CFD High Lift Calculations Using USM3D

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Outline

- TetrUSS System
- Flow Condition and Cases
- Down select of Turbulence Model
- CD by Components
- Surface Pressure
- Sectional/Cumulative CL and CD
- Observations

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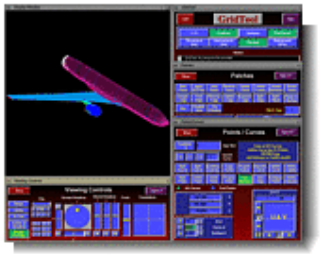
TetrUSS

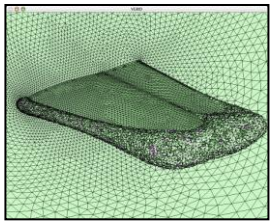
Tetrahedral Unstructured Software System



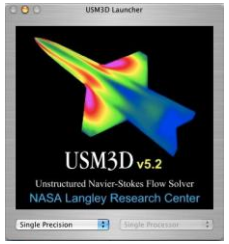
Geometry Setup
GridTool

TetrUSS is a loosely integrated, flexible aero analysis and design system that

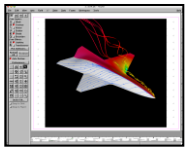
- *provides initial solutions to complex problems within days*
- *provides accurate representation of flow physics*
- *heavily used in NASA and Industry projects*
- *continually improved to meet project needs*



Grid Generation
VGRID OpenGL



Flow Solver
USM3D



Visualization
SimpleView
and
Commercial Packages

Tools & Utilities

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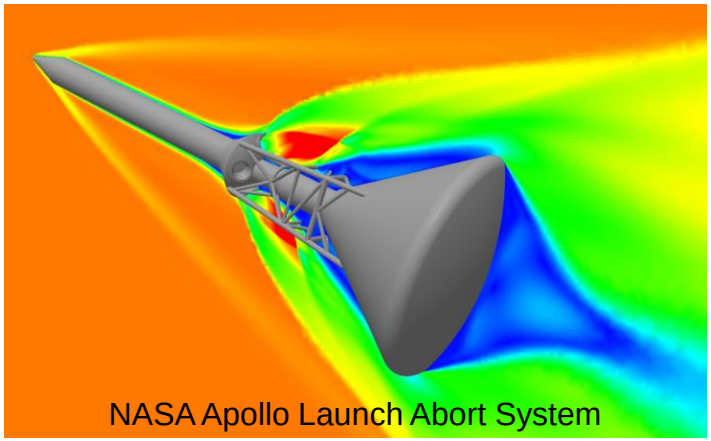
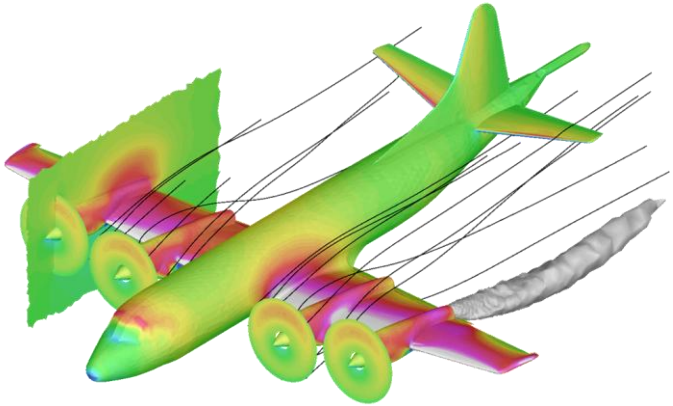
USM3D
Tetrahedral Flow Solver

- **Tetrahedral cell-centered, finite volume**
  - Single- and overset-grid
- **Euler and Navier-Stokes**
  - Several 1- and 2-equation turbulence models
  - *SA and SST used for the present study*
- **Time Integration**
  - Steady-state w/ local time stepping
  - 2nd order time accuracy
- **Upwind spatial discretization**
  - FDS, AUSM, HLLC, LDFSS, FVS
  - Min-mod and Venkat limiters
- **Standard and special BC's**
- **Parallelized for clusters**
  - SGI, Sun, PC/Linux, Alpha/Linux, Mac OS X, IBM, HP
  - input/output files in global form



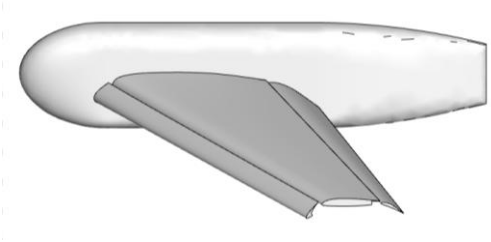
NASA Apollo Launch Abort System



B. D. Goble and J. R. Hooker
Lockheed Martin Aeronautics Company

High Lift Cases

M_∞=0.2, T_∞=520 °R, Re_c=4.3x10^6



Configuration 1 - Slat 30, Flap 25 full span

Configuration 8 - Slat 30, Flap 20 full span

Geometry	Turbulence Models	Grids
Configuration 1	SA and SST	Coarse, Medium and Fine
Configuration 8	SA	Medium

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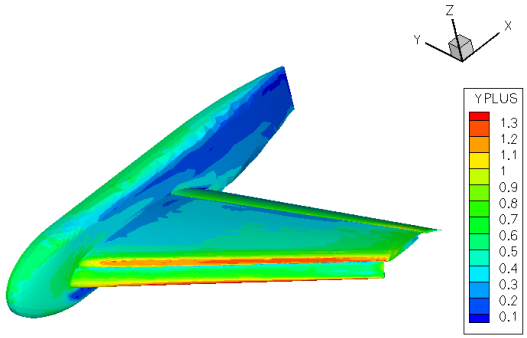
Configuration 1 Grid Statistics

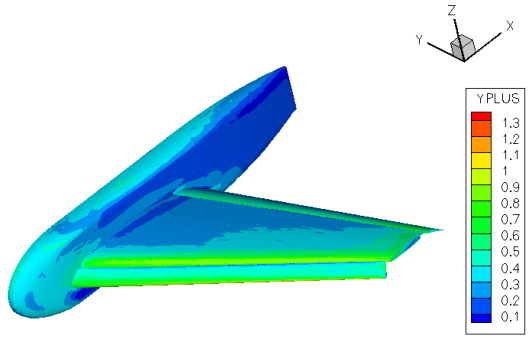
Tet-Cellcentered-A-v1

Computer: Pleiades Harpertown nodes, Q1 2010

Configuration 1 - Slat 30, Flap 25 full span

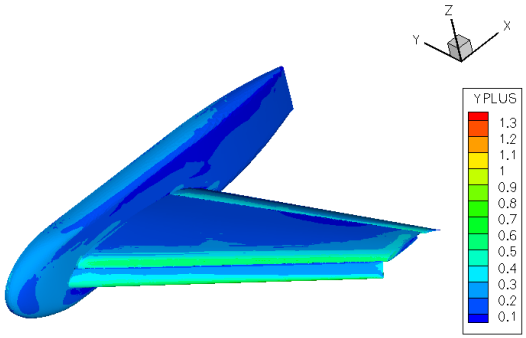


$Y^+=1$



Y+ Variations

$Y^+=2/3$



$Y^+=4/9$

Coarse grid
Cells = 7.237,190
nfacs = 108,006
CPU = 96
WallTime= 2 hours

Medium grid
Cells = 21,743,354
nfacs = 278,590
CPU = 128
WallTime = 8 hours

Fine Grid
Cells= 62,644,381
nfacs = 668,822
CPU = 512
WallTime = 6 hours

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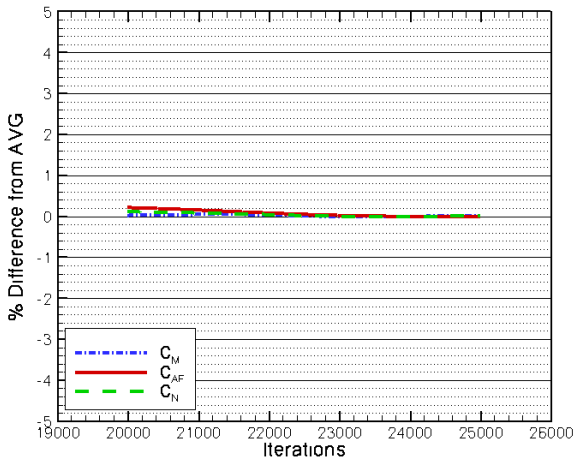
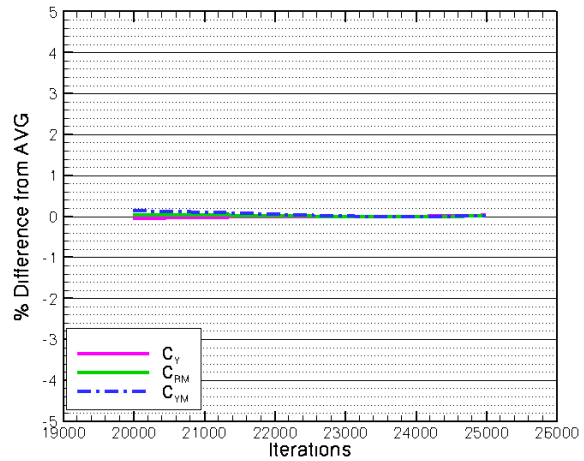
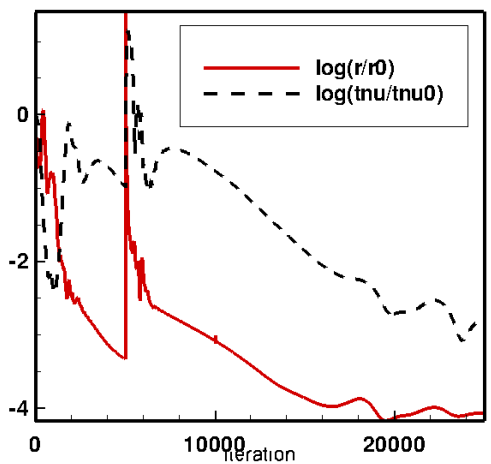
Sample of Convergence for SA results

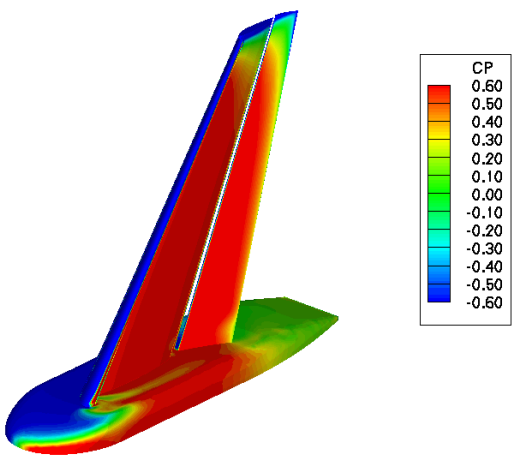
C_{AF} = -0.7575, C_N = 2.8439, C_M = -0.4350, C_Y = -0.7957, C_{RM} = 1.2973, C_{YM} = 0.3042

All F&M converge <0.1% last 5000 iterations









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Down Select of Turbulence Model

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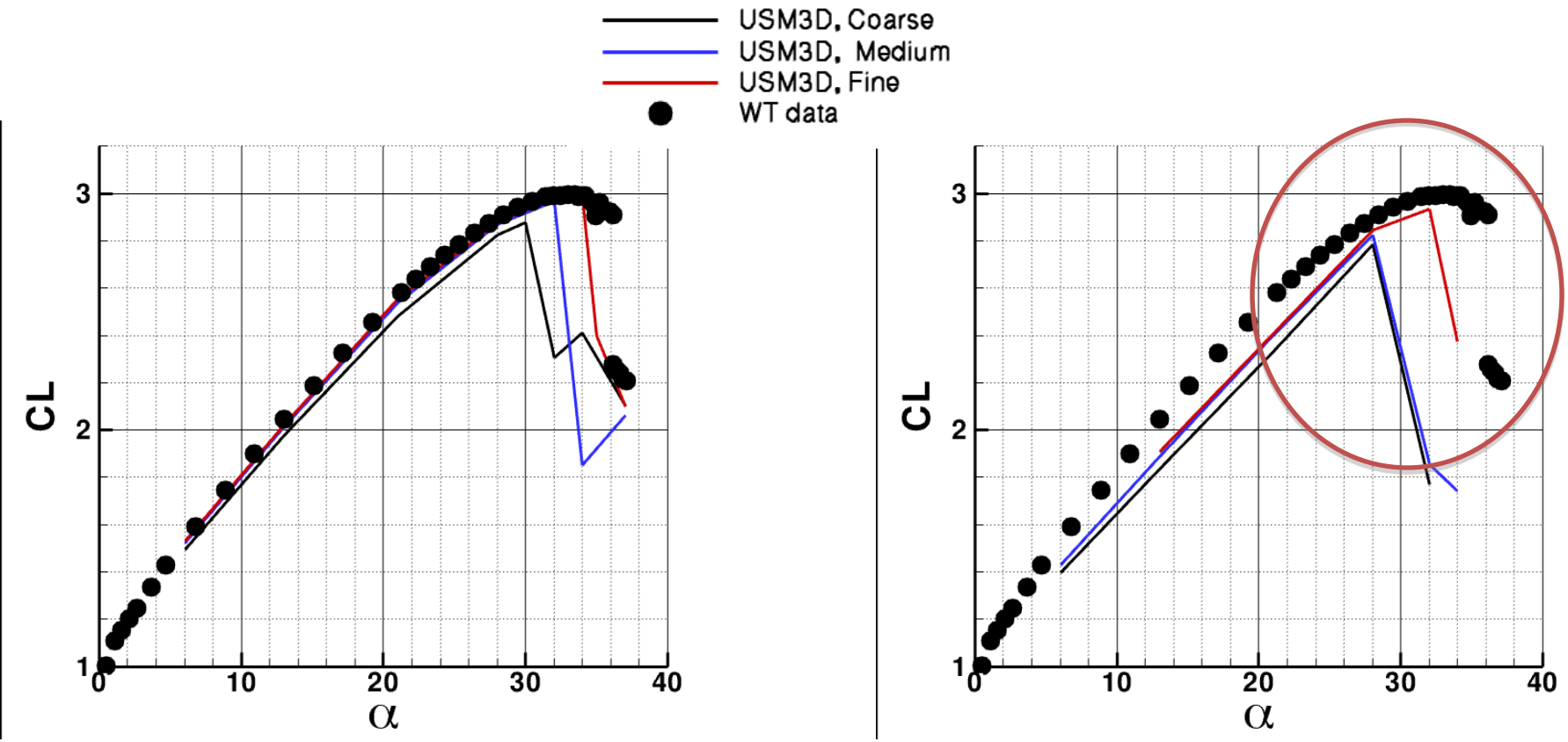
Grid Sensitivity of CL
SA and SST Models

