

FUN3D and CFL3D Computations for the First High Lift Prediction Workshop

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January 2011

Solvers

CFL3D

- Structured point-matched grids
- Spalart-Allmaras and Menter SST turbulence models
- Thin-layer (3 directions) or full Navier-Stokes viscous operator

FUN3D

- Node-centered on unstructured tetrahedral and mixed-element grids
- Spalart-Allmaras turbulence model
- Full Navier-Stokes viscous operator

In the Paper (but not here)

Uniform Refinement and α -Sweeps

- CFL3D: full Navier-Stokes SA, thin-layer SA, thin-layer SST
- FUN3D: tetrahedral and mixed-element grids
- Flow initialization: freestream and α -sequenced

Flap Effectiveness (Configuration 8)

- CFL3D: full Navier-Stokes SA
- FUN3D: tetrahedral and mixed-element grids

Adaptation

- Comparison of error estimation techniques
- Motivation for further development

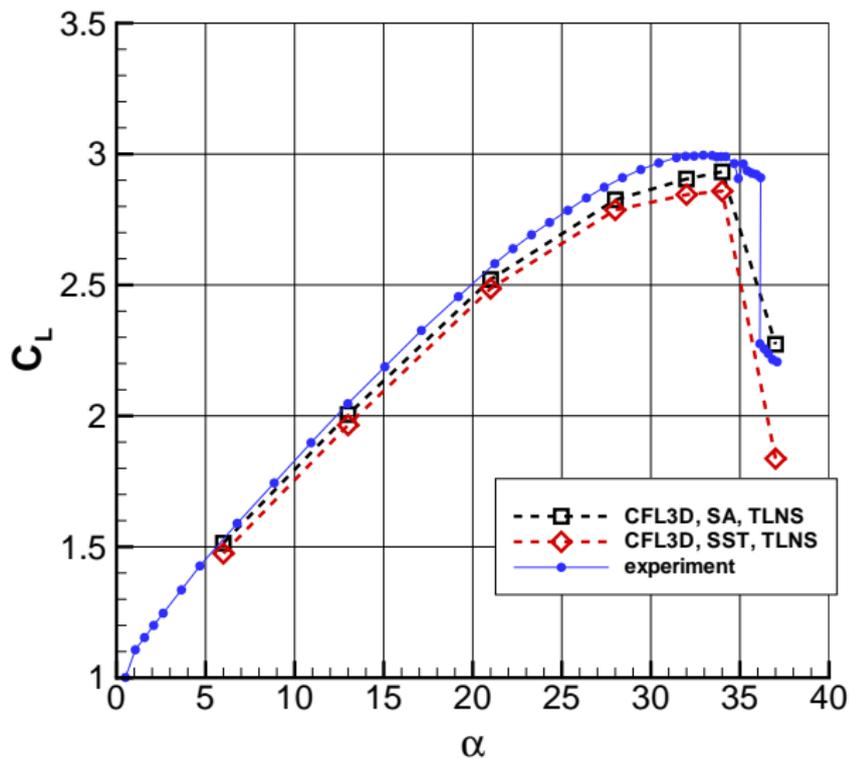
Outline

- 1 Modeling Sensitivities
- 2 Support Brackets
- 3 Grid Adaptation
- 4 Coarse Grid Adaptation Details
- 5 Medium Grid Adaptation Details
- 6 Summary

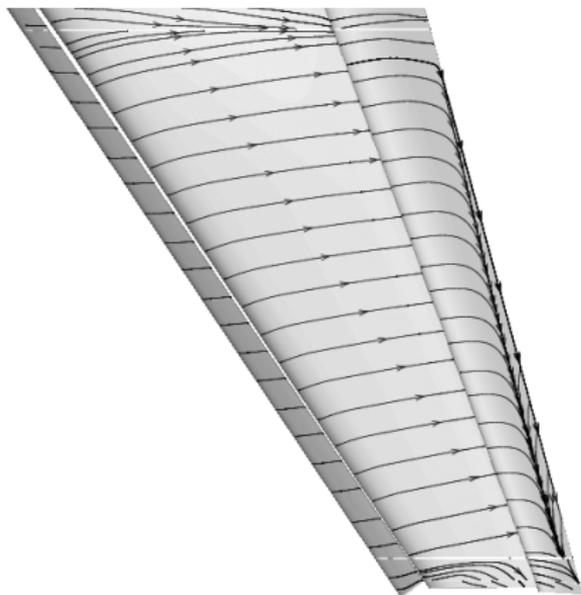
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Turbulence Model

