Results from DoD HPCMP CREATE^{TM}-AV Kestrel for the 3rd AIAA High Lift Prediction Workshop

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DOD HPC MODERNIZATION PROGRAM

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Kestrel Overview

- High-fidelity, physics-based tool for problems of interest to the DoD acquisition community
- Contains 3 CFD solvers, all of which can be run in steady-state or time-accurate modes
  - KCFD
    - Up to 2nd Order, unstructured cell-centered Finite-Volume
    - SA, SARC, Menter BSL, Menter SST, and their DDES variants
    - Menter 1-equation (intermittency) transition model
  - SAMAir
    - Up to 5th Order, Cartesian Finite-Volume
    - Overset; coupled to near-body solver through PUNDIT
    - SA, SARC, Menter BSL, Menter SST with infinite wall distance
  - COFFE
    - SA-neg, SA-neg-QCR
  - AIAA References
    - 2016-1051 (KCFD), 2015-0040 (SAMAir), 2016-0567 (COFFE)

Summary of Cases

- KCFD
  - All runs started from uniform, free-stream conditions
  - Workshop meshes (Pointwise for HL-CRM, VGRID for JSM)
- KCFD/SAMAir
  - All runs started from uniform, free-stream conditions
  - Workshop meshes trimmed at 5% MAC above surfaces
- COFFE
  - Runs for Cases 1 and 3 started from uniform, free-stream conditions, and runs for case 2 utilized **alpha continuation**
  - Workshop mesh for P1 results, P2 meshes generated by Steve Karman, Pointwise, Inc.

Summary of Cases

- CRM

case	Solver	Alpha	SA	Menter	Menter-trans
1a	KCFD	8,16	yes	yes	no
1a	KCFD/SAMAir	8,16	yes	no	no
1a	COFFE P2	8,16	yes	no	no

- JSM

case	Solver	Alpha	SA	Menter	Menter-trans
2a	KCFD	sweep	yes	yes	yes
2a, 2b	KCFD/SAMAir	sweep	yes	yes	no
2a, 2c	COFFE P1,P2	sweep	yes	no	no

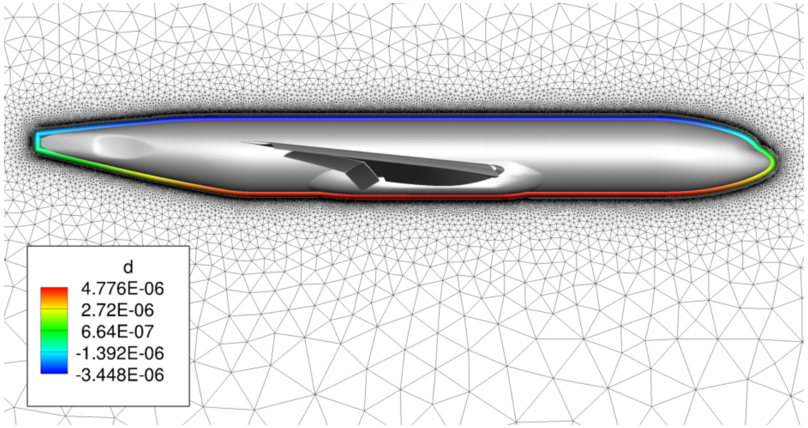
- Airfoil

case	Solver	Alpha	SA	Menter	Menter-trans
3	KCFD	0	yes	yes	no
3	KCFD/SAMAir	0	no	no	no
3	COFFE P1	0	yes	no	no

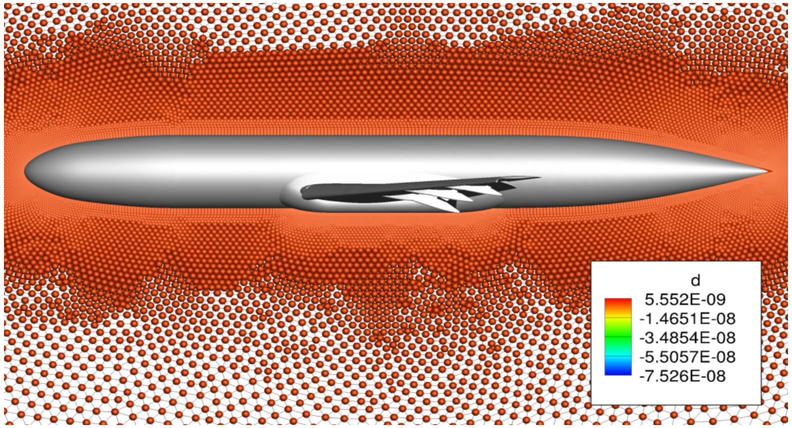
Finite-Volume Mesh Systems

- KCFD single and dual-mesh runs used the workshop grids with prismatic elements in BL
- Kestrel detected nodes strictly outside the symmetry plane defined by point (0,0,0) and normal (0,1,0)
- Affects overset domain connectivity
- Kestrel pre-processing tool Carpenter used to correct non-planar points
  - HL-CRM non-planar points found near the surface
  - All JSM nodes slightly off the symmetry plane

HL-CRM

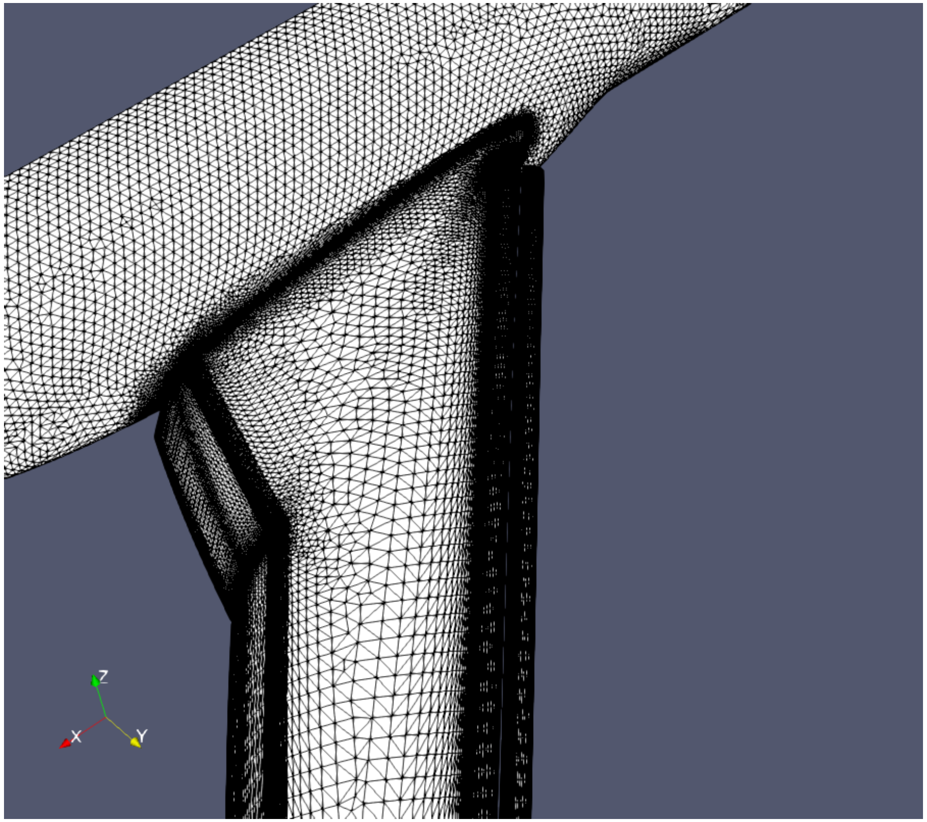


JSM



Case 1a: HL-CRM

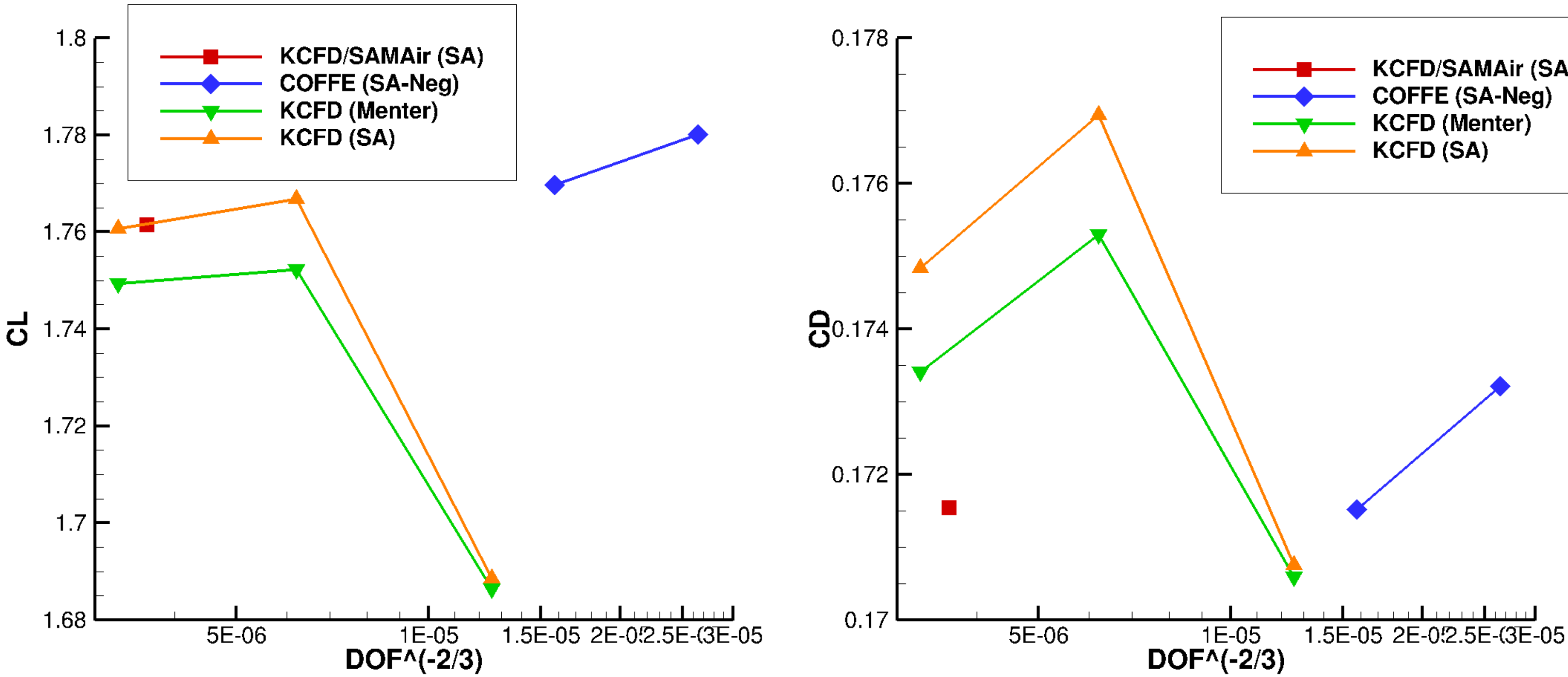
- Mach 0.2, AoA 8, 16, Re_MAC = 3,260,000.0



