Version 2
August 20, 2024

Freestream static temperature updated for ONERA OAT15A

DPW-8 & AePW-4 Workshop Update

AIAA AVIATION
July 30, 2024

https://aiaa-dpw.larc.nasa.gov

Agenda

- **Welcome and Introductions**
- **Nominal Calendar**
- **Working Groups Update**
  - DPW-Centric Working Groups
  - AePW-Centric Working Groups
  - Hybrid Working Groups
- **Grids Overview**
- **Workshop Structure**
- **Hybrid Groups Open Discussion**
- **Community-Centric Open Discussion**

Hybrid Organizing Committee

- **Pawel Chwalowski (AePW)**
  NASA Langley Aeroelasticity Branch
  pawel.chwalowski@nasa.gov

- **Brent Pomeroy (DPW)**
  NASA Langley Configuration Aerodynamics Branch
  brent.w.pomeroy@nasa.gov

- **Ben Rider (DPW)**
  Boeing Commercial Airplanes, Product Development, High-Speed Aerodynamics
  ben.j.rider2@boeing.com

- **Bret Stanford (AePW)**
  NASA Langley Aeroelasticity Branch
  bret.k.stanford@nasa.gov

Workshop Leadership Global Presence

Source: OpenStreetMap
Open source, subject to Open Database License

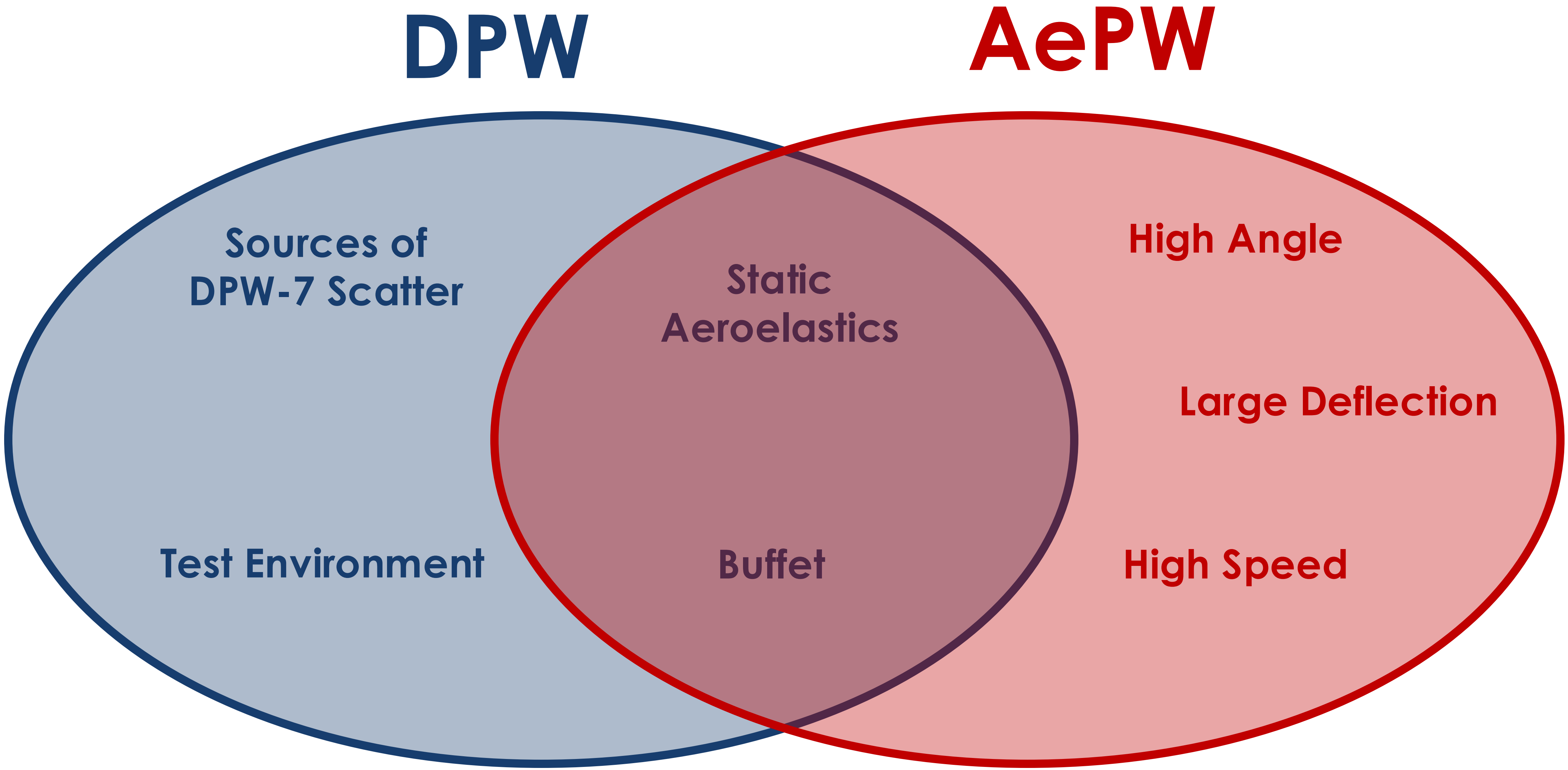
Workshop Goals

- Build upon the rich history of DPW and AePW
- Advance the state of the art within each individual community
- Mature understanding of coupled fluid-structure interaction
- Identify strengths and weaknesses of tools
- Develop and establish a model for interdisciplinary workshops
- Engage student participation

