Airframe Noise Research

David P. Lockard

Acoustics TWG, NASA LaRC, April 21-22, 2015

FUN3D Solutions for a Nose Landing Gear using Wall Functions

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And

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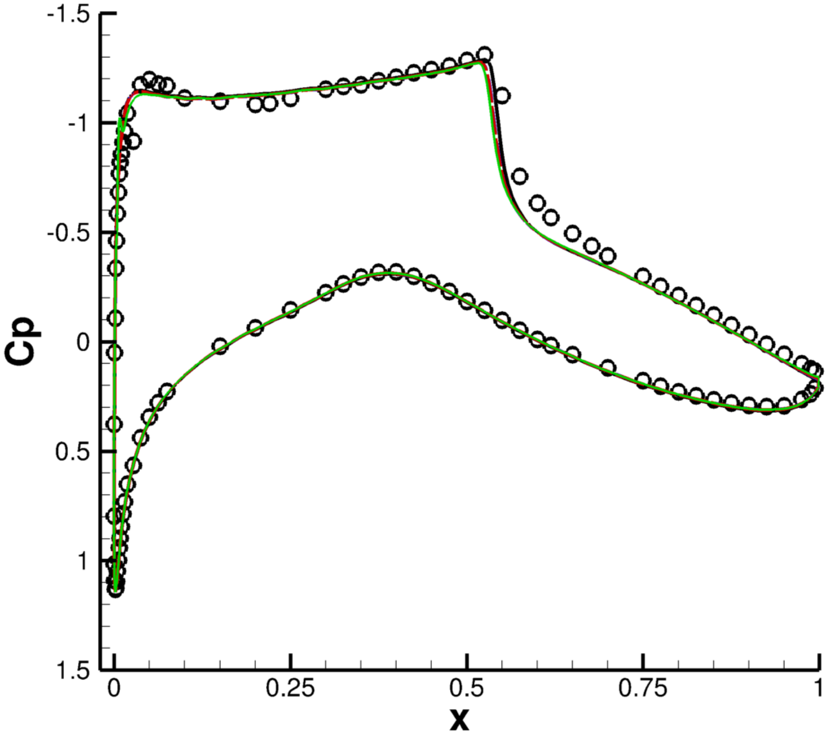
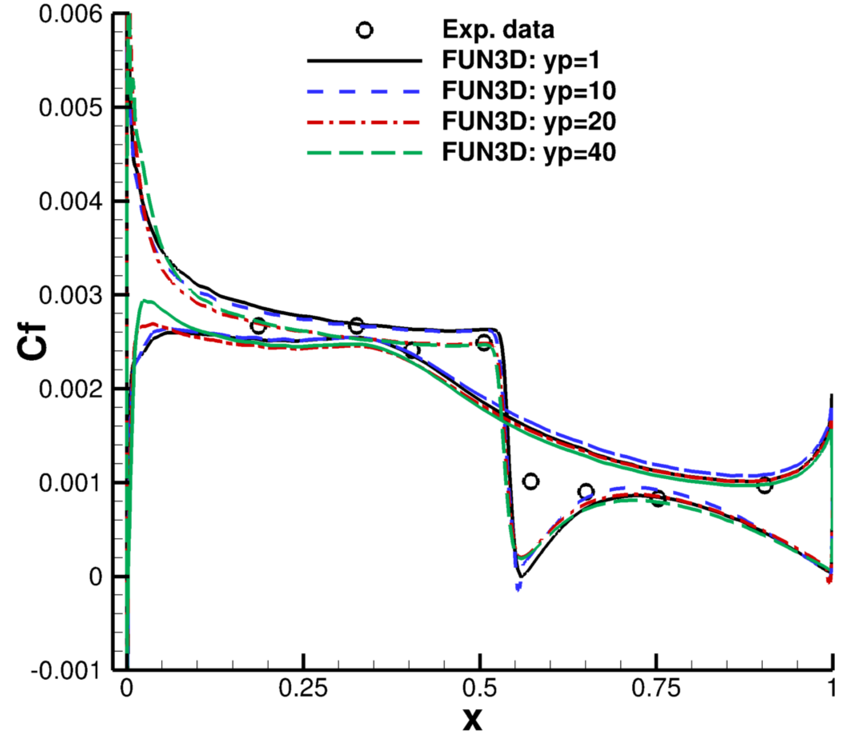
Assessment of Wall-functions for Aero-acoustic Applications

- Explore the use of the newly developed wall-function capability in the FUN3D code for simulating unsteady flow
- The wall-function approach based on the approach outlined by Knopp et al., was incorporated recently in the unstructured grid flow solver, FUN3D
  - ***Knopp, Arrutz and Schwarmborn: Journal of Comp. Physics, vol. 220, pp.19-40, 2006***
  - ***Carloson, Vatsa and White: AIAA Paper-2015-xxxx, AIAA Aviation 2015 Conference, June 2015***
- Currently tested for one-equation model of Spalart-Allmaras and two-equation model of Menter
- Demonstrated to work well on grids where y^+ at wall varies from *O(1)* to *O(100)*

Initial Validation of FUN3D Wall-function Capability for RAE 2822 Airfoil

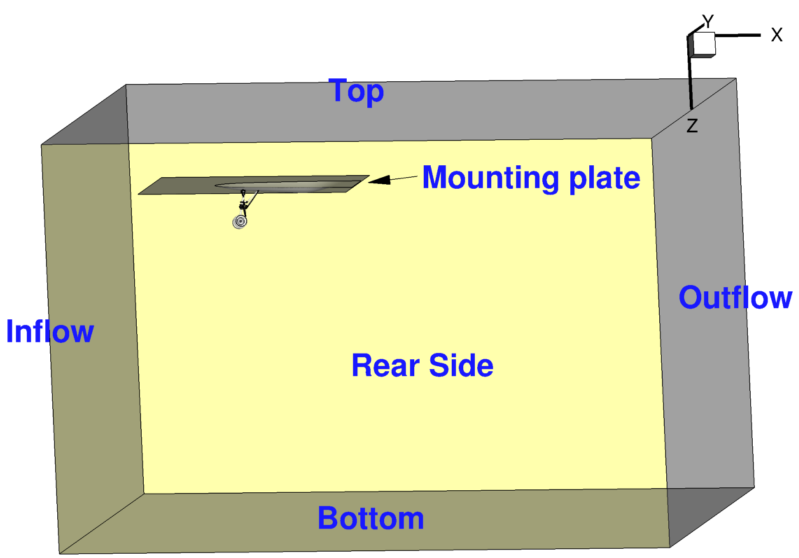


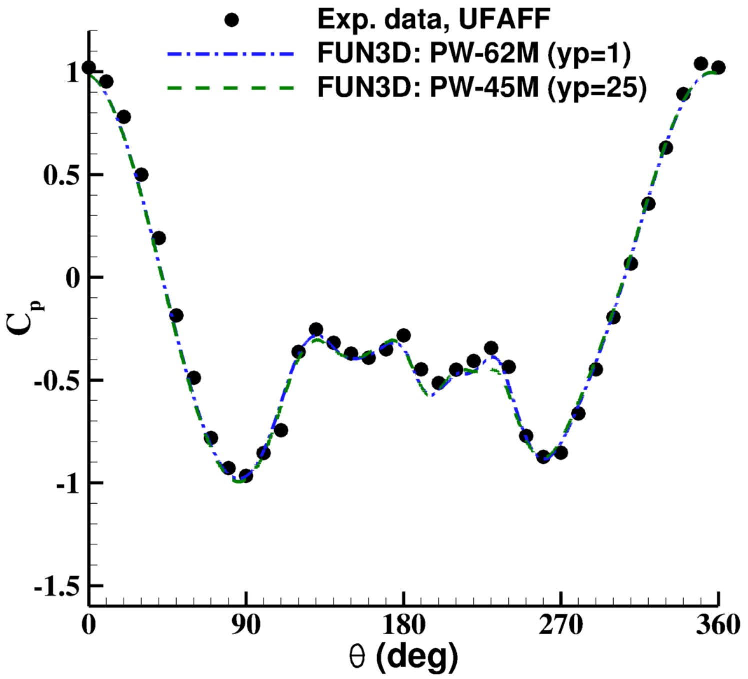


M=0.73, Alpha=2.8º

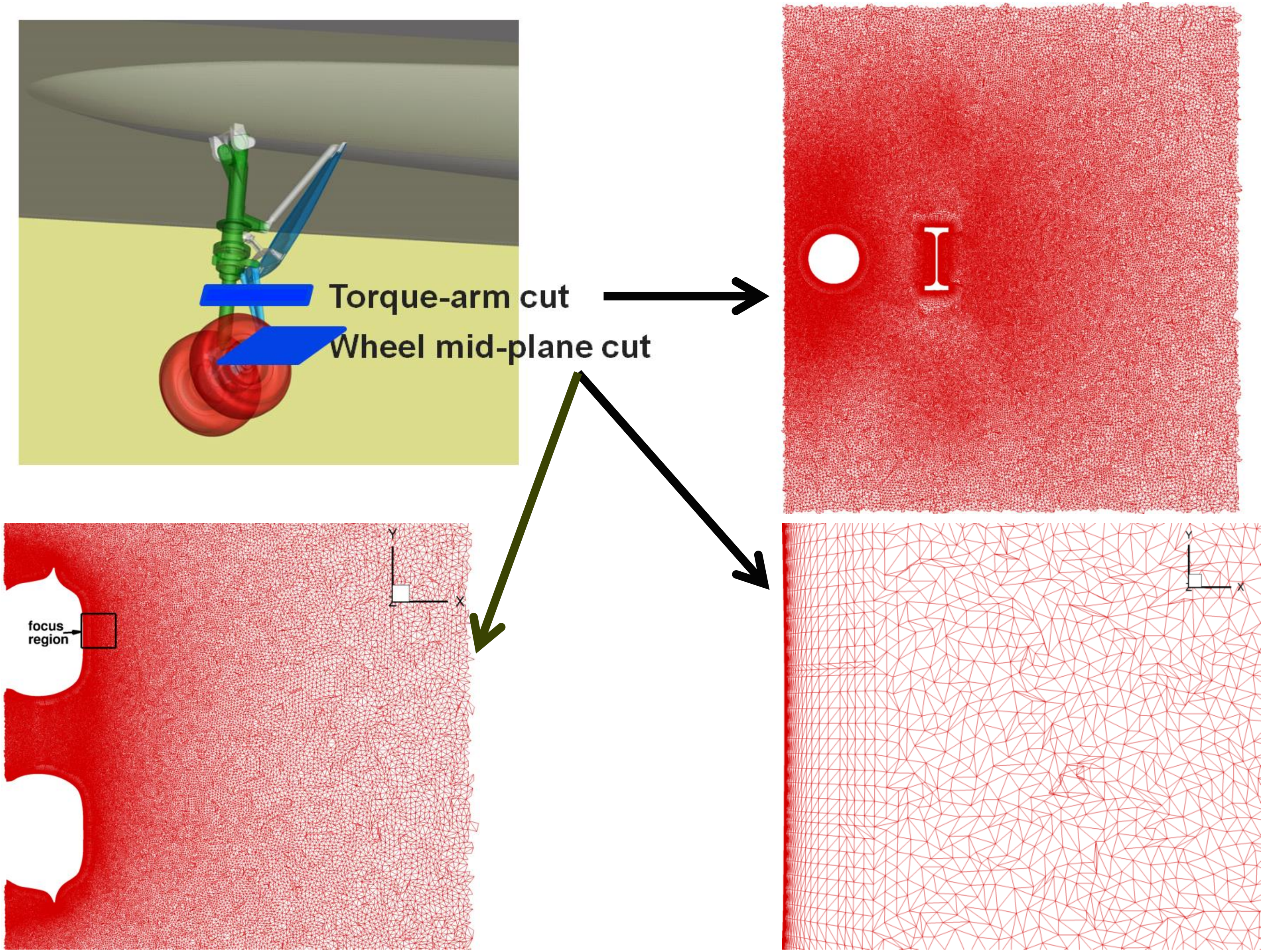
Simplified Nose Landing Gear: Computational Setup and Surface Pressure

- Grids used in this study were generated for the partially dressed, cavity closed configuration using Pointwise
  - 62 million node grid (PW-62M (y^+=1)), near wall spacing is *O(1)*
  - 45 million node grid (PW-45M (y^+=25), near wall spacing is *O(25)*
  - Surface grids are identical



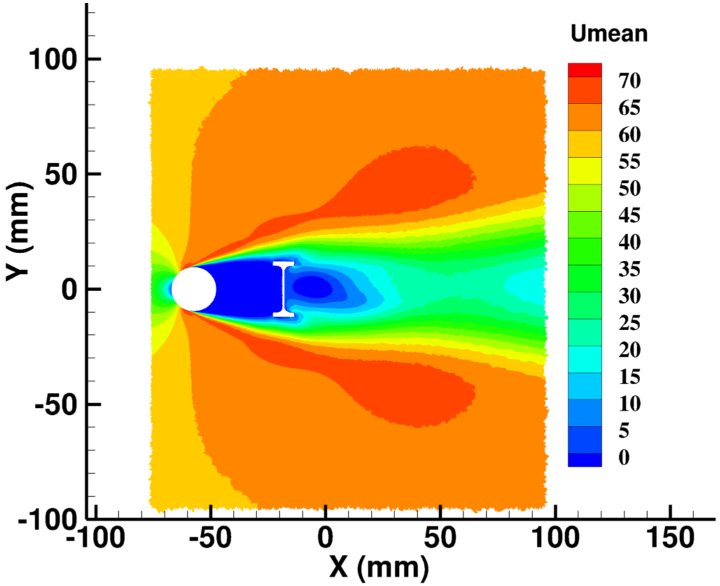


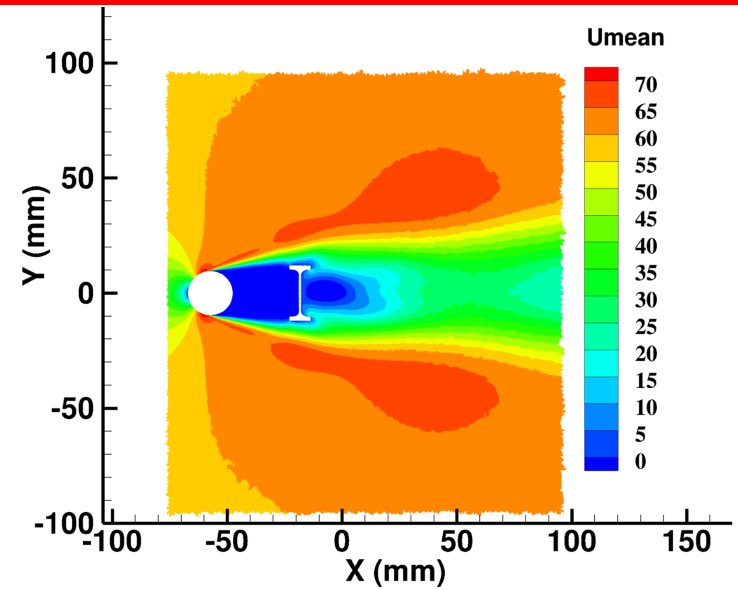
Sample Grid Cuts at Torque-arm and Wheel mid-plane (62 million node grid)



