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

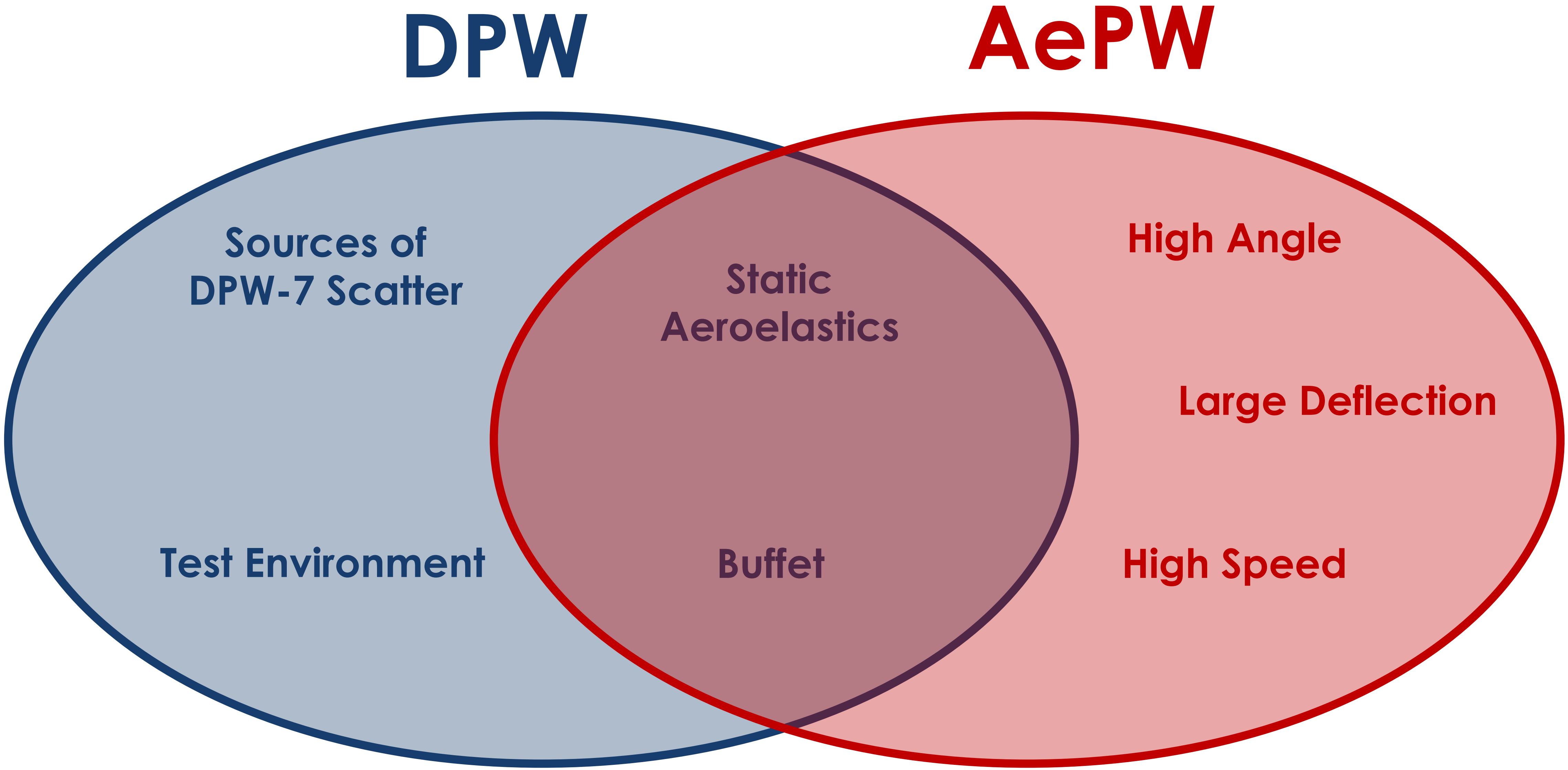
Workshop Goals

- 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

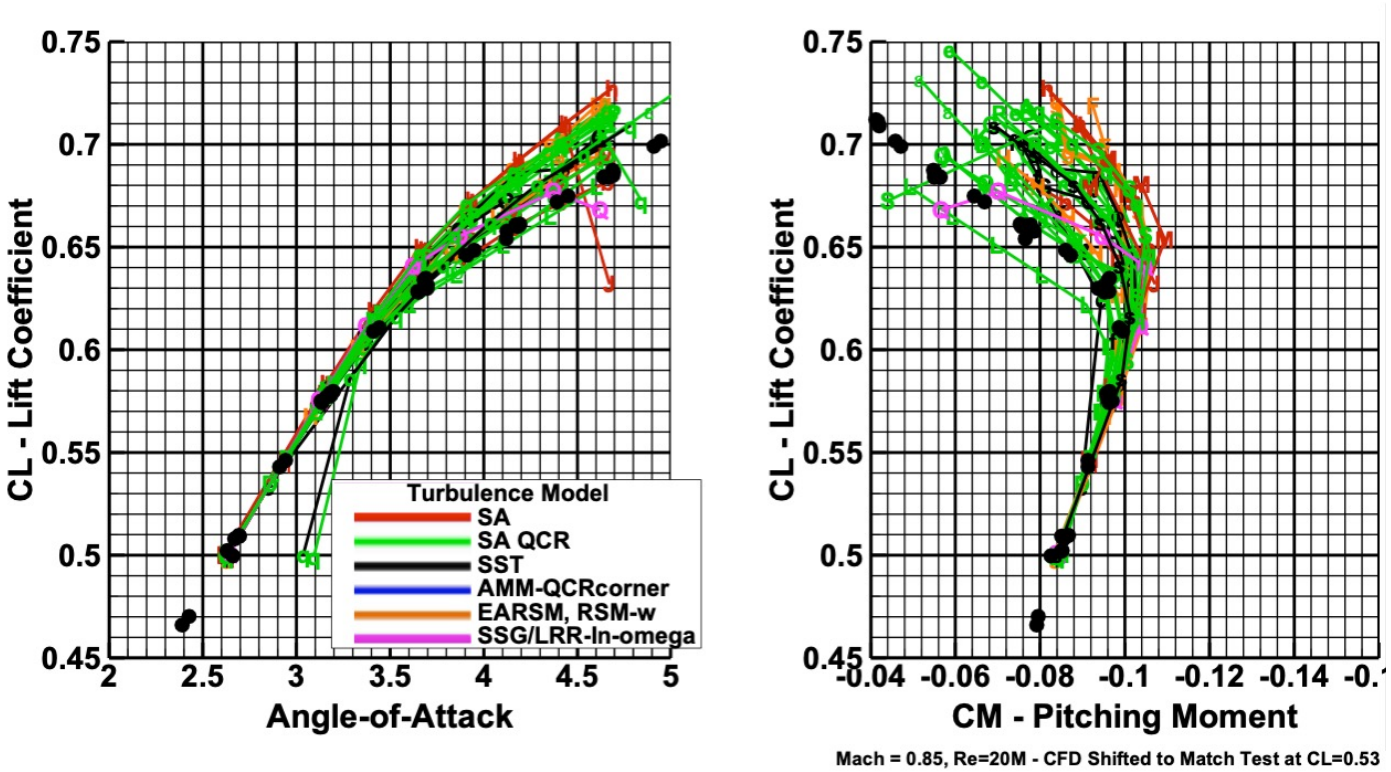
- **May 2024**
  - Working groups begin
  - First test cases defined
- **July 2024**
  - AVIATION in-person meeting
- **Fall 2024**
  - Additional test cases defined
  - Preliminary data may be due
- **January 2025**
  - SciTech in-person meeting
  - Mini Workshop 1 (possibly), hybrid
- **June 2025**
  - 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

