Noise Scattering Study for a NACA 0012 Airfoil with a Shielding Flap

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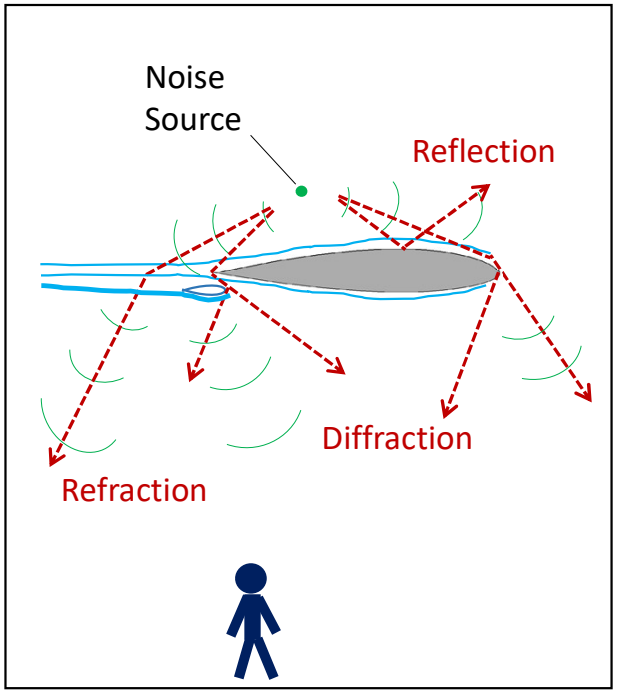
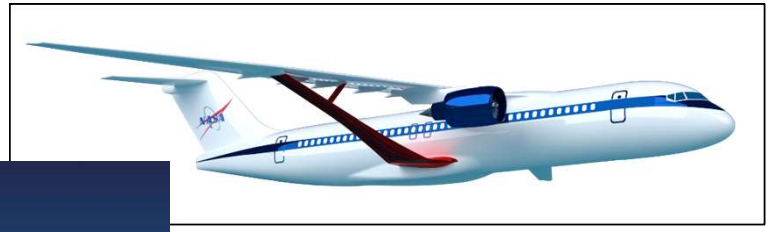
Introduction

- Scattering of engine noise from an aircraft wing and fuselage impacts noise levels on the ground
- Need to further validate and improve noise scattering prediction tools for aircraft system noise assessment

