AePW-4 High-Angle Working Group Meeting

June 13, 2024

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Agenda June 13th

- Review May 9th kickoff meeting
- CAD, Wing configuration, Grids, Computational domain, Flow conditions, etc.
- BSCW FUN3D DDES results at Mach 0.8, 5° (time permitting)

- July 11th meeting: BSCW Reduced-order model flutter results at AoA = 0°, 3°, 5° presentation by Walt Silva

AePW Goals and Motivation

- An open and impartial forum to assess and evaluate the current state-of-the-art and state-of-the-practice in computational aeroelastic modeling
  - How effective are current solvers at predicting aeroelastic physics critical to aircraft analysis and design?
  - How can we understand the reasons for why our solvers may fail?
  - Can we establish best-practices for using aeroelastic solvers?
  - Can we establish uncertainty bounds for computational results?
  - Can we specify requirements on future validation experiments?
- What computational and experimental areas of research need further development?

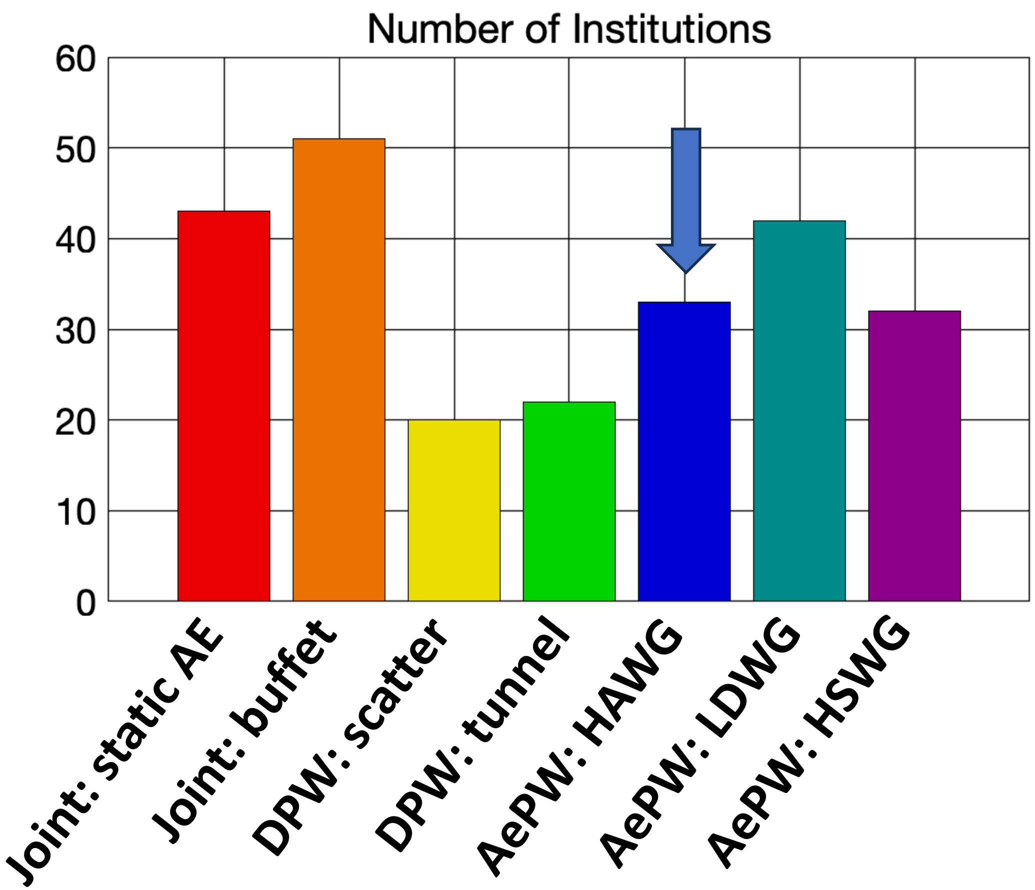
Organizing Committee

- Kirk Brouwer, AFRL (High-Speed WG)
- Carlos Cesnik, University of Michigan
- Pawel Chwalowski, NASA LaRC (High-Angle WG)
- Adam Jirasek, USAFA
- Jeff Ouellette, NASA LaRC
- Rafael Palacios, Imperial College London (High-Deformation WG)
- Daniella Raveh, Technion
- Markus Ritter, DLR
- Walt Silva, NASA LaRC
- Bret Stanford, NASA LaRC (AePW-4)

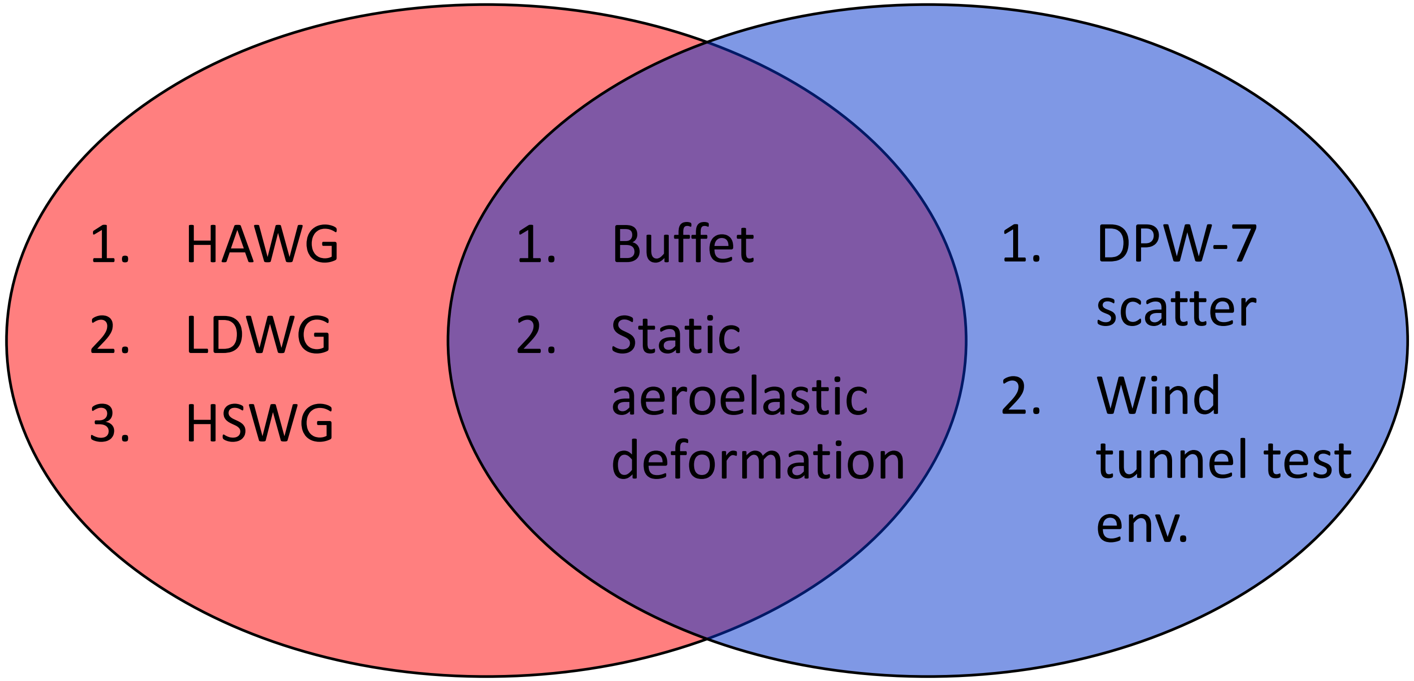
Transition to AePW-4; Joint Working Groups with DPW-8

