DPW-8 & AePW-4
All-Hands Meeting and Mini Workshop 3

January 15, 2026

In-Person and Virtual

https://www.aiaa-dpw.org
https://nescacademy.larc.nasa.gov/workshops/AePW4/public

Agenda

- **Workshop overview and logistics**
- **AePW-centric working groups**
  - High-Angle
  - Large Deformation
  - High Speed
- **DPW-centric working groups**
  - Sources of DPW-7 Scatter
  - Test Environment
- **Hybrid working groups**
  - Static Deformation
  - Buffet

Workshop Logistics

Date and Time

- **Saturday, June 6 and Sunday, June 7**
- **Nominally 8:00 to 6:00**
- **Saturday**
  - Community-centric working groups
  - Two separate rooms, agendas developed independently by each community
  - 25 Years of DPW Celebration
- **Sunday**
  - Everyone meets together in one room

Registration

- **Will be handled through the AIAA website**

  Early Member: $399

  Early Non-Member: $549

  Early Student: $99

  Costs go up after early-bird deadline

  Virtual: $299 (in person is strongly encouraged)

  Planned to open in February or March

- **Conference registration is not required for the workshop**

Presentations

- **Participant presentations are planned for the workshop**
- **Handled outside of the AIAA conference abstract process**
- **Presentation-only**
  - Will be posted on the websites
  - Ensure export compliance before presenting
  - 10-25 minutes, depending upon working group and amount of your content
  - One presentation should cover all solvers you used
  - We're evaluating whether we can do virtual presentations (not ideal)
- **SciTech '27 will contain follow-on special sessions (either presentation only or paper/presentation)**
- **A virtual collection in a journal (e.g., Journal of Aircraft) is also planned**

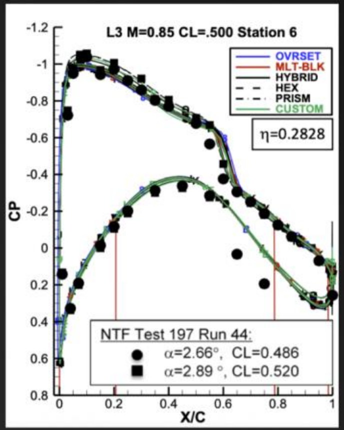
DPW Sneak Peek

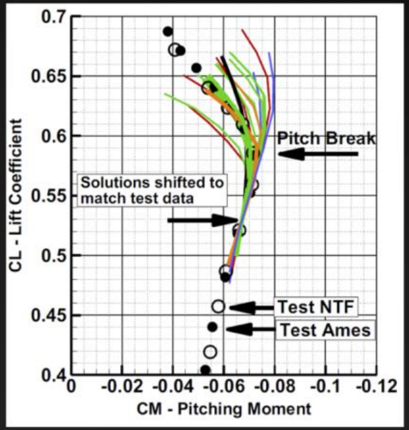
- **25 Years of DPW celebration**
- **Will include a few retrospective presentations**
- **Former organizing committee members have been invited**
- **Optional Saturday evening dinner (sponsors desired)**

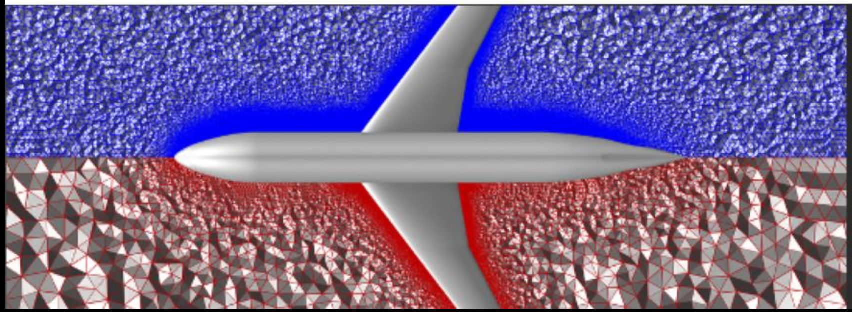
DRAG PREDICTION WORKSHOP SERIES

25 YEARS OF DPW CELEBRATION DINNER

- DPW-1 (2001): Laying the Foundation
- DPW-2 (2003): Full Configuration Drag
- DPW-3 (2006): Wing-Body Junction Interactions
- DPW-4 (2009): Entrance of the Common Research Model
- DPW-5 (2012): Common Grids and Separation Onset
- DPW-6 (2016): Aeroelastics and Nacelle-Pylon Interactions
- DPW-7 (2022): Expanding the Envelope
- DPW-8 (2026): Collaborative Drag and Aeroelasticity







JUNE 6, 2026

SAN DIEGO, CA

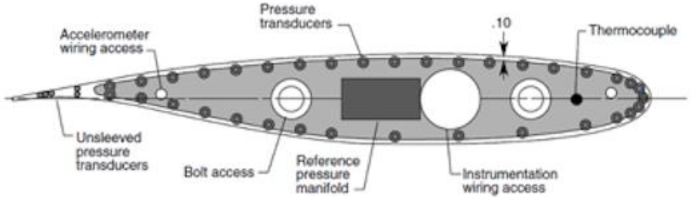
HELD IN CONJUNCTION WITH DPW-8

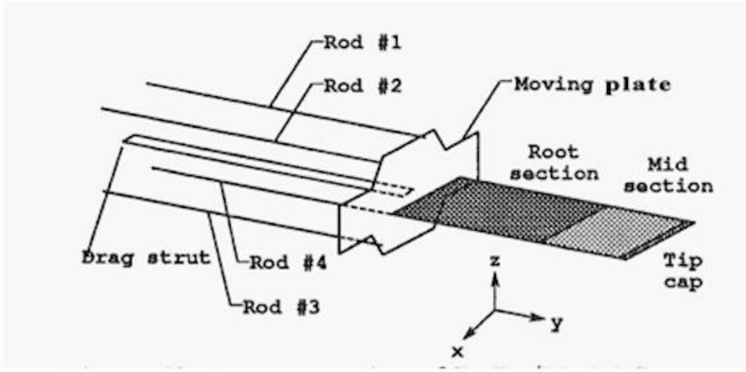
DINNER RSVP IS SEPARATE FROM WORKSHOP REGISTRATION
(DPW-8 WORKSHOP REGISTRATION NOT REQUIRED FOR DINNER)

High-Angle Working Group

Working Group Update: AePW-4 High Angle

- **Led by Pawel Chwalowski, NASA Langley**
  - We meet the 2nd Thursday of every month at 10 EST
- **Focus on transonic aeroelastic flutter for the Benchmark Supercritical Wing (BSCW)**
  - Tested in the NASA LaRC Transonic Dynamics Tunnel (TDT) in the early 1990s, as part of the Benchmark Models Program
  - A rigid rectangular wing attached to a pitch and plunge apparatus (PAPA)
  - Experimental flutter points at a range of Mach and AoAs
  - Finite element model as well as a family of unstructured meshes are available
- **BSCW is currently tested in TDT: (uPSP, PIV, sweep of Mach and AoAs)**





High Angle WG: Workshop Cases

- **Case 1**
  - 3D wing flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° - 6°
- **Case 2**
  - 3D wing flutter prediction at Mach 0.74, 0.76, 0.78 and angle-of-attack 3°
- **Case 3**
  - 2D wing flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° - 6°

We have about 10 teams performing flutter calculations

High Angle WG: Workshop Cases

- **Case 1**
  - 3D wing flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° - 6°

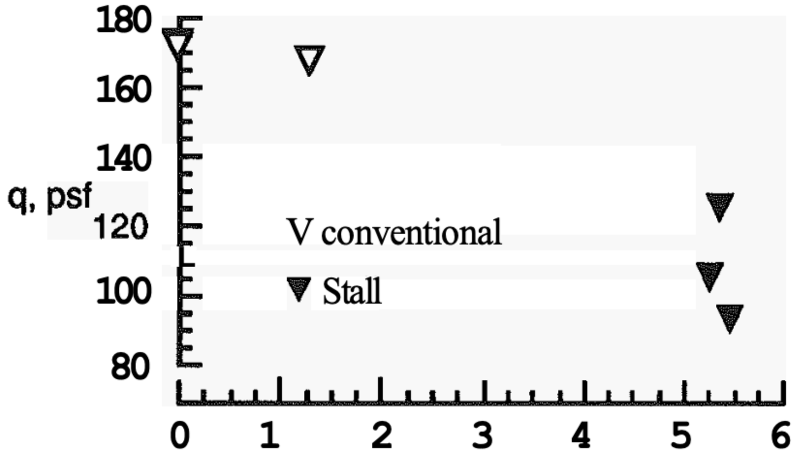


Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Dansberry et. al., 1993

High Angle WG: Workshop Cases

- **Case 1**
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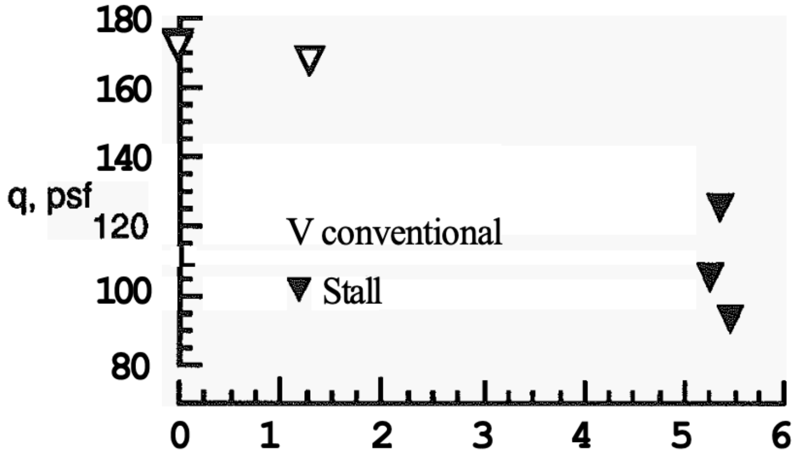


Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Dansberry et. al., 1993

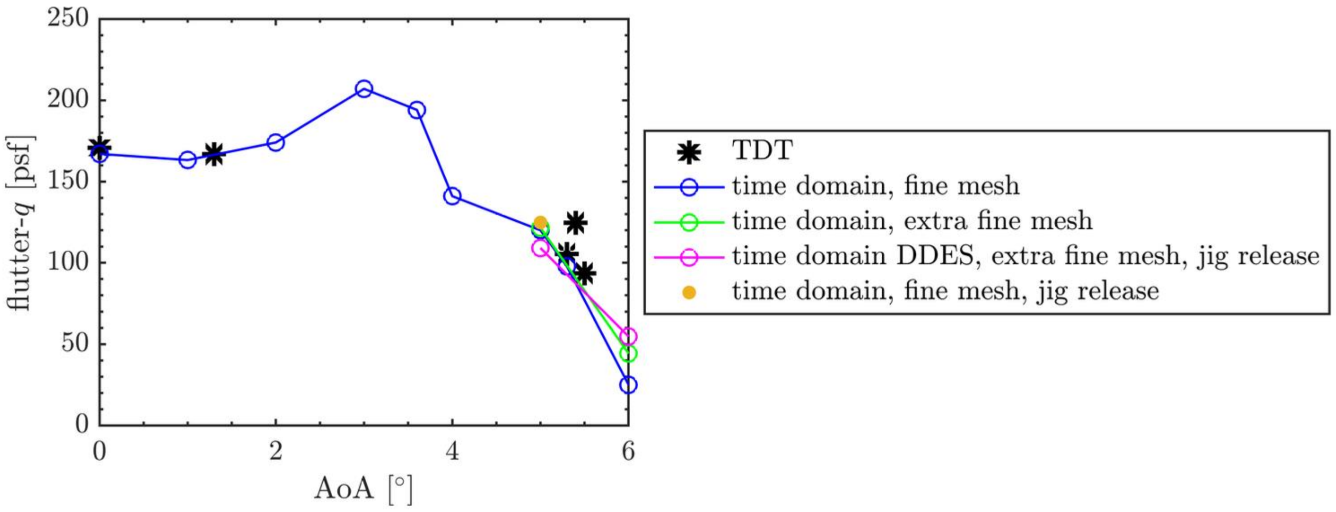


Figure 12: Variations in the computed flutter-q, compared to jig released dynamic perturbations.

Stanford et. al., 2024

High Angle WG: Key Questions

- **What is the current predictive capability of transonic flutter?**
  - Are uRANS solutions sufficient to predict flutter at BSCW experimental conditions considering a separated flow?
  - How do we determine uncertainty in our analyses, considering nonlinear aerodynamic model, linear structural dynamics model, the coupling between models, and the experimental data?
- **Is there a quantifiable relationship between the shock buffet and the flutter onset?**
- **Will additional experimental data help to assess the shock motion and the separated flow features near flutter?**
- **Is the reduction of spatial dimension from 3D to 2D helpful in BSCW flutter analysis?**

Large Deformation Working Group

Working Group Update: AePW-4 Large Deformation

- **Led by Rafa Palacios, Imperial College**
  - We meet the 3rd Thursday of every month at 10 EST
- **Focus on the Pazy very flexible benchmark wing and its swept variants**
  - Designed and tested at the Technion
  - ~600mm span wing with thin Aluminum spar and printed Nylon chassis
  - CAD and Finite element models are available
  - Extensive wind tunnel data available at flutter, post-flutter, LCO, and (coming soon!) sub-critical flutter

S20 S10 Pazy

Revivo and Raveh, SciTech 2025

Small and Large Amplitude LCO of the S10 wing

Large Deformation WG: Key Questions

- **What are the unique aeroelastic phenomena of very flexible structures that undergo large deformations?**
  - Flutter around large-deflection equilibrium, post-flutter behaviors (e.g., small/large amplitude LCO)
  - How do these vary for different geometries and boundary conditions?
- **For swept flexible wings, how is flutter affected by**
  - Aerodynamic sweep
  - Structural bending-torsion coupling
  - Wing deformation
- **What are adequate structural/aerodynamic (steady and unsteady) models?**
  - For straight/swept wings, flutter onset, small/large amplitude LCO
  - Recommendations for a production environment

Large Deformation WG: Workshop Cases

- **Swept wing flutter prediction**
  – S10 and S20 swept wings in LE/TE weight configurations
- **Post-flutter / LCO response characterization**
  – Straight Pazy wing
  – S10 and S20 swept wings
- **Subcritical flutter prediction**
- **Potentially a large-amplitude gust response case**

Large Deformation WG: Progress

- **72 members in mailing list**
- **Monthly tag-ups on the third Thursday of the month (since April 24)**
- **Repo with meeting presentations and videos hosted at Imperial. Contact Rafa Palacios @ Imperial College**
- **Active contributors (with apologies if I miss anyone):**

ZHAW	(individual)
Technion	Imperial College
University of Pittsburgh	Kaunas University of Technology
Polytechnique Montreal	Indian Institute of Science
University of Michigan	Sapienza University of Rome
University of São Paulo	French Air Force and Space Academy
Georgia Institute of Technology	University of Michigan
NASA	

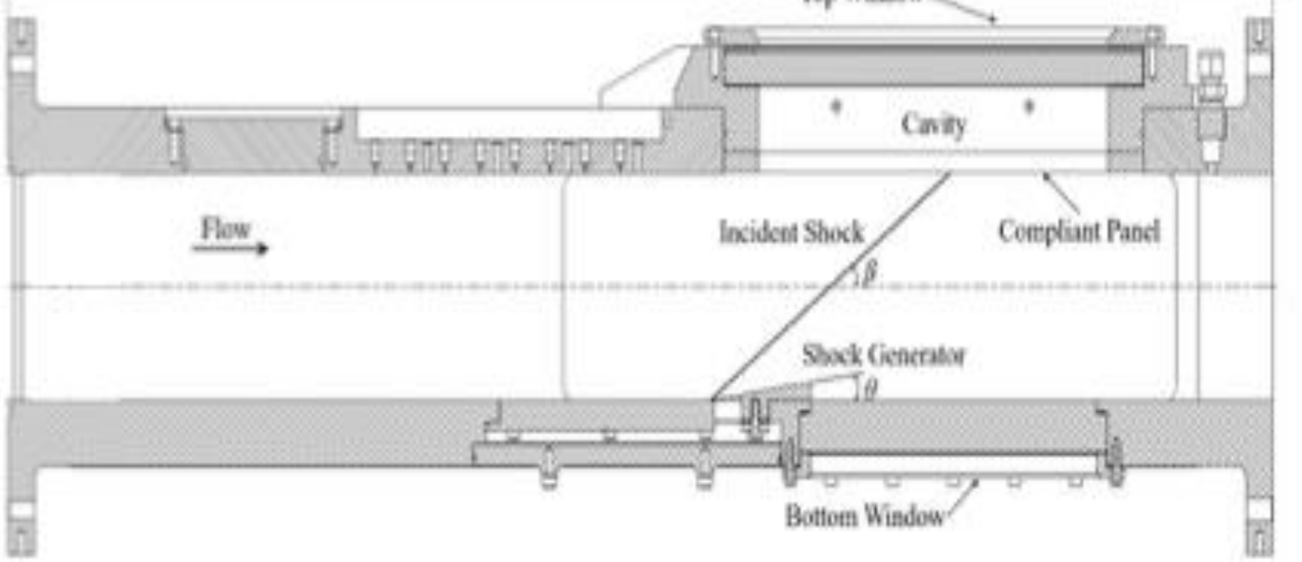
LDWG contact: r.palacios@imperial.ac.uk

High-Speed Working Group

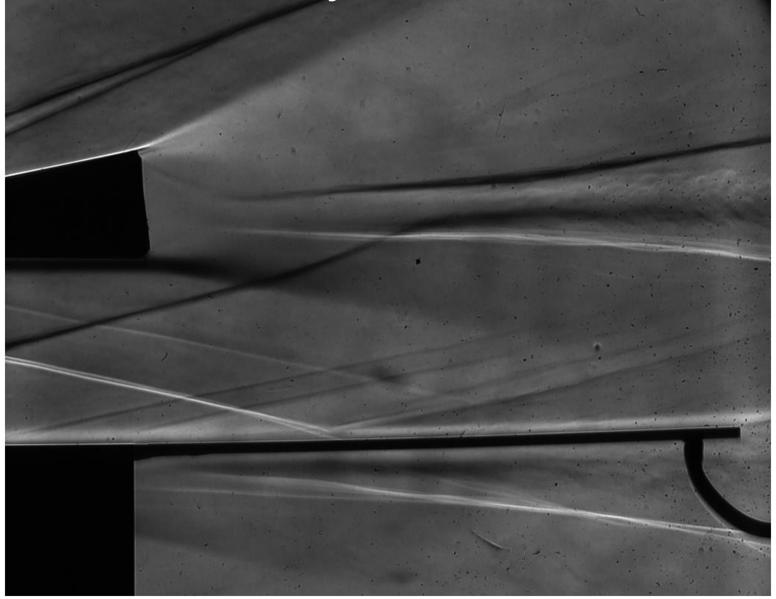
Working Group Update: AePW-4 High Speed

- **Led by Kirk Brouwer, AFRL/RQHS SSC**
- **Focus on two challenge problems**
  - RC-19: Large-amplitude, nonlinear dynamics of a thin panel with/without SBLI
  - HyMAX: Linear response of a cantilevered plate to transitional/separated SBL

AFRL RC-19 Setup



UNSW HyMAX Schlieren



High-Speed WG: Progress

- **Current participation: 109 members on the email chain**
  - 8 groups working on RC-19, 5 groups working on HyMAX
- **Monthly tag-ups on the 4th Thursday of the month**
- **HSWG off-cycle relative to other AePW groups**
  - First workshop at SciTech 2023 (2024/2025 informal meetups)
- ***Near term:*** Wrap up current iteration at Aviation 2026 Workshop (present results/lessons learned)
- ***Long term:*** Selection of follow-on challenge problem

	AFRL-SSC	Duke	NASA	DLR	UNSW	MIT	Stevens	UC/ARL	Metacomp	Hexagon	Technion
RC-19	✓	✓	✓	✓	✓			✓	✓	✓	✓
HyMAX		✓			✓	✓	✓	✓			

HSWG Key Questions

Objective: Assess the SoA of aerothermoelastic toolsets in high-speed applications

- What are the physical mechanisms that drive the various types of aerothermoelastic instabilities in high-speed flows?
- How accurately can dynamic aerothermoelastic instabilities be calculated? (Identifying onset of the instability vs the post-threshold behavior)
- Develop guidelines/metrics for modeling instabilities: What level of model fidelity is required? How much accuracy is lost when using lower fidelity methods?
- What is the uncertainty in our models? How does uncertainty propagate when coupling multiple models?
- What are the gaps/uncertainties in current experimental datasets that need to be addressed with follow-on or new experiments?
- How well do the SoA models handle complex structures and flow environments (transition, separation, SBLI, 3-D effects)?

HSWG Future Directions

- AFRL-Supported AE/ATE Experiments (Packaged consistent with RC-19 challenge problem):
  - RC-19 updates: Separated SBLI with snap-through & swept, attached SBLI with multiple instabilities
  - M6HRF: Compliant panel tests with quasi-static and dynamic responses (Led by Zach Riley)
  - H2K: Separated (transitional/turbulent) SBLI-induced aeroelastic experiments (Collaboration with DLR)

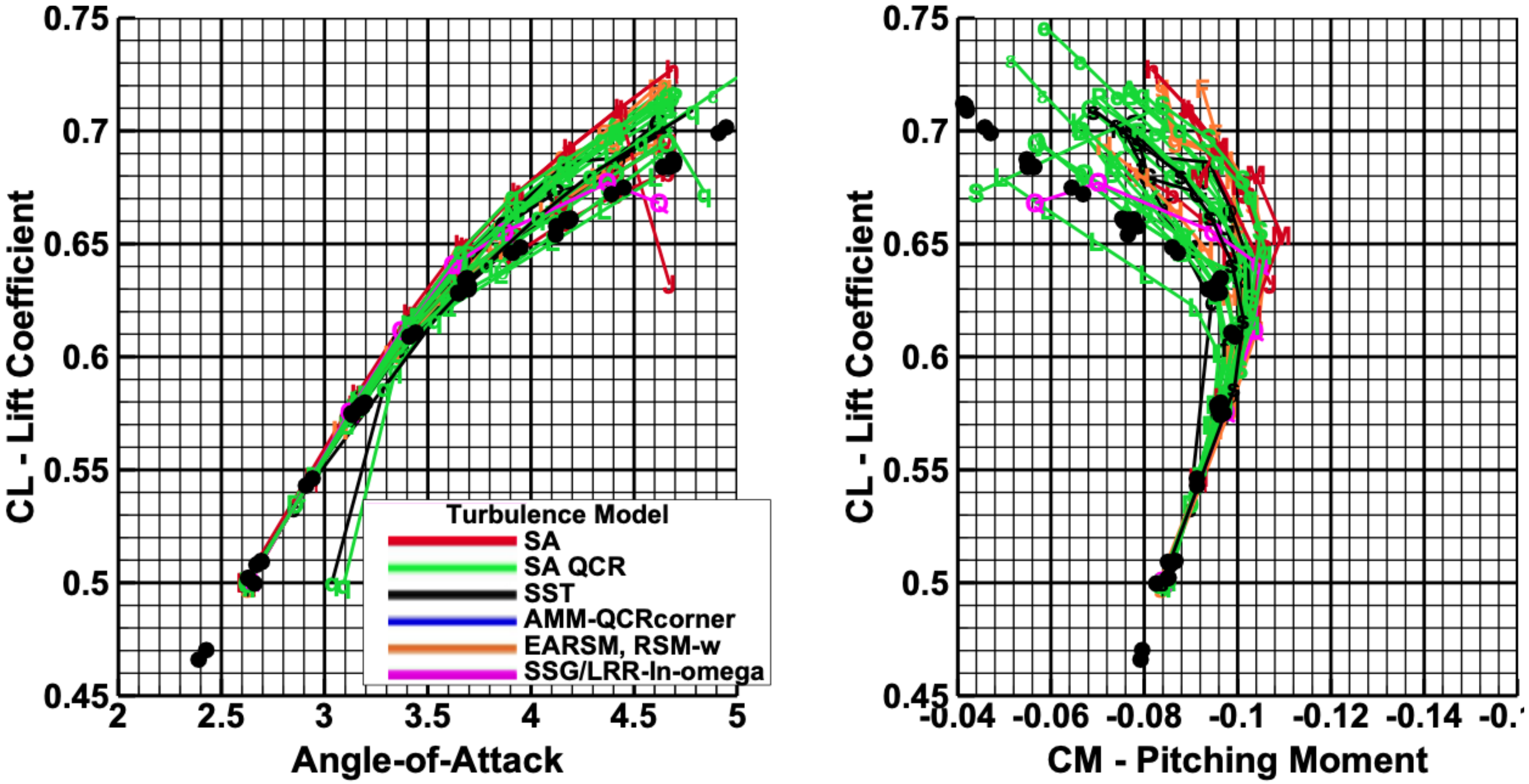
- Variations of HyMAX
  - Plans to test a similar configuration to HyMAX in the AFRL M6HRF
  - Will allow for longer flow times, *O(min)*, with the potential to observe flutter in the presence of thermal effects

- Other experiments/Inputs from AePW HSWG participants/AIAA FSI DG?
  - Compliant panel experiments at NCSU lead by Prof. Narayanaswamy (Collaborators at Duke – Prof. Dowell)

Sources of DPW-7 Scatter Working Group

Source of Scatter – Motivation

- **Seek to identify deviations in DPW-7 CRM data**
- **Significant spread in solvers post pitchup (all submissions plotted)**



Mach = 0.85, Re=20M - CFD Shifted to Match Test at CL=0.53

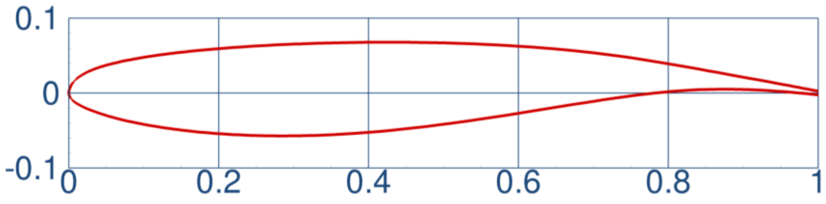
Curves collapsed to match experimental data near cruise point

Image source:
Tinoco, E., et al., "Summary Data from the Seventh AIAA CFD Drag Prediction Workshop," AIAA 2023-3492

Sources of Scatter – Overview

- **Three test cases examined so far**
  - Test Case 1a: ONERA OAT15A
    - Establish initial level of scatter
  - Test Case 1b: Joukowksi Airfoil
    - Order of accuracy check
  - Test Case 1c: ONERA OAT15A
    - Reduced scatter
  - Test Case 3: W1/W2 from DPW3
    - Reduced scatter
- **Future test case**
  - Test Case 2: CRM Wing/Body Cruise
    - Examine scatter for 3D and QCR2000
- **Sustained meeting cadence and structure**
  - Approx 20 people on distribution list
  - Average 5-10 attendees in each meeting
  - Meeting Tuesdays 10am ET on 2nd and 4th week of the month

Test Case 1a: Workshop-Wide Validation

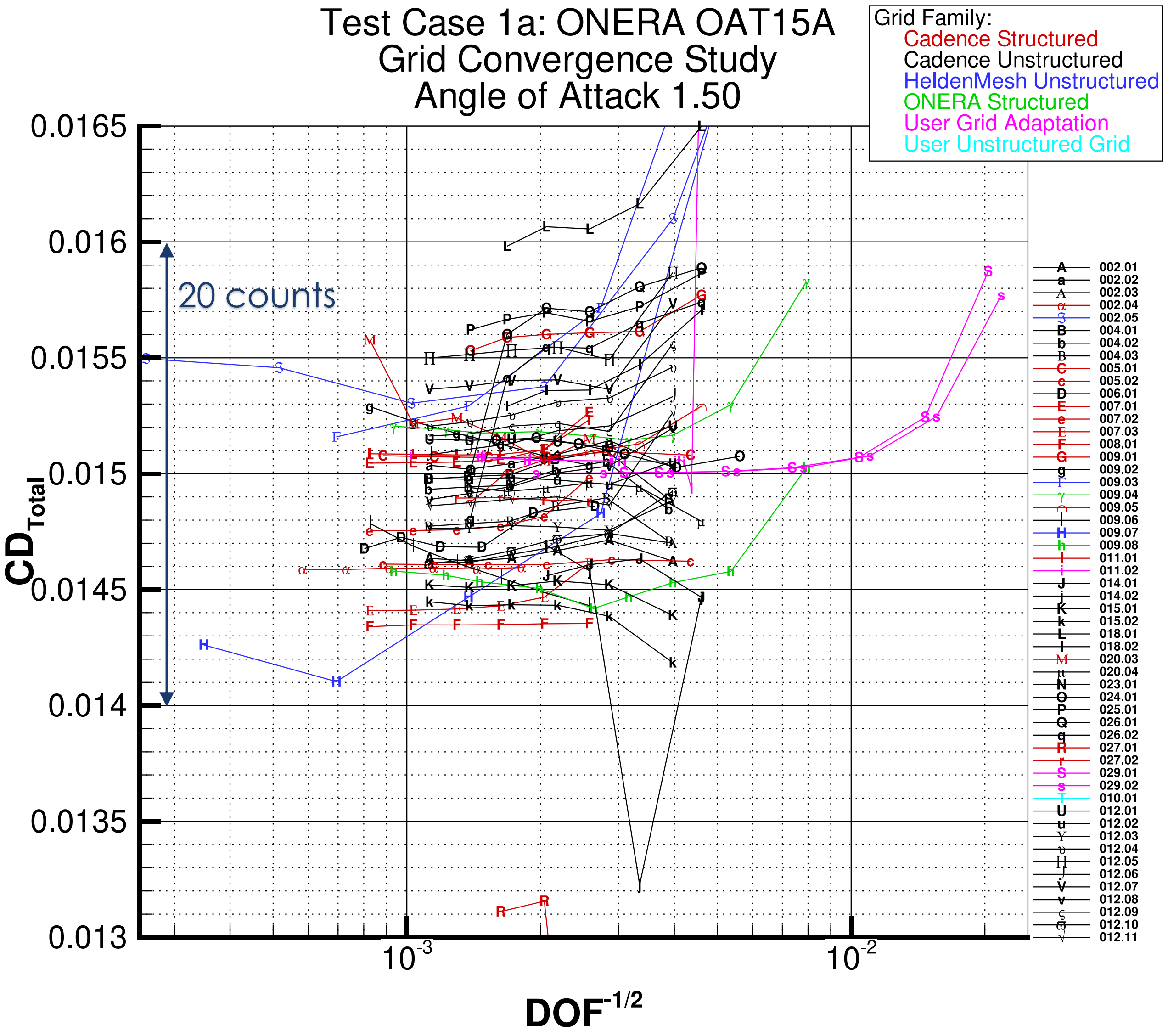


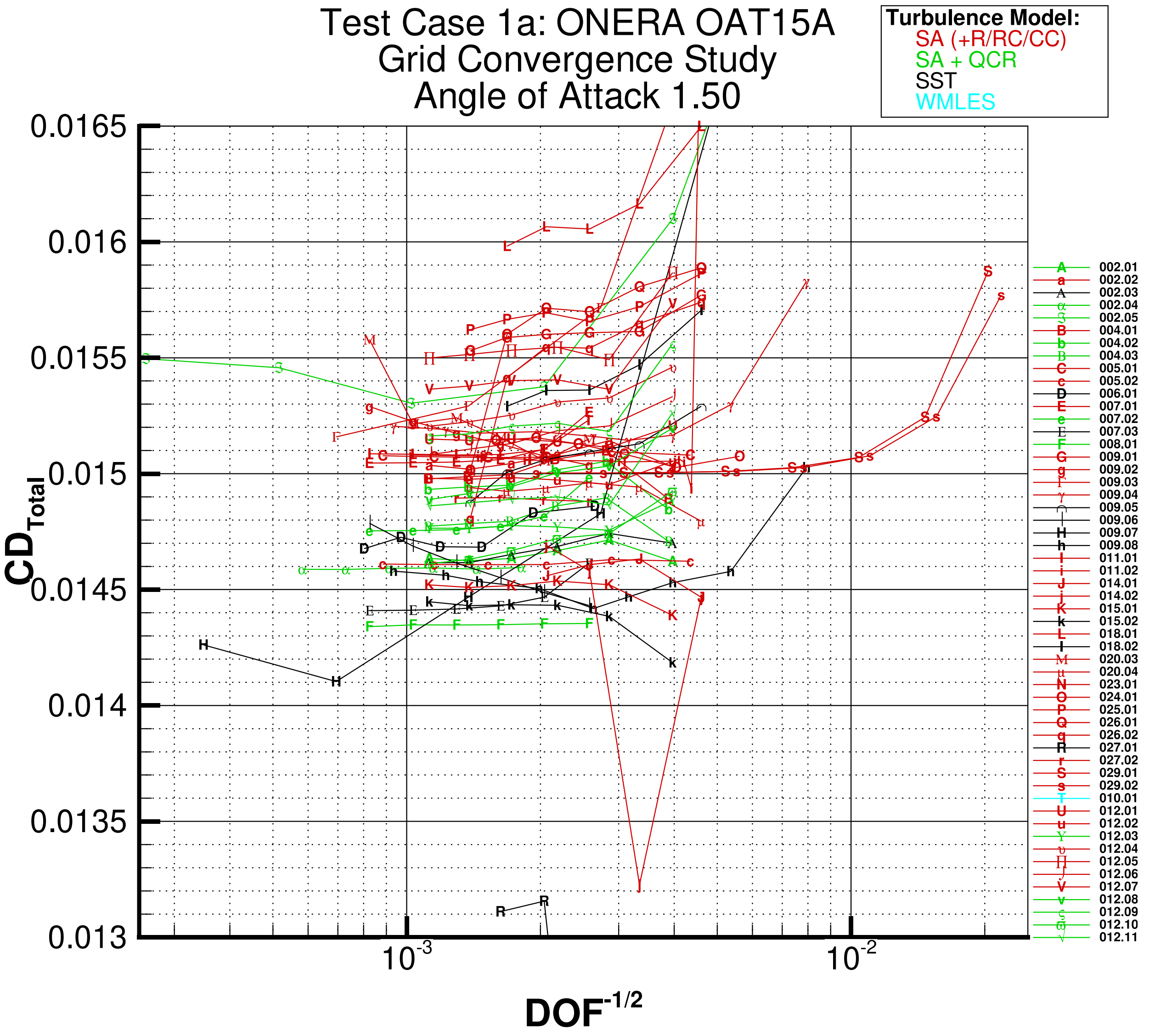
ONERA OAT15A Transonic Airfoil

- **Validation of steady CFD analysis, required**
- **Users are encouraged to employ best practices**
- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted
  - Purely 2D simulations (one cell wide)
- **Grids**
  - Six-member RANS grid family; four are required, six are desirable
  - Encourage use of committee-supplied grids; user-generated grids are acceptable
  - Committee-supplied grid is one cell wide with a 230mm chord (same as experiment) and follows RANS best practices
- **Conditions**
  - Mach 0.73, Re_c=3m (based on chord length), T_{static}= 271 K (487.8 R)
  - Alpha: 1.36, 1.50, 2.50, 3.00, 3.10

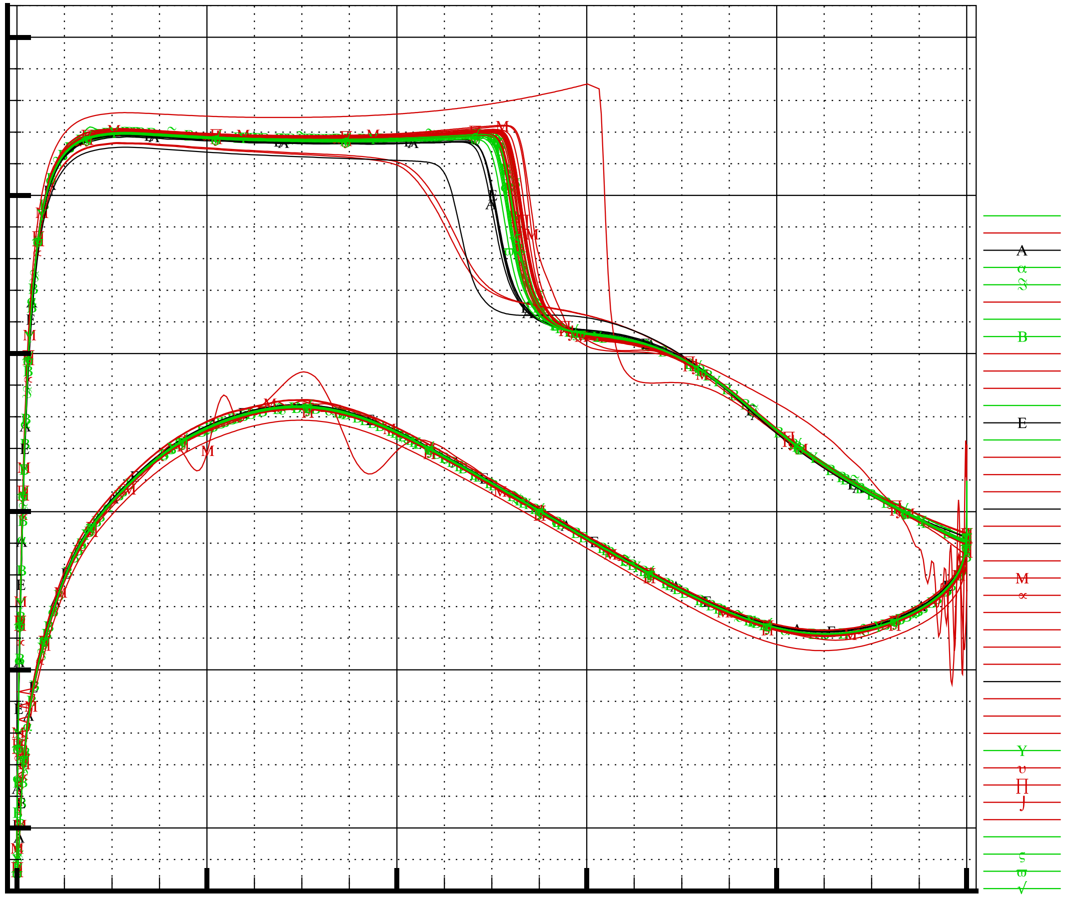
Jaquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009. Pages 1985-1994.

