Progress & Plans for the 2nd Aeroelastic Prediction Workshop (AePW-2)

Presented by Pawel Chwalowski

On behalf of the
AePW-2 Organizing Committee

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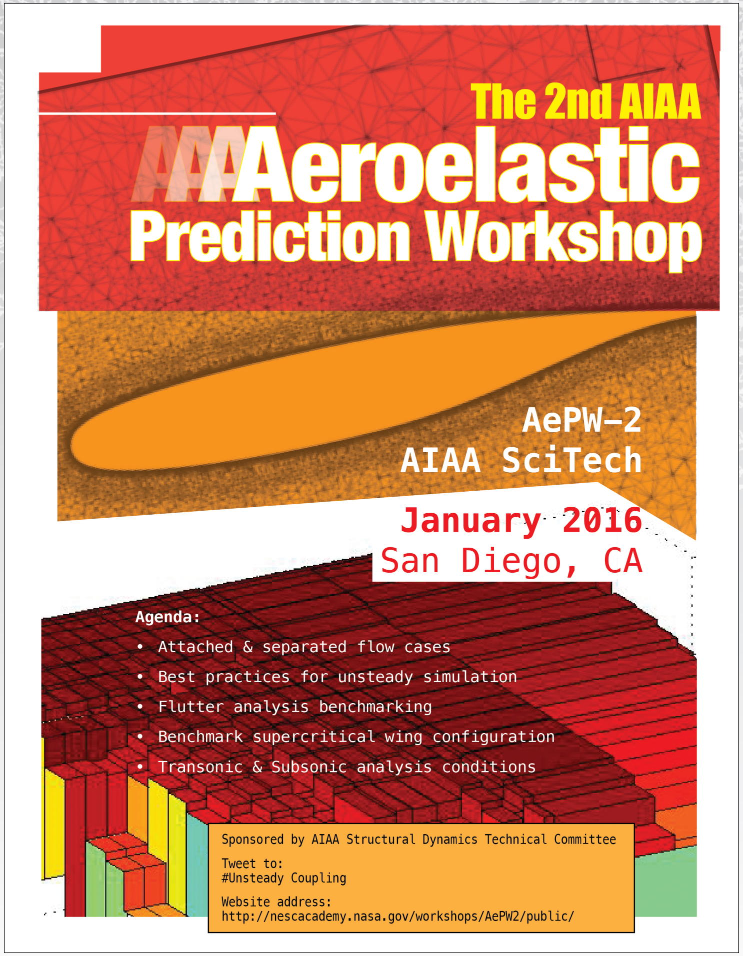
Swedish Defense Research Agency, FOI

Alessandro Scotti
Pilatus

ASE summit
April 14-15, 2015
NASA Ames Research Center,
Moffett Field, CA

Plans & Analyses are progressing towards AePW-2



We invite you to participate

- Kickoff Meeting: SciTech 2015
- Workshop: SciTech 2016
- Computational Results Submitted by Nov 15, 2015
- Computational Team Telecons: 1st Thursday of every calendar month, 11 a.m. U.S. Eastern Time

Aeroelastic computational benchmarking

- **Technical Challenge:**

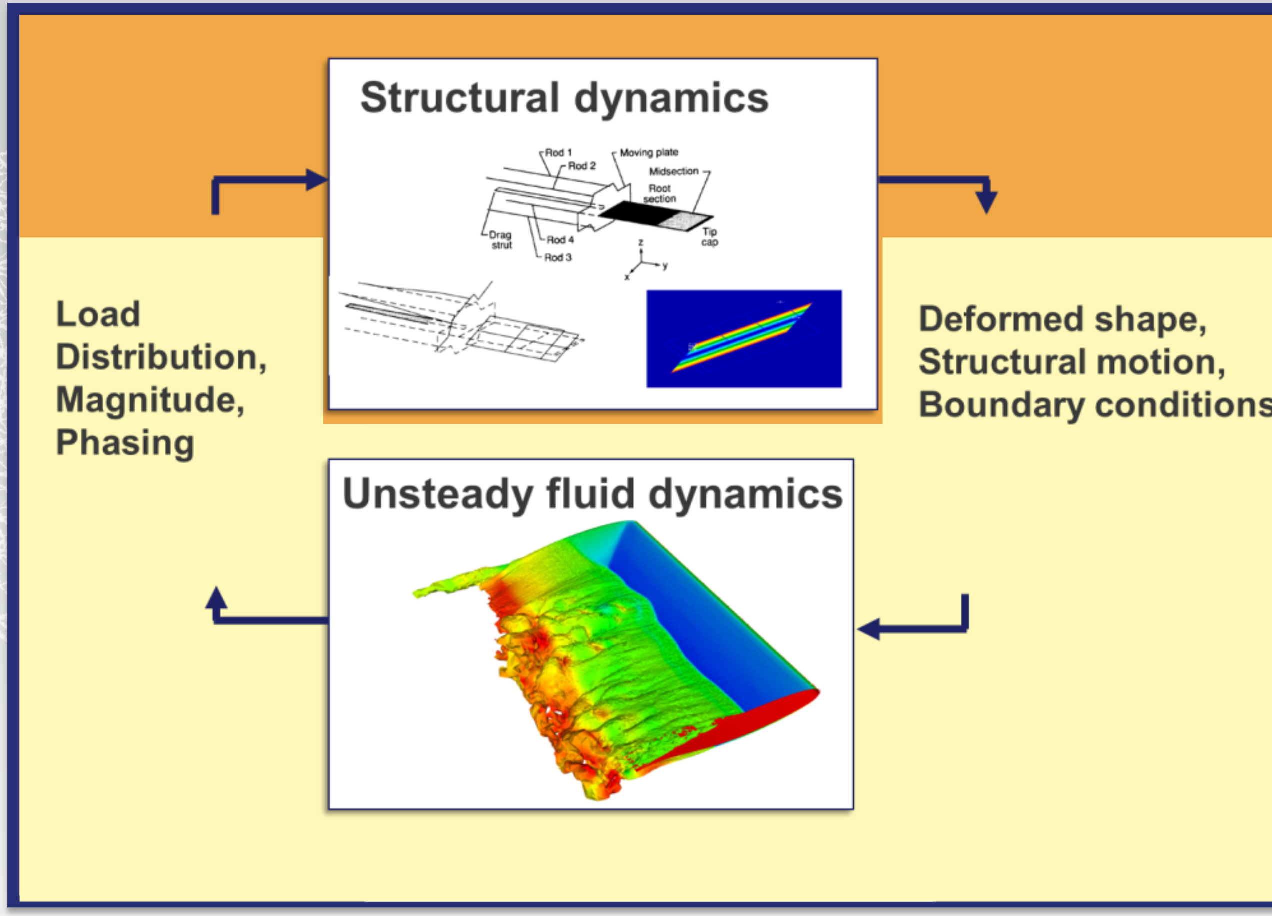
  Assess state-of-the-art methods & tools for the prediction and assessment of aeroelastic phenomena

- **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
  - Establish best practices

