OVERFLOW Drag Prediction for the DPW-W1/W2 Wing-Alone Configuration

Tony J. Sclafani, Mark A. DeHaan,

Neal A. Harrison, John C. Vassberg

The Boeing Company

Phantom Works

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Outline

- Flow Solver / Computing Platform
- Grid Information
- Case 2: *DPW-W1 and DPW-W2 Wing-Alone*
  - Convergence Histories and Residuals
  - Grid Sensitivity Study
  - Drag Polar
  - Streamlines / Pressures / Spanloads
- Conclusions

DPW-W1/W2 Wing-Alone
Flow Solver / Computing Platform

OVERFLOW MPI Version 2.0z

- Setup was consistent with DPW2
- Spalart-Allmaras turbulence model
- Roe upwind scheme
- Viscous terms computed in all three directions (full N-S)

Parallel Processing Done on a PC Cluster

- Linux operating system
- 906 Opteron dual CPU nodes with 4 GB of memory each
- Wing-alone medium grid run on 4 processors (2 nodes)
  - 5 hours per 1000 fine grid iterations
  - Full convergence reached after 3600 fine grid iterations
  - Roughly 18 hours of wall clock time needed per case for the medium grid

DPW-W1/W2 Wing-Alone
Grid Information

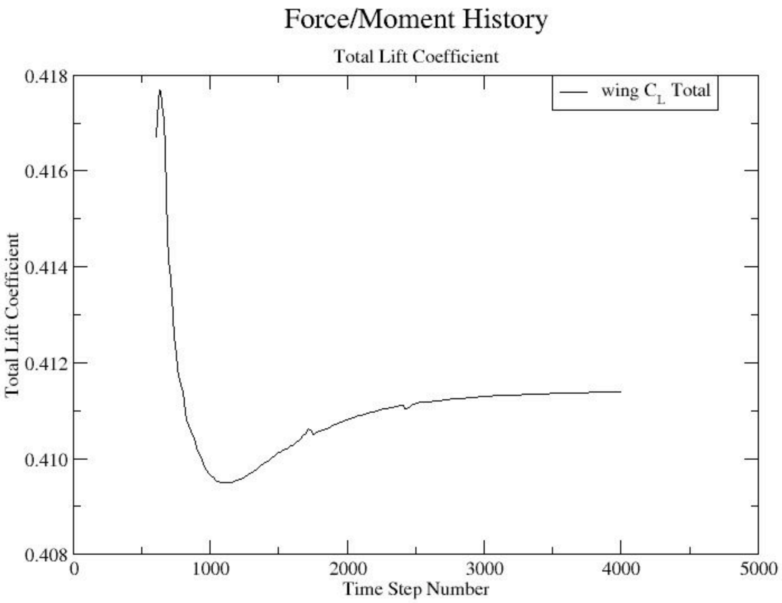
- The W1 and W2 grid systems consisted of 5 zones.
- The medium grid is typical for drag-quality design studies.

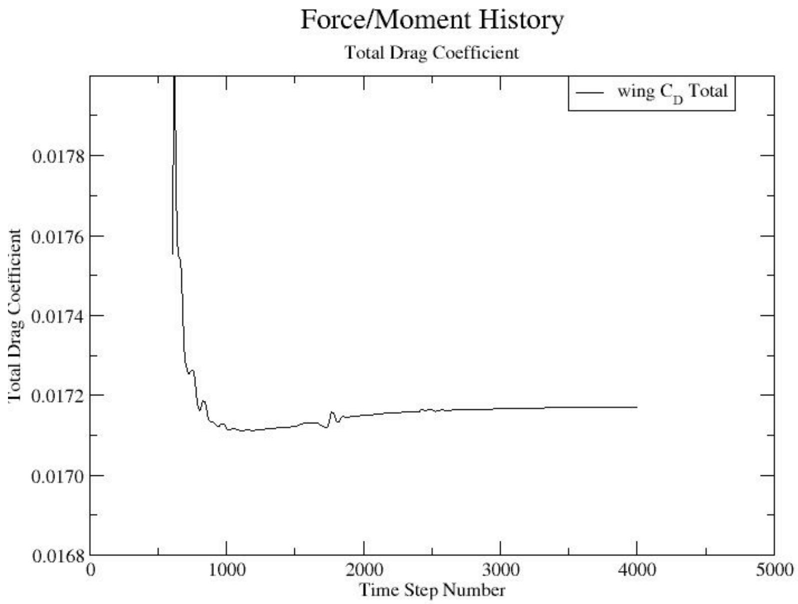
W1/W2

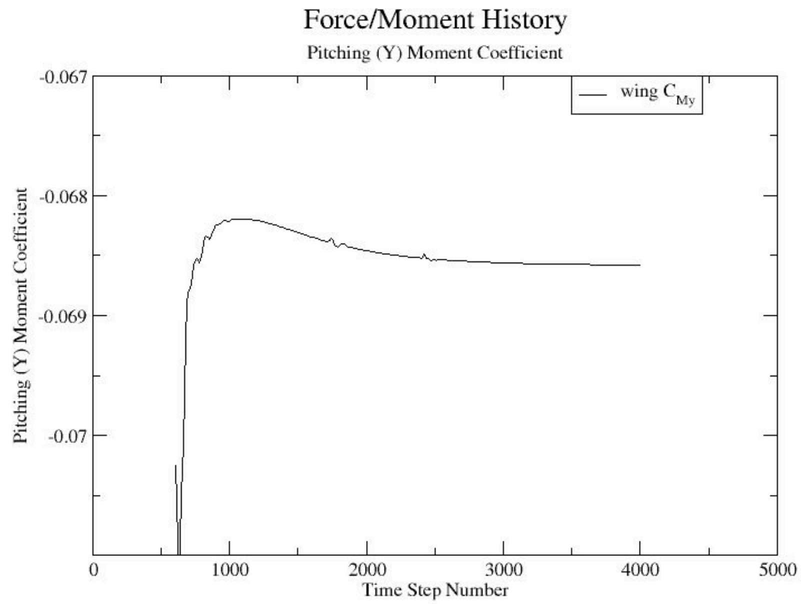
Grid	Points	1^{st} Cell Size	y^+	Constant Cells	Growth Rate
Coarse	1,442,285	.00055 mm	.90	2	1.29
Medium	4,856,149	.00038 mm	.62	3	1.19
Fine	16,265,909	.00025 mm	.41	4	1.12
Extra Fine	55,014,321	.00016 mm	.19	6	1.08