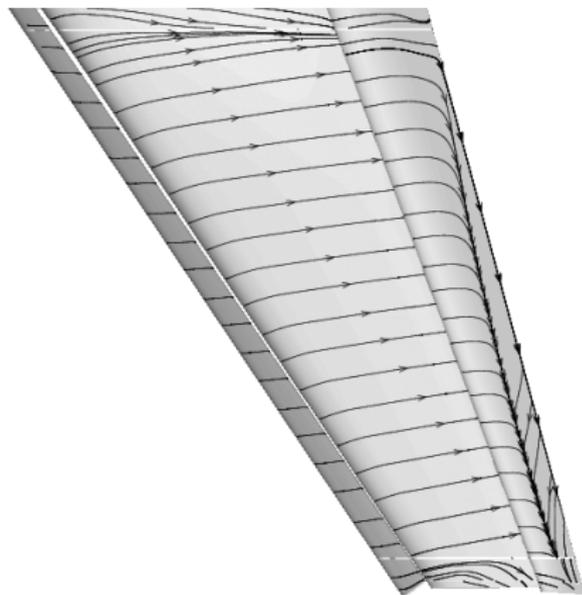


Turbulence Model, $\alpha = 13^\circ$



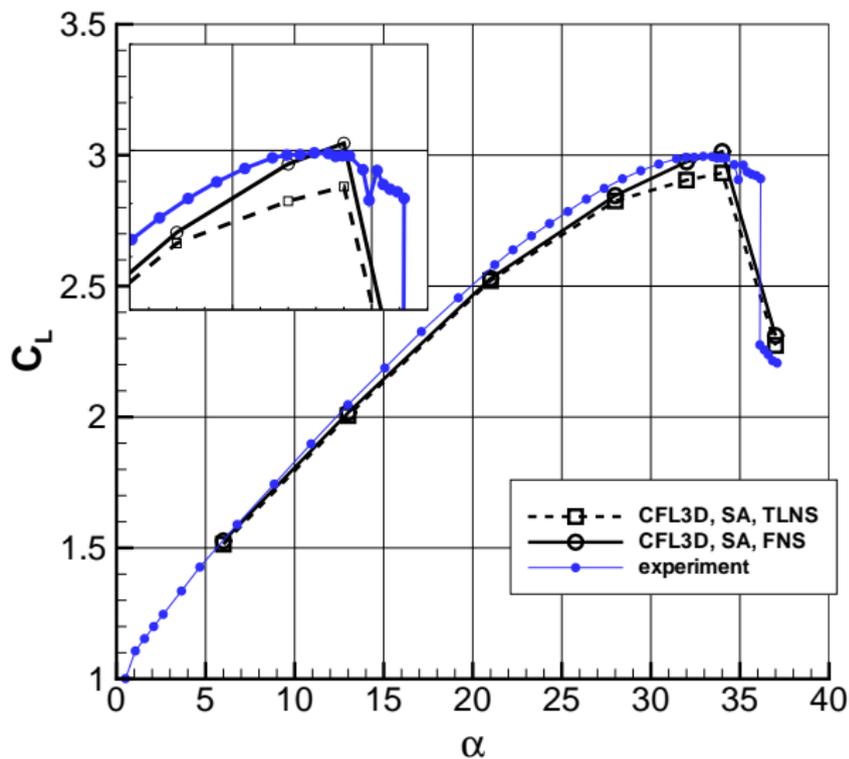
Spalart-Allmaras

CFL3D Thin-Layer

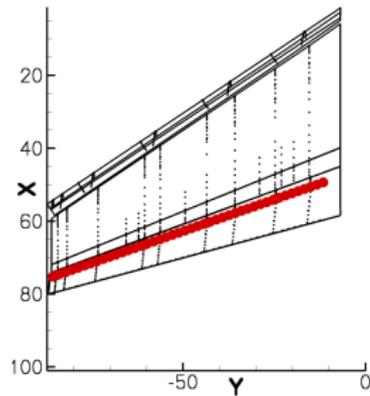
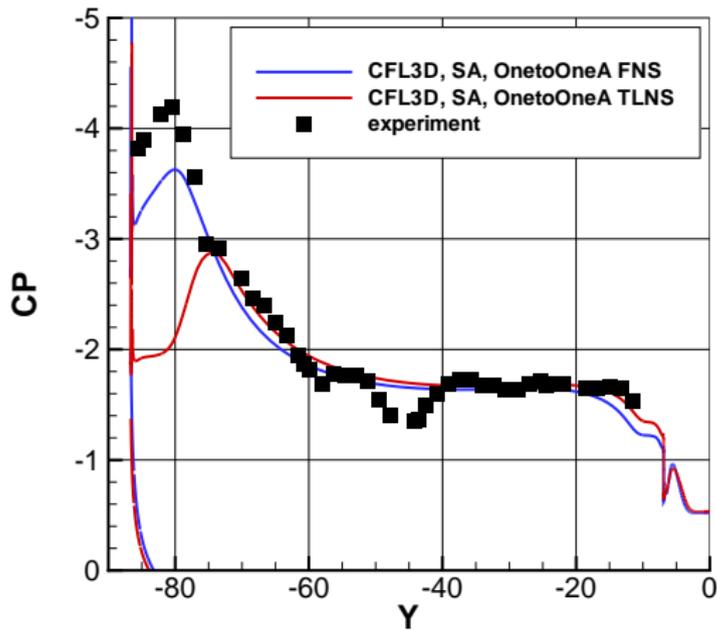


