AePW-3 High Angle Working Group

October 27, 2022

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

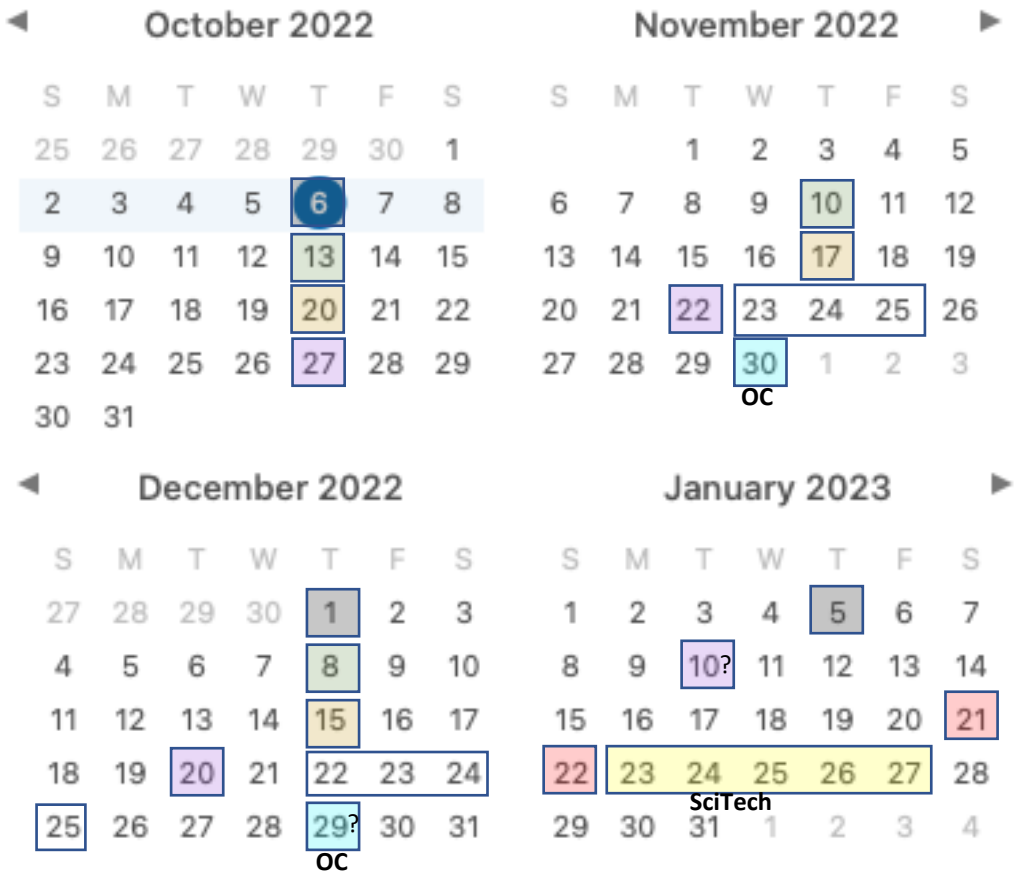
Next AePW-3 Meeting: December 1, 2022

Next High Angle Working Group Meeting, November 22, 2022

High Angle Working Group, October 27, 2022

Agenda:

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



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

High Angle Working Group Teams / Participants

Cases:

1. Flutter
2. Shock buffet

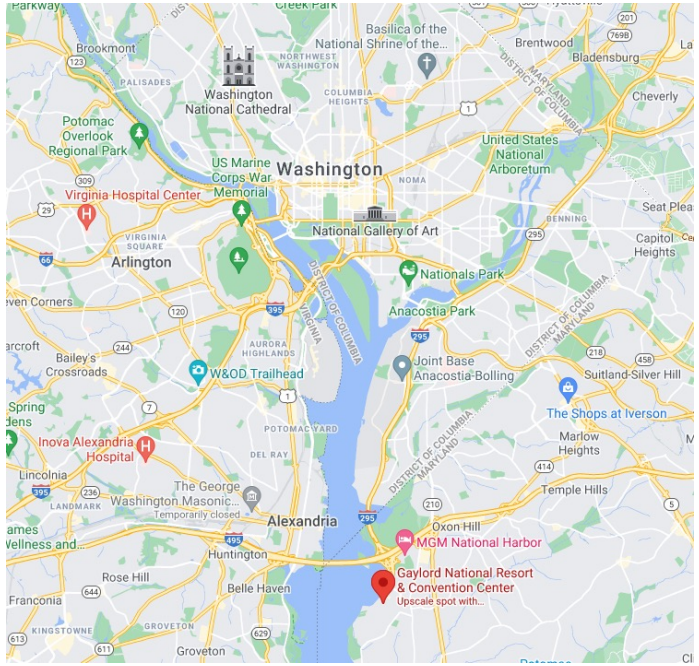
Red – Yes

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

SciTech 2023: AePW-3 Workshop

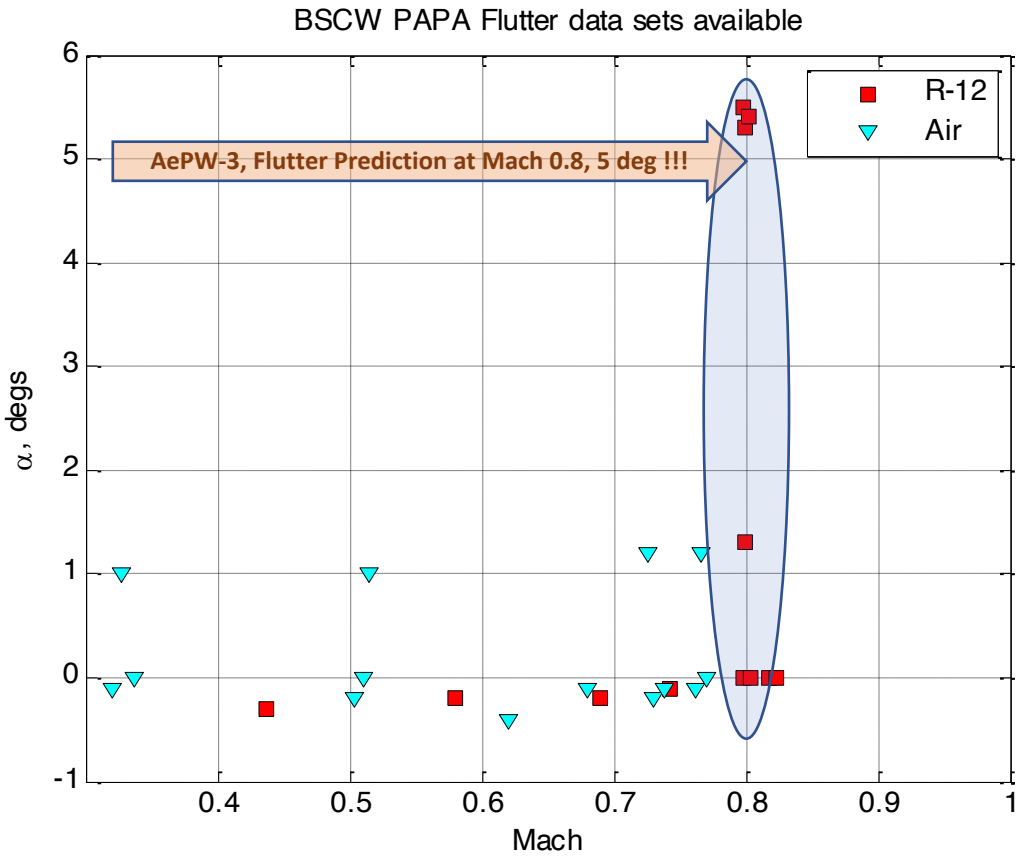
AIAA Science and Technology Forum and Exposition (2023 AIAA SciTech Forum)
23–27 January 2023
Gaylord National Harbor
National Harbor, MD



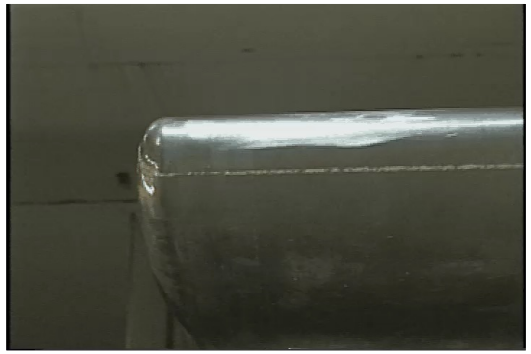
- Workshop will take place 85 days from today, January 21-22, 2023.
- Conference and workshop registrations are open:
  - The base workshop registrations fees are set by AIAA as:
    $299 early member/$399 late member/$499 standard non-member.
    Fee includes breakfast in the morning and two coffee breaks.
  - No student discount registration fee (unfortunately!)
  - According to AIAA, it is possible to register for the workshop only.
- Workshop format:
  - All four working groups will present results in the same room.
  - Emphasis is on shorter presentations but enough time for discussion.
  - 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.
- It is time for working group leaders to think about how/what to request from workshop participants and how to present all the results together!!!
- Joint Publications at SciTech 2024.
- We are considering a special AIAA Journal publication with AePW-3 results.
- One AePW-3 session at SciTech conference – Tuesday, January 24.

- 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	

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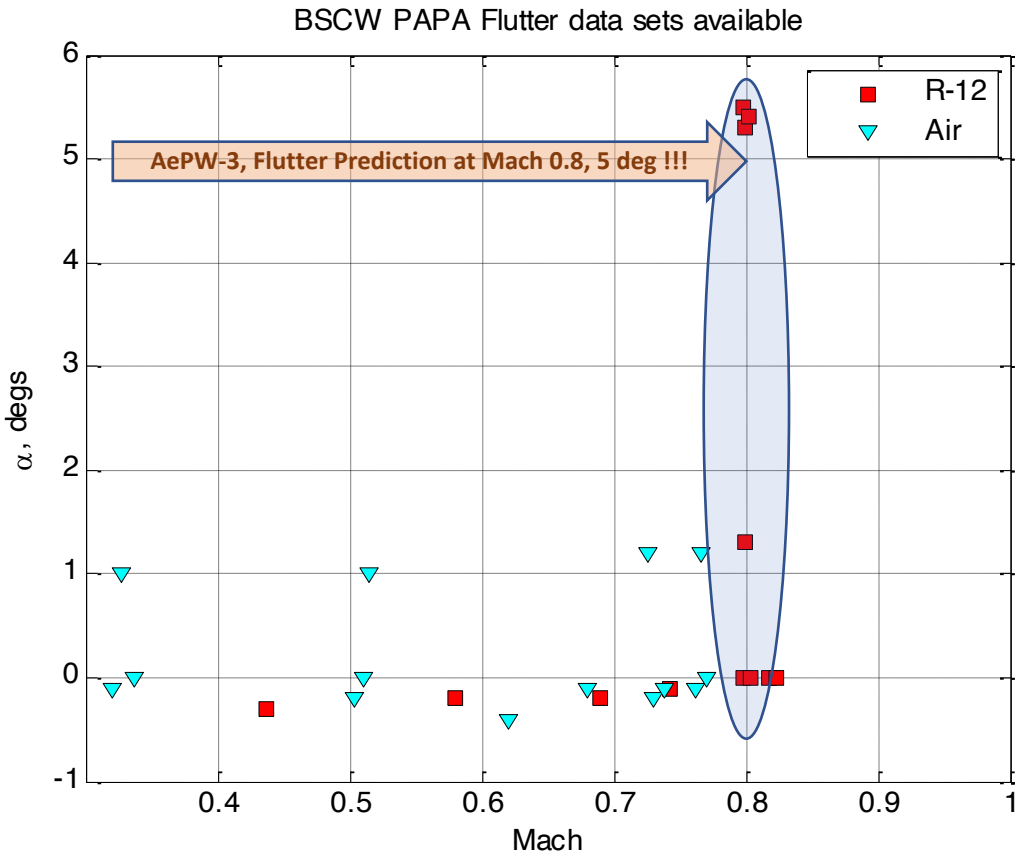


Case 1. BSCW flutter prediction at Mach 0.8, AoA = 5 deg.

⇒ 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.

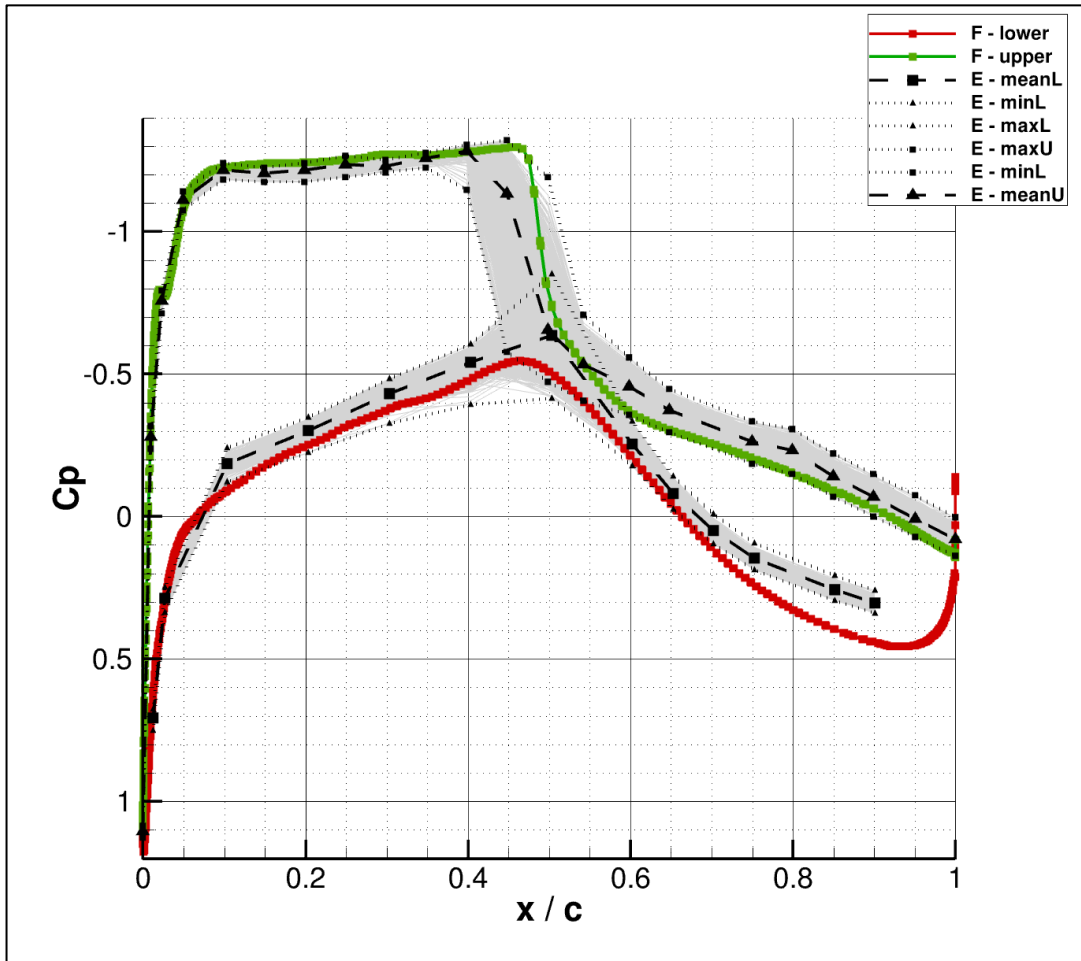
⇒ Time-step size and temporal resolution study, if applicable.