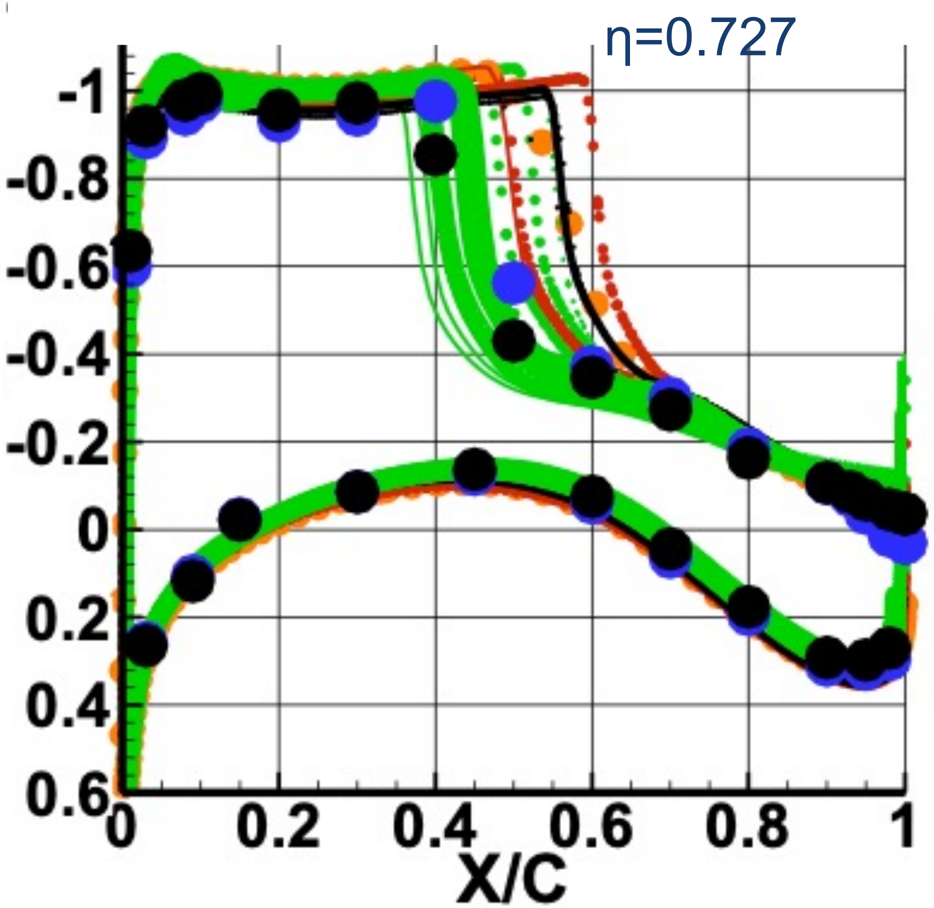
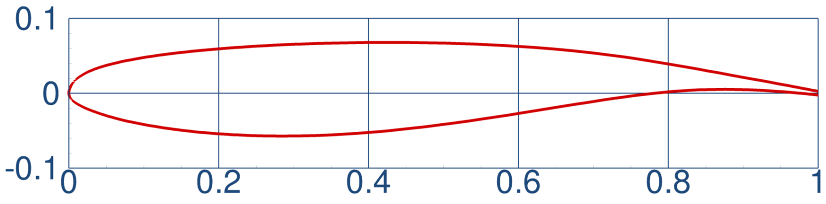


Image source:
Tinoco, E., et al., "Summary Data from the Seventh AIAA CFD Drag Prediction Workshop," AIAA 2023-3492

Test Case 1: Workshop-Wide Validation

AIAA
SHAPING THE FUTURE OF AEROSPACE



ONERA OAT15A Transonic Airfoil

- **Used for all four DPW and hybrid working groups**
- **Validation of steady CFD analysis, required**
- **Users are encouraged to employ best practices for selected CFD codes**
- **Settings**
  - Steady CFD (e.g., RANS)
  - Prefer some version of SA, multiple turbulence models can be submitted
- **Grids**
  - Six-member 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}= 300K (540 R, 80.33 F)
  - 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.

