TotalSim US Contributions to HiLiftPW-3 using OpenFOAM and FUN3D

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Presentation Outline

- Flow Solver
- Grids
- Case 1 Results
- Case 2 Results
- Conclusion

CFD Solver Description

- OpenFOAM
    - Open source C++ library used as a CFD platform
    - Large array of physics models available
    - Primarily Polyhedral meshes
    - Finite Volume cell centered
    - Navier Stokes
    - KOmega SST, Spalart Allmaras, and Gamma-Ret-Theta turbulence models
- FUN3D
    - Parallel 3D unstructred
    - Mixed-element Meshes
    - Full Navier Stokes
    - Node Centered
    - KOmega SST, SA-neg, and Gamma-Ret-Theta turbulence models

Summary of Cases Completed OpenFOAM

Case 1	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	yes	yes	
1b (full gap w adaption)	no	no	
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Case 2	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction	Other
2a (no nacelle)	yes	no	no	
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	yes	no	no	
2d (with nacelle w adaption)	no	no	no	
Other				

Case 3	2D Verification study	Other
k-Omega	yes	
k-Omega Restart	yes	
Spalart Allmaras	yes	

TOTALSIM US

Summary of Cases Completed FUN3D

Case	Alpha=8, Fully turb, grid study	Alpha=16, Fully turb, grid study	Other
1a (full gap)	yes	yes	
1b (full gap w adaption)	no	no	
1c (partial seal)	no	no	
1d (partial seal w adaption)	no	no	
Other			

Case	Polar, Fully turb	Polar, specified transition	Polar, w transition prediction	Other
2a (no nacelle)	yes	no	no	
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	yes	no	no	
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	no	
Other		

Turbulence Models Used

	OpenFOAM	FUN3D
Case 1		- SST
Case 2a	- SST	- SST - KKL - SA - **SA-neg** - SA-trans
Case 2c	- SST	- SST - **SA-neg** - SA-trans
Case 3	- SST - GammaRetTheta - Spalart Allmaras	

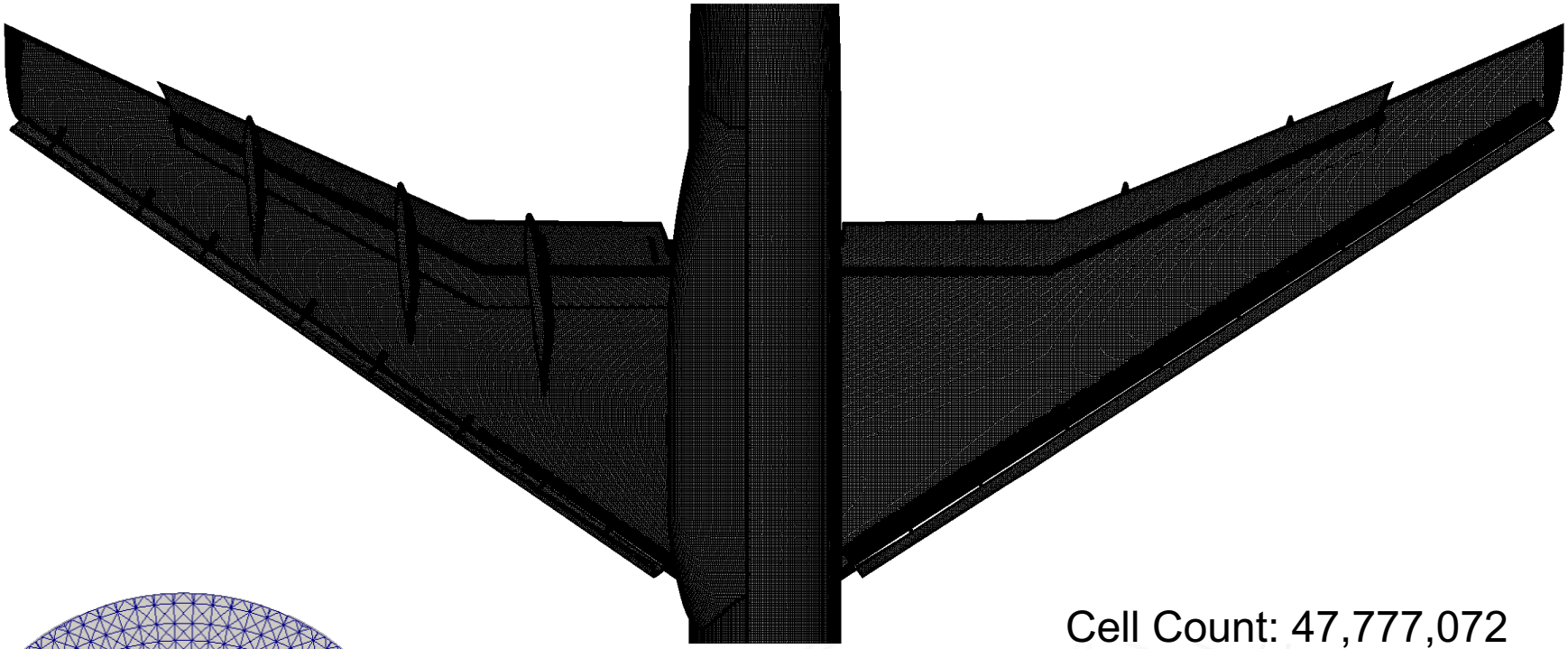
Grids Used

- CASE1
  - Committee provided grids B1-HLCRM_UnstrTet_PW
- CASE 2
  - Committee provided grid C1-JSM_UnstrTet_VGRID
    - Full Tet volumes work well in Fun3D
  - TotalSim generated grid using Pointwise
    - Was not able to show good correlation using Committee provided grid
    - Additional refinement added to regions showing premature separation
      - Case2a – 43.3M nodes (256.5M cells)
      - Case2c – 59.0M nodes (350.0M cells)
- CASE 3
  - TMR provided unstructured Hex meshes
    - 561x97
    - 1121x193
    - 2241x385

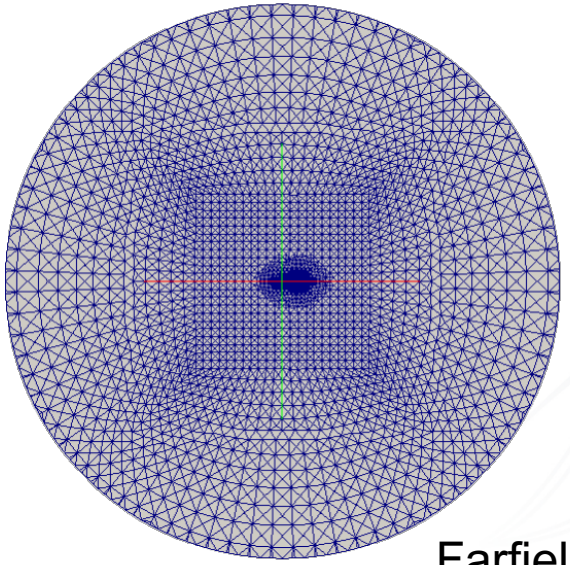
Comparison of Grids FUN3D

	Generated Grids (nodes)		Provided Grids (nodes)	
Case 1			Fine	70 million
			Medium	26 million
			Coarse	8 million
Case 2a	Fine		Fine	
	Medium	43.3 million	Medium	16.4 million
	Coarse		Coarse	
Case 2c	Fine		Fine	
	Medium	59.0 million	Medium	21.0 million
	Coarse		Coarse	

OpenFoam/SnappyHexMesh Grids

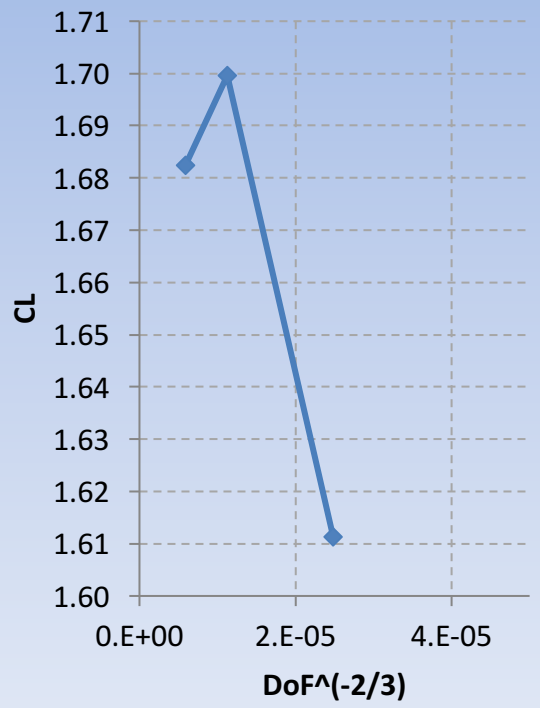


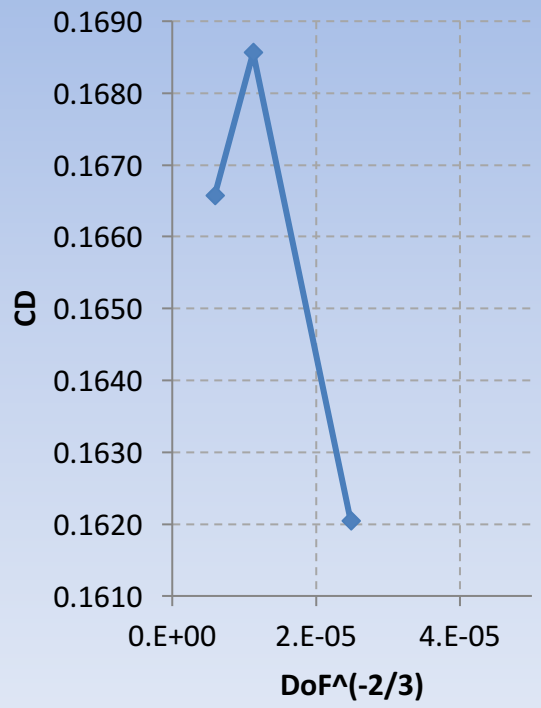
Cell Count: 47,777,072
% Hexahedra: 88.2%
% Polyhedra: 10.5%

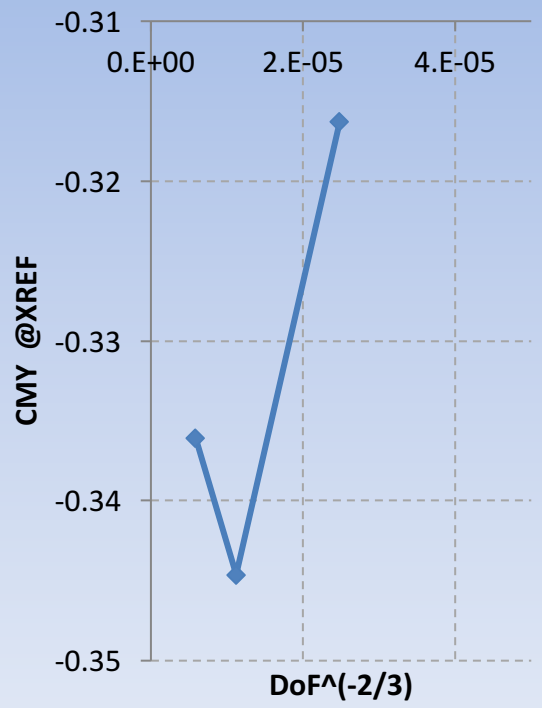


Farfield

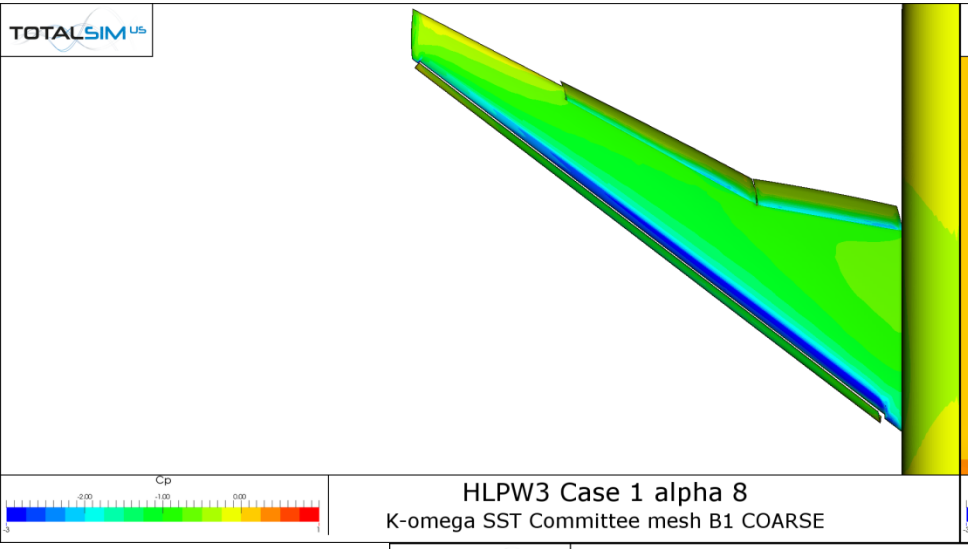
Case 1 AOA 8° FUN3D Grid Convergence



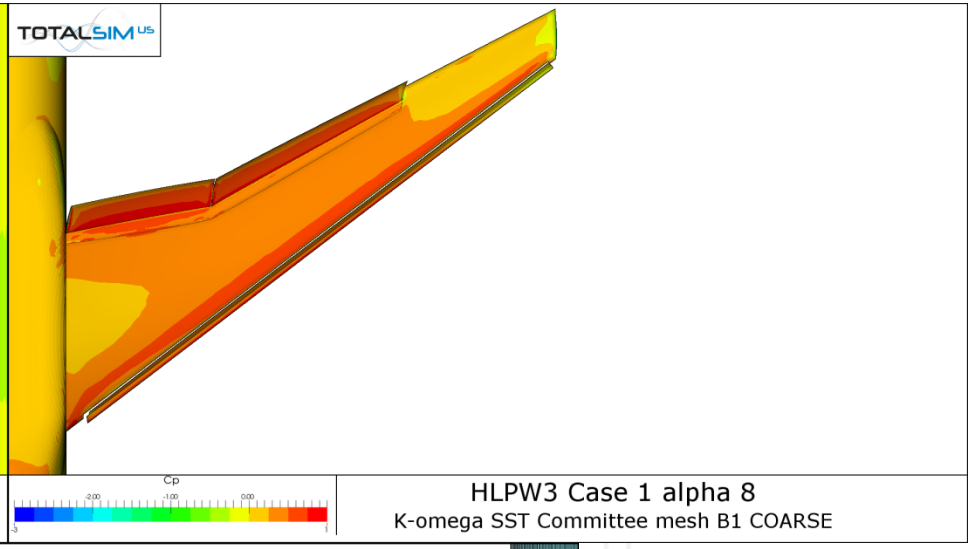




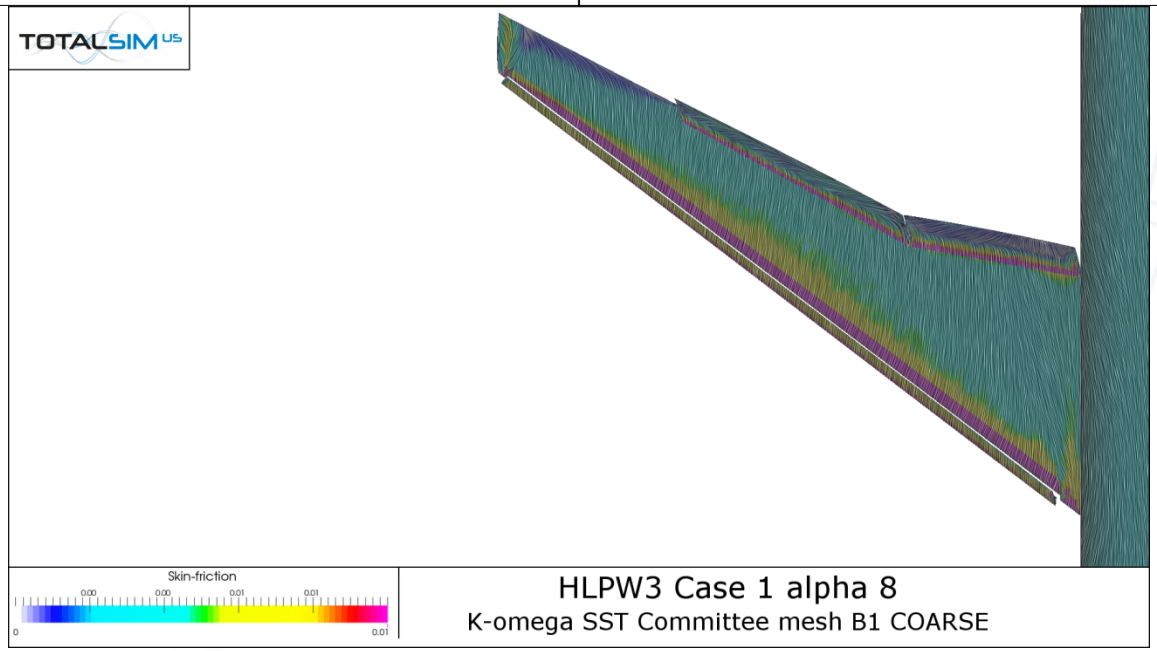
Case 1 AOA 08° FUN3D Grid Convergence (Coarse)



HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 COARSE

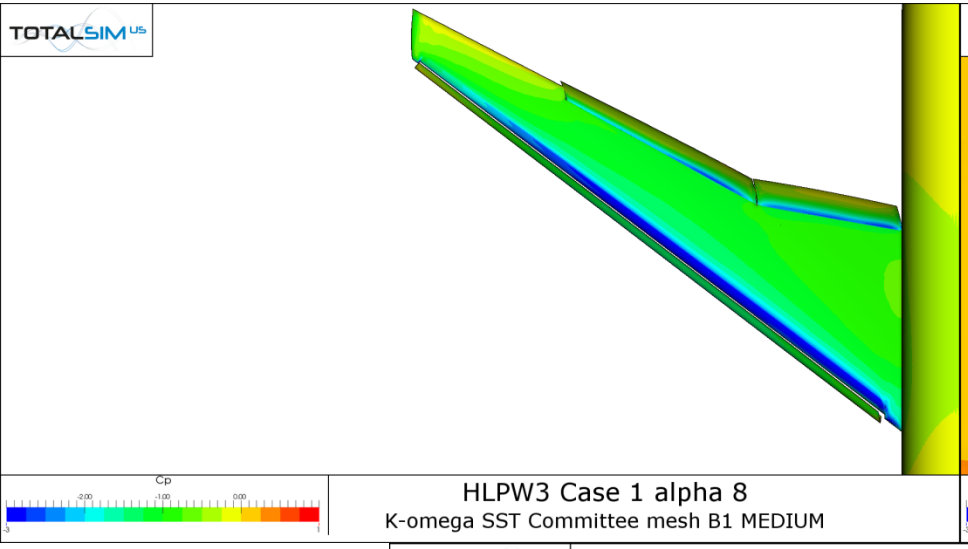


HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 COARSE

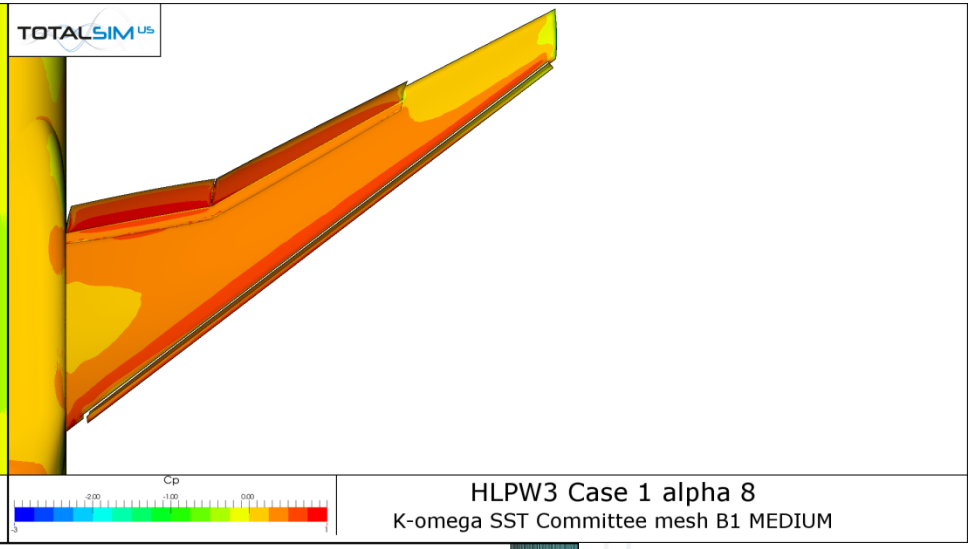


HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 COARSE

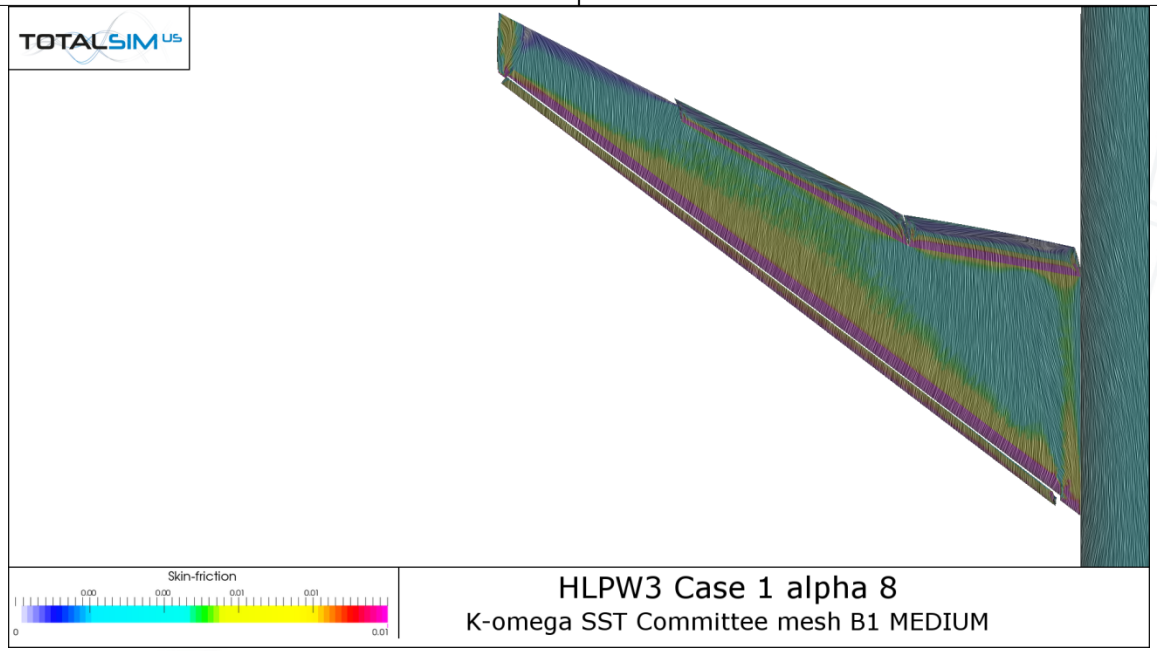
Case 1 AOA 08° FUN3D Grid Convergence (Medium)



HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 MEDIUM

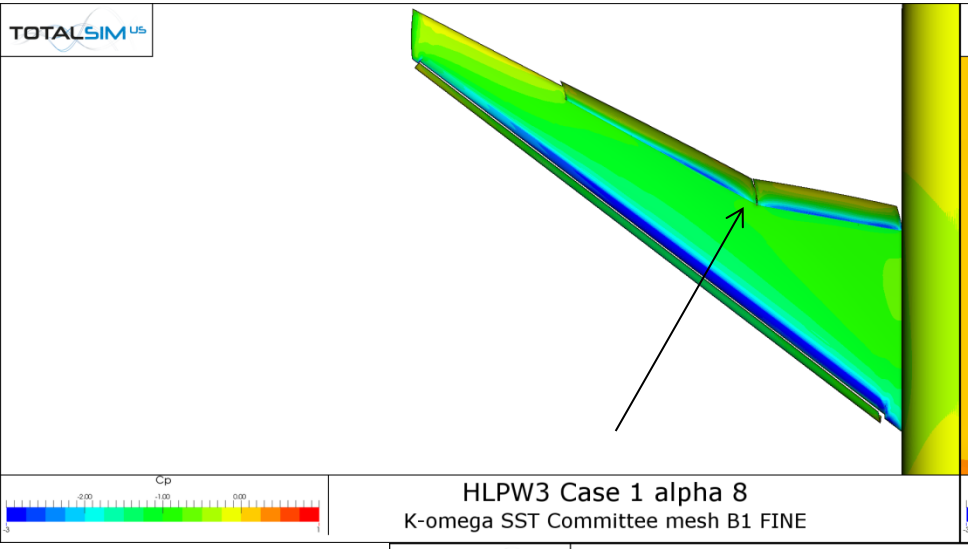


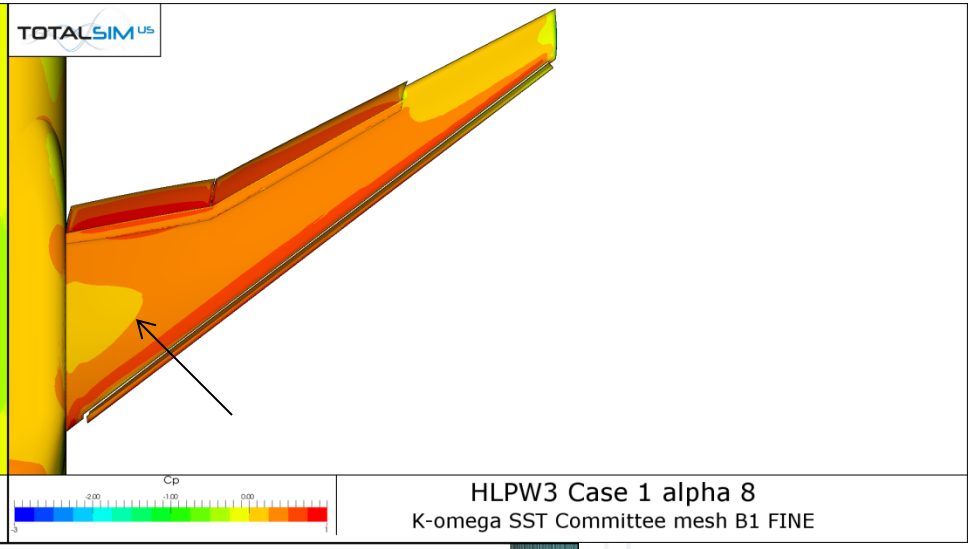
HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 MEDIUM

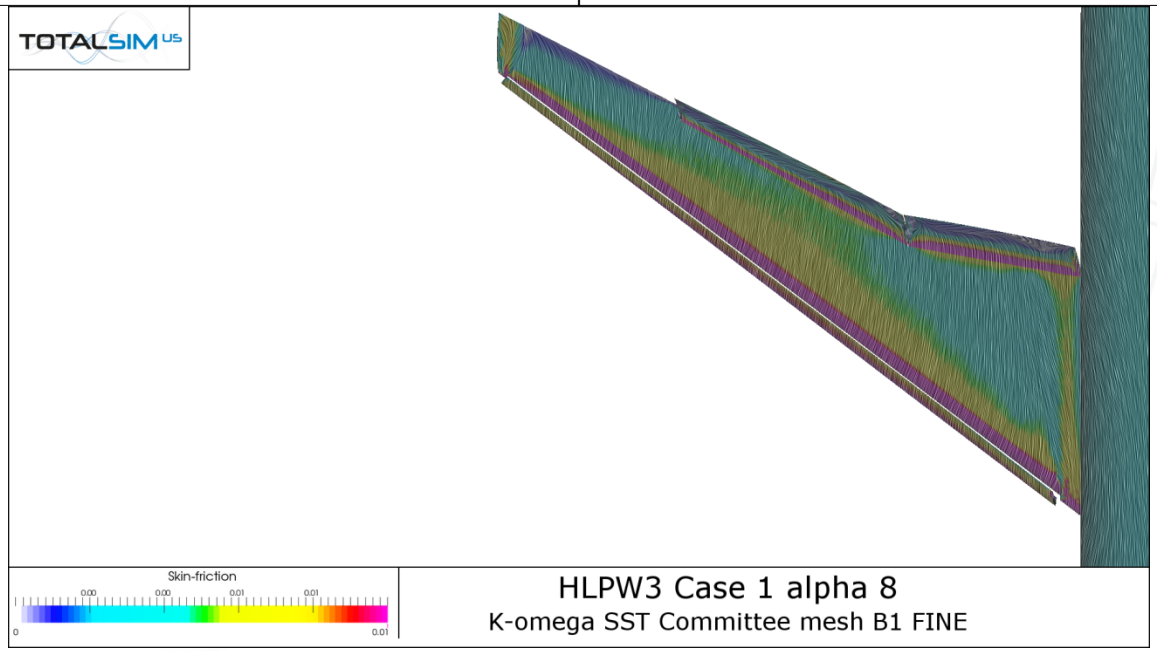


HLPW3 Case 1 alpha 8
K-omega SST Committee mesh B1 MEDIUM

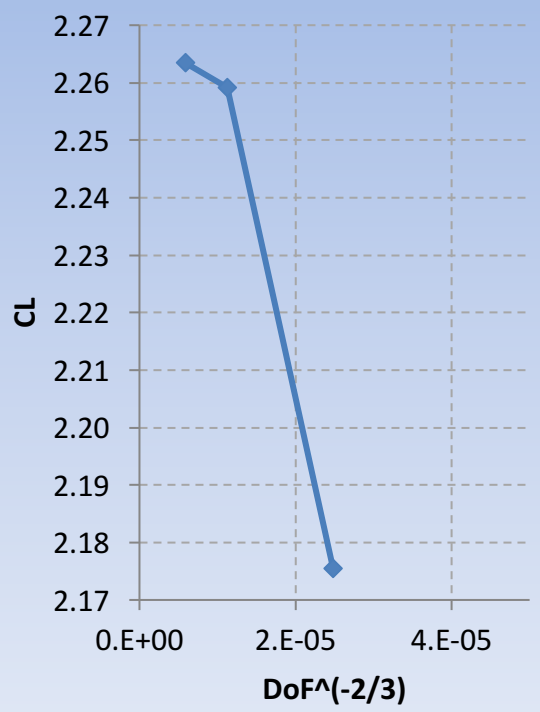
Case 1 AOA 08° FUN3D Grid Convergence (Fine)

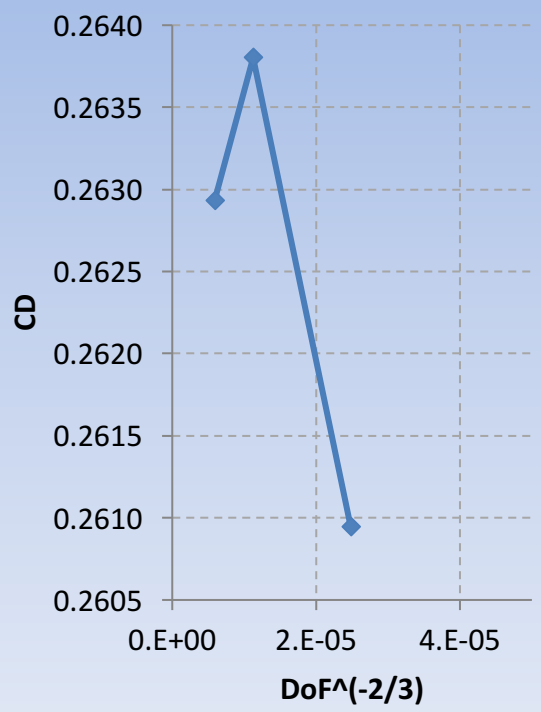


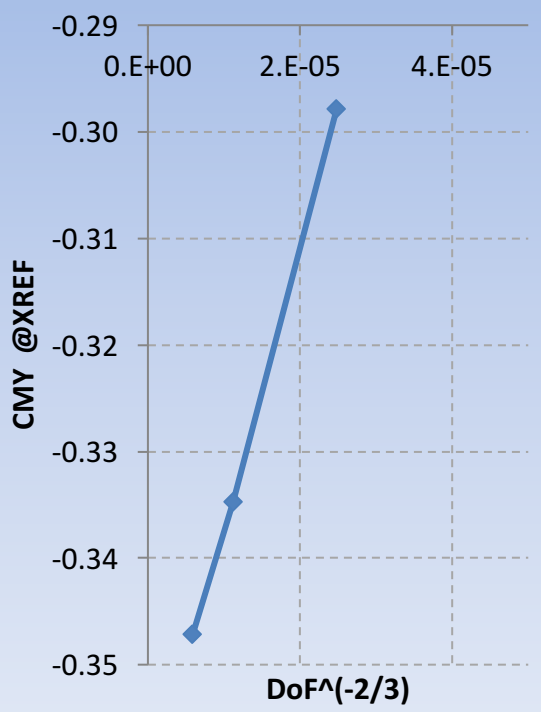




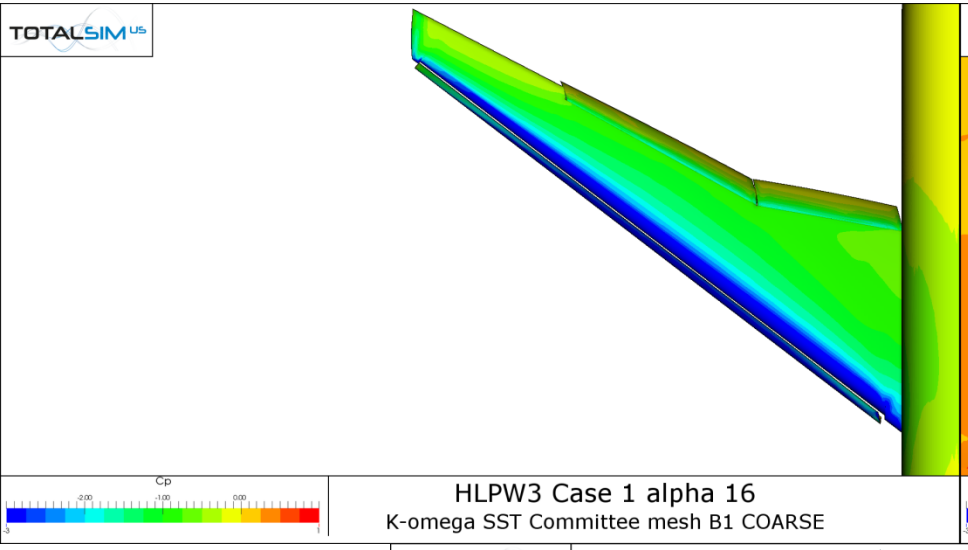
Case 1 AOA 16° FUN3D Grid Convergence



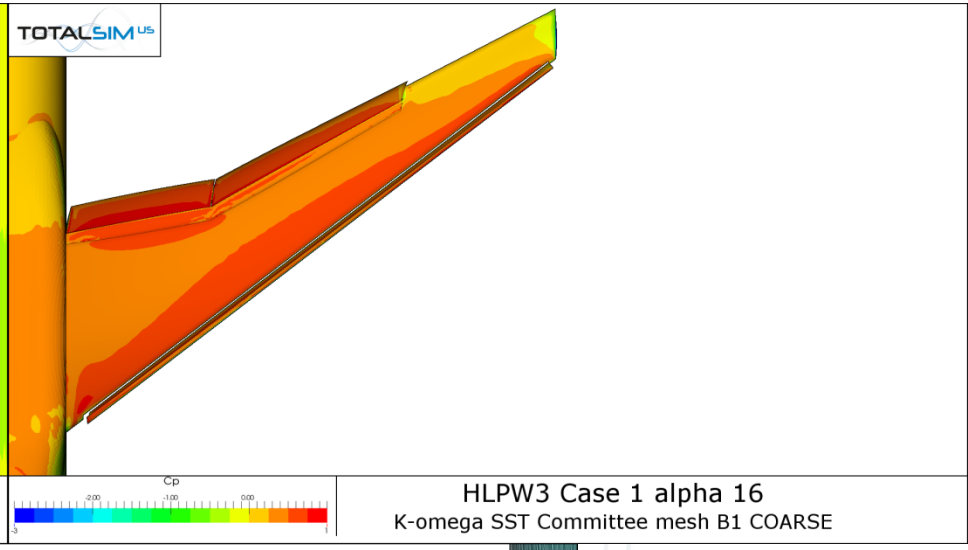




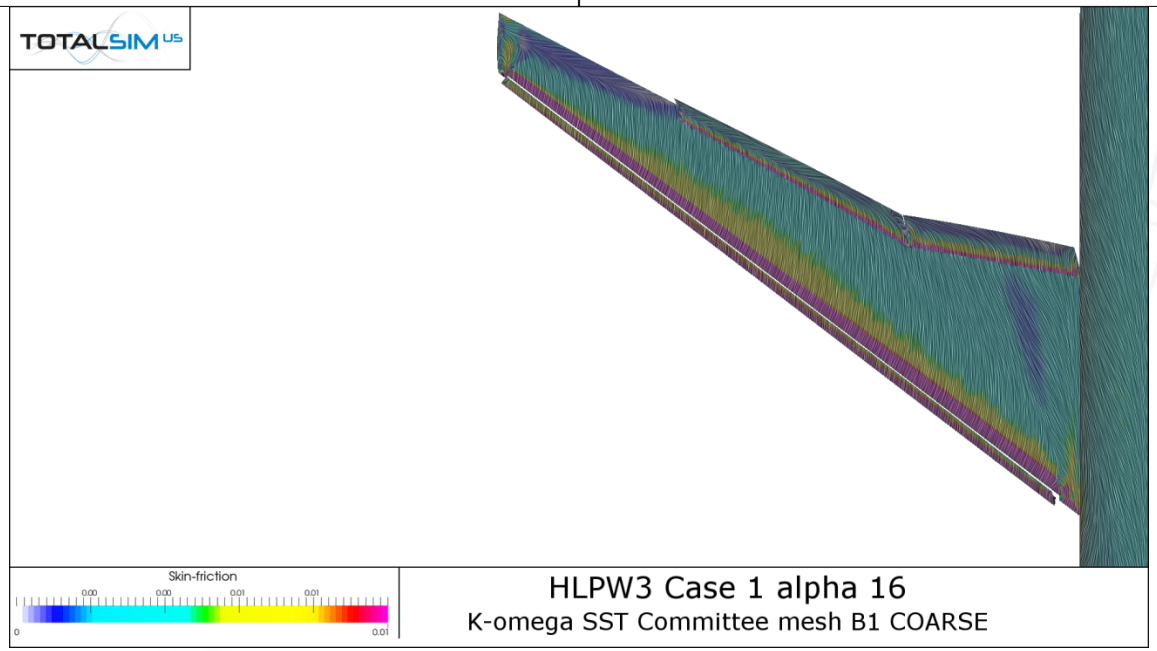
Case 1 AOA 16° FUN3D Grid Convergence (Coarse)



HLPW3 Case 1 alpha 16
K-omega SST Committee mesh B1 COARSE

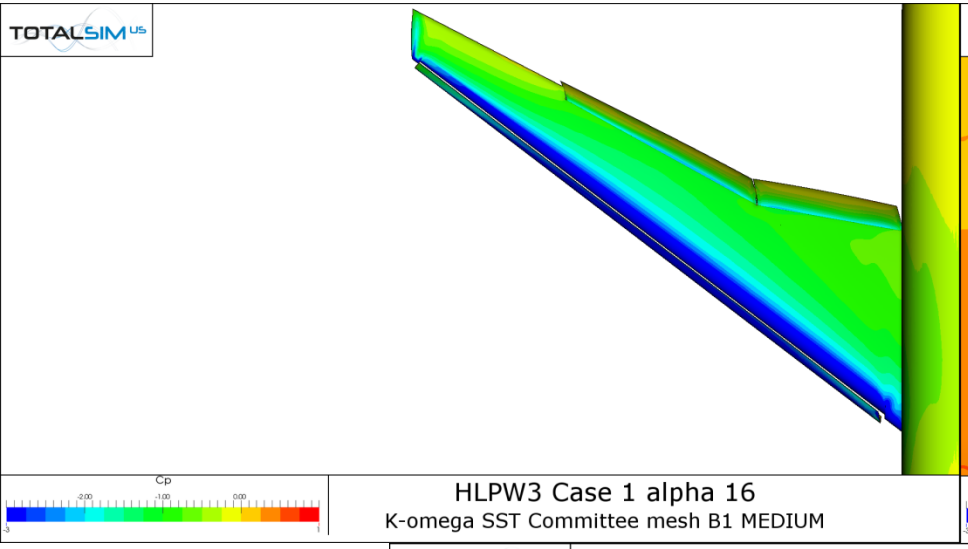


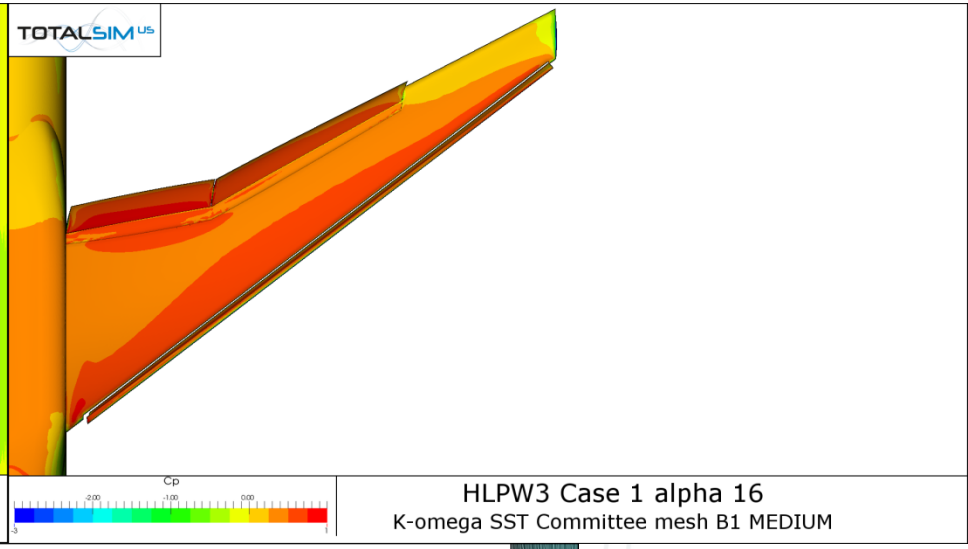
HLPW3 Case 1 alpha 16
K-omega SST Committee mesh B1 COARSE