P2 unstructured mesh: 15,943,343 nodes, 11,794,638 Tets

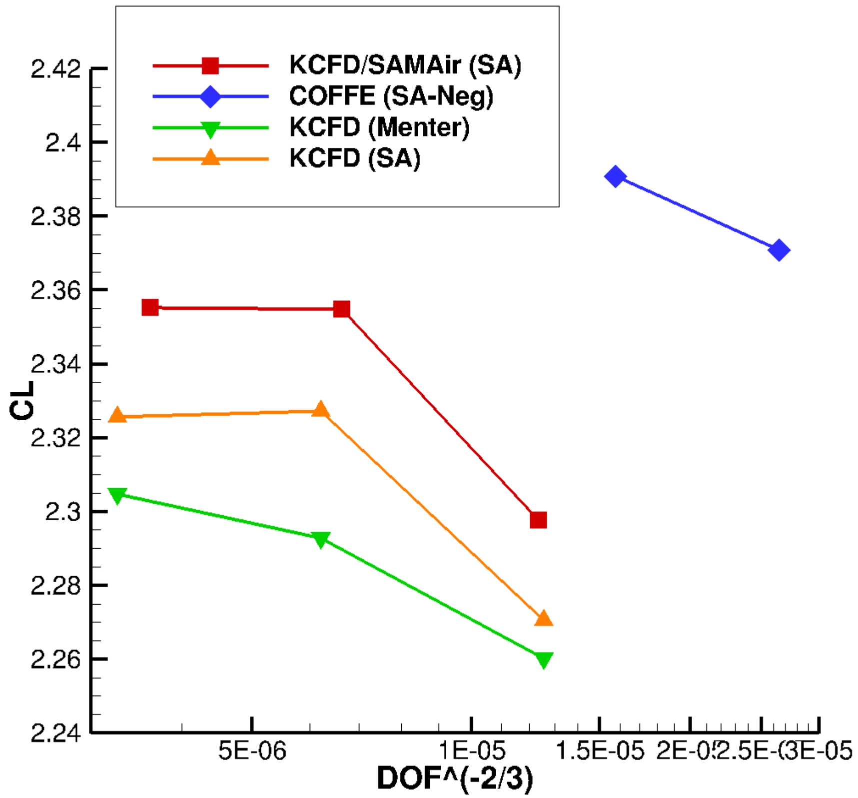
Case 1a: HL-CRM AoA = 8 degrees

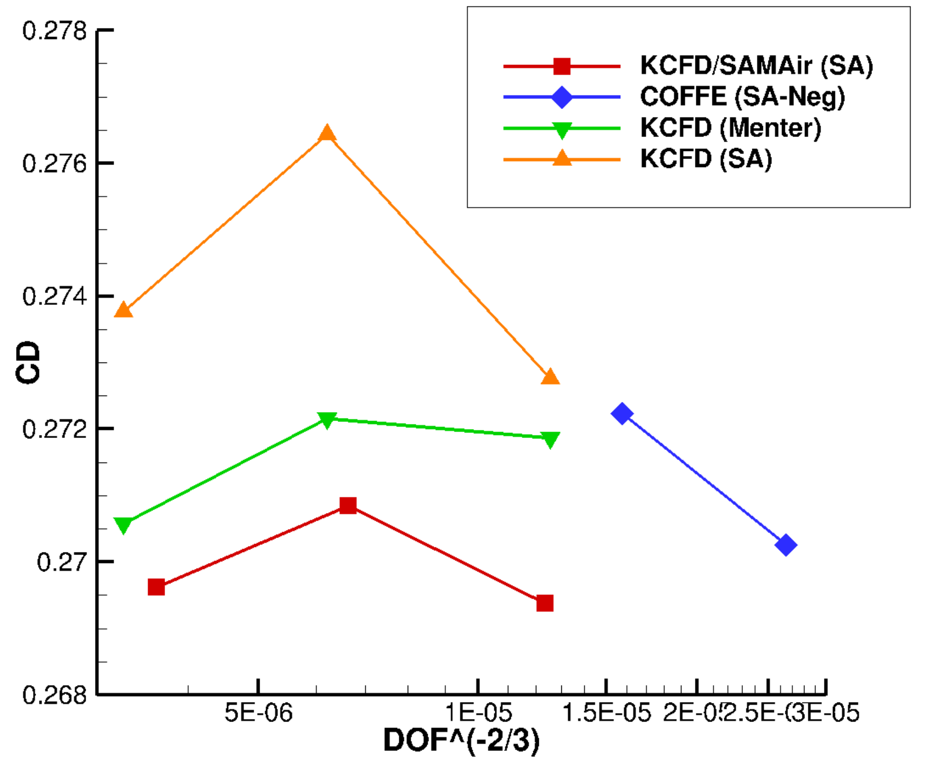
- Fine mesh solutions differ by 1.2% in lift and 1.9% in drag



Case 1a: HL-CRM AoA = 16 degrees

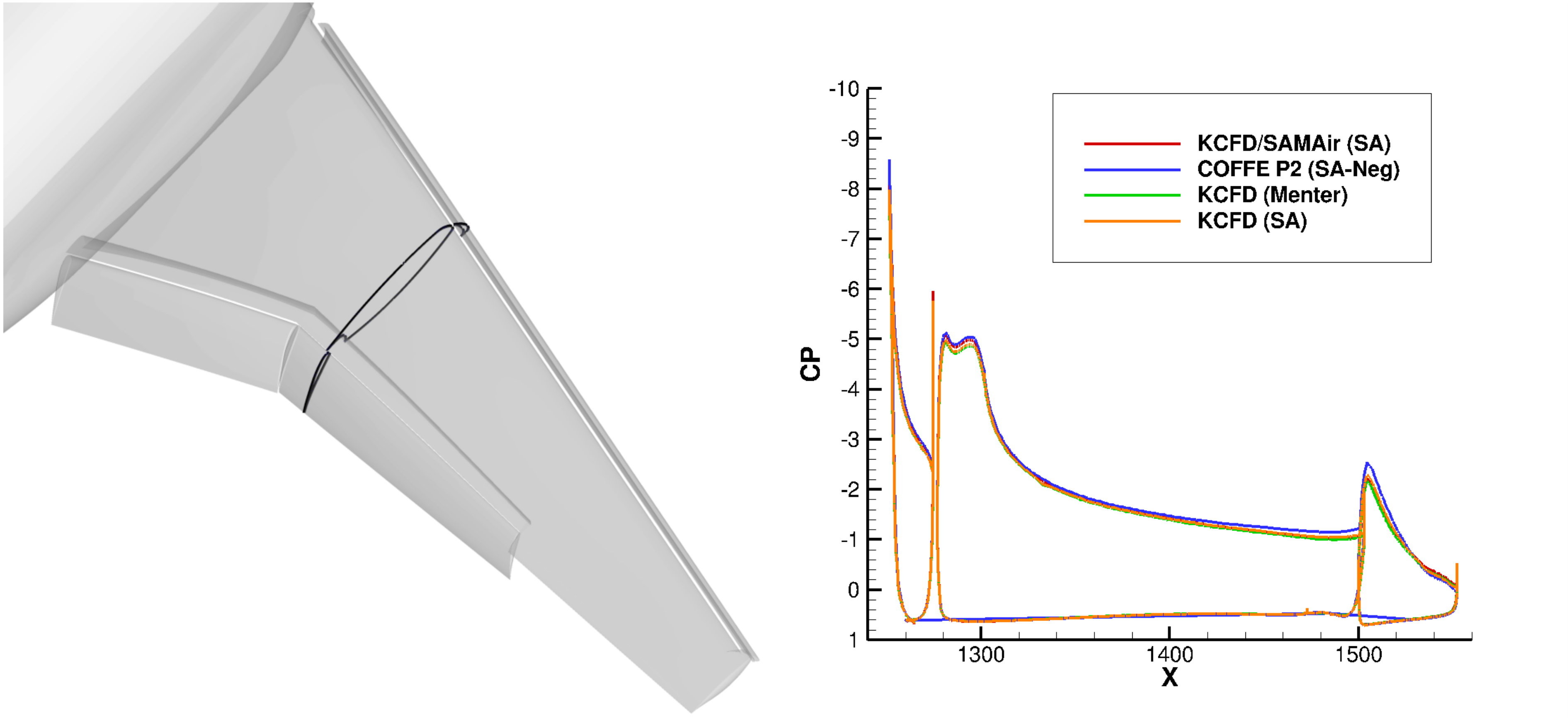
- Fine mesh solutions differ by 3.7% in lift and 1.5% in drag





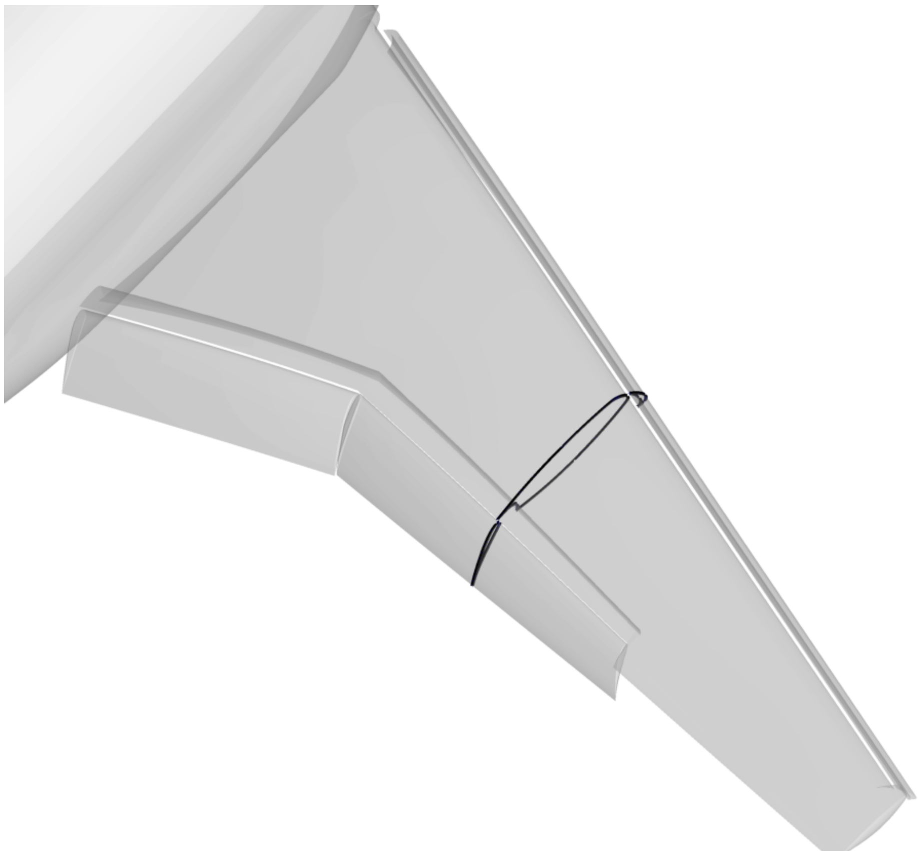
Case 1a: HL-CRM AoA = 16 degrees, eta = 0.418

