



Jet Noise Flyover and Scale Model Tests

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Introduction



Motivation/Objective

- Previous system studies for future supersonic aircraft in support of ICAO efforts indicated jet noise was a dominant noise source
- Uncertainty in jet-noise predictions was unacceptably high
- Improved noise predictions for aircraft in flight are necessary – predictive tools are based on scale-model data or models developed from scale-model data
- Current study is a new flight test with comparisons to scale model data and SAE ARP876

Jets of Interest

- Single-stream jets
- High subsonic to low supersonic speeds



A Little History



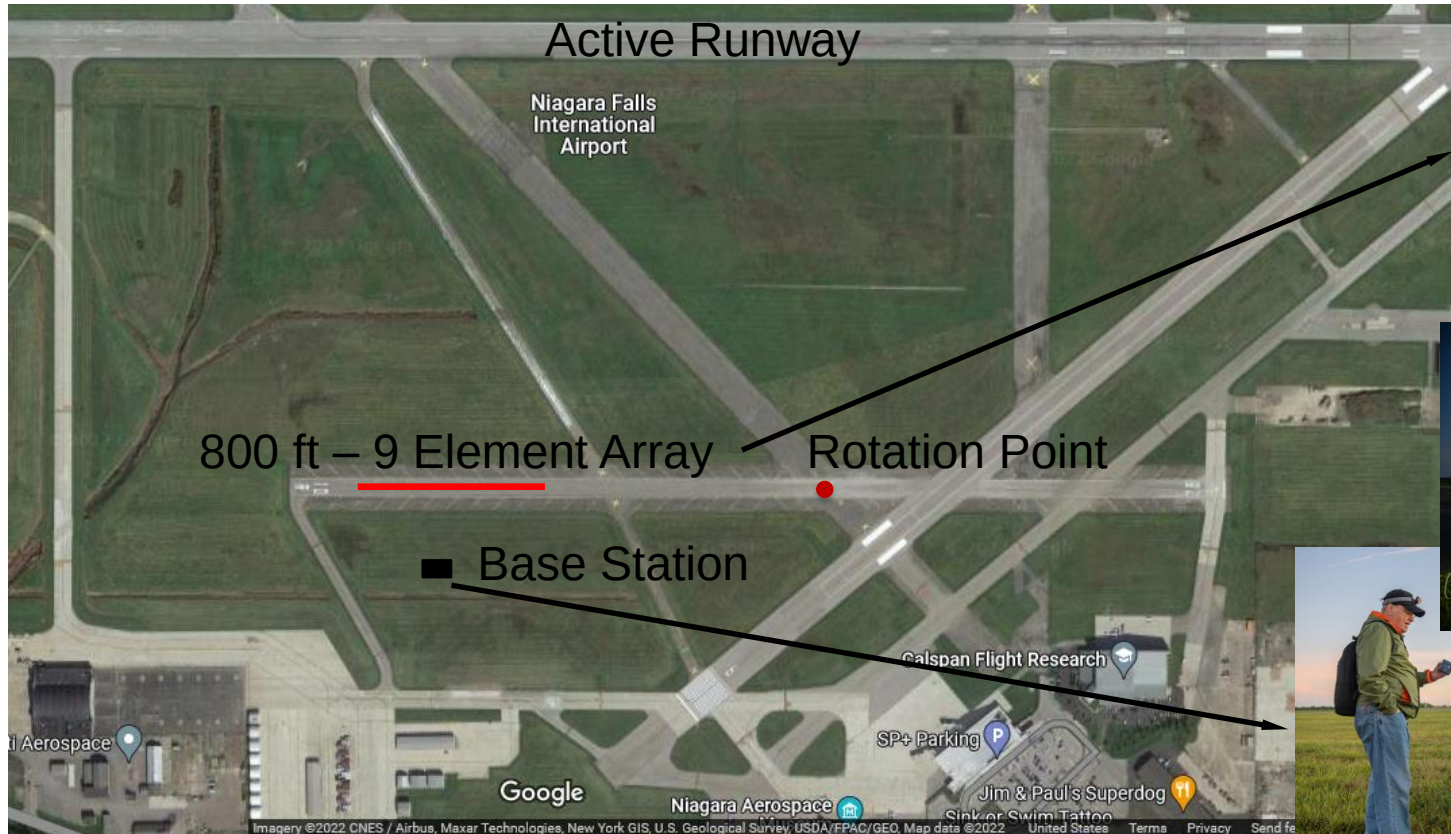
- First NASA Learjet 25 acoustic flight test conducted in 2001
 - Intent was to determine efficacy of chevrons for noise reduction
 - Learjet 25 used as it has a jet-noise dominated turbojet engine
 - Aircraft executed level flyovers at 500 ft
 - Aircraft was not instrumented to collect engine and flight data
 - GPS system was not functioning during test (okay for purpose of flight)
- First Learjet scale-model test conducted in 2018 (AAPL/NATR)
 - Two nozzles
 - 3.21 scale factor model of the CJ610-6 nozzle for flight test comparisons
 - Conical single stream nozzle for model development
 - Nozzles produced similar spectra
 - Jet conditions from flight test were uncertain