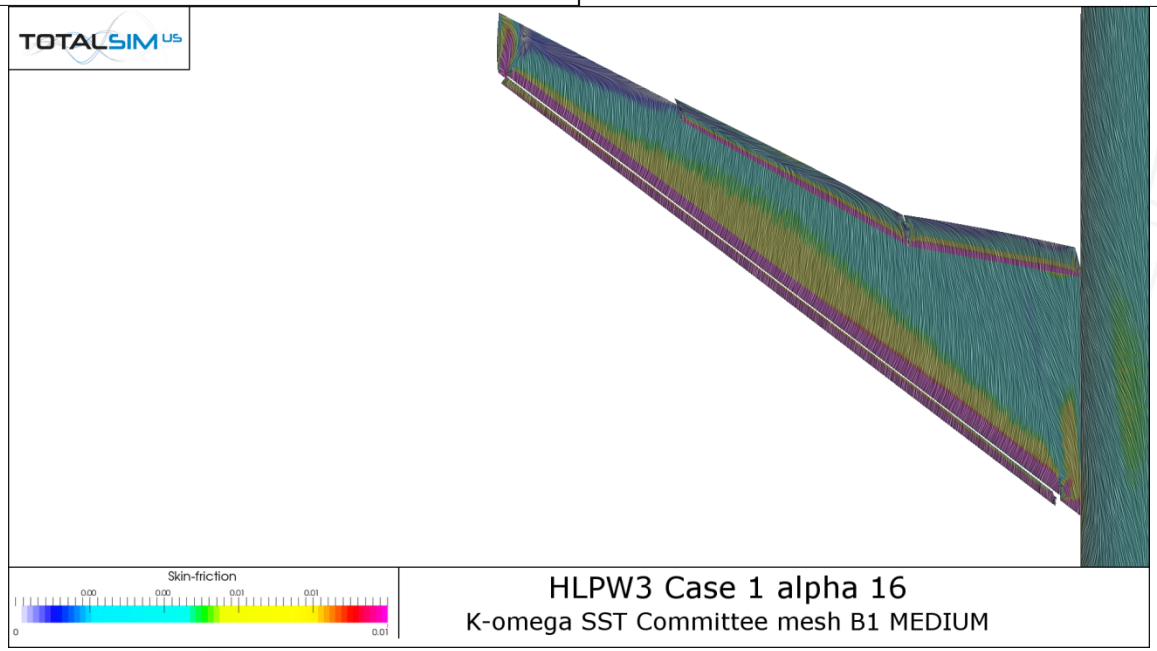


HLPW3 Case 1 alpha 16
K-omega SST Committee mesh B1 COARSE

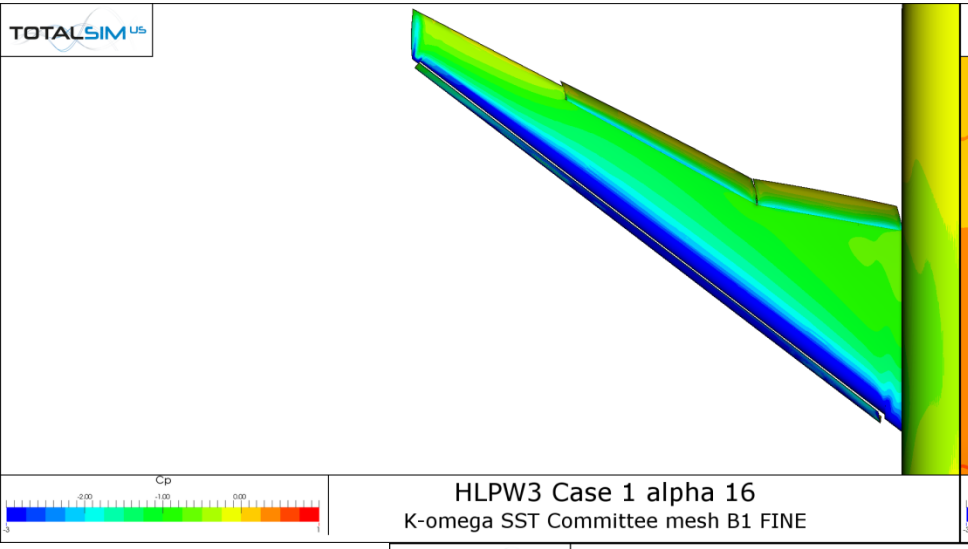
Case 1 AOA 16° FUN3D Grid Convergence (Medium)

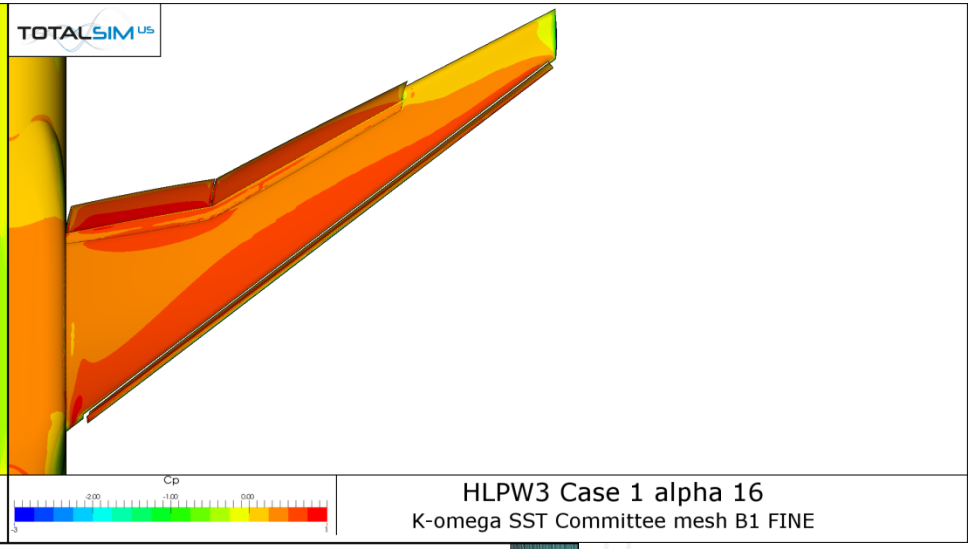


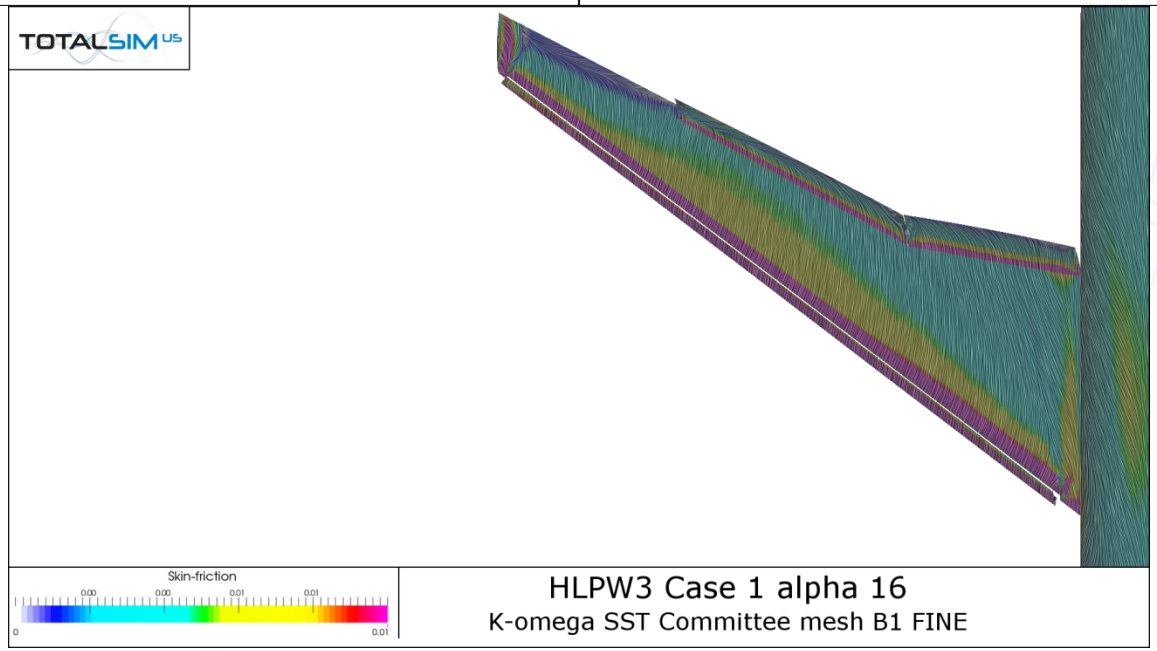




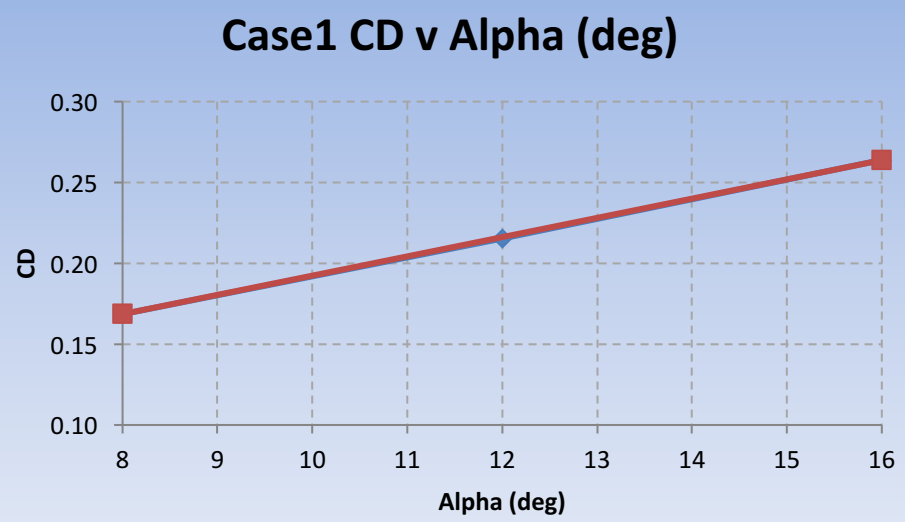
Case 1 AOA 16° FUN3D Grid Convergence (Fine)

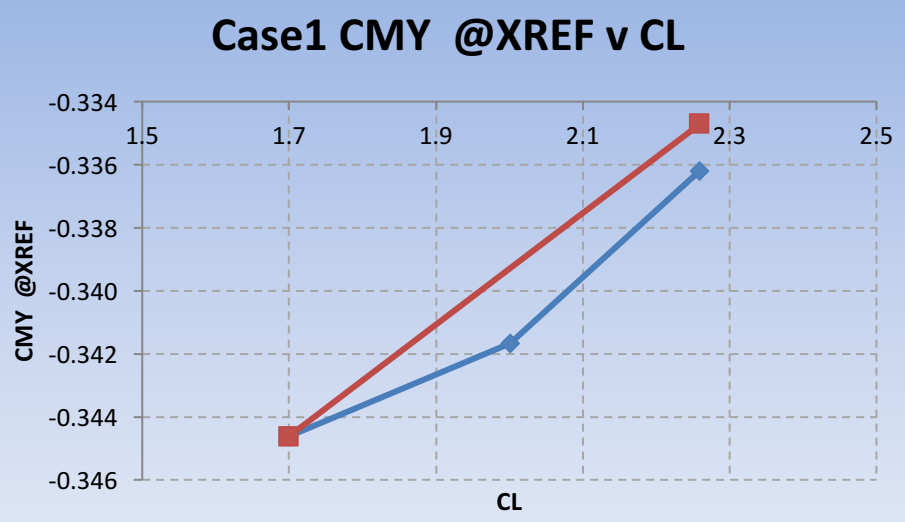


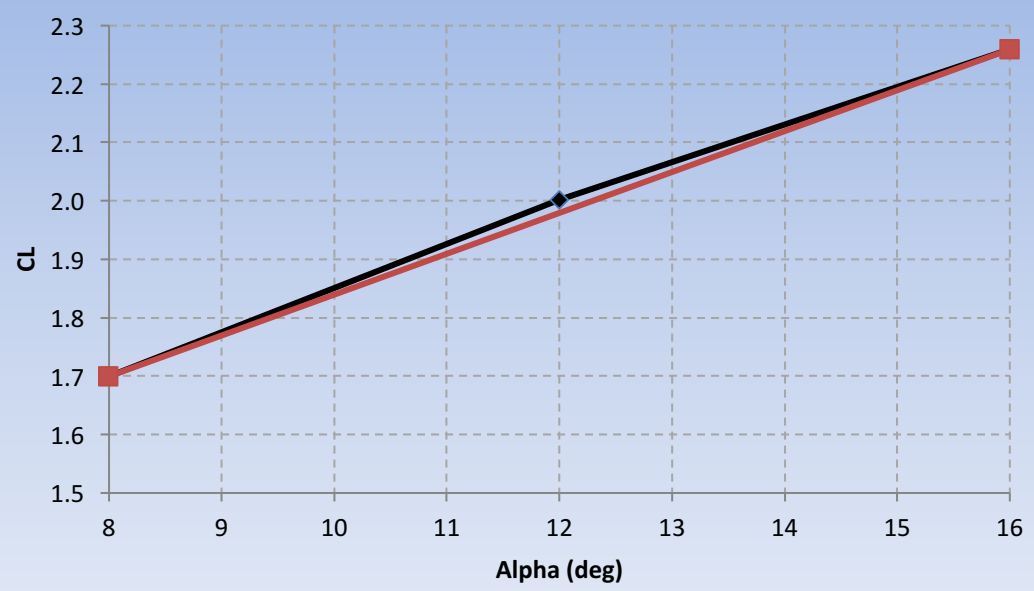




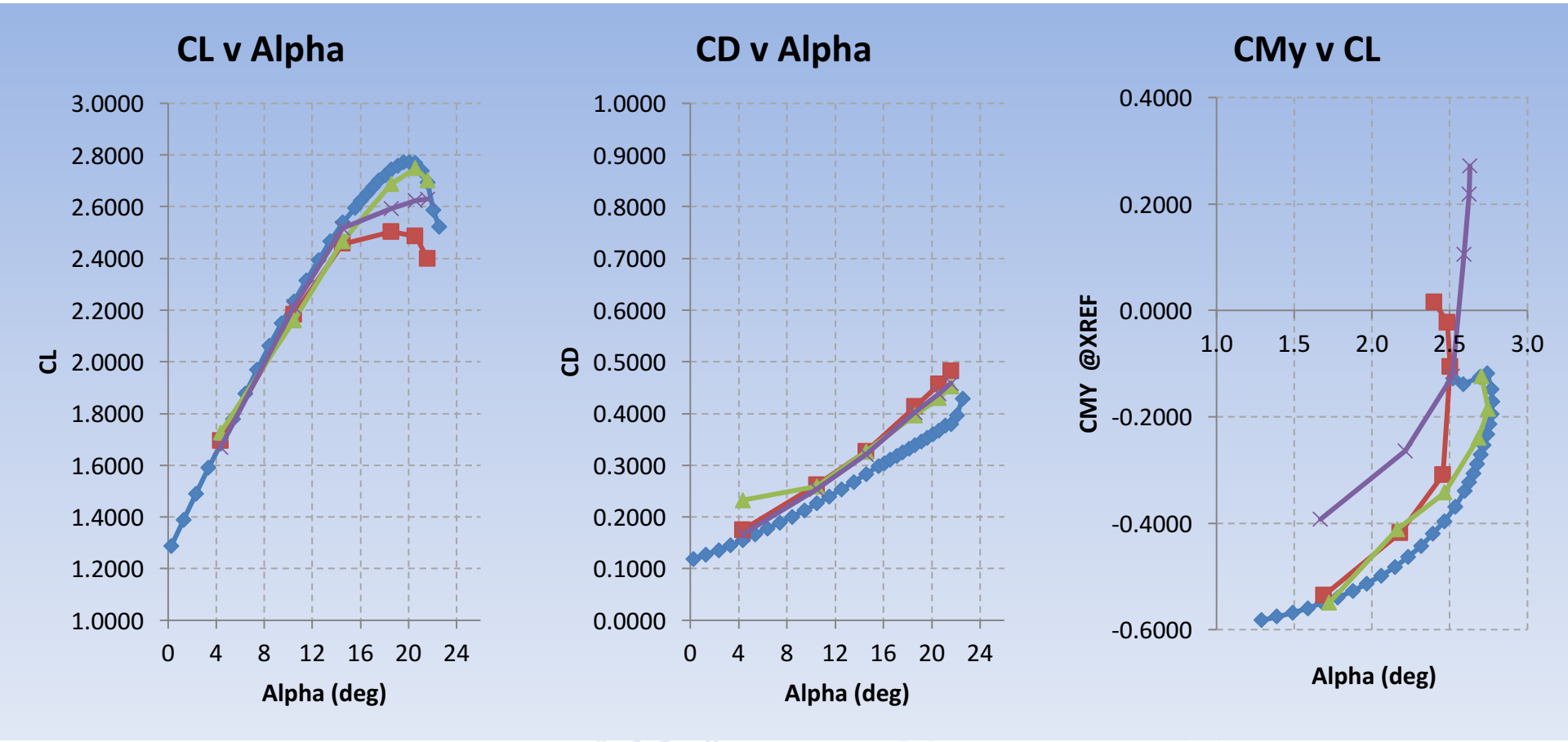
Case 1 Path Dependency FUN3D Grid Convergence





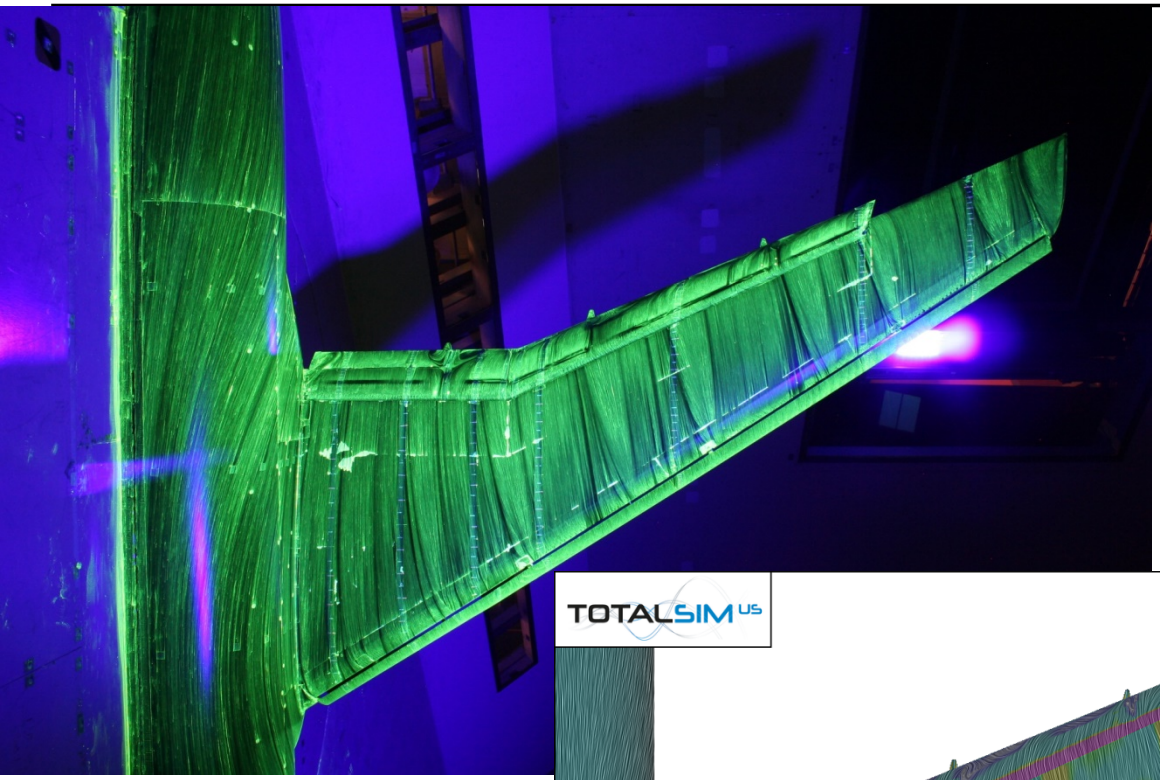


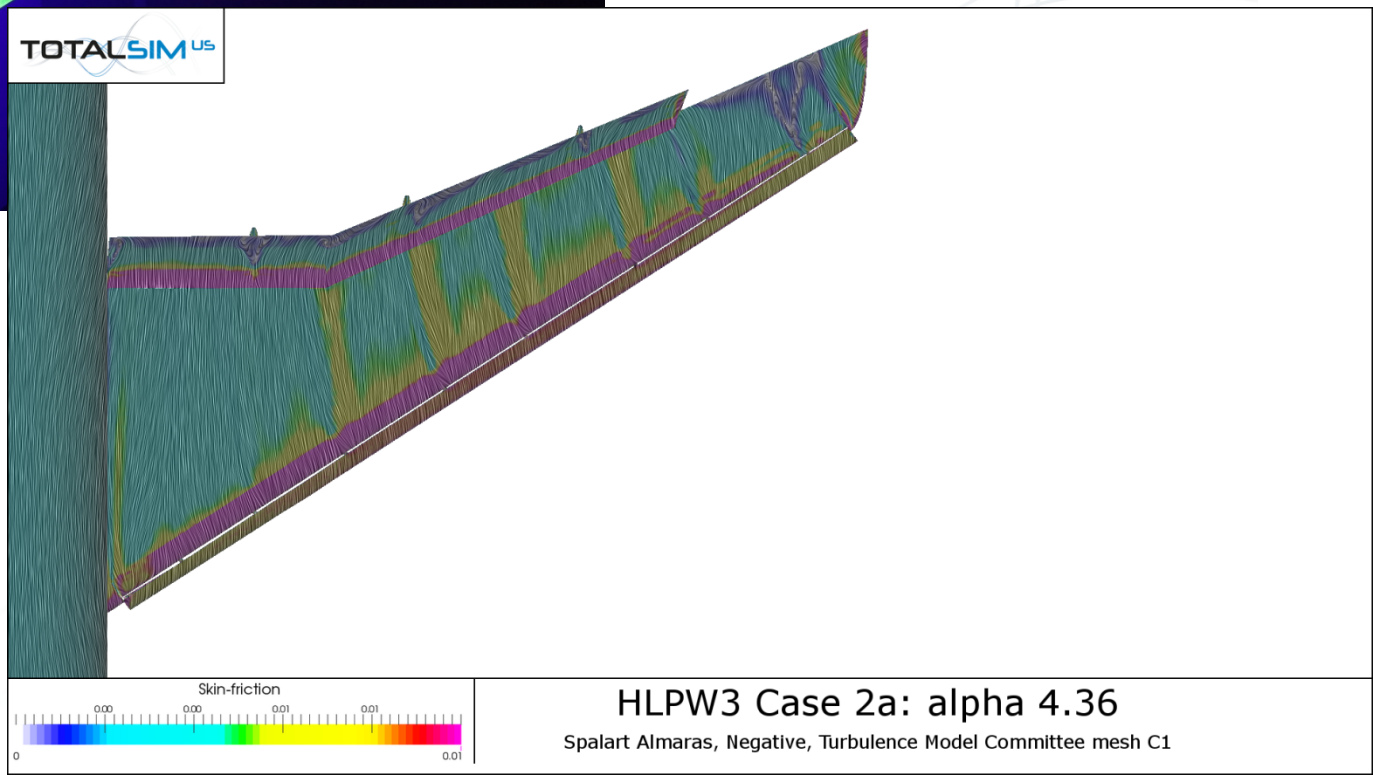
Case 2a Correlation Data



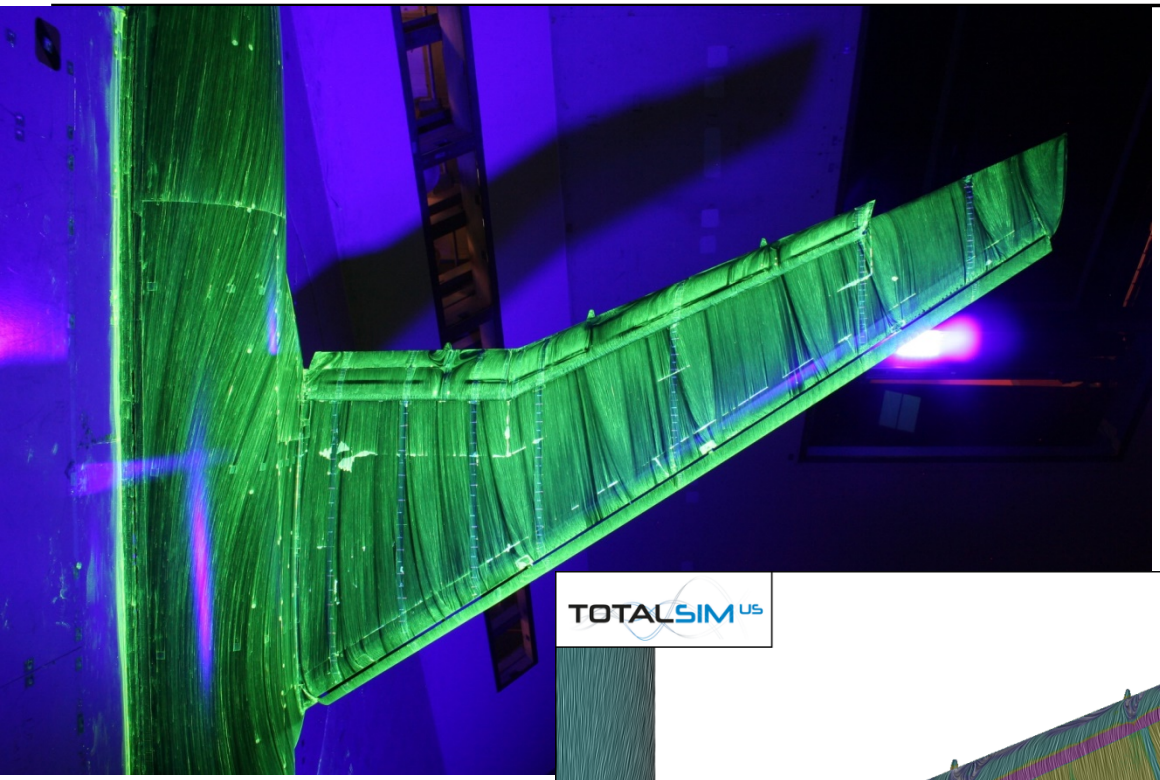
Case2a-NPoff_exp
Case2F3D-NPoff_saneg
Case2F3D-NPoff_newGrid
Case2OF-NPoff_sphere

