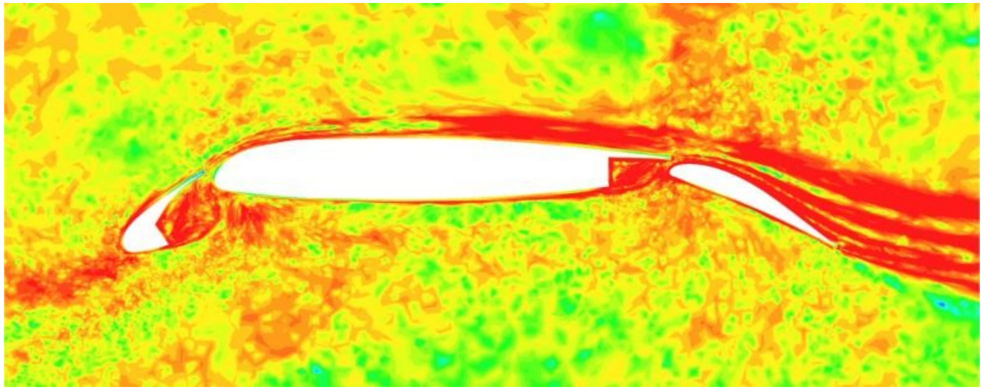
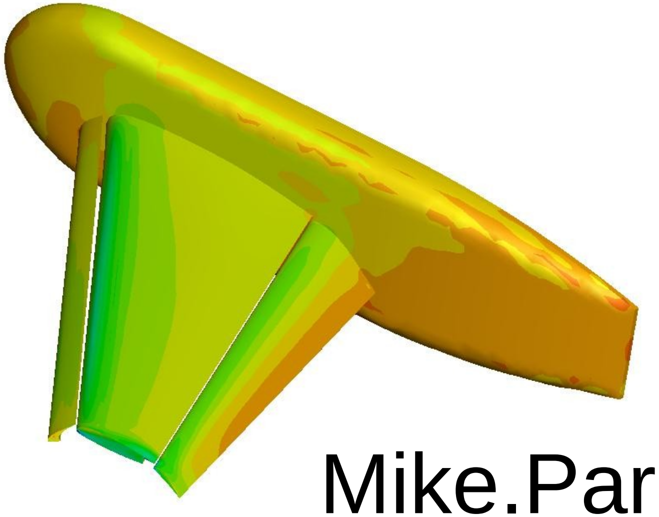
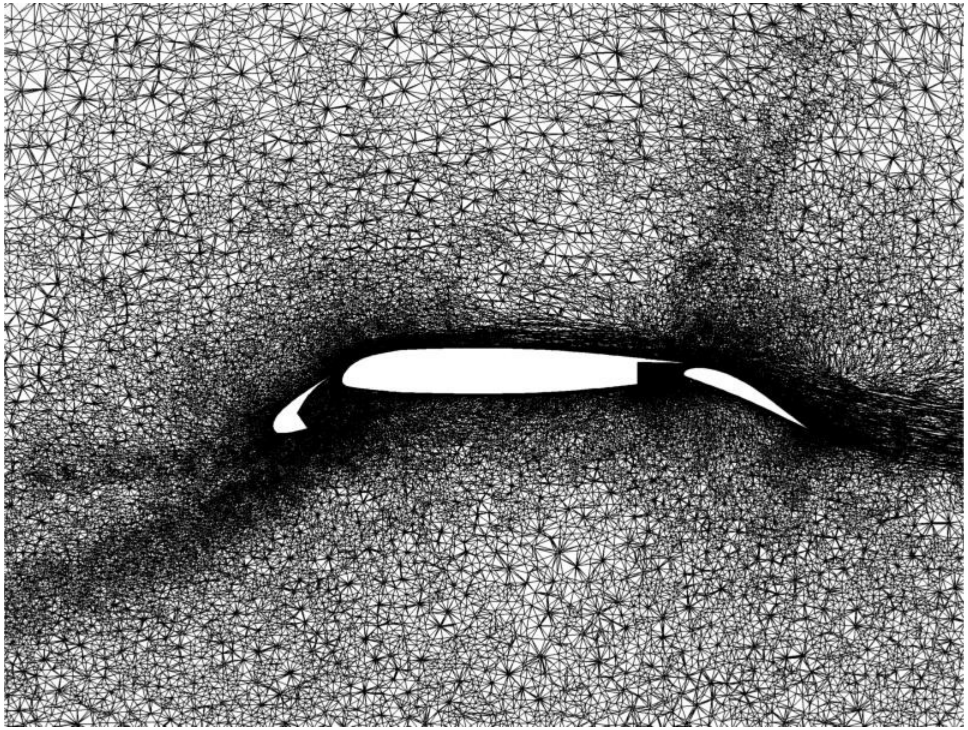
Output-Based Grid Adaptation Applied to the HiLiftPW-1







Mike.Park@NASA.gov
Computational AeroSciences Branch
NASA Langley Research Center

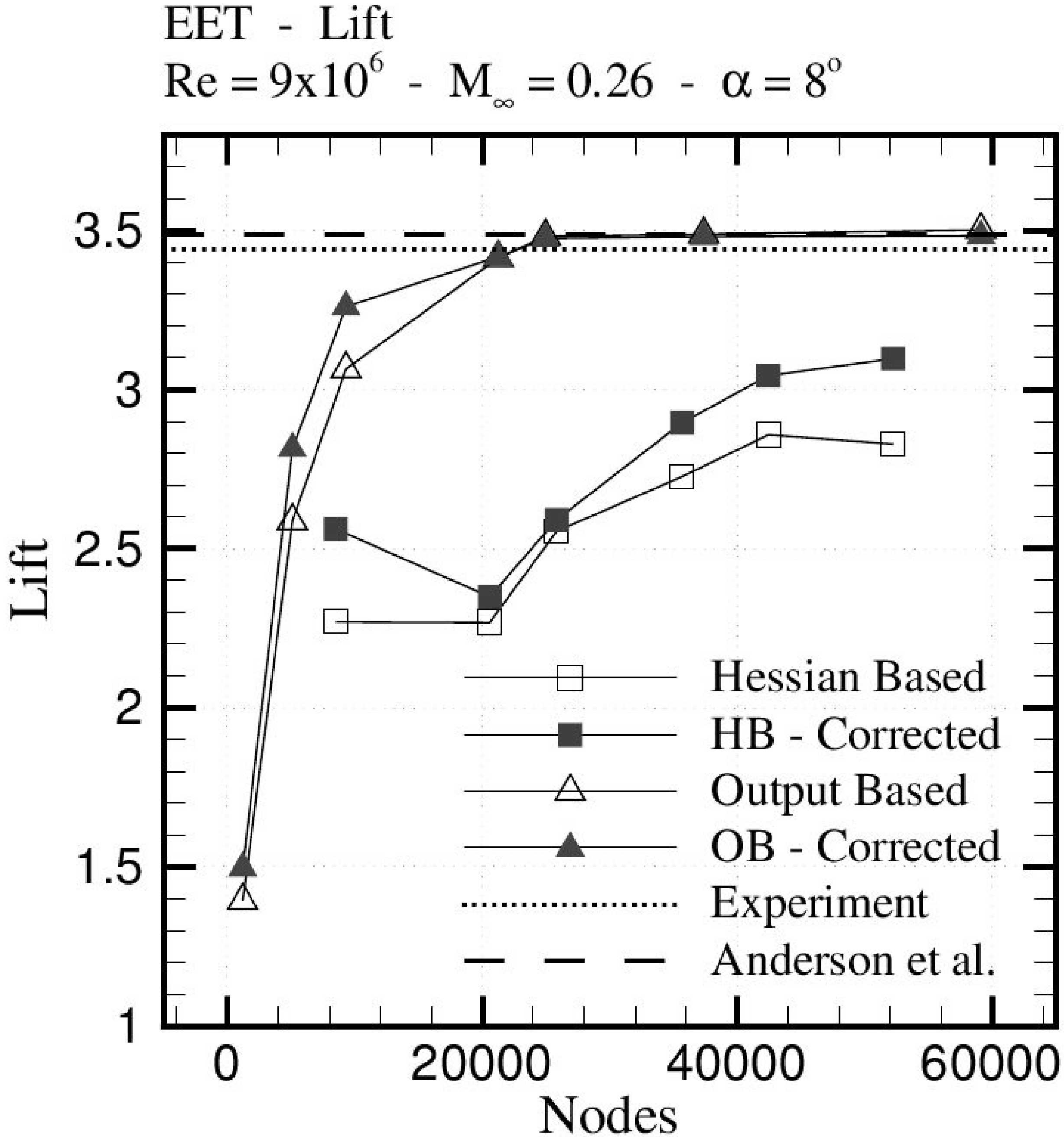
Output-Based Adaptation

- Mathematically rigorous approach involving the adjoint solution that reduces estimated error in an engineering output
- Improvement over feature-based techniques, which ignore the transport of errors potentially resolving features in incorrect locations
- Motivated by the 2D work of Venditti and Darmofal