Recent Flight Test (September 2022)

Niagara Falls International Airport

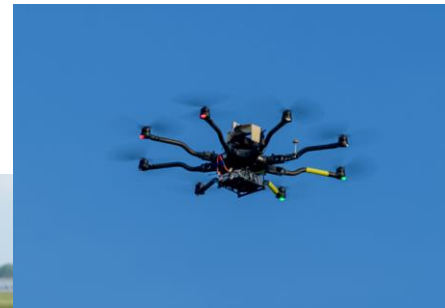


Instrumentation



- Aircraft owned and operated by Calspan Corp. under NASA contract
- Data acquired by Calspan Corp.
 - Engine Pressure Ratio (EPR), Exhaust Gas Temperature (EGT), and engine RPM recorded continuously, pitot tube pressures for air speed
- Data acquired by NASA
 - Aircraft position (and IMU output)
 - Acoustics from 9 element array
 - Wind speed from the LiDAR system
 - Temperature, pressure, and humidity as functions of altitude from NASA Langley drone

All data were acquired with GPS based timestamps



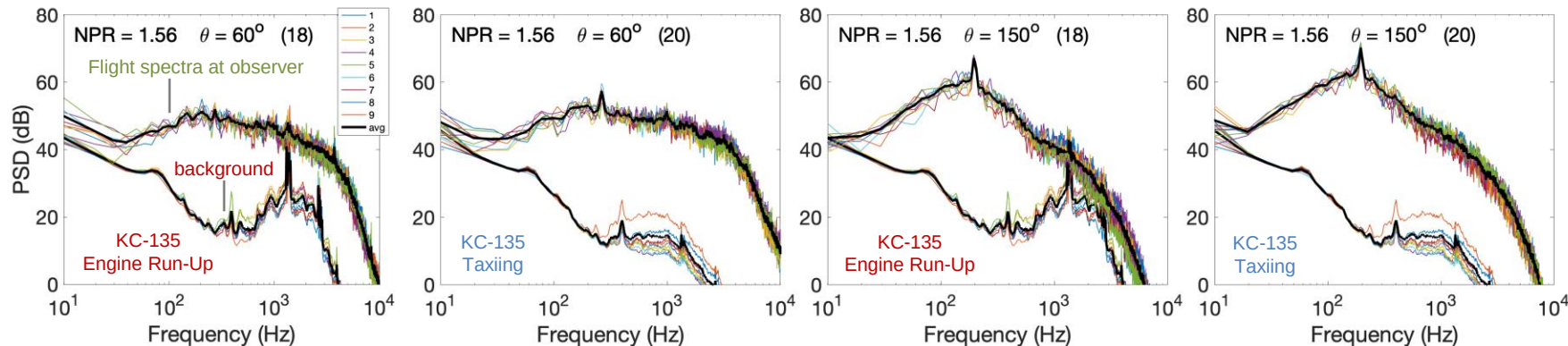
Flight Operations



- 4 sorties over 2 days, 17 – 20 flyovers per sortie
 - Total of 73 flyovers
- No flaps or landing gear
- One engine at idle
- Drone was deployment 3 times per sortie – beginning middle, and end
- Sortie time ~ 2 hours