⇒ Definition of spatial and temporal schemes and mesh type.

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

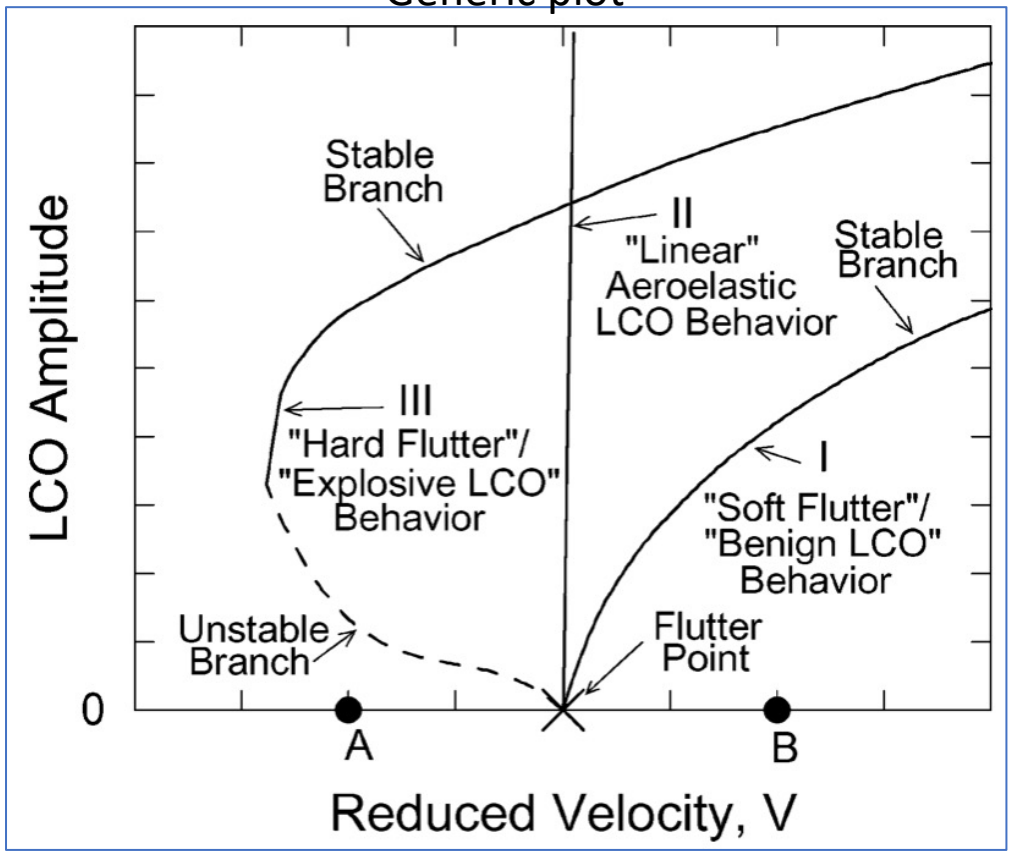
- Data submission: Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - CL, CD, and Cm coefficients at Q = 100 psf
    - Steady rigid or unsteady rigid (mean values)
    - Cm reference point is the leading edge of the wing
  - Cp vs. x/c at 60% wing at Q = 100 psf
    - Steady rigid or unsteady rigid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

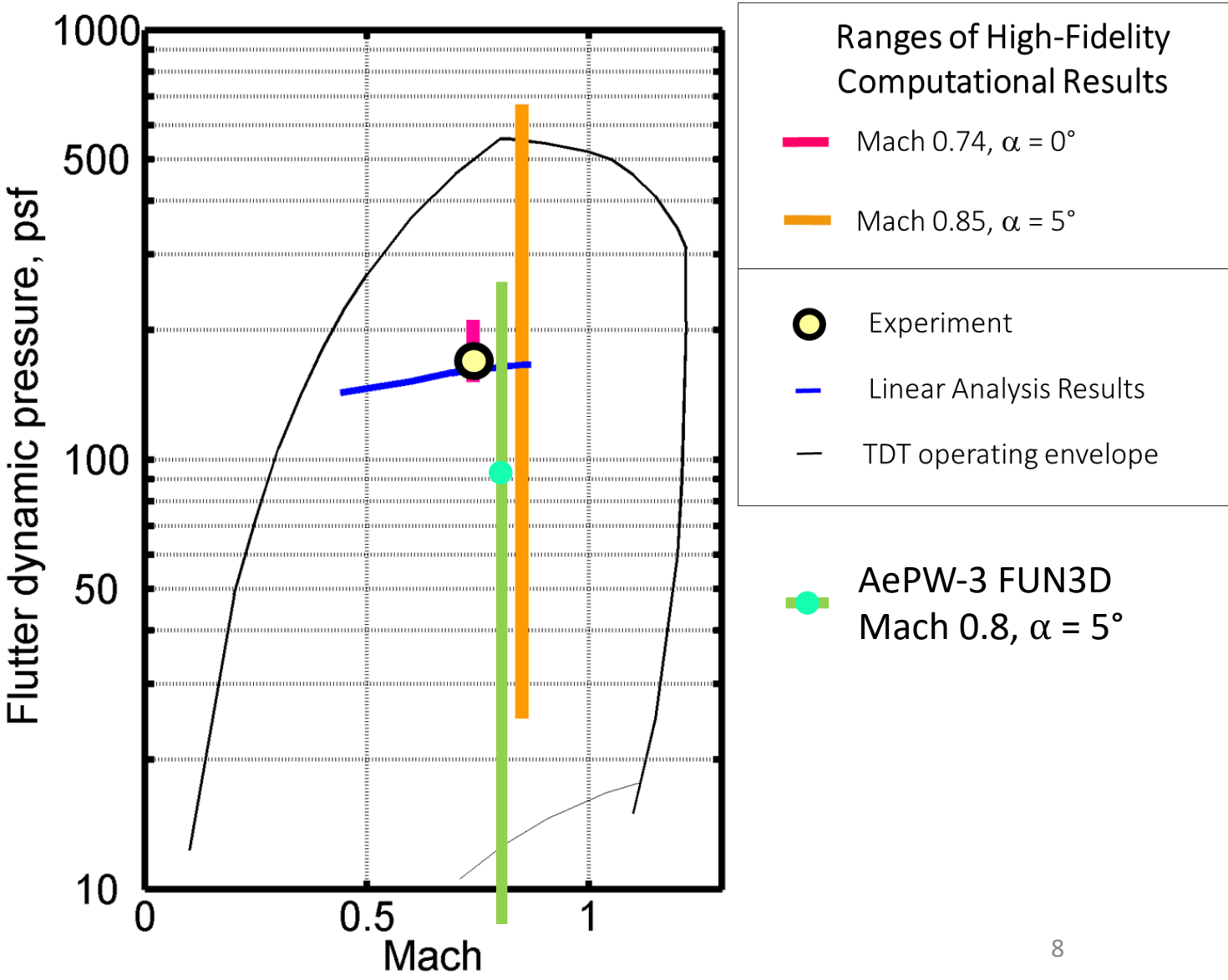


- Data submission: Flutter prediction: BSCW at Mach 0.8, AoA = 5deg
  - Flutter Q at two or more mesh resolutions
  - Time vector, generalized displacement/velocity at ALL Qs
    Or time vector, plunge/pitch histories
  - UNITS !!!
  - Perturbation method.
  - Splined mode shapes.

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 (?)

- 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

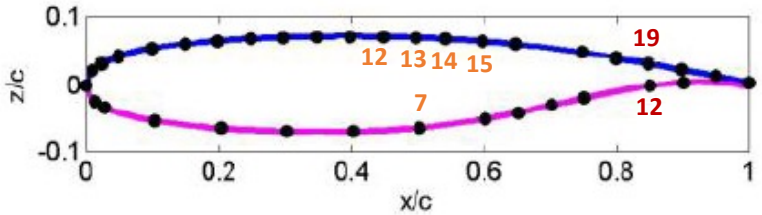
Case 2. BSCW shock buffet at Mach 0.8, AoA = 5deg, Q = 169 psf

⇒ 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

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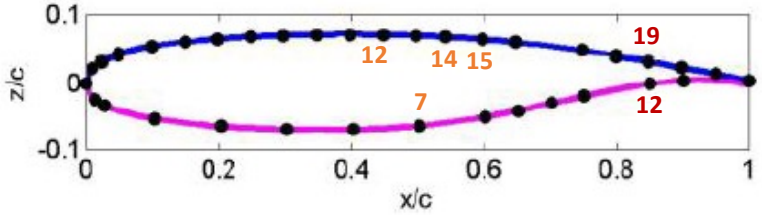

PSD Matlab function

```
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
```

High Angle Working Group Teams / Participants

Cases:

1. Flutter
2. Shock buffet

Red – Yes

Blue - Maybe

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Technion, Israel	1,2
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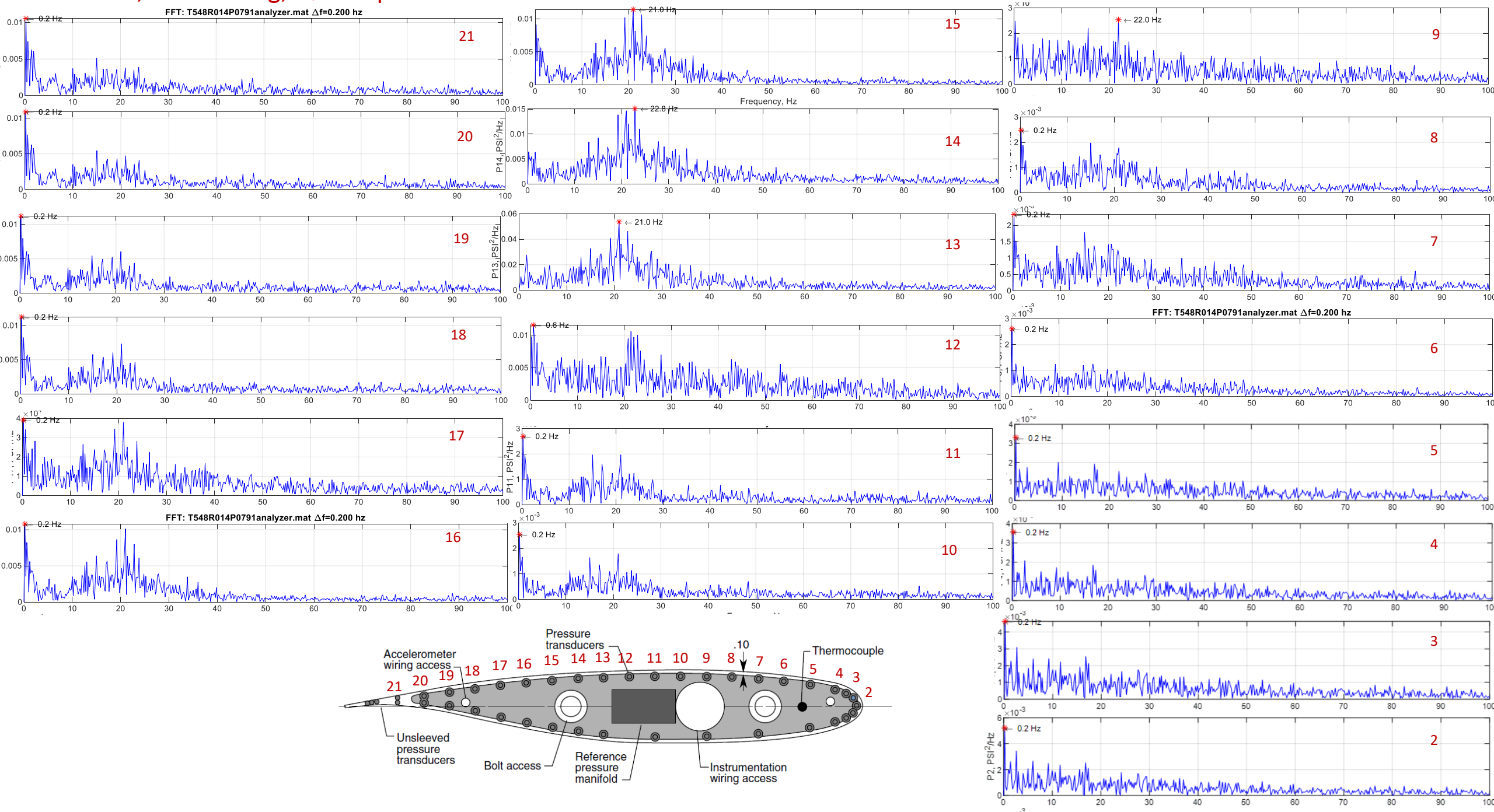
Bombardier, Canada	1
CREATE-AV, USA	1,2
Hexagon, Japan	1
Duke University, USA	1
Metacomp Tech., USA	1

High Angle Working Group, September 20, 2022

Agenda:

- Workshop and SciTech 2023
- Workshop data submission and preparation: Flutter data, Kevin.

