DPW-8 & AePW-4

Static Deformation Working Group

March 21, 2025

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AIAA
SHAPING THE FUTURE OF AEROSPACE

Administrative Information

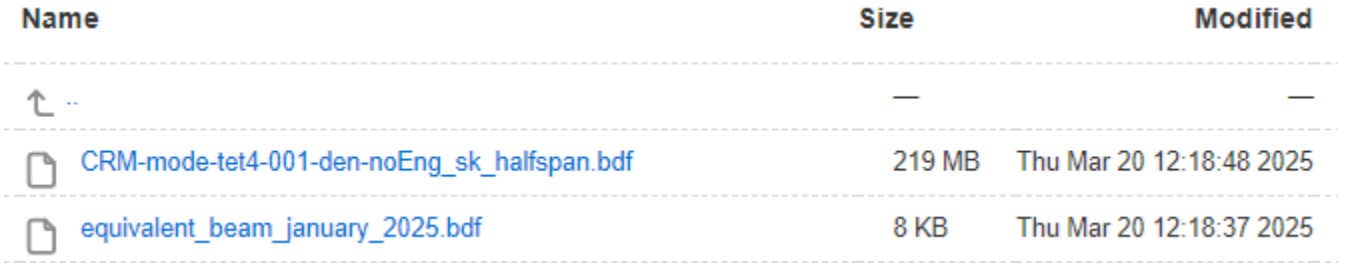
- **Meeting schedule**
  - Third Friday of the month; 10:00 Eastern Time (will adjust with US Daylight Saving Time)
- **For questions about the working group, please email** dpwaiaa@gmail.com
- **Websites**
  - Static Deformation Working Group website
    https://aiaa-dpw.larc.nasa.gov/WorkingGroups/Group2/group2.html
  - Geometry/Grid websites
    https://aiaa-dpw.larc.nasa.gov/geometry.html
    https://aiaa-dpw.larc.nasa.gov/grids.html
  - Postprocessing website (including ONERA OAT15A experimental results)
    https://aiaa-dpw.larc.nasa.gov/postprocessing.html
  - Large File Upload
    https://nasagov.app.box.com/f/fd164563283b4e85857d1a0975b0b363

Agenda

- **NASA CRM Wing/Body Grids Released!**
  - https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2
    - Grids at airplane scale
    - Scale to 2.7% for model size

Name	Size	Modified
..	—	—
Ames_Grids.REV01	—	Tue Mar 18 12:30:00 2025
Cadence_Grids.REV00	—	Fri Mar 7 14:45:11 2025
Helden_Grids.REV00	—	Fri Mar 7 14:45:11 2025

- **Structural Model**
  - https://dpw.larc.nasa.gov/DPW8/Static_Deformation/Test_Case_2/NASA_CRM_FEM.REV00
    - Half-span FEM
    - Equivalent Beam Model



Name	Size	Modified
..	—	—
CRM-mode-tet4-001-den-noEng_sk_halfspan.bdf	219 MB	Thu Mar 20 12:18:48 2025
equivalent_beam_january_2025.bdf	8 KB	Thu Mar 20 12:18:37 2025

- **Phil Jones: FEM Discussion**
- **Test Case 2a Conditions**

Test Case 2a: Wing/Body Deformation

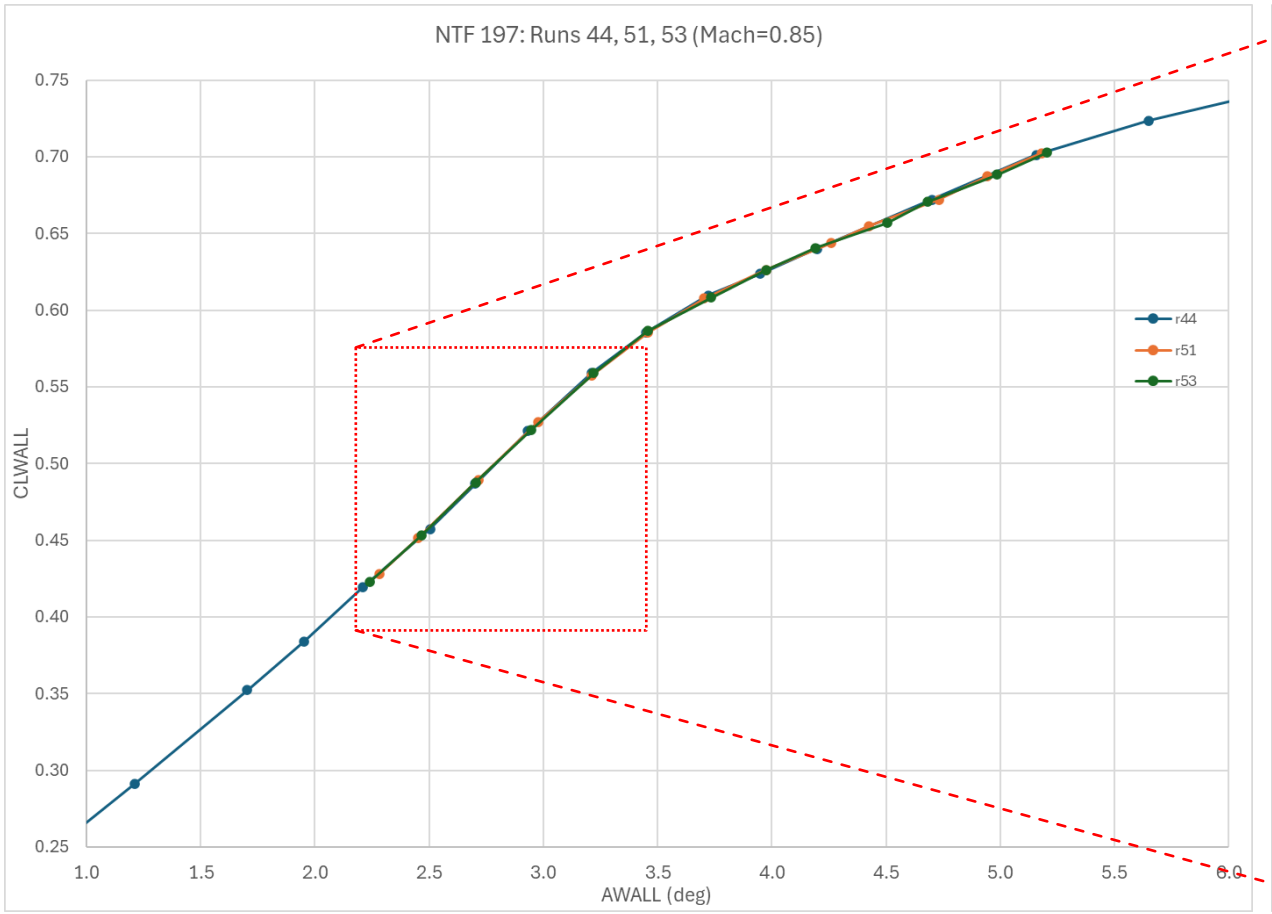
- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body**
  - Reynolds number: 5M (LoQ)
  - Dynamic Pressure: Q_∞ =1384 psf
  - Mach Number: 0.85
  - CL = 0.5000 +/- 0.0001 (Angle of Attack ~ 2.75 deg)
  - Temperature: 120.0 F (579.67 R / 322.04 K)
  - Reference Information: https://aiaa-dpw.larc.nasa.gov/Workshop7/DPW7-geom.html