Zoomed view: focus region

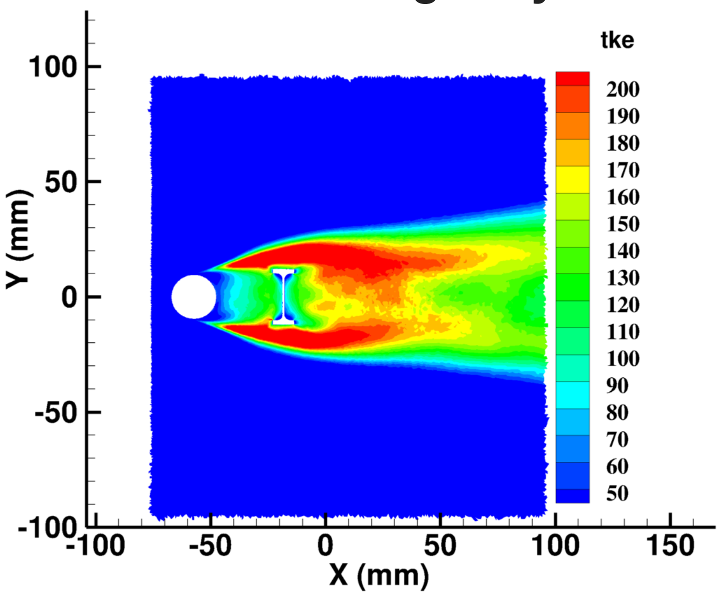
Comparisons of Time-averaged Velocity and Turbulence Kinetic Energy at Torque-arm cut

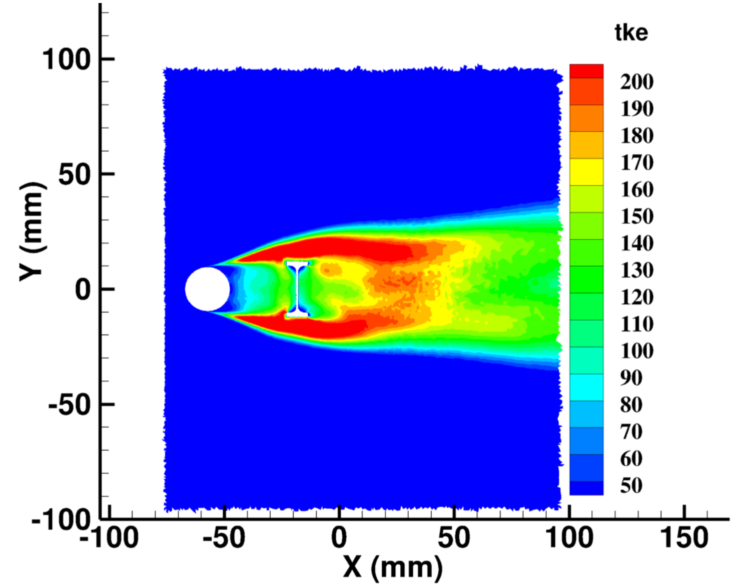




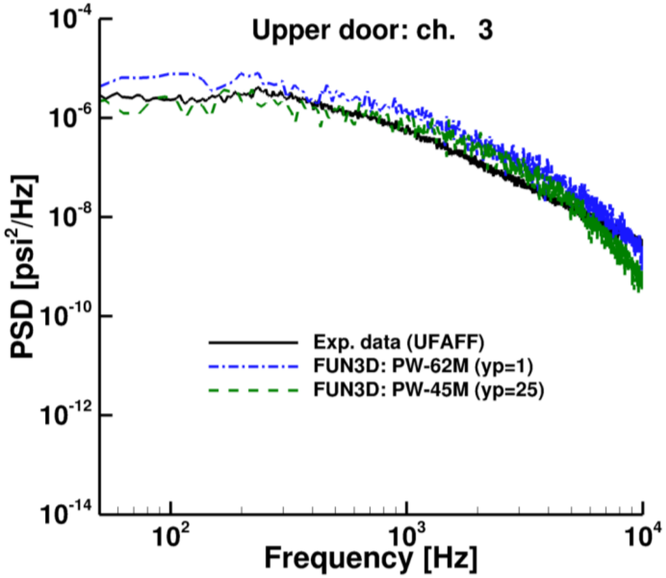
45 million node grid: $y^{+}=25$

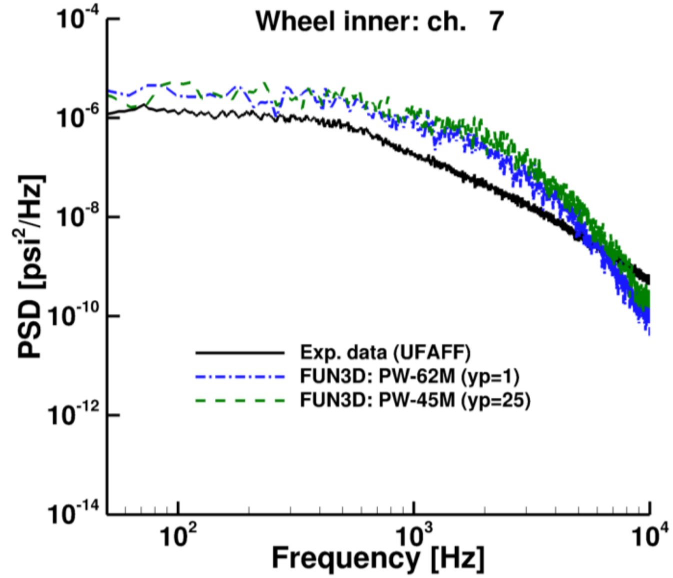
62 million node grid: $y^{+}=1$

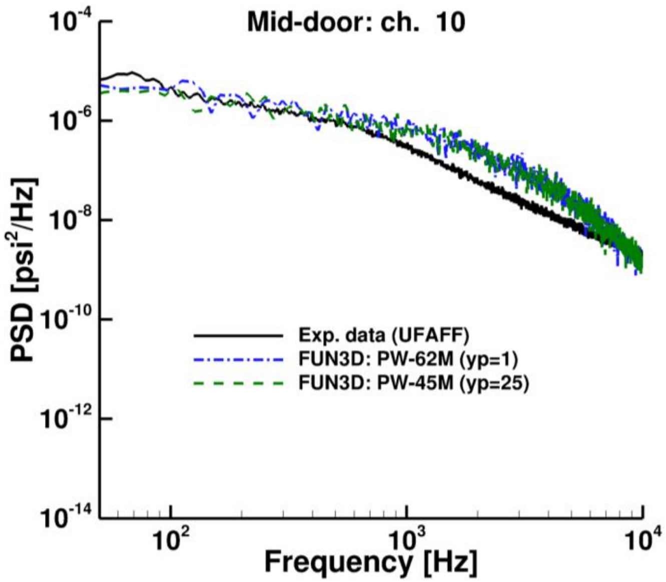


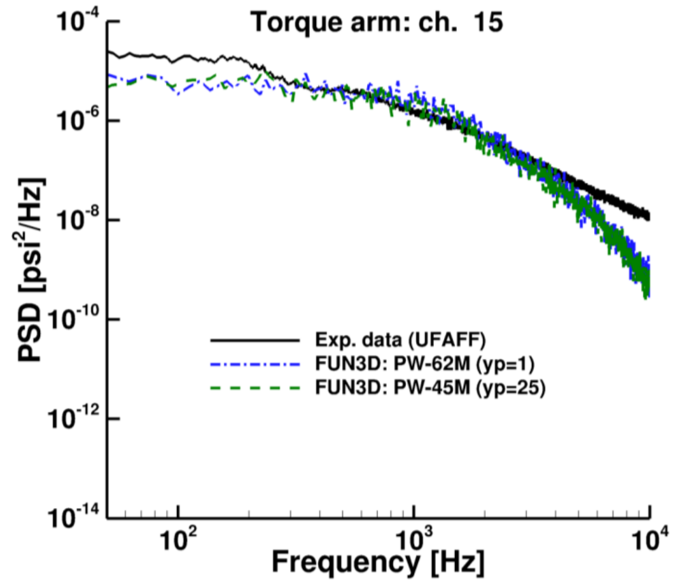


Effect of using Wall-functions on Power Spectral Density Distributions

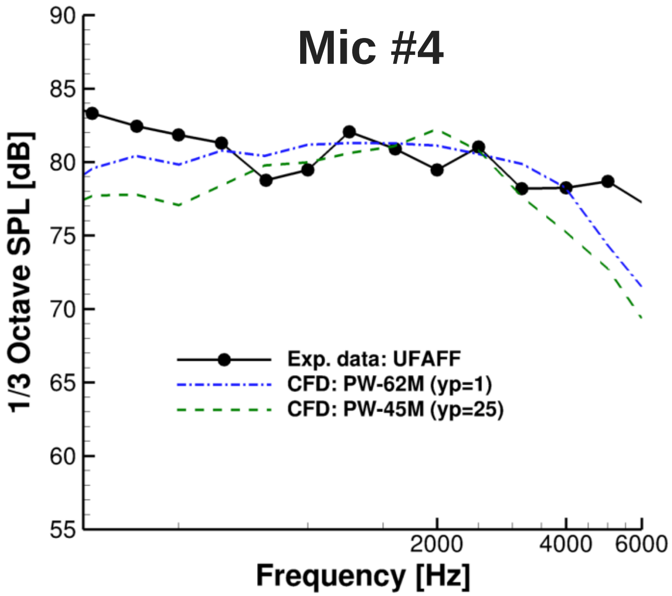


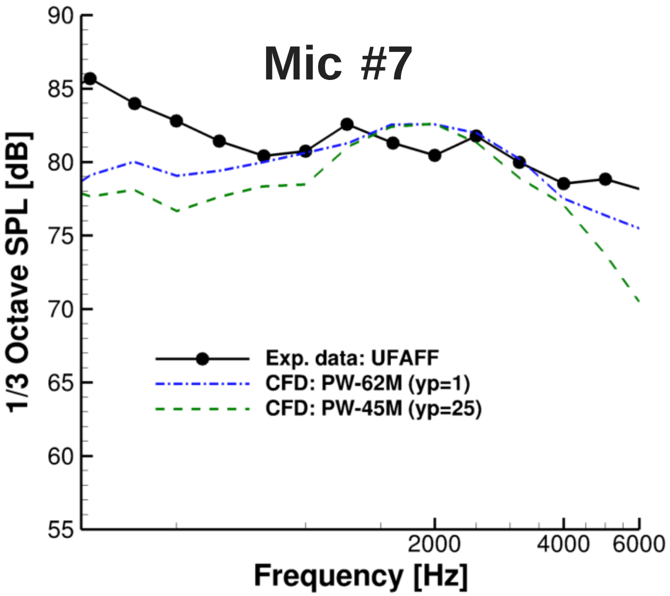






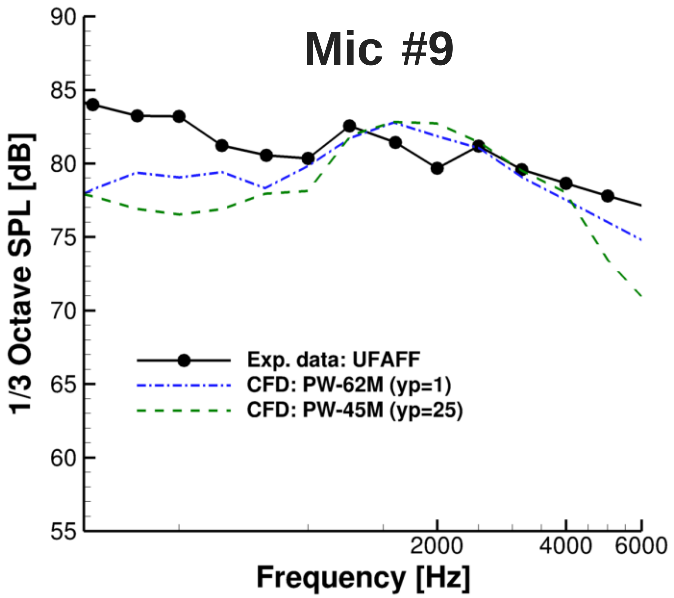
Effect of using Wall-functions on Far-field Sound Pressure Levels





Upstream

Overhead



Downstream

Summary

- Demonstrated the wall-function capability of the unstructured grid flow code FUN3D for simulating the unsteady flow over a nose landing gear configuration
- Solution accuracy on wall-function grids comparable to standard integrate-to-wall grids for:
  - time-averaged and unsteady solutions
  - surface pressure power spectral density (PSD)
  - sound pressure levels (SPL) in far-field
- Minimal overhead associated with wall-function approach on a per node basis
  - Requires less computational resources to obtain solutions with comparable accuracy

Comparison of Computational and Experimental Results for the 18%-Scale, Semi-Span Model in the LaRC 14x22 Tunnel

Mehdi R. Khorrami and David P. Lockard

ERA ITD50A

NASA Langley Research Center, Hampton, VA

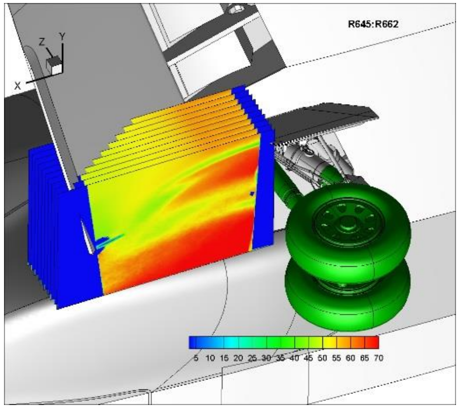
Aeroacoustic Testing of an 18%-Scale Aircraft Model

