A Summary of
The Lateral Cutoff Analysis and Results from NASA's Farfield Investigation of No-boom Thresholds

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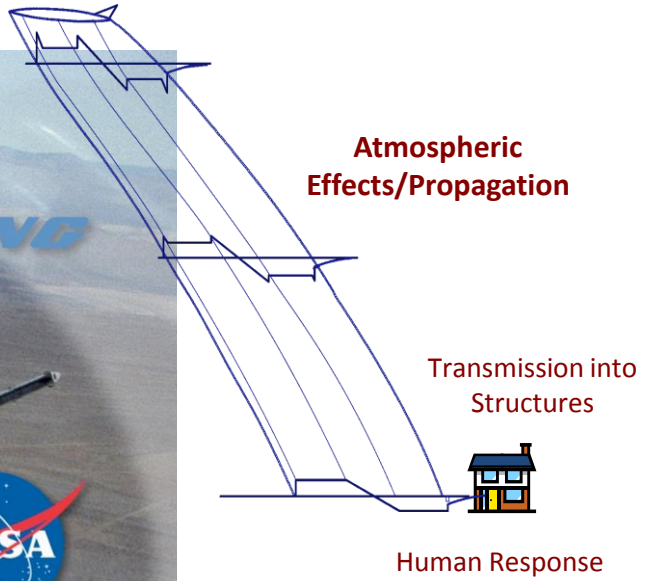
FARFIELD INVESTIGATION OF NO-BOOM THRESHOLDS (FAINT)



Aeronautics Flight Research

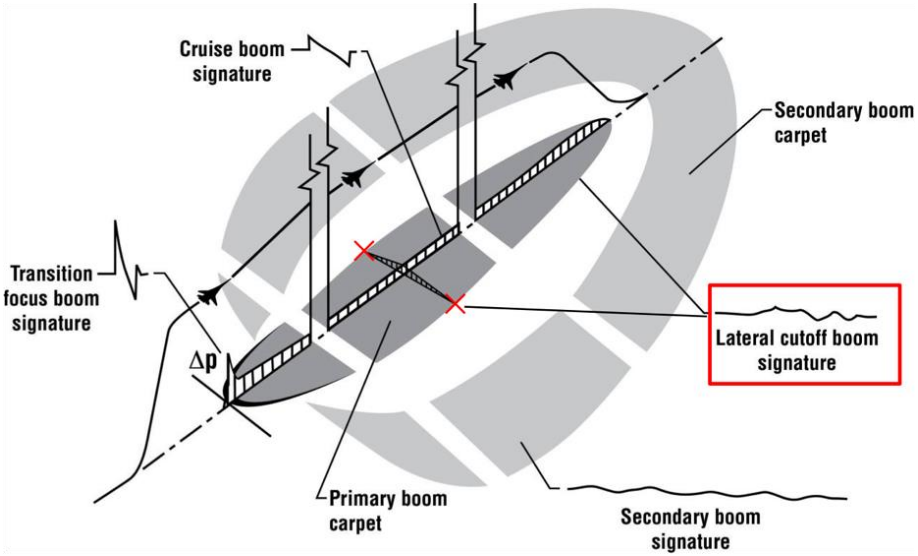
- Over 60 years of flight research (NACA Muroc Flight Test Unit)
- Edwards Air Force Base (EAFB)
- Remote Location
- 350 Testable Days Per Year
- Extensive Range Airspace
- Supersonic Corridor