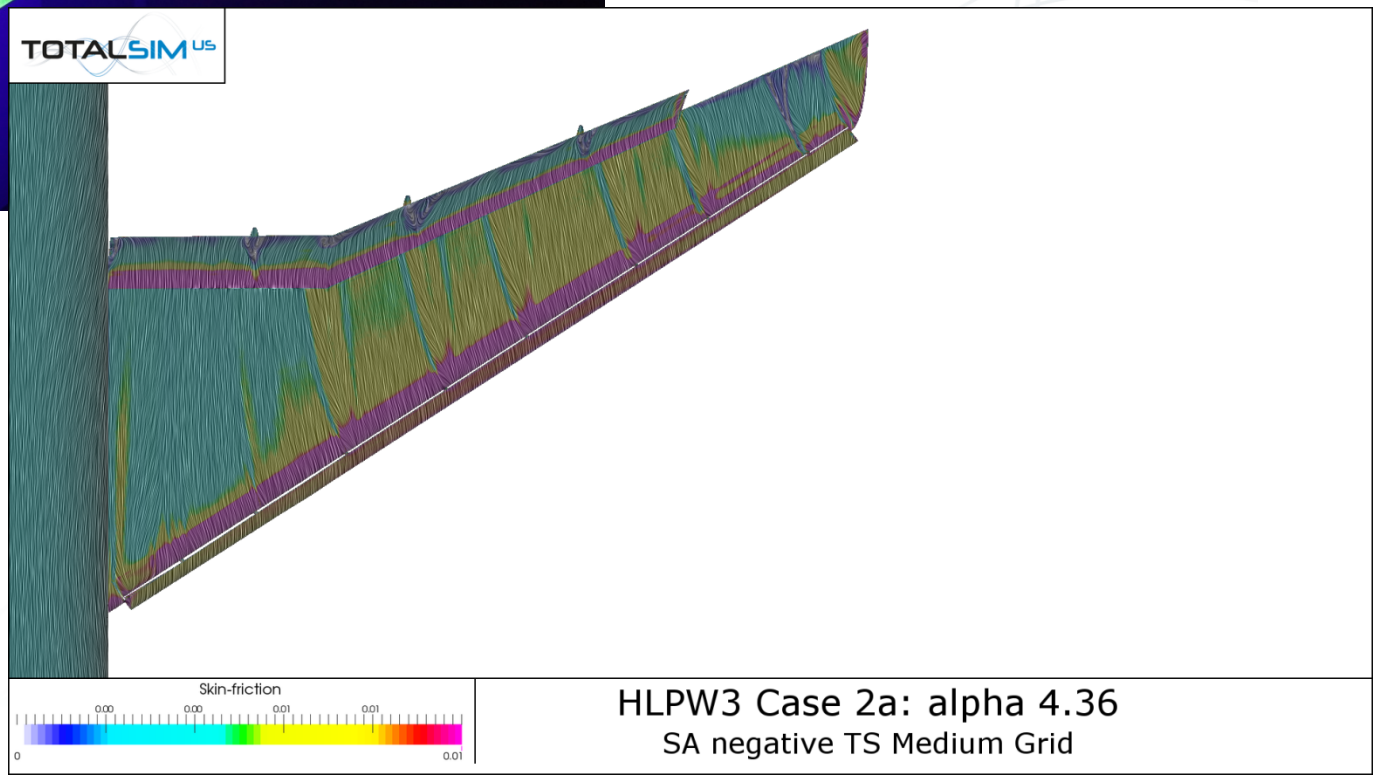
Case 2a AOA 4.36° Surface Streamline



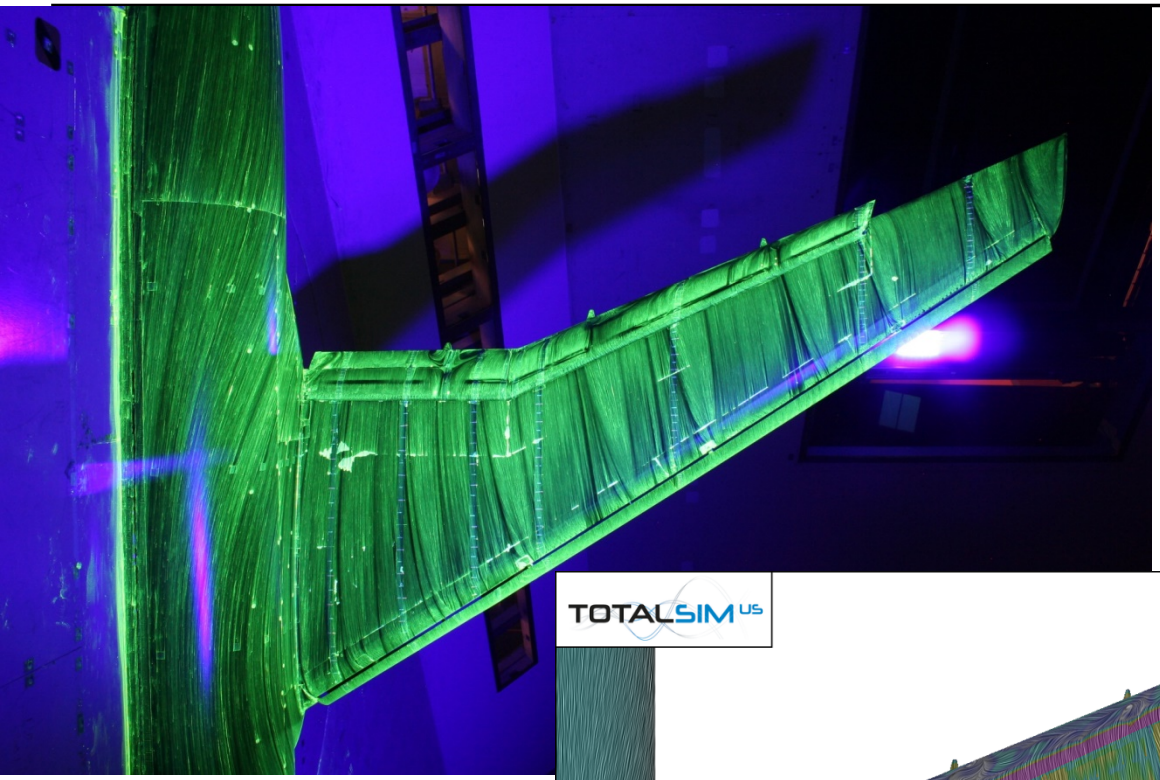


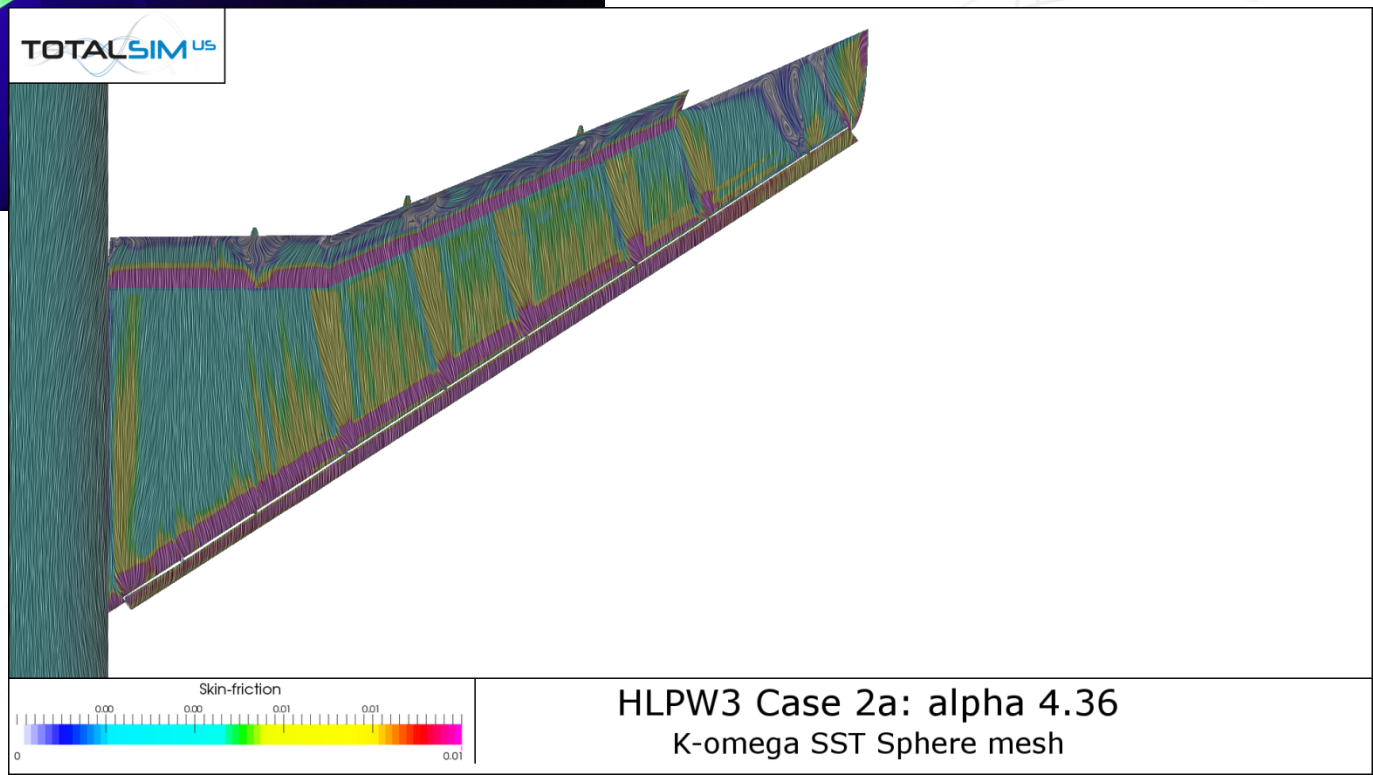
Case 2a AOA 4.36° Surface Streamline



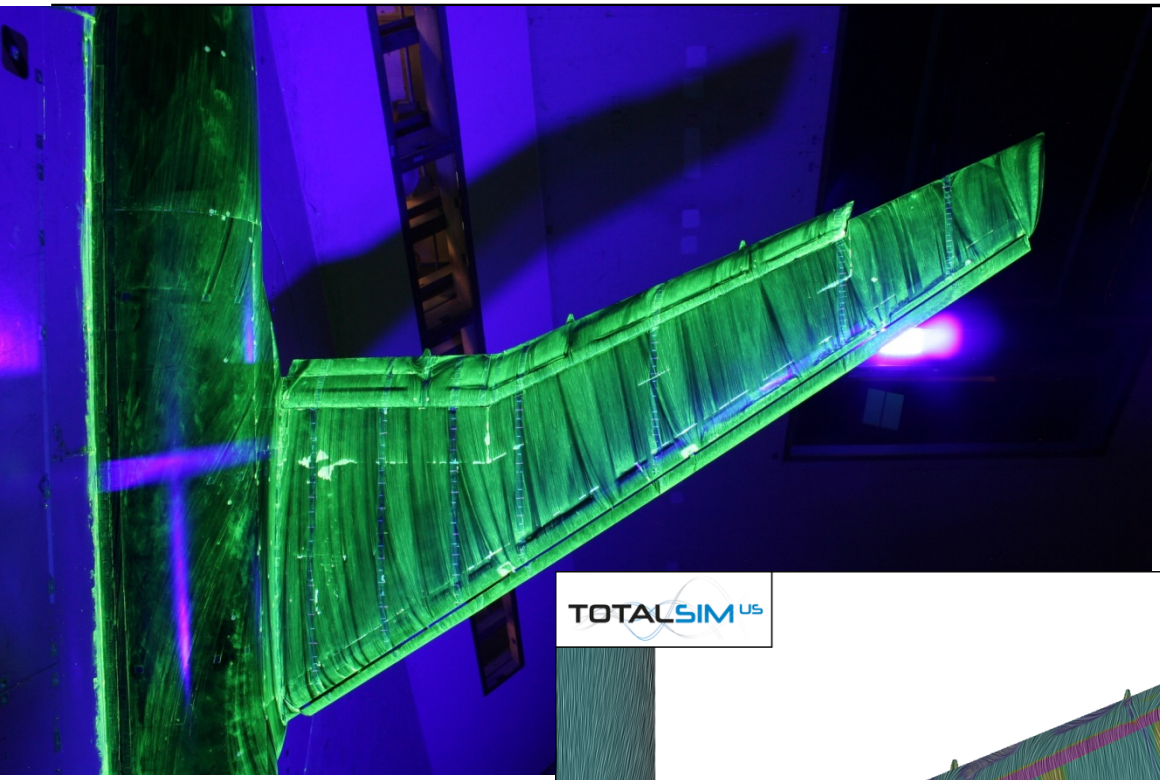


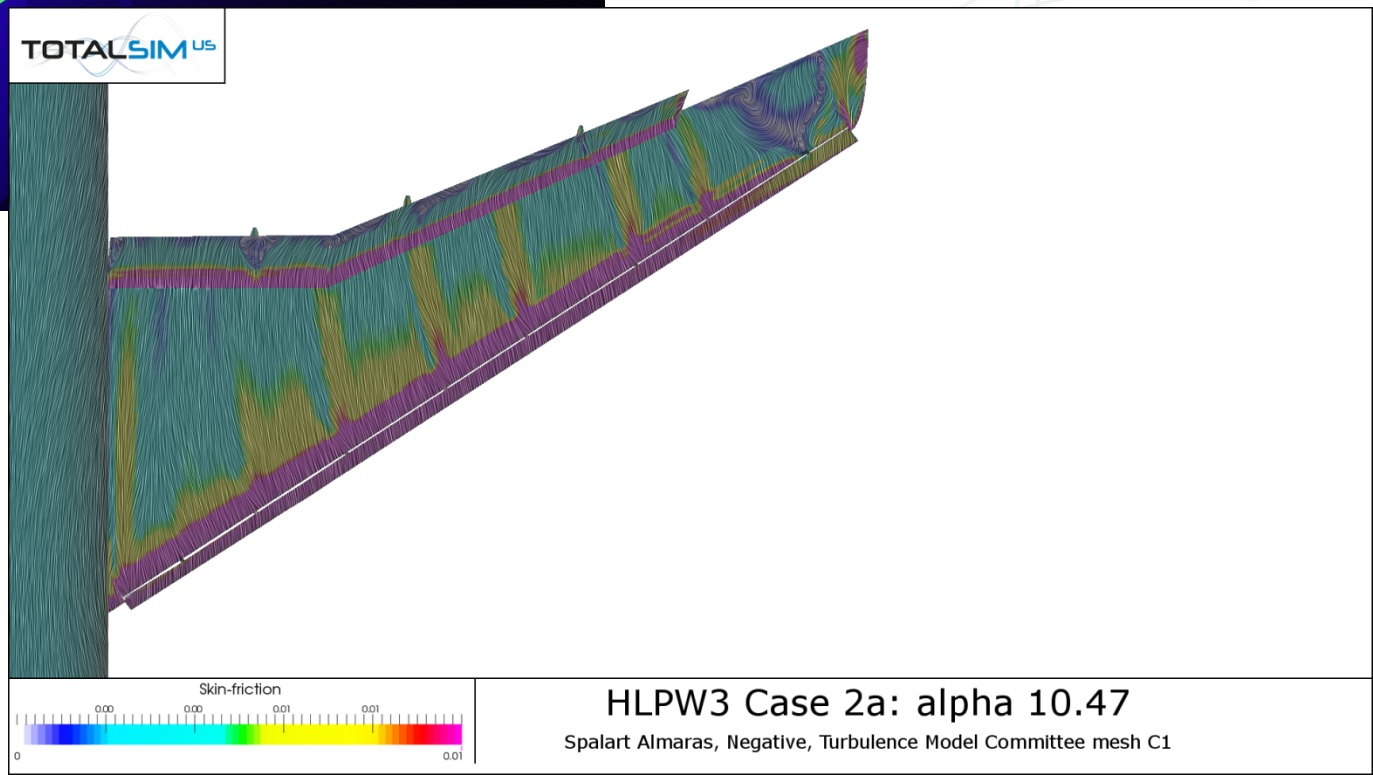
Case 2a AOA 4.36° Surface Streamline



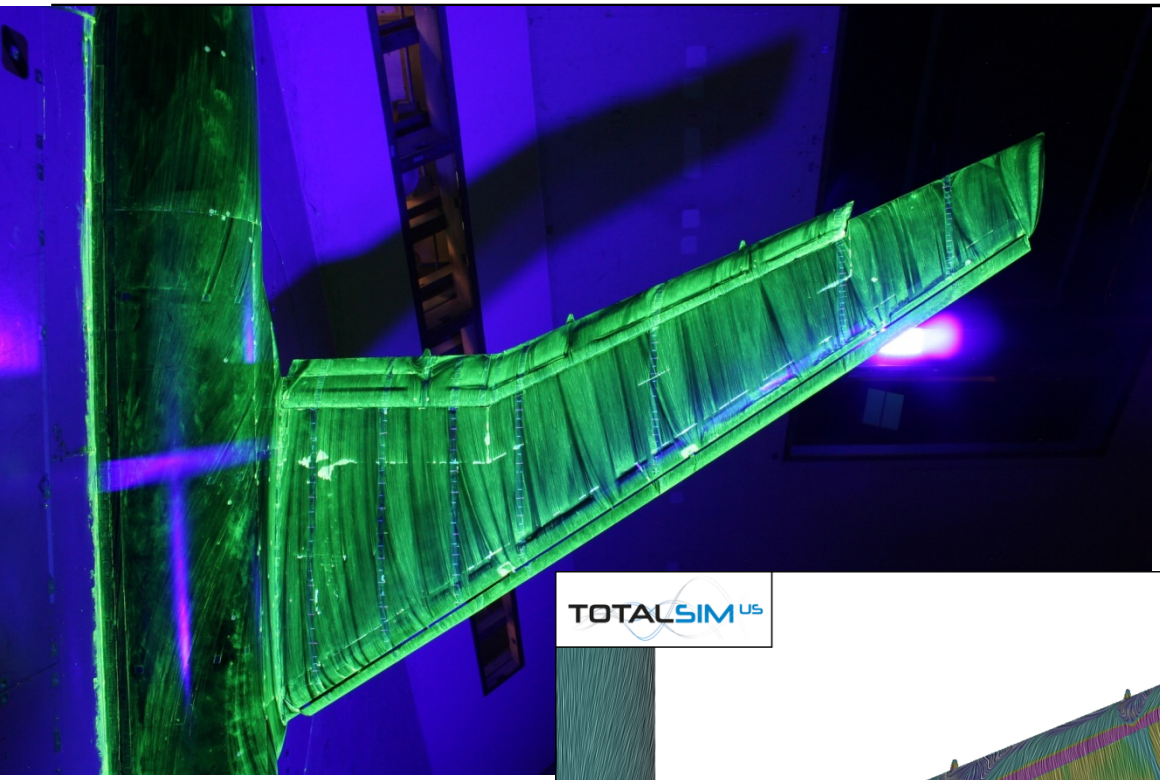


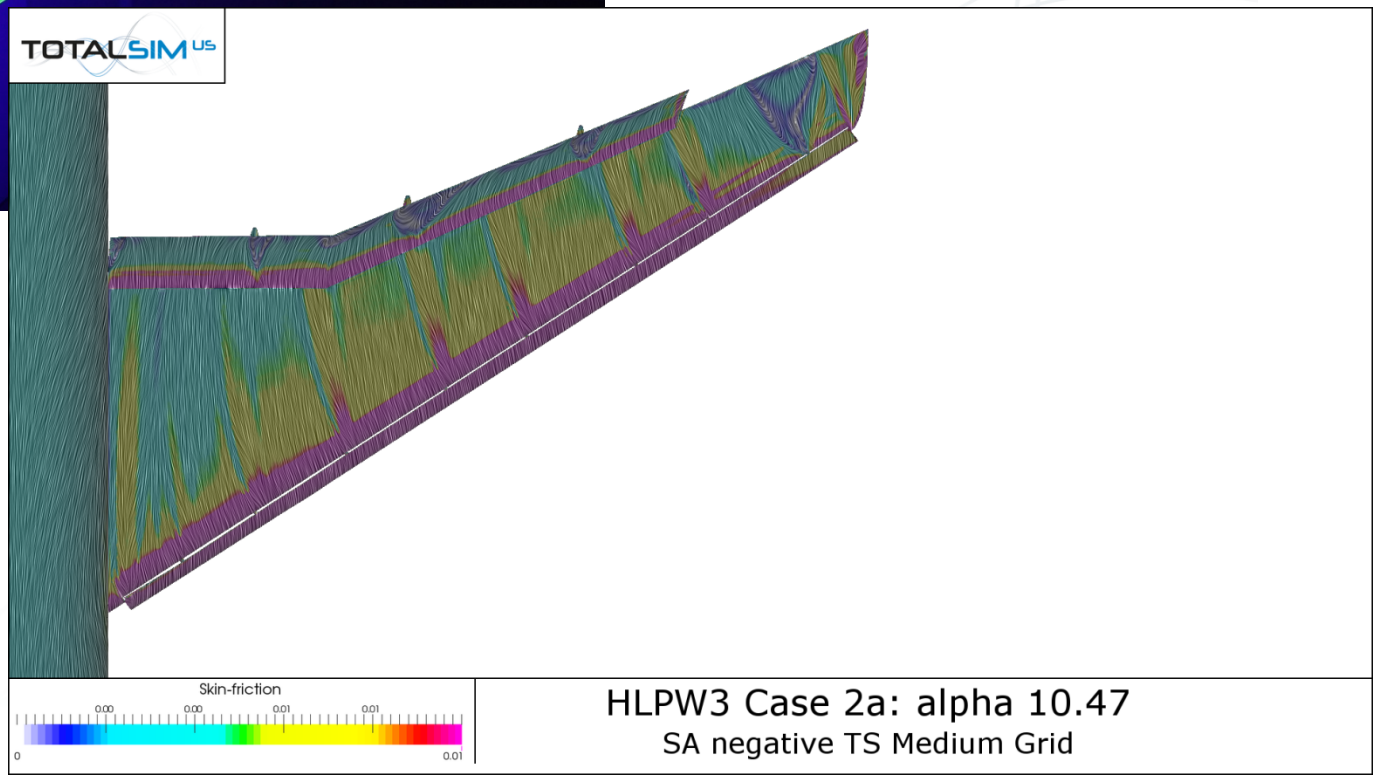
Case 2a AOA 10.47° Surface Streamline



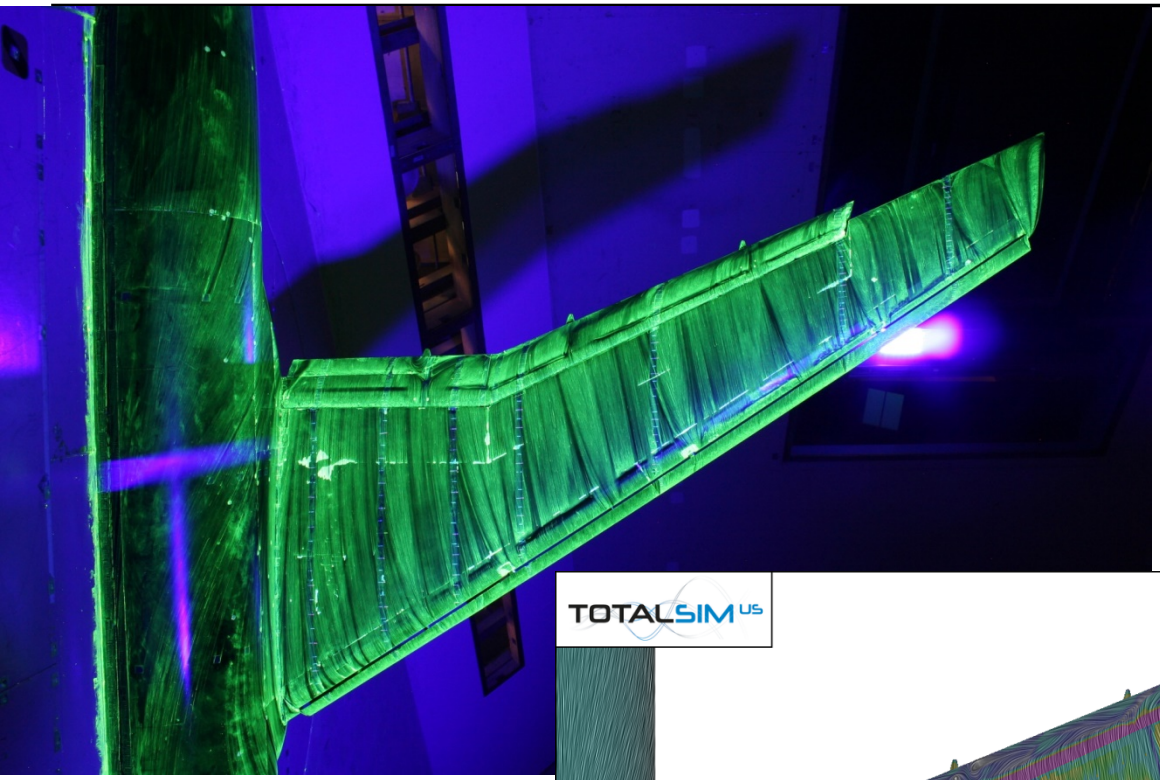


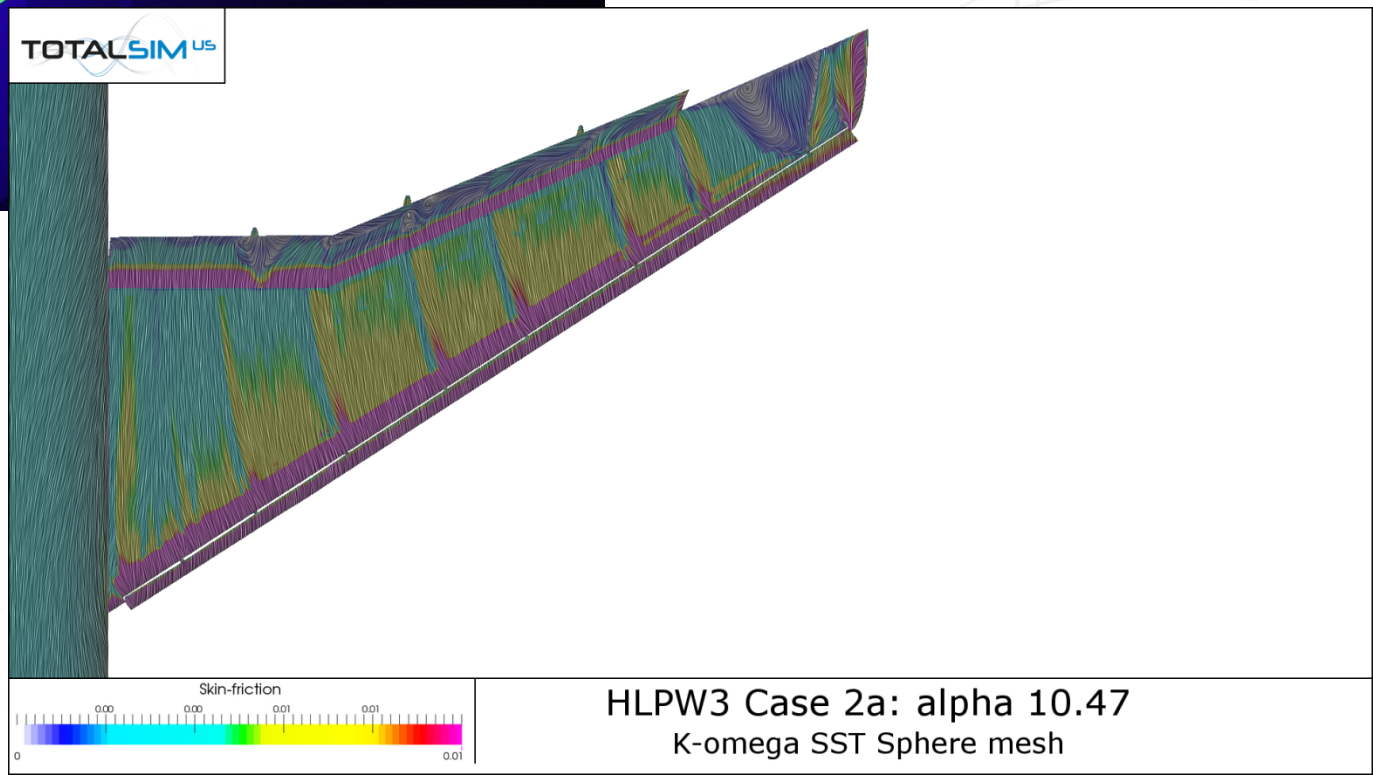
Case 2a AOA 10.47° Surface Streamline



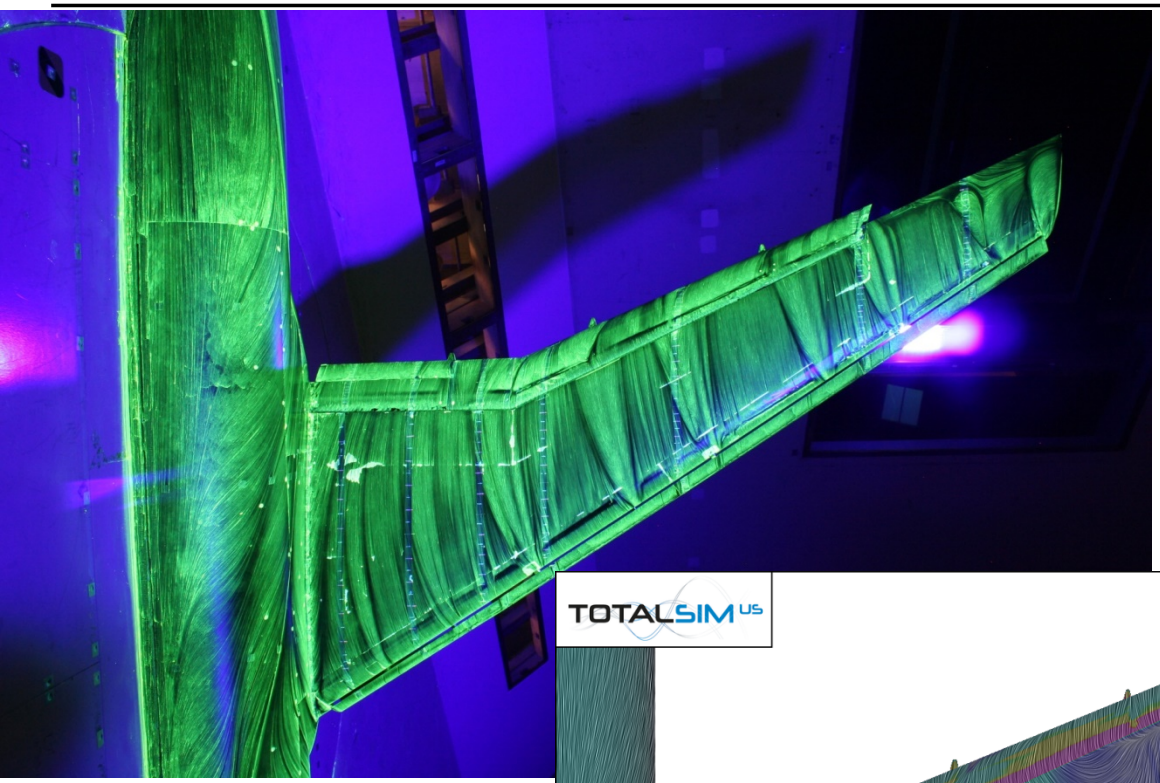


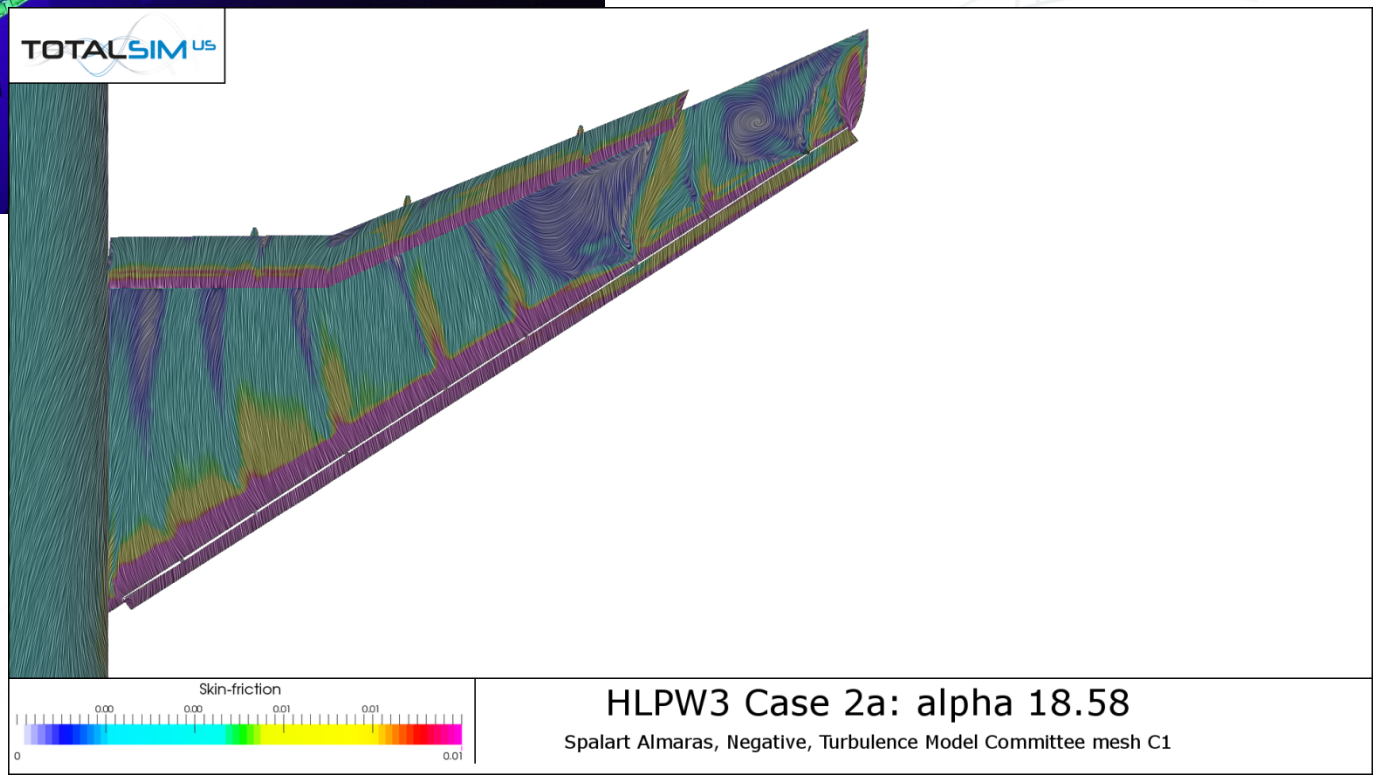
Case 2a AOA 10.47° Surface Streamline



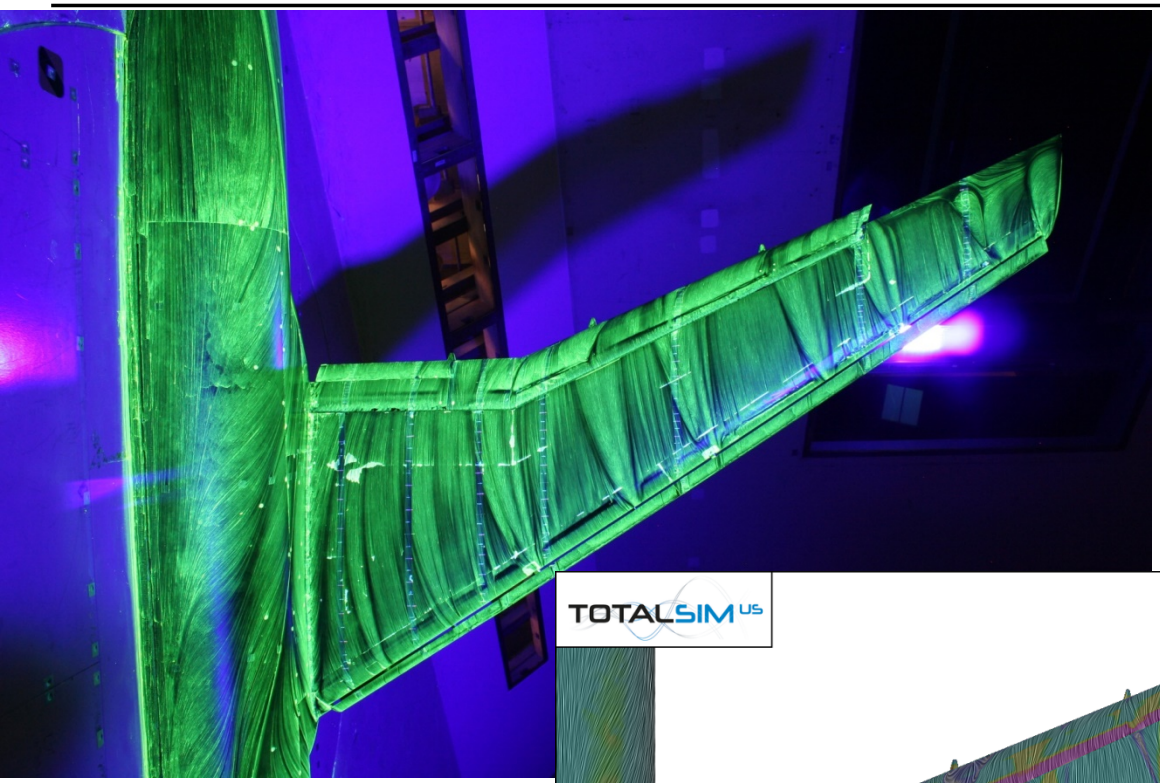


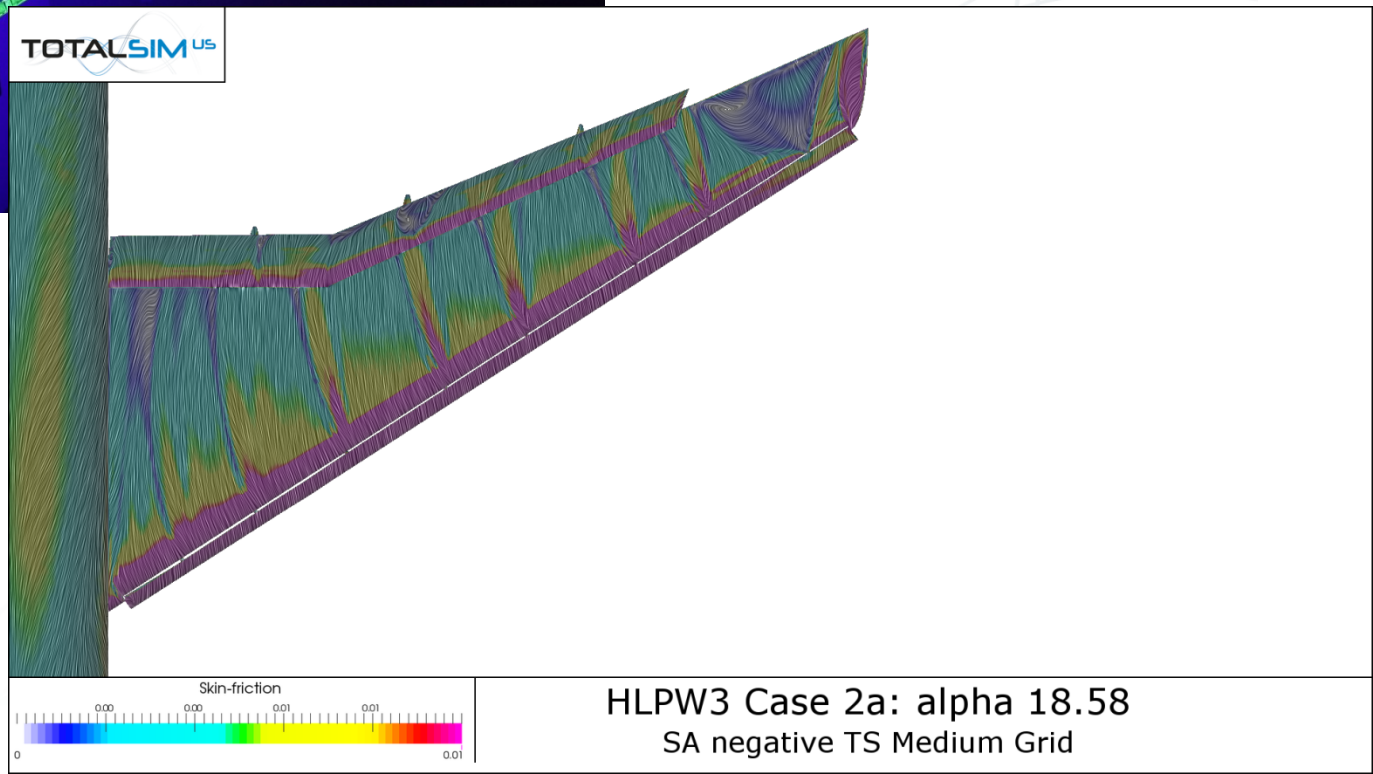
Case 2a AOA 18.58° Surface Streamline



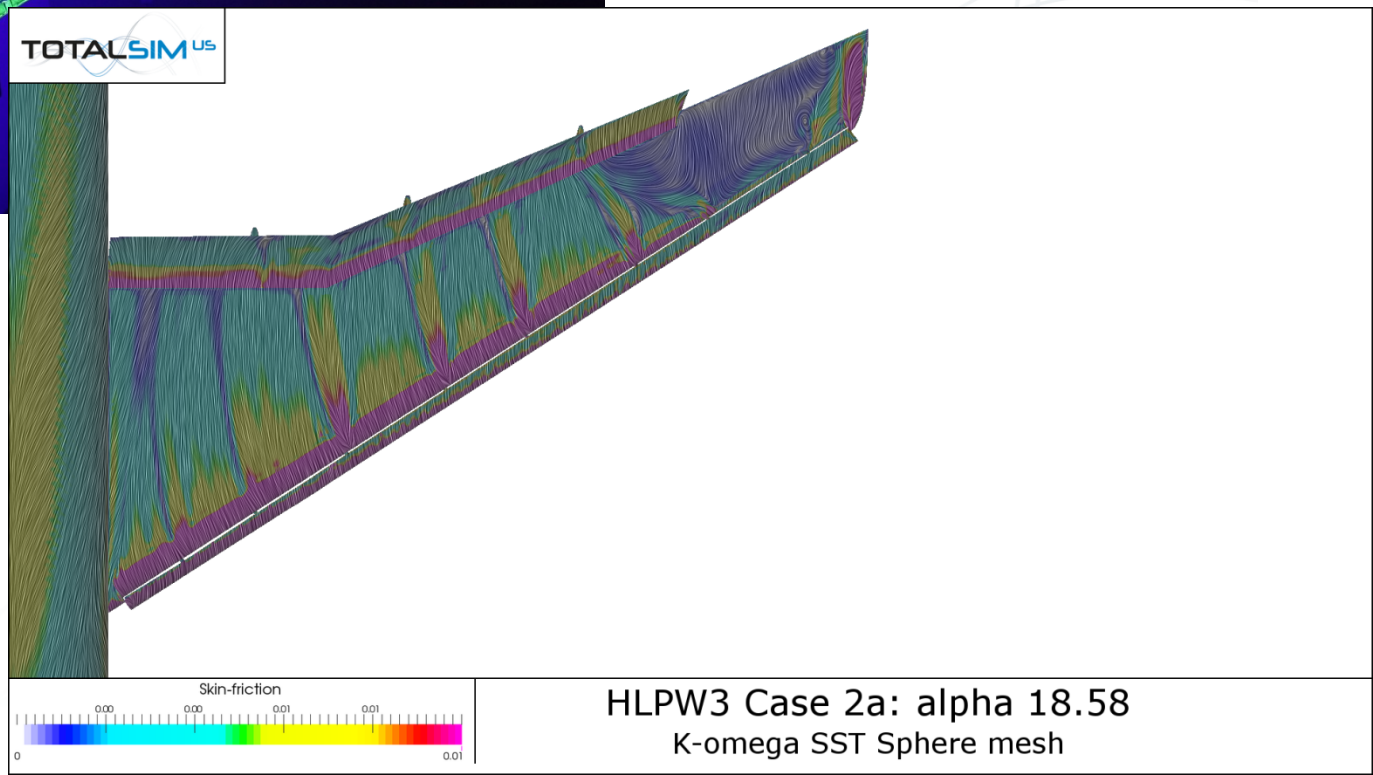


Case 2a AOA 18.58° Surface Streamline

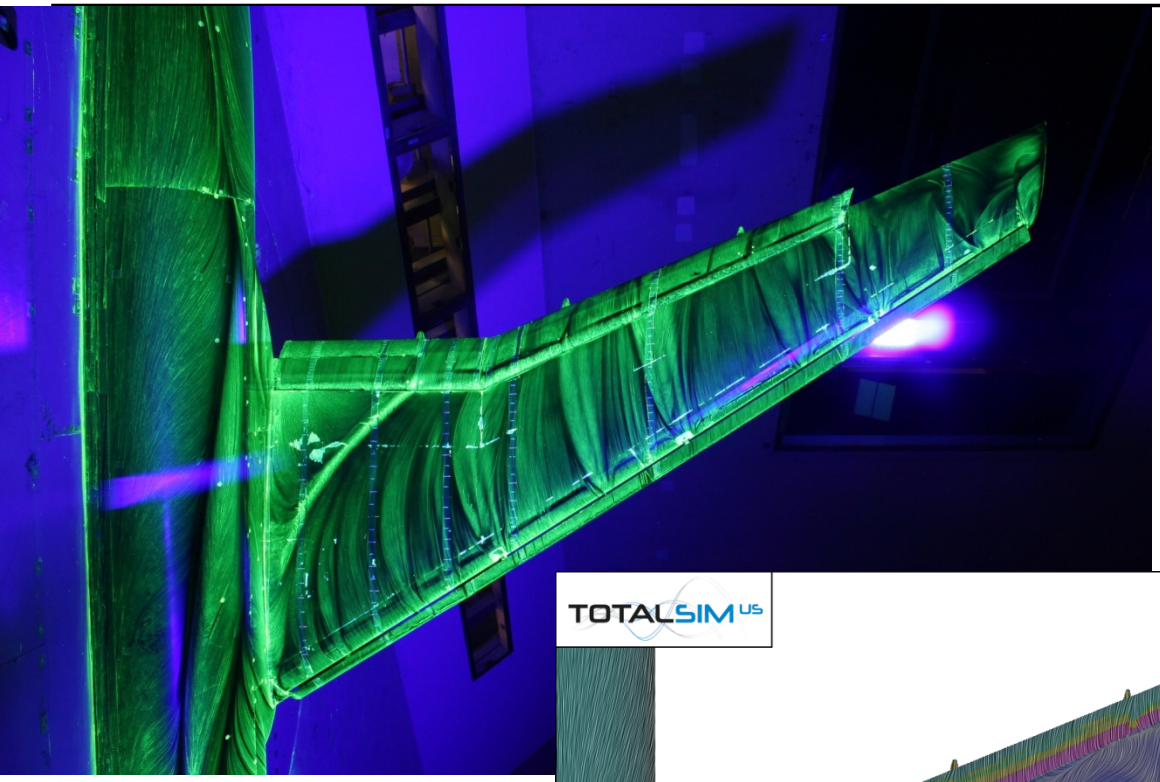


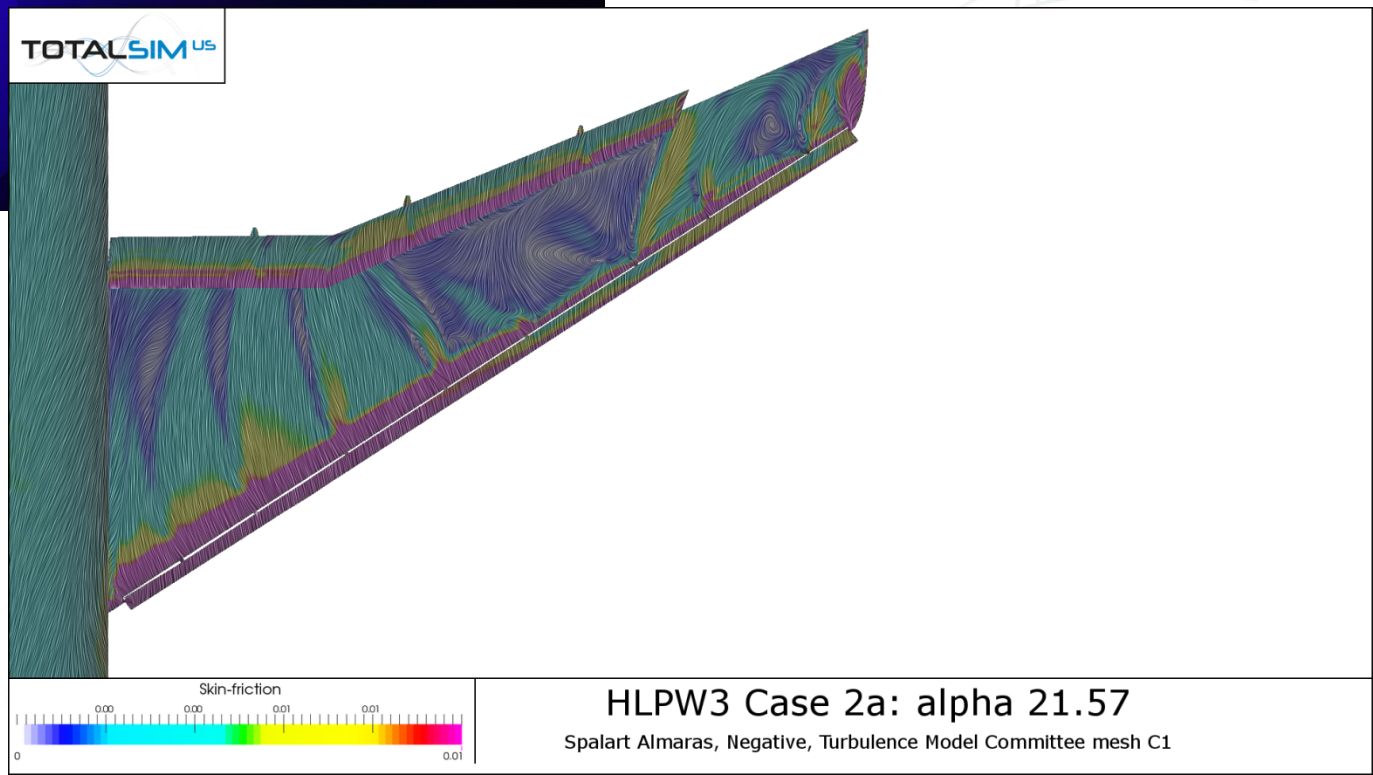


Case 2a AOA 18.58° Surface Streamline

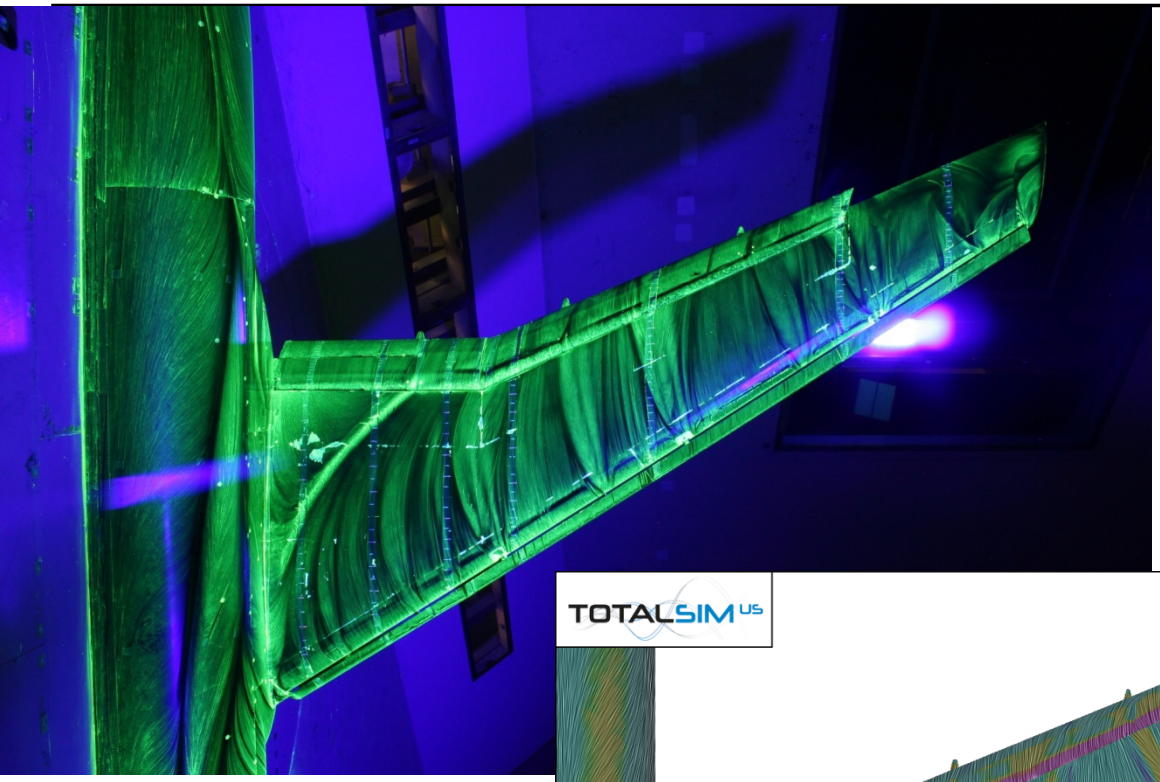


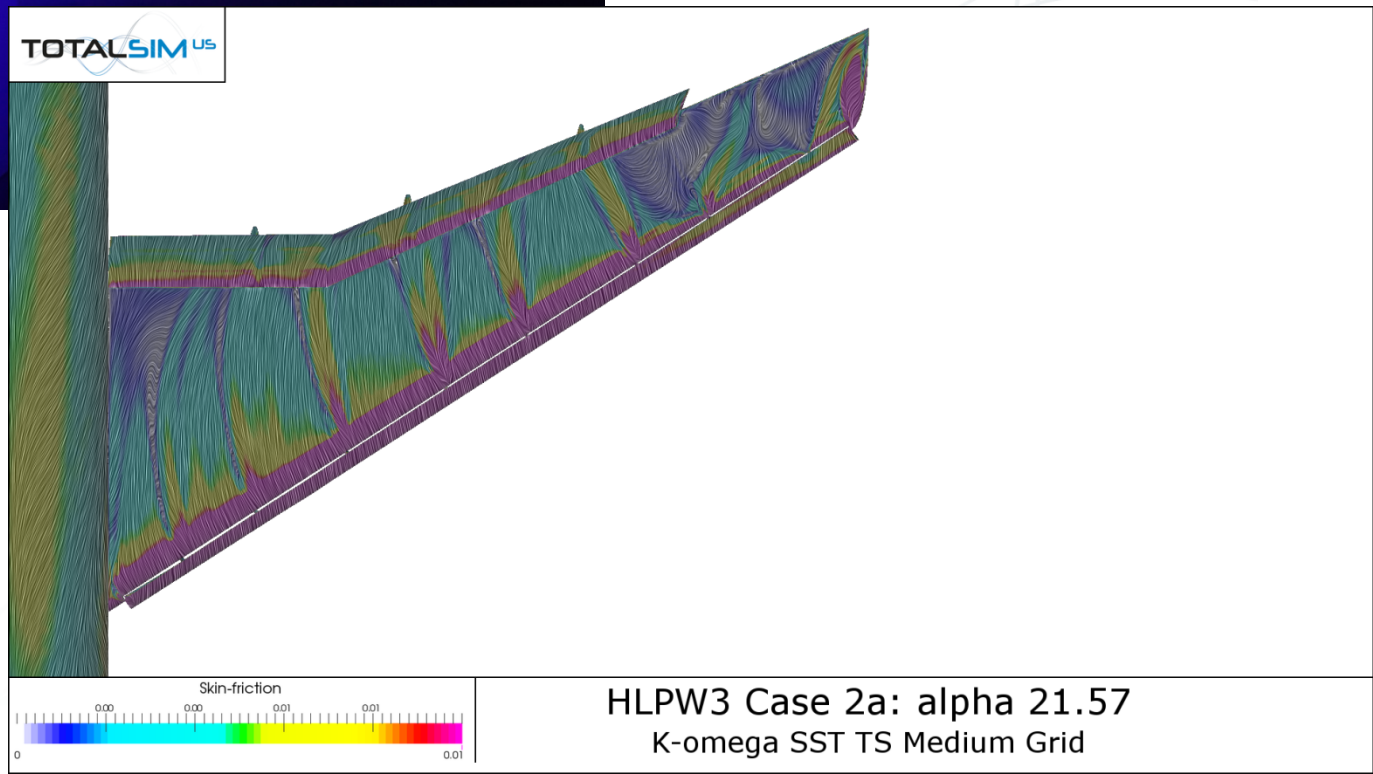
Case 2a AOA 21.57° Surface Streamline



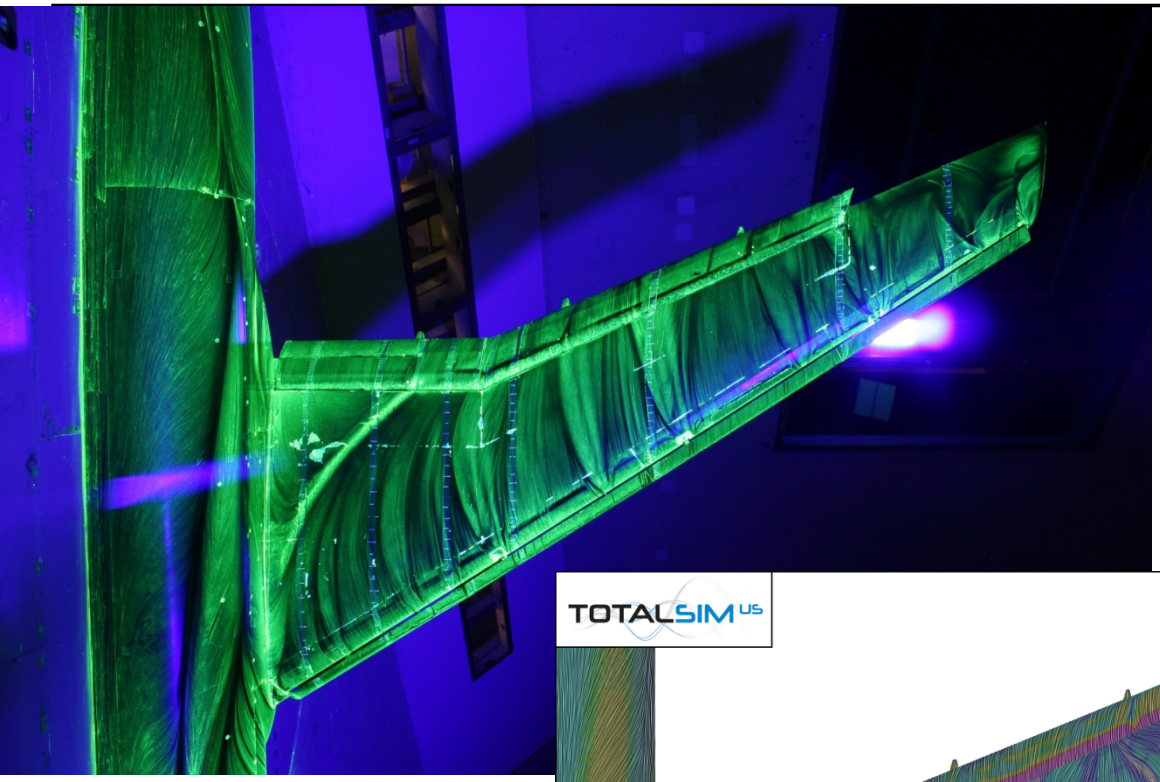


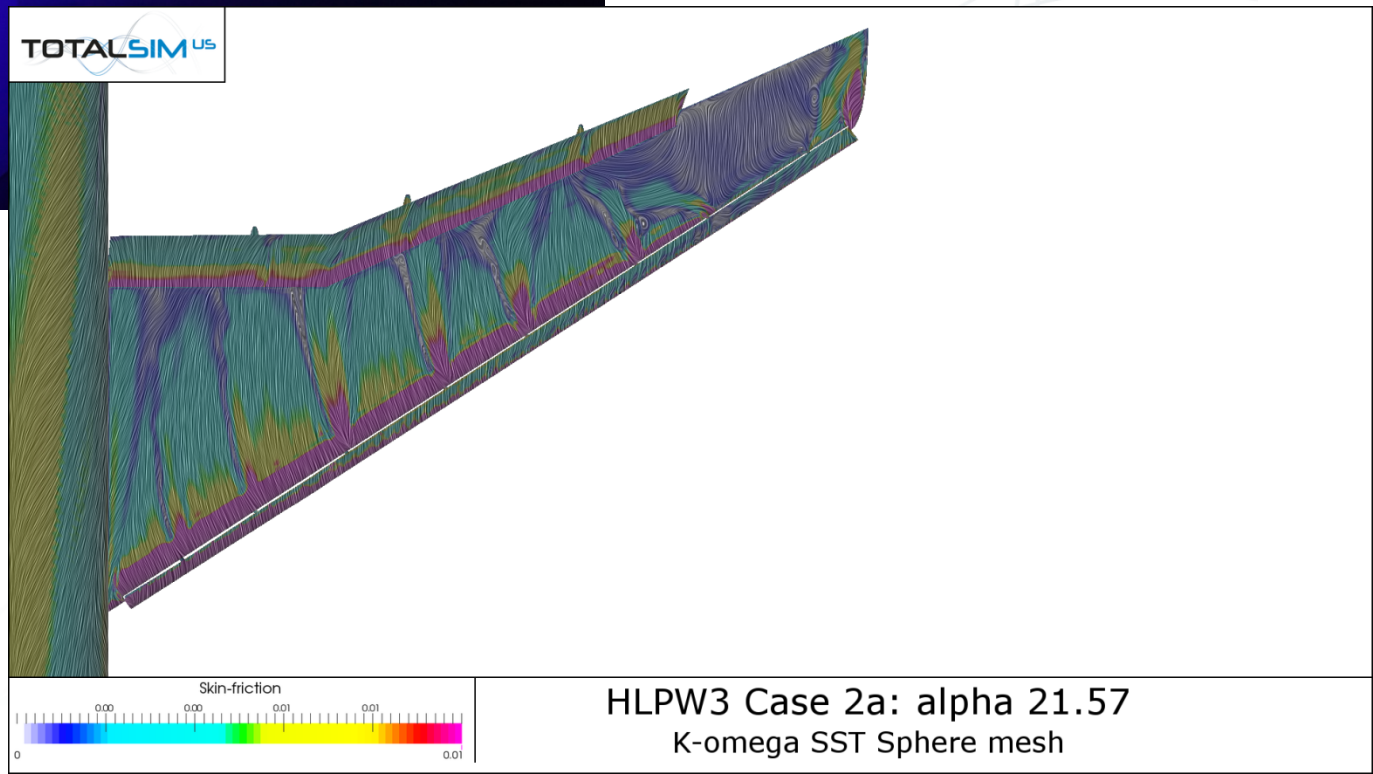
Case 2a AOA 21.57° Surface Streamline



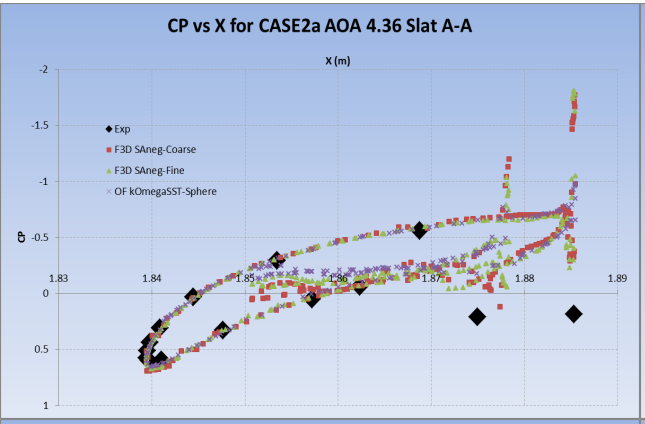


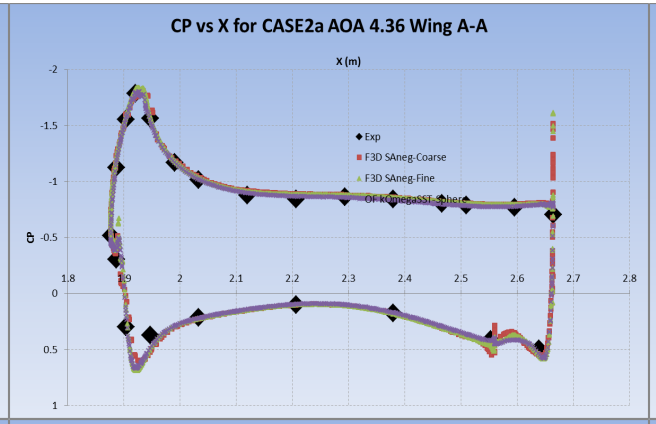
Case 2a AOA 21.57° Surface Streamline

