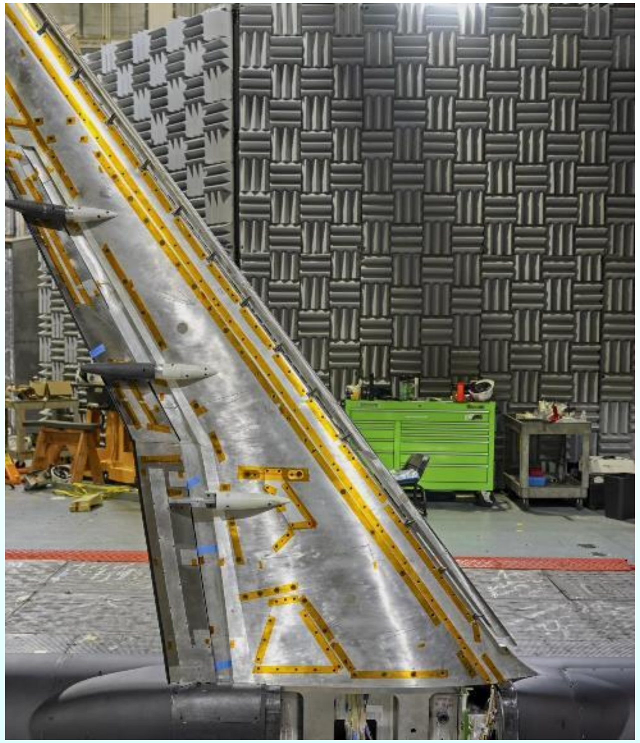
Airframe Noise Research

David P. Lockard

Acoustics TWG Meeting, October 2021

Advanced Air Transport Technology
(AATT) Project

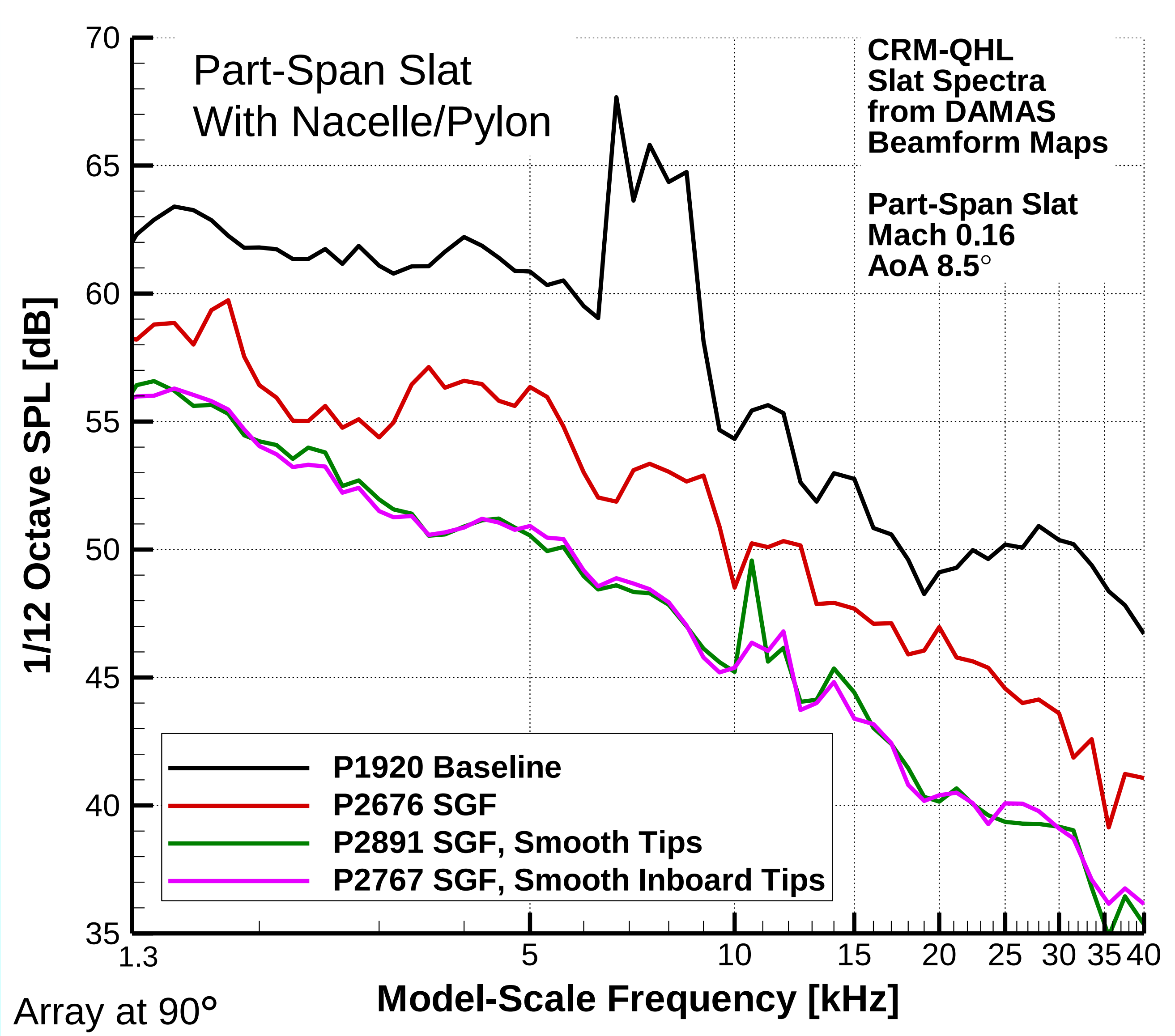
High-Lift Common Research Model (CRM-HL)

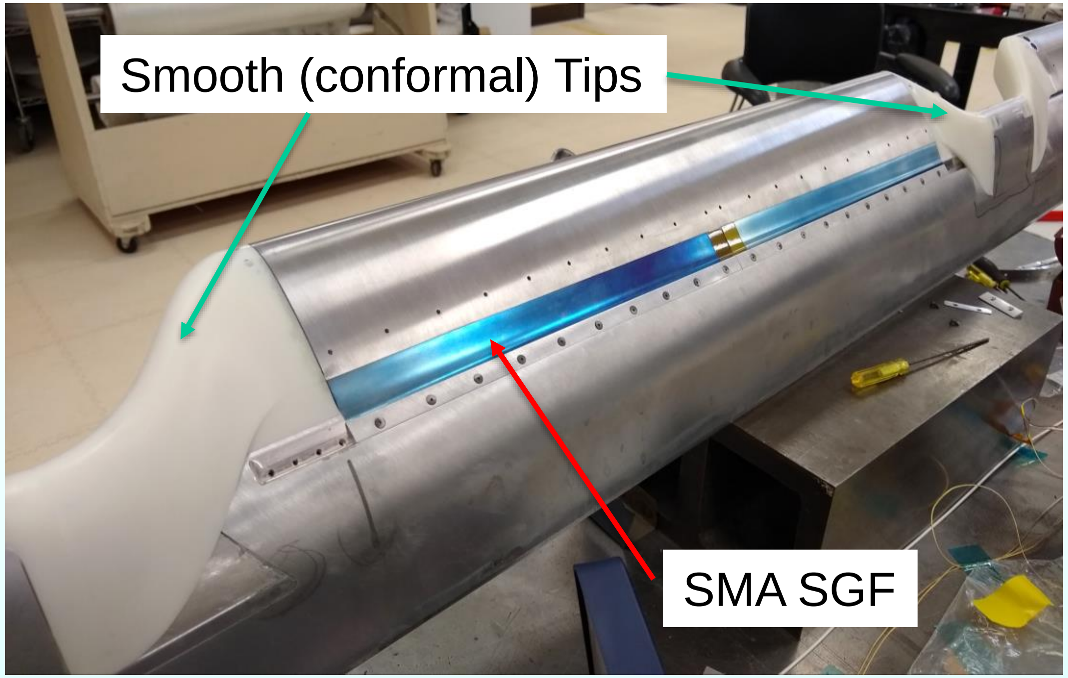


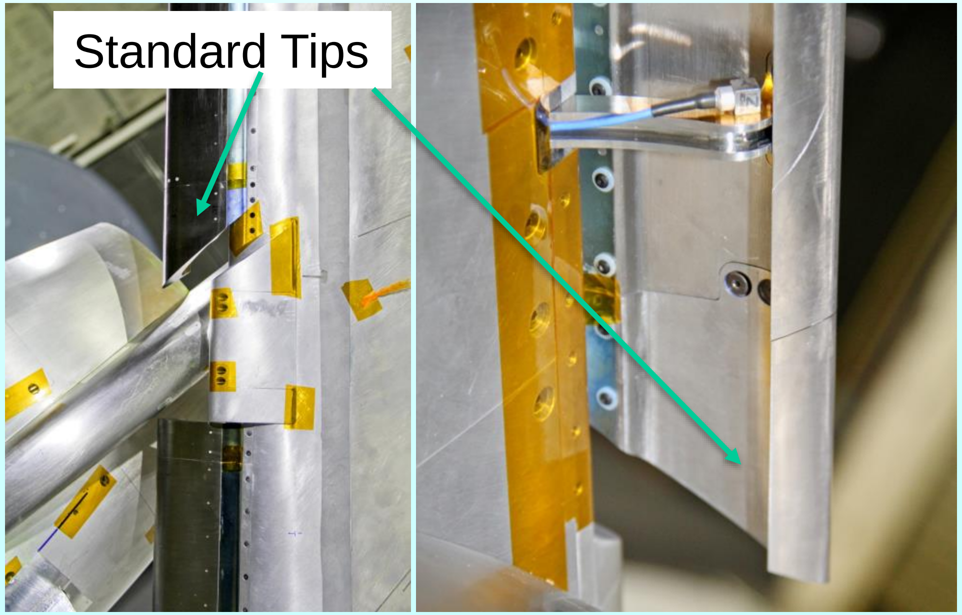
An open geometry high-lift configuration based on the high-speed CRM. Developed by Boeing® in 2015 using modern design practices

- NASA Langley Research Center 14- by 22-Foot Subsonic Tunnel (14x22) testing with aerodynamic and acoustic data collection
  - Continued processing of the experimental data from 2020/2021
  - Unsteady numerical simulations being used to help understand some of the results

Shape Memory Alloy (SMA) Slat-Gap Filler (SGF)

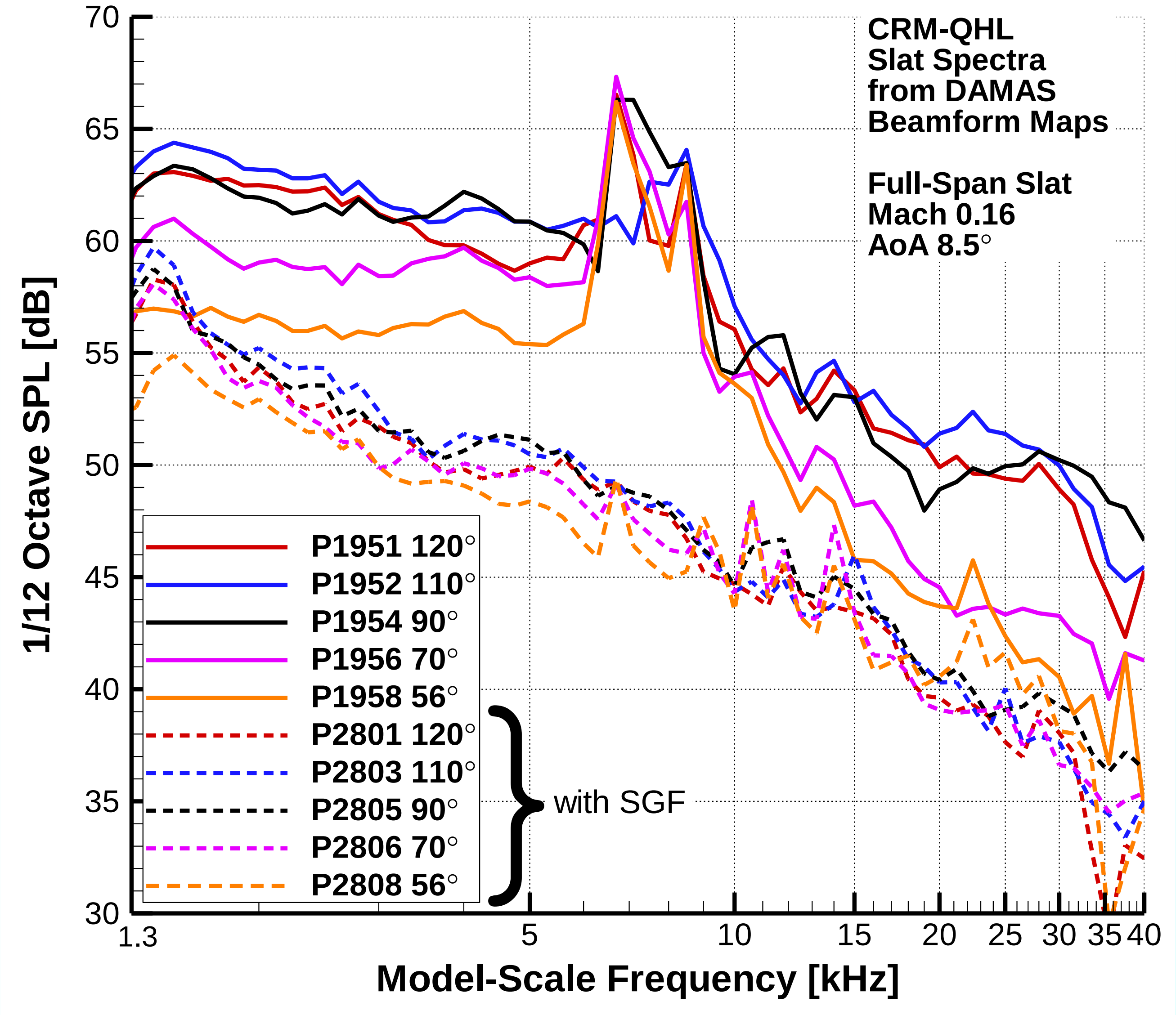






The SMA allows the gap to be opened rapidly should an anomalous high AoA condition occur