DPW-W1/W2 Wing-Alone
Convergence Histories

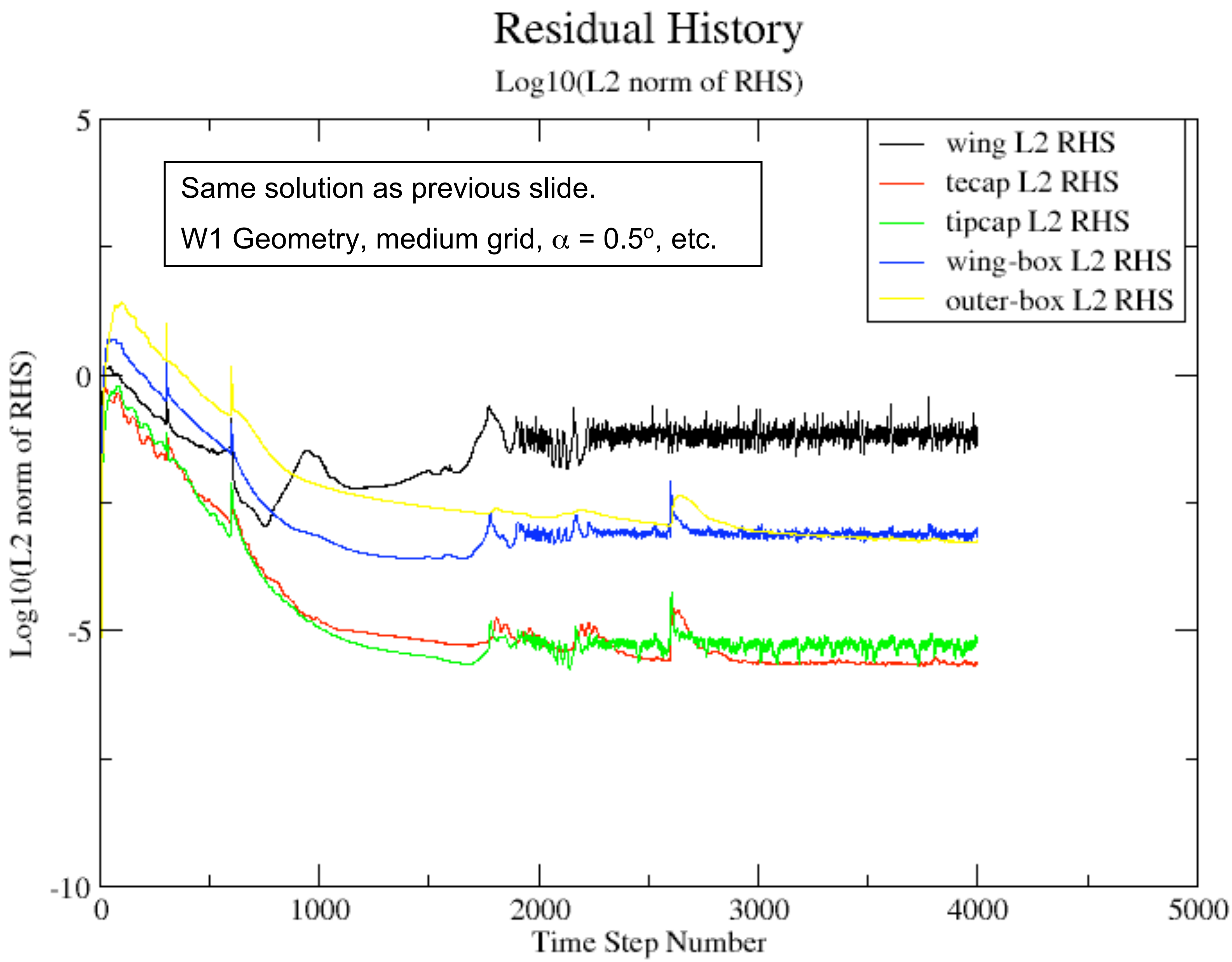
- W1 geometry
- Fully turbulent
- Reynolds Number = 5 million
- Mach = 0.76
- $\alpha = 0.5^{o}$
- Medium grid
- These flat-line convergence histories are representative of the coarse/fine grid as well as W2 solutions at the above condition.



