# DPW-8 & AePW-4
# All-Hands Meeting and Mini Workshop 1

January 9, 2025

In-Person and Virtual

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

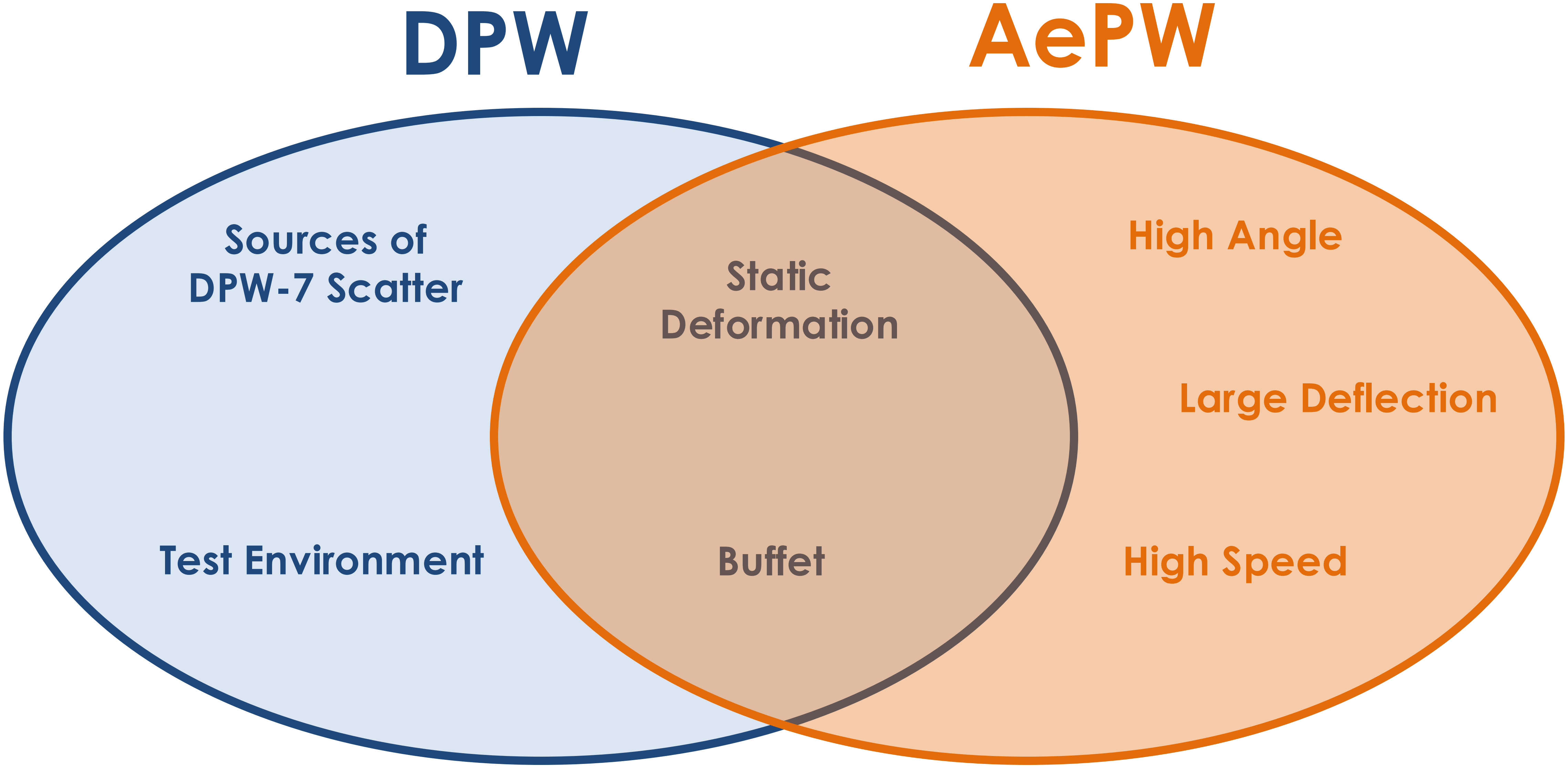
# Outline

| | |
|---|---|
| 9:30 | Introduction and Motivation |
| 9:40 | Working Group Updates |
| 10:15 | Mini Workshop |
| 10:50 | CRM Look-Ahead |
| 11:25 | Open Discussion |
| 1:00 | Bayhill 26 Available for Discussion Until 3:00 |

# Workshop Overview

- **DPW and AePW will hold a co-hosted workshop at Aviation 2026 (San Diego, CA)**
  - DPW-8 and AePW-4
- **The next generation of computational goals is highly multidisciplinary**
  - There are things that DPW does well, that AePW does not: and vice-versa
  - If we work together, we can push the SOA further, faster, than if we remain separate
- **We are using a working group (WG) model, with 7 total WGs**
  - Two of the WGs live entirely under the DPW umbrella
  - Three of the WGs live entirely under the AePW umbrella
  - Two of the WGs are co-sponsored
- **Goals**
  - Benchmark methods performance between multiple codes and schemes
  - Establish SOA for static and dynamic FSI; identify opportunities for improvement
  - DPW: mature the foundations required for accurate predictions
  - AePW: progress toward best practices for aeroelastic solvers

# Working Groups Layout



**DPW**

**AePW**

Sources of DPW-7 Scatter

Test Environment

Static Deformation

Buffet

High Angle

Large Deflection

High Speed

# Workshop Leadership

| Name | Role | Email Address |
|---|---|---|
| Brent Pomeroy | DPW, Buffet WG | brent.w.pomeroy@nasa.gov |
| Ben Rider | DPW, Static Deformation WG | ben.j.rider2@boeing.com |
| Bret Stanford | AePW, Buffet WG | bret.k.stanford@nasa.gov |
| Pawel Chwalowski | AePW, High Angle WG | pawel.chwalowski@nasa.gov |
| Marshall Galbraith | Scatter WG | galbramc@mit.edu |
| Kevin Holst | Scatter WG | kholst@utk.edu |
| Ed Tinoco | Scatter WG | entinoco@icloud.com |
| Sheida Hosseini | Test Environments WG | seyedeh.sheida.hosseini@nasa.gov |
| Melissa Rivers | Test Environments WG | s.m.rivers@nasa.gov |
| Garrett McHugh | Static Deformation WG | garrett.mchugh@nasa.gov |
| Stefan Keye | Static Deformation WG | stefan.keye@dlr.de |
| Andrea Sansica | Buffet WG | sansica.andrea@jaxa.jp |
| Daniella Raveh | Buffet WG | daniella@technion.ac.il |
| Hadar Ben-Gida | Buffet WG | bengida1989@gmail.com |
| Fulvio Sartor | Buffet WG | fulvio.sartor@onera.fr |
| Jeff Housman | Buffet WG | jeffrey.a.housman@nasa.gov |
| Johan Jansson | Buffet WG | jjan@kth.se |
| Rafa Palacios | Large Deformation WG | r.palacios@imperial.ac.uk |
| Kirk Brouwer | High Speed WG | kirk.brouwer.1@us.af.mil |

# Workshop Leadership Global Presence

Source: OpenStreetMap
Open source, subject to Open Database License

# Goals for Today

1. **Give a brief status update for each of the 7 Working Groups (WGs)**
    - Emphasis on "Key Questions"

2. **The two joint WGs, as well as the Scatter group, have considered a preliminary 2D airfoil case: we will present some of this data in the form of a mini-workshop**

3. **Finally, the two joint WGs will soon transition from the airfoil case to more realistic wing-body-tail problems (CRM)**
    - Grid requirements and update
    - Discussion of available experimental data
    - Discussion of available finite element models

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# Outline

9:30 Introduction and Motivation

**9:40 Working Group Updates**

- AePW: High Angle, High Speed, and Large Deformation
- DPW: Source of Scatter and Test Environment
- Hybrid: Static Deformation and Buffet

10:15 Mini Workshop

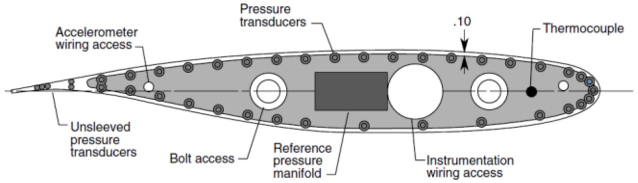
10:50 CRM Look-Ahead

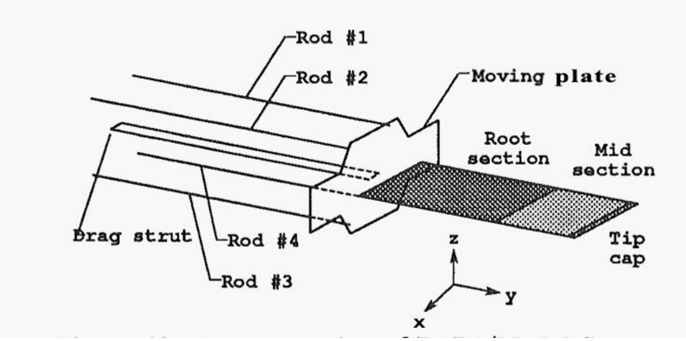
11:25 Open Discussion

1:00 Bayhill 26 Available for Discussion Until 3:00

# Working Group Update: AePW High Angle

- **Led by Pawel Chwalowski, NASA Langley**
  - 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 available, as well as a family of unstructured meshes
- **Scheduled to be tested again in TDT in summer of 2025 (uPSP, PIV, sweep of Mach and AoA's )**





# High Angle WG: Current Workshop Cases

- **Mandatory case in 3D**
  - Flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° – 6°

- **Optional case in 3D**
  - Flutter prediction at Mach 0.74, 0.76, 0.78 and angle-of-attack 3°

- **Mandatory case in 2D (?)**
  - Flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° – 6°

Currently we have 7 teams utilizing time-domain, frequency domain, and ROM methods to compute flutter dynamic pressure and frequency.

# High Angle WG: Key Questions

- Are uRANS solutions sufficient to predict flutter at BSCW experimental conditions, considering a separated flow?
- Will additional experimental data be available 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?
- Is there a quantifiable relationship between the shock buffet and the flutter onset?
- How do we determine uncertainty in our analyses, considering nonlinear aerodynamic model, linear structural dynamics model, the coupling between models, and the experimental data?

# Working Group Update: AePW High Speed

- **Leadership: Kirk Brouwer, US Air Force Research Laboratory**
- **Meets the fourth Thursday of every-other-month at 5:00 pm Eastern time**
  - And at 8:00 am ET on the alternating months
- **Selected challenge problems**
  - RC-19: large-amplitude, nonlinear dynamics of a thin panel with and without SBLI
  - HyMAX: Linear response of a cantilevered plate to transitional, separated SBLI
- **Current participation: 109 members on the email chain, 6 groups working on RC-19, 4 groups working on HyMAX**
- **Near term goals: Continue working until more participants make comparisons with experiments (Several participants presenting at AIAA Aviation)**

| | Duke | NASA | DLR | UNSW | MIT | Stevens | UC/ARL | Metacomp |
|---|---|---|---|---|---|---|---|---|
| RC-19 | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| HyMAX | ✓ | | | | ✓ | ✓ | ✓ | |

Distribution Statement A: Approved for Public Release; Distribution is Unlimited. AFRL-2025-0019

# High Speed WG: Future Directions

- **RC-19 updates:**
  - – Separated SBLI with snap-through
  - – Swept SBLI configurations (attached, swept SBLI configuration already tested and a separated swept SBLI is planned)

- **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:**
  - – M6HRF compliant panel tests led by Zach Riley (AFRL)
  - – Inputs from AePW HSWG participants/AIAA FSI DG?

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# High Speed WG: Key Questions

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

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# Working Group Update: AePW Large Deformation

- **Leadership: Rafa Palacios, Imperial College London**
  - Monthly tag-ups on the third Thursday of the month
  - Repo with meeting presentations and videos hosted at Imperial
  - 62 members on mailing list
- **Focus so far on assessment of potential experimental configurations**
- **Candidate test case shortlist:**
  - Pazy Wing (LCO, swept wing): Technion
  - Delft-Pazy wing (gust response, floating wingtip): TU Delft
  - EASE (pitch/plunge mounted, ASE): U. Michigan
- **Recent straw poll showed much work on simulation has started, mostly on Pazy wing. That will pick momentum during 2025**

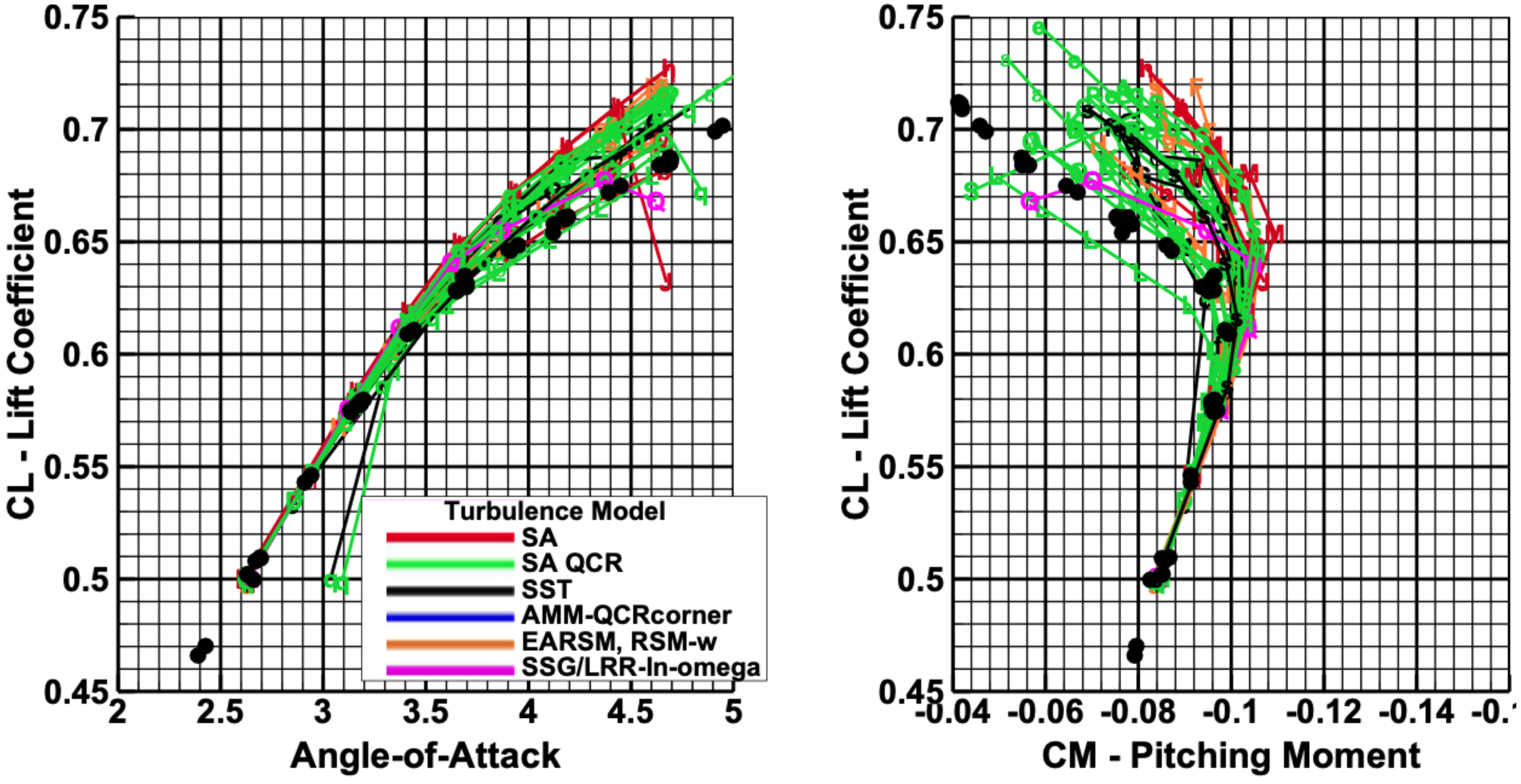
# Large Deformation WG: Key Questions

- **What are the unique aeroelastic phenomena of very flexible structures that undergo large deformations?**
  - Post-flutter behaviour, large-amplitude gust response, control surface forces
  - How do these vary for different geometries and boundary conditions (sweep, rigid-body motions)?
- **What are the structural/aerodynamic nonlinearities driving the LCO of very flexible wings?**
- **What are adequate structural/aerodynamic (steady and unsteady) modeling assumptions?**
  - Benchmarking of solution methods
  - Recommendations for a production environment

Distribution Statement A: Approved for Public Release; Distribution is Unlimited. AFRL-2025-0019

# Working Group Update: DPW Scatter

- **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

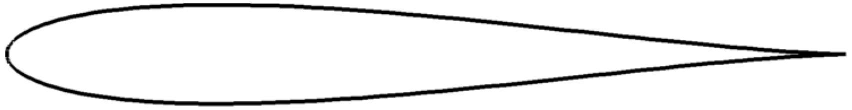
# Scatter WG: Update

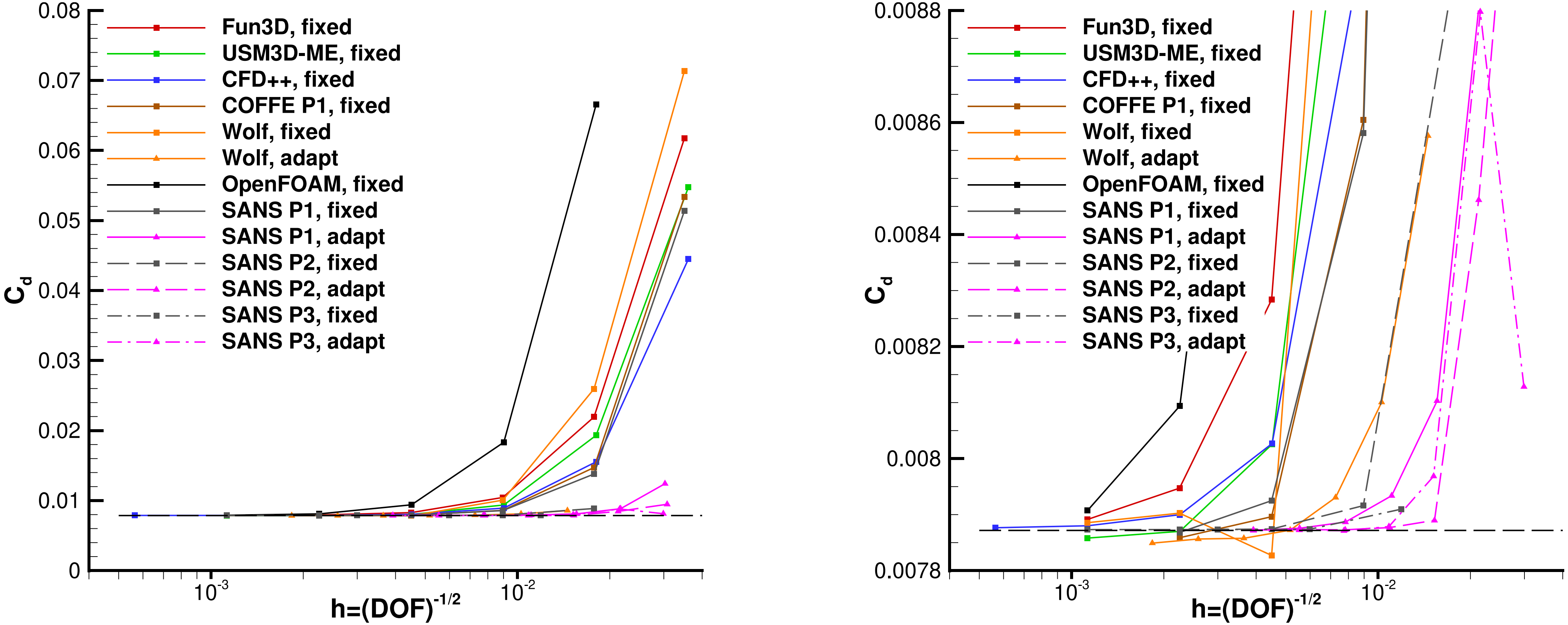
- **Three test cases defined to varying degrees**
  - Test Case 1a: ONERA OAT15A (now)
    - Establish current level of scatter
    - **These data will be shown later, as part of the mini-workshop**
  - Test Case 1b: Joukowksi Airfoil
    - Pin-point causes of scatter
  - Test Case 1c: ONERA OAT15A
    - Significantly reduced scatter
  - Test Case 2: CRM Wing
    - Examine scatter for 3D

- **Sustained meeting cadence and structure**
  - Approx 20 people on distribution list
  - Average 15 attendees in each meeting
  - Meeting Tuesdays 10am ET on 2nd and 4th week of the month

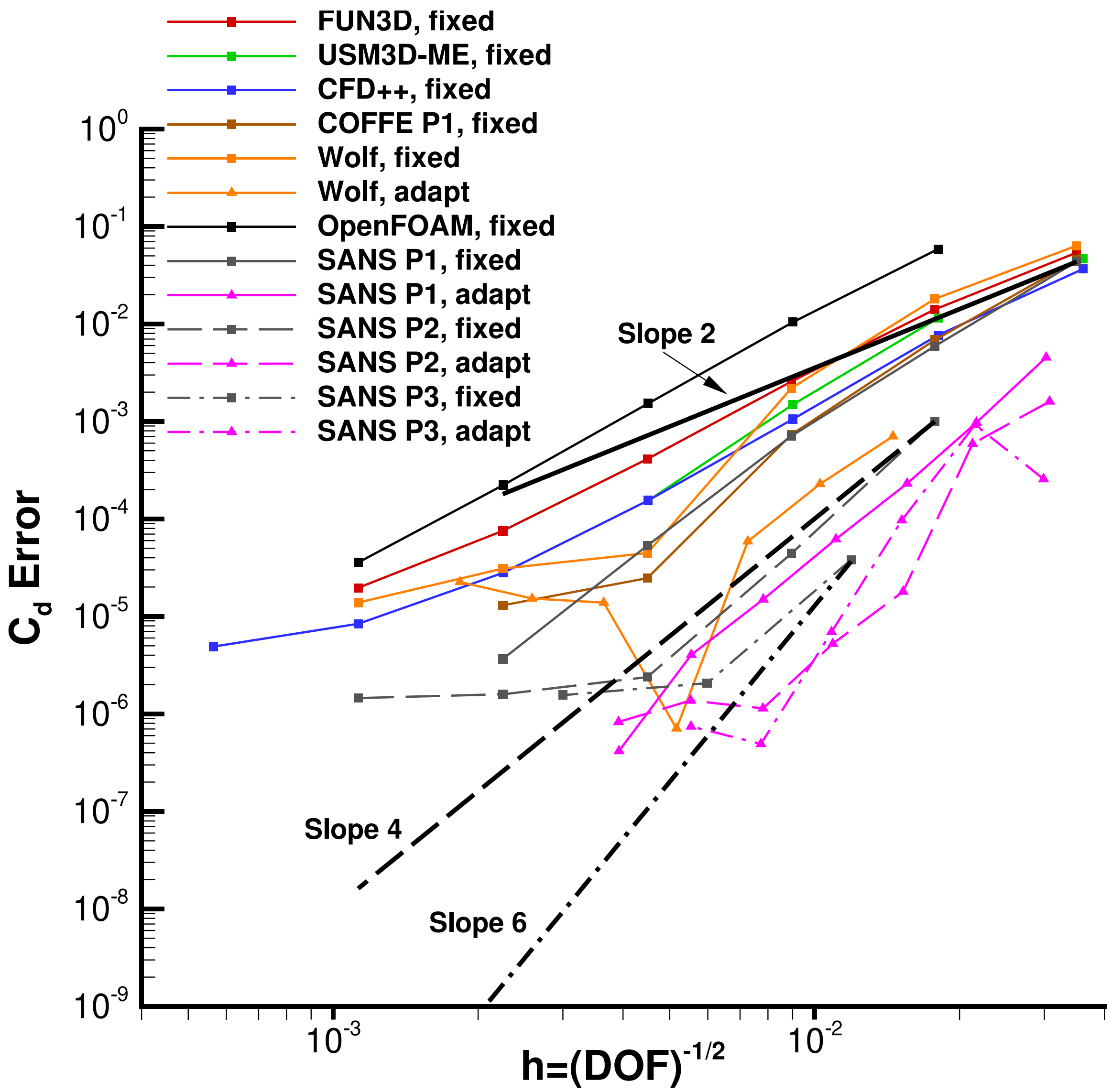
# Scatter WG: Joukowski Airfoil

- High-Fidelity CFD Verification Workshop 2024
- Cusped trailing edge – remove inviscid singularity
- Zero angle of attack – stagnation point at leading edge





# Scatter WG: Joukowski Airfoil Order of Accuracy



# Scatter WG: Key Questions

- What is the source of scatter amongst the the DPW-7 CRM simulations?
- Can RANS capture the early portion of pitchup?
- What grid metrics are needed to adequately capture the shock?

# Working Group Update: DPW Test Environments

- **35 participants expressed interest in original survey**
- **Working Group High Level Goal:**
  - Increase understanding and quantify expectations for comparisons between free-air CFD and measured Wind Tunnel "truth"
  - Force/Moment balance and pressure tap measurements
- **Anticipated Timeline**
  - DPW-8
    - Phase 0: ONERA OAT15A Airfoil
    - Phase 1: Tare and interference from Model mounting systems
      - NASA CRM
      - NASA CRM + Upper Sweep Strut & Sting
      - NASA CRM + Upper Sweep Strut & Sting + Arc Sector
  - DPW-8 +
    - Phase 2: Wind Tunnel Walls
      - NASA CRM
      - NASA CRM + Upper Sweep Strut & Sting
      - NASA CRM + Upper Sweep Strut & Sting + Arc Sector

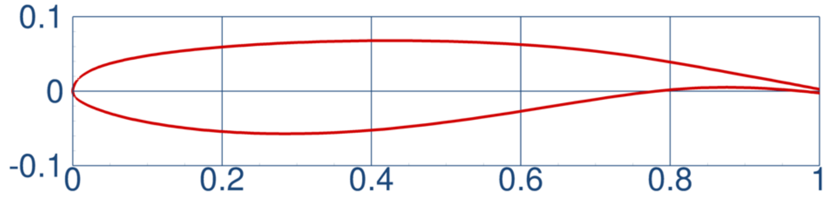
Stay tuned for monthly meeting invites!

Interested to participate?
Reach out to Sheida @
seyedeh.sheida.hosseini@nasa.gov

# Test Environments 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?

# Joint WGs: Buffet and Static Deformation



- **Both joint WGs (and the DPW-Scatter group also) have considered a preliminary 2D airfoil case**
  - Steady AoA-sweep of the transonic ONERA OAT15A
  - We will present some of this data in the form of a mini-workshop

- **The Buffet WG has also considered unsteady buffeting flow over ONERA OAT15A**
  - We have a few submitted results for these cases, but not many

- **Once the airfoil work is completed, both joint WGs will transition to CRM cases**
  - Static Deformation WG: a steady CRM model tested at NASA
  - Buffet WG: a buffeting CRM model tested at JAXA, both rigid buffet and aeroelastic buffet

# Working Group Update: Static Deformation

- **Leadership**
  - Ben Rider, Boeing Commercial Airplanes
  - Stefan Keye, DLR
  - Garrett McHugh, NASA Langley
- **Third Friday of every month at 10:00 Eastern time**
- **Approximately 75 people on the distribution list, with an average of 25 attendees in each meeting**

# Working Group Update: Static Deformation

- **Four subcases:**
  1. Steady ONERA OAT15A results
     - Considered by the Buffet and Scatter WGs also
     - Focus of the upcoming mini-workshop
  2. Validation of the NASA CRM structural FEM
  3. Steady flow over the flexible NASA CRM model: wing/body
  4. Steady flow over the flexible NASA CRM model: wing/body/nacelle/pylon

- **The CRM work will simulate the NASA LaRC NTF test**
- **Committee-supplied grids and FEMs**
- **Focus on computed forces/moments, wing deflection/twist, and sectional Cp distribution**

# 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?**

# Working Group Update: Buffet

- **Leadership:**
  - Hadar Ben-Gida
  - Brent Pomeroy
  - Daniella Raveh
  - Andrea Sansica
  - Bret Stanford
- **Third Tuesday of every month, 10:00 Eastern**
- **Approximately 110 people on the distribution list, with an average of 50 attendees in each meeting**

# Working Group Update: Buffet

- **Four subcases:**
  1. Steady ONERA OAT15A results
     - Considered by the Static Deformation and Scatter WGs also
     - Focus of the upcoming mini-workshop
  2. Unsteady buffeting ONERA OAT15A results
     - Still collecting this data from participants
  3. Buffeting flow over the rigid JAXA CRM model
  4. Buffeting flow over the flexible JAXA CRM model
- **Four subgroups**
  1. URANS (Fulvio Sartor)
  2. Hybrid RANS/LES (Jeff Housman)
  3. WMLES and Beyond (Johan Jansson)
  4. Non-time-domain methods (TBD)

# Buffet WG: Key Questions

- What is the current state of the art of beyond-RANS, static-geometry simulations leading up to and beyond buffet?
- What gridding best-practices can be established for scale-resolving simulations?
- What is the state-of-the-art for unsteady CFD coupled with a dynamic structural model, and how accurate are these schemes?