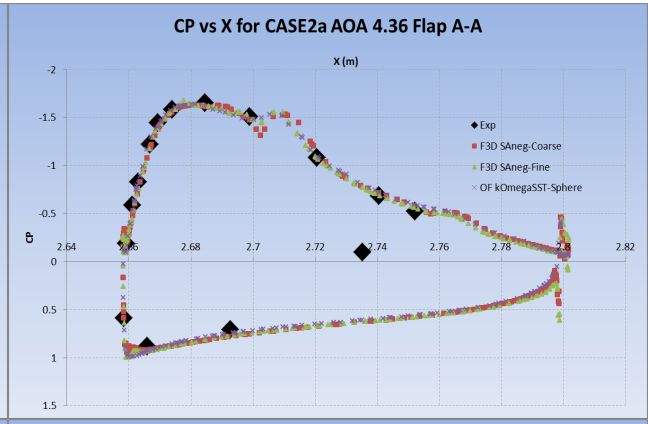


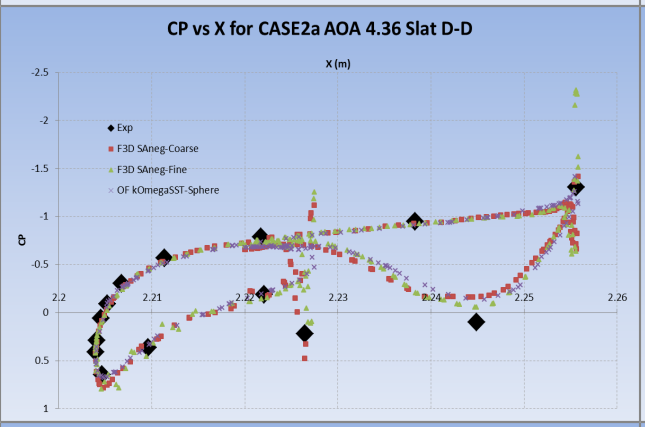


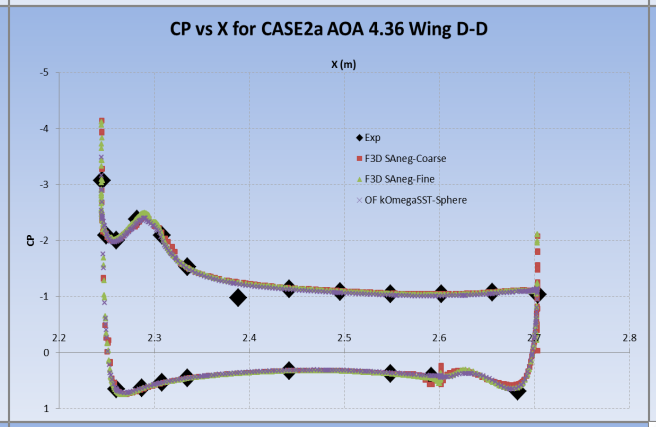
Case 2a FUN3D AOA 4.36° Cp Plots

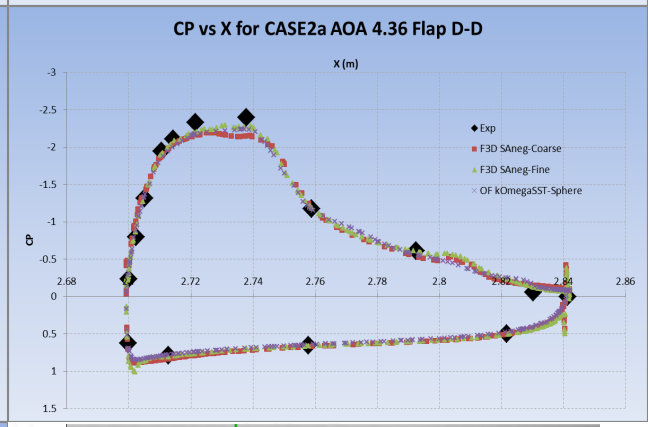


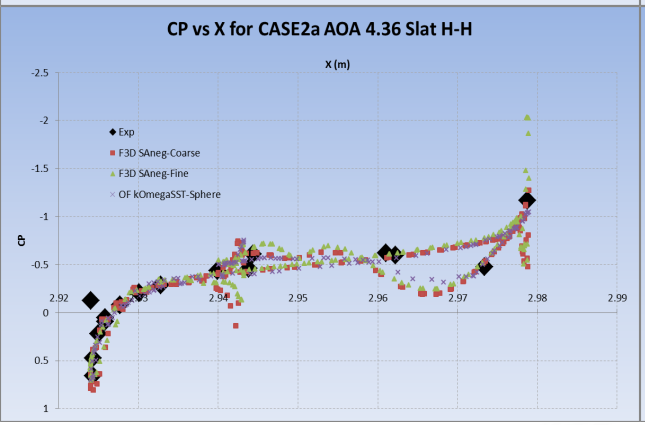


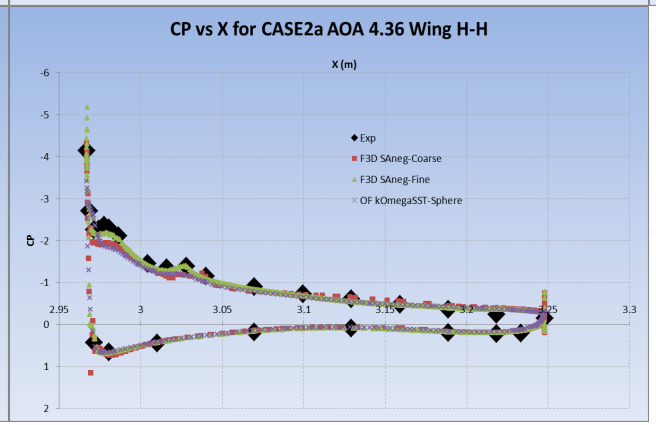


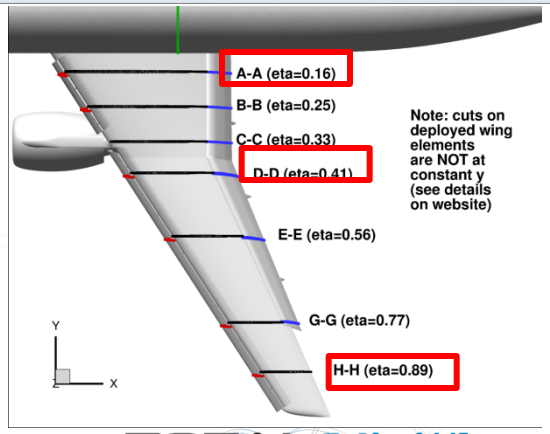




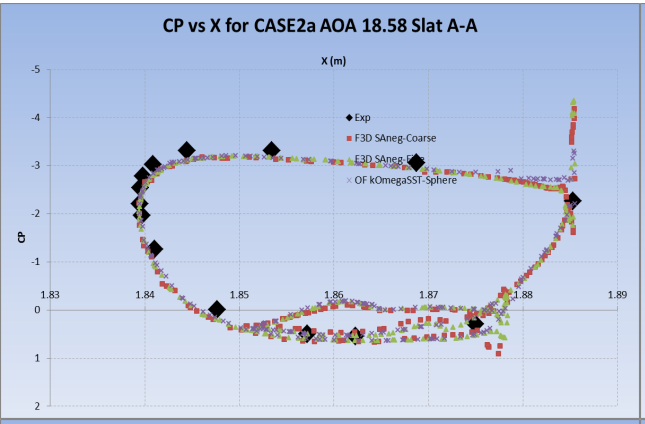


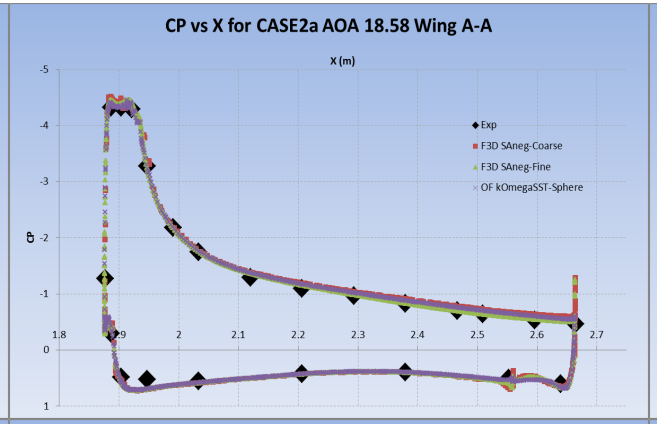


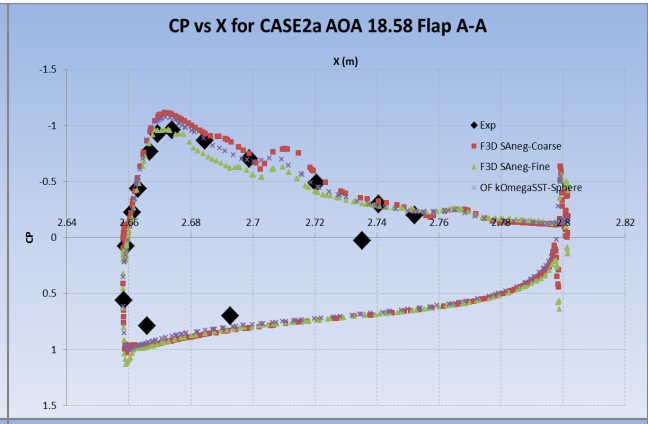


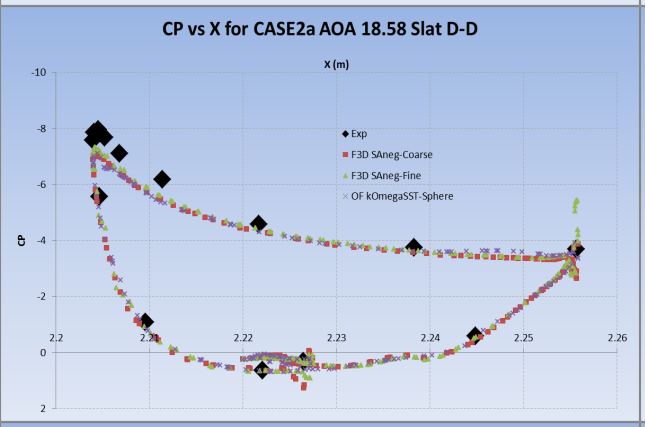


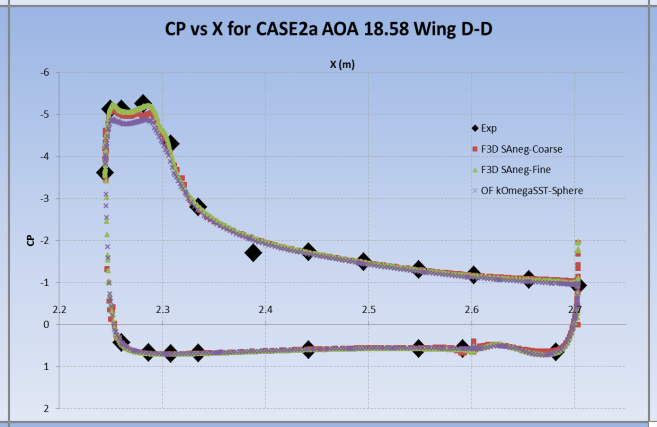
Case 2a FUN3D AOA 18.58° Cp Plots

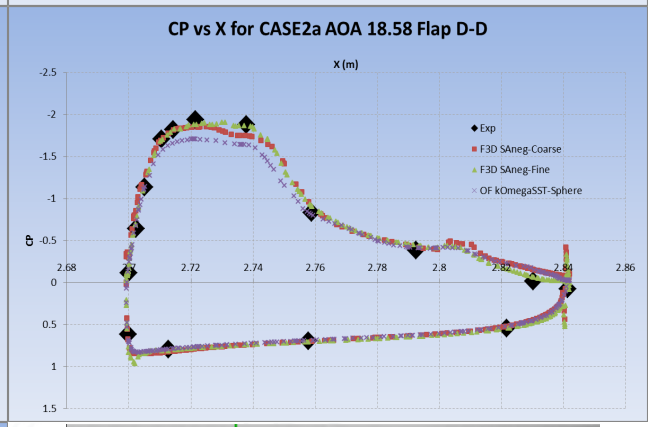


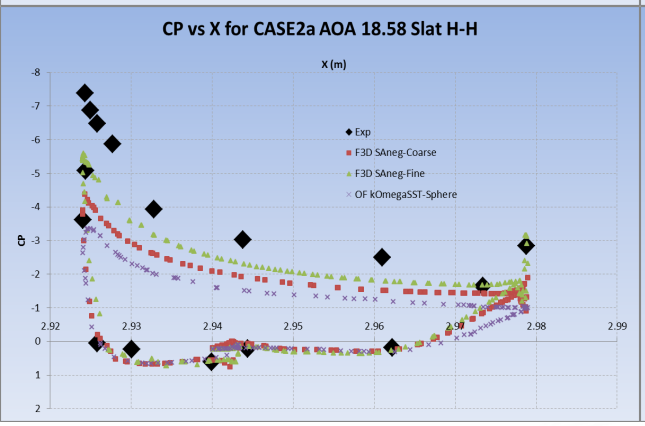


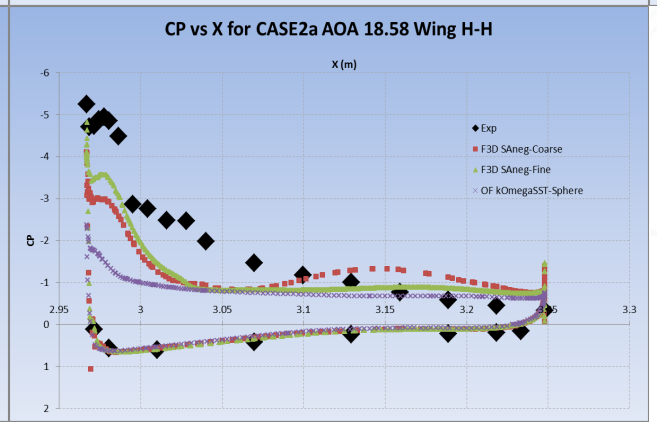


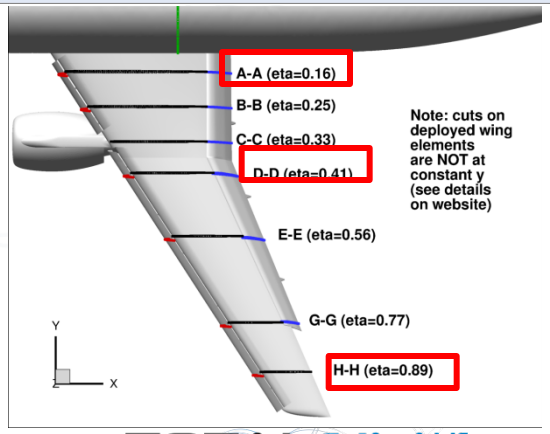




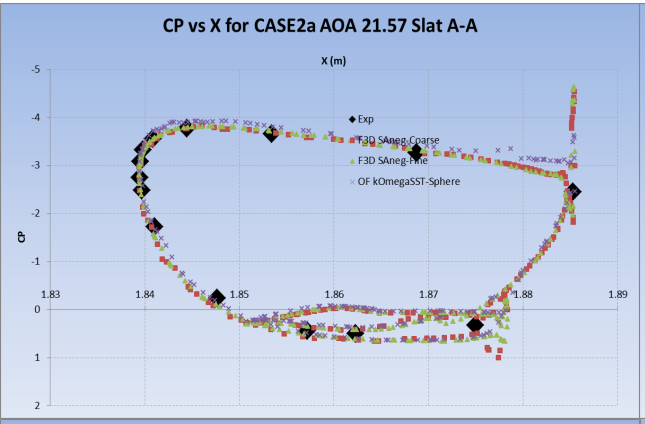


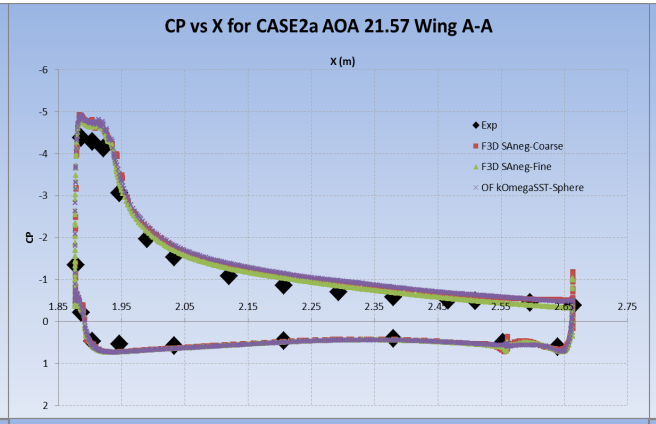


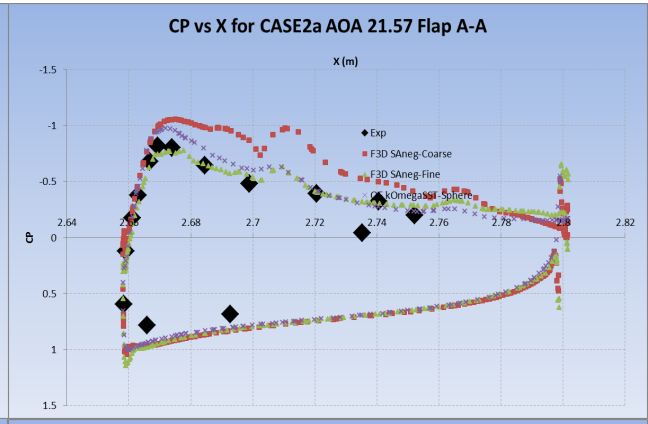


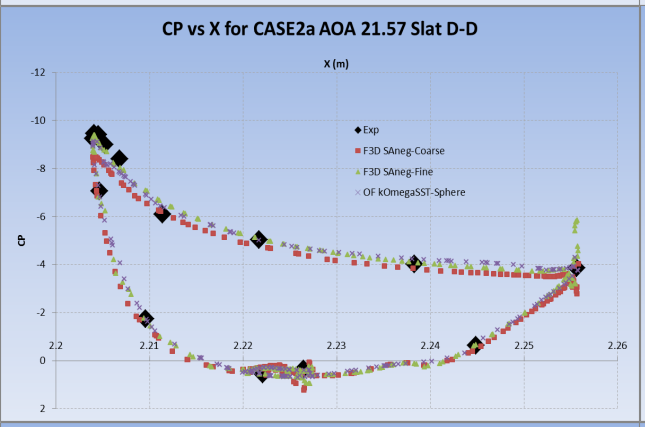


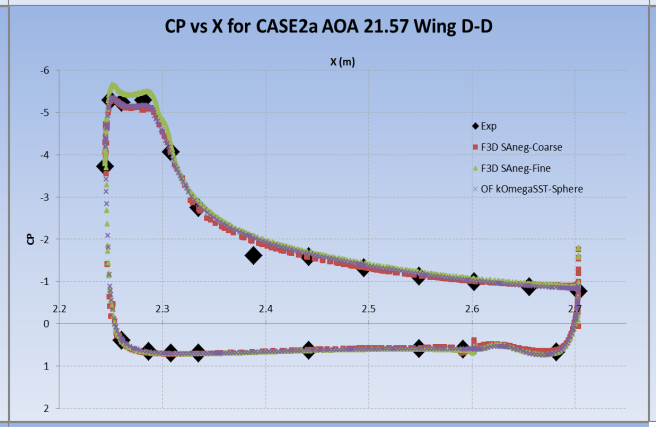
Case 2a FUN3D AOA 21.57° Cp Plots

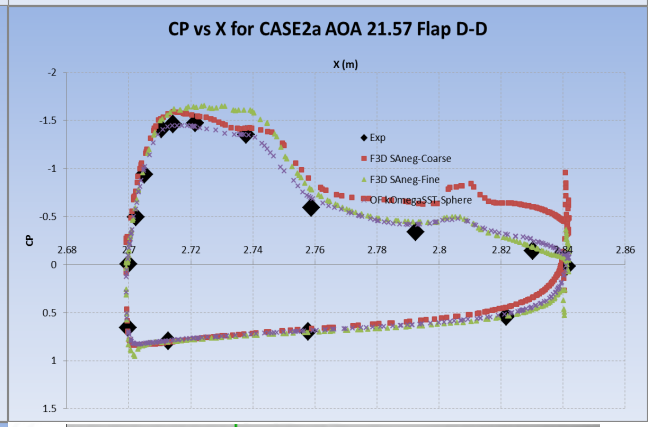


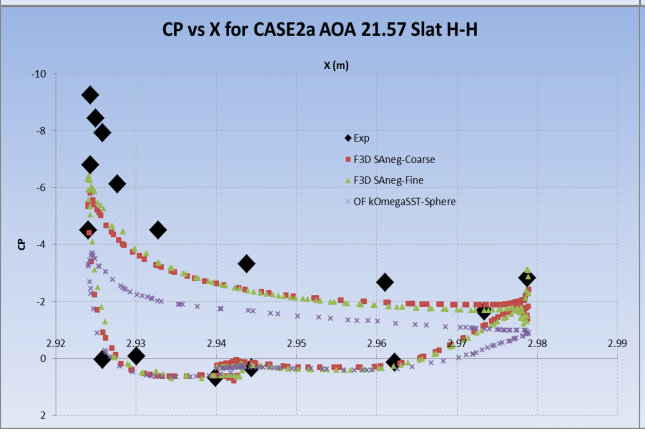


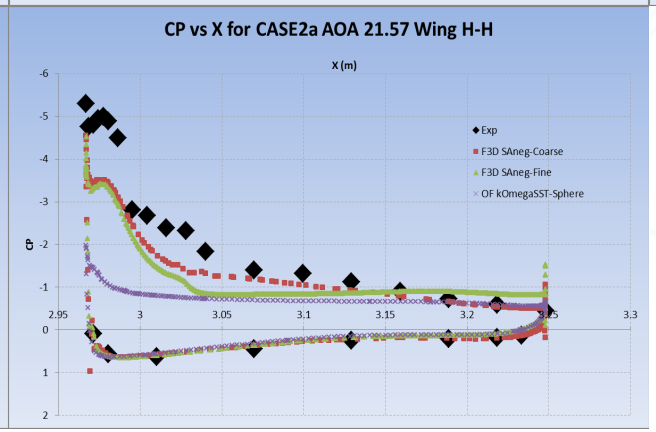


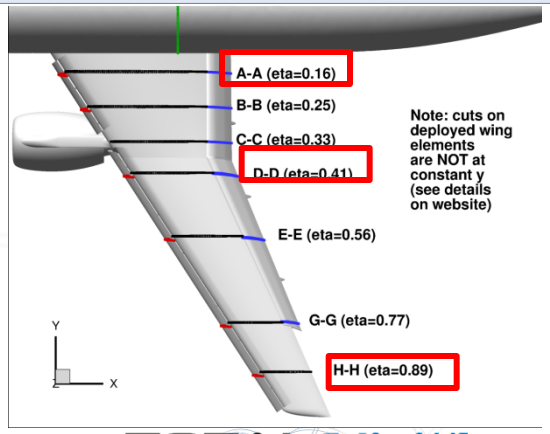




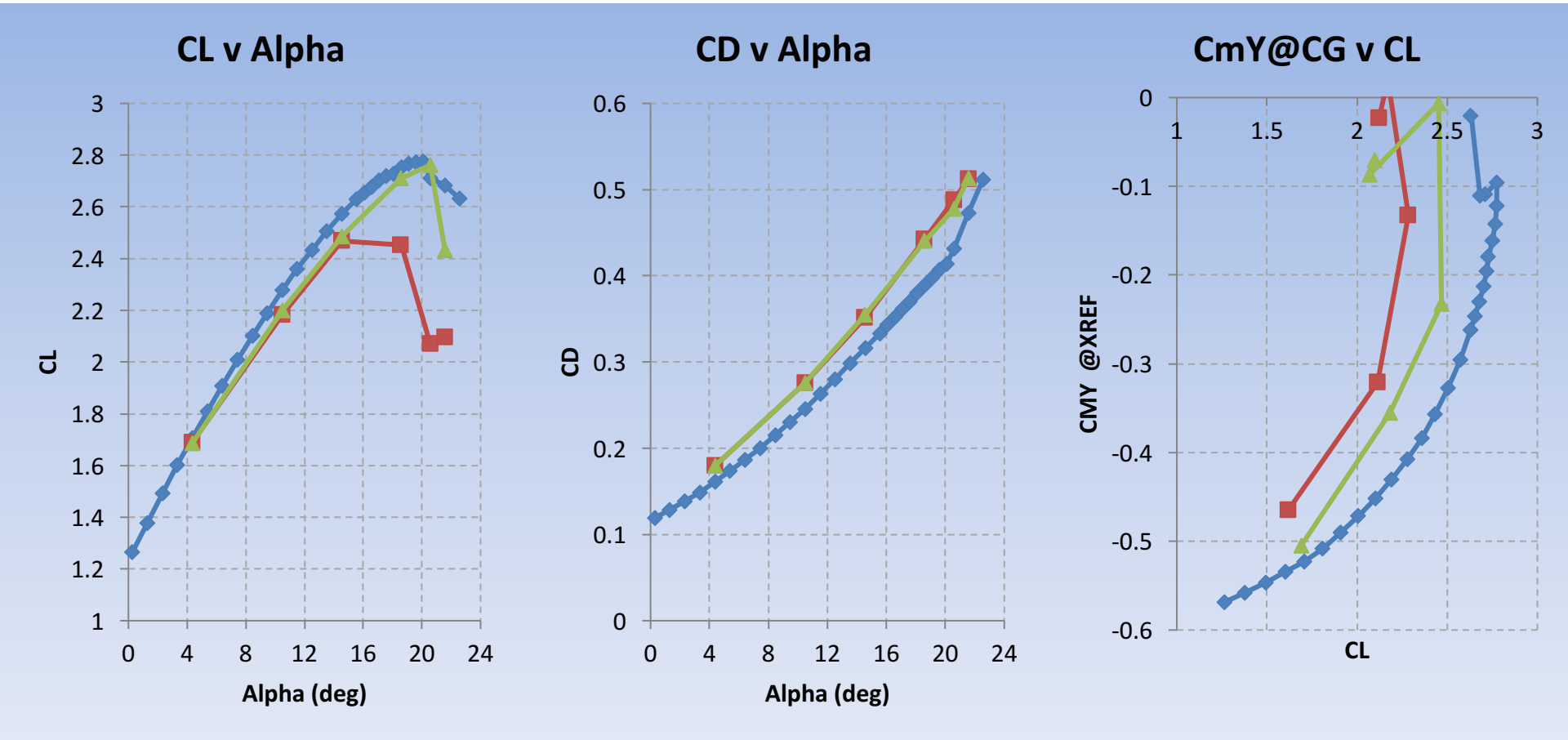






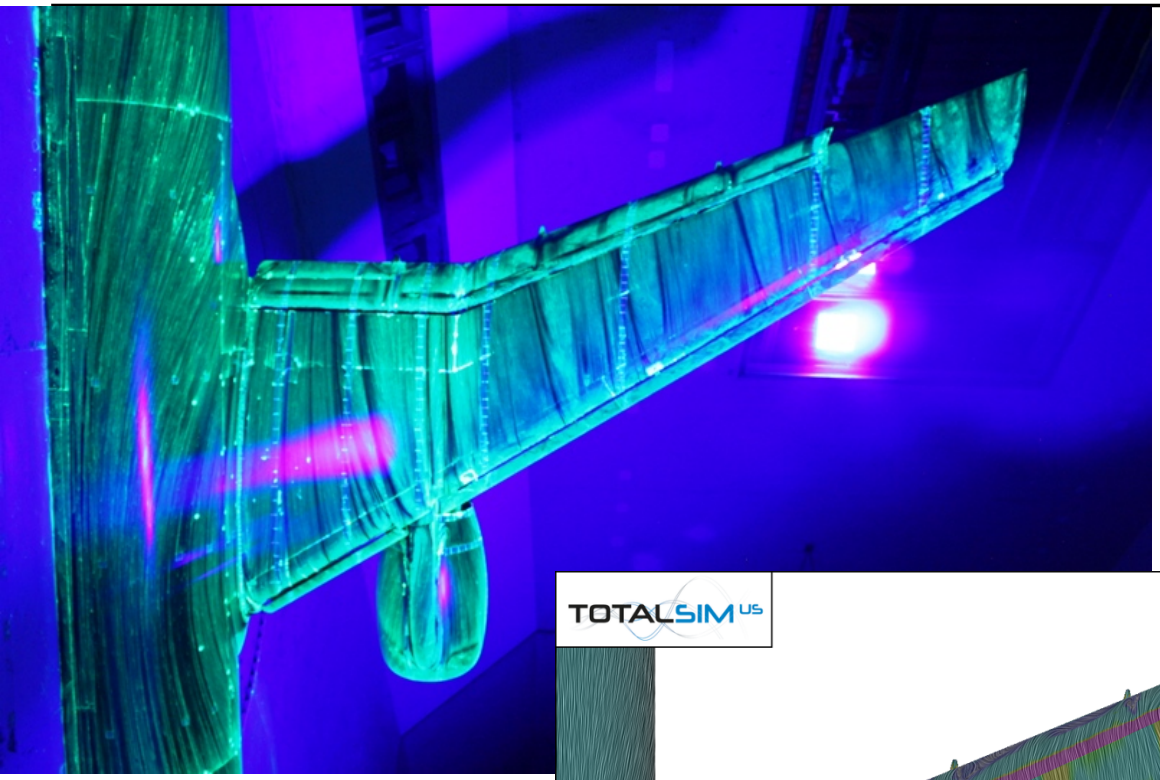


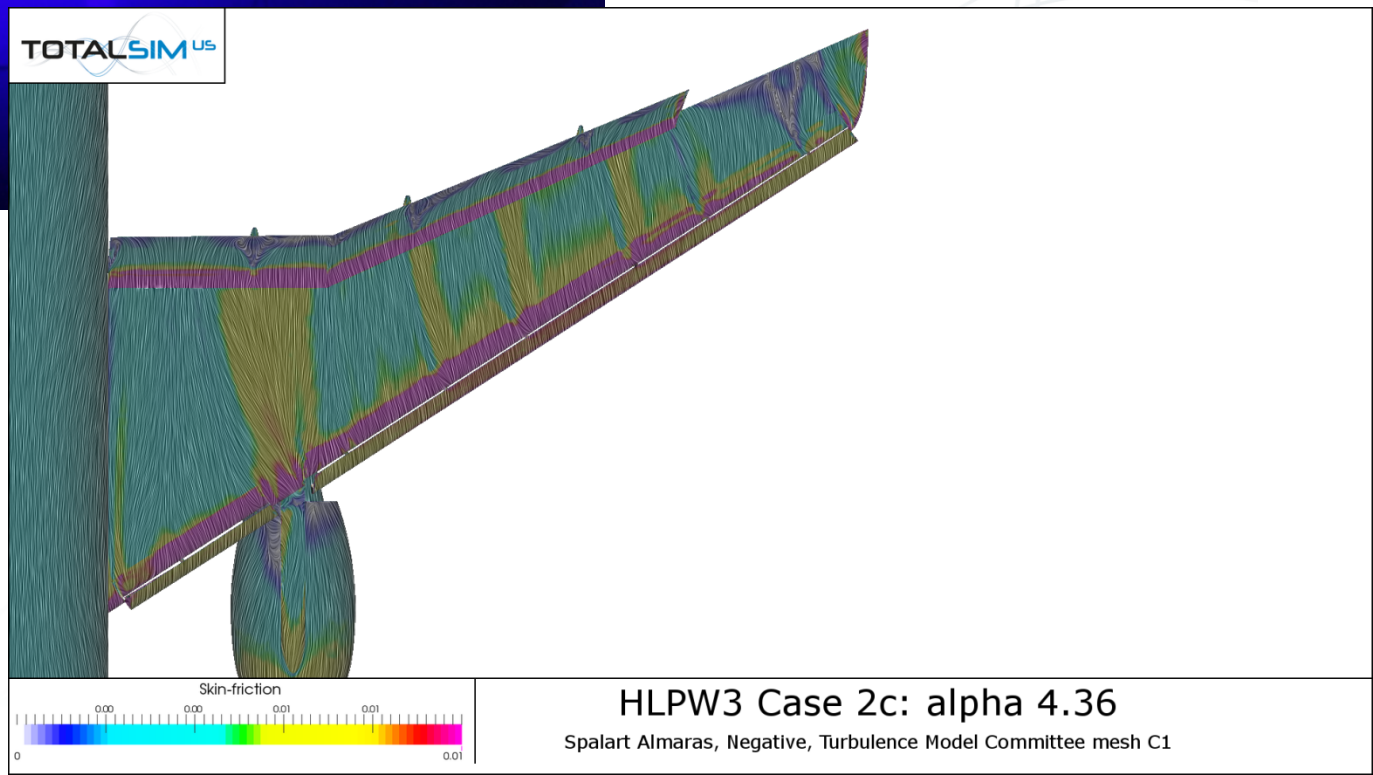
Case 2c Correlation Data



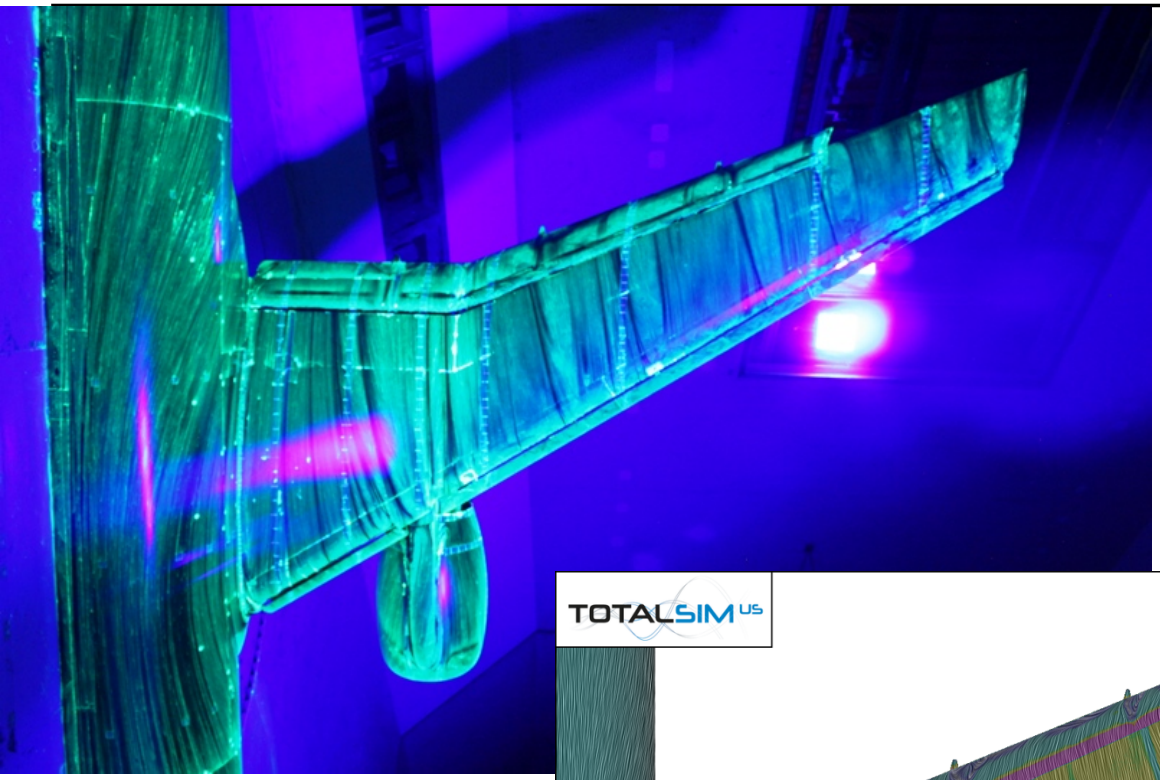
OpenFoam results are currently in progress