A Special Note For Students

- **Students (undergrad and grads) are strongly encouraged to participate**
- **Workshop seeks to develop the student**
- **Minimize barrier to entry to submit data**
  - Compute resources for students may be limited
  - All test cases do not need to be completed
  - Minimum for participation is one polar at one grid density
- **Compute time and postprocessing licenses are available, if needed**
- **Contact `dpwaiaa@gmail.com` for more information**

Working Groups Layout



Nominal Schedule

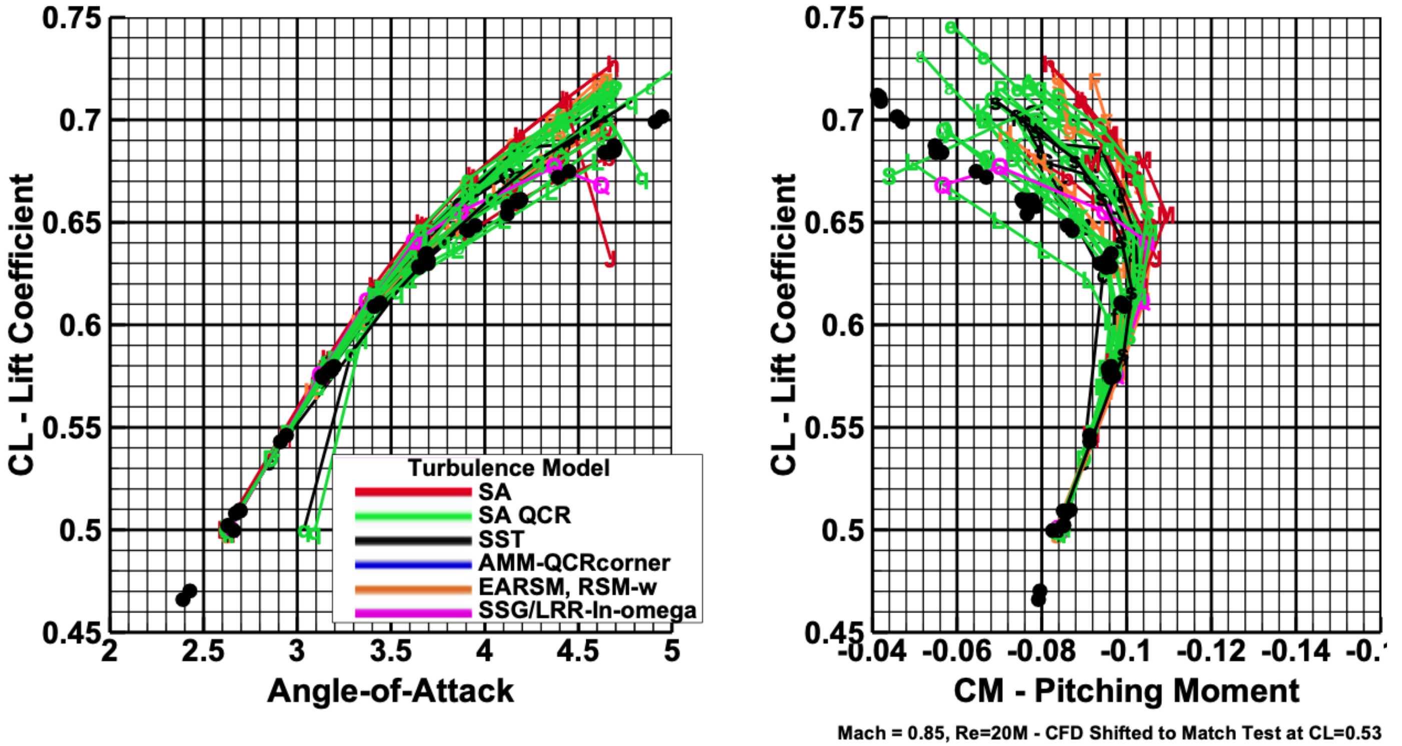
- **May 2024**
  - Working groups begin
  - First test cases defined
- **July 2024**
  - AVIATION in-person meeting
- **Fall 2024**
  - Additional test cases defined
  - Preliminary data may be due
- **January 2025**
  - SciTech in-person meeting
  - Mini Workshop 1 (possibly), hybrid
- **June 2025**
  - AVIATION in-person meeting
- **Summer 2025**
  - Additional test case data may be due
- **Fall 2025**
  - Mini Workshop 2 (possibly), virtual
- **January 2026**
  - SciTech in-person meeting
- **March 2026**
  - Delivery of final data set (as needed)
- **June 2026**
  - Two-day workshop at AVIATION
- **January 2027**
  - SciTech Special Sessions, Orlando, FL

Working Groups Update

- **DPW Centric**
  - Source of Scatter Working Group
  - Test Environment Working Group
- **AePW Centric**
  - High-Angle Working Group
  - Large Deformation Working Group
  - High-Speed Working Group
- **Hybrid**
  - Static Deformation Working Group
  - Buffet Working Group

Source of Scatter – Motivation (1/2)