Scattering of sound



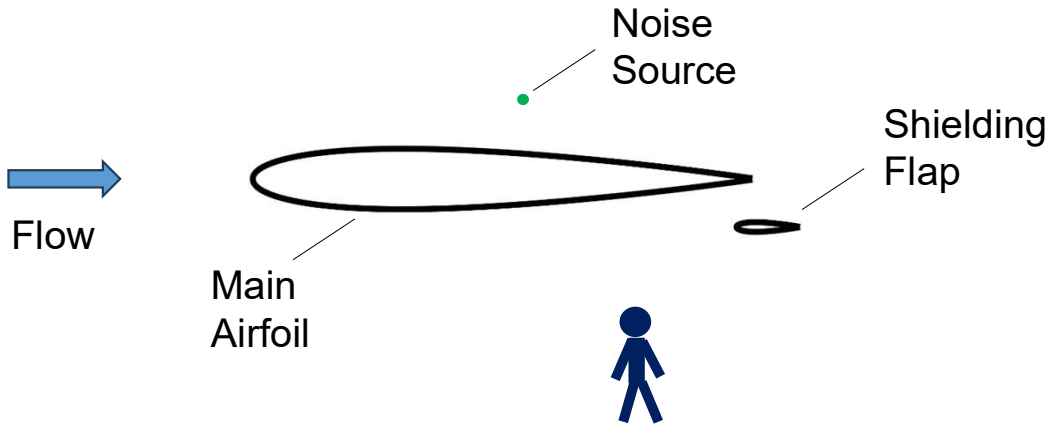


Transonic Truss-Braced Wing

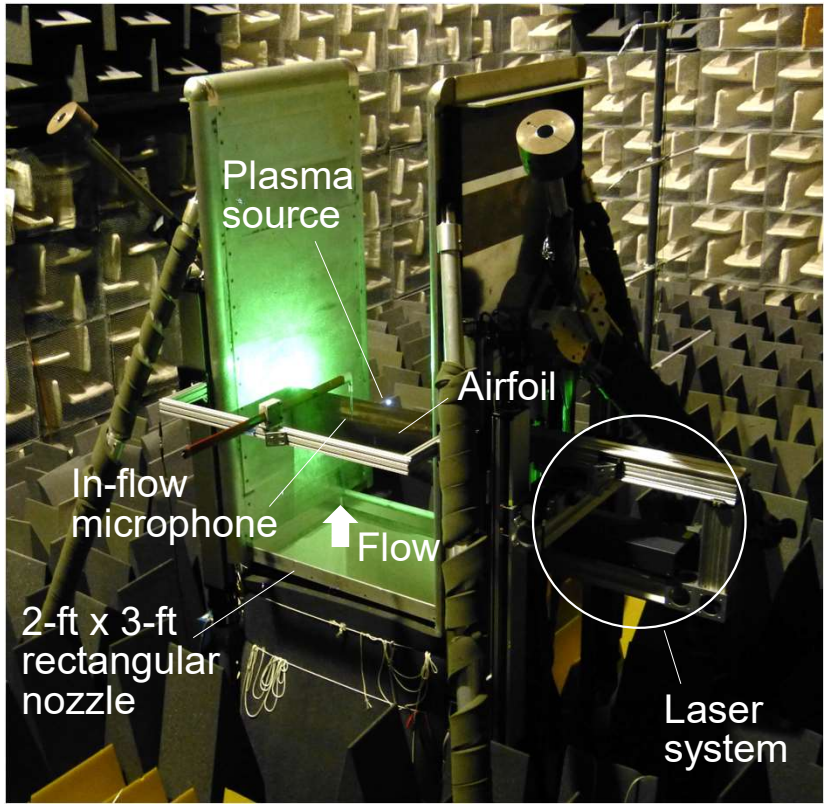
Hybrid Wing Body

Objectives

- Expand the experimental database available to validate NASA noise scattering prediction tools
- Include parameter variations to capture the physics relevant to prediction codes
  - Scattering from multiple bodies (main airfoil and flap)
  - Smooth and sharp-edge scattering
  - Effect of gap flow and boundary layers
- Support the initial exploration of a Shielding Flap noise reduction concept
  - Effect of a small flap on the shielding of a sound source by a NACA 0012 airfoil



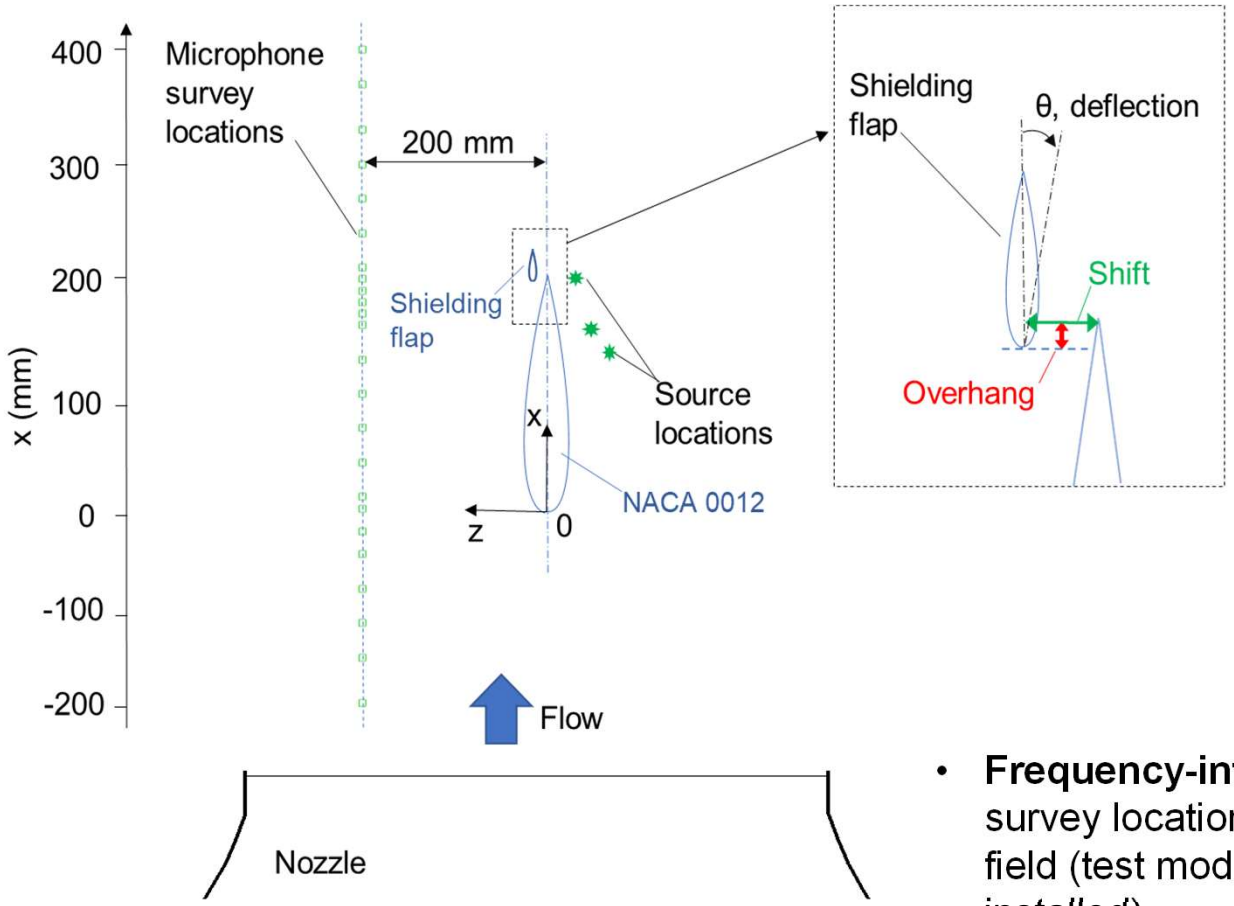
Experimental Setup - NASA Quiet Flow Facility



NASA Quiet Flow Facility (QFF) test chamber

- Open jet nozzle
- Test model:
  - NACA 0012 main airfoil with a Shielding Flap
- In-flow microphone:
  - 1/8” microphone with nosecone
  - Mounted on a linear traverse
- Sound source:
  - Laser-induced plasma
  - Minimally intrusive, omnidirectional and repeatable

Setup and Parameter Variation



- **Main airfoil:** NACA 0012 (20 cm chord)
- **Shielding flap:**

  Geometry: NACA 0015 or flat plate (2.54 cm chord)

