Aeroelastic Prediction Workshop:

Status Report
Presented to the
AIAA Structural Dynamics
Technical Committee

Presented
on behalf of the AePW
Organizing Committee
by
Jennifer Heeg, NASA
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April 5, 2011

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Objectives in making this presentation

- Inform TC of progress
- Address questions & concerns of SDTC,AIAA
- Ask for participation from TC members' companies, universities, agencies, …
- Distribute sufficient information to enable participation

Objectives of AePW

Assess state-of-the-art Computational Aeroelasticity(CAe) methods as practical tools for the prediction of static and dynamic aeroelastic phenomena and responses on relevant geometries

- 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
  - Additional existing data sets?
  - New experimental data sets?
  - Analytical methods developments?

Guiding Principles

- Provide an **impartial** international **forum** for evaluating the **effectiveness of CAe methods**
- Promote **balanced participation** across academia, government labs, and industry
- Use common **public-domain** subject geometries, simple enough to permit high-fidelity computations
- **Provide** baseline **grids** and baseline **structural models** to encourage participation and help reduce variability of CAe results
- **Openly discuss** and identify areas needing **additional research** and development
- Conduct rigorous statistical analyses of CAe results to **establish confidence levels in predictions**
- Schedule **open-forum sessions** to further engage interaction among all interested parties
- Maintain a **public-domain-accessible database** of geometries, grids, and results
- **Document** workshop findings; **disseminate** this information through publications and presentations

Building block approach to validation

- Utilizing the classical considerations in aeroelasticity
  - Fluid dynamics
  - Structural dynamics
  - Fluid/structure coupling

Validation Objective of 1st Workshop

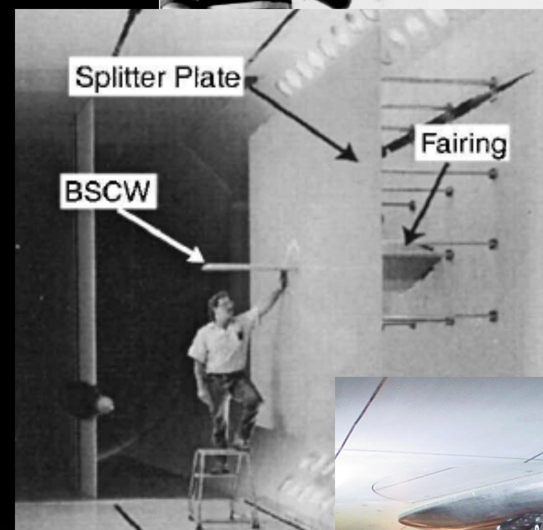
- Unsteady aerodynamic pressures due to forced modal oscillations

Future Workshops

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

Configurations Selected

- Rectangular Supercritical Wing
  - Simple, rectangular wing
  - Static and forced oscillation pitching motion
  - Attached fully turbulent flow, moderate shock strength
- Benchmark Supercritical Wing
  - Simple, rectangular wing
  - Data acquired under mixed attached/ separated flow conditions
- HiReNASD
  - 3-D aeroelastic wing with generic fuselage model
  - Steady and forced (structural resonance) oscillation testing
  - Data includes balance forces for integrated load comparisons, mean and fluctuating pressure data, and surface deformation data from optical and strain measurements during testing



Aeroelastic Prediction Workshop Schedule

- Identify organizing committee by Dec 1, 2010
- Data Release & Workshop Kickoff: IFASD, June 2011, Paris
- 9 months to perform computations
- Workshop: SDM, April 2012, Honolulu
- Perform revised computations; perform comparative analyses
- Prepare papers for formal conference presentations

Activity	FY10	FY11	FY12	FY13	FY14	FY15
Advocate						
Form organizing committee						
Workshop kick-off			Kickoff at IFASD			
Config, grids, etc. available on-line						
Perform analysis of selected config.						
Conduct 1st Aeroelastic Prediction Workshop						
Update / improve CFD results / code(s)						
Perform comparisons, Statistical analyses						
Present conference papers						

AIAA AePW Liason Information

- SDTC Liason: Brent Whiting participating in AePW Organizing Committee
- AePW Liason with AIAA:
  - Jennifer Florance (NASA) coordinating with Megan Scheidt, AIAA Technical Activities Division
  - "AIAA Organized Activities at Conferences Proposal" form submitted (Proposal #11397E5)
  - Specified attendance based on High Lift PW (60 / 120)
  - Targeting weekend prior to next SDM, April 21-22,2012

AePW Website Info

- https://c3.ndc.nasa.gov/dashlink/projects/47/

- **Content is viewable by the world**
- **Contributions limited to members**
- **Membership by application to OC members or commitment to the workshop**

Reference Information Attached

- Publications & Briefings to be given
- Subcommittee Summaries
  - Test cases chosen
  - Gridding guidelines
  - Comparison data to be provided from computations
  - Experimental comparison data status
- Short term time line
- Configurations & Selection Rationale
- Participant Information Resources
- Overlapping activities

