2nd Boom Prediction Workshop: Overview of Propagation Cases

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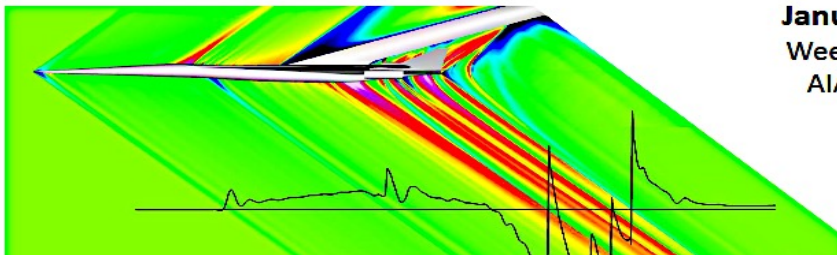
2nd Boom Prediction Workshop Flyer

2nd AIAA Sonic Boom Prediction Workshop
Sponsored by the Applied Aerodynamics Technical Committee

The World's Forum for Aerospace Leadership



January 7-8, 2017
Weekend Preceding
AIAA SciTech 2017
Grapevine, Texas

Second Sonic Boom Prediction Workshop:

The two part workshop will cover both the state-of-the-art for predicting near field sonic boom signatures with CFD as well as propagation of the near field pressures to the ground. Participants are encouraged to apply their best practices for computing solutions for the provided cases. There is particular interest in exploring refinement techniques including grid adaptation and alignment with flow characteristics.

- Low Boom Body-of-Revolution (required).
- Wing-Body (required).
- Full Airplane with Flow Through Nacelles (req.)
- Full Airplane with Powered Nacelles (optional).

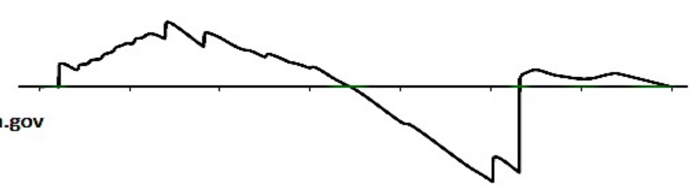
Important Dates:

April 30, 2016:	Notice of Intent Due from Participants.
May 31, 2016:	Acceptance Notification from Committee.
Sept. 30, 2016:	Participant Data Submittal Deadline.
January 7-8, 2017:	**2nd Sonic Boom Prediction Workshop**

Sonic Boom Prediction Workshop Organizing Committee:

Kenrick Waithe	*Boom Technology*
Mike Park, Alexandra Loubeau, Lori Ozoroski, Linda Bangert & Alaa Elmiligui	*NASA Langley*
Susan Cliff	*NASA Ames*
Don Howe	*Gulfstream Aerospace*
John Morgenstern	*Lockheed Martin*
Todd Magee & Eric Adamson	*Boeing*
Yoshi Makino	*JAXA*
Jean-Luc Hantrais-Gervois	*ONERA*
Gecheng Zha	*Univ. of Miami*
Claudio Pita & Erick Gantt	*Pointwise*

For more information:
http://lbpw.larc.nasa.gov/
aiaa-boompw-committee@lists.nasa.gov



Outline

- Motivation and goals
- Boom Propagation and loudness calculation
- Survey to determine cases
- Cases
  - Atmospheric profiles
- Note on atmospheric pressure interpolation
- 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

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Boom Propagation Workshop

- The focus today is on the propagation aspect
- 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

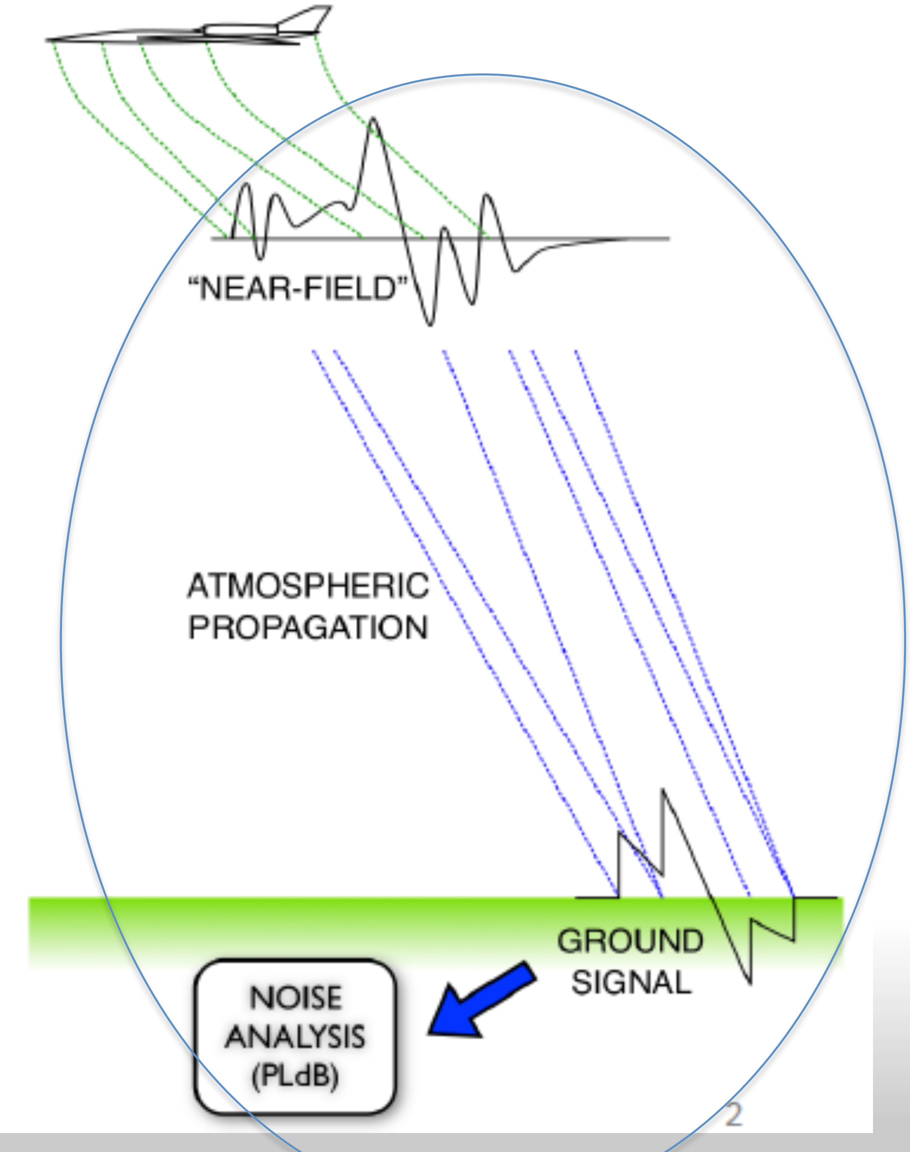
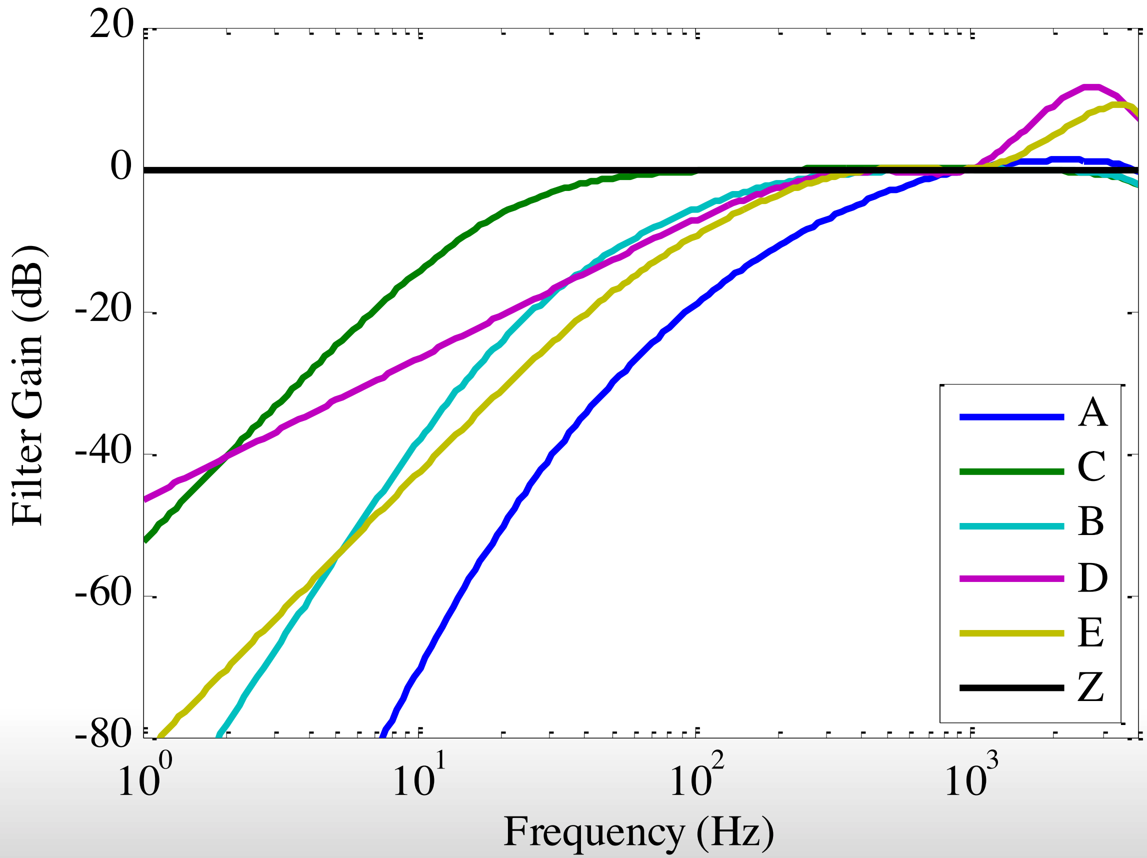


Figure Source: Mathias AIAA xxxx-xxxx

Loudness Calculation

- Several loudness metrics are available: A/B/C/D/E/Z weighting
- Each has different weighting at different frequencies



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Summary of Perceived Level (PL)

- Metric for perceived level of loudness developed by Stevens
  - Developed to predict behavior of human auditory system in response to sound
- Adapted for use with sonic booms by Shepherd and Sullivan
- PL has been shown to correlate well with human perception of sonic booms heard outdoors
  - PL is used today to evaluate supersonic aircraft designs

- Uses signal spectrum in one-third-octave bands
- Uses a set of frequency weighting contours that vary with level
  - (By contrast, A-weighting contour does not vary with level)
  - Based on equal loudness contours for bands of noise
  - Extends down to 1 Hz, but this is an approximation
- Band of highest weighted level is the most important to overall level

S. S. Stevens. Perceived level of noise by Mark VII and decibels (E). J. Acoust. Soc. Am., 51(2):575–601, 1972.
K. P. Shepherd and B. M. Sullivan. A loudness calculation procedure applied to shaped sonic booms. NASA Technical Report TP-3134, 1991.

