Study of CFD Variation on Transport Configurations from the Second Drag Prediction Workshop

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Methods

- CFL3D – finite volume upwind Roe
  - using 1-to-1 ICEM grids (thin-layer in all 3 directions) and overset grids (thin-layer in normal direction)
  - 3 turbulence models (SA, SST, EASM-ko)
  - EASM-ko is nonlinear explicit algebraic stress in k-omega formulation
- OVERFLOW – finite difference upwind Roe
  - using overset grids (thin-layer in normal direction)
  - 2 turbulence models (SA, SST)

Case 1 – CL=0.5, fully turbulent

Code / Grid	Turb model	wb(c)	wb(m)	wb(f)	wbnp(c)	wbnp(m)	wbnp(f)
CFL3D, 1to1	SA	1.1	1.2	1.3	1.4	1.5	1.6
CFL3D, 1to1	SST		1.7			1.8	
CFL3D, 1to1	EASM		1.9			1.10	
CFL3D, overset	SA	1.11	1.12	1.13	1.14	1.15	1.16
OVERFLOW, overset	SA	1.17	1.18	1.19	1.20	1.21	1.22
OVERFLOW, overset	SST		1.23			1.24	

(shaded = not done yet)

Case 2 – drag polar, transition specified

Code / Grid	Turb	Case	-3	-2	-1.5	-1	0	1	1.5
CF, 1	SA	wb(m)	2.1	2.2	2.3	2.4	2.5	2.6	2.7
CF, 1	SST	wb(m)	2.8		2.9		2.10		2.11
CF, 1	EASM	wb(m)	2.12		2.13		2.14		2.15
CF, O	SA	wb(m)	2.16	2.17	2.18	2.19	2.20	2.21	2.22
OV, O	SA	wb(m)	2.23	2.24	2.25	2.26	2.27	2.28	2.29
CF, 1	SA	wbnp (m)	2.30	2.31	2.32	2.33	2.34	2.35	2.36
CF, O	SA	wbnp (m)	2.37	2.38	2.39	2.40	2.41	2.42	2.43
OV, O	SA	wbnp (m)	2.44	2.45	2.46	2.47	2.48	2.49	2.50

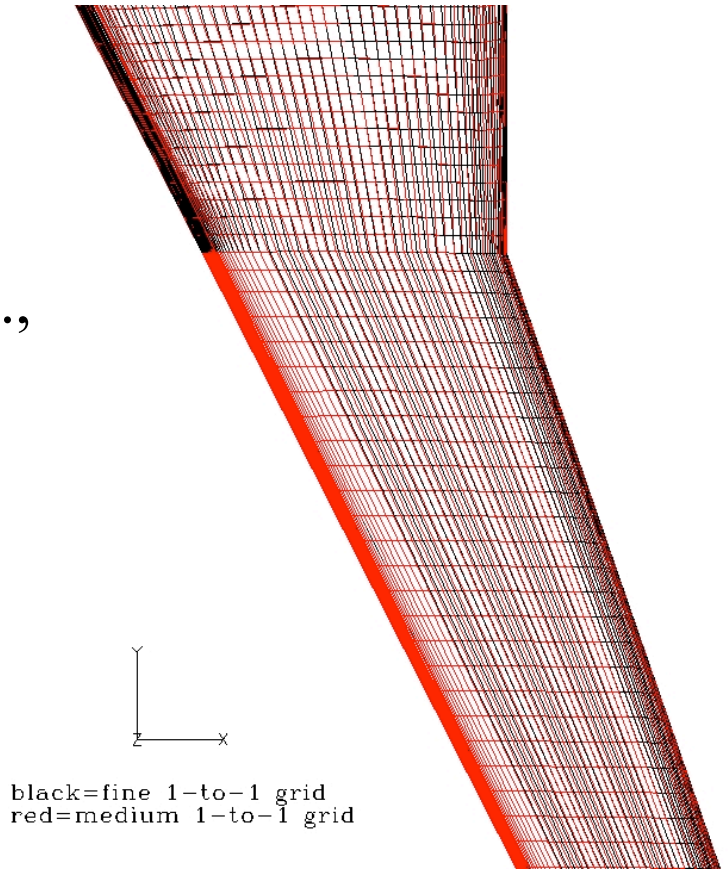
Case 3 – CL=0.5, transition specified

Code / Grid	Turb	wb(m)	wbnp(m)
CF, 1	SA	3.1	3.2
CF, O	SA	3.3	3.4
OV, O	SA	3.5	3.6

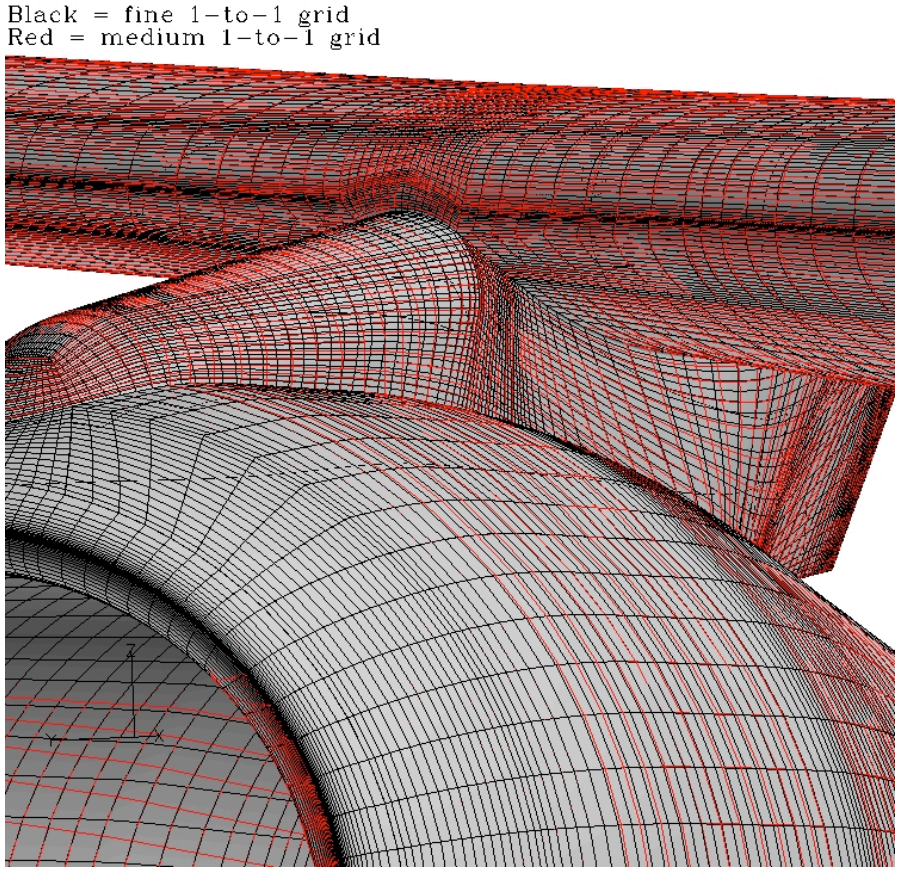
Grid issues

ICEM 1-to-1 grids:

- less than factor 2 between successive grids
- no uniform refinement, e.g., similar surface point distribution between successive grids

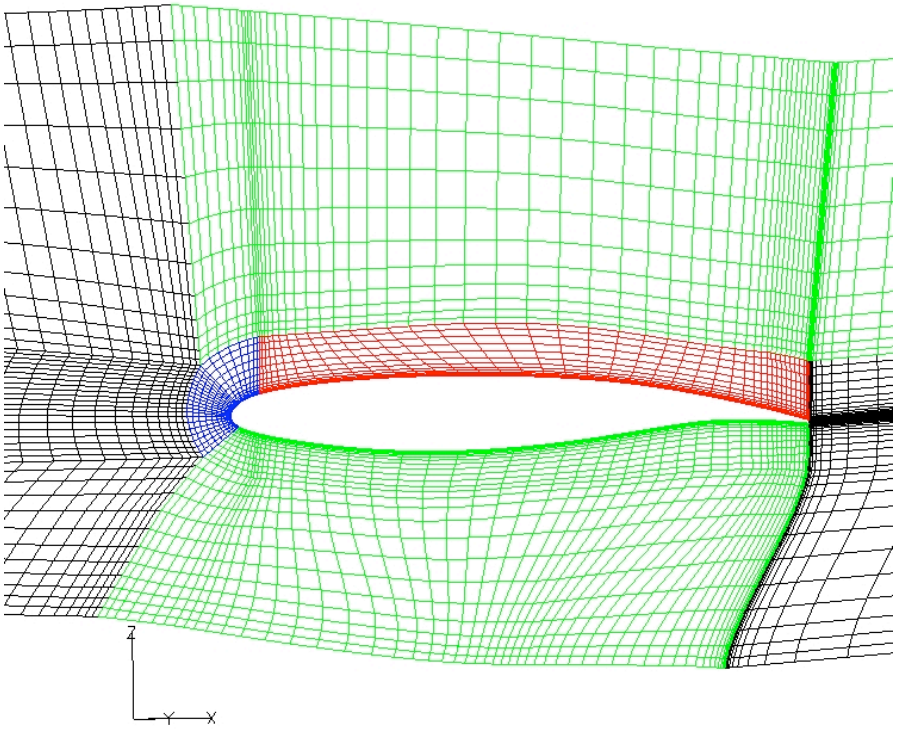


Grid issues, cont'd



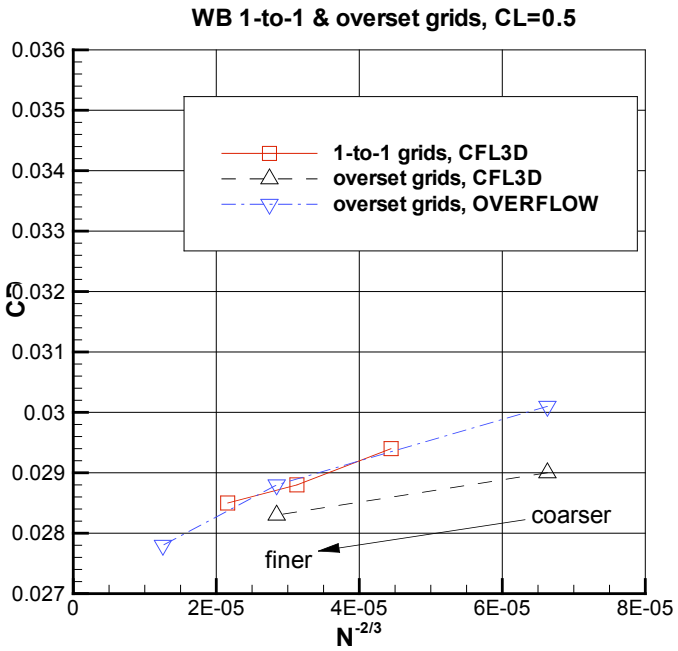
Grid issues, cont'd

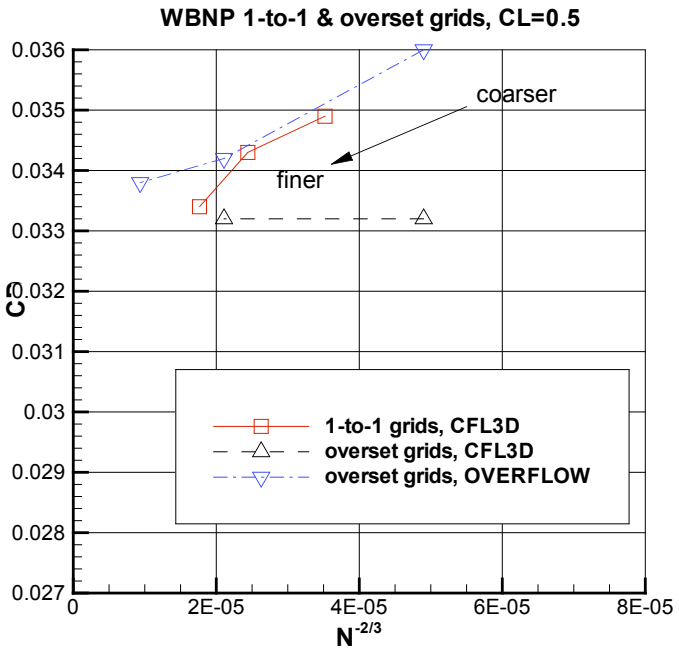
ICEM 1-to-1 WBNP grids:
- non-smooth
- non-orthogonal in places
- sudden grid spacing changes



