Contributions to HiLiftPW-3 Using Structured, Overset Grid Methods

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Outline

- Introduction
- Description of HiLiftPW-3 Geometries and Cases
- Computational Methodologies
- Results
- Conclusion
- Acknowledgments

Introduction

- Two geometries of interest
  - High-Lift Common Research Model (HL-CRM)
    - Completely predictive
  - JAXA Standard Model (JSM)
    - Transitional test case

- Structured, overset grids generated and provided by the organizing committee

- Two overset solvers considered in this paper
  - OVERFLOW (UTK and NASA)
  - LAVA (NASA)

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HL-CRM Geometry

- Open-source high-lift configuration based on the Common Research Model (Lacy and Sclafani, 2016)

HL-CRM Cases (Case 1)

- **Case 1a (requested):** Full-Chord Flap Gap grid-refinement study
- **Case 1b (optional):** Full-Chord Flap Gap with grid adaptation
- **Case 1c (optional):** Partially Sealed Chord Flap Gap for medium-resolution grid only
- **Case 1d (optional):** Partially Sealed Chord Flap Gap with grid adaptation

Free-stream Mach Number	0.2
Angles of Attack	8° and 16°
Mean Aerodynamic Chord (MAC)	275.8 in (full scale)
Reynolds Number (based on MAC)	3.26×10^6
Reference Static Temperature	518.67 °R (288.15 K)
Reference Static Pressure	14.700 psi (760.21 mm-Hg)

JSM Geometry

- Representative of a 100-person-class transport with a modern high-lift system (Yokokawa et al., 2006 and 2008)

JSM Cases (Case 2)

- **Case 2a (requested):** Nacelle/Pylon Off
- **Case 2b (optional):** Nacelle/Pylon Off with grid adaptation
- **Case 2c (requested):** Nacelle/Pylon On
- **Case 2d (optional):** Nacelle/Pylon On with grid adaptation

Free-stream Mach Number	0.172
Angles of Attack	4.36°, 10.47°, 14.54°, 18.58°, 20.59°, and 21.57°
Mean Aerodynamic Chord (MAC)	529.2 mm (model scale)
Reynolds Number (based on MAC)	1.93×10^6
Reference Static Temperature	551.79 °R (306.55 K)
Reference Static Pressure	14.458 psi (747.70 mm-Hg)

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Flow Solvers and Approach

- OVERFLOW 2.2 (UTK and NASA)
  - Node-centered, finite-difference
  - RHS discretization: 3^{rd}-order MUSCL w/ Roe fluxes
  - LHS algorithm: ARC3D scalar pentadiagonal solver
  - Turbulence model: Spalart-Allmaras SA-noft2-RC-QCR2000
  - Transition model: Coder AFT2017b (SA-RC-QCR2000-AFT2017b)
- Turbulence model variant and inclusion of transition modeling studied
- Time accuracy effects studied
  - BDF2 implicit scheme
  - Timestep chosen to give 2 orders of magnitude drop in unsteady residual in 10-20 subiterations

Flow Solvers and Approach

- LAVA (NASA)
  - Node-centered, finite-difference
  - RHS discretization: 2nd-order MUSCL w/ Roe fluxes
  - Van Albada limiter
  - Turbulence model: Spalart-Allmaras SA-noft2-RC-QCR2000

- ”Cold starts” used for all cases

Computational Resources

- All simulations run on NAS Pleiades
  - SGI ICE system
  - Over 11,000 nodes with over 245,000 cores
  - Intel Xeon (Broadwell, Haswell, Ivy Bridge, Sandy Bridge)
- OVERFLOW simulations run on 420 cores (fully turbulent) and 560 cores (transitional)
  - 24-48 hours of wall-clock time to convergence
- LAVA required 2000 cores with 48 hours of wall clock time

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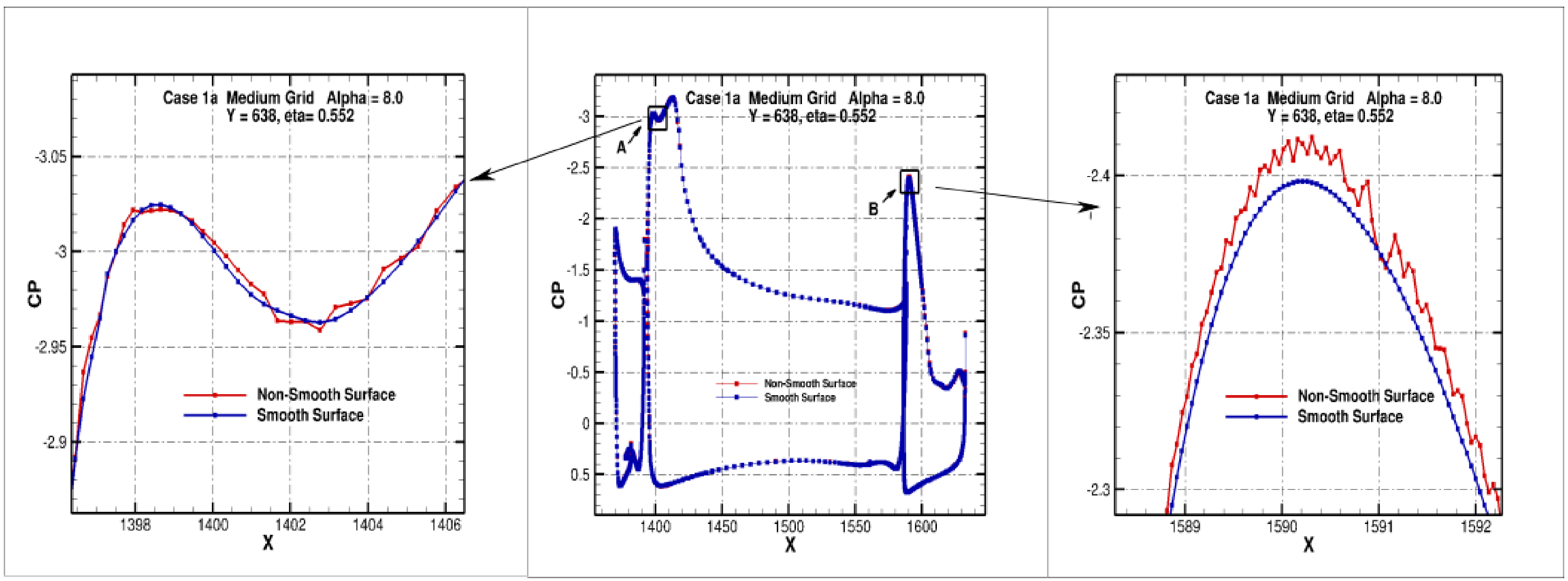
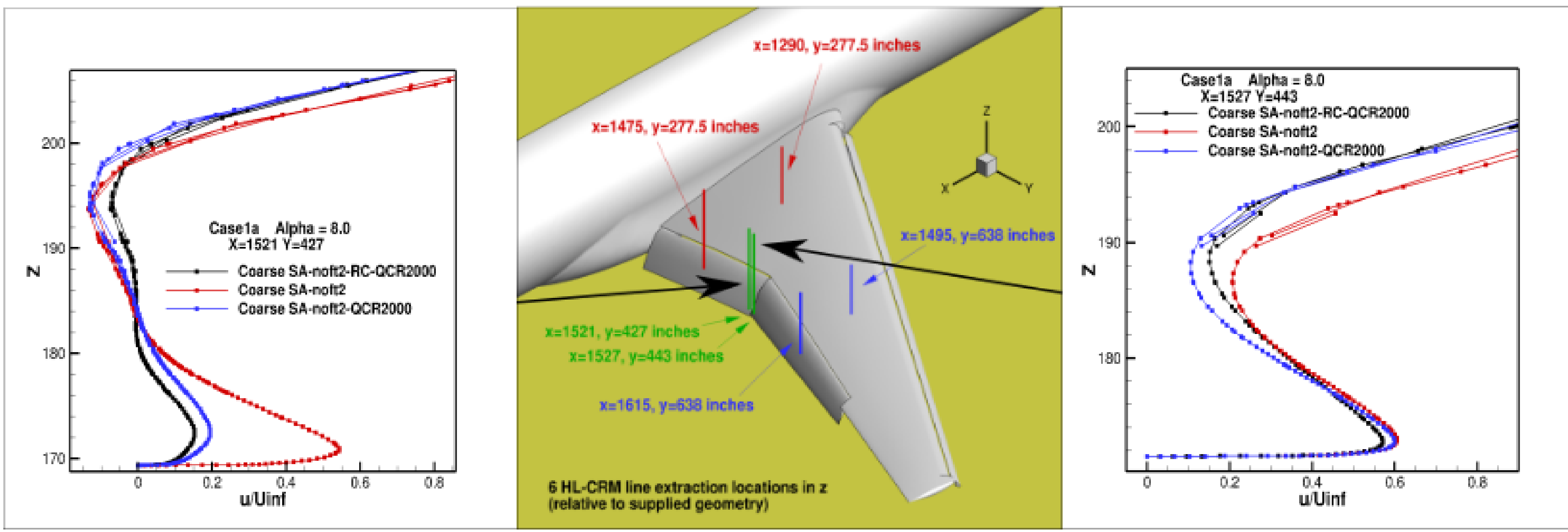
Case 1: Surface Smoothness Issues

