Identification of Noise Acceptance Onset for Noise Certification Standards of Supersonic Airplanes
Project 41

Lead investigator: Vic Sparrow, Penn State
Project manager: Sandy Liu, FAA

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ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

- Supersonic aircraft are coming:

Shaped, low-boom

NASA/Lockheed

Conventional, N-wave

Boom

Aerion

- FAA needs technical work done to complement in-house activities
- Contribute to CAEP Working Group 1 (Noise Technical) regarding en-route supersonics and sonic boom certification procedures

Objectives

- Help develop a certification standard for the en-route, supersonic portion of flight
  - Continuing
  - Approach is to continue supporting CAEP WG1 (Noise Technical)
- Understand and predict secondary sonic boom
  - New to Project 41
  - Approach is to explore existing NASA/FAA capabilities

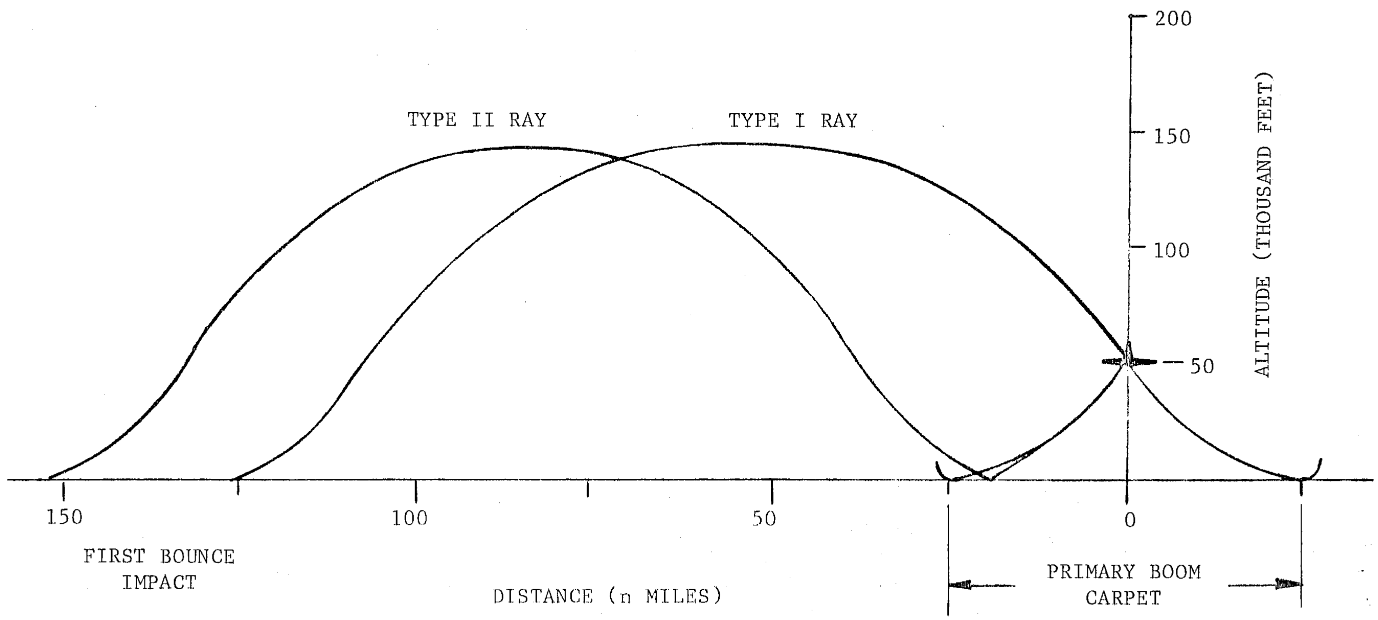


FIGURE 1. SCHEMATIC OF REFRACTIVE SONIC BOOM PROPAGATION
Source: BA 171, June 20, 1979, Ray Vector Azimuth Angle 278 Degrees

[Rickley & Pierce, 1980]

Schedule and Status

Milestone	Planned Date	Revised Date*
New project period begins	1 August 2018	1 April 2019
First technical report (advisory committee slides) will be submitted	15 Sept. 2018	Completed
Submission of journal article on averaging and cross-correlation approaches for deturbing	1 November 2018	1 July 2019
Aviation Noise Impacts White Paper available for CAEP meeting	1 November 2018	Completed
Initial tool available for predicting secondary sonic boom (matching Rickley and Pierce results)	1 February 2019	Very close to completion
CAEP Meeting, Montreal, Canada	1 February 2019	Completed
Advisory committee slides are due	1 April 2019	Completed
Presentation by graduate research assistant at ASA meeting (Louisville, KY)	May 2019	Completed
Prediction methodology/codes available for secondary sonic boom	15 July 2019	15 March 2020
Special report available to FAA on predicting secondary sonic booms (including predictions for Boom Supersonic envisioned aircraft)	15 July 2019	15 March 2020