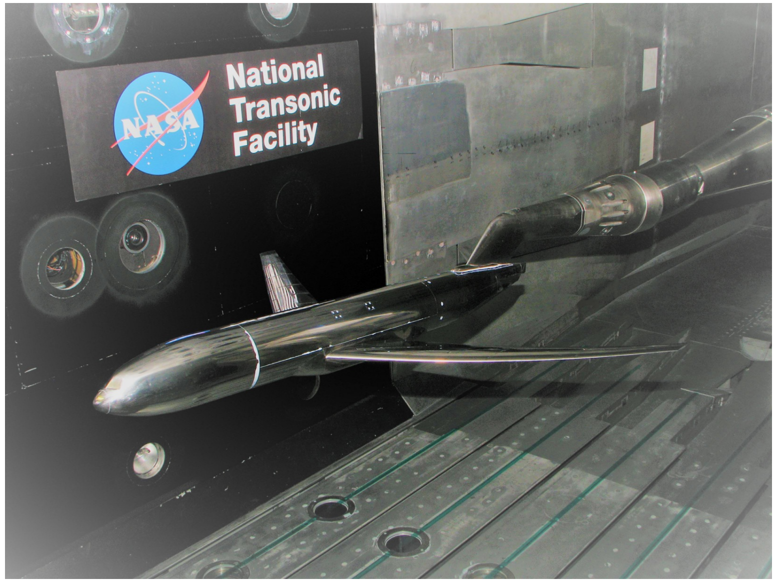
Source of Scatter – Current Status

- **Leadership**
  - Ed Tinoco, retired 🇺🇸
  - Raj Nangia, on behalf of the Royal Aeronautical Society 🇬🇧
  - ***and YOU???***
- **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 🇺🇸
  - Melissa Rivers, NASA Langley 🇺🇸
  - ***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

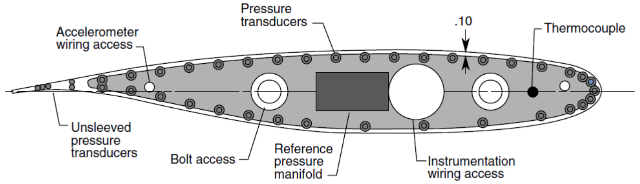
High Angle Working Group – Current Status

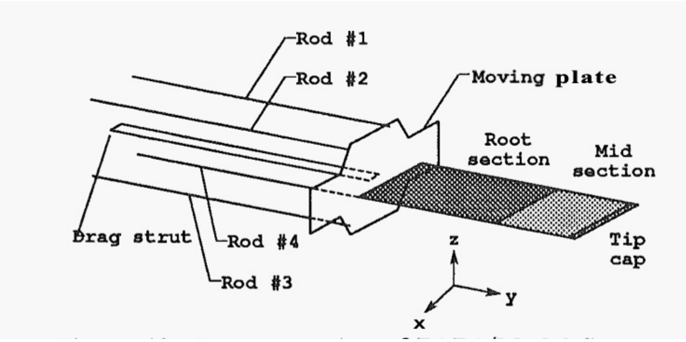
- **Leadership**
  - Pawel Chwalowski, NASA Langley 🇺🇸
- **Has met three times**
- **Second Thursday of every month at 10:00 Eastern time**

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

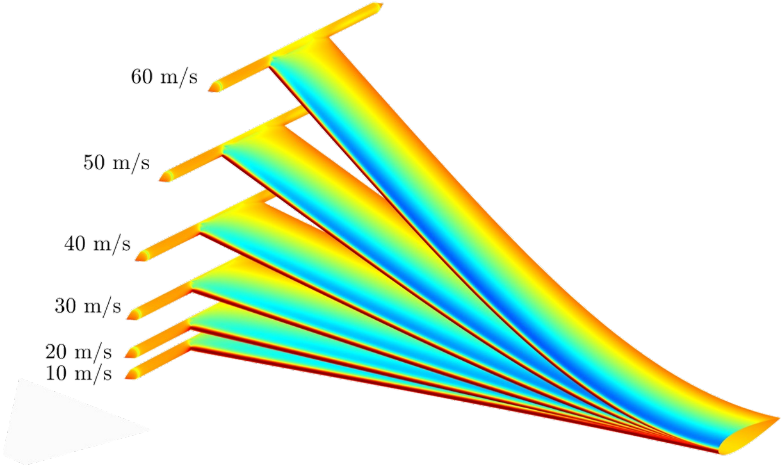
- **Leadership**
  - Rafael Palacios, Imperial College 🇬🇧
- **Has met four times**
- **Third Thursday of every month at 11:00 Eastern time**

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



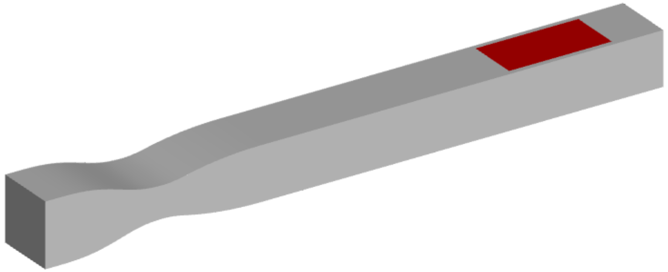
High Speed Working Group – Current Status

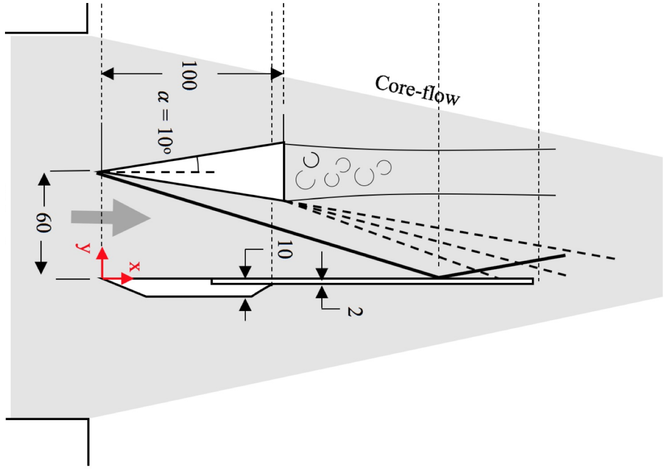
- **Leadership**
  - Kirk Brouwer, US Air Force Research Laboratory 🇺🇸
- **Has met three times**
- **Fourth Thursday of every-other-month at 5:00 pm Eastern time**
  - And at 8:00 am ET on the alternating months

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

High Speed Working Group – Summary

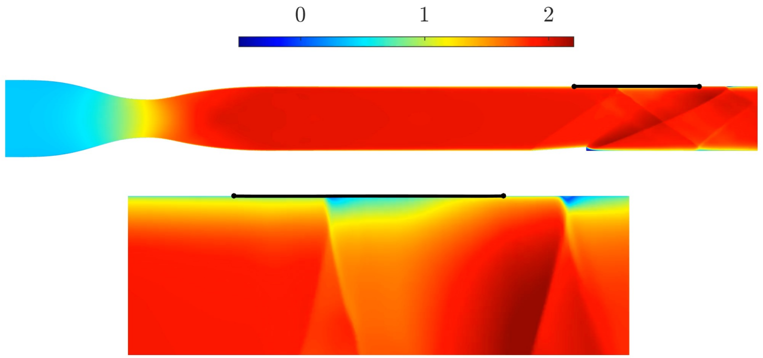
- **Focus on supersonic and hypersonic FSI problems**
- **The current iteration of this group will continue with the same 2 test cases considered in AePW-3**
  - AFRL's RC19 case: Mach-2 flow over a flexible panel
  - University of New South Wales' HyMax case: wedge-based shock impingement on a cantilevered 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?