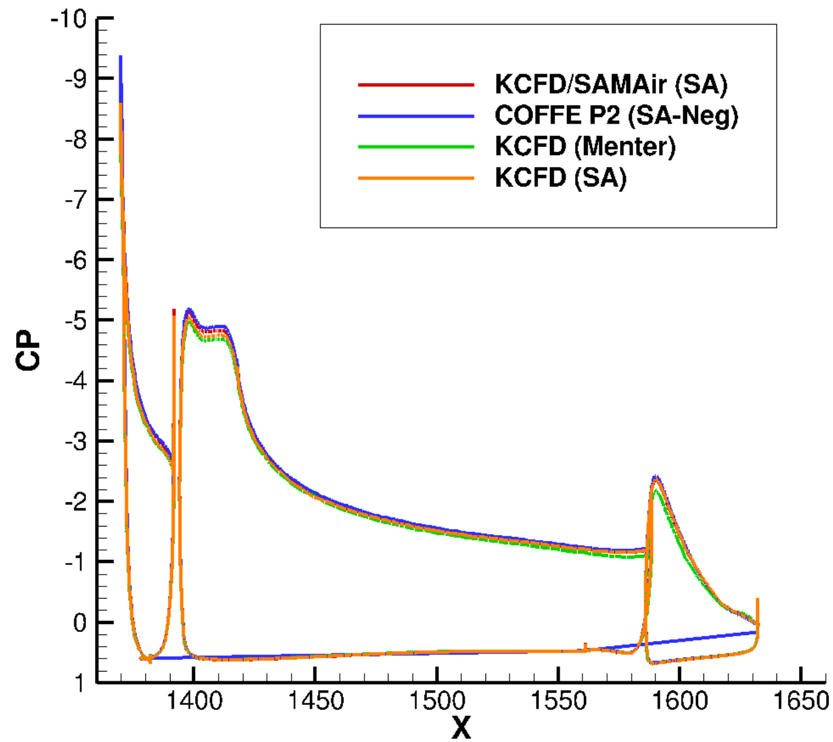
- Similar Cp profiles – plotting issue for lower surface
- COFFE predicts lower pressure on slat and flap



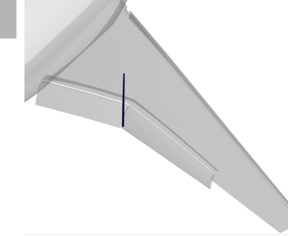
Case 1a: HL-CRM AoA = 16 degrees, eta = 0.552

- Similar Cp profiles – plotting issue for lower surface
- COFFE predicts lower pressure on slat

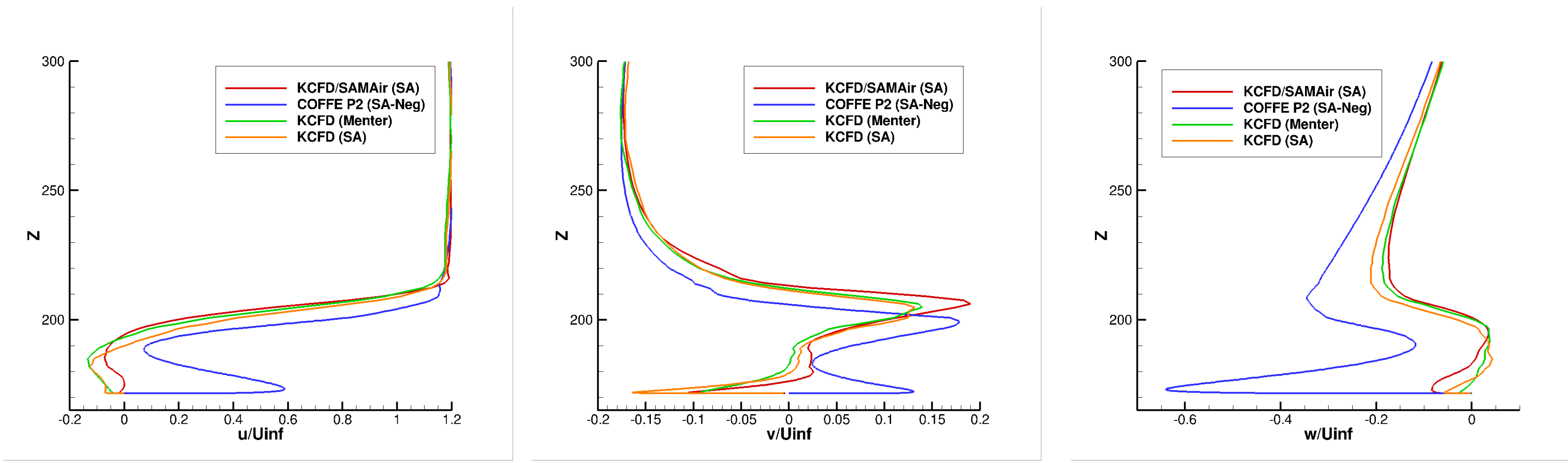




Case 1a: HL-CRM AoA = 16 degrees

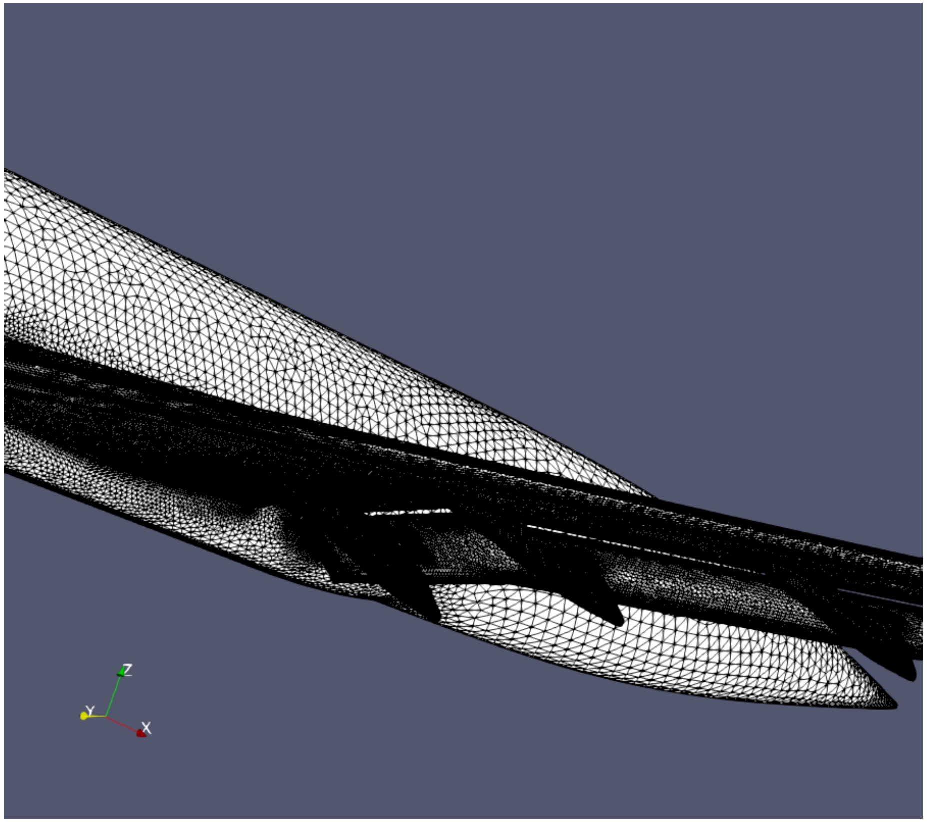


- Largest velocity differences occur on outboard flap near junction with inboard flap – opposite flow near the surface



Case 2a: JSM WB

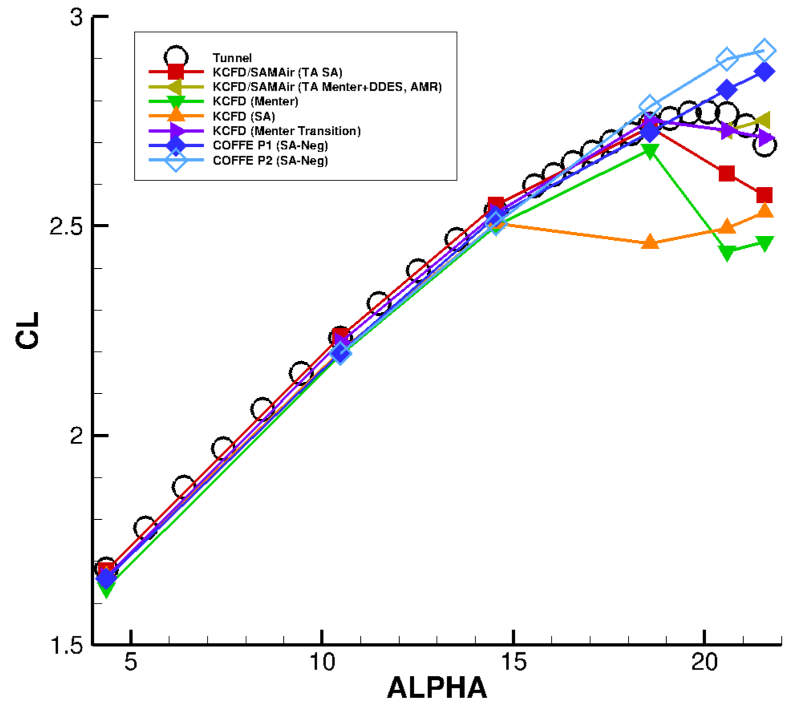
- Mach 0.172, AoA 4.36, 10.47, 14.54, 18.58, 20.59, and 21.57, Re_MAC = 1,930,000.0



