OVERFLOW Drag Prediction for the DLR-F6 Wing / Body / Nacelle / Pylon Transport Configuration

Tony J. Sclafani, Mark A. DeHaan, John C. Vassberg

Phantom Works
The Boeing Company
Huntington Beach, California, USA

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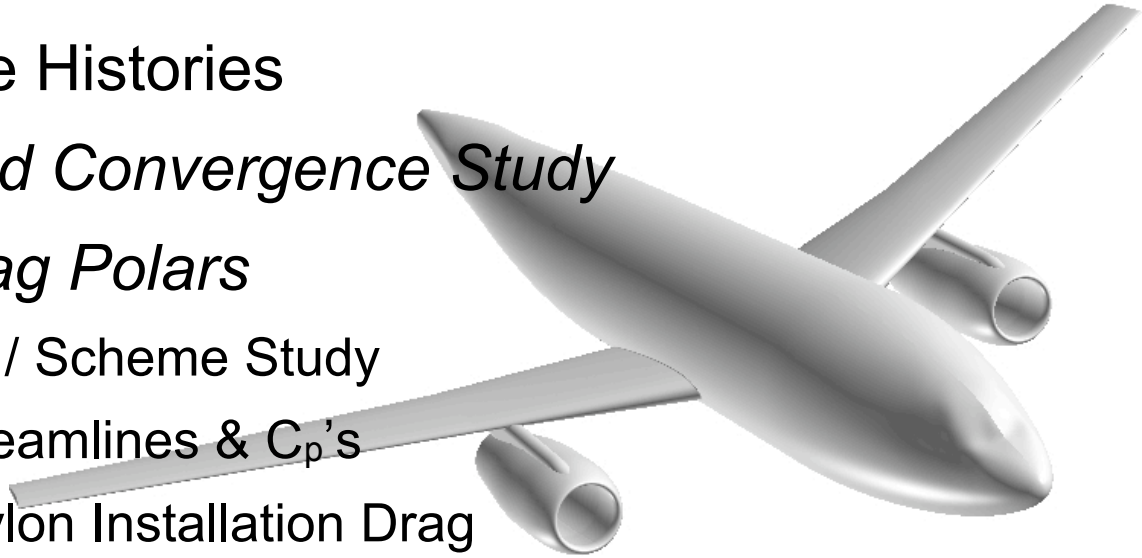
Outline

- Flow Solver / Grid Information
- Computing Platform / Solution Information
- Convergence Histories
- Case 1 – *Grid Convergence Study*
- Case 2 – *Drag Polars*
  - Turb Model / Scheme Study
  - Surface Streamlines & C_p's
  - Nacelle / Pylon Installation Drag
- Case 3 – *Tripped vs Fully Turbulent*
- Conclusions



Flow Solver / Grid Information

OVERFLOW MPI Version 1.8s

a) Spalart-Allmaras with Roe Upwind **(Cases 1, 2, and 3)**

b) Spalart-Allmaras with Central Difference **(Case 2)**

c) Baldwin-Barth with Central Difference **(Case 2)**

Structured Over-Set Grids (ref. *AIAA Paper 2003-4124*)

Grid	WB (12 zones)	WBNP (23 zones)
Coarse	1.9 M	3.1 M
Medium*	6.8 M	10.7 M
Fine	23.1 M	35.8 M

*Note: The medium grid is typical for drag-quality design studies.

Computing Platform / Solution Information

Parallel Processing Done on a PC Cluster

- Linux Operating System
- 178 Dual-Processor Nodes with 2 GB of Memory Each
- WB-Medium Grid Run on 8 Processors

  ~ 1.9 hours per 100 fine grid iterations
- WBNP-Medium Grid Run on 10 Processors

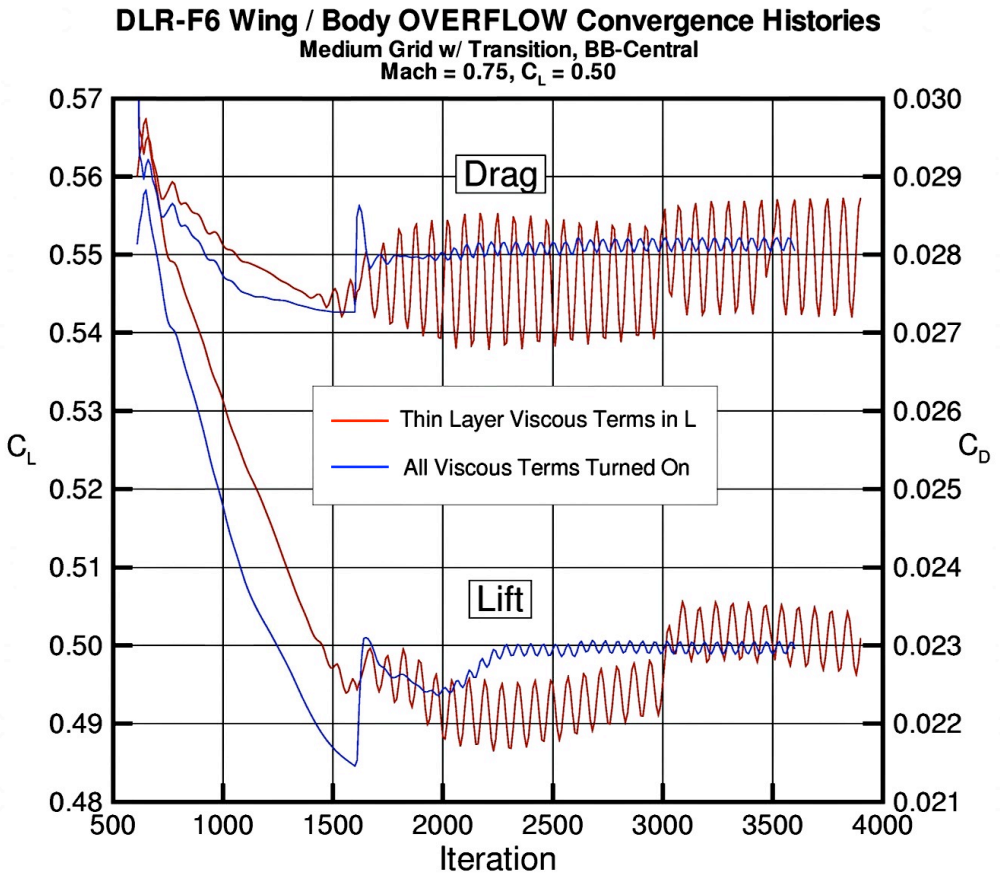
  ~ 2.5 hours per 100 fine grid iterations

Solutions

- Case 1: 8 solutions, fully turbulent, SA-Upw
- Case 2: 29 solutions, transition, SA-Upw/SA-Cen/BB-Cen
- Case 3: 4 solutions, SA-Upw, taken from Cases 1 & 2

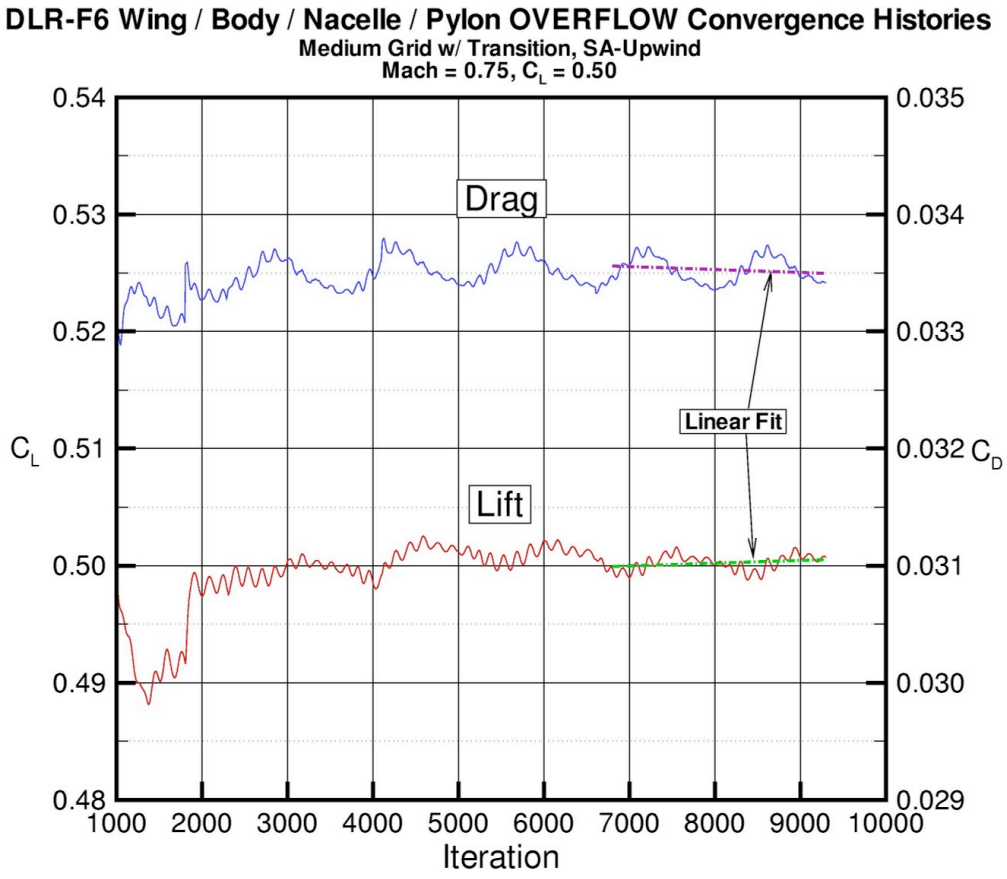
WB Convergence Histories

- Baldwin-Barth solutions were oscillatory
  - Particularly with thin-layer viscous terms in L only.
- Turning on all viscous terms reduced amplitude of oscillation
- With all viscous terms on, computation time increased about 50% per iteration