*= 8 mo. delay of funds

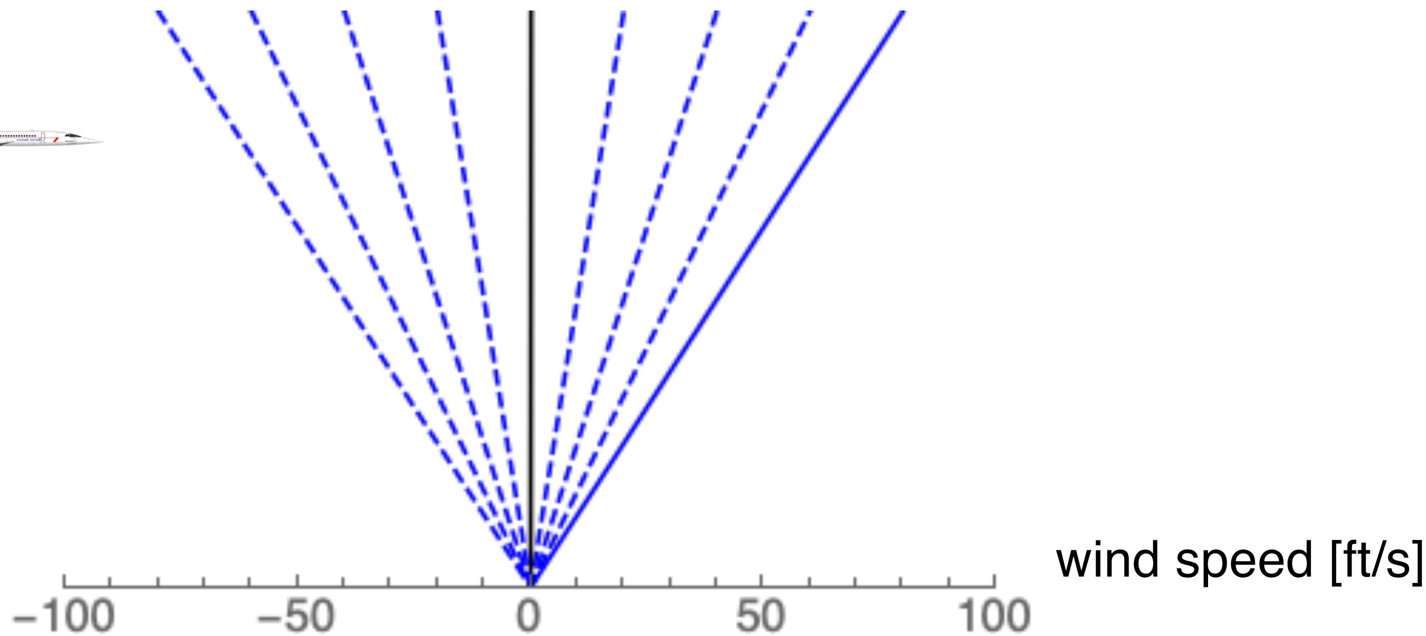
Certification Efforts: Wind effects

- In Spring and Summer 2019 Penn State began looking at "standard atmosphere" with pure headwinds and tailwinds
  - Long way to go, but will give you a glimpse of ongoing efforts

- Look at linear mean wind gradients, zero wind at ground:

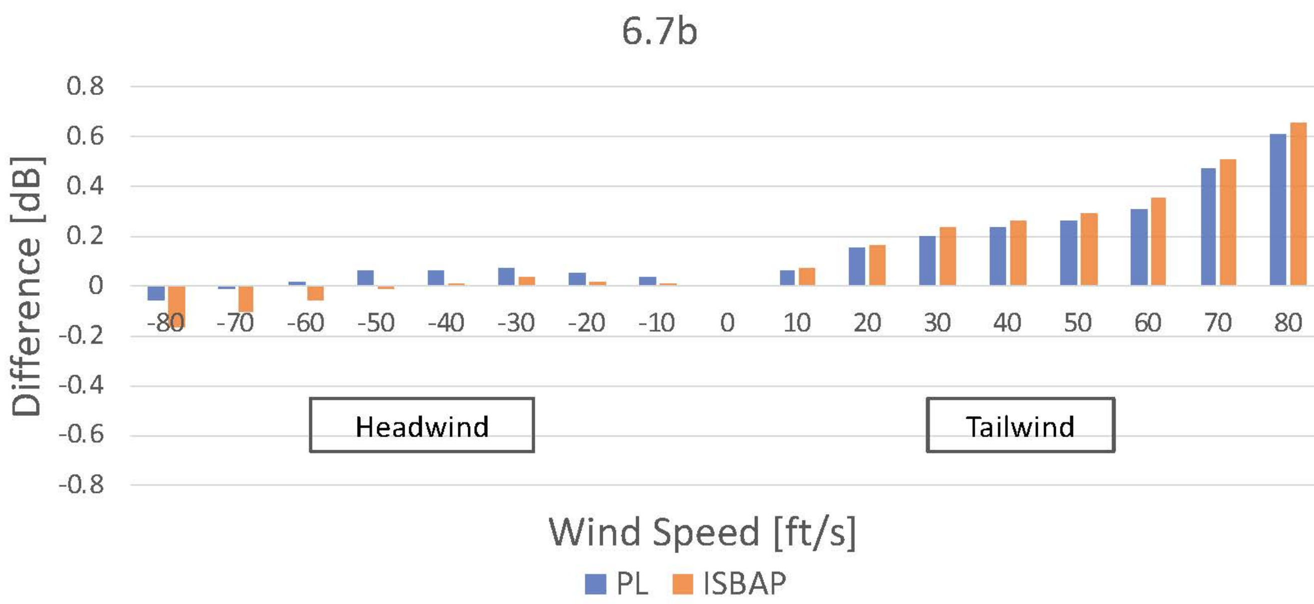
LM-1021
55 kft
M=1.6

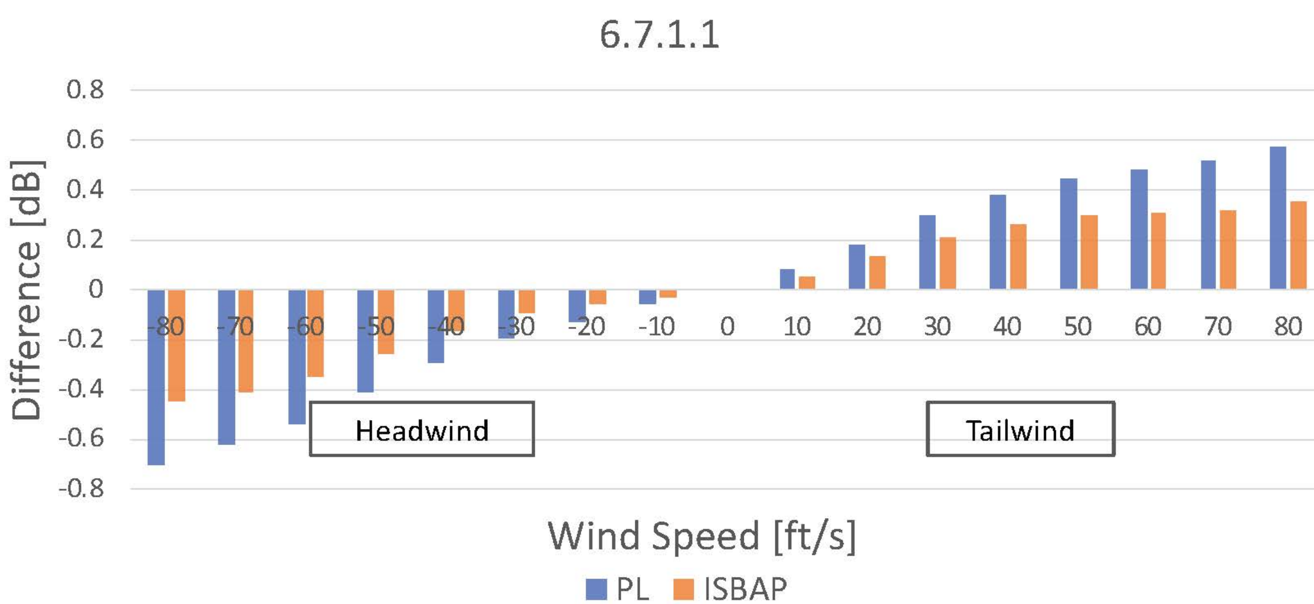
92.6 PLdB,
if no wind



Linear gradients; 2 versions of PCBoom

- Plots show dB differences in two key sonic boom metrics
- Top: PCBoom 6.7b (2016) shows odd asymmetry between headwind & tailwind
- Bottom: PCBoom 6.7.1.1 (2018/2019) shows more symmetry; has updated handling of wind (Lonzaga)





Effects of headwinds/tailwinds

- Preliminary results show
  - Both headwinds and tailwinds can affect received sonic boom levels on the ground plus or minus 0.7 dB for popular metrics
  - Results here are consistent with those in "Boom Book" of Maglieri, *et al.,* (pp. 25-26), but they only look at overpressure
  - These simplistic wind results strengthen case that atmospheric state is a key for putting bounds on conditions for boom certification testing
- Caveats: More work to do!!
  - Need to look at wider selection of winds including non-linear profiles, cross-winds, higher gust values, off-track, etc.
  - Need to compare with other published results.