Calculation Steps for Perceived Level (PL)

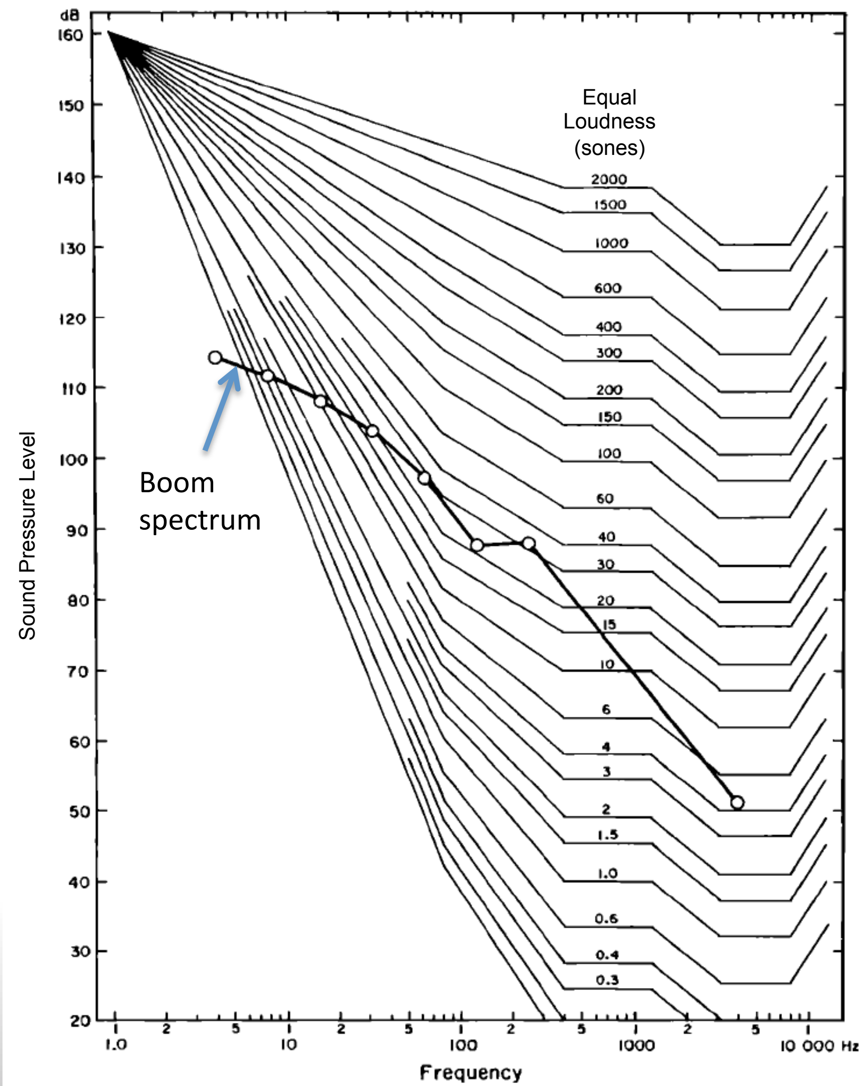
1. Calculate Sound Pressure Level of signal in 1/3-octave bands
2. Apply frequency weighting for loudness of individual bands
   - where loudness of 1 sone is referenced to 1/3-oct band of noise at 3150 Hz at 32 dB
3. Apply summation rule for total loudness

$$S_t = S_m + F(\Sigma S - S_m)$$

where
S_t = total loudness
S_m = loudness of loudest band
ΣS = sum of loudnesses of all the bands
F = fractional factor based on S_m

4. Convert to PL in dB

$$PL = 32 + 9\log_2(S_t)$$

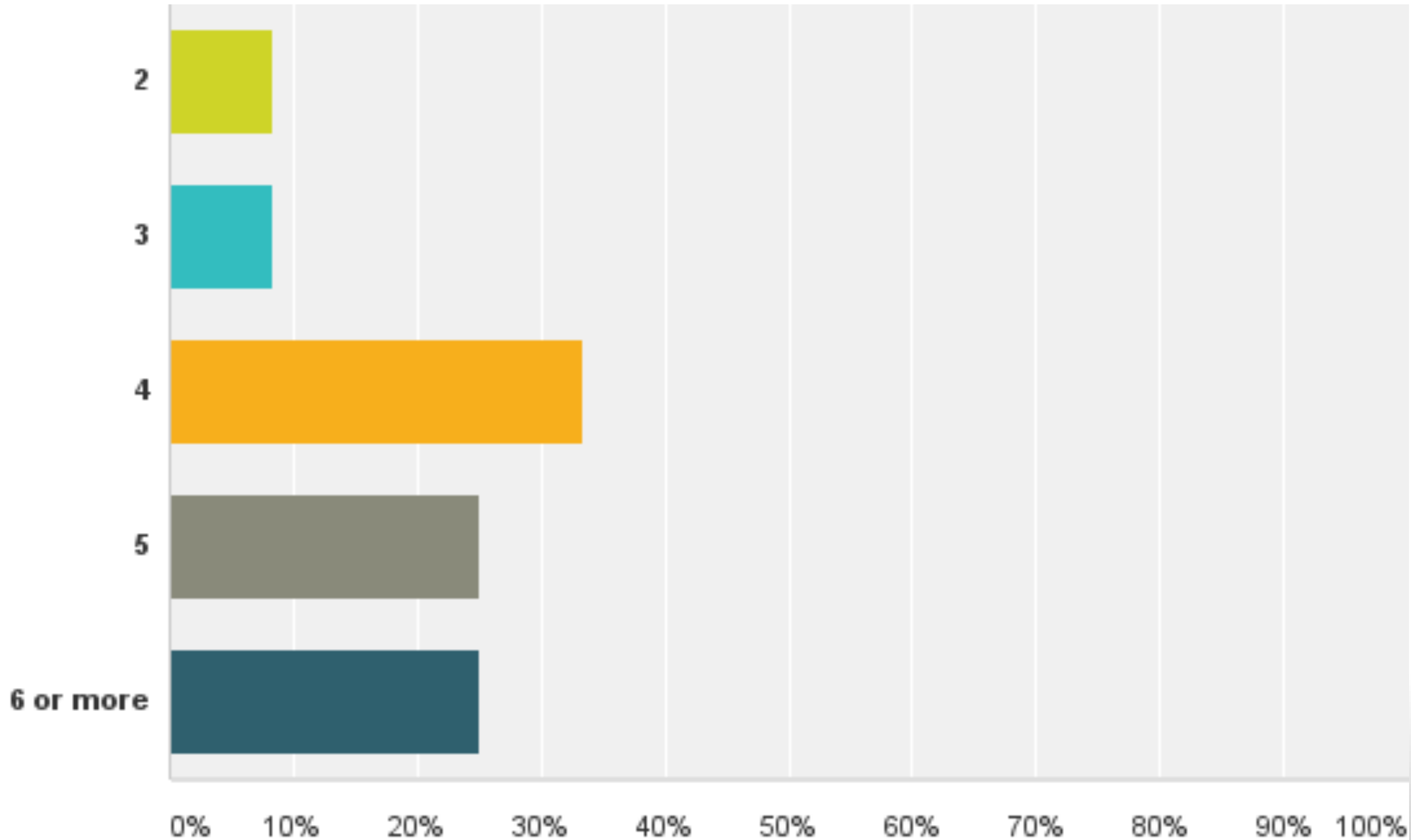


S. S. Stevens. Perceived level of noise by Mark VII and decibels (E). J. Acoust. Soc. Am., 51(2):575–601, 1972.

Survey

Q2: How many propagation test cases should be included in the workshop?

