Recent NASA research into the psychoacoustics of Urban Air Mobility vehicles

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Urban Air Mobility

- Over the past few years, NASA has become interested in what's called "Urban Air Mobility" (UAM).

- This concept involves passenger air vehicles operating between, for instance, a "vertiport" in an urban center, and a nearby airport.

Psychoacoustic Testing for UAM

- There has been a lot of pontification on the role that noise will play in the rollout of UAM concepts.
- NASA maintains several psychoacoustics labs across the country that may be used to investigate the human response to the noise of UAM, even before recordings of vehicles are available.

Exterior Effects Room (EER) at NASA Langley

Psychoacoustic Testing for UAM

NASA has plans to conduct several lab tests over the next two years for UAM-like sounds (via the EER as well as other facilities).

The questions we are interested in investigating include:

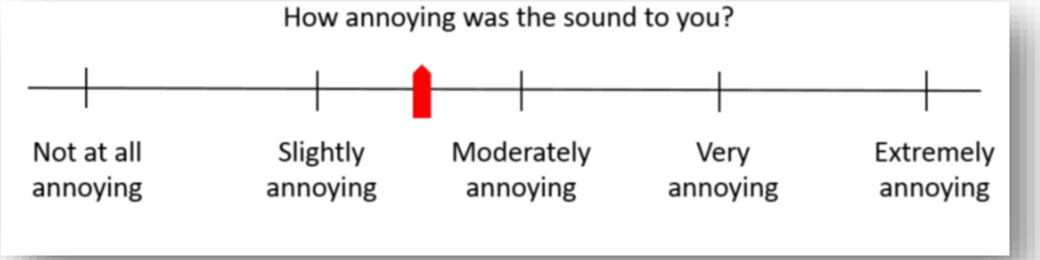
1. What are the qualitative attributes of UAM sound that lead to annoyance? Do things like the presence of tones from motors, impulsiveness of the rotors, or frequency fluctuation in the sound lead to more annoyance?
2. What way should we be integrating annoyance over time? How does annoyance build up over the course of a single event? How does it build up over the course of multiple events?
3. What role does background sound play in the annoyance of UAM? How does a preexisting (e.g., urban) soundscape impact the perception of UAM vehicles?

These tests are meant to produce data that will be used in building models of annoyance that are inclusive of these effects.

Investigating Sound Quality: TUSQ

The Test of UAM Sound Quality (TUSQ) is set to run in the EER over the summer.

- The sounds will be 5s “snippets” of notional UAM noise.
  - Subjects will be asked to respond with their annoyance on a scale, which is then “calibrated” to determine equivalent loudness



- “Synthesis by analysis”: Leverage auralization capability and embellish it with operational features gleaned form real-world vehicles.
  - Will subjects respond to the SQ factors of the sounds, or will they tend to respond to vehicle design parameters such as blade-passage frequency (BPF)?
  - Will models based on the data be able to “encode” the complex relationships between vehicle design parameters and SQ? (Will it have to?)

Investigating Sound Quality: TUSQ

What can we do with these data?

- We can investigate the efficacy of existing methods of evaluating SQ:

$$PA = N \times \left(1 + \sqrt{w_{FR}^2 + w_S^2}\right)$$

  - This is often attributed to Fastl/Zwicker, though seems to have come from ???

- In general, we can investigate the idea that annoyance is equivalent to loudness with some perturbation for SQ:

$$Annoyance = Loudness + f(T, S, R, FS, I, \dots)$$

  - The function of sound quality can be anything – from something that we can write down as an equation, to some exotic machine learning approach.

Events and Operational Scenarios

We next need to figure out how to integrate such a model over different time horizons.