Menter SST

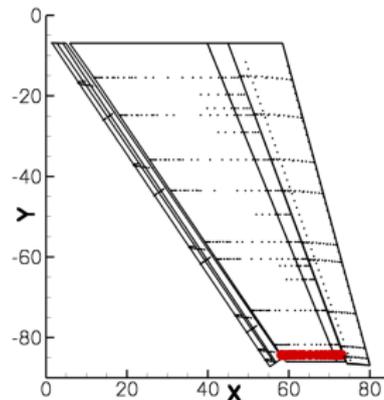
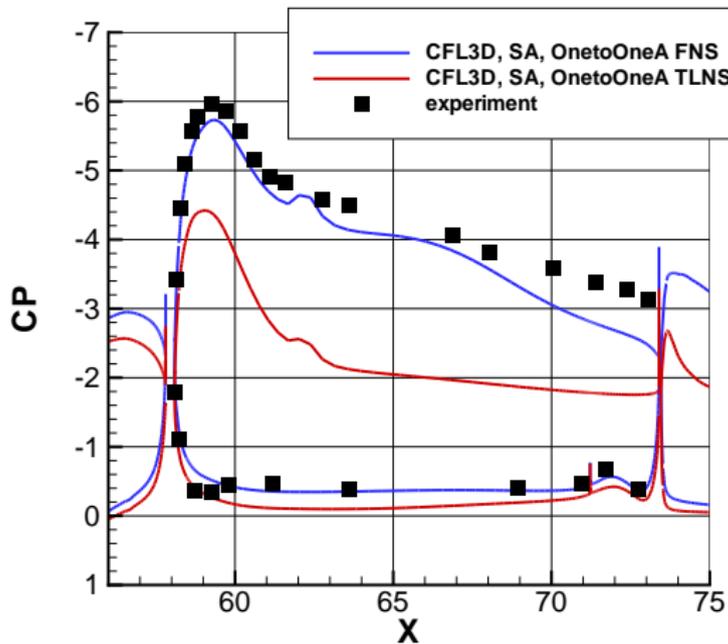
Viscous Operator



Viscous Operator, $\alpha = 28^\circ$, flapfwdspan



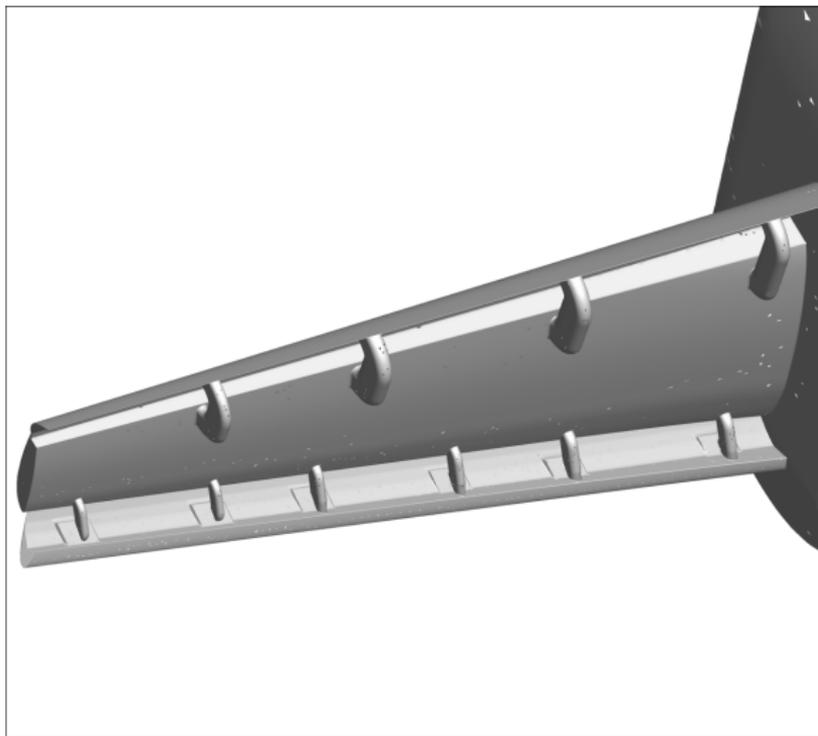
Viscous Operator, $\alpha = 28^\circ$, $\eta = 98\%$