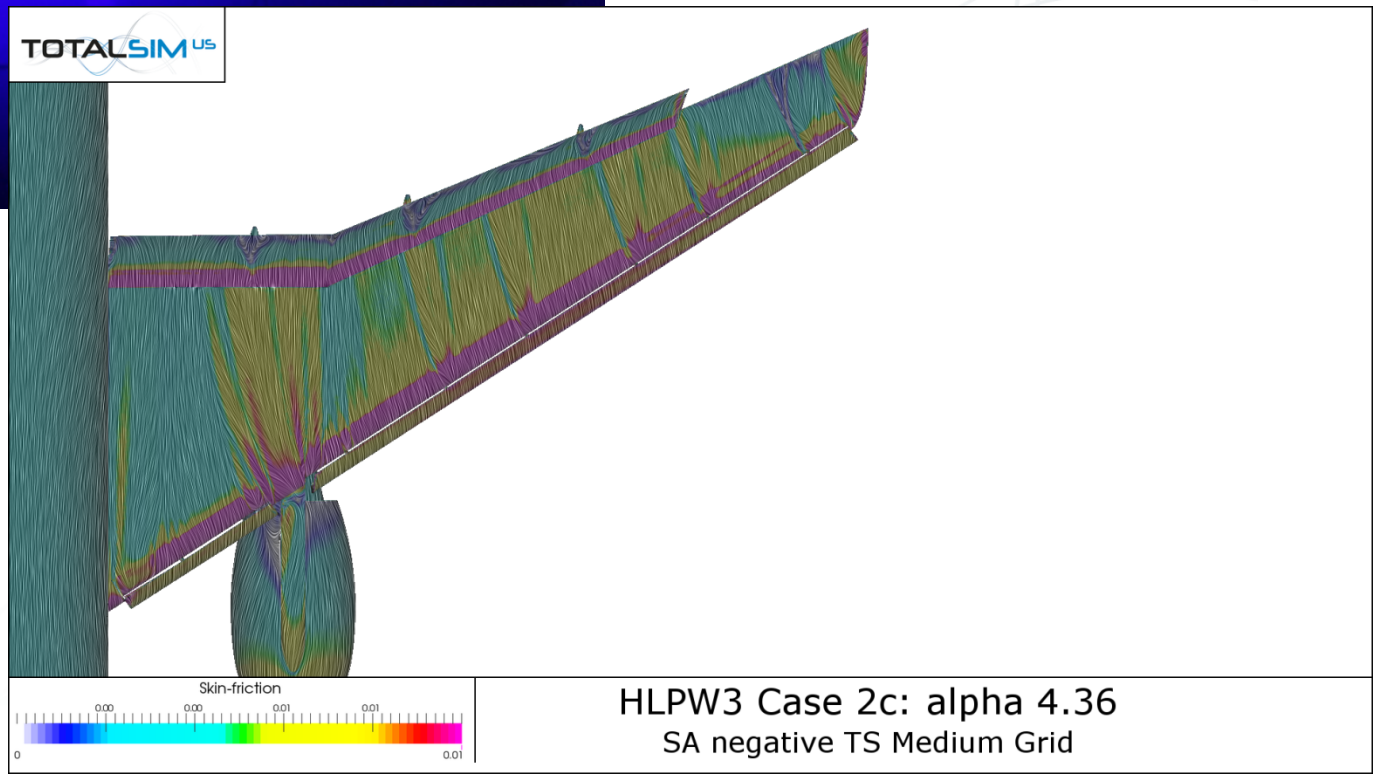
Case 2c AOA 4.36° Surface Streamline



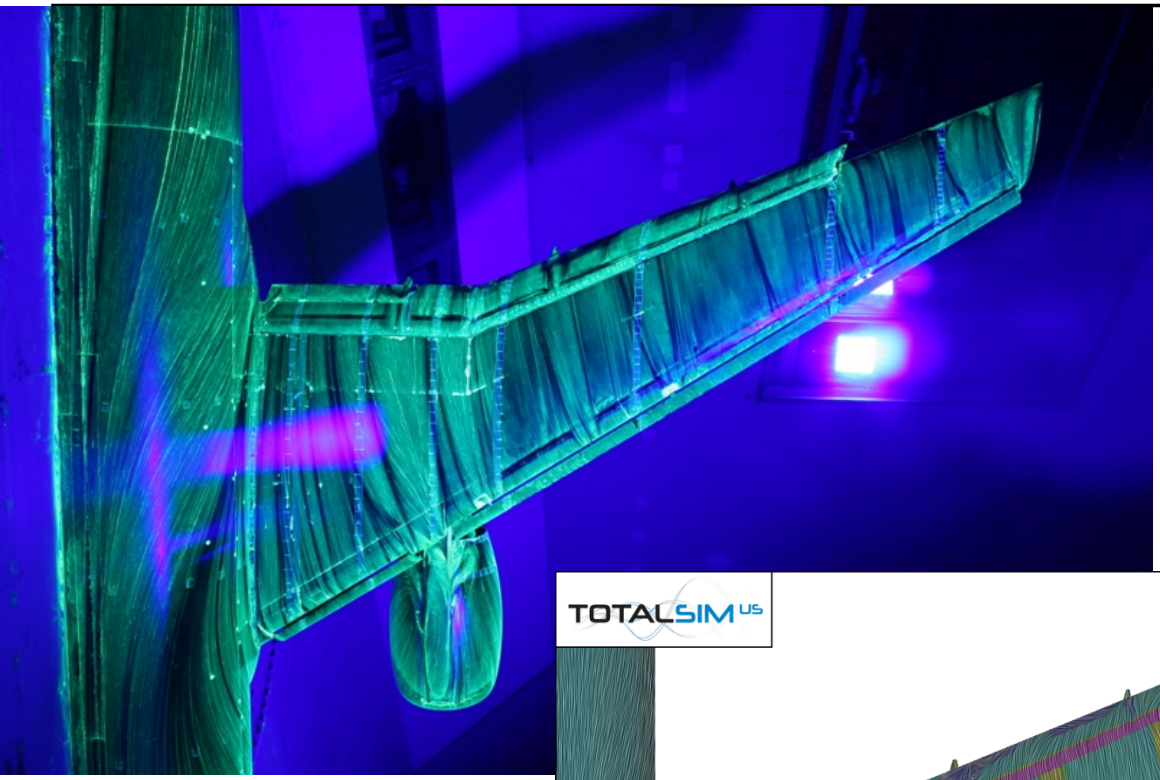


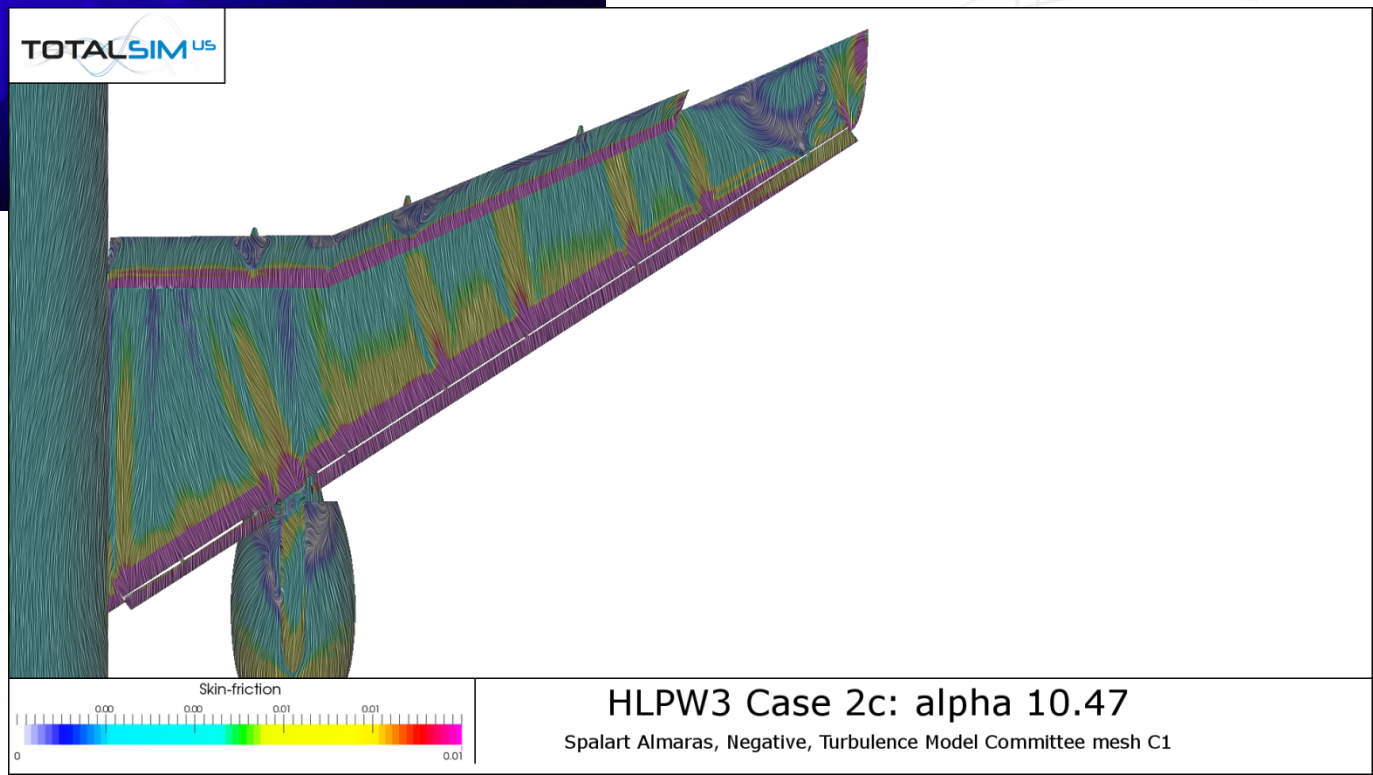
Case 2c AOA 4.36° Surface Streamline



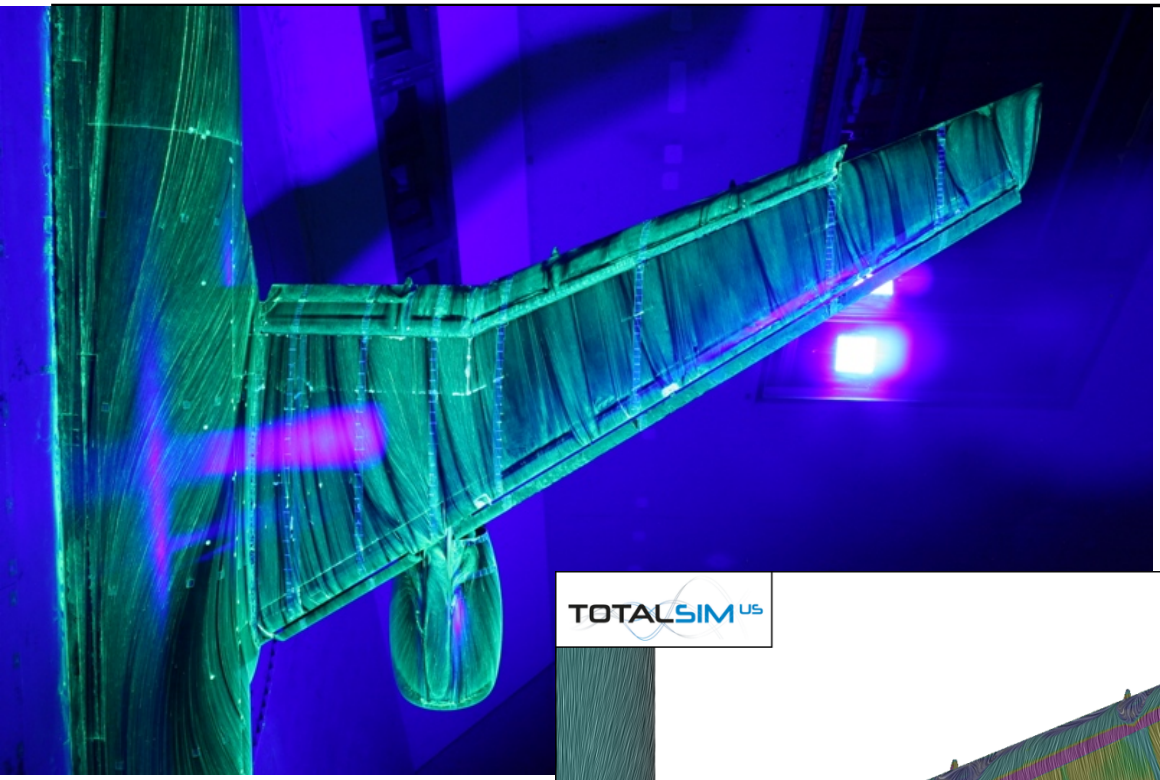


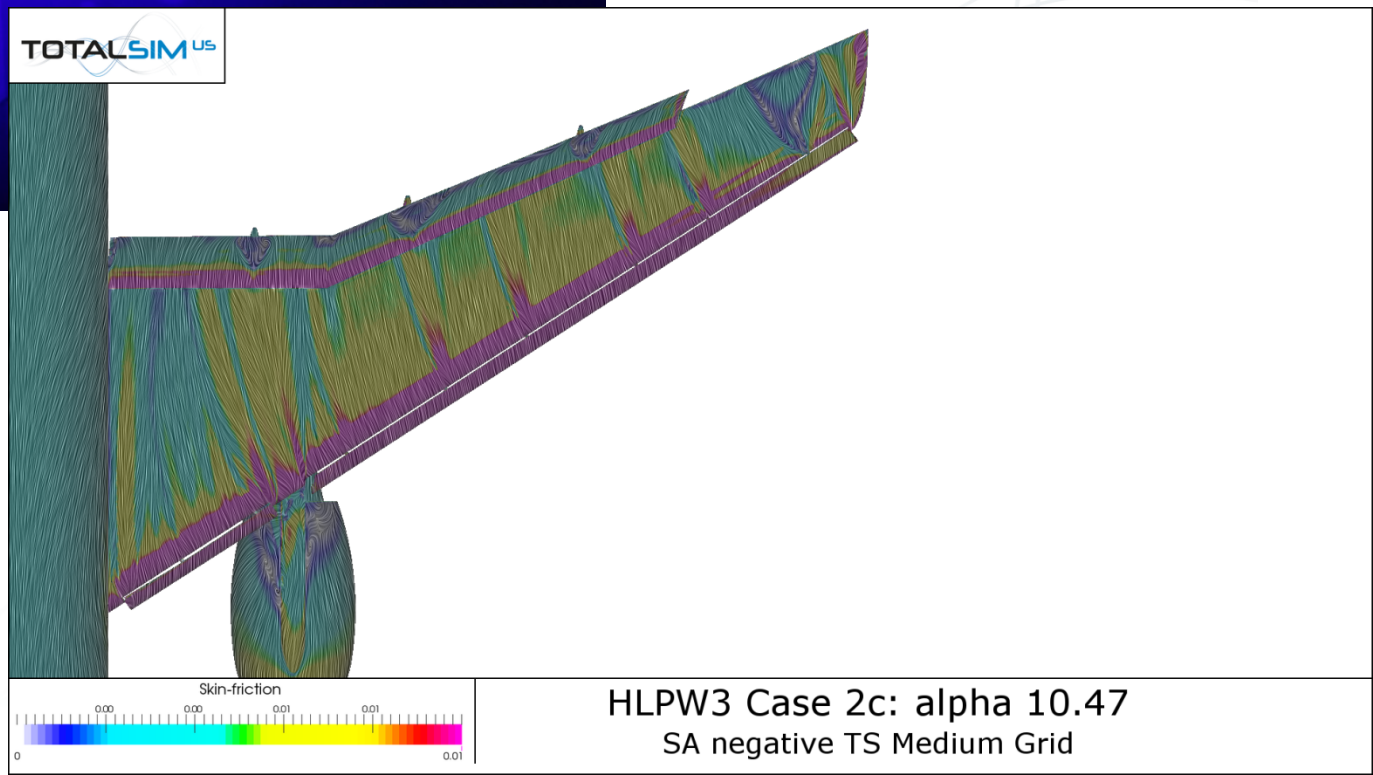
Case 2c AOA 10.47° Surface Streamline



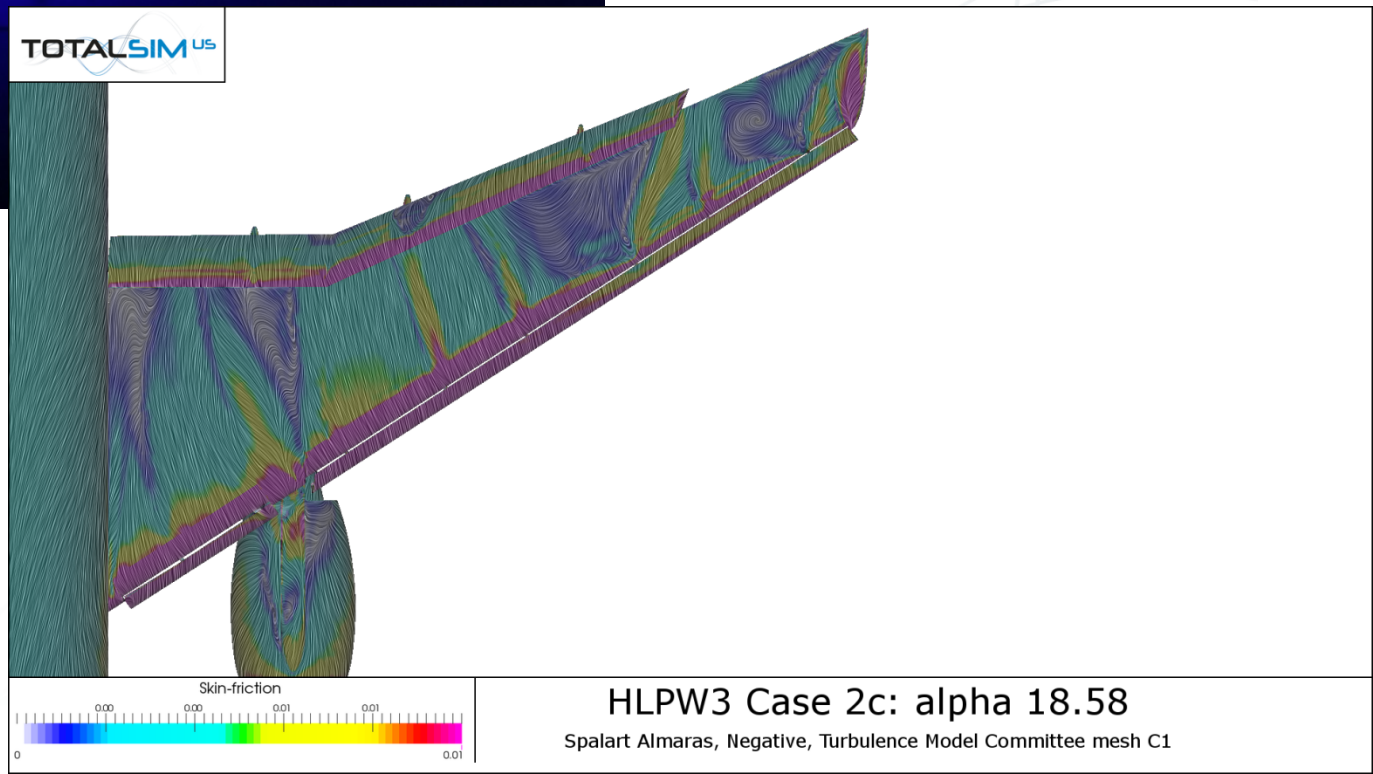


Case 2c AOA 10.47° Surface Streamline

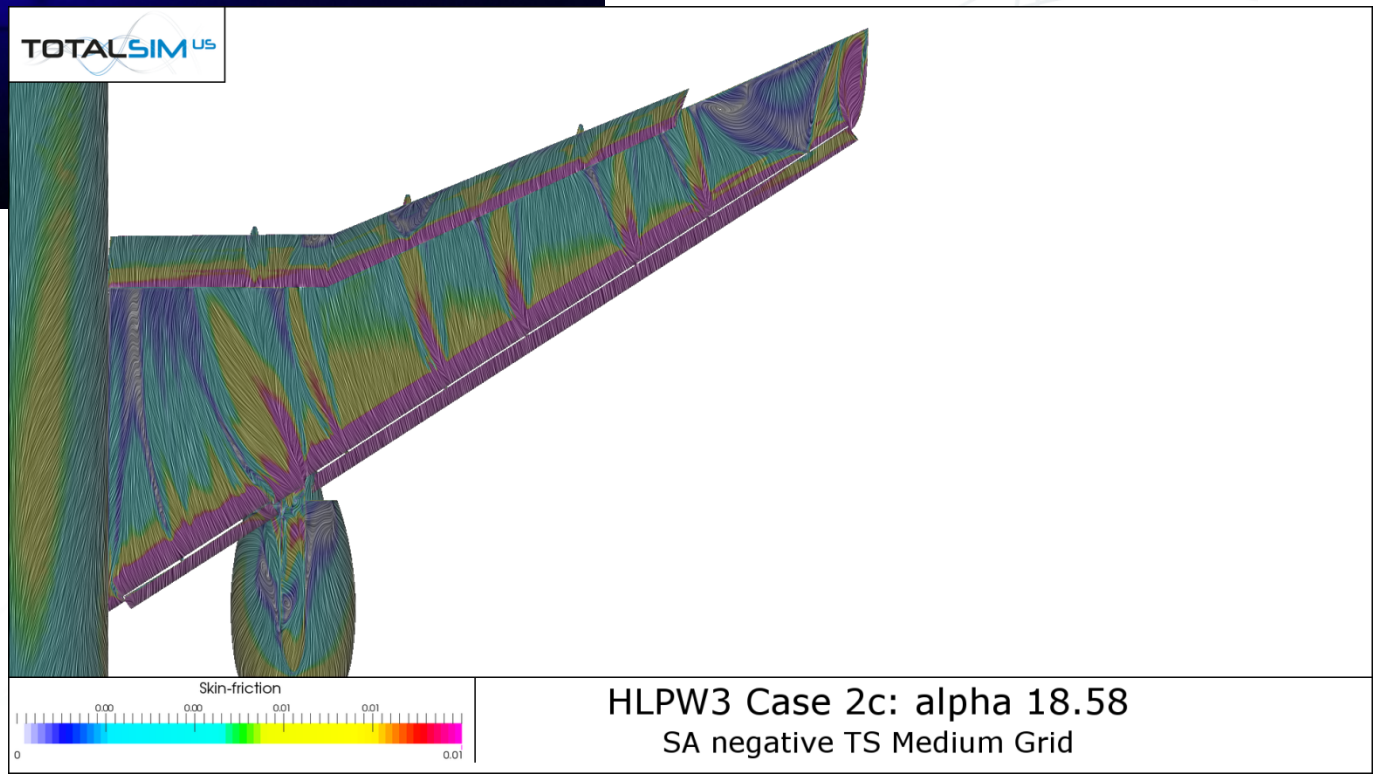




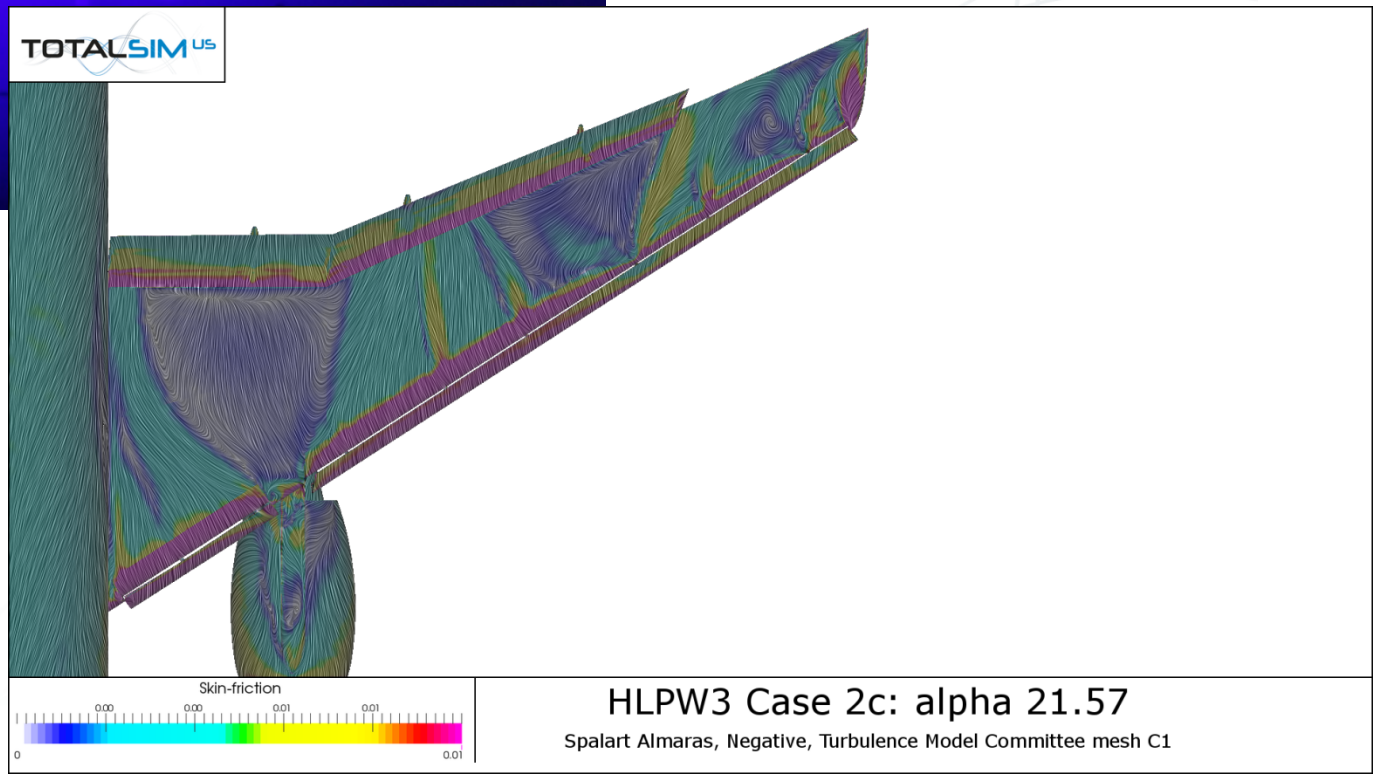
Case 2c AOA 18.58° Surface Streamline



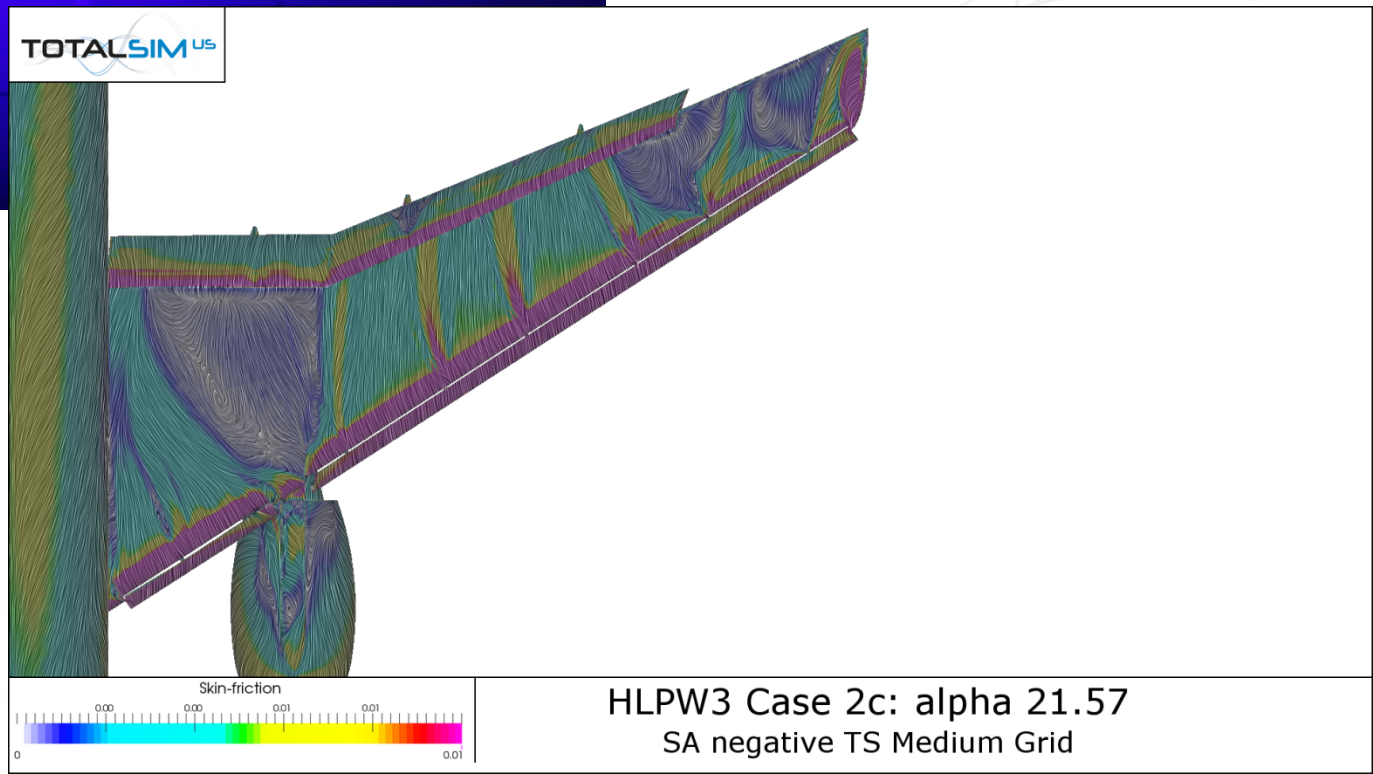
Case 2c AOA 18.58° Surface Streamline



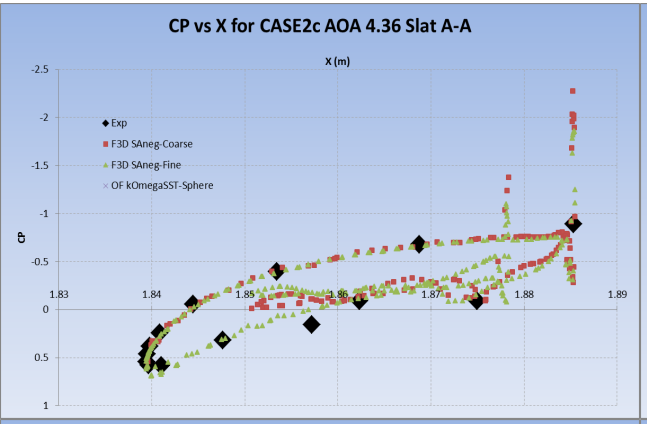
Case 2c AOA 21.57° Surface Streamline

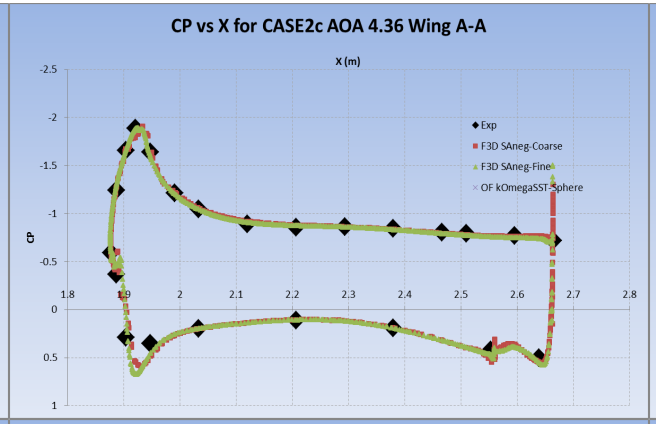


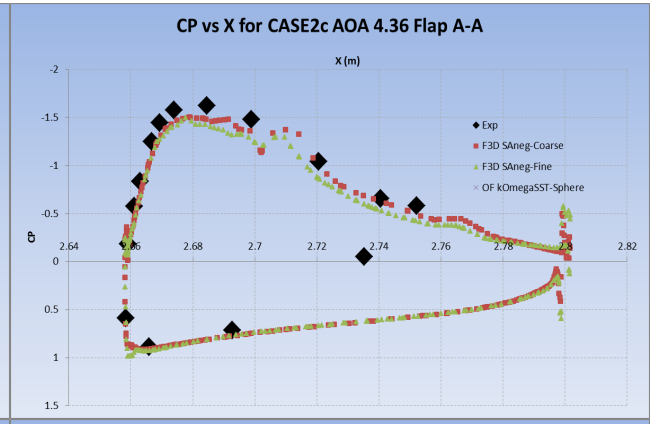
Case 2c AOA 21.57° Surface Streamline

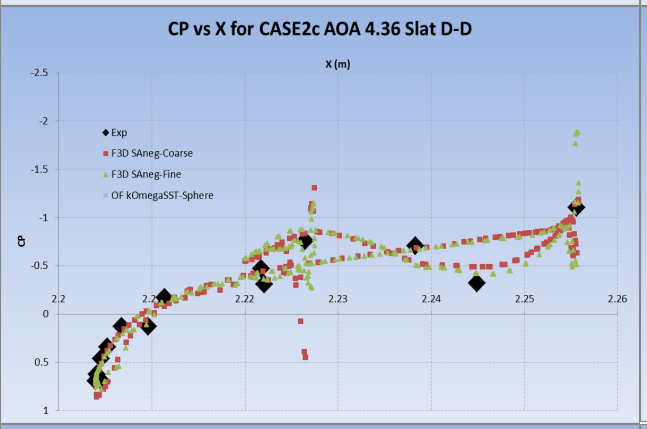


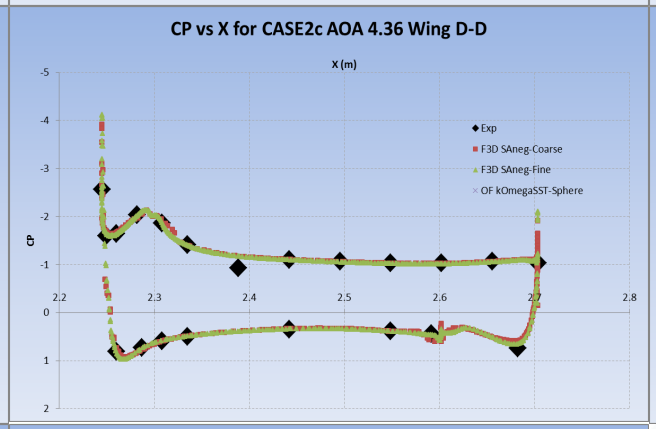
Case 2c FUN3D AOA 4.36° Cp Plots

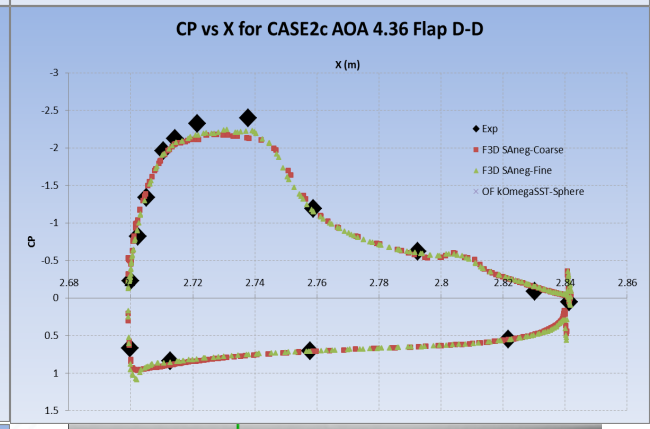


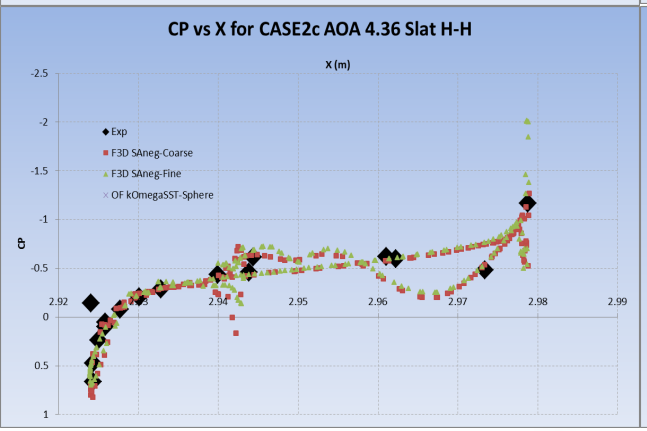


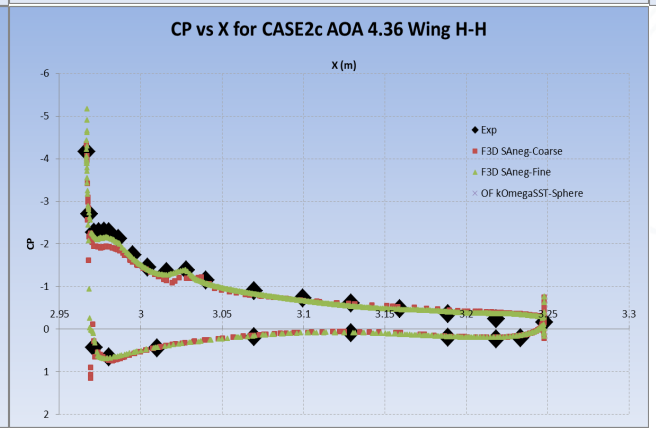


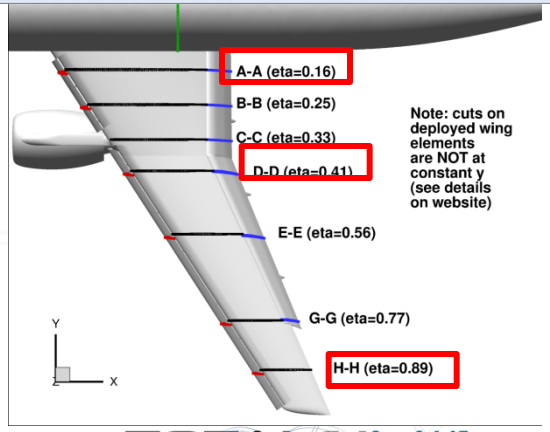




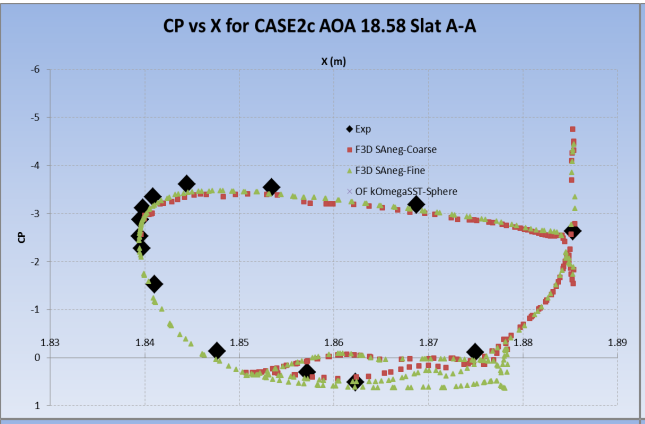


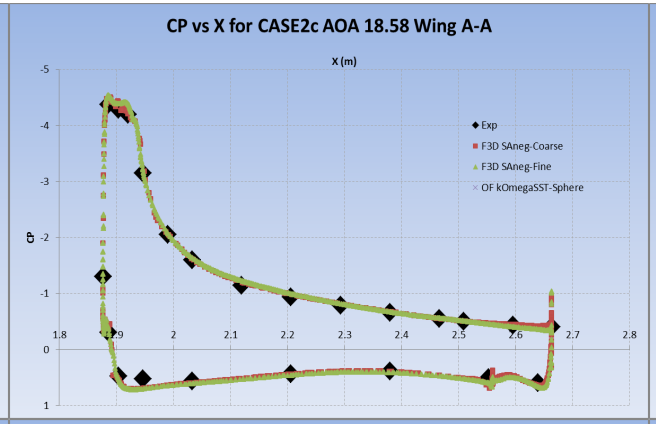


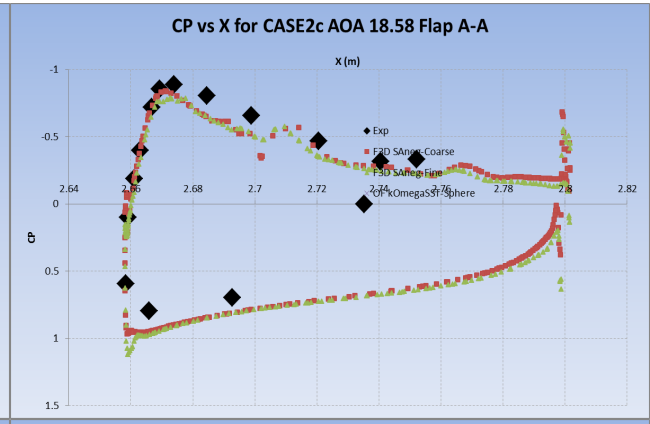


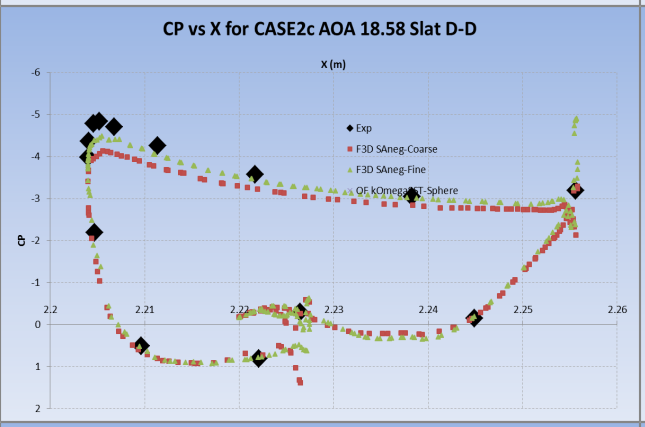


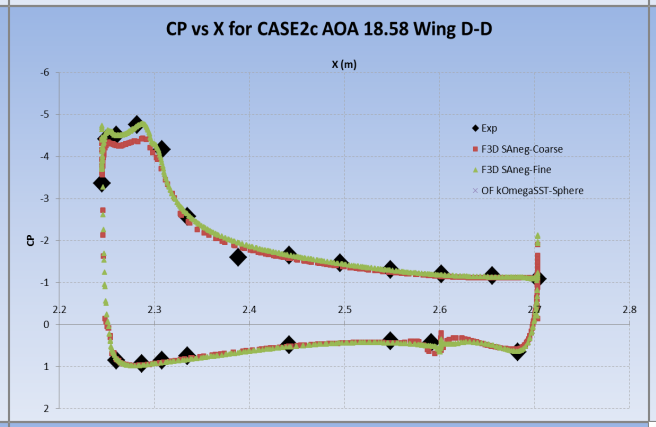
Case 2c FUN3D AOA 18.58° Cp Plots

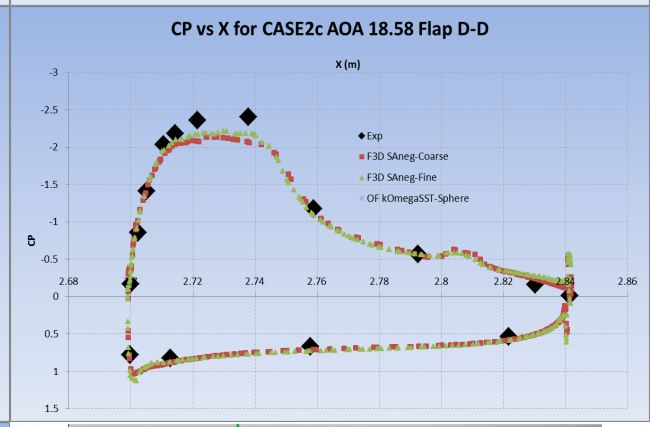


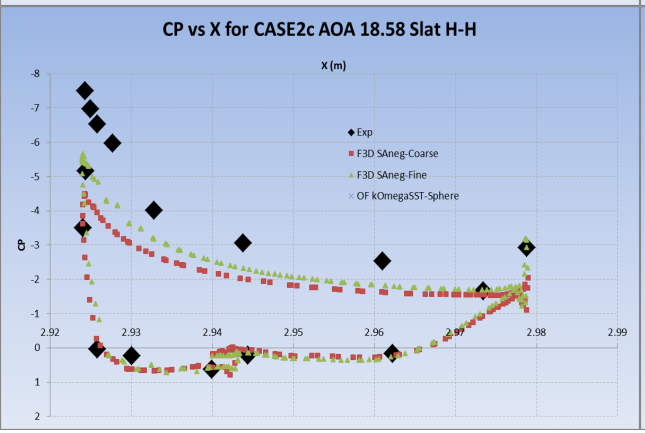


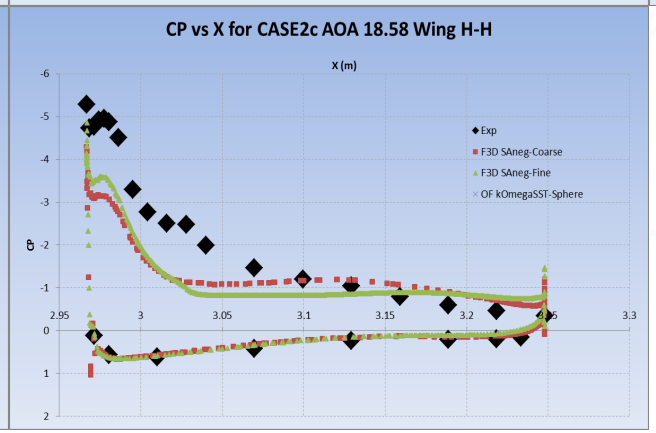


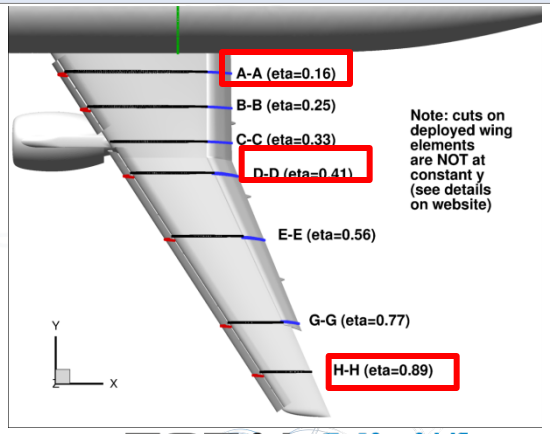




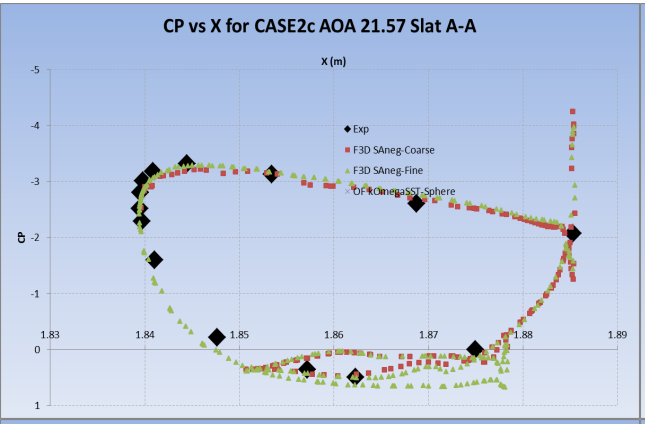


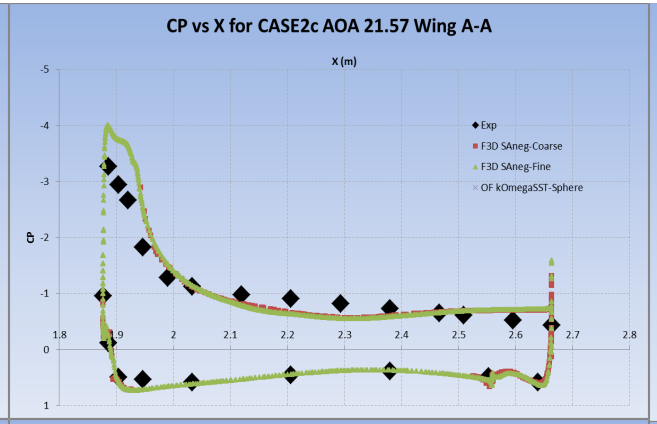


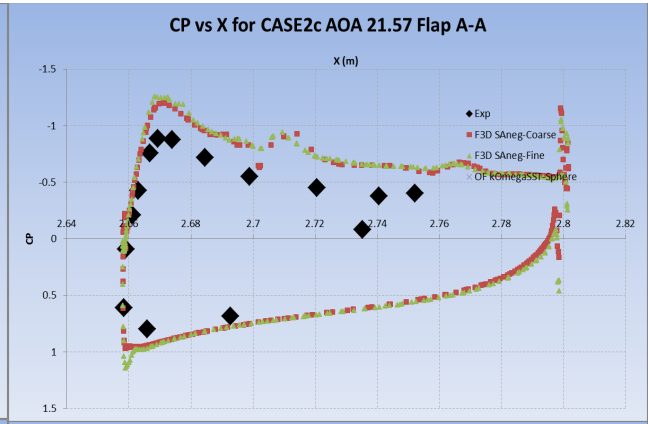


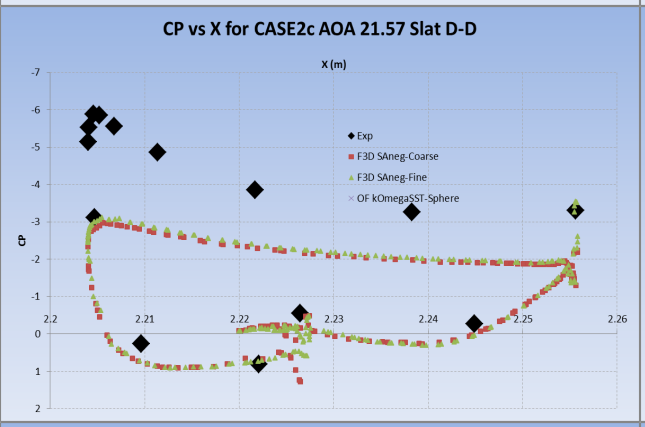


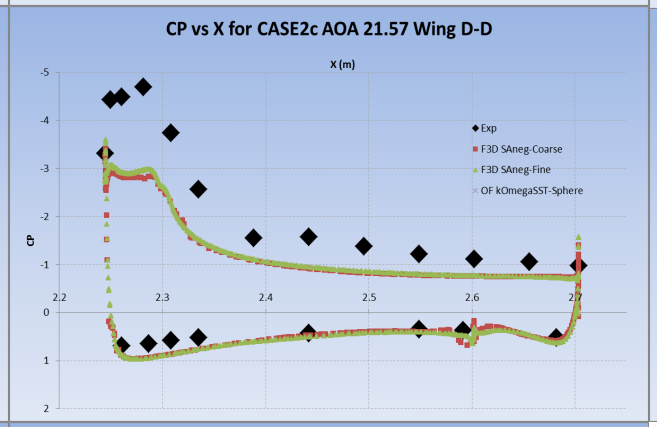
Case 2c FUN3D AOA 21.57° Cp Plots

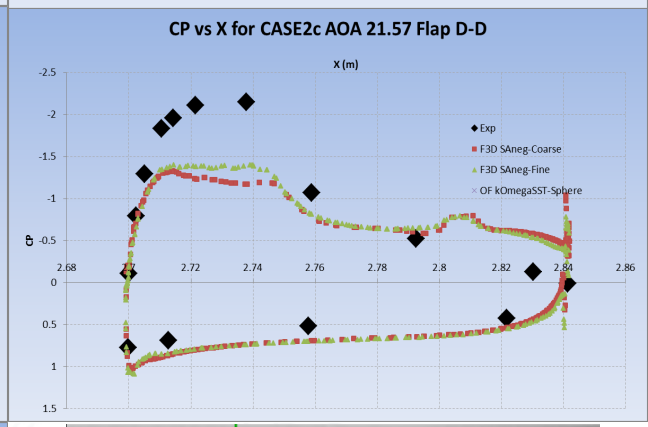


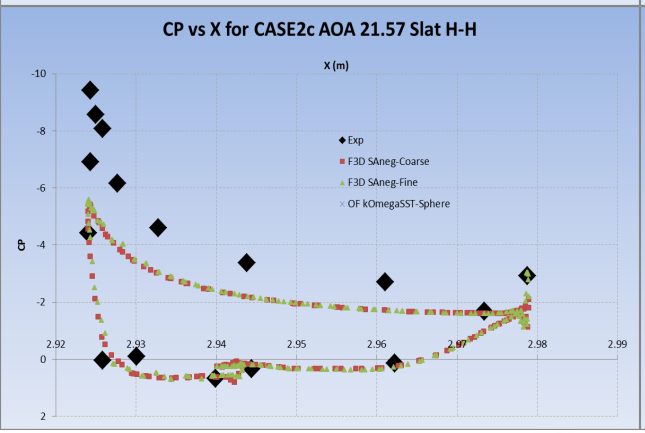


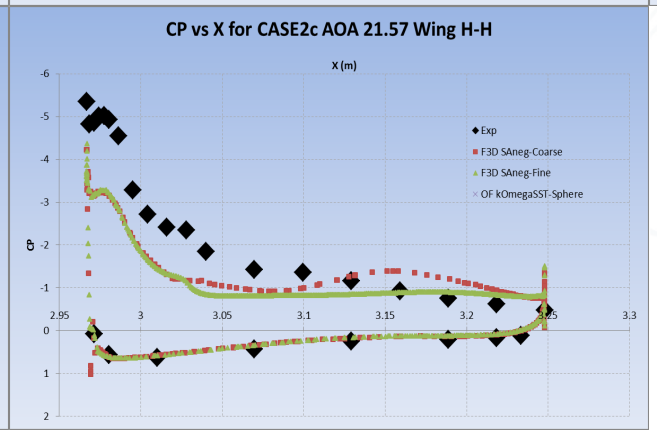


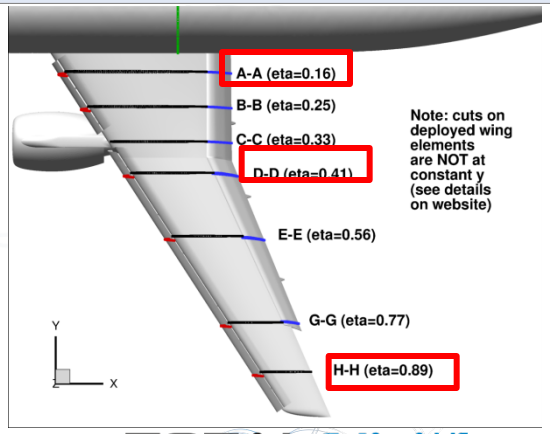










