DPW-8 & AePW-4
Kickoff Meeting

Vision and Plan: A Community Discussion

January 8, 2024

AIAA SciTech Forum

Agenda

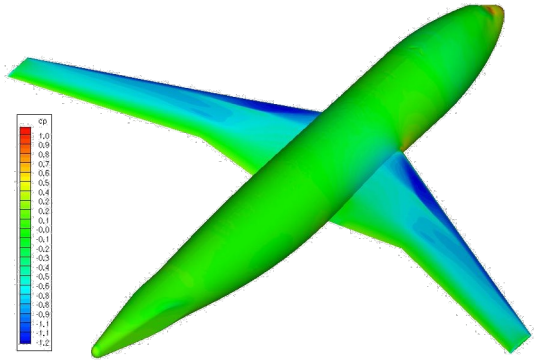
- **Welcome and Introductions**
- **DPW**
  - History
  - Motivation
- **AePW**
  - History
  - Motivation
- **Joint Workshop**
  - Proposal
  - Goals and Objectives
  - Collaborative Working Groups
- **Independent Kickoff Meetings**
  - AePW stays here
  - DPW moves to Bayhill 23

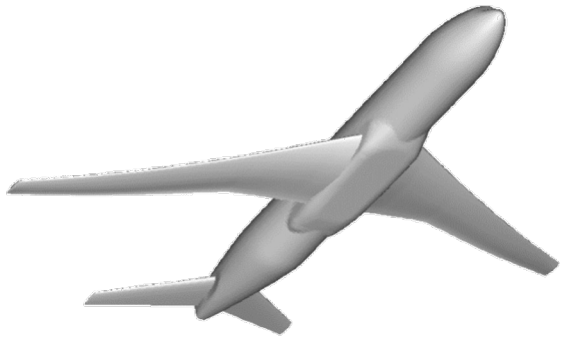
Hybrid Organizing Committee

- Pawel Chwalowski (AePW), NASA Langley
- Brent Pomeroy (DPW), NASA Langley
- Ben Rider (DPW), Boeing Commercial Airplanes
- Bret Stanford (AePW), NASA Langley

DPW History

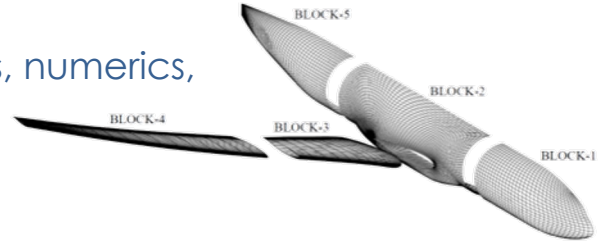
- **DPW-1: 2001 (Anaheim)**
  - Configurations: DLR F4 wing/body (AGARD-AR-303)
  - Goals: Absolute drag





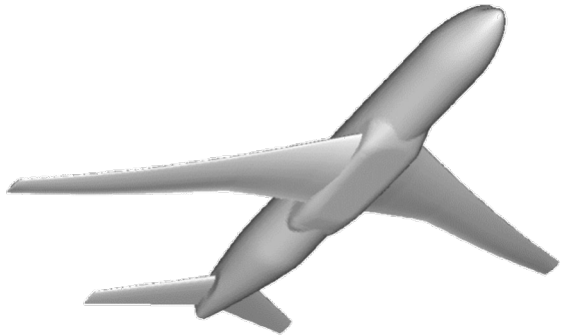
- **DPW-2: 2003 (Orlando)**
  - Configurations: DLR F6 wing/body/pylon/nacelle
  - Goals: Absolute drag & incremental drag (WB/WBPN)
- **DPW-3: 2006 (San Francisco)**
  - Configurations: DLR F6 wing/body/pylon/nacelle with FX2B fairing, DPW-W1/W2 (Wing Alone)
  - Goals: Absolute drag & incremental drag (F6/F6+FX2B, DPW-W1/W2)