- Original HL-CRM overset grids were projected onto a surface triangulation rather than the smooth CAD
  - Leads to oscillatory pressure behavior
- New grids generated with projection directly to CAD

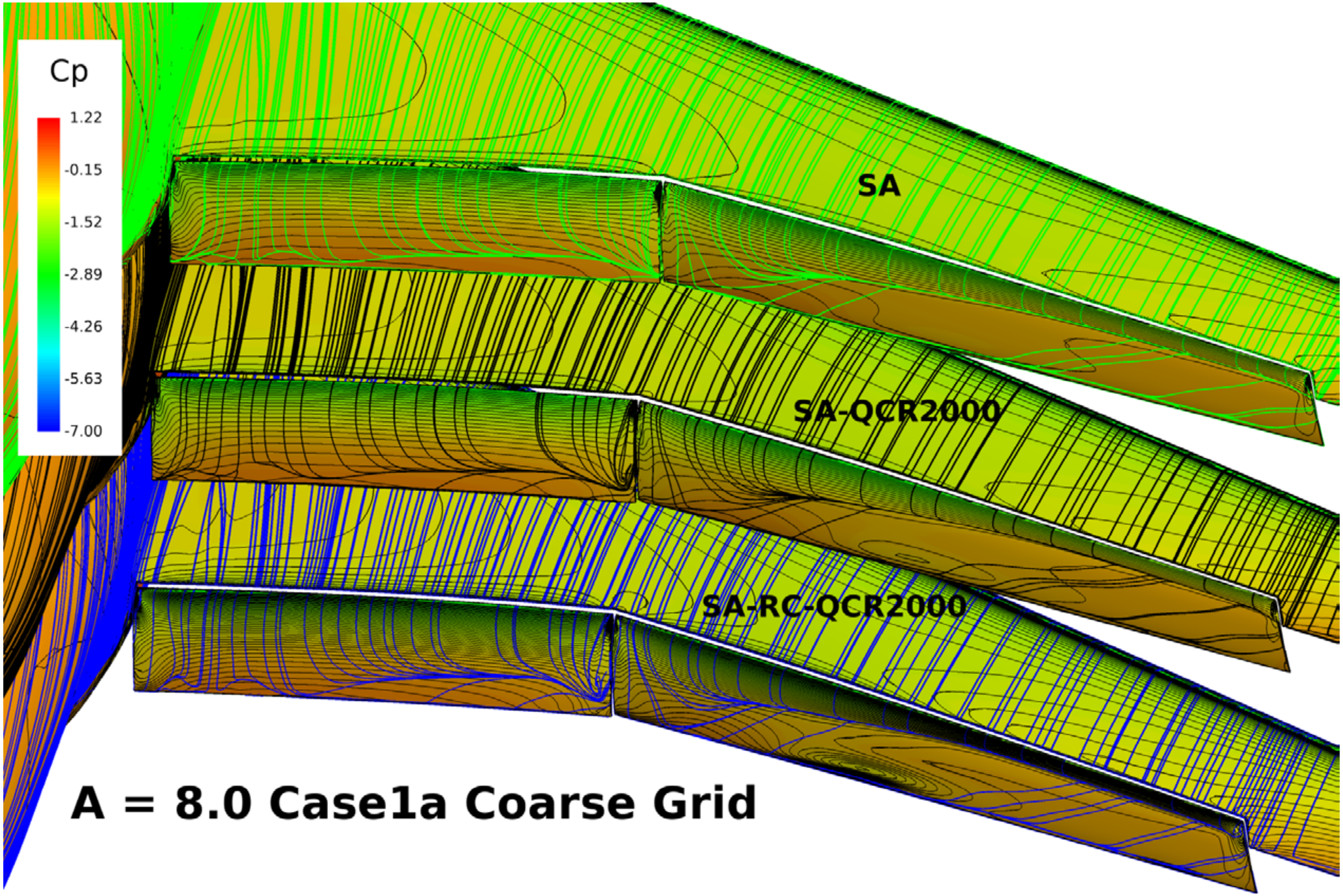


Case 1: Turbulence Modeling Effects

- Use (or exclusion) of QCR had a prominent effect on the flow behavior around the flap gap
  - QCR typically regarded as primarily affecting juncture flows