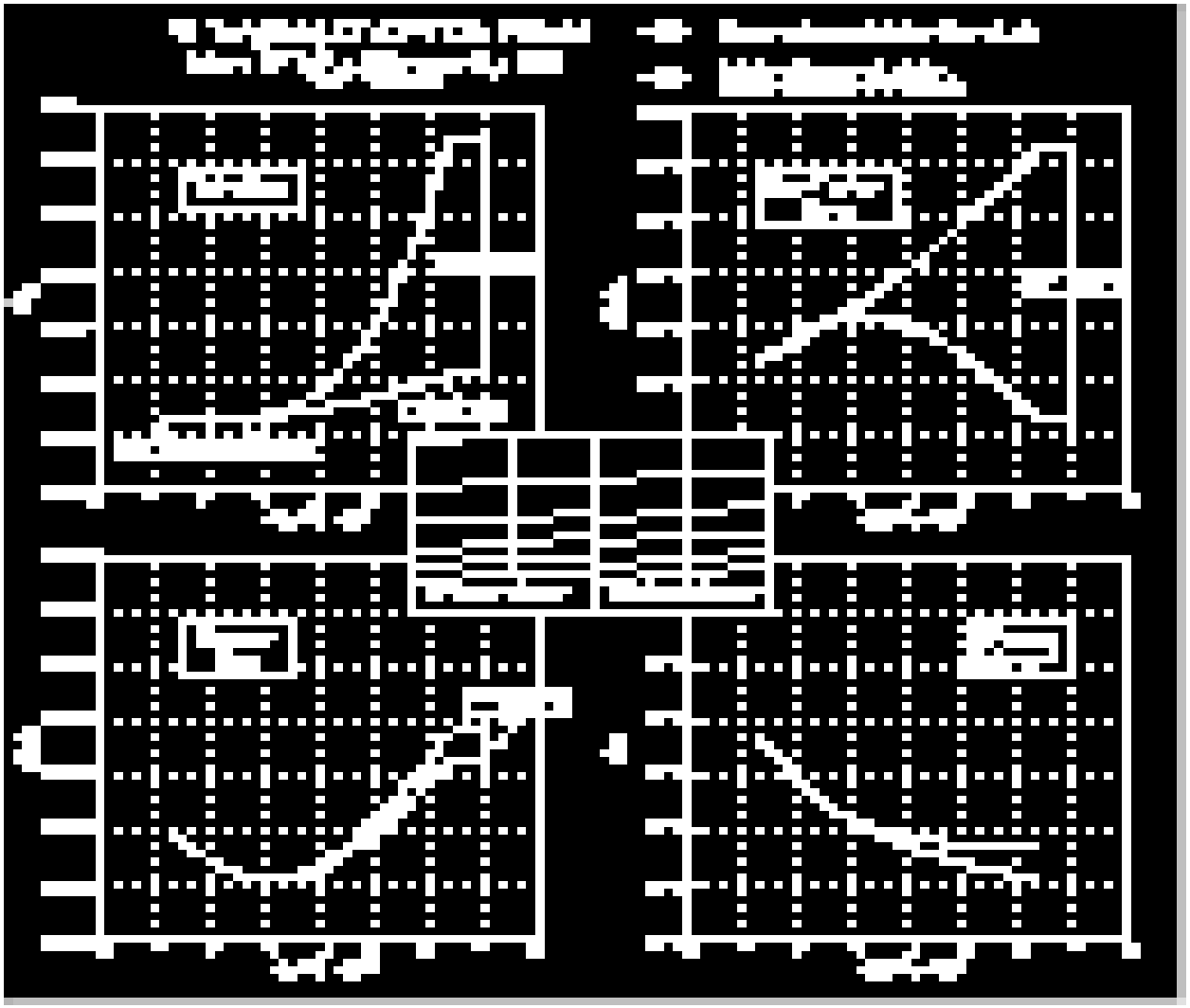


WBNP Convergence Histories

- All WBNP solutions were oscillatory (even with all viscous terms turned on).
- Final forces and moment values were obtained from a linear fit of the numerical data.

