SBPW3: OVERVIEW OF PROPAGATION WORKSHOP

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Outline

- Motivation and goals
- Boom Propagation Workshop
- Cases
    - Notice of Intent
    - C25P
        - Optional Focus Cases
    - C609
- Atmospheric profiles
- SBPW3 Wind and Azimuthal Angle Conventions
- Summary

Motivation and Goals

Motivation:

- Impartially compare propagated signatures from multiple teams/codes under standard and non-standard atmospheric conditions
- Understand the state of current boom prediction methods across the international sonic boom community
- Explore the effect of the atmosphere on the evolution of shaped sonic booms

Goals/Objectives:

- Aid in supersonic aircraft noise certification process
- Verify analysis techniques within multiple codes across international teams
- Understand modeling gaps, if any
- Improve awareness of sonic boom physics at realistic atmospheric conditions particularly at lateral cut-offs

Boom Propagation Workshop

- Yesterday was about CFD (near-field) predictions
- The subject today is atmospheric propagation
- Assumption: The input pressure waveform is sufficiently far away from the aircraft so the 3D effects are fully resolved
- Asking participants to use their best practices to predict ground signatures and their corresponding loudness values and ground intersection locations:
  - At several azimuthal angles, including lateral cut-offs
  - Under realistic atmospheric conditions including winds, but ignoring atmospheric turbulence

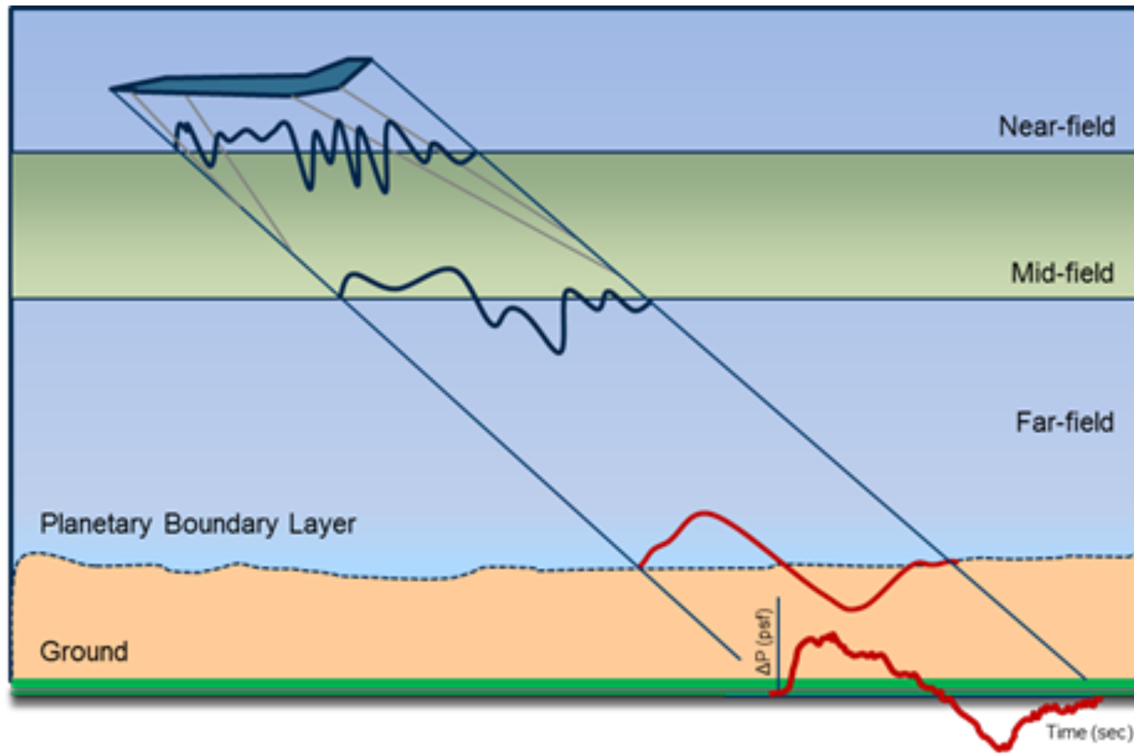


Figure Source: “Status of Certification Procedures for Quiet Supersonic Flight”, Robbie Cowart, *AIAA AVIATION 2019, Dallas, TX*