https://aiaa-dpw.larc.nasa.gov

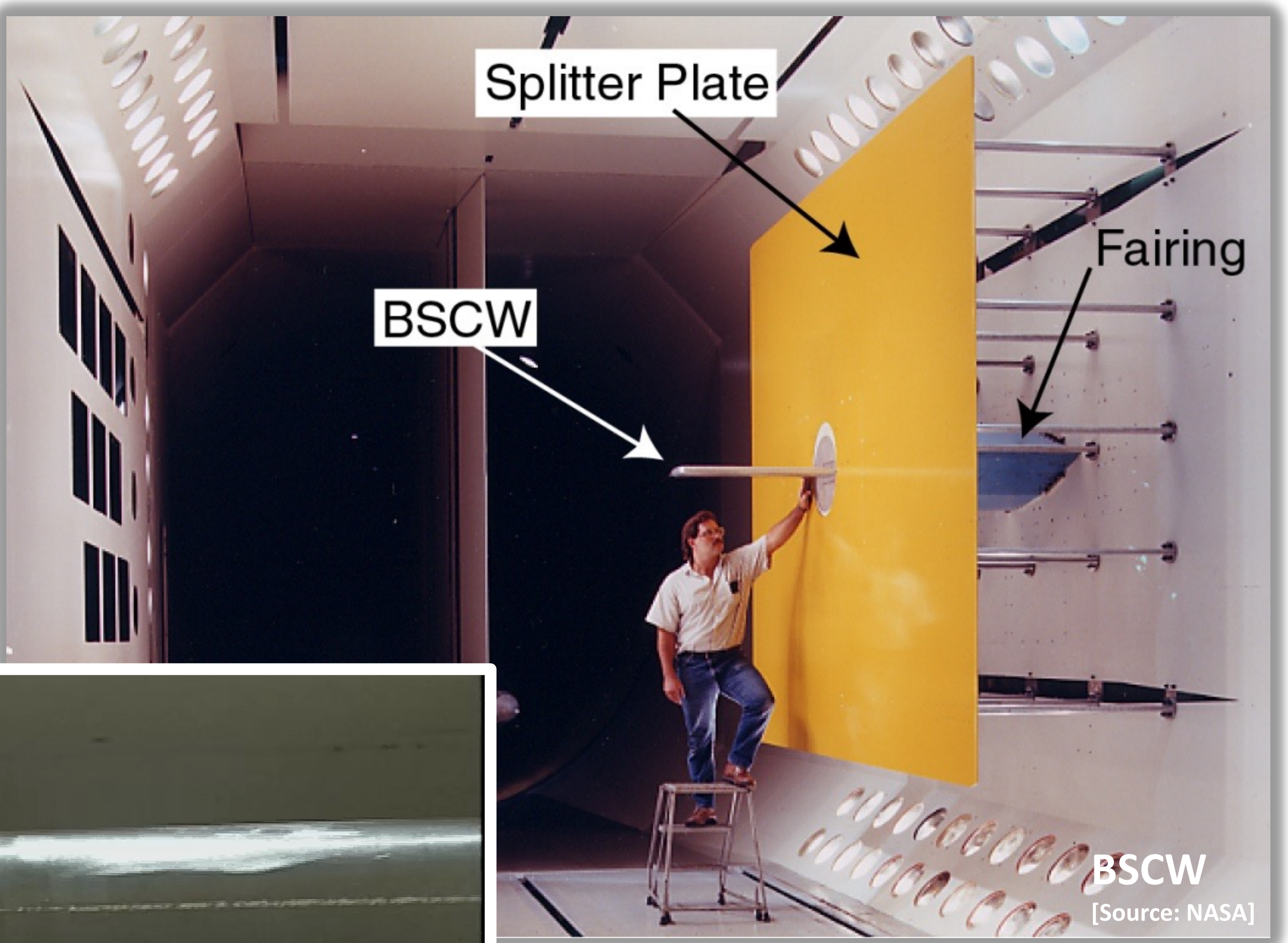
Joint workshop will take place at AIAA Aviation 2026