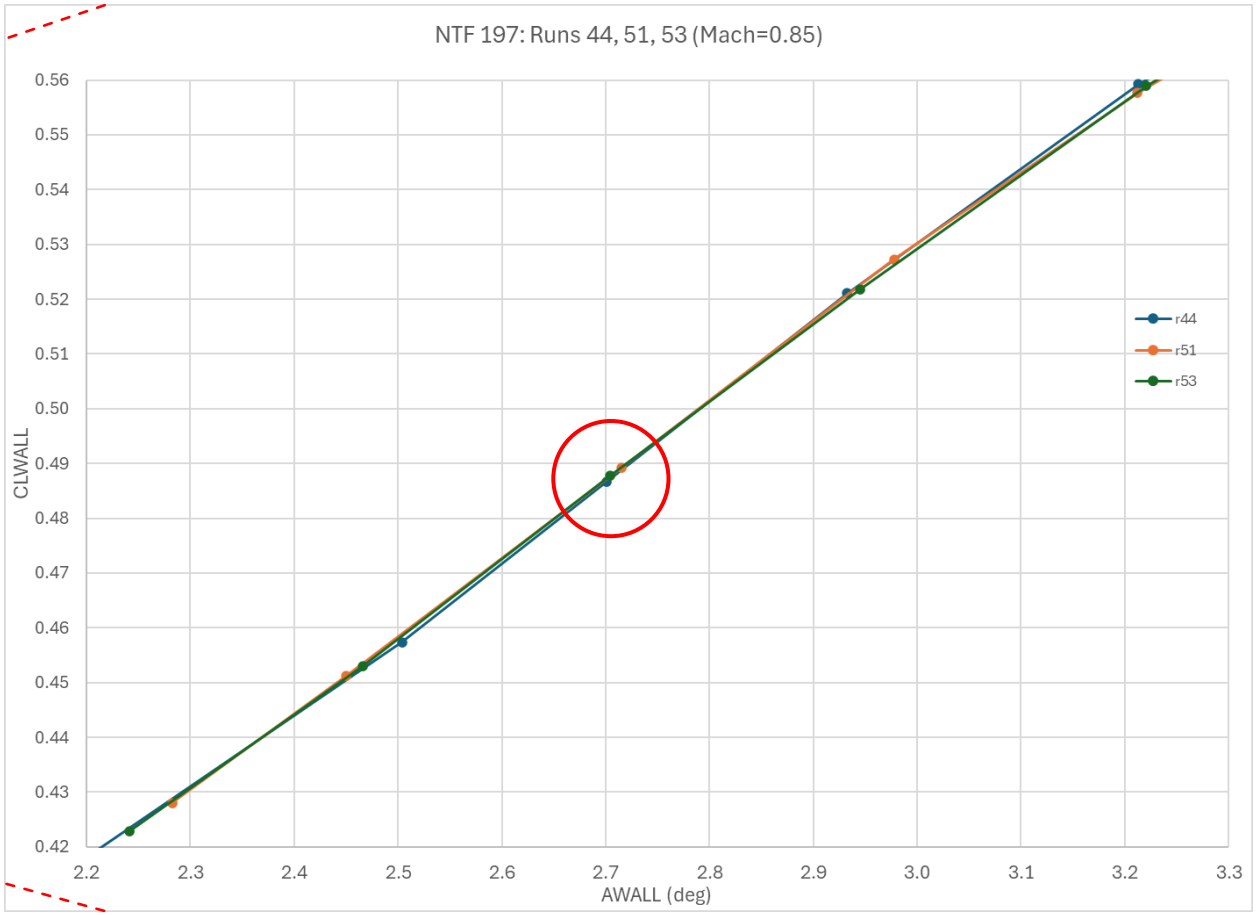
Grid: Level 1-6

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

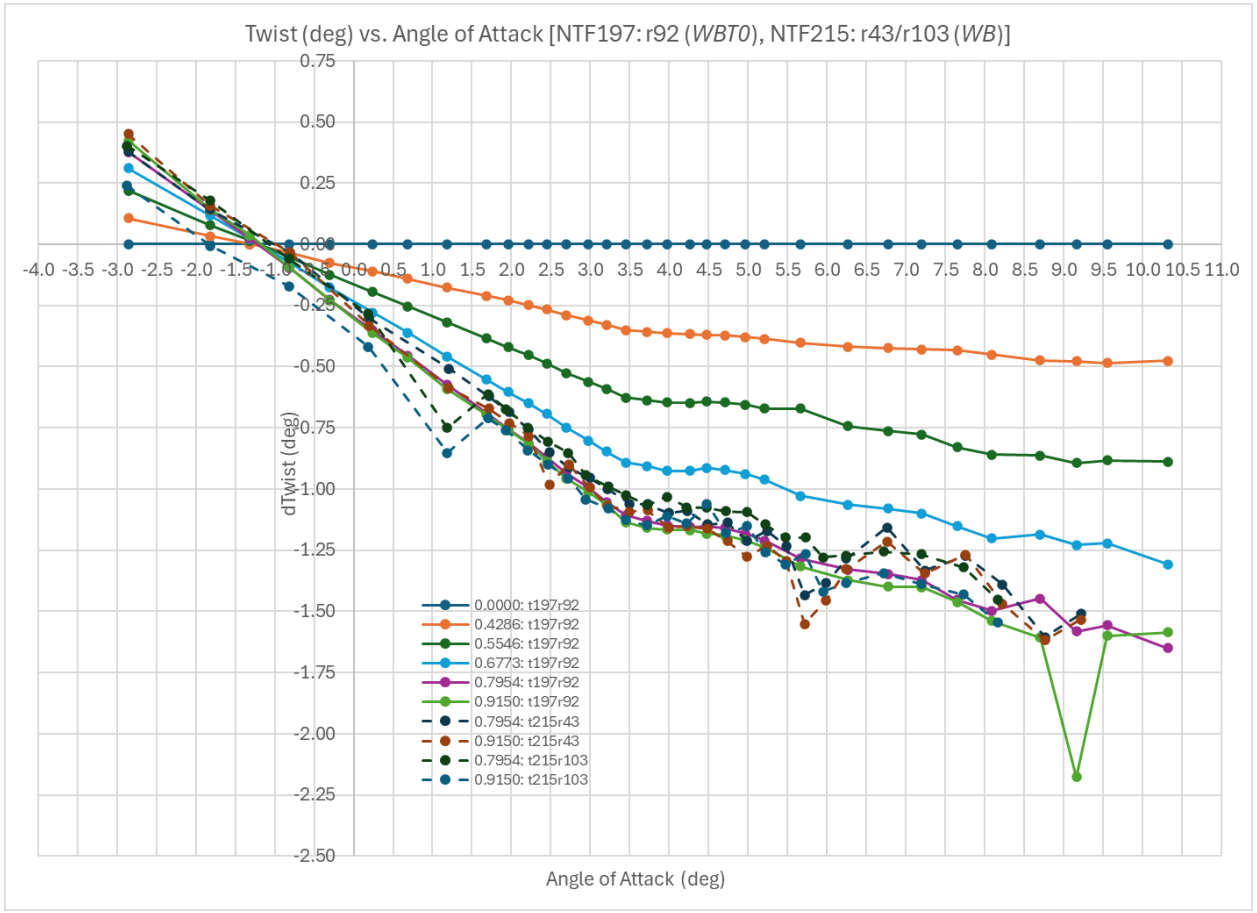
- **Committee-supplied**
  - NASA CRM geometry in jig/unloaded condition
    - Trip location – Wing: 10% chord upper/lower surface
  - MSC NASTRAN® finite-element model of the NASA CRM
  - Grid Family (L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine)
- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

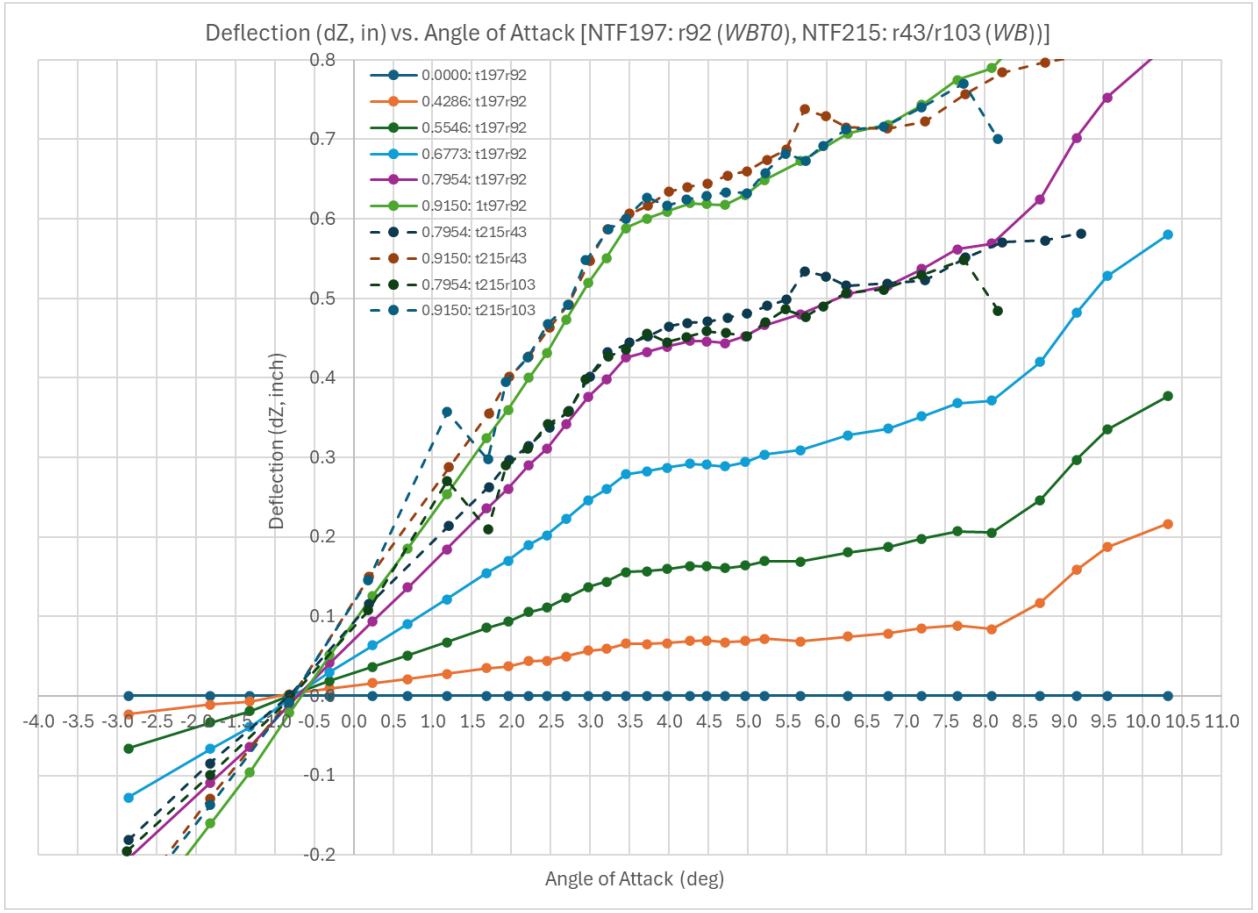
NTF197: Wing/Body [Rey=5M, M=0.85]