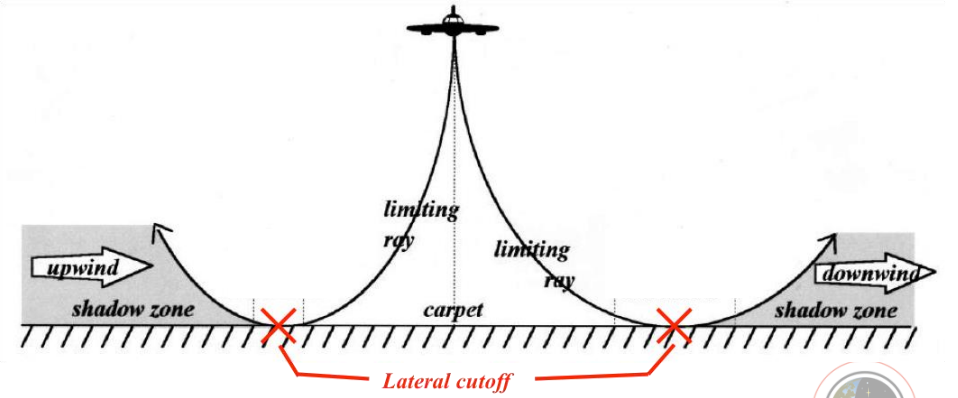
TOPICS OF DISCUSSION

- Motivation & Objectives
- Test Set-up & Execution
- Analysis
  - Metrics for lateral cutoff acoustics
  - “Acoustic lateral cutoff”
  - Transition region & shadow zone measurements and analysis
  - Numerical prediction comparisons
- Summary & Considerations
- Future Work

Motivation & Background

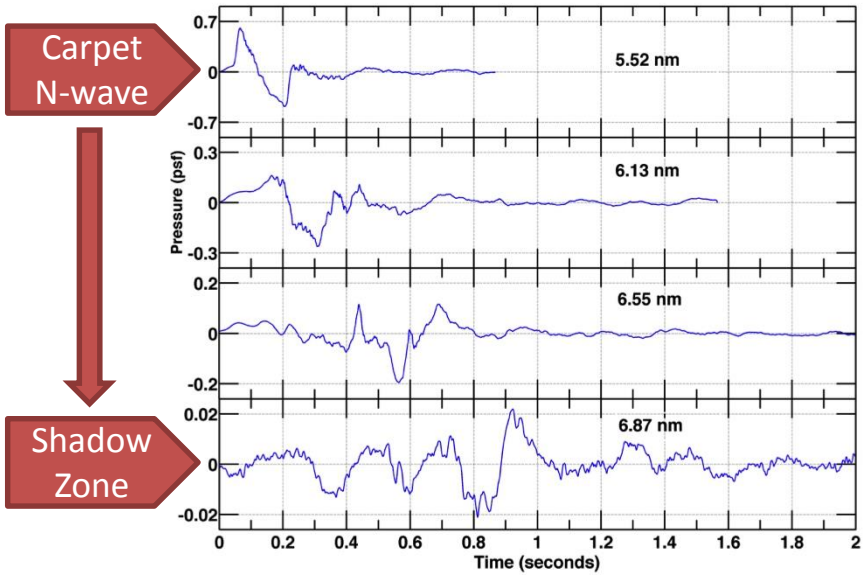
- **Need: <u>Understanding of entire sonic boom envelope</u>**
- Limitations to common numerical predictions:
  - Based on geometrical acoustics
  - Complex/unreliable solutions at carpet edge
  - No solutions in shadow zones