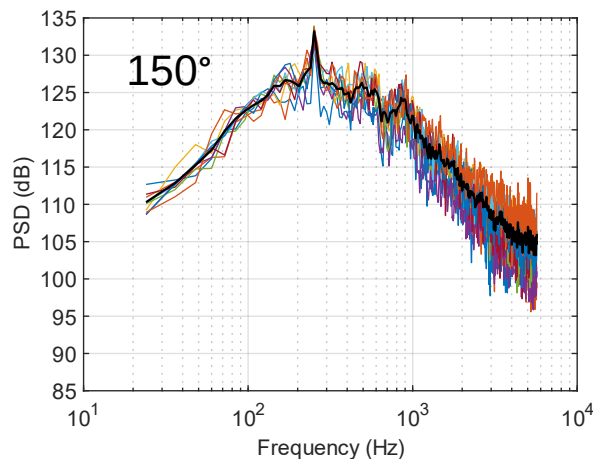
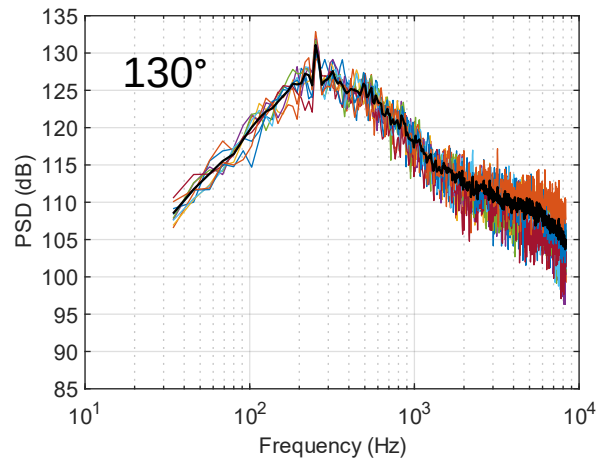
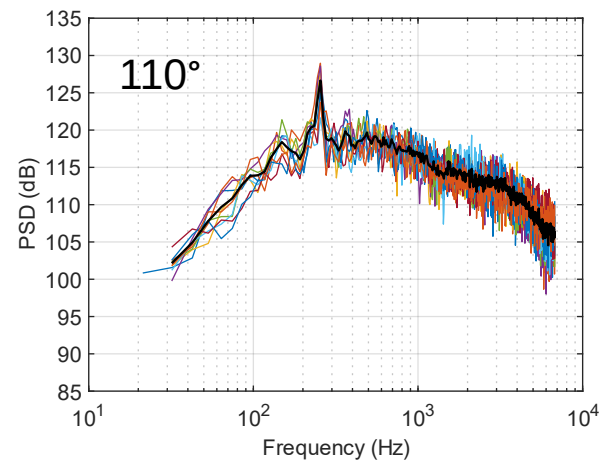
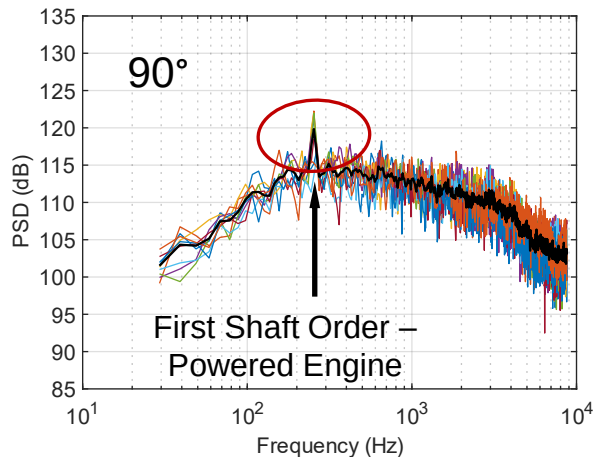
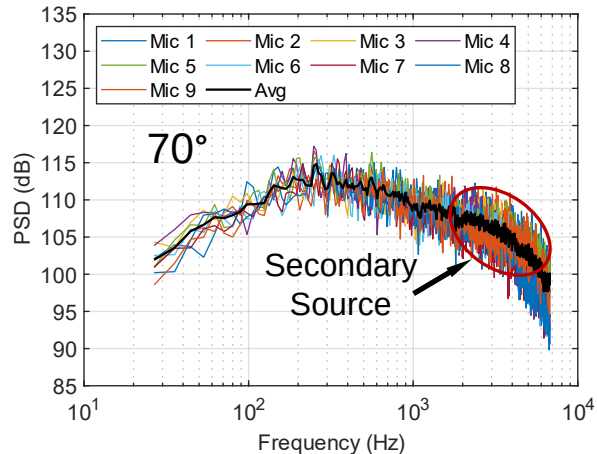


Background Measurements



- Procedure: first 30s of each flyover pass determines background levels
 - background noise spectrum unique to each flyover (can reject if S/N is bad)
 - overall data acquisition starts roughly 60s before relevant emission time interval
- Runs 18 & 20 – level flight – can average 0.512s flight-data over microphones
- $9 \times 9 = 81$ segments averaged for flight data (top curves)

