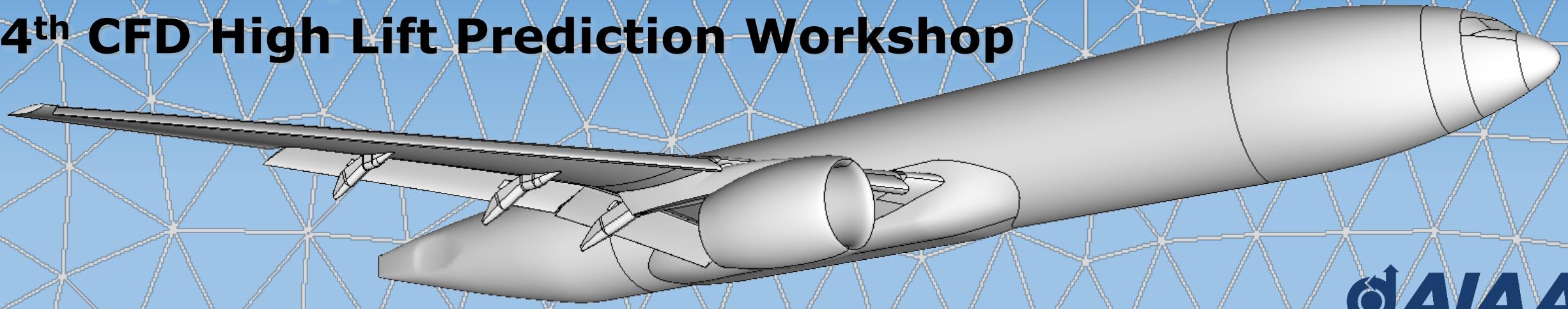
3rd Geometry and Mesh Generation Workshop
4th CFD High Lift Prediction Workshop



AIAA
SHAPING THE FUTURE OF AEROSPACE

HLPW-4/GMGW-3: Mesh Adaptation for RANS Technology Focus Group Workshop Summary

Mike Park (NASA)
Frederic Alauzet (INRIA)
Todd Michal (Boeing, retired)

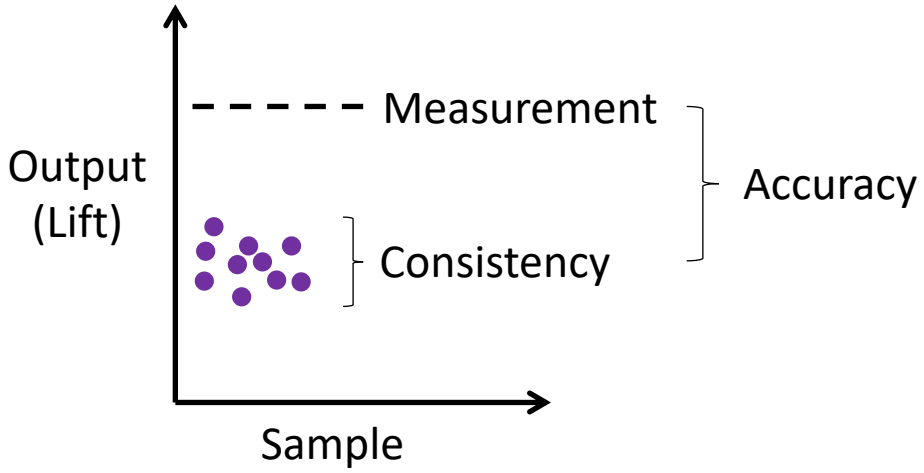
HLPW-4 Technical Focus Groups

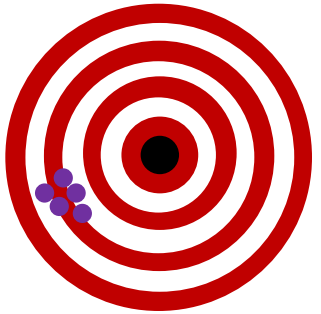
- Geometry Modeling and Preparation for Meshing (GEOM)
- Fixed Grid RANS (RANS)
- Mesh Adaptation for RANS (ADAPT)
- High Order Discretization (HO)
- Hybrid RANS/LES (HRLES)
- Wall-Modeled LES and Lattice-Boltzmann (WMLESLB)

Enhance CFD prediction capability for practical high-lift aerodynamic design and optimization

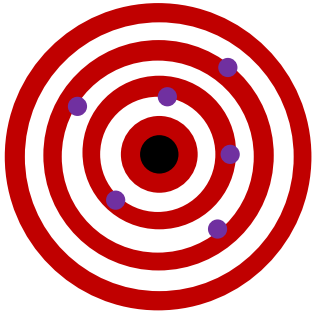
Mesh Adaptation for RANS (ADAPT)

- Verification of mesh adapted solutions of the Reynolds-averaged Navier-Stokes (RANS) with the Spalart-Allmaras (SA) turbulence model
- Comparisons to experiment are a lower priority
- Consistency as a contribution to prediction





Low Accuracy
High Consistency

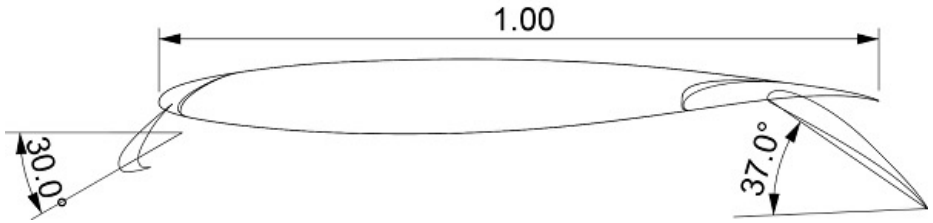


High Accuracy
Low Consistency

ADAPT TFG Key Questions

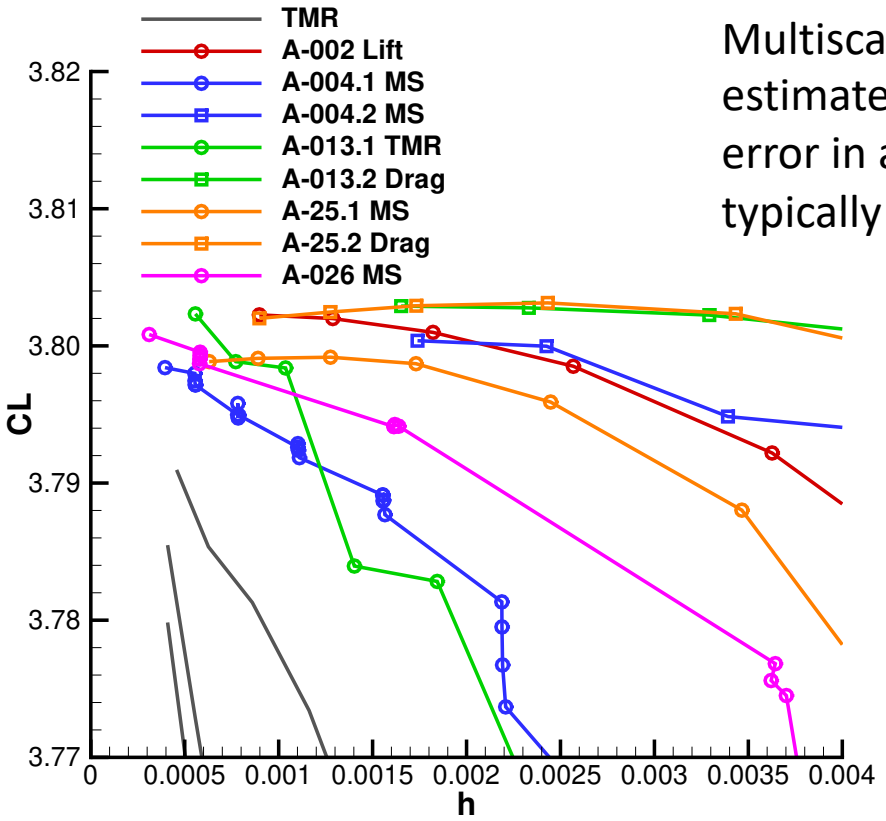
#	Key Question
1	Can adaptive mesh convergence be achieved on the CRM-HL model across the angle of attack range?
2	What are the best practices/lessons learned and outstanding technical issues for adaptive mesh modeling of high-lift applications (e.g., error estimate choice, flow solver settings, complexity schedule, solution continuation, geometry handling)?
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4	Where can mesh adapted RANS contribute to prediction of high-lift flow physics?

Airfoil verification



KQ 1	Can adaptive mesh convergence be achieved on the CRM-HL model across the angle of attack range?

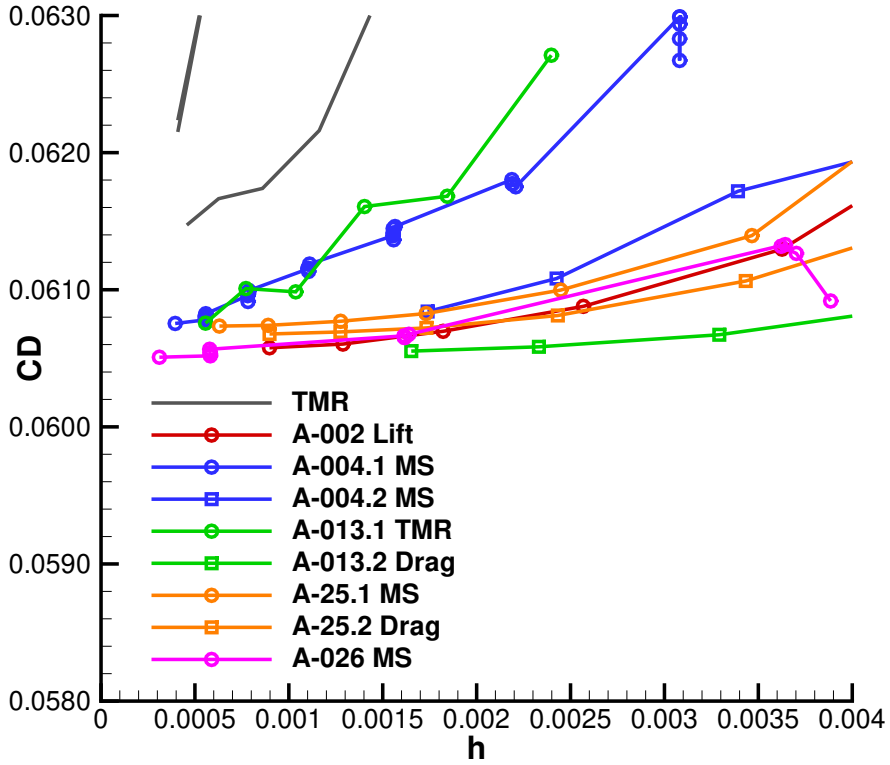
- Extracted from the CRM-HL, case3



Multiscale (MS) controls estimated interpolation error in a scalar field, typically Mach

Lift and Drag are goal-oriented (adjoint)