Grid effect, CL=0.5

fully turbulent

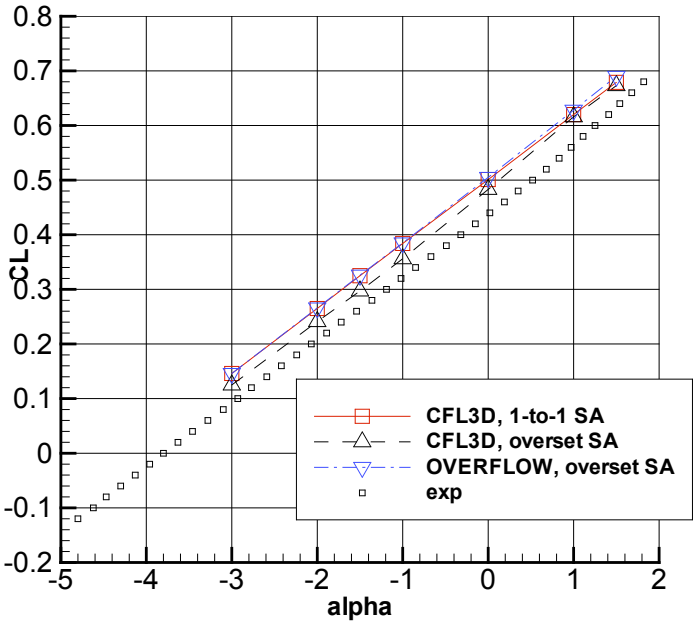




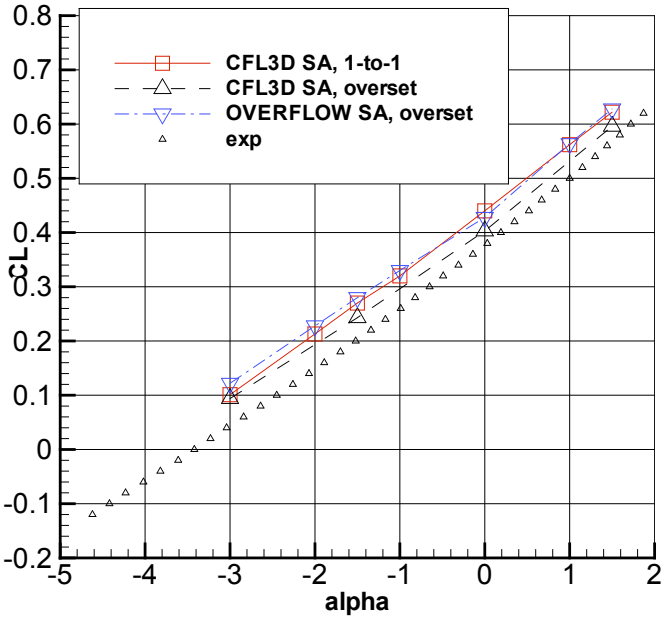
Lift curve on medium grids

transition specified

WB



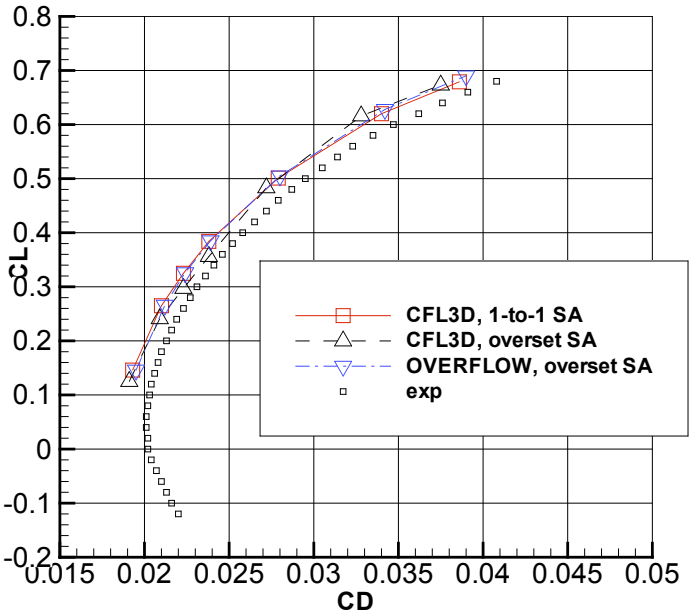
WBNP



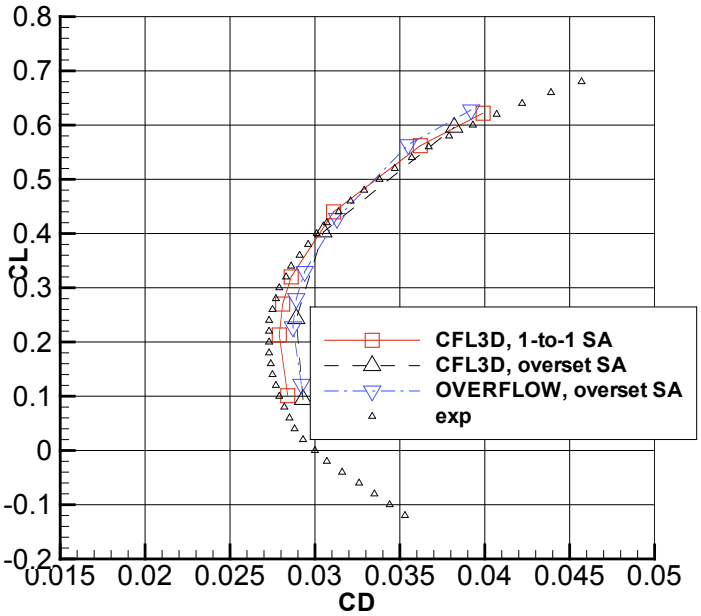
Drag polar on medium grids

transition specified

WB



