DPW-VI Status

John Vassberg
Chairman, DPW-OC

August 28, 2015

DPW Nomenclature

- AE — Aero-Elastic
- AoA — Angle-of-Attack / Alpha
- CFD — Computational Fluid Dynamics
- CL,CD,CM — Coefficients of Lift, Drag, Pitching-Moment
- CRM — NASA Common Research Model
- DPW OC — Drag Prediction Workshop Organizing Committee
- FEM — Finite-Element Model
- M-DOF — Million Degrees-of-Freedom
- N — Grid Size in Number DOFs
- PD — Public Domain
- SOA — State of the Art
- SOP — State of the Practice
- TMR — Transition Modeling Resource Website
- WBNPT — Wing/Body/Nacelle/Pylon/Tail (Any Combination)
- WT — Wind Tunnel

DPW Series – Brief History

- **DPW Charter Formalized** **Jan 2000**
  - State of the Art/Practice CFD Drag Prediction
- **DPW-I, Anaheim, CA** **Jun 2001**
  - DLR-F4 WB, Fixed CL & Drag Polar Studies
  - Scatter > 100 Counts → SOP Worse Than Expected
- **DPW-II, Orlando, FL** **Jun 2003**
  - DLR-F6 WB & WBNP, Fixed-CL Grid Convergence
  - Scatter > 50 Counts, Drag Deltas, Juncture Flow Issues
- **DPW-III, San Francisco, CA** **Jun 2006**
  - DLR-F6 WB & WBF, DPW-W1/W2 Wing-Only Fixed AoA
- **DPW-IV, San Antonio, TX** **Jun 2009**
  - CRM WBT, Trim-Drag Study, Blind CFD Predictions
- **DPW-V, New Orleans, LA** **Jun 2012**
  - CRM WB, Common Grid Study, TMR Verification Case
- **DPW-VI, Washington, DC** **Jun 2016**
  - CRM WB & WBNP, Aero-Elastic Deflection Study

DPW-VI: Organizing Committee

- Olaf Brodersen, DLR
- Ed Feltrop, Cessna
- Martin Gariepy, École Polytechnique de Montréal
- David Hue, ONERA
- Stefan Keye, DLR
- Kelly Laflin, Cessna
- Mori Mani, Boeing
- Dimitri Mavriplis, UWy
- Joe Morrison, NASA
- Mitsuhiro Murayama, JAXA
- Ben Rider, Boeing
- Chris Roy, VaTech
- Ed Tinoco, Retired
- John Vassberg, Boeing
- Rich Wahls, NASA

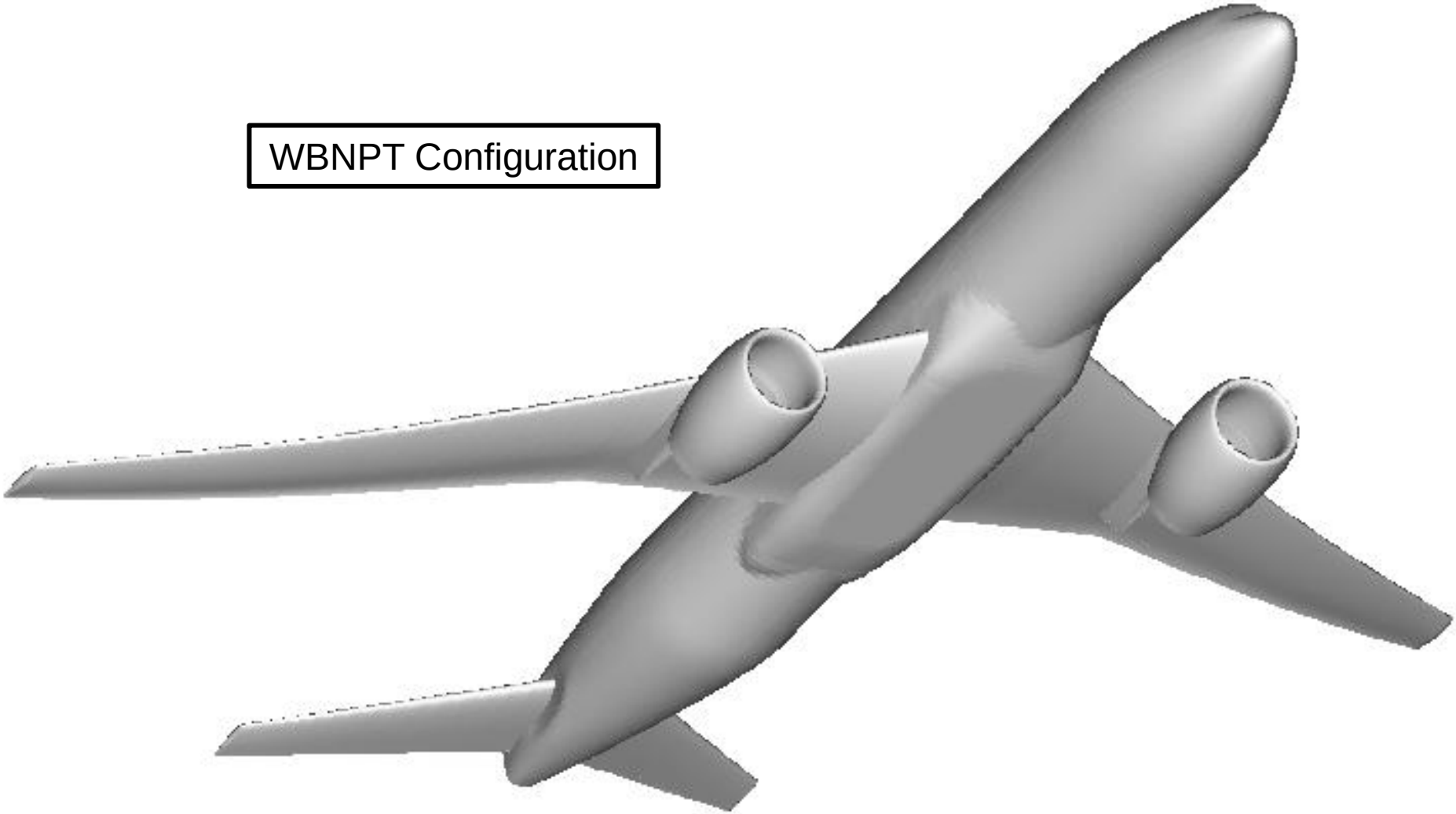
15 Members
5 New Members
10 Institutions
5 Countries
3 Continents