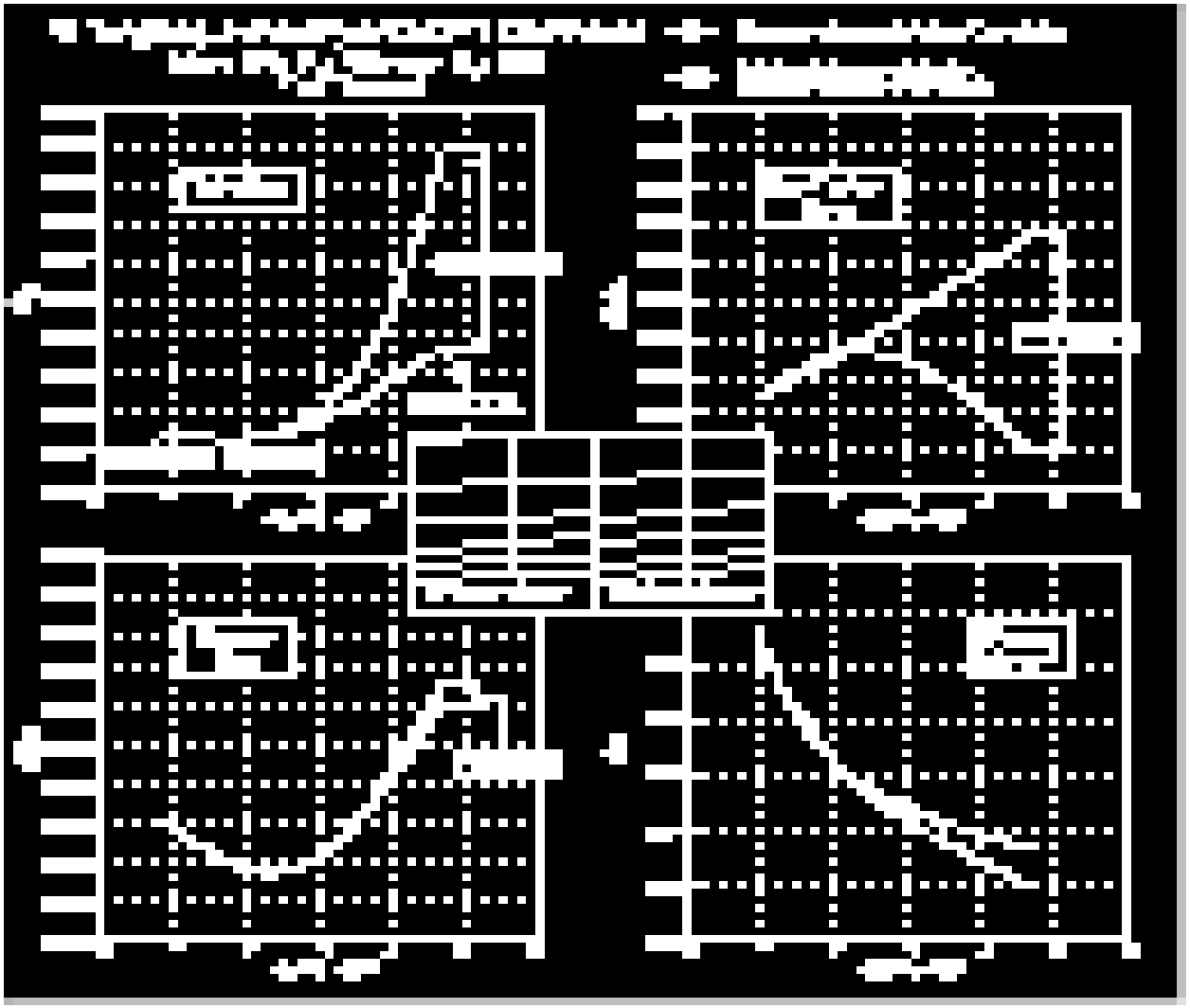


Case 1 – *WB Grid Convergence Results*



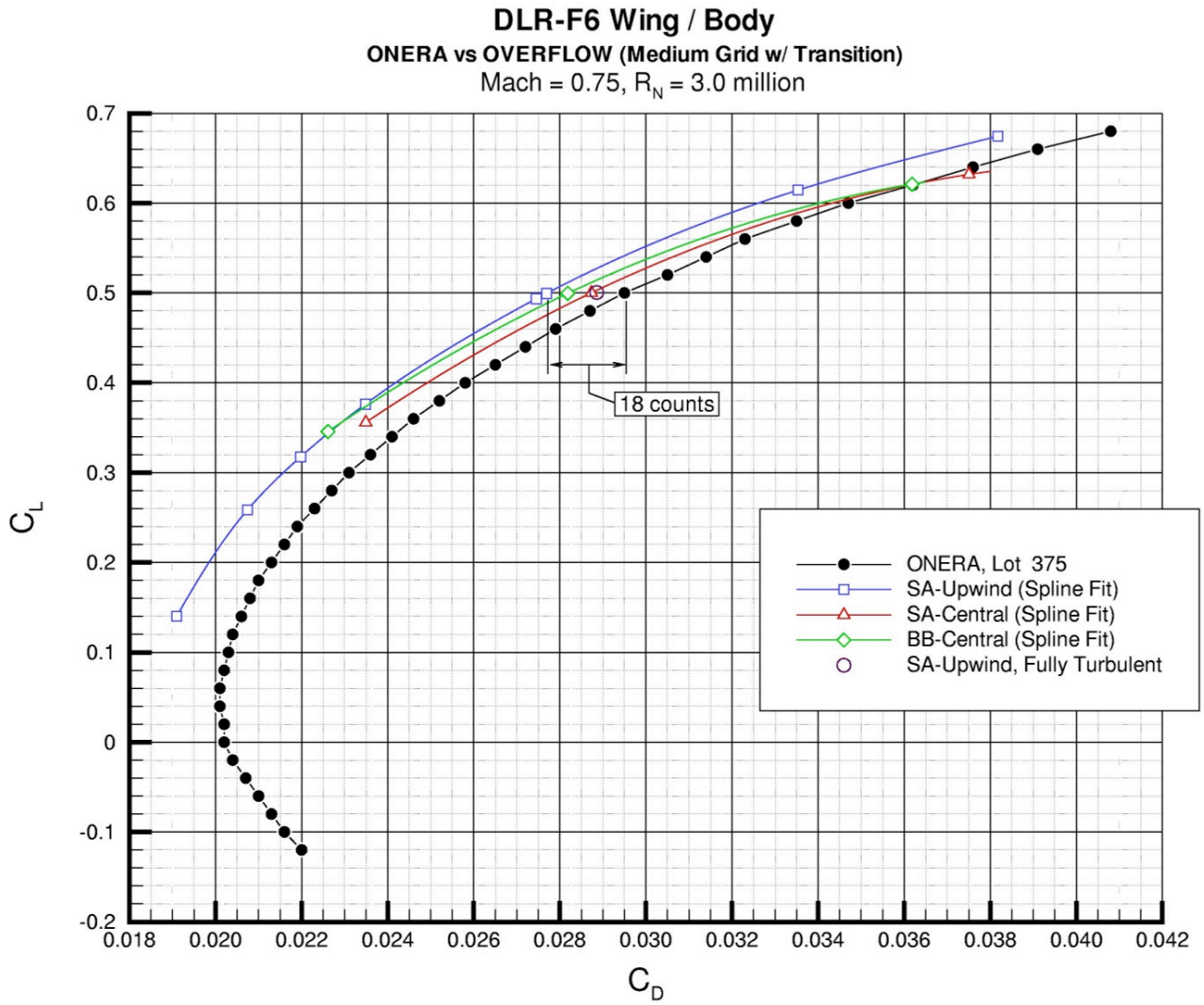
Note: The only differences between the baseline & modified coarse grids are the L=2 surfs.

Case 1 – *WBNP Grid Convergence Results*



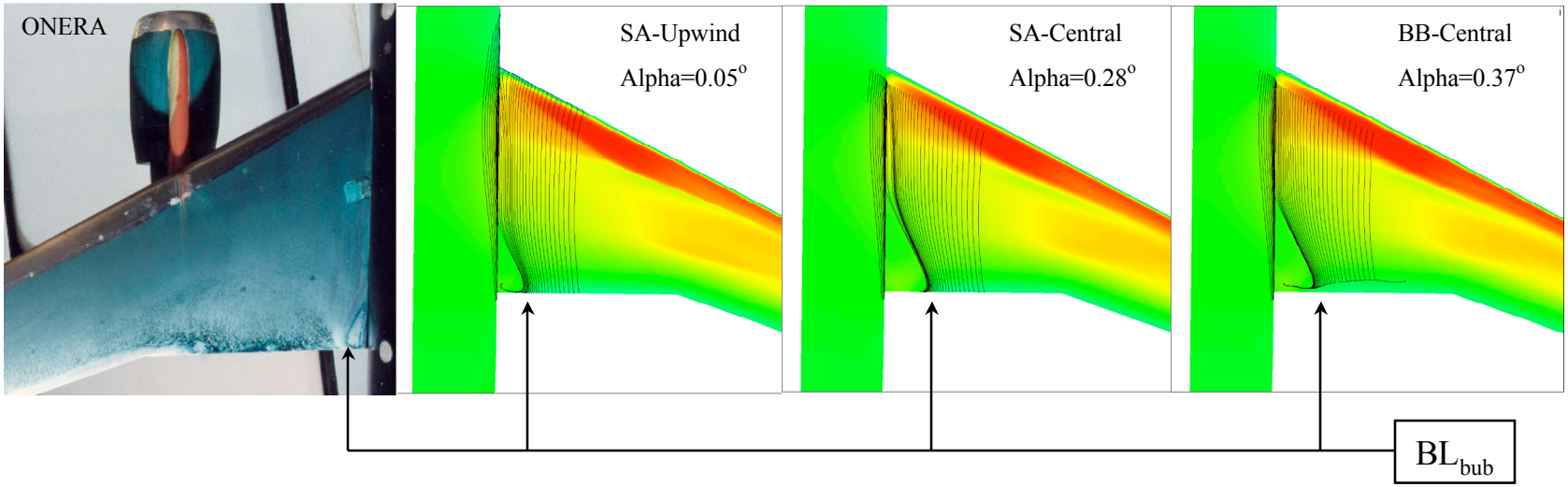
Note: The only differences between the baseline & modified coarse grids are the L=2 surfs.