# Outline

9:30 Introduction and Motivation

9:40 Working Group Updates

**10:15 Mini Workshop**

- Steady ONERA OAT15A test case
- Unsteady ONERA OAT15A test case
- Data submission process

10:50 CRM Look-Ahead

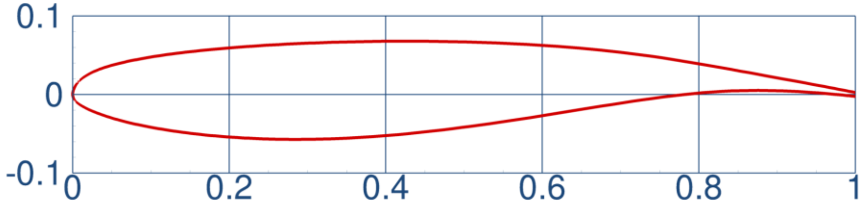
11:25 Open Discussion

1:00 Bayhill 26 Available for Discussion Until 3:00

# Steady ONERA OAT15A Test Case

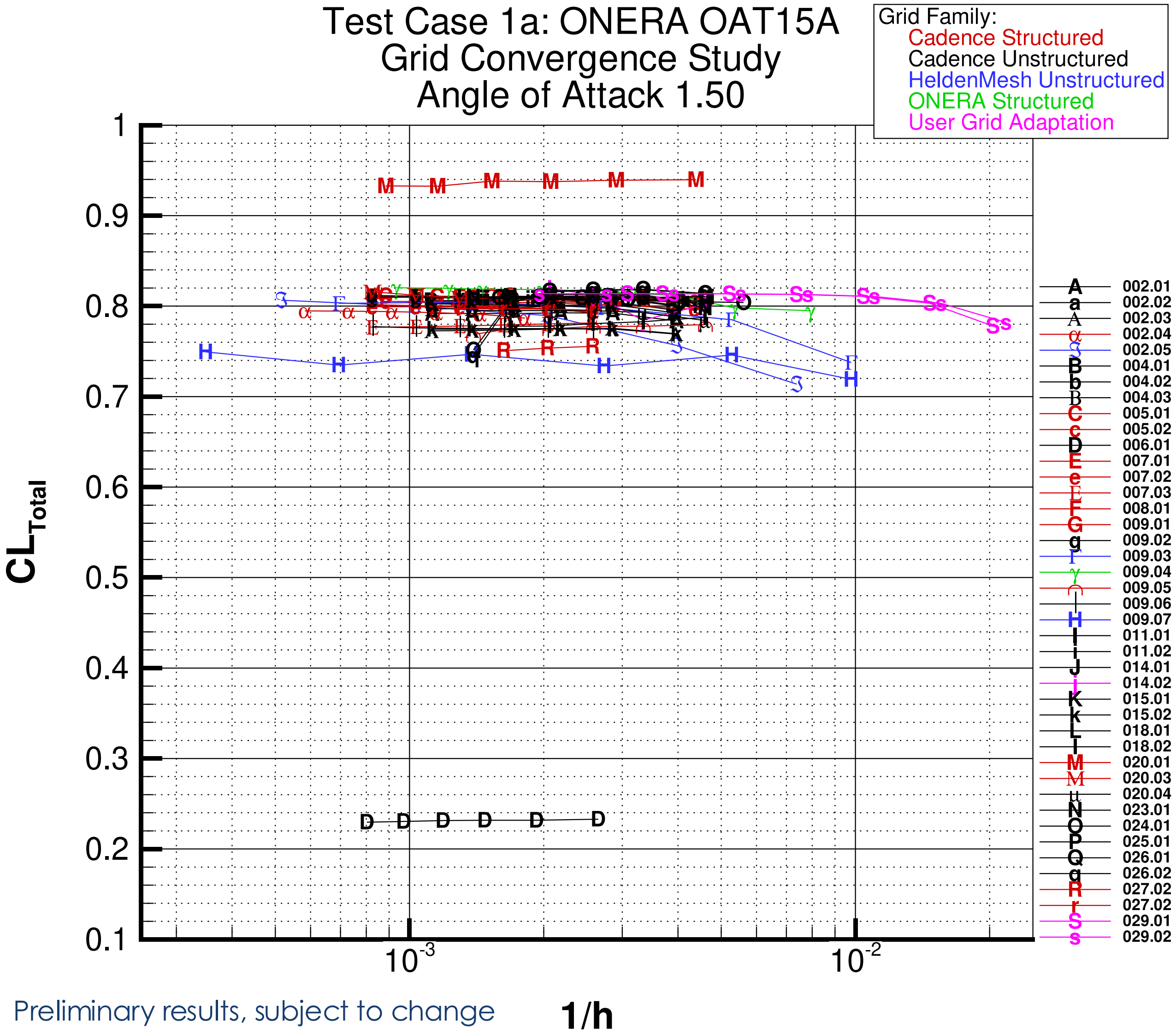
- **Validation of steady CFD analysis, required**
- **Users are encouraged to employ best practices**
- **Settings**
  - – Steady CFD (e.g., RANS)
  - – Prefer some version of SA, multiple turbulence models can be submitted
  - – Use periodic boundary conditions for sidewall boundary conditions
- **Grids**
  - – Six-member grid family; four are required, six are desirable
  - – Encourage use of committee-supplied grids; user-generated grids are acceptable
  - – Three committee-supplied once-cell-wide grid topologies are provided
- **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**
  - – Experimental conditions (for reference): $P_{total}$=102.4 kPa; $P_{static}$=71.8 kPa

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

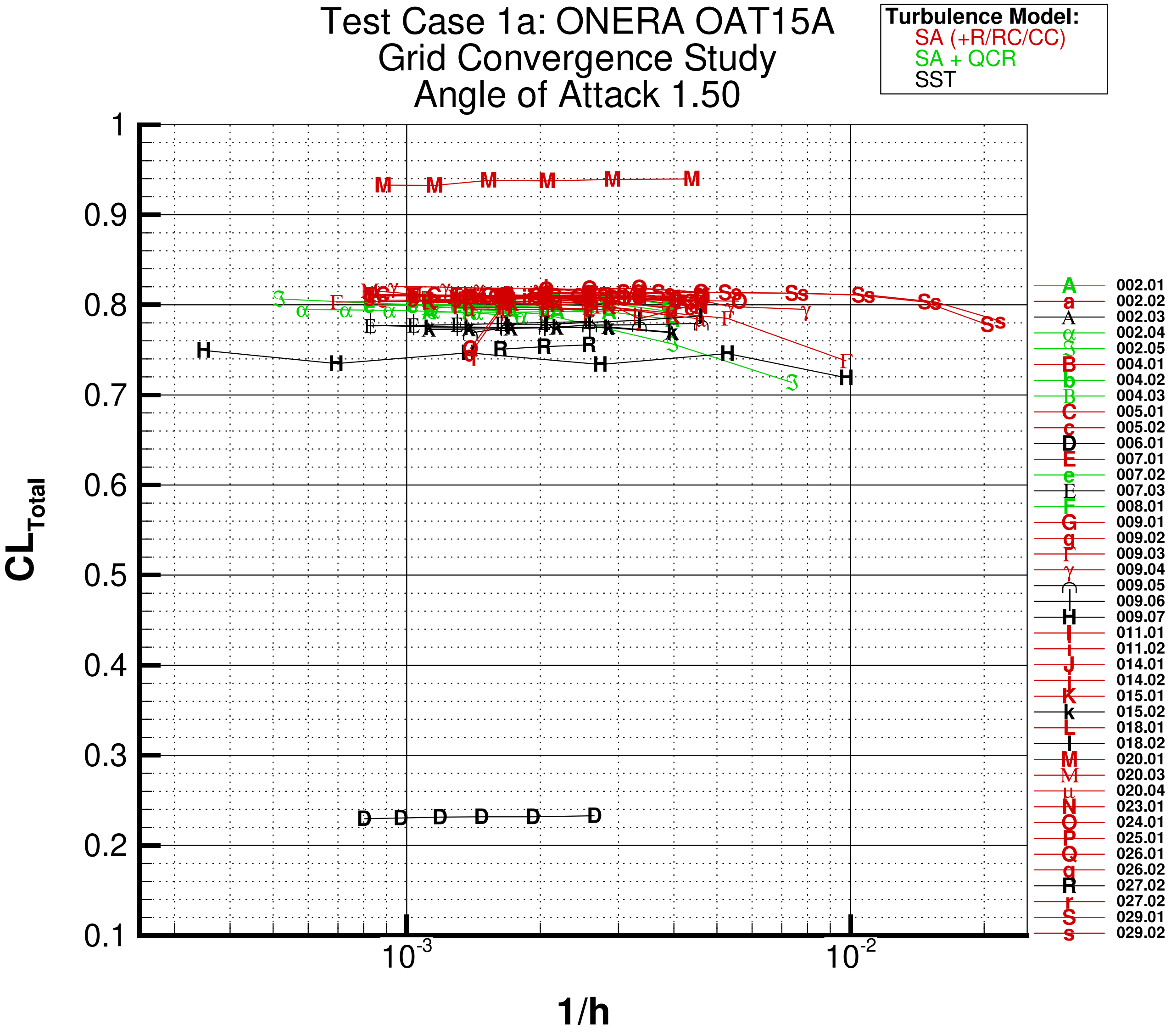


ONERA OAT15A Transonic Airfoil

# ONERA OAT15A $C_L$ Convergence: $\alpha = 1.5°$



Test Case 1a: ONERA OAT15A
Grid Convergence Study
Angle of Attack 1.50



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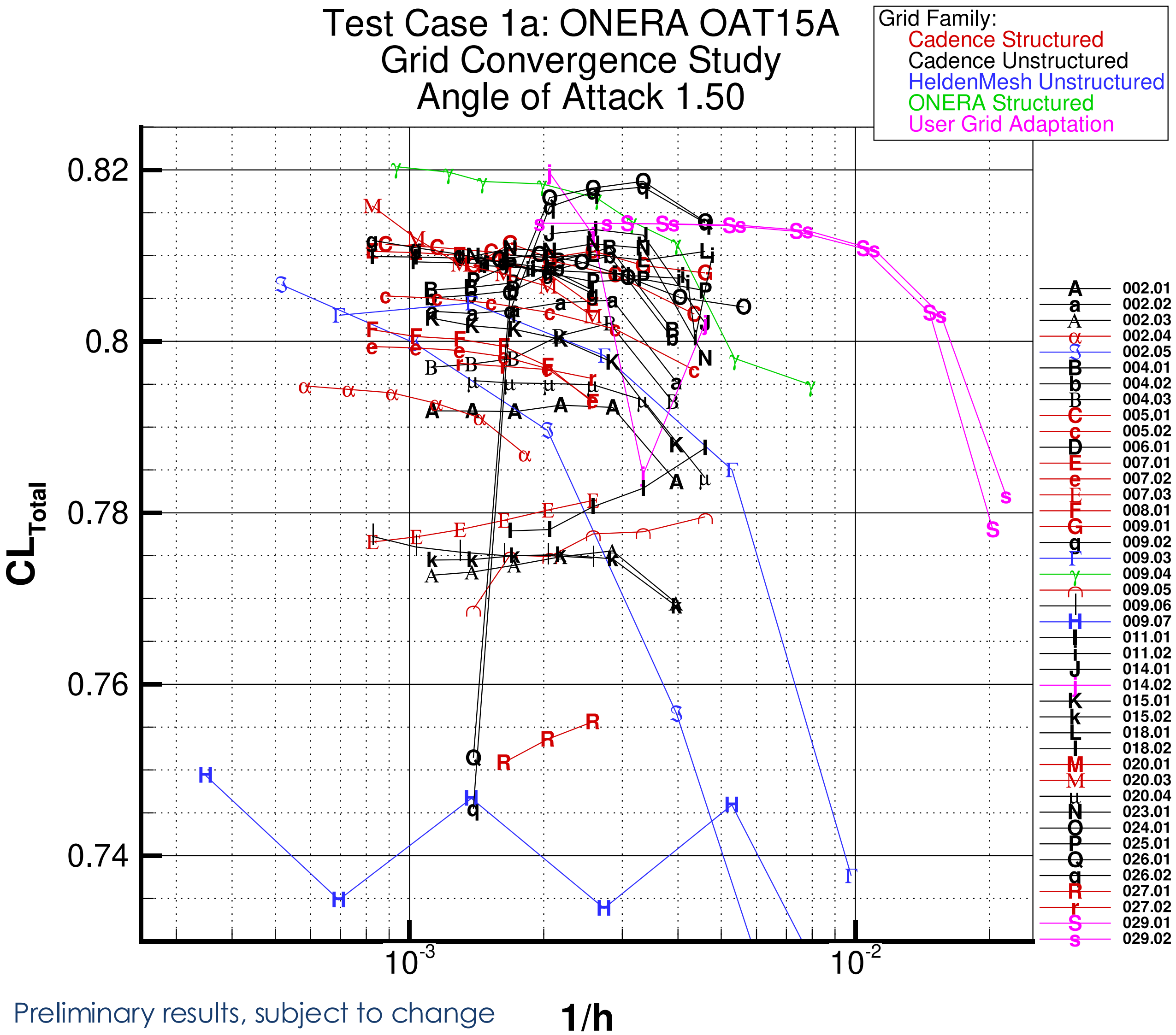
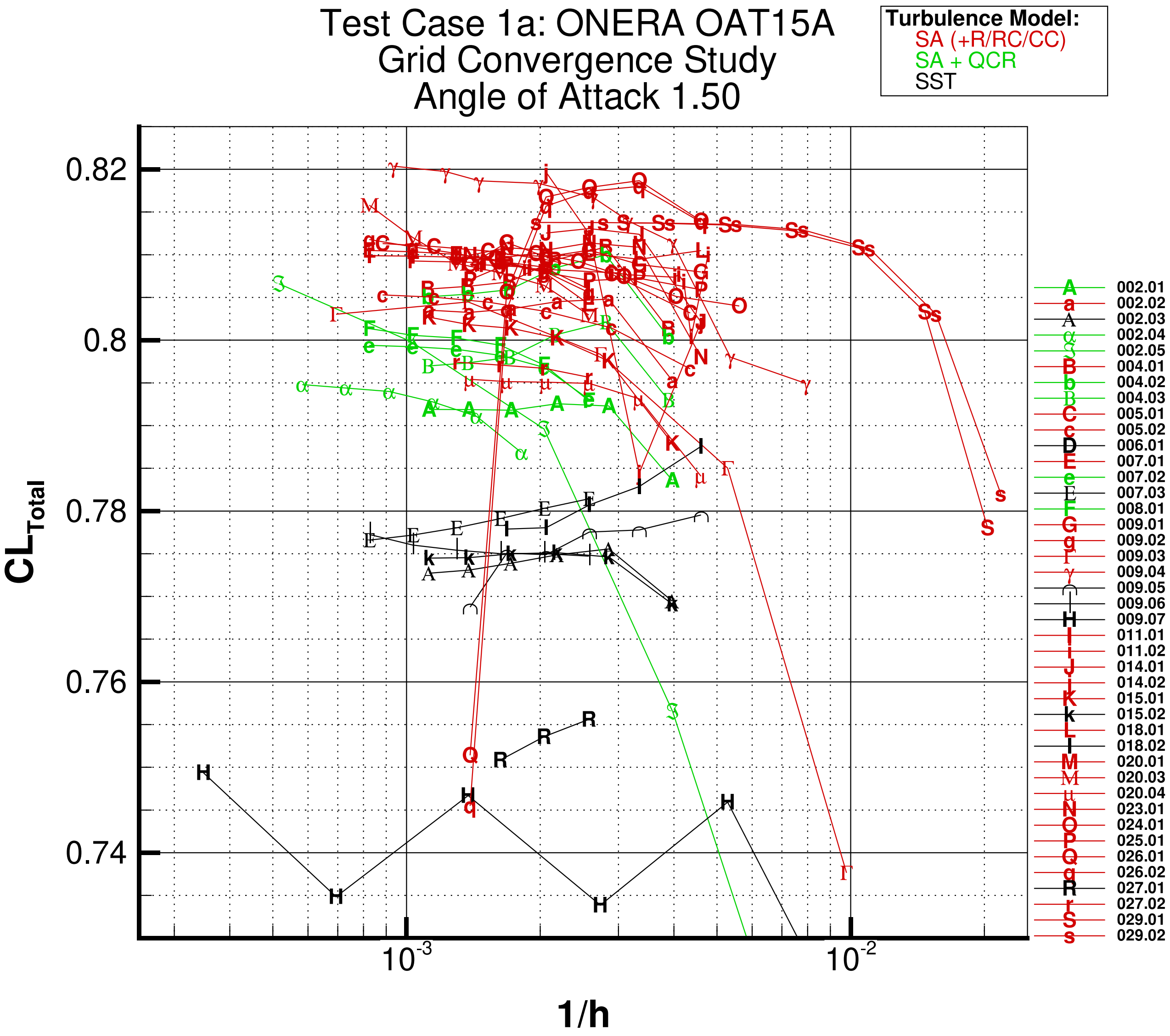
Preliminary results, subject to change
Current as of 1/8/2025

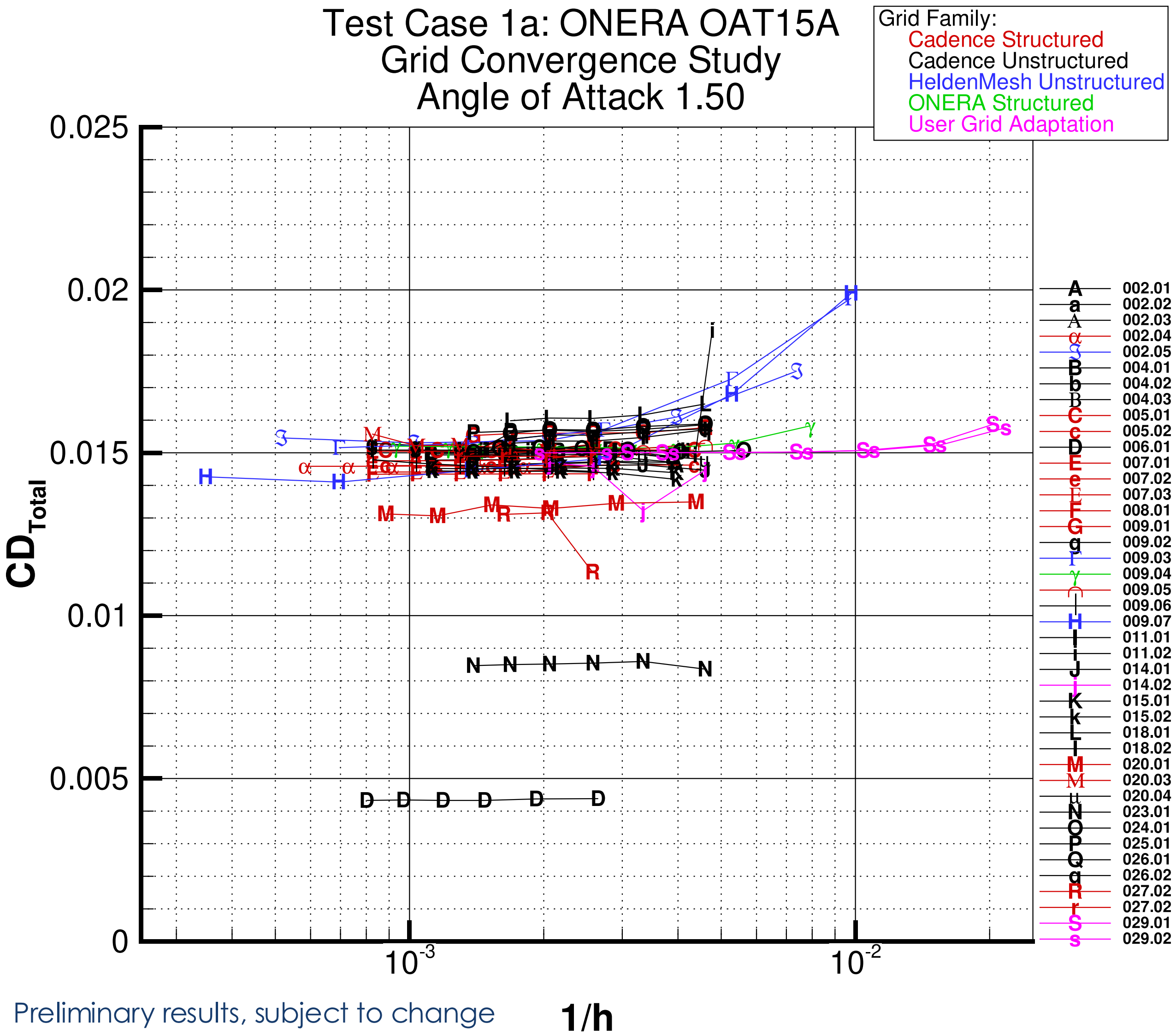
# ONERA OAT15A $C_L$ Convergence: $\alpha = 1.5°$

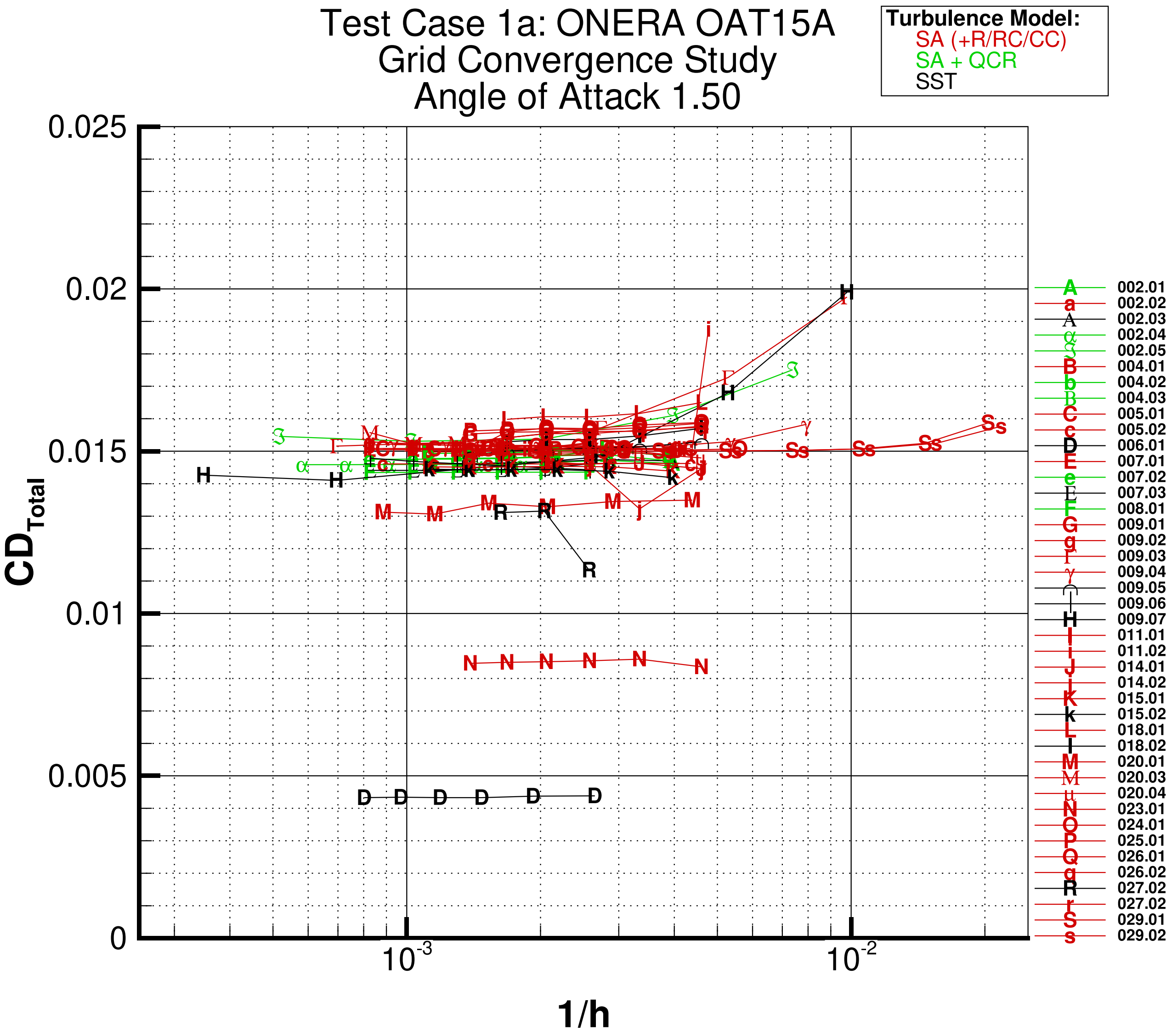




Preliminary results, subject to change
Current as of 1/8/2025

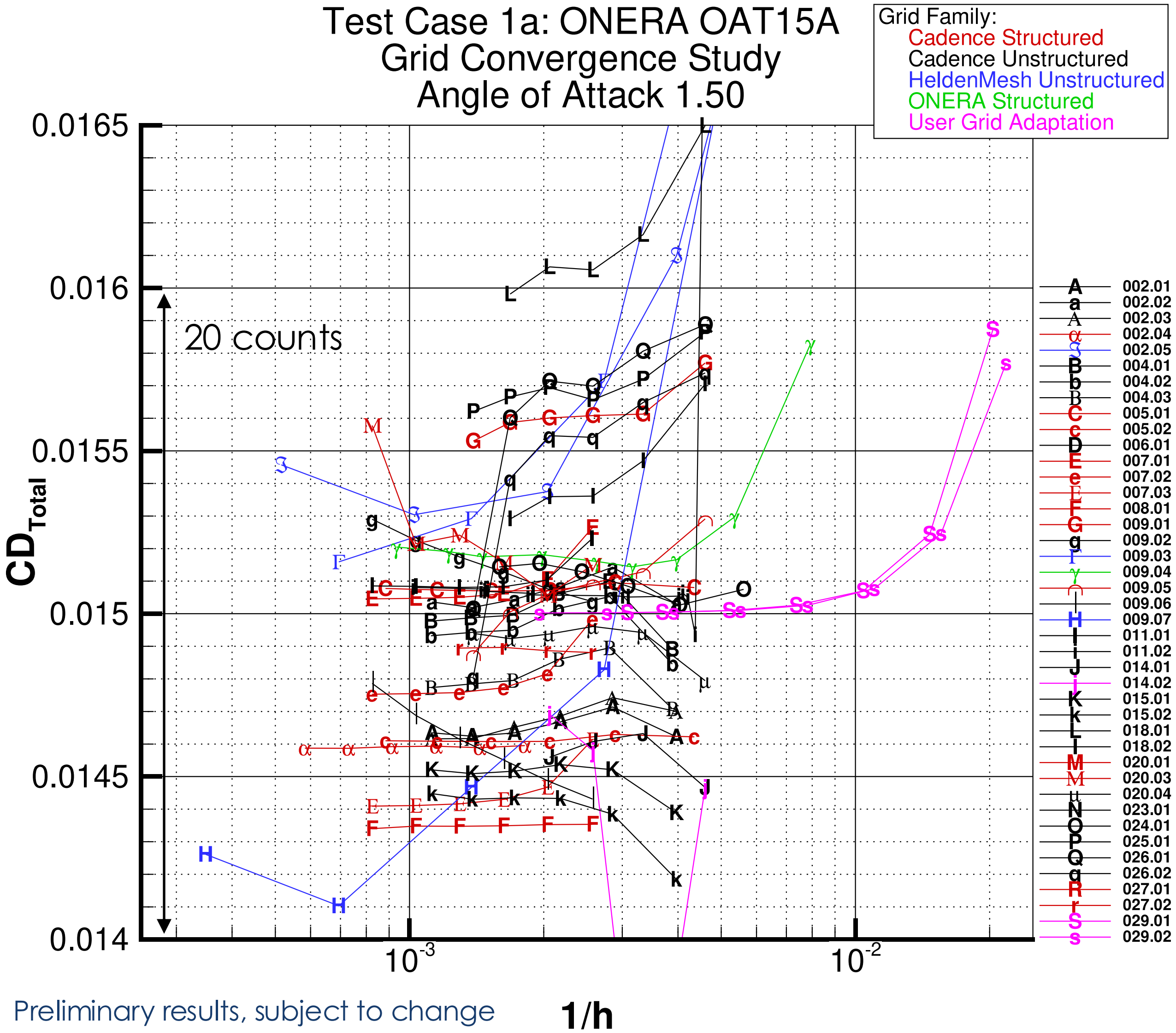
# ONERA OAT15A $C_D$ Convergence: $\alpha = 1.5^\circ$