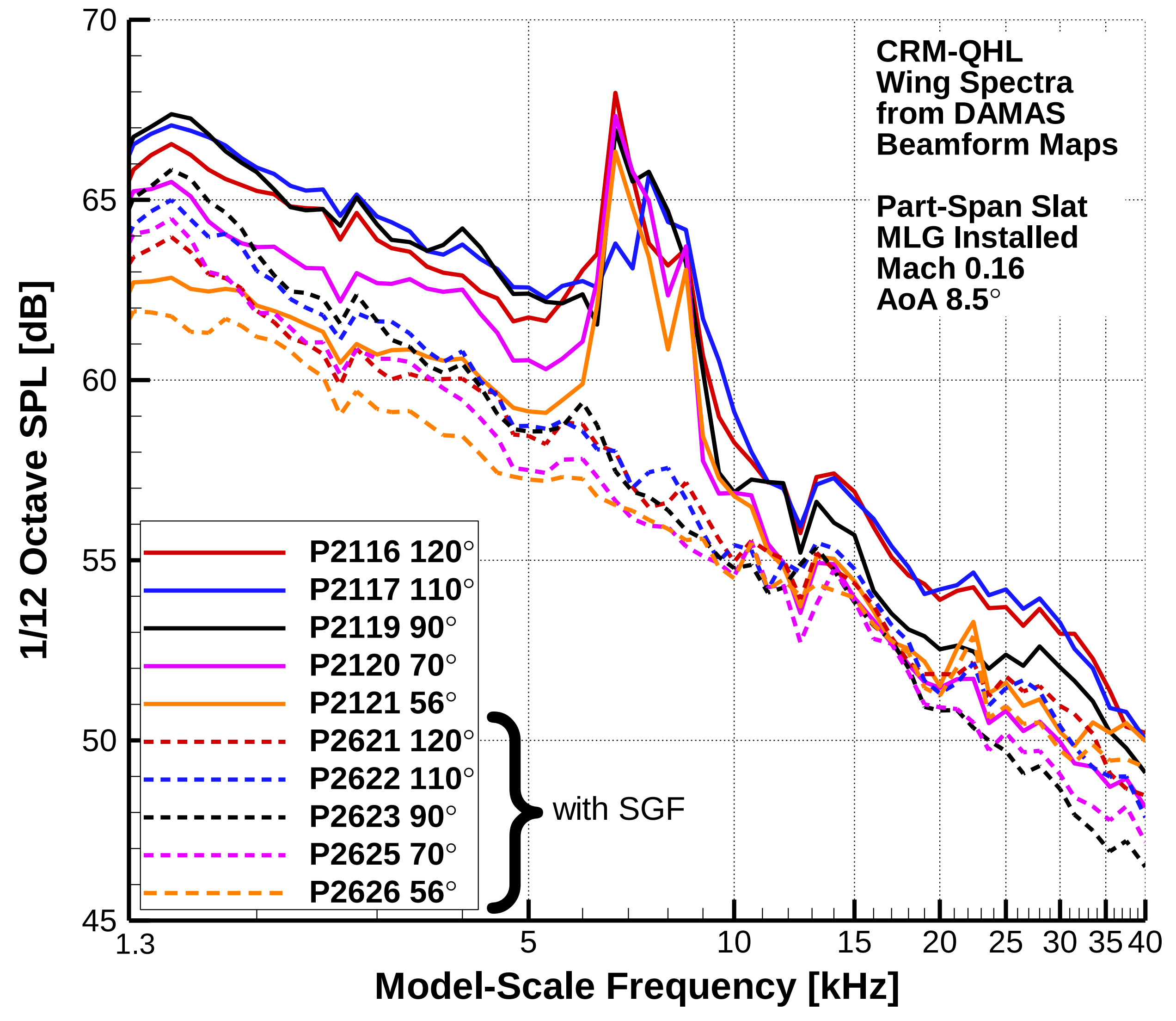
Slat-Gap Filler (SGF) Directivity



Part-Span Slat With Nacelle/Pylon

- Noise reduction achieved for all directivity angles measured
  - Near noise floor with the SGF
  - Likely some contamination at 56° (from inlet) and 120° (from collector and thick shear layer)

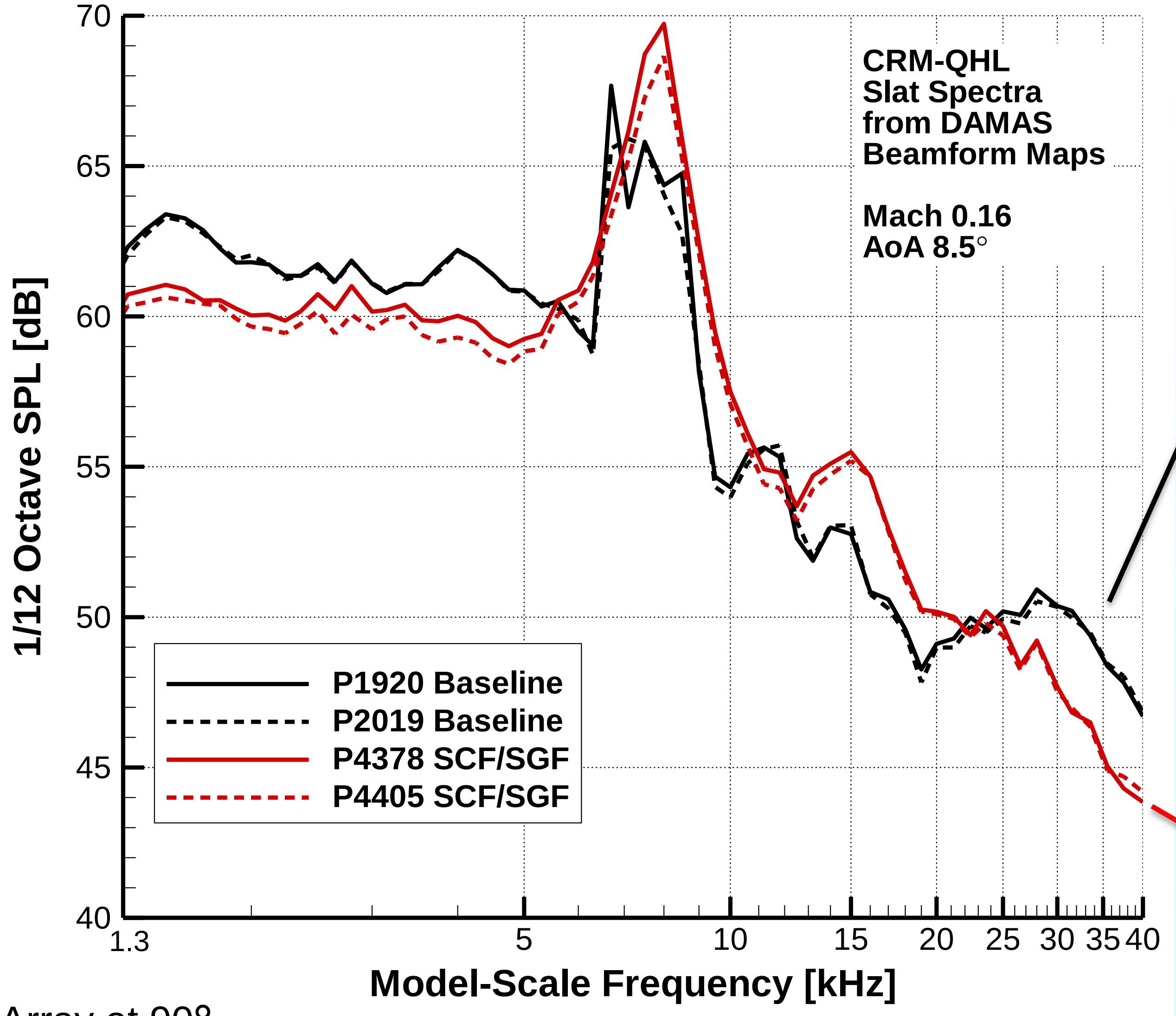
MLG + SGF Spectra from the Whole Wing (PSS Directivity)



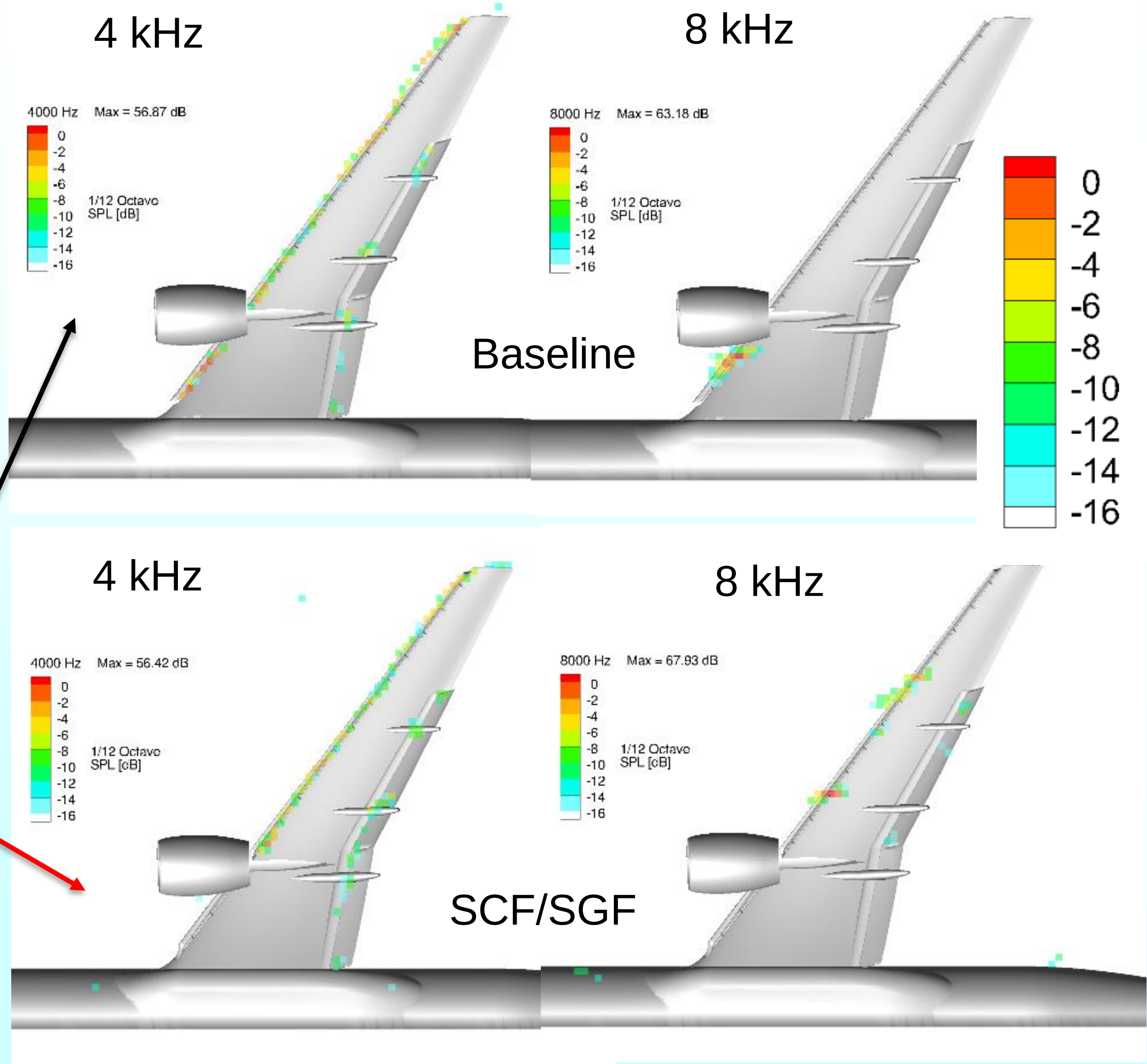
Part-Span Slat with Nacelle and Main Landing Gear

- Noise reduction achieved for all directivity angles measured
  - Similar reduction for all angles except for extreme upstream (56°) and high frequencies, which are dominated by gear noise

Slat-Cove Filler Spectra from Experiment (Mach 0.16)



