OVERFLOW Analysis of the NASA Common Research Model Using WENO and MUSCL Schemes

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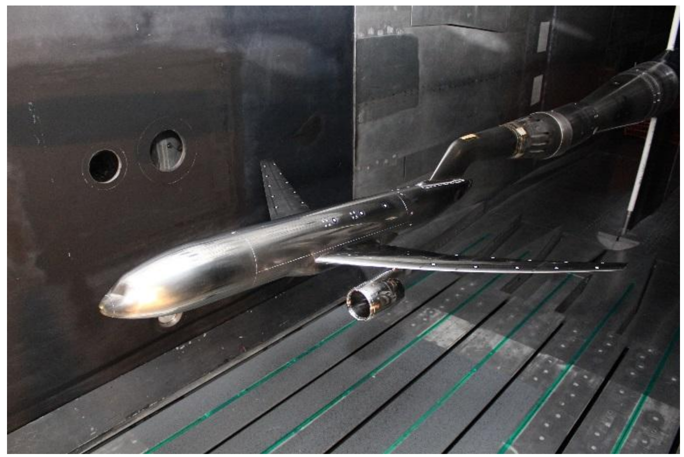
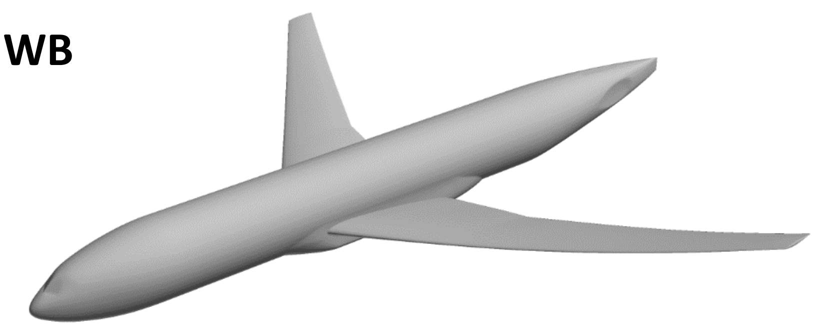
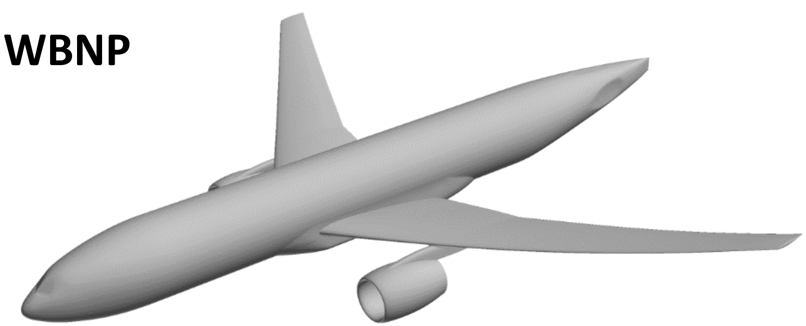
Geometry