DPW-VI: (Working) Schedule of Events

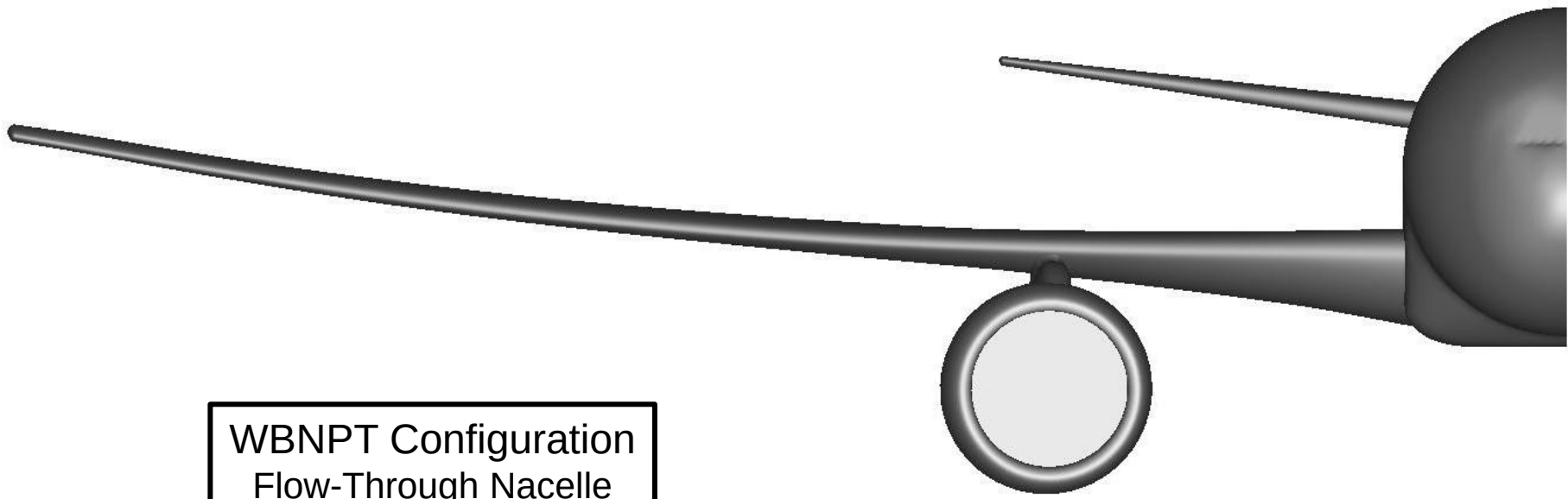
• Rough Draft Test Cases	15 Jan 2015 √
• Finalize Aero-Elastic Deformations	31 Jan 2015 √
• Finalize IGES Geometry Definitions	31 Apr 2015 √
• Finalize Test Cases	15 May 2015 √
• Finalize DPW-VI Flyer	01 Jun 2015 √
• Release IGES Files to Public Domain	21 Jun 2015
• Release Standard Grids to PD	31 Jul 2015
• Notice of Intent to Participate	01 Dec 2015
• Acceptance Notification	31 Jan 2016
• Data Submittal	01 May 2016
• Workshop, WDC	11-12 Jun 2016

- Registration- Handled by AIAA

NASA Common Research Model (CRM)



NASA Common Research Model (CRM)



WBNPT Configuration
Flow-Through Nacelle
Horizontal Tail @ iH=0°
Undeflected Wing

DPW-VI: Requested Test Cases

- **Case 1: Verification Study**
  - 2D NACA0012 Airfoil - Turbulence Modeling Resource (TMR)
  - M=0.15, Re=6 million, AoA=10 deg, Farfield BC @ 2400 Chords
  - Solution Converged on Adapted or Fixed Sequence Grid Family

- **Case 2: CRM Nacelle-Pylon Drag Increment**
  - Mach=0.85, Re=5 million, CL=0.5 +/-0.0001, ae2.75deg geometry
  - Grid Convergence Study on Baseline WB & WBNP Grid Families
  - [CD, CM, AoA, Mass-Flux] .vs. $N^{-(2/3)}$ [or other metric]

- **Case 3: CRM WB Static Aero-Elastic Effect**
  - Mach=0.85, Re=5 million
  - AoA Sweep with ETW Deflections
  - AoA=[2.50, 2.75, 3.00, 3.25, 3.50, 3.75, 4.00] degrees
  - Medium Baseline Grids: [7 Solutions on 7 Grids]

DPW-VI: Optional Test Cases

- **Case 4: CRM WB Grid Adaptation**
  - Mach=0.85, Re=5 million, CL=0.5 +/-0.0001, ae2.75deg geometry
  - Start Adaption Process from Tiny (or Coarse) Baseline Mesh
  - Participants Document Adaptation Process
- **Case 5: CRM WB Coupled Aero-Structural Simulation**
  - Mach=0.85, Re=5 million, CL=0.5 +/-0.0001
  - Medium Baseline Grid
  - FEM Supplied by NASA via CRM Website (Melissa Rivers)
    - Modal Shapes and Frequencies available
- **Cases 1-5: Participant Generated Grids**
  - Provide Documentation of Their Grid Systems
  - Submit Their Grids to the Public Domain
  - Also Run the Cases on the Baseline Grids