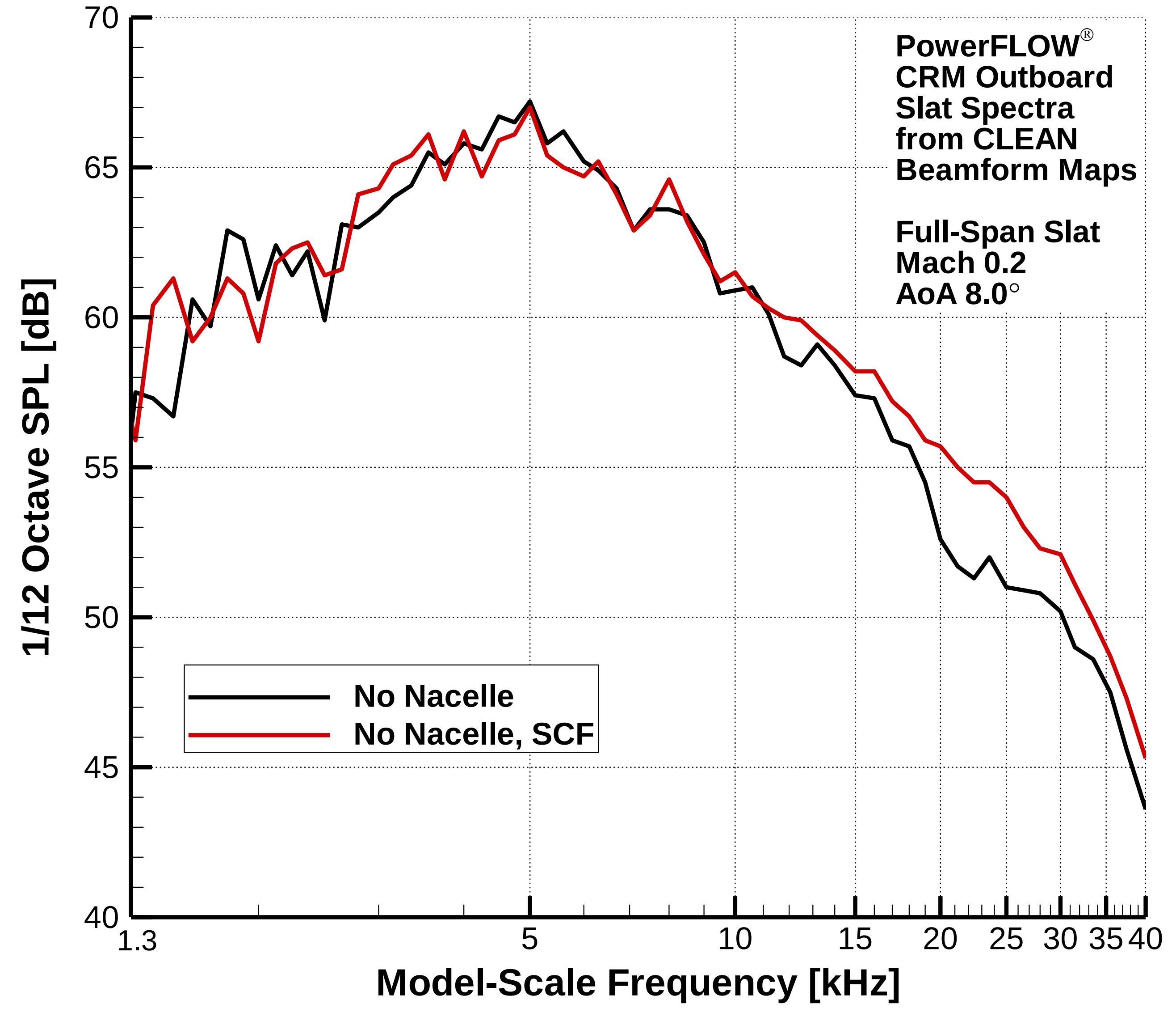
Array at 90°

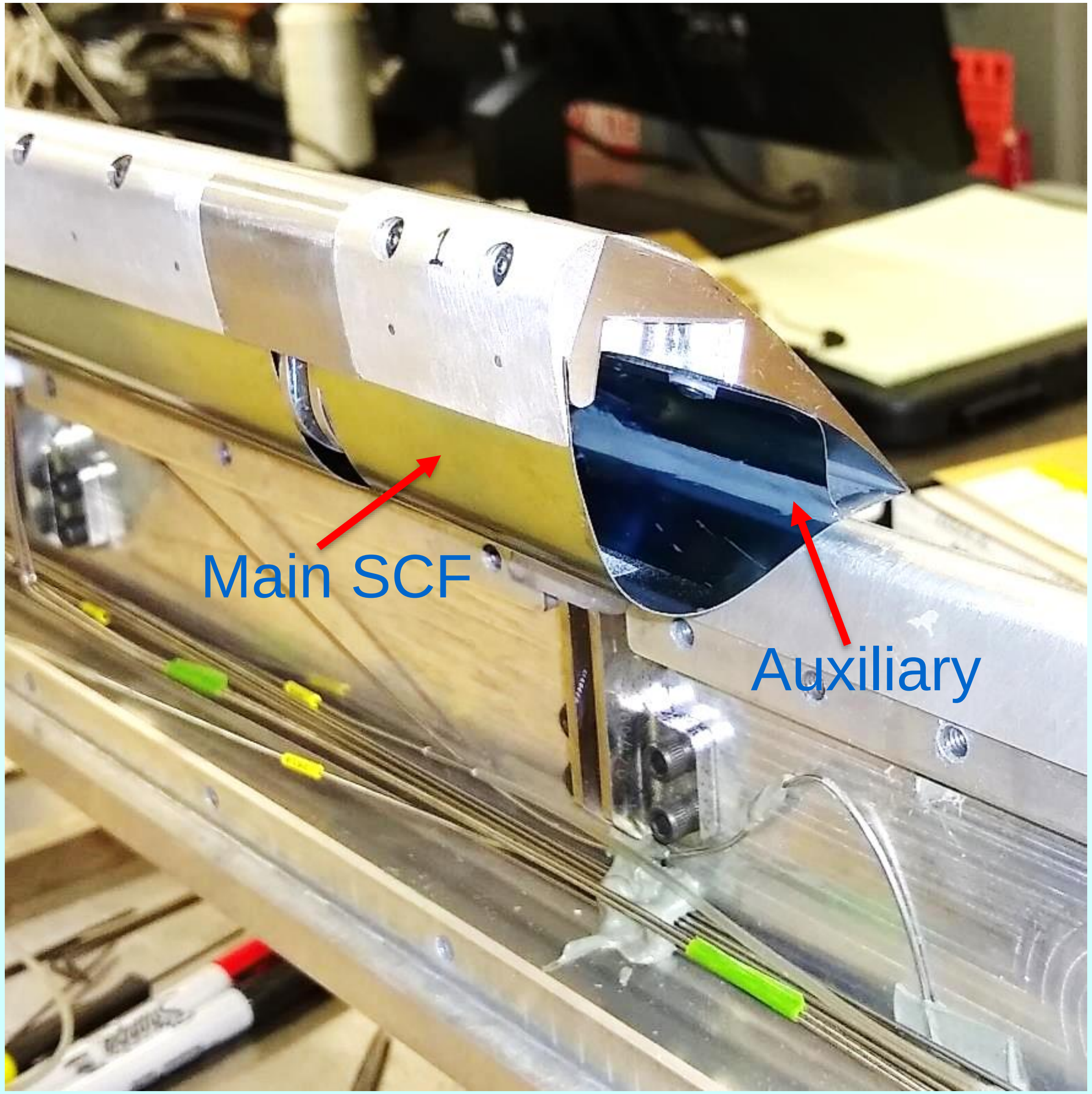


Most Noise Reduction Attributable to the SGF on Inboard Slat

SCF on Outboard Slat, SGF Inboard

Slat-Cove Filler Spectra from Simulations (Mach 0.2)



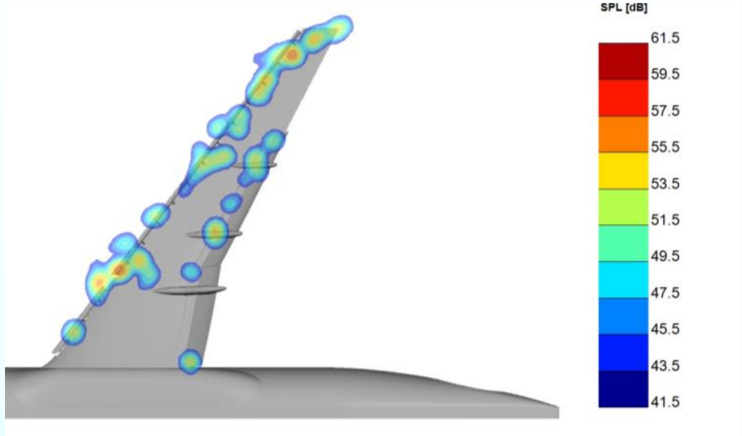


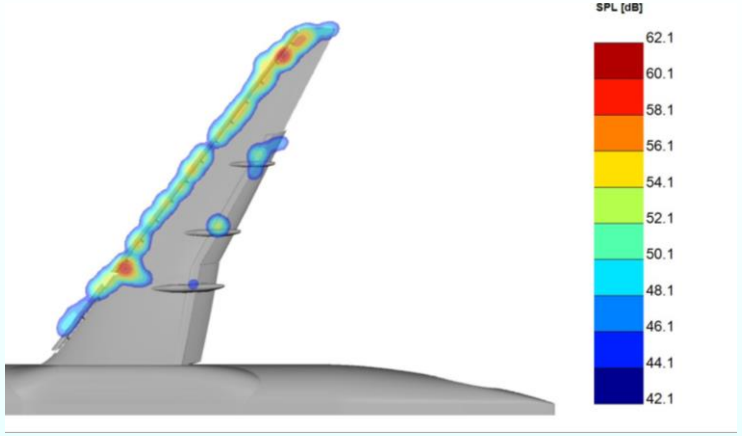
PowerFLOW® unsteady simulation + Ffowcs-Williams Hawkings