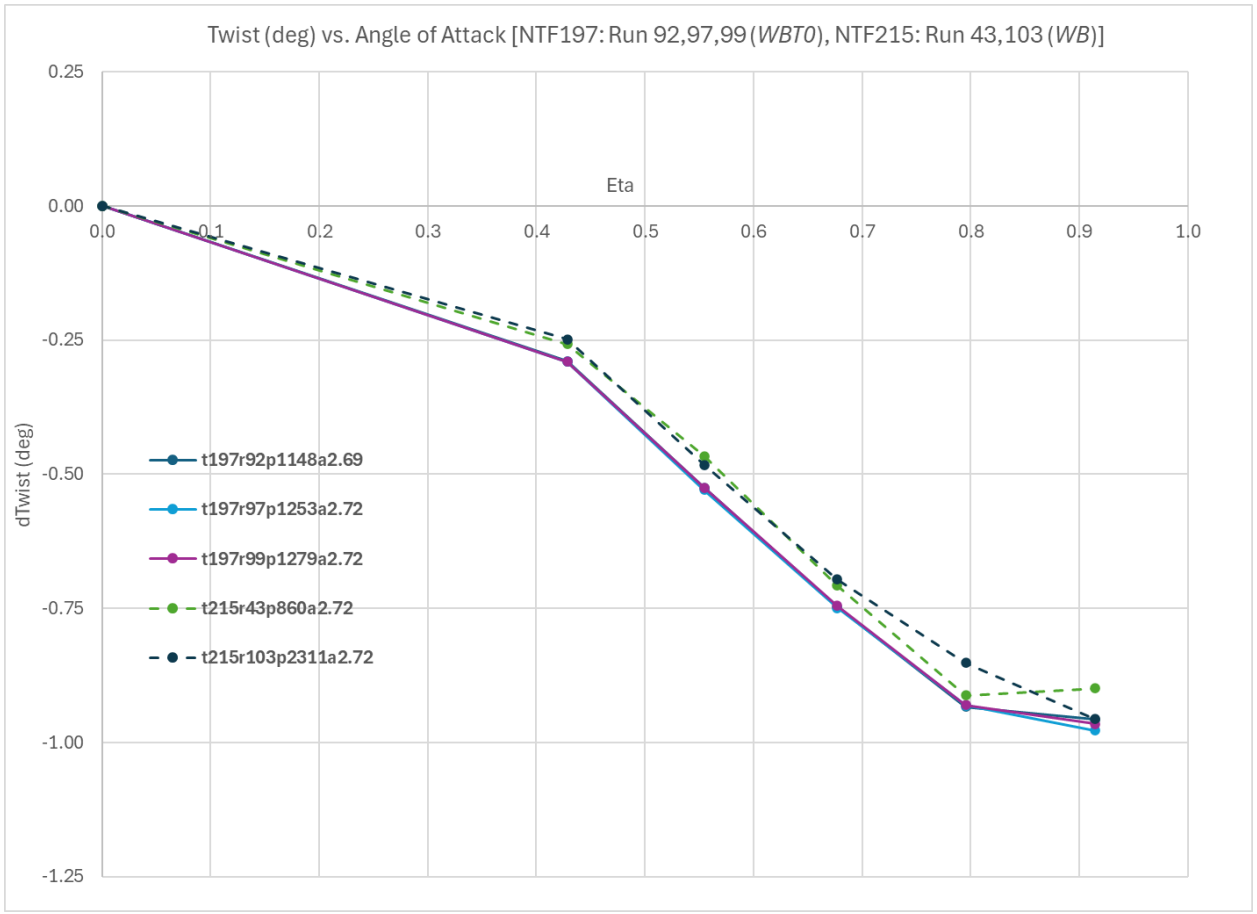
NTF197/215: Twist (Δdeg) & Deformation (ΔZ, in)

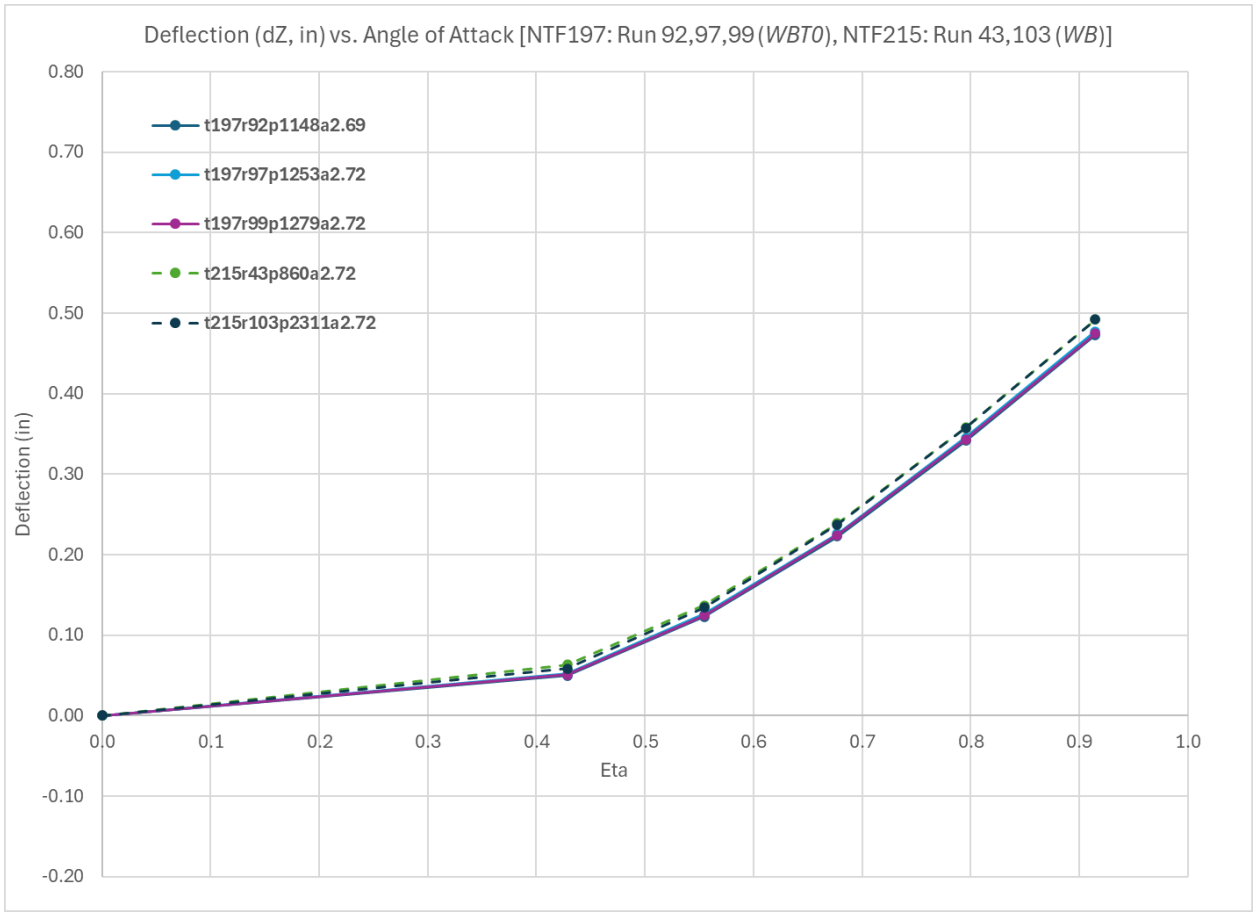




Note: t197r92 is Wing/Body/Tail=0 Configuration

NTF197/215: Twist (Δdeg) & Deformation (ΔZ, in)





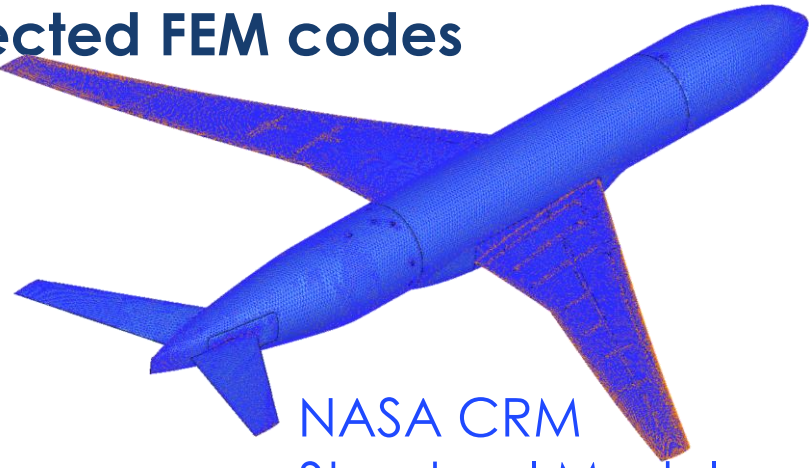
Note: t197r92 is Wing/Body/Tail=0 Configuration

Key Questions: Static Deformation Working Group

- **What level of accuracy can transonic wing deformations be calculated?**
- **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?**

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

Test Case 2b: Wing/Body Deformation (polar)

- **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})
  - Angles of attack: -1.50, 0.00, 1.50, **2.70**, 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

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
  - MSC NASTRAN® finite-element model of the NASA CRM
  - Grid Family (L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine)
- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

Test Case 2c: Wing/Body Deformation (polar)

- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body**
  - Reynolds number: 20M (HiQ)
  - Dynamic Pressure: Q_∞ = ?
  - Mach number: 0.85(M_{cruise})
  - Angles of attack: -1.50, 0.00, 1.50, **2.70**, 3.10, **3.50**, 4.00, 4.50
  - Temperature: ? F (? R / ? K)
  - Reference Information: https://aiaa-dpw.larc.nasa.gov/Workshop7/DPW7-geom.html

Grid: Level 3
Grid: Level 1-6

Comparison Data
NTF197: r?,r?
NTF197: r?,r? *(WBT0)*
NTF215: r?
NTF229: r?
ETW ESWIRP: r?