- **Seek to identify deviations in DPW-7 CRM data**
- **Consistent results seen in linear range and into pitchup (CL ~0.61)**
- **Significant spread in solvers post pitchup (all submissions plotted)**



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

Source of Scatter – Motivation (2/2)

- **Potential sources of C_L/C_M spread have been hypothesized**
  - Significant differences in SA vs k-w models
  - Can RANS adequately capture early pitchup?
  - Grid resolution can affect shock location

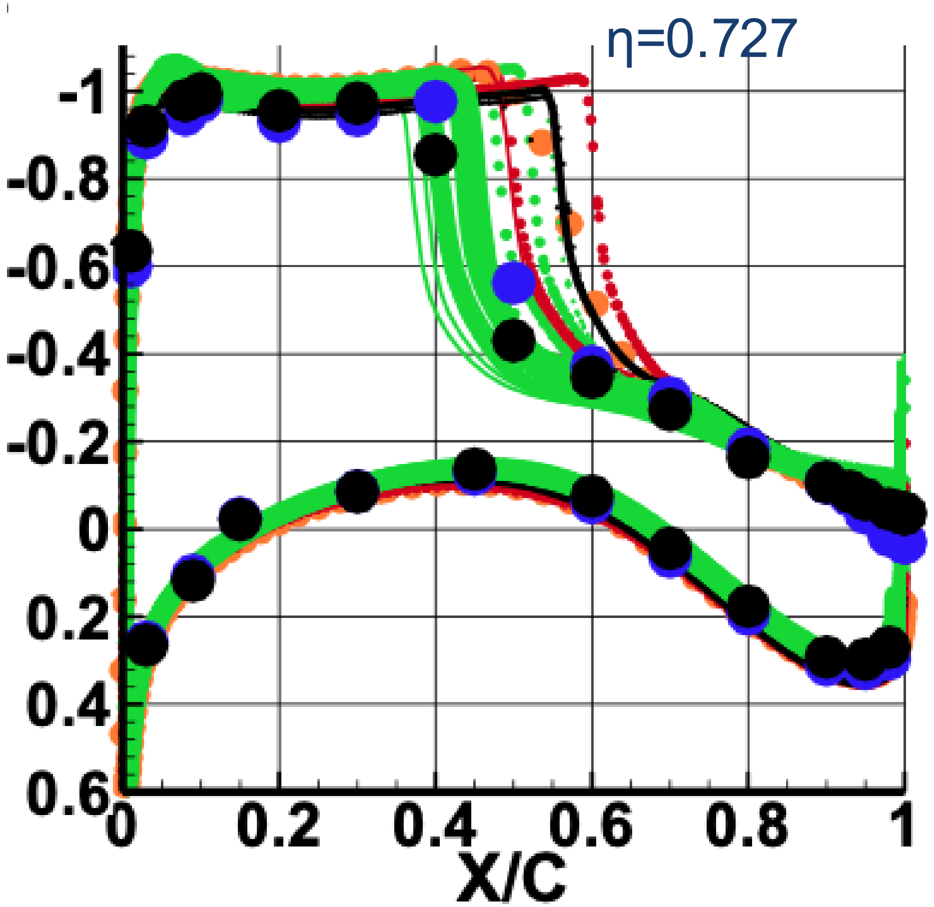
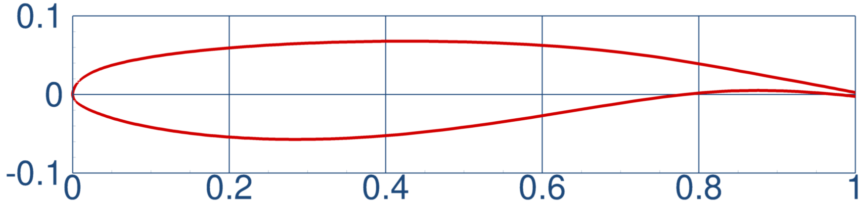


Image source:
Tinoco, E., et al., "Summary Data from the Seventh AIAA CFD Drag Prediction Workshop," AIAA 2023-3492

Test Case 1: Workshop-Wide Validation

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

- **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

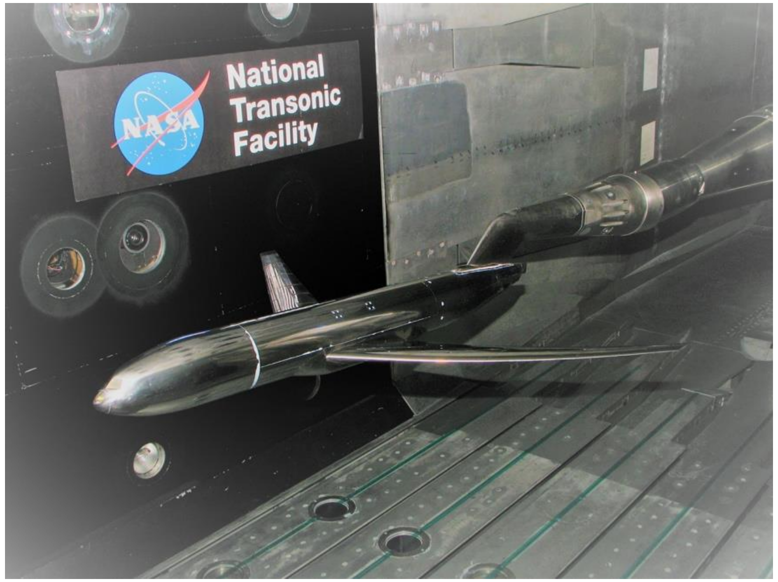
Source of Scatter – Current Status

- **Leadership**
  - Ed Tinoco, retired US
  - Raj Nangia, on behalf of the Royal Aeronautical Society GB
  - ***<u>and YOU???</u>***
- **Has not yet met**
- **Planning to meet soon**