Why interest in secondary booms?

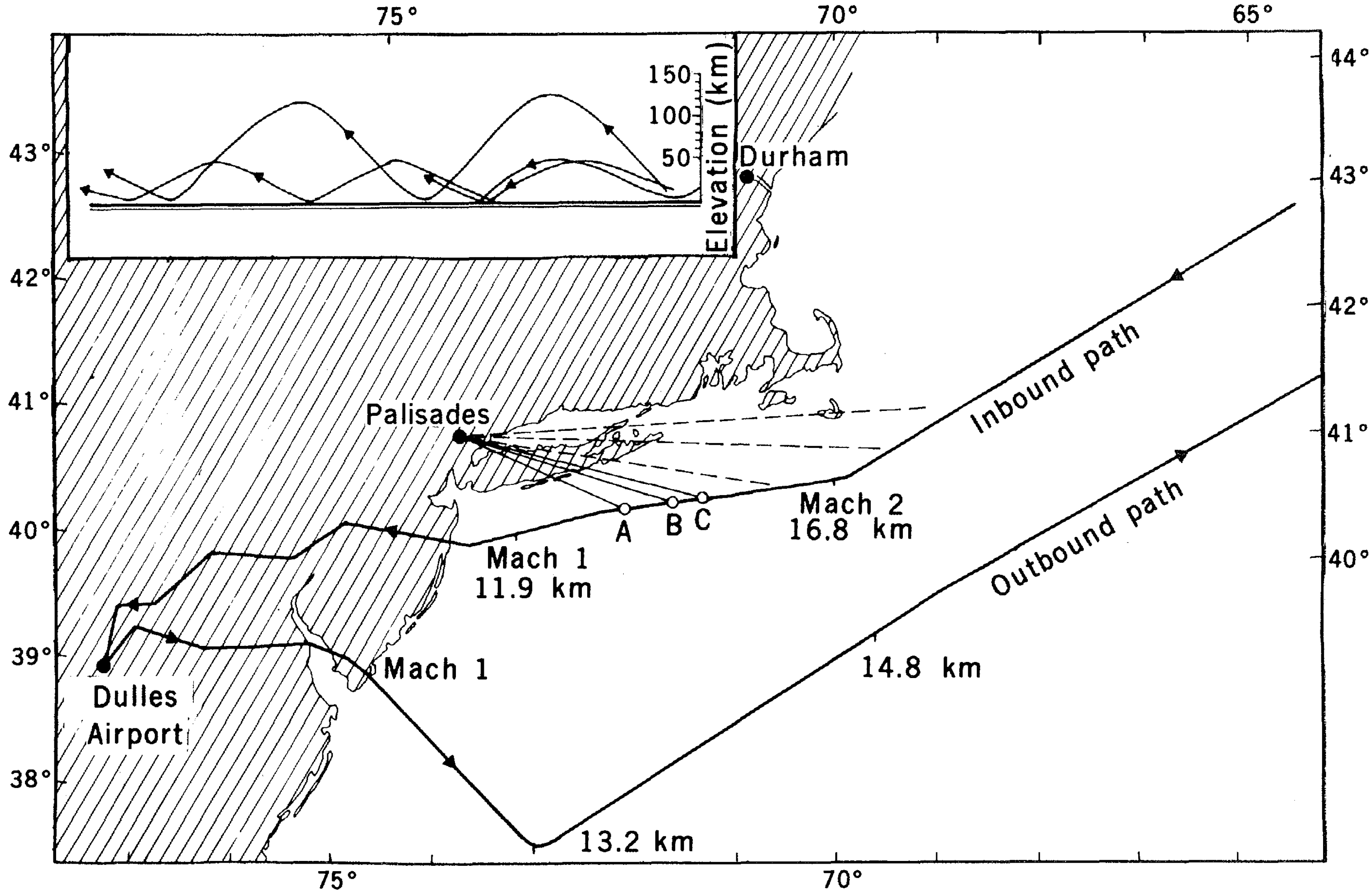


Fig. 2. Map showing the inbound and outbound flight paths of the Concorde supersonic transport. Elevation and speed are marked on the tracks. Points A, B, and C are average source locations for the first three signals received at Palisades. Although both inbound and outbound signals are recorded at Durham, instrumentation for directional determinations has not been completed at this site. The inset shows a schematic ray tracing indicating ray paths through the stratosphere (about 40 to 50 km) and the thermosphere (100 to 130 km).