- **Committee-supplied**
  - NASA CRM geometry in jig/unloaded condition
    - Trip location – Wing: 10% chord upper/lower surface
  - MSC NASTRAN® finite-element model of the NASA CRM
  - Grid Family (L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine)
- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

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, **2.70**, 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

Comparison Data
NTF197: r?,r?
NTF197: r?,r? *(WBT0)*
NTF215: r?
NTF229: r?
ETW ESWIRP: r?
Ames216: r?

- **Committee-supplied**
  - NASA CRM geometry in jig/unloaded condition
    - Trip location – Wing: 10% chord upper/lower surface
  - MSC NASTRAN® finite-element model of the NASA CRM
  - Grid Family (L1:**T**iny/L2:**C**oarse/L3:**M**edium/L4:**F**ine/L5:e**X**tra-fine/L6:**U**ltra-fine)
- **Comparison metrics**
  - Forces / Moments
  - Sectional Twist / Deformation
  - Sectional C_P distribution
  - Residuals (Flow & Structural Solver)

Nominal Schedule

- **June, 2024**
  - First Working Group Meeting ✔
  - ONERA OAT15A geometry release ✔
- **July, 2024**
  - ONERA OAT15A grids released ✔
  - AVIATION in-person meeting ✔
- **November, 2024**
  - All workshop virtual meeting (11/8) ✔
- **January, 2025**
  - SciTech Forum: Mini Workshop 1 ✔
- **March, 2025**
  - CRM Grids Available ✔
  - FEM Validation Data released
- **July, 2025**
  - Special Session: ONERA OAT15a
  - AVIATION in-person meeting
- **Summer/Fall, 2025 (?)**
  - Mini Workshop 2
- **January, 2026**
  - SciTech in-person meeting
- **February, 2026**
  - Delivery of final data set (perhaps alternate submissions prior to this date)
- **June, 2026**
  - Workshop in San Diego, CA

Working Group Meeting Cadence

- **Currently set up for 10:00 Eastern time on third Friday of each month**
  - A suitable meeting time is very difficult for global participants
  - Recurring meeting invite sent

- **Next meeting: Friday, April 18th**
  - Please contact ben.j.rider2@boeing.com if you are interested to present grids or solutions

dpwaiaa@gmail.com

Backup

Geometry

- **Geometry Webpage**
  - https://aiaa-dpw.larc.nasa.gov/geometry.html
  - Test Case 1a: ONERA OAT15A (***updated Sept 5, 2024***)
    https://aiaa-dpw.larc.nasa.gov/Geometry/ONERA-OAT15A-090524.zip
  - Test Case 1b: NASA CRM FEM Validation
    TBD
  - Test Case 2: NASA CRM Geometry (from DPW-7)
    https://aiaa-dpw.larc.nasa.gov/Workshop7/DPW7-geom.html

RANS Committee-Supplied Grids Status

- **The ONERA OAT15A RANS committee-supplied grids have been updated**
  - Intended to be used for RANS
  - Grids are one cell wide

- **Participants are strongly encouraged, but not required to use these supplied grids for RANS simulations**

- **RANS gridding guidelines have been posted to the grids website (v3, July 1)**
  - https://aiaa-dpw.larc.nasa.gov/ref/gridding_guidelines_v3_07012024.pdf

RANS Committee-Supplied Grids (Updated)

- **ONERA OAT15A grids posted to DPW webpage**
  - Helden Aerospace (HeldenMesh)

    https://dpw.larc.nasa.gov/DPW8/Helden_Grids.REV01/Helden-ONERA-OAT15A.zip

  - Cadence (Pointwise)

    https://dpw.larc.nasa.gov/DPW8/Cadence_Grids.REV01/Cadence-ONERA-OAT15A_230mmChord_780mmSpan_upZ_2024_09_05_Structured.zip

    https://dpw.larc.nasa.gov/DPW8/Cadence_Grids.REV01/Cadence-ONERA-OAT15A_230mmChord_780mmSpan_upZ_2024_09_05_Unstructured.zip

  - ONERA

    https://dpw.larc.nasa.gov/DPW8/Deck-ONERA_Grids.REV00/Deck-ONERA-OAT15A.zip

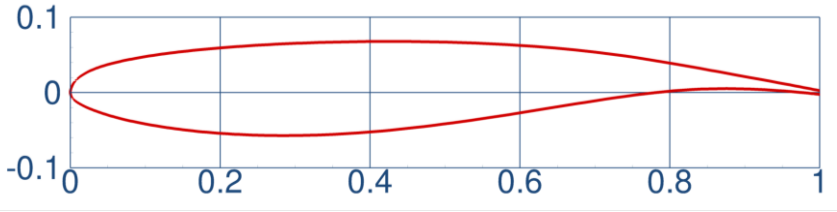
Data Submission for ONERA OAT15A

- **Please follow these instructions:**
  - https://aiaa-dpw.larc.nasa.gov/postprocessing.html
- **Case 1a**
  - Grid Metrics:
    - https://aiaa-dpw.larc.nasa.gov/Forms/DPW8-AePW4_CustomGridMetrics_v5.dat
  - Force/Moments:
    - https://aiaa-dpw.larc.nasa.gov/Forms/DPW8-AePW4_ForceMoment_v5.dat
  - CP cuts:
    - https://aiaa-dpw.larc.nasa.gov/Forms/DPW8-AePW4_SectionalCuts_v5.dat
  - Convergence:
    - https://aiaa-dpw.larc.nasa.gov/Forms/DPW8-AePW4_Convergence_v5.dat
- **GitHub is being used to collect data files**

Data Submission for ONERA OAT15A

- **Submission Label**
  - <### Participant ID>.<## Submission Number>
- **Participant IDs (3 digits) will be assigned by Working Group leaders**
  - Unique ID
    - One for each combination of Organization/Group of Participants
- **Submission Number (2 digits) label a solver/grid/computational approach**
  - Solver/Grid variations will be tracked with submission numbers
  - If a participant ran multiple turbulence models (SA/SST/SA-RC-QCR) with multiple grid families and solvers for Test Case 1a (ONERA OAT15A), they could use:
    - ###.01 for SolverA on Cadence Unstructured grids with SA-neg
    - ###.02 for SolverA on Cadence Unstructured grids with SST
    - ###.03 for SolverA on HeldenMesh grids with SA-neg
    - ###.04 for SolverB on HeldenMesh grids with SA-neg
    - ###.05 for SolverB on HeldenMesh grids with SA-neg-RC-QCR
  - Submission Numbers may change across Test Cases, Participant IDs will not
    - No need to maintain common Submission Numbers