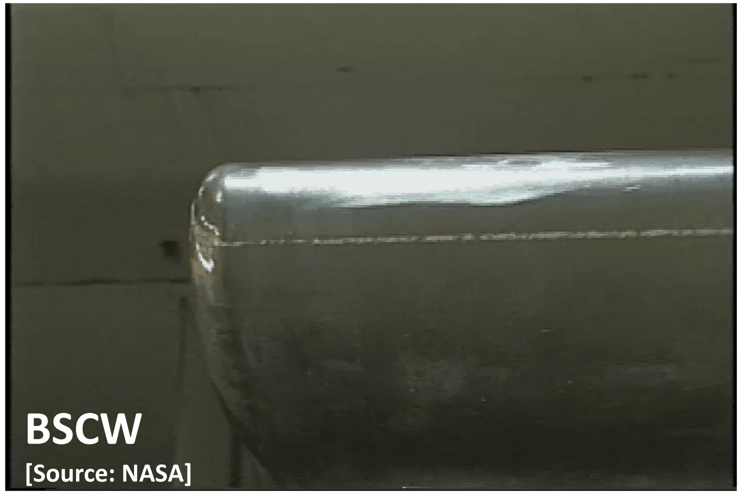


Venn Diagram of Working Groups

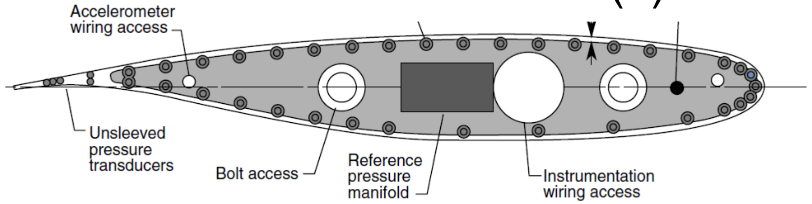


High-Angle WG: BSCW Wing Configuration

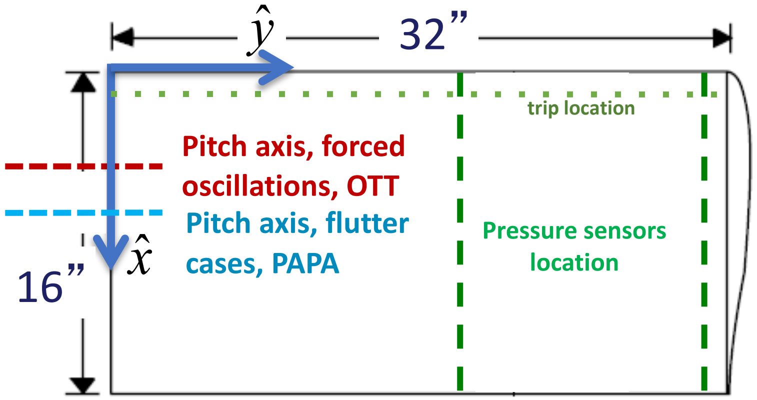




Airfoil section is SC(2)-0414



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

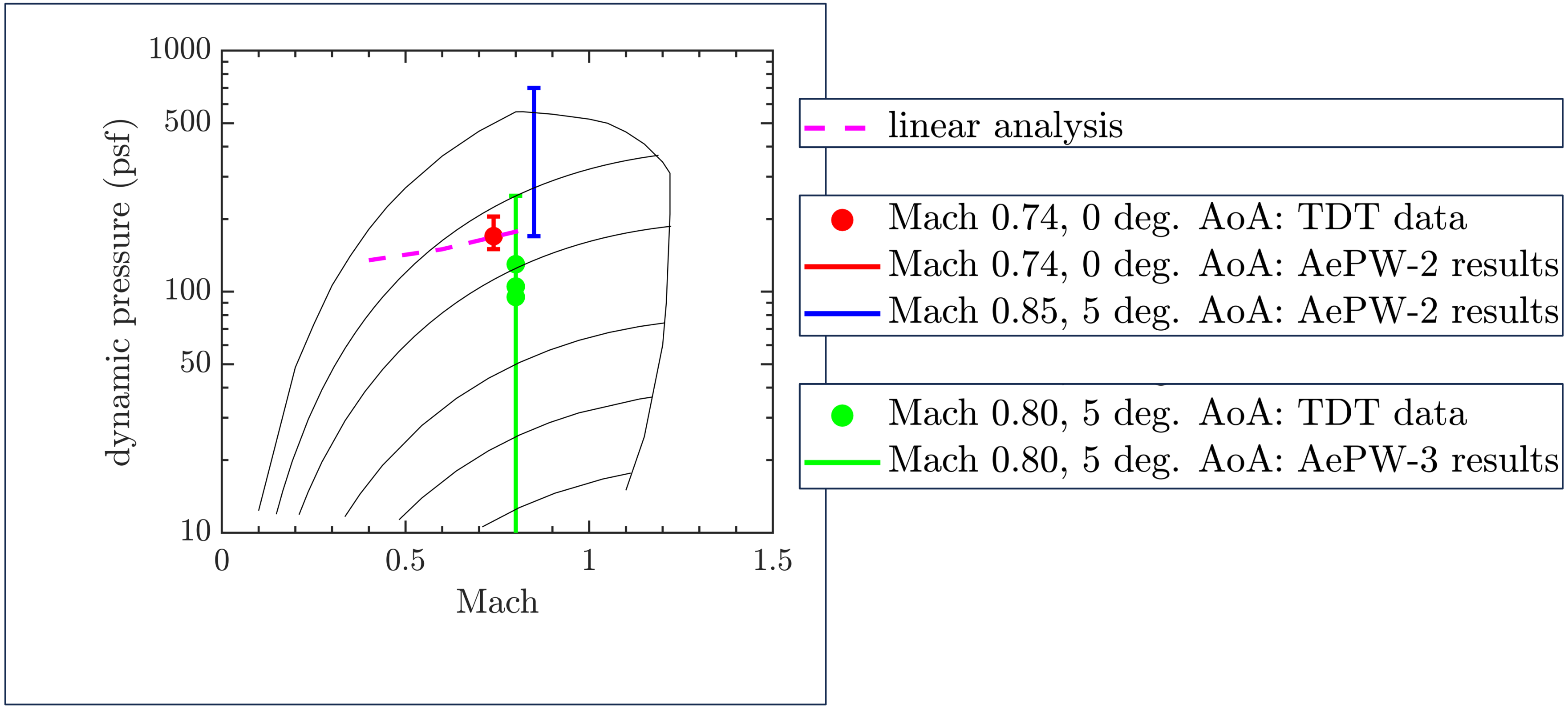


Model planform. Dimensions are in inches.

BSCW Wing Configuration Past Workshop Conditions

- AePW-1:
  - Steady-rigid and forced-oscillation cases at Mach 0.85, AoA = 5° ✓
- AePW-2:
  - Forced-oscillation case at Mach 0.70, AoA = 3° ✓
  - Flutter prediction at Mach 0.74, AoA = 0° ✓
  - Unsteady-rigid, forced-oscillation, and flutter cases at Mach 0.85, 5° ✓ ✓ ✓
- AePW-3:
  - <u>Flutter prediction at Mach 0.80, AoA = 5°</u> ✓
  - Shock-buffet case at Mach 0.80, AoA = 5° ✓
  - AIAA Paper 2024-0417 and 2024-0418

AePW-3: What have we learned?