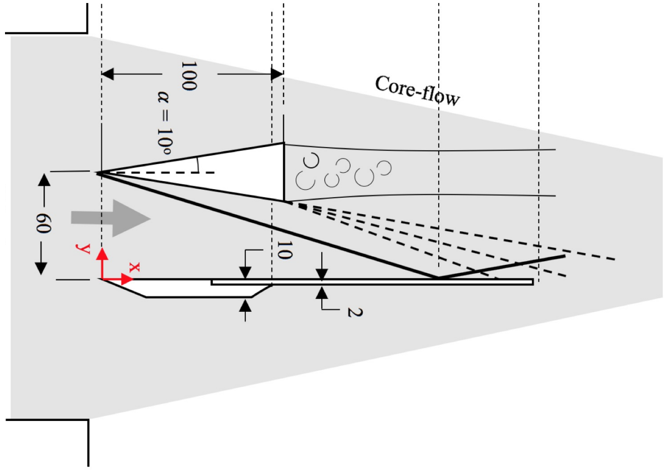


High Speed Working Group – Test Cases

- **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

- **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

Static Deformation – Current Status

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

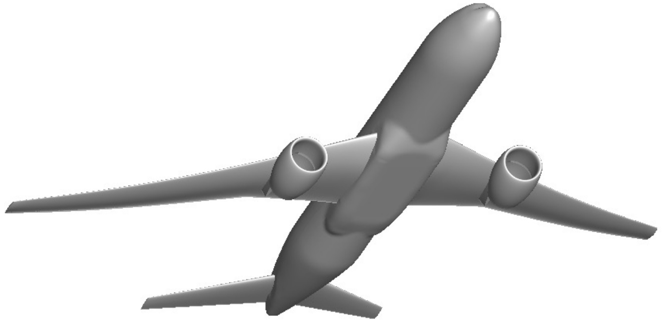
Point of Contact: Ben Rider (ben.j.rider@boeing.com)

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**

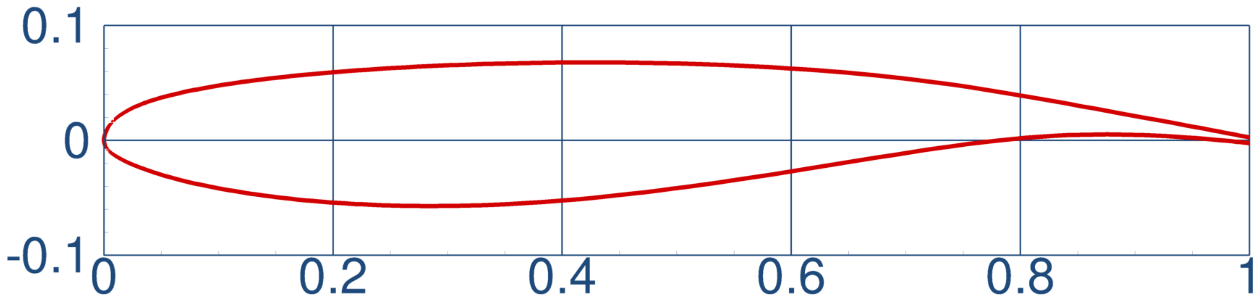
Static Deformation – Summary

- **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

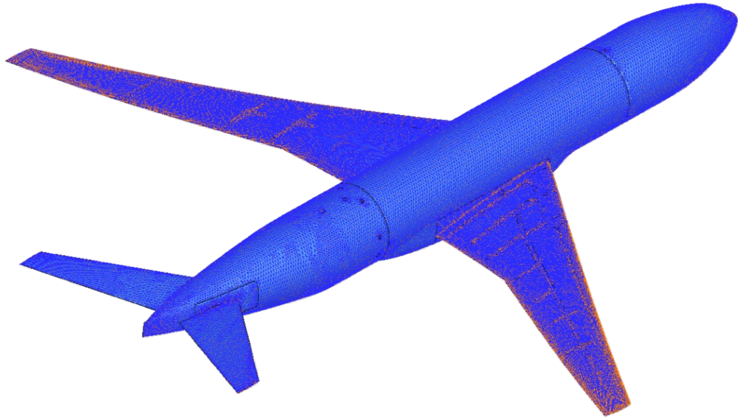
- **Identical to Scatter Working Group Test Case 1**



ONERA OAT15A Transonic Airfoil

Test Case 1b: FEM Validation

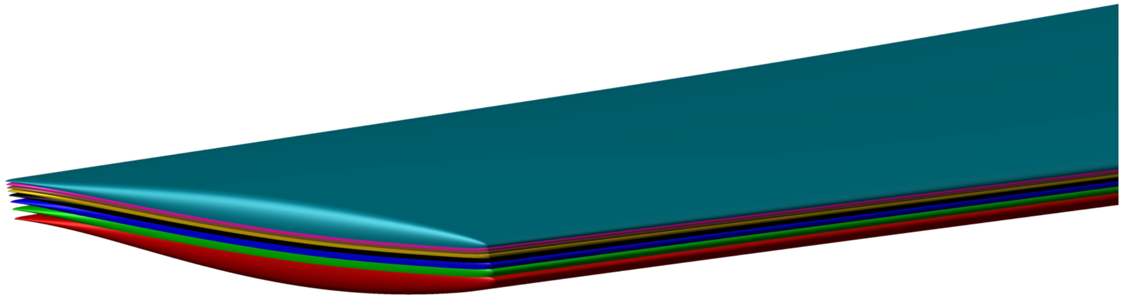
- **Validation of Structural Model for NASA CRM**
- **Users are encouraged to employ best practices for selected FEM codes**
- **Approach**
  - Linear Eigenvalue Analysis (e.g. NASTRAN® SOL103)
  - Rigid suspension at sting
  - Steady or scale-resolving schemes
- **Grid**
  - MSC NASTRAN® solid 4-node 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 🇮🇱
  - Brent Pomeroy 🇺🇸
  - Daniella Raveh 🇮🇱
  - Andrea Sansica 🇯🇵
  - Bret Stanford 🇺🇸
- **Subgroup leaders**
  - Jeff Housman 🇺🇸
  - Johan Jansson 🇸🇪
  - Fulvio Sartor 🇫🇷