  Shift: 0 to 19.05 mm

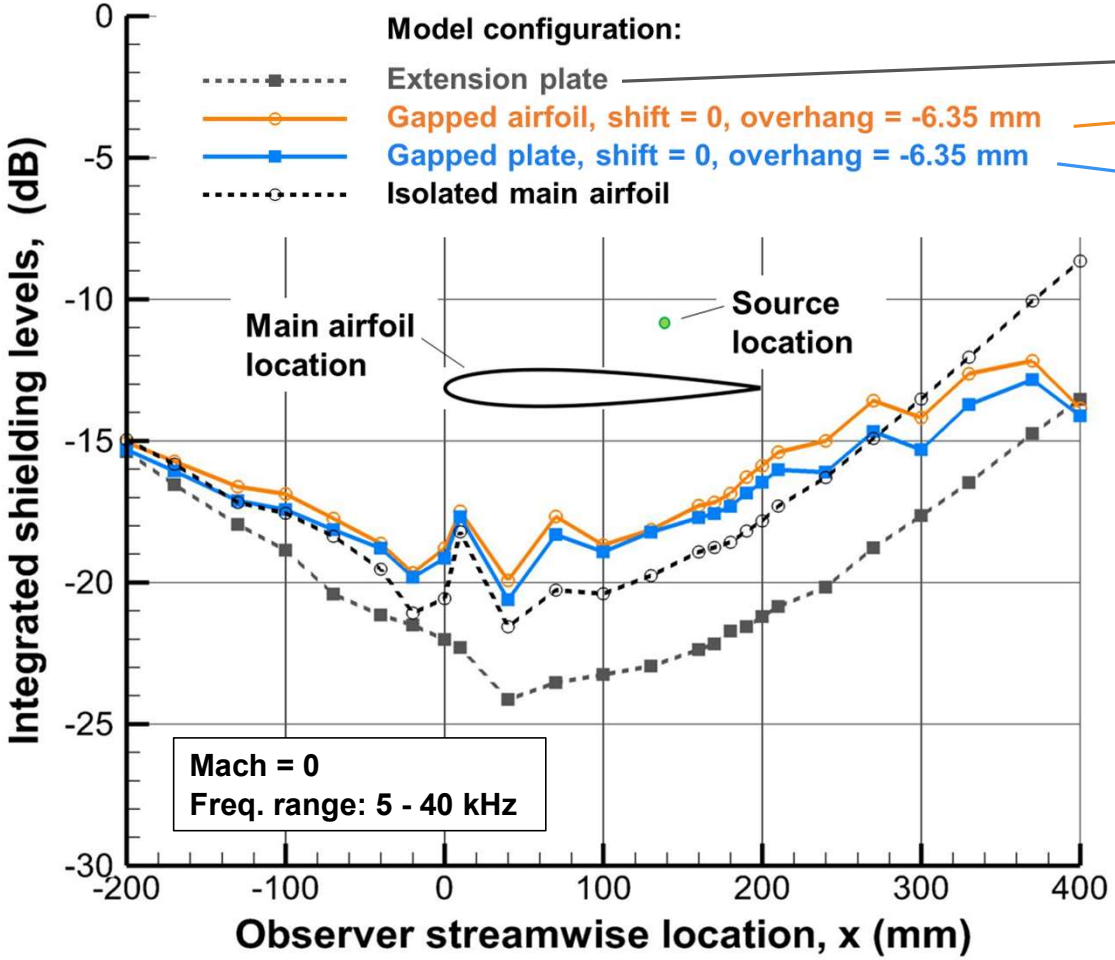
  Overhang: 6.35 to -12.7 mm

  Deflection: 0° and +/- 10°
- **Noise source location:** 70%, 75% and 100% chord of main airfoil
- **Flow Mach:** 0, 0.13 and 0.16

- **Frequency-integrated shielding levels** obtained at each survey location from measurements of isolated source field (test model removed) and scattered field (test model installed)