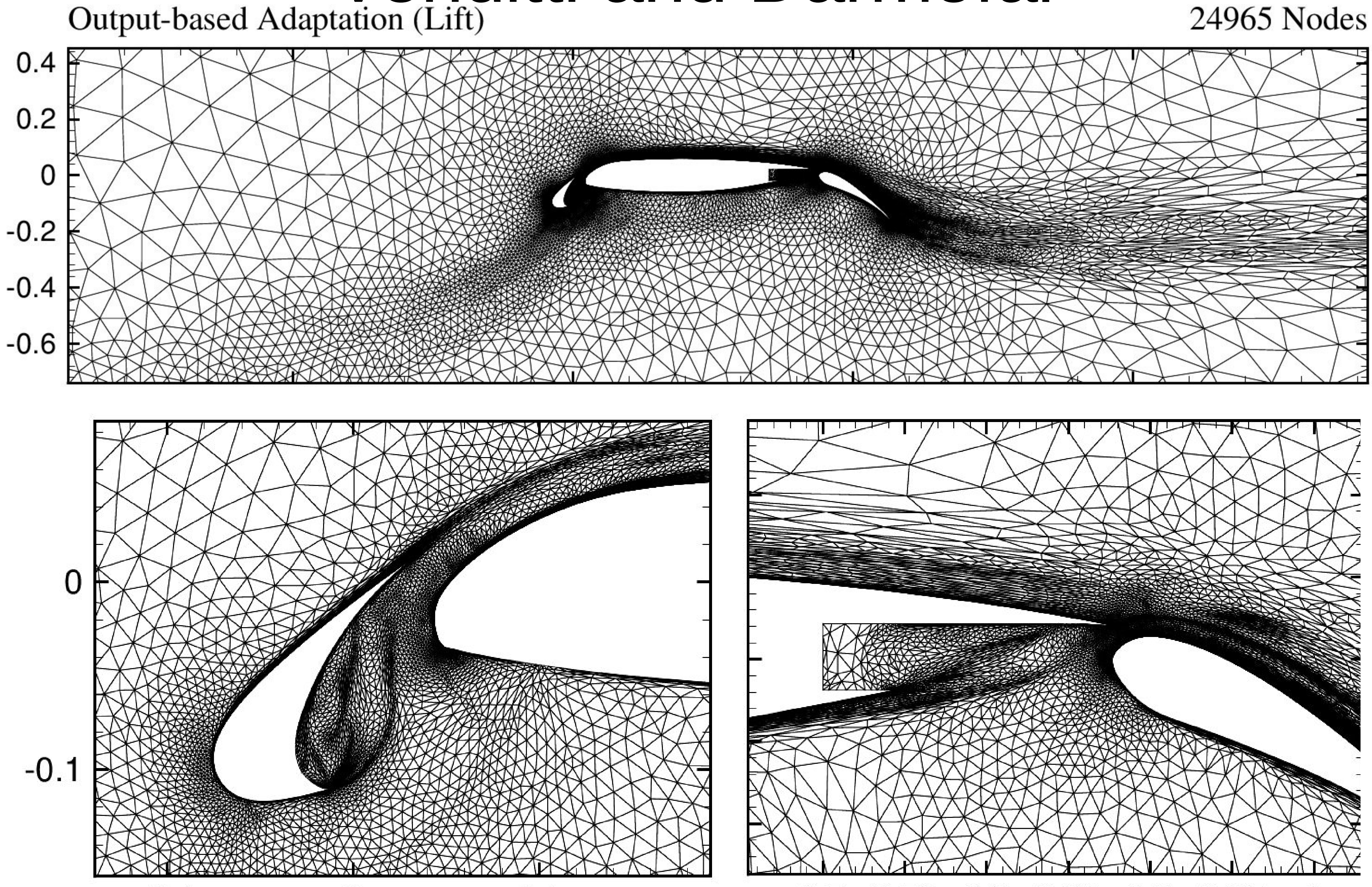
Venditti and Darmofal

- AIAA-2003-3845
- Applied 2D output-based (lift) adaptation to Advanced EET Three Element Airfoil
- Compared it to a feature-based technique (Pure Hessian Based)

Venditti and Darmofal



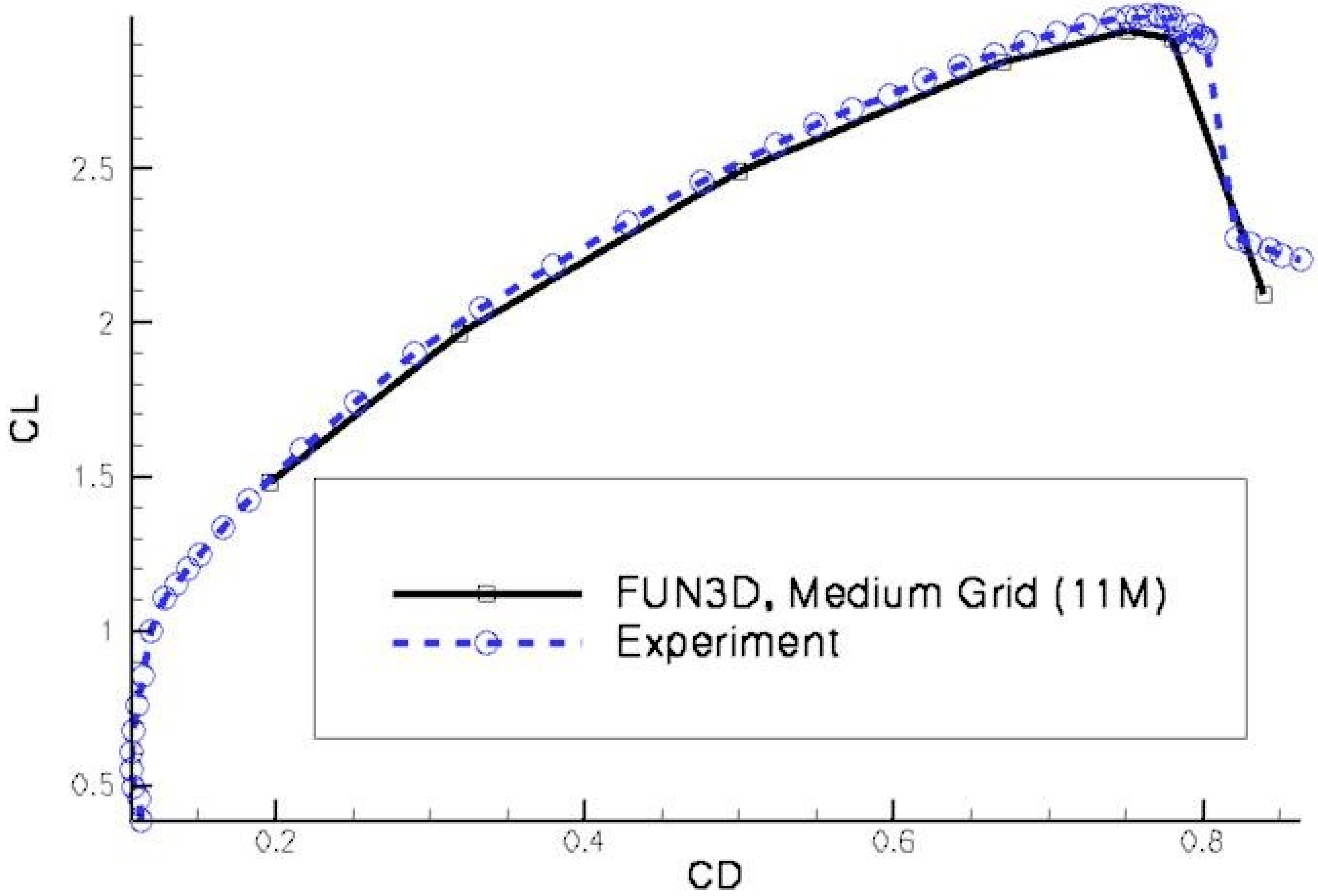
Venditti and Darmofal



FUN3D Calculations

- Roe flux without a reconstruction limiter
- Spalart-Allmaras (S-A) one-equation turbulence model
- Committee provided tetrahedral node-based initial grids
- Restarted from converged solutions at lower angles of attack

Configuration 1 Drag Polar

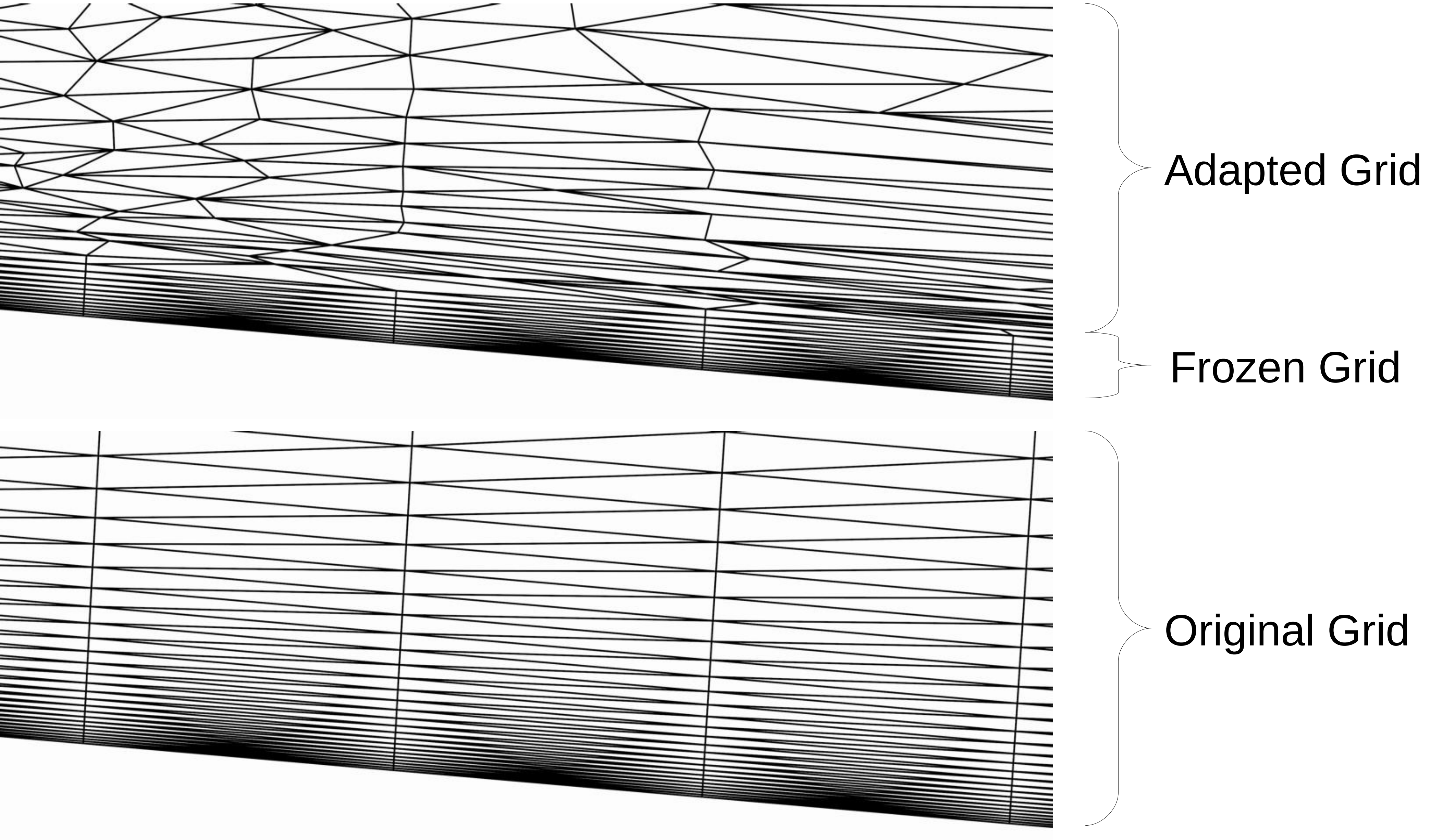


- Submitted all the required cases for the committee provided node-based tetrahedral grids