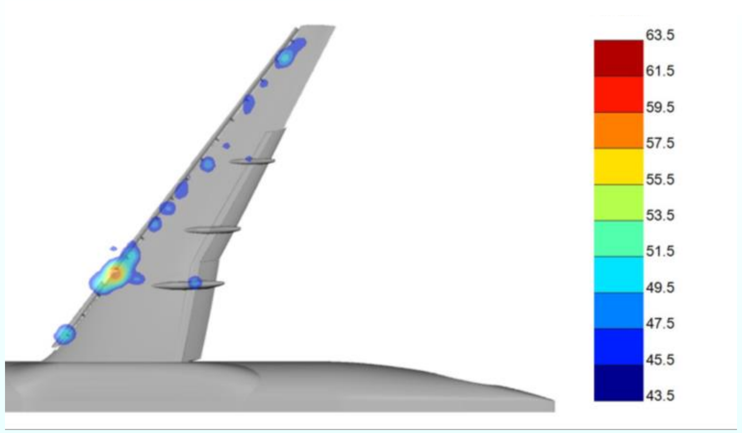
Beamform Maps from Simulations

Baseline without Nacelle/Pylon

1/12th Octave SPL



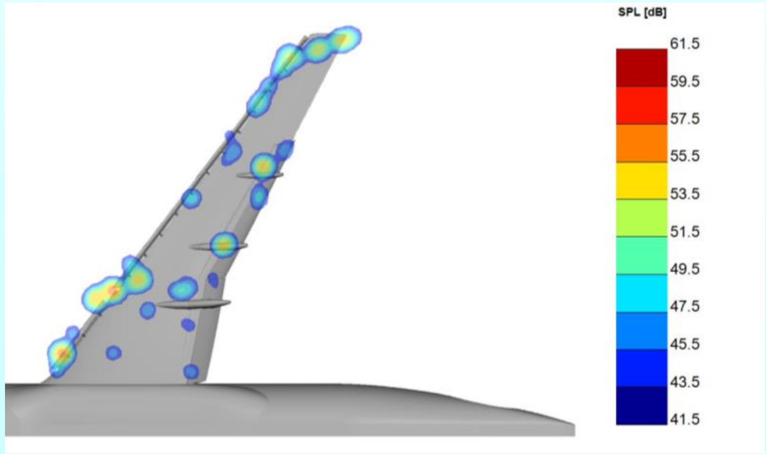


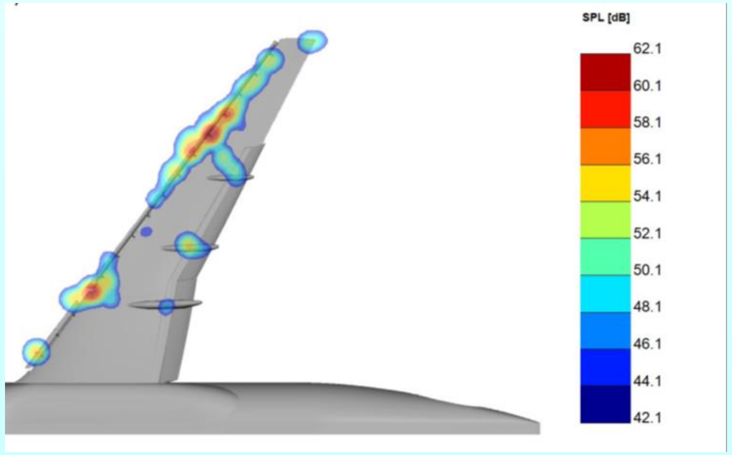


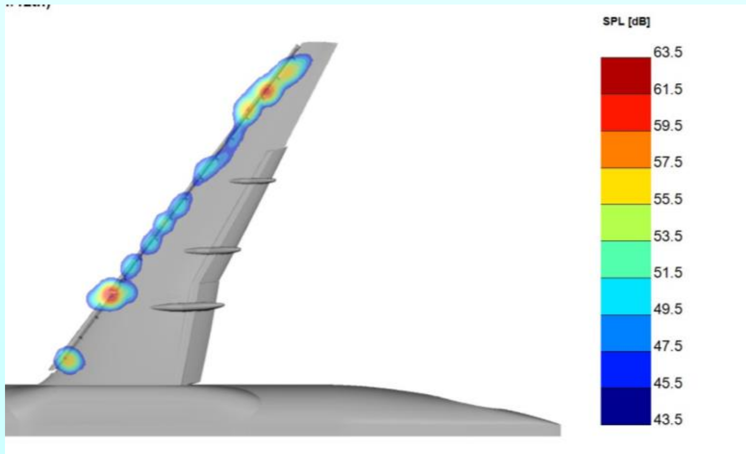
3 kHz

5 kHz

13.2 kHz





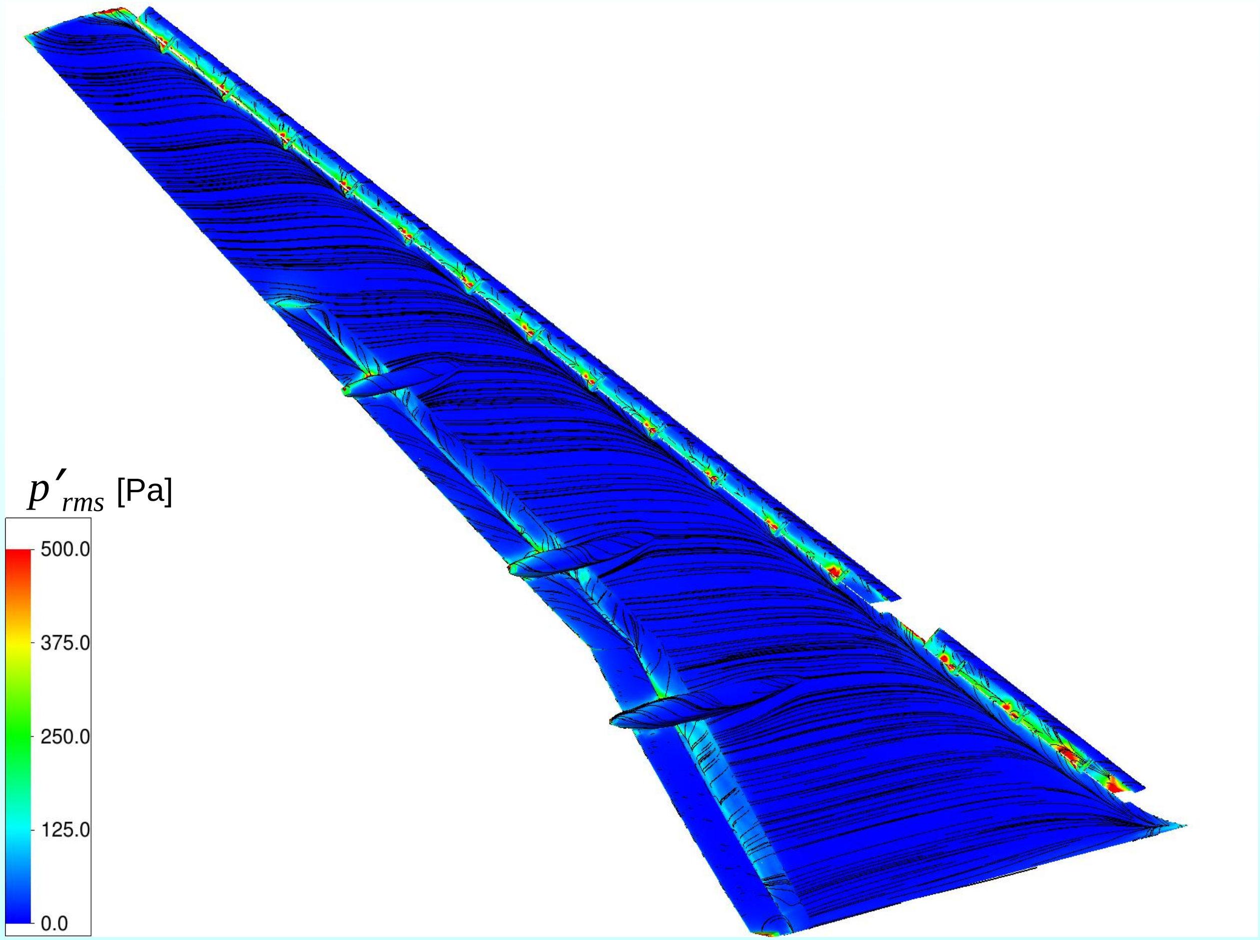


The levels are the same for each column

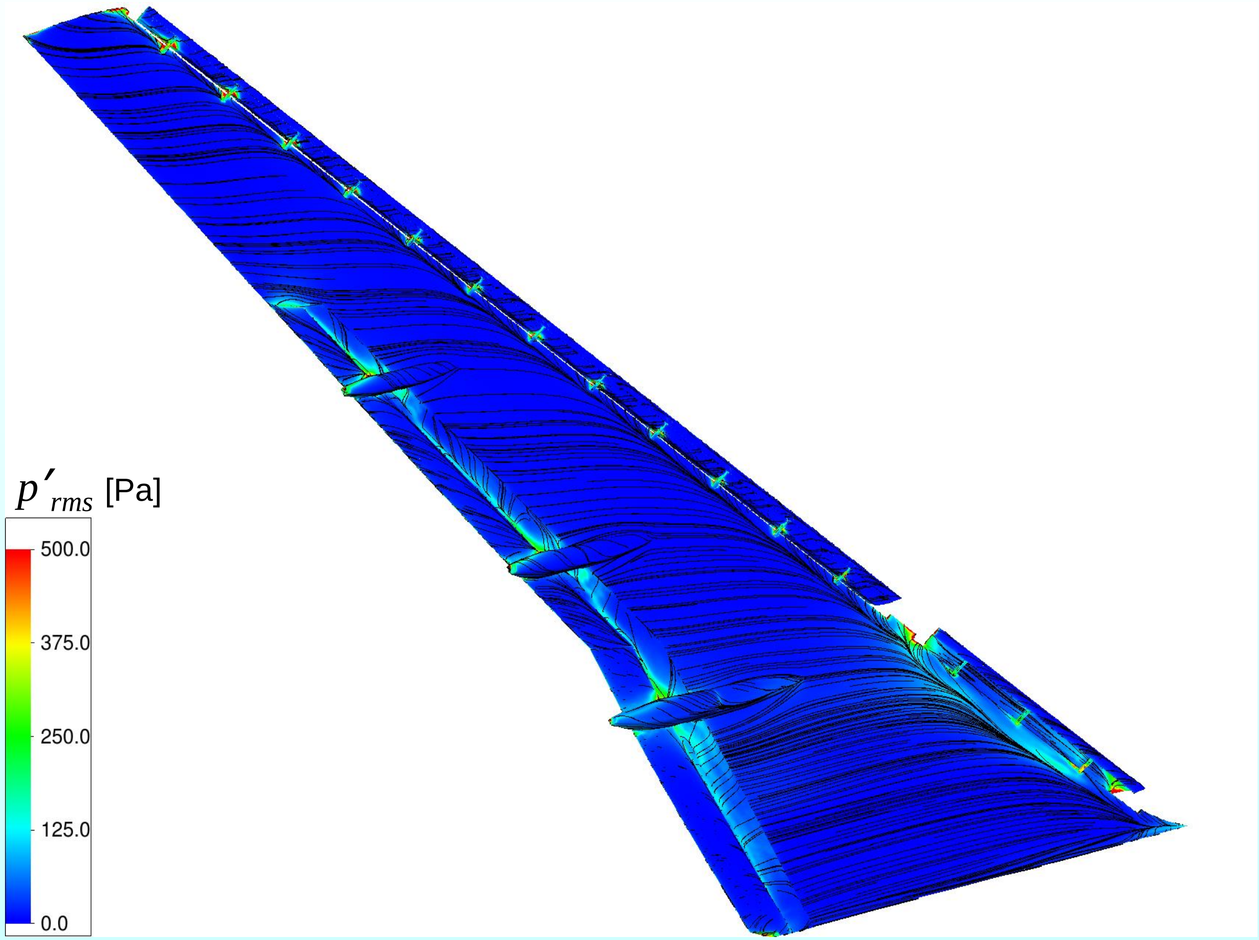
Slat-Cove Filler without Nacelle/Pylon

Fluctuating Surface Pressure Contours

Unsteady numerical simulation results with PowerFLOW®
Mach 0.2, AoA = 8 deg

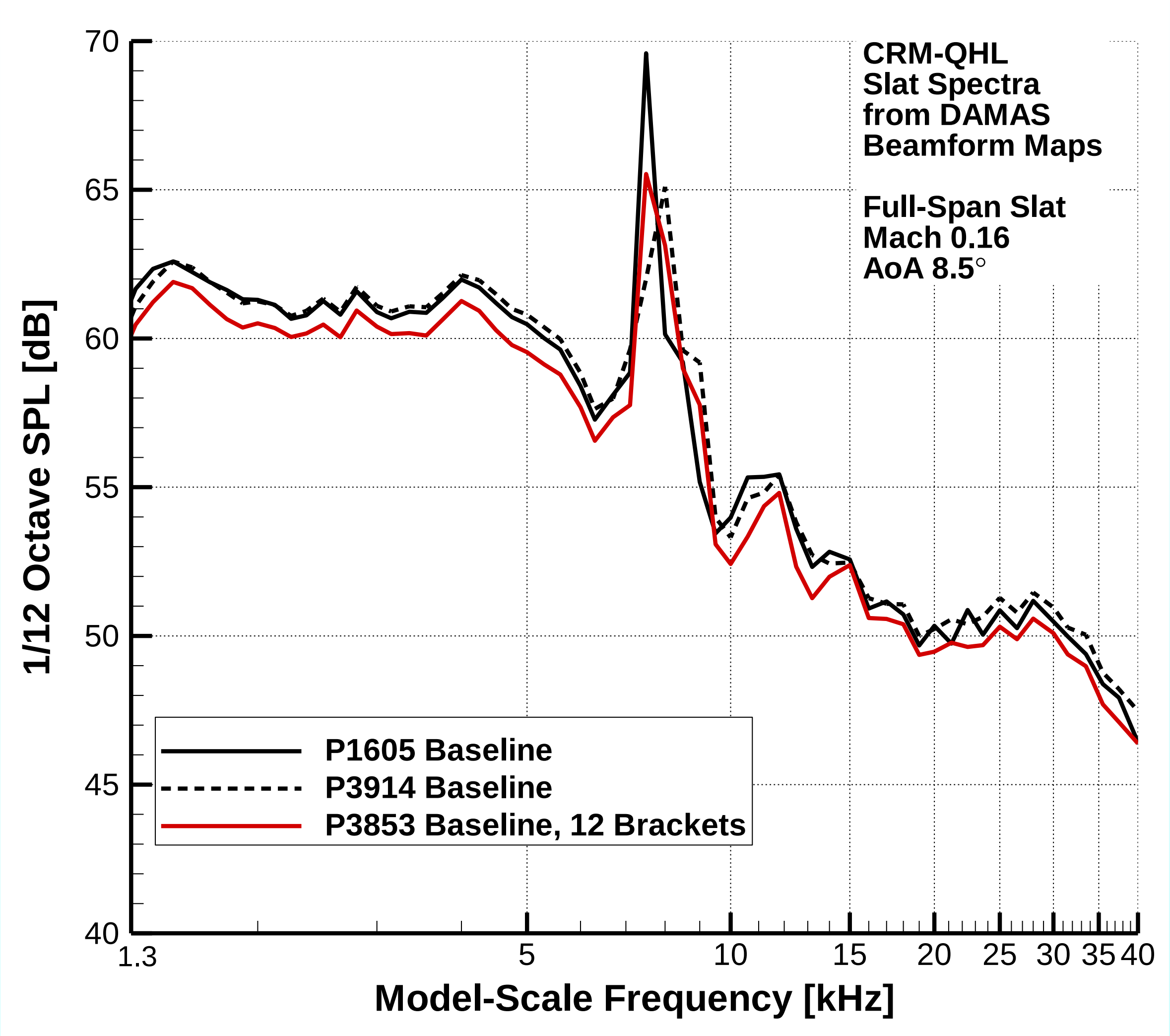


Baseline without Nacelle/Pylon

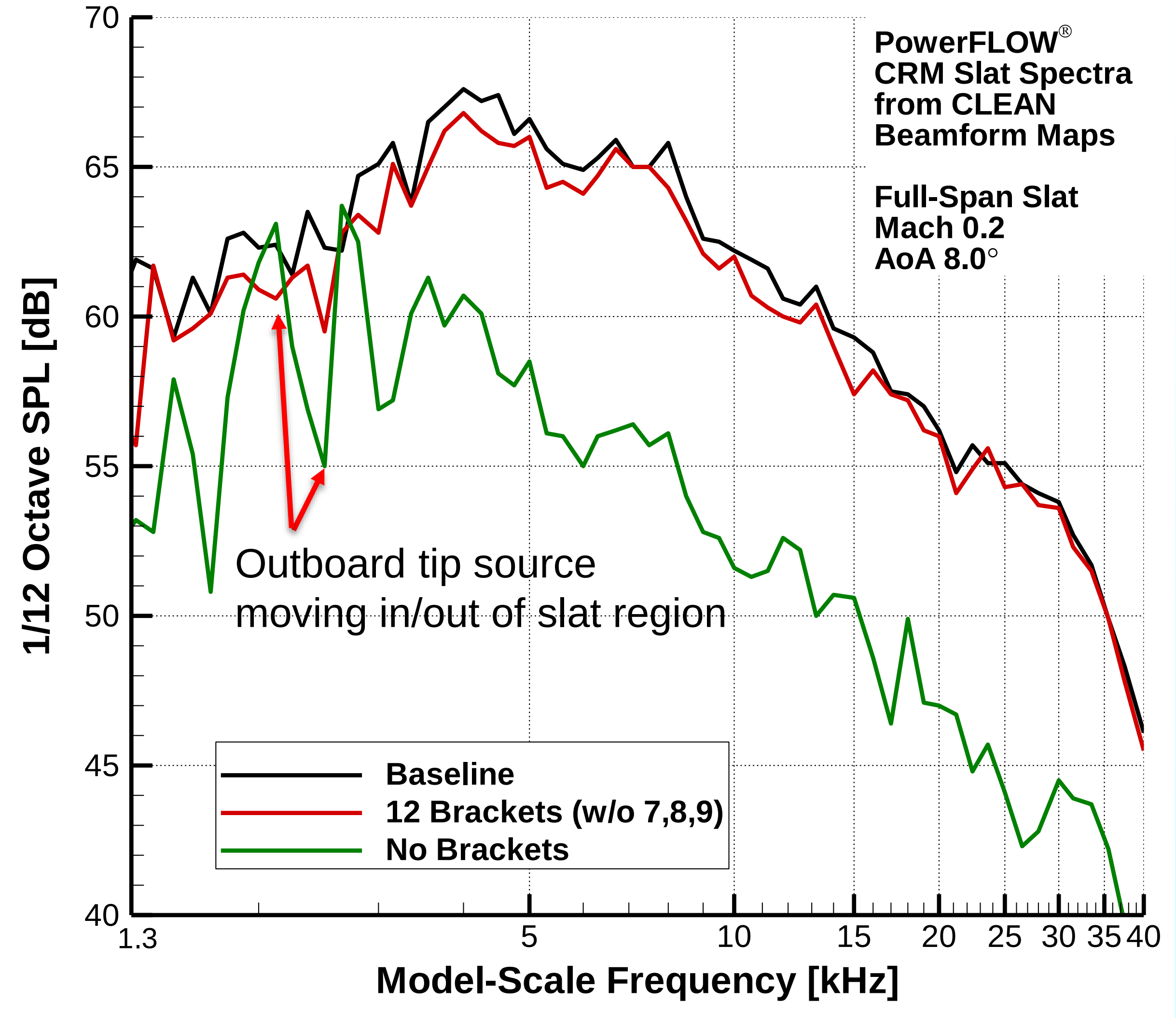


Slat-Cove Filler without Nacelle/Pylon

Effect of Brackets on Spectra



Experiment at Mach 0.16

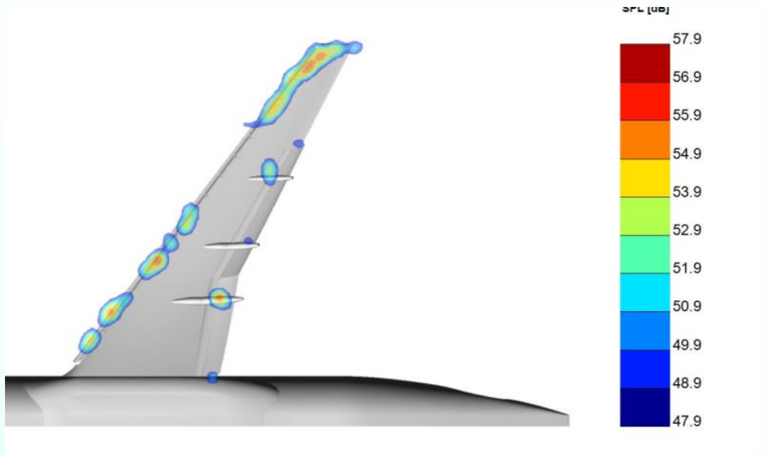


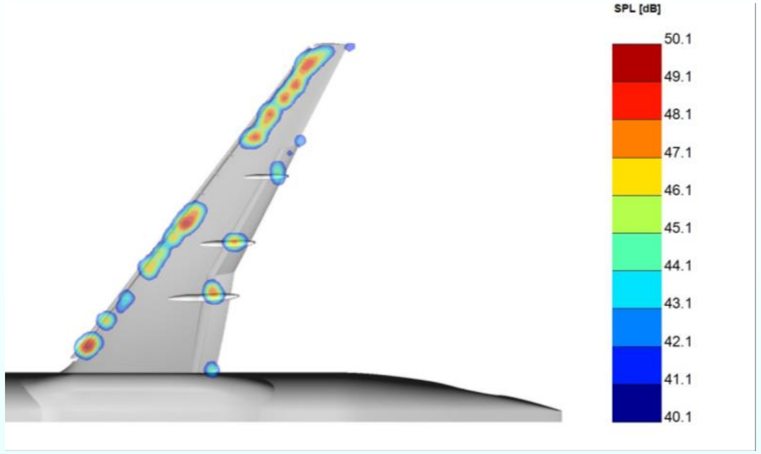
Simulation at Mach 0.2