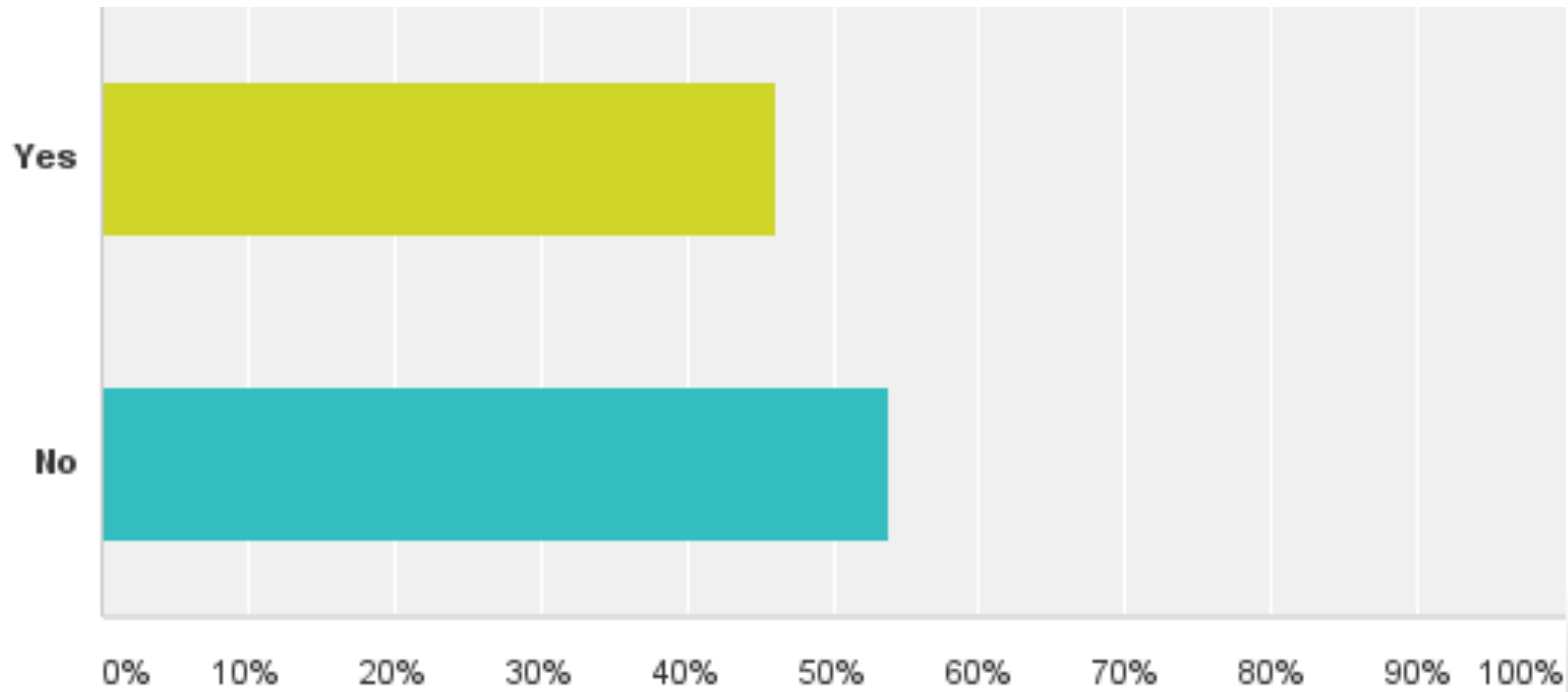
- Answered: 12 Skipped: 1



Survey

Q3: Should the test cases be limited to booms from shaped aircraft designs (i.e., designs that result in undertrack cruise boom PL of 75-85 dB)?

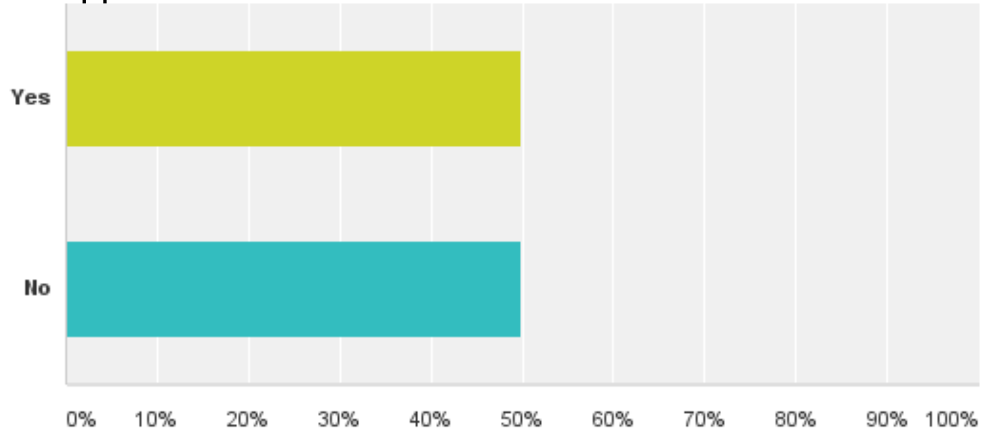
- Answered: 13   Skipped: 0



Survey

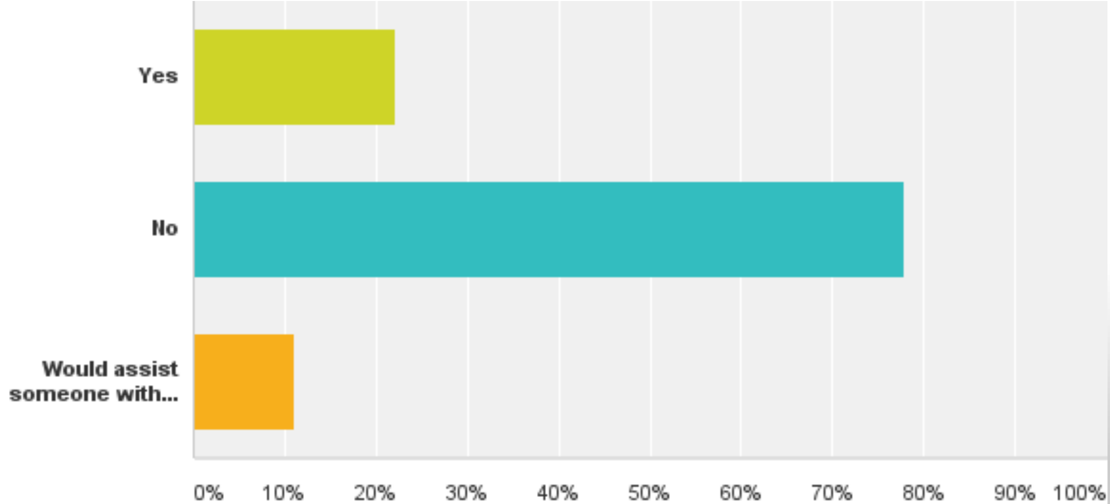
Q4: Should we use waveforms that are tied to an underlying aircraft design/concept?

- Answered: 12 Skipped: 1



Q5: If you answered "Yes" to question #4 above, are you willing to volunteer designs?

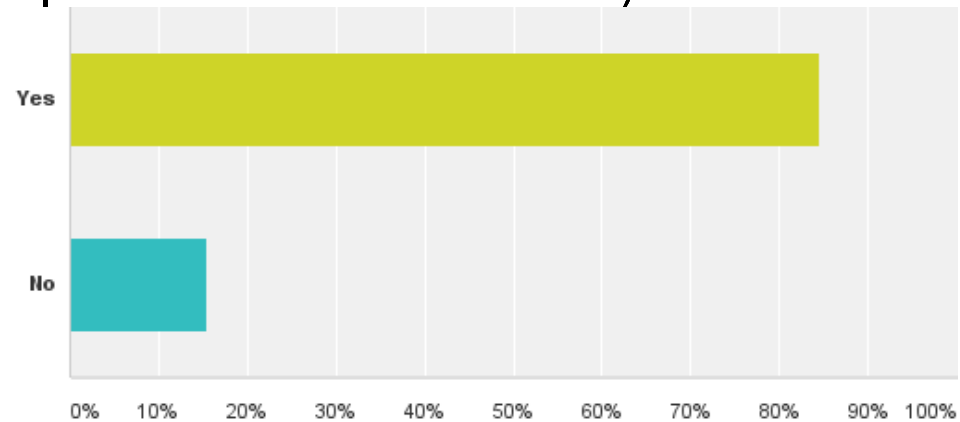
- Answered: 9 Skipped: 4



Survey

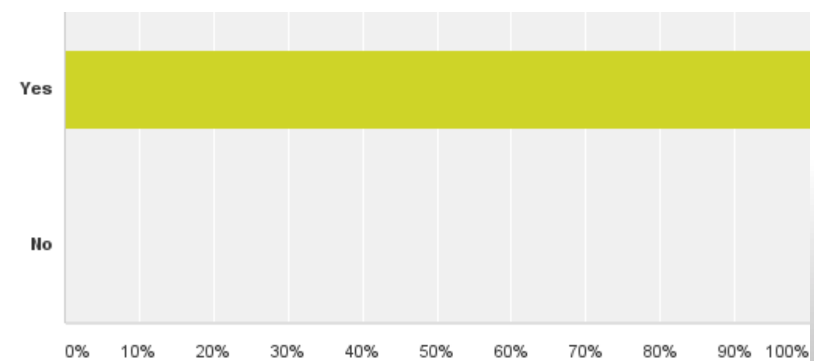
Q6: Should we include the nearfield signature from the shaped aircraft design used in the first Sonic Boom Prediction Workshop (SBPW)? (See http://lbpw.larc.nasa.gov/sbpw1/test-cases/lm-1021/)

- Answered: 13 Skipped: 0



Q7: Realistic atmospheric conditions vary a great deal from the "averaged" standard atmospheric profiles. Should non-standard atmospheres be supplied for at least one case?

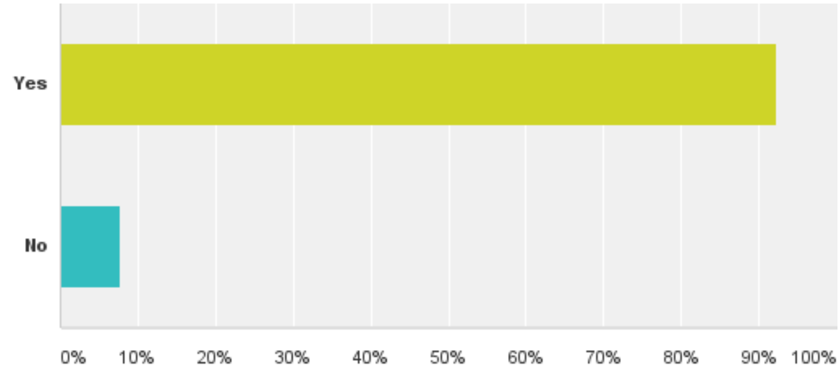
- Answered: 13 Skipped: 0



Survey

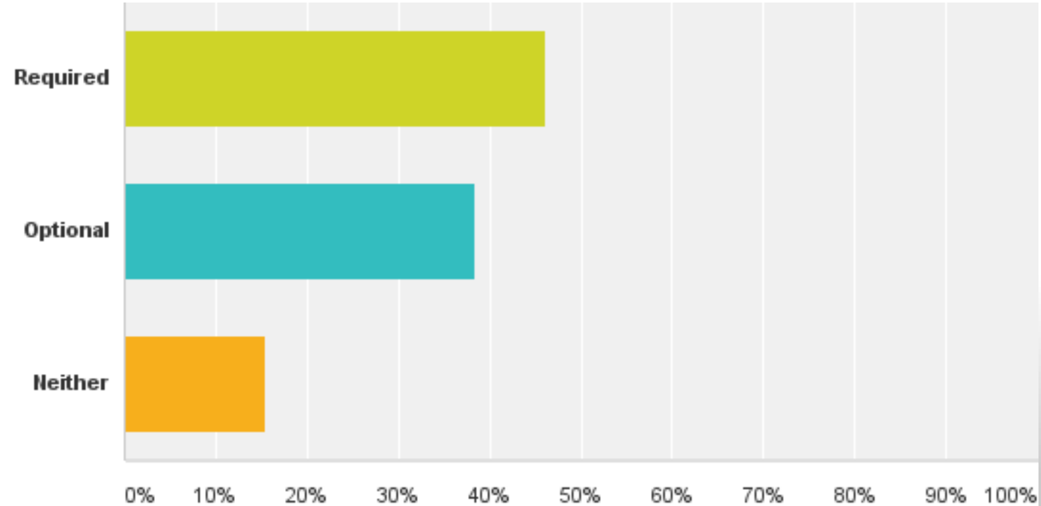
Q9: Should modeling of wind effects be included?