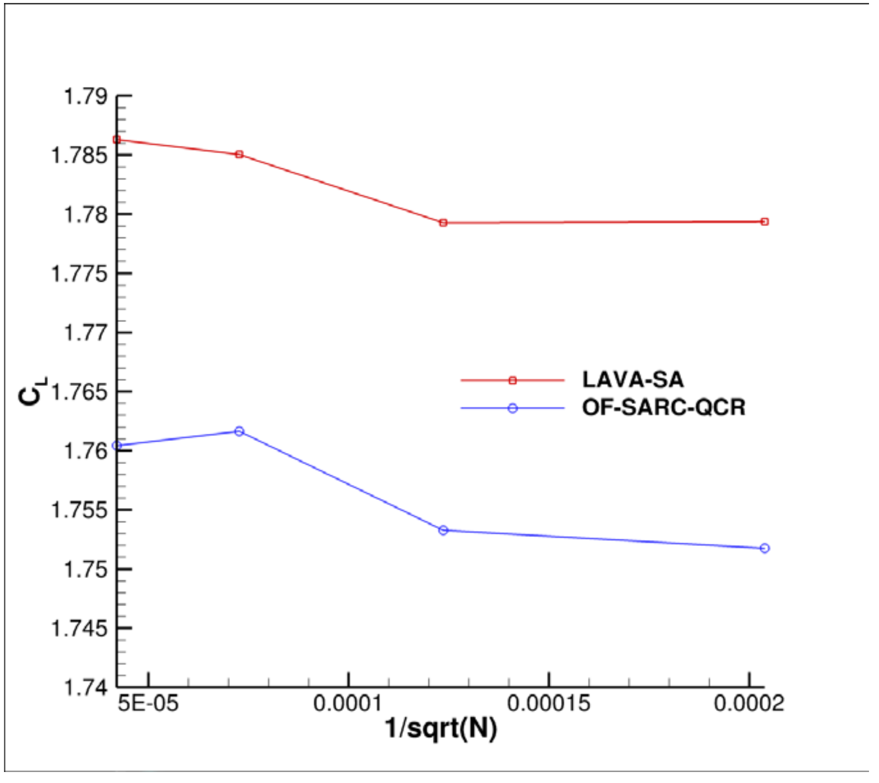


Case 1: Turbulence Modeling Effects

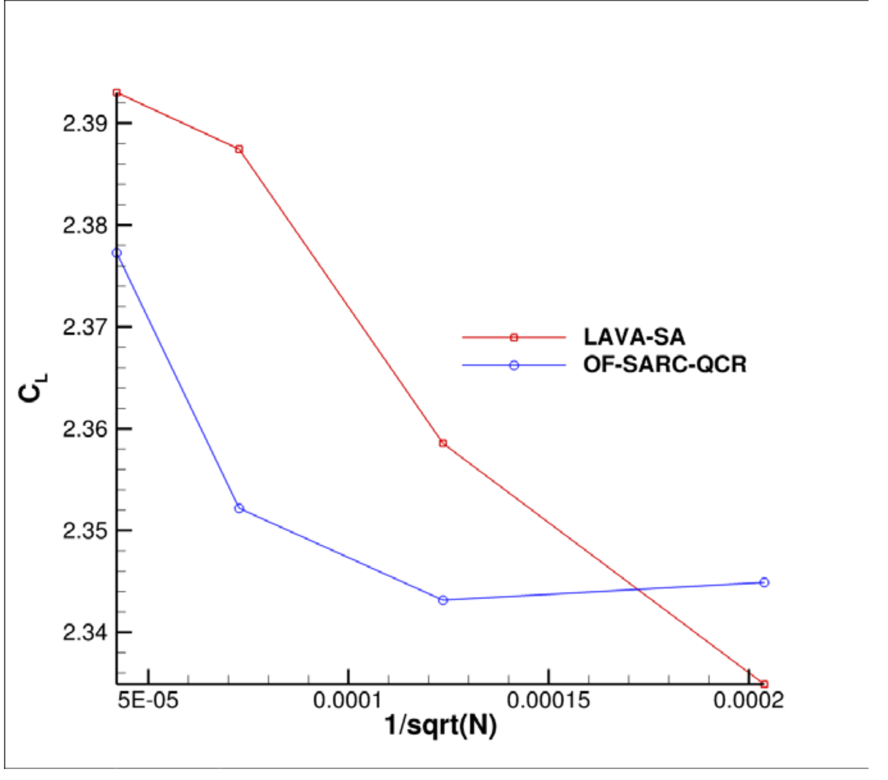


Case 1: Grid Refinement Study

- Lift



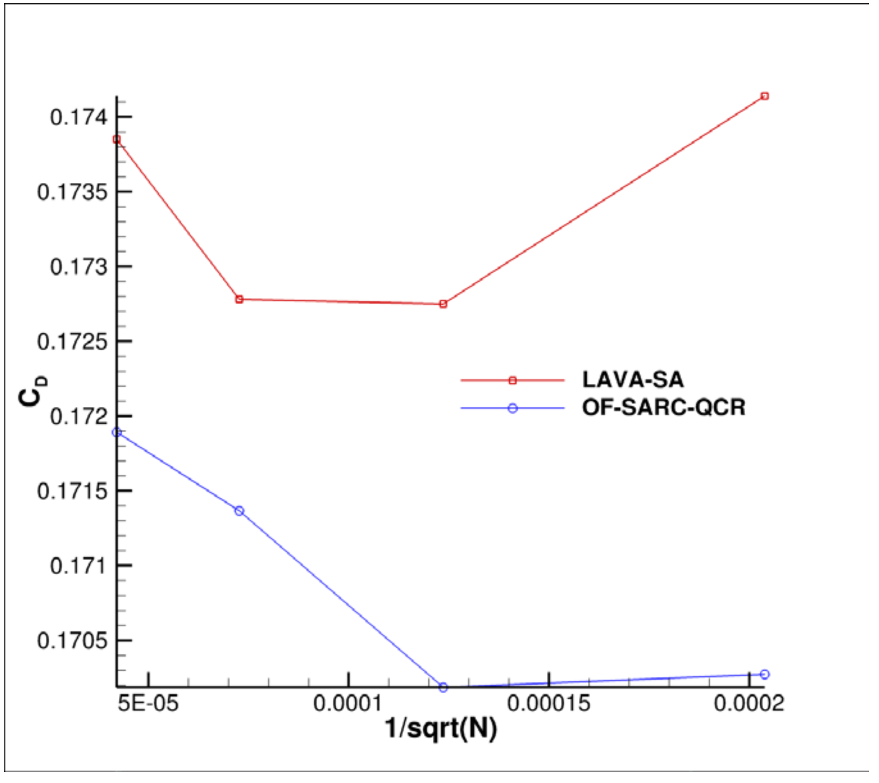
α = 8°



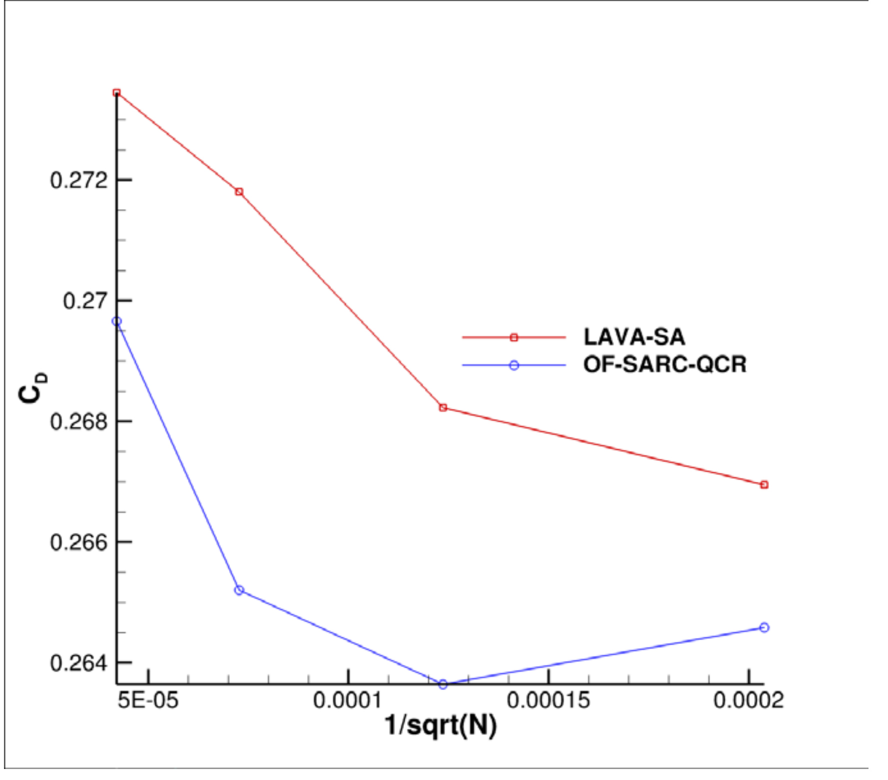
α = 16°

Case 1: Grid Refinement Study

- Drag



