Effects of Terrain and Manmade Structures on Aircraft Noise Prediction

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I. Project Overview

II. Evaluation of Selected Methods
   A. Benchmarking Results
   B. Evaluation of Empirical Datasets
   C. Airport Measurements

III. Blended Method
ACRP 02-79 Project Overview

➢ Develop and Evaluate Noise Propagation Methods
  - Aircraft noise reflection and diffraction from terrain and manmade structures
  - Both ground and airborne aircraft operations

➢ Recommend Methods for Inclusion into AEDT
  - Both the physics and the software integration process
  - Influence these methods will have on AEDT’s data input requirements, computational load, while considering uncertainty

➢ Provide Recommendations for Potential Additions to the AEDT User Guide
  - Influence terrain and manmade structures have on aircraft noise at receivers
  - Applications these new methods have for airport noise analyses
  - Guidance on when these methods should be employed
ACRP 02-79 Project Results and Status

- Primary Methods Selected
- Evaluation of Methods Nearing Completion
  - Benchmarking cases completed
  - Measured datasets
  - Sensitivities
- Airport Noise Measurements
  - LAX & LGB
  - Interesting acoustical observations
  - Excellent database
- Designed Blended Method
  - Balancing physics and computational frameworks
  - AEDT Integration
I. Project Overview and Status

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III. Coordination Plan for Review
Benchmarking Dataset
## Benchmarking Dataset

**Source**

<table>
<thead>
<tr>
<th>Heights (m)</th>
<th>Distance from Façade (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>25</td>
</tr>
<tr>
<td>12.5</td>
<td>100</td>
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<tr>
<td>50</td>
<td>400</td>
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<tr>
<td>100</td>
<td>2000</td>
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<tr>
<td>400</td>
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<td>800</td>
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**Receiver**

<table>
<thead>
<tr>
<th>Heights (m)</th>
<th>Distance from Façade (m)</th>
<th>Distance from Rear (m)</th>
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<td>2000</td>
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<tr>
<td>2048</td>
<td>250</td>
<td>500</td>
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</table>

**Building**

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Width (m)</th>
<th>Depth (m)</th>
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</thead>
<tbody>
<tr>
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<td>32</td>
<td>64</td>
</tr>
<tr>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

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**Pink Noise: 100 dB/OTOB**

**Results in ΔdB (With – Without Building)**

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**Logos and Images:**

- ISO 9613-2
- NORD2000
- TNM
- AAM
- Barrier Reflection Tool
- Volpe
- Cross-Spectrum Acoustics
- ATS Consulting
Benchmarking Dataset

Comparison of Model & Methods Results

Building (64 H x 16 D x 64 W), Source Distance at 400 m

- Source Height: 1.5 m
- Source Height: 100 m
- Source Height: 800 m
Building (64 H x 16 D x 64 W), CadnaA ISO 9613-2

Effect of Source Distance

Source Height: 1.5 m

Source Height: 100 m

Source Height: 800 m
Benchmarking Dataset

Effect of Source Height

Building (64 H x 16 D x 64 W), CadnaA ISO 9613-2

Source Distance: 25 m

Source Distance: 400 m

Source Distance: 2,000 m
Source at Distance of 100m and at Height of 12.5m, SoundPLAN NORD2000

Benchmarking Dataset

Effect of Building Width

Building: 8 m H x *W x 8 m D

Building: 64 m H x *W x 64 m D
Summary

- Provides a detailed comparison of models and methods
- Demonstrates general trends
- Provides an initial estimate of the region of influence for buildings
- Will be compared with measured airport data
- Aid in defining the transition regions for the blended method
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Empirical Datasets

Models/Methods evaluated by comparing predictions to legacy empirical datasets

- Focused on reflection and shielding effects
- Examined with and without effect implemented
Empirical Datasets

Terrain

Narvik

Grand Canyon
<table>
<thead>
<tr>
<th>Empirical Datasets</th>
<th>Terrain – Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airborne Elevated Sources:</strong></td>
<td></td>
</tr>
<tr>
<td>ISO 9613-2</td>
<td>NORD2000</td>
</tr>
<tr>
<td><strong>Ground-To-Ground Propagation:</strong></td>
<td></td>
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<tr>
<td>ISO 9613-2</td>
<td>NORD2000</td>
</tr>
</tbody>
</table>
Empirical Datasets

Manmade Structures and Barriers

NYC Urban Helicopter

NCHRP Highway

TNM Validation
<table>
<thead>
<tr>
<th>Manmade Structures – Summary</th>
</tr>
</thead>
</table>

**Building Reflection from Distant Source:**
- ISO 9613-2
- NORD2000
- TNM
- NCHRP Barrier Reflection Tool

**Noise Wall Reflection:**
- ISO 9613-2
- TNM
- NCHRP Barrier Reflection Tool

**Diffraction Over Noise Walls:**
- ISO 9613-2
- TNM
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III. Blended Method
Most sites provide shielding and reflections from one-story houses.