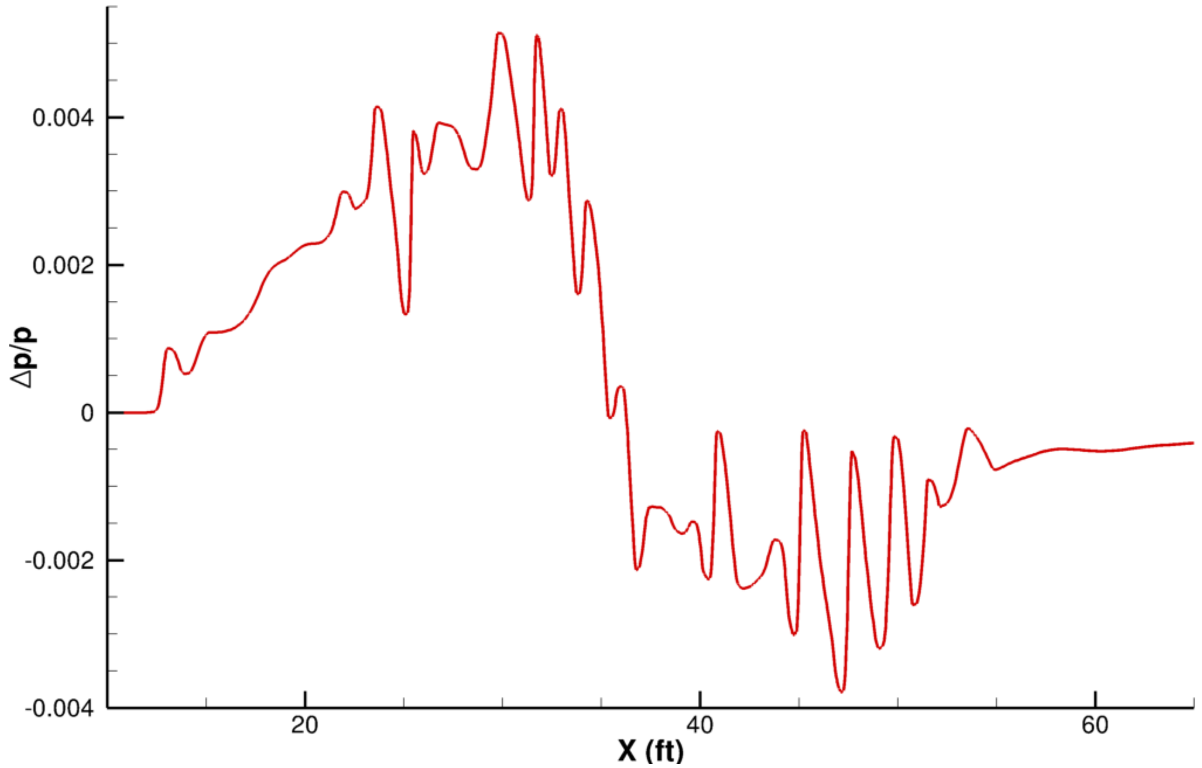
Workshop Culture

- Adjectives such as good, bad, right, and wrong oversimplify issues and are avoided
- Concentrate on describing observed differences and communicate why things are different

Overview of Cases (0) – Notice of Intent

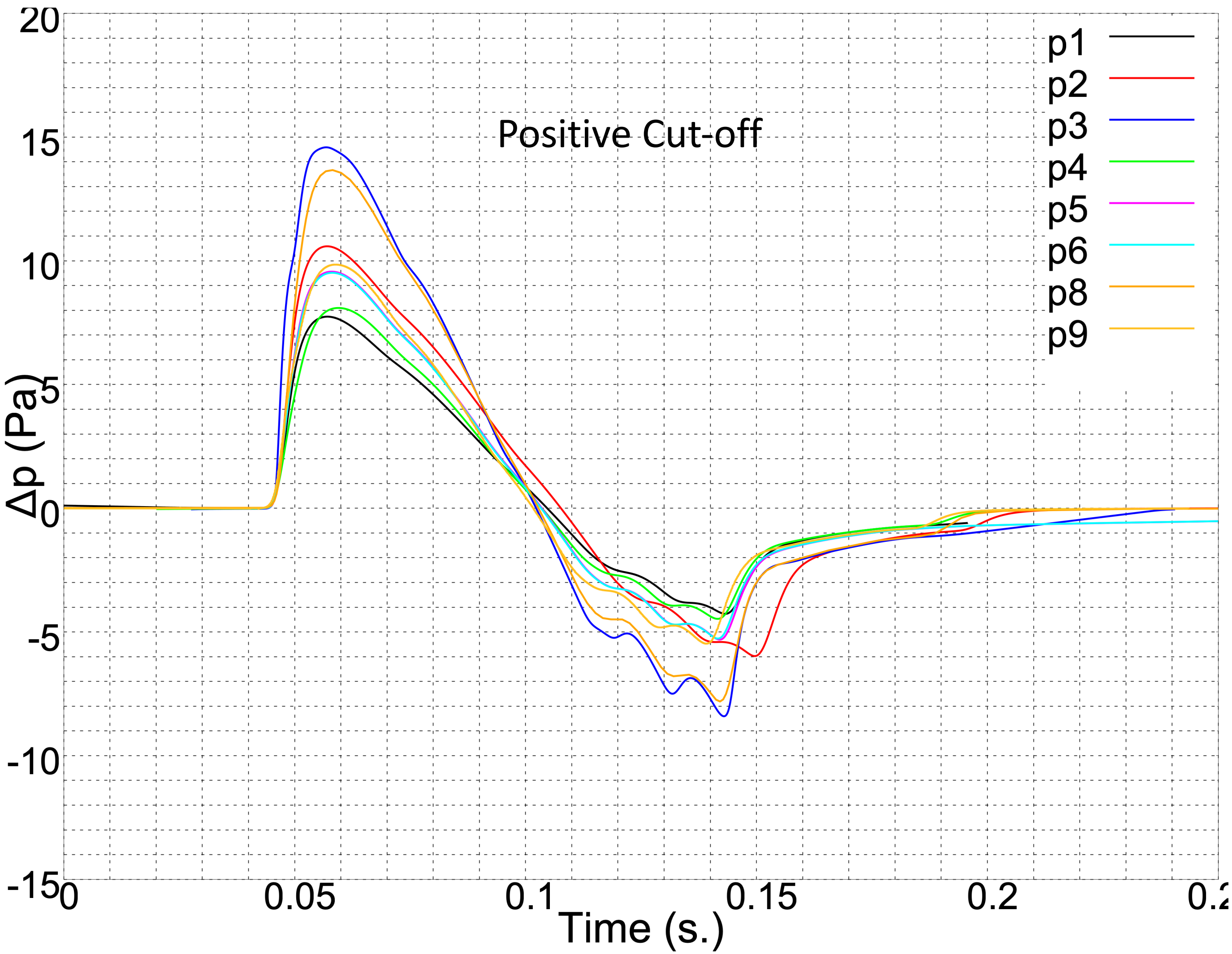
CASE 0: Axi-symmetric body of revolution

- Flow Conditions: M=1.6, Altitude = 15760 m, R/L = 3.0, L = 32.92 m
- Required Data/Runs: Predict sonic boom signatures at azimuthal angles of -45^0 , 0^0 and 45^0 increments using the prescribed atmospheric profiles