WB



WBNP



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Common Overset Grid System

WB Grid Sizes

T:	7,398,176
C:	14,355,678
M:	24,698,828
F:	39,098,858
X:	58,227,000
U:	82,754,486

WBNP Grid Sizes

T:	11,865,177
C:	22,999,565
M:	39,542,953
F:	62,566,221
X:	93,176,522
U:	132,381,764

- Generated by Boeing (Long Beach) and provided by DPW organizing committee

Objectives and Strategy

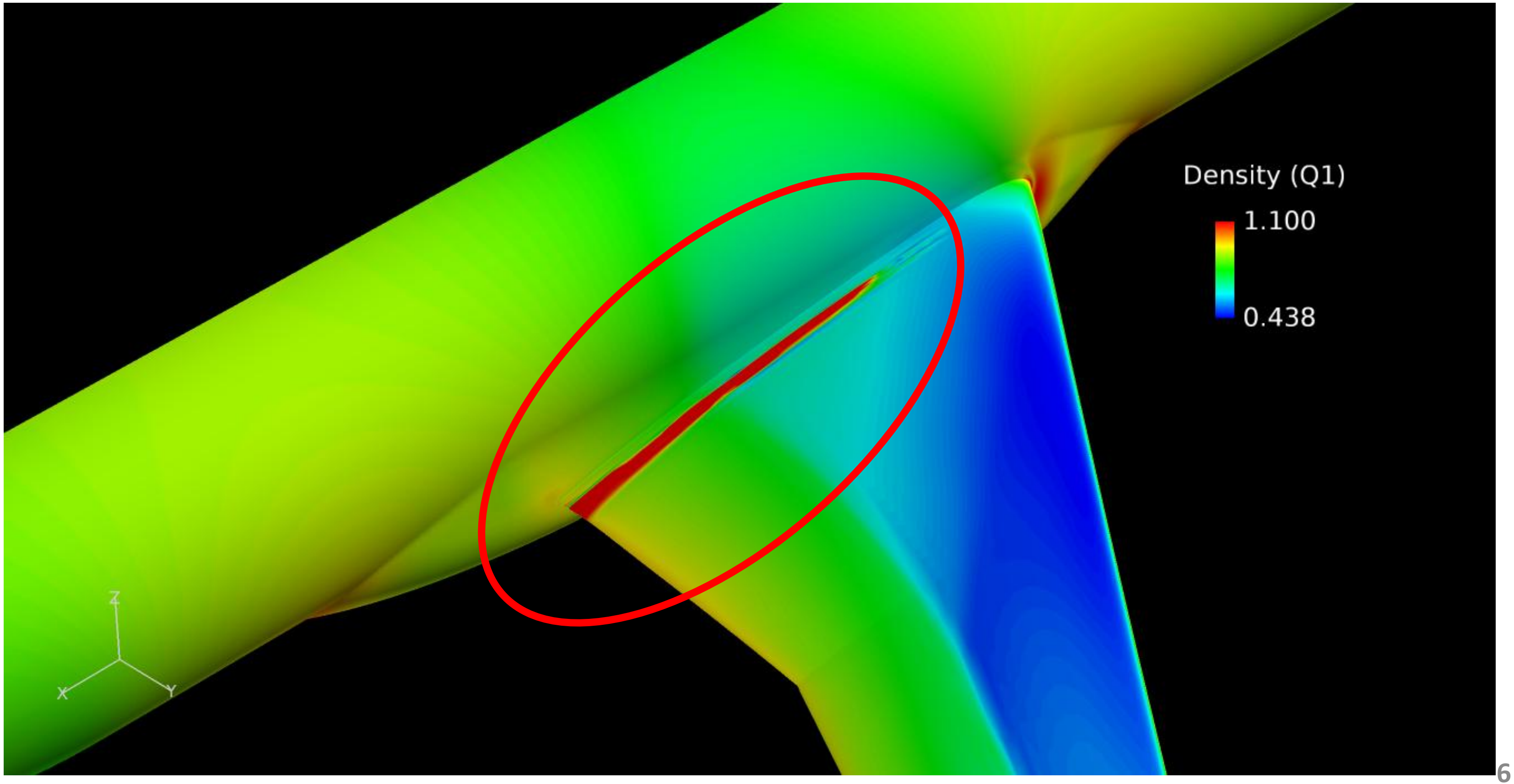
- Goal: Assess benefits of using higher-order convective fluxes for cruise drag prediction
- Solver: OVERFLOW 2.2l
  - Structured, overset solver developed by NASA
- Cases: 2 and 3
  - WB and WBNP grid convergence, nacelle-pylon drag increment
  - Alpha sweep with static aeroelastic deflections, buffet study

Objectives and Strategy

- 5^{th}-order WENO vs. 3^{rd}-order MUSCL with Roe fluxes
  - 2^{nd}-order viscous fluxes for both
- ARC3D scalar pentadiagonal LHS for first 5000 iterations
  - Grid sequencing and multigrid for convergence acceleration
- Switch to SSOR left-hand side until convergence
  - No artificial dissipation (DIS2 = 0, DIS4 = 0)
  - No multigrid
- USURP force/moment integration
- OVERFLOW's C_L driver used to update AoA during solution

Objectives and Strategy

- SSOR + multigrid did not lead to favorable results



Turbulence Modeling

- Spalart-Allmaras model with Spalart-Shur rotation/curvature correction and the quadratic constitutive relation (‘SA-RC-QCR2000’)
  - RC correction beneficial in tip region
  - QCR improves predictions in wing-body junctures (side-of-body separation) by introducing turbulence anisotropy

- Case are assumed a priori to be fully attached (or nearly so) with an attainable and meaningful steady RANS solution

