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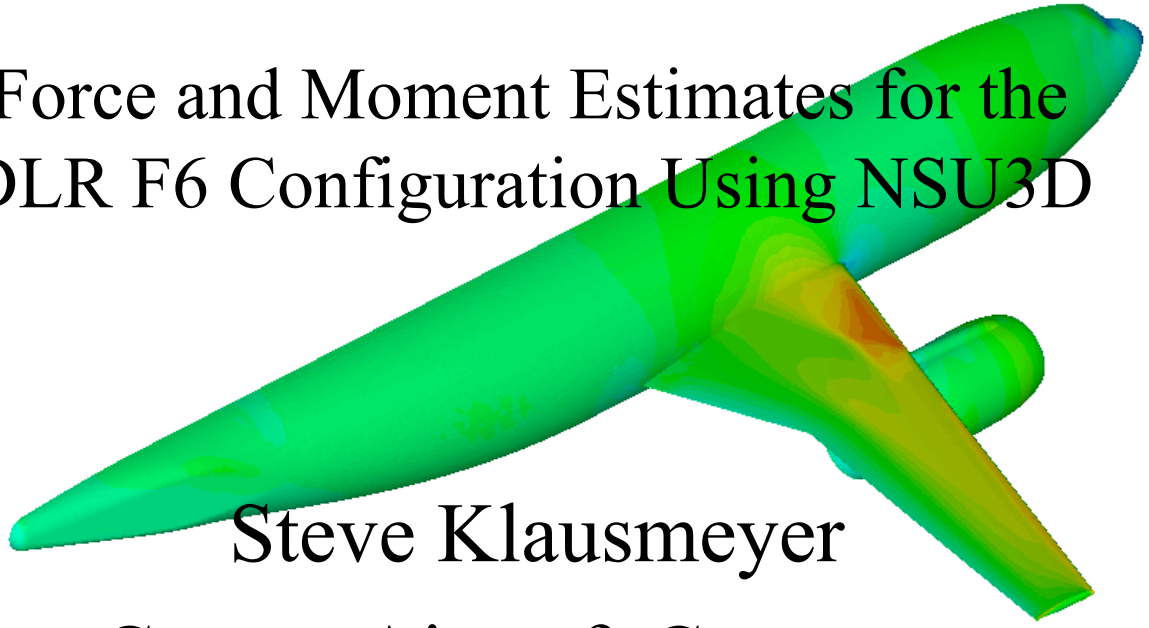
Force and Moment Estimates for the DLR F6 Configuration Using NSU3D



Steve Klausmeyer

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Goals

- Further refine and quantify in-house drag prediction
  - Evaluate incremental drag capability
- Evaluate ICEM for unstructured viscous mesh generation
  - Flow solver compatibility
  - Force and moment accuracy

NSU3D

- Unstructured grid, mixed element, node based
- Thin-layer RANS with Spalart-Allmaras turbulence model
- Multigrid with automated coarse level generation via agglomeration
- Implicit lines through boundary layer speed convergence
- Distributed memory parallel implementation
- Cache-based optimizations

ICEM

- Features
  - CATIA interface
  - Mesh sizes specified directly on patches
  - Multi-Use --> structured, unstructured, mixed

- Issues
  - Memory requirements for large meshes
  - Prism grid quality and robustness
  - Octree mesh growth

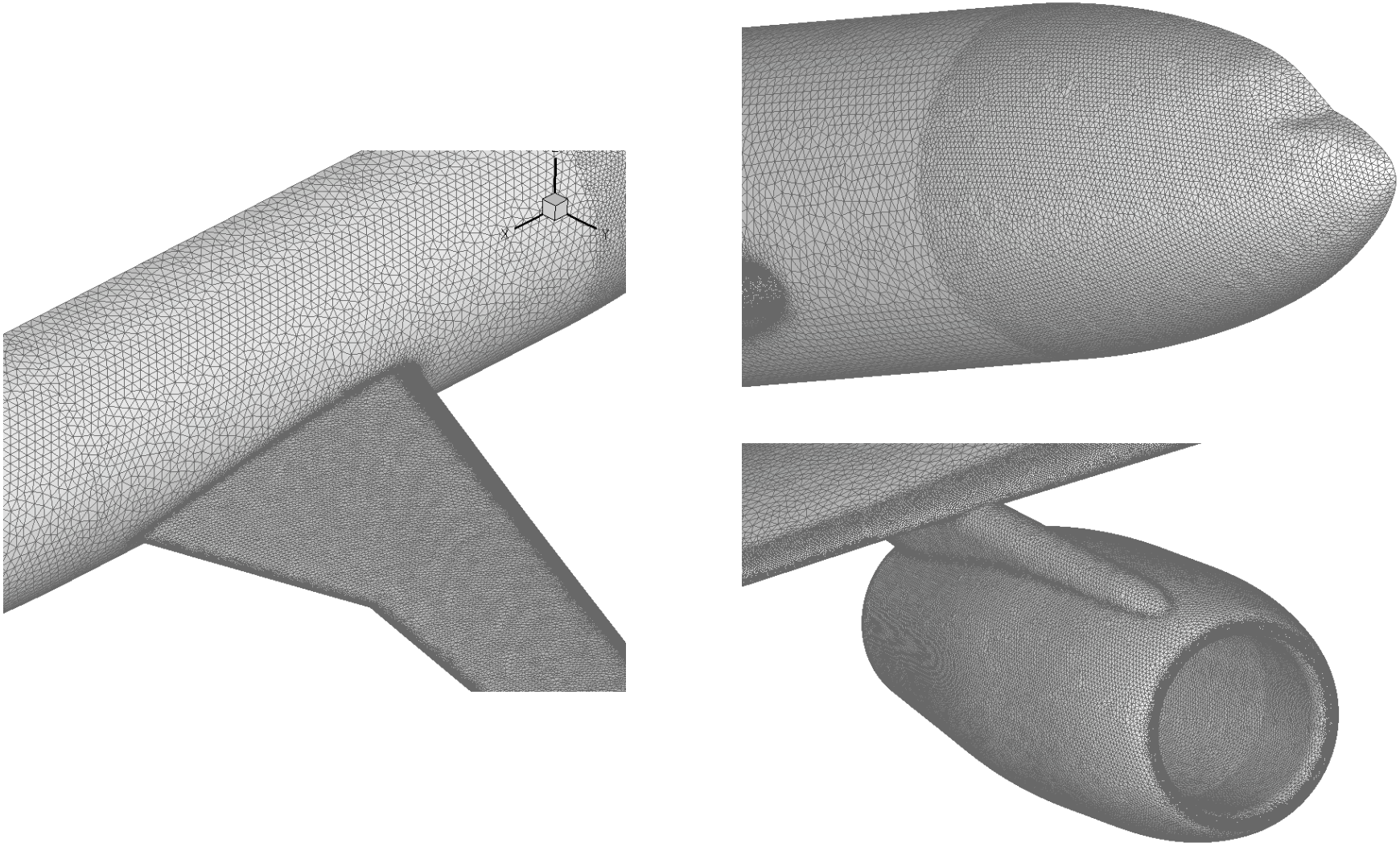
Mixed Element Unstructured Meshes

- Self-generated using the Tetra & Prism modules within ICEM
- 25 prism layers
- Isotropic surface elements