P2 unstructured mesh: 28,901,748 nodes, 21,461,509 Tets

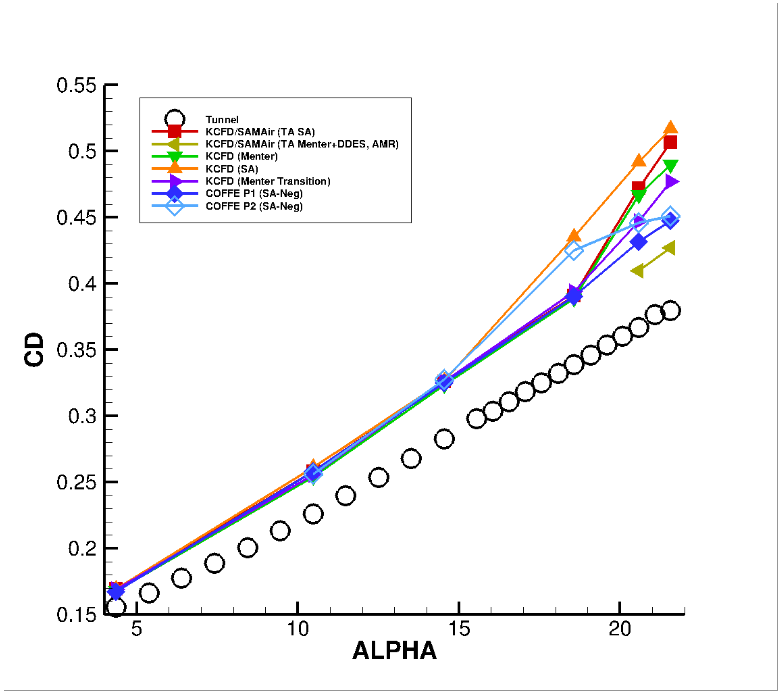
Case 2a: JSM WB Lift Curve

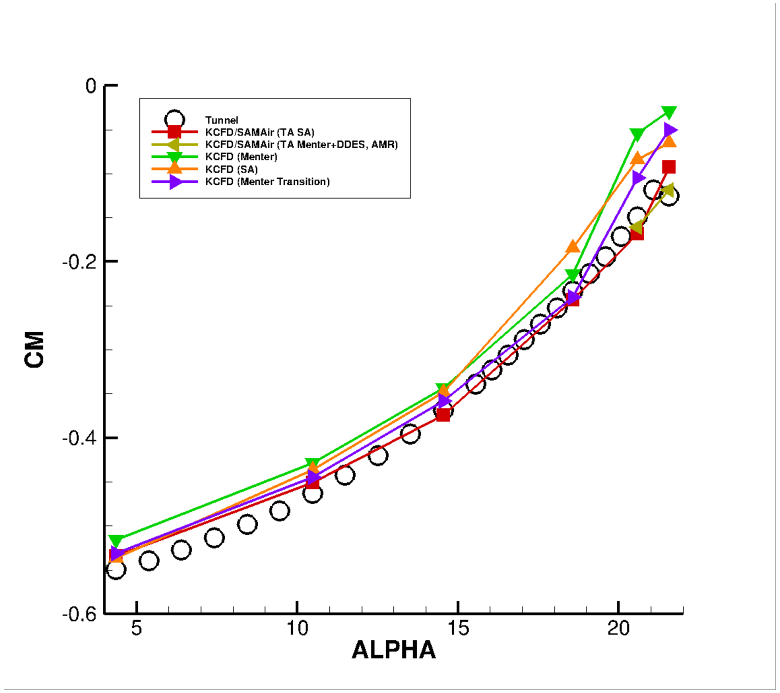
- All models compare well with experiment up to AoA = 14.54 degrees
- COFFE over-predicts (as compared to experiment) CL Max, while most fully-turbulent finite-volume runs under-predict CL Max
- Menter transition model with KCFD produces good match to experimental lift curve throughout the AoA range
- Variations between local and global time-stepping



Case 2a: JSM WB Drag and Moment

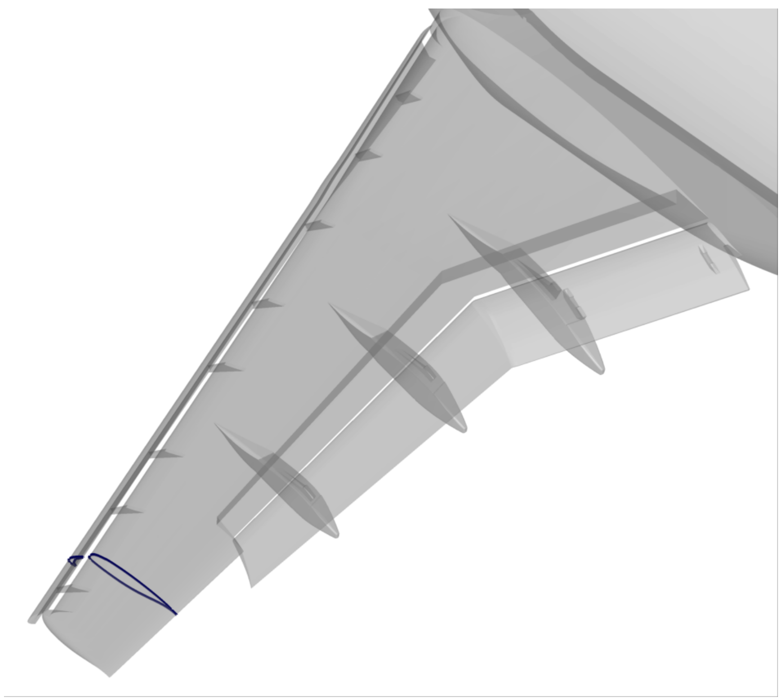
- All models over-predict drag as compared to experiment
- No coefficient of moment values for COFFE
- Strong agreement with experiment for moment

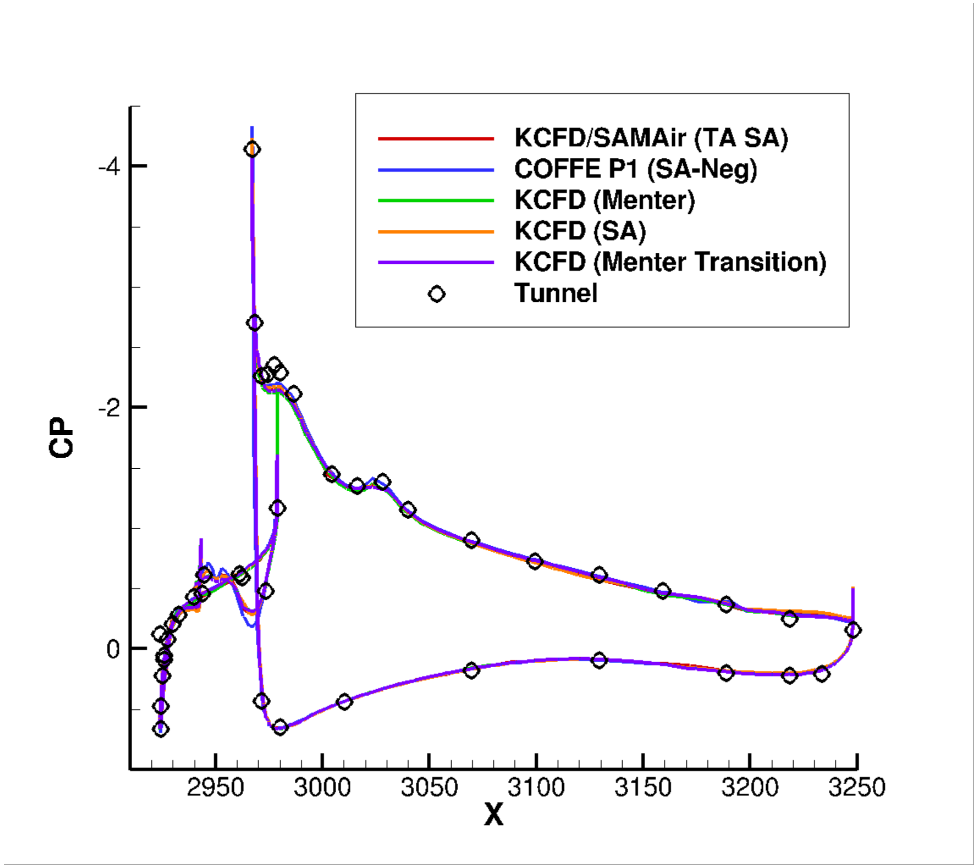




Case 2a: JSM WB AoA = 4.36 degrees

- Excellent agreement between CFD and experimental coefficient of pressure at low AoA even at the wing tip

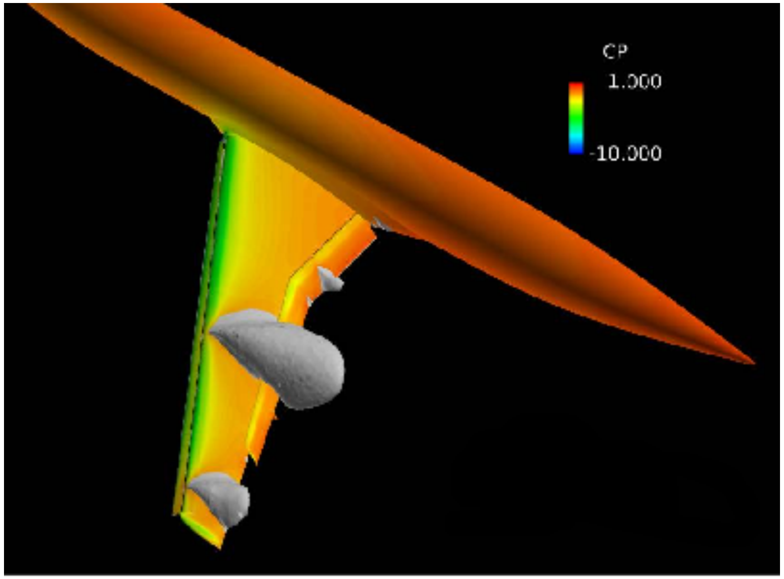




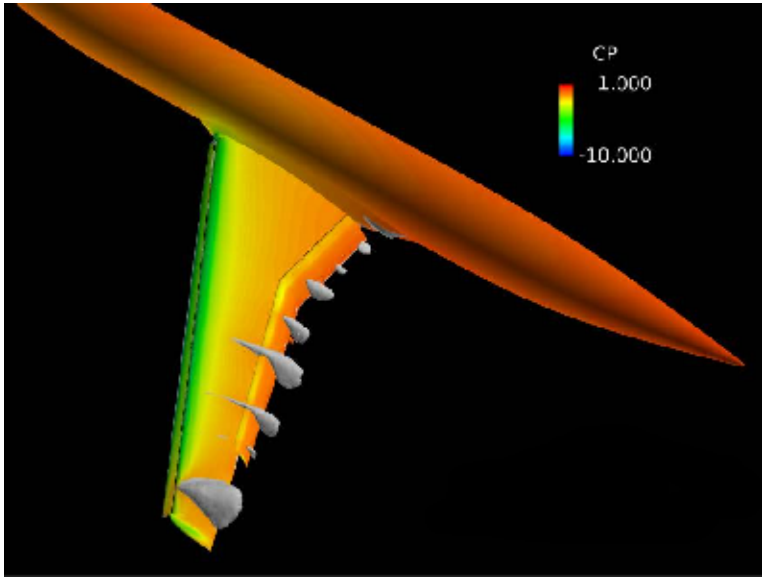
Case 2a: JSM WB Slat Bracket Separation, AoA = 18.58 degrees -- KCFD

- Slat bracket separation strongly influences forces at high AoA
- Steady-state (local time-stepping strategy) Menter solutions do not have the large, mid-span separation region predicted by the steady-state SA model