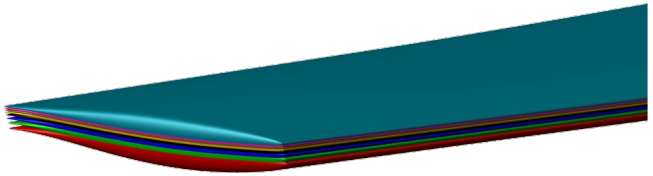
- **DPW-4: 2009 (San Antonio)**
  - Configurations: NASA CRM wing/body/horizontal tail (https://aiaa-dpw.larc.nasa.gov/Workshop4/AIAA-2008-6919-Vassberg.pdf)
  - Goals: Absolute drag & incremental drag (Tail On/Off), Tail trimming/downwash, Rey# Variations *(Blind predictions)*
- **DPW-5: 2012 (New Orleans)**
  - Configurations: NASA CRM wing/body with *unified baseline grid* (https://aiaa-dpw.larc.nasa.gov/Workshop5/AIAA.2011-3508.pdf)
  - Goals: Committee provided "Common" grid system to isolate grid effects from solver methods, numerics, implementation



DPW History

- **DPW-6: 2016 (Washington, D.C.)**
  - Configurations: NASA CRM wing/body/*[pylon/nacelle]*
  - Goals: Absolute drag & incremental drag (WB/WBPN), Static aeroelastic effects, coupled aeroelastic effects, grid adaption
- **DPW-7: 2022 (Chicago)**
  - Configurations: NASA CRM wing/body
  - Goals: Predict the effect of transonic shock-induced separation on the variation of CL and CMy with increasing AOA
- **DPW-8: 2025 (Las Vegas)**
  - Configurations: NASA CRM wing/body/*[pylon/nacelle]//[strut/tunnel]*
  - Goals: Build on past DPWs to improve confidence in aircraft performance prediction by focusing on remaining challenges with focused working groups





- **For more detail on previous DPWs: Tinoco, NASA CR Summary Report (CR-2019-220284)**
  - https://ntrs.nasa.gov/api/citations/20190027400/downloads/20190027400.pdf

DPW-8: Motivation & Background

- **Continue expanding the envelope**
- **Accurate aerodynamic performance prediction provides *significant value* throughout aircraft product life-cycle; design, certification, in-service support**
- **Drag prediction for a known geometry in steady (mostly attached) flow is generally achievable, but questions remain:**
  - Confidence in the geometry?
    - Jig shape is defined but deformed loaded shape is required for accurate predictions
  - Confidence in the evolution from steady to unsteady flow?
    - When does unsteadiness begin and steady assumptions are no longer valid?
  - Source of the remaining scatter?
    - Function of grid type, solver scheme, turbulence model
  - Excessive Aft Loading?
    - Primarily at low Reynolds numbers
  - Unknown uncertainty from comparing free-air CFD to wind tunnel test data
    - Some existing global corrections to upflow/forces/moments, tare & interference not quantified
    - No corrections for spanwise variations to sectional pressures

DPW-8 Goals

- **Build on past DPWs to improve confidence in aircraft performance prediction**
- **Mature the foundations required for accurate prediction**
  - To accurately predict drag, we need confidence in numerical models
  - Building upon good models, we need accurate definition of geometry under load
  - Unsteady analysis requires confidence in unsteady schemes
- **Determination of accuracy requires comparison to "truth"**
  - Experimental data are one form of "truth" but can have significant differences that must be understood to make practical comparisons to CFD
- **Leverage comprehensive experimental data sets for high-quality comparisons**
- **Increase student participation**

AePW-4 Kickoff Meeting

Aeroelastic Prediction Workshop

January 8th, 2024

AIAA SciTech Forum

Agenda

- AePW goals and motivation
- Organizing Committee
- AePW history
- AePW-3 working groups
- Transition to AePW-4

AePW Goals and Motivation

- An open and impartial forum to assess and evaluate the current state-of-the-art and state-of-the-practice in computational aeroelastic modeling
  - How effective are current solvers at predicting aeroelastic physics critical to aircraft analysis and design?
  - How can we understand the reasons for why our solvers may fail?
  - What computational and experimental areas of research need further development?
  - Can we establish best-practices for using aeroelastic solvers?
  - Can we establish uncertainty bounds for computational results?
  - Can we specify requirements on future validation experiments?