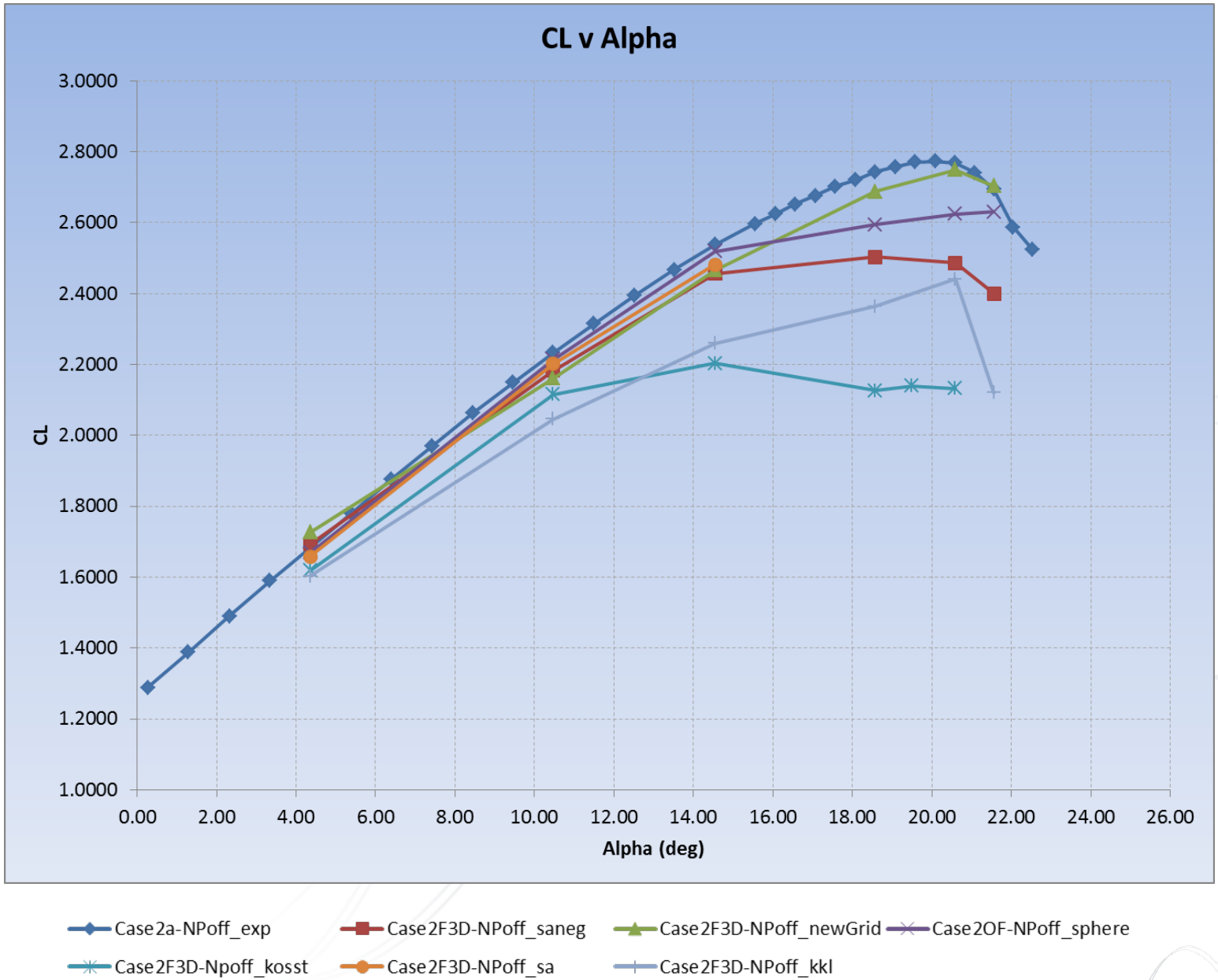


Summary

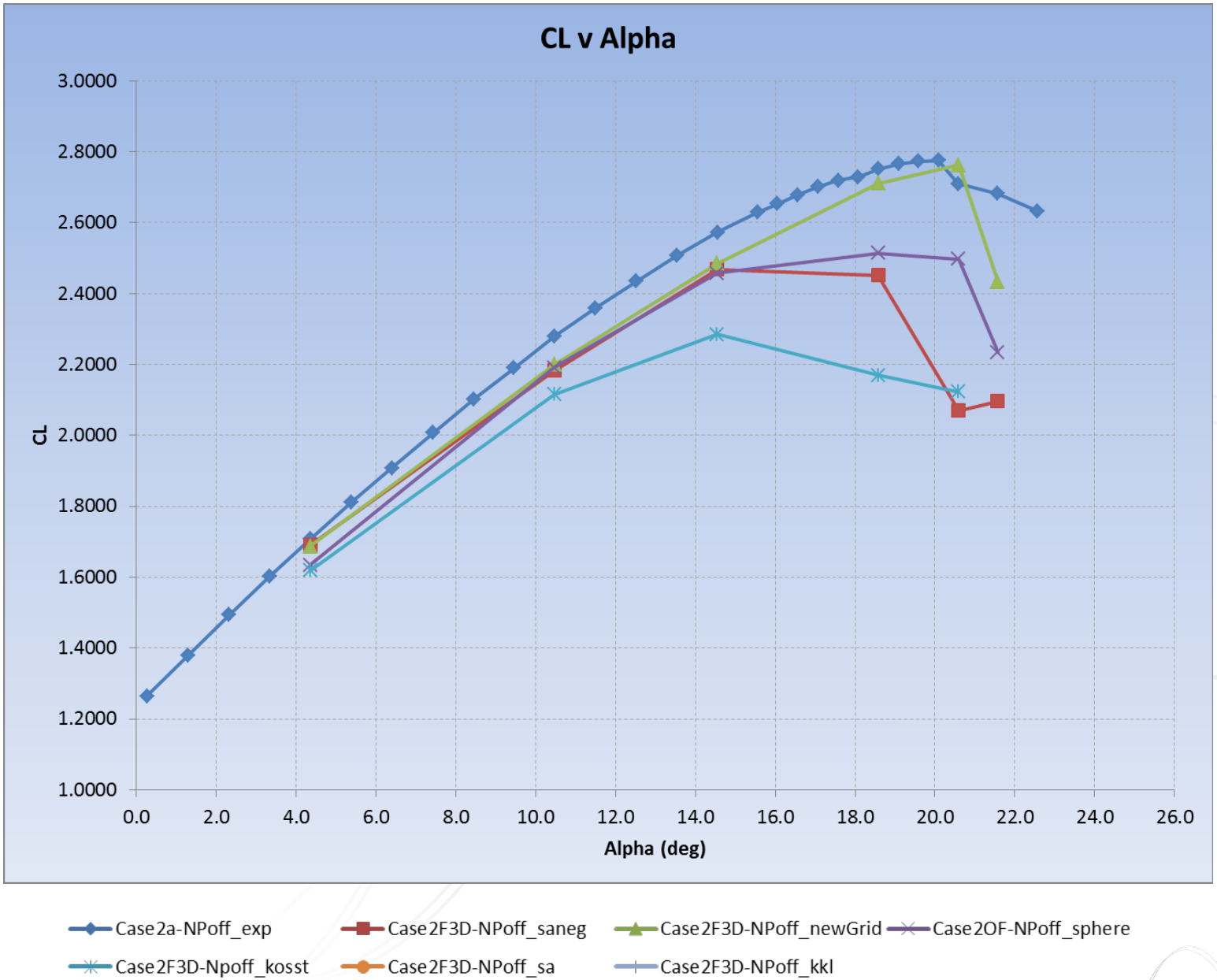
- Fun3D can accurately predict CL in the linear range of the JSM body given a proper mesh
    - Roughly predicts the proper trend of CLmax and stall onset
- OpenFoam does a fair job of predicting CL in the majority of the linear range
    - Results tend to deviate from experimental correlation before Clmax
    - Case 2c results are still in progress
    - Moments reported by OF need closer inspection

Additional Slides

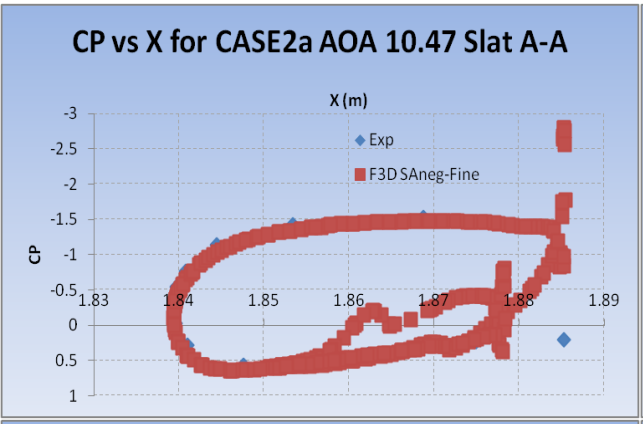
Case 2a Turbulence Model Comparison

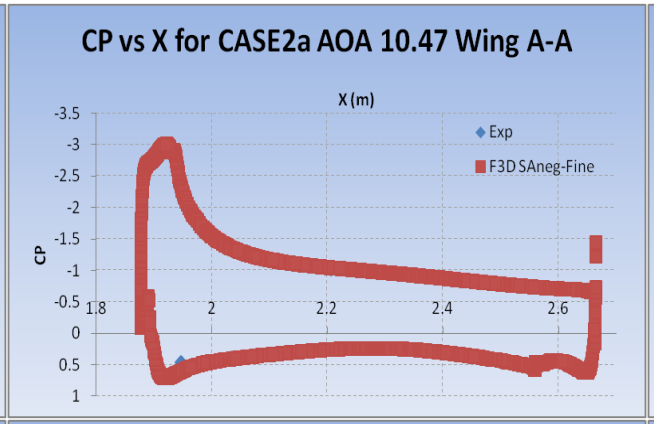


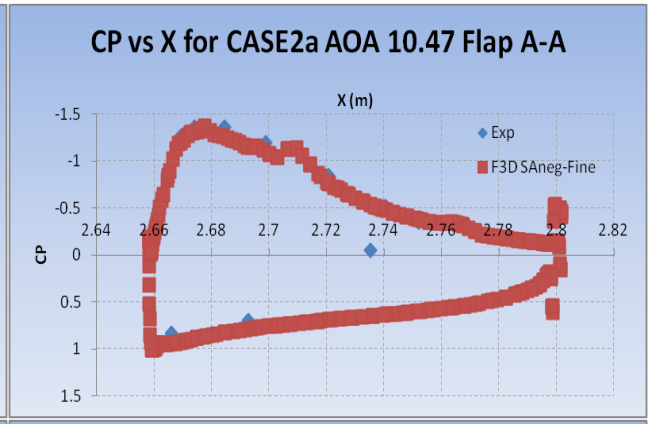
Case 2a Turbulence Model Comparison

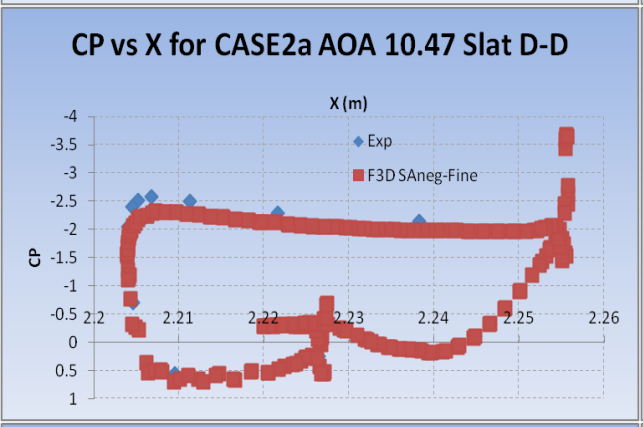


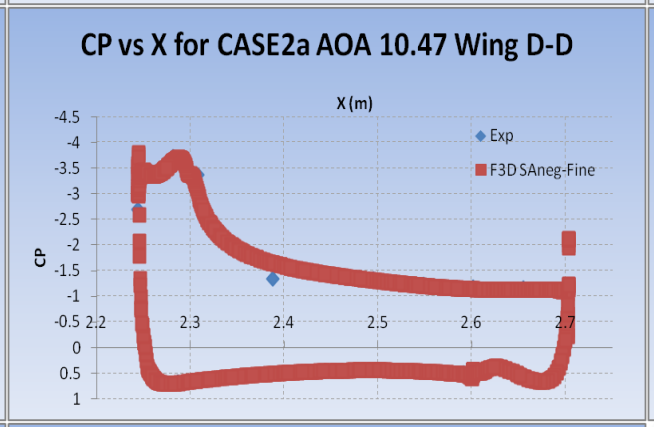
Case 2a FUN3D AOA 10.47° Cp Plots

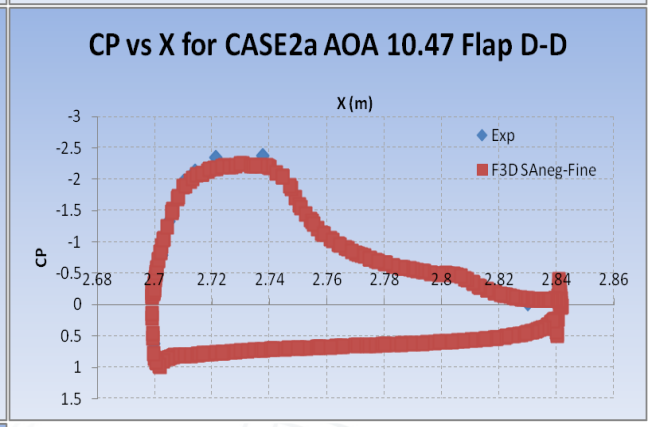


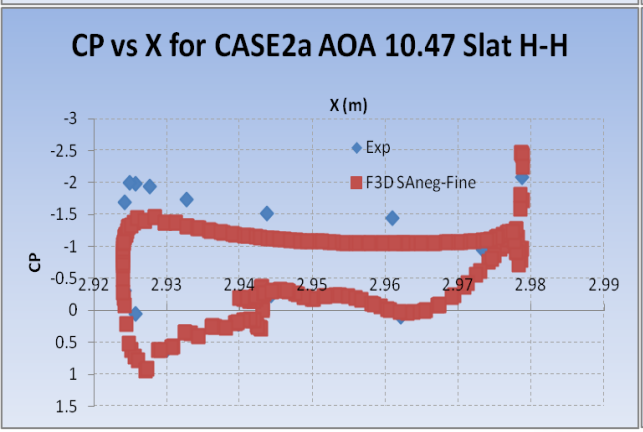


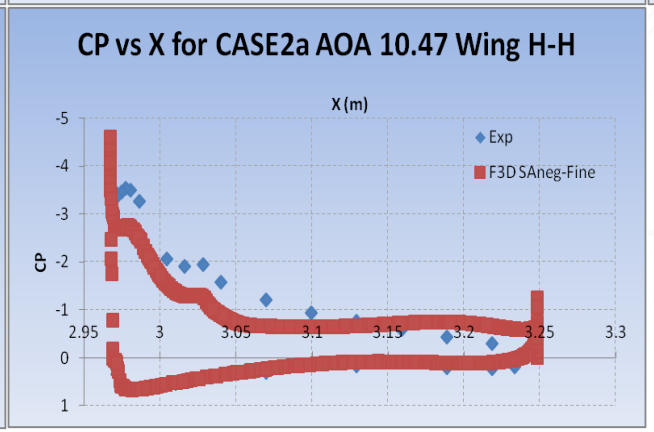




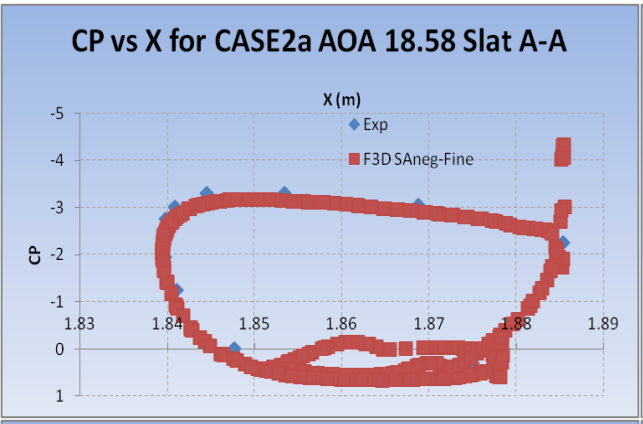


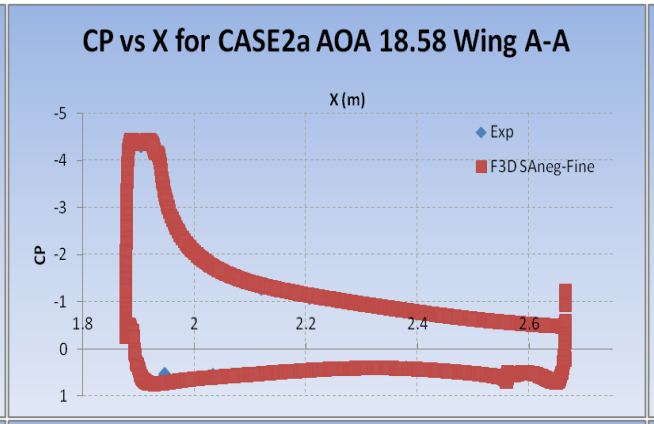


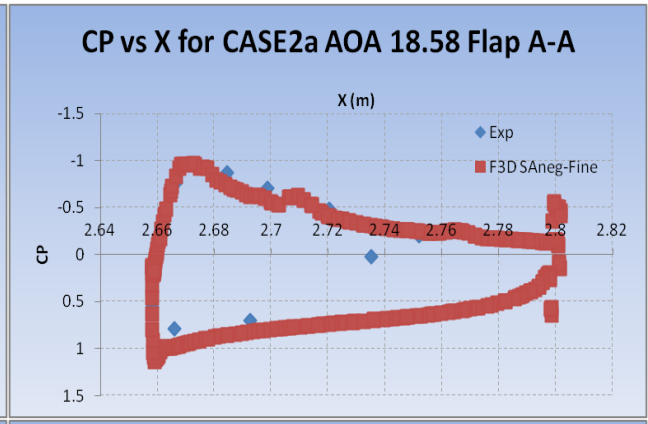


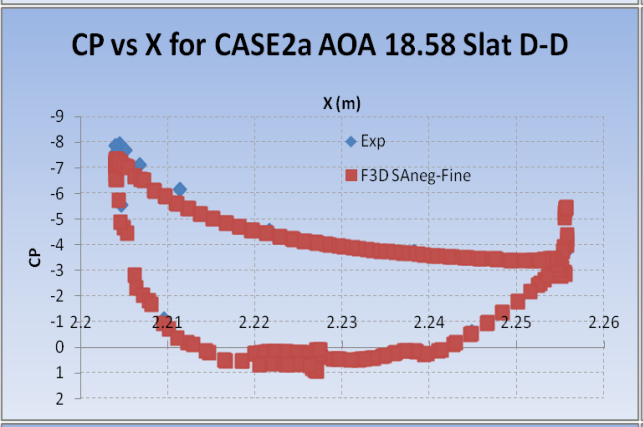


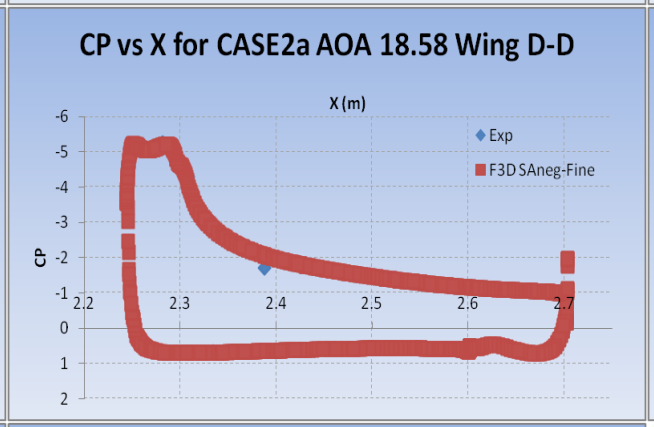
Case 2a FUN3D AOA 18.58° Cp Plots

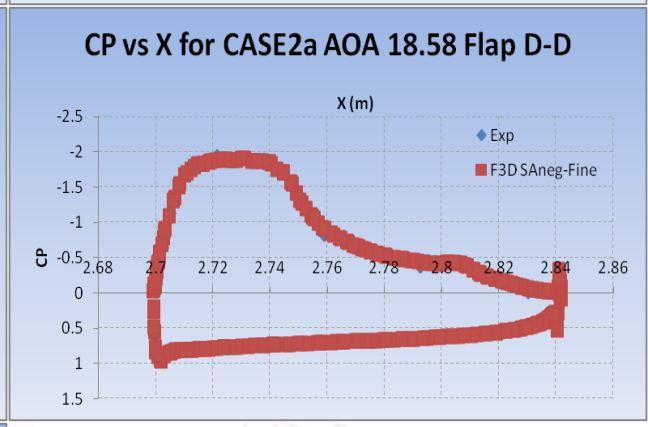


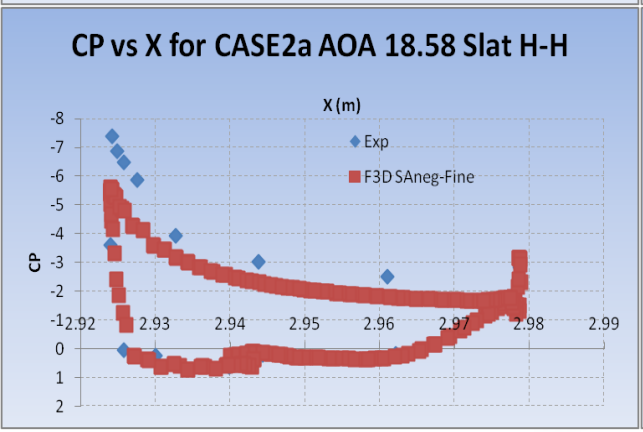


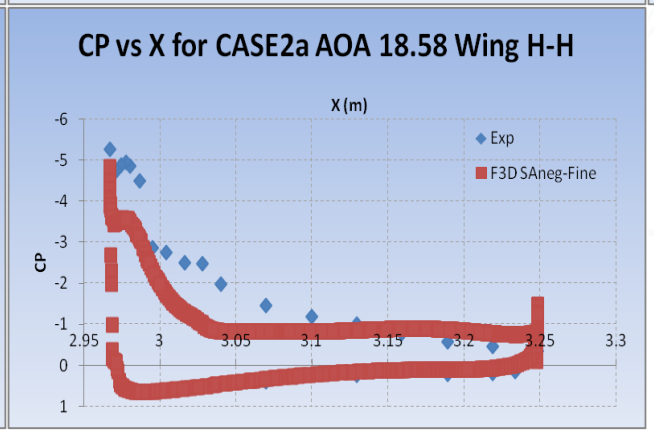




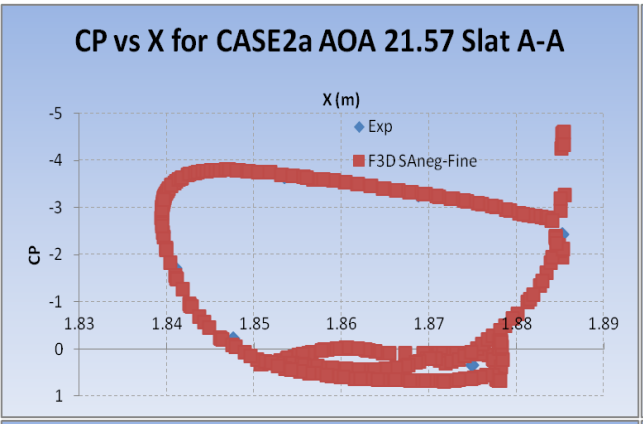


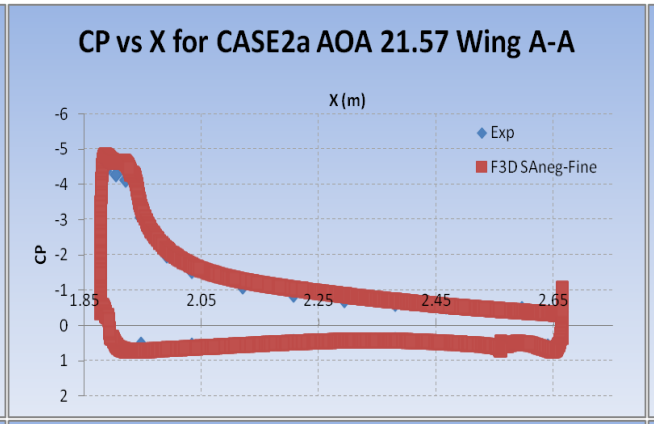


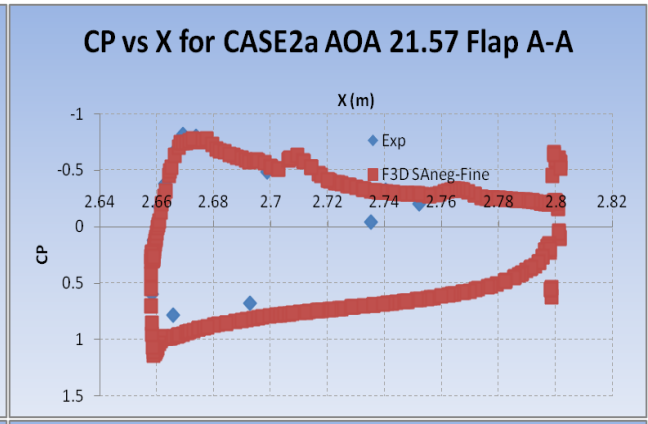


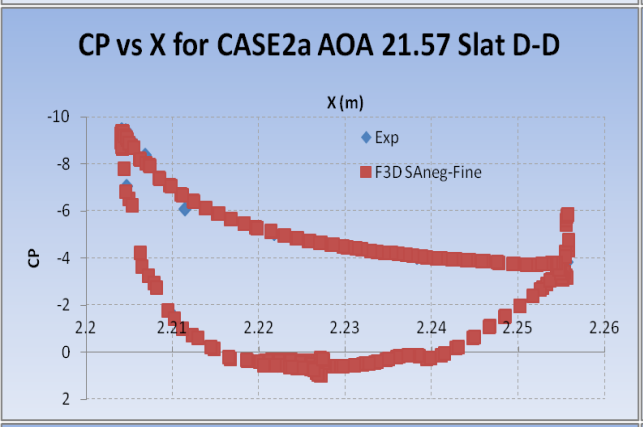


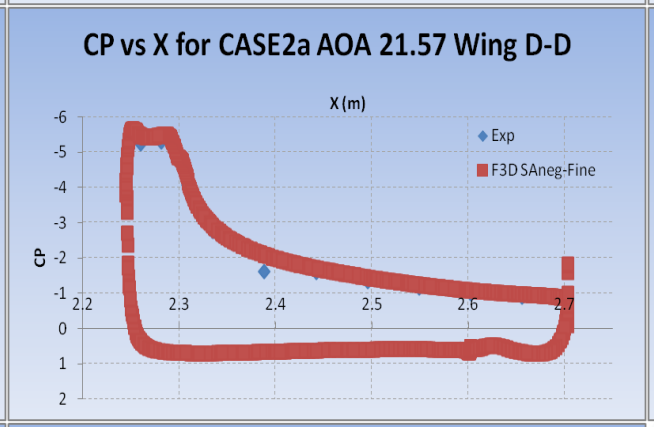
Case 2a FUN3D AOA 21.57° Cp Plots

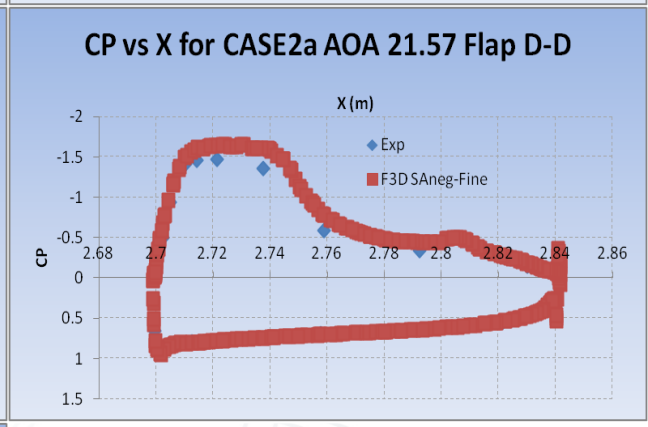


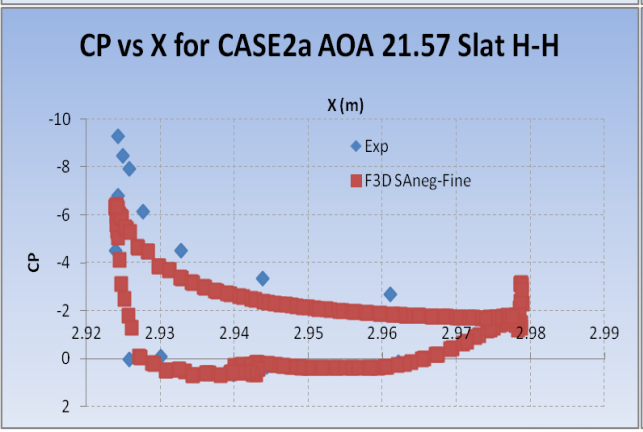


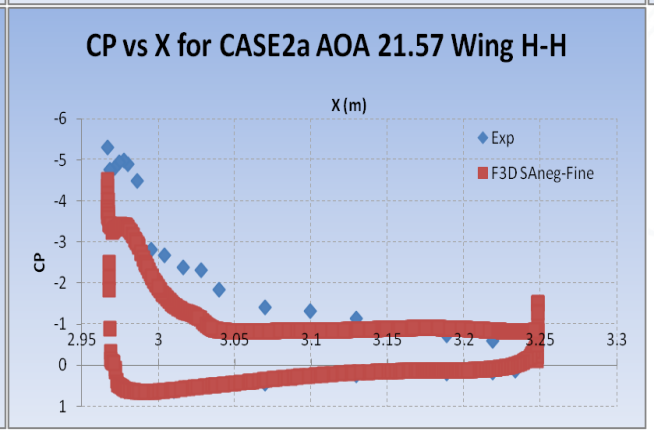




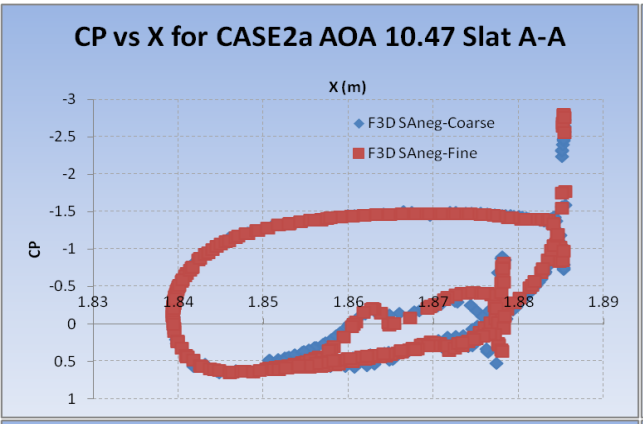


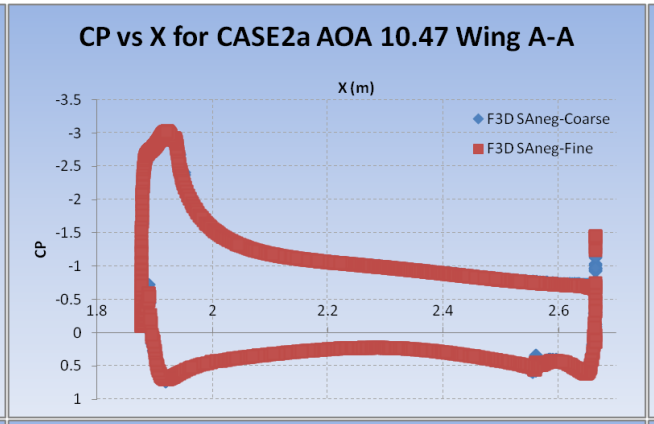


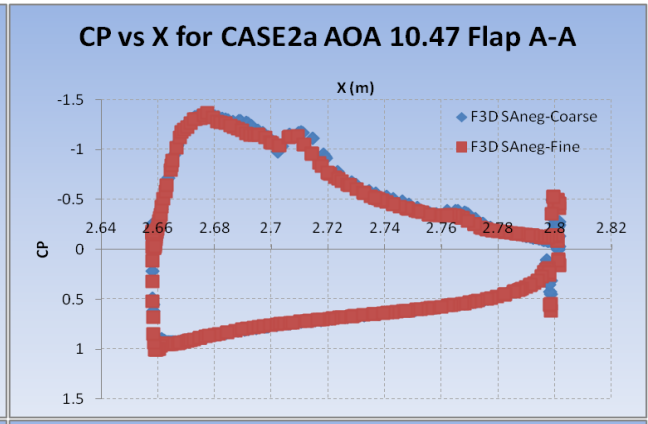


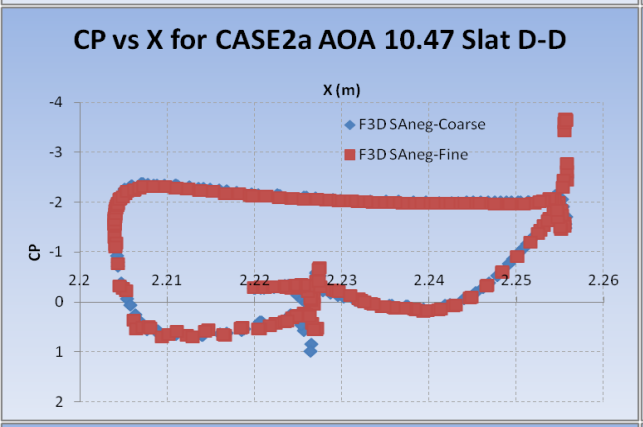


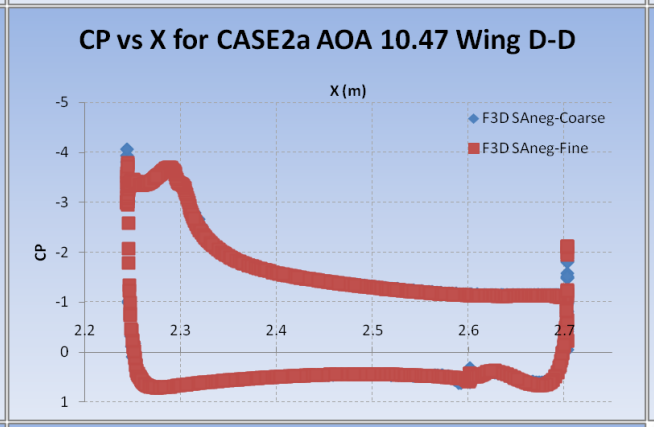
Case 2a FUN3D AOA 10.47° Cp Plots Committee Grid vs. In House Grid