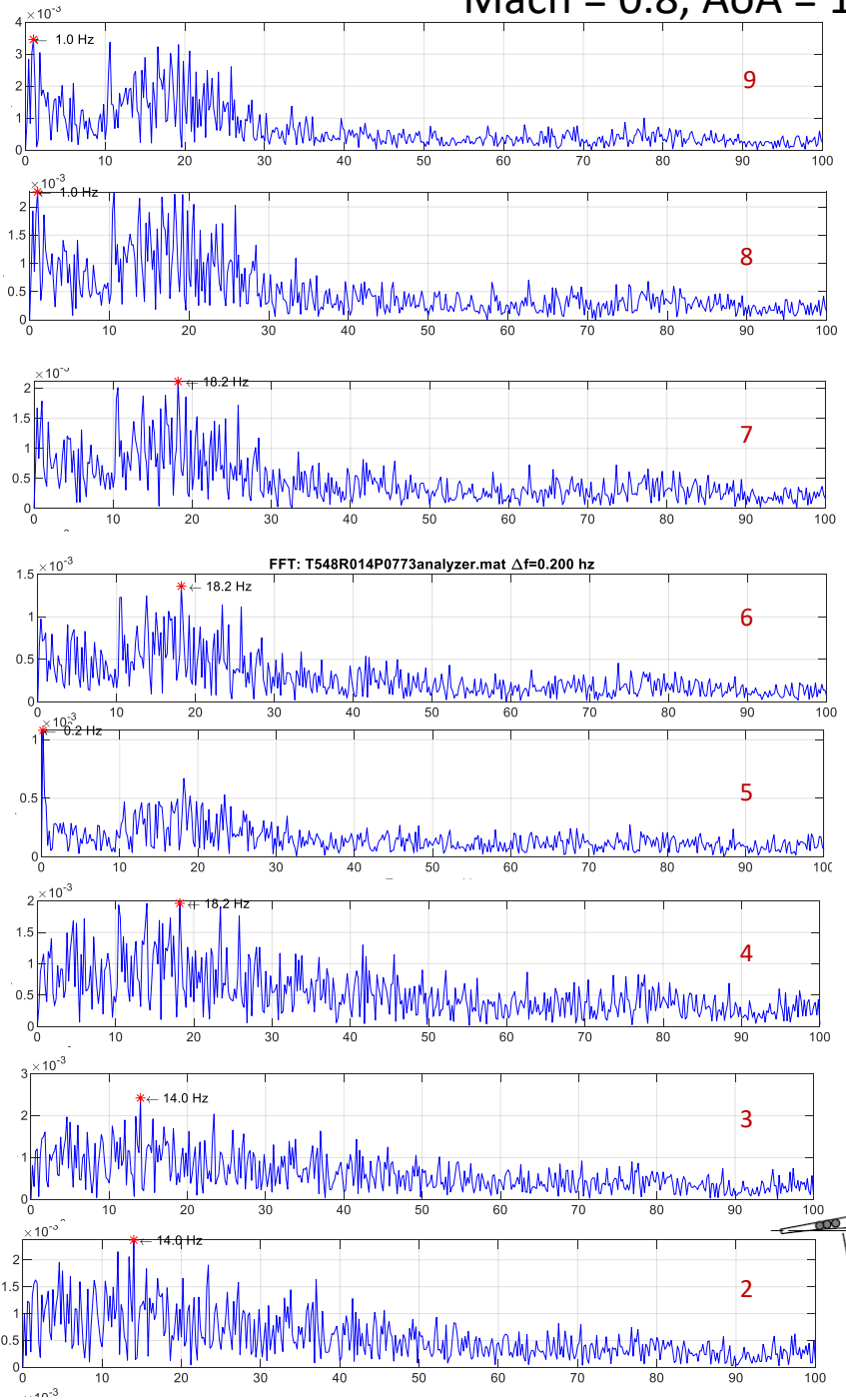
Mach = 0.8, AoA = 5deg, Q=170 psf



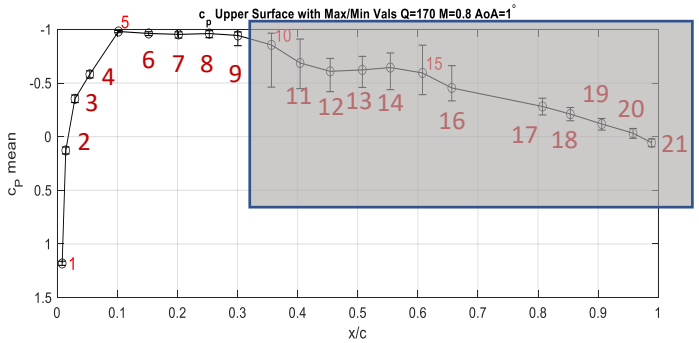
Mach = 0.8, AoA = 1deg

Q=170 psf

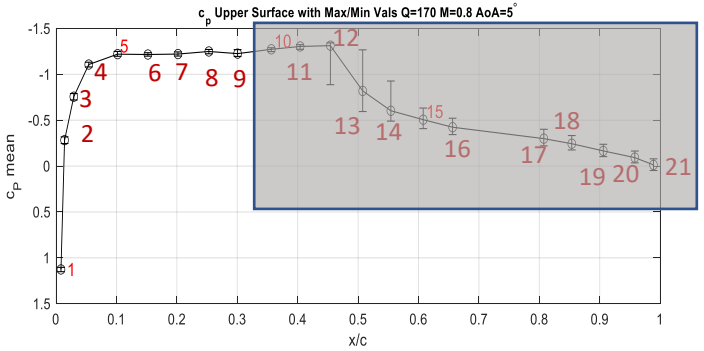
Mach = 0.8, AoA = 5deg

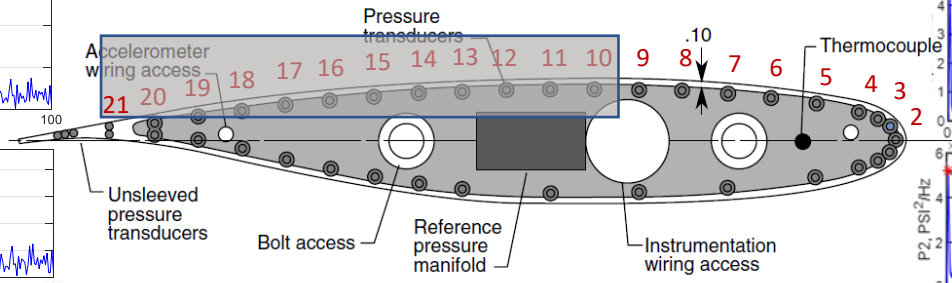


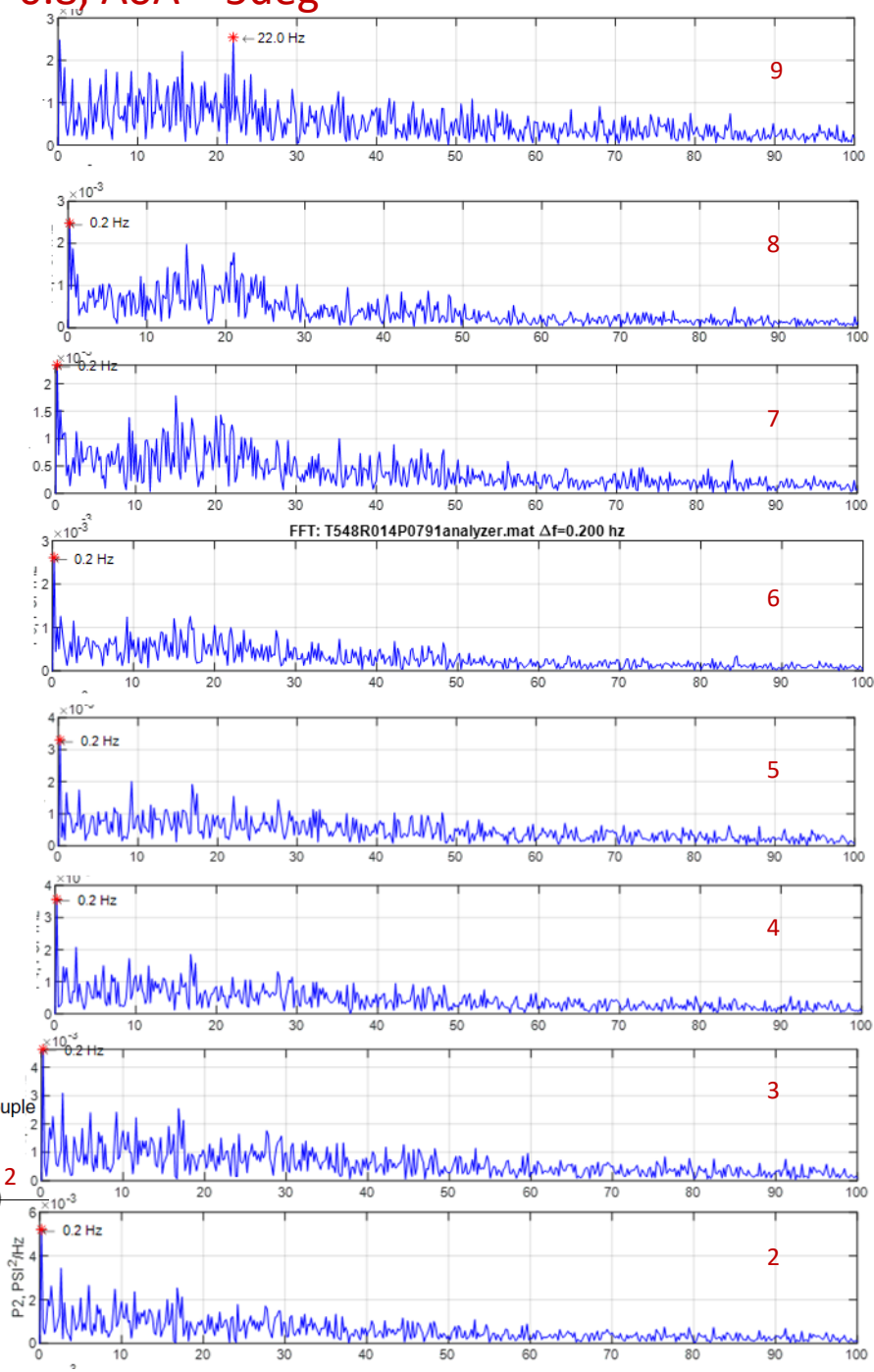
Mach = 0.8, AoA = 1deg, Mean Cp



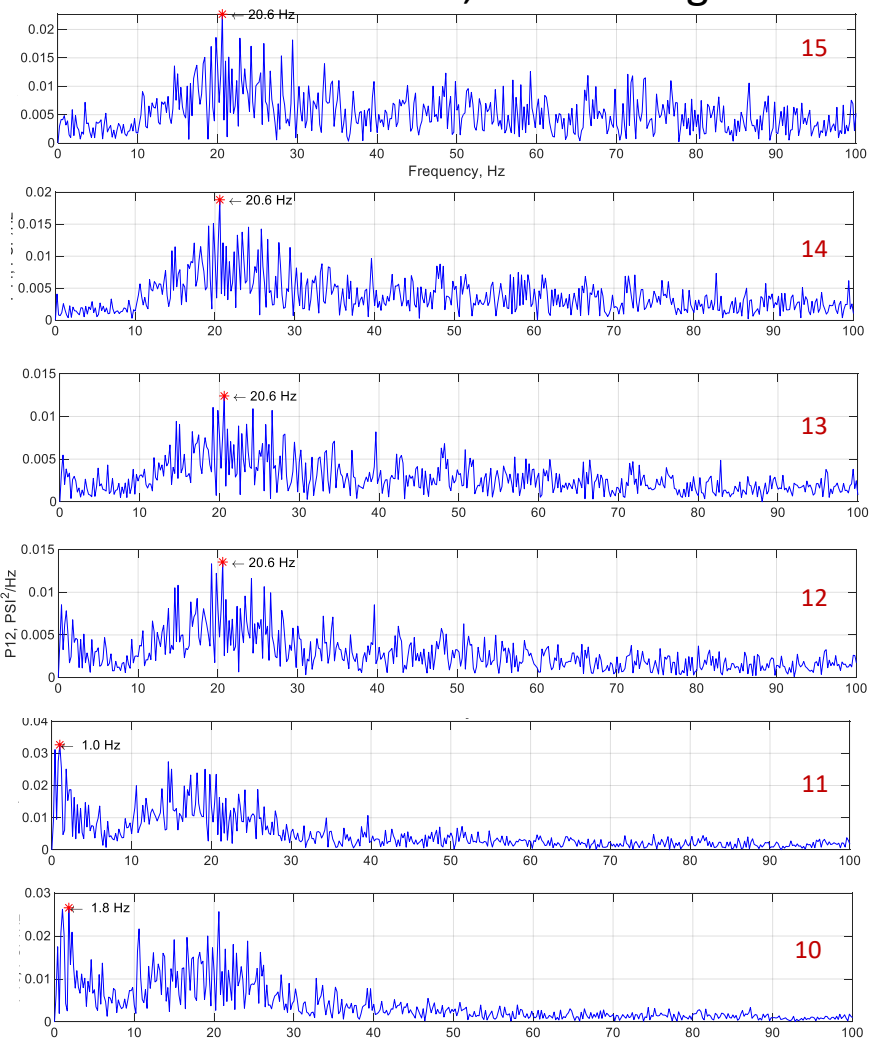
Mach = 0.8, AoA = 5deg, Mean Cp



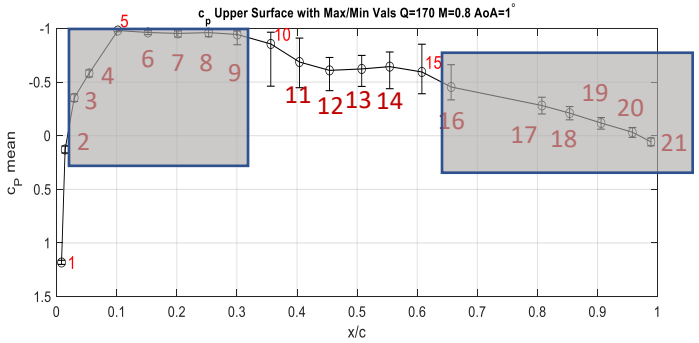




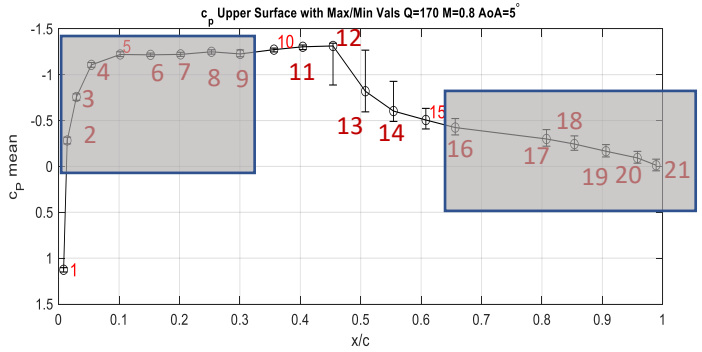
Mach = 0.8, AoA = 1deg