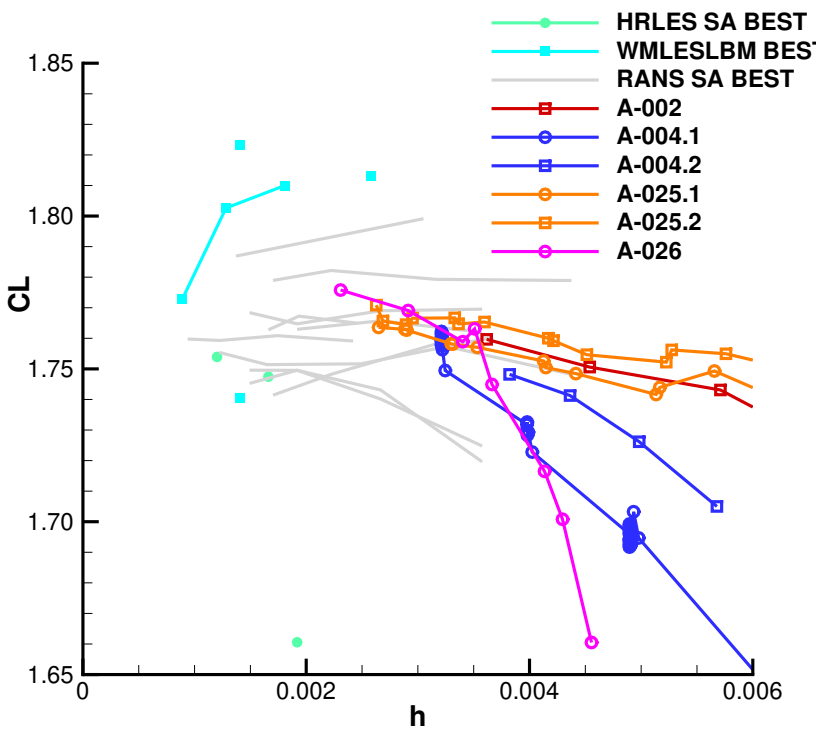
$h = N^{-1/2}$

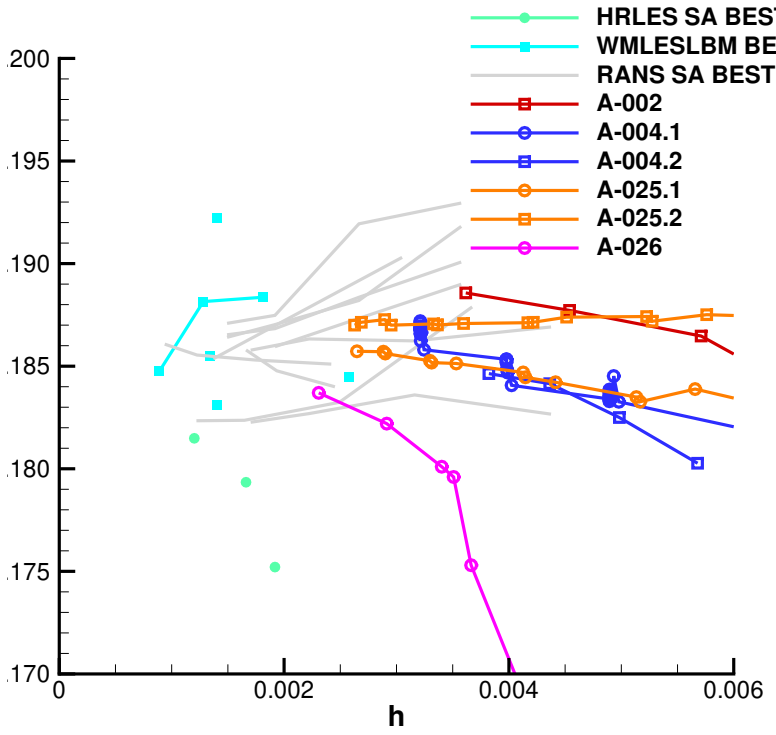


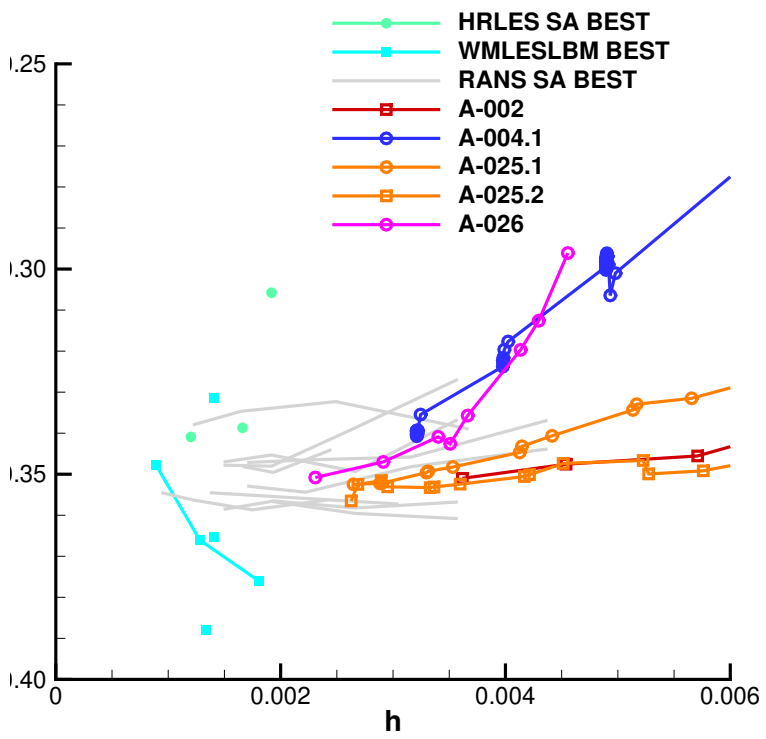
3D CRM-HL

KQ 1	Can adaptive mesh convergence be achieved on the CRM-HL model across the angle of attack range?

- Mesh refinement at 7.05° case1b (SA)
  - Best practice, ADAPT and RANS verification





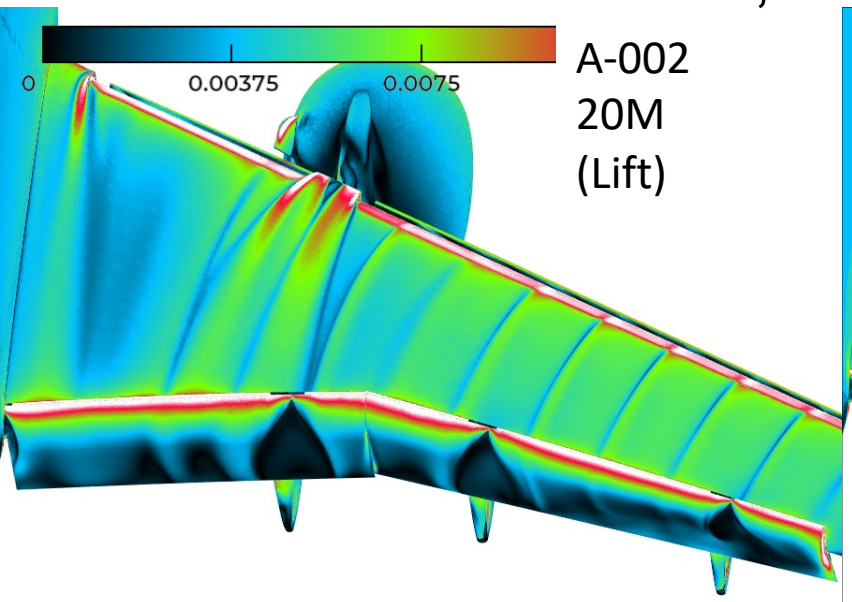


$h = N^{-1/3}$

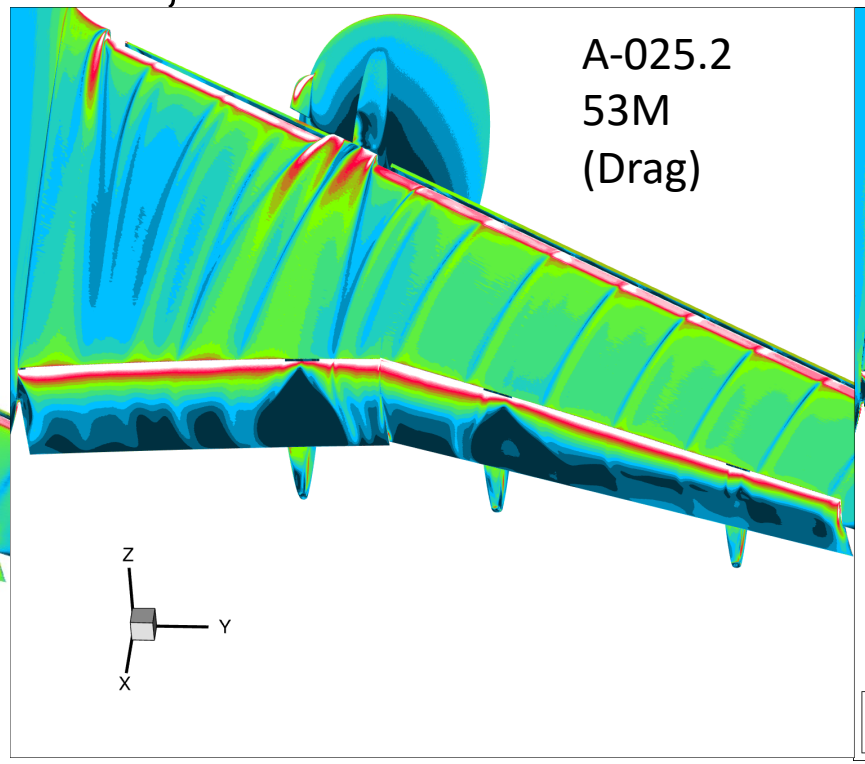
Skin Friction Contours

KQ 1	Can adaptive mesh convergence be achieved on the CRM-HL model across the angle of attack range?

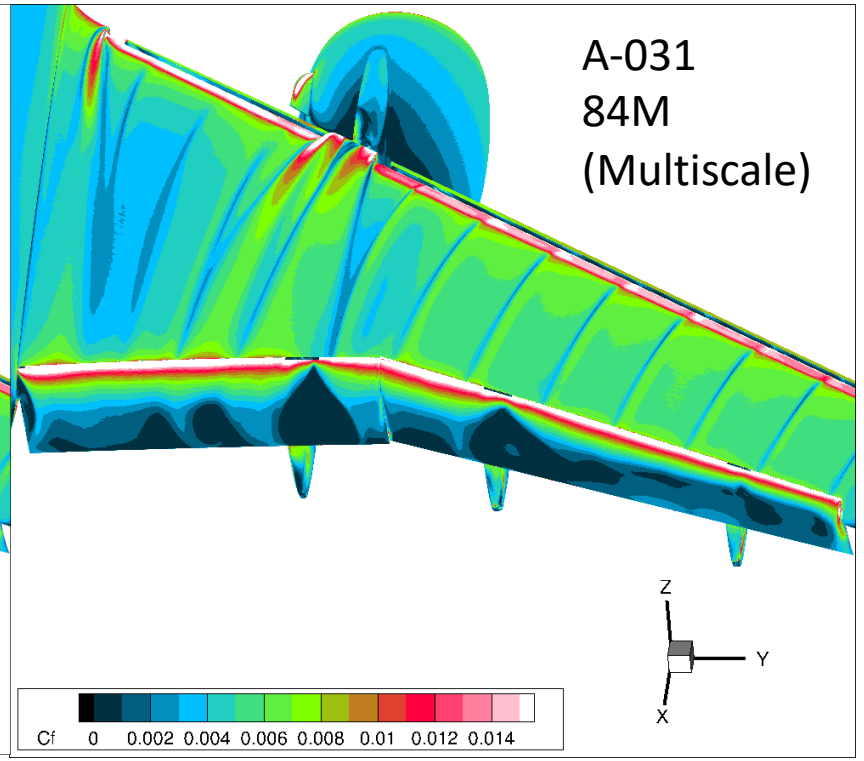
- Final solution at 7.05° case1b (SA)
  - 3 different solvers, metrics, remeshers



A-002
20M
(Lift)



A-025.2
53M
(Drag)