- WB grid sizes: 1.2m 2.6m 6.2m
- WBNP grid sizes: 1.6m 4.0m 8.0m

- Generation times: ~ 8 hours for medium WB mesh

Surface Meshes - Medium



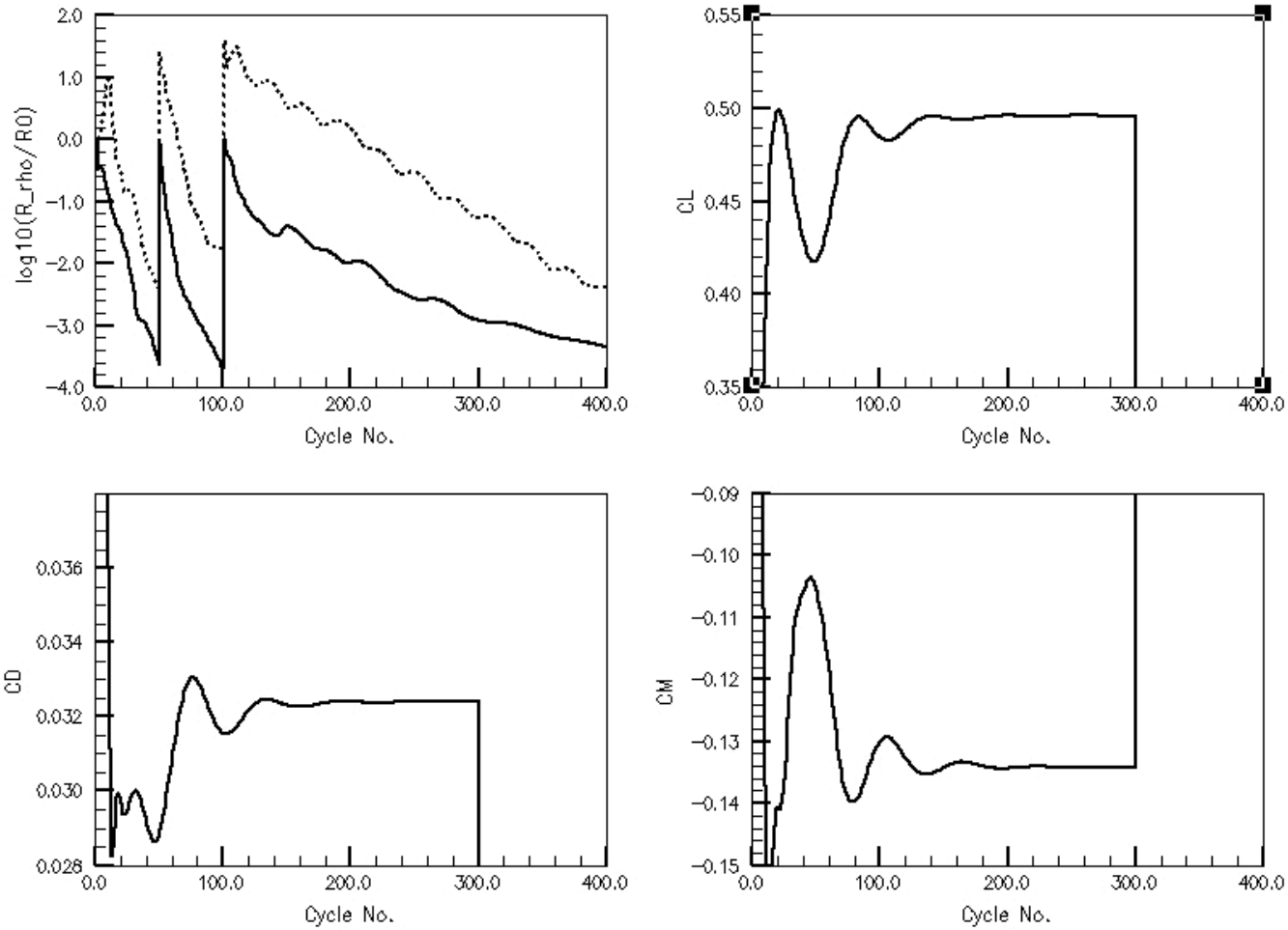
Computer Resources

- 48 node Linux cluster.
  - 1.7 GHz Athlon processors
  - 48 Gbyte total memory
  - 3 16 node banks
- 32 node Linux cluster
  - Alpha VP2000 motherboards
  - 32 Gbyte total memory
- 8 node SGI ONYX
  - 600 MHz R14000 processors
  - 6 Gbyte memory with 6 Gb swap

Solution Statistics

- Each solution utilized 16 nodes
- For the medium WB mesh
  - 275 Mbytes per node (4.4 Gbytes total)
  - 3.6 hrs for 500 multigrid cycles
  - Drag polar or drag rise within a 24 hour window.

Typical Solution Convergence



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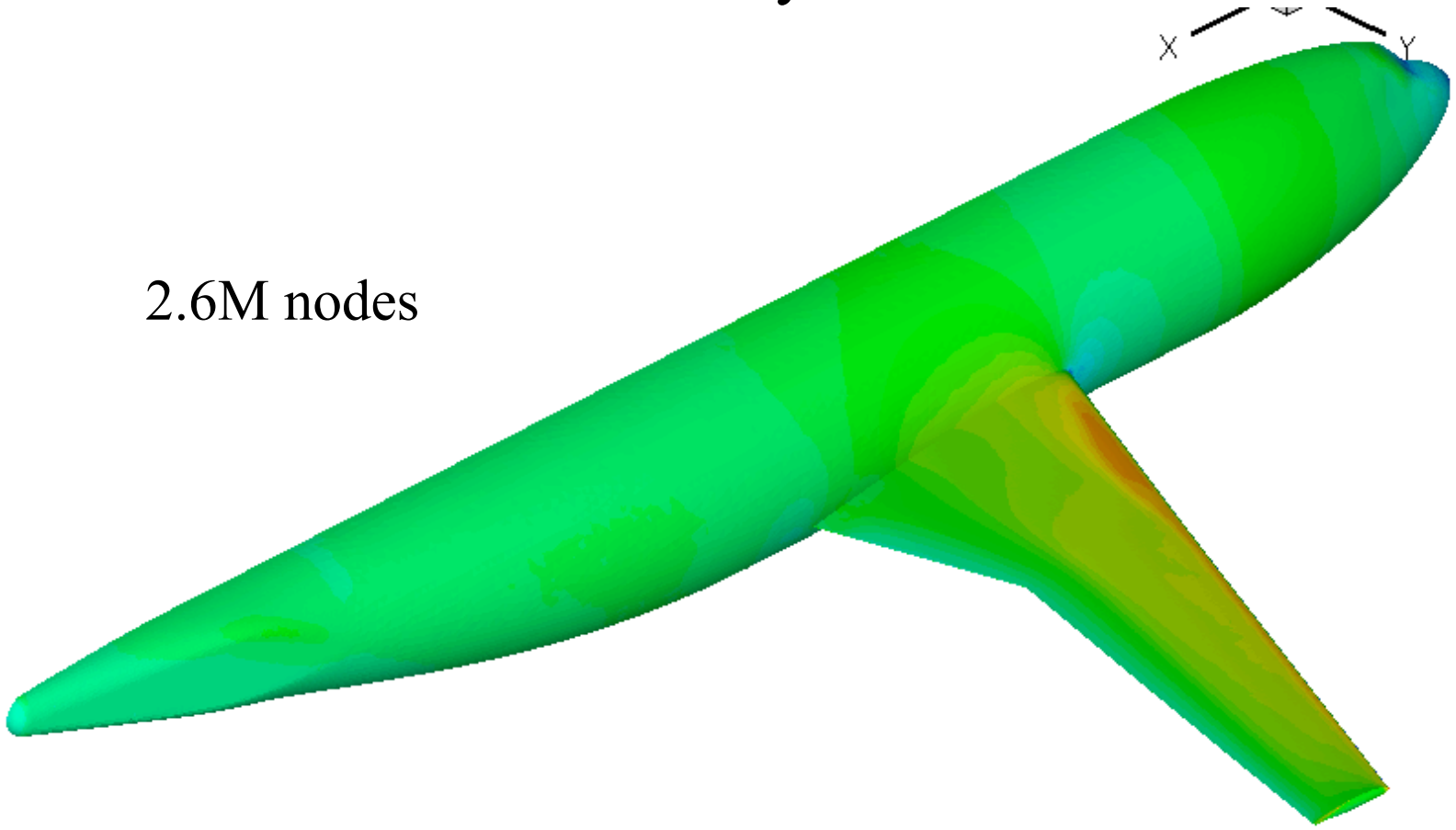
Flow Features

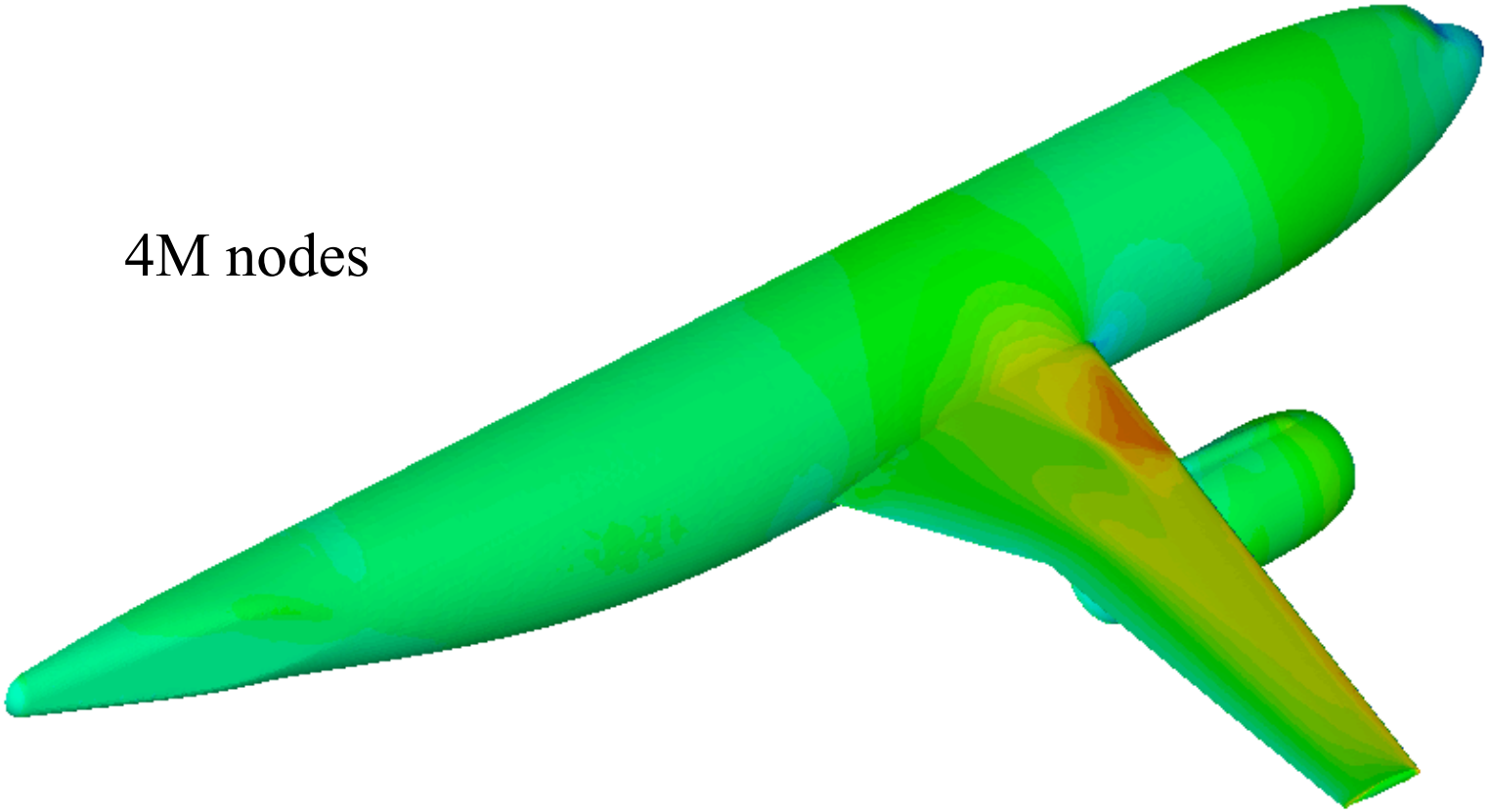
WB Surface Pressure
M=0.75 CL=0.5
Re=3M Fully Turbulent