Point of Contact: Ed Tinoco (entinoco@icloud.com)

Test Environment – Motivation

- **Significant spread between experimental and computational results**
- **Simulations to be representative of National Transonic Facility (NTF) tests**
- **Determine effect of test section geometry**
  - NTF geometry recently released
  - Captured through optical measurement methods
  - Includes slots and gaps
- **Quantify effect of mounting hardware**
  - Geometry was digitized during a test
  - Updated loft in final preparation



Source: NASA

Test Environment – Current Status

- **Leadership**
  - Ben Rider, Boeing Commercial Airplanes US
  - Melissa Rivers, NASA Langley US
  - ***and YOU???***
- **Has not yet met**
- **Planning to meet soon**

Point of Contact: Ben Rider (ben.j.rider@boeing.com)

Working Groups Update

- **DPW Centric**
  - Source of Scatter Working Group
  - Buffet Working Group
- **AePW Centric**
  - High-Angle Working Group
  - Large Deformation Working Group
  - High-Speed Working Group
- **Hybrid**
  - Static Deformation Working Group
  - Buffet Working Group

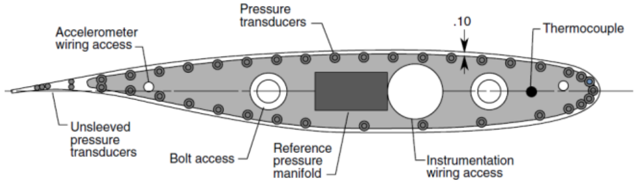
High Angle Working Group – Current Status

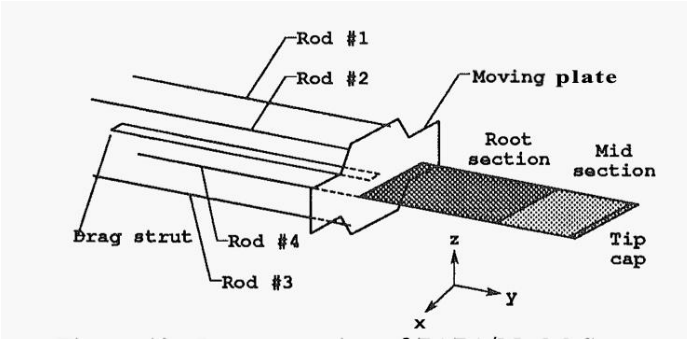
- **Leadership**
  - Pawel Chwalowski, NASA Langley US
- **Has met three times**
- **Second Thursday of every month at 10:00 Eastern time**

Point of Contact: Pawel Chwalowski (pawel.chwalowski@nasa.gov)

High Angle Working Group – Summary

- **Focus on transonic aeroelastic flutter**
  - This WG dates back to AePW-1, held in 2012
  - Previous iterations of this WG had also considered transonic buffet
  - There will be some overlap here with the Buffet and the Static Deformation WGs
- **Utilize the Benchmark Supercritical Wing (BSCW)**
  - Tested in the NASA LaRC Transonic Dynamics Tunnel (TDT) in the early 1990's, 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 AoA's
  - Finite element model available, as well as a family of unstructured meshes





High Angle Working Group: Test Case

- **AePW’s 2 and 3 had considered isolated data points at relatively high Mach and AoA values: massively separated flow**
  - The spread in computational flutter predictions was very large
  - Because all we had was the experimental flutter point itself (and no other type of flow/pressure data), it was difficult to understand why/where exactly the codes were struggling
- **New strategy: consider an entire AoA-sweep at Mach 0.8**
  - 0° to 2°: attached flows, but shocks on the upper and lower surfaces
  - 3°: minor flow separation
  - 4° to 6°: massive flow separation
    - Large sensitivity to grid, time step, turbulence model, etc.; also some numerical evidence of a subcritical LCO
- **This will increase the burden of each participant, but also hopefully improve our understanding of how solvers begin to struggle with increased transonic effects**
- **Planned TDT re-test in 2025: these predictions will help guide the test plan**