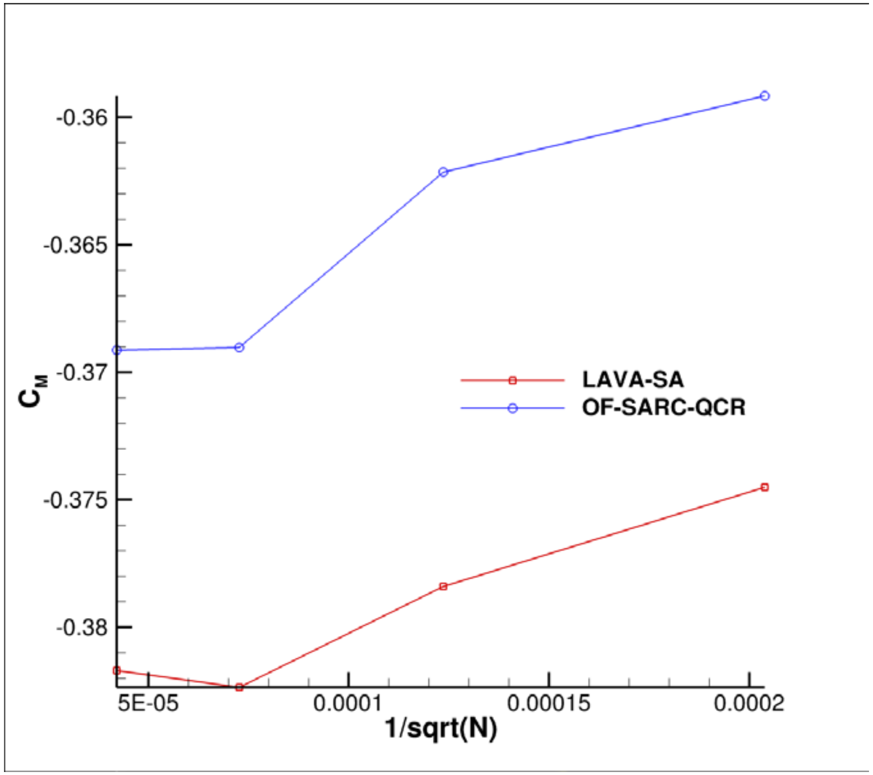
α = 8°



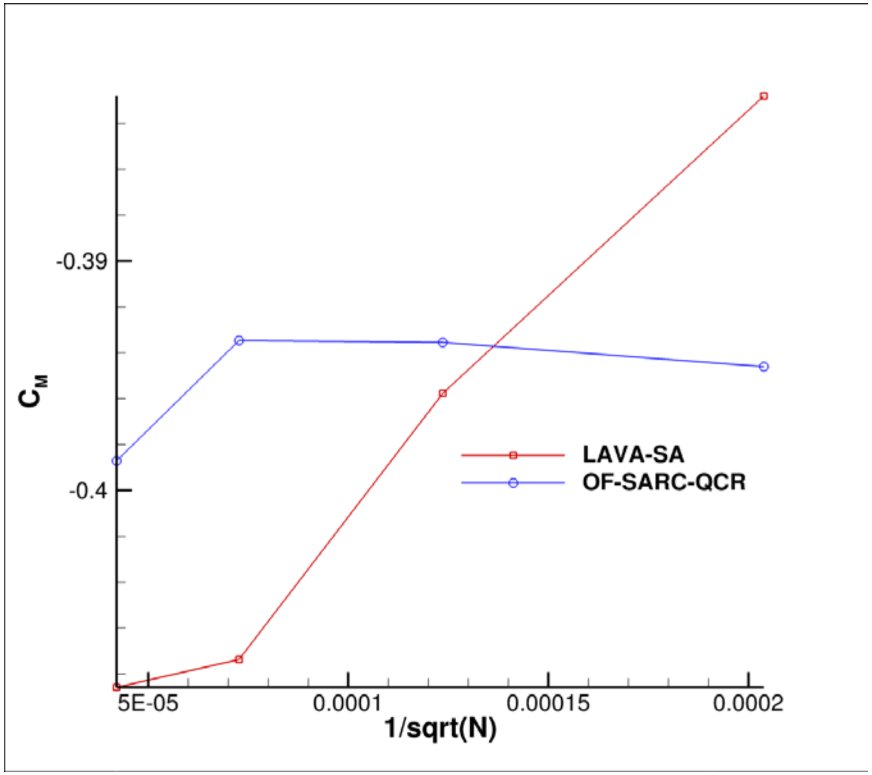
α = 16°

Case 1: Grid Refinement Study

- Pitching Moment



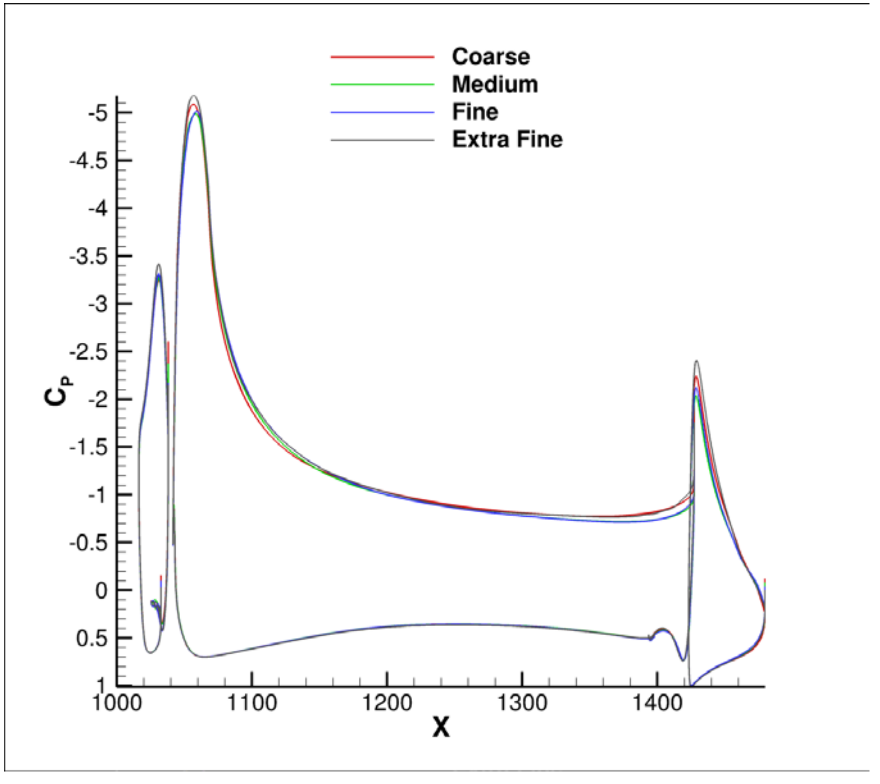
α = 8°



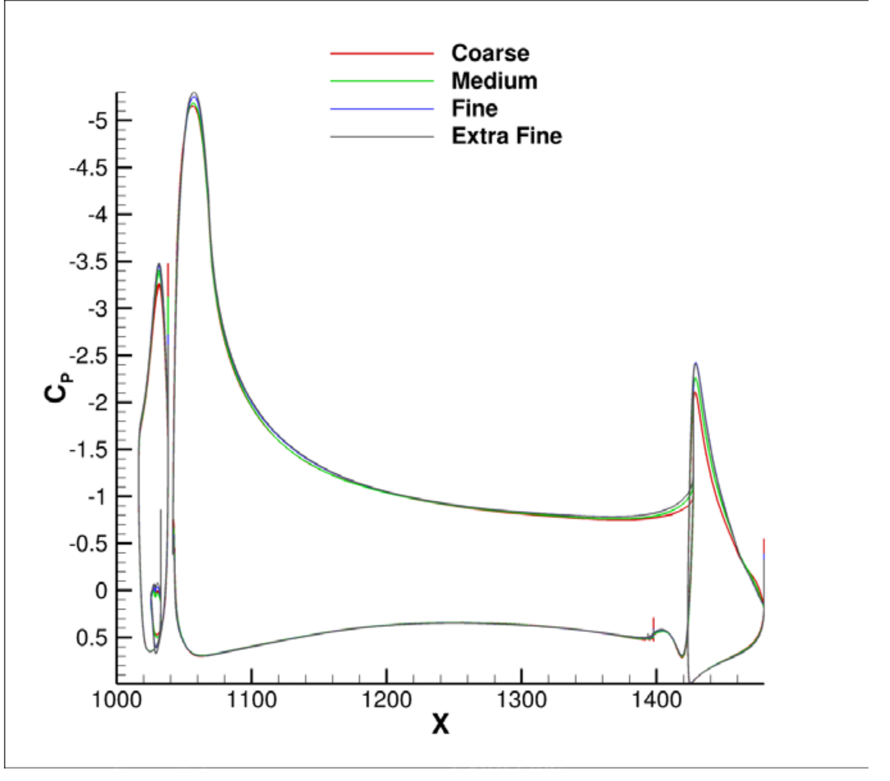
α = 16°

Case 1: Grid Refinement Study

- Representative behavior (η = 0.151, α = 16°)