2.6M nodes

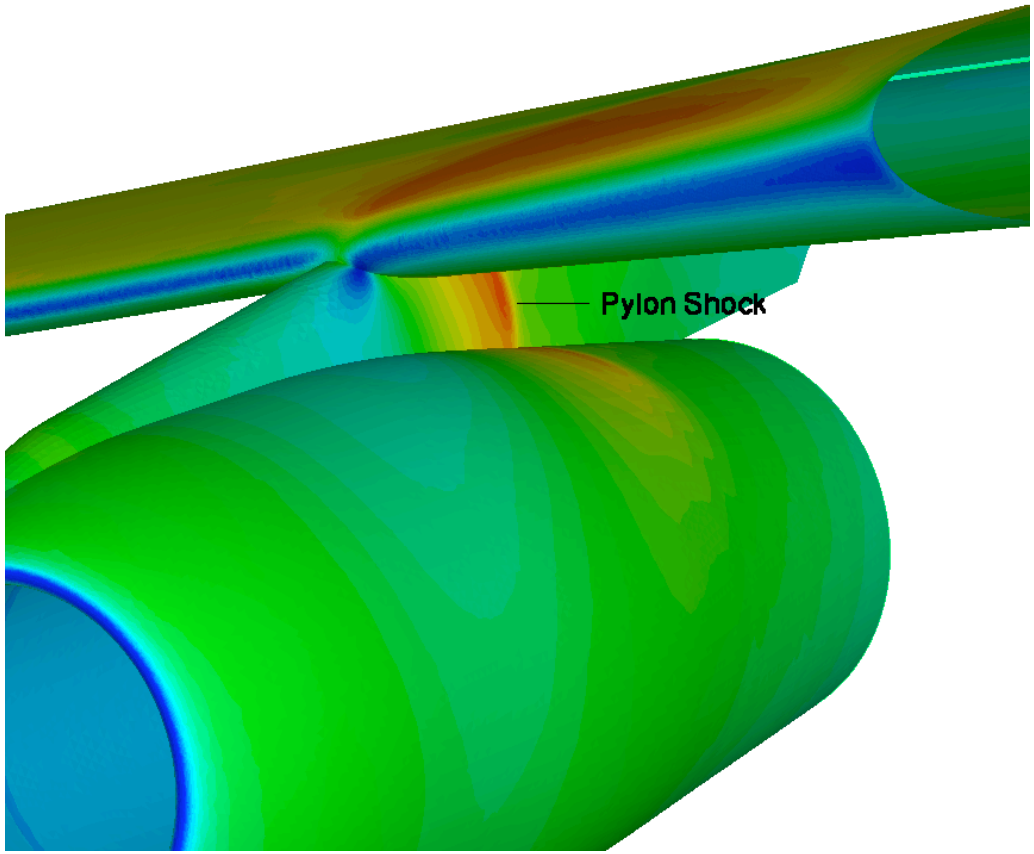


WBNP Surface Pressure
M=0.75 CL=0.5
Re=3M Fully Turbulent

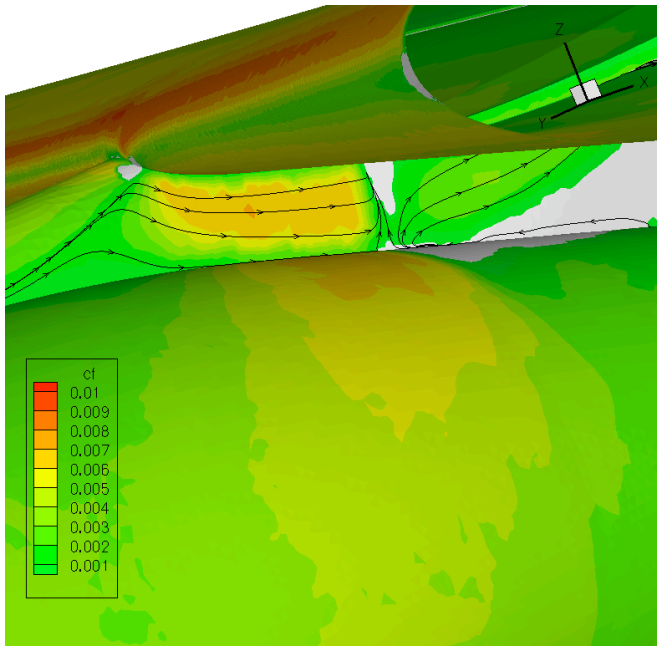
4M nodes



Flow Features



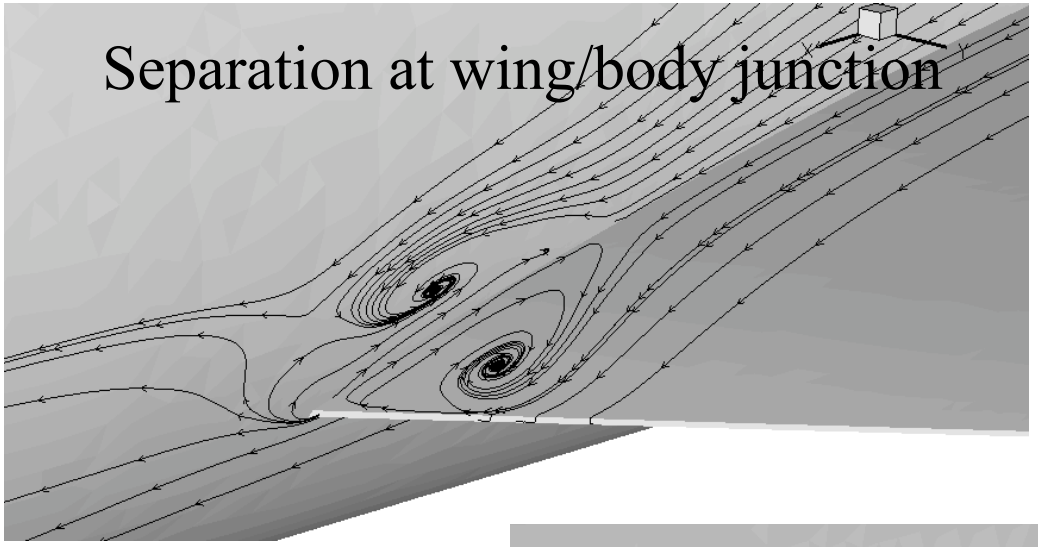
Pressure



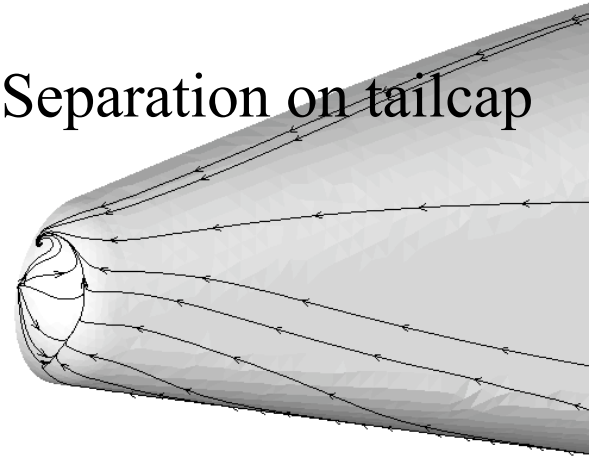