KCFD - SA

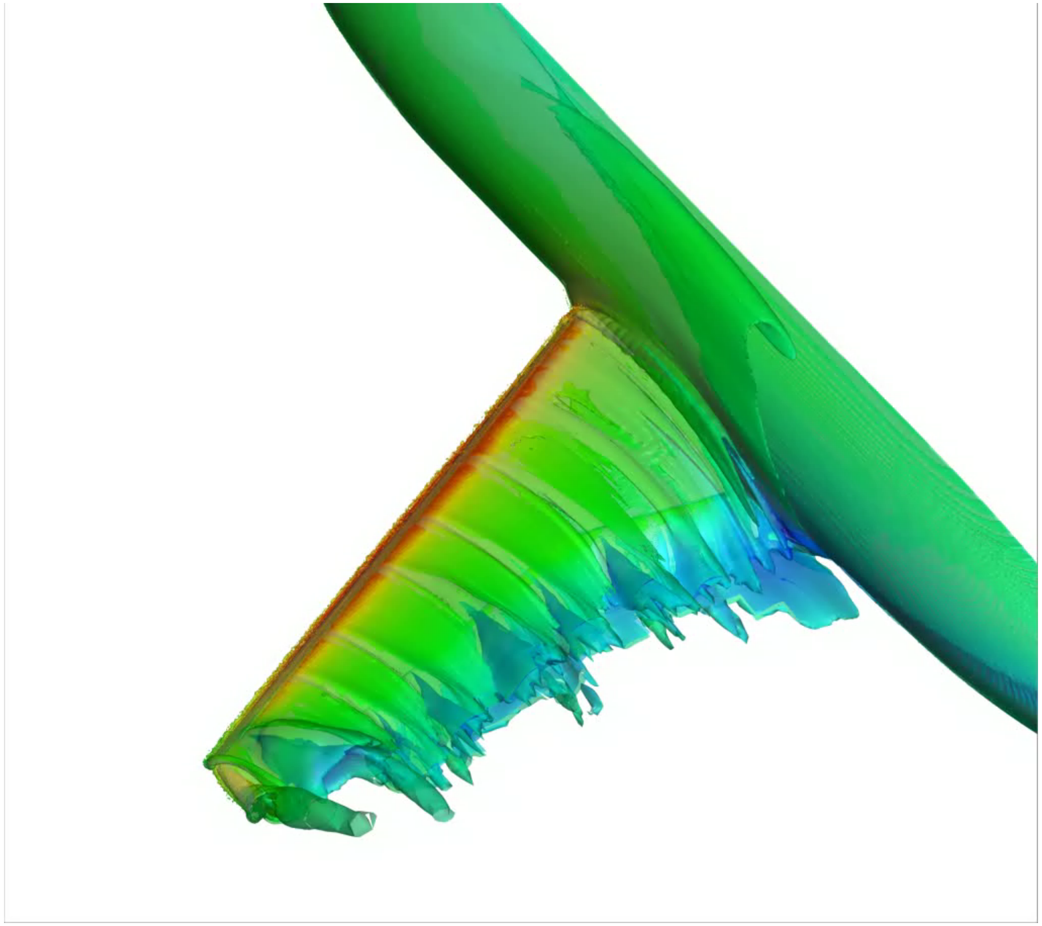


KCFD – Menter-BSL

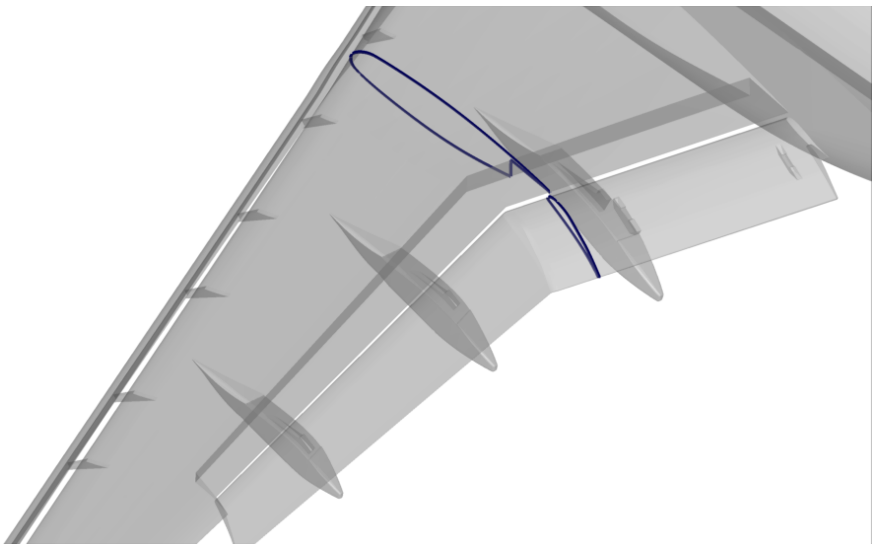


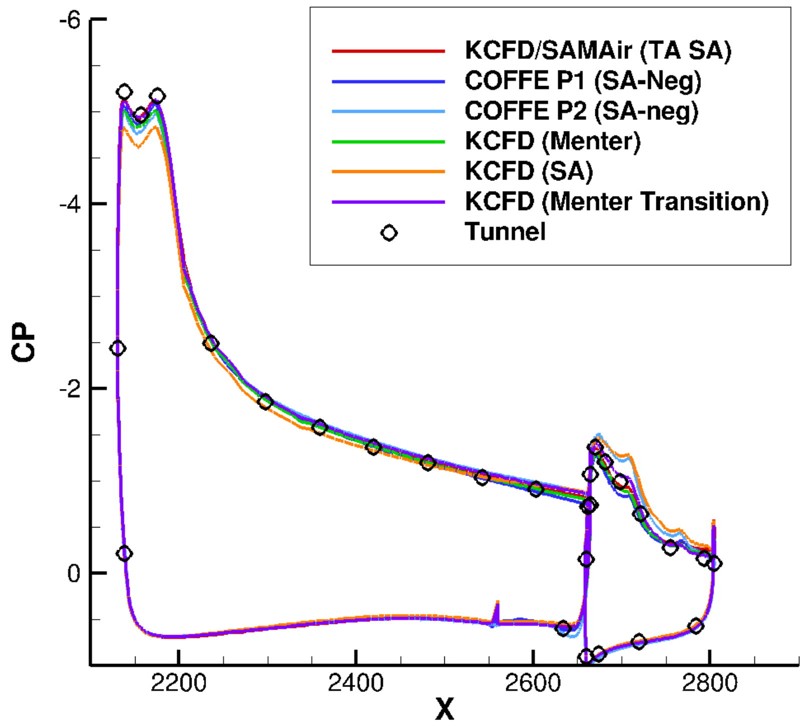
Case 2a: JSM WB AoA = 18.58 degrees

- Dual-mesh (KCFD+SAMAir); time-accurate SA, no AMR

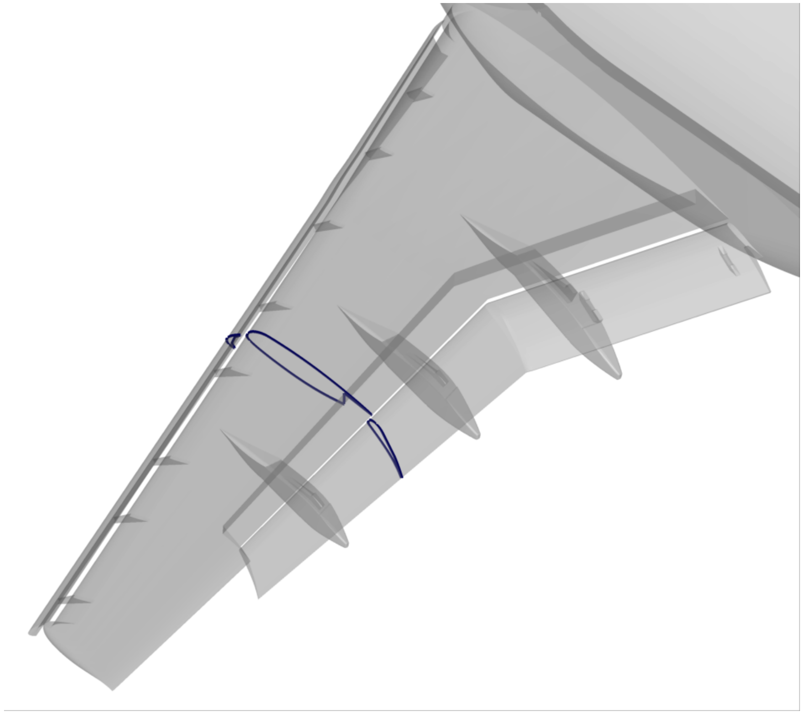


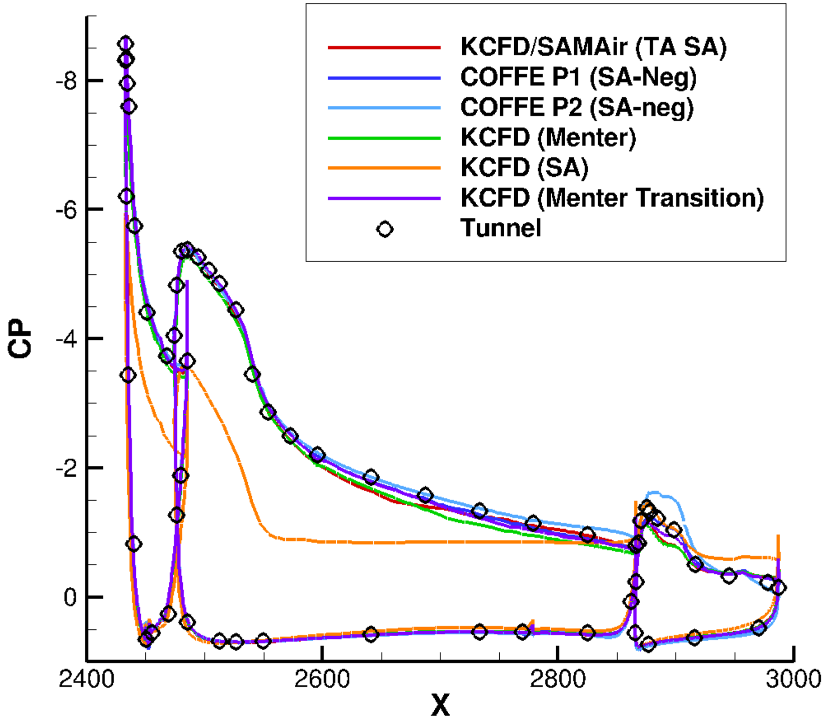
Case 2a: JSM WB AoA = 18.58 degrees, Section C-C





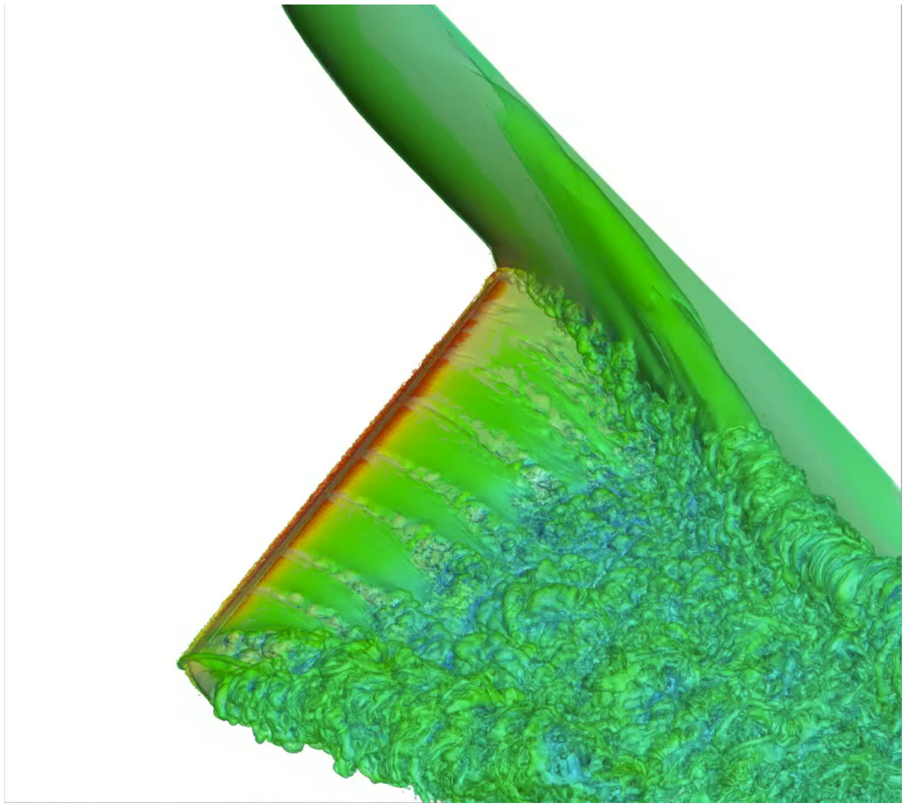
Case 2a: JSM WB AoA = 18.58 degrees, Section E-E



