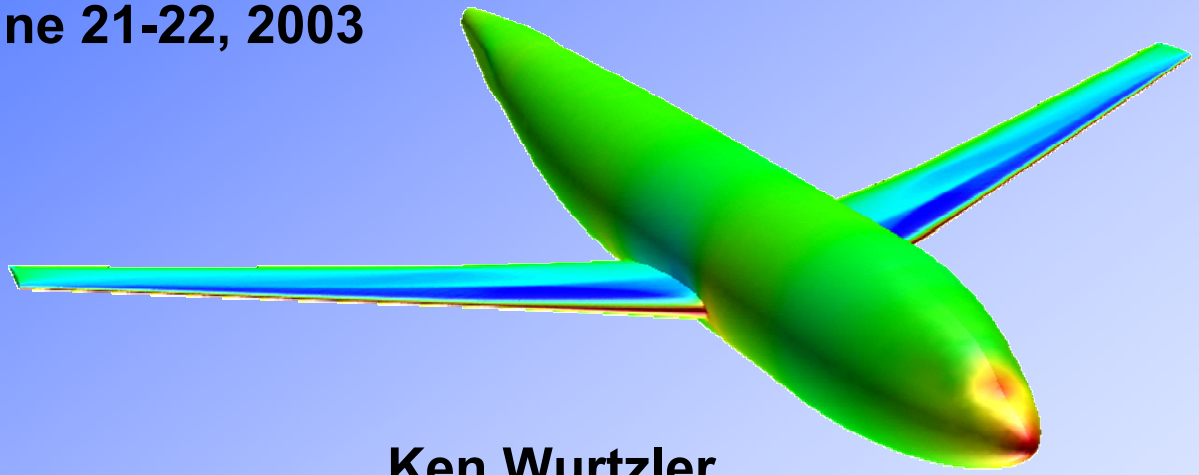
2nd AIAA CFD Drag Prediction Workshop

June 21-22, 2003



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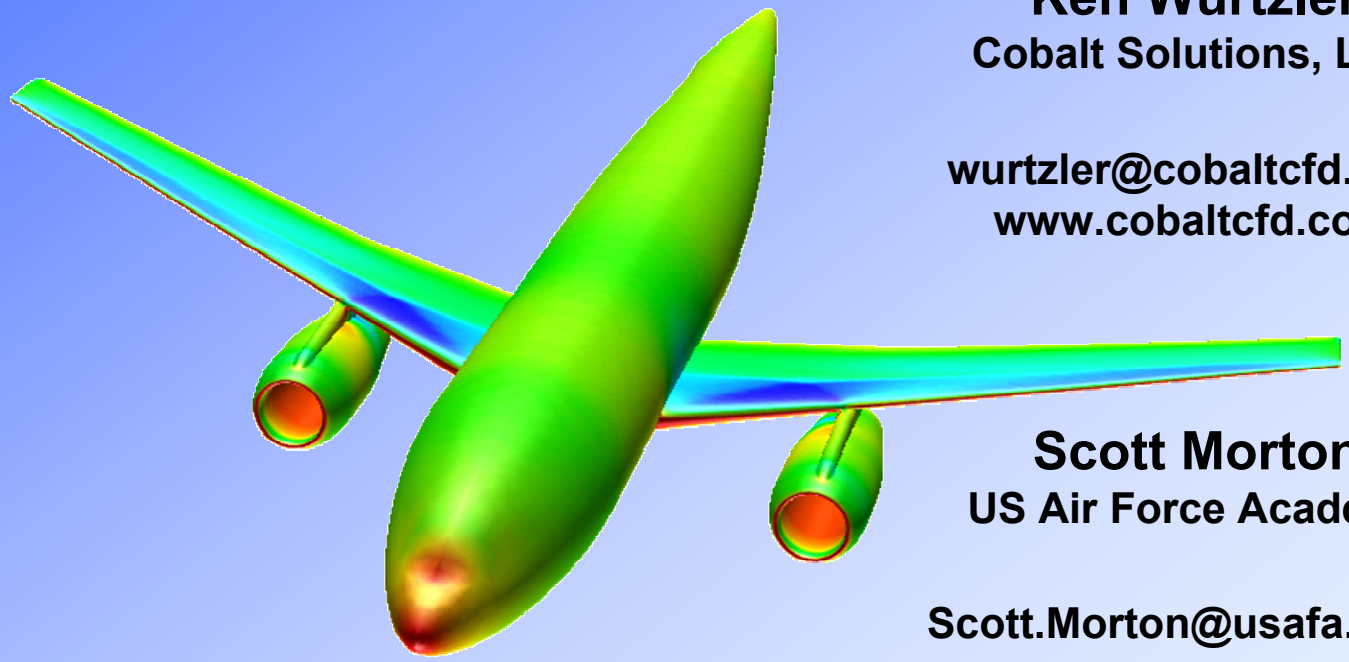

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- Navier-Stokes solver (AIAA-99-0786) with significant upgrades to the spatial and temporal operators
- Hybrid grid used – prisms and tetrahedra
- 96 to 416 nodes [IBM SP3]
- Time-step = 6e-5 [based on 0.1*chord/U_{inf}]

- Menter's SST turbulence model [Menter, F. R., Improved Two-Equation k-w Turbulence Models for Aerodynamic Flows, NASA TM-103975, October 1992.]

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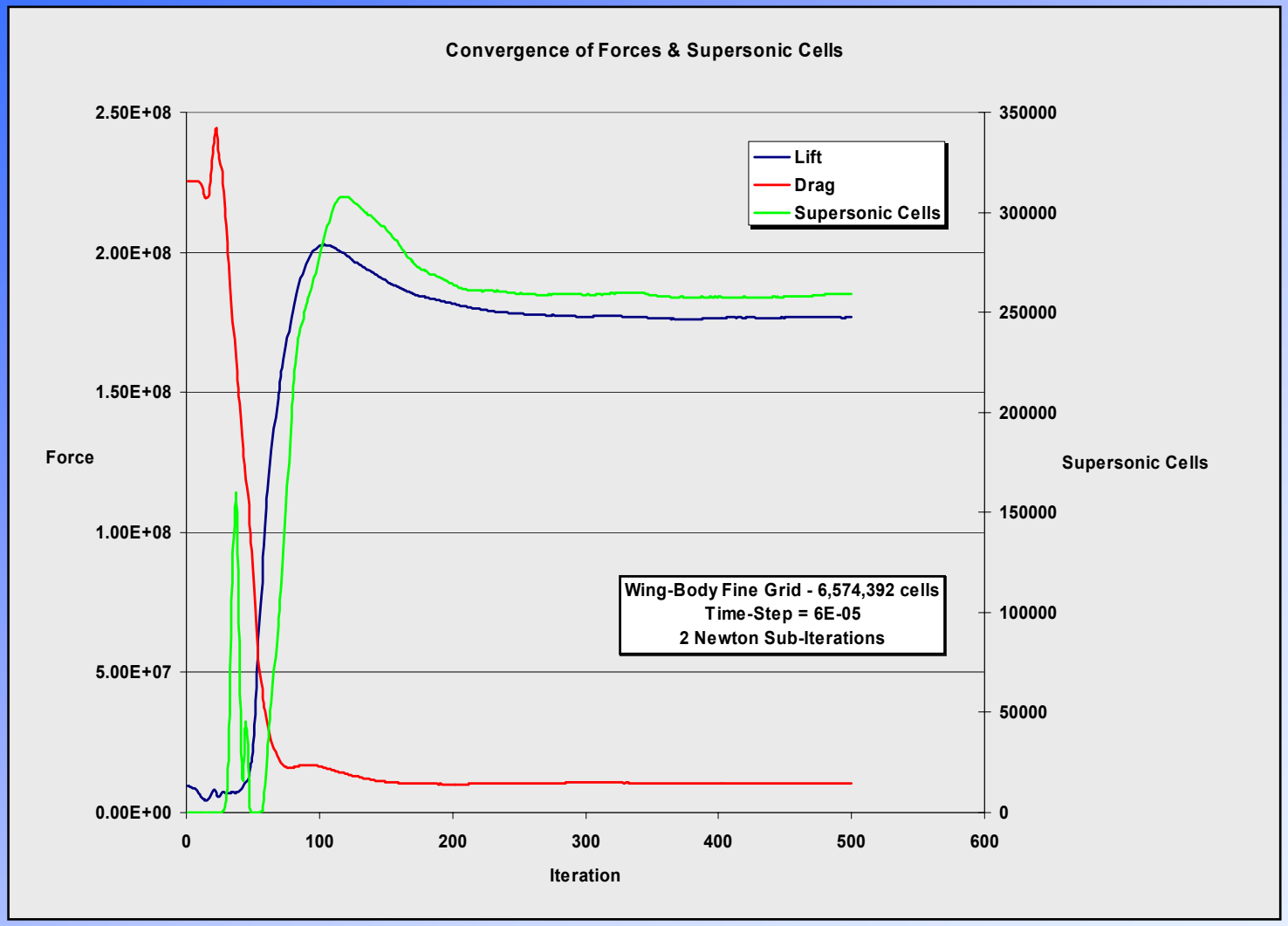
Convergence of Wing-Body Case



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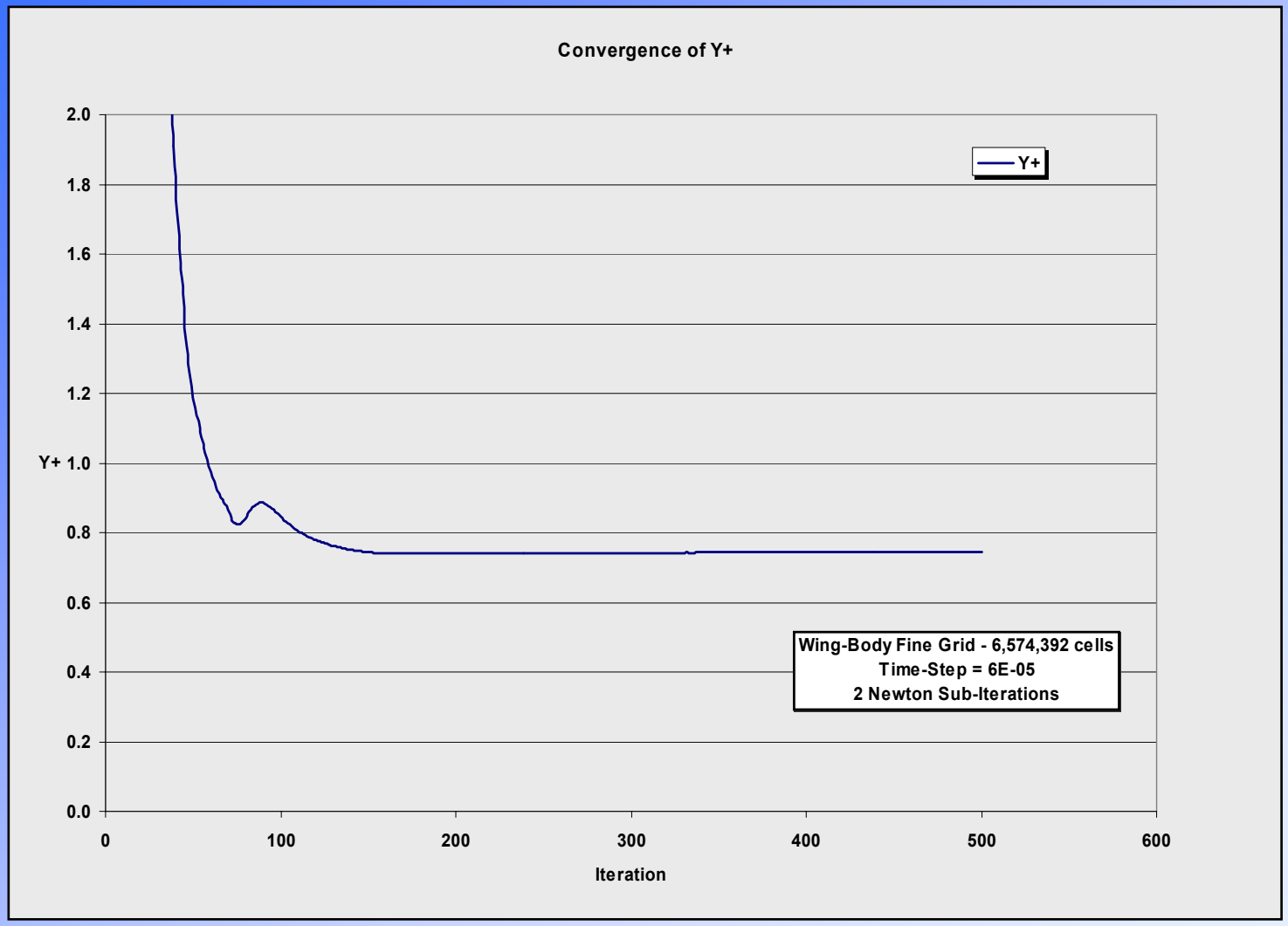
Convergence of Wing-Body Case



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Wing-Body Grids

Coarse	ifact=1.30	- 122,141 viscous triangles - 5,268,540 tets - 3,802,848 tets/prisms
Medium	ifact=1.15	- 153,234 viscous triangles - 6,714,822 tets - 4,876,014 tets/prisms
Fine	ifact=1.0	- 200,133 viscous triangles - 8,975,988 tets - 6,574,392 tets/prisms

Y+ $\approx$ 0.8
Growth Rate in Boundary Layer = 1.25
Gridtool/VGRIDns

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Location of Surface Triangles – Wing-body

		Fine	Medium	Coarse
Upper Wing	–	63,075	48,839	38,660
Lower Wing	–	61,499	46,284	38,625
Trailing Edge	–	62,437	48,138	38,963
Wing Tip	–	2,531	1,891	1,516
Fuselage	–	10,591	8,082	6,377

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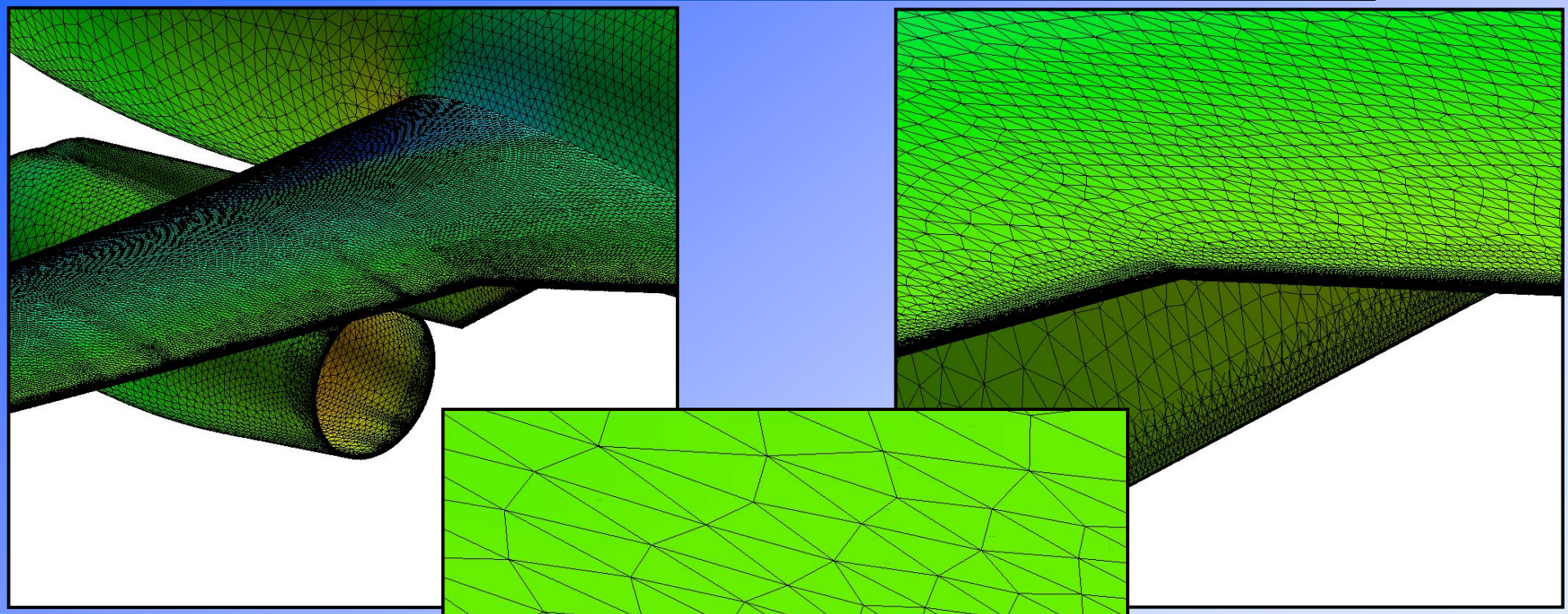
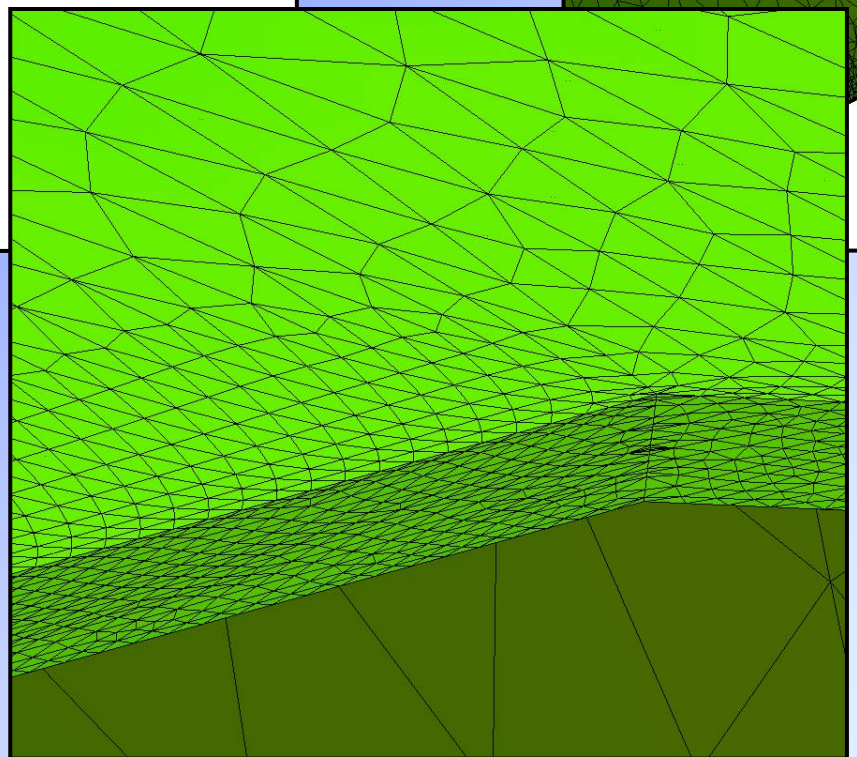
Location of Surface Triangles – Wing-Body-Nacelle-Pylon