Skin Friction

Flow Features

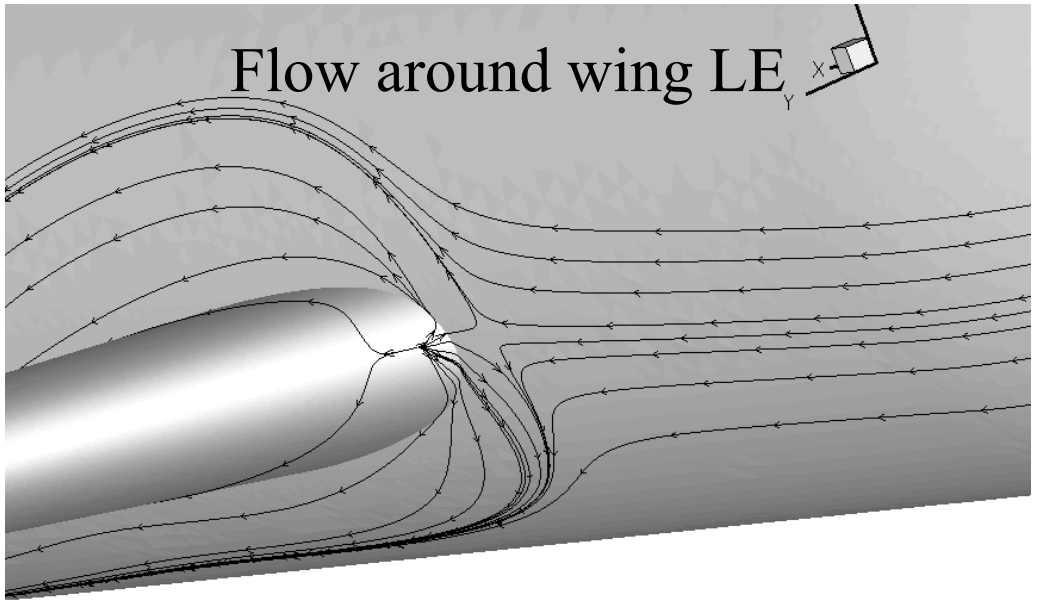
Separation at wing/body junction



Separation on tailcap



Flow around wing LE



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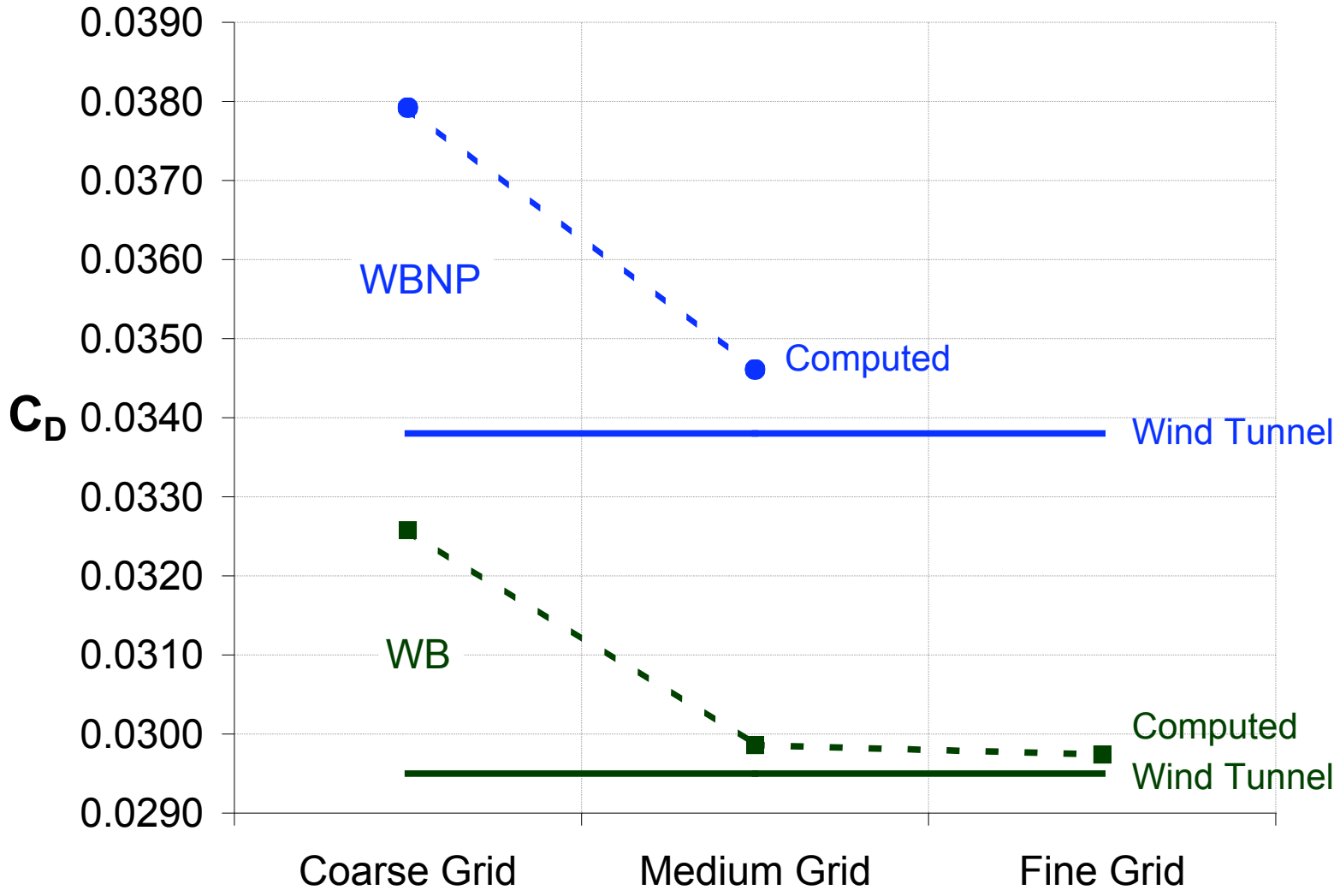
Case 1 – Grid Convergence

