Contribution to HiLiftPW-3

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PID: 020

3rd High Lift Prediction Workshop
Denver, CO June 3-4, 2017

Summary of cases completed: Auburn Grid, Menter SST

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	yes	
Other		

Summary of cases completed: Auburn Grid, Wilcox k-omega

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)	no	no	no	
2b (no nacelle w adaption)	no	no	no	
2c (with nacelle)	no	no	no	
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	no	
Other		

Summary of cases completed: Auburn Grid, SAS

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	
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2c (with nacelle)	no	no	no	
2d (with nacelle w adaption)	no	no	no	
Other				

Case	2D Verification study	Other
3	yes	
Other		

Summary of cases completed: Committee Grid, Menter SST

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			

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Other		

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Other				

Case	2D Verification study	Other
3	yes	
Other		

Summary of *Tenasi*

Tenasi **Unstructured Flow Solver**

- General multi-element, node centered, finite volume scheme
- Multiple flow regimes
- Fully implicit with multiple techniques to solve the system of equations
- Up to 4th order temporal accuracy
- At least 2nd order spatial variable reconstruction
- Roe Approximate Riemann or HLLC flux evaluation
- Highly scalable parallel algorithm
- Characteristic Variable Boundary Conditions (CVBC)

Turbulence models

- Loosely coupled with mean flow equations
- 3 one equation models with SGS modeling
- 4 two equation models (3 with SGS modeling)
- 2 Reynolds stress models
- Langtry-Menter transition model implemented
- Hybrid RANS-LES model under development

Verification study results

- The Incompressible and the non-preconditioned Arbitrary Mach Number flow regimes produced similar results with two turbulence models (SAS and SST)
  - Incompressible regime converged quicker and further
- When limiting is used, the Venkatakrishnan limiter offered better convergence than the Barth limiter
- Non-limited solutions were slightly more accurate than the limited solutions.

Brief overview of grid systems

Grid System	Case(s)	If committee grid, report any problems/issues If user grid, reason for generating grid system
Committee **(Case1a: B3-HLCRM_UnstrHexPrismPyrTet_PW,** **Case2: E-JSM_UnstrMixed_ANSA)**	1a, 2a, 2c	No problems with the committee grids with appropriate choice of turbulence model
User **(Unstructured multi-elements grid generated using Pointwise)**	1a, 2a, 2c	Generated grid system to investigate the difficulties in creating grids for the high lift configurations and to have better control on the mesh compatibility with the solver
Other		

- The provided committee grid systems were compatible with the solver
  - In most cases, the committee grids did not have any issues
- The created grid systems are multi-element grids with hexahedrals, prisms, pyramids and tetrahedrals elements generated using Pointwise
- The only problem encountered with the CAD model was in one of the surfaces on the wing-fuselage fairings of the HL-CRM
  - The faulty surface had overlapping boundaries
  - The mesh generation problem was fixed by creating mesh using boundaries of neighboring surfaces

Brief overview of grid systems

- Some deviations from the gridding guidelines are present in the created grids in order to maintain the quality of the grids
    - Trailing edge spacings across the high lift elements are adjusted based on the number of points on the trailing edges
    - Spanwise spacings are also adjusted

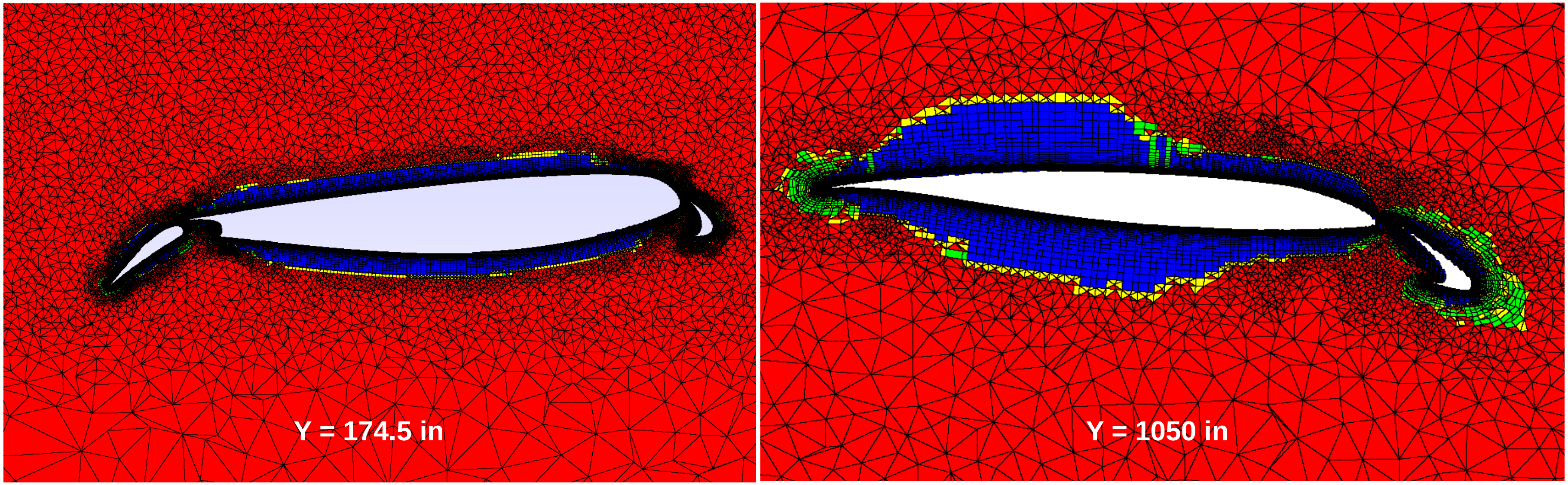


Figure: Preview of the generated multi-element grid of the HL-CRM at constant Y cuts in two different locations

Brief overview of HL-CRM results

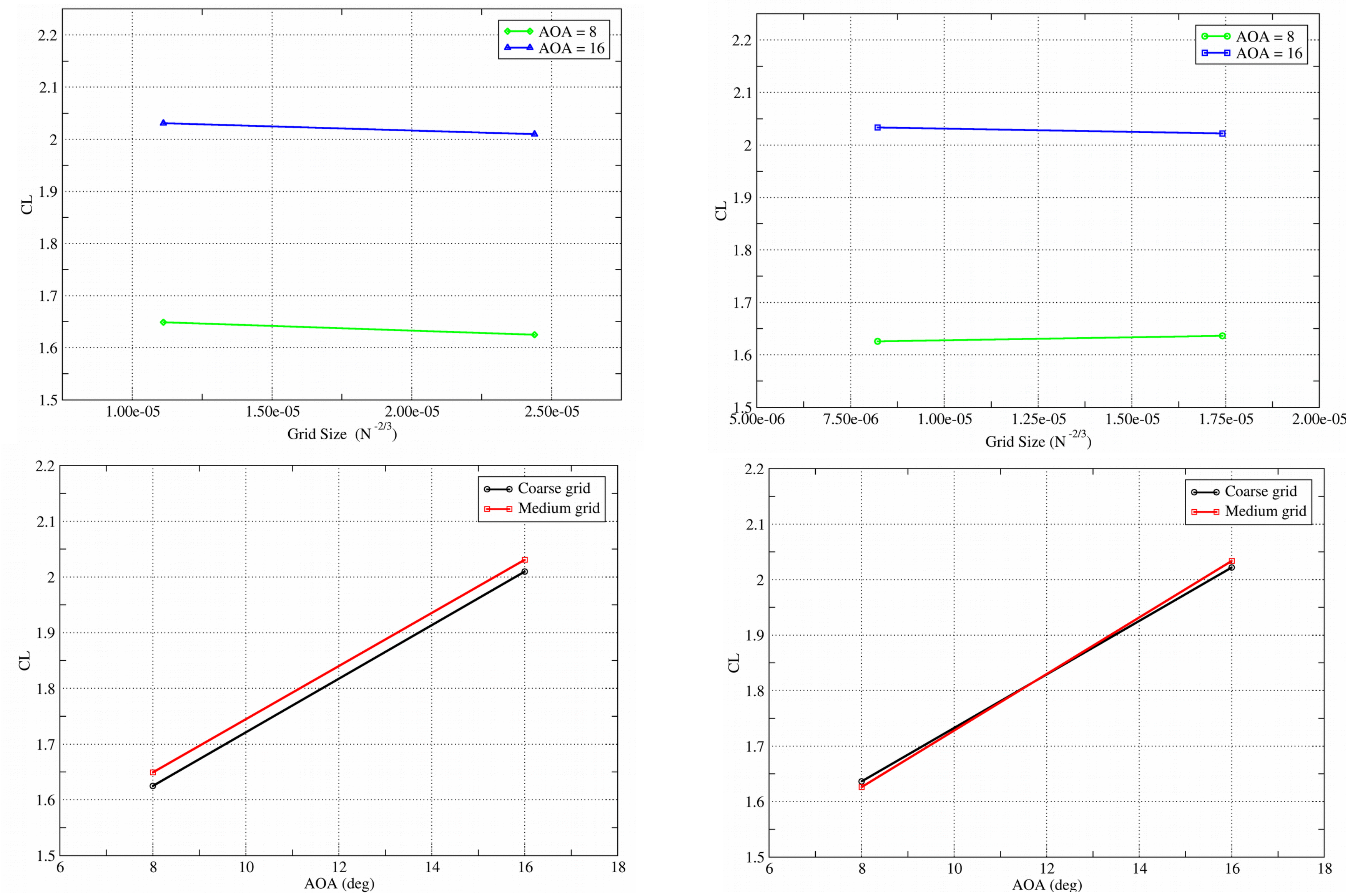
- Grid refinement increased the prediction of CL for a given angle of attack
- For a given CL, coarser grid over-predicts the CD and CM compared to finer grid
- Turbulence models show less effect on the force and moment prediction
- CP Convergence: Grid Refinement
  - Grid refinement shows significant effect on the CP at midspan of the wing
  - Grid refinement shows significant effect on the CP at higher angle of attack

Brief overview of HL-CRM results

- CP comparison: Auburn Grid VS Committee Grid
  - The results are comparable at coarse grid level
  - Significant differences in CP prediction at midspan of the wing-chord due to differences in the mesh element size
- CP comparison: Turbulence Model comparison
  - Menter SST, Wilcox k-omega, and SAS model results on CP are comparable to each other at all angles of attack
- Velocity profile
  - Effects of grid refinement is more pronounced at higher angle of attack
  - The Y-component (v) and Z-component (w) of the velocity are more sensitive to grid refinement than the X-component (u) of the velocity
  - Resolution of wake by different turbulence models are almost identical

Brief overview of HL-CRM results

Lift Convergence

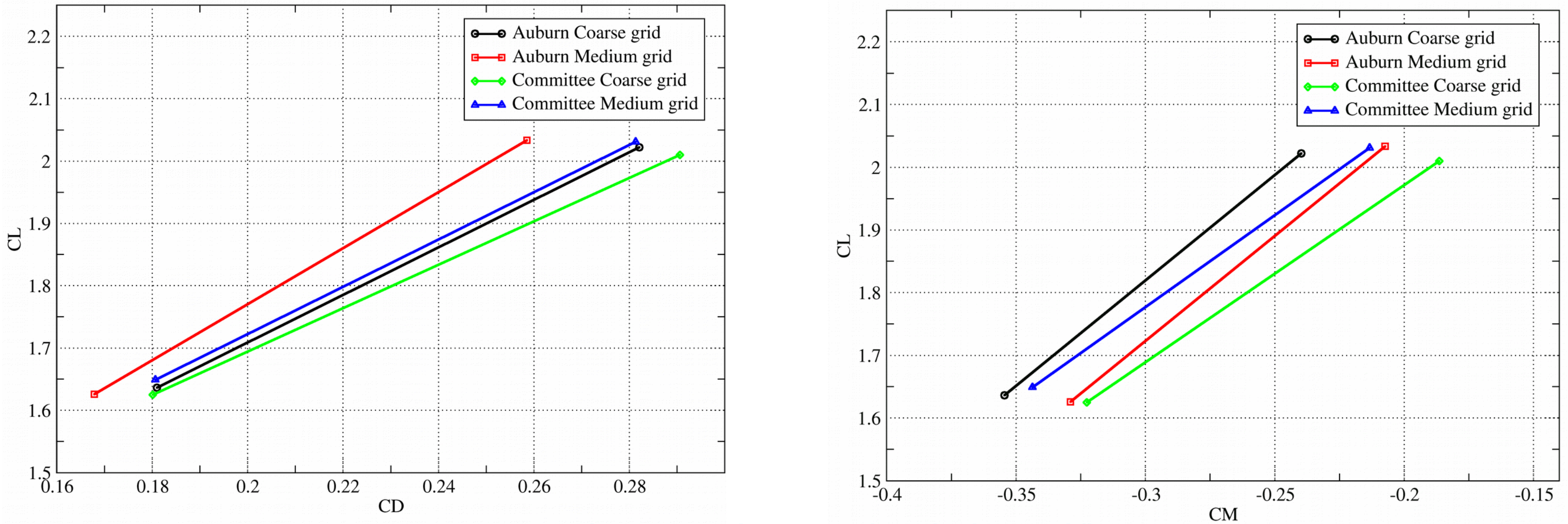


(a) Committee Grid

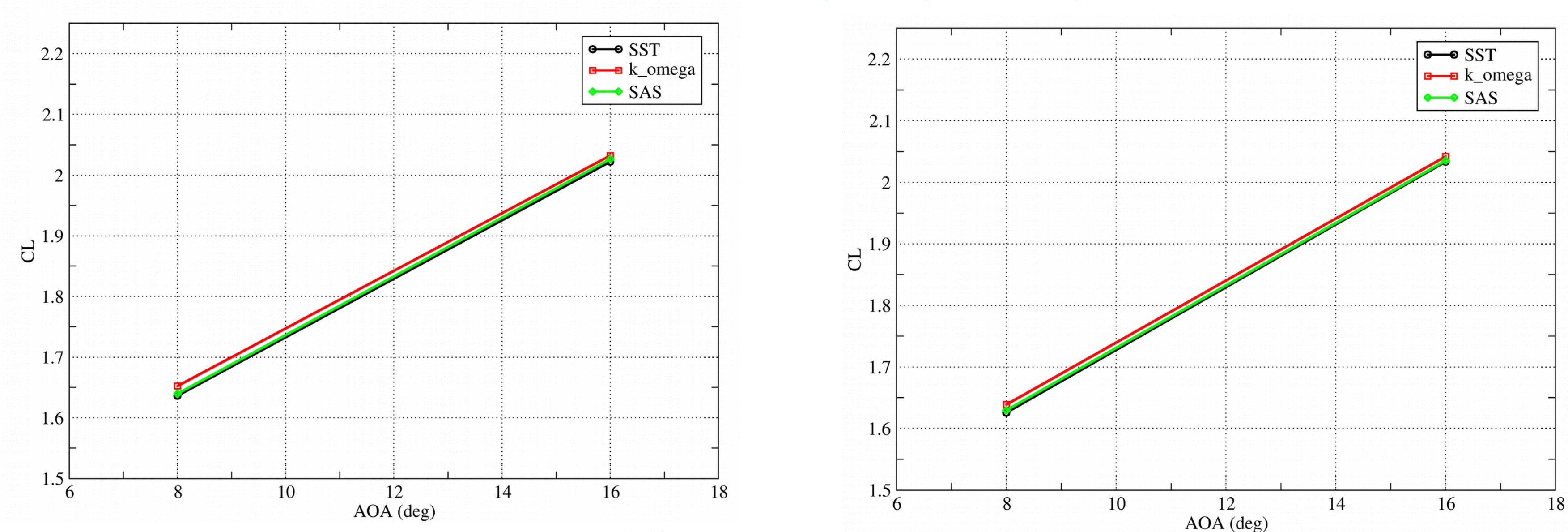
(b) Auburn Grid

Brief overview of HL-CRM results

Force and Moments Comparison

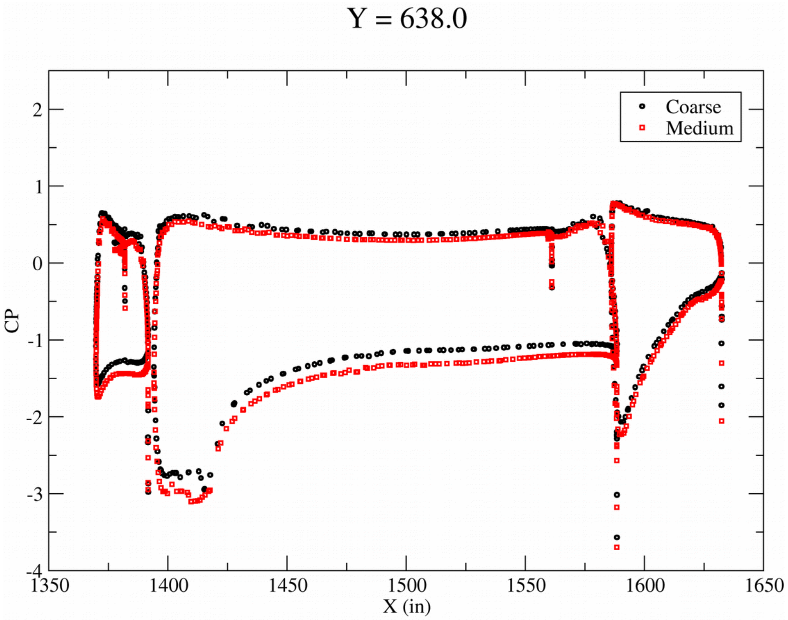


Turbulence Model Comparison (Auburn Grid)



