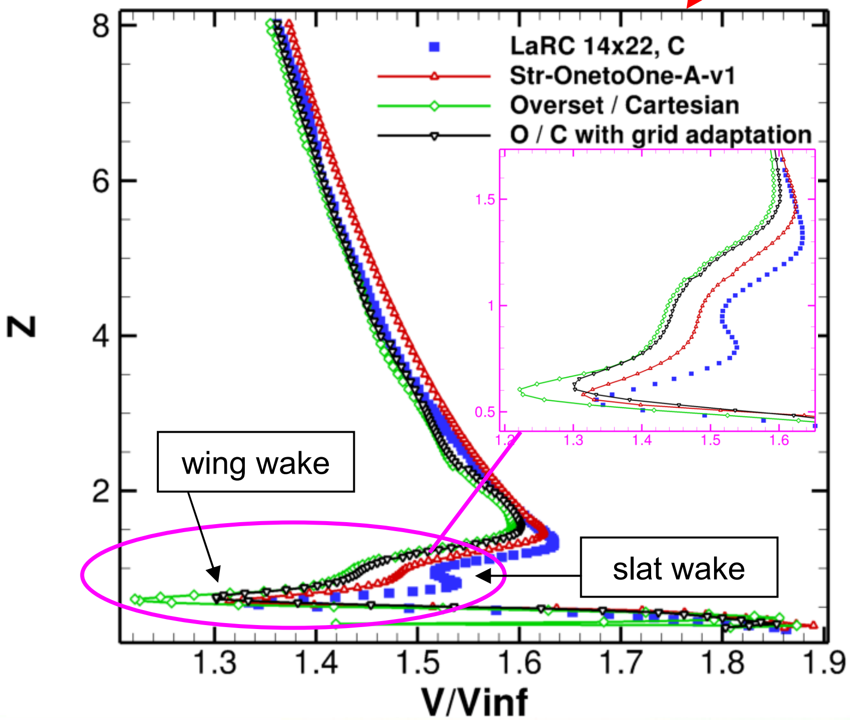
Off-body velocity probe (2/2)

- Off-body grid adaptation effective for wing wake resolution in C

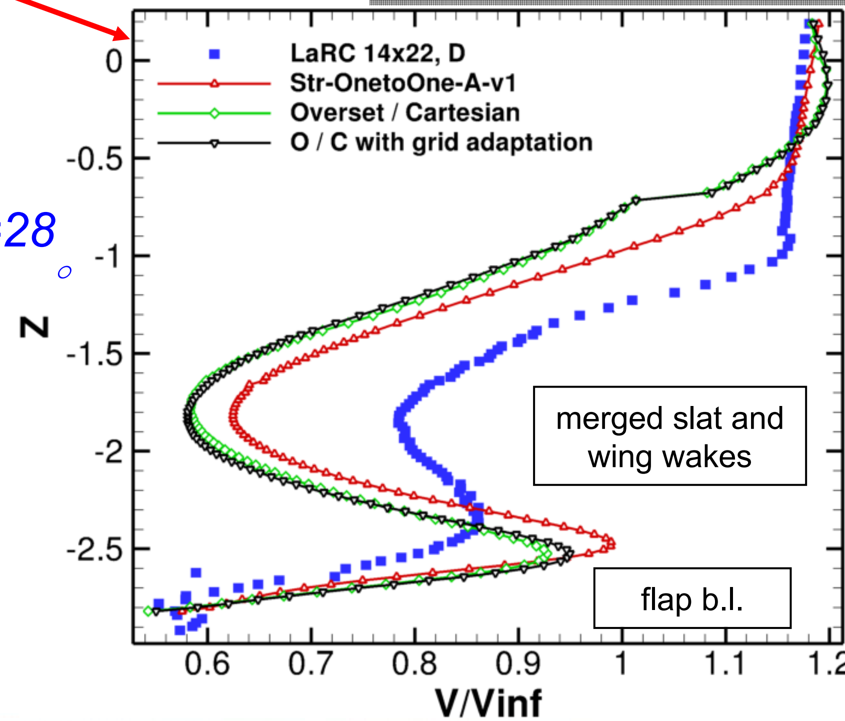
- Flap position issues for C and D probes