Reference Information Slides

Publications/Briefings

- RTO RTG 203 Telecon (March 31) J.Heeg
- AIAA/SDTC briefing at SDM (April 5) J.Heeg
- AFDC briefing (April 28-29, Huntington Beach) K. Bhatia
- AHS Forum (May, Virginia Beach) M.Smith
- IFASD OC paper (June 28) J.Heeg
- IFASD AePW discussion panel (June 28)
  - J.Heeg, P. Chwalowski, J. Ballmann, A. Boucke, B.Perry, M. Ritter, M. Dalenbring, others?
- RTO meeting on Aeroelastic Benchmarking (July 1)

Configuration & Test Case Subcommittee Report: Test Case Selections

- Rectangular Supercritical Wing:
  - Steady Cases
    - M = 0.825, α = 2° (RTO Case 6E23, TDT pt. 626)
    - M = 0.825, α = 4° (RTO Case 6E24, TDT pt. 624)
  - Dynamic Cases
    - M = 0.825, α = 2°, θ = 1.0°, f = 10 Hz. (RTO Case 6E54, TDT pt. 632)
    - M = 0.825, α = 2°, θ = 1.0°, f = 20 Hz. (RTO Case 6E56, TDT pt. 634)
- Benchmark Supercritical Wing (Semi-Blind)
  - Steady Case
    - M = 0.85, α = 5°
  - Dynamic Cases
    - M = 0.85, α = 5°, θ = 1°, f = 1 Hz
    - M = 0.85, α = 5°, θ = 1°, f = 10 Hz
- HiReNASD
  - Steady (Static Aeroelastic) Cases
    - Mach 0.80, Re = 7.0 million, α = 1.5°, static aeroelastic, (exp. 132).
    - Mach 0.80, Re = 23.5 million, α = -1.34°, static aeroelastic, (exp. 250).
  - Dynamic Cases: forced oscillation at 2^{nd} Bending mode frequency
    - Mach 0.80, Re = 7.0 million, α = 1.5°, (exp. 159).
    - Mach 0.80, Re = 23.5 million, α = -1.34°, (exp. 271).

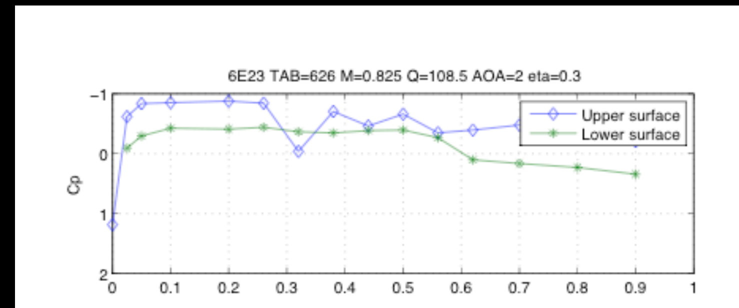
Gridding Guidelines Subcommittee Report

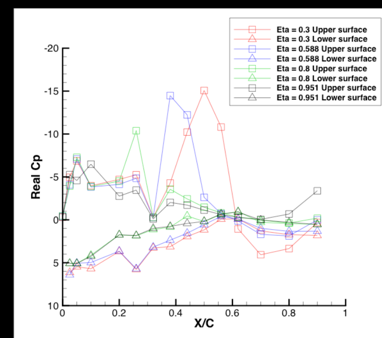
- **Gridding guidelines and rules from Drag Prediction Workshop and High Lift Prediction Workshop will be adopted as the initial guidelines for AePW.**
- **NASA is responsible for preparing IGES files:**
  - **Measured geometry should be used for all configurations**
  - **For RSW and BSCW IGES files will be generated with and without splitter plates**
  - **For HIRENASD, the IGES file supplied by Thorsten Hansen will be compared against files on Aachen website to establish baseline**
  - **IGES files should be ready by March 30**
- **Unstructured and structured grids will be constructed and made available to the participants.**
- **IGES files for RSW & BSCW are ready (March 30, 2011) for gridding**
  - **Volunteers to generate grids: Thorsten Hansen, Marilyn Smith, Eric Blades, Markus Ritter**
- **Initial analyses prior to IFASD will be conducted using new grid family:**
  - **RSW and BSCW (NASA)**
  - **HIRENASD (FOI Sweden)**