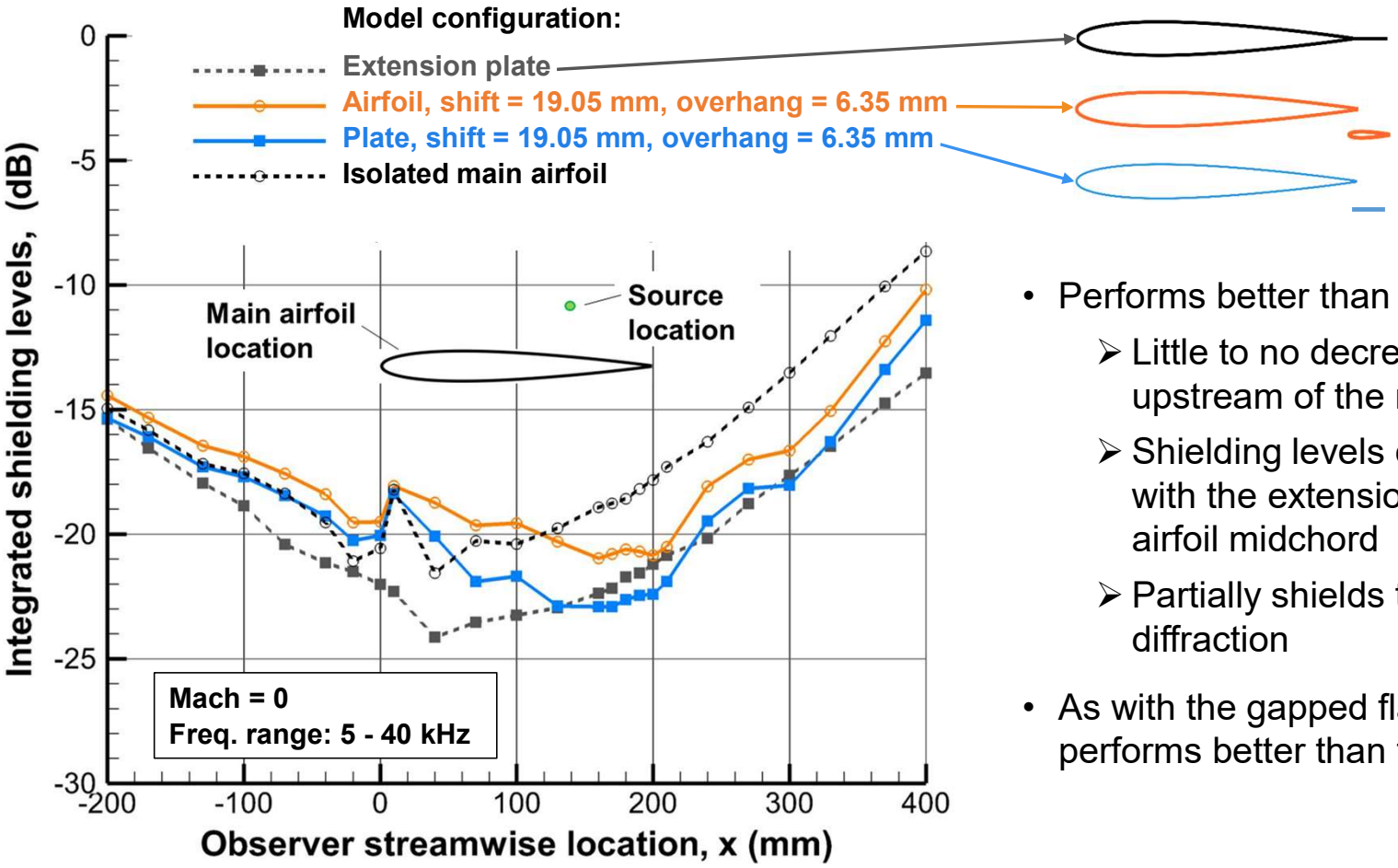
Test Results

Effects of Shielding Flap Configuration - Gapped Flap



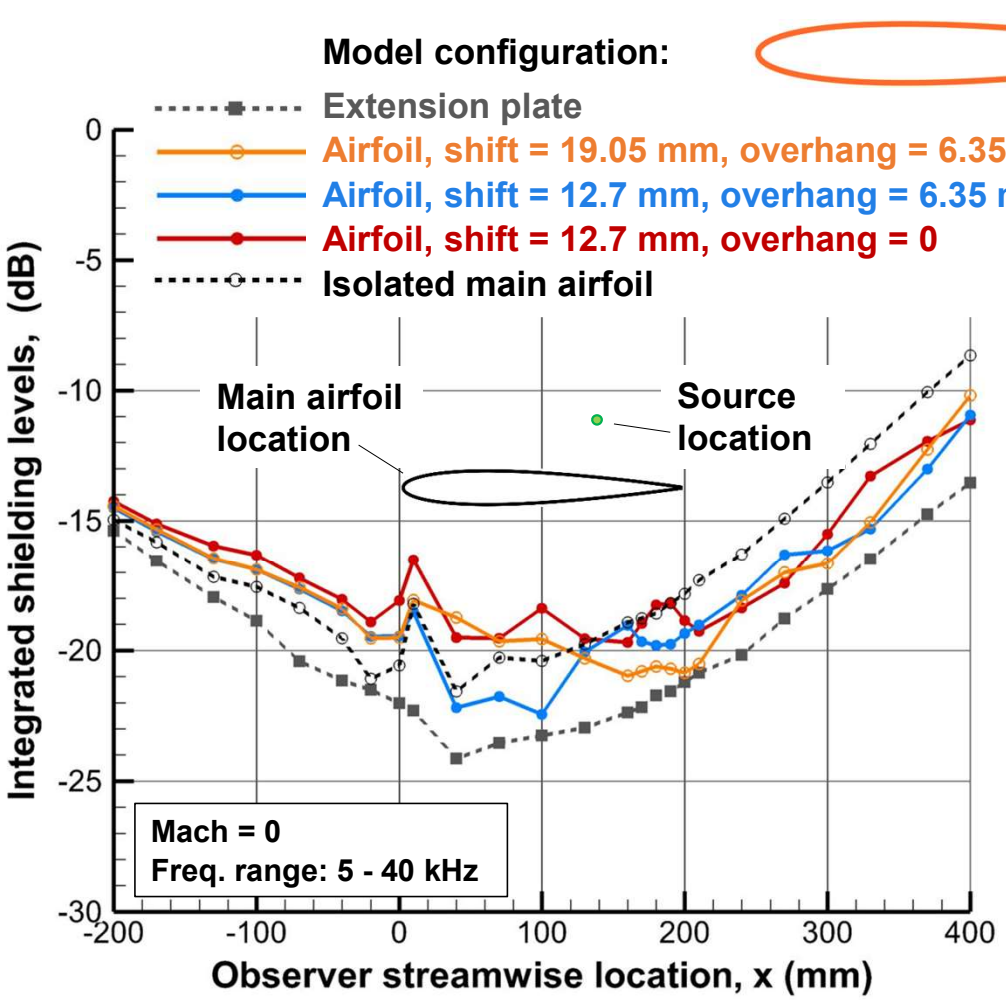
- Gapped flap configuration versus isolated main airfoil:
  - Decreased shielding, except at most upstream and downstream observer locations
- Gapped plate provides higher shielding levels than the gapped airfoil
  - Likely due to increased scattering and reflections from the airfoil's larger and curved leading edge
  - Difference in the shielding levels accentuated when doubling the gap size