Organizing Committee

- Eric Blades, ATA Engineering
- Carlos Cesnik, University of Michigan
- Pawel Chwalowski, NASA LaRC
- Adam Jirasek, USAFA
- Jeff Ouellette, NASA LaRC
- Rafael Palacios, Imperial College London
- Daniella Raveh, Technion
- Markus Ritter, DLR
- Walt Silva, NASA LaRC
- Bret Stanford, NASA LaRC

AePW History

- AePW-1 (Honolulu, 2012)
  - https://c3.ndc.nasa.gov/dashlink/static/media/other/AEPW.htm
  - Focus on transonic unsteady aerodynamics of rigid wings, forced oscillations (no flutter)
  - Rectangular Supercritical Wing (RSW), Benchmark Supercritical Wing (BSCW), HIRENASD
- AePW-2 (San Diego, 2016)
  - https://nescacademy.nasa.gov/workshops/AePW2/public/
  - BSCW flutter: an easy case (Mach 0.74, 0 deg. AoA), and a really hard blind case (Mach 0.85, 5 deg. AoA)
- AePW-3 (National Harbor, 2023)
  - https://nescacademy.nasa.gov/workshops/AePW3/public/
  - Split into four distinct working groups

AePW-3 Working Groups

1. High Angle Working Group (HAWG)
   - Led by Pawel Chwalowksi (NASA)
   - Continuation of AePW-2: focus on BSCW transonic flutter and buffet

2. Large Deflection Working Group (LDWG)
   - Led by Markus Ritter (DLR)
   - Focus on large structural deflections of a subsonic high aspect ratio wing (Pazy wing, Technion)

3. Flight Test Working Group (FTWG)
   - Led by Jeff Ouellette (NASA)
   - Focus on body freedom flutter mechanisms of the X-56A

4. High Speed Working Group (HSWG)
   - Led by Eric Blades (ATA)
   - Focus on supersonic and hypersonic FSI: RC19 test case (AFRL), and the HyMax test case (UNSW)

Transition to AePW-4…

- We will have two joint working groups with DPW-8:
  1. Static Aeroelastic Deformation Group
  2. Unsteady Aerodynamic and Buffet Group

- What working groups do we want entirely under the AePW umbrella?
  - Which of the four AePW-3 WGs has enough momentum to continue on for another cycle (need workshop participation and leadership)?
  - Is there interest in starting new working groups, and/or looking at new configurations?
  - Are there efforts that are of interest to the community, but cannot be completed in time for the AePW-4 workshop (summer 2025)?