- Answered: 13   Skipped: 0



Q10: Do you think off-track cases should be included as required or optional cases? We could ask for signature predictions at prescribed roll angles and for the limiting ray at lateral cutoff.

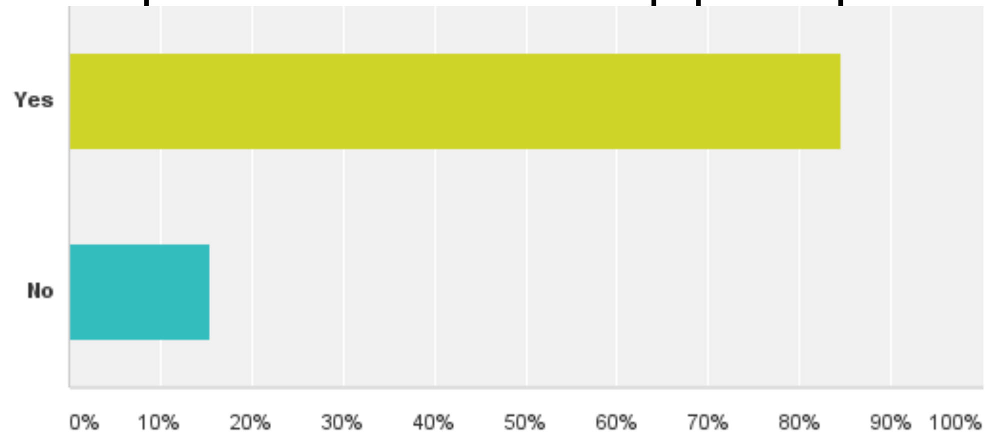
- Answered: 13   Skipped: 0



Survey

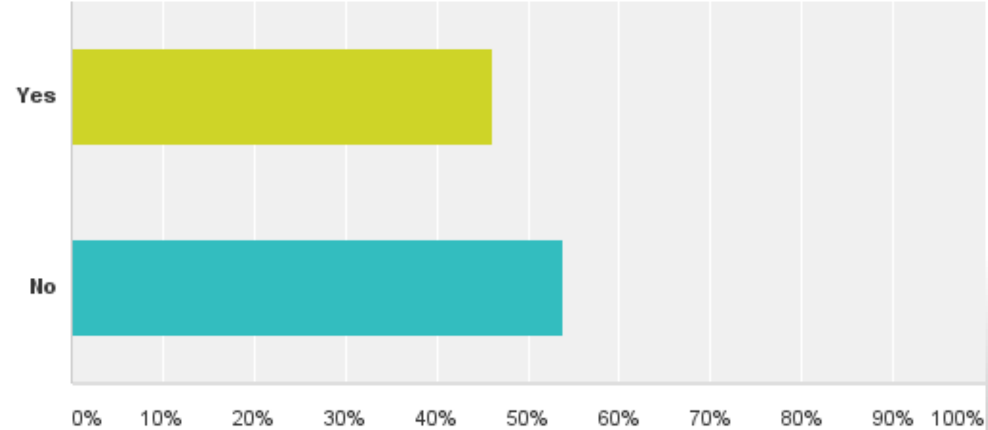
Q12: Do you think ray paths, propagation times, and ground intersection locations should be requested from workshop participants?

- Answered: 13 Skipped: 0



Q14: Do you want the participants to calculate booms from non-focusing aircraft maneuvers such as slow turn rate, climb rates, and mild acceleration?

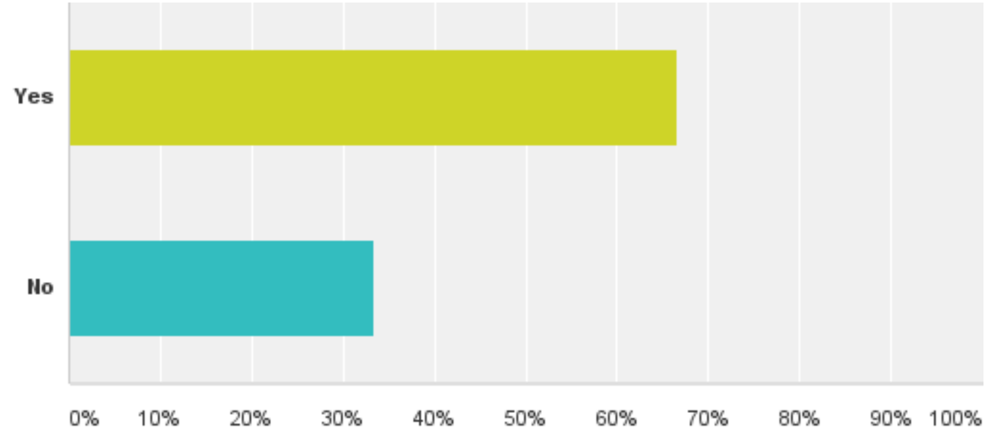
- Answered: 13 Skipped: 0



Survey

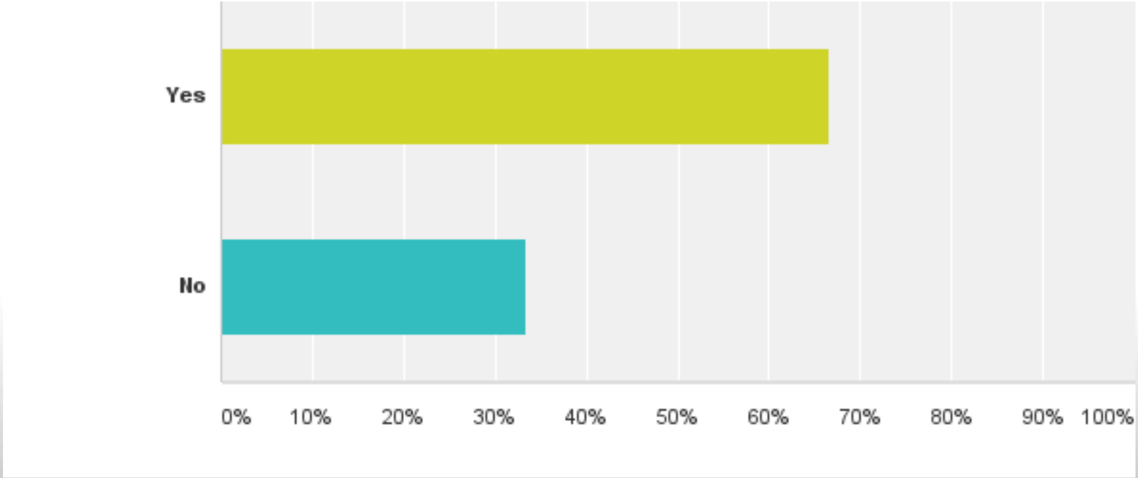
Q16: Should we ask for sampling frequency and step size?

- Answered: 12 Skipped: 1



Q17: Should we ask for convergence histories if multiple sampling frequencies and step sizes are used?