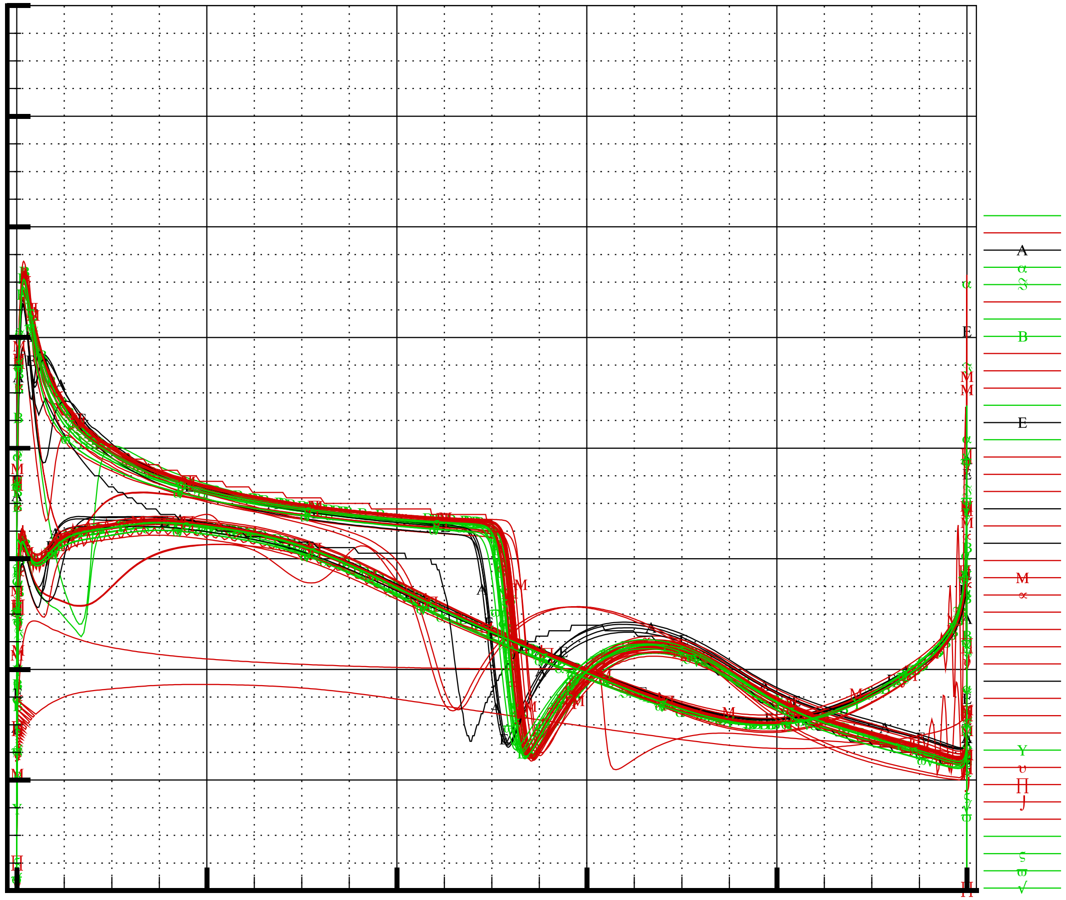
ONERA OAT15A C_D Convergence: $\alpha = 1.5°$





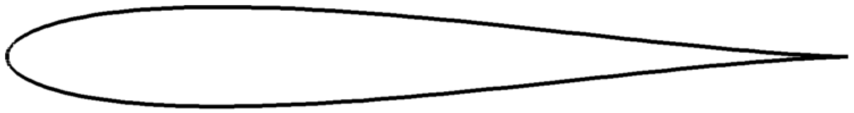
ONERA OAT15A C_p and C_f: $\alpha = 1.5^\circ$





Test Case 1b: Joukowski Airfoil

- **Validation of steady CFD analysis, required**
  - https://github.com/Drag-Prediction-Workshop/DPW8-Scatter/blob/main/TestCase1b/Joukowski.pdf
- **Settings**
  - Steady CFD RANS **French Vanilla SA-[neg] (All terms!)**
    - Adiabatic Wall (not isothermal)
    - Characteristic Farfield (***100 chords away - no circulation***)
    - Use periodic boundary conditions for sidewall boundary conditions
  - Converge residuals to machine precision (~1e-10)



- **Grids**
  - Committee-supplied grid family (High-Fidelity CFD Verification Workshop 2024)
- **Conditions**

Mach	Re_c	T_{static}	α	γ	Pr	Pr_t	Farfield $\chi = \tilde{\nu}/\nu$
0.15	6×10^6	520.0 R	0.0°	1.4	0.72	0.9	3

- **Sutherland's Law**

$$\mu(T) = \mu_0 \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T_0 + S}{T + S}\right)$$

$$\mu_0 = 1.716 \times 10^{-5} \frac{\text{kg}}{m\,s}$$

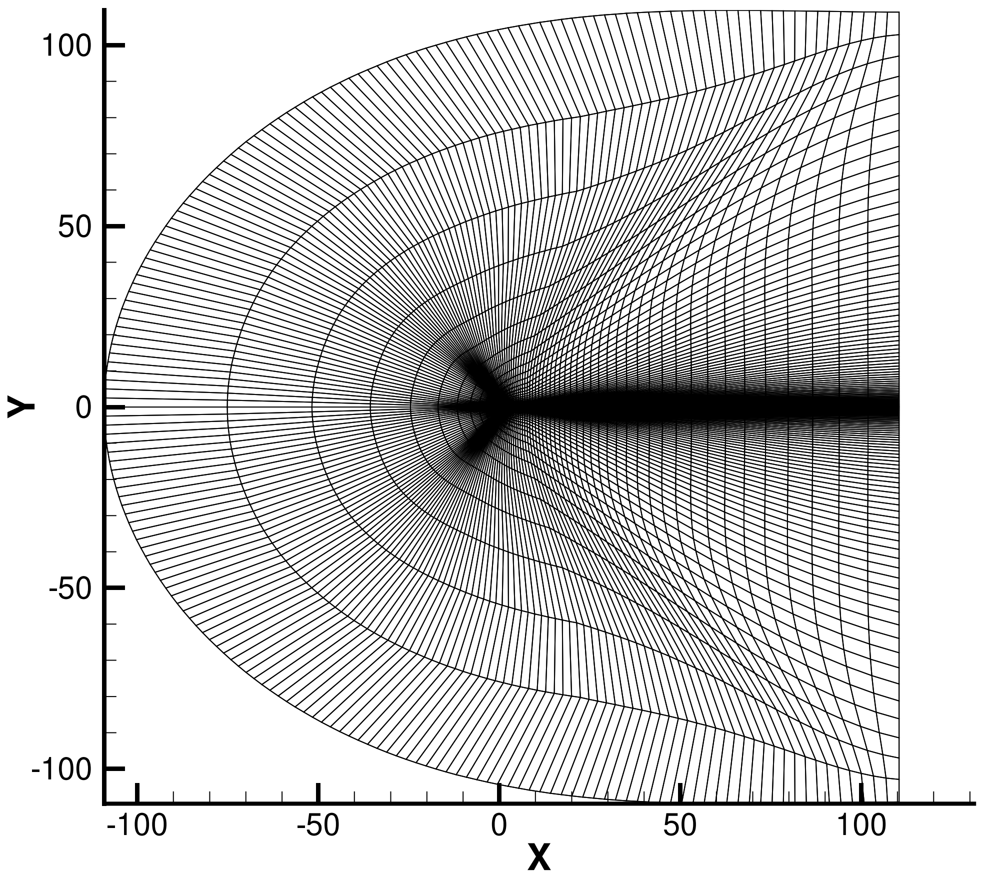
$$T_0 = 491.6^\circ\, R$$

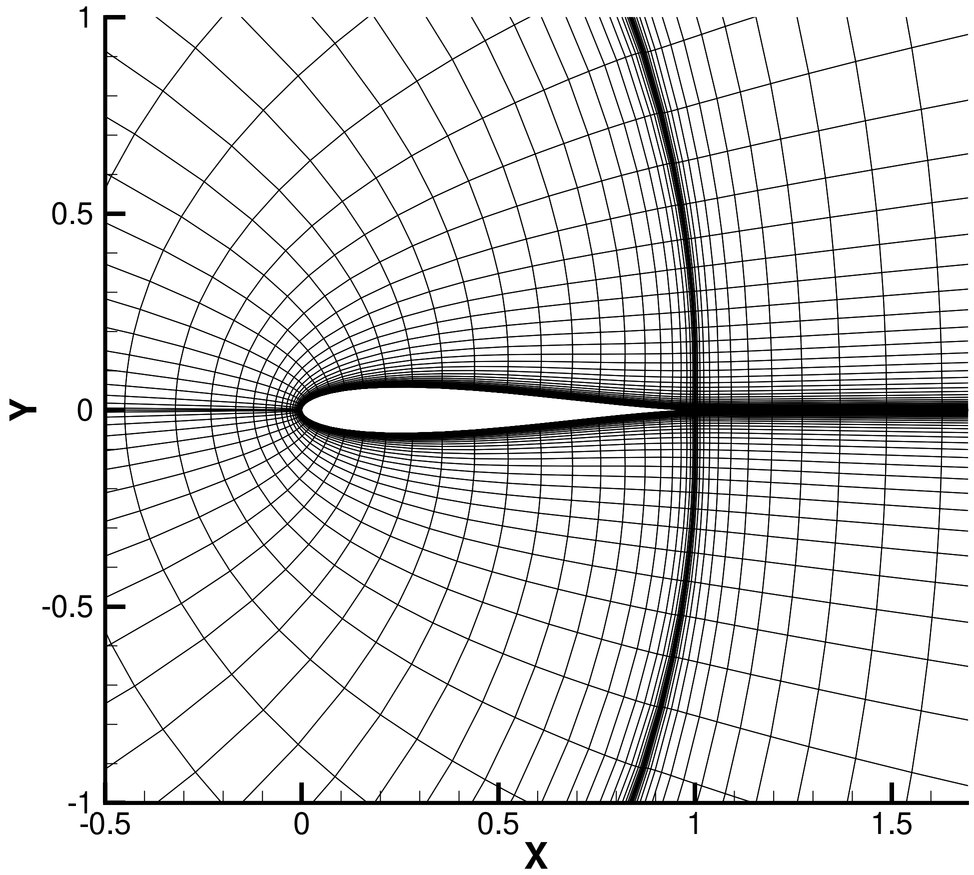
$$S = 198.6^\circ\, R$$

$$\frac{\mu(T)}{\mu_{ref}} = \left(\frac{T}{T_{ref}}\right)^{3/2} \left(\frac{1 + S/T_{fef}}{T/T_{fef} + S/T_{fef}}\right)$$

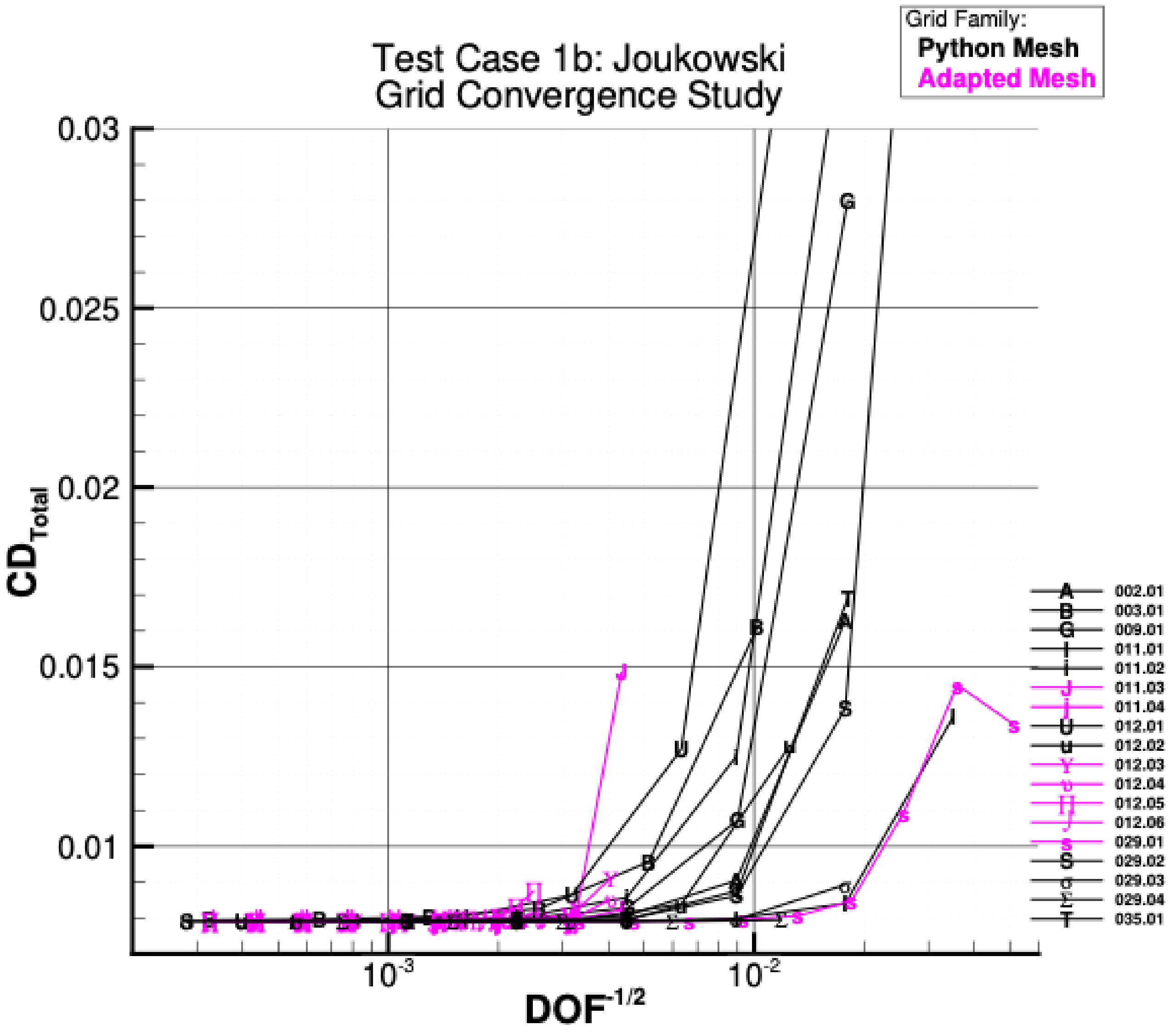
Test Case 1b: Joukowski Airfoil Mesh

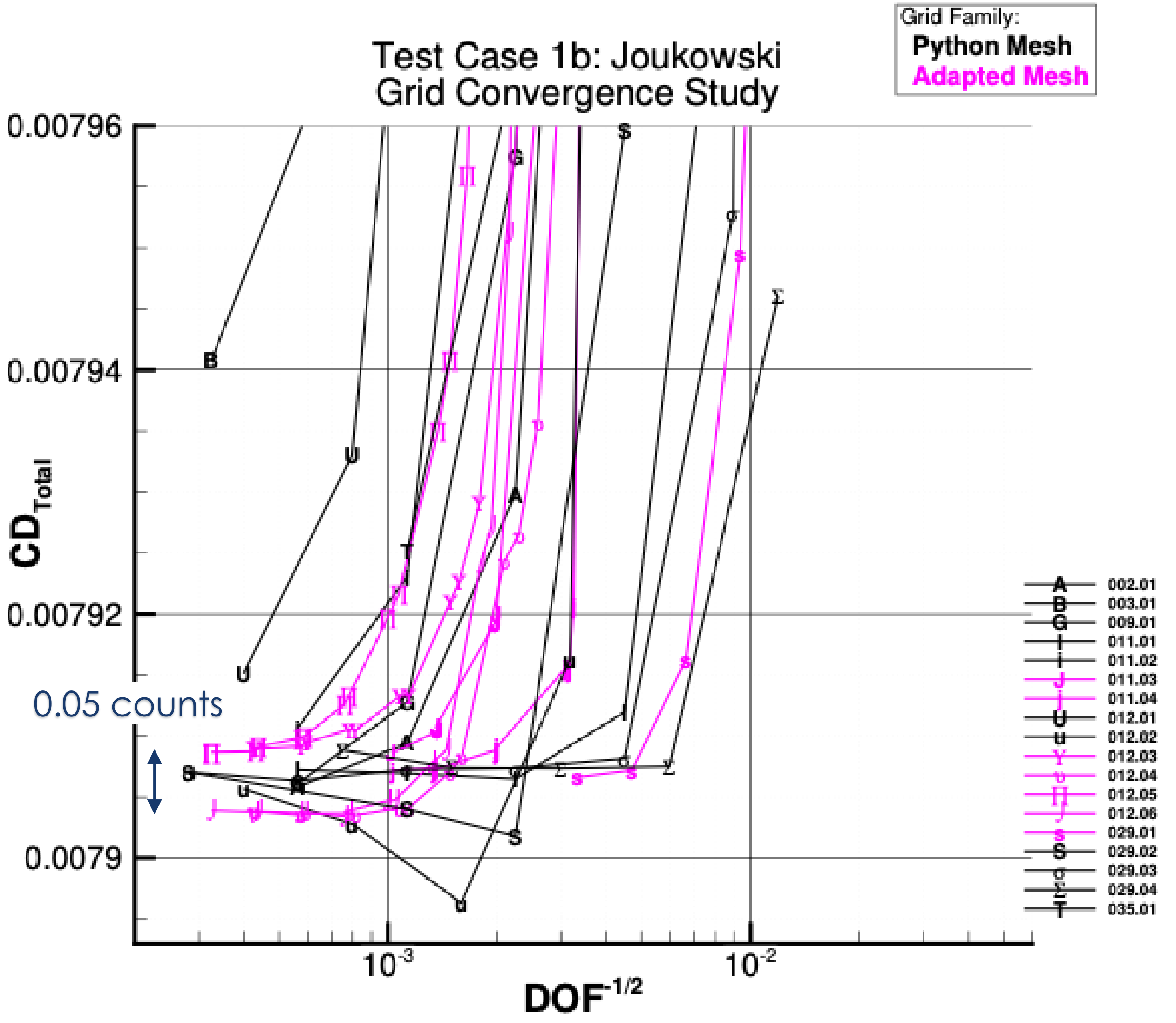
- Cusped trailing edge – remove inviscid singularity
- Zero angle of attack – stagnation point at leading edge
- Custom mesh to observe order of accuracy (Joukowski conformal mapping)



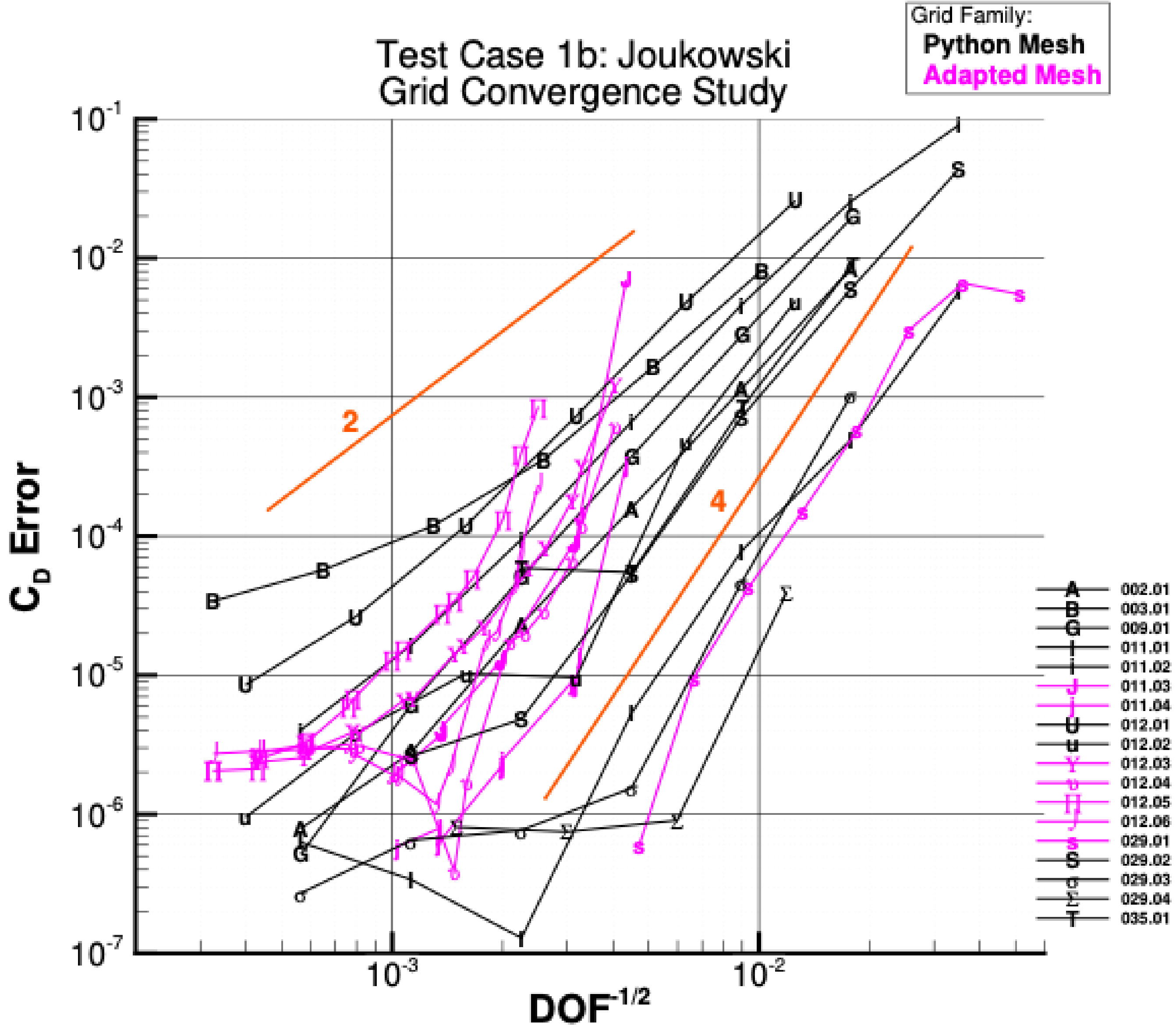


Joukowski C_D Convergence





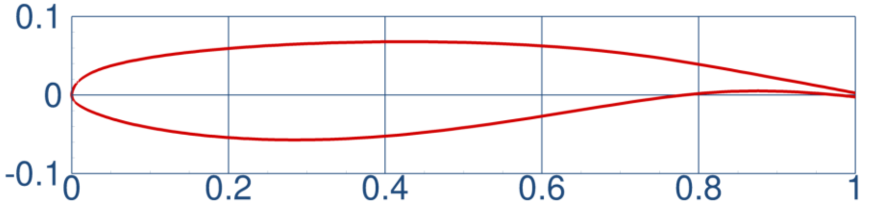
Joukowski Airfoil – Order of Accuracy



Test Case 1c: ONERA OAT15A Airfoil

- **Verification of steady CFD analysis, required**
- **Settings**
  - Steady CFD RANS **French Vanilla SA-[neg] (All terms!)**
    - Adiabatic Wall (not isothermal)
    - Characteristic Farfield (***1000 chords away***)
    - Use periodic boundary conditions for sidewall boundary conditions
  - Converge residuals to machine precision (~1e-10)

Jaquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009. Pages 1985-1994.



ONERA OAT15A Transonic Airfoil

- **Grids**
  - Six-member grid family; four are required, six are desirable
  - Encourage use of committee-supplied grids; user-generated grids are acceptable
    - Cadence Structured/Unstructured, Helden Mesh Unstructured
- **Conditions**

Mach	Re_c	T_{static}	α	γ	Pr	Pr_t	Farfield $\chi = \tilde{\nu}/\nu$
0.73	3×10^6	271 K (487.8 R)	1.5°	1.4	0.72	0.9	3

- **Sutherland's Law**

$$\mu(T) = \mu_0 \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T_0 + S}{T + S}\right)$$

$$\mu_0 = 1.716 \times 10^{-5} \frac{\text{kg}}{m\ s}$$

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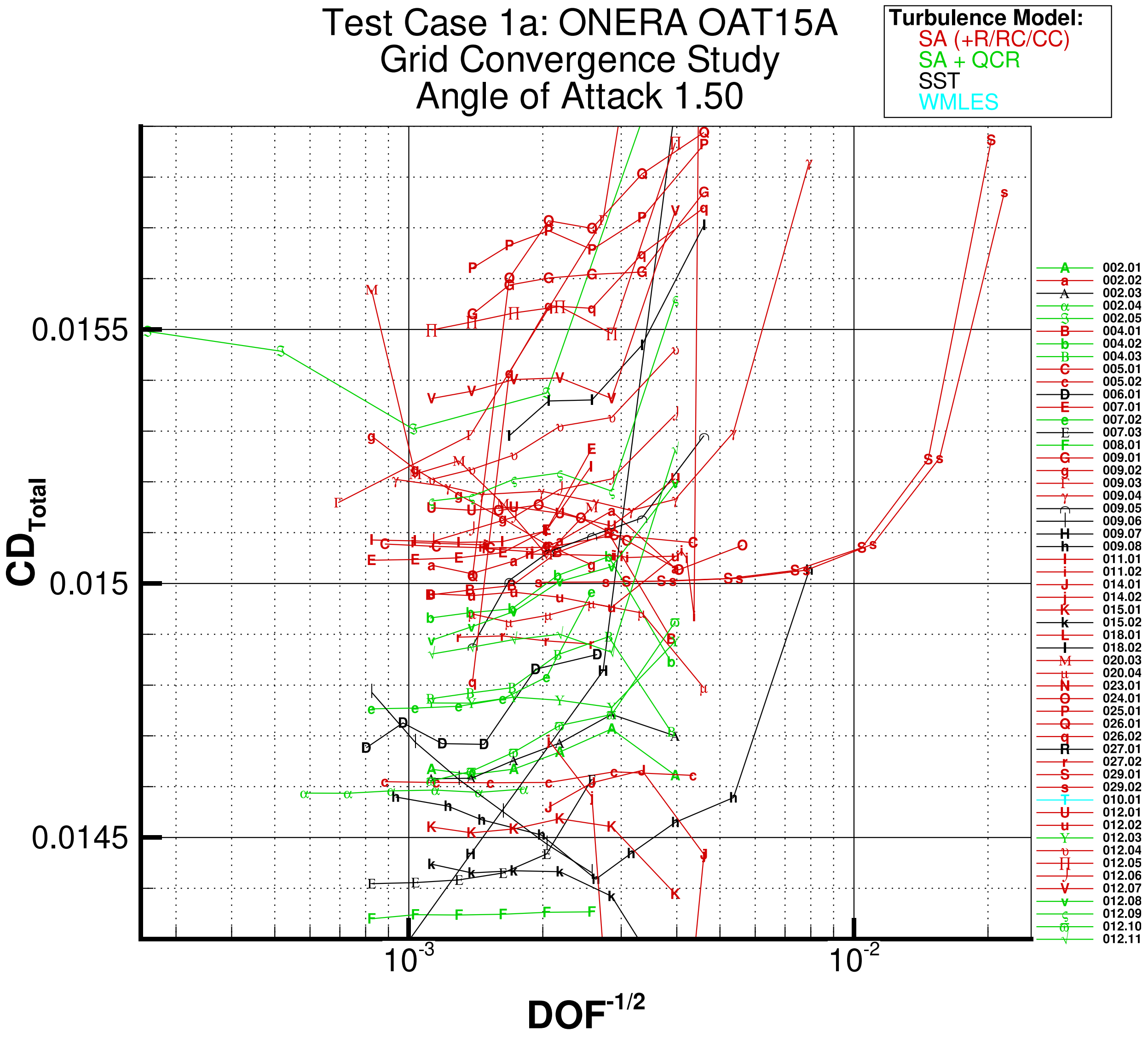
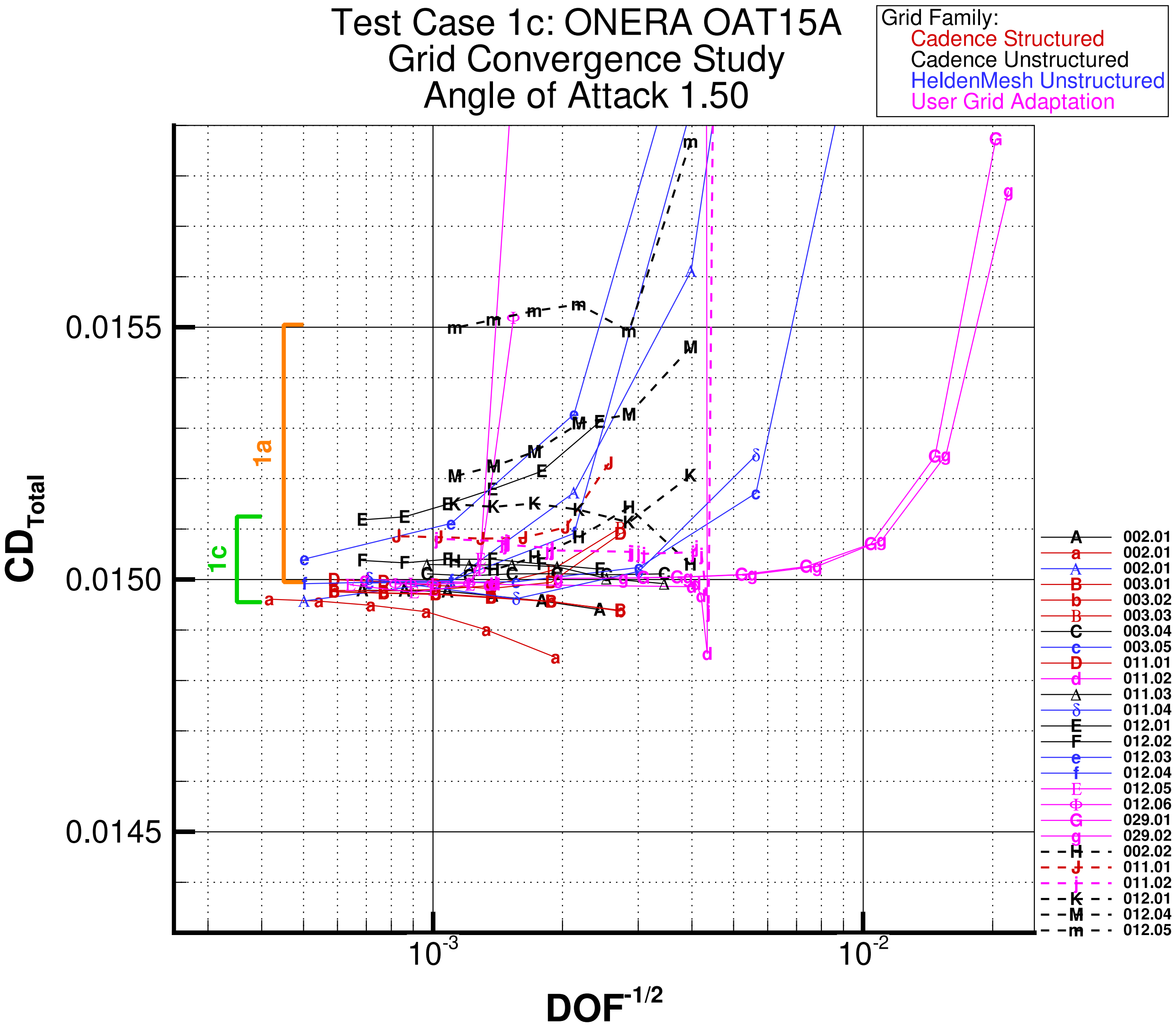
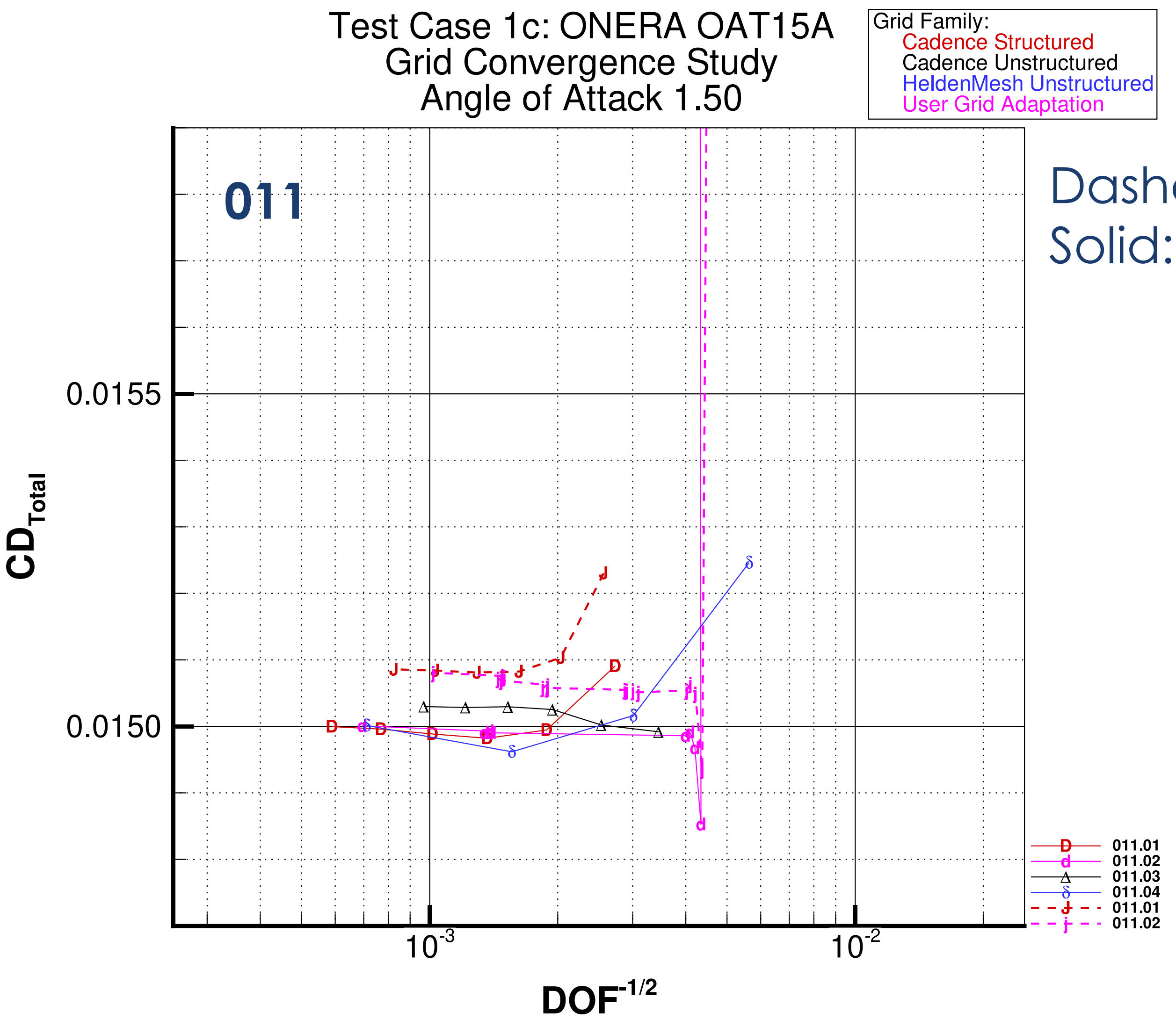
$$\frac{\mu(T)}{\mu_{ref}} = \left(\frac{T}{T_{ref}}\right)^{3/2} \left(\frac{1 + S/T_{fef}}{T/T_{fef} + S/T_{fef}}\right)$$

