Drag Prediction Using NSU3D
(Unstructured Multigrid NS Solver)

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NSU3D Description

- Unstructured Reynolds Averaged Navier-Stokes solver
  - Vertex-based discertization
  - Mixed elements (prisms in boundary layer)
  - Edge data structure
  - Matrix artificial dissipation
    - Option for upwind scheme with gradient reconstruction
  - No cross derivative viscous terms
    - Thin layer in all 3 directions

Solver Description (cont'd)

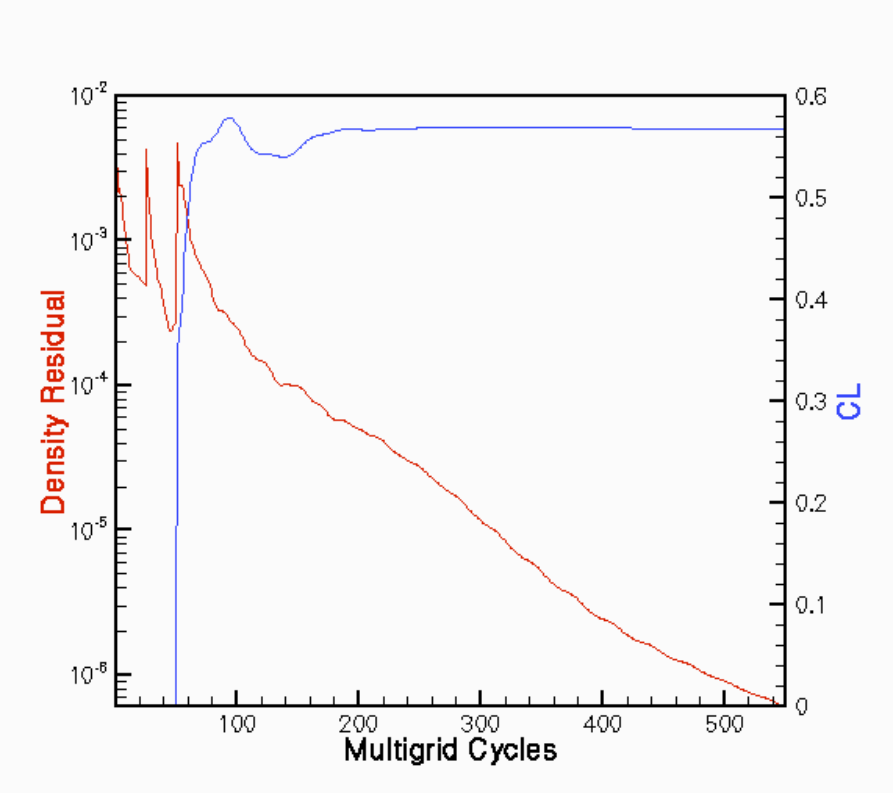
- Spalart-Allmaras turbulence model
  - (original published form)
  - Optional k-omega model
- Transition specified by zeroing out production term in turbulence model
  - More robust than S-A trip term
  - Based on surface patches
    - Laminar patches
    - Laminar normal distance

Solution Strategy

- Jacobi/Line Preconditioning
  - Line solves in boundary layer regions
    - Releives aspect ratio stiffness
- Agglomeration multigrid
  - Fast grid independent convergence rates
- Parallel implementation
  - MPI/OpenMP hybrid model
    - DPW runs: MPI on 16 cpu cluster

Performance

- Convergence in 500 multigrid cycles
  - Grid independent
  - Poor convergence for negative alpha nacelle cases
- 16 Pentium IV 1.7GHz: Intermediate grids
  - 5 hours for 3M pt grid
  - 7.5 hours for 5M pt grid



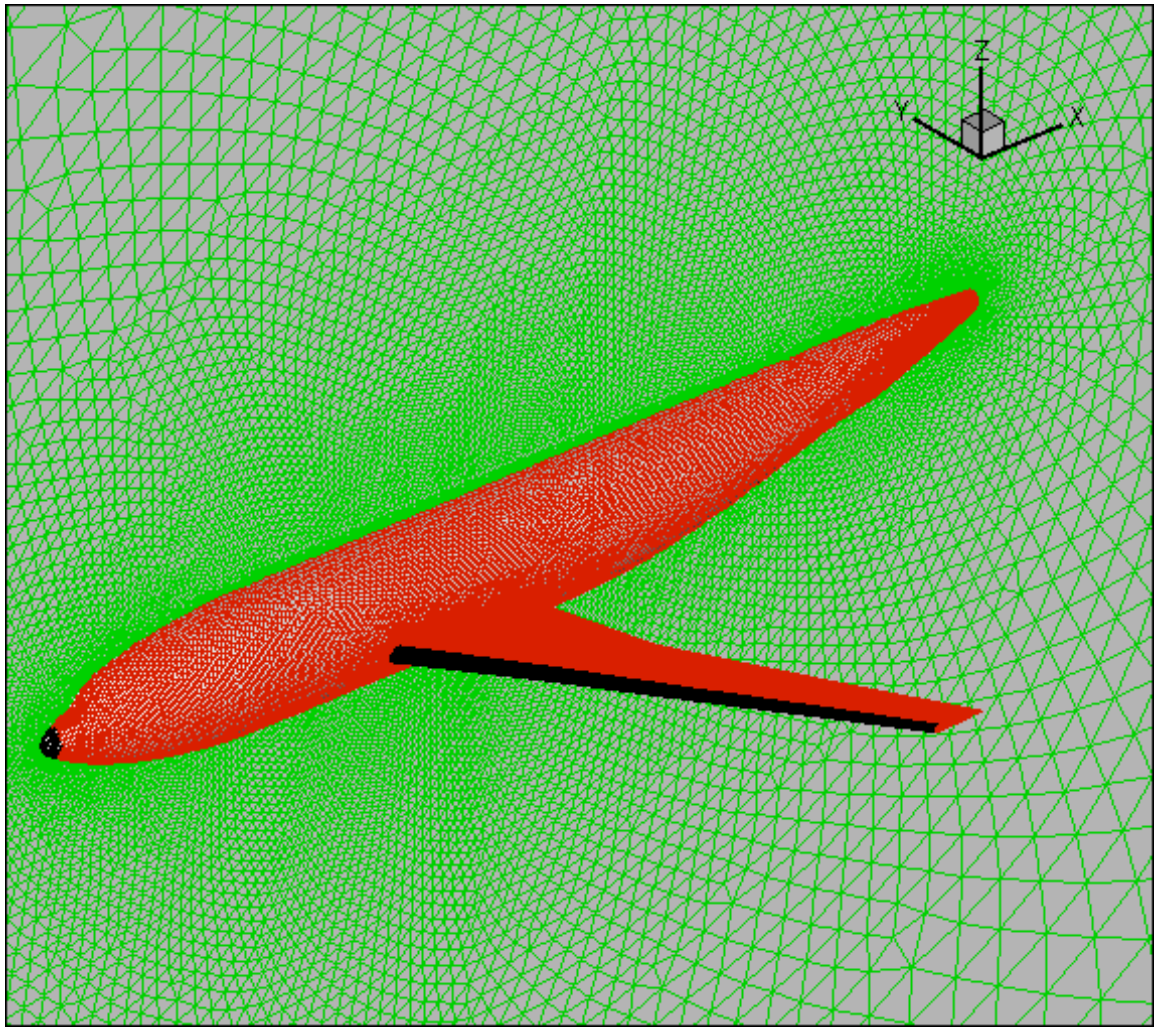
Grid Generation

- Runs based on NASA Langley supplied VGRIDns unstructured grids
- Tetrahedra in Boundary Layer merged into prismatic elements
- Sequence of 3 grids for each configuration
- Transition based on surface patches

Grid Specifications

Configuration	Coarse	Medium	Fine
Wing-Body			
Points	1,121,301	3,010307	9,133,352
Cells	6,558,758	17,635,283	53,653,279
WB+Nacelle			
Points	1,827,470	4,751,207	10,278,588
Cells	10,715,204	27,875,222	60,412,948

Intermediate Grid (WB: 3M pts)