- **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)

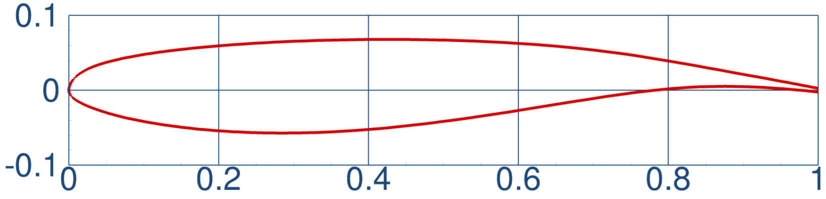
Buffet – Motivation

- **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



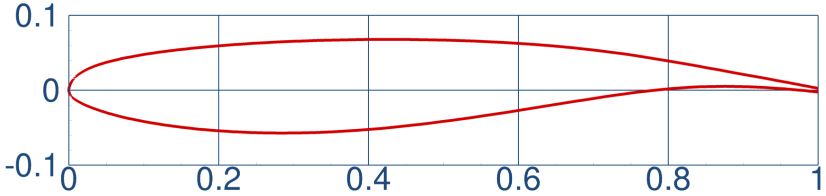
ONERA OAT15A Transonic Airfoil

- **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**
  - Pre-pitchup conditions the same as other working groups
  - Additional alpha: 3.25, 3.40, 3.50, 3.60, and 3.90

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

- **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



ONERA OAT15A Transonic Airfoil

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

AIAA DPW8
STRUCTURED OVERSET GRIDS STATUS

William M. Chan, Andrew M. Chuen

Computational Aerosciences Branch

NASA Ames Research Center

Ames Research Center

AUTOMATION SOFTWARE FLOW CHART

Clean BRep Solid Geometry (.stp/.igs/.egads)

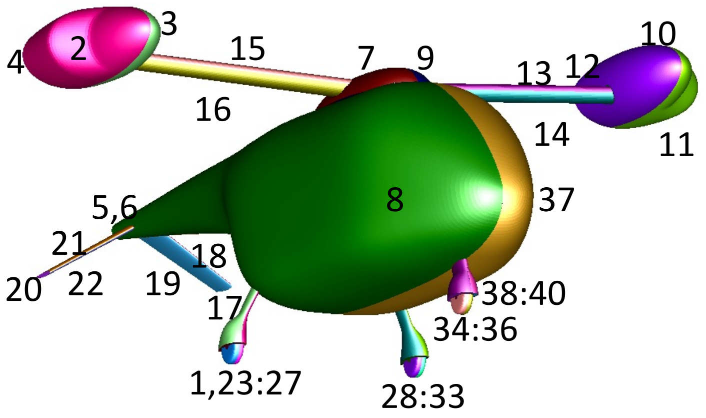
↓

Geometric components specification file ⟷

Right_LandGear
1,23:27

Left_Tail
17:19

…



↓

EPOGS {
EGADS2SRF

↓

POGS (Pre-processor for Overset Grid Simulations)
}

- Surface grids
- Volume grids
- Domain Connectivity data
- Input files for flow solver & component aeroloads computation

Manual repairs & adjustments if needed (negative Jacobians, overlap)

Global Control Parameters

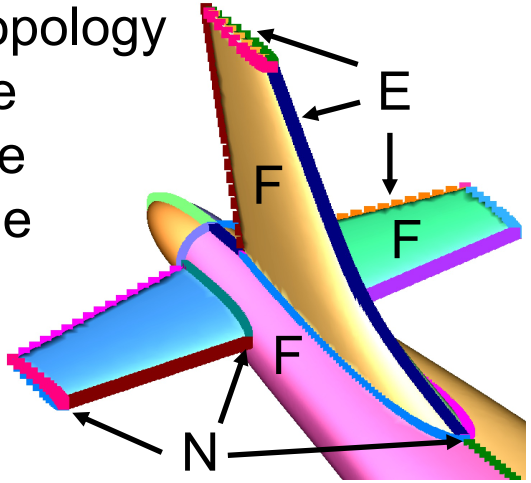
Max grid spacing	Wall normal spacing
Max dihedral angle	Distance to far field
Max stretching ratio	# Fringe layers
# Pts on shortest edge	Min Donor stencil quality

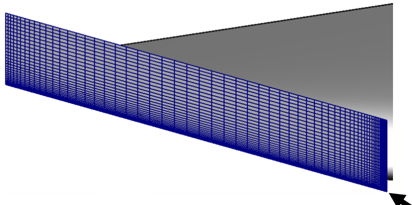
Mesh Automation Metrics

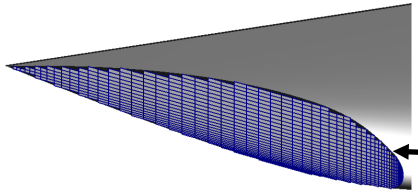
% grids free of negative cell areas/Jacobians
% fringe pts with acceptable donor stencils

REVIEW OF SURFACE MESH AUTOMATION

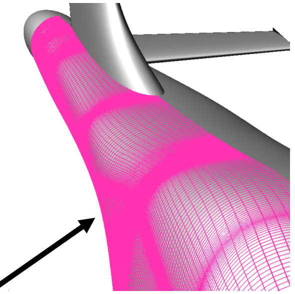
BRep Topology
F = Face
E = Edge
N = Node