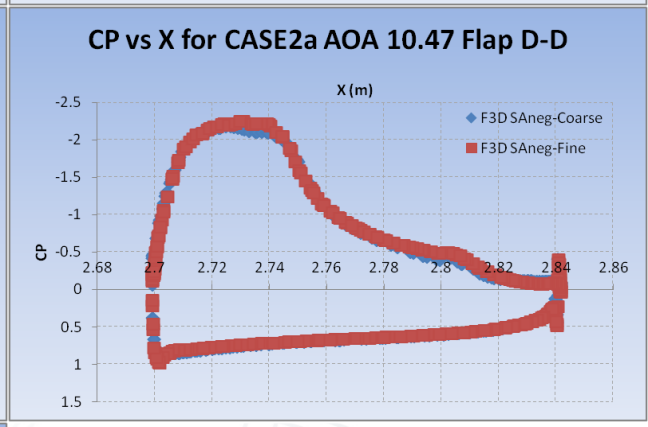


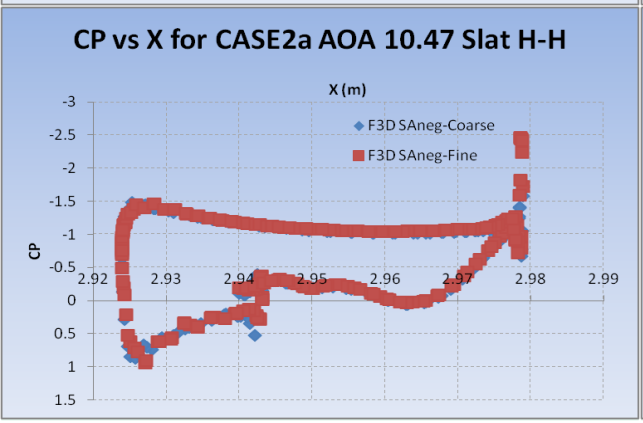


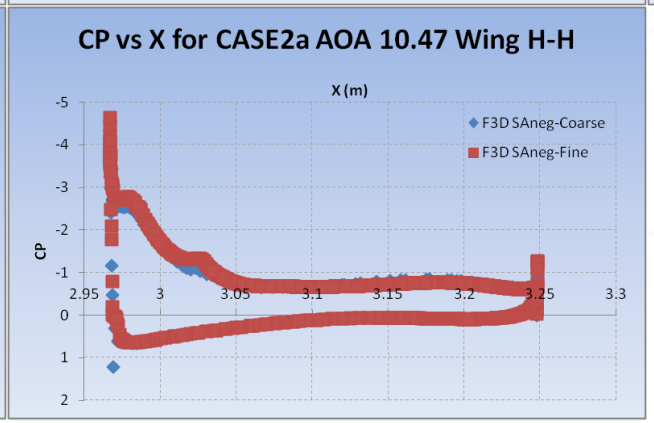




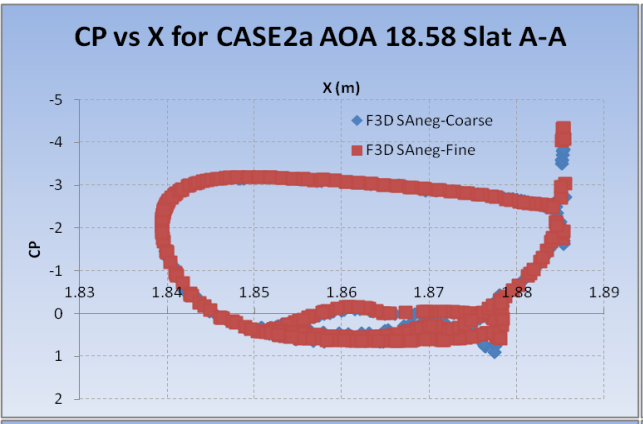


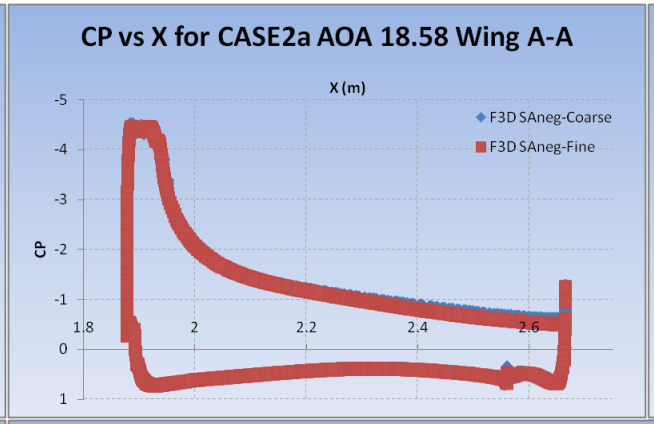


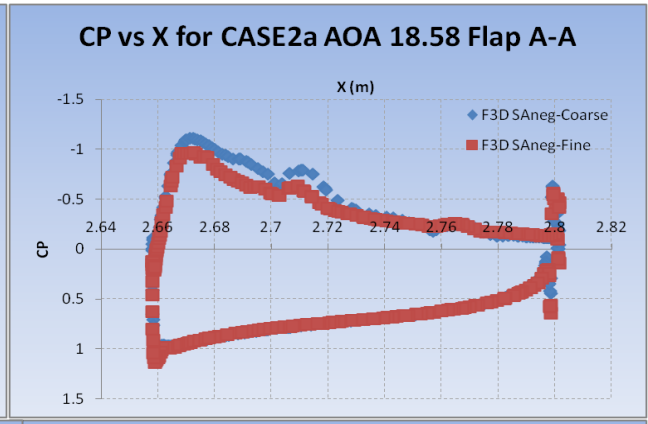


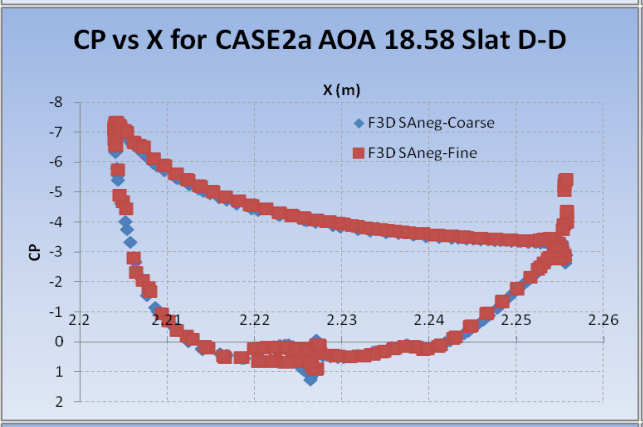


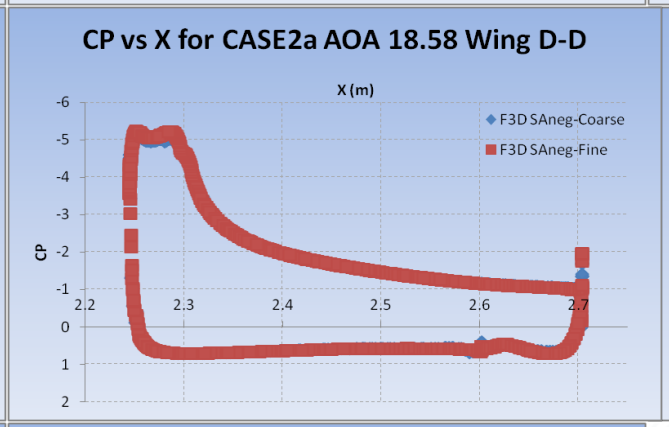
Case 2a FUN3D AOA 18.58° Cp Plots Committee Grid vs. In House Grid

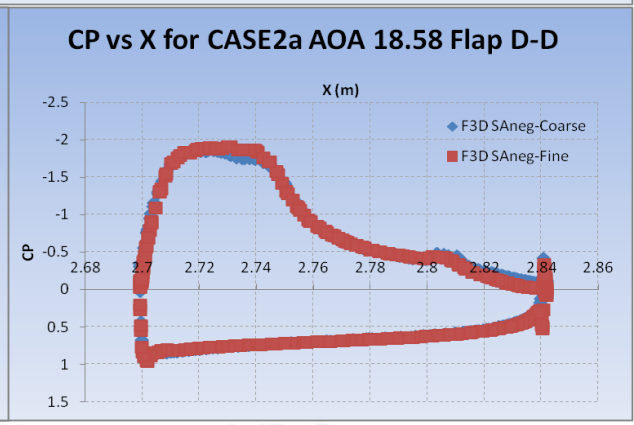


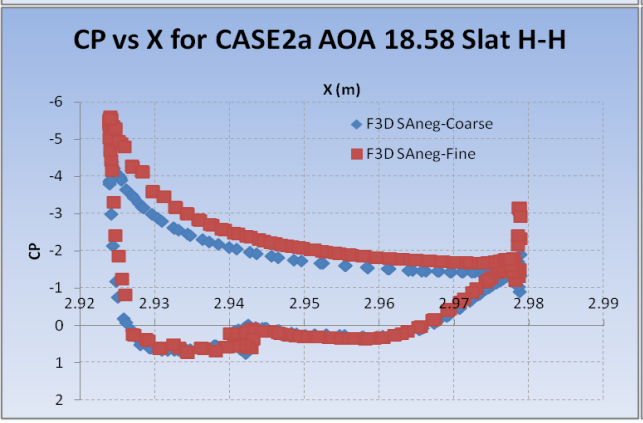


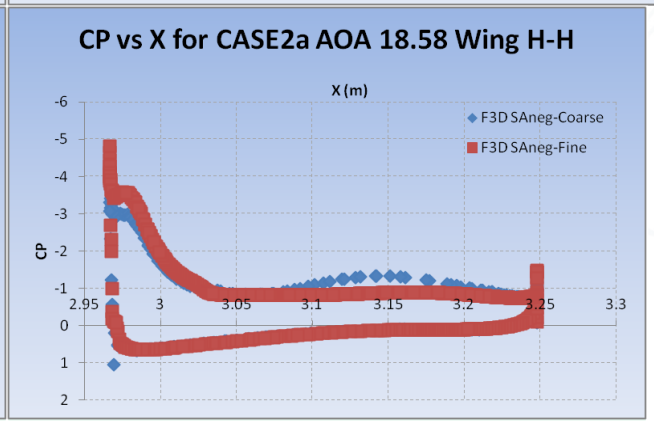




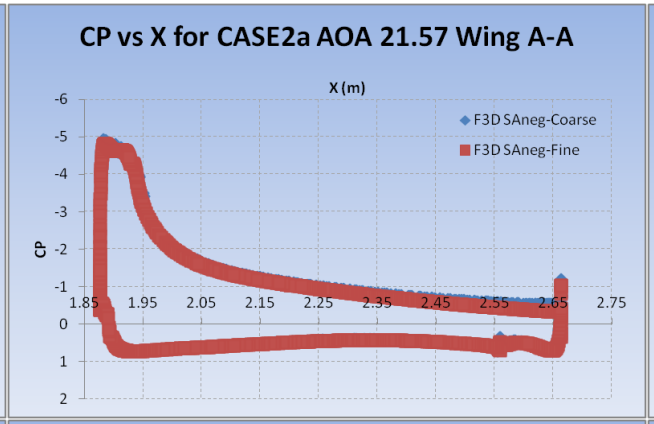


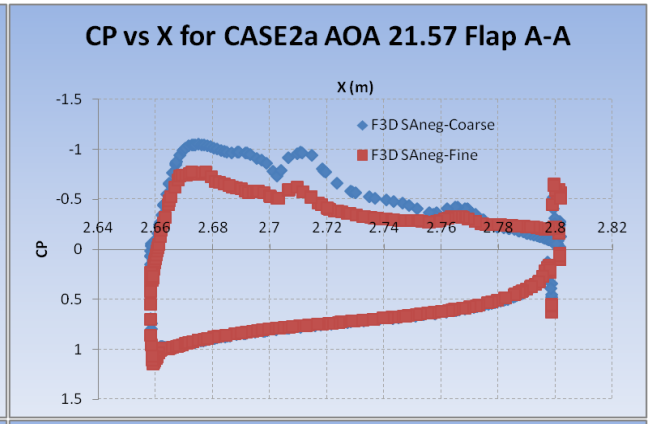


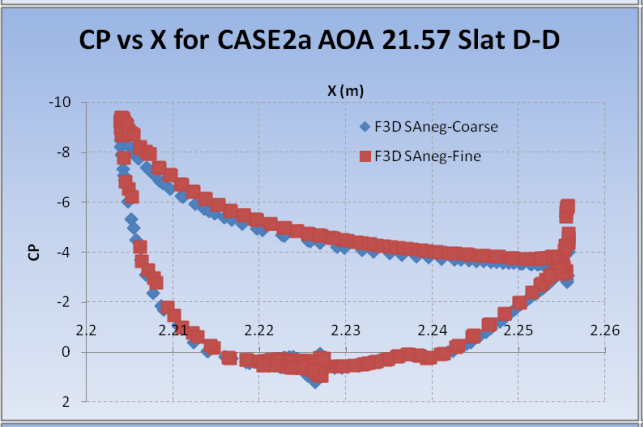


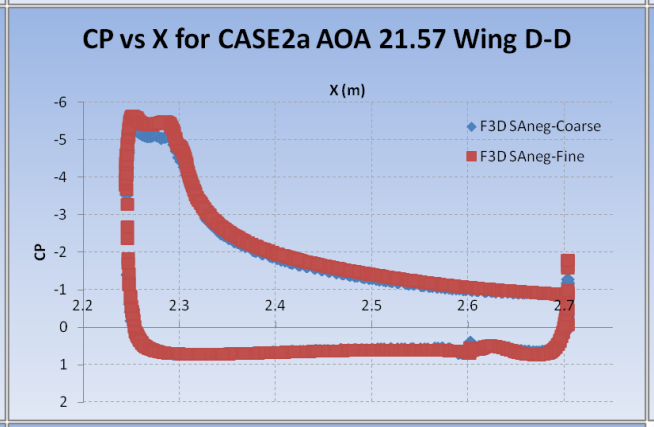


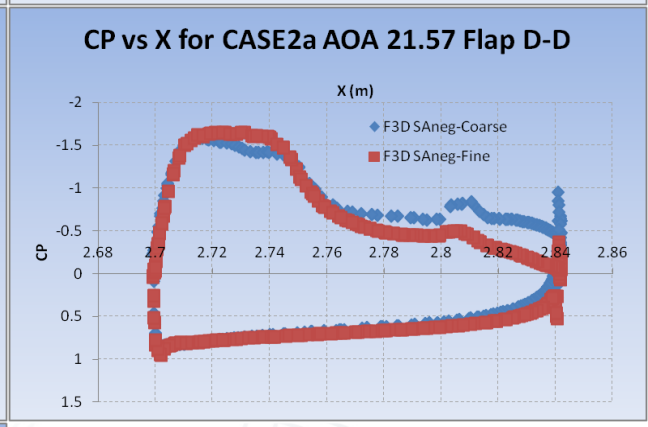
Case 2a FUN3D AOA 21.57° Cp Plots Committee Grid vs. In House Grid

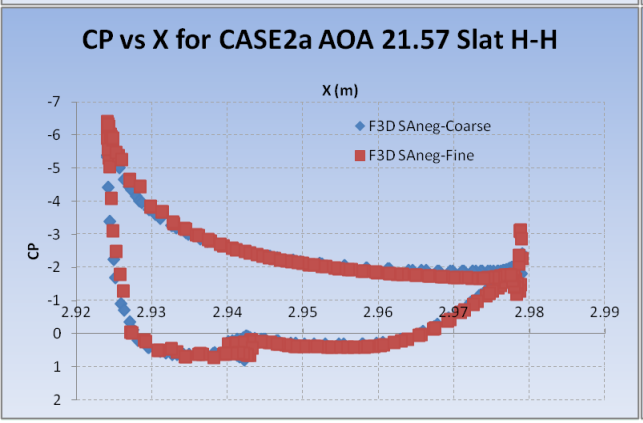


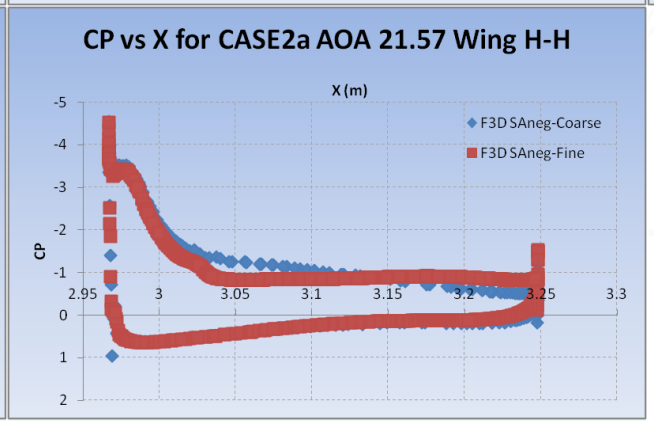




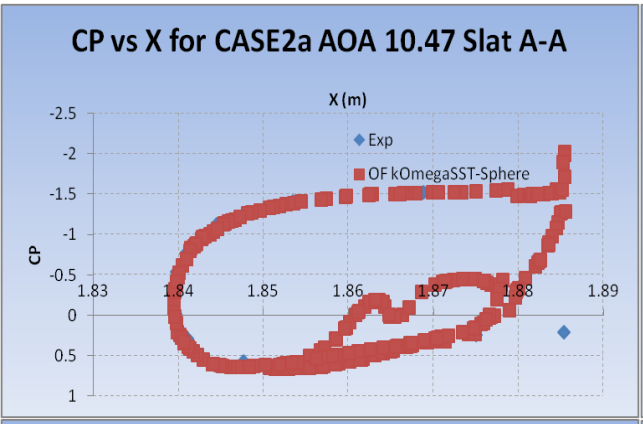


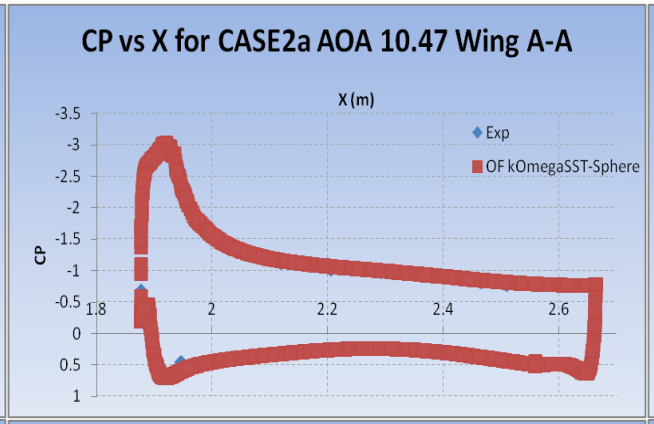


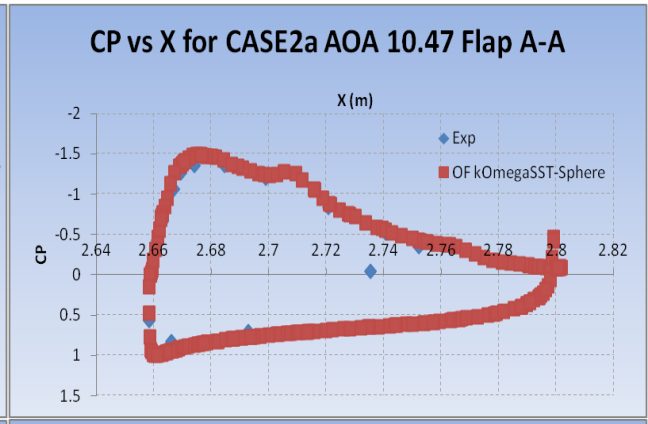


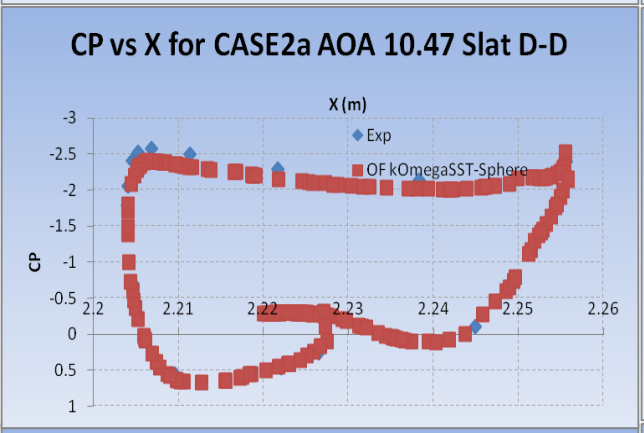


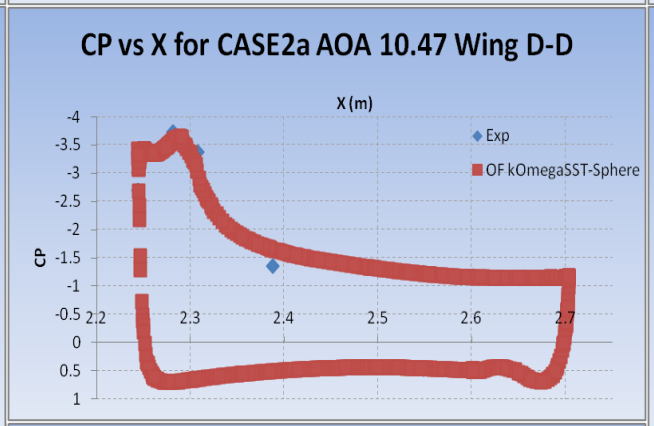
Case 2a OF AOA 10.47° Sphere Grid Cp Plots

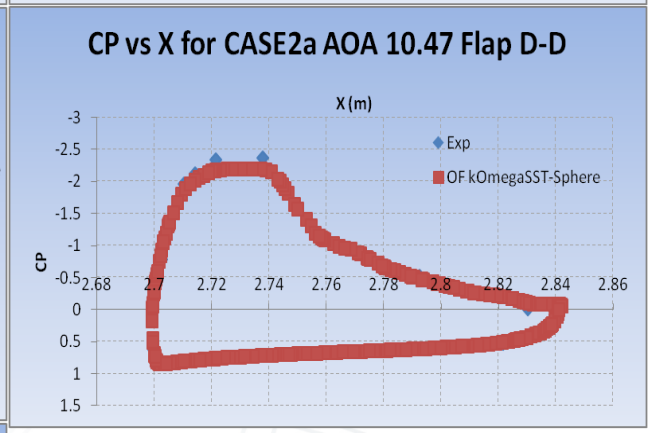


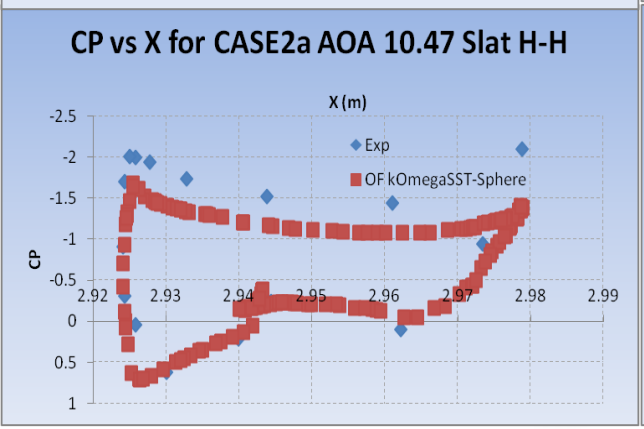


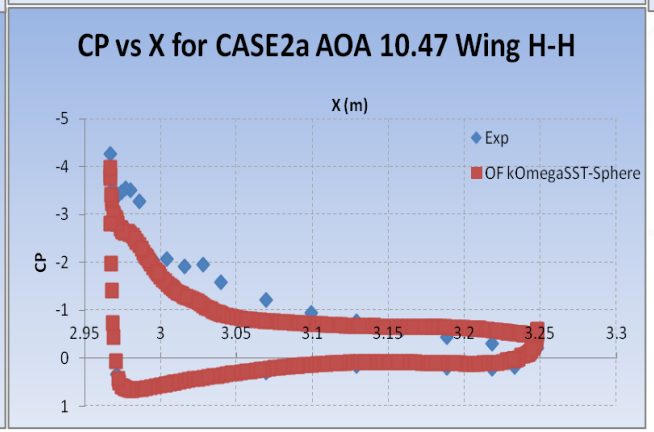




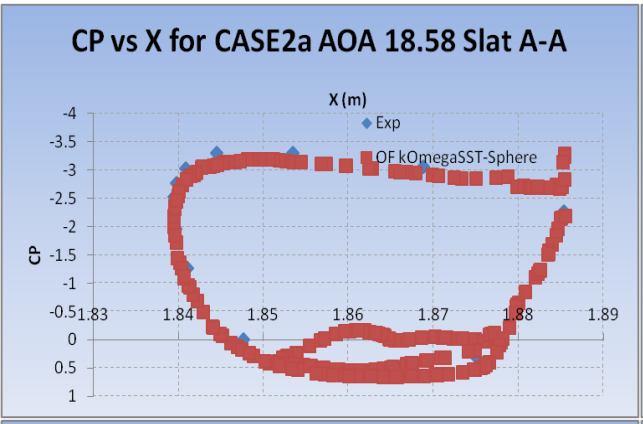


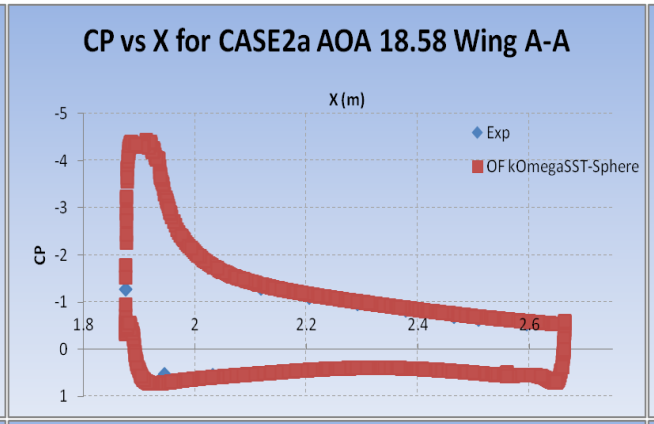


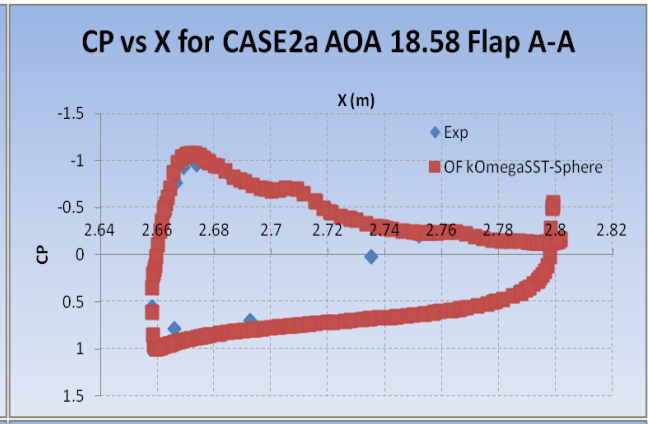


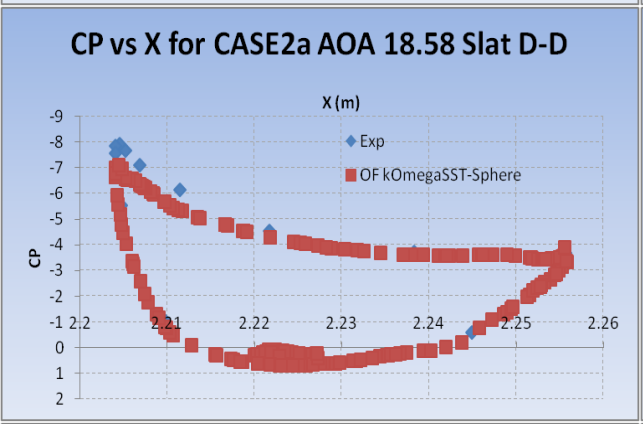


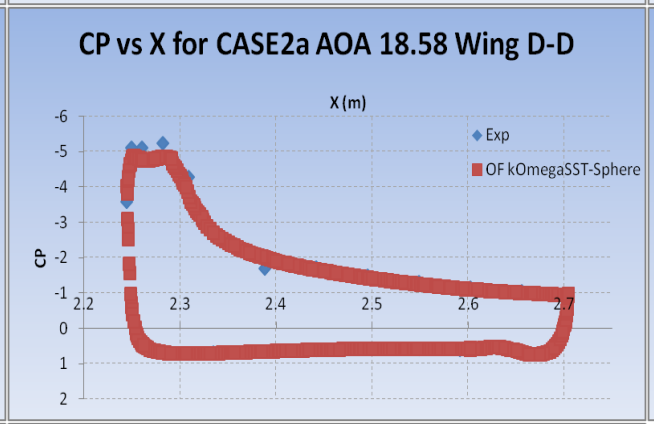
Case 2a OF AOA 18.58° Sphere Grid Cp Plots

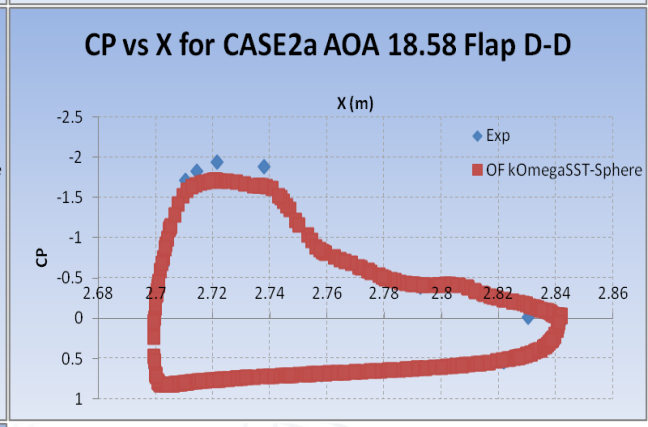


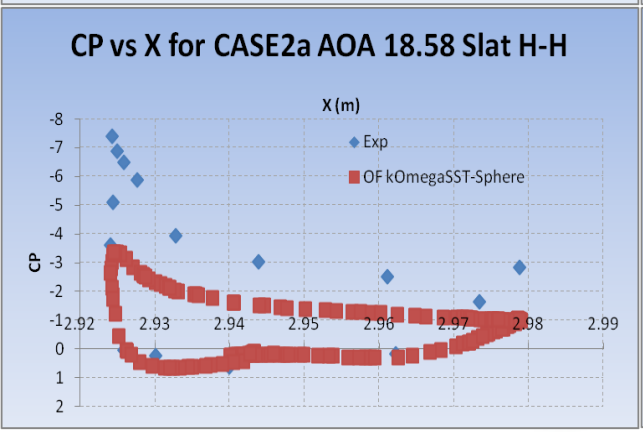


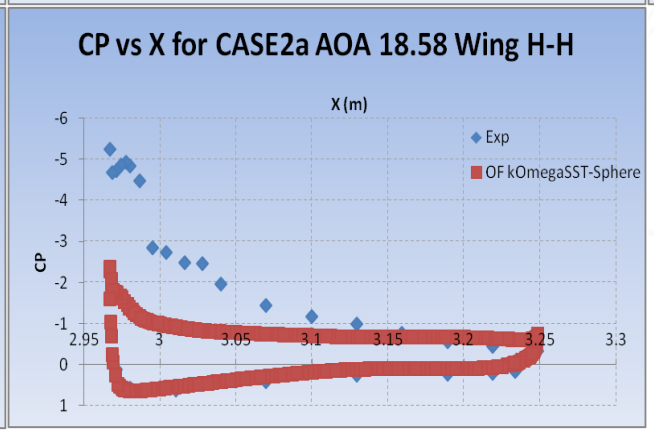




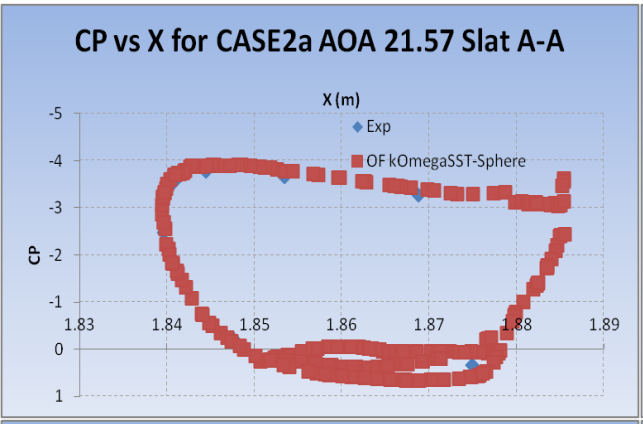


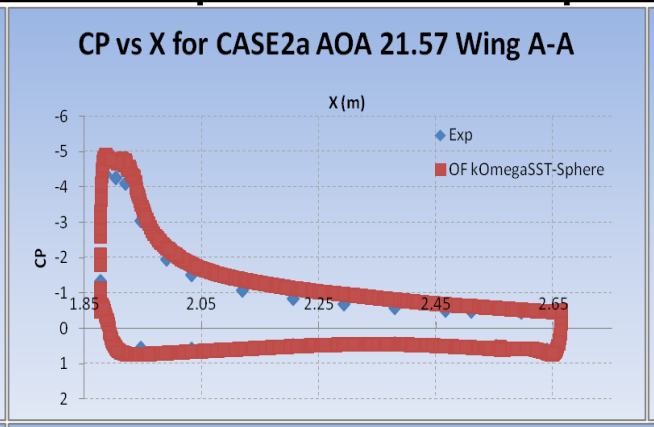


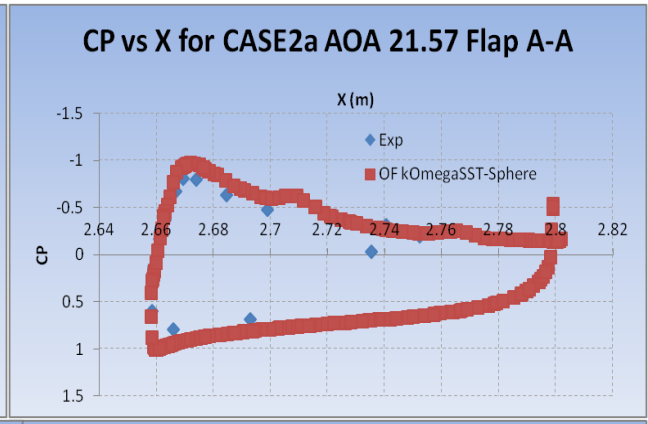


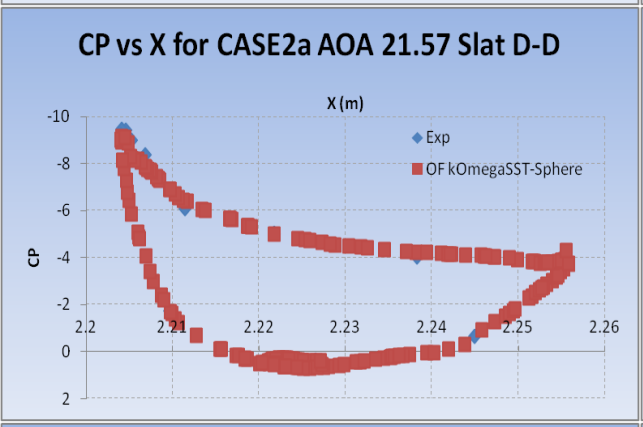


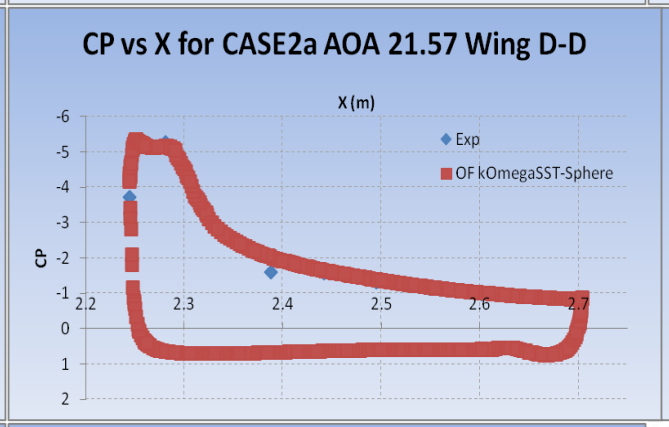
Case 2a OF AOA 21.57° Sphere Grid Cp Plots