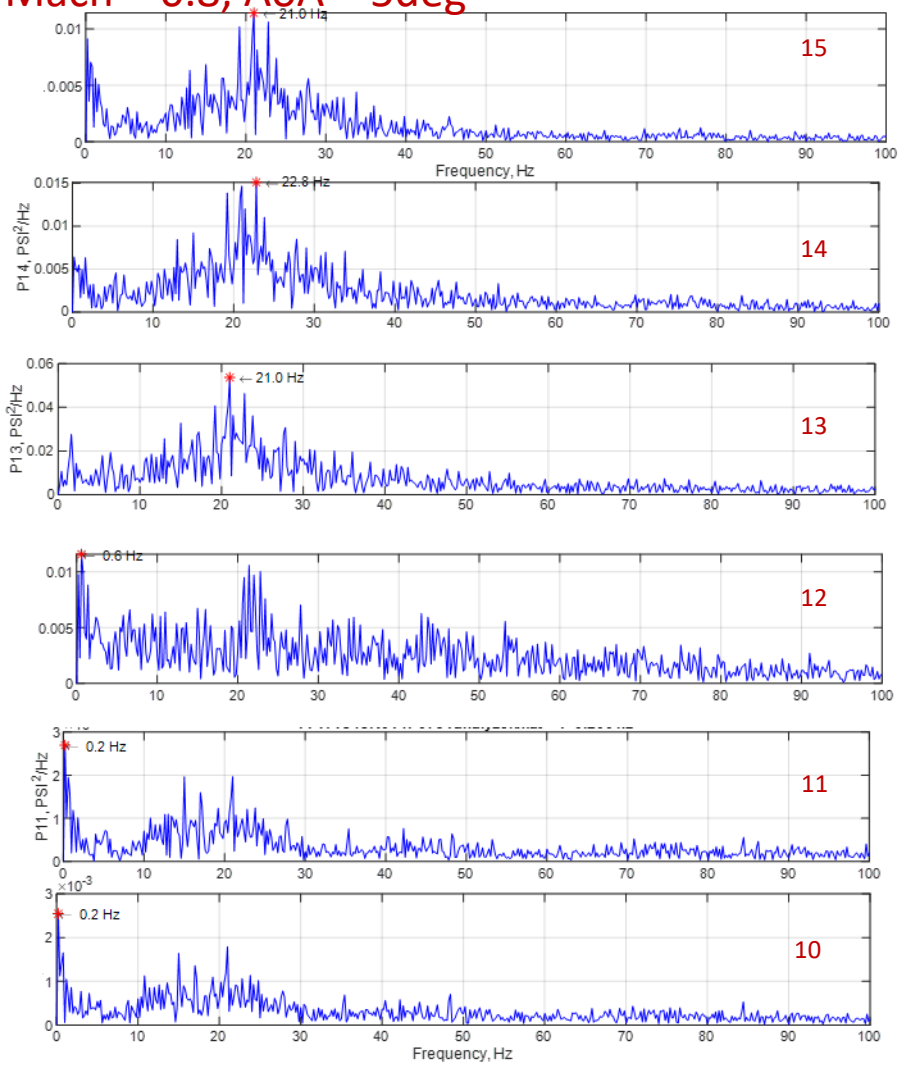
Mach = 0.8, AoA = 1deg, Mean Cp

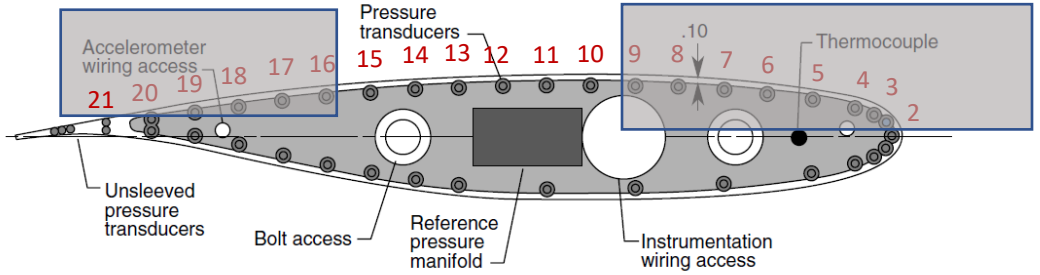


Mach = 0.8, AoA = 5deg, Mean Cp

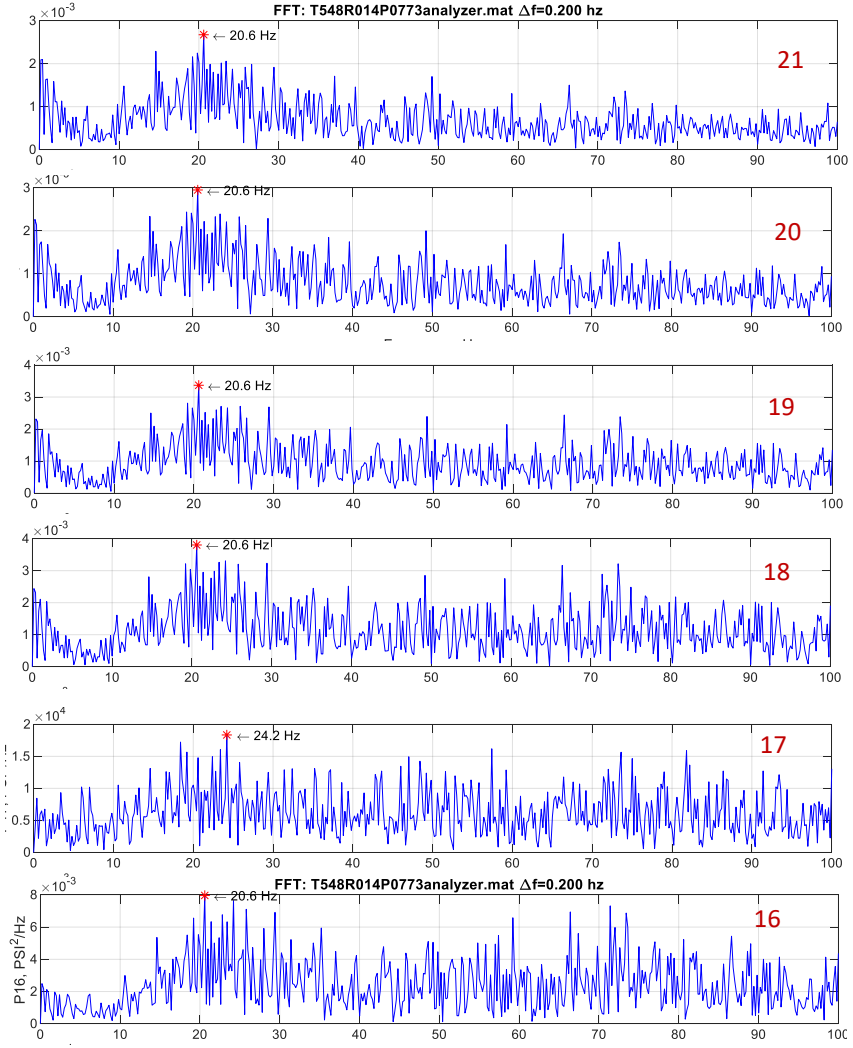


Mach = 0.8, AoA = 5deg

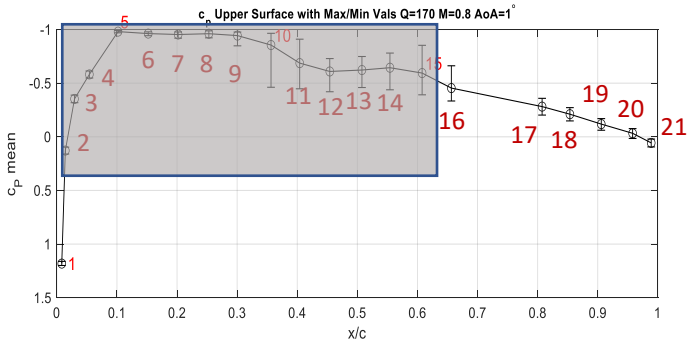




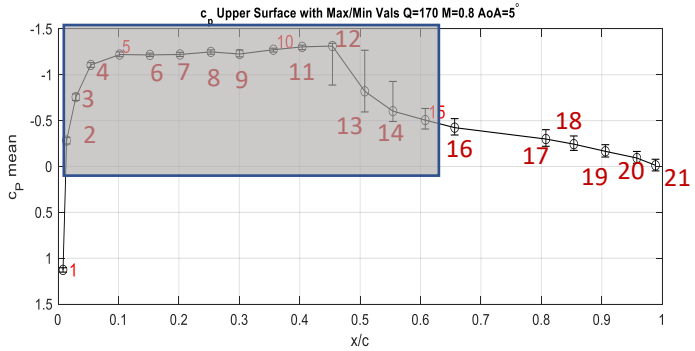
Mach = 0.8, AoA = 1deg



Mach = 0.8, AoA = 1deg, Mean Cp



Mach = 0.8, AoA = 5deg, Mean Cp



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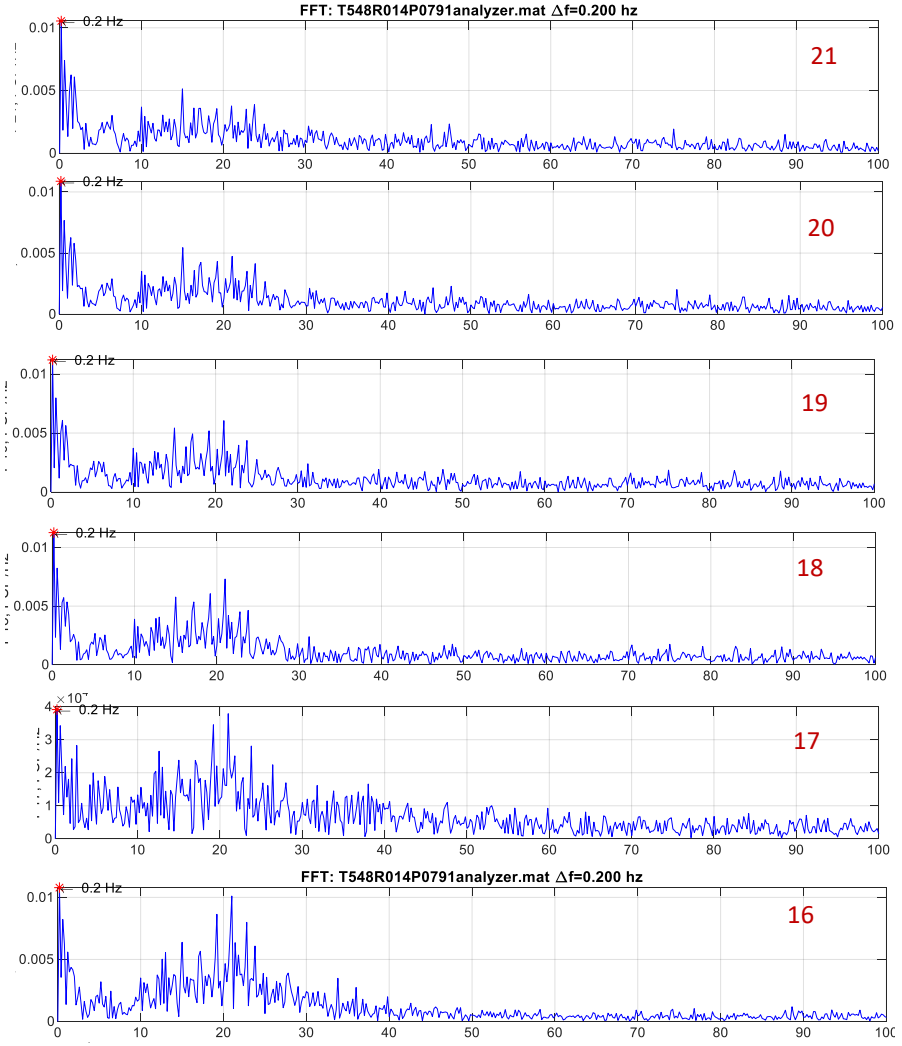
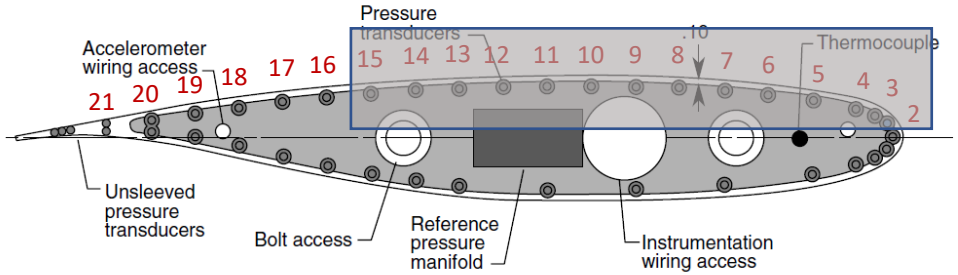