- Large spread in BSCW flutter predictions from AePW-3 (though not as bad as AePW-2)
- We need more experimental data: more flutter data points, and more on-and off-body flow data at each flutter point

Past Experimental Data

EXPERIMENTAL UNSTEADY PRESSURES AT FLUTTER ON THE SUPERCRITICAL WING BENCHMARK MODEL

AIAA-93-1592-CP

Bryan E. Dansberry, Michael H. Durham*, Robert M. Bennett**, José A. Rivera*, Walter A. Silva*, and Carol D. Wieseman*; Structural Dynamics Division, NASA Langley Research Center, Hampton, VA 23681-0001
and David L. Turnock*
Lockheed Engineering and Sciences Corporation

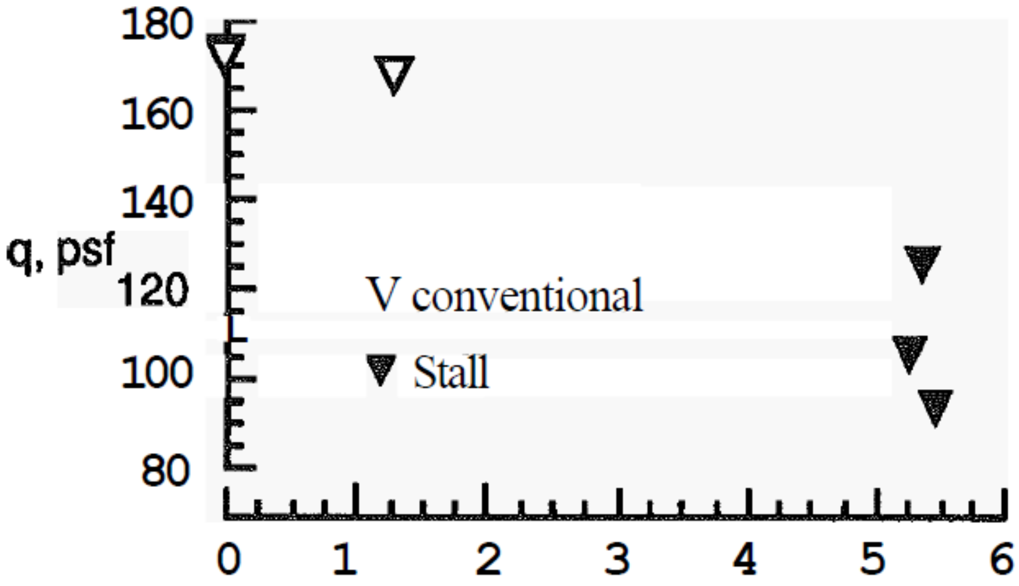


Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Past Experimental Data

EXPERIMENTAL UNSTEADY PRESSURES AT FLUTTER ON THE SUPERCRITICAL WING BENCHMARK MODEL

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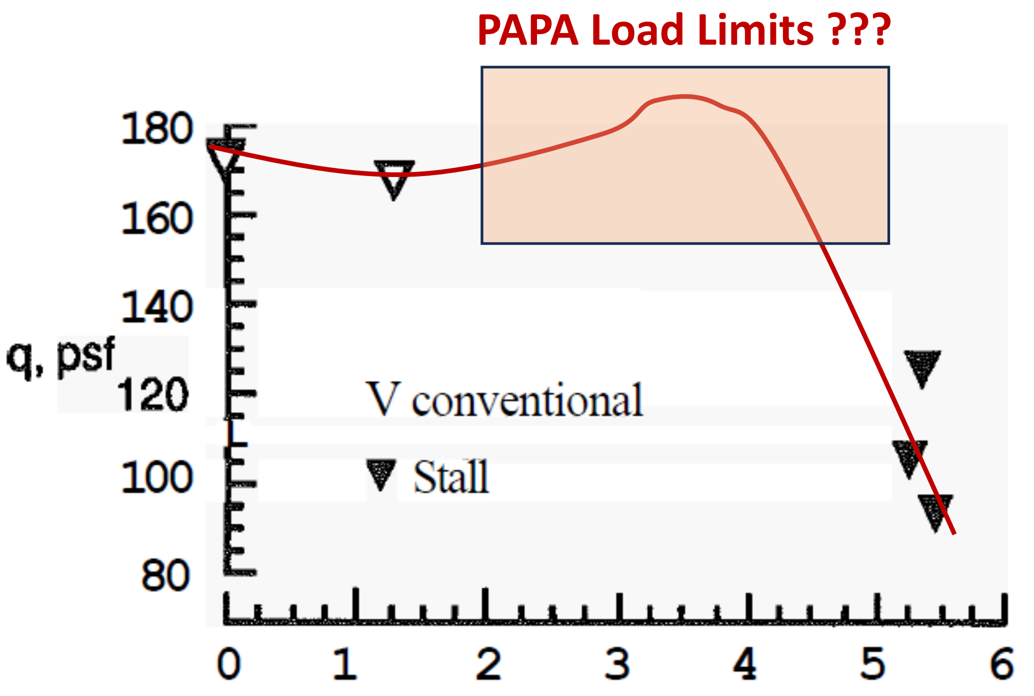


Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Future Experiment: Spring 2025

- Re-examine factor of safety for PAPA load limits
- Unsteady Pressure Sensitive Paint
- Flutter Stopper
- Two rows of pressure sensors + several on splitter plate
- PIV
- Flutter and buffet data at Mach, Q, AoA range

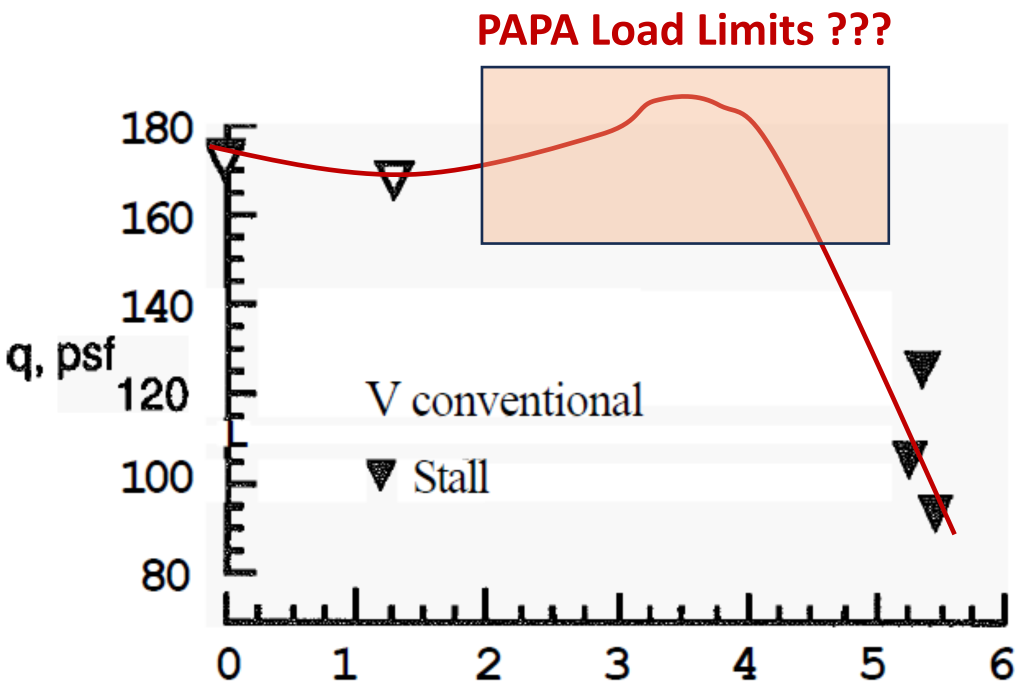


Figure 9. Stall flutter boundary in R-12 at M = 0.80.