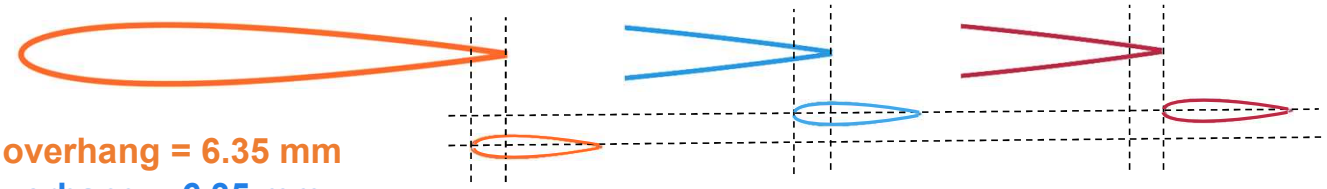
Shifted Flap with Positive Overhang



- Performs better than the gapped flap
  - Little to no decrease in shielding below and upstream of the main airfoil
  - Shielding levels close to those achieved with the extension plate downstream of the airfoil midchord
  - Partially shields the main airfoil trailing edge diffraction
- As with the gapped flap configurations, the plate performs better than the airfoil

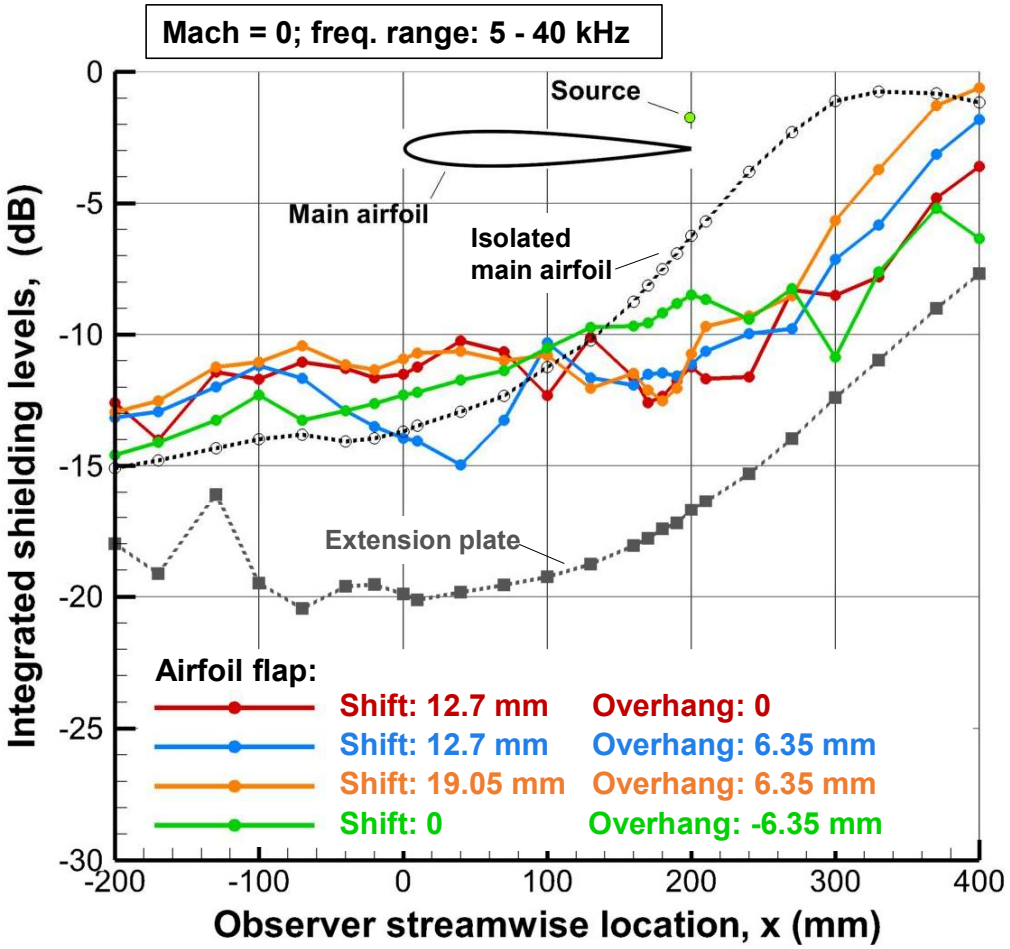
Effects of Changes in Flap Shift and Overhang





