Propagation and Radiation

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- Beom Soo Kim – PhD
- Amanda Lind – PhD
- Kieran Poulain – Masters (ACS)
- Rachel Romond – PhD
- Joyce Rosenbaum – PhD
- Joe Salamone – PhD
- Brian Tuttle – PhD
Last Year’s Highlights

Graduate Students:
Sang Cho – PhD
Andrew Christian – Masters (ACS)
Whitney Coyle – PhD
Alexandre Jolibois – PhD
Kim Riegel – PhD
Beom Soo Kim – PhD
Amanda Lind – PhD
Denise Miller – PhD
Kieran Poulain – Masters (ACS)
Joyce Rosenbaum – PhD
Joe Salamone – PhD
Brian Tuttle – PhD
Today’s Highlights

Graduate Students:
  Sang Cho – PhD
  Andrew Christian – Masters (ACS)
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  Alexandre Jolibois – PhD
  Kim Riegel – PhD
  Beom Soo Kim – PhD
  Amanda Lind – PhD
  Rachel Romond – PhD
  Kieran Poulain – Masters (ACS)
  Joyce Rosenbaum – PhD
  Joe Salamone – PhD
  Brian Tuttle – PhD
Update on sonic boom propagation

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and
Ph.D. defense of Kim Riegel
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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of PARTNER sponsoring organizations.
Selected Research Highlight

• PARTNER Center Project 8 extension of NASA-sponsored research on ray-tracing model for sound around buildings
  – Penn State University
  – Investigators: K. Riegel and V. Sparrow
  – Ph.D. thesis will be released soon.

• Predict sound levels in urban canyons
  – Improved outdoor signatures needed for subjective tests and for use as input to outdoor-indoor transmission models
  – Method: Ray-tracing with/without radiosity (diffusion model)
    • Diffusion: NON-SPECULAR reflections
  – Preliminary result: there is no “buildup” of sound energy in between buildings during the passage of a sonic boom
Urban Canyon

Environment 1

Environment 2

Boom Direction
Input Signal

<table>
<thead>
<tr>
<th>Material</th>
<th>63 Hz</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
<th>8000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Varied Parameters

• Diffusion – 0% or 50%
• Elevation Angle – 20° and 40°
• Azimuthal Angle – 0°, 45° and 90°
• Heights – 3 meters, 6 meters, 12 meters, 24 meters
  – 1, 2, 4, and 8 stories
• Width – 5.5 meters, 9 meters, 16 meters
  – 1 meter sidewalk on each side
  – 1 lane, 2 lanes, or 4 lanes
Frequency Range

• Using PLdB requires that all frequency content is included for analysis
  – Makes the results more comparable to other sonic boom studies

• 12 and 24 meter building this will be accurate except at the very lowest frequencies

• 3 and 6 will be accurate for a much smaller range of frequencies
Single City Block – Signal Shape

- Diffusion significantly changes the shape of the signals
  - Reduces amplitude significantly
- No trend in amplitude as height increases
Single City Block - Sidewalk

• Note the regular pattern of shadow zones
  – Increased number of shadow zones with height

• 0° azimuthal angle
  – No trend observed with any of the varied parameters

• Consistently lower PLdB for 50% diffusion
  – Regular pattern along sidewalk
**Single City Block**
- **Wall**
  - These movies show the stark shadow zones
    - Distinct patterns
  - Diffuse shows less stark shadow zones
    - Lower levels all around
  - 45° azimuthal angle, 20° elevation angle
Four-way Intersection – Signal Shape

- Microphone A has very similar signal shapes to the previous environment
- Microphone B has similar shape to no buildings for all 0° azimuthal angle runs
Four Way Intersection - Sidewalk

- Still has strong shadow zones
  - Continued through the other side of the intersection
- 0° azimuthal angle clearly shows the intersection in the PLdB levels
- Diffuse PLdB is still lower next to the buildings
Four Way Intersection - Wall

- Gap in the buildings are obvious here
- Still has a distinct pattern of shadow zones

No diffusion

50% diffusion
Conclusions

• PARTNER work on understanding low-boom sonic booms continues.

• Current work shows
  – It is possible to model sonic boom reflections around high-rise buildings (skyscrapers)
  – Importance of diffuse sound energy
  – No “buildup” of sound energy
  – For tall buildings, sometimes little sound energy makes it to the ground

• Work is continuing in related PARTNER projects.

