Sonic Boom Prediction Workshop 2020

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Introduction

- Cases submitted
- PCBoom propagation software
- Plots/analysis of submitted cases
- Difficulties encountered along the way
- Conclusions

Cases Submitted

- Case 1 (C25P)
  - Lateral cutoff angles determined
  - Ground Intersections, Signatures, and Loudness Levels computed at all requested azimuths
  - Focus case not submitted
- Case 2 (C609)
  - Cutoff angles determined for measured/standard atmospheres
  - Ground Intersections, Signatures, and Loudness Levels computed at all requested azimuths for measured atmosphere
  - Resubmitted Case 2 standard atmosphere with all requested azimuths for all quantities after clarification of desired azimuths

Case	Negative Cutoff [°]	Positive Cutoff [°]
Case 1	-77.88	68.51
Case 2 (Measured)	-63.59	70.00
Case 2 (Standard)	-44.35	44.35

Propagation Prediction Code (PCBoom 6.7.1.1)

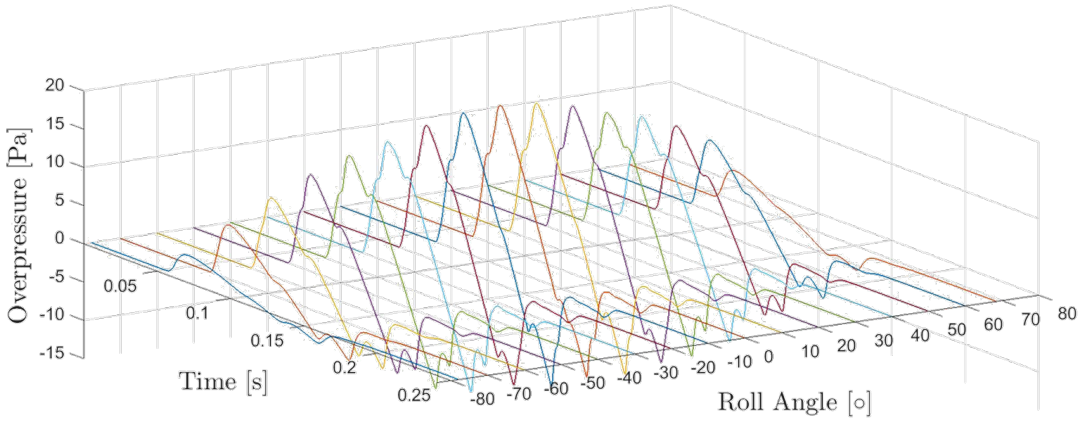
- Thomas Mode Input
  - Accepts single azimuth starting signatures
  - Legacy code based on Thomas' waveform parameter method, but here is mainly used for raytracing
- Split-step pseudospectral Burgers' postprocessor
  - Absorption processes handled in frequency domain; nonlinear in time domain
  - Step size based on absorption rather than nonlinear considerations; augmented wind effects incorporated, as of 6.7.1
  - Orders of magnitude faster than previous version (6.7b)

Loudness/Computing Platform

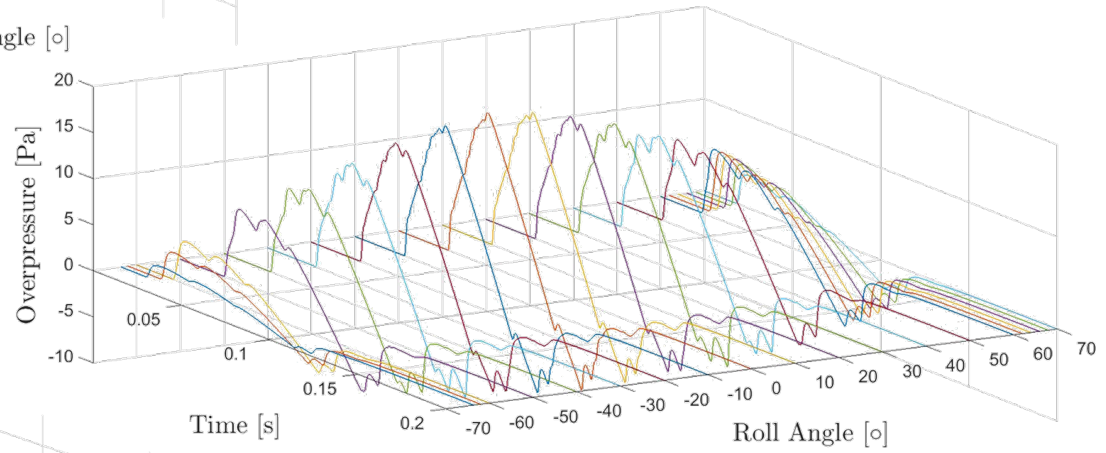
- Loudness levels computed with in-house loudness code
  - A, B, CSEL computed in time domain with bilinear transform correction
  - PL calculation based on Shepherd/Sullivan code
- Computing platform
  - Windows 10 Enterprise, 3.3 GHz Intel Core i5-4590 Processor, 4 cores, 28 GB shared memory