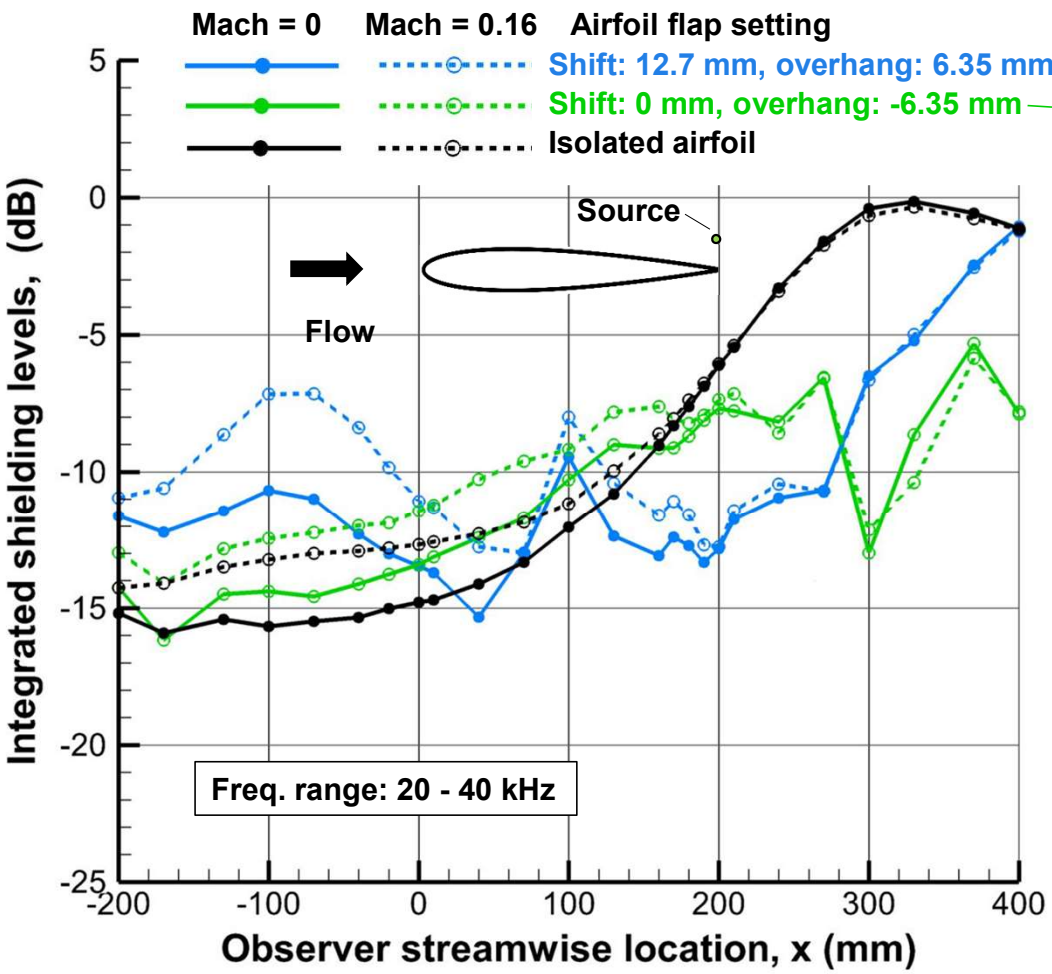
- Reducing the shift:
  - ➢ Increased shielding below the main airfoil
- Eliminating the overhang:
  - ➢ Reverts to an increase in noise below the main airfoil
- Shifted flap configurations:
  - ➢ Provide added shielding benefit downstream of the main airfoil
  - ➢ Performed better than the non-shifted (gapped) flap configurations
- Flap with smallest shift and positive overhang performed best when considering the full frequency range

Effects of Sound Source Location



- Similar shielding effects on the sound field for all three source locations with installation of the flap
- Effects, however, much more pronounced with the source located closest to the airfoil trailing edge
  - Effects downstream of main airfoil: flap blocks direct path between sound source and microphones, hence large decrease in noise
  - Effects upstream of main airfoil: more pronounced increase in noise with addition of a flap may be due to strengthened contribution of the noise scattered by the flap edges

Effect of Freestream Flow



- The presence of flow was found to significantly affect shielding levels in the higher frequency range
  - Notable decrease in shielding below and upstream of the main airfoil
- Change in shielding levels likely associated with sound refraction from the mean flow velocity gradient near the model surfaces
  - More pronounced effects observed for the flapped model configurations

Summary & Conclusions

- A noise scattering test was performed to
  - Expand the noise scattering database available for validation of prediction tools
  - Capture the effects of a small flap on the shielding of a sound source by a NACA 0012 airfoil

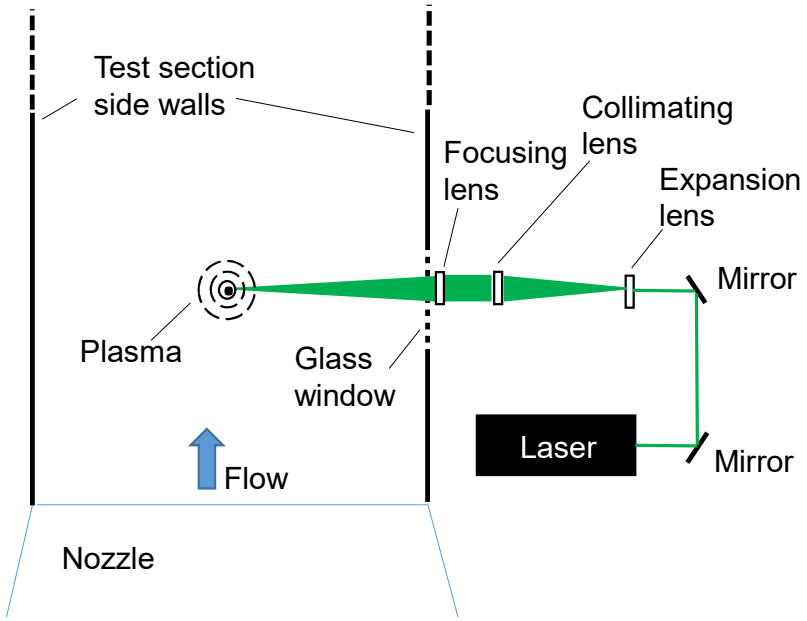
- Shielding Flap concept exploration:
  - Shifted flap configurations with or without an overhang led to better shielding performance than the gapped flap configurations
  - Best shielding performance achieved with the smallest shift and a positive overhang
  - For both the gapped and shifted configurations tested, the plate provided higher shielding levels than the airfoil (difference in edge geometry)
  - Effects on shielding (increase or decrease) much more pronounced with sound source closest to main airfoil trailing edge
  - Presence of flow significantly affects shielding levels in the higher frequency range with decrease in shielding below and upstream of the main airfoil

Thank you for your attention!