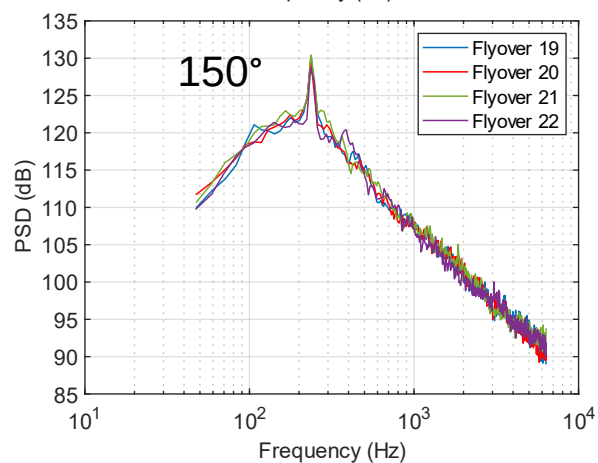
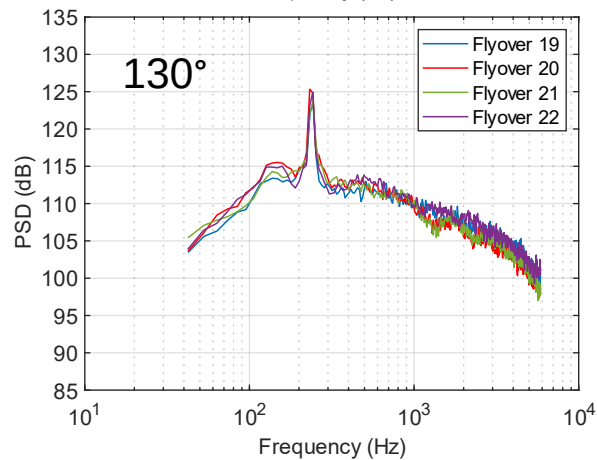
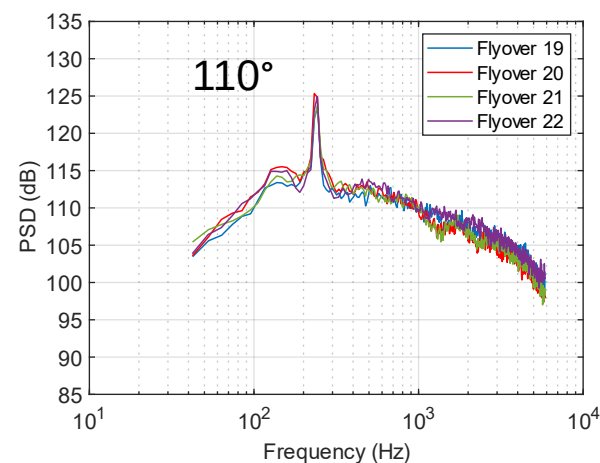
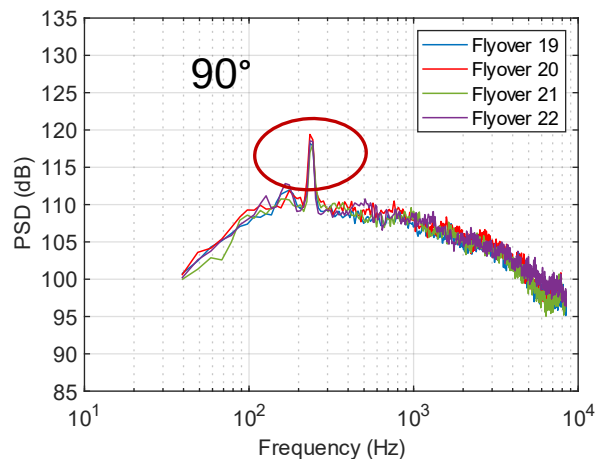
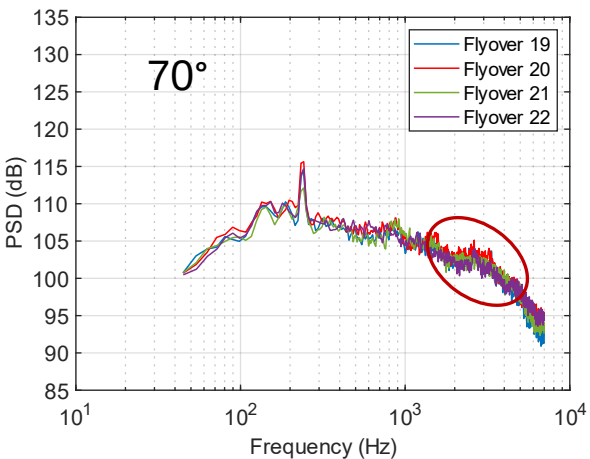
Results for 9 Microphones at NPR = 1.91



- 0.512 s used with 4096 FFT transform
- FFTs from 9 microphones at the same emission angle are averaged
- Average FFT uses 81 segments

Comparisons Between Multiple Flyovers

NPR = 1.56



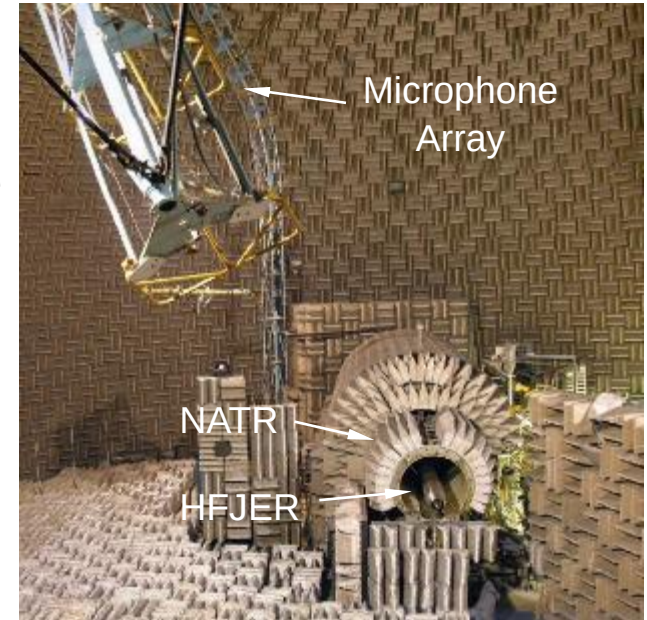


Scale Model Tests (September – October 2022)