Quadratic Constitutive Relation

- Non-linear Reynolds-stress closure

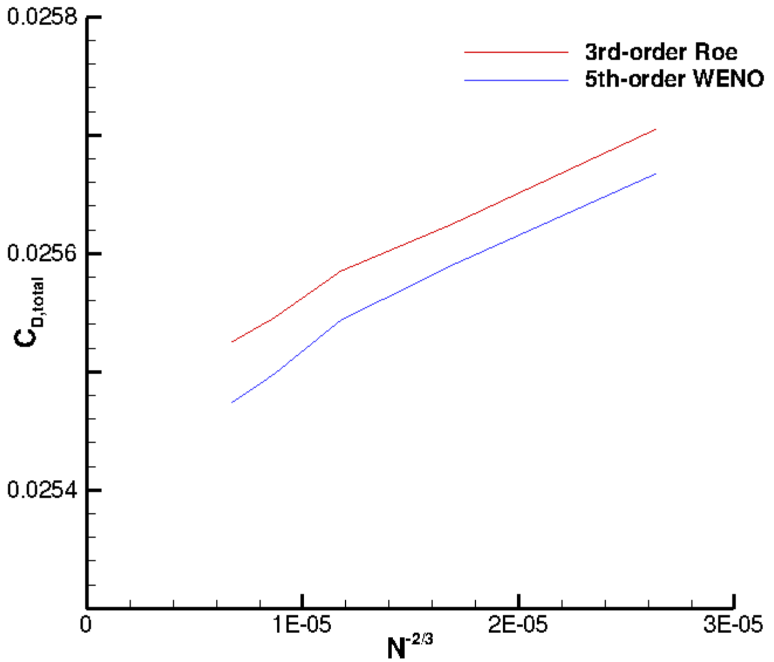
$$\tau_{ij} = \tau_{ij}^{linear} - C_{nl1}\left[O_{ik}\tau_{jk}^{linear} + O_{jk}\tau_{ik}^{linear}\right]$$

$$\tau_{ij}^{linear} = 2\mu_t\left[S_{ij} - \frac{1}{3}\frac{\partial u_k}{\partial x_k}\delta_{ij}\right] - \underbrace{\frac{2}{3}\rho k\delta_{ij}}_{omitted} \qquad O_{ij} = \frac{\Omega_{ij}}{\sqrt{\frac{\partial u_m}{\partial x_n}\frac{\partial u_m}{\partial x_n}}}$$

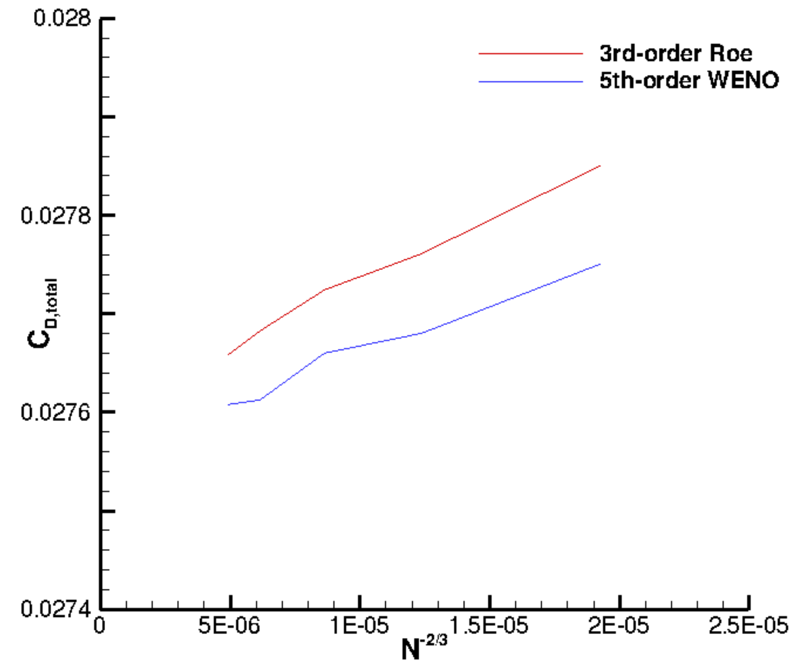
- Promotes 4:2:3 principal stress ratio in planar shear layers
  - Accepted value: C_{nl1} = 0.3 (used here)
  - 'True' values: C_{nl1} = 0.358 (a_1 = 0.31); C_{nl1} = 0.370 (a_1 = 0.30)