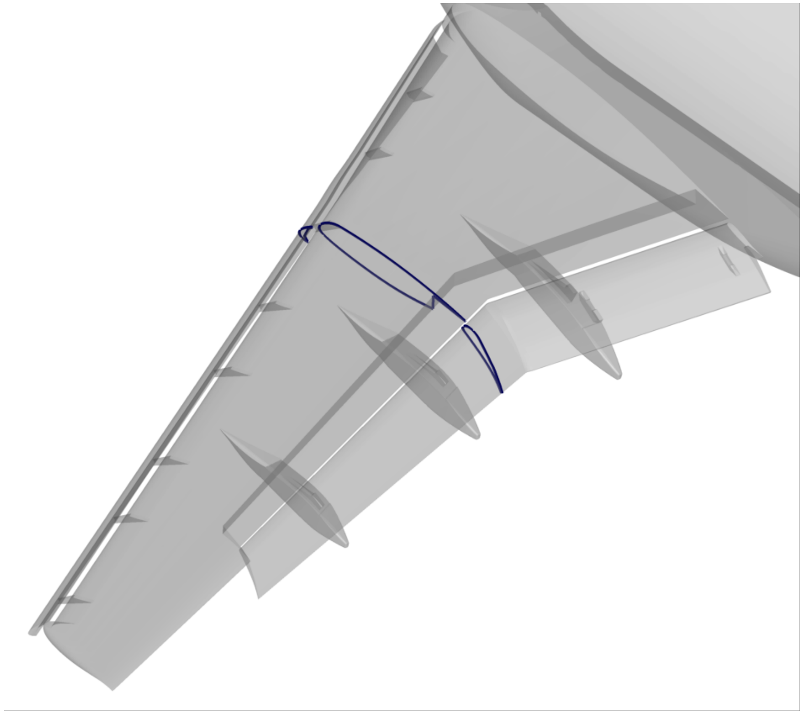


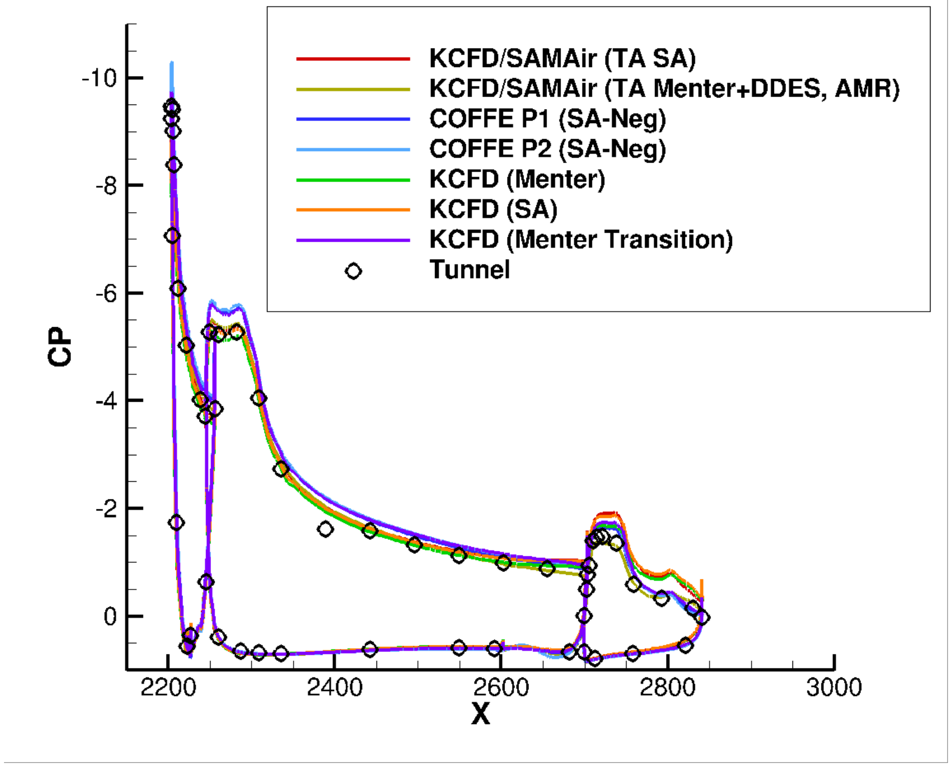
Case 2a: JSM AoA = 21.57 degrees

- Dual-mesh (KCFD+SAMAir); time-accurate Menter BSL + DDES with Vorticity-based Cartesian AMR

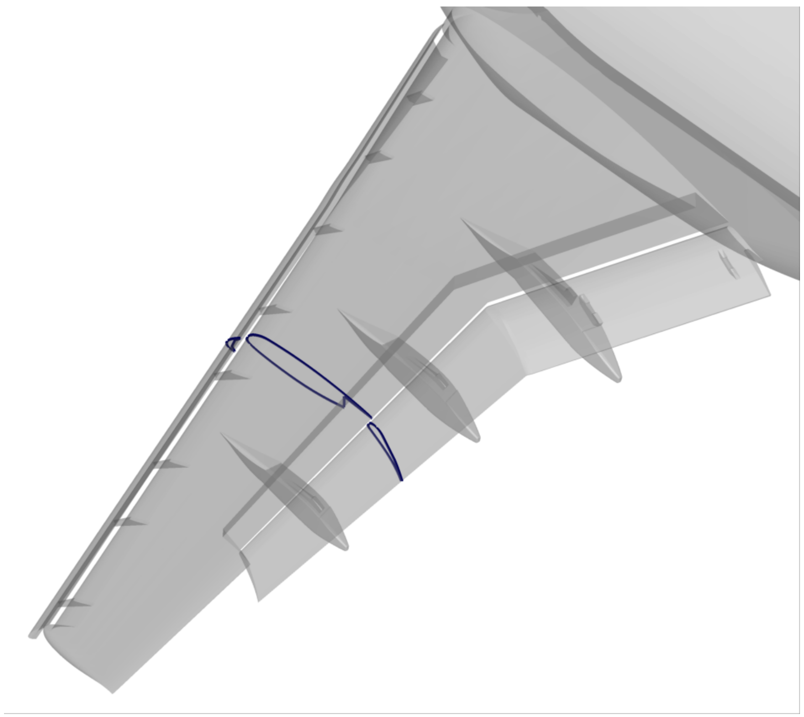


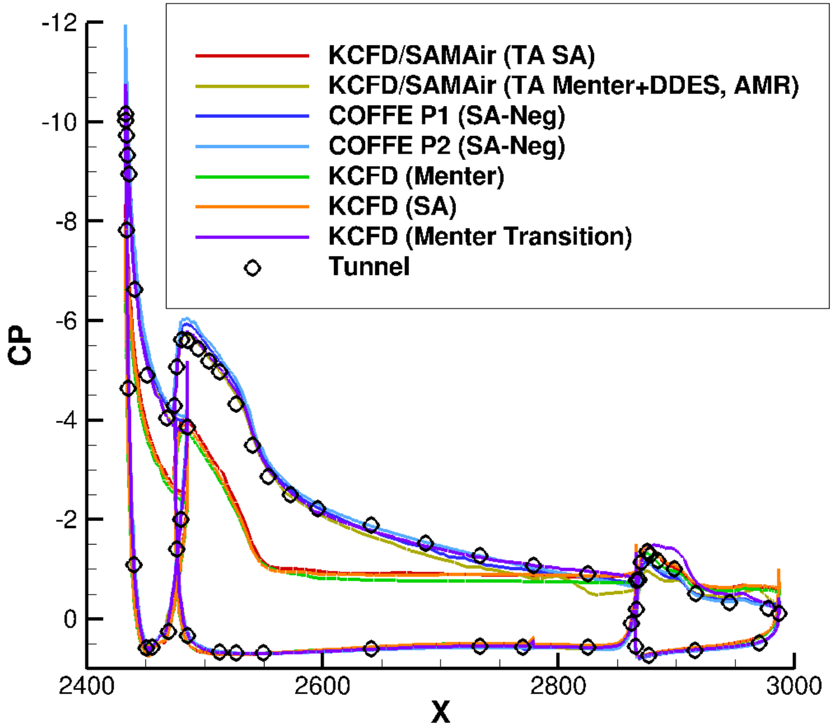
Case 2a: JSM WB AoA = 21.57 degrees, Section D-D