Case 2 – *WB Drag Polars*



Case 2 – *Side-of-Body Flow Viz*

Medium WB Grid with Transition: Mach = 0.75, C_L = 0.50, R_N = 3.0 M

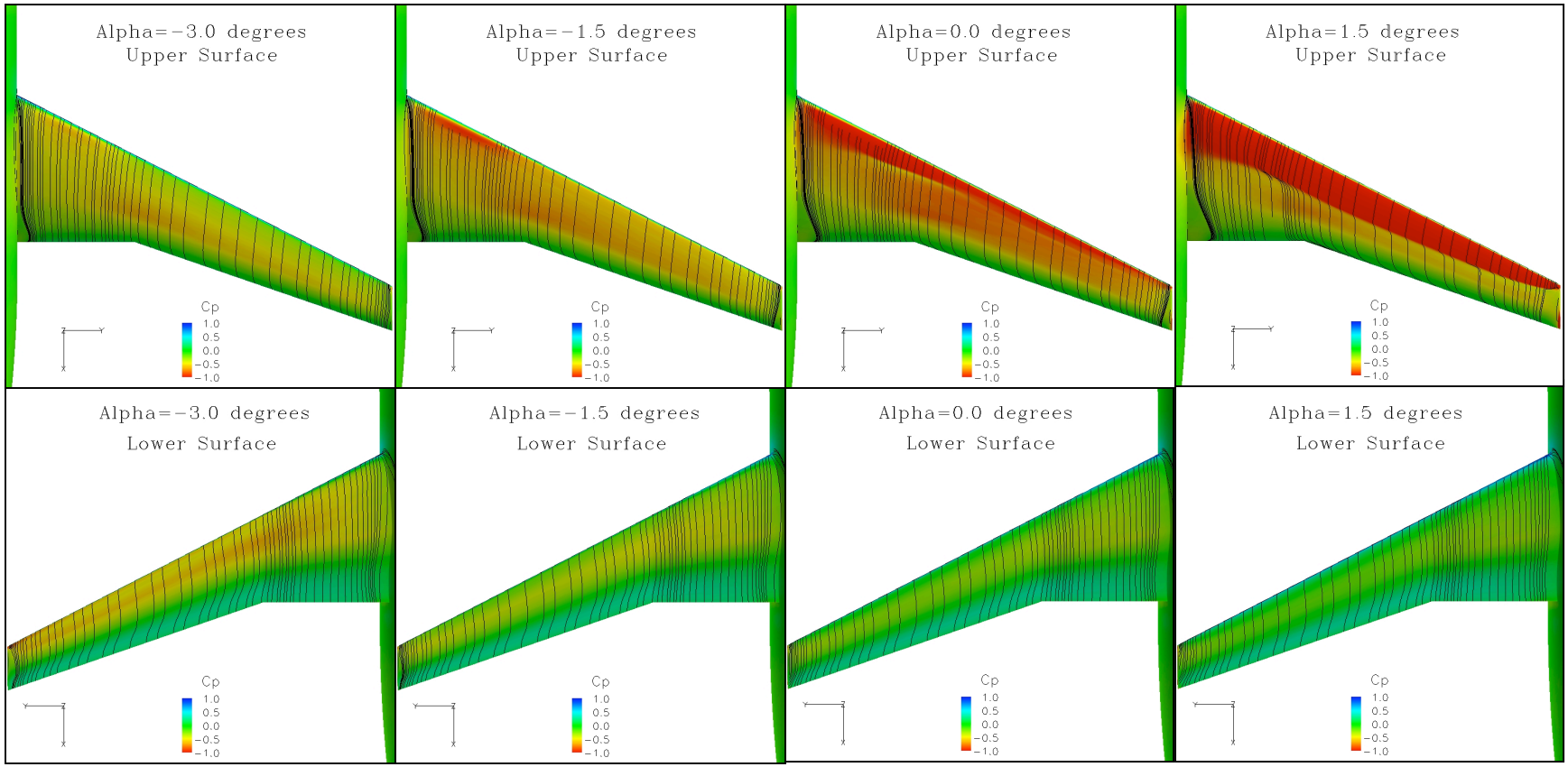


Source	BL_{bub} (mm)	□ (mm)
ONERA	90.9*	-
OVERFLOW, SA-Upwind	98.2	7.3
OVERFLOW, SA-Central	112.3	21.4
OVERFLOW, BB-Central	109.7	18.8

* Scaled off photo

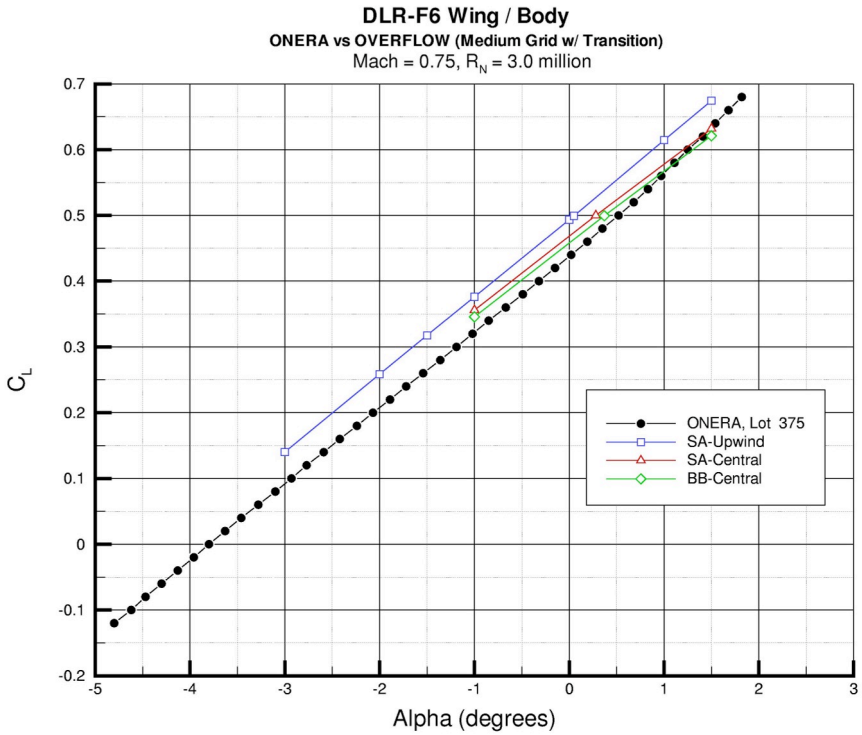
Case 2 – *WB Surface Cp and Streamlines*

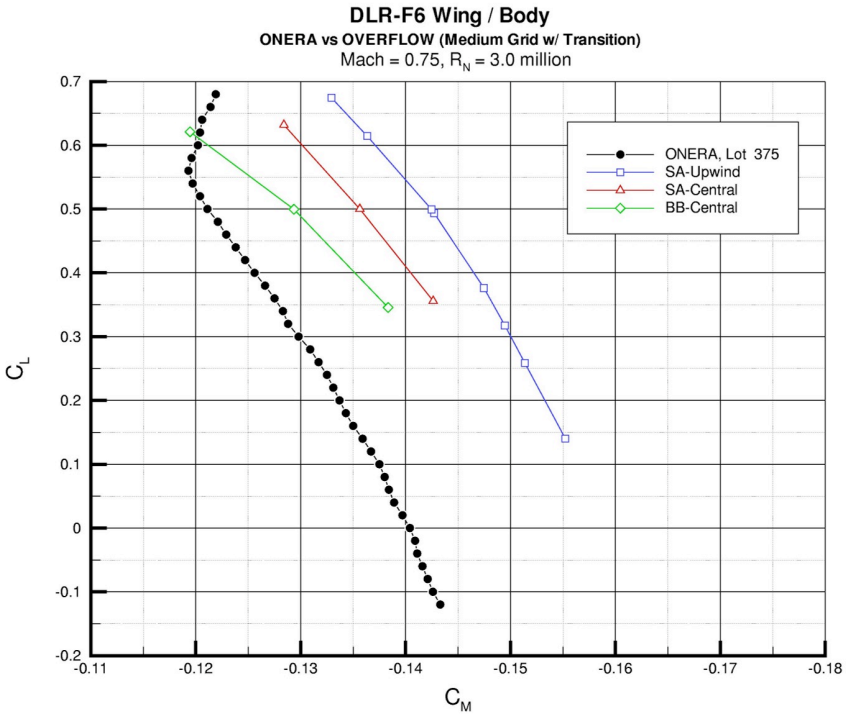
Medium Grid w/ Transition, Mach = 0.75, SA-Upwind



