

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



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- Kestrel Overview
- Case Summary – Turbulence Model Choices
- NASA High Lift Common Research Model (HL-CRM)
- Angle of Attack = 8 and 16 degrees
 - Coefficients of lift and drag
 - Coefficient of pressure at various span-wise locations
- JAXA Standard Model Wing Body (WB) and Wing Body Nacelle Pylon (WBNP)
- Angle of Attack Sweep
 - Coefficients of lift and drag
 - Coefficient of pressure at various span-wise locations
- DSMA661 (Model A) Airfoil
- Verification Exercise
 - Coefficients of lift and drag

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

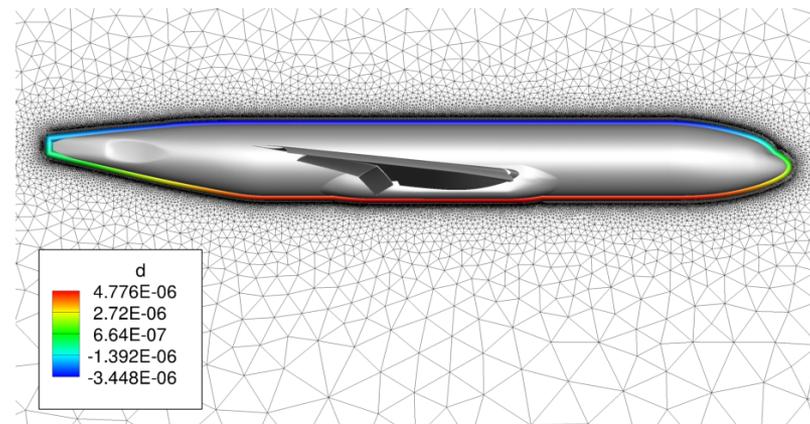
- Airfoil

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

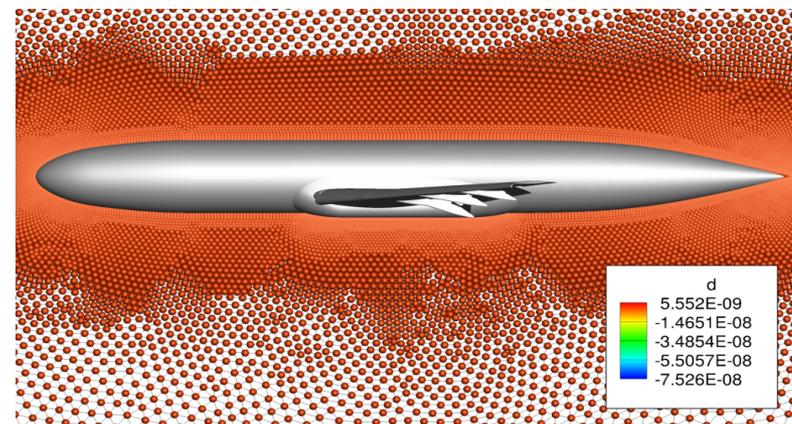
Finite-Volume Mesh Systems

- 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

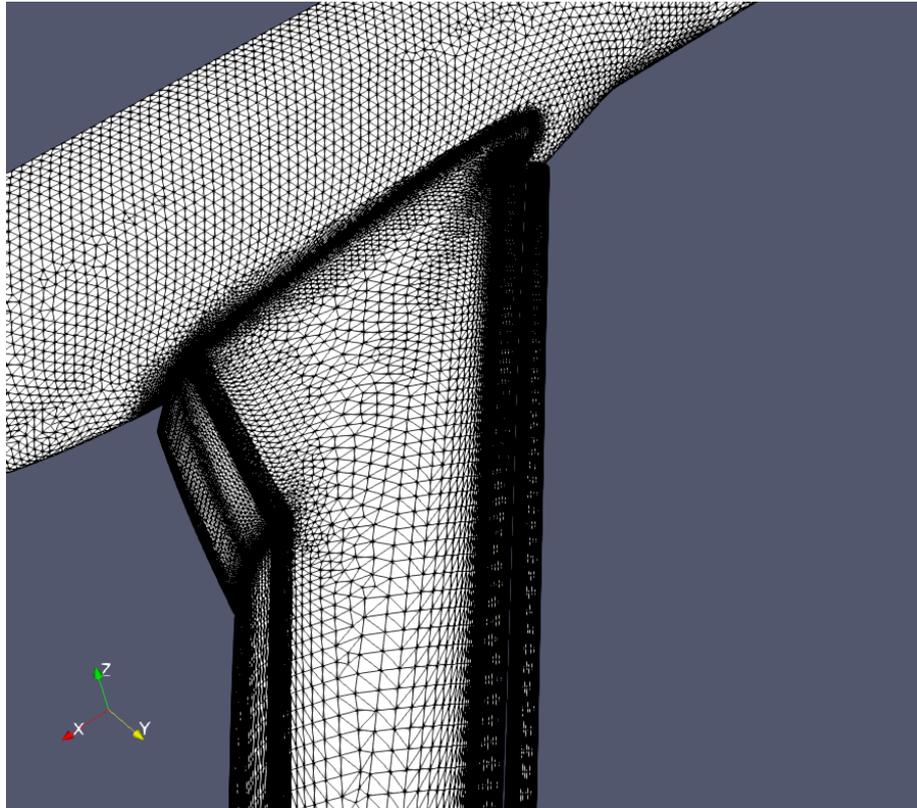


JSM



Case 1a: HL-CRM

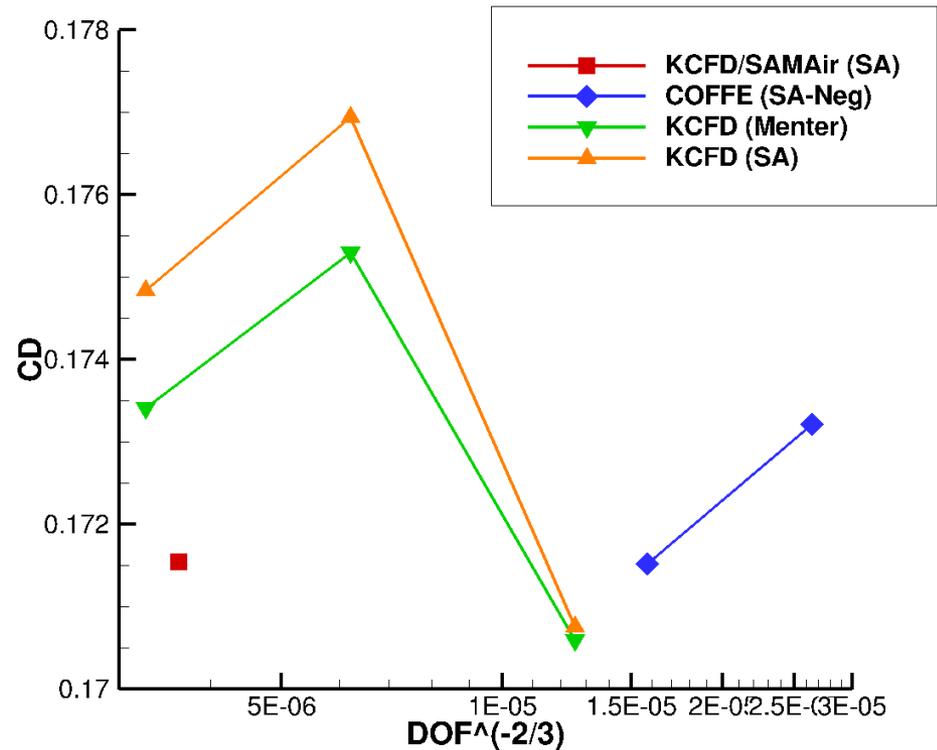
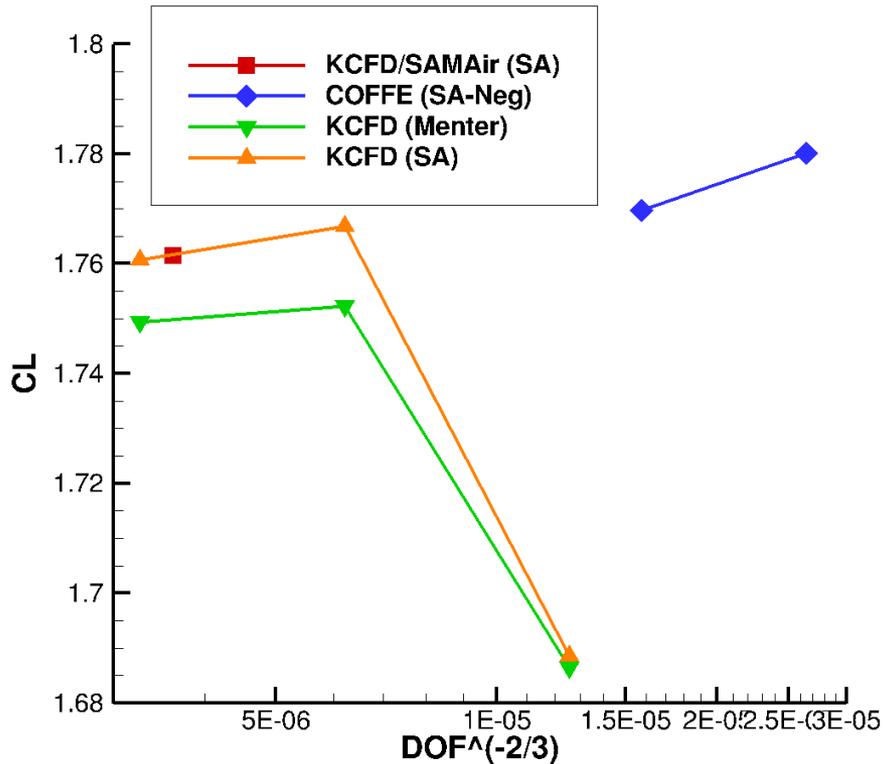
- Mach 0.2, AoA 8, 16, $Re_{MAC} = 3,260,000.0$