DPW-VI: Baseline Grid Families

Name	WB	WBNP	Δy_1
Tiny (T)	~20	25-30	0.001478”
Coarse (C)	~30	40-45	0.001285”
Medium (M)	~45	60-70	0.001118”
Fine (F)	~70	85-100	0.000972”
Extra Fine (X)	~100	130-150	0.000845”
Ultra Fine (U)	~150	190-225	0.000735”

Nominal Size of Grid System in M-DOF

At Least 4 Sequential Mesh Levels & Bias Towards Finest

DPW-VI: Gridding Guidelines (1/2)

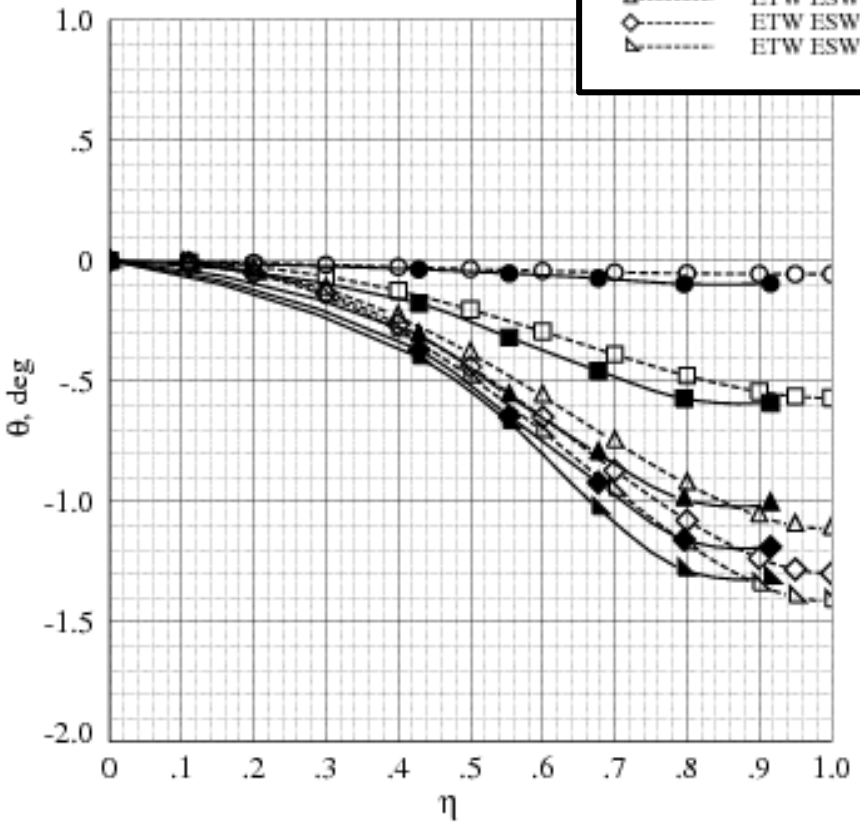
- **Tiny Grid**
  - Viscous Wall Spacing: $Y^+ \sim 1.0 \rightarrow \Delta y_1 = 0.001478$”
  - At Least 2 Constantly-Spaced Cells at Viscous Walls, $\Delta y_2 = \Delta y_1$
  - Growth Rates < 1.2X Normal to Viscous Walls
  - Wing Spanwise Spacing < 0.1%*Semispan at Root, Engine & Tip
  - WNP Chordwise Spacing < 0.1%*C (local chord) at LE & TE
  - Wing & Nacelle TE Base >> 8 Cells [Pylon TE is Sharp]
  - Spacing Near Fuselage Nose & Afterbody < 1%*Cref
- **Grow Next-Finer Grid in Family by ~ 1.5X in Size**
  - Scale Dimensions in All Three Computational Directions by ~ 1.15X
  - Grid Spacings Reduce by 0.87=(1/1.15) per Mesh Level
    - 0.1% in Tiny → [T,C,M,F,X,U] = [0.100, 0.087, 0.076, 0.066, 0.057, 0.050]%

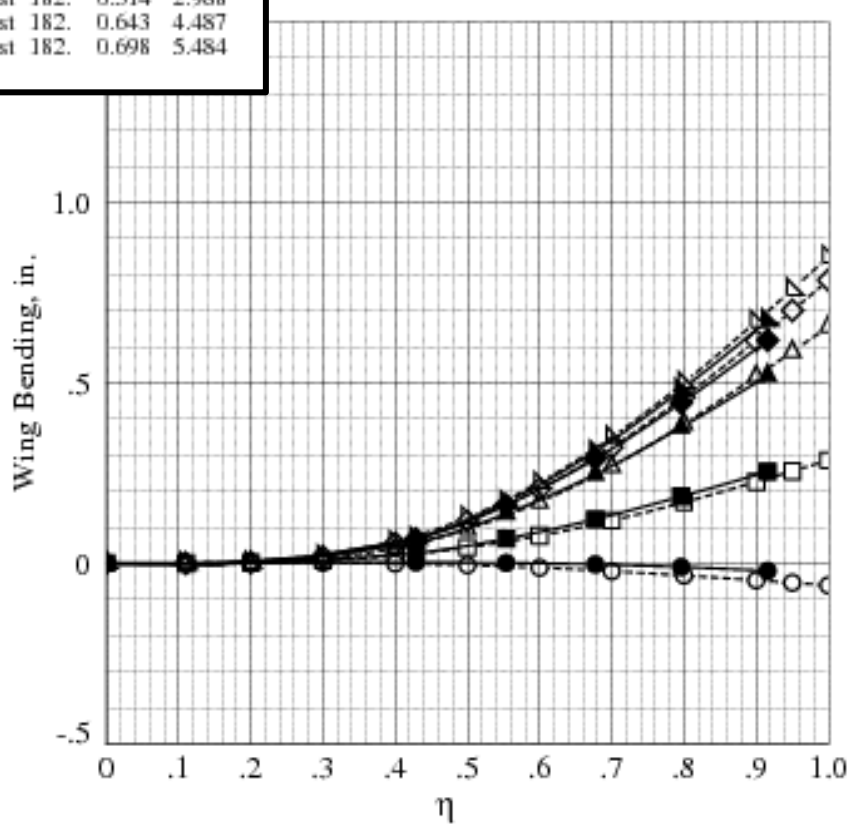
DPW-VI: Gridding Guidelines (2/2)