Ground Signatures

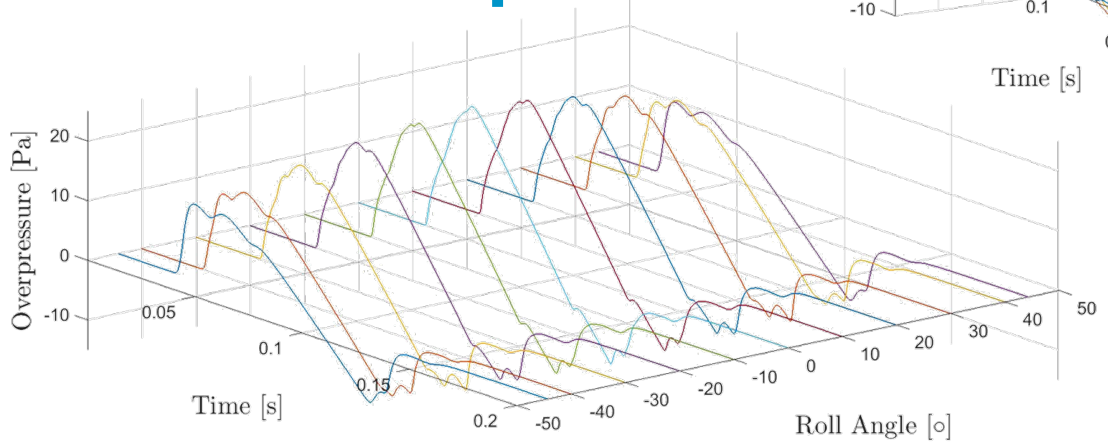
C25P



C609 Measured Atmosphere

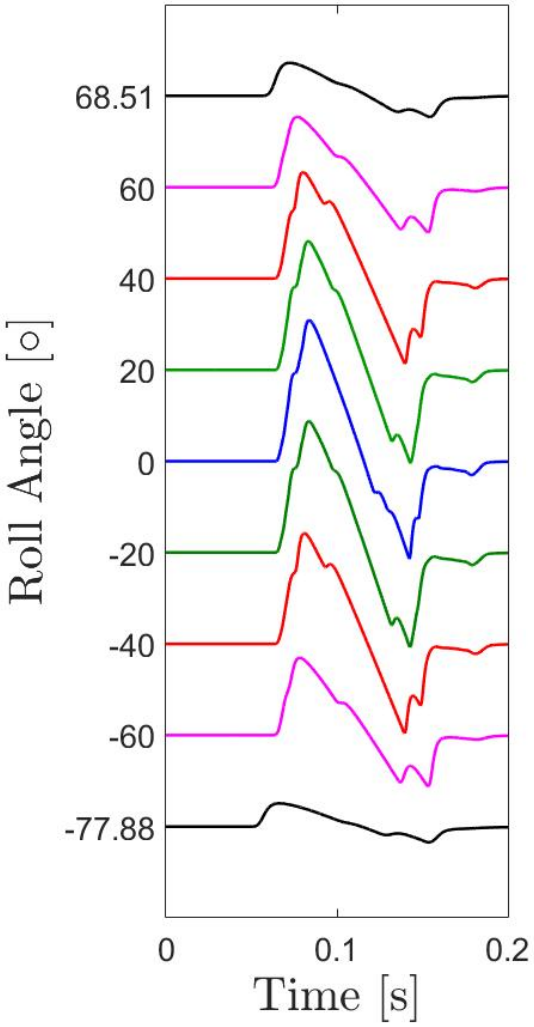


C609 Standard Atmosphere

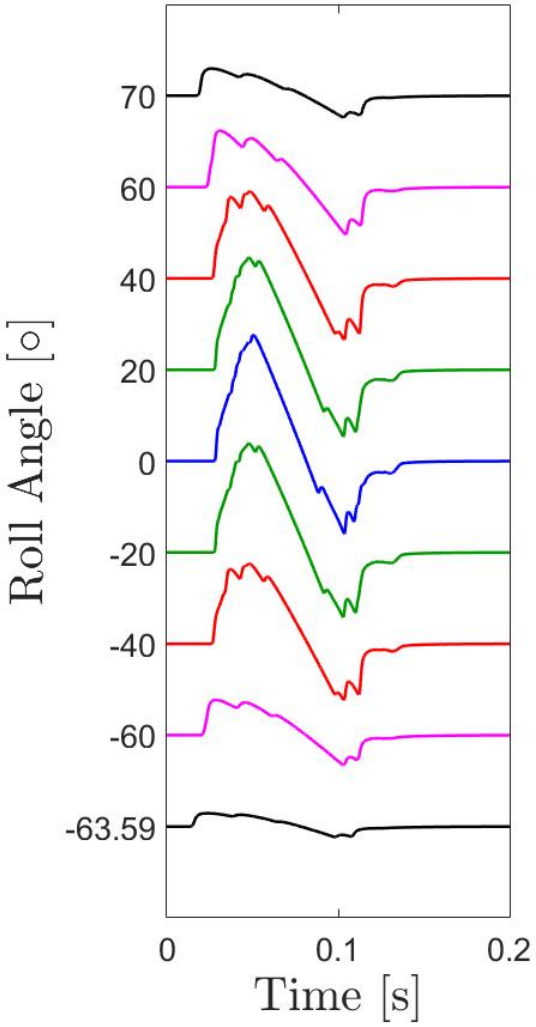


Ground Signatures (cont.)