AePW building block approach to validation

Utilizing the classical building blocks of aeroelasticity

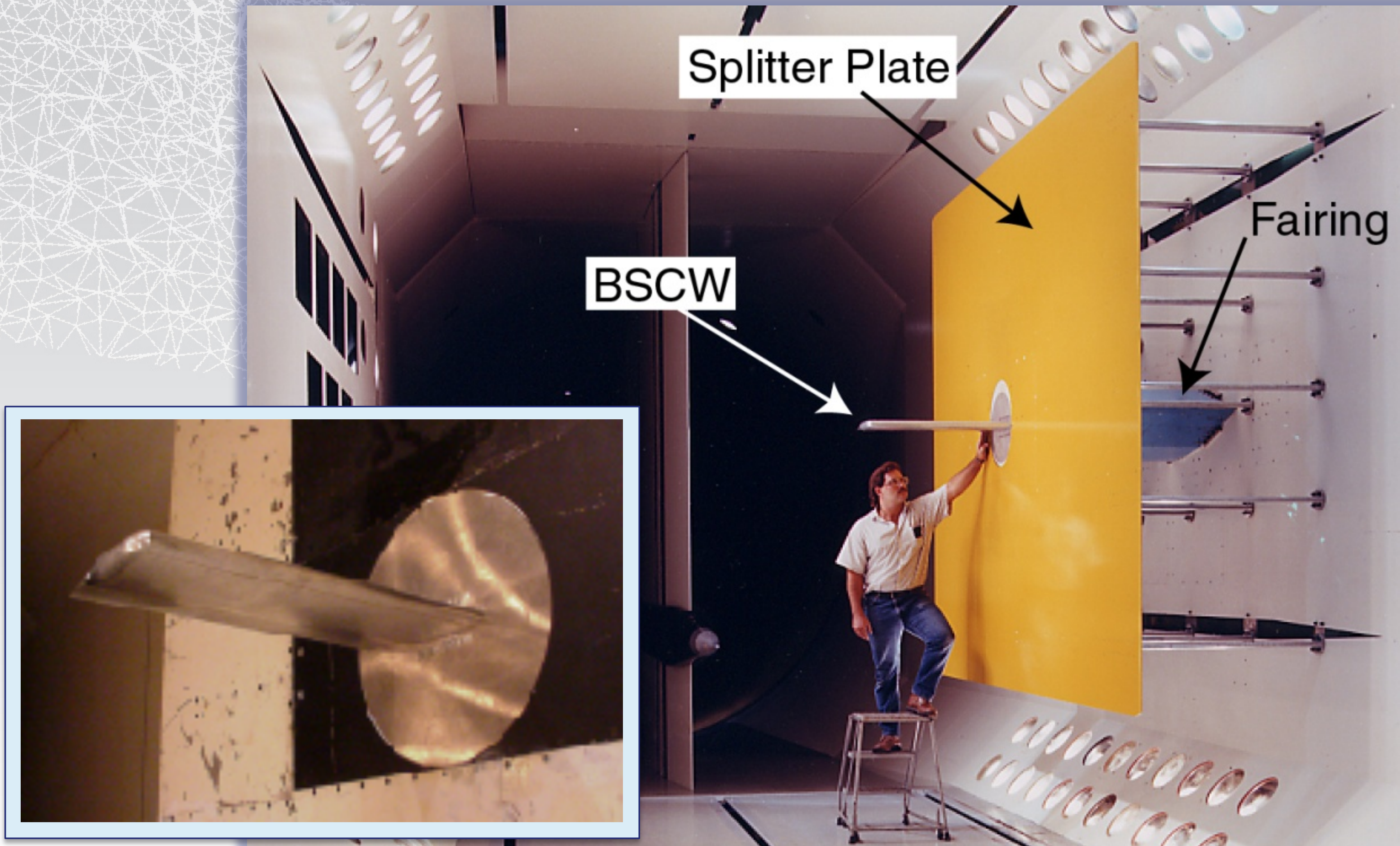
- Fluid dynamics
- Structural dynamics
- Fluid/structure coupling



AePW-1: Focused on Unsteady fluid dynamics

AePW-2: Extend focus to coupled aeroelastic simulations

Benchmark Supercritical Wing (BSCW)



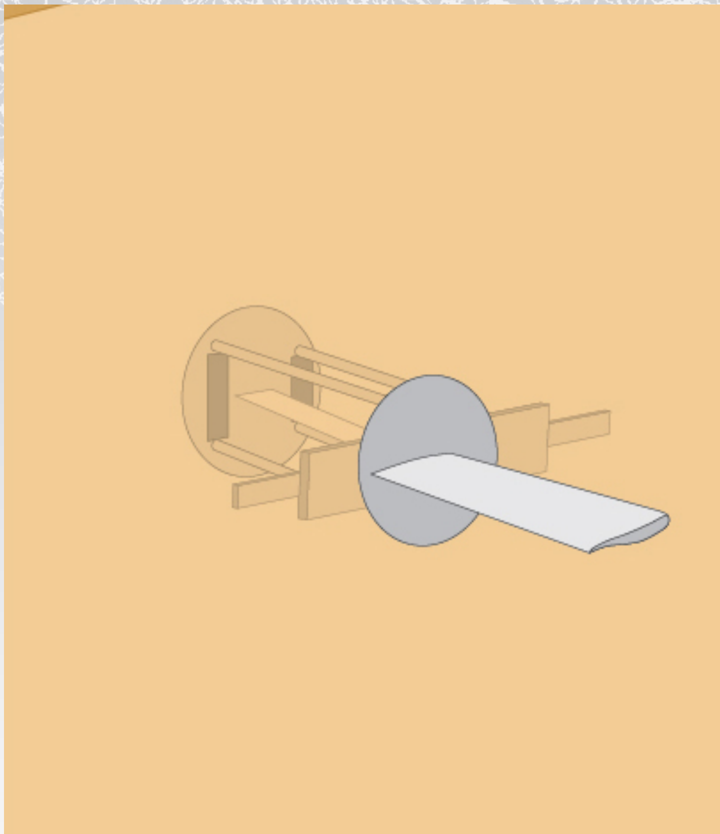
You are invited to participate in AePW-2

