AePW-3 High Angle Working Group

November 29, 2022

https://nescacademy.nasa.gov/workshops/AePW3/public

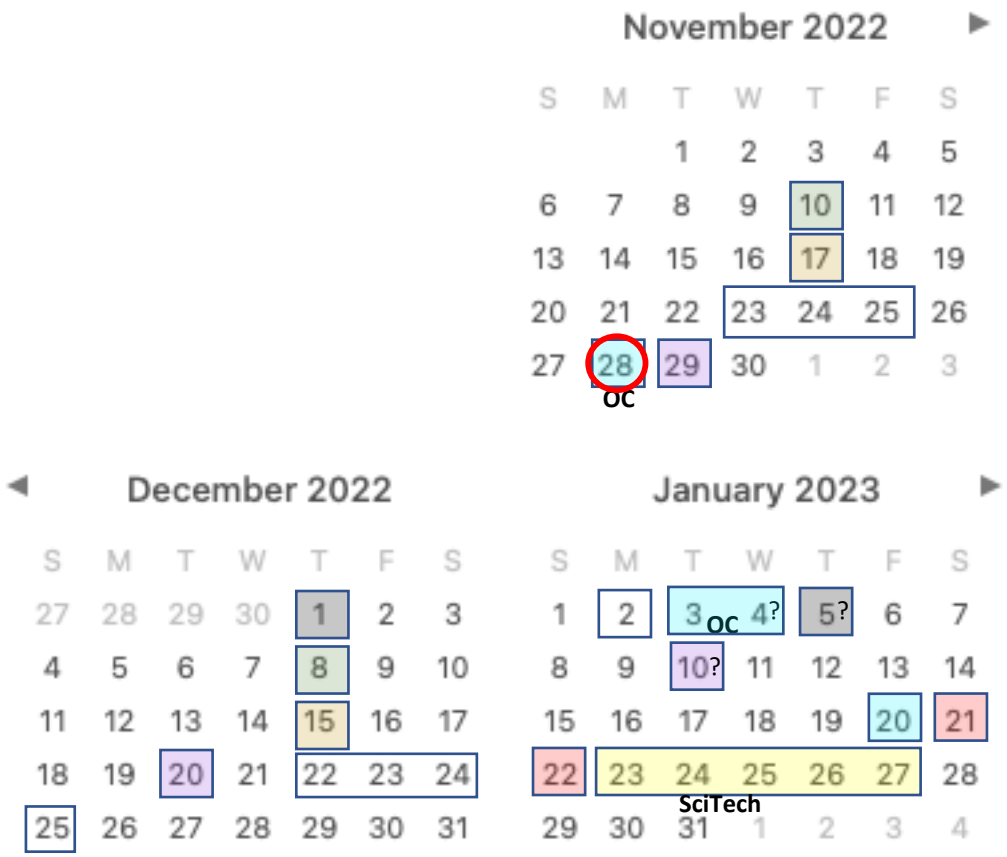
Next AePW-3 Meeting: December 1, 2022

Next High Angle Working Group Meeting, December 20, 2022

High Angle WG, November 29

Agenda:

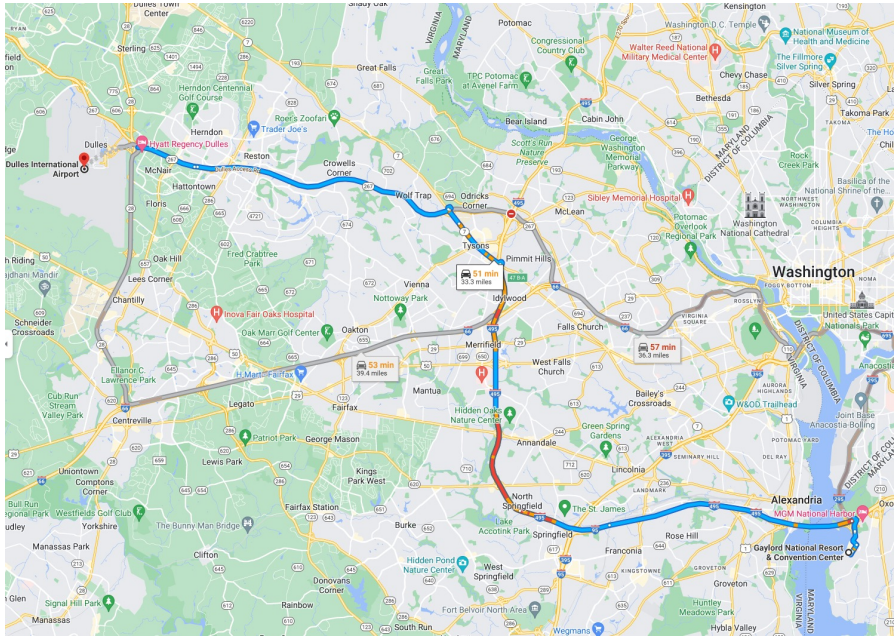
- Workshop and SciTech 2023
- Workshop data submission and preparation: NASA, Pawel



- ALL
- HDWG
- FSWG/HSWG
- HAWG
- OC
- US holidays
- SciTech 2023
- AePW-3

SciTech 2023: AePW-3 Workshop

AIAA Science and Technology Forum and Exposition (2023 AIAA SciTech Forum)
23–27 January 2023
Gaylord National Harbor
National Harbor, MD



40 to 60 minutes drive time from Dulles Airport to National Harbor

- Workshop will take place 53 days from today, January 21-22, 2023.
- Conference and workshop registrations are open:
  - The base workshop registrations fees are set by AIAA as: $299 early member/$399 late member/$499 standard non-member.
  - No student discount registration fee (unfortunately!)
  - It is possible to register for the workshop only.
- Workshop format:
  - All four working groups will present results in the same room.
  - Time allocation for presentations will depend on number of teams participating in workshop.
  - Each working group session will have an introductory presentation and a final presentation with results.
- Virtual access: Yes, there is still workshop fee to participate virtually. AIAA recommends against virtual participation because of organizational and technical issues based on past workshops.
- We will have a breakout room available for side discussions.
- Joint Publications at SciTech 2024.
- We will consider a special AIAA Journal publication with AePW-3 results.

High Angle Working Group Teams / Participants

Cases:

1. Flutter
2. Shock buffet

Red – Yes

Blue - Maybe

TEAM	Cases
NASA Langley, USA	1,2
Technion, Israel	1,2
USAFA, USA	1,2
BAE Systems, UK	1
UZ, Switzerland	1
IIS, India	1,2
UN, Australia	1,2
Bombardier, Canada	1
CREATE-AV, USA	1,2
Hexagon, Japan	1
Duke University, USA	1
Metacomp Tech., USA	1

AePW-3 Workshop Agenda, Day 1, Saturday, January 21, 2023

Preliminary

7:00	**Registration**	
7:00 – 8:00	Breakfast	
8:00	01	Welcome / Overview
8:30	02	Walt Silva: Importance of Benchmark Experiments
9:00	03	High Angle WG Overview / Experimental Data
9:30	Break, 15 minutes	
9:45	04	BSCW Flutter: 2 hours / 6 presentations / 15 minutes each + summary
11:45	Lunch, 1.25 hours	
13:00	05	BSCW Shock Buffet: 2 hours / 5 presentations + summary
15:00	Break, 15 minutes	
15:15	06	Flight Test WG Overview / Flight Data
15:30	07	1 hour / 4 presentations / 15 minutes each / summary discussion
16:30	Adjourn	

AePW-3 Workshop Agenda, Day 2, Sunday, January 22, 2023

Preliminary

7:00	**Registration**	
7:00 – 8:00	Breakfast	
8:00	08	Welcome / Overview
8:15	09	High Deflection WG Overview / Experimental Data
8:45	10	1 hour / 4 presentations / 15 minutes each
9:45	Break, 15 minutes	
10:00	11	1.5 hours / 6 presentations / 15 minutes each + summary
11:30	Lunch, 1.25 hours	
12:45	12	High Speed WG Overview / Experimental Data
13:15	13	Hymax: 1.5 hours / 6 presentations / 15 minutes each
14:45	Break, 15 minutes	
15:00	14	RC19: 1.5 hours / 6 presentations / 15 minutes each + summary
16:30	Break, 15 minutes	
16:45	15	Future Direction for AePW / General Discussion
18:30	Adjourn	

High Angle Working Group:
BSCW flutter analysis at Mach 0.8 and shock-buffet environment

Dansberry, B., et al., "Experimental Unsteady Pressures at Flutter on the Supercritical Wing Benchmark Model ," AIAA Paper 93-1592-CP

