



CFD Computations for Common Research Model Using the Code HiFUN

Govindasamy. T & Balan R
Project Associates

N. Balakrishnan
Associate Professor

Computational Aerodynamics Laboratory,
Department of Aerospace Engineering,
Indian Institute of Science, Bangalore-560012, India

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Outline



- Introduction
- Typical Grids
- Results
- Conclusions



Introduction



Tools employed

- **Grid generator:** ICEMCFD and TGRID.
- **Solver:** HiFUN***
- **Post-processing software:** ENSIGHT and TECPLOT.

*** www.sandi.co.in

Features of the code- HiFUN

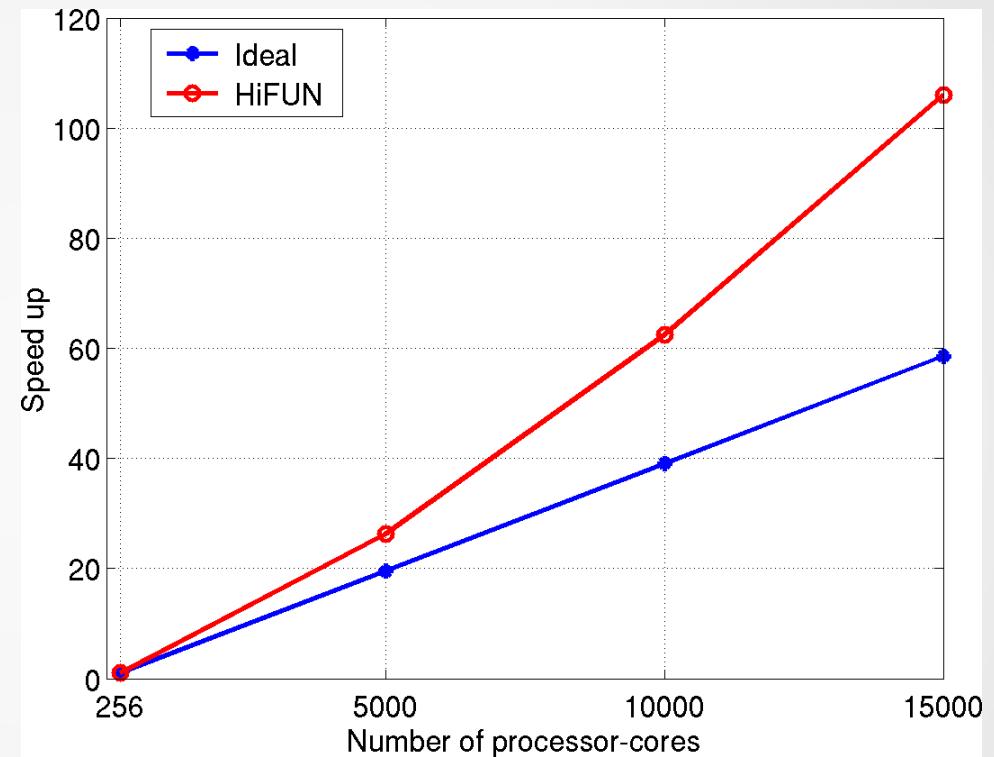


- Unstructured cell centre finite volume methodology.
- Higher order accuracy: linear reconstruction procedure.
- Flux limiting: Venkatakrishnan Limiter.
- Inviscid flux computation: Roe scheme.
- Convergence acceleration: matrix free symmetric Gauss Seidel relaxation procedure.
- The viscous flux discretization: Green–Gauss theorem based diamond path reconstruction.
- Eddy viscosity computation: Spalart Allmaras TM.
- Parallelization: MPI.

Parallel performance



Sahasrat (Cray XC40)
33 K Xeon cores @ 1 Petaflop



Reference: Parallel performance of HiFUN Solver on Cray XC40 - CAd TN 2015:03

N. Balakrishnan

CAd Lab, IISc

Computational details:

WB: Medium grid with about 45 million field cells



- Computer platform: Sahasrat-Cray-XC40
- Number of processors: 1024
- Operating system: Linux Cray customized OS x86_64
- Compiler: Cray Fortran compilers
- Run time wall clock: 2 hours
- Memory requirement of HiFUN: 45 Gb



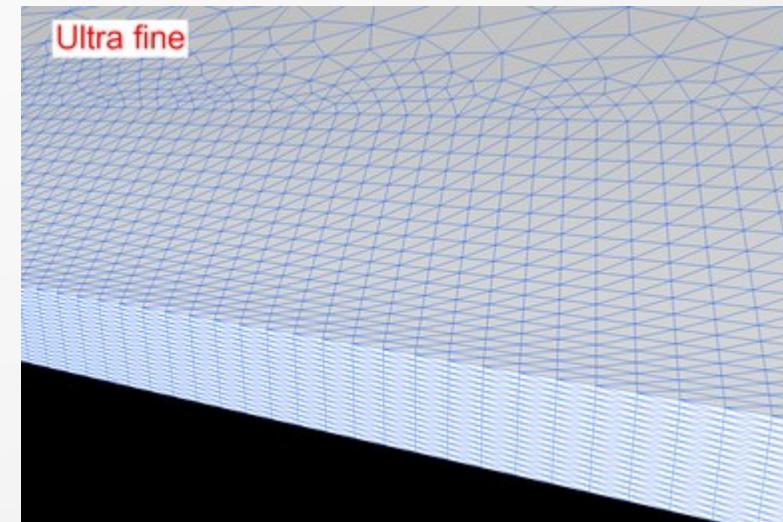
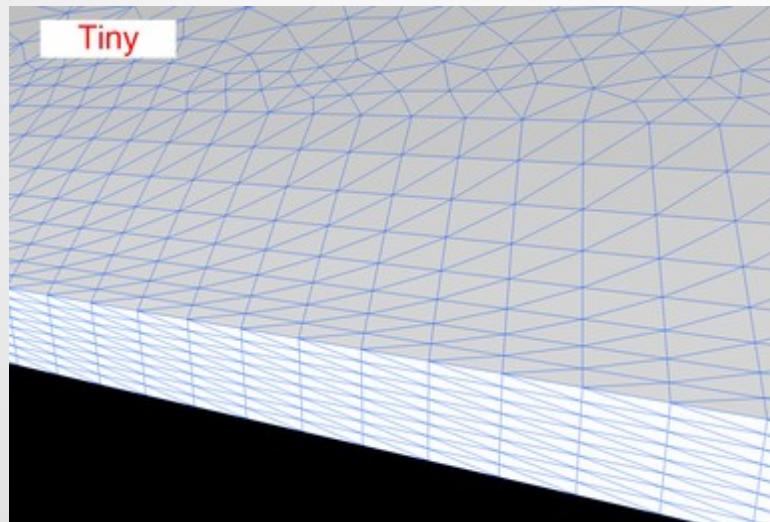
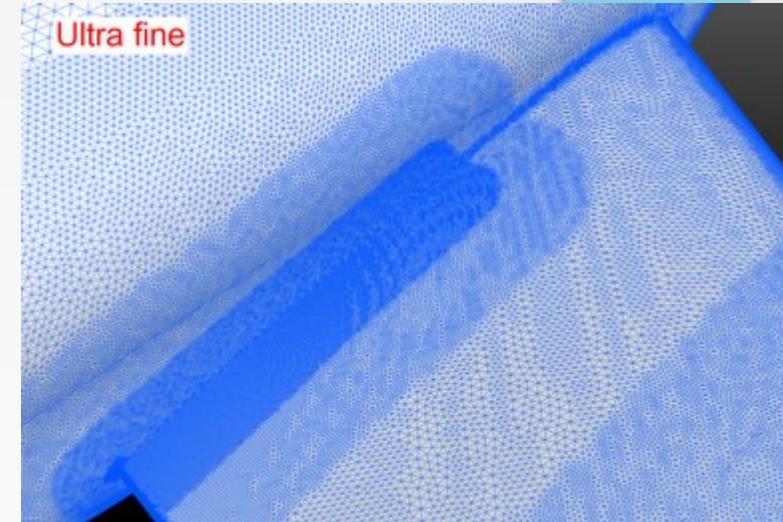
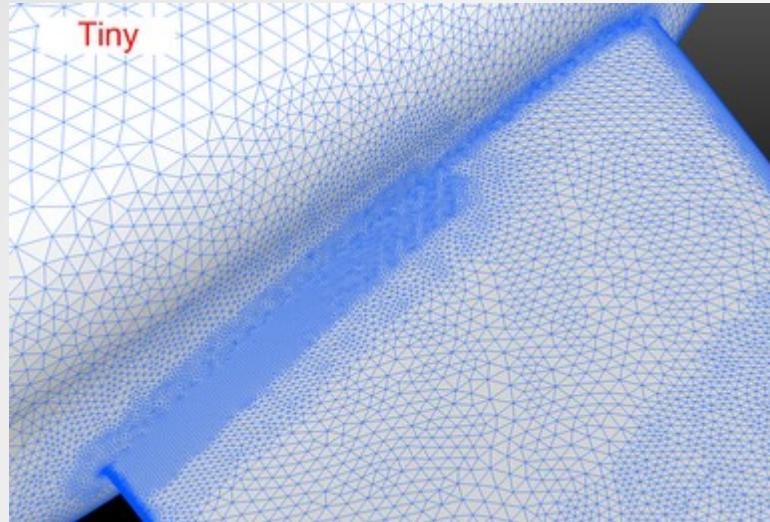
Typical Grids



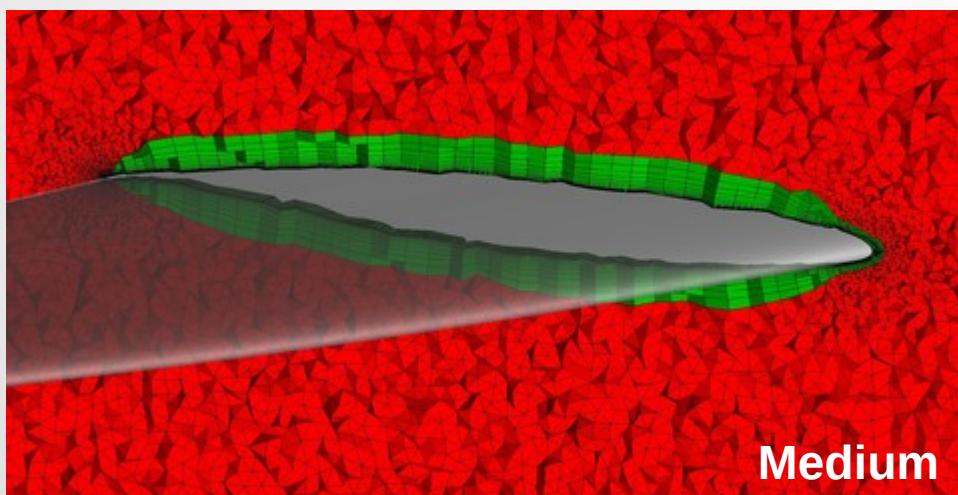
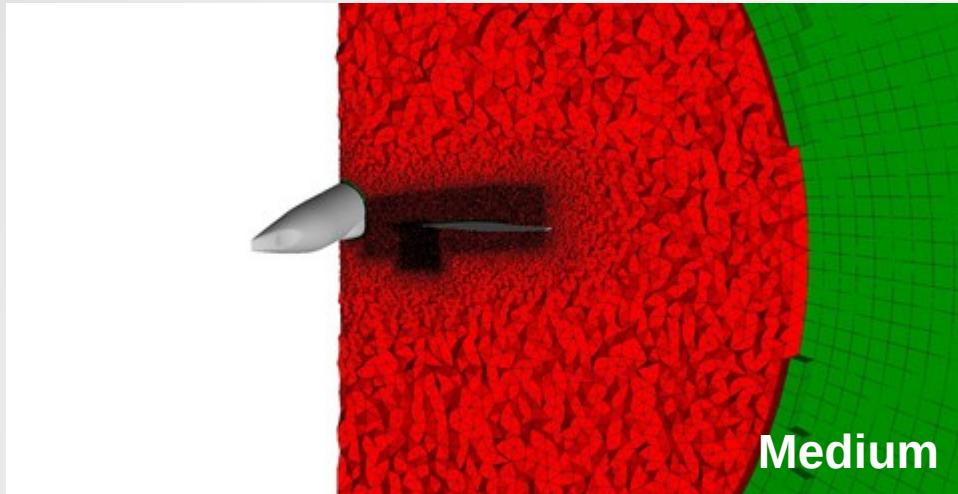
Grid details

- Grids have been generated according to the gridding guidelines provided by the DPW6 committee.
 - ✓ Total grid size,
 - ✓ First spacing,
 - ✓ 2 layers of constant spacing in viscous padding,
 - ✓ No of elements at the T.E
 - ✓ Farfield distance
 - ✓ Grid spacing reduction between various mesh levels by 0.87, etc.
- Boundary layer is grown using aspect ratio based algorithm.
- 40 percent of the total volume cells inside the viscous padding.
- Body is discretized with triangles and the fluid domain is discretized with prisms, tets, pyramids and hex elements.

Surface mesh



Volume mesh





Grid details

WB configuration

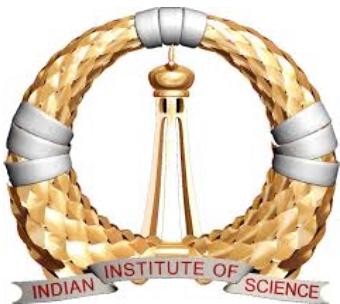
Grids	Total grid size (as per guidelines)	Total grid size (as generated)	No of elements on the body
Tiny	~20 m (0.6 m)	20,020,431	401,782
Coarse	~30 m (2 m)	30,011,540	533,098
Medium	~45 m (5 m)	45,361,230	720,650
Fine	~70 m (17 m)	68,041,757	961,489
Extra Fine	~100 m (41 m)	100,955,603	1,261,727
Ultra Fine	~150 m (138 m)	151,0268,68	1,648,811

WBNP configuration

Grids	Total grid size (as per guidelines)	Total grid size (as generated)	No of elements on the body
Tiny	20-30 m	26,529,525	476,220
Coarse	40-45 m	40,124,341	603,135
Medium	60-70 m	59,997,874	778,759
Fine	85-100 m	90,186,887	1,027,280
Extra Fine	130-150 m	137,947,275	1,454,909
Ultra Fine	190-225 m	200,051,932	1,816,492

Values in brackets are DPW5 grid sizes

Grids	No of layers in the viscous padding	BL max growth rate (on fuselage)
T	22	1.53
C	25	1.45
M	29	1.36
F	33	1.32
XF	38	1.26
UF	44	1.2



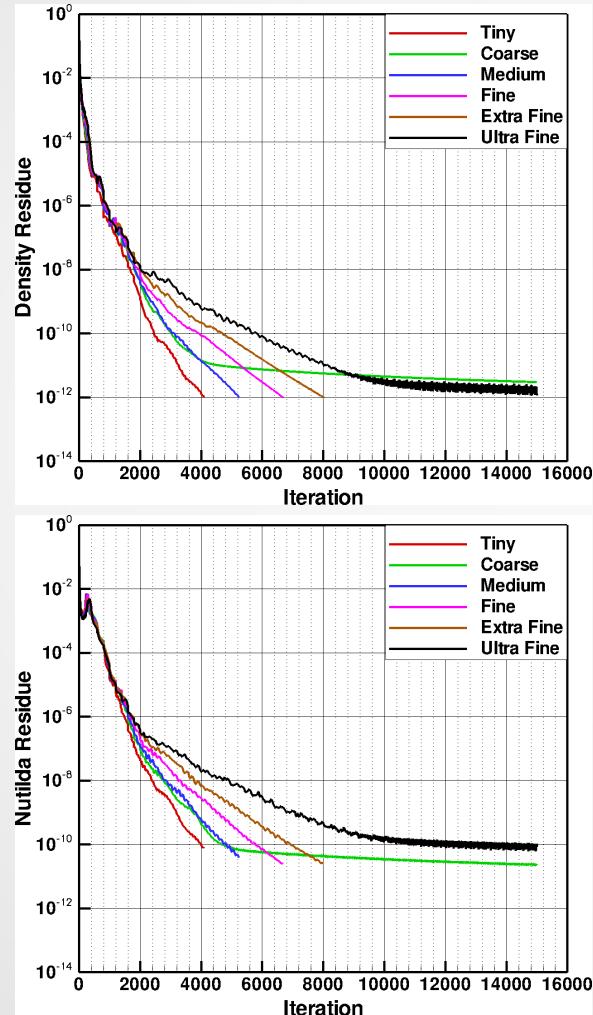
Results:

Grid convergence study: Case 2A & Case 2B

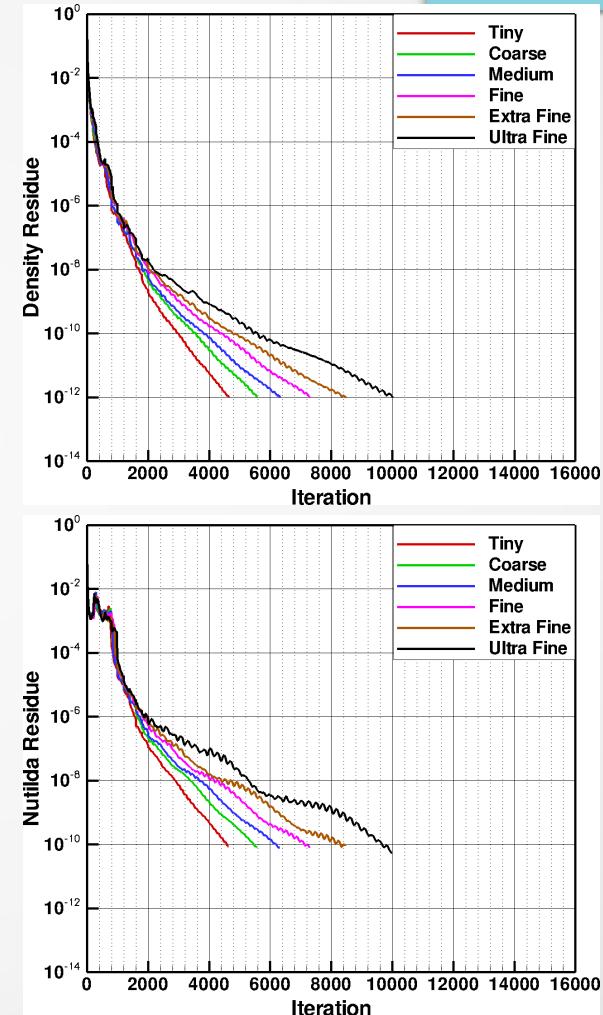
Density & nutilda residue convergence



WB

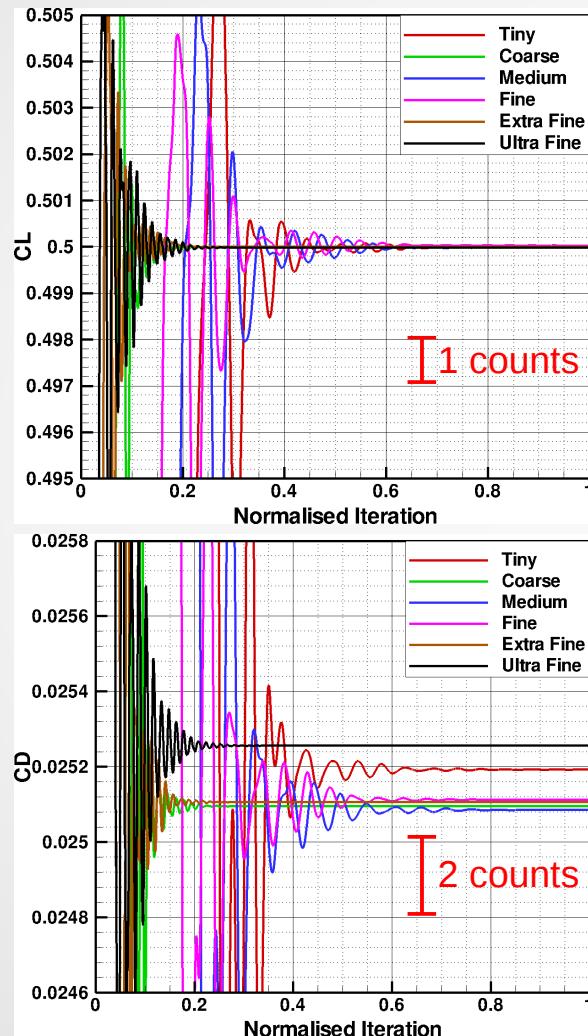


WBNP

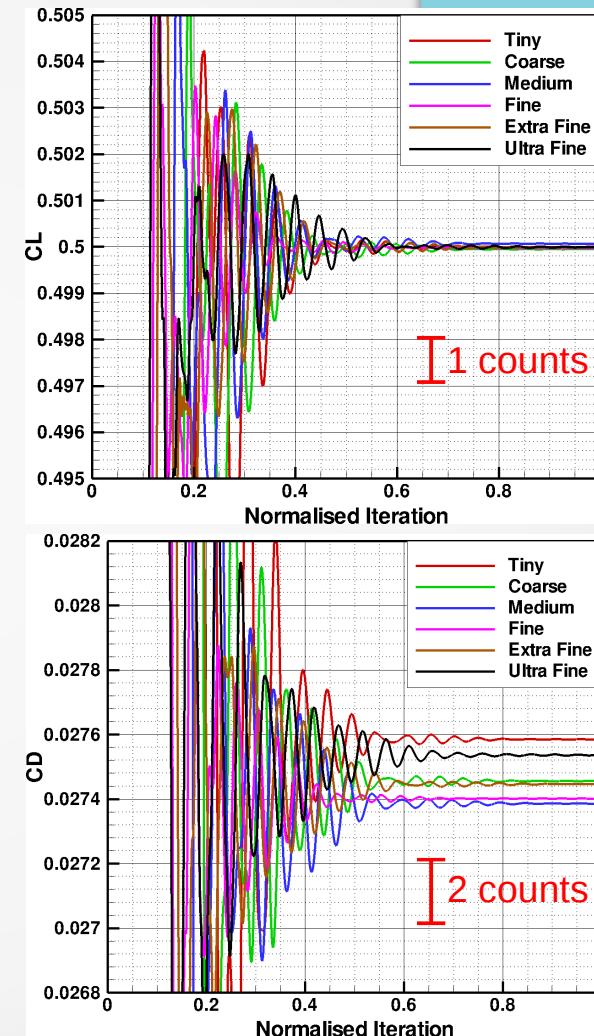


CL & CD: Iterative convergence

WB

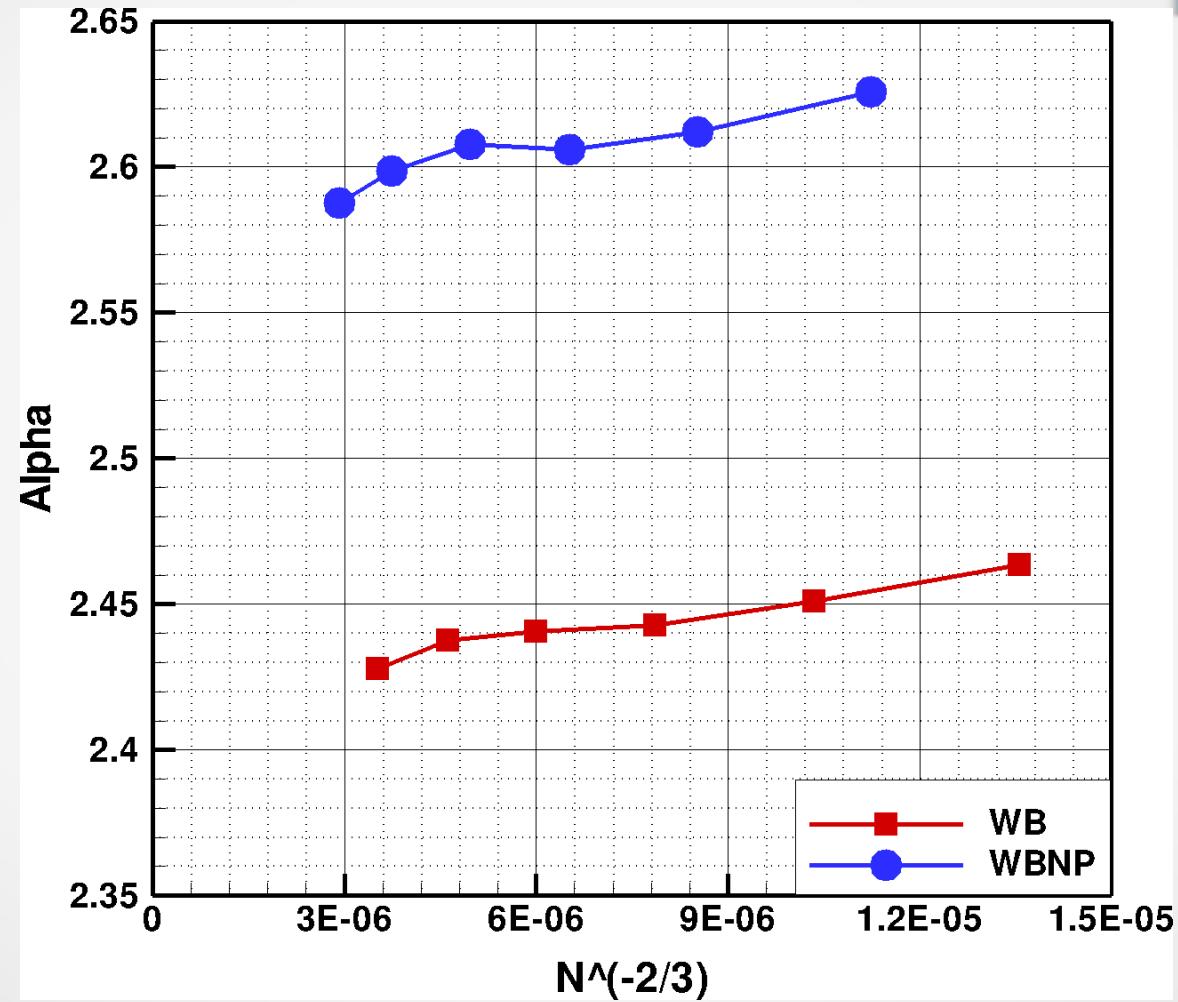


WBNP

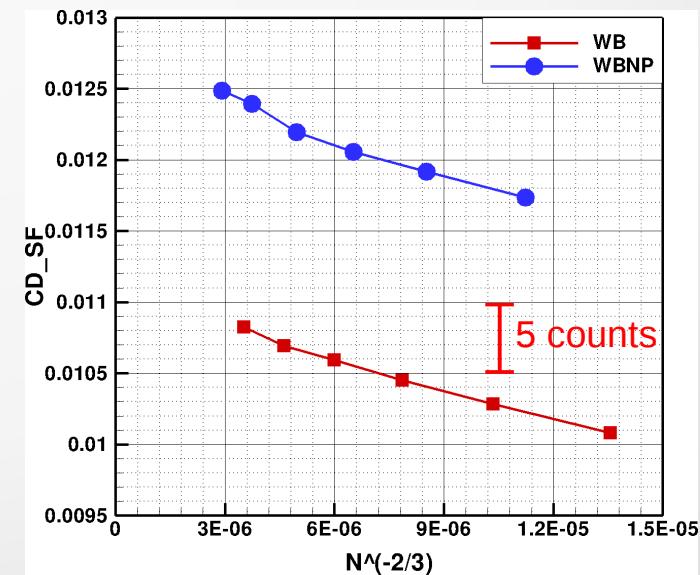
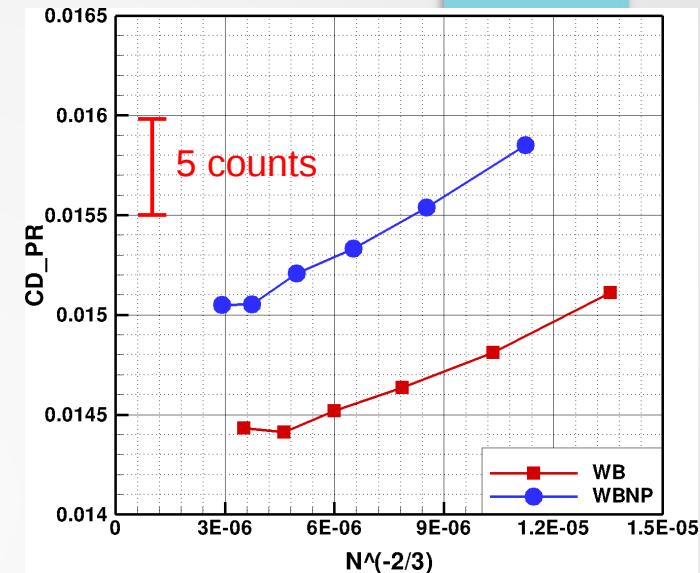
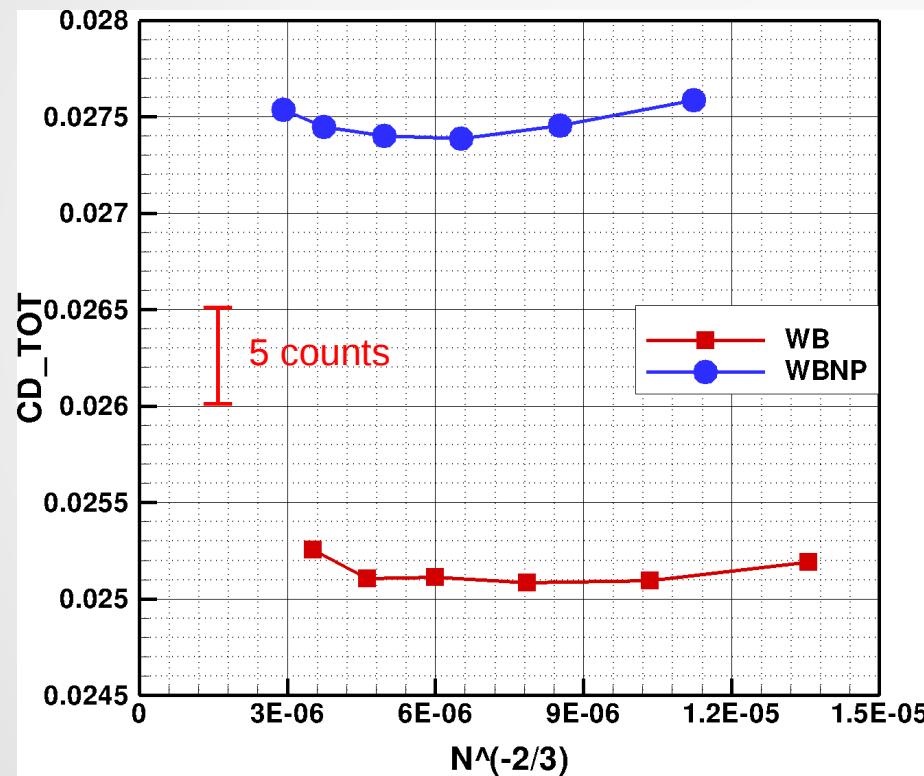