Extend focus to coupled aeroelastic simulations

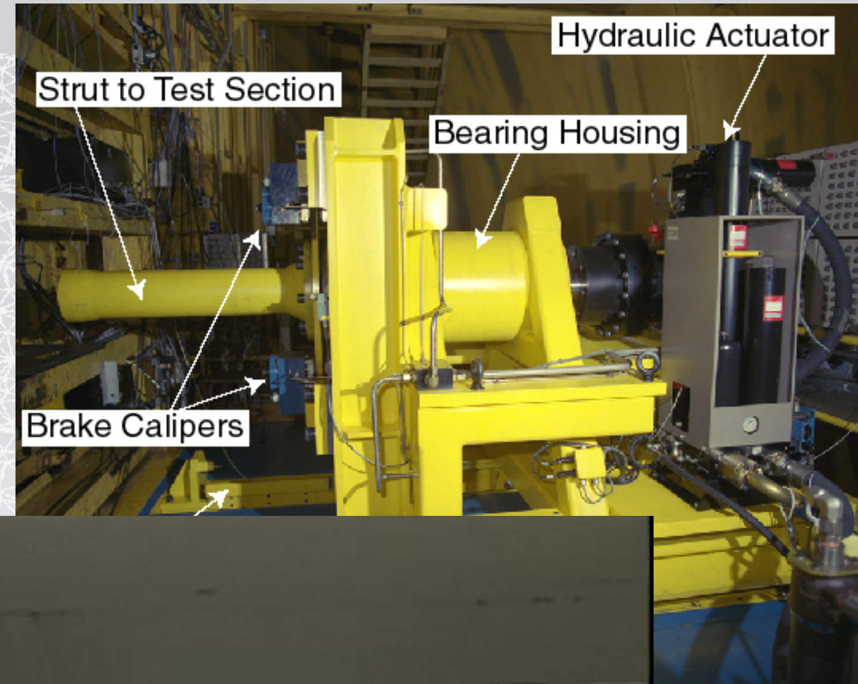
	Case 1	Case 2	Optional Case 3		
			A	B	C
Mach	0.7	0.74	0.85	0.85	0.85
Angle of attack	3°	0°	5°	5°	5°
Dynamic Data Type	Forced oscillation	Flutter	Unforced Unsteady	Forced Oscillation	Flutter
Notes:	• Attached flow solution. • Oscillating Turn Table (OTT) exp data.	• Unknown flow state. • Pitch and Plunge Apparatus (PAPA) exp. data.	• Separated flow effects. • Oscillating Turn Table (OTT) experimental data.	• Separated flow effects. • Oscillating Turn Table (OTT) experimental data.	• Separated flow effects on aeroelastic solution. • No experimental data for comparison.

Experimental data from 2 wind tunnel tests are being used for comparison data

TDT Test 470:
Pitch And Plunge Apparatus (PAPA)



TDT Test 548: Oscillating TurnTable (OTT)



AePW-2 Analyses/Commitments to date (3/30/201)

	Analysis Team	Code	POCs	Email contact
1	Technion - IIT	EZNSS	Daniella Raveh	daniella@technion.ac.il
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6	NLR	EZNSS?	Bimo Pranata	bimo.prananta@nlr.nl
7	NLR	NASTRAN	Bimo Pranata	bimo.prananta@nlr.nl
8	Indian Institute of Science	FLUENT	kartik venkatraman	kartik@aero.iisc.ernet.in
9	Istanbul Technical University	SU2	Melike Nikbay	nikbay@itu.edu.tr
10	ATA Engineering	Loci/CHEM	Eric Blades	eric.blades@ata-e.com
11	Embraer S.A.	CFD++,ZTRAN, NASTRAN *	Guilherme Ribeiro Begnini	guilherme.benini@embraer.com.br
12	Politechnico di Milano	Various codes	Sergio Ricci	sergio.ricci@polimi.it
13	AFRL	FUN3D	Rick Graves	Rick.Graves@us.af.mil
14	Mississippi State		Manav Bhatia	Bhatia@ae.msstate.edu

Example Results:
Case #1: Attached flow Forced Oscillation case

	Case 1	Case 2	Optional Case 3		
			A	B	C
Mach	0.7	0.74	0.85	0.85	0.85
Angle of attack	3	0	5	5	5
Dynamic Data Type	Forced Oscillation	Flutter	Unforced Unsteady	Forced Oscillation	Flutter
Notes:	• Attached flow solution • Oscillating Turn Table (OTT) exp data	• Unknown flow state • Pitch and Plunge Apparatus (PAPA) exp data	• Separated flow effects • Oscillating Turn Table (OTT) experimental data	• Separated flow effects • Oscillating Turn Table (OTT) experimental data	• Separated flow effects on aeroelastic solution • No experimental data for comparison