Back up slides

Laser-Induced Sound Source

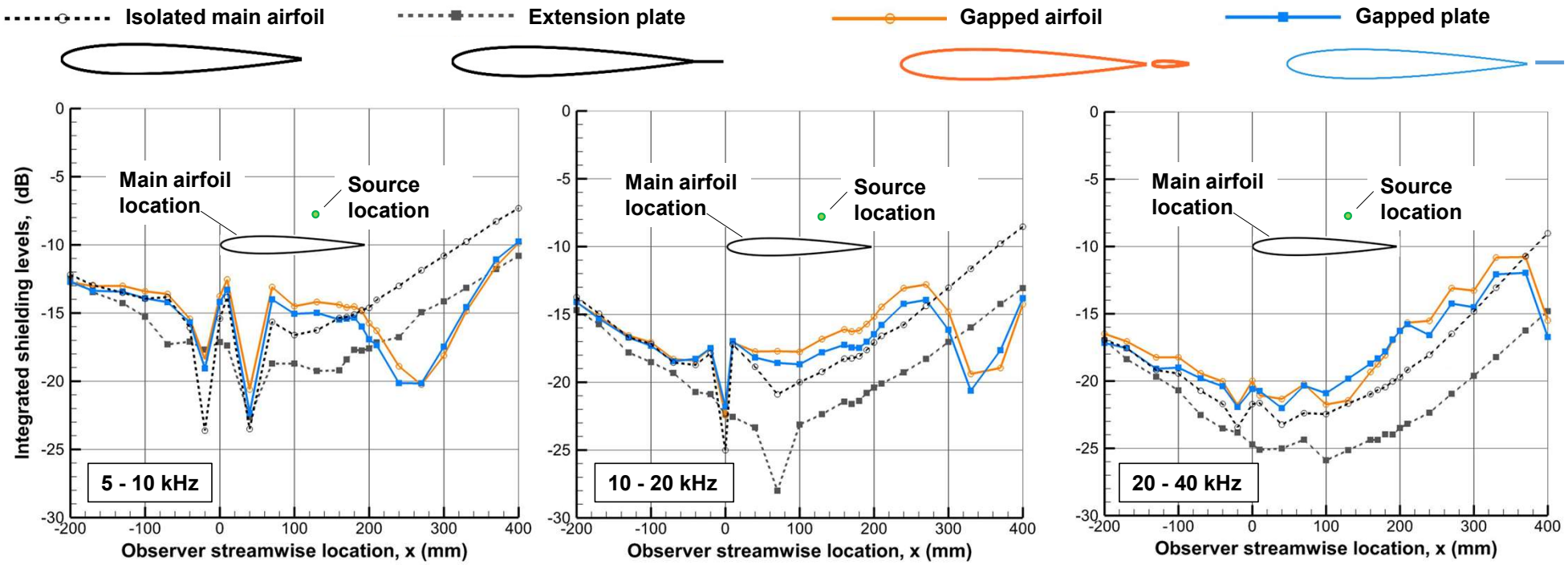
- Localized plasma generated by a high energy, focusing, laser beam.
- Plasma rapidly expands to generate a nearly omnidirectional pressure wave, which propagates as an isentropic acoustic wave in the far field.



Laser and optical lens set-up

- Laser system:
  - Nd:YAG, Gemini PIV
  - energy pulse: ~120 mJ
  - wavelength: 532 nm
  - pulse width: 3-5 ns
- Lenses: 3” diameter, achromatic
- Plasma produced in the test section midspan plane

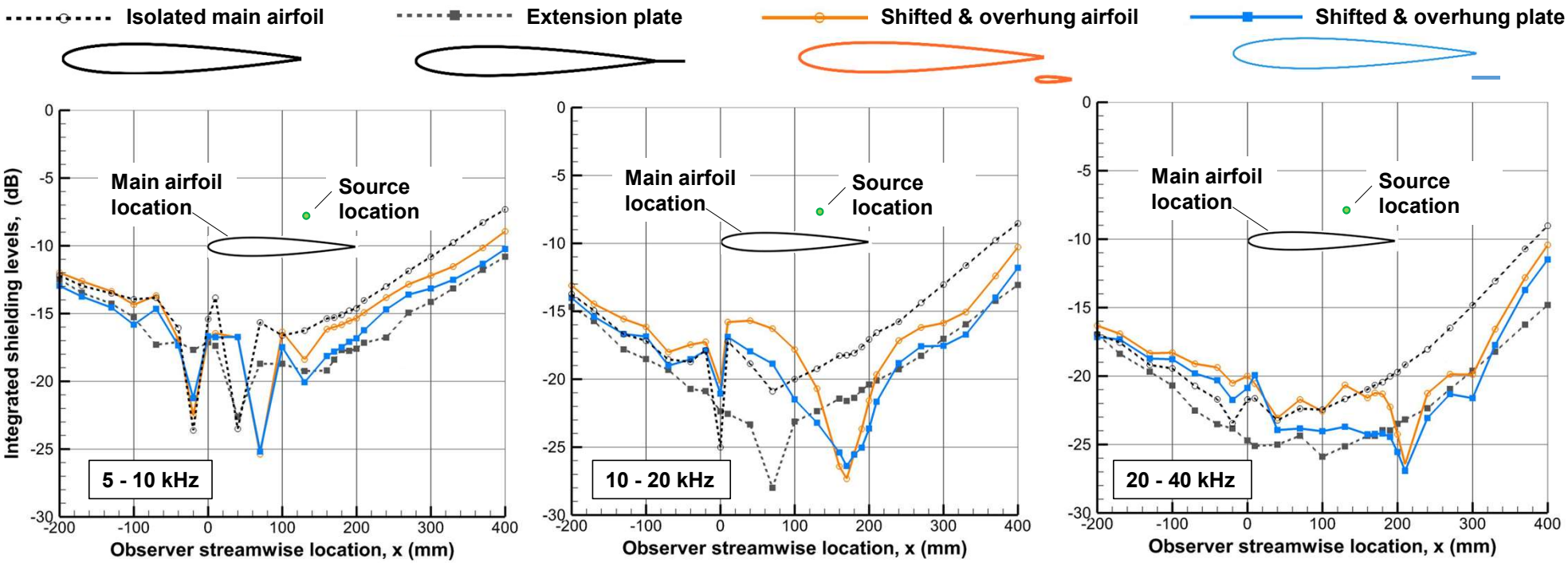
Effects of Shielding Flap Configuration - Gapped Flap