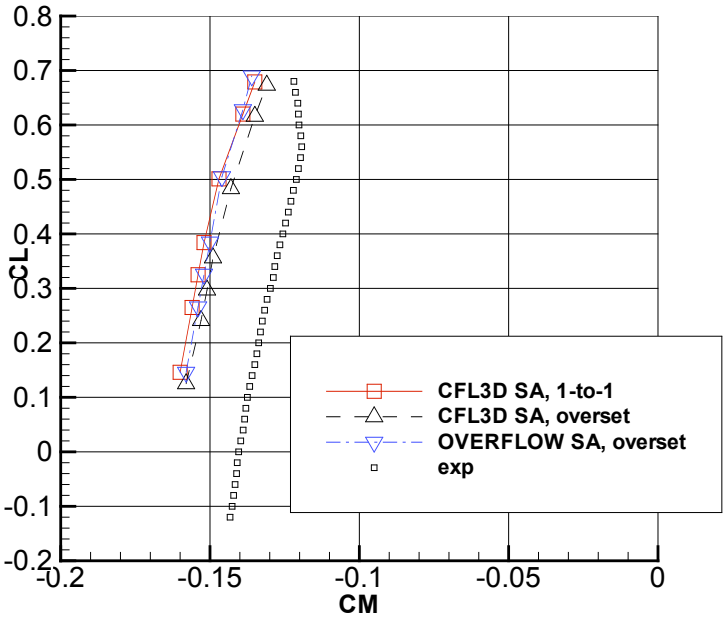
WBNP



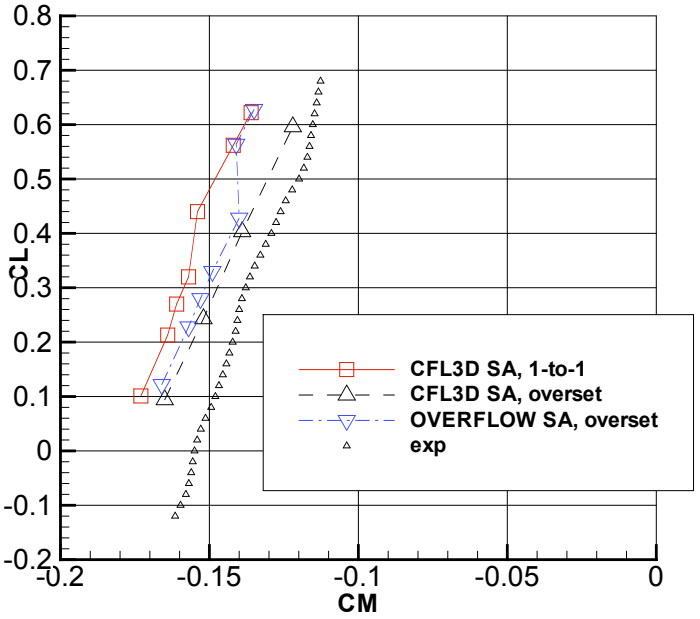
C_M on medium grids

transition specified

WB

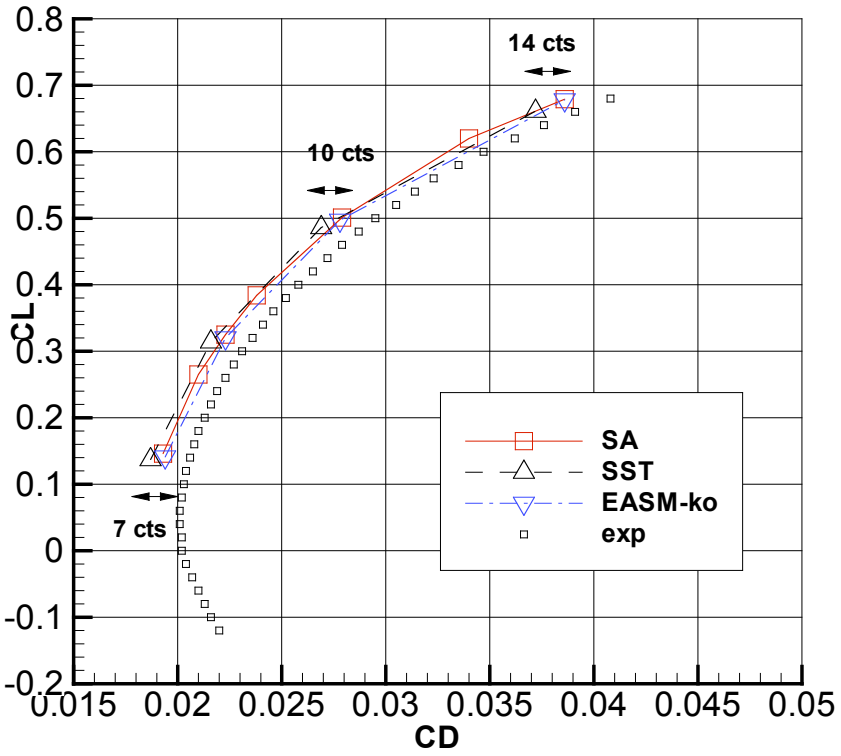


WBNP



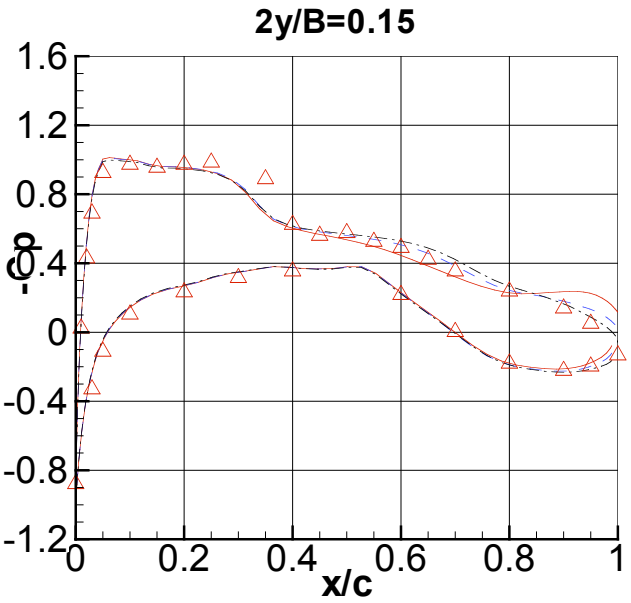
Turbulence model effect on drag

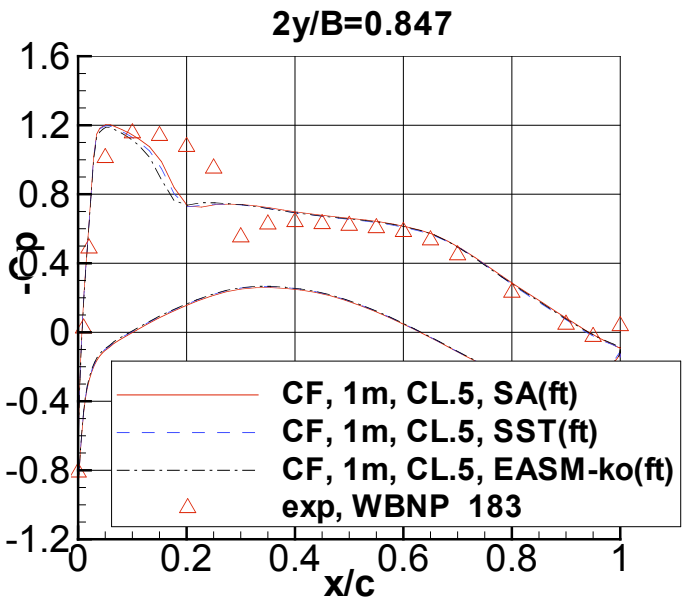
WB, CFL3D, medium 1-to-1 grid, transition specified