Preliminary results, subject to change
Current as of 1/8/2025

# ONERA OAT15A $C_D$ Convergence: $\alpha = 1.5^\circ$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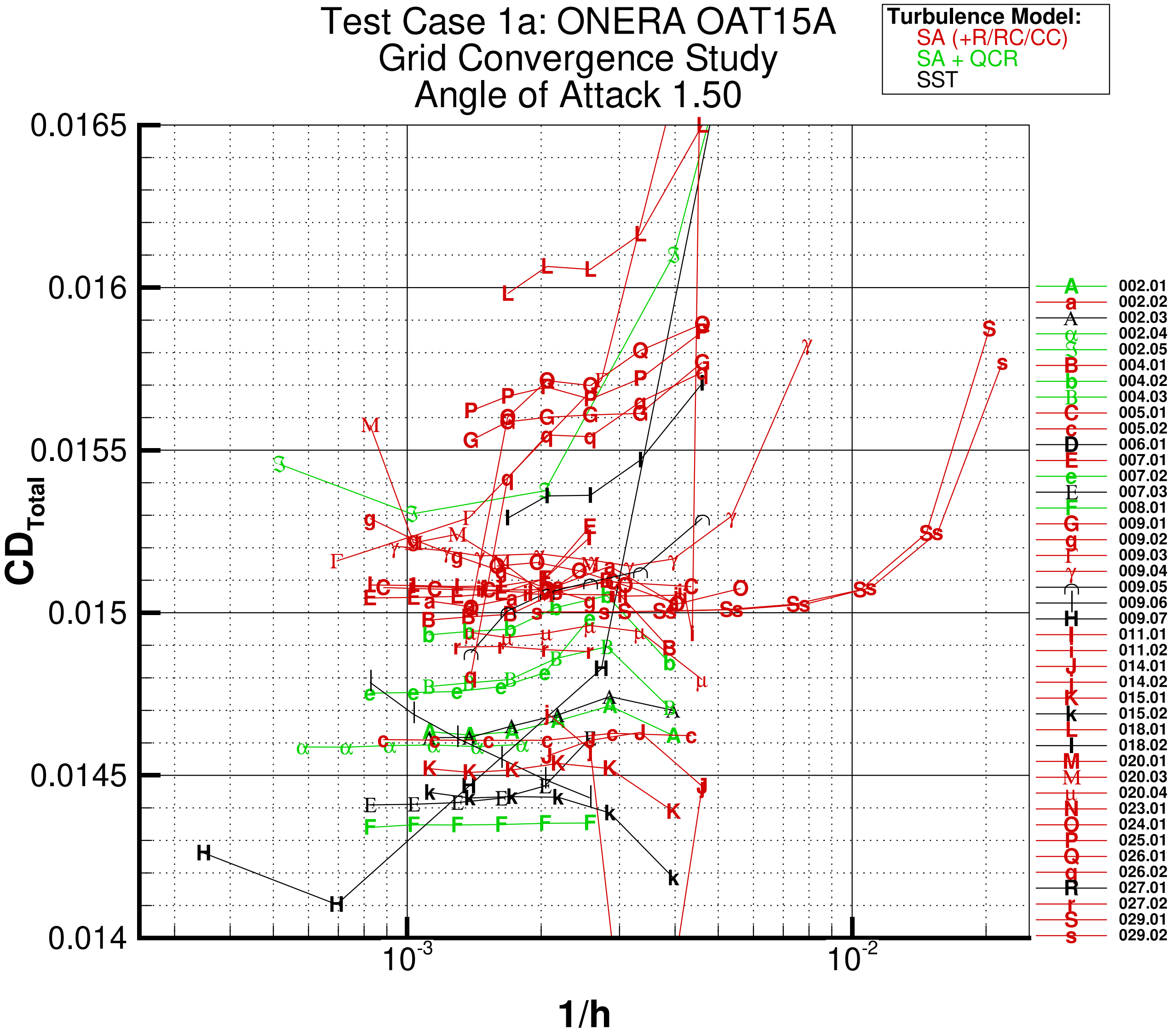
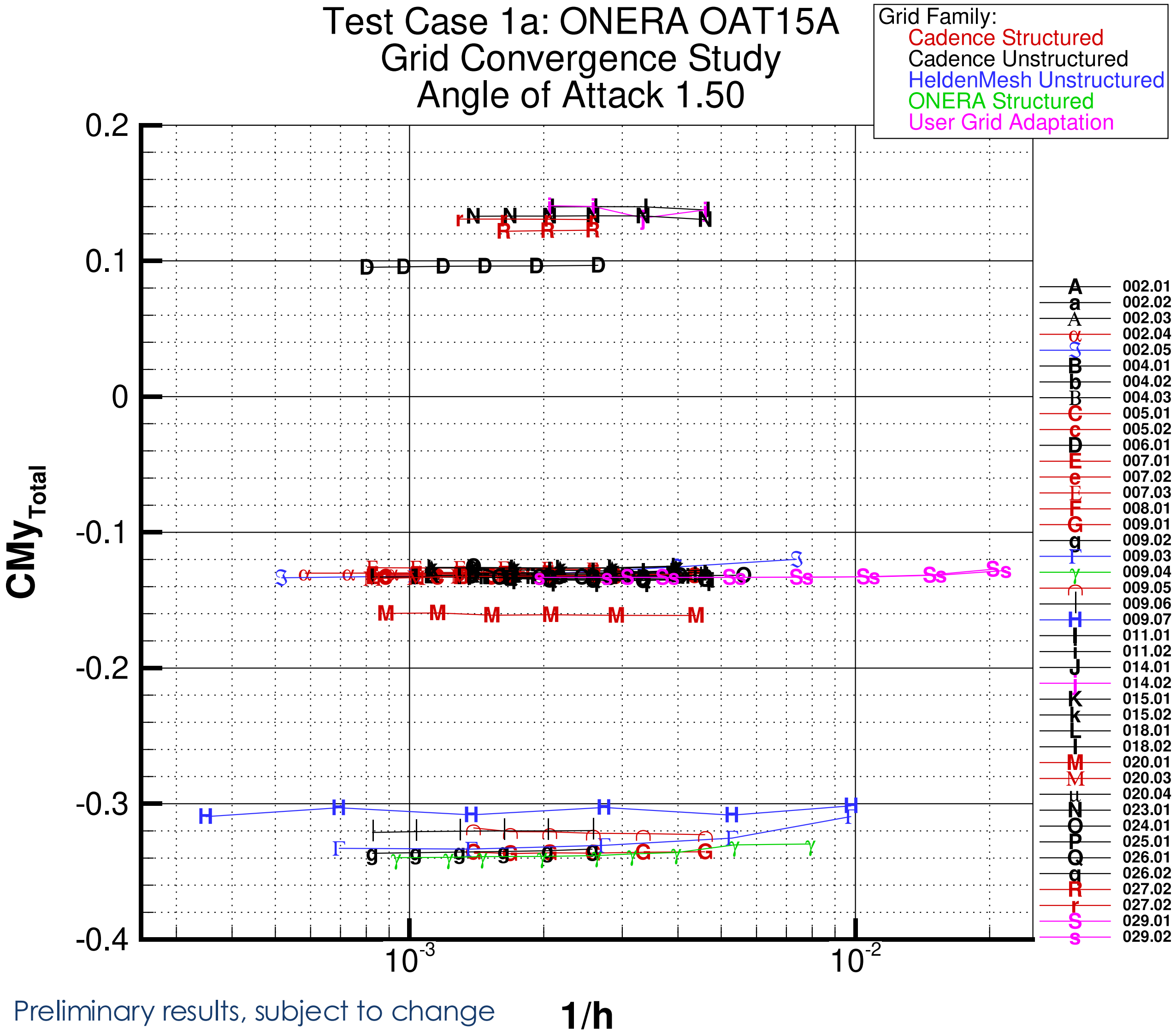
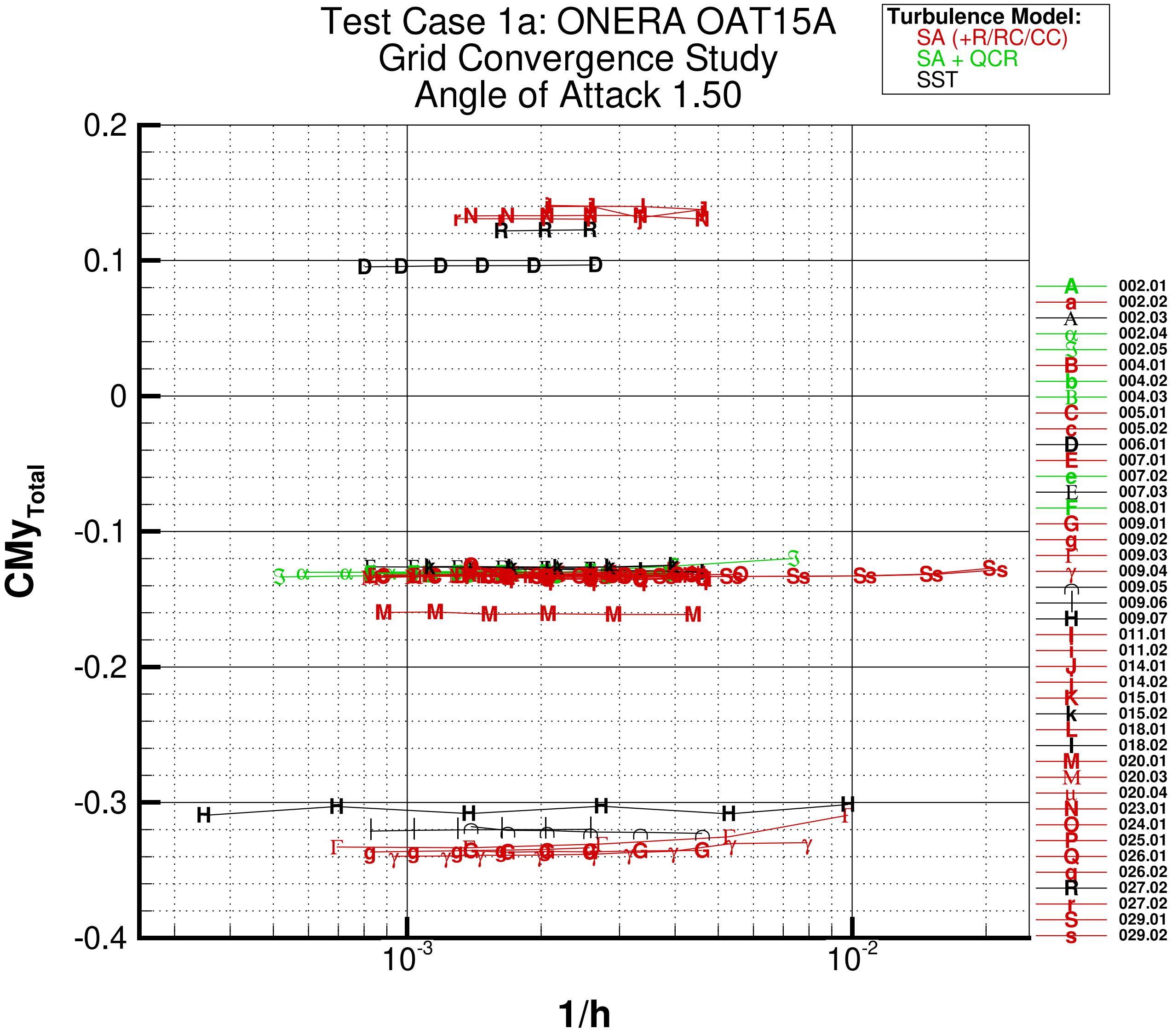
Angle of Attack 1.50


Test Case 1a: ONERA OAT15A
Grid Convergence Study
Angle of Attack 1.50

Preliminary results, subject to change
Current as of 1/8/2025

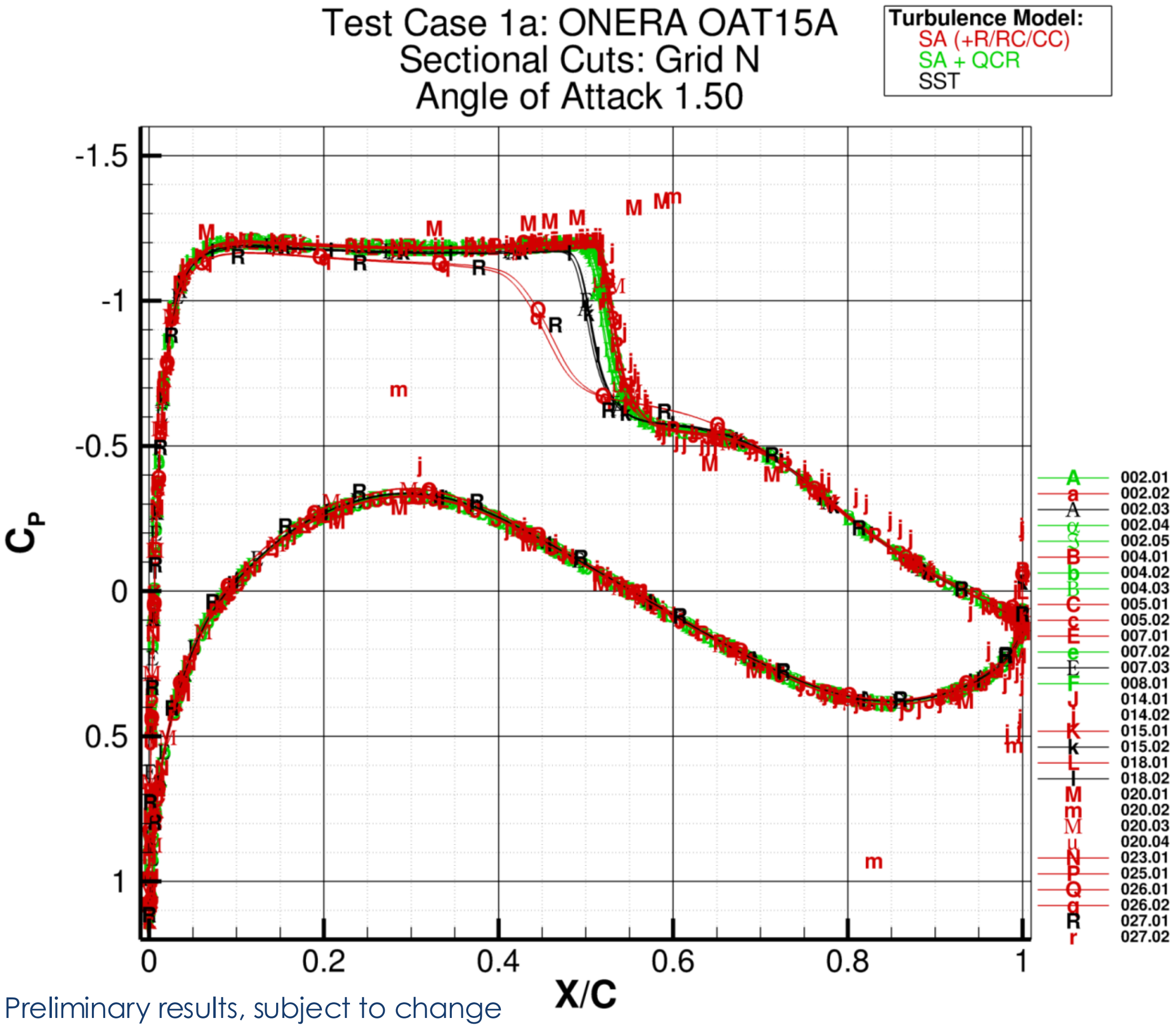
# ONERA OAT15A $C_M$ Convergence: $\alpha = 1.5°$

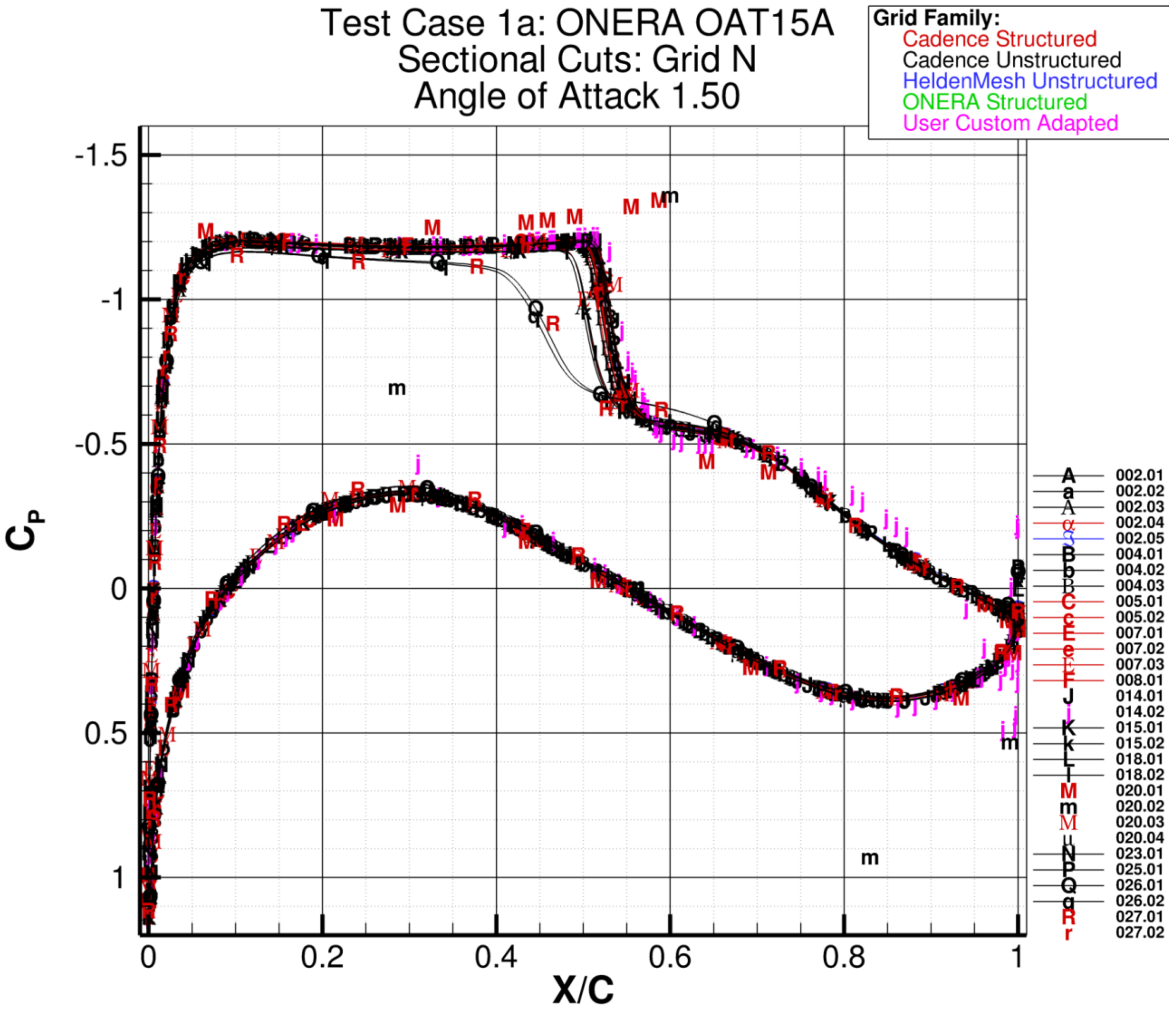




Preliminary results, subject to change
Current as of 1/8/2025

# ONERA OAT15A Cp Sectional Cuts: $\alpha = 1.5^\circ$





Preliminary results, subject to change
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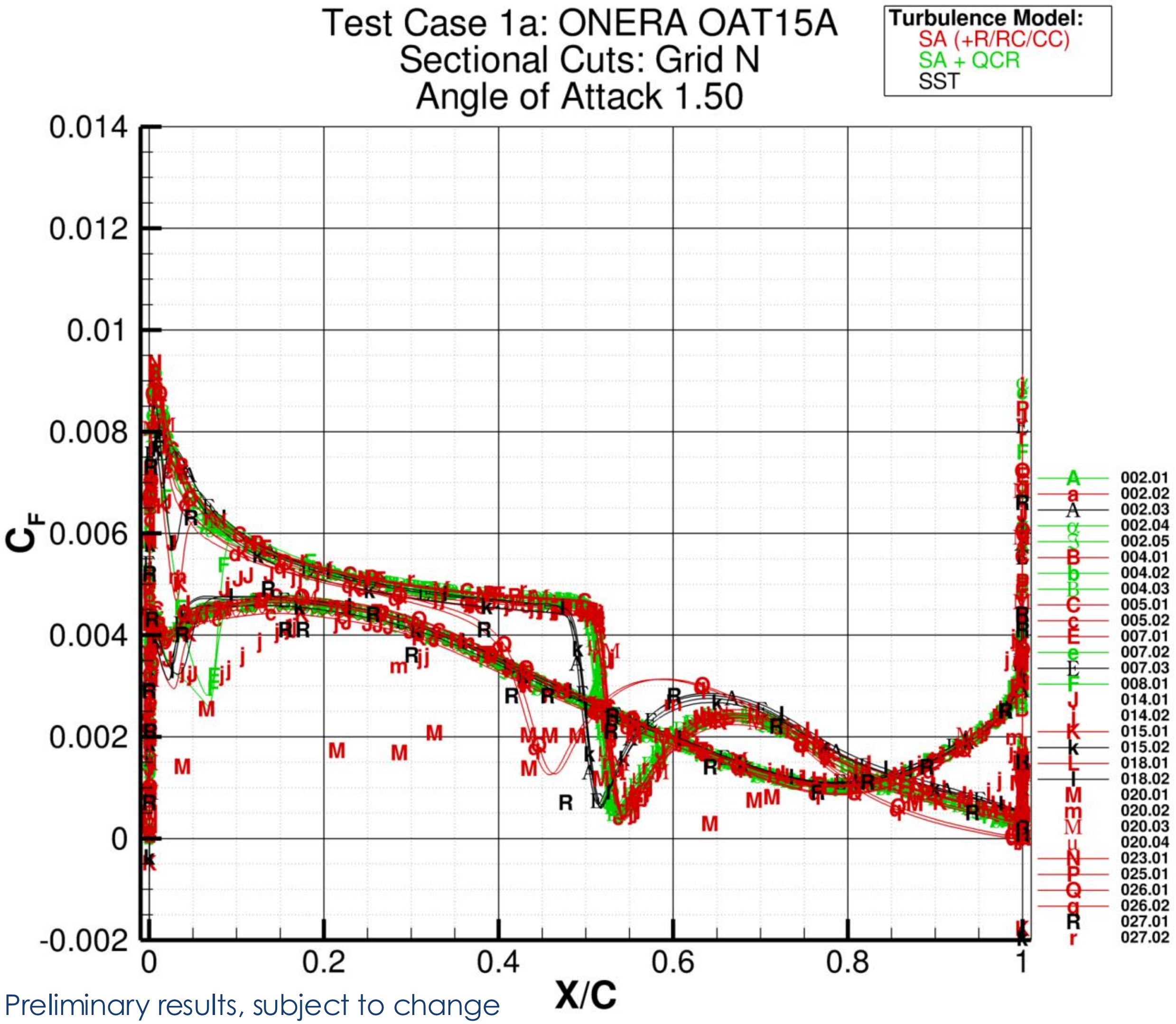
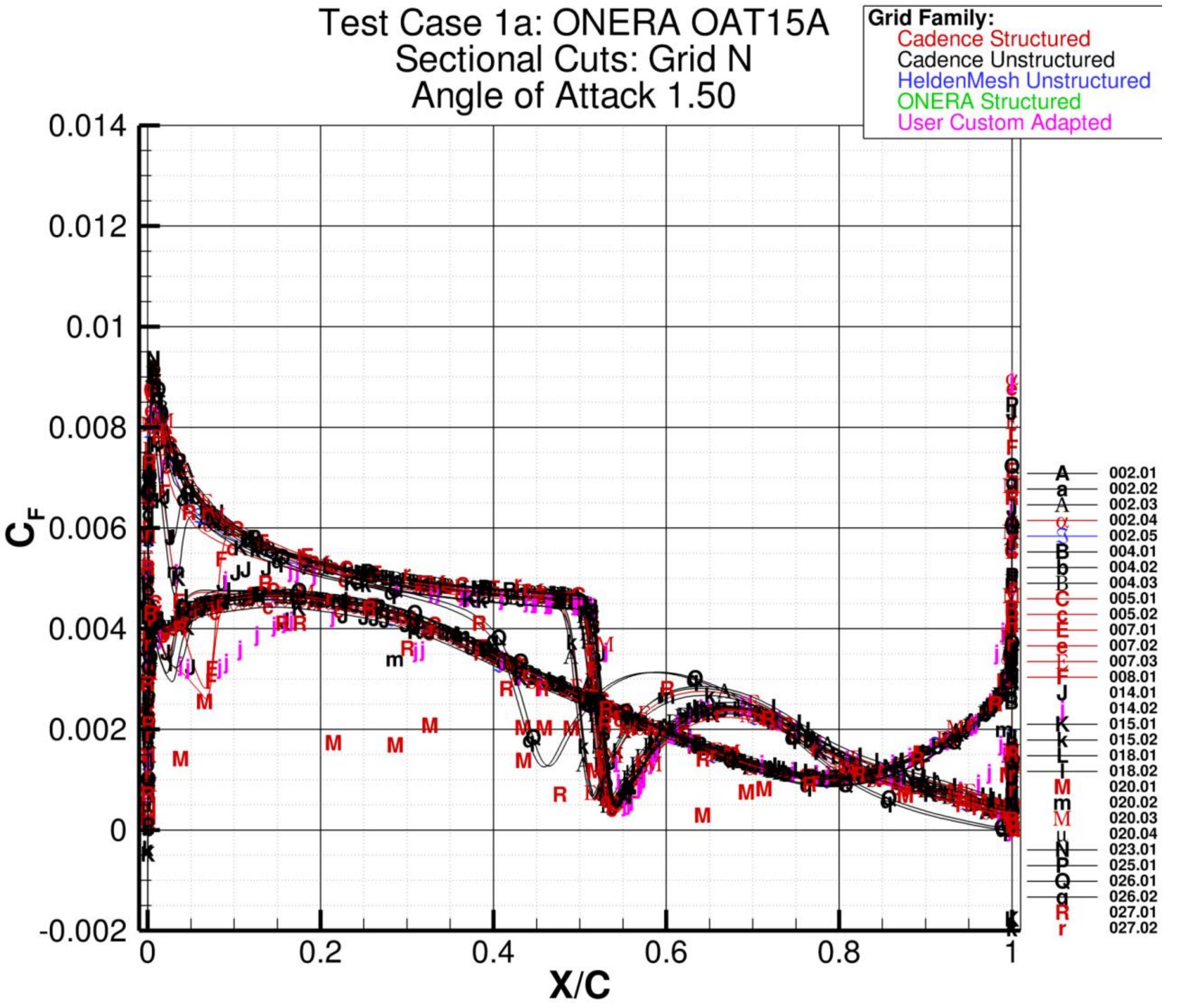
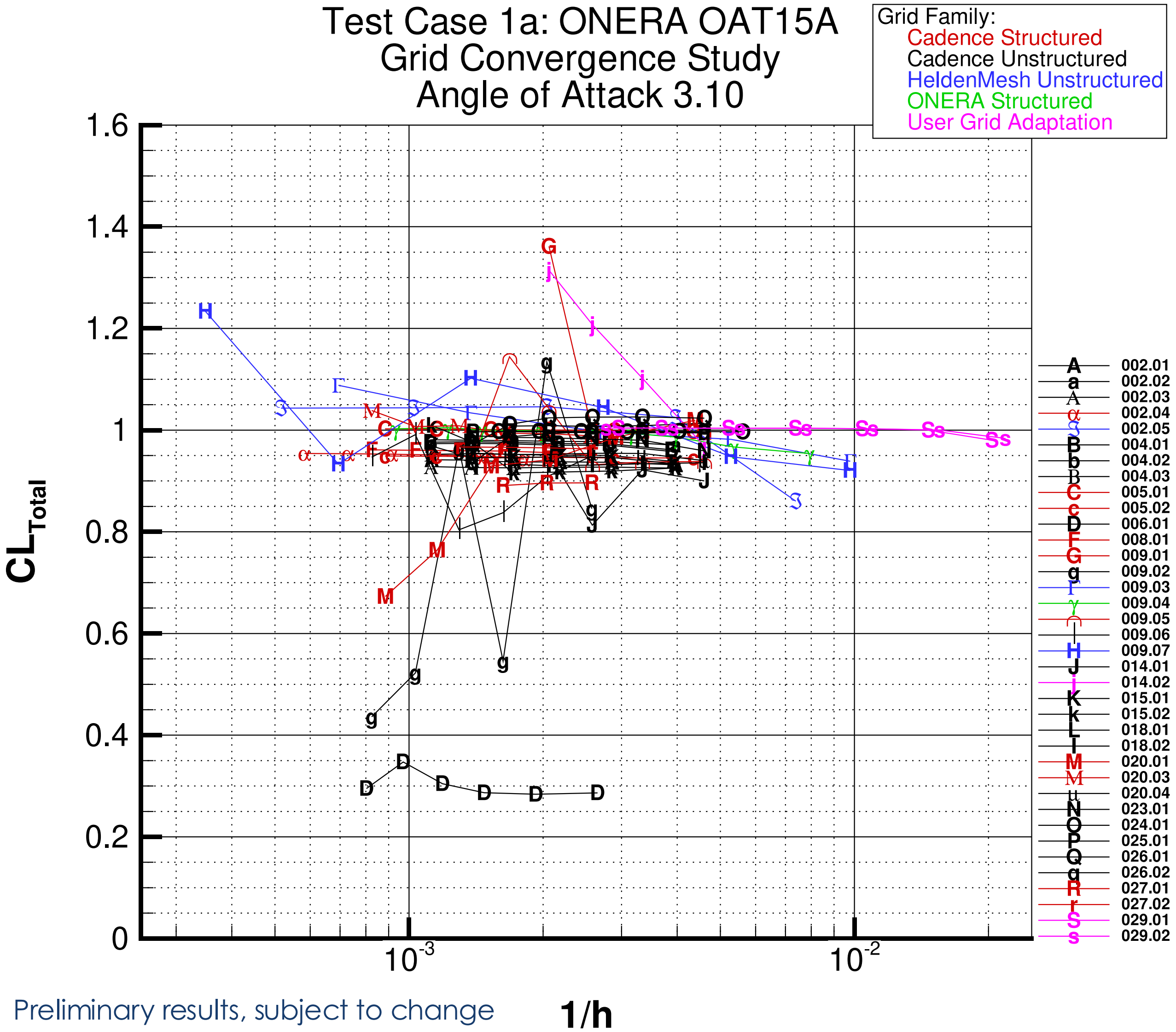
# ONERA OAT15A Cf Sectional Cuts: $\alpha = 1.5°$