Current Computational Effort w/FUN3D

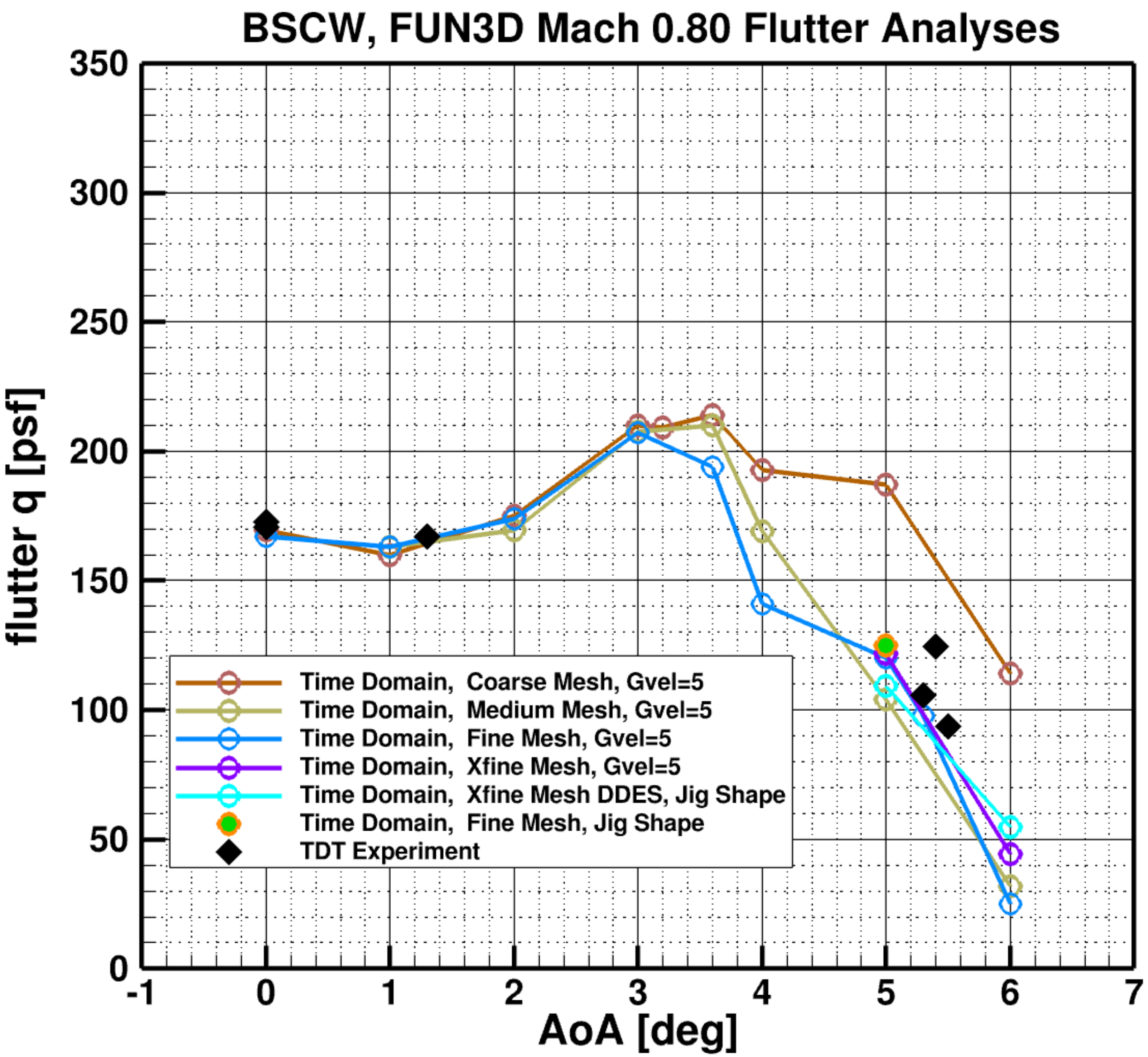
…trying to cover different methods…

- **FUN3D URANS time domain analysis:**
  Rigid steady → Static aeroelastic →
  Dynamic aeroelastic (with initial excitation using Gvel=5)

- **Working on:**
  Rigid steady → Dynamic aeroelastic (Jig shape)

- **Working on:**
  Scale-resolving DDES FUN3D time domain analysis:
  Rigid steady → Static aeroelastic →
  Dynamic aeroelastic (with initial excitation using Gvel)