Coarse Grid **Medium Grid**

Brief overview of HL-CRM results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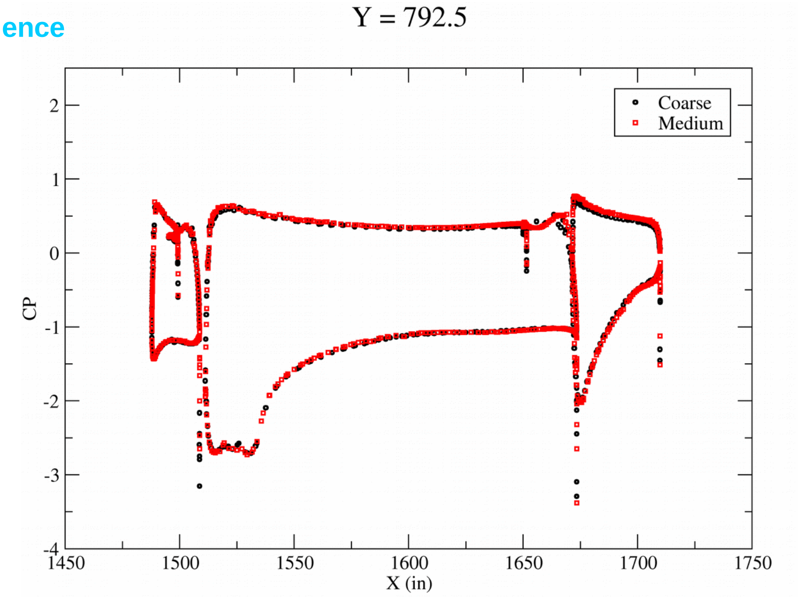
CP Convergence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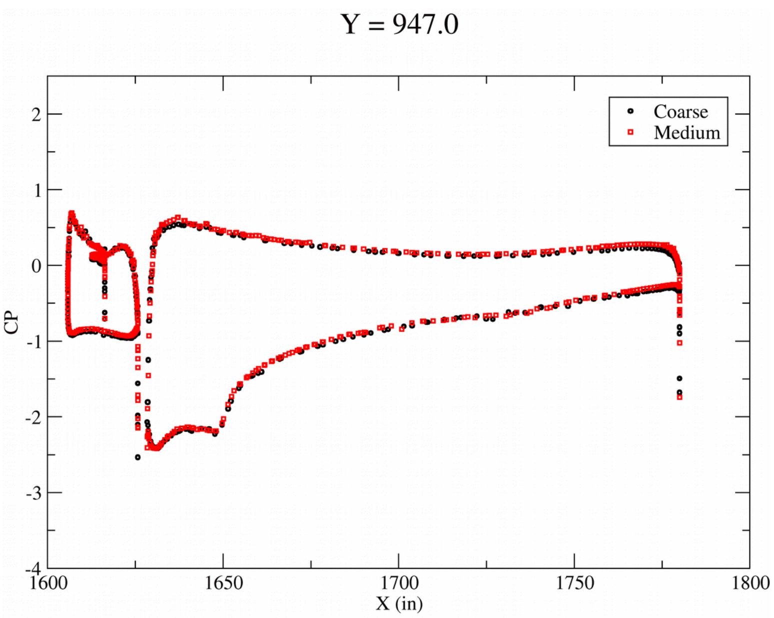
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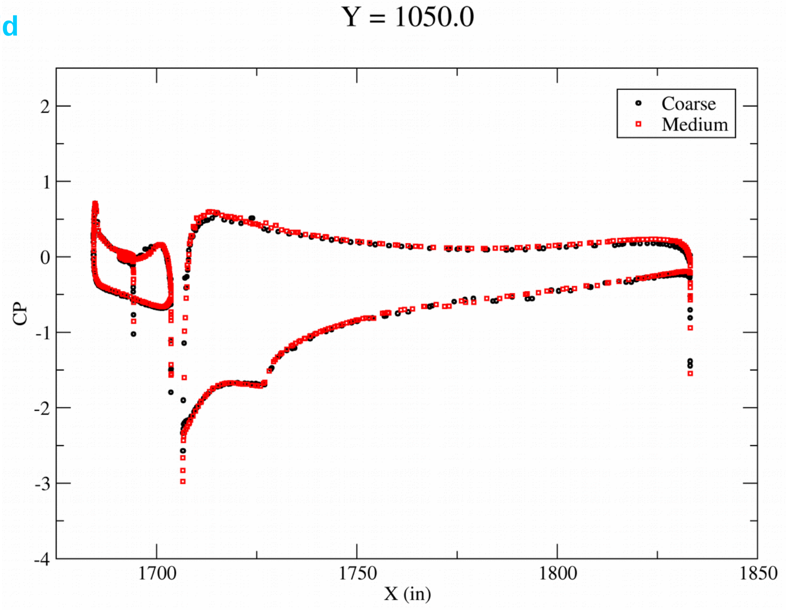
Auburn Grid
AOA 8^0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Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)

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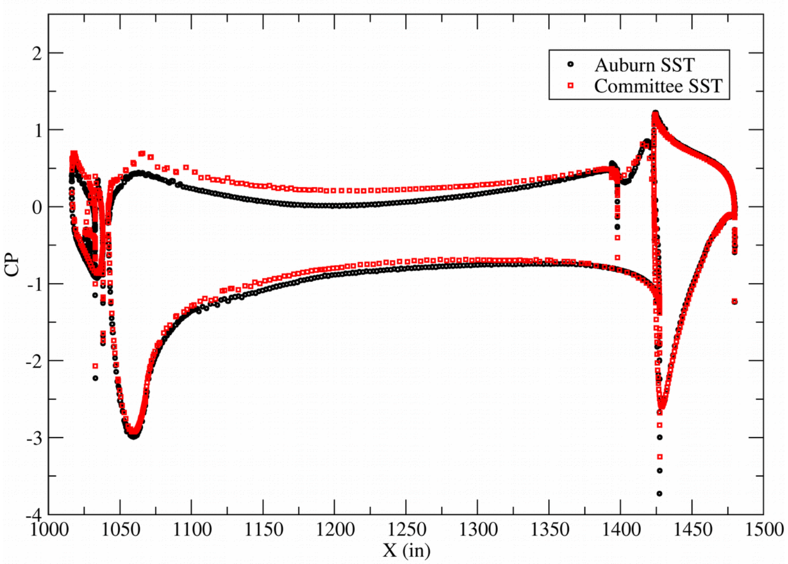
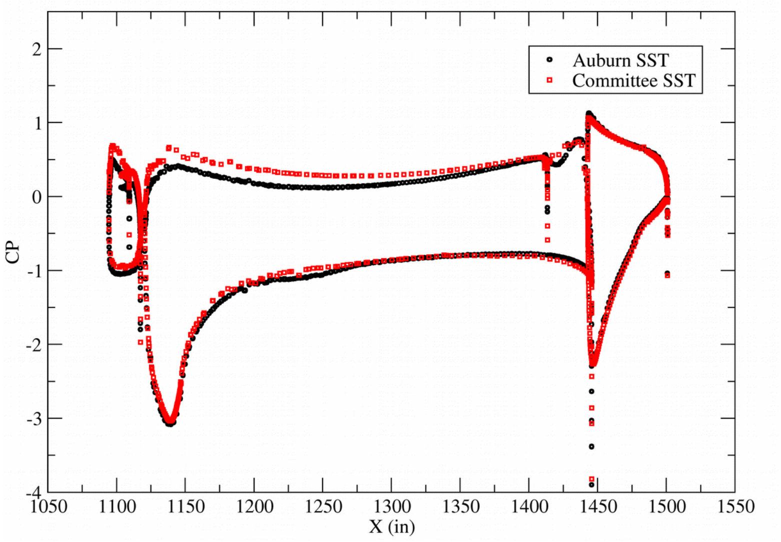
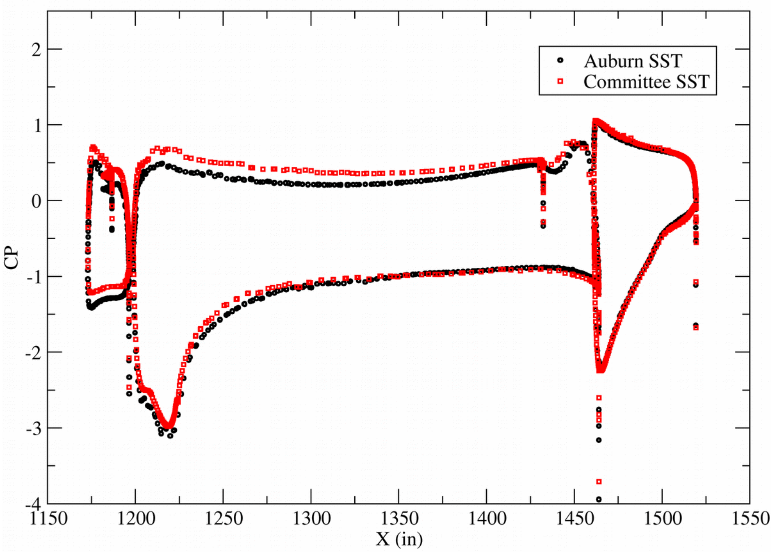


Y = 277.5

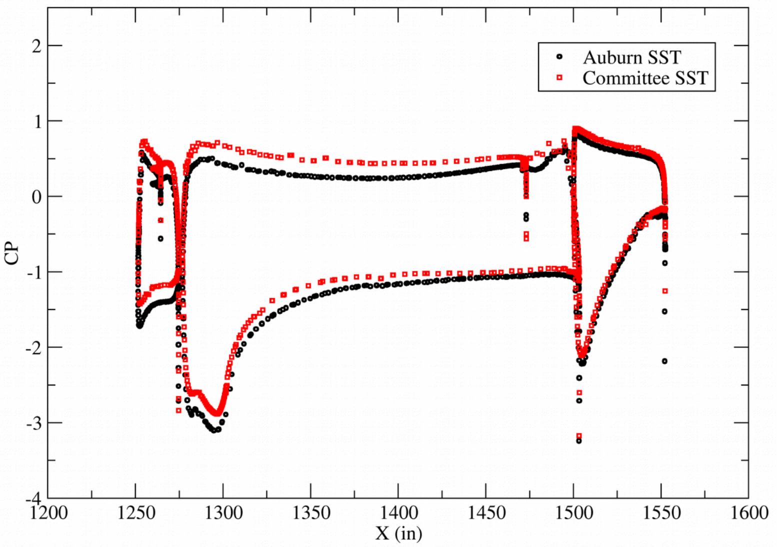


Medium Grid
AOA 8^0

Y = 380.5

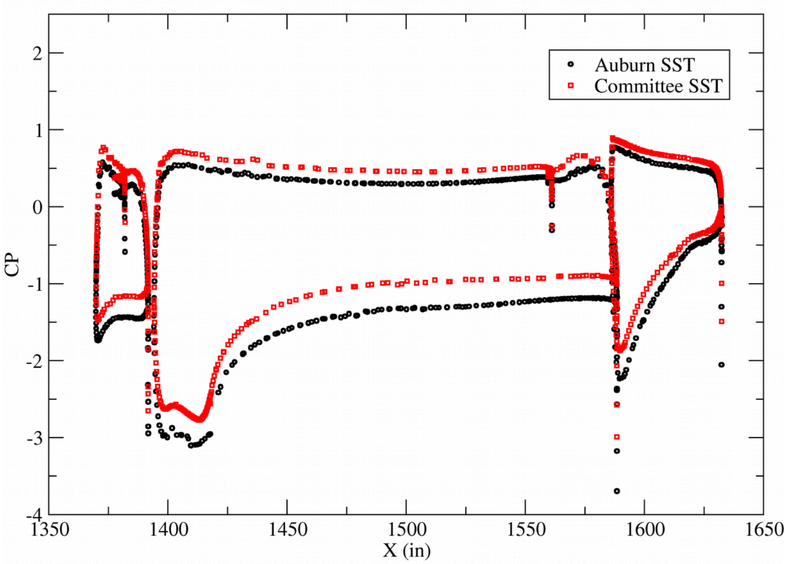


Y = 483.5



Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)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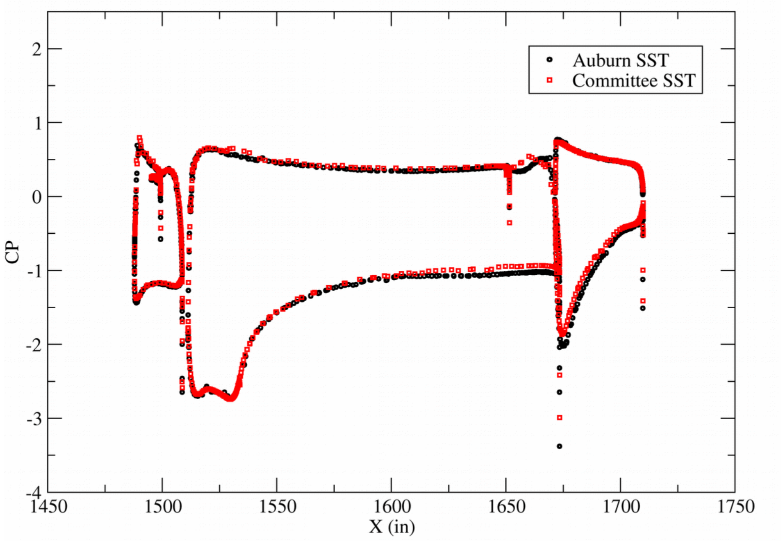
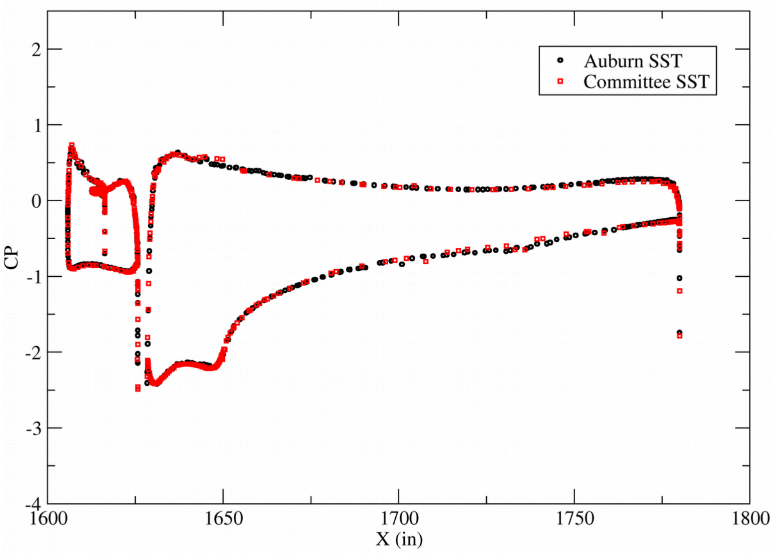

Y = 792.5

Medium Grid
AOA 8^0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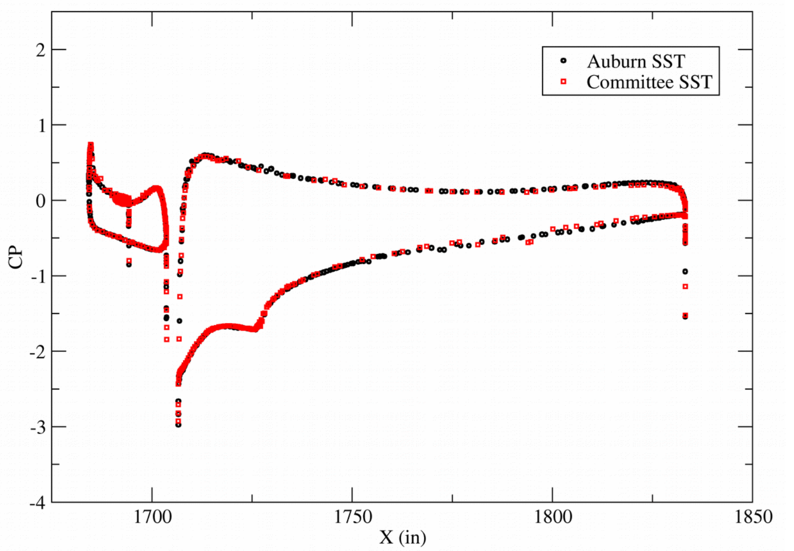
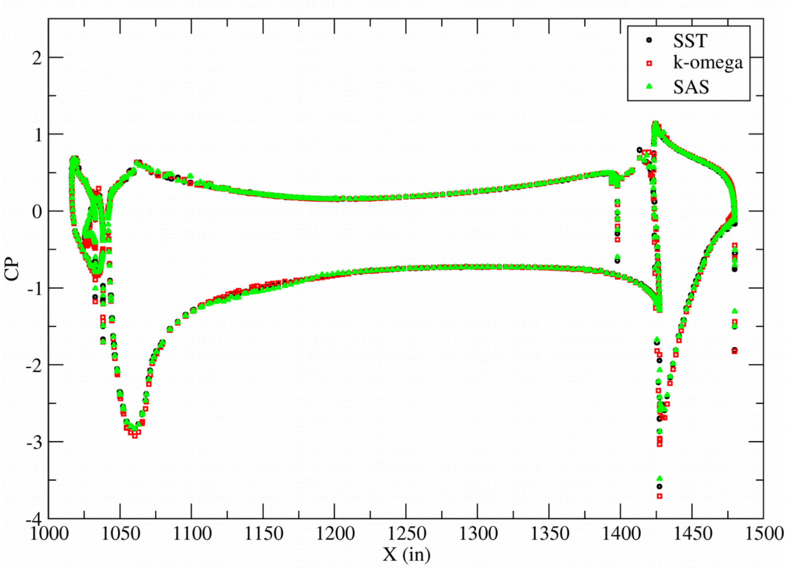

Y = 1050.0

Brief overview of HL-CRM results

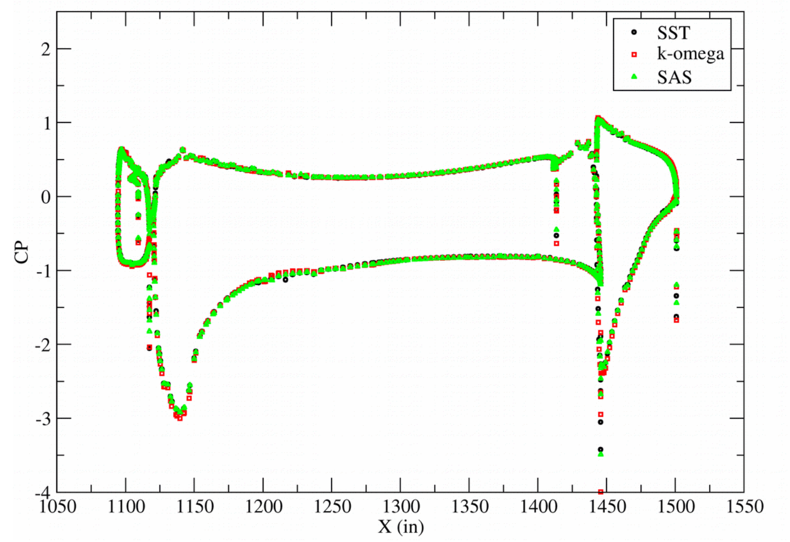
Turbulence Model Comparison (Auburn Grid)