ONERA OAT15A C_D Convergence: $\alpha = 1.5°$





ONERA OAT15A C_D Participant Improvements



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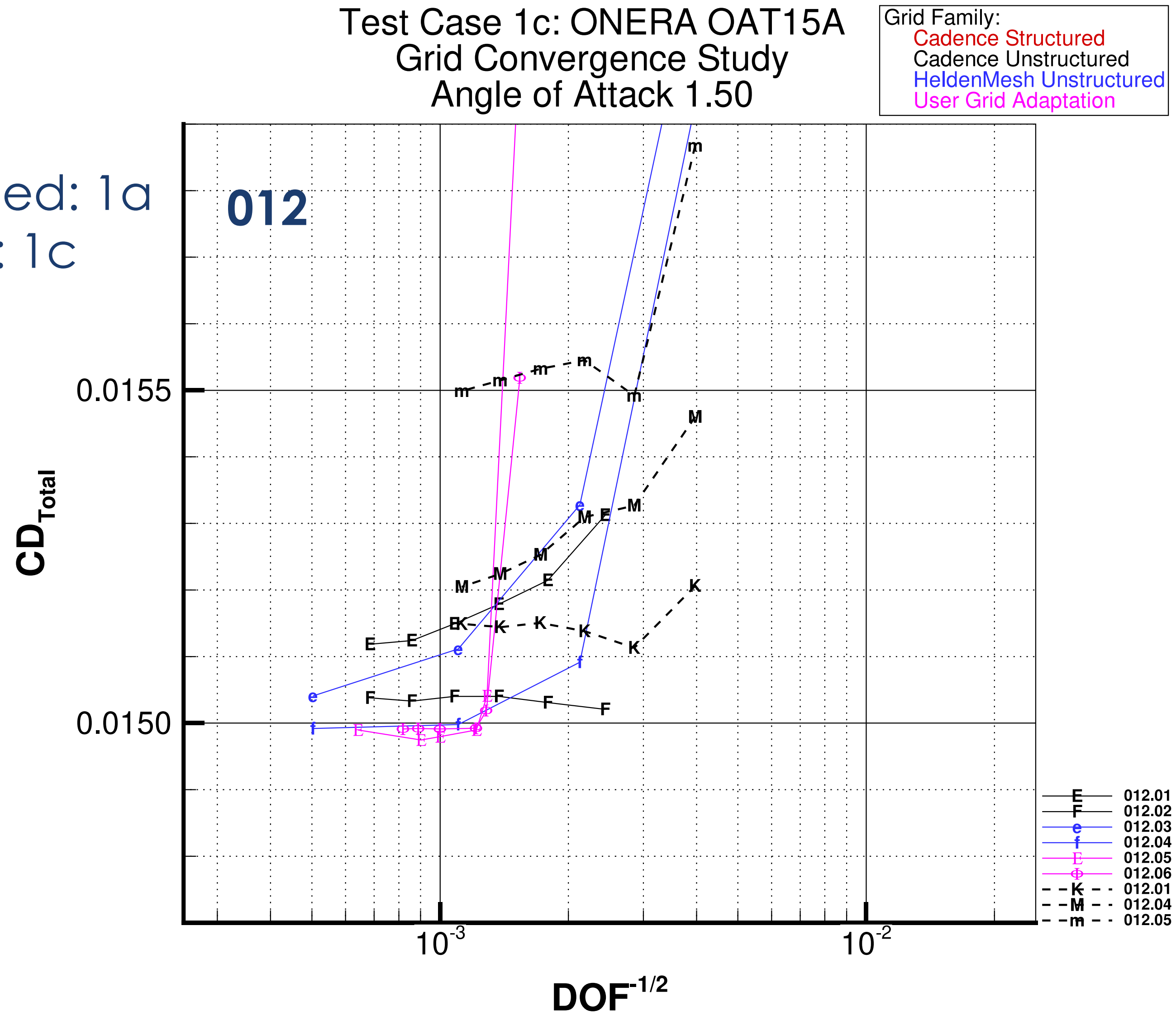
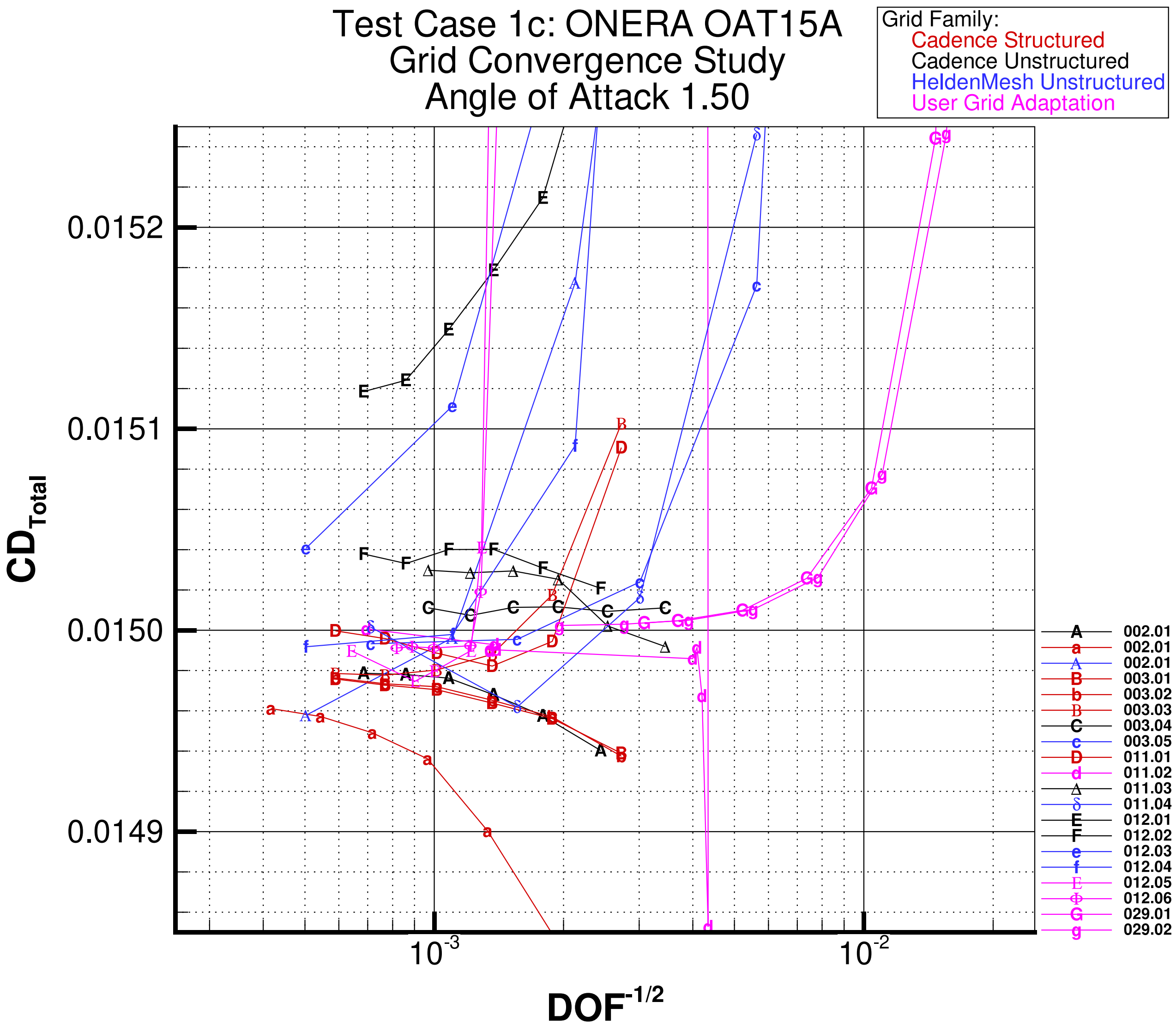
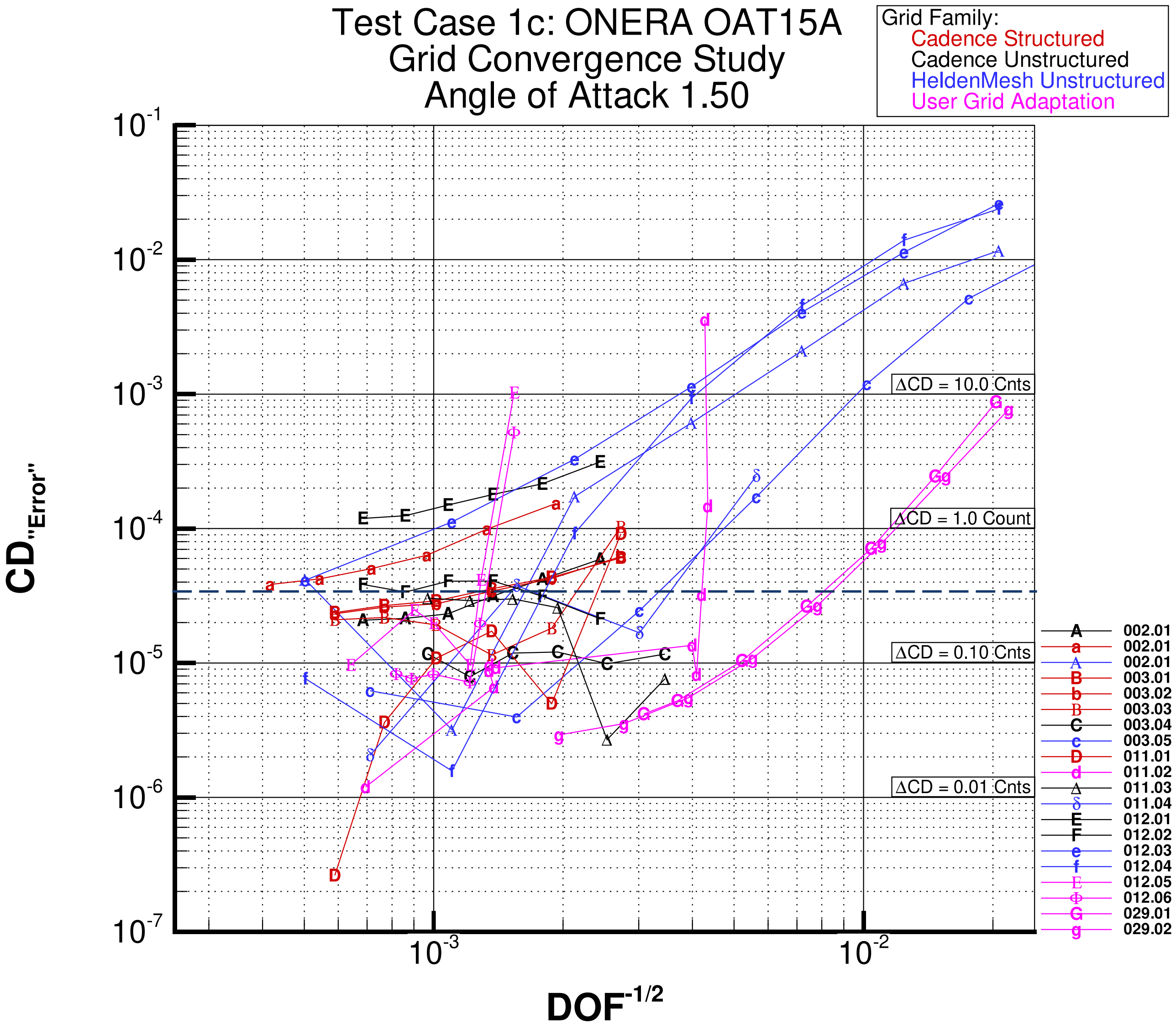
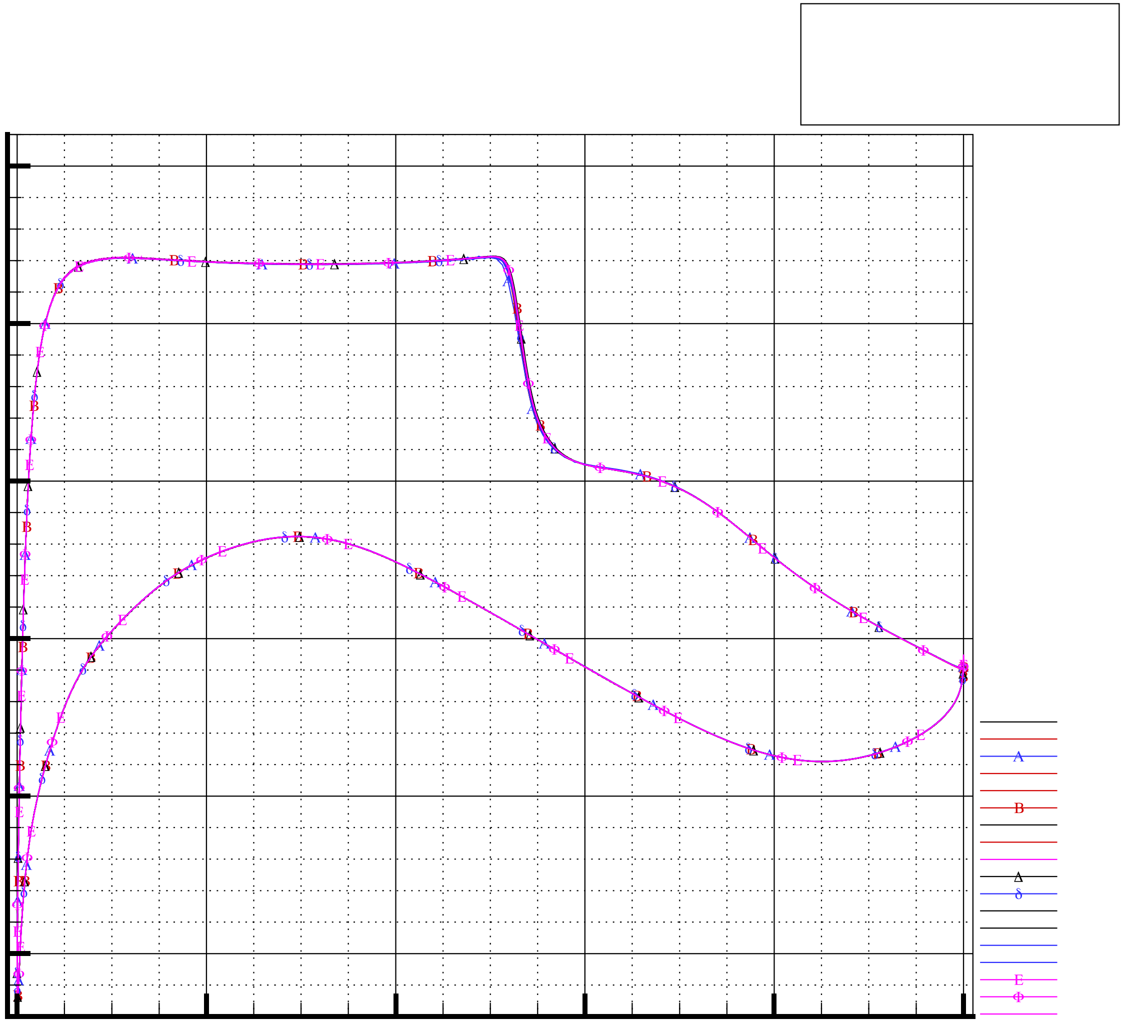


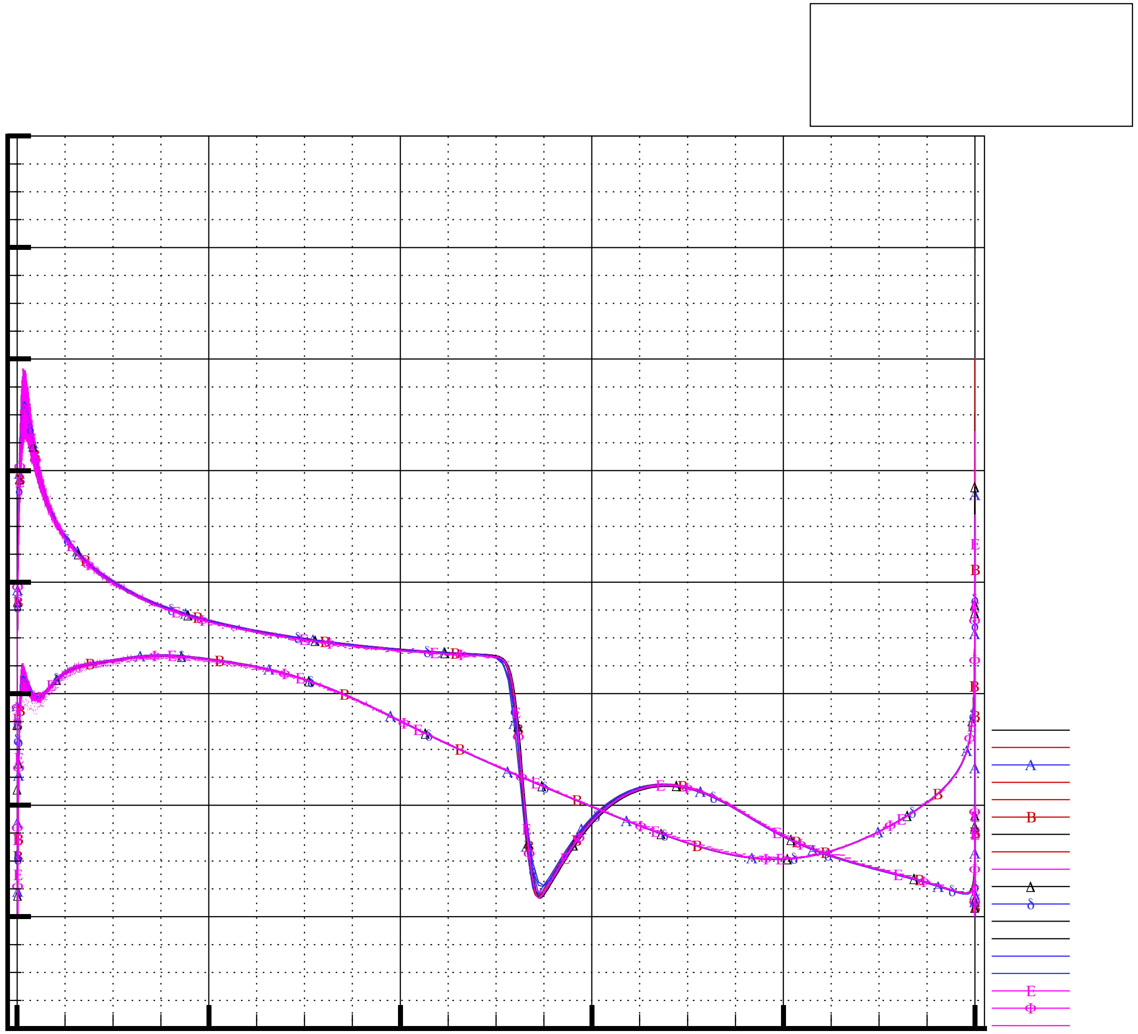
ONERA OAT15A C_D Convergence: $\alpha = 1.5°$





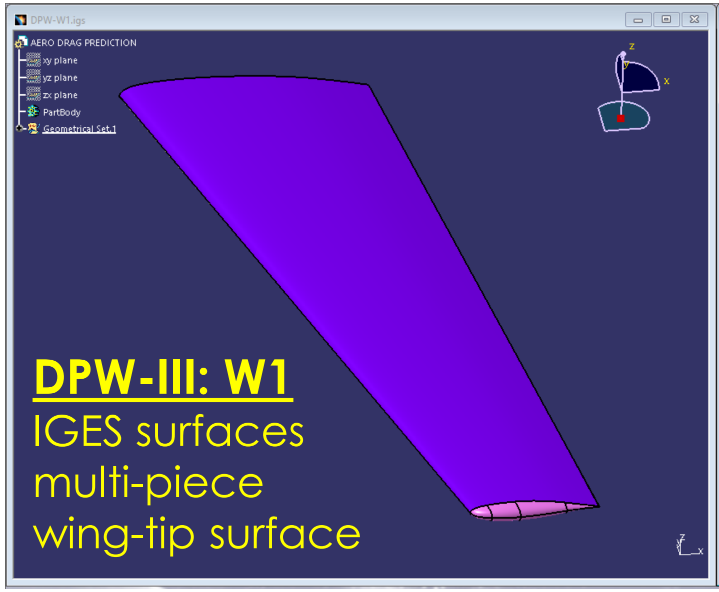
ONERA OAT15A C_p and C_f $\alpha = 1.5°$

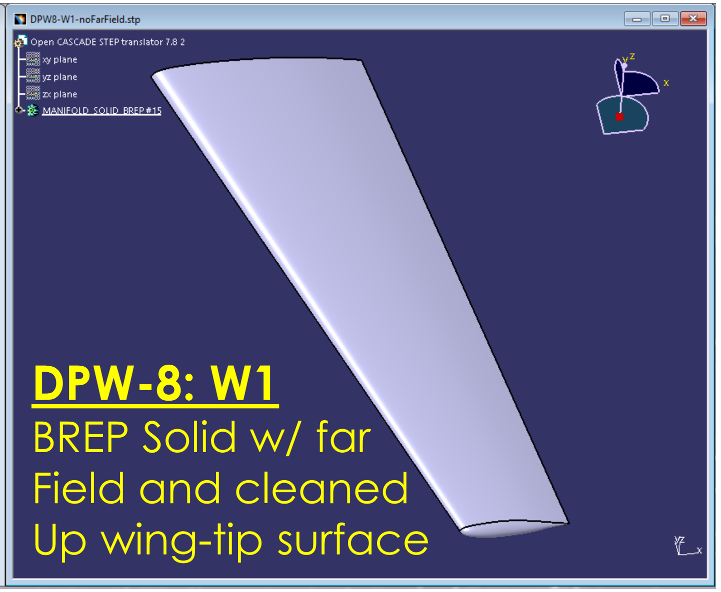


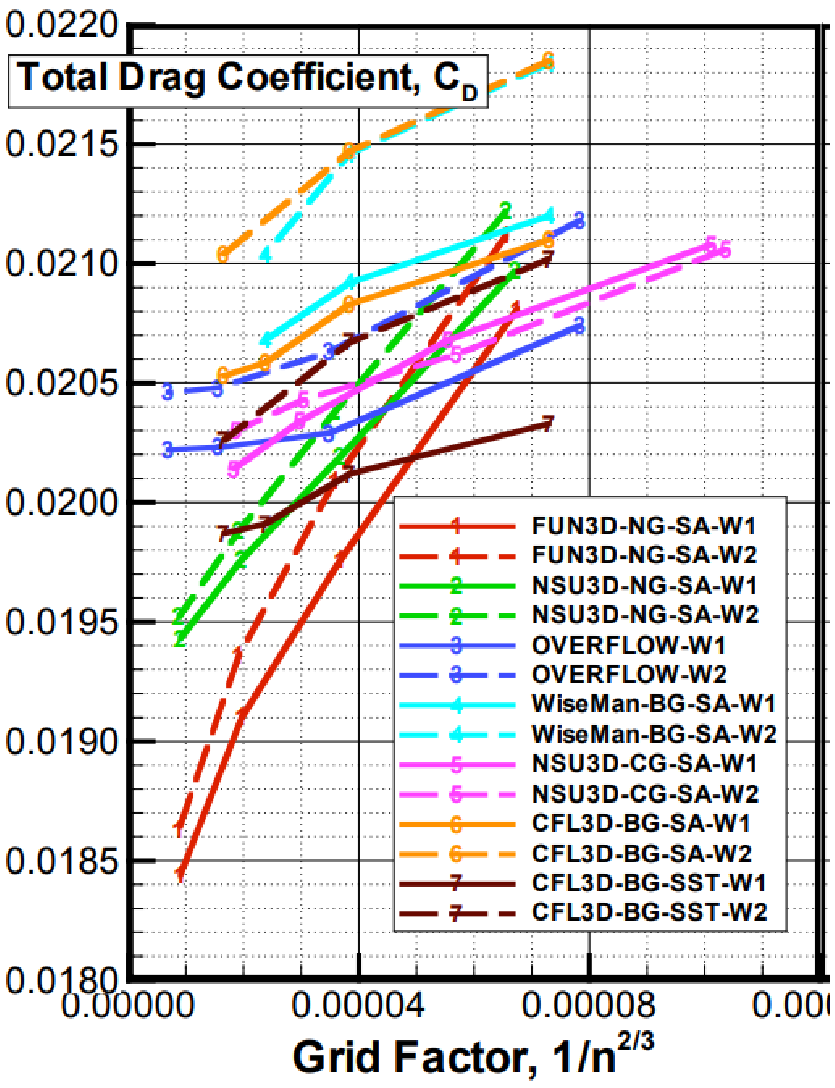


Test Case 3: DPW-III W1 (20 years later)

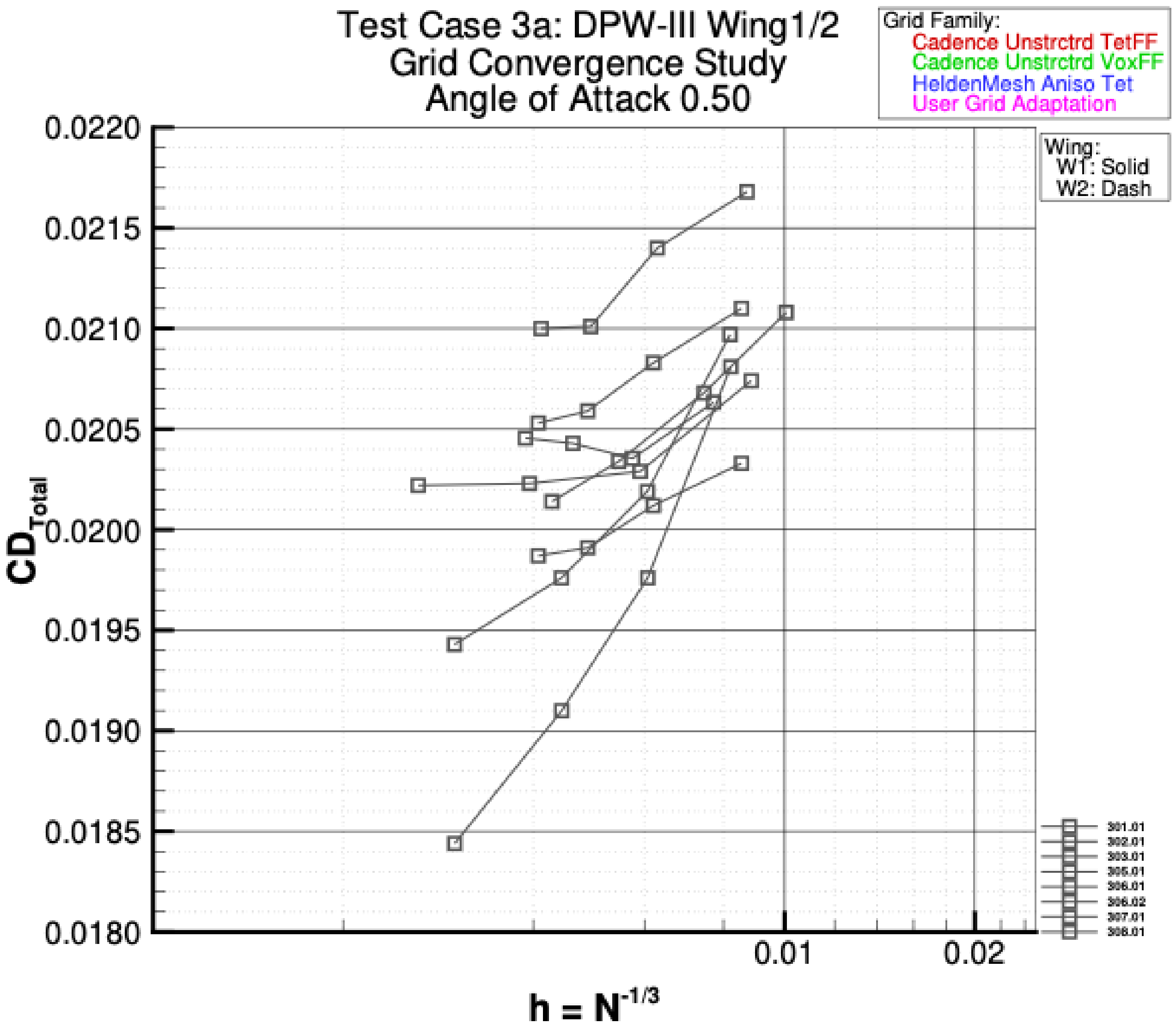
- **DPW-III: Wing-Only Test Case**
  - W1 & W2, incremental comparison
- **DPW-8: Scatter WG**
  - Revisit W1/W2 case to measure the progress over 20 years
- **Grids**
  - Cadence Tet/Voxel Farfield, Helden Mesh Anisotropic Tet, Adapted

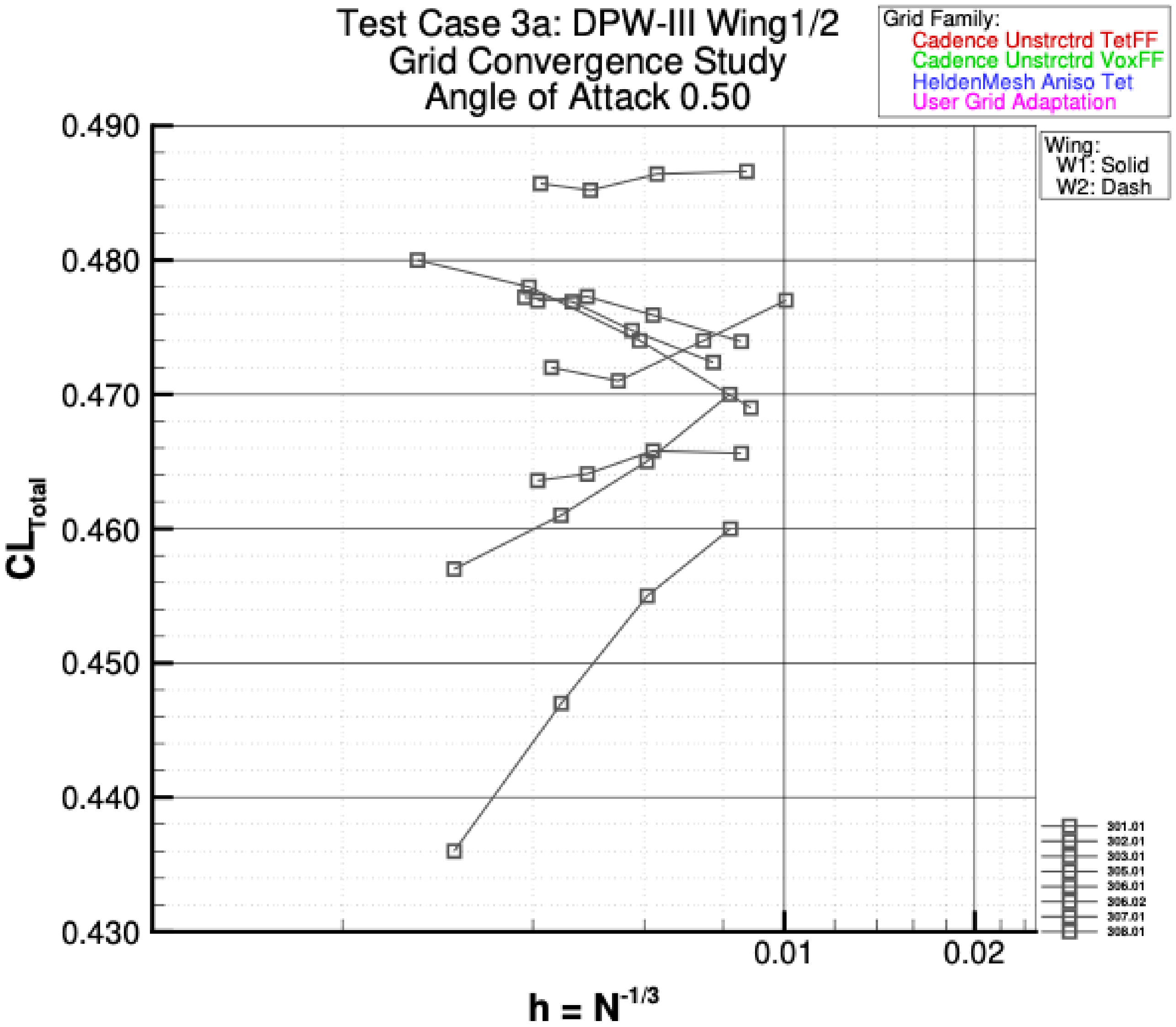




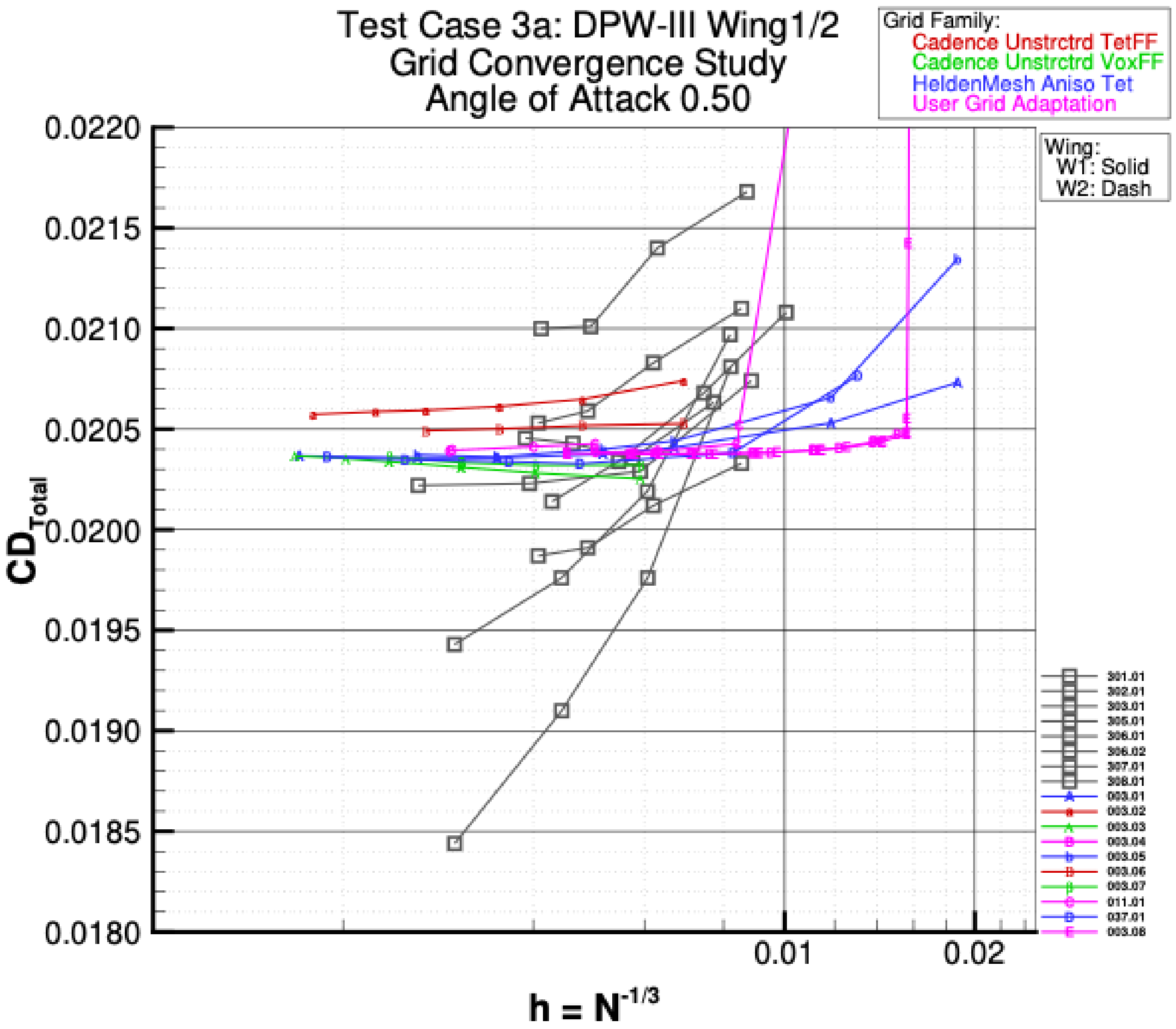


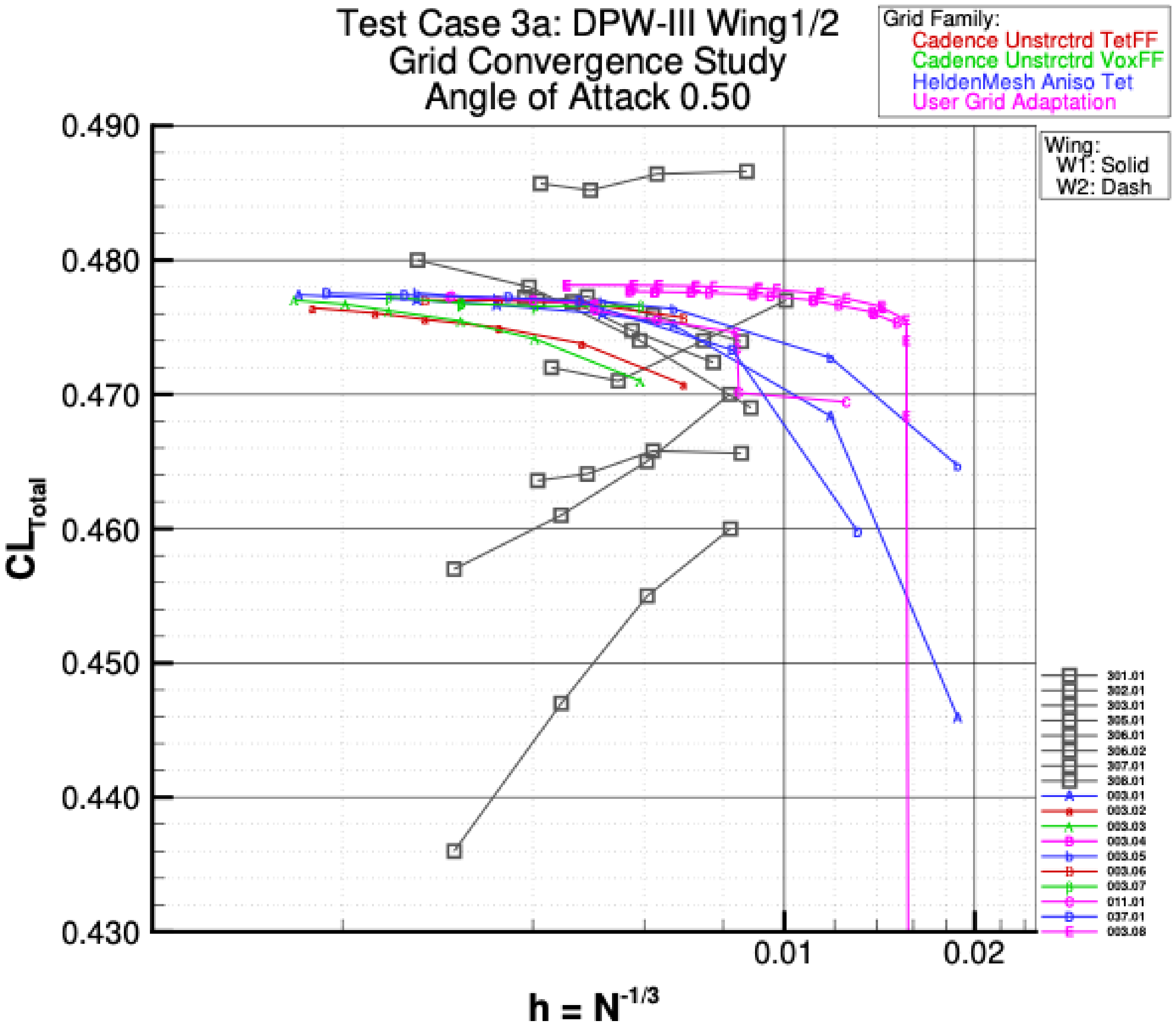
W1 C_D and C_L Convergence: $\alpha = 0.5°$