- **Working on:**
  Adding URANS solutions for Xfine Mesh



Current Computational Effort w/FUN3D

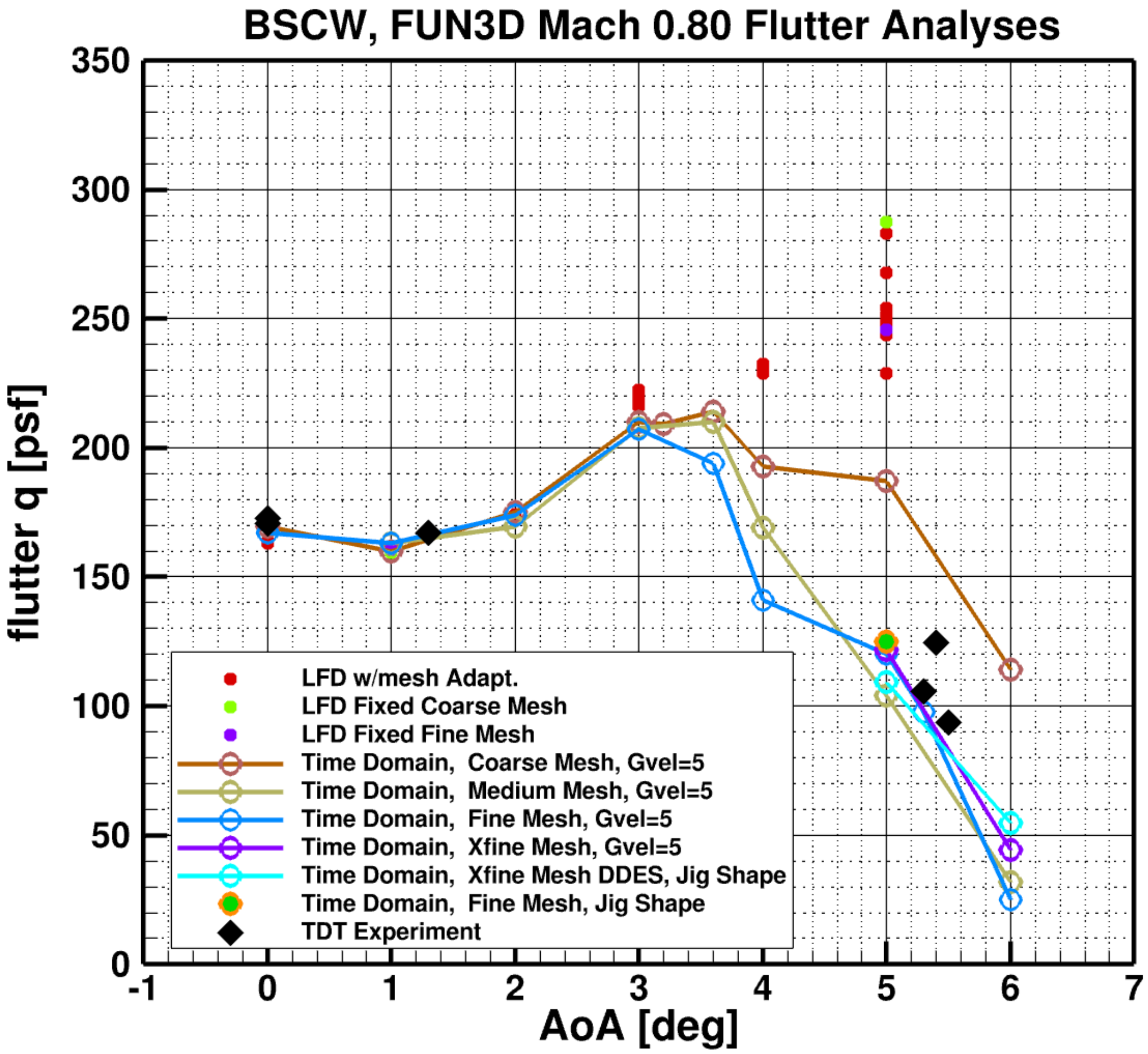
…trying to cover different methods…

- **FUN3D Linearized Frequency Domain (LFD):**
  Rigid steady → Static aeroelastic → LFD

  LFD + Mesh Adaptation

- **Working on:**
  Adding angle-of-attack sweeps

- **ROM**



AePW-4 High-Angle WG Cases

- Mandatory
  - Flutter prediction at Mach 0.80 and angle-of-attack sweep: 0° – 6°
- Optional
  - Flutter prediction at Mach 0.78, 0.76, 0.74 and angle-of-attack 3°

Schedule/Timeline/Logistics

- Monthly meetings on second Thursday of each month at 10 am EDT

- IFASD 2024: 17 – 21 June 2024, The Hague - Bret Stanford
- AIAA Aviation 2024: Las Vegas, NV - Bret Stanford
- AIAA SciTech 2025: Orlando, FL (?)
- Spring 2025: New BSCW Experiment (Data release ?)

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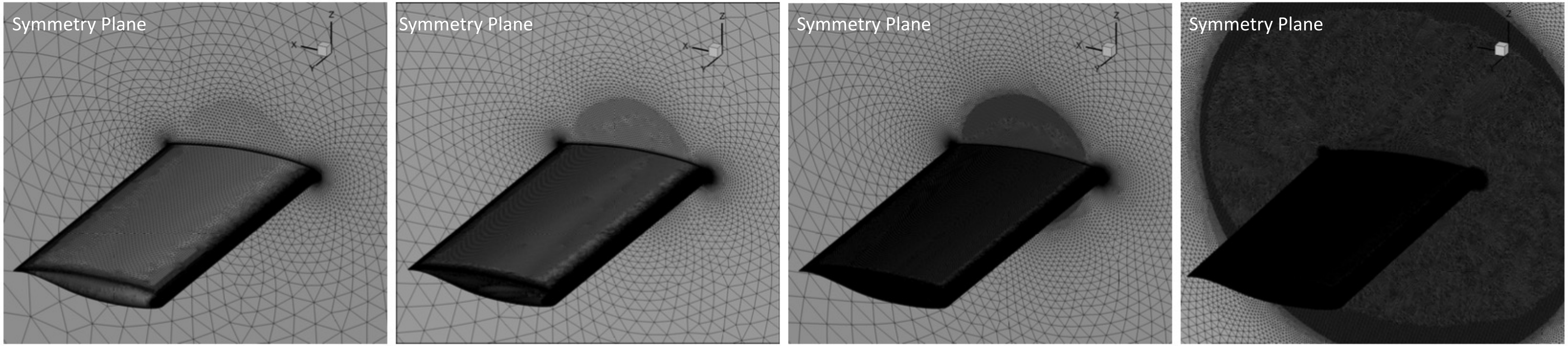
- AIAA Aviation 2026: DPW-8 and AePW-4 Workshop

CAD, Grids, Computational domain, Flow conditions,….

- On AePW-2 website: https://nescacademy.nasa.gov/workshops/AePW2/public/ under Analysts Information you can download BSCW iges file. Gridding guidelines adopted from the DPW are also listed.
- Note that the iges file consists of BSCW wing mounted on a splitter plate. But…
- For AePW-1, AePW-2, and AePW-3, we assumed wing-only that is attached to a plane of symmetry.
- Several grids are also available for download. But do we need to build and provide new grids?
- BSCW structural model is described, and NASTRAN files are available.

CAD, Grids, Computational domain, Flow conditions,….