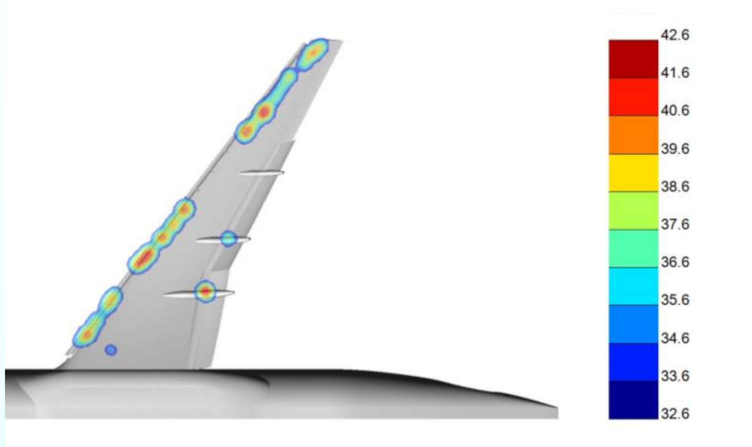
Beamform Maps from Simulations

Baseline without Backets 7, 8, 9

1/12th Octave SPL



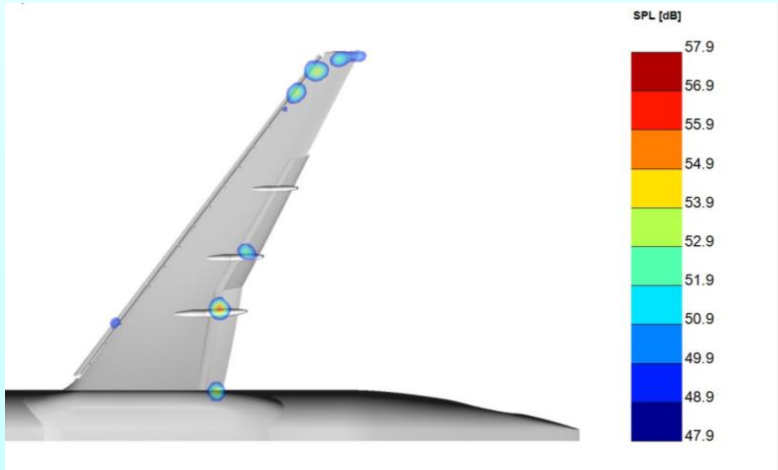


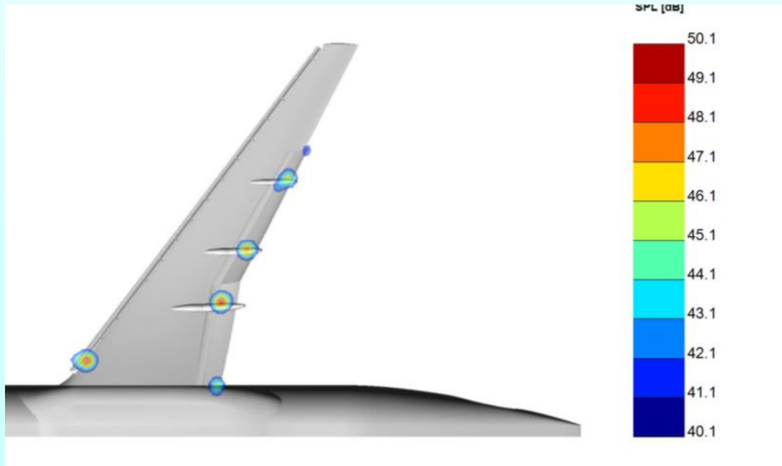


4 kHz

13.2 kHz

31 kHz



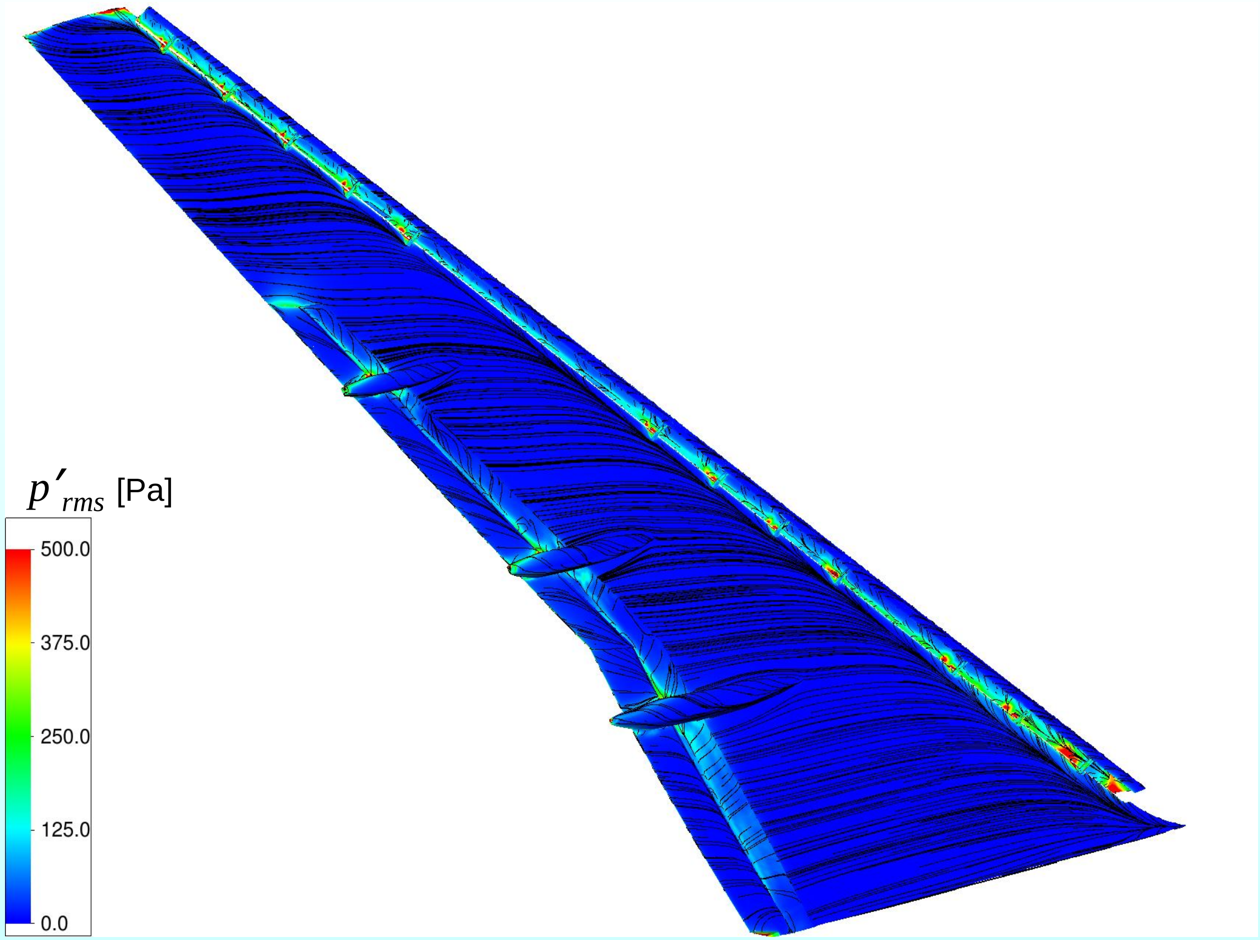


The levels are the same
for each column

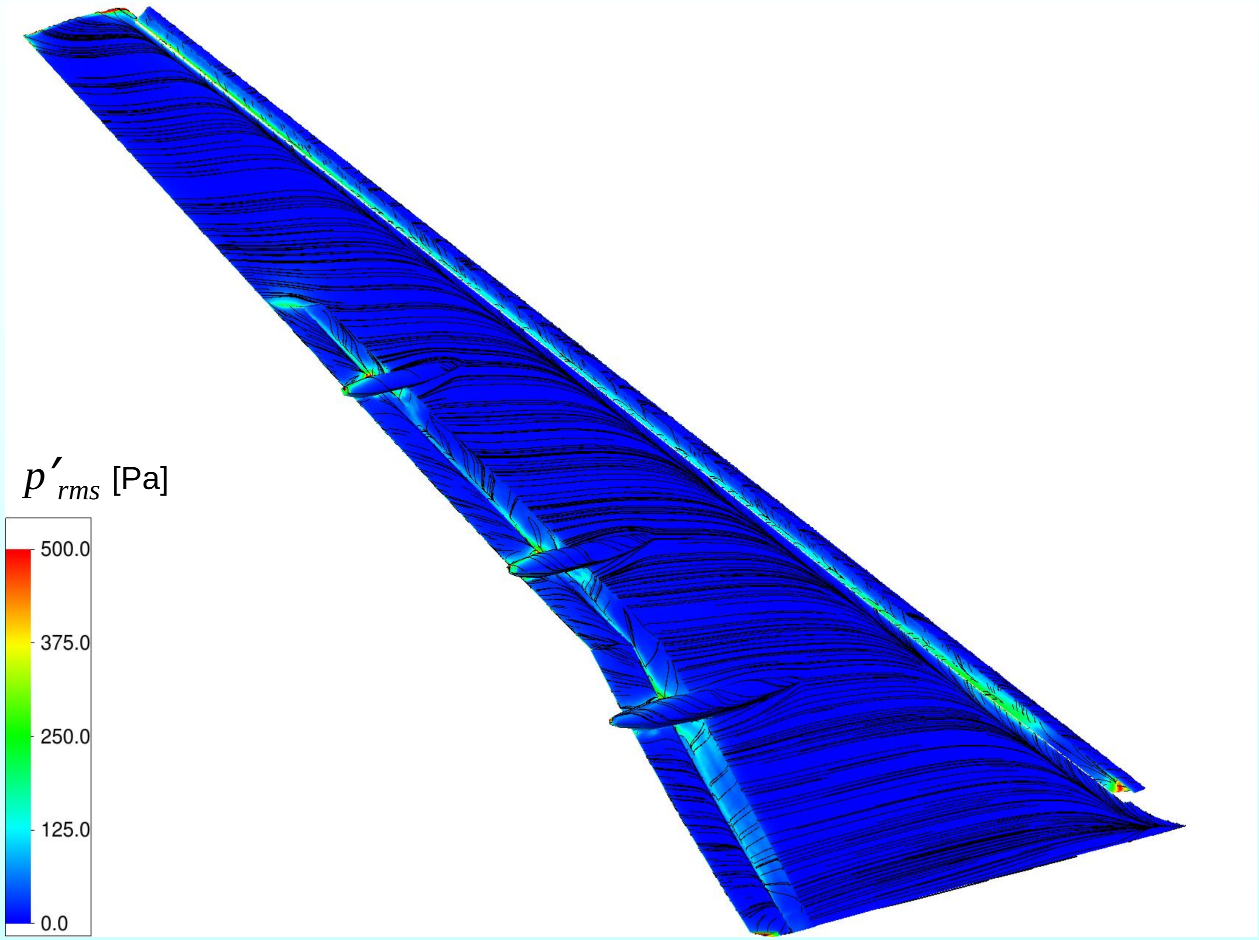
No Brackets

Fluctuating Surface Pressure Contours

Unsteady numerical simulation results with PowerFLOW®
Mach 0.2, AoA = 8 deg

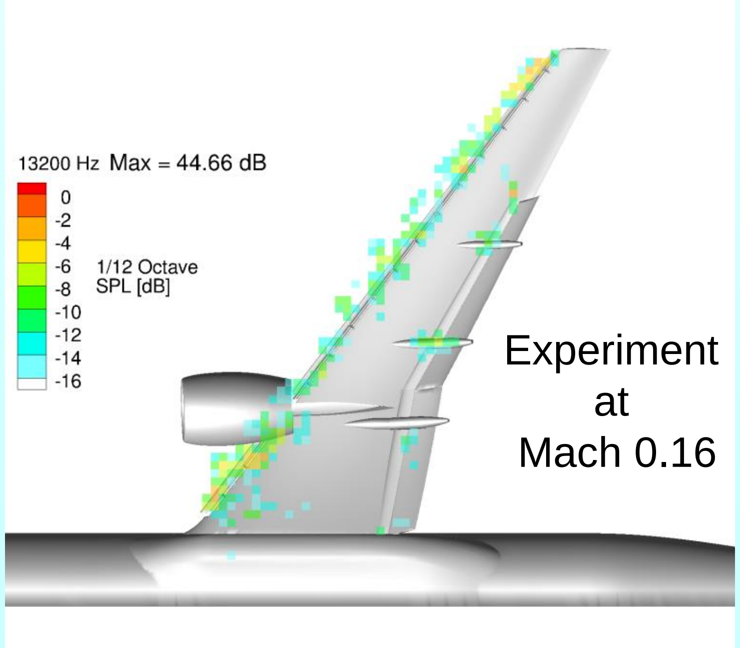


Without brackets 7, 8, 9



Without all brackets

Ffowcs-Williams Hawkings (FWH) Effects



- Noise source around pylon very intense in simulations and experiment
  - Source should be shielded by the nacelle, but solid surface FWH made the nacelle transparent
- Permeable surface FWH has been shown to give more accurate predictions, but computational requirements are often prohibitive