Large Deformation Working Group – Current Status

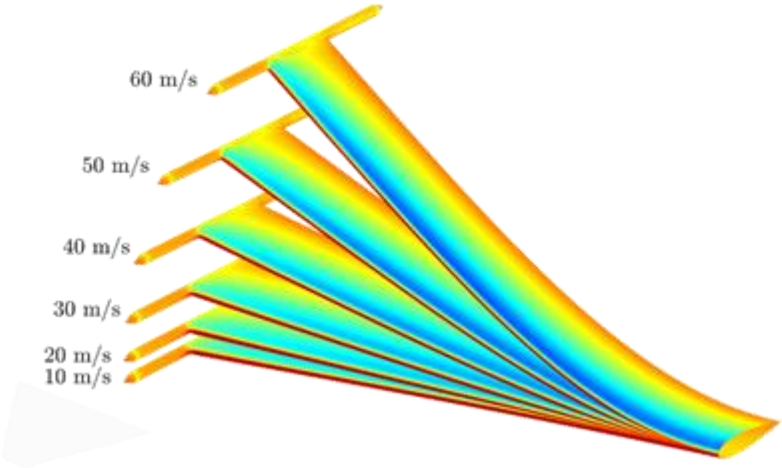
- **Leadership**
  – Rafael Palacios, Imperial College GB
- **Has met four times**
- **Third Thursday of every month at 11:00 Eastern time**

Point of Contact: Rafael Palacios (r.palacios@imperial.ac.uk)

Large Deformation Working Group – Summary

- **Focus on aeroelastic problems with structural nonlinearities**
  - Slender, high aspect ratio wings
  - The previous iteration of this WG (AePW-3) had considered Technion's Pazy Wing
  - Increased AoA → change in structural stiffness → shift in flutter boundaries

- **The current iteration of this group is still deciding where to go next**
  - Delft has experimental Pazy wing data of large-deflection unsteady response due to a sinusoidal gust
  - Technion is in the beginning research stages of a swept Pazy Wing
  - University of Michigan's EASE configuration: high aspect ratio wing, with control surfaces, attached to a PAPA



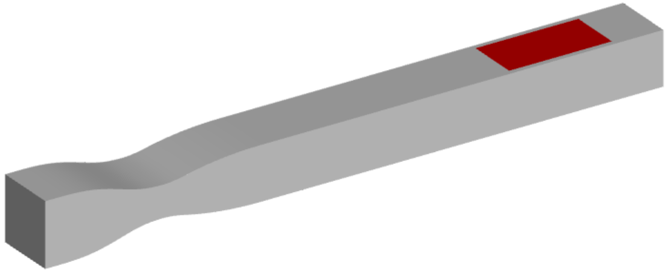
High Speed Working Group – Current Status

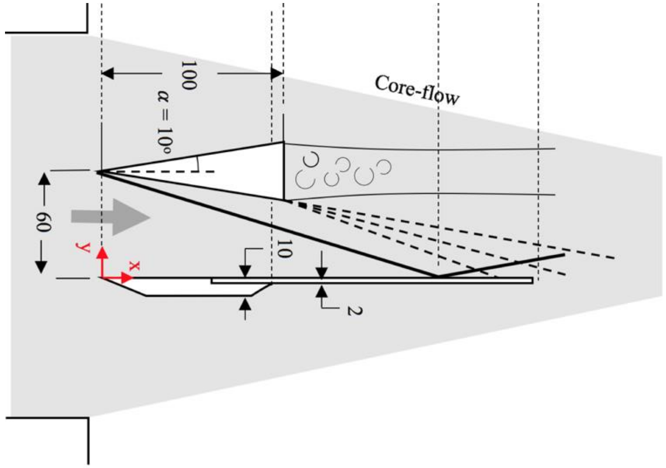
- **Leadership**
  - Kirk Brouwer, US Air Force Research Laboratory US
- **Has met three times**
- **Fourth Thursday of every-other-month at 5:00 pm Eastern time**
  - And at 8:00 am ET on the alternating months

Point of Contact: Kirk Brouwer (kirk.brouwer.1@us.af.mil)

High Speed Working Group – Summary

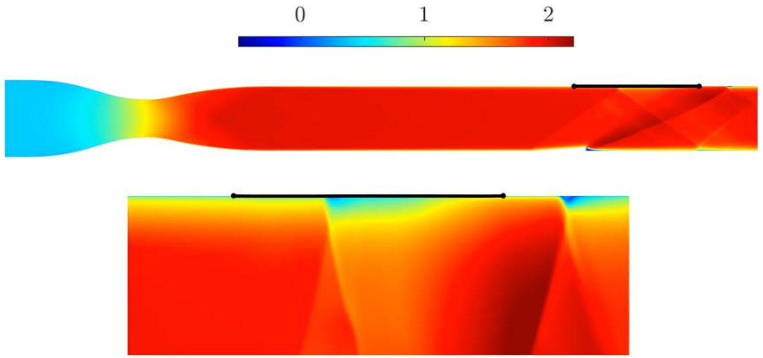
- **Focus on supersonic and hypersonic FSI problems**
- **The current iteration of this group will continue with the same 2 test cases considered in AePW-3**
  - AFRL's RC19 case: Mach-2 flow over a flexible panel
  - University of New South Wales' HyMax case: wedge-based shock impingement on a cantilevered plate at Mach 6
- **This WG got off to a relatively late-start in the AePW-3 cycle**
  - A mini-workshop was held at SciTech 2024
  - This WG has also, historically, struggled to attract interest from the broader high-speed FSI community
    - Unclear relationship with the AIAA High Speed FSI DG, e.g.
    - Issues stemming from the potentially-sensitive nature of these problems?



