NASA Ames Contribution to HiLiftPW1

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Introduction

- Non-Goals

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  - Show the Best Results Among the Participants
  - Demonstrate Superior Accuracy and Efficiency
  - Explain Various Phenomena

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  - Confusion
    - (Hopefully Not)

Current Approach

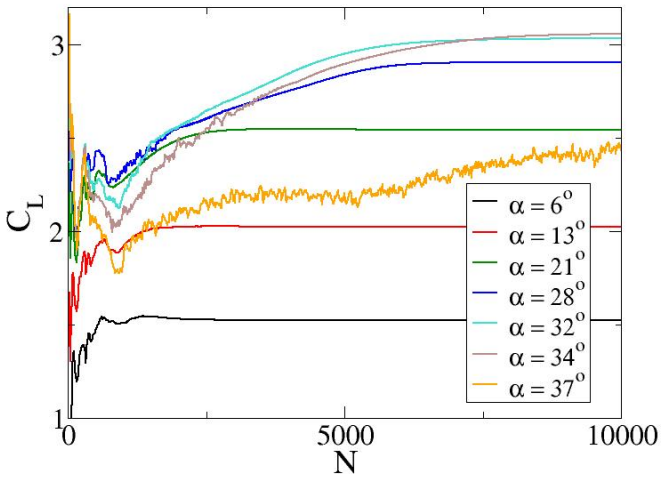
- Code: OVERFLOW2.2, Over-Set Structured RANS Code
- Grids: Str-Overset-A-v3, Coarse, Medium, Fine, X-fine (Supplied by HiLiftPW-1 Committee)
- Numerical Approach
  - 3rd Order Roe, Central, HLLC
  - Steady State Mode: Spatially variable time step, FMG
  - Some Cases Run In Time Accurate Dual-Time-Stepping Mode
  - Full-Navier-Stokes
  - Turbulence Models: Spalart-Allmaras (SA), SST
- Computational Statistics:

Grid	# Pts	# Cases	# CPUS	CPU Hrs
Coarse	10,653,004	192	32	256
Medium	24,965,818	110	64	640
Fine	83,302,438	70	128	1000
X-fine	281,560,012	30	512	8000

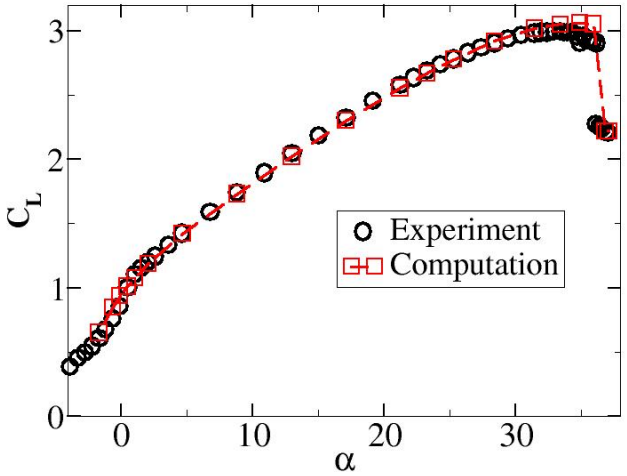
- Total: $\approx 0.5 \times 10^6$ CPU Hrs / 12 Weeks on NASA Pleiades

Representative Results: Medium Grid

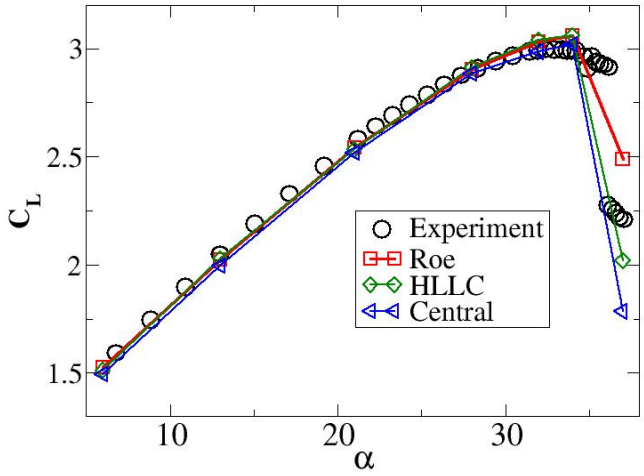
Typical Cl Convergence



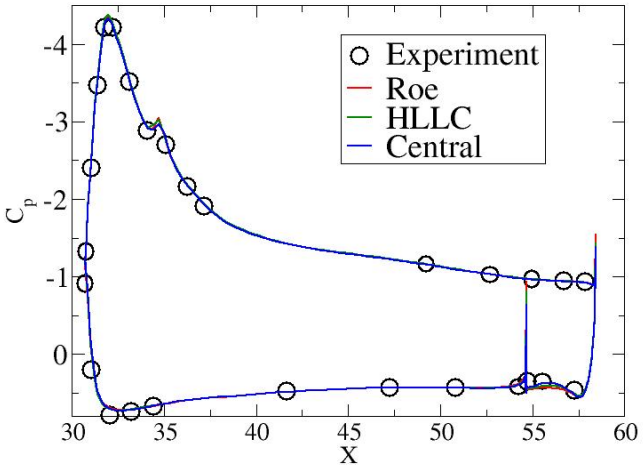
Cl - α



Cl - α: Case2



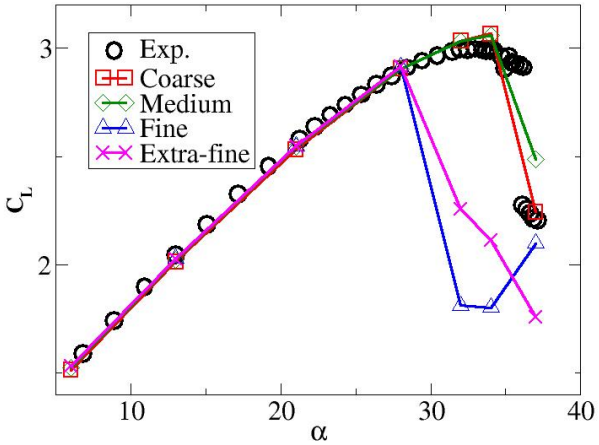
$\alpha = 28^o$ Wing Mid-Span



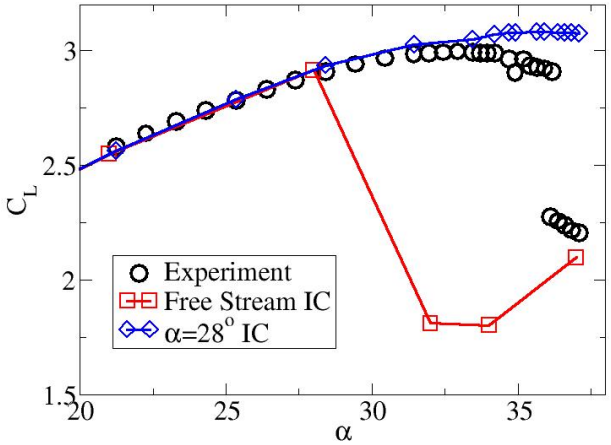
CL-α for Grid Refinement

- Standard Solution Processes Fail On Finer Meshes
- Pre-Stall Results and Initial Condition (IC) Dependence
- Non-time-Accurate to Time-Accurate Integration Can Push Stall Boundary Up
- Incremental Restarts With α can Avoid Early Stall