- If there are no AePW-only WGs for AePW-4, that's OK…

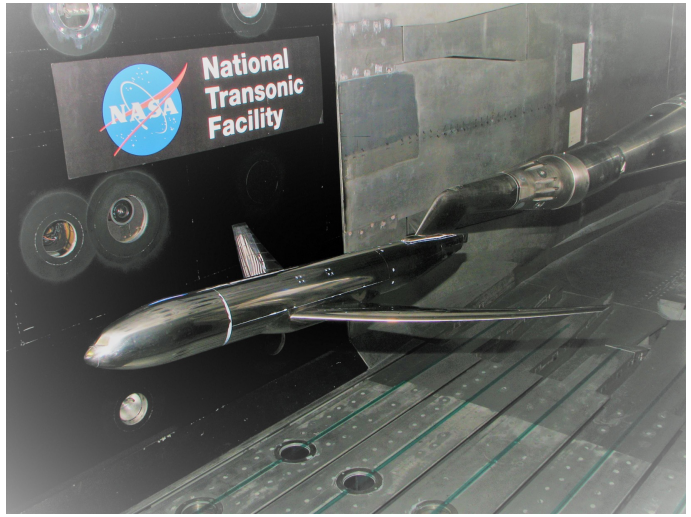
Workshop Proposal

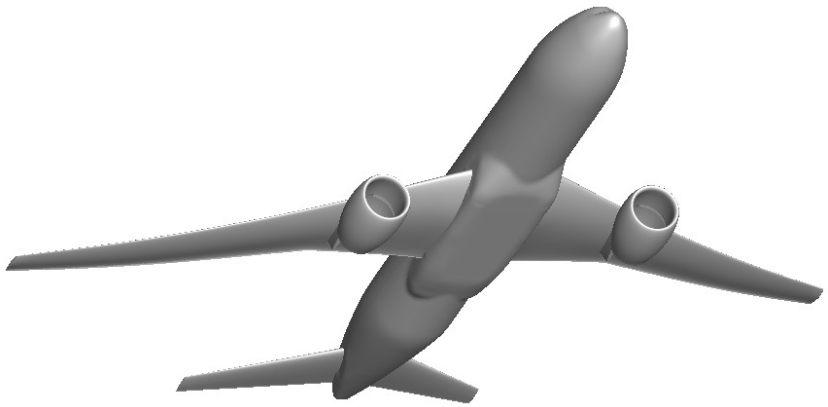
DPW-8 and AePW-4 Proposal

- **Next generation of computational goals is highly multidisciplinary**
  - Experts exist in both fields have lessons learned largely isolated to a field
  - Maximum collaboration made with symbiotic partnership between communities
- **Enable technical advances to cutting edge in industry**
  - DPW can grow with increased fidelity aeroelastic methods
  - AePW can grow with increased geometric complexity of aerodynamic models
- **Planned coordination between DPW-8 and AePW-4**
  - Multiple working groups
  - Will contain discipline-specific independent working groups and co-hosted groups
  - Structure: first day is independent working groups, second is co-hosted
- **Goals**
  - Benchmark methods performance between multiple codes and schemes
  - Perhaps align with possible future TDT test (difficult to commit to this task)
  - Establish workshop collaboration best practices to support new partnerships

DPW-8 and AePW-4 Configurations

- **NASA/Boeing Common Research Model**
  - Well studied and tested
  - Provides good comparison to other workshops
  - Rich legacy of NASA and Onera experimental data recently supplemented JAXA data
  - Finite element model available for NASA model, being developed for JAXA models
- **Components**
  - Different working groups require various geometries
  - Will include: wing/body, wing/body/tail, and wing/body/tail/nacelle/pylon





Two Joint Working Groups

Static Aeroelastic Deformation

1. Collaborative effort with both communities
2. Compute fluid/structure interactions in linear regime

Ben Rider, Stefan Keye, Garrett Mchugh

Unsteady Aerodynamics and Buffet

1. Collaborative effort with both communities
2. Compute unsteady flowfield (fixed geometry)
3. Compute fluid/structure interactions in linear regime and past pitchup

Brent Pomeroy, Andrea Sansica, Daniella Raveh

Open Discussion

AePW stays here

DPW moves to Bayhill 23

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Brent Pomeroy (brent.w.pomeroy@nasa.gov)

Ben Rider (ben.j.rider2@boeing.com)

Bret Stanford (bret.k.stanford@nasa.gov)

Please sign the attendance form!