Steady rigid pressure distributions

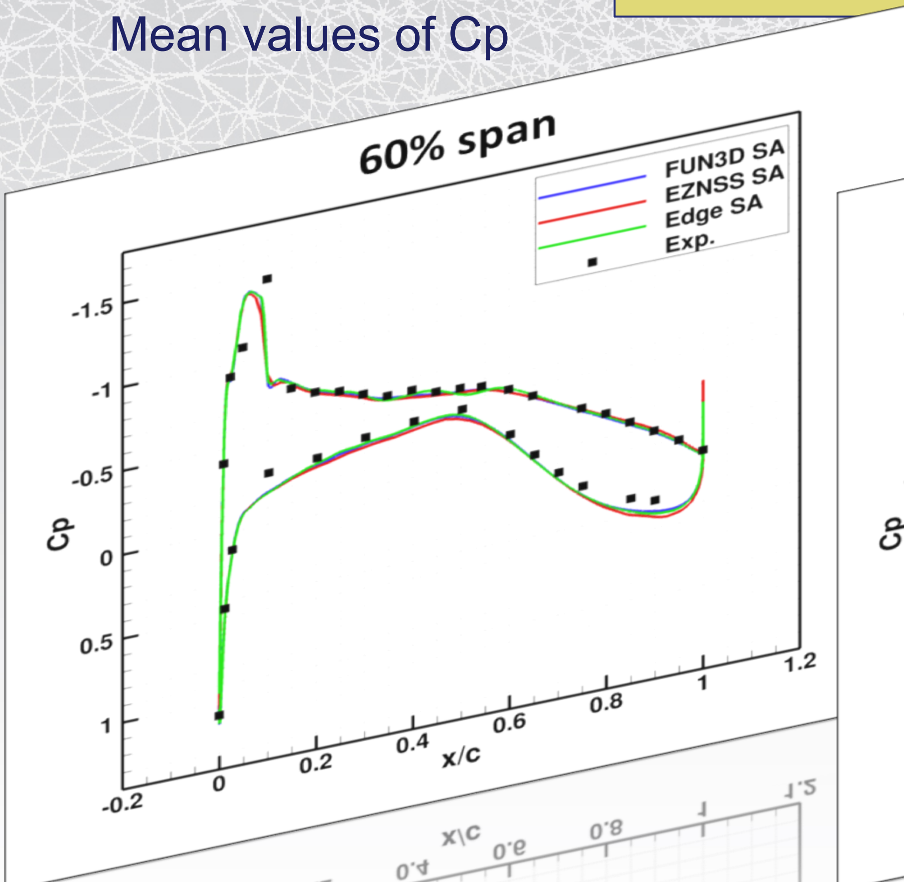
Example Results for Case #1

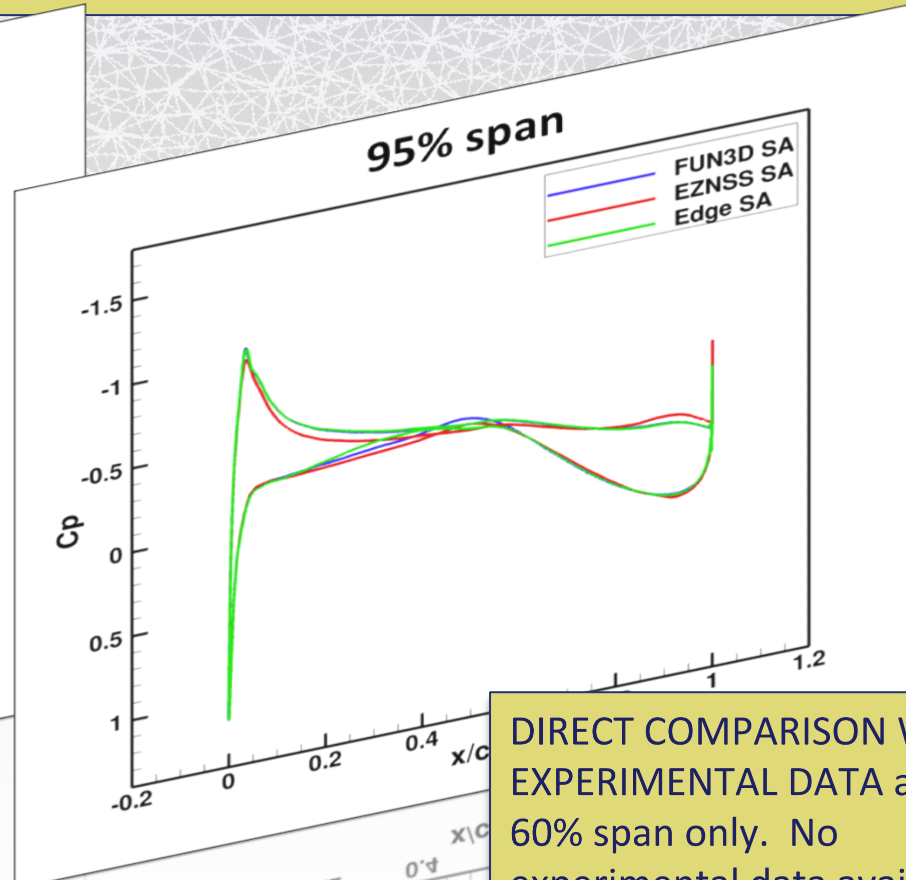
Mean values of Cp

These computational results agree much better with the experimental data than the case for AePW-1 (Case #3 for AePW-2)

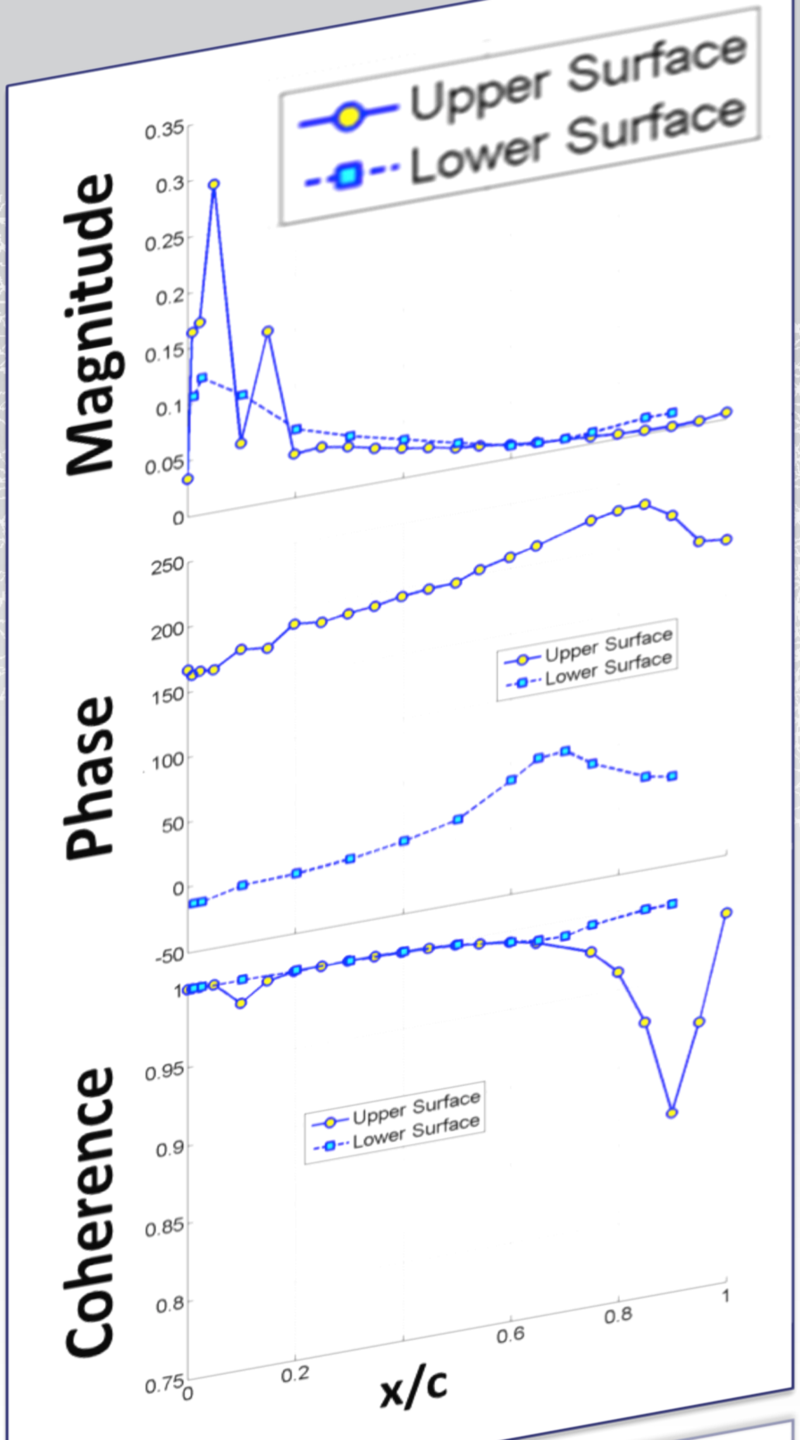
Static pressure comparisons are a relatively easy and almost-for-free comparison enroute to the unsteady results comparisons

Results from 3 separate analysis codes are shown here. (Reynolds Averaged Navier Stokes simulations with Spalart-Allmaras turbulence models)





DIRECT COMPARISON WITH EXPERIMENTAL DATA at 60% span only. No experimental data available at 95% span.