SA Model CLmax
Coarse 30, Medium 32, Fine 34

SST Model CLmax
Coarse 28, Medium 28, Fine 32



Underpredicts CL For Alpha<28

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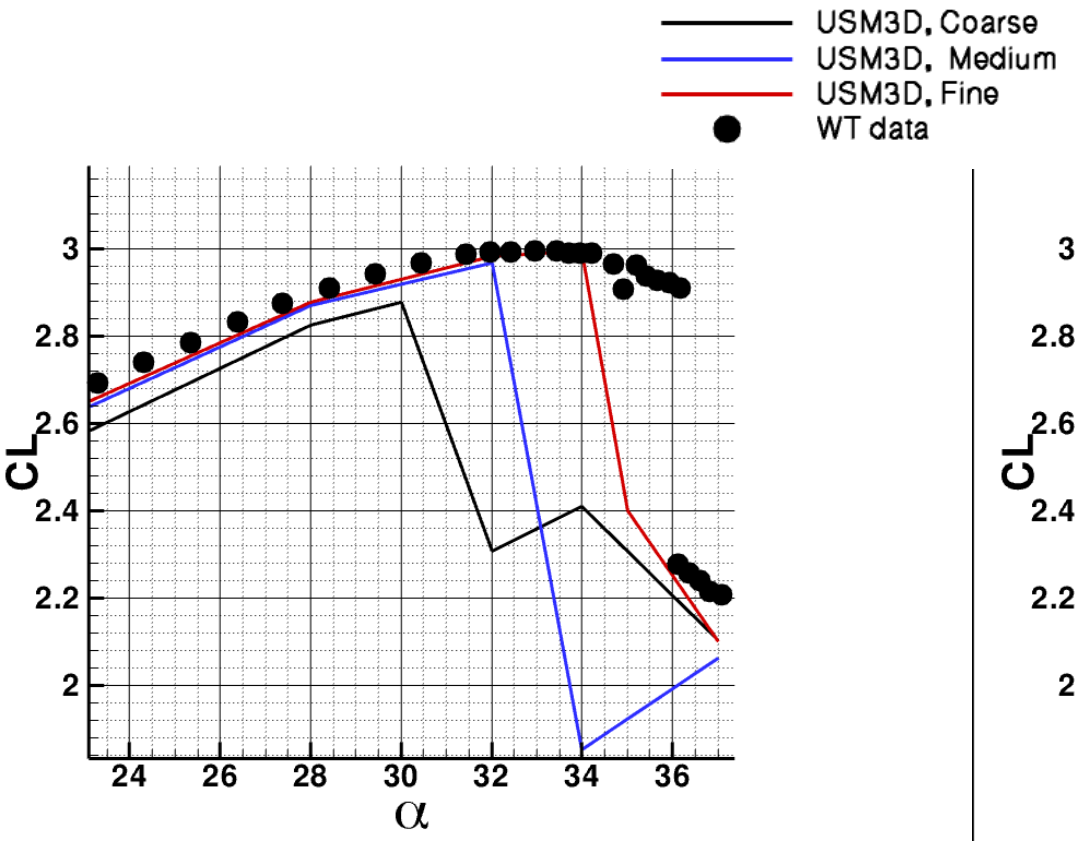
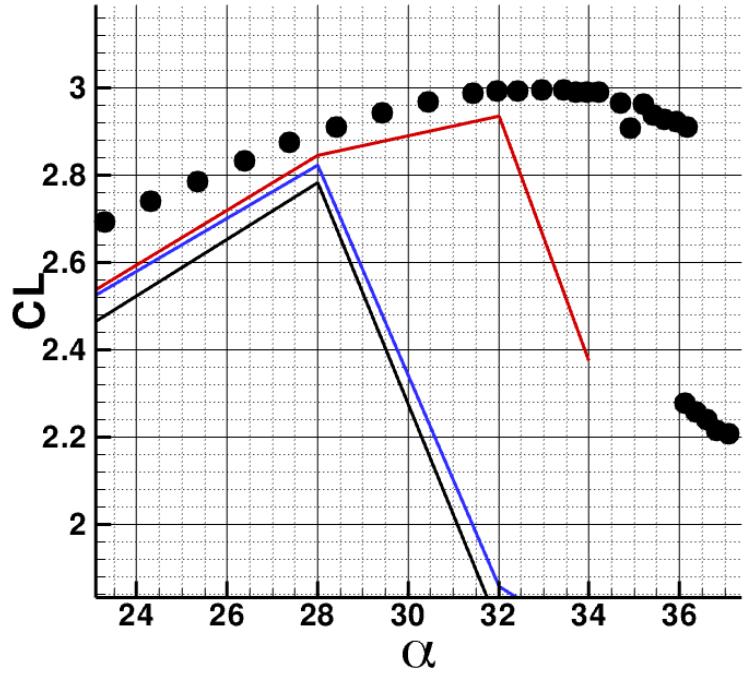
Grid Sensitivity of CL
SA and SST Models

SA Model CLmax
Coarse 30, Medium 32, Fine 34

SST Model CLmax
Coarse 28, Medium 28, Fine 32





Underpredicts CL For Alpha<28

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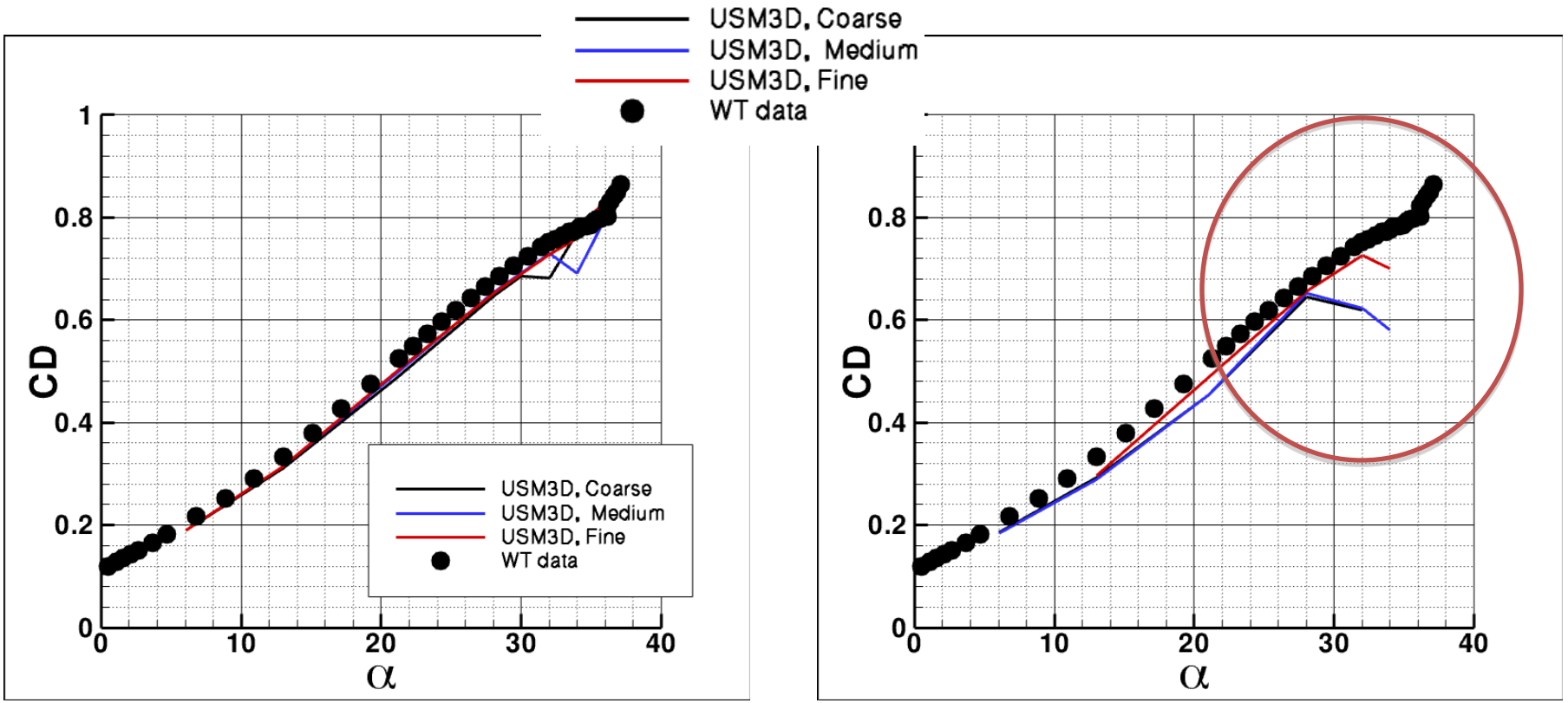
Grid Sensitivity of CD
SA and SST Models

Underpredicts CD For Alpha<28



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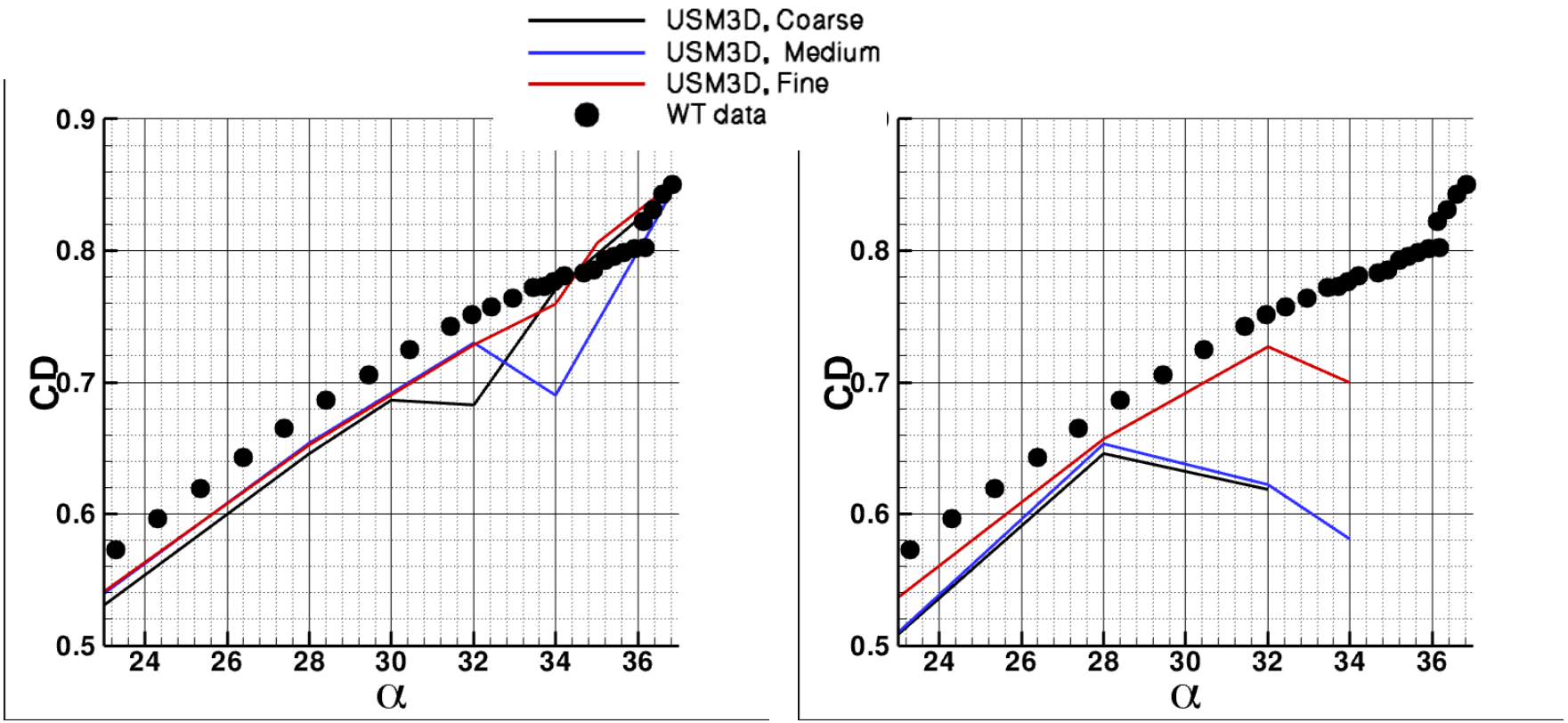
Grid Sensitivity of CD
SA and SST Models