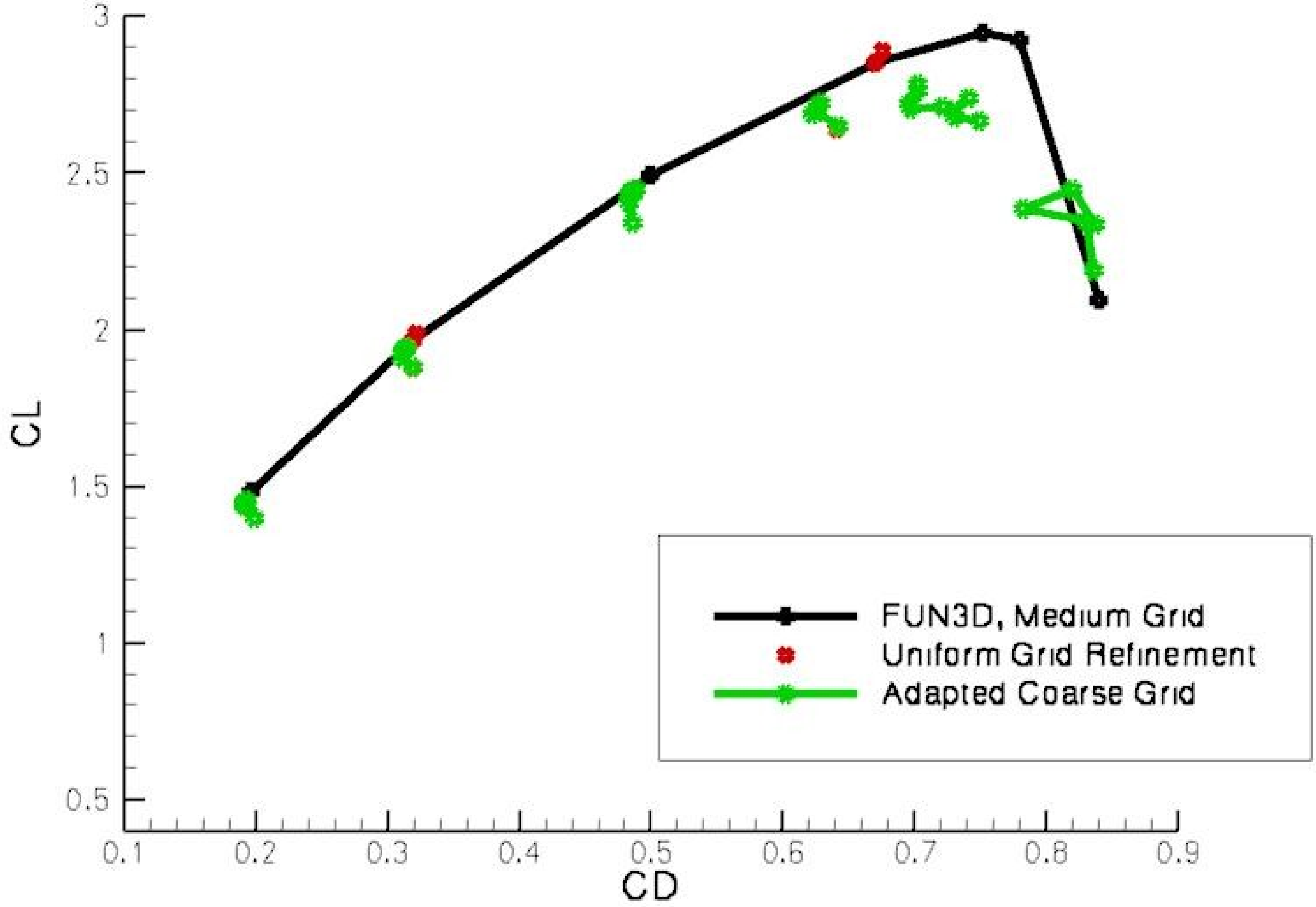
FUN3D Output-based Adaptation

- Venditti and Darmofal technique implemented in 3D
  - Utilizes an embedded grid (memory limitation)
- Output-based adaptation for drag (expect similar results for lift)
- Boundary layer grid (s < 0.14, y+ < ~200) frozen due to limitations in grid mechanics
- Most challenging application attempted to date
  - 1024 cores on NASA Pleiades

Frozen Boundary Layer Grid



Configuration 1 Drag Polar



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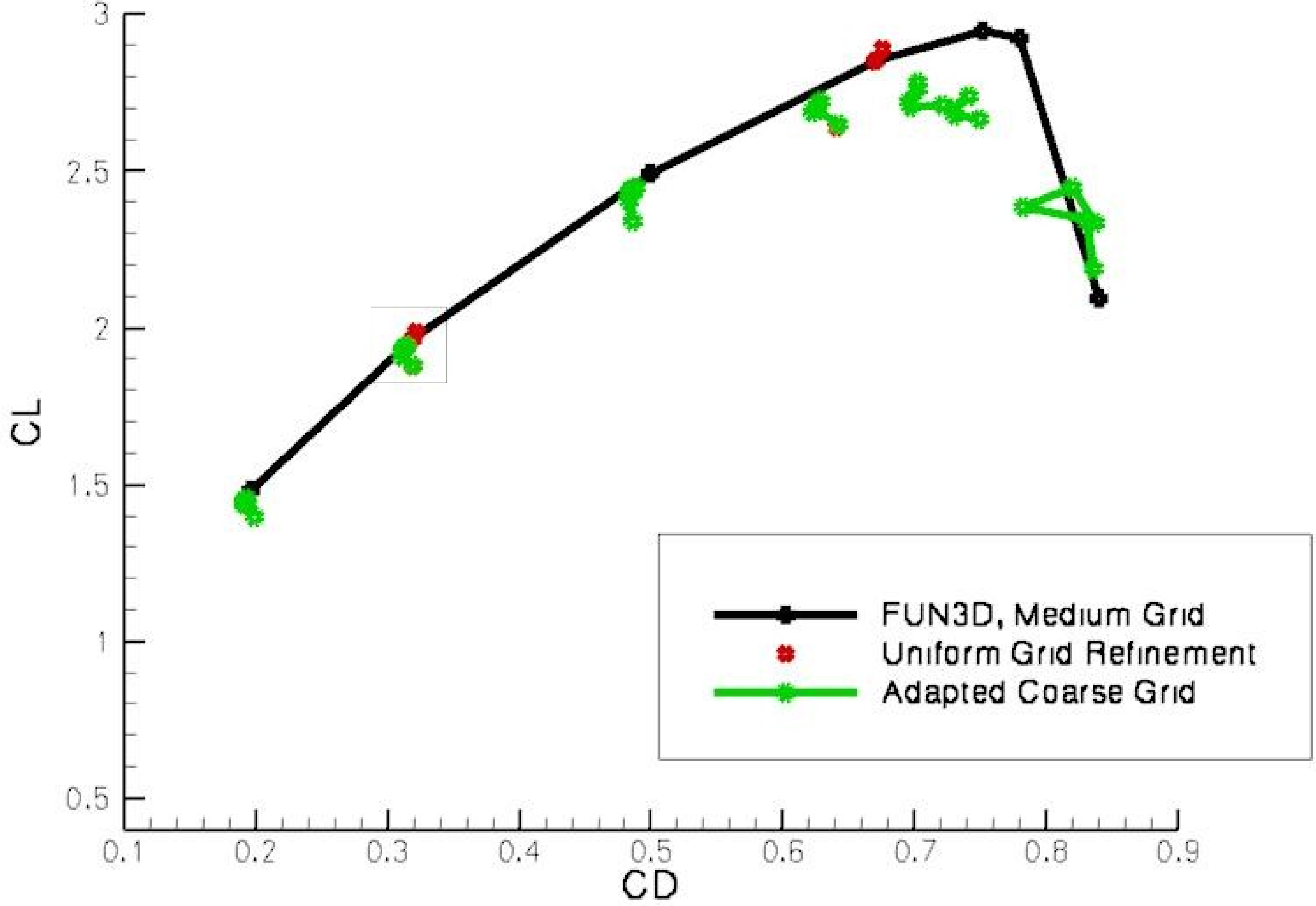