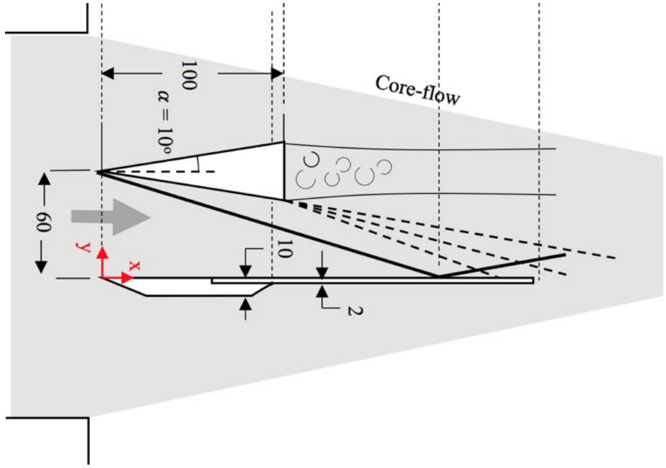


High Speed Working Group – Test Cases

- **RC-19**
  - Flexible panel mounted to the ceiling of a Mach 2 tunnel
  - Three tuning knobs
    - Temperature delta between the panel and its support frame
    - Cavity pressure behind the panel
    - The angle of a wedge on the floor of the tunnel
  - Panel response is very sensitive (numerically and experimentally) to these parameters



- **HyMax**
  - Wedge-based shock impingement on a cantilevered plate at Mach 6
  - Three test cases: two wedge angles, and also an oscillating wedge
  - Relatively few participants had considered HyMax in AePW-3



Working Groups Update

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  - High-Angle Working Group
  - Large Deformation Working Group
  - High-Speed Working Group
- **Hybrid**
  - Static Deformation Working Group
  - Buffet Working Group

Static Deformation – Current Status

- **Leadership**
  - Ben Rider, Boeing Commercial Airplanes US
  - Stefan Keye, DLR DE
  - Garrett McHugh, NASA Langley US
- **Has met two times**
- **Third Friday of every month at 10:00 Eastern time**

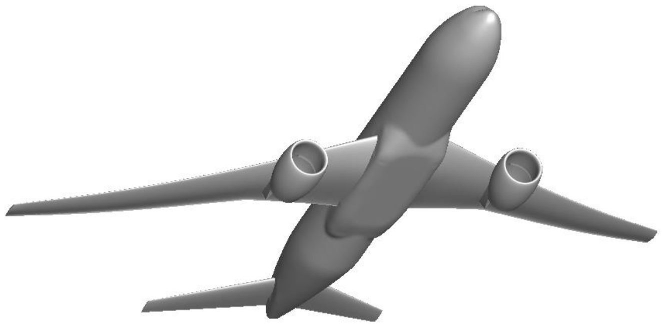
Point of Contact: Ben Rider (ben.j.rider@boeing.com)

Static Deformation – Motivation

- **Leverage knowledge from both fields to advance state of the art**
  - Increase understanding within each field, individually
  - Synthesize methods to increase understanding of static deformation predictions
- **Determine practices that accurately model fluid structure interaction to predict accurate deformations and resulting aerodynamics**
- **Evaluate the effectiveness of existing tools and methods**
- **Provide guidance for simulations while relying upon users to implement his/her code's best practices**
- **Establish workshop model for future multidisciplinary communities**

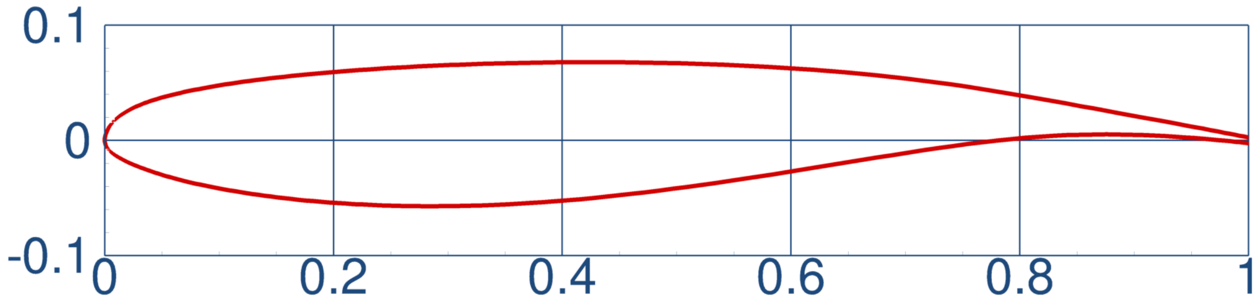
Static Deformation – Summary

- **Large amount of interest**
  - 68 participants on email distribution list
  - Represent five continents (North America, South America, Europe, Asia, Oceania)
  - Some overlap with Buffet Working Group
- **Utilize NASA/Boeing Common Research model**
  - Well studied and tested
  - Provides good comparison to other workshops
  - Rich legacy of NASA, ETW, ONERA, and JAXA experimental data sets
  - Finite element model (FEM) available for NASA and JAXA models
  - Will include wing/body as well as wing/body/nacelle/pylon
- **Test cases**
  - Three primary test cases, two two-part test cases
  - Committee-supplied grids are available