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

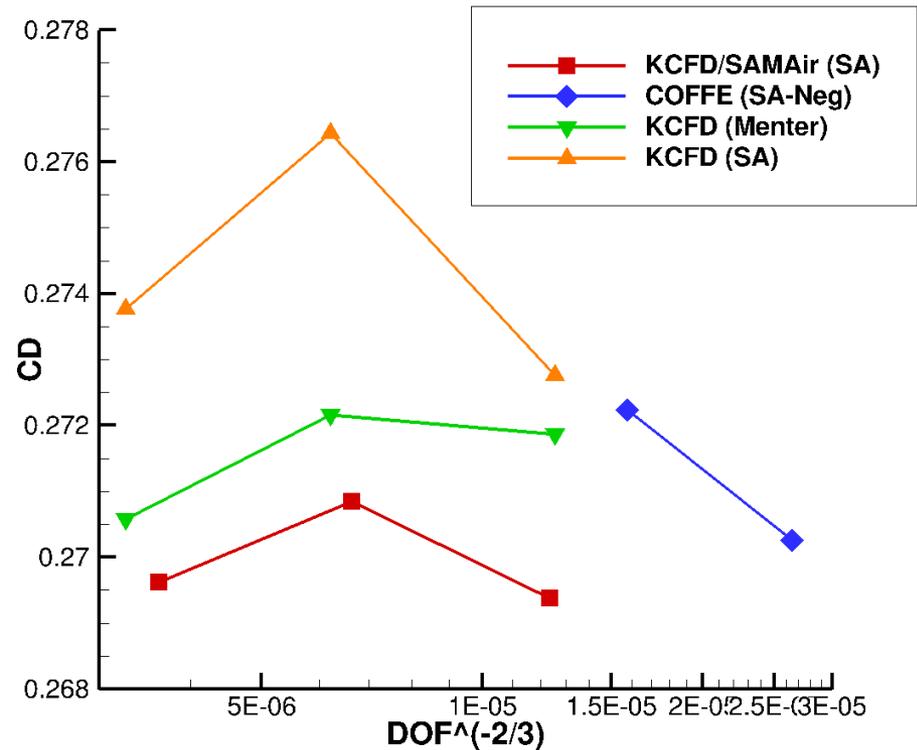
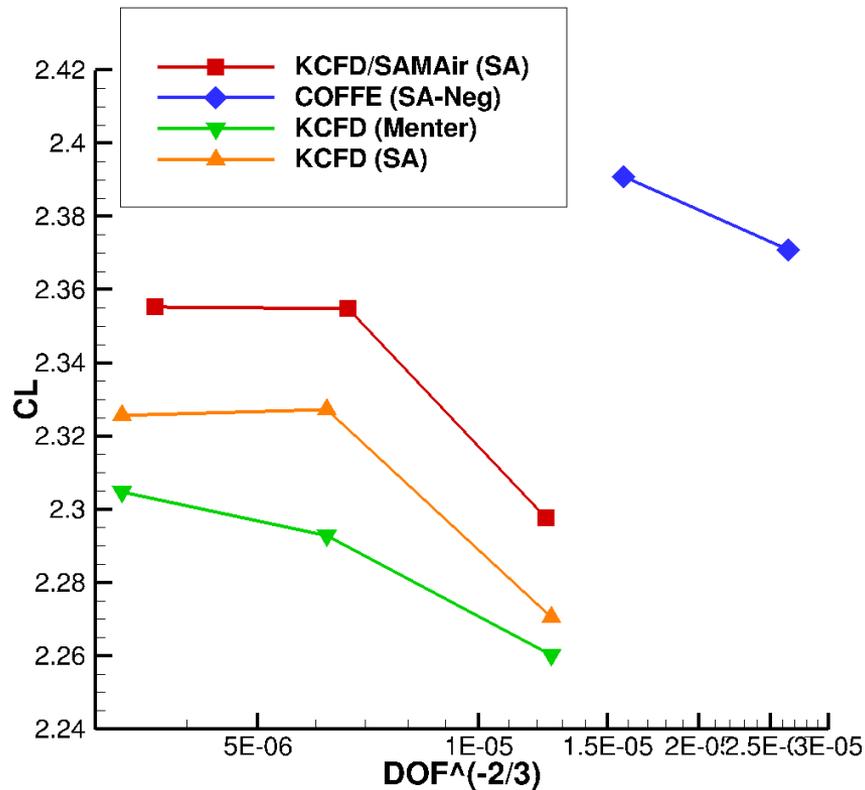
Case 1a: HL-CRM AoA = 8 degrees

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



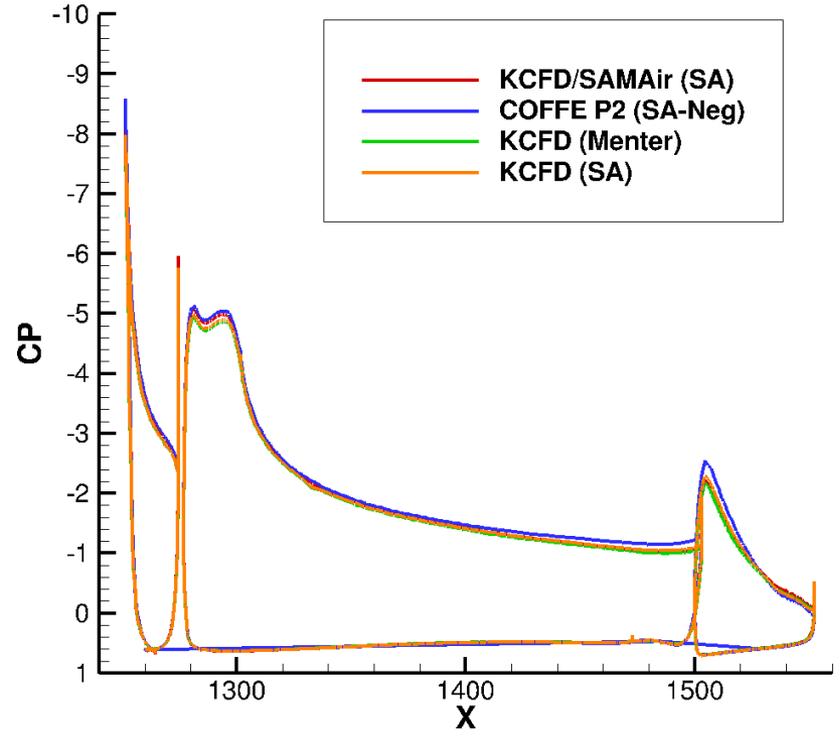
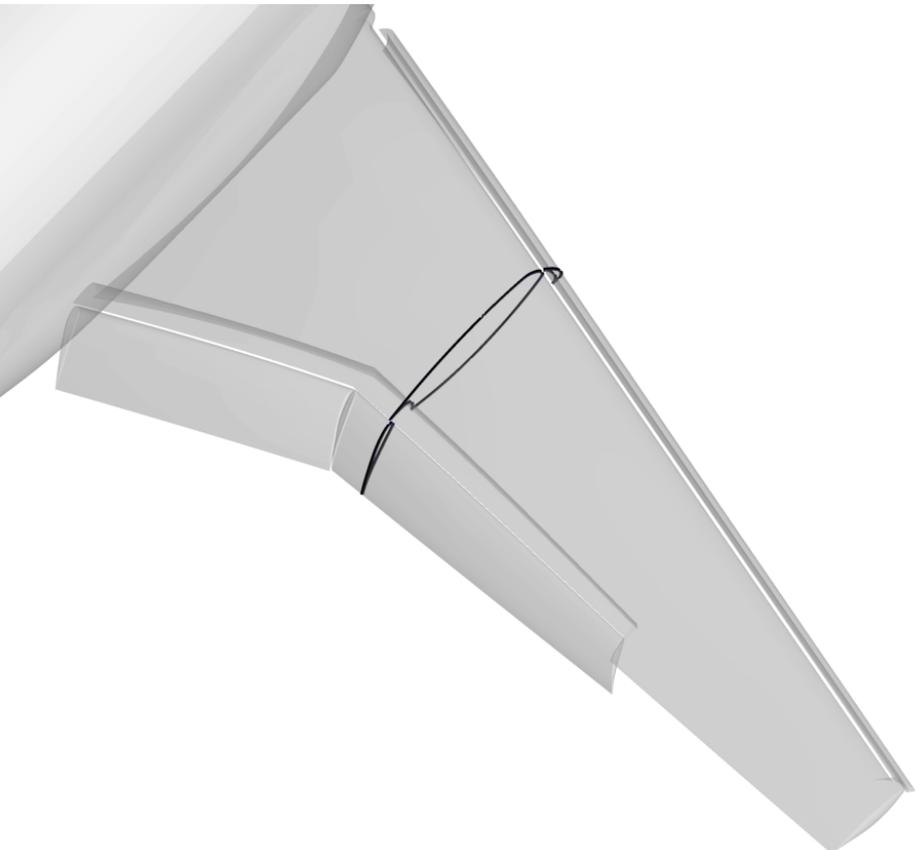
Case 1a: HL-CRM AoA = 16 degrees

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



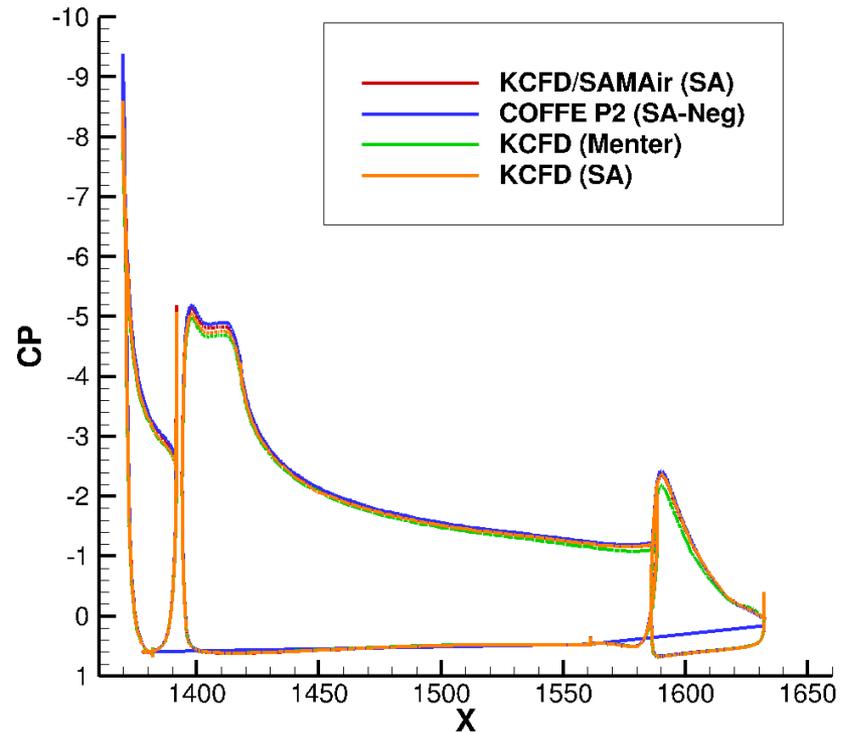
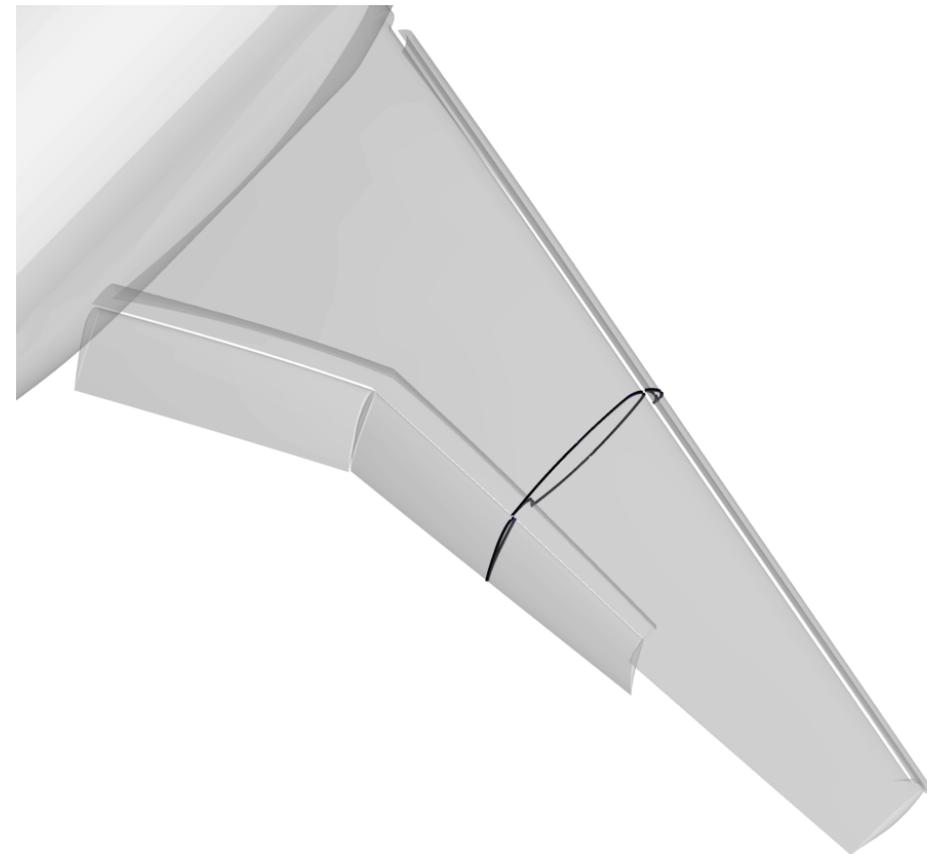
Case 1a: HL-CRM AoA = 16 degrees, eta = 0.418