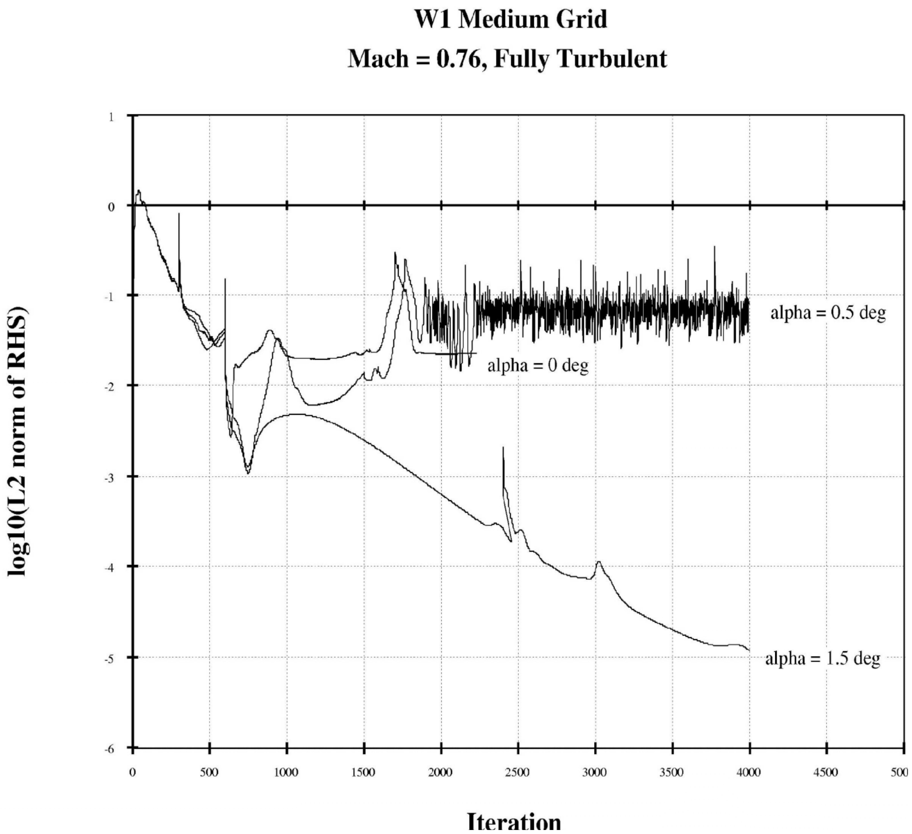




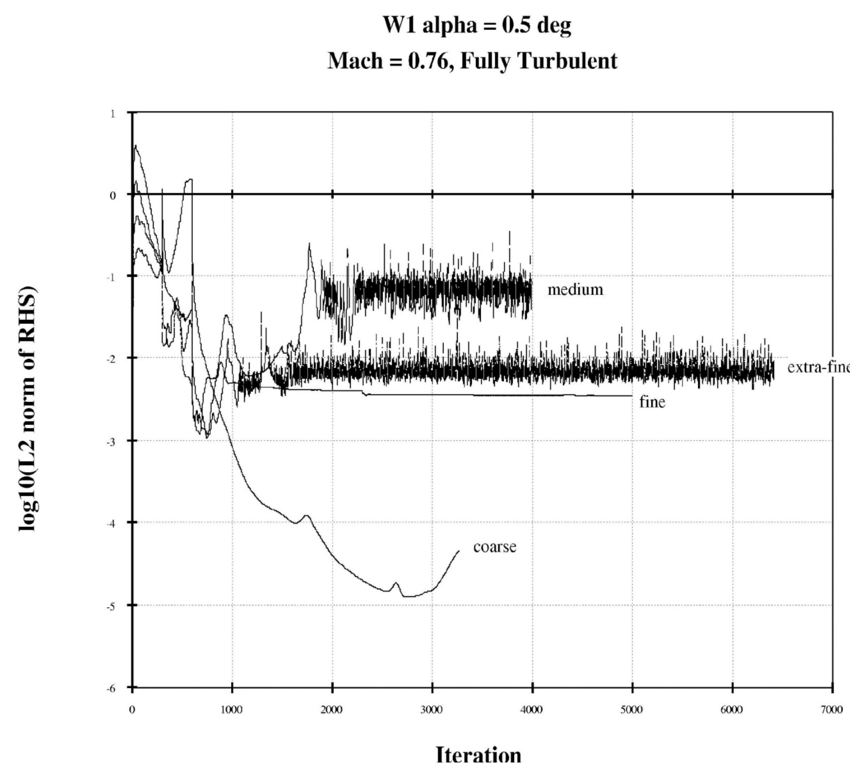
DPW-W1/W2 Wing-Alone
Residuals



DPW-W1/W2 Wing-Alone
Residuals (cont.)



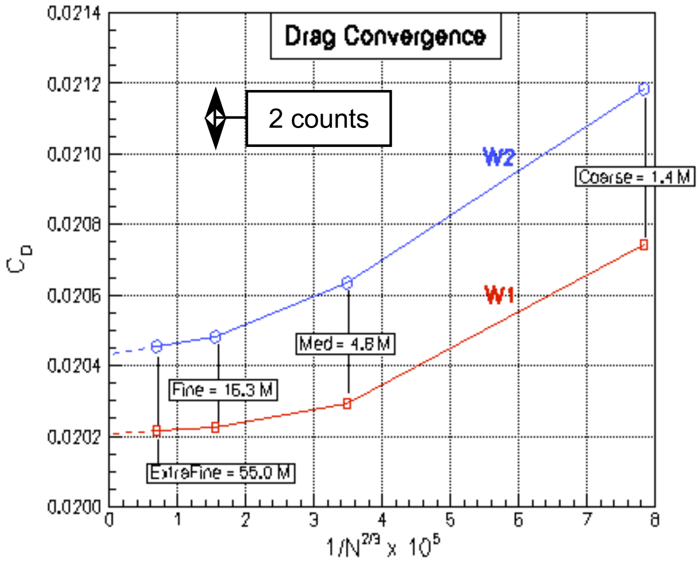
- All residuals are for the wing grid.
- More time is needed to understand why residual level and behavior changes with alpha and grid refinement.
- W1 and W2 have similar residuals.
  - Increments are good.

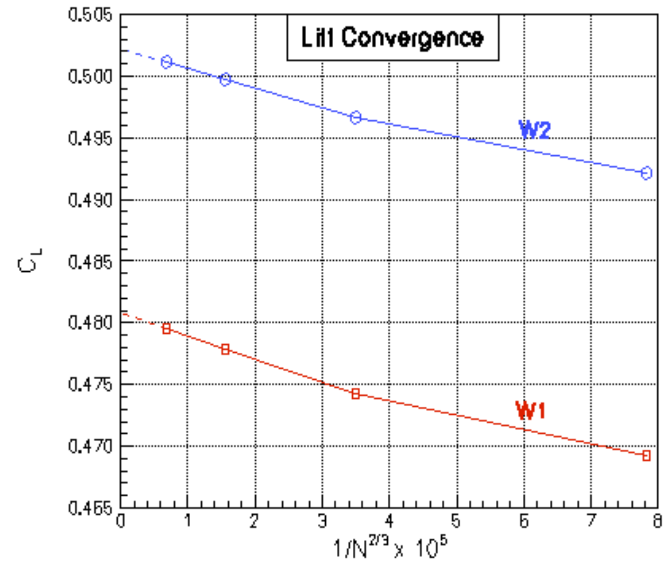


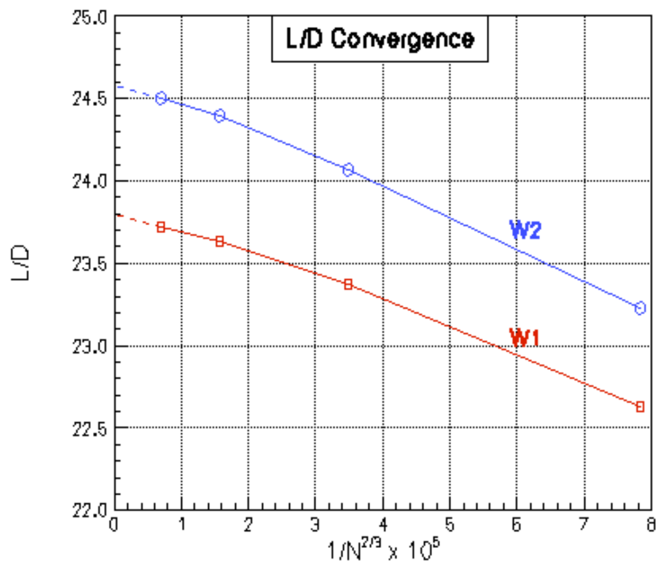
DPW-W1/W2 Wing-Alone
Grid Sensitivity Study