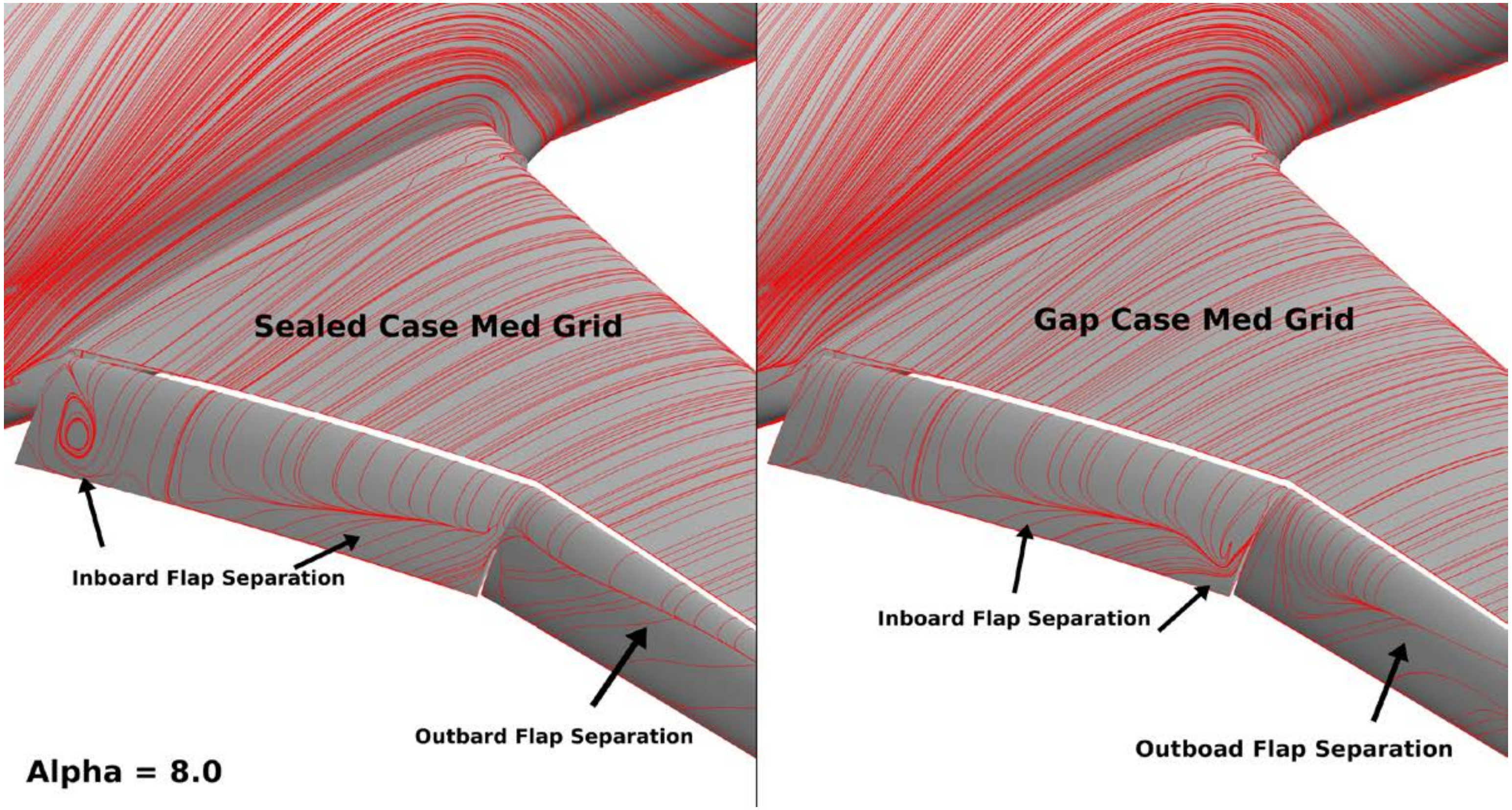
α = 8°



α = 16°

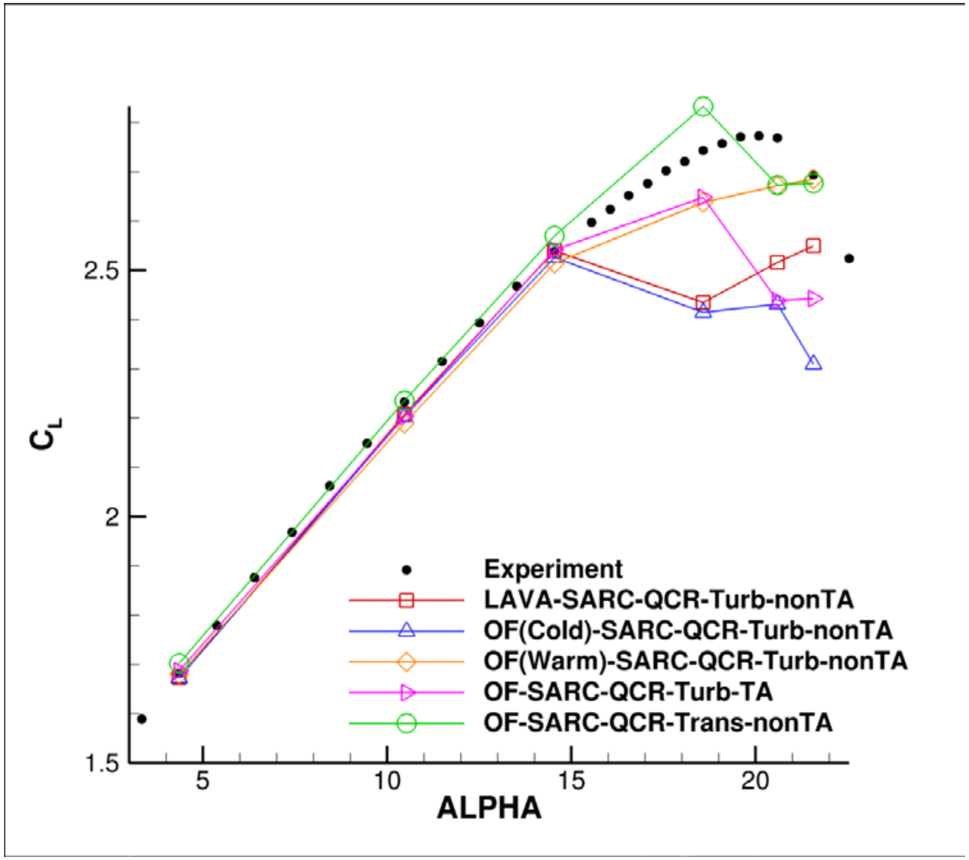
Case 1: Effect of Flap Gap Seal

- Gap seal reduces separation near the gap, but induces separation inboard



Case 2: Nacelle/Pylon Off

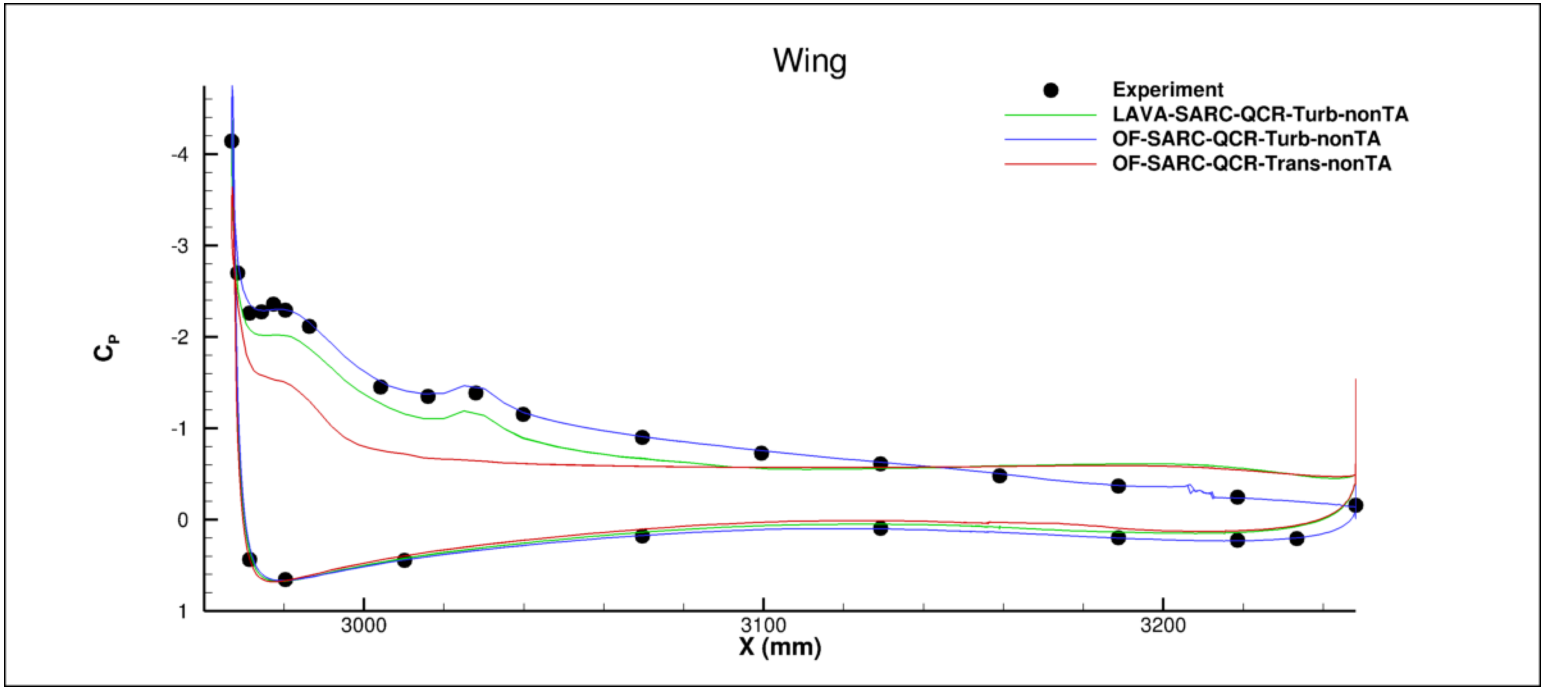
- Strong effect of turbulence/transition modeling