Effect of Grid Size on Drag



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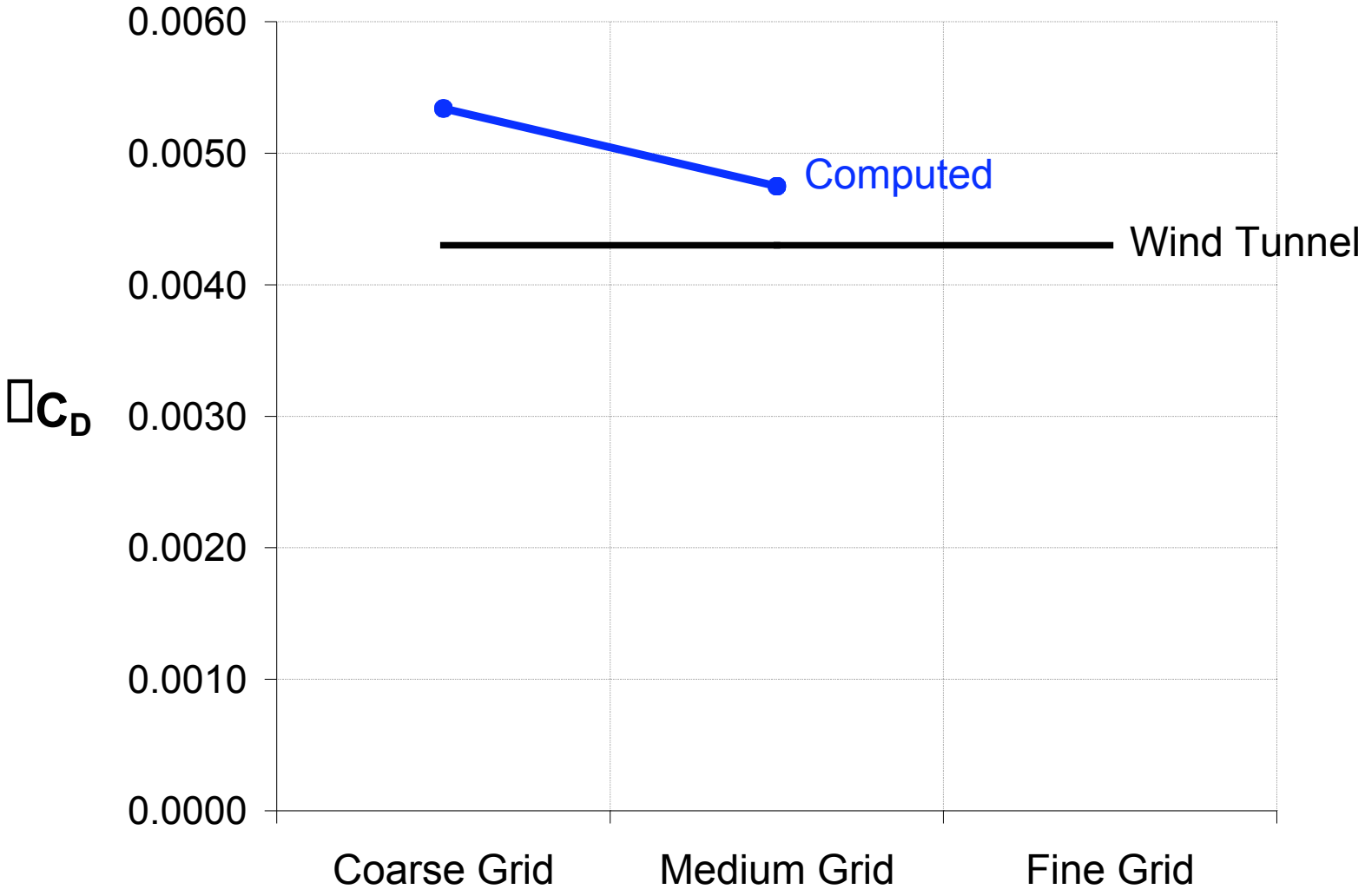
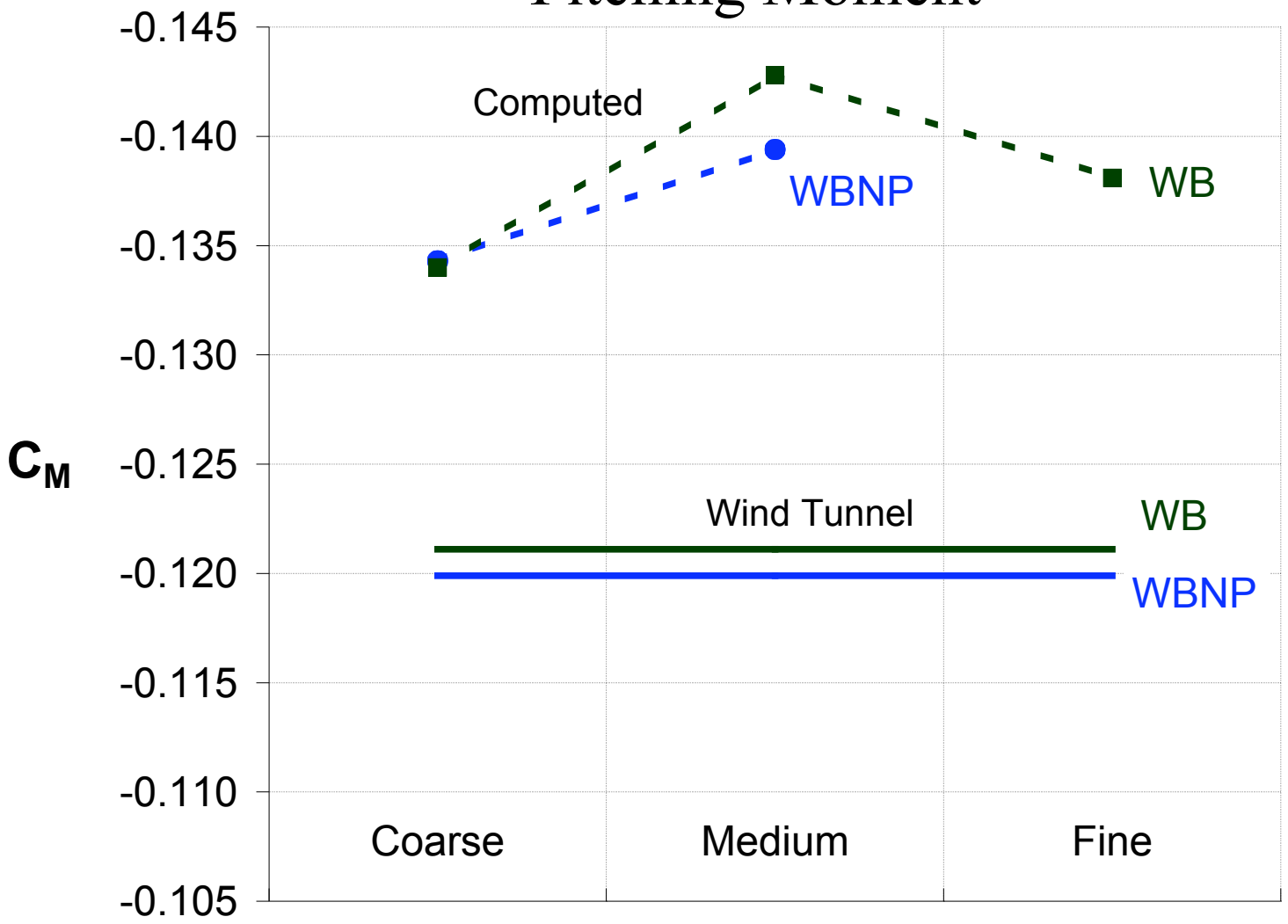
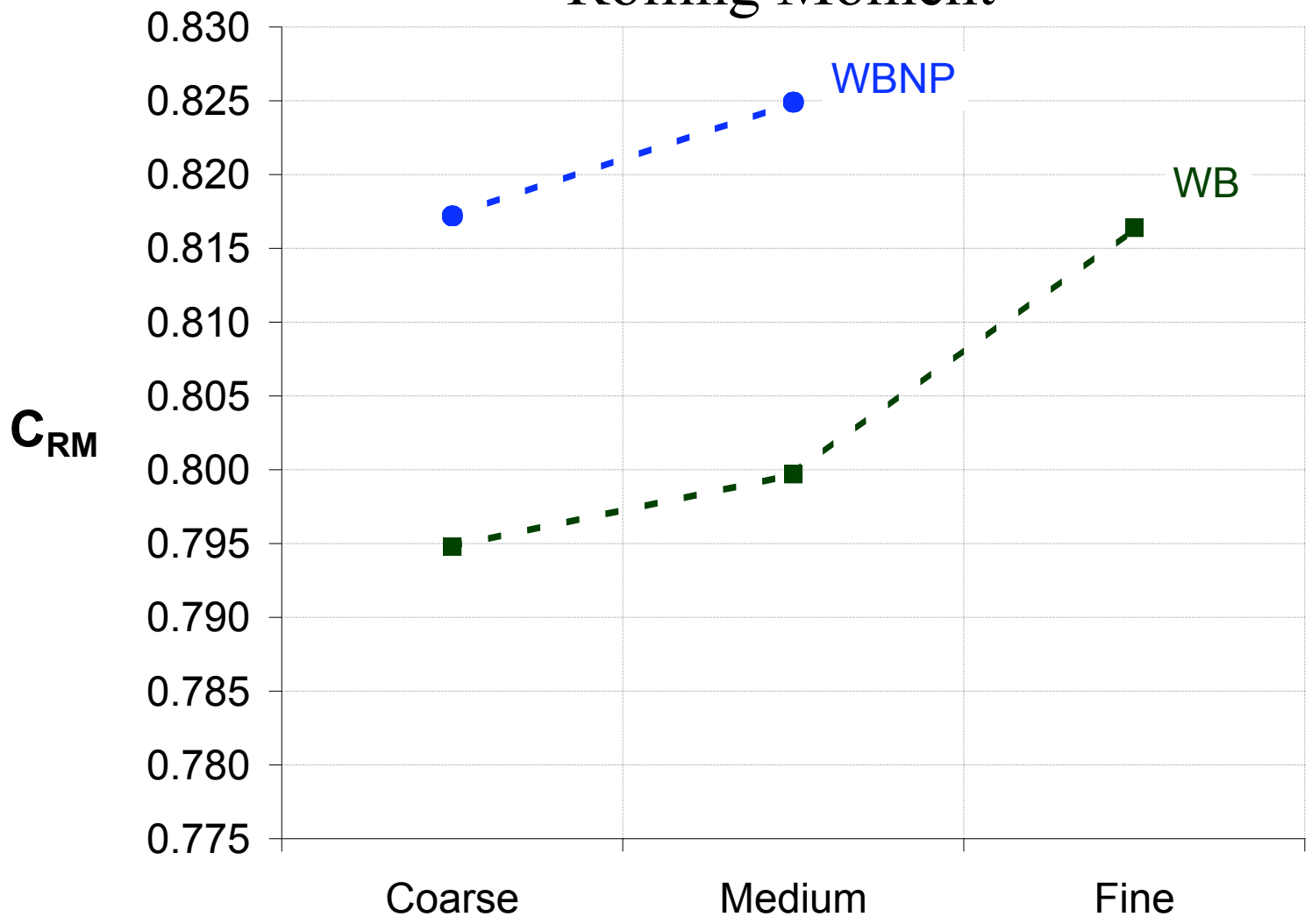
Effect of Grid Size on Nacelle Installation Drag