- **Multiple entries in NASA LaRC 14’x22’ tunnel**
  - Phase1: October 2010 → Aerodynamic measurements
  - Phase2: February 2013 → Aero and acoustic measurements
- **Phase2 test campaign**
  - Aerodynamic measurements
  - Acoustic: Microphone array and free-field microphones
  - Off-surface flow: PIV and LV
- **PIV measurements documented gear-flap interaction effects**
  - Processing of PIV database completed
  - Measured off-surface flowfield being used to benchmark high-fidelity simulations

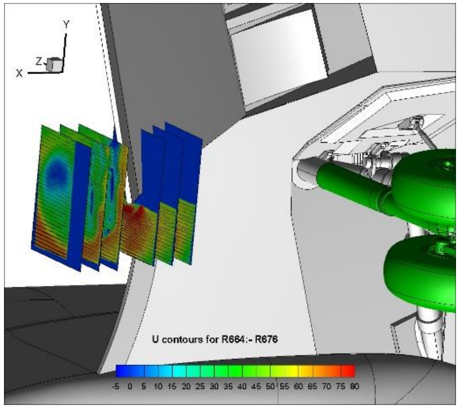
PIV Configuration - 2013

“On the Accuracy of Simulated Gear-Flap Flow Interaction”

By Mehdi R. Khorrami, Ramond Mineck, Ehab Fares;,Chung-Sheng Yao, Luther N. Jenkins



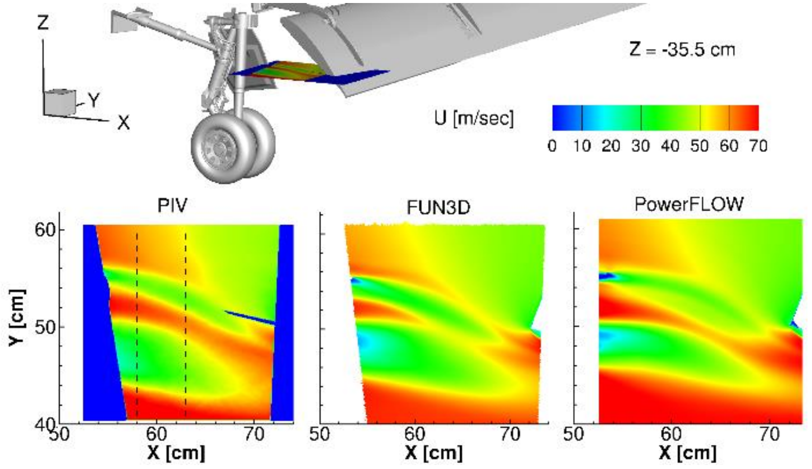
2D-PIV setup capturing gear wake and gear-flap interaction

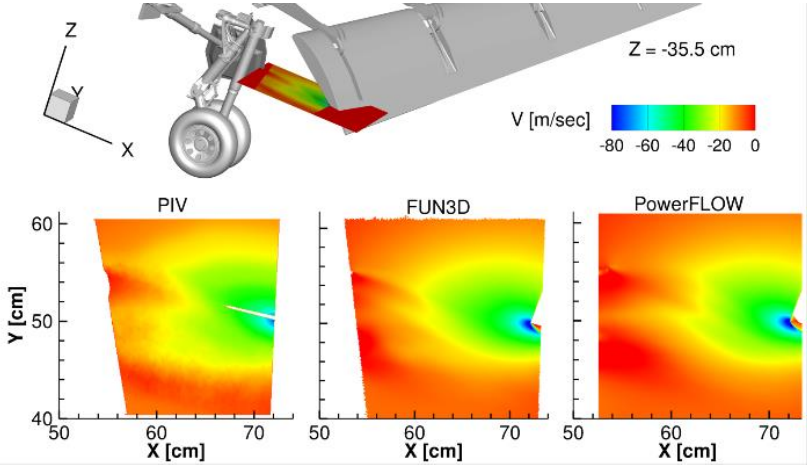


Stereo PIV setup capturing gear effects on flap tip vortex

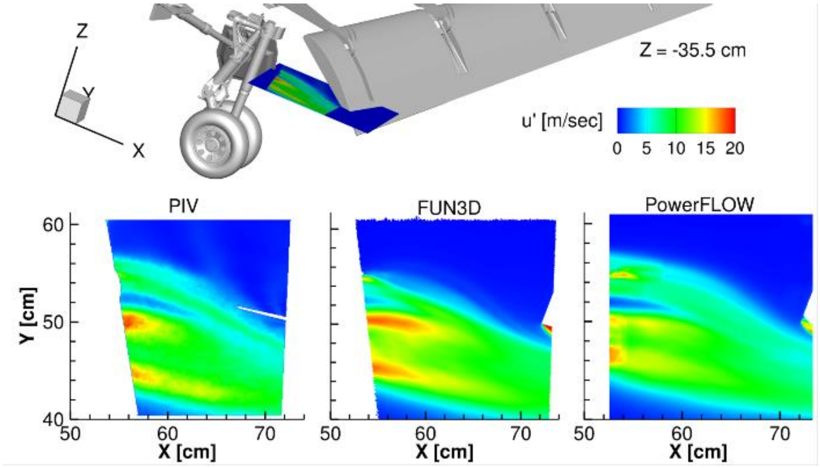
Gear-Flap Interaction Zone
(Simulated vs. Measured Flowfield: Velocity Contours)

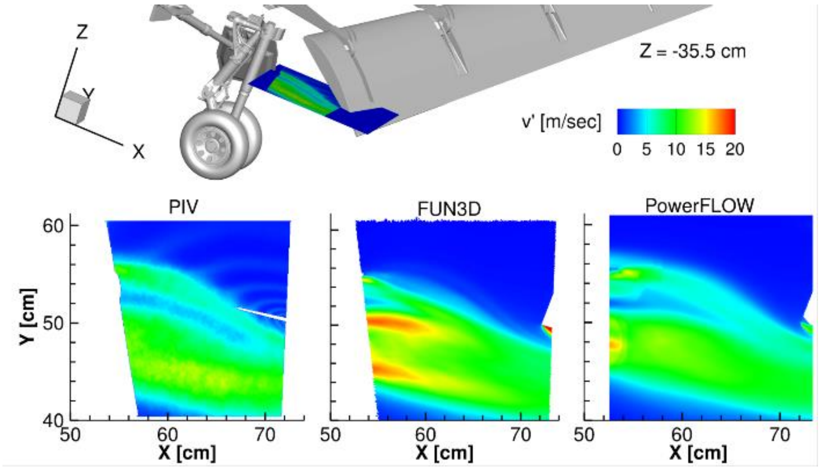
Mean velocity components





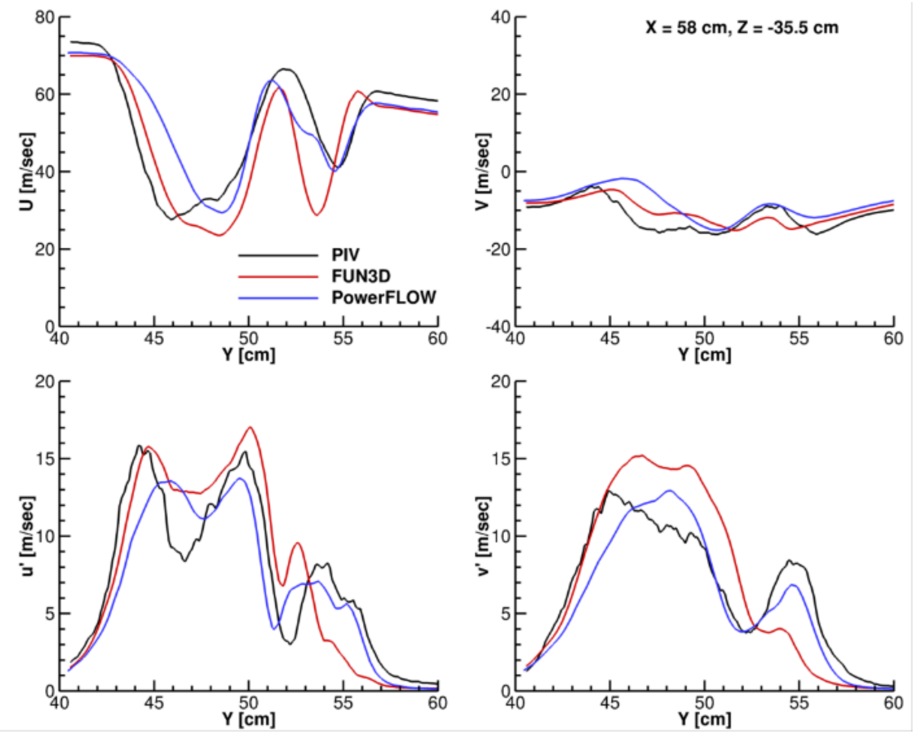
Fluctuating velocity components

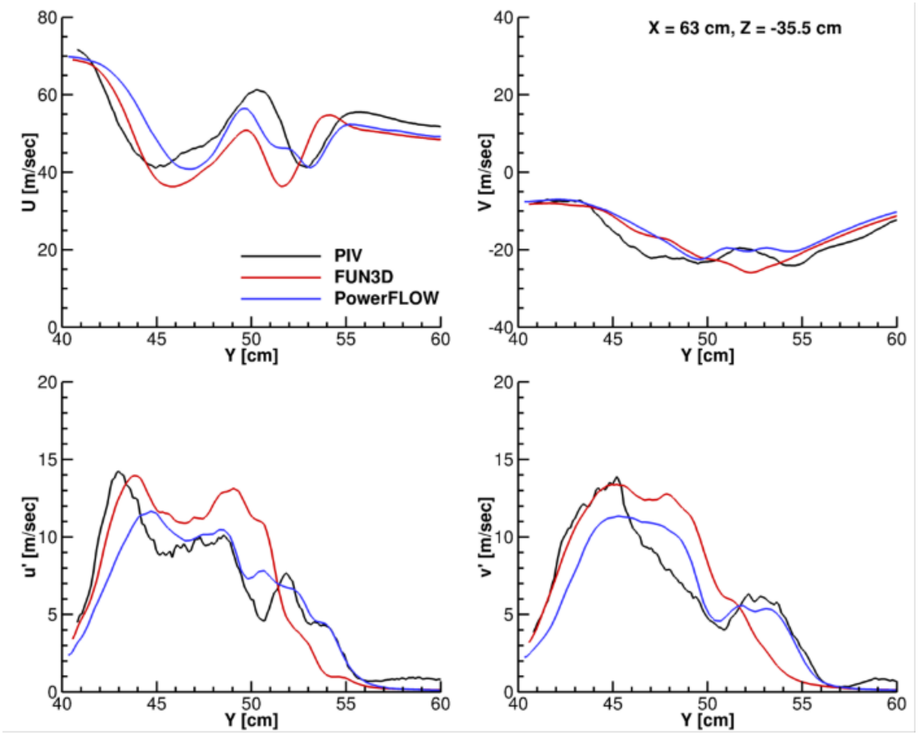




Gear-Flap Interaction Zone
(Simulated vs. Measured Flowfield: Velocity Profiles)

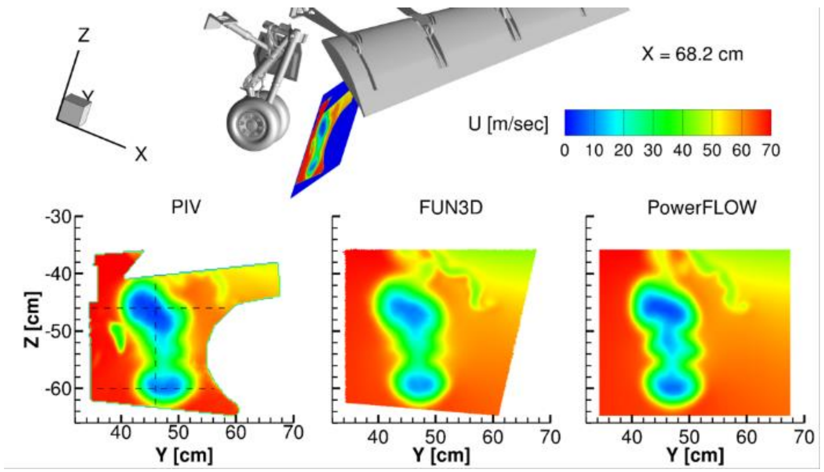
Mean and fluctuating velocity components

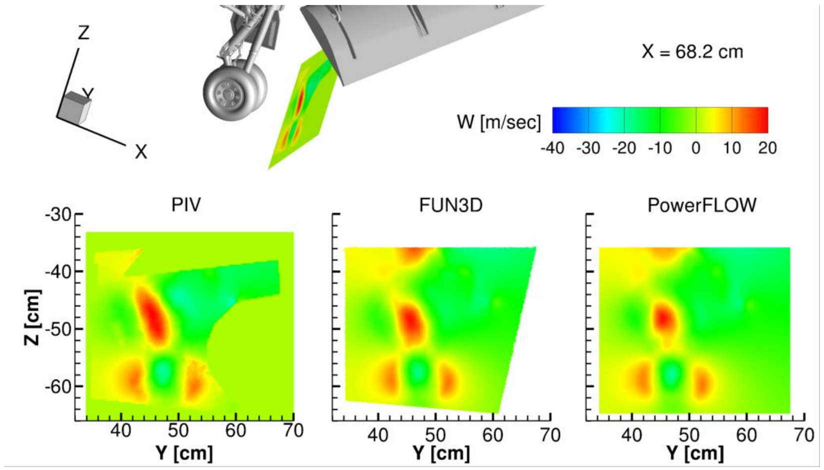




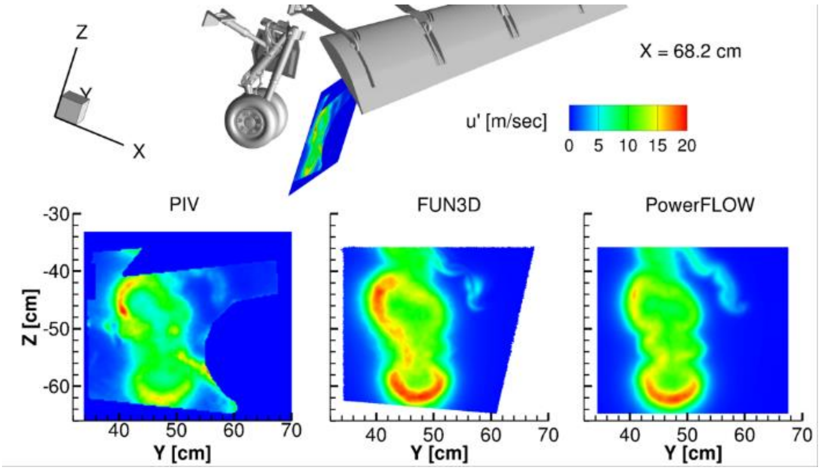
Gear-Flap Interaction Zone
(Simulated vs. Measured Flowfield: Velocity Contours)