Underpredicts CD For Alpha<28



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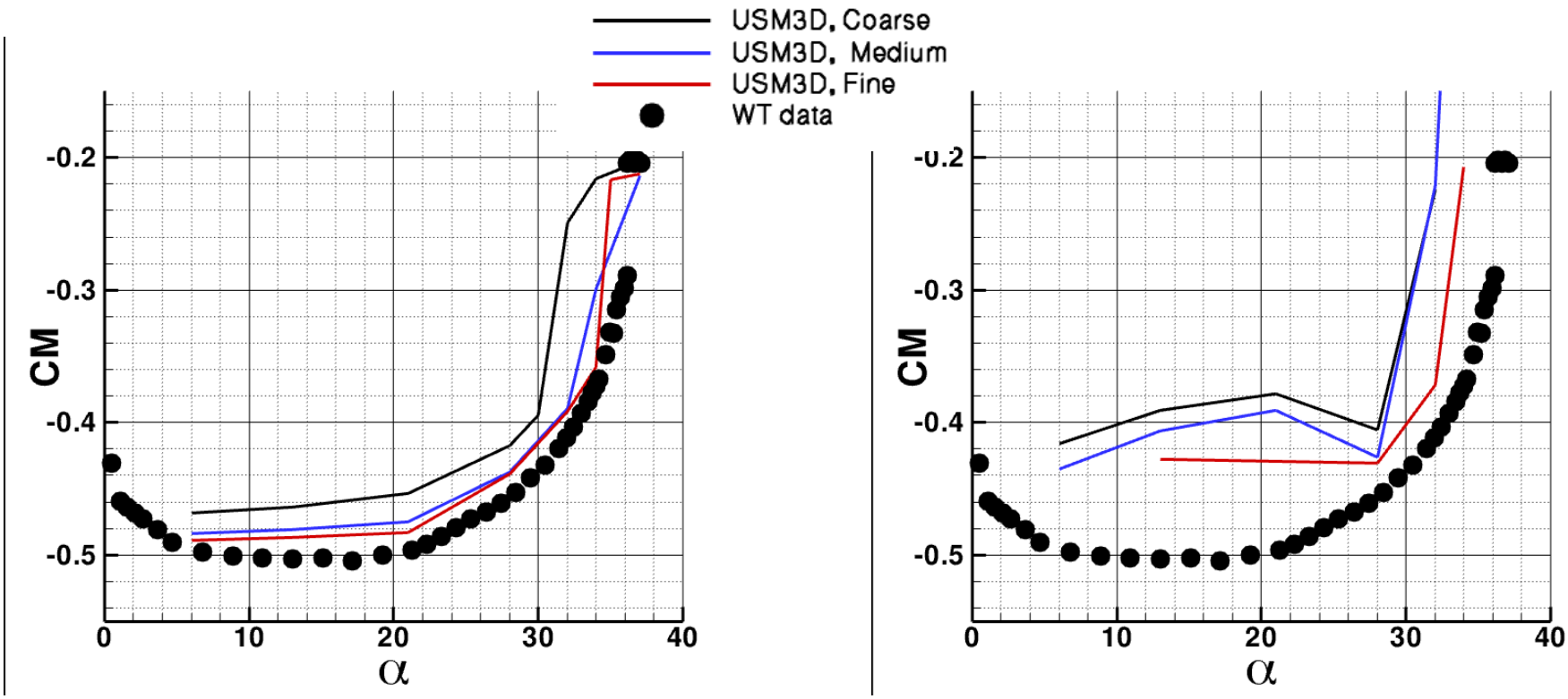
Grid Sensitivity of CM SA and SST Models

SA results improves with grid refinement

SST overpredicts CM



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Grid Convergence
SA Only

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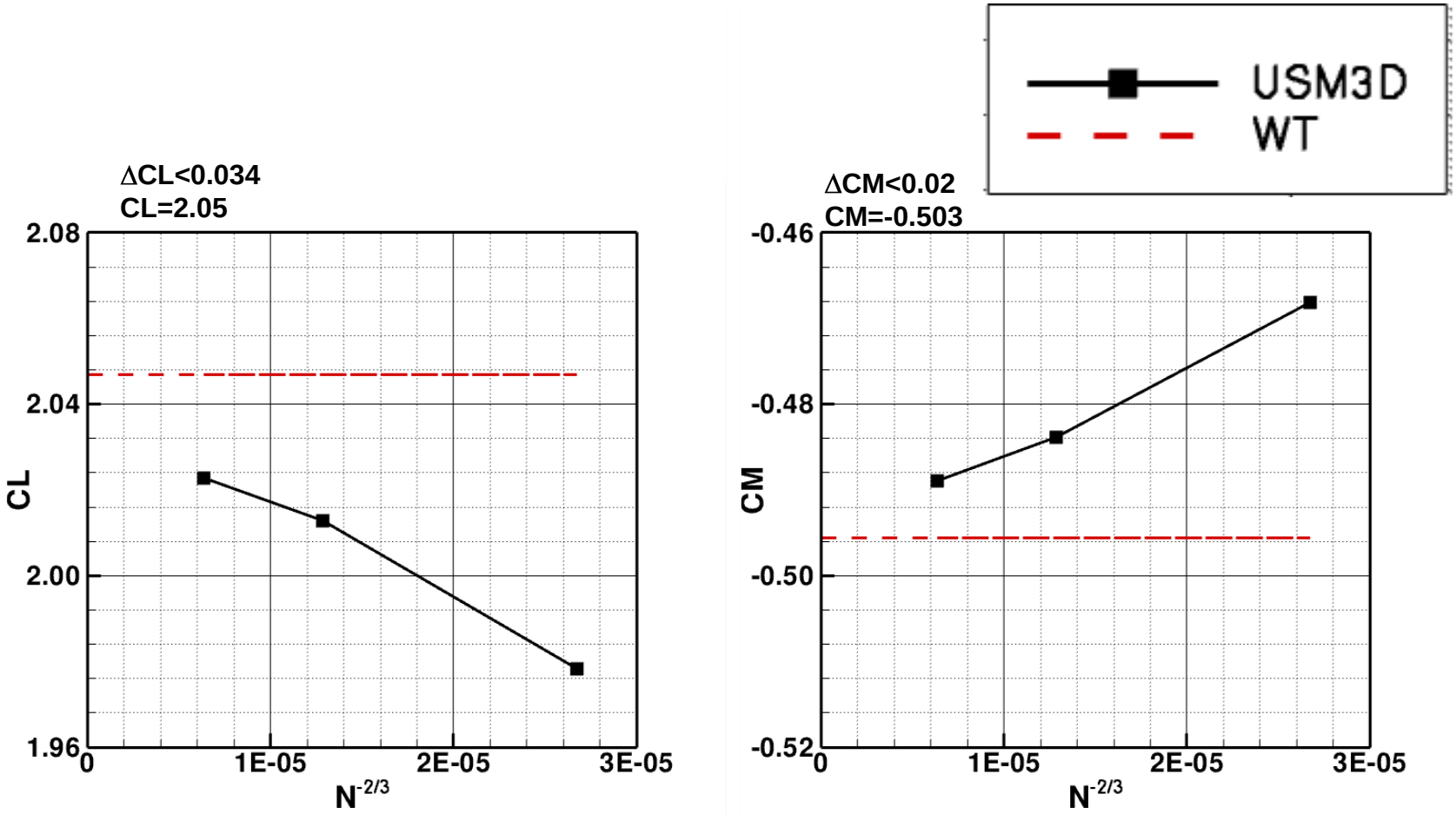
Configuration 1, CL/CM vs Grid, α=13



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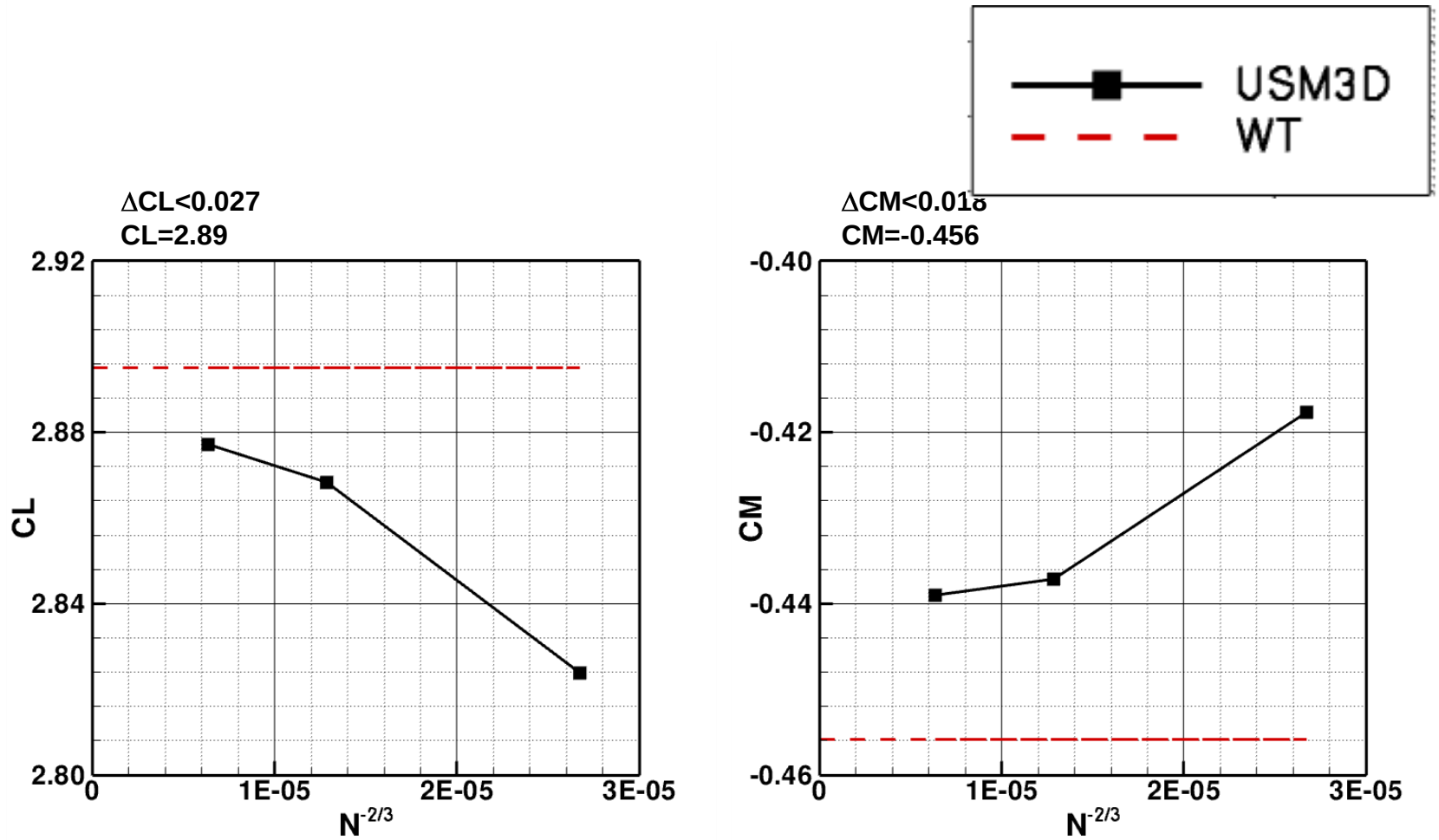
Configuration 1, CL/CM vs Grid, α=28



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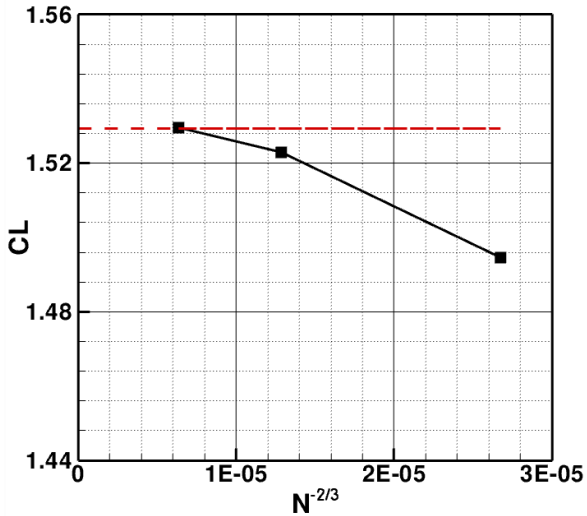
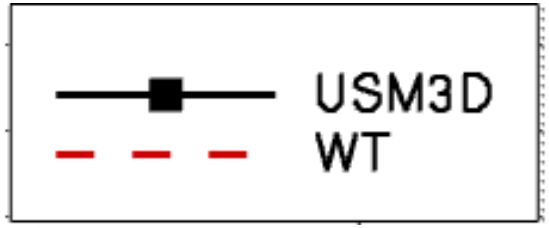
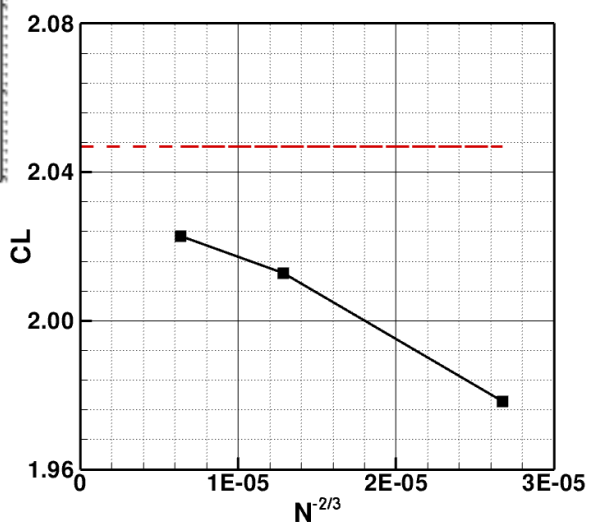
Configuration 1, CL vs Grid