Test Case 1a: Workshop-Wide Validation



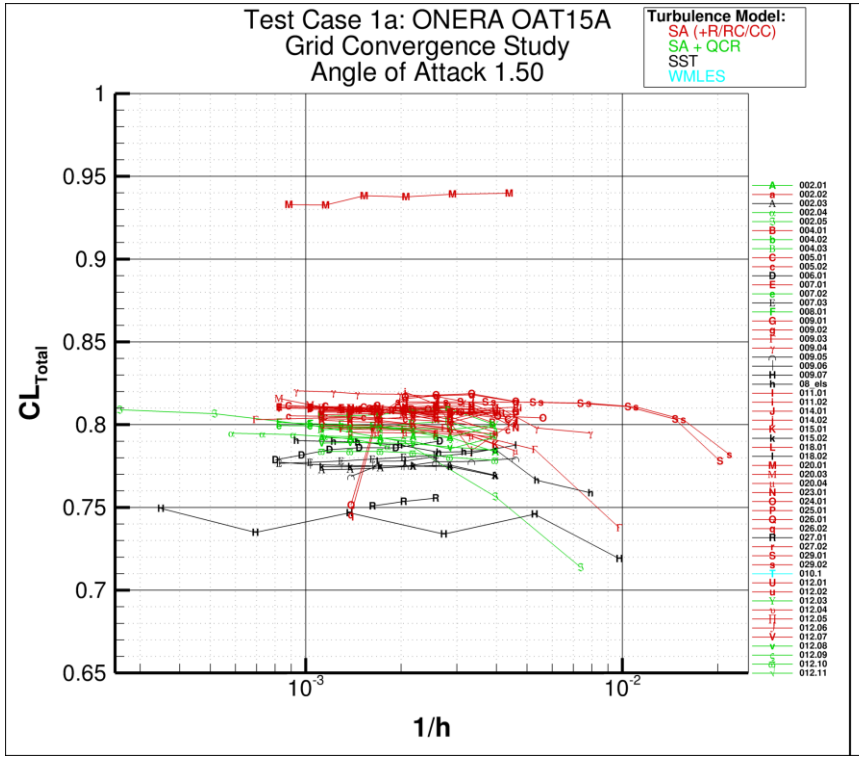
ONERA OAT15A Transonic Airfoil

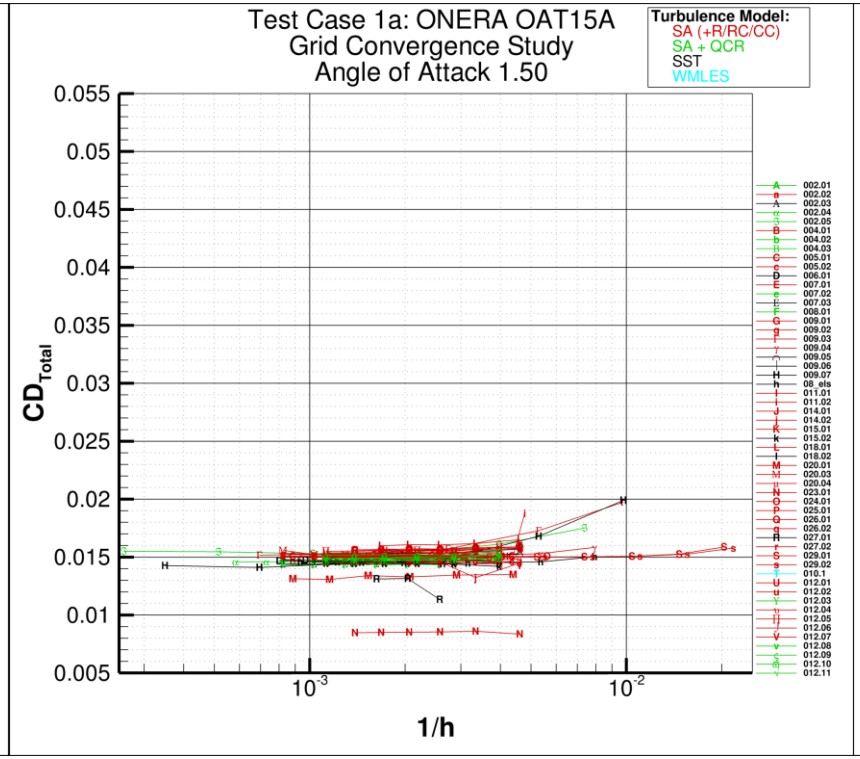
- **Validation of steady CFD analysis, required**
- **Users are encouraged to employ best practices**
- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted
  - Purely 2D simulations (one cell wide)
- **Grids**
  - Six-member RANS grid family; 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

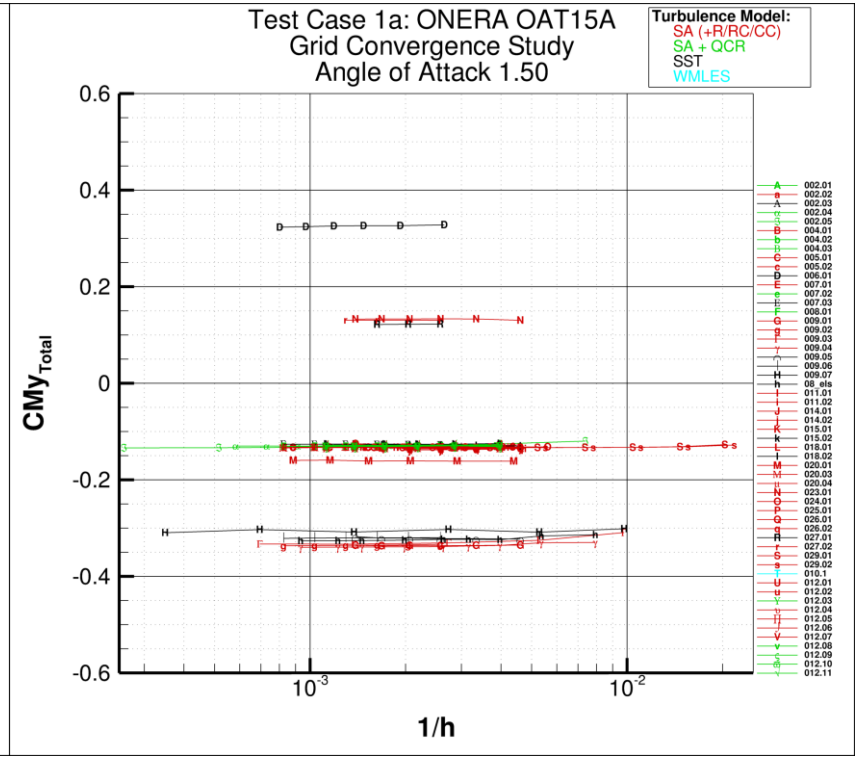
Jaquin, et al. "Experimental Study of Shock Oscillation over a Transonic Supercritical Profiles." AIAA Journal, Vol. 47, No. 9, 2009. Pages 1985-1994.