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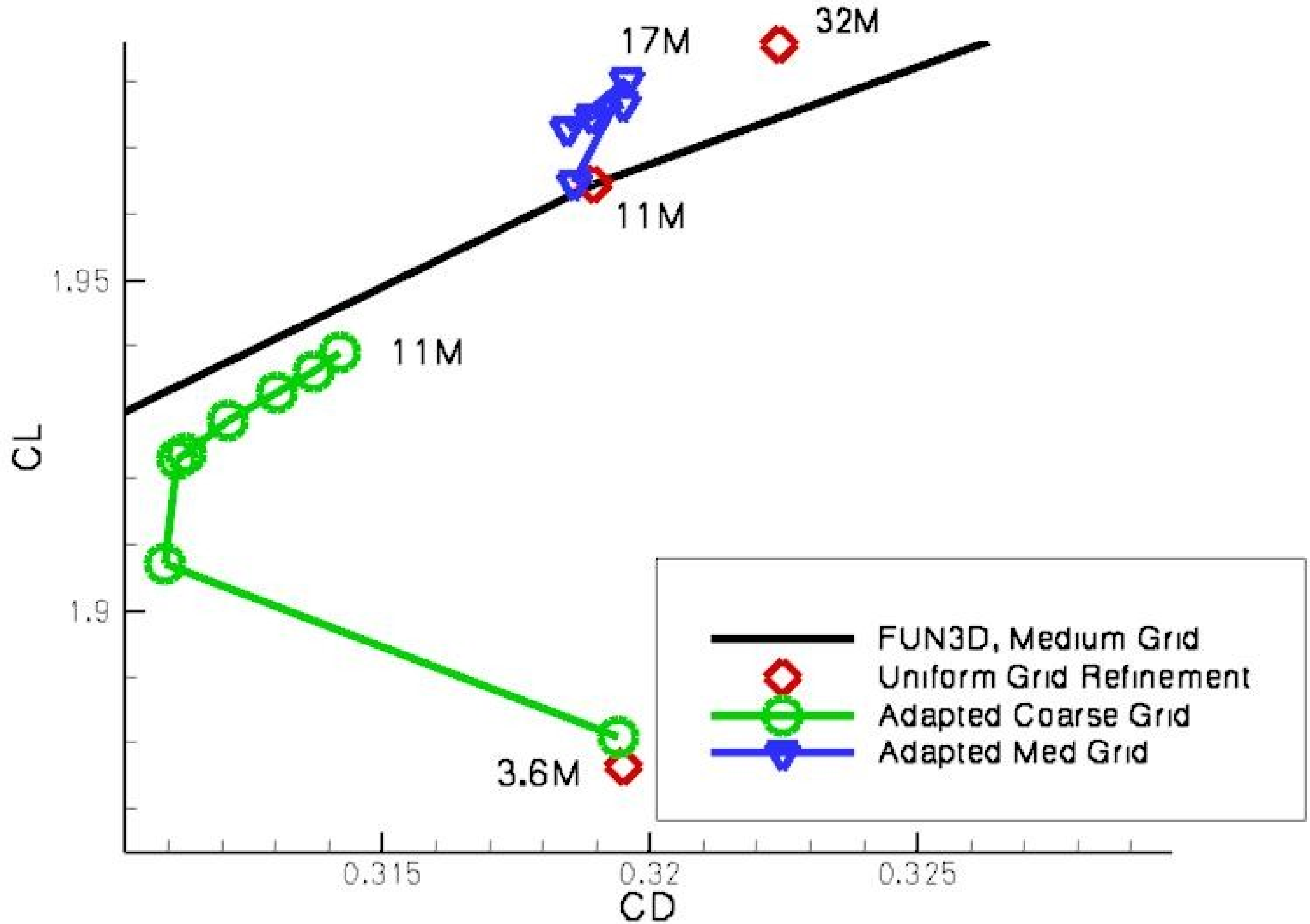

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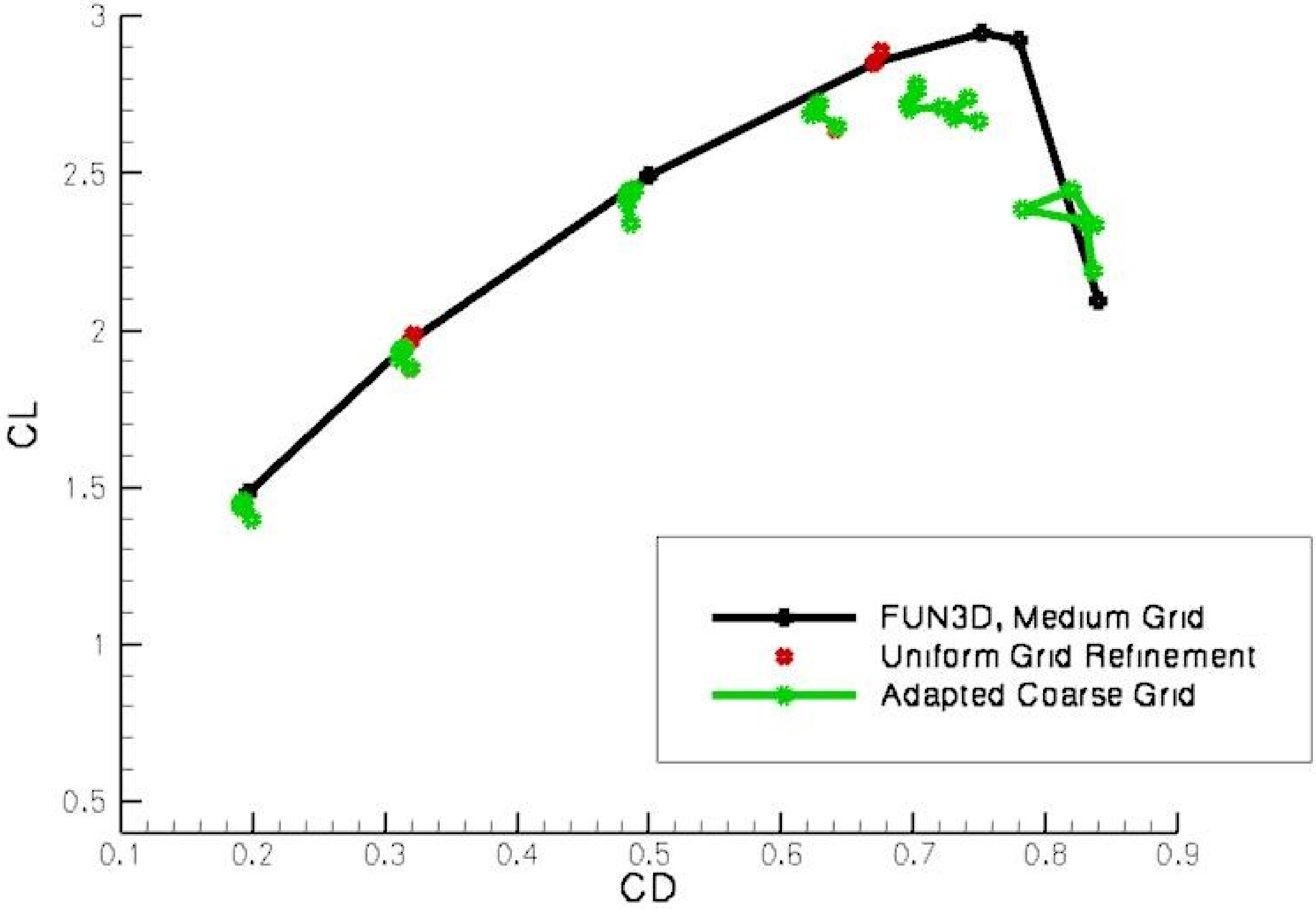
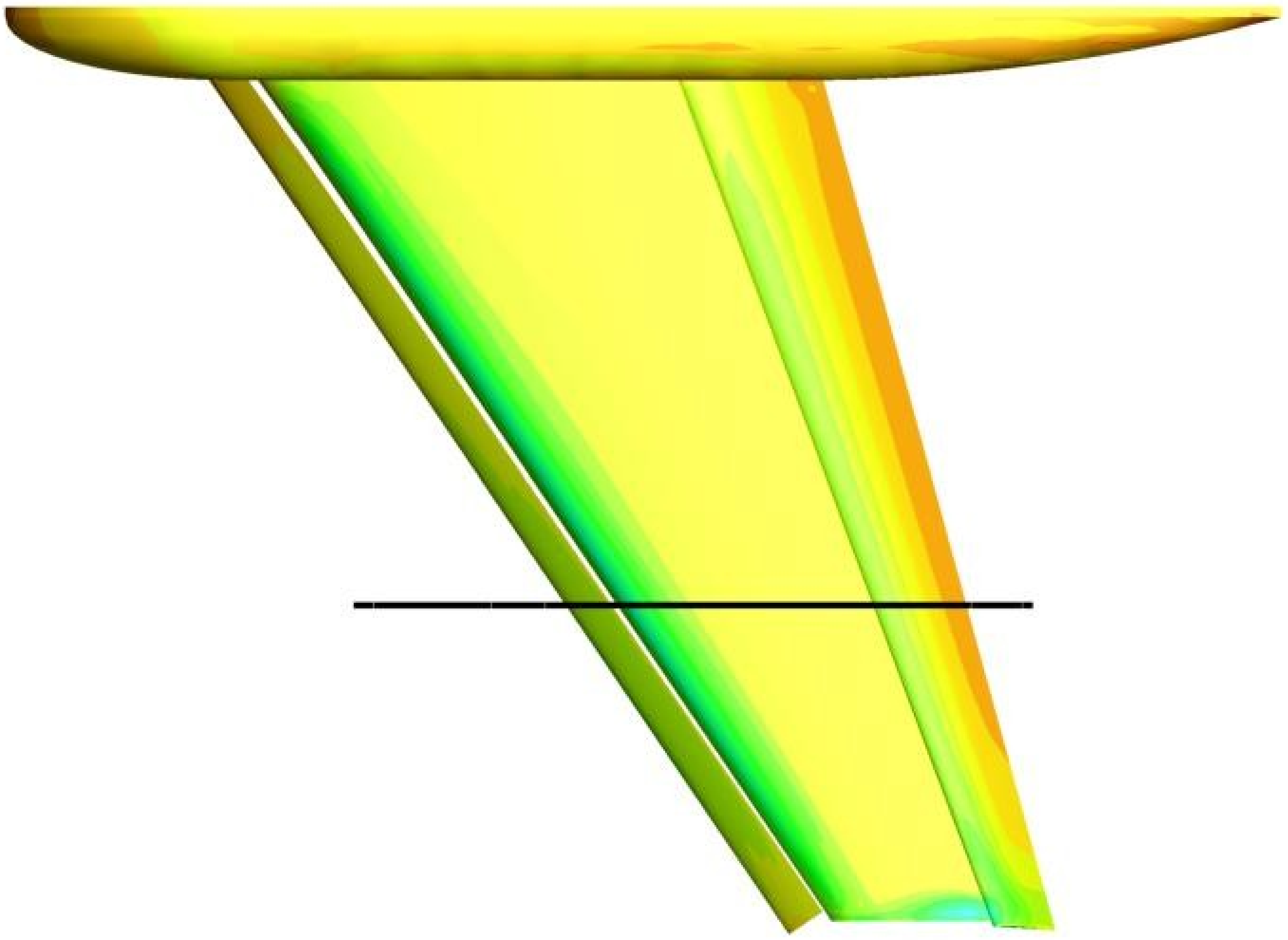