Turbulence model effect on Cp

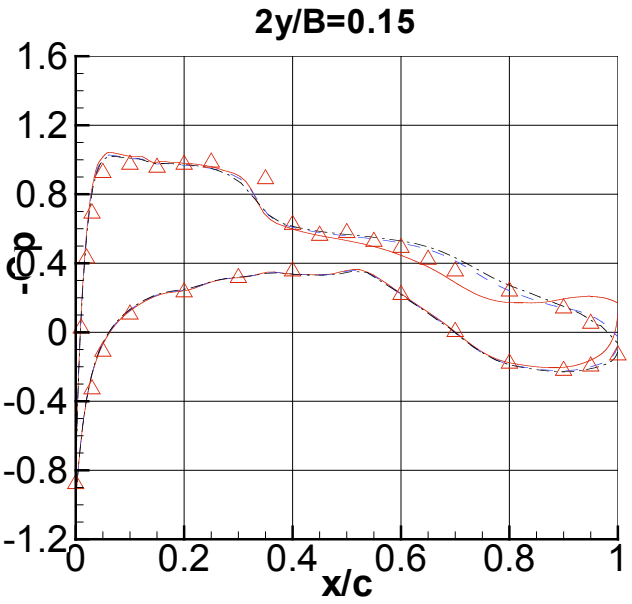
typically significant only at root station

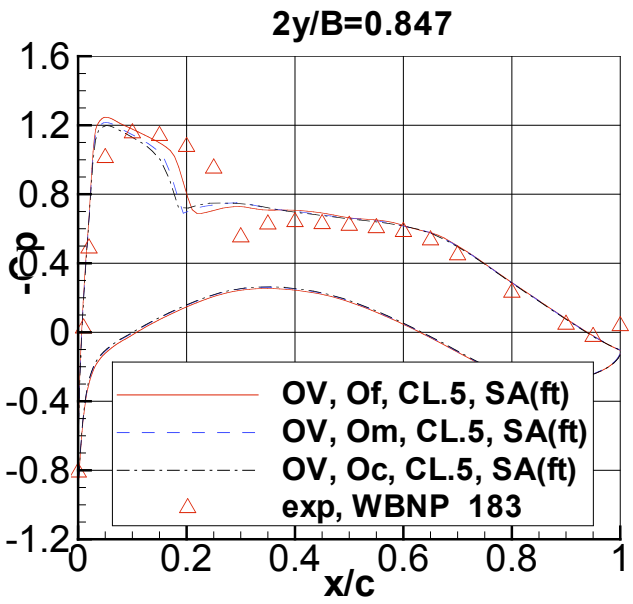




Overset grid density effect on Cp

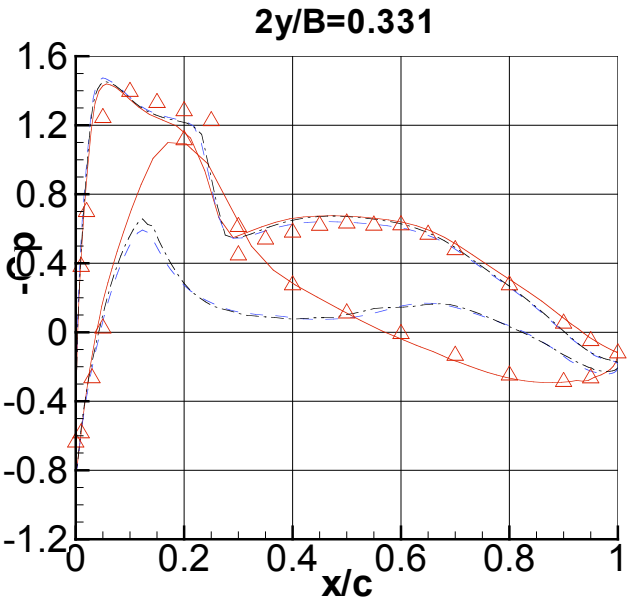
largest effects seen at root and tip stations
biggest change between med & fine grids

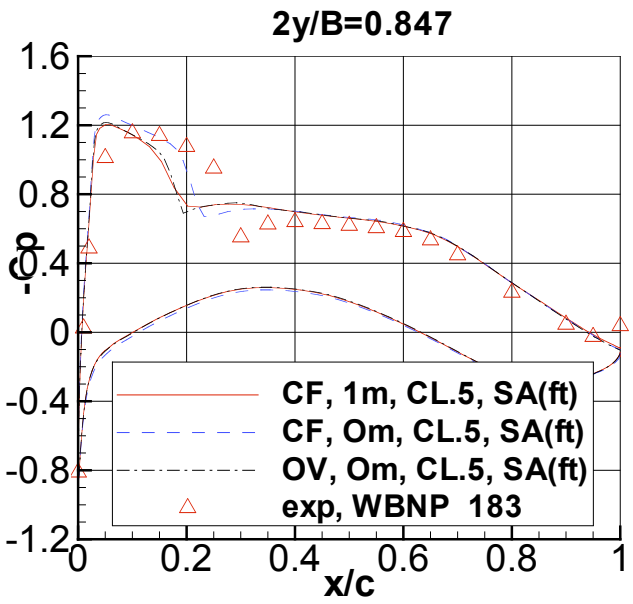




Grid type effect on Cp

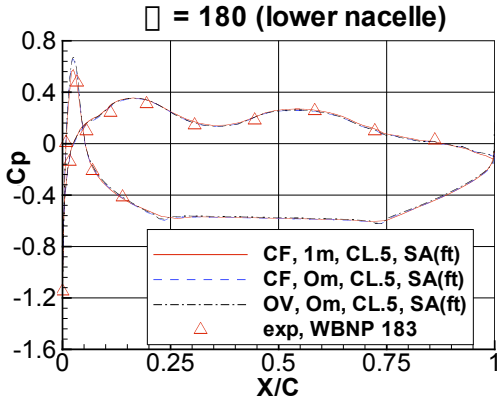
dramatic difference at station inboard of nacelle