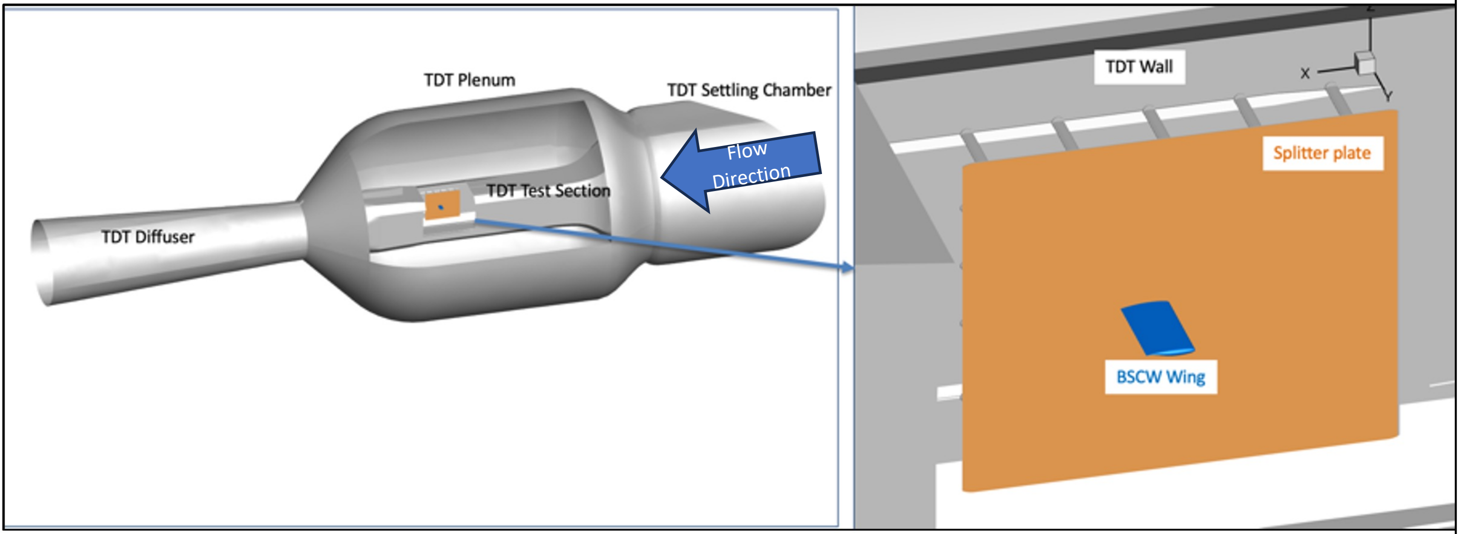


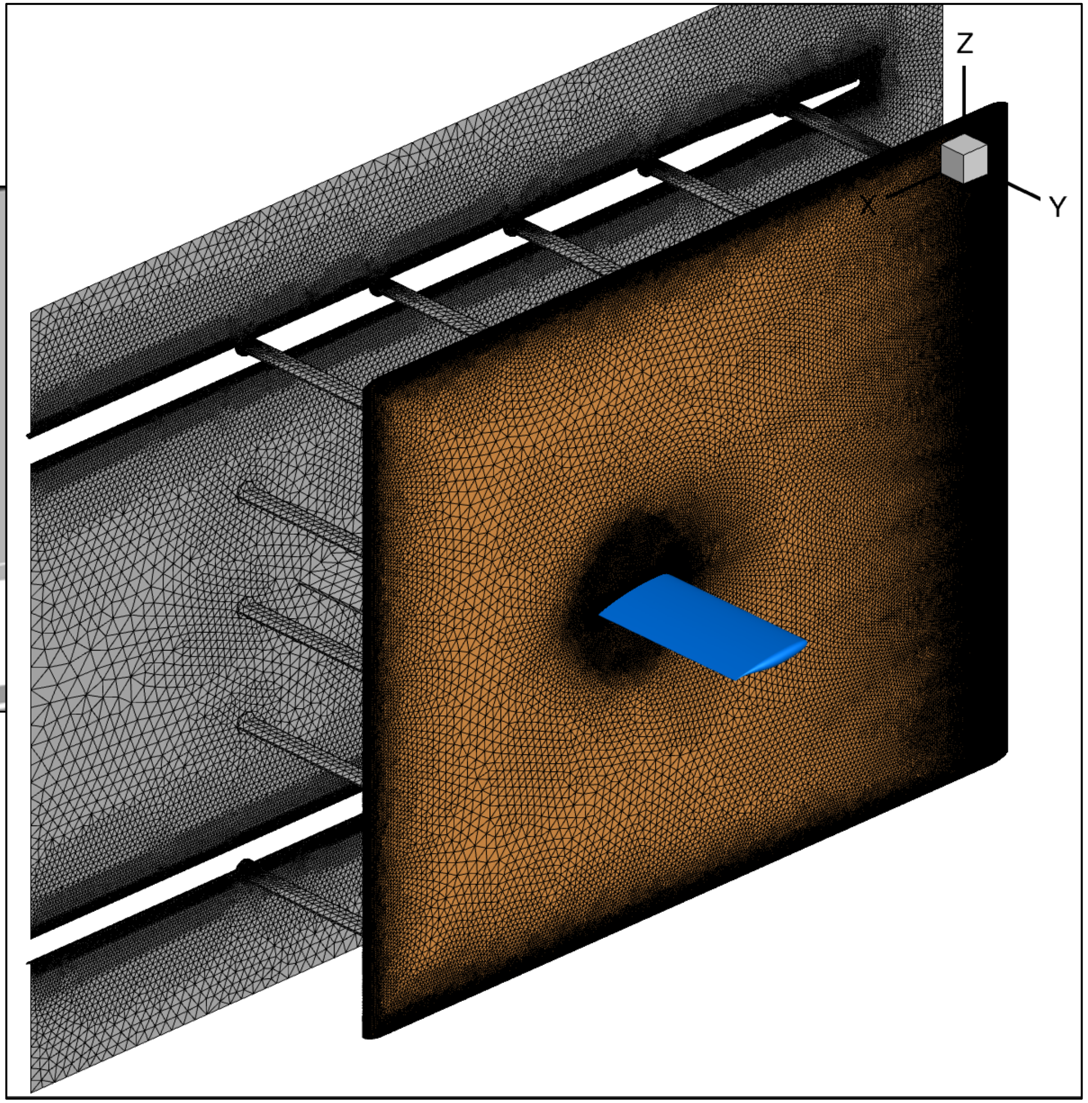
(a) Coarse grid, 3M nodes. (b) Medium grid, 9M nodes. (c) Fine grid, 27M nodes. (d) Xfine grid, 99M nodes.