Backup

NTF & ETW Experimental Data

- **2.7% scale full span NASA CRM tested in several wind tunnels**
  - National Transonic Facility
  - Ames 11-Ft Wind Tunnel
  - European Transonic Windtunnel
- **Model details**
  - wing/body (WB), wing/body/nacelle/pylon (WBNP), wing/body/horiz tail = 0° (WBT0)

Data Set	Mach	Re, million	Alpha	model deformation	F&M	Static Taps	Kulites	Strain Gauge	FEM	Release Status
NTF 197	0.7 to 0.87	5, 19.8, 30	-3° to +12° @low Re_c -3° to +6° @ high Re_c	X	X	X	X	X	X	on website
Ames 216	0.7 to 0.87	5	-3° to +12°	X	X	X	X	X		on website
NTF 215	0.7 to 0.87	5, 19.8, 30	-3° to +12° @low Re_c -3° to +6° @ high Re_c	X	X	X				subset on website
NTF 229	0.7 to 0.87	5, 19.8, 30	-3° to +12° @low Re_c -3° to +6° @ high Re_c	X	X	X				will be on website
ETW	0.25 to 0.87	5, 19.8, 30	-3° to +12° @low Re_c -3° to +6° @ high Re_c	X	X	X				link to data on website

JAXA Experimental 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	Static, loaded deformation	F&M	Static Taps	Kulites	Oil Flow	Wake PIV	TSP	PSP	uPSP	Strain Gauge	FEM	Release Status
A.1	Steady	2.3	-2 to 6 every ~1.2 deg	X	X	X		X	X					In Work	Public
A.2	Steady	2.3	-2 to 7	X	X	X				X	X			In Work	Requested
B.1	Unsteady	1.5	4.84, 5.89	X	X		X							In Work	Public
B.2	Unsteady	2.3	-2 to 7		X		X					X	X	In Work	Requested

Current Grid Desires (1/2)

- **Basic list will be finalized after SciTech 2024**
- **General topology needs**
  - Unstructured all tets
  - Unstructured, mixed element (prisms in BL and tets in farfield)
  - Structured overset
  - Other feedback?
- **Grid regime needs**
  - A few different Reynolds numbers
  - Minimal geometry deflections
- **Best practices for different schemes?**
  - RANS/DDES/LES?
  - May or may not need WMLES - how hard is this to do?

Current Grid Desires (2/2)

- **Most work is on a medium grid, only one grid family needed (possibly)**
- **Verification**
  - OAT15A transonic airfoil
  - Grid density family (three or four)
- **Jig CRM (undeformed shape)**
  - Wing/body → grid density family (three or four, including one very coarse)
  - Wing/body/nacelle/pylon-geometry does exist and is on the NASA CRM website → grid density family (three or four), ~30m-300m
- **Experimentally-measured deformations**
  - Wing/body relative to JAXA data, possibly a grid family (if it's a reasonable request)
  - Wing/body grid at ETW deflections
- **Wind tunnel test environment**
  - Less mature, needs not yet fully identified

DPW-8 Community Discussion

January 8, 2024

AIAA SciTech Forum

DPW-8 Organizing Committee

Ben Rider, Co-Chair (Boeing Commercial Airplanes)

Brent Pomeroy, Co-Chair (NASA)

John Vassberg, Chair Emeritus (JetZero)

Hadar Ben-Gida (Israeli Air Force)

Olaf Brodersen (DLR)

Stefan Keye (DLR)

Kelly Laflin (Textron Aviation)

Mitsuhiro Murayama (JAXA)

Raj Nangia (Royal Aeronautical Society)

Ilias Petropoulos (ONERA)

Melissa Rivers (NASA)

Andrea Sansica (JAXA)

Chris Toomer (University of the West of England)

Ed Tinoco (Retired from Boeing Commercial Airplanes)

Four DPW Working Groups and Focus

Steady, Fixed Geometry

1. Identify sources of scatter from DPW-7 results
2. "Traditional" DPW focus

Ed Tinoco, Raj Nangia, Olaf Brodersen

Static Aeroelastic Deformation

1. Collaborative effort with AePW
2. Compute fluid/structure interactions in linear regime

Ben Rider, Stefan Keye, Garrett Mchugh

Unsteady Aerodynamics and Buffet

1. Collaborative effort with AePW
2. Unsteady CFD (fixed geometry) calculations
3. Compute fluid/structure interactions in linear regime and past pitchup