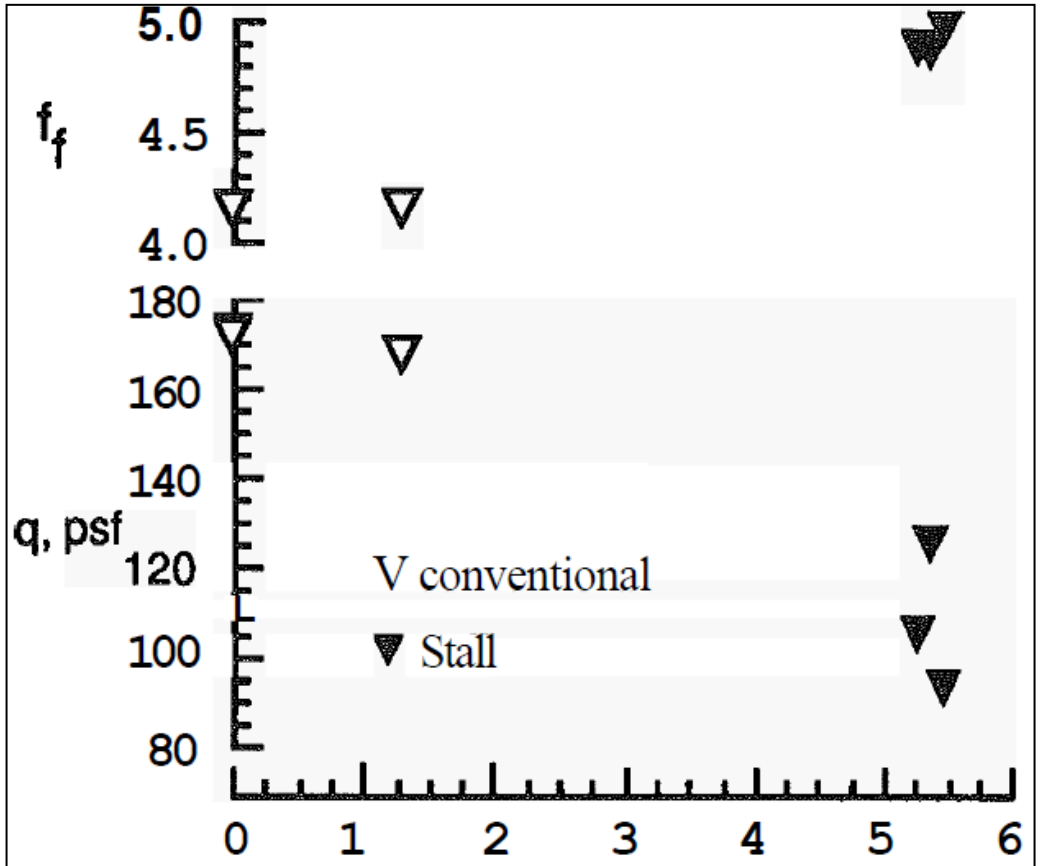


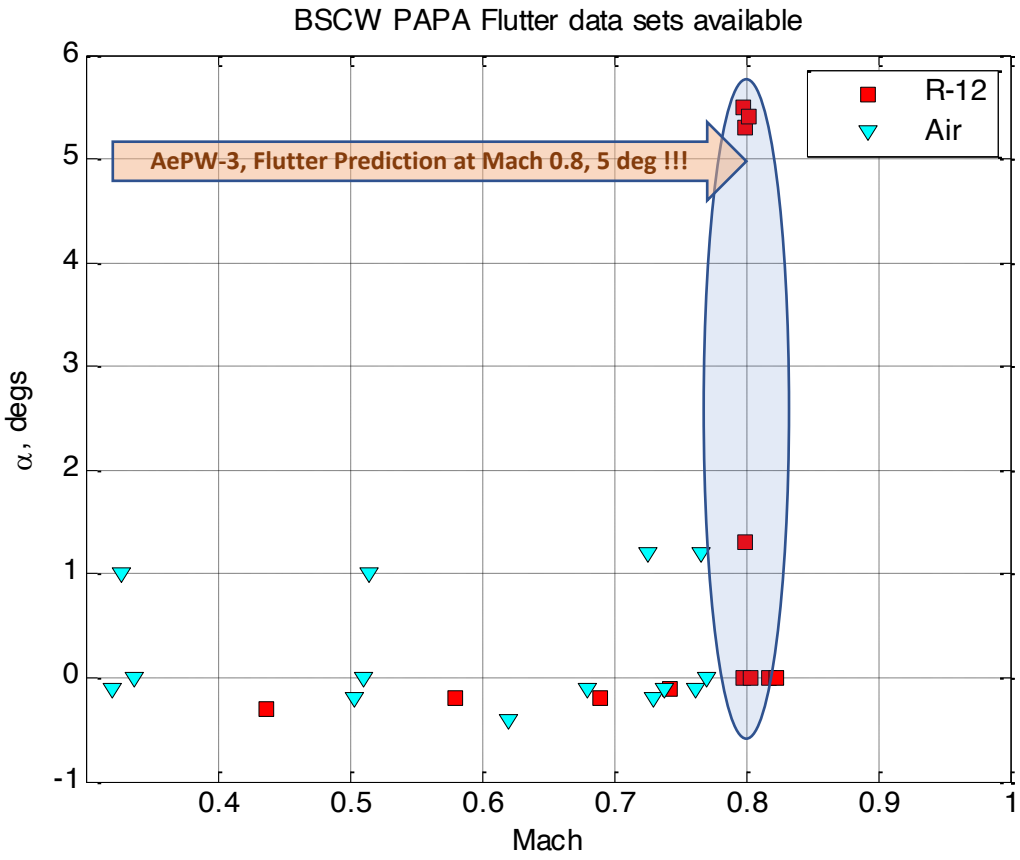
Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Table 2. AePW-3 Workshop Test Cases.

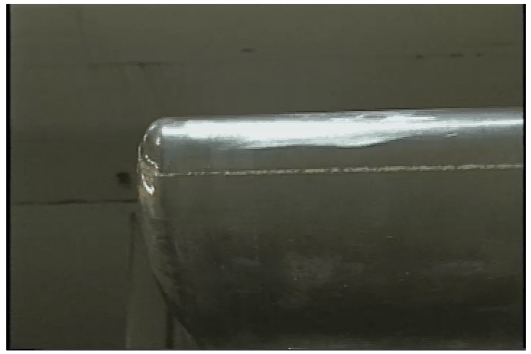
	Case #1	Case #2
Mach	0.8	0.8
AoA	5°	5°
Dynamic Data Type	Flutter Unsteady	Unforced Unsteady
Notes	- Attached / Separated - PAPA exp. data - R-134a	- Shock buffet (?) - OTT exp. data - R-134a

- Two topics for AePW-3 High Angle Working Group
  - Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Buffet analysis, BSCW rigid wing, unsteady flow

Flutter prediction based on experimental data published in AIAA-93-1592



Buffet analysis based on experimental data described in AIAA-2013-1802

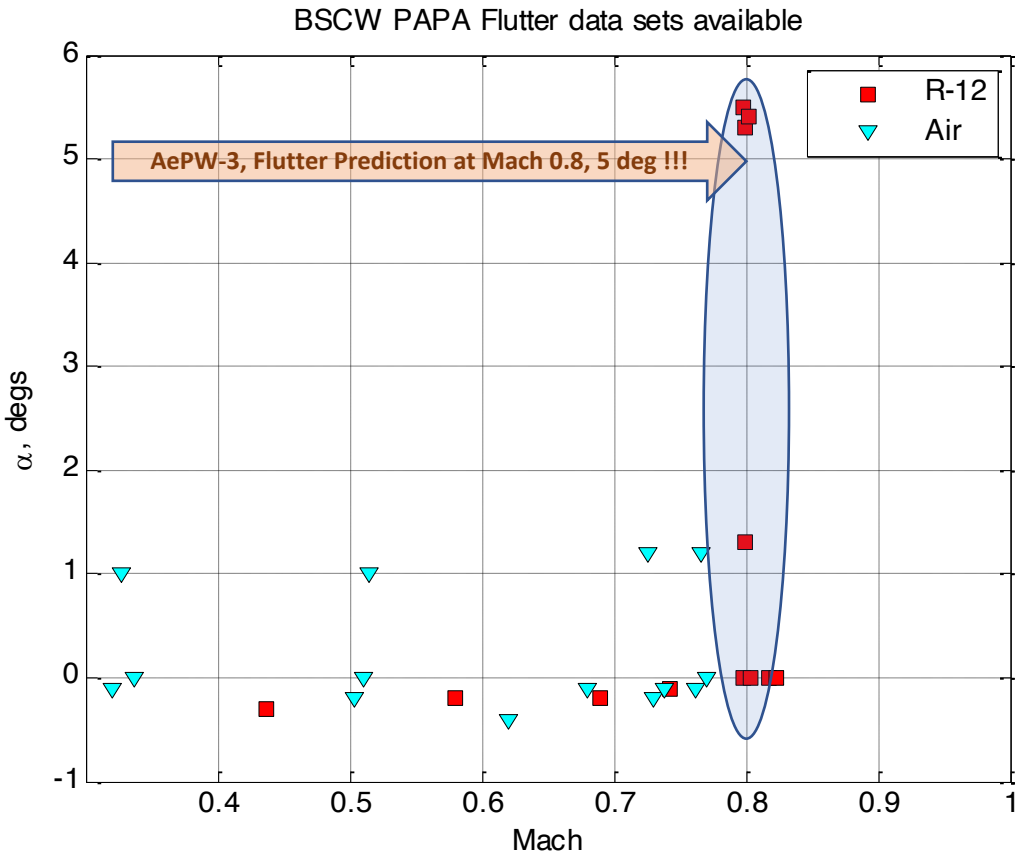


AoA = -1*, 0, 1, 2*, 3, 5 deg

Q / Mach psf	0.5	0.6	0.7	0.8	0.85	0.87
100	x	x	x	x		x
170	x	x	x	x		x
200				x	x	

- Two topics for AePW-3 High Angle Working Group
  - Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Buffet analysis, BSCW rigid wing, unsteady flow

Flutter prediction based on experimental data published in AIAA-93-1592



Case 1. BSCW flutter prediction at Mach 0.8, AoA = 5 deg.