Test Case 1a: Results

- **Grid Convergence Study**
  - Alpha = 1.50°

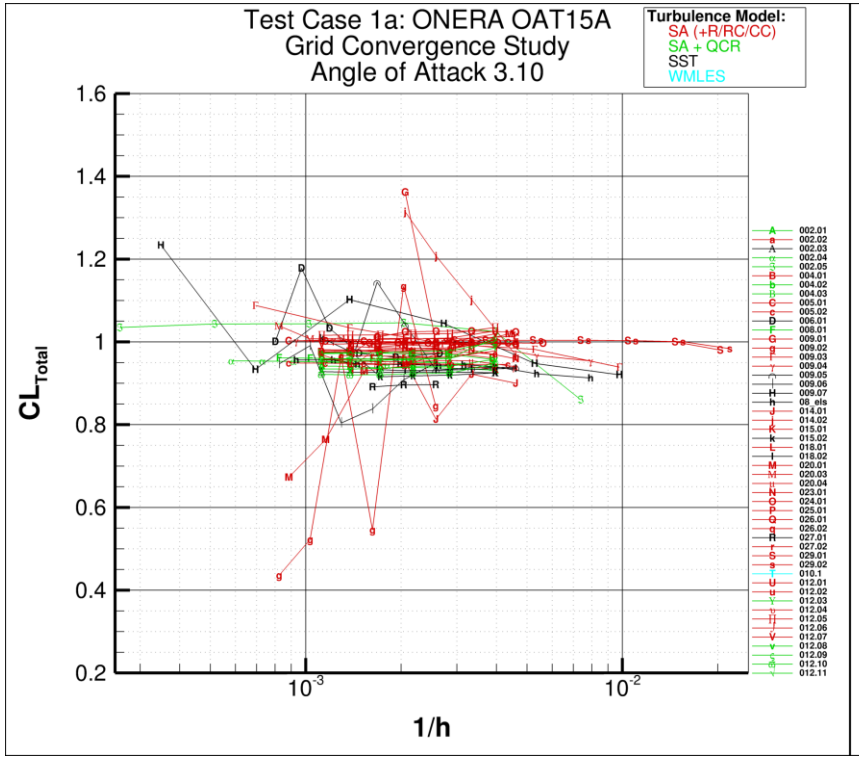


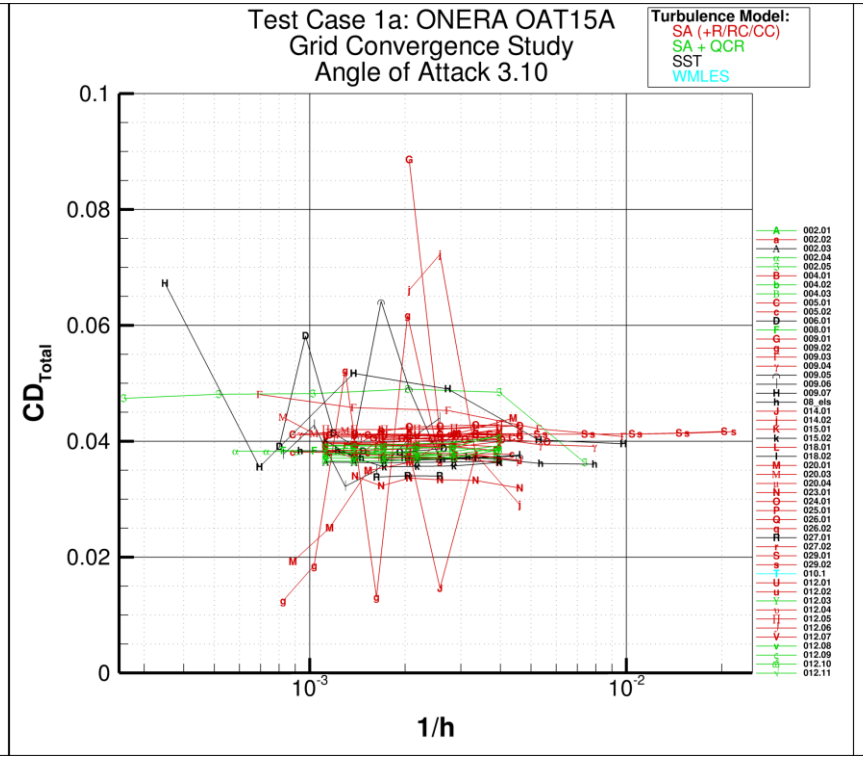


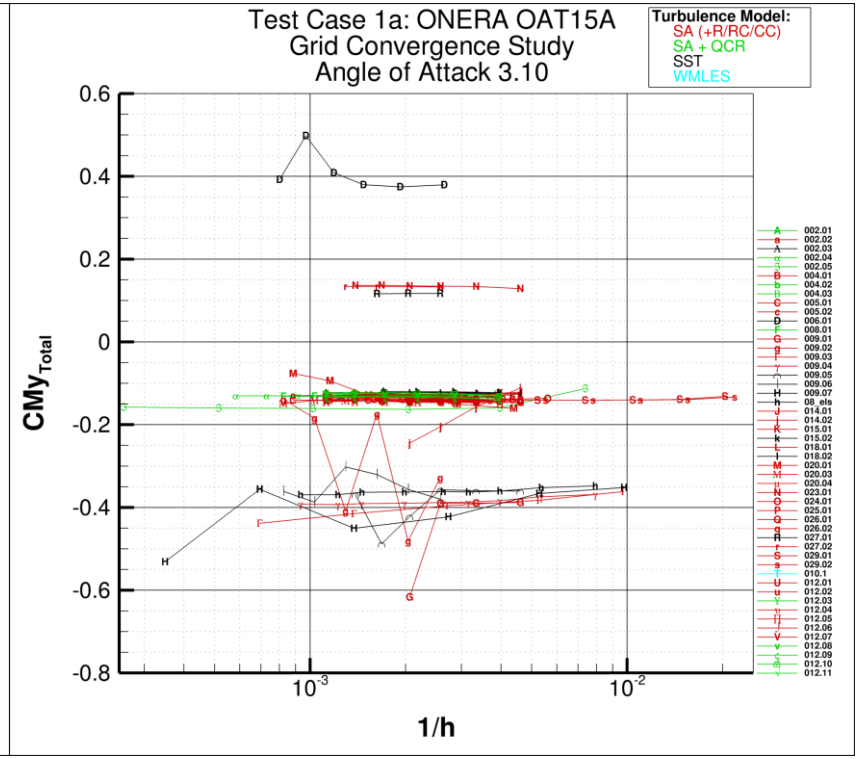


Test Case 1a: Results

- **Grid Convergence Study**
  - Alpha = 3.10°

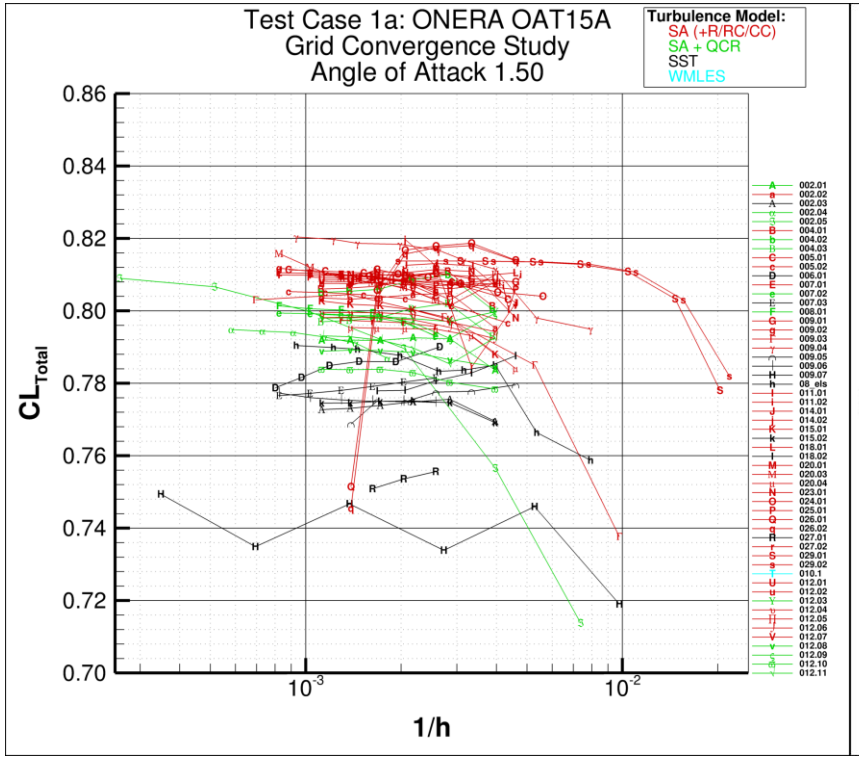


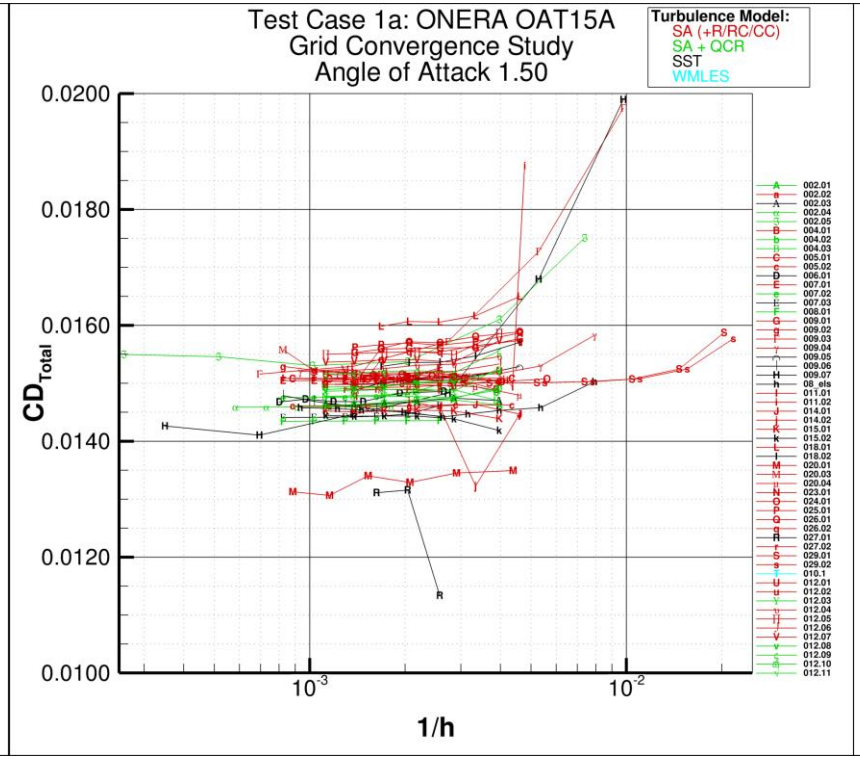