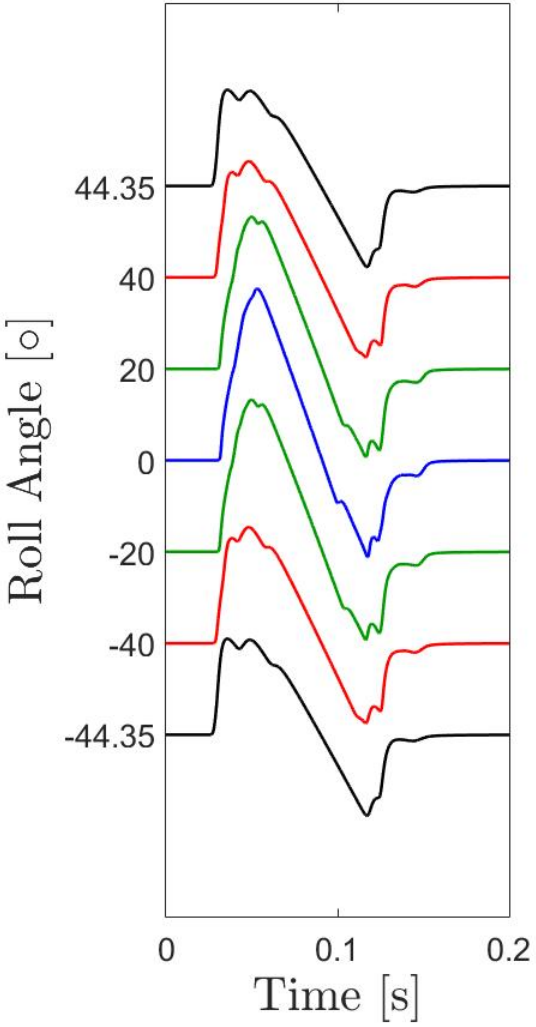
C25P



C609 Measured

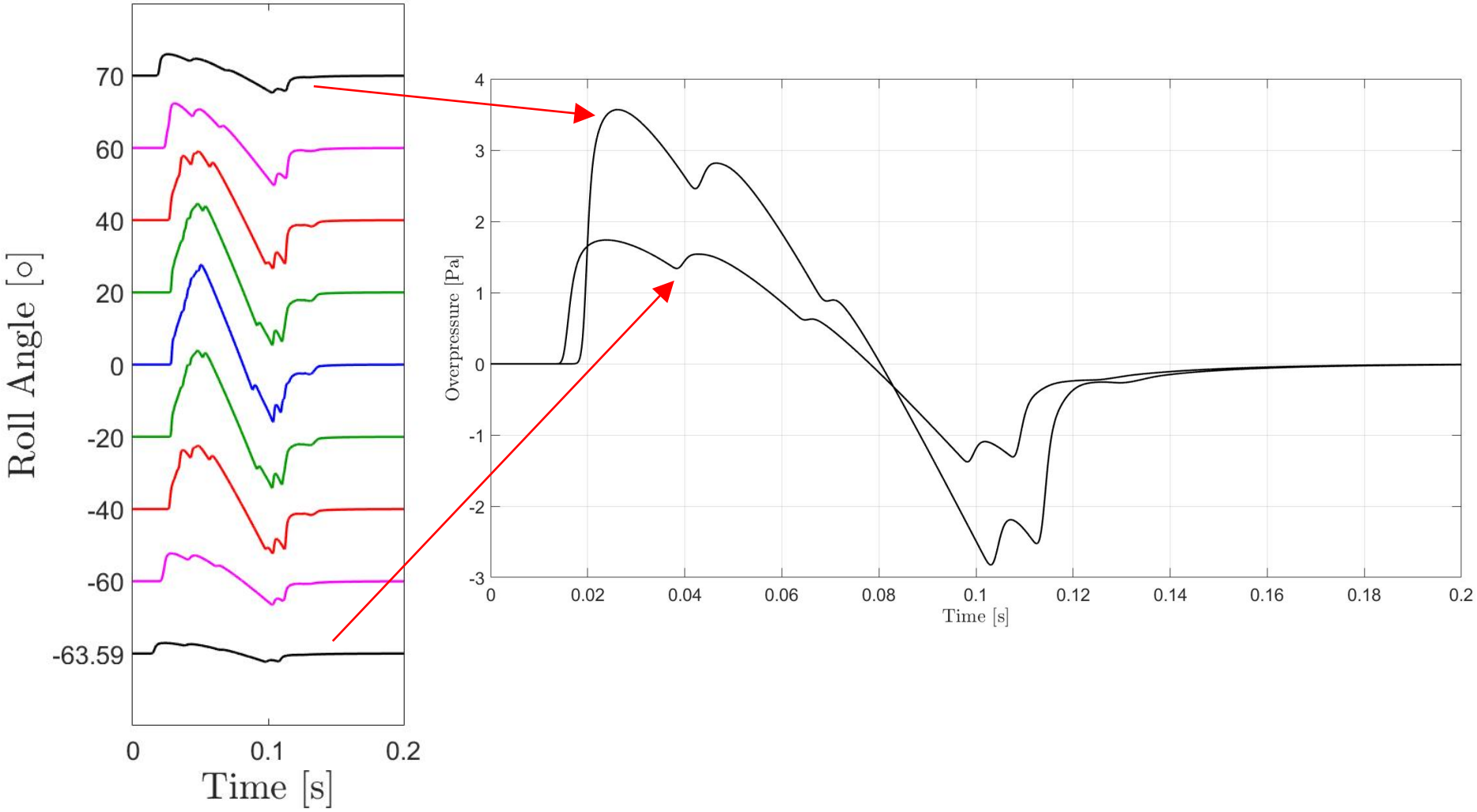


C609 Standard