⇒ Flutter Q at two or more mesh resolutions.

⇒ Time vector, generalized displacement/velocity, dynamic pressure, free stream velocity, perturbation method.

⇒ Damping values vs. Q at two or more mesh resolutions – what method LogDec, etc.

⇒ Time history of vertical displacement: leading edge and trailing edge at all Qs and all mesh resolutions.

⇒ Rigid steady CL, CD, and Cm coefficients, Q = 100 psf

⇒ Cp vs. x/c at 60% wing span from rigid steady solution, Q = 100 psf.

⇒ Cp and skin friction distribution on entire surface: Tecplot ??? Tecplot layout/macro, PyTecplot???

⇒ Cp vs. x/c at 60% wing span from the static aeroelastic solution, if applicable.

⇒ Perturbation size and type, if applicable, at the start of the dynamic solution.

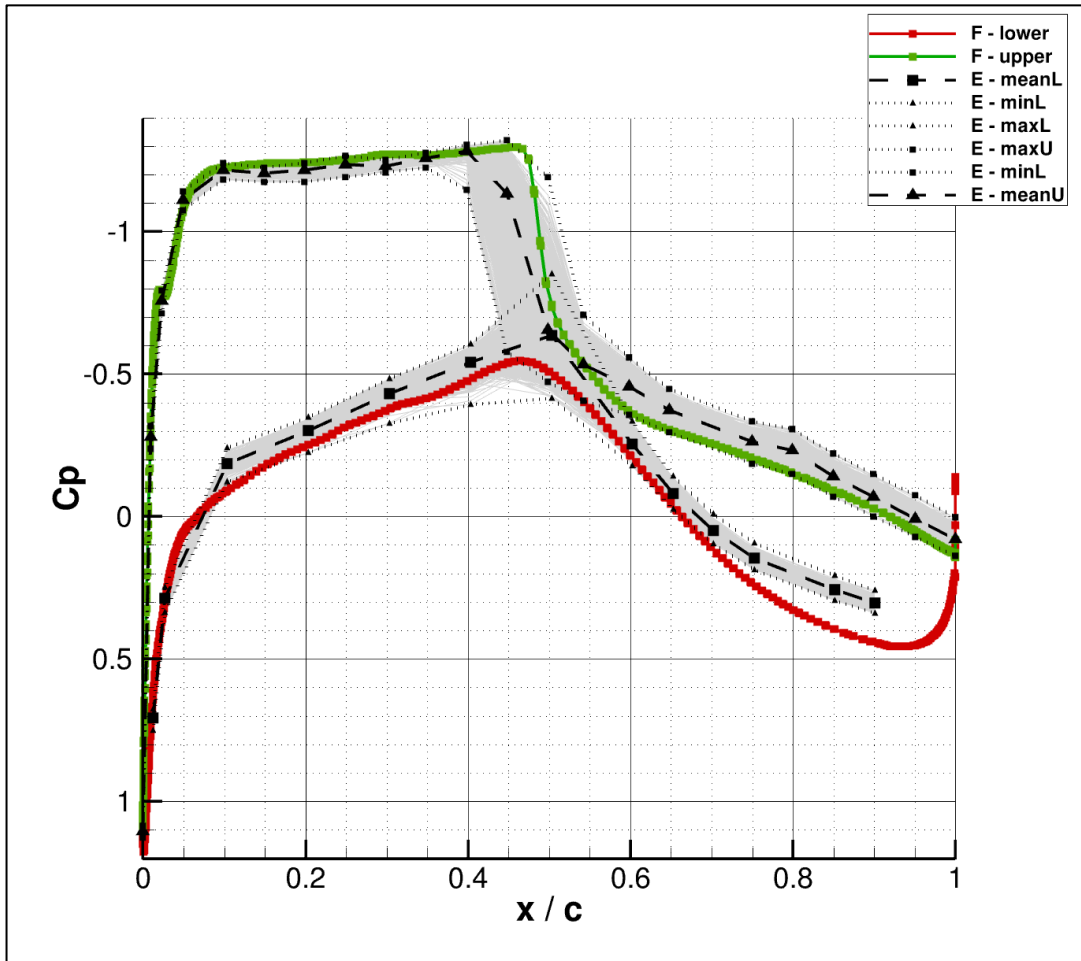
⇒ Time-step size and temporal resolution study, if applicable.

⇒ Definition of spatial and temporal schemes and mesh type.

⇒ Turbulence model information, and/or URANS vs. LES (?)

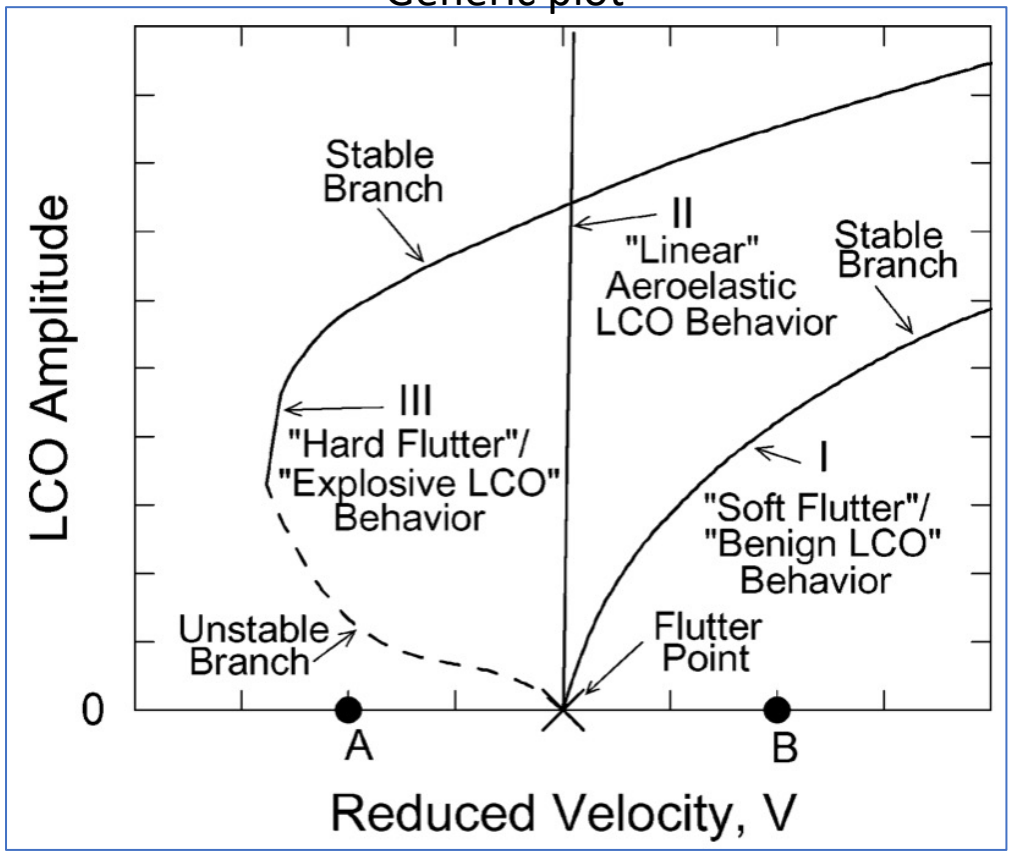
- Data submission: Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - CL, CD, and Cm coefficients at Q = 100 psf
    - Steady rigid or unsteady rigid (mean values)
    - Cm reference point is the leading edge of the wing
  - Cp vs. x/c at 60% wing at Q = 100 psf
    - Steady rigid or unsteady rigid (mean values)
    - Upper and lower surfaces separated and sorted from the leading to trailing edge

  - Surface pressure and skin friction: Tecplot file ?
    - Is it possible to convert your output to Tecplot?
    - If not, please provide ascii file with
      x, y, z, cp, skin friction