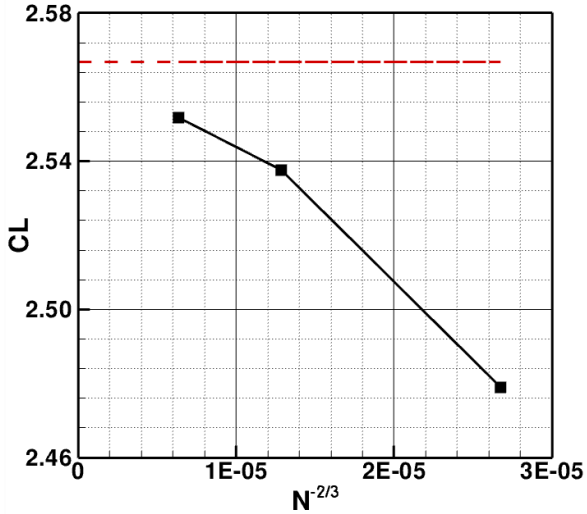


α=6

ΔCL<0.006
CL=1.53

α=13

ΔCL<0.034
CL=2.05

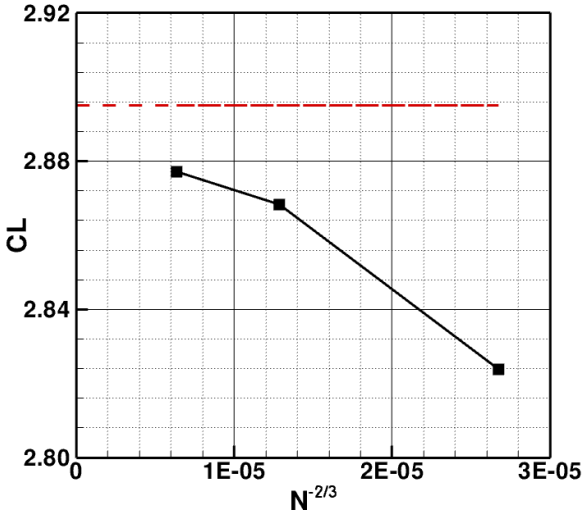


α=21

ΔCL<0.029
CL=2.57

α=28

ΔCL<0.027
CL=2.89



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CD by Components
SA Only

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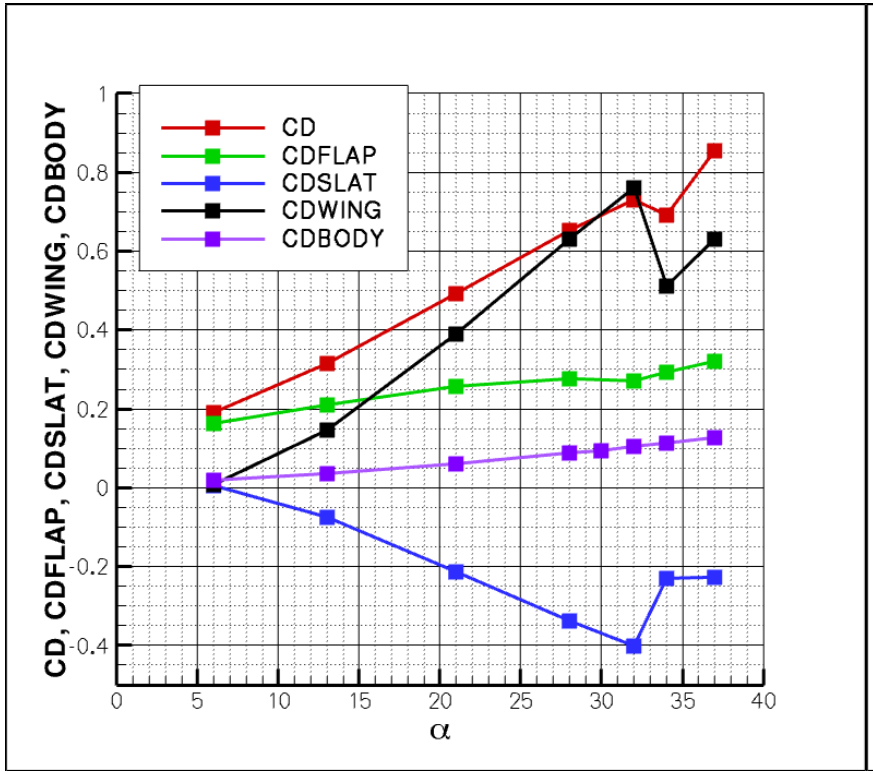
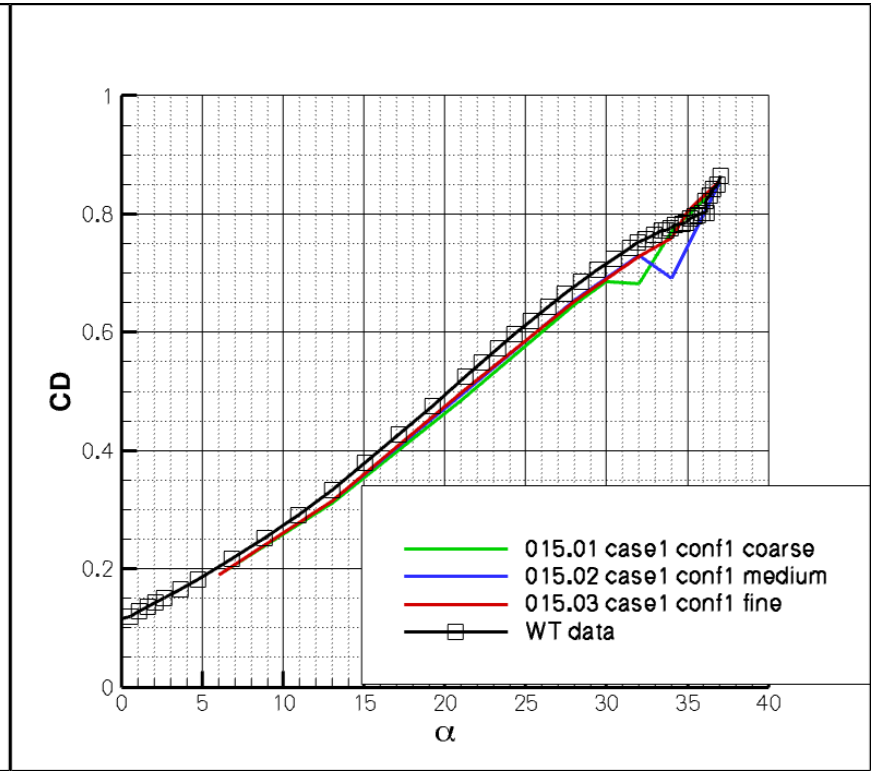
CD by Components
Configuration 1





At α=6, the flap generates 95% of the drag
For α>13, the main wing generates most of the drag
The slat generates thrust (-ve Drag) for all αs

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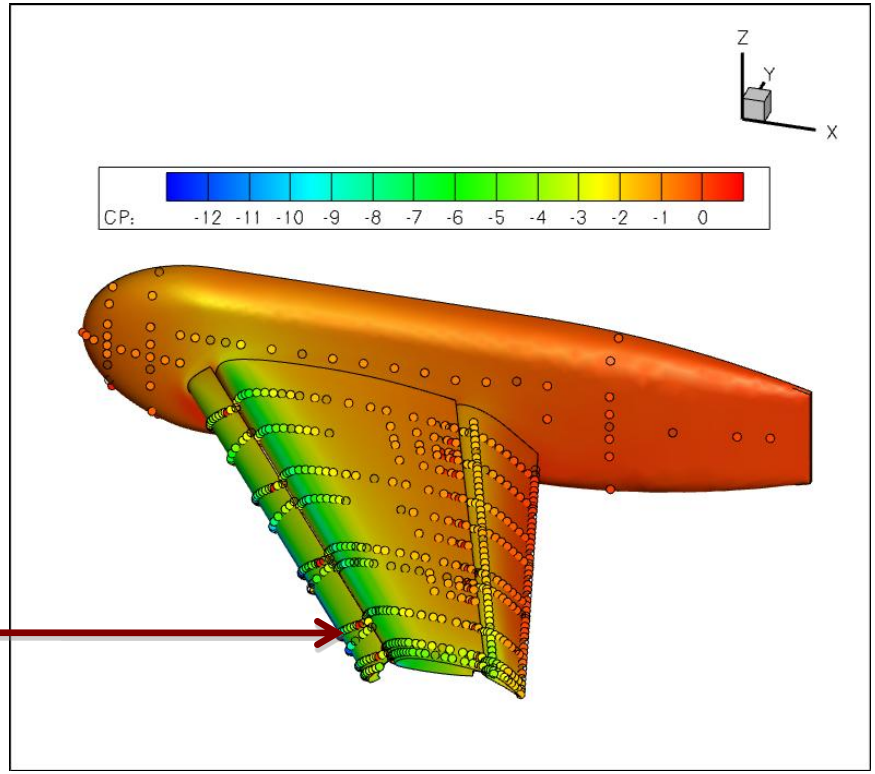
Surface Pressure, SA Only



ST85

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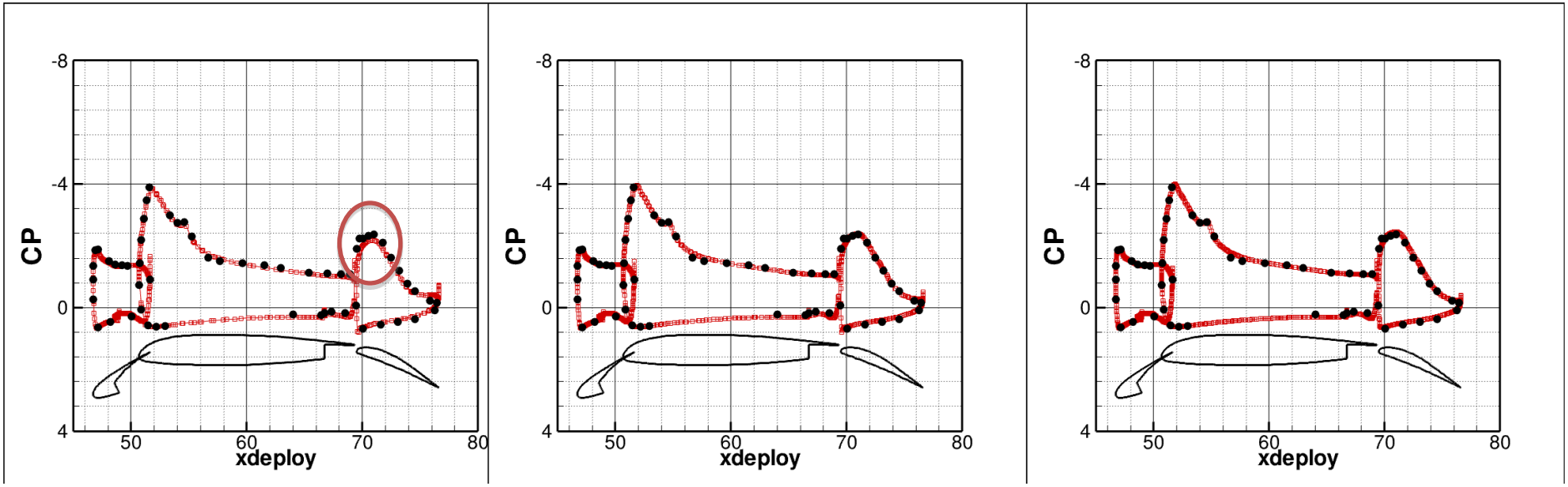
ST85, Surface Pressure Configuration 1, α=13

USM3D
WT Data

Coarse | Medium | Fine



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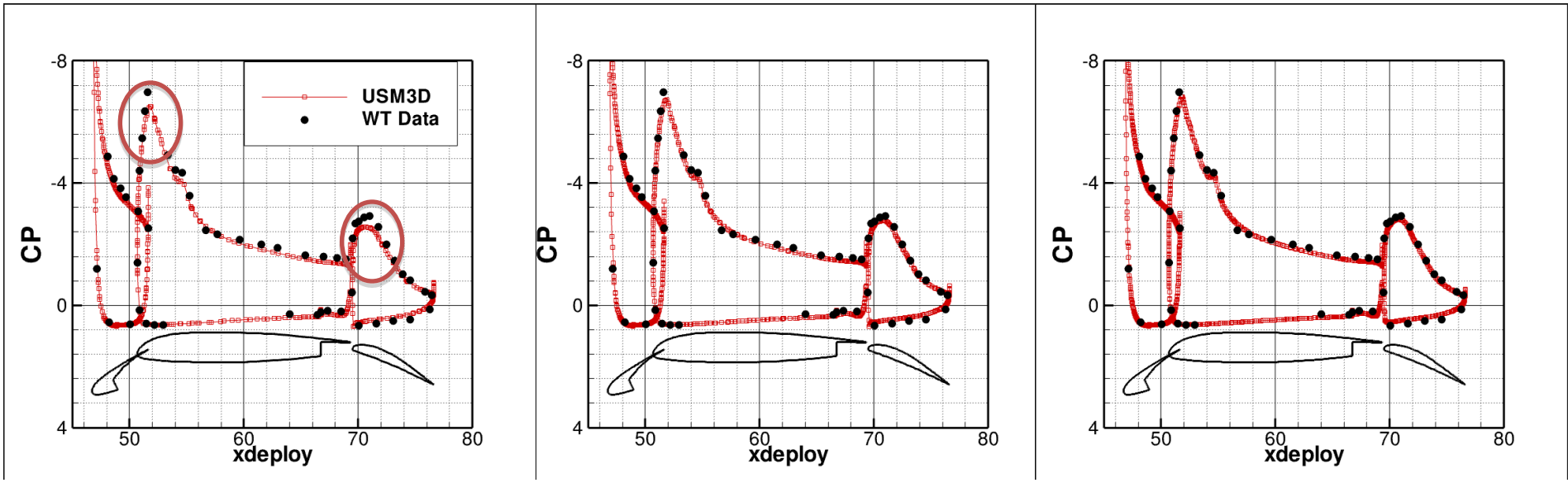
ST85, Surface Pressure Configuration 1, α=28