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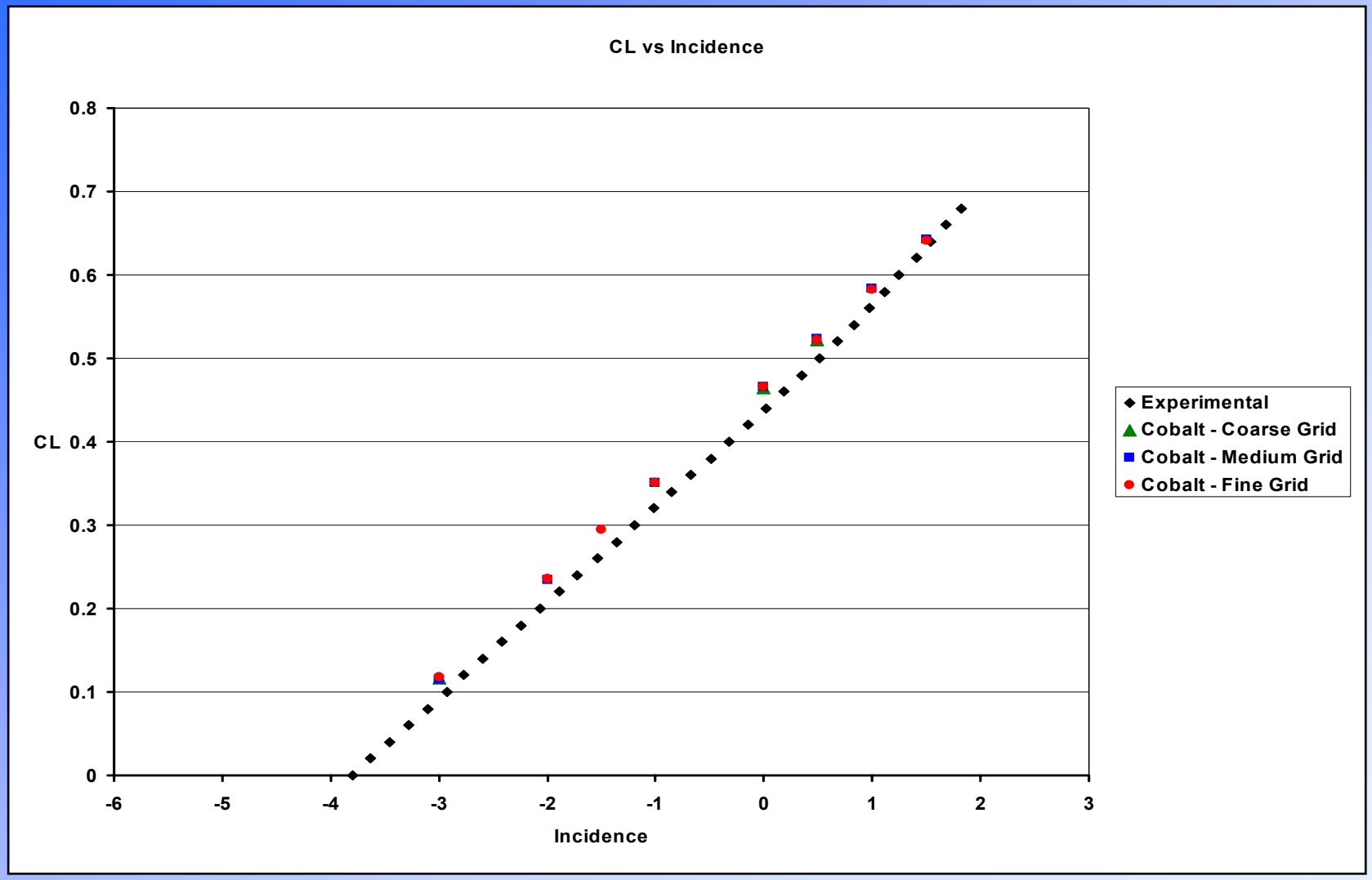
Wing-Body CL vs Incidence



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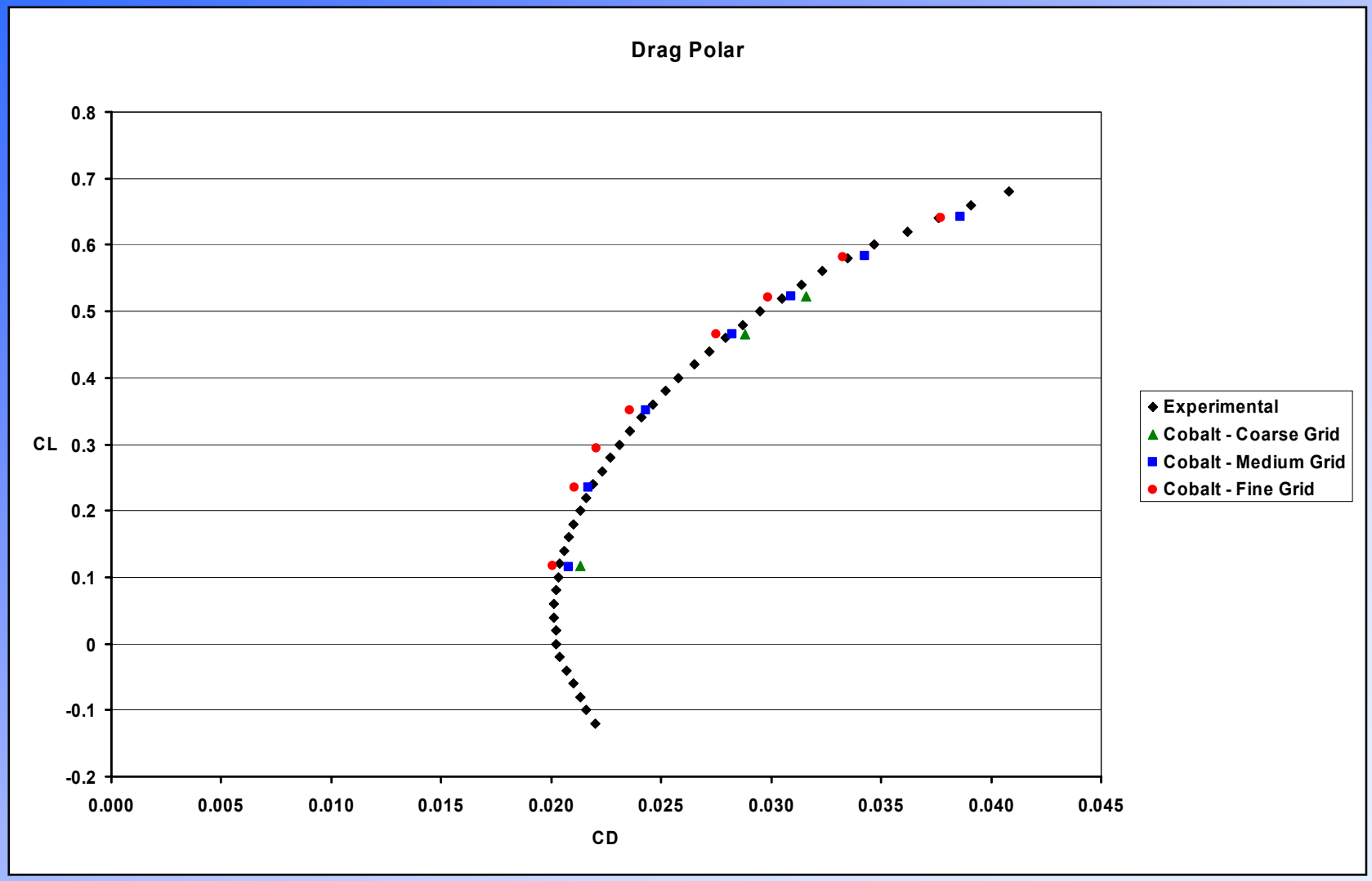
Wing-Body Drag Polar



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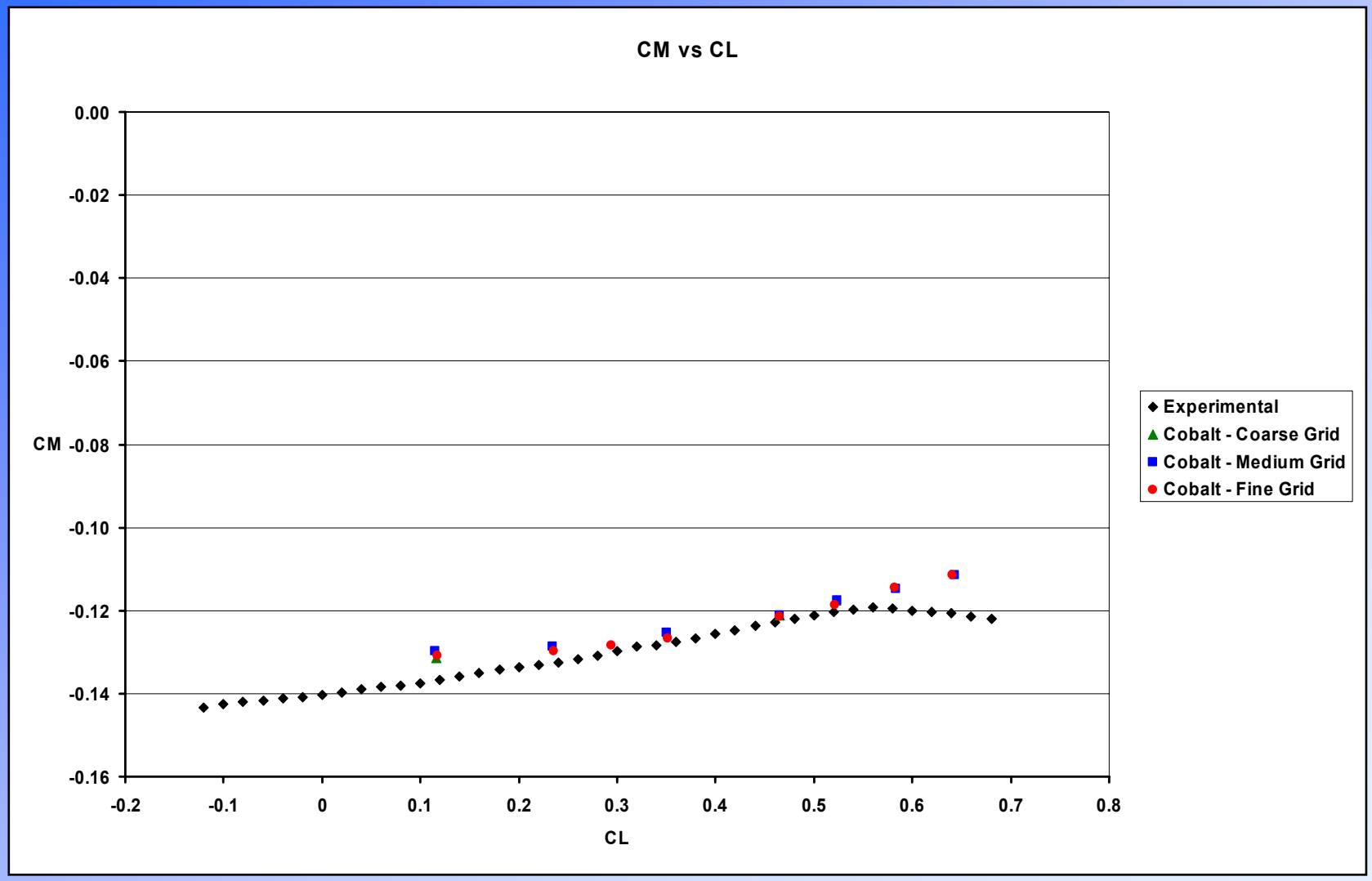
Wing-Body CM vs CL



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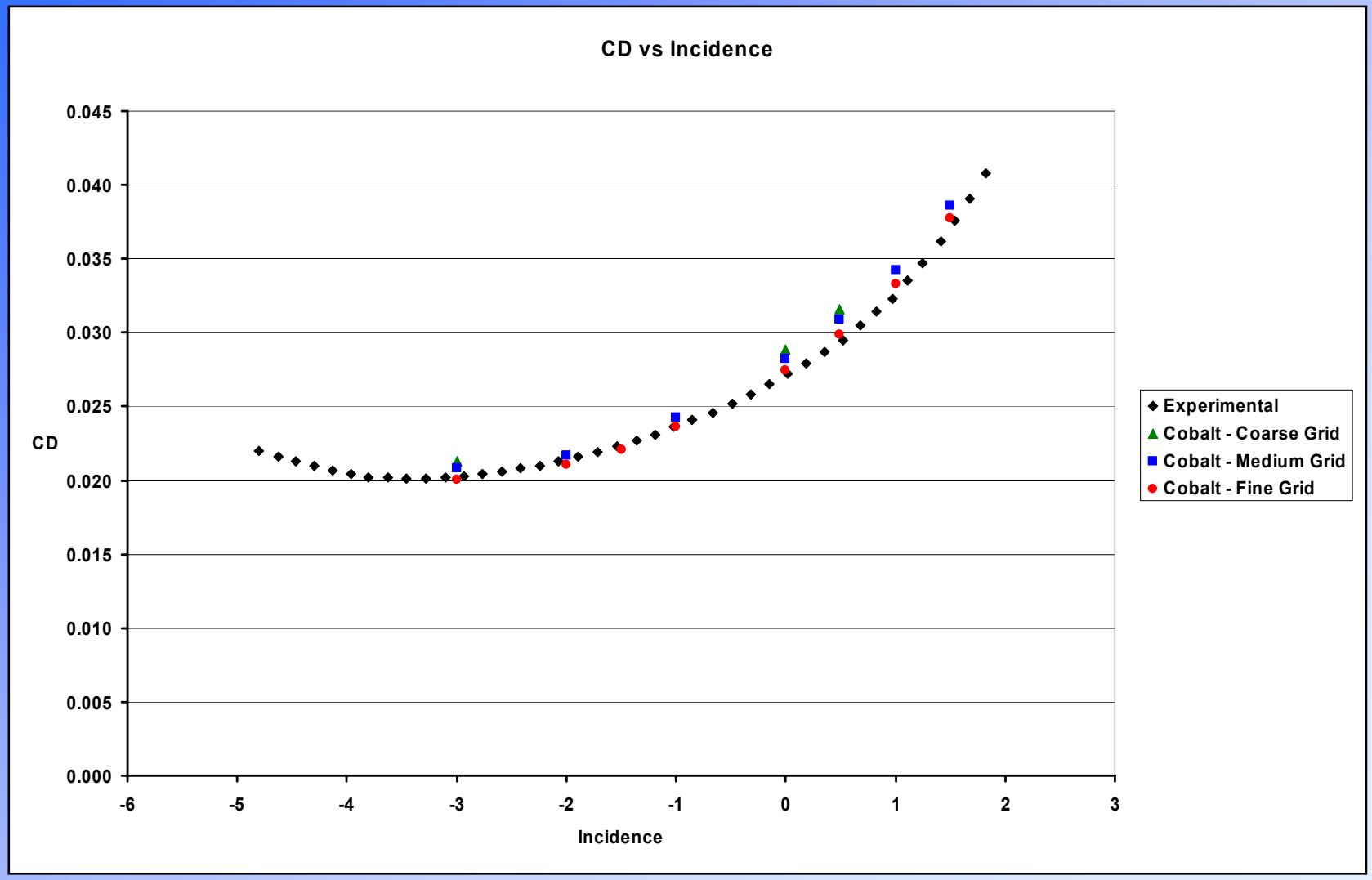
Wing-Body CD vs Incidence



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Wing-Body Alpha = 0.49 Data Comparison

	Experimental	Cobalt	% Difference
CL	0.4984	0.5213	4.59%
CD	0.0294	0.0299	1.7%
CM	-0.1213	-0.1188	2.06%

Alpha = 0.303 for single point grid convergence

Experimental CL, CD and CM extrapolated from force data.