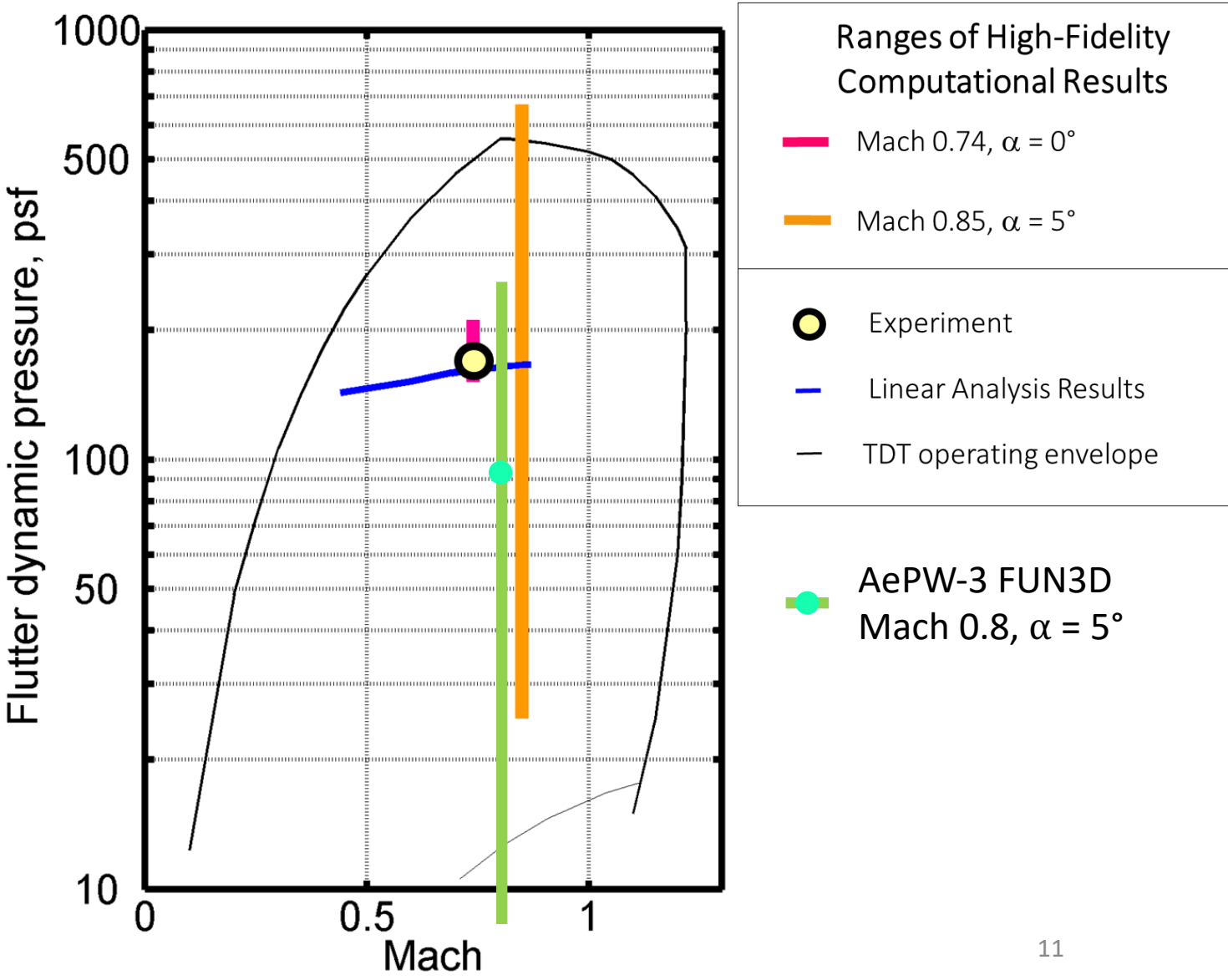


- Data submission: Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Flutter Q at two or more mesh resolutions
  - Time vector, generalized displacement/velocity at ALL Qs
    Or time vector, plunge/pitch histories
  - UNITS !!!
  - Perturbation method.
  - Splined mode shapes.

Generic plot



AePW-2



- Data submission: Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Time-step size and/or temporal resolution study, if applicable.
  - Definition of spatial and temporal schemes and mesh type.
  - Turbulence model information, and/or URANS vs. LES (?)
  - How long does it take to obtain a flutter point: # of cores, wall time, etc.

- Two topics for AePW-3 High Angle Working Group
  - Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Buffet analysis, BSCW rigid wing, unsteady flow

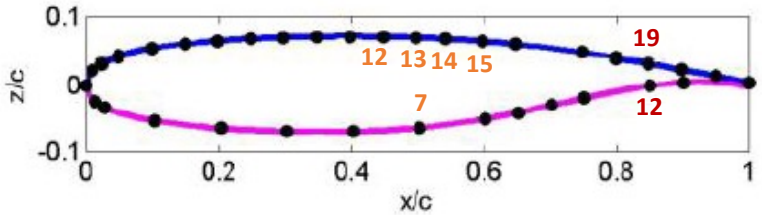
Case 2. BSCW shock buffet at Mach 0.8, AoA = 5deg, Q = 169 psf

⇒ Steady CL, CD, and Cm coefficients.
⇒ Steady Cp vs. x/c at 60% wing span from rigid steady solution.
⇒ Cp and skin friction distribution on entire surface: Tecplot ??? Tecplot layout/macro, PyTecplot???
⇒ Unsteady:

1. Mean Cp vs. x/c at 60%
2. RMS Cp vs. x/c at 60%
3. RMS surface pressure, Tecplot ???, Shock shape ???
4. PSD – CL (global time history)
5. PSD – Cp at additional points behind the shock.
6. Time-step size and temporal resolution, if applicable.
7. Definition of spatial and temporal schemes and mesh type.
8. Turbulence model information, and/or URANS vs. LES (?)

Table 3. Pressure orifice locations, x/c, at 60% span

Upper		Lower	
Transducer #	x/c	Transducer #	x/c
1	0	1	0.012
2	0.009	2	0.027
3	0.023	3	0.103
4	0.049	4	0.203
5	0.099	5	0.303
6	0.149	6	0.403
7	0.198	7	0.503
8	0.249	8	0.602
9	0.298	9	0.652
10	0.348	10	0.702
11	0.398	11	0.752
12	0.448	12	0.851
13	0.498	13	0.901
14	0.542		
15	0.598		
16	0.648		
17	0.749		
18	0.799		
19	0.849		
20	0.899		
21	0.95		
22	1		



AoA = -1*, 0, 1, 2*, 3, 5 deg

Q / Mach psf	0.5	0.6	0.7	0.8	0.85	0.87
100	x	x	x	x		x
170	x	x	x	x		x
200				x	x	

- Data submission: Shock-buffet prediction: BSCW at Mach 0.8, AoA = 5deg, Q=169 psf
  - Time history of CL, CD, and Cm coefficients
    time, CL, CD, Cm
  - Time history of Cp at discrete points
    time, 12, 13,……..
  - RMS Cp vs. x/c at 60%
  - RMS surface pressure, Tecplot
  - PSD – CL (global time history)
  - PSD – Cp at 12, 13,…….
  - Strouhal number
  - How long does it take to obtain a solution point: # of cores, wall time, et

Table 3. Pressure orifice locations, x/c, at 60% span

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19	0.849		
20	0.899		
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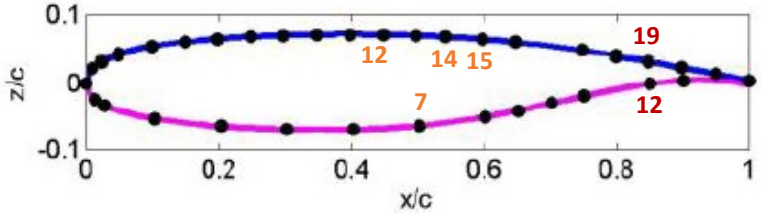
22	1		



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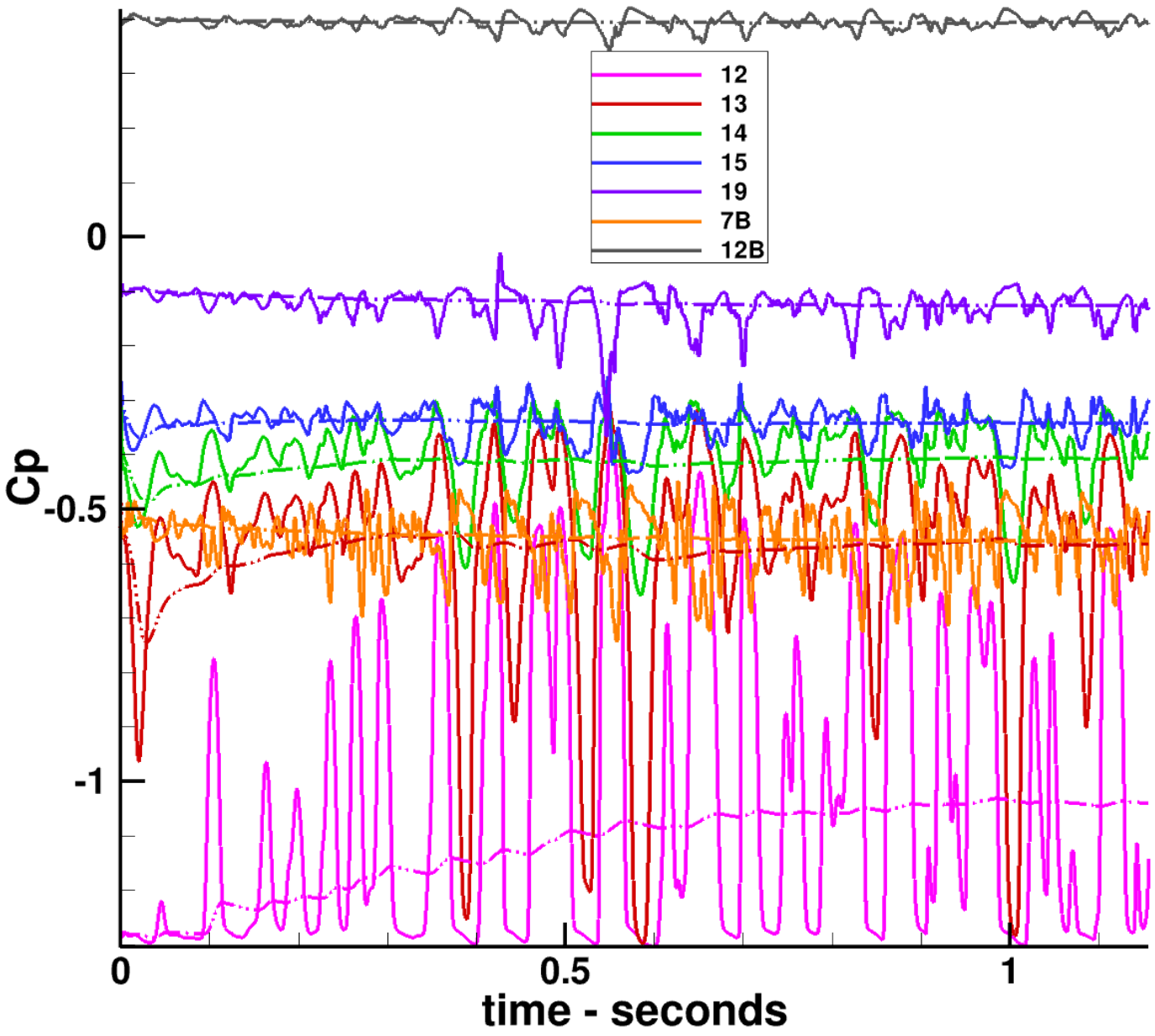