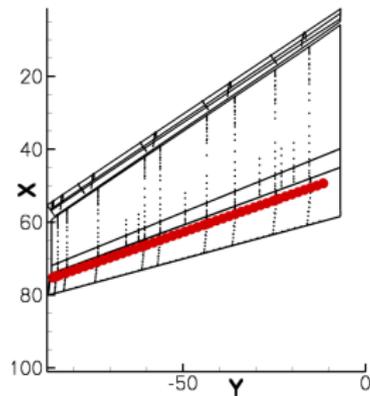
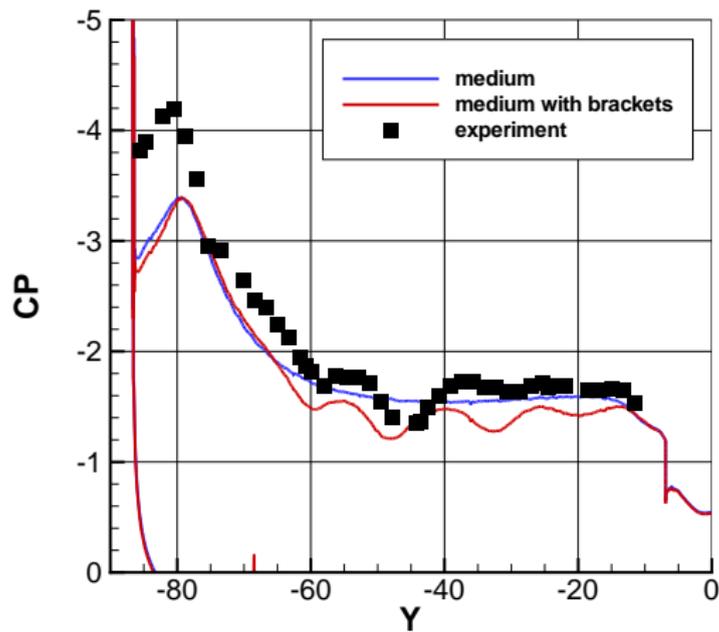
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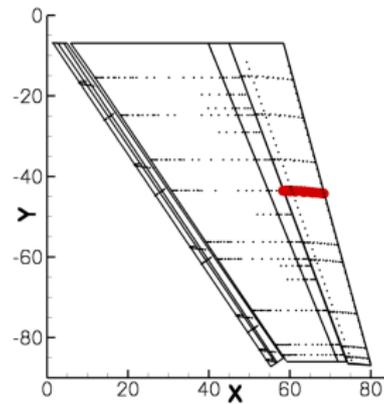
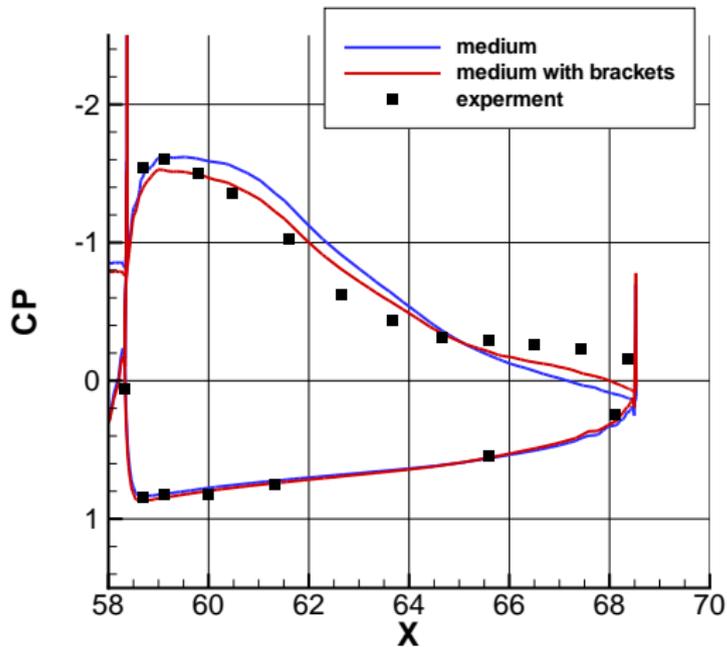
Support Brackets



Support Brackets, $\alpha = 28^\circ$, flapfwdspan



Support Brackets, $\alpha = 28^\circ$, $\eta = 50\%$



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Grid Adaptation

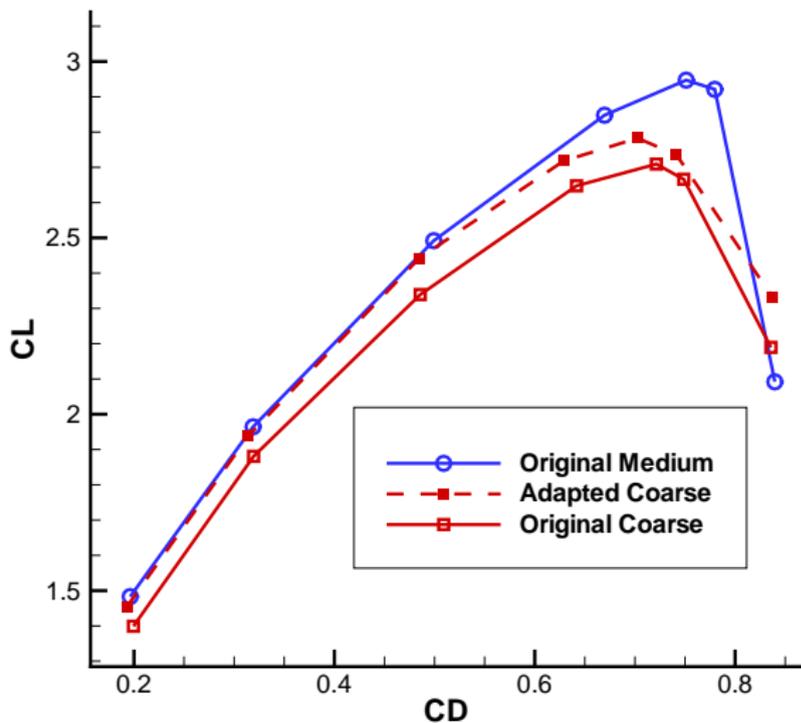
FUN3D+refine

- Unstructured tetrahedral grids with frozen boundary layers
- Includes the adjoint solution to improve the calculation of drag
- Anisotropy derived from Mach number Hessian