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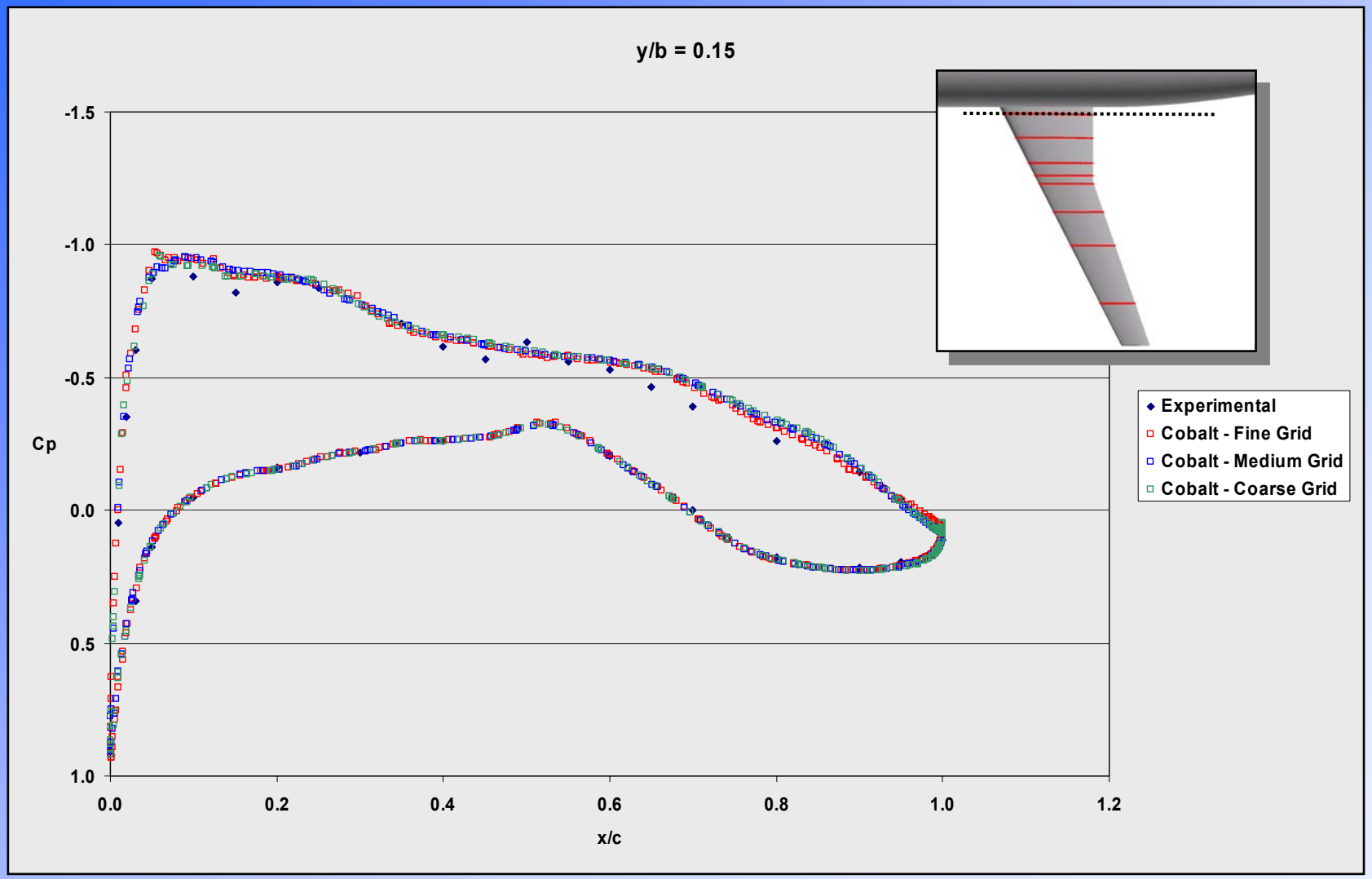
Wing-Body Cp Plots – y/b = 0.15



Alpha = 0.49°

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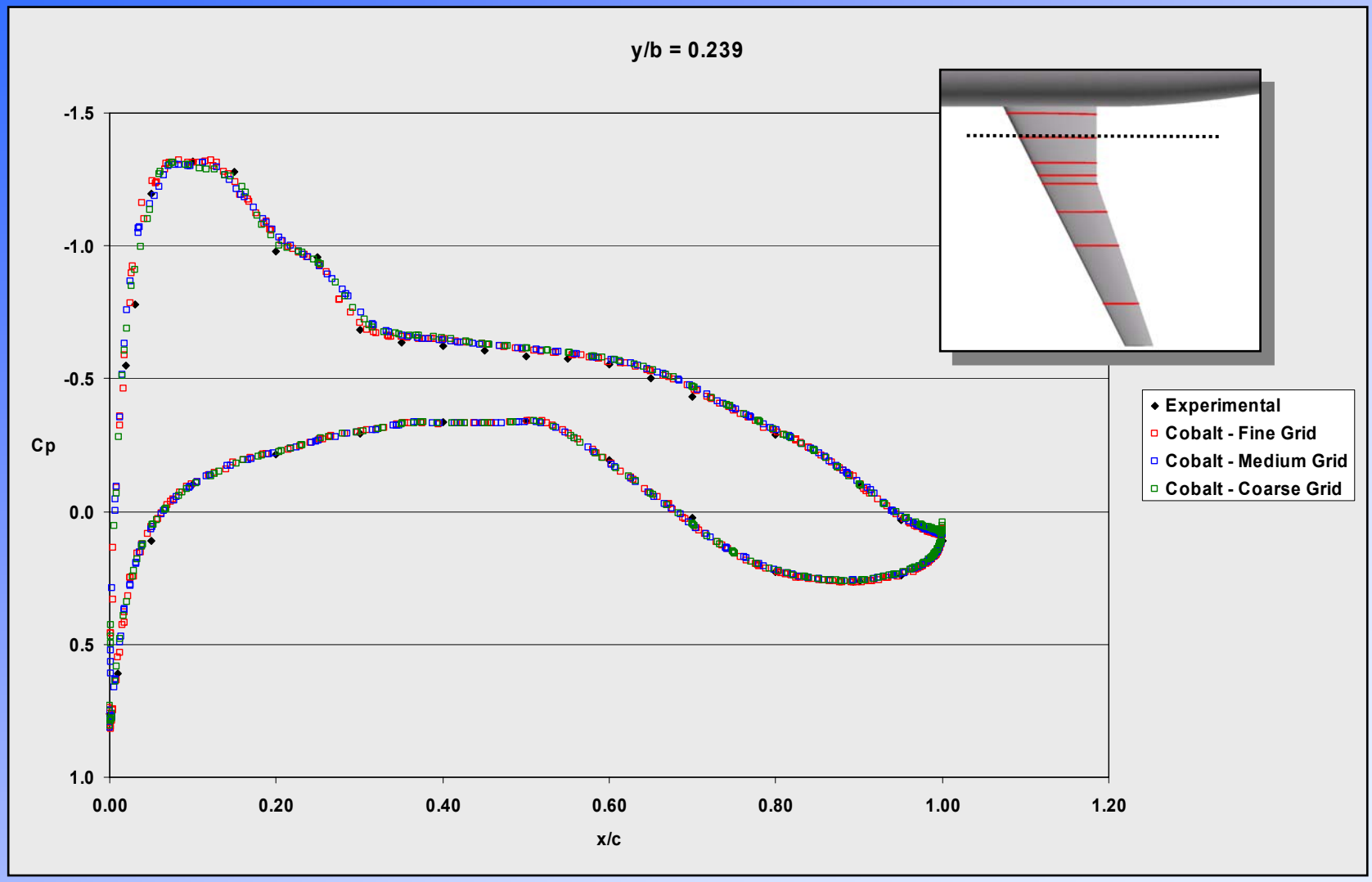
Wing-Body Cp Plots – y/b = 0.239



Alpha = 0.49°

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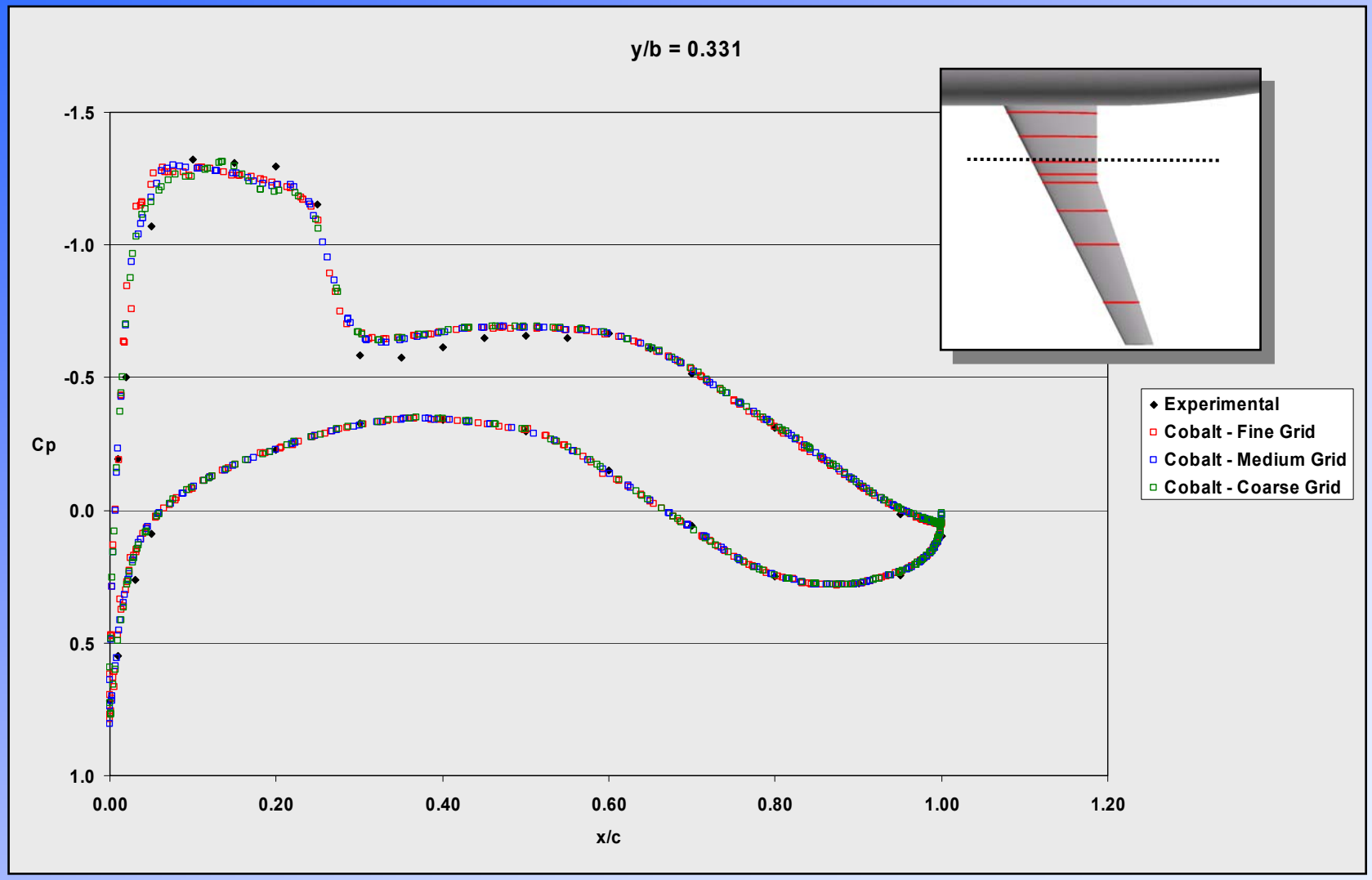
Wing-Body Cp Plots – y/b = 0.331



Alpha = 0.49°

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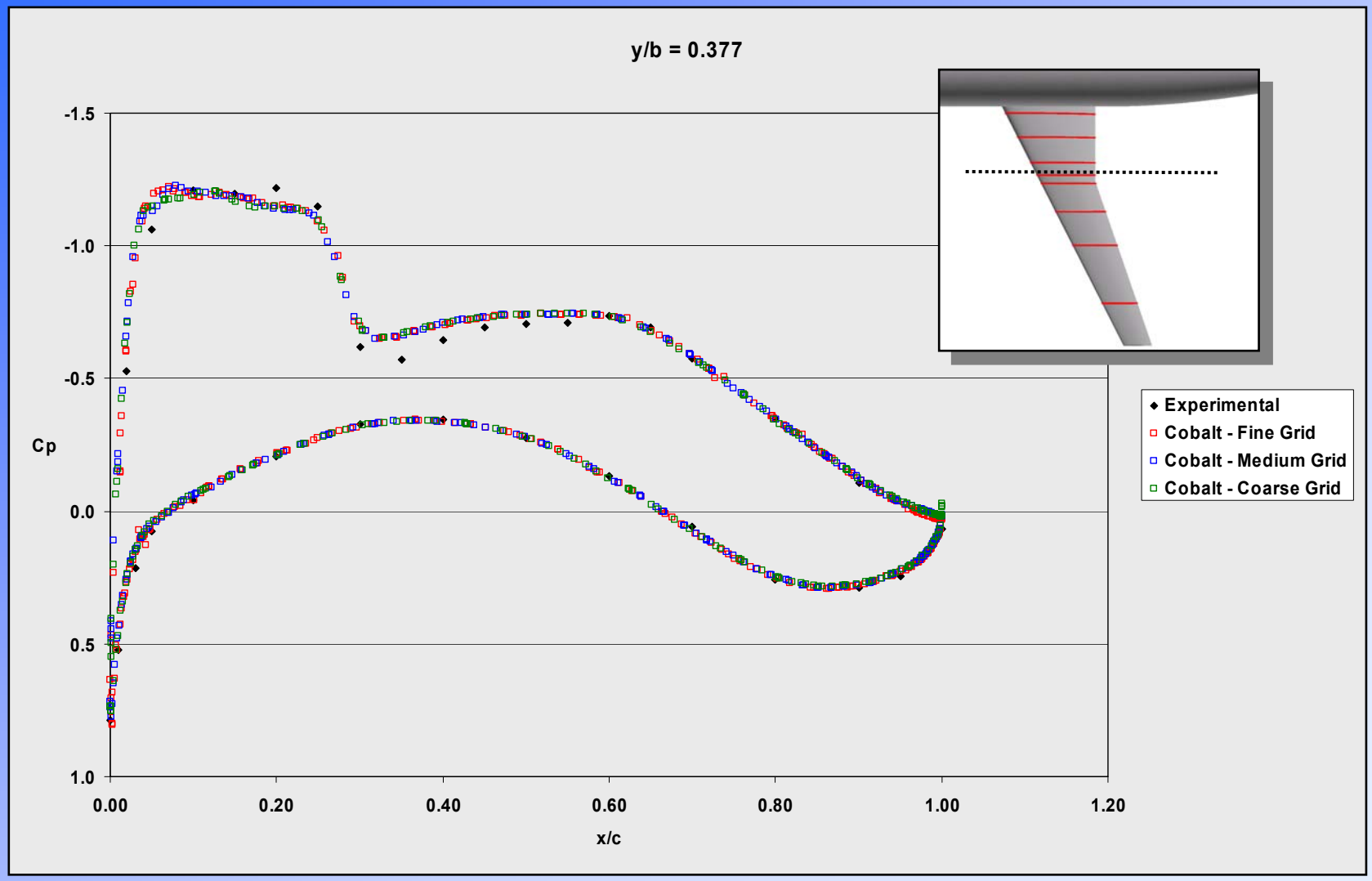
Wing-Body Cp Plots – y/b = 0.377



Alpha = 0.49°

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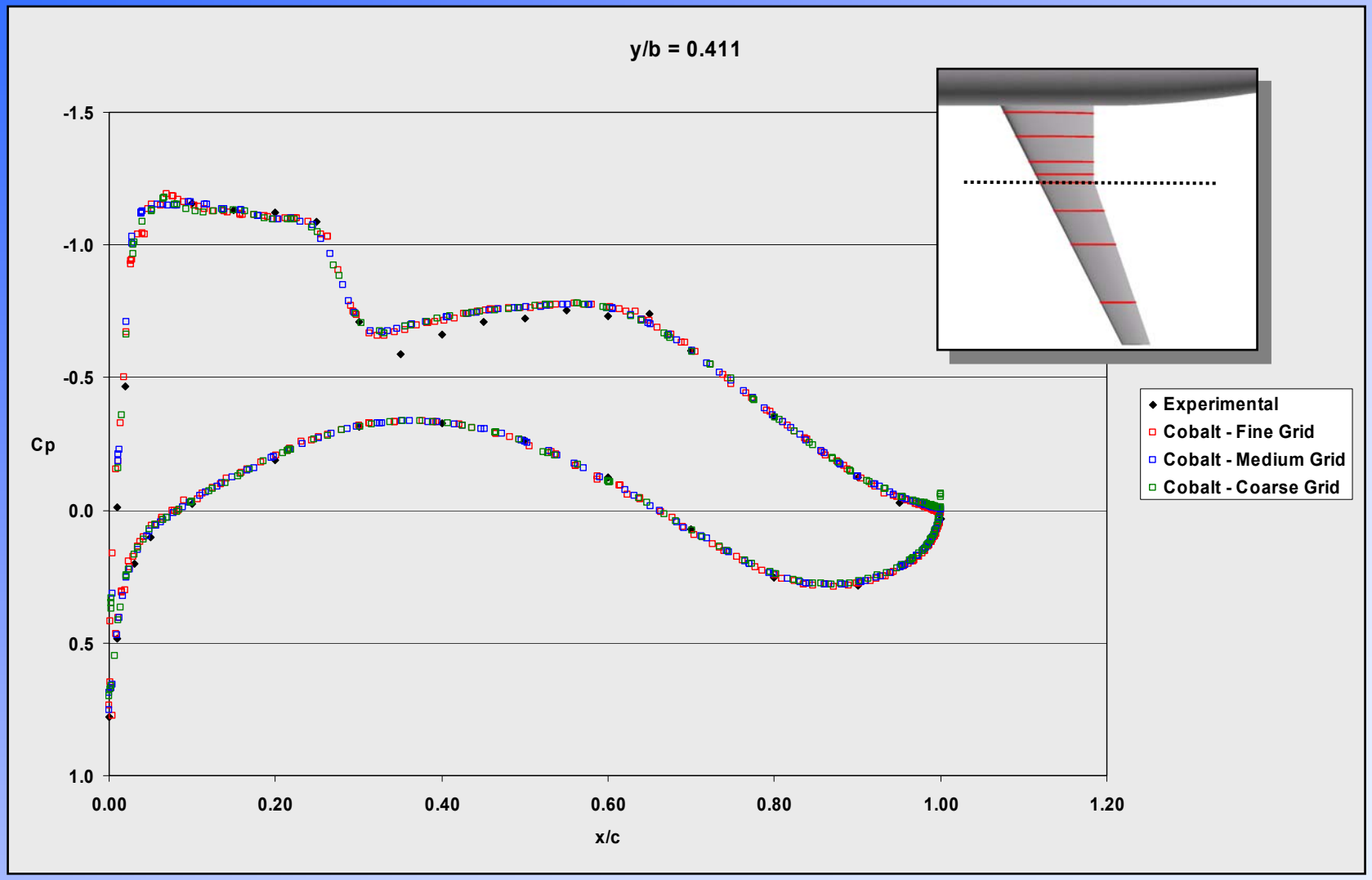
Wing-Body Cp Plots – y/b = 0.411