Mach 0.8, AoA = 5deg Preliminary Buffet Analysis

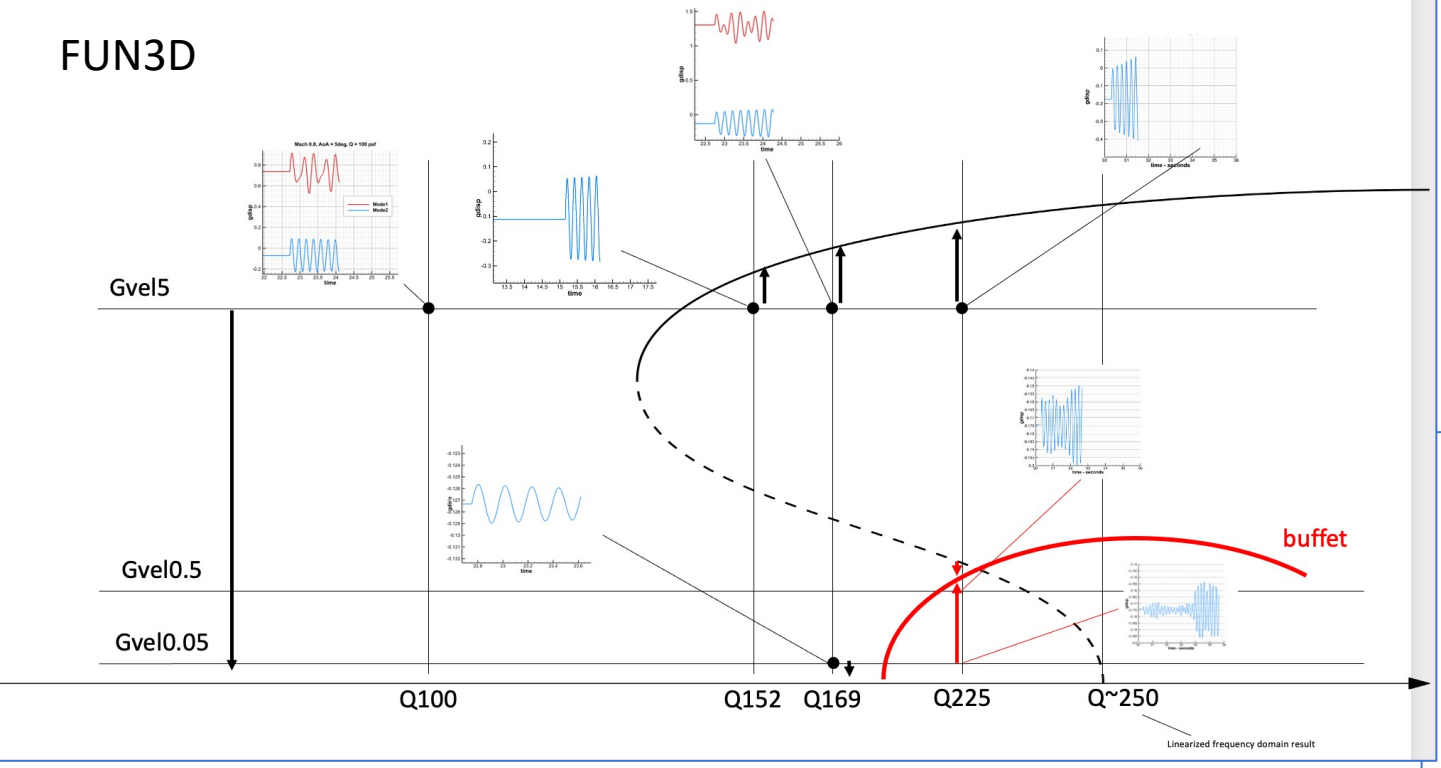
Parameter	Units													
Mach		0.799	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.801	0.801
qbar	psf	10.02	25	35	50	75	100	134	143	152	168.8	200	225	250
Mach	1/ft	0.799	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.801	0.801
qbar	psf	10.02	25	35	50	75	100	134	143	152	168.8	200	225	250
Rec		237461	592224	829213	1184801	1777732	2371336	3178880	3392751	3606668	4006103	4748658	5343835	5939368
Re	1/ft	178096	444168	621910	888601	1333299	1778502	2384160	2544563	2705001	3004577	3561493	4007876	4454526
V	ft/s	440.45	440.63	440.59	440.51	440.39	440.21	440.05	440	439.96	439.88	439.7	439.58	439.46
a	ft/s	551.08	550.94	550.85	550.71	550.48	550.25	549.94	549.86	549.78	549.62	549.34	549.11	548.88
T_static	deg_F	80.87	80.83	80.83	80.82	80.81	80.8	80.78	80.77	80.77	80.76	80.74	80.73	80.71
rho	slugs/ft3	0.000103	2.58E-04	0.000361	0.000515	0.000774	0.001032	0.001384	0.001477	0.001571	0.001745	0.002069	0.002329	0.002589
gamma		1.1121	1.1122	1.1123	1.1124	1.1126	1.1128	1.1131	1.1131	1.1132	1.1133	1.1136	1.11E+00	1.1139
mu	lb-sec/ft2	2.56E-07	2.56E-07	2.56E-07	2.56E-07	2.56E-07	2.56E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07	2.55E-07
Pr		0.68394	0.68404	0.6841	0.68419	0.68435	0.6845	0.68471	0.68477	0.68483	0.68493	0.68513	0.68528	0.68544
H	psf	40	99.7192	139.609	199.446	299.181	399.003	534.692	570.612	606.532	673.587	798.205	898.014	997.829
P	psf	28.2069	70.3193	98.4486	140.644	210.975	281.366	377.05	402.38	427.711	474.996	562.873	633.255	703.643
T_stagnation		100	100	100	100	100	100	100	100	100	100	100	100	100
X		0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

High Angle Working Group, August 25, 2022

Agenda:

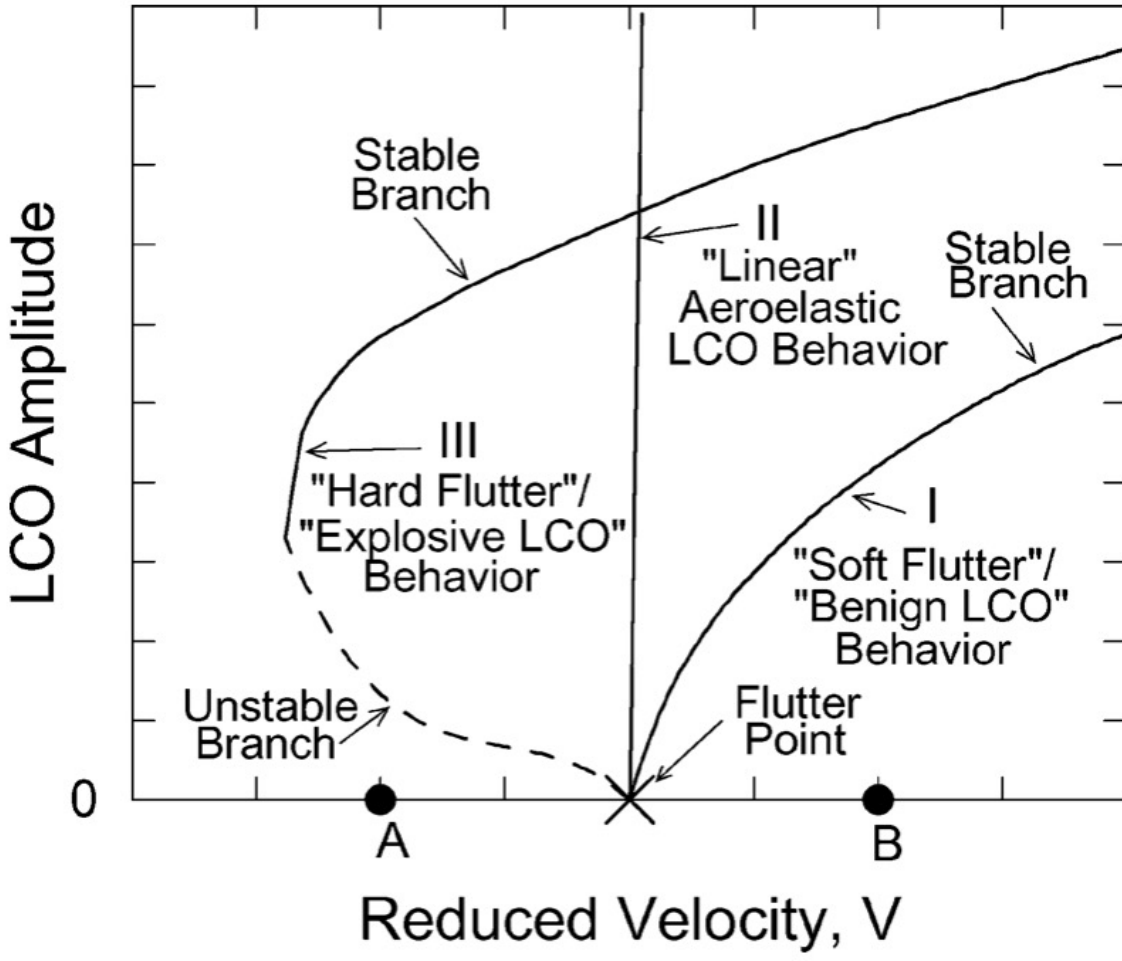
- Workshop and SciTech 2023
- Workshop data submission and preparation
- Two-Dimensional Aeroelastic Flutter-Onset and Limit Cycle Oscillation Computations for the NASA Benchmark Supercritical Wing Configuration: Jeff Thomas
- Progress on FUN3D 2D buffet computations: Pawel

