A SUMMARY OF
THE LATERAL CUTOFF ANALYSIS AND RESULTS FROM NASA’S
FARFIELD INVESTIGATION OF NO-BOOM THRESHOLDS

20th International Symposium on Nonlinear Acoustics

2nd International Sonic Boom Forum

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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:** Understanding of entire sonic boom envelope
- **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 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**

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\(^1\) PCBoom was developed by Wyle (El Segundo, California)
• 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\text{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 $58.6 \text{ dB } PL_{SEL}$
  - At four times the acoustic energy ($+6 \text{ dB}$) of the ambient noise, sonic boom waveform characteristics are consistently discernable.
  - $\geq 65 \text{ dB } PL_{SEL}$
• Considerable noise beyond predicted lateral cutoff
• Exponential-like decay
• Data supports 65 dB $PL_{SEL}$ as an “acoustic lateral cutoff”
Temperature Inversion Effects

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

Higher noise levels
- 80 dB at 6.6 nm (12 km)

Indistinct decay
- <60 dB expected at 8 nm (15 km)
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?