- Transition specified by laminar patches

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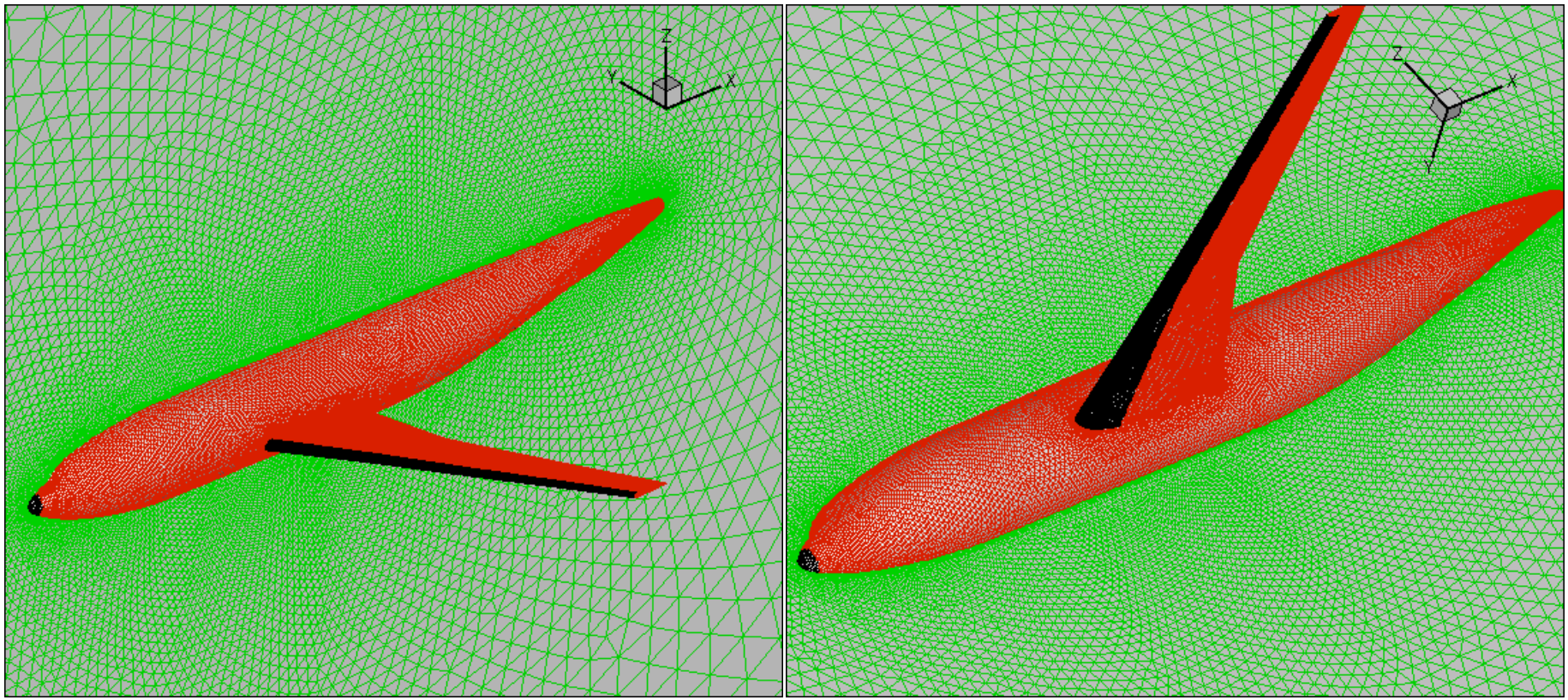
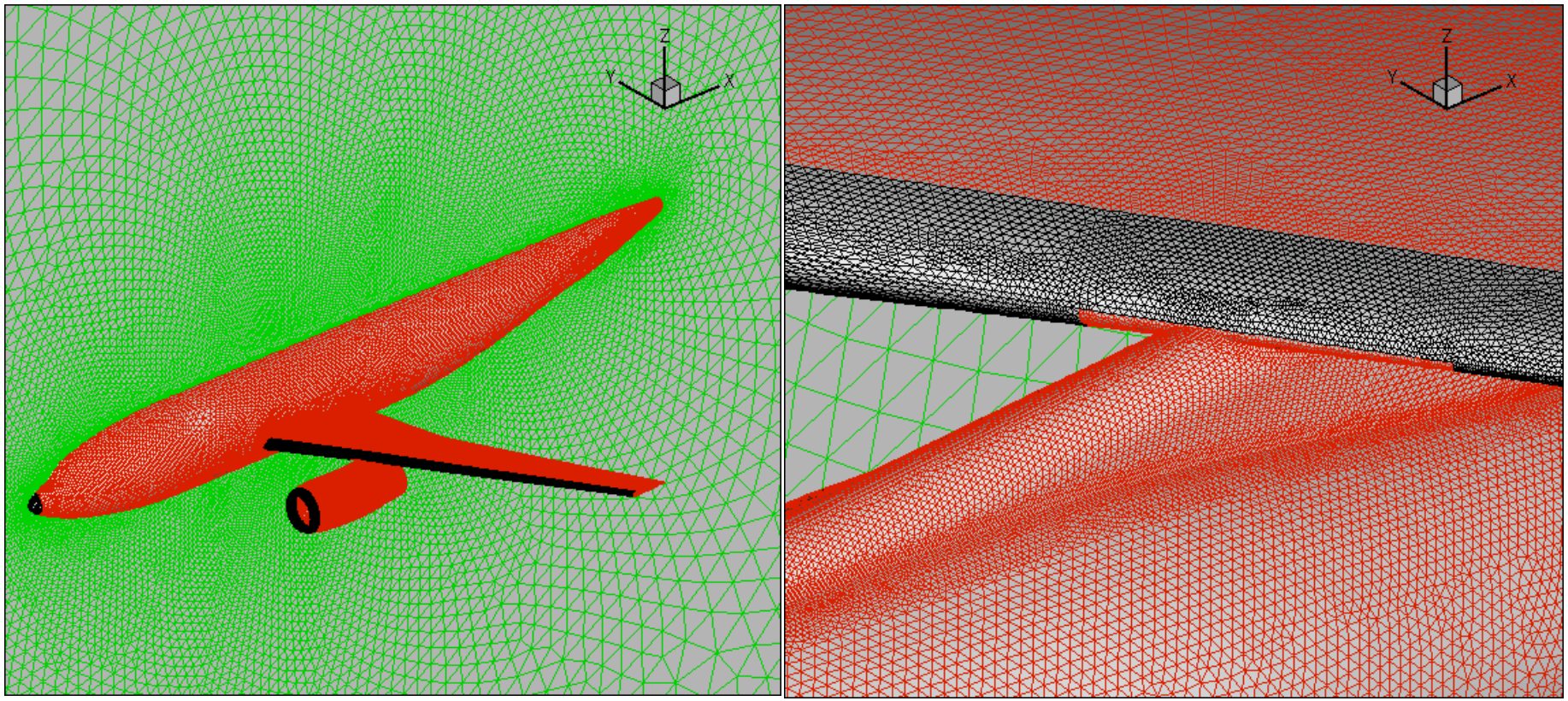


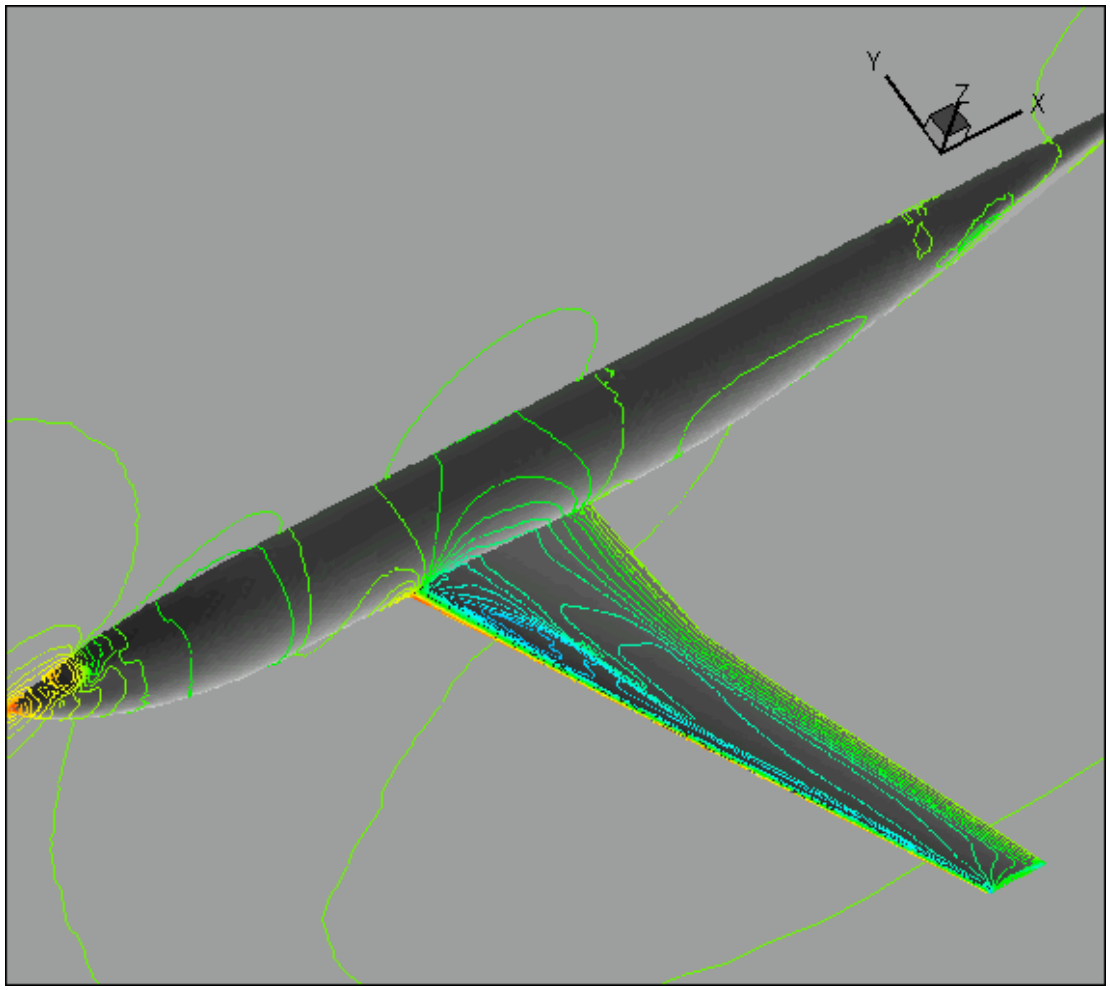
- Transition specified by laminar patches

Intermediate Grid (WBN: 5M pts)



- Transition specified by laminar patches

Solution on Intermediate Grid (C_L=0.5)