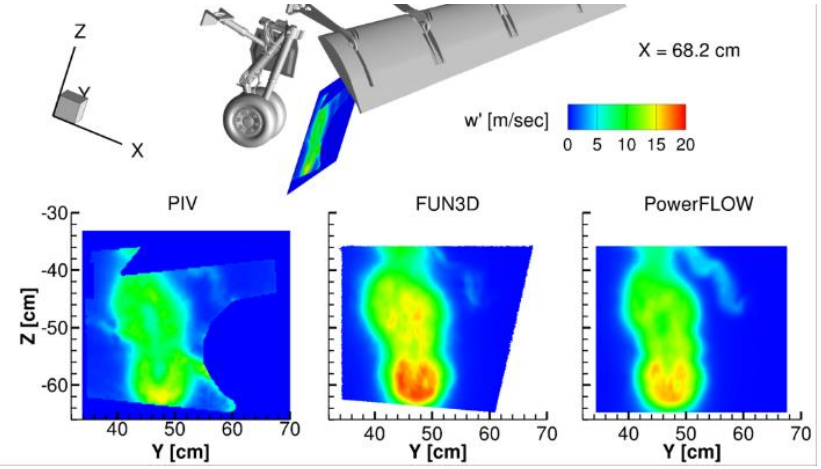
Mean velocity components





Fluctuating velocity components

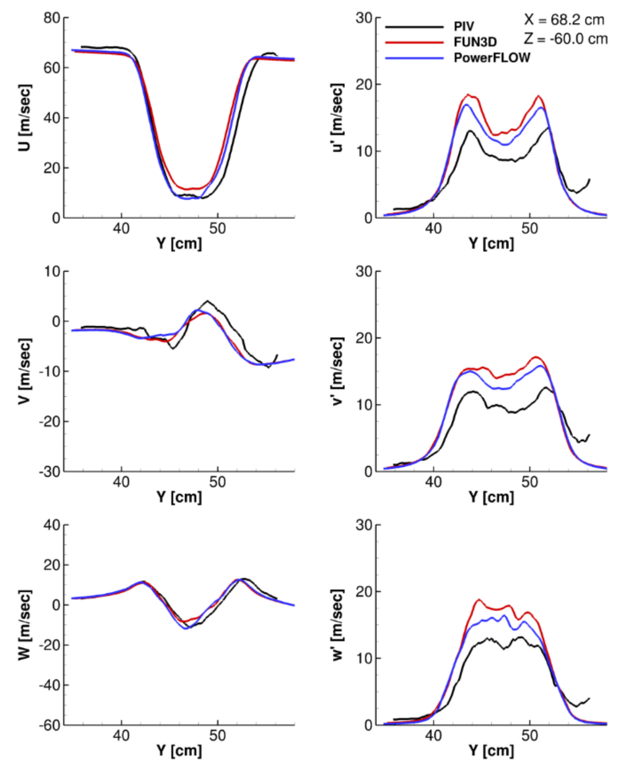




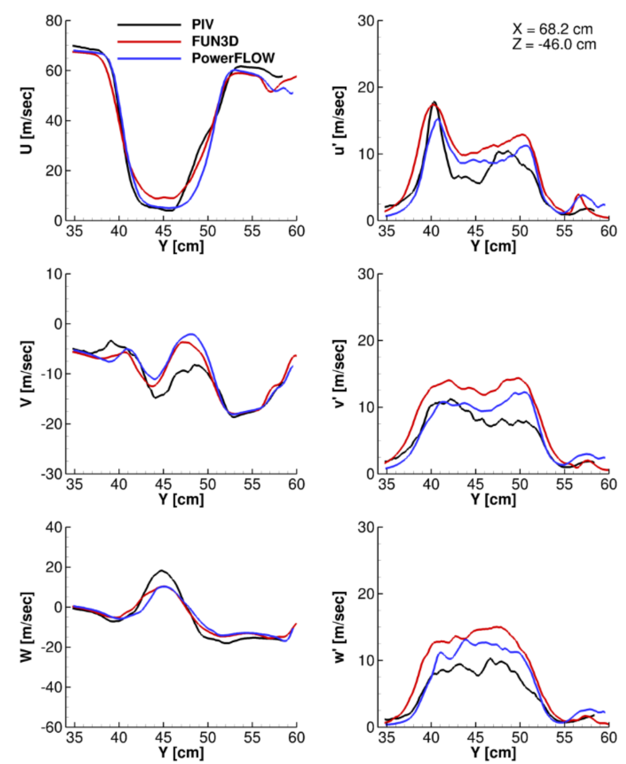
Gear-Flap Interaction Zone
(Simulated vs. Measured Flowfield: Velocity Profiles)

Mean and fluctuating velocity components

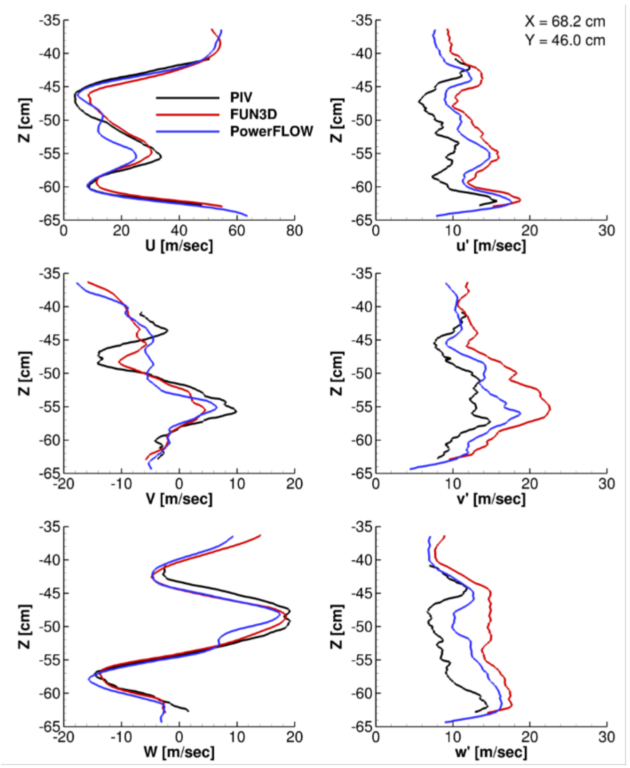
Profiles along Y coordinate



Profiles along Y coordinate

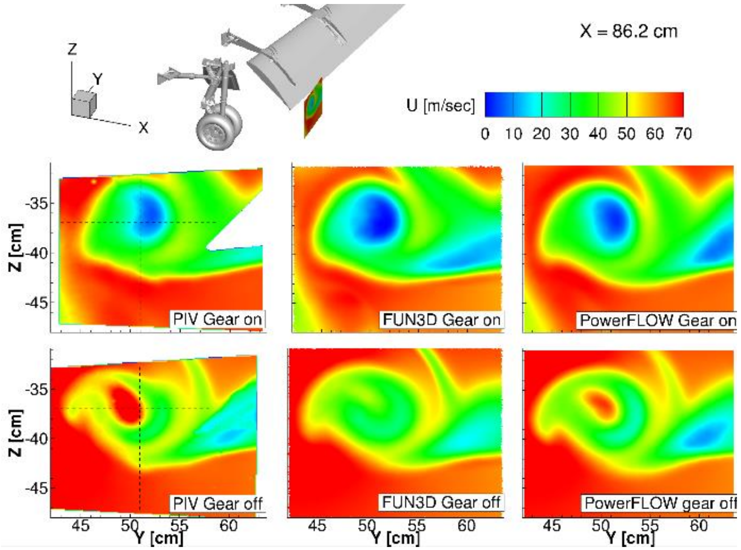


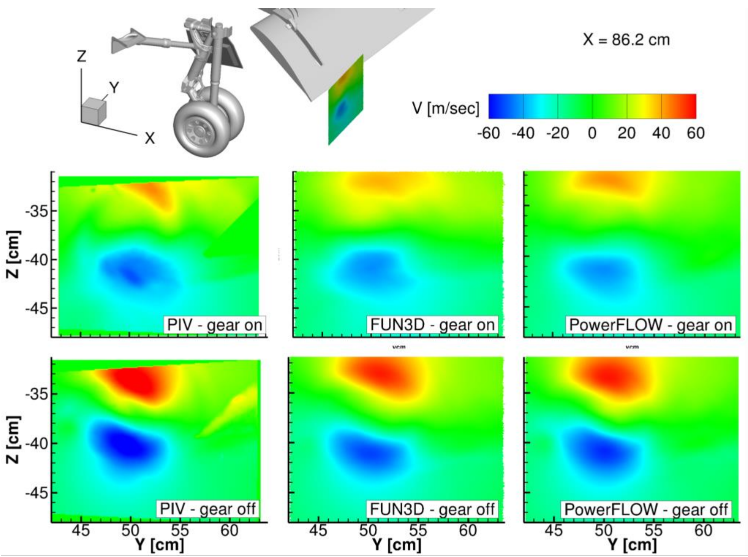
Profiles along Z coordinate



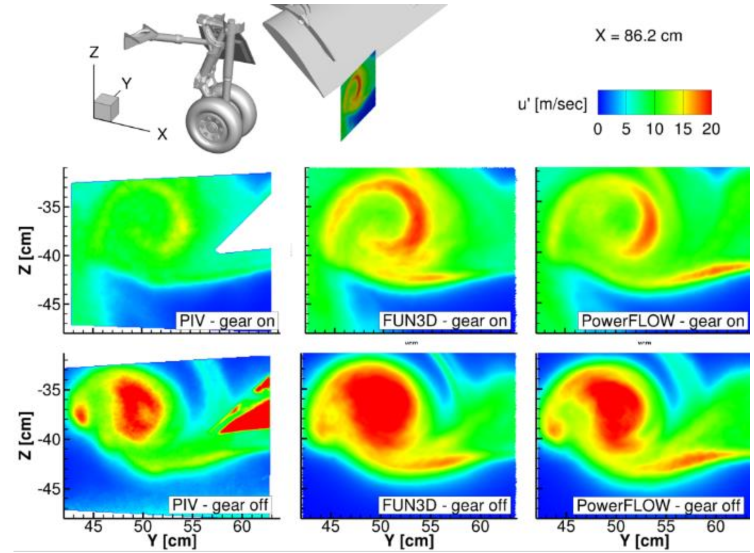
Gear Effects on Inboard Flap Tip Vortex
(Simulated vs. Measured Flowfield: Velocity Contours)