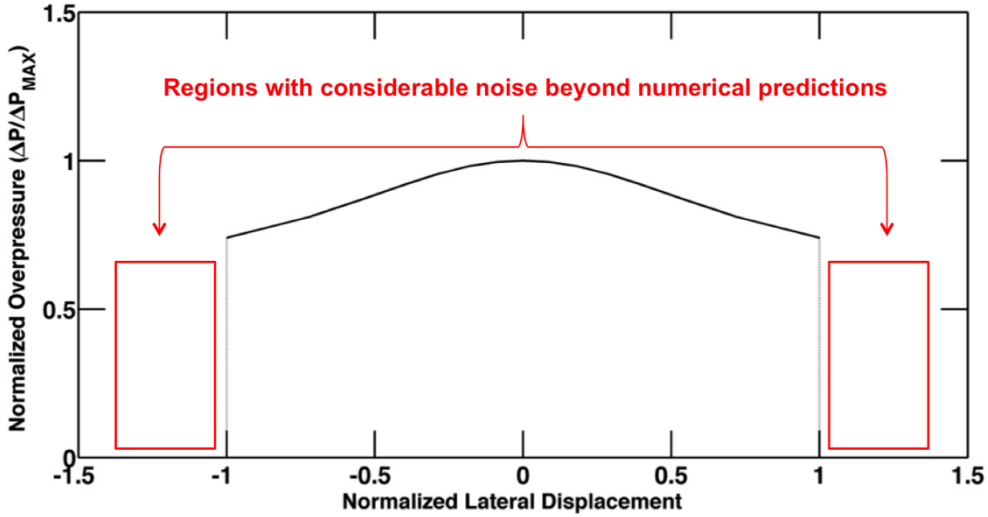




PRIMARY OBJECTIVES

- Study lateral evolution of pressure signatures
  - Finely spaced measurements
  - Attenuation and increase in signature length
  - Evanescent decay in shadow zone

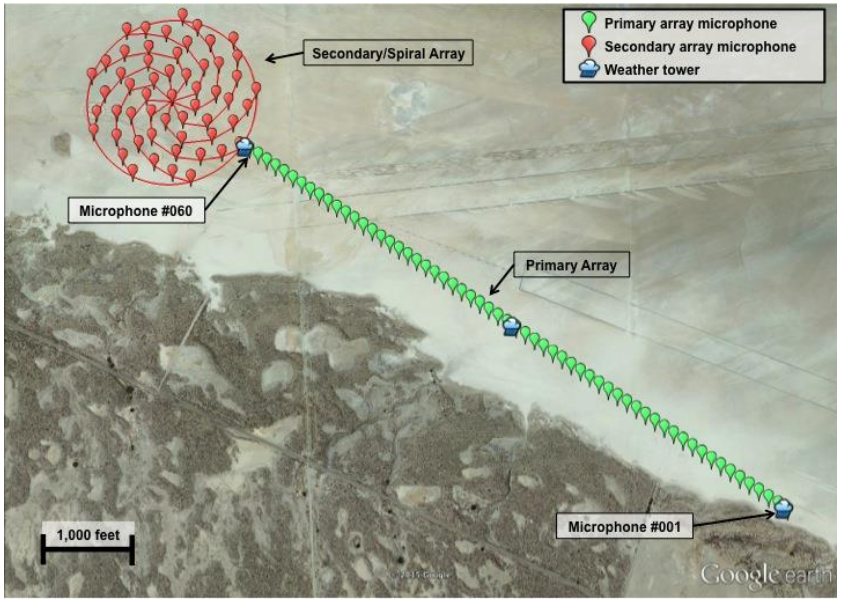


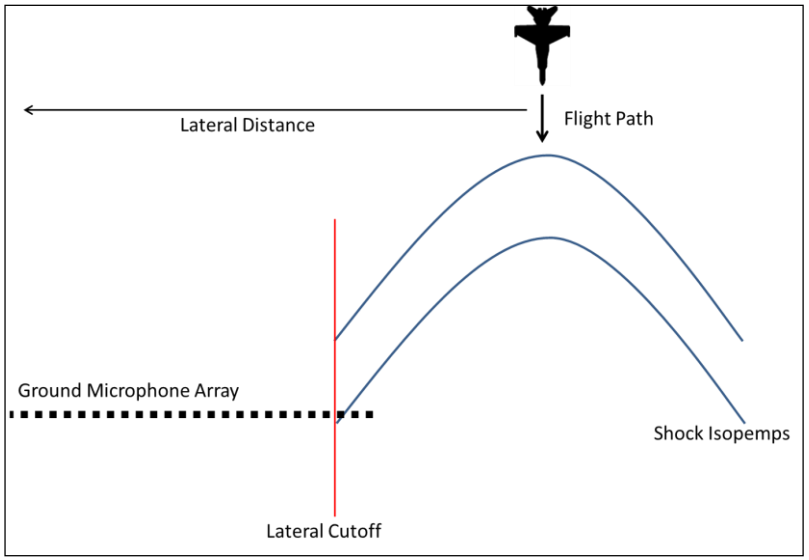


- Analyze noise beyond common numerical predictions
- Define audible extent of of sonic boom noise region
- Build database