Aircraft were readily localized even when not visible.
Evaluation of Selected Methods: Airport Measurements

Kittyhawk Ave
Several sites were selected to measure the effect of reflections from a four-story apartment building.

Measurements immediately in front of the large building were compared with nearby sites that had no large reflectors.
Evaluation of Selected Methods: Airport Measurements

Hotel District

Measurement Notes

Buildings between two and ten stories provided reflections and shielding of aircraft flyovers.
Evaluation of Selected Methods: Airport Measurements

Data Analysis

- Isolated events by aircraft type and airline, where possible
- 566 individual measured SEL events
- 46 comparison events on average, grouped by operation type and shielding/reflection effect
- Calculated SEL and $L_{A\text{max}}$ for each event with AEDT
- Calculated difference between average measured values ($M_{SEL}$) versus predicted ($P_{AEDT}$)
- Compared the calculated Gain/Loss ($GL_{BM}$) with the differences

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Number of Flights</th>
<th>Number of Sites</th>
<th>Number of Individual Recordings Removed</th>
<th>Total Measured Data Points</th>
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</thead>
<tbody>
<tr>
<td>LGB</td>
<td>30</td>
<td>11</td>
<td>32</td>
<td>298</td>
</tr>
<tr>
<td>El Segundo</td>
<td>20</td>
<td>9</td>
<td>4</td>
<td>176</td>
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<tr>
<td>Kittyhawk</td>
<td>14</td>
<td>3</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>Playa del Oro</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>50</td>
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</tbody>
</table>
Summary of Results

- Overall SEL Comparisons

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<thead>
<tr>
<th>Operation Type</th>
<th>Measured-AEDT</th>
<th>Offset TNM</th>
<th>Offset ISO 9613-2</th>
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<tbody>
<tr>
<td></td>
<td>Ave</td>
<td>St Dev</td>
<td>Ave</td>
</tr>
<tr>
<td>All</td>
<td>-1.9</td>
<td>4.8</td>
<td>0.9</td>
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<tr>
<td>Arrival</td>
<td>-0.1</td>
<td>2.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Departure</td>
<td>-2.3</td>
<td>4.9</td>
<td>1.4</td>
</tr>
</tbody>
</table>

- Grouped SEL Comparisons

<table>
<thead>
<tr>
<th>Op Type</th>
<th>Effect</th>
<th>Measured-AEDT</th>
<th>Offset TNM</th>
<th>Offset ISO 9613-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave</td>
<td>St Dev</td>
<td>Ave</td>
<td>St Dev</td>
</tr>
<tr>
<td>Arrivals</td>
<td>Shielding</td>
<td>-0.9</td>
<td>3.5</td>
<td>-0.3</td>
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<tr>
<td></td>
<td>Reflection</td>
<td>0.3</td>
<td>2.3</td>
<td>0.5</td>
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<tr>
<td>Departures</td>
<td>Shielding</td>
<td>-5.8</td>
<td>4.6</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Reflection</td>
<td>0.6</td>
<td>3.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>
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III. Blended Method
Overview of Blended Method

AAM Terrain Algorithms

- NoiseMap integration method
- Included over entire calculation region
Overview of Blended Method

**TNM 3.0**
- Populate with building data
- Each unique trajectory
- Calculate OTOB gain/loss factors
- Dense array
Utilizing linear acoustics, predictions obtained in the existing AEDT integrated framework can be combined with reflection gains and insertion loss from nearby structures.
Blended Method Calculation

AEDT

Building Effect

Blended
Advantages

- One-time calculation of gain/loss on a 1/3-octave band basis
- Develop a library of gain/loss factors that can be applied to AEDT results
- Toggle results on/off
- Provide efficient computations
- Capture localized building effects
Based on Magnitude of Effects
- Driven by shielding loss
- Driven by arrivals

Extent
- Based on <0.5 dBA shielding effect
- Based on 152 m AGL
- 2,621 m along extended runway centerline
- 2,200 m lateral to runway

Transition Region
- Simple linear interpolation
- 1,000 ft distance (<0.5 dBA change)
Interface with AEDT
- Operations defined using current AEDT input method
- Buildings imported via 3D layers and/or direct user input

TNM 3.0 (modified) calculates building gain/loss

Returns a library of gain/loss grids to AEDT

AEDT applies gain/loss grids to output to account for building gain/loss (blended method)