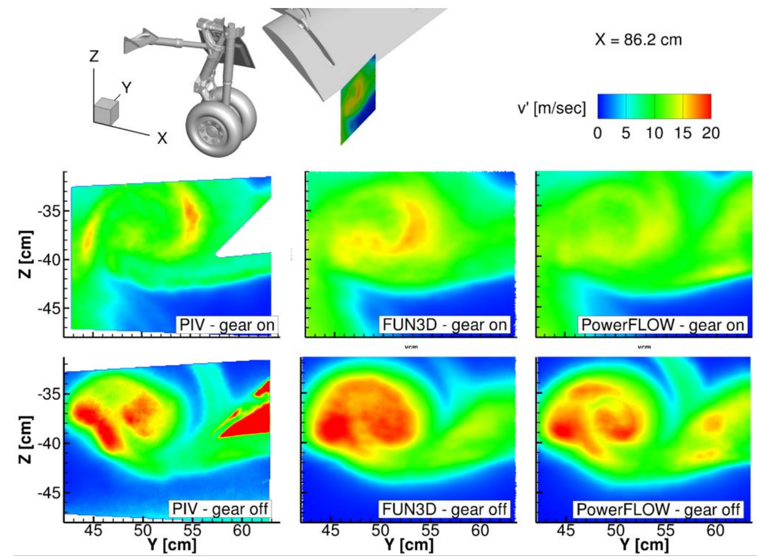
Mean velocity components





Fluctuating velocity components

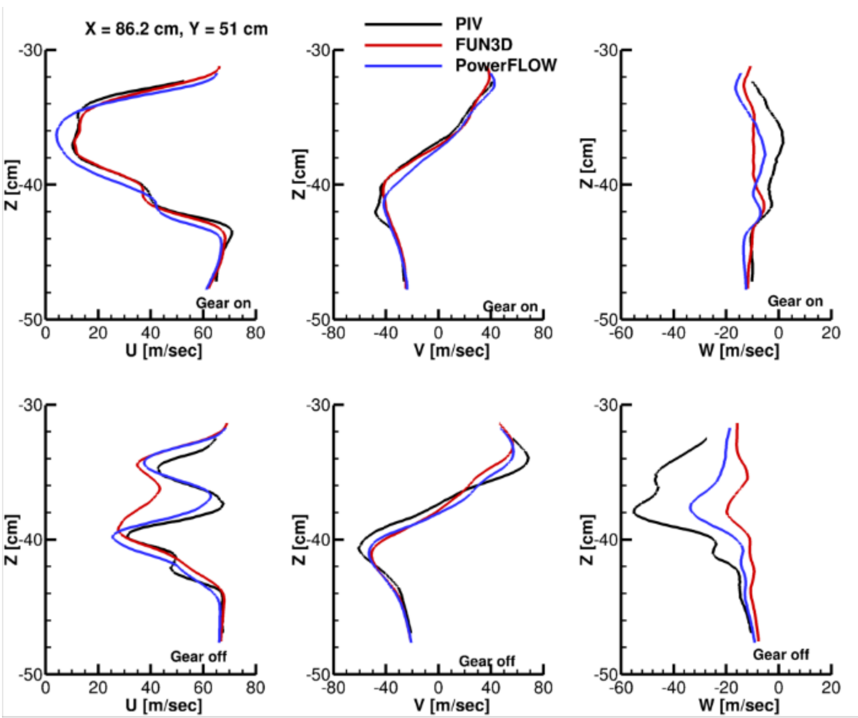


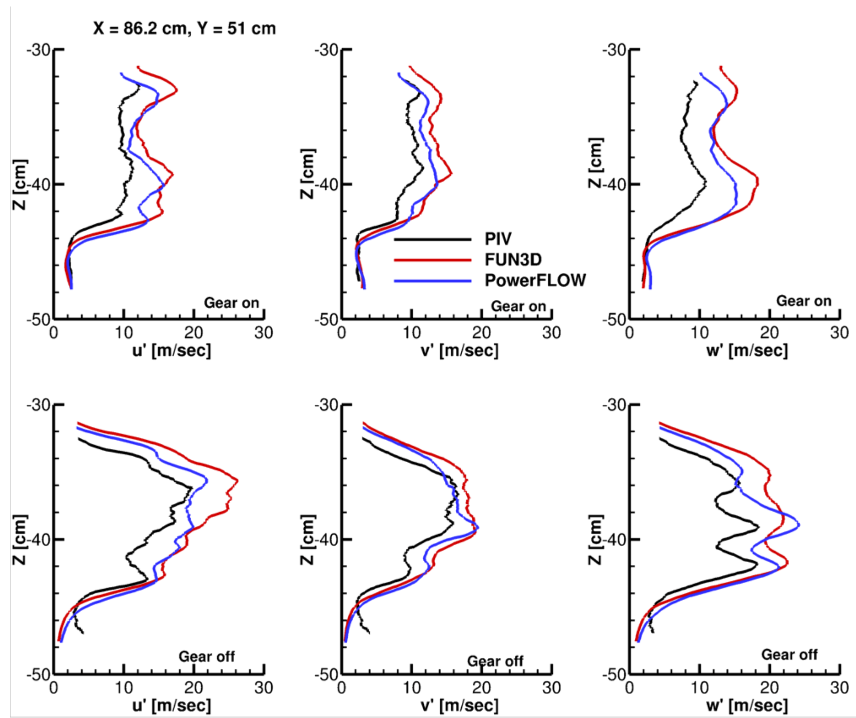


Gear Effects on Inboard Flap Tip Vortex
(Simulated vs. Measured Flowfield: Velocity Profiles)

Mean and fluctuating velocity components

Profiles along Z coordinate





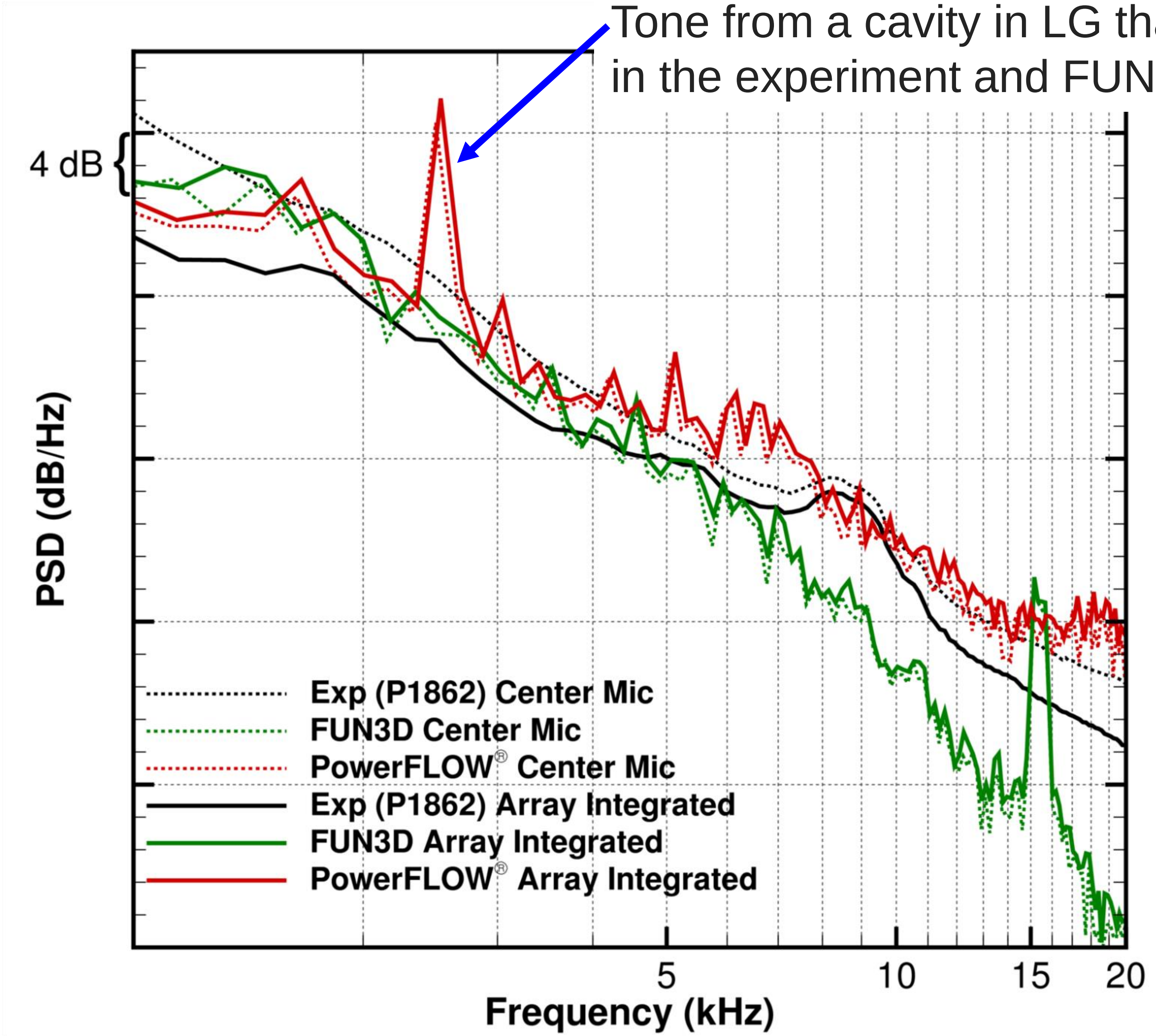
Acoustic Comparisons

- Computations and experiments are in good agreement in the near field
  - Mean and fluctuating surface pressure
  - Flow velocities at the locations of PIV data

- Acoustic predictions from CFD use solid surface pressure data + Acoustic Analogy (Ffowcs Williams-Hawkings Equation)
  - Predicted signal at array center compared with experimental microphone array output
    - Good agreement obtained with data from PowerFLOW® and FUN3D CFD codes
  - New comparisons involve using CFD to predict the signals at all microphone locations and applying the same array processing to those signals
    - Signals from CFD do not suffer from extraneous noise but are extremely short in time duration compared with experiment
  - Experimental and CFD array data has been processed in a similar fashion using conventional beamforming and two deconvolution techniques: DAMAS and CLEAN-SC

Spectral Comparison

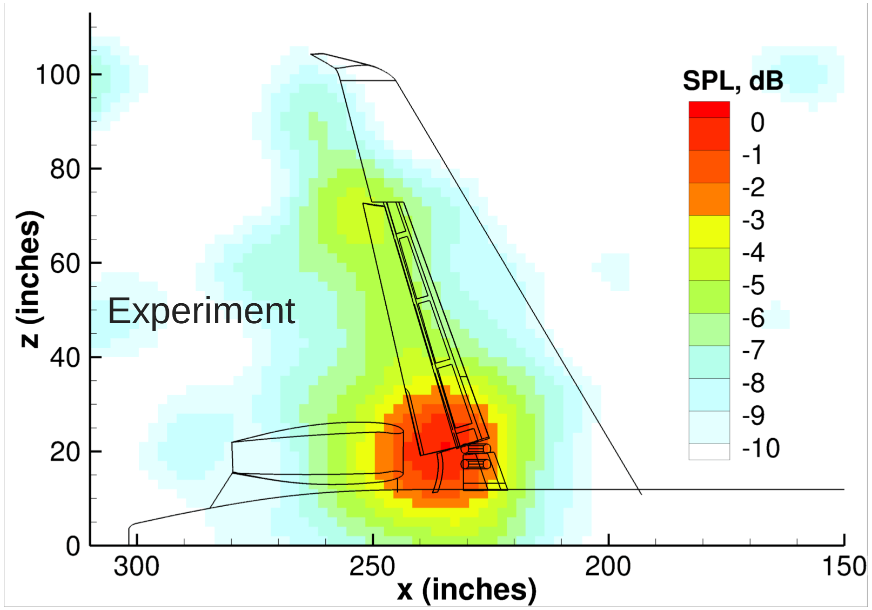
Tone from a cavity in LG that was covered in the experiment and FUN3D grid

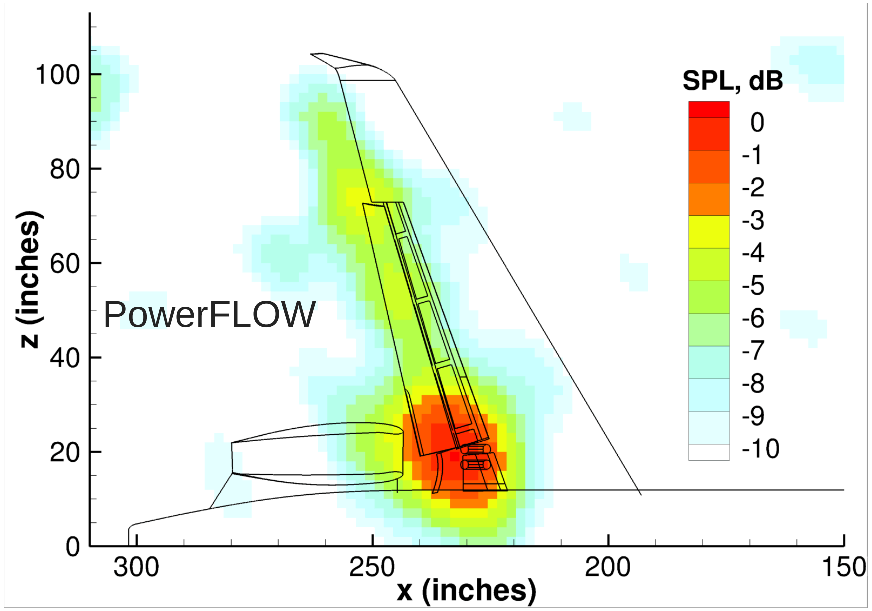


M=0.2, AoA = 3 deg
Gear on
Flap at 39 deg
Array at 90 deg to model

Unified DAMAS V10R2

Conventional Beamforming Source Strengths

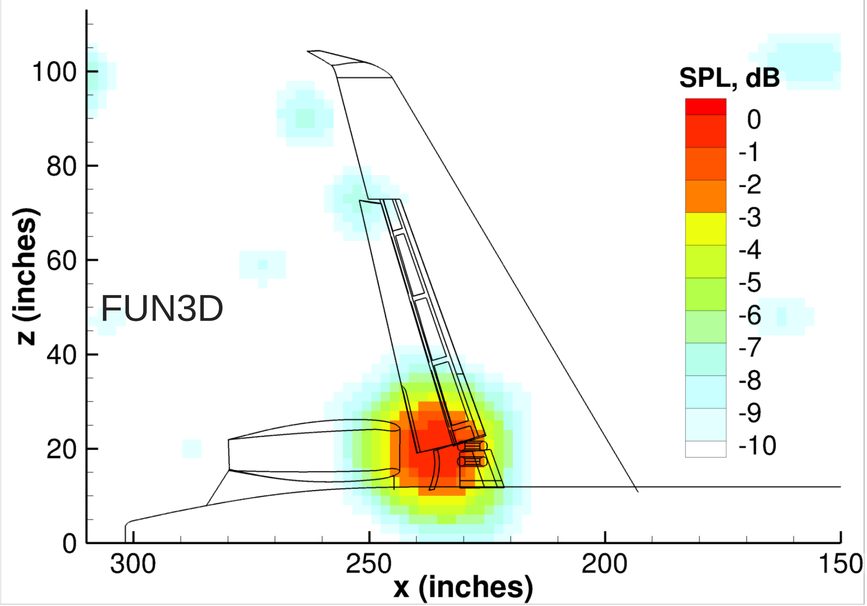




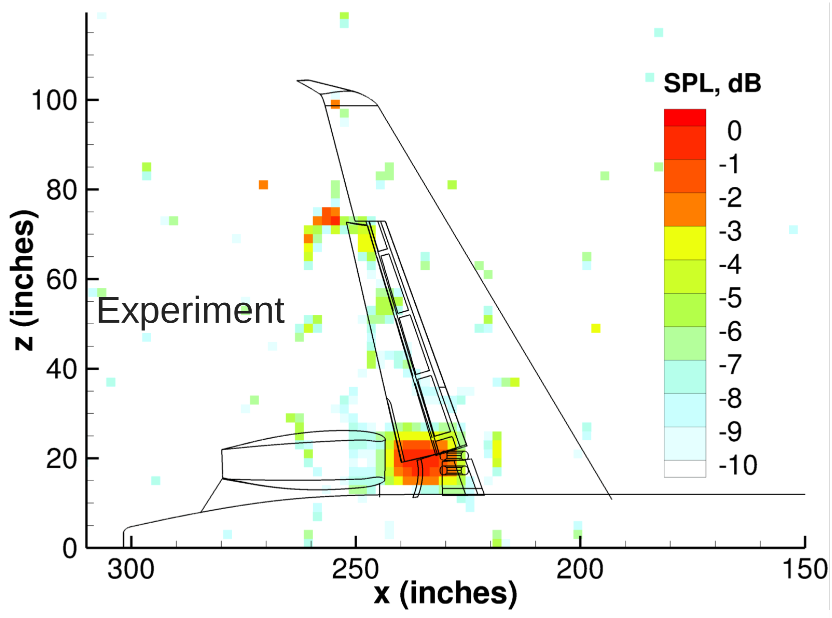
M=0.2, AoA = 3 deg
Gear on
Flap at 39 deg
Array at 90 deg to model