Case 2: CRM Nacelle-Pylon Drag Increment

Case 2: Drag Convergence

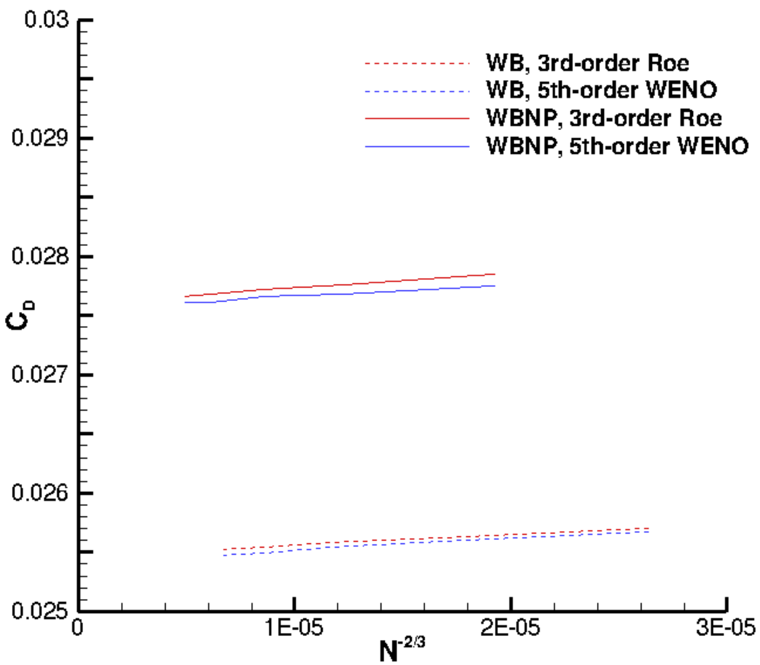


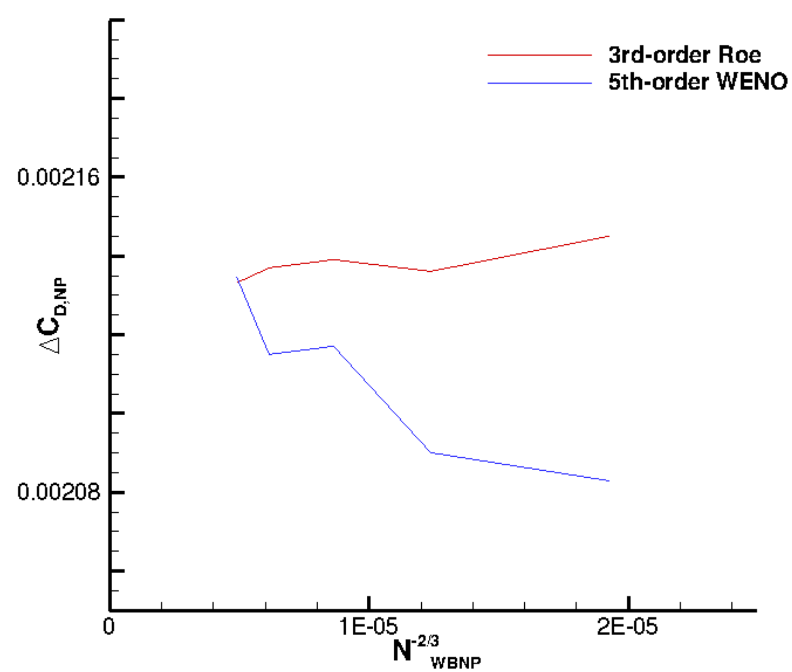
WB



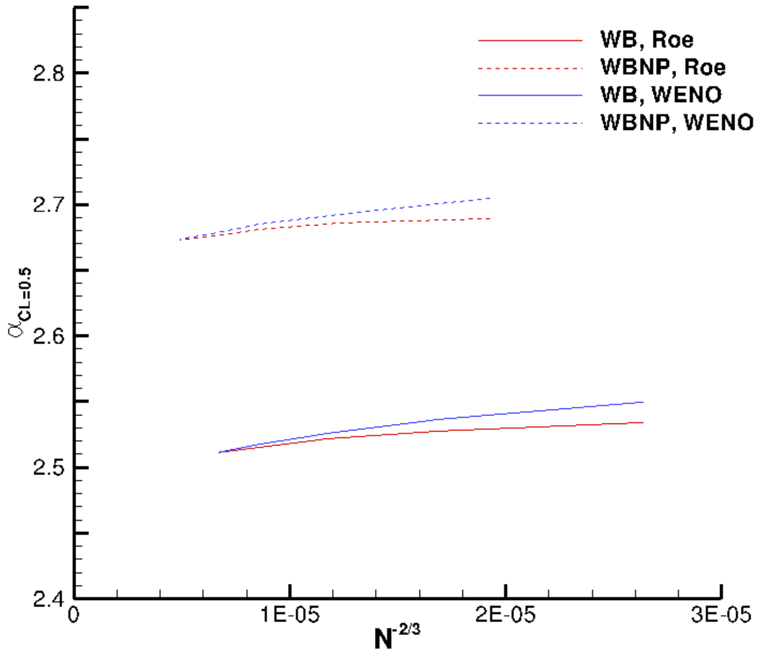