Early Stall
Fine, X – Fine Grids



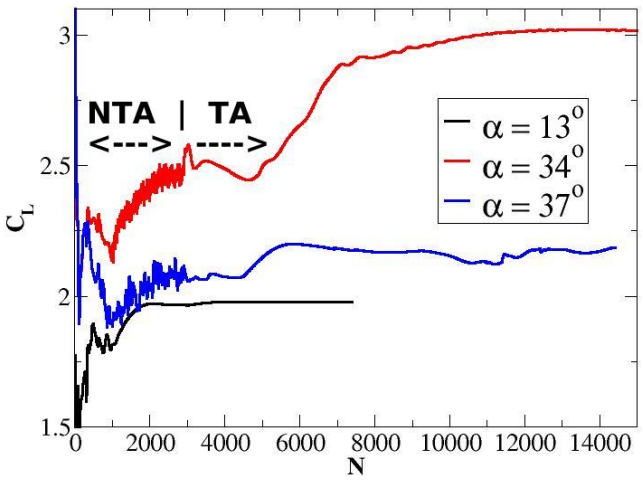
Incremental α Result
Fine Grid



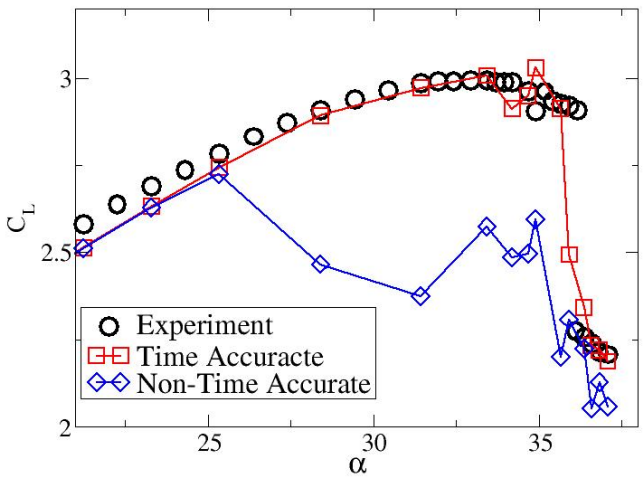
Different Solution Paths

- Central Difference Scheme in Non-Time Accurate Mode
- Early Stall at About $\alpha = 25^o$
- Time-Accurate Mode Extends Stall Boundary to $\alpha = 36^o$

Cl Convergence

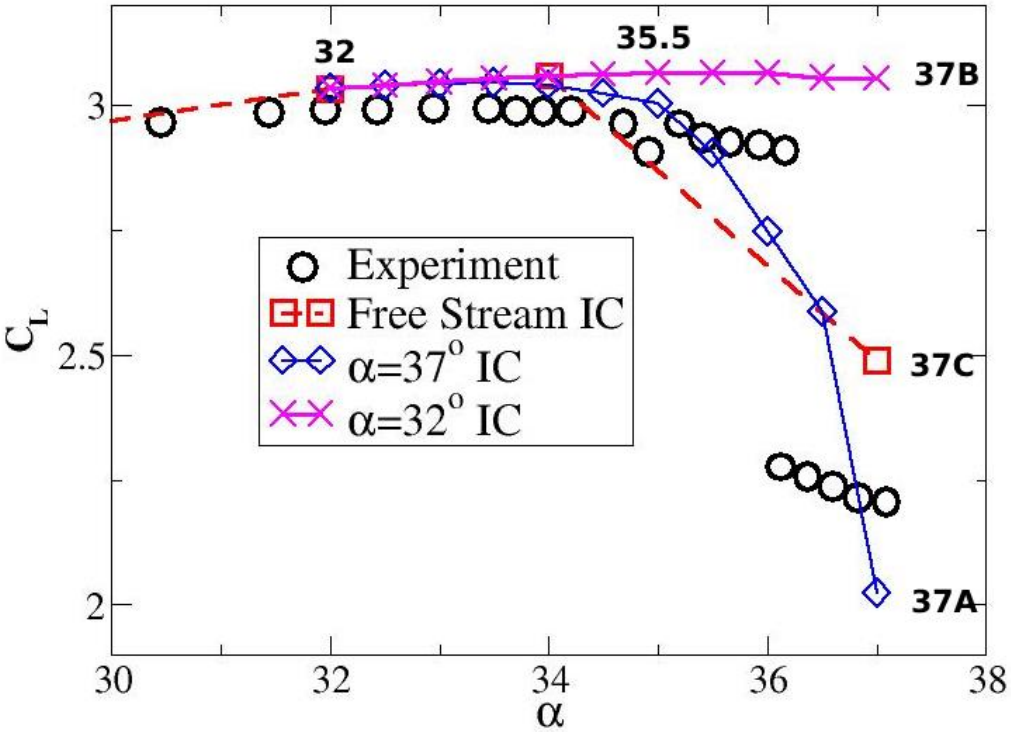


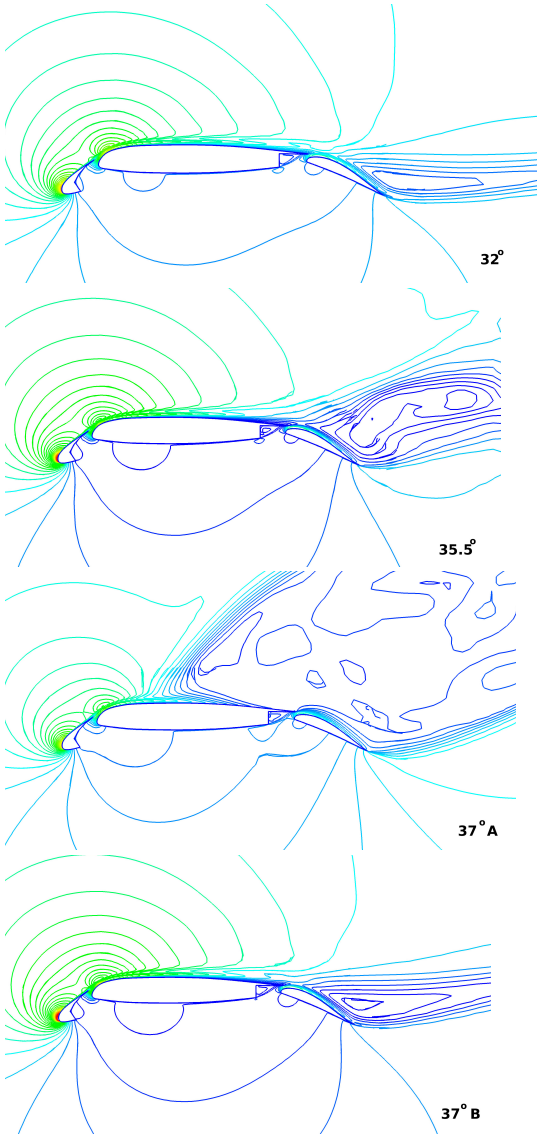
Cl $-$ α



Hysteresis: Starting Solution Dependence Medium Grid

- $\alpha = 37^o$C Steady State: Free Stream IC
- $\alpha = 37^o A \rightarrow \alpha = 32^o$
  - $\alpha = 37^o$A Unsteady Cont. of $\alpha = 37^o$C
  - Stalled Case Reattaches !
- $\alpha = 32^o \rightarrow \alpha = 37^o B$
  - Does Not Stall !