Coarse Grid
AOA 8^0

Y = 174.5



Y = 277.5



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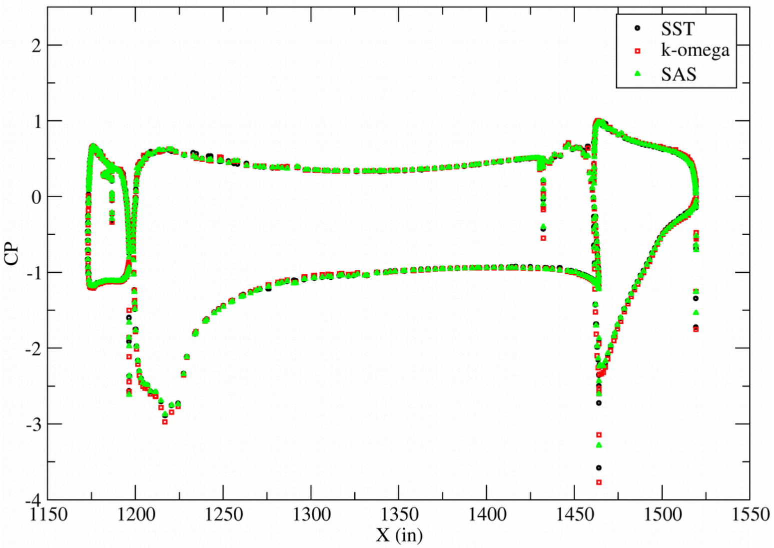

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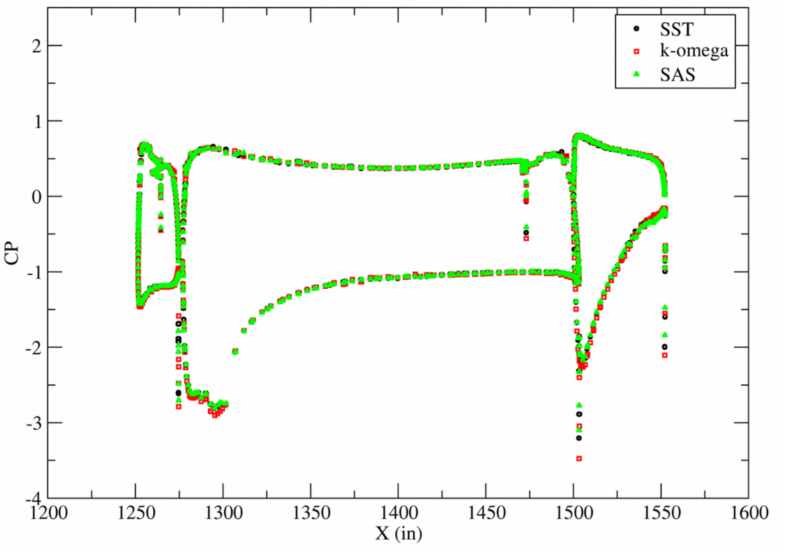
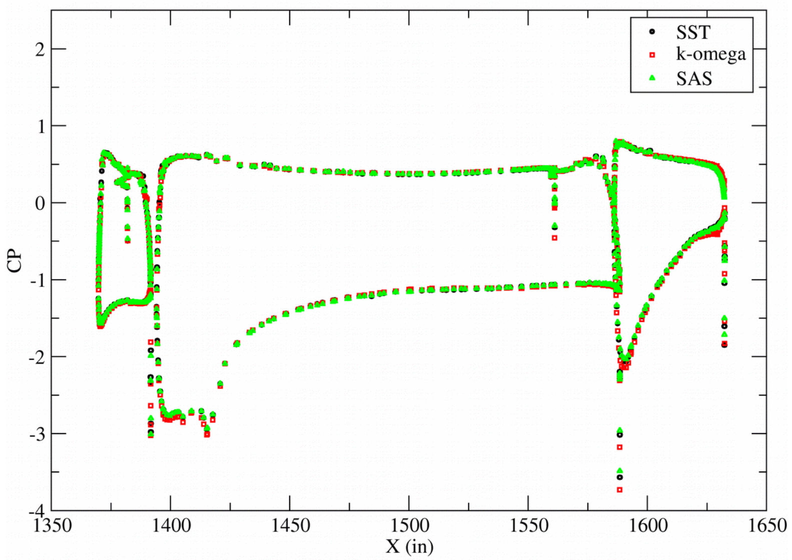


Brief overview of HL-CRM results

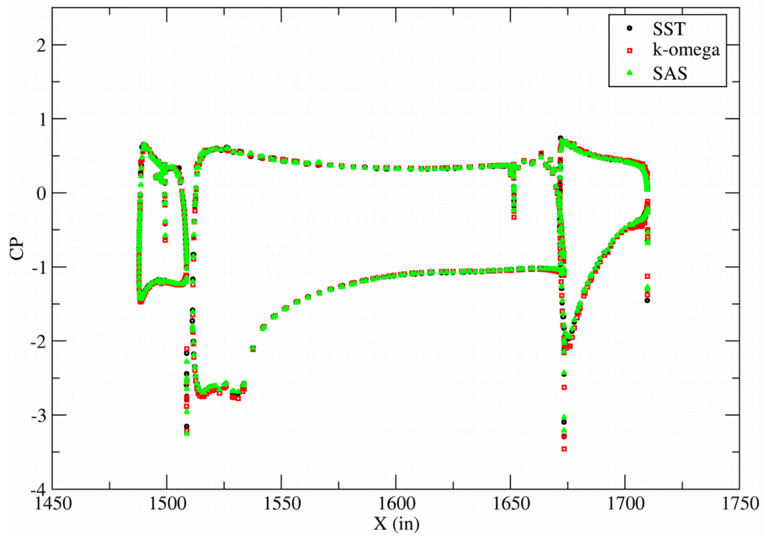
Turbulence Model Comparison (Auburn Grid)

Coarse Grid
AOA 8^0

Y = 638.0



Y = 792.5



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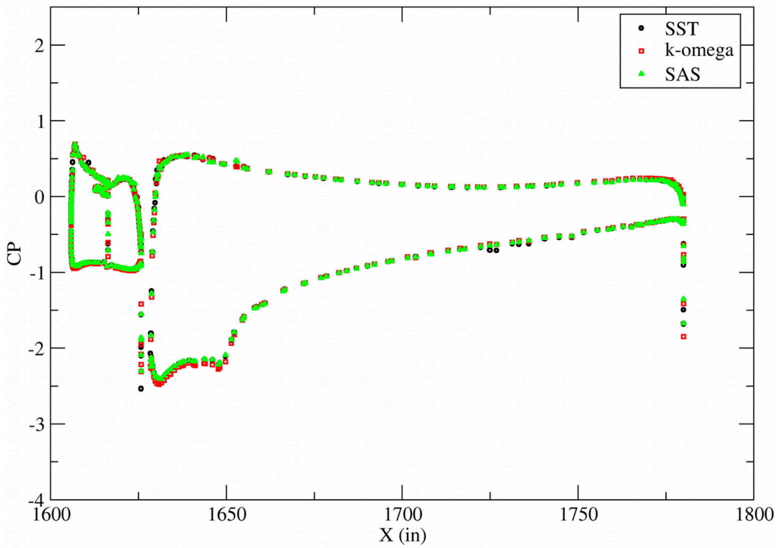

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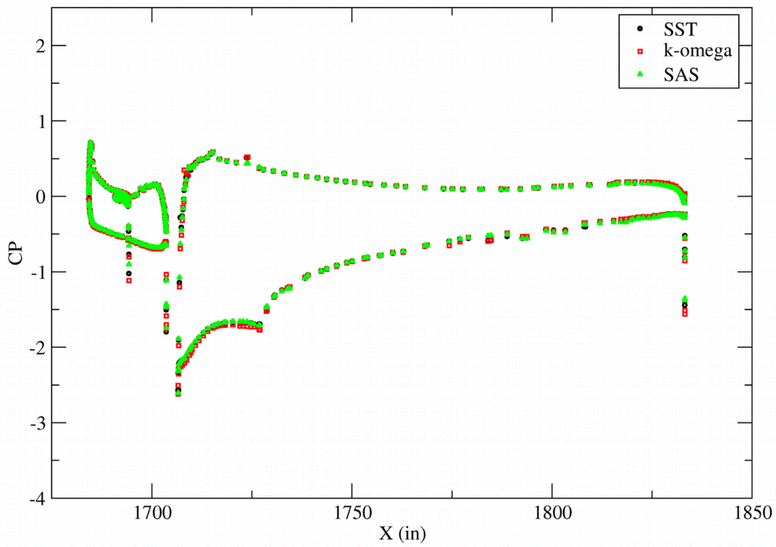
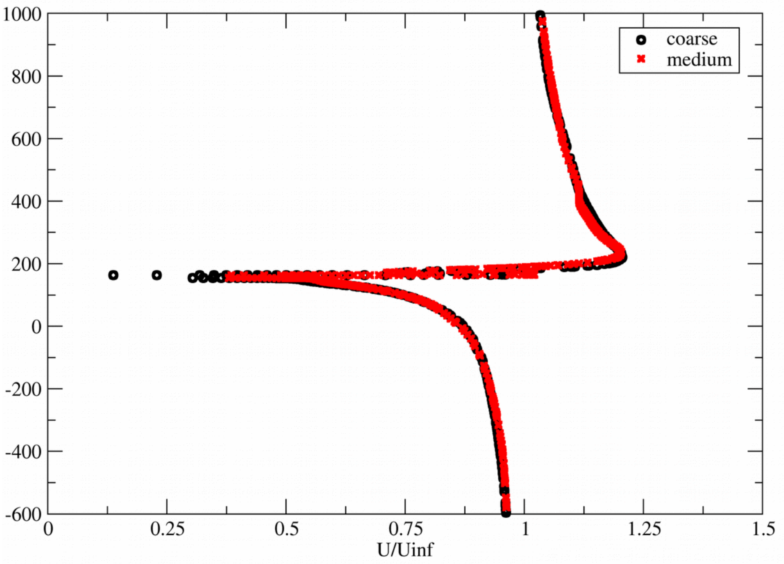


Brief overview of HL-CRM results

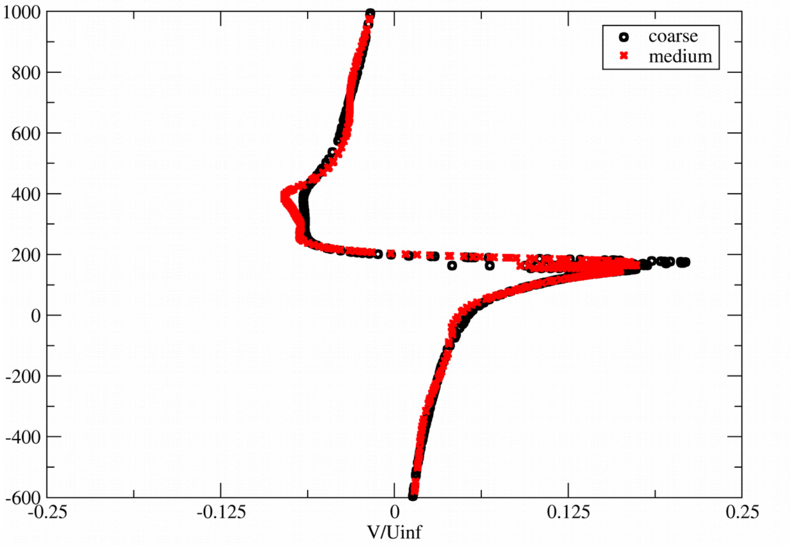
Velocity Convergence

X= 1475, Y = 277.5



Auburn Grid
AOA 8^0

X= 1475, Y = 277.5



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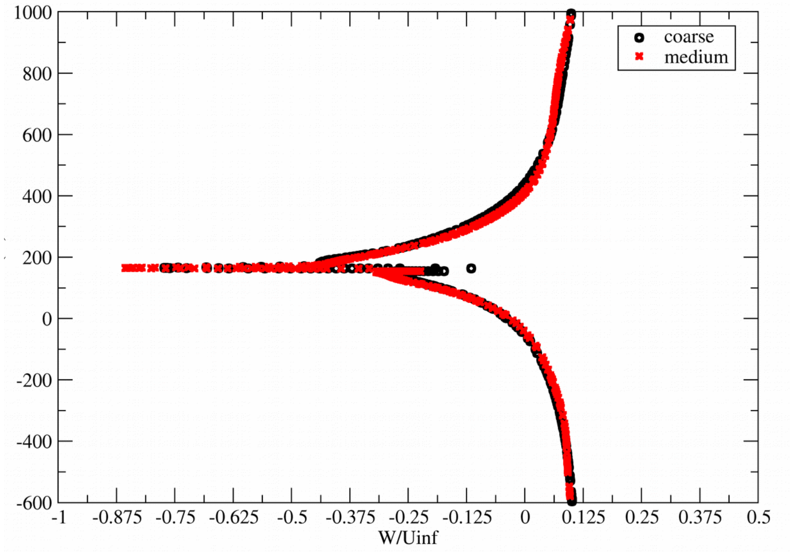
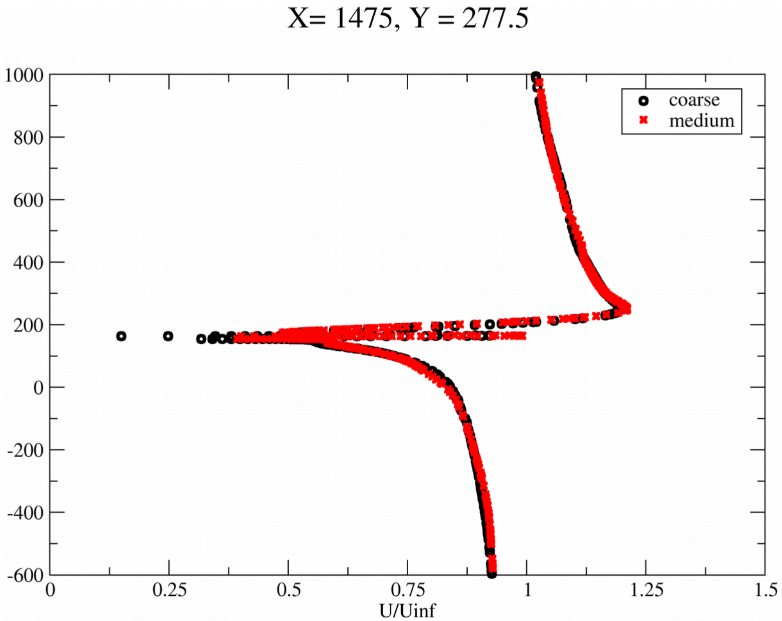
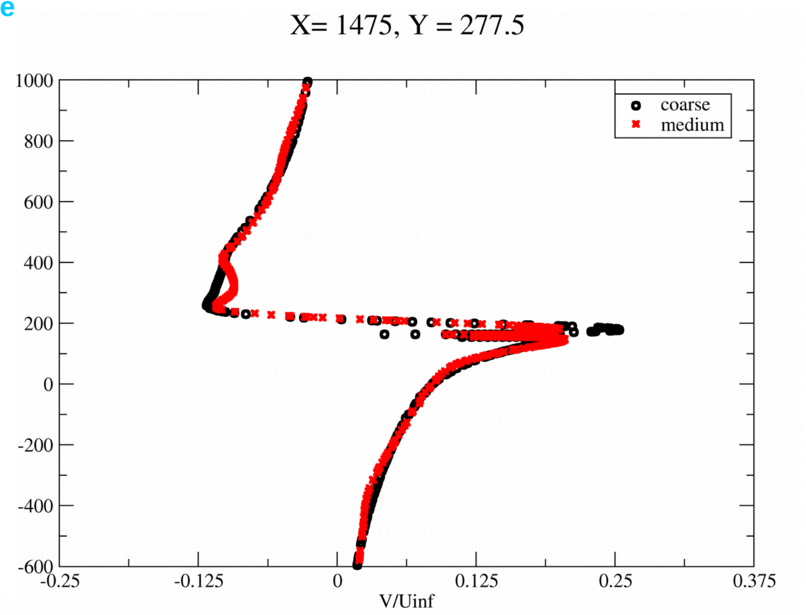