Alpha = 0.49°

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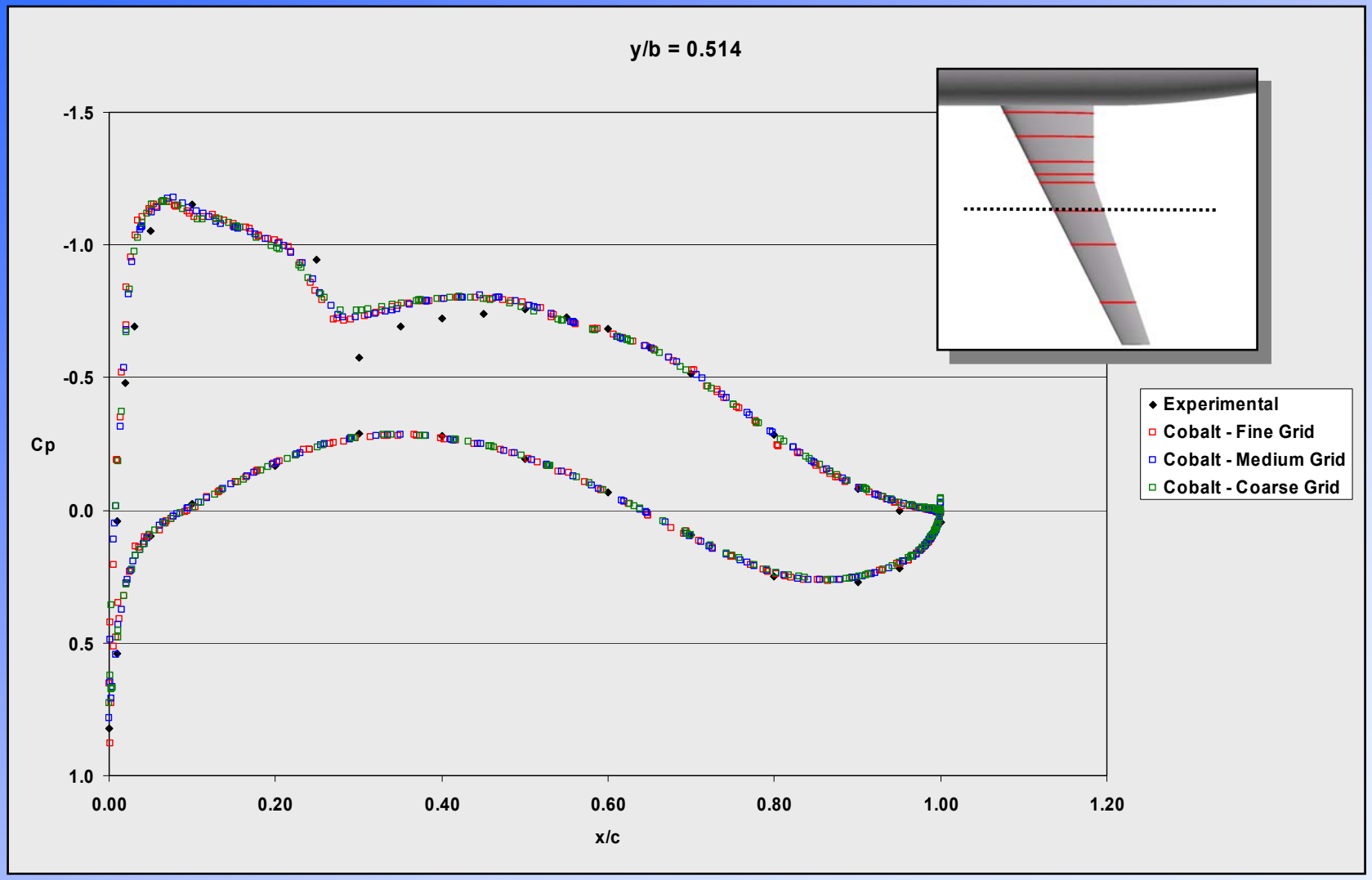
Wing-Body Cp Plots – y/b = 0.514



Alpha = 0.49°

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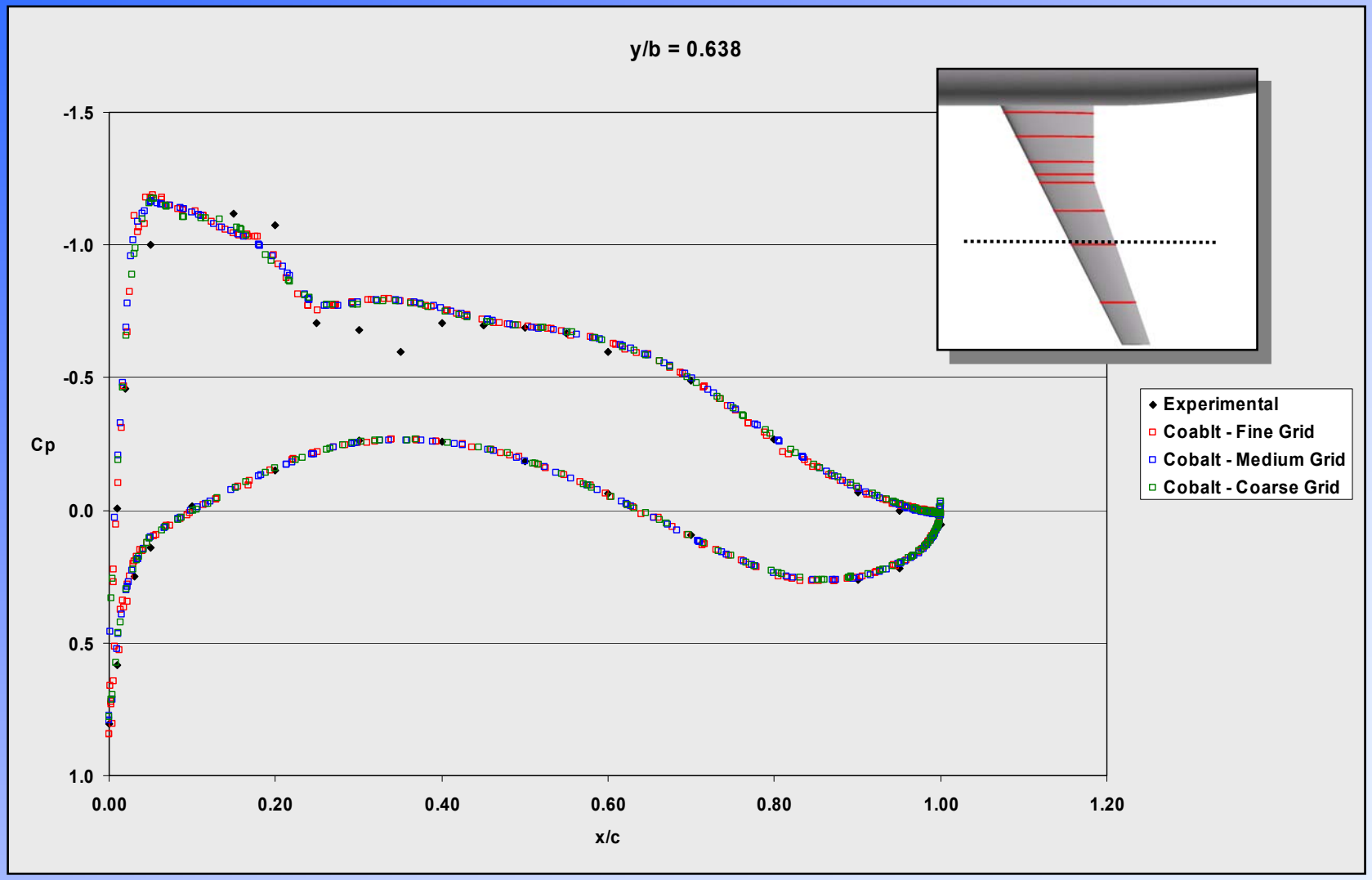
Wing-Body Cp Plots – y/b = 0.638



Alpha = 0.49°

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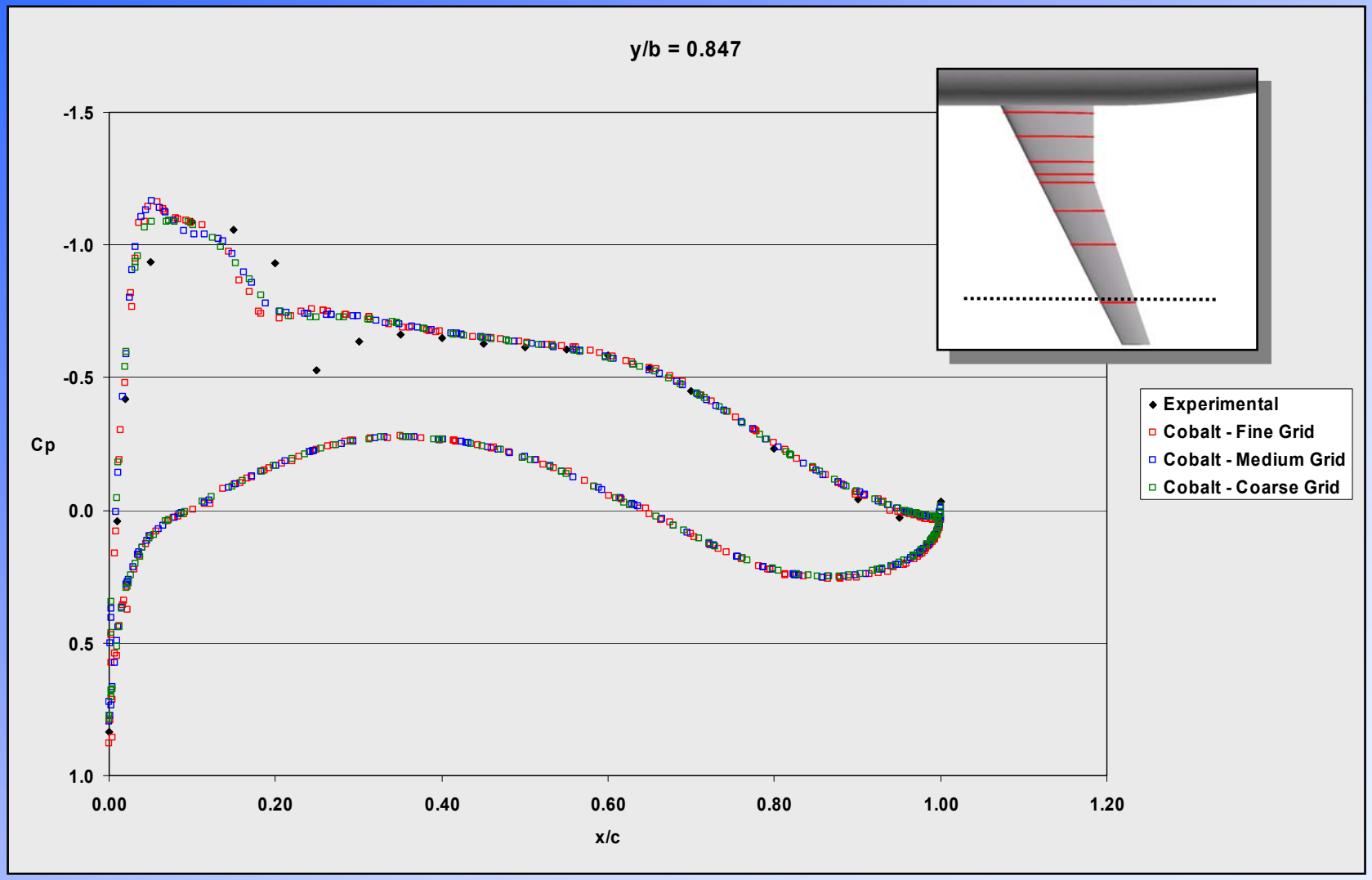
Wing-Body Cp Plots – y/b = 0.847



Alpha = 0.49°

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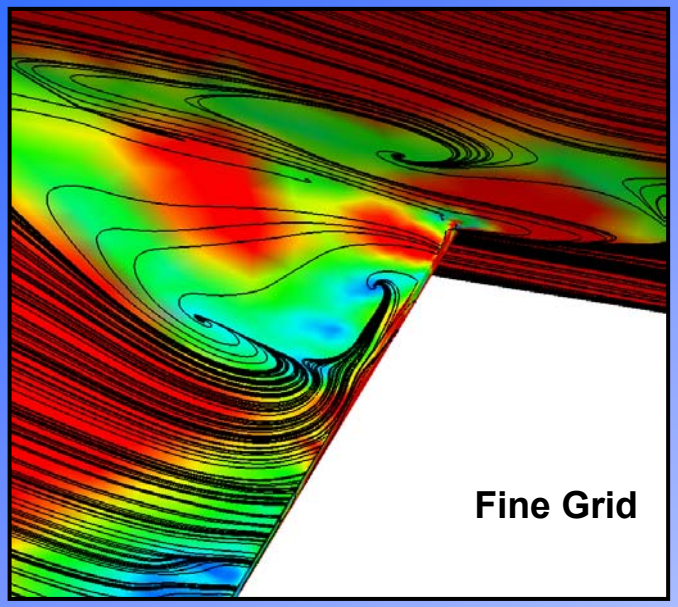
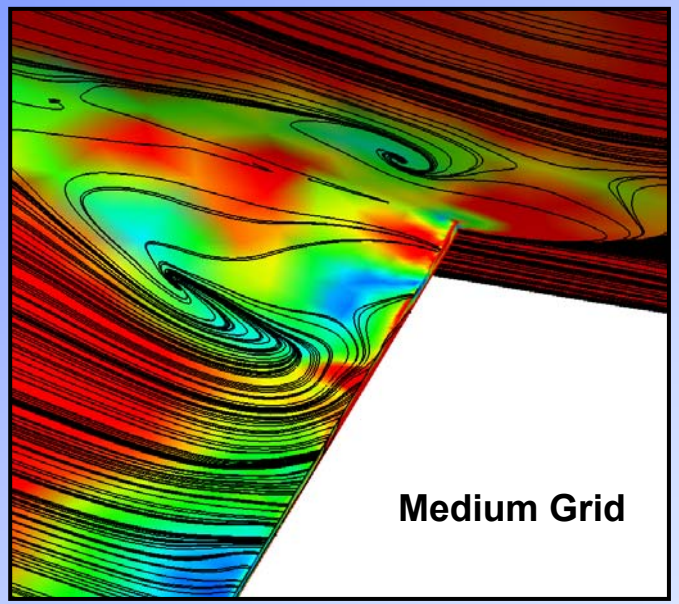
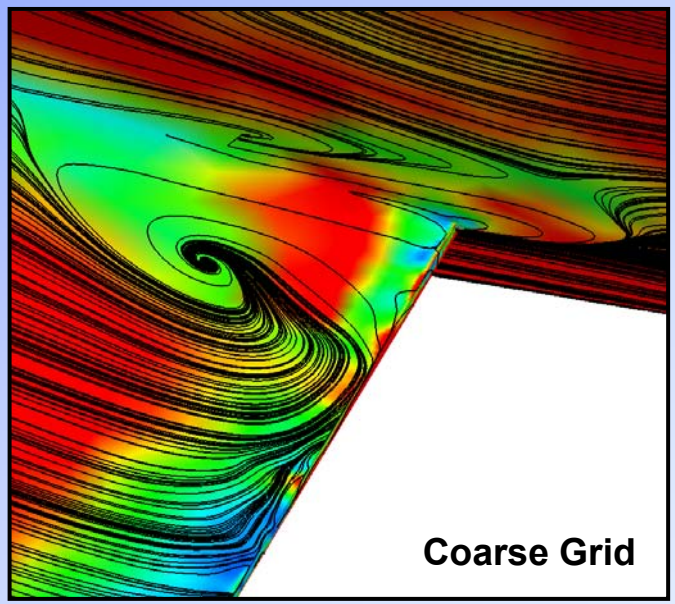
Wing-Body 'Bubble' Image







Surface Colored by C_f
CL = 0.50

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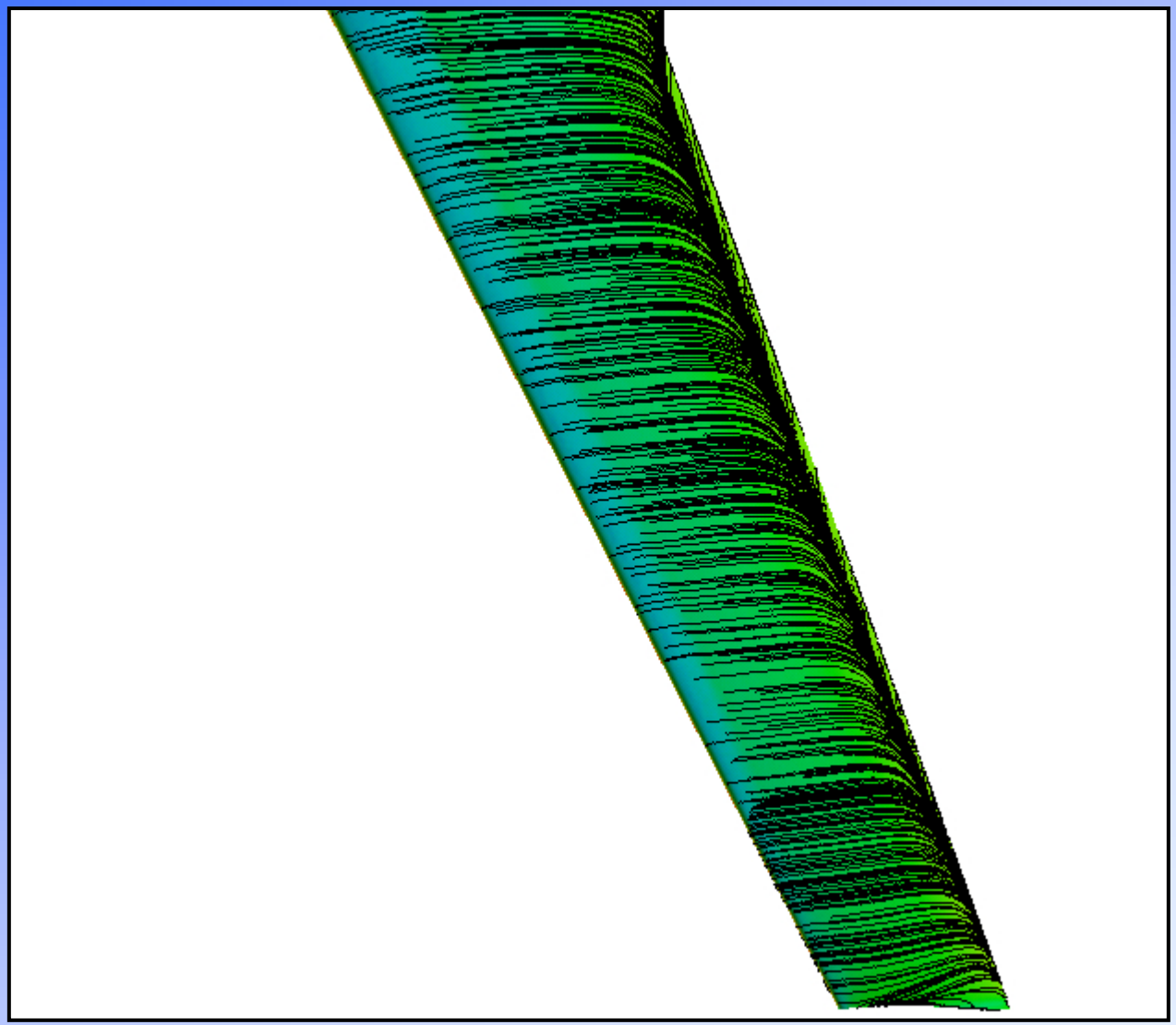
Wing-Body Trailing Edge Separation