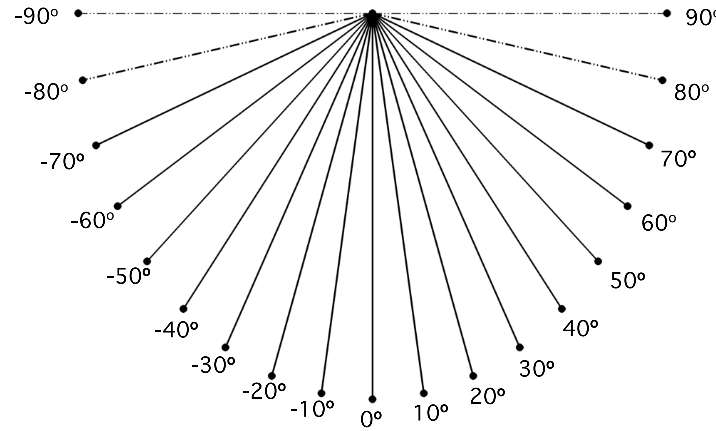


Overview of Cases (0) – Notice of Intent

CASE 0: Axi-symmetric body of revolution



Case 1: NASA C25P

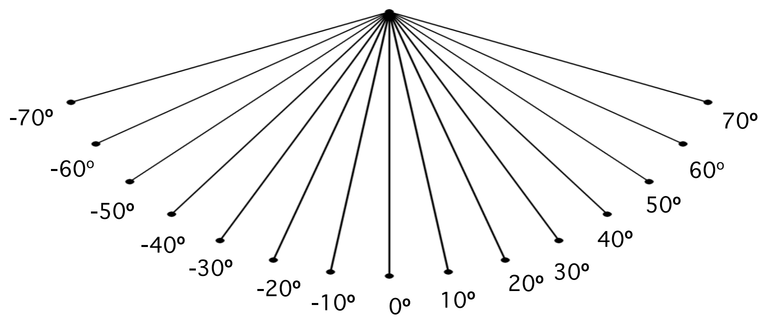


- A powered equivalent of the NASA C25D configuration that was used in SBPW2
- Flow Conditions: M=1.6, Altitude = 15760 m, R/L = 3.0, L = 33.53 m
- Near-field provided from -90^0 to 90^0 in 10^0 increments

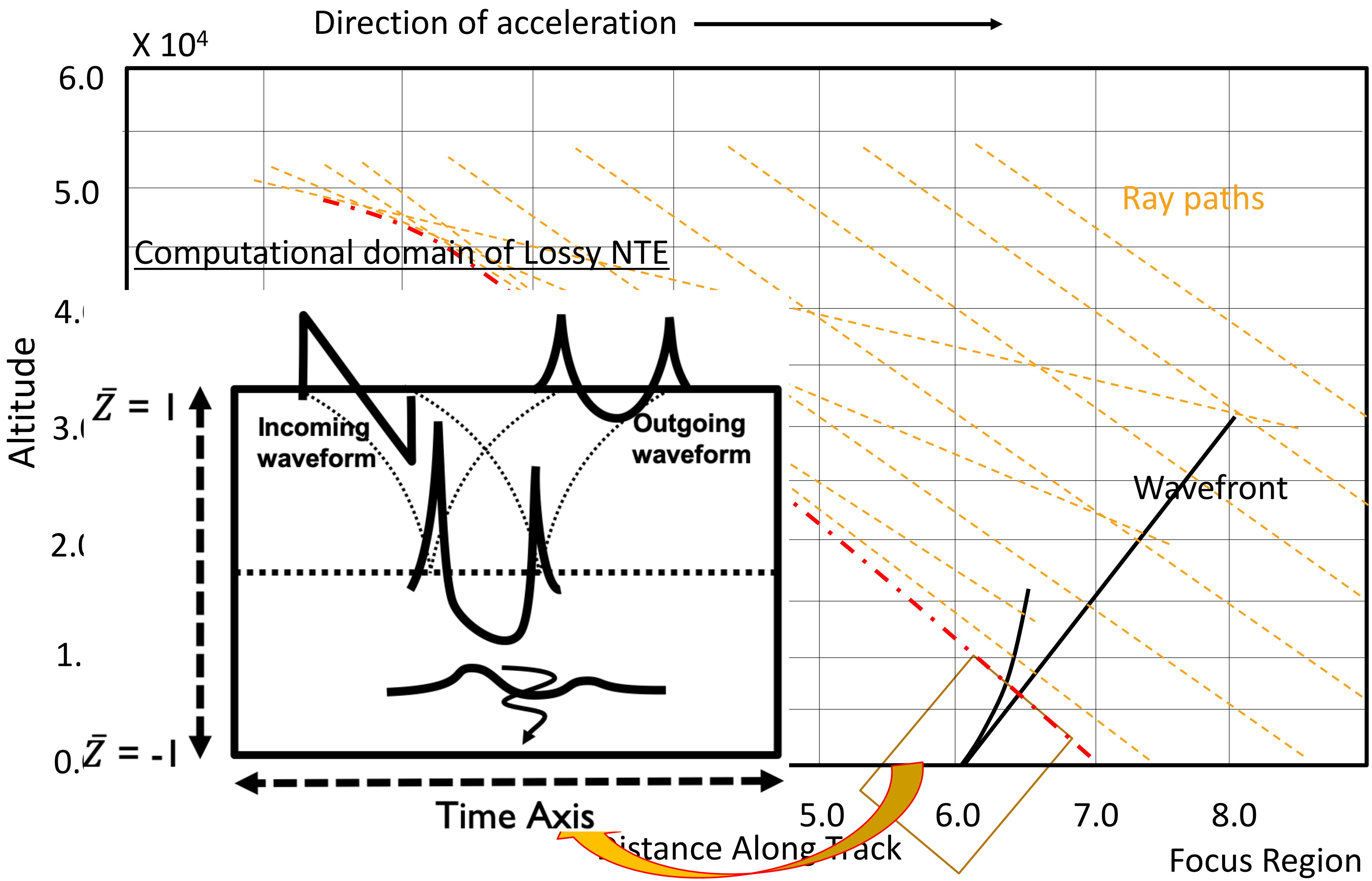
Case 1 Runs

Required Data/Runs:

- Predict sonic boom signatures at azimuthal angles of -70^0 through 70^0 in 10^0 increments using the prescribed atmospheric profiles
- Determine lateral cut-off azimuthal angles, and ground intersection locations on both sides of the flight track
- Loudness metrics (PL, ASEL, BSEL, CSEL)

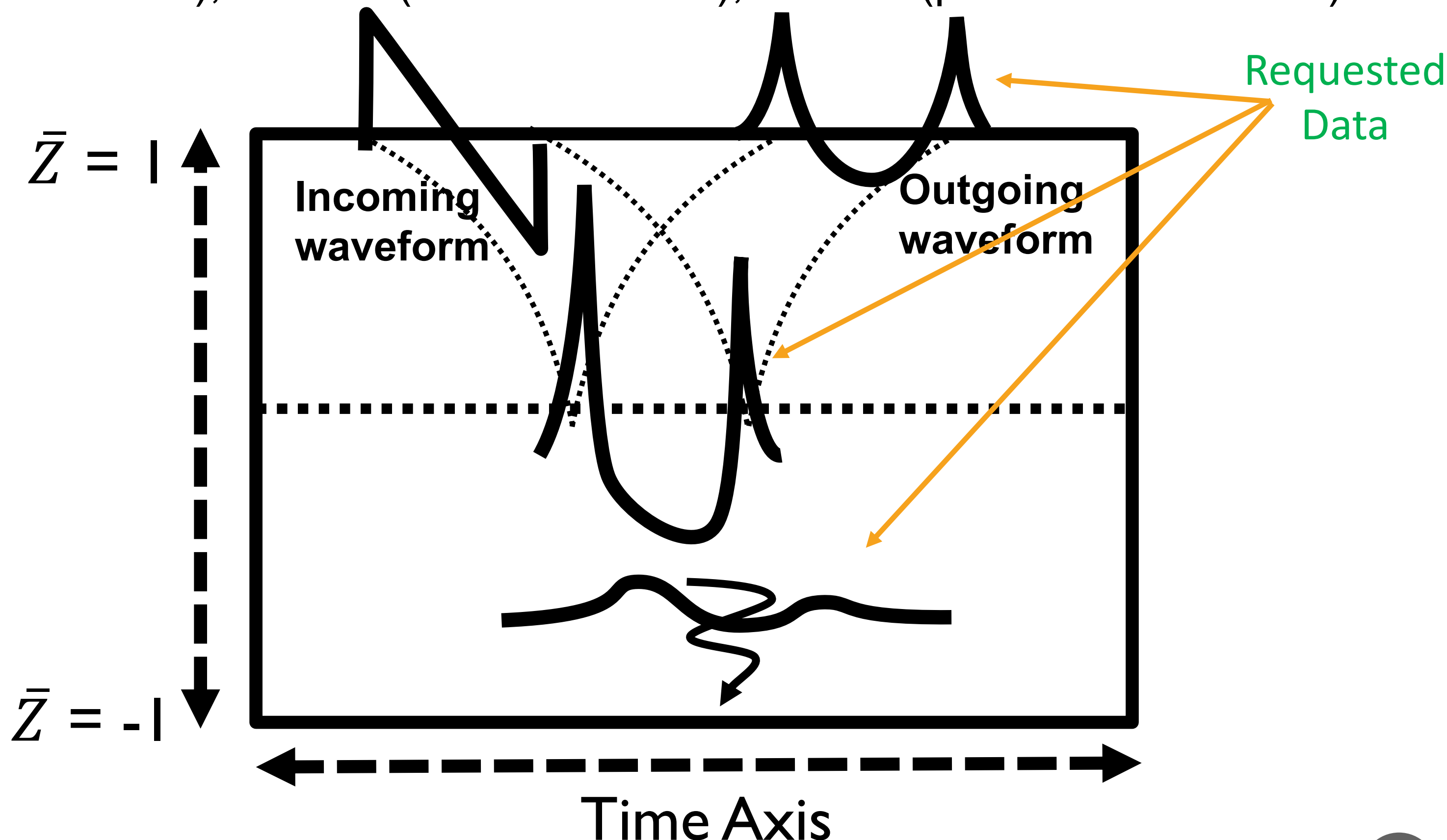


Optional Runs: Sonic Boom Focusing

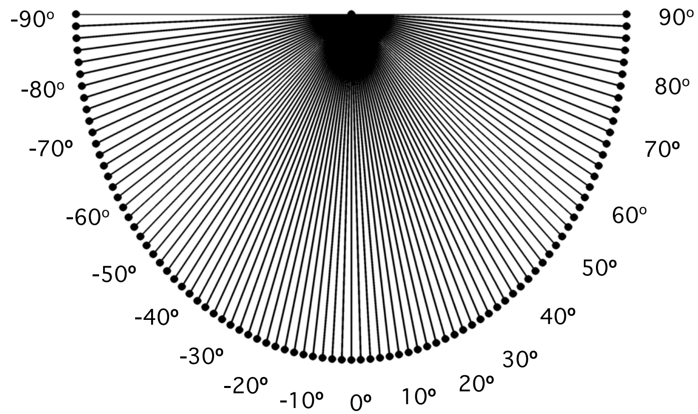


Optional Runs: Sonic Boom Focusing

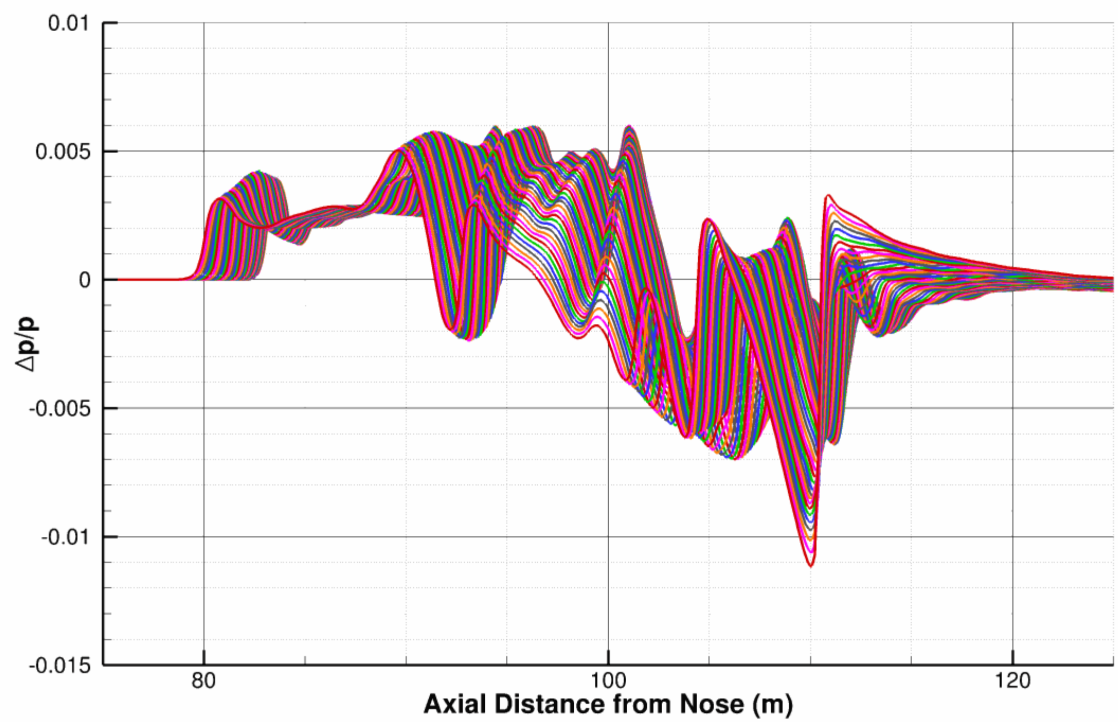
- Focus prediction for level acceleration
  - Mach = 1.4121, dM/dt = 0.015681, d^2M/dt^2 = 0.000359