Wing-Alone OVERFLOW Results

Mach = 0.76, R_N = 5.0 million, Fully Turbulent

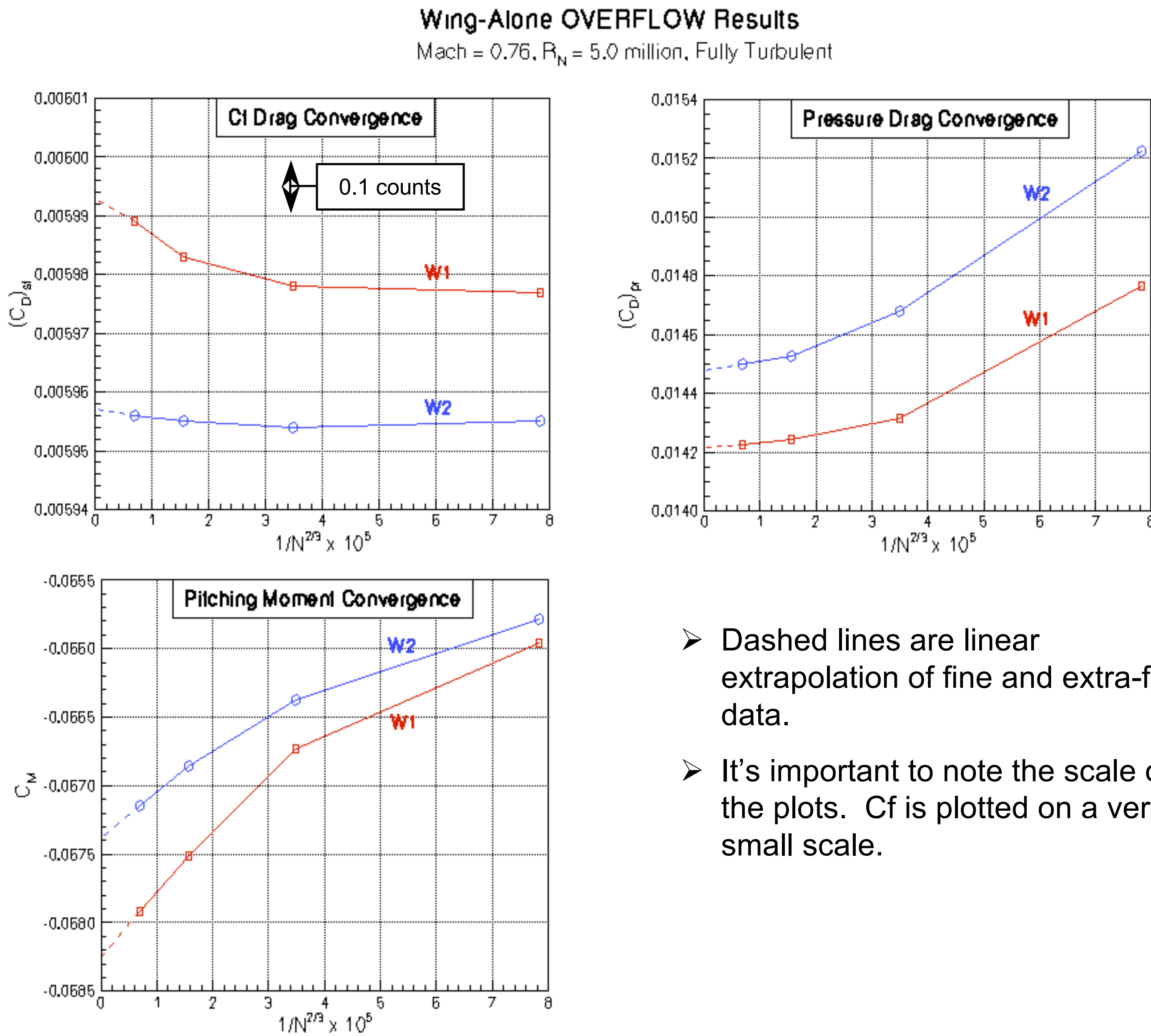






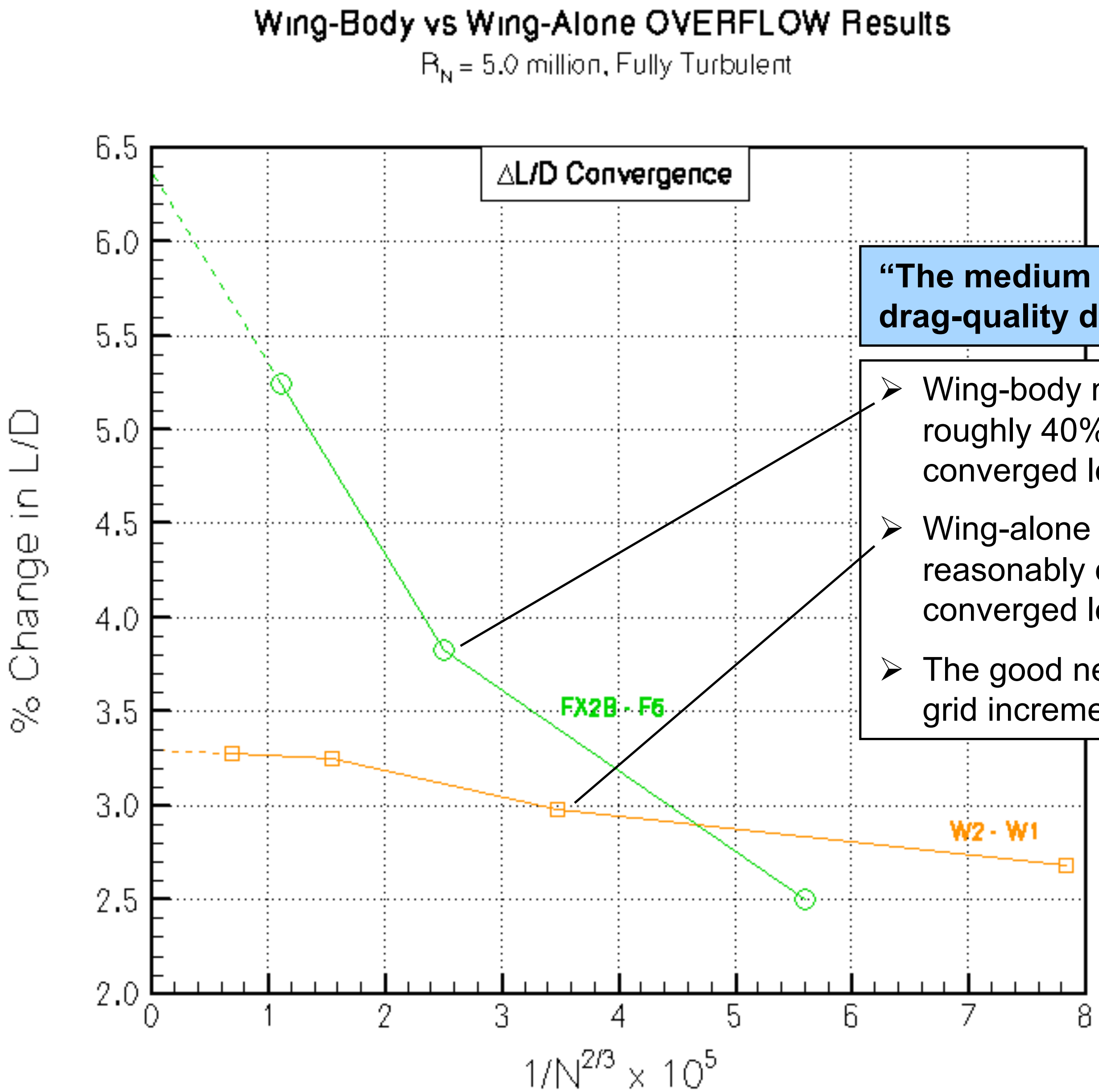
- Dashed lines are linear extrapolation of fine and extra-fine data.
- Drag data for the medium grid are close to the asymptotic range of convergence.
- Lift data for the medium grid are in the asymptotic range.