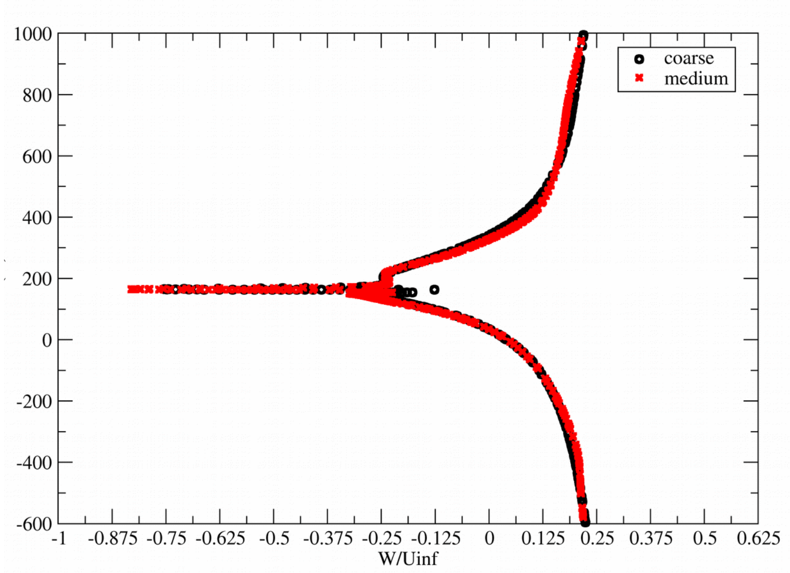
Brief overview of HL-CRM results

Velocity Convergence


X= 1475, Y = 277.5

Auburn Grid
AOA 16^0


X= 1475, Y = 277.5

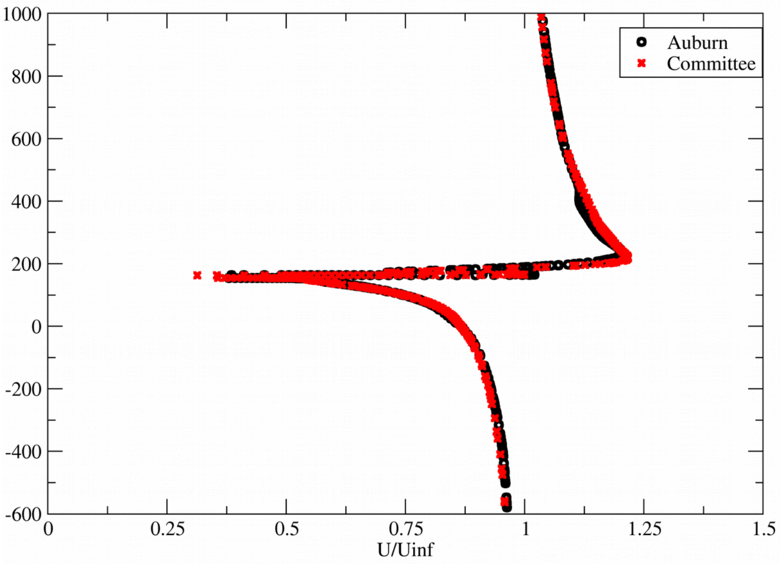

X= 1475, Y = 277.5

Brief overview of HL-CRM results

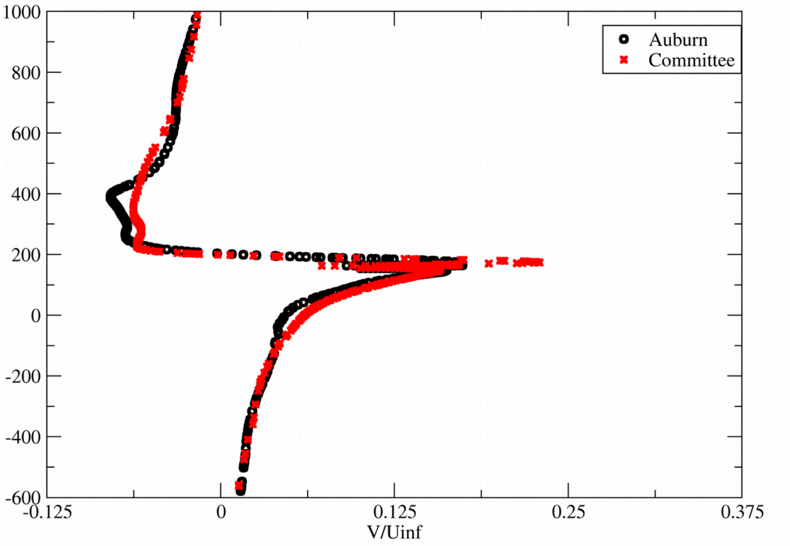
Grid Comparison (Auburn VS Committee)

Medium Grid
AOA 8^0

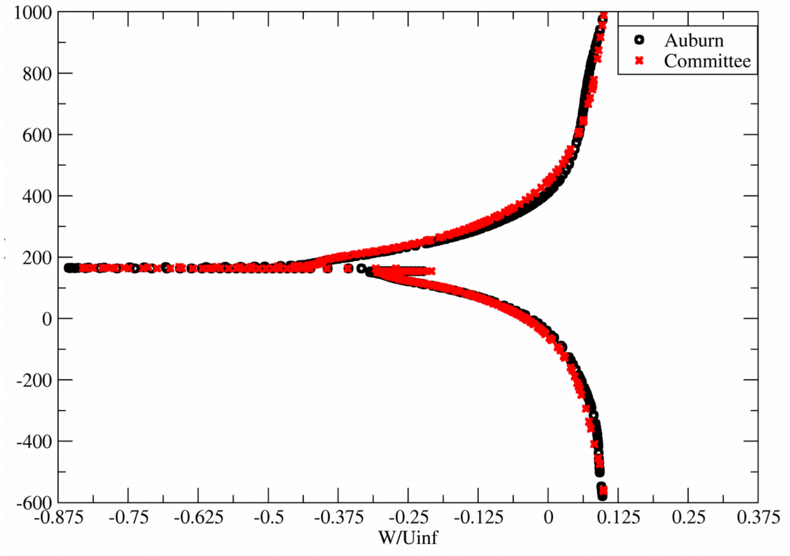
X = 1475, Y = 277.5



X = 1475, Y = 277.5



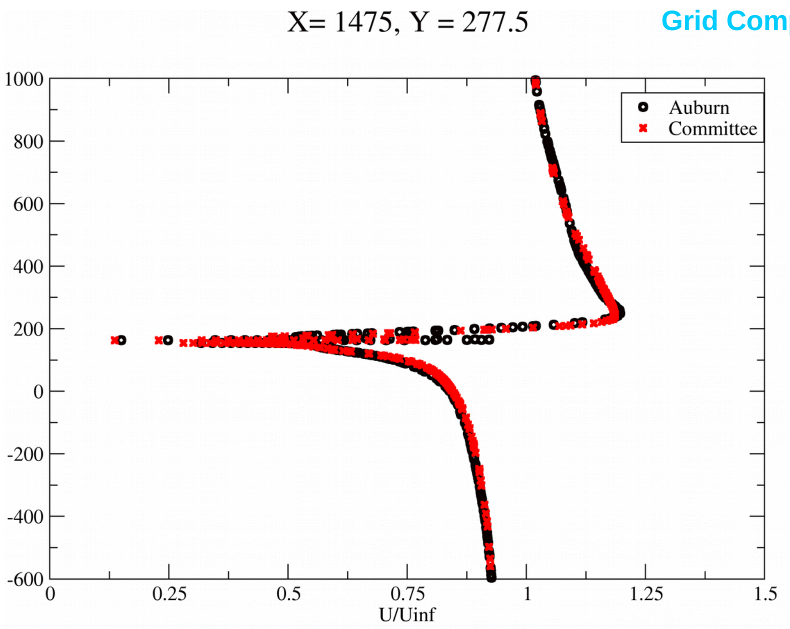
X = 1475, Y = 277.5

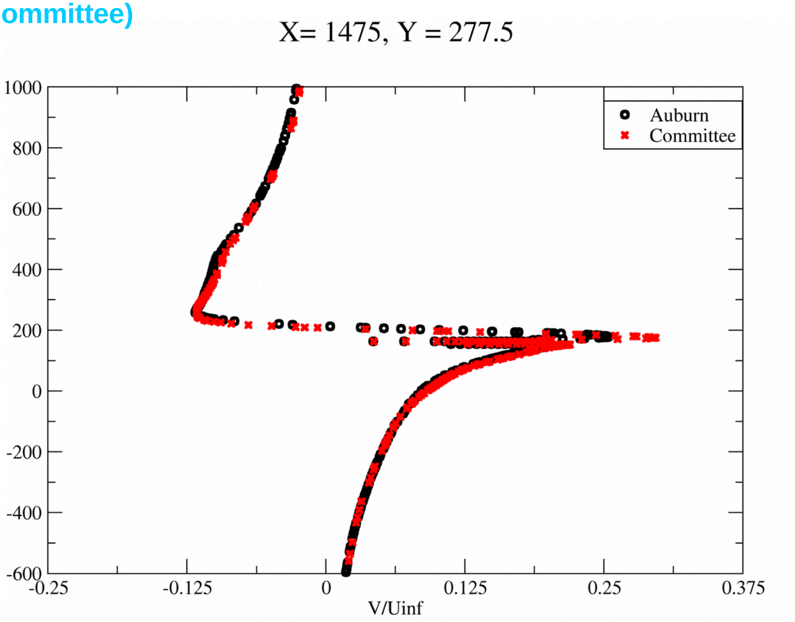


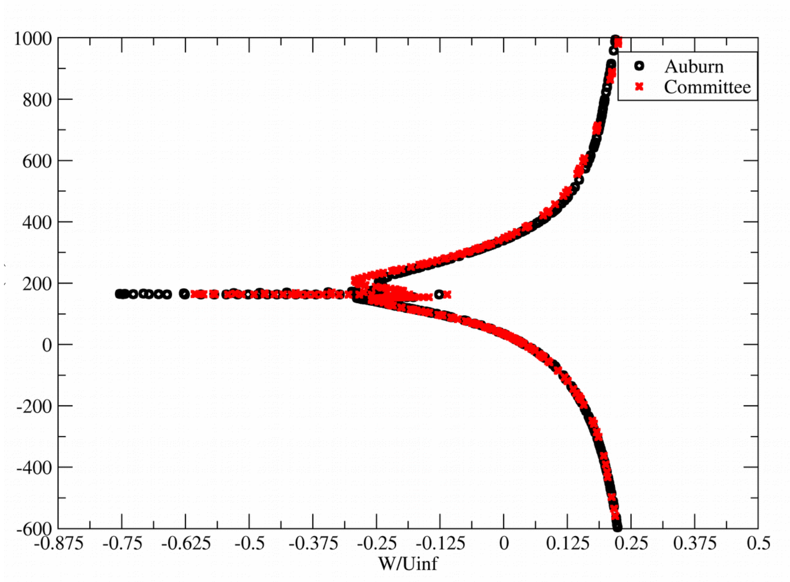
Brief overview of HL-CRM results

Grid Comparison (Auburn VS Committee)

Coarse Grid
AOA 16^0



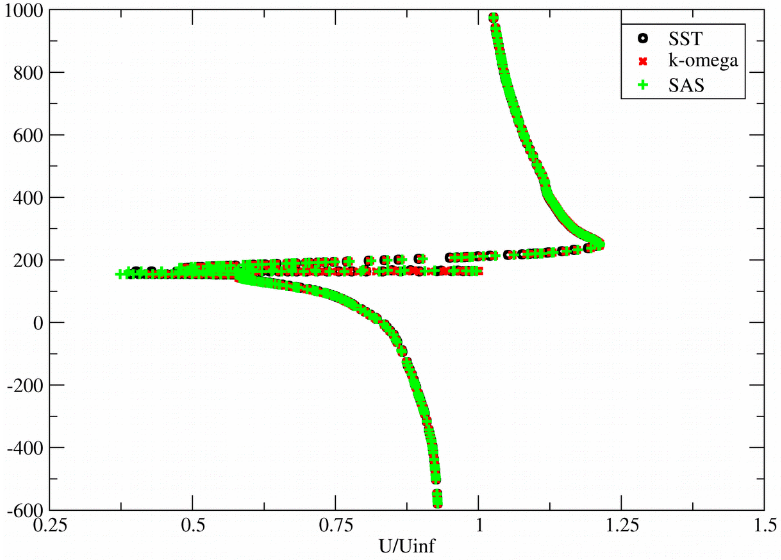




Brief overview of HL-CRM results

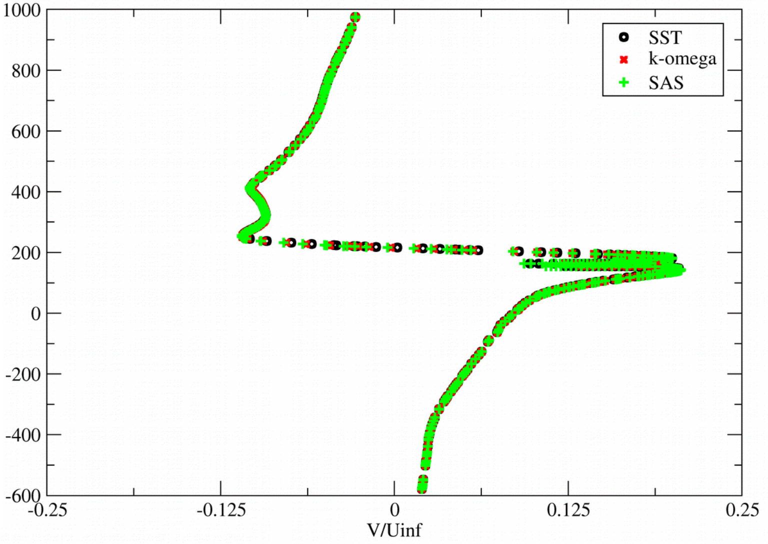
Turbulence Model Comparison (Auburn Grid)

X = 1475, Y = 277.5

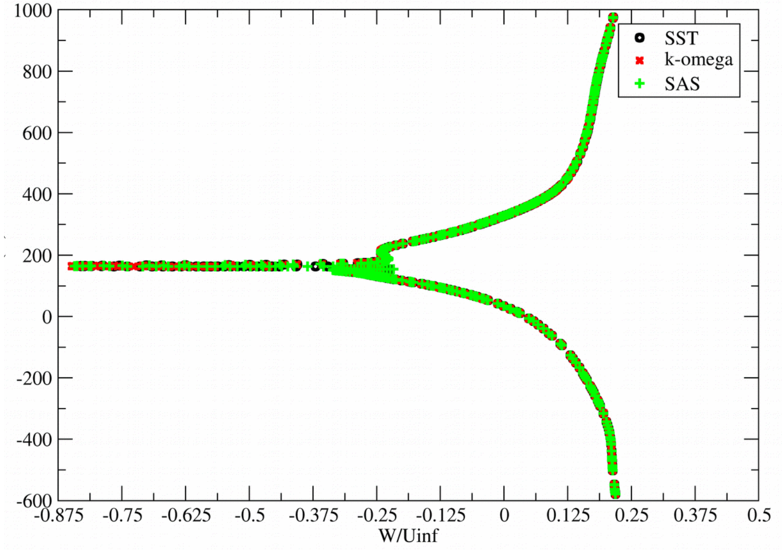


Medium Grid
AOA 16^0

X = 1475, Y = 277.5



X = 1475, Y = 277.5



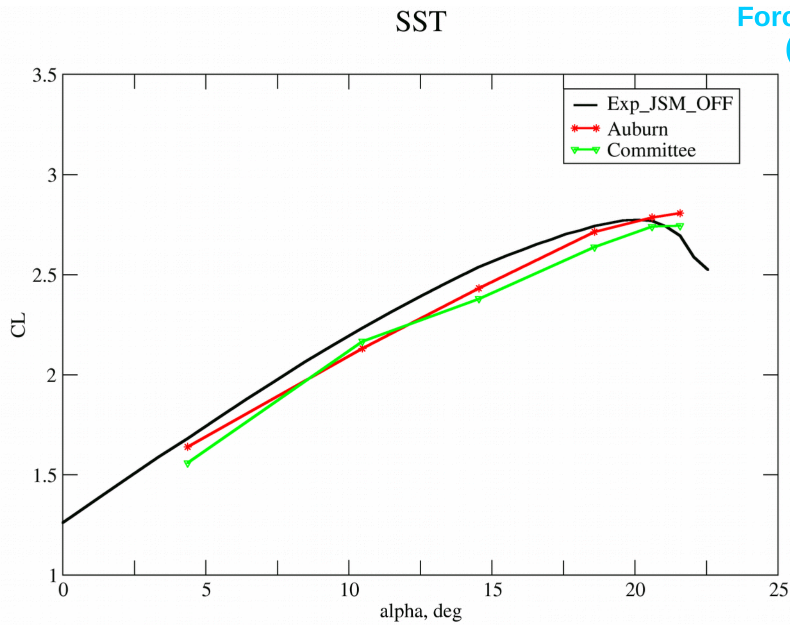
Brief overview of JSM results

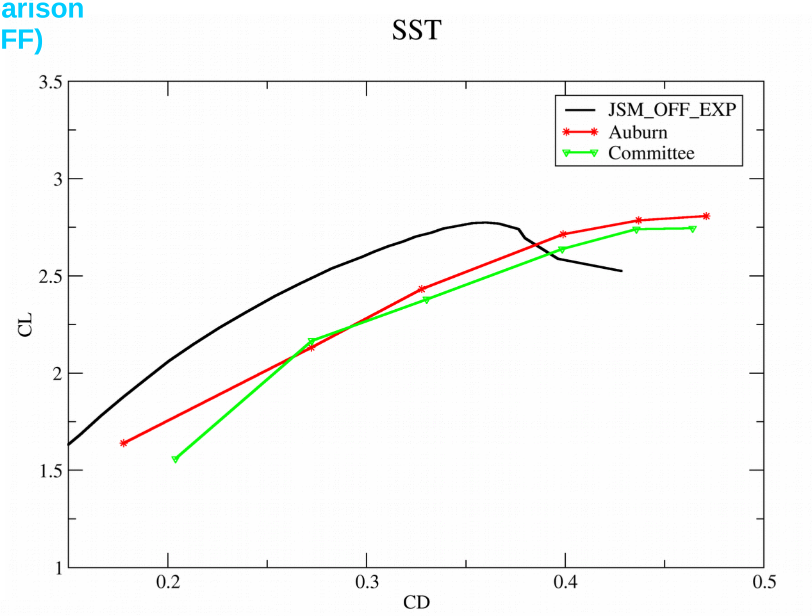
- Force and Moment Comparison
  - CFD under-predicts the CL at linear region of the lift curve
  - CFD over-predicts the CL_{max} and stall occurs at much higher angle of attack than experiments
  - For a given CL, CFD over-predicts CL and CM than experiments
- JSM Nacelle/Pylon OFF Configuration (CP comparison)
  - For most part, CP comparison with experiments are satisfactory
  - It takes longer distance to recover pressure towards the root of the wing compared to experiments
  - Auburn grid results are relatively closer to experiments than Committee grid
  - The prediction of CP at low pressure side is poorer compared to high pressure side of the wing
- JSM Nacelle/Pylon ON Configuration (CP comparison)
  - Wilcox k-omega results are relatively better at predicting CP than Mentor SST model
  - More investigation is required on the effect of turbulence models on the Nacelle/Pylon ON configuration (comparing results of two different models with Auburn Grid)

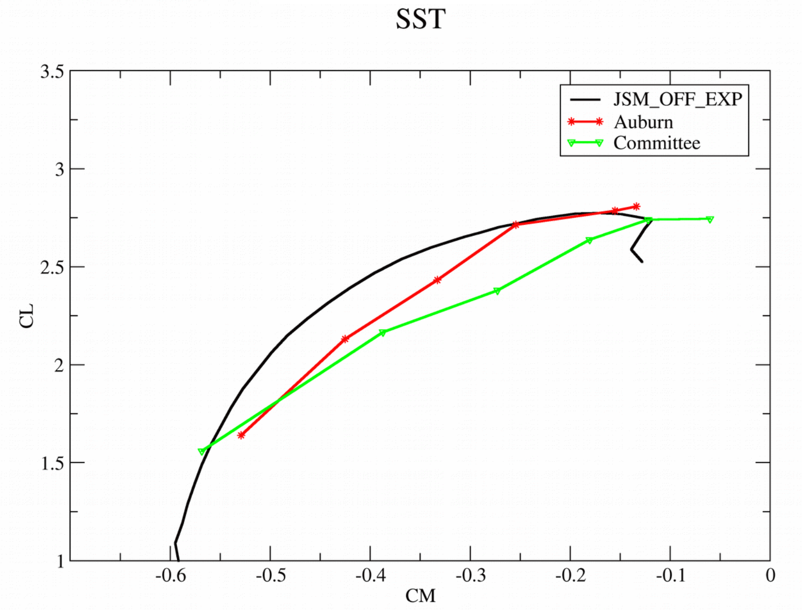
Brief overview of JSM results

Force and Moment Comparison
(JSM Nacelle/Pylon OFF)