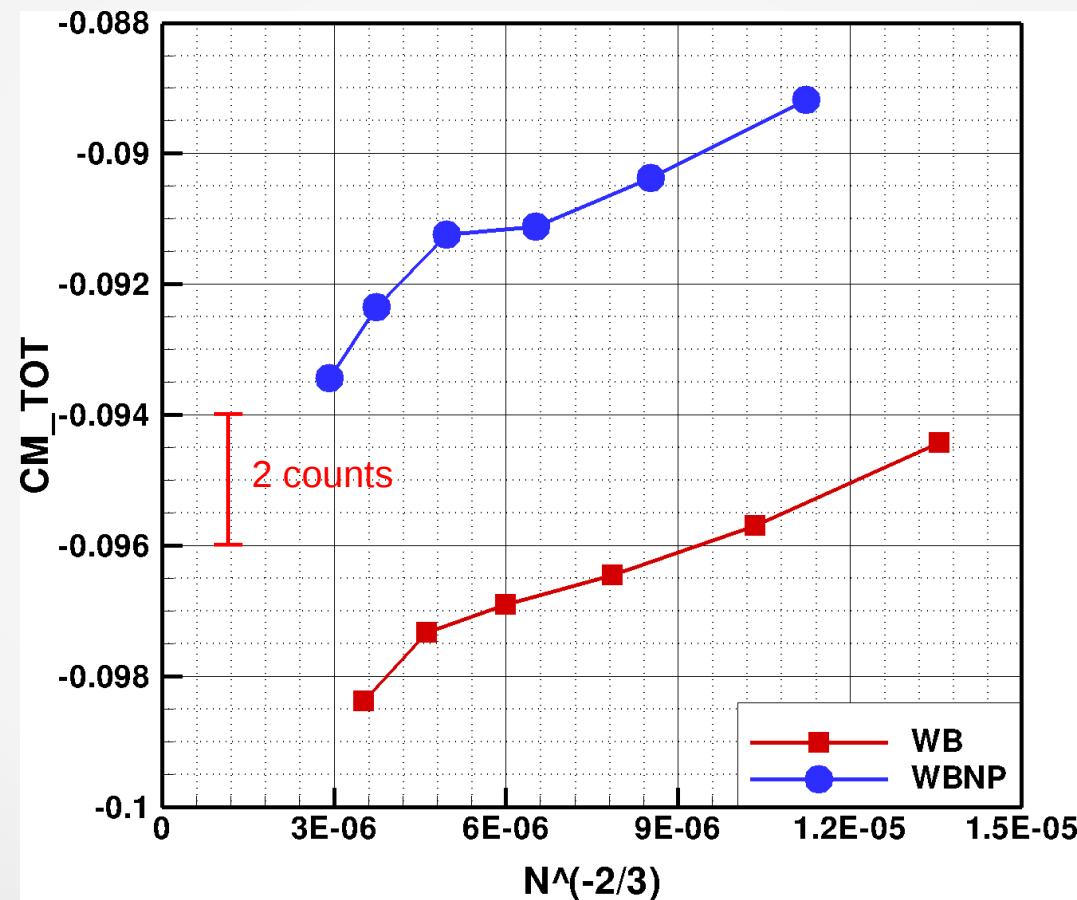
Grid convergence study



Grid convergence study



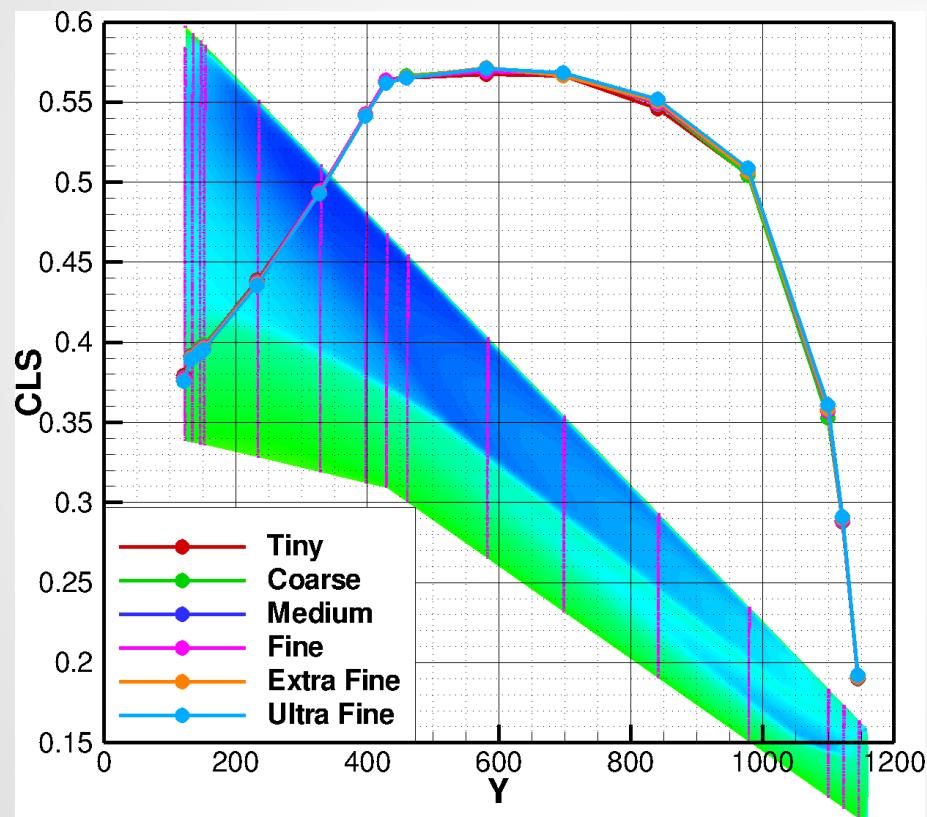
Grid convergence study



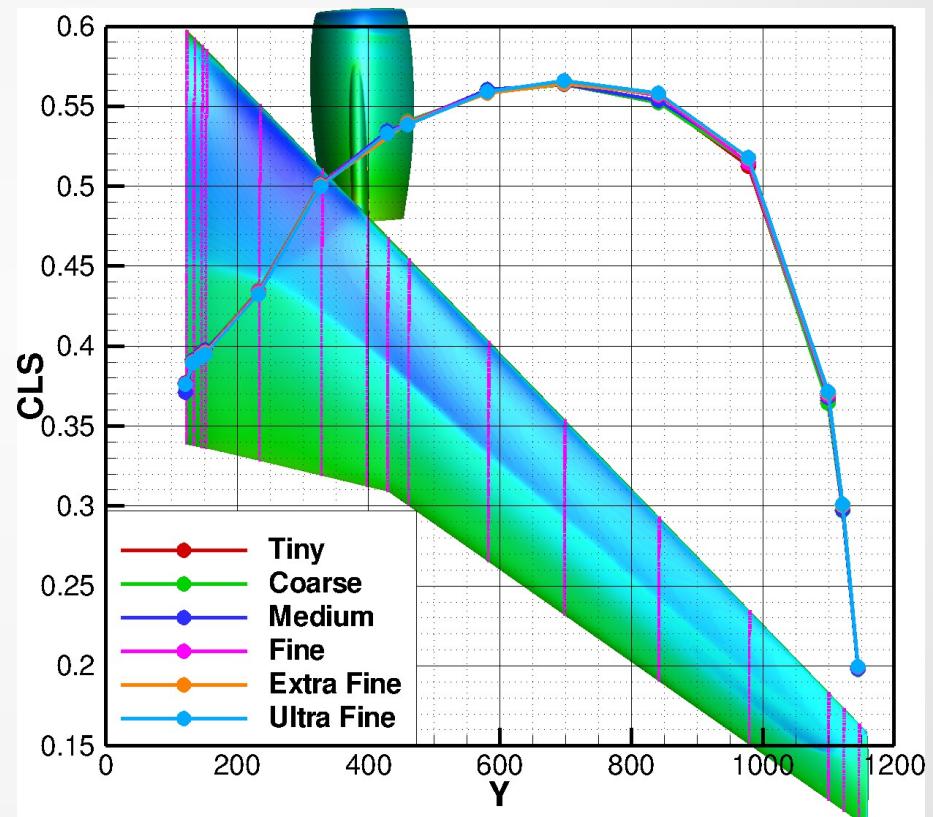
Sectional lift distribution



WB



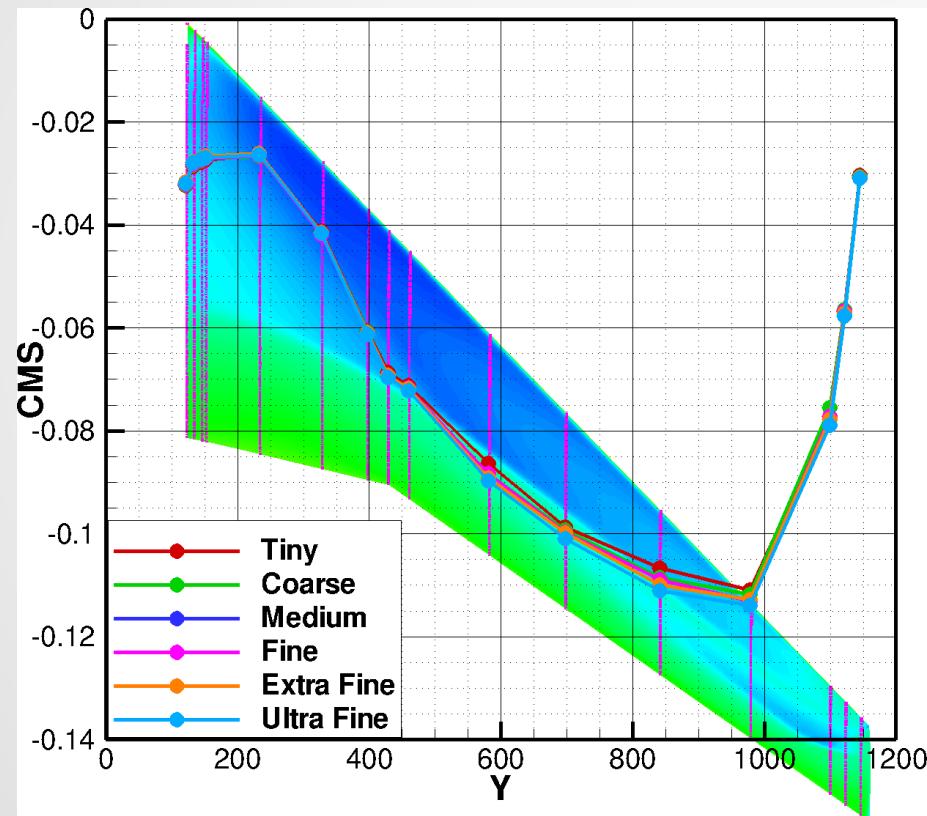
WBNP



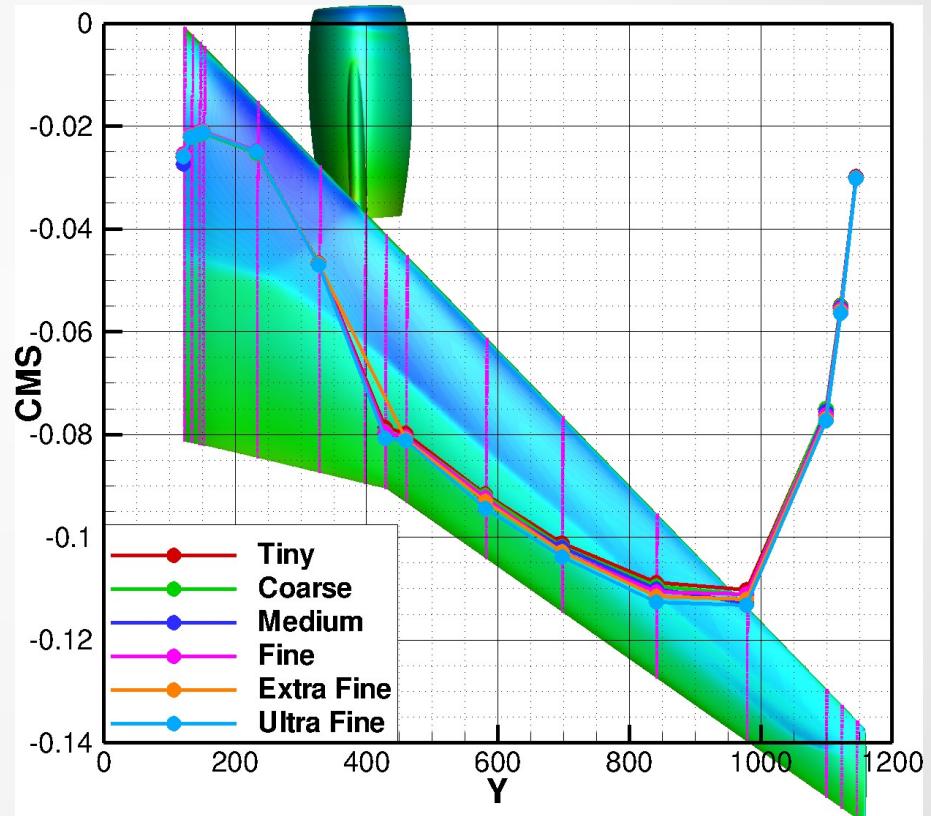
Sectional Moment distribution



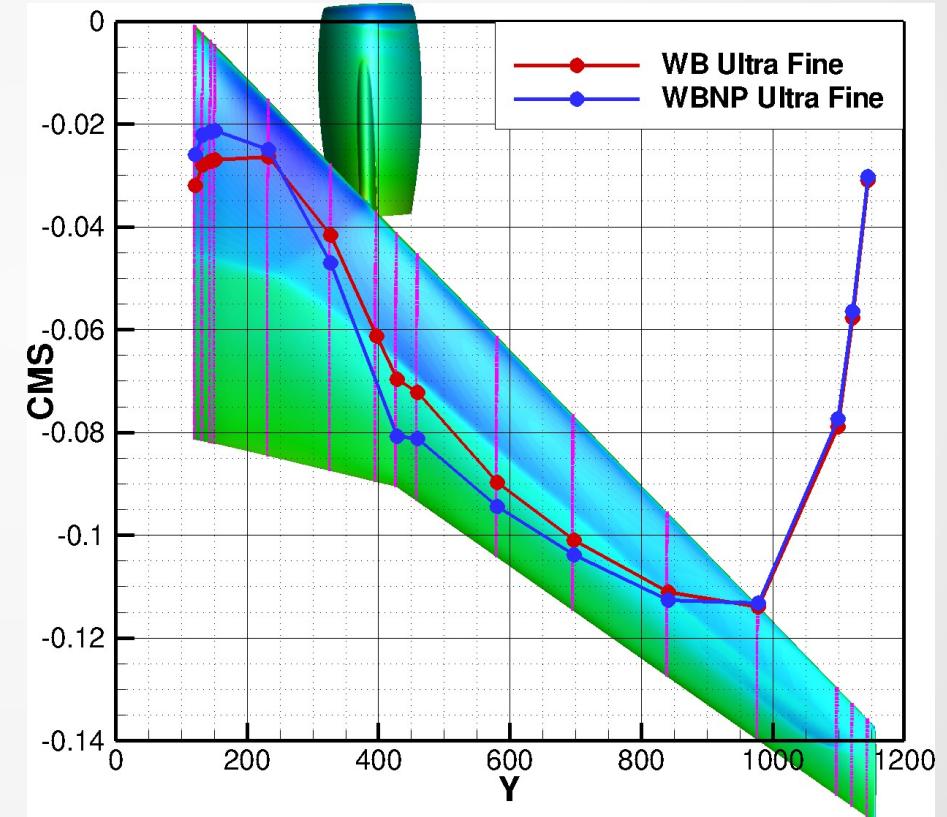
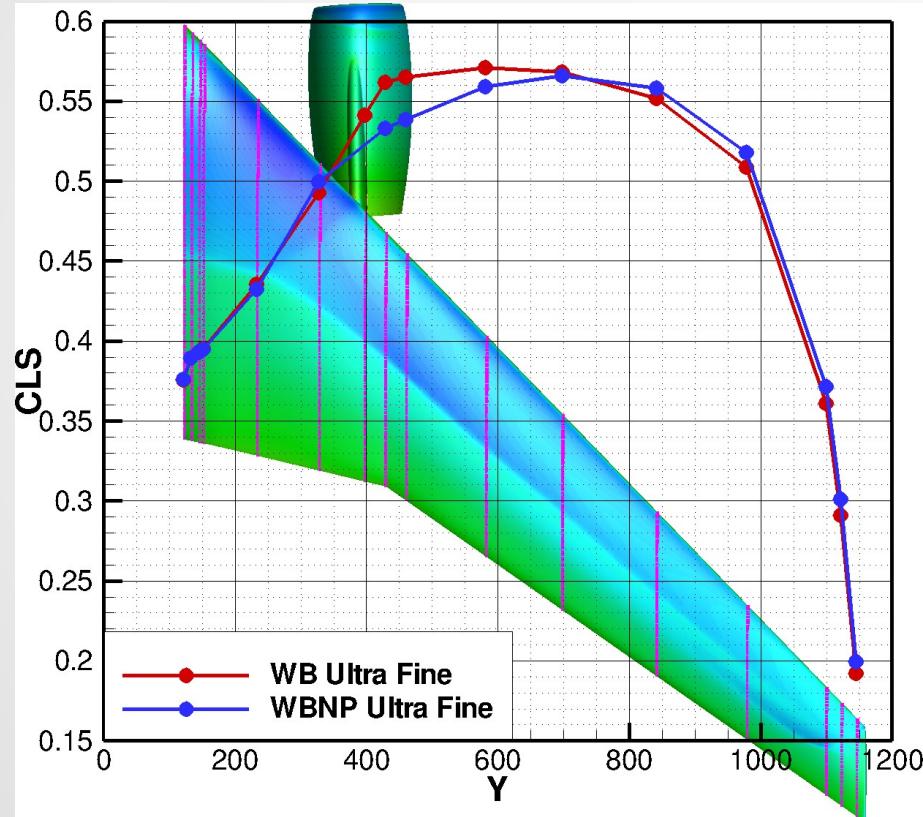
WB