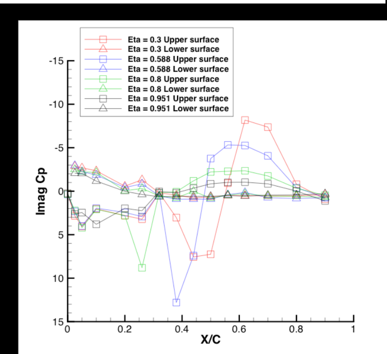
CONFIGURATION	REQUIRED CALCULATIONS				
	GRID CONVERGENCE STUDIES	STEADY CALCULATIONS		DYNAMIC CALCULATIONS	
RECTANGULAR SUPERCRITICAL WING					
Steady-Rigid Cases					
M = 0.825, α = 2°	C_L, C_D, C_M vs $N^{-2/3}$	C_p vs x/c	C_L, C_D, C_M	n/a	n/a
M = 0.825, α = 4°	C_L, C_D, C_M vs $N^{-2/3}$	C_p vs x/c	C_L, C_D, C_M	n/a	n/a
Forced-Oscillation-Rigid Cases					
M = 0.825, α = 2°, θ = 1°, excitation frequency = 10 Hz	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency
M = 0.825, α = 2°, θ = 1°, excitation frequency = 20 Hz	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency
BENCHMARK SUPERCRITICAL WING					
Steady-Rigid Cases					
M = 0.850, α = 5°	C_L, C_D, C_M vs $N^{-2/3}$	C_p vs x/c	C_L, C_D, C_M	n/a	n/a
Forced-Oscillation-Rigid Cases					
M = 0.850, α = 5°, θ = 1°, excitation frequency = 1 Hz	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency
M = 0.850, α = 5°, θ = 1°, excitation frequency = 1 Hz	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency
HIRENASD					
Static-Aeroelastic Cases					
M = 0.800, α = 1.50°, Re = 7.0 million	C_L, C_D, C_M vs $N^{-2/3}$	C_p vs x/c, vert displ* vs x/c, twist* vs x/c	C_L, C_D, C_M	n/a	n/a
M = 0.800, α = -1.34°, Re = 23.5 million	C_L, C_D, C_M vs $N^{-2/3}$	C_p vs x/c, vert displ* vs x/c, twist* vs x/c	C_L, C_D, C_M	n/a	n/a
Forced-Oscillation-Aeroelastic Cases					
M = 0.800, α = 1.50°, Re = 7.0 million, excitation frequency = 2^{nd} bending mode frequency	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency **
M = 0.800, α = -1.34°, Re = 23.5 million, excitation frequency = 2^{nd} bending mode frequency	TBD		n/a	Magnitude and Phase of C_p vs x/c at excitation frequency	Magnitude and Phase of C_L, C_D, C_M at excitation frequency **

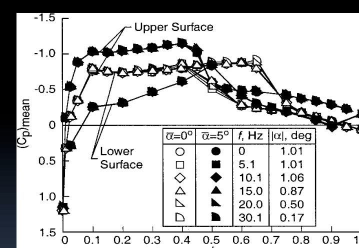
Experimental Data & Uncertainty Subcommittee Report

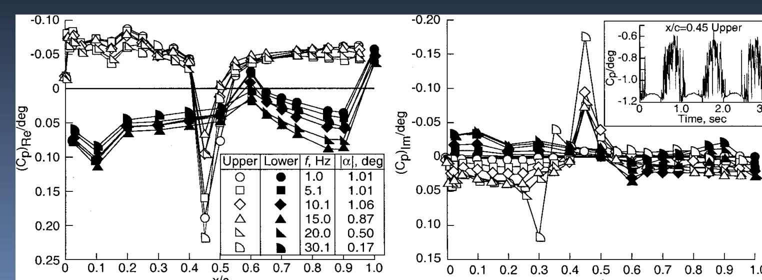
- Rectangular Supercritical Wing
  - Static data 6E23, 6E24 extracted from RTO CD
  - Dynamic data for test cases 6E54, 6E56
- Benchmark Supercritical Wing
  - Semi-blind, so no data will be released beyond that appearing in Journal article
  - Time history data available to AePW for uncertainty analyses &











Experimental Data & Uncertainty Subcommittee Report

- HiReNASD
  - Time histories being analyzed by Aachen University & NASA
    - Pressure data
    - Balance data
    - Accelerometers
    - Forcing functions
  - Processed data being analyzed for displacements
    - Stereo pattern tracking
    - Strain gauges
  - Wind-off data sets also being analyzed
  - Treatment of uncertainty in experimental data- under discussion and debate