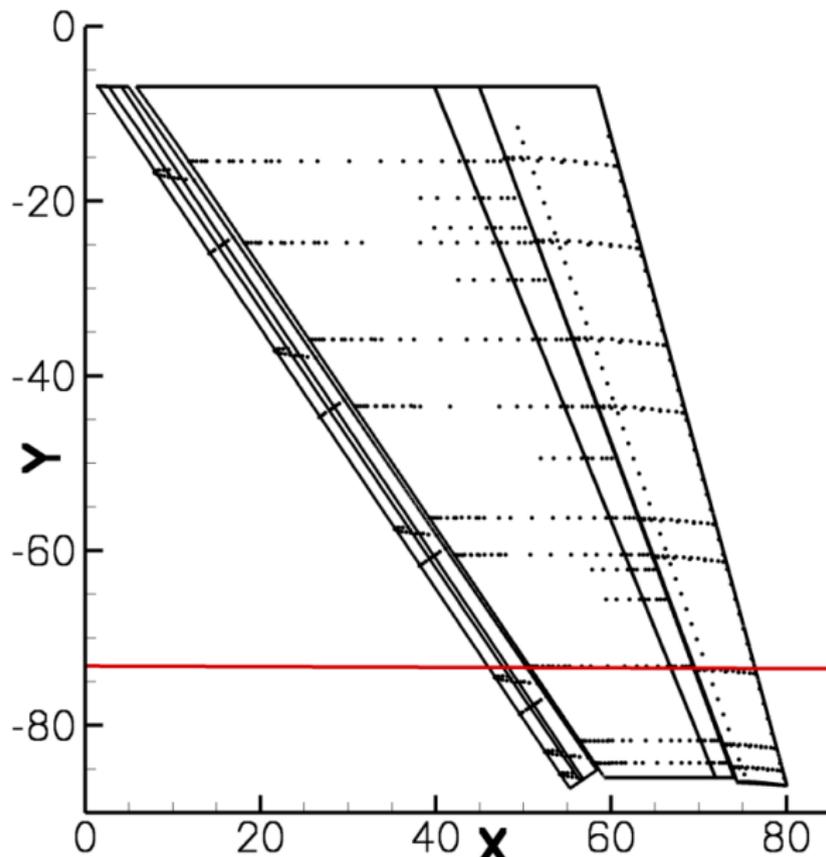
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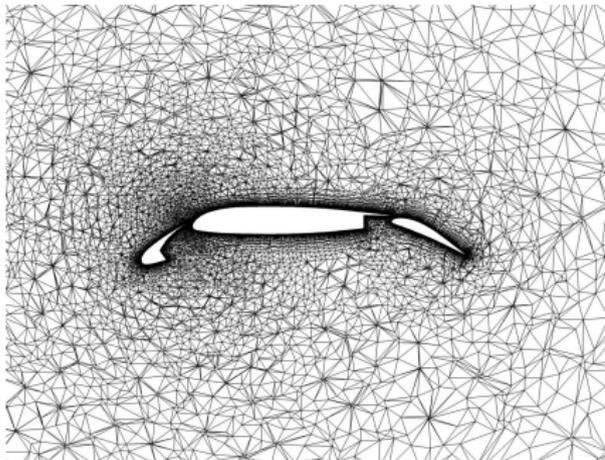
Adaptation



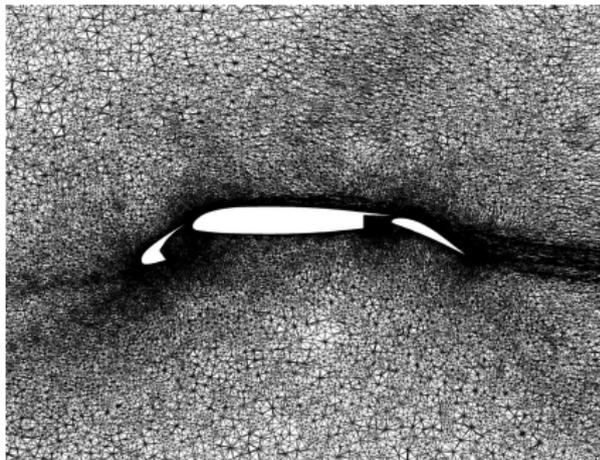
Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$



Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$

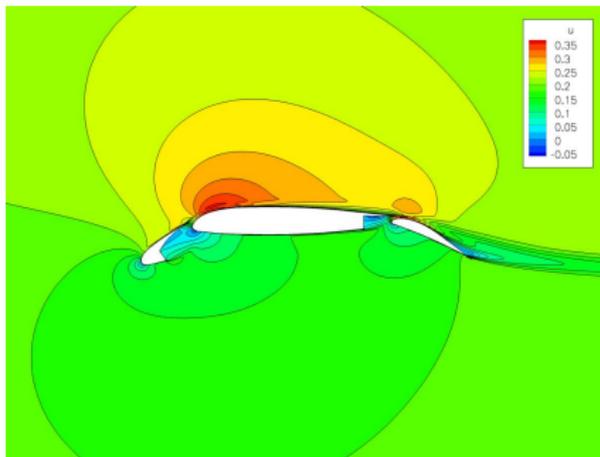
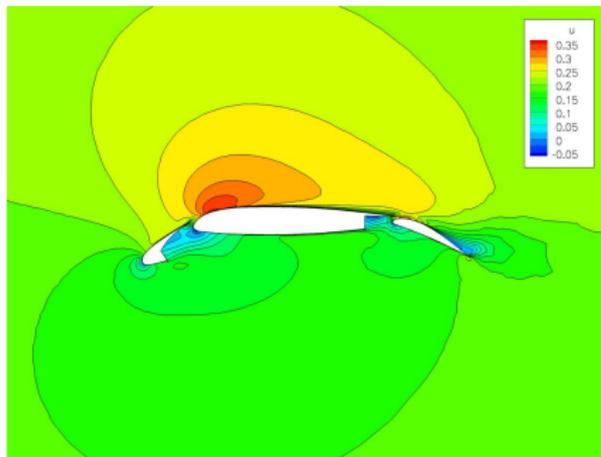