Case #1 Frequency Response Functions for Forced Oscillation C_p / α

- Forced oscillation at 10 Hz
- FRFs shown at 10 Hz, as functions of chord
- Shown here only for the experimental data
- Experimental data available only at 60% span

Case #2: Low Mach number Flutter Simulations

Extend focus to coupled aeroelastic simulations

	Case 1	Case 2	Optional Case 3		
			A	B	C
Mach	0.7	0.74	0.85	0.85	0.85
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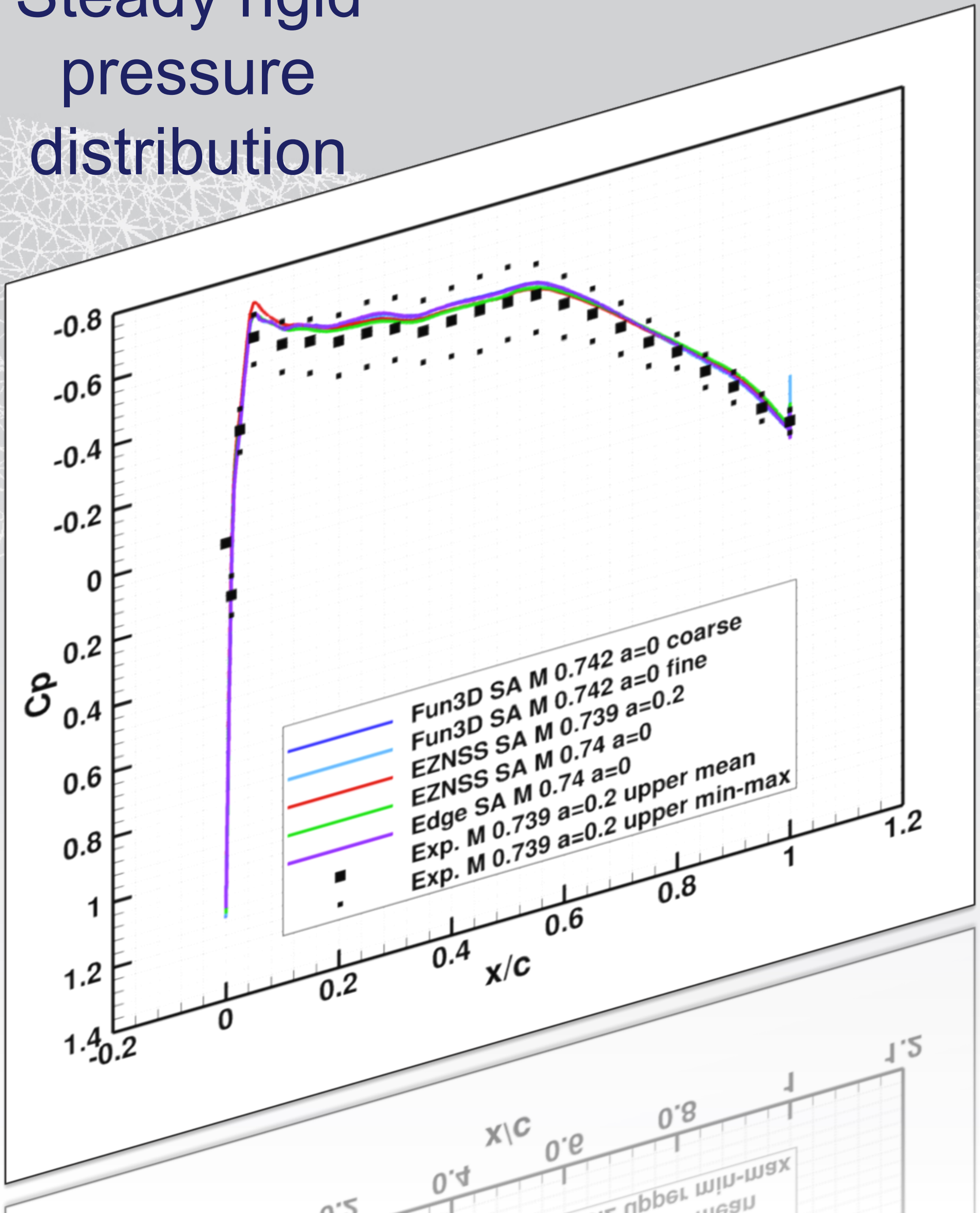
Steady rigid pressure distribution



Example results for Case #2
Mean values of Cp at 60% Span Station Upper Surface

Results from 3 separate analysis codes are shown here.
(Reynolds Averaged Navier Stokes simulations with Spalart-Allmaras turbulence models)

Small perturbations on the angle of attack and Mach number were investigated. These perturbations are not part of the AePW-2 case matrix.

DIRECT COMPARISON WITH EXPERIMENTAL DATA

Example Results

AePW-2 Case#2

Animation of Flutter

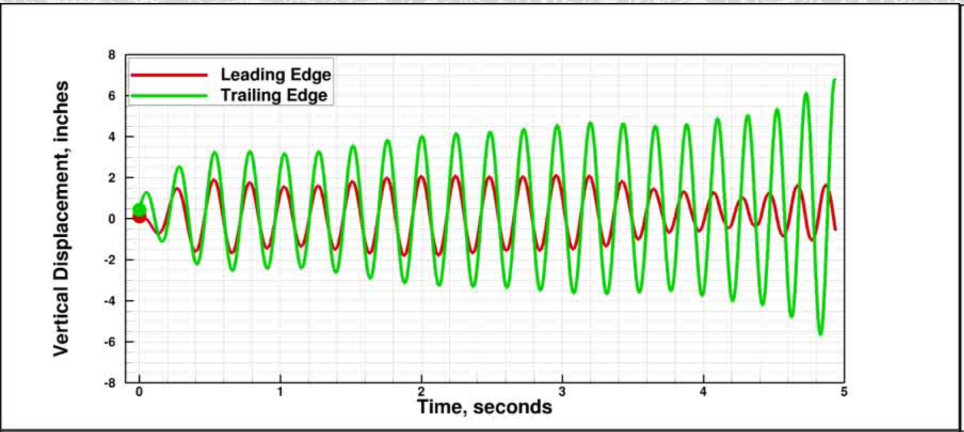
FUN3D URANS with SA turbulence model coupled with modal structural solver