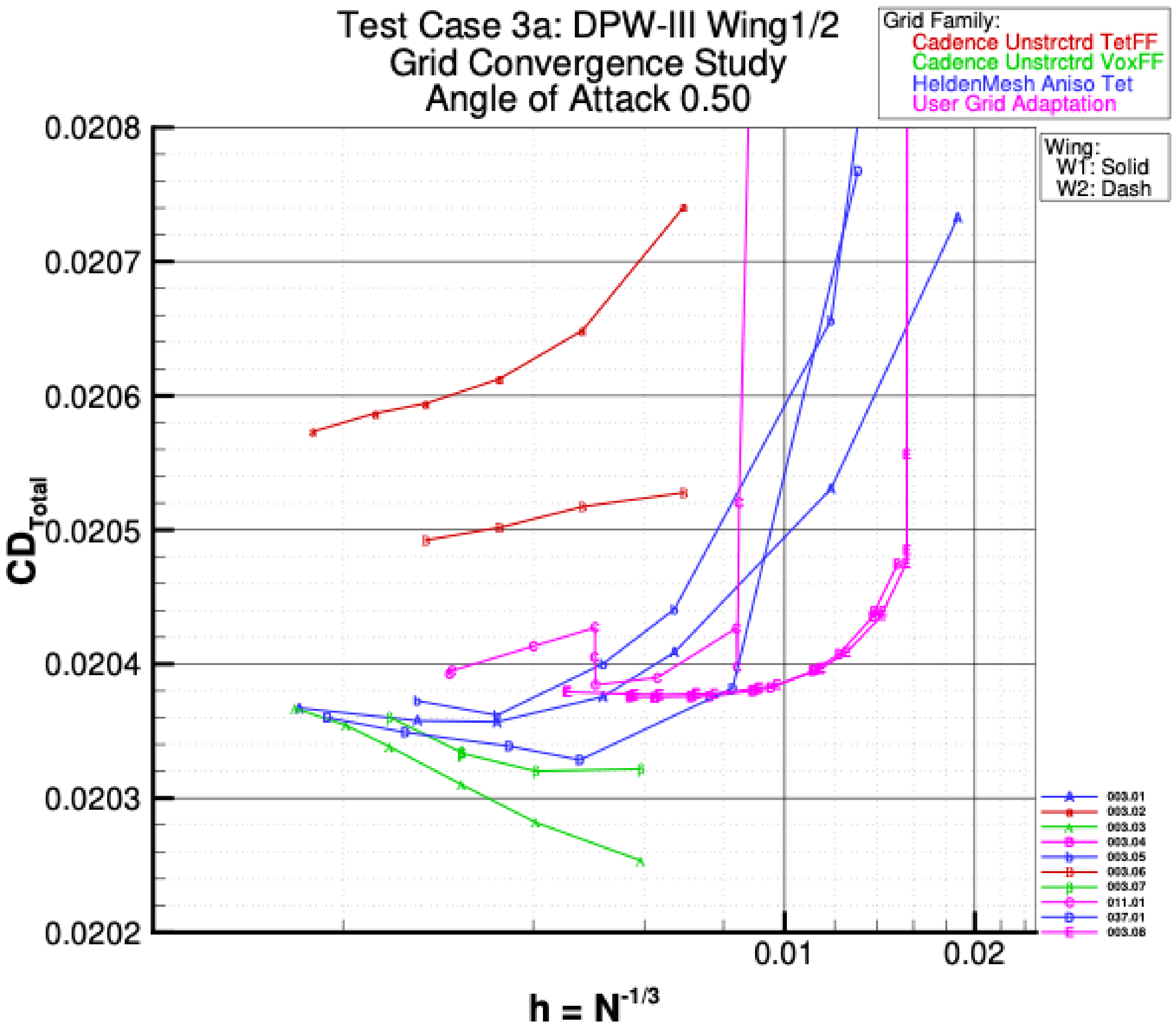


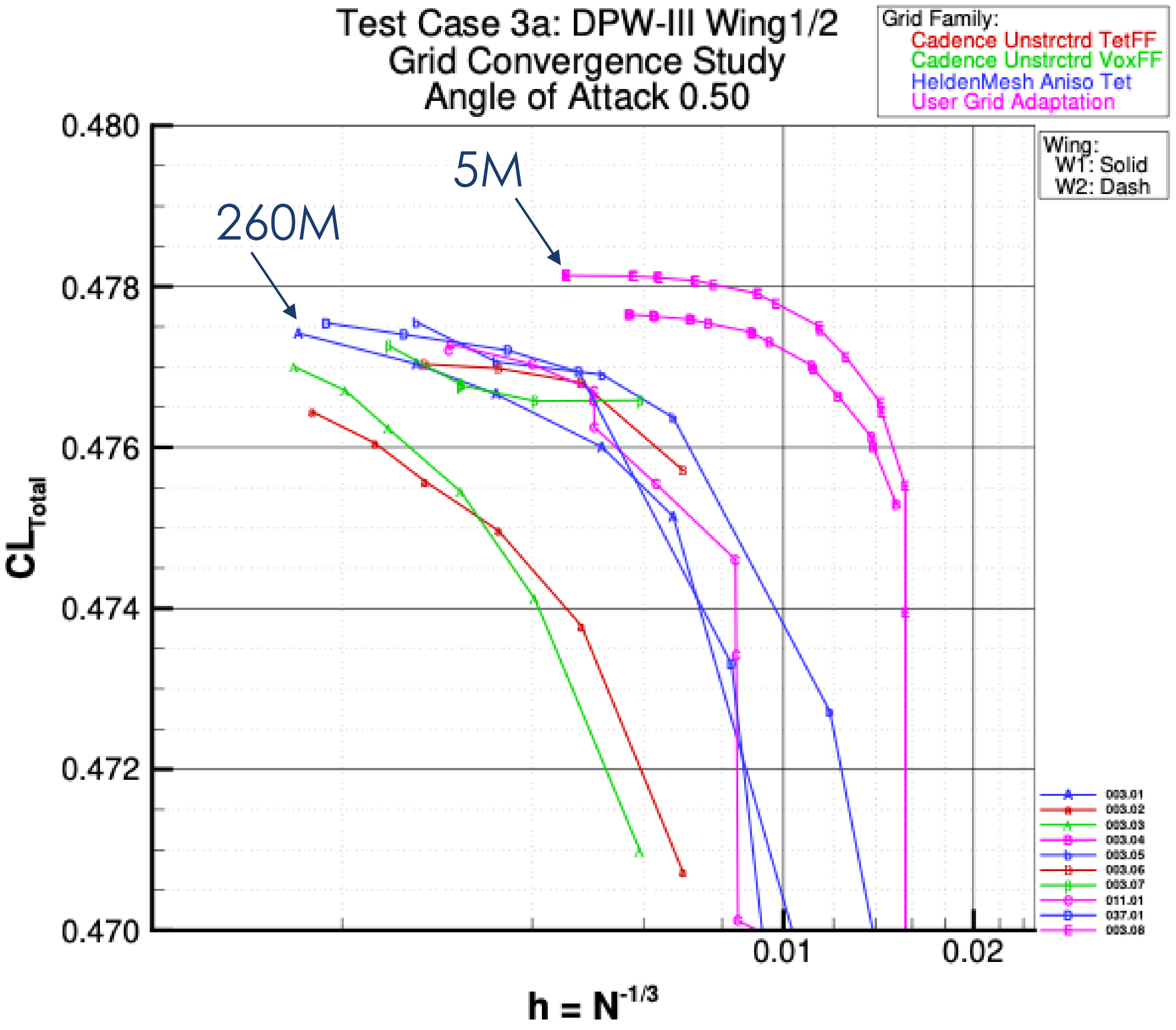
W1 C_D and C_L Convergence: $\alpha = 0.5°$



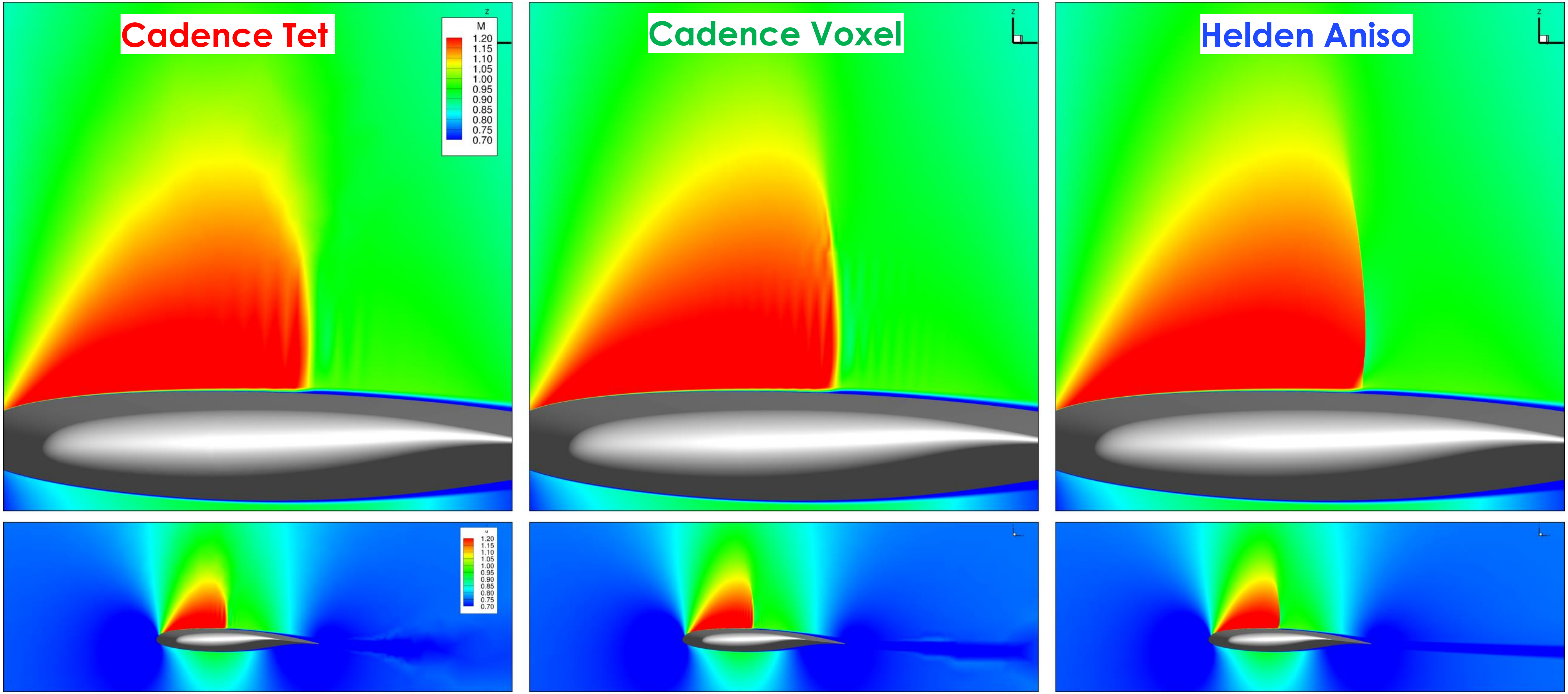


W1 C_D and C_L Convergence: $\alpha = 0.5°$

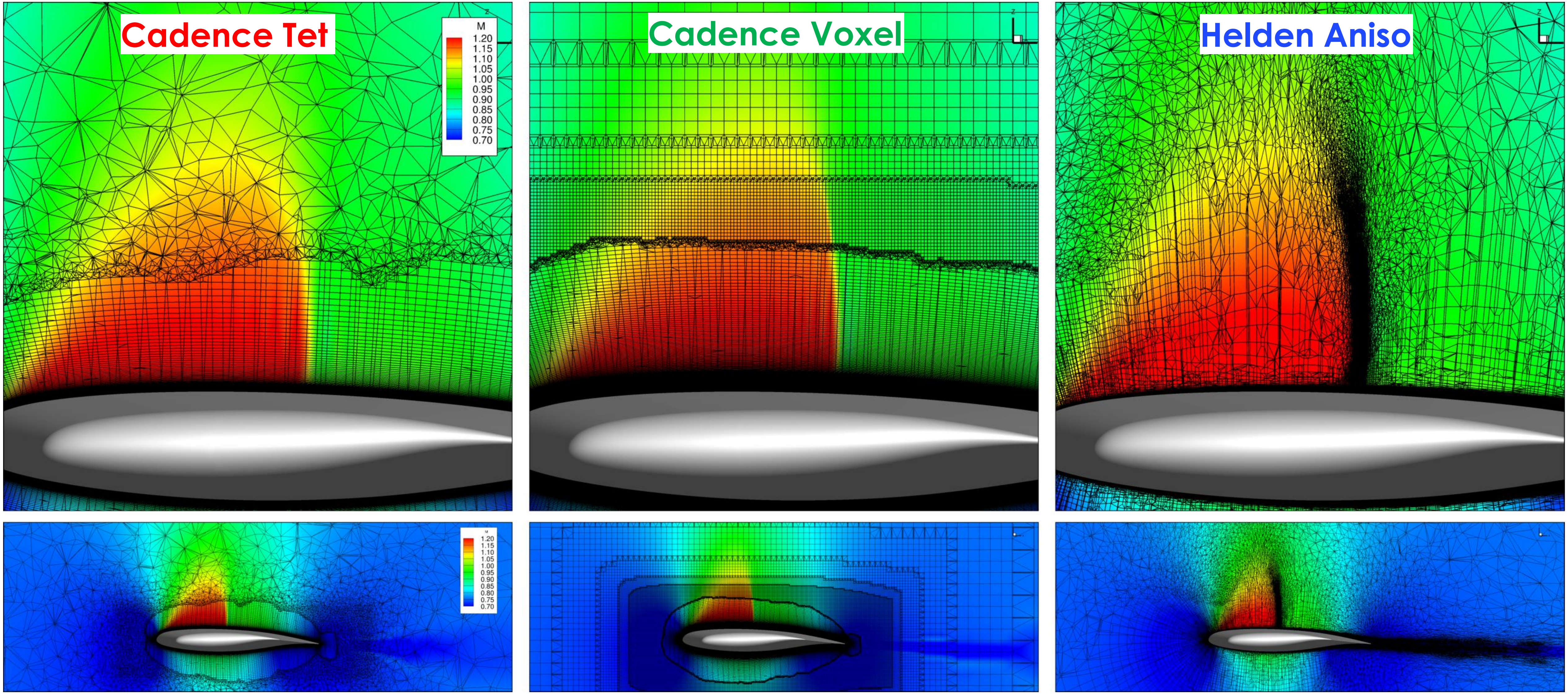




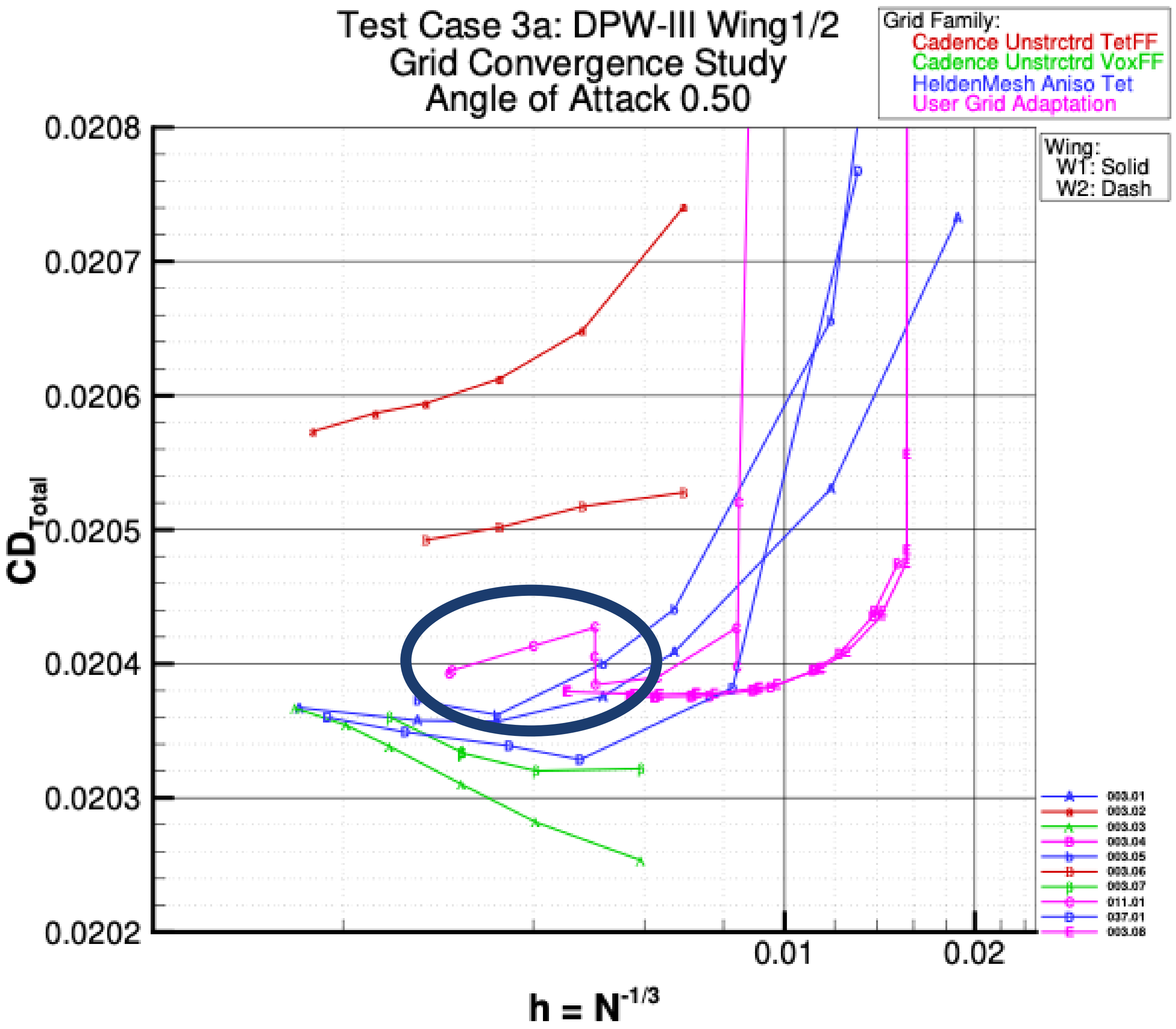
W1 Mach: $\alpha = 0.5°$

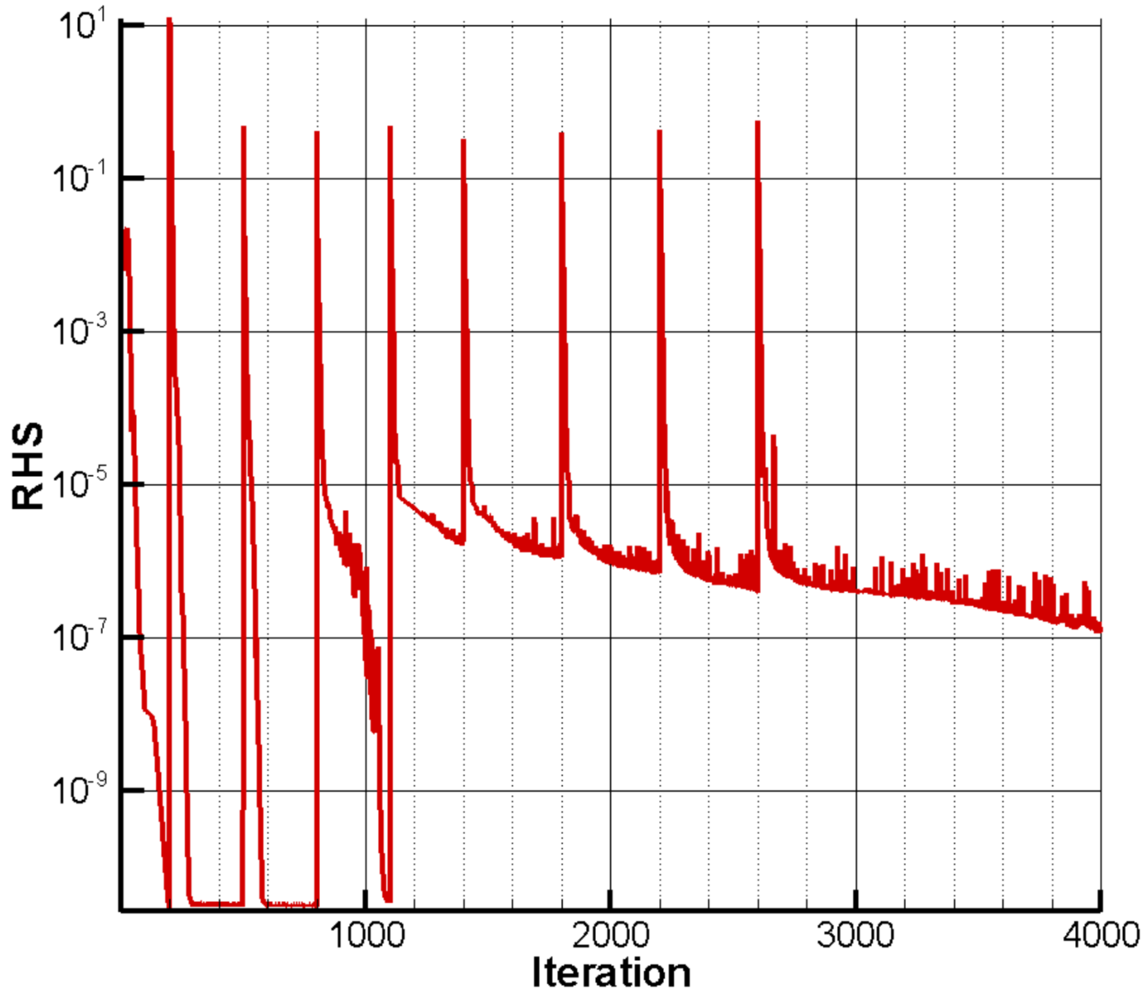


W1 Mach: $\alpha = 0.5°$

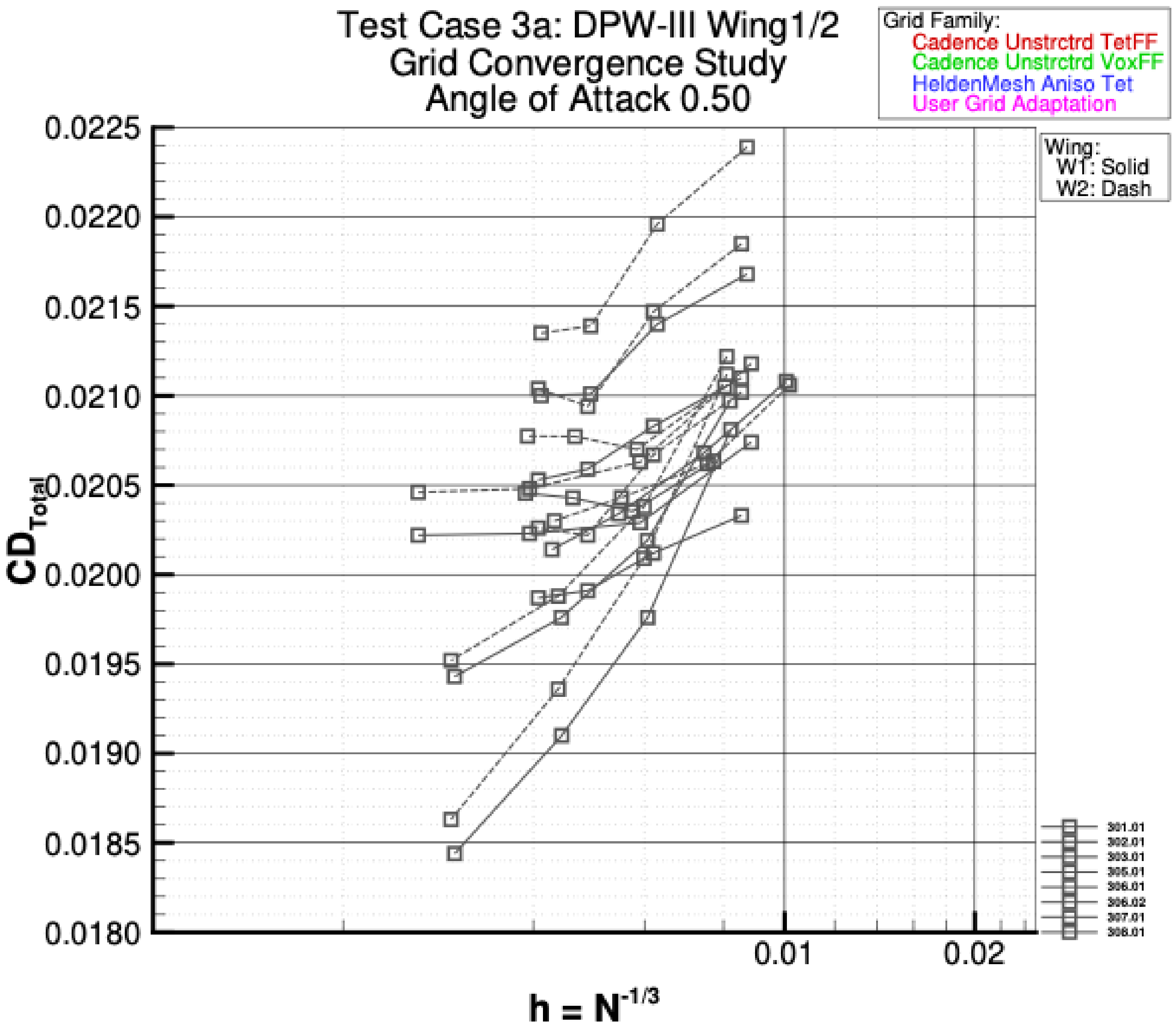


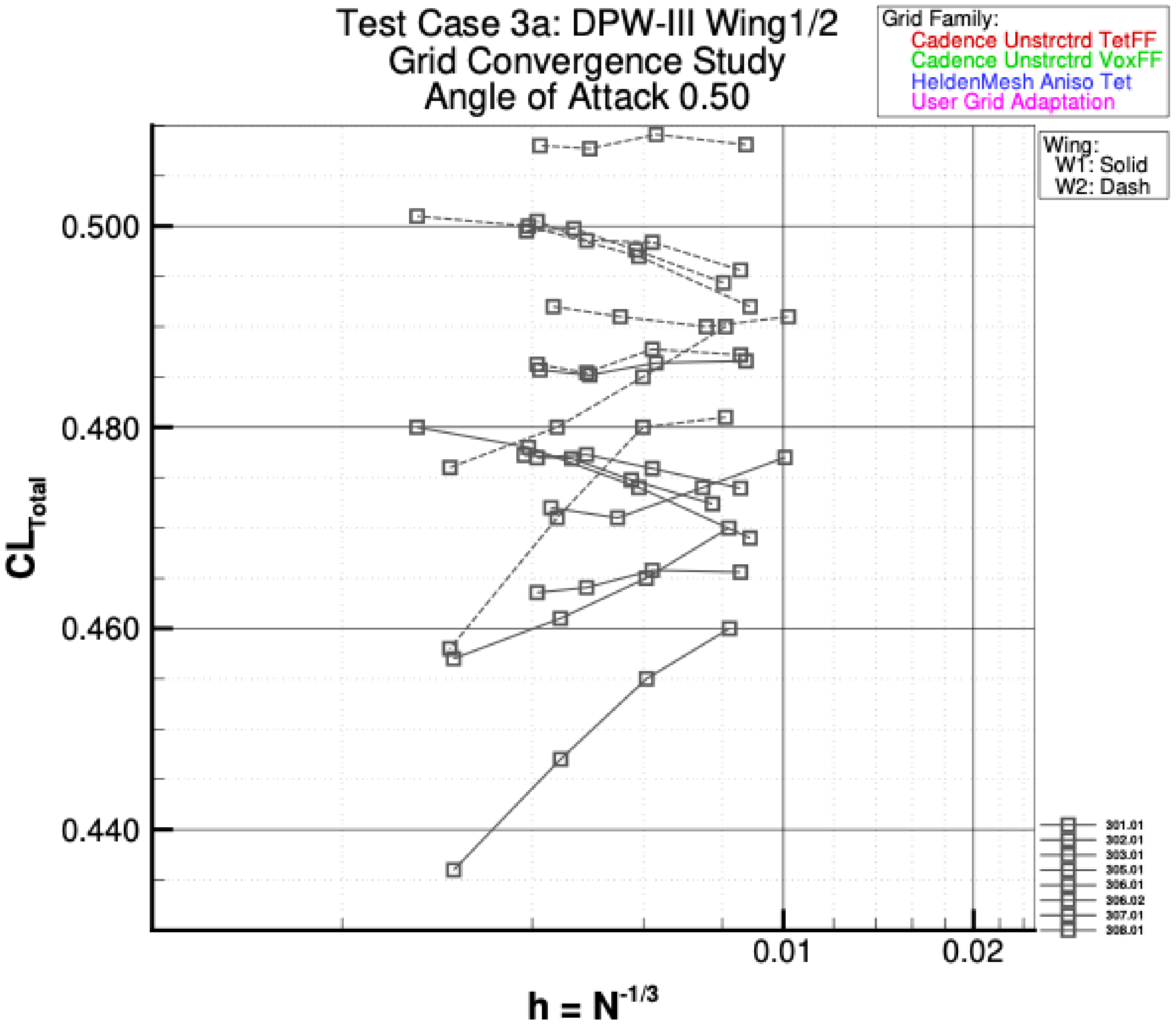
W1 C_D Oddities



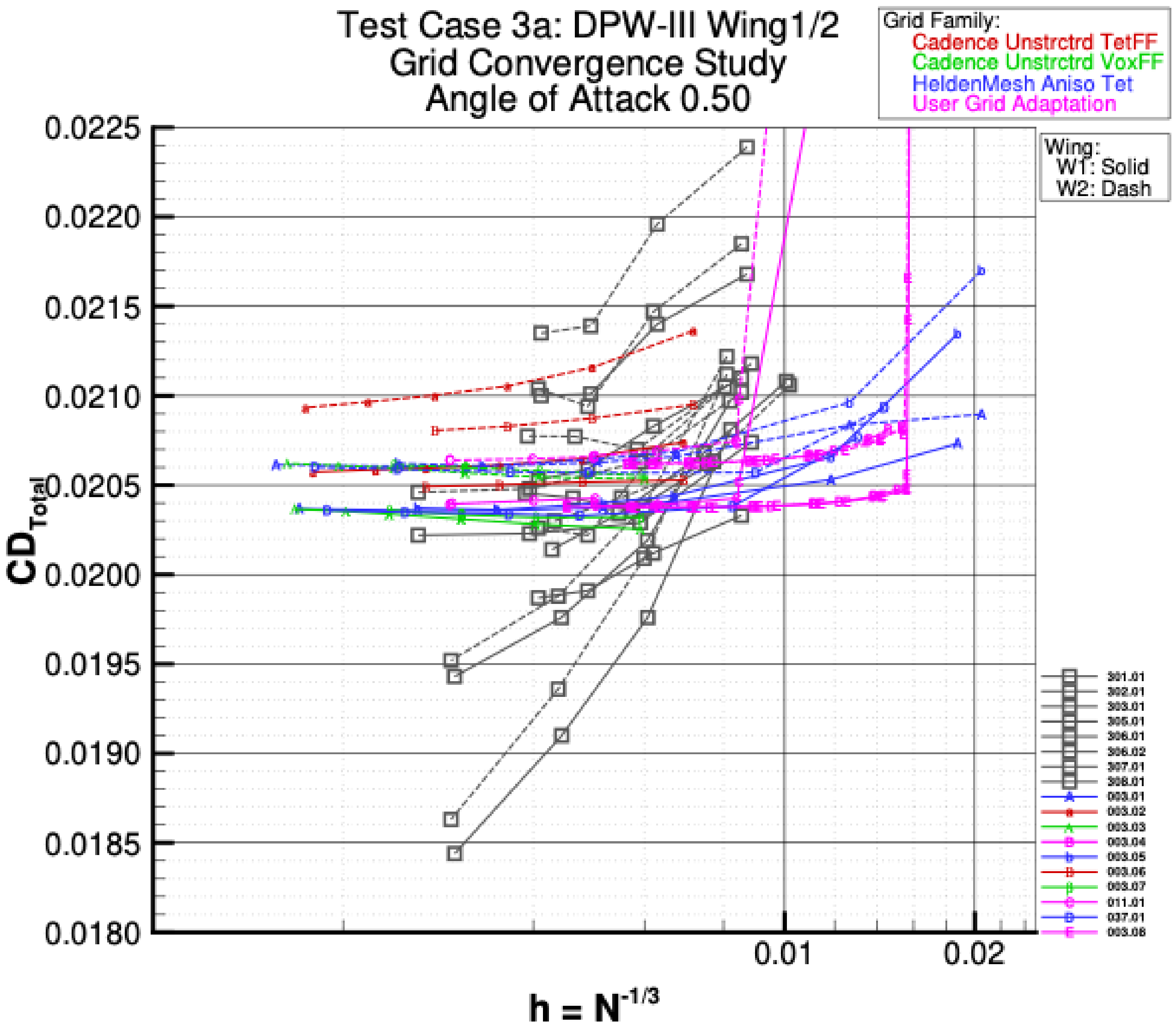


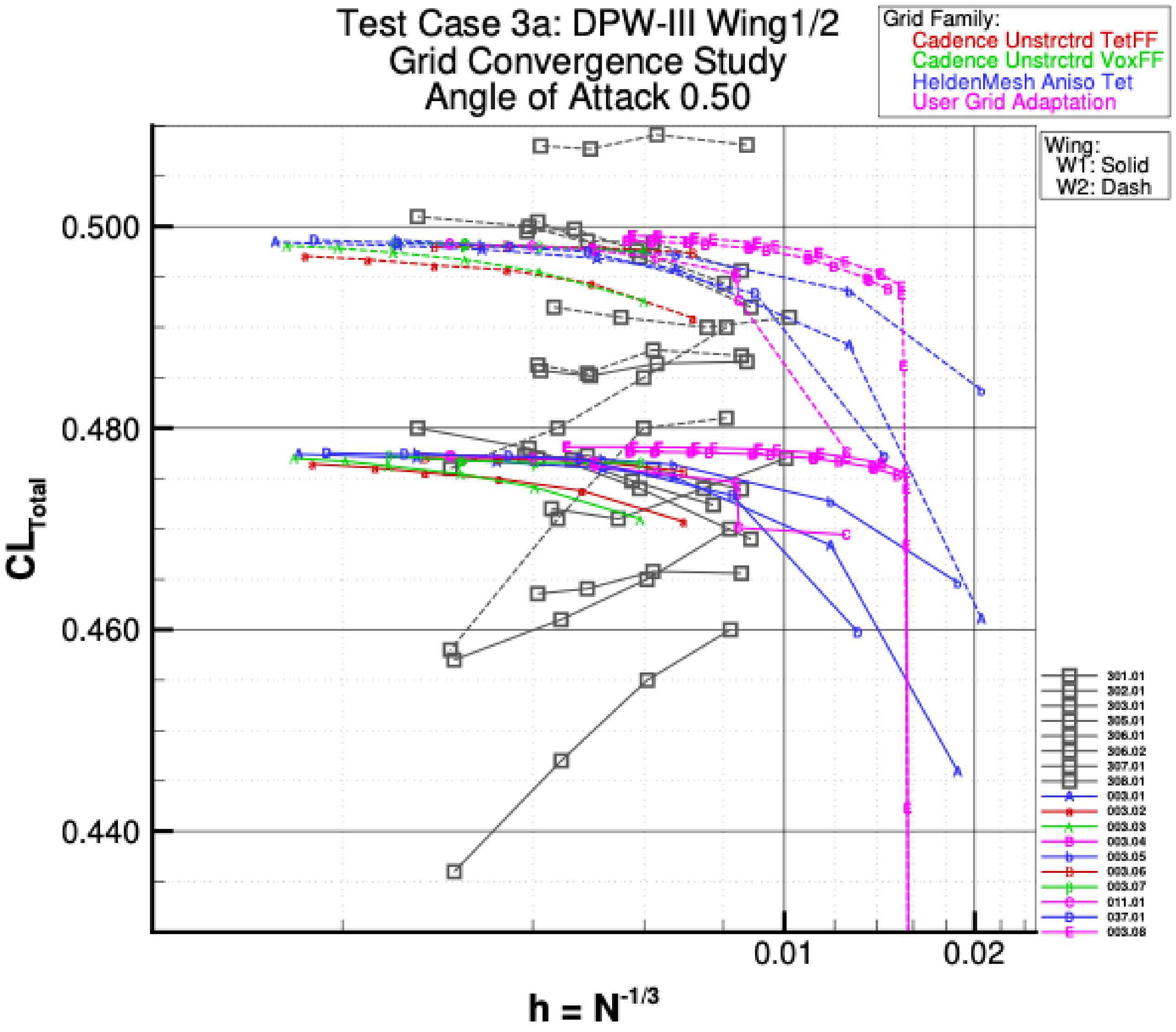
W1/W2 C_D and C_L Convergence: $\alpha = 0.5°$



