



The notional impact of background noise on the human response to UAVs

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Unmanned Aerial Vehicles



- NASA is interested in staying out in front of future challenges presented by emerging aircraft sectors.
 - One of the challenges we can address is the notional impact of the noise of these future aircraft.
- Unmanned aircraft (UAVs) are an emerging technology with unknown noise impact.



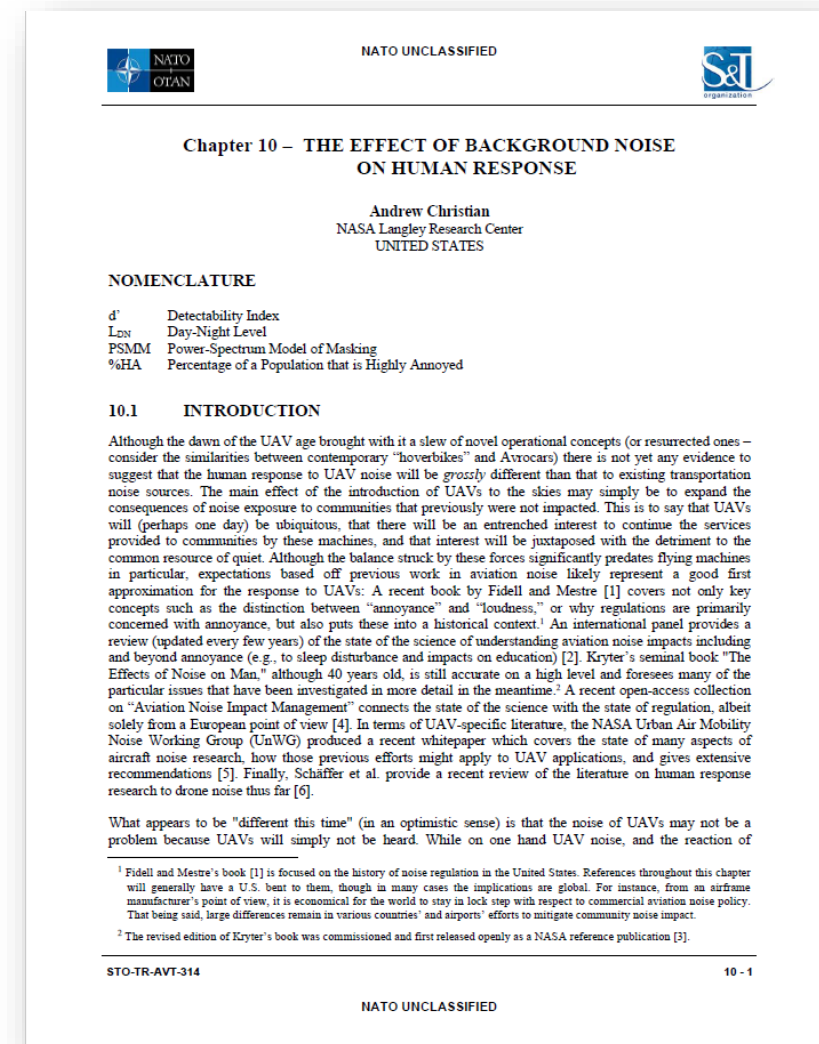
Unmanned Aerial Vehicles



- Proponents of UAV-based industries would like to think that annoyance will not be a problem due to the noise of their vehicles simply not being heard over the existing soundscape.
- No measures of noise that are in wide use today for aviation take background sound into consideration, and thus would not predict this outcome.



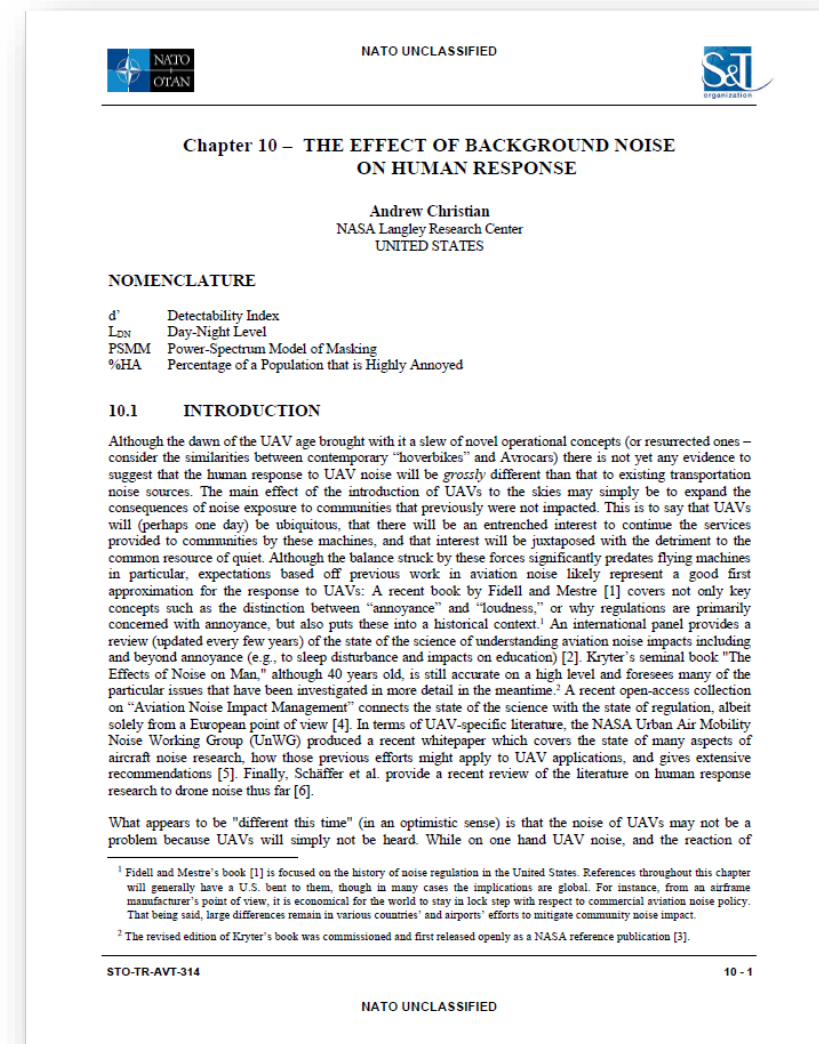
- A report was compiled containing a review/outlook on this issue:
 - NATO AVT-314: Assessment and reduction of installed propeller and rotor noise from unmanned aircraft
 - Chapter 10: The Effect of Background Noise on Human Response
- This report is hard to get, but NASA still has the right to distribute it (e.g., as a PoMA).
- This presentation will cover the major points of the report.



The Biggest Takeaway