Configuration 1, eta=0.65, AoA=13



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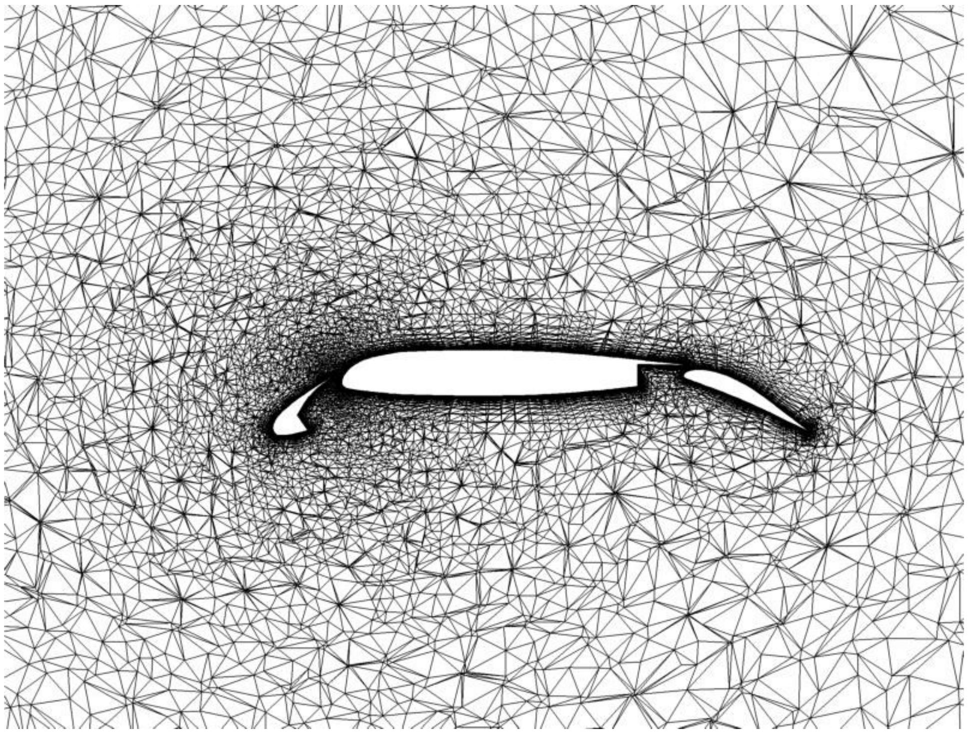
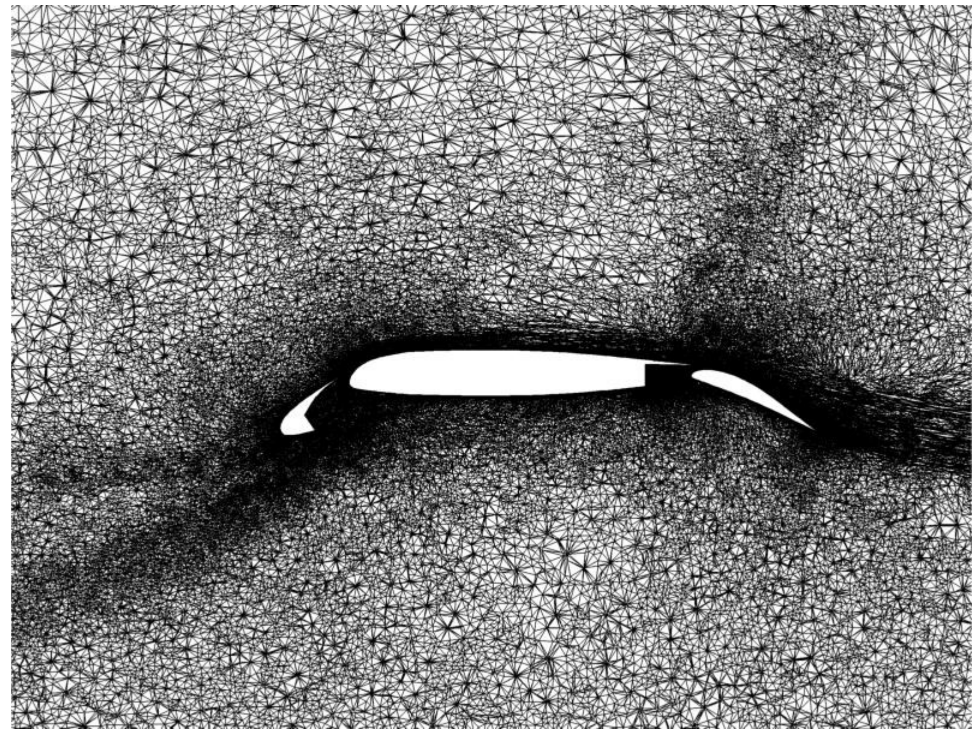


Coarse Grid (3.6M)



Adapted Grid (11M)

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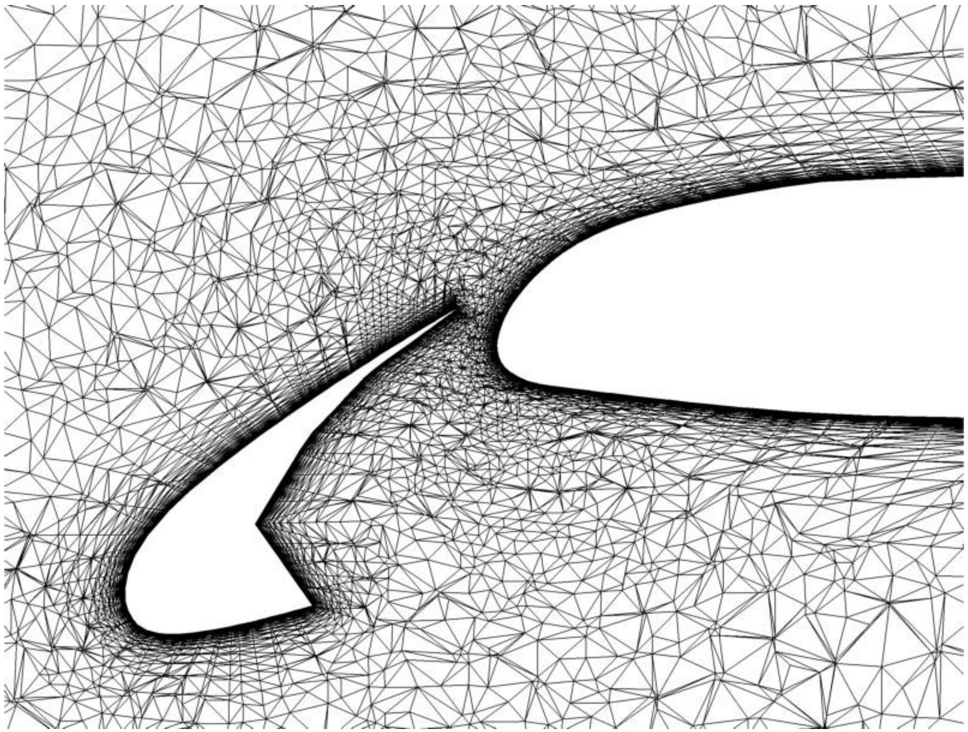

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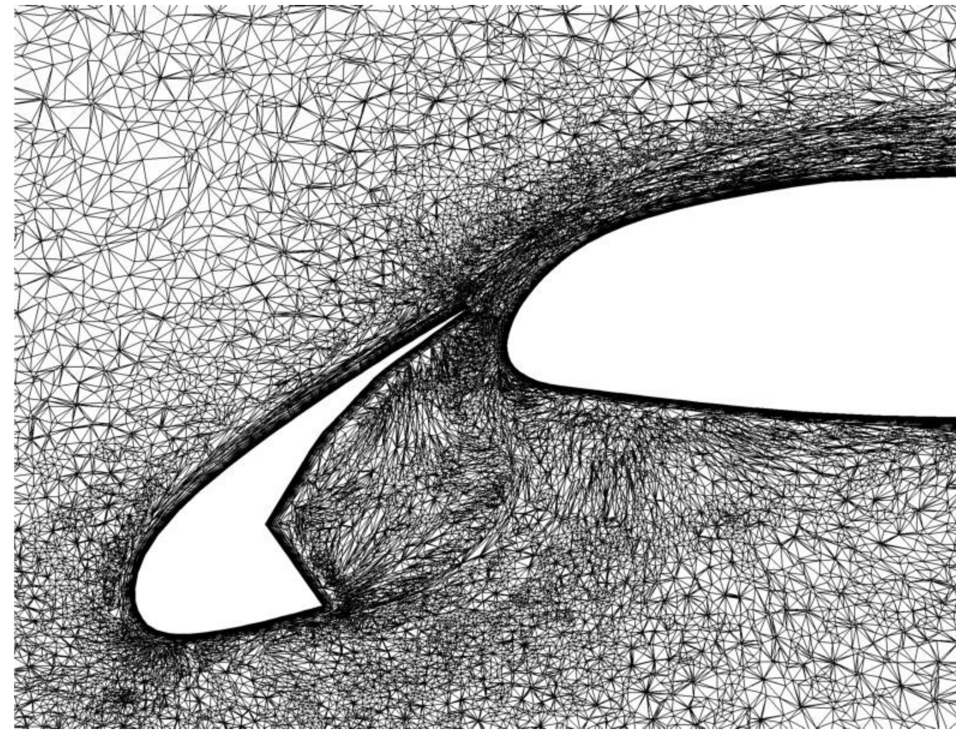