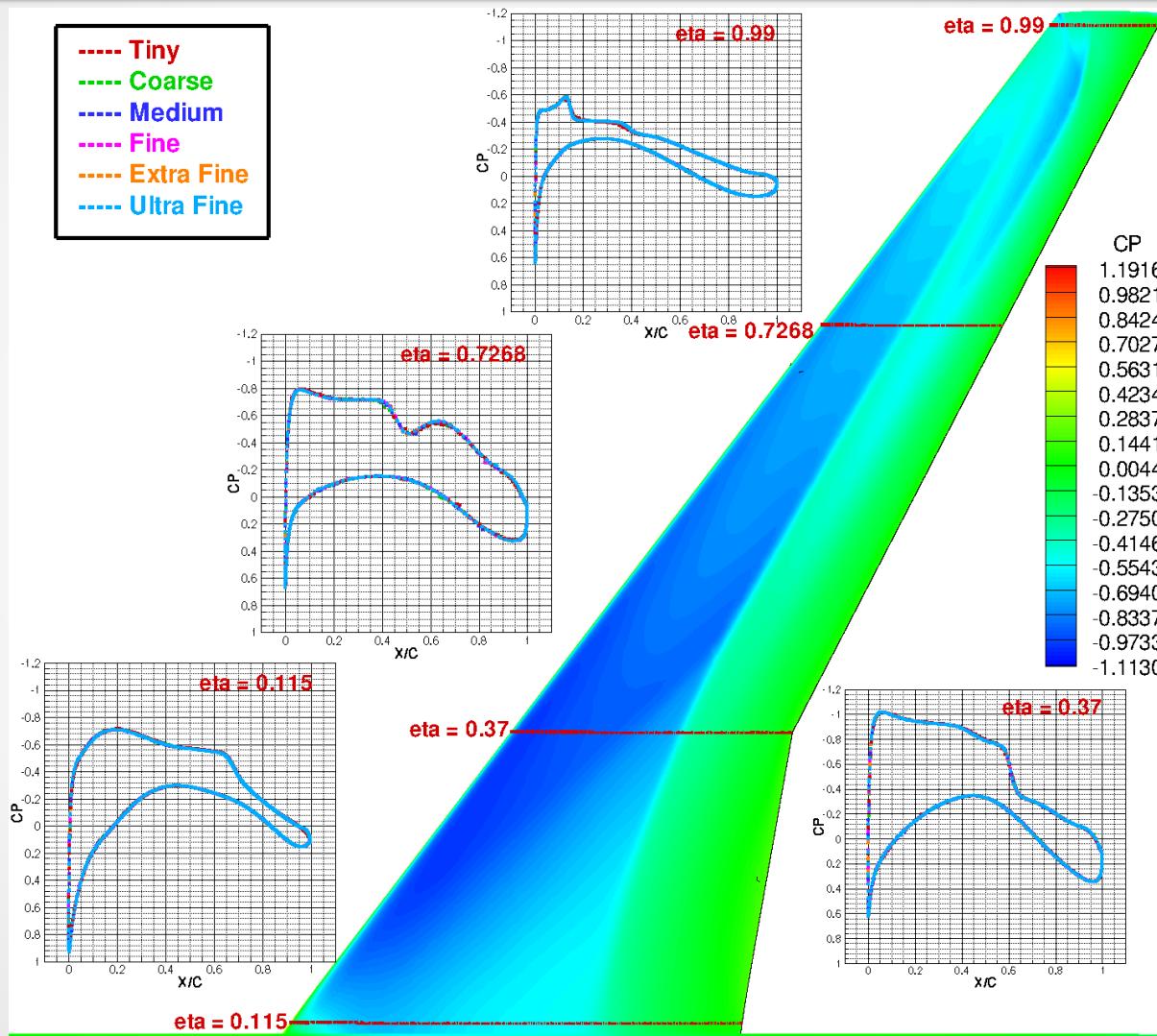
WBNP



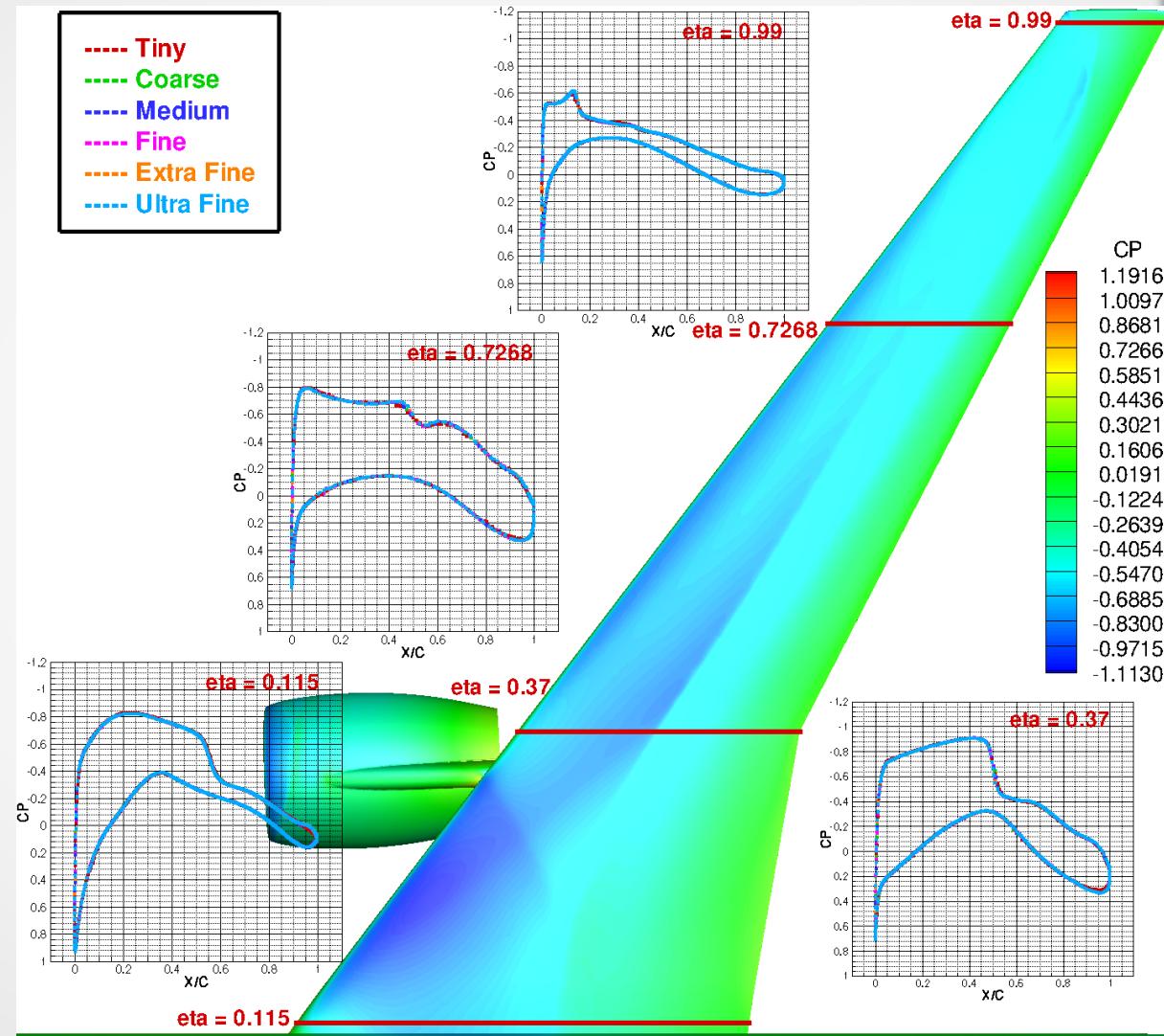
Sectional lift & moment distribution



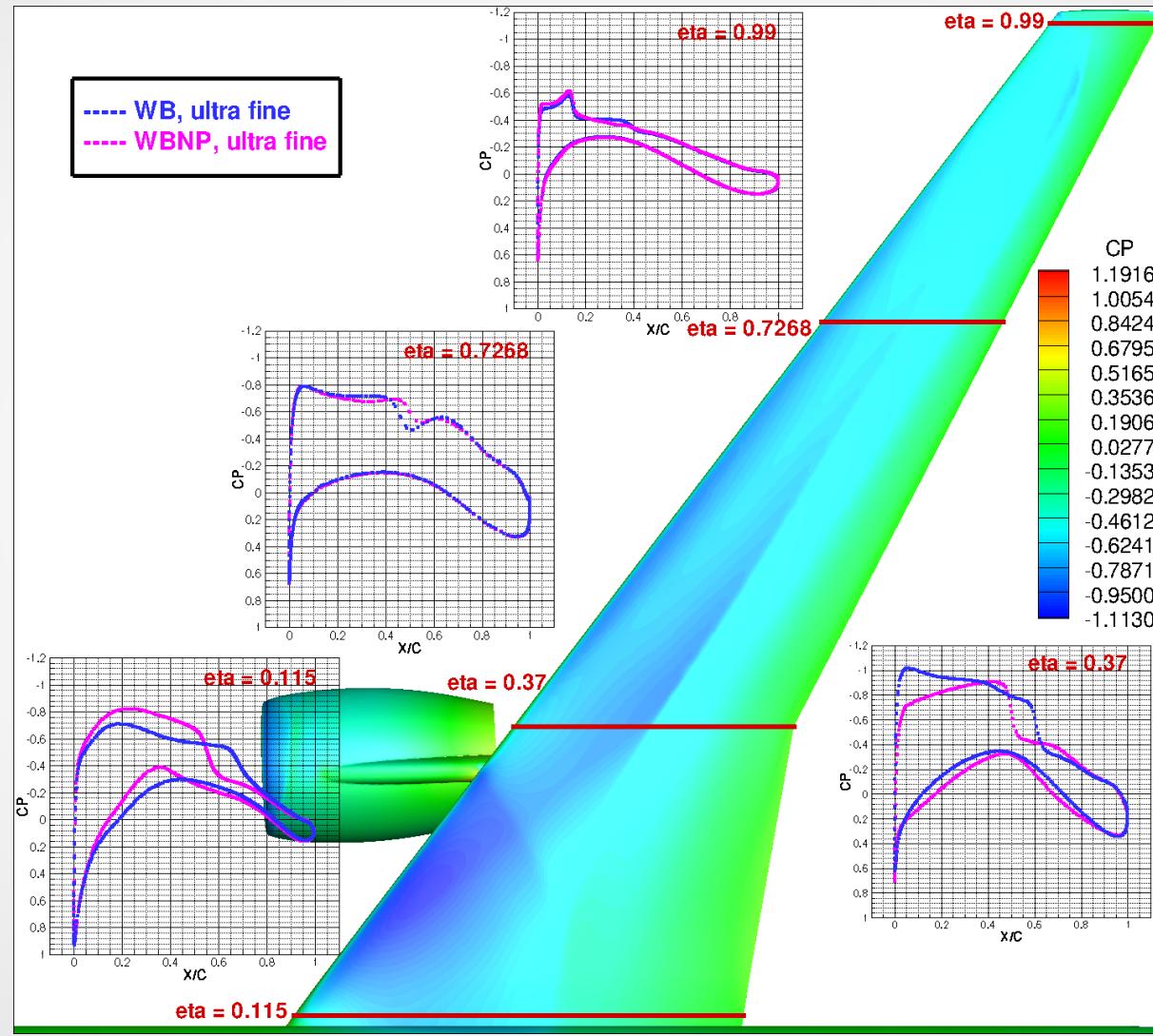
WB: Sectional Cp



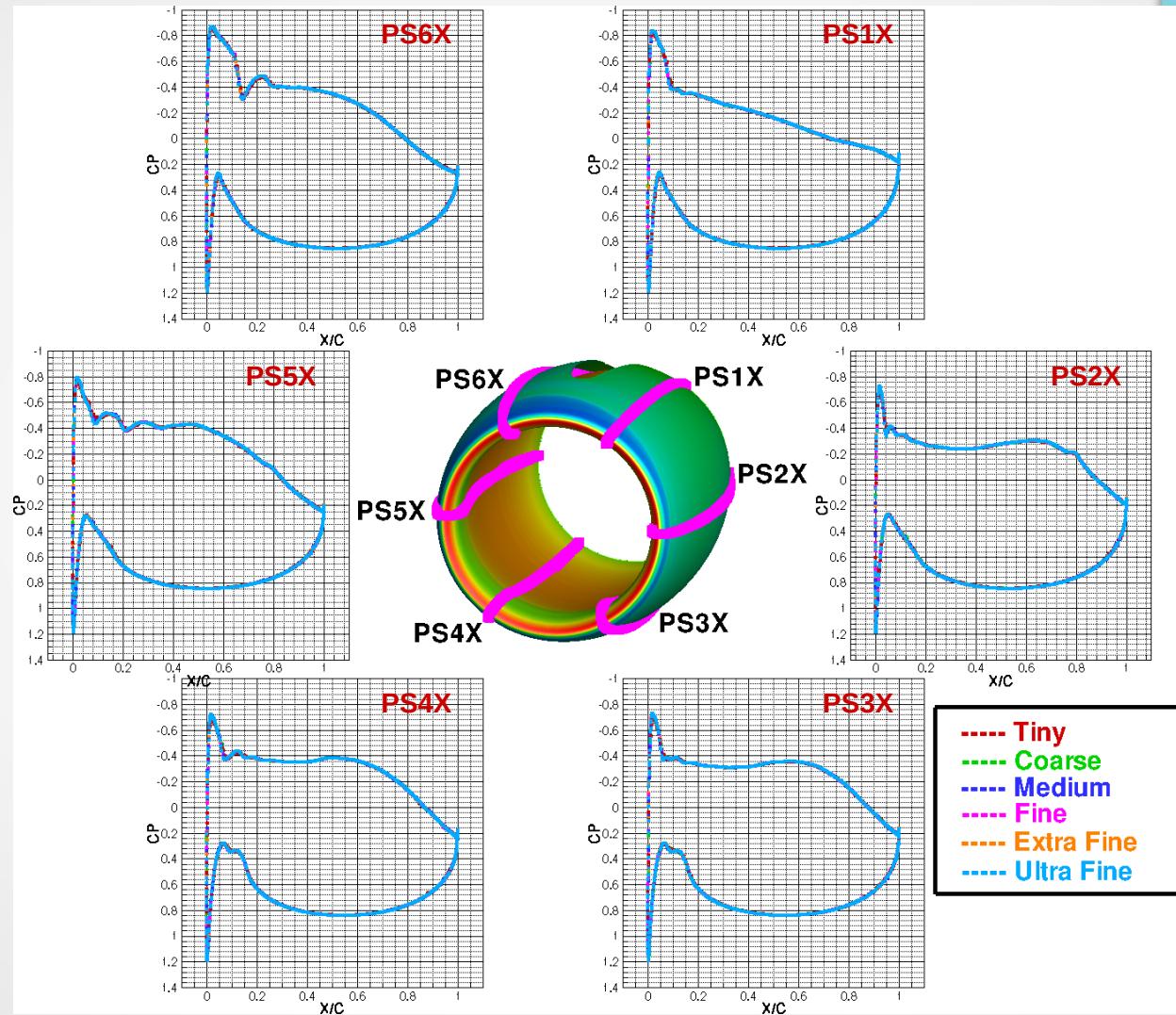
WBNP: Sectional Cp



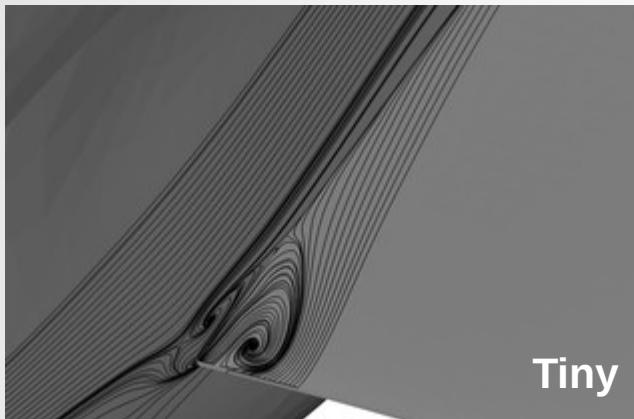
WB & WBNP : Sectional Cp



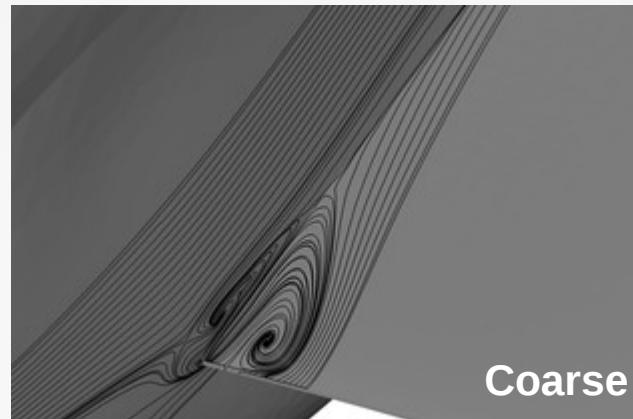
Nacelle: Sectional Cp



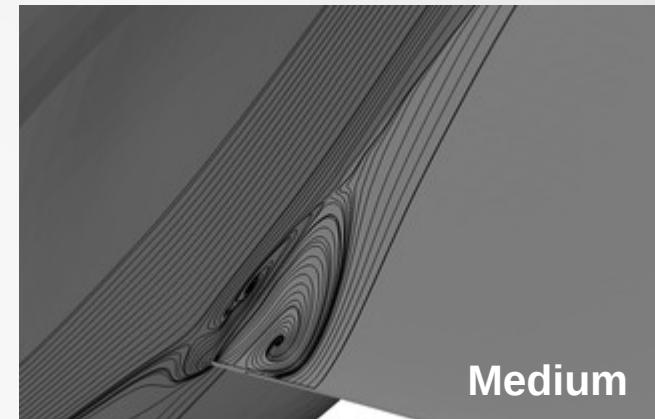
Junction bubble: WB



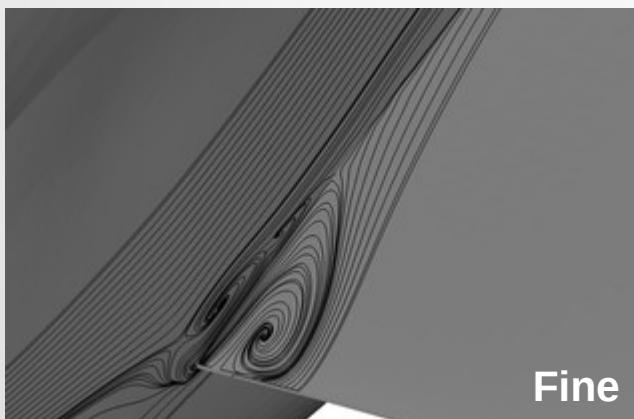
Tiny



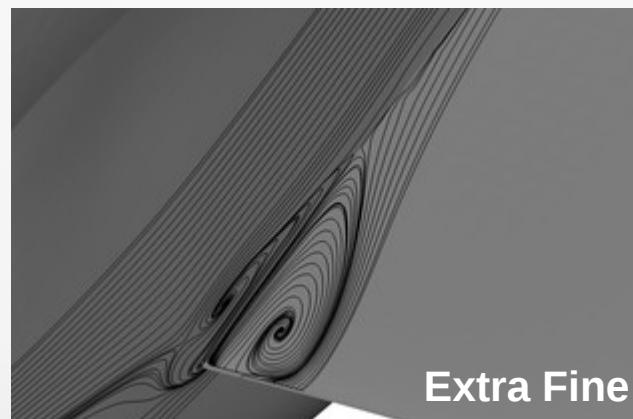
Coarse



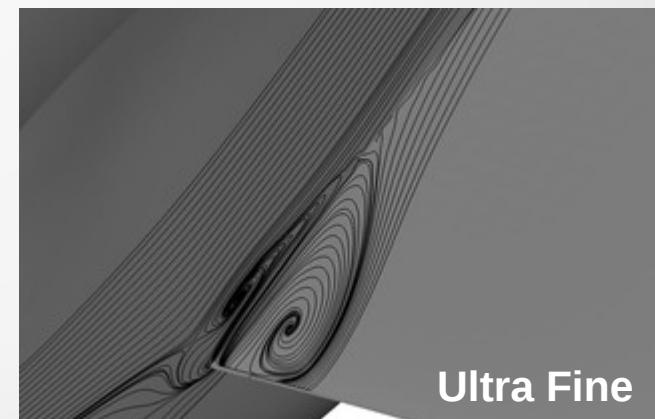