A = 5deg, Q=169 psf

Table 3. Pressure orifice locations, x/c, at 60% span

Upper		Lower	
Transducer #	x/c	Transducer #	x/c
1	0	1	0.012
2	0.009	2	0.027
3	0.023	3	0.103
4	0.049	4	0.203
5	0.099	5	0.303
6	0.149	6	0.403
7	0.198	7	0.503
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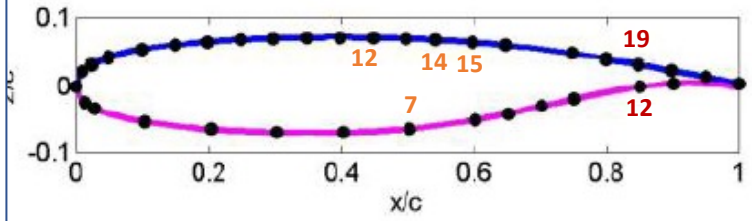
18	0.799		
19	0.849		
20	0.899		
21	0.95		
22	1		

tc.



PSD Matlab function

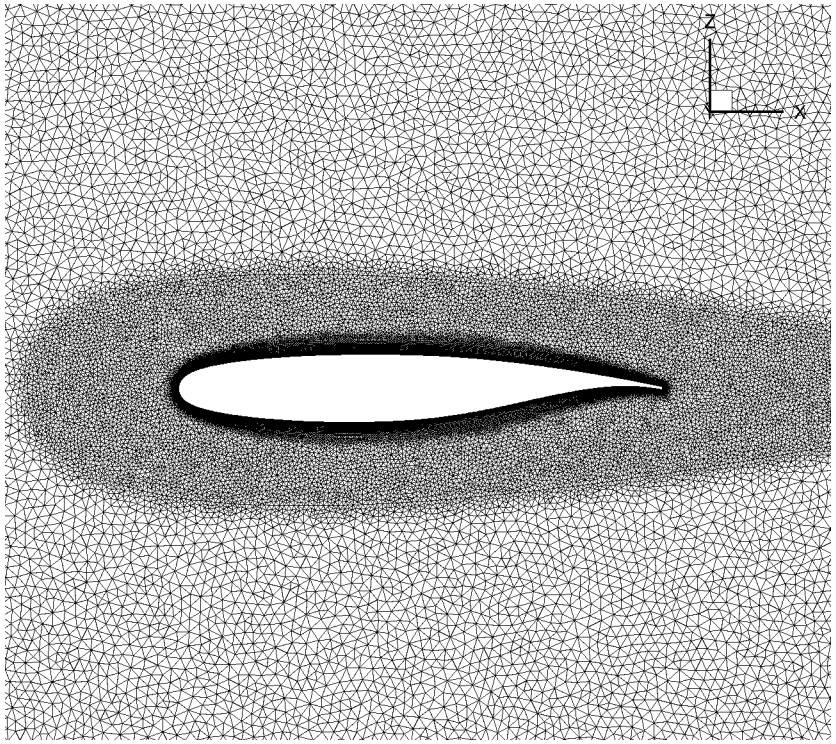
```
clear
close all
clc

load(['Mach0p8Q170.mat'])  % Load .mat file of interest
aid=5;  % Index of angle of interest from vector 'angles'
Pid=[12 13 14 15 19 29 34]; % Index of pressure taps of interest (1-35)
% FRF/PSD settings
nfft_psd=2^11;        % Number of frequncies specified
overlap_fac=0.667;  % Window overlap factor
N_overlap=floor(overlap_fac * nfft_psd);
% uses hamming window
% replace hamming(nfft_psd) with rectwin(nfft_psd) for rectangular window or

for j=1:numel(angles)
    % Remove Previous frequency data
    Data{j}=rmfield(Data{j},{'magPSD','freqPSD','redfreqPSD',...
        'strouhalPSD','magFFT','freqFFT','redfreqFFT','strouhalFFT'});
    for i=1:35
%         Data{j}.cPmax(i)=max(Data{j}.cP(:,i));
%         Data{j}.cPmin(i)=min(Data{j}.cP(:,i));
%         Data{j}.cPmean(i)=mean(Data{j}.cP(:,i));
        [Data{j}.magPSD(:,i) Data{j}.freqPSD(:,i)]=pwelch(Data{j}.cP(:,i)-...
            mean(Data{j}.cP(:,i)),hamming(nfft_psd),N_overlap,nfft_psd,...
            Data{j}.samp);

        Data{j}.redfreqPSD(:,i)=(Data{j}.freqPSD(:,i)*2*pi*(16/12))./(2*...
            Data{j}.V);
        Data{j}.strouhalPSD(:,i)=(Data{j}.freqPSD(:,i)*(16/12))./(...
            Data{j}.V);
    end
end

for j=1:numel(angles)  % FFT of full time sample (Bin for zero Hz freq excluded, way too high?)
    for i=1:35
        Data{j}.fft(:,i)=fft((Data{j}.cP(:,i)-mean(Data{j}.cP(:,i)))*...
            (Data{j}.Q/144),length(Data{j}.cP(:,i)));
        Data{j}.magFFT(:,i)=abs(Data{j}.fft(1:length(Data{j}.cP(:,i))/2+...
            1,i))*2/length(Data{j}.cP(:,i));
        Data{j}.freqFFT(:,i)=Data{j}.samp*(0:length(Data{j}.cP(:,i))/2)/...
            length(Data{j}.cP(:,i));
        Data{j}.redfreqFFT(:,i)=(Data{j}.freqFFT(:,i)*2*pi*(16/12))./(2*...
            Data{j}.V);
        Data{j}.strouhalFFT(:,i)=(Data{j}.freqFFT(:,i)*(16/12))./(...
            Data{j}.V);
    end
end

% Upper and lower x/c values corresponding to pressure taps 1-35 if needed
xocupper=[0 0.009 0.023 0.049 0.099 0.149 0.198 0.249 0.298 0.348...
    0.398 0.448 0.498 0.542 0.598 0.648 0.749 0.799 0.849 0.899 0.95 1];
xoclower=[0.012 0.027 0.103 0.203 0.303 0.403 0.503 0.602 0.652 0.702...
    0.752 0.851 0.901];
% Plot all PSDs
for i=1:length(Pid)
    figure
    loglog(Data{aid}.freqPSD(:,Pid(i)),Data{aid}.magPSD(:,Pid(i)),'r-o')
    grid on
    title(['M=' num2str(round(Data{aid}.Mach,2)) ', AoA=' num2str(angles(aid)) ', Q=' num2str(round(Data{5}.Q),-1) 'psf, Pt ' num2str(Pid(i))])
    xlabel('Frequency [Hz]')
    ylabel('Magnitude [PSI^2/Hz]')
end

%Plot all cPs
for i=1:length(Pid)
    figure
    plot(Data{aid}.time,Data{aid}.cP(:,Pid(i)),'b-')
    grid on
    title(['M=' num2str(round(Data{aid}.Mach,2)) ', AoA=' num2str(angles(aid)) ', Q=' num2str(round(Data{5}.Q),-1) 'psf, Pt ' num2str(Pid(i))])
    xlabel('Time [seconds]')
    ylabel('Cp')
end
```