- **WB Grids Consistent with Those within WBNP Systems**
  - Helps Minimize Deltas due to Grid → Better NP-Deltas
- **WBNP Grid Sizes ~ 1.3X-1.5X WB Grid Sizes**
  - Pick Factor, Then Keep Constant Throughout Grid Family
- **Farfield Boundary > 100*Semispans**
  - Note: This is Farther than before, which was 100*Crefs
- **Miscellaneous Notes:**
  - Try to be Multigrid Friendly on Structured Meshes
  - Store Grid Coordinates in 64-bit Precision
  - If Storing Grids in Plot3D Format, Keep Zones < 33M Nodes
  - Itemize Surface Elements by Components [W, B, N, P, Sym, Far]
  - Itemize Element Count for Unstructured Meshes
    - Volume: Tetrahedra, Prisms, Pyramids, Hexahedra
    - Surface: Triangles, Quads

CRM Wing Deflections in NTF, ETW

Facility	Run	C_L	α
NTF Test 197	92.	-0.021	-0.8167
NTF Test 197	92.	0.240	1.179
NTF Test 197	92.	0.494	2.975
NTF Test 197	92.	0.647	4.705
NTF Test 197	92.	0.704	5.665
ETW ESWIRP Test	182.	-0.034	-0.9497
ETW ESWIRP Test	182.	0.226	0.9998
ETW ESWIRP Test	182.	0.514	2.988
ETW ESWIRP Test	182.	0.643	4.487
ETW ESWIRP Test	182.	0.698	5.484





DPW-6 Utilizes ETW Deflections

CRM WBNPT Geometry Definitions (IGES)

Size	Date	Time	Name
25853452	Jul 16	10:40	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae2.50deg_cf.igs
25824424	Jul 16	10:58	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae2.75deg_cf.igs
26077968	Jul 16	11:10	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae3.00deg_cf.igs
25973664	Jul 16	11:24	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae3.25deg_cf.igs
26253366	Jul 16	11:57	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae3.50deg_cf.igs
25789738	Jul 16	12:07	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae3.75deg_cf.igs
25773912	Jul 16	12:19	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_ae4.00deg_cf.igs
17608516	Jul 16	10:42	DPW6_CRM_wbnpt_ih+0_v08_2015-07-01_cf.igs

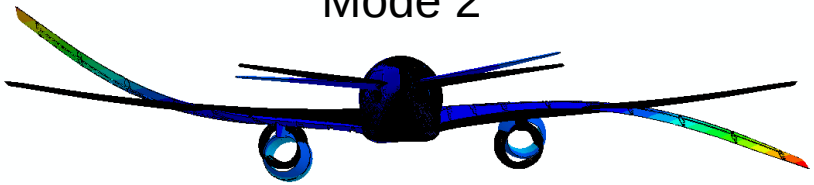
Notes:

* DPW6 Common Research Model Wing/Body/Nacelle/Pylon/Tail Configuration
* Horizontal Tail rigged at iH = 0 degrees
* Geometry Version v08 created on 16 July, 2015
* Aero-Elastic Deflections of ETW at M=0.85, Re=5 million, Alpha=*As_In_Name*
* Deflected IGES/STEP Files Courtesy of Mark Gammon (CADfix Developer)
* Deflected Discrete Surface Triangulations Courtesy of Stefan Keye (DLR)
* Although Included in IGES/STEP Files, DPW6 Test Cases Do Not Utilize Tail