  - Altitude = 13716 m, Ground altitude = 58 m
  - Diffraction boundary layer thickness = 682.45 m
- Determine focused signatures and associated loudness metrics at $\bar{Z}$ = -1.0 (evanescent wave), $\bar{Z}$ = 0.0 (Focus location), $\bar{Z}$ = 1.0 (post-focus location)



Case 2: LBFD C609



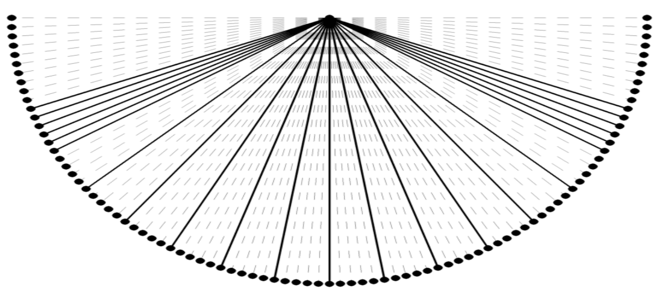
- NASA-Lockheed Low-Boom Flight Demonstrator (LBFD): A Variant of X-59 QueSST
- Flow Conditions: M=1.4, Altitude = 16459.2 m , R/L = 3.0, L = 27.43 m
- Near-field provided from -90^0 to 90^0 in 2^0 increments



Case 2 Runs

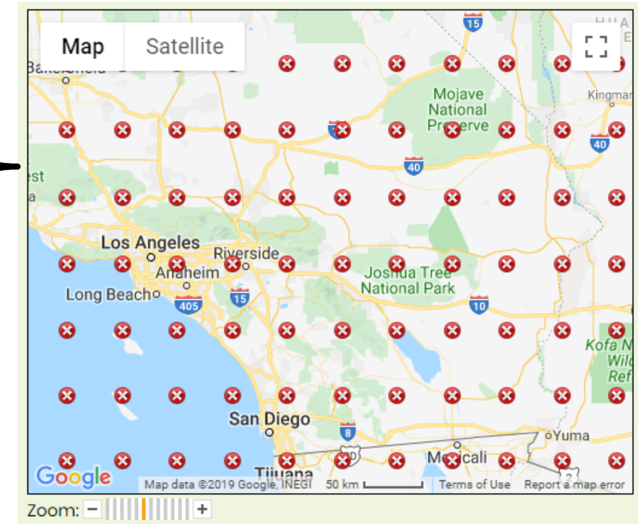
Required data/runs:

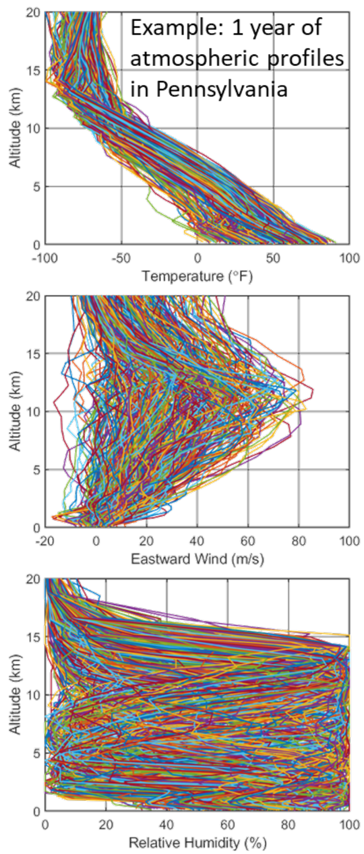
- Use prescribed as well as standard atmosphere
- Ground signatures, lateral cut-off azimuthal angles, loudness metrics for azimuthal angles:
  - From -60 to 60 in 10 degree increments (with 0 being under-track)
  - From -70 to -60 in 2 degree increments
  - From 60 to 70 in 2 degree increments
  - Corresponding to the lateral cut-off on either side of the flight track



Atmospheric Profiles

- Profiles drawn from Climate Forecast System Reanalysis (CFSR) database
- Spatial resolution
  - 0.5ºx0.5º lat/long: Roughly 35 mile separation
  - E.g. 3 points between Los Angeles and San Diego



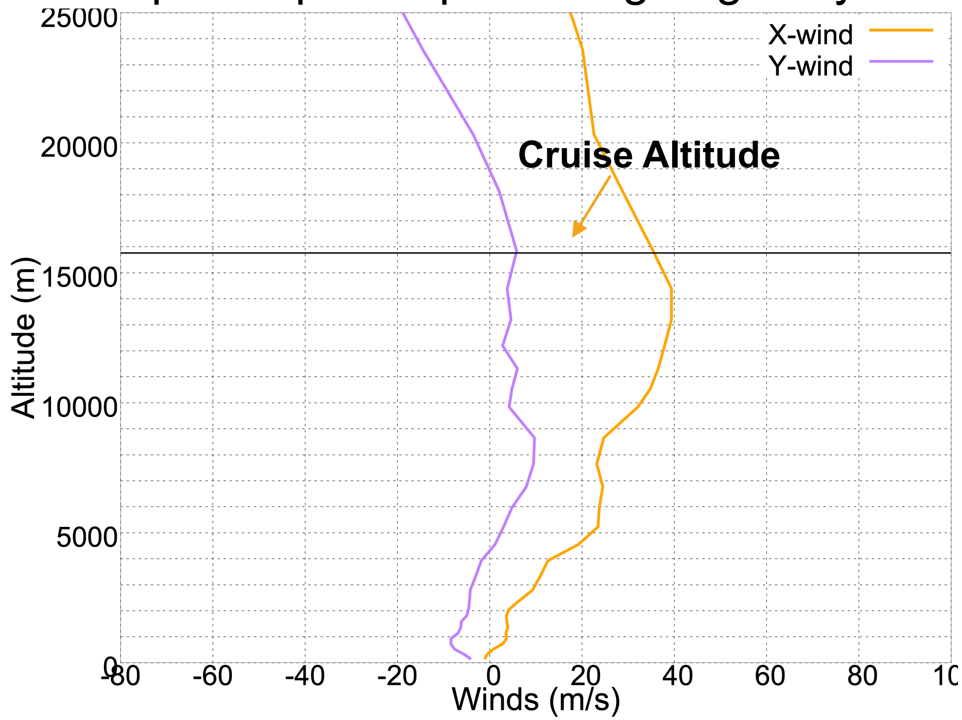


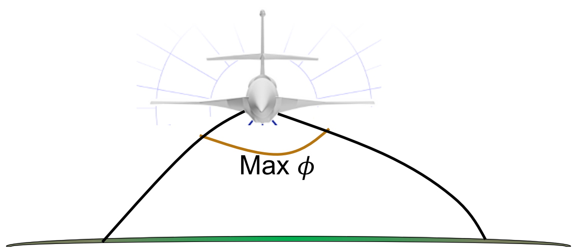
- Temporal resolution
  - Every 6 hours from 1979 to present
    - 00:00, 06:00, 12:00, 18:00 UTC
- Vertical resolution
  - Varies, 37 isobaric pressure levels
    - 1000 mbar to 1 mbar

Case 1 Profile

Approach:

- Took all valid profiles at an arbitrarily chosen location over the past 5 years
- Filtered atmospheres that produce:
  - A physically narrow/medium/wide east-heading carpet
  - A low/medium/high PL east-heading carpet
  - An angularly narrow/medium/wide east-heading carpet
- Picked atmospheric profile producing angularly widest carpet for Case 1