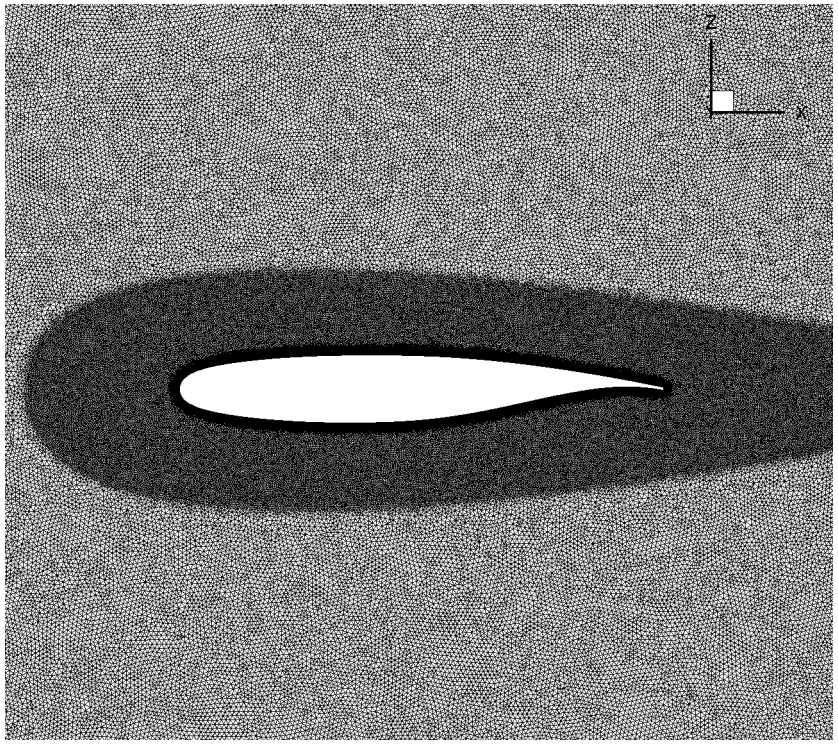
BSCW 2D Shock Buffet Analysis

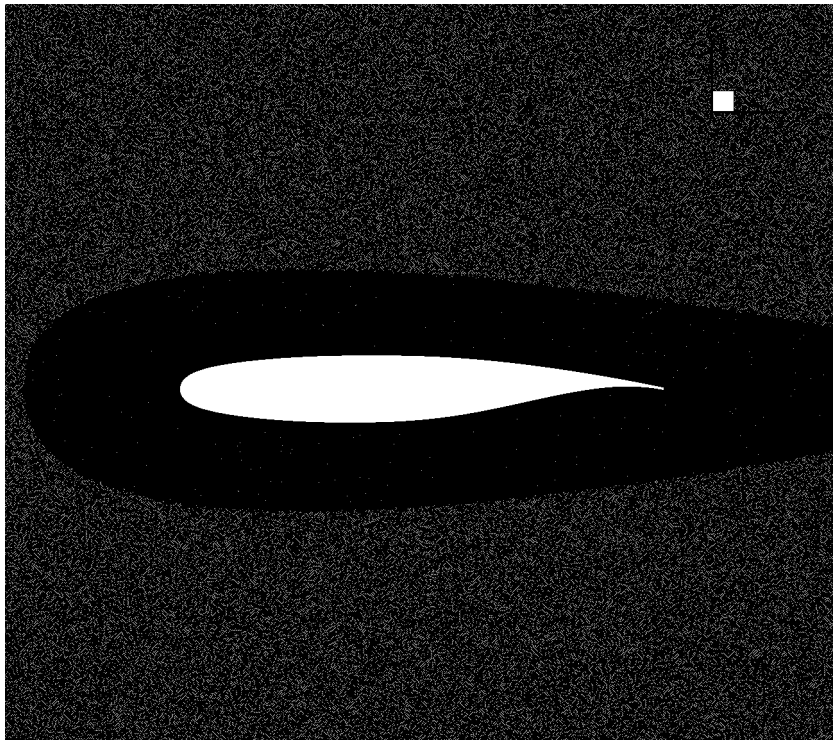
Pawel Chwalowski

- Meshes generated using Pointwise
- 2D implies a mesh with a unit depth of one cell in ‘spanwise’ direction
- Three meshes generated: Coarse, Medium, Fine
- URANS analysis with SA, SA w/compressibility correction (CC), and DDES
- Mach 0.6, 0.7, 0.74, 0.78, 0.8 with matched-point conditions from TDT’s tunnel parameter code across AoAs and at Q = 169 psf !
- 2D conclusions applied to 3D coarse BSCW mesh currently used in AePW-3 analysis

Three meshes generated: Coarse, Medium, Fine







SA + CC + Limiter

N – Steady Flow
Y – Fluctuations in CL
N – Initial fluctuations in CL

Coarse Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4	N	N	Y	N	N
5	N	Y	Y	N	N
6	N	Y	Y	N	

DDES -> N

Medium Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4				N	
5			N	N	
6				N	

+ QCRRC

Medium Mesh, dt = 0.00002 sec, 160 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			Y	N	
6					

animation

Medium Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			N		
6					

- CC + DDES

Medium Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			Y		
6					

SA + CC + Limite

N – Steady Flow

Y – Fluctuations in CL

N – Initial fluctuations in CL

Coarse Mesh, dt = 0.0002 sec, 16

AoA (deg.) / Mach	0.60	0.70	0
4	N	N	
5	N	Y	
6	N	Y	

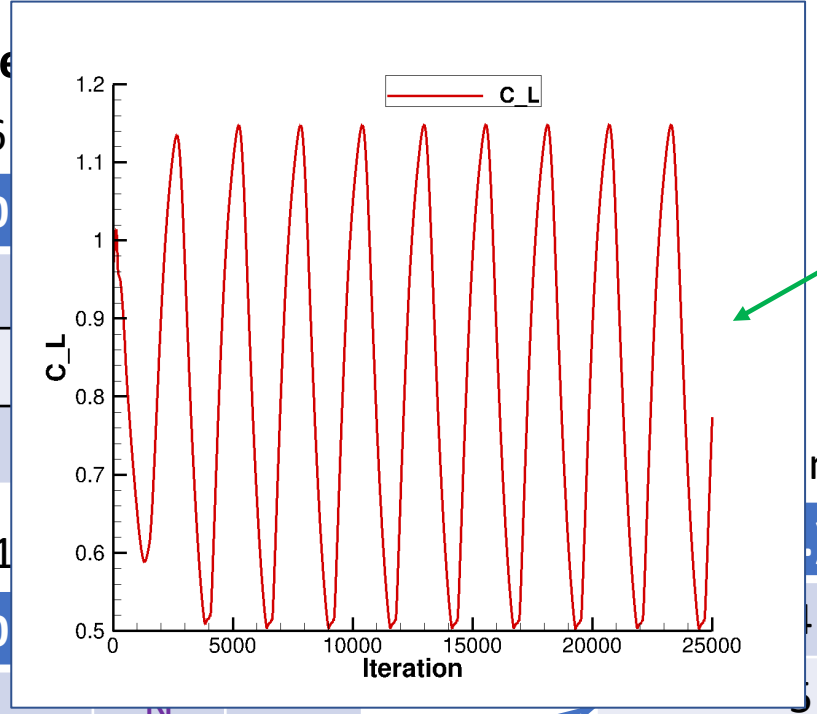
Medium Mesh, dt = 0.0002 sec, 1

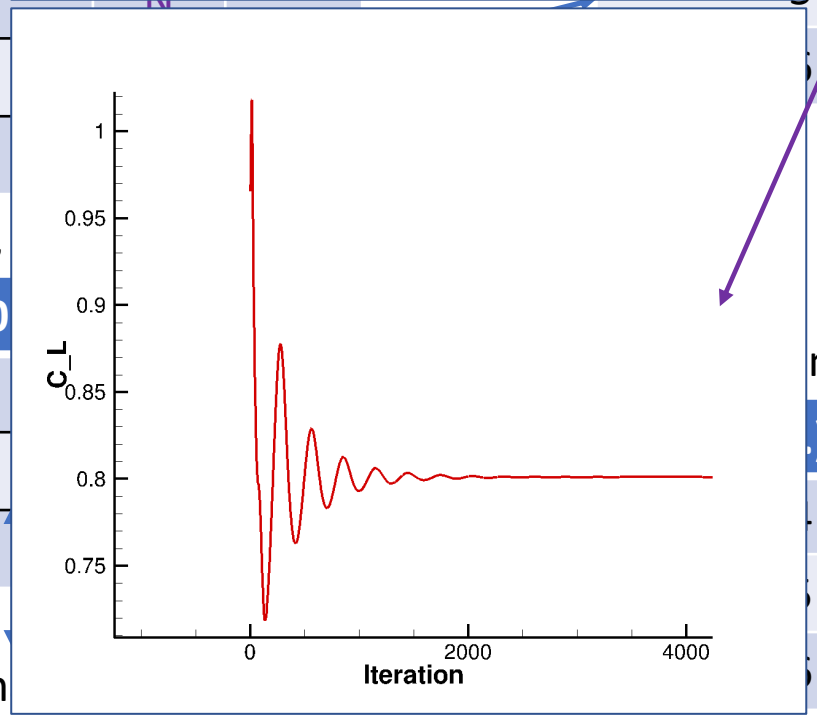
AoA (deg.) / Mach	0.60	0.70	0
4			
5			
6			