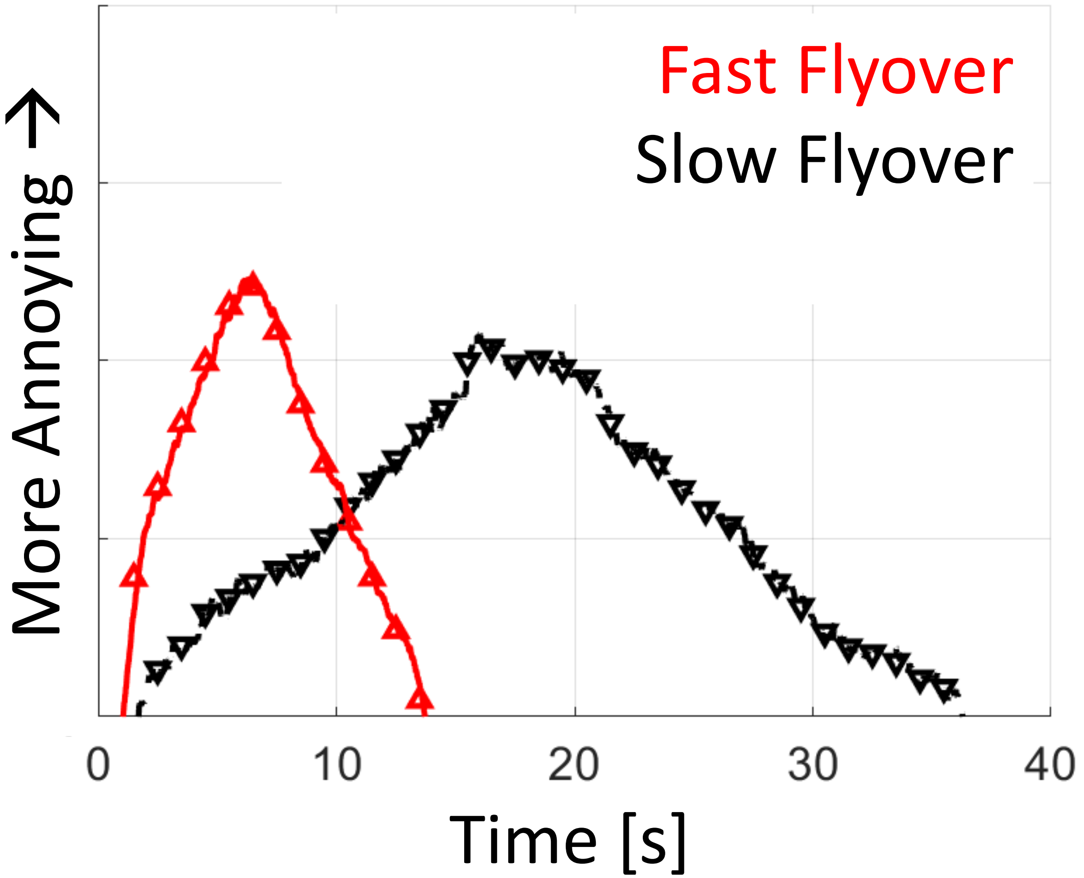
- The ***sensation*** of ***loudness*** builds over very short times but then stays constant (or is at least ill-defined).
- The ***attitude*** of ***annoyance*** continues to build over long periods of time.

- What is the correct way to aggregate a prediction of annoyance:
  1. Over the course of a single event?
  2. Between a scenario of multiple events (in a laboratory setting)?

Single Events

Which flyover is more annoying overall?

- We need to test how human subjects weigh various combinations of:
  - Length of an event
  - Peak annoyance
  - SQ changes over time
- We can leverage the synthesis by analysis techniques from the earlier test to help us fabricate flyover sounds that vary in prescribed ways.



“Noise and Number” Testing

How does annoyance grow between events?

- What happens when we change:
  - The number of overflights?
  - The level of the whole scenario?
  - The spacing between overflights?
  - The makeup of a fleet?

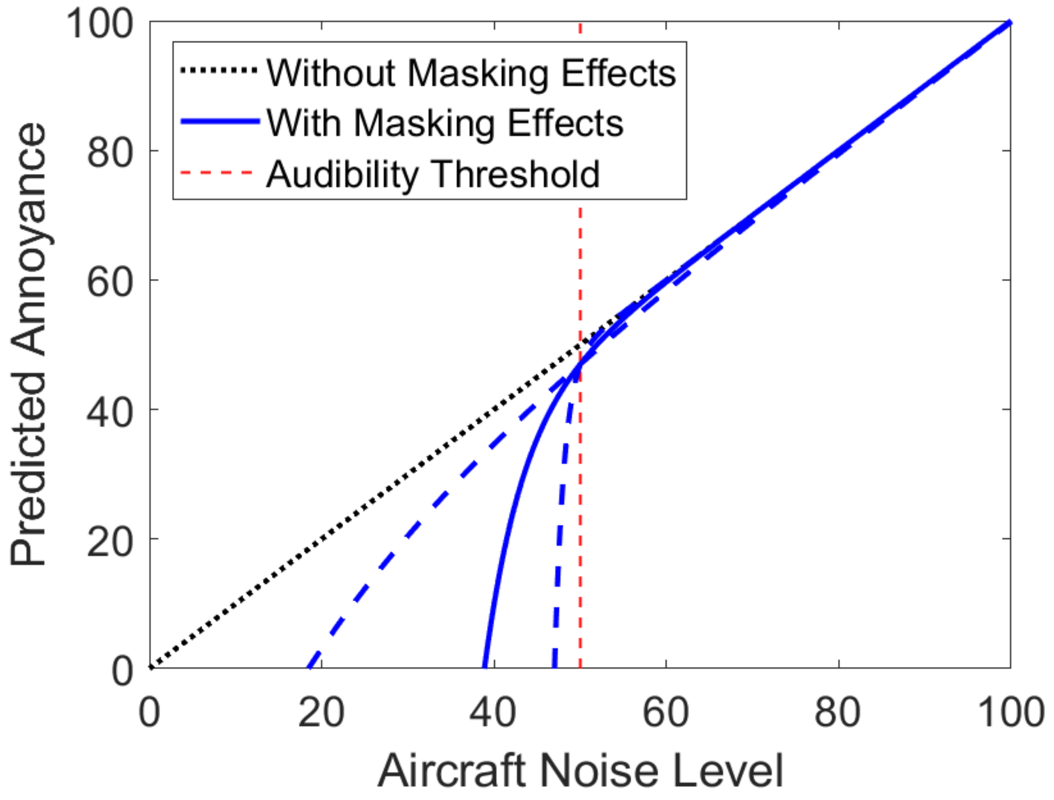
- Now we can use the single events from earlier to build up scenarios that subjects can respond to.
  - Can we leverage other datasets with new statistical machinery to find conclusions?