FEM Modal Shapes & Frequencies

Mode 1

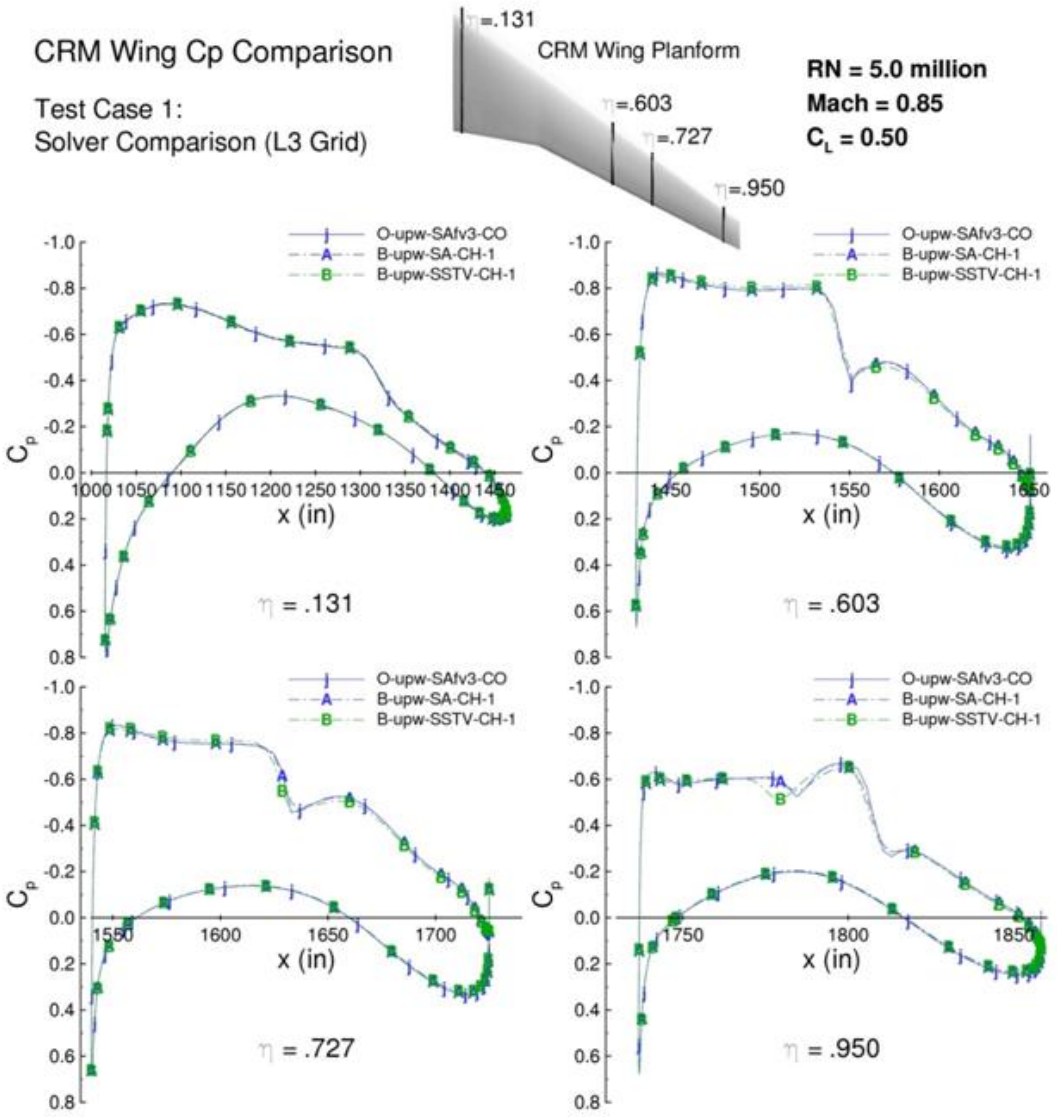
Mode 2



Mode 3

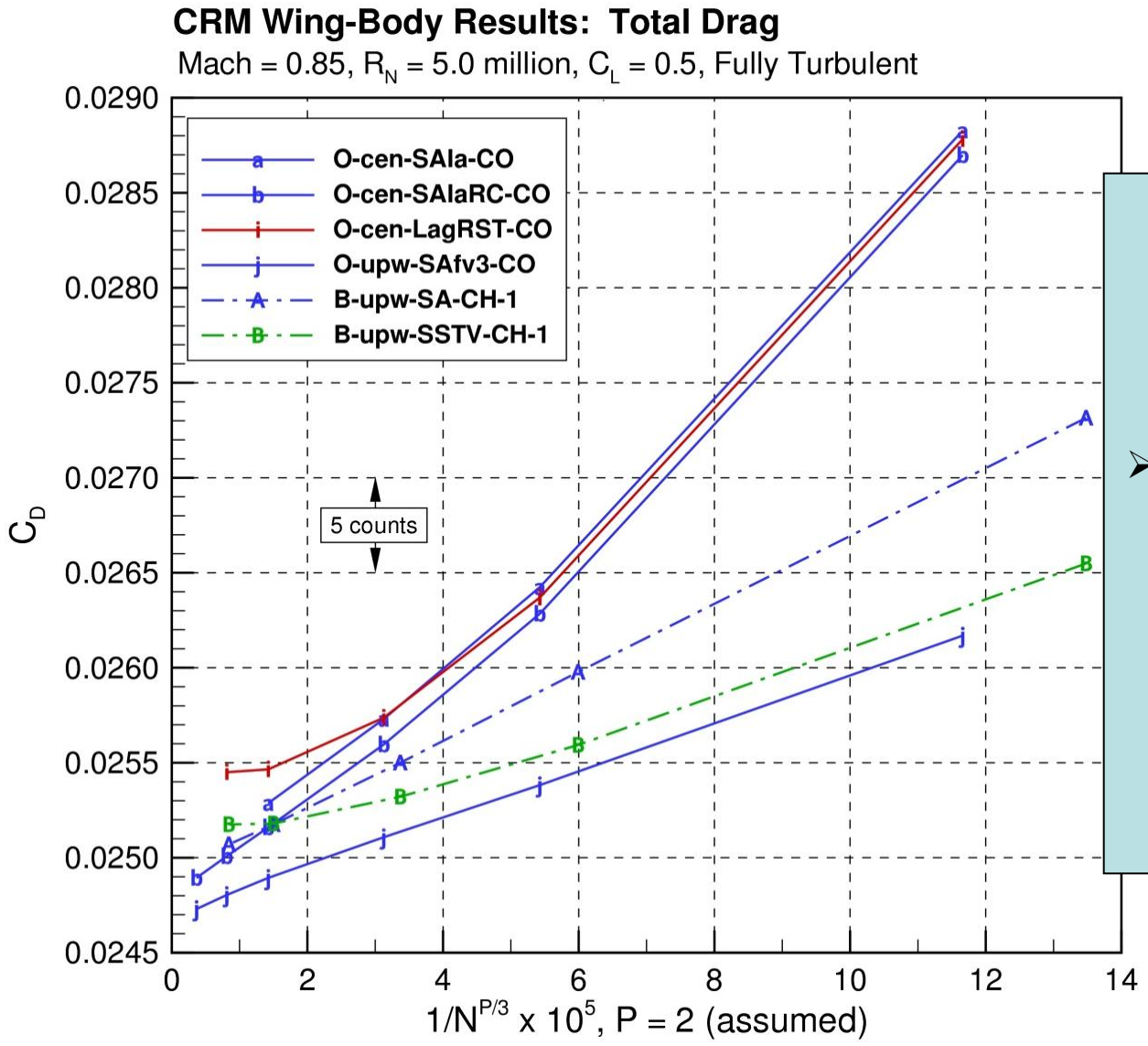
Mode	Frequency (Hz)
1	39.398
2	40.958
3	58.531
4	63.638
5	68.536
6	71.789
7	82.503
8	85.588
9	107.43
10	113.79
11	122.95
12	127.18
13	151.16
14	162.29
15	166.98
16	177.64
17	202.51
18	204.49
19	206.54
20	267.08