Medium Mesh, dt = 0.00002 sec,

AoA (deg.) / Mach	0.60	0.70	0
4			
5			
6			

anim





m Mesh, dt = 0.0002 sec, 16 steps/chord

) / Mach	0.60	0.70	0.74	0.78	0.80
			N		

- CC + DDES

m Mesh, dt = 0.0002 sec, 16 steps/chord

) / Mach	0.60	0.70	0.74	0.78	0.80
			Y		

SA + CC + Limiter

N – Steady Flow
Y – Fluctuations in CL
N – Initial fluctuations in CL

Coarse Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4	N	N	Y	N	N
5	N	Y	Y	N	N
6	N	Y	Y	N	

DDES -> **N**

Medium Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4				N	
5			N	N	
6				N	

Medium Mesh, dt = 0.00002 sec, 160 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			Y	N	
6					

animation

Medium Mesh, dt = 0.000002 sec, 1600 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5				N	
6					

SA + CC + Limiter

N – Steady Flow

Y – Fluctuations in CL

N – Initial fluctuations in CL

Coarse Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4	N	N	Y	N	N
5	N	Y	Y	N	N
6	N	Y	Y	N	

DDES -> **N**

Medium Mesh, dt = 0.0002 sec, 16 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4				N	
5			N	N	
6				N	

Medium Mesh, dt = 0.00002 sec, 160 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			Y	N	
6					

animation

Fine Mesh, dt = 0.000002 sec, 1600 steps/chord

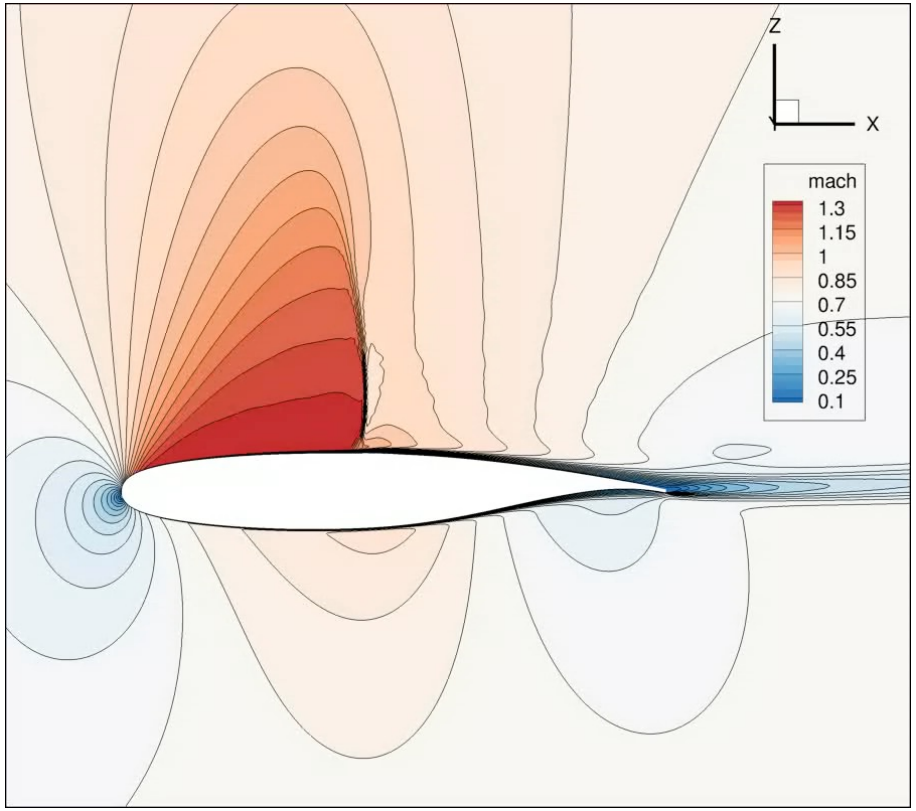
AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5				N	
6					

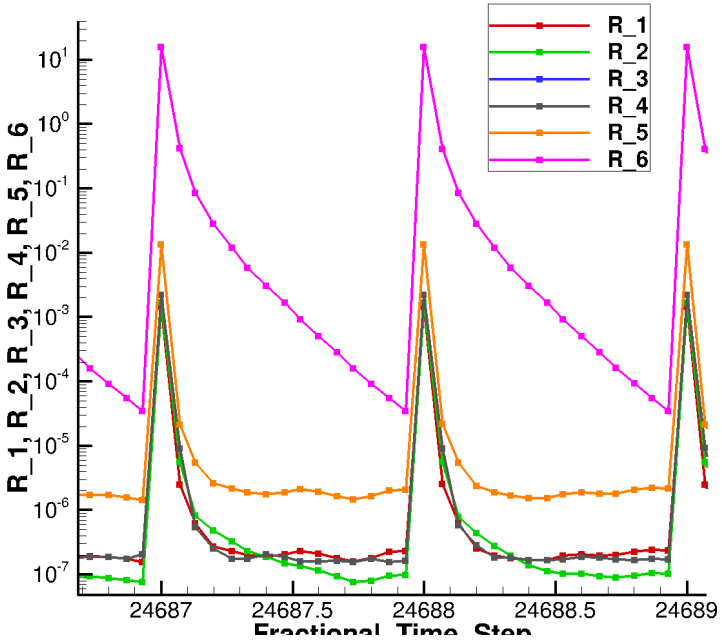
DDES -> **N**

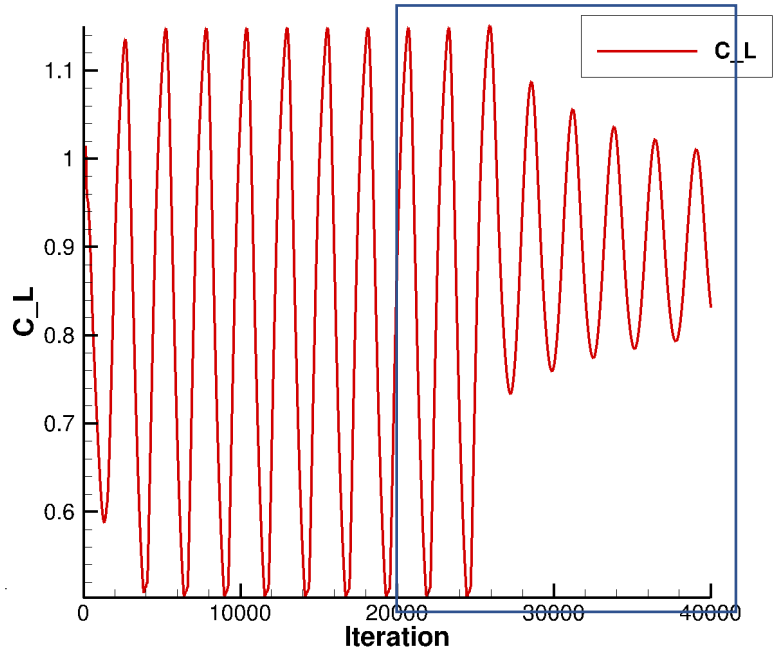
Medium Mesh, dt = 0.00002 sec, 160 steps/chord

AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5			Y		
6					

animation

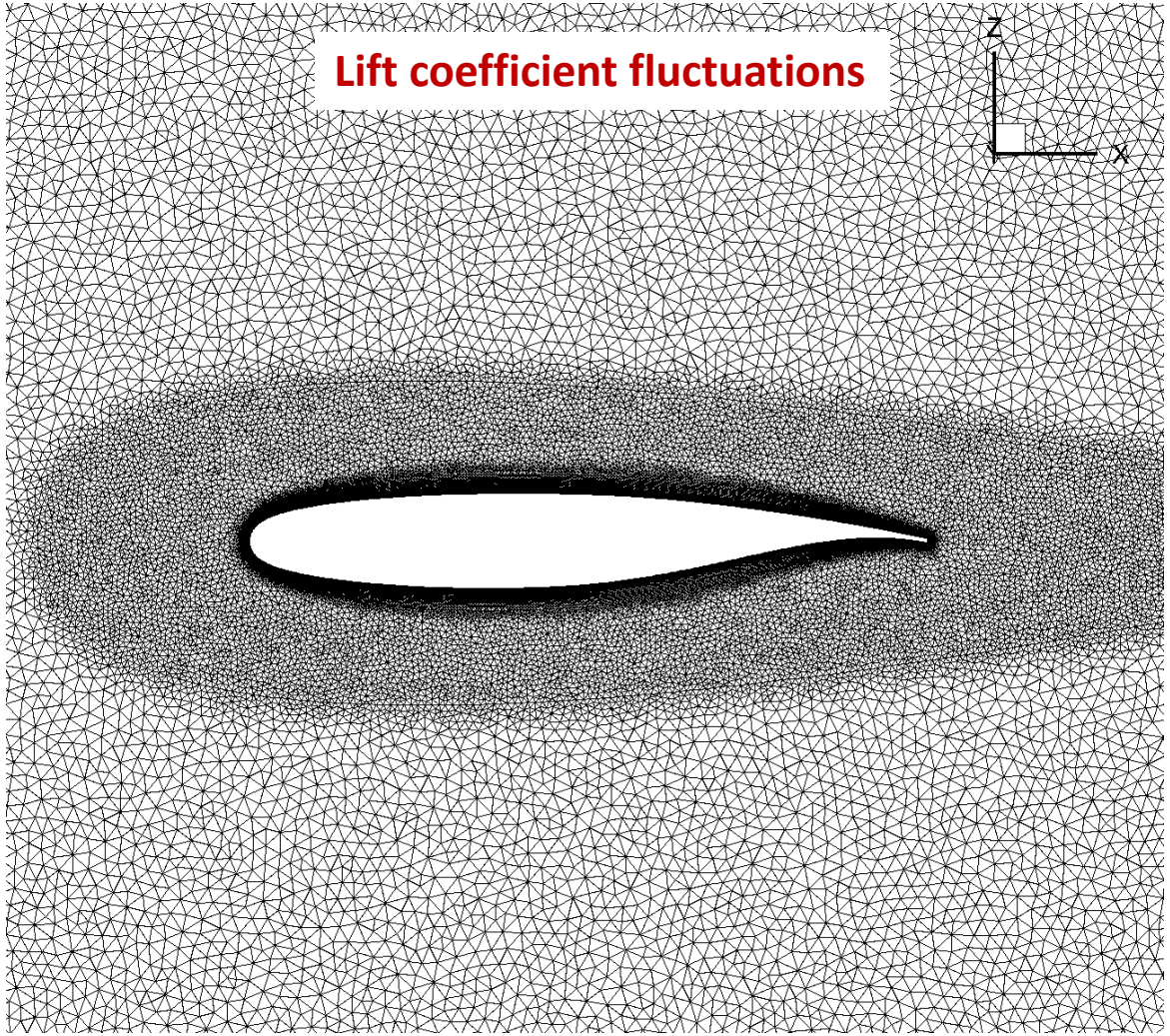




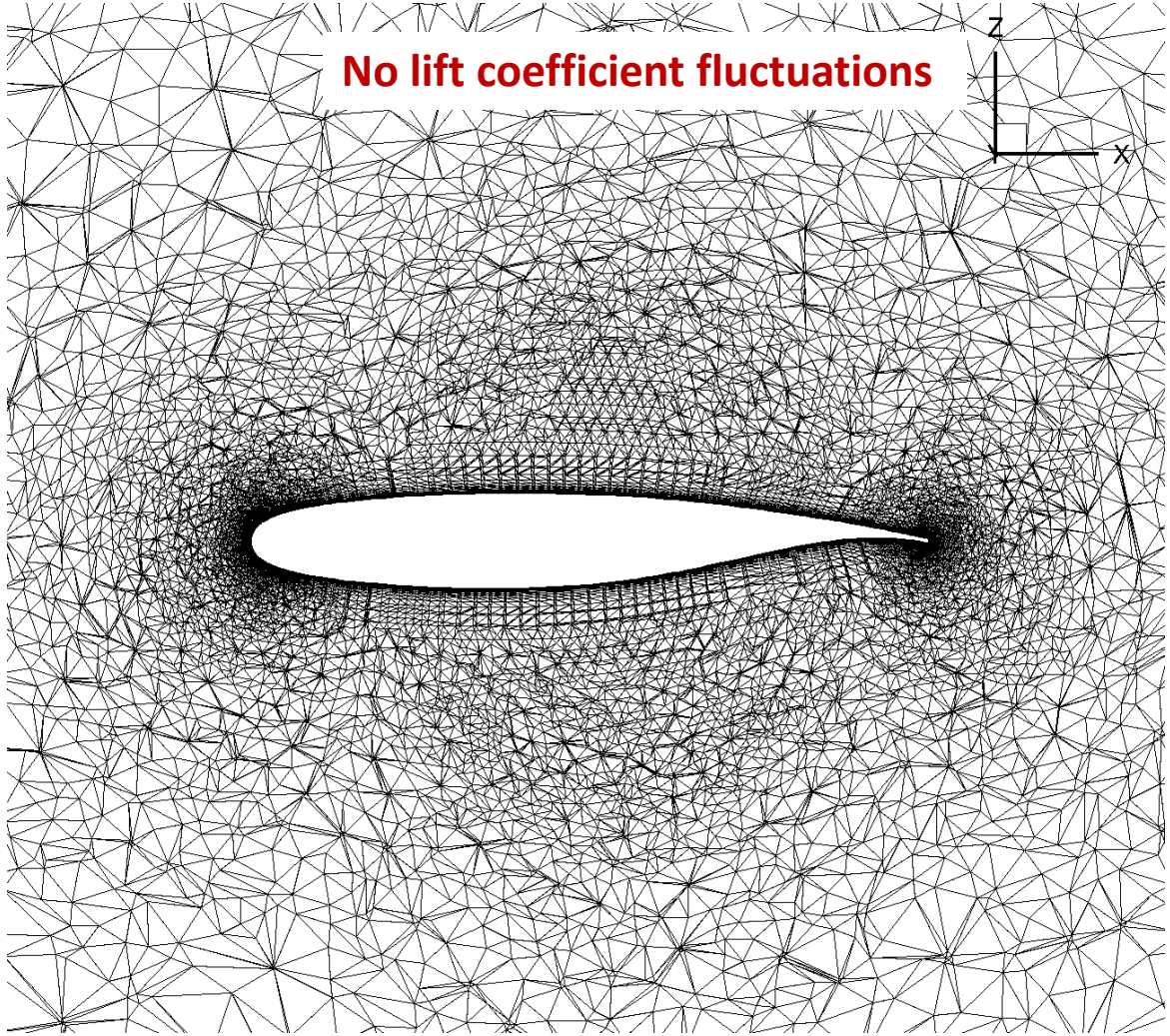
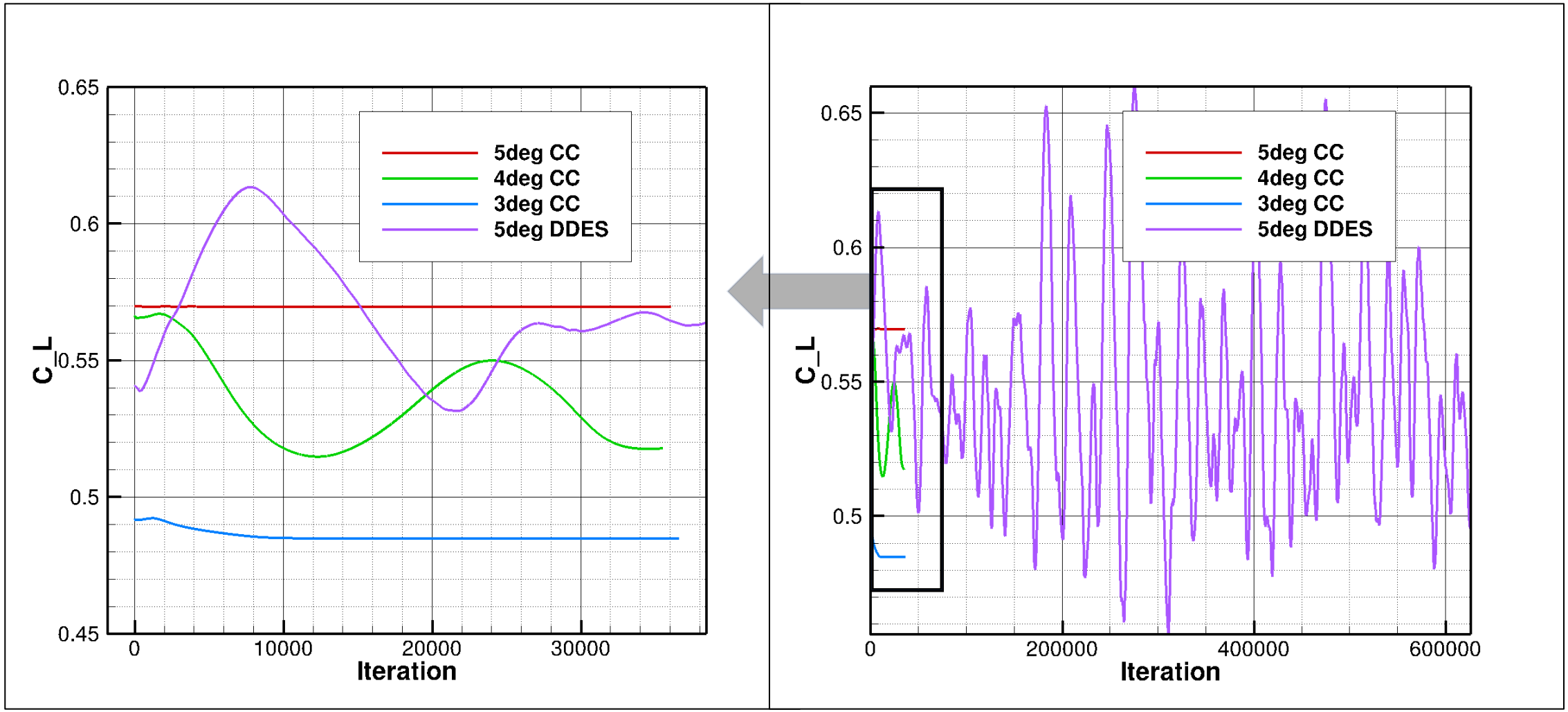


2D vs. 3D Mach 0.74, AoA = 5deg w/ Compressibility Correction and Limiter

Coarse 2D



Coarse 3D (BSCW Coarse, 3M) at 60% wingspan



3D Fine Mesh (27M) Mach 0.8, AoA = 3, 4, 5deg
FUN3D w/ Compressibility Correction and Limiter vs. DDES