Medium



Fine

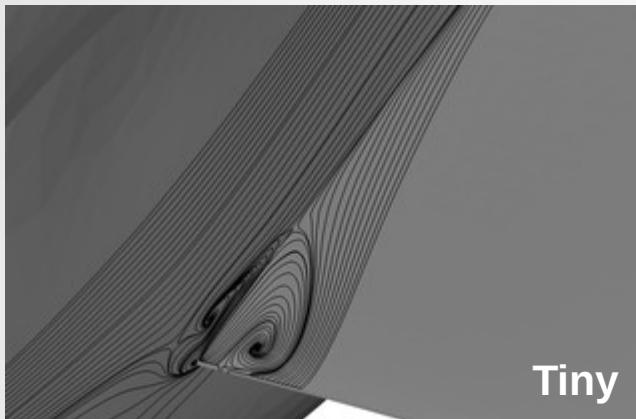


Extra Fine

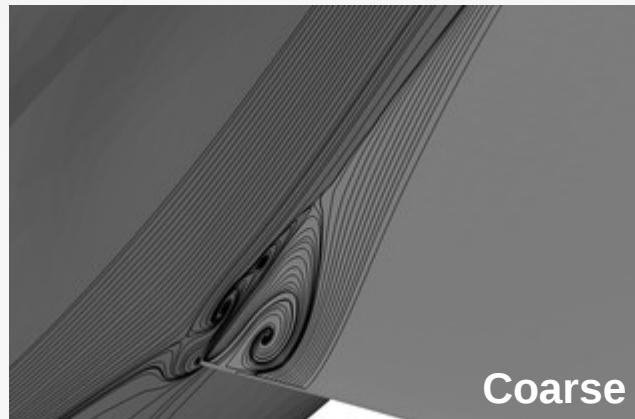


Ultra Fine

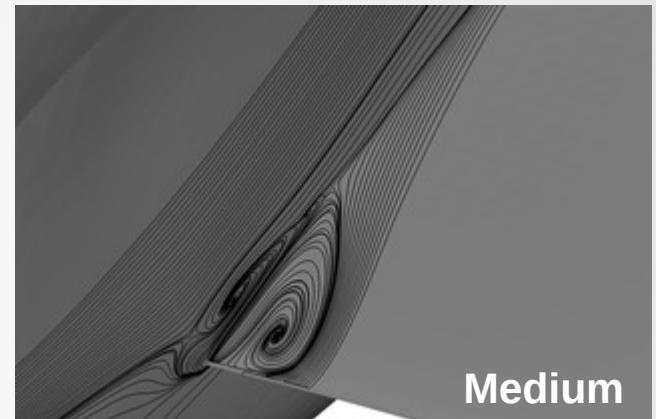
Junction bubble: WBNP



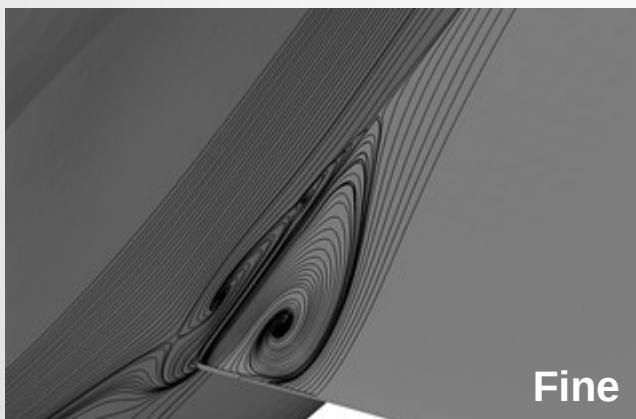
Tiny



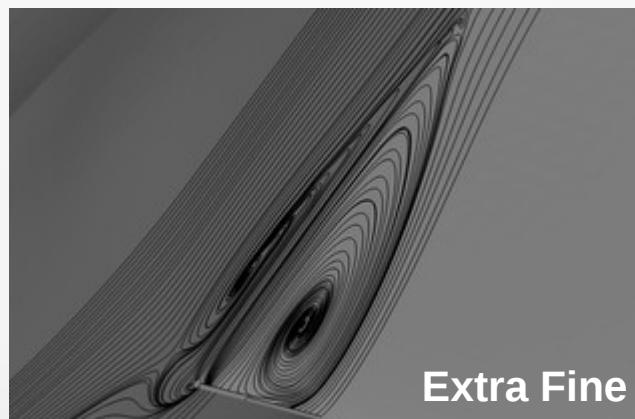
Coarse



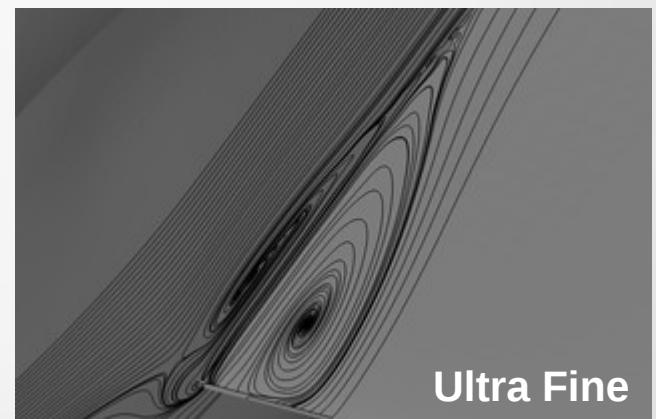
Medium



Fine



Extra Fine

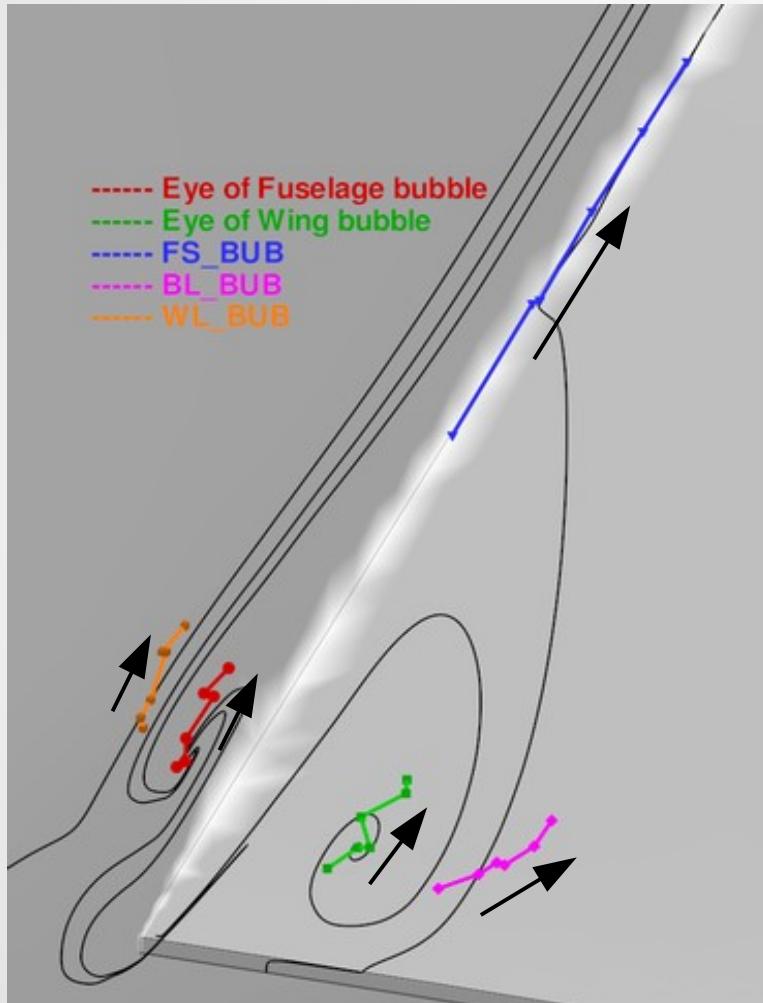


Ultra Fine

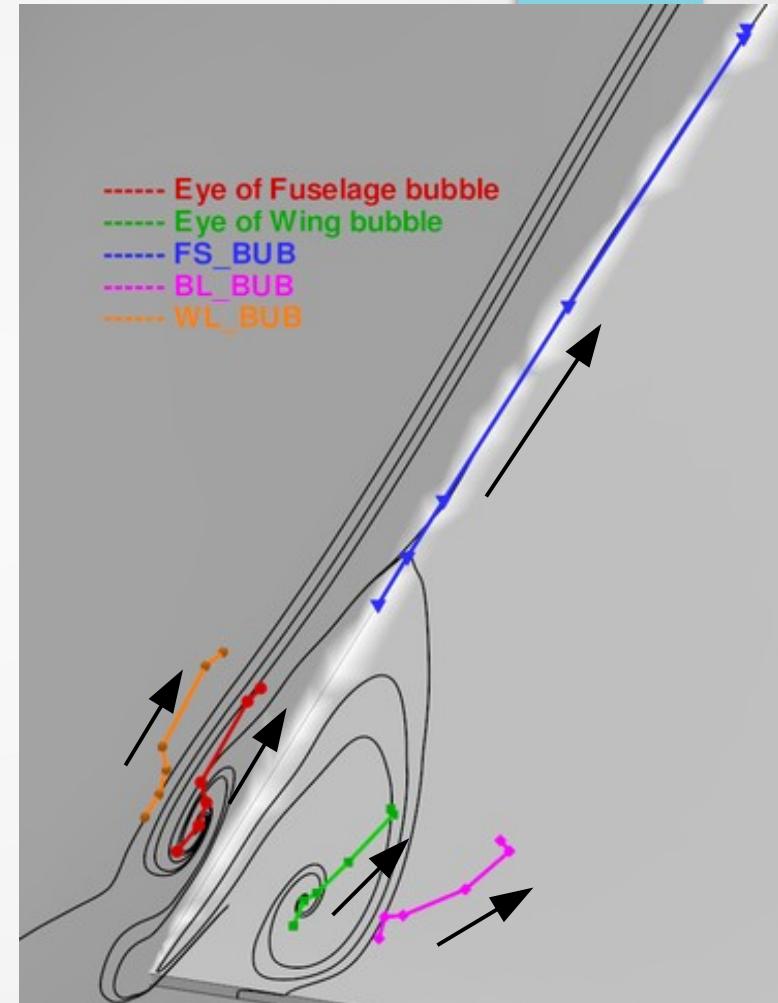
Variation of bubble parameters with grid



WB



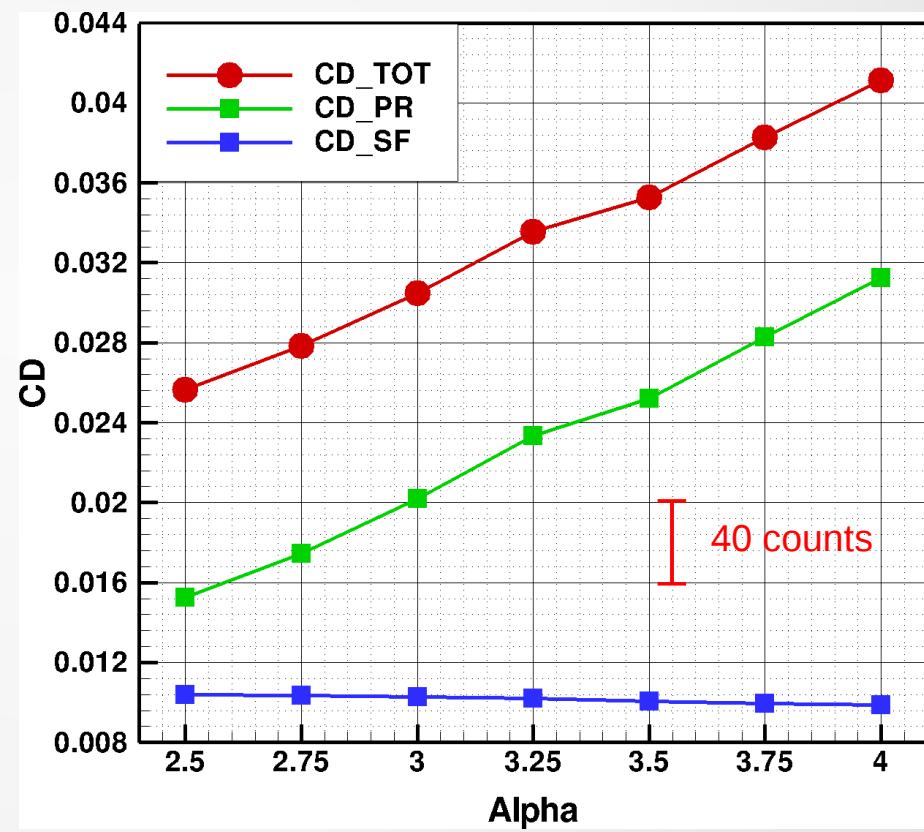
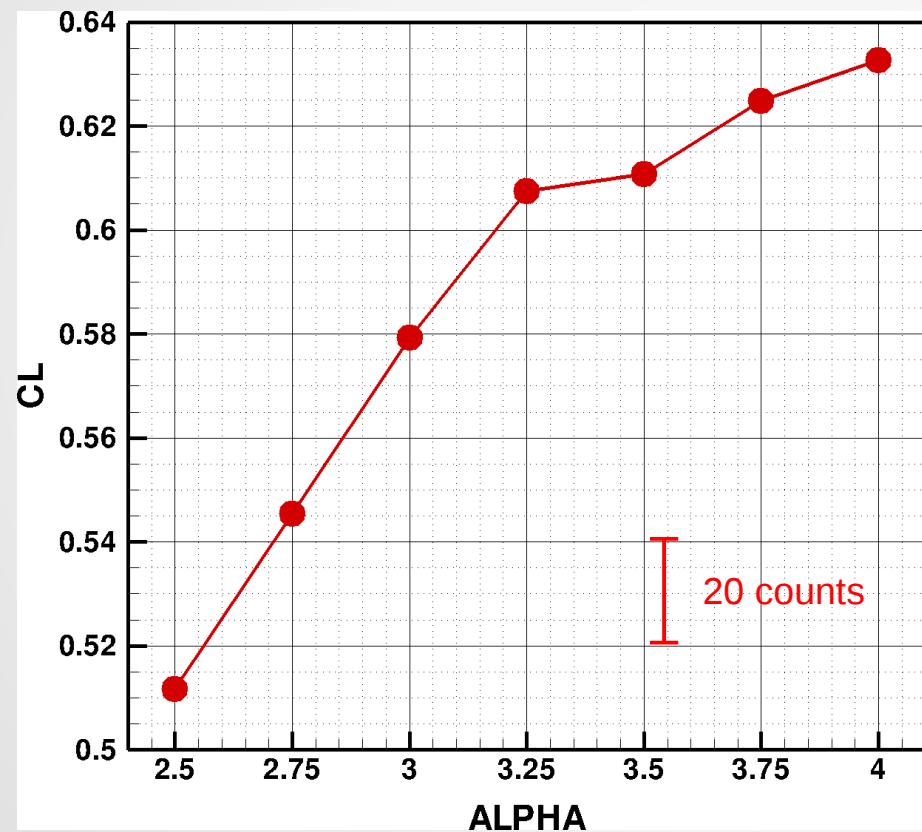
WBNP