Test Setup and Execution

- Flight Conditions
  - F-18B airplane
  - Mach 1.22 – 1.29 and 35000 – 41000 ft *(10.7 – 12.5 km)* pressure altitude
- 7375 ft *(2.2 km)*, 125 ft *(38 m)* spaced linear microphone array at 2300 ft *(0.7 km)* MSL
  - 60 microphones
- Initial PCBoom[1] used for flight planning

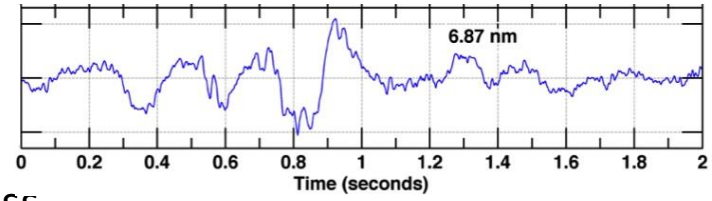


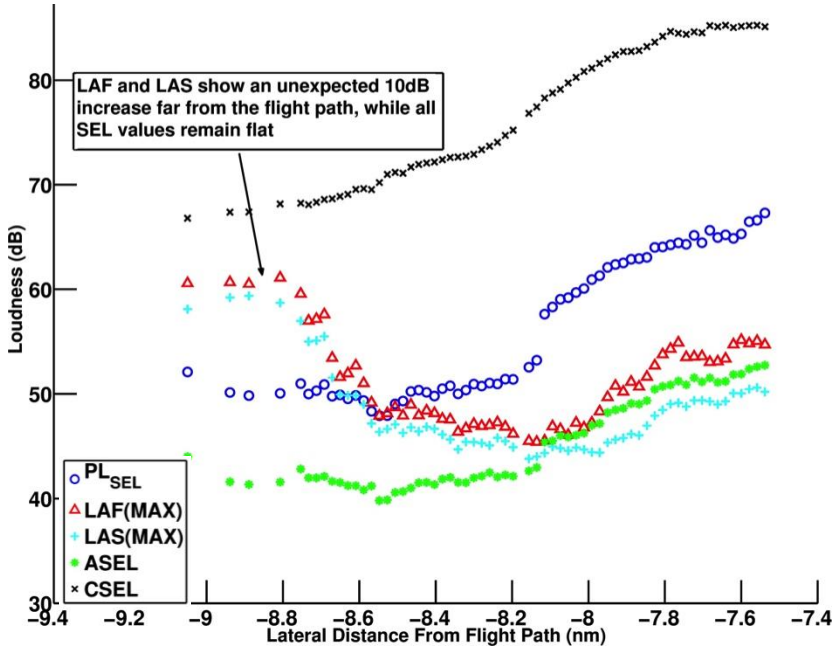


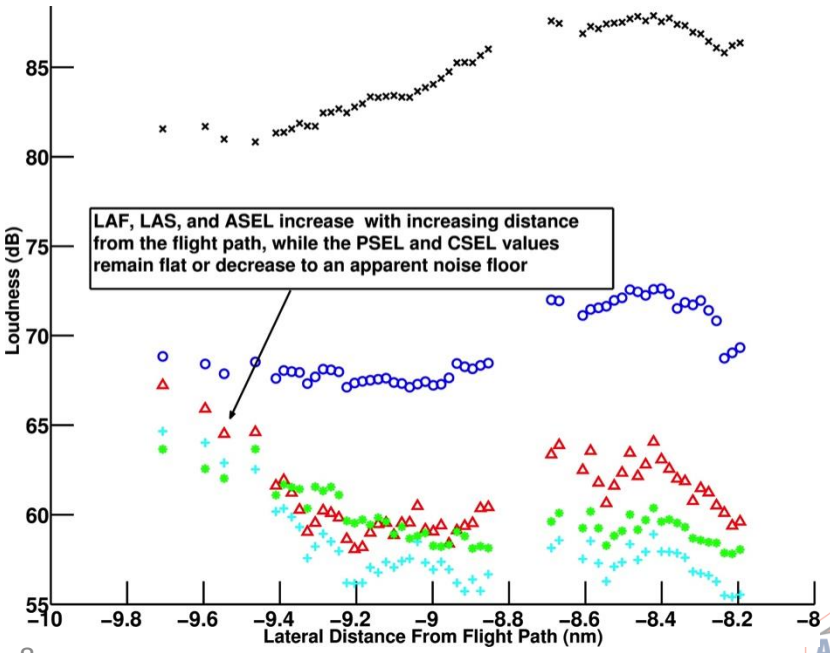
[1] PCBoom was developed by Wyle (El Segundo, California)

