Aeroelastic Prediction Workshop

Aeroelastic Prediction Workshop- Welcome & Overview

Presented by:

Jennifer Heeg

Aeroelasticity Branch, NASA Langley Research Center

On behalf of the AePW Organizing Committee

Organizing Committee Roster

Name	Affiliation
Bhatia, Kumar	Boeing Commercial Aircraft
Ballmann, Josef	Aachen University
Blades, Eric	ATA Engineering, Inc.
Boucke, Alexander	Aachen University
Chwalowski, Pawel	NASA
Dietz, Guido	European Transonic Windtunnel (ETW)
Dowell, Earl	Duke University
Florance, Jennifer	NASA
Hansen, Thorsten	ANSYS Germany GmbH
Heeg, Jennifer	NASA
Mani, Mori	Boeing Research & Technology
Mavriplis, Dimitri	University of Wyoming
Perry, Boyd	NASA
Ritter, Markus	Deutsches Zentrum für Luft- und Raumfahrt (DLR)
Schuster, David	NASA
Smith, Marilyn	Georgia Institute of Technology
Taylor, Paul	Gulfstream Aerospace
Whiting, Brent	Boeing Research & Technology
Wieseman, Carol	NASA

Acknowledgments

Workshop sponsorship and organization

AIAA Structural Dynamics Technical Committee

AIAA Structural Dynamics Conference Team

product managers

K.C Niedermeyr and

Elizabeth Carter

Event planner Cathy Chenevey

NASA Engineering & Safety Center

Funding of NASA participation,
geometry generation & workshop organization

NASA Subsonic Fixed Wing Program

HIRENASD Research Project

Aachen University

HIRENASD Project Funding

German Research Foundation (DFG)

Grid Generation

Ansys, ATA, Georgia Tech, Technion University, ISCFDC, NASA

Aeroelastic Computational Benchmarking

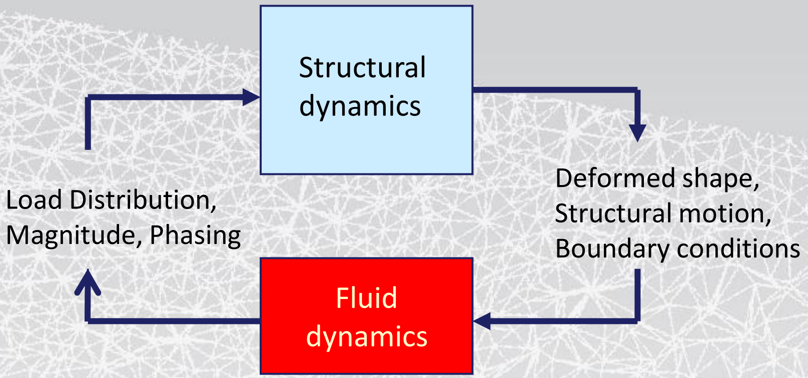
- **Technical Challenge: Assess state-of-the-art methods & tools for the prediction and assessment of aeroelastic phenomena**

- **Fundamental hindrances to this challenge**
  - No comprehensive aeroelastic benchmarking validation standard exists
  - No sustained, successful effort to coordinate validation efforts
- **Approach**
  - Perform comparative computational studies on selected test cases
  - Identify errors & uncertainties in computational aeroelastic methods
  - Identify gaps in existing aeroelastic databases
  - Provide roadmap of path forward

Building block approach to validation

Utilizing the classical considerations in aeroelasticity

- Fluid dynamics
- Structural dynamics
- Fluid/structure coupling



Validation Objective of 1st Workshop

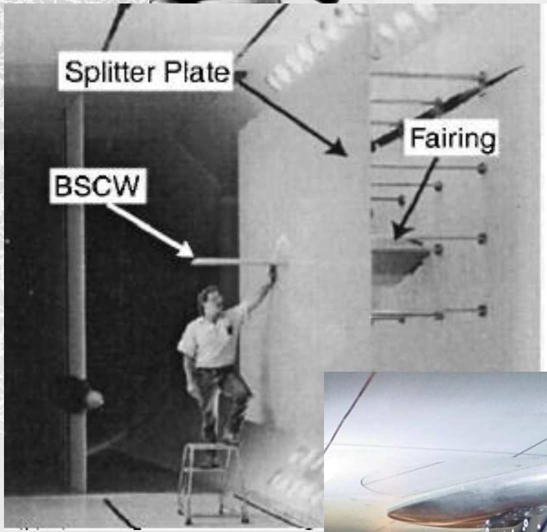
Unsteady aerodynamic pressures due to forced modal oscillations