$\alpha = 28^{o}$



Brackets

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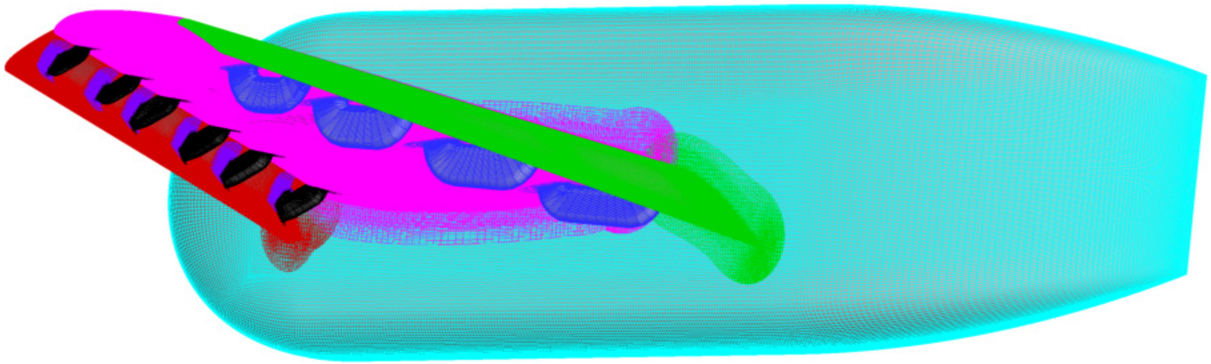
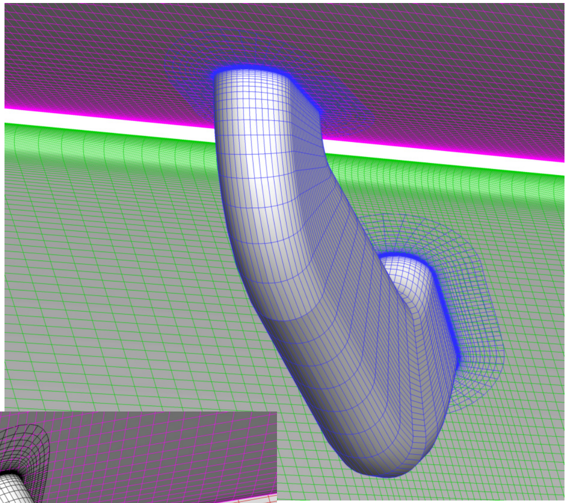
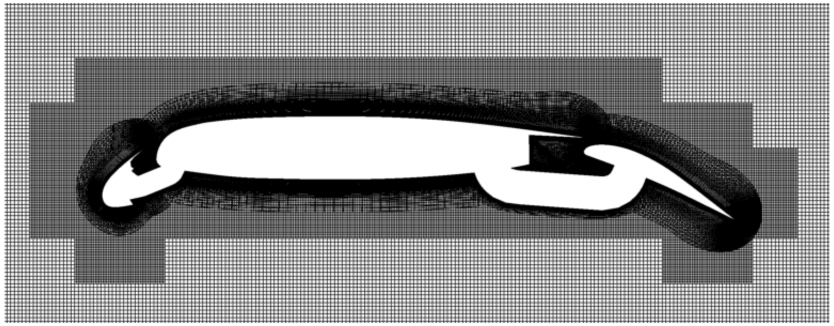
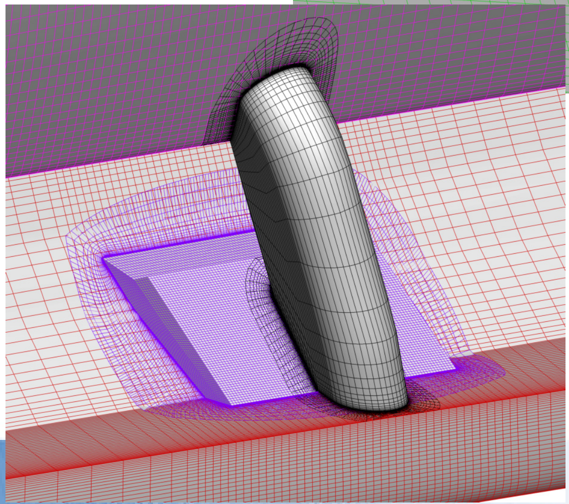
- Initially, computations were planned on the brackets-on geometry with the Overset/Cartesian approach
- A 88M points grid was built, but convergence issues were encountered for AoA above 6°