FUN3D



September 20
AePW-3 High Angle Working Group meeting

Generic plot

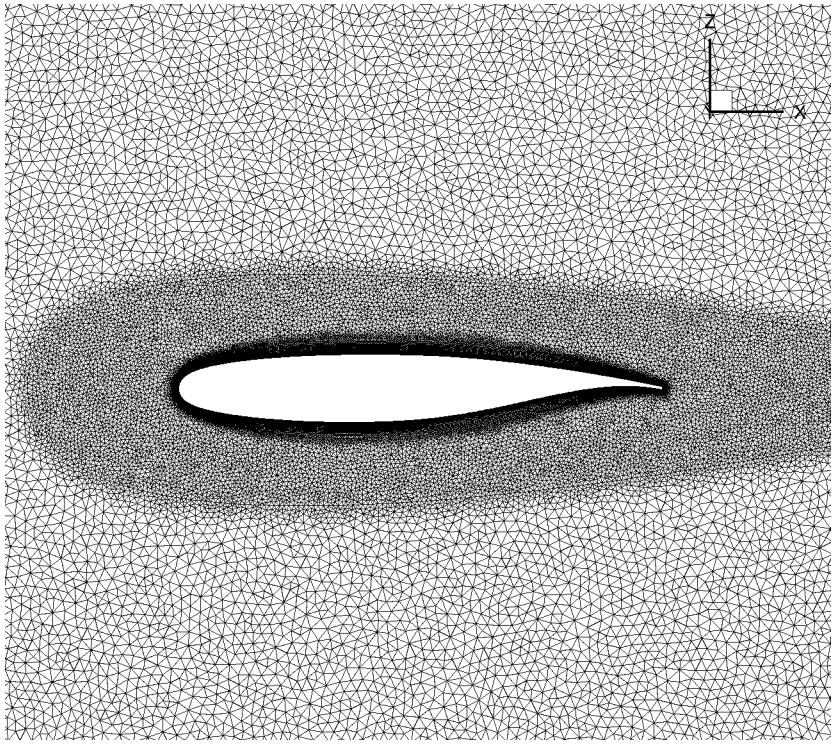


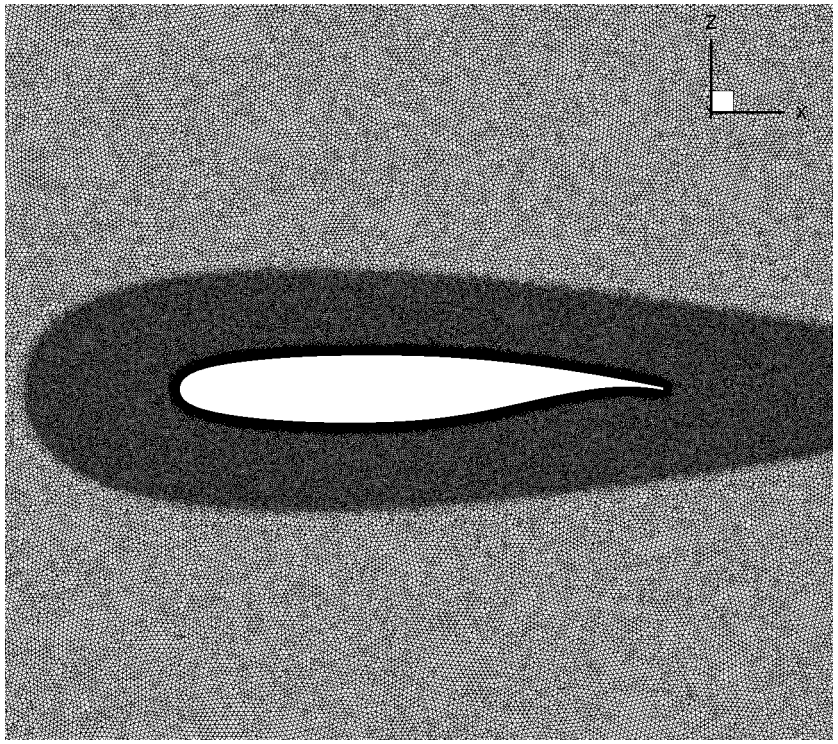
BSCW 2D Shock Buffet Analysis

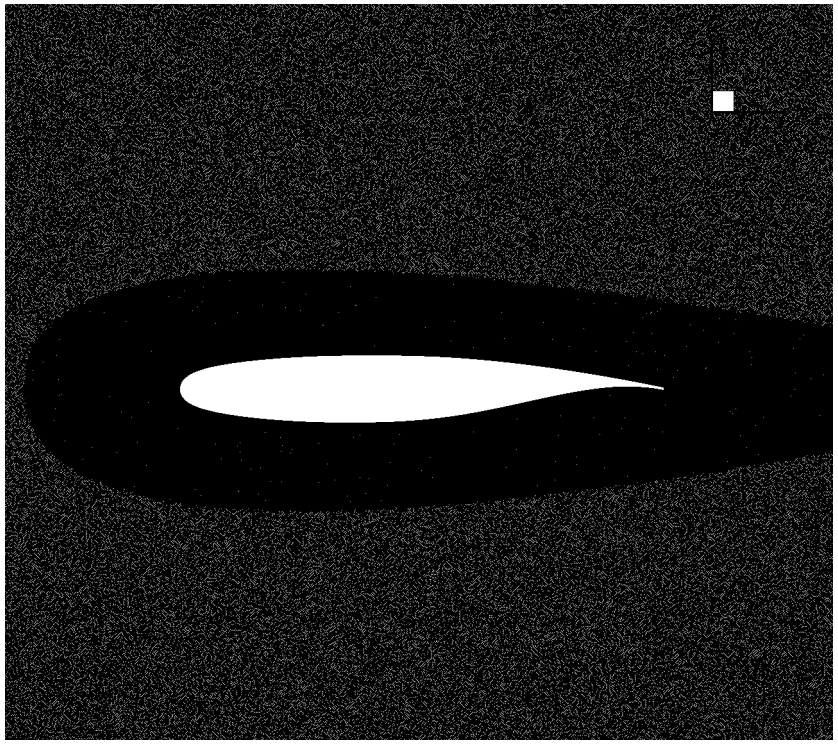
Pawel Chwalowski

- 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	

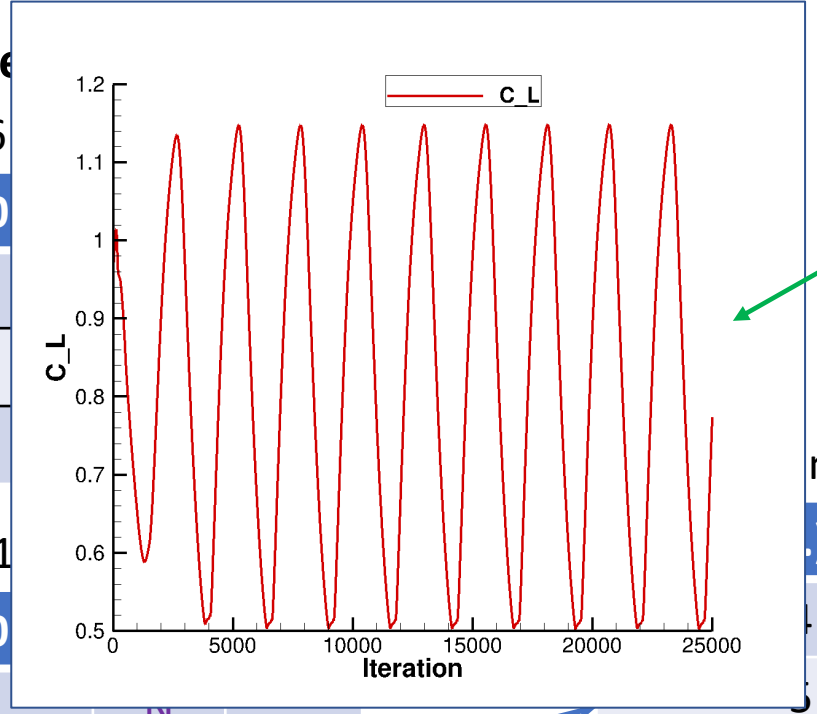
Medium Mesh, dt = 0.0002 sec, 1

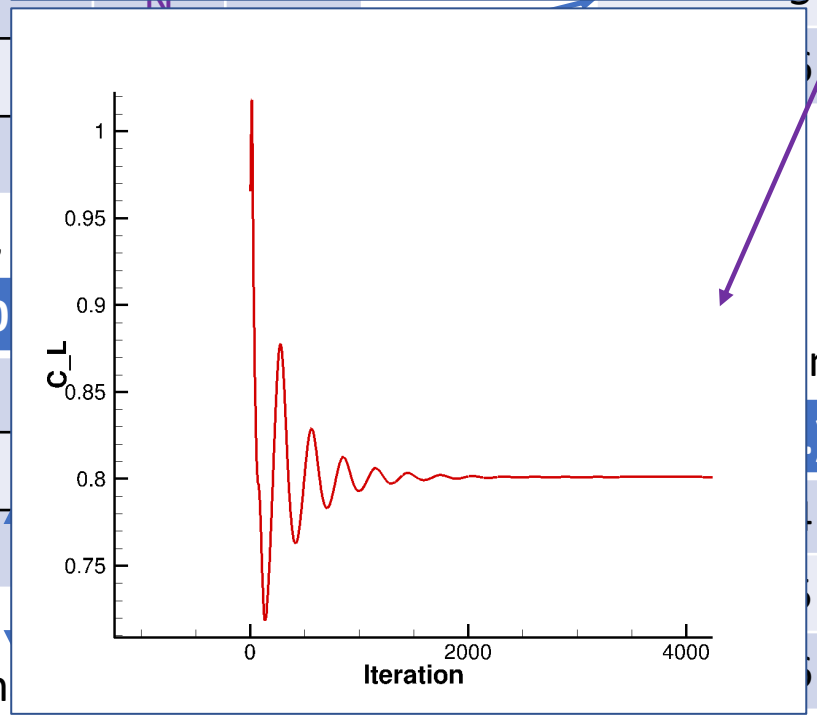
AoA (deg.) / Mach	0.60	0.70	0
4			
5			
6			

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

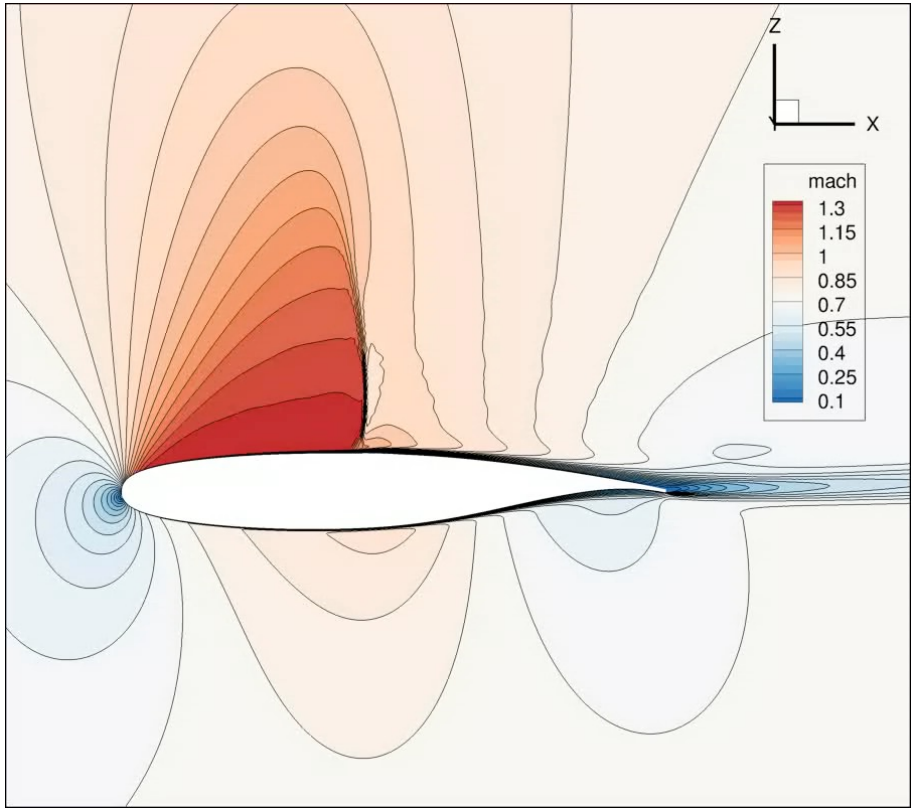
AoA (deg.) / Mach	0.60	0.70	0.74	0.78	0.80
4					
5				N	
6					

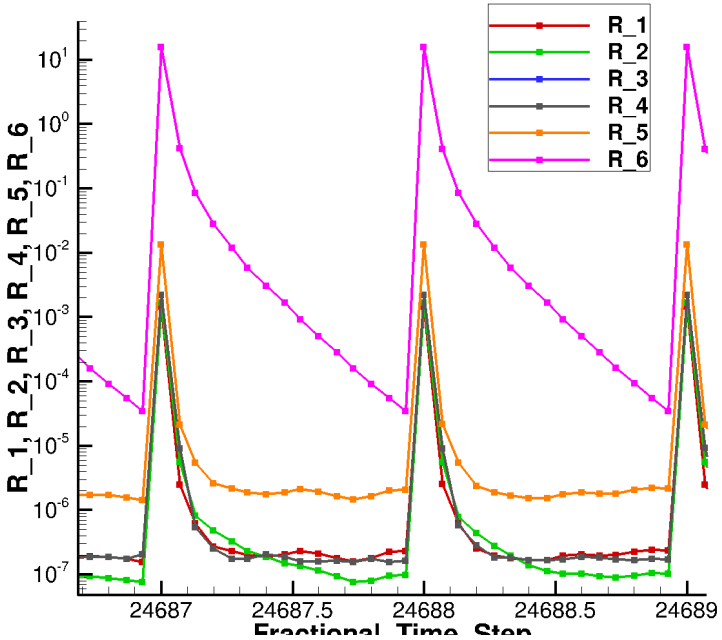
DDES -> **N**

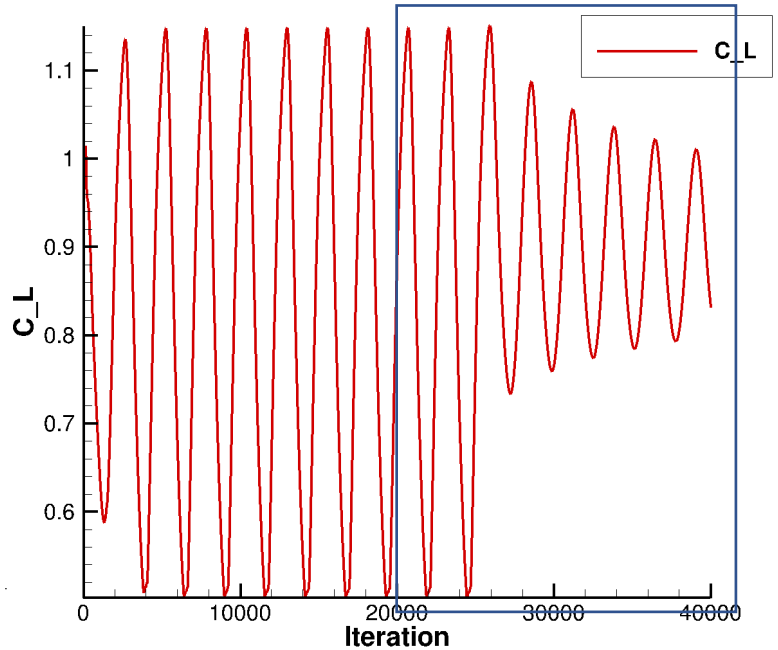
Medium Mesh, dt = 0.00002 sec, 160 steps/chord