Oil flow on upper wing surface – Alpha 0.49°

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Wing-Body-Nacelle-Pylon Grids

Coarse	ifact=1.30	- 139,600 viscous triangles - 6,114,050 tets - 4,718,050 tets/prisms
Medium	ifact=1.15	- 175,550 viscous triangles - 7,797,527 tets - 6,042,027 tets/prisms
Fine	ifact=1.0	- 232,572 viscous triangles - 10,528,768 tets - 8,202,958 tets/prisms

Y+ $\approx$ 0.8
Growth Rate in Boundary Layer = 1.25
Gridtool/VGRIDns

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Location of Surface Triangles – Wing-Body-Nacelle-Pylon

		Fine		Medium		Coarse
Upper Wing	–	58,678		44,689		35,854
Lower Wing	–	57,148		42,443		34,822
Trailing Edge	–	55,987		42,207		32,385
Wing Tip		–	2,028		1,589	
1,206						
Fuselage	–	9,344		7,144		5,658
Pylon	–	9,036		6,889		5,438
Nacelle	–	40,351		30,589		24,237

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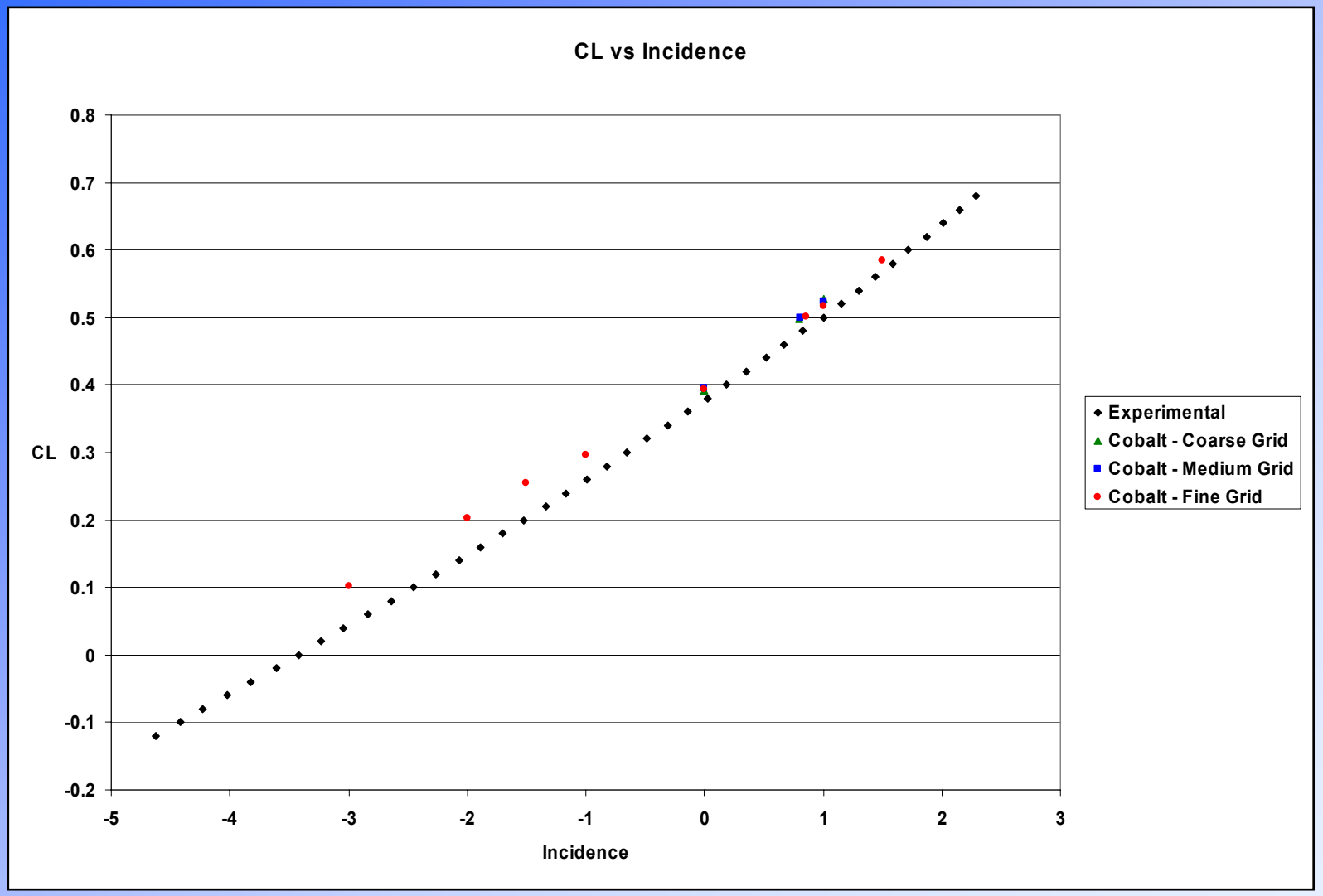
Wing-Body-Nacelle-Pylon CL vs Incidence



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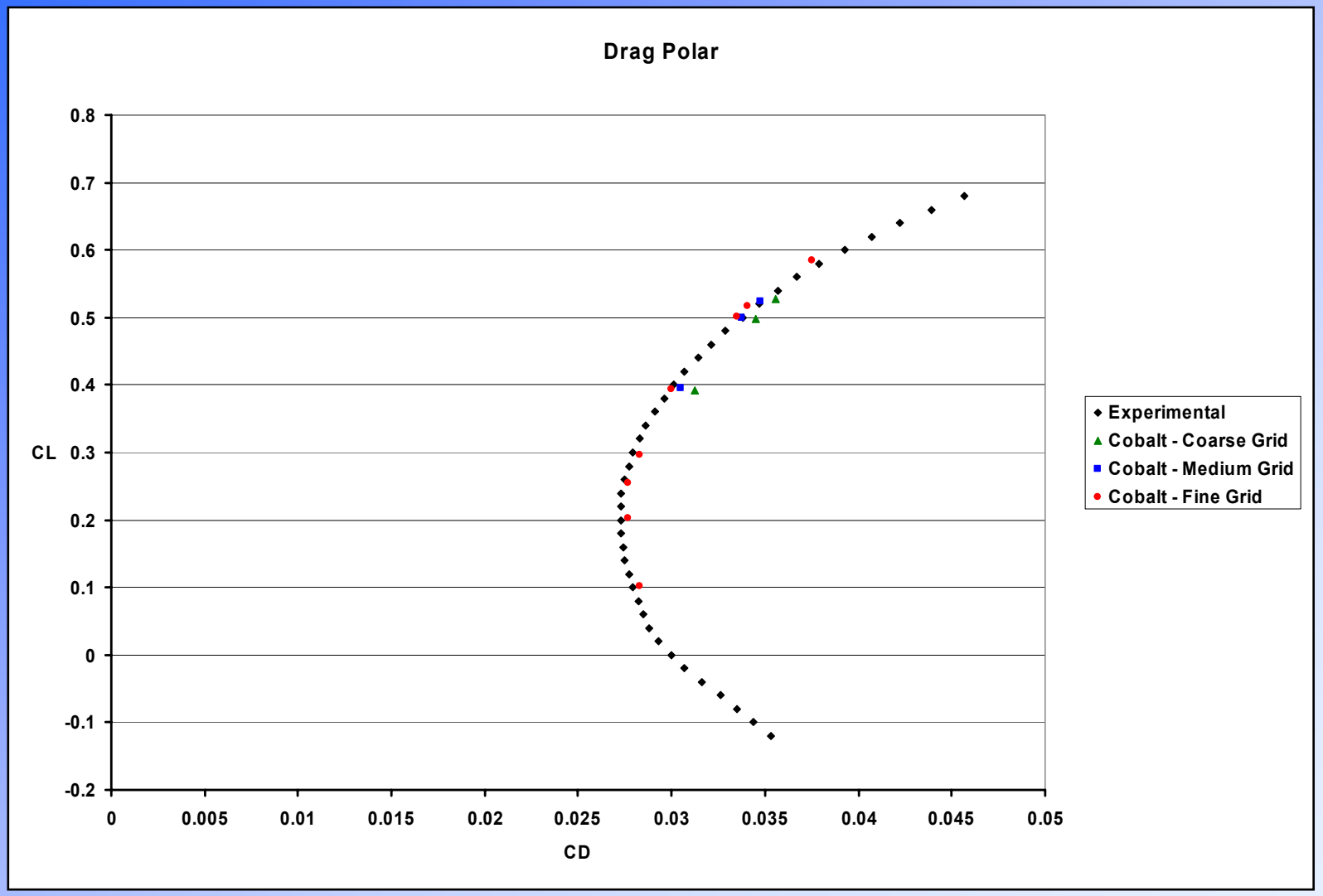
Wing-Body-Nacelle-Pylon Drag Polar



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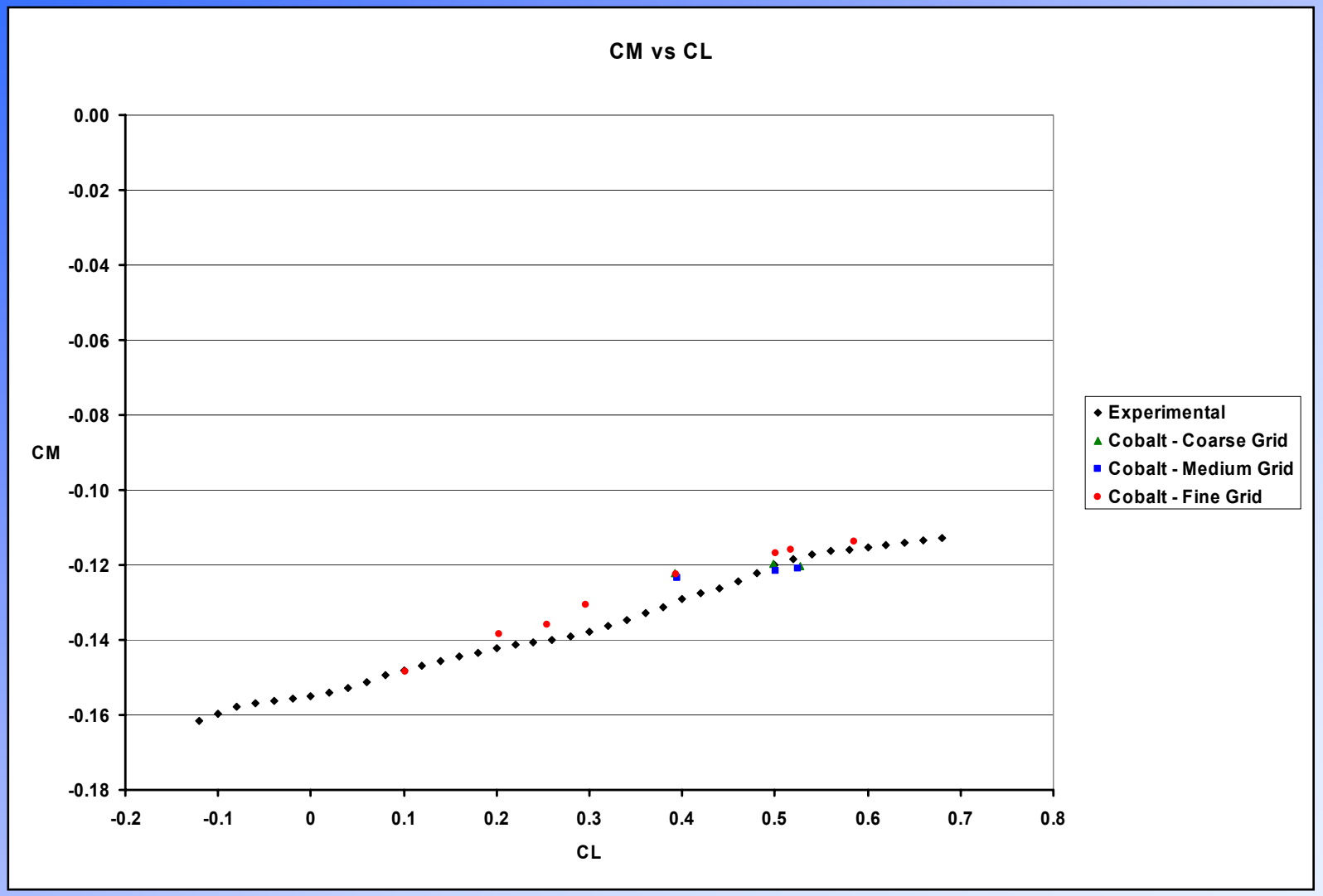
Wing-Body-Nacelle-Pylon CM vs CL



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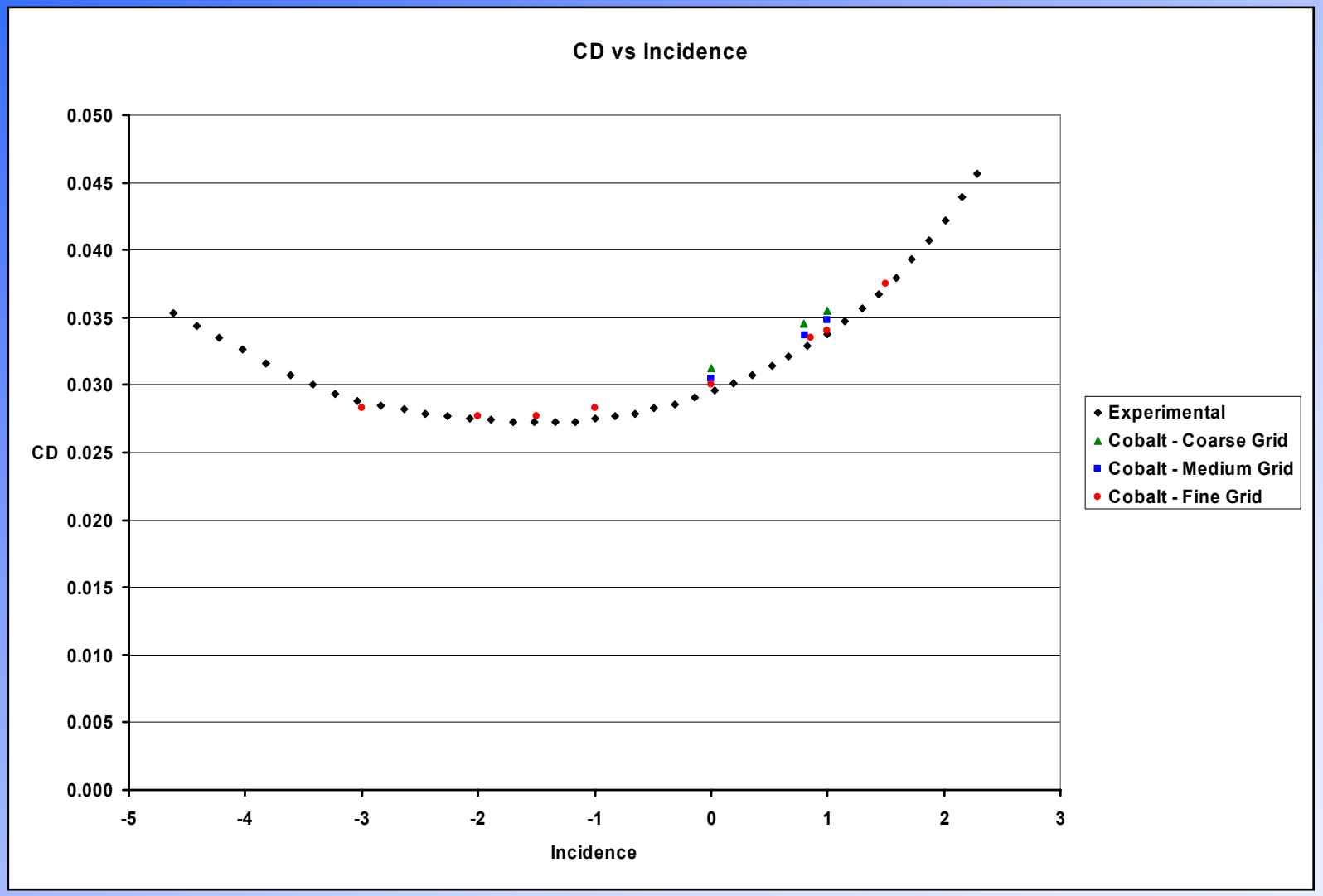
Wing-Body-Nacelle-Pylon CD vs Incidence



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Wing-Body-Nacelle-Pylon Alpha = 1.0 Data Comparison

	Experimental	Cobalt	% Difference
CL	0.5005	0.5171	3.2%
CD	0.0338	0.0340	0.6%
CM	-0.1199	-0.1161	3.2%

Alpha = 0.861 for single point grid convergence

Experimental CL, CD and CM extrapolated from force data.