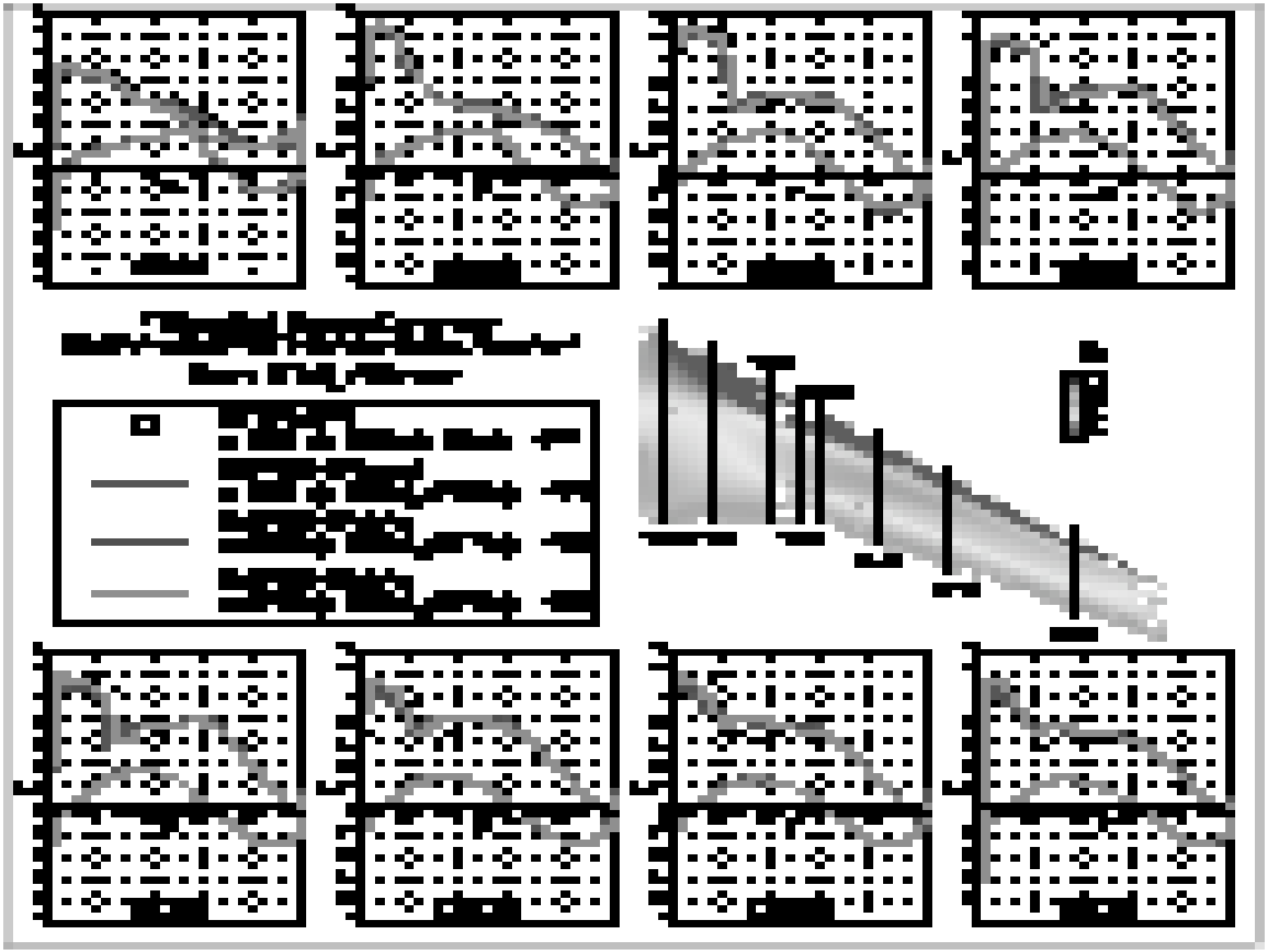
Alpha Sweep →

Case 2 – *WB C_L and C_M Curves*

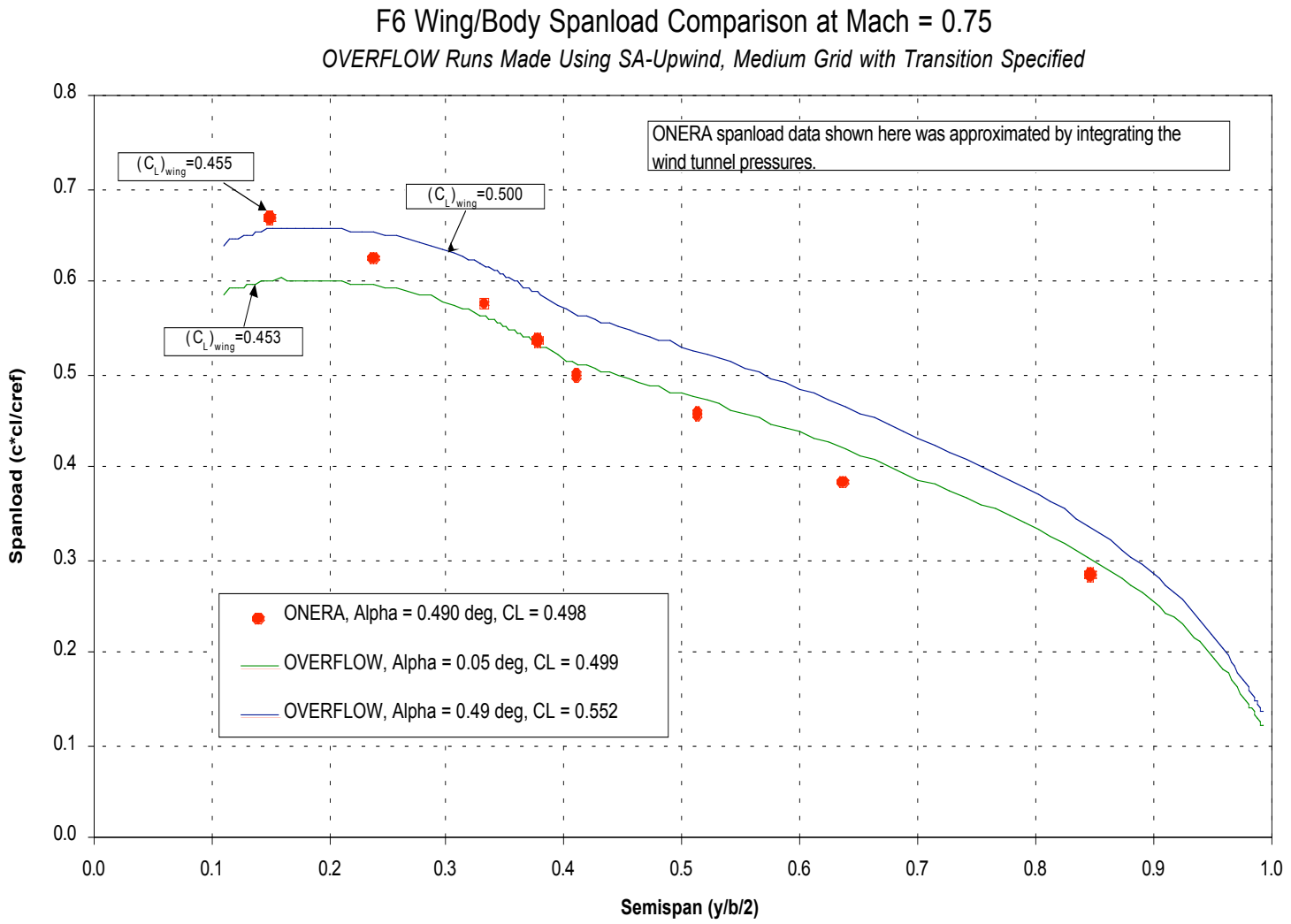




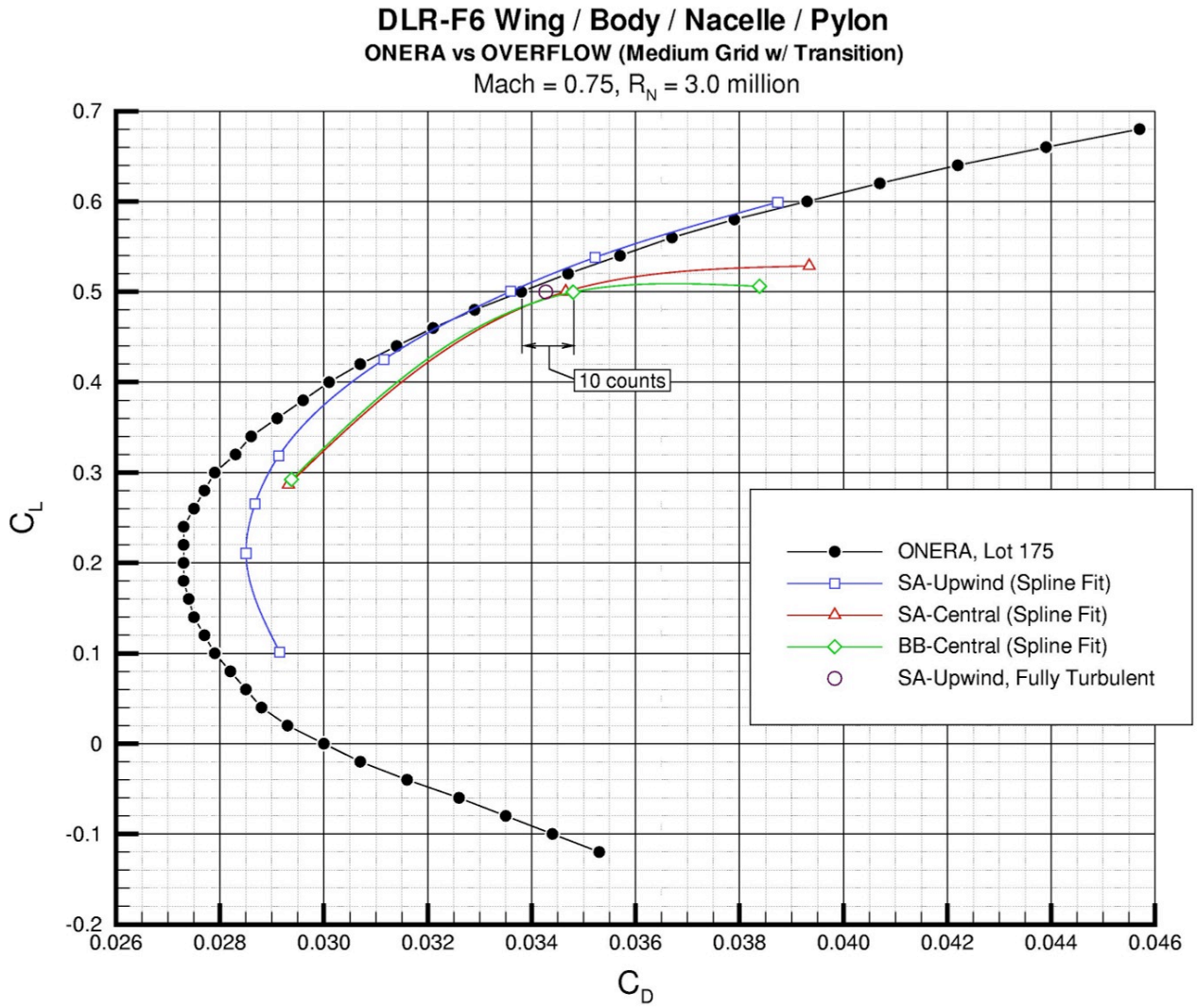
Case 2 – *WB Pressure Comparison*



Case 2 – *WB Spanload Comparison*



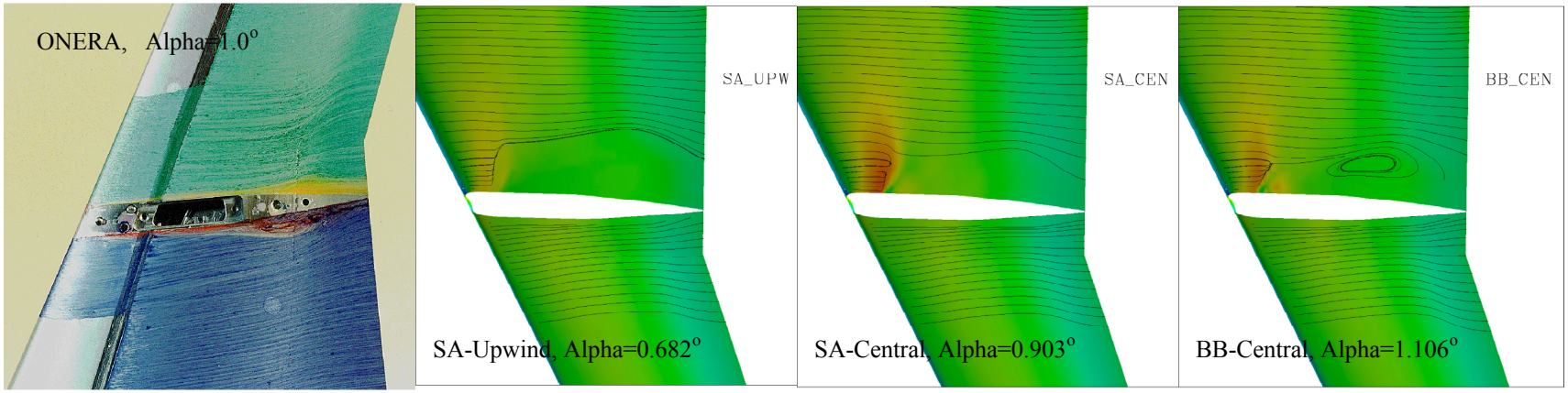