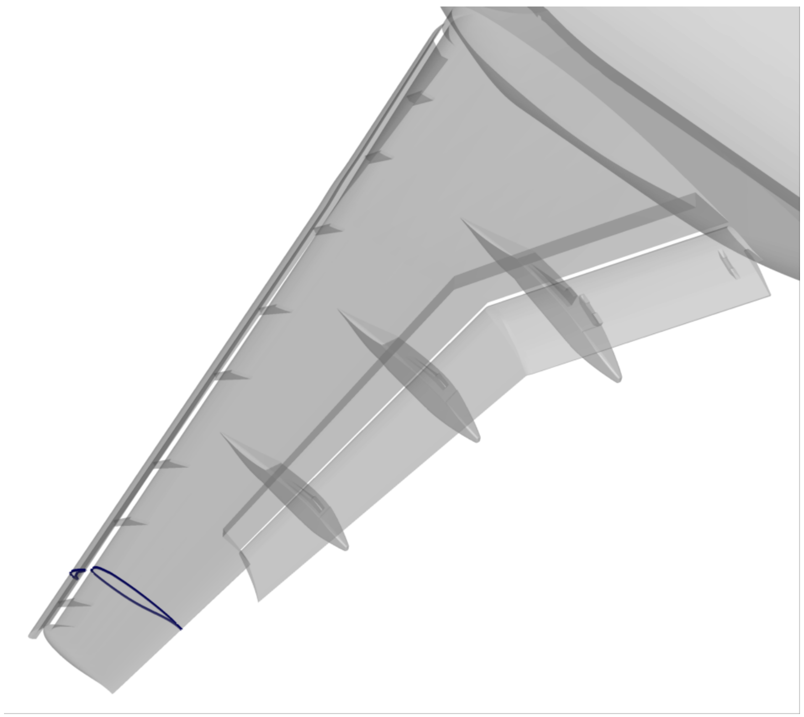


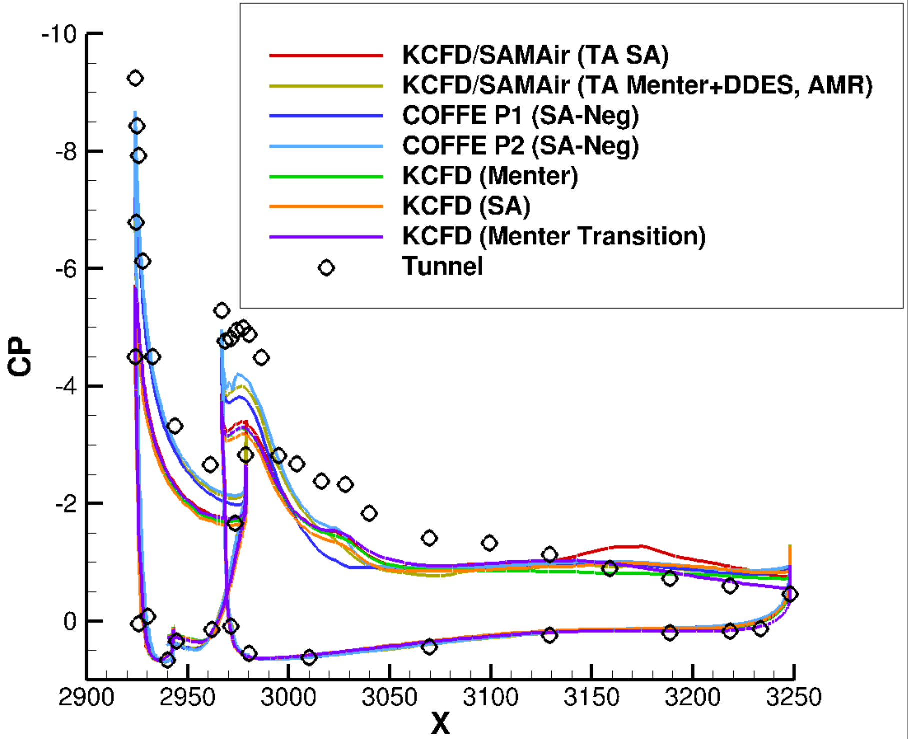
Case 2a: JSM WB AoA = 21.57 degrees, Section E-E



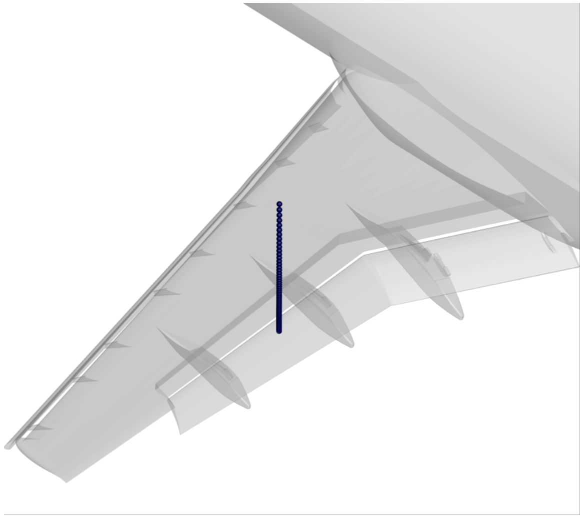


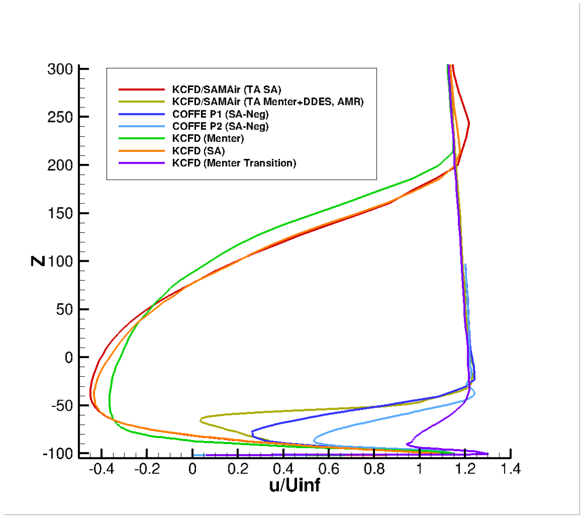
Case 2a: JSM WB AoA = 21.57 degrees, Section H-H

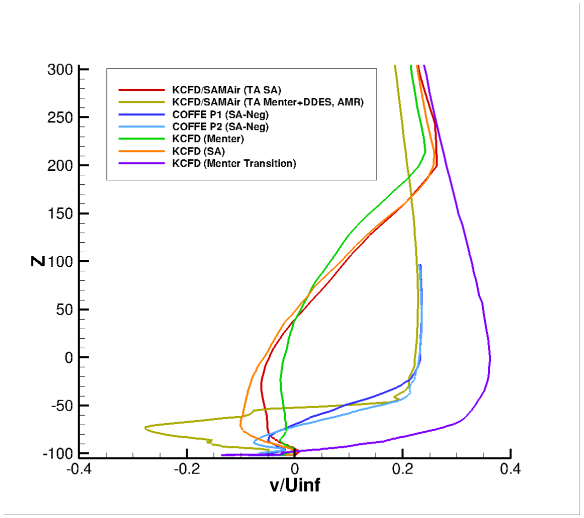


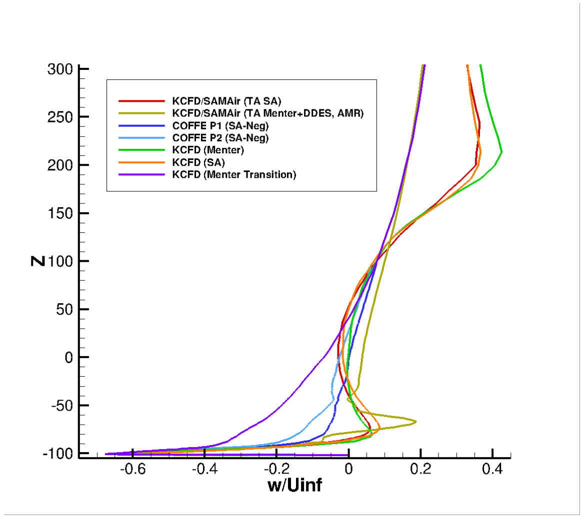


Case 2a: JSM WB AoA = 21.57 degrees



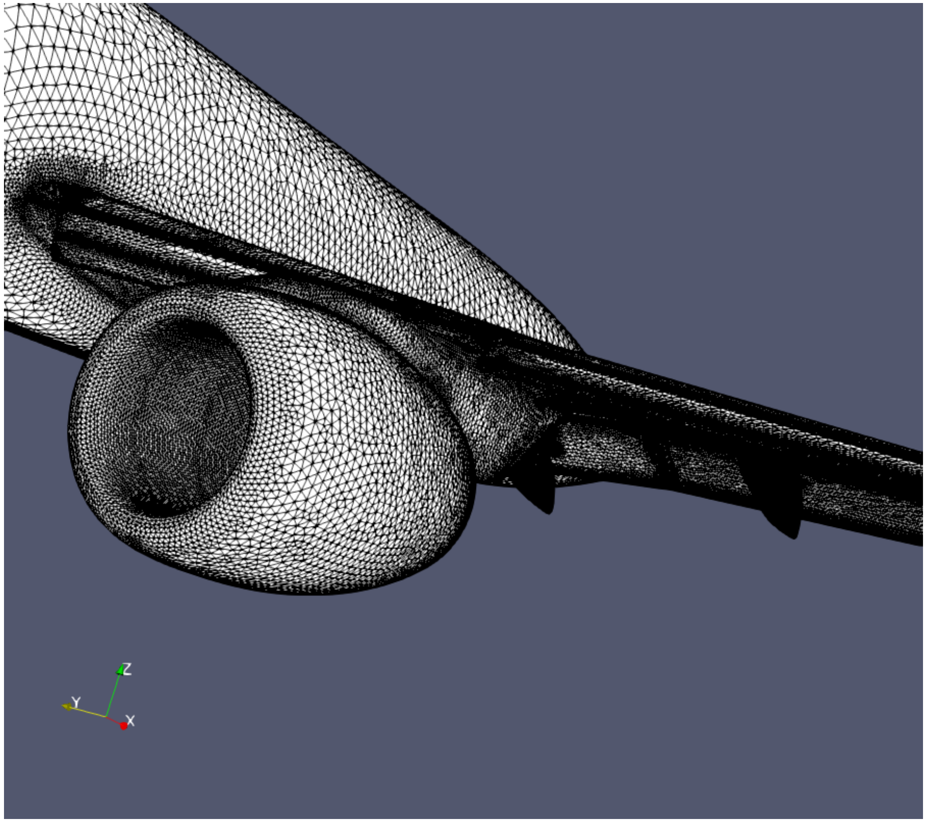






Case 2c: JSM WBNP

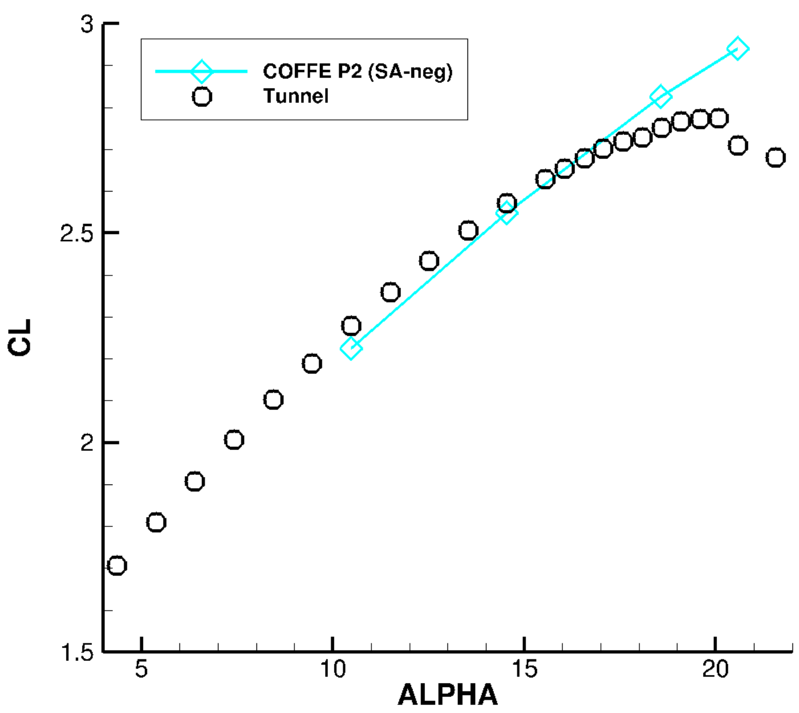
- Mach 0.172, AoA 4.36, 10.47, 14.54, 18.58, 20.59, and 21.57, Re_MAC = 1,930,000.0