- Multiple possible solutions depending on initial condition



Case 2: Nacelle/Pylon Off

- Selected pressure distribution (4.36 deg)

Main element, η = 0.89

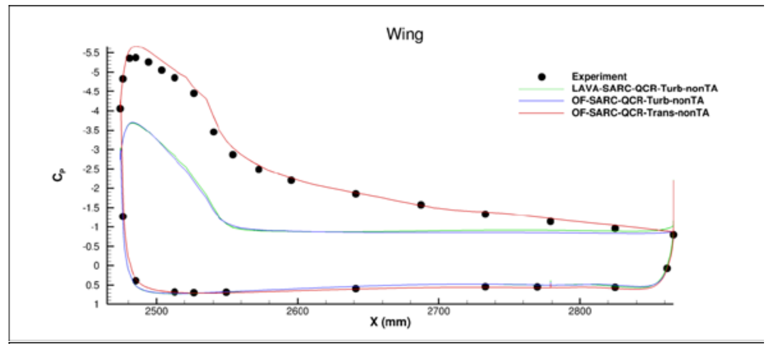


Case 2: Nacelle/Pylon Off

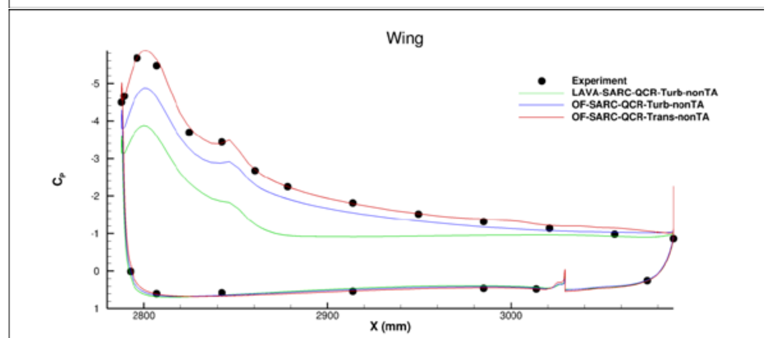
- Selected pressure distribution (18.58 deg)