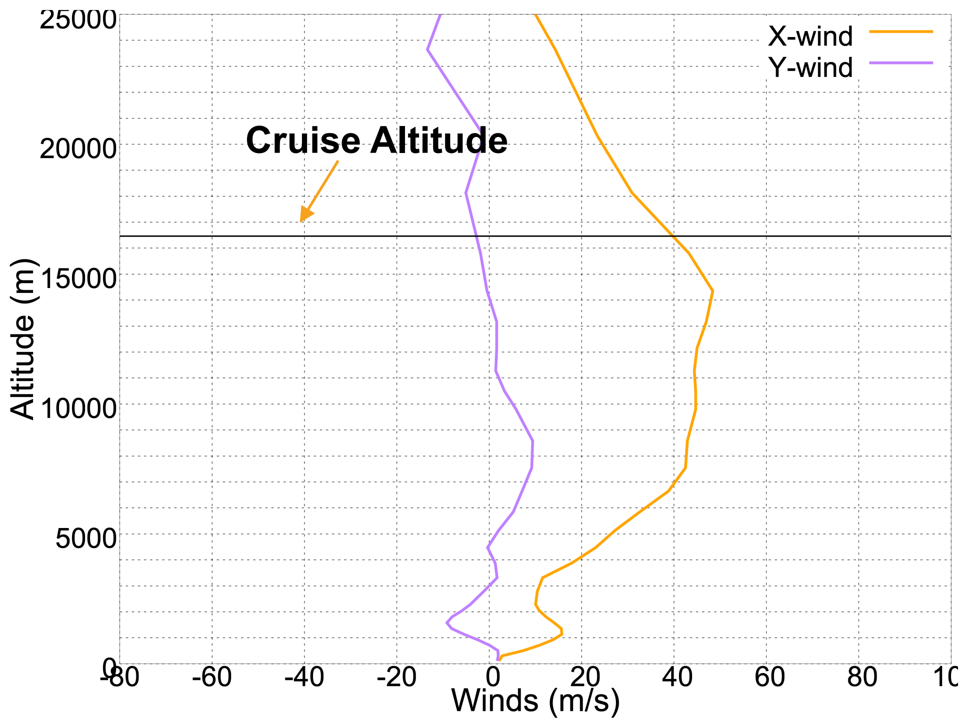


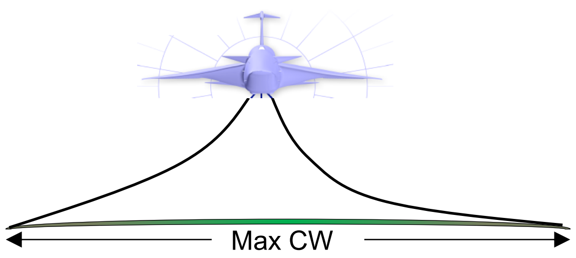


Case 2 Profile

- Chose atmospheric profile producing a physically wide carpet
  - Primary reason was to predict and see propagation algorithmic differences at large cut-off angles

Atmosphere	-ve angle	+ve angle	-ve width	+ve width
Standard Atmosphere	-44.83	44.83	28150 m	-28150 m
Chosen Atmosphere	-64.05	70.6	80340 m	-54200 m



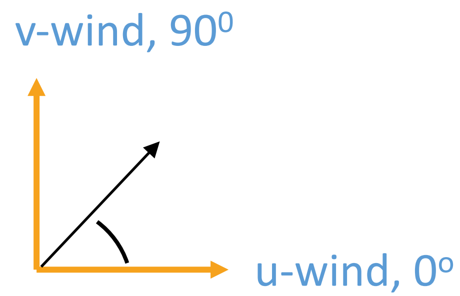


SBPW3 Wind Conventions

- In the workshop atmospheric profiles, X-WIND corresponds to u-wind and Y-WIND corresponds to v-wind
- We following the convention of **Meteorological Vector Winds**

Example: Consider air particles moving from the south west to the north east represented by the black arrow ↗

Meteorological Vector Winds



$$\theta_{met\ vect} = 45^o$$

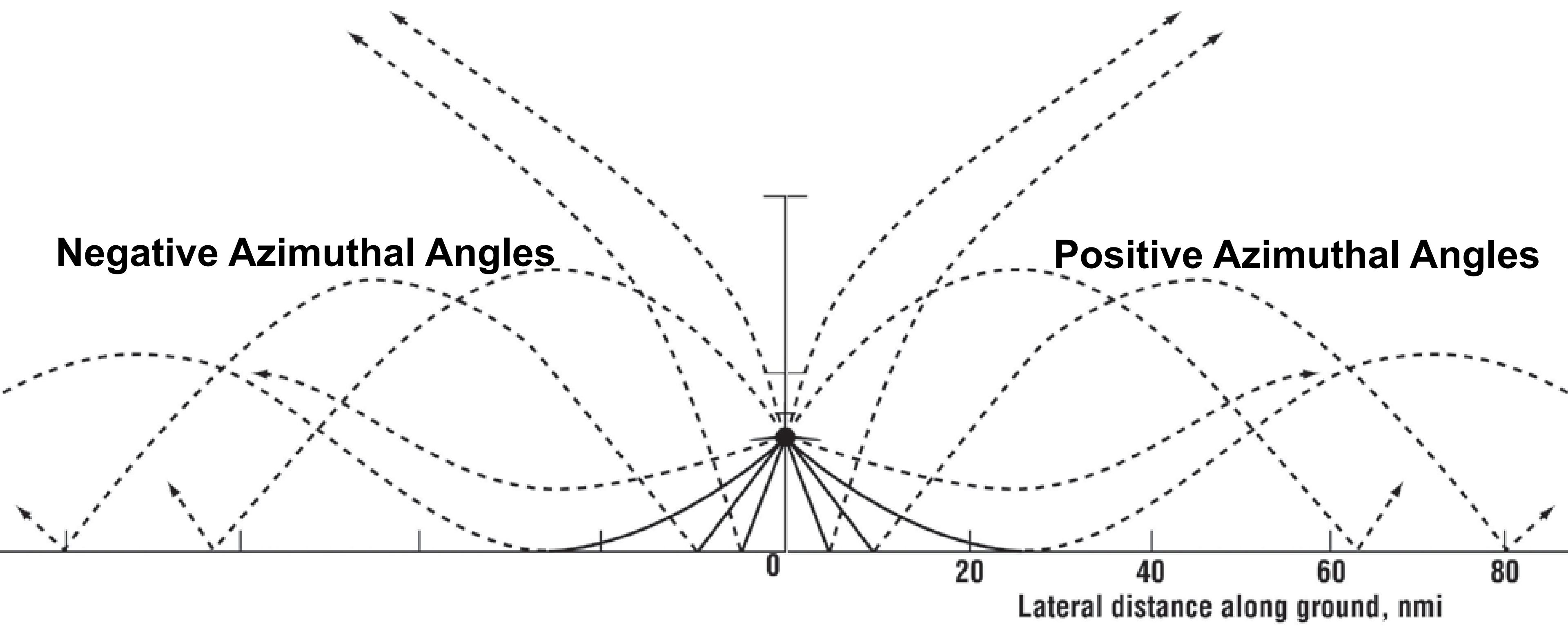
0° Positive u-wind: air particles moving from west to east