WBNP

Case 2: ΔC_D Convergence

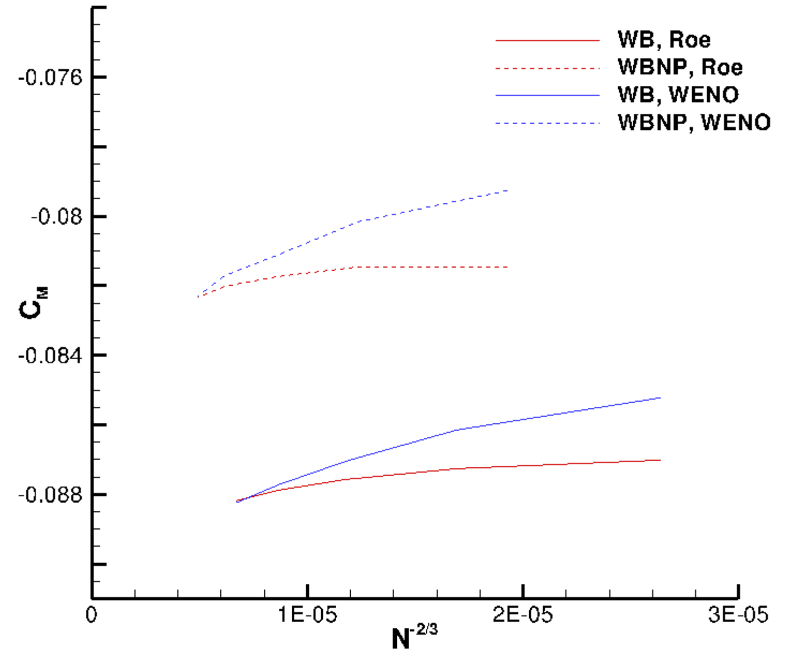




Case 2: Alpha and Pitching-Moment Convergences



Angle of Attack



Pitching-Moment Coefficient