Case 2 – *WBNP Drag Polars*



Case 2 – *Side-of-Pylon Flow Viz*

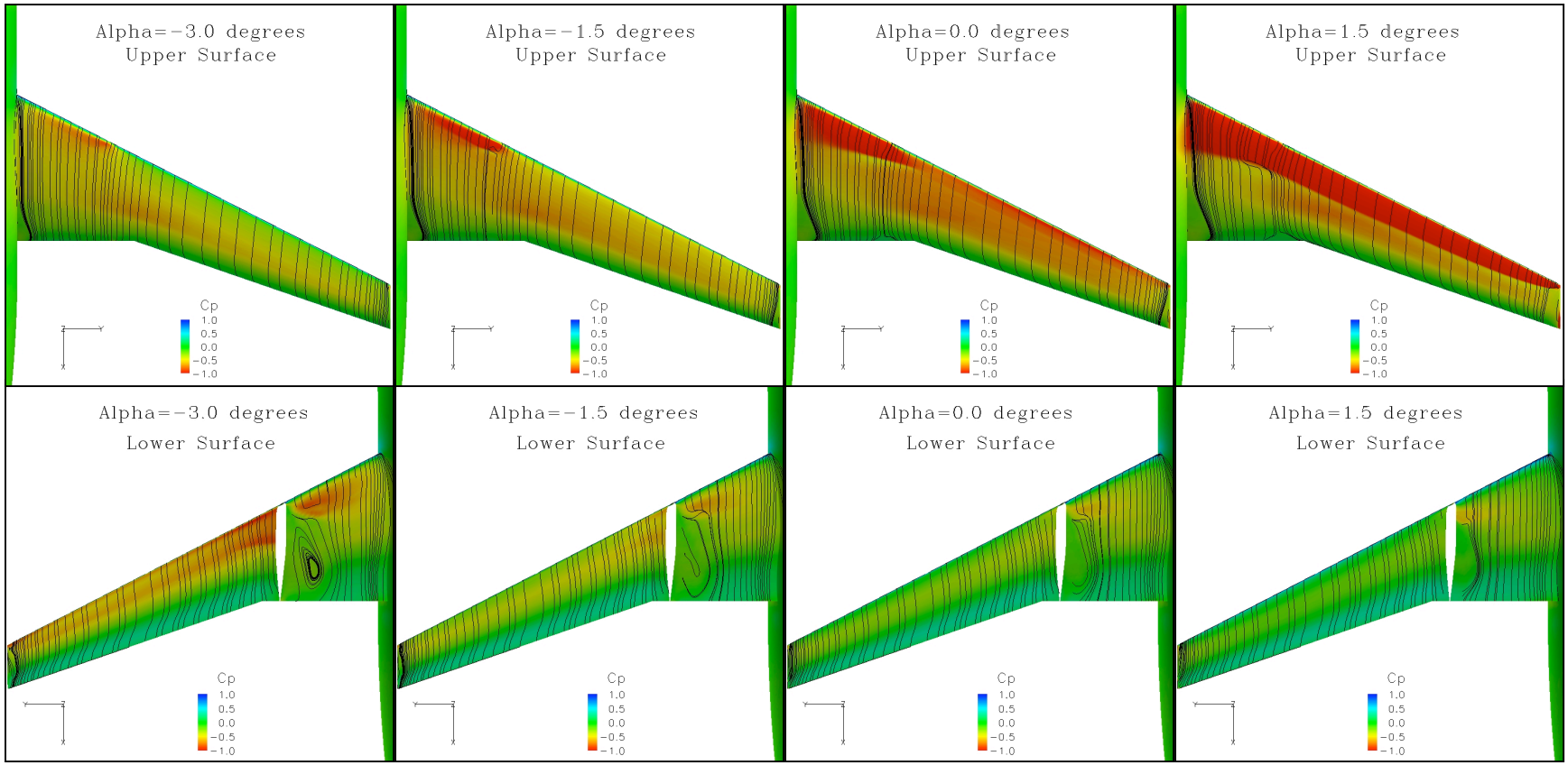
Medium WBNP Grid with Transition:

Mach = 0.75, C_L = 0.50, R_N = 3.0 M



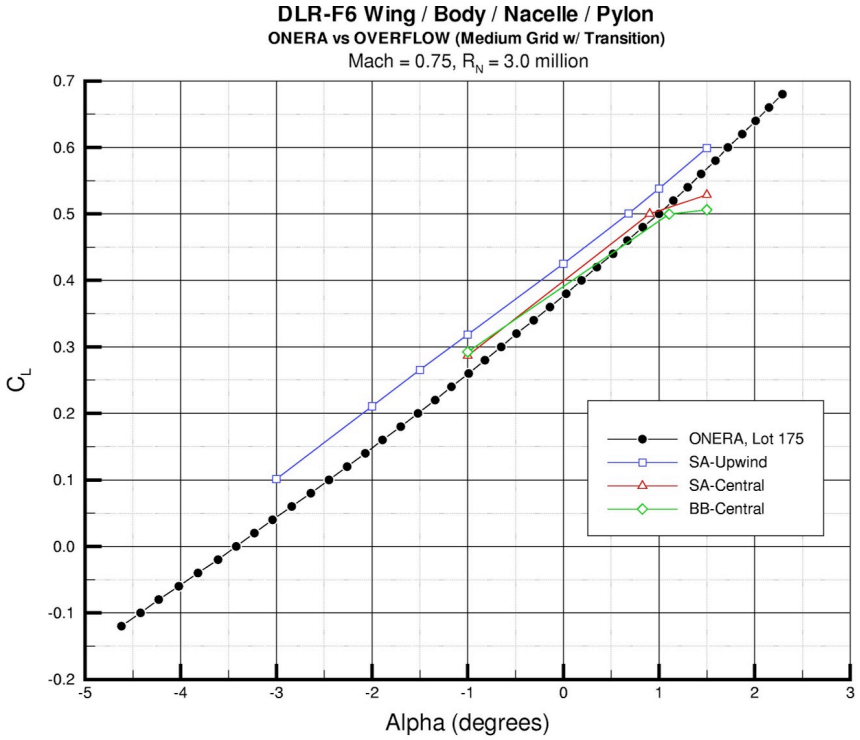
Case 2 – *WBNP Surface Cp and Streamlines*