- L/D comparison shows W2 improvement

DPW-W1/W2 Wing-Alone
Grid Sensitivity Study (cont.)



- Dashed lines are linear extrapolation of fine and extra-fine data.
- It's important to note the scale of the plots. Cf is plotted on a very small scale.

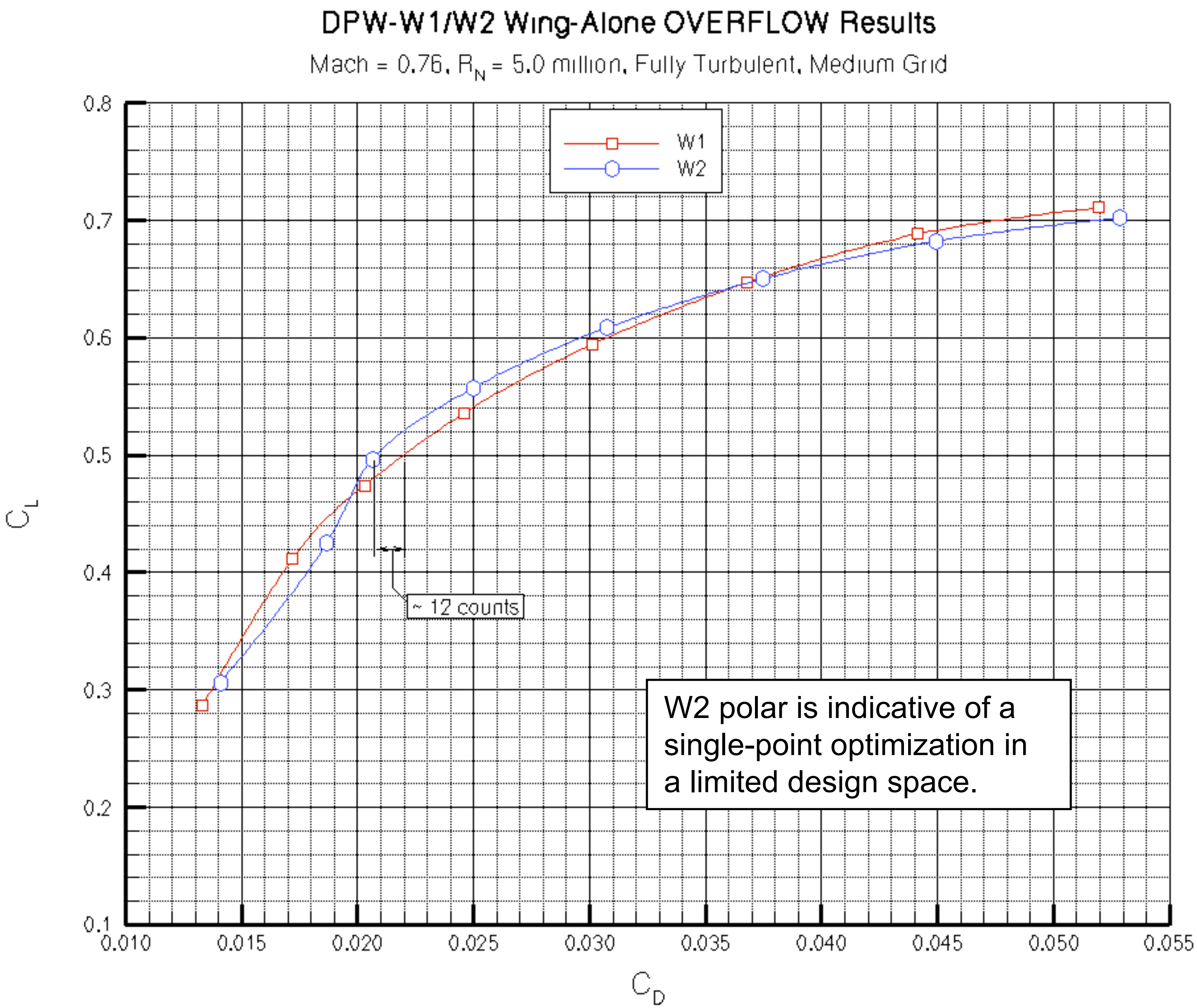
Wing-Body vs Wing-Alone
ΔL/D Convergence Comparison