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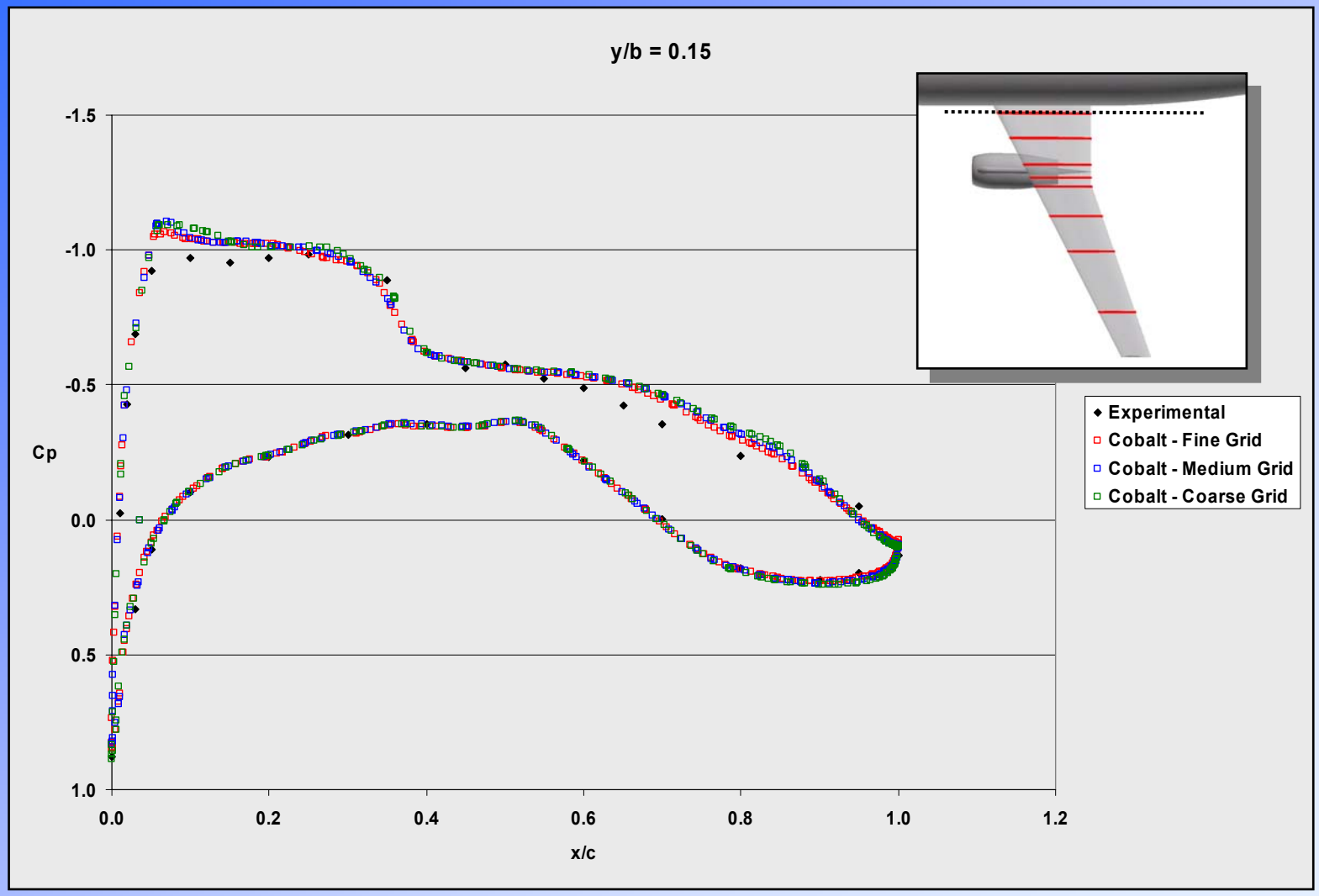
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.15



Alpha = 1.0°

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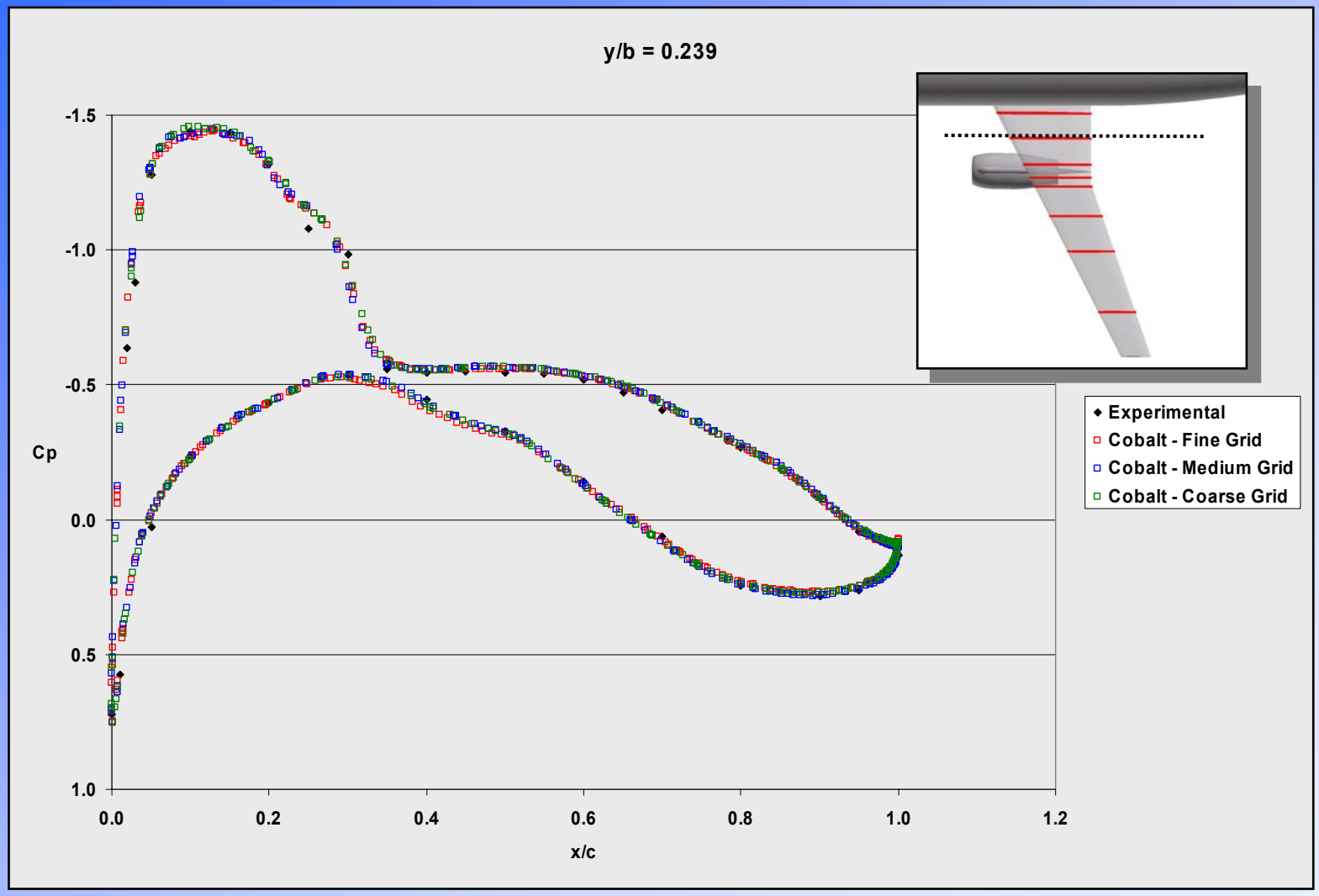
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.239



Alpha = 1.0°

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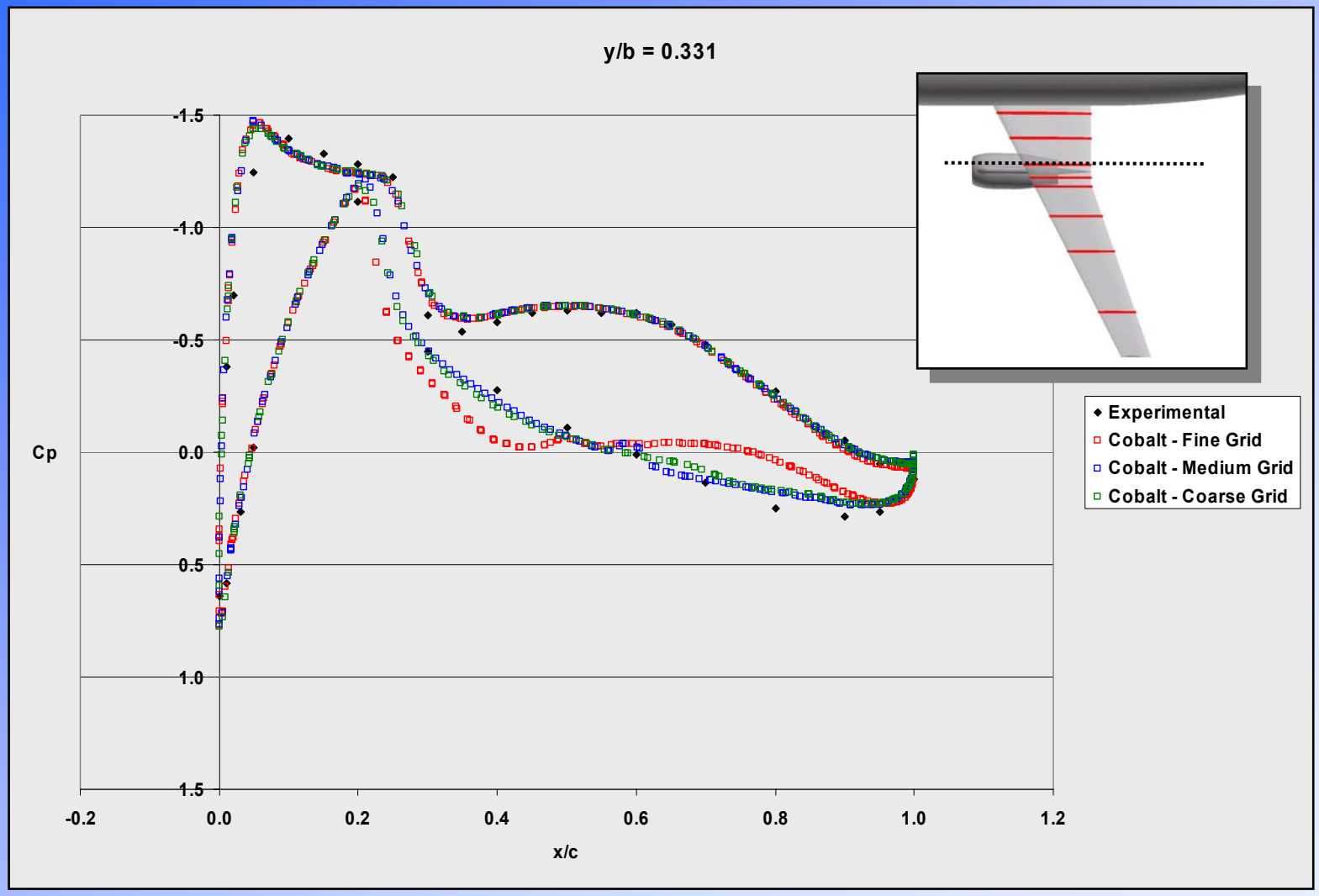
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.331



Alpha = 1.0°

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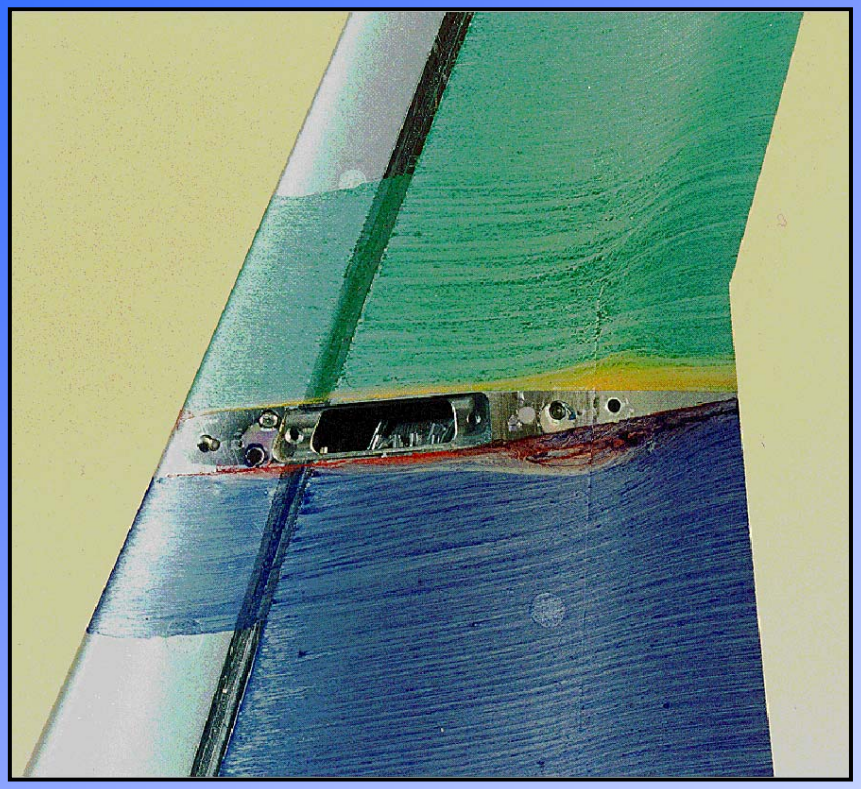
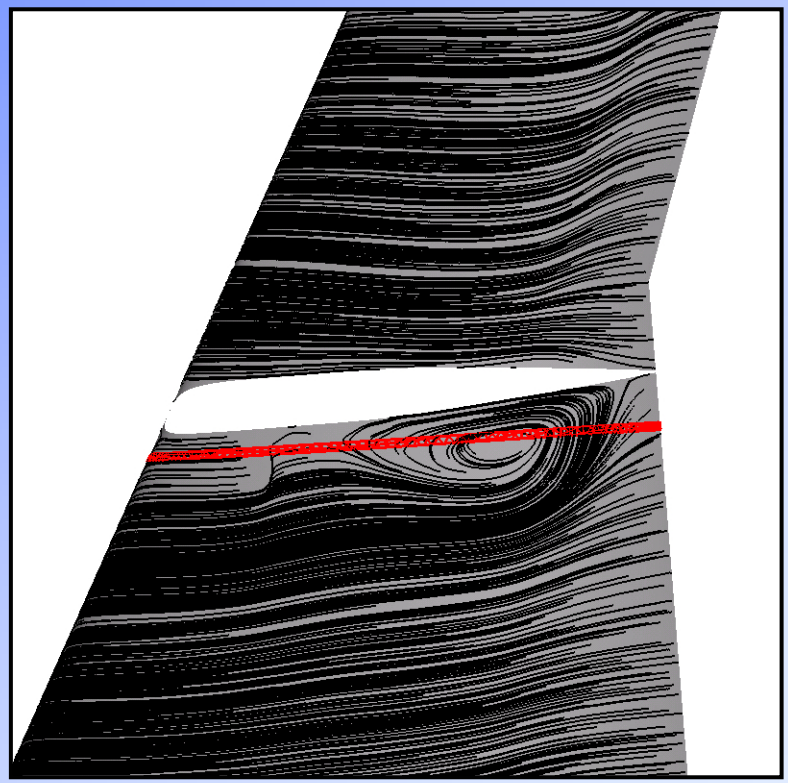
Separation Bubble Under Wing – Wind Tunnel Image





Alpha = 1.0

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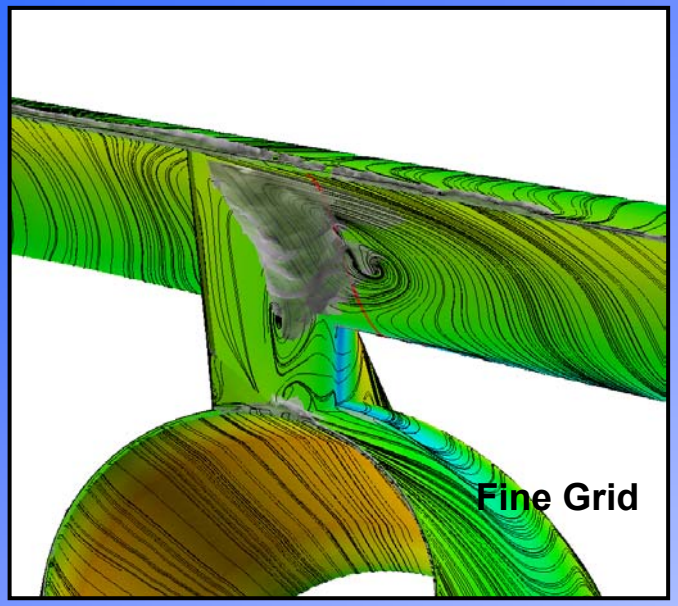
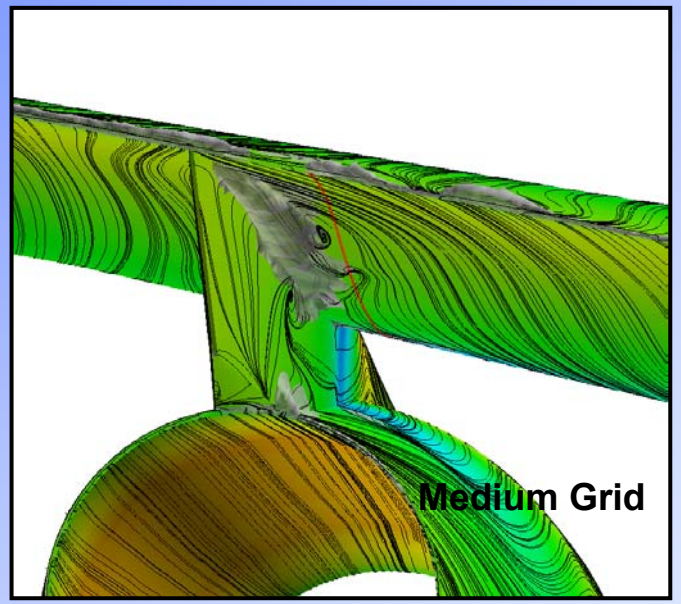
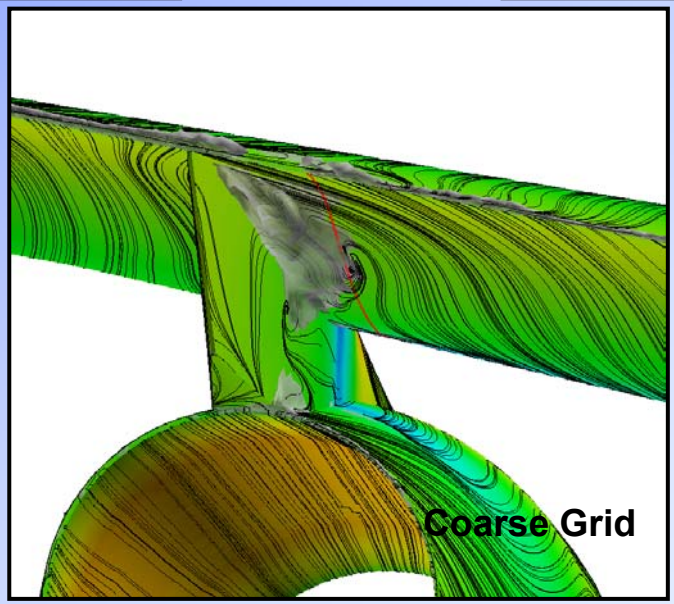
Wing-Body-Nacelle-Pylon with Isosurface of Separation