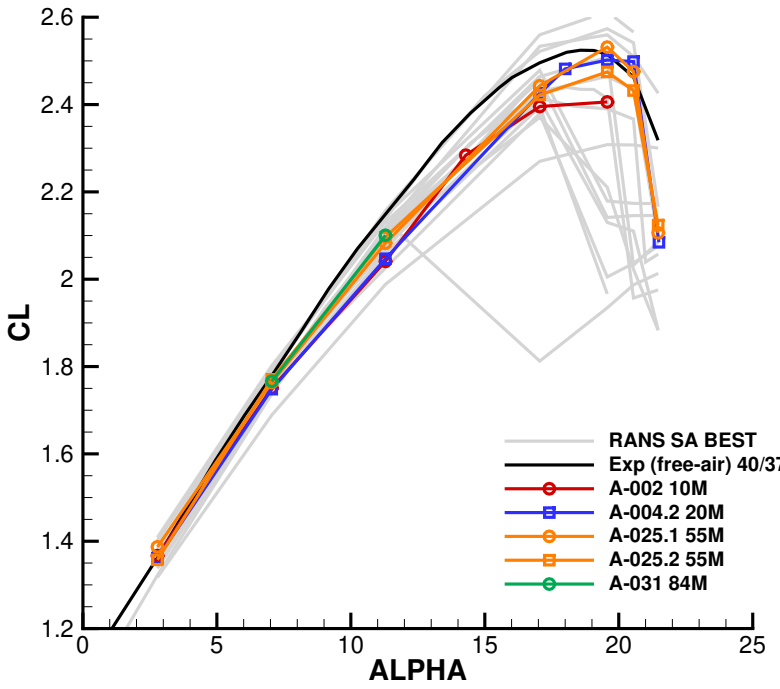


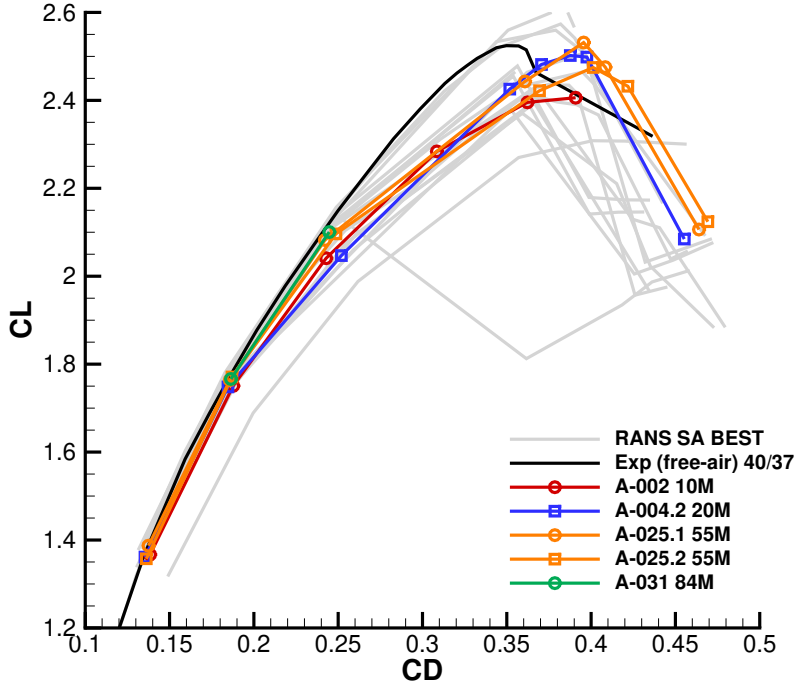
A-031
84M
(Multiscale)

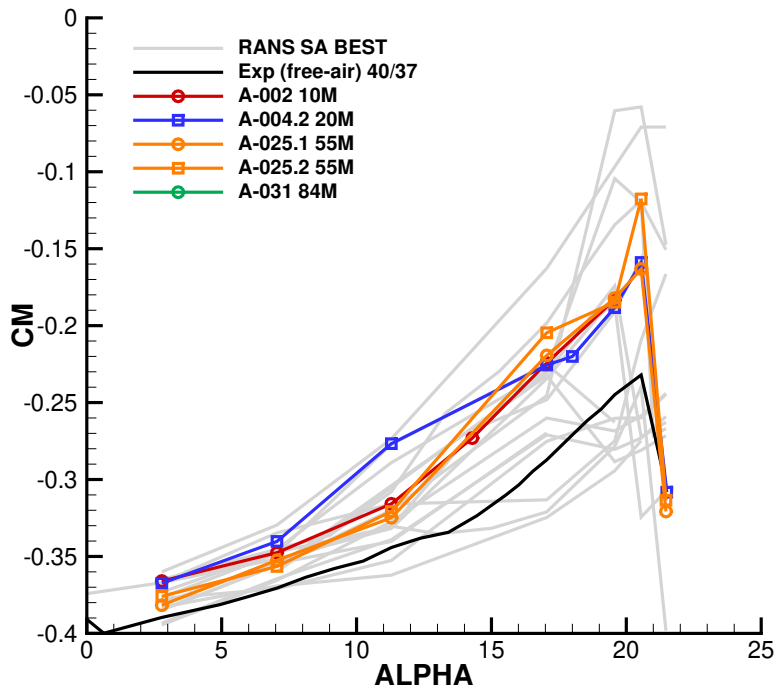
Angle of Attack Range Case2a

KQ 1	Can adaptive mesh convergence be achieved on the CRM-HL model across the angle of attack range?

- Adapt FG with full iterative convergence (SA)
- Fixed-Mesh RANS FG best practice (SA)







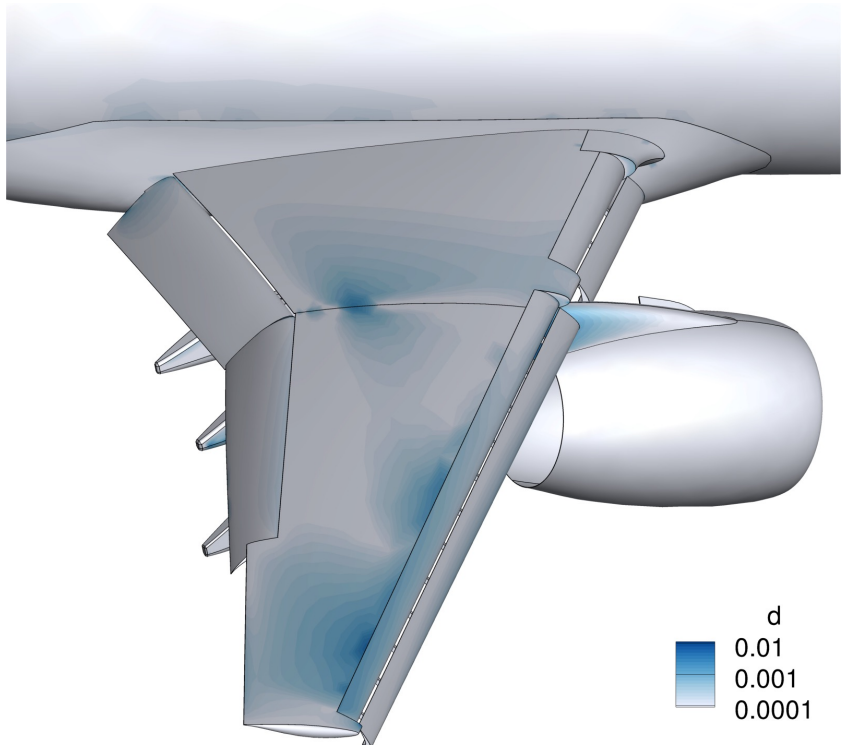
ADAPT TFG Key Questions

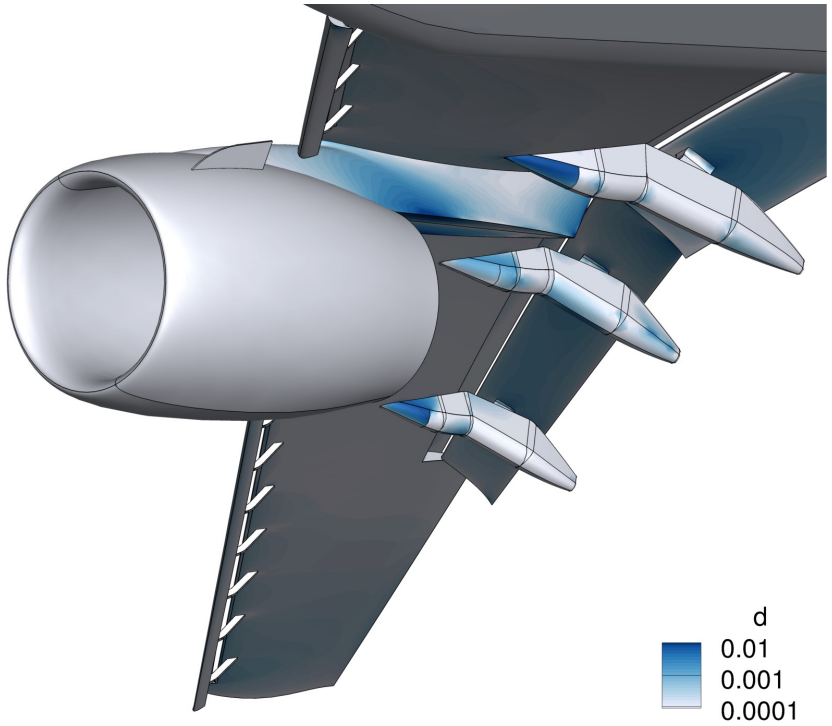
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Geometry Tolerance

KQ 2	What are the best practices/lessons learned and outstanding technical issues for adaptive mesh modeling of high-lift?

- Adaptive meshing required tighter boundary representation tolerances than provided, which is typical of “complex” models and currently addressed via geometry surrogates in ADAPT
- Meshing guidelines 0.00239 inches for the coarsest mesh and 0.00035 inches for finest. CRM-HL Mean Aerodynamic Chord 275.8 in.





Best Practices in ADAPT

KQ 2	What are the best practices/lessons learned and outstanding technical issues for adaptive mesh modeling of high-lift?

- Goal-oriented methods on coarse meshes converge faster to fine-mesh solutions than multiscale methods
- Multiscale methods required more mesh adaptations (and flow solves) to produce slat wakes than goal-oriented methods

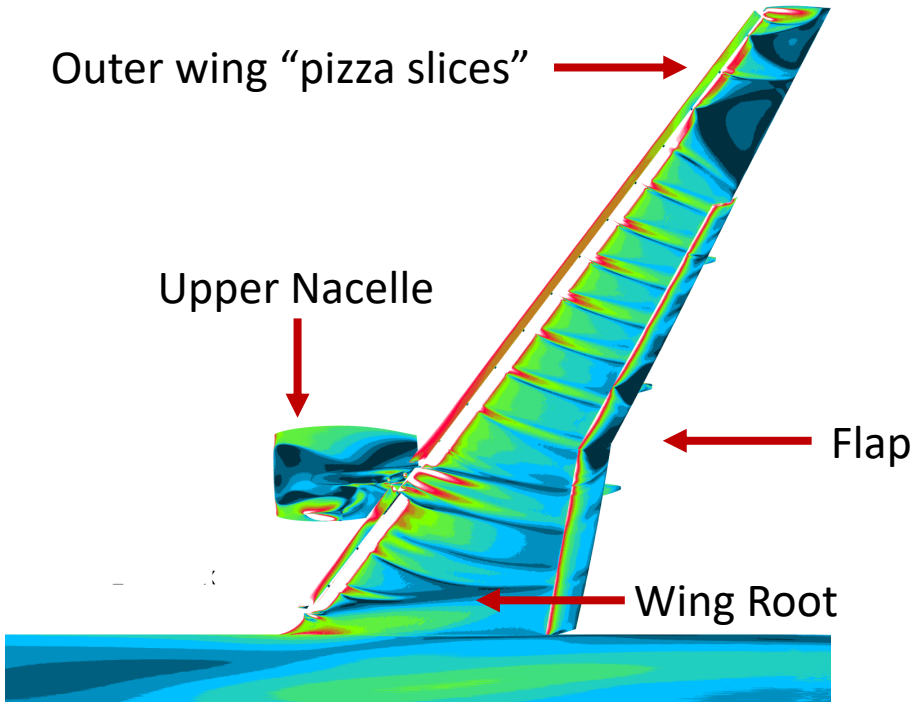
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Multiple Solutions

KQ 3	Can the causes of multiple solutions and techniques to encourage the “desired” branch be identified?