Future Workshops

- Directed by results of this workshop
- Directed by big-picture assessment of needs & interests

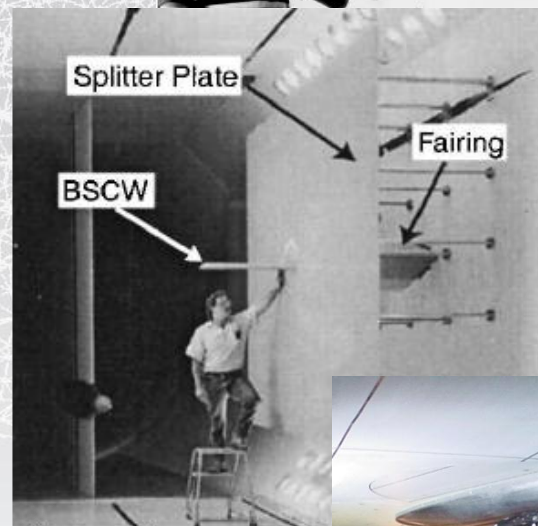
Configurations Selected

- Rectangular Supercritical Wing (RSW)
- Benchmark Supercritical Wing (BSCW)
- High Reynolds number Aero-Structural Dynamics Model (HIRENASD)



Configuration / Data Set Selection Rationale

- Start simple?
- Cases chosen to focus on the steady and unsteady aerodynamic solutions and their variation
- All configurations have
  - Transonic flow
  - Unsteady pressure data
  - Forced transition to turbulent flow
  - Steady data
  - Forced oscillation data



Configuration / Data Set Selection Compromises

- Configurations are not “aeroelasticky”
- Deflection data is sparse
- Expected flow phenomena does not encompass all possible applicable flows for aeroelastic configurations
- Results from workshop comparisons can not be directly translated to critical aeroelastic quantities
- Results of this workshop will only tell us how well we can predict the class of phenomena that we are looking at:
  - Forced transition
  - Shock-separated flow
  - Forced oscillations
  - Uncoupled and weakly coupled aerodynamics

Rectangular Supercritical Wing (RSW)

- Simple, rectangular wing
- Structure treated as rigid
- Static and forced oscillation pitching motion

Known deficiencies:

- Splitter plate deficiencies
  - Small size
  - Located in the tunnel wall boundary layer (6“ off of the wall)
- Tunnel wall slots open
- Potential bad data points, not identified as such in the literature

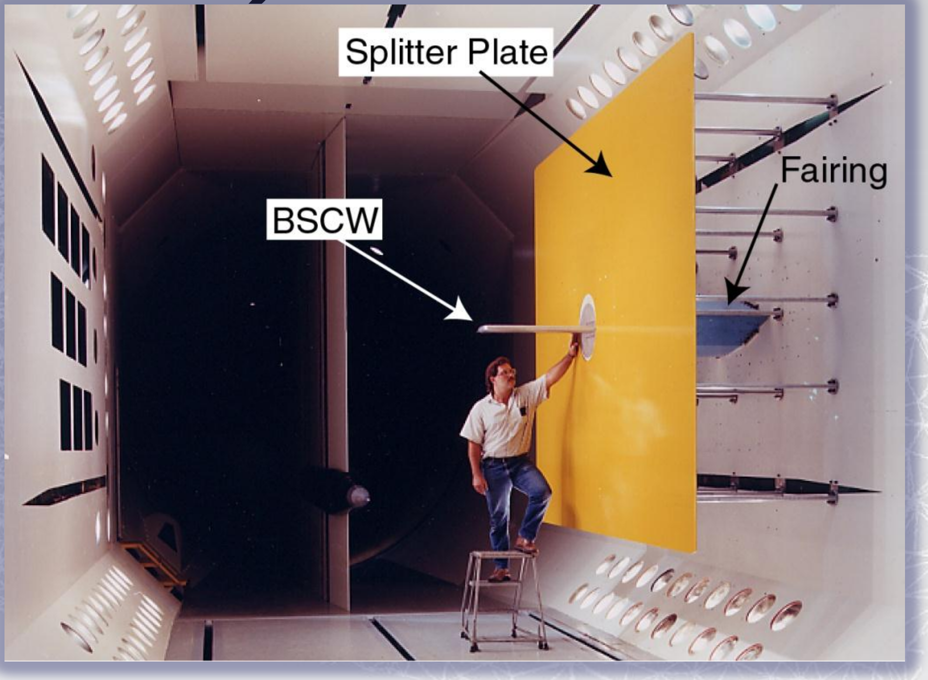
M=0.825, Re_c=4.0 million, test medium: R-12

a) Steady Cases
   i. $\alpha = 2°$
   ii. $\alpha = 4°$

b) Dynamic Cases:
   $\alpha = 2°, \theta = 1°$
   i. f = 10 Hz
   ii. f = 20 Hz

Benchmark Supercritical Wing (BSCW)