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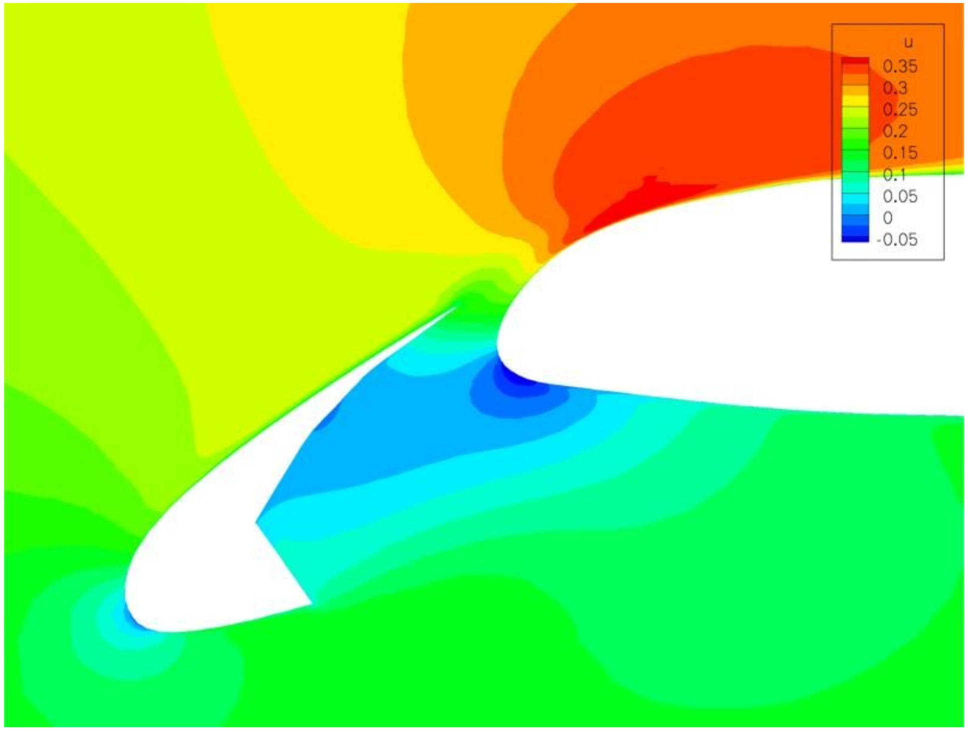

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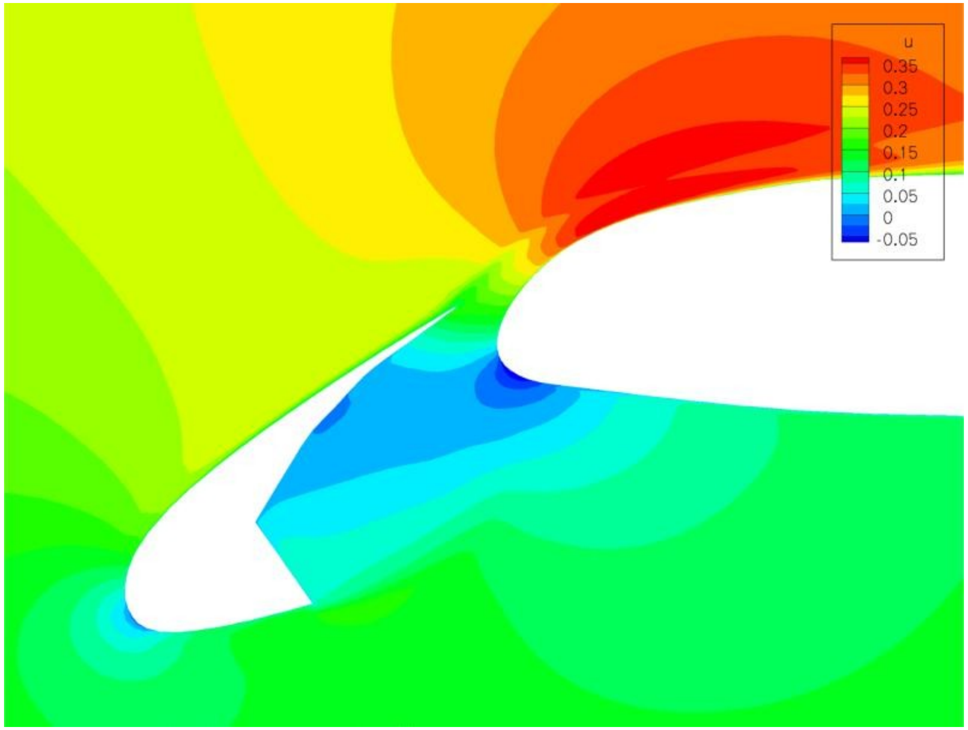

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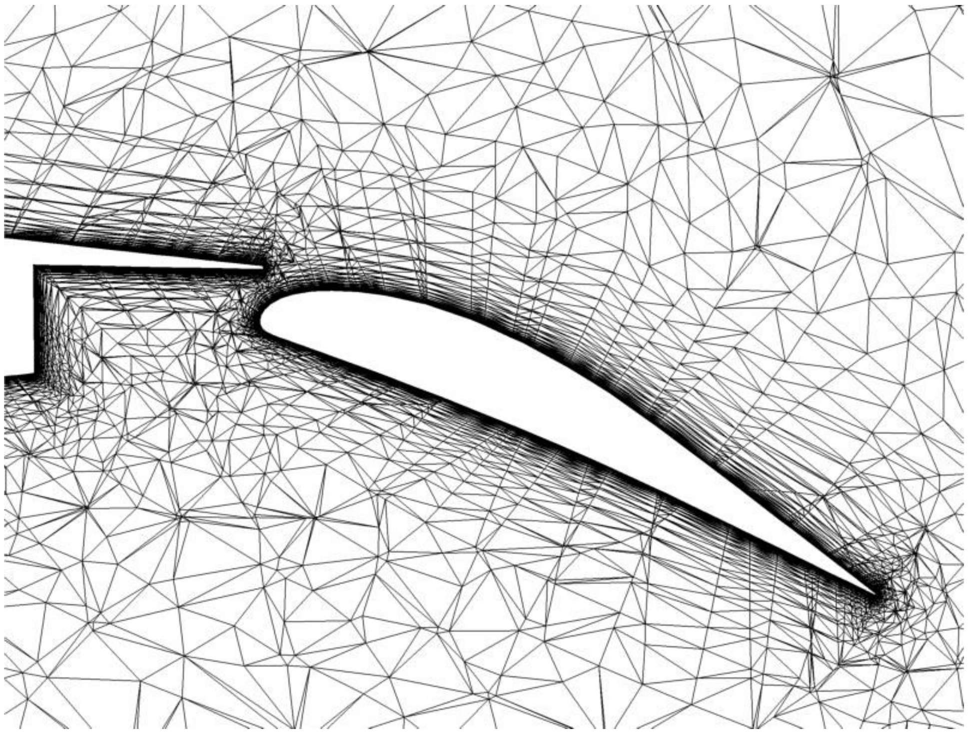

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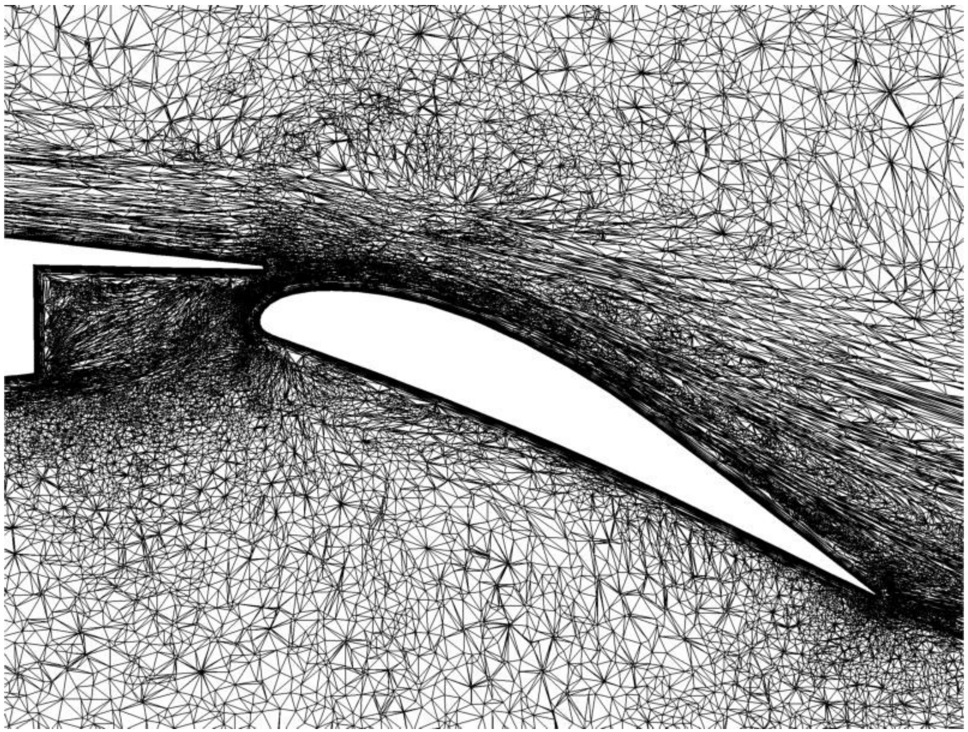