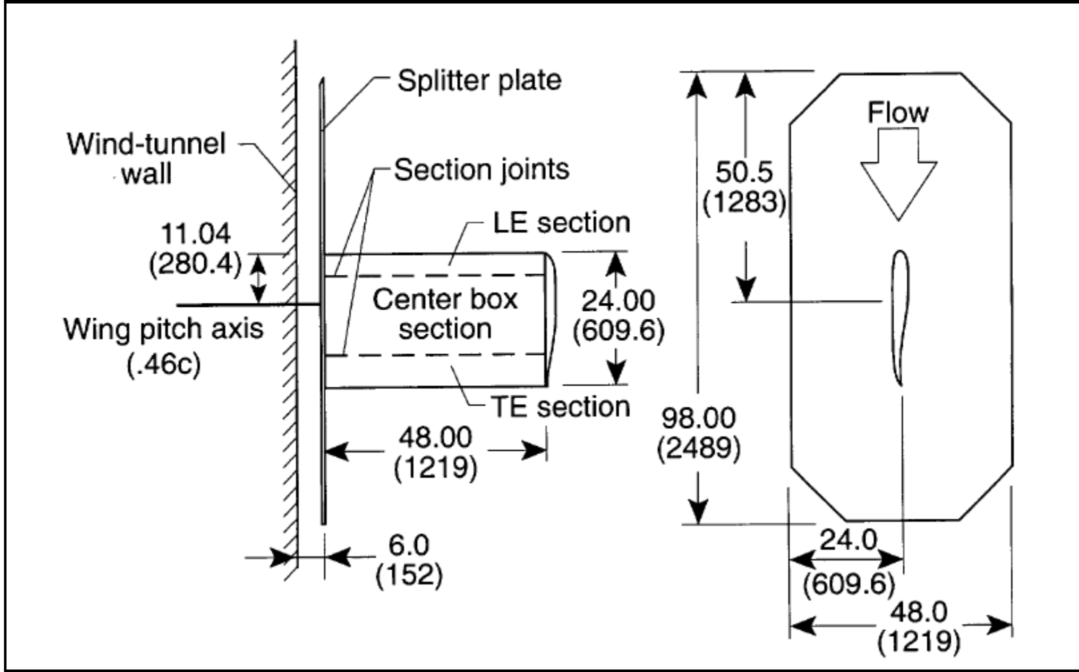
AePW Short-Term Timeline: March-June 2011

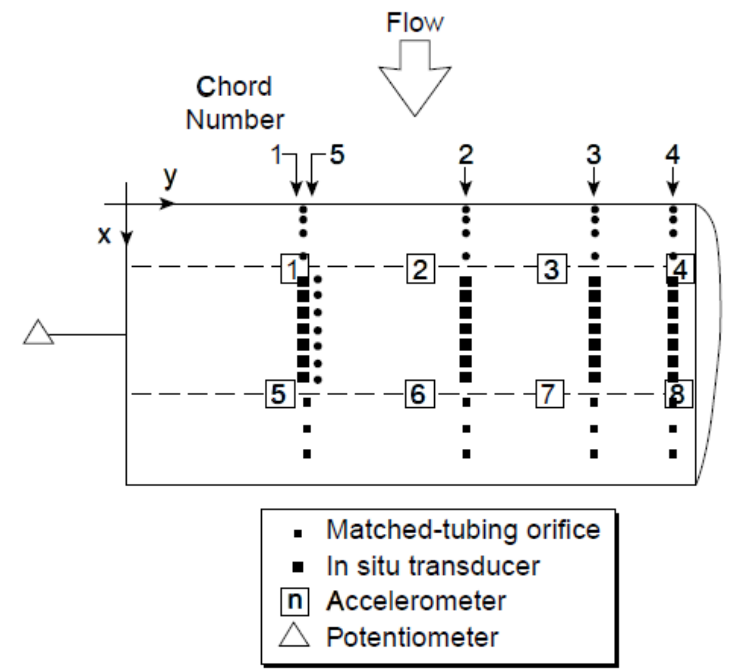
Activity	March	April	May	June
	7 14 21 28	7 14 21 28	7 14 21 28	7 14 21 28
Presentations AIAA SDTC AFDC IFASD				
IFASD Paper Preparation Draft to OC for review Draft to NASA reviewers Submit paper to IFASD Draft of slides to OC				
Configuration / Test Cases Subcommittee (SC) Done?				
Experimental Uncertainty / Data Prep SC Decision on data format (same for all configs) Data ready (all configs) and available on AePW OC website (RSW & HIRENASD only) Data available on AePW public website (RSW, HIRENASD)				
Gridding Guidelines SC Grids complete (all configs) Preliminary analysis and report to OC (all configs) Material ready for IFASD discussion panel on AePW				
Structural Modeling and Interpolation SC Decision point on structural models Decision point on data and formats Grid-interpolated structural model available (HIRENASD) Data / models available on AePW public website				
Preliminary Comp. Evaluations Complete RSW (performed by analyst) BSCW (performed by third party to maintain “blind” status)				

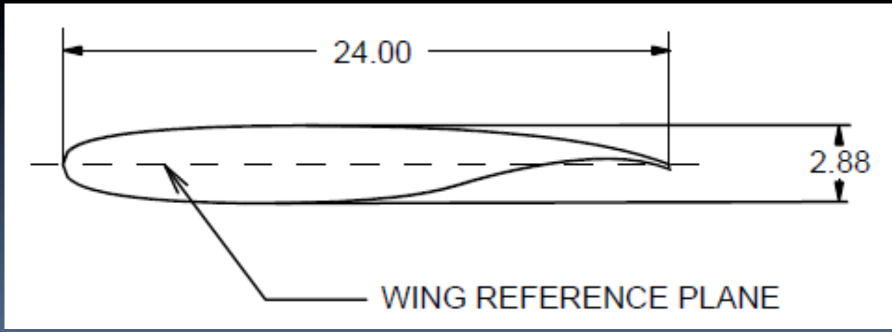
Case 1 Selection Rationale
Rectangular Supercritical Wing (RSCW)

- Cases chosen to focus on the steady and unsteady aerodynamic solutions and their variation.
- Mach 0.825 generates transonic conditions with a terminating shock; highest Mach number with forced transition
- Steady Data: Two static angles of attack chosen
  - $\alpha = 2.0°$generates a moderate-strength shock with some potential for shock-separated flow; corresponding forced oscillation data exists.
  - $\alpha = 4.0°$generates strong shock with greater potential for shock-separated flow .
- Unsteady Data: Two forced oscillation frequencies chosen to evaluate methods abilities to distinguish frequency effects.
  - Non-zero mean AoA introduces a wing loading bias for which code-to-code comparisons can be accomplished.

RSW Model Layout and Airfoil

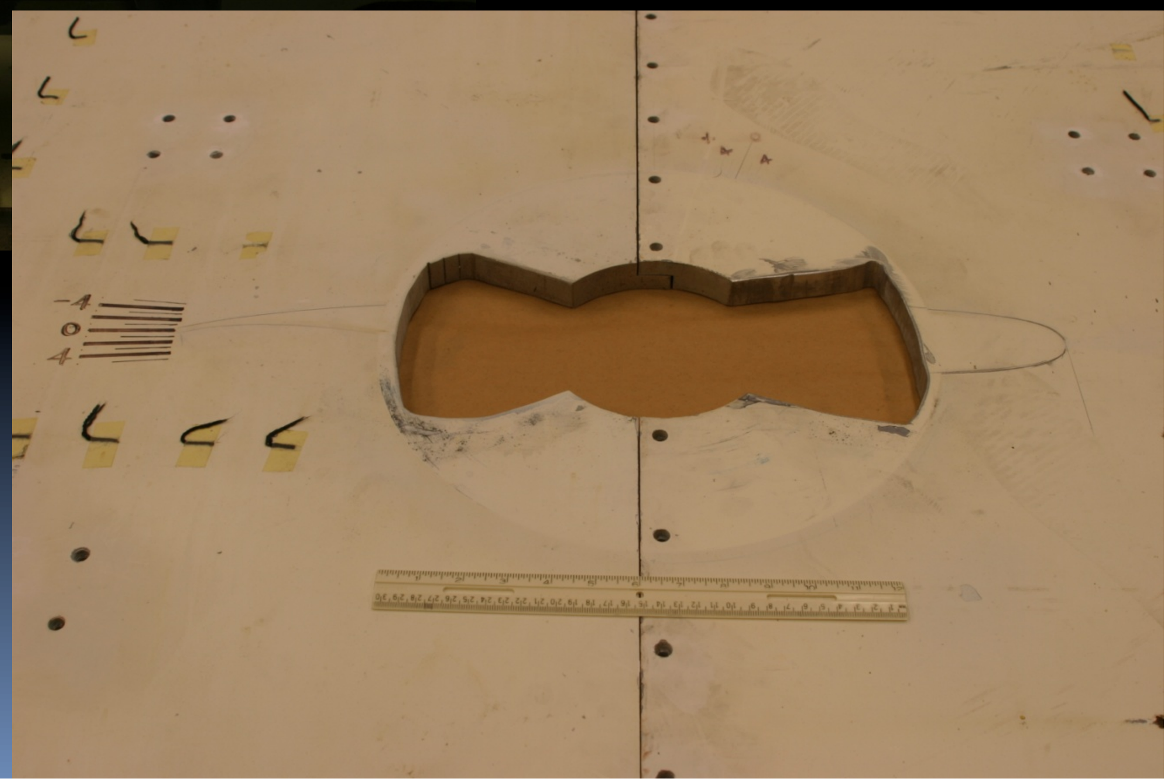






Experimental data acquired in R-12 @ Re = 4 million/ft (8 million based on wing chord), Mach=0.825

RSW Model Layout and Airfoil



Case 2 Selection Rationale
Benchmark Supercritical Wing (BSCW)

- Highly nonlinear aerodynamic phenomena.
  - Known shock-separated transient flow.
  - Relatively obscure data that serves as a virtually blind test case for the methods.
- Better data detail and insight than for RSCW.
  - Statistical and time-history data are available for comparison.
  - Unfortunately only one span station of data.
  - Model could be retested for future workshops.

BSCW Geometry and Test Configuration

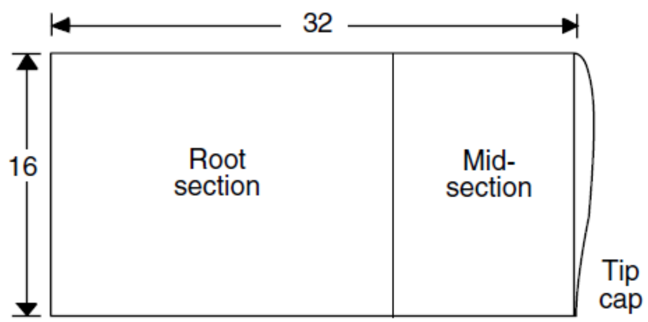


Figure 1. Planform of model. Dimensions are in inches.

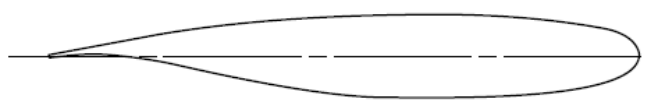
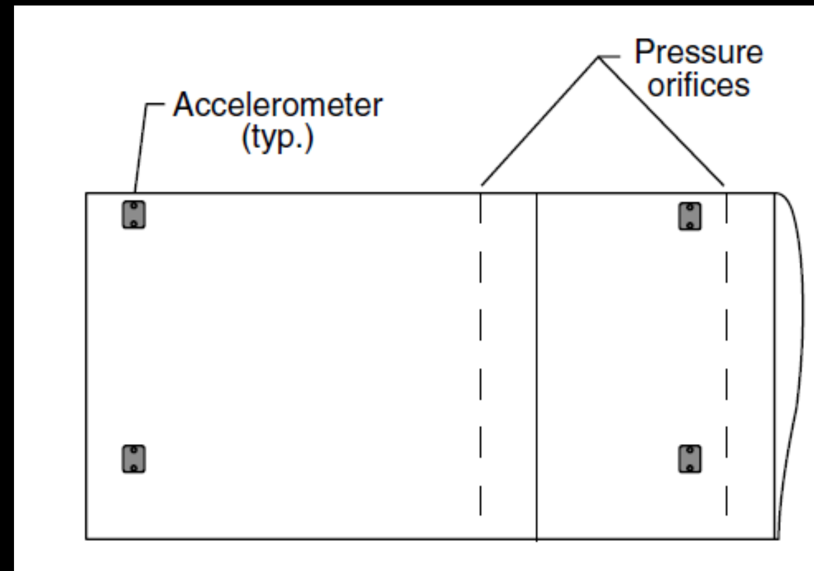
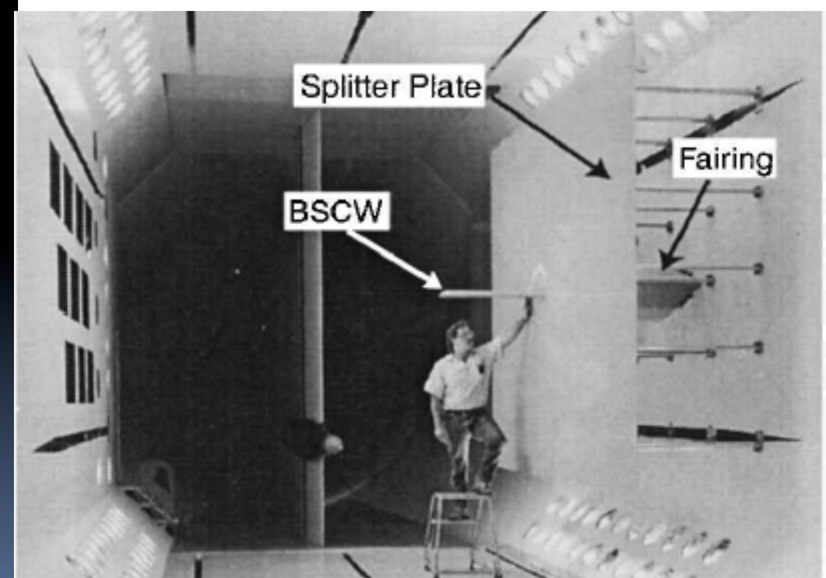
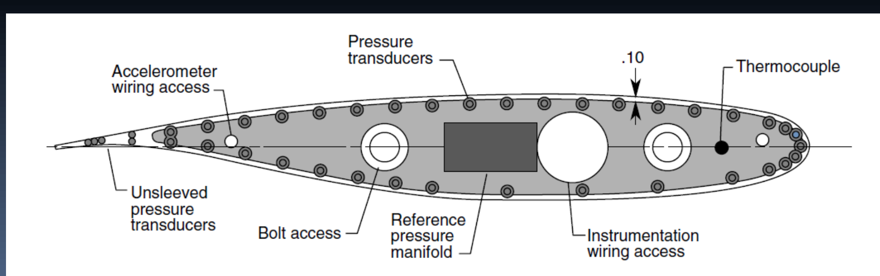


Figure 2. NASA SC(2)-0414 airfoil.







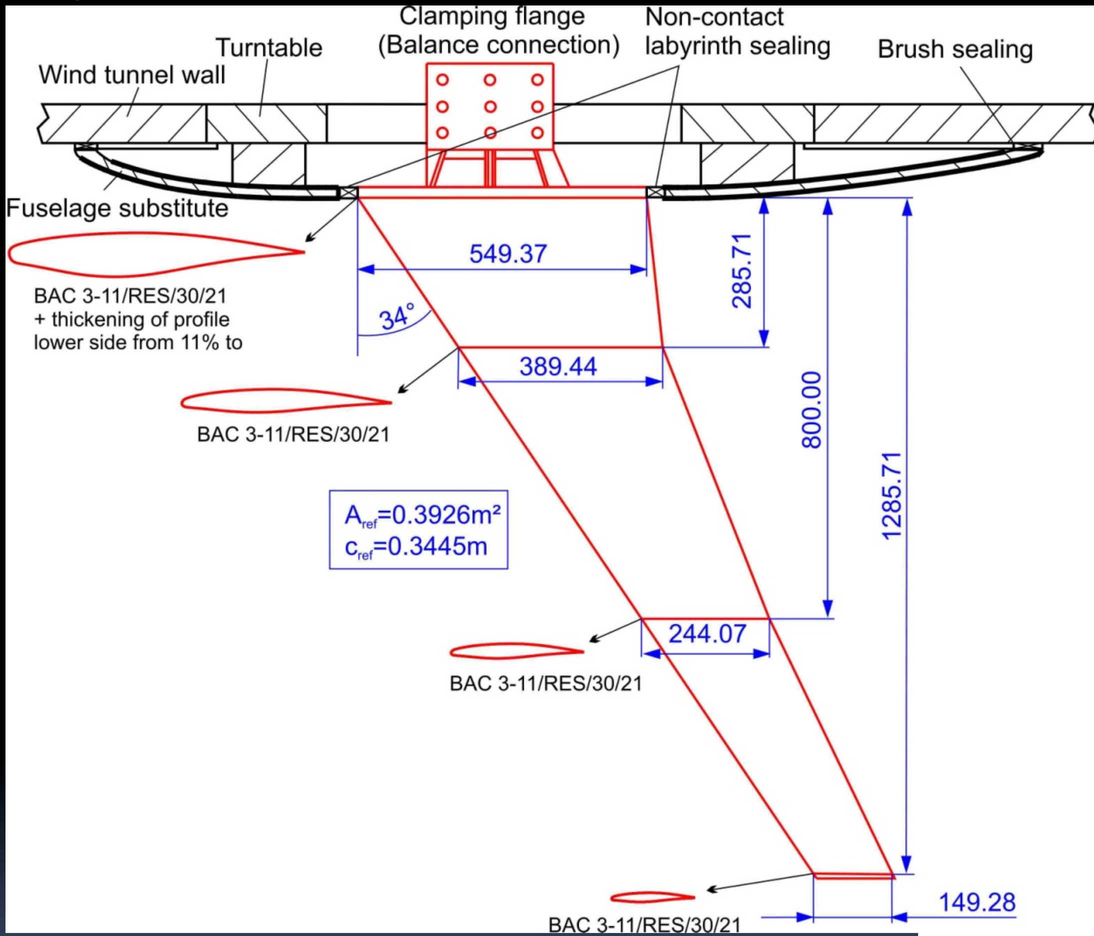
Experimental data acquired in R-134a @ q = 200 psf, Re = 5.3 million/ft. (7 million based on wing chord), Mach=0.85

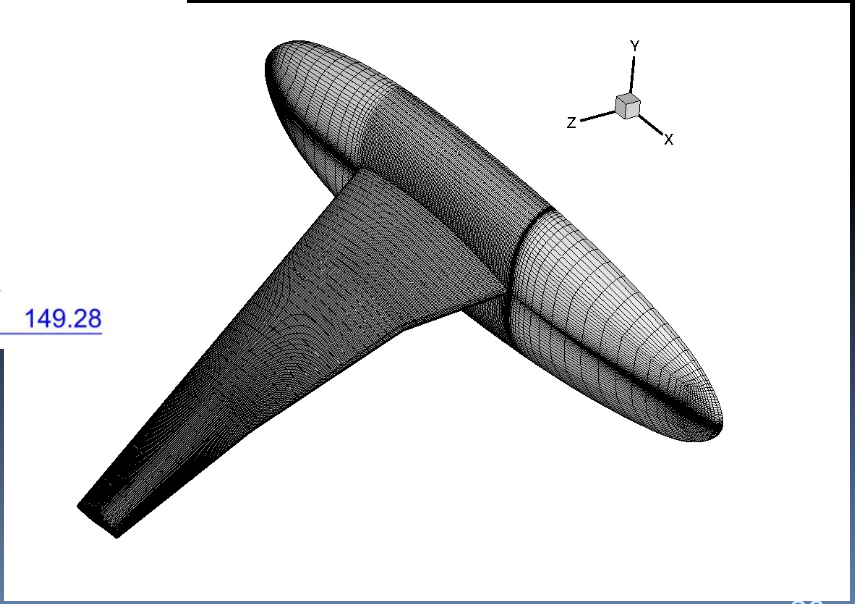
Case 3 Selection Rationale
HIRENASD Wing

- Aircraft-representative geometry, rather than "unit problem"
- Initial test for fully coupled aeroelastic analysis.
- Steady cases demonstrate prediction capabilities for static aeroelastic problems.
- Dynamic cases demonstrate structural dynamics coupling with unsteady aerodynamics techniques.
  - Relatively weak aeroelastic coupling make it a good entry-level aeroelastic test case.

HIRENASD Geometry

(https://heinrich.lufmech.rwth-aachen.de/en/windtunnel-assembly)

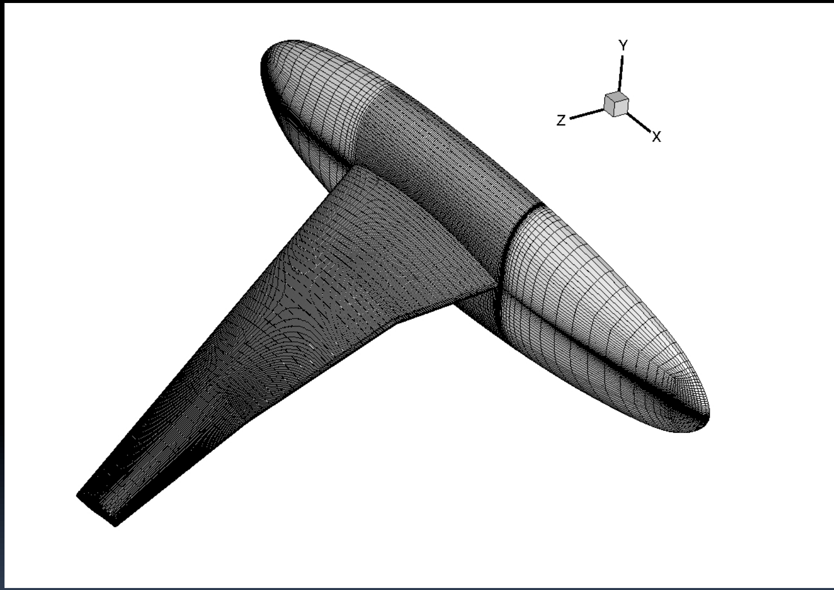




Mach 0.80, Re = 7.0 million and Re = 23.5 million

High Reynolds Number Aero-Structural Dynamics (HIRENASD) Wing

- 3-D aeroelastic wing with generic fuselage model.
  - Steady and forced (structural resonance) oscillation testing
  - Moderate and high Reynolds number data.
- Well known geometric and structural properties.
- Data includes balance forces for integrated load comparisons, mean and fluctuating pressure data, and surface deformation data from optical and strain measurements during testing.



Participant Information Sources

- Organizing committee website:
  - https://c3.ndc.nasa.gov/dashlink/projects/47/
- Workshop website, open for public viewing, member postings:
  - https://c3.ndc.nasa.gov/dashlink/projects/39/
- Links to:
  - HIRENASD website (German and English languages)
    - http://www.lufmech.rwth-aachen.de/HIRENASD/
    - https://heinrich.lufmech.rwth-aachen.de/index.php?lang=en&pg=home
  - NASA White Paper reviewing experimental data sets
    - http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100016316_2010017232.pdf
  - 2011 International Forum on Aeroelasticity & Structural Dynamics
    - http://www.ifasd2011.com/
  - Fun3D
    - http://fun3d.larc.nasa.gov/
  - Drag and High-Lift Prediction Workshops
    - http://aaac.larc.nasa.gov/tsab/cfdlarc/aiaa-dpw/
    - http://hiliftpw.larc.nasa.gov/

Mapping configurations to Activities & Organizations

	NASA	NASA	NASA	RTO	RTO	AePW	AePW	AePW
	SFW-AeroD, 2010	SFW-AeroD, 2011	SFW-AeroD, 2012-14	AVT 203, 2011-12	AVT 203, 2013-2014	1	2	3
AGARD 445.6	Principal	Secondary						
RSW		Principal				Principal		
BSCW		Principal				Principal		
HiRENASD, Case Set 1		Principal		Principal		Secondary	Principal	
HiRENASD, Case Set 2			Principal	Principal			Principal	
TBD Aeroelasticity Benchmark			Principal		Principal			Principal

Self-rating By each Organization:

- Principal config
- Secondary config