- Matching C_L

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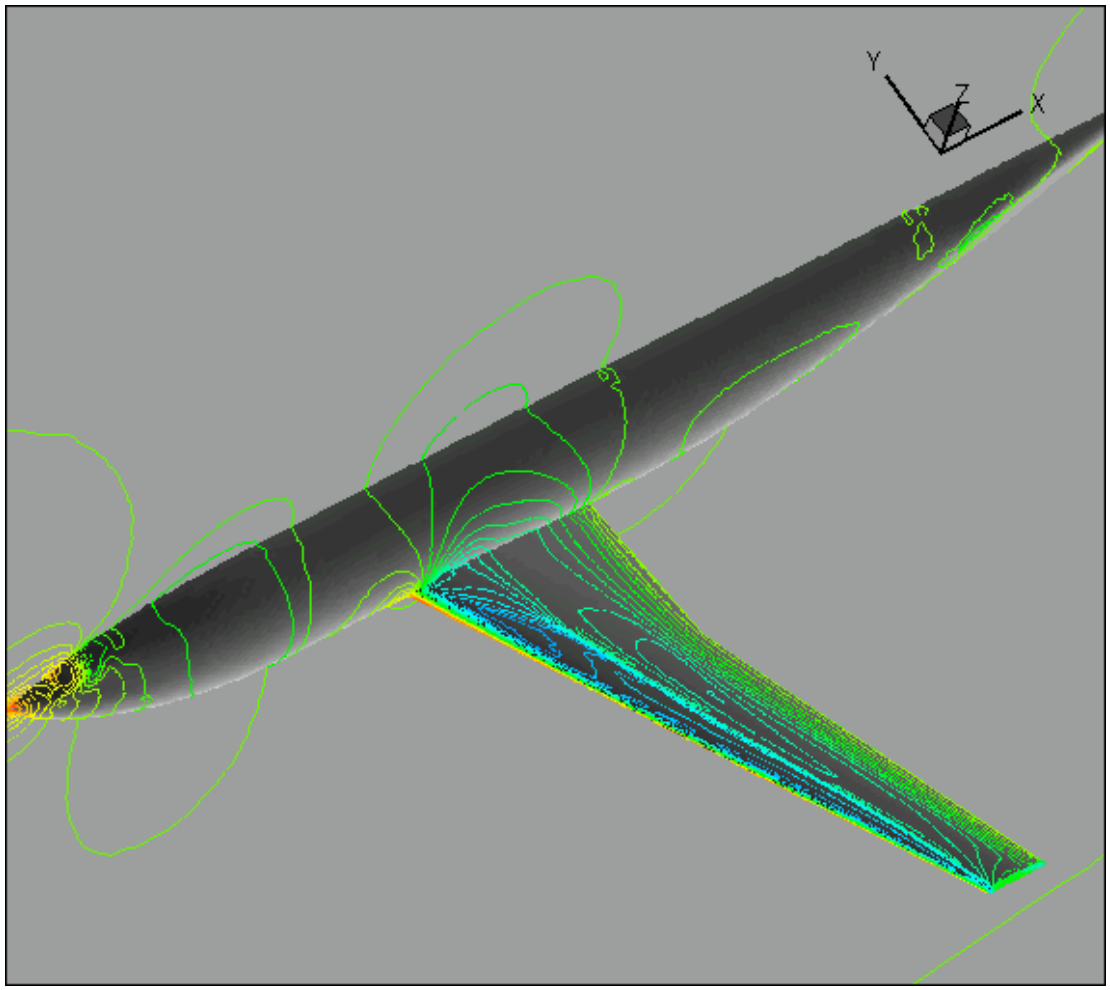
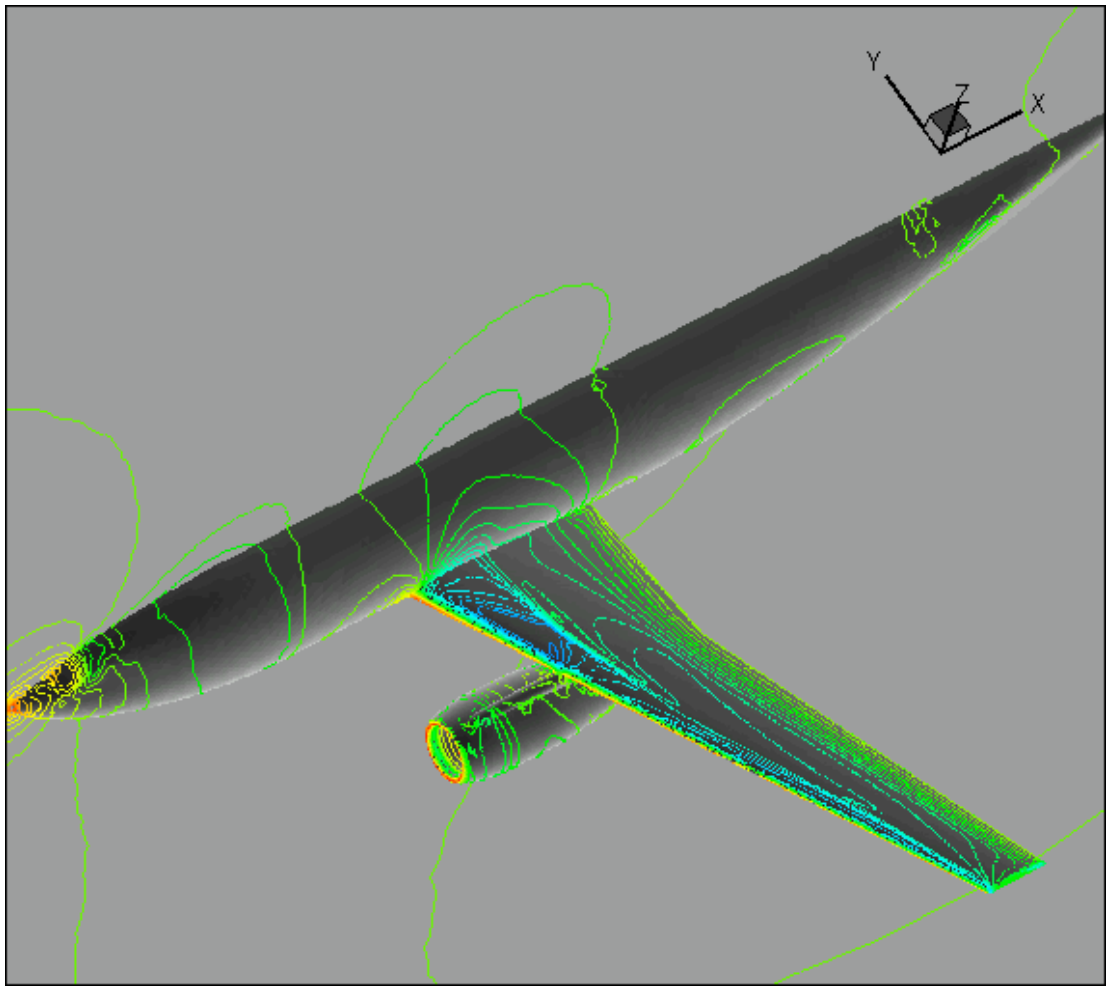


- Matching Incidence

Solution on Intermediate Grid (C_L=0.5)



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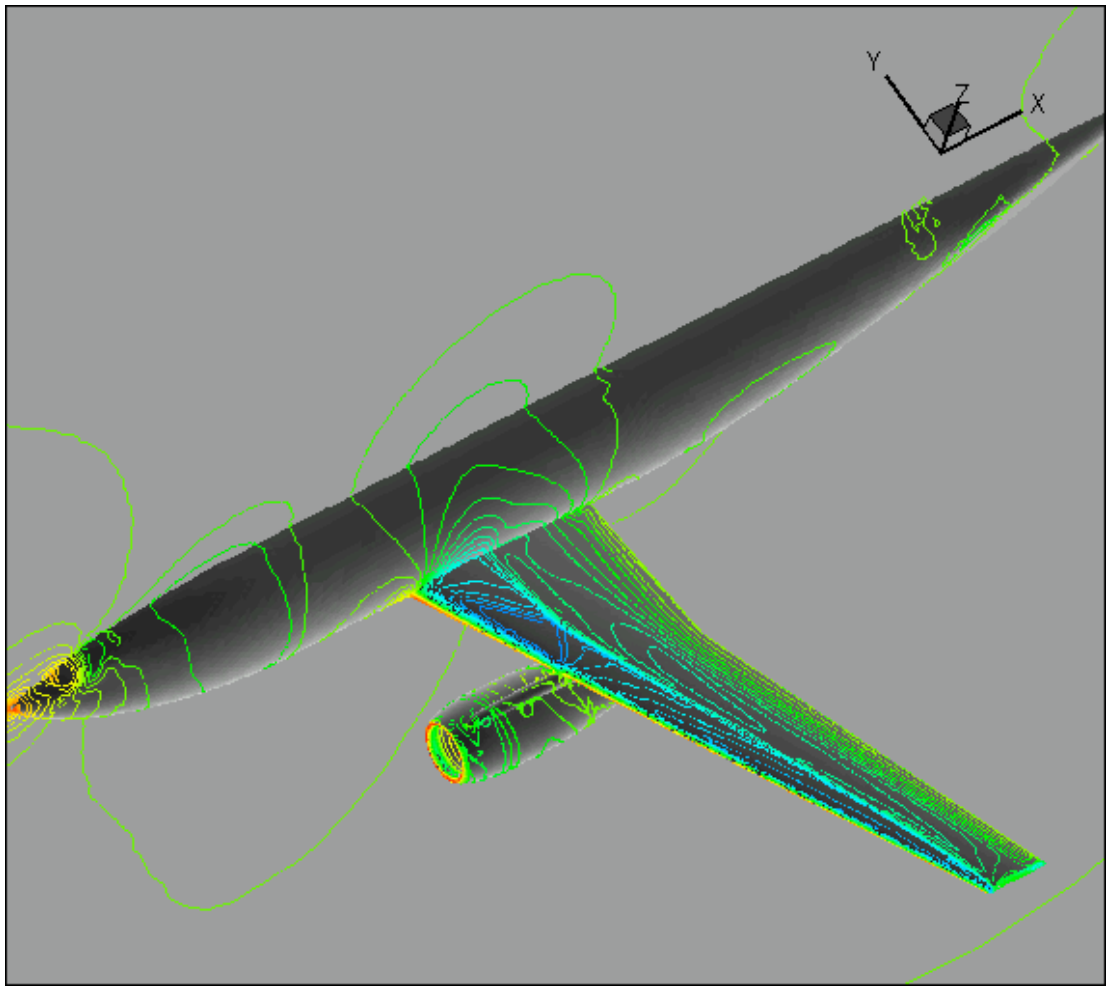
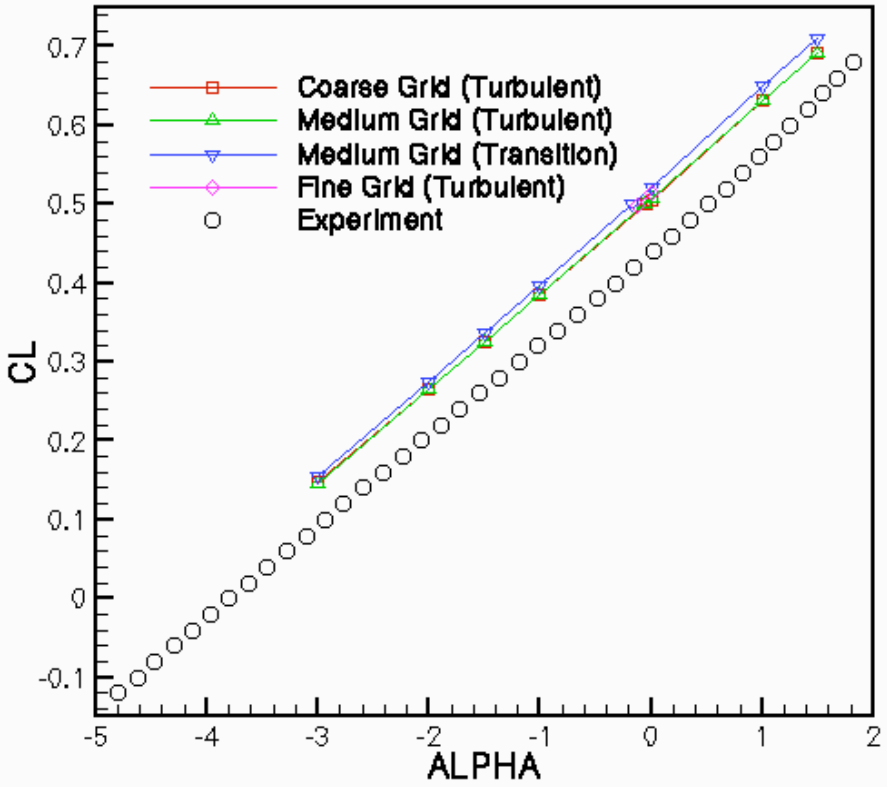
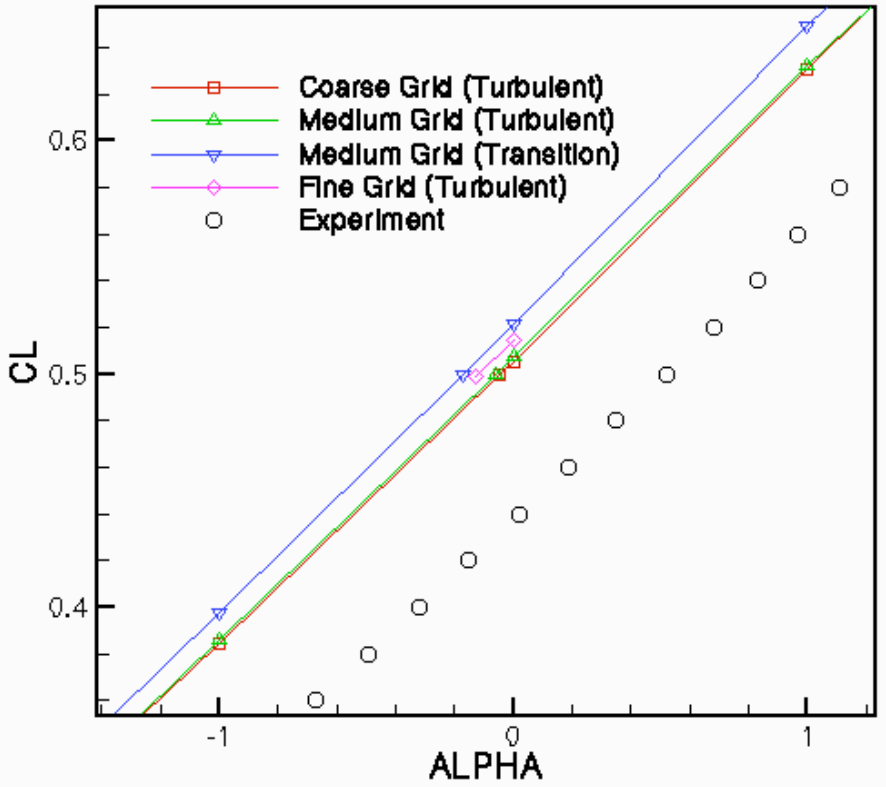