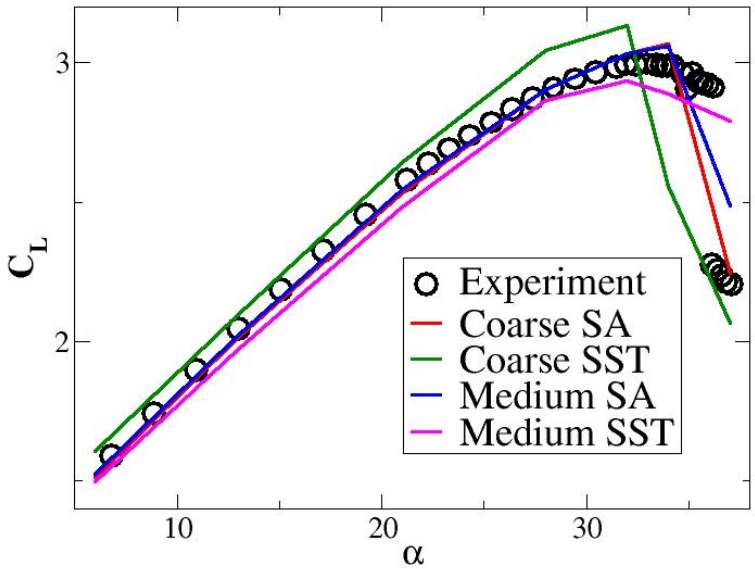


Turbulence Model Effects

- Spalart-Allmaras (SA) - SST
- Grid Refinement for $\alpha = 13^o$

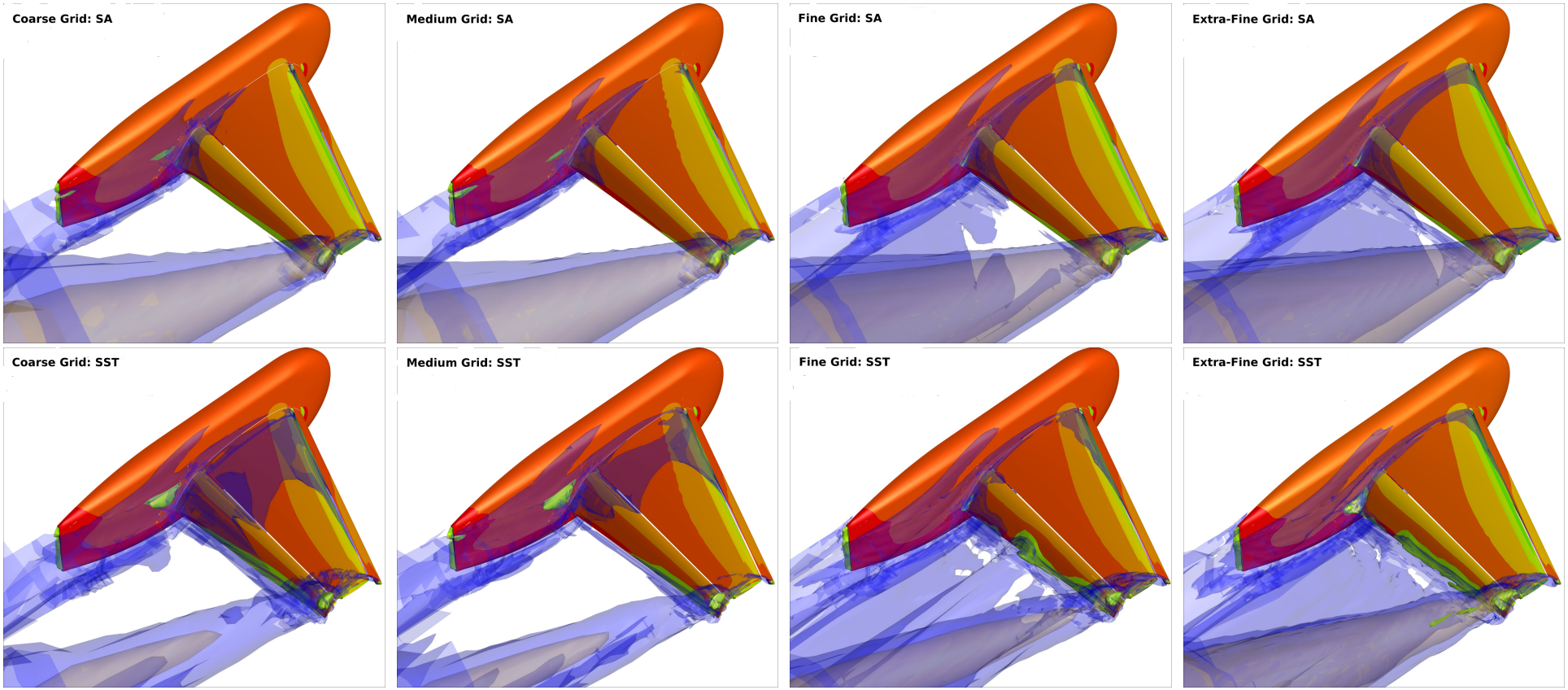
Grid	TM	C_L	C_D
Exper.		2.047	0.3330
Coarse	SA	2.000	0.3285
Medium	SA	2.017	0.3364
Fine	SA	2.028	0.3283
X-Fine	SA	2.028	0.3271
Coarse	SST	1.954	0.3175
Medium	SST	1.967	0.3270
Fine	SST	1.960	0.3134
X-Fine	SST	1.950	0.3084

$C_L - \alpha$ Comparison SA - SST

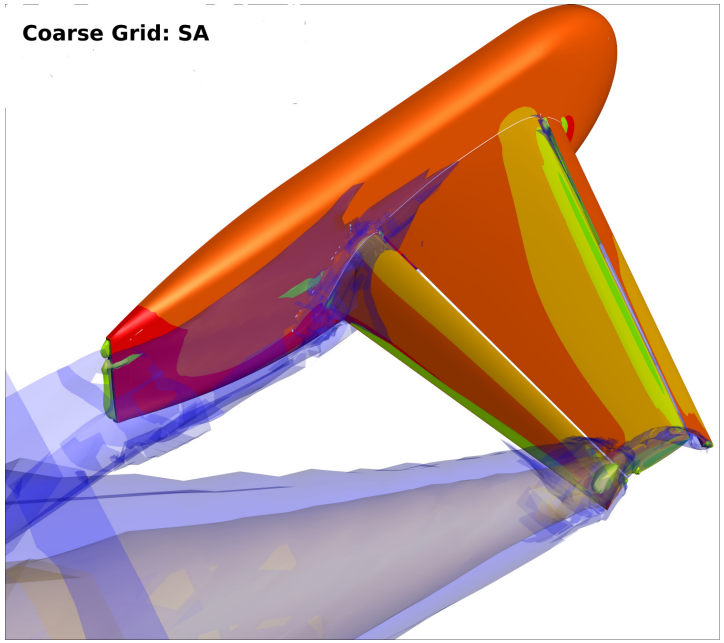


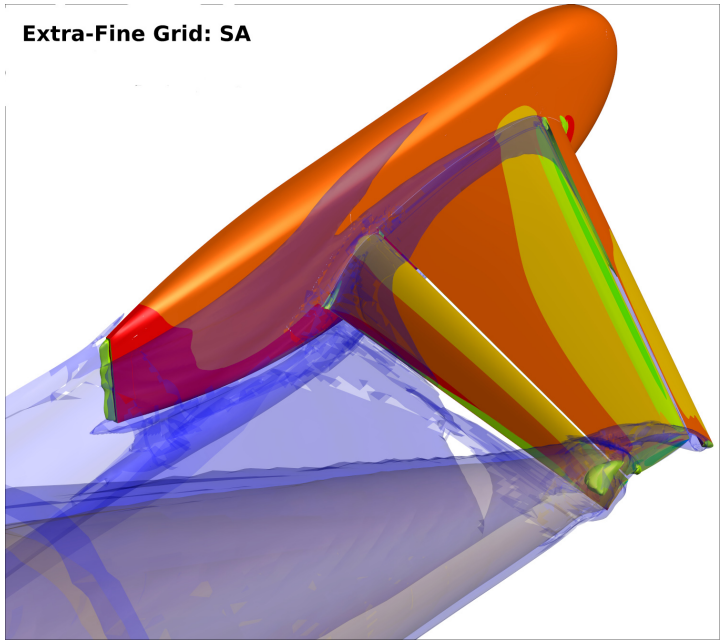
Turbulence Model Analysis: $\alpha = 13^o$

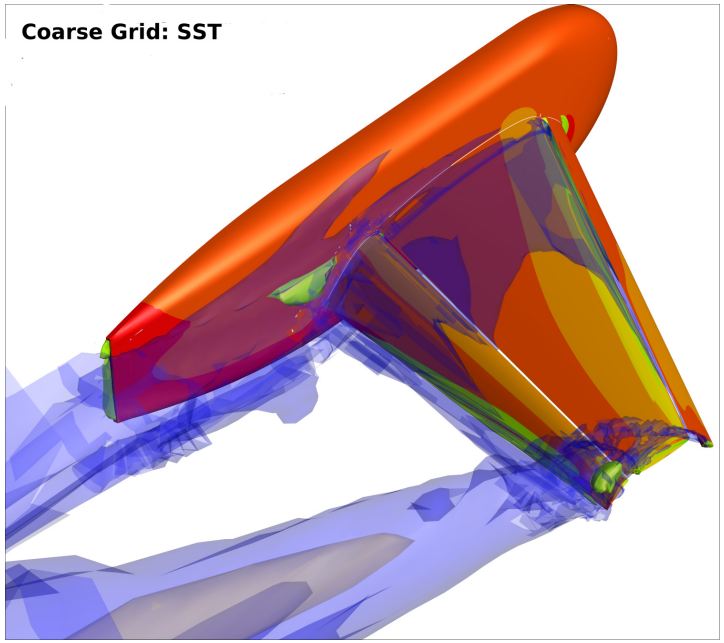
- Surface Colored by C_p
- Reversed U: lime-green
- $\frac{\mu_t}{Re} = 0.05$ (blue), 0.005 (red)