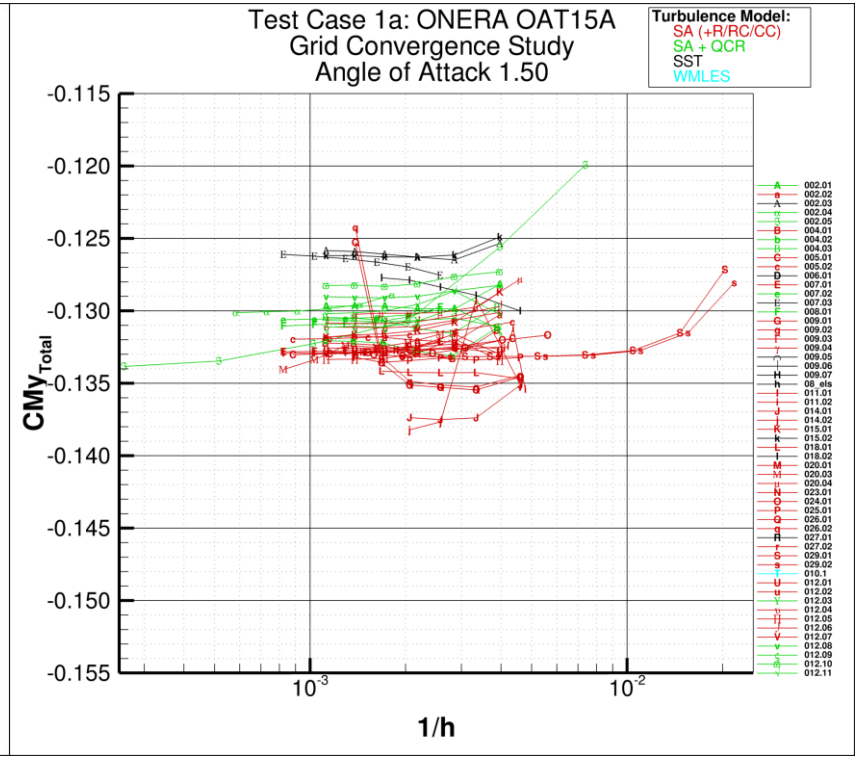


Test Case 1a: Results

- **Grid Convergence Study**
  - Alpha = 1.50°







Test Case 1a: Results

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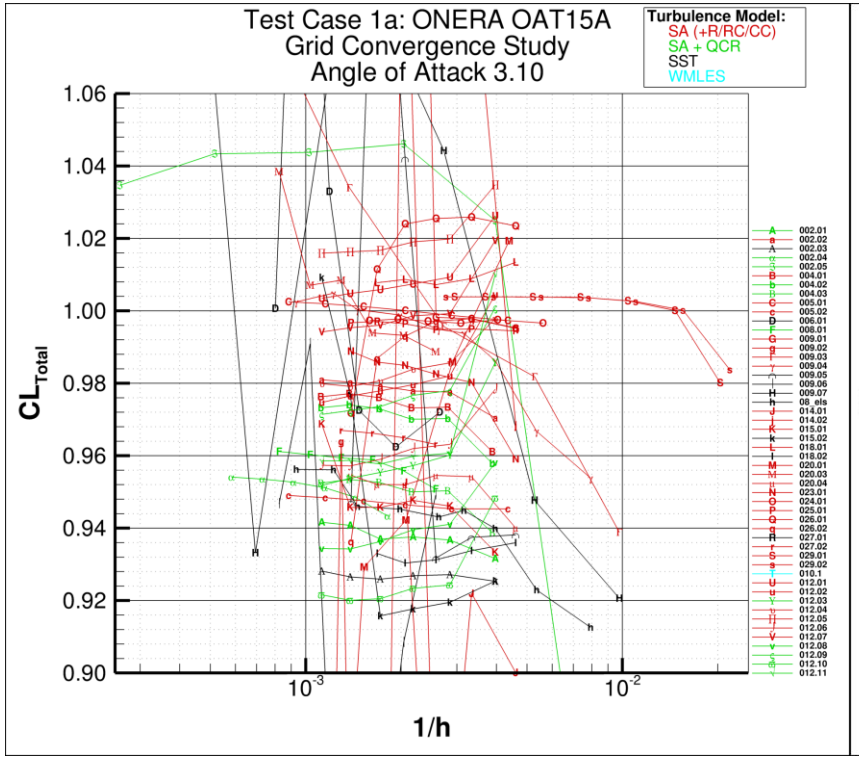
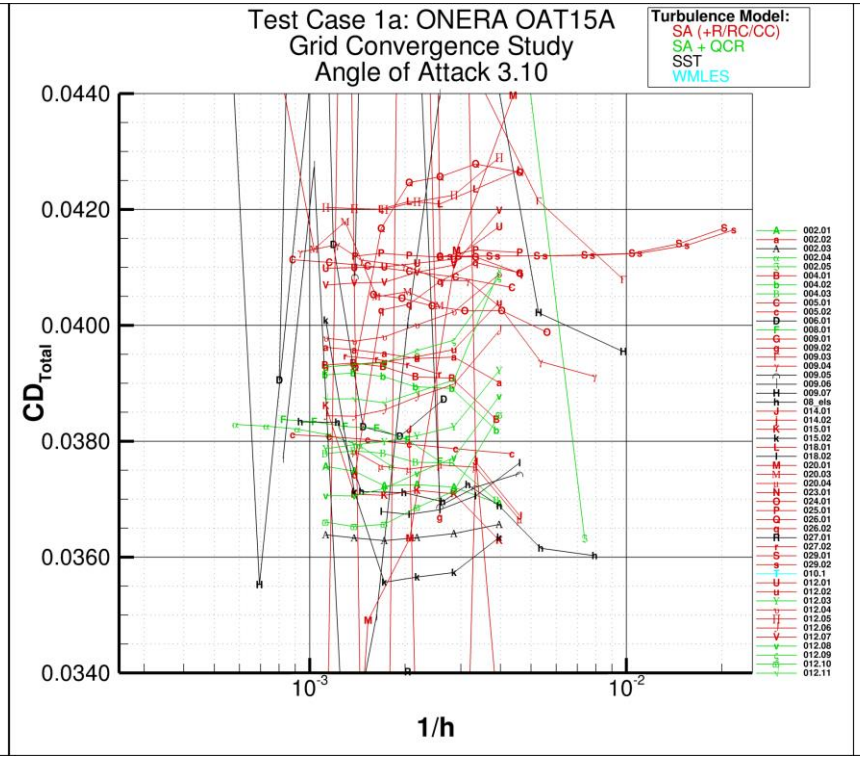
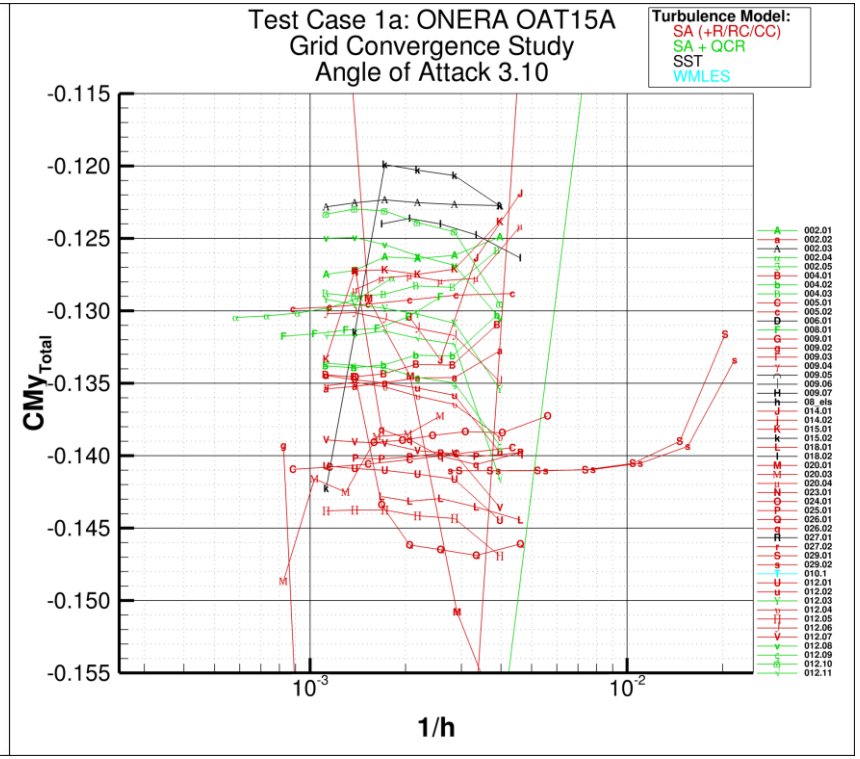
  - Alpha = 3.10°