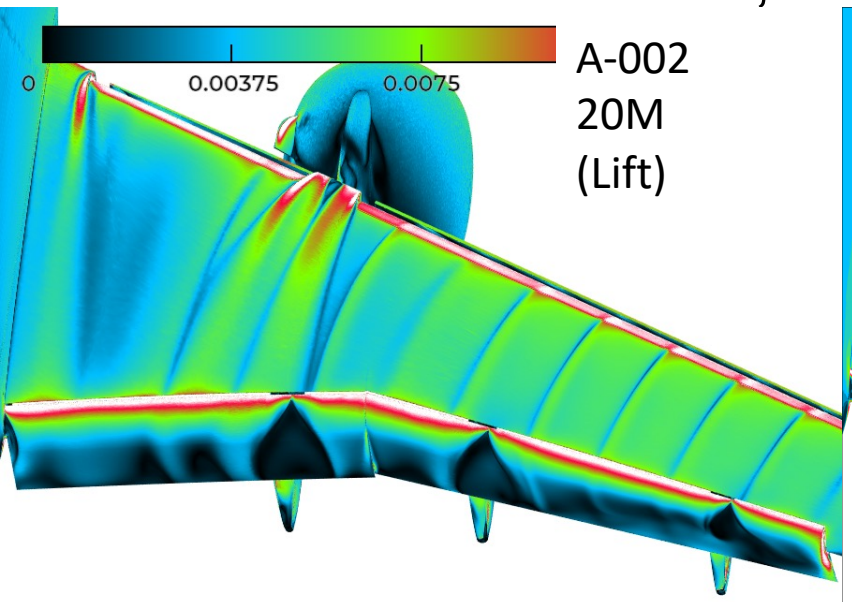
- Multiple solutions is where converged CFD solutions are dependent on initial conditions (complicated by coarse mesh, history encoded in adapted mesh, and incomplete iterative convergence)
- Some suspected areas of suspected multiple solutions appear to converge to common solution with mesh refinement and some suspected areas remain



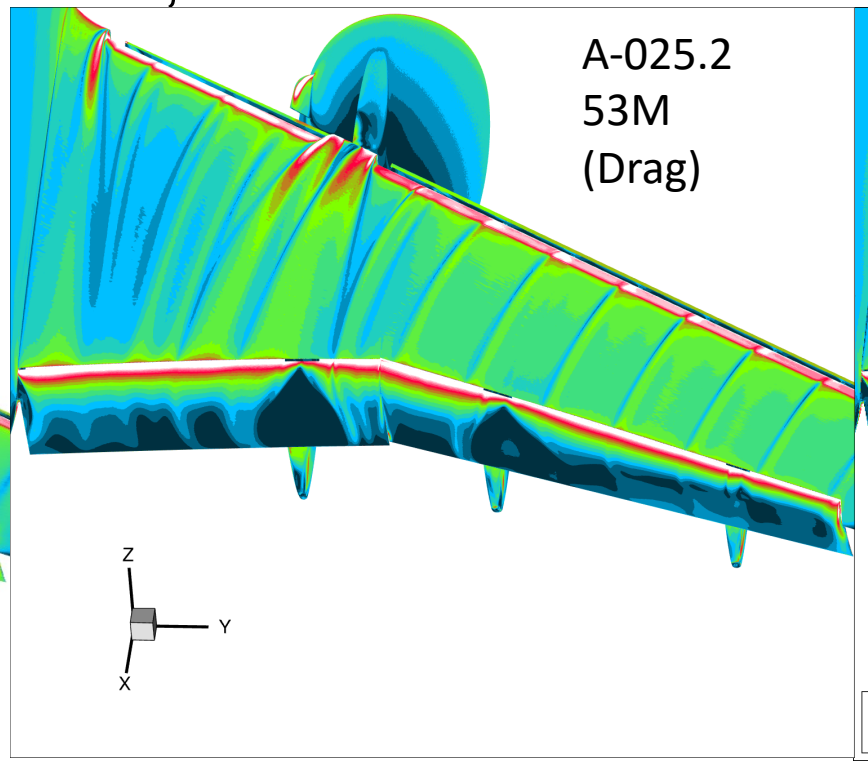
Multiple Solutions, Flap

KQ 3	Can the causes of multiple solutions and techniques to encourage the “desired” branch be identified?

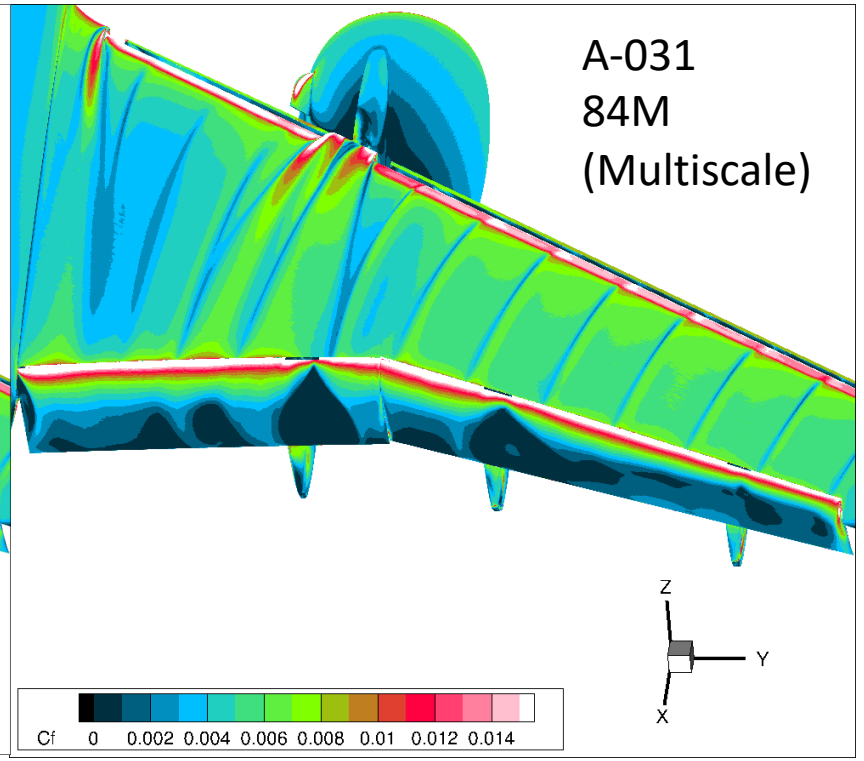
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A-002
20M
(Lift)



A-025.2
53M
(Drag)

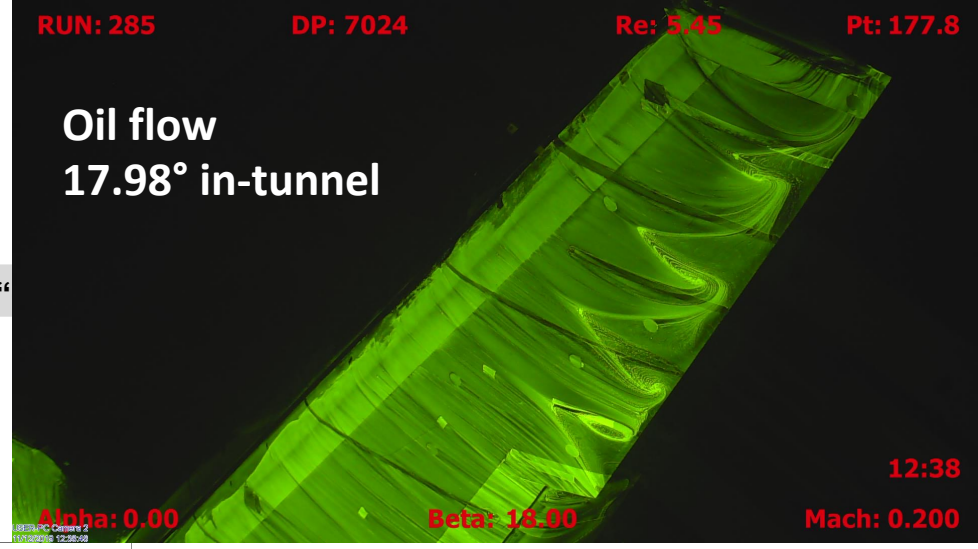


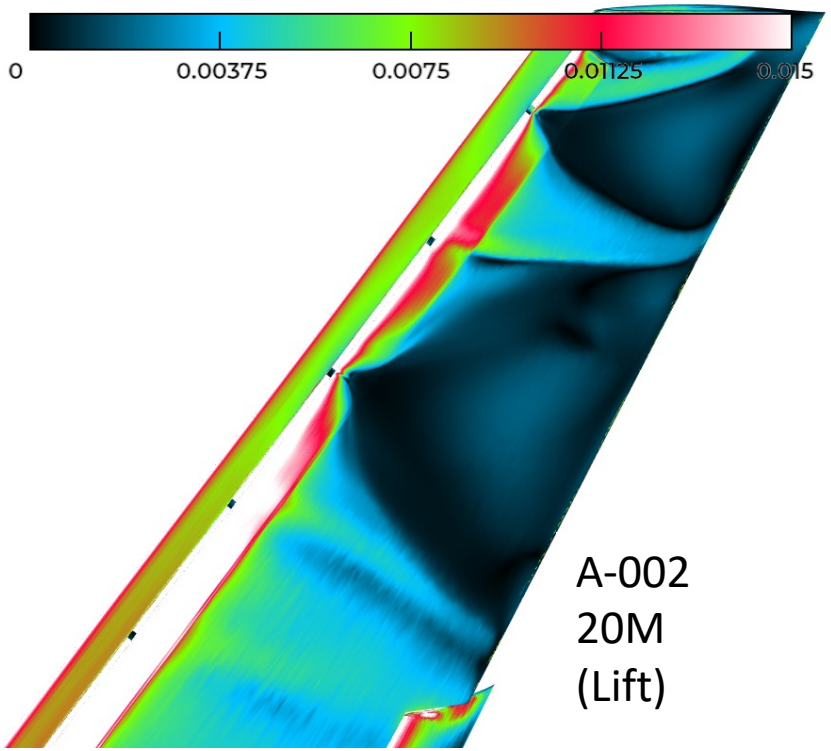
A-031
84M
(Multiscale)

Multiple Solutions, Outer Wing

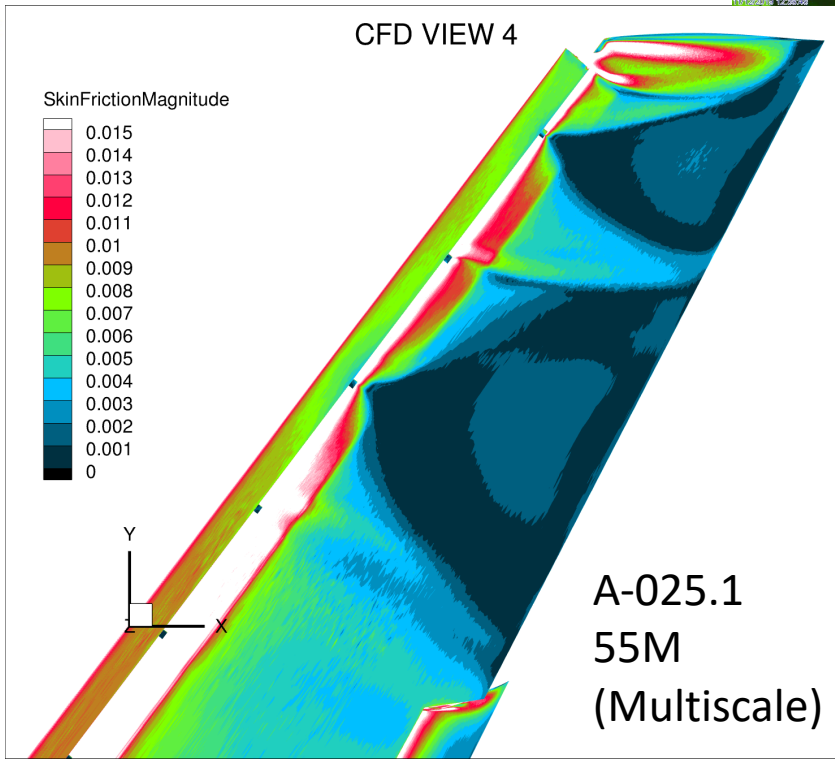
KQ 3	Can the causes of multiple solutions and techniques to encourage the “

- Consistency for outer wing at 19.57° angle of attack (SA)