Test Case 1a: Workshop-Wide Validation

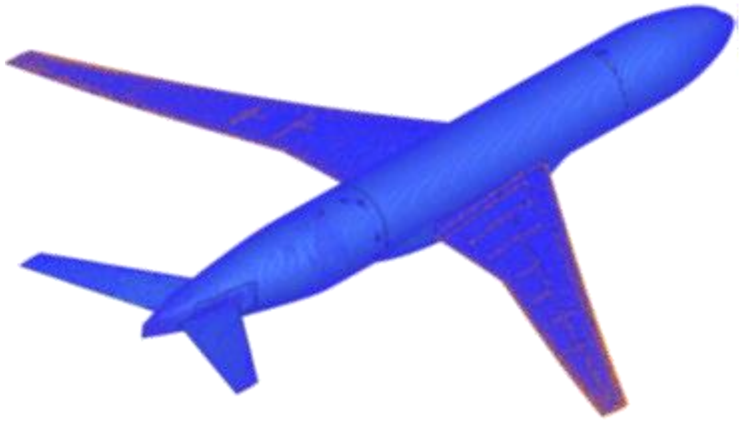
- **Identical to Scatter Working Group Test Case 1**



ONERA OAT15A Transonic Airfoil

Test Case 1b: FEM Validation

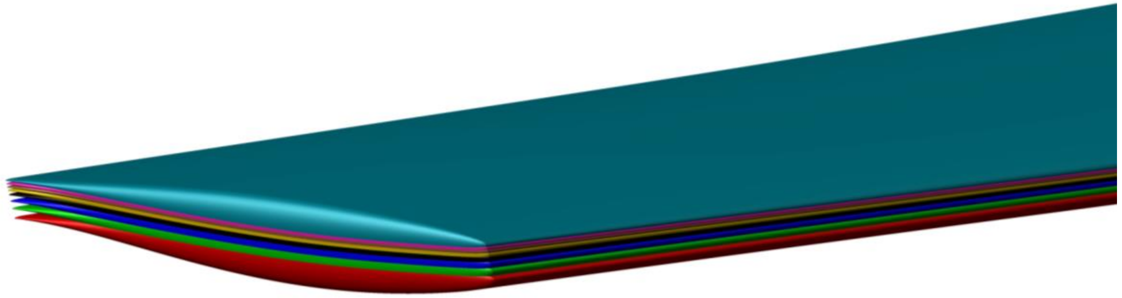
- **Validation of Structural Model for NASA CRM**
- **Users are encouraged to employ best practices for selected FEM codes**
- **Approach**
  - Linear Eigenvalue Analysis (e.g. NASTRAN® SOL103)
  - Rigid suspension at sting
  - Steady or scale-resolving schemes
- **Grid**
  - MSC NASTRAN® solid 4-node tetrahedral finite-element structural model
  - Model consists of 6.8million elements, 4.1million degrees-of-freedom
  - Grids will be supplied by NASA Langley
  - Wind tunnel sting will be added as beam model (date ???)



NASA Structural Model

Test Case 2a: Wing/Body Deformation

- **CFD/FEM unloaded-to-loaded simulation**
- **Match NASA Langley NTF test**
  - One condition
  - Reynolds number (Re) 5 million
  - Mach 0.85
  - Pre-pitchup
- **Committee supplied**
  - Jig (unloaded) geometry
  - FEM
  - Six-member grid family
- **Metrics**
  - Forces and moments (F&M)
  - Sectional twist/deformation
  - Sectional C_P distribution



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

- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body**
  - Available Reynolds numbers: 5M (LoQ), 20M (LoQ), 20M (HiQ), 30M (HiQ)
  - Range of Mach numbers: 0.70, 0.85, 0.87 (M_{cruise} = 0.85)
  - Range of angles of attack: -3.0 – 12.0 deg (AOA_{cruise} ~ 2.75-3.00 deg)
- **Committee-supplied**
  - Jig (unloaded) geometry
  - FEM
  - Six-member grid family
- **Comparison metrics**
  - Forces and moments (F&M)
  - Sectional twist/deformation
  - Sectional C_P distribution

Test Case 3 – Wing/Body/Nacelle/Pylon

- **CFD/FEM start from unloaded (wind-off) geometry/grid**
- **CRM Wing/Body/Nacelle/Pylon (WBNP)**
  - Available Reynolds numbers: 5M (LoQ)
  - Range of Mach numbers: 0.70, 0.85, 0.87 (M_{cruise} = 0.85)
  - Range of angles of attack: -3.0 – 12.0 deg (AOA_{cruise} ~ 2.75-3.00 deg)
- **Committee-supplied**
  - Jig (unloaded) geometry
  - FEM
  - Six-member grid family
- **Comparison metrics**
  - Forces and moments (F&M)
  - Sectional twist/deformation
  - Sectional C_P distribution

Buffet – Current Status

- **Working group leadership**
  - Hadar Ben-Gida IL
  - Brent Pomeroy US
  - Daniella Raveh IL
  - Andrea Sansica JP
  - Bret Stanford US
- **Subgroup leaders**
  - Jeff Housman US
  - Johan Jansson SE
  - Fulvio Sartor FR

- **Has met three times**
- **Third Tuesday of every month, 10:00 Eastern**
- **Defined three test cases**

Point of Contact: AIAA Buffet Group (aiaabuffet@gmail.com)