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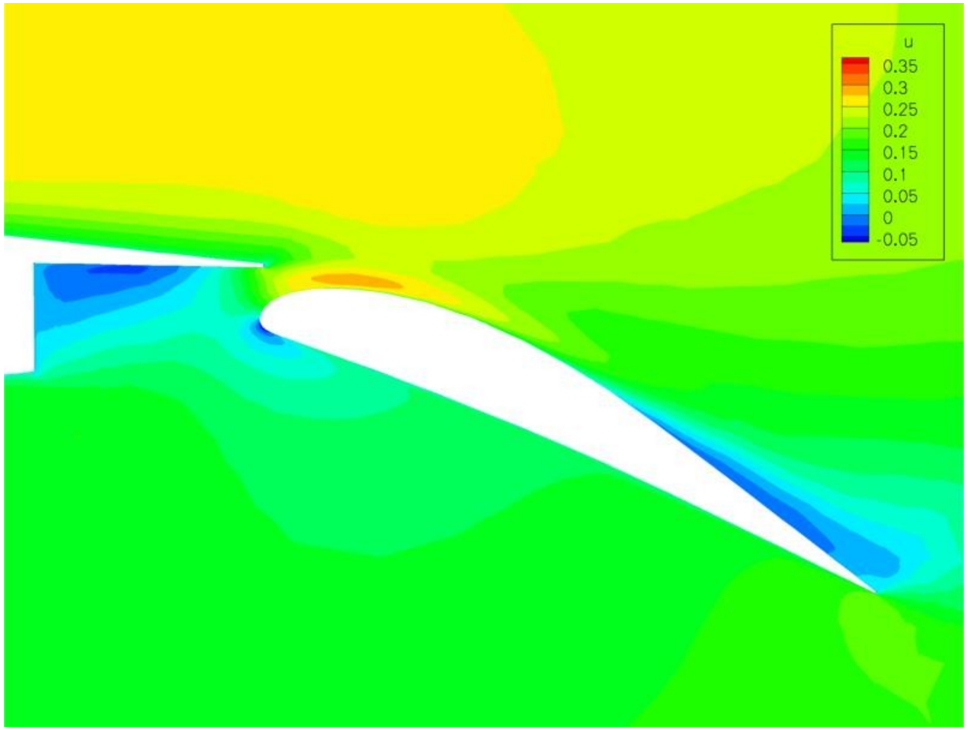

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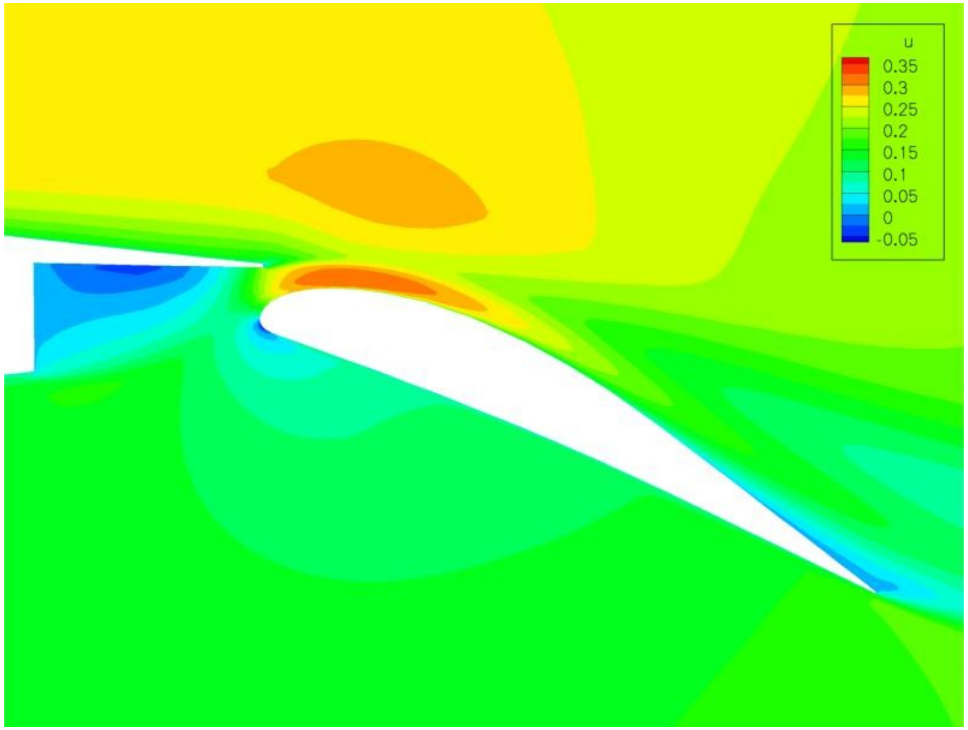

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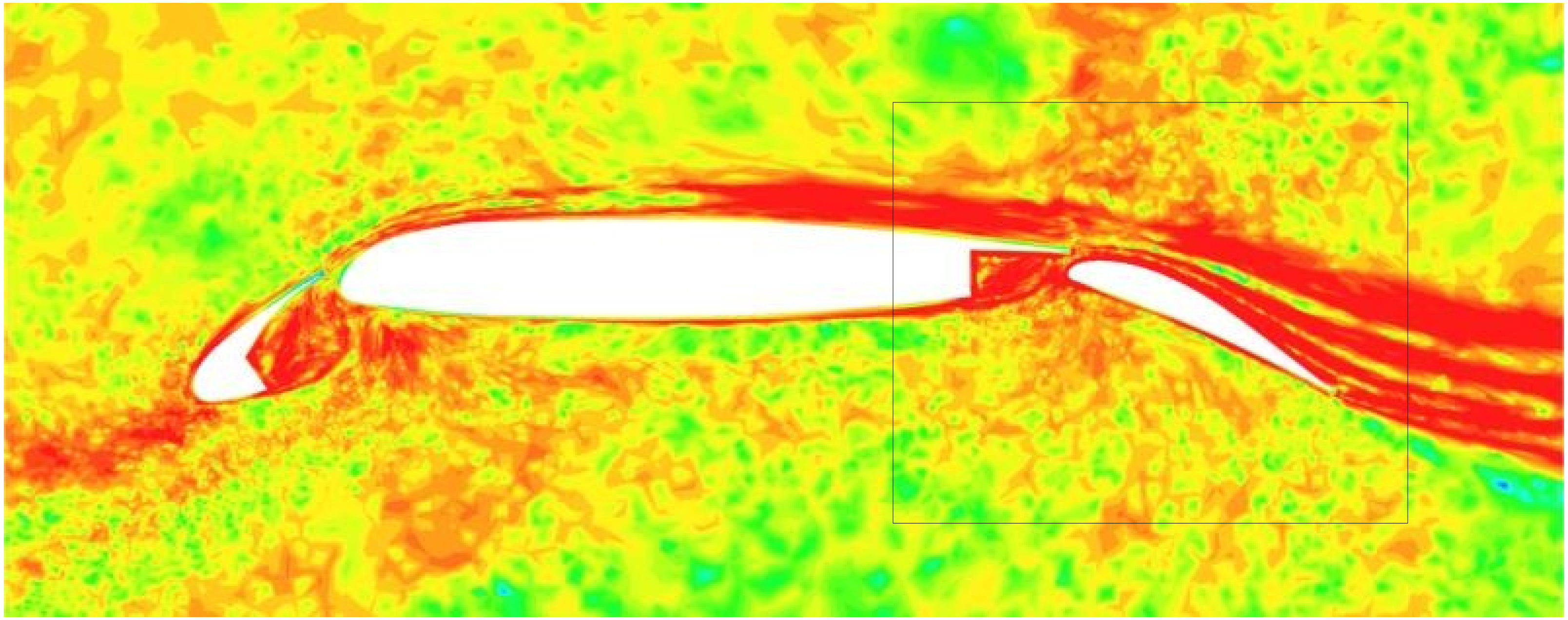