- Answered: 12 Skipped: 1



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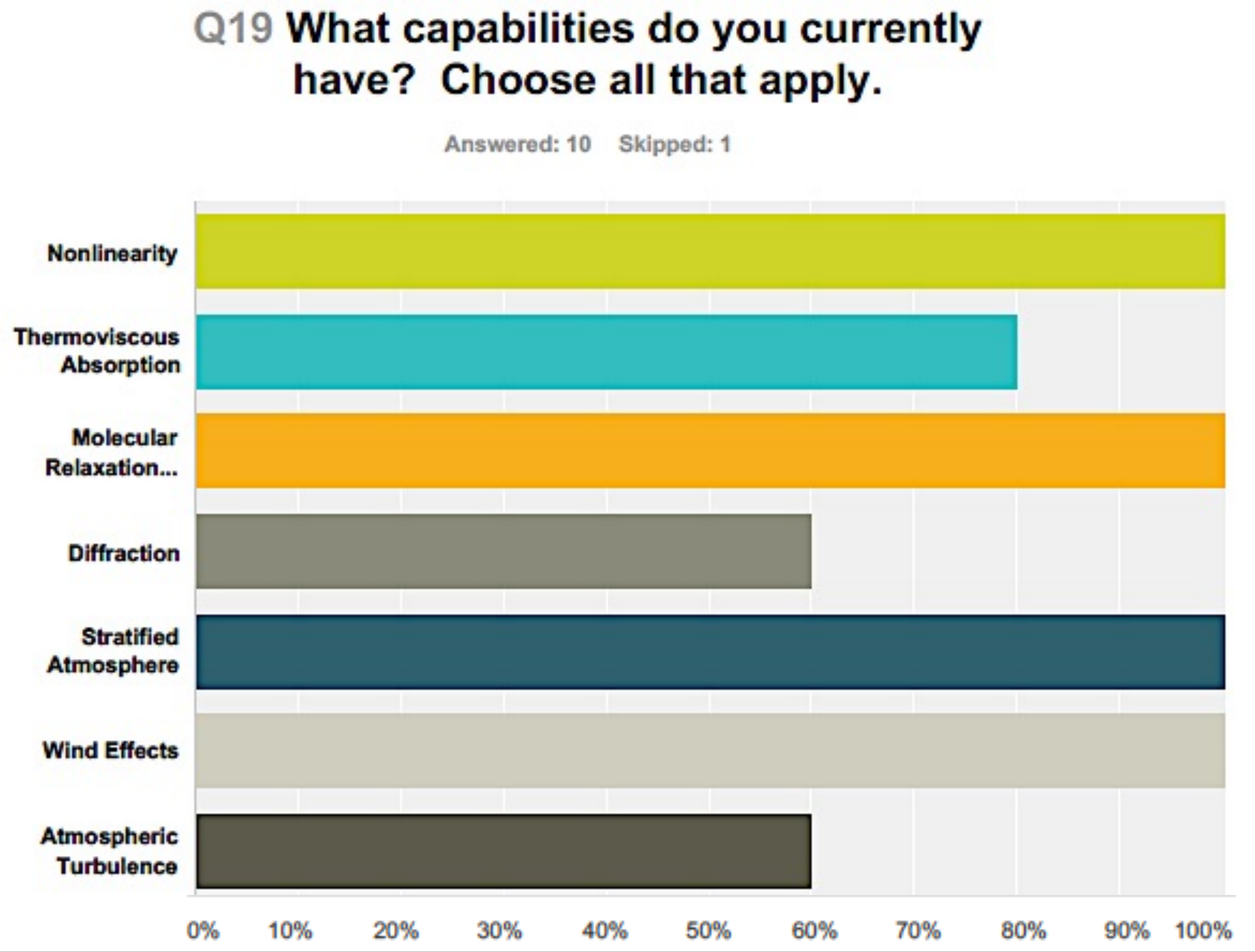
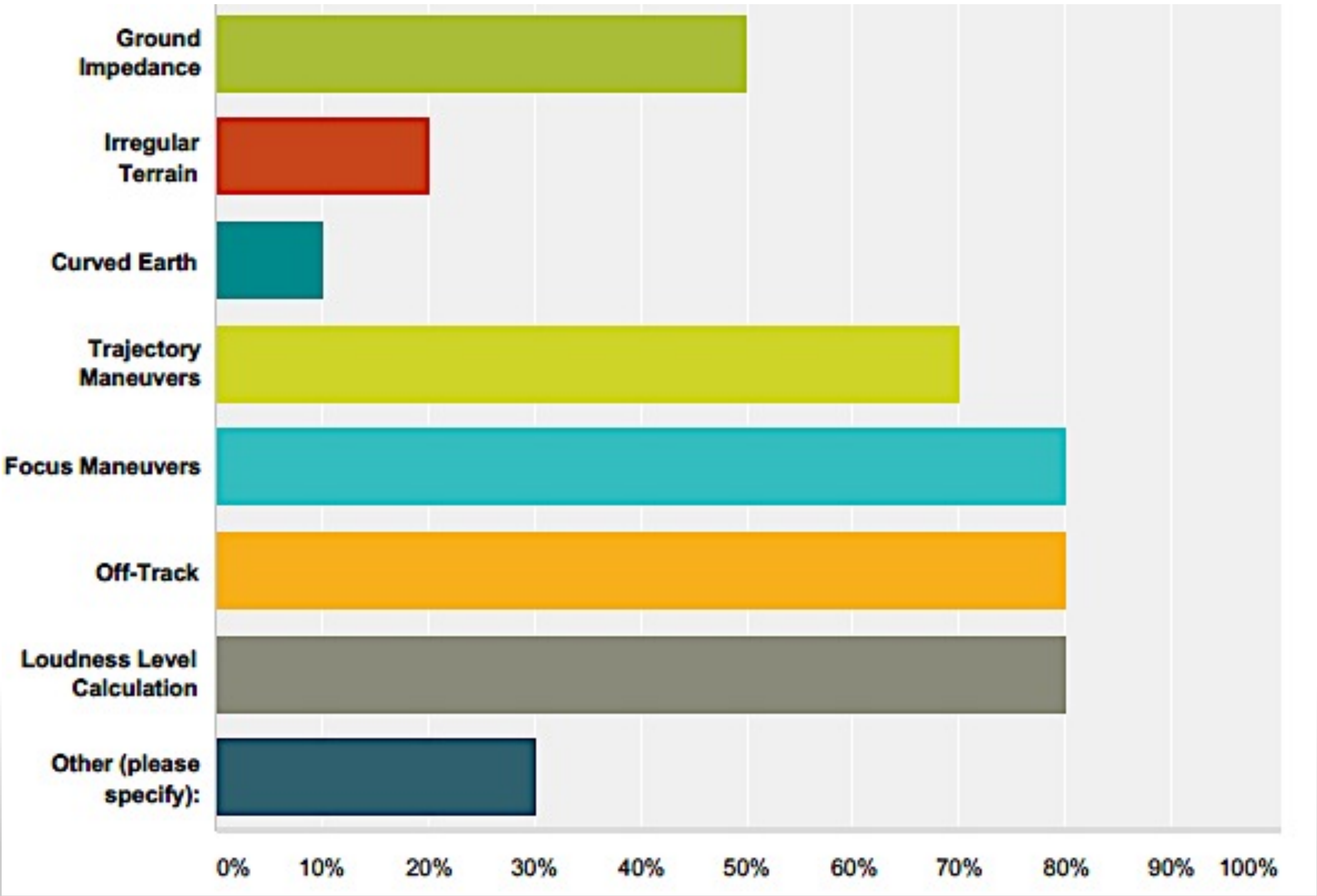

Q19 What capabilities do you currently have? Choose all that apply.
Answered: 10 Skipped: 1
Nonlinearity
Thermoviscous Absorption
Molecular Relaxation...
Diffraction
Stratified Atmosphere
Wind Effects
Atmospheric Turbulence
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Survey



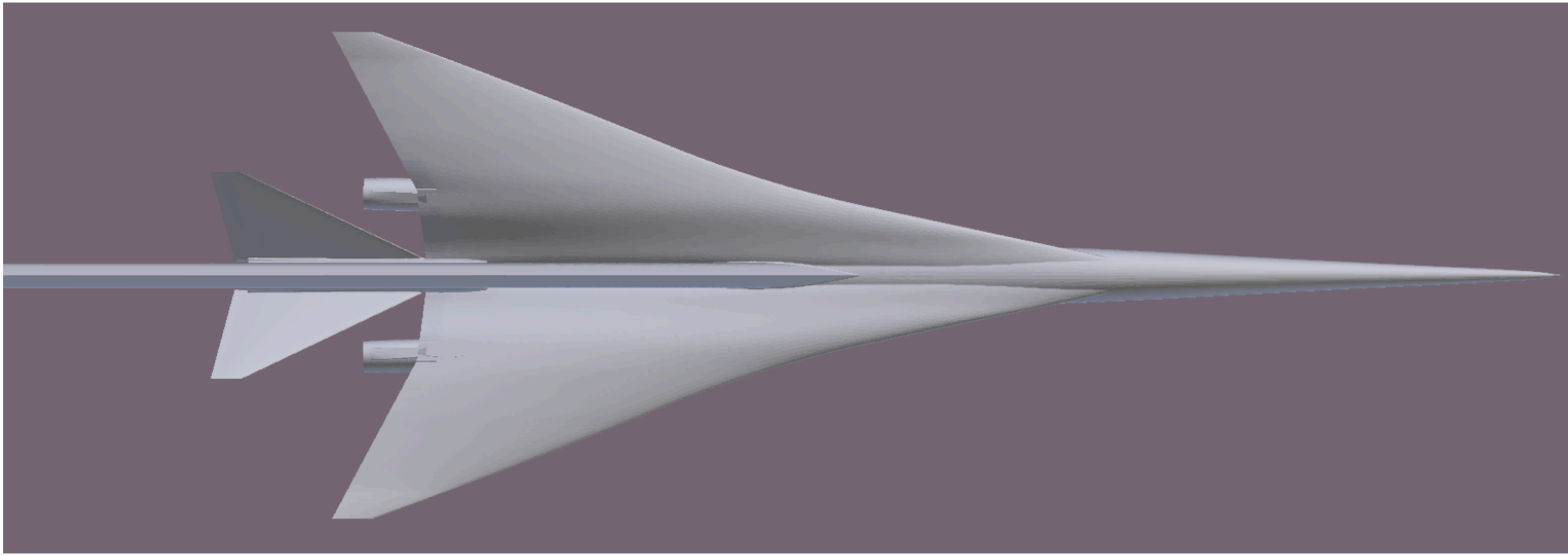
Ground Impedance
Irregular Terrain
Curved Earth
Trajectory Maneuvers
Focus Maneuvers
Off-Track
Loudness Level Calculation
Other (please specify):
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

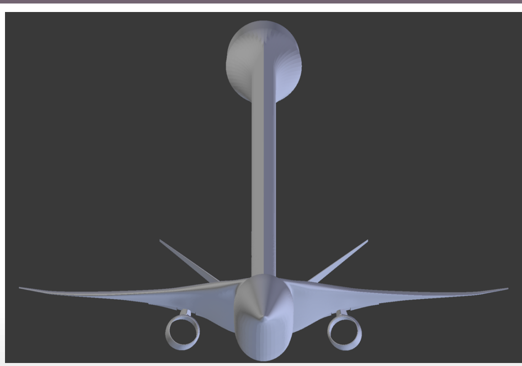
Overview of Cases (1)

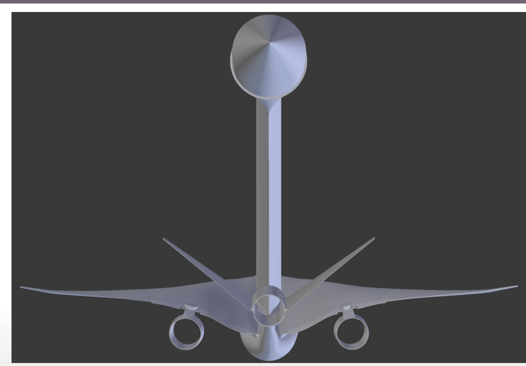
CASE 1: NASA N+2 LM 1021-01 Configuration