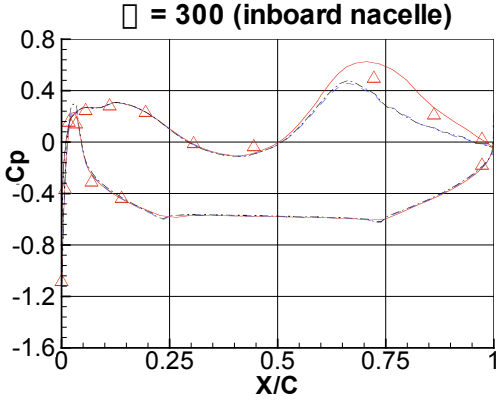


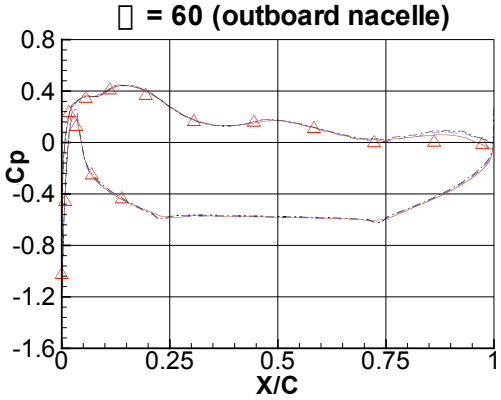


Grid type effect on nacelle Cp

difference at inboard location

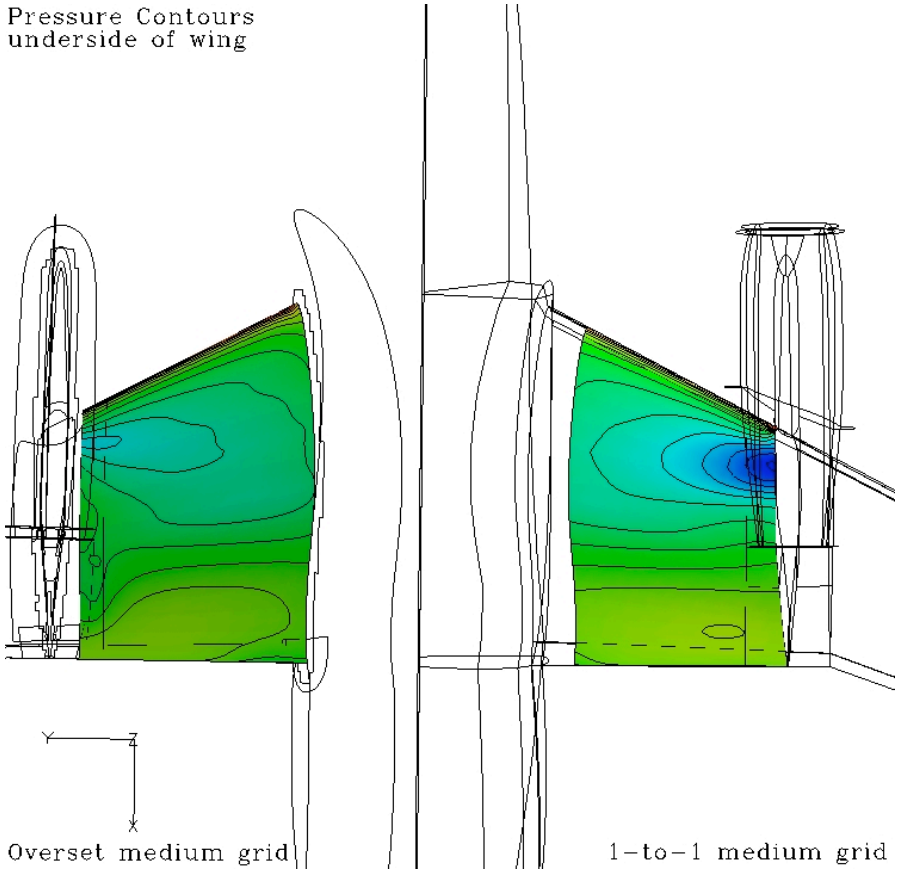






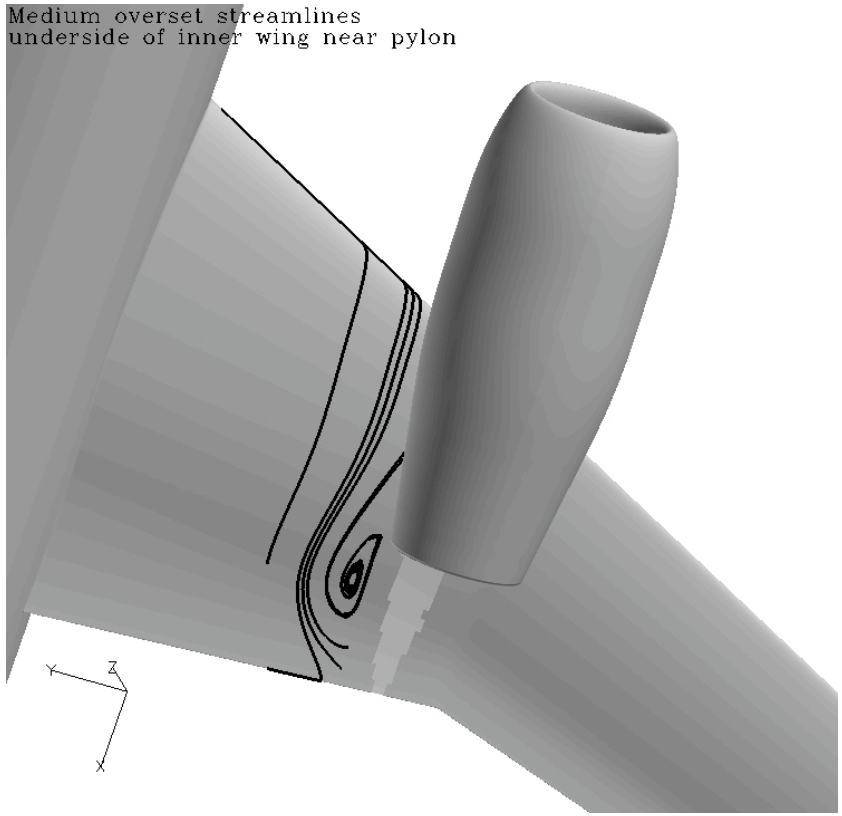
Lower-wing pressure contours

overset 1-to-1

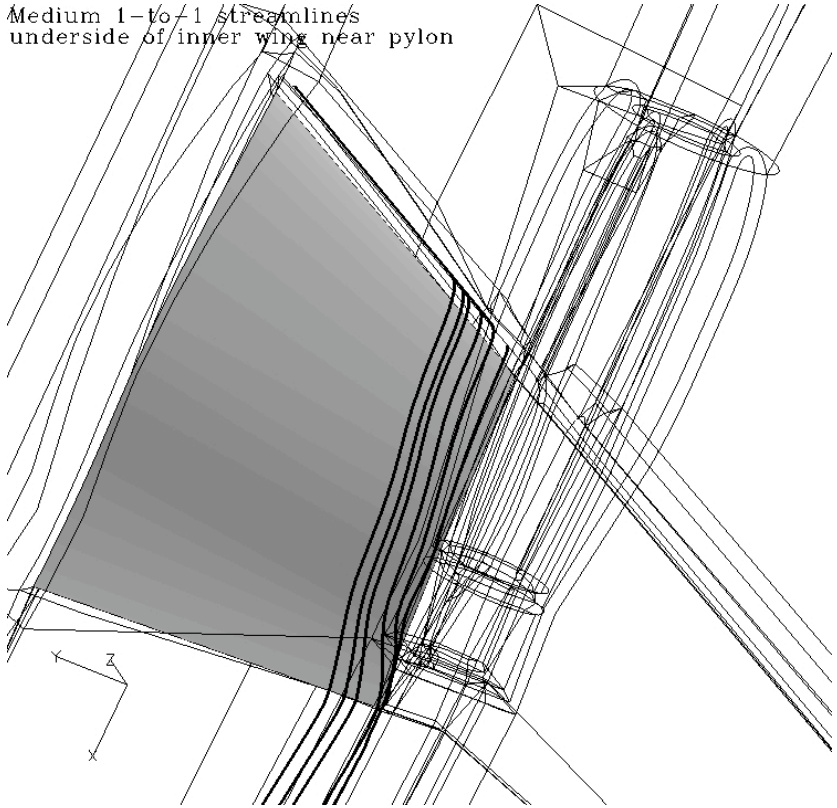


Lower wing streamlines

overset

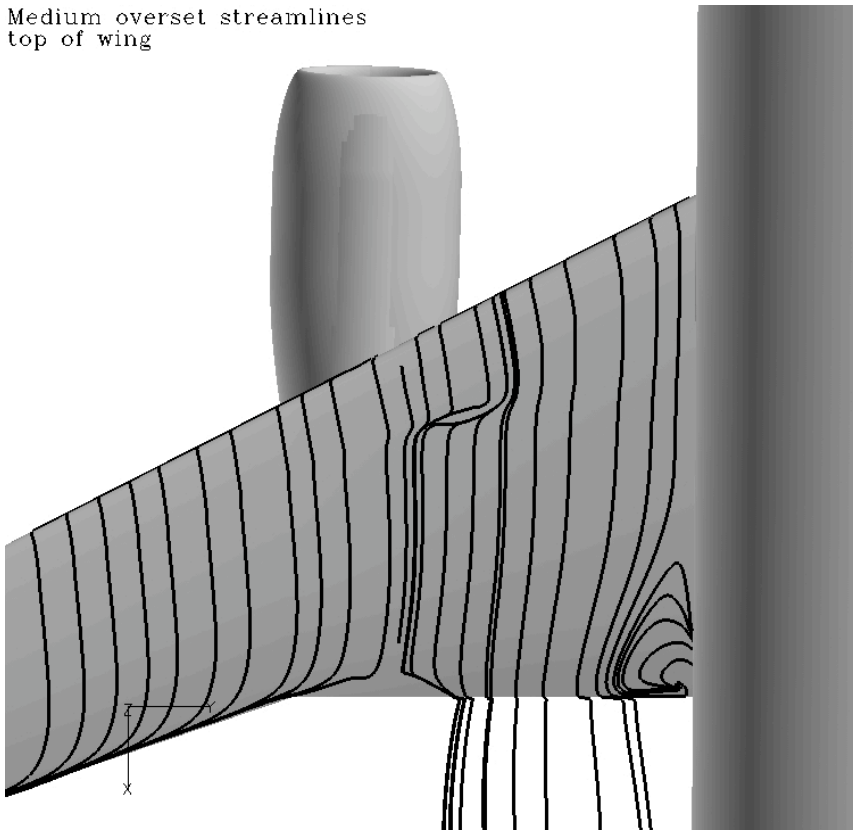


1-to-1

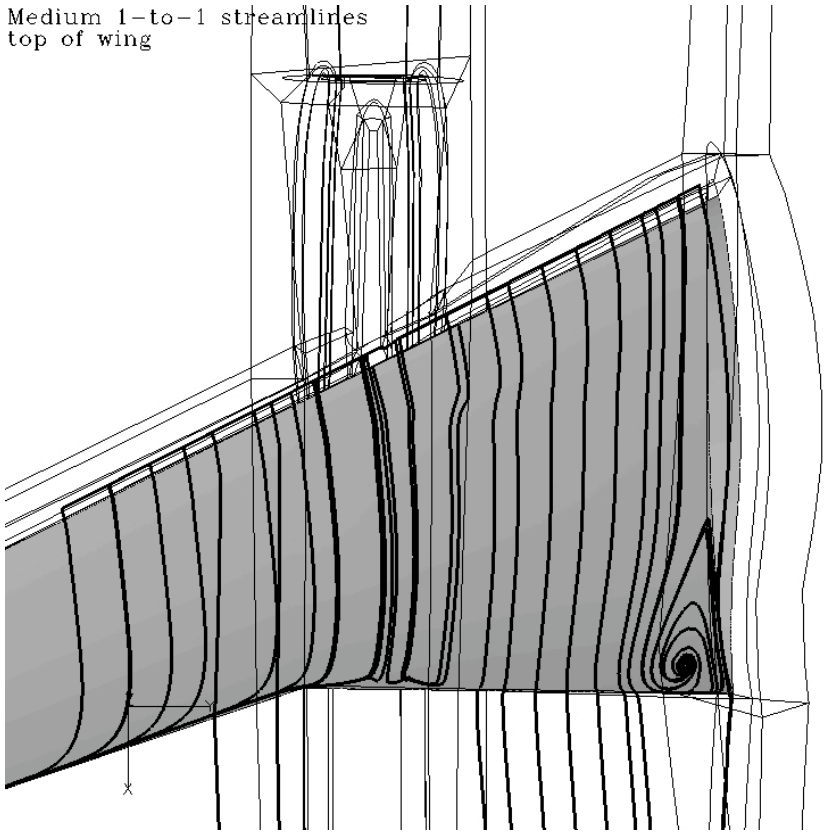


Upper wing streamlines

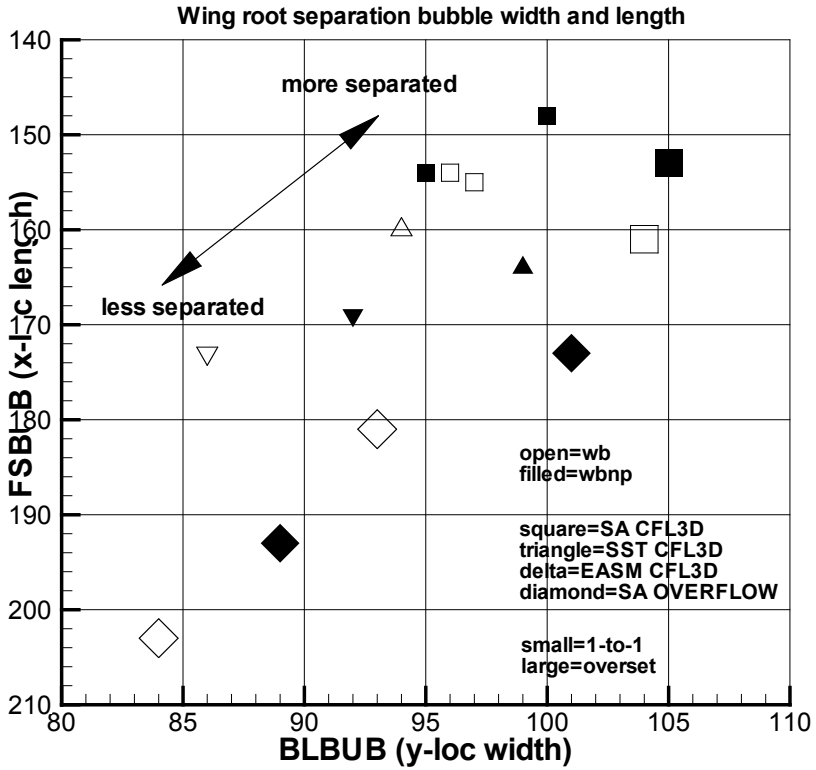
overset



1-to-1

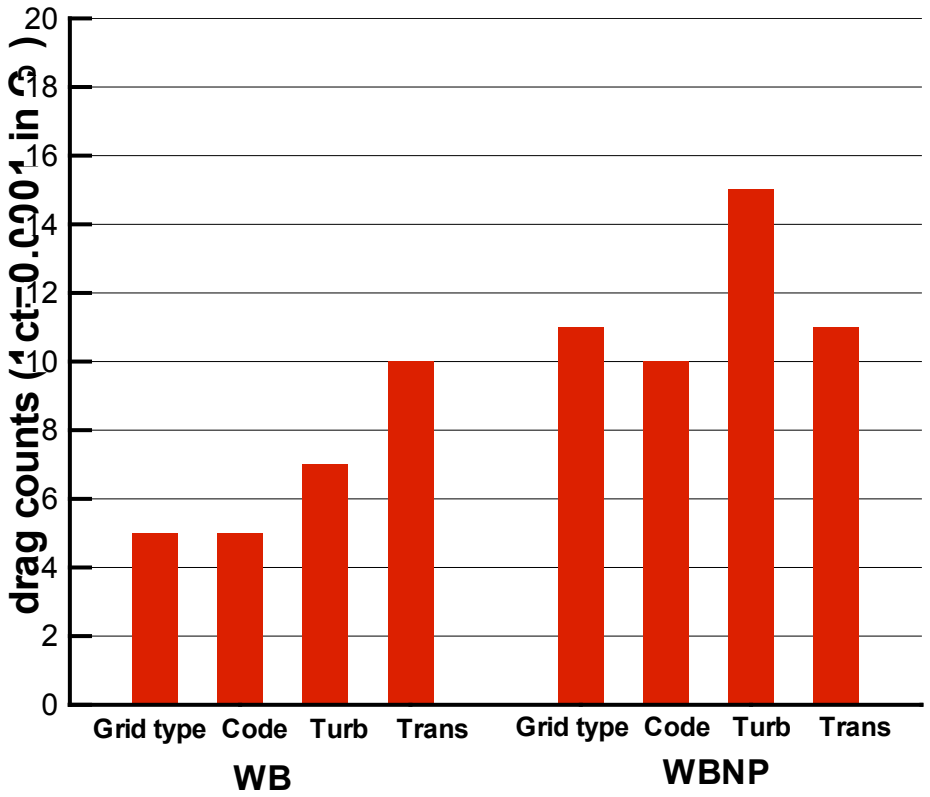