[Balachandran, *et al.*, 1978]

Compare primary to secondary

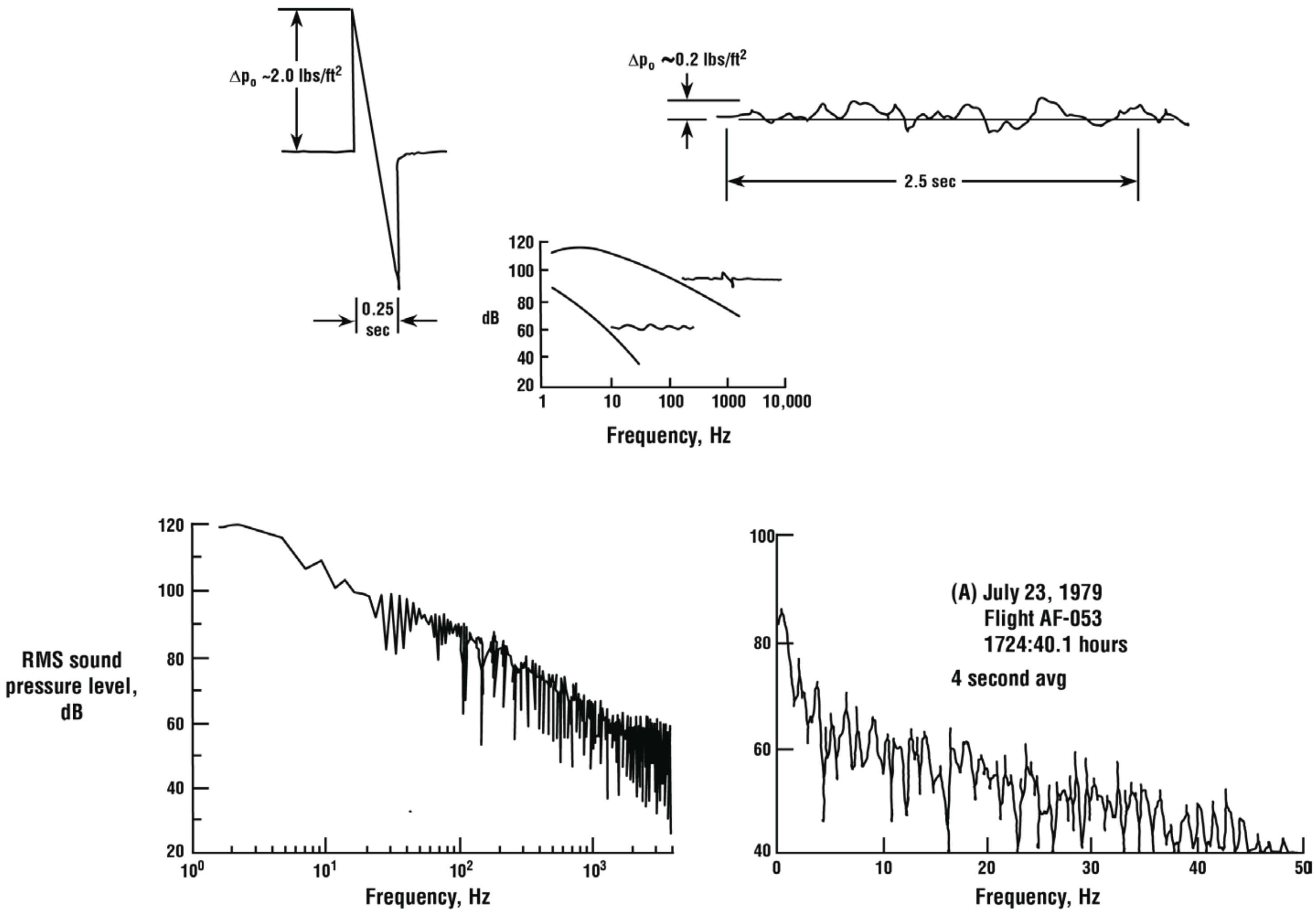
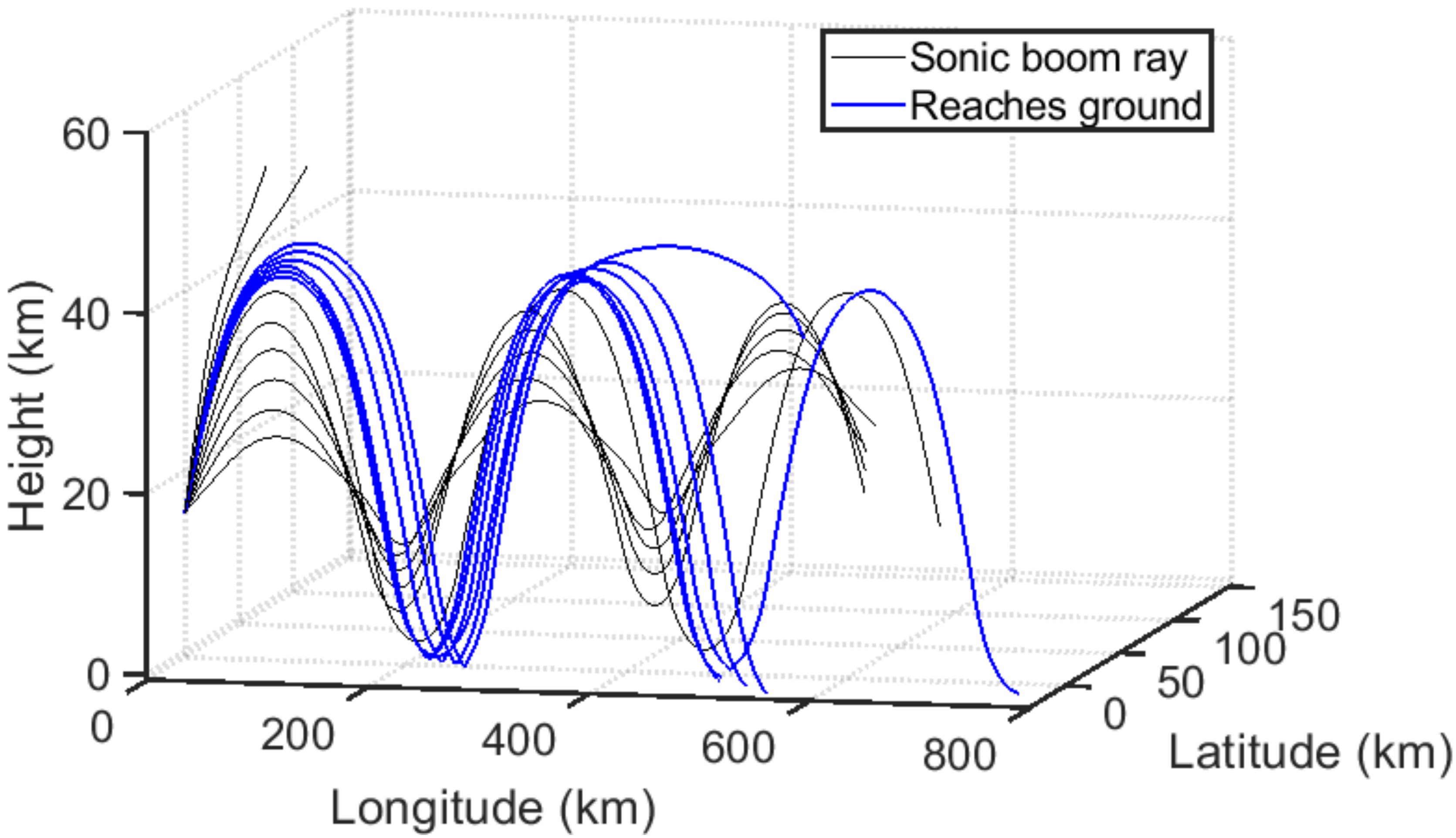