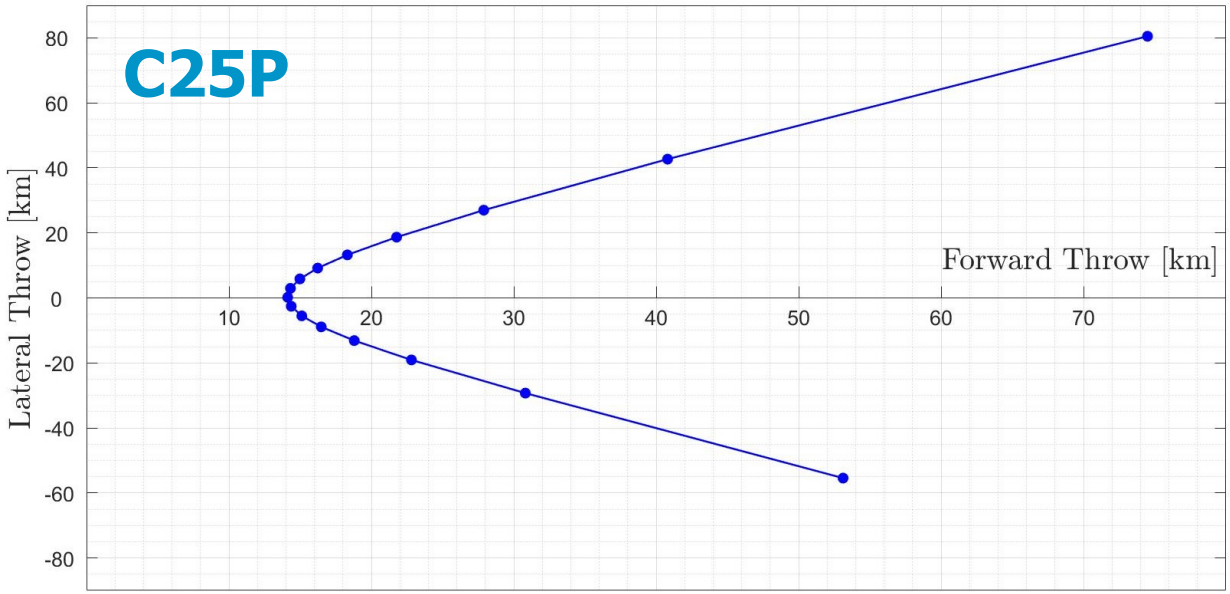


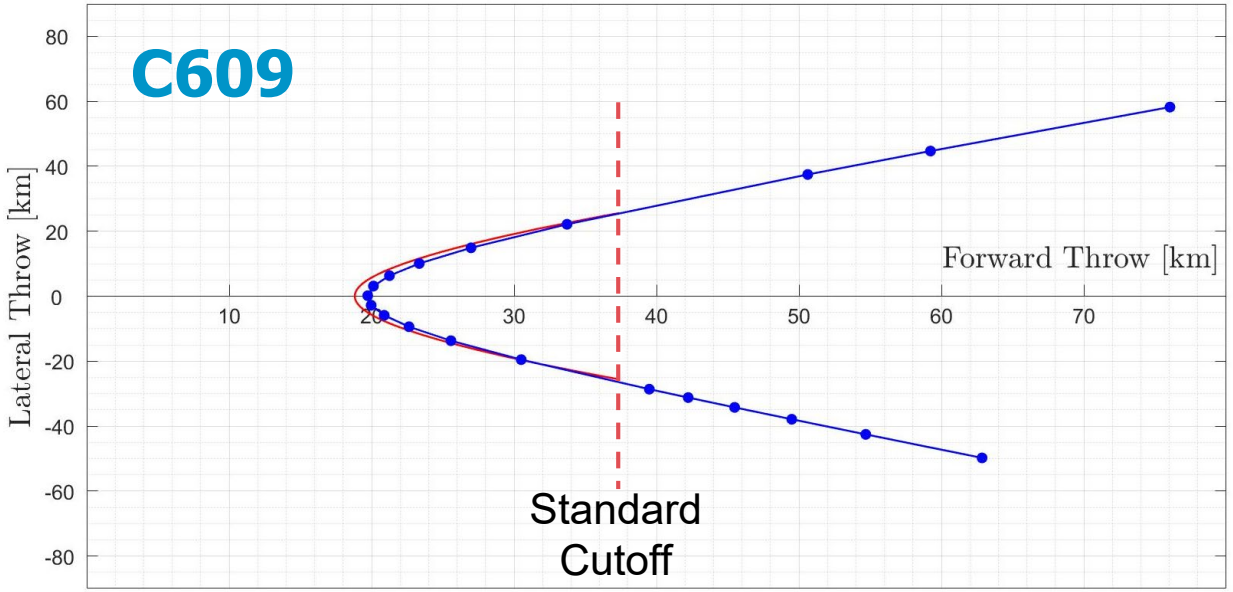
Ground Signatures (cont.)

