Objective:
• Assess the accuracy of AEDT in estimating noise compared to real-world measurements in both the vicinity of airports as well as further afield under various modeling assumptions
• Enable incorporation of high-fidelity weather in AEDT noise modeling for real-world flights

Project Benefits:
• One of the main benefits of this project is to suggest possible improvements that could be made in future releases that enhance the predictive capability with respect to real world measurement data

Research Approach:
• Support GaTech and collaborate regarding high-fidelity weather.
• Finish developing an in-house ray tracing code to include inhomogeneous atmosphere for noise predictions around airports.
• Understand the influence of AEDT’s atmospheric absorption and acoustic impedance corrections in noise calculations, if they were a function of high-fidelity weather.
• Eventually compare the in-house code with AEDT predictions, to assess the extent of differences caused by weather effects.

Major Accomplishments (to date):
• Supported GaTech colleagues in importing Spire Global high-fidelity weather into AEDT for the first time.
• Successfully made initial noise predictions at SFO with in-house code.

Future Work / Schedule:
• Compare in-house noise results including inhomogeneous atmosphere to AEDT’s homogeneous assumption.
• Assess sensitivity of atmospheric absorption & acoustic impedance AEDT corrections to atmospheric variability.
P62 Investigation team includes

• Harshal Patankar, Penn State Research Assistant
  – Developed in-house ray tracing code for noise prediction
  – Developed interface with Spire Global high-resolution data

• Emma Shaw, Penn State Research Assistant
  – Focused on real-world weather influence on AEDT noise predictions

• Will Cromarty, Spire Global (spire.com)
  – Enabled the connection with high-resolution atmospheric data

• GaTech and Volpe colleagues, particularly:
  – Michelle Kirby, Tejas Puranik, Ana Gabrielian, Eric Boeker, Juliet Page

Special thanks to FAA participants Bill He (PM), Joe DiPardo, Chris Hobbs!
Modeling a flight outside of AEDT

Looking at a 737-800 arriving at SFO

Available data:
- Time-history of flight trajectory, speed, thrust (from AEDT)
- Lmax and SEL readings at Noise monitor #12 available

Focus of the work:
- Modeling aircraft source level (evolving along the trajectory) similar to what AEDT does
- Correctly accounting for meteorological conditions (Path)
Modeling the source

Spectral class data - to define the "shape" of the spectrum

NPD table – to obtain the absolute source level (at 1000 ft) as a function of thrust values

- Removing the built-in absorption (SAE ARP 1845)
- Removing the effect of spherical spreading

Source spectrum close to aircraft (to be used in in-house ray tracing)

Graphs showing spectral class data and spectral levels adjusted from NPD table.
Meteorological conditions (Path)

- Comparing AEDT airport weather with 'close to real-world' conditions (Data thanks to our industry partner - Spire Global)
- Looking at the vertical inhomogeneity in temperature and humidity (at a grid point closest to SFO)

- Inhomogeneous conditions are considerably drier and colder than the homogeneous conditions – would expect more absorption in the case of inhomogeneous conditions.
In-house ray tracing setup

- Included Source spectrum as a function of thrust.
  - Time history of thrust values provided by Georgia Tech (using AEDT)
- Included the effect of moving source:
  - Doppler effect (frequency shift)
  - Amplitude correction
- Correctly included atmospheric absorption.
- Performed calculations with homogeneous conditions (AEDT airport weather) and inhomogeneous conditions.

The goal is to predict OASPL at noise monitor #12 and compare it with measurements (and eventually with AEDT).
**Initial results (not yet comparing to AEDT)**

**Note:**
- The measured $L_{max}$ is 71.9 dB (for a microphone at 7.5 m above the ground).
- The predictions shown here are for a (virtual) microphone placed on the ground (ground reflection not yet added).

- The $L_{max}$ predictions (ground mic. -- pressure doubling) are about 3.5-4 dB higher than the measured $L_{max}$ (mic. 7.5 m above the ground).
- For longer propagation distances, the effect of inhomogeneous meteorological conditions is clearly visible.

**Key takeaway:**
Correctly accounting for meteorological conditions will be important especially at longer propagation distances.
Work now in progress

• Include ground reflection.
• Include directivity along with the source level
• **Validation:** Compare our predictions with AEDT (for homogeneous atmosphere case).
• Carefully reference the time scale for comparing the predictions with measured data (SEL and Lmax).
• Eventually, look at the other events involving multiple noise monitors.

Maybe incorporate high-fidelity weather in AEDT noise modeling in the future?

• It could be too slow to put full 3-D ray tracing into AEDT directly.
• For starters, maybe just include high-fidelity weather in existing AEDT adjustments.
Segment-scale weather adjustments

- New task in 2021.
- Only possible recently due to high-fidelity weather (3-D) being available [Spire Global].
- Determine if AEDT’s atmospheric absorption adjustment \( (AA_{ADJ}) \) and acoustic impedance adjustment \( (AI_{ADJ}) \) are substantially affected by real-world weather.
- Each segment of a noise calculation in AEDT goes through a different part of the atmosphere, so what is the sensitivity of \( AA_{ADJ} \) and \( AI_{ADJ} \) to real weather?
- Examine initially for SFO airport. Then extend to several different airports to see if SFO is a unique case.
Potential use of high-fidelity weather with $\text{AA}_{\text{ADJ}}$ and $\text{AI}_{\text{ADJ}}$

**Radio Occultation** (refracted signals)

- **GPS signals sent out**
- **Spire satellites analyze the data**

Schematic from https://spire.com/weather/

**Approach**

- Using high-fidelity weather, include temperature map in use of acoustic impedance adjustment $\text{AI}_{\text{ADJ}}$.
- Would use both temperature and humidity maps to similarly correct the atmospheric absorption adjustment $\text{AA}_{\text{ADJ}}$.

\[
\begin{align*}
T(x, y, z) \\
\text{c}(T(x, y, z)) \\
\text{c}(T(x, y, z)) \quad \text{for} \\ \\
\text{c}(T(x, y, z)) \quad \text{for} \\
\text{c}(T(x, y, z)) \quad \text{for} \\
\text{c}(T(x, y, z)) \quad \text{for} \\
\end{align*}
\]

\[
\text{AI}_{\text{ADJ}} = 10 \log_{10} \left( \frac{\rho c}{409.81} \right)
\]
Next Steps

- Complete in-house noise prediction modeling for SFO airport to determine noise prediction including inhomogeneous atmospheres and compare to AEDT results.
- Assess sensitivity of AEDT’s atmospheric absorption adjustment ($AA_{ADJ}$) and acoustic impedance adjustment ($AI_{ADJ}$) to real-world weather, and their role in making noise predictions.
  - Complete work with SFO airport.
  - Compare SFO results to those at several other airports to see if the $AA_{ADJ}$ and $AI_{ADJ}$ sensitivity results are similar at those airports.
- Continue supporting GaTech on high fidelity weather data and modeling.

We would like to acknowledge our project partners at Georgia Tech, Eric Boeker and Juliet Page from Volpe, Spire Global, our airline partners, and Bert Ganoung from SFO Airport for their feedback and support in this project.