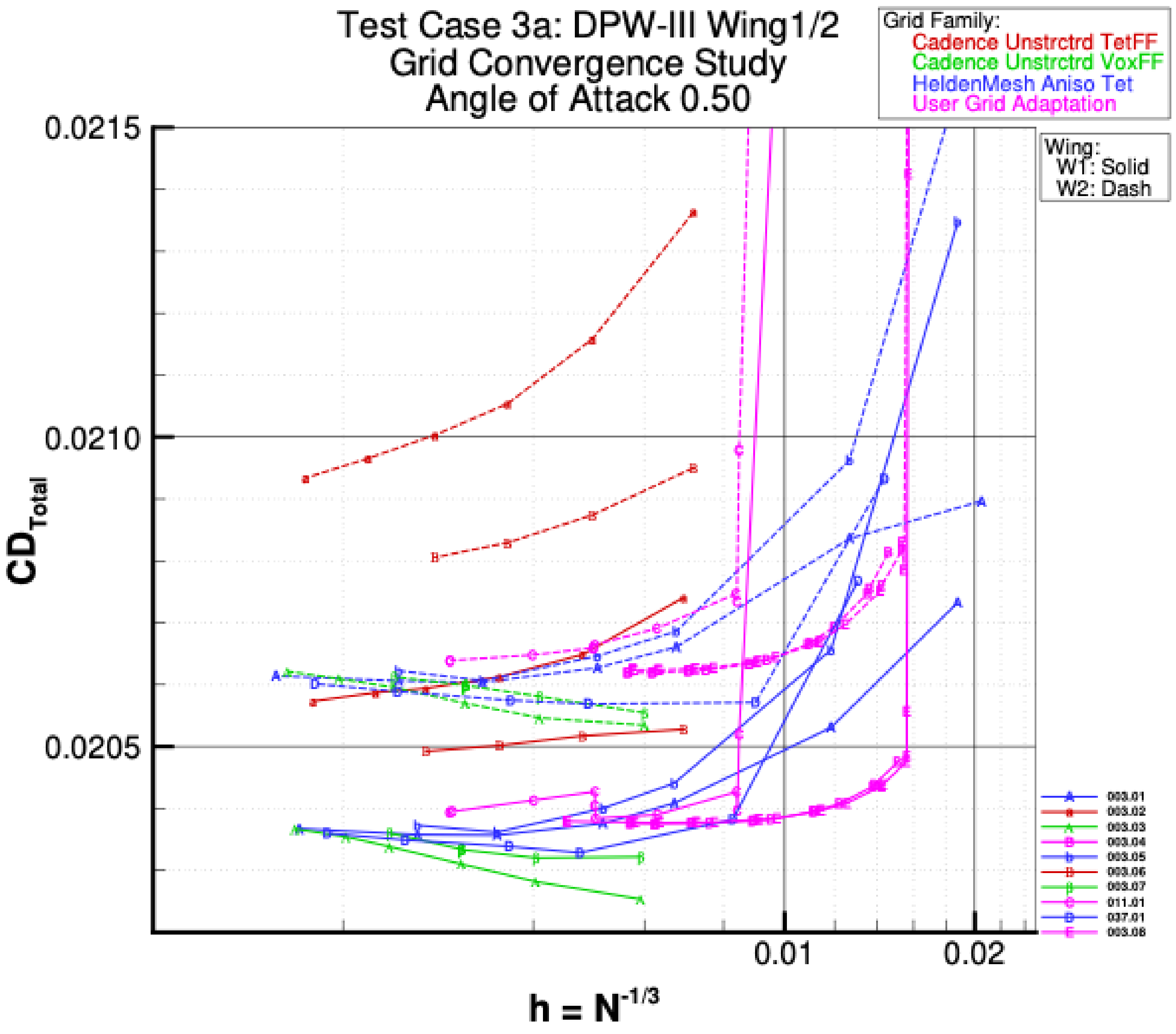


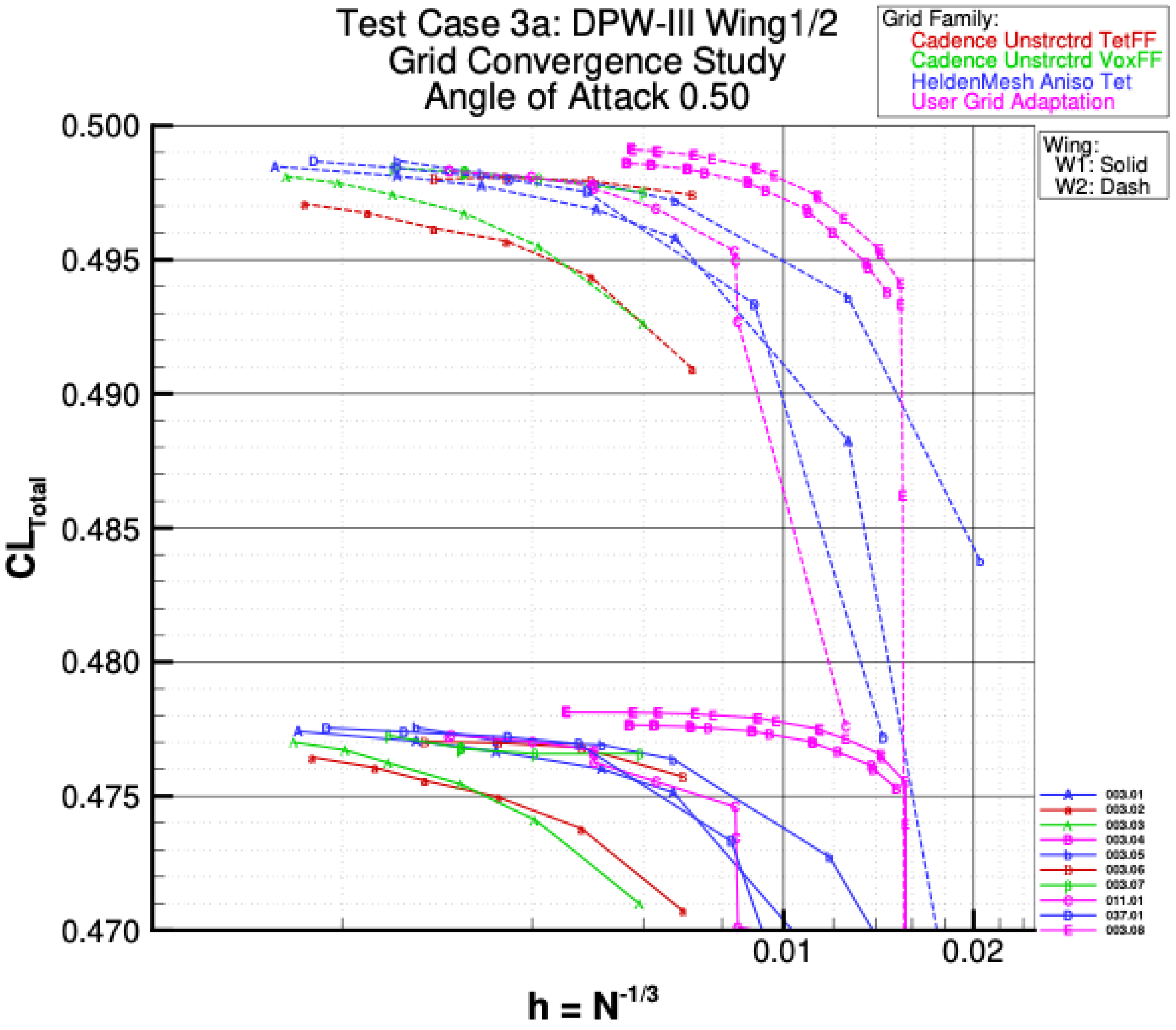
W1/W2 C_D and C_L Convergence: $\alpha = 0.5°$



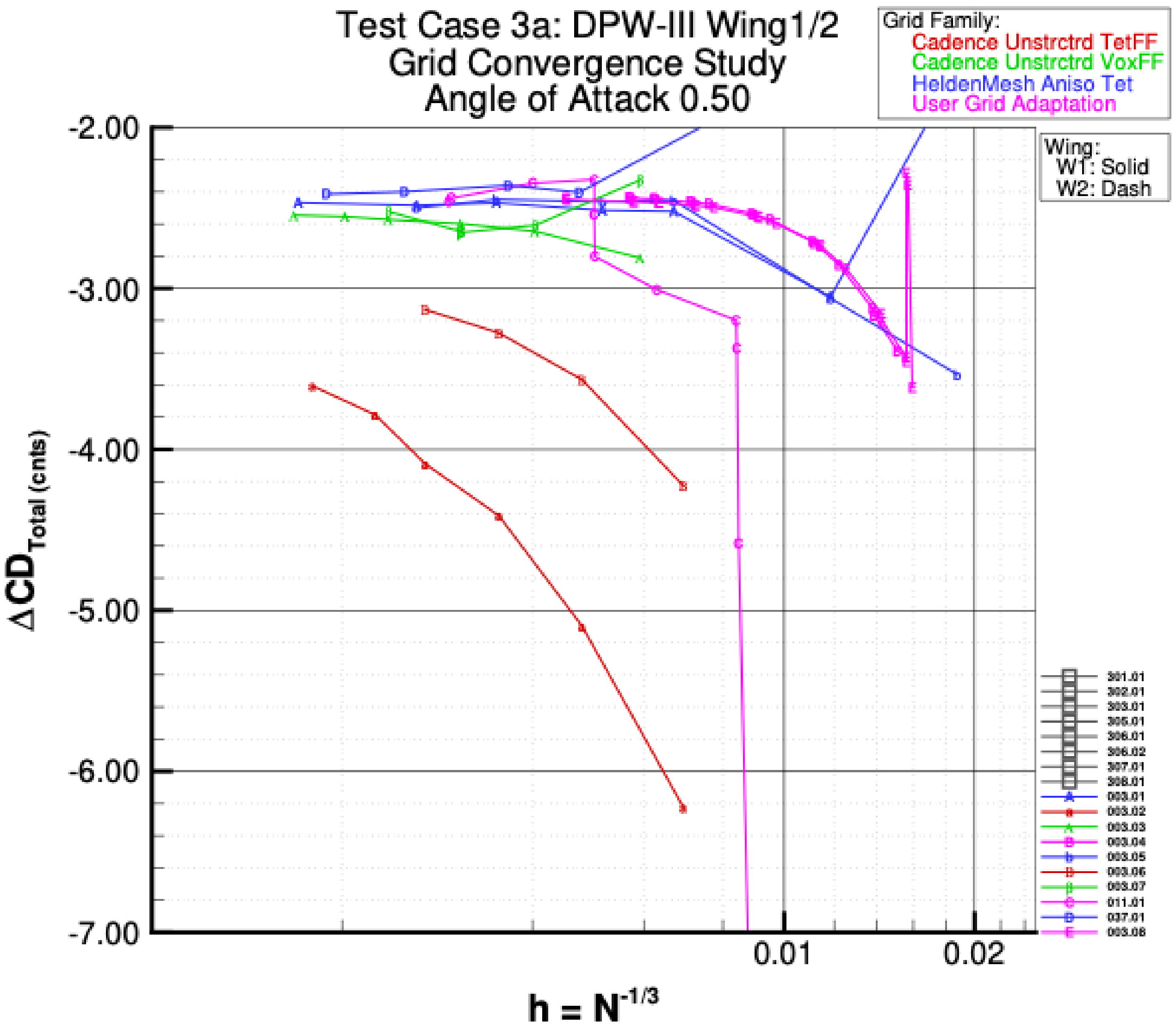


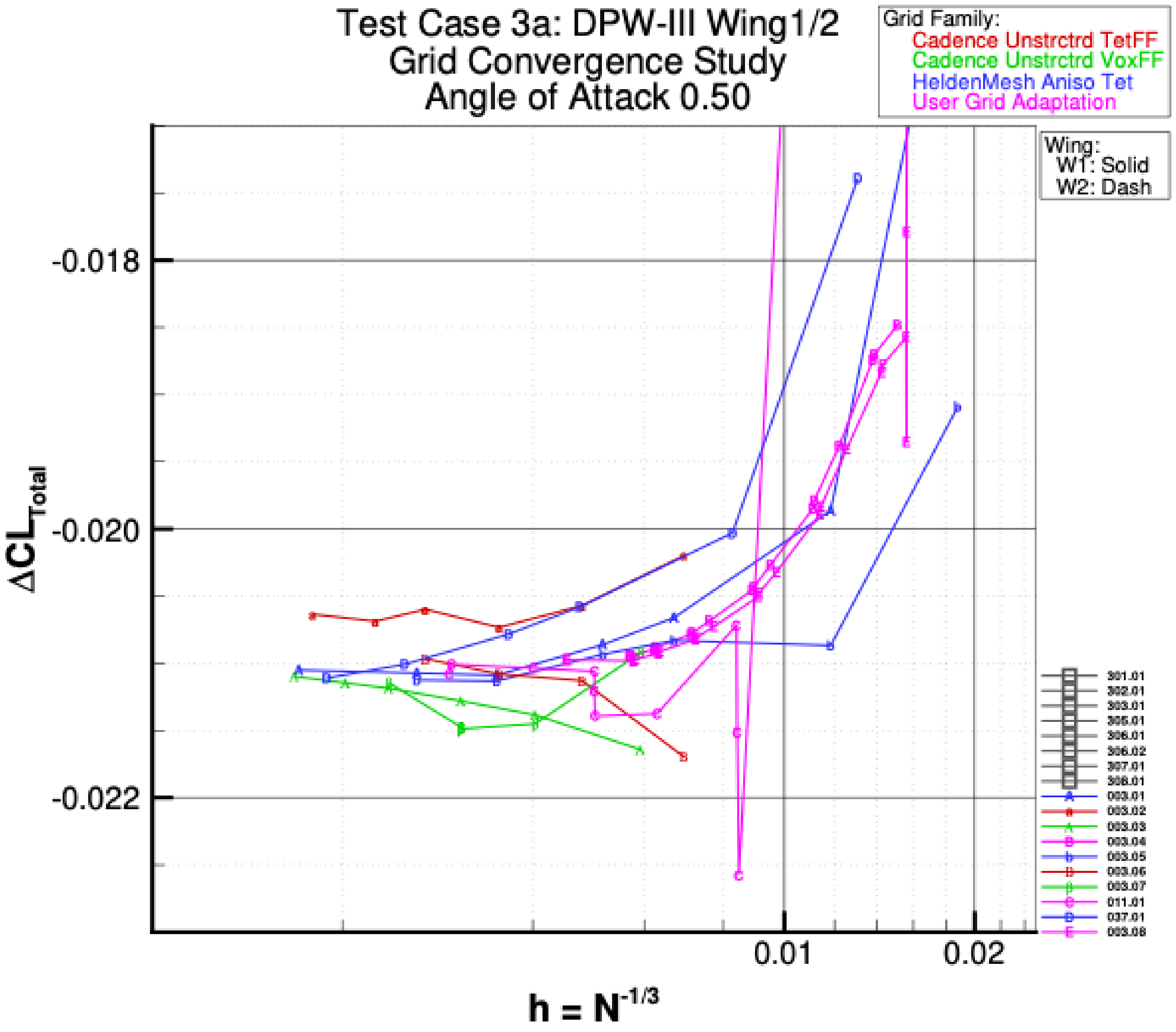
W1/W2 C_D and C_L Convergence: $\alpha = 0.5°$





W1/W2 ΔC_D and ΔC_L Convergence: $\alpha = 0.5°$





Test Case 2a: Wing/Body Cruise

AIAA

- **Verification of steady CFD analysis, required**
- **Settings**
  - Steady CFD RANS **French Vanilla SA-[neg] vs QCR2000 (All terms!)**
    - Adiabatic Wall (not isothermal)
  - Converge residuals to machine precision (~1e-10)
- **Grids: https://www.aiaa-dpw.org/DPW8/Scatter/Test_Case_2**
  - NASA CRM geometry including deformed wing matching condition
    - (L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine)
    - Six-member grid family; four are required, six are desirable
  - Encourage use of committee-supplied grids; user-generated grids are acceptable
- **Reference Units**

Sref (semi-span grid)	Cref	Semispan	Moment Center
297360.0 sq.in	278.5 in	1156.75 in	(1325.90, 0.00, 177.95)

- **Conditions**

Mach	Re_c	α	T_{static} (120° F)	γ	Pr	Pr_t	Farfield $\chi = \tilde{\nu}/\nu$
0.85	5×10^6	2.50°	579.67 R | 322.04 K	1.4	0.72	0.90	3

- **Sutherland's Law**

$$\mu(T) = \mu_0 \left(\frac{T}{T_0}\right)^{3/2} \left(\frac{T_0 + S}{T + S}\right) \quad \mu_0 = 1.716 \times 10^{-5} \frac{\text{kg}}{m\, s} \quad T_0 = 491.6^\circ R \quad S = 198.6^\circ R$$

$$\frac{\mu(T)}{\mu_{ref}} = \left(\frac{T}{T_{ref}}\right)^{3/2} \left(\frac{1 + S/T_{fef}}{T/T_{fef} + S/T_{fef}}\right)$$

Comparison Data

NTF197: r44,r51,r53
NTF215: r43,r103
NTF229: r296,r300,r302
Ames216: r35,r126,r130,r133

Conclusion

- **Test Case 1a: ONERA OAT15A**
  - Surprisingly large scatter!
- **Test Case 1b: Joukowski**
  - Excellent agreement between participants
  - Clear demonstration of 2^{nd}-order accuracy (and higher!)
- **Test Case 1c: ONERA OAT15A**
  - Reduction in scatter!
    - Consistent Turbulence Model
    - Consistent problem definition (nothing left to participants)
    - Fairfield Distance
    - Residual Convergence
- **Test Case 3a: W1/W2 increment**
  - Looking better after 20 years!
  - Need more participants…
- **Test Case 2a: Wing/Body Cruise**
  - SA-[neg] vs SA-[neg]-QCR2000
- **You want to Participate!**
  - Contact galbramc@mit.edu or Ben.J.Rider2@boeing.com

Scatter Reduction Working Group

dpwaiaa@gmail.com

Scatter Reduction Working Group Leadership

- **Marshall Galbraith, Massachusetts Institute of Technology**
- **Kevin Holst, University of Tennessee, Knoxville**
- **Ben Rider, The Boeing Company**

Geometry/Grid Far Field Details

NASA CRM (Full Scale)
MAC = 275.8"
Semispan = 1156.75"

AIAA

DPW7: iges files (box)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (inch)	-22440.9,	23838.6	23139.75	~ 84.0	~ 20.0
Y (inch)	0.0	35433.1	35433.1	~ 128.6	~ 30.6
Z (inch)	-23405.5	23838.6	23838.6	~ 86.5	~ 20.6

https://aiaa-dpw.larc.nasa.gov/Workshop7/Geometry/2021-03-02_Version_01/DPW7geometries.zip

DPW8

DPW8: HeldenMesh (box)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (inch)	-55160.0	55160.0	55160.0	200.0	~ 47.7
Y (inch)	0.0	55160.0	55160.0	200.0	~ 47.7
Z (inch)	-55160.0	55160.0	55160.0	200.0	~ 47.7

https://dpw.larc.nasa.gov/DPW8/Scatter/Test_Case_2/Helden_Grids.REV00/

DPW8: Cadence (box)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (inch)	-115582.5	118237.9	116910.2	~ 424.2	~ 101.1
Y (inch)	0.0	116834.7	116834.7	~ 423.9	~ 101.0
Z (inch)	-115584.0	116018.1	115801.1	~ 420.2	~ 100.1

https://dpw.larc.nasa.gov/DPW8/Scatter/Test_Case_2/Cadence_Grids.REV00/

DPW7

DPW7: Vassberg (sphere)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (inch)	-30328.203	32996.560	31662.382	~ 114.8	~ 27.4
Y (inch)	0.0	31664.519	31664.519	~ 114.8	~ 27.4
Z (inch)	-31449.638	31865.992	31657.815	~ 114.8	~ 27.4

https://dpw.larc.nasa.gov/DPW7/Vassberg_Grids.REV00/

DPW7: JAXA (sphere)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (MAC)	-413.890	424.690	419.290	~ 419.3	~ 100
Y (MAC)	0.0	419.349	419.349	~ 419.3	~ 100
Z (MAC)	-418.675	420.005	419.340	~ 419.3	~ 100

https://dpw.larc.nasa.gov/DPW7/JAXA_Grids.REV00/

DPW7: NLR (sphere)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (m)	-2949.98	3050.00	2999.99	~ 428.2	~ 102.1
Y (m)	0.0	3000.00	3000.00	~ 428.2	~ 102.1
Z (m)	-2995.1	3004.99	3000.05	~ 428.2	~ 102.1

https://dpw.larc.nasa.gov/DPW7/NLR_Grids.REV00/DPW7-NLR-grids/

DPW7: DLR (box)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (m)	-570.0	630.0	1200.0	~ 171.3	~ 40.9
Y (m)	0.0	900.0	900.0	~ 128.5	~ 30.6
Z (m)	-594.5	605.5	1200.0	~ 171.3	~ 40.9

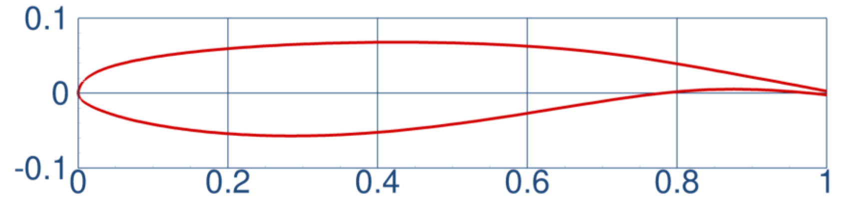
https://dpw.larc.nasa.gov/DPW7/DLR_Grids.REV00/

DPW7: GGNS (box)	Min	Max	+/- Range	Range / MAC	Range / Semispan
X (inch)	-22400.0	22400.0	22400.0	~ 81.2	~19.4
Y (inch)	0.0	22400.0	22400.0	~ 81.2	~19.4
Z (inch)	-22400.0	22400.0	22400.0	~ 81.2	~19.4

Adapted grids (not publicly released)

Test Environment Working Group

Test Case 1a: Workshop-Wide Validation

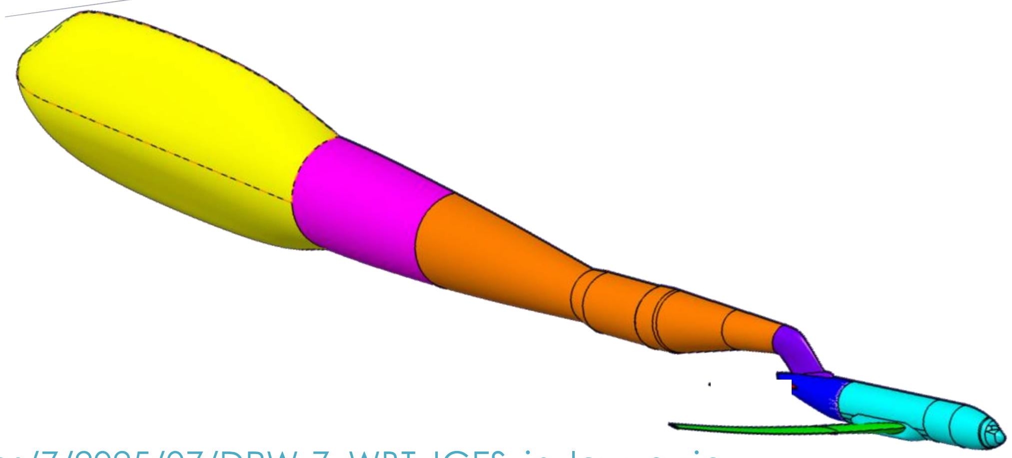


ONERA OAT15A Transonic Airfoil

- **Validation of steady CFD analysis, required**
- **Users are encouraged to employ best practices**
- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted
  - Purely 2D simulations (one cell wide)
- **Grids**
  - Six-member RANS grid family; four are required, six are desirable
  - Encourage use of committee-supplied grids; user-generated grids are acceptable
  - Committee-supplied grid is one cell wide with a 230mm chord (same as experiment) and follows RANS best practices
- **Conditions**
  - Mach 0.73, Re_c=3m (based on chord length), T_{static}= 271 K (487.8 R)
  - Alpha: 1.36, 1.50, 2.50, 3.00, 3.10

Jaquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009. Pages 1985-1994.

Test Case 2a: T&I Study (Wing/Body)



- **CRM Wing/Body with Upper Swept Strut**
  1. Wing/Body (2.7% model scale in tunnel)
  2. Wing/Body + ***Upper Swept Strut***
     - Wing deformed to matching condition (from DPW7)
     - Aft strut surface (shown in yellow) replaces interface to arc sector
- **Geometry**
  - https://commonresearchmodel.larc.nasa.gov/wp-content/uploads/sites/7/2025/07/DPW-7_WBT_IGES_in_low_q.zip
  - https://dpw.larc.nasa.gov/DPW8/Test_Environment/Test_Case_1/Geometry/Sting_No_Arc_Sector_Bulb_noRotation_2025_09_03.igs
- **Conditions & Reference Units**

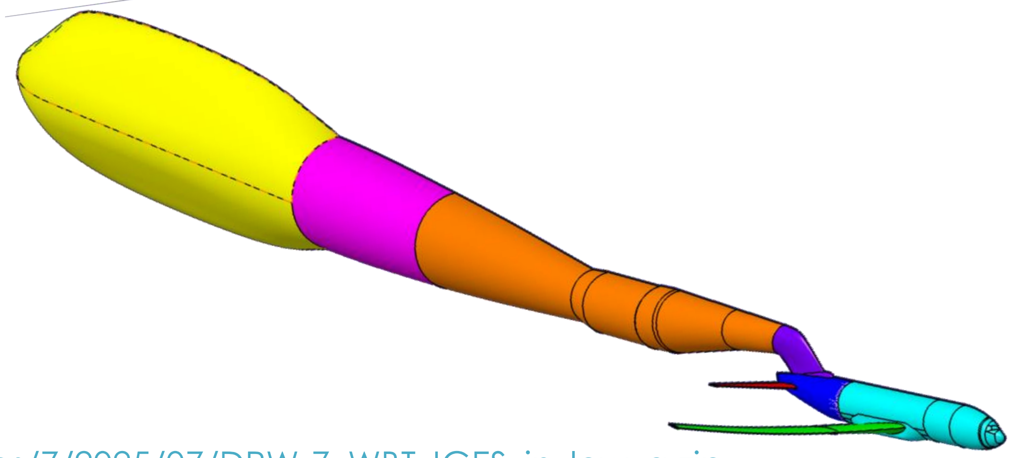
Mach	Re_c	T_{static} (120° F)	α
0.85	5×10^6	579.67 R | 322.04 K	$-1.50°, 0.00°, 1.50°, 2.50°, 2.75°, 3.00°, 3.25°, 3.50°, 3.75°, 4.00°, 4.25°$

Sref (semi-span grid)	Cref	Semispan	Moment Center
216.77544 sq.in	7.5195 in	31.23225 in	(156.0003, 0.00, -0.00035)

- **Comparison metrics**
  - Forces / Moments
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

Comparison Data
NTF197: r44,r51,r53
NTF215: r43,r103
NTF229: r296,r300,r302
Ames216: r35,r126,r130,r133

Test Case 2b: T&I Study (Wing/Body/Tail)



- **CRM Wing/Body with Upper Swept Strut**
  1. Wing/Body/Horizontal Tail (2.7% model scale in tunnel)
  2. Wing/Body/Horizontal Tail + ***Upper Swept Strut***
     - Wing deformed to matching condition (from DPW7)
     - Aft strut surface (shown in yellow) replaces interface to arc sector
- **Geometry**
  - https://commonresearchmodel.larc.nasa.gov/wp-content/uploads/sites/7/2025/07/DPW-7_WBT_IGES_in_low_q.zip
  - https://dpw.larc.nasa.gov/DPW8/Test_Environment/Test_Case_1/Geometry/Sting_No_Arc_Sector_Bulb_noRotation_2025_09_03.igs
- **Conditions & Reference Units**

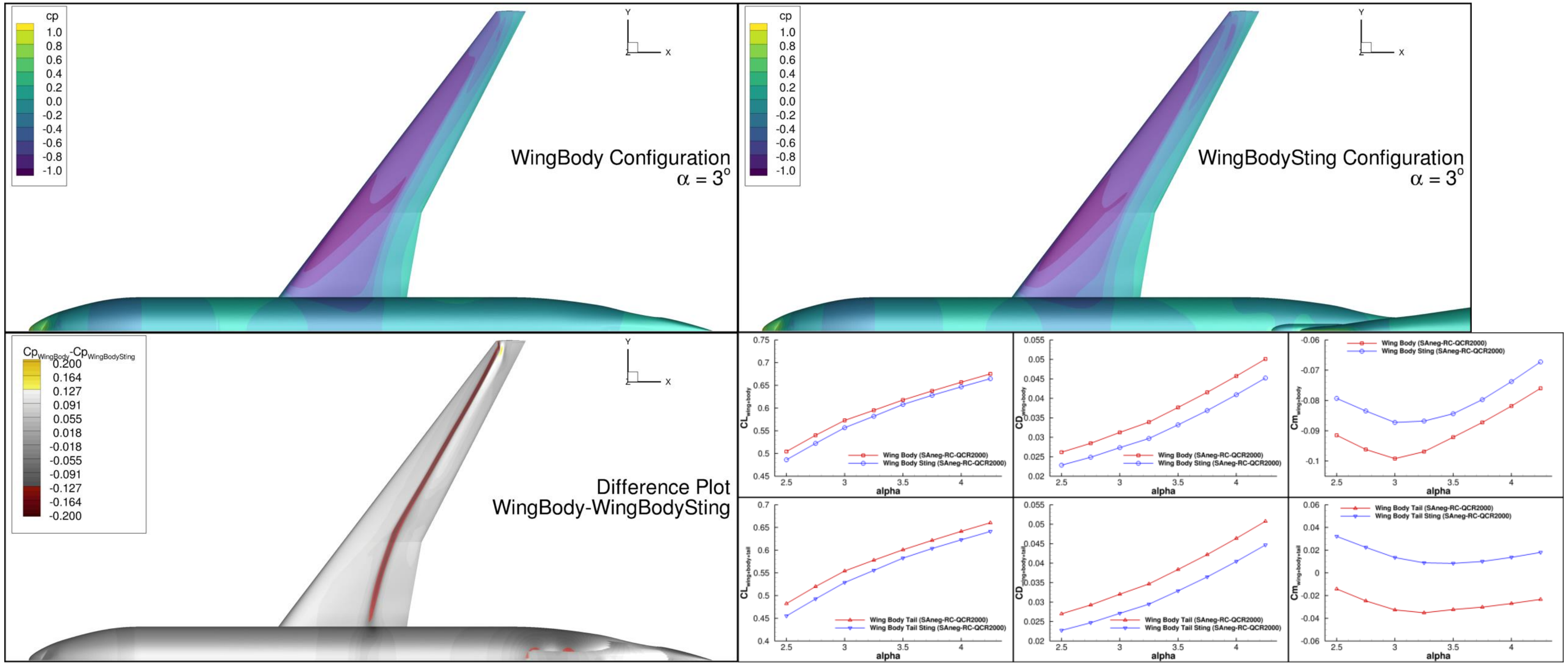
Mach	Re_c	T_{static} (120° F)	α
0.85	5×10^6	579.67 R | 322.04 K	$-1.50°, 0.00°, 1.50°, 2.50°, 2.75°, 3.00°, 3.25°, 3.50°, 3.75°, 4.00°, 4.25°$

Sref (semi-span grid)	Cref	Semispan	Moment Center
216.77544 sq.in	7.5195 in	31.23225 in	(156.0003, 0.00, -0.00035)

- **Comparison metrics**
  - Forces / Moments
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

Comparison Data
NTF197: r92,r97,r99
NTF215:
NTF229:
Ames216:

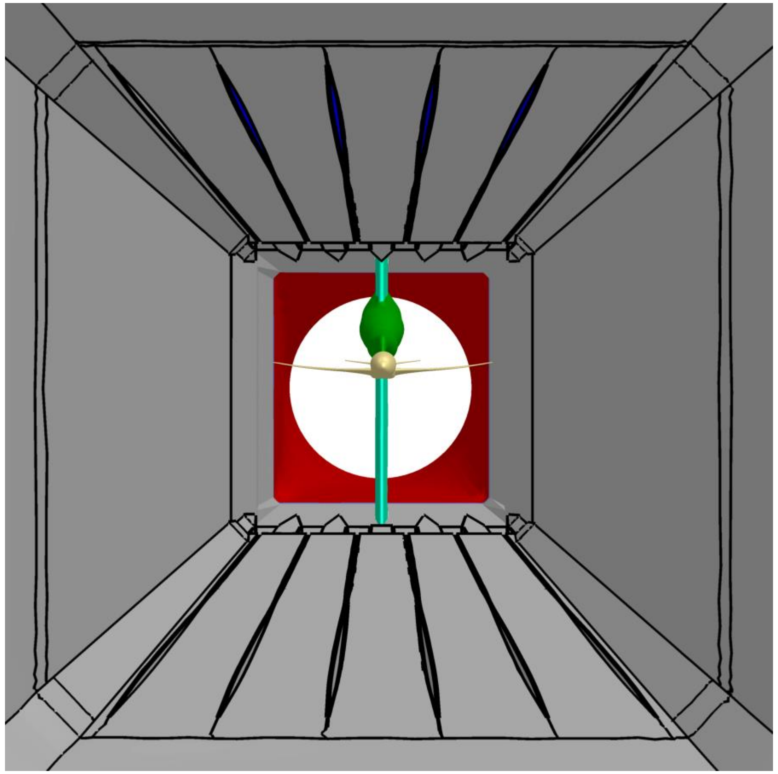
Test Case 2a: Preliminary Findings



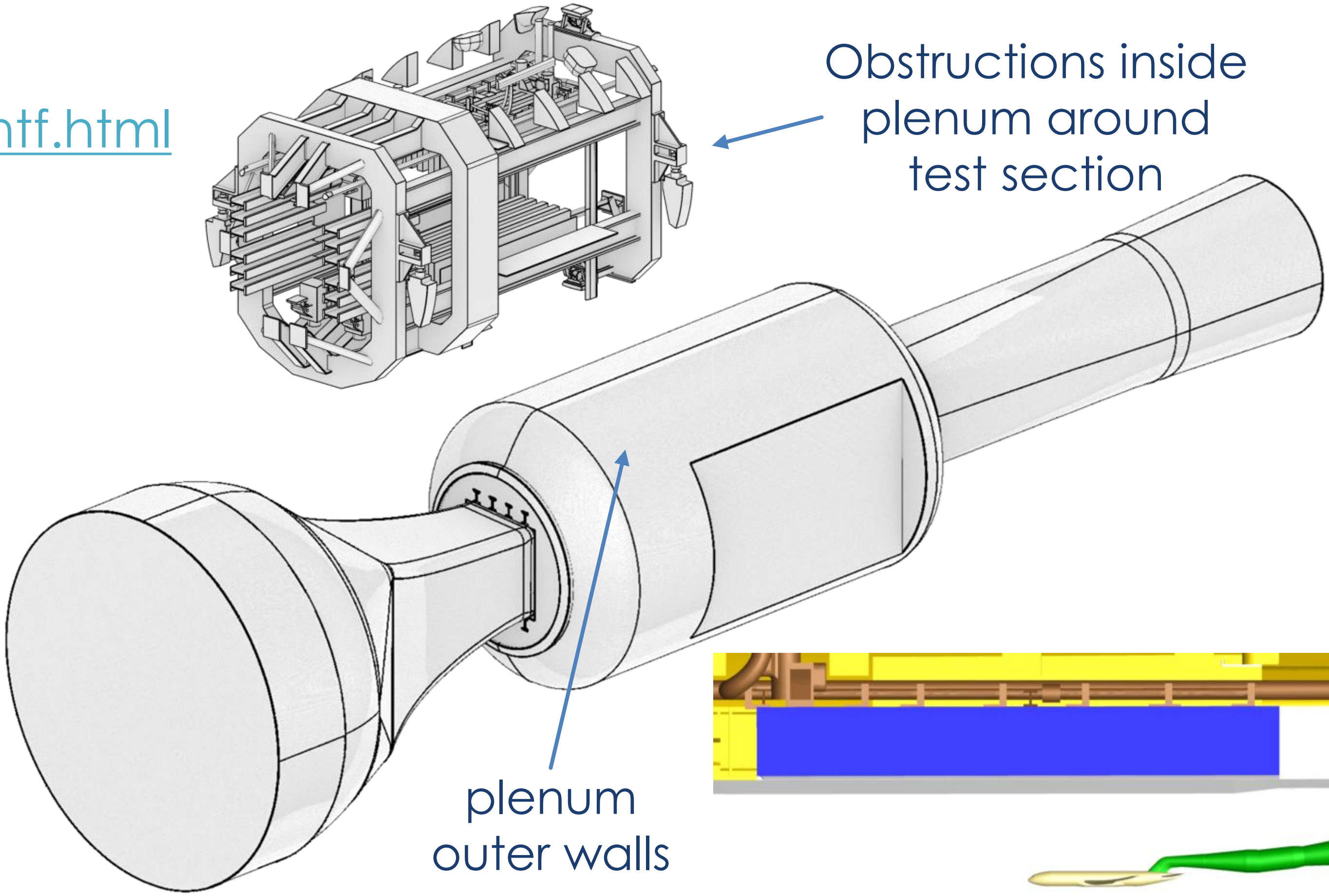
- **Preliminary steady-state RANS analysis has been performed using SAneg-RC-QCR2000**
- **Inclusion of the sting moves the wing shock forward reducing the lift and drag as well as the static stability of the aircraft**
- **Contour plots at 3-degrees AOA show the shock movement and integrated loads demonstrate the shift caused by the sting**

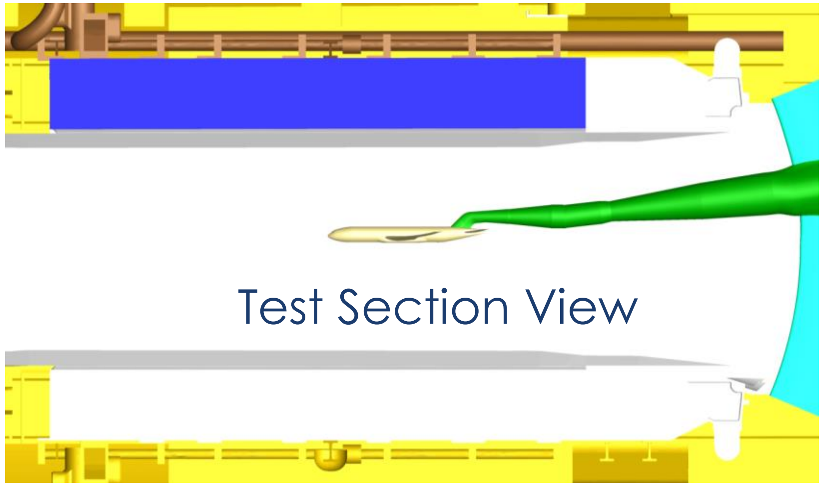
NTF Geometry Available

- **NTF Geometry is available:**
  - https://www.aiaa-dpw.org/ntf.html



Test Section View





Test Section View

Wind Tunnel Test Environment WG: Key Questions

- How much of the spread between experimental and computational results is due to the test environment?
- What methods are needed to quantify the effect of the mounting hardware on force/moment and pressure measurements?
- Can state-of-the-art methods accurately simulate the full NTF test section, including slots and gaps?

Static Deformation Working Group

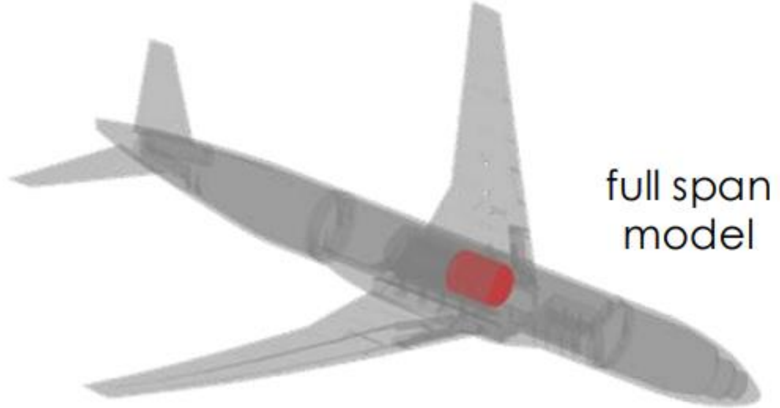
Test Case 1b: FEM Validation

- **Validation of Structural Model for NASA CRM**
  - Tap Test planned for comparison to normal mode solutions of FEM models
  - Static Loads Tests will be conducted to compare deflection measurements (and maybe twist) to Linear Static FEM solutions
- **Users are encouraged to employ best practices for selected FEM codes**
- **Settings**
  - Linear Eigenvalue Analysis (e.g. NASTRAN® SOL103)
- **Conditions**
  - Rigid suspension at sting
- **Grid**
  - MSC NASTRAN® solid 4-node tetrahedral finite-element structural model
  - Model consists of $6.8 \cdot 10^6$ elements, $4.1 \cdot 10^6$ degrees-of-freedom
  - Supplied by NASA Langley's Configuration Aerodynamics Branch
  - Wind tunnel sting will be added as beam model

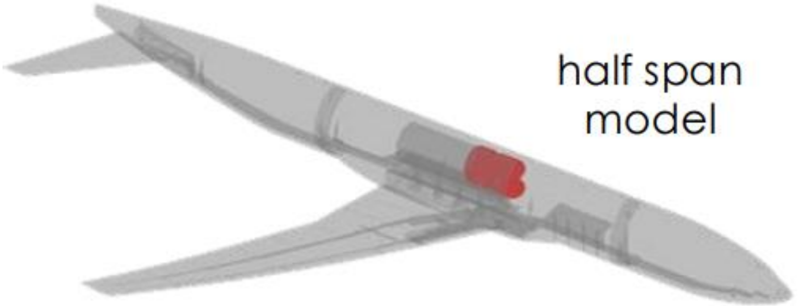
NASA CRM Structural Model

Static Deformation WG: FEMs

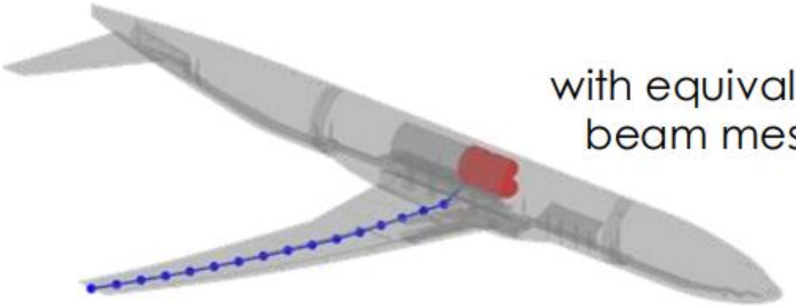
- **Tet-blasted Nastran full-span FEM, clamped inside the fuselage in-between the wings (red cylinder)**
  - Created for DPW-5 by J. Moore at LaRC
  - Used occasionally by participants since DPW-5, but never validated experimentally



- **Halved the model to accommodate half span CFD**
  - Not easy to do: the original FEM had elements that lived on both sides of the symmetry plane

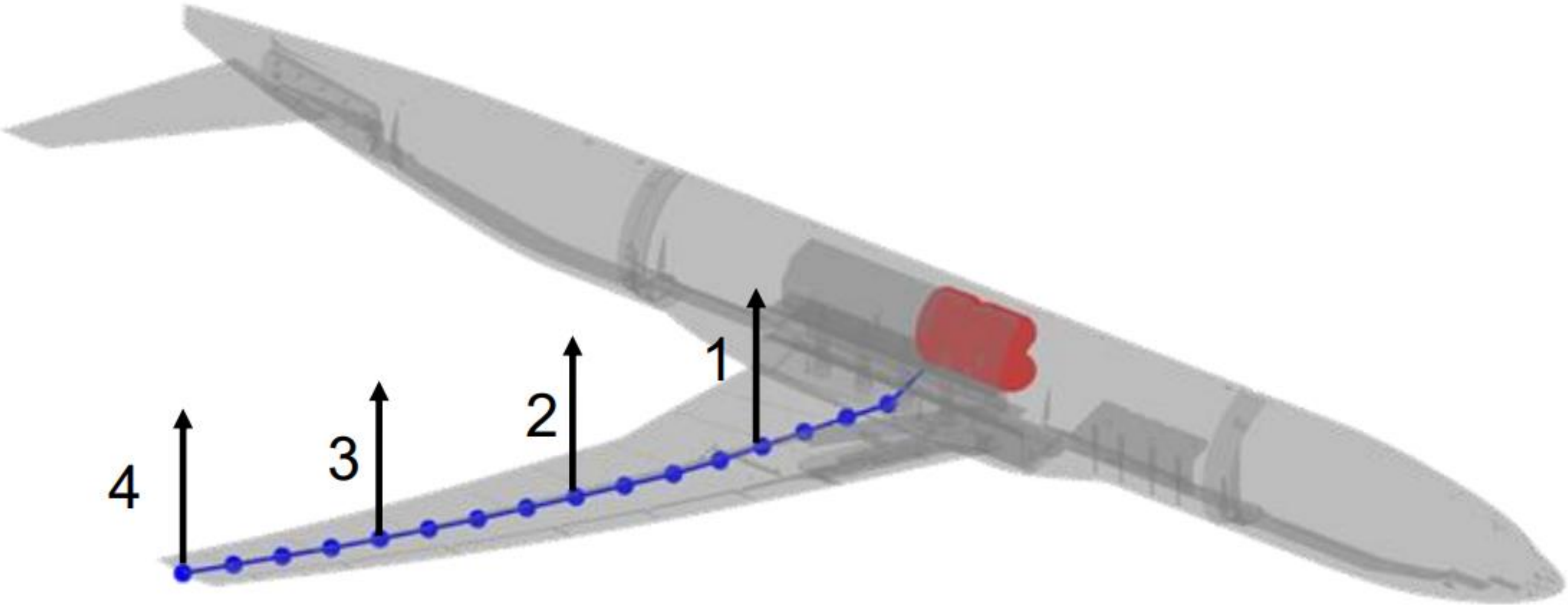


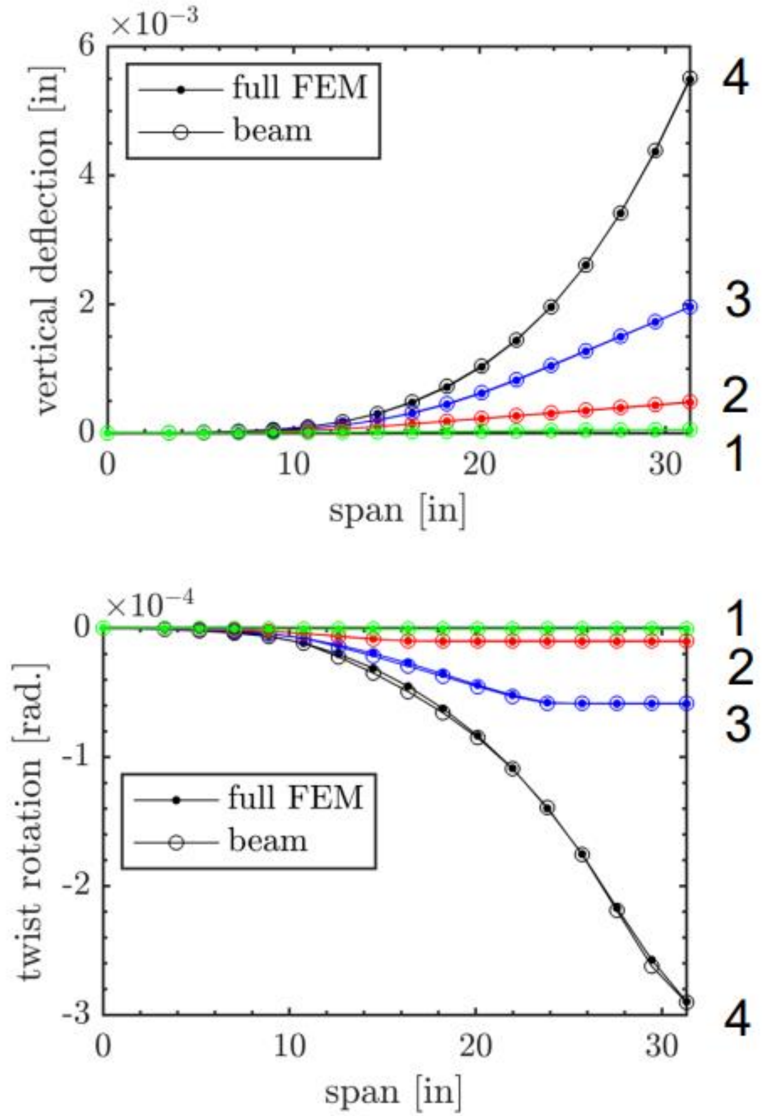
- **Created an equivalent beam model**



Static Deformation WG: Eq. Beam Verification

- **Four unit (1-lb) vertical load cases:**





Test Case 2a: Wing/Body Deformation (cruise)

- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body**
  - Reynolds number: 5M (LoQ)
  - Dynamic Pressure: Q_∞ =1384 psf
  - Mach number: 0.85(M_{cruise})
  - CL = 0.5000 +/- 0.0001 (Angle of Attack ~ 2.75 deg)
  - Temperature: 120.0 F (579.67 R / 322.04 K)
  - Reference Information: https://aiaa-dpw.larc.nasa.gov/Workshop7/DPW7-geom.html

Grid: Level 1-6

Comparison Data
NTF197: r44,r51,r53
NTF197: r92,r97,r99 *(WBT0)*
NTF215: r43,r103
NTF229: r296,r300,r302
ETW ESWIRP: r164,r182,r153
Ames216: r35,r126,r130,r133

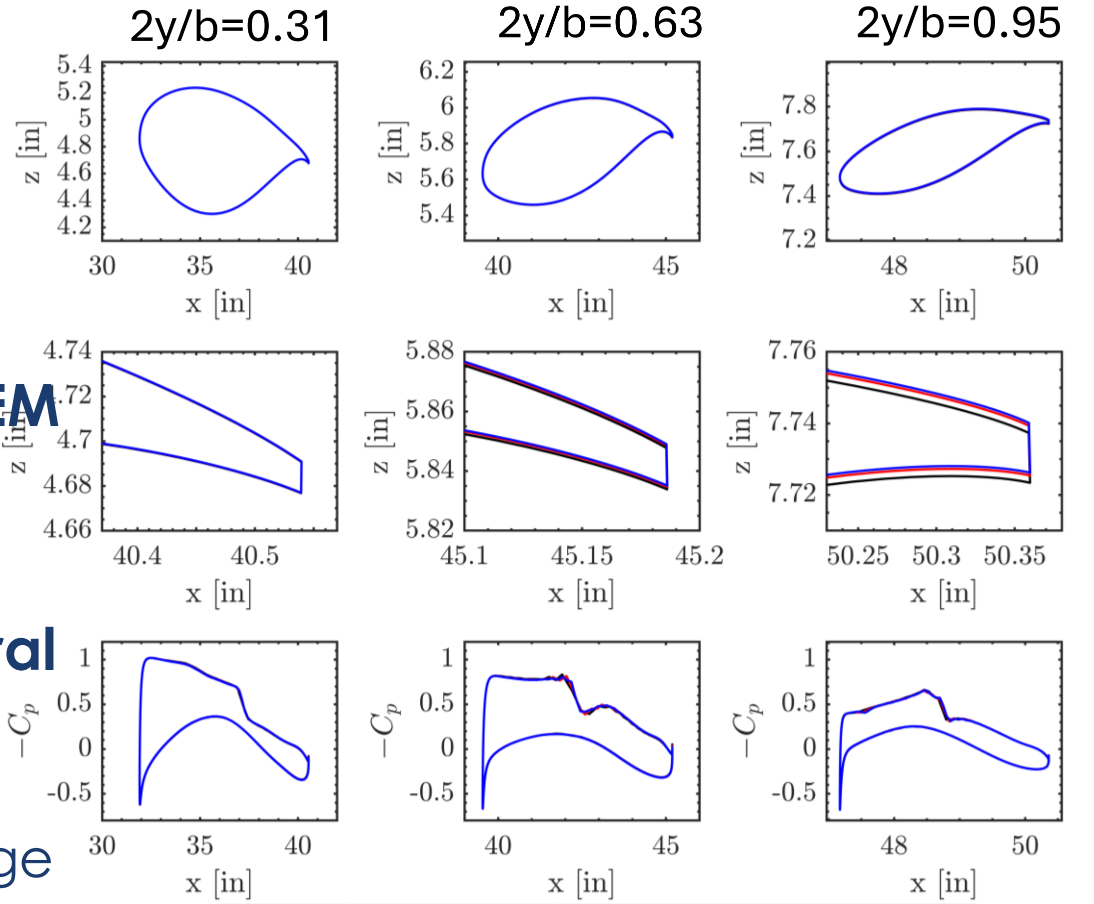
- **Committee-supplied**
  - NASA CRM geometry in jig/unloaded condition
    - Trip location – Wing: 10% chord upper/lower surface
  - Grid Family: *https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2*
    - L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine
  - NASA CRM finite-element model: *https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2/FEM_Models*

Measured Span Stations
η = (0.00,0.4286, 0.5546, 0.6773, 0.7954, 0.9150)

- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

Preliminary Aeroelastic Results

- **Mach 0.85, Re 5M, Q 1384 psf**
- **Aerodynamics Model: FUN3D**
  - RANS, SA-neg, QCR, stabilized finite element method
- **Structural model: 1st 20 modes of semispan FEM**
  - Interpolated those mode shapes onto the CFD surface mesh with a radial-basis function
- **Coupling: FUN3D coupled to a modal structural solver (which also lives inside FUN3D) in time**
  - Very large time steps, and structural modal damping set to a very large value, to encourage rapid convergence to a static aeroelastic solution
- **3-4 separate runs to find the AoA for CL=0.5**



	L1	L2	L3
AoA	2.5448	2.5085	2.4956
CL	0.49997	0.50000	0.49999
CD	0.02607	0.02580	0.02570
CM	-0.03450	-0.03680	-0.03767

Test Case 3: Wing/Body/Nacelle/Pylon

- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body/Nacelle /Pylon**
  - Reynolds number: 5M (LoQ)
  - Dynamic Pressure: Q_∞ =1384 psf
  - Mach number: 0.85 (M_{cruise})
  - Angles of attack: -1.50, 0.00, 1.50, **2.75**, 3.10, **3.50**, 4.00, 4.50
  - Temperature: 120.0 F (579.67 R / 322.04 K)
  - Reference Information: https://aiaa-dpw.larc.nasa.gov/Workshop7/DPW7-geom.html

Grid: Level 3
Grid: Level 1-6

- **Committee-supplied**
  - NASA CRM geometry in jig/unloaded condition
    - Trip location – Wing: 10% chord upper/lower surface
  - Grid Family: *https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2*
    - L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine
  - NASA CRM finite-element model: *https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2/FEM_Models*

Measured Span Stations
η = (0.00,0.4286, 0.5546, 0.6773, 0.7954, 0.9150)

- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

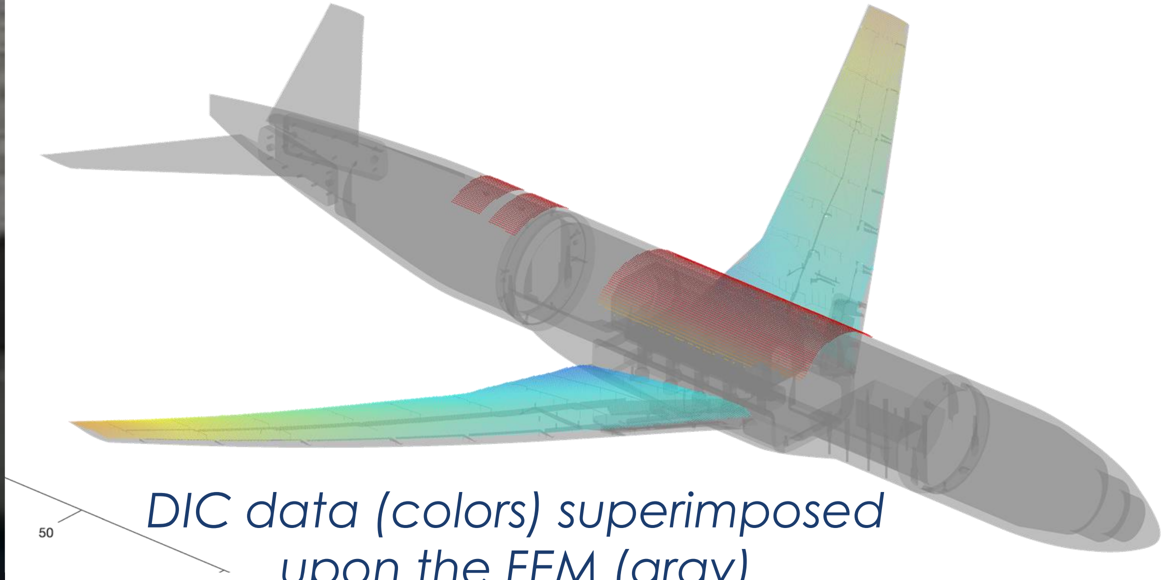
Static Deformation WG: Key Questions

- **What level of accuracy can be attained for transonic wing deformation calculations?**
- **What is the uncertainty in configuration force/moments due to aeroelastic deformation uncertainty?**
- **What are the most efficient/accurate methods for coupling the aero/structural computations?**
  - What are the computational time/accuracy savings between using a full fidelity vs reduced beam structural model?
  - Do modal solutions compare well to direct fluid-structure mapping solutions?
  - Does a full vs symmetry plane solution result in different solutions?
- **What accuracy is lost by using a "lower fidelity" aerodynamic analysis method?**

Digital Image Correlation for FEM Validation

- April 2025: static loads test + tap test of the CRM model structure

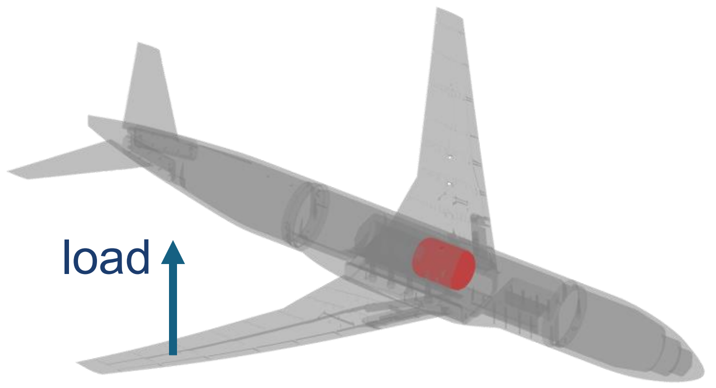
- Digital image correlation (DIC) was used to track model deformation under loads, with a speckle pattern adhered to the two wings and fuselage

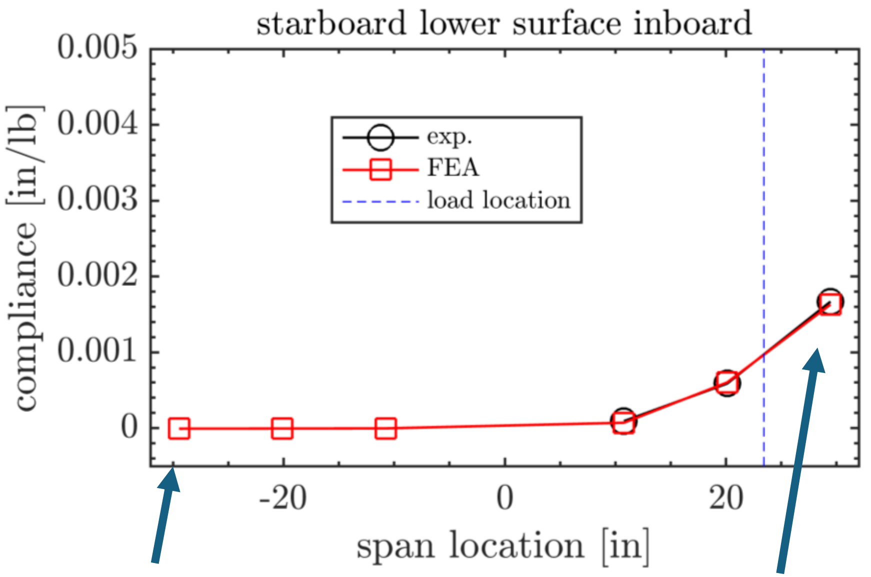


DIC data (colors) superimposed upon the FEM (gray)

Structural Compliance Response Comparison

- **Apply a series of point loads at a given span station**
- **DIC measures full-field displacement data, but we only look at vertical displacements at 6 points:**
  - 2Y/b = [-0.93, -0.64, -0.34, 0.34, 0.64, 0.93]
- **At each point, we fit the DIC results to a linear curve, and the slope of that line is the compliance: in/lb**
- **Compare compliance at each point to the FEM result**

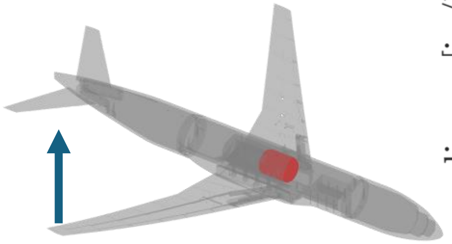


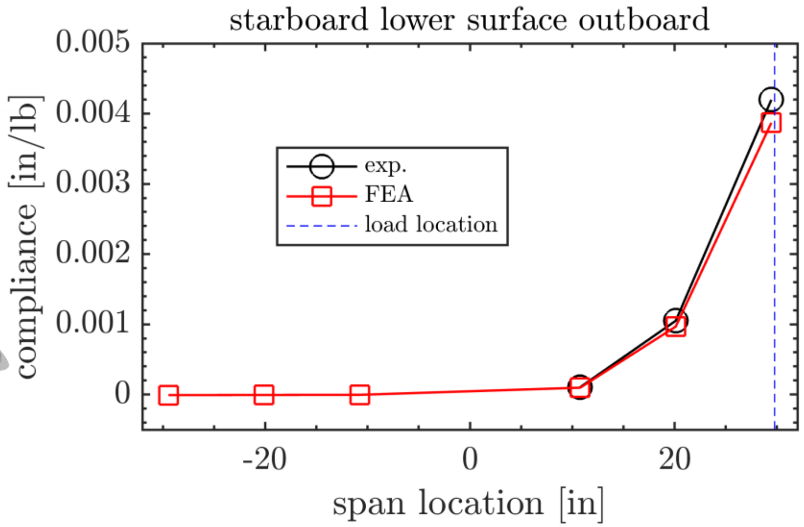


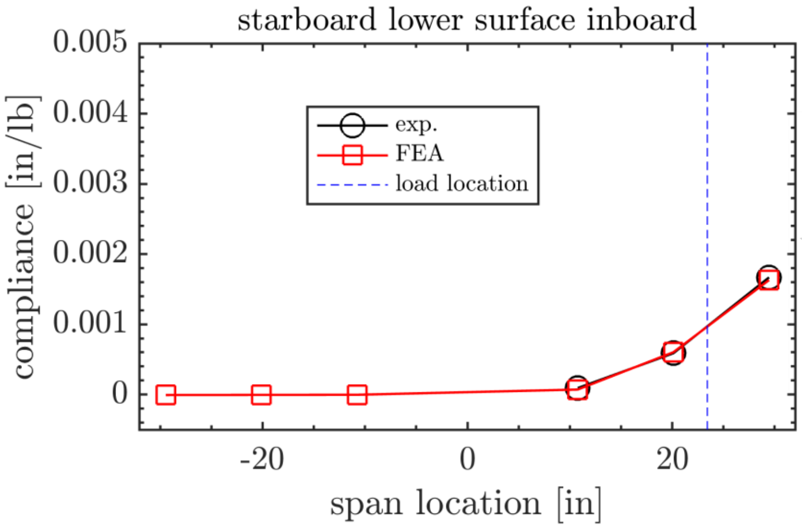
~0 compliance → very little structural communication between starboard and port

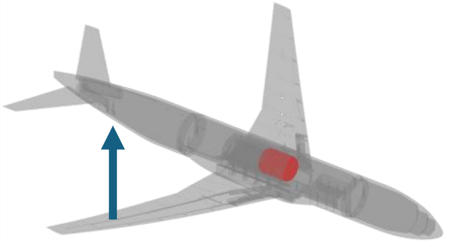
largest compliance, b/c furthest away from wing root

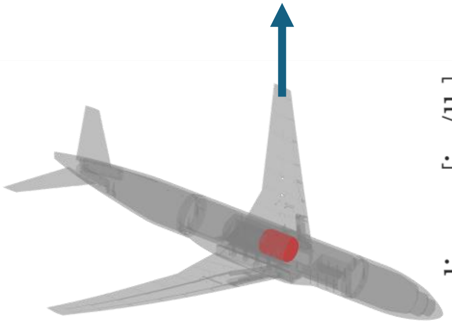
Structural Compliance Response Comparison

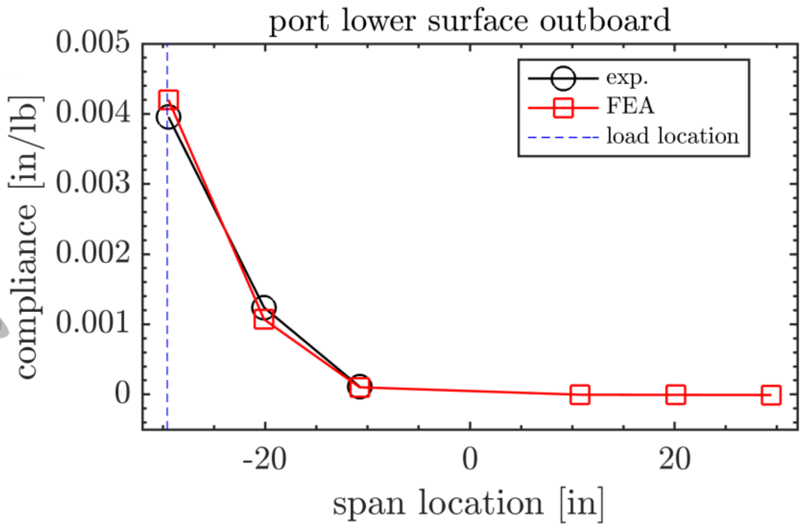


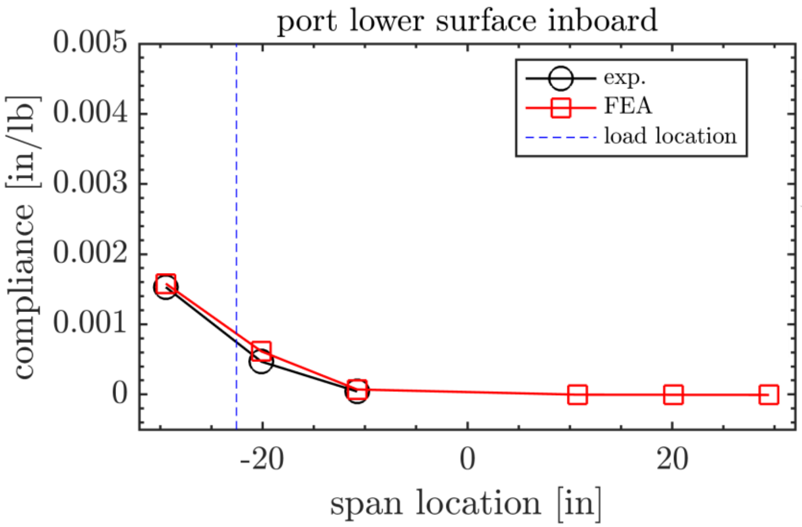


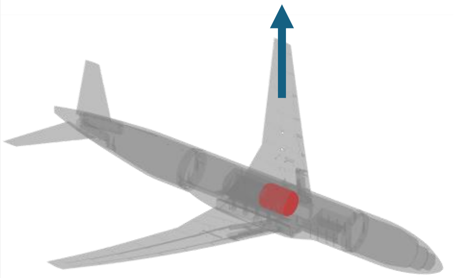










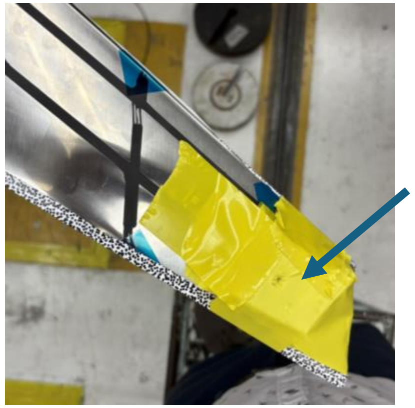


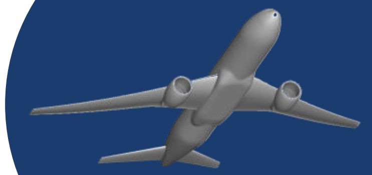
Take-Aways

- **The FEM is *~8% too stiff* on the starboard side, but *~6% too flexible* on the port side**

- **Testing uncertainties:**
  - We were worried about scratching the wing, and so applied the weight pan tip to a pad on the wing: this made it difficult to precisely measure the x/y/z of the load location
  - There was a ton of rolling motion from the sting, both rigid-body and flexible, and this had to be subtracted-off

- **Another consideration: the FEM is ~7% stiffer on the starboard side than the port side: it's unclear how realistic that is, and this test was not precise enough to validate it**