Facility

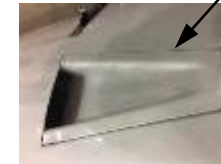


- Aero-Acoustics Propulsion Laboratory
 - 65 ft geodesic dome
 - Acoustic wedges on walls and floor
 - Far-field microphone array at ~ 45 ft from jet centerline
 - Houses the Nozzle Acoustic Test Rig (NATR)
- NATR
 - 53" simulated flight stream
 - Reaches Mach numbers up to 0.35
 - Houses the High Flow Jet Exit Rig (HFJER)
- HFJER
 - Three-stream jet engine simulator
 - Capable of producing temperatures and pressures of most commercial aircraft engines



Scale-Model Nozzles

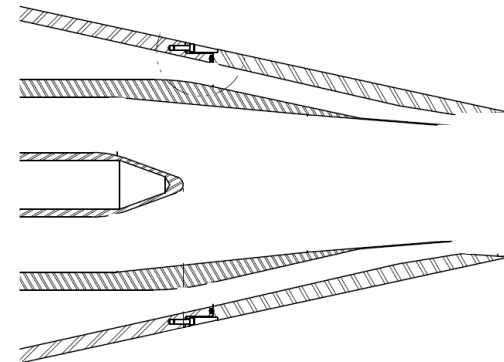
- CJ610 Engine
 - Secondary non-powered stream used to exhaust cooling air
 - Secondary nozzle not circular
- Scale-models
 - Lear model
 - 3.21 physical scale factor
 - Duplicated inner nozzle contours
 - Secondary stream geometry captured
 - Nozzle trailing edges captured
 - Flow through secondary nozzle expected to be low
 - Previous acoustic tests indicated no azimuthal angle dependence
 - SGL Model
 - Single-stream nozzle with contour identical to that used for the Lear model primary nozzle



Vents



Scoop

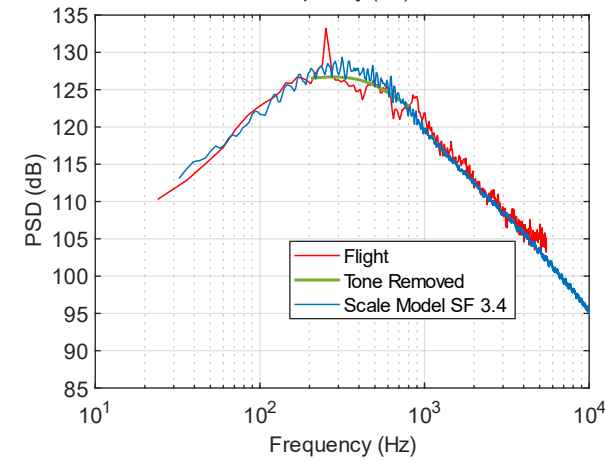
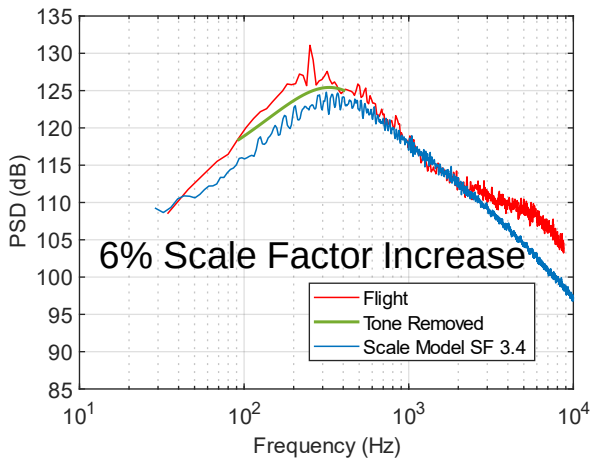
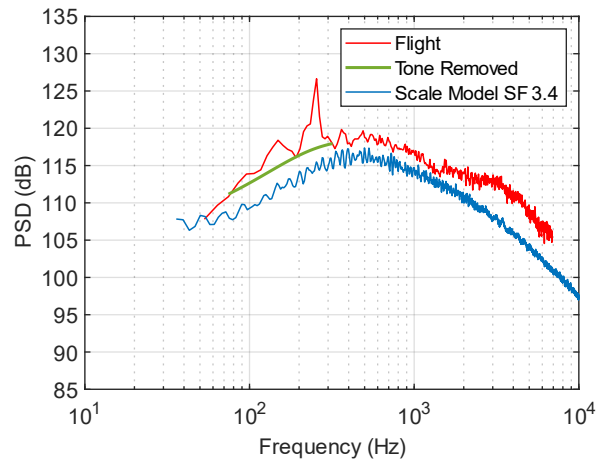
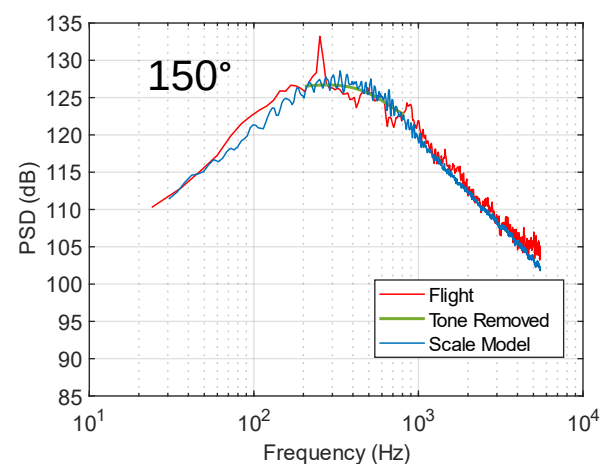
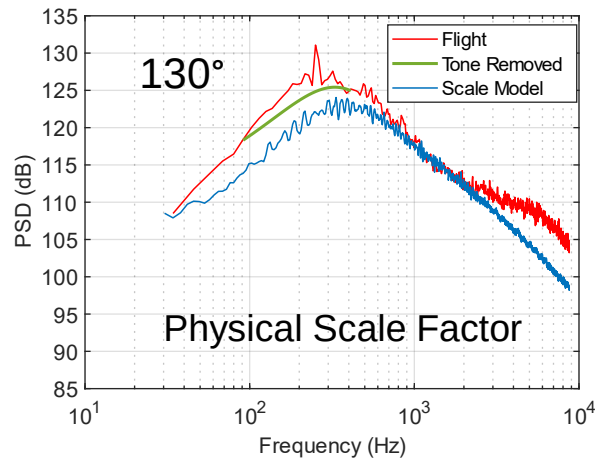
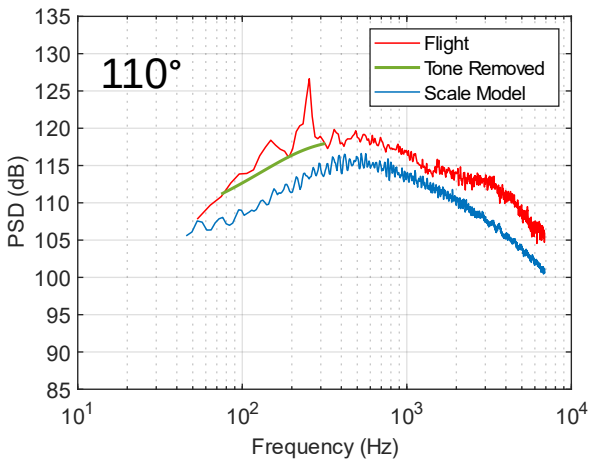