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

animation

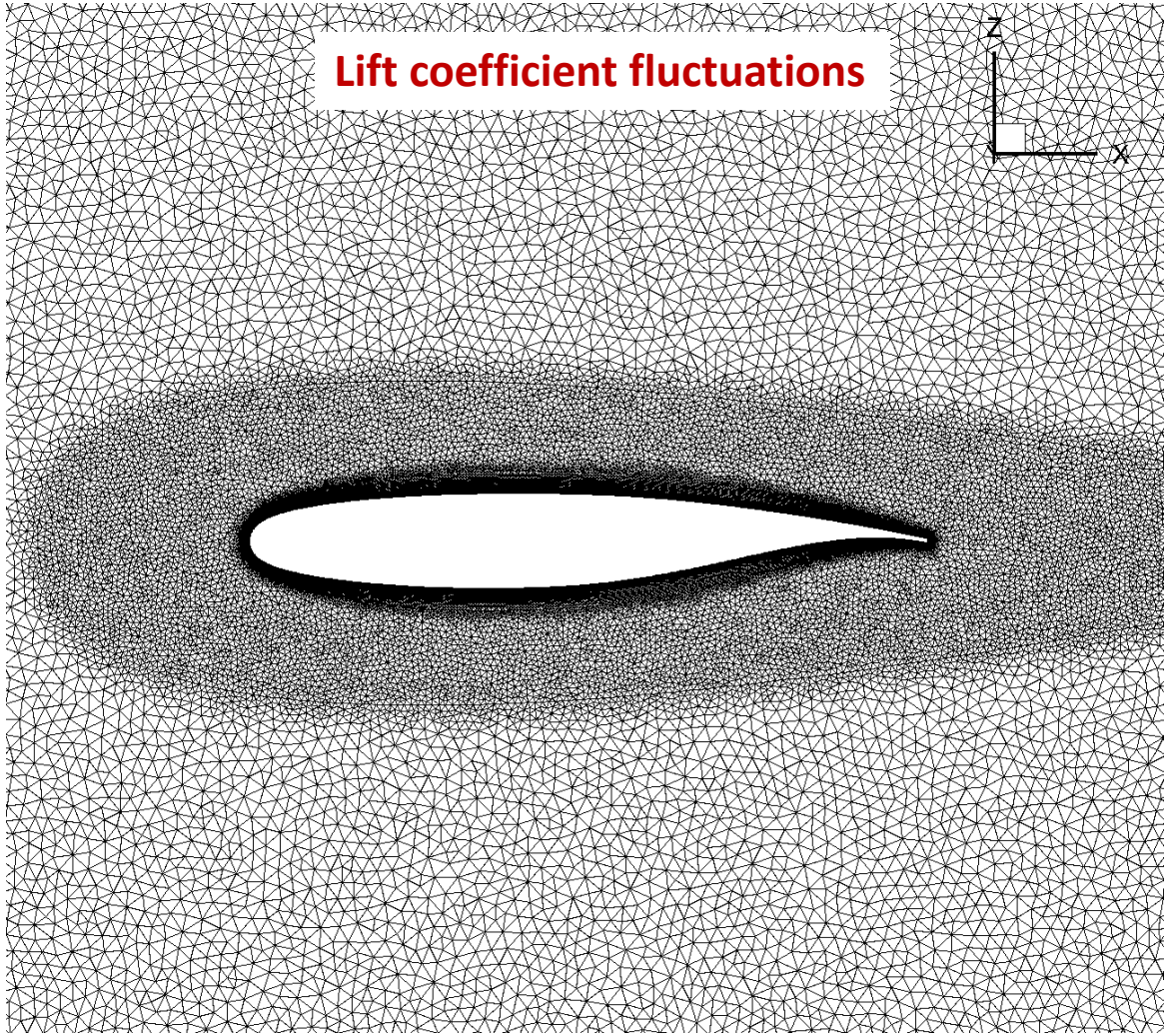




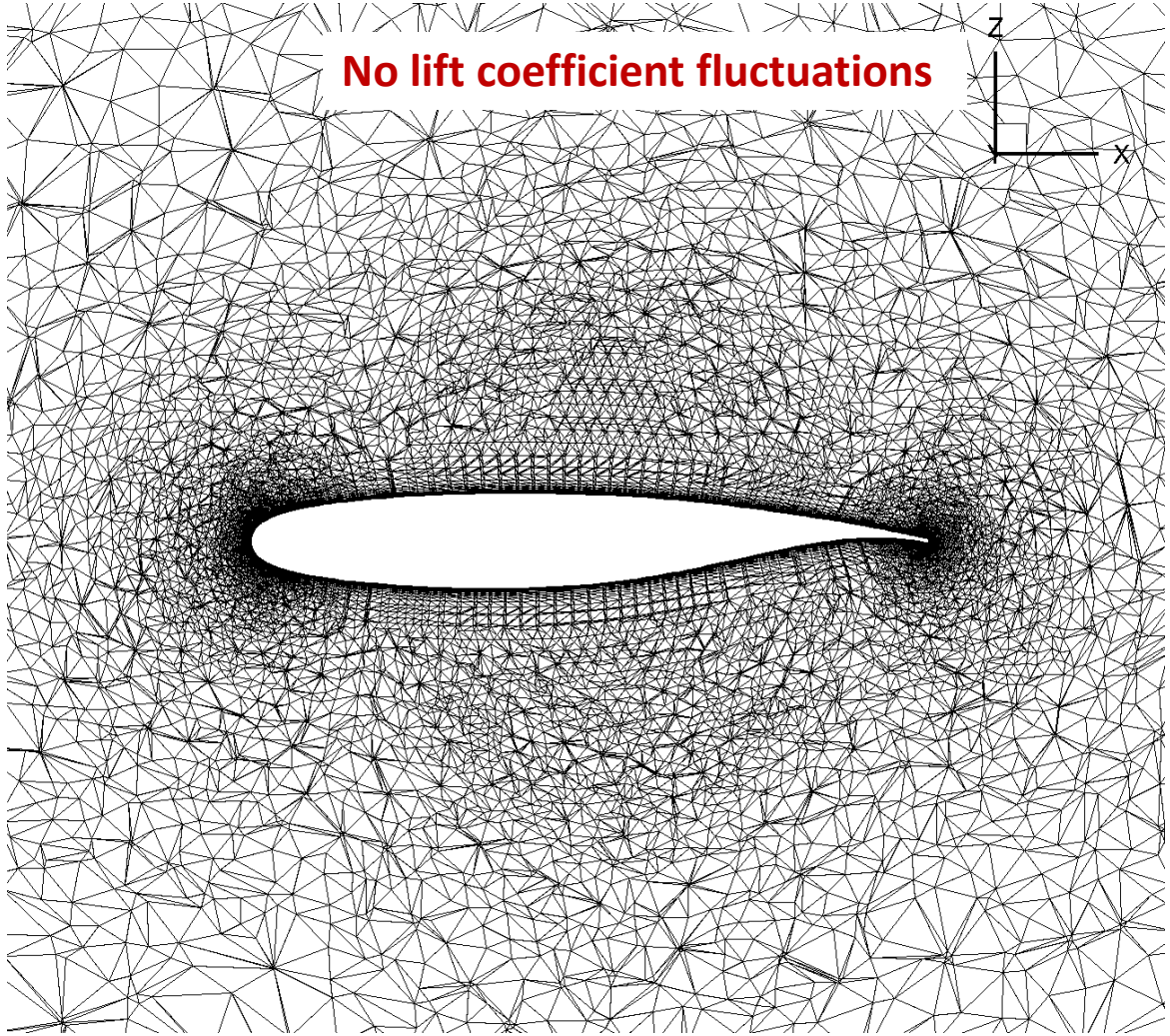


2D vs. 3D Mach 0.74, AoA = 5deg w/ Compressibility Correction and Limiter

Coarse 2D

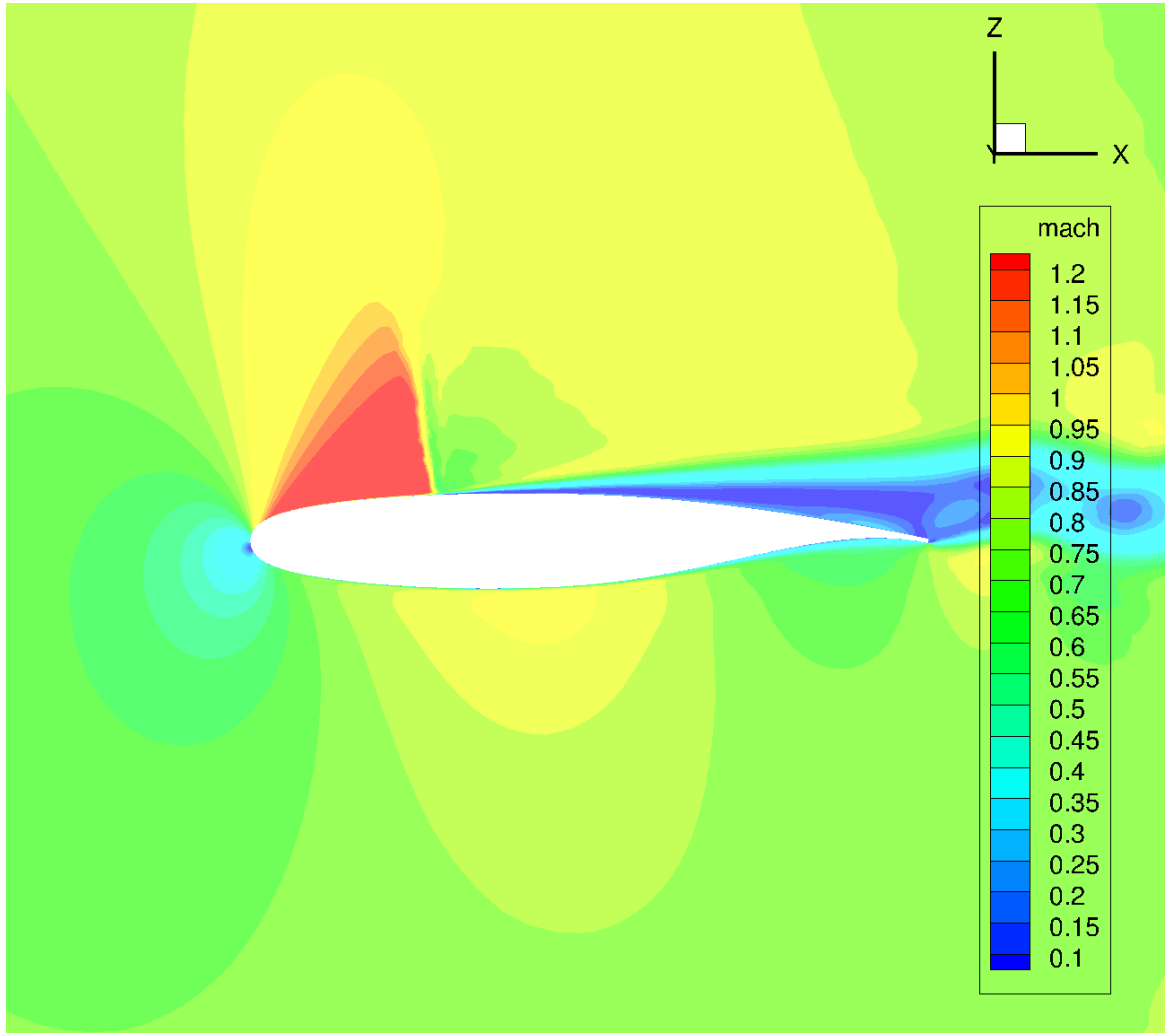


Coarse 3D (BSCW Coarse, 3M) at 60% wingspan

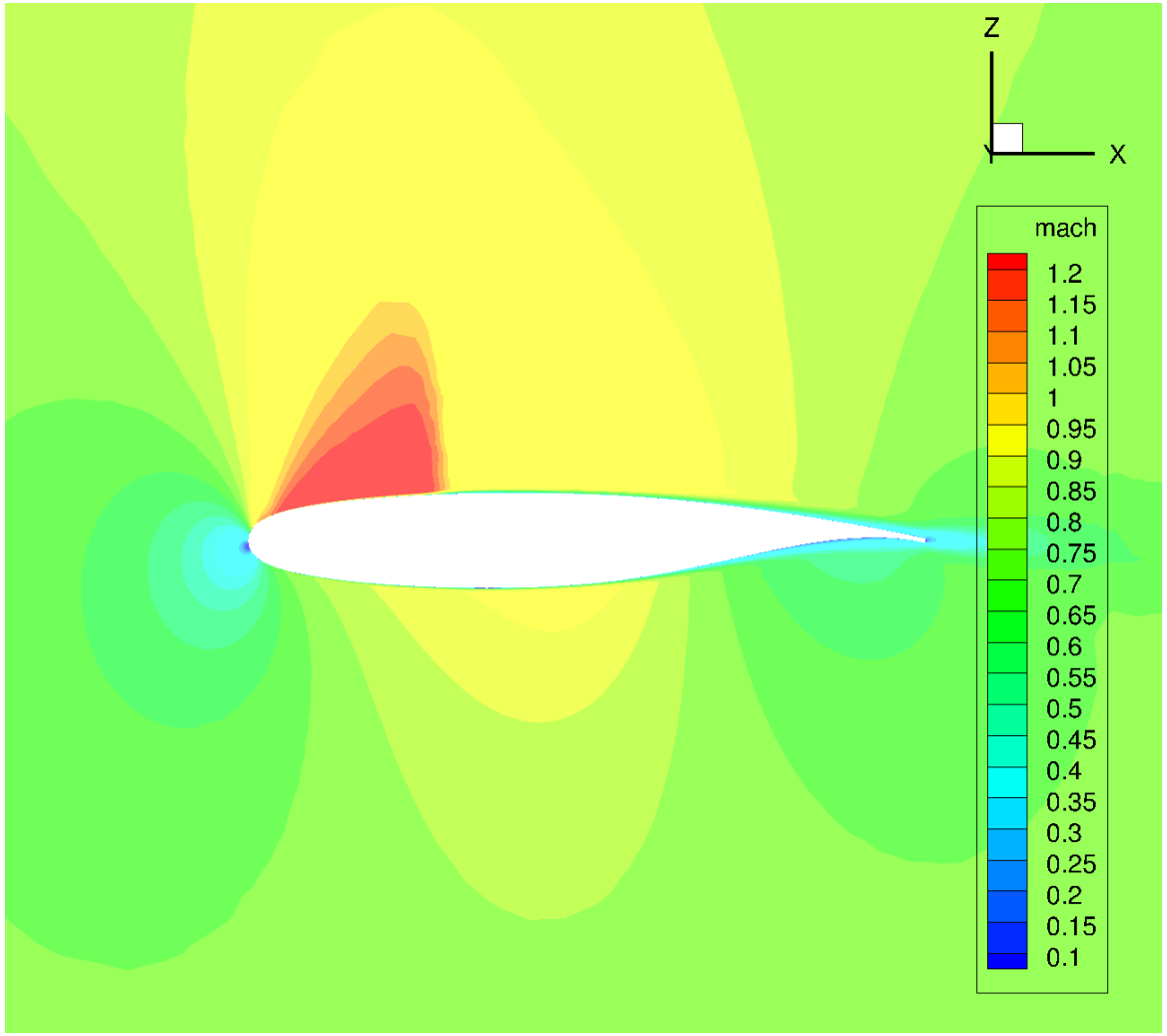


2D vs. 3D Mach 0.74, AoA = 5deg w/ Compressibility Correction and Limiter
Mach contours at the beginning of unsteady simulation