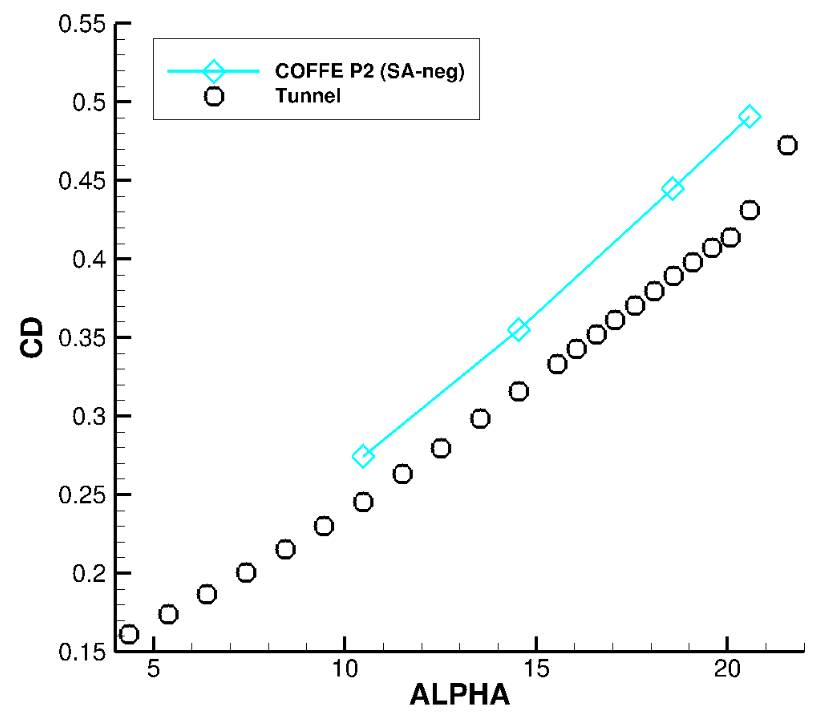


P2 unstructured mesh: 35,038,543 nodes, 26,024,374 Tets

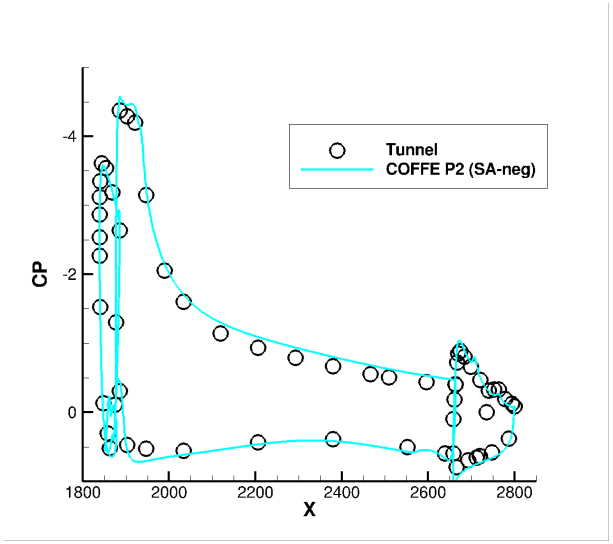
Case 2c: JSM WBNP Lift Curve

- COFFE P2

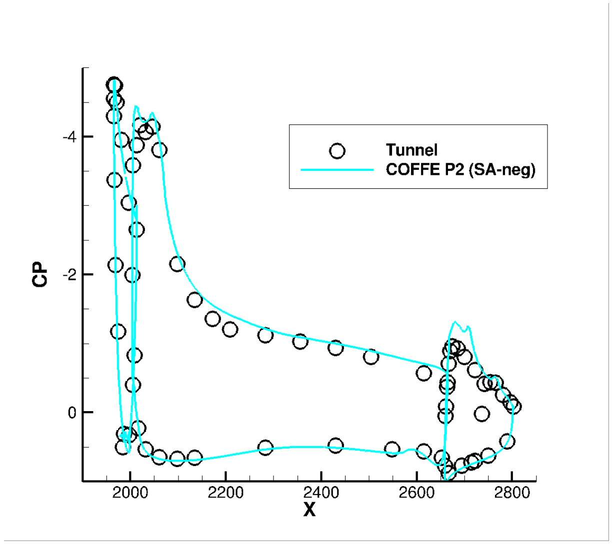




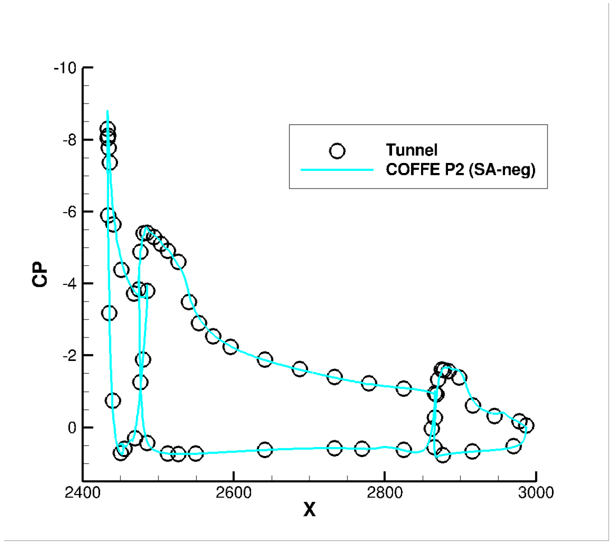
Case 2c: JSM WBNP CP for AoA 18.58



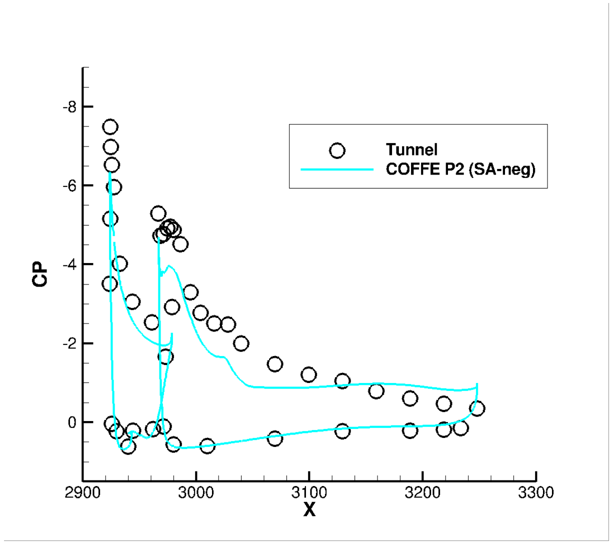
A-A



B-B

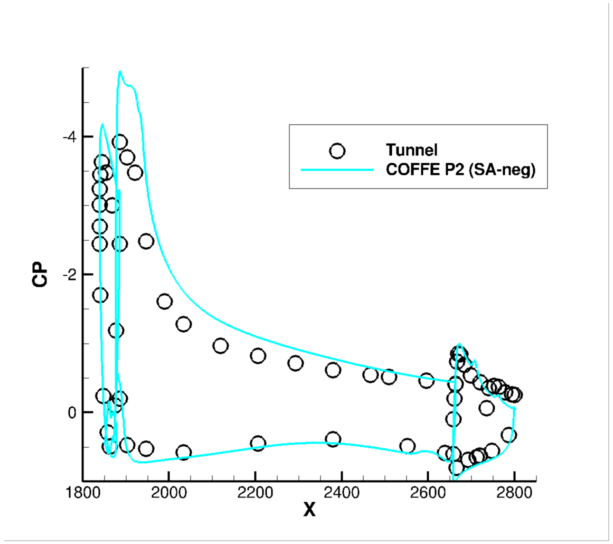


E-E

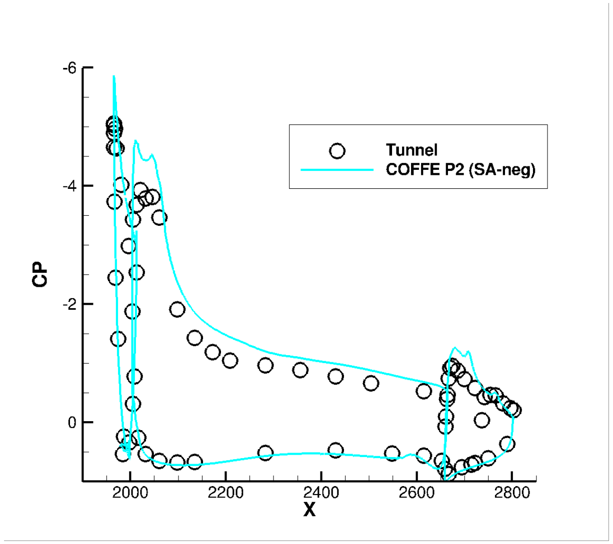


H-H

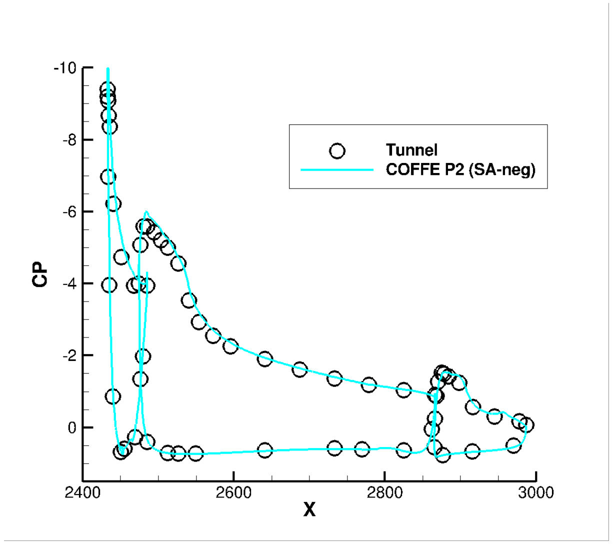
Case 2c: JSM WBNP CP for AoA 20.59



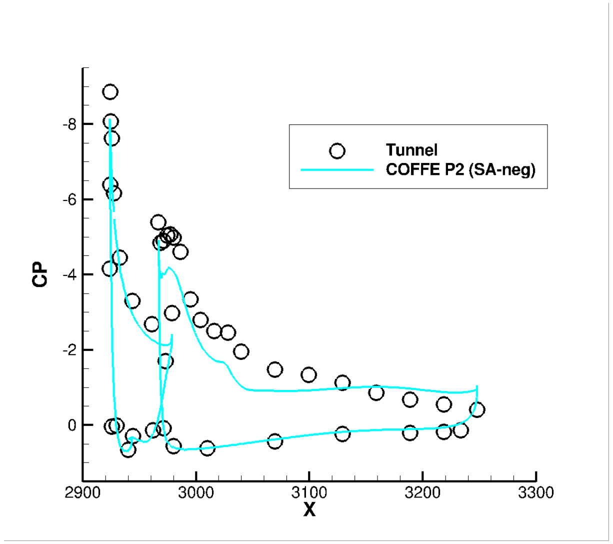
A-A



B-B



E-E



H-H

Summary

- Kestrel's wide variety of flow solvers and turbulence model options make it a powerful tool that enables self-validation – giving users more confidence in their answers
- Kestrel provides excellent solutions as compared to JSM experiments at low-moderate AoA, and advanced options (COFFE, transition, dual-mesh, DDES) provide credible solutions at higher AoA
- Prediction of flow-field around JSM significantly more challenging than HL-CRM
- Correct modeling of the flow within the element gaps and around the support structures is critical
- Increased mesh resolution in these areas could possibly improve CFD predictions

Acknowledgements

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