Surface colored by Cp
CL = 0.50

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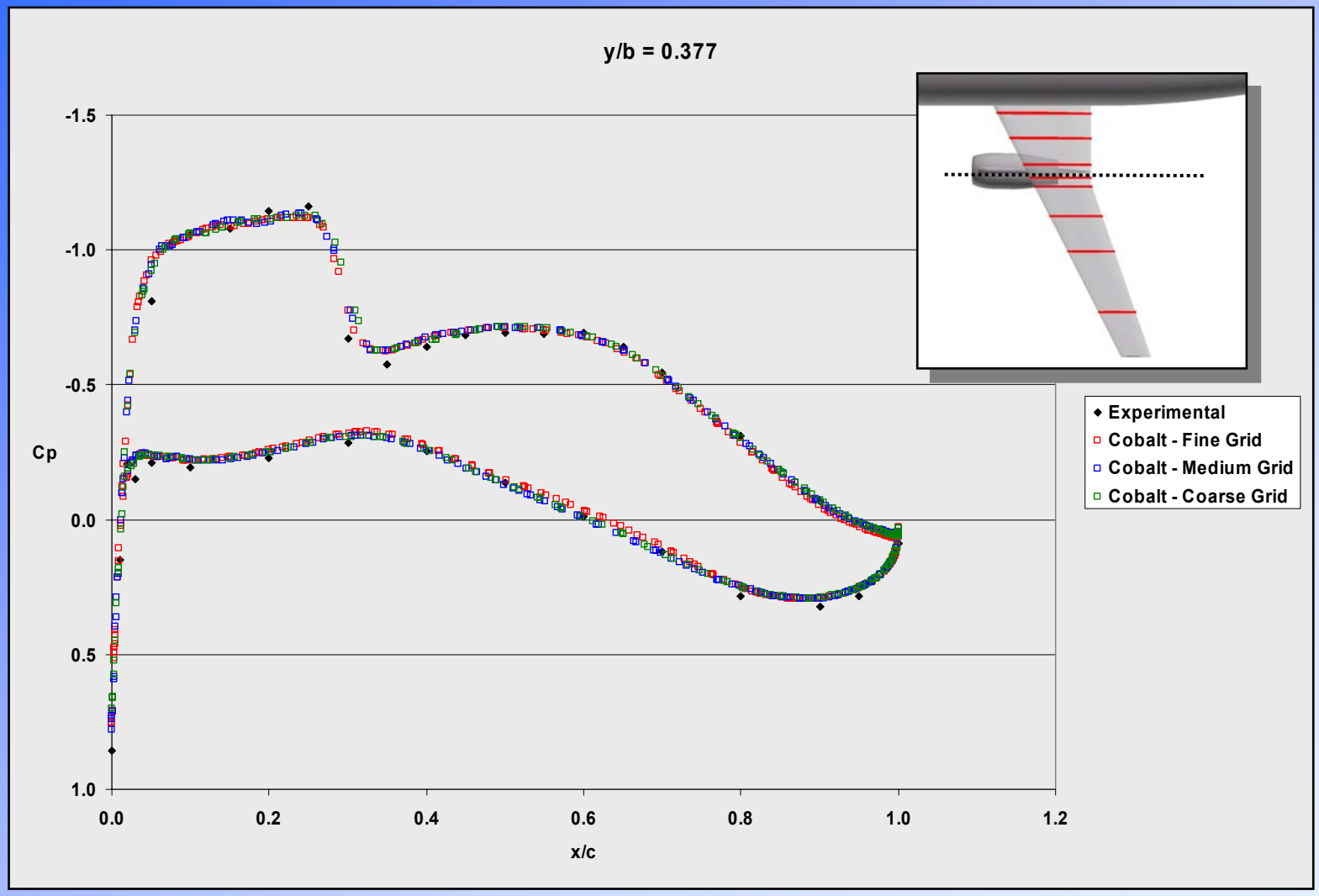
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.377



Alpha = 1.0°

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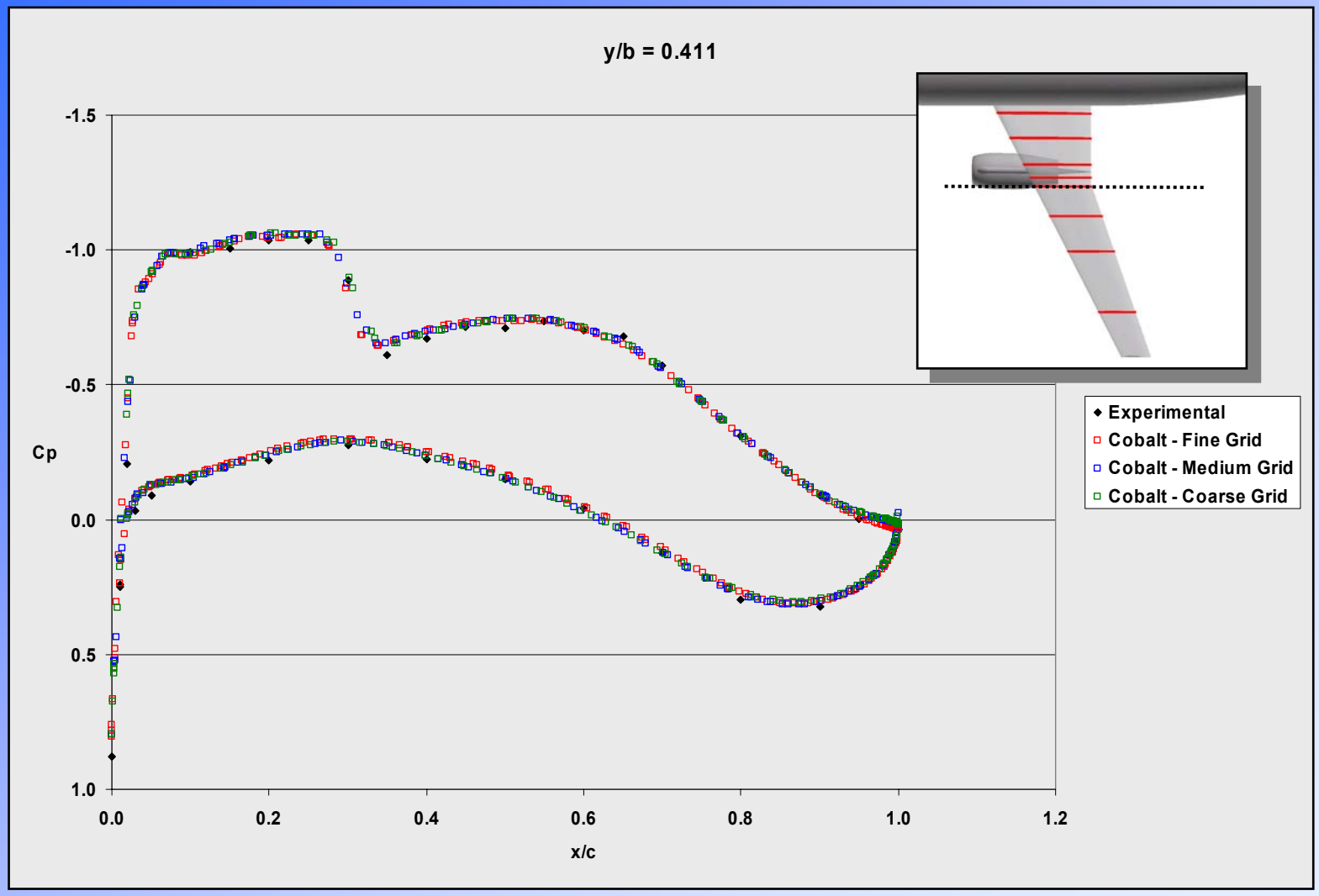
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.411



Alpha = 1.0°

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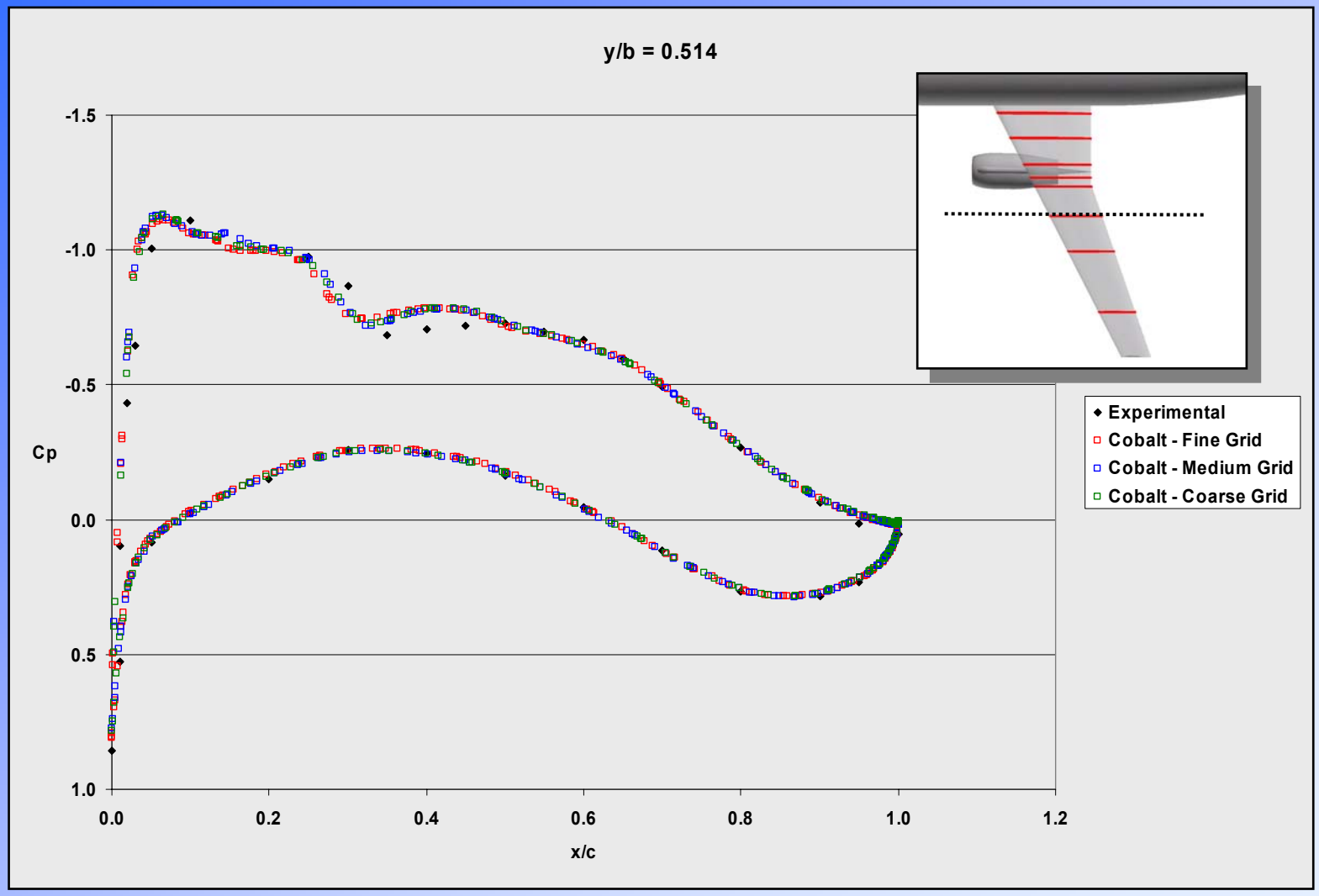
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.514



Alpha = 1.0°

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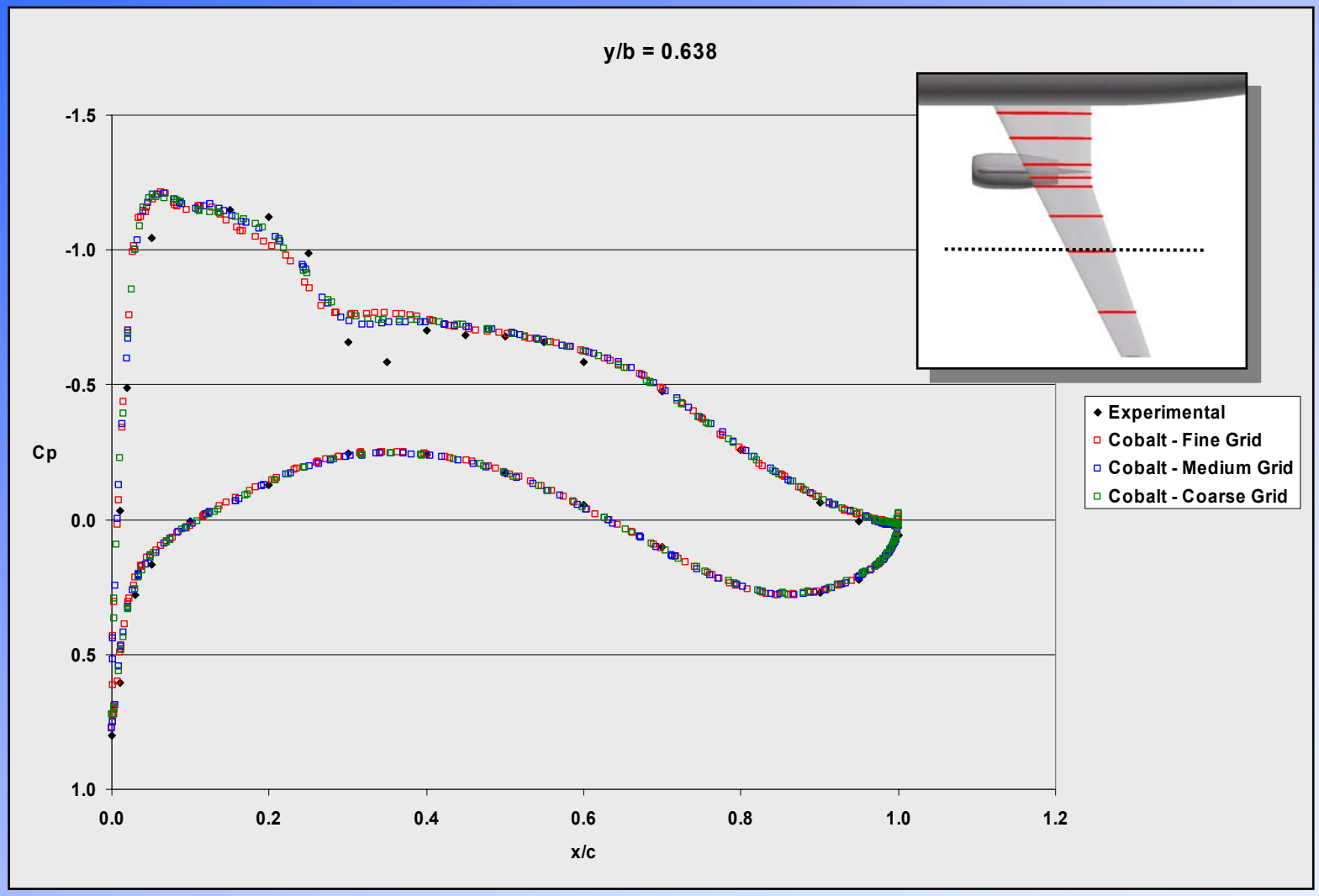
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.638