Reference

Source Emission and Propagation
Project 2

Presentation by Vic Sparrow, lead investigator
Hua (Bill) He, project manager

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Modified from slides for
18th Advisory Board Meeting
March 27-29, 2012
Arlington, VA
Motivation

- Develop improved models for the emission of sound from aircraft and propagation from source to receiver
- Enhance AEDT* and its impact on aviation environmental management

Tasks of previous years
- Thrust reverser operations during landing
- Low frequency propagation
- Effects of terrain and meteorology and long range propagation

Task just completed
- High altitude en-route noise

Task just underway
- Linking AERMOD/AERMET meteorology outputs to noise propagation models

*AEDT: Aviation Environmental Design Tool
Motivation for en-route modeling

- Need to predict noise over broad area
  - current aircraft
  - future advanced propulsions, such as open rotor
- Technical gaps in modeling sound propagation at long ranges

Objective

- Improve models of sound propagation from cruise altitude

Context

- Concerns over noise impact in low-ambient noise areas such as natural parks
- Need to model noise in all phases of flight
Funding / participants

• Past year funding from FAA’s ATMP* noise research program (Western Pacific Office). Progress still reported to and managed under COE/Partner. Contracts managed by DOT Volpe National Transportation Systems Center

• Contract to Penn State
  – Victor Sparrow, Kieran Poulain

• Volpe project management team
  – Eric Boeker, Noah Schulz, Clay Reherman

• FAA PARTNER Bridge Funding 2011/2012
  – Penn State: Victor Sparrow, Rachel Romond

*ATMP: Air Tour Management Plan
Propagation Plan / Schedule (Penn St.)

• Project officially started on February 4, 2011

• Task 1: Assess existing models to accurately account for long distance noise propagation
  – Due 3 August 3, 2011  Delivered on time.

• Task 2: Assess need for additional en-route data
  – Due August 3, 2011  Delivered on time.

• Task 3: Develop recommendations for modification of existing tools to model long distance noise propagation
  – Tech. report on using AEDT noise source databases with updated propagation algorithms due November 4, 2011
  – Final reports due March 29, 2012  Delivered on time.
Comparison of INM vs. other software

- $L_{A,\text{max}} [\text{dB}_A]$ vs. range in downwind refracting plane
- Stationary point source at $z_s=10$ km
- Temperature & humidity profiles from 2004 Bass/Sutherland paper
- B 777 1/3 OB spectrum retro fitted from INM NPD curves
- Linear wind speed profile: $v(z) = 3 \times z$ where $z$ in km [not applicable in INM]
- INM inputs: $15^\circ$C, various RH tested, 1 m long segment [CPU $\approx 5$ s]
NPD Refinement Procedure

Summary of proposed method – for each slant distance:

Spectral class normalized at 70 dB at 1 kHz, taken 305 m from source

For each 1/3 OB frequency:
- ANSI S1.26 vertical cumulative absorption (with PT to 1/3 OB correction term) for specific weather model

Add level difference to original NPD

Refined NPD

LogΣ (1/3 OB) = SPL

For each 1/3 OB frequency:
- SAE absorption (T=20°C, rh=70%)

Back to source position
Influence of atmospheric data on refined NPD

- 2010 seasonal weather average above Pittsburgh, PA.
- B777-300 departure NPD (80,000 pounds of thrust)

Summer seasons enhance louder levels (humidity)
Influence of spectral class on refined NPD

- Bass/Sutherland 2004 weather model
- two distinct spectral classes: id 105 (B777-300) and id 104 (MD-83)

The refined process handles the spectral class dependent inputs
Extend slant-distances for en route

- Largest slant-distance in INM is 25,000 feet
- Need extension for slant-ranges from 25,000 to 135,000 feet
- Use Bass/Sutherland 2004 weather model & B777-300 departure NPD data
- From 35,000 feet onwards: inclined straight lines (no refraction)
Effect of wind direction on contour shape ~ moving source effects included ~

- SEL contours $[\text{dB}_A]$ using AERNOM & moving source effects
- Overflight track at $z_s=10$ km, aircraft moves in $+X$ direction.
- Temperature & humidity profiles from 2004 Bass/Sutherland paper
- B 777 1/3 OB spectrum retro fitted from INM NPD curves
- Linear wind speed profile: $v(z) = 5 \times z$ where $z$ in km

Wind direction same as flight

Crosswind

AEDT cannot do this currently.
New: linking noise prediction to dispersion modeling

- Penn State work just begun
- Assess efficacy of emissions atmospheric models for noise prediction

\[ c(z) \] is speed of sound profile. Other symbols are from meteorology.
Summary

• Penn State contract with Volpe was completed successfully and on time.
  – Lots of good things for FAA/Volpe to think about.
  – There is much left to do.

• Recommend that INM could be improved by
  – Including NPD refinement based on atmospheric profiles
  – Extending slant range distances for en-route modeling
  – Eventually move toward curved ray approach

• We value your feedback. Thanks!
References


- Nord 2000 (2010), www.delta.dk,


Thanks!

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