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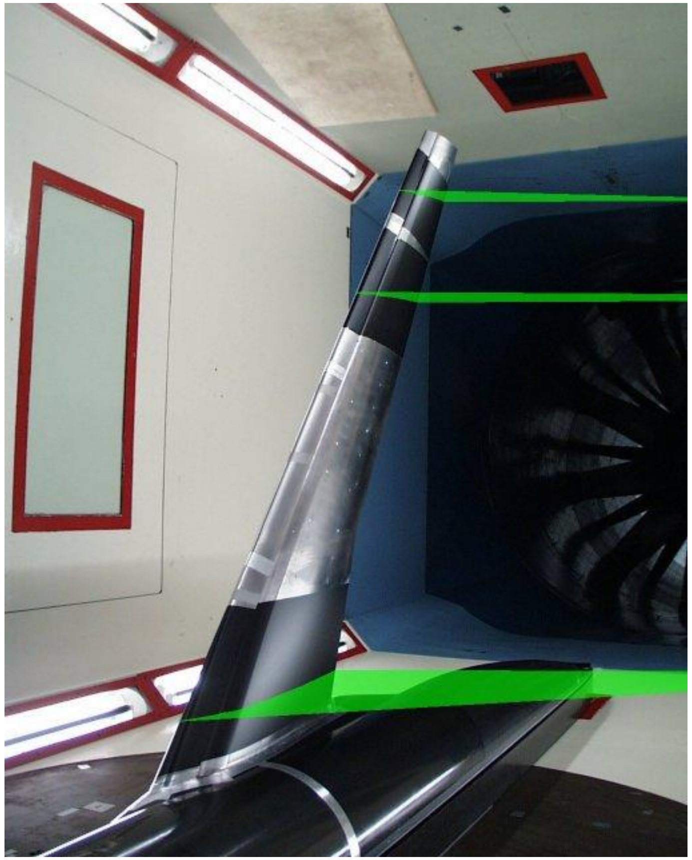
Conclusions

- Workshop test cases
  - Grid refinement study: low sensitivity of the selected mesh to grid refinement with the *elsA* software.
  - Flap deflection study: good overall agreement with WT data, although the force and moment increments due to flap deflection are difficult to predict.

- Grid comparison study
  - Motivated by the need to evaluate and improve our overset methods.
  - Good overall agreement between the results obtained on the three grids.
  - CLmax over-predicted by 1 to 2% depending on the grid type.
  - Differences mainly observed in tip region and in stall behavior.
  - Hard to conclude on the superiority of an approach over the other in terms of absolute prediction accuracy due to differences between WT and CFD conditions.
  - Overset/Cartesian approach offers a good compromise between meshing effort and solution quality.

What can be expected from HiLiftPW-2

- Selected test cases based on the DLR F11 configuration (EUROLIFT project)
- More realistic transport aircraft high-lift configuration
- Reynolds number scale effect assessment
- Good opportunity to confirm the maturity of our overset tools and possibly to test our hybrid mesh generation capabilities
- Which level of geometrical complexity (brackets, nacelle, strakes)?



DLR F11 WT model

- Thank you for your attention !

- Any questions?