USM3D
WT Data

Coarse | Medium | Fine



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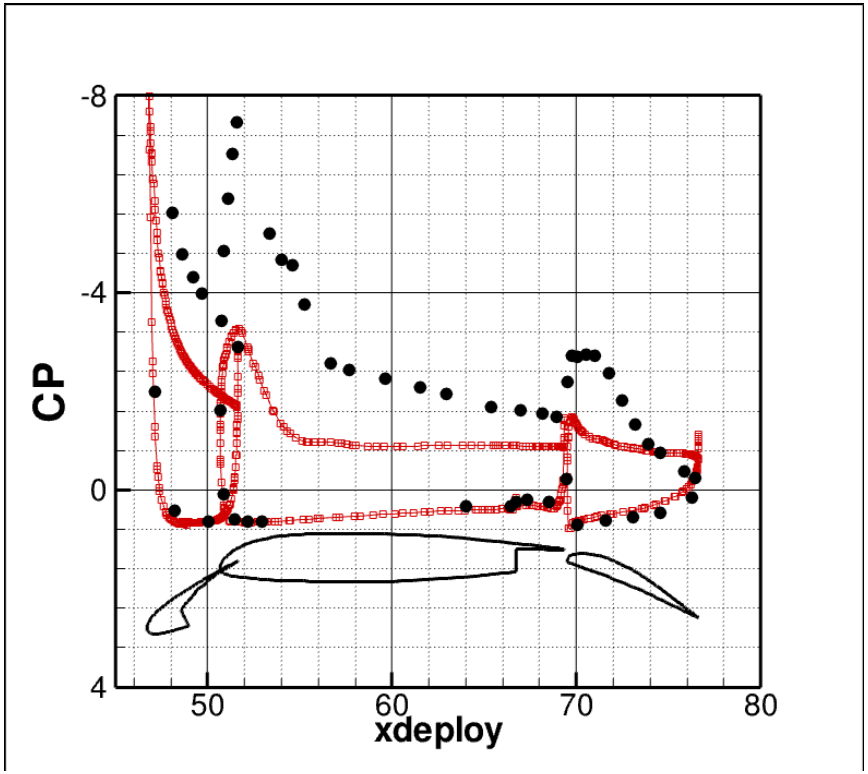
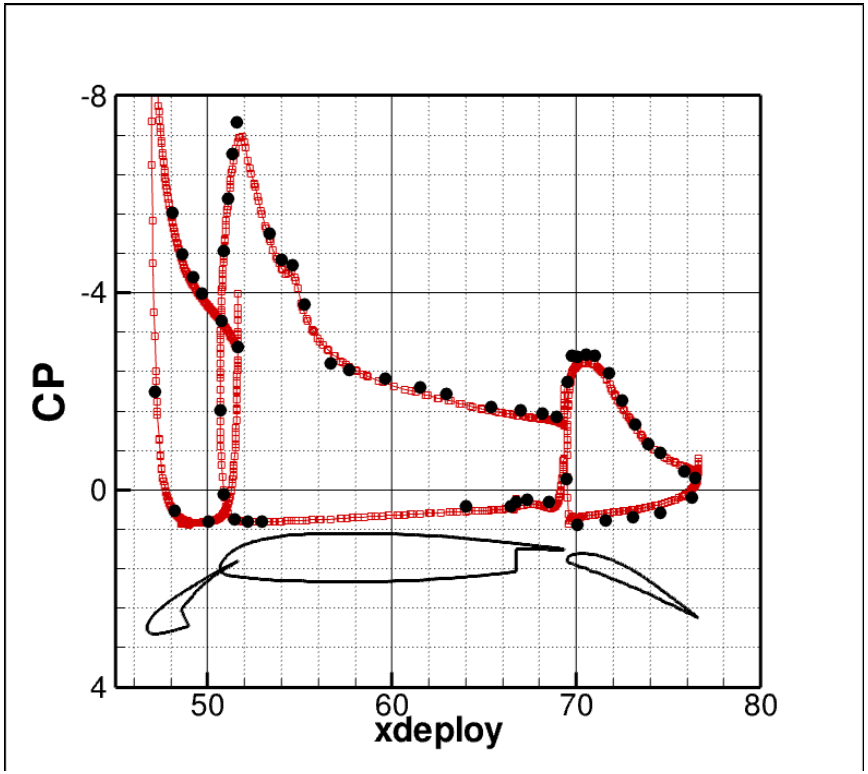
ST85, Surface Pressure
Config1, Coarse and Medium Grids, α=32

USM3D
WT Data

Coarse



Medium



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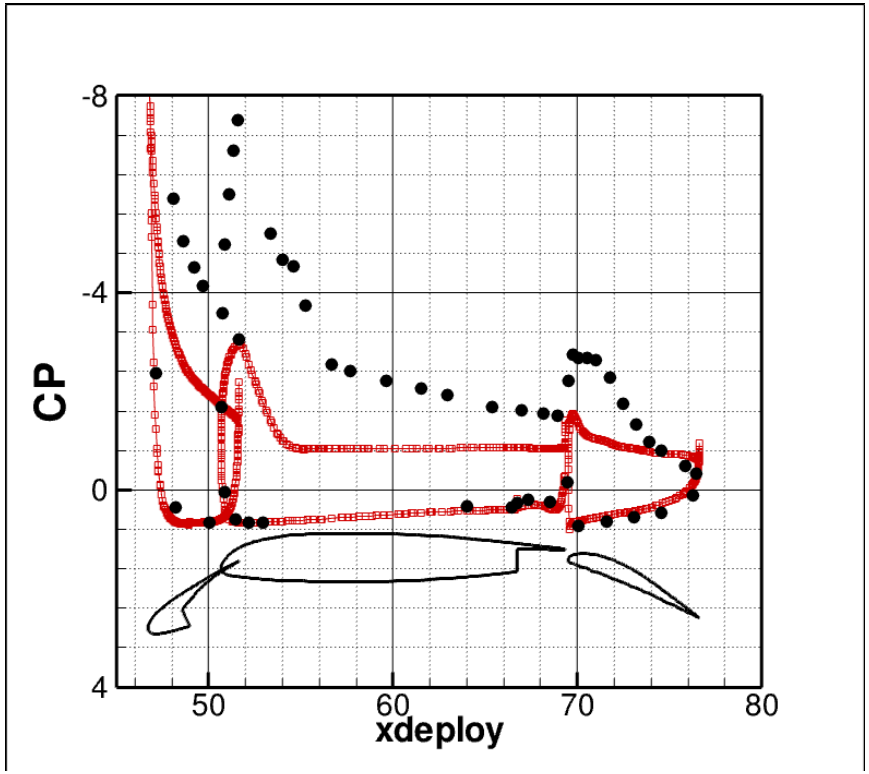
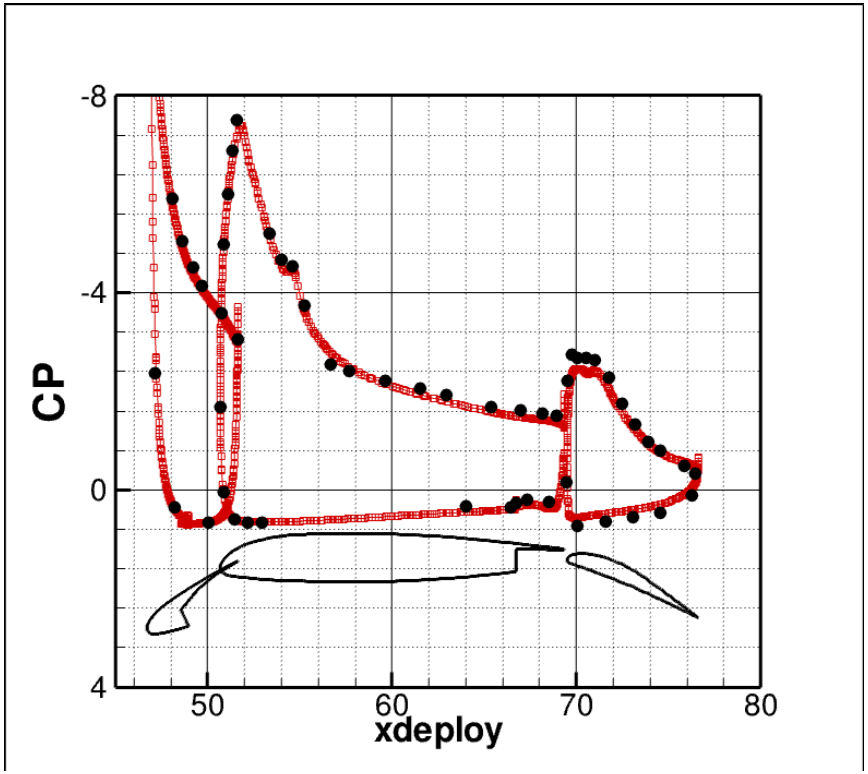
ST85, Surface Pressure
Config1, Medium and Fine Grids, α=34

USM3D
WT Data

Medium



Fine



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Sectional/Cumulative CL and CD
SA Only

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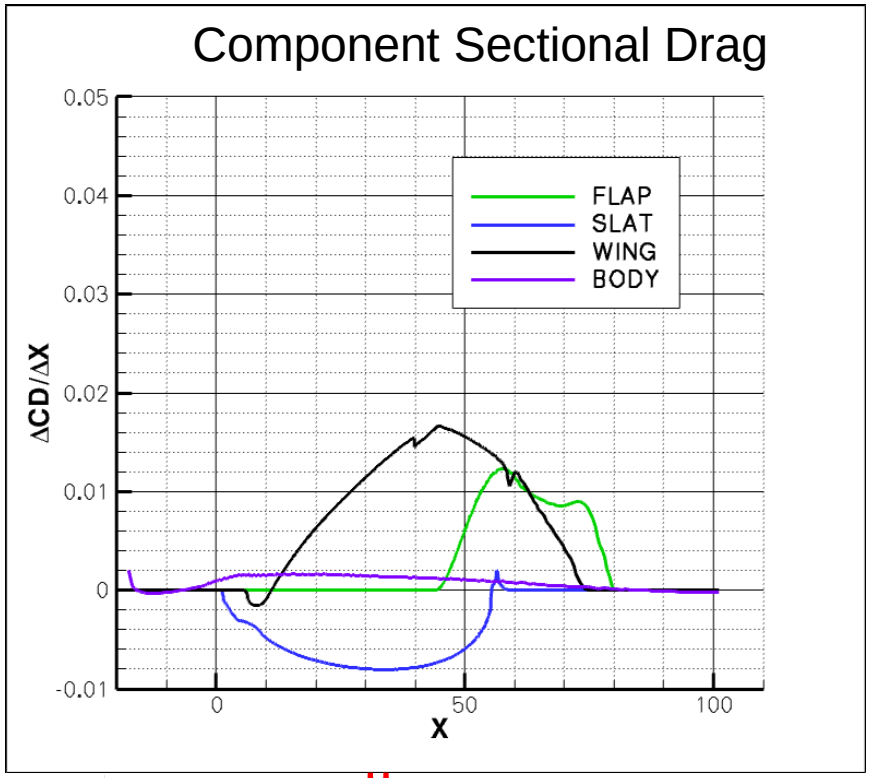
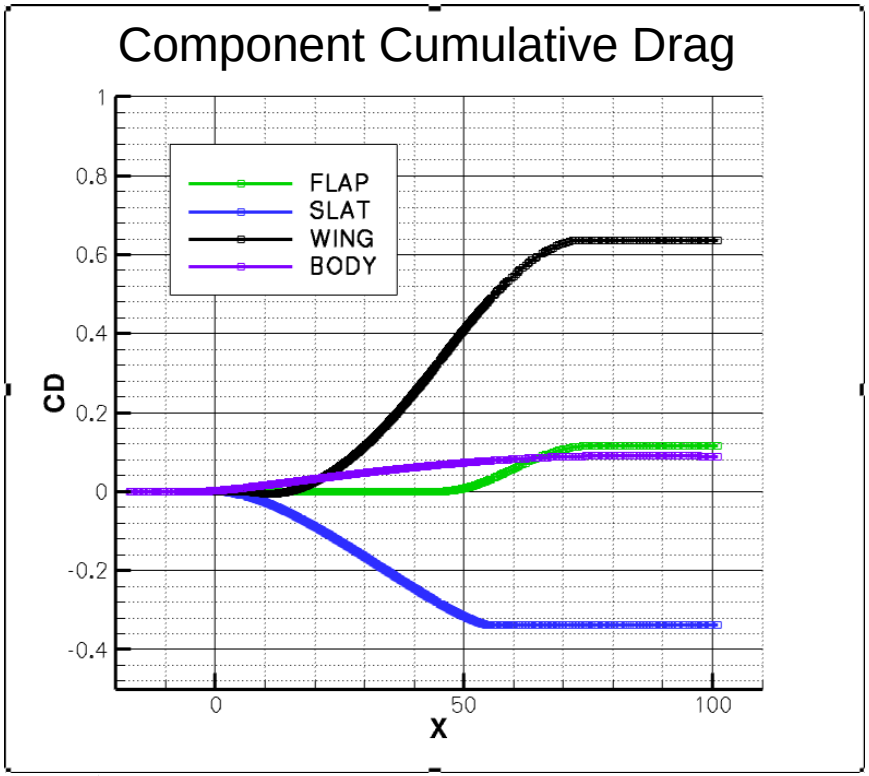
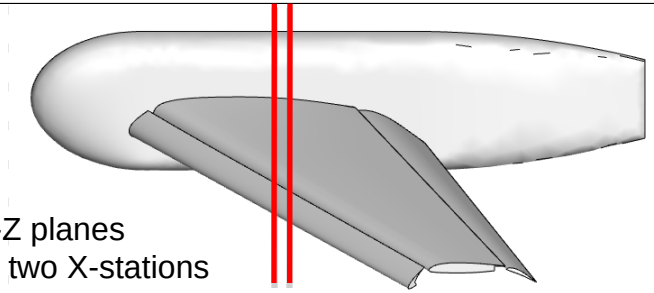
Sectional/Cumulative CD
Config 1, Medium Grid, α=28