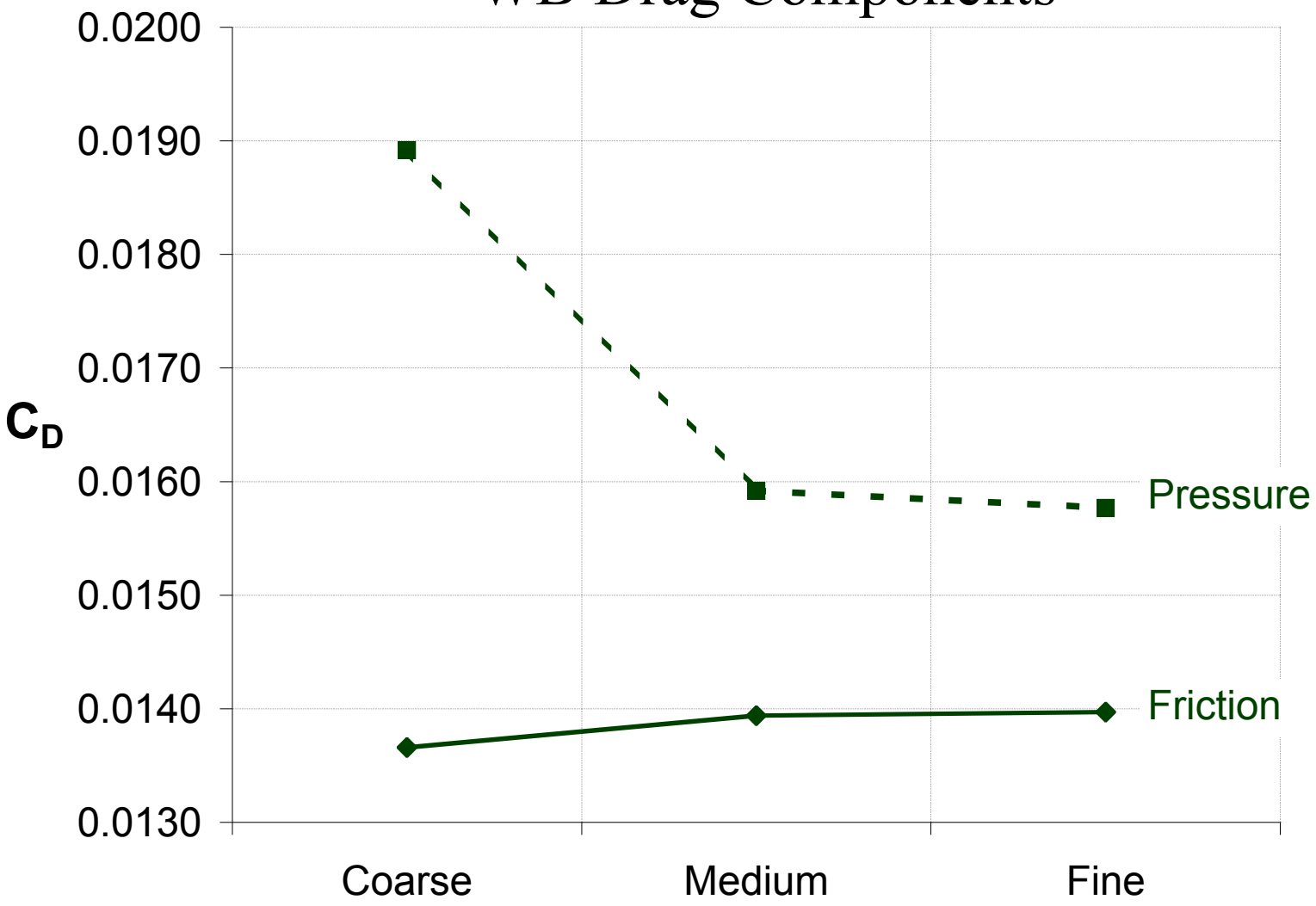
Effect of Grid Size on Pitching Moment



Effect of Grid Size on Rolling Moment



Effect of Grid Size on WB Drag Components



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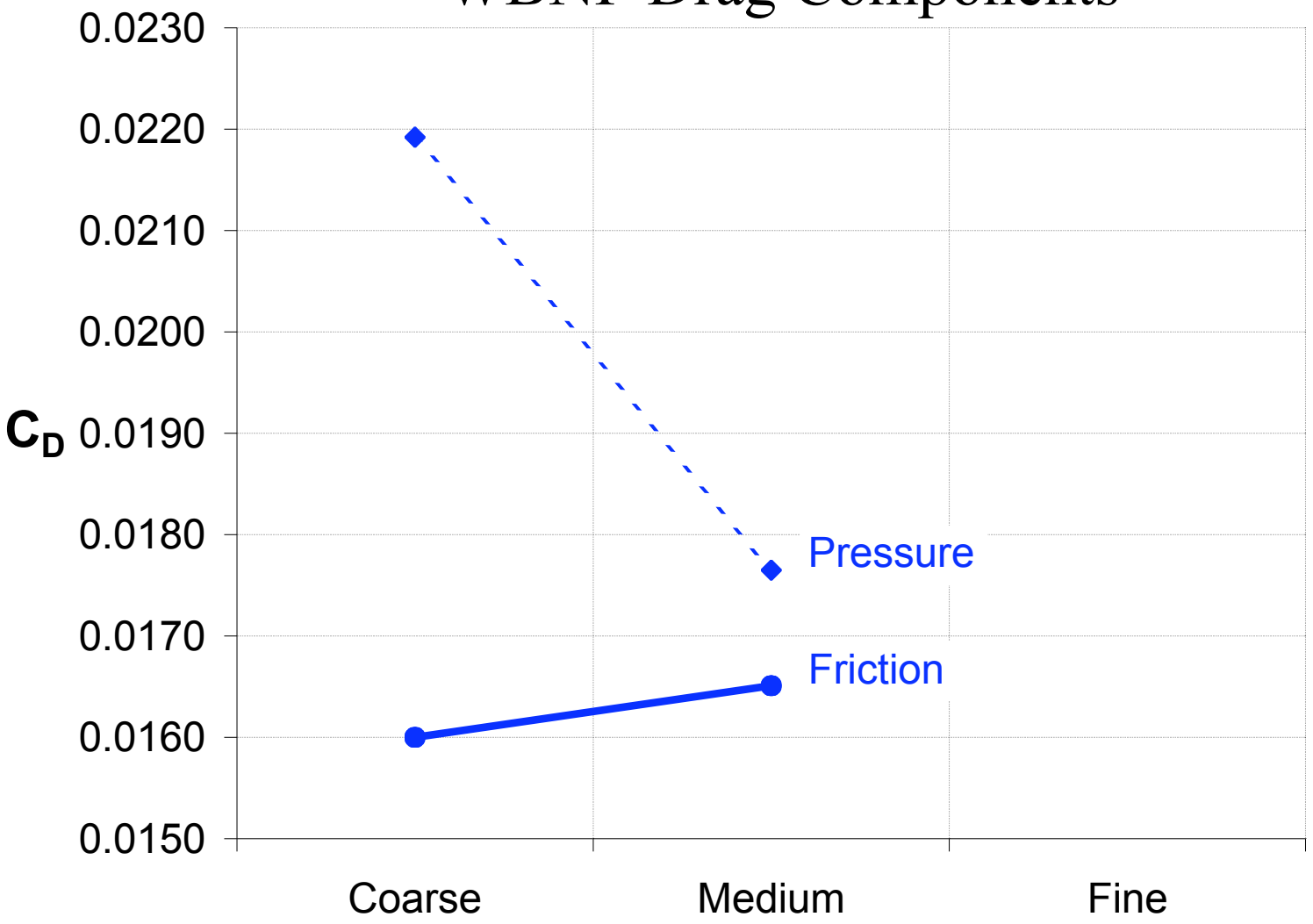
Effect of Grid Size on WBNP Drag Components