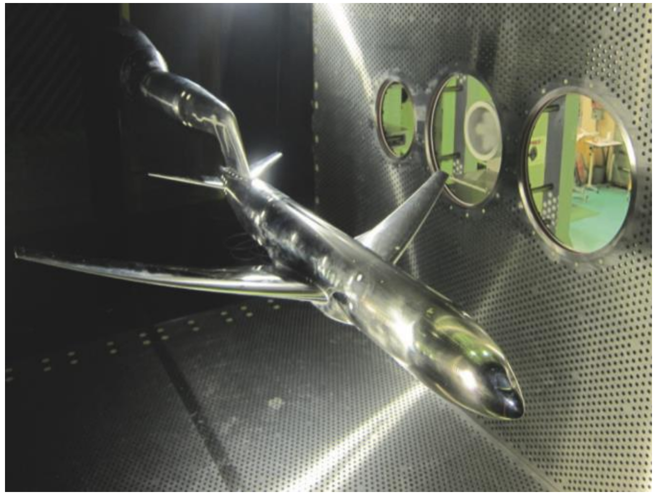




Buffet Working Group

Test Case Overview

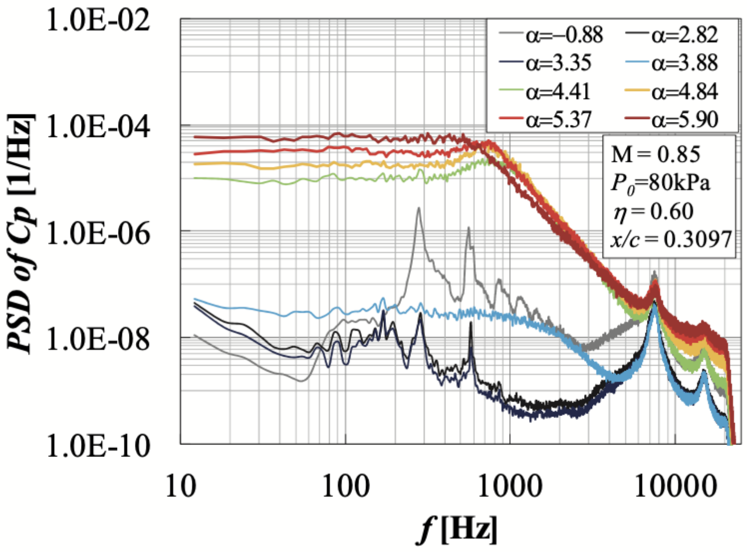
- **Test Case 2**
  - Unsteady CFD, rigid wing
  - Committee-supplied geometry (and grids) for four alphas
  - Two pre-buffet alphas; two post-buffet alphas
  - Experimental data: static pressure, Kulites, F&M, wing deformation



- **Test Case 3**
  - Unsteady CFD, dynamic wing
  - Committee-supplied wind-off (“jig”) geometry and grid, stick-model FEM
  - One pre-buffet alpha, one close to onset, one post buffet
  - Experimental data: static pressure, Kulites, F&M, wing root strain gauge, uPSP

Status & Lessons Learned

- **Test Case 2**
  - Unsteady CFD, rigid wing
  - Limited submissions to date makes definitive statements challenging as of today
  - Work is ongoing by many groups
  - URANS struggles (SA, SST, Reynolds-stress model)
  - At times, post-buffet URANS simulations frequently indicate a RANS-like solution; isolated success in some solvers at moderate and fine grids
  - Scale-resolving schemes show significant improvement
  - Computational cost can be prohibitive (as expected)



- **Test Case 3**
  - Unsteady CFD, dynamic wing
  - Participants are making progress (see next slide)
  - Some solvers do not have dynamic wing (FSI) capabilities

Progress Toward Test Cases 2 and 3

Participant	Test Case 2	Test Case 3
Company 1		
Company 2		
Company 3		
Company 4		
Government 1		
Government 2		
Government 3		
Government 4		
Government 5		
Government 6		
Academia 1		
Academia 2		
Academia 3		

Progress Toward Test Cases 2 and 3

Participant	Test Case 2	Test Case 3
Company 1	In progress (nearly done)	
Company 2	In progress	
Company 3	In progress	
Company 4	No	
Government 1	In progress and also submitted	
Government 2	In progress	
Government 3	In progress	
Government 4	In progress	
Government 5	In progress	
Government 6	Paused	
Academia 1	Submitted	
Academia 2	In progress (nearly done)	
Academia 3	In progress	

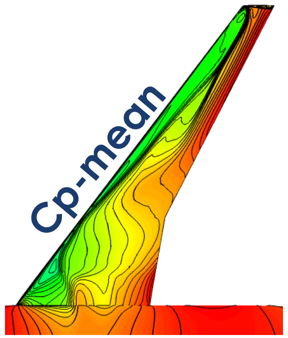
Progress Toward Test Cases 2 and 3

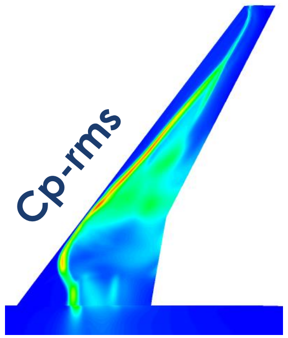
Participant	Test Case 2	Test Case 3
Company 1	In progress (nearly done)	Interested
Company 2	In progress	No
Company 3	In progress	In progress
Company 4	No	No
Government 1	In progress and also submitted	No
Government 2	In progress	Interested
Government 3	In progress	Interested
Government 4	In progress	No
Government 5	In progress	In progress
Government 6	Paused	Interested
Academia 1	Submitted	Interested
Academia 2	In progress (nearly done)	Interested
Academia 3	In progress	Interested

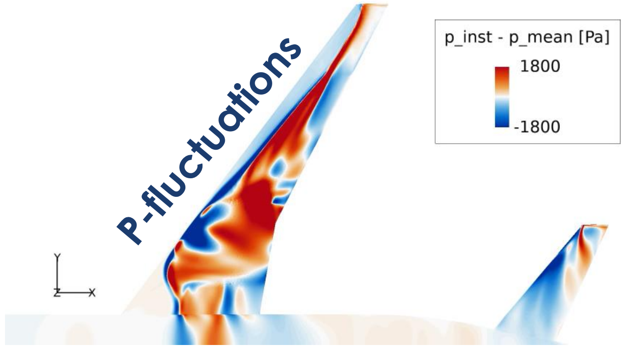
Participant Briefs

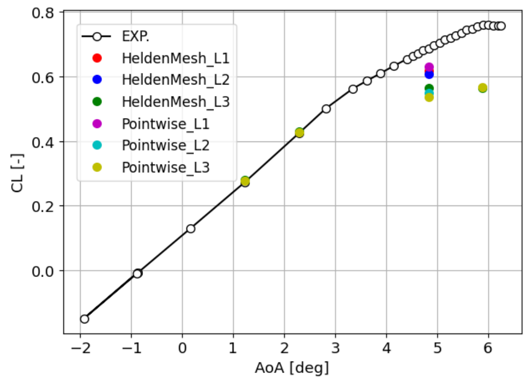
Participant Briefs – JAXA

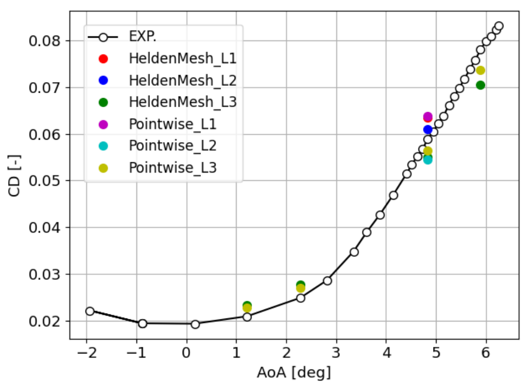
- **Solver: FaSTAR, URANS (SA-R-QCR2000-comp)**
- **Tested sensitivities at 4.84 deg:**
  - Pointwise (L1-L3), HeldenMesh (L1-L3)
  - Dt=0.01 vs 0.001; sub-it=30-120
  - 1st vs 2nd Turbulent fluxes order
  - Initialisation: uniform flow vs from RANS
- **AoA sweep for PW-L3 and HM-L3**
  - Pre-buffet OK!
  - Mostly no buffet, except for PW-L3
  - Results quantitatively incorrect

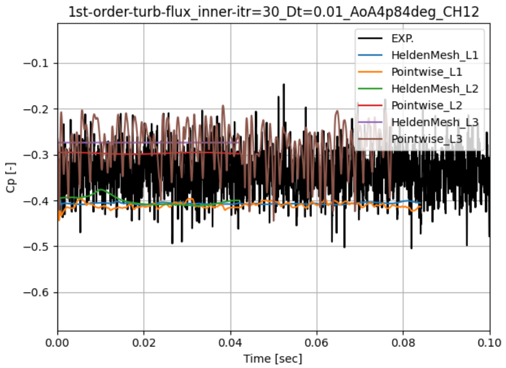


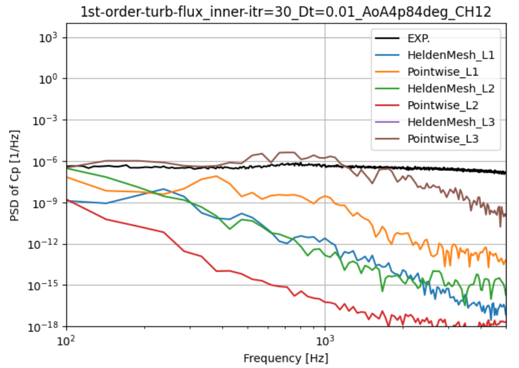


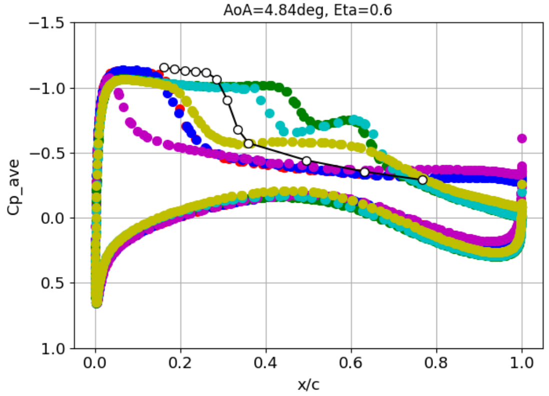


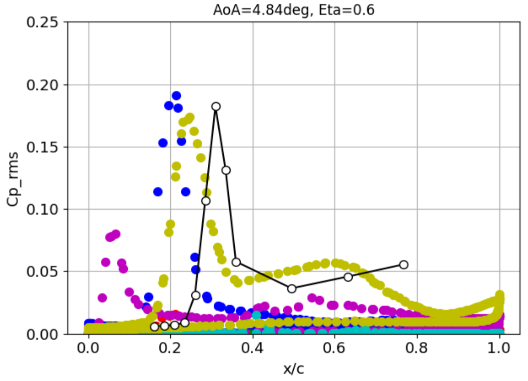












Participant Briefs – JAXA

- **Are URANS hopeless?**
  - Maybe we are pushing it, when applying URANS far from buffet onset
  - Linearized-URANS (Global Stability Analysis, GSA) predicts onset well
  - Mechanisms (buffet cells) are qualitatively and quantitatively in good agreement with the experiments

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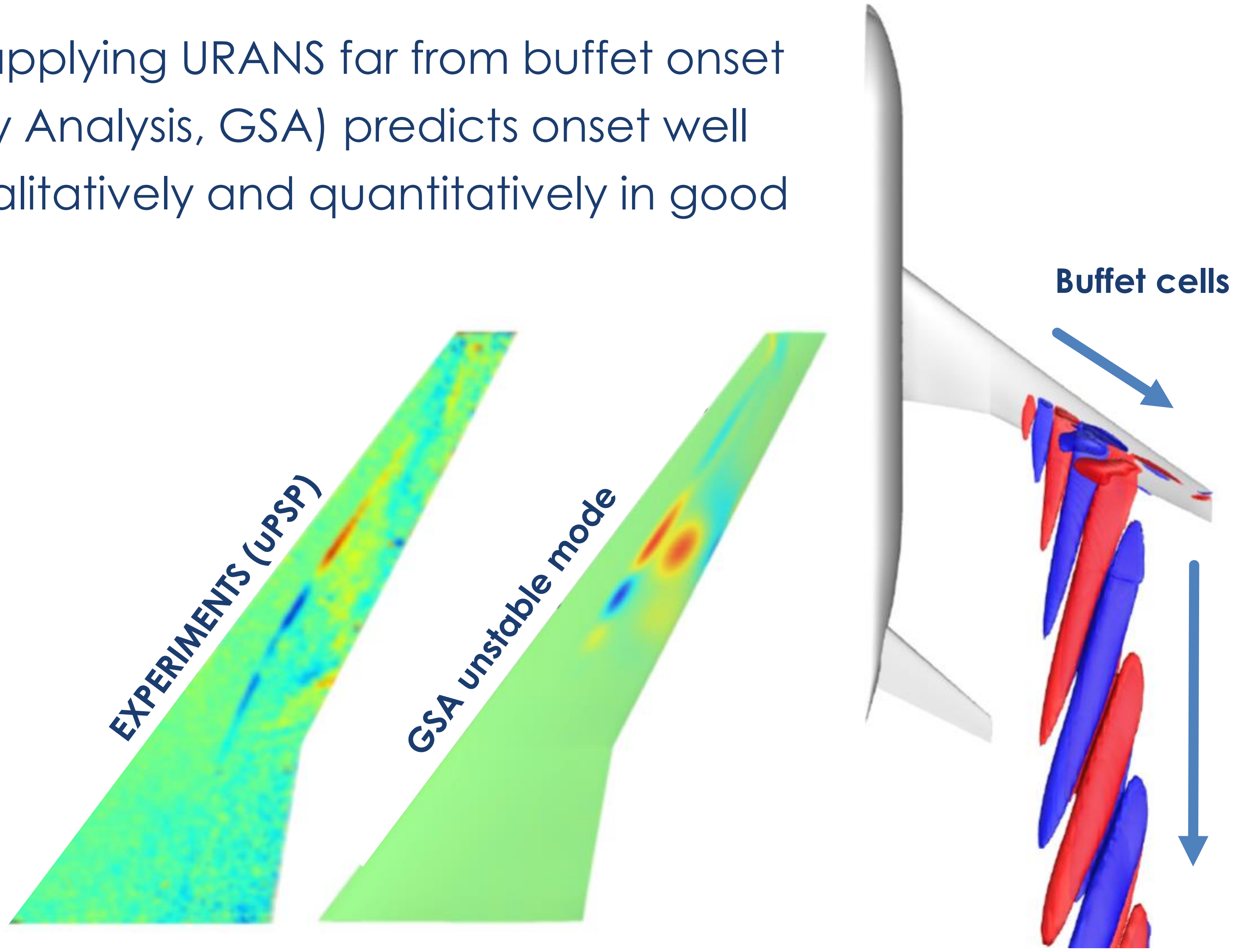
Global Stability Analysis of Full-Aircraft Transonic Buffet at Flight Reynolds Numbers

Andrea Sansica* and Atsushi Hashimoto†
Japan Aerospace Exploration Agency, Tokyo 182-8522, Japan

https://doi.org/10.2514/1.J062808

Fully three-dimensional (3D) global stability analysis (GSA) is performed on the NASA Common Research Model at turbulent transonic buffet conditions. The framework here proposed is based on a Jacobian-free approach that enables GSA on large 3D grids, making this the first stability study on a full-aircraft at typical flight Reynolds numbers. The Reynolds-averaged Navier–Stokes solutions compare reasonably well with the available experiments and are used as base flows for the stability analyses. GSA is first performed at wind tunnel Reynolds number conditions, and a buffet-cell mode localized in the wing outboard region is found to be responsible for the onset. When the side-of-body (SOB) separation becomes larger at higher angles of attack, two additional modes are detected: a high-frequency mode localized in the SOB region and a low-frequency long-wavelength buffet-cell mode that may represent the link with the shock-oscillation instability found in two-dimensional airfoils. The existence of the buffet-cell mode is confirmed at flight Reynolds numbers. However, due to the presence of large SOB separation at the onset angle of attack, this mode is distributed along the whole wing and an SOB separation mode also appears. As well as characterizing buffet on industry-relevant geometries and flow conditions, this study proves that the proposed GSA framework is feasible for large 3D numerical grids and can represent a useful tool for buffet onset prediction during design and certification phases of commercial aircraft.



Participant Briefs – RMIT

- Michael Candon
- Royal Melbourne Institute of Technology

Solver

CFD Solver Overview

- Cadence grids L1 and L3.
- Fluent 2025 R2 - coupled pressure-based solver.
- SIMPLE scheme.
- Reynolds Stress Model (stress-ω)
- $\Delta t = 5.29 \times 10^{-6}$ s -> 100 timesteps per CTU.
- $\Delta t = 2.645 \times 10^{-6}$ s -> 200 timesteps per CTU.
- 10 or 20 sub-iterations / timestep
- Residuals 1e-5 - 1e-8

$$M_\infty = 0.85,\ \ p = 49{,}880\text{Pa},\ \ Re_c \approx 1.51M$$
$$\alpha_0 = 5.89^\circ$$

Baseline model:

- **Convective fluxes (all):** Second-order upwind
- **Shear flow correction:** On (default)
- **Time Integration:** Bounded second-order implicit

Variant 1:

- **Convective fluxes (all):** Second-order upwind
- **Shear flow correction:** Off
- **Time Integration:** Second-order implicit

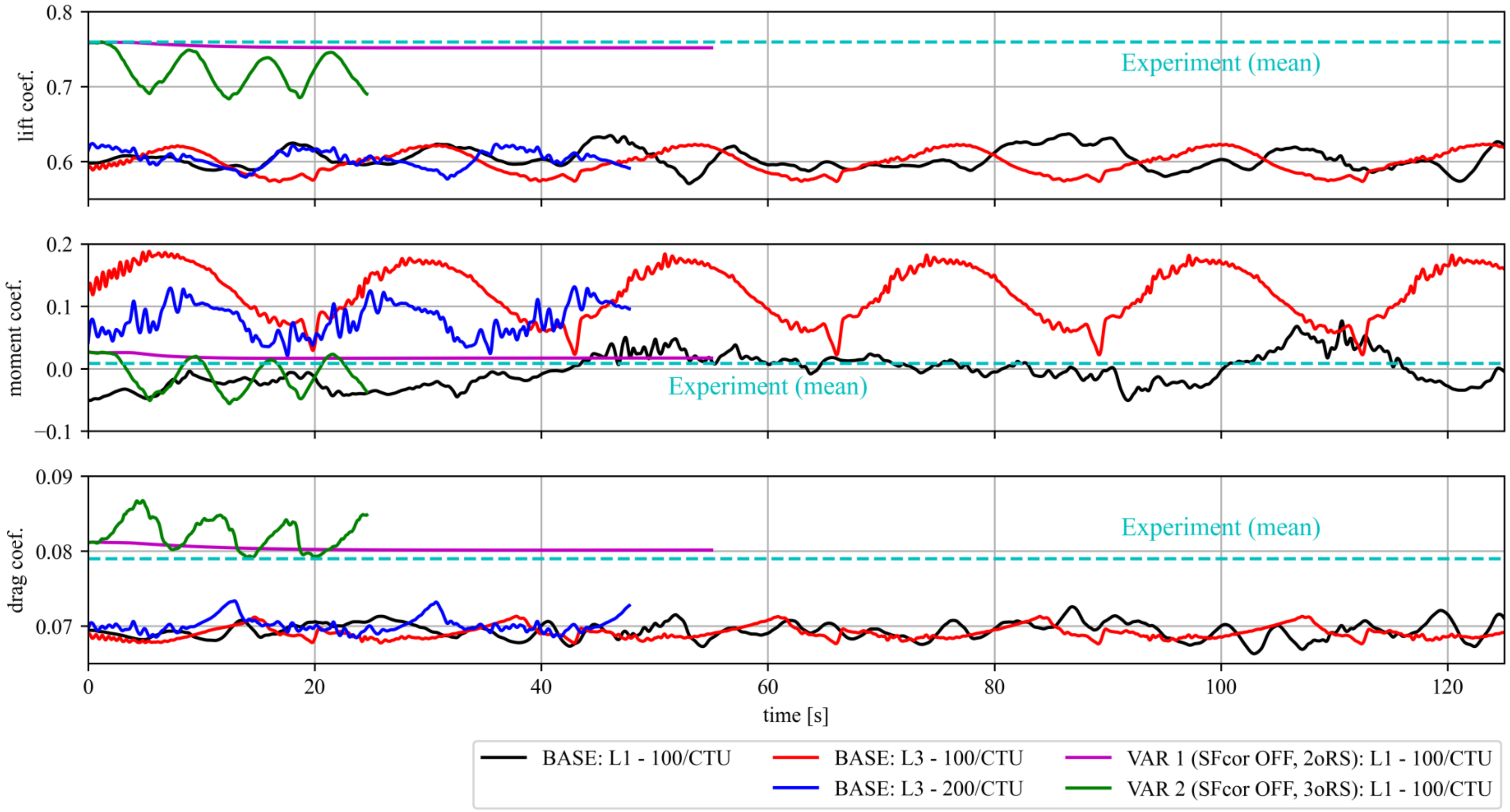
Variant 2:

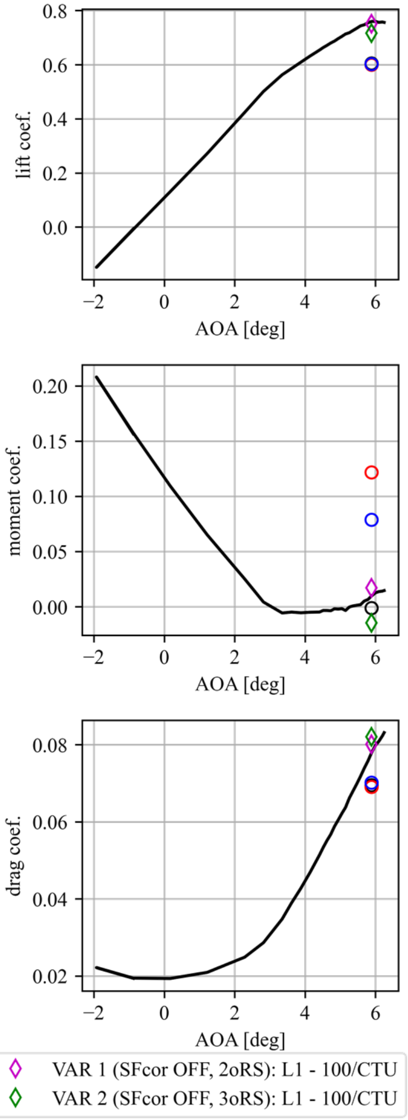
- **Convective fluxes (mean flow + ω):** Second-order upwind
- **Convective fluxes (Reynolds stresses):** Third-order MUSCL
- **Shear flow correction:** Off
- **Time Integration:** Second-order implicit

Lessons learned (brief)

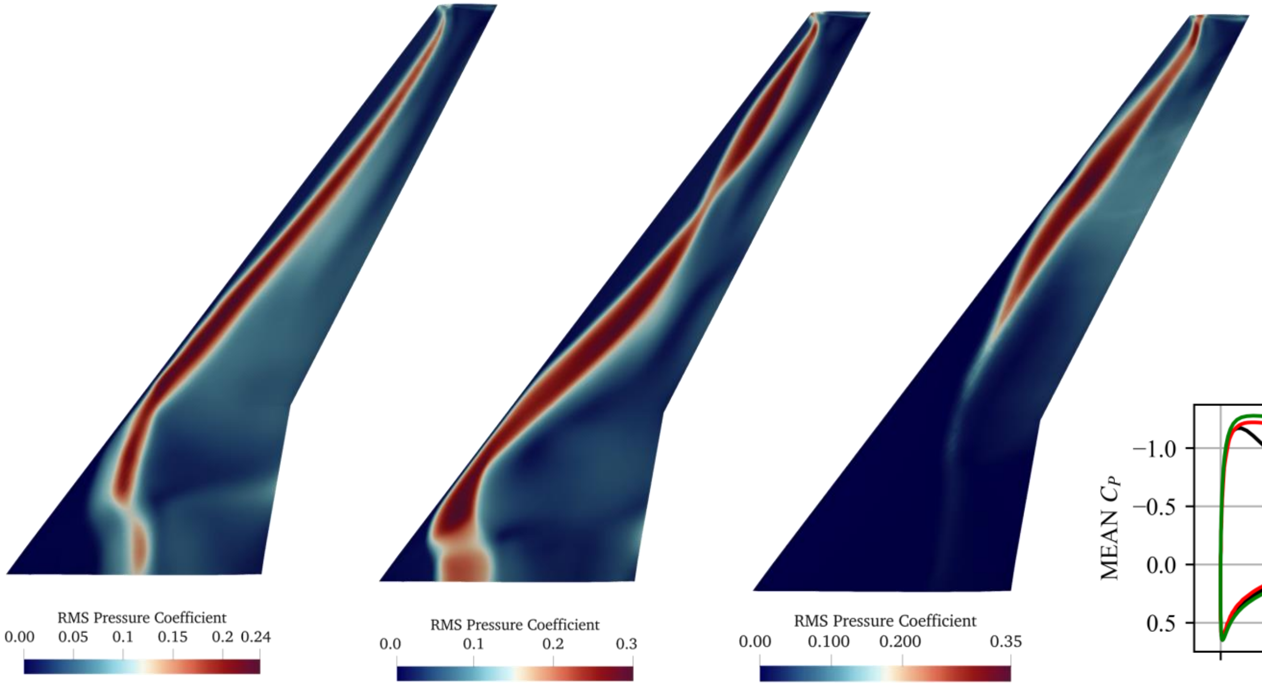
- No one- or two-equation eddy viscosity models have buffeted (many variants tested, up to L4).
- RSM stress-omega gets buffet (buffet cell too aggressive and upstream).
- Turning off Shear flow correction helps with over prediction of separation.

Forces ($\alpha_0 = 5.89^{\circ}$)





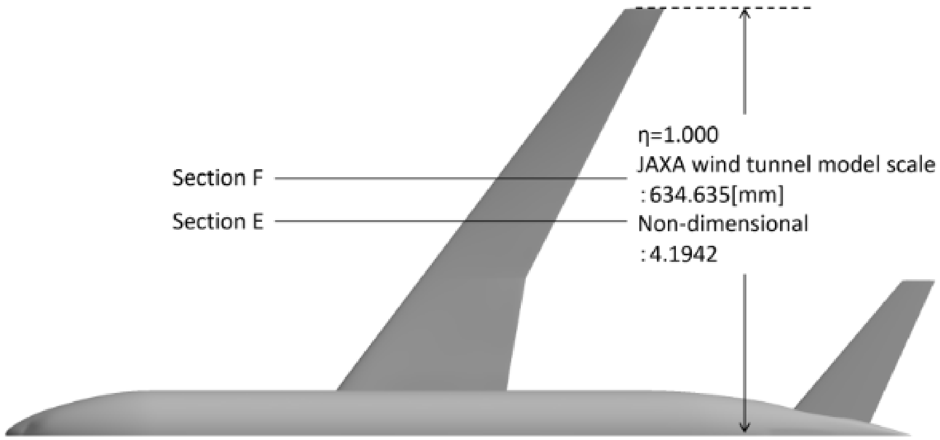
Pressure Coefficient ($\alpha_0 = 5.89^{\circ}$)

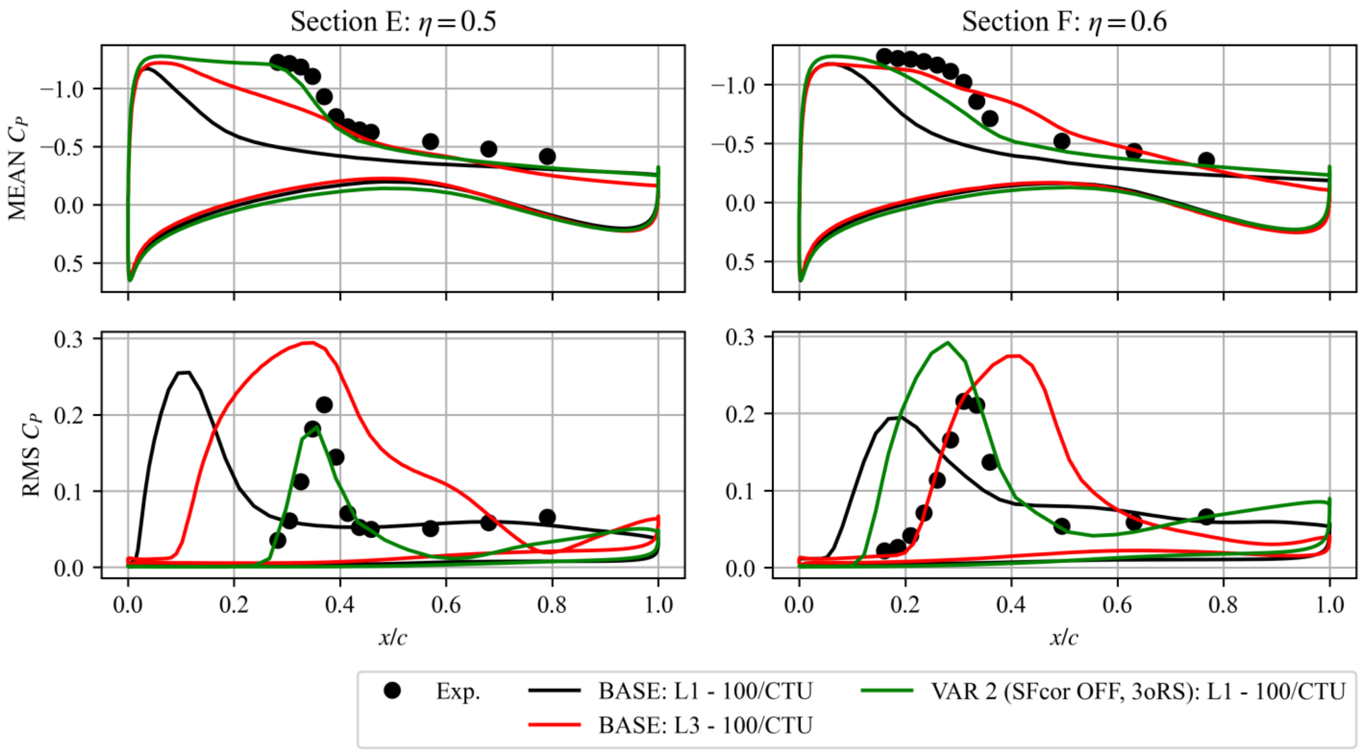


BASELINE (L1 100/CTU)

BASELINE (L3 100/CTU)

VAR 2 (L1 100/CTU)





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- RMIT RACE Supercomputing Hub
- Funding from AOARD/AFOSR

Participant Briefs

- **Hadar Ben-Gida**
- **Technion – Israel Institute of Technology**

Numerical Methodology

LBM/VLES

- SIMULIA PowerFLOW (v6-2025R2)

- **Core scheme**:
  - **39-state LBM solver**[19] with *Bhatnagar-Gross-Krook* (**BGK**) ***collision model***[20]
  - ***Spatial discretization***: 2nd order accurate
  - ***Time integration***: explicit ($CFL < 1$)
  - ***Initialization method***: cold start
  - ***Wall model***: extended turbulent wall model, dynamically accounting for pressure gradients[23]
  - ***SGS closure***: *RNG k-ϵ turbulence model*
    - Recalibrate the collision model to characteristic turbulent flow time scales [21,22]
    - Eddy viscosity ratio was set to $\nu_t/\nu = 0.3$ ($l_t = 5\ \mu$m)
  - ***Transition treatment***: fully turbulent, with laminar patches on the leading edges and fuselage nose (upstream of the tripping)
  - **Variable cubic Cartesian grid + immersed boundary method**
  - ***Simulation time***: 100 CTUs (0.65 sec)

$$\hat{f}_i(\vec{x} + c_i\Delta t, t + \Delta t) = \hat{f}_i(\vec{x}, t) + C_i(\vec{x}, t),$$

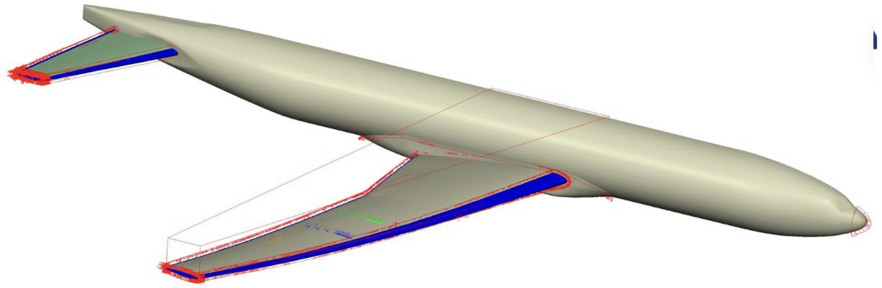
$$C_i(\vec{x}, t) = -\left[\hat{f}_i(\vec{x}, t) - \hat{f}_i^{\text{eq}}(\vec{x}, t)\right]\frac{\Delta t}{\tau}$$

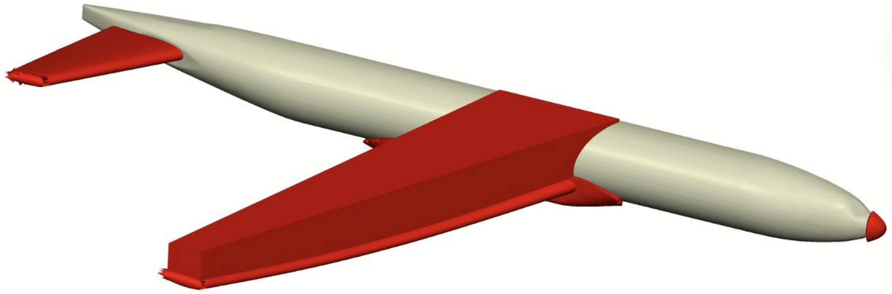
[19] Nie X. et al. (2009) “A lattice-Boltzmann / finite-difference hybrid simulation of transonic flow.” 47th AIAA Aerospace Sciences Meeting, 5-8 January, Orlando, FL.
[20] Bhatnagar et al. (1954) “A model for collision processes in gases. I. Small amplitude processes in charged and neutral one-component systems.” Physical Review 94, p. 511-525
[21] Chen, H. et al. (2003) “Extended-Boltzmann kinetic equation for turbulent flows.” Science 5633, p. 633-636.
[22] Yakhot V. and Orszag S. A. (1986) “Renormalization group analysis of turbulence. I. Basic theory.” In: Journal of Scientific Computing 1(1), p. 3-51.
[23] Fares E. and Noelting S. (2011) “Unsteady flow simulation of a high-lift configuration using a lattice Boltzmann approach.” 49th AIAA Aerospace Sciences Meeting, 4-7 January, Orlando, FL.