Main element

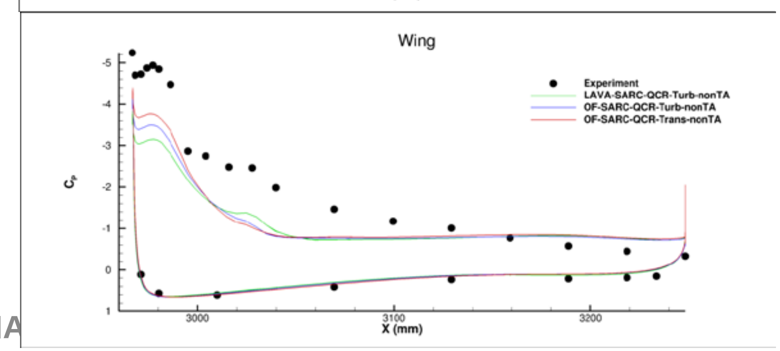
η = 0.56



η = 0.77

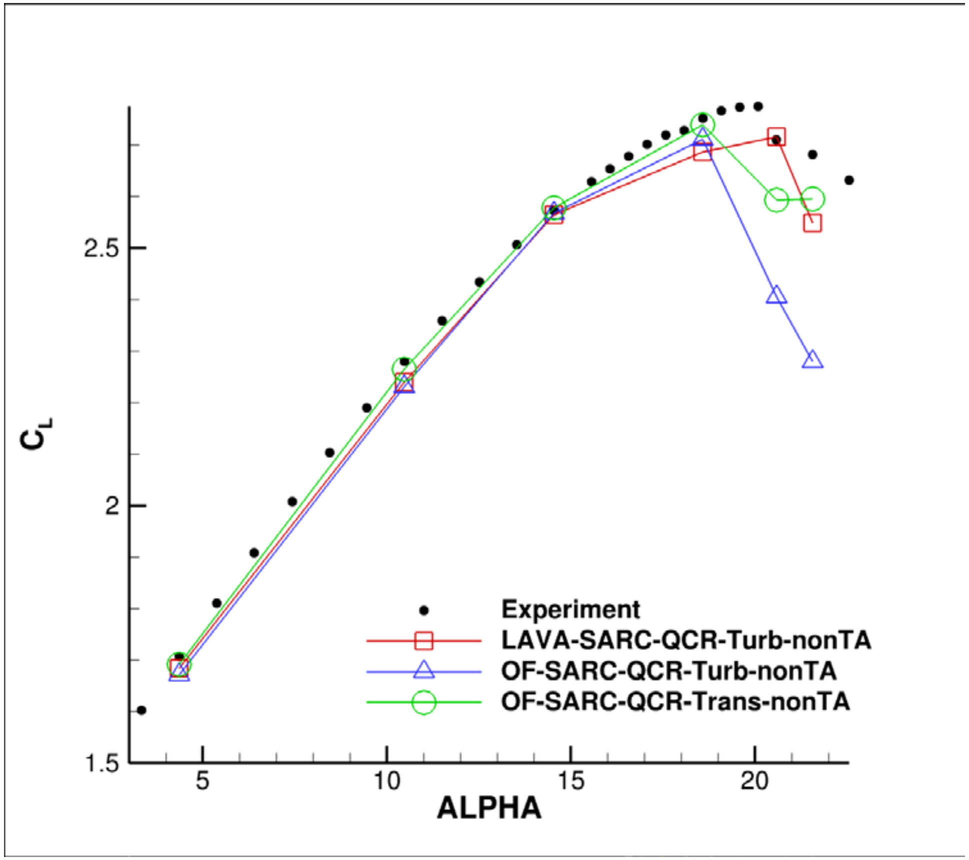


η = 0.89



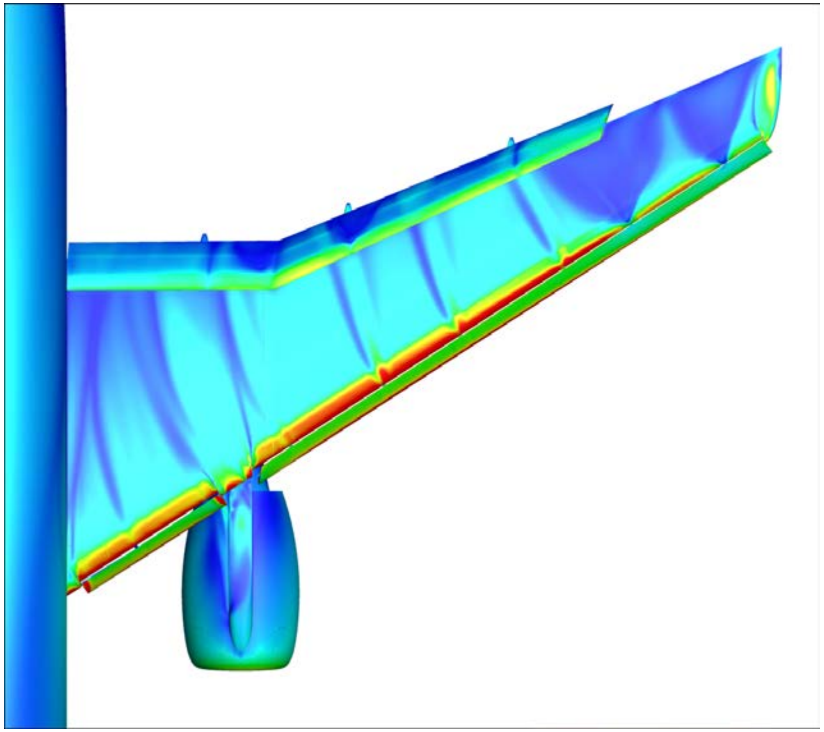
Case 2: Nacelle/Pylon On

- Strong effect of turbulence/transition modeling
- No evidence of multiple solutions



Case 2: Nacelle/Pylon On

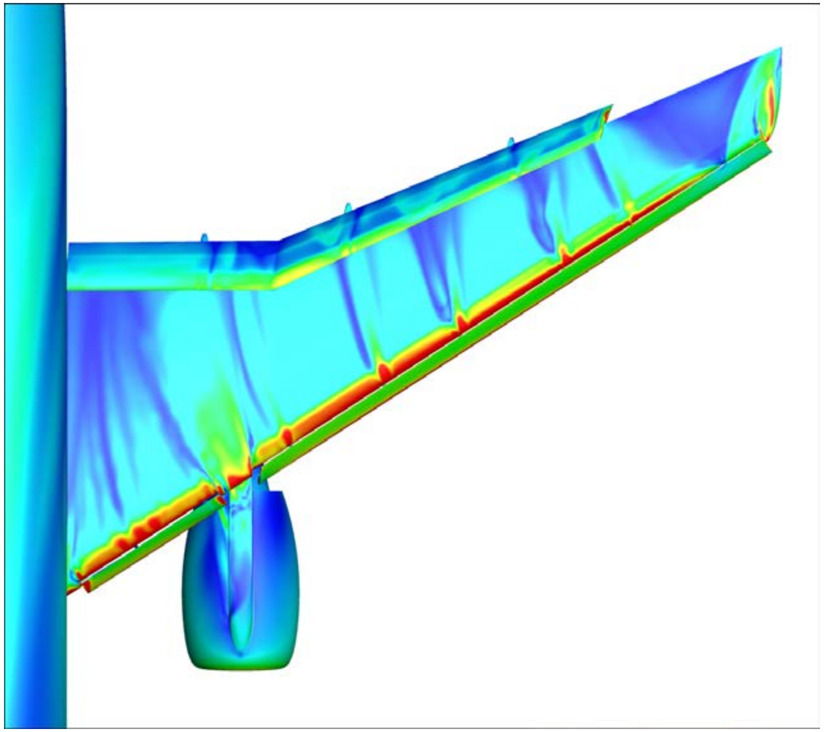
- Surface flow patterns (α = 18.58°)