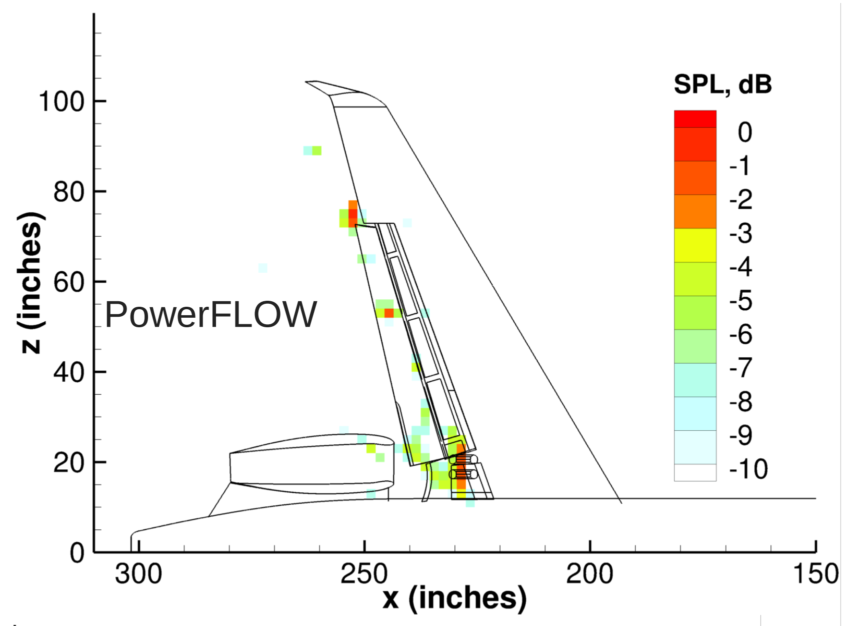
5 kHz model scale
0.5 kHz full scale

Unified DAMAS V10R2



DAMAS Beamforming Source Strengths





M=0.2, AoA = 3 deg
Gear on
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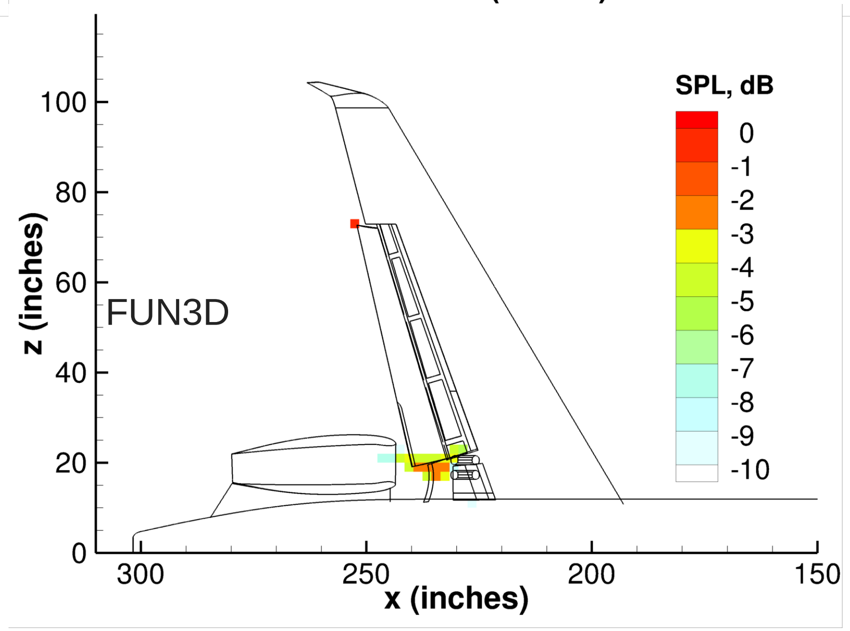
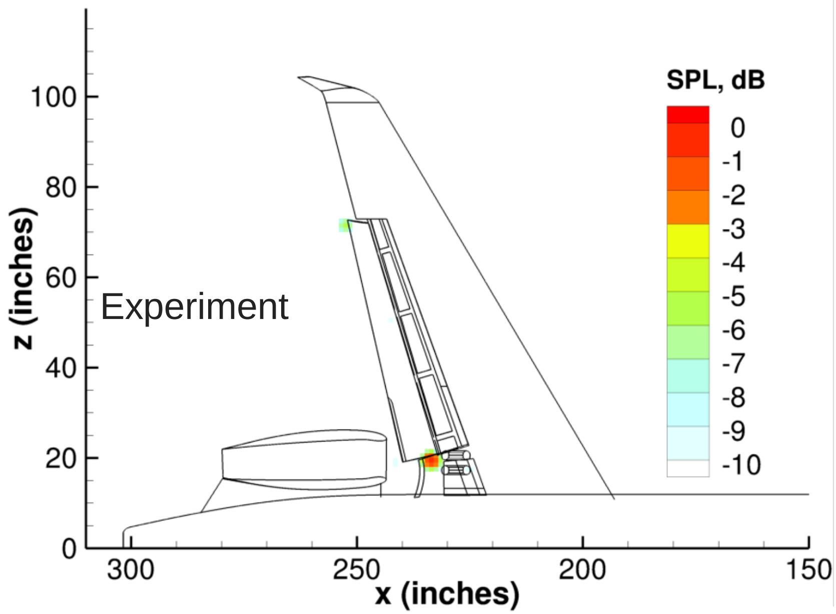
Array at 90 deg to model

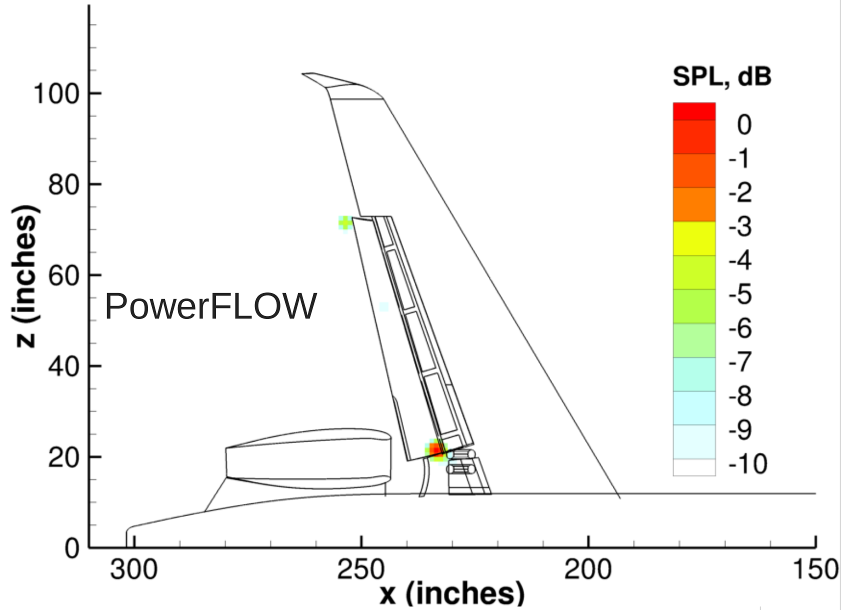
2.8 kHz model scale
0.5 kHz full scale

Unified DAMAS V10R2



CLEAN-SC Beamforming Source Strengths

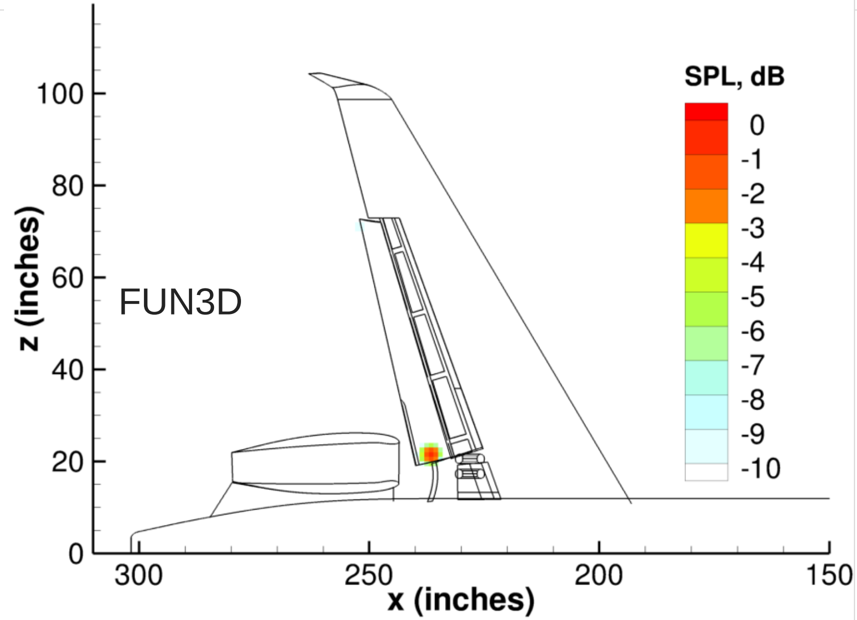




M=0.2, AoA = 3 deg
Gear on
Flap at 39 deg
Array at 90 deg to model

5 kHz model scale
0.9 kHz full scale

AVEC Array Processing Software
Version 3.14



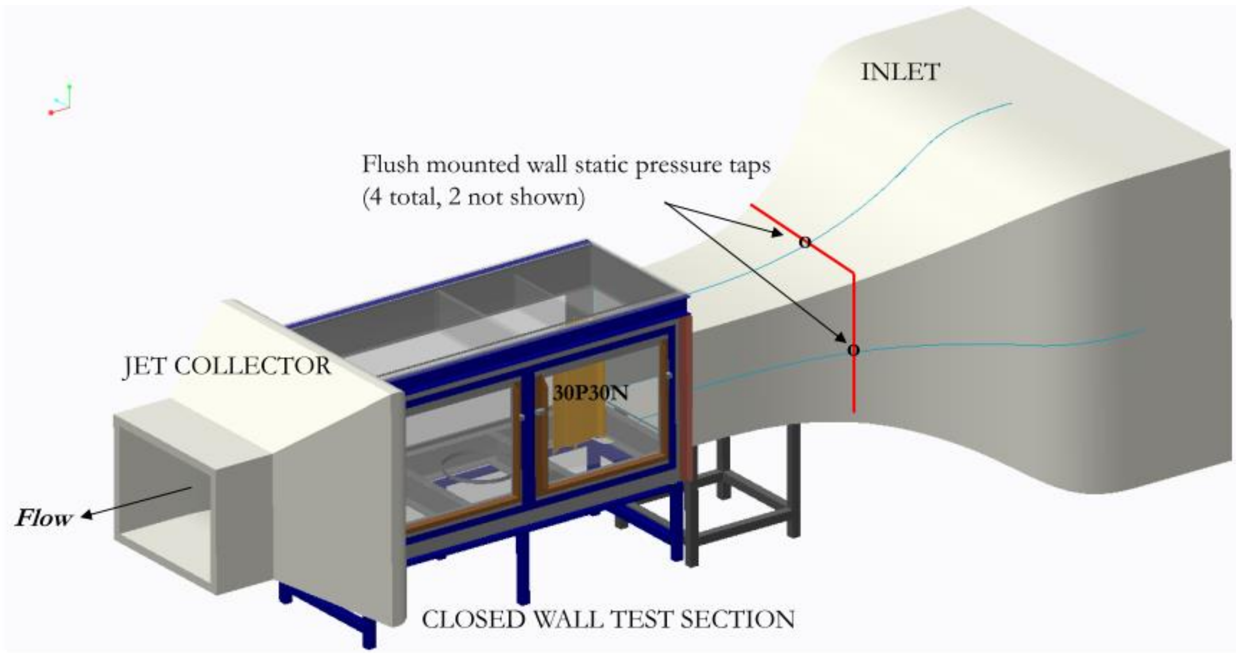
Summary

- Good comparisons between CFD and PIV in the wake of the landing gear and inboard flap despite differences in configuration
  - Open-jet experiment and free-field with floor in computations
  - Flow angularity in experiment

- Synthetic array results look reasonable despite short time records
- Array processing does not improve spectral comparisons between computations and experiment for this semi-span model test
- Beamforming contours of source strength provide an additional means of comparison

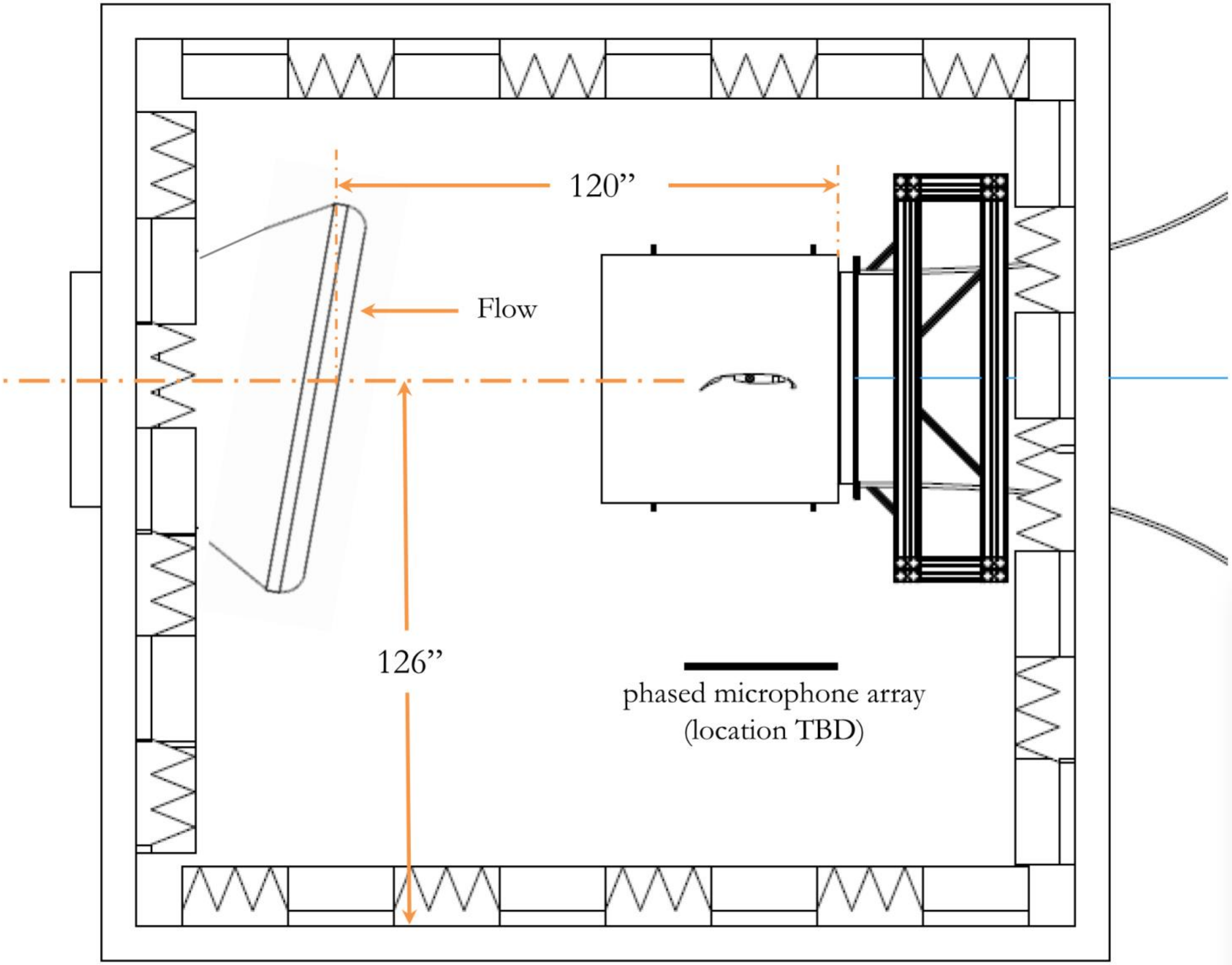
Aeroacoustic Measurements of Slat Noise: FSU Aeroacoustic Facility