Original Coarse



Adapted Coarse

Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$

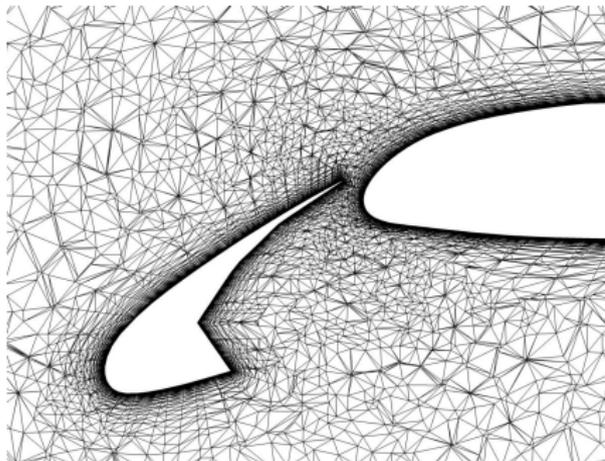


Original Coarse

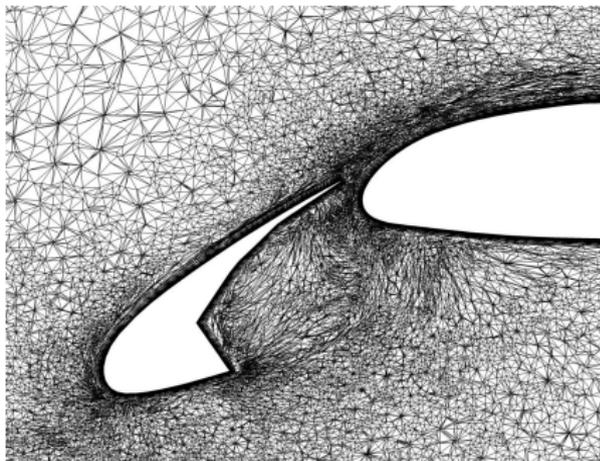
Adapted Coarse

X-Component of Velocity

Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$

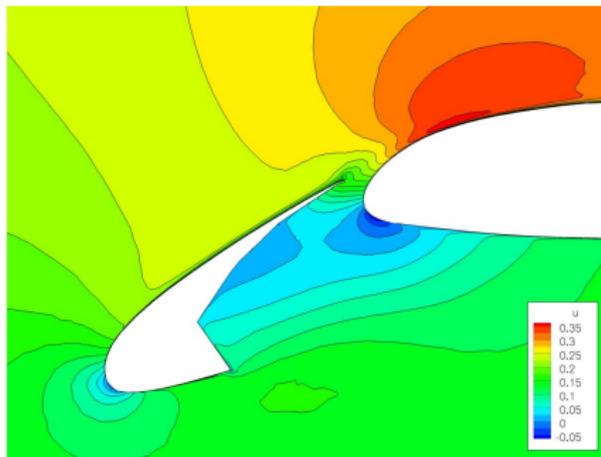


Original Coarse

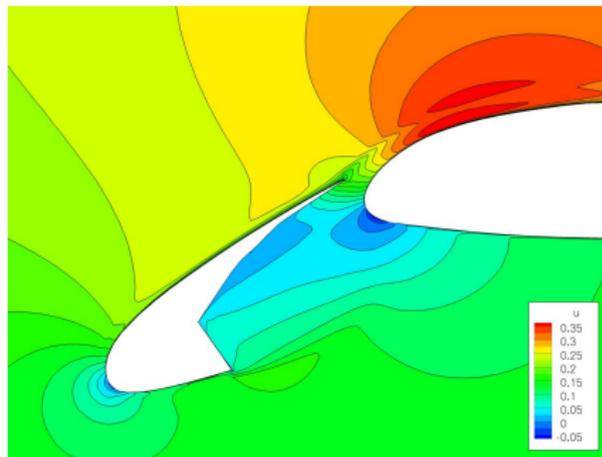


Adapted Coarse

Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$



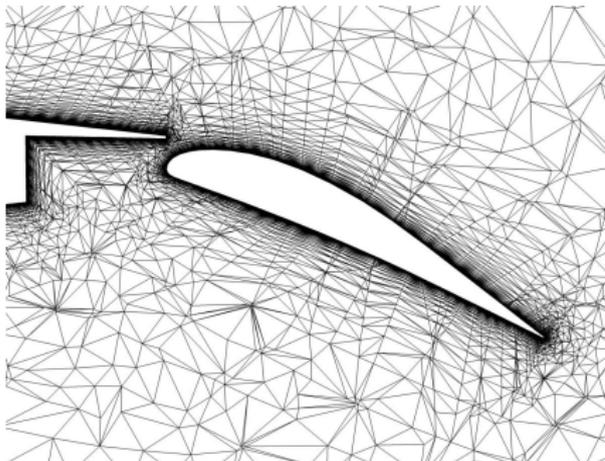
Original Coarse



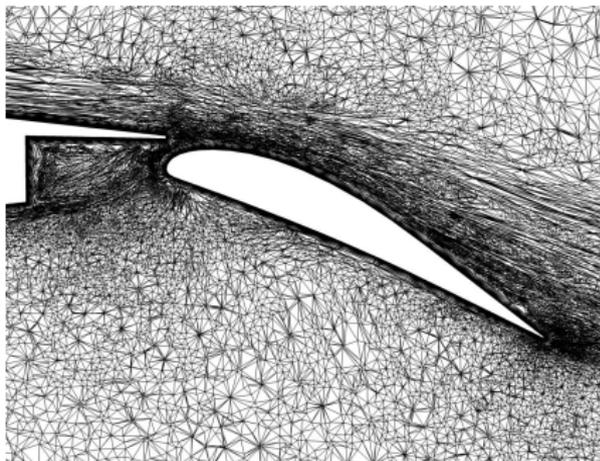
Adapted Coarse

X-Component of Velocity

Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$

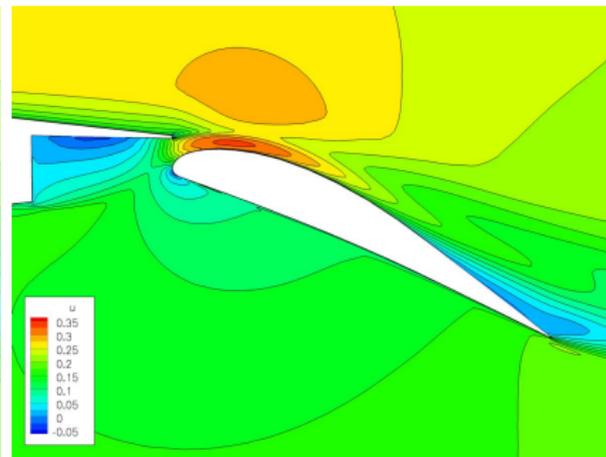
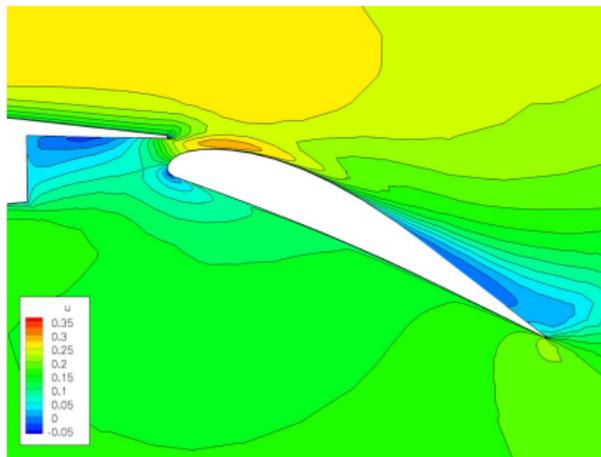


Original Coarse



Adapted Coarse

Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$



Original Coarse

Adapted Coarse

X-Component of Velocity

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Adaptation

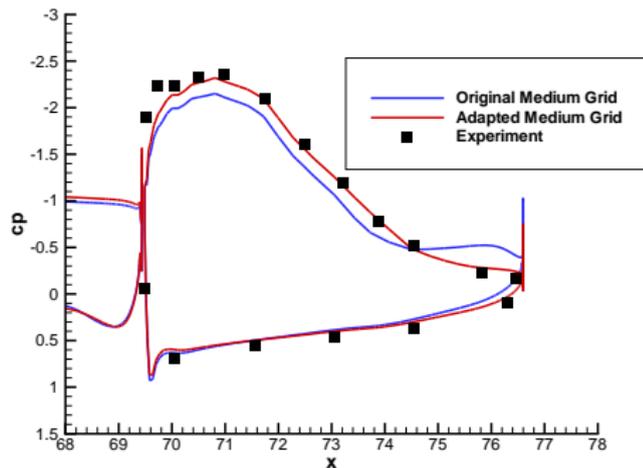
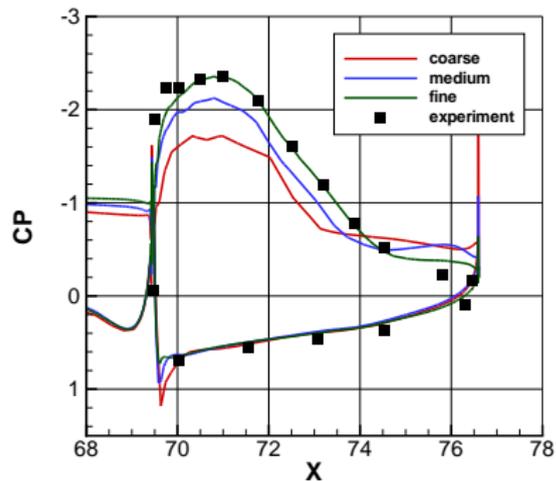
Medium Grid