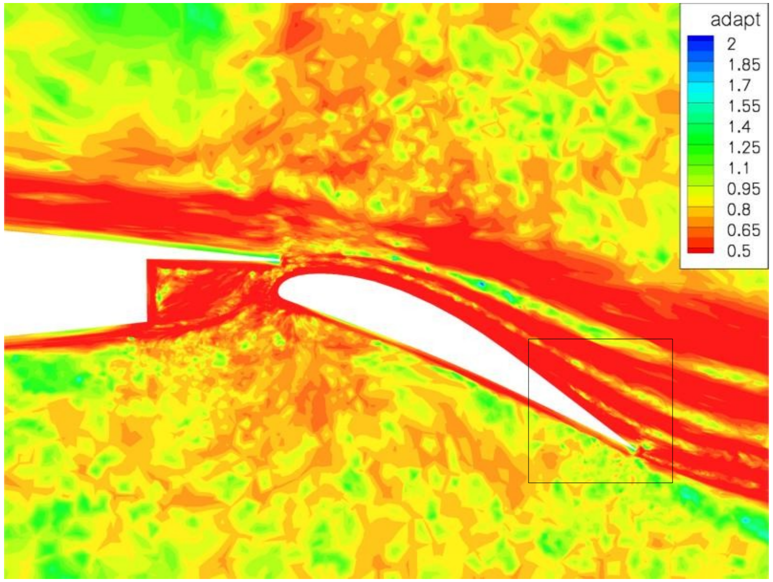

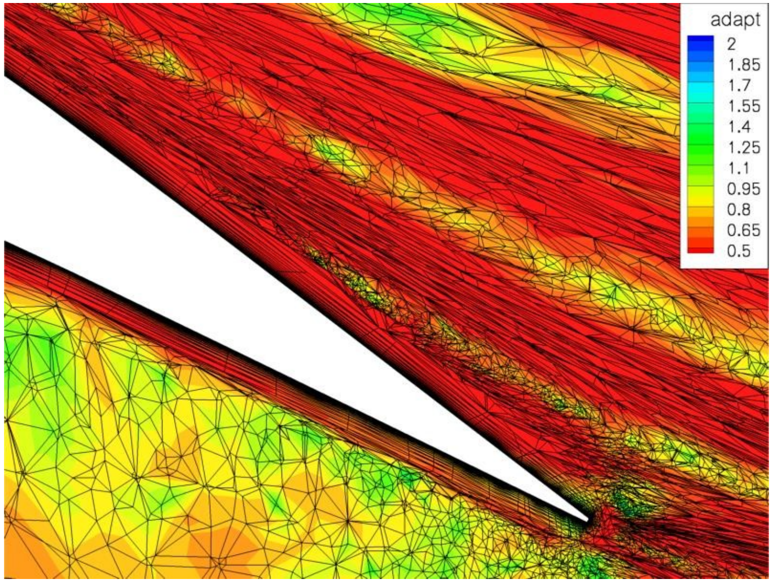

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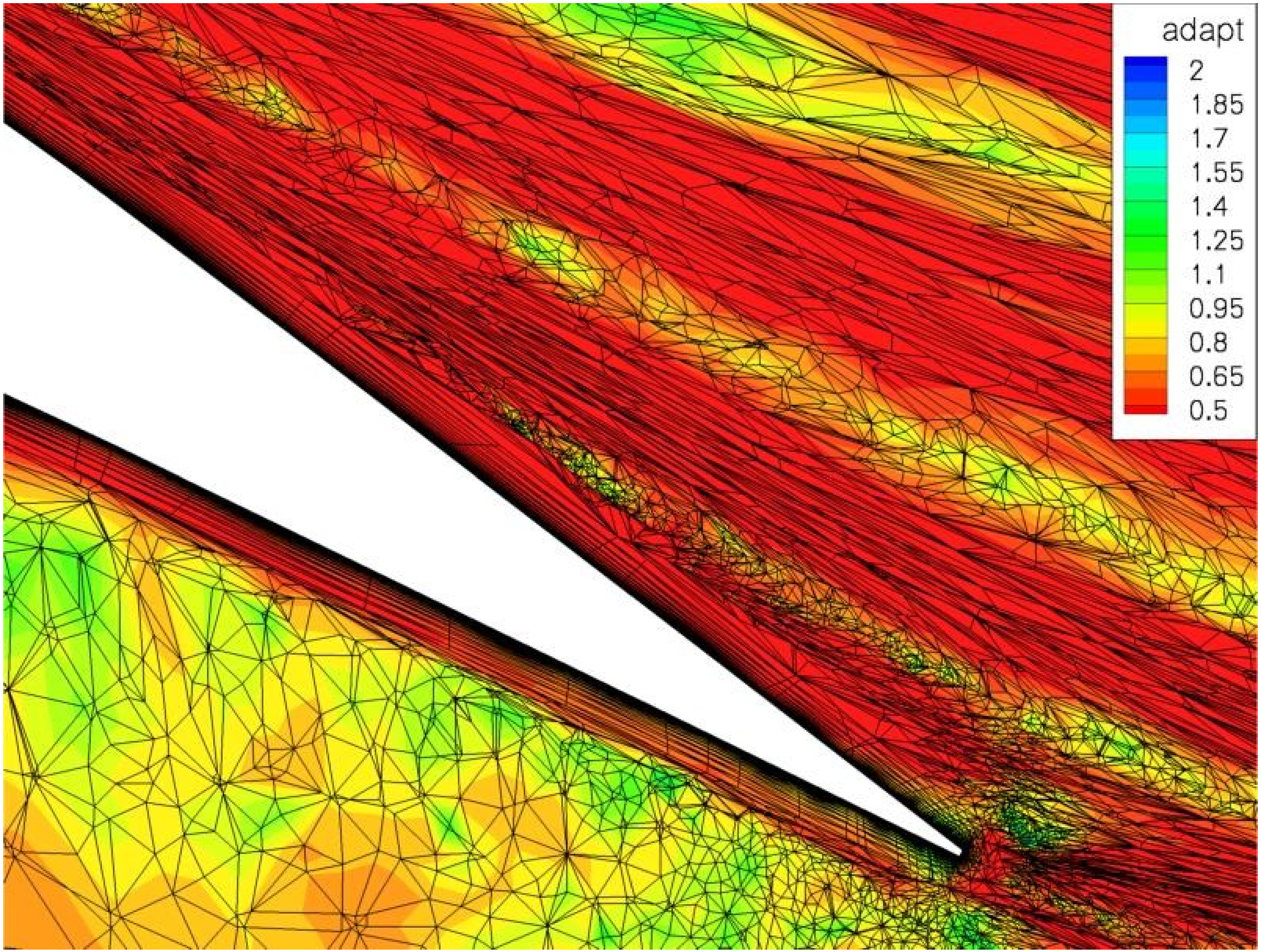
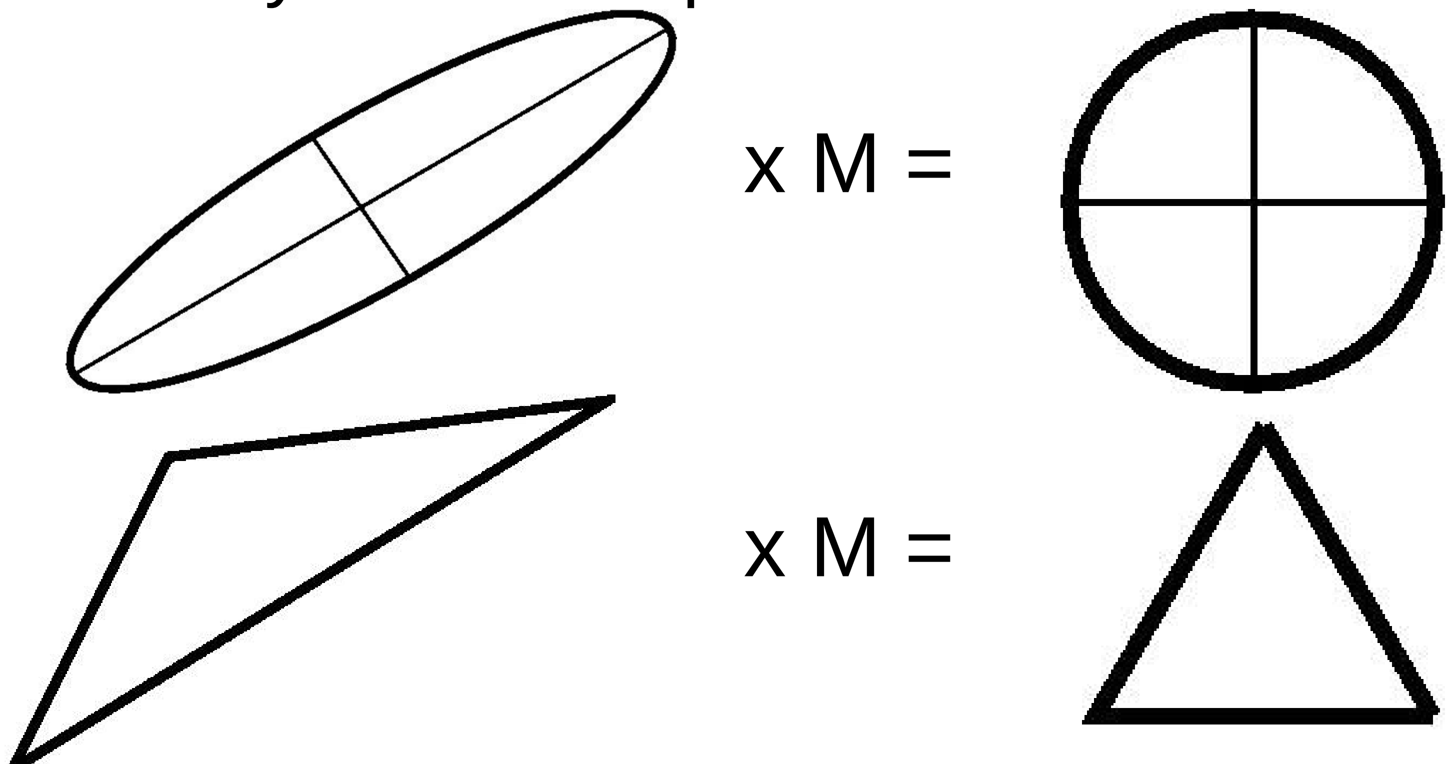


Conclusions

- Adapted 3D grid distribution similar to previous 2D example
- Change in lift and drag due to adaptation showed similar trend to uniform grid refinement
- Adapted grid better resolves slat wake and reduces flap flow separation
- Adaptation limited by inability of grid mechanics to modify near wall boundary layer region and memory required by embedded grid error estimate

Adaptation Mechanics

- Parallel node insertion, node movement, element collapse, and element swap
  - Very general approach to iteratively drive mesh to satisfy an anisotropic metric M



Adaptation Mechanics

- Output-based size specification scales the stretching and orientation of the Mach Hessian grid metric

$$M = \left| \frac{\partial^2 \mathrm{Mach}}{\partial x^2} \right| = X \begin{bmatrix} \left(\frac{1}{h_1}\right)^2 & & \\ & \left(\frac{1}{h_2}\right)^2 & \\ & & \left(\frac{1}{h_3}\right)^2 \end{bmatrix} X^T$$

Adaptation Mechanics

- Output-based size specification scales the stretching and orientation of the Mach Hessian grid metric

$$e_\kappa = \frac{|(\hat{\lambda} - \bar{\lambda})R(\hat{u})| + |(\hat{u} - \bar{u})R_\lambda(\hat{\lambda})|}{2}$$

$$\frac{h_{\text{request}}}{h_{\text{current}}} = \left(\frac{e_{\text{tol}}}{\sum e_\kappa} \frac{e_{\text{tol}}}{N e_\kappa} \right)^\omega$$