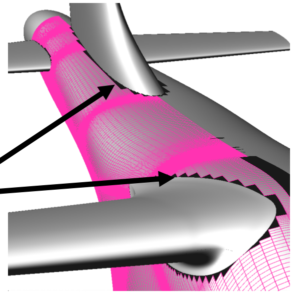




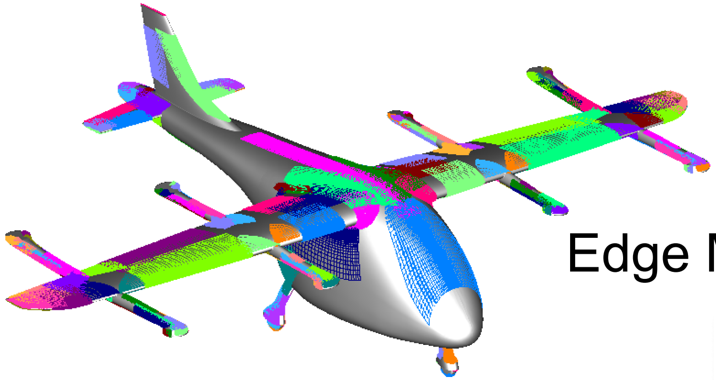
Face Meshes



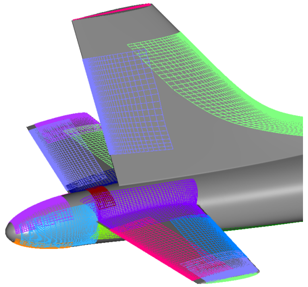
Original untrimmed BRep face

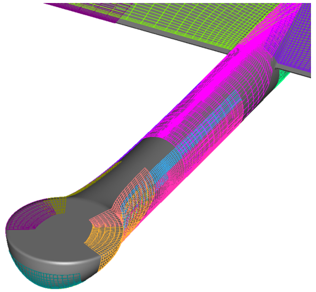


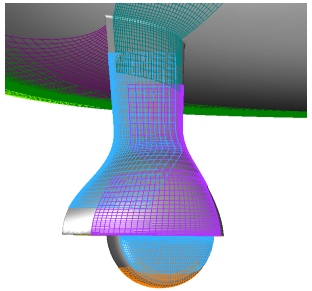
Trimmed BRep face with iblanks representing on/off geometry status