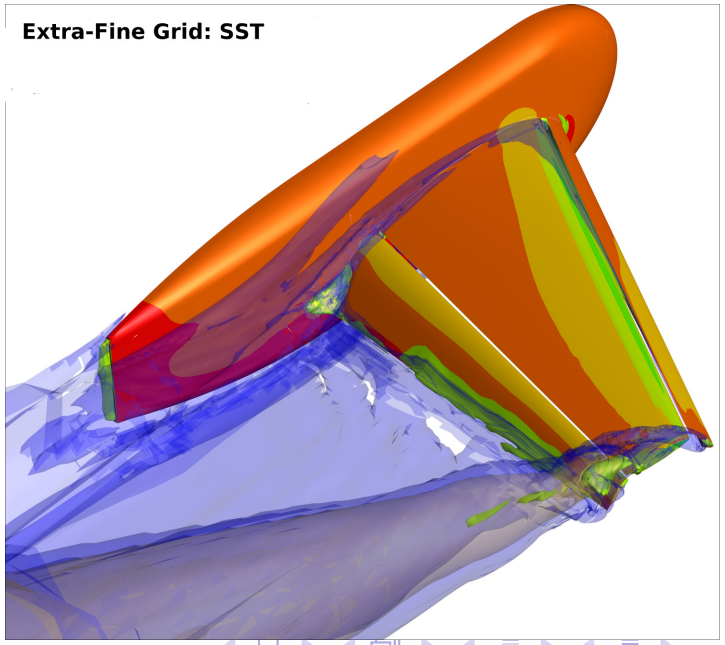


Coarse – Extra-Fine Grid: SA – SST



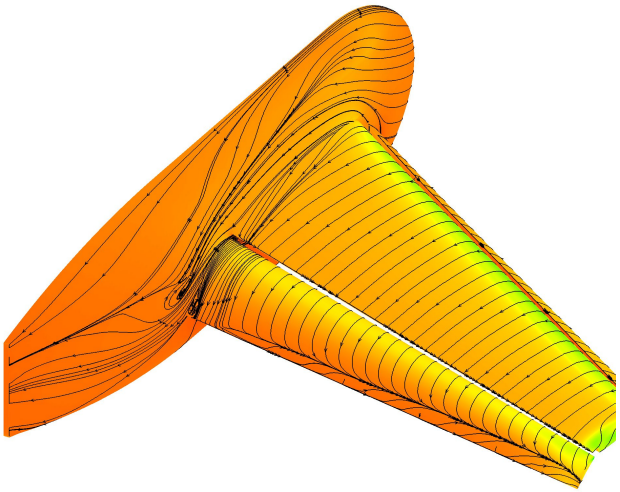




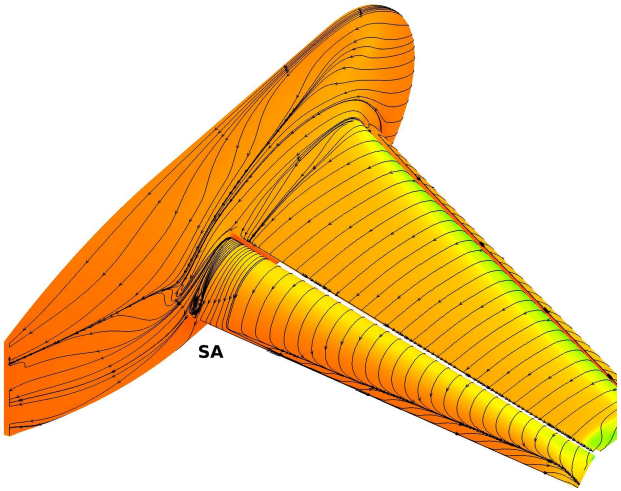


TM Comparison, Surface Flow Topologies: $\alpha = 13^o$

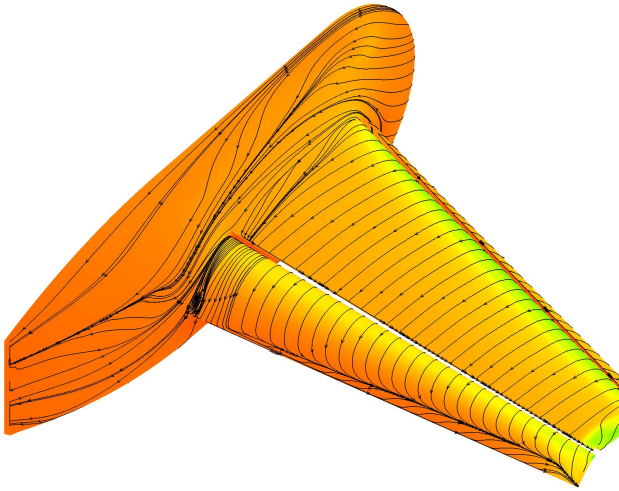
Coarse Grid SA



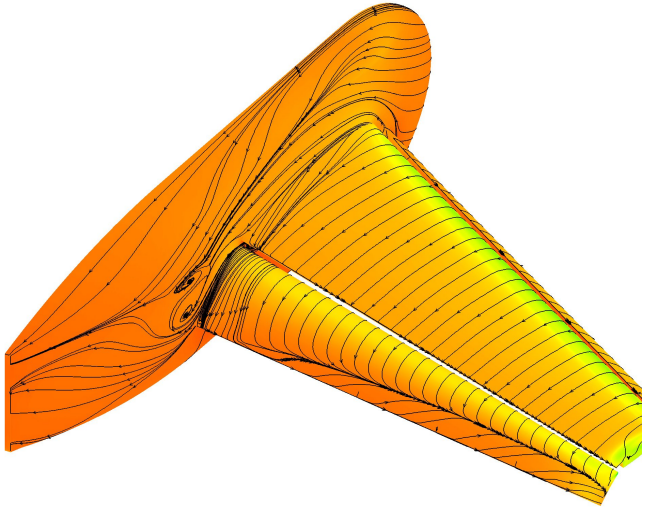
Medium Grid SA



Fine Grid SA



Coarse Grid SST



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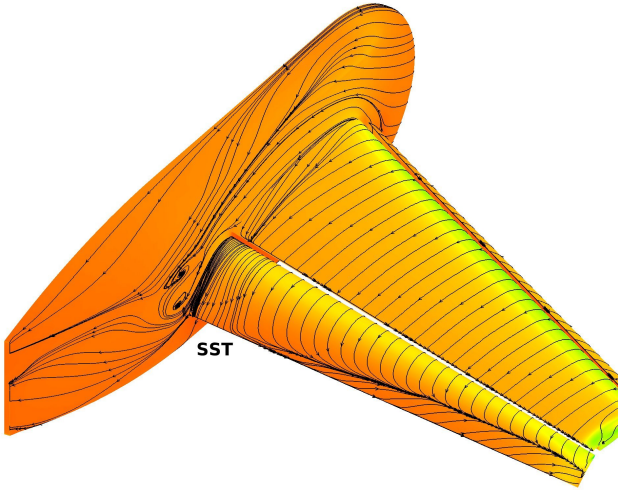
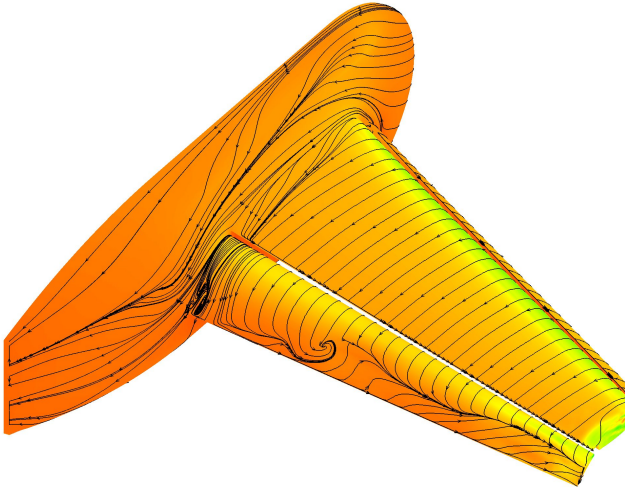