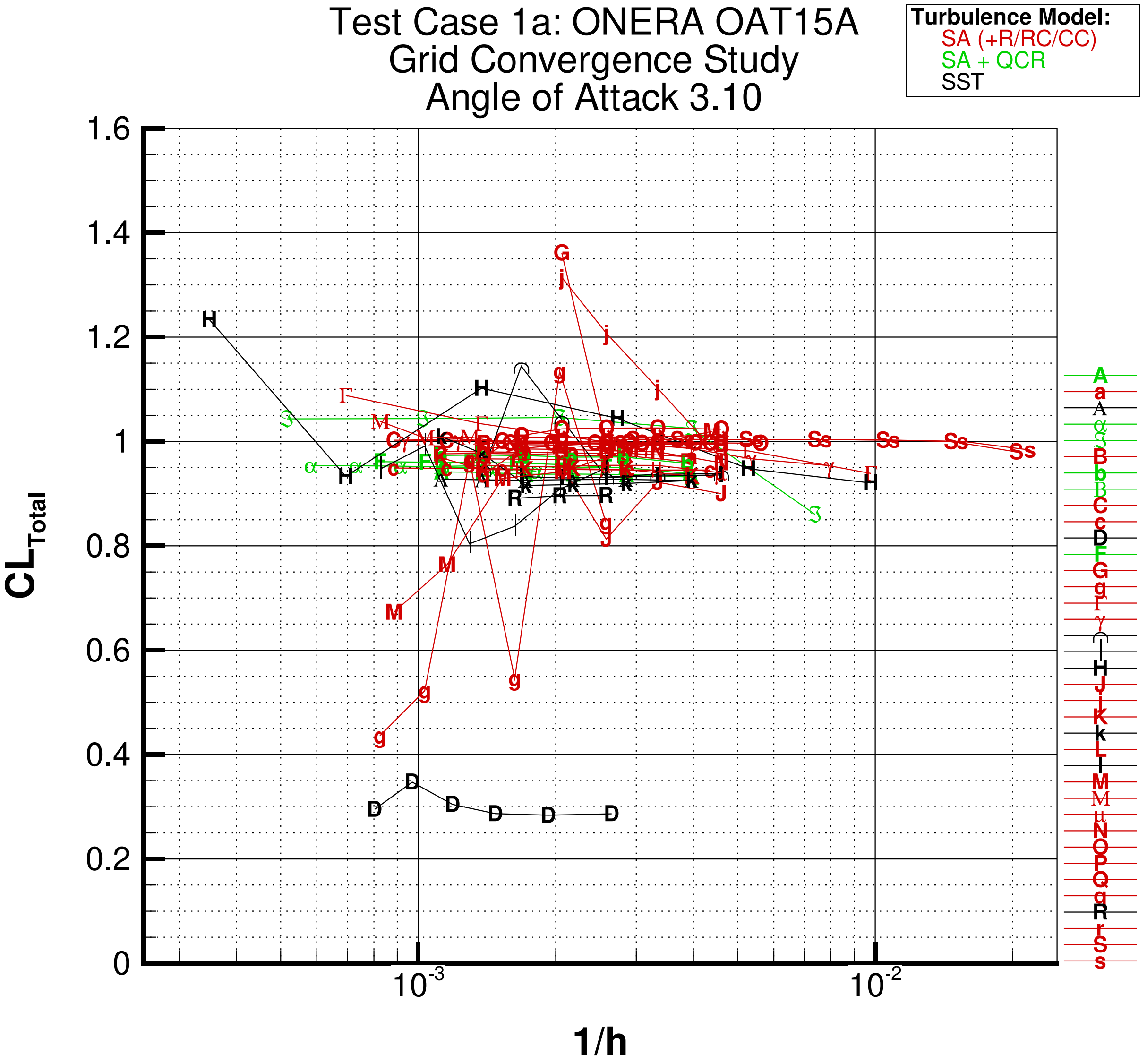




Preliminary results, subject to change
Current as of 1/8/2025

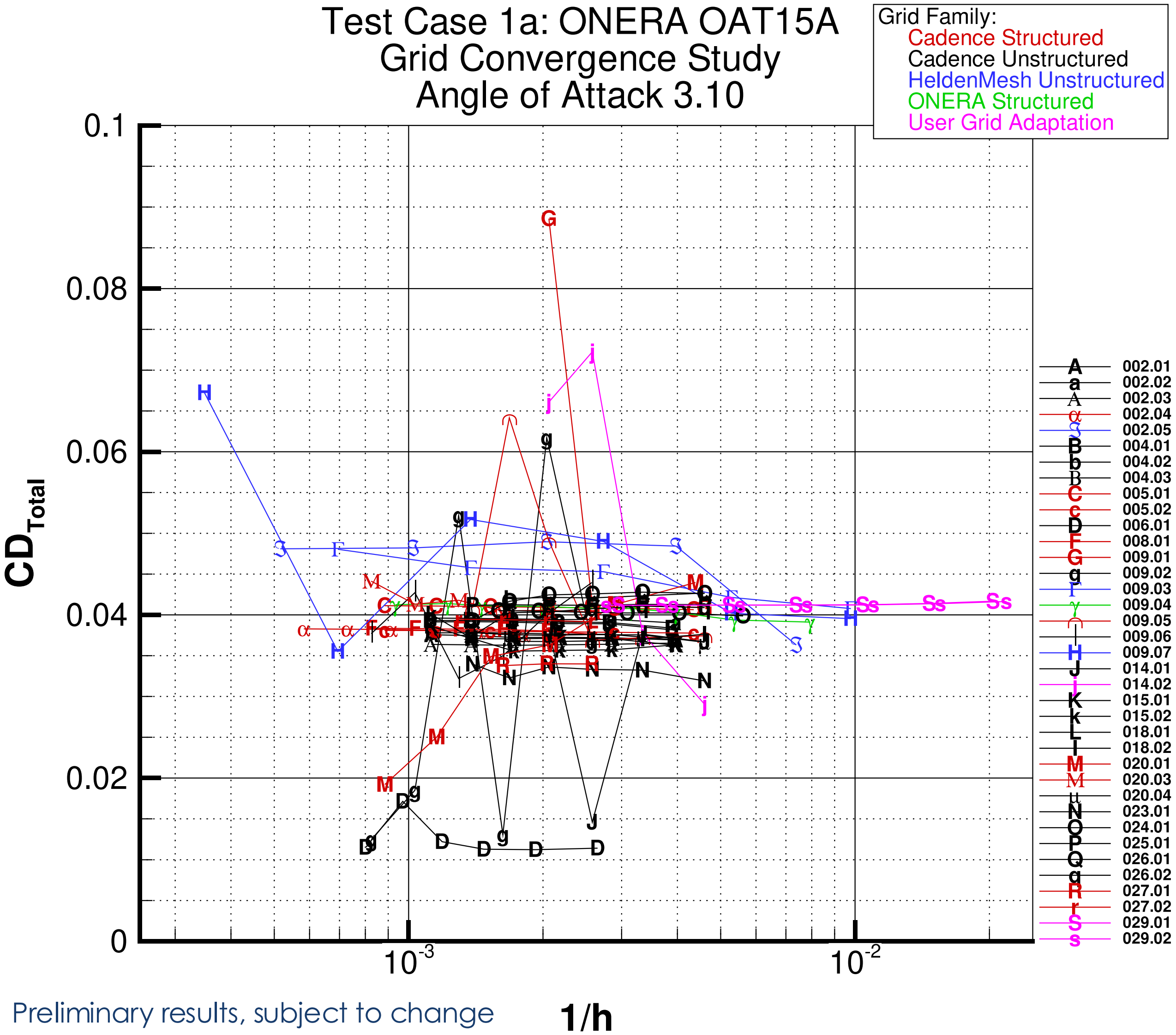
# ONERA OAT15A $C_L$ Convergence: $\alpha = 3.1°$

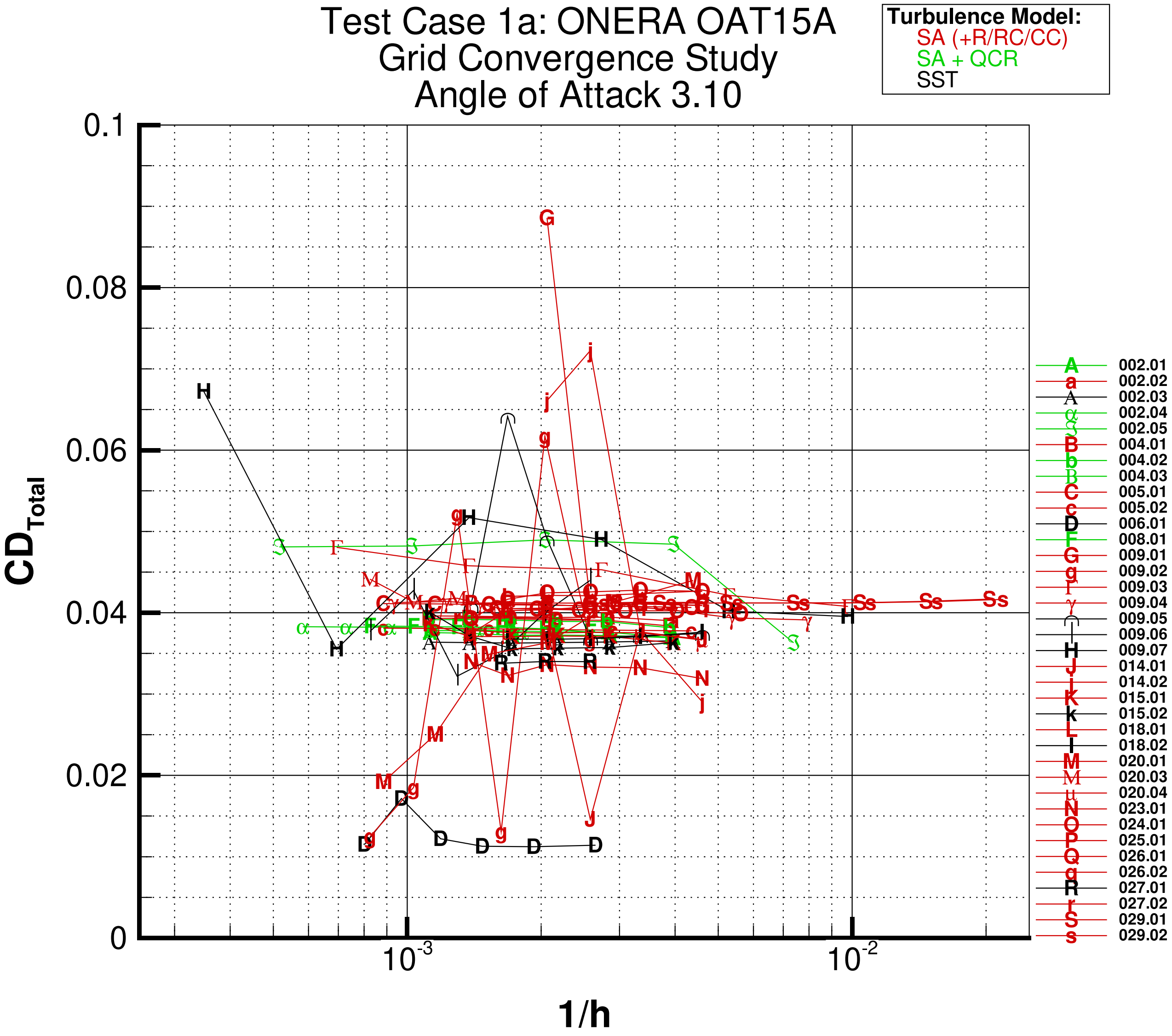




Preliminary results, subject to change
Current as of 1/8/2025

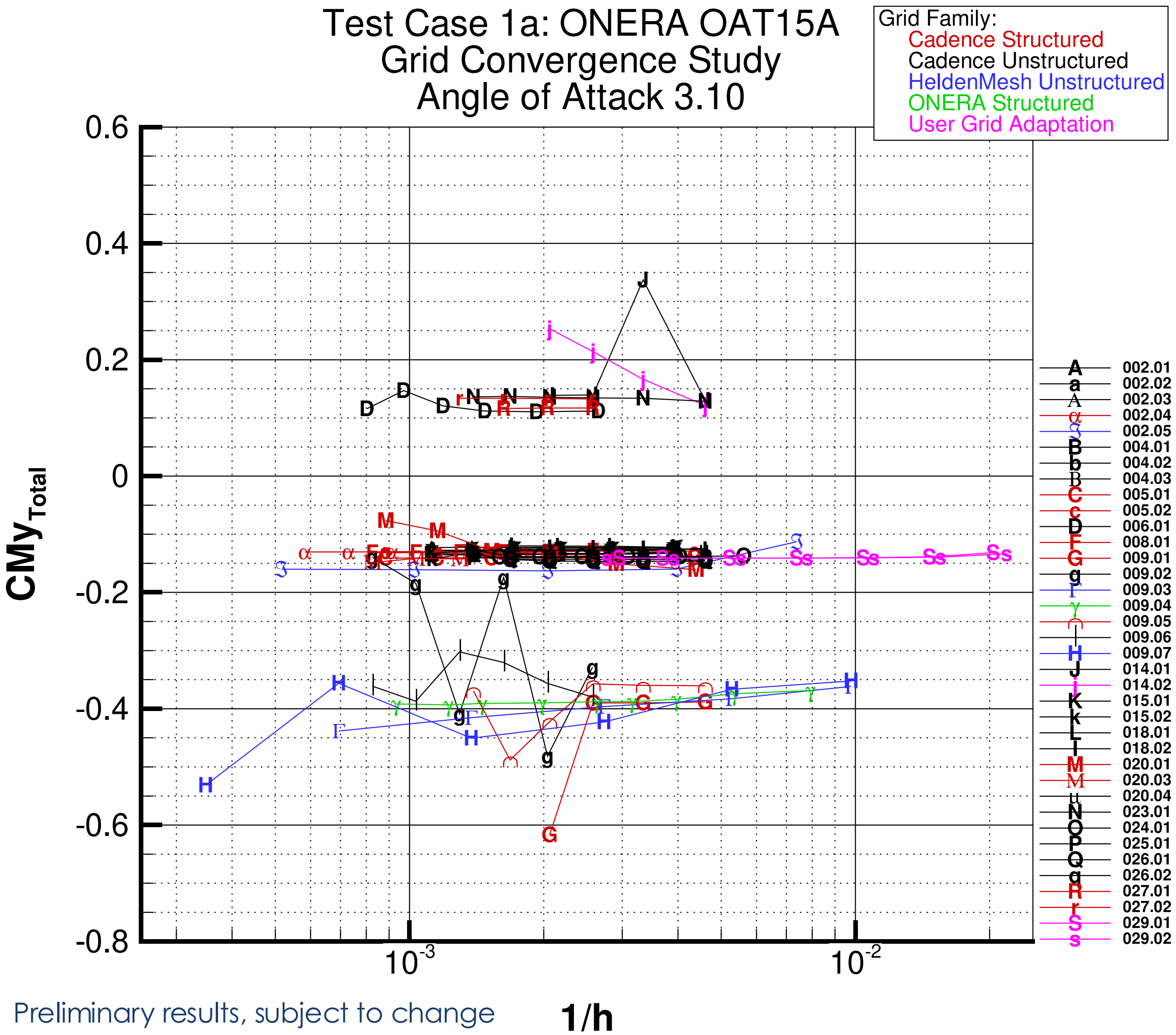
# ONERA OAT15A $C_D$ Convergence: $\alpha = 3.1°$

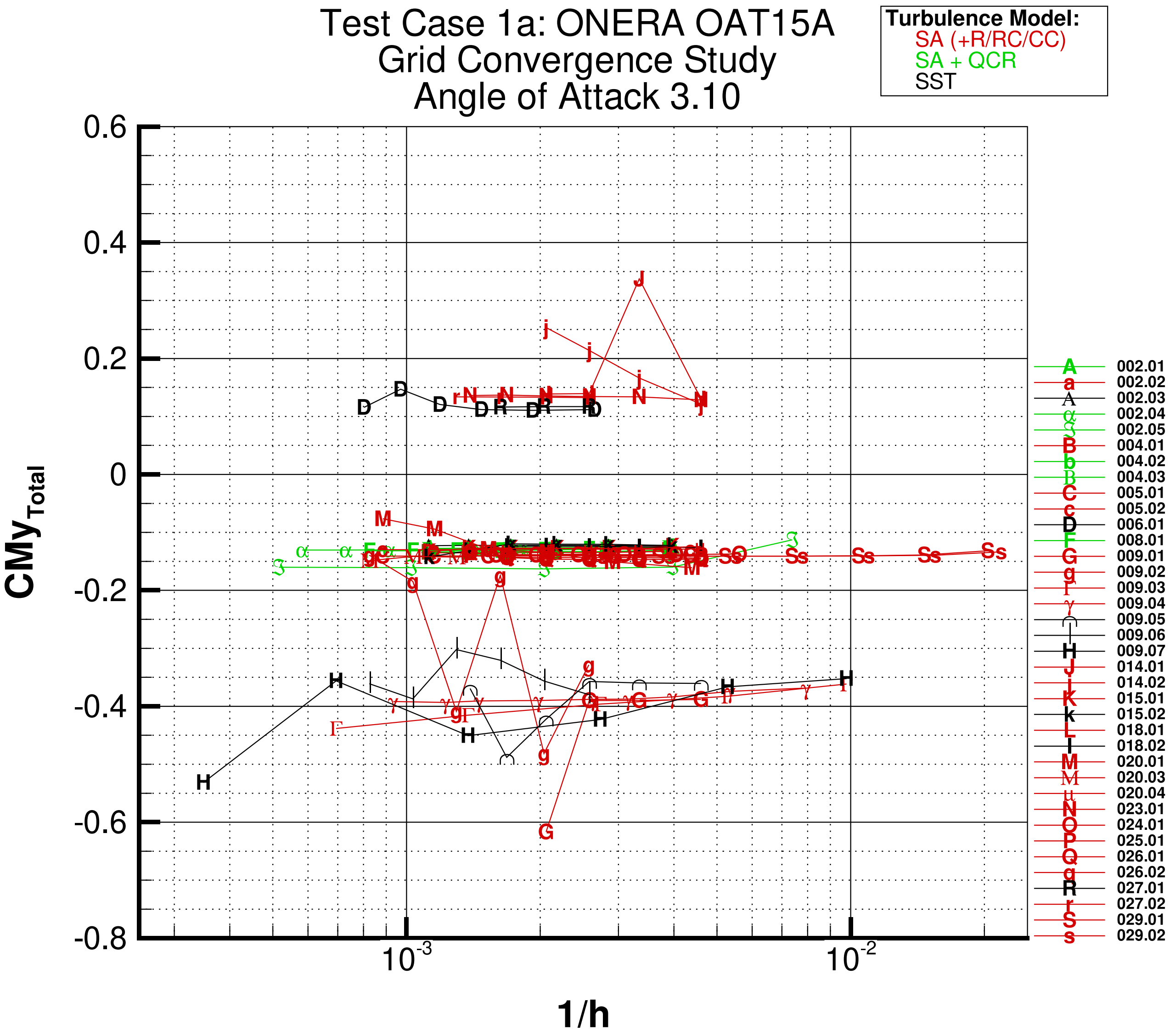




Preliminary results, subject to change
Current as of 1/8/2025

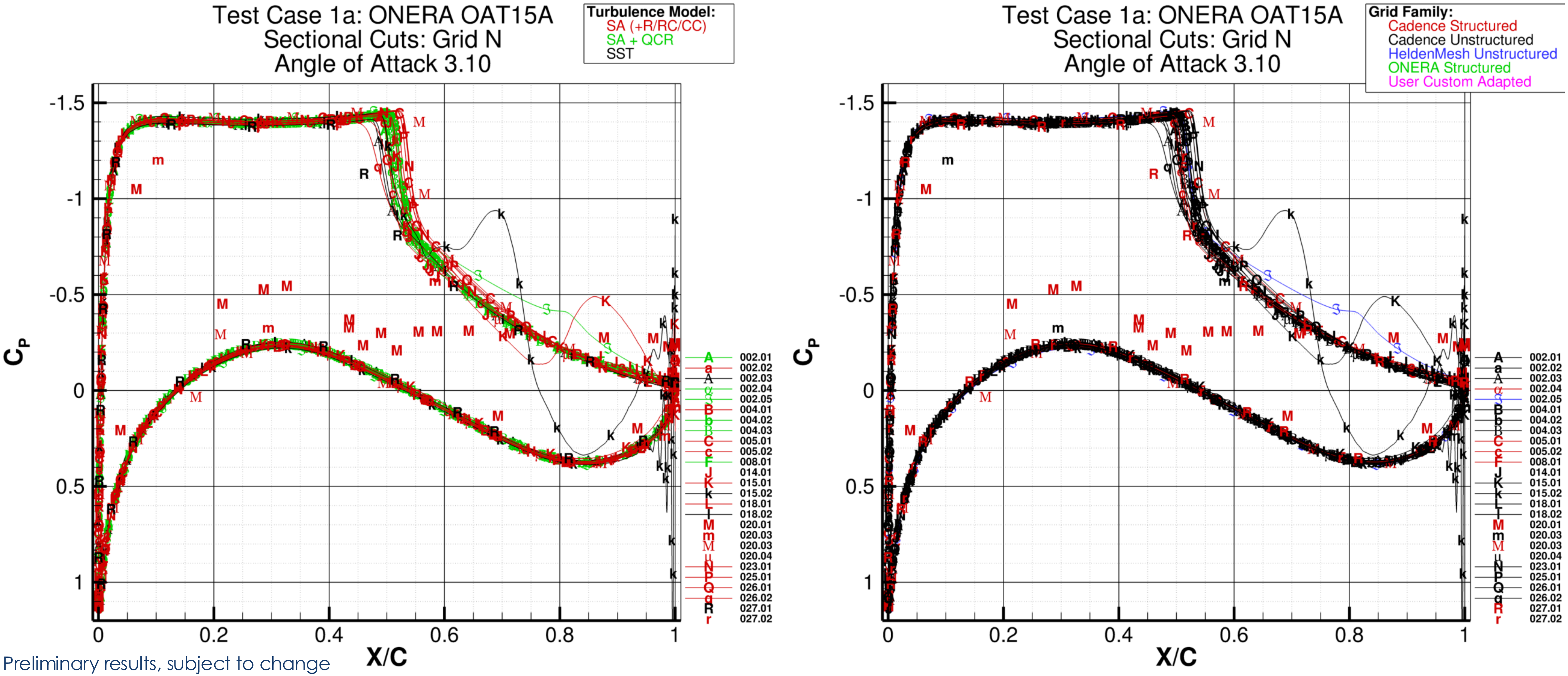
# ONERA OAT15A $C_M$ Convergence: $\alpha = 3.1^\circ$





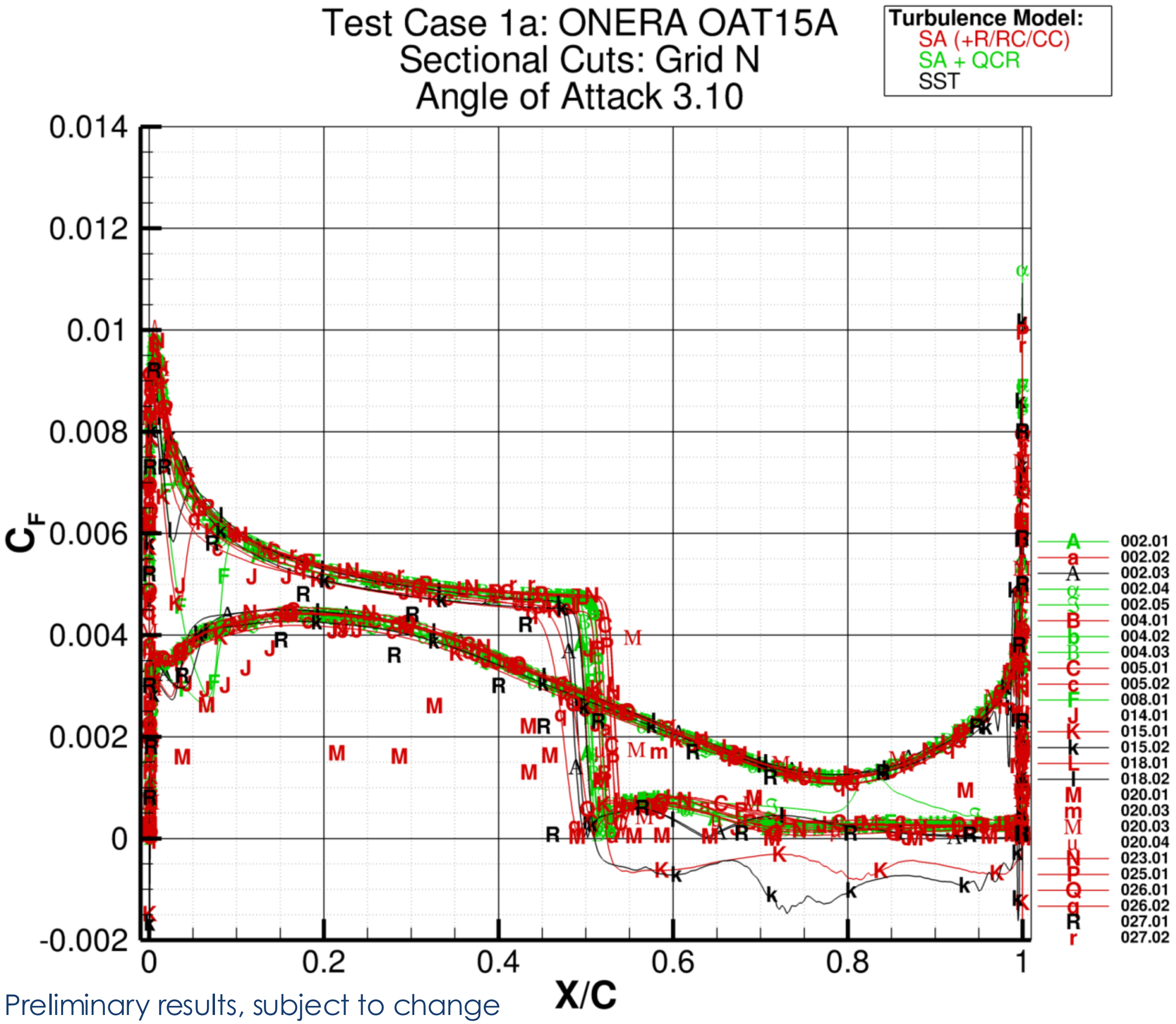
Preliminary results, subject to change
Current as of 1/8/2025

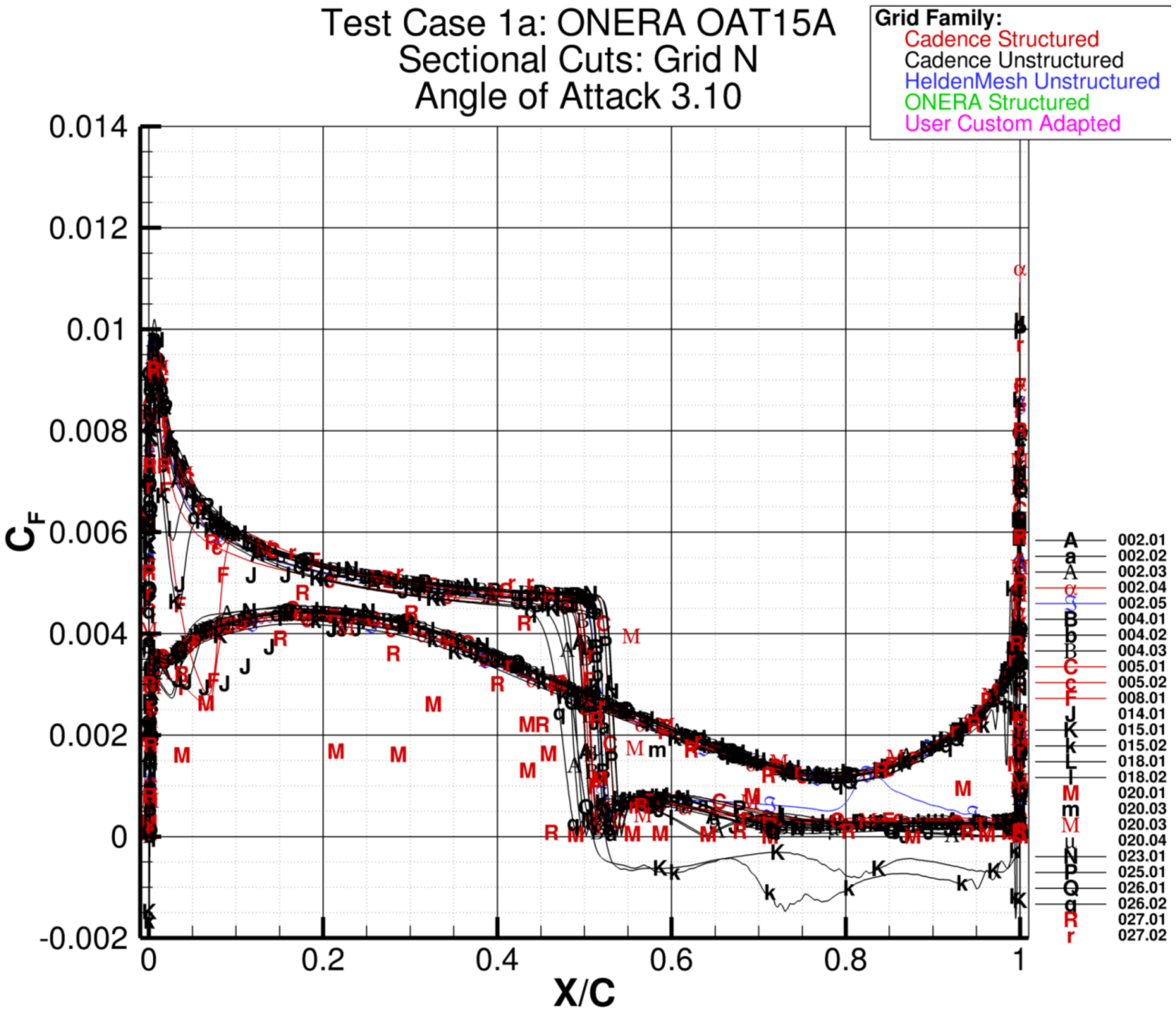
# ONERA OAT15A Cp Sectional Cuts: $\alpha = 3.1°$



Preliminary results, subject to change
Current as of 1/8/2025

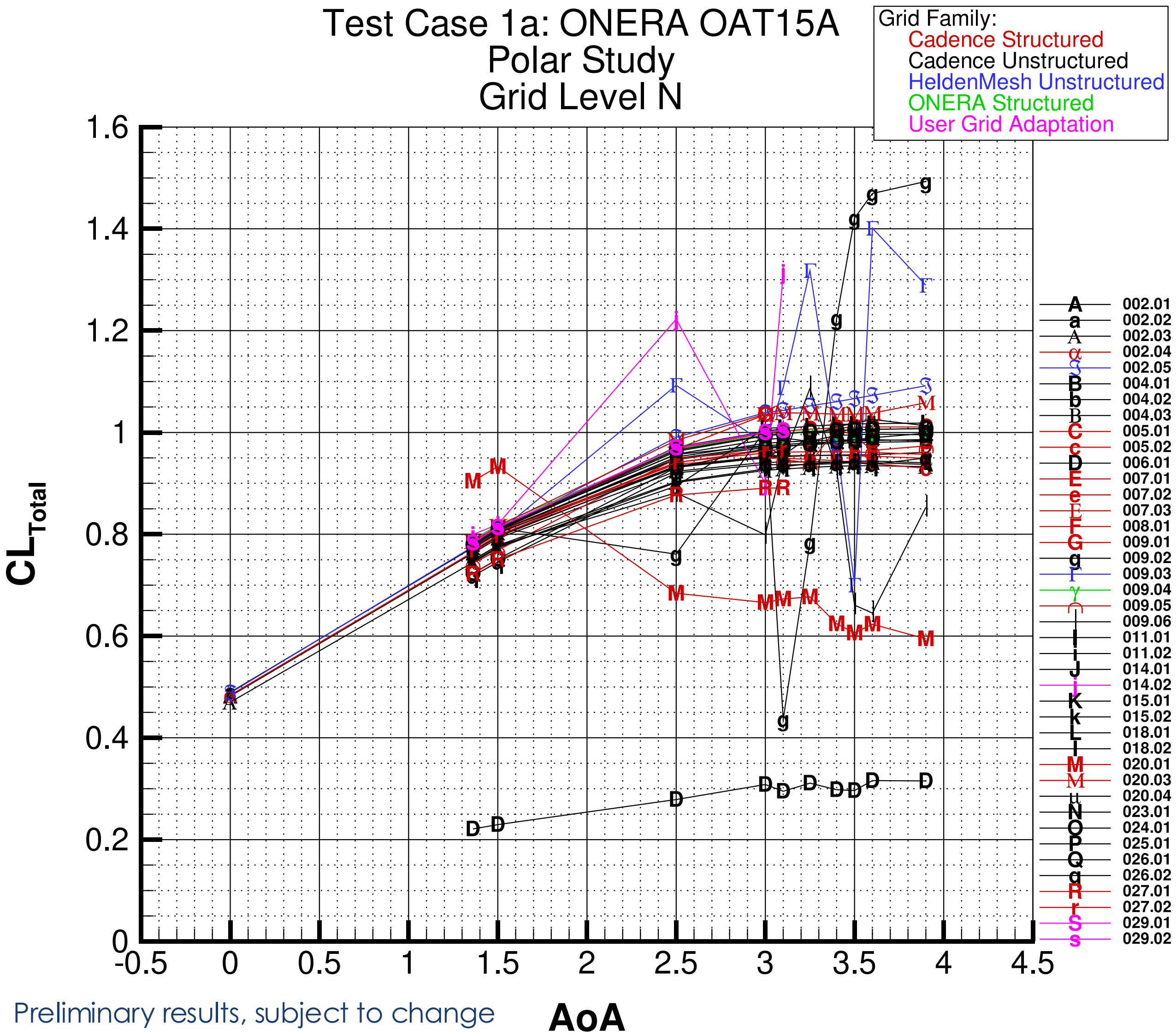
# ONERA OAT15A Cf Sectional Cuts: $\alpha = 3.1°$