Medium Grid

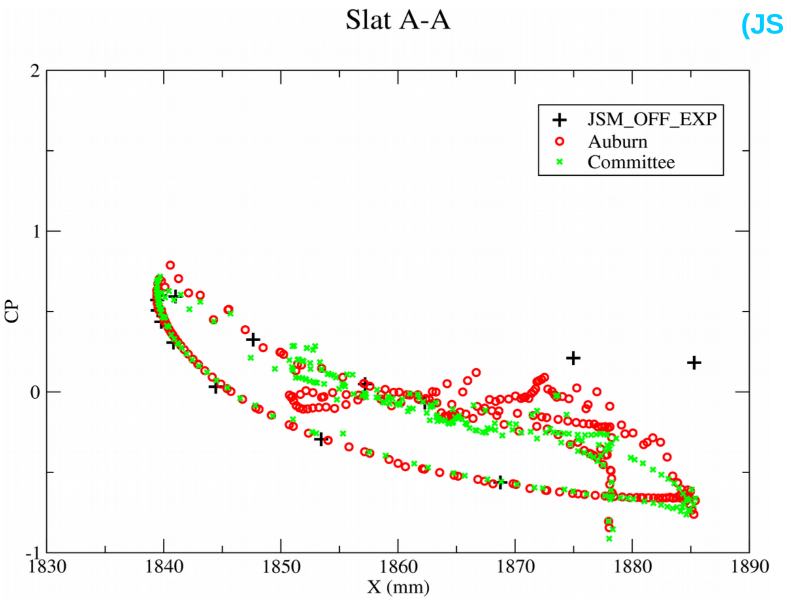




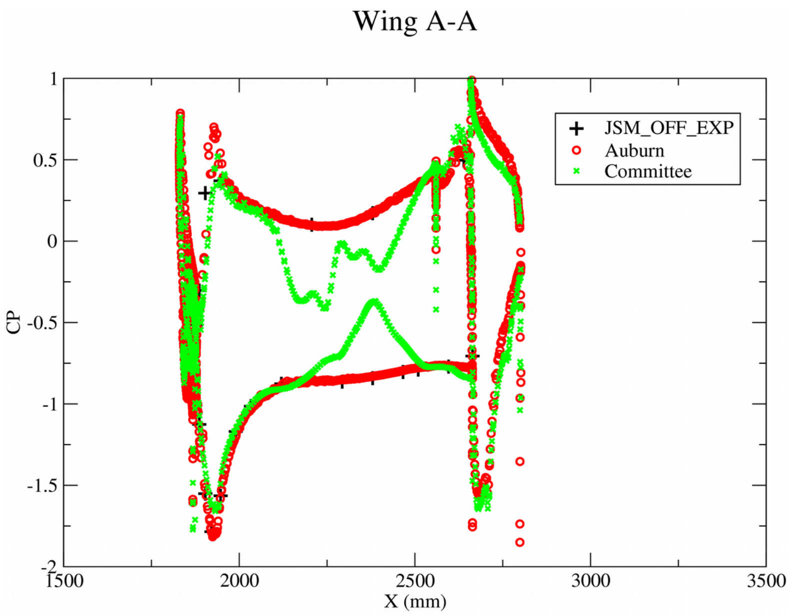


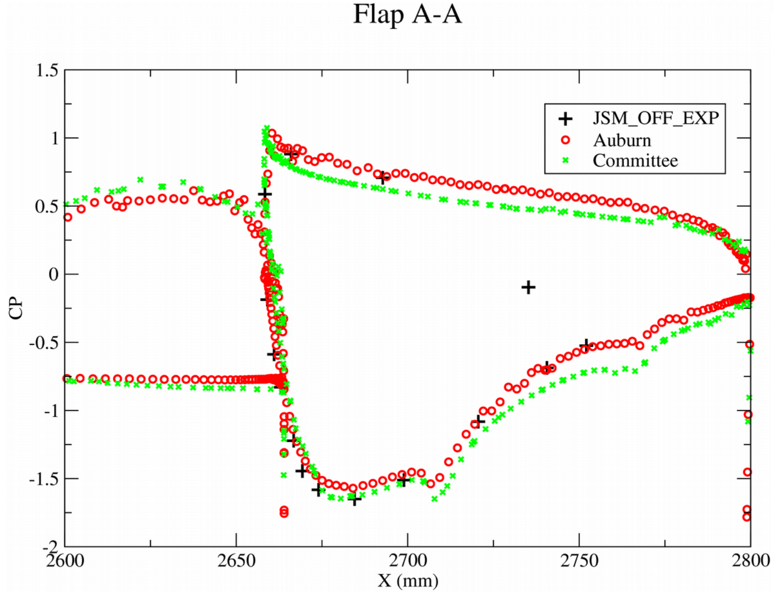
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)



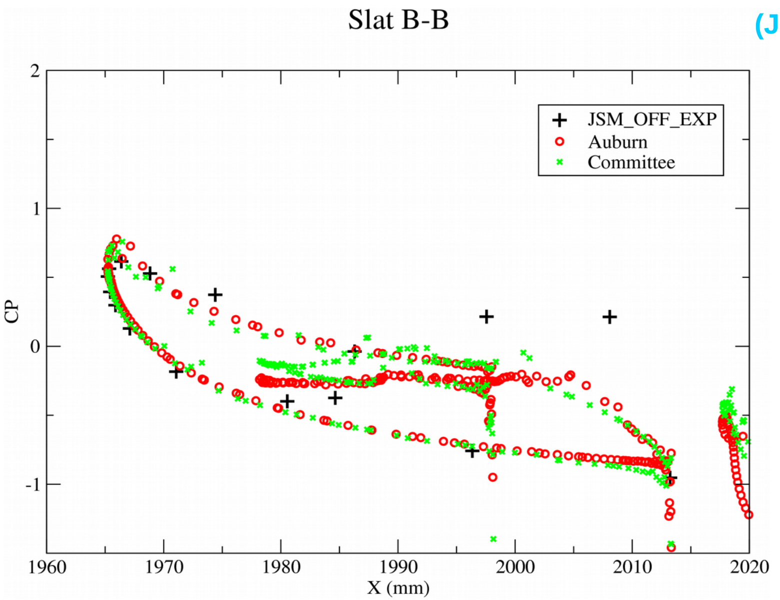
Medium Grid
4.36^0



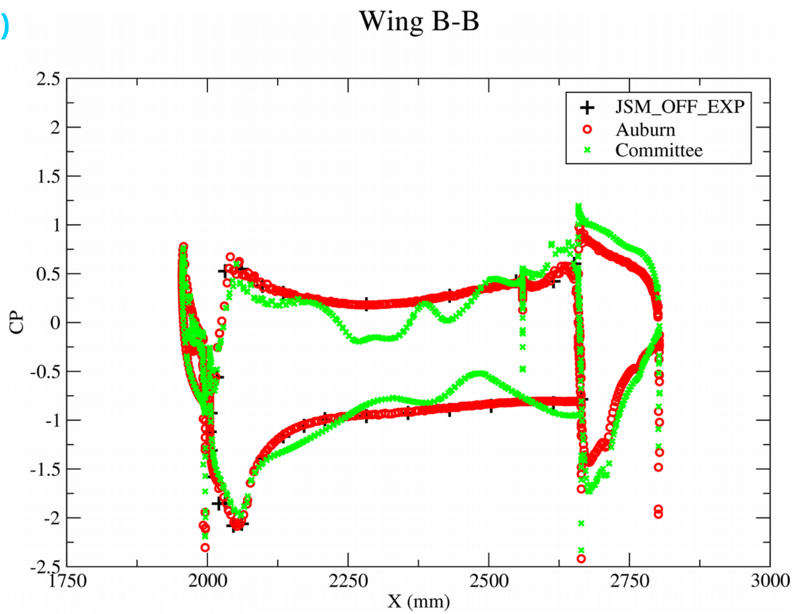


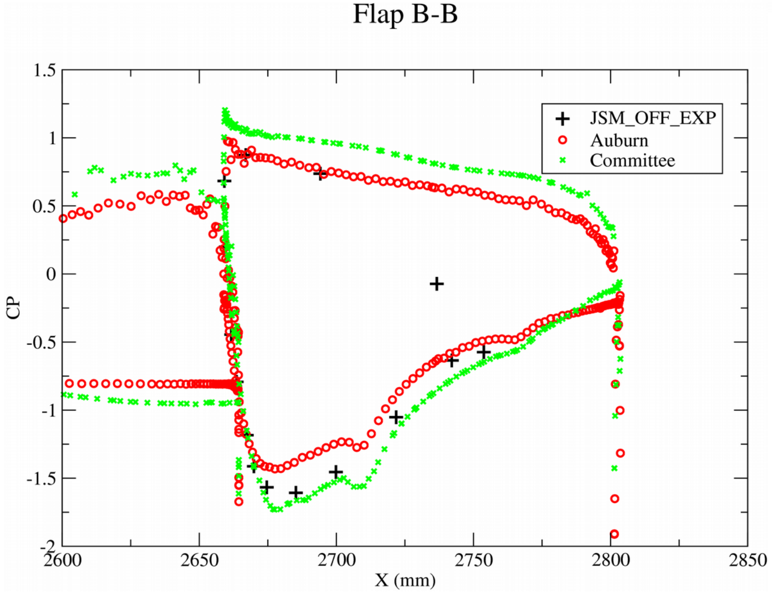
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)



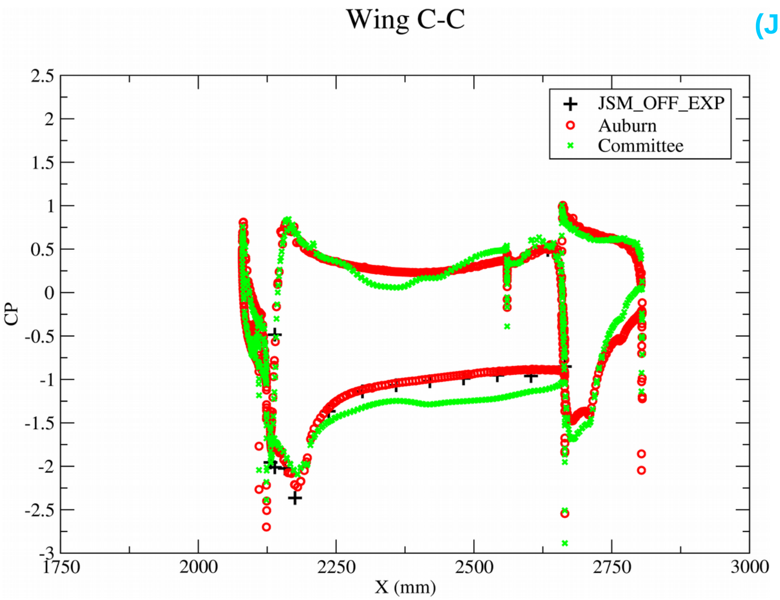
Medium Grid
4.36^0





Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)



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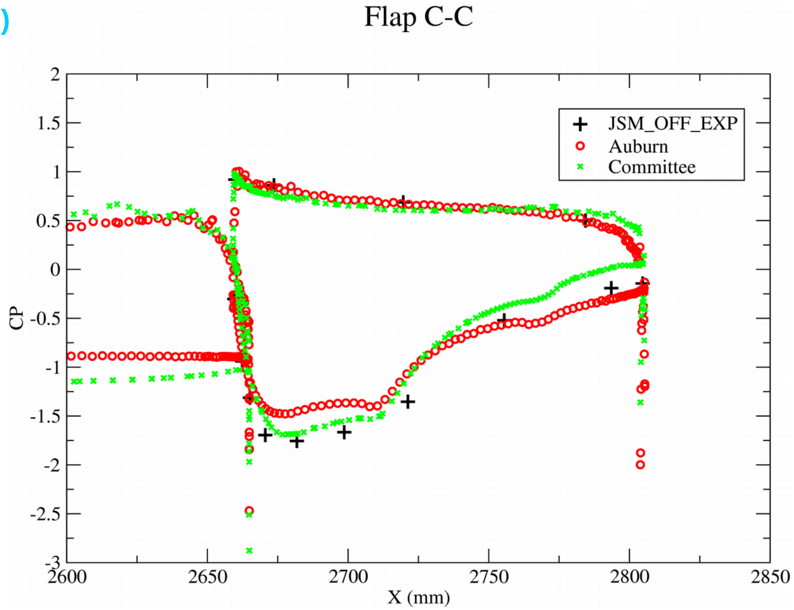
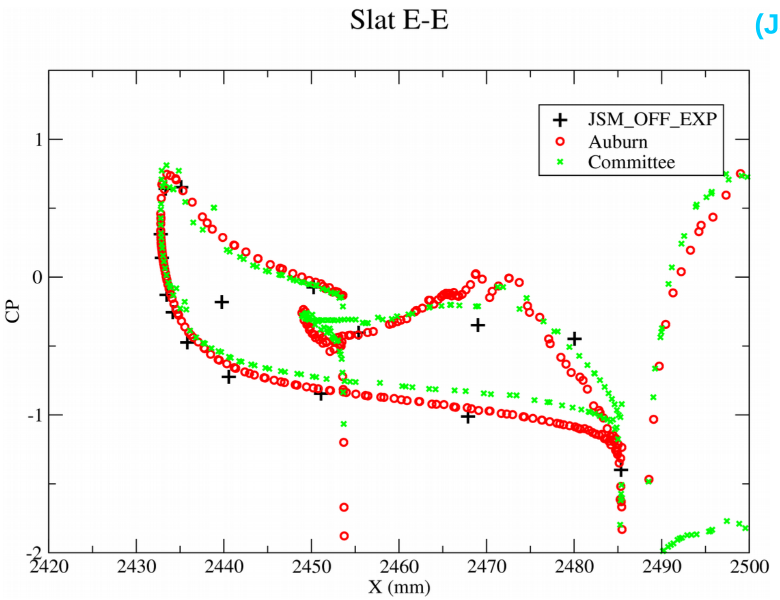
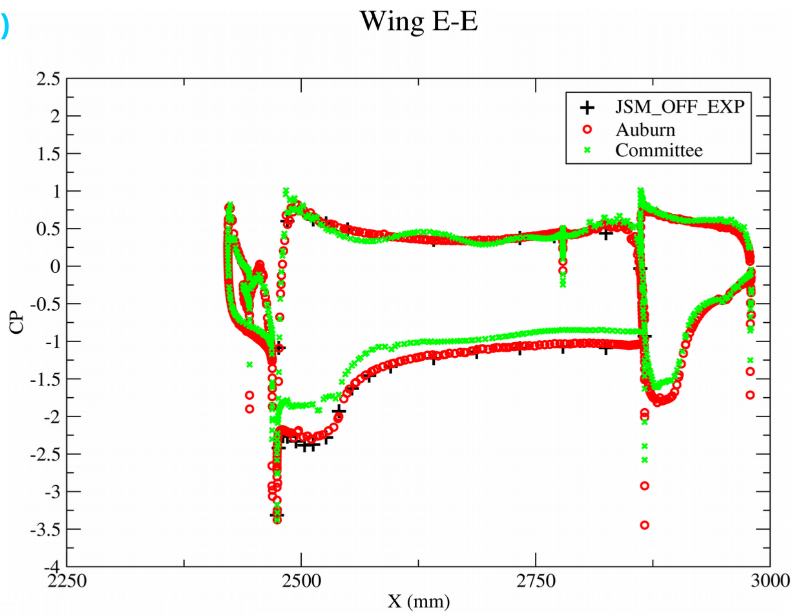


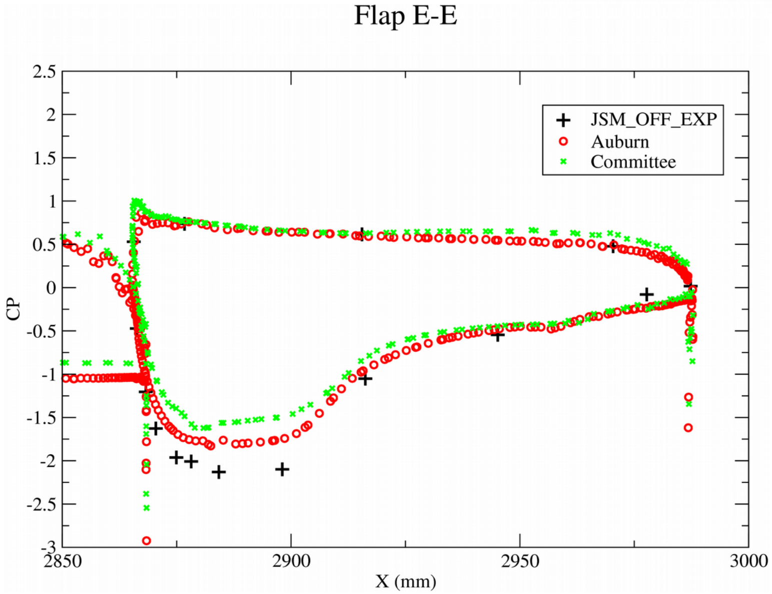
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)