- Matching Incidence

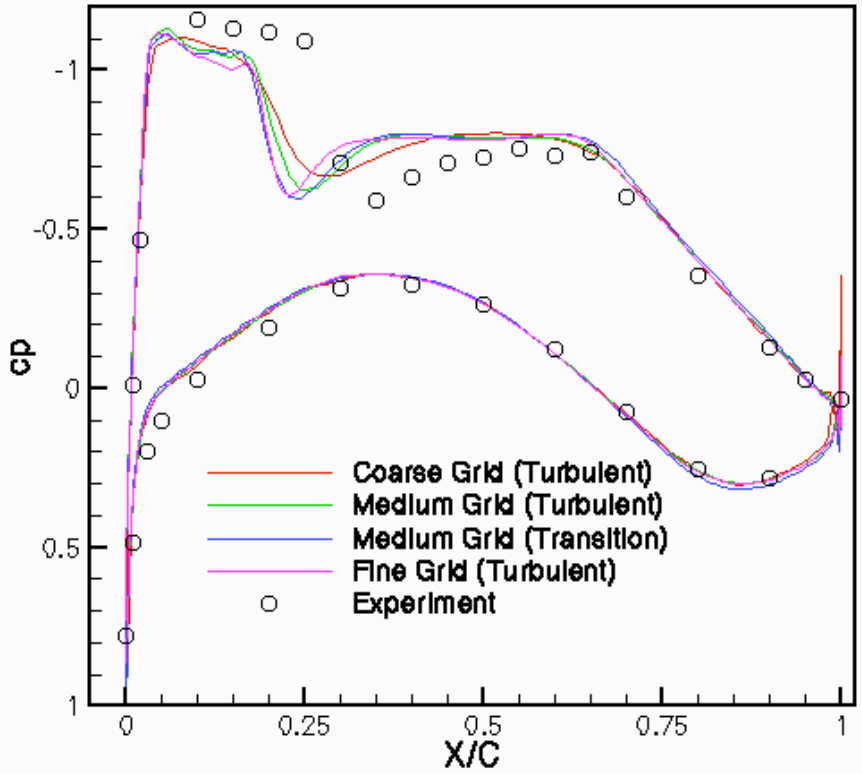
Lift vs. Incidence (Wing-Body)

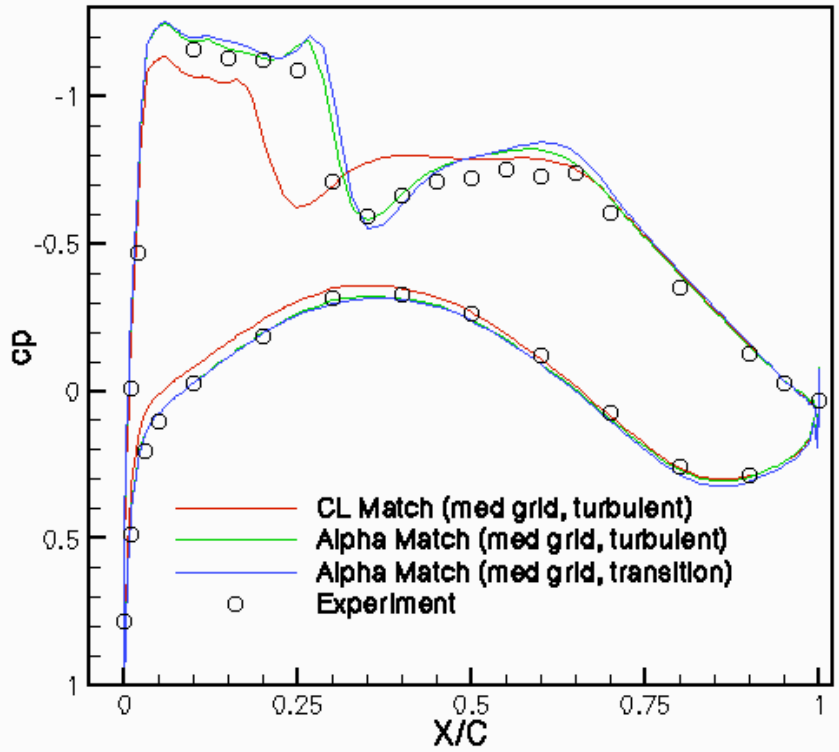




- Large Lift overprediction (incidence shift)

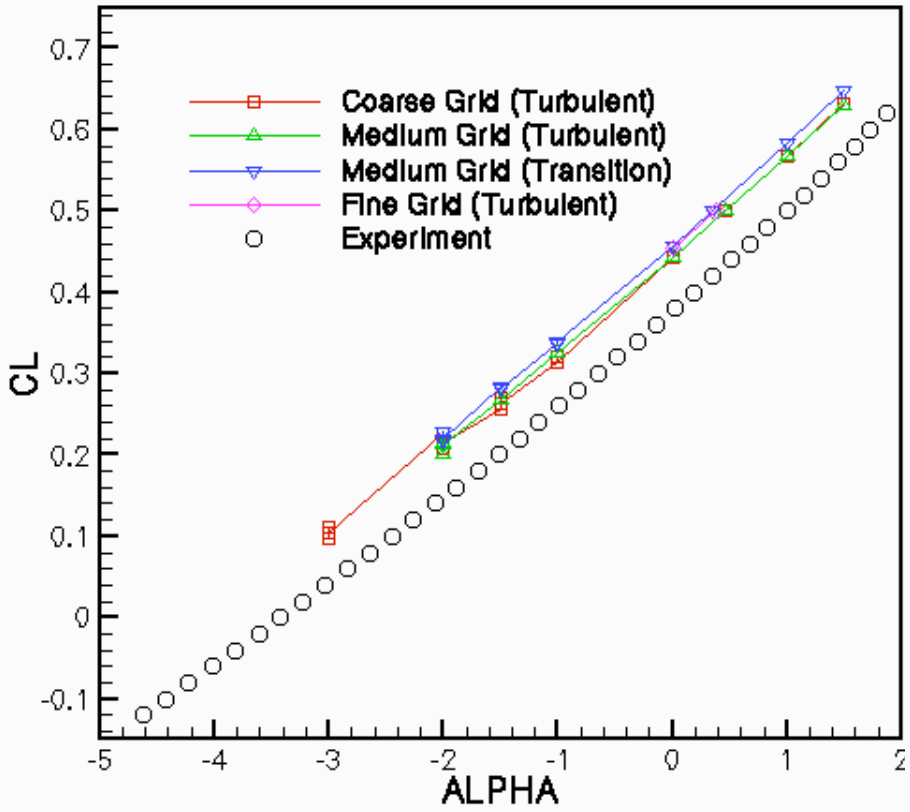
Surface Pressure at y/b=0.411(WB)