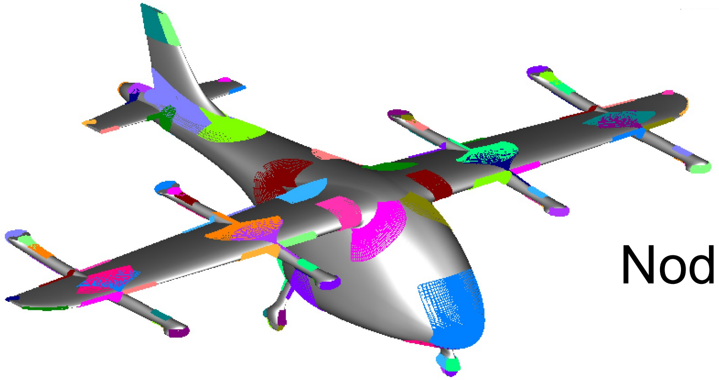


Edge Meshes

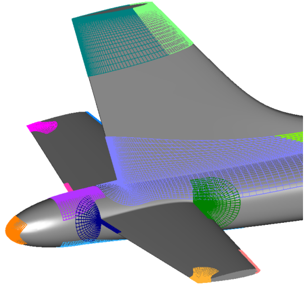


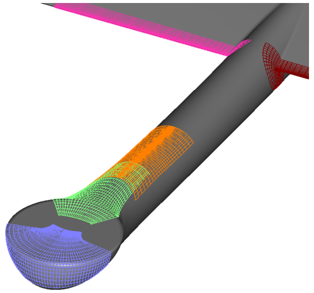


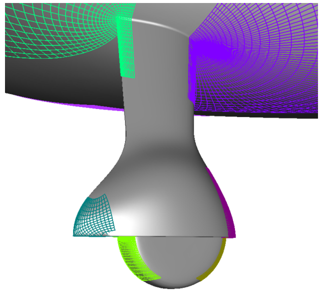




Node Meshes



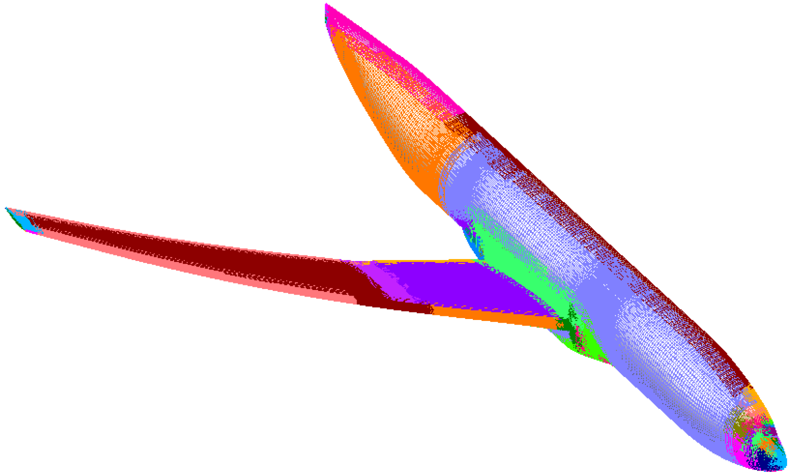


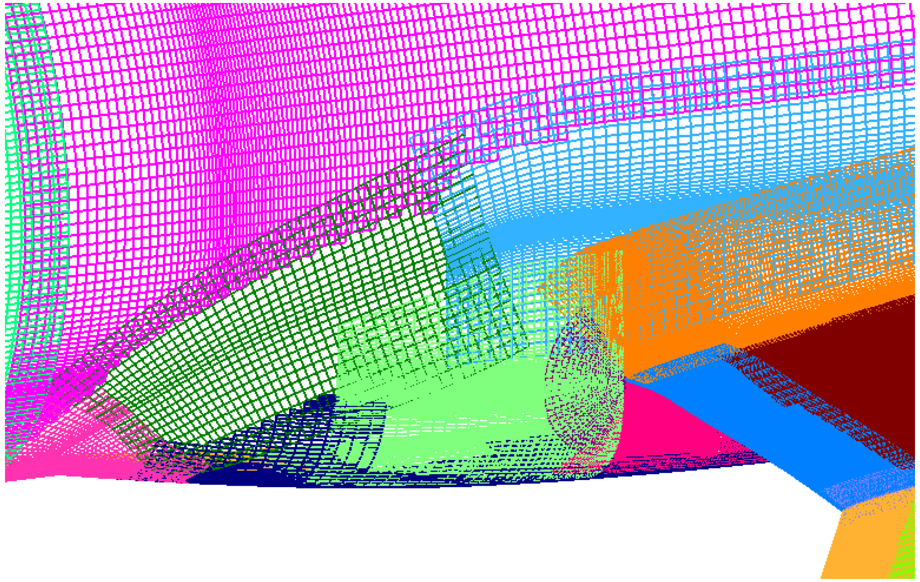


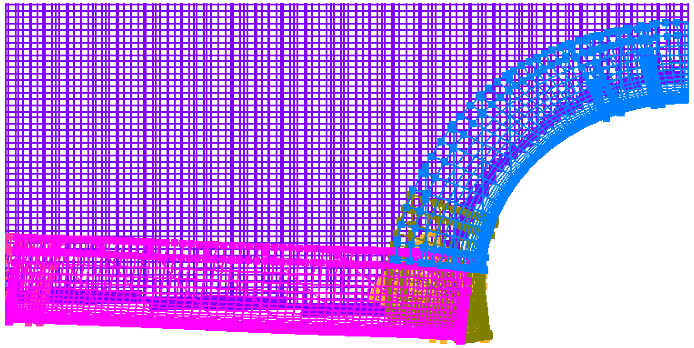
Ames Research Center

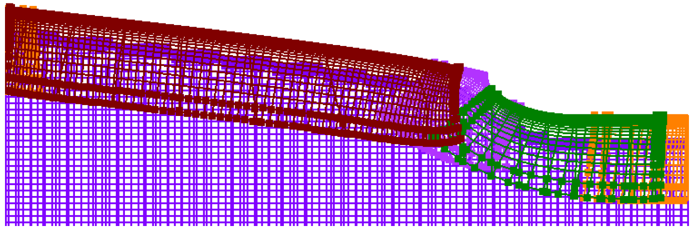
7TH AIAA DRAG PREDICTION WORKSHOP (DPW7)

Wing Deflection at alpha = 3.0 deg., Re = 5M

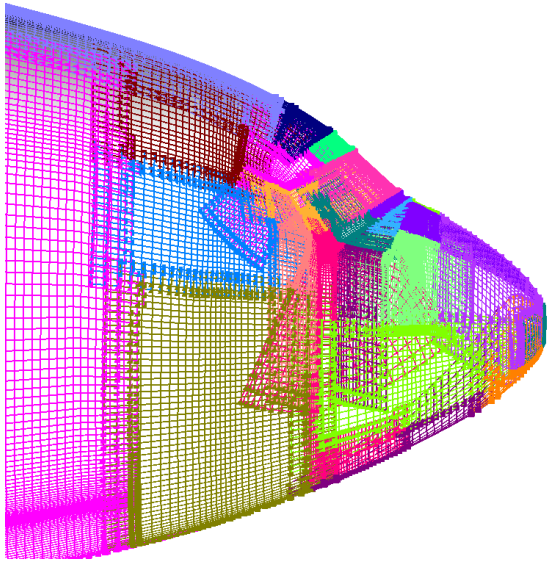


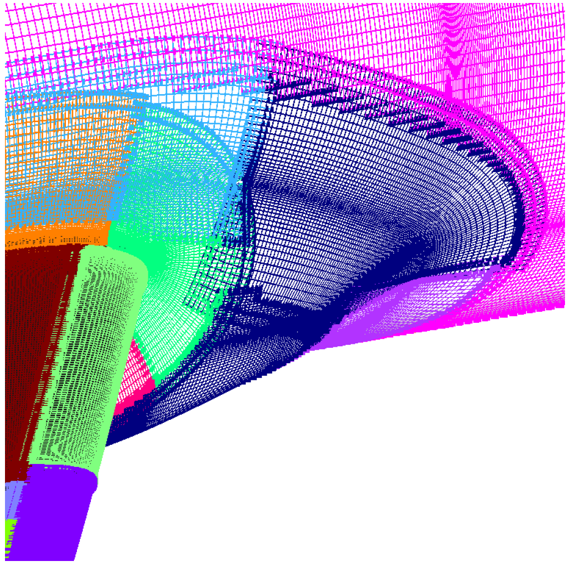


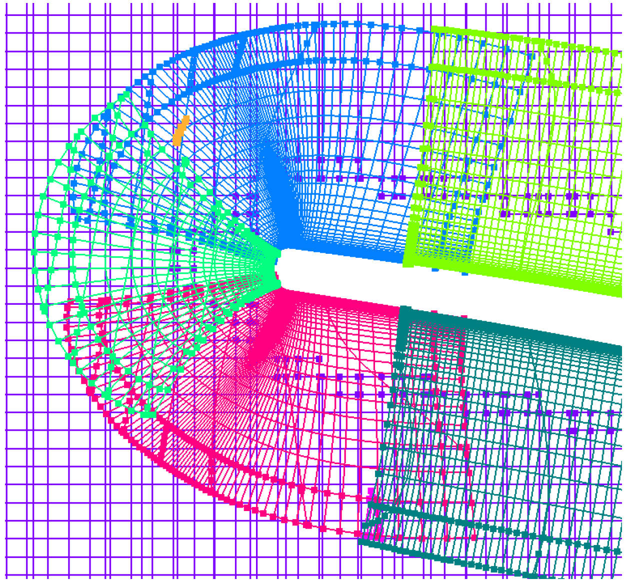




Case	# Surface grid pts	# Near-body volume grid pts
Coarse	0.23 M	13.6 M
Fine	0.64 M	66.1 M