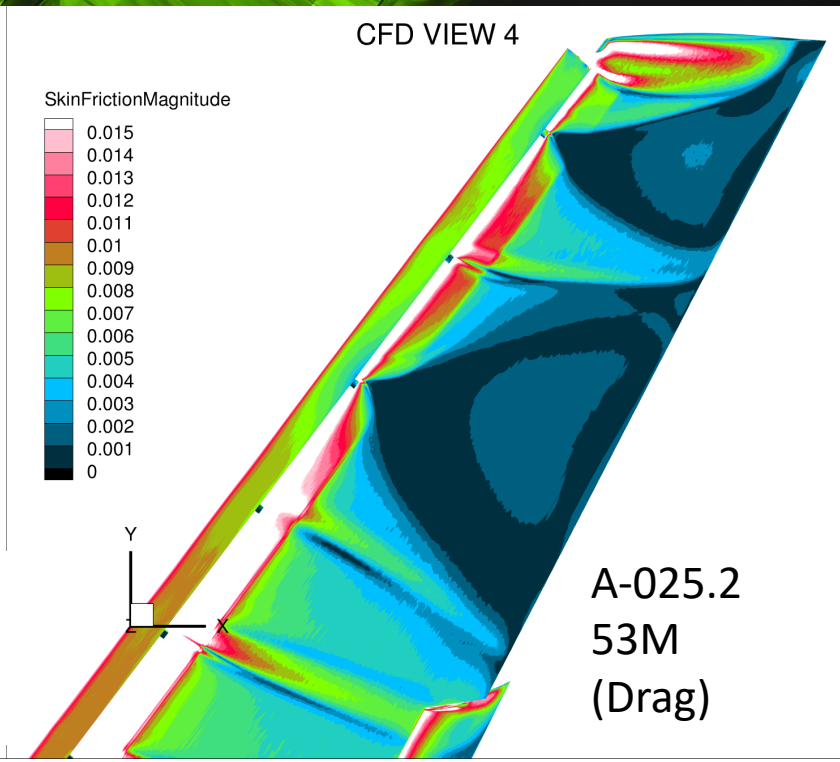




A-002
20M
(Lift)



A-025.1
55M
(Multiscale)

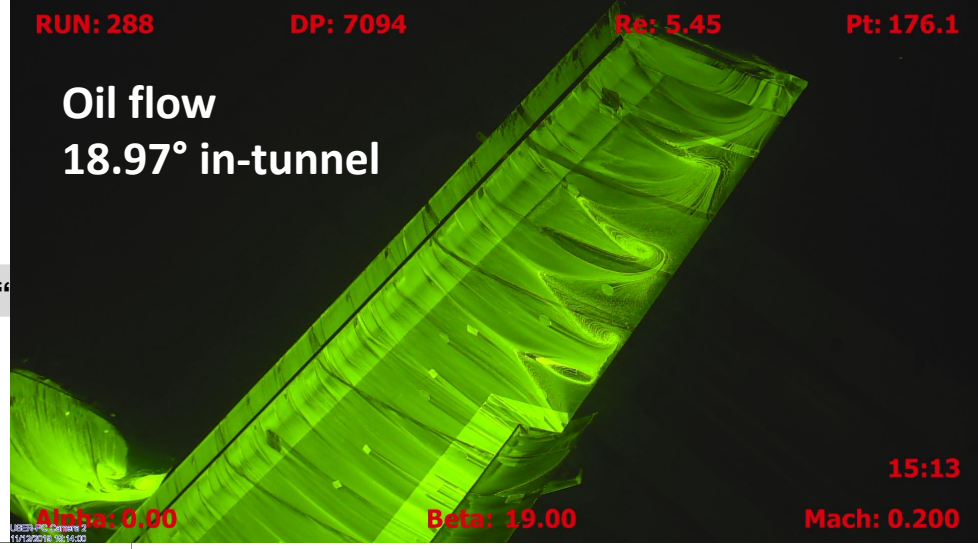


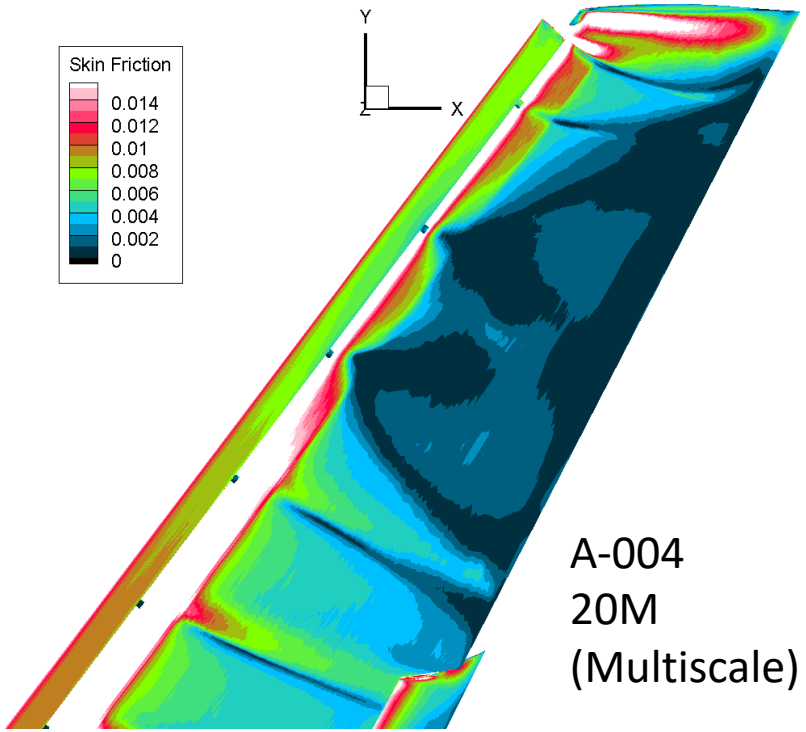
A-025.2
53M
(Drag)

Multiple Solutions, Outer Wing

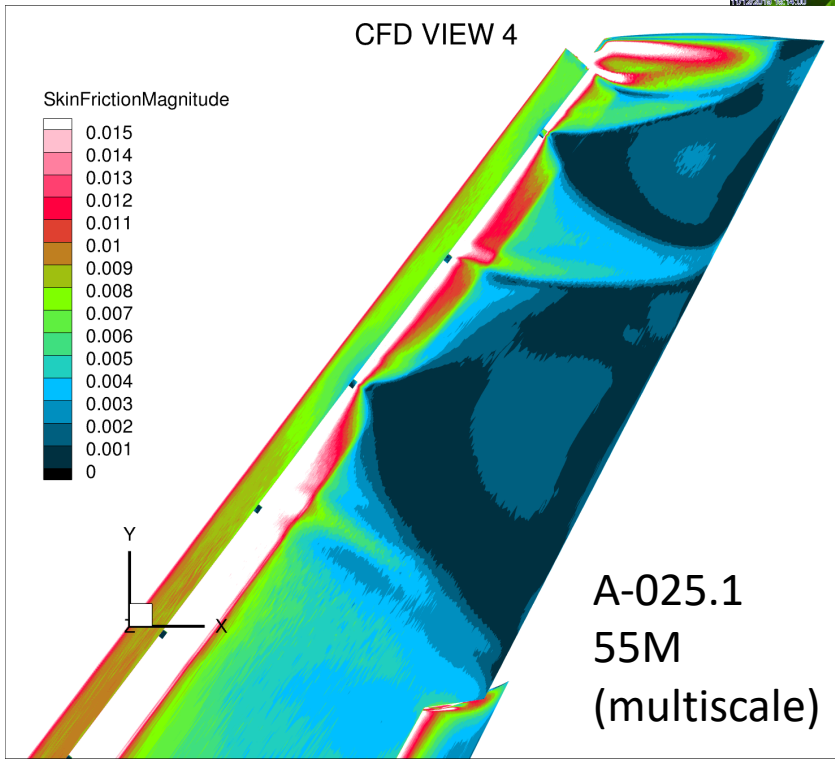
KQ 3	Can the causes of multiple solutions and techniques to encourage the “

- Lack of consistency for outer wing at 20.55° angle of attack (SA)

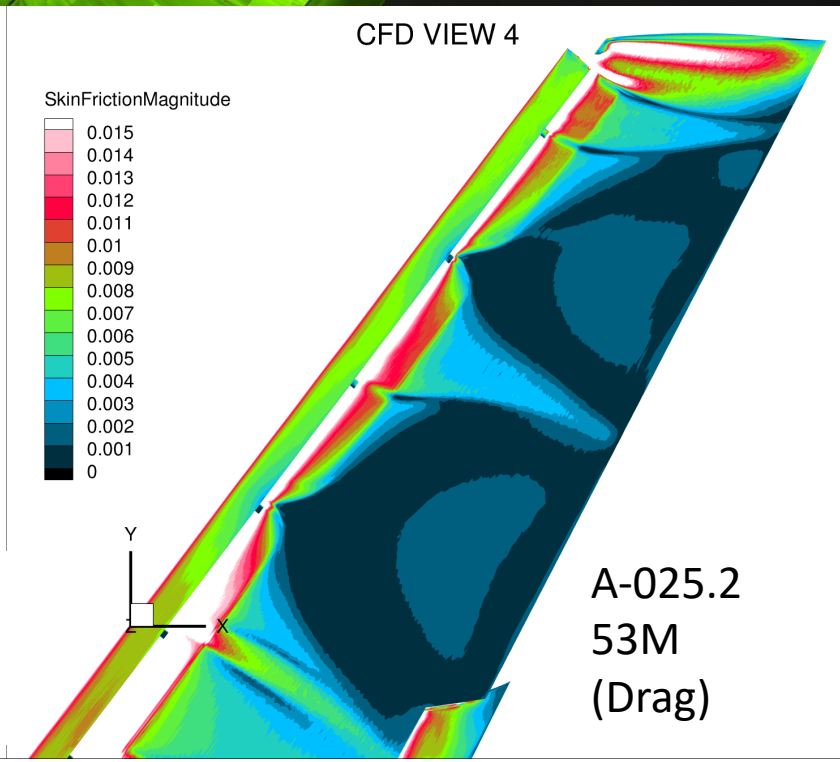




A-004
20M
(Multiscale)



A-025.1
55M
(multiscale)



A-025.2
53M
(Drag)