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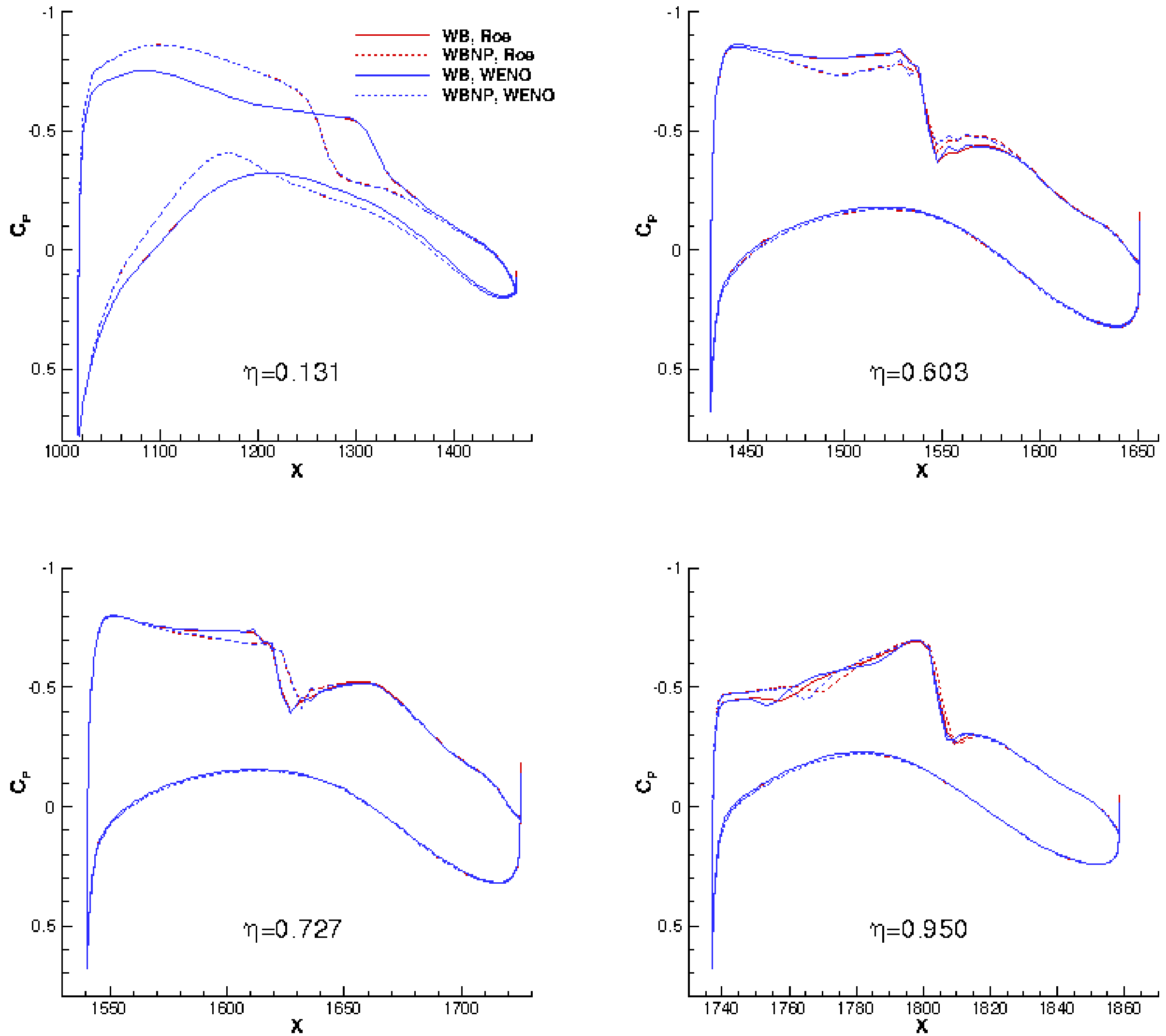
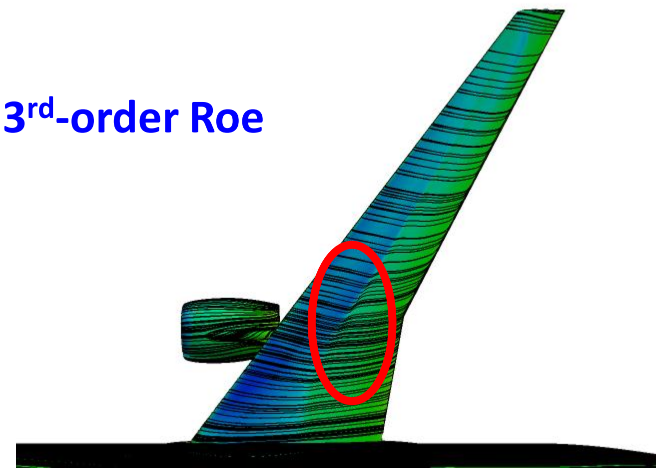
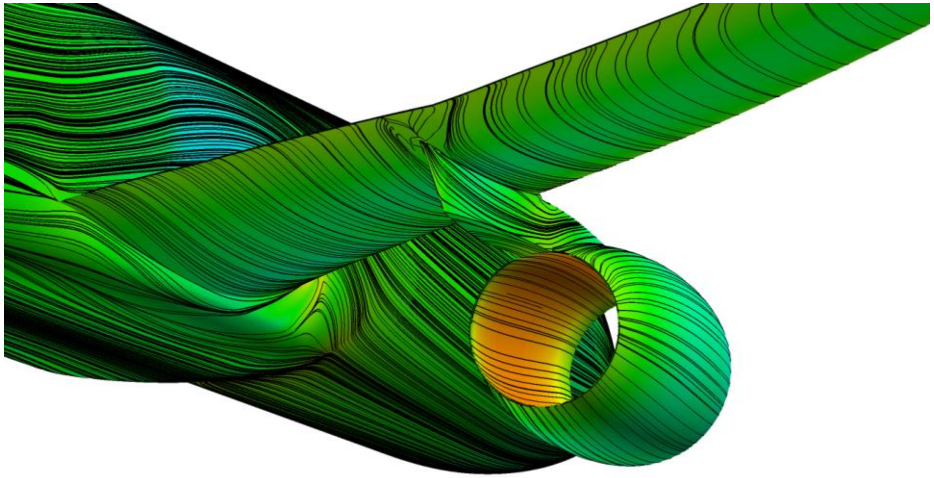
Case 2: C_p Comparisons (Medium Grid)