Sample CP Distributions from DPW-V



Sclafani AIAA.2013-0048

Sample Grid Convergence from DPW-V

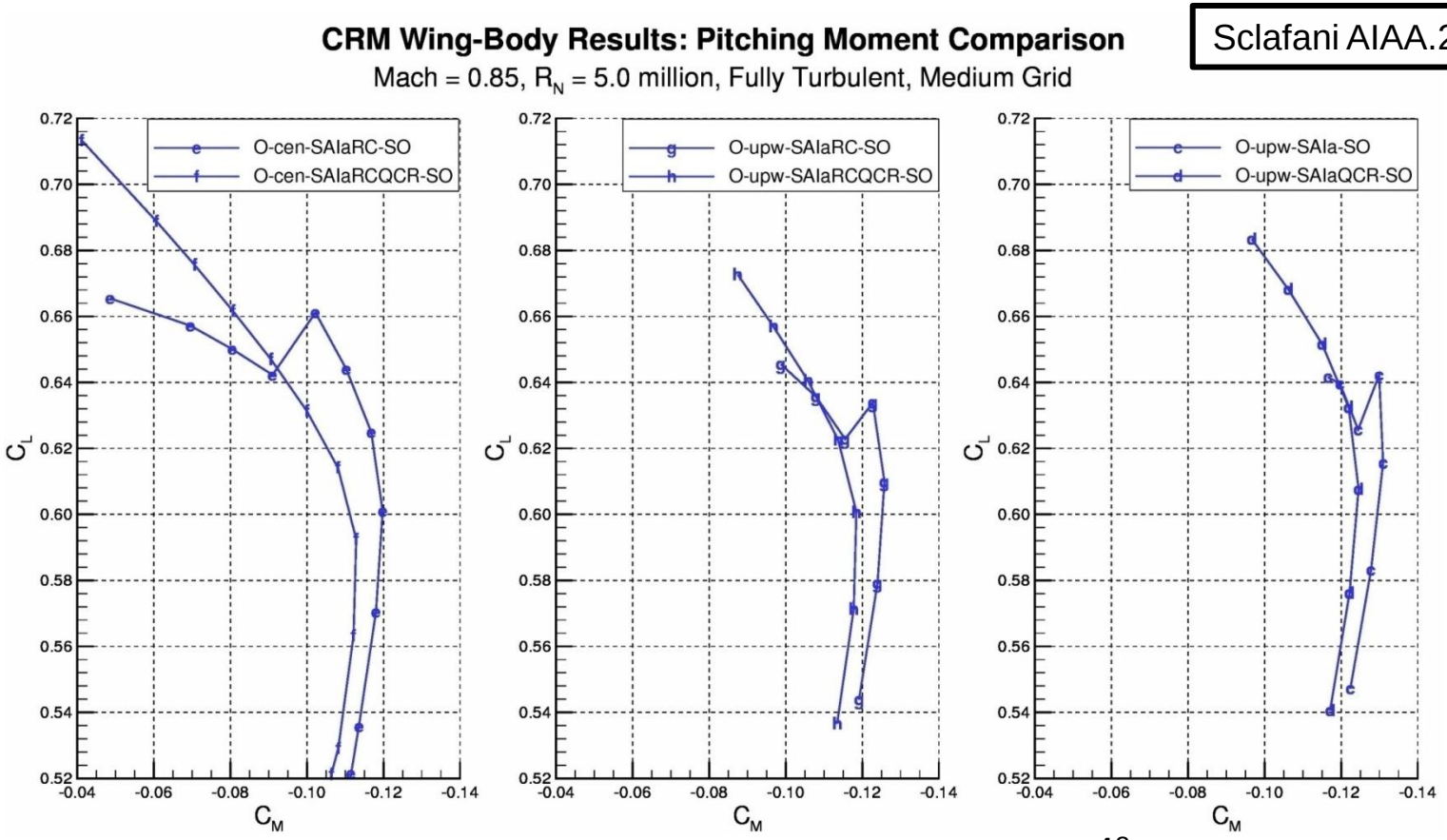


- All SA results trend in a consistent manner with grid refinement and have a relatively small spread in C_D at the finest grid level (~5 counts)
- Lag RST exhibits nonlinear trend for finer grid levels
- BCFD SST-V data also breaks from a linear trend for the two most dense grid levels
- Upwind data follows a lower slope trend line compared to central