- Simple, rectangular wing
- Structure treated as rigid
- Data acquired under mixed attached/separated flow conditions



Known deficiencies:

- Limited number of pressure transducers in experimental data
- Limited number of discrete frequencies of oscillation
- Mach number is at edge of acceptable range for quality pressure data with splitter plate

M=0.85, Re_c=4.49 million, test medium: R-134a

a) Steady Case
   i. $\alpha = 5°$

b) Dynamic Cases
   i. $\alpha = 5°$, $\theta = 1°$, f = 1 Hz
   ii. $\alpha = 5°$, $\theta = 1°$, f = 10 Hz

HIRENASD

- 3-D aeroelastic wing with generic fuselage model
- Fixed transition
- Treated as aeroelastic here
  - Relatively weak aeroelastic coupling
- Forced oscillation at 2nd bending mode frequency
- Time history data available
- Data includes
  - Balance loads
  - Mean and fluctuating pressure data
  - Limited set of surface deformation

<u>Known deficiencies:</u>

- Limited deflection data
- Only excited at natural frequencies

Test medium: Nitrogen

Experiments at matching test conditions:

- Steady Cases
- Dynamic Cases: Oscillations near the natural frequencies

Comparison Data Matrix

CONFIGURATION	REQUIRED CALCULATIONS			
	GRID CONVERGENCE STUDIES	TIME CONVERGENCE STUDIES	STEADY CALCULATIONS	DYNAMIC CALCULATIONS
Steady-Rigid Cases (RSW, BSCW)	C_L, C_D, C_M vs. $N^{-2/3}$	n/a	• Mean C_p vs. x/c • Means of C_L, C_D, C_M	n/a
Steady-Aeroelastic Cases (HIRENASD)	C_L, C_D, C_M vs. $N^{-2/3}$	n/a	• Mean C_p vs. x/c • Means of C_L, C_D, C_M • Vertical displacement vs. chord • Twist angle vs. span	n/a
Forced Oscillation Cases (all configurations)	• Magnitude and Phase of CL, CD, CM vs. $N^{-2/3}$ at excitation frequency	•Magnitude and Phase of C_L, C_D, C_M vs. dt at excitation frequency	n/a	• Magnitude and Phase of C_p vs. x/c at span stations corresponding to transducer locations • Magnitude and Phase of C_L, C_D, C_M at excitation frequency • Time histories of C_p's at a selected span station for two upper- and two lower-surface transducer locations

Analysis Contributor Status

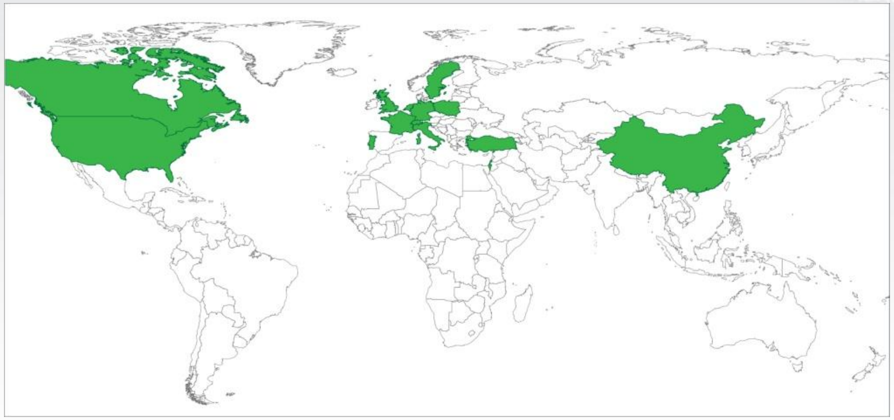
- 17 analysis teams providing data for workshop