LAVA

Case 2: Nacelle/Pylon On

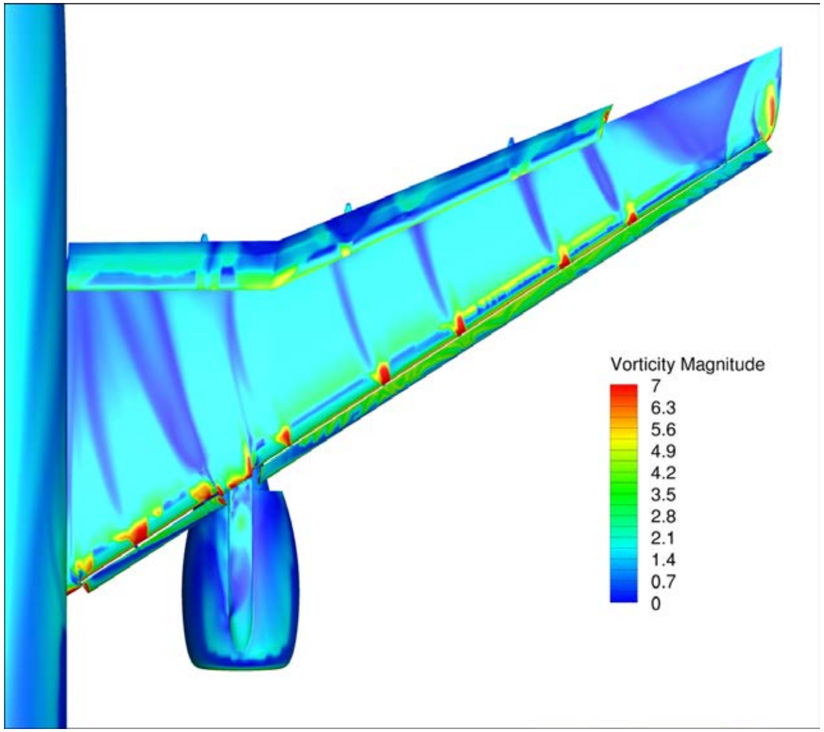
- Surface flow patterns (α = 18.58°)



OVERFLOW (fully turbulent)

Case 2: Nacelle/Pylon On

- Surface flow patterns (α = 18.58°)

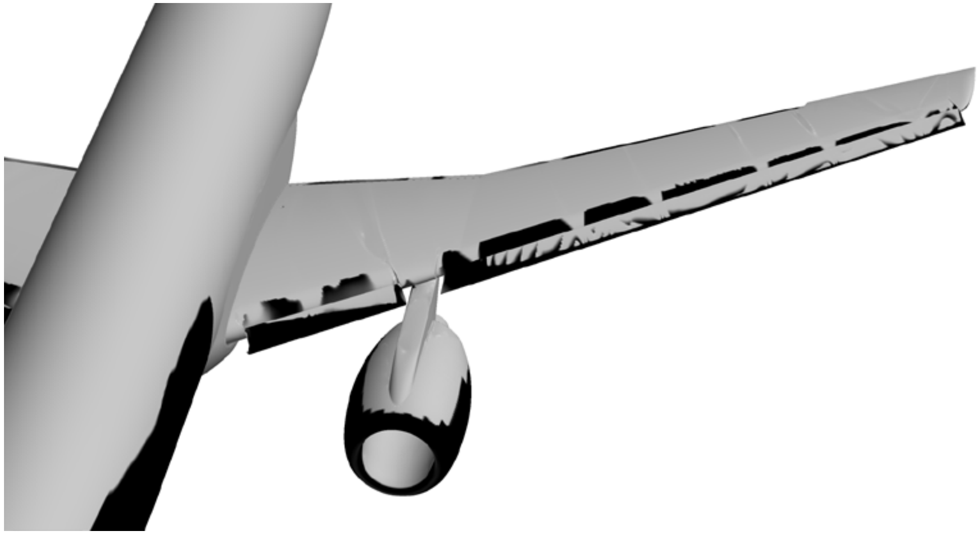


OVERFLOW (transitional)

Case 2: Nacelle/Pylon On

- Transition patterns (α = 18.58°)

Experiment (China clay)

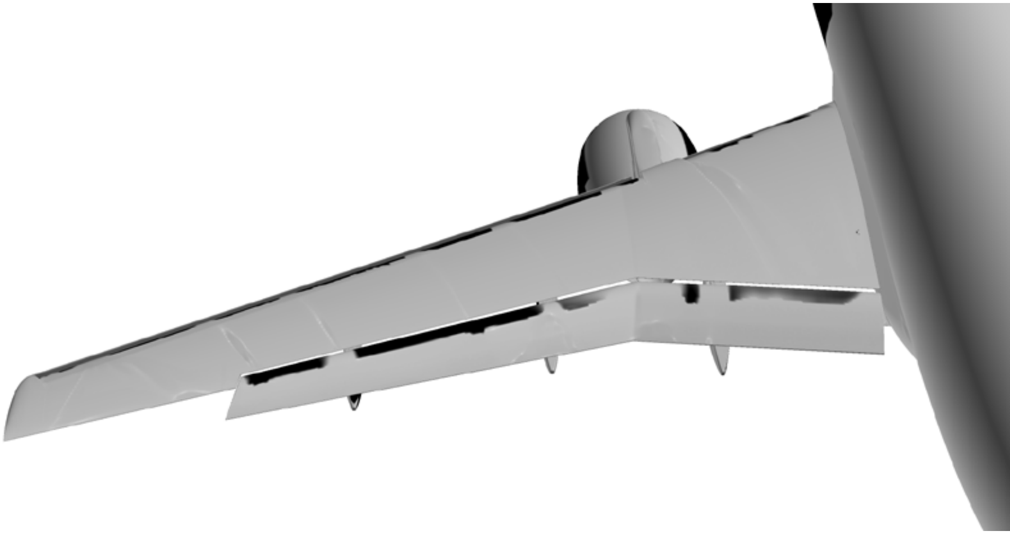


OVERFLOW (turbulent index)

Case 2: Nacelle/Pylon On

- Transition patterns (α = 18.58°)

Experiment (China clay)



OVERFLOW (turbulent index)

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Conclusions (HL-CRM)

- Fully predictive, so no experimental data available for comparison

- Surface smoothness had an impact on surface pressure distributions
  - Grid should be projected to smooth CAD rather than triangulated surfaces

- Use of QCR had a strong influence of flap separation patterns with the unsealed flap gap

Conclusions (JSM)

- Evidence of multiple solutions observed for nacelle/pylon off
  - "Warm" versus "cold" starts influenced final solution
  - Time accurate results more consistent with warm starts
  - Phenomenon not observed with nacelle/pylon on

- Excluding QCR had an impact, but not a consistent shift
  - Nacelle/pylon off: Excluding QCR delays stall with AoA
  - Nacelle/pylon on: Excluding QCR accelerates stall with AoA

- Transition modeling had an overall positive impact
  - Better agreement in aerodynamic coefficients
  - Predicted transition patterns consistent with experiment
  - Not a panacea – separation patterns still have discrepancies

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Questions?