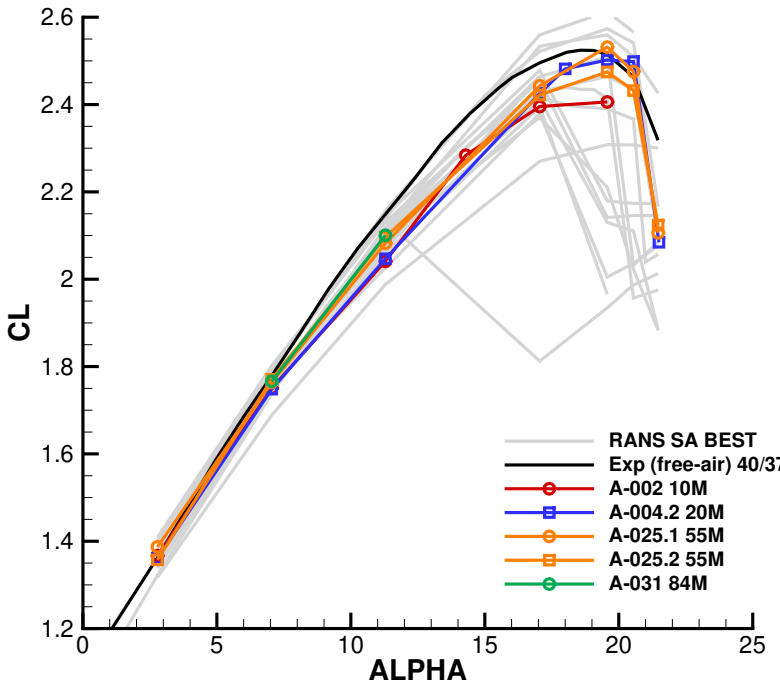
ADAPT TFG Key Questions

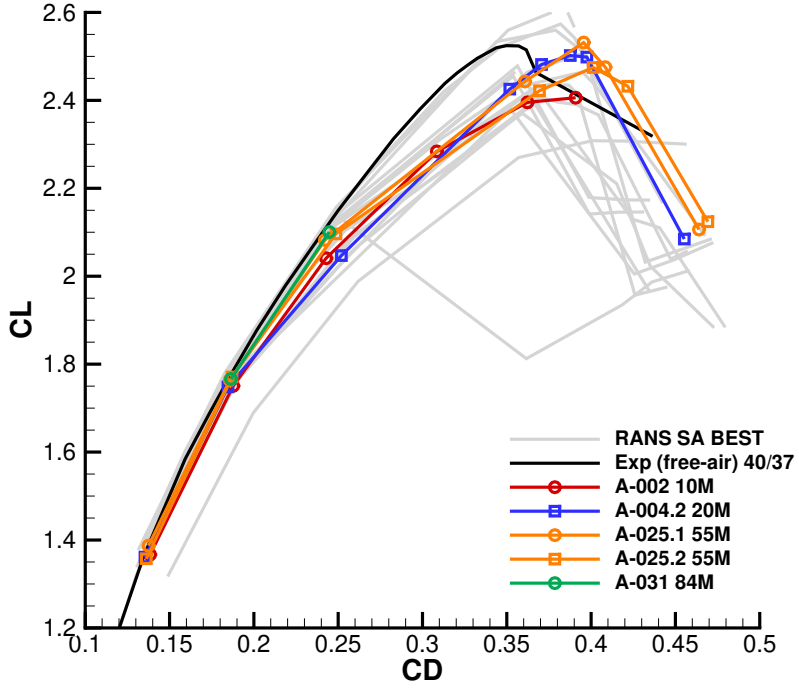
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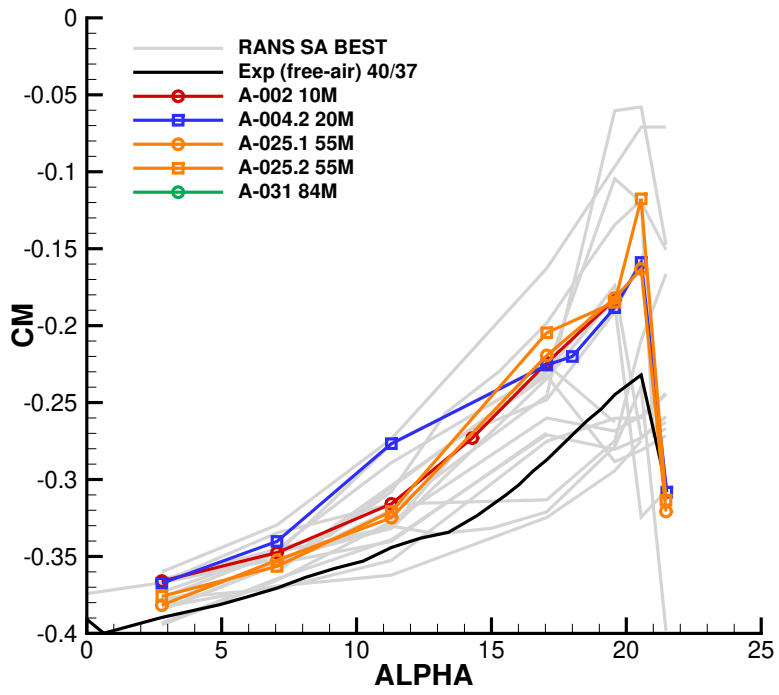
Angle of Attack Range Case2a

KQ 4	Where can mesh adapted RANS contribute to prediction of high-lift flow physics?

- Adapt FG with full iterative convergence (SA)
- Fixed-Mesh RANS FG best practice (SA)