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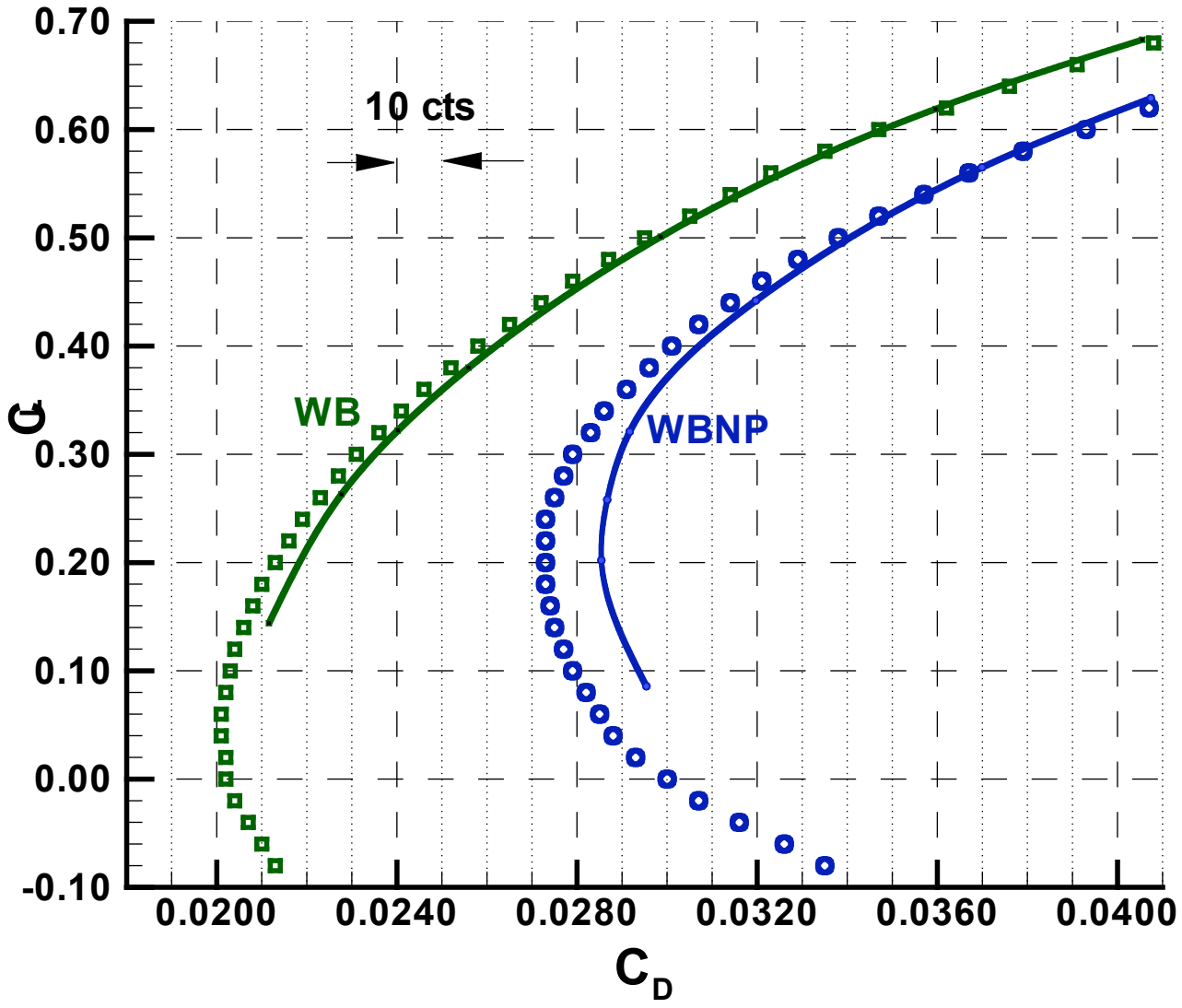
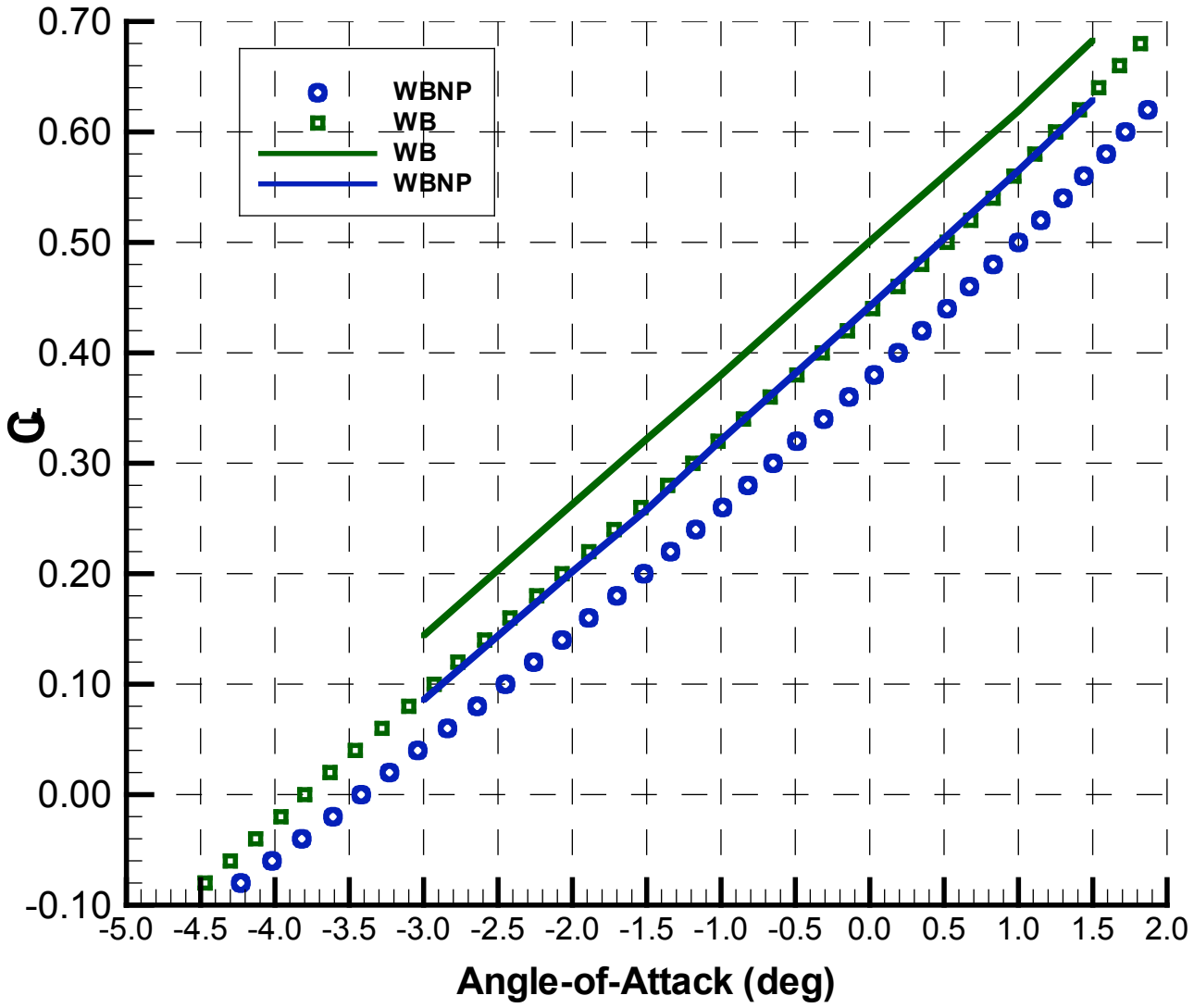
Case 2 – Alpha Sweep

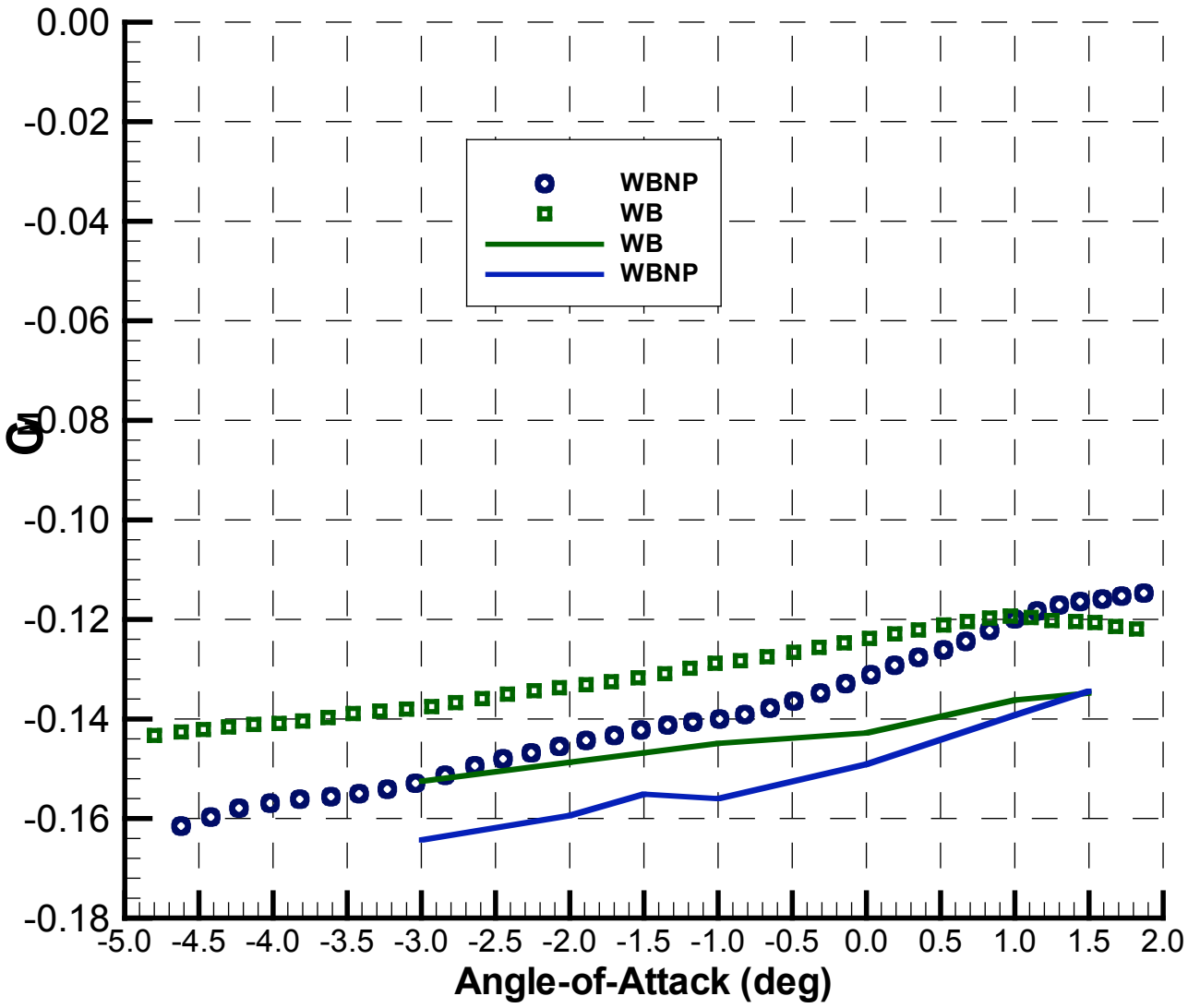
Drag Polar


0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
C_L
10 cts
WB
WBNP
0.0200
0.0240
0.0280
0.0320
0.0360
0.0400
C_D