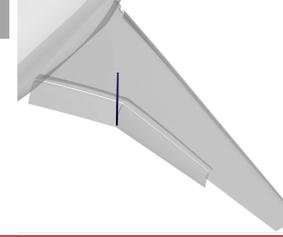
- Similar Cp profiles – plotting issue for lower surface
- COFFE predicts lower pressure on slat and flap



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

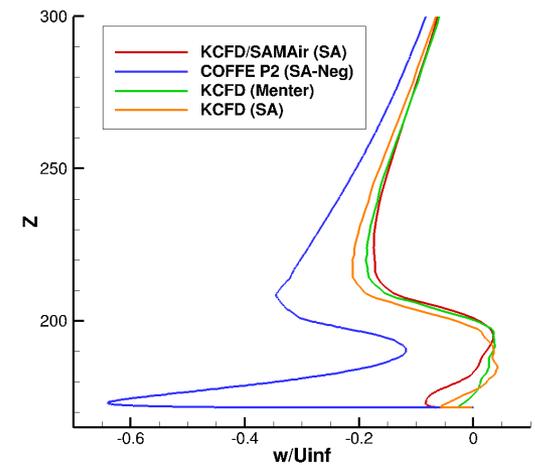
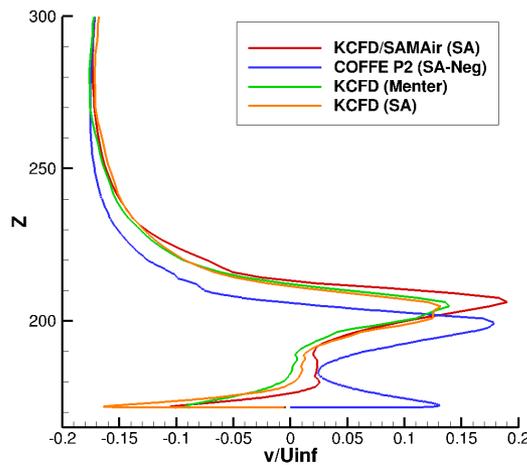
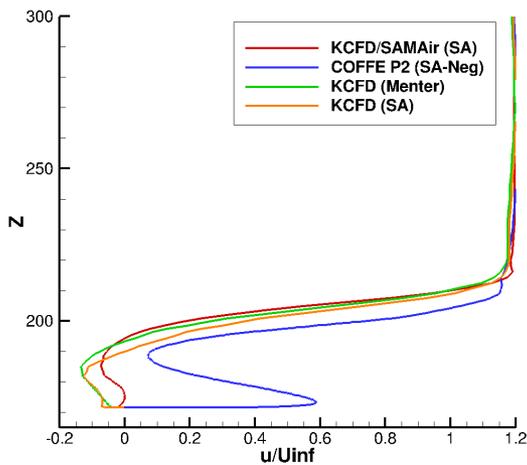
- Similar Cp profiles – plotting issue for lower surface
- COFFE predicts lower pressure on slat





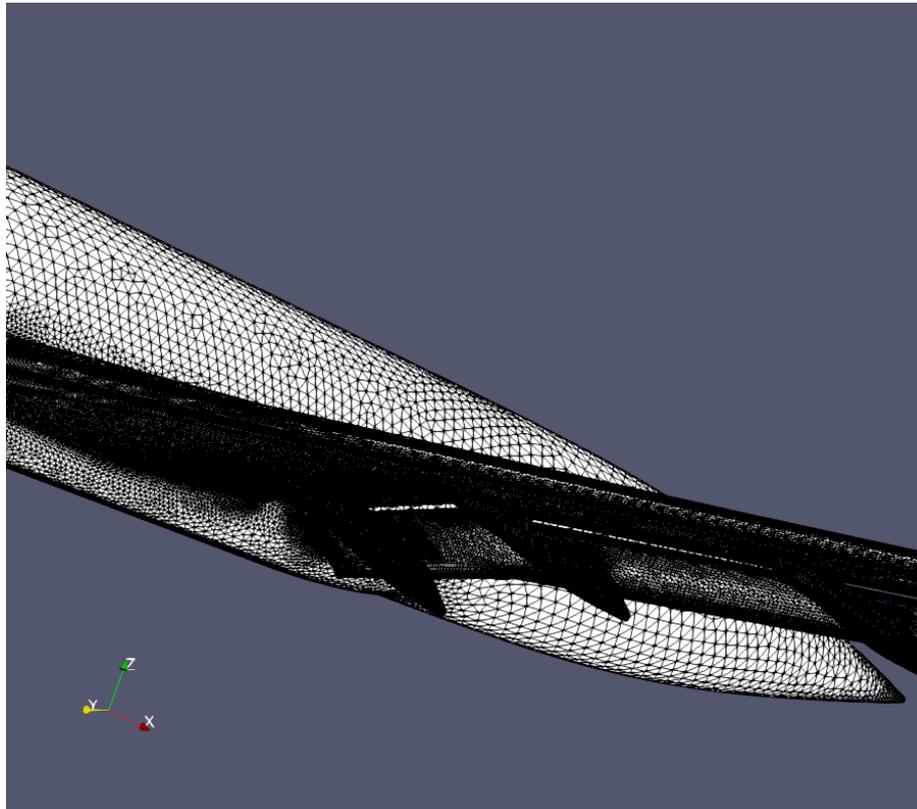
Case 1a: HL-CRM AoA = 16 degrees

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



Case 2a: JSM WB

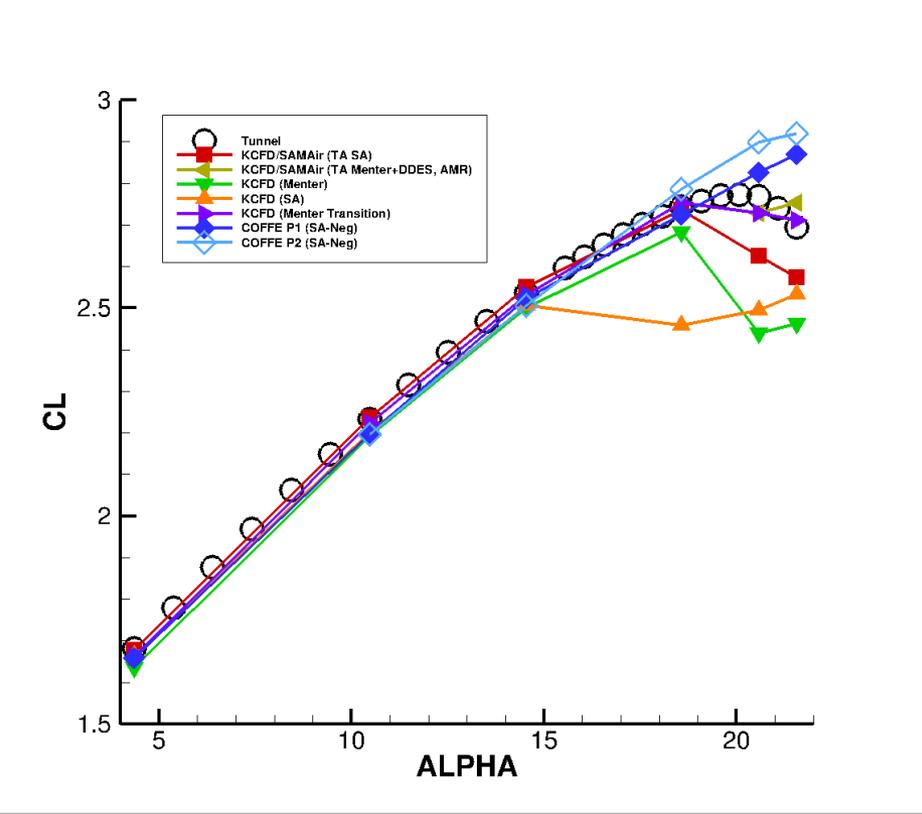
- Mach 0.172, AoA 4.36, 10.47, 14.54, 18.58, 20.59, and 21.57, Re_MAC = 1,930,000.0



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

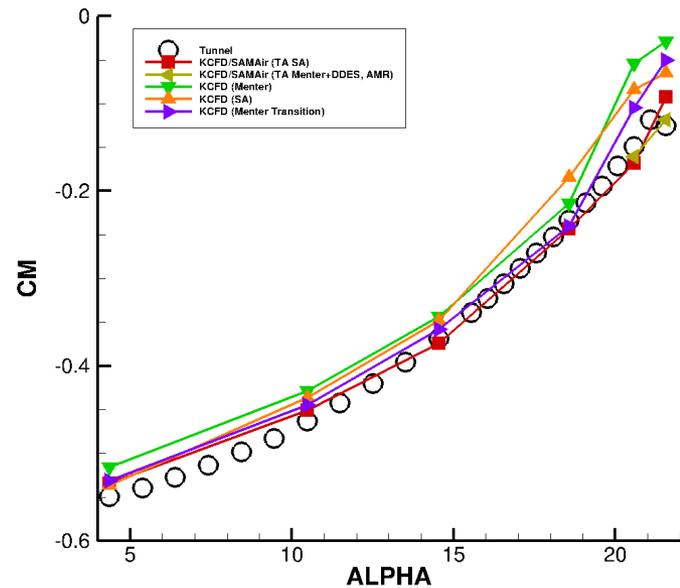
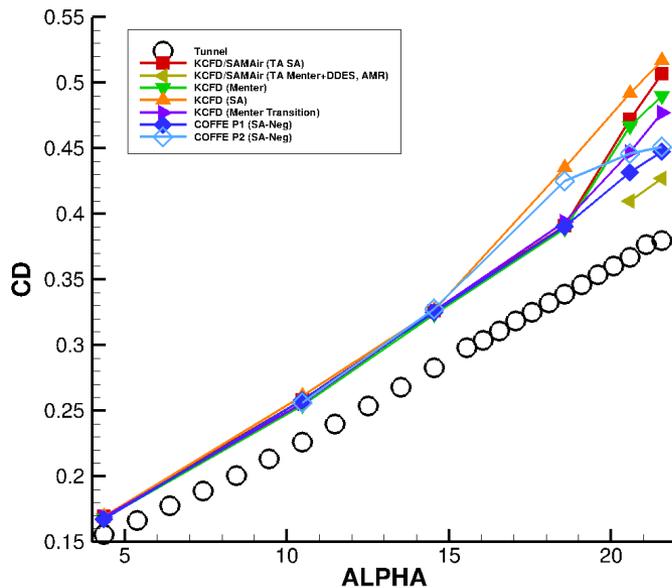
Case 2a: JSM WB Lift Curve