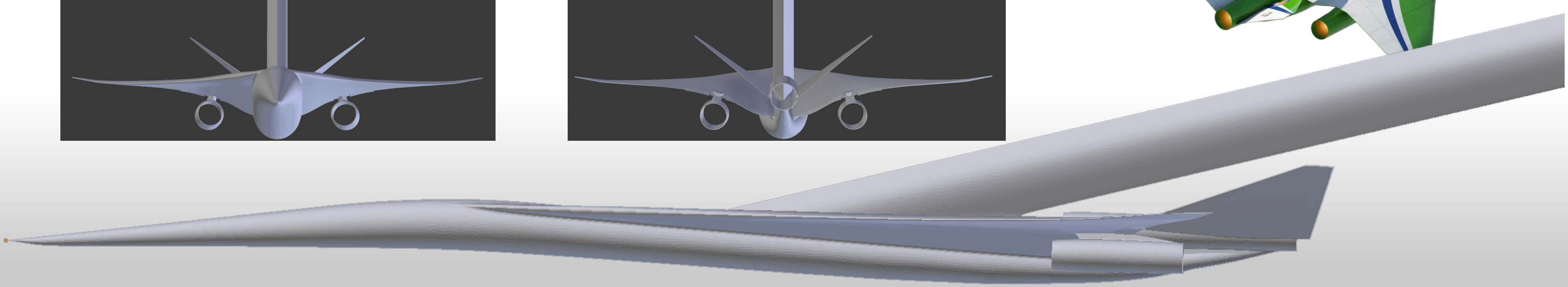
- Used as an optional near-field case in the 1st sonic boom prediction workshop
- Flow Conditions: M=1.6, Altitude = 55000 ft, R/L = 3.1299, L = 233.33 ft
- Heading East
- Required Run:
  - Extrapolate at roll angles of -30^0, 0^0, and 30^0 using atmospheric profile 1
- Optional Runs:
  - Extrapolate at roll angles of -30^0, 0^0, and 30^0 using a standard atmospheric profile
  - Extrapolate at roll angles of -30^0, 0^0, and 30^0 using atmospheric profile 2
  - Extrapolate at roll angles of -30^0, 0^0, and 30^0 using a standard atmospheric profile, but fixing the relative humidity to 70% at all altitudes
- Required Data:
  - Ground signatures and sampling frequencies
  - Lateral cut-off angles on both sides of the carpet
- Optional data:
  - Compute ground signatures corresponding to the lateral cut-off angle
  - Loudness metrics (PL, ASEL) corresponding to all the ground signatures reported
  - Loudness convergence history

Case 1: LM1021









Images from Aftosmis, Nemec; SBPW1 Presentation

Case 1: LM1021

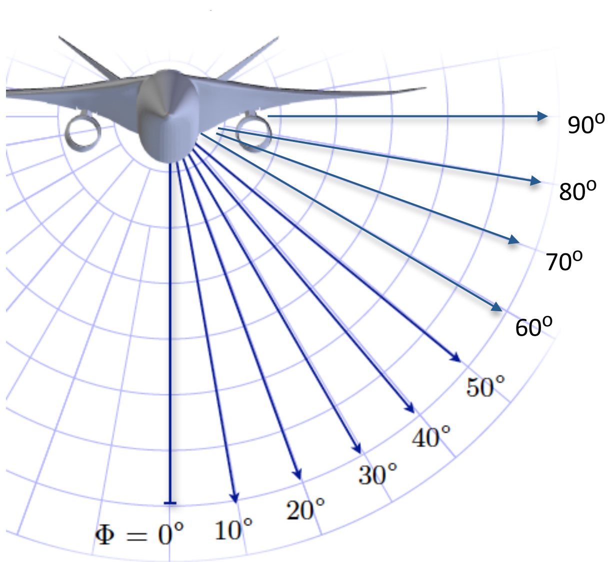
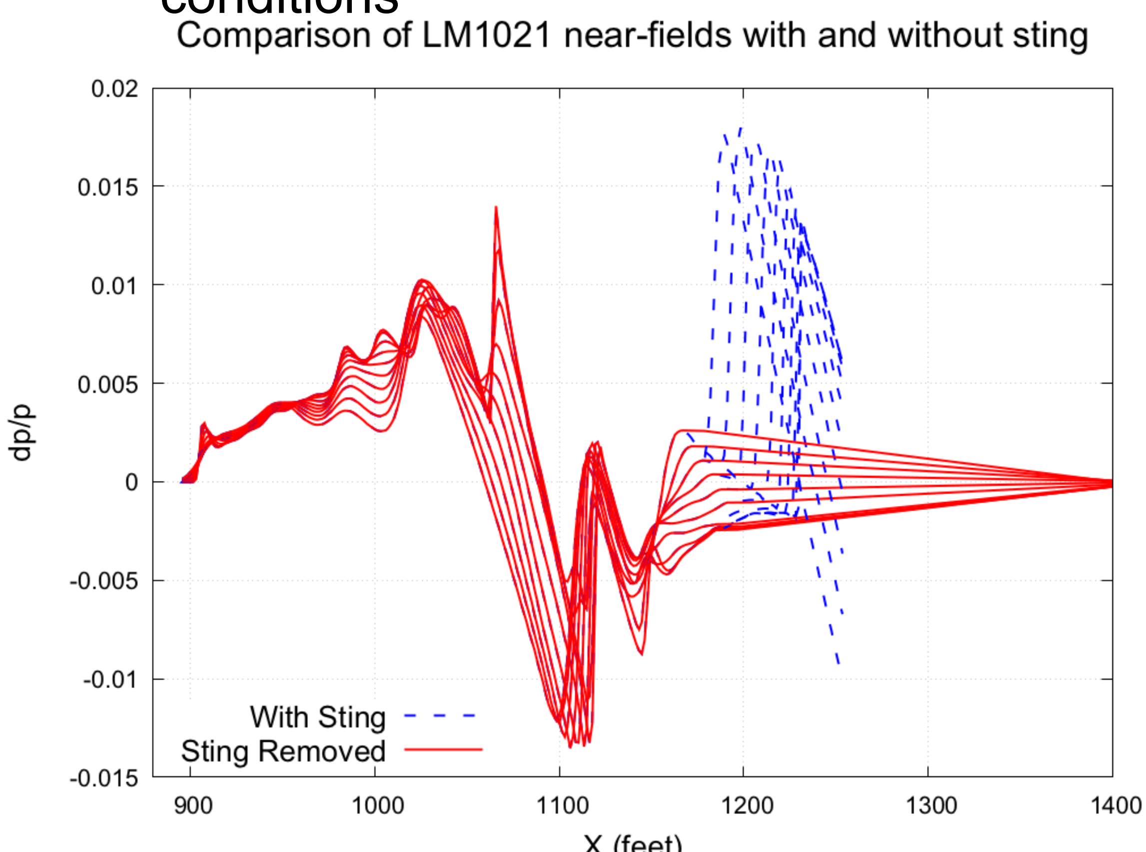


Image from Aftosmis,Nemec; SBPW1 Presentation

- Near-field pressure profiles contained dp/p at 10^0 intervals as shown, including the sting
  - Removed the sting contribution
  - Closed-out linearly to ambient pressure conditions



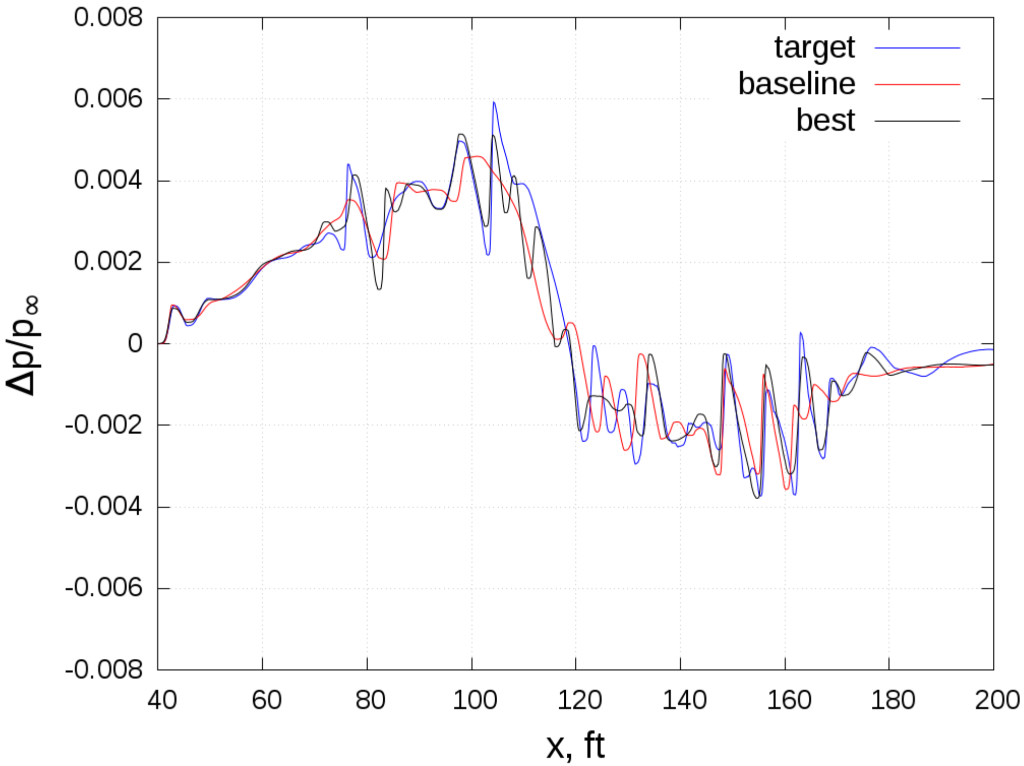
Overview of Cases (2)