C609 Measured



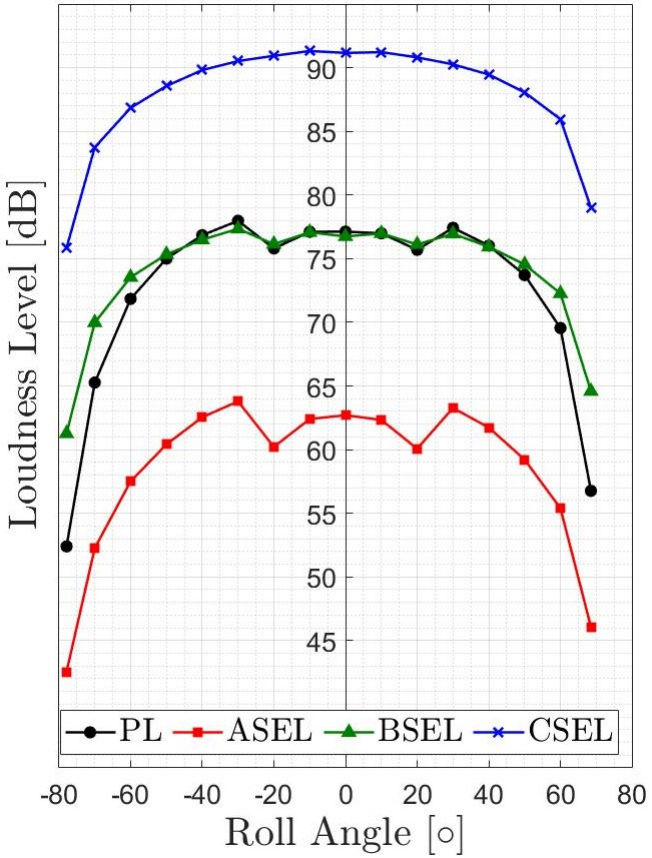
Ground Intersections



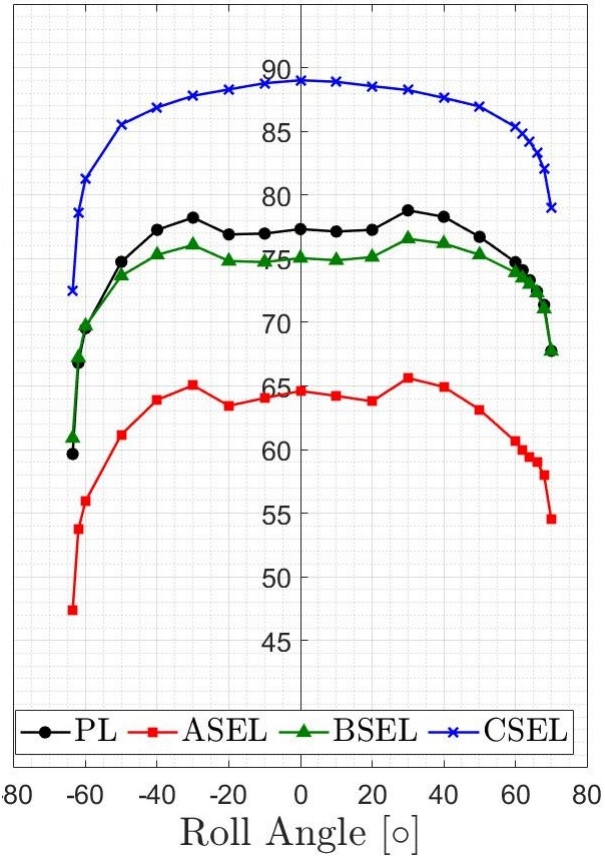


Loudness vs. Roll Angle

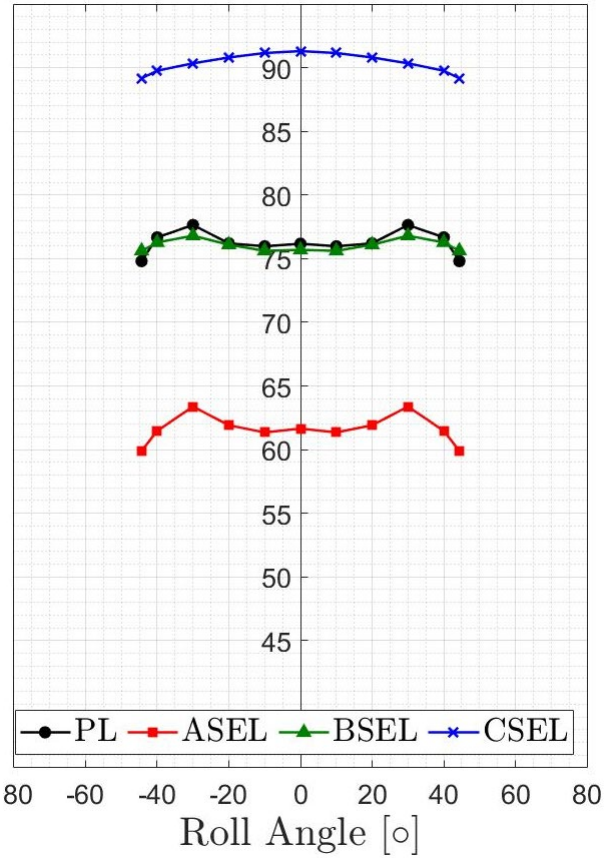
C25P



C609 Measured

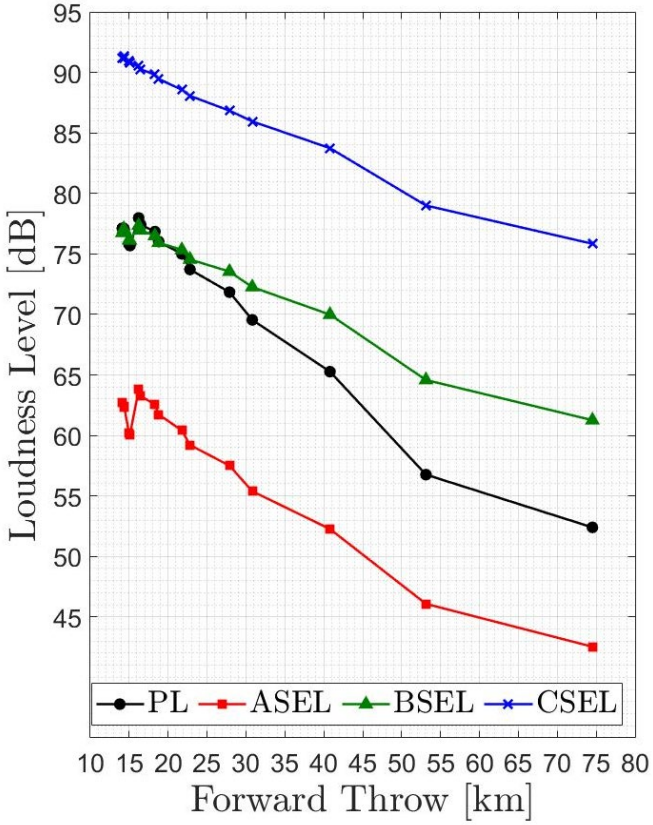


C609 Standard

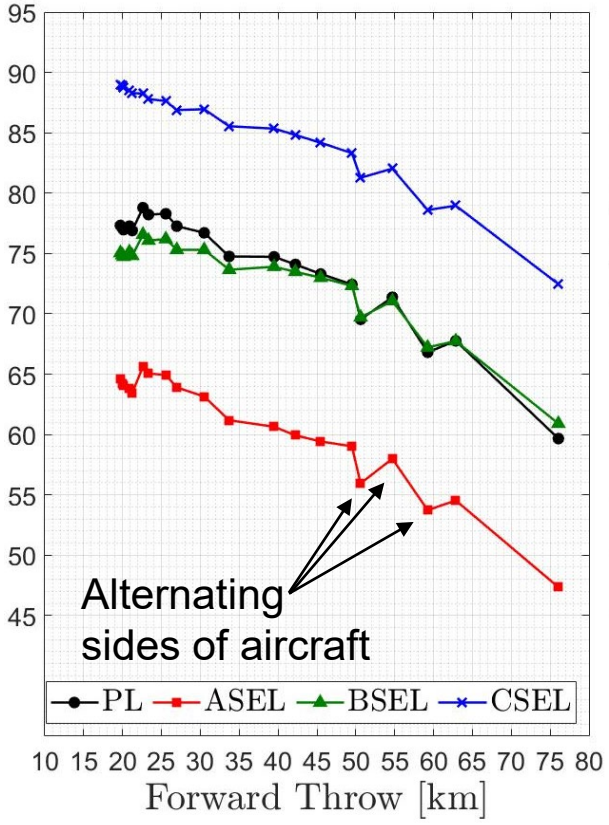


Loudness vs. Distance

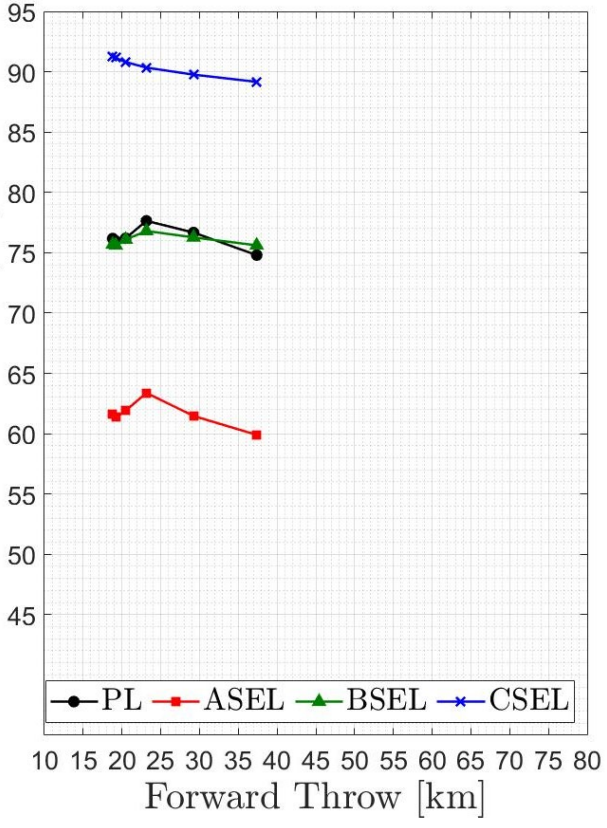
C25P



C609 Measured



C609 Standard

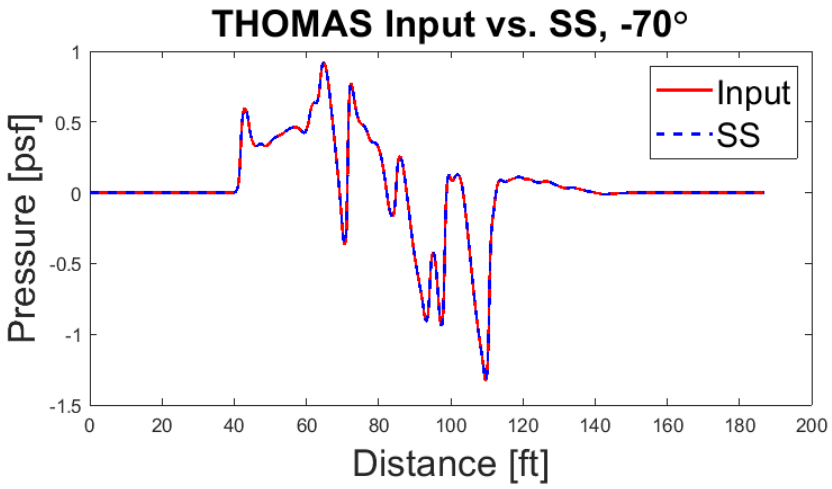


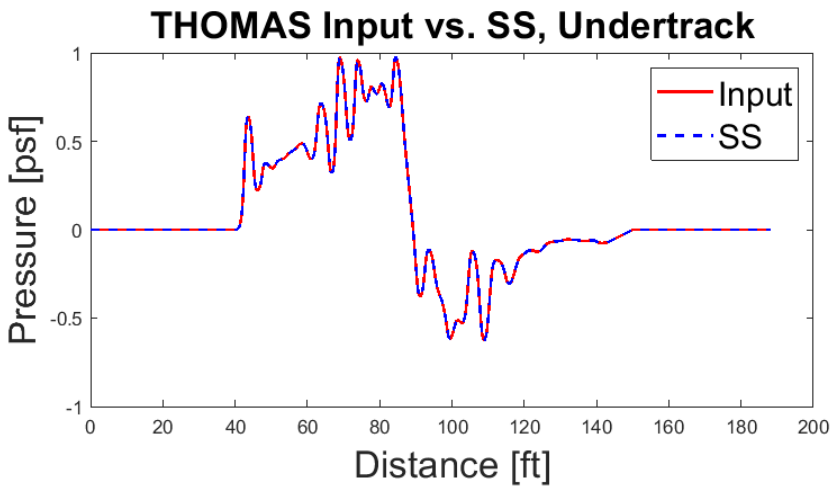
Challenges

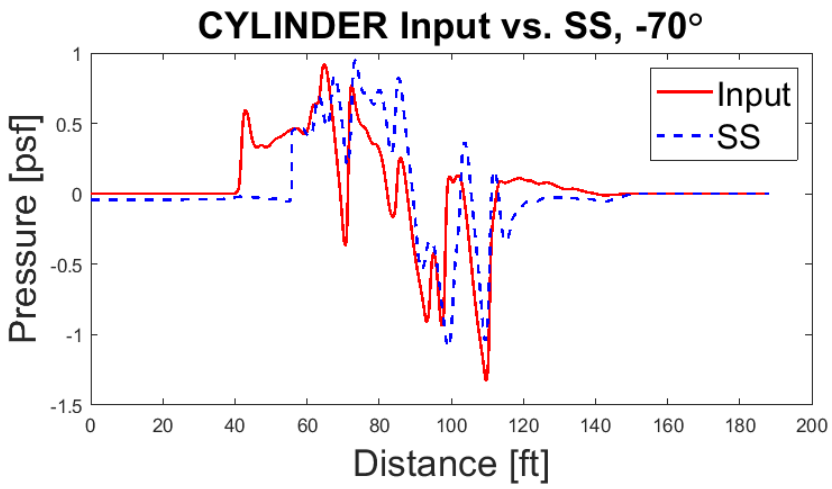