- 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



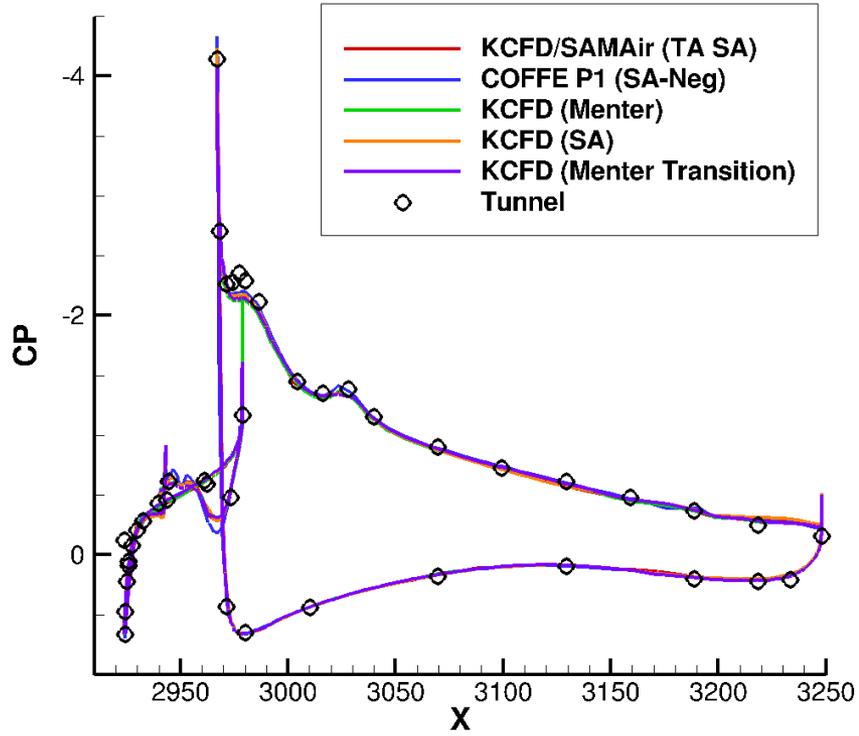
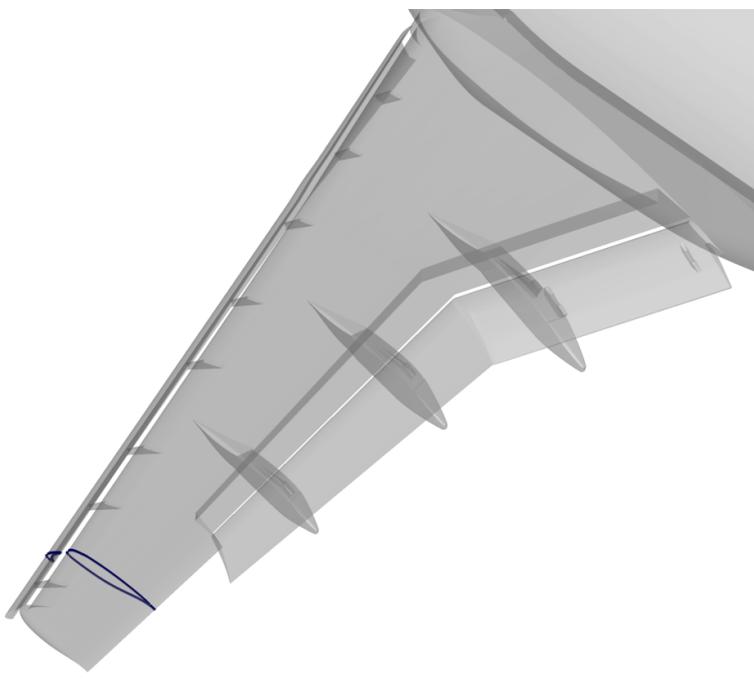
Case 2a: JSM WB Drag and Moment

- 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

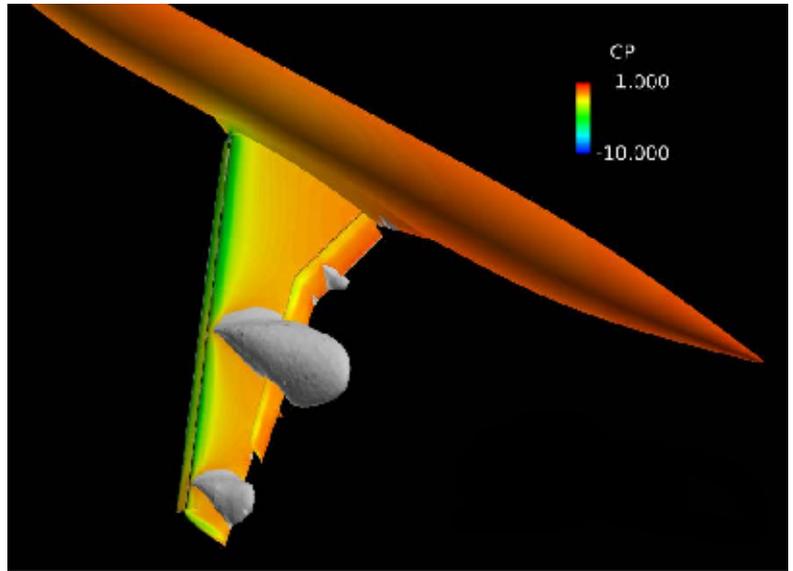


Case 2a: JSM WB Slat Bracket

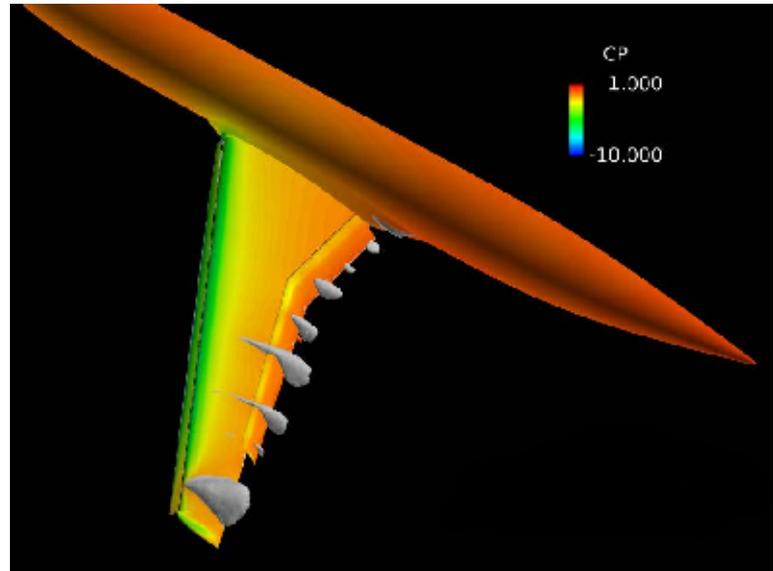
Separation, AoA = 18.58 degrees -- KCFD

- 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

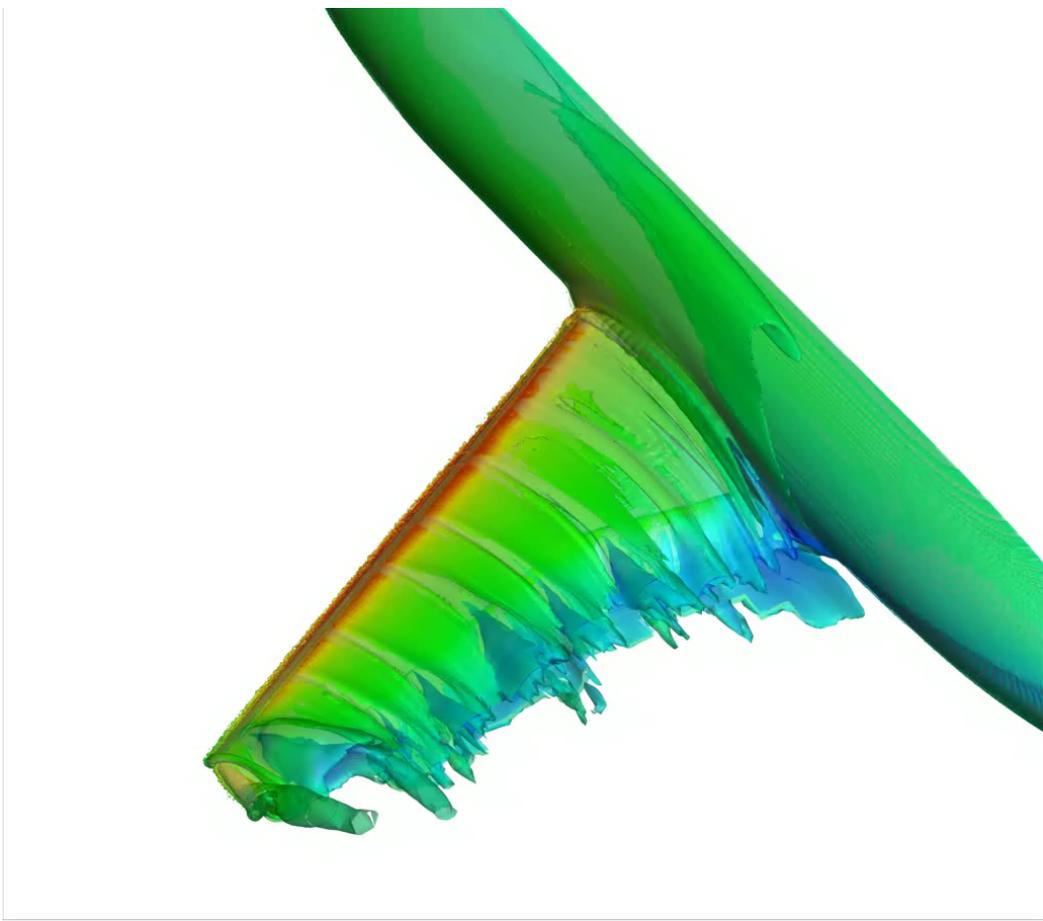


KCFD - Menter-BSL

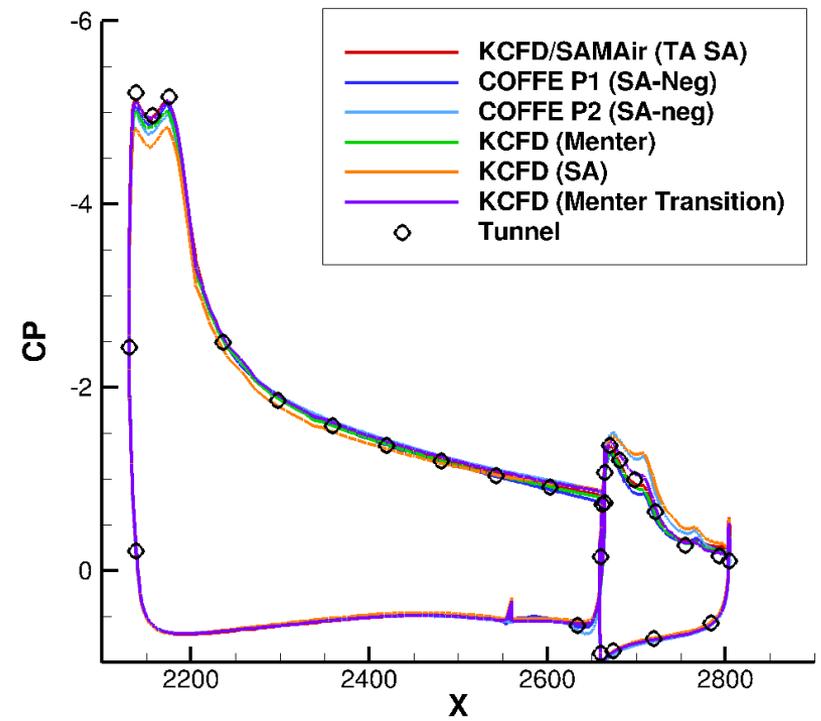
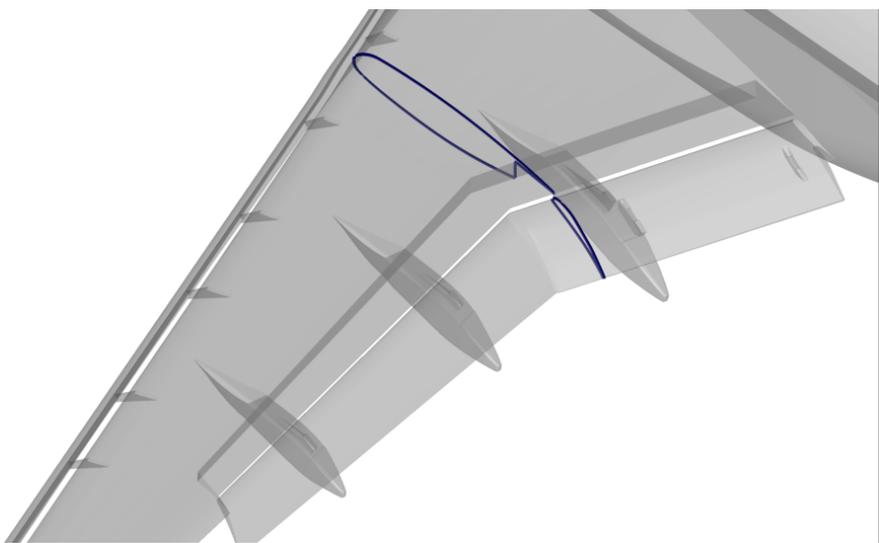