CASE 2: Axi-symmetric body of revolution

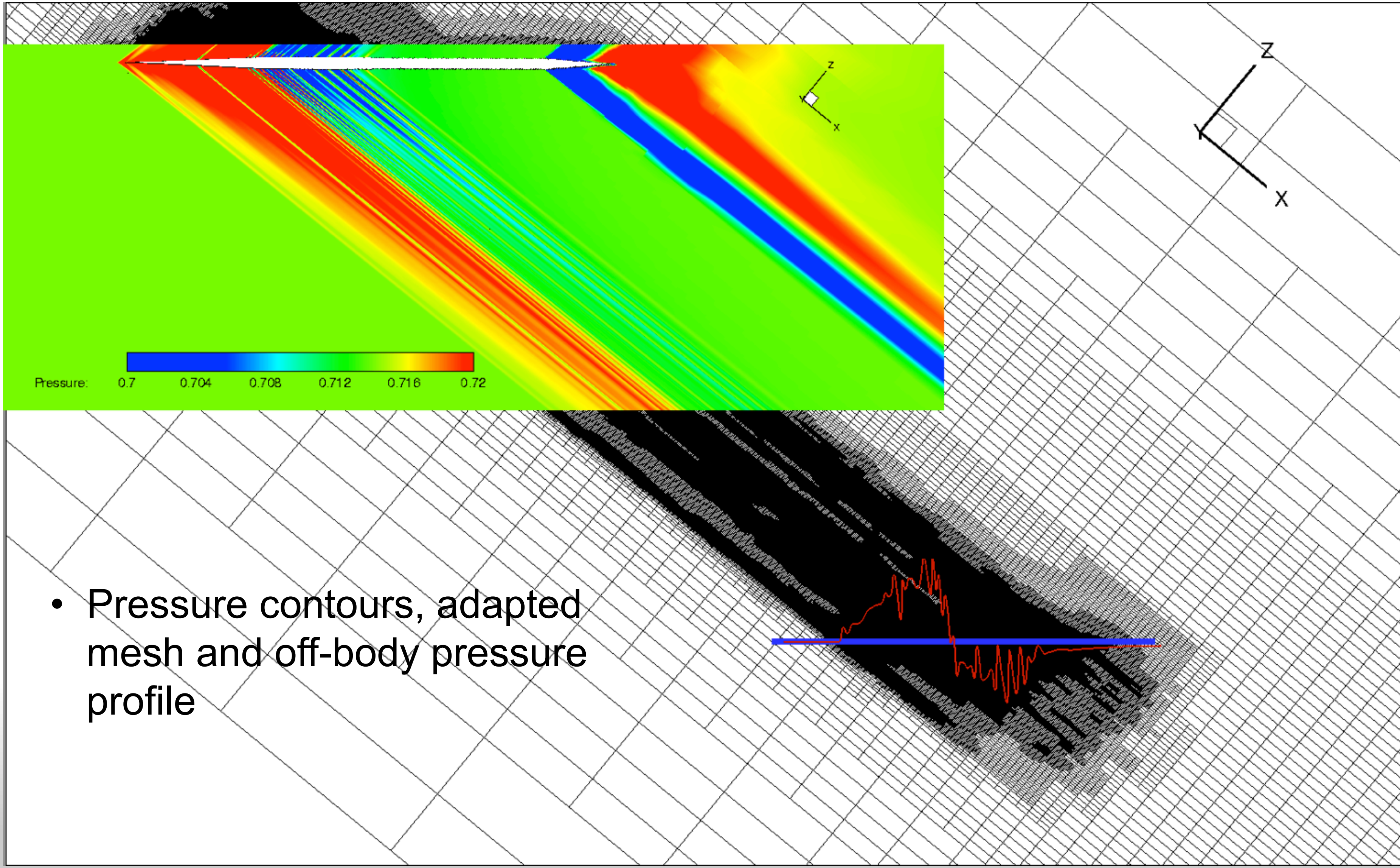
- Generated by CART3D design framework to match NASA Concept25d's near-field waveform at 3BL
- Flow Conditions: M=1.6, Altitude = 52000 ft, R/L = 3.0, L = 141.0 ft
- Heading East
- Required Run:
  - Extrapolate at roll angles of -45^0, 0^0, and 45^0 using a atmospheric profile 3
- Optional Runs:
  - Extrapolate at roll angles of -45^0, 0^0, and 45^0 using a standard atmospheric profile
  - Extrapolate at roll angles of -45^0, 0^0, and 45^0 using a atmospheric profile 4
  - Extrapolate forms at roll angles of -45^0, 0^0, and 45^0 using a standard atmospheric profile, but fixing the relative humidity to 70% at all altitudes
- Required Data:
  - Ground signatures and sampling frequencies
  - Lateral cut-off angles on both sides of the carpet
- Optional data:
  - Compute ground signatures corresponding to the lateral cut-off angle
  - Loudness metrics (PL, ASEL) corresponding to all the ground signatures reported
  - Loudness convergence history

Case 2: Axi-symmetric body of revolution

- Used Concept 25D from the near-field workshop as a starting point
  - Could not use the dp/p directly from C25D
  - Used C25D dp/p as target, and attempted to generate an axi-symmetric body of revolution to closely match the dp/p
  - Cart3D simultaneous adjoint-based mesh adaptation and optimization were used
  - After a couple of passes, did not attempt to drive the design closer to the target



Case 2: Axi-symmetric body of revolution



- Pressure contours, adapted mesh and off-body pressure profile

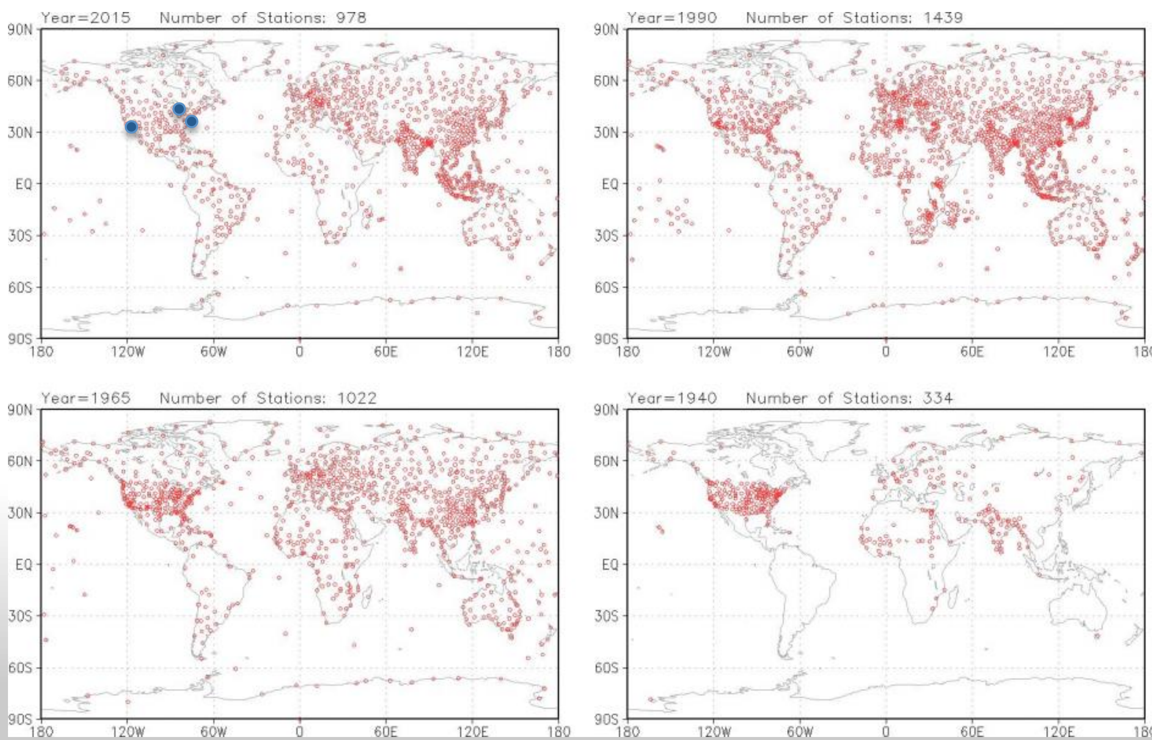
Atmospheric Profiles

Objective:

- Obtain realistic atmospheric data that can provide a "large-enough" variation in loudness metrics

Approach:

- NOAA's Integrated Global Radiosonde Archive (IGRA[1]) contains a database of measured soundings at 978 active sites; a diverse population of observed upper-air measurements
- Offers a way to model geographical and seasonal variations in sonic boom metrics
- For this study three locations were chosen: Wallops Island (VA), Edwards AFB (CA), Green Bay (WI)

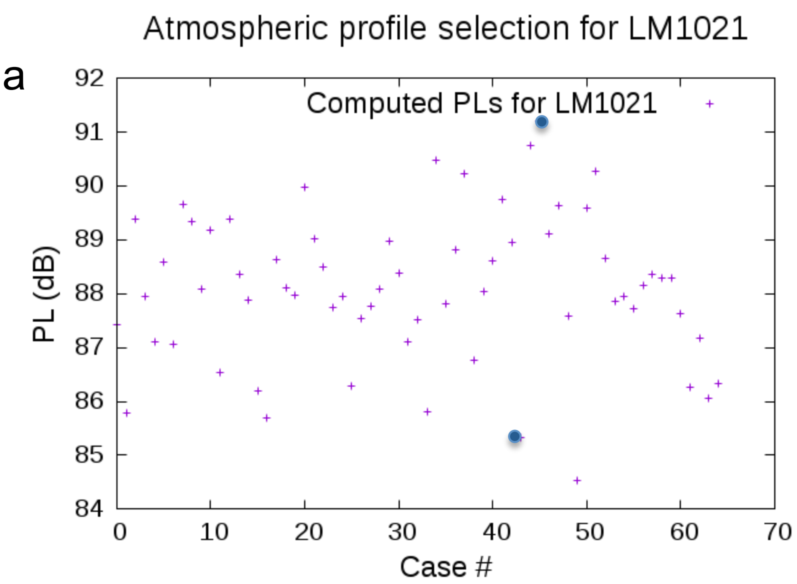


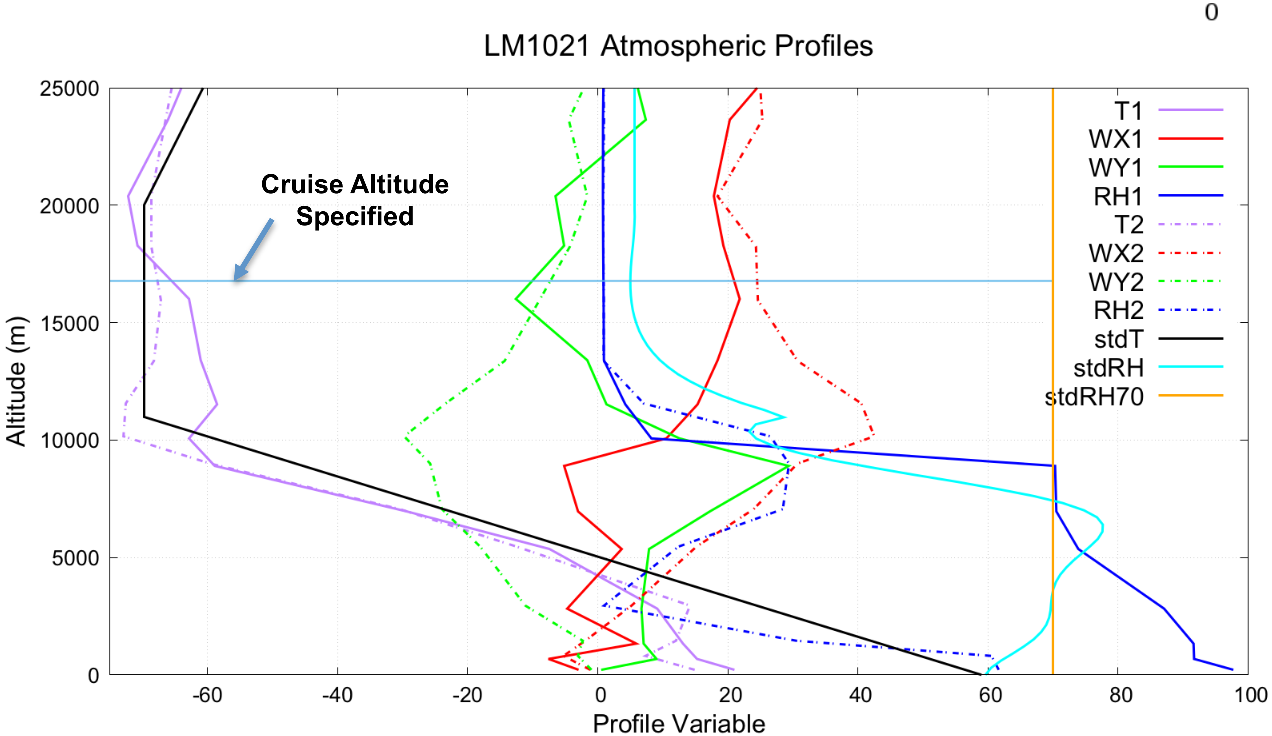
[1]https://www.ncdc.noaa.gov/data-access/weather-balloon/integrated-global-radiosonde-archive