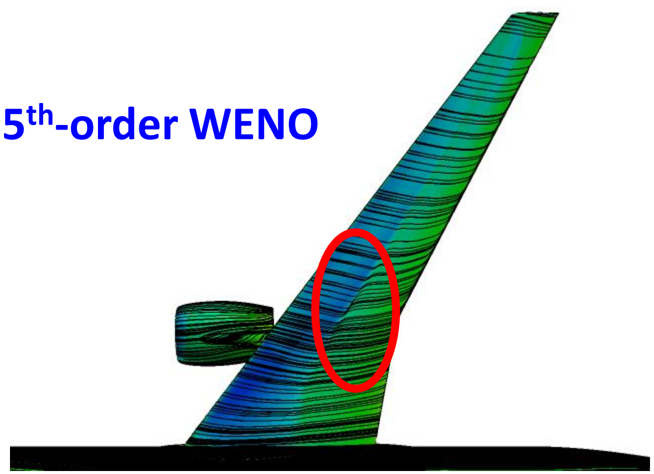
Case 2: CRM-WBNP Surface Streamlines (Medium Grid)

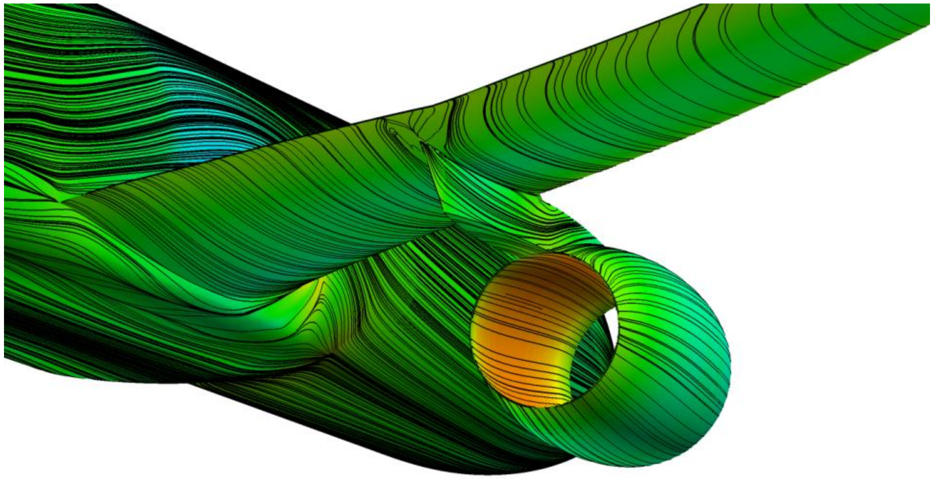
3rd-order Roe





5th-order WENO



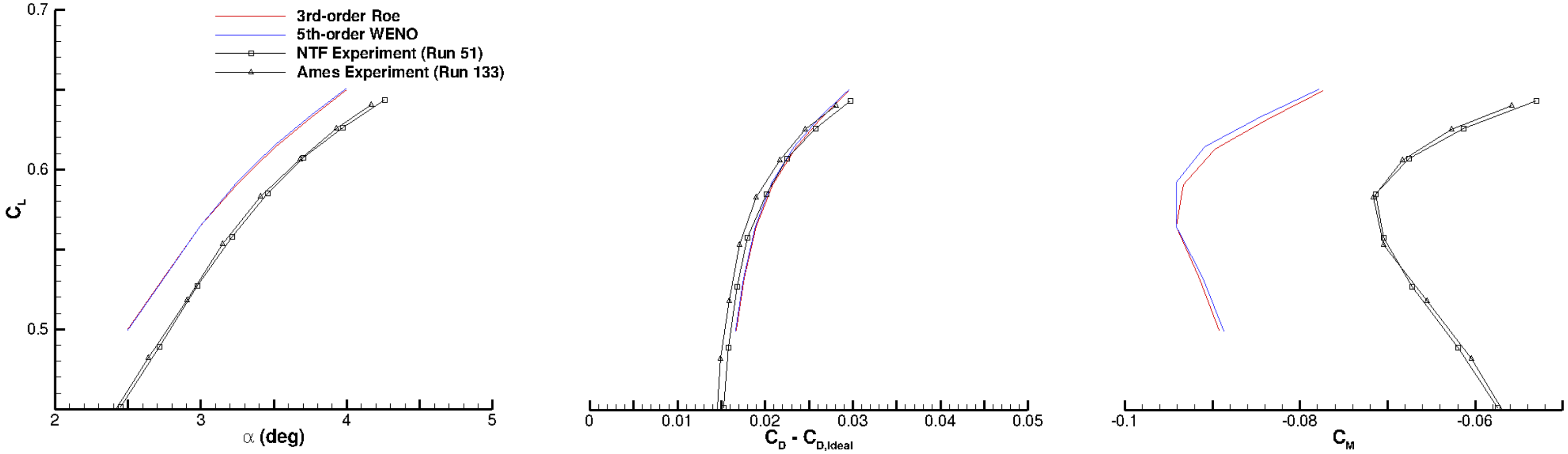


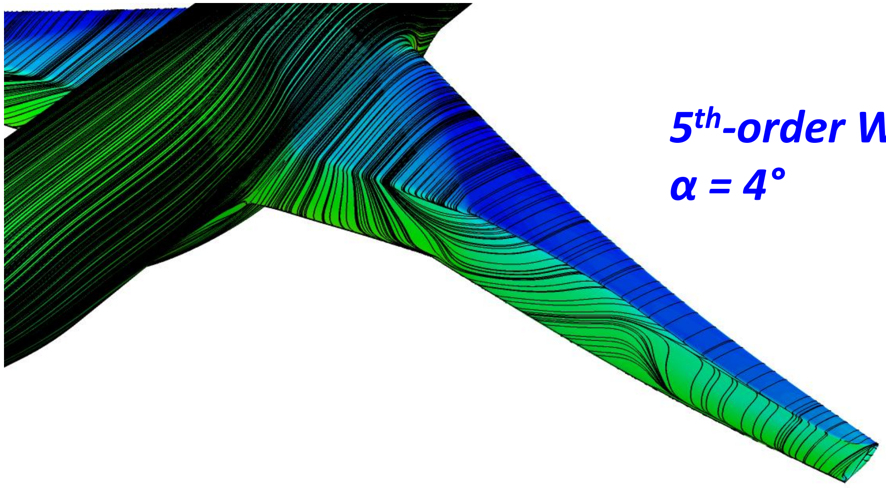
Case 3: CRM-WB Static Aero-Elastic Effect

Strategy

- Same solver parameters as Case 2(a)
  - 3^{rd}-order Roe vs. 5^{th}-order WENO, SSOR LHS, no dissipation
- Restart from lower alphas
  - Converge $\alpha = 2.50°$ first
  - Start $\alpha = 2.75°$ from $\alpha = 2.50°$ solution, etc.
- Run until force/moment convergence