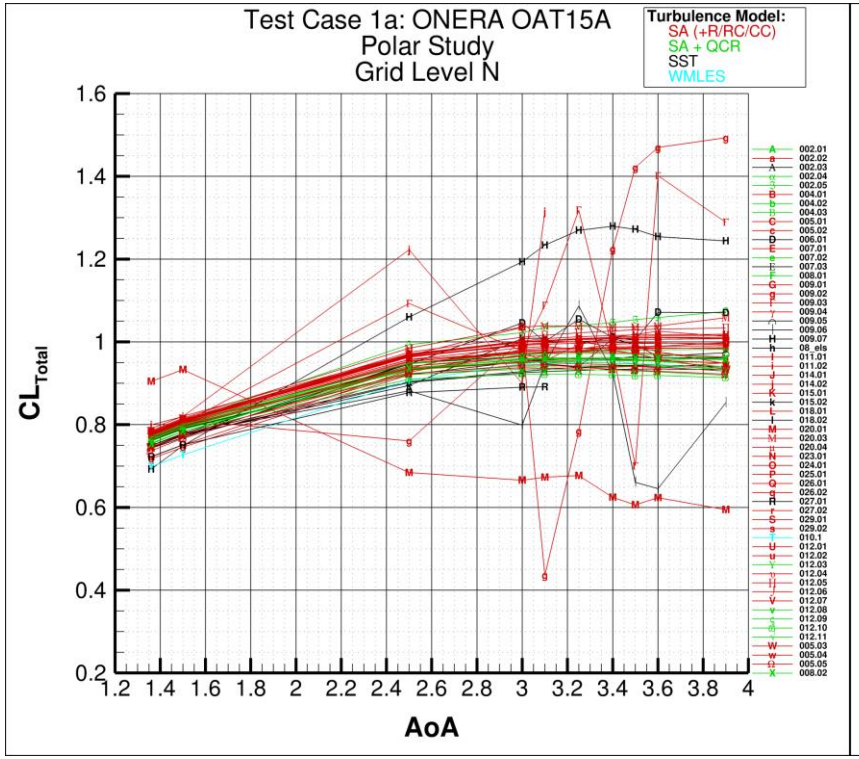


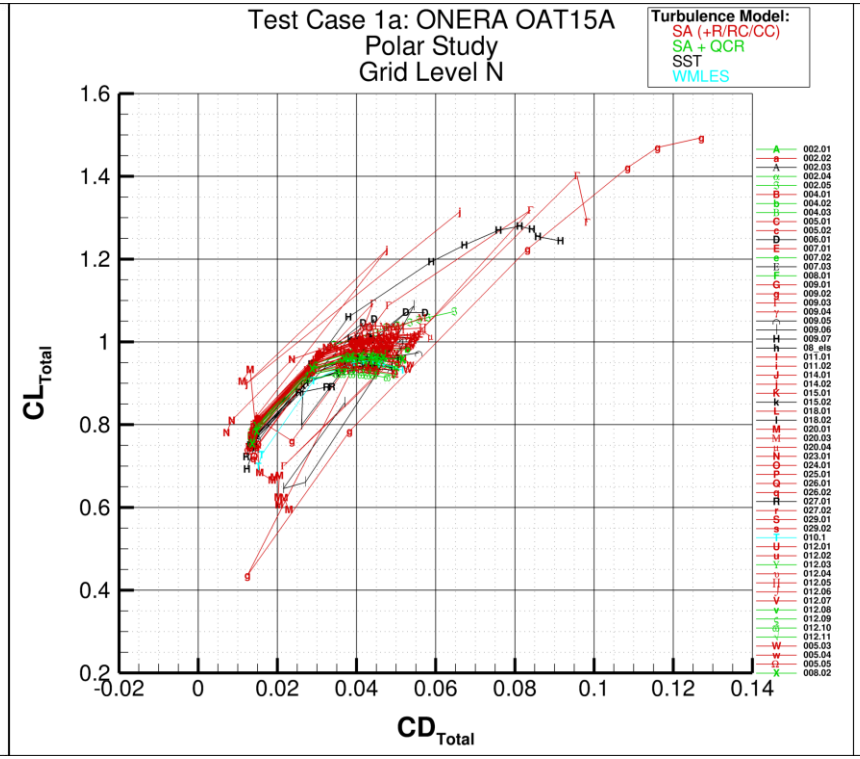


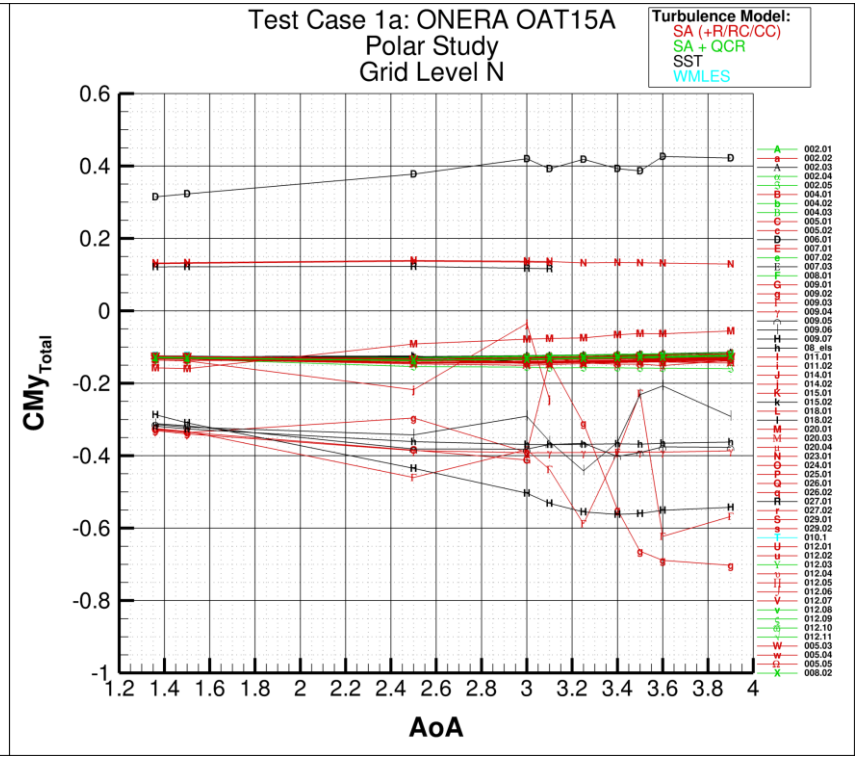


Test Case 1a: Results

- **Lift, Drag, Pitching Moment Polars**
  - Finest Submitted Grid Level

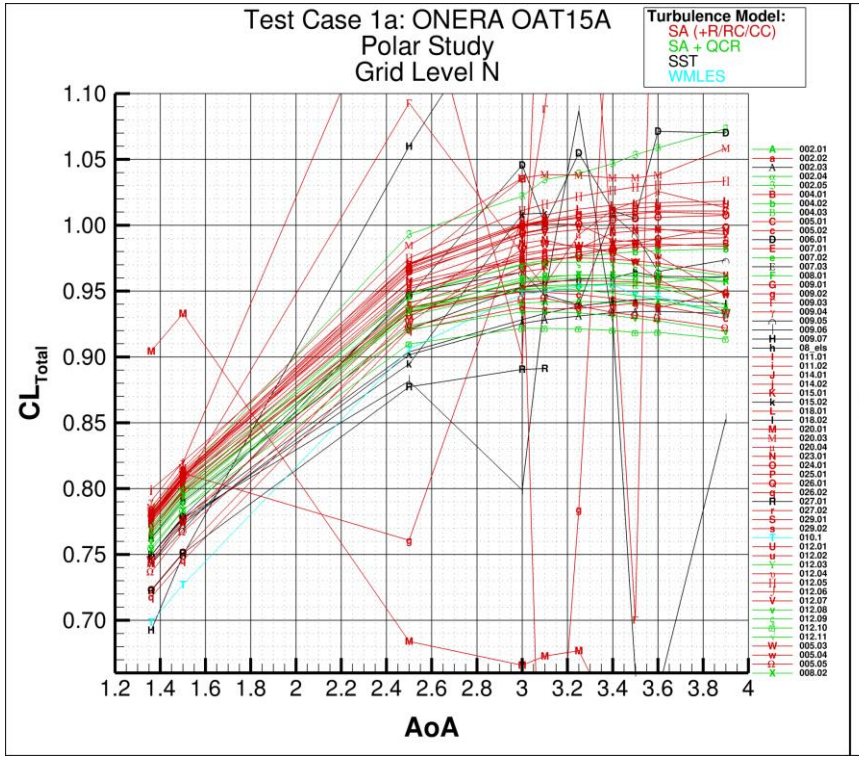


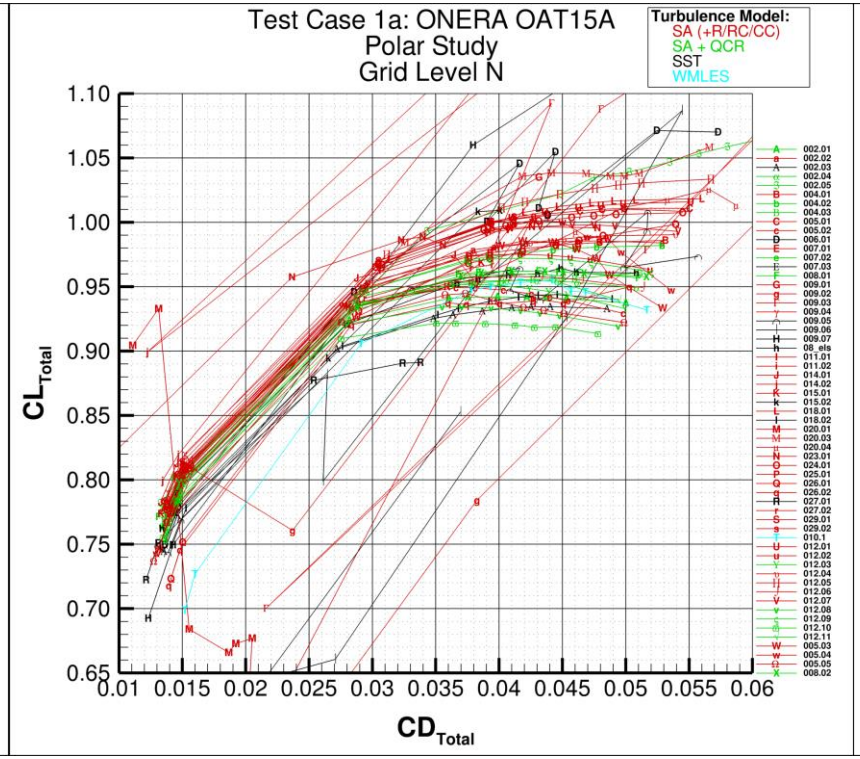


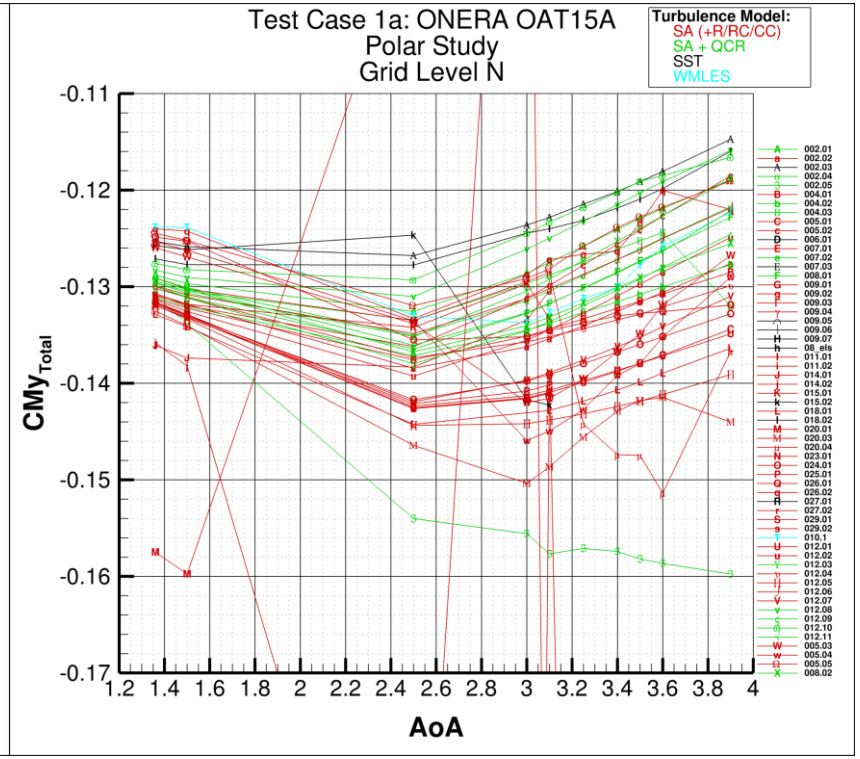


Test Case 1a: Results

- **Lift, Drag, Pitching Moment Polars**
  - Finest Submitted Grid Level







Static Deformation Working Group Leadership

- Stefan Keye, DLR
- Garrett McHugh, NASA Langley
- Ben Rider, The Boeing Company

Additional Conversation Topics

- **Potential questions to address for ONERA OAT15A validation**
  - Effect of wake resolution and extent of increased resolution?
  - Dependence upon farfield bounding box?
  - Relationship between anisotropic and isotropic grid cells?
  - And others?