Coarse 2D

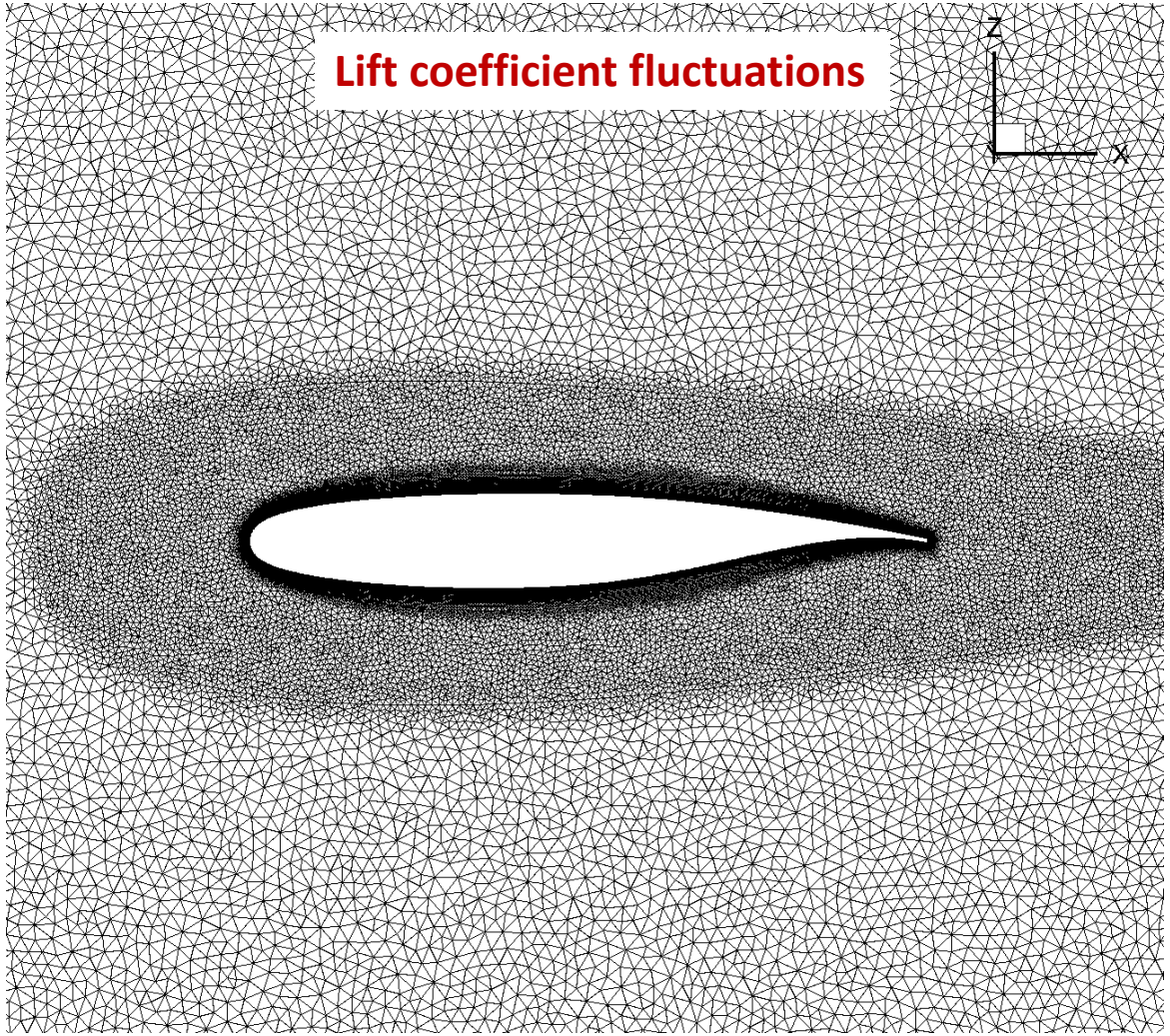


Coarse 3D (BSCW Coarse, 3M) at 60% wingspan

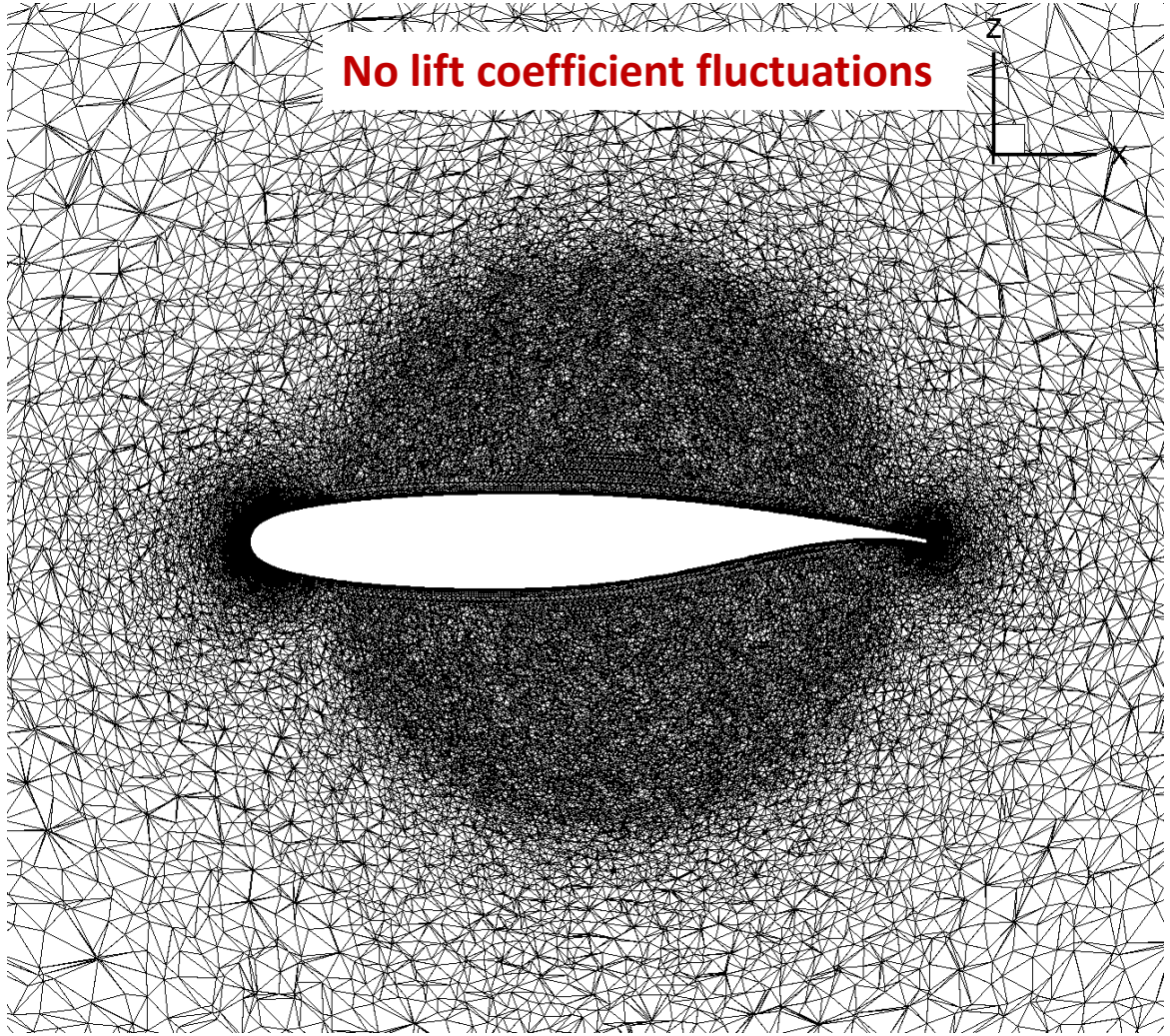


2D vs. 3D Mach 0.74, AoA = 5deg w/ Compressibility Correction and Limiter

Coarse 2D

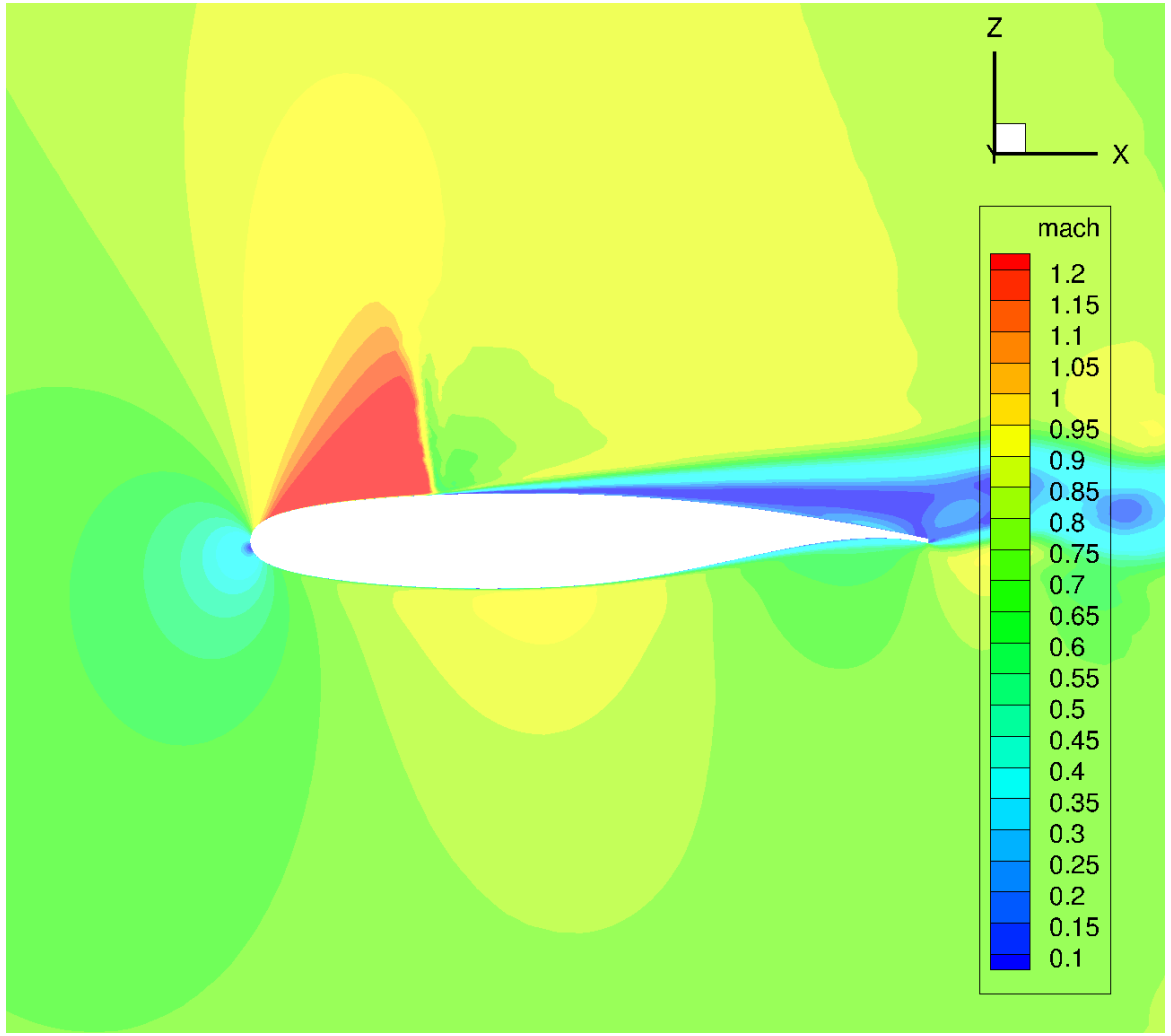


Fine 3D (BSCW Fine, 27M) at 60% wingspan

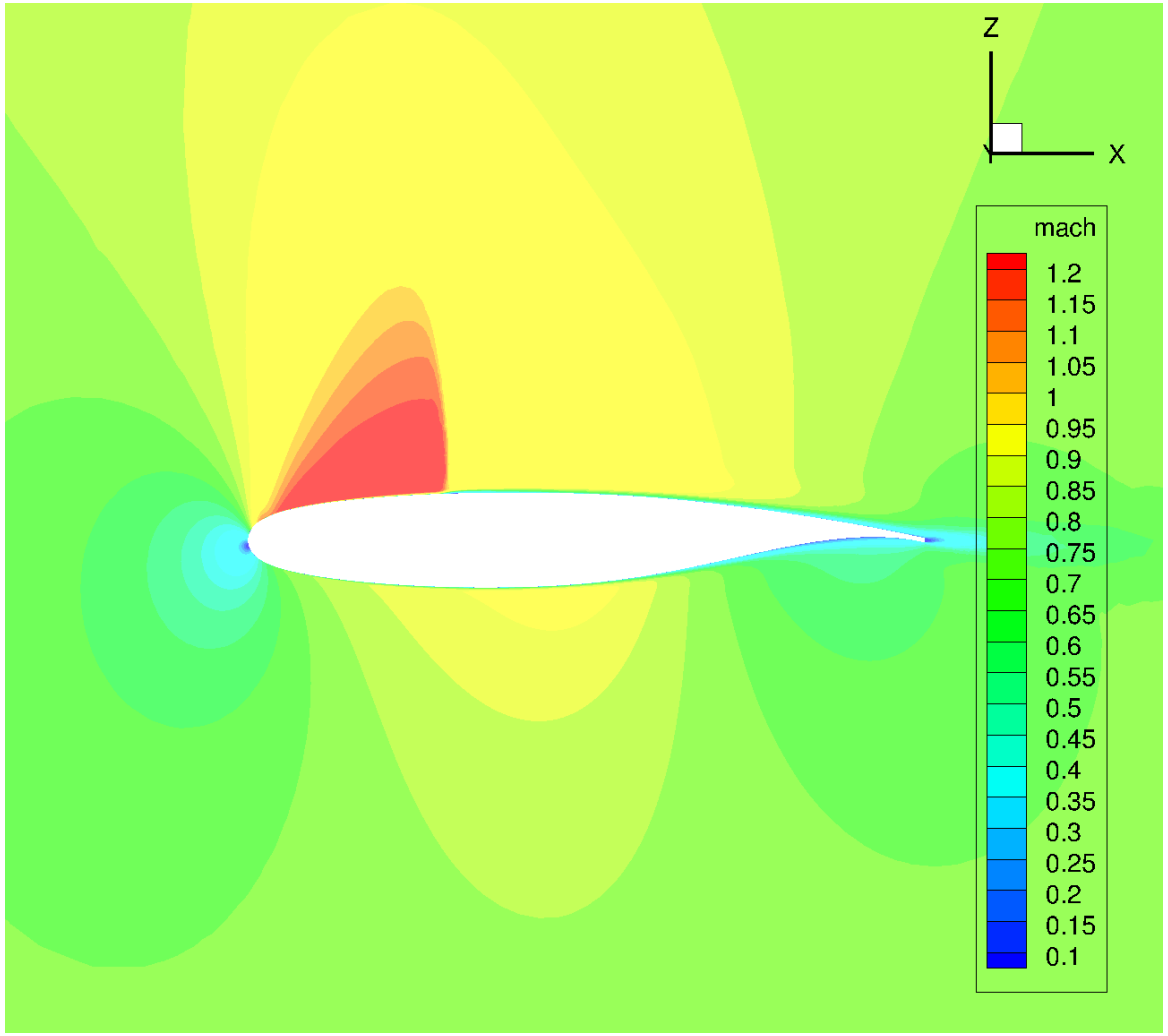


2D vs. 3D Mach 0.74, AoA = 5deg w/ Compressibility Correction and Limiter
Mach contours at the beginning of unsteady simulation

Coarse 2D



Fine 3D (BSCW Fine, 27M) at 60% wingspan



Wavelet transform, **AIAA 2015-0559**: https://doi.org/10.2514/6.2015-0559

```
%
% compute the wavelet transform
%
signal=dp(:,212);                    % signal, time-varying pressure
wname='morl';                        % wavelet name (morl = morlet)
scales=0:0:0;                        % scales
fpseudo=scal2frq(scales,'morl',dt);  % convert scales to pseudo-frequencies
cwtc=cwt(sig,scales,wname);          % continuous wavelet transform function call
temp=sum(sum(cwtc.^2));              % sum over both dimensions (time, scales) to get total power
cwtp=cwtc.^2./temp;                  % ratio cwt power to total power
cwtp=cwtp*std(sig)^2;                % cwt power scaled by total signal power (RMS^2)
%
% integrate (sum) power over all time for each scale
%
for kk=1:nscales                     % for each scale
  for jj=1:siglen                    % integrate (sum) over all time
    cwtpf(kk)=cwtpf(kk)+cwtp(kk,jj); % cwt power at each scale (frequency)
  end
end
```