Medium Grid
4.36^0

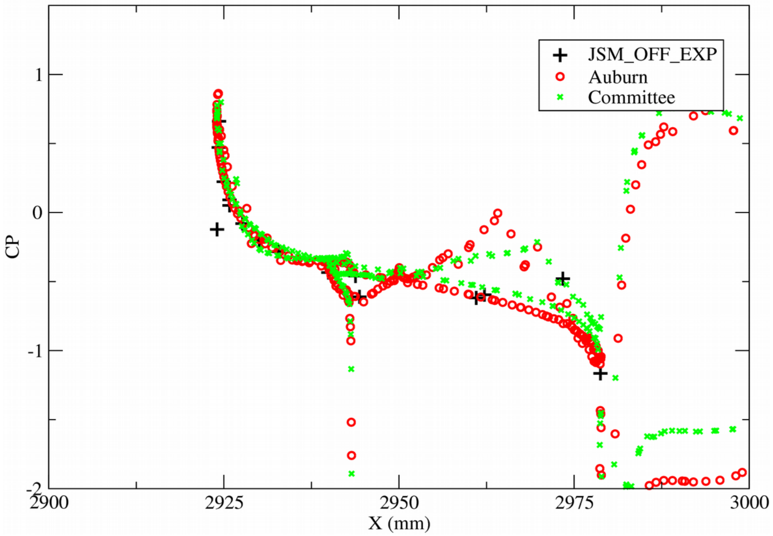




Brief overview of JSM results

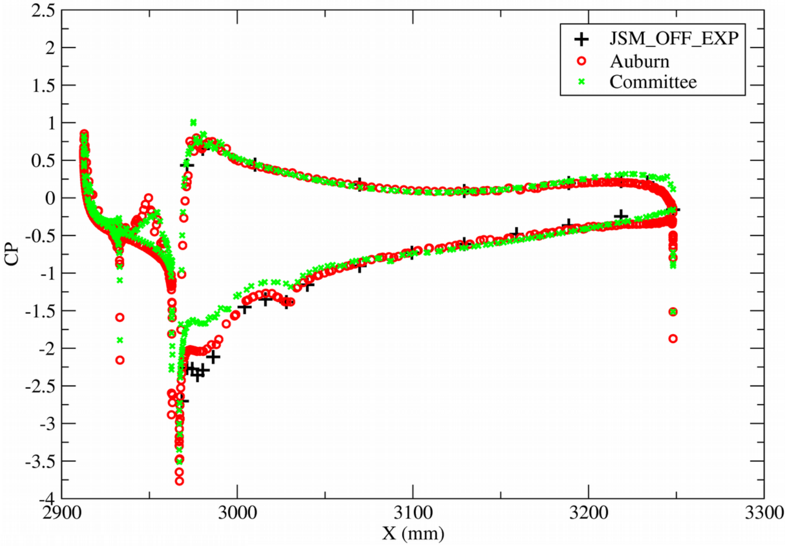
CP Comparison
(JSM Nacelle/Pylon OFF)

Slat H-H

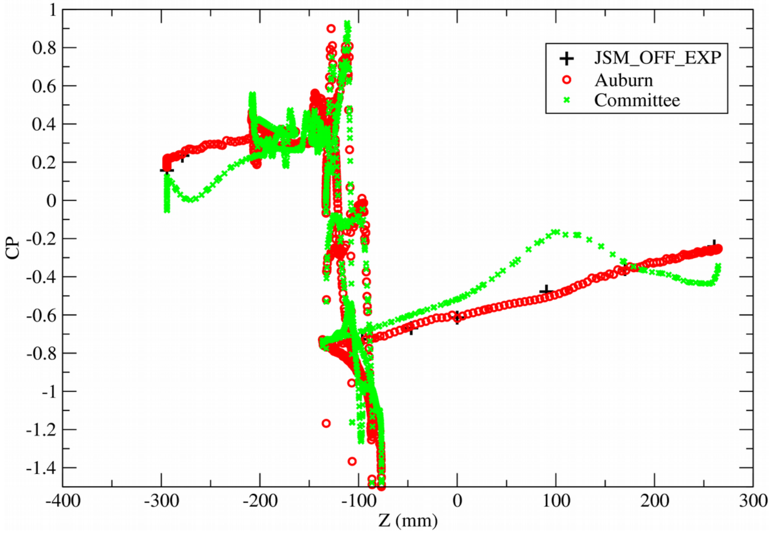


Medium Grid
4.36^0

Wing H-H



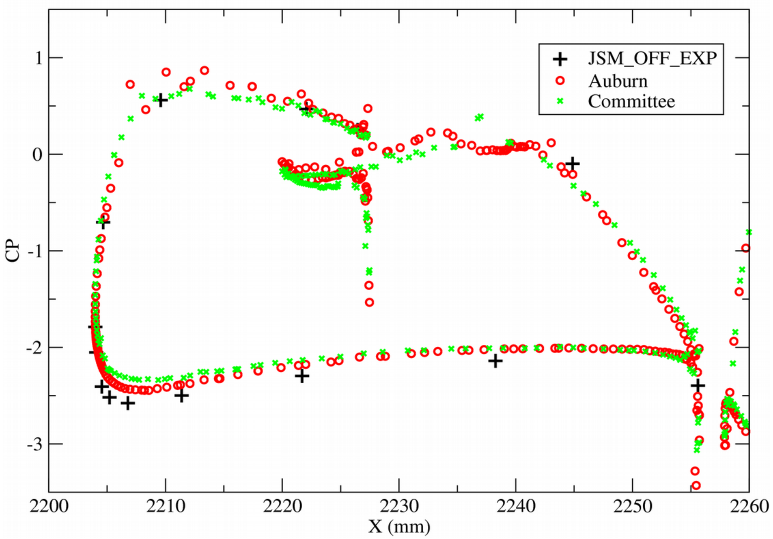
Fuselage N-N



Brief overview of JSM results

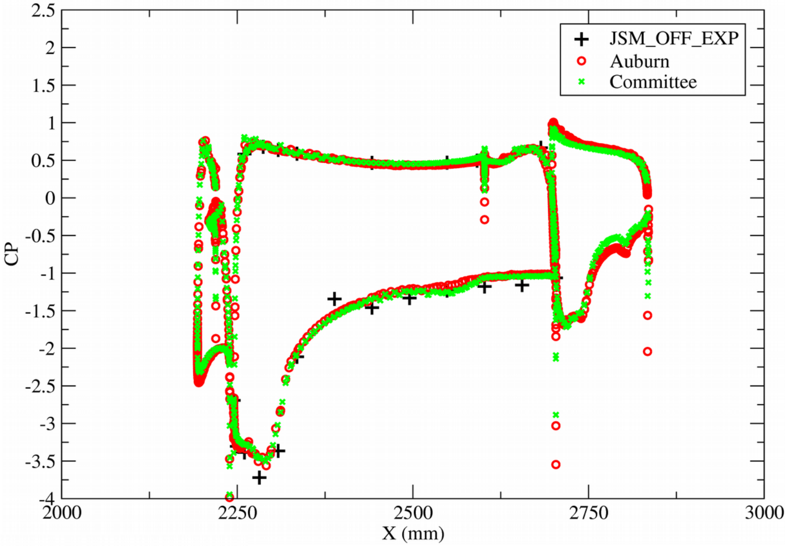
CP Comparison
(JSM Nacelle/Pylon OFF)

Slat D-D

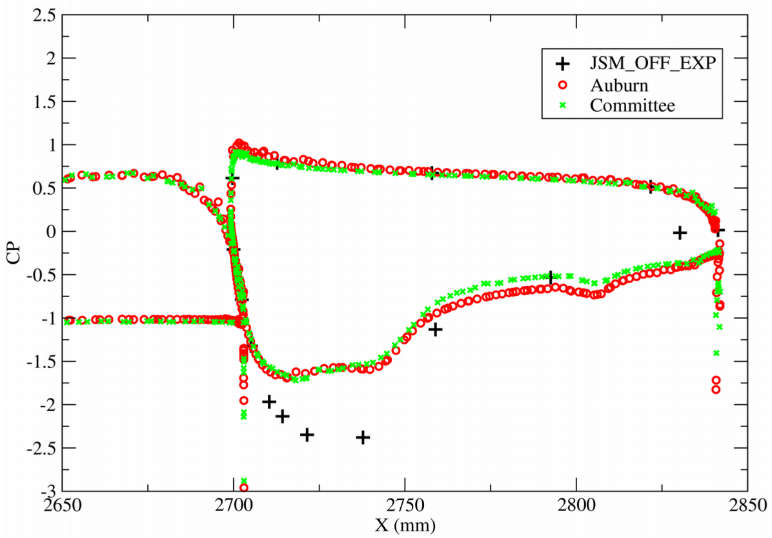


Medium Grid
10.47^0

Wing D-D

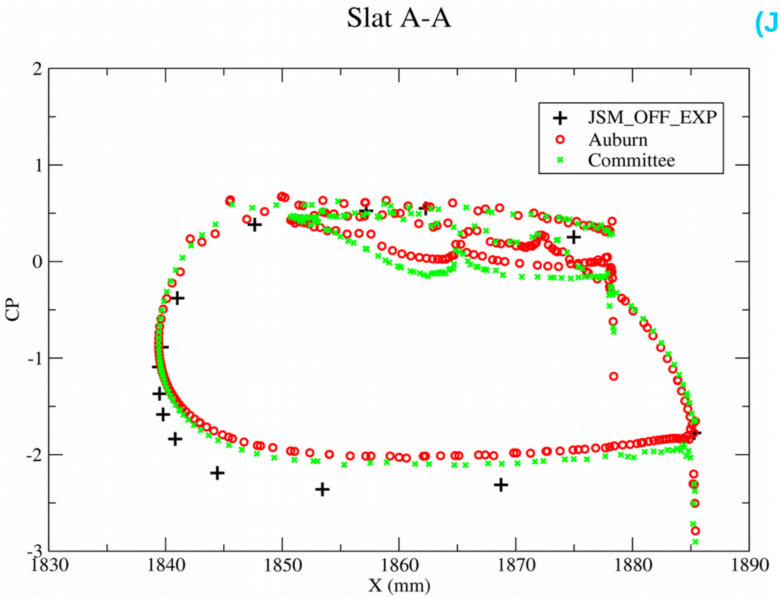


Flap D-D

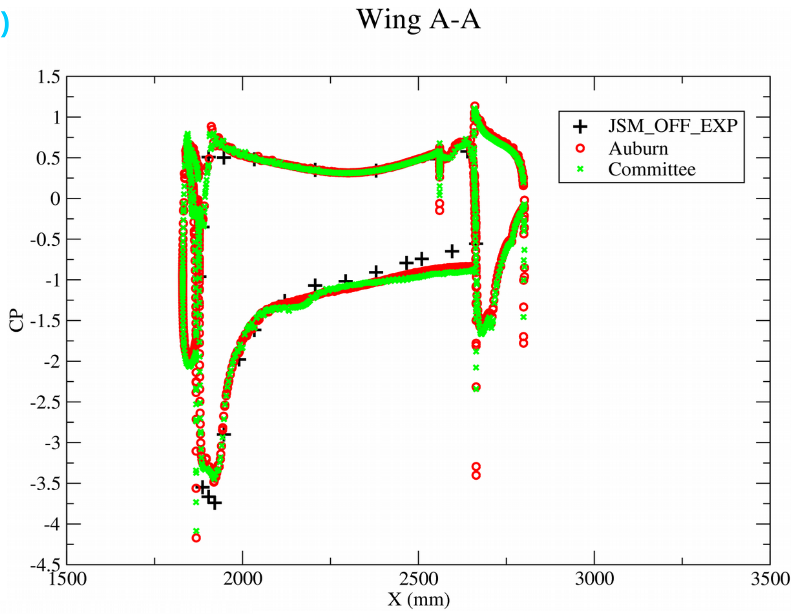


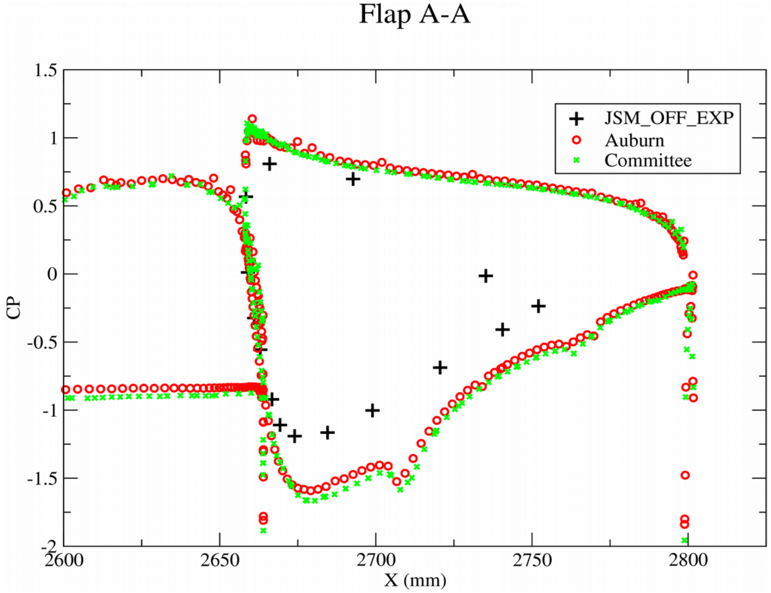
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon OFF)



Medium Grid
14.54⁰

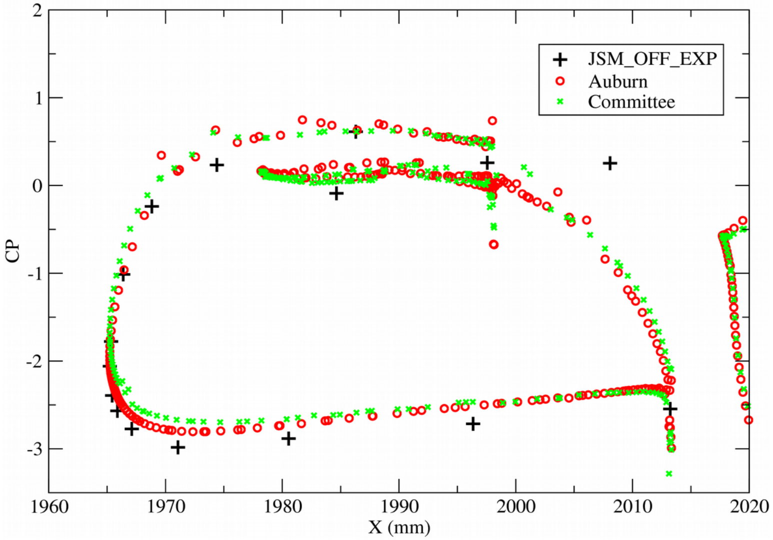




Brief overview of JSM results

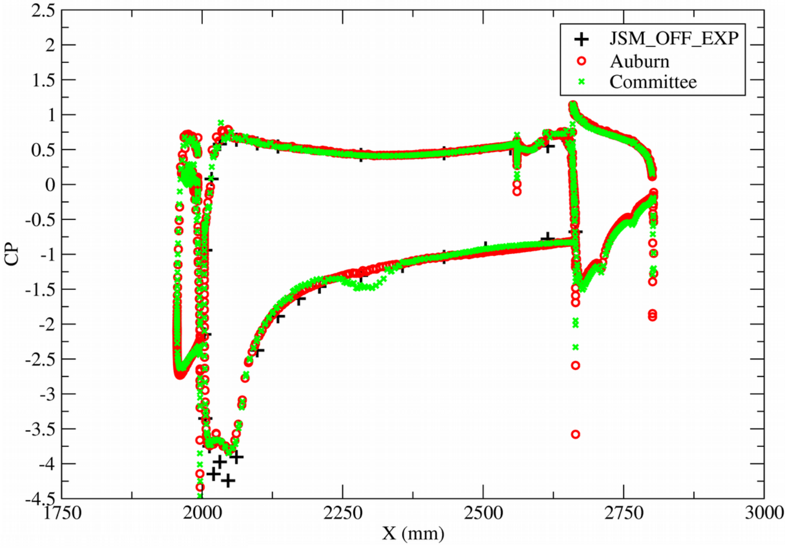
CP Comparison
(JSM Nacelle/Pylon OFF)