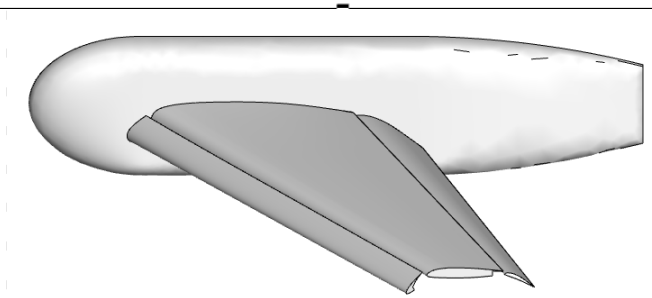






Y-Z planes
at two X-stations

α=28



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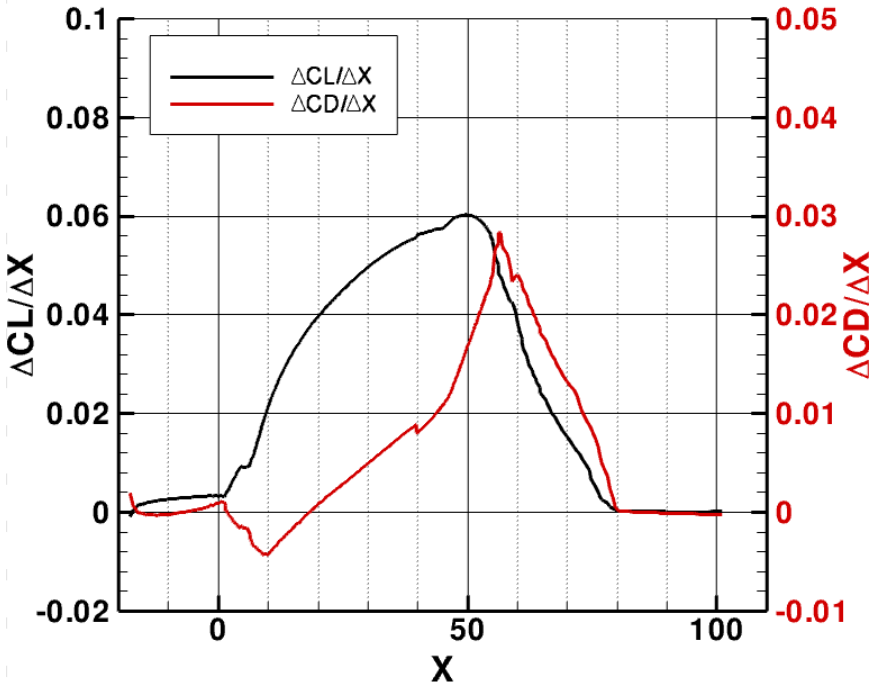
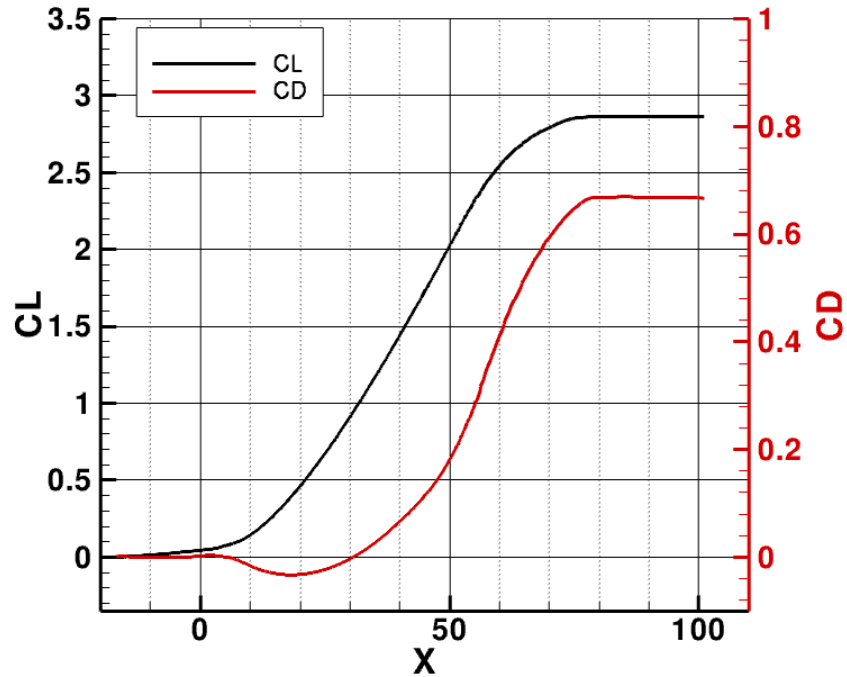
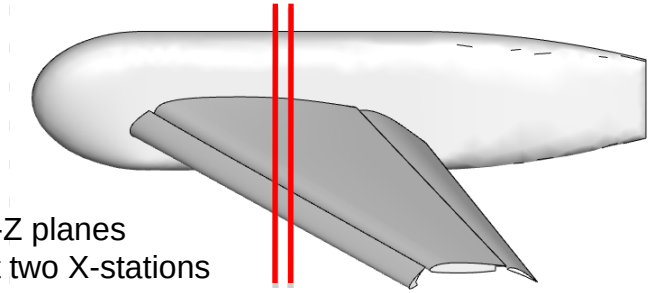
Sectional/Cumulative CL and CD Config 1, Medium Grid, α=28

Total Sectional Lift and Drag



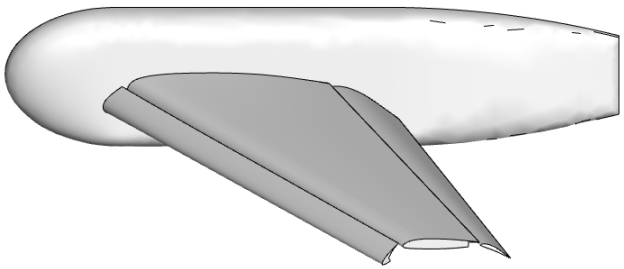
Total Cumulative Lift and Drag





Y-Z planes
at two X-stations

α=28



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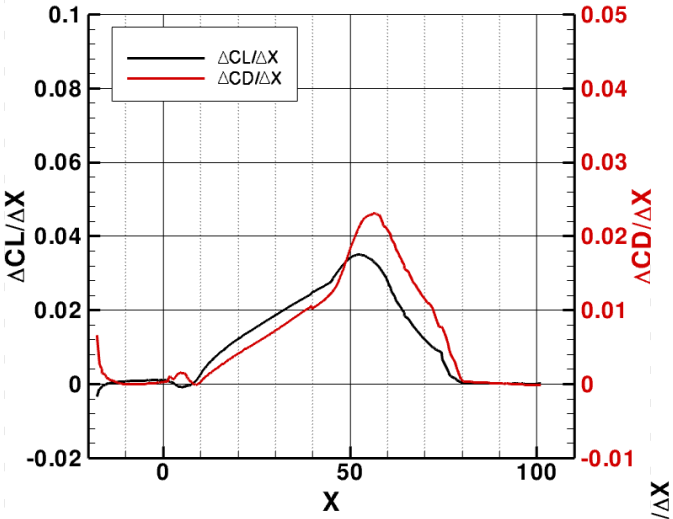
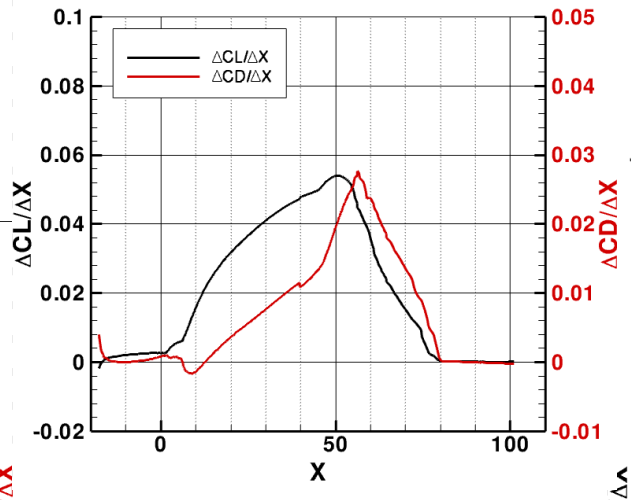
Sectional/Cumulative CL and CD

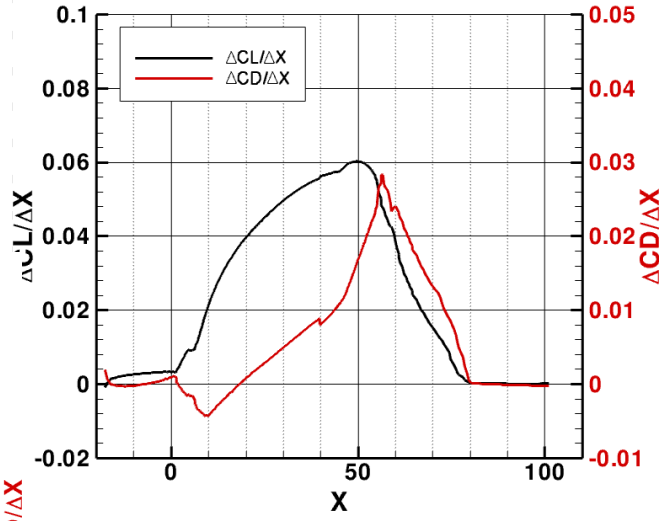
α=6

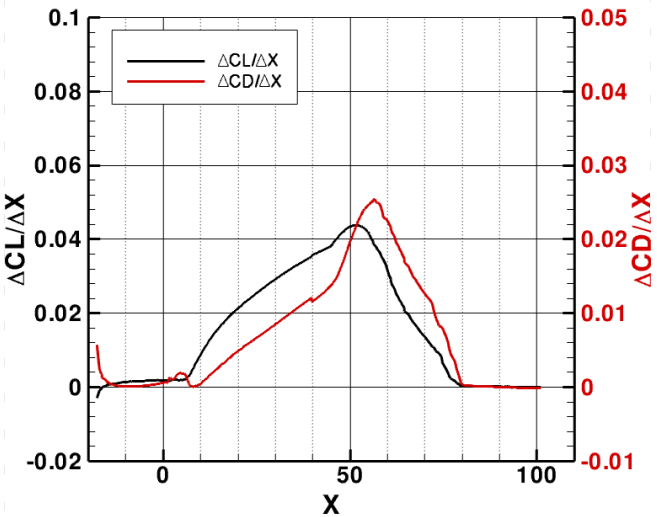


α=21

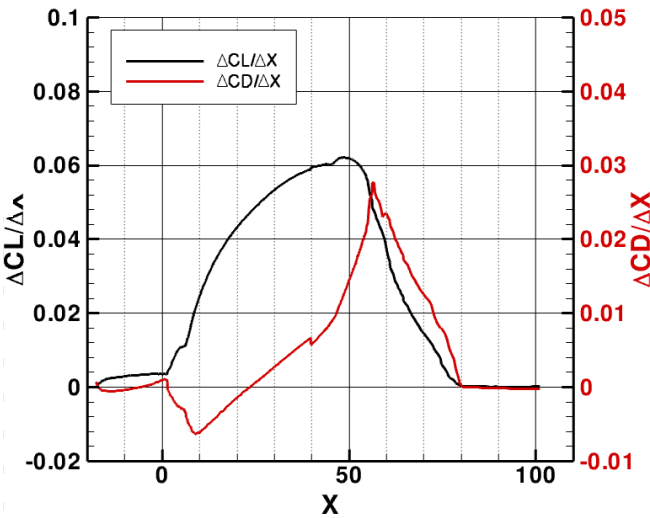


α=28





α=13



α=32

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Observations

- SST model underpredicts CL and overpredicts CM
- SA model produces generally better results than SST and was selected for the rest of the study
- With grid refinement, CLMAX and stall angle are much closer to experimental data
- Medium grid is sufficient to produce generally good results with less resources upto a stall angle of 32 degree
- Coarse grid produces good result upto 28 angle of attack and can be used for quick evaluation of the high lift configuration