The DNA Test

What happens when UAM noise interacts with a cityscape?

- Now we want to combine single events/scenarios in the presence of a background.
  - Will the UAM sounds be masked?
  - How does **Detection** lead to **Noticeability** lead to **Annoyance**?

- This is a very hard test to do, and there is only limited literature to draw upon.
  - The methodology has been in development for several years now.

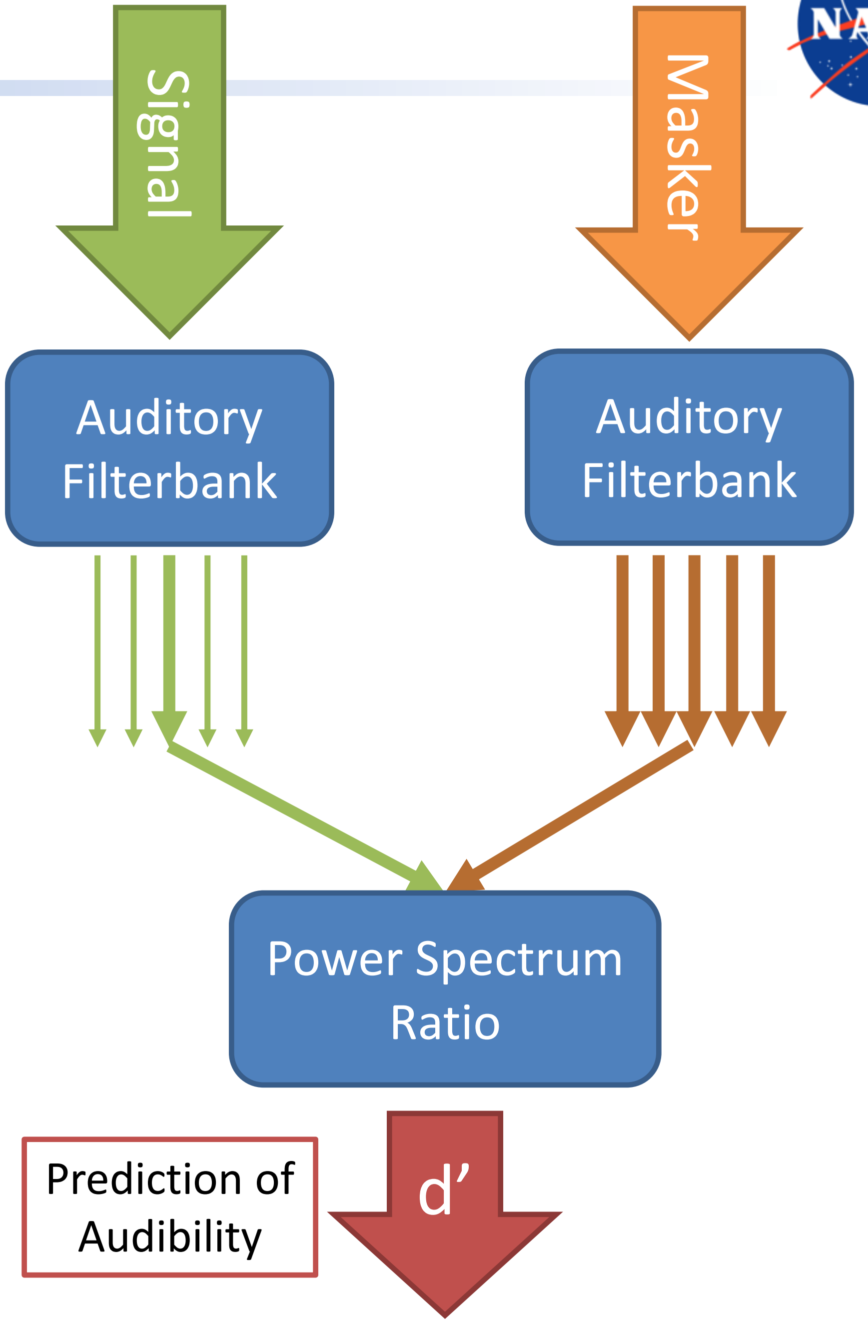


Models of Audibility

In support of the development of the DNA test, several models of auditory masking have been investigated.

- These range from:
  - basic "power spectrum" models that operate on 1/3rd-octave bands
  - to advanced loudness-based models
  - to other models from literature.

- Ultimately, these models will need the data from the DNA test to discern between performance/accuracy/bias, etc.



Characterizing the Existing Soundscape

- Of course, before one can run a computer model of mask*ing*, one will need a mask*er.*

- A recent NASA TM detailing best practices for the recording and documentation of environmental sound was published.
  - TM-20210017504 on the NASA Technical Reports Server (NTRS)

NASA/TM–20210017504

Methods for Recording and Documenting Ambient Environmental Sound for use in Listening Tests

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