Sclafani AIAA.2013-0048

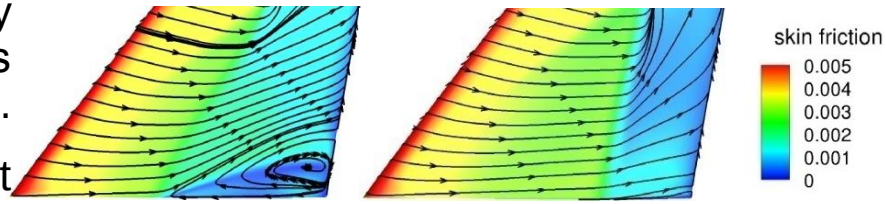
QCR Effect on SOB Flow at Buffet On-Set

Sclafani AIAA.2013-0048



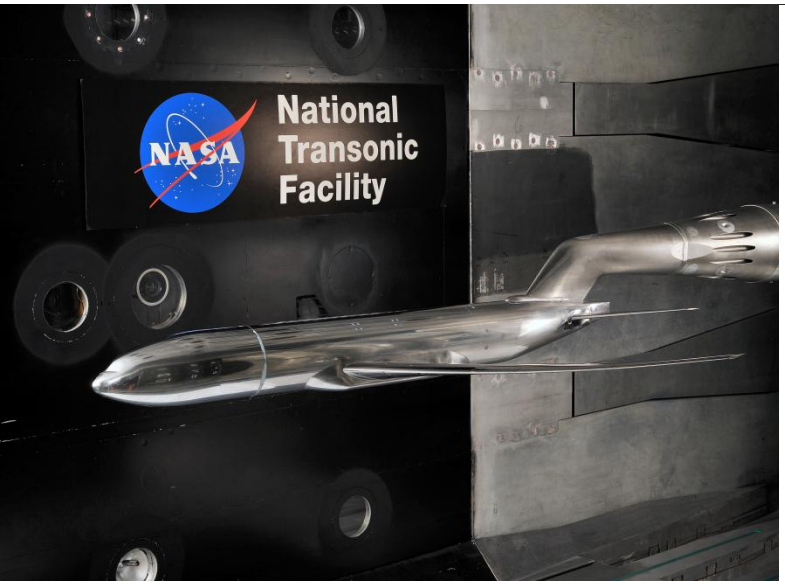
- When QCR is used, side-of-body separation does not form at the CRM's wing-body juncture.
- The nose-up shift in pitching moment at lower C_L's is caused by a more triangular spanload with QCR turned on.

$\alpha = 4^o$

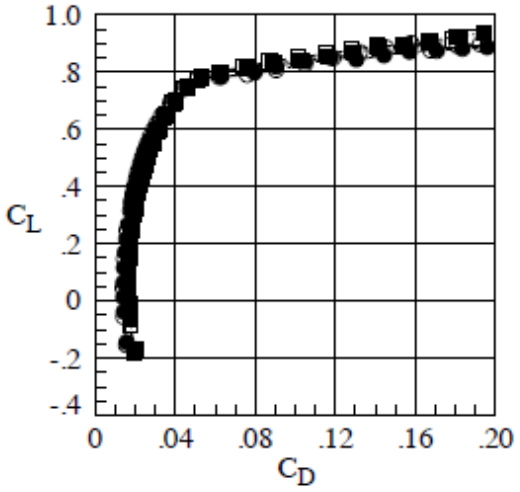


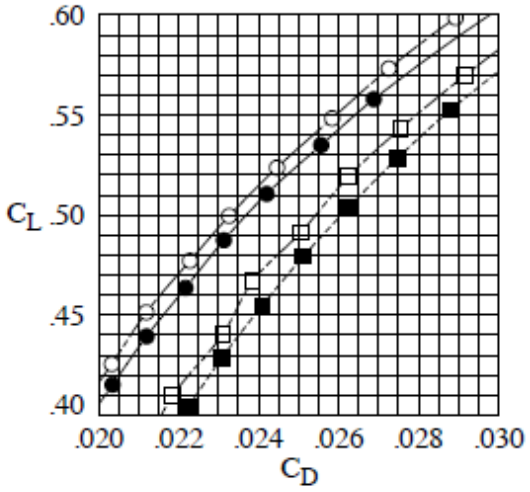
QCR Off QCR On

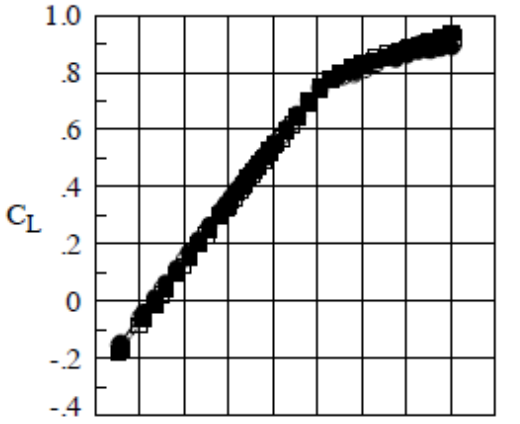
Sample NTF & Ames 11’ WT Data

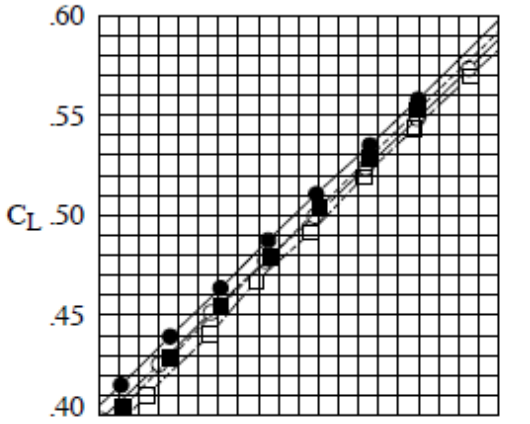


Facility	Run	Config	M_∞	$Re_c, 10^6$
LaRC NTF	39.	WB	0.70	5.00
LaRC NTF	69.	WBPN	0.70	4.99
Ames 11-ft	118.	WB	0.70	5.00
Ames 11-ft	107.	WBPN	0.70	5.00









Courtesy Melissa Rivers

6th AIAA CFD Drag Prediction Workshop

Sponsored by the
Applied Aerodynamics TC

2-Day Workshop Preceding

AIAA AVIATION 2016
Washington, D.C. USA

June 11-12, 2016

For more information and results from past workshops, visit the DPW website at:

http://aaac.larc.nasa.gov/tsab/cfdlarc/aiaa-dpw/

or send email to:

aiaadpw@gmail.com

CFD Drag Prediction Workshop VI

*In addition to **CFD practitioners**, **flow-solver developers** and **grid-generation experts**...*

The DPW Organizing Committee invites members of the

Solution-Adaptation** & **Aero-Elastic

communities to participate in DPW VI.

Focus

The focus of this workshop will be the NASA Common Research Model (CRM) with wind-tunnel measured wing twist; both wing-body and wing-body-pylon-nacelle configurations will be considered. CFD predictions of absolute and incremental force and moment values will be examined and compared. The workshop will include grid convergence and code verification studies. Additionally, an angle-of-attack sweep with static aero-elastic deformations will be considered. Grids will be made available for all required cases.

Optionally, participants are invited to perform solution-adaptation calculations and/or a coupled aero-structural simulation of the CRM wing-body configuration. A finite element model will be made available to participants to calculate twist/deflection due to aerodynamic load.

CFD Drag Prediction Workshop VI

Organizing Committee

John Vassberg, Ben Rider, Mori Mani
The Boeing Company

Olaf Brodersen, Stefan Keye
DLR

Martin Gariepy
École Polytechnique de Montréal

Mitsuhiro Murayama
JAXA

Joseph Morrison, Richard Wahls
NASA Langley Research Center

David Hue
ONERA

Edward Tinoco
Retired

Edward Feltrop, Kelly Laflin
Textron Aviation

Dimitri Mavriplis
University of Wyoming

Chris Roy
Virginia Tech

Dates

Check the DPW website for additional information and updates.

Release Geometry	Jun 1, 2015
Release Standard Grids	Aug 1, 2015
Notice of Intent to Participate	Dec 1, 2015
Abstract Deadline	Apr 1, 2016
Data Submittal Deadline	May 1, 2016

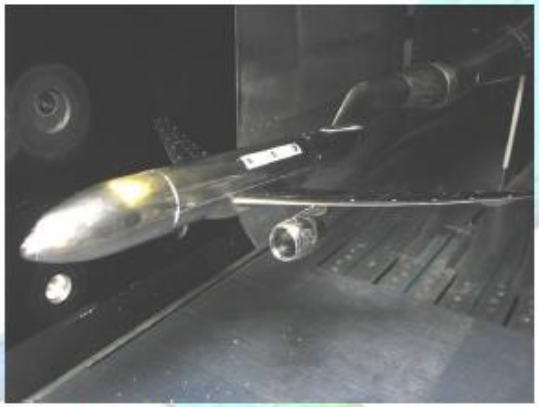
Workshop registration will be handled through normal AIAA procedures.

Workshop presentations will not be official AIAA papers; however, several participants will be invited to support a special session on drag prediction to be held during the AIAA SciTech Meeting, January 2017.

CFD Drag Prediction Workshop VI

Objectives

- To build on the success of past AIAA Drag Prediction Workshops.
- To assess the state-of-the-art computational methods as practical aerodynamic tools for aircraft force and moment prediction of industry relevant geometries.
- To provide an impartial forum for evaluating the effectiveness of existing computer codes and modeling techniques using Navier-Stokes solvers.
- To identify areas needing additional research and development.



NASA Common Research Model (CRM)

AIAA
American Institute of Aeronautics and Astronautics

CFD Drag Prediction Workshop VI

General Information

- This workshop is open to participants worldwide. Efforts will be made to ensure representation from all areas of industry, academia and government laboratories.
- Participation in the drag studies is not required to attend the workshop. Everyone is welcome!
- Open forums will be included in the workshop to discuss the solutions and modeling techniques.
- Results will be made available after the workshop in a report and on the DPW website.
- A nominal registration fee will be required for attendance.
- AIAA membership is not required

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS
APA
Applied Aerodynamics Technical Committee

CFD Drag Prediction Workshop VI

Test Cases

Check the DPW VI website for additional details and updates.

Required

Case 1: 2D Code Verification Study

Case 2: CRM Nacelle-Pylon Drag Increment / Grid Convergence Study (single condition on a family of grids)

Case 3: CRM Wing-Body Static Aero-Elastic Effect (7 solutions on 7 grids)

Optional

Case 4: CRM Wing-Body Solution Adaptation and/or a 2D Solution Adaptation Study

Case 5: CRM Wing-Body Coupled Aero-Structural Simulation (FEMA supplied)

Case 6: Participant Generated Grids

All participants are encouraged to build their own grids using 'best practice' techniques. IGES and STP models are available for grid construction. Grid size requirements can be found on the DPW VI website. All grids used for results presented at the workshop must be submitted to the DPW Organizing Committee to be made available to all interested parties. *Note: All results and grids will be published electronically on the DPW website:*

http://aaac.larc. nasa.gov/tsab/cfdlarc/aiaa-dpw/

Questions?

DPW-VI Workshop
11-12 June, 2016

Weekend Before AIAA
Applied Aerodynamics Conference

Washington, DC