Brent Pomeroy, Andrea Sansica, Daniella Raveh

Wind Tunnel Test Environment

1. Quantify effect of wind tunnel geometry
2. Determine impact of various mounting systems and wall interference

Melissa Rivers, Ben Rider, TBD

DPW-8 Schedule Proposal

- January, 2024 — Geometry defined for grid generation
- February, 2024 — Participant signup
- April, 2024 — First pass of grids available for analysis
- June, 2024 — Begin monthly Working Group meetings
- July, 2024 — Full set of grids established
- June 1, 2025 — Data submission deadline
- July 19-20, 2025 — Workshop (Las Vegas, NV)
- July, 2025 — Special Session #1, if needed (Las Vegas, NV)
- January, 2026 — Special Session #2 (Orlando, FL)
- Unknown — Potential special session in prep for or after uPSP test???

Pre-Workshop Tagups

- Monthly or bi-weekly meetings
- Identify strengths and weaknesses of various solvers/processes
- Seek to increase confidence in data before the workshop
- Active collaboration and participation is key to success
- Implemented across numerous other workshops

DPW-8: Technical Working Groups

- **Steady Fixed Geometry Group**
  - Goal: Identify sources of scatter in "standard" steady rigid CFD analysis (i.e. RANS)
  - Verification Case(s): 2D OAT15A airfoil
  - Test Case 1: CRM Wing/Body Geometry
    - Alpha sweep at cruise Mach (focus on Alpha > 3.0 where majority of scatter has been identified)

- **Wind Tunnel Geometry Group**
  - Goal: Improve comparisons of wind tunnel to free air CFD for Forces & Moments, pressure distribution
  - Verification Case(s): 2D OAT15A airfoil
  - Test Case 1: CRM Wing/Body Geometry with NTF/Ames Upper Swept Strut
    - Alpha sweep at M=0.85 with and without model mounting system
  - Test Case 2: CRM Wing/Body/Horizontal Geometry with NTF/Ames Upper Swept Strut
  - Test Case 3: CRM Wing/Body Geometry with wind tunnel walls (NTF)

Proposals are notional … to be defined in 2024Q1

DPW-8: Technical Working Groups

- **Static Aeroelastic Deformation Group (jointly with AePW)**
  - Goal: Accurate coupled Aero/Structural analysis (steady flow)
  - Verification Case(s): 2D OAT15A airfoil
  - Test Case 1a: CRM Wing/Body Geometry at a single Q, Rey, Mach, Alpha
  - Test Case 1b: CRM Wing/Body Geometry sweep(s) of Alpha or Mach centered on Case 1a condition
  - Test Case 2: CRM Wing/Body/Nacelle/Pylon Geometry at a single Q, Rey, Mach, Alpha

- **Unsteady Aerodynamic/Buffet Group (jointly with AePW)**
  - Goal: Unsteady aerodynamic analysis allowing identification of the initialization of unsteadiness and characterization of chordwise vs. spanwise unsteadiness
  - Verification Case(s): 2D OAT15A airfoil
  - Test Case 1: CRM Wing/Body/Tail Geometry unsteady CFD with static wing, pre- and post-stall (required)
  - Test Case 2: CRM Wing/Body/Tail Geometry unsteady CFD/FSI dynamic wing, pre- and post-stall (optional)
  - Test Case 3: CRM Wing/Body/Tail Geometry to inform future Ames Test (blind)

Proposals are notional … to be defined in 2024Q1

Open Discussion

Email Workshop and Working Group Interest to Ben & Brent

ben.j.rider2@boeing.com
brent.w.pomeroy@nasa.gov

Questions for the Community

- **What grid type(s) will you need?**
- **First set of mesh family**
  - What Rey
  - Which config
  - What needs to deform?
- **Which geometries**
  - One WBNP jig
  - One WB jig
  - One WB pre-deformed geometry
  - Note: “jig” means 1G as-designed (on CRM website) geometry, which is wind-off for both the NASA and JAXA models
- **Which cases need families?**