METRICS FOR LATERAL CUTOFF ACOUSTICS

- Overpressure alone not sufficient for sonic boom analysis
- Familiar metrics less applicable for waveforms near lateral cutoff due to variable duration and impulsiveness
- **Perceived Sound Exposure Level (PL_{SEL})**
  - 99% energy windowing
  - Sound Exposure Level (SEL) 1-second normalized integration (ISO 1996)
  - Stevens' Mark VII Perceived Level weighting

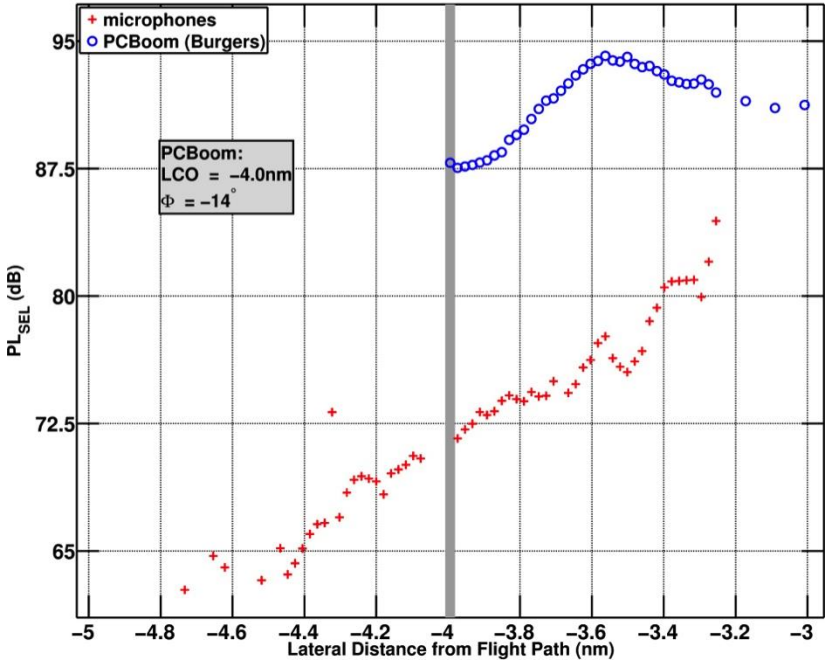


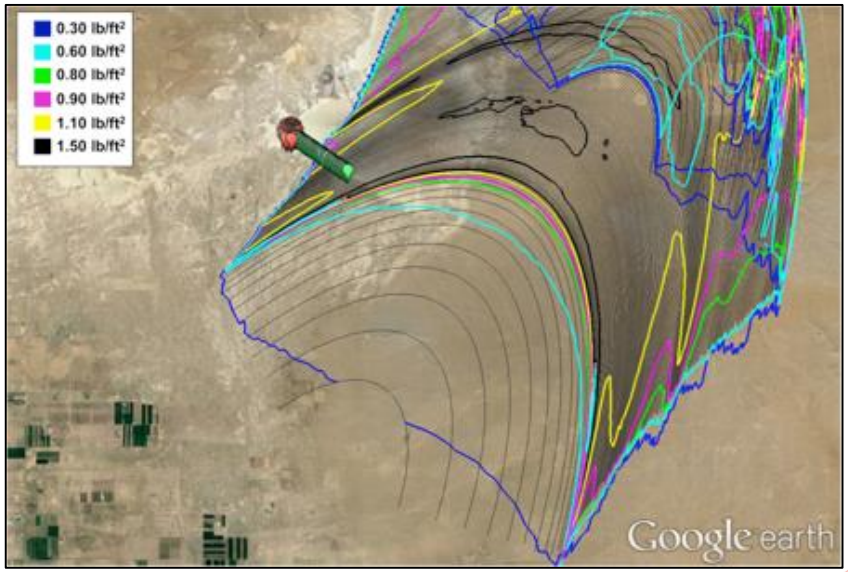




Measured Data vs. Numerical Predictions