Slat B-B

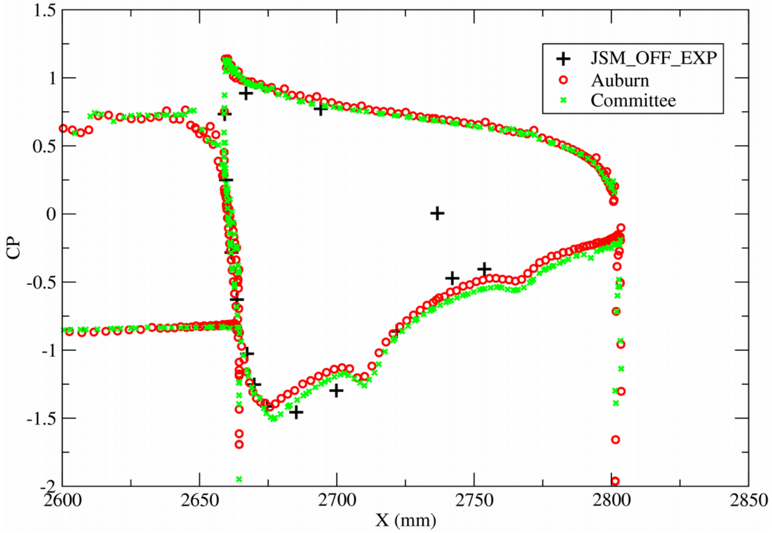


Medium Grid
14.54^0

Wing B-B



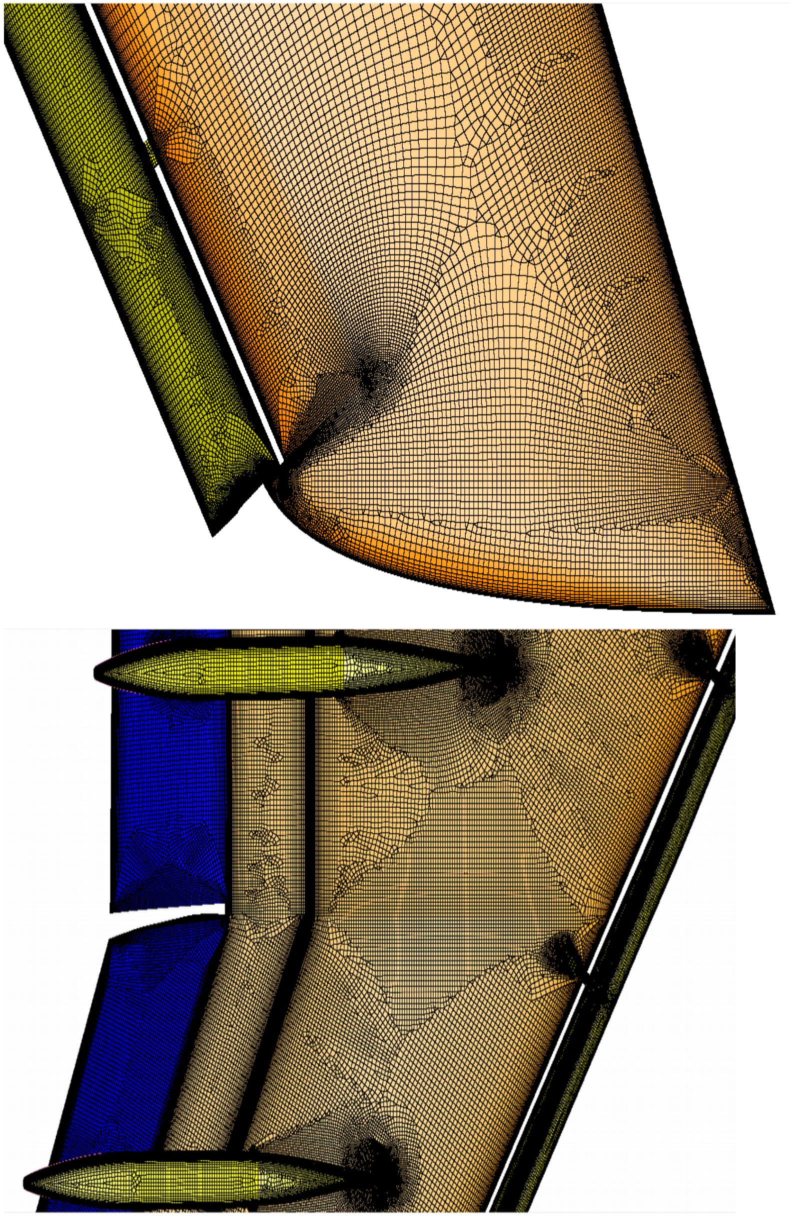
Flap B-B



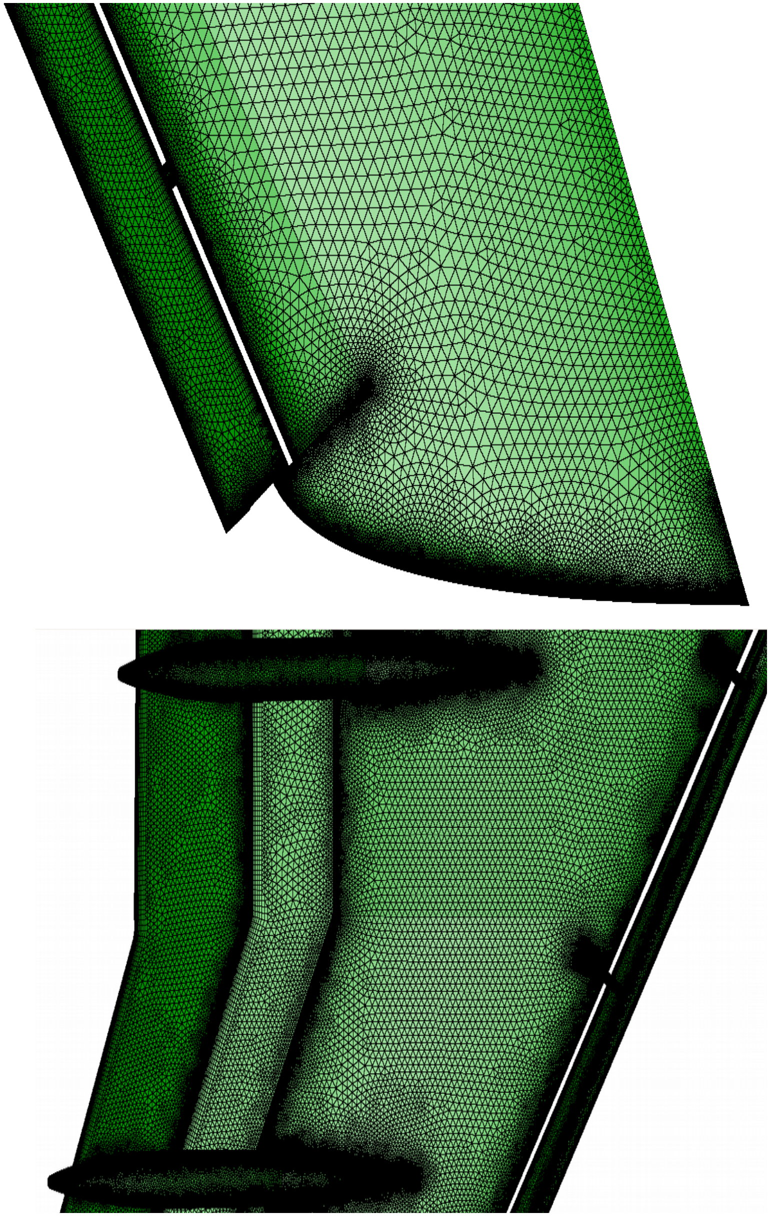
Brief overview of JSM results

GRID Comparison
(Auburn VS ANSA)

Medium Grid
JSM
Nacelle/Pylon
OFF



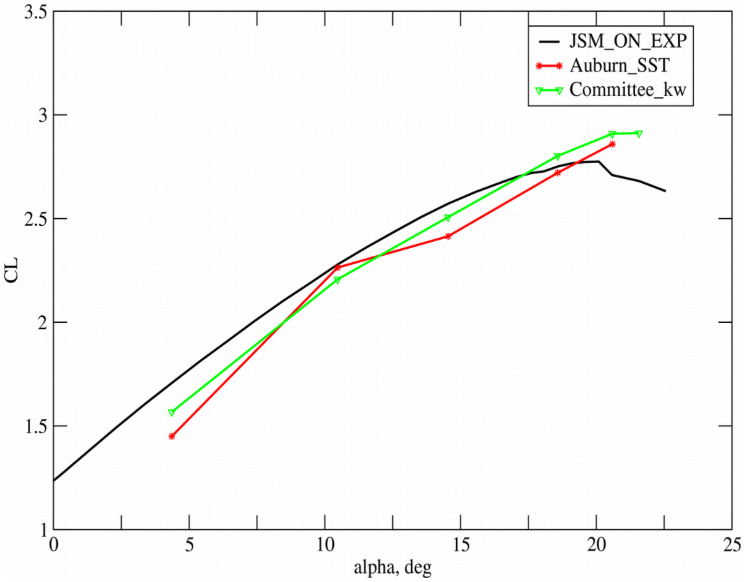
Auburn Grid



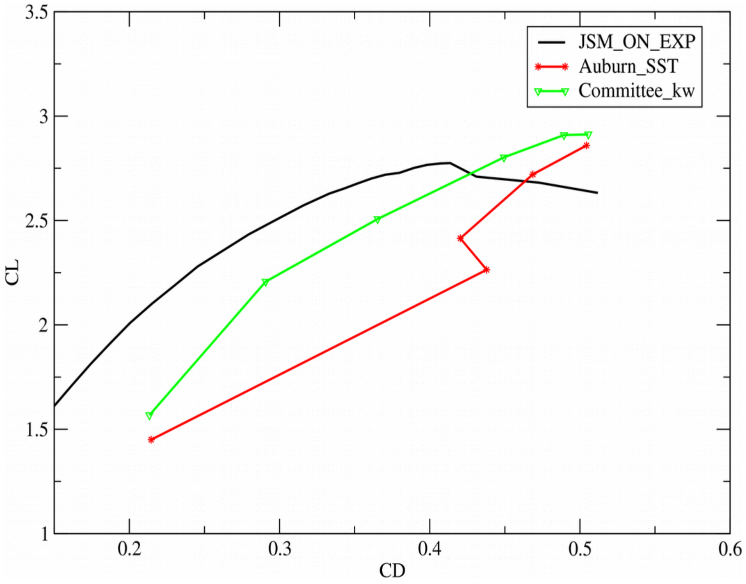
ANSA Grid

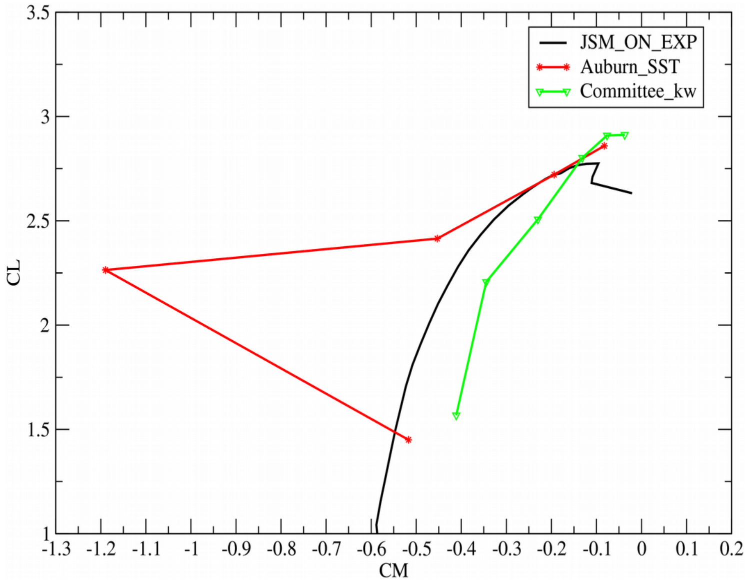
Brief overview of JSM results

Force and Moment Comparison
(JSM Nacelle/Pylon ON)



Medium Grid

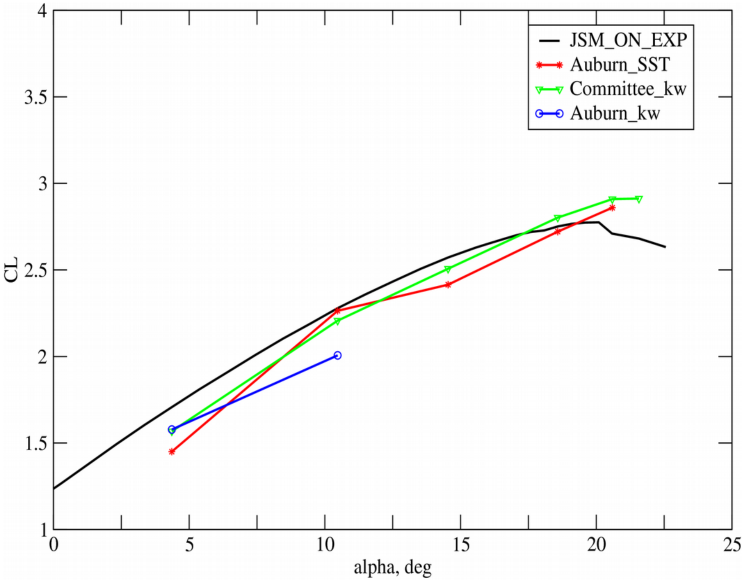


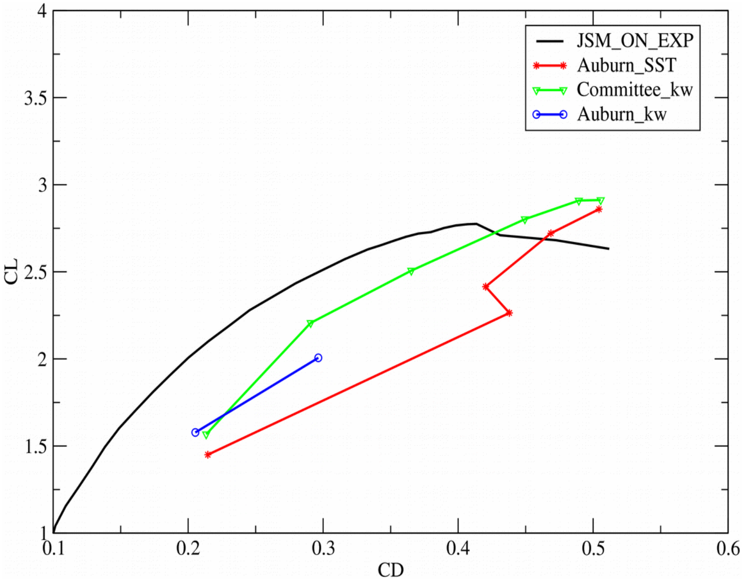


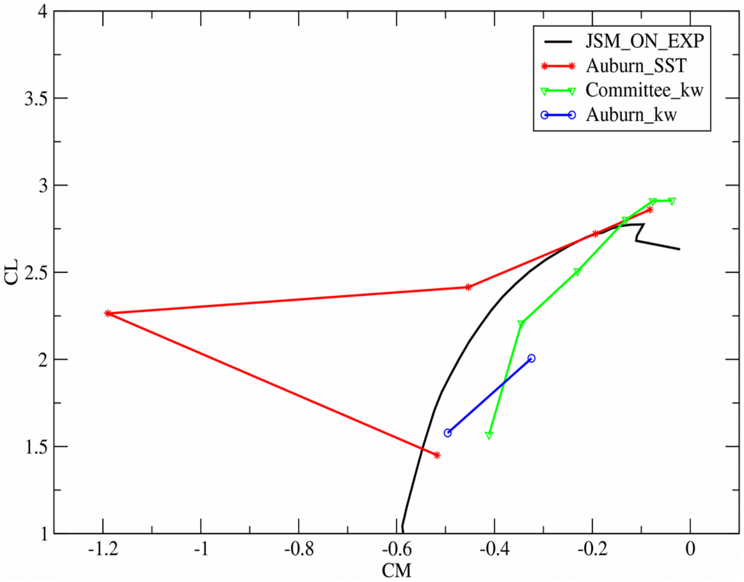
Brief overview of JSM results

Force and Moment Comparison
(JSM Nacelle/Pylon ON)

Medium Grid

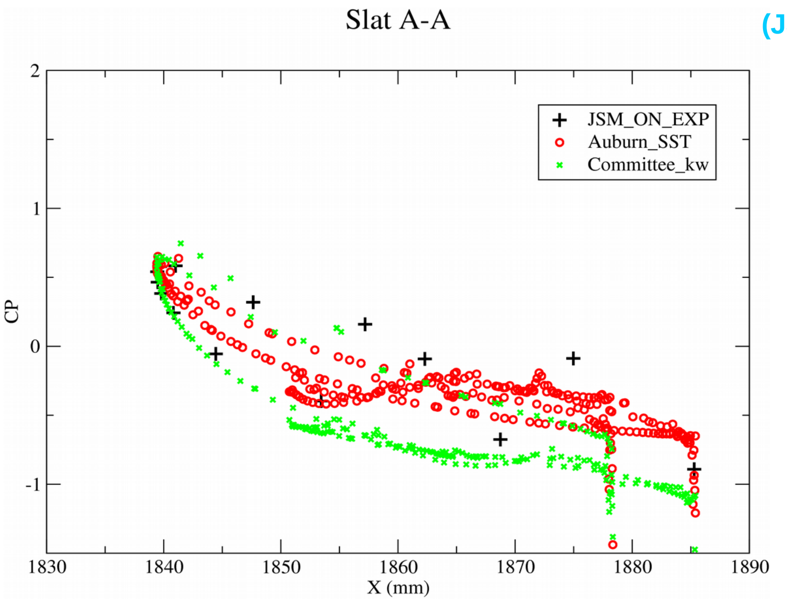




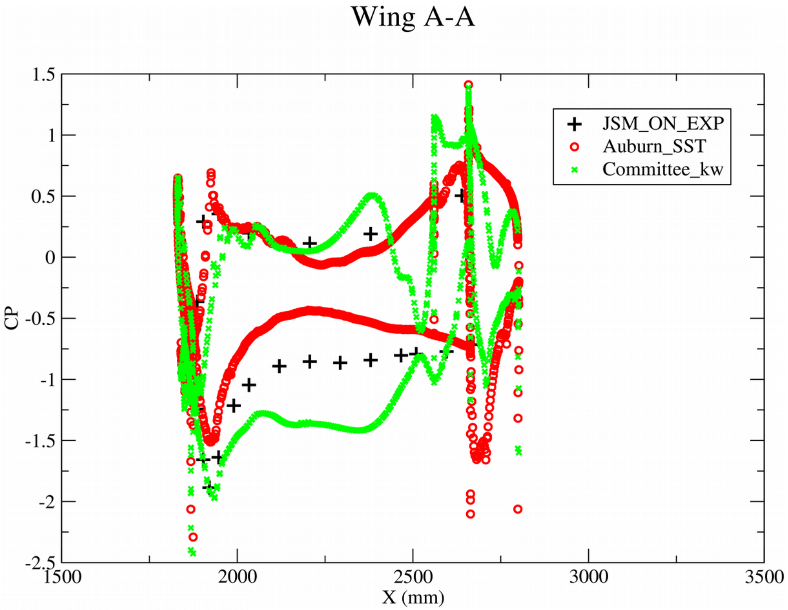


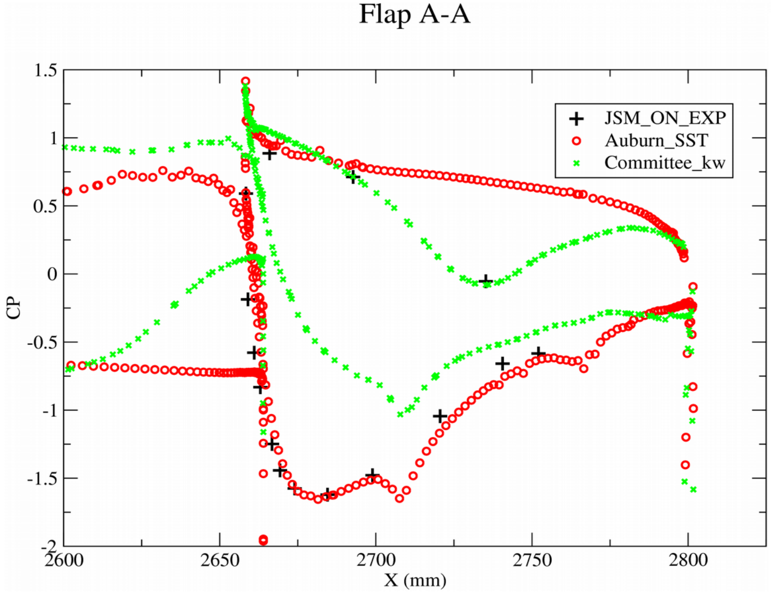
Brief overview of JSM results

CP Comparison (JSM Nacelle/Pylon ON)