- **Florida State University/NASA Collaboration**

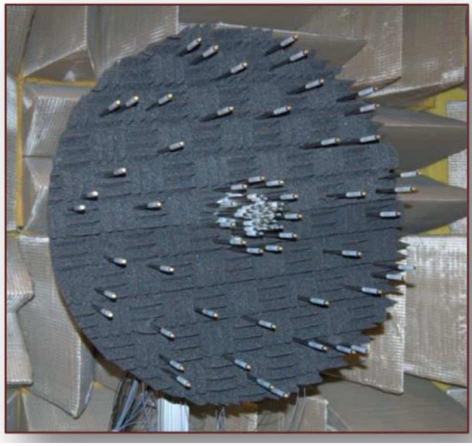


Kyle A. Pascioni
Prof. Louis Cattefesta

Previous Measurements: Open-Jet Setup

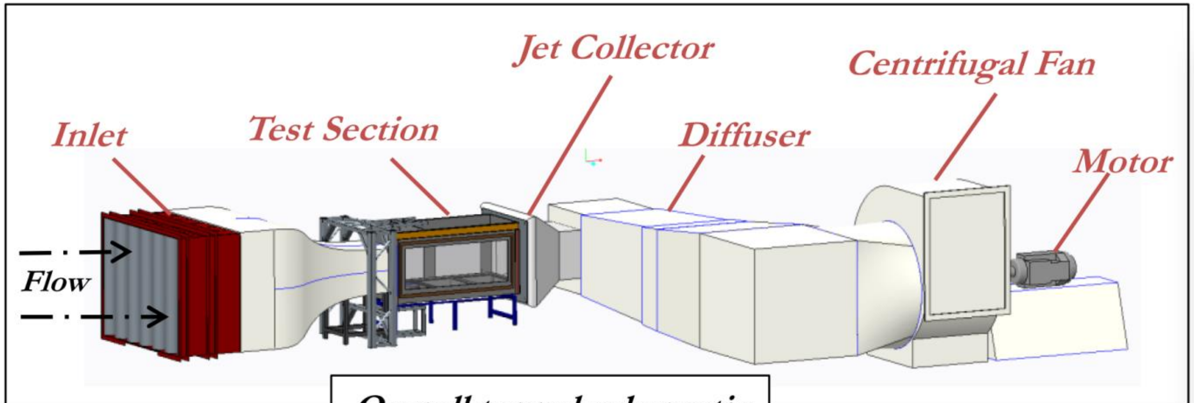


Top view of Anechoic chamber

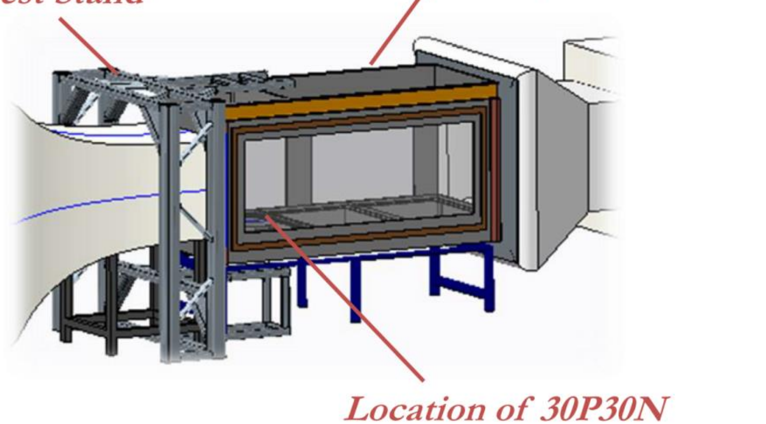


80-channel phased microphone array

Recent Measurements: Closed-Wall Setup

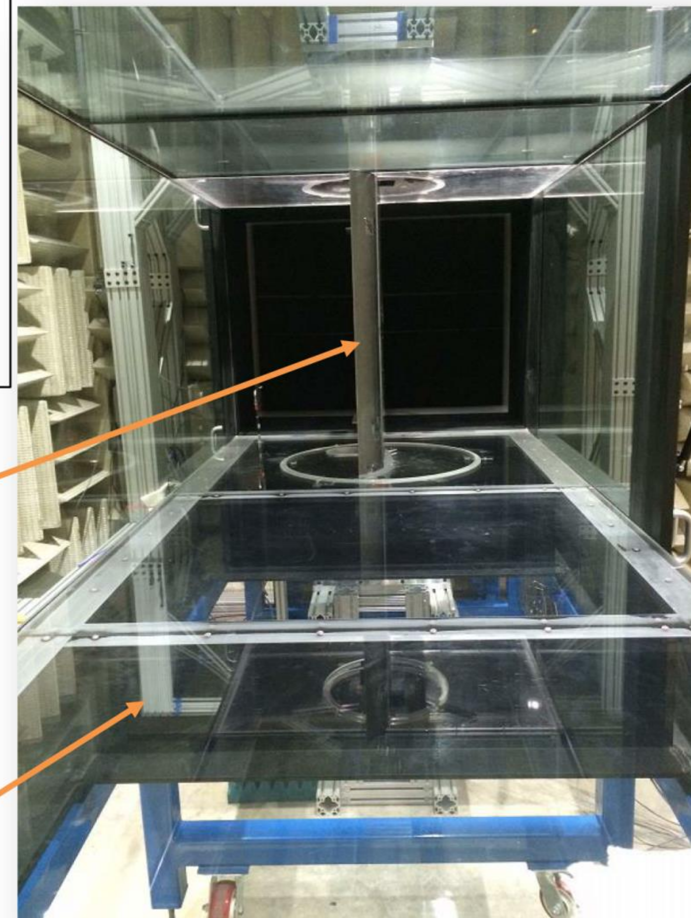


Overall tunnel schematic



Test section close up

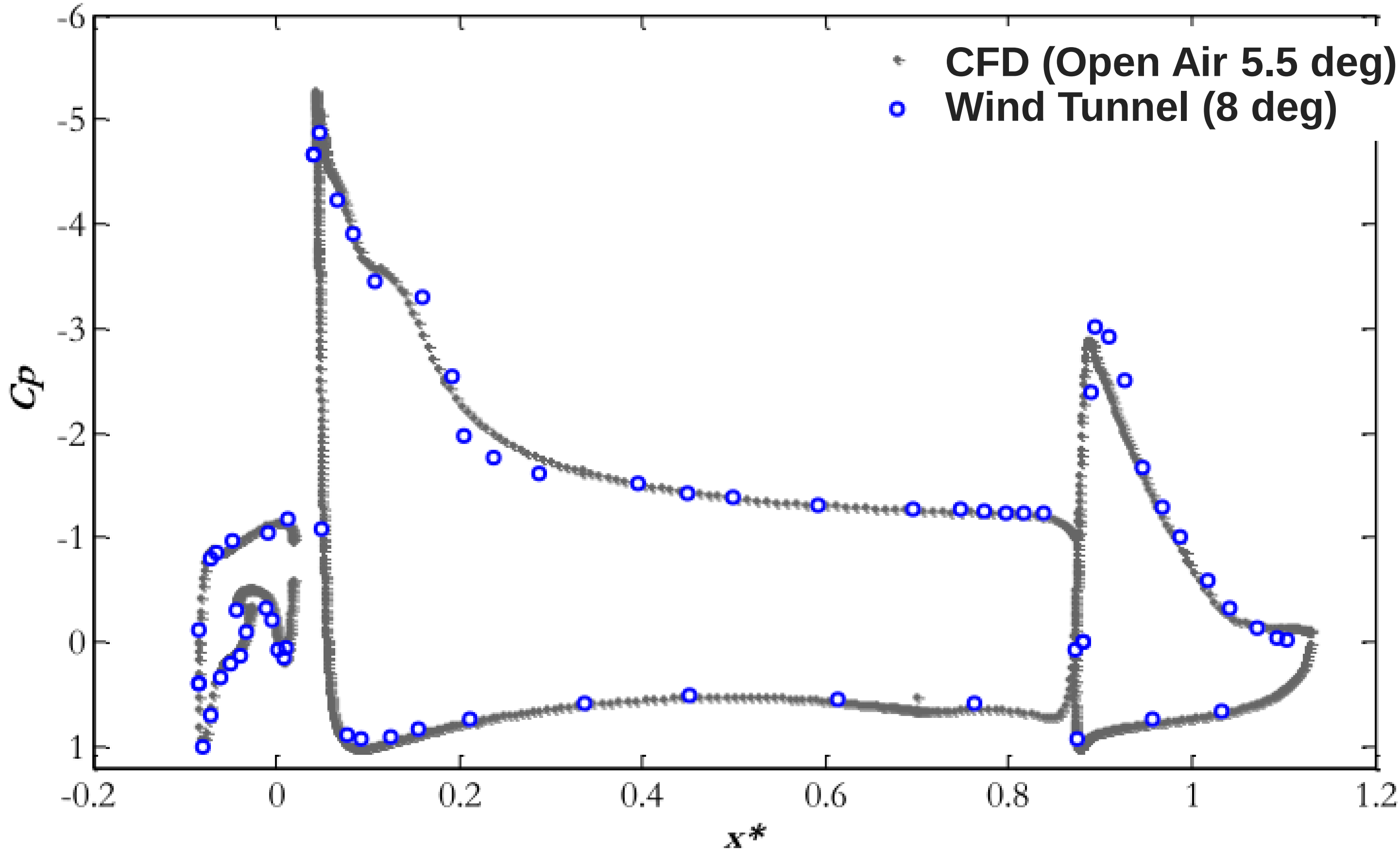
30P30N



Closed-wall test section

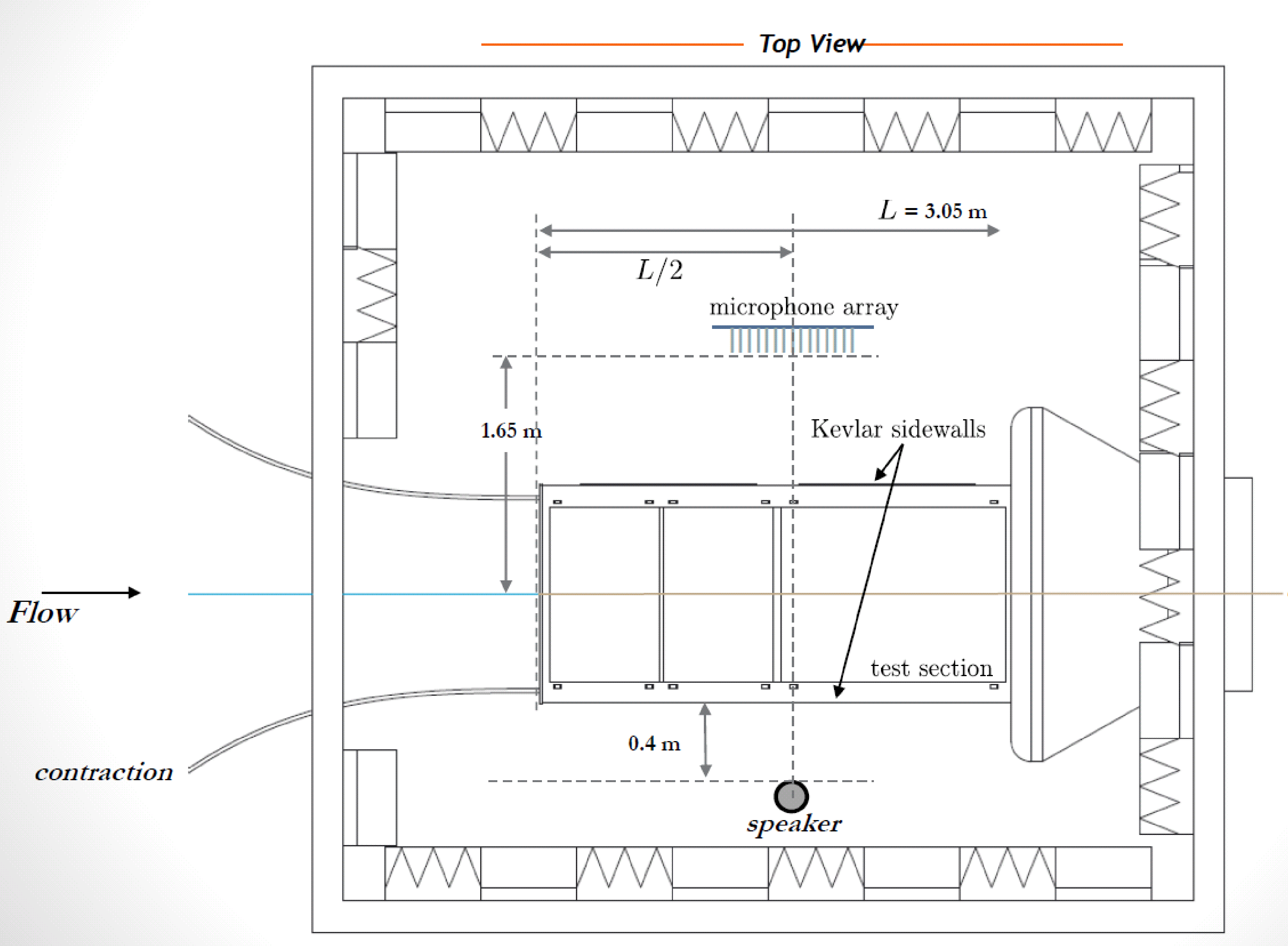
Looking upstream in test section from jet collector