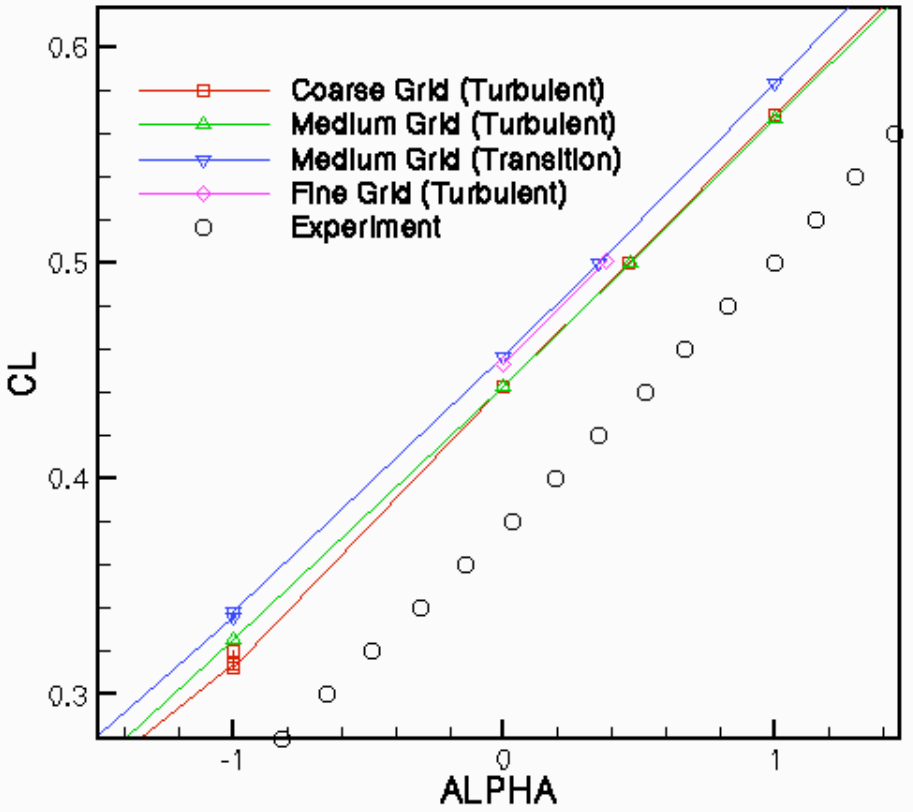




- Solution converges with grid refinement
- Poor match with experiment for specified C_L
- Better match for specified incidence

Lift vs. Incidence (WB-Nacelle)





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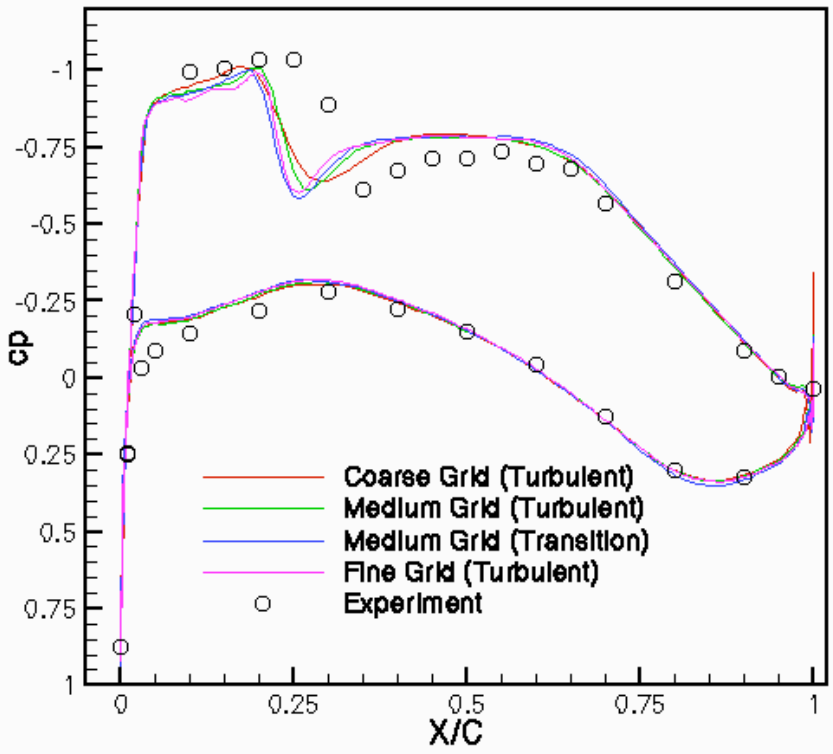

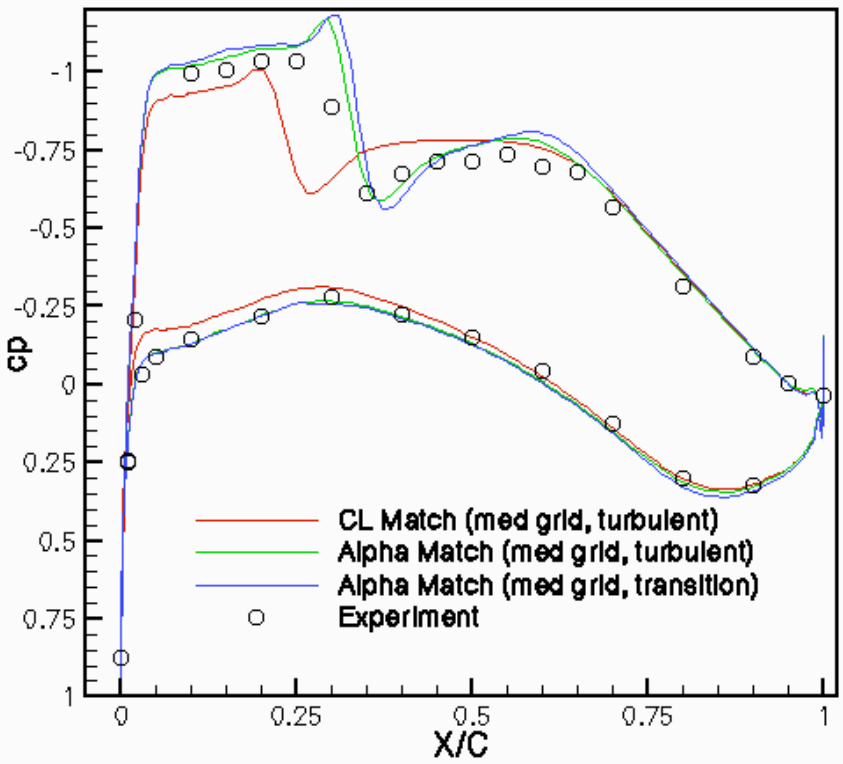

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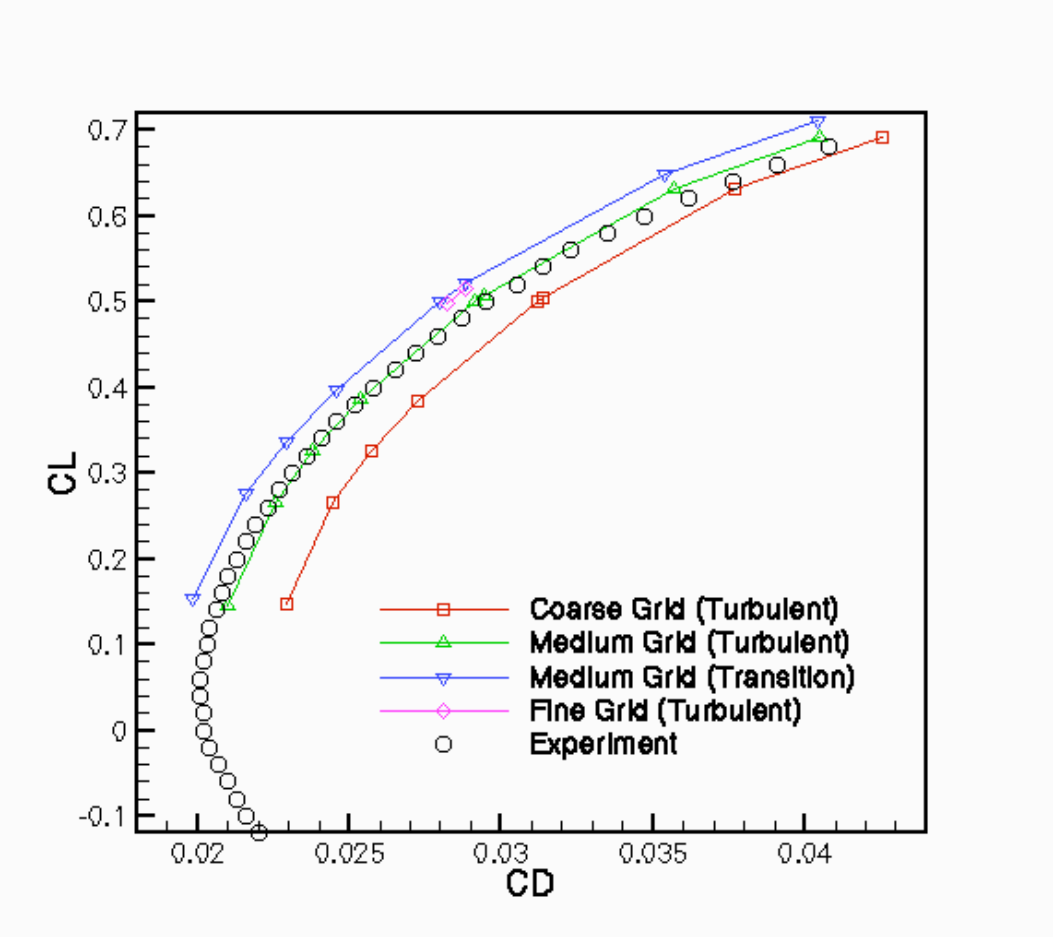
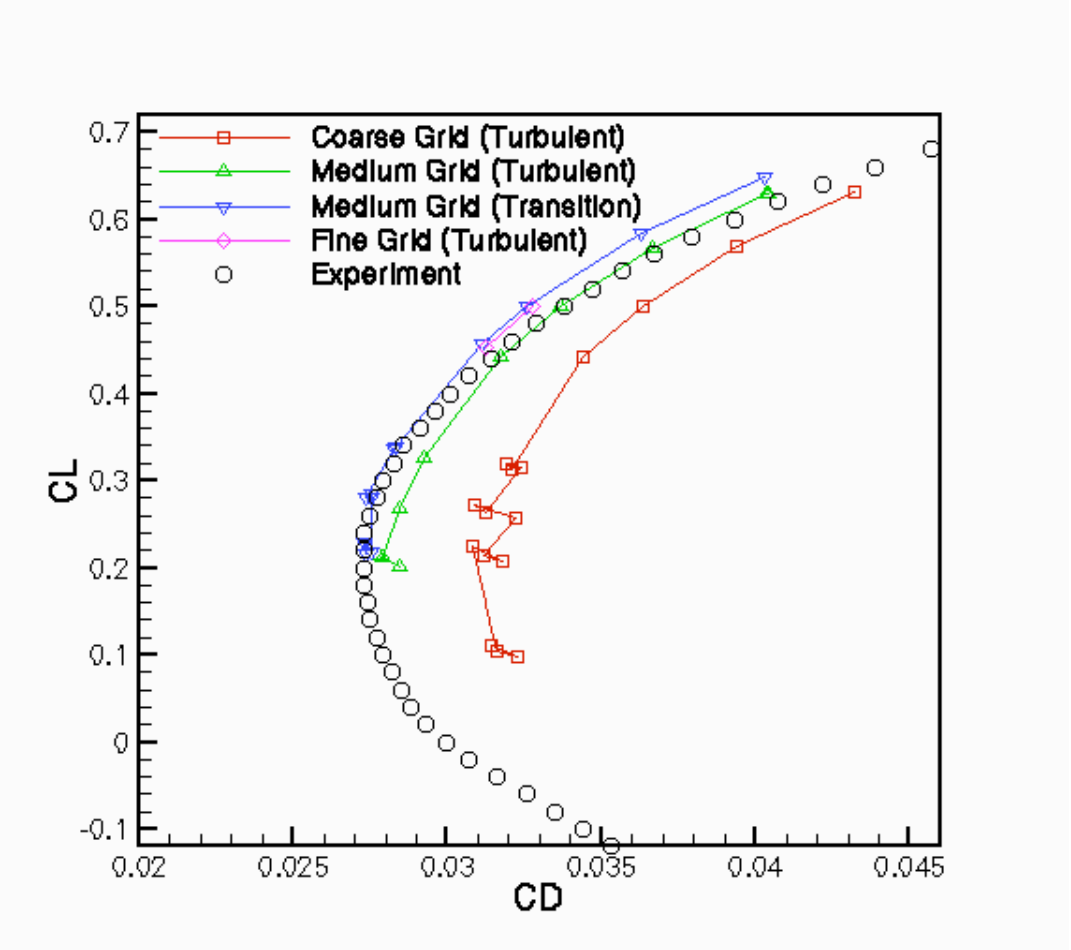
Drag Polar (Wing-Body)