Case 2a: JSM WB AoA = 18.58 degrees

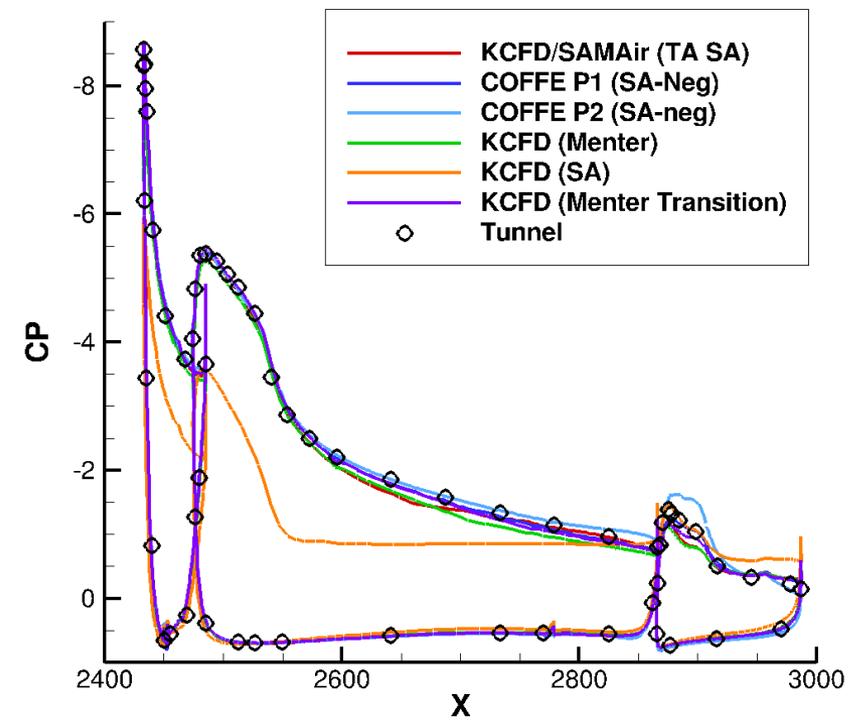
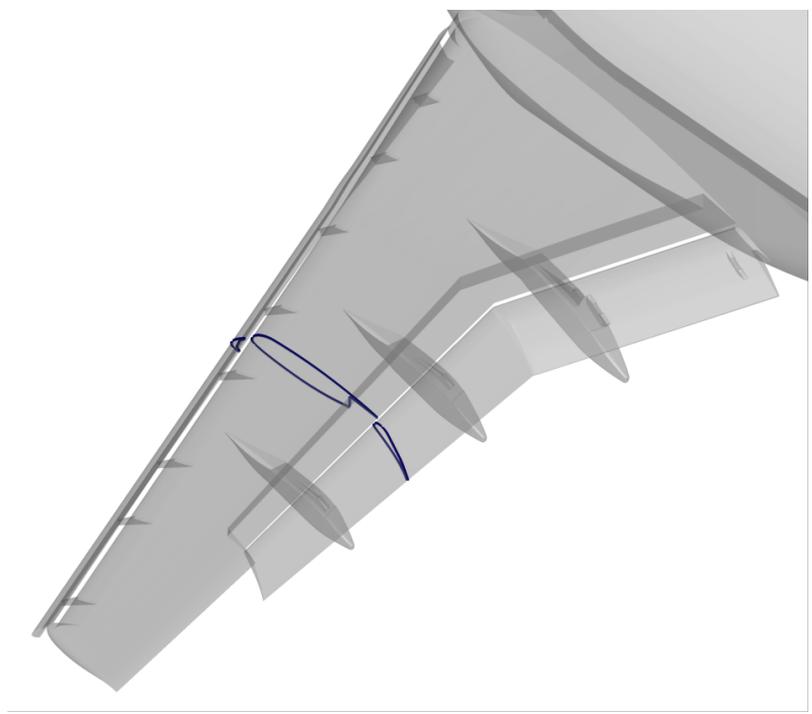
- Dual-mesh (KCFD+SAMAir); time-accurate SA, no AMR



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

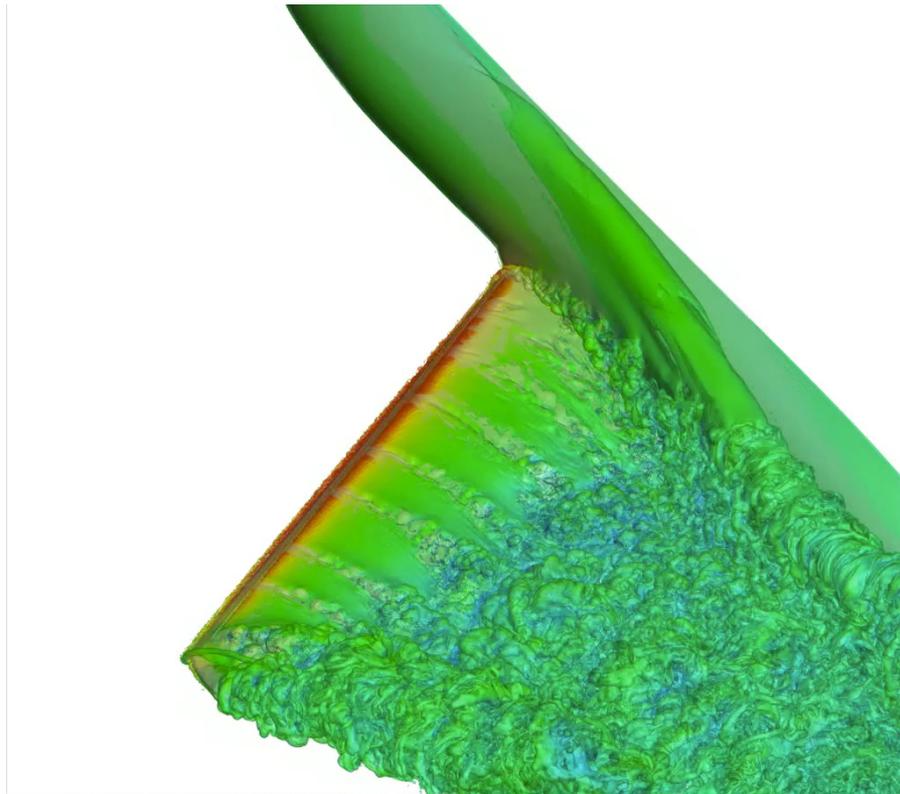


Case 2a: JSM WB AoA = 18.58 degrees, Section E-E

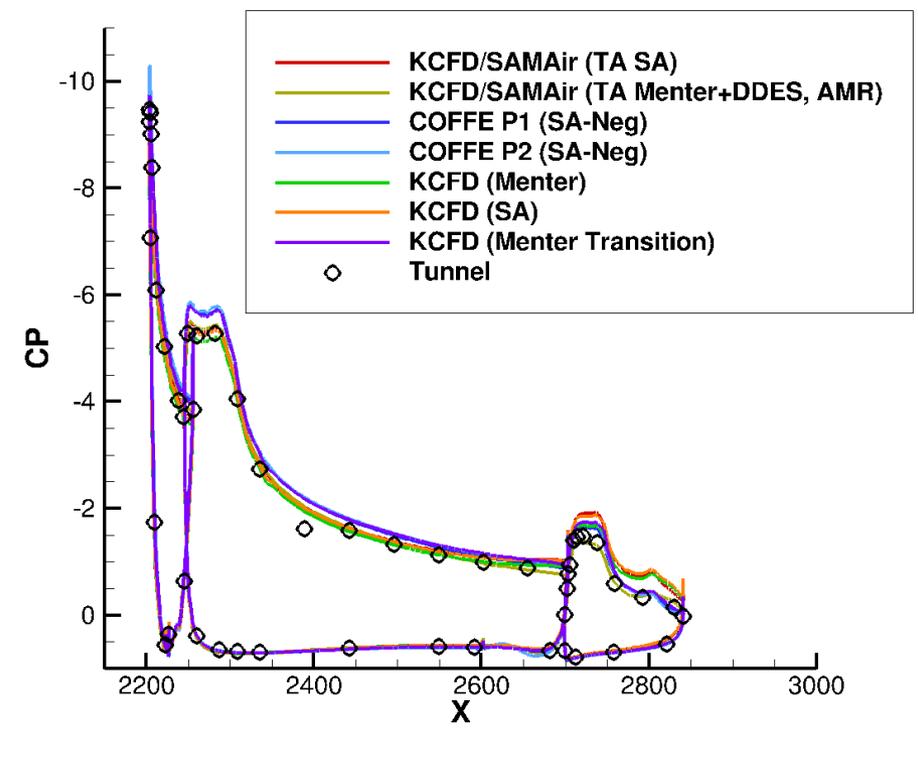
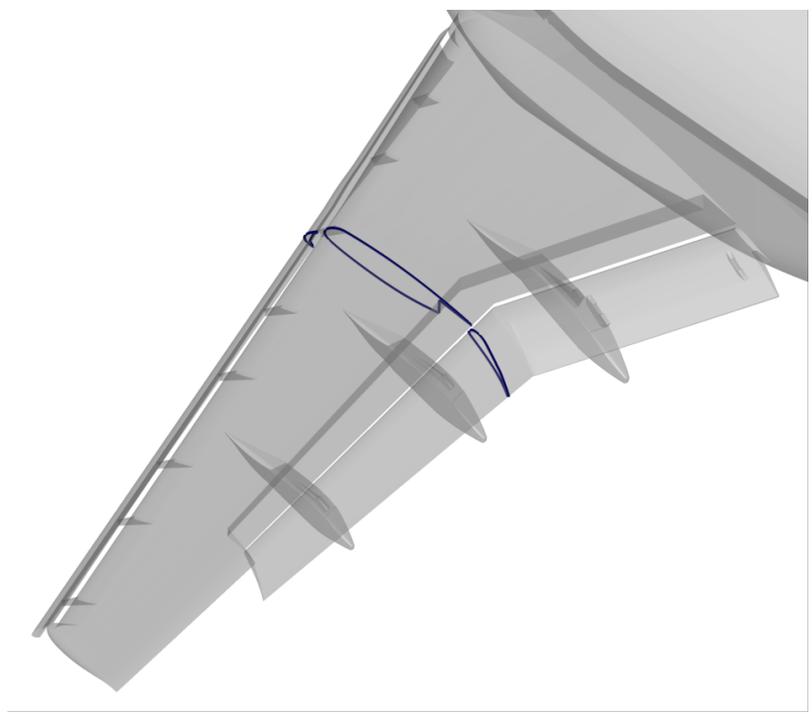