Comparisons

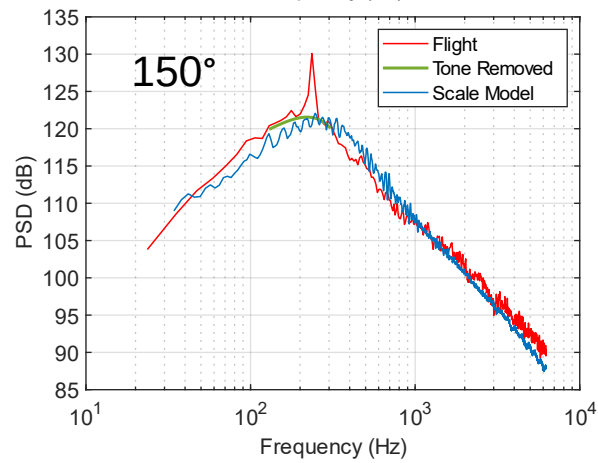
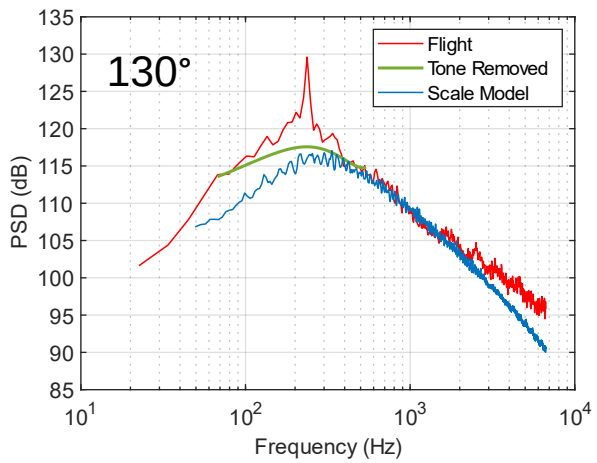
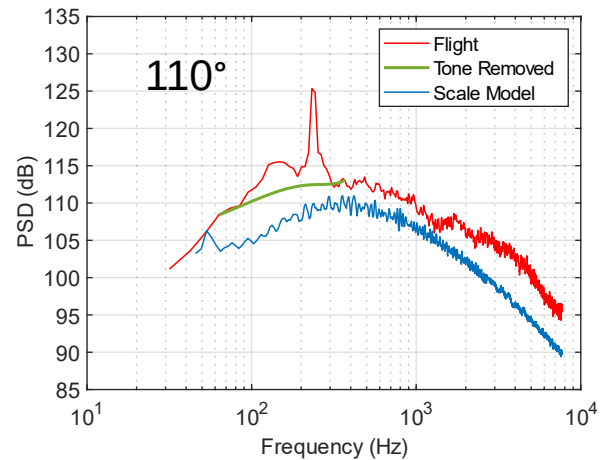
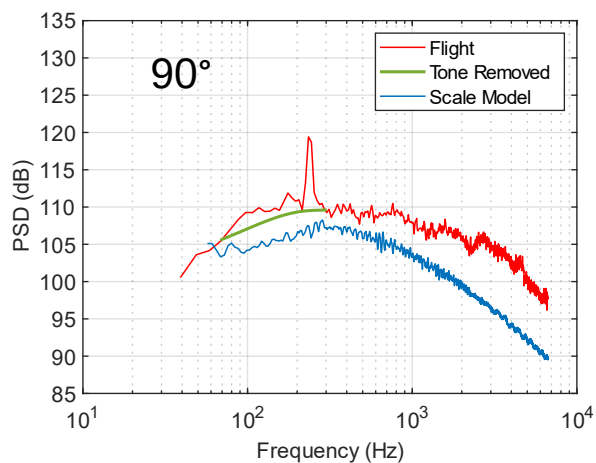
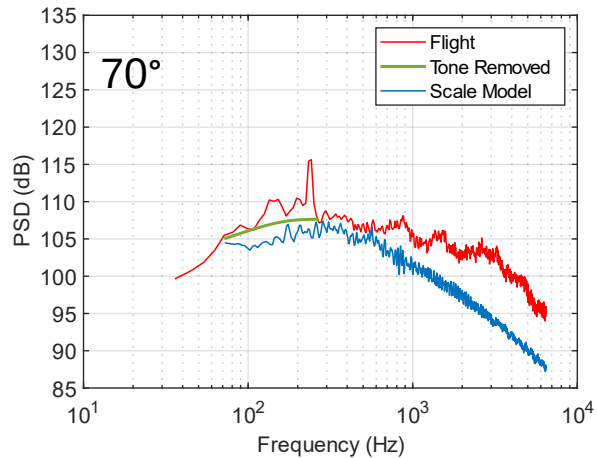
Comparisons Between Scale Model and Flight