Fine Grid SST



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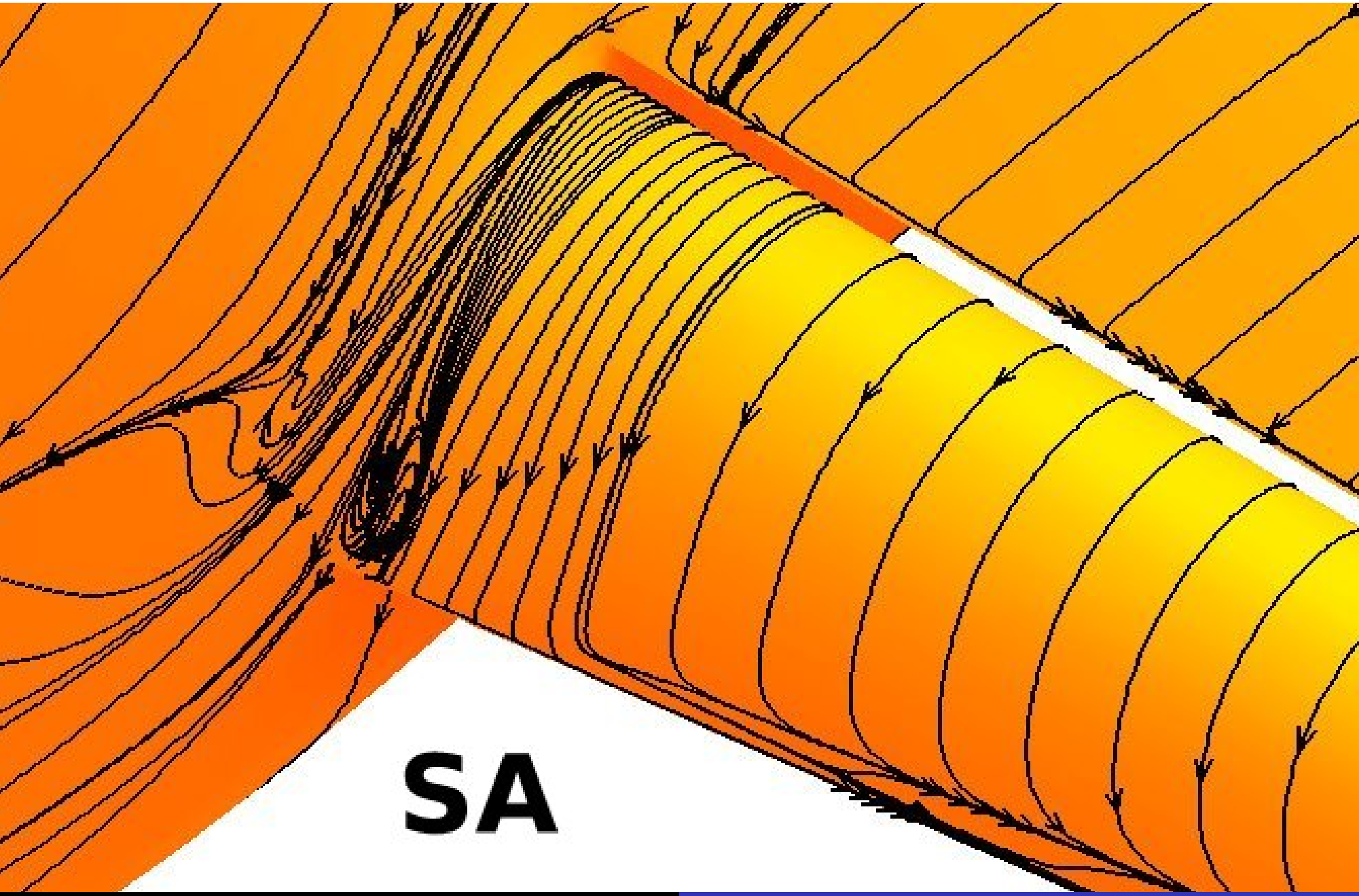

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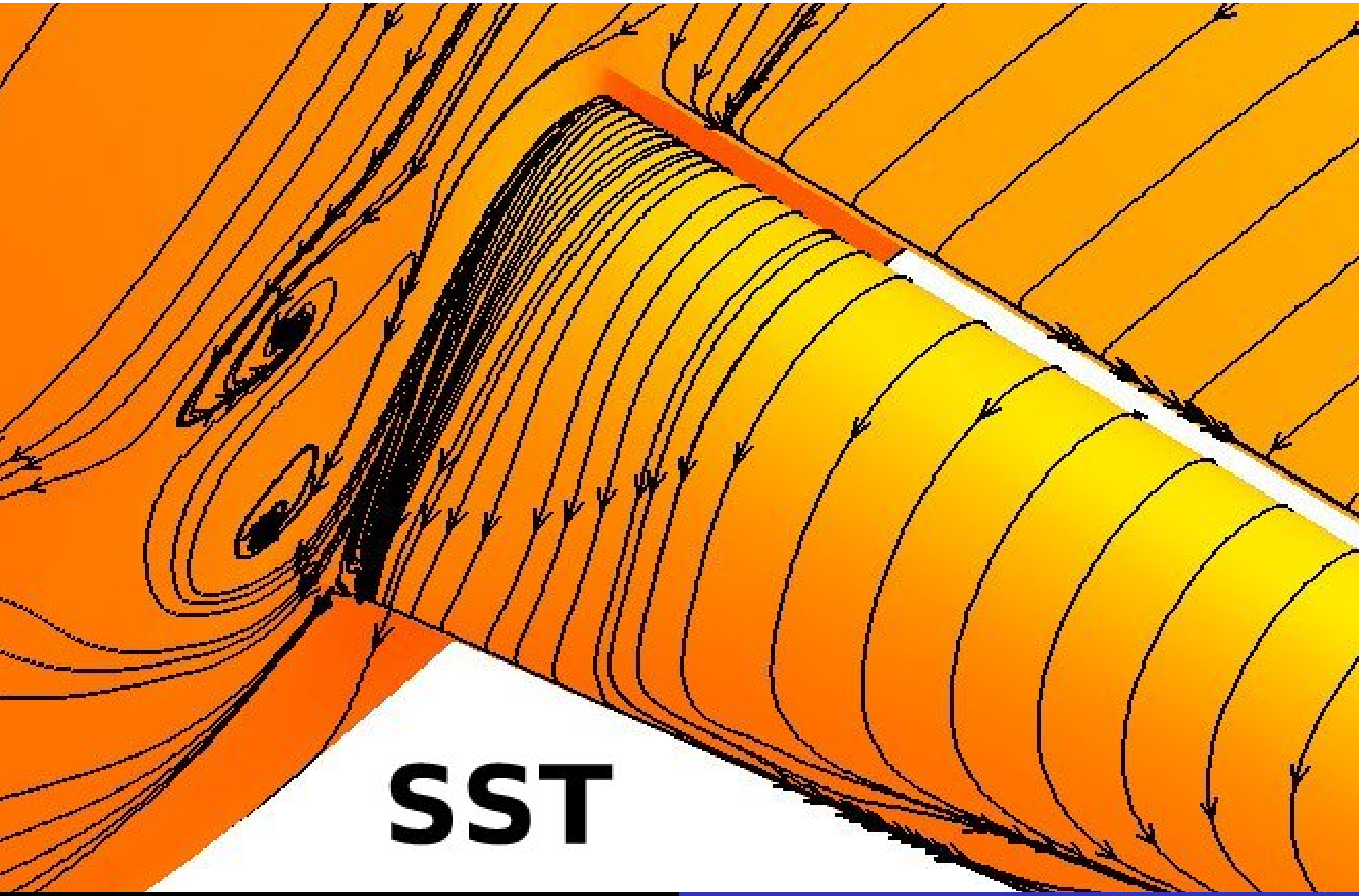
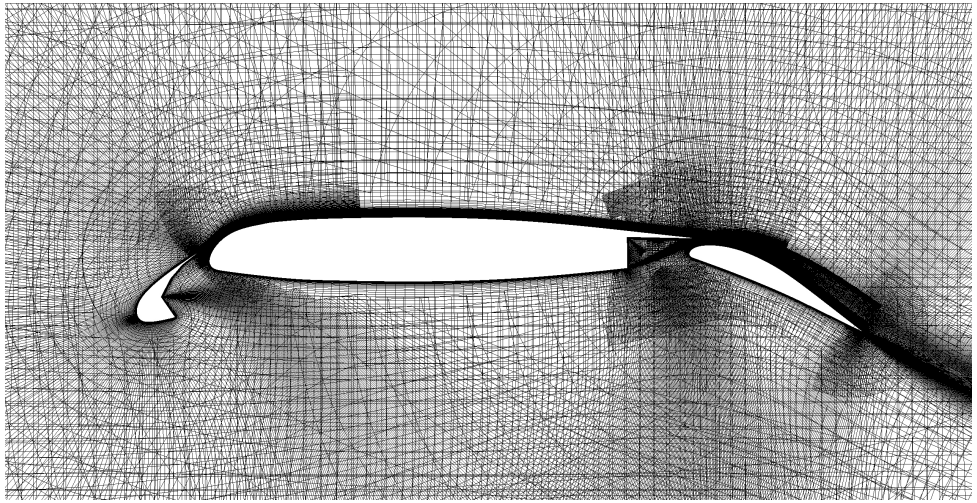