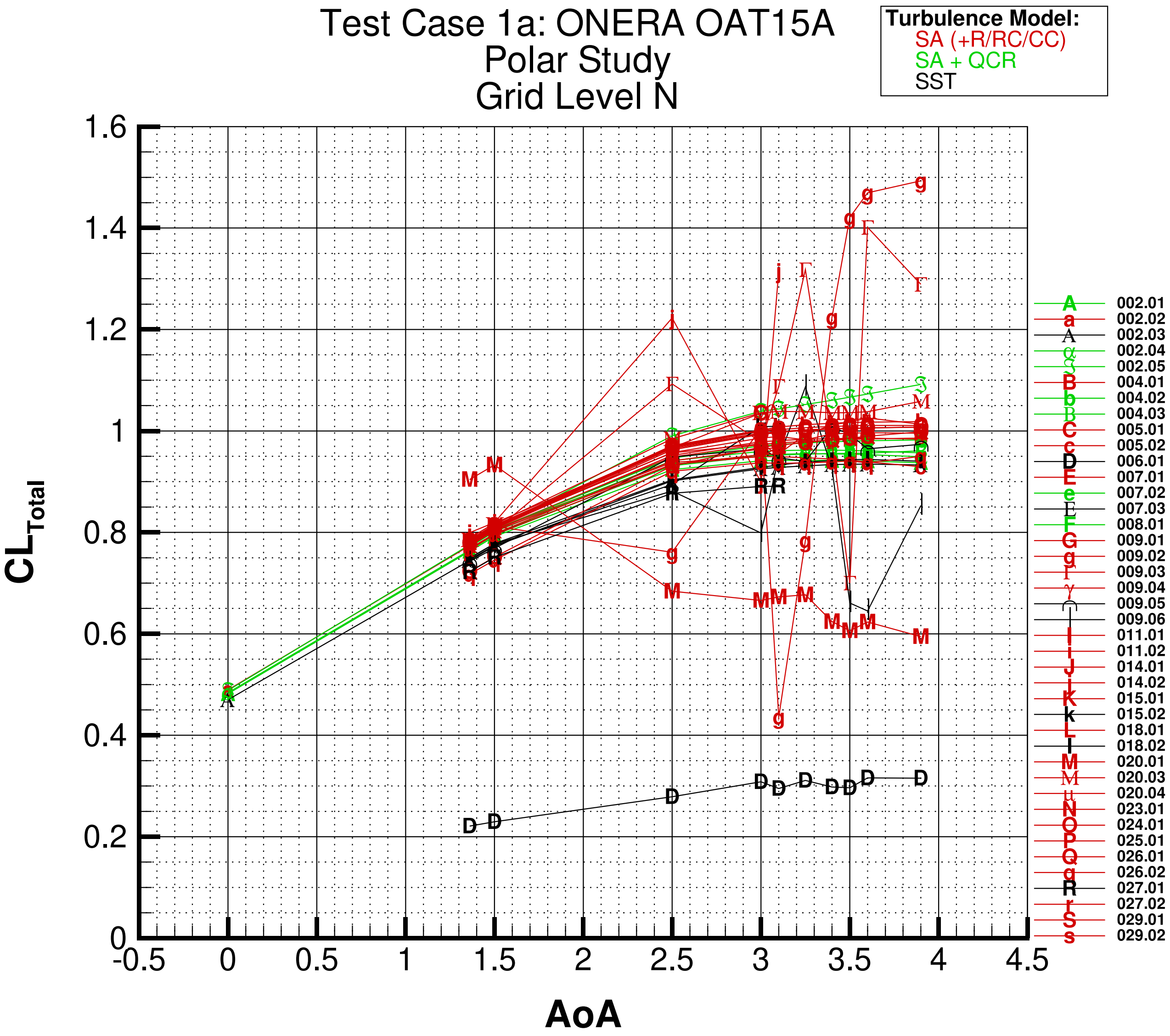




Preliminary results, subject to change
Current as of 1/8/2025

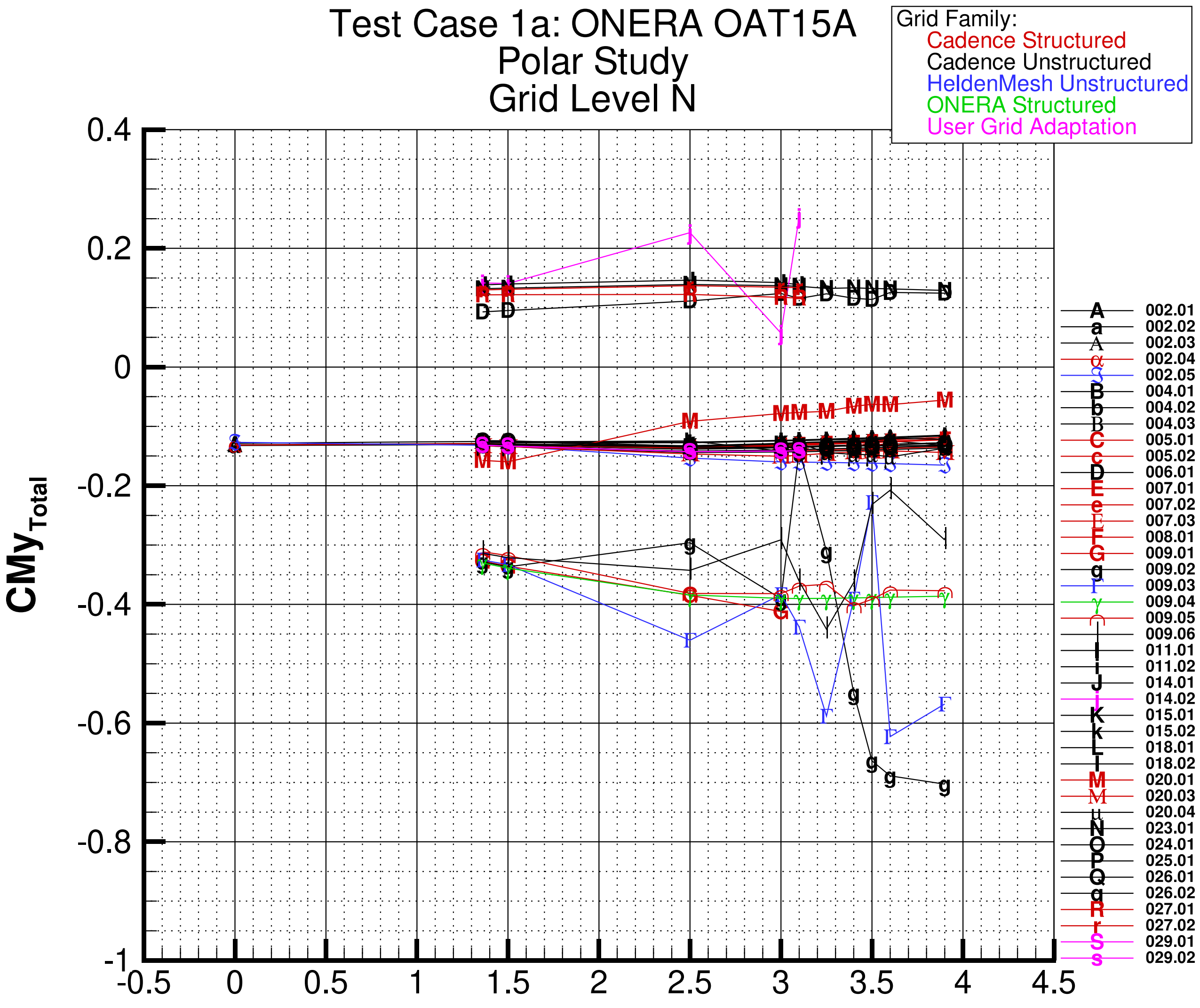
# ONERA OAT15A $C_L - \alpha$ Polar: Finest Mesh

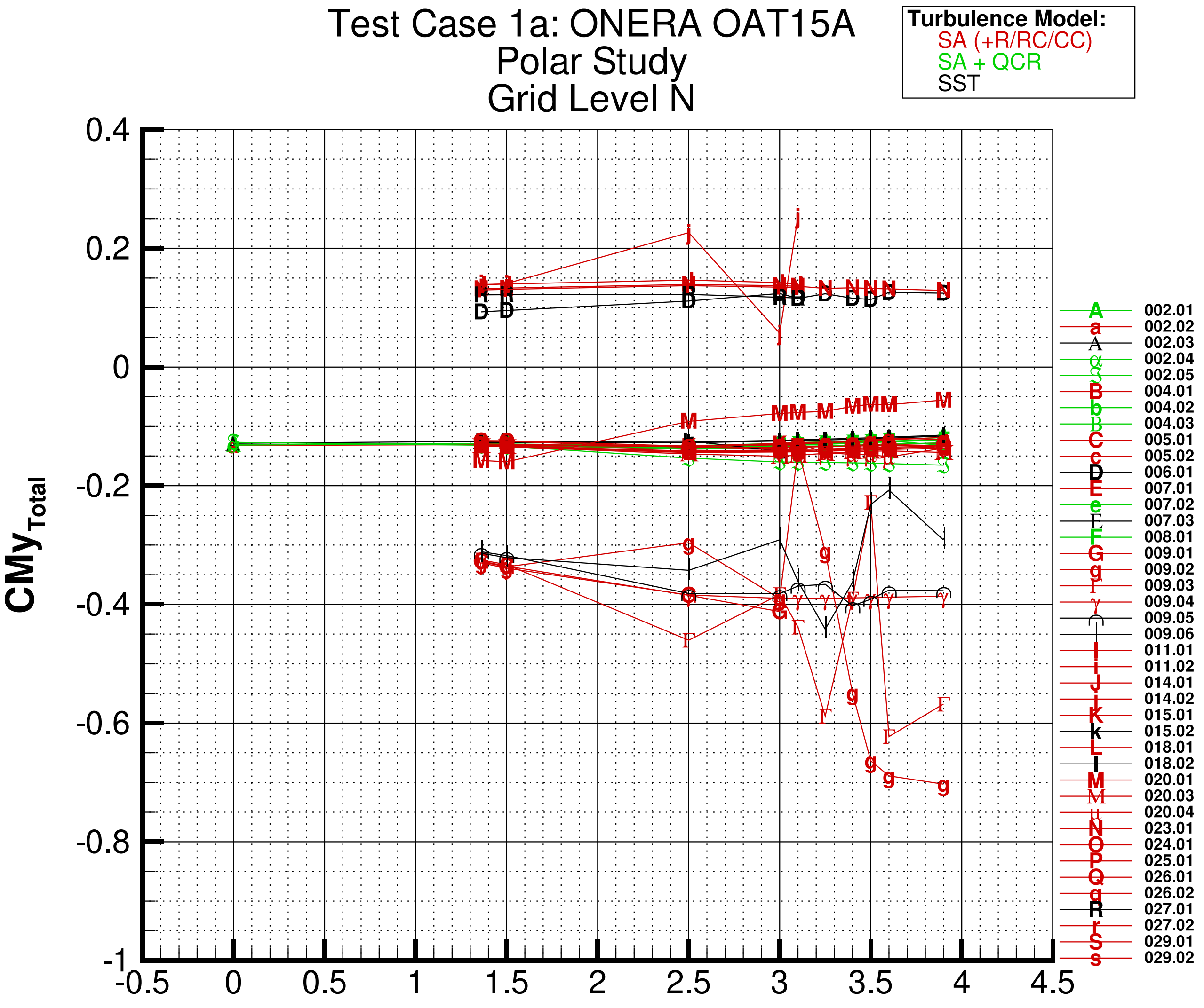




Preliminary results, subject to change
Current as of 1/8/2025

# ONERA OAT15A $C_M - \alpha$ Polar: Finest Mesh

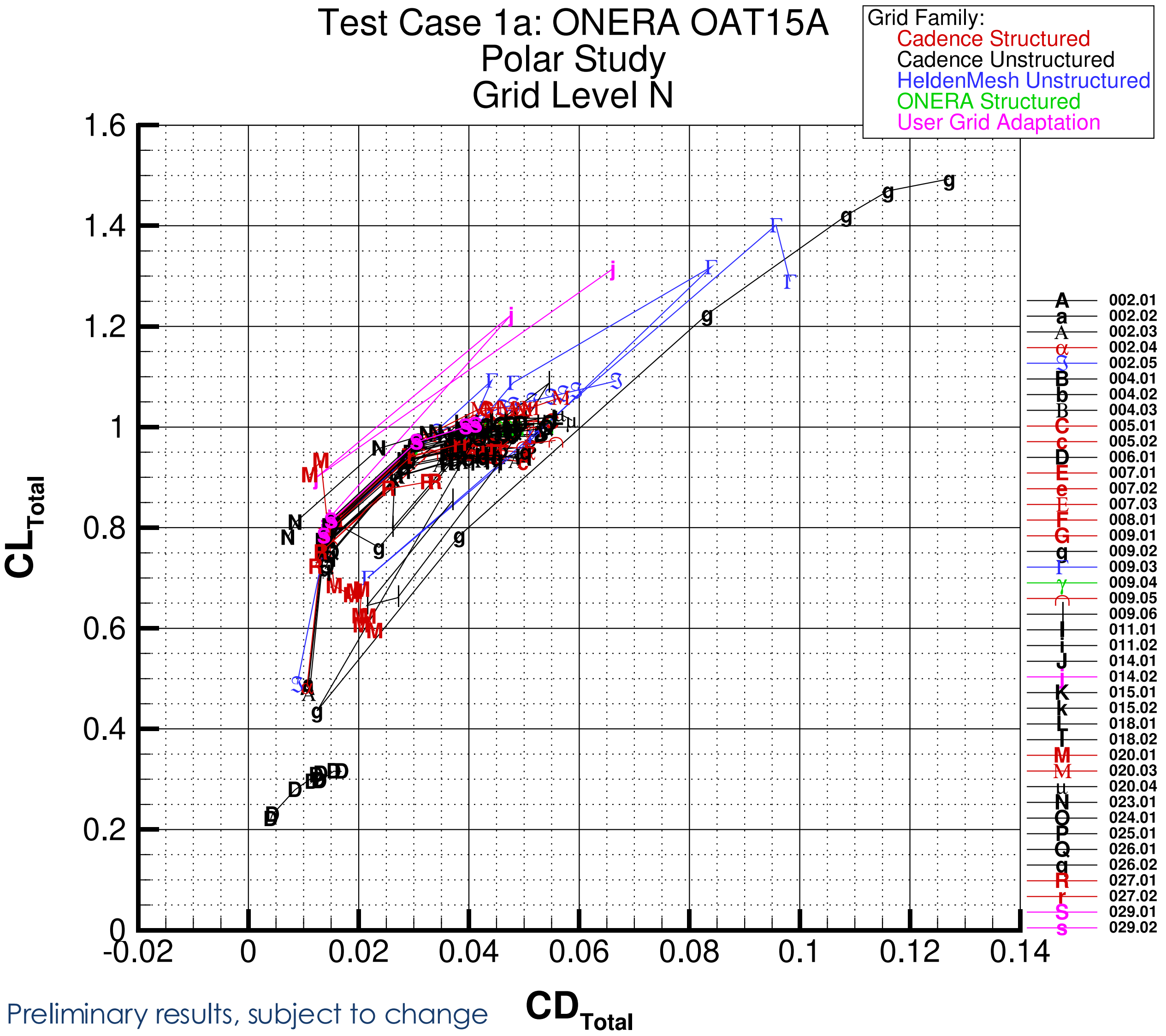


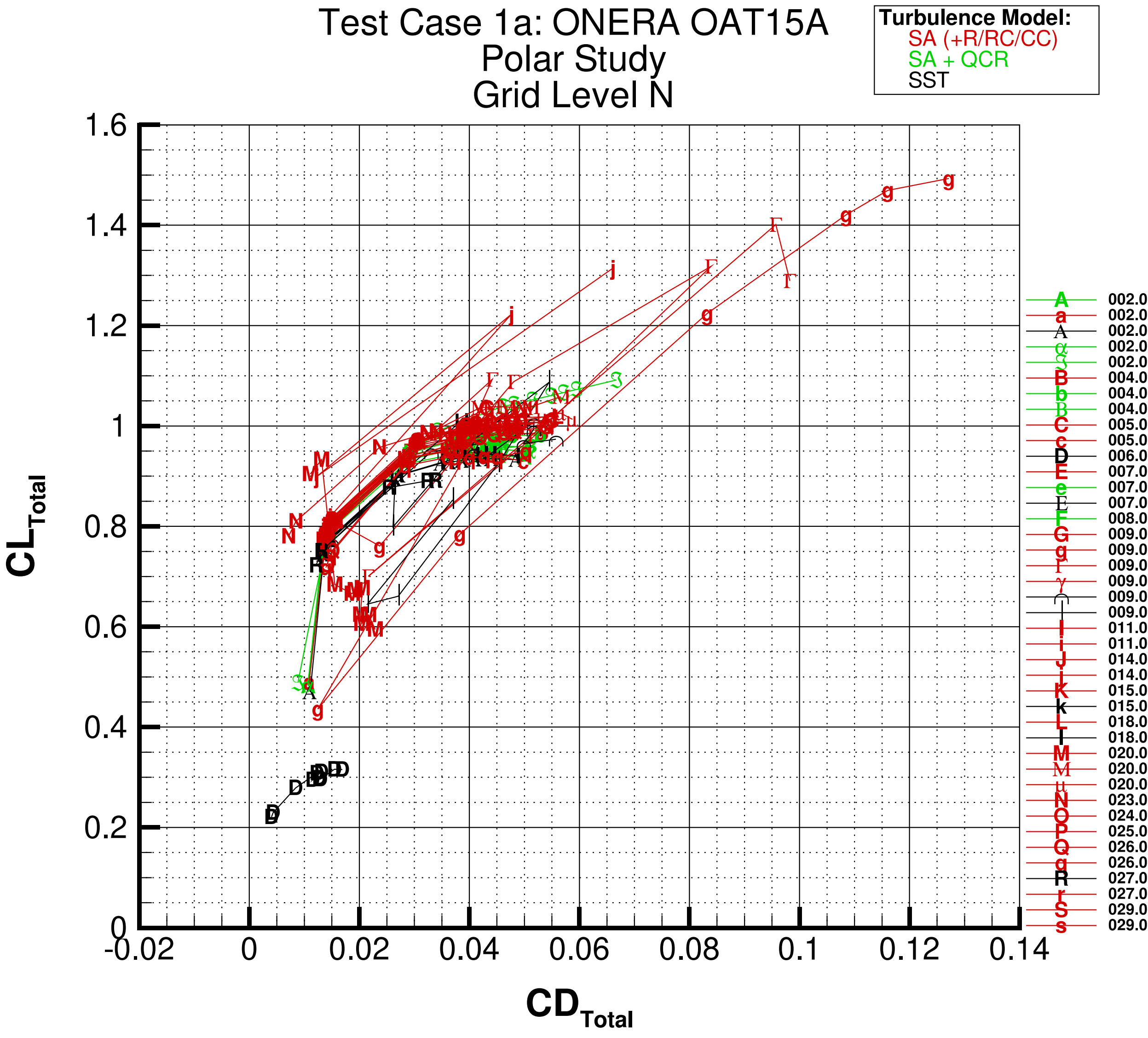


**AoA** **AoA**

Preliminary results, subject to change
Current as of 1/8/2025

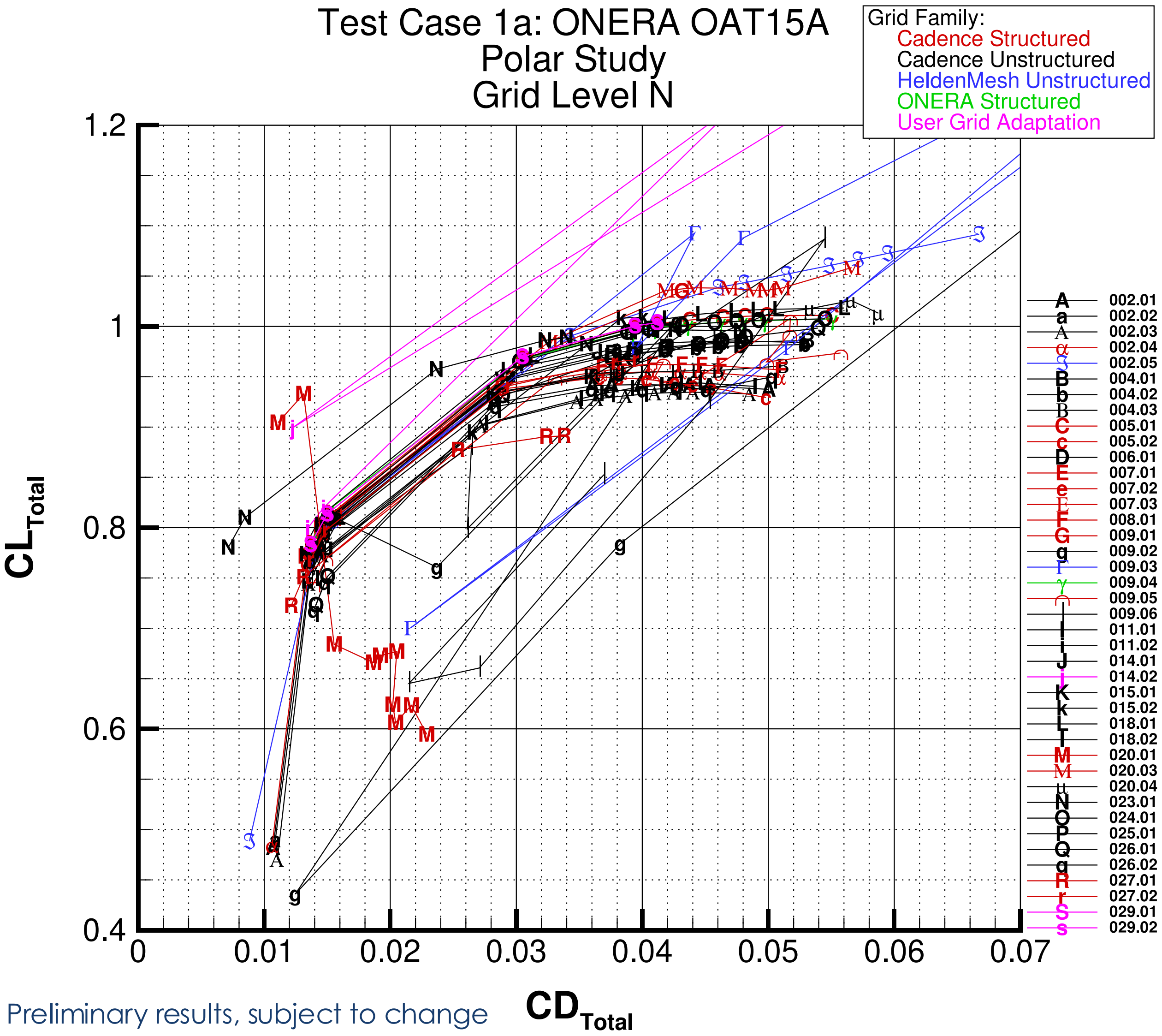
# ONERA OAT15A $C_L - C_D$ Polar: Finest Mesh

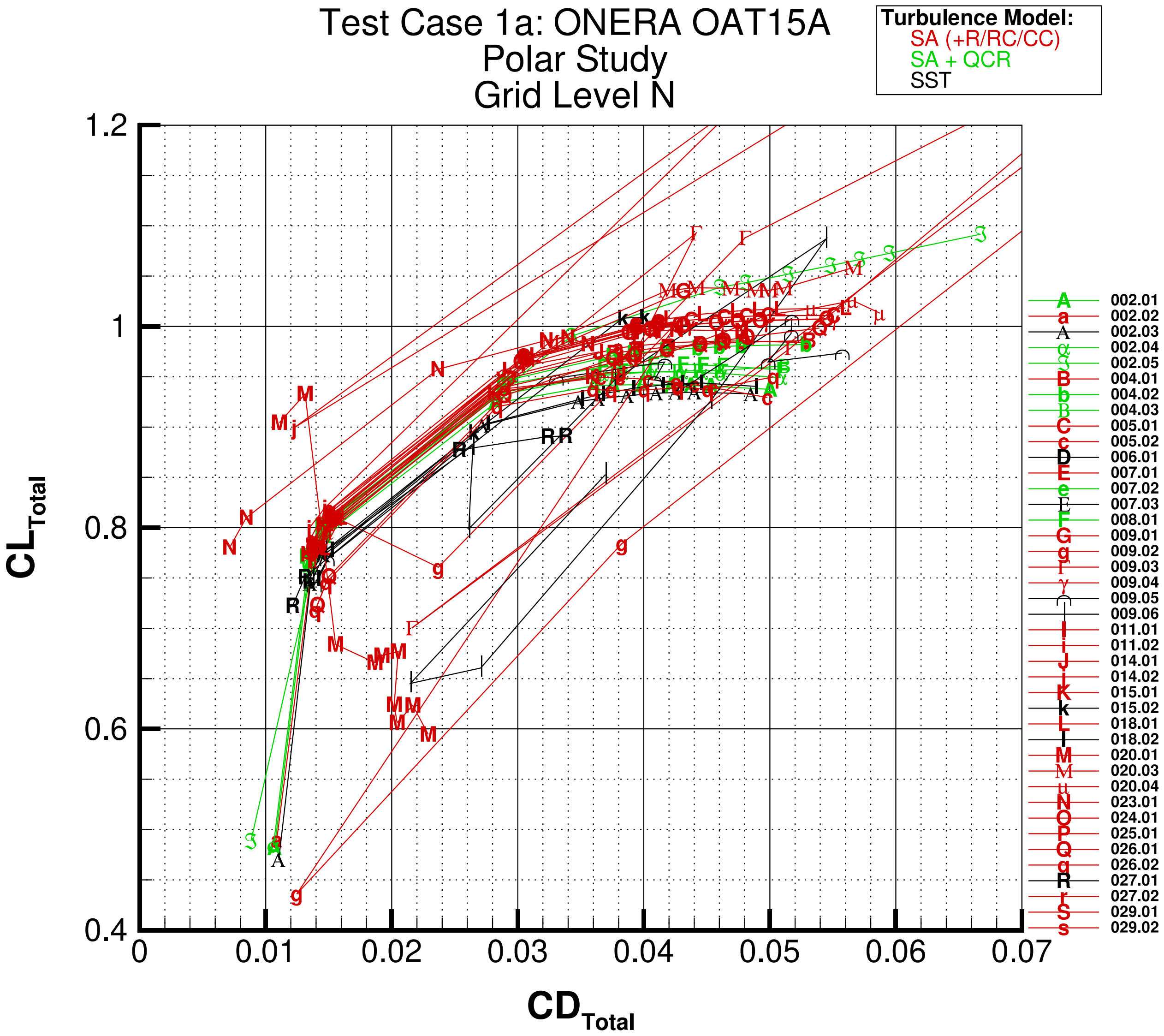




Preliminary results, subject to change
Current as of 1/8/2025

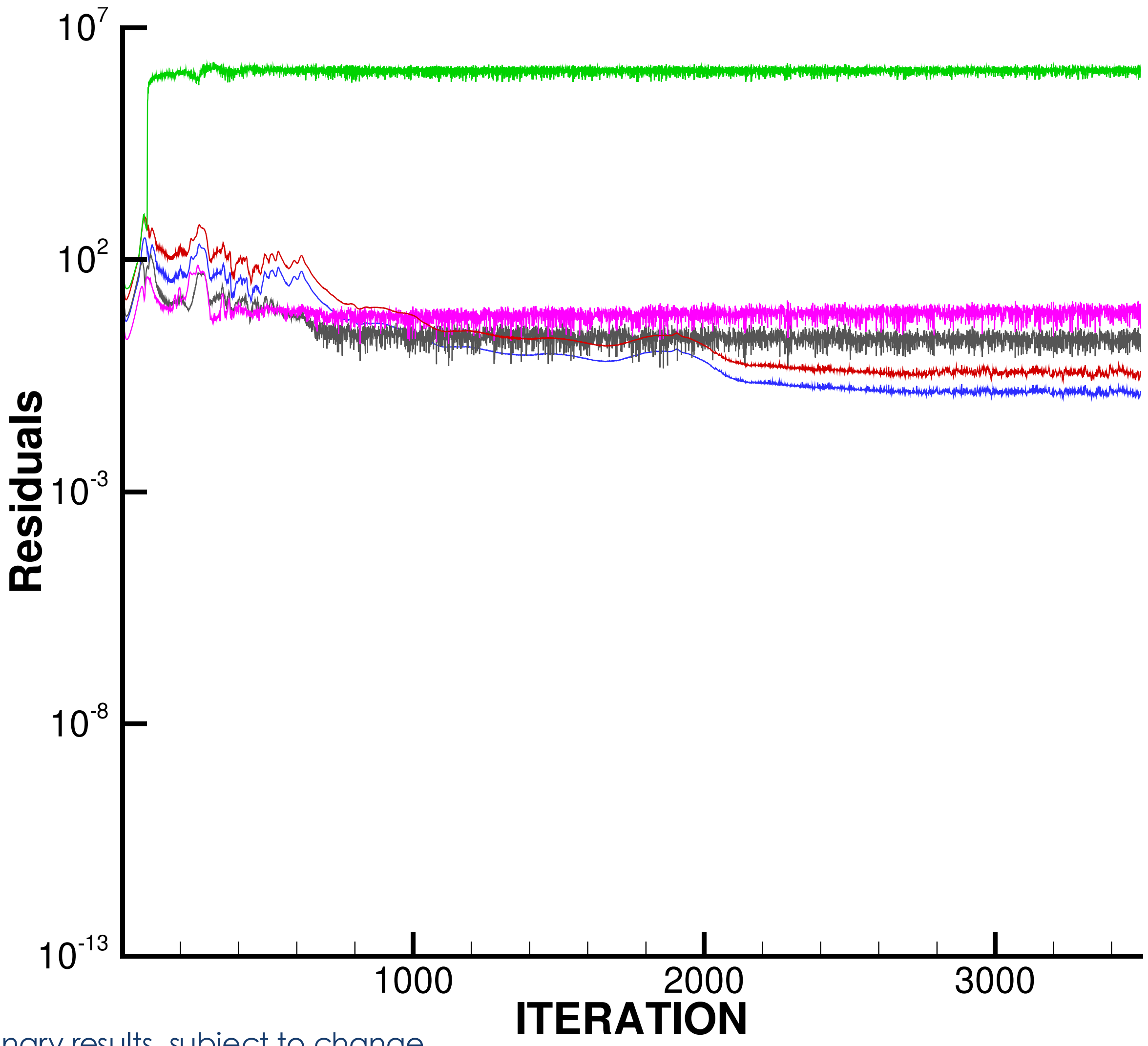
# ONERA OAT15A $C_L - C_D$ Polar: Finest Mesh