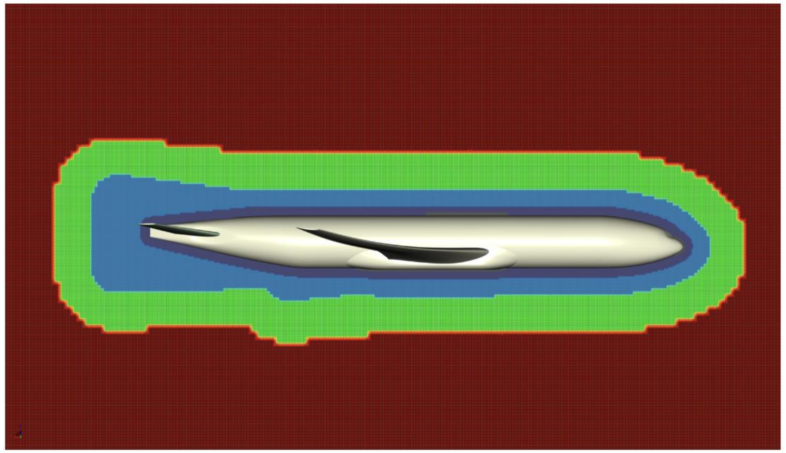
Grid Configurations
Overview

- **Cartesian 'in-house' grid**
  - 14 variable resolution (VR) regions
  - 5 refinement levels (x1.5)
  - Isentropic voxels

Grid level	Finest $\Delta y_w \times 10^5$	Total cell count	y^+
L1	182	21 M	250
L2	121	54 M	150
L3	81	156 M	100
L4	54	470 M	70
L5	36	1,500 M	40

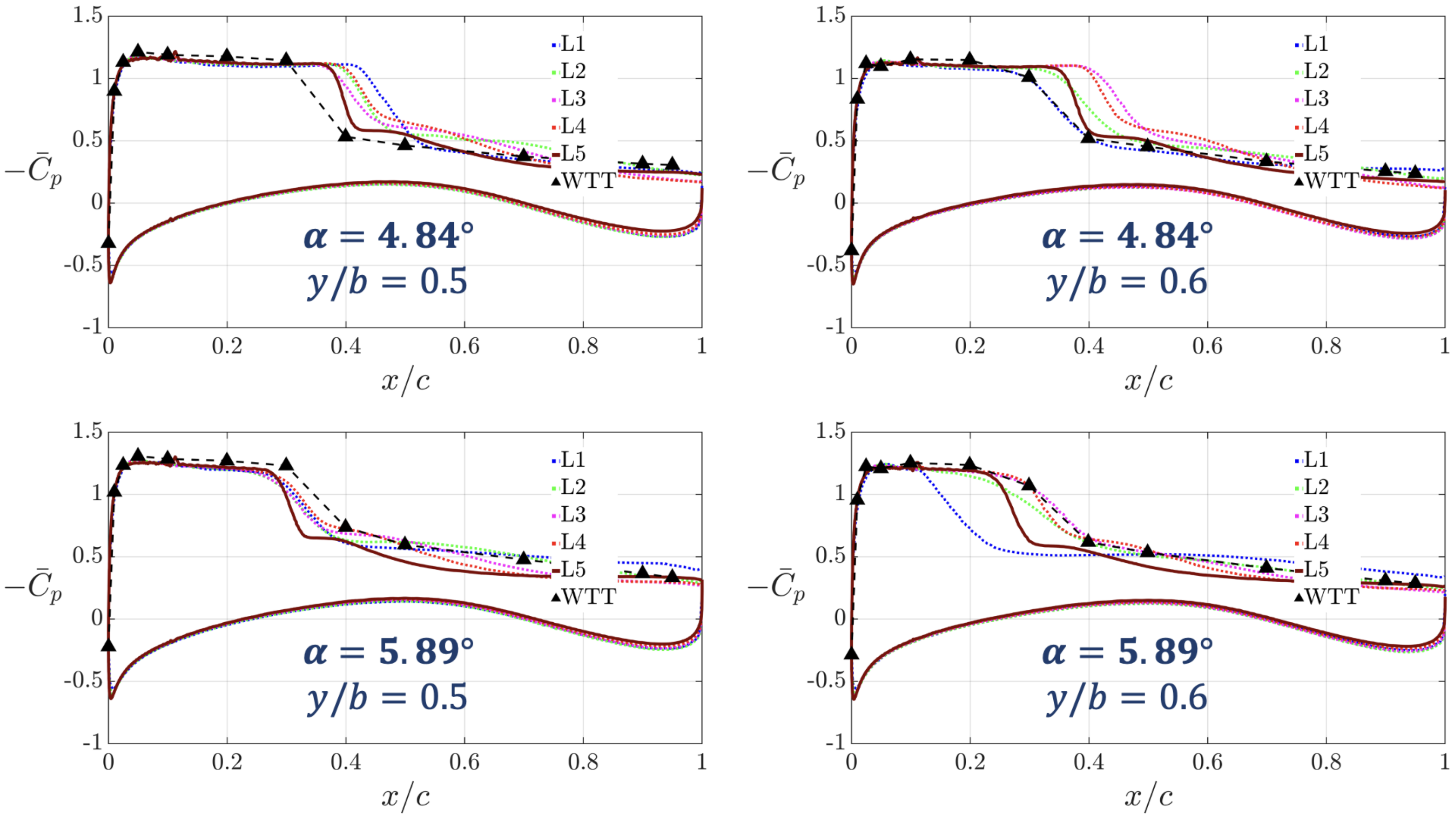


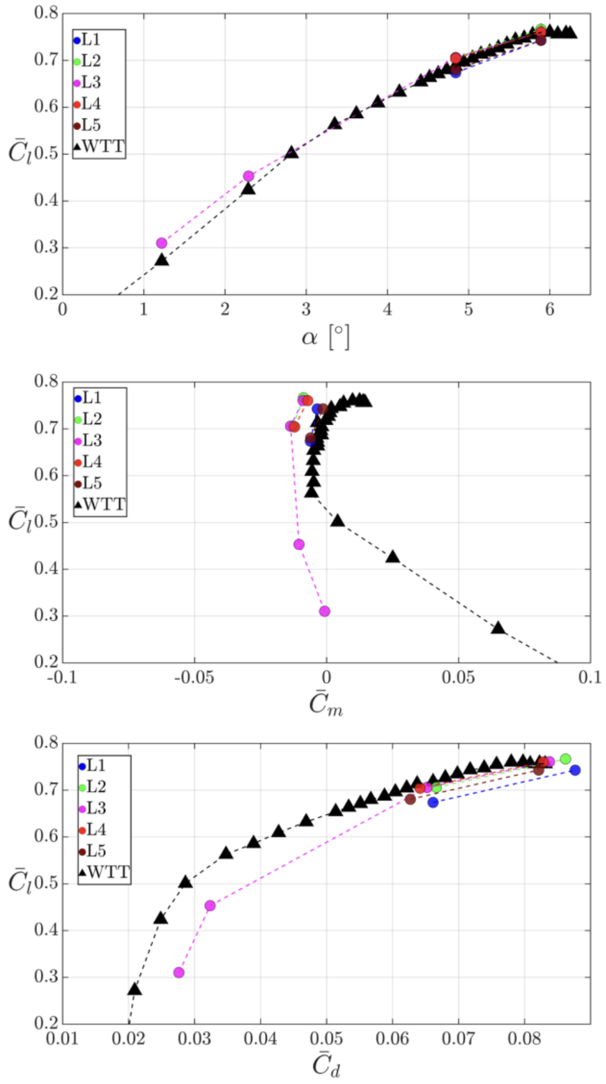




Results

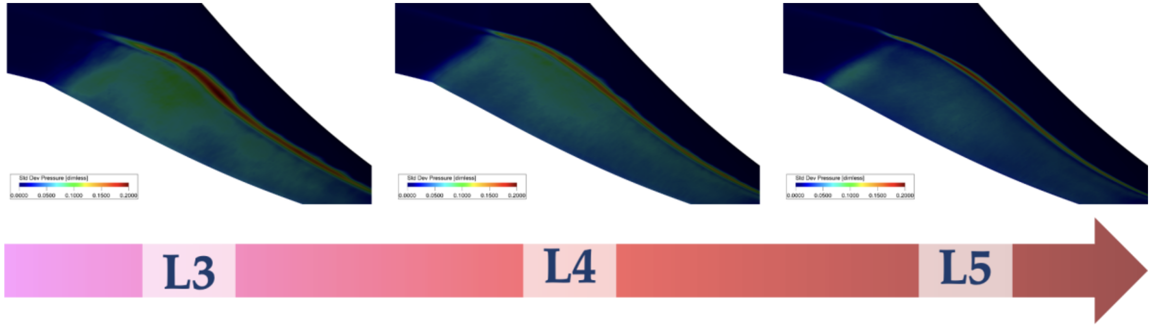
Mean F&M, $\overline{C}_p$

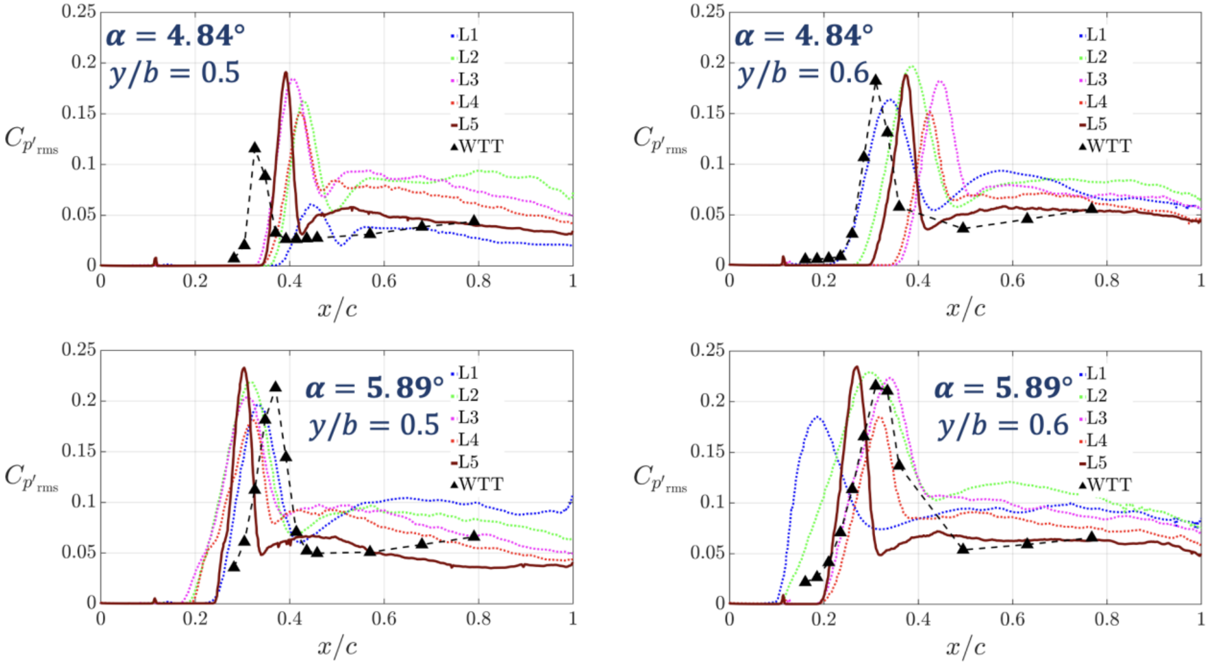


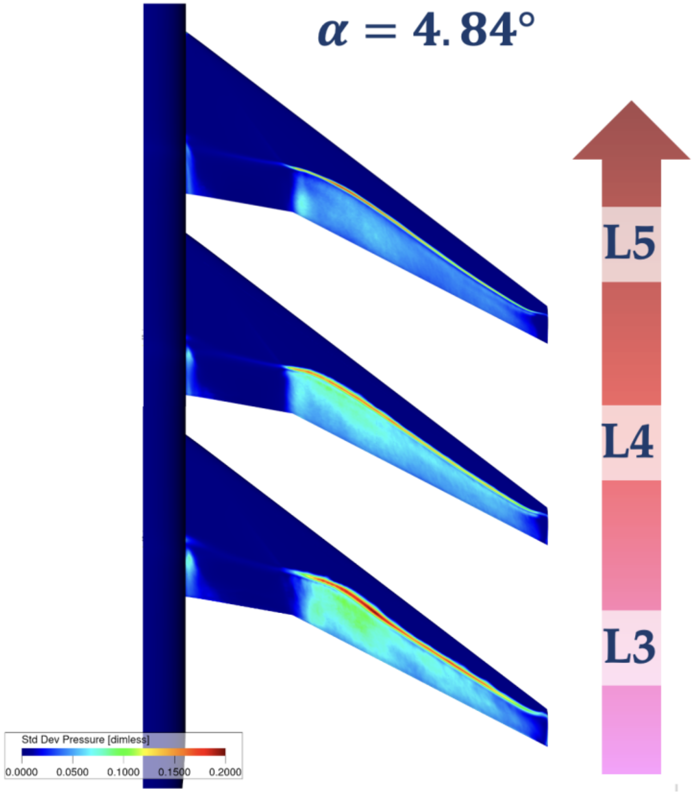


Results

$C_{p'_{\mathrm{rms}}}$

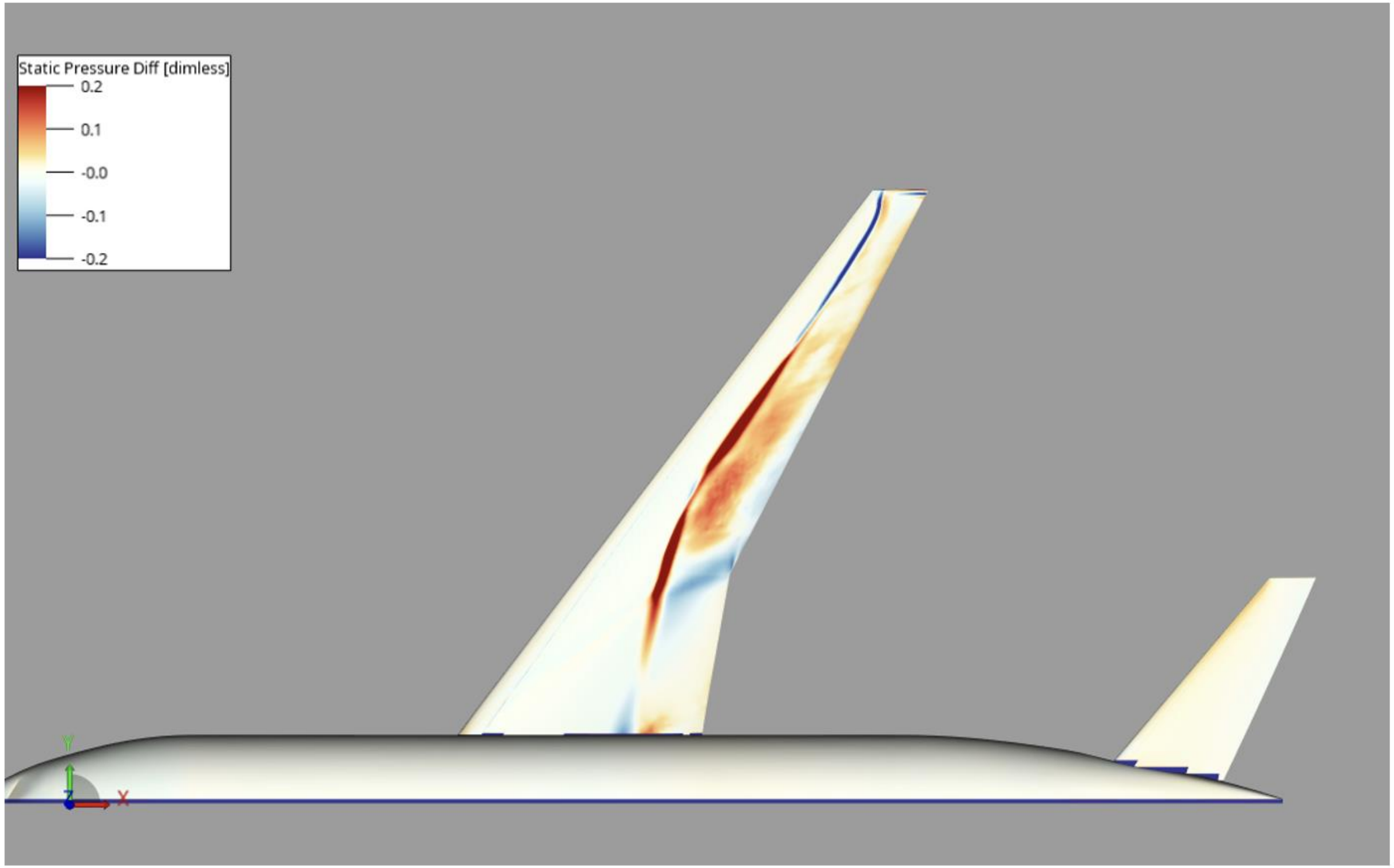






Results

$C_{p'_{\text{rms}}}$ - *difference between* L3 *to* L5 @ $\alpha = 4.84°$



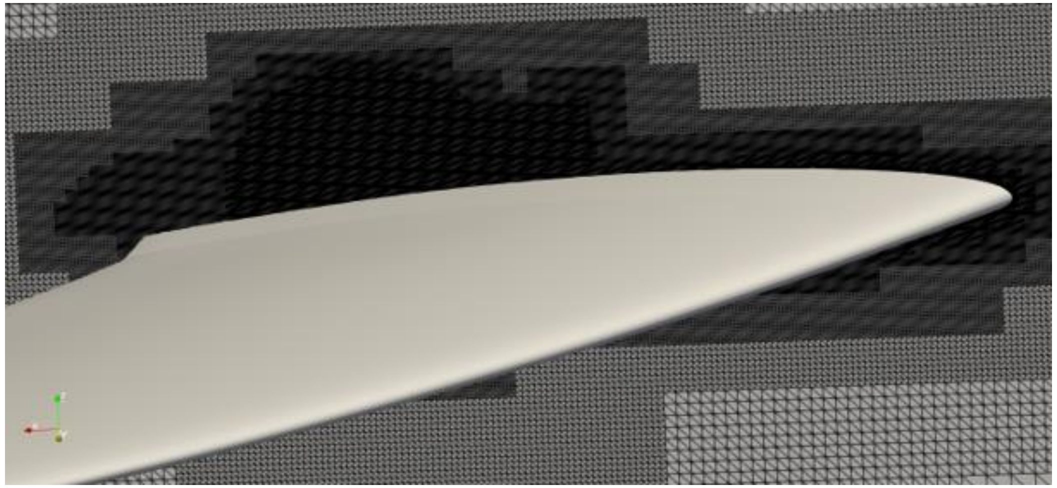
Participant Briefs – Embraer

- **Eduardo Molina, Joao Luiz Perez**
- **Embraer**

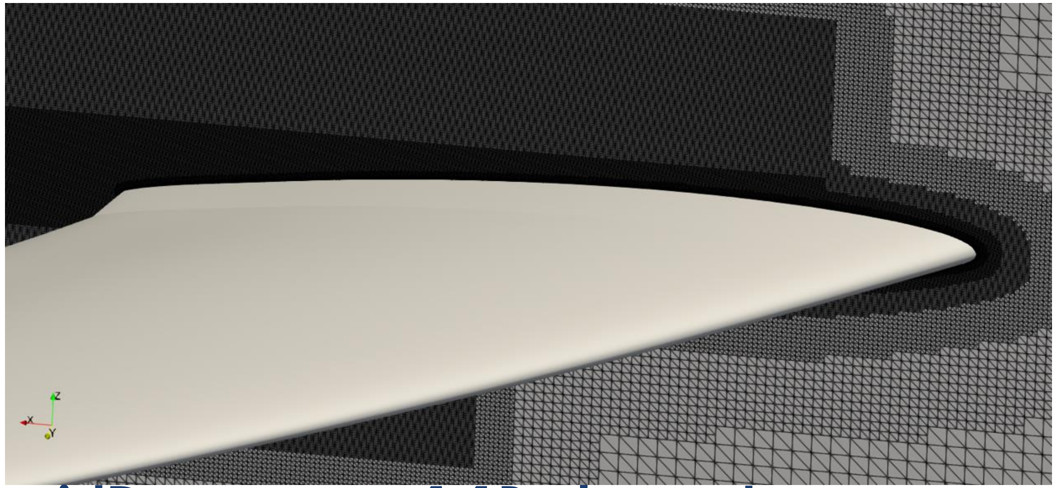
Volcano ScaLES (v2025.09)

- Immersed Boundary WMLES
- 4th Order Kinetic Energy Preserving Discretization
- Explicit SSP 3rd Order Runge-Kutta

- Cartesian Recursive Octree Mesh
- Numerical Tripping
- Dynamic Smagorinsky Model

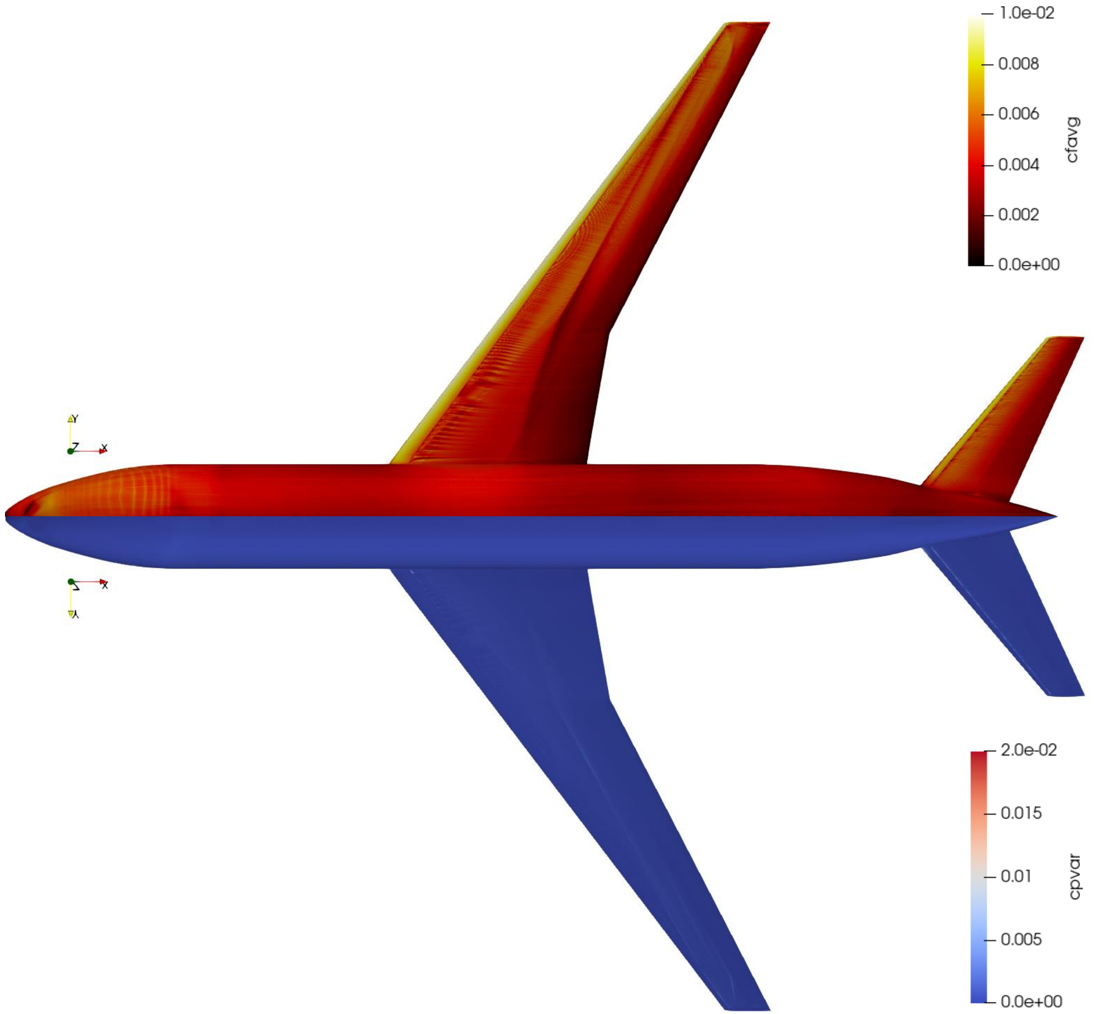


gridA+: approx. 670M elements

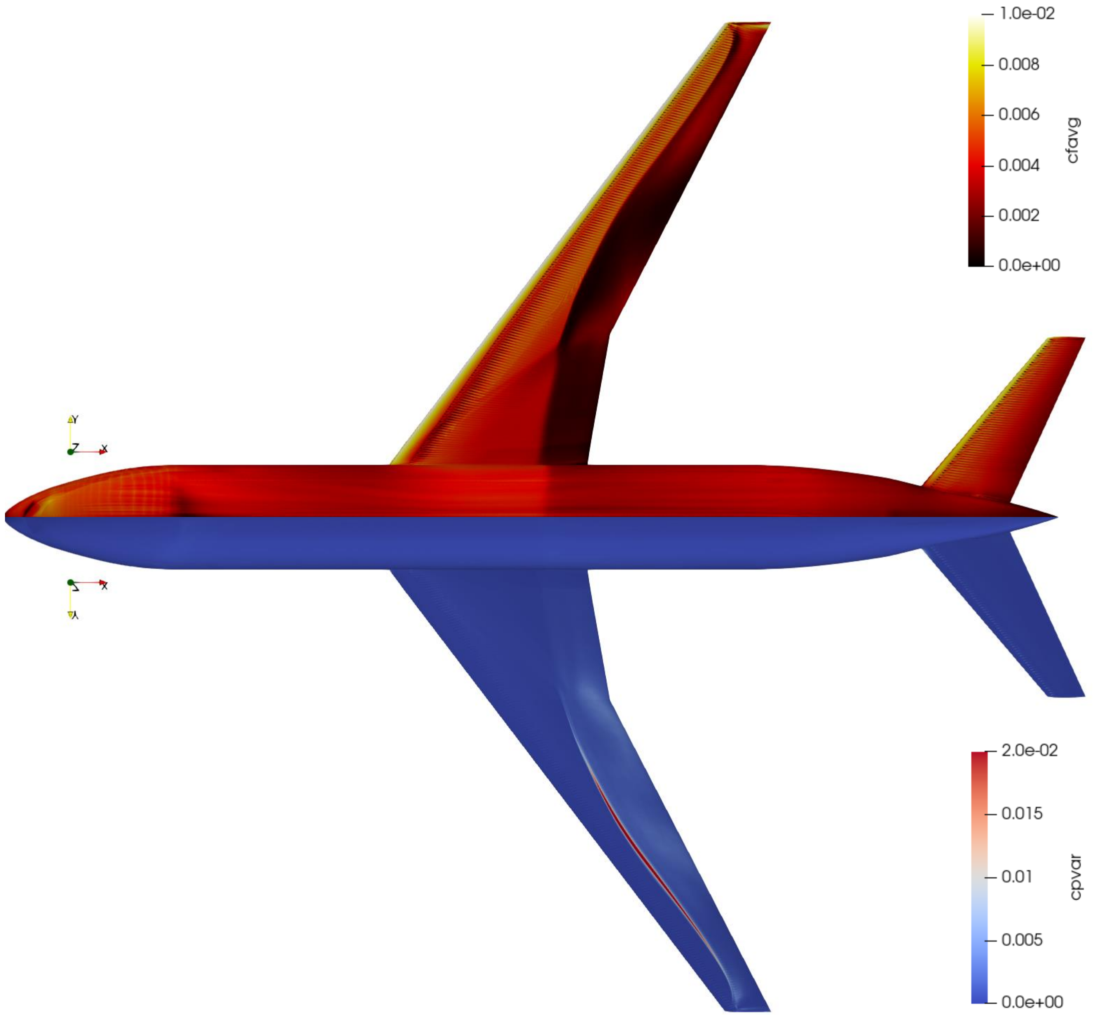


gridD+: approx. 1.1B elements

Participant Briefs – Embraer

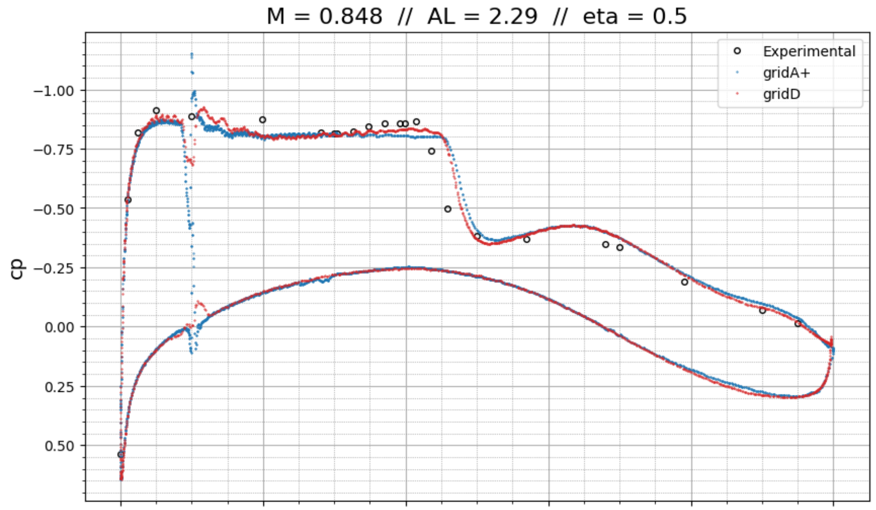


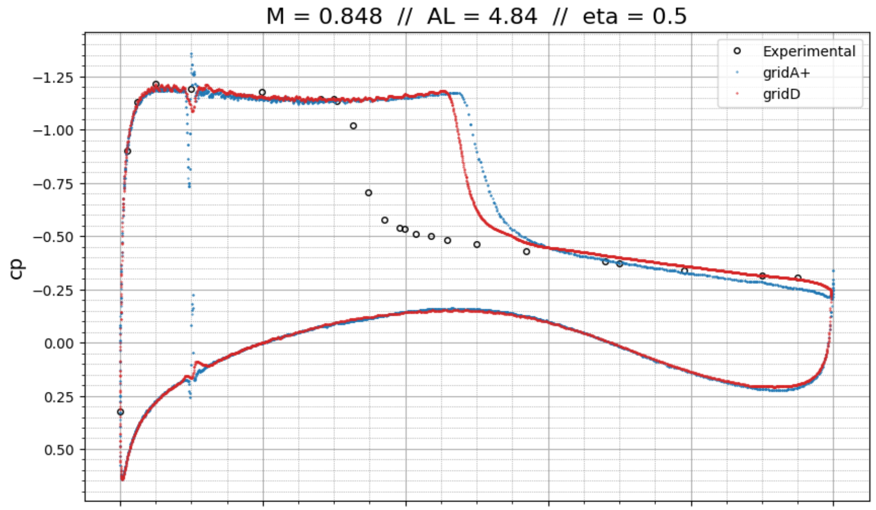
AoA = 2.29◦

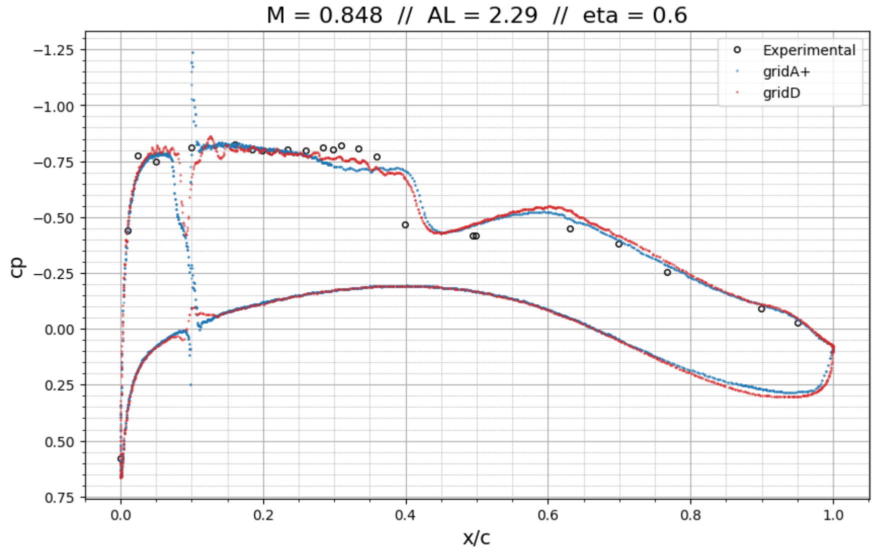


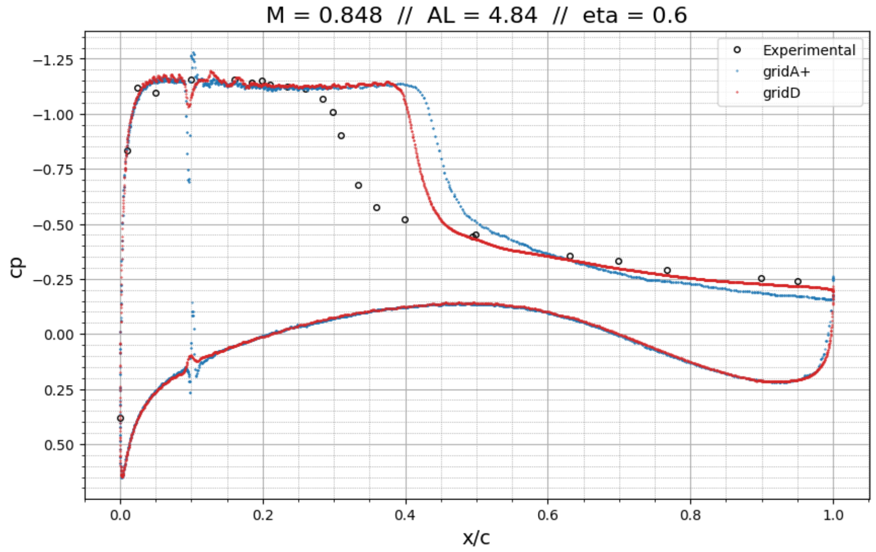
AoA = 4.84◦

Participant Briefs – Embraer



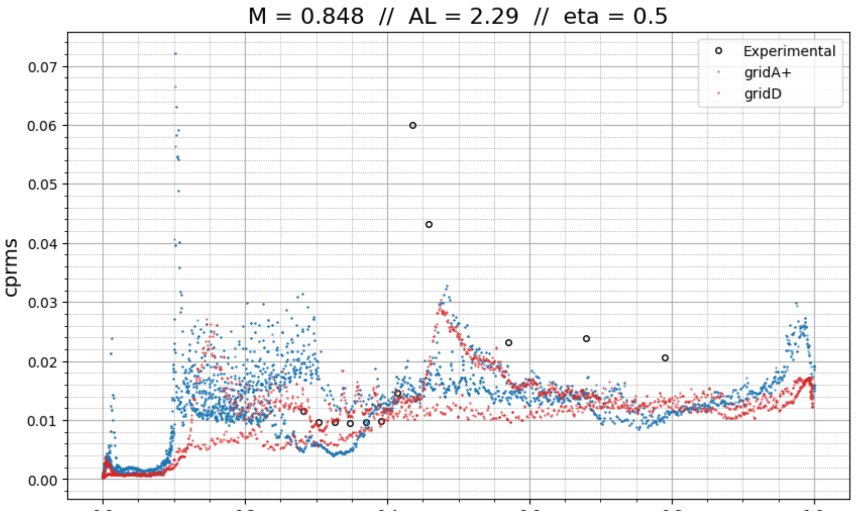


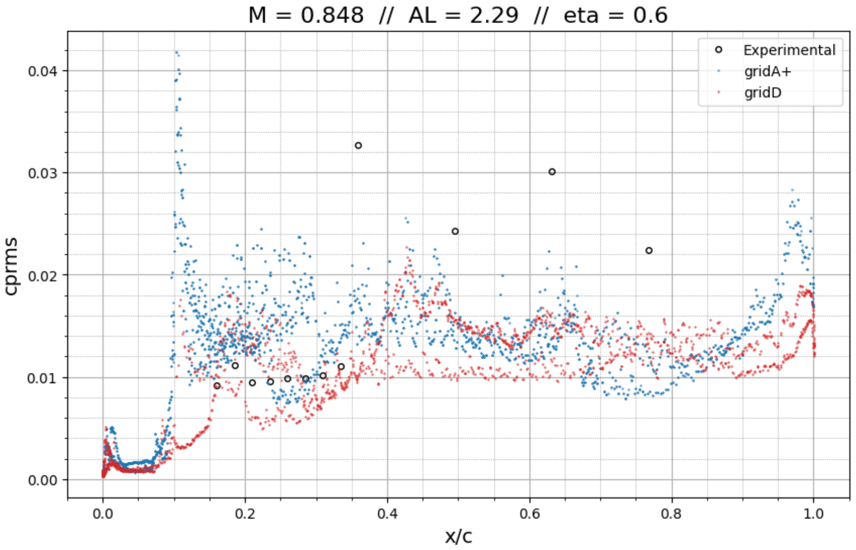


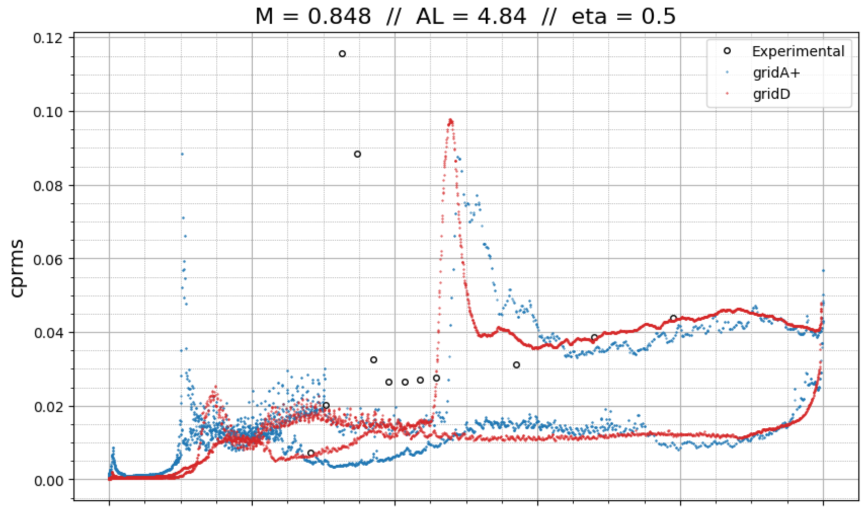


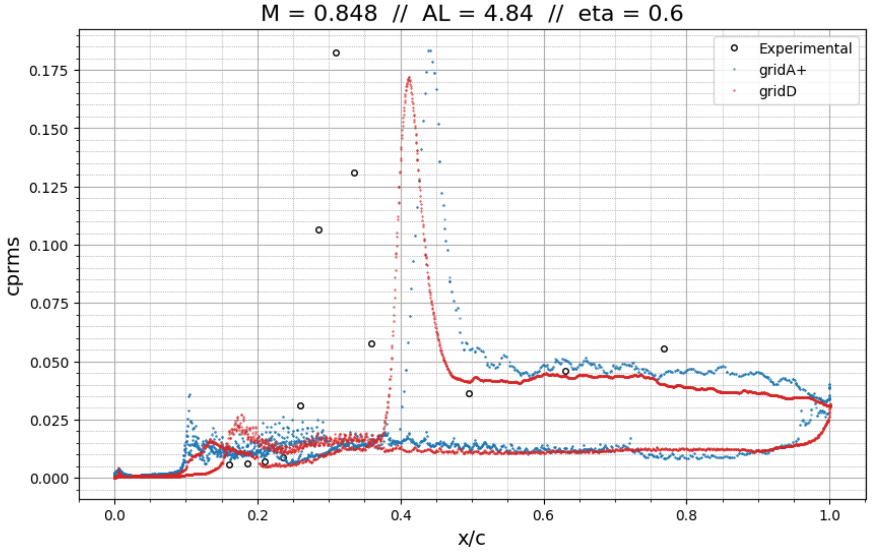
AoA = 2.29° **AoA = 4.84°**

Participant Briefs – Embraer









AoA = 2.29°

AoA = 4.84°

See you in June!

AIAA

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