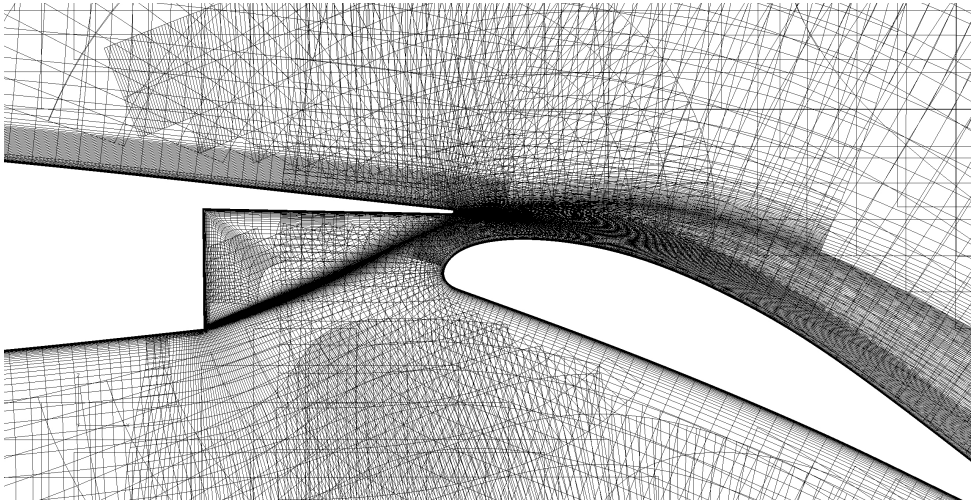
Grid Topologies/Strategies

- Workshop Supplied Over-set Grids
  - C-Mesh Topology for Slat, Wing, Flap, Tips and Collars
  - Pegasus Generated Domain Connectivity
- Proposed New Grids Systems
  - Near Body (NB) O-mesh Topology (Limited Off Body Extent)
  - Off-Body (OB) Cartesian
  - DCF/X-Ray Domain Connectivity
  - Off-Body Adaption for Wake and Vortex Capturing

Workshop Over-set Grid

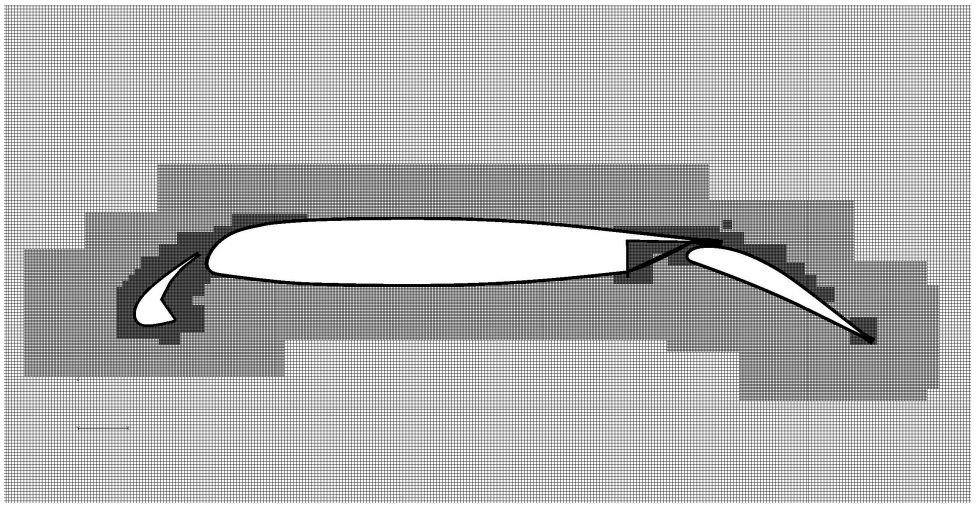


Wing-Flap Region

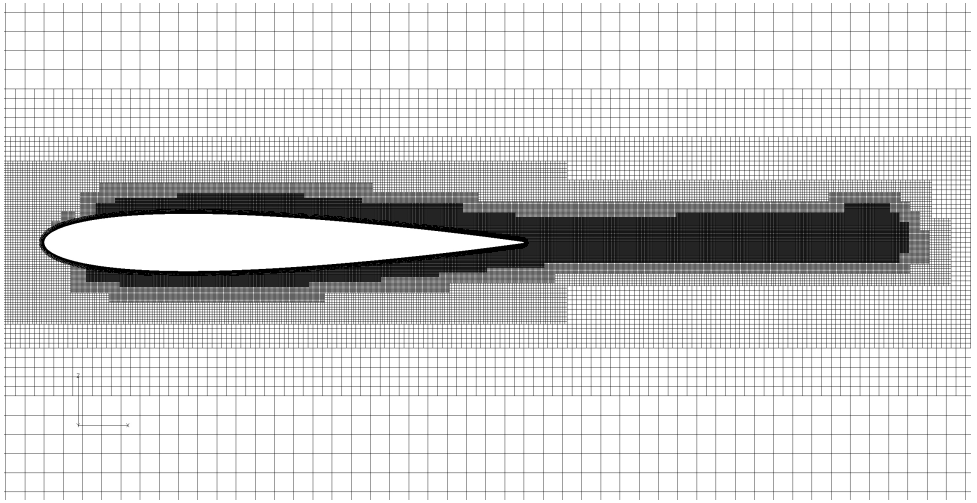


Cartesian OB, Localized Workshop C-Mesh NB

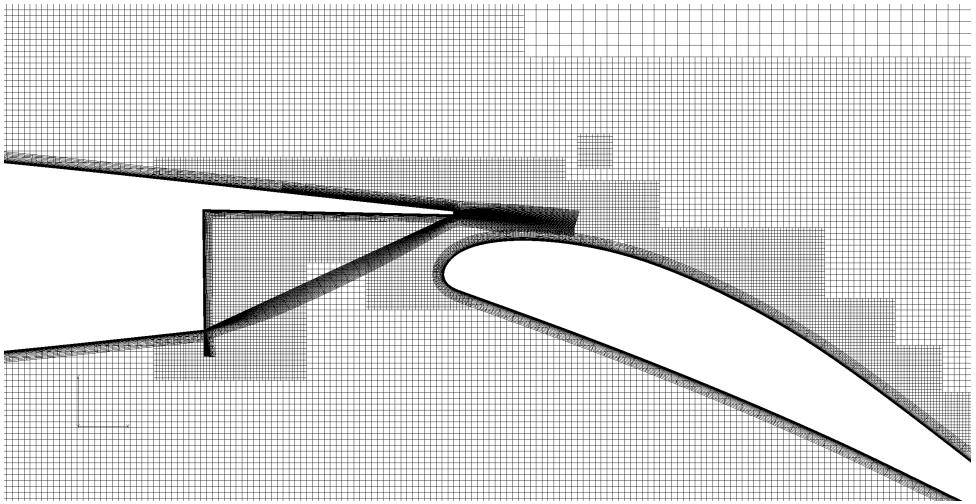
Span Section View (With Adaption)