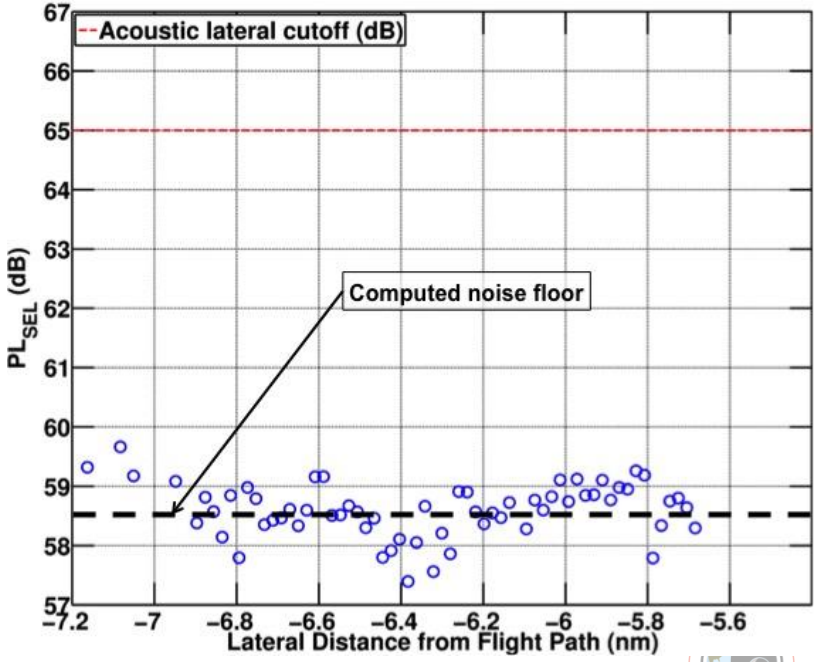
- Five cases where PCBoom predicts lateral cutoff on the microphone array, most likely due to:
  - Inability to model shadow zone
  - In-flight adjustments to measure evanescent waves
  - Expected reduction in accuracy beyond 70% of predicted carpet width
- Considerable noise 1 – 2 nm *(1.9 – 3.7 km)* beyond numerical predictions
- Predicted PL_{SEL} typically higher than measured (4 out of 5 cases)





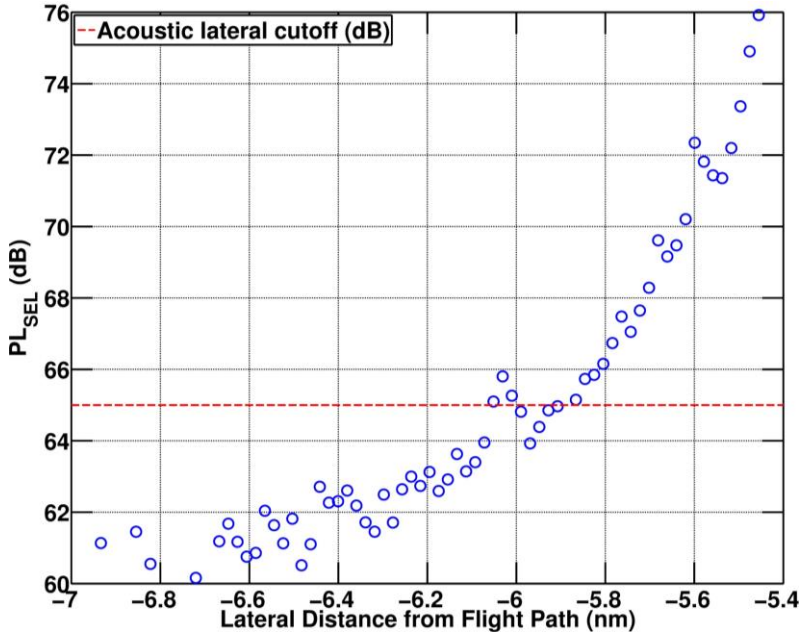
"Acoustic Lateral Cutoff"