Slat A-A

Medium Grid
4.36^0

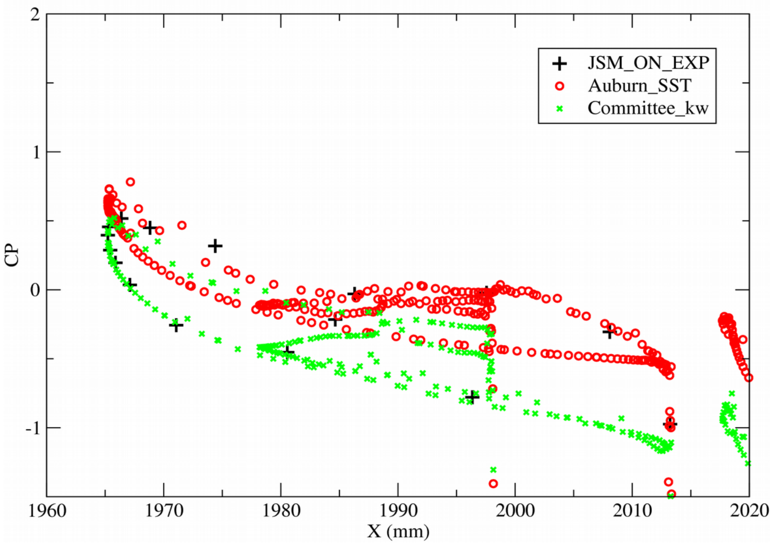

Wing A-A

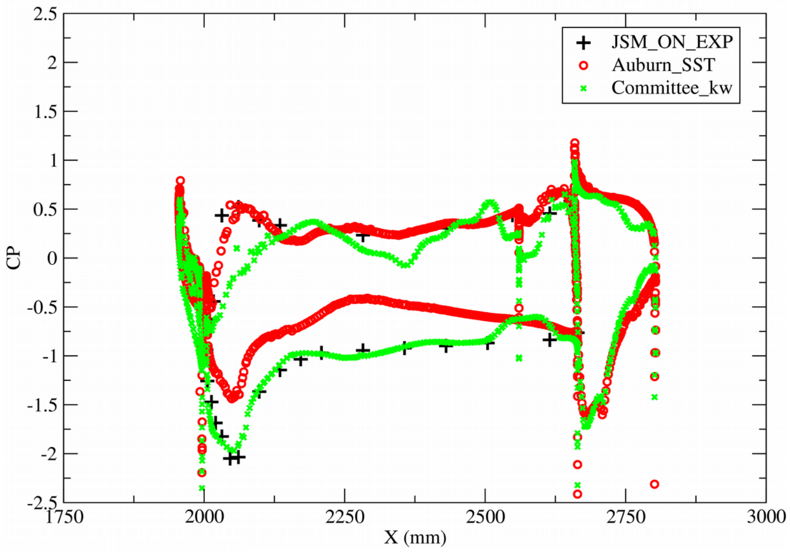

Flap A-A

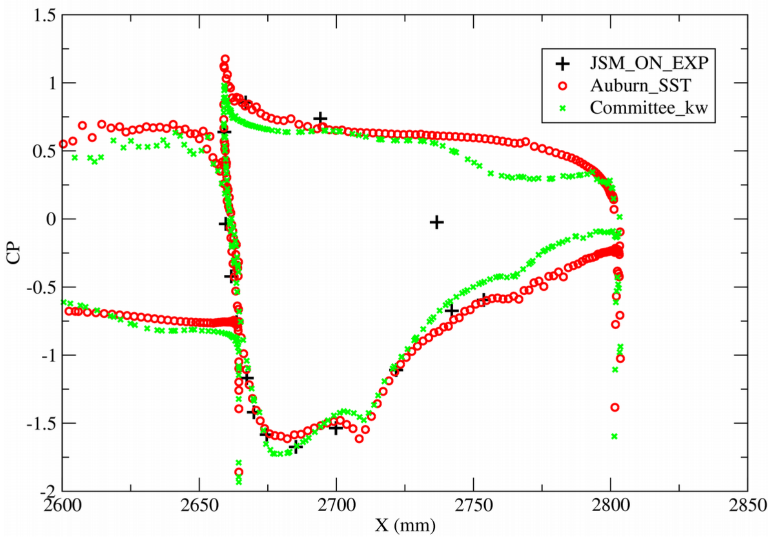
Brief overview of JSM results

CP Comparison (JSM Nacelle/Pylon ON)

Medium Grid 4.36^{0}


Slat B-B

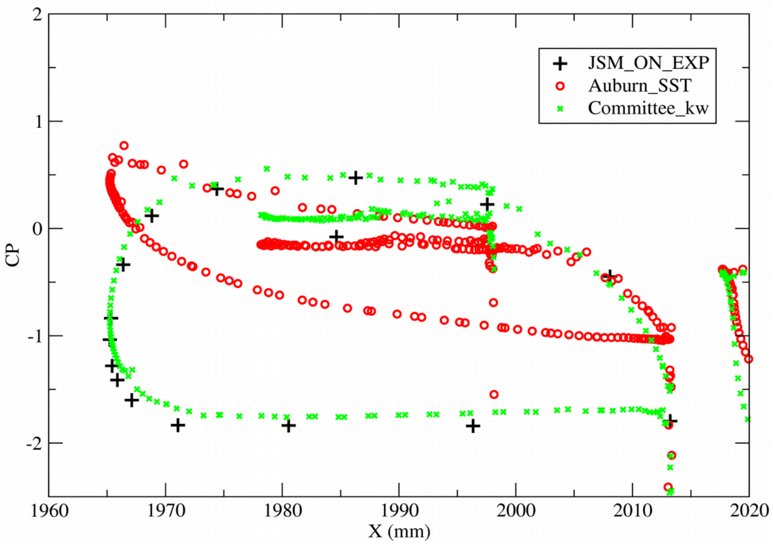

Wing B-B


Flap B-B

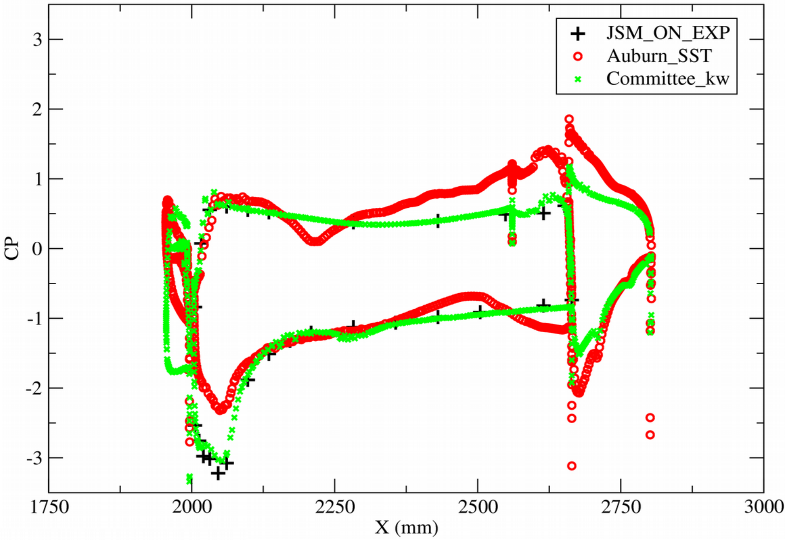
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon ON)

Slat B-B

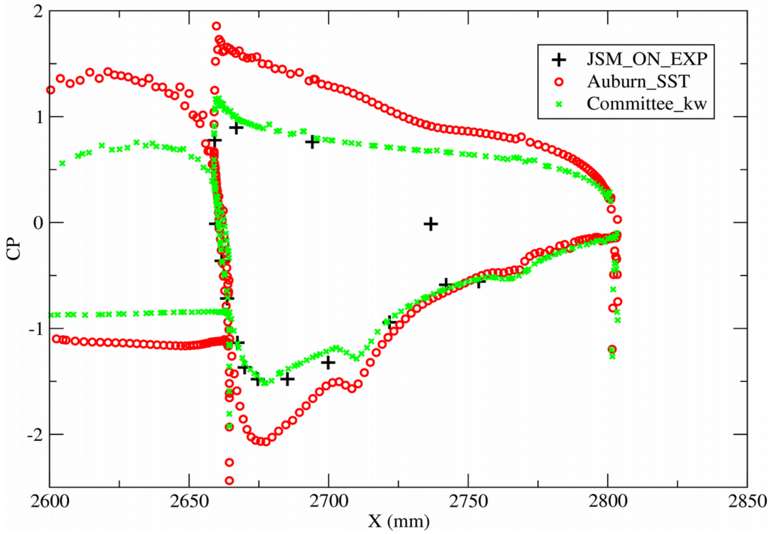


Wing B-B



Medium Grid
10.47^0

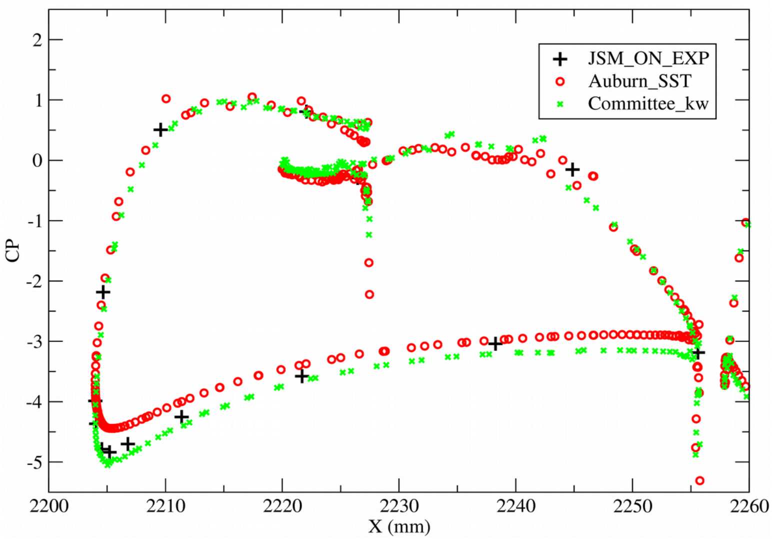
Flap B-B

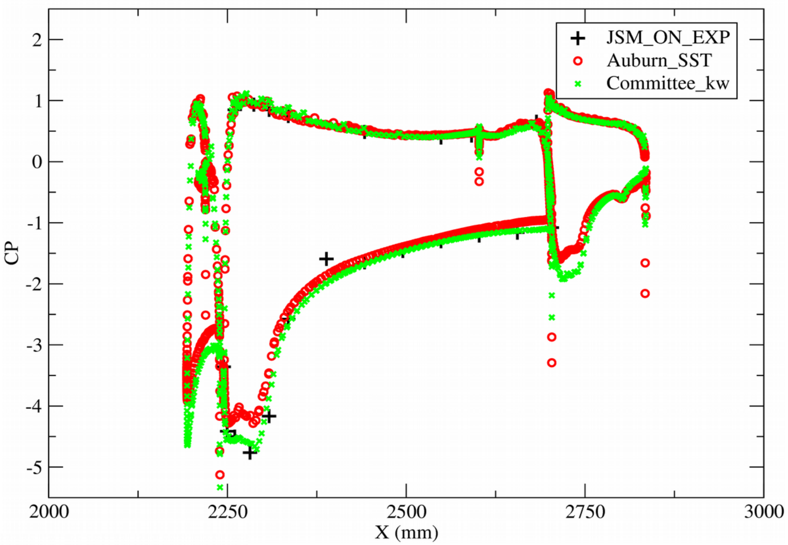


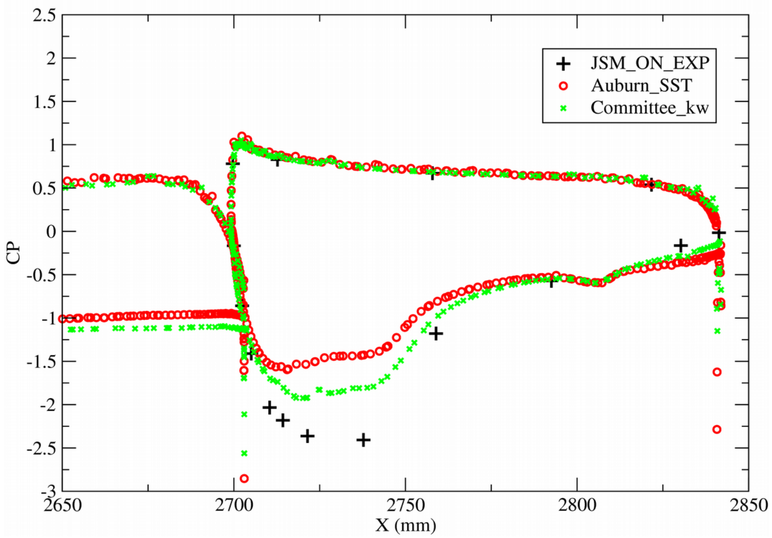
Brief overview of JSM results

CP Comparison (JSM Nacelle/Pylon ON)

Medium Grid 18.58^0

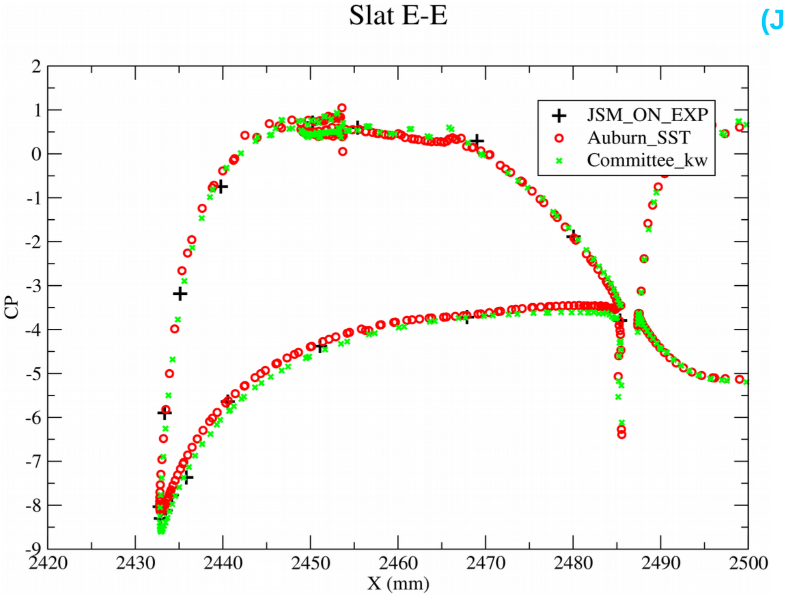

Slat D-D


Wing D-D

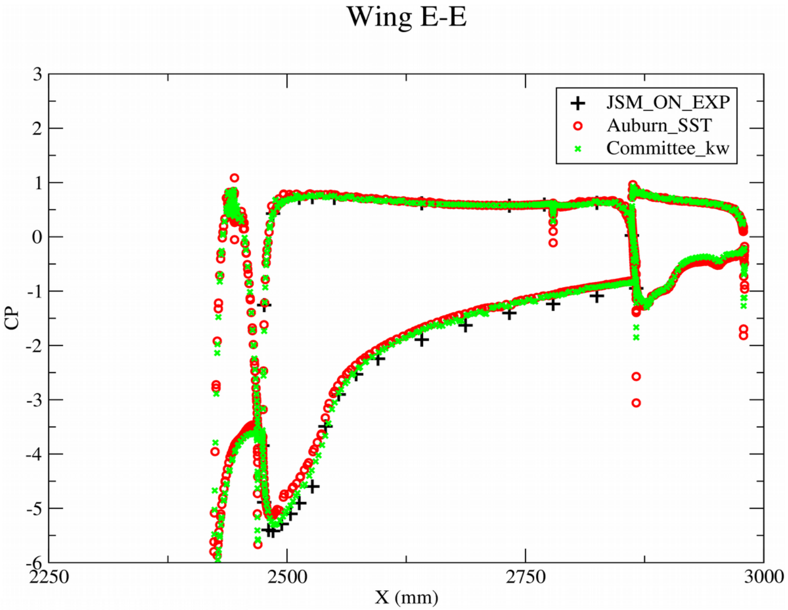

Flap D-D

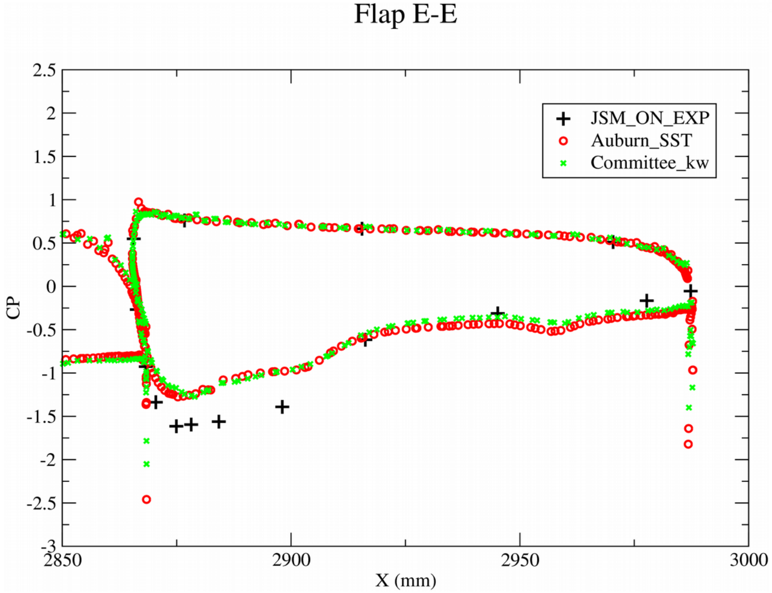
Brief overview of JSM results

CP Comparison
(JSM Nacelle/Pylon ON)



Medium Grid
18.58^0





Summary

- Mesh generation for high lift configurations is challenging
- Turbulence model plays significant influence on the force and moment prediction
- CFD predicts CP with acceptable accuracy for most of the wing elements
- Provided committee grids are compatible with the solver and did not show any convergence issue
- Flow field associated with Nacelle/Pylon ON configuration is difficult to resolve with SST model (based on TENASI results…work in progress)
- Since half-span test data is consistent with the CFD results, half-span tests are valid for high lift experiments
- Prediction of CLmax and stall might improve with the transition modeling in the CFD solutions (work in progress)
- Hybrid RANS-LES modeling might improve the overall CFD predictability of high-lift flow field (work in progress)