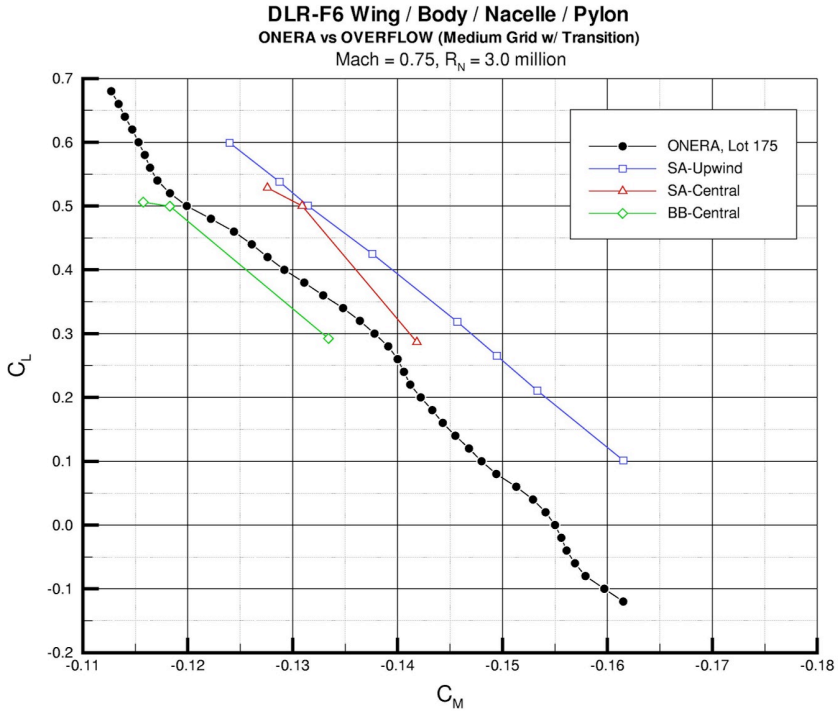
Medium Grid with Transition – SA Upwind



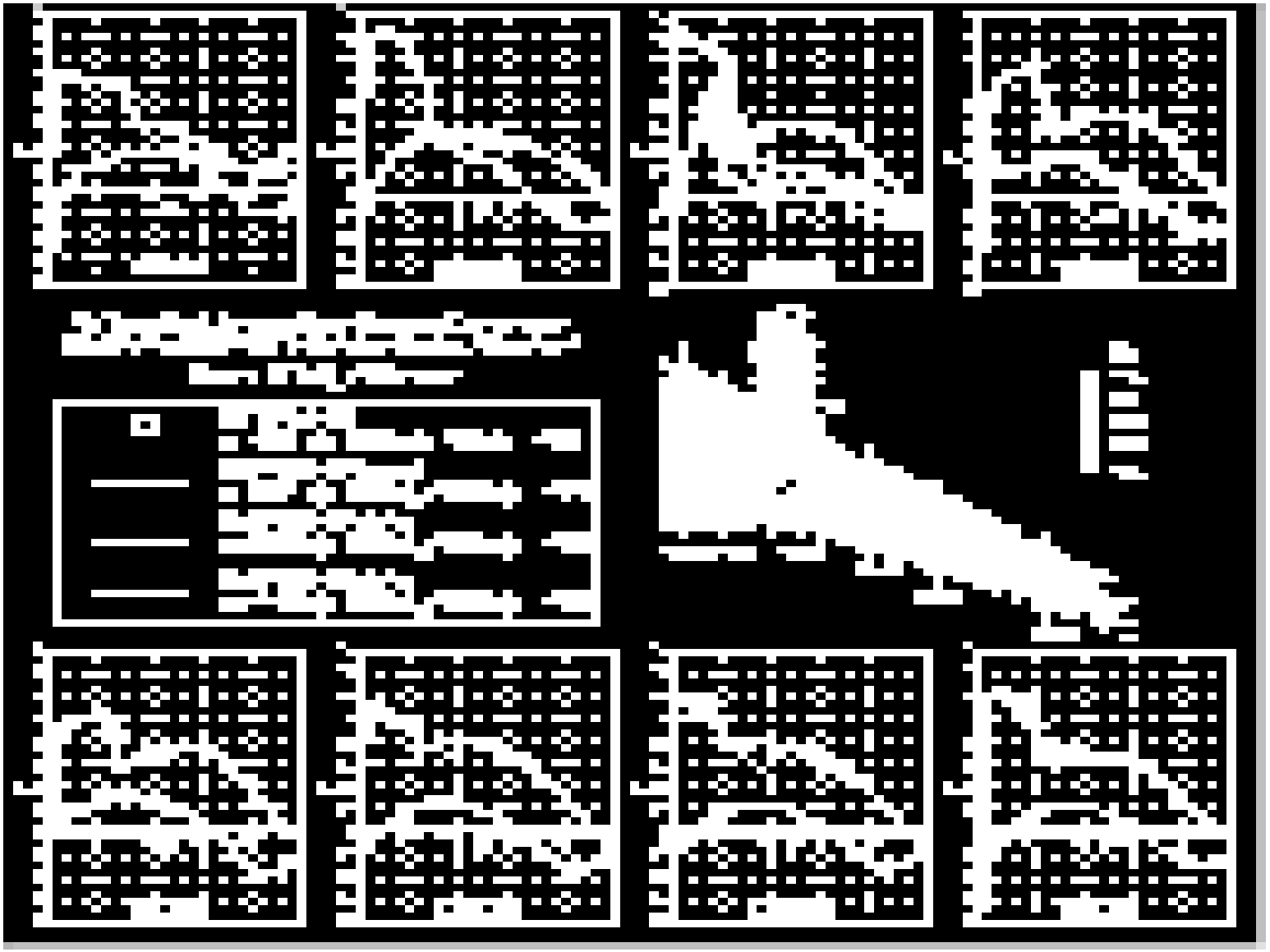
Alpha Sweep ⟶

Case 2 – *WBNP C_L and C_M Curves*



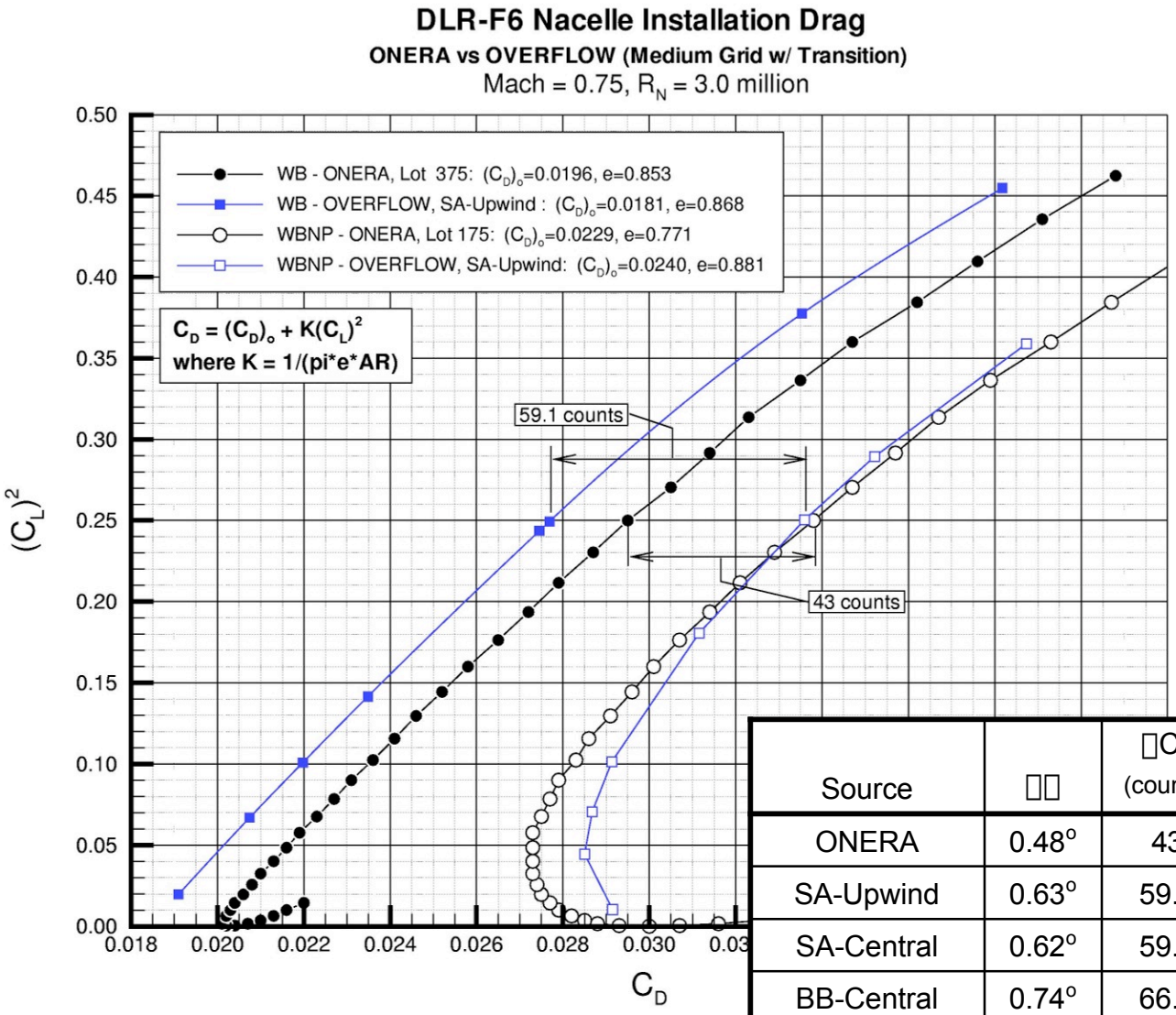


Case 2 – *WBNP Pressure Comparison*



Case 2 – *WBNP Pressure Comparison*

Case 2 – *NP Installation Drag*



C_L = 0.50

□ = (WBNP – WB)

Source	□□	□C_D (counts)	□C_M	$(C_D)_{internal\text{-}sf}$ (counts)	MFR
ONERA	0.48°	43	.0012	5.8	N/A
SA-Upwind	0.63°	59.1	.0110	5.5	0.76
SA-Central	0.62°	59.2	.0047	5.6	0.75
BB-Central	0.74°	66.1	.0111	5.3	0.75

Case 3 – *Tripped vs Fully Turbulent*

Mach = 0.75, R_N = 3.0 M, C_L = 0.50, SA-Upwind Results

Medium WB Grid:

Type	□ (deg)	C_D (counts)	C_M
Tripped (5/15/15/5)	0.050	276.9	-0.14246
Fully Turbulent	0.159	288.6	-0.13673
	□ = 0.109º	*11.7 counts*	*0.00573*

Medium WBNP Grid:

Type	□ (deg)	C_D (counts)	C_M
Tripped (5/15/15/5)	0.682	336.0	-0.13145
Fully Turbulent	0.781	342.7	-0.12586
	□ = 0.099º	*6.7 counts*	*0.00559*

Conclusions

Case 1 – *Grid Convergence Study*

- Coarse grids lacked constant spacing for first two cells off surface.