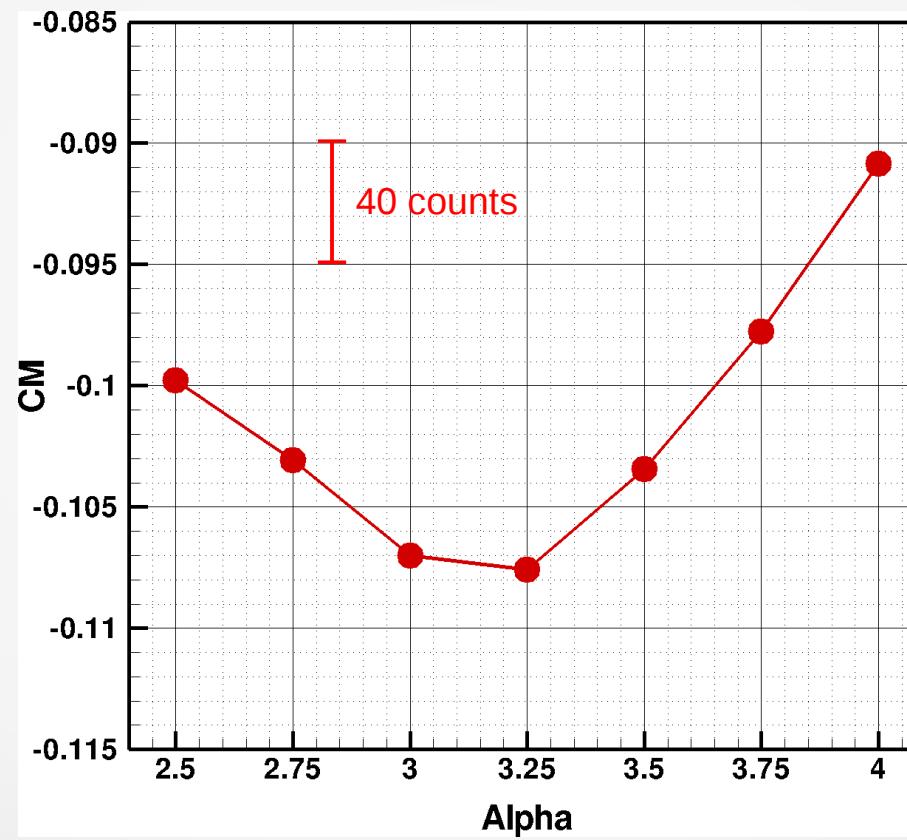


Case 3: Aero elastic study

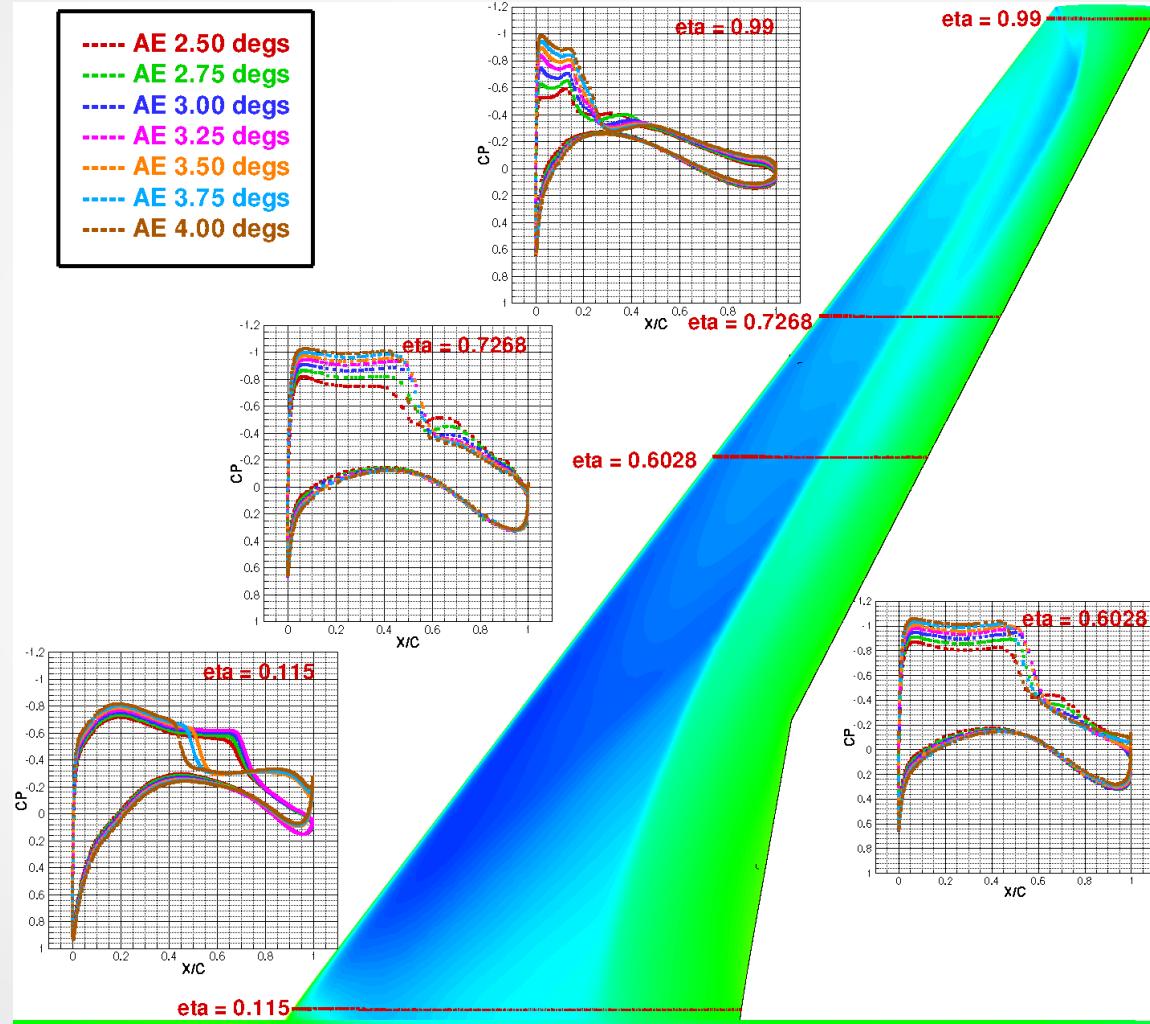
Aero elastic study



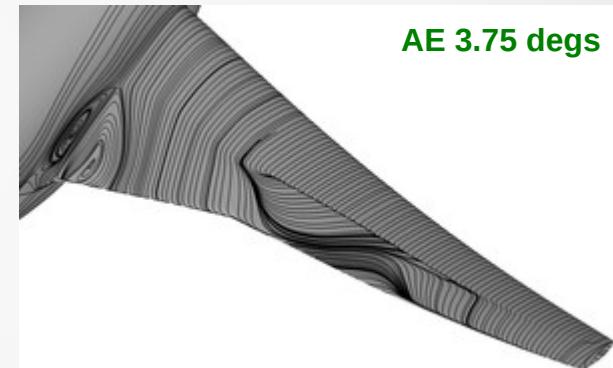
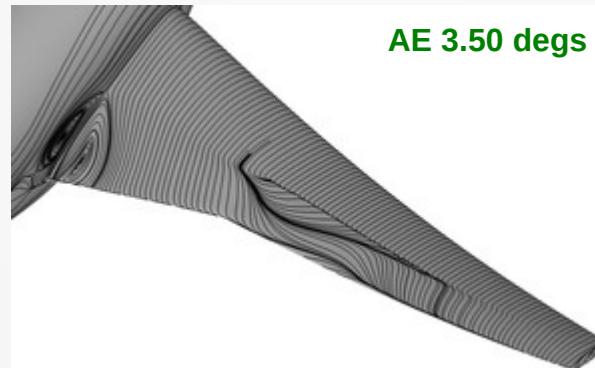
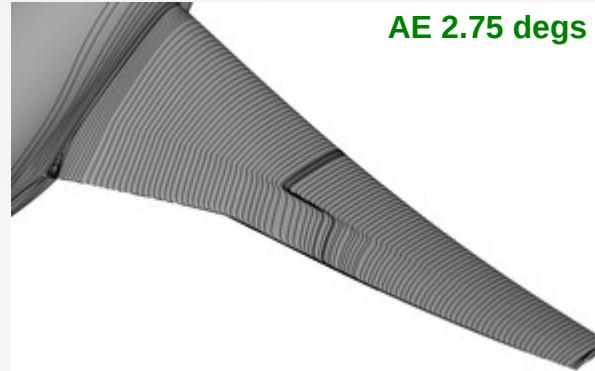
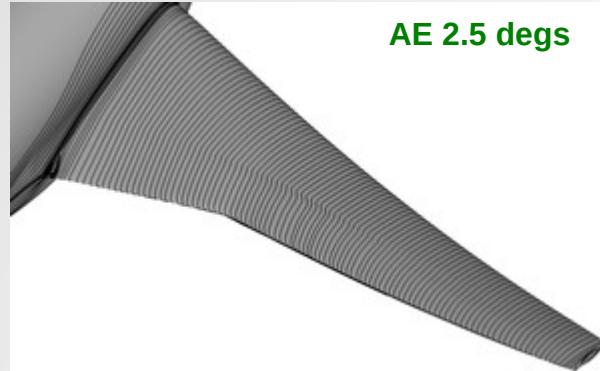
Aero elastic study



AE study: Sectional Cp distribution

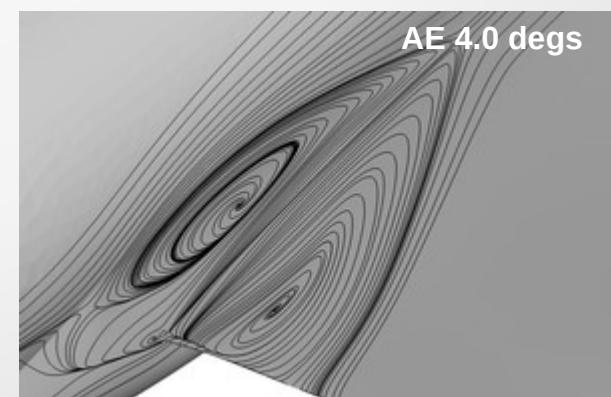
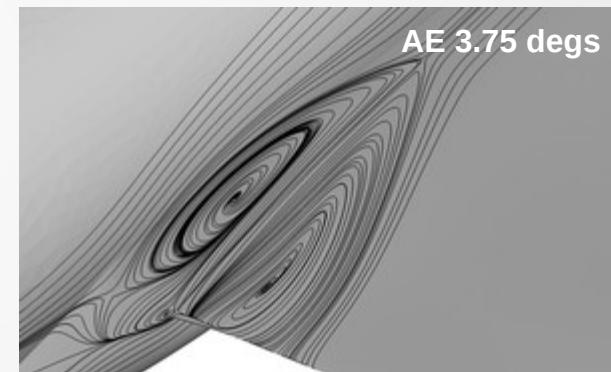
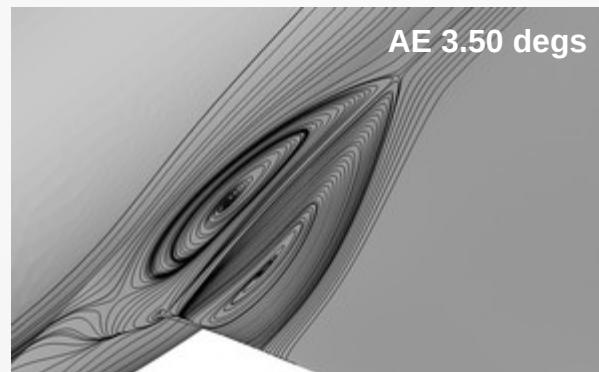
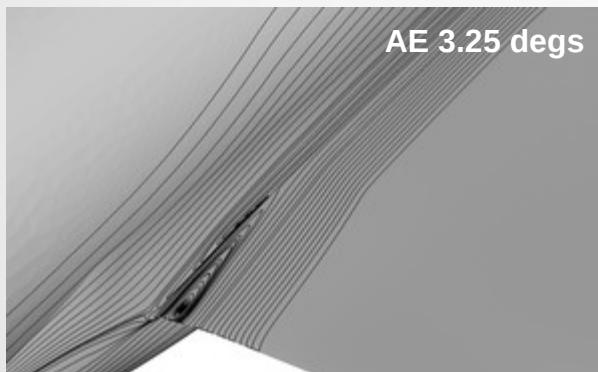
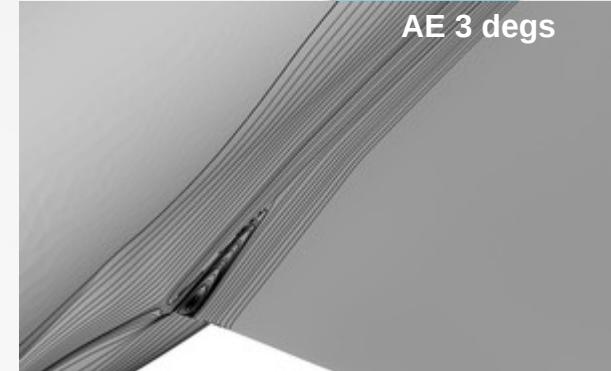
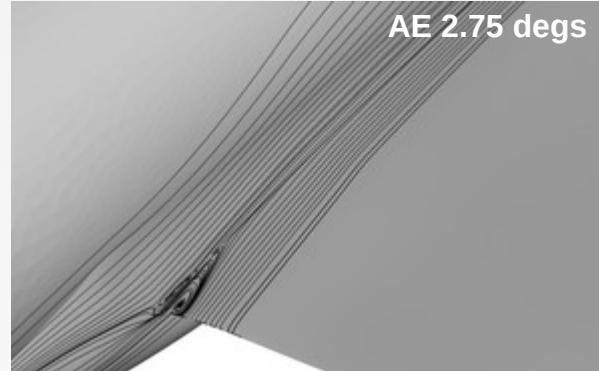
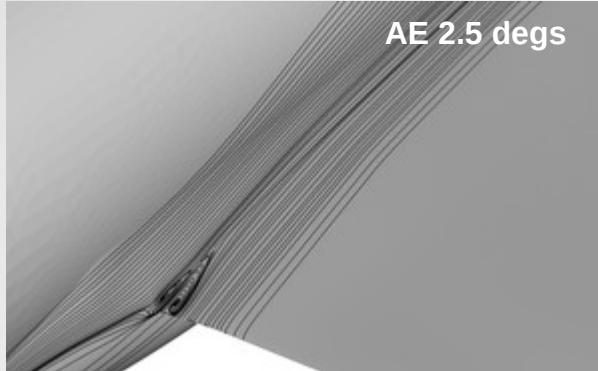


Shock induced flow separation





Junction bubble





Conclusions



Concluding remarks

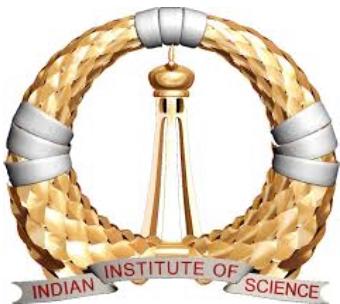
Considered Cases: Case 1, Case 2 & Case 3

- For the sequence of grids chosen C_p shows less sensitivity.
- Bubble in the Wing-body junction grows with refinement – appears to converge in the last two levels.
- Static Aero-elastic study: lift curve slope change at 3.25 degrees associated with large bubble in the wing-body junction.

Acknowledgments



- Supercomputer Education and Research Centre (SERC), IISc.
- Parthiban Sarath, Ravindra. K, Nikhil Vijay Shende
S&I Engineering Solutions Pvt. Ltd., Bangalore.



Thank You

Contact:

N. Balakrishnan: nbalak@aero.iisc.ernet.in



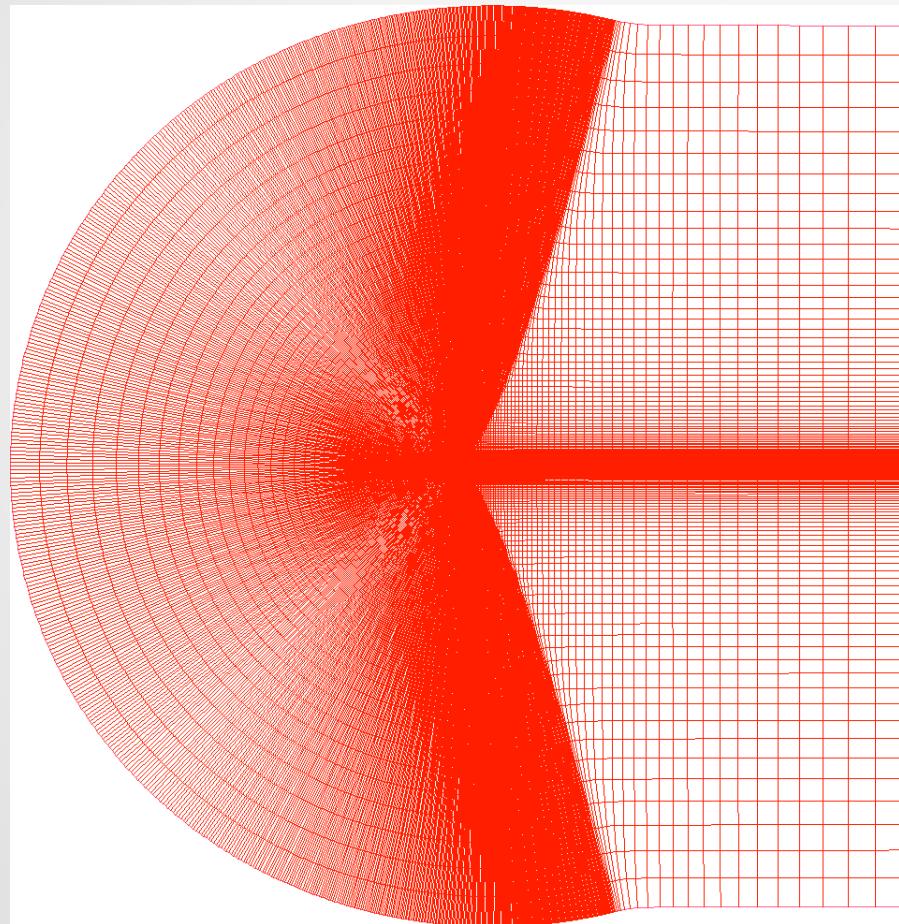
Case 1

NACA0012: Verification Study

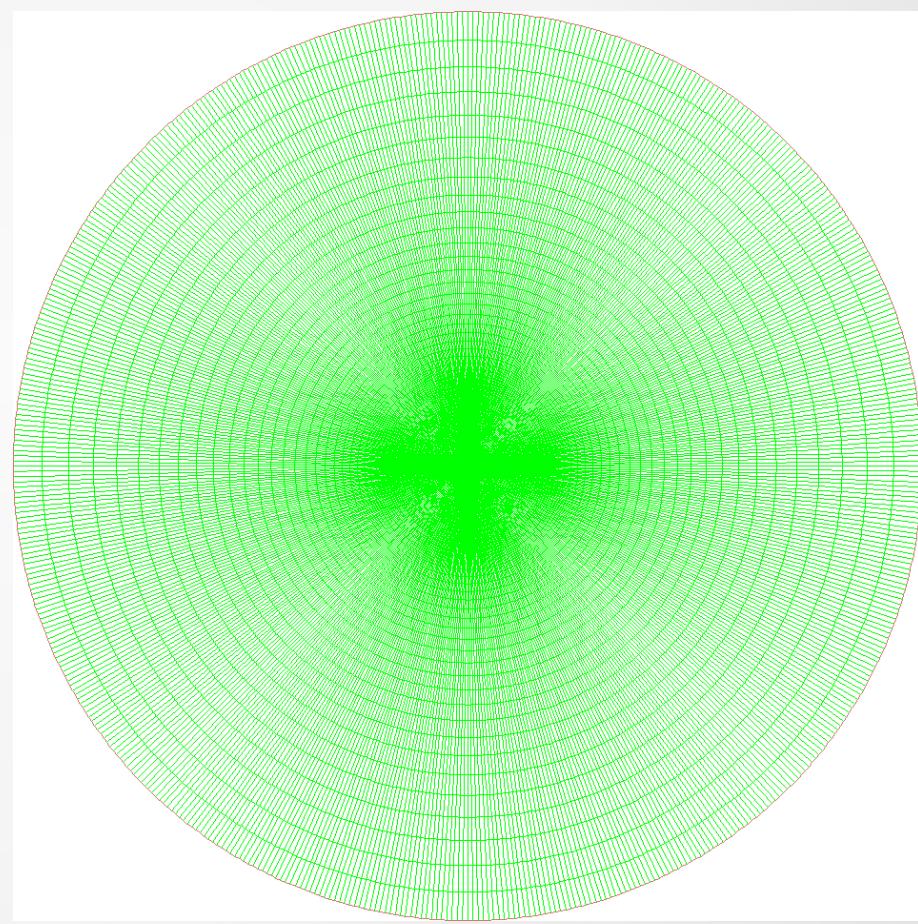
C-Grid & O-Grid: Differences



C-Grid



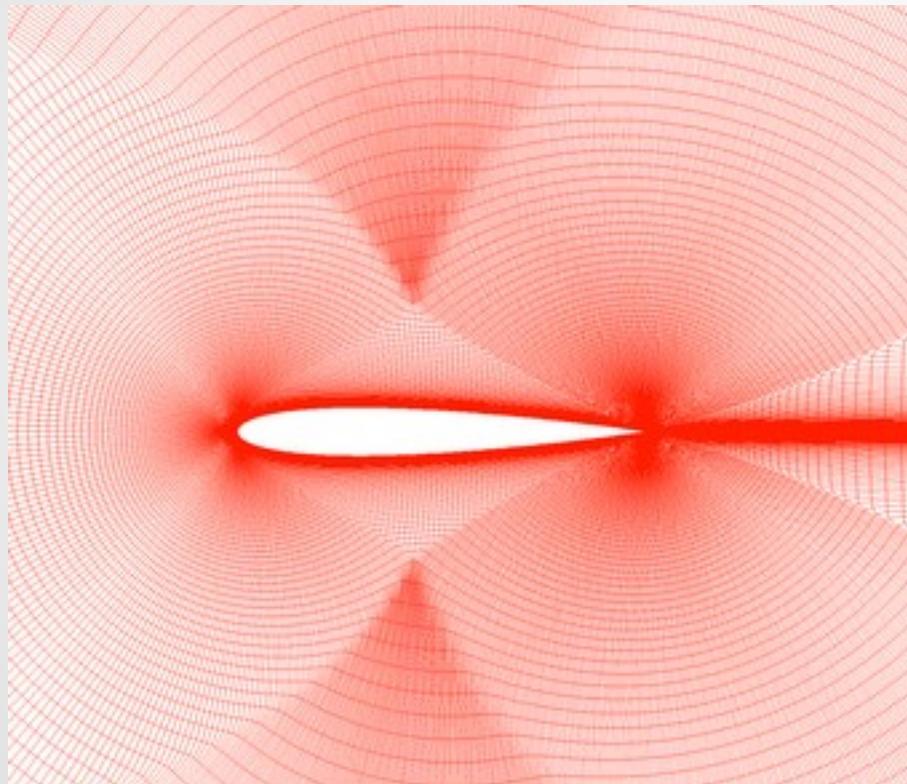
O-Grid



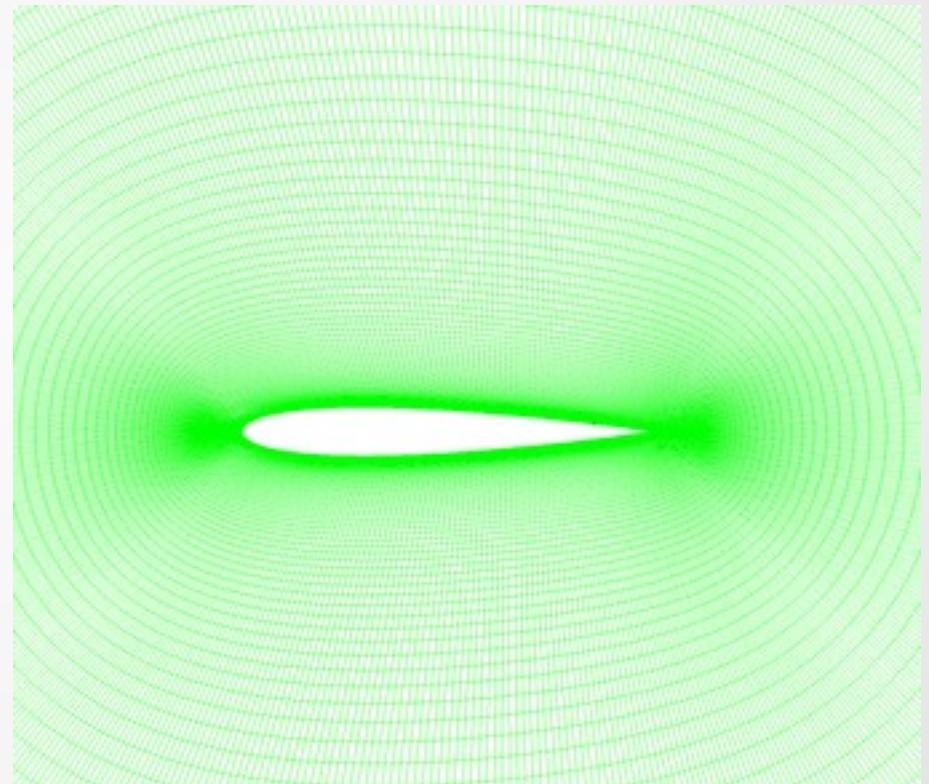
C-Grid & O-Grid: Differences



C-Grid



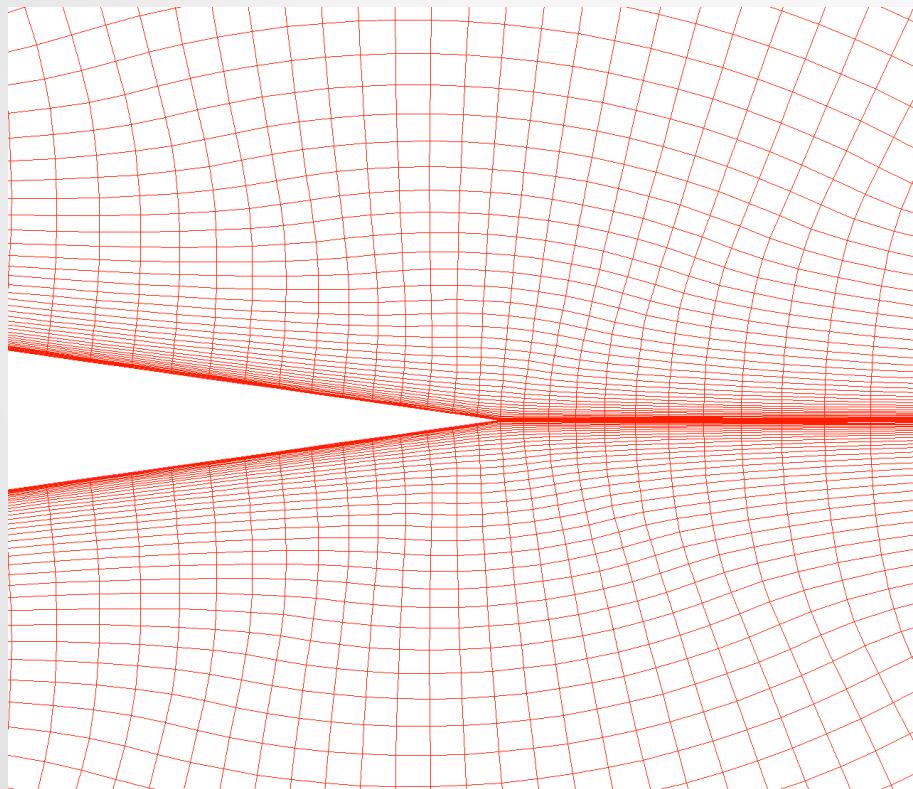
O-Grid



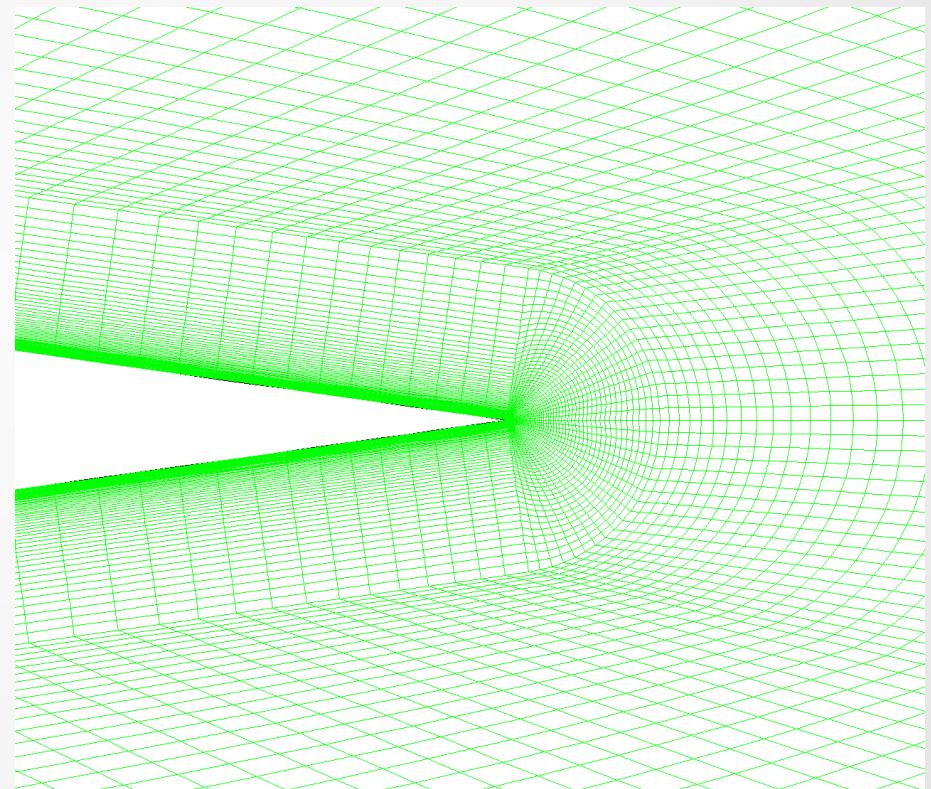
C-Grid & O-Grid: Differences



C-Grid



O-Grid



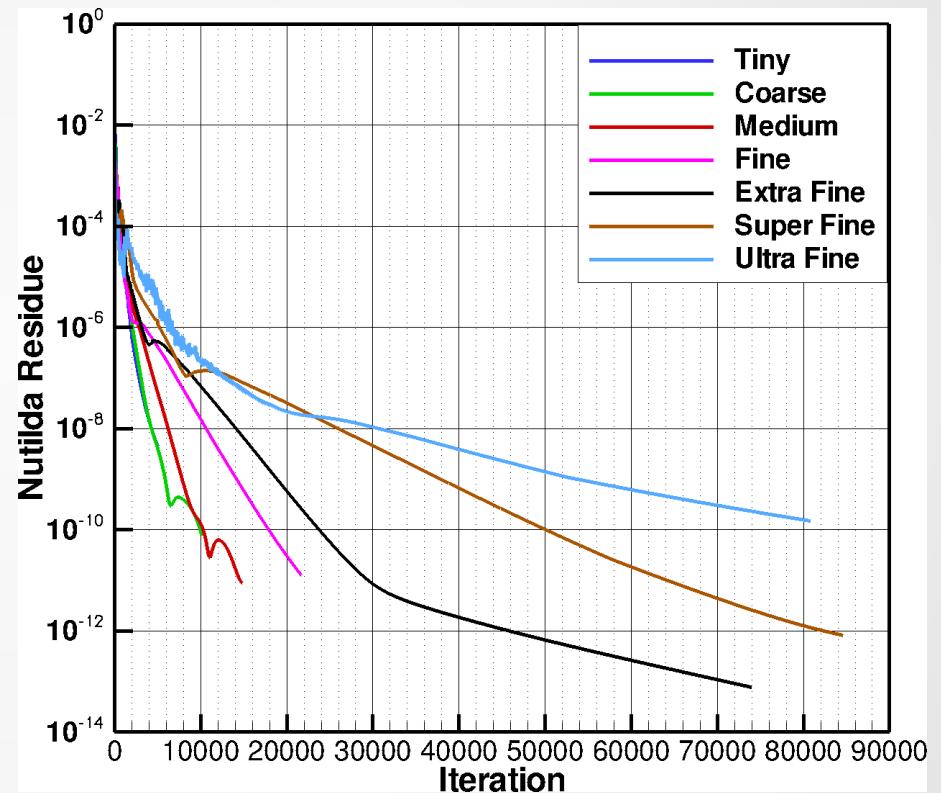
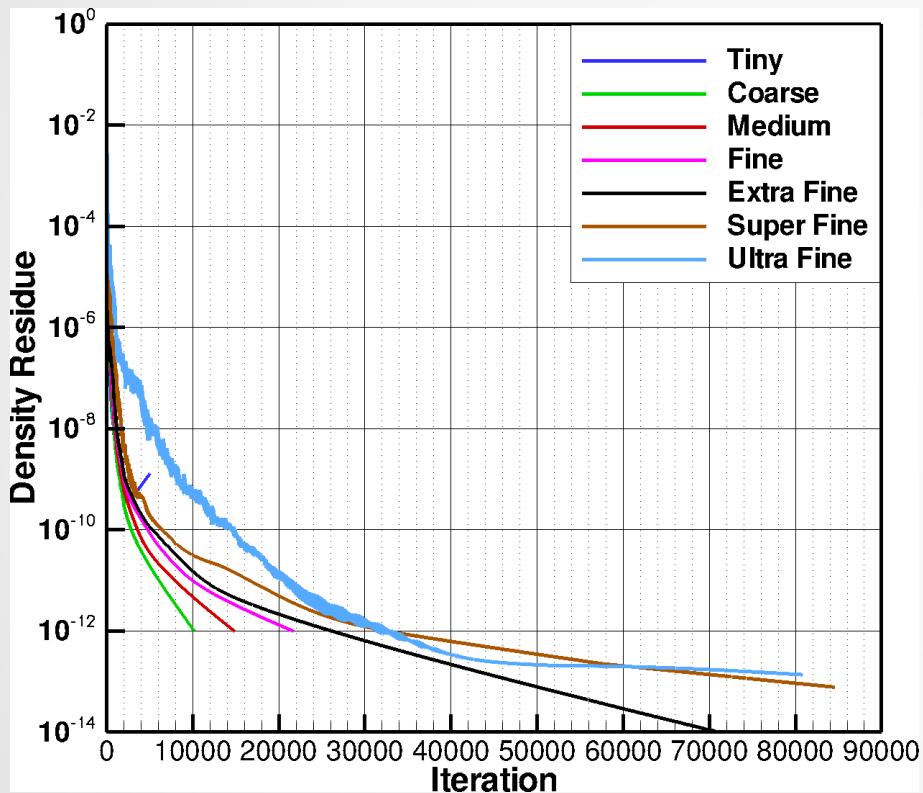
C-Grid & O-Grid: Differences