- PCBoom produces spurious outputs for large input cylinders. Two workarounds found, with similar results:
  - Use partial cylinder around angle of interest
  - Thomas Mode (single angle input)
- Multiple Coordinate Systems
  - PCBoom Input (Tecplot)
  - PCBoom Output
  - SBPW 3 Submission Format

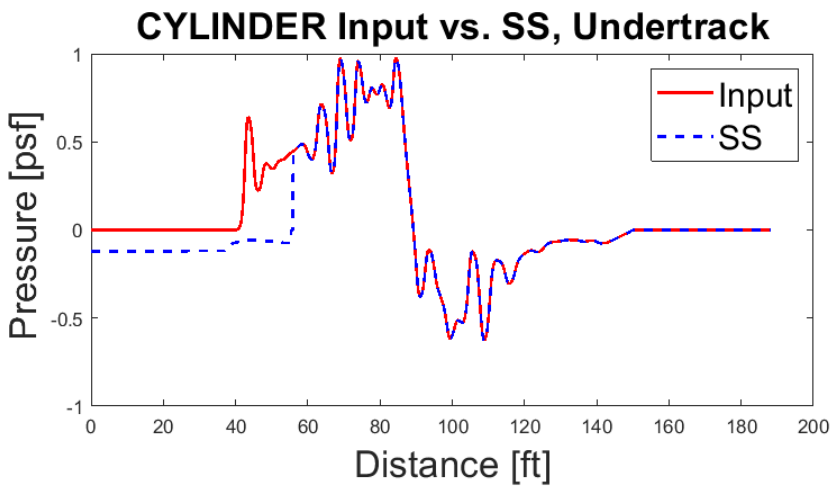
PCBoom Cylinder Breakdown - Case 2 Measured Atmosphere

*Input = User input signature to PCBoom
**SS = Starting Signature in PCBoom .un6 file









Conclusions

- Changes in atmosphere have a dramatic effect on the propagation of the C609 signatures
  - Strong asymmetry in ground footprint due to wind
  - PL/BSEL appear less sensitive to changes in atmosphere than ASEL/CSEL, though in opposite directions. Max differences from -40 to 40 degrees given below

PL	ASEL	BSEL	CSEL
+1.62 dB	+3.46 dB	-1.28 dB	-2.88 dB

  - 75 PLdB nominal cruise boom for X-59 (C609) is not unreasonable, though levels were typically slightly higher (sometimes up to 4 dB). However, ground intersection is dramatically enlarged when winds are present; Lateral spread of footprint increased ~60 km, Forward throw nearly 40 km

- For larger and/or nonuniformly sampled cases, PCBoom's Thomas mode is more reliable than Cylinder mode.
  - Requires separate run for each angle, but 6.7.1.1 runs very quickly, so typically not a problem.

Acknowledgements

- Juliet Page, Volpe
  - Suggestion of Thomas Mode for running cases, general troubleshooting advice and education on the PCBoom software.
- Joel Lonzaga & Will Doebler, NASA LaRC
  - Help with PCBoom formatting and syntax, understanding changes made in PCBoom 6.7.1, general troubleshooting advice and education on the PCBoom software.
- The Sonic Boom Prediction Workshop Organizing Committee

Thank You!

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