Alpha = 1.0°

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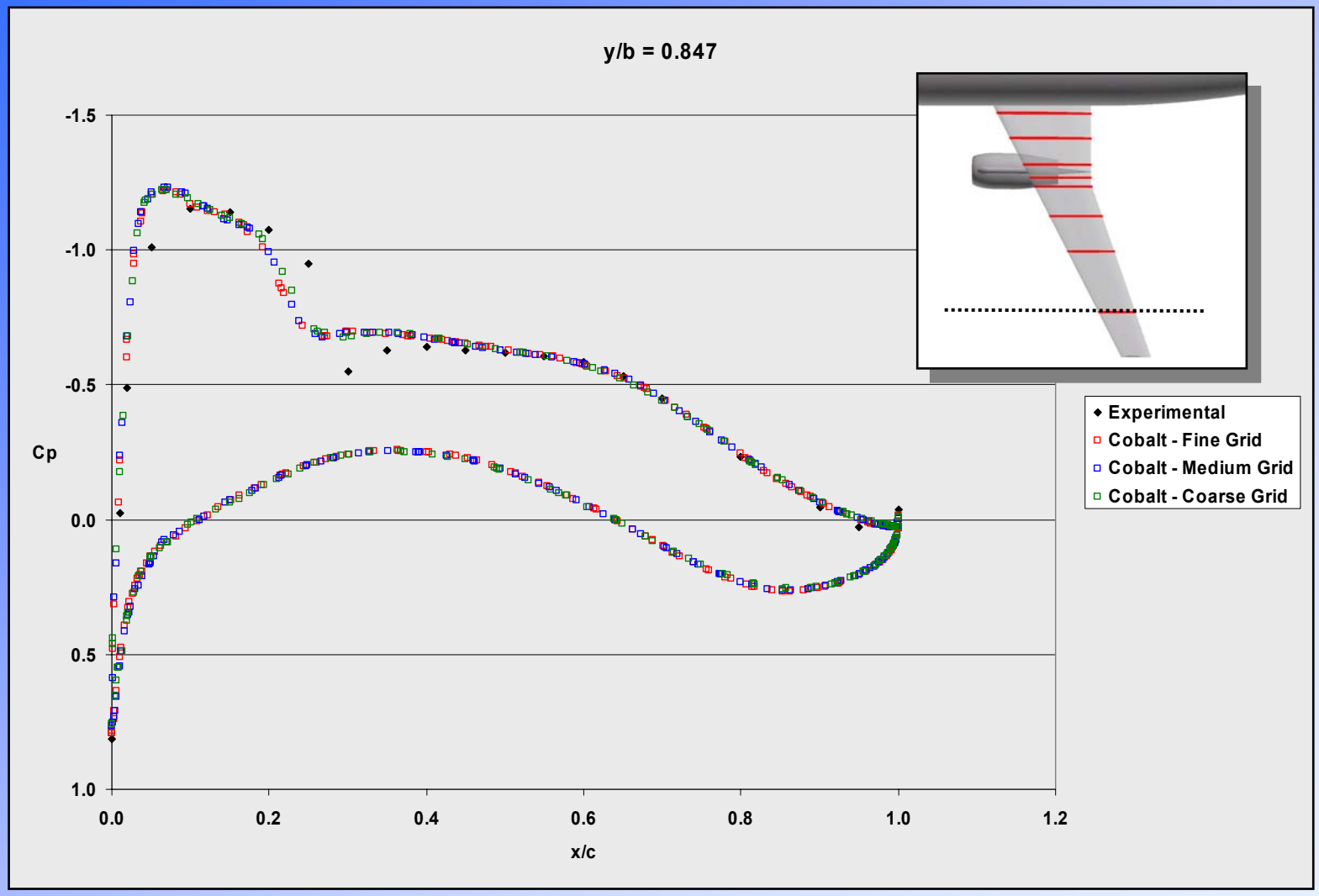
Wing-Body-Nacelle-Pylon Cp Plots – y/b = 0.847



Alpha = 1.0°

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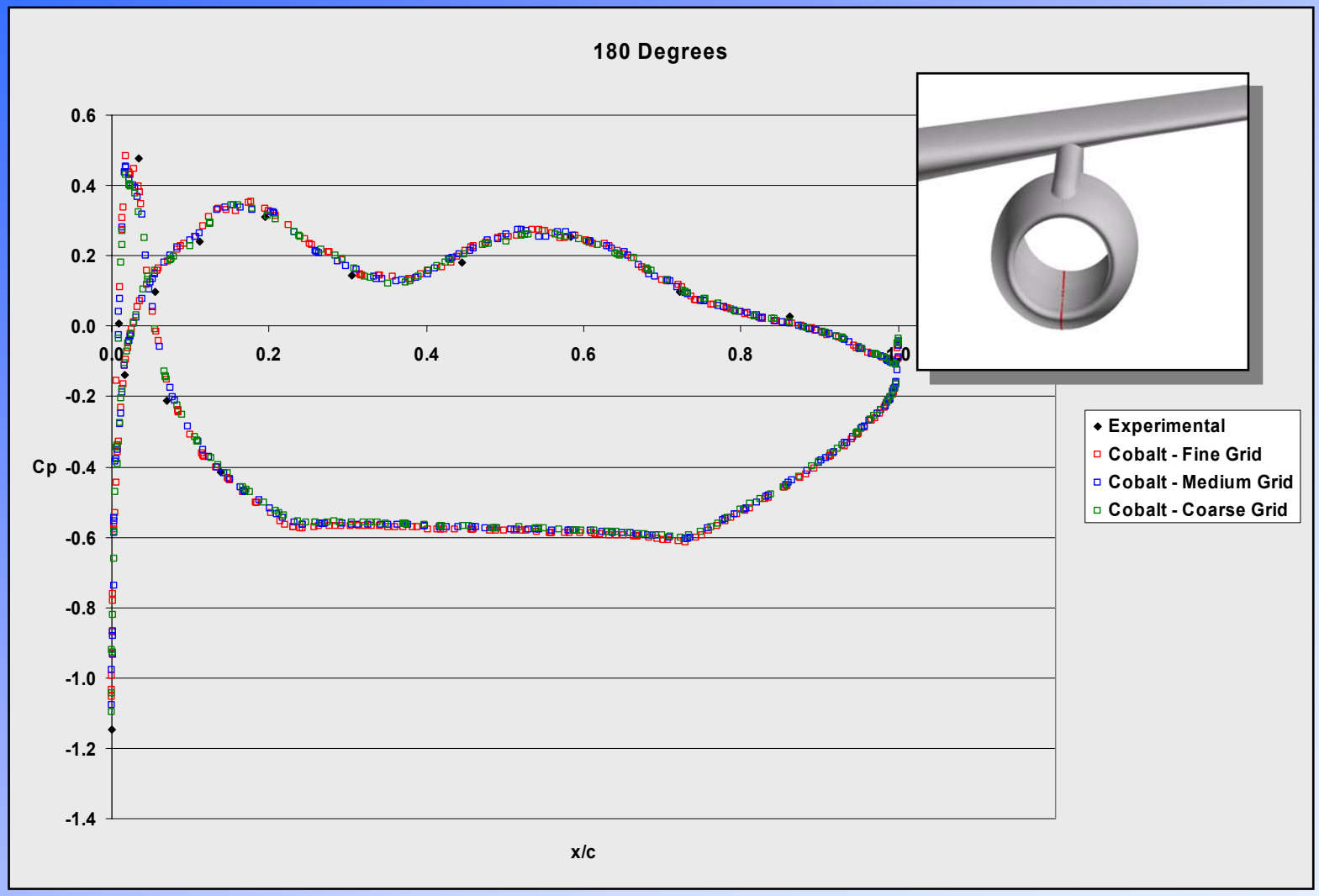
Wing-Body-Nacelle-Pylon Cp Plots – 180°



Alpha = 1.0°

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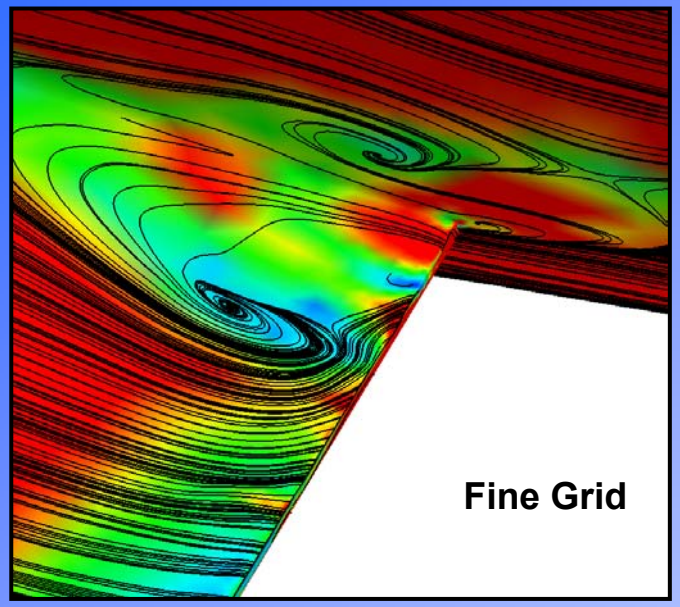
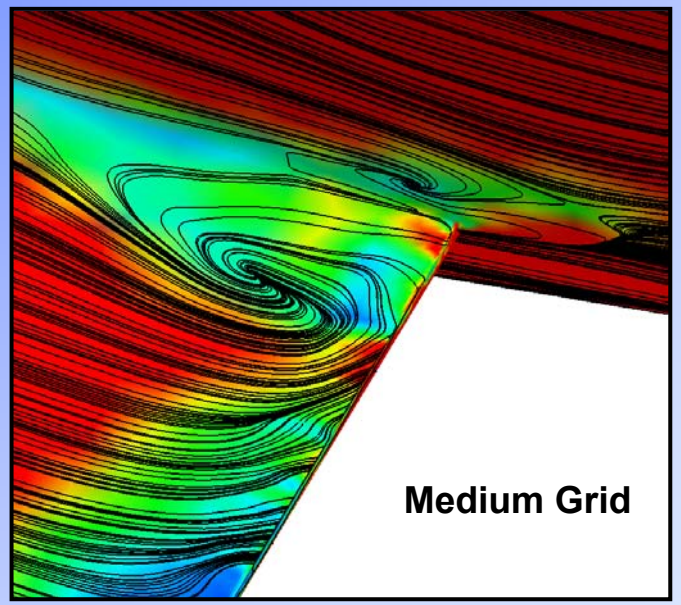
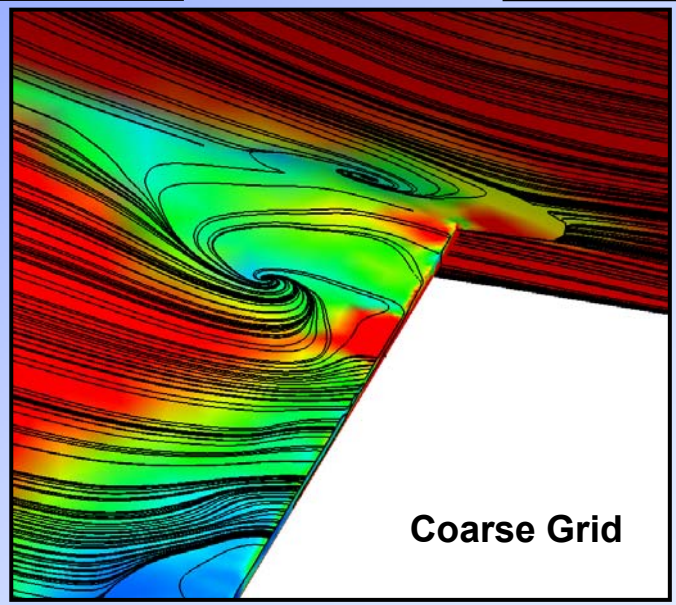
Wing-Body-Nacelle-Pylon 'Bubble' Image







Surface Colored by C_f

CL = 0.50

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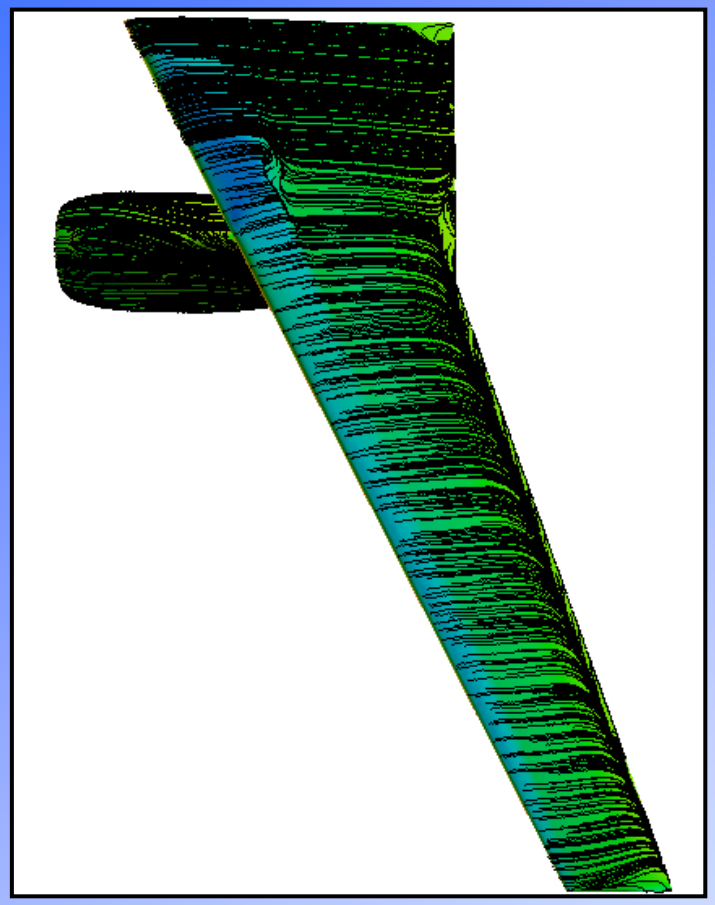
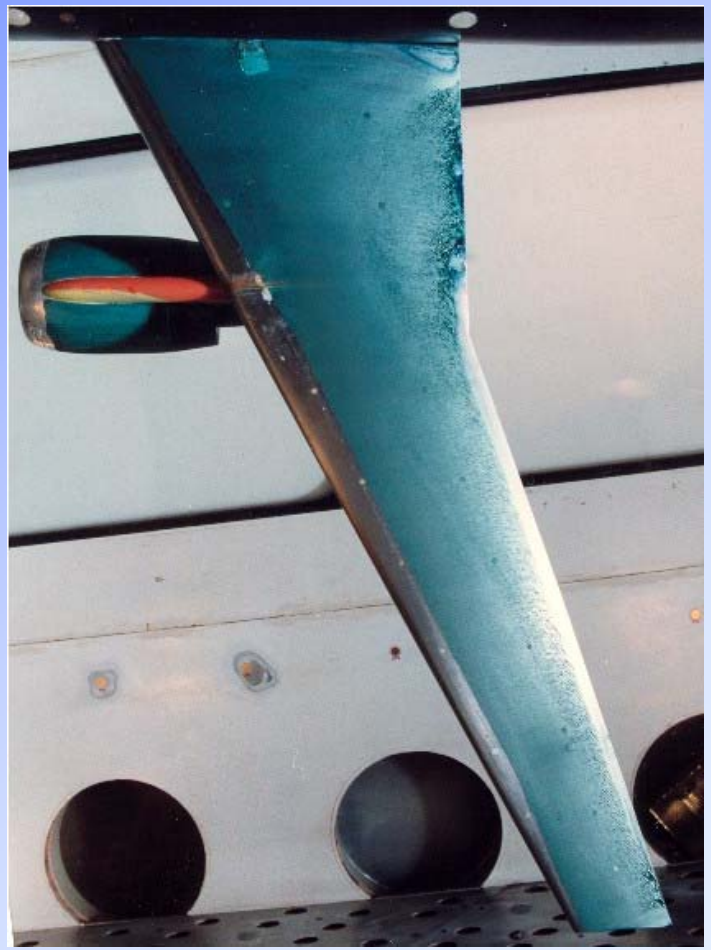
Wing-Body-Nacelle-Pylon Trailing Edge Separation





Oil flow on upper wing surface

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- Drag Prediction Workshop -

Production Blanking

- An internal boundary condition type has been added to Cobalt to allow tripping of all turbulence models. The user defines regions in the grid where turbulence- model production terms are zeroed out.

- The production blanking type does not apply a boundary condition to the specified region. Instead, it zeroes out the production terms of the turbulence model of any cell within the box. Its effect is to trip the boundary layer to turbulent flow right outside of the user-defined box.

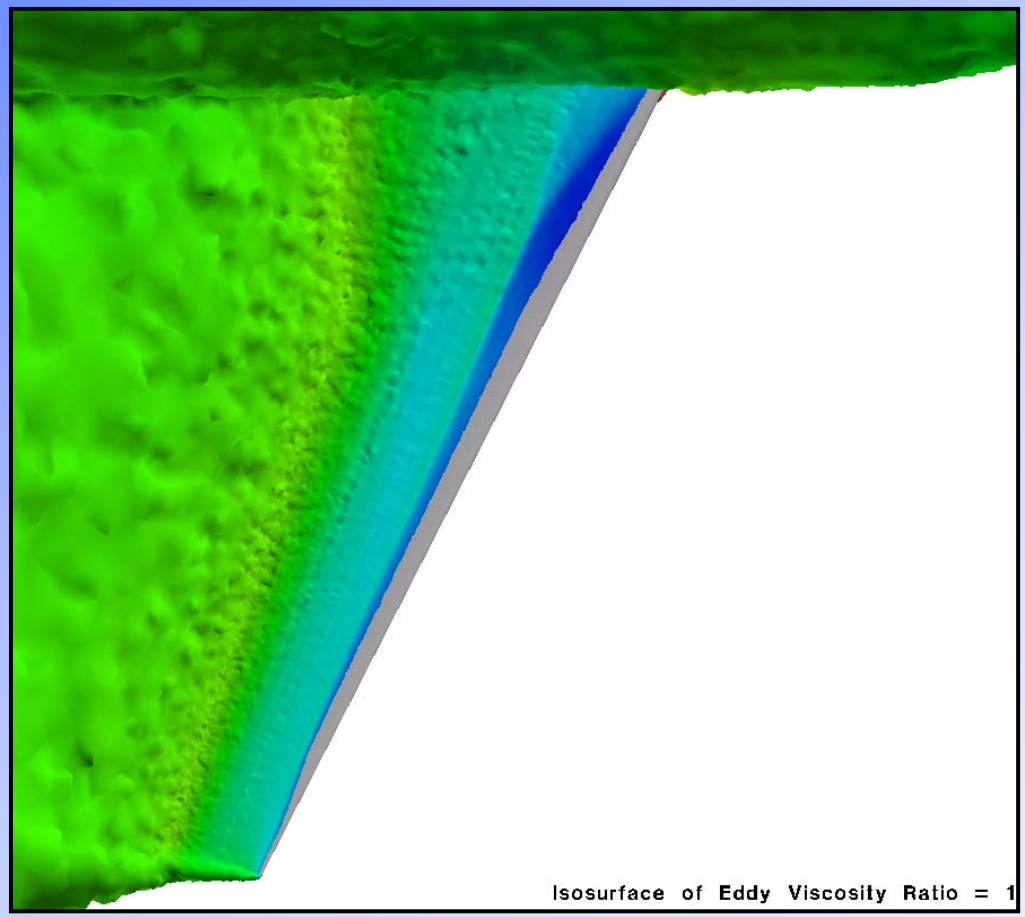
- Drag Prediction Workshop -

Production Blanking

CL_{TRIP} = 0.5346
CL = 0.5213
CL_{EXP} = 0.4984

CD_{TRIP} = 0.0298
CD = 0.0299
CD_{EXP} = 0.0294

CM_{TRIP} = -0.1253
CM = -0.1188
CM_{EXP} = -0.1213



cobalt solutions