90° Positive v-wind: air particles moving from south to north

Modified from original developed by Will Doebler (william.j.doebler@nasa.gov)
NASA Langley Research Center

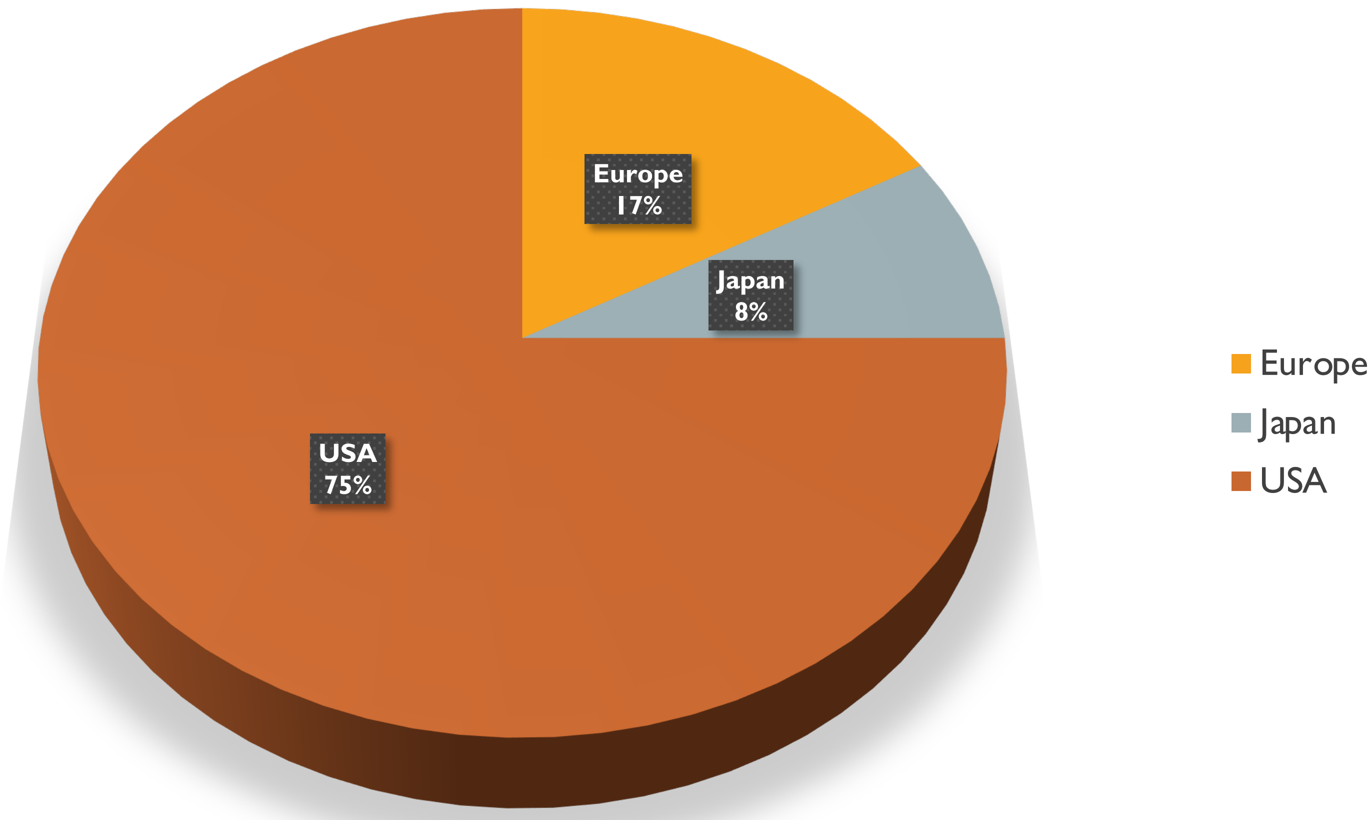
SBPW3 Azimuthal Angle Conventions

Assume aircraft is flying into the plane of the paper



Participants

- 12 separate submissions: P1 – P12



Acknowledgments

- All Participants
- NASA Commercial Supersonic Technology (CST) project
- Boom prediction workshop organizing committee and participants
- Will Doebler for assisting in down-selecting atmospheric profiles

Agenda

7:15 am - 8:00 am	Breakfast	
8:00 am – 8:05 am	Introduction	Lori Ozoroski
8:05 am – 8:30 am	Overview	Sriram Rallabhandi
8:30 am – 9:00 am	NASA Ames	Wade Spurlock
9:00 am – 9:30 am	Dassault	Pierre-Elie Normand
9:30 am – 10:00 am	ONERA	Gerald Carrier
10:00 am – 10:30 am	Break	
10:30 am – 11:00 am	NASA Langley	Sriram Rallabhandi
11:00 am – 11:30 am	Volpe	R. Downs & J. Page
11:30 am – 12:00 pm	Penn State	Luke Wade
12:00 pm – 1:00 pm	Lunch Provided by AIAA included in the registration fee	
1:00 pm – 1:30 pm	NASA Langley	Joel Lonzaga
1:30 pm – 2:00 pm	JAXA	Masashi Kanamori
2:00 pm – 2:30 pm	Boeing	Hao Shen
2:30 pm – 3:00 pm	Break	
3:00 pm – 3:30 pm	Boom Supersonic	Enrico Fabiano
3:30 pm – 4:00 pm	Lockheed Martin	John Morgenstern
4:00 pm – 4:30 pm	FAA	Sandy Liu
4:30 pm – 5:00 pm	Summary	S. Rallabhandi & A. Loubeau
5:00 pm – 5:30 pm	Discussion	

Thank You! – Any Questions?