- Adaptation ran over the entire α -range
- Still investigating stalled convergence of turbulence model on adapted grids

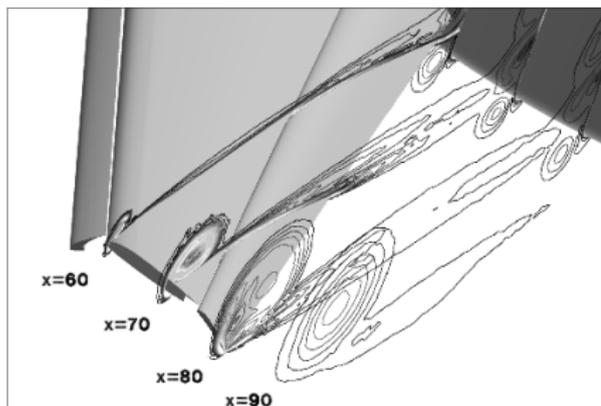
At $\alpha = 13$ and Below

- Small-scale unsteadiness
- Motivates the need for time-accurate adaptive methods
- Presenting snapshot of the solution on the final grid

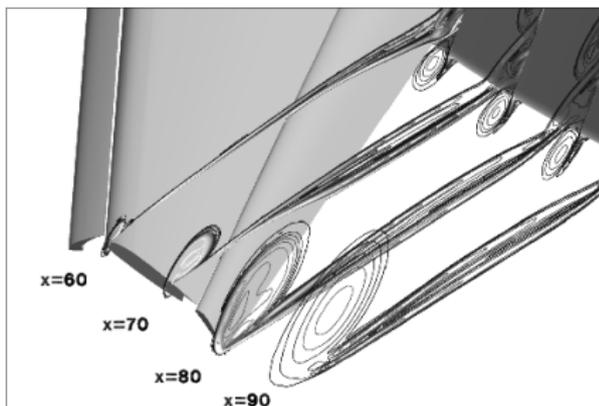
Adaptation, $\alpha = 13^\circ$, $\eta = 85\%$



Adaptation, $\alpha = 28^\circ$



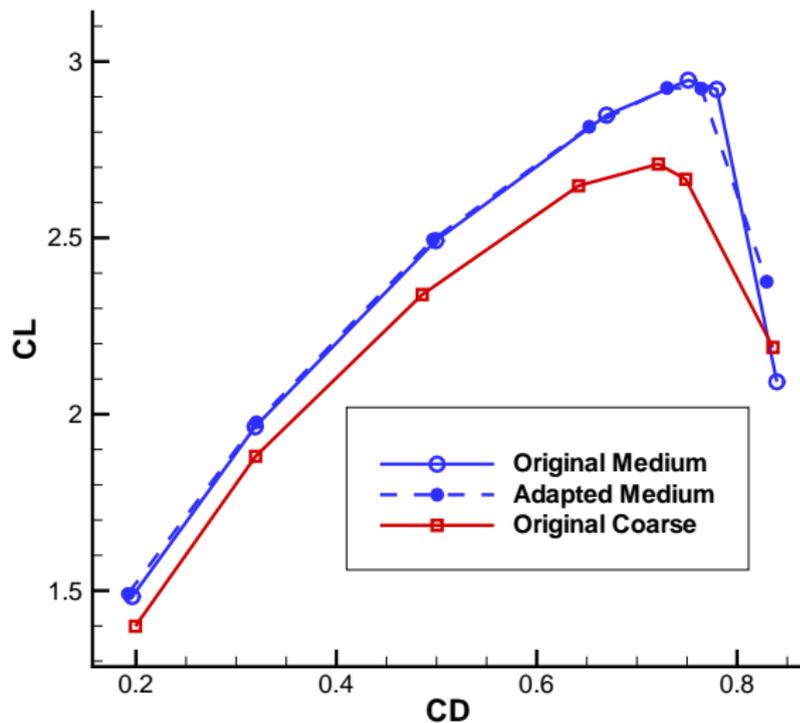
Original Medium



Adapted Medium

Vorticity Magnitude Contours

Adaptation



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Summary

Modeling sensitivities

- Full Navier-Stokes (FNS) showed a strengthened tip vortex as compared to thin-layer
- Spalart-Allmaras (SA) turbulence model showed less separation than Menter SST
- FNS and SA increased lift, improving comparison to experiment

Summary

Coarse grid adaptation

- Adapted coarse grid showed increased lift
- Adapted coarse grid polar similar to medium grid polar at lower α
- Adaptation strengthened gap jets and reduced flow separation on flap

Medium grid adaptation

- Flap separation was reduced yielding a better comparison to measurements than fine grid
- Wake and vortex resolution improved
- Slight increase in lift at lower α
- Small-scale unsteadiness motivates need for time-accurate adaptation