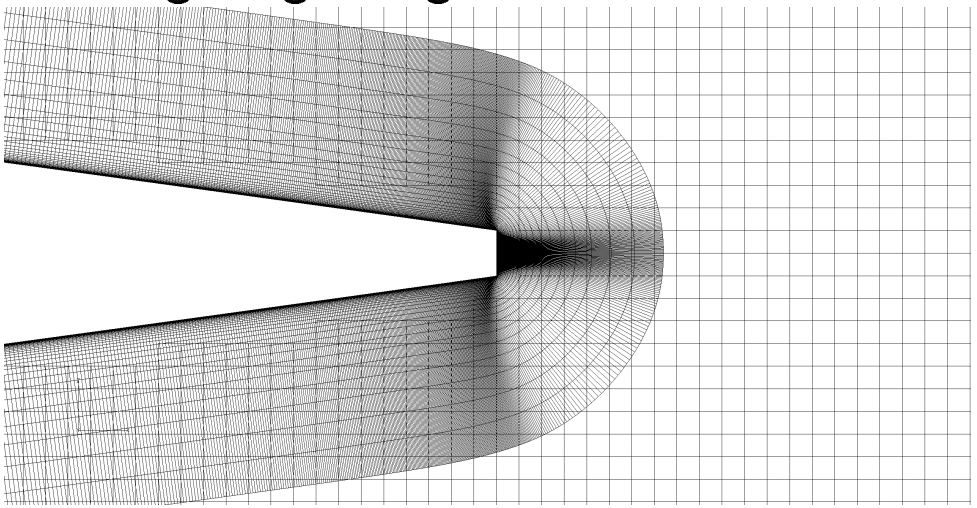
Proposed O-Mesh NB with Adaption



Wing-Flap Region



Trailing Edge Region

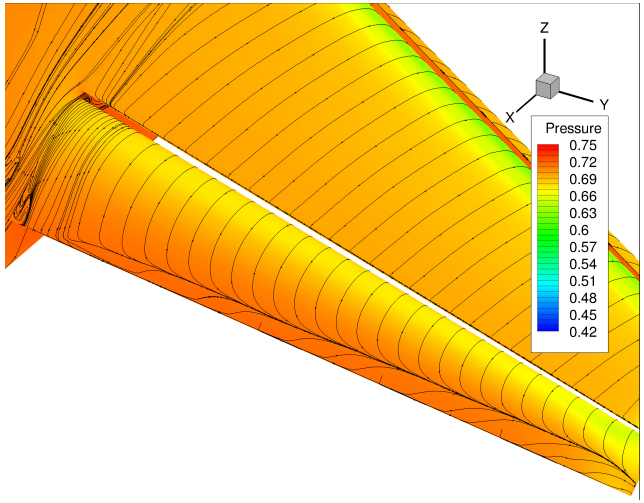


Future Plans

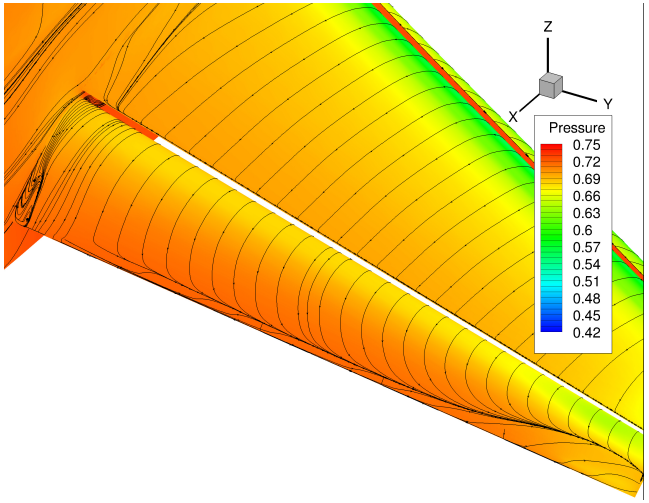
- Review Current Results in Light of Workshop
- Improve Robustness, Efficiency and Accuracy
- Analyze Turbulence Model Results and Accuracy
- Develop New NB/OB/Adaption Grid Framework
- Expand Envelope of Cases and Methods
- Help to Develop Guidelines and Goals For Future Workshops

Angle of Attack, Surface Flow Topologies

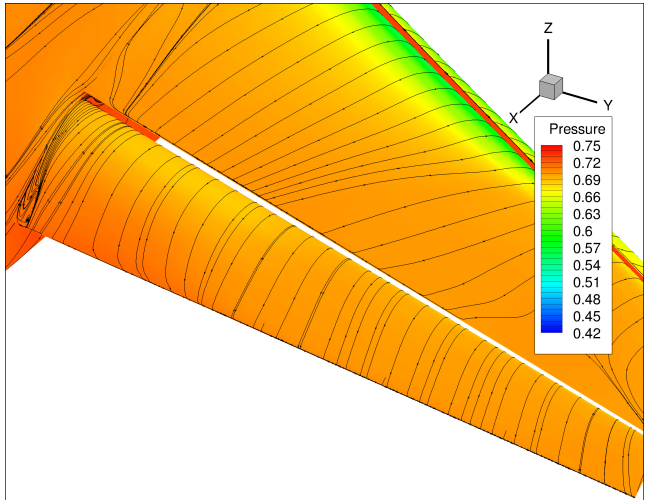
Coarse Grid SA $\alpha = 13^o$



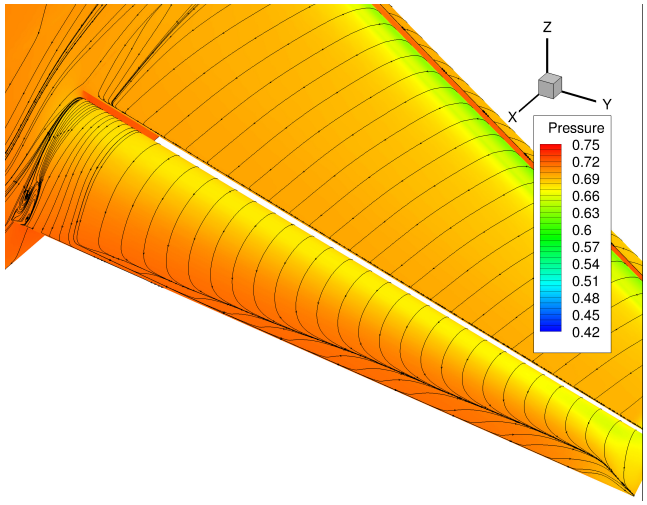
Coarse Grid SA $\alpha = 28^o$



Coarse Grid SA $\alpha = 37^o$



Fine Grid SA $\alpha = 13^o$



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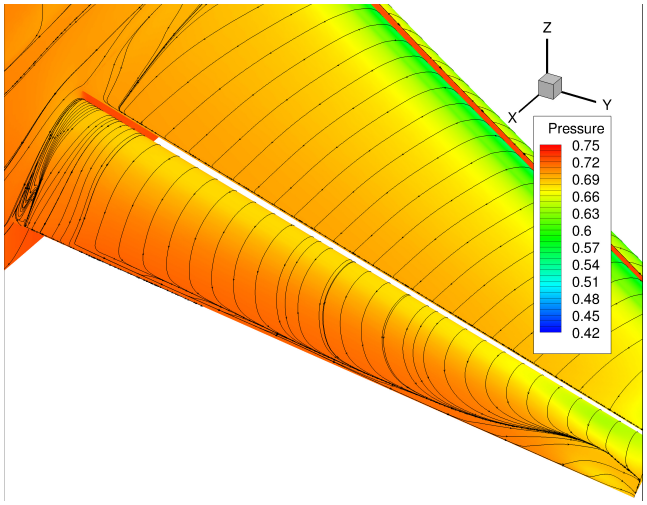