NPR = 1.91



Comparisons Between Scale Model and Flight

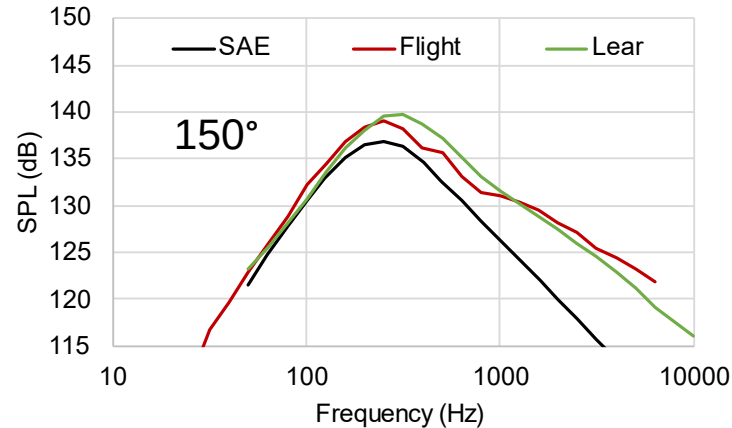
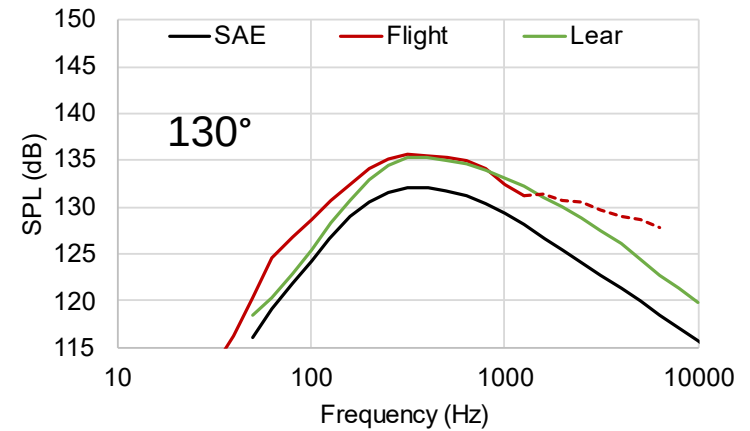
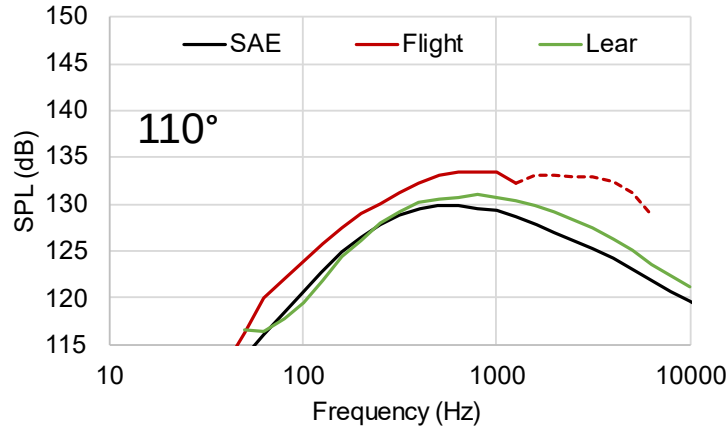
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6% Scale Factor Increase