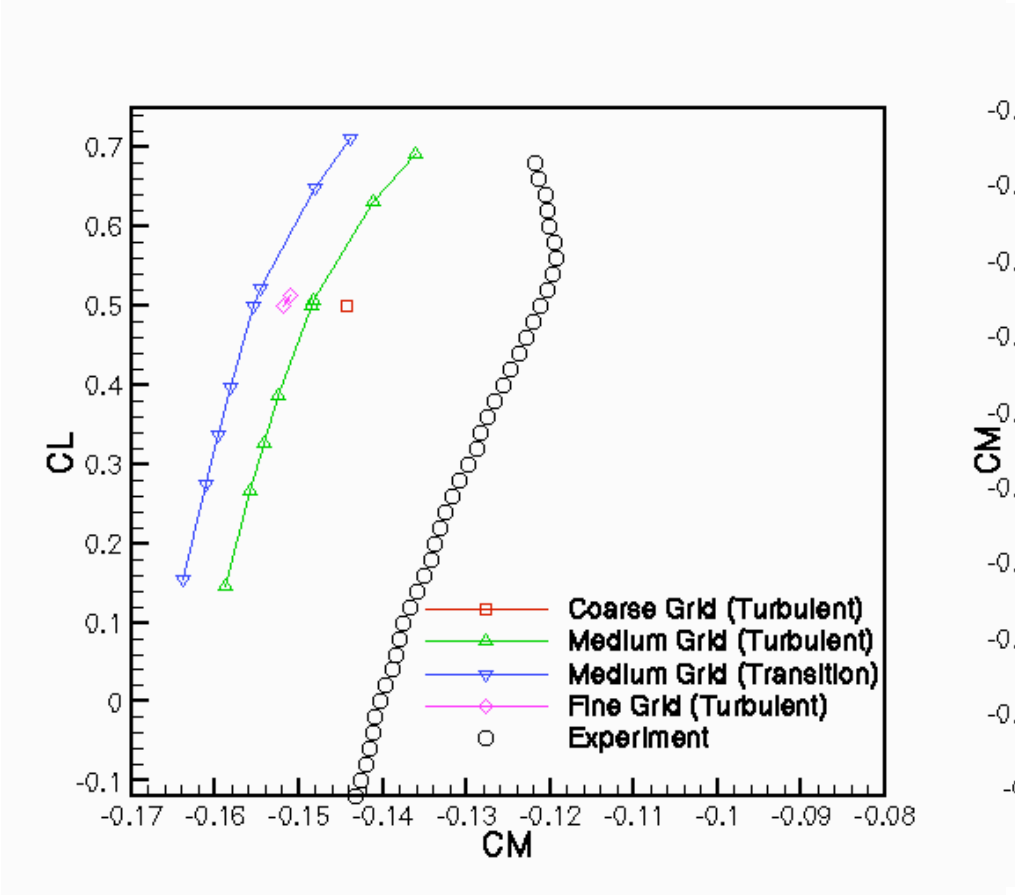
- Coarse grid inadequate
- Correct shape, slight underprediction

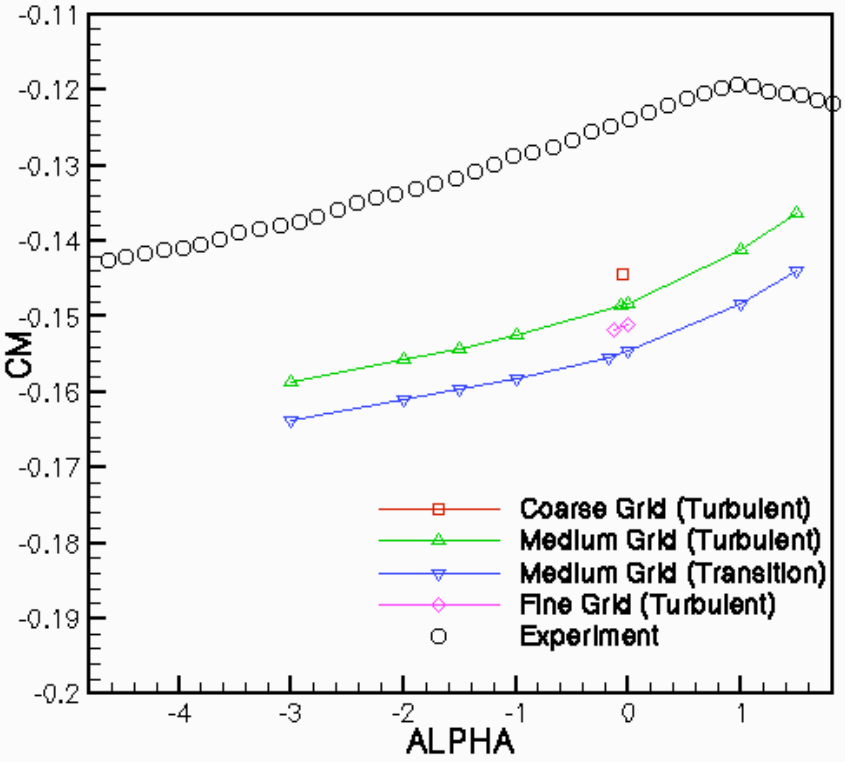
Drag Polar (Wing-Body-Nacelle)



- Coarse grid inadequate
- Correct shape, slight underprediction
- Convergence issues at negative incidences

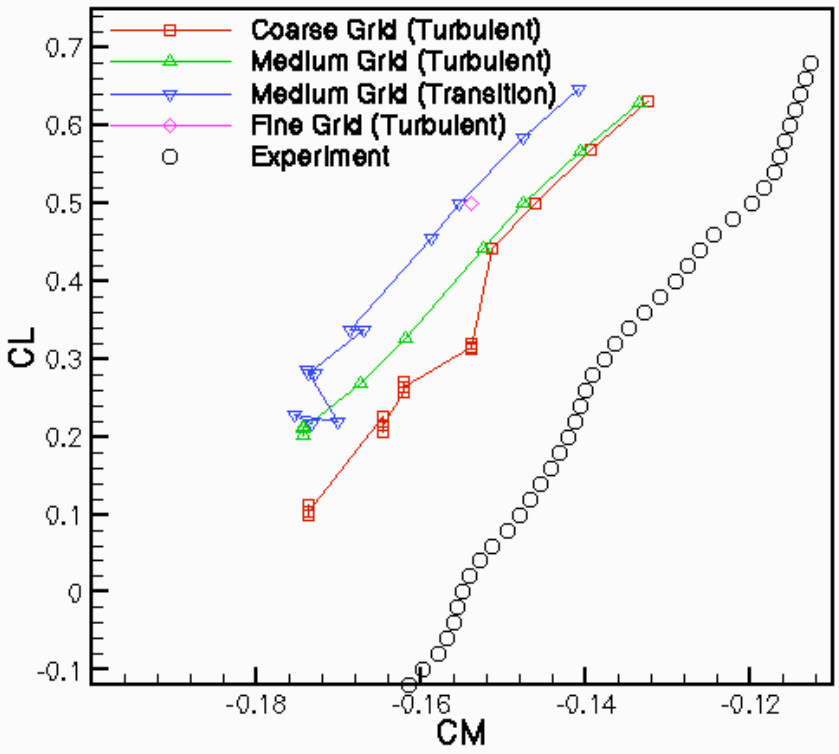
Moment (Wing-Body)

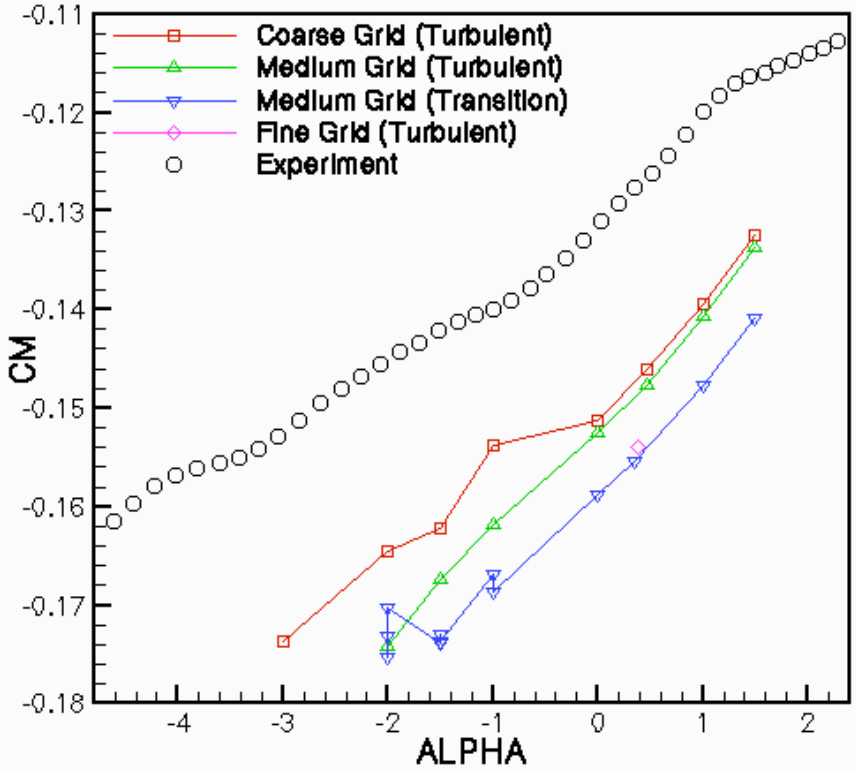




- Poor moment prediction
  - Related to incidence shift

Moment (Wing-BodyNacelle)