Mean Surface Pressure Measurements: Comparison with Open Air CFD Simulations

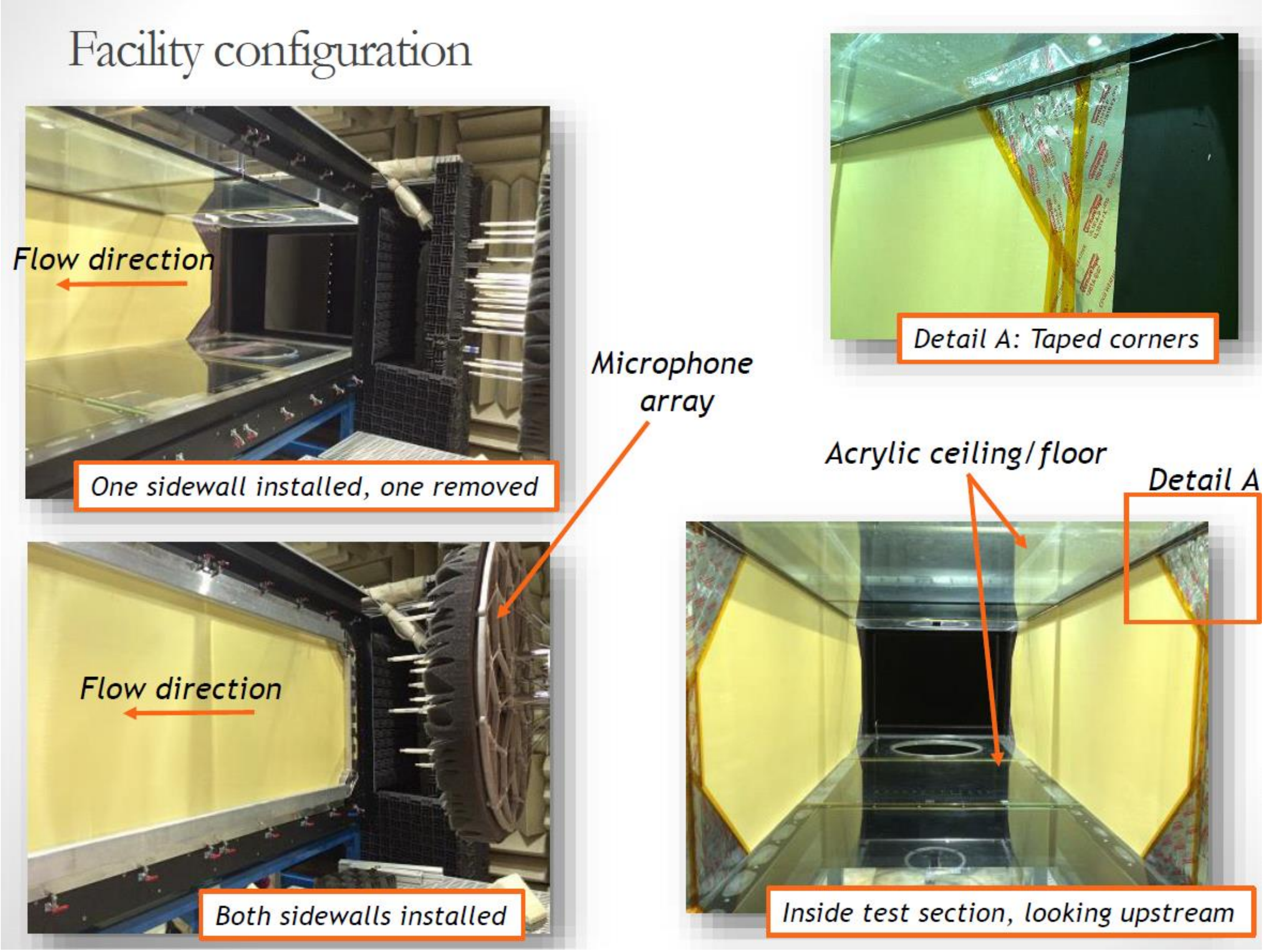


- Adequate simulation of aerodynamic environment at approach-like angle of attack
    - Closed-wall configuration required to obtain reasonable pressure distribution

Kevlar Wall Setup

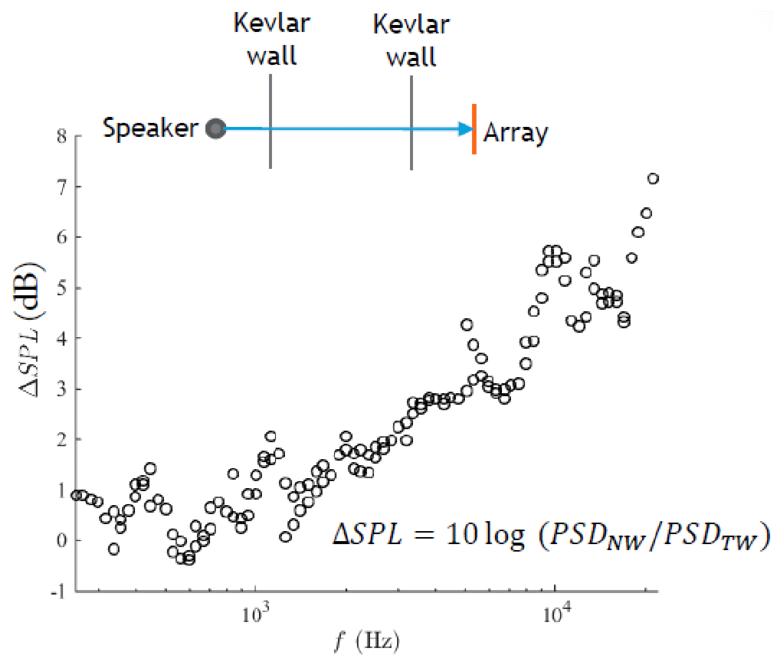


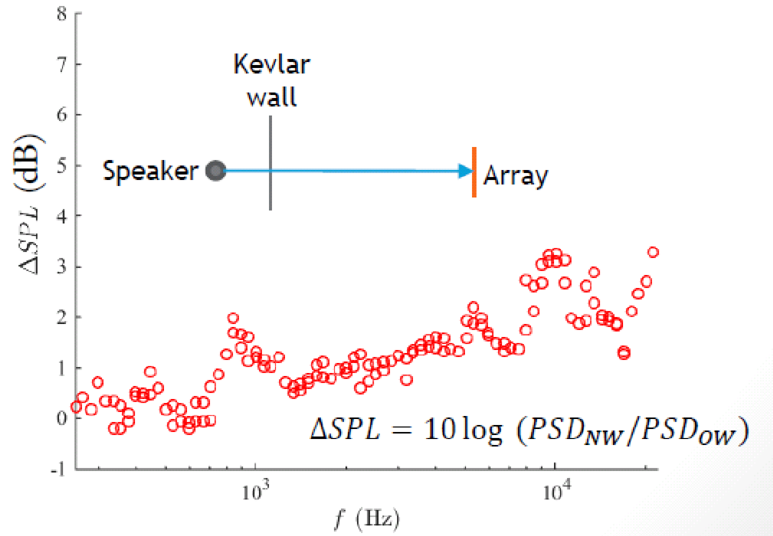
Characterizing the Kevlar Wall



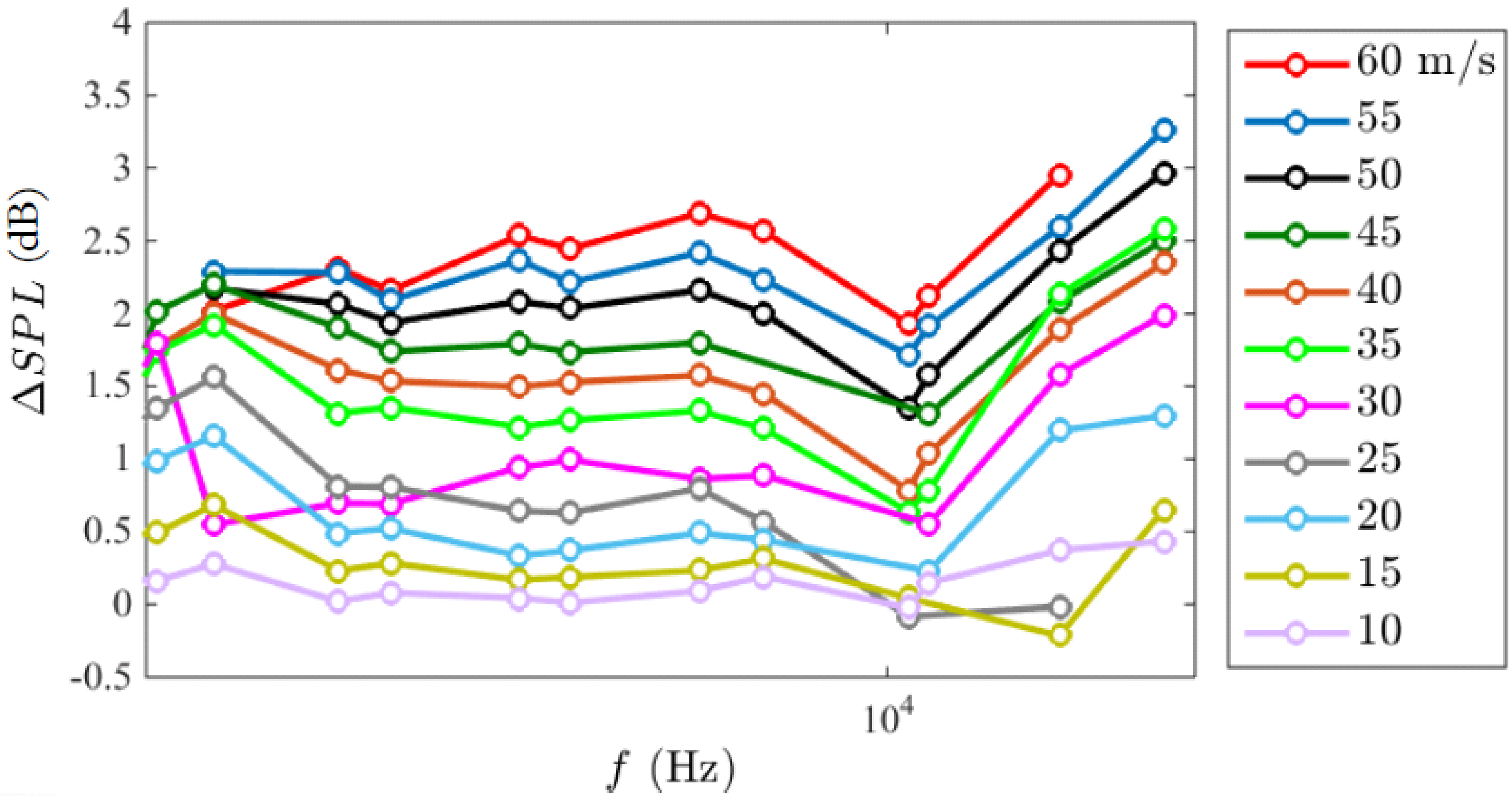
Kevlar Wall Acoustic Attenuation: No Flow

- ΔSPL is difference between speaker to microphone transmission with and without Kevlar walls present
  - Attenuation due to transmission through either one (top) or two (bottom) walls



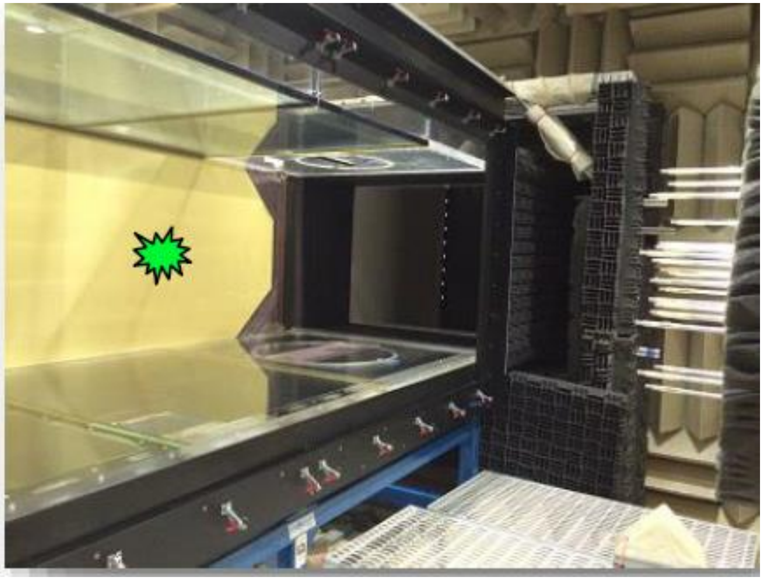


Kevlar Wall Acoustic Attenuation: With Flow



- ΔSPL is the difference between the no flow condition and various tunnel speeds, both with two Kevlar walls.
- Greater reduction with tunnel speed due to scattering effects of higher amplitude turbulent fluctuations

Plasma Acoustic Point Source for Kevlar Characterization



- Use a laser-generated acoustic point source to measure the array's point spread function (PSF)
- With the measured PSF, deconvolution more accurate for advanced beamforming techniques such as DAMAS
  - Conduct w/ and w/out Kevlar wall: difference defining acoustic transmission loss
  - Conduct w/ and w/out flow, two Kevlar walls present: difference defining boundary layer losses

Summary

- Kevlar wall configuration developed for airframe noise testing in the FSU facility
- Initial characterization of the transmission losses across the Kevlar wall established
    - Lift also changes requiring a modification to the angle to attack
- More advanced plasma source to be used to measure the in-situ array response (point spread function)
- Testing of 30p30n slat noise to follow