Case 2a: JSM AoA = 21.57 degrees

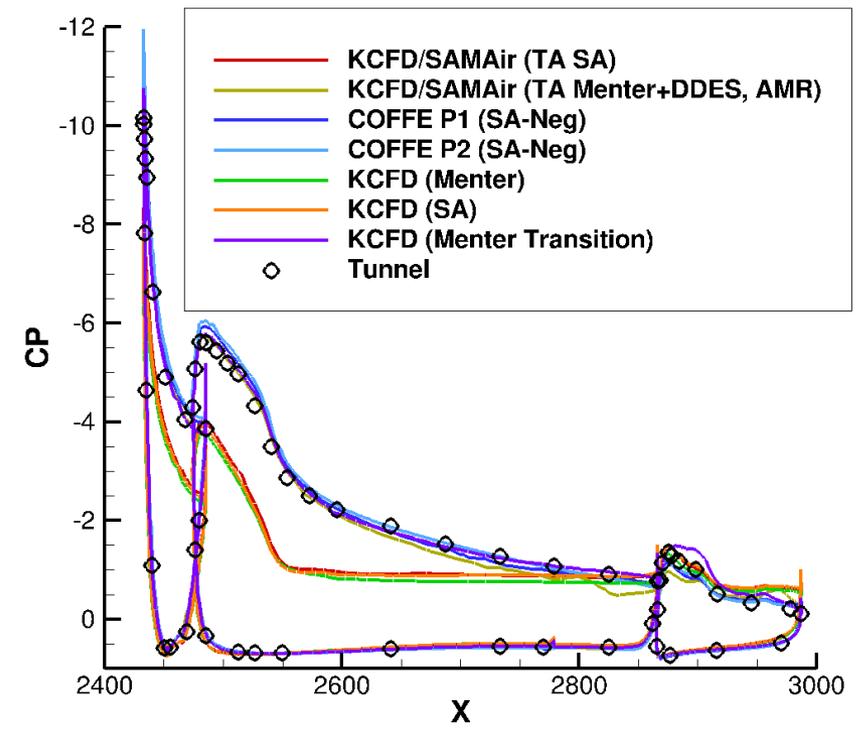
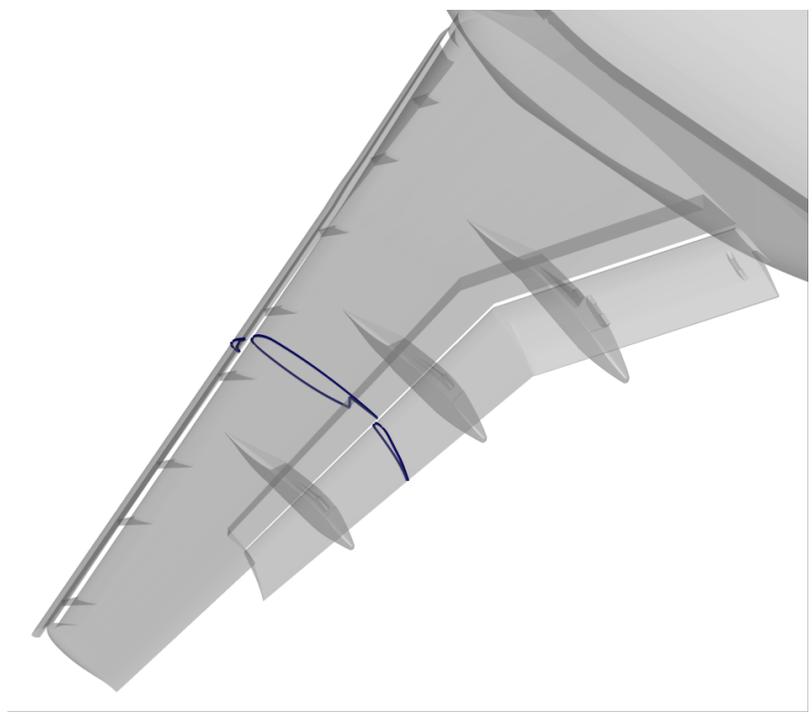
- Dual-mesh (KCFD+SAMAir); time-accurate Menter BSL + DDES with Vorticity-based Cartesian AMR



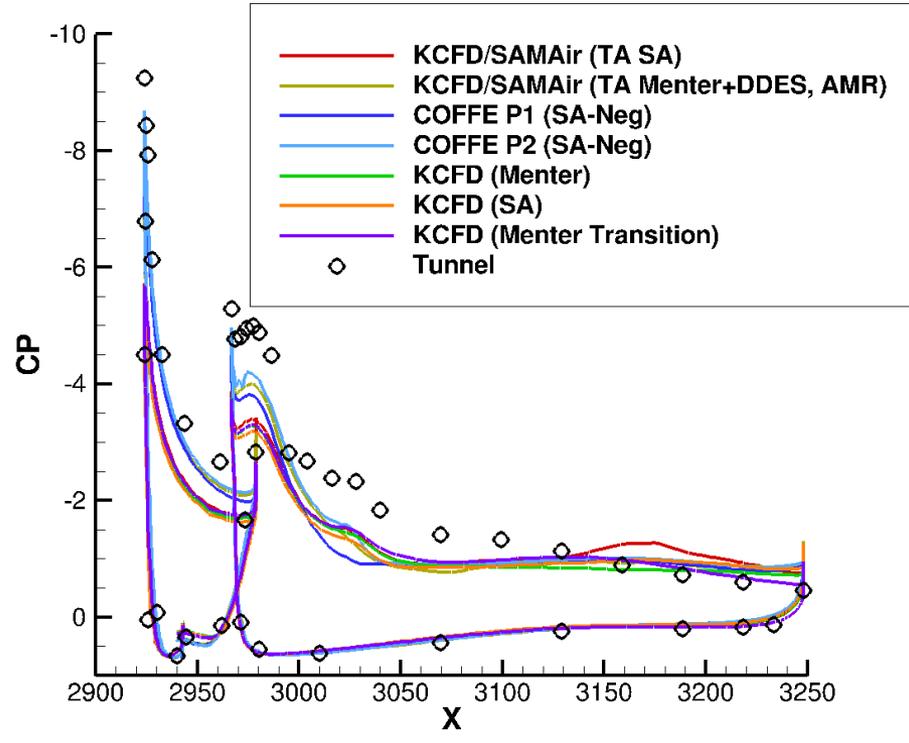
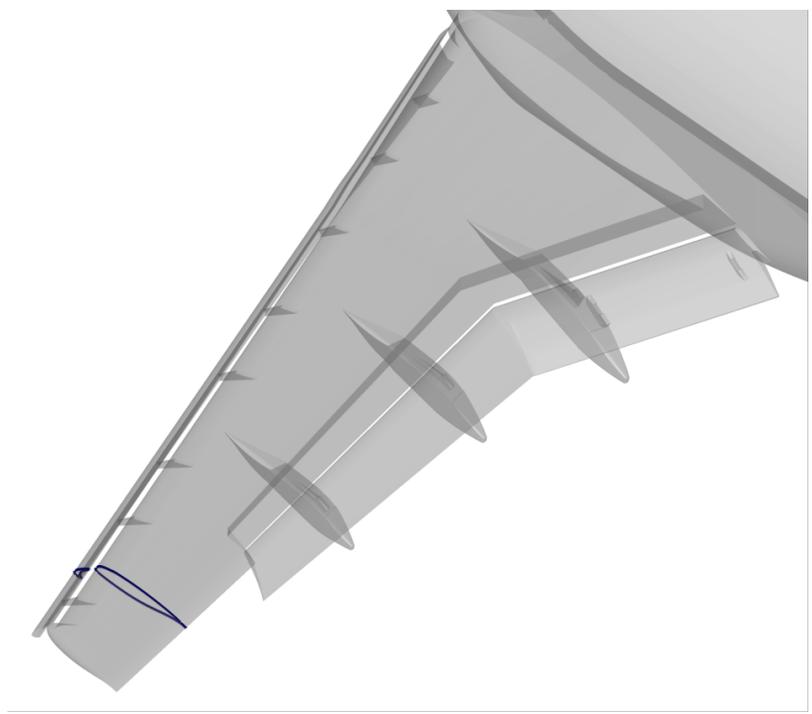
Case 2a: JSM WB AoA = 21.57 degrees, Section D-D



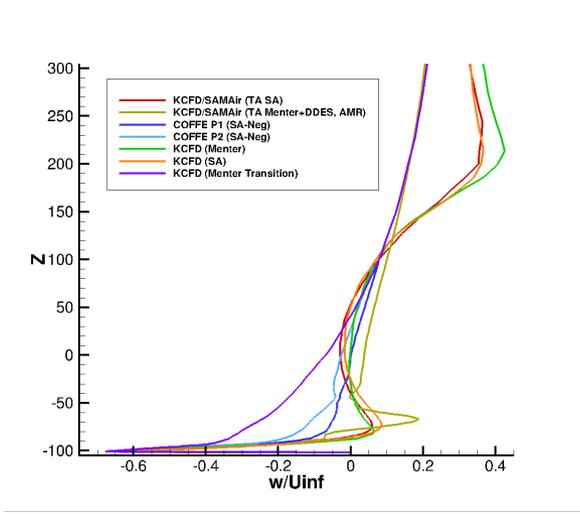
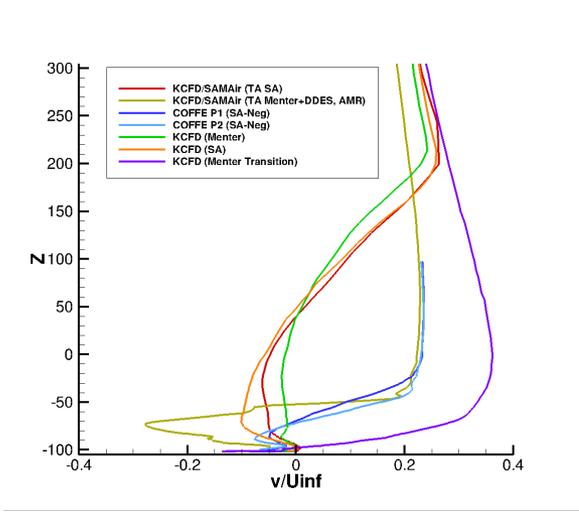
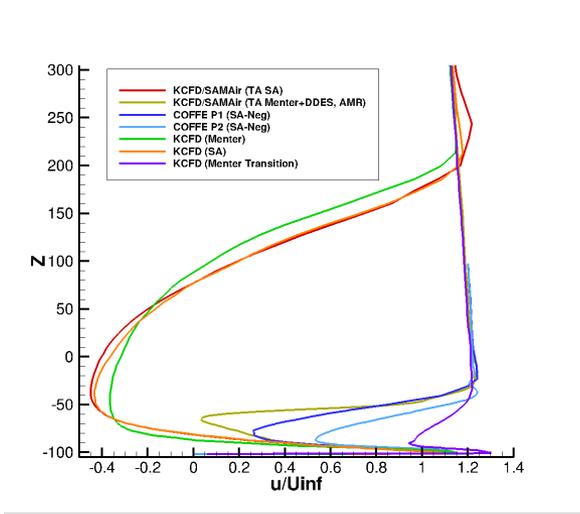
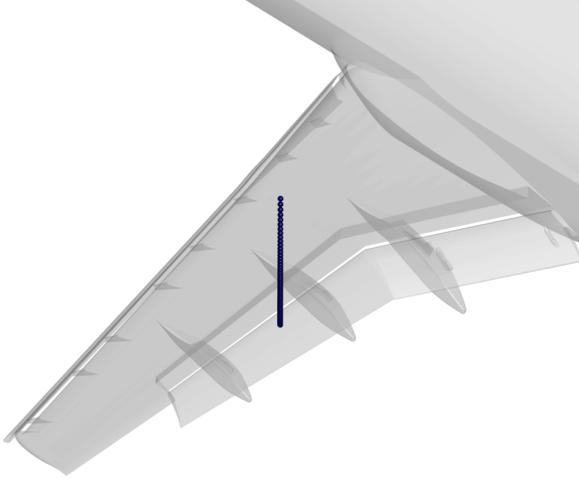
Case 2a: JSM WB AoA = 21.57 degrees, Section E-E