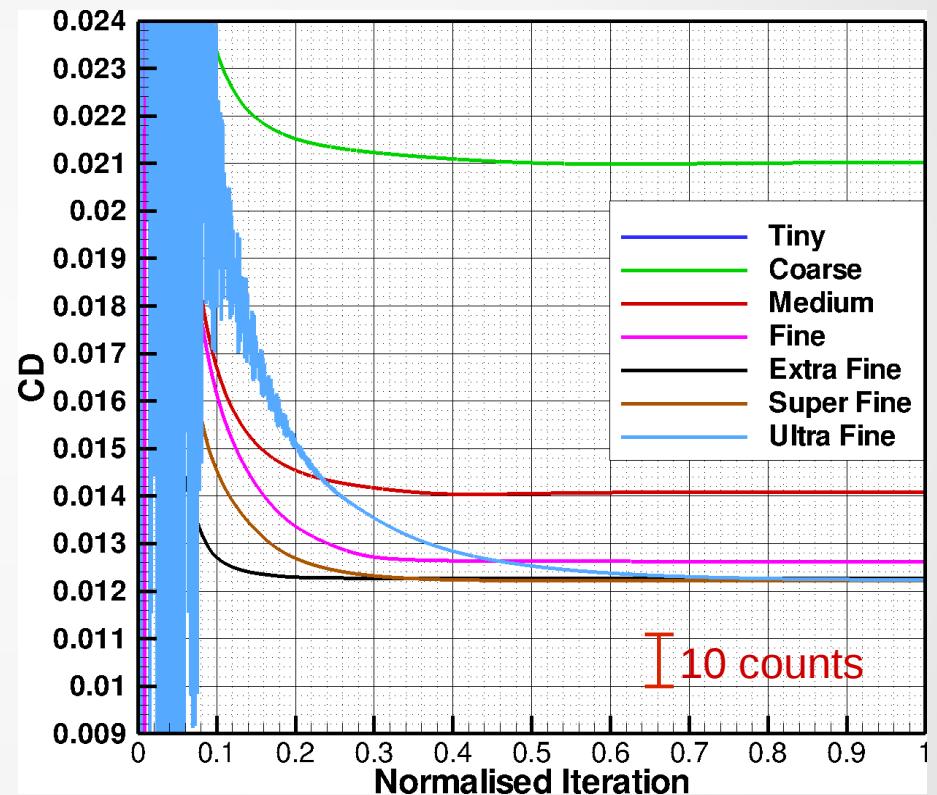
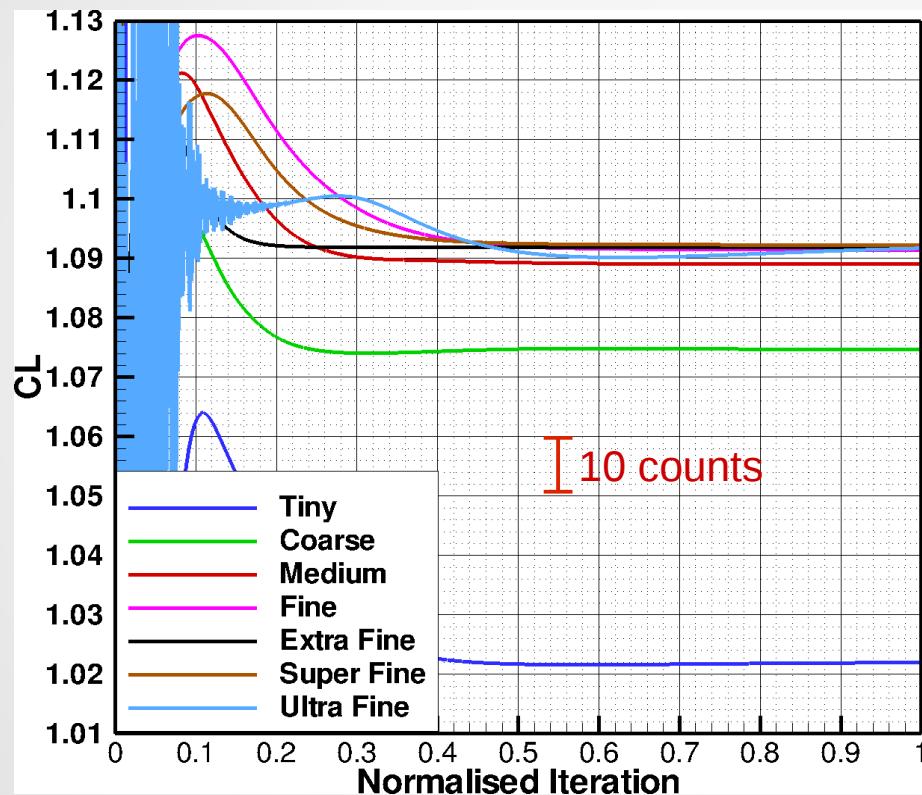
Grids	Estimated Y plus	First spacing (Mid chord region)	Growth Rate from wall	C-Grid Family 2 grid size	O-Grid size
Tiny	2	9.0e-6 m	1.8	3,584	2,296
Coarse	0.82	3.7e-6 m	1.35	14,336	8,942
Medium	0.39	1.7e-6 m	1.16	57,344	35,278
Fine	0.182	8.2e-7 m	1.07	229,376	140,126
Extra-Fine	0.09	4.0e-7 m	1.05	917,504	552,568
Super-Fine	0.045	2.0e-7 m	1.02	3,670,016	2,218,232
Ultra-Fine	0.022	1.0e -7 m	1.0125	14,680,064	8,793,208

Note: In the O grid, the number of points on the body and in radial direction are same as that in the C-grid.

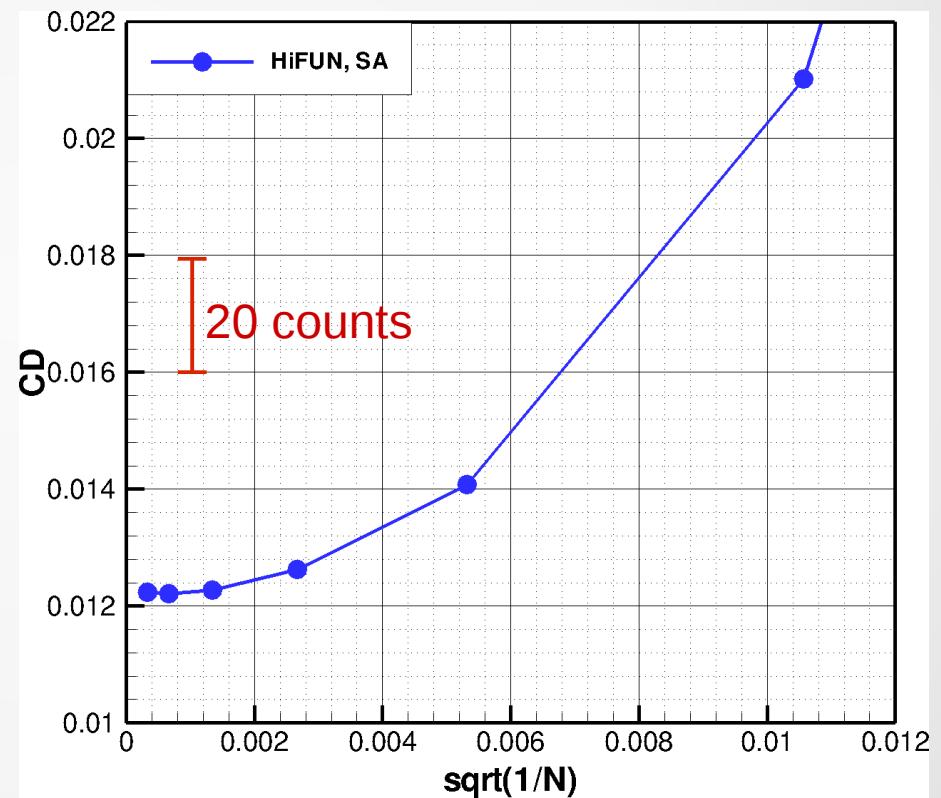
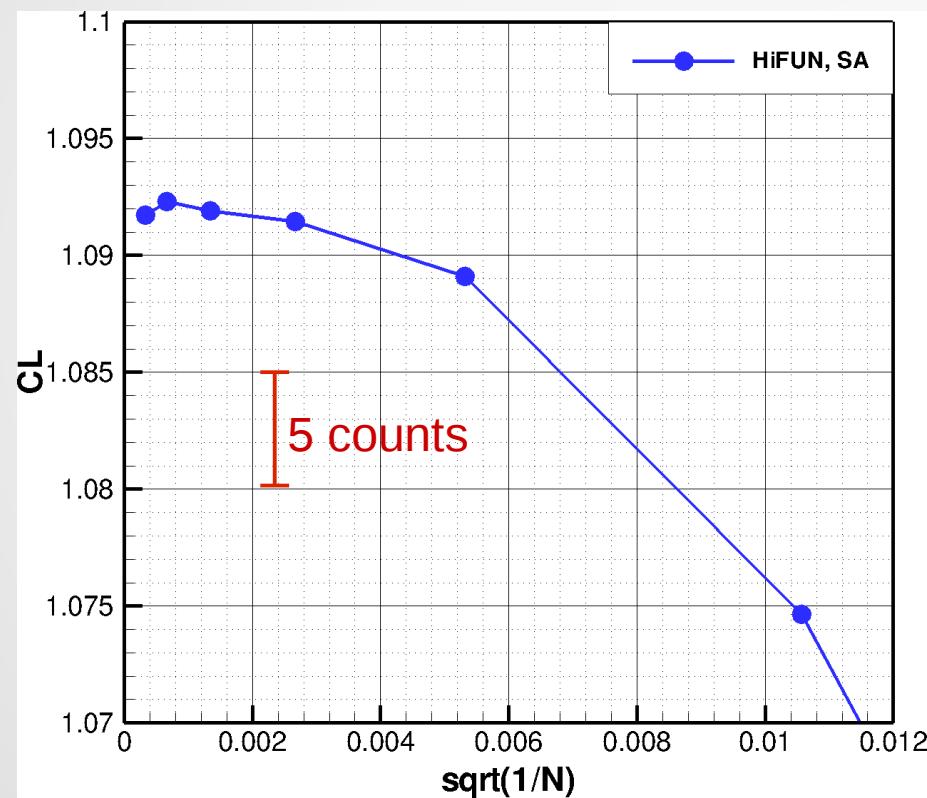
Residue convergence



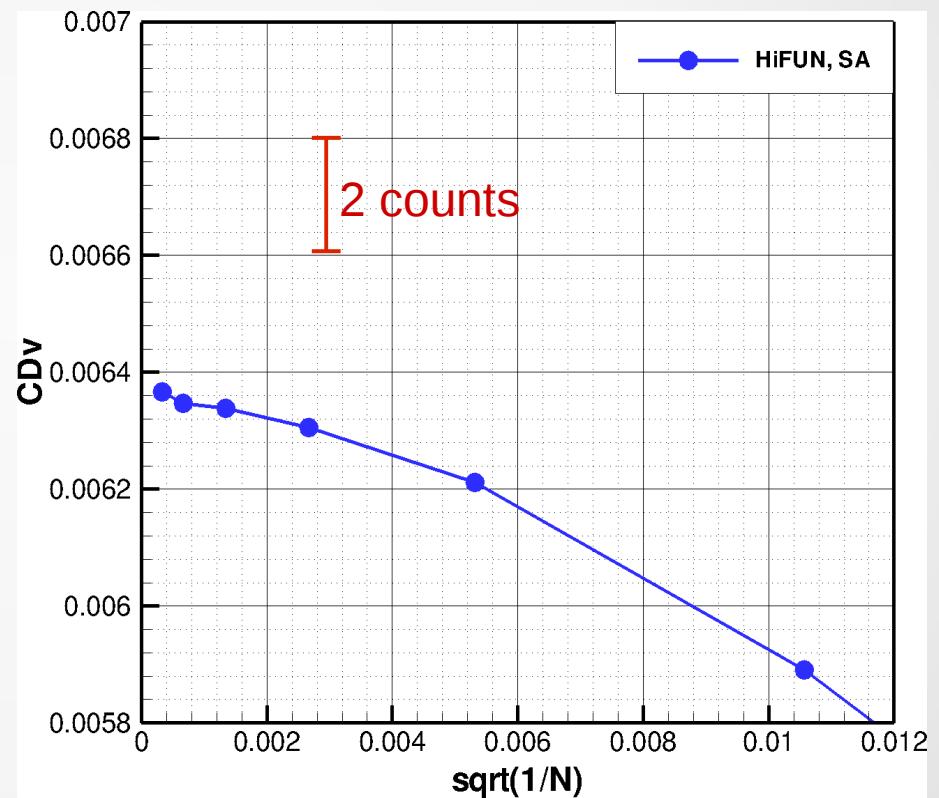
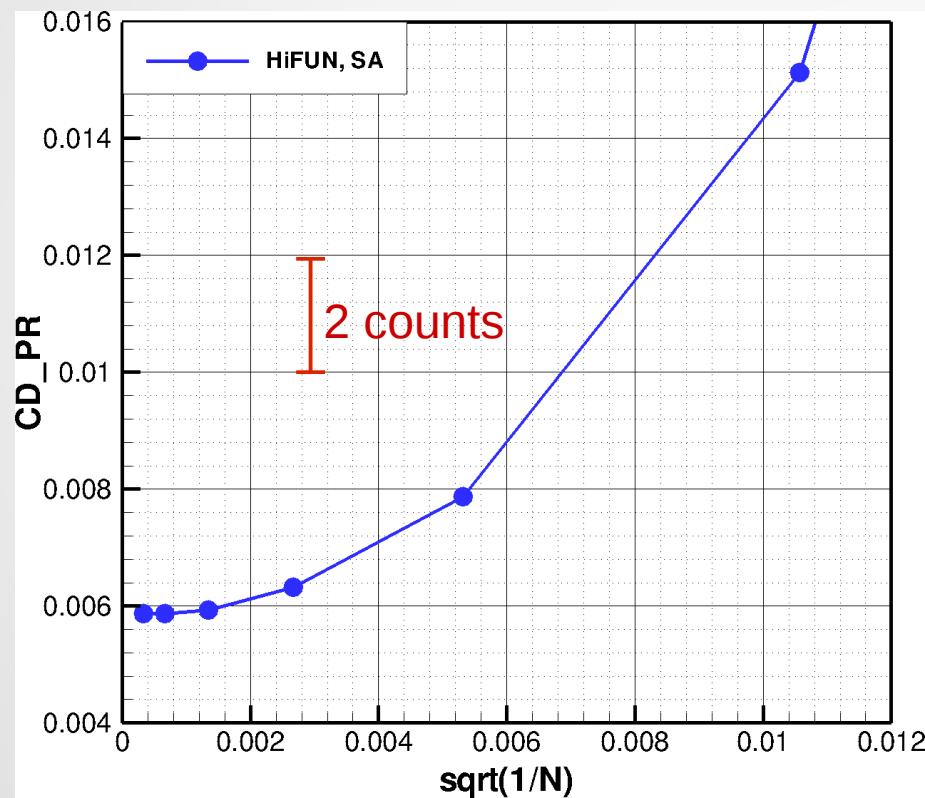
Iterative convergence



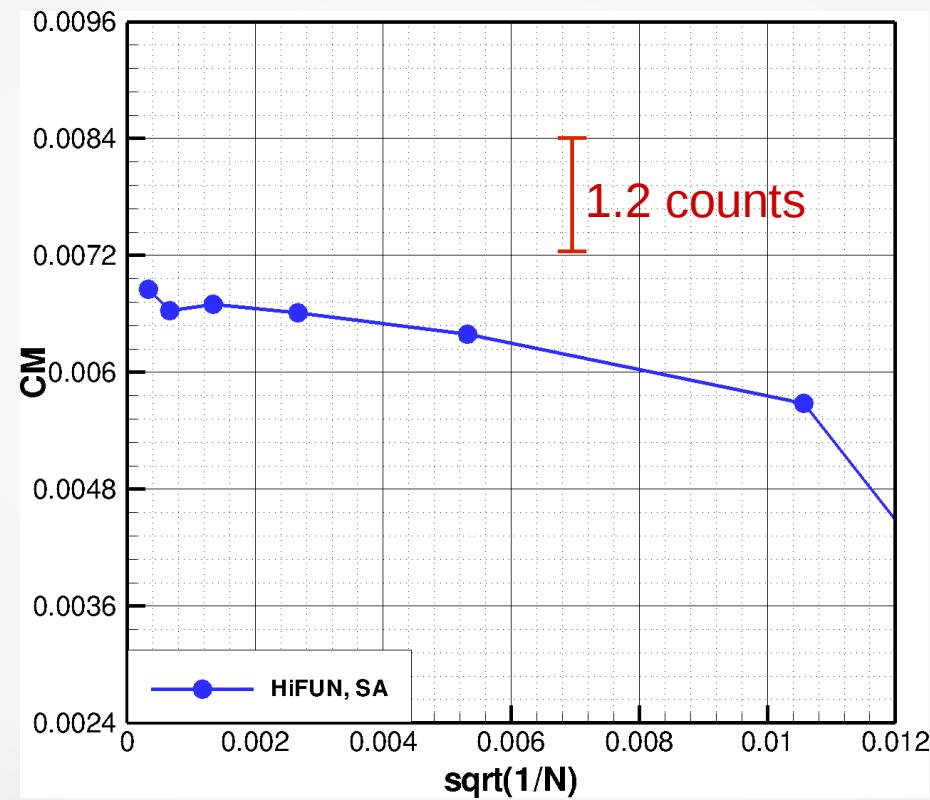
Grid convergence study: Forces



Grid convergence study: Forces



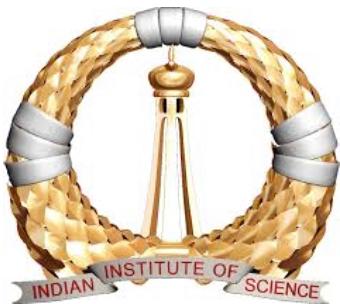
Grid convergence study: Moments



Forces & moments comparison



Grids	CL	CD	CDp	CDv	Cm
3 Codes: FUN3D, CFL3D, TAU	1.0909 - 1.0911	0.01227 - 0.012275	0.00606 - 0.00607	0.006205 - 0.006206	0.00676 - 0.0068
Tiny	1.021969	0.058237	0.053186	0.005050	-0.002947
Coarse	1.074645	0.021022	0.015131	0.005891	0.005683
Medium	1.089100	0.014079	0.007867	0.006212	0.006389
Fine	1.091450	0.012625	0.006319	0.006305	0.006611
Extra-Fine	1.091908	0.012271	0.005932	0.006338	0.006700
Super-Fine	1.092297	0.012217	0.005871	0.006347	0.006632
Ultra-Fine	1.091728	0.012235	0.005868	0.006366	0.006853



Thank You

Contact:

N. Balakrishnan: nbalak@aero.iisc.ernet.in