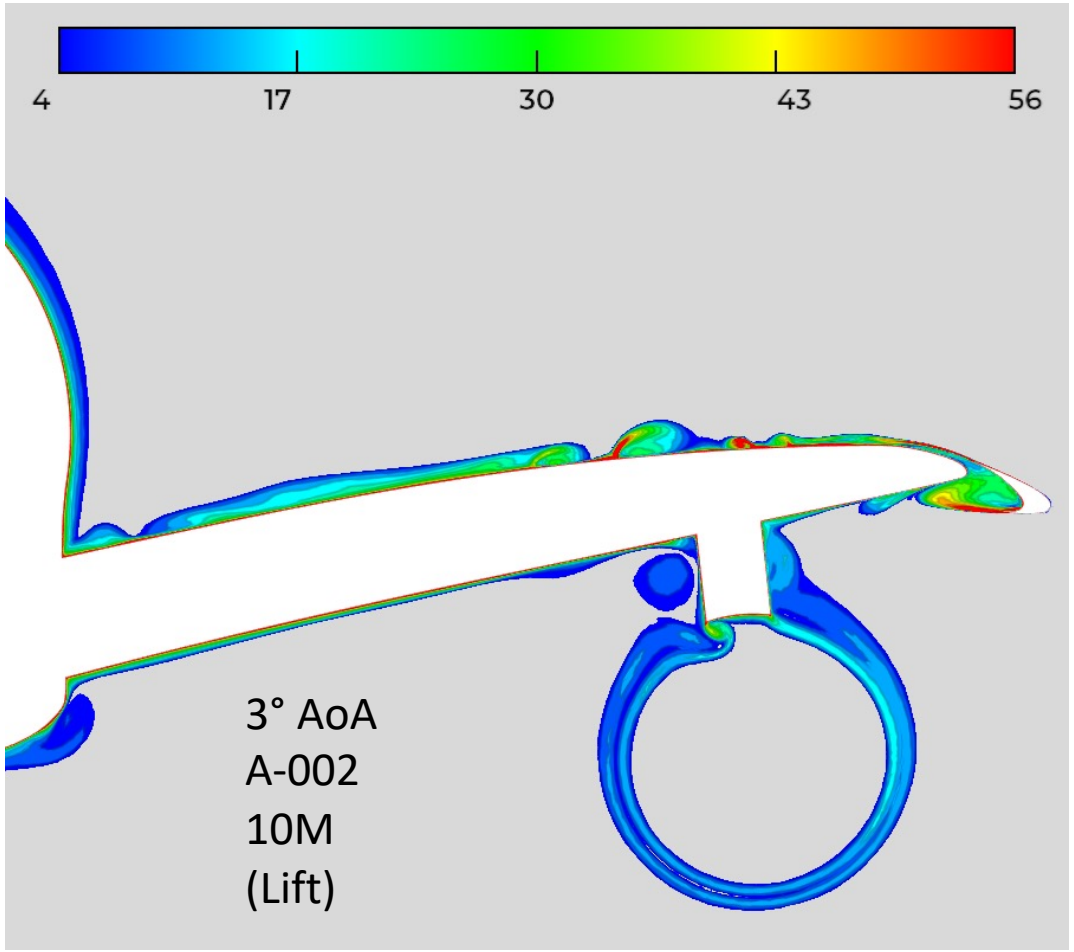


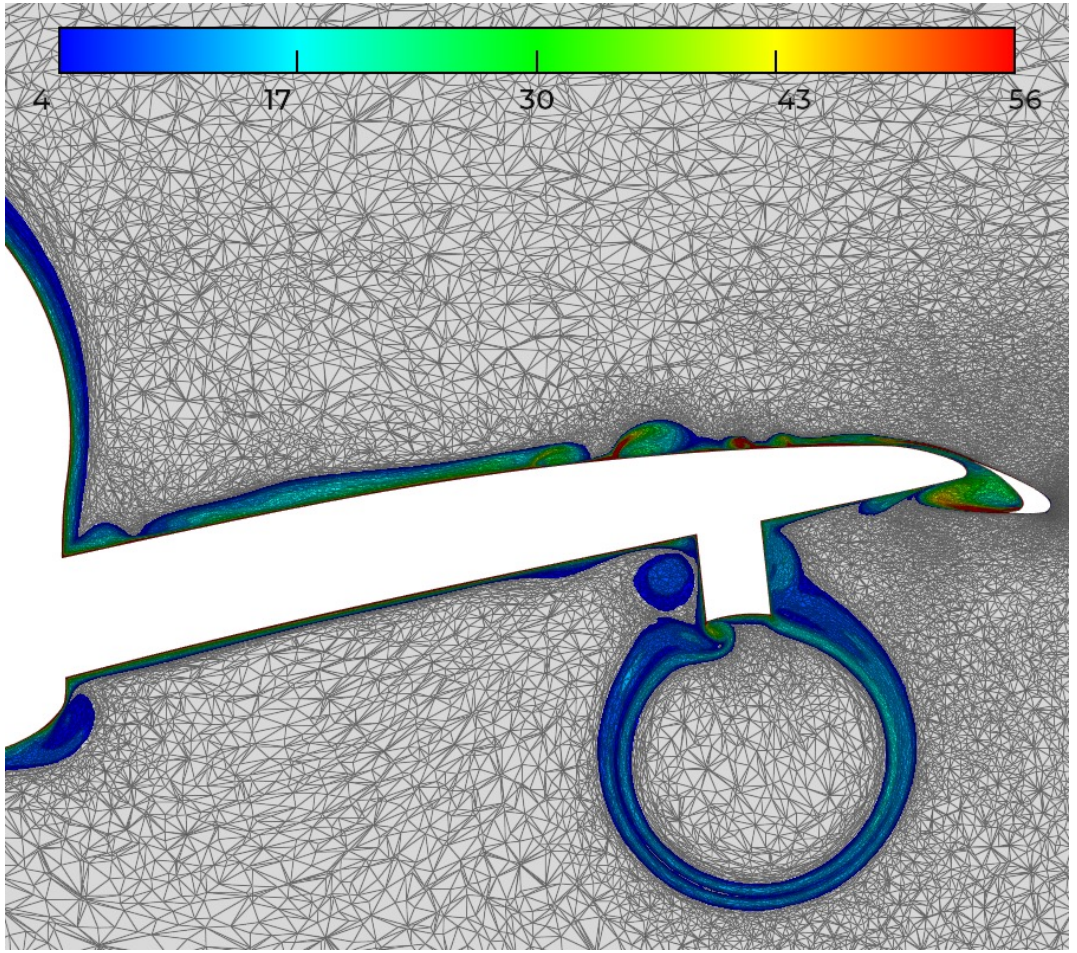




Angle of Attack Range Mesh Slice

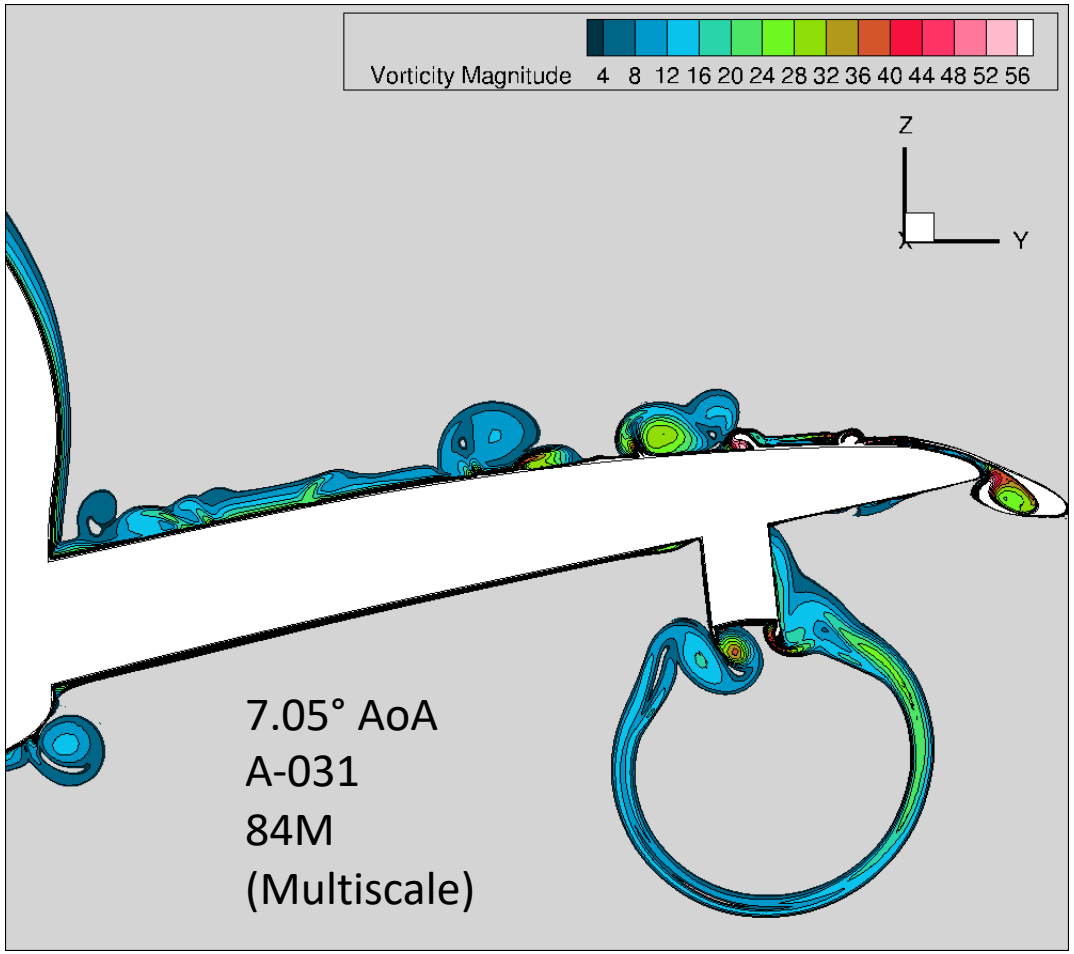
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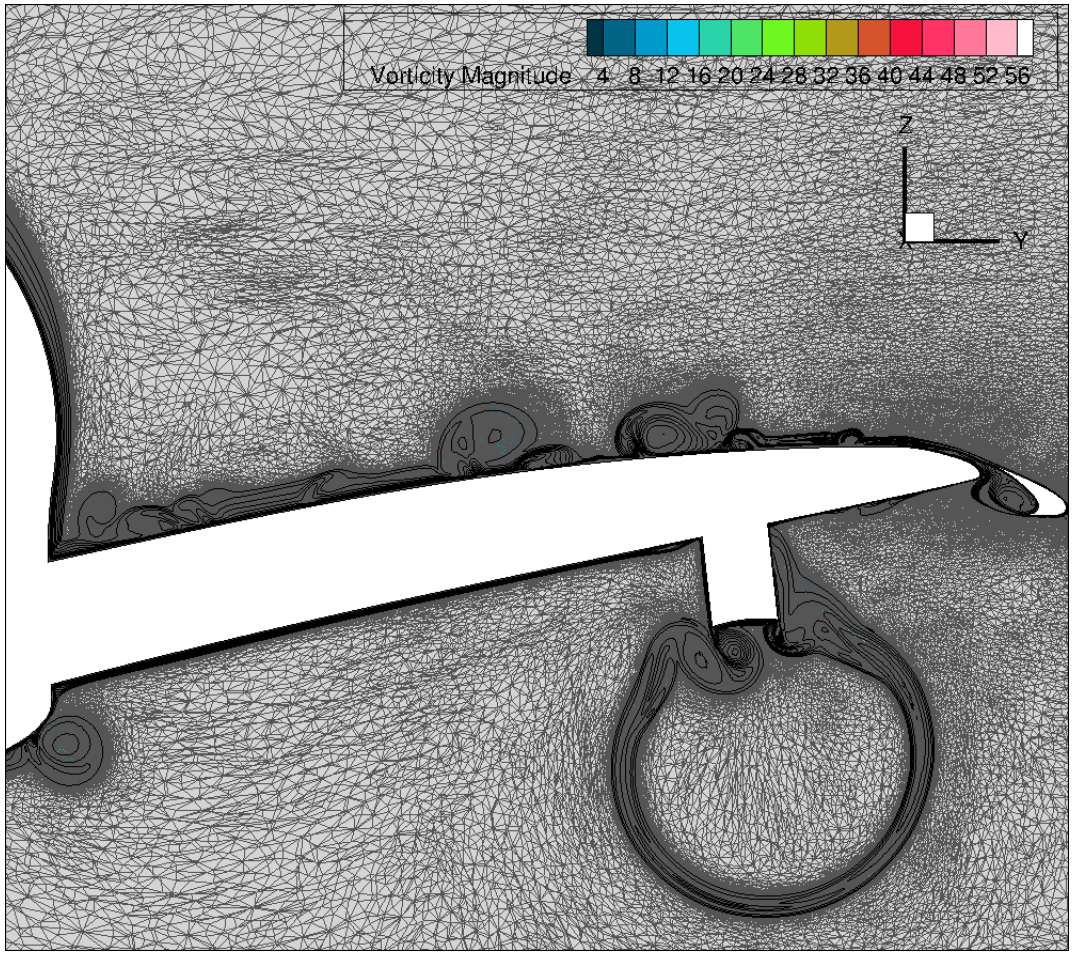




Angle of Attack Range Mesh Slice

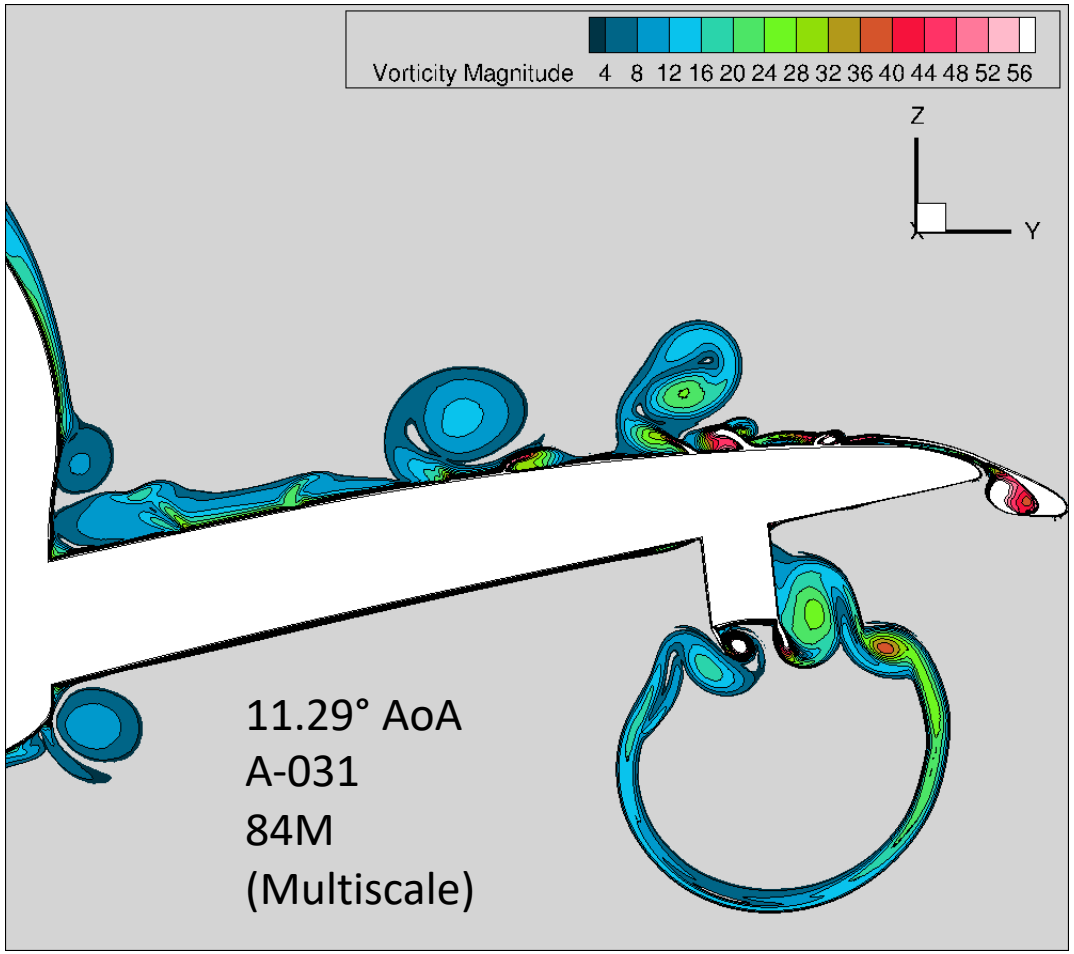
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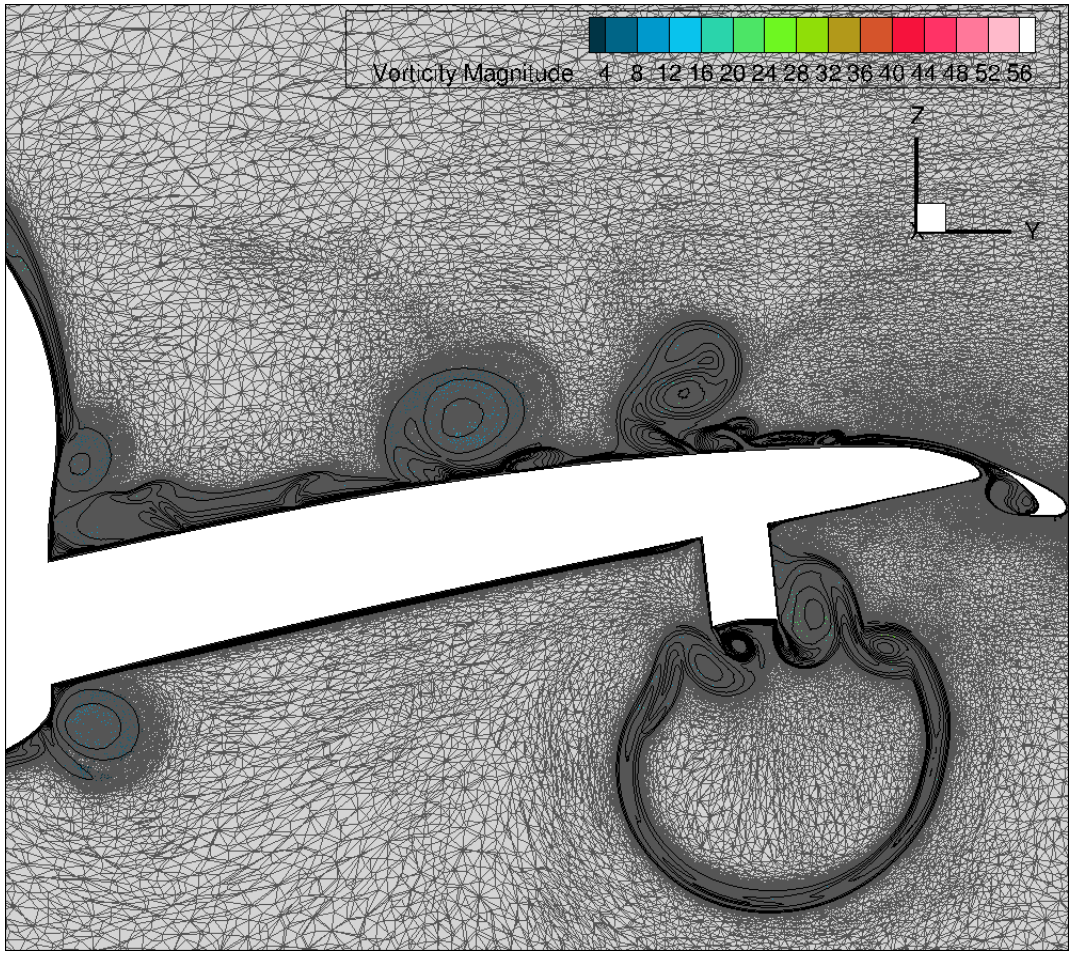