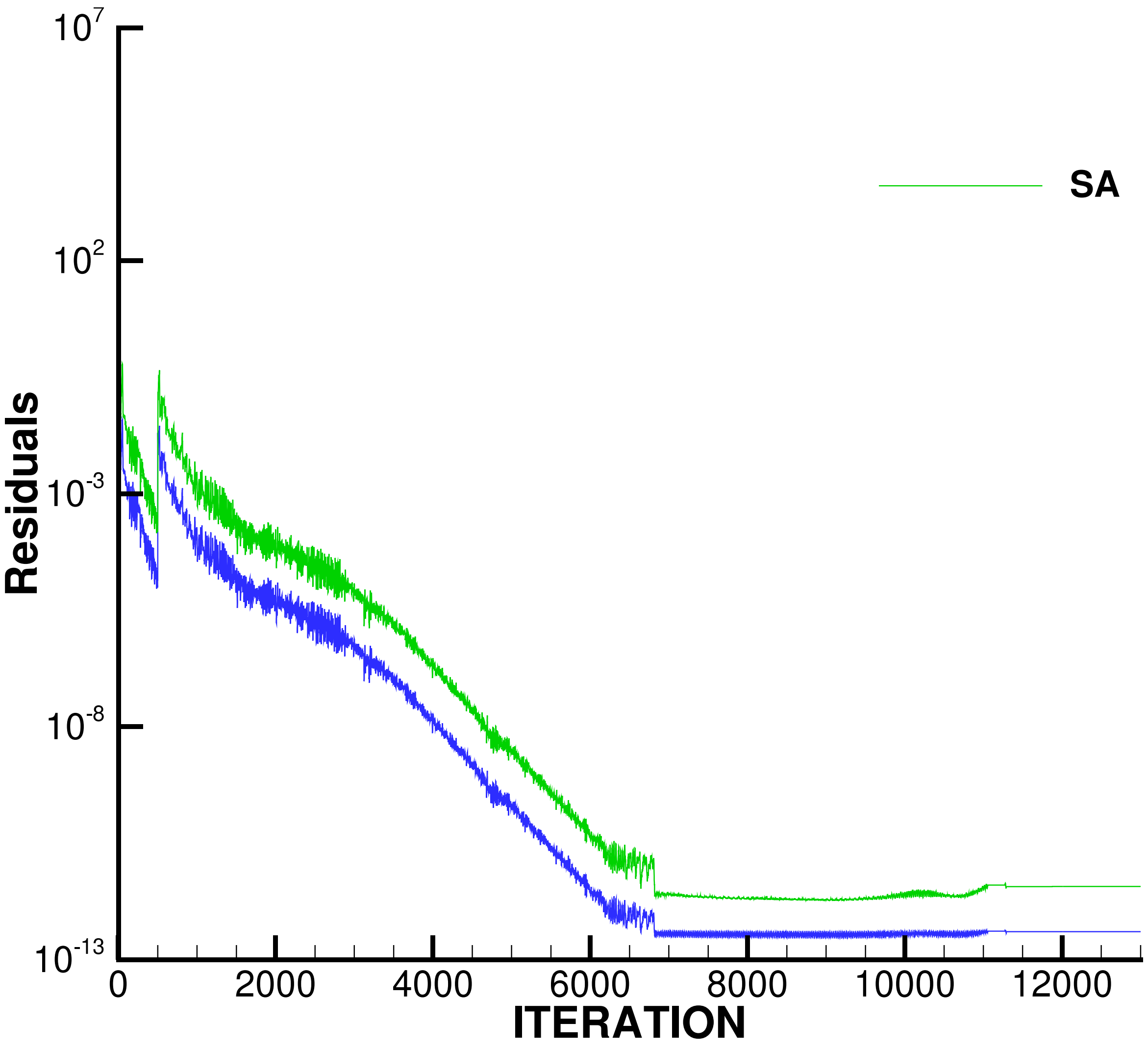




Preliminary results, subject to change
Current as of 1/8/2025

# Source of Scatter: Residual Convergence

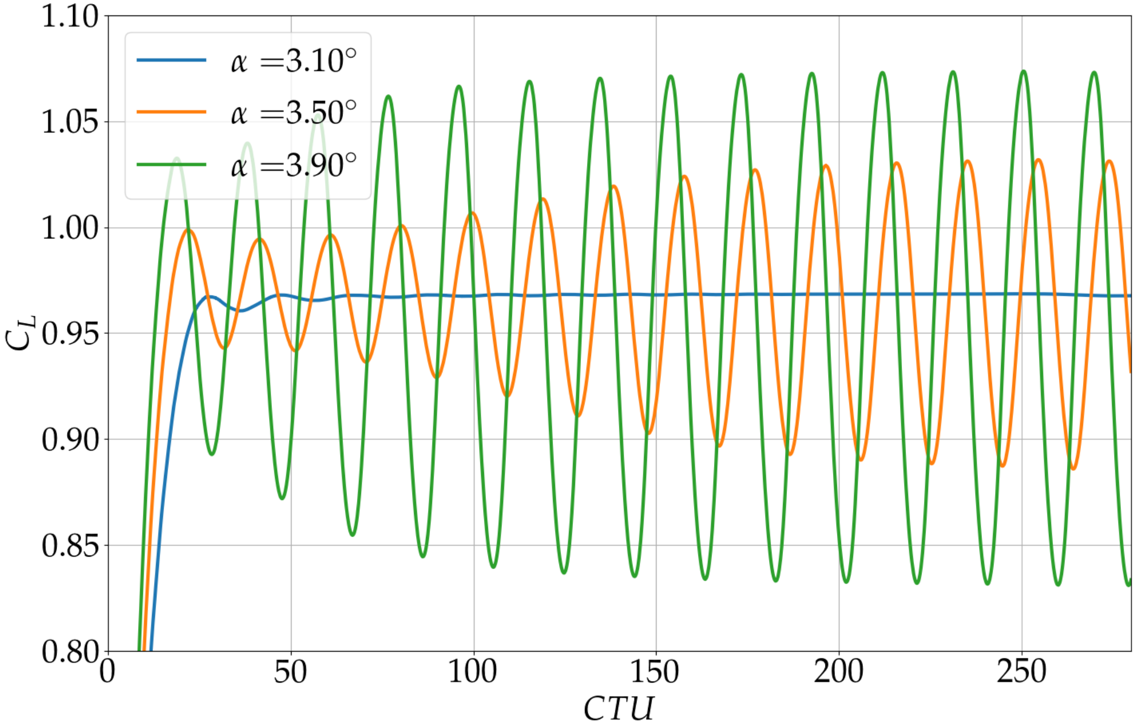




Preliminary results, subject to change
Current as of 1/8/2025

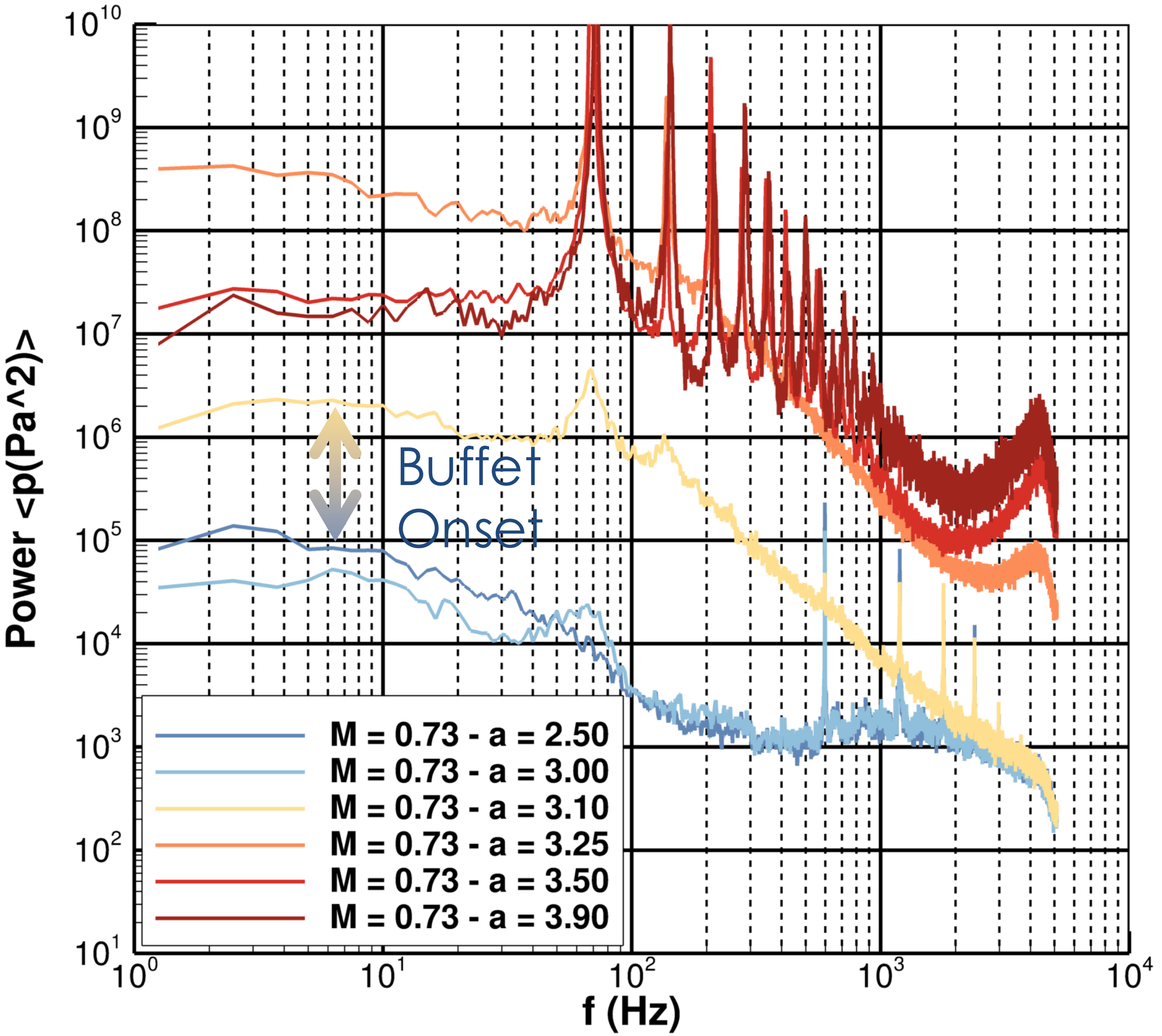
# ONERA OAT15A Buffet Test Case: Overview

- **Extension of steady ONERA OAT15A**
  - Validation of unsteady CFD analysis
  - RANS and unsteady data required from 3.25 to 3.90 deg
  - Users encouraged to employ best practices
- **Analyses**
  - Sensitivity to time-integration parameters, grid resolution, turbulence model
  - Buffet onset angle of attack
  - Spectral content and frequencies
- **Preliminary data thus far**
  - Limited data set available today
  - All data due February 14

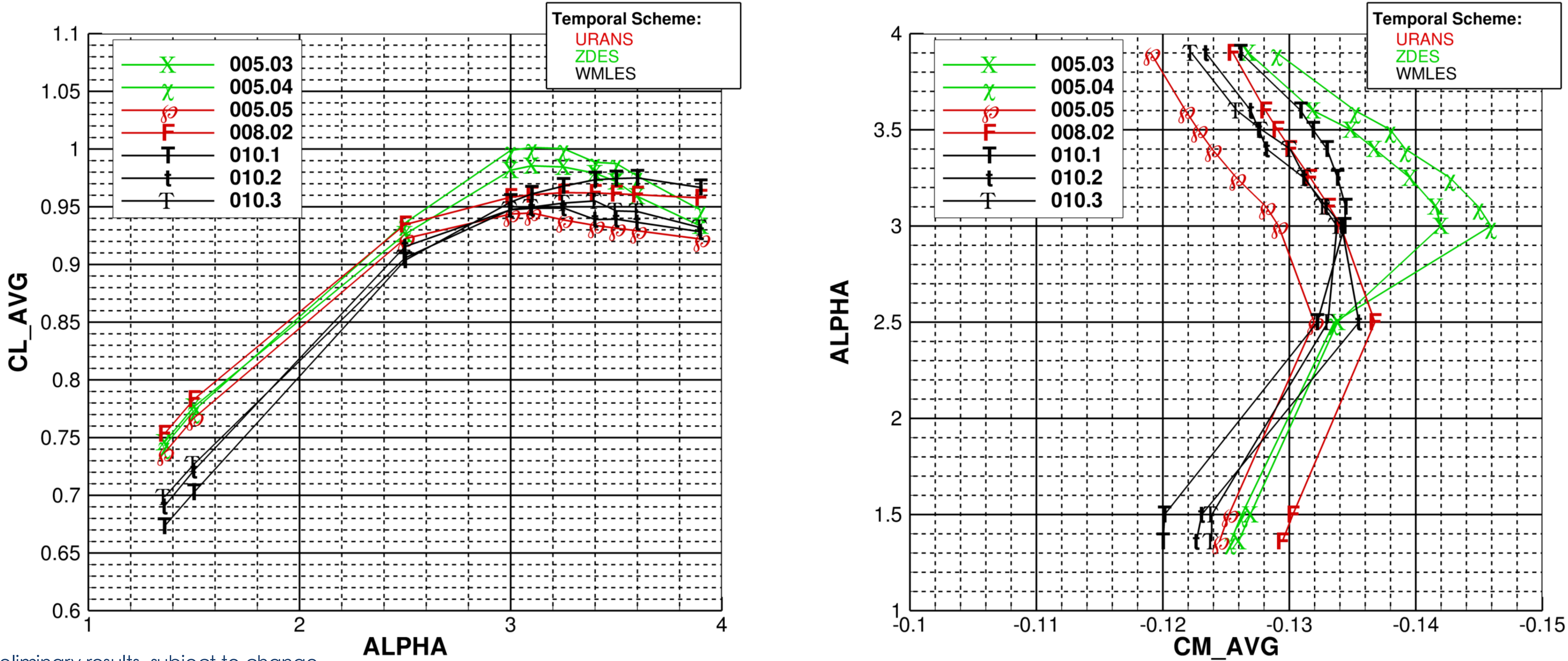


# ONERA OAT15A Buffet Test Case: Experiment

- **Rich experimental data set**
  - ONERA S3Ch wind tunnel
  - Kulites at multiple chordwise locations
  - Availability of two-dimensional data, including all requisite corrections
- **Buffet onset observed near 3.1 deg**
  - Increased spectral power
  - Similar peak frequencies for subsequent angles of attack

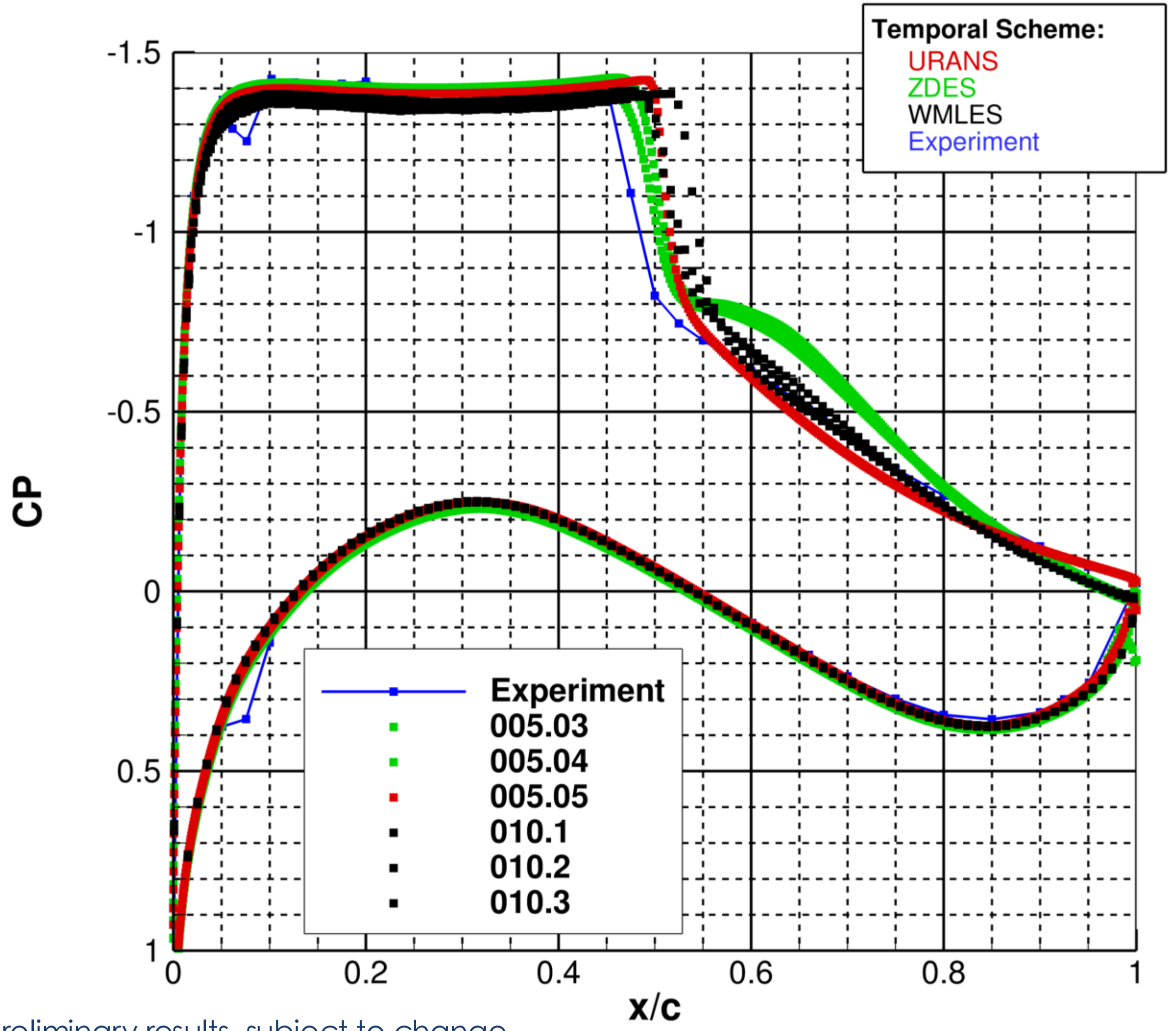


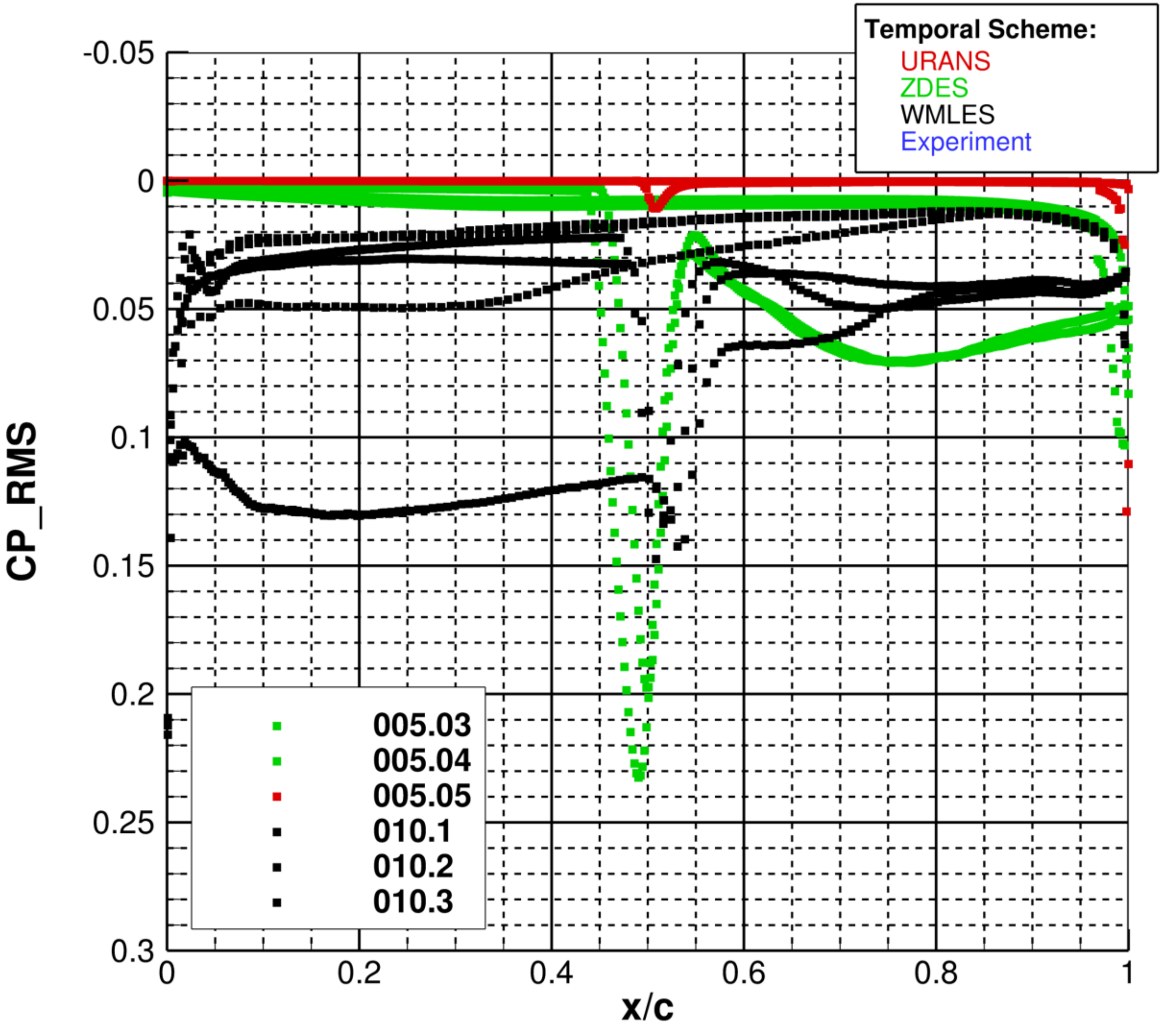
# ONERA OAT15A Buffet Test Case: First Look F&M



Preliminary results, subject to change
Current as of 1/8/2025

# ONERA OAT15A Buffet Test Case: First Look CP

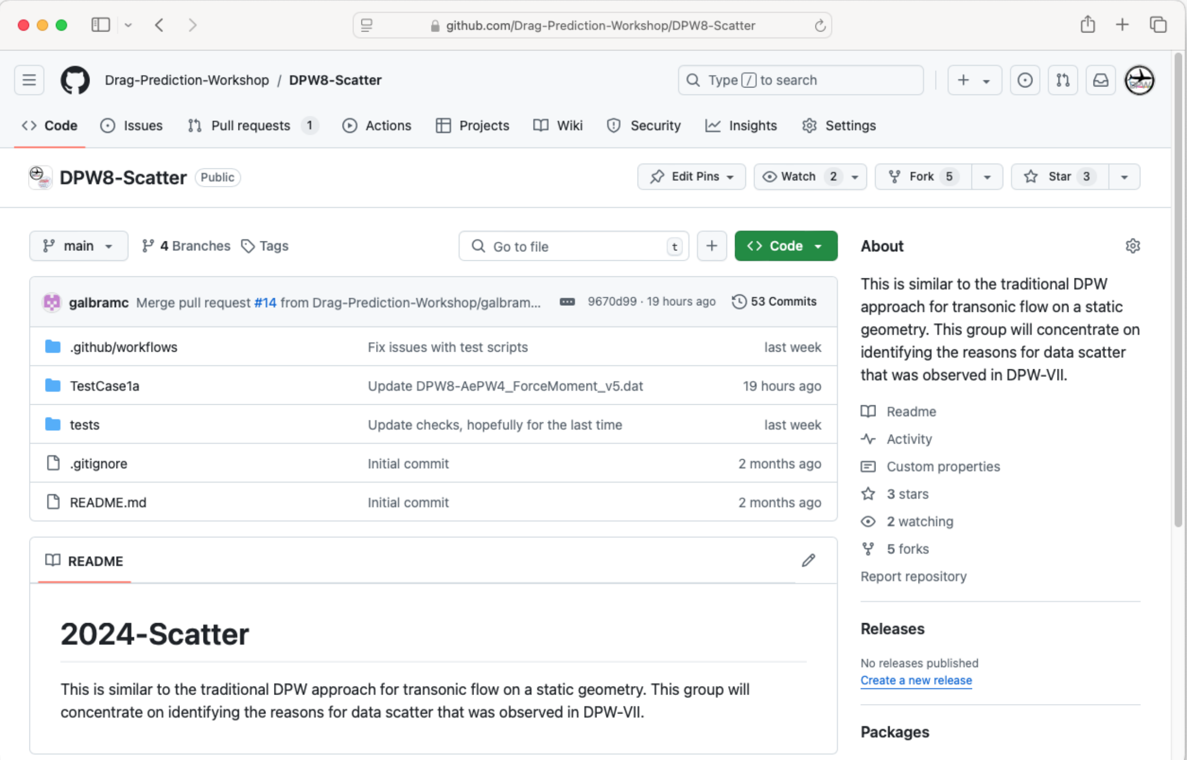




Preliminary results, subject to change
Current as of 1/8/2025

# GitHub

- **Leverage experience from High-Fidelity CFD Workshop**
- **One stop shop for all DPW-centric and hybrid groups data**
  - Improves version control
  - Ensures all committee members are looking at the most recent data
  - Facilitates easy plotting for the committee
- **Public and outward-facing**
  - Top-level README.md identifies institutions, individuals, and codes
  - All data are freely downloadable



galbramc Merge pull request #14 from Drag-Prediction-Workshop/galbram... 9670d99 · 19 hours ago 53 Commits

| | | |
|---|---|---|
| .github/workflows | Fix issues with test scripts | last week |
| TestCase1a | Update DPW8-AePW4_ForceMoment_v5.dat | 19 hours ago |
| tests | Update checks, hopefully for the last time | last week |
| .gitignore | Initial commit | 2 months ago |
| README.md | Initial commit | 2 months ago |

2024-Scatter

This is similar to the traditional DPW approach for transonic flow on a static geometry. This group will concentrate on identifying the reasons for data scatter that was observed in DPW-VII.

About

This is similar to the traditional DPW approach for transonic flow on a static geometry. This group will concentrate on identifying the reasons for data scatter that was observed in DPW-VII.