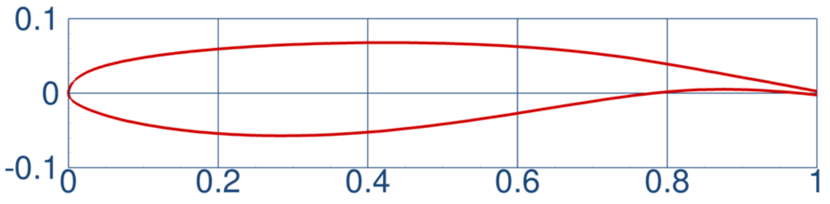
Buffet – Motivation

- **Leverage knowledge from both fields to advance state of the art**
  - Increase understanding within each field, individually
  - Synthesize methods to increase understanding of buffet predictions
- **Determine practices that accurately resolve unsteady, fixed-geometry at buffet conditions**
- **Exercise capabilities of solvers to simulate unsteady FSI buffet**
- **To provide an impartial forum for evaluating the effectiveness of existing tools and methods**
- **Provide guidance for simulations while relying upon users to implement his/her code's best practices**
- **Establish workshop model for future multidisciplinary communities**

Buffet – Summary

- **Largest amount of interest of all working groups**
  - Nearly 100 participants on email distribution list
  - Some overlap with Static Deformation and High-Angle Working Groups
  - Will split into three subgroups (URANS, hybrid RANS/LES, WMLES)
- **Utilize JAXA wing/body/tail geometry**
  - Well studied and tested
  - Provides good comparison to other workshops
  - Rich legacy of NASA, ETW, ONERA, and JAXA experimental data sets
  - Finite element model (FEM) available for NASA and JAXA models
  - Will include wing/body/tail CRM configuration
- **Test cases**
  - Three primary test cases, two two-part test cases
  - Committee-supplied grids are available

Test Case 1a: Workshop-Wide Validation

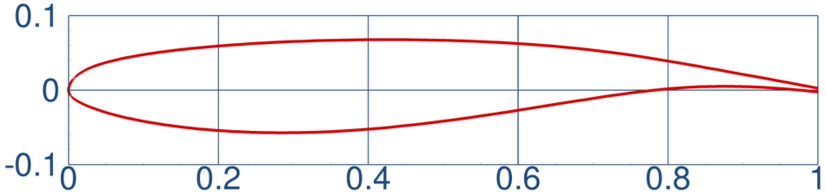


ONERA OAT15A Transonic Airfoil

- **Mostly the same as other working groups**
- **Validation of steady CFD analysis, required**
- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted
- **Grids**
  - Six-member RANS grid family; four are required, six are desirable
  - Encourage use of committee-supplied grids; user-generated grids are acceptable
- **Conditions**
  - Mach 0.73, Re_c=3m (based on chord length), T_{static}= 271 K (487.8 R)
  - Additional alpha: 3.25, 3.40, 3.50, 3.60, and 3.90
  - 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.

Test Case 1b: Unsteady CFD Validation



ONERA OAT15A Transonic Airfoil

- **Mostly the same as Test Case 1a**
- **Validation of unsteady CFD analysis, required**
- **Settings**
  - Unsteady CFD (URANS, hybrid RANS/LES, WMLES, LES, etc.)
  - Prefer some version of SA, multiple turbulence models can be submitted
- **Grids**
  - Same geometry as Test Case 1a
  - Specialized grids for unsteady schemes will likely be generated by participants
- **Conditions**
  - Same as Test Case 1a

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 2: Unsteady CFD, Static Wing

- **Optional**
- **Unsteady CFD with static geometry/grid**
- **Reynolds number 1.5 million**
- **CRM wing/body/tail**
- **Committee-supplied**
  - JAXA geometry at 4.84 and 5.89 degrees
  - NASA geometry at pre-buffet condition (perhaps CL=0.50)
  - Grids for associated geometry
  - Trip location (optional to use)
- **Comparison metrics**
  - Time-averaged F&M and C_P data
  - Unsteady pressure signals at select locations
  - Frequency content at select locations

Test Case 3: Unsteady FSI

- **Optional**
- **Coupled unsteady CFD and dynamic geometry/grid**
- **Reynolds number 2.3 million**
- **Committee-supplied**
  – Undeformed JAXA jig geometry and grid
  – JAXA FEM model
  – Trip location (optional to use)
- **Comparison Metrics**
  – Time-averaged F&M and C_P data
  – Unsteady pressure signals at select locations
  – Frequency content at select locations
  – Surface C_P (uPSP)
  – Strain gauge
  – Structural response

Workshop Structure

- **Two full-day workshop at AVIATION '26**
- **First day**
  - Community centric in two separate rooms
  - Technical lessons learned
  - Future plans
- **Second day**
  - Everyone together
  - Hybrid groups
  - Workshop lessons learned
  - Future plans

Grids Update

- Helden Aerospace (Heldenmesh)
- Cadence (Pointwise)
- NASA Ames (Chimera Grid Tools)

`https://aiaa-dpw.larc.nasa.gov`

Website Content

- `https://aiaa-dpw.larc.nasa.gov`
- **DPW site contains field-specific and shared data**
  - Working Group pages for four DPW-focused groups
  - Geometry
  - Grids
  - Postprocessing data file templates
  - Experimental results
- **AePW is working on a page**

SHAPING THE FUTURE OF AEROSPACE