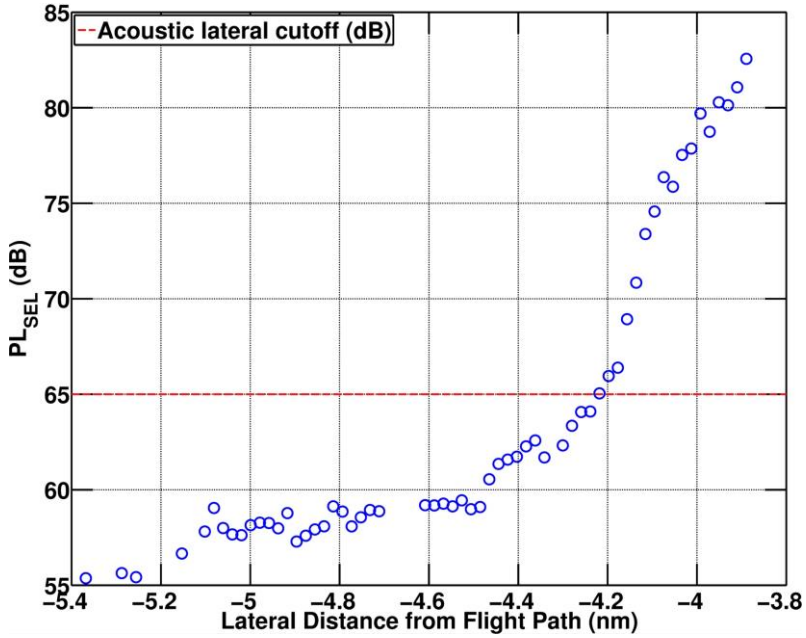
- Lateral cutoff definition: The lateral extent of geometrical acoustics, where ray tracing becomes tangent to the ground
- "Acoustic lateral cutoff" definition: The lateral extent of *considerable* sonic boom noise.
  - Ambient noise floor of 58.6 dB PL_{SEL}
  - At four times the acoustic energy (+6 dB) of the ambient noise, sonic boom waveform characteristics are consistently discernable
  - **➔65 dB PL_{SEL}**