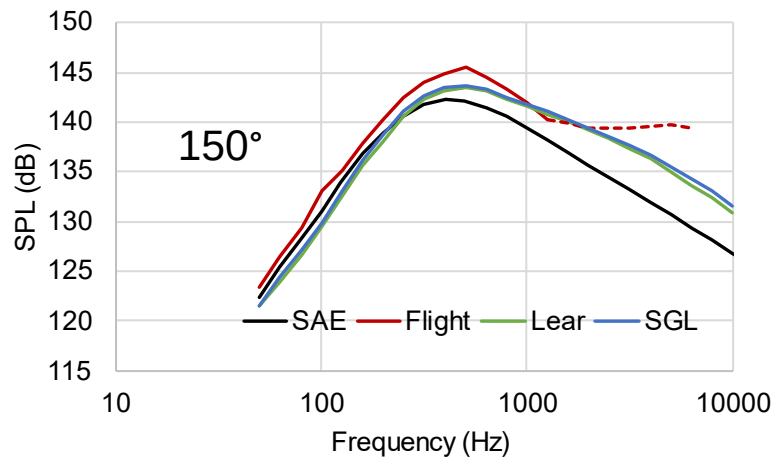
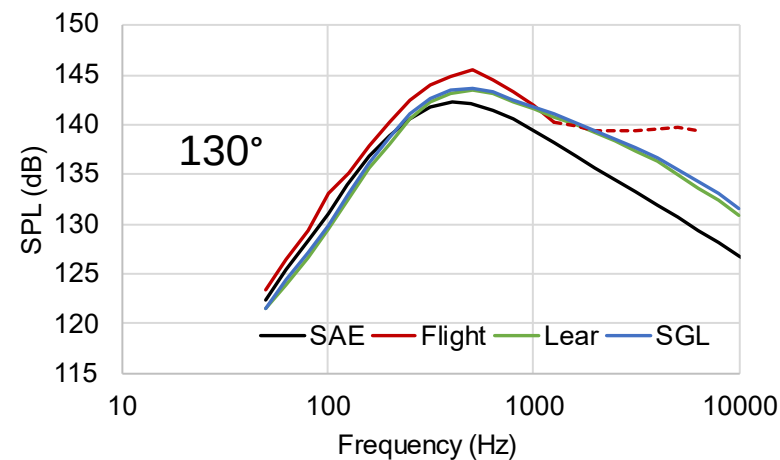
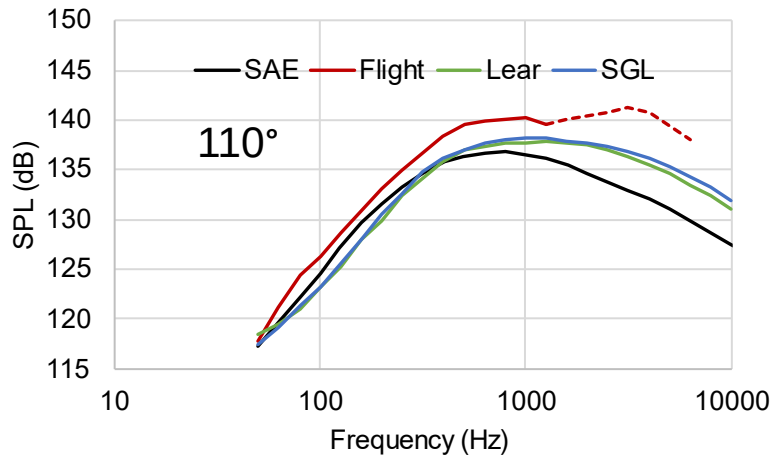
Comparisons with SAE Predictions

NPR = 1.91



Comparisons with SAE Predictions

NPR = 1.56



6% Scale Factor Increase

Conclusions



- Good frequency alignment between the flight and scale model data is achieved with a 6% increase of the physical scale factor.
- With increased scale factor, flight and scale-model peak levels were within ~ 1 dB
- Levels for flight data were above those for the scale-model data for $90^\circ \leq \theta \leq 110^\circ$
- The SAE ARP model did not match the flight or scale model data at most emission angles