  - Instead, simulations with the full-span slat or without the nacelle were used to evaluate the noise with the solid surface FWH
- When are solid surface FWH predictions unreliable? Why are they inaccurate?

Ffowcs-Williams Hawkings Scattering Test Setup

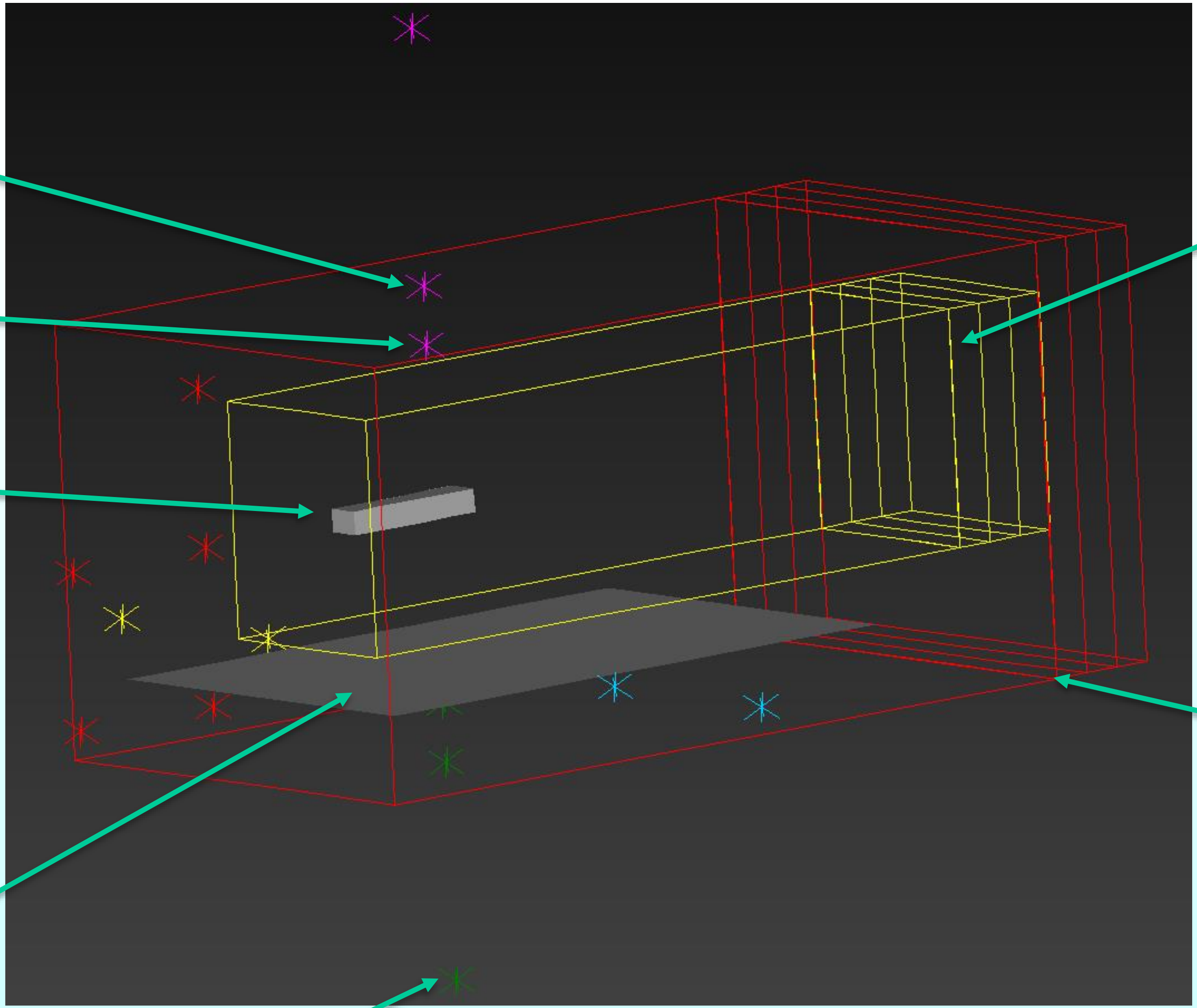
Observer outside red (outer) FWH surface

Observer inside red (outer) FWH surface

Viscous box

Mach 0.2

Thin, inviscid plate



Inner permeable FWH surface with four end caps. Surrounds box but not plate.

PowerFLOW® fluid and FWH solvers used

Outer permeable FWH surface with four end caps. Surrounds box and plate.

Observer locations: Green – below plate, Pink – above box, Red – upstream, Yellow and Cyan – to the sides of the plate

Solid Geometry

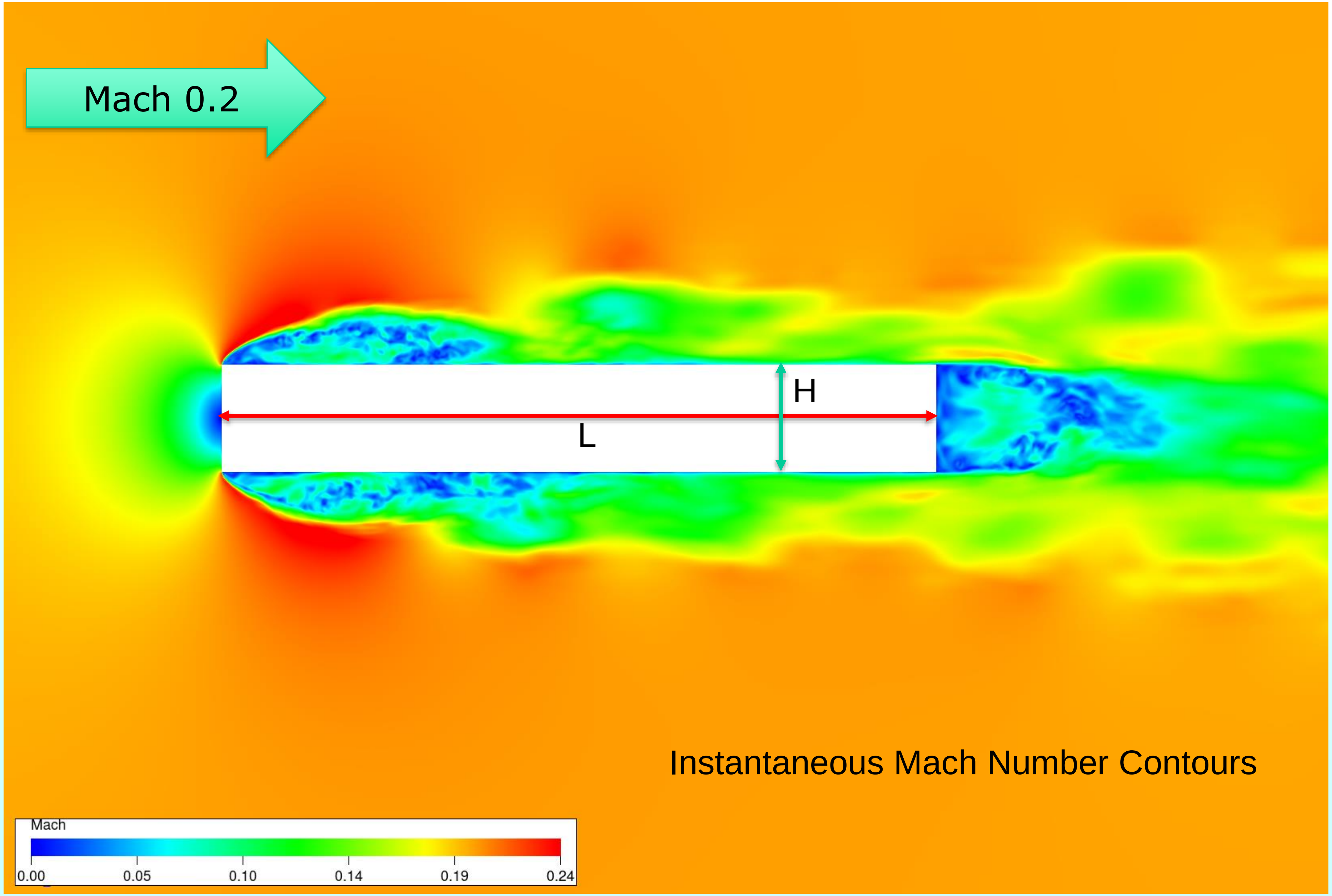
Viscous Box
L = 0.2 m
W = 0.04 m
H = 0.03 m