Gapped flap configuration:

- Provides increased shielding downstream of main airfoil
- Shielding levels can exceed those achieved in the absence of a gap (extension plate configuration)

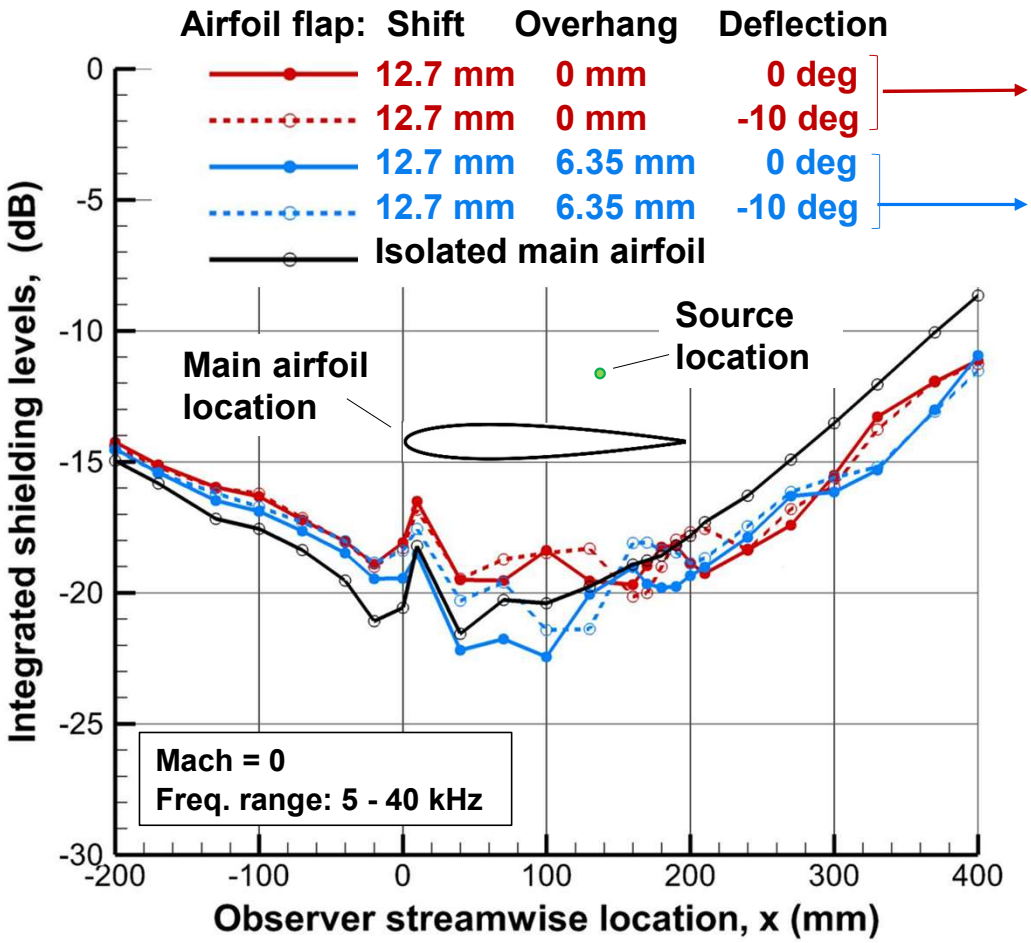
Shifted Flap with Positive Overhang

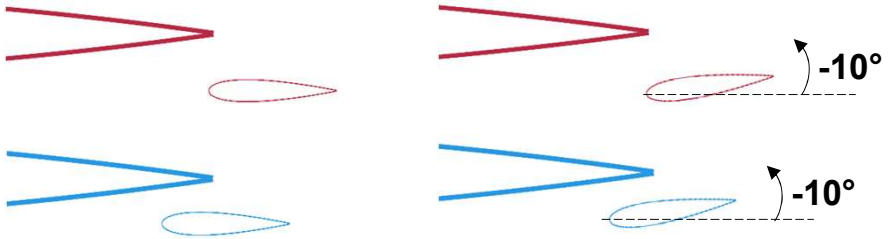


Shifted and overhung flap configuration:

- Provides increased shielding downstream of main airfoil mid-chord
- Shielding levels can exceed those achieved in the absence of a gap (extension plate configuration)

Effects of Airfoil Flap Deflection





Flap deflection:

- Minimal effects on shielding (no flow case)
- Slight decrease in shielding below the main airfoil for the flap with overhang
  - ➢ flap surfaces redirecting more of the main airfoil trailing edge scattering through the gap