Readme
Activity
Custom properties
3 stars
2 watching
5 forks
Report repository

Releases

No releases published
Create a new release

Packages

# GitHub

- **Data Submission Instructions**
  - https://aiaa-dpw.larc.nasa.gov/Forms/GitHubSubmissionSlides.pdf

**Scatter Reduction WG**
- **TestCase1a**
  - *001_AeroCompanyX*
    - README.md (notes about submissions)
    - 01_CFDcode_Cadence_SA_etc.
      - DPW8-AePW4_ForceMoment_v5.dat
      - DPW8-AePW4_Convergence_v5.dat
      - DPW8-AePW4_SectionalCuts_v5.dat
    - 02_ CFDcode_Cadence_SST_etc.
    - 03_ CFDcode_Helden_SA_etc.
    - 04_ CFDcode_Onera_SA_etc.
  - *002_UniversityX*
    - README.md (notes about submissions)
    - 01_CFDinHouse_CustomGrid_SA
    - 02_CFDinHouse_CustomGrid_SA-RC
    - 03_OtherCode_CustomGrid_SA-RC

Replace “XXX” **inside** data files with “001.01”

*Please use supplied file names to ease post processing.*

*Please split future submissions of **Convergence** and **SectionalCuts** into individual files for each simulation (append this descriptor after the original file name)*

*i.e.:*

*DPW8-AePW4_Convergence_v5_ALPHA1.36_GRID1.dat*

*Original name*

*Descriptor:*

*ALPHA & GRID #*

# ONERA OAT15A Open Discussion

# Outline

9:30 Introduction and Motivation

9:40 Working Group Updates

10:15 Mini Workshop

**10:50 CRM Look-Ahead**

- Grid requirements and updates
- Discussion of available experimental data
- Discussion of available finite element models

11:25 Open Discussion

1:00 Bayhill 26 Available for Discussion Until 3:00

# Grid Requirements and Update

- **Committee developed gridding guidelines leveraging historic knowledge**
  - Six-member grid family
  - Progressively finer surface grid and decreased $y^+$
  - Consistent with DPW-7
  - Different viscous grid spacing for various Reynolds numbers
- **Grids from NASA Ames, Helden, and Cadence**
- **User-generated grids are welcomed**
  - Requested to provide these grids for the community to use
  - Recommend to follow the gridding guidelines, but not required

# NASA Ames – Overset

| Configuration | Wing Loading a (deg.) | L1 | L2 | L3 | L4 | L5 | L6 |
|---|---|---|---|---|---|---|---|
| CRM Wing/Body | 2.50 | | | x | | | |
| CRM Wing/Body | 2.75 | | | x | | | |
| CRM Wing/Body | 3.00 | 🟨x | 🟨x | 🟨x | 🟨x | 🟨x | 🟨x |
| CRM Wing/Body | 3.25 | | | x | | | |
| CRM Wing/Body | 3.50 | | | x | | | |
| CRM Wing/Body | 3.75 | | | x | | | |
| CRM Wing/Body | 4.00 | | | x | | | |
| CRM Wing/Body | 4.25 | | | x | | | |
| JAXA Wing/Body/Tail | 4.84 | 🟩x | 🟩x | 🟩x | 🟩x | 🟩x | 🟩x |
| JAXA Wing/Body/Tail | 5.89 | | | 🟩x | | | |
| JIG Wing/Body | 0.0 | 🟩x | 🟩x | 🟩x | 🟩x | 🟩x | 🟩x |
| JIG Wing/Body/Tail | 0.0 | | | 🟨x | | | |
| JIG Wing/Body/Nacelle/Pylon | 0.0 | x | x | 🟨x | x | x | x |

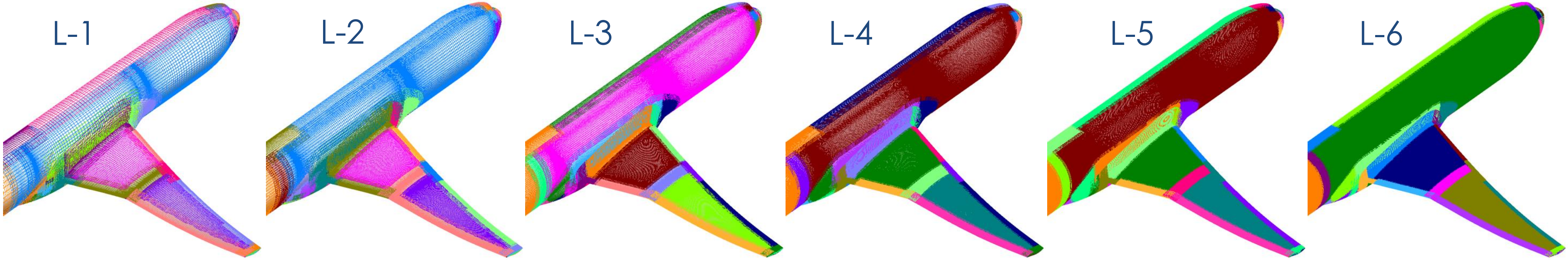
🟩x - surf. & vol. grids
- connectivity data
- various input files *
(🟩flow-solver ready)

🟨x - surf. + vol. grids
- various input files *

x to be completed

* - component loads computation (FOMOCO)
- flow solver b.c. (OVERFLOW)

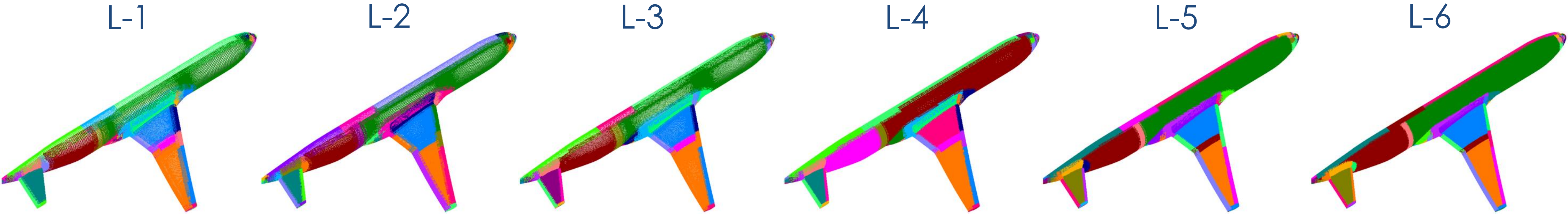
# Mesh Family for Jig Wing/Body



maxa - max dihedral angle
maxe - max cell size
npmin - min #pts on discretized BREP edge
maxsr - max stretching ratio

| L | maxa (deg) | maxe | npmin | maxsr | Ds wall (x $10^{-4}$) | # grid | # Surf. Pt (M) | # Total Vol. Pt (M) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 15.0 | 9 | 1.19 | 5.423 | 67 | 0.13 | 11.7 |
| 2 | 4.5 | 10.0 | 13 | 1.135 | 3.615 | 68 | 0.25 (x1.9) | 27.3 (x2.3) |
| 3 | 4.0 | 6.667 | 17 | 1.10 | 2.410 | 73 | 0.46 (x1.8) | 62.6 (x2.3) |
| 4 | 3.5 | 4.444 | 21 | 1.07 | 1.607 | 73 | 0.88 (x1.9) | 160.0 (x2.6) |
| 5 | 3.0 | 3.0 | 25 | 1.05 | 1.071 | 74 | 1.65 (x1.9) | 409.0 (x2.6) |
| 6 | 2.5 | 2.0 | 29 | 1.04 | 0.714 | 76 | 3.45 (x2.1) | 1053.7 (x2.6) |

# Mesh Family for JAXA Wing-Body Tail $\alpha$=4.84°

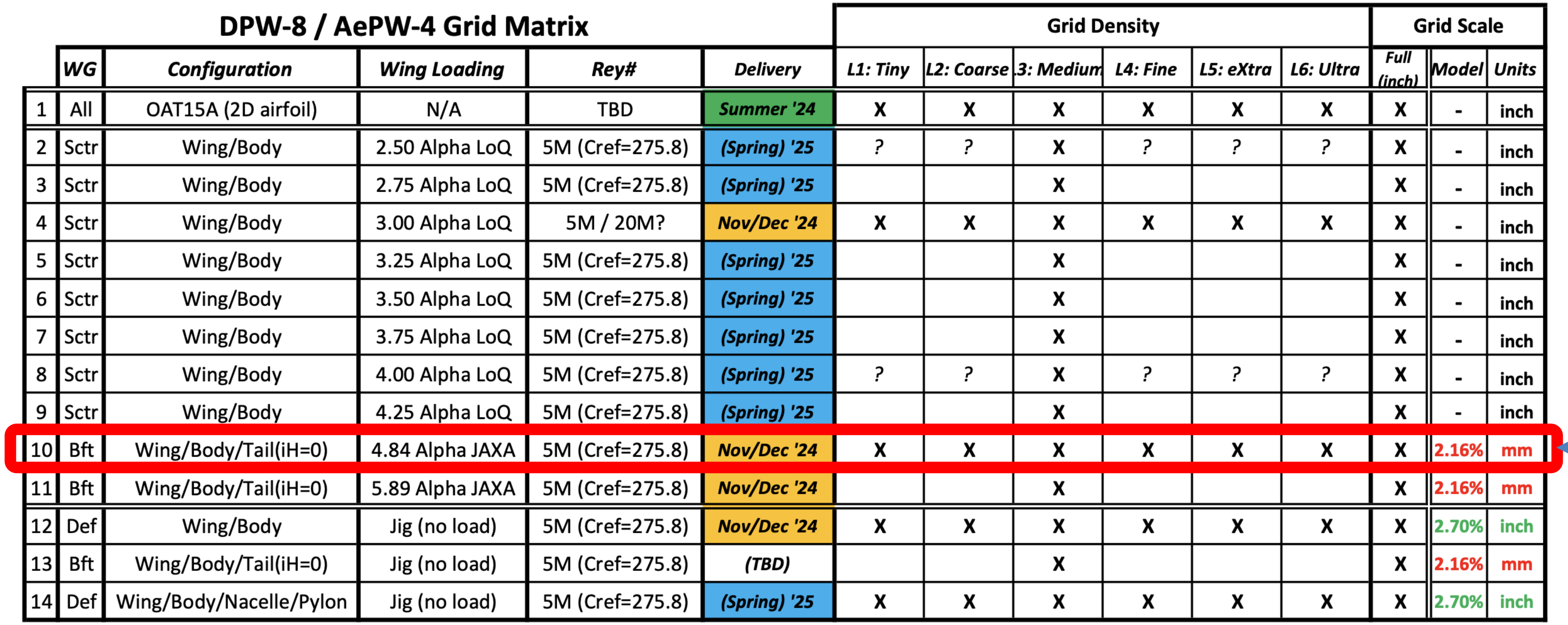


maxa - max dihedral angle
maxe - max cell size
npmin - min #pts on discretized BREP edge
maxsr - max stretching ratio

| L | maxa (deg) | maxe | npmin | maxsr | Ds wall (x $10^{-4}$) | # nb grid | # Surf. Pt (M) | # Total Vol. Pt (M) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 15.0 | 9 | 1.19 | 5.423 | 81 | 0.21 | 16.5 |
| 2 | 4.5 | 10.0 | 13 | 1.135 | 3.615 | 80 | 0.39 (x1.9) | 39.8 (x2.4) |
| 3 | 4.0 | 6.667 | 17 | 1.10 | 2.410 | 86 | 0.74 (x1.9) | 96.0 (x2.4) |
| 4 | 3.5 | 4.444 | 21 | 1.07 | 1.607 | 85 | 1.38 (x1.9) | 241.6 (x2.5) |
| 5 | 3.0 | 3.0 | 25 | 1.05 | 1.071 | 93 | 2.72 (x2.0) | 647.8 (x2.7) |
| 6 | 2.5 | 2.0 | 29 | 1.04 | 0.714 | 116 | 5.37 (x2.0) | 1574 (x2.4) |

# Helden – Meshing Status / Overview

- **Using process from AIAA HLPW5 to develop best mesh characteristics**
  - Uses spatial adaption to identify regions for refinement (surface and volume) & overall mesh characteristics
  - Detailed meshing refinement studies



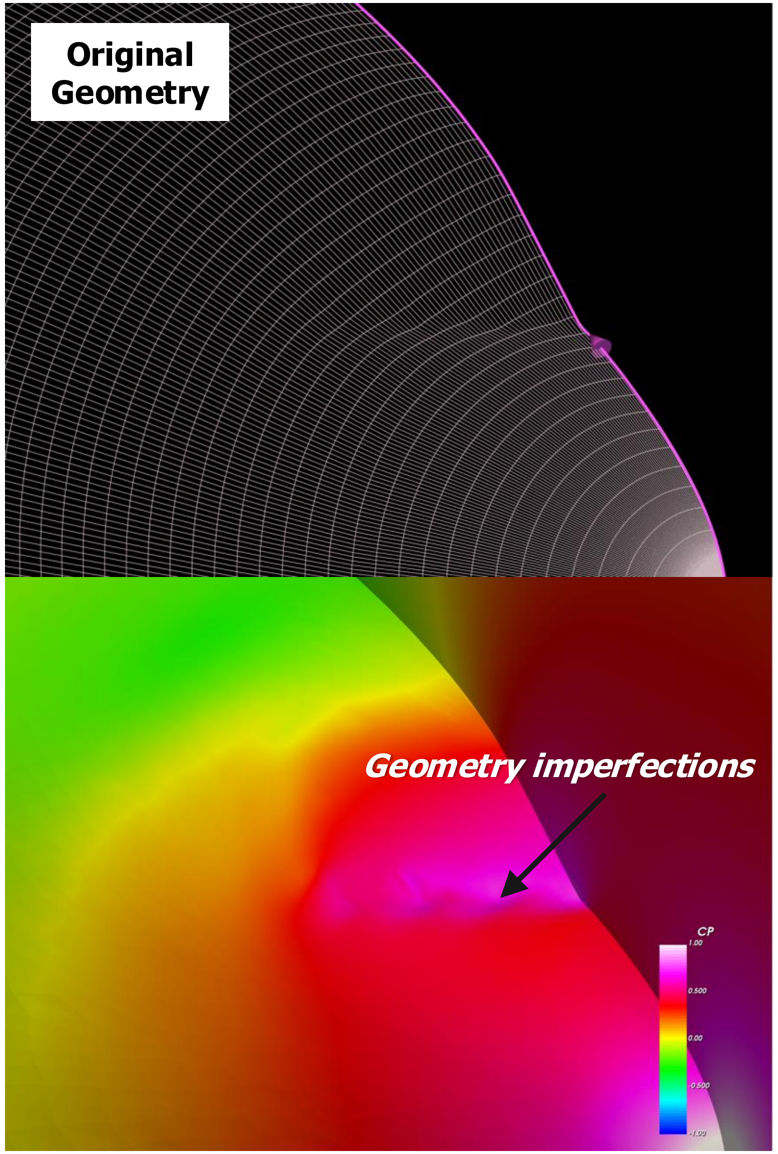
**DPW-8 / AePW-4 Grid Matrix**

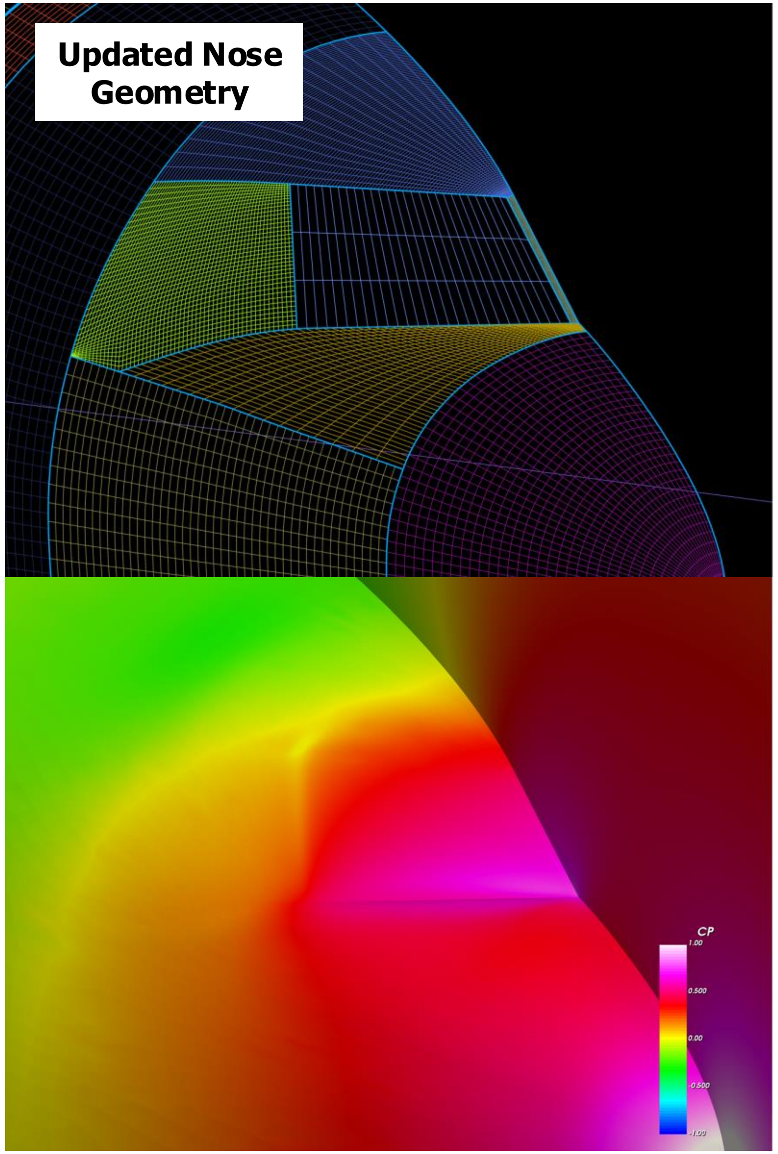
| | | | | | | Grid Density | | | | | | Grid Scale | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***WG*** | ***Configuration*** | ***Wing Loading*** | ***Rey#*** | ***Delivery*** | ***L1: Tiny*** | ***L2: Coarse*** | ***3: Medium*** | ***L4: Fine*** | ***L5: eXtra*** | ***L6: Ultra*** | ***Full (inch)*** | ***Model*** | ***Units*** |
| 1 | All | OAT15A (2D airfoil) | N/A | TBD | ***Summer '24*** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **-** | **inch** |
| 2 | Sctr | Wing/Body | 2.50 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | *?* | *?* | **X** | *?* | *?* | *?* | **X** | **-** | **inch** |
| 3 | Sctr | Wing/Body | 2.75 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | | | **X** | | | | **X** | **-** | **inch** |
| 4 | Sctr | Wing/Body | 3.00 Alpha LoQ | 5M / 20M? | ***Nov/Dec '24*** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **-** | **inch** |
| 5 | Sctr | Wing/Body | 3.25 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | | | **X** | | | | **X** | **-** | **inch** |
| 6 | Sctr | Wing/Body | 3.50 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | | | **X** | | | | **X** | **-** | **inch** |
| 7 | Sctr | Wing/Body | 3.75 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | | | **X** | | | | **X** | **-** | **inch** |
| 8 | Sctr | Wing/Body | 4.00 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | *?* | *?* | **X** | *?* | *?* | *?* | **X** | **-** | **inch** |
| 9 | Sctr | Wing/Body | 4.25 Alpha LoQ | 5M (Cref=275.8) | ***(Spring) '25*** | | | **X** | | | | **X** | **-** | **inch** |
| 10 | Bft | Wing/Body/Tail(iH=0) | 4.84 Alpha JAXA | 5M (Cref=275.8) | ***Nov/Dec '24*** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **2.16%** | **mm** |
| 11 | Bft | Wing/Body/Tail(iH=0) | 5.89 Alpha JAXA | 5M (Cref=275.8) | ***Nov/Dec '24*** | | | **X** | | | | **X** | **2.16%** | **mm** |
| 12 | Def | Wing/Body | Jig (no load) | 5M (Cref=275.8) | ***Nov/Dec '24*** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **2.70%** | **inch** |
| 13 | Bft | Wing/Body/Tail(iH=0) | Jig (no load) | 5M (Cref=275.8) | ***(TBD)*** | | | **X** | | | | **X** | **2.16%** | **mm** |
| 14 | Def | Wing/Body/Nacelle/Pylon | Jig (no load) | 5M (Cref=275.8) | ***(Spring) '25*** | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **2.70%** | **inch** |

Helden Meshes for Rows 4, 10, 11, and 12 available shortly.

Used to define mesh family characteristics

# Nose Geometry Modifications Required

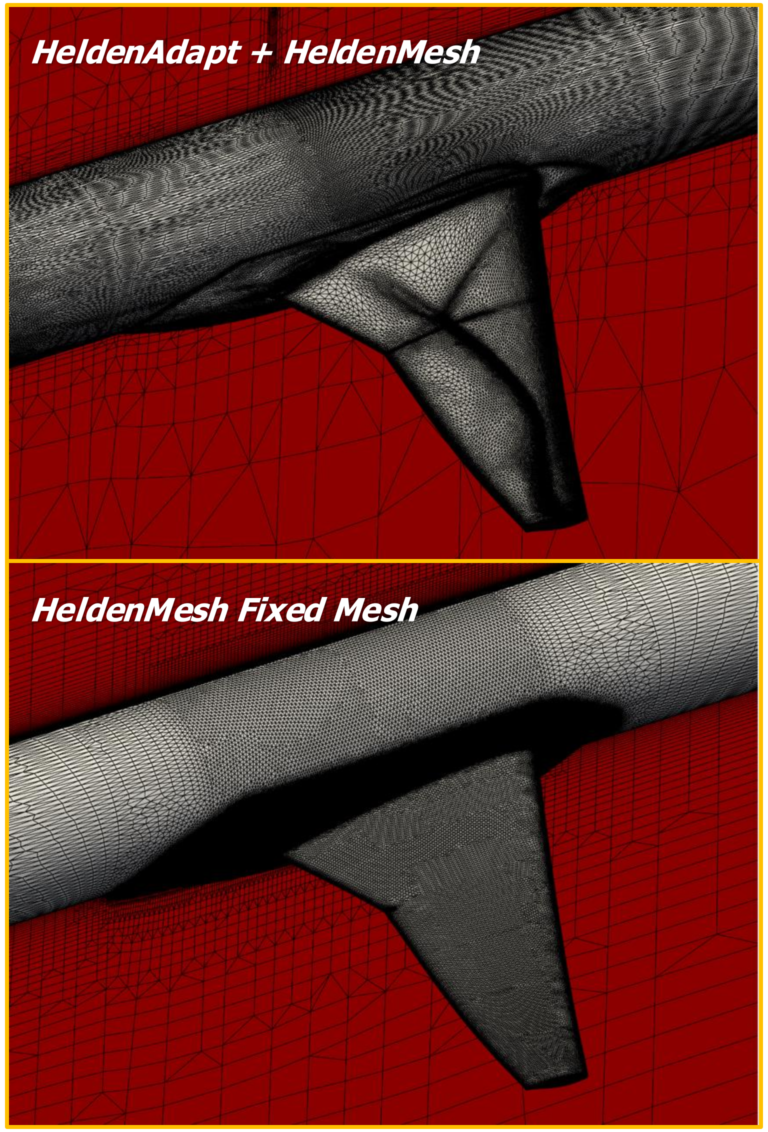




- **Unsmooth CAD model provided for workshop is not representative of what was manufactured for wind tunnel testing.**
- **The model manufacturer reshaped the fuselage based on best practices.**
- **Manufactured CAD model was not available.**
- **Helden updated a CAD loft based on previous CRM lofts.**
  - wbh_aoa487_buffet_deformed_updatednose.iges
  - wbh_aoa592_buffet_deformed_updatednose.iges
- **Recommend using reshaped CAD model.**

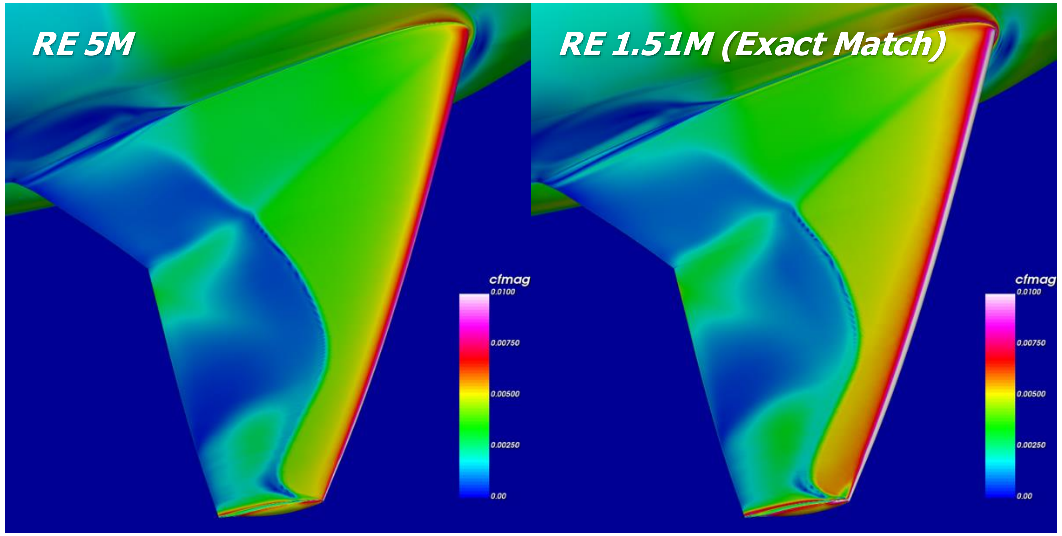
# Using Adaptation to Inform Mesh Development

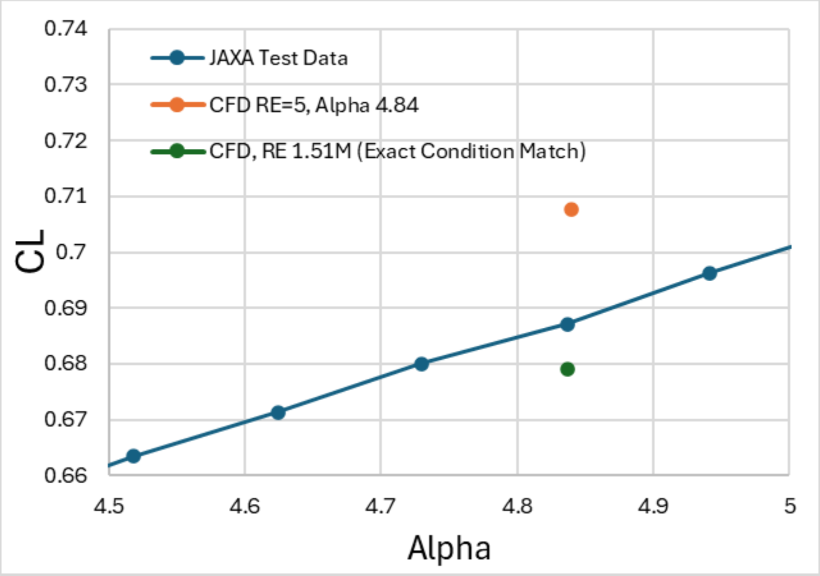
- **HeldenAdapt process used to generate solution adaptive grids**
  - Process takes an existing flow solution and converts it to a mesh spacing field
    - Uses Mach Hessian, so you are adding grid wherever the 2nd derivative of Mach is high
  - New mesh built from scratch using HeldenMesh with hybrid elements in boundary layer and high anisotropic stretching
  - These grids will be used to find what the grid resolved CL and CD are and to tell us how to design the fixed mesh series
    - Where to put mesh and to what levels
- **Fixed mesh refinement series will be created for Alpha 4.84 Wing, Alpha 5.8 Wing, and Jig Wing**
  - Built without adaption but refined in generalized regions
    - Areas of curvature
    - Leading edges / trailing edges
    - Wing upper surface
    - Wing/fuselage fairing
  - Adapted meshes are impractical for Jig Wing (where wing shape and shock location is variable)

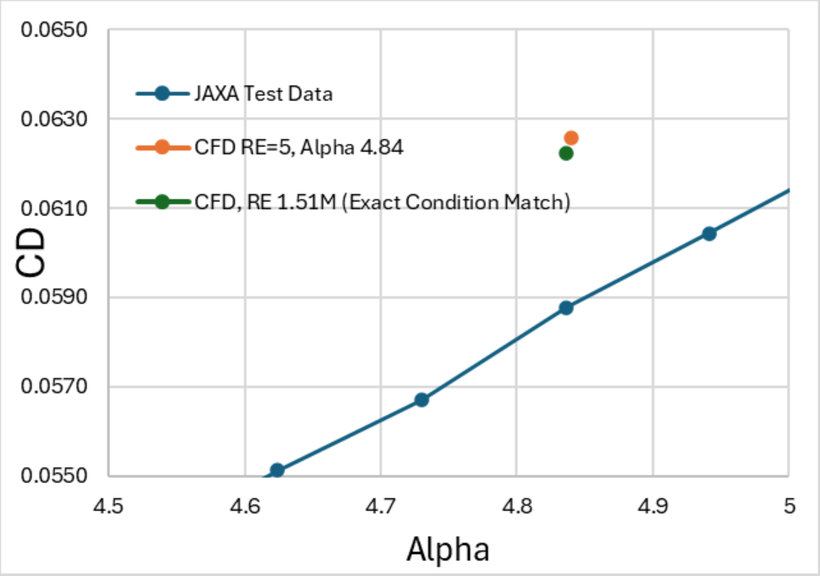


# Impact of Re on Flow Characteristics

- **USM3DME run at the exact test conditions (RE 1.51M) vs. CFD conditions (RE 5M)**
- **Results show differences in shock location, lift, and skin friction contours**
  - ΔCL = 0.0284 (4%)
  - ΔCD = -0.0003 (0.4%)
- **Re effects on lift are significant**