CASE 1 Profiles

Approach:

- Took all valid profiles at the three chosen locations in a winter month (February, 2013)
- Propagated LM1021 near-field to the ground-level at the corresponding location and computed loudness metrics for each atmospheric profile
- Picked two profiles that generated the best and worst loudness
- Only under-track loudness used in profile selection



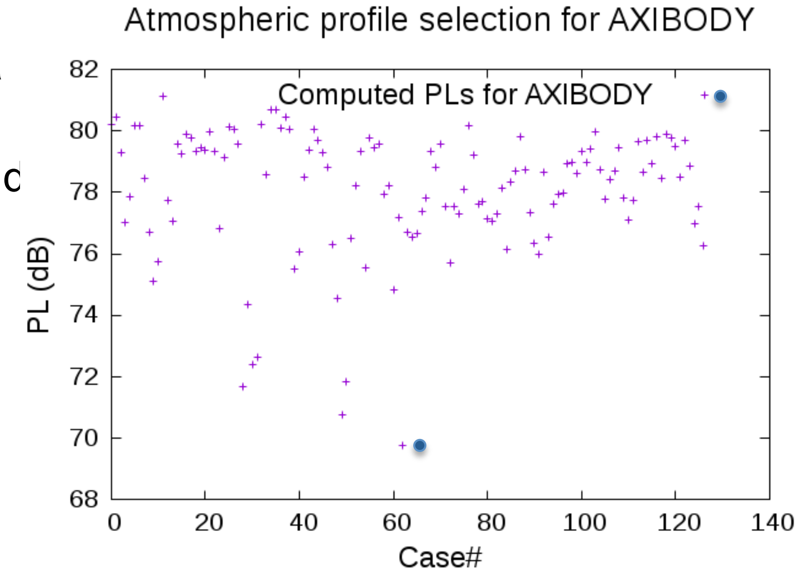


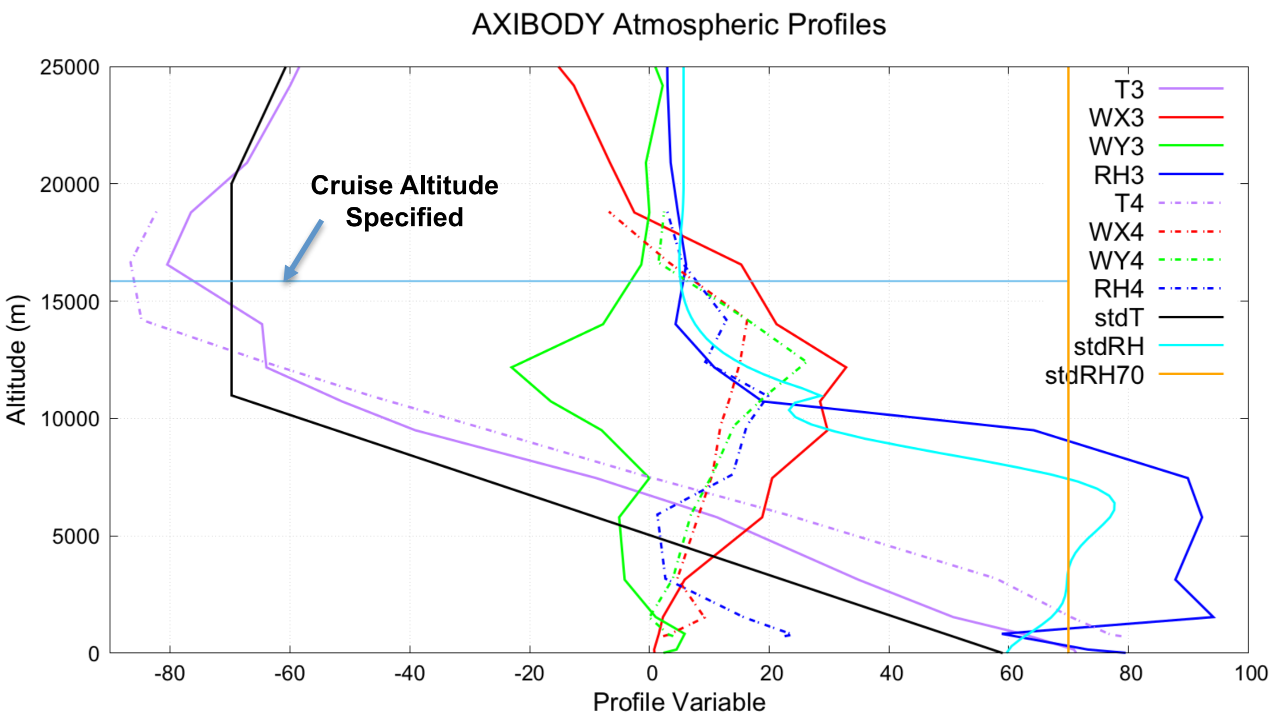
- Both profiles were from Green Bay,WI on consecutive days, February 17th and 18th
- Profile 1 has one of the highest PL, and profile 2 has one of the lowest PL

CASE 2 Profiles

Approach:

- Took all valid profiles at the three chosen locations in a summer month (August, 2012)
- Propagated Axi-symmetric body near-field to the ground level at the corresponding location and computed loudness metrics for each atmospheric profile
- Picked two profiles that generated the best and worst loudness
- Profiles compared against standard atmosphere

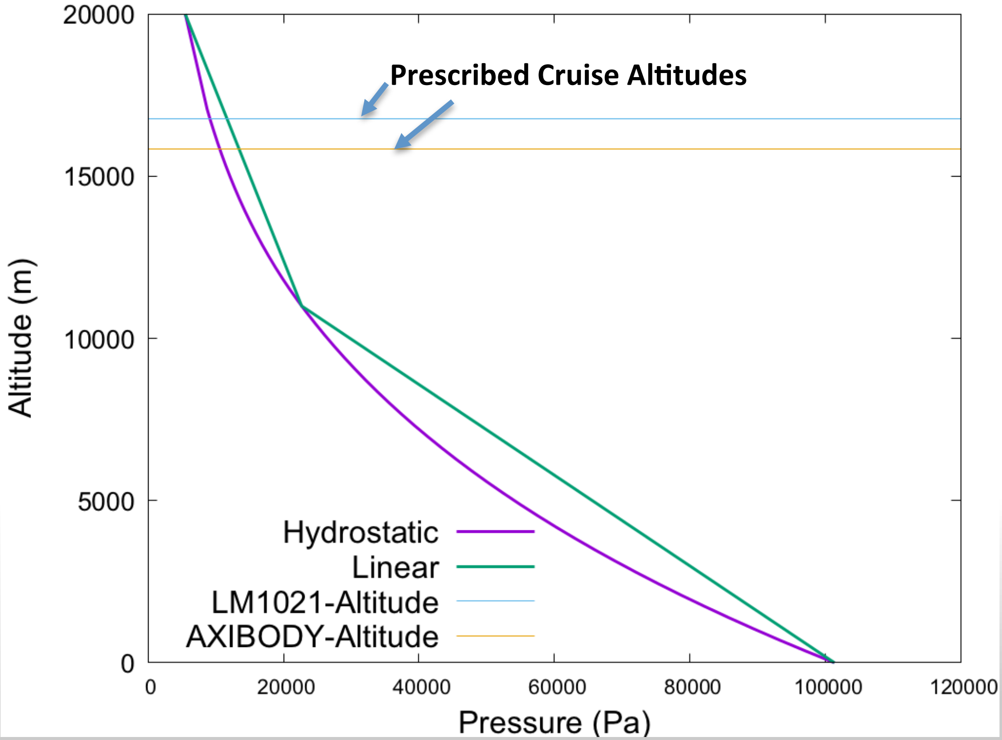




- Profile 3 (Higher PL) is measured at Wallops, on August 1, and 5PM
- Profile 4 (Lower PL) is measured at Edwards AFB, on August 6 at 12 PM

Atmospheric Pressure Interpolation

- Specified atmospheric pressure, but originally failed to specify interpolation scheme, assumed everyone would use hydrostatic
- During first submissions, some participants used linear interpolation
  - Mainly affects the conversion from dp/p to dimensional units (~20-30% difference)
  - Sent out an email (November 15) to resubmit if possible
  - Included a finer resolution of all pressure profiles for participants to use
- For fair assessment, comparisons made against both interpolation schemes



Participant List

- Submissions received from
  - ONERA
  - Gulfstream
  - Spike Aerospace – Submitted results, but not here today
  - JAXA
  - NASA Ames
  - NASA Langley – originally 3, but two dropped out
  - Dassault
  - Volpe (2)
  - Lockheed Martin
  - Boeing

Acknowledgments

- NASA Commercial Supersonic Technology (CST) project
- Boom prediction workshop organizing committee and participants
- Donna Speller Turner, OHCM for compiling survey
- Tom Ozoroski, ASAB, NASA Langley for help with IGRA
- Irian Ordaz, Mike Aftosmis for Cart3D related discussions
- Juliet Page for help figuring out the atmospheric pressure interpolation discrepancy

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Summary

- More to follow after the participant talks