Figure 3. *Comparison of Concorde primary and secondary sonic boom signatures and spectra. One pound per square foot (psf) equals 47.88 pascals. Adapted from Holbeche (1972) and Rickley and Pierce (1980).*

[Rogers & Maglieri, 2015]

Penn State has been working with secondary boom capabilities in PCBoom

- April 2019 calculations in PCBoom and plotted in Matlab for Concorde flight conditions:



Locations secondary booms can be heard

1980 results: Rickley & Pierce, FAA-AEE-80-22

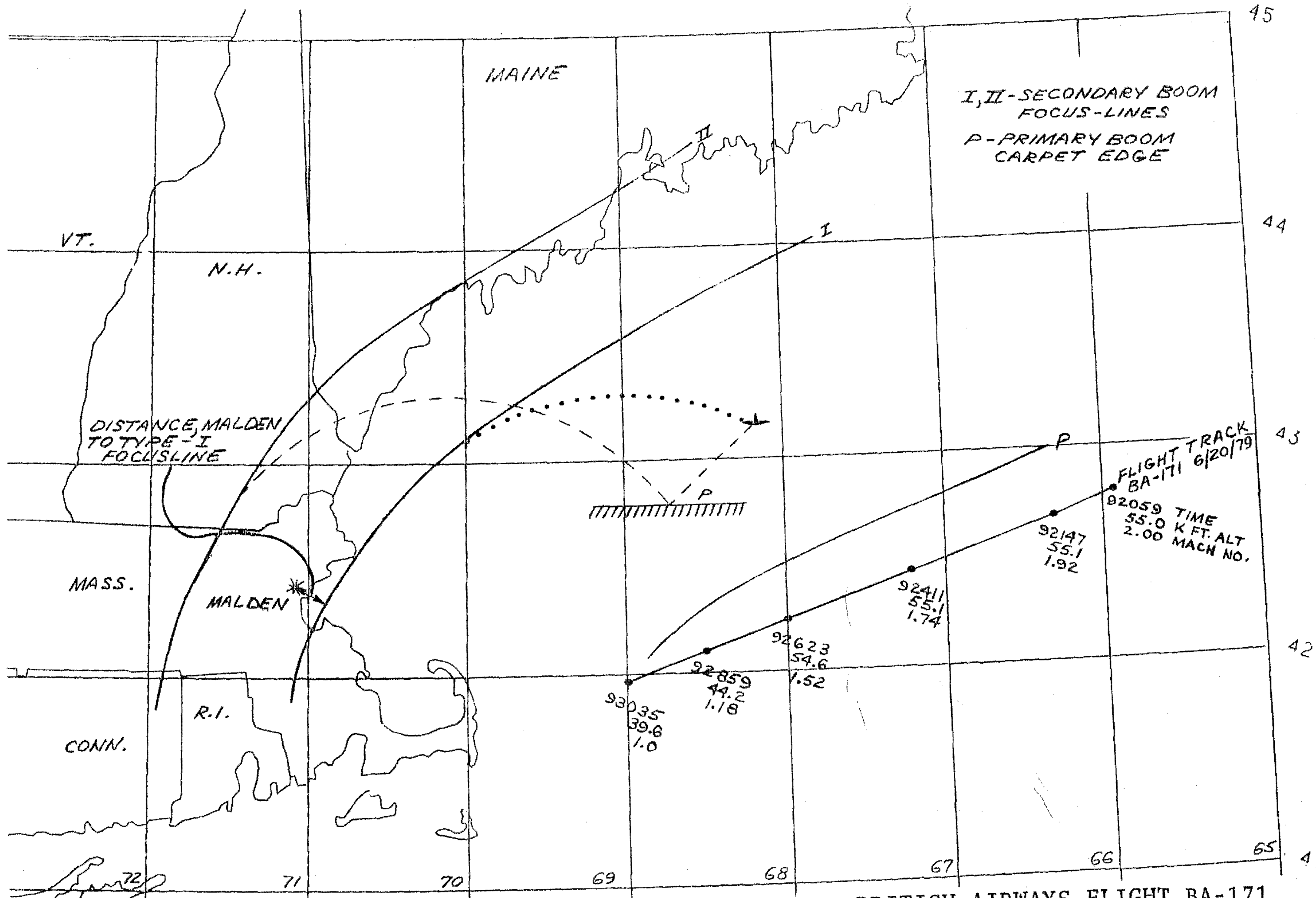
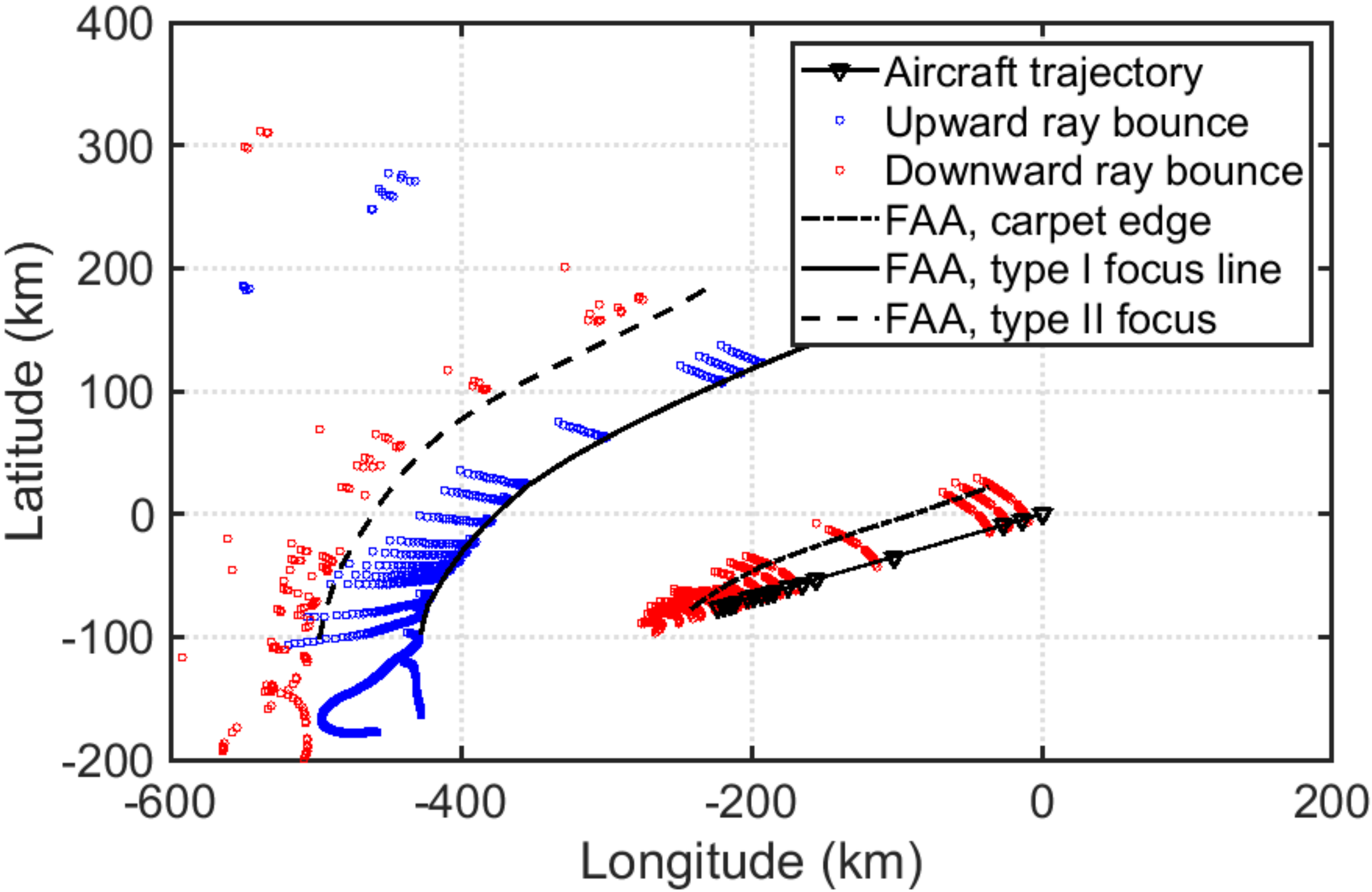