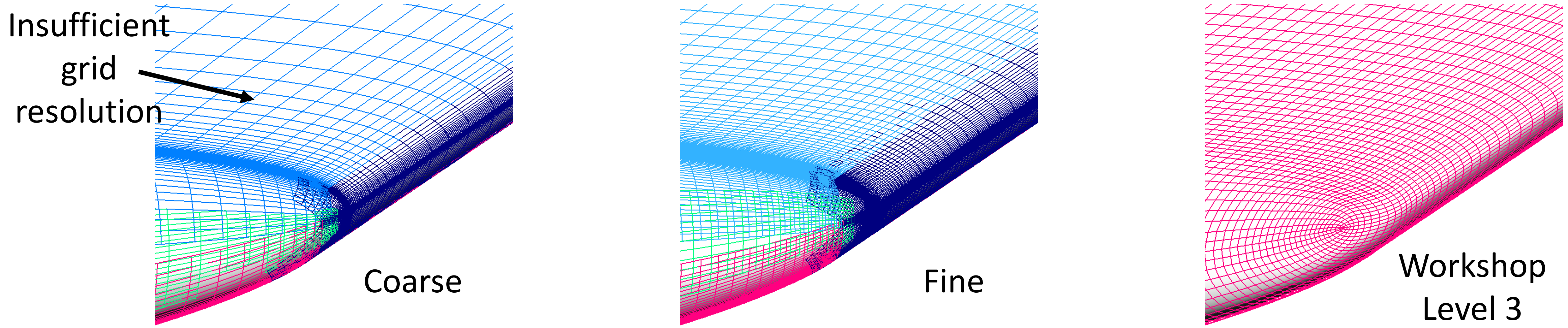




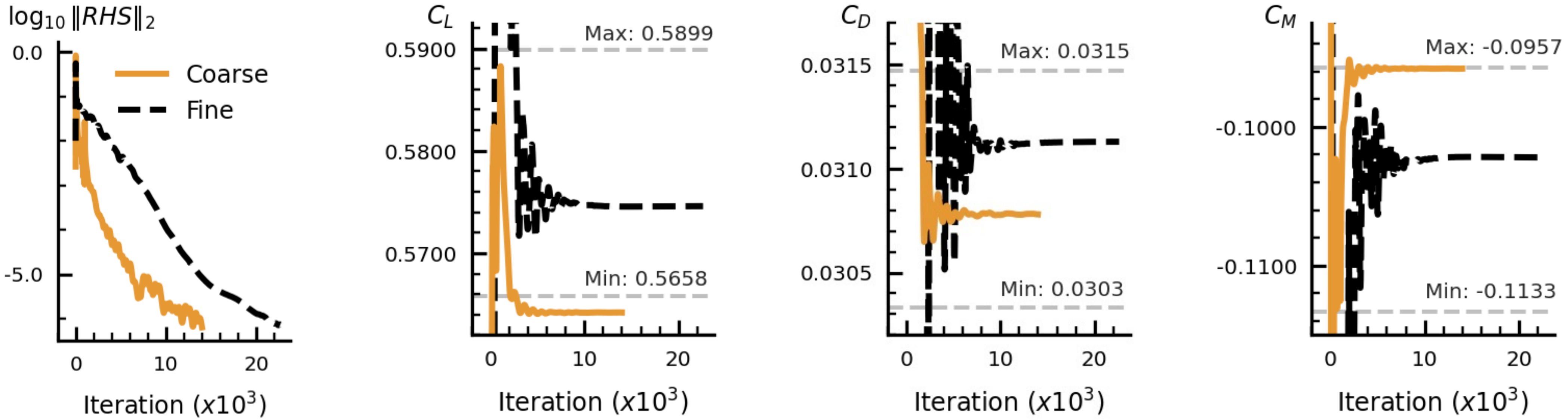


7TH AIAA DRAG PREDICTION WORKSHOP (DPW7)

Residuals & Aerodynamic Loads Convergence



- Workshop min/max from 8 different solvers/datasets



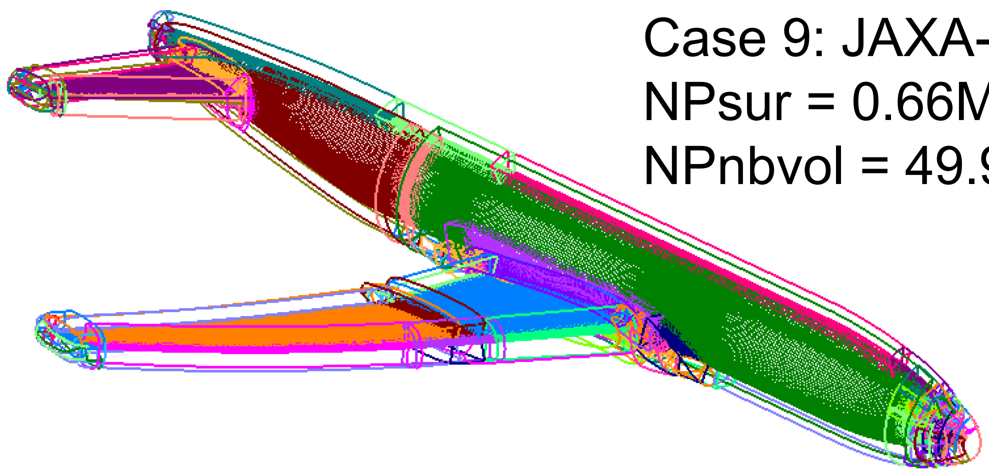
Ames Research Center

DPW8 GRID SYSTEMS STATUS

July 29, 2024

#	Case	Level
1	DPW7-WB-2.50	3
2	DPW7-WB-2.75	3
3	DPW7-WB.3.00	1,2,3,4,5,6
4	DPW7-WB-3.25	3
5	DPW7-WB-3.50	3
6	DPW7-WB-3.75	3
7	DPW7-WB-4.00	3
8	DPW7-WB-4.25	3
9	JAXA-WBT-4.84	3
10	JAXA-WBT-5.89	3
11	JIG-WB	1,2,3,4,5,6
12	JIG-WBT	1,2,3,4,5,6
13	JIG-WBPN	1,2,3,4,5,6

Level	maxa	maxe	maxsr	npmin	Ds_wall	NPsur	NPnbvol
Tiny (1)	5.0	15.0	1.25	9	5.423e-4	-	-
Coarse (2)	4.5	10.0	1.20	13	3.615e-4	0.22M	13.0M
Medium (3)	4.0	6.667	1.15	17	2.410e-4	0.41M	31.1M
Fine (4)	3.5	4.444	1.10	21	1.607e-4	-	-
Extra-Fine (5)	3.0	3.0	1.05	25	1.071e-4	-	-
Ultra-Fine (6)	2.5	2.0	1.025	29	0.714e-4	-	-



Case 9: JAXA-WBT-4.84
NPsur = 0.66M
NPnbvol = 49.9M