Angle of Attack Range Mesh Slice

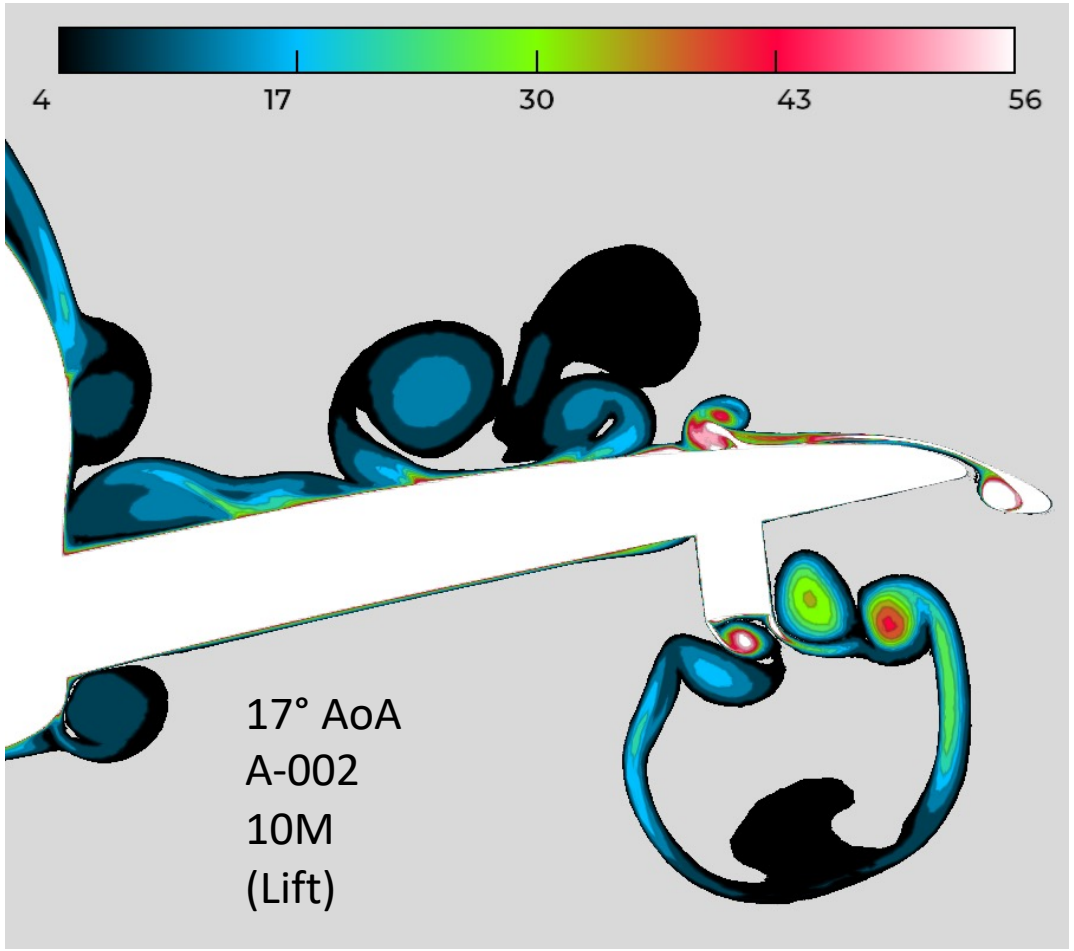
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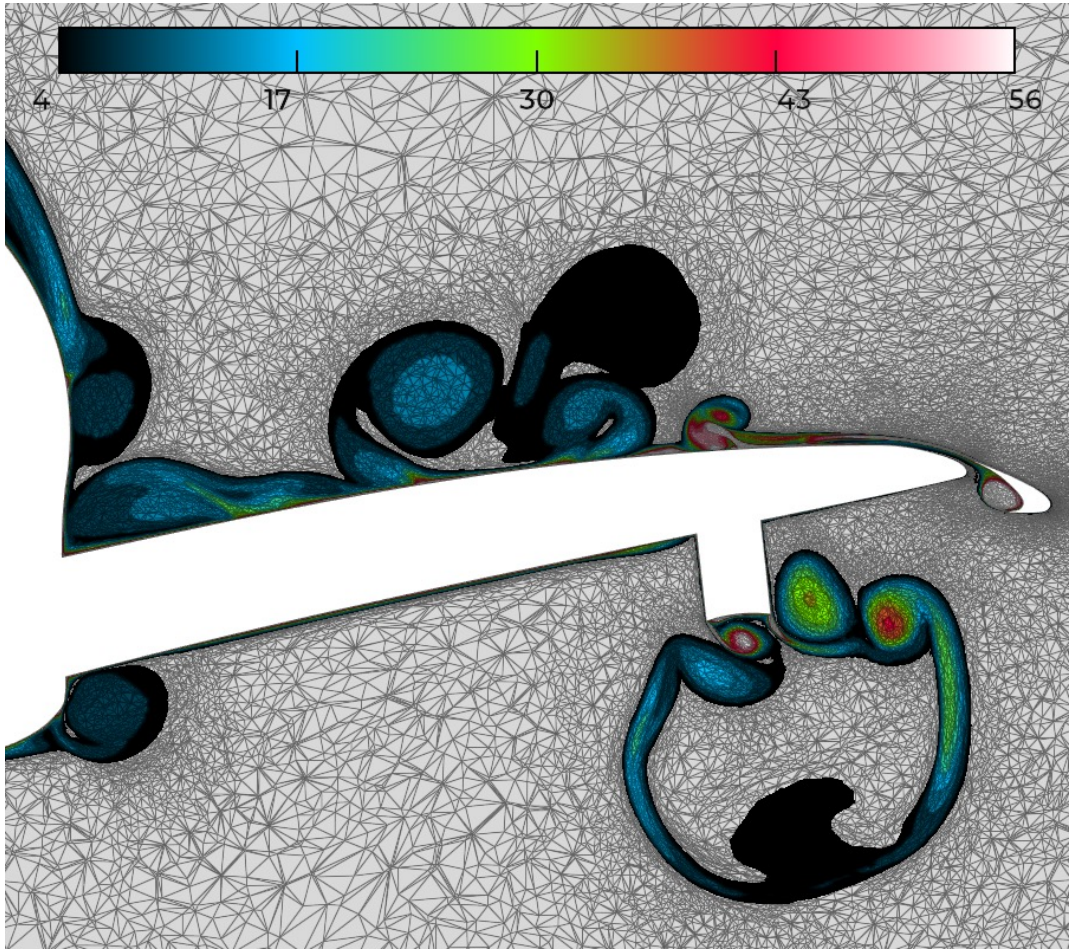




Angle of Attack Range Mesh Slice

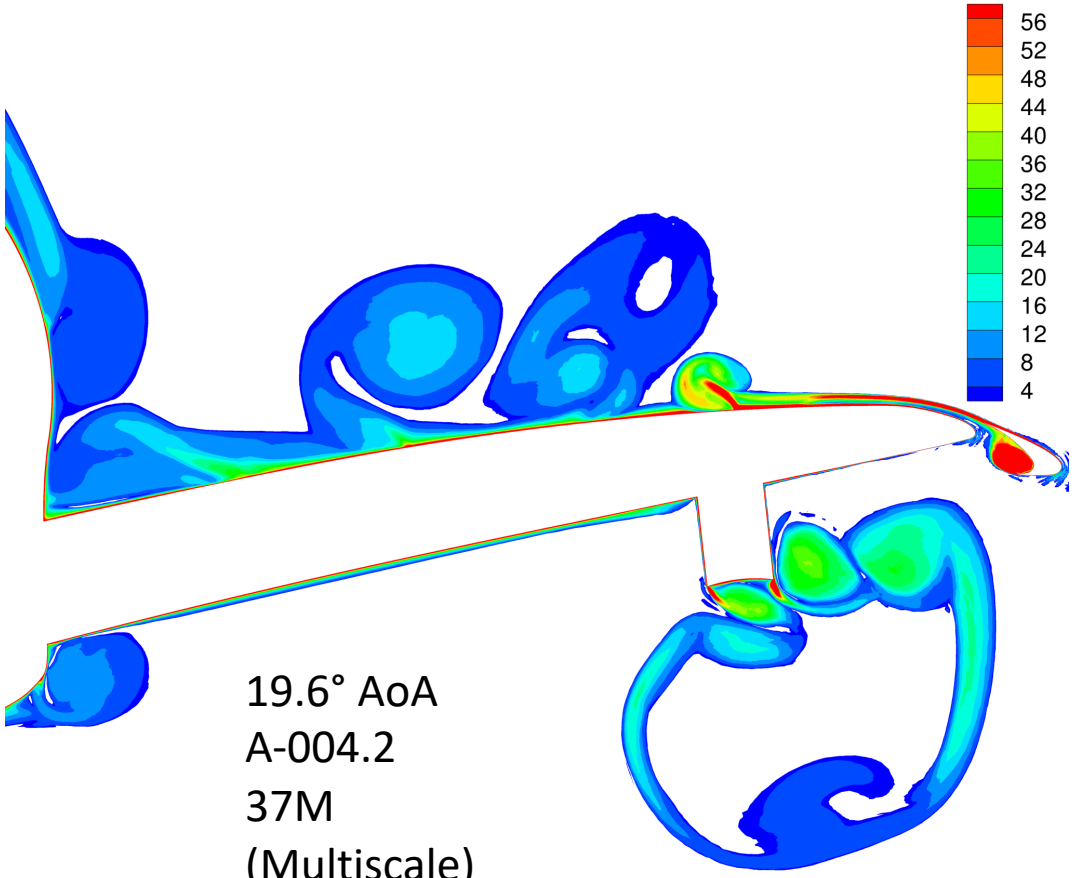
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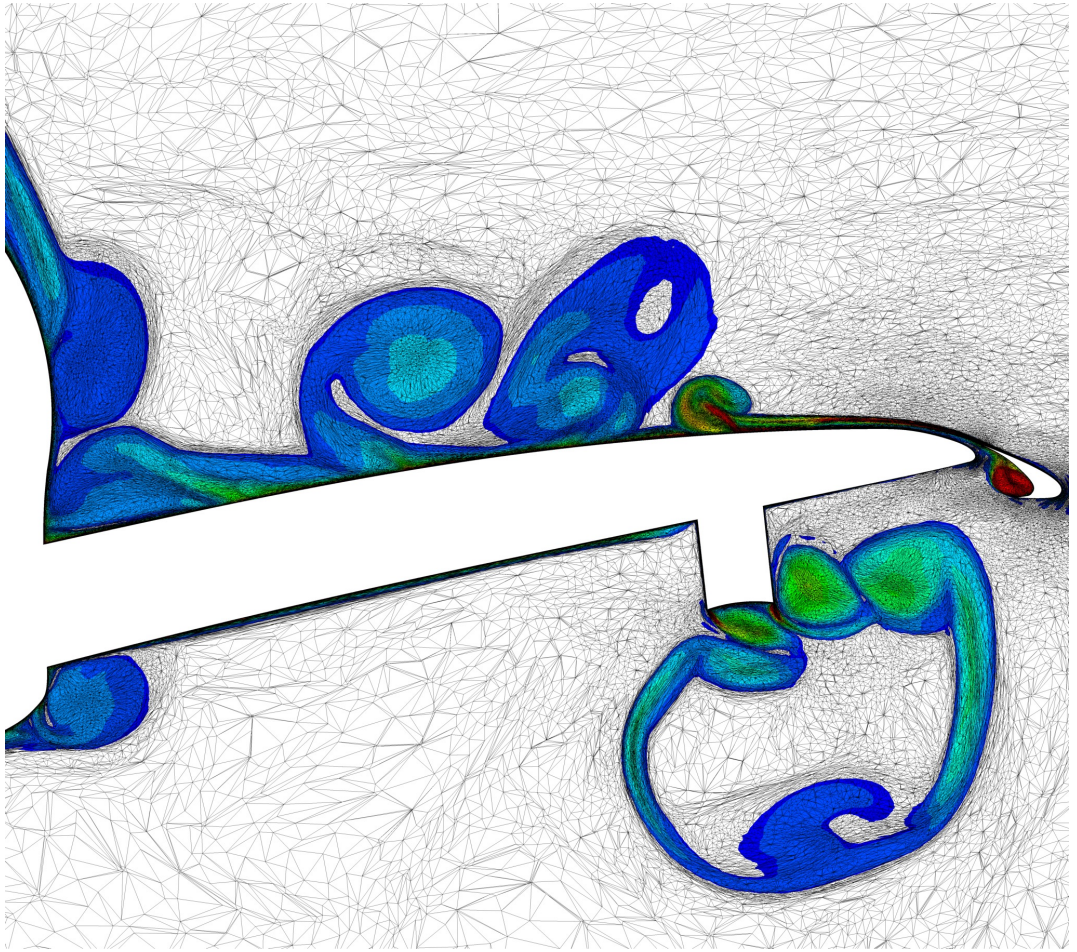




Angle of Attack Range Mesh Slice

KQ 4	Where can mesh adapted RANS contribute to prediction of high-lift flow physics?





Acknowledgements

- HLPW-4 organizing committee, TFG leaders, participants, observers, and attendees!
- Discussions during ADAPT TFG meetings and the workshop contribute to the content and recommendations of this summary.
- This work was partially supported by the Transformational Tools and Technologies (TTT) Project of the NASA Transformative Aeronautics Concepts Program (TACP) under the Aeronautics Research Mission Directorate.

Open Questions

- What is the impact of modeling effects when mesh variation is controlled? SA-RC-QCR20?? and other RANS turbulence models?
- Can mesh adaptation extensions to HRLES and WMLESLB lower variation for those methods and enable verification, which was not possible in HLPW-4?
- Can incremental unit problems for verification of high-lift relevant flows be defined that enable tighter collaboration between Technical Focus Groups and include eddy-resolving methods: highly loaded flaps, nacelle, slat wakes, wing root juncture?