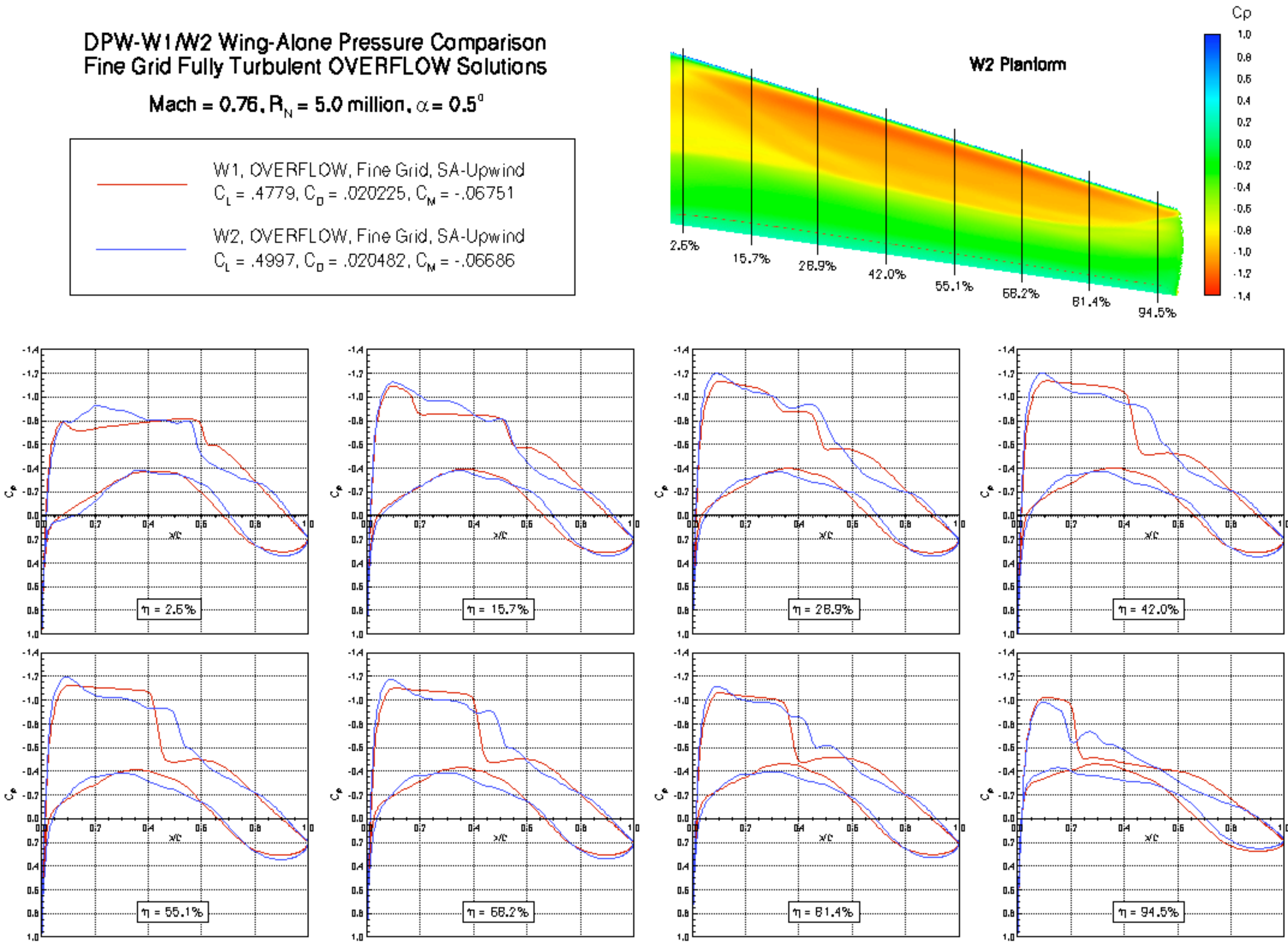
"The medium grid is typical for drag-quality design studies."

- Wing-body medium grid ΔL/D is roughly 40% below the grid-converged level.
- Wing-alone medium grid ΔL/D is reasonably close to the grid-converged level (9% low).
- The good news is the medium grid increments are conservative.