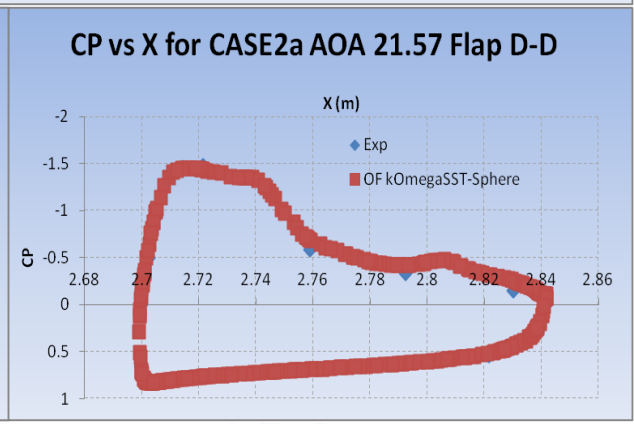


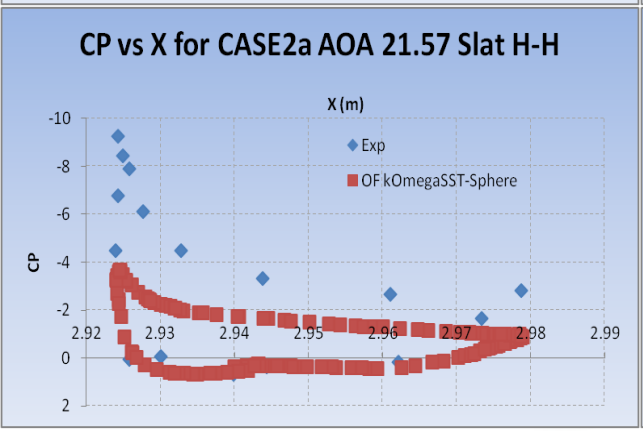


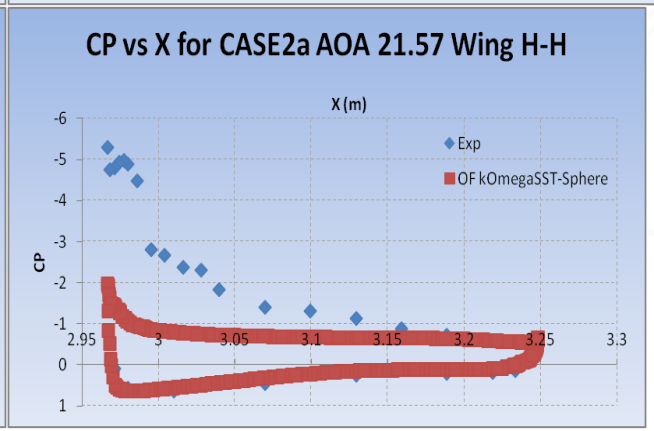




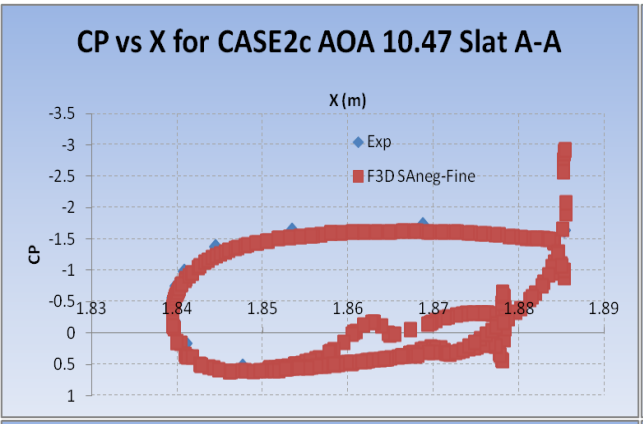


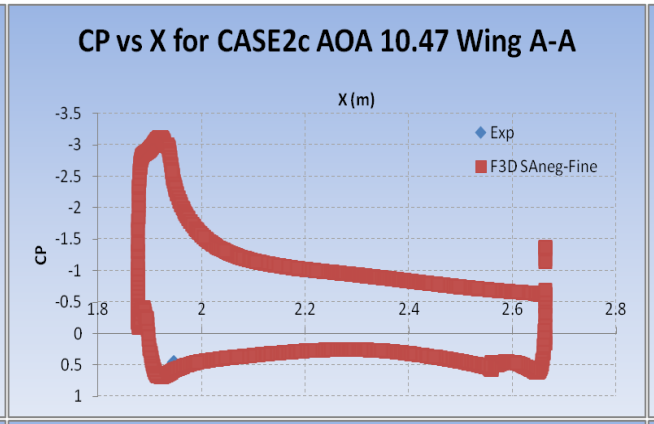


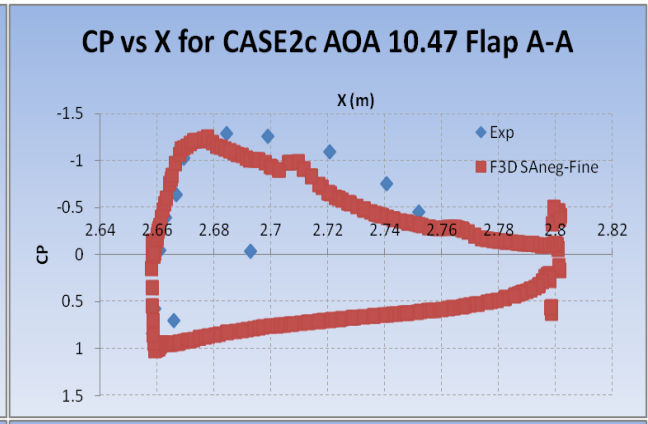


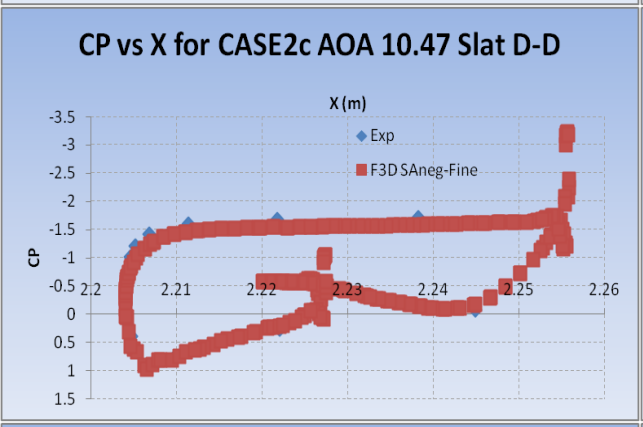


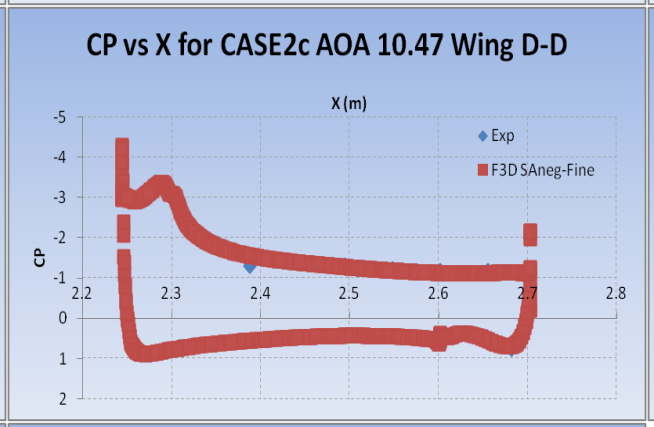
Case 2c FUN3D AOA 10.47° Cp Plots

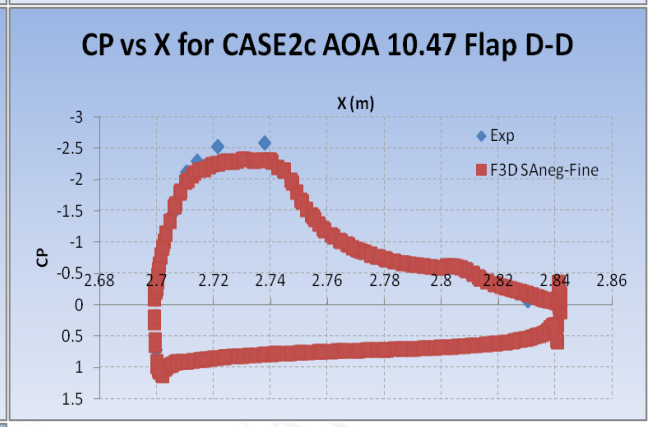


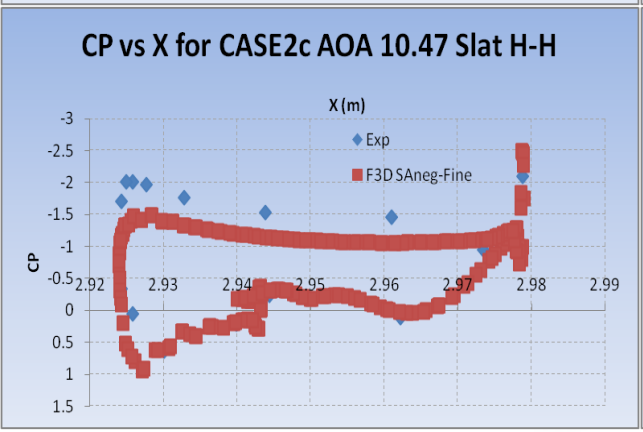


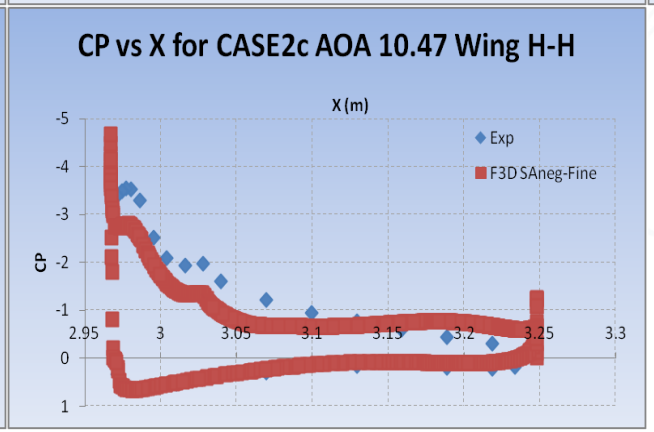




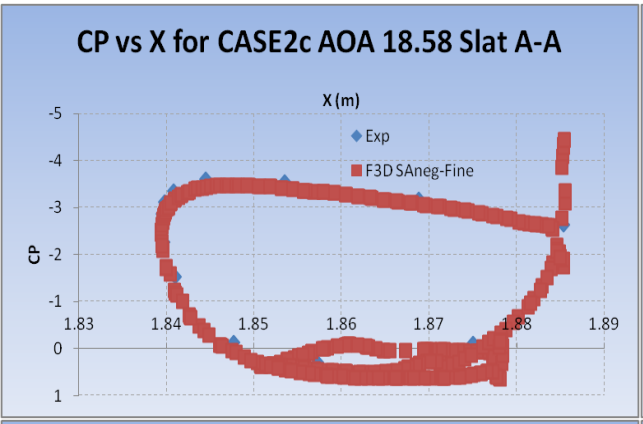


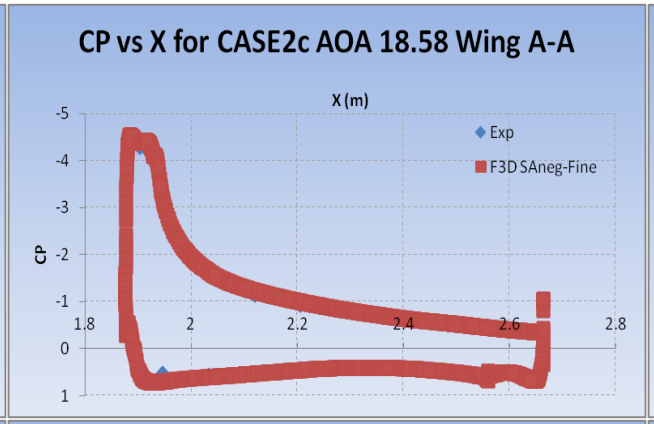


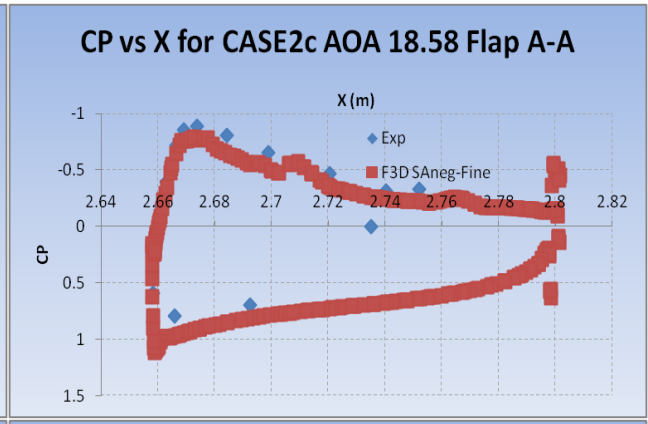


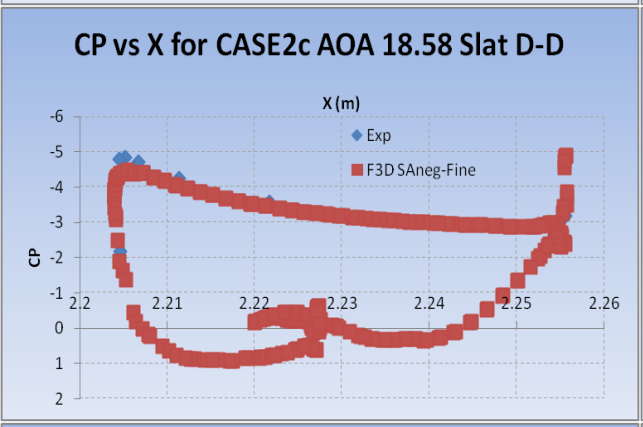


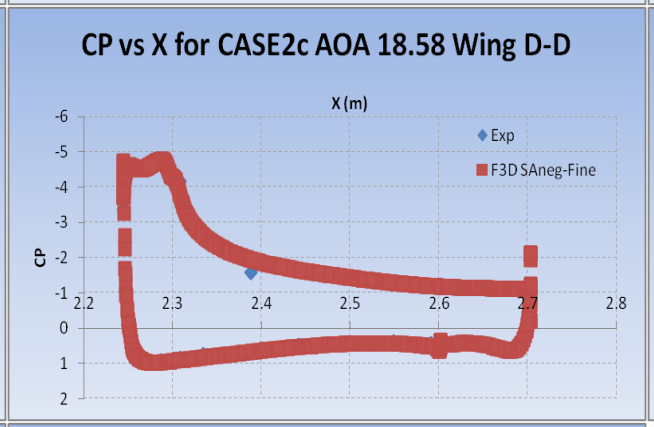
Case 2c FUN3D AOA 18.58° Cp Plots

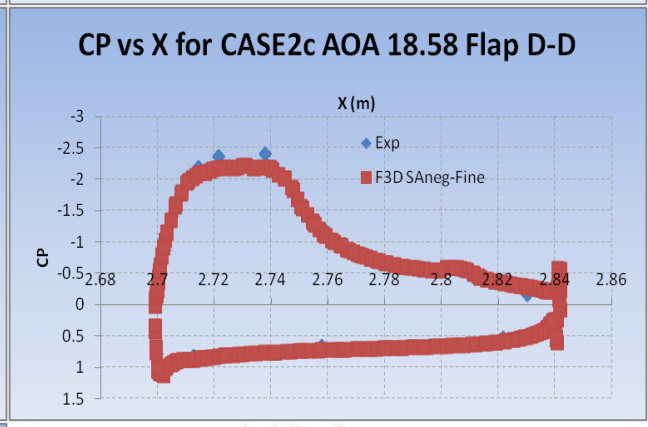


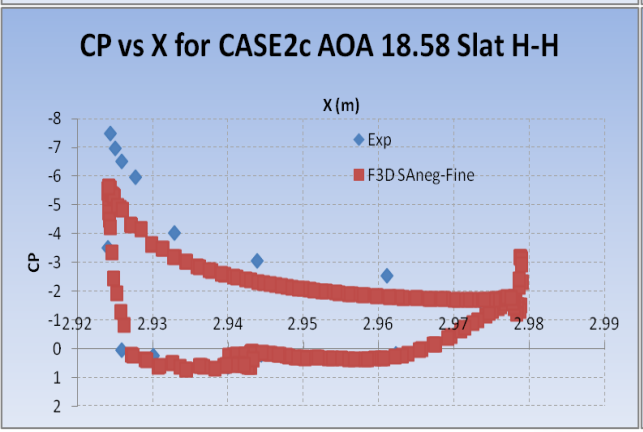


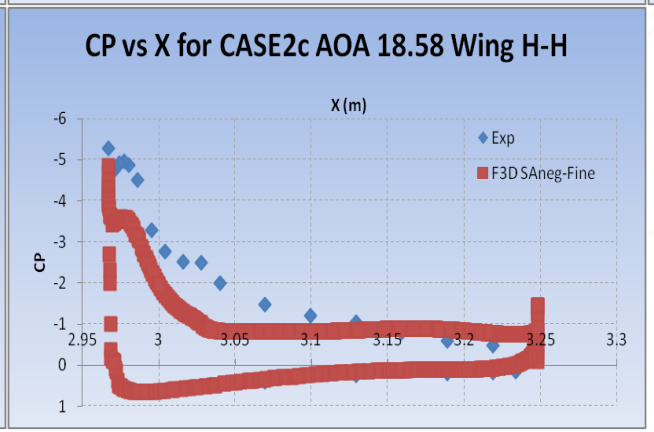




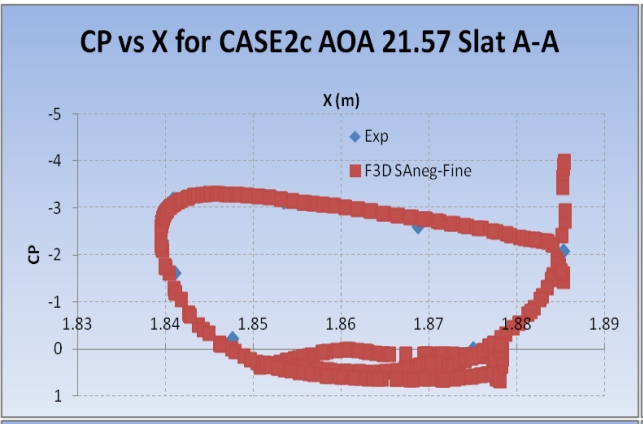


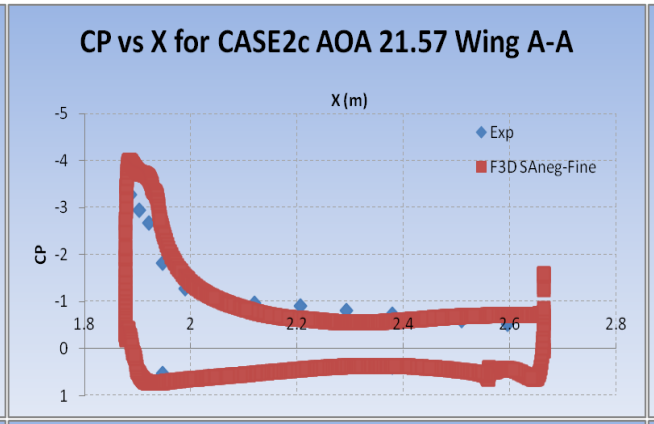


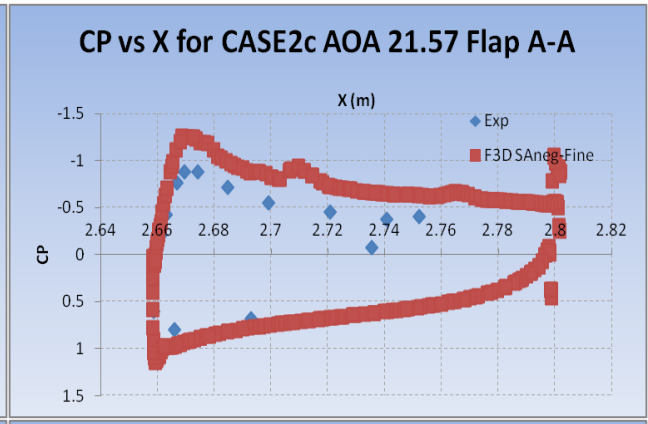


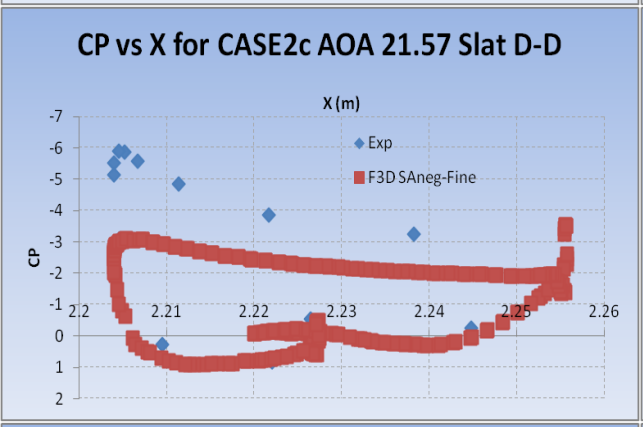


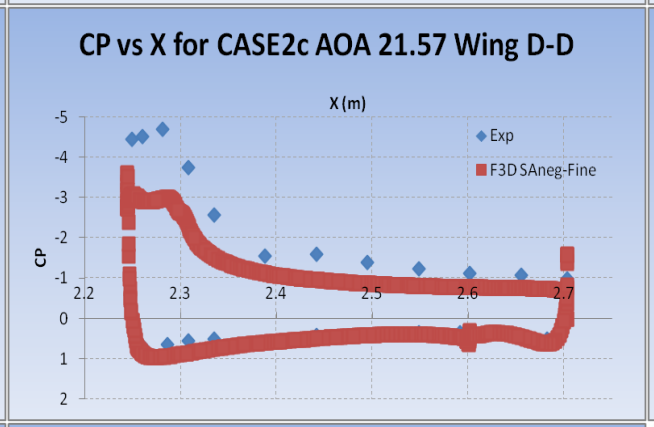
Case 2c FUN3D AOA 21.57° Cp Plots

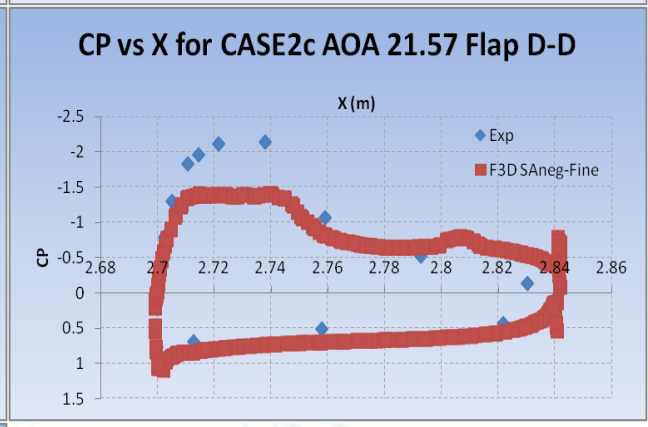


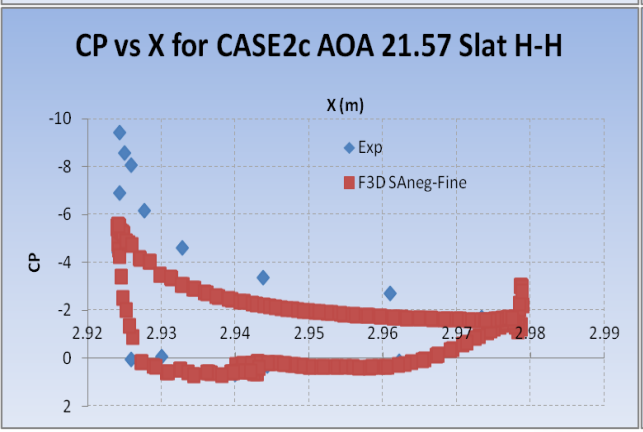


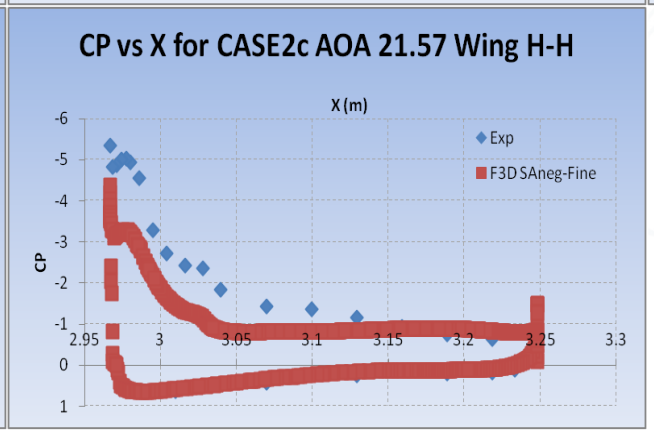




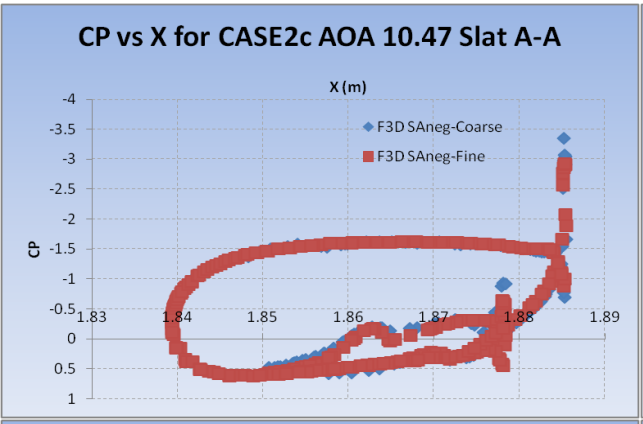


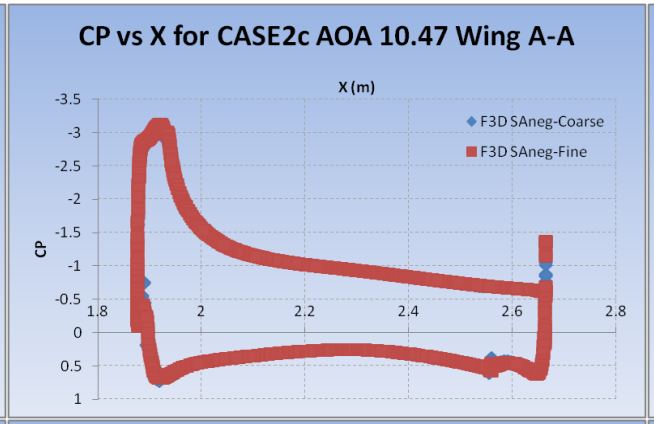


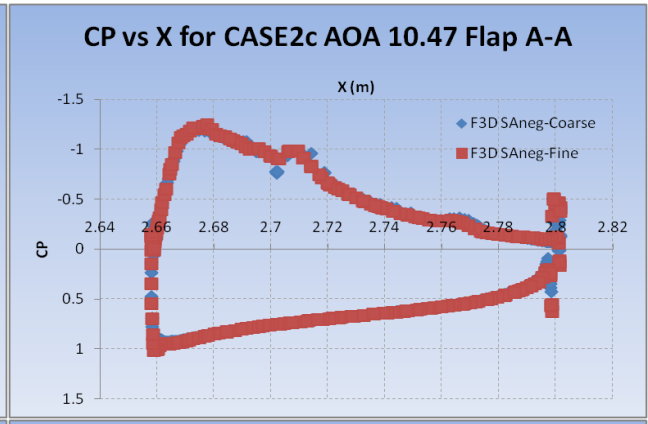


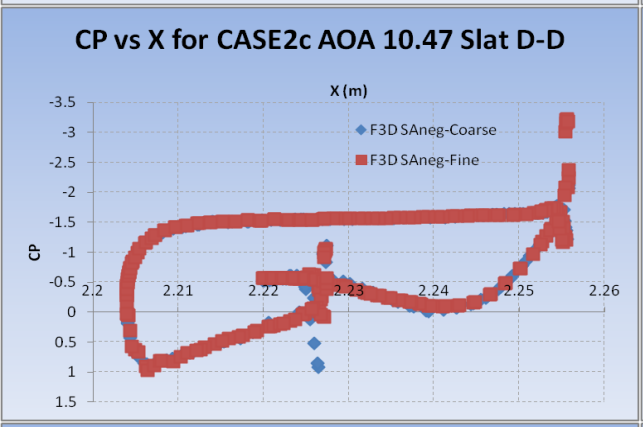


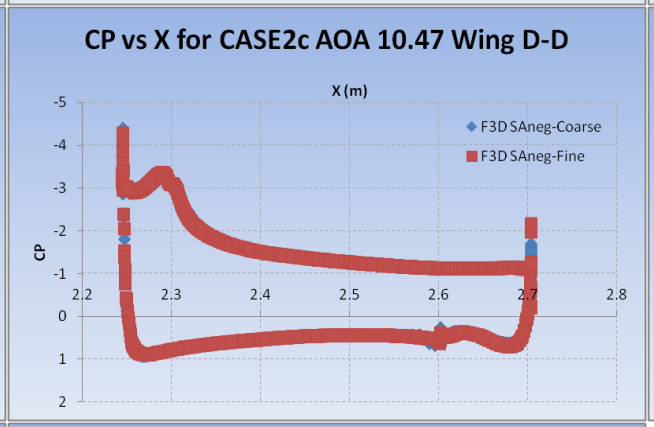
Case 2c FUN3D AOA 10.47° Cp Plots Committee Grid vs. In House Grid

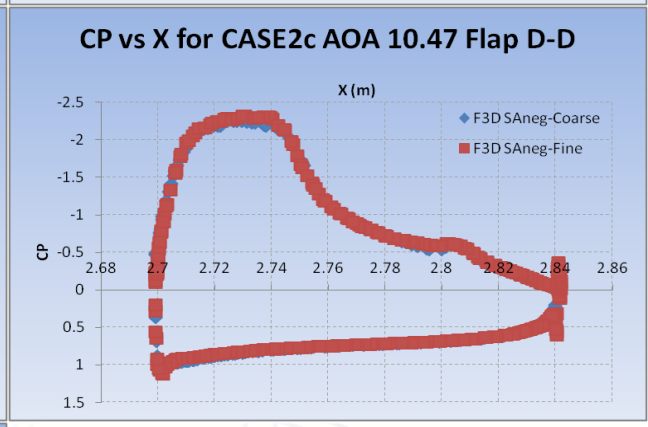


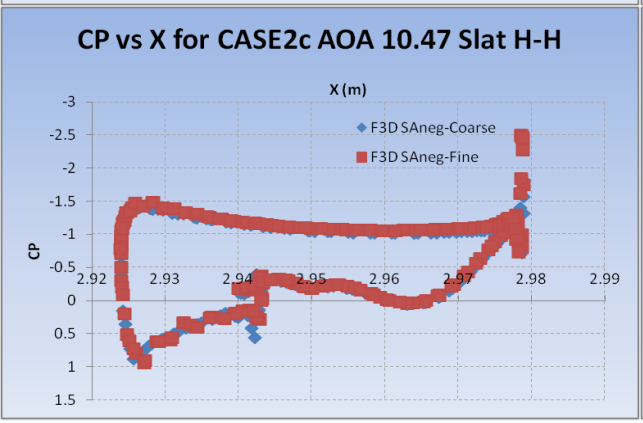


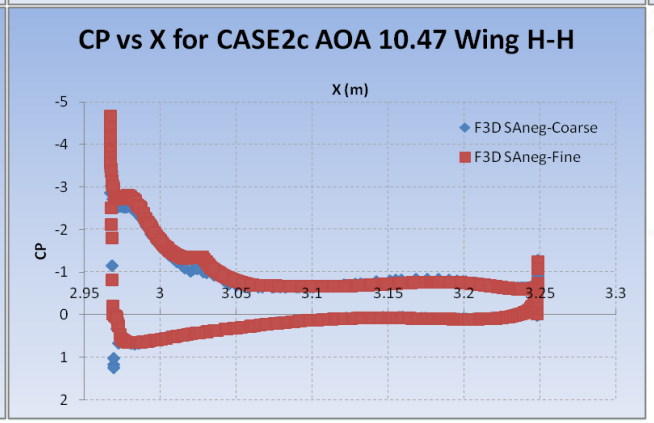




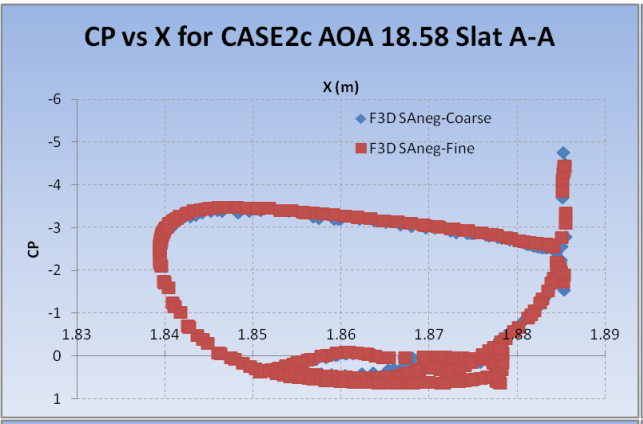


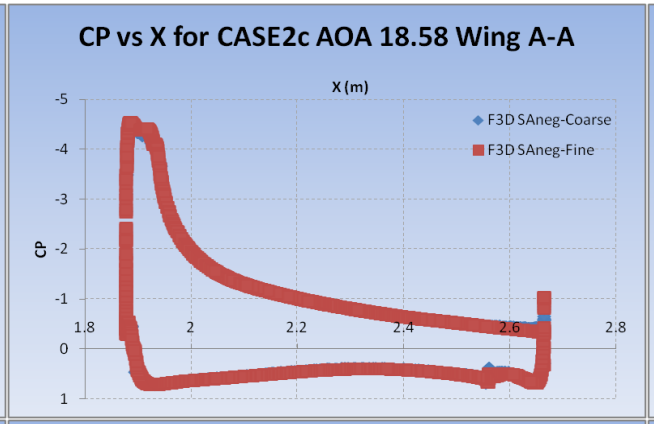


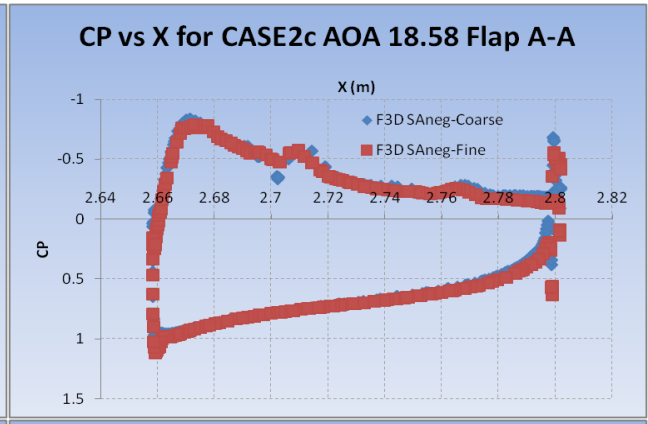


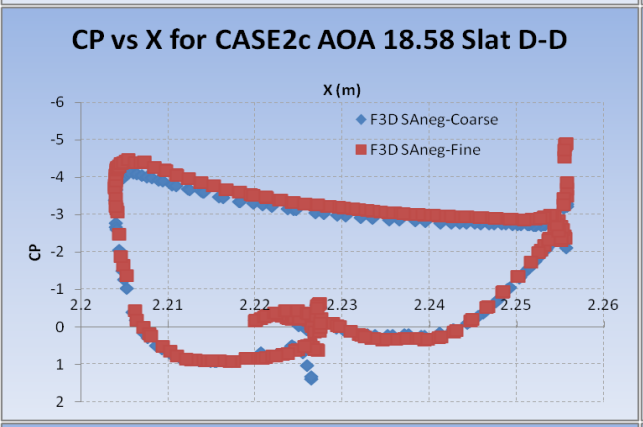


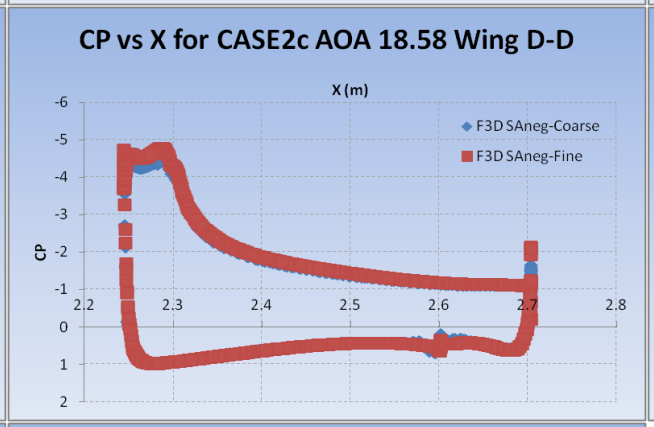
Case 2c FUN3D AOA 18.58° Cp Plots Committee Grid vs. In House Grid

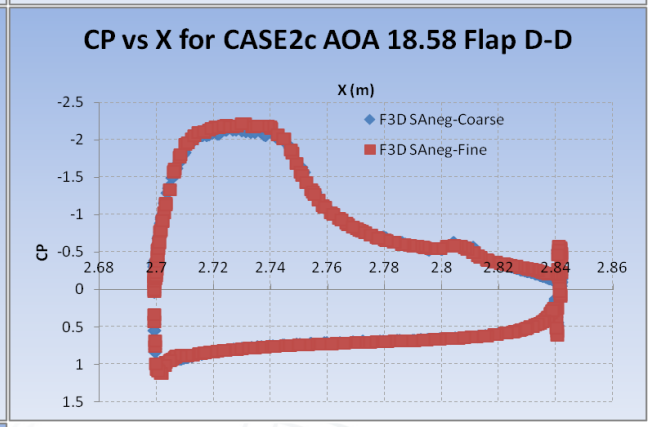


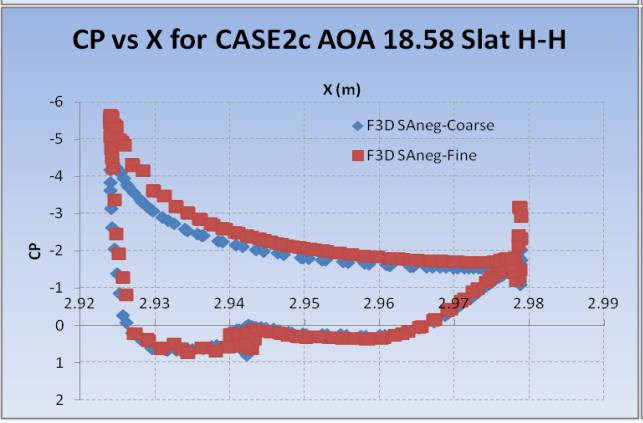


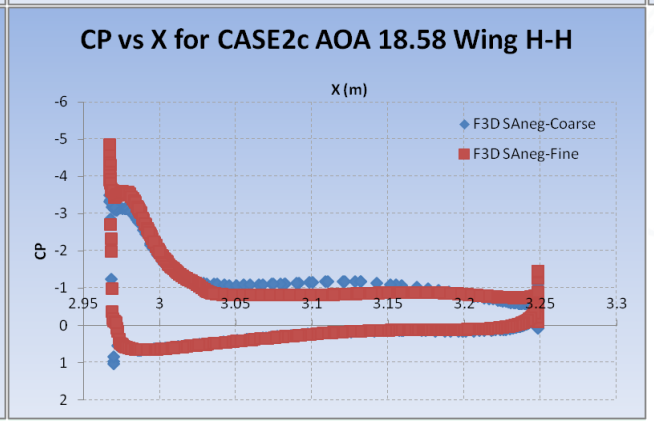
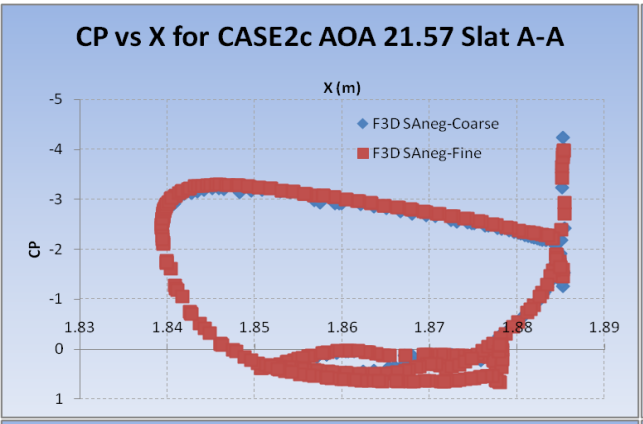
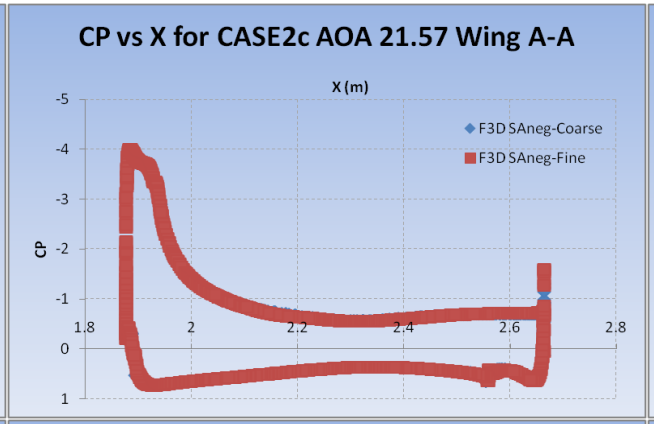
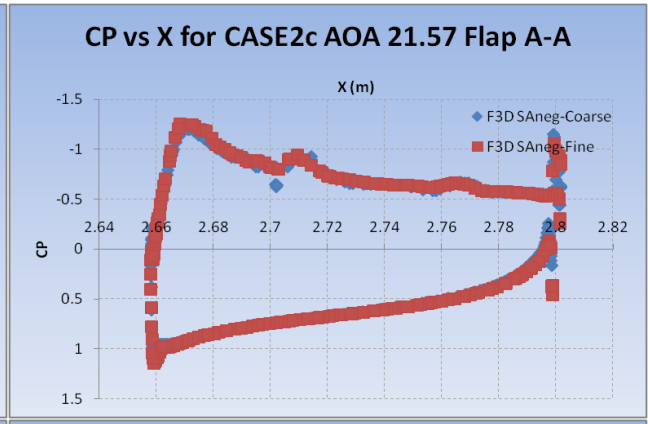
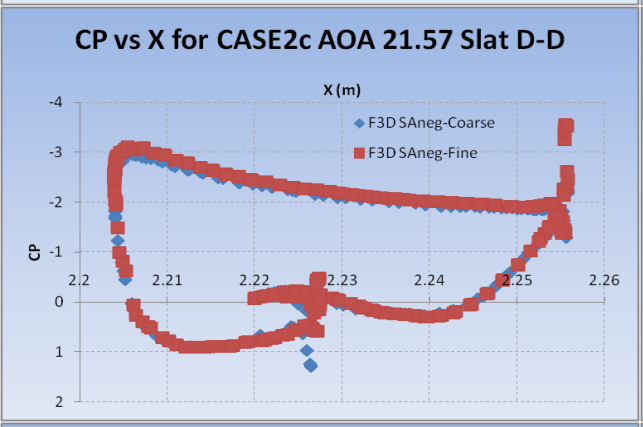
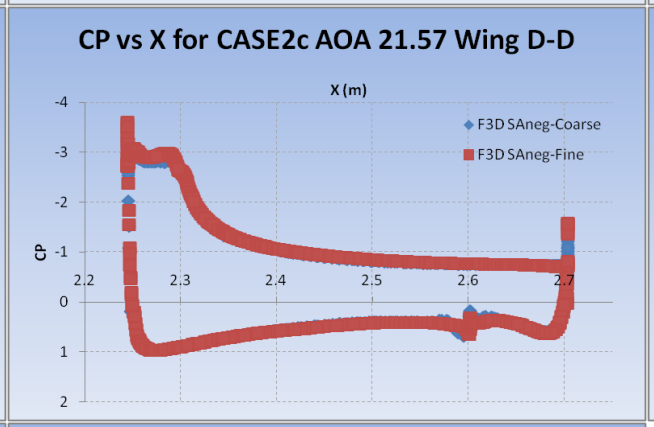
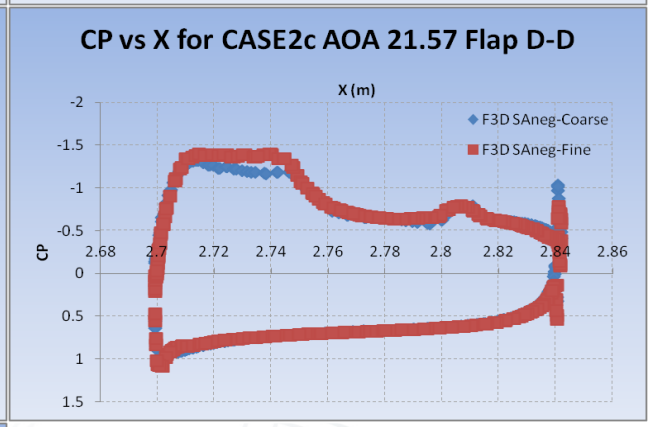
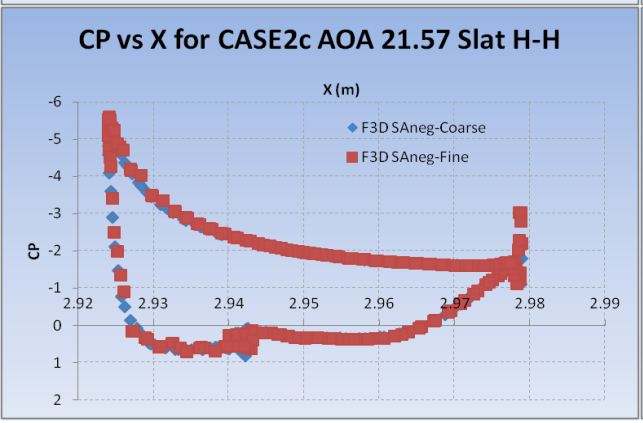
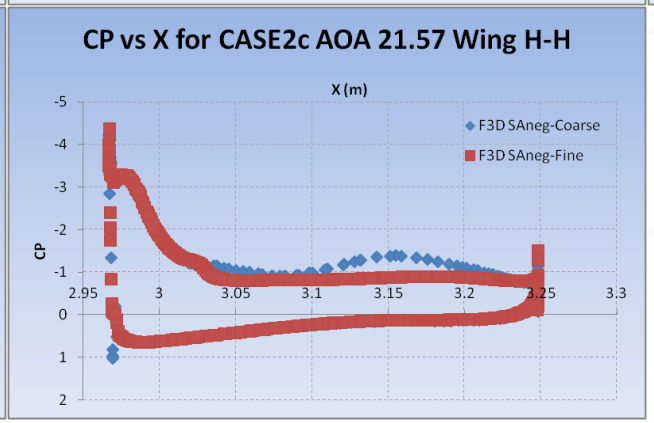












Case 2c FUN3D AOA 21.57° Cp Plots Committee Grid vs. In House Grid