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

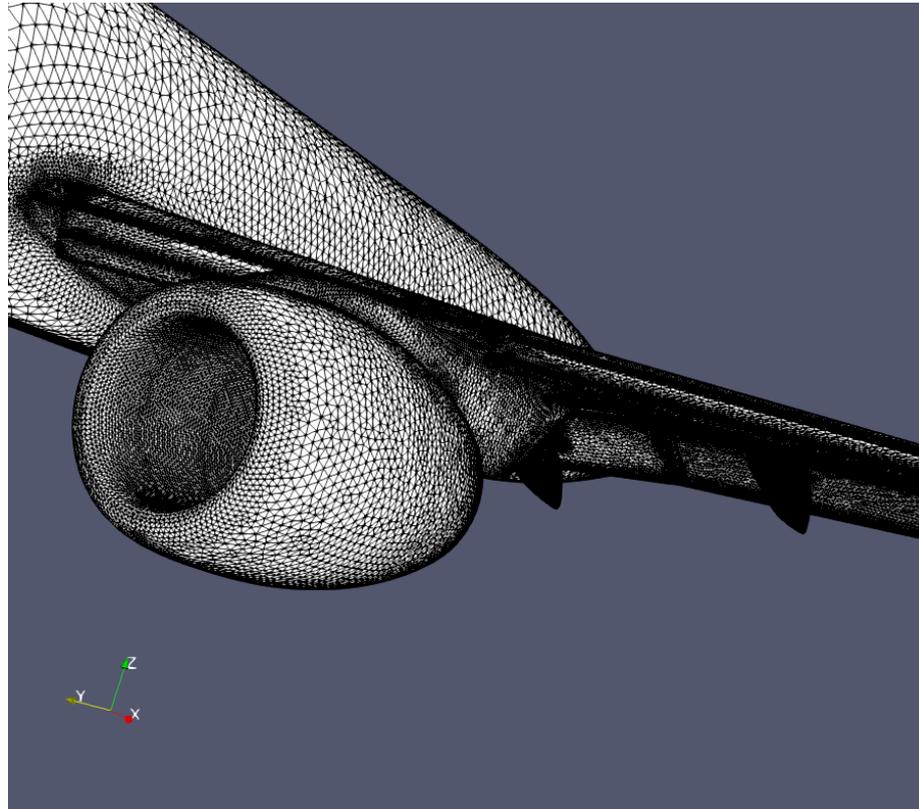


Case 2a: JSM WB AoA = 21.57 degrees



Case 2c: JSM WBNP

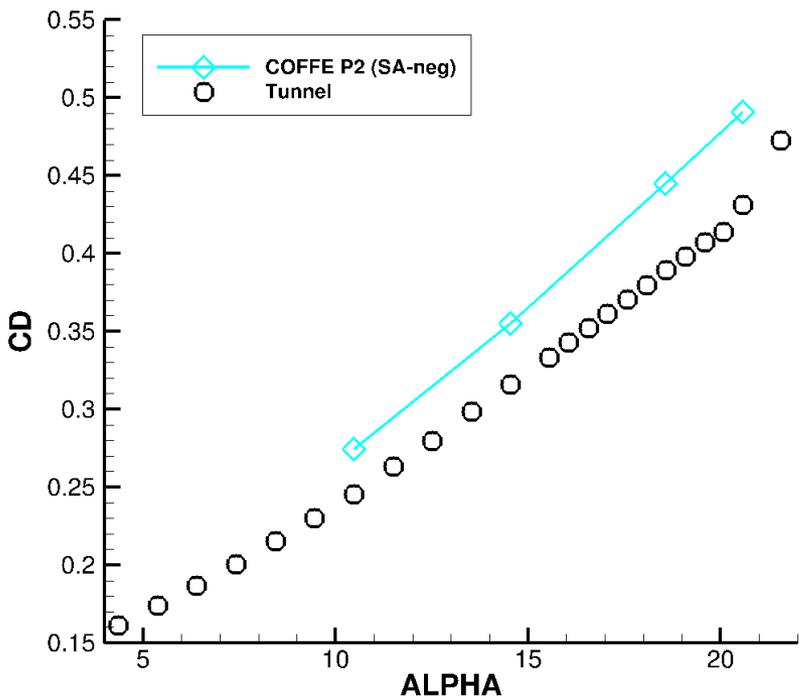
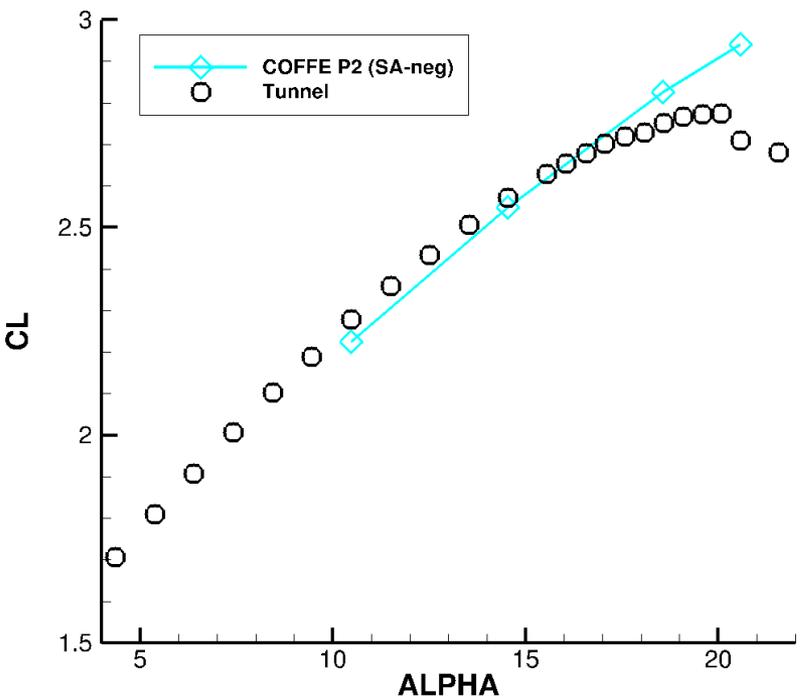
- Mach 0.172, AoA 4.36, 10.47, 14.54, 18.58, 20.59, and 21.57, $Re_{MAC} = 1,930,000.0$



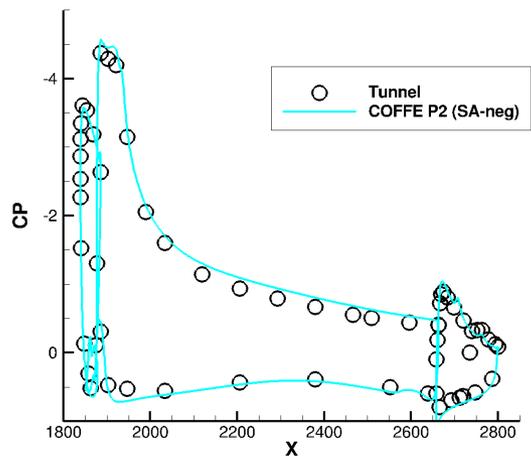
P2 unstructured mesh: 35,038,543 nodes, 26,024,374 Tets