Node centered…. ‘nc’
Cell centered…. ‘cc’

Computational Domain: Wing-only vs. BSCW-in-tunnel

BSCW-in-tunnel





CAD, Grids, Computational domain, Flow conditions,….

AePW-3 Summary Paper, https://doi.org/10.2514/6.2024-0418

Table 2 BSCW flow conditions: Mach 0.8 with range of dynamic pressure (q); chord Reynolds number (Re_c); Reynolds number per foot (Re); velocity (V); speed of sound (a); static temperature, (T_{static}); density (ρ); ratio of specific heat (γ); viscosity (μ); Prandtl number (Pr); total pressure (H); and static pressure (P).

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
q [psf]	10.02	25.00	35.00	50.00	75.00	100.00	134.00	143.00	152.00	168.80	200.00	225.00	250.00
Re_c	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	440.00	439.96	439.88	439.70	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} [$^\circ F$]	80.87	80.83	80.83	80.82	80.81	80.80	80.78	80.77	80.77	80.76	80.74	80.73	80.71
ρ [slug/ft^3]	0.000103	0.000258	0.000361	0.000515	0.000774	0.001032	0.001384	0.001477	0.001571	0.001745	0.002069	0.002329	0.002589
γ	1.1121	1.1122	1.1123	1.1124	1.1126	1.1128	1.1131	1.1131	1.1132	1.1133	1.1136	1.1138	1.1139
μ [lb-sec/ft^2]	2.555e-07	2.555e-07	2.555e-07	2.555e-07	2.555e-07	2.555e-07	2.554e-07	2.554e-07	2.554e-07	2.554e-07	2.554e-07	2.554e-07	2.554e-07
Pr	0.68394	0.68404	0.68410	0.68419	0.68435	0.68450	0.68471	0.68477	0.68483	0.68493	0.68513	0.68528	0.68544
H [psf]	40.00	99.72	139.61	199.45	299.18	399.00	534.69	570.61	606.53	673.59	798.21	898.01	997.83
P [psf]	28.21	70.32	98.45	140.64	210.97	281.37	377.05	402.38	427.71	475.00	562.87	633.25	703.64

CAD, Grids, Computational domain, Flow conditions,….

Mach 0.74

Mach	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
q [psf]	50.00	75.00	100.00	134.00	143.00	152.00	168.80	200.00
Re_c	1275964	1914959	2554246	3423935	3654400	3884927	4315413	5115471
Re [1/ft]	956973	1436219	1915684	2567951	2740800	2913695	3236560	3836603
V [ft/s]	407.58	407.37	407.23	407.09	407.04	406.99	406.89	406.71
a [ft/s]	550.82	550.56	550.30	549.93	549.84	549.74	549.56	549.23
T_{static} [$^\circ F$]	83.60	83.59	83.58	83.55	83.55	83.54	83.54	83.52
ρ [slug/ft^3]	0.000602	0.000904	0.001206	0.001617	0.001726	0.001836	0.002039	0.002418
γ	1.1116	1.1119	1.1121	1.1124	1.1125	1.1125	1.1127	1.1130
μ [lb-sec/ft^2]	2.564E-07	2.564E-07	2.564E-07	2.564E-07	2.564E-07	2.564E-07	2.564E-07	2.563E-07
Pr	0.68325	0.68343	0.68360	0.68385	0.68391	0.68398	0.68410	0.68432
H [psf]	221.92	332.99	444.03	594.95	634.93	674.92	749.56	888.22
P [psf]	164.50	246.83	329.14	441.01	470.65	500.29	555.62	658.40

CAD, Grids, Computational domain, Flow conditions,….

Mach 0.76

Mach	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
q [psf]	50.00	75.00	100.00	134.00	143.00	152.00	168.80	200.00
Re_C	1245425	1868520	2492233	3341185	3566044	3790959	4210646	4991103
Re [1/ft]	934069	1401390	1869175	2505889	2674533	2843219	3157984	3743327
V [ft/s]	418.22	418.15	418.01	417.82	417.78	417.73	417.67	417.50
a [ft/s]	550.43	550.18	549.93	549.58	549.49	549.40	549.23	548.92
T_{static} [$^\circ F$]	82.72	82.70	82.69	82.67	82.67	82.66	82.65	82.63
ρ [slug/ft^3]	0.000572	0.000858	0.001145	0.001535	0.001639	0.001742	0.001936	0.002295
γ	1.1118	1.1120	1.1122	1.1125	1.1125	1.1126	1.1128	1.1130
μ [lb-sec/ft^2]	2.560E-07	2.560E-07	2.560E-07	2.560E-07	2.560E-07	2.560E-07	2.560E-07	2.559E-07
Pr	0.68360	0.68377	0.68394	0.68417	0.68423	0.68430	0.68441	0.68463
H [psf]	213.86	320.74	427.68	573.16	611.67	650.19	722.01	855.54
P [psf]	155.96	233.91	311.91	418.00	446.09	474.18	526.56	623.94

CAD, Grids, Computational domain, Flow conditions,….

Mach 0.78

Mach	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
q [psf]	50.00	75.00	100.00	134.00	143.00	152.00	168.80	200.00
Re_c	1216355	1824869	2433950	3262935	3482495	3702106	4112185	4874236
Re [1/ft]	912266	1368652	1825462	2447201	2611871	2776579	3084139	3655677
V [ft/s]	428.90	428.83	428.70	428.53	428.48	428.43	428.35	428.19
a [ft/s]	550.03	549.79	549.55	549.22	549.13	549.05	548.88	548.58
T_{static} [$^\circ F$]	81.82	81.80	81.79	81.77	81.76	81.76	81.75	81.73
ρ [slug/ft^3]	0.000544	0.000816	0.001088	0.001460	0.001558	0.001656	0.001840	0.002182
γ	1.1119	1.1121	1.1123	1.1125	1.1126	1.1127	1.1128	1.1131
μ [lb-sec/ft^2]	2.556E-07	2.556E-07	2.556E-07	2.556E-07	2.556E-07	2.556E-07	2.555E-07	2.555E-07
Pr	0.68396	0.68413	0.68429	0.68451	0.68457	0.68463	0.68474	0.68495
H [psf]	206.41	309.56	412.78	553.16	590.33	627.50	696.88	825.74
P [psf]	148.06	222.05	296.08	396.78	423.44	450.10	499.87	592.30

AePW-4 High-Angle Working Group Meeting

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