  - Effects skin friction (8.6 count diff for WB and 10.2 counts for WBNP).
- Medium grids are adequate in size for drag calculations.

Case 2 – *Drag Polars*

- SA-Upwind WB polar shape was similar to the test data's.
- All methods produced exaggerated side-of-pylon separation which caused a rotation and/or shift of the polar.
- Nacelle/pylon increment off by 16 counts (amount of shift in WB polar).

Case 3 – *Tripped vs Fully Turbulent*

- Going from fully turbulent to tripped at $C_L = 0.50$ reduces:
  - WB drag by 11.7 counts
  - WBNP drag by 6.7 counts

Conclusions (continued)

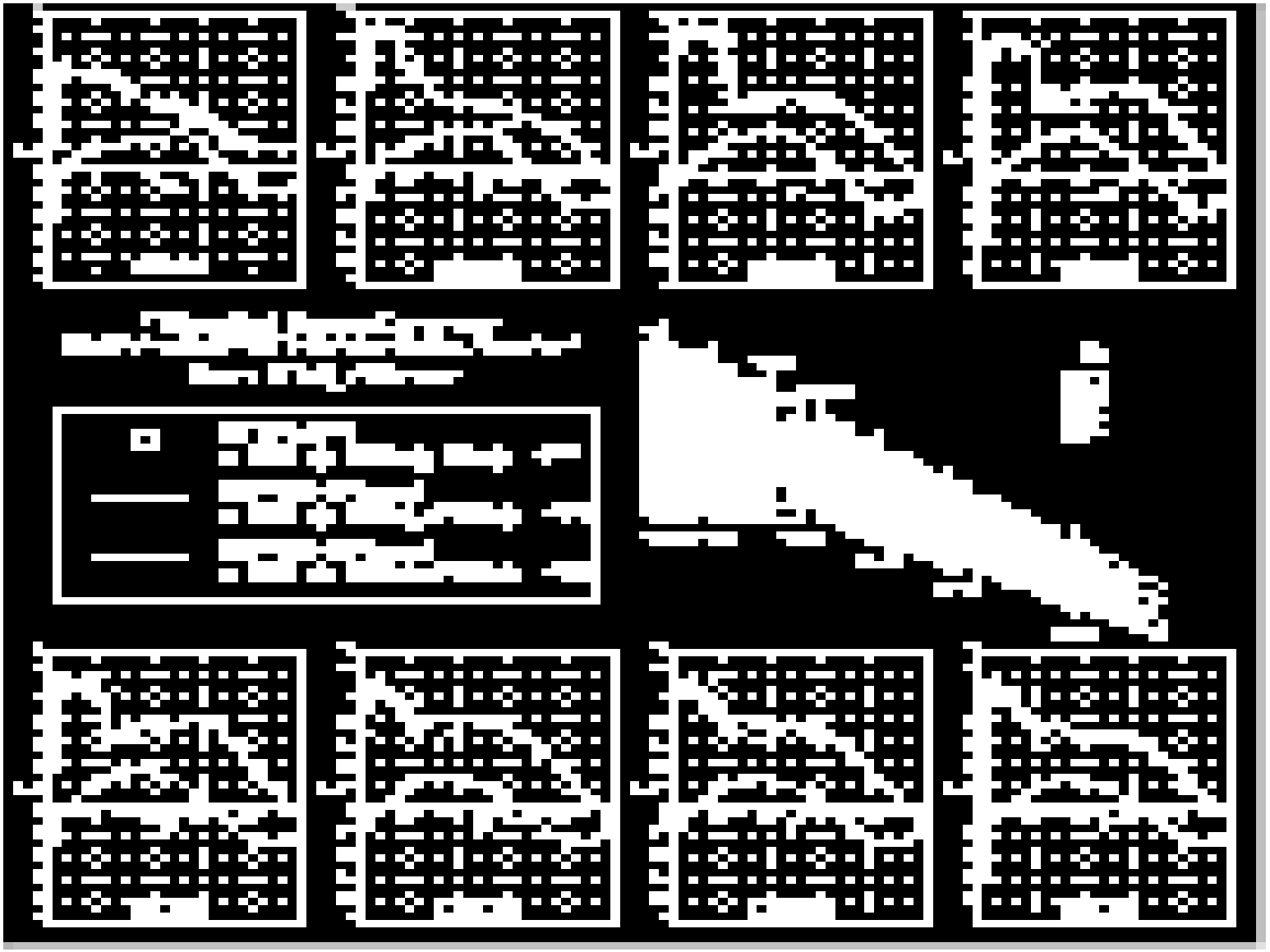
Based on recent OVERFLOW drag analyses of in-service Boeing aircraft, these DLR-F6 results are in poor agreement with the test data.

- Separated flow regions are larger than normal.
- Possible inconsistencies between test data and CFD.

Additional runs made just prior to the workshop include a 2-equation turbulence model (SST).

- Implementation in OVERFLOW needs to be tested.
- Preliminary results show a minor improvement.

Additional Runs – *WB Cp Comparison*



Additional Runs – *WB Cp Comparison, □-Match*