FIGURE 44. SECONDARY SONIC BOOM FOCUS-LINES SOURCE: BRITISH AIRWAYS FLIGHT BA-171
JUNE 20, 1979

2019 Penn State results, using PCBoom 6.7b:



Summary

- Contributions to CAEP WG1 efforts continuing
  - Learning things along the way to help with future certification
- Preliminary results show matches in secondary boom locations between FAA 1980 report and 2019 efforts
- Will continue to push forward on
  - Low-boom certification efforts
  - N-wave (and low-boom) secondary sonic boom predictions using PCBoom software

Very thankful
to FAA and our industrial partners!

References

- N. Balachandran, W. Donn, D. Rind, "Concorde sonic booms as an atmospheric probe," Science 197 (4298) 47-49 (1978).
- E. Rickley and A. Pierce, "Detection and assessment of secondary sonic booms in New England," FAA-AEE-80-22, May 1980, accessible as ADA088160.
- P. Rogers and D. Maglieri, "Concorde booms and the mysterious East Coast noises," Acoustics Today 11 (12) 34-42 (2015).
- K. Plotkin, J. Page, E. Haering, "Extension of PCBoom to over-the-top booms, ellipsoidal earth, and full 3-D ray tracing," AIAA 2007-3677, 13th AIAA/CEAS Aeroacoustics Conf. (2007).
- H. Poling, "Impact on weather and flight conditions on secondary booms," in *1995 NASA High Speed Research Program Sonic Boom Workshop, Vol. 1*, NASA-CP-3335 (July 1996), pp. 136-150.

Contributors

- Gulfstream
  Robbie Cowart, Joe Salamone
- Boom
  Steve Ogg, Greg Busch, Enrico Fabiano
- NASA
  Ed Haering
- Volpe National Transportation Systems Center
  Juliet Page
- The Pennsylvania State University
  Victor W. Sparrow, Project Director, and Penn State ASCENT PI
  Trevor Stout, Assistant Research Professor (until May 2019)
  Luke Wade and Josh Kapcsos, Research Assistants
- Queensborough Community College (CUNY), Department of Physics
  Kim Riegel