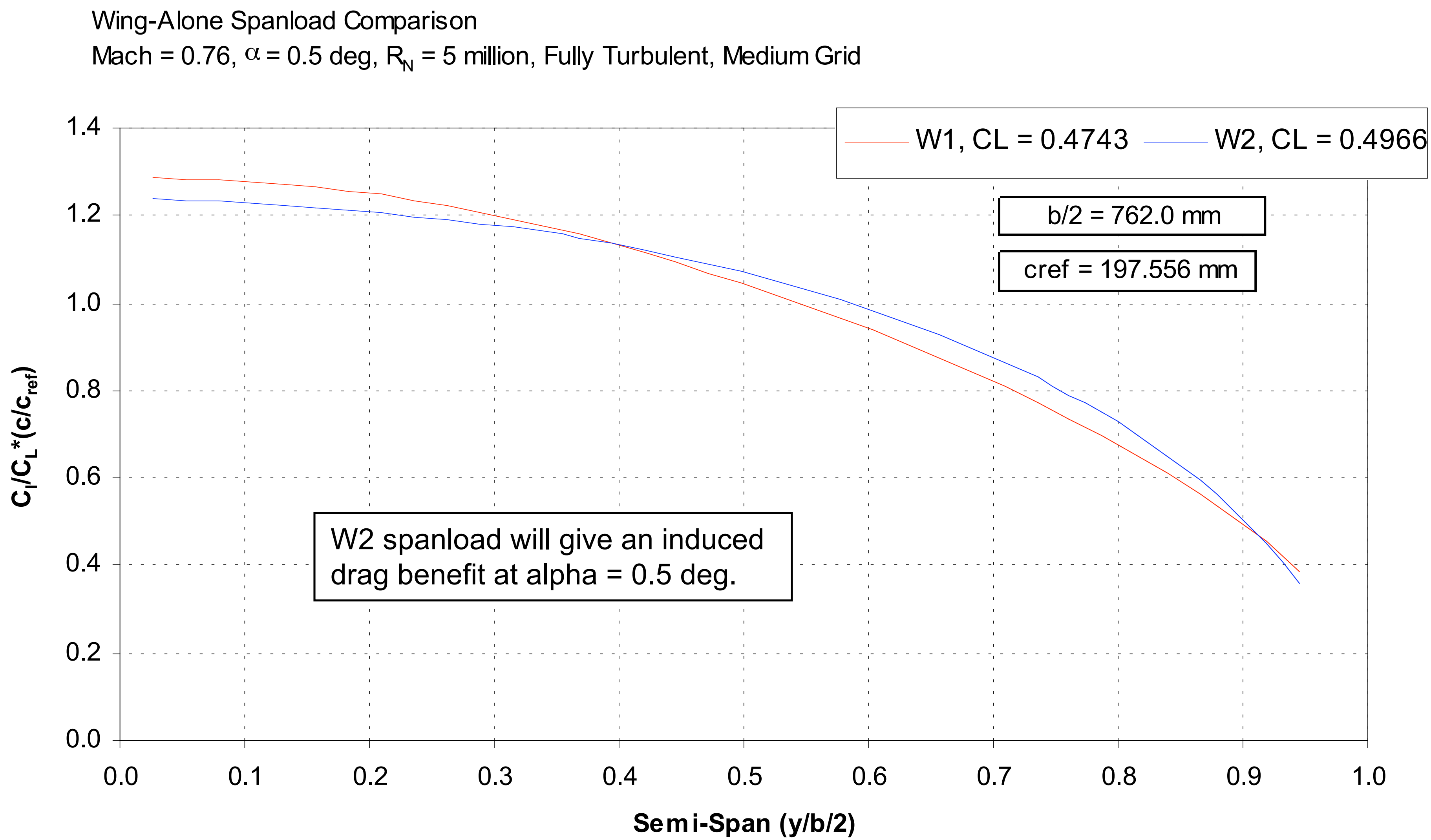
DPW-W1/W2 Wing-Alone
Drag Polar



DPW-W1/W2 Wing-Alone
Wing Pressure Comparison

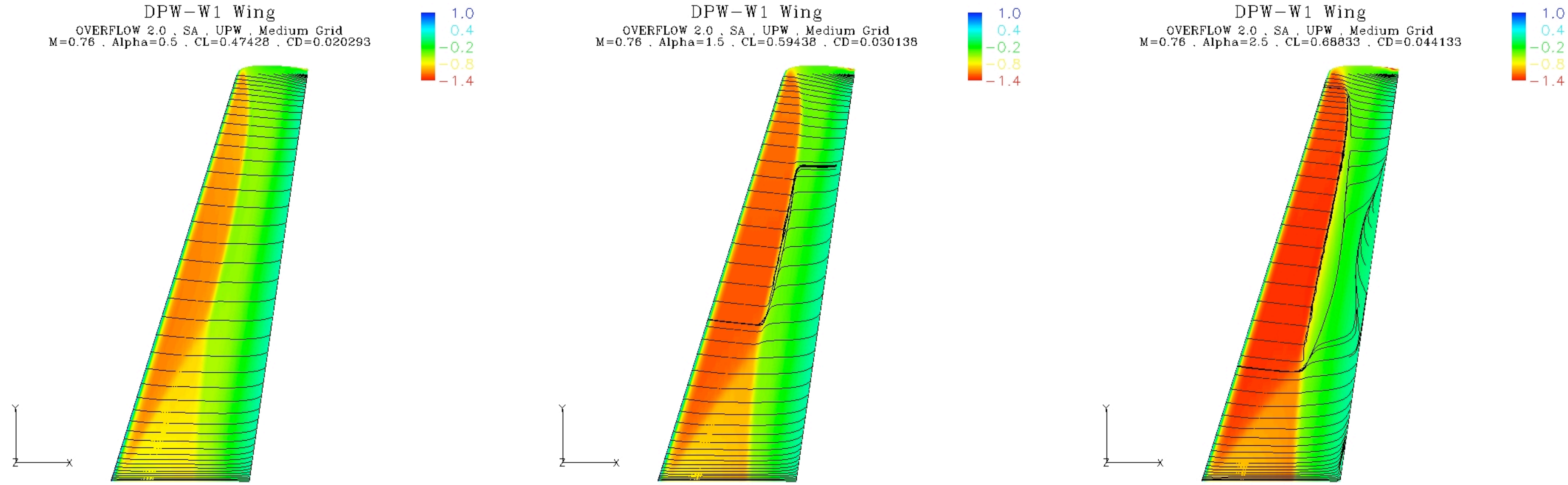


DPW-W1/W2 Wing-Alone
Spanload Comparison

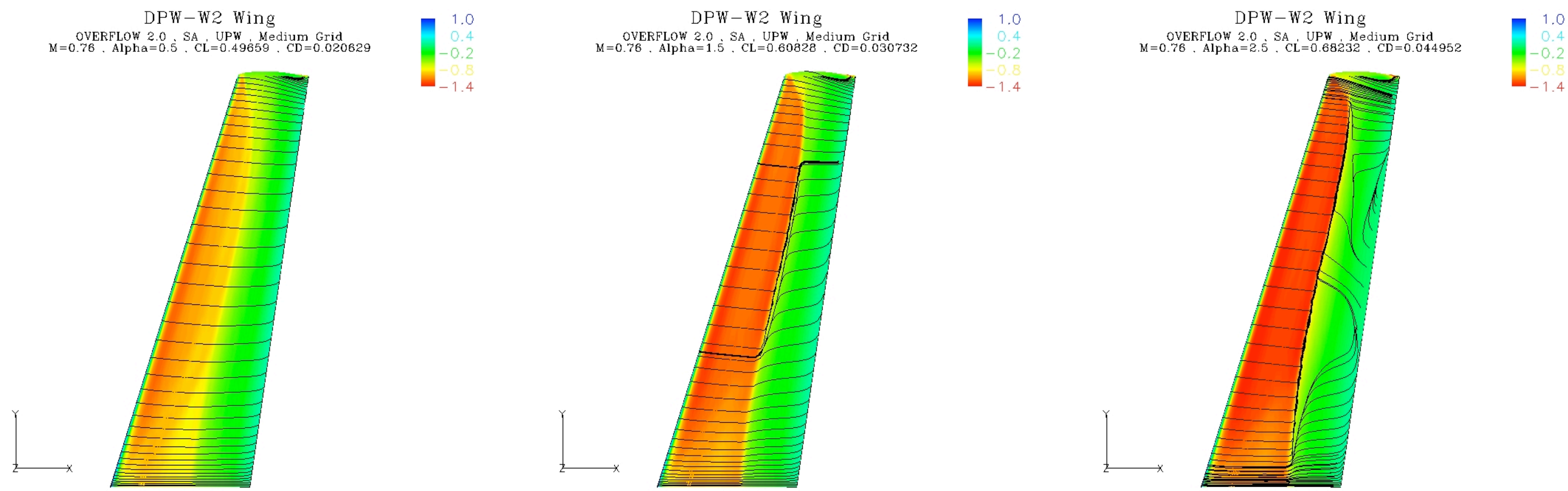


DPW-W1/W2 Wing-Alone

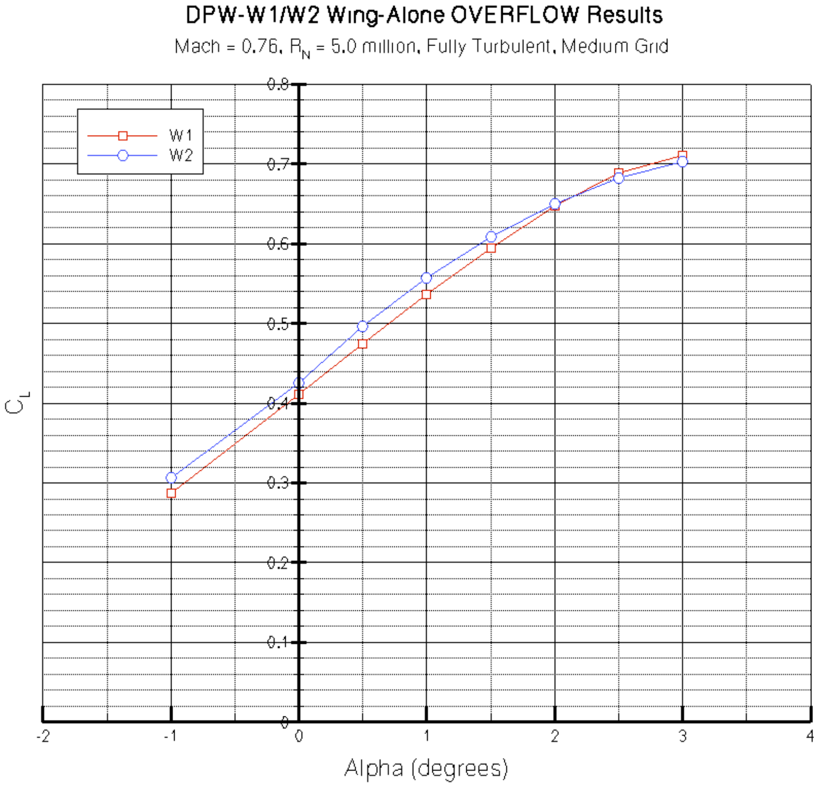
Surface Streamlines

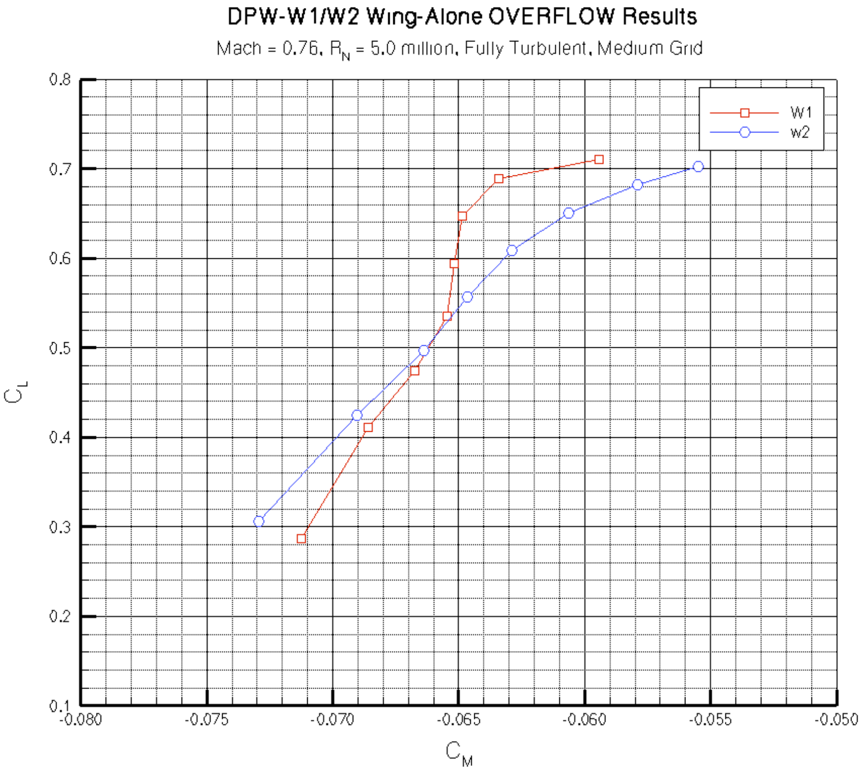


$\alpha = 0.5^o$ | $\alpha = 1.5^o$ | $\alpha = 2.5^o$



DPW-W1/W2 Wing-Alone
C_L and C_M Curves





DPW-W1/W2 Wing-Alone
Conclusions

Convergence Histories

- No CL or CD fluctuation
  - Lift varied by less than 0.00001 over last 100 iterations
  - Drag varied by less than 0.000001 over last 100 iterations
- Variation of residual with alpha and grid size not understood at time of workshop.
  - Wing grid residual drops one order for medium grid at 0.5^{o}
  - Both W1 and W2 solutions had similar residuals

Grid Convergence Study

- Results of the wing-alone grid sensitivity study look reasonable.
- The extra-fine grid solutions helped establish the asymptotic range of grid convergence.
- Grid convergence on Δ(L/D) between the wing-body and wing-alone configurations looks very different.
  - Wing-body separation suspected to be the problem.
  - Difficult (if not impossible) to get accurate incremental drag using solutions where separated flow is present.