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Backup Charts

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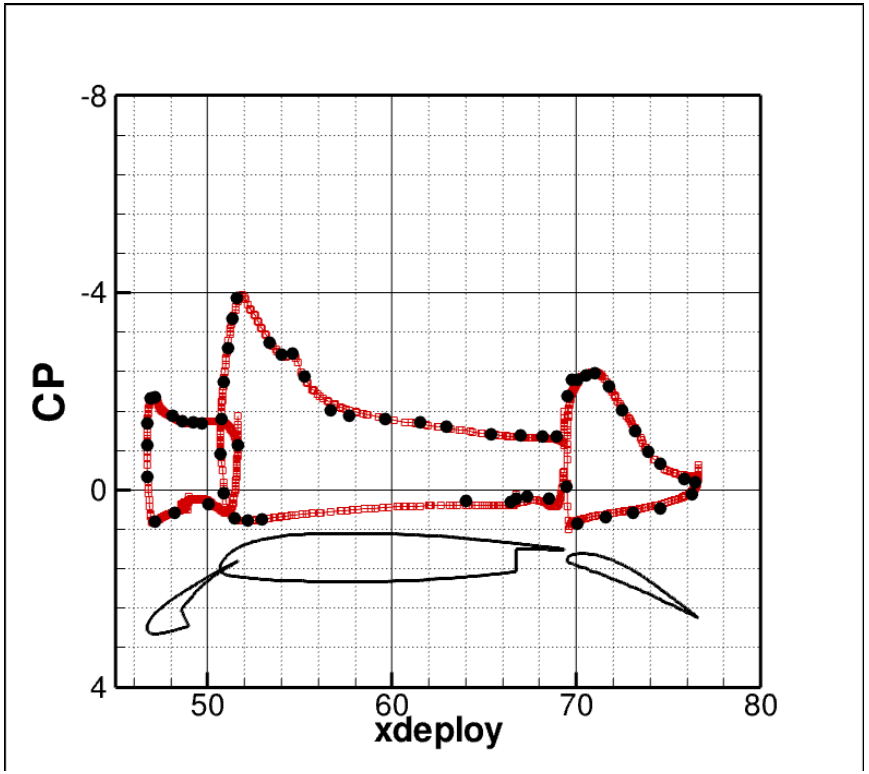
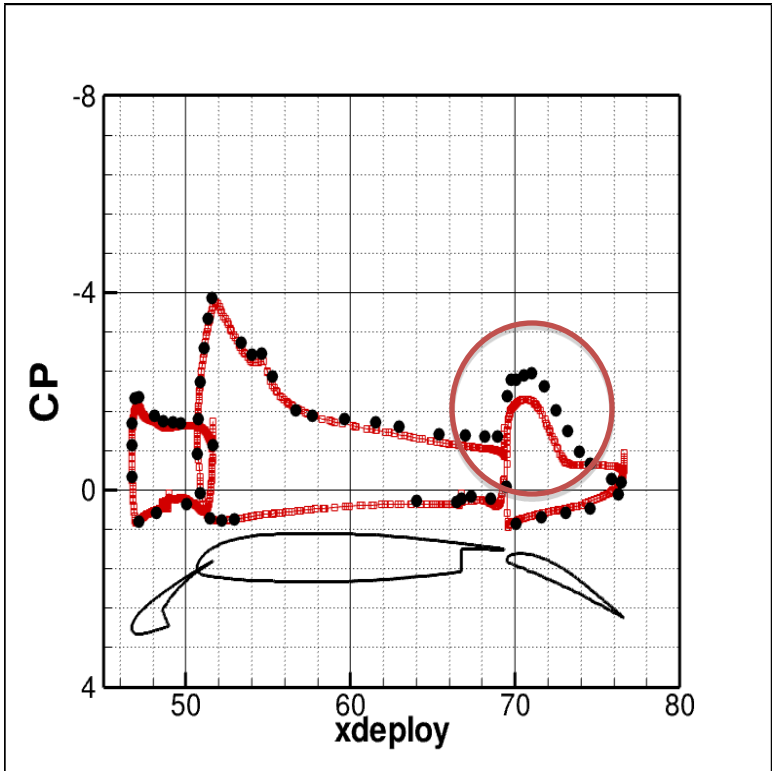
ST85, Surface Pressure
Config1, Medium Grids, α=13

USM3D
WT Data

SA



SST



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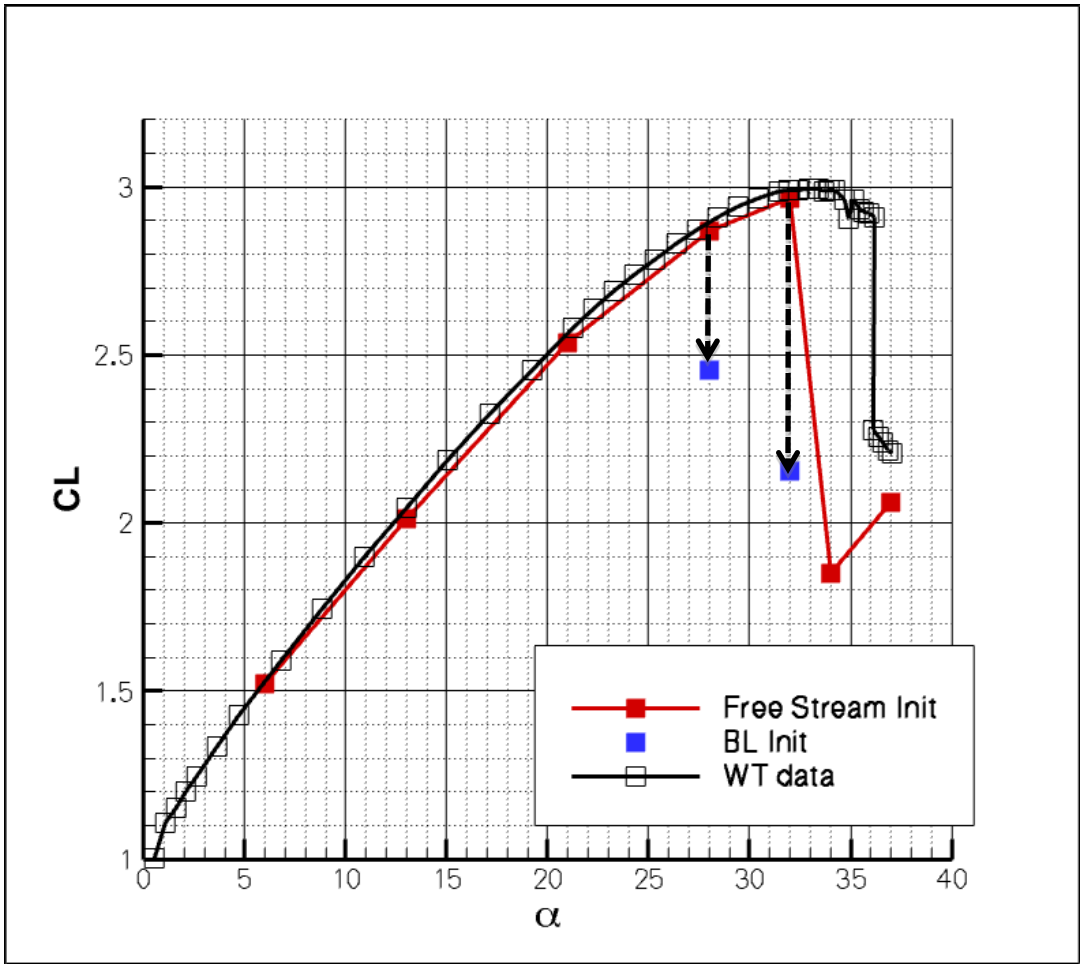
Effect of Initialization on CL



α=28, Medium Grid Config1

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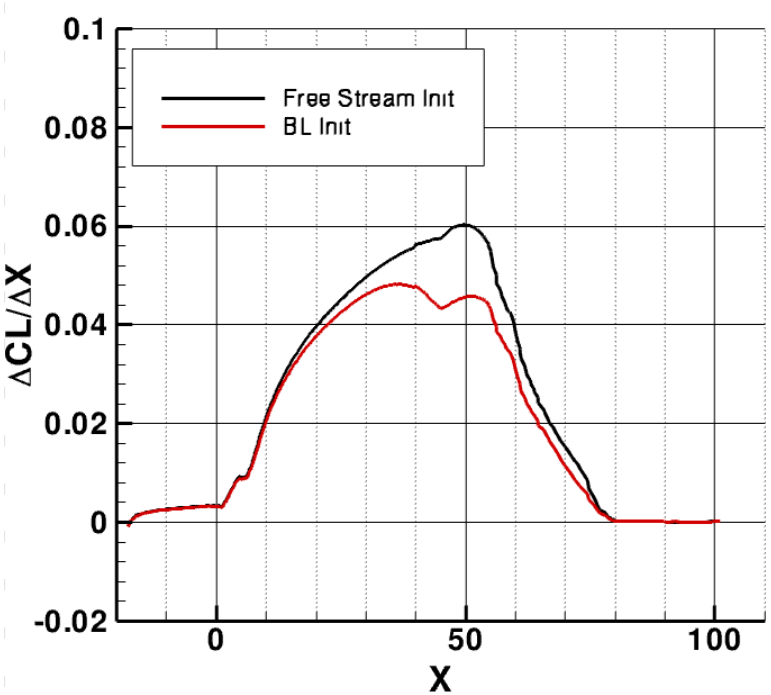
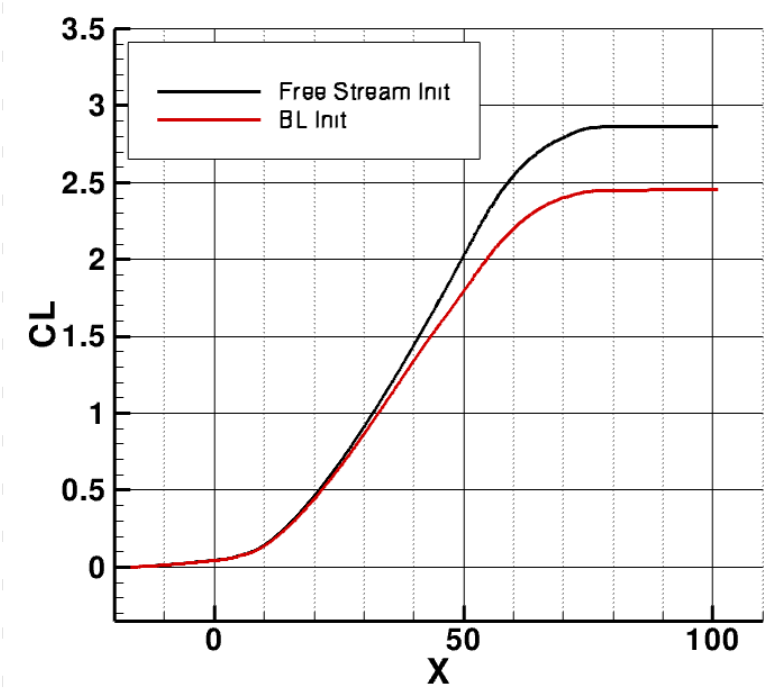
Effect of Initialization

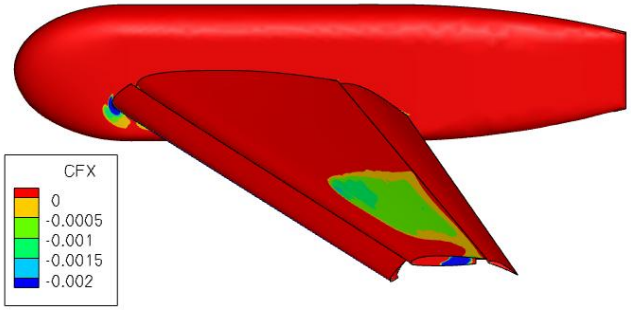
α=28, Medium Grid Config1

Sectional Lift

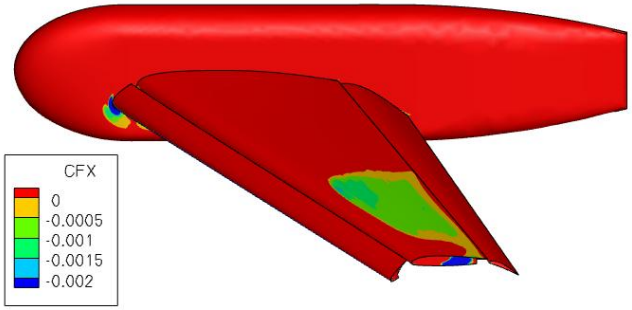


Cumulative Lift





BL Initialized



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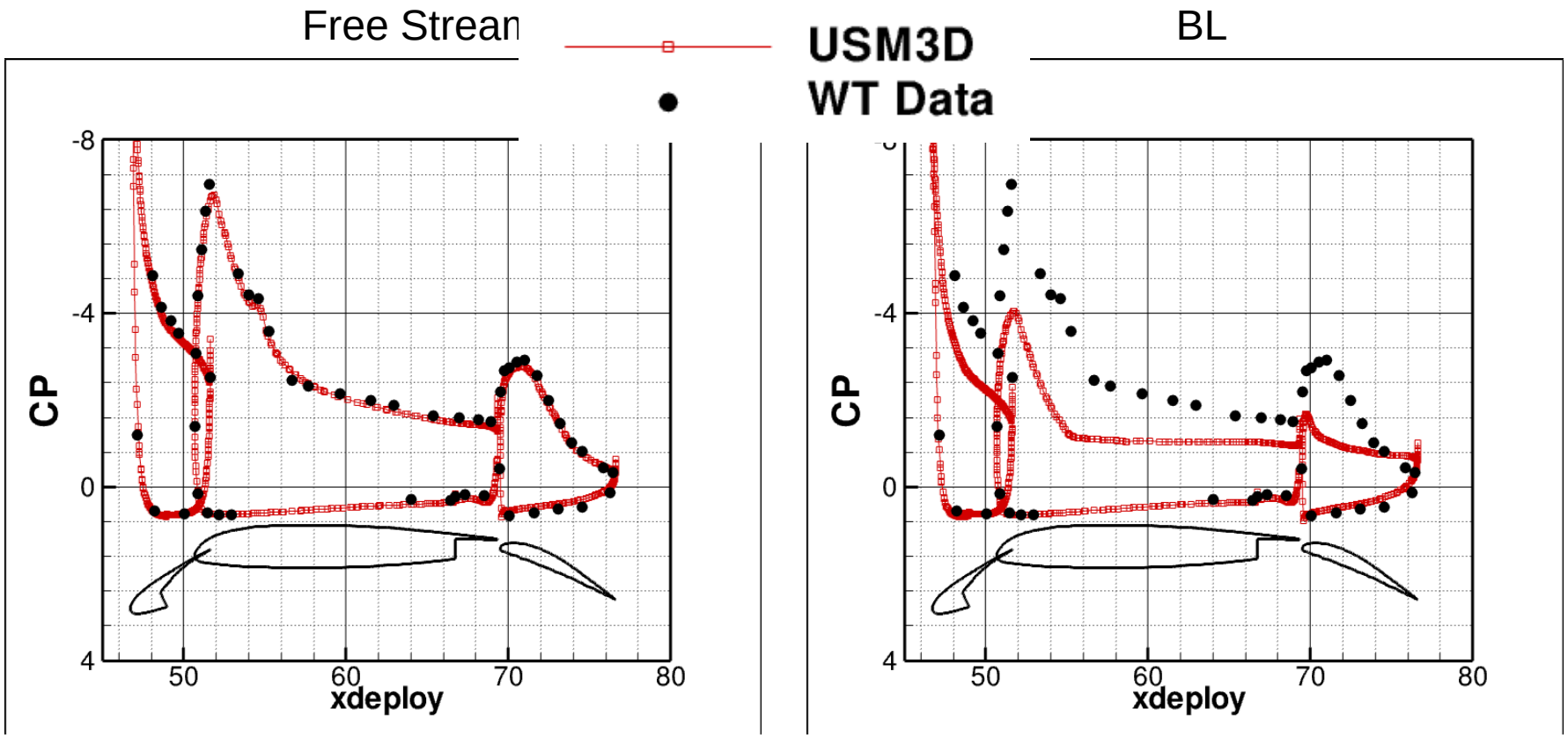
Effect of Initialization on Surface Pressure