Case 2c: JSM WBNP Lift Curve

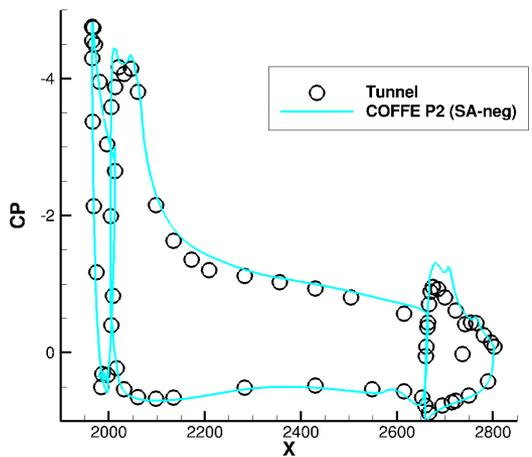
- COFFE P2



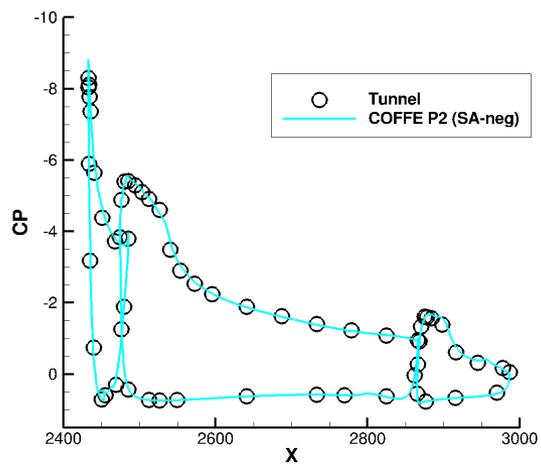
Case 2c: JSM WBNP CP for AoA 18.58



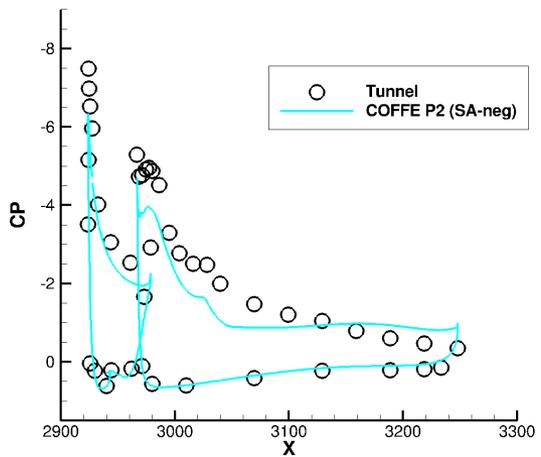
A-A



B-B

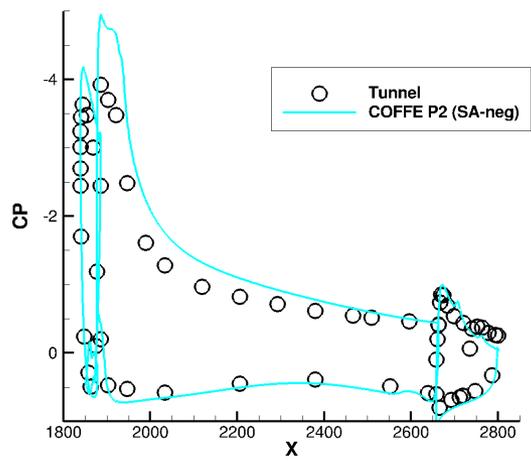


E-E

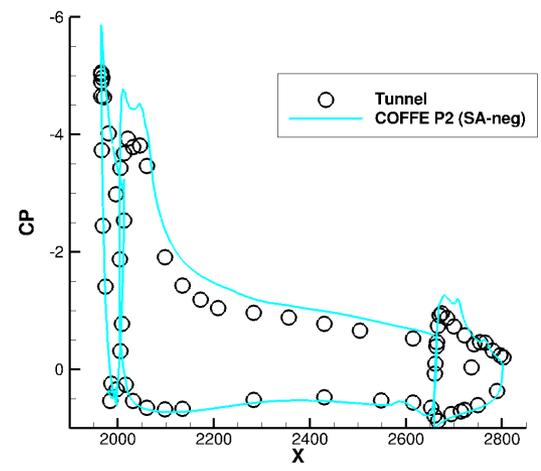


H-H

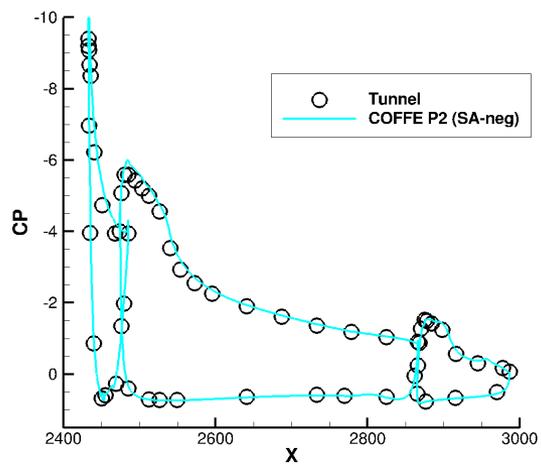
Case 2c: JSM WBNP CP for AoA 20.59



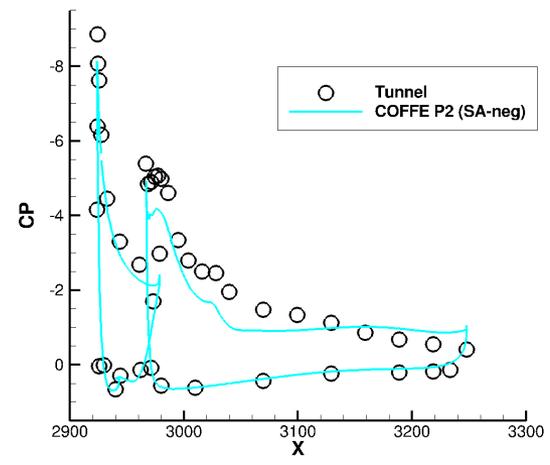
A-A



B-B



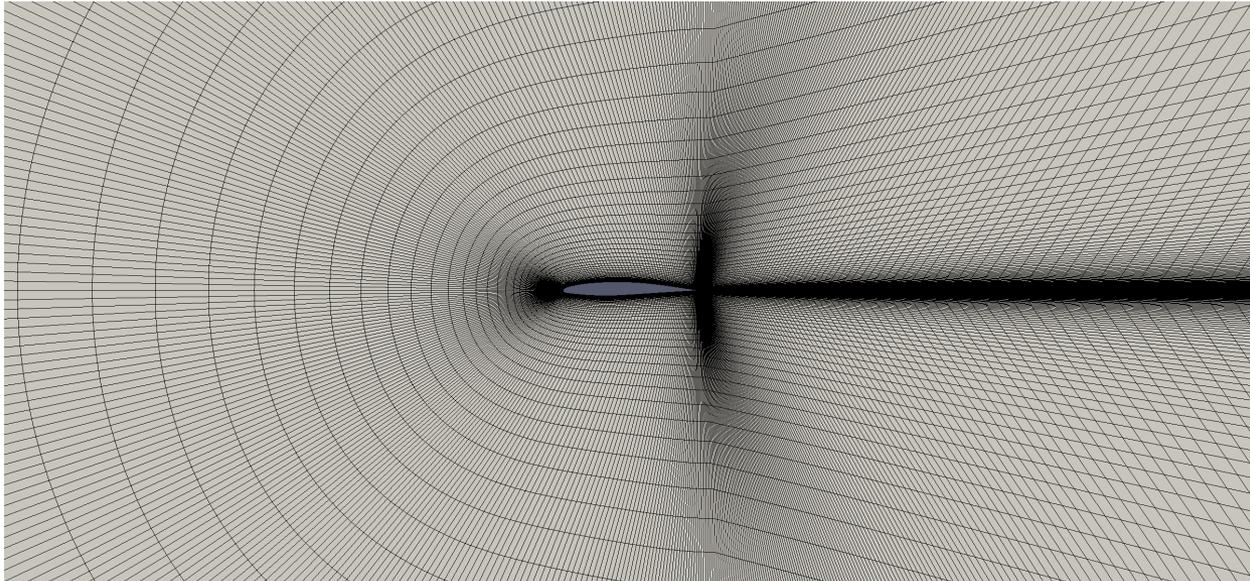
E-E



H-H

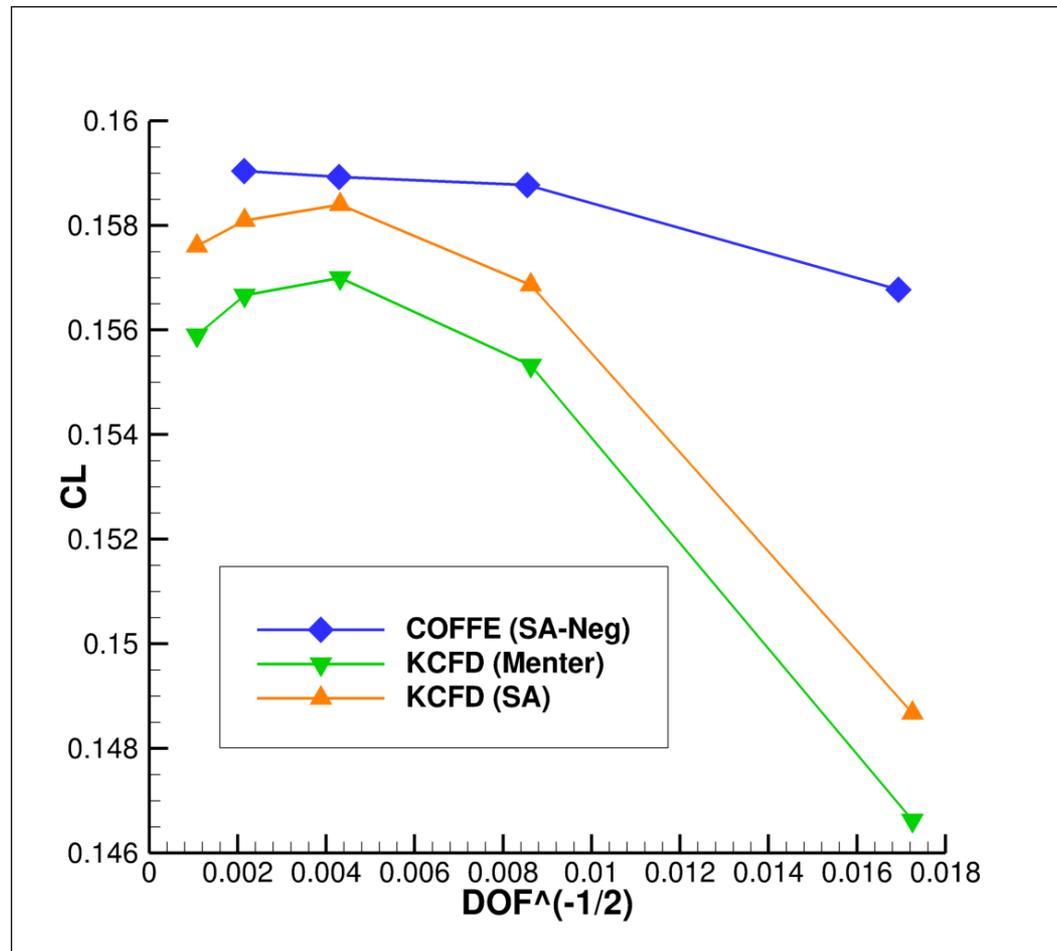
Case 3: DSMA661 (Model A) Airfoil

- Verification exercise
- Mach 0.088, AoA 0.0, and $Re_C = 1,200,000.0$
- Series of quadrilateral meshes
- <https://turbmodels.larc.nasa.gov/airfoilwakeverif.html>
- KCFD – SA, MenterBSL
- COFFE – SA Neg



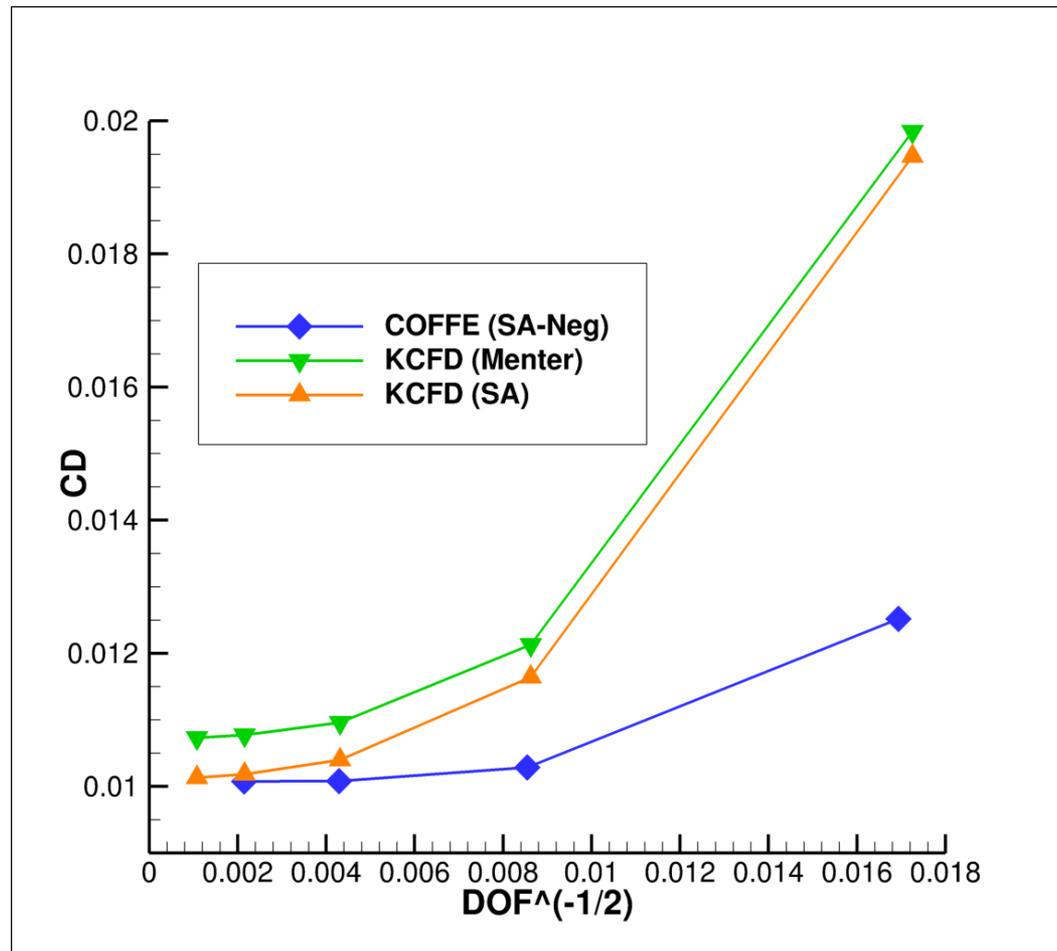
Case 3: DSMA661 (Model A) Airfoil

- Coefficient of Lift Vs. Degrees of Freedom



Case 3: DSMA661 (Model A) Airfoil

- Coefficient of Drag Vs. Degrees of Freedom



- 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

- Material presented in this brief is a product of the CREATE™-AV element of the Computational Research and Engineering for Acquisition Tools and Environments (CREATE) Program that is part of the U. S. Department of Defense High Performance Computing Modernization Program Office