Lift

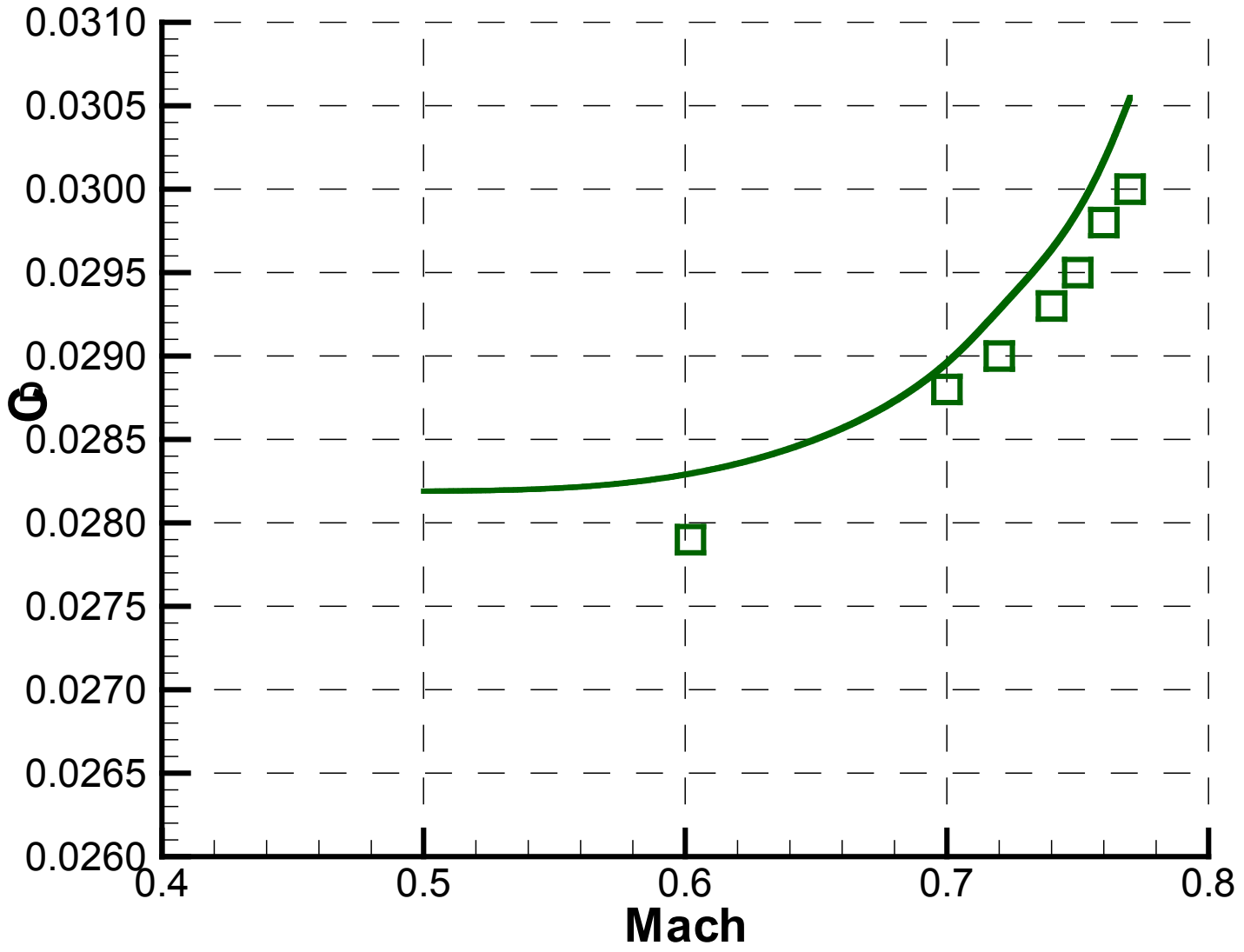

WBNP
WB
WB
WBNP
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
CL
-5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
Angle-of-Attack (deg)

Pitching Moment

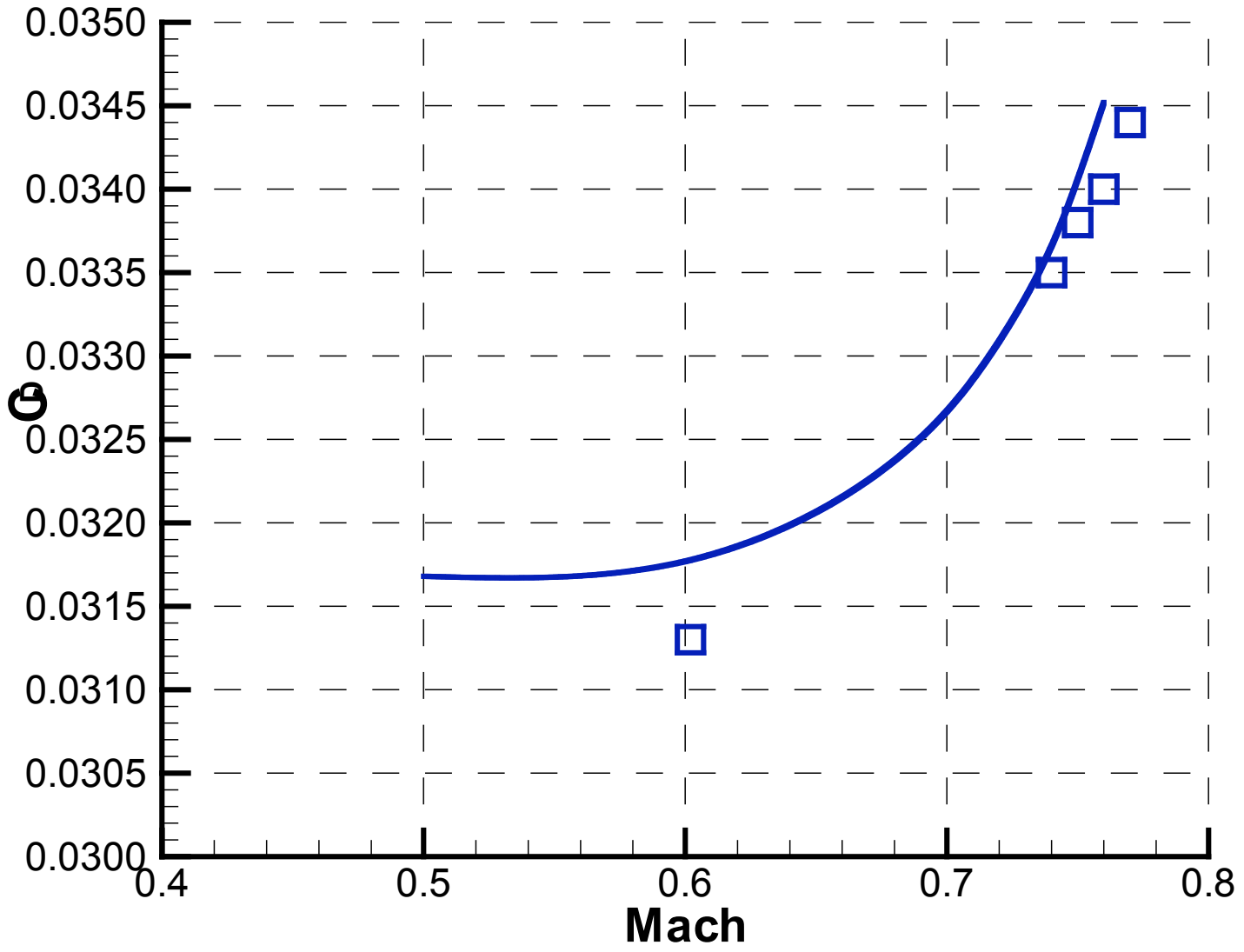


Case 4 – Drag Rise

WB Drag Rise


0.0310
0.0305
0.0300
0.0295
0.0290
0.0285
0.0280
0.0275
0.0270
0.0265
0.0260
CD
0.4
0.5
0.6
0.7
0.8
Mach

WBNP Drag Rise



Conclusions

This was a lot of work.

More Conclusions

- Current methodology approaching adequacy for prediction of drag changes due to minor airframe modifications.
- There is enough variation in parasite, induced, and wave drag characteristics to warrant further investigation before using to develop a full drag basis.
- Flow solver performance
  - Robust - tolerant of meshes with isolated regions of poor grid quality
  - No startup trauma difficulties
  - Fast convergence --> allows overnight drag polar runs
- Grid generation
  - Developed procedures for generating acceptable prism meshes.
  - Prism mesh robustness and quality is an issue.

Further Work

- Perform similar exercise on a business jet configuration with fuselage mounted nacelles.
- Tripped boundary layer study with new version of code.
- Study induced drag prediction at lower Mach number (0.5)
- Investigate alpha shift
  - Grid resolution
  - Comparisons with in-house configurations
- Investigate pitching moment discrepancy