α=28, Medium Grid Config1

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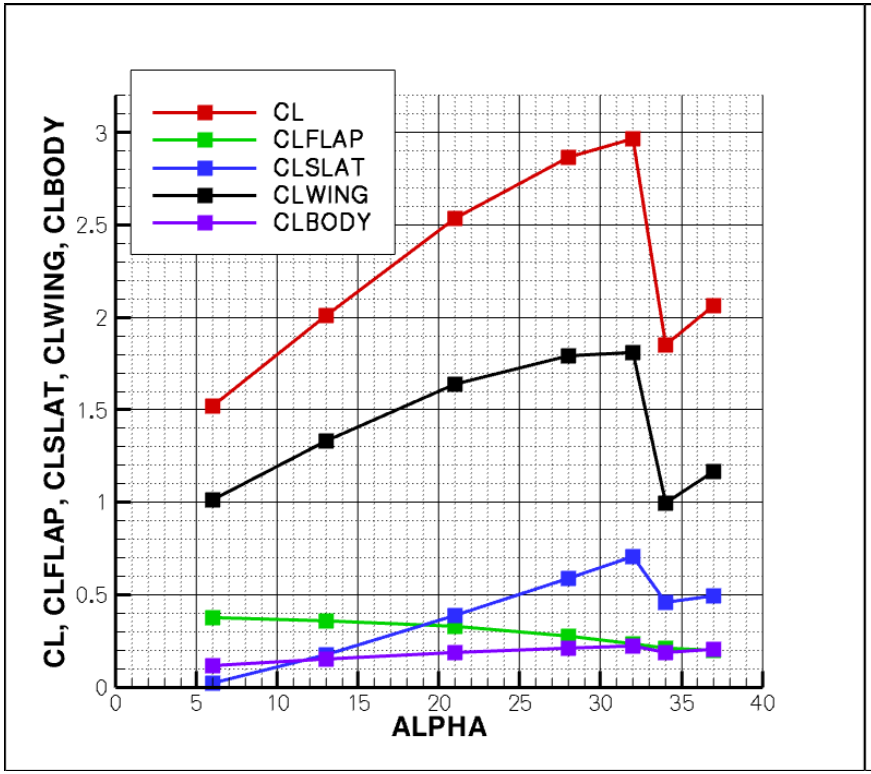
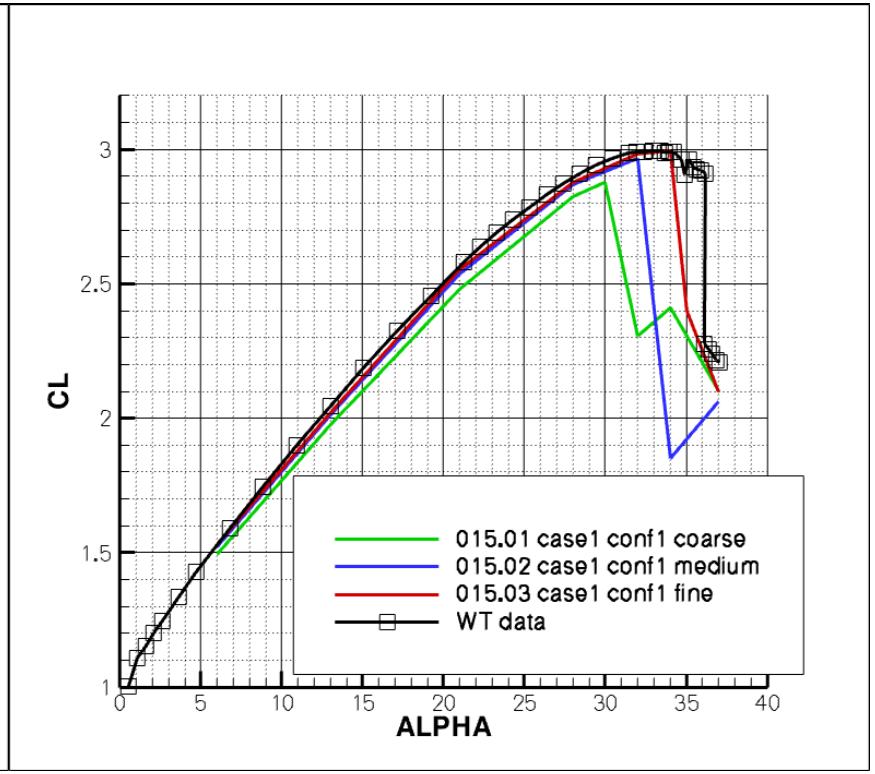
CL by Components
Config 1, Medium Grid





66% of lift generated by the main wing

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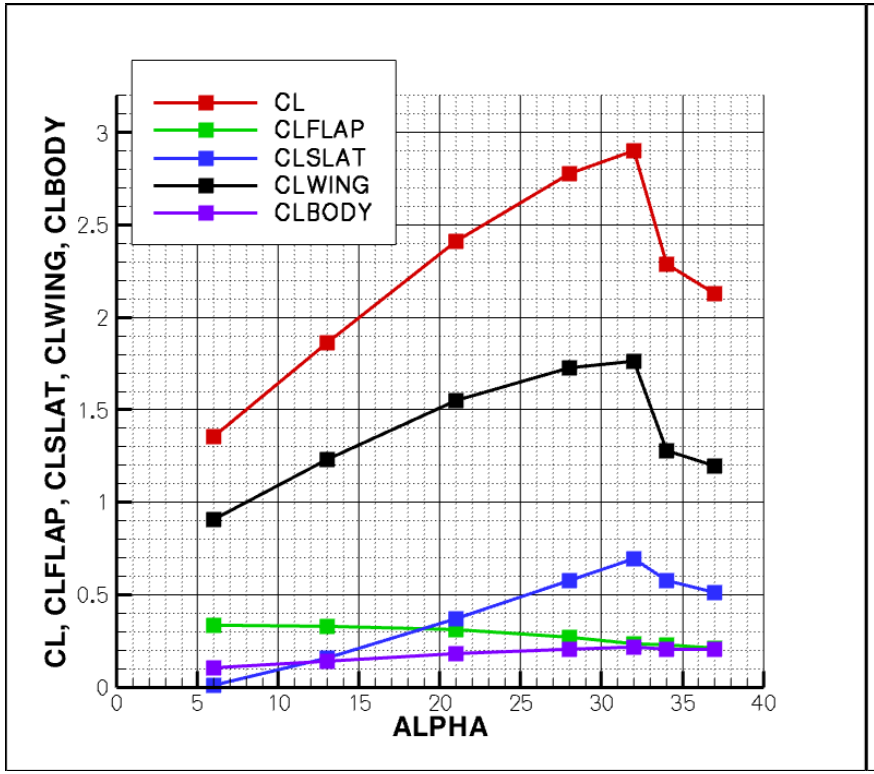
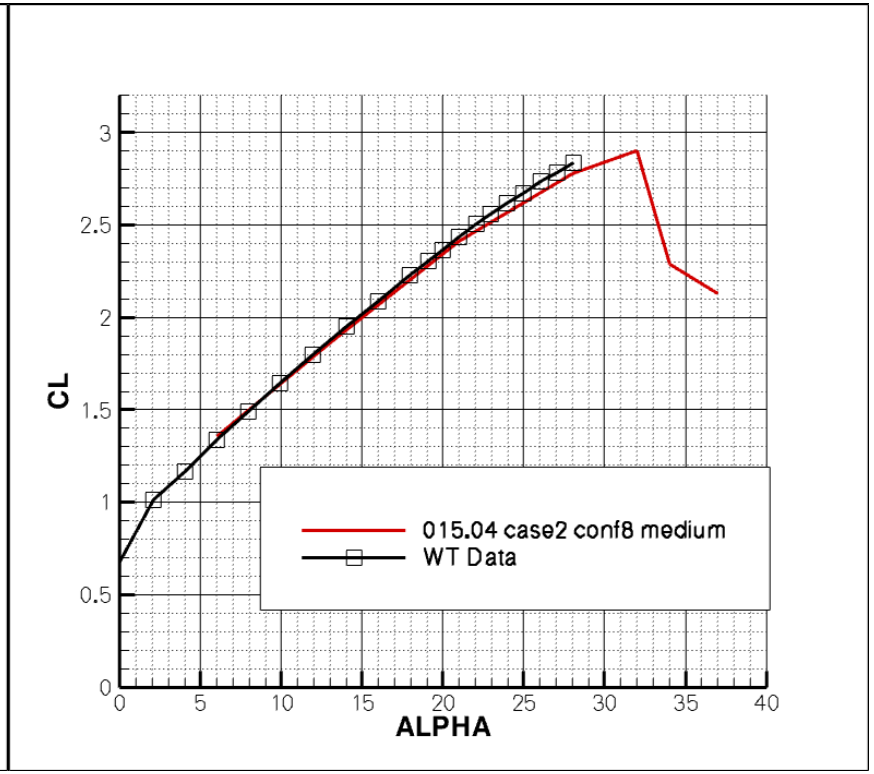
CL by Components
Config 8, Medium Grid





66% of lift generated by the main wing

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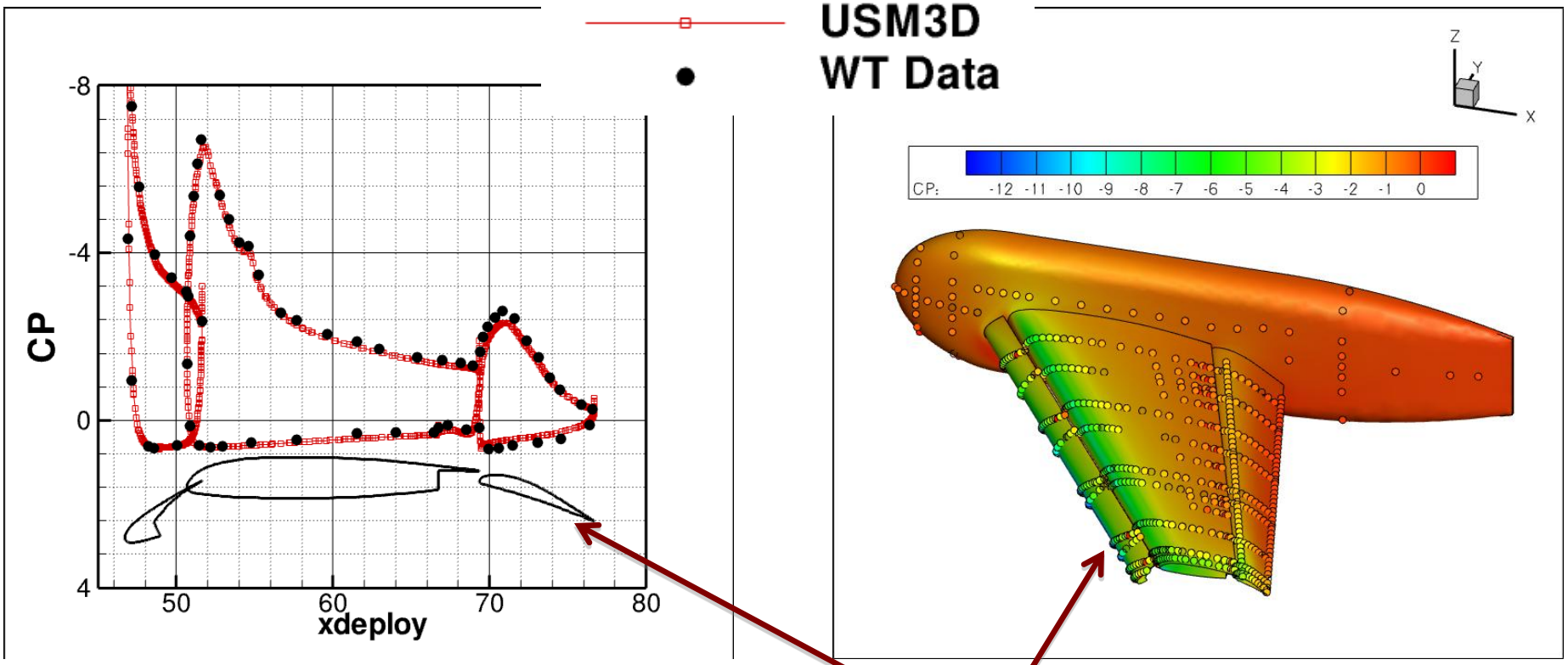
ST85, Surface Pressure
Config 8, Medium Grid, α=28



ST85

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