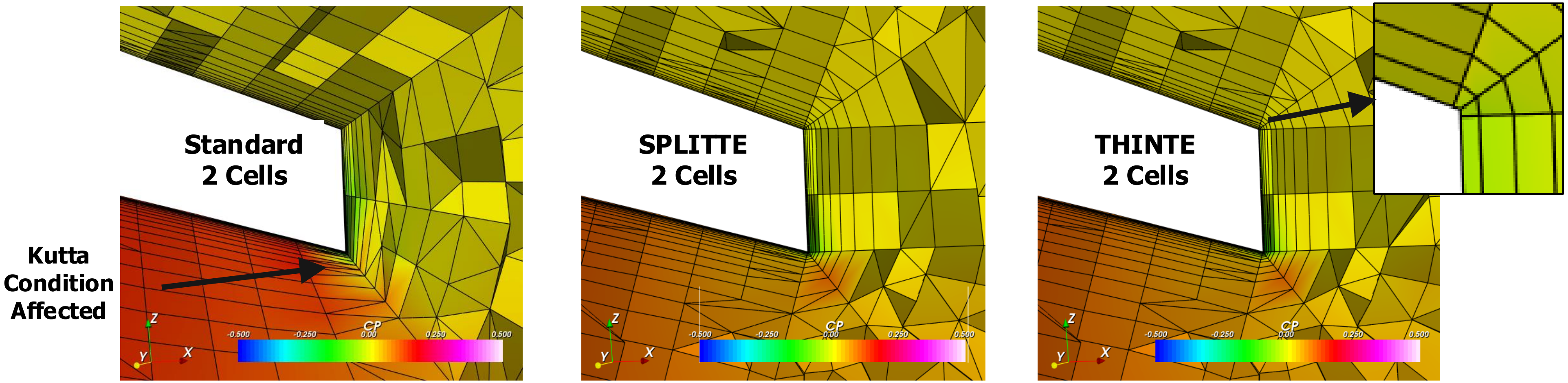


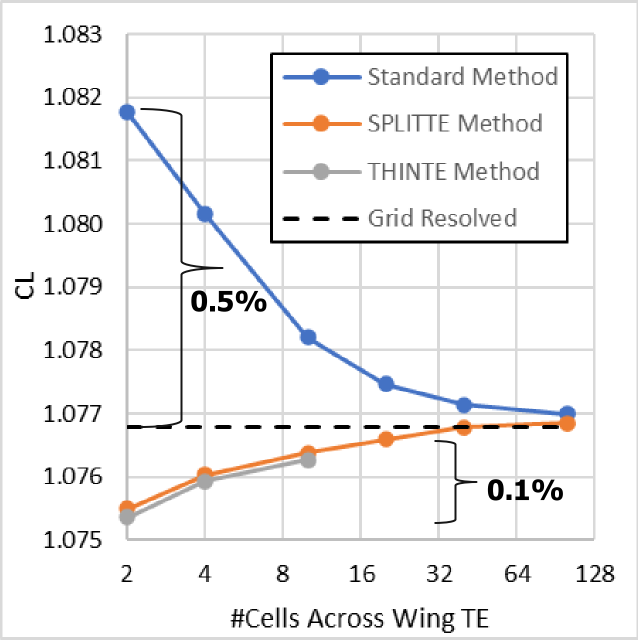


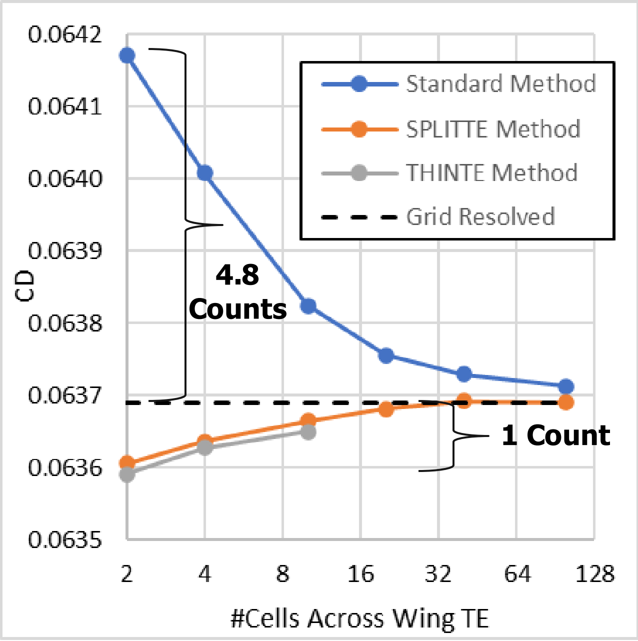


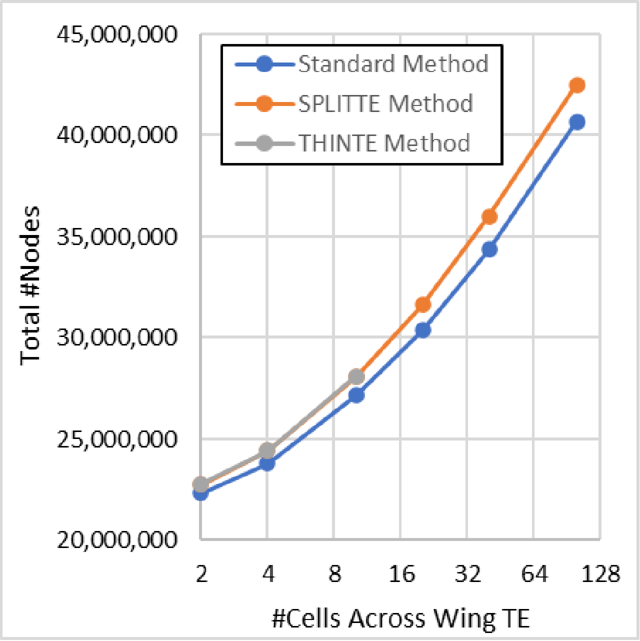
# AIAA HLPW5 Relevant Finding

- **Required mesh TE spacing can be reduced by changing mesh topology.**









# Cadence

| Configuration | Wing Loading a (deg.) | L1 y+=1 | L2 | L3 | L4 | L5 | L6 |
|---|---|---|---|---|---|---|---|
| CRM Wing/Body | 2.50 | | | 🟩 x | | | |
| CRM Wing/Body | 2.75 | | | 🟩 x | | | |
| CRM Wing/Body | 3.00 | 🟩 x | 🟩 x | 🟩 x | 🟩 x | 🟩 x | 🟩 x |
| CRM Wing/Body | 3.25 | | | 🟩 x | | | |
| CRM Wing/Body | 3.50 | | | 🟩 x | | | |
| CRM Wing/Body | 3.75 | | | 🟩 x | | | |
| CRM Wing/Body | 4.00 | | | 🟩 x | | | |
| CRM Wing/Body | 4.25 | | | 🟩 x | | | |
| JAXA Wing/Body/Tail | 4.84 | 🟥 x | 🟥 x | 🟥 x | 🟥 x | 🟥 x | 🟥 x |
| JAXA Wing/Body/Tail | 5.89 | | | 🟥 x | | | |
| JIG Wing/Body | 0.0 | 🟨 x | 🟨 x | 🟨 x | 🟨 x | 🟨 x | 🟨 x |
| JIG Wing/Body/Tail | 0.0 | | | 🟨 x | | | |
| JIG Wing/Body/Nacelle/Pylon | 0.0 | 🟨 x | 🟨 x | 🟨 x | 🟨 x | 🟨 x | 🟨 x |

🟩 x - Surf. & vol. grids
- Completed

🟨 x - Surf. + vol. grids
- Preliminary Versions

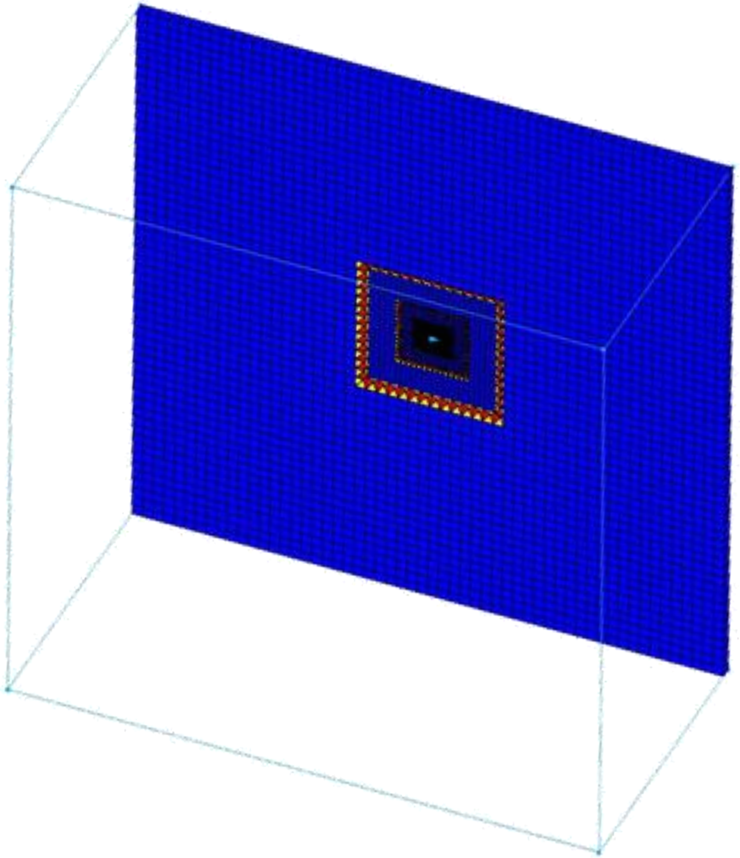
🟥 x - To be completed

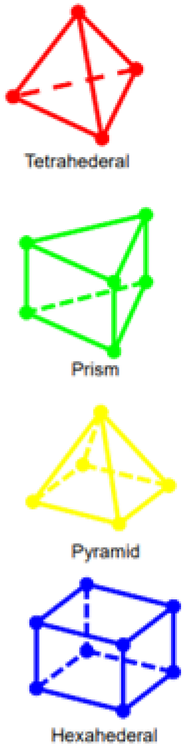
- Grids built in batch via Glyph script

- Grid Formats (Pointwise, CGNS)

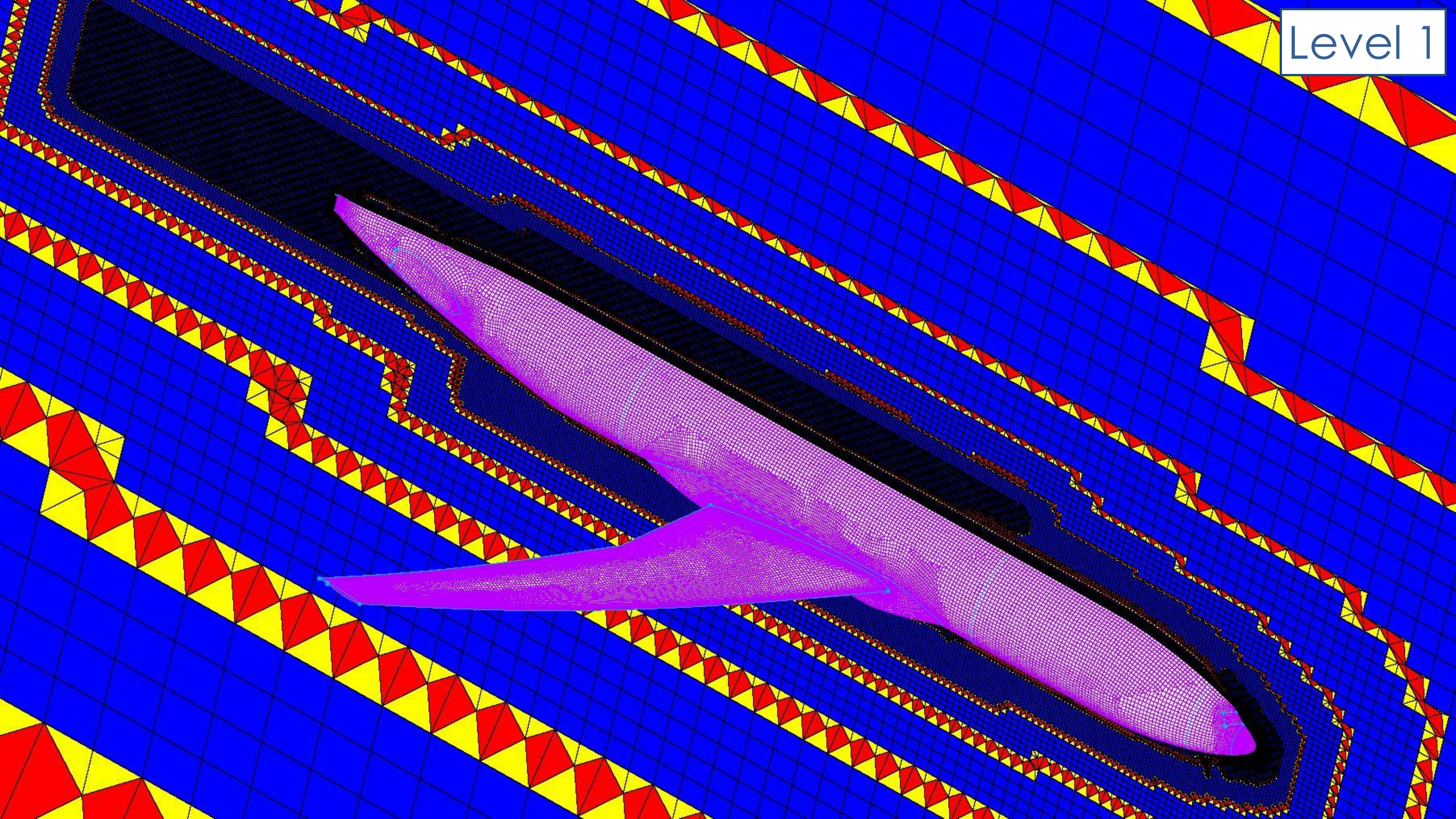
# Mesh Family – Characteristics

- **Grid Topology: Voxel**
- **DPW-8 Gridding Guidelines**
  - Farfield Size = 115,675in (~100*Semispan)
  - Y+ = 1 @ Level 1
  - Growth Rate: $1.16^{\frac{1}{1.5^\wedge(Level\ -1)}}$
  - Constant Layers on Viscous Wall: 2 (Level 1)
  - Viscous Wall Spacing: $\Delta y = \frac{C_{ref}}{Re_c * \sqrt{\frac{C_f}{2}}}$
    - $C_{ref}$ = 278.5in
    - $Re_C$ = 5,000,000
    - Cf = $x = \frac{0.455}{ln^2(0.06*Rex)}$
    - $Re_X$ = 0.1*$Re_C$



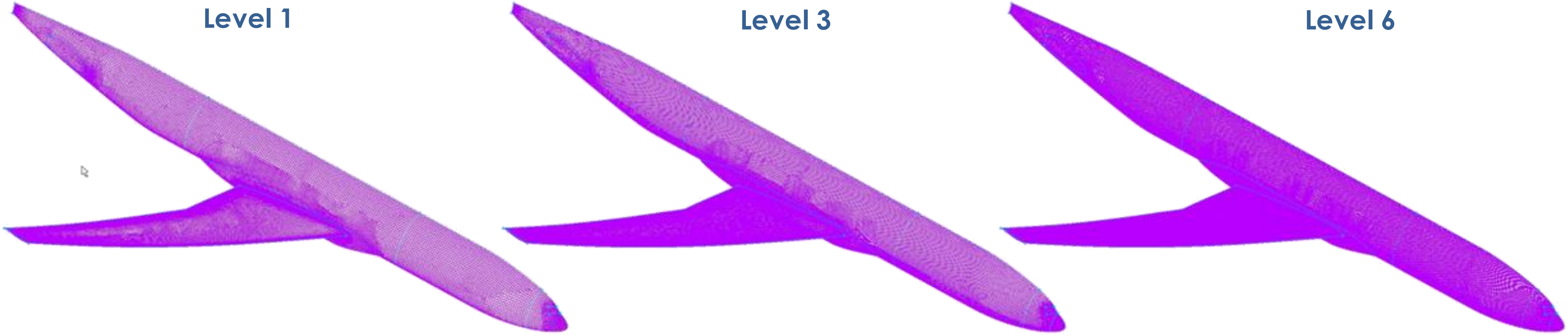


| Name | L | Wing/Body Δy1 (DPW-8) | T-Rex Growth Rate | #Δy1 | Refinement Factor (DPW-7) |
|---|---|---|---|---|---|
| Tiny (T) | 1 | 0.0011921972 | 1.160000 | 2 | 1.5000 |
| Coarse (C) | 2 | 0.0007947981 | 1.104007 | 3 | 1.3333 |
| Medium (M) | 3 | 0.0005960986 | 1.068189 | 4 | 1.2500 |
| Fine (F) | 4 | 0.0004768789 | 1.044958 | 5 | 1.2000 |
| Extra Fine (X) | 5 | 0.0003973991 | 1.029752 | 6 | 1.1667 |
| Ultra Fine (U) | 6 | 0.0003406278 | 1.019737 | 7 | |



Level 1

# Mesh Family - Wing/Body a=3.0°

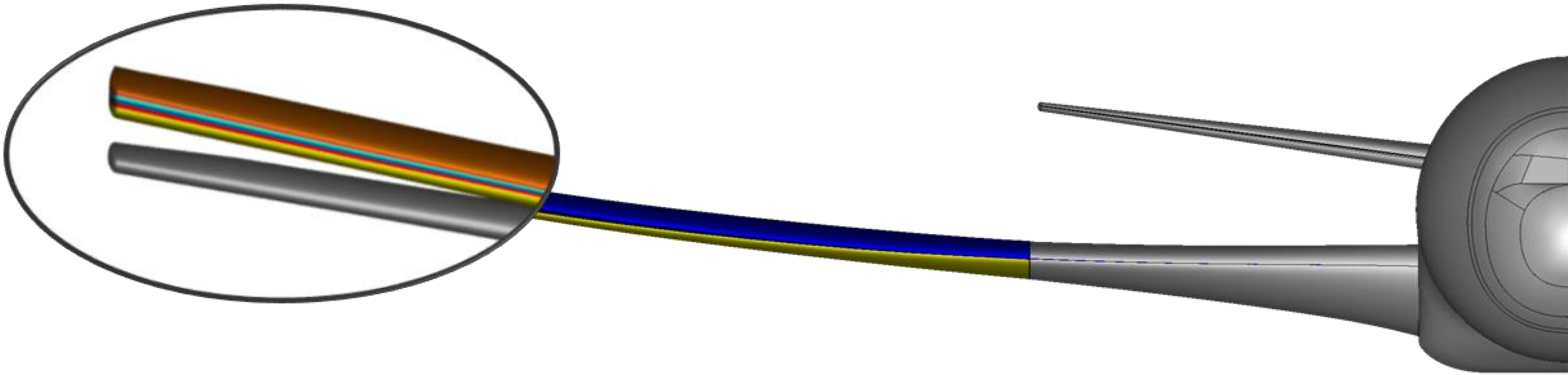


| | Surface | | | | Volume | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **L** | **Tris (K)** | **Quads (K)** | **Cells (K)** | **Points (K)** | **Tets (M)** | **Pyrms (M)** | **Prisms (M)** | **Hexes (M)** | **Cells (M)** | **Points (M)** |
| 1 | 17.7 | 230.3 | 248.0 | 238.3 | 8.6 | 1.5 | 0.2 | 18.1 | 28.4 | 20.2 |
| 2 | 29.5 (x1.7) | 467.1 (x 2.0) | 496.6 (x 2.0) | 480.6 (x 2.0) | 17.3 (x 2.0) | 2.9 (x 2.0) | 0.5 (x 2.3) | 49.8 (x 2.7) | 70.5 (x 2.5) | 54.0 (x 2.7) |
| 3 | 33.3 (x 1.1) | 802.2 (x 1.7) | 835.5 (x 1.7) | 817.2 (x 1.7) | 30.2 (x 1.7) | 5.1 (x 1.7) | 1.0 (x 2.1) | 123.2 (x 2.5) | 159.4 (x 2.3) | 130.6 (x 2.4) |
| 4 | 43.6 (x 1.3) | 1271.1 (x 1.6) | 1314.7 (x 1.6) | 1290.8 (x 1.6) | 39.6 (x 1.3) | 7.3 (x 1.4) | 2.3 (x 2.3) | 256.0 (x 2.1) | 305.2 (x 1.9) | 266.5 (x 2.0) |
| 5 | 61.5 (x 1.4) | 1872.2(x 1.5) | 1933.7(x 1.5) | 1900.4 (x 1.5) | 64.3 (x 1.6) | 10.7 (x 1.5) | 4.1 (x 1.8) | 417.8 (x 1.6) | 496.9 (x 1.6) | 434.6 (x 1.6) |
| 6 | 66.1 (x 1.1) | 2731.7 (x 1.5) | 2797.8 (x 1.4) | 2761.7 (x 1.5) | 89.8 (x 1.4) | 15.0 (x 1.4) | 7.3 (x 1.8) | 752.0 (x 1.8) | 864.0 (x 1.7) | 776.3 (x 1.8) |

# Alpha Sweep - Wing/Body Level 3

| | Surface | | | | Volume | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Tris** | **Quads** | **Cells** | **Points** | **Tets** | **Pyrms** | **Prisms** | **Hexes** | **Cells** | **Points** |
| **α = 2.50** | 3.34E+04 | 8.02E+05 | 8.36E+05 | 8.17E+05 | 3.01E+07 | 5.07E+06 | 9.97E+05 | 1.23E+08 | 1.59E+08 | 1.31E+08 |
| **Delta %** | 1.20 | 0.06 | 0.08 | 0.06 | 0.27 | 0.20 | 2.17 | 0.04 | 0.07 | 0.05 |

Count Variation < 2.5%



# NASA Experimental CRM Data

- **Same model tested in three facilities and five tests**
- **Extensive database developed for computational and experimental research**
  - Wide range of Mach numbers, Reynolds numbers, and alpha
  - Multiple modular components: wing, body, nacelle/pylon, horizontal tail
  - First used for DPW-IV with blind comparisons
- **See: M. Rivers, "Wind Tunnel Test Result Summary for the NASA Common Research Model," AVIATION 2023 presentation, available on the DPW experiment website**

| Data Set | Mach | Re | Alpha | Configuration | Static, Loaded Deformation | PIV | PSP |
|---|---|---|---|---|---|---|---|
| NTF 197 | 0.7 to 0.87 | 5, 19.8, 30 | -3 to 12 @low Re<br>-3 to 6 @ high Re | WB, WBNP, WBT0, WBT-2, WBT+2 | X | | |
| Ames 216 | 0.7 to 0.87 | 5 | -3 to +12 | WB, WBNP, WBT0, WBT-2, WBT+2 | X | | |
| NTF 215 | 0.7 to 0.87 | 5, 19.8, 30 | -3 to +12 @low Re<br>-3 to +6 @ high Re | WB, WBNP, WBT0 | X | | |
| NTF 229 | 0.7 to 0.87 | 5, 19.8, 30 | -3 to +12 @low Re<br>-3 to +6 @ high Re | WB, WBT0 | | X | X |
| ETW ESWIRP | 0.25 to 0.87 | 5, 19.8, 30 | -3 to +12 @low Re<br>-3 to +6 @ high Re | WBT0 | X | | |

# JAXA Experimental CRM Data

- **80% scale NASA CRM tested in JAXA 2m x 2m transonic wind tunnel**
  - Reynolds numbers of 1.5 and 2.3 million
- **Model details**
  - 80% scale NASA CRM (2.16% full-scale vehicle)
  - Wing/body/tail
  - Wind-off wing shape is the as-defined (in 2008) 1-G shape (same as NASA CRM)

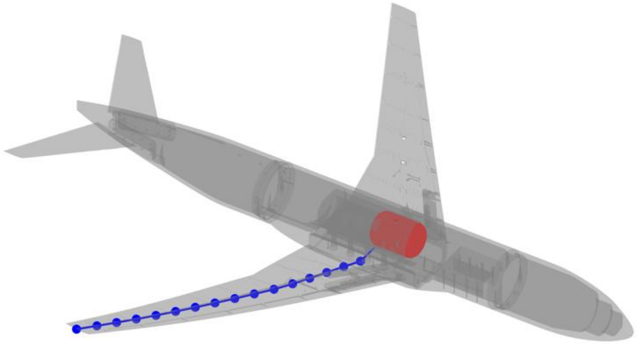
| Data Set | Wing | Re | Alpha | Onset | Static, Loaded Deformation | F&M | Static Taps | Kulites | Oil Flow | Wake PIV | TSP | PSP | uPSP | Strain Gauge | FEM | Release Status | DPW Buffet WG Case |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A.1 | Steady | 2.3 | -2 to 6 every ~1.2 | ~3.7 (**) | X | X | X | | X | X | | | | | | Public | N/A |
| A.2 | Steady | 2.3 | -2 to 7 | ~3.7 (**) | X | X | X | | | | X | X | | | | N/A | N/A |
| B.1 | Unsteady Wing (*) | 1.5 | 4.84, 5.89 | Unknown | X [1] | X | | X | | | | | | | | Released [2] | 2 |
| B.2 | Unsteady Wing (*) | 2.3 | -2 to 7 | 3.7 | | X | | X | | | | | X | X | Released [3] | Requested | 3 |

(*) Same wing, but different tripping dots heights accounting for different Reynolds numbers
(**) Strictly speaking, steady and unsteady wings are different, but the onset might be similar
https://cfdws.chofu.jaxa.jp/apc/dpw

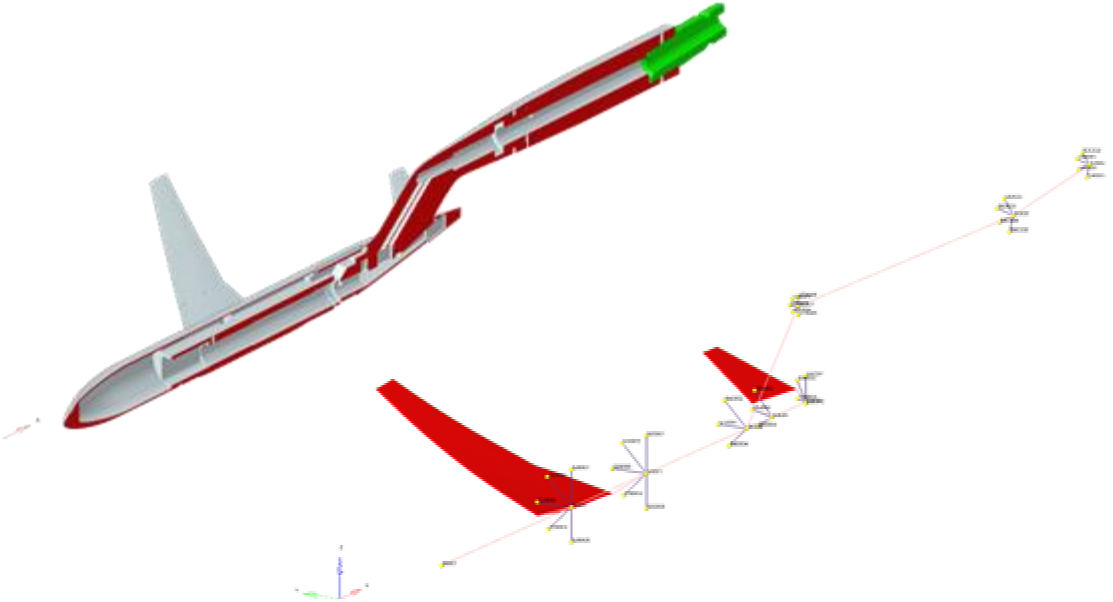
[1] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/geometry.html
[2] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/upc.html
[3] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/

# Finite Element Models

- **NASA CRM Model:**
  - Tet-blasted full-span FEM, clamped inside the fuselage, in-between the wings (red cylinder)
  - How to extend clamped BC back to the sting attachment near the tail?
  - It would not be easy to halve this model into a semi-span version
  - We have also created a semi-span equivalent beam model (blue)



- **JAXA CRM Model:**
  - JAXA has created detailed full- and semi-span FEM models, but they are unsure if they can be released
  - The modal content of the FEMs has been mapped onto simpler stick/plate models, and this has been released



# Static Deformation Working Group: Look Ahead

- **NASA FEM validation**
- **Wing/body deformation**
  - Provided with a committee-supplied unloaded wing geometry
  - Multiple grid densities and angles of attack
  - Wide variety of data at multiple Reynolds numbers
- **Wing/body/nacelle/pylon deformation**
  - Difficult problem will stretch tools and methods to maintain high-quality grids
  - Optional
  - Multiple grid densities and angles of attack

# Buffet Working Group: Look Ahead

- **Rigid CRM test case**
  - Unsteady CFD with committee-supplied static wing geometry
  - Optional
  - Not all unsteady CFD codes have unsteady FSI
  - Pre-buffet and post-buffet
- **Dynamic CRM test case**
  - Unsteady CFD, unsteady FSI with committee-supplied jig wing geometry
  - Difficult problem will stretch tools and methods
  - Extensive analysis, limited flow conditions

# Workshop: Look Ahead

- **Working groups will further separate/fragment, by design**
  - There will be significant overlap
  - Deliverables and timeline will vary between the groups
- **AVIATION 2025 Special Session**
  - July 21-215, 2025
  - Caesar's Forum, Las Vegas, NV
  - 21 papers and presentations
  - Date and time to be determined
  - Will hopefully include a hybrid component
- **Workshop**
  - June 8-12, 2026
  - Manchester Grand Hyatt, San Diego, CA
  - Possibly held the weekend before or the weekend after the conference

# Outline

9:30 Introduction and Motivation

9:40 Working Group Updates

10:15 Mini Workshop

10:50 CRM Look-Ahead

**11:25 Open Discussion**

**1:00 Bayhill 26 Available for Discussion Until 3:00**

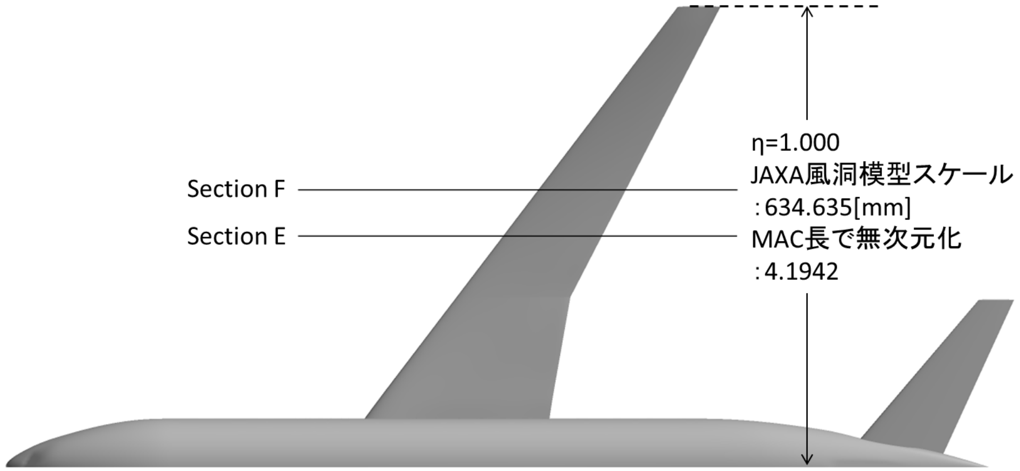
SHAPING THE FUTURE OF AEROSPACE

dpwaiaa@gmail.com

# Backup

# Test Case 2 Vision

- **Unsteady CFD with committee-supplied static wing geometry**
  - CRM
  - Optional
  - Want to include DPW and AePW communities
  - Not all unsteady CFD codes have unsteady FSI

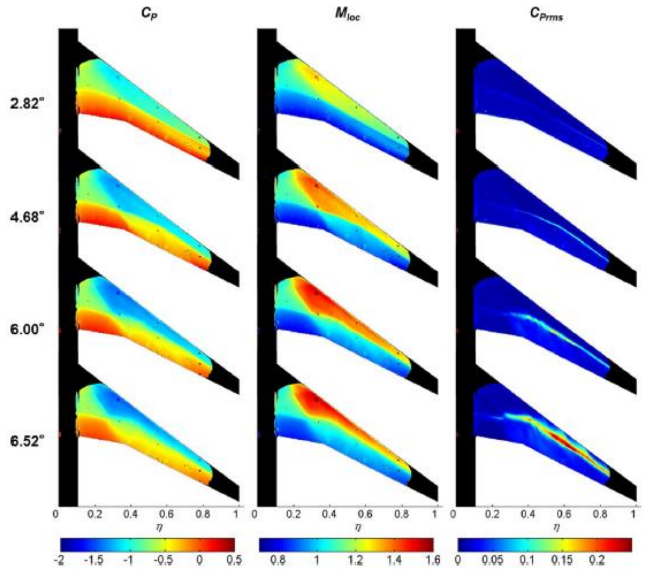


- **CRM Wing/body/tail**
  - JAXA Reynolds number =1.5 million
  - Does not contain FSI
  - Unsteady CFD with committee-supplied, already deformed grids [1]
  - Provide experimentally-measured static deformation at:
    - two pre- buffet onset alphas (in consideration)
    - two post- buffet onset alphas (4.84 and 5.89 deg) [2]

[1] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/geometry.html
[2] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/upc.html

# Test Case 3 Vision

- **Unsteady CFD, unsteady FSI with committee-supplied jig wing geometry**
  - CRM
  - Optional
  - Want to include DPW and AePW communities
  - Hardest analysis point
- **CRM Wing/body/tail**
  - JAXA Reynolds number = 2.3 million
  - Contains FSI, FEM is provided [3]
  - Provide jig (wind-off) geometry for the wing
  - Calculate both static deformation and structural dynamic response
  - Will compare deformed shape, surface pressures, etc.
- **Extensive analysis, limited flow conditions**
  - One alpha pre-buffet (required), one alpha post-buffet (optional)



[3] Released on: https://cfdws.chofu.jaxa.jp/apc/dpw/