Re_L = 100,000

Leading edge at 0.15 m

Inviscid Plate
W = 0.5 m
L = 0.8 m

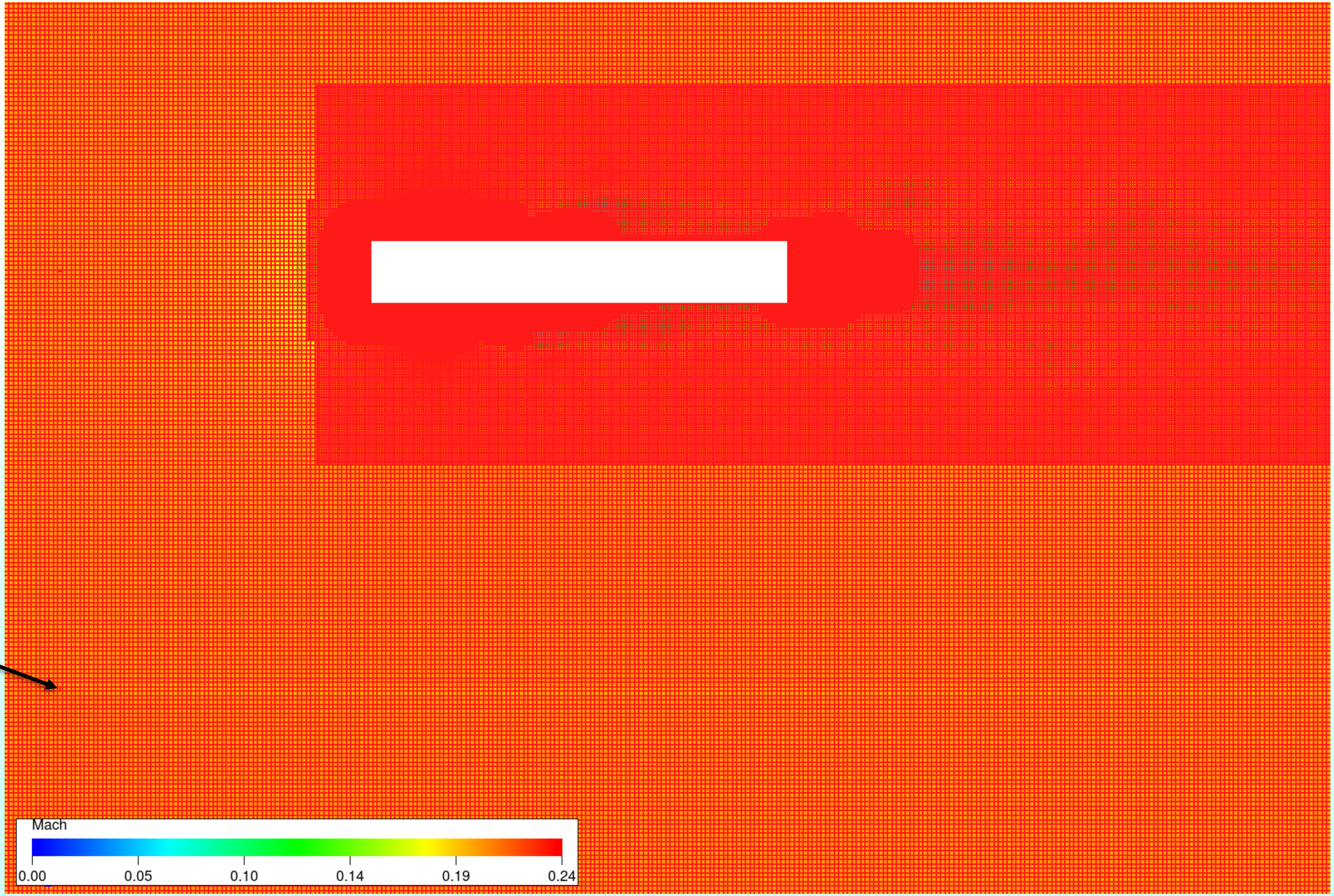
Leading edge at 0 m



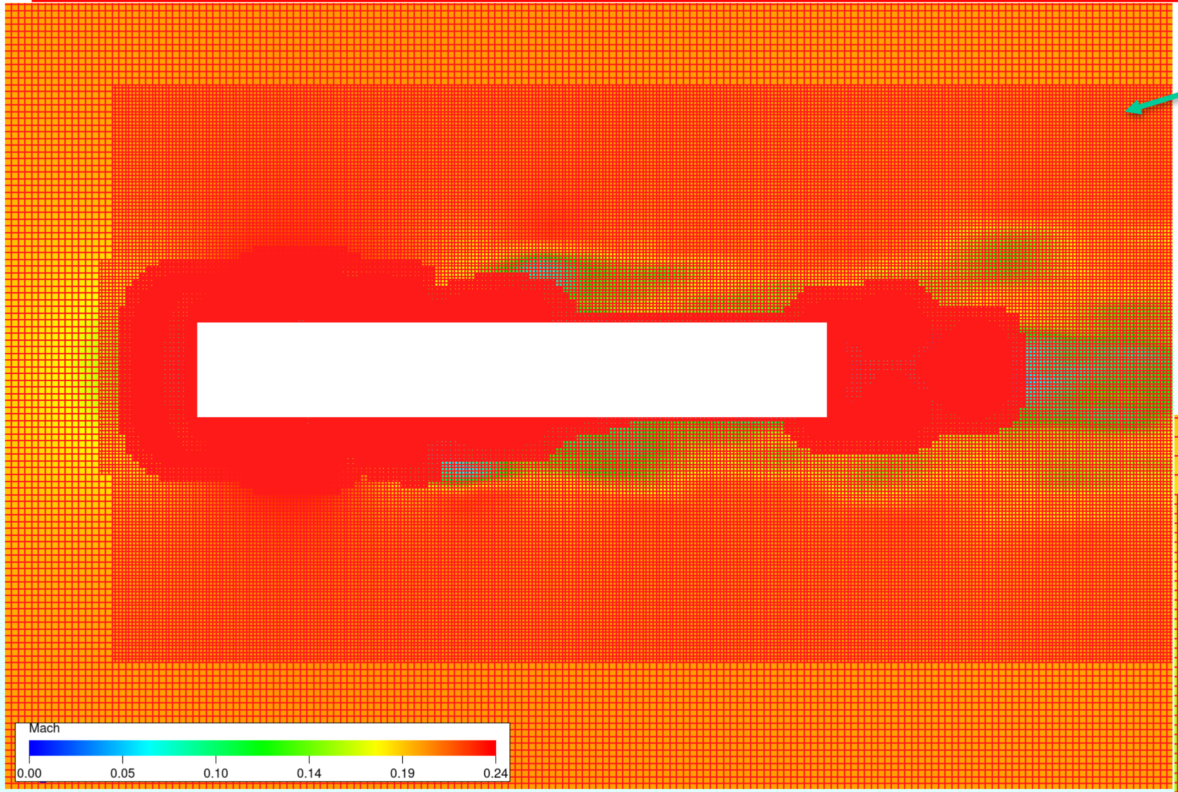
Instantaneous Mach Number Contours

Grids

Plate

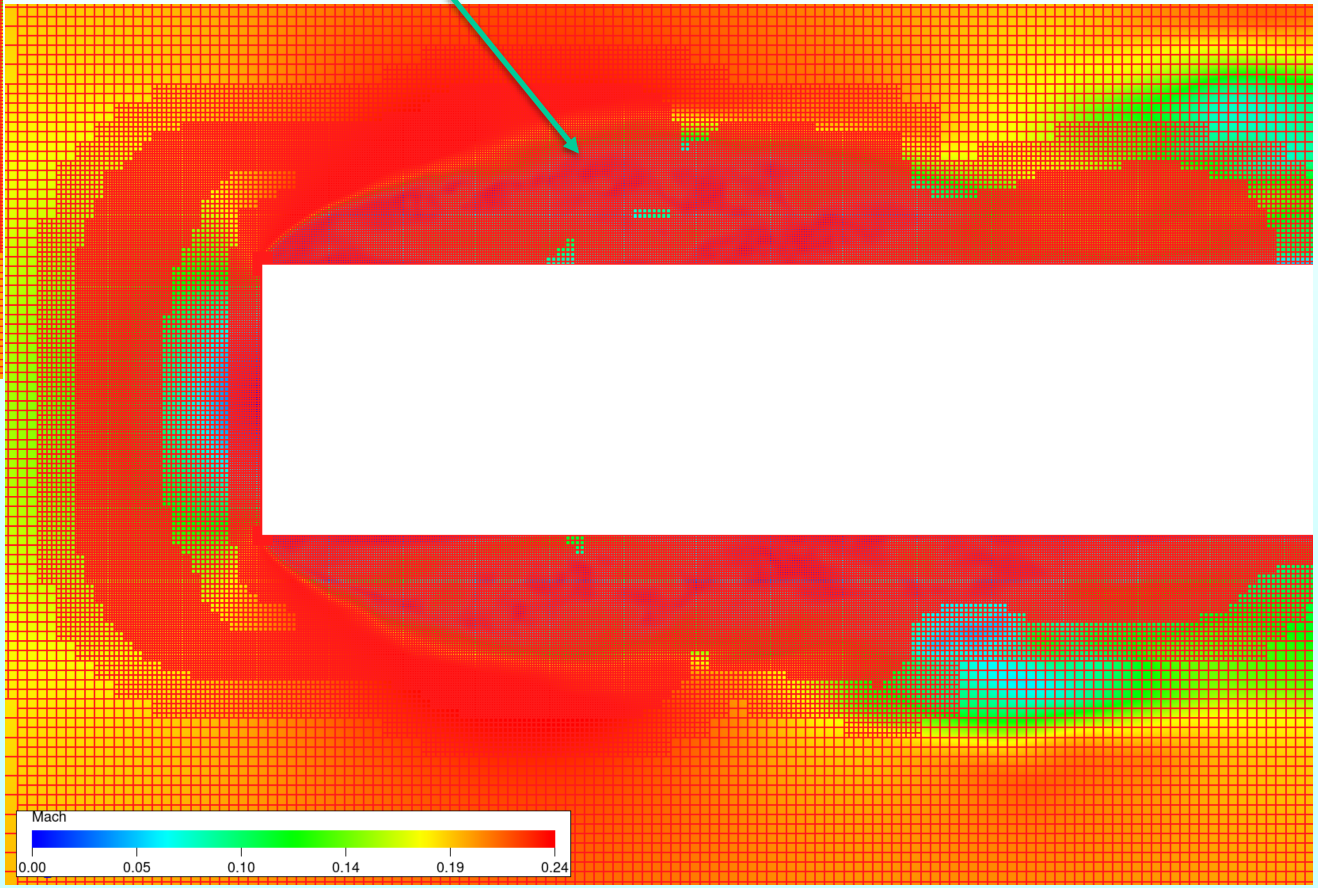


Grid Refinement Regions



Rectangular refinement regions

Refinement region based on lambda2

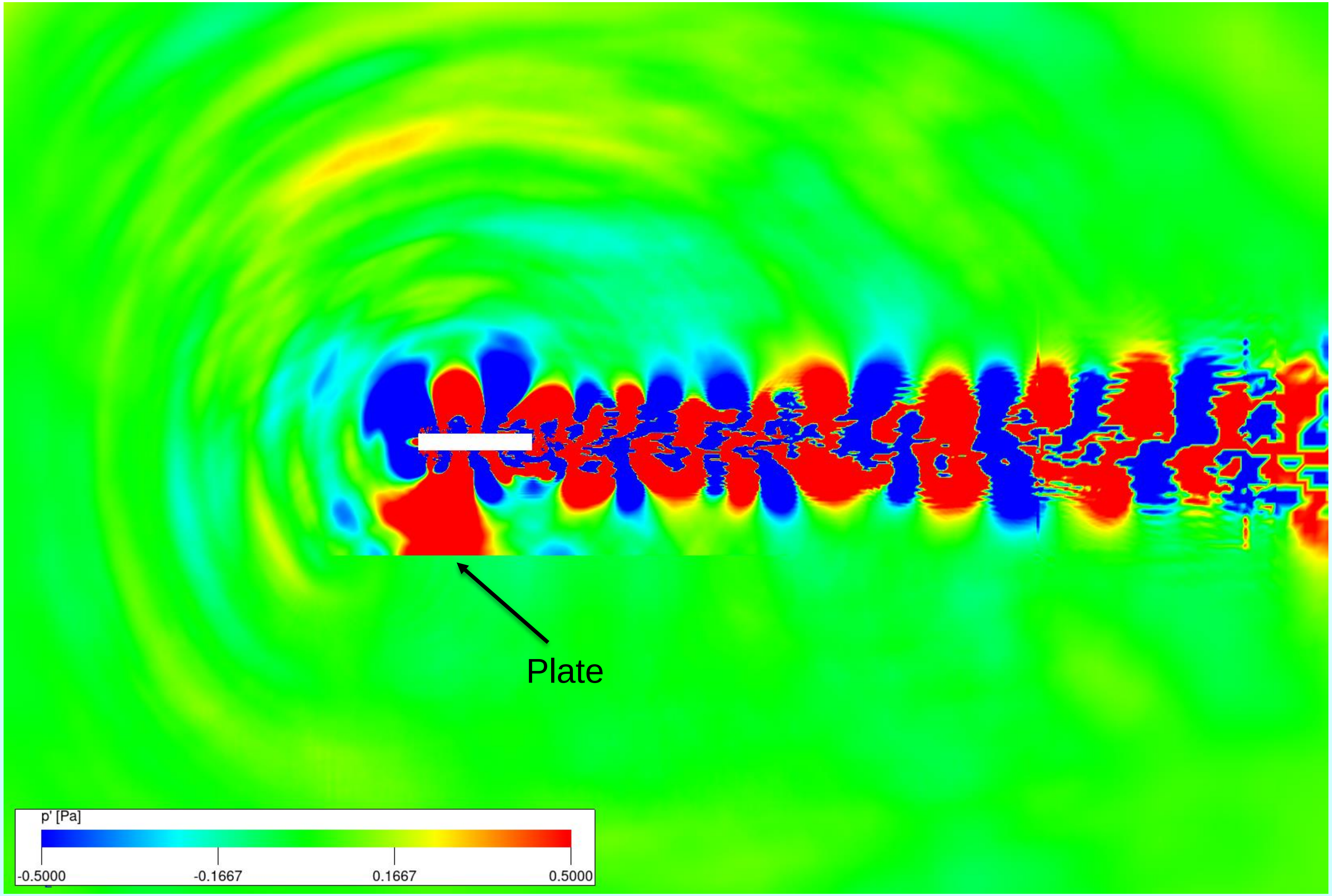


Four Grid Levels

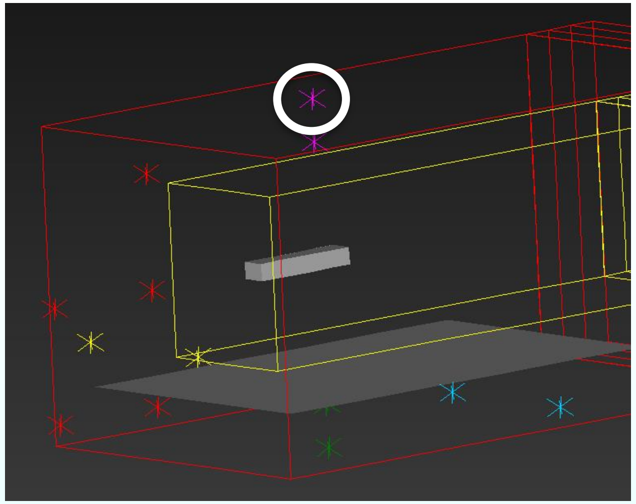
	Voxels	FE Voxels	Timesteps	15 PPW Freq
L1	136M	9.8M	4.4M	5.4 kHz
L2	450M	31M	6.6M	8.0 kHz
L3	1.5B	100M	10M	12.0 kHz
L4	4.3B	289M	7.5M	18.1 kHz