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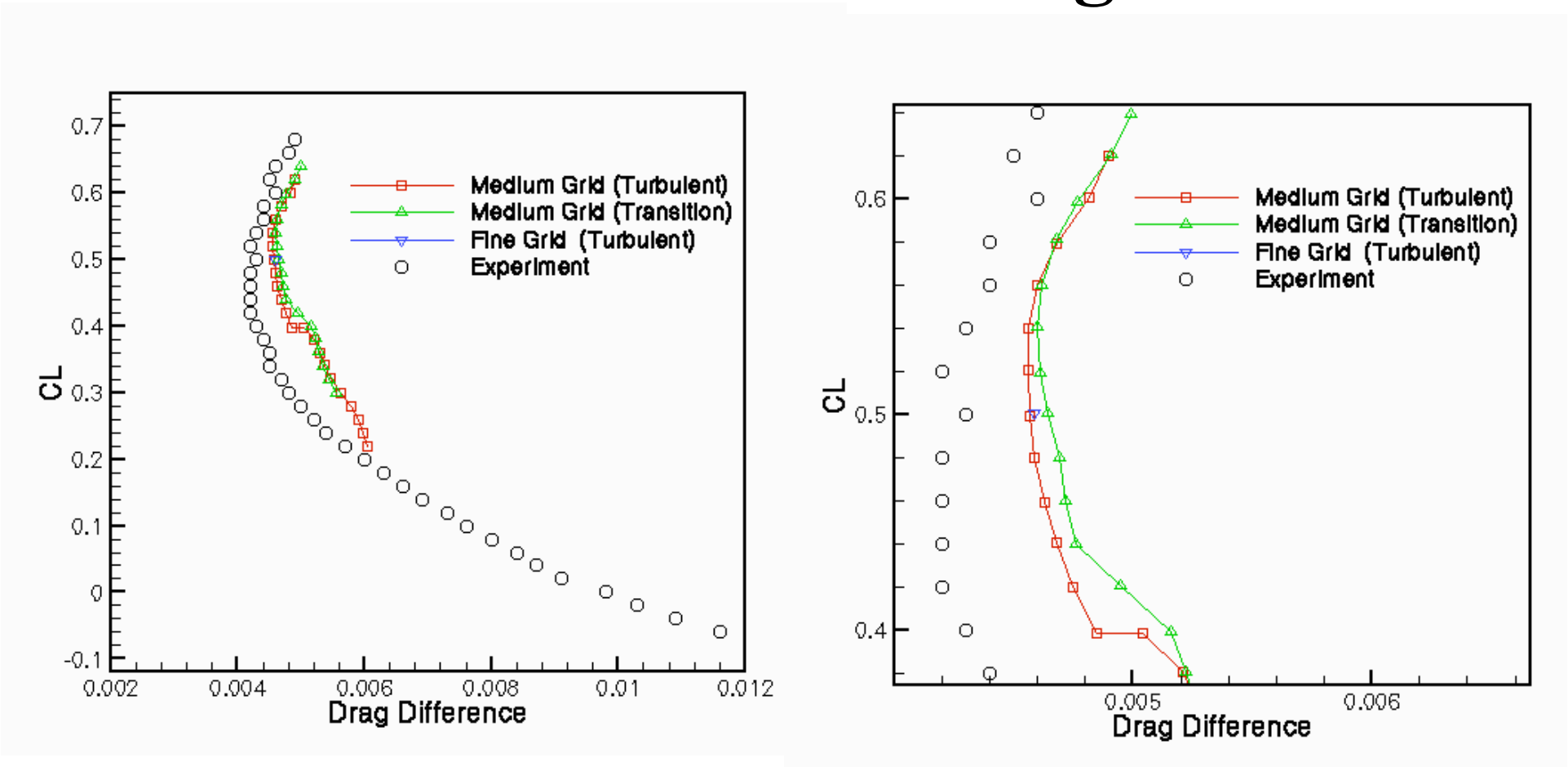
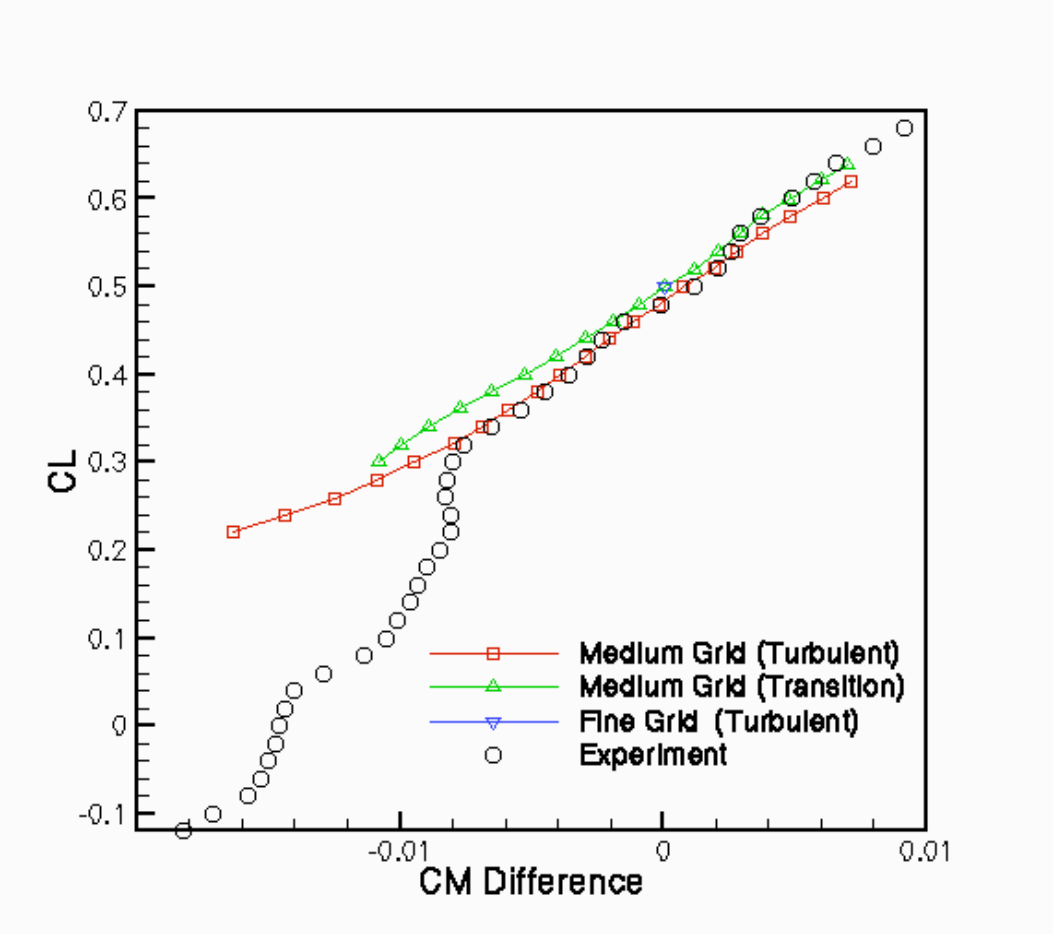
Incremental Drag



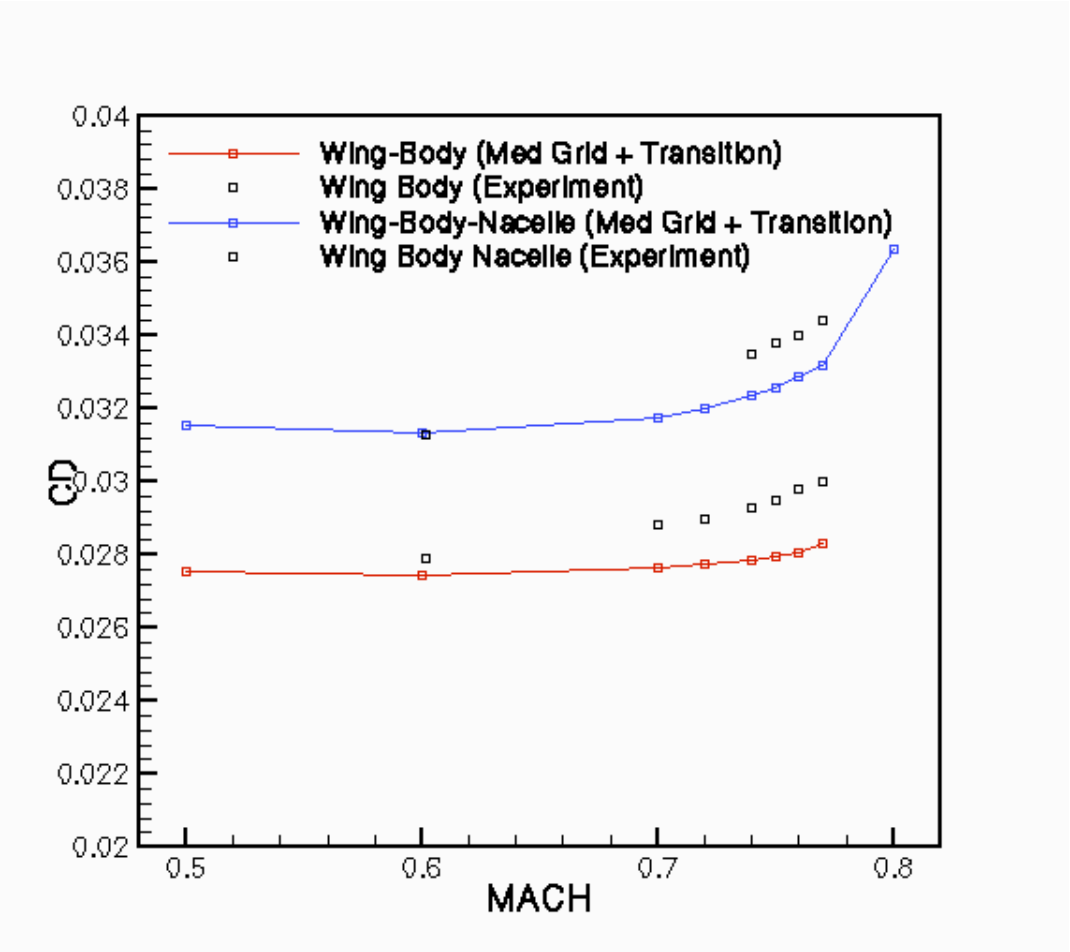
- Within 2 to 4 counts at C_L=0.5
- Transition effects cancel out
- More discrepancies at lower lift