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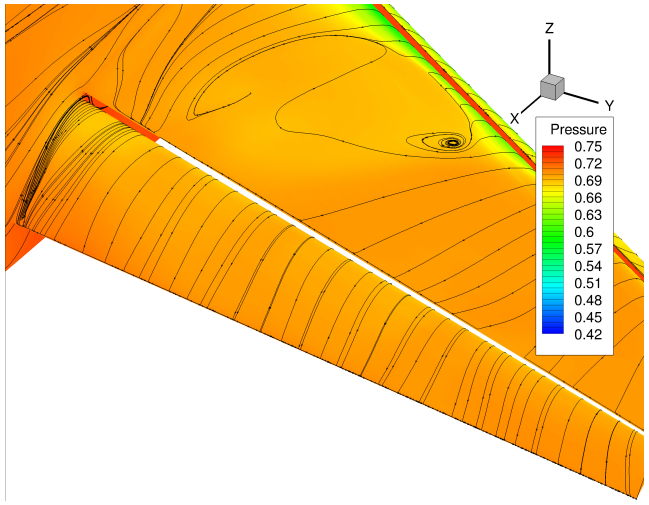
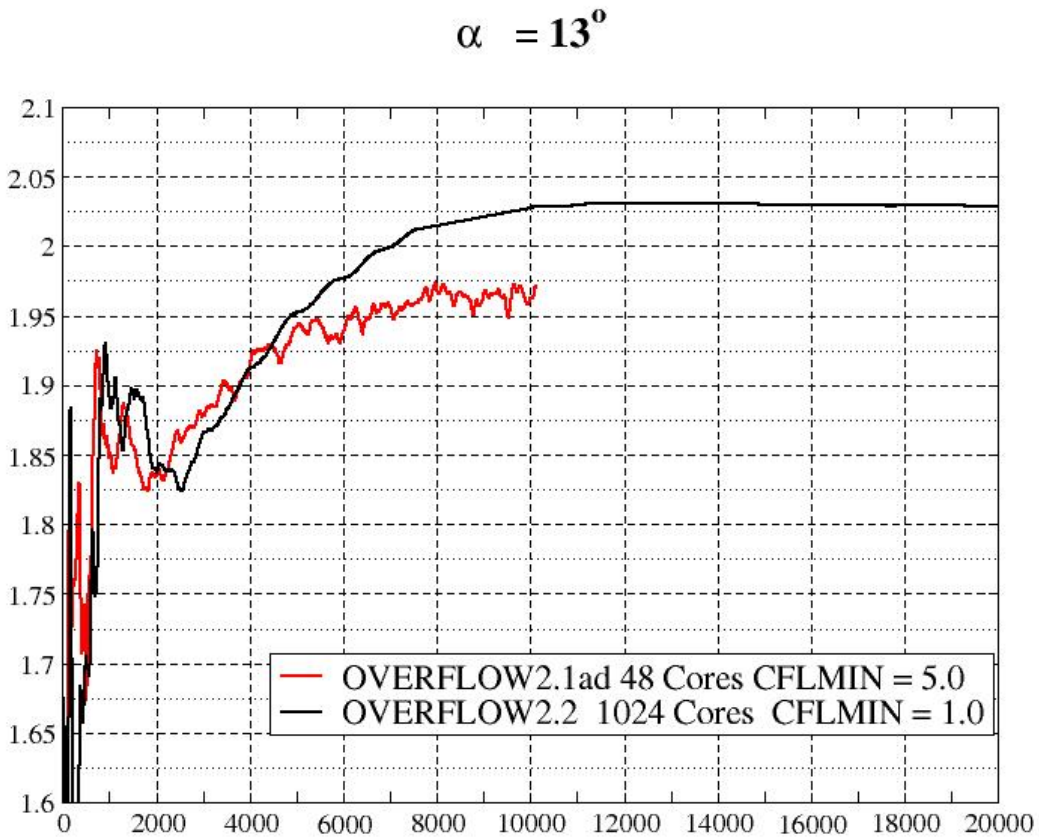


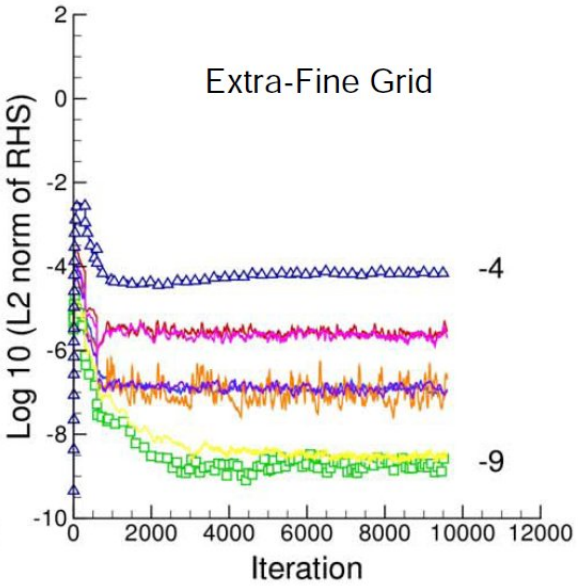
Extra-Fine Comparison

- OVERFLOW Runs: Boeing/Ames
- Convergence Characteristics
- $\alpha = 13^o$ CL History

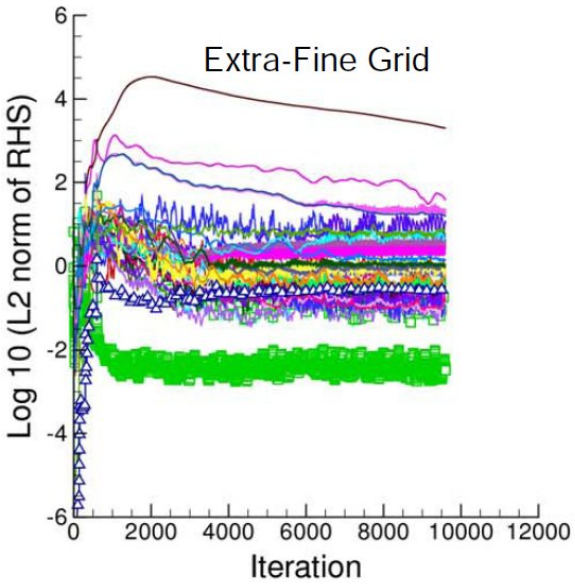


Extra-Fine Comparison

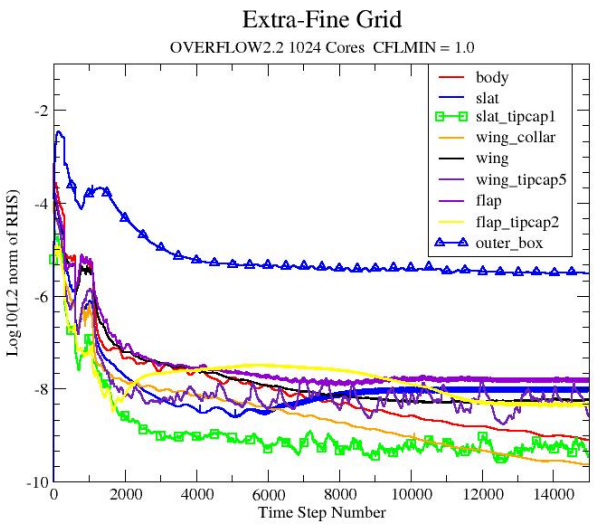
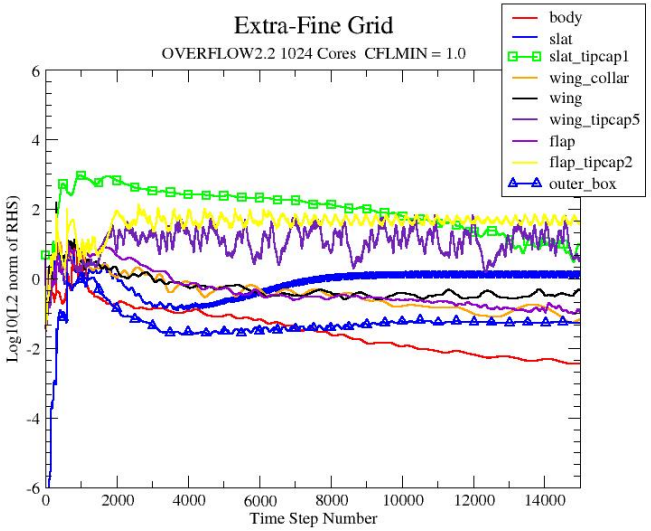
Boeing Resid History



Boeing Turb History



Ames Resid History



Ames Turb History