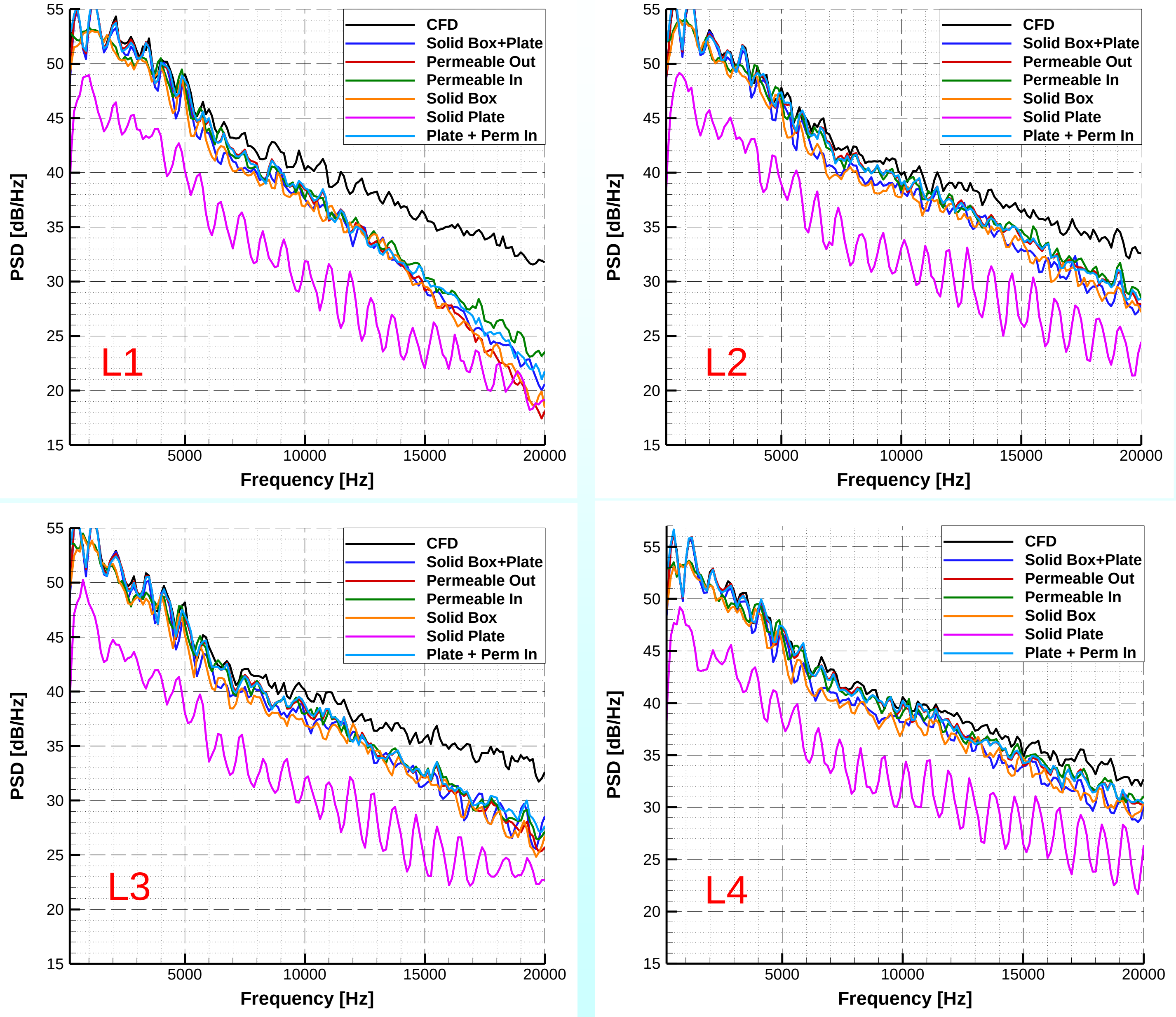
FE = fine equivalent

Instantaneous Pressure Contours



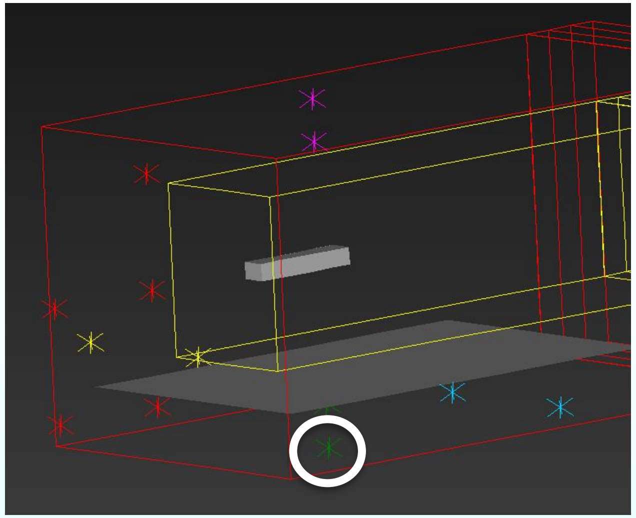
Spectra Above the Box

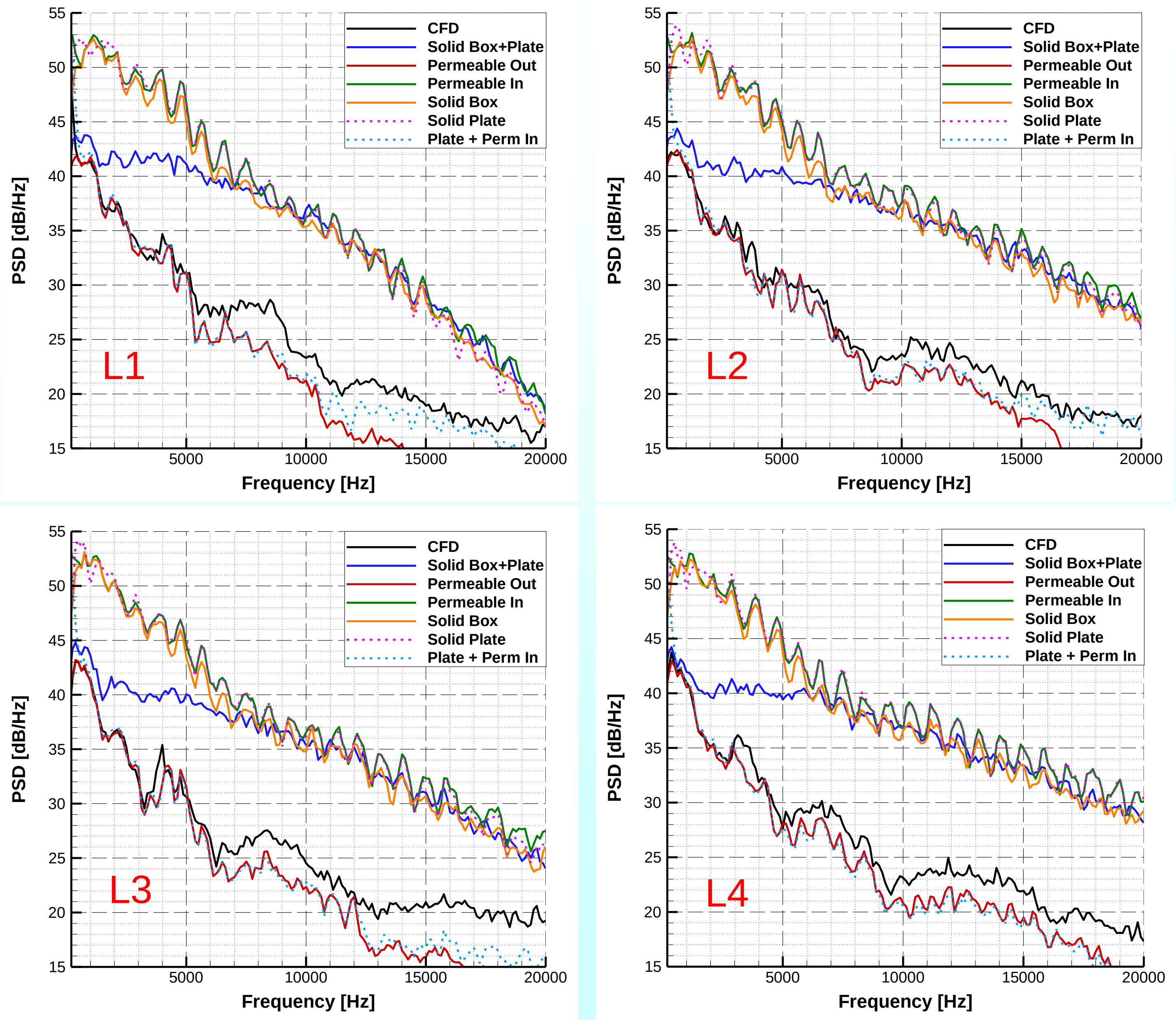




- CFD obtained by directly sampling the simulation
- All other results use the FWH with the surface specified
- Gradual improvement in higher frequencies as grid is refined
- Similar results for all FWH predictions except plate alone

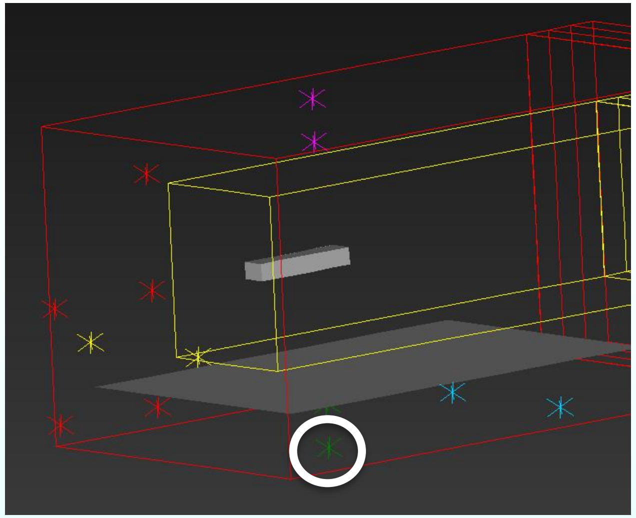
Spectra Below the Plate



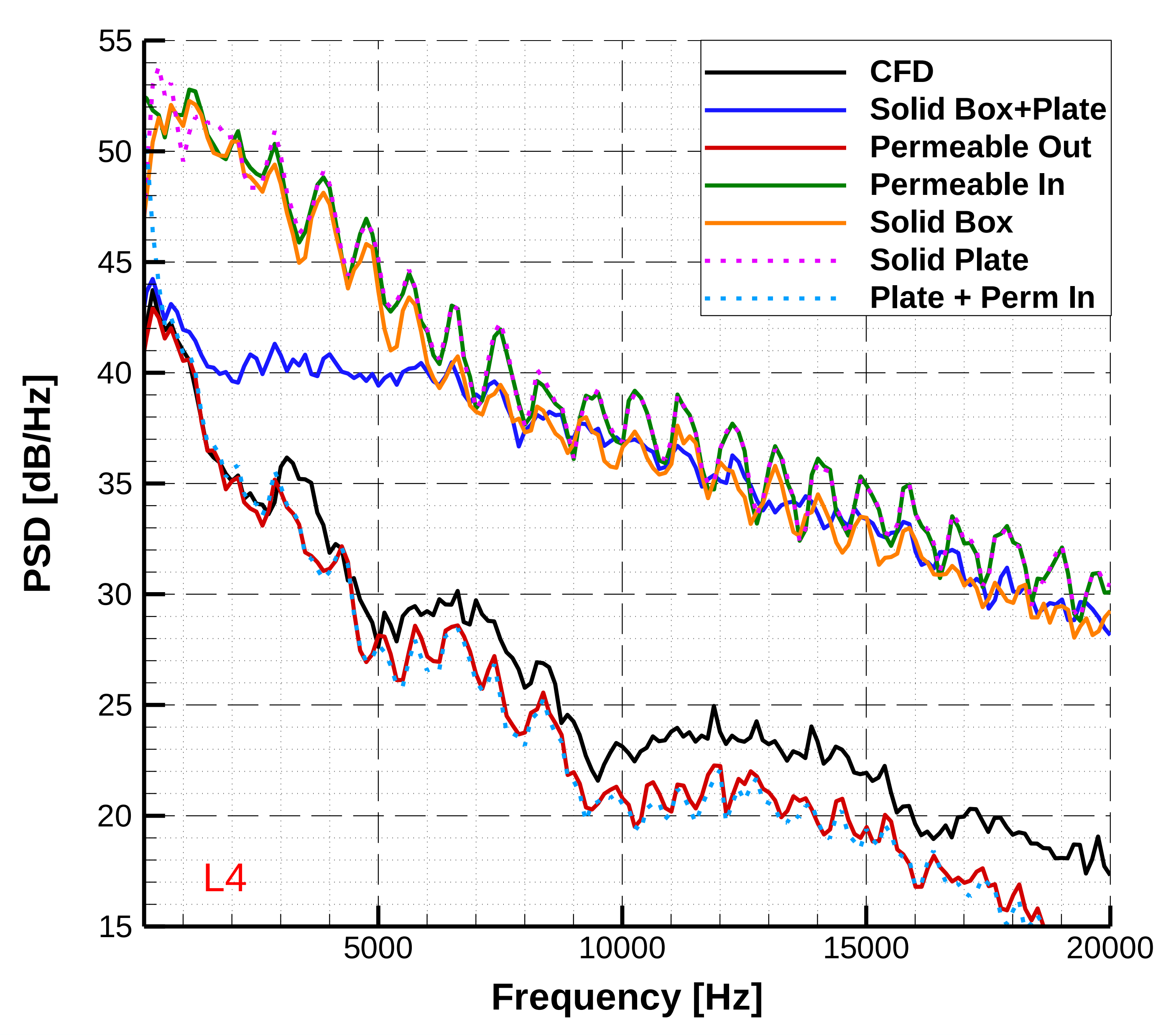


- Spectral shapes and trends similar for all meshes
- Conclusions about FWH are the same regardless of the grid level

Spectra Below the Plate



- Solid and inner permeable FWH results do not account for shielding by the plate
- Solid box, solid plate, inner permeable all have similar spectra, but combinations produce very different results
  - Phase must be different
    - Caused by propagation through unsteady, nonuniform flow around the box



CRM Data Dissemination

- Five papers are planned for the 2022 AIAA Aeroacoustics Conference
  - Background noise reduction in the 14x22
  - Structural design and assessment of noise reduction devices
  - Aerodynamic results from the CRM-HL 14x22 test
  - Acoustic results from the CRM-HL 14x22 test
  - Comparisons between simulations and the 14x22 CRM-HL test

- Aerodynamic and acoustic data from the baseline model will be used in future Benchmark problems for Airframe Noise Configurations (BANC) workshops

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- 14x22 Data Analysis
  - Charlotte Teague, Joe Peterson
- Model Shop
  - Steve Geissinger, …
- Metals Shop
  - John Lowe, Aaron Wright, Johnnie West, …

Questions?

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