Case 3: Force and Moment Comparisons





5th-order WENO
α = 4°

Observations and Conclusions

Observations and Conclusions

- Higher-order convective fluxes had no impact on formal order of accuracy
  - Two fringe layers (PEGASUS connectivity)
  - Viscous terms and grid metrics remain 2nd-order
  - SA convective terms are 1st order

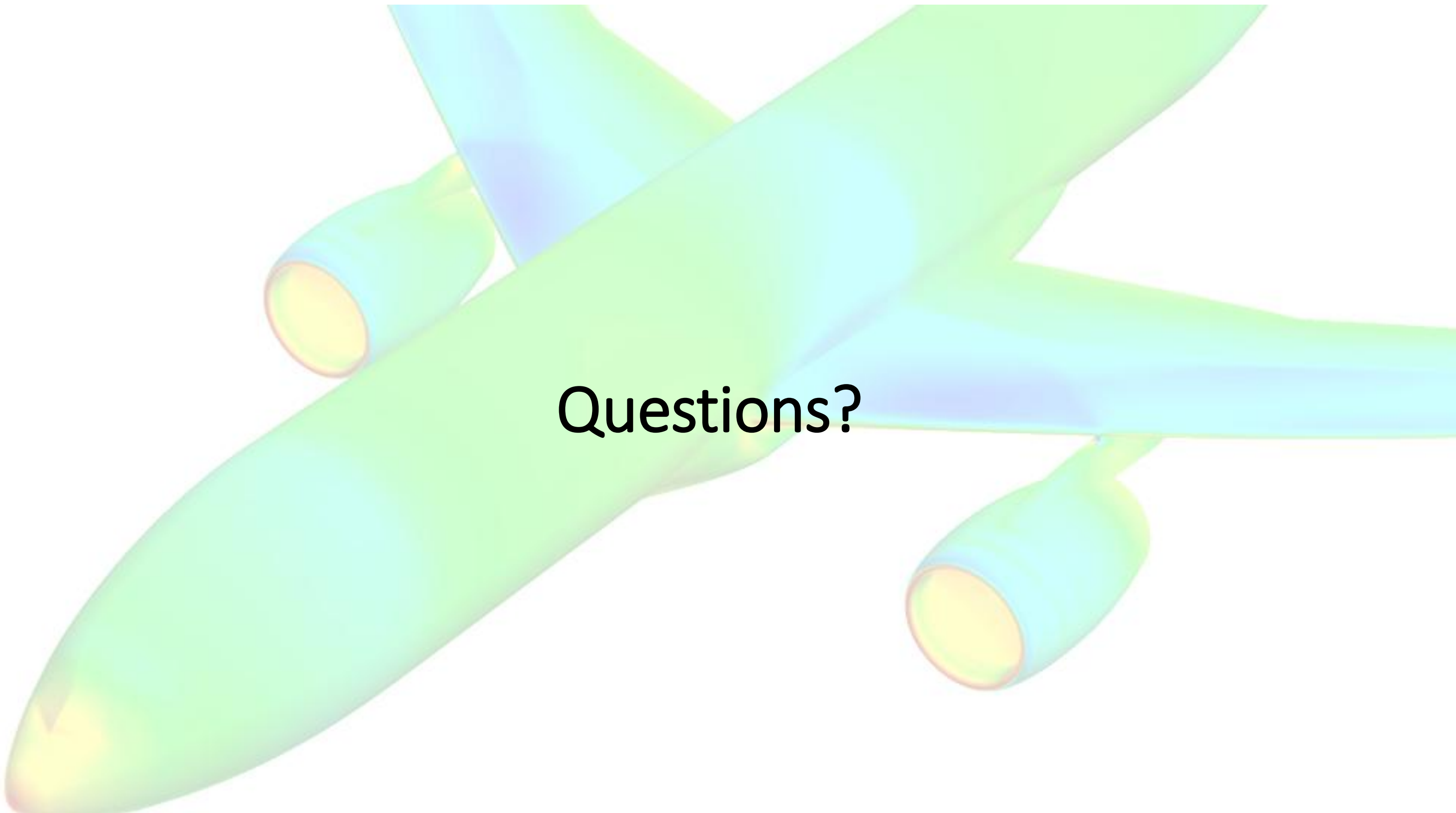
- WENO and Roe solutions are not converging to the same continuum values
  - Similar convergence qualities, small (< 1 ct) offset in drag values
  - Requires further investigation

Observations and Conclusions

- WENO solutions showed oscillations around the shockwave
  - WENOM limiter used, perhaps not effective enough
  - Alternative may be to set DIS2 ≠ 0

- Lift and pitching-moment polar comparisons imply too much lift predicted outboard
  - Need to compare predicted and measured lift distributions
  - Sting not modeled

- SSOR solutions are slow
  - D3ADI showed promise for upwind RHS and DIS4 = 0



Questions?