Incremental Moment



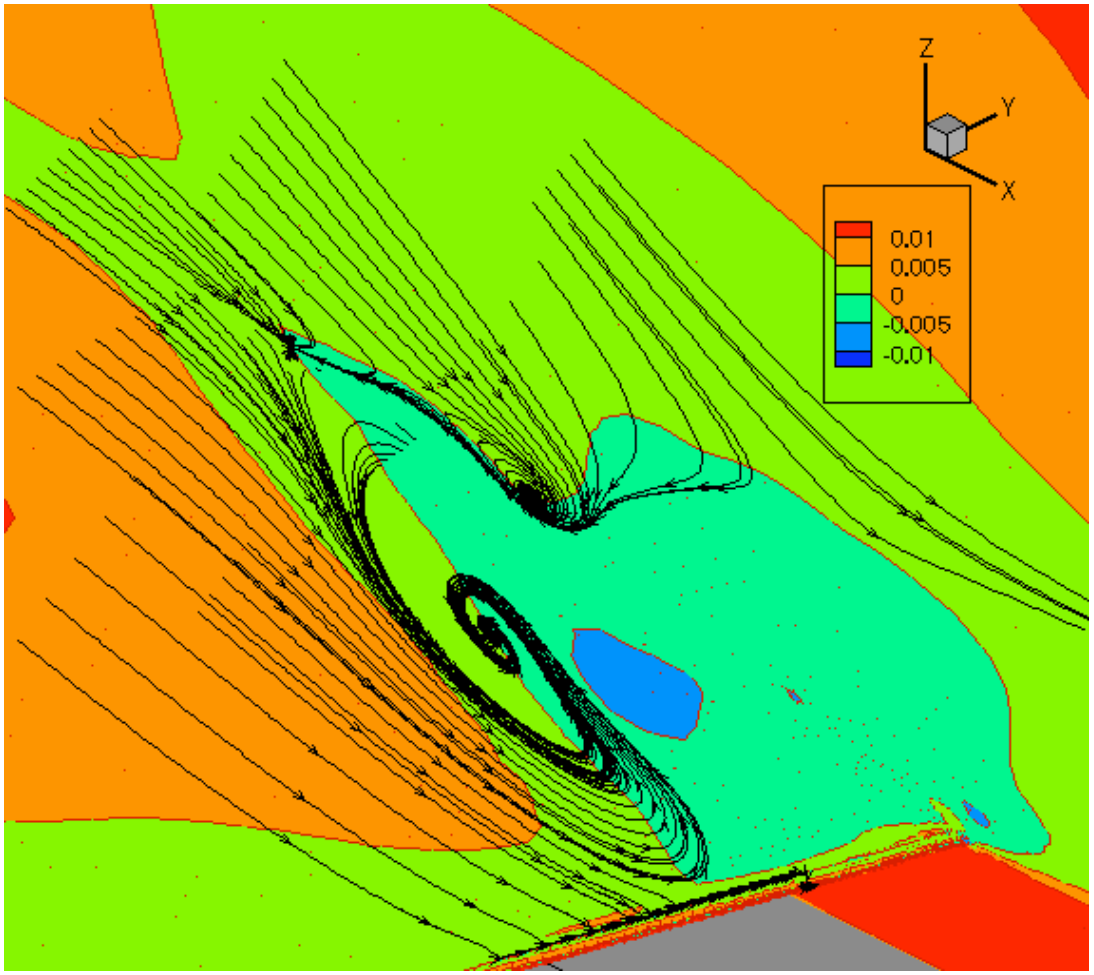
- Good prediction in spite of poor absolute values
  - Cross over well predicted
  - Discrepancies at lower lift

Drag Rise Curves



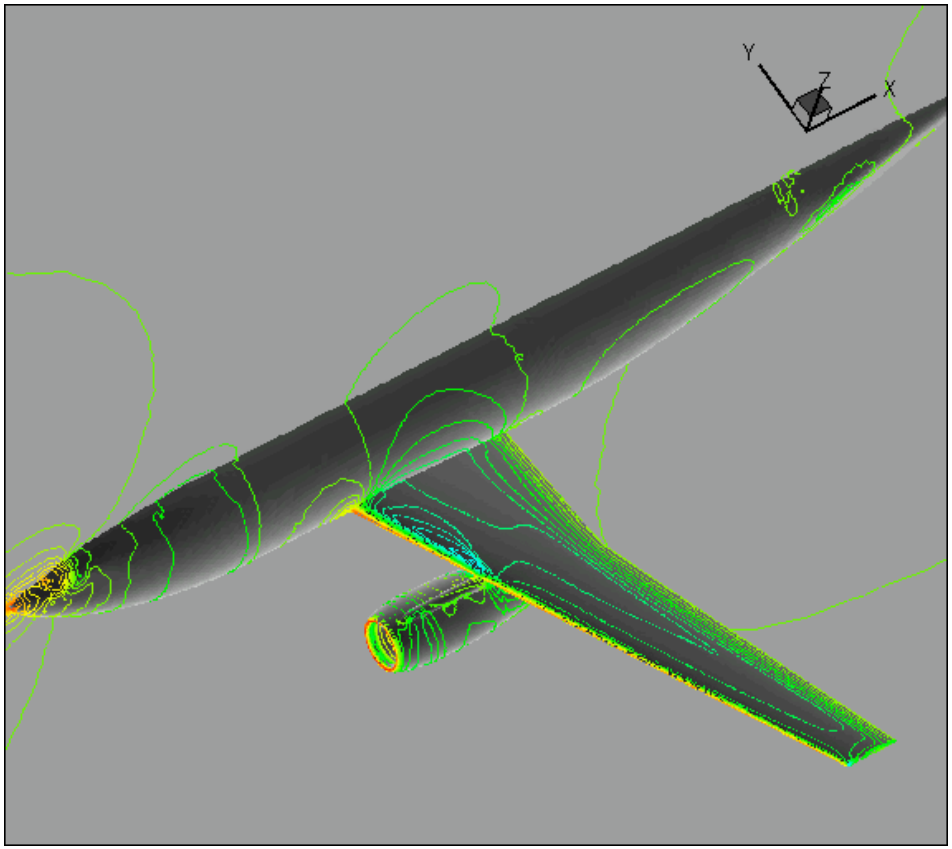
- Medium grids, transition
- General trend, Drag underpredicted
- C_l vs incidence issues

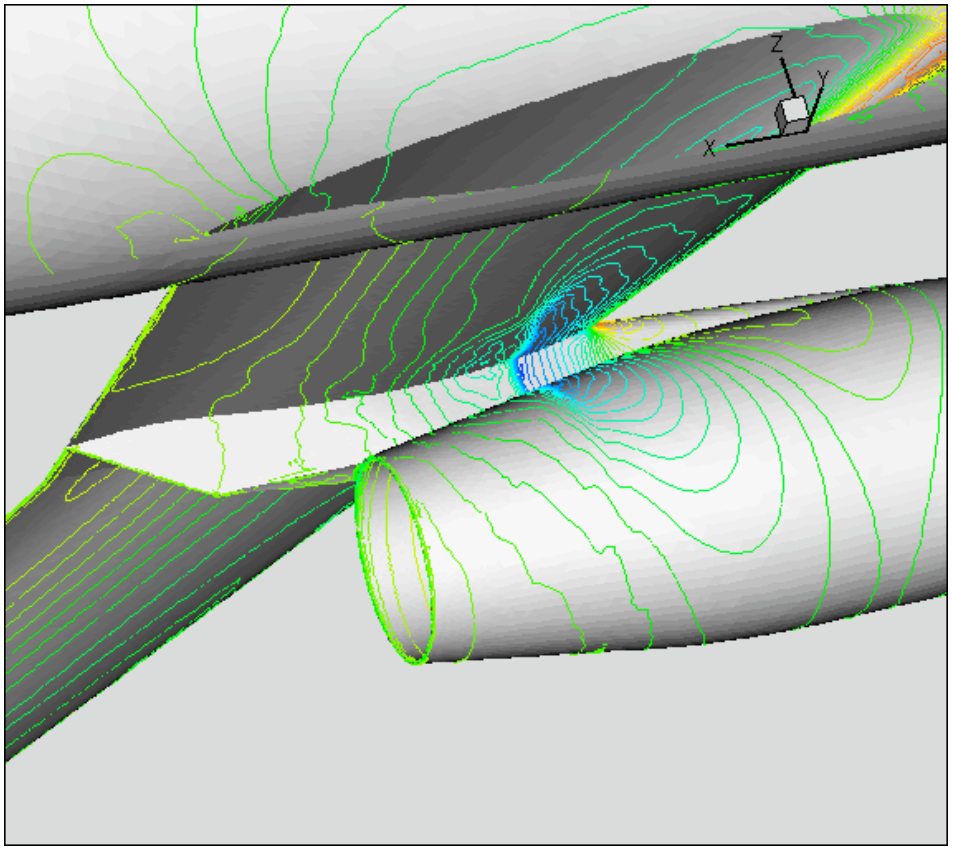
Flow Details



- Separation bubble on WB-Nacelle (fine grid)

Flow Details





- Strong shock inboard pylon (-2 deg)
- Ahead of specified transition region on lower wing

Conclusions

- CL – Incidence Issues
- Better success at prediction of increments
- Grid Generation approach may be more important than actual resolution
- Aero is still a tough problem
  - Worthy of funding