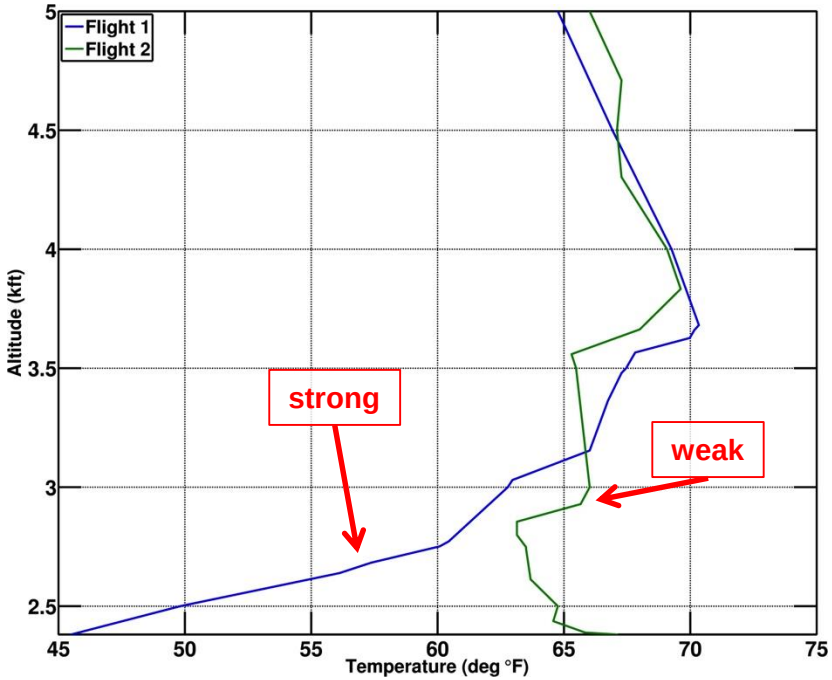
LATERAL GROUND MEASUREMENTS

- Considerable noise beyond predicted lateral cutoff
- Exponential-like decay
- Data supports 65 dB PL_{SEL} as an “acoustic lateral cutoff”





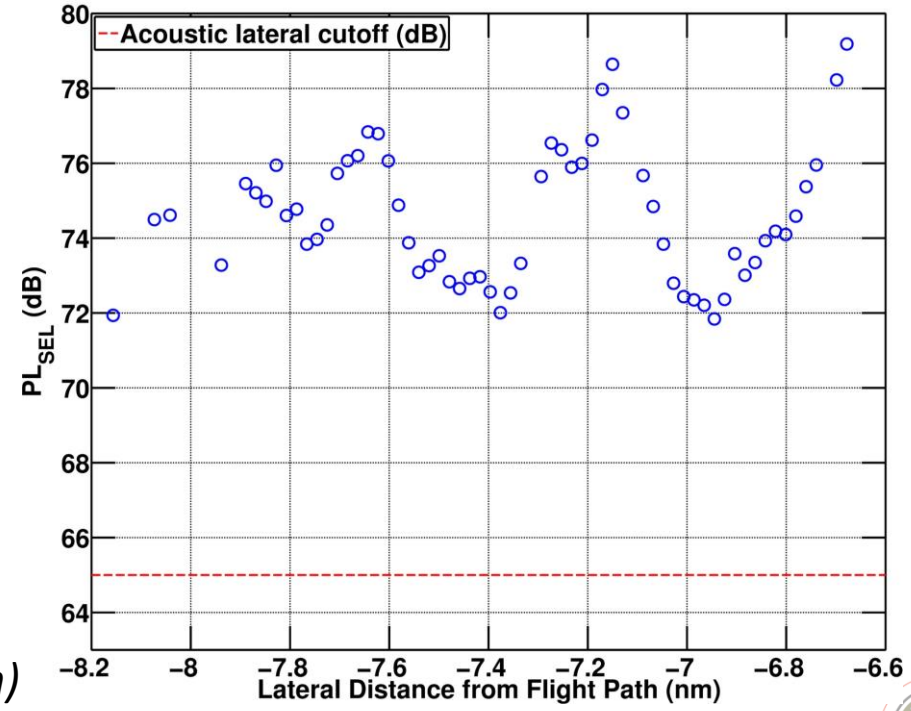
Temperature Inversion Effects



Temperature profile near the ground

- Higher noise levels
  - 80 dB at 6.6 nm *(12 km)*
- Indistinct decay
  - <60 dB expected at 8 nm *(15 km)*

- Measurements taken during strong temperature inversions showed higher variability
- Strong, distinct oscillations



Lateral measurements during strong temperature inversion

SUMMARY

- Conclusions
  - PL_{SEL} shown to be a more consistent and applicable metric for sonic boom measurements near lateral cutoff
  - Acoustic lateral cutoff defined as 65 dB PL_{SEL}
  - Temperature inversions may cause significantly higher noise levels than expected
  - Current definition of lateral cutoff does not adequately represent a sonic boom's noise region
    - Common sonic boom numerical predictions may not capture 2 nm of considerable noise
- Future considerations
  - Downwind lateral cutoff measurements
  - Vertical measurements near lateral cutoff
  - Varying strengths of temperature inversions

FUTURE WORK

- Database for research validation:
  - Analytical theories
    - ex. Coulouvrat: effects of crosswinds
  - Shadow zone computer codes
    - ex. Lossy Nonlinear Tricomi Equation (LNTE)
- Beamforming
- Mach cutoff analysis

QUESTIONS?