T.E. wing-root bubble size



Summary of various effects on drag

at CL=0.5



Summary

- Grid has a big effect on physics (inboard of nacelle), although this effect may be masked if only look at integrated quantities
- Provided “b2b-icem” 1-to-1 grids not suitable for grid study (too little variation); WBNP grid of poor quality
- SA turbulence model tends to give the most wing root separation, EASM the least
- SST turbulence model drag generally lowest; by 7-15 cts
- Individual effects due to grid type, code, turb model, and transition at C_L=0.5: 5-10 cts for WB, 10-15 cts for WBNP

Typical CPU timings

for the DPW-II cases

- Typically 2000-5000 cycles needed per case
- CFL3D
  - 60e-6 sec/gridpt/cycle/node PC cluster (1-to-1)
  - 30e-6 sec/gridpt/cycle/node PC cluster with Myrinet (1-to-1)
  - 60-110e-6 sec/gridpt/cycle/node Alpha cluster with Myrinet (1-to-1 faster than overset for multi-processors)
  - 230e-6 sec/gridpt/cycle/node Origin 2000 cluster (1-to-1)
  - 17e-6 sec/gridpt/cycle Cray SV1 single processor
- OVERFLOW
  - 30e-6 sec/gridpt/cycle/node PC cluster
  - 75e-6 sec/gridpt/cycle/node Origin 3000 cluster (mlp version)