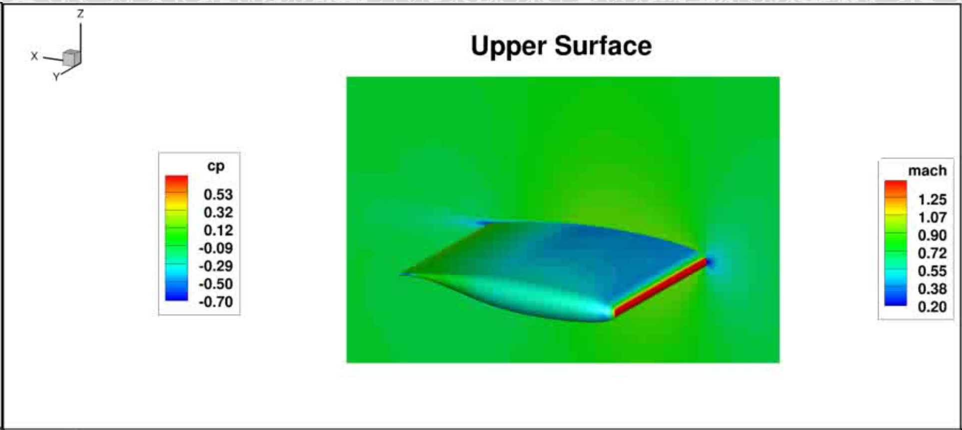
Mach 0.74, AoA=0°, q = 168.8 lb_f/ft^2

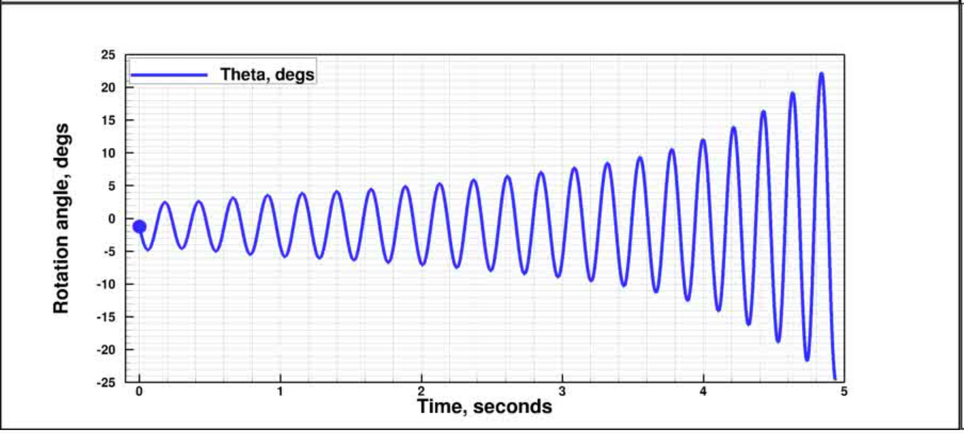
Animation of the BSCW computational results using FUN3D near experimental flutter dynamic pressure

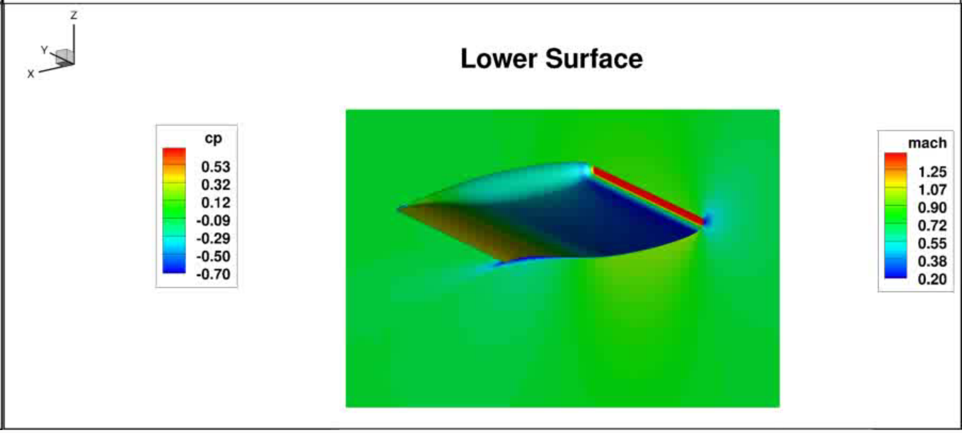
Leading and Trailing Edge Vertical Displacement;
Rotation Angle