Industry	University	Government
5	7	5

- 26 total analyses committed for workshop

RSW	BSCW	HIRENASD
6	6	14

- 10 nations represented



Updated April 17, 2012

	Summary of Rectangular Supercritical Wing Entries					
Analyst	A	B	C	D	E	F
CODE	NSMB	FUN3D	CFL3D	ANSYS CFX	NSU3D	PMBv1.5
TURBULENCE MODEL	SA	SA	SA	SST	SA	SAE
GRID TYPE	Str	Unstr	Str	Str	Unstr	Blstr

Str = Structured

Blstr = Block structured

Unstr = Unstructured

	Summary of Benchmark Supercritical Wing Entries					
Analyst	A	B	C	D	E	F
CODE	NSMB	FUN3D	CFL3D	NSU3D	ANSYS CFX	Overflow 2.2c
TURBULENCE MODEL	SA	SA	SA	SA	SST	SST-kω
GRID TYPE	Str	Unstr	Str	Unstr	Str	Str

Str = Structured

Unstr = Unstructured

Summary of HIRENASD Entries

Analyst	A	B	C	D	E
CODE	ENFLOW	NSMB	CFD++ & NASTRAN	EZNSS	Edge
TURBULENCE MODEL	kTNT	k-ω MSS	2 Eq. Realizable k-ε	SA	SA
GRID TYPE	Strmb	Str	Unstr	Str	Unstr

Analyst	G	H	I	J	K
CODE	elsA	NSU3D	ZEUS	FUN3D	ANSYS CFX
TURBULENCE MODEL	SA	SA	Unknown	SA	SST
GRID TYPE	Str	Unstr	Str	Unstr	Str

Str = Structured

Strmb = Structured multi-block

Unstr = Unstructured

AePW Agenda

Saturday, April 21

Time	Meeting Room 1	Meeting Room 2
0800-0830	Welcome & Workshop Overview – Jennifer Heeg	
0830-0900	Overview of Rectangular Supercritical Wing Test Case – Boyd Perry	RSW Analysts' Working Group Meeting Discussion Leader: Dave Schuster (NASA)
0900-0930	Experimental Data Reduction Methods – Jennifer Heeg	
0930-1000	Break	
1000-1230	RSW Analysis Presentations (6)+ Comparison Discussion	Session Chair: Alexander Boucke
1230-1330	Lunch	
1330-1400		BSCW Analysts' Working Group Meeting Discussion Leader: Pawel Chwalowski (NASA)
1400-1430	Overview of Benchmark Supercritical Wing Test Case – Rob Scott	
1430-1500	Break	
1500-1730	BSCW Analysis Presentations (6) + Comparison Discussion	Session Chair: Brent Whiting
1730-1830	Informal discussion groups, as desired	Working Group meeting reviews

AePW Agenda

Sunday, April 22

Time	Meeting Room 1		Meeting Room 2
0800-0830			HIRENASD Analysts' Working Group Meetings Discussion Leaders: Markus Ritter (DLR) and Dimitri Mavriplis (Univ. of Wyoming)
0830-0900	Overview of HIRENASD Test Case – Alexander Boucke		
0900-0930	Structural Dynamics Modeling for HIRENASD – Carol Wieseman		
0930-1000	Break		
1000-1230	HIRENASD Analysis Presentations (8)	Session Chair: Kumar Bhatia	
1230-1330	Lunch		
1330-1530	HIRENASD Analysis Presentations (5) + Comparison Discussion	Session Chair: Paul Taylor	
1530-1600	Break		
1600-1700	Meeting Summary & Discussion of Path Forward		
1700-1800	Informal discussion groups, as desired		Working Group meeting reviews
1900-2100			RTO AVT-203

AePW Draft Agenda
(draft date: Jan 3, 2012)

Analysts Working Groups:

Composition of each working group:
- Analysts of that configuration
-Volunteer discussion & meeting leader (one of analysts for that configuration)
-Volunteer technical recorder (one of analysts from other configurations?)

Working Group Meetings:
- Hold telecons for each working group prior to April
- Established & announced objectives of AePW working group meetings
- Analysts notified before-hand of time, place, objectives

Draft Objectives:
- Minimize repeated information: things in common can be shown once
- Give analysts fresh insights
- Spur discussion
- Coordination of future efforts & re-analyses

Draft Deliverables:
-5-10 minute summary presentation of common results, insights & issues raised
-Notes for working group meeting reviews

AePW Agenda

Working Group Meeting Reviews:

Anticipated Attendees:

- Organizing committee members
-Discussion & meeting leader for configurations discussed on that day
-Technical recorder for configurations discussed on that day
-Analysts of configurations discussed on that day, in accordance with their own interest
- Technical challengers

Objectives:

-Firm up & document
  - Issues raised
  - Lessons learned
  - Plan going forward

Technical Working Group Leaders

Role:	RSW	BSCW	HIRENASD
Discussion Leader	Dave Schuster	Pawel Chwalowski	Markus Ritter & Dimitri Mavriplis
Technical Issue Recorder	Reik Thormann	Thorsten Hansen	

Gridding Acknowledgements

	Organization	Configuration	Software	Description
Marilyn Smith	Georgia Tech	RSW	SolidMesh	Unstructured
Thorsten Hansen	Ansys Germany	RSW, BSCW	ICEM CFD	Structured hexahedral
Pawel Chwalowski	NASA	RSW, BSCW, HIRENASD	VGRID	Unstructured mixed and tetrahedral
Eric Blades	ATA Engineering	BSCW	SolidMesh	Unstructured, node-based, mixed
Markus Ritter	DLR	HIRENASD	Centaur	Unstructured mixed
Daniella Raveh	Technion	HIRENASD		Overset structured

HIRENASD Project Partners

Aachen University:

Department of Mechanics

Institute for Lightweight Structures

Institute for Geometry and Applied Mathematics

Shock Wave Laboratory

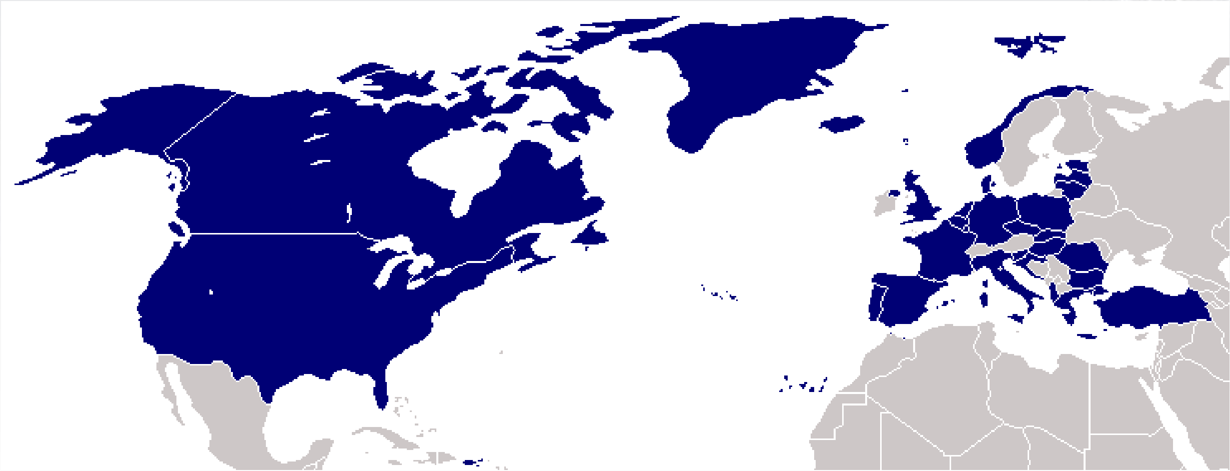
Thanks to ...

- German Research Foundation (***DFG***) for funding ***HIRENASD***
- ***Airbus Industry*** for supporting the balance for dynamic force measurement
- ***DLR*** for advice concerning data acquisition and providing AMIS II
- ***ETW*** for providing windtunnel adaptations, for e.g. dynamic force measurement, and continuous advice during preparation of model and measuring equipment

Collaborative Activity with NATO Task Group

Joint Exercise on Aeroelastic Prediction

- *Technical Objectives*
  - *Assess & document available experimental databases*
  - *Perform comparative computational studies on a limited number of selected test cases by working teams*
  - *Refine the definition of technical gaps & uncertainties in existing aeroelastic databases & computational methods*
  - *Define preliminary requirements for additional experimentation & analytical methods developments*
  - *Identify future collaborative activities*



Some questions to consider

- What differentiates the analyses from each other?
- … from the experimental data?
- What is well-captured?
- What is not?
- How can we look at this data/other data to address what is not well-captured?
- What are the implications wrt aeroelastic analysis?
- What is common among the testcases?
- How can we process/treat the data differently to better capture the characteristics? … capture additional characteristics?

Thank you for your attention
&
Welcome to the AIAA Aeroelastic Prediction Workshop

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Presentations Available…

- Convert to pdf
- Add to AePW website
  - Goal: Thursday April 26
- Analysts: if you object to the posting of your results, please let me know today