Surface Cp and Mach contours at 60% wing span









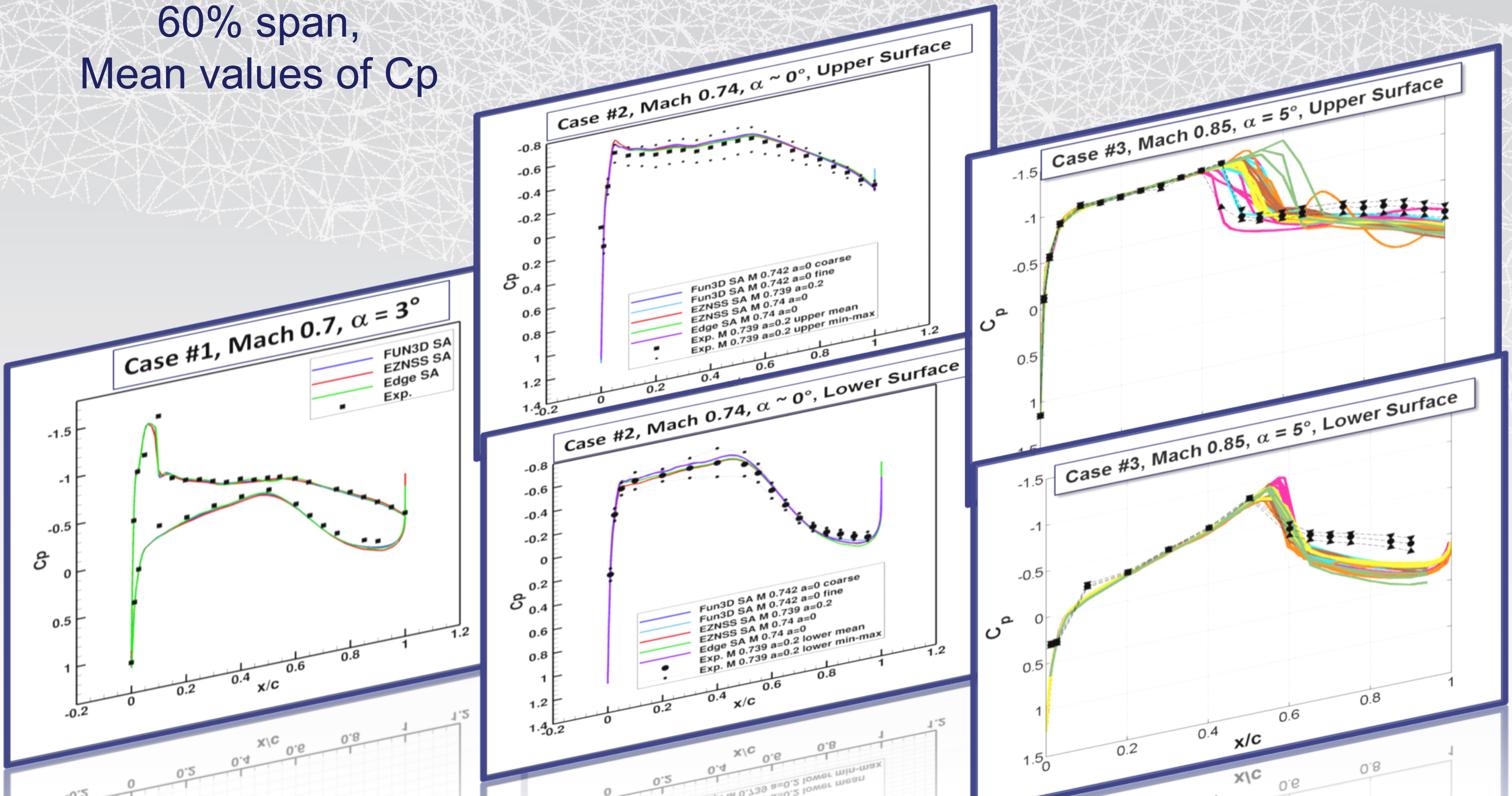
Steady rigid pressure distributions

Case comparisons
60% span,
Mean values of Cp

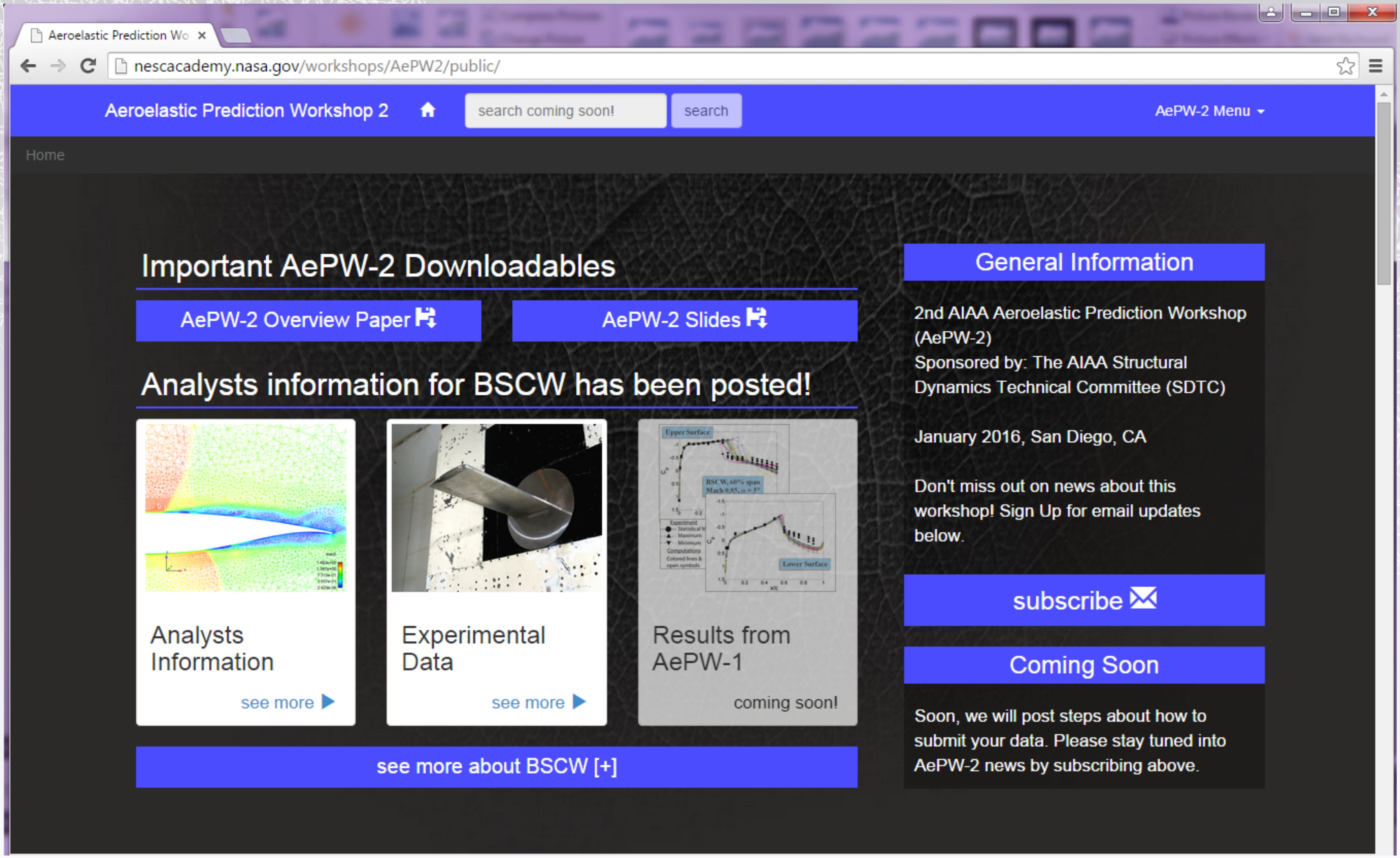
For the primary forced oscillation case, Case #1, disagreements with experimental data limited to the peak of the upper surface shock.

For the primary flutter case, Case #2, shows a well-matched rigid pressure distribution without much variation among the computational results.

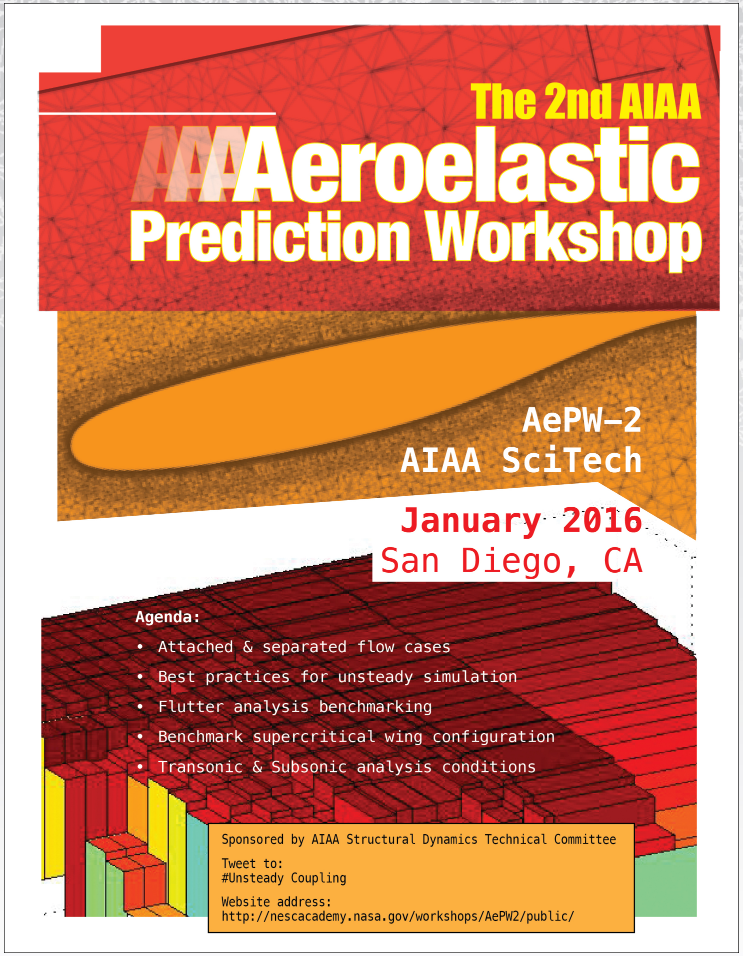
The complexity of the Case #3 is indicated by the variation among the computational results & difference from the experimental data →Shock location, shock strength, aft loading especially on lower surface.



Website: nescacademy.nasa.gov/workshops/AePW2/public/



Thank you



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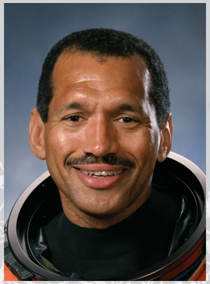
  U.S. dial in #: 844-467-4685;

  passcode 5398949869;

  webex at https://nasa/webex.com/nasa

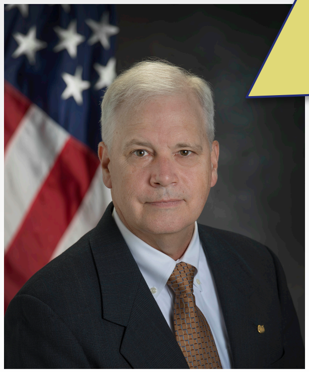
  Webex meeting number changes each month. Sign up at web site to be added to the email list for monthly webex info

Back up slides



Why should our organization participate? What do we get out of participating?

- Evaluation of your own methodologies and/or abilities to apply computational tools
- Experience of others brought to bear on examining your results in a critical thinking environment
- Inclusion of your results in determining best practices, uncertainty levels in predictions
- Identification of
  - Areas where your tools meet your required level of predictive and analytical capabilities
  - Benefits to be gained by added analytical complexity
  - Areas where you want to further refine your capabilities
- Detailed supporting information for
  - Advocacy within your organization
  - Advocacy to your customers
- Leveraging the work of others



How does validation of aeroelastic tools differ from validation of aerodynamic tools?

- Obvious (?) differences:
  - Coupling with structural dynamics
  - Unsteady effects matter
- More subtle differences:
  - Distribution of the pressures matters (integrated quantities such as lift and pitching moment tell you little regarding aeroelastic stability)
  - Phasings of the pressures relative to the displacements matter

What are you trying to do?

- **Assess the goodness** of computational tools for predicting aeroelastic response, including flutter
- **Understand why** our tools don't always produce successful predictions
  - Which aspects of the physics are we falling short of predicting correctly?
  - What about our methods causes us to fall short of successful predictions?
- Establish **uncertainty bounds** for computational results
- Establish **best practices** for using tools
- Explicitly **illustrate the specific needs** for validation experimentation- i.e. why what we have isn't good enough

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
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- **Approach**
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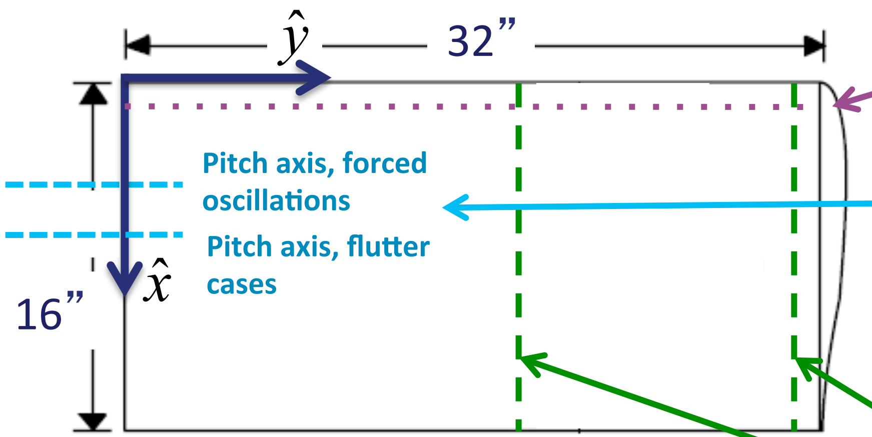
BSCW Test Configurations



Model planform. Dimensions are in inches.

<u>Transition Strip</u>: 7.5% chord

<u>Pitch Axis:</u>
<u>Forced Oscillation, (OTT Test)</u>: Pitching motion about 30% chord
<u>Flutter, (PAPA Test):</u> Pitching motion about 50% chord

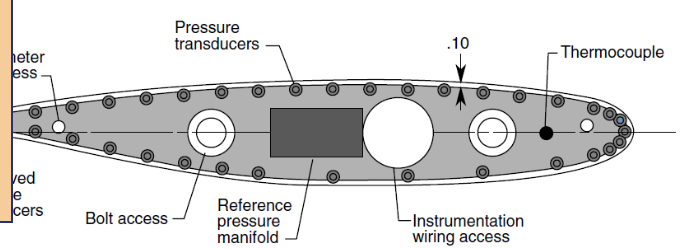
<u>Unsteady Pressure Measurements</u>:

- 1 chord fully-populated at 60% span for both tests
- Outboard chord at 95% span populated for the PAPA test only (not for forced oscillation cases)

<u>60% span station: 40 In-Situ Unsteady Pressure Transducers</u>:

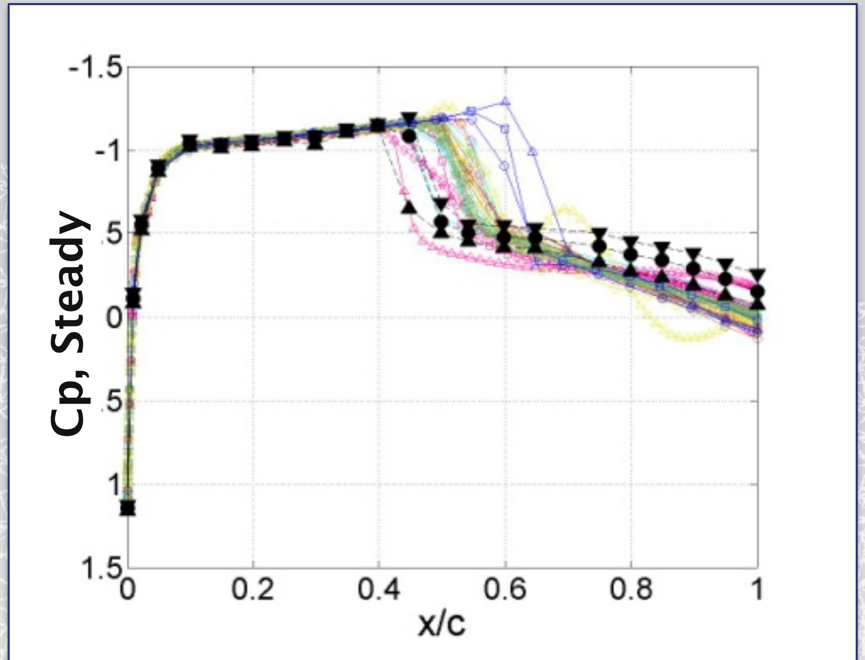
- 22 upper surface
- 17 lower surface
- 1 leading edge

Airfoil section is SC(2)-0414



Cross-section at 60% span, showing the layout of the unsteady pressures.

AePW-1 Results:
BSCW, Mach 0.85, Re 4.5M, $\alpha = 5°$
Upper surface at 60% span



- ● Experimental data
- ▲ Bounds, ± 2 std

Colored lines with open symbols:

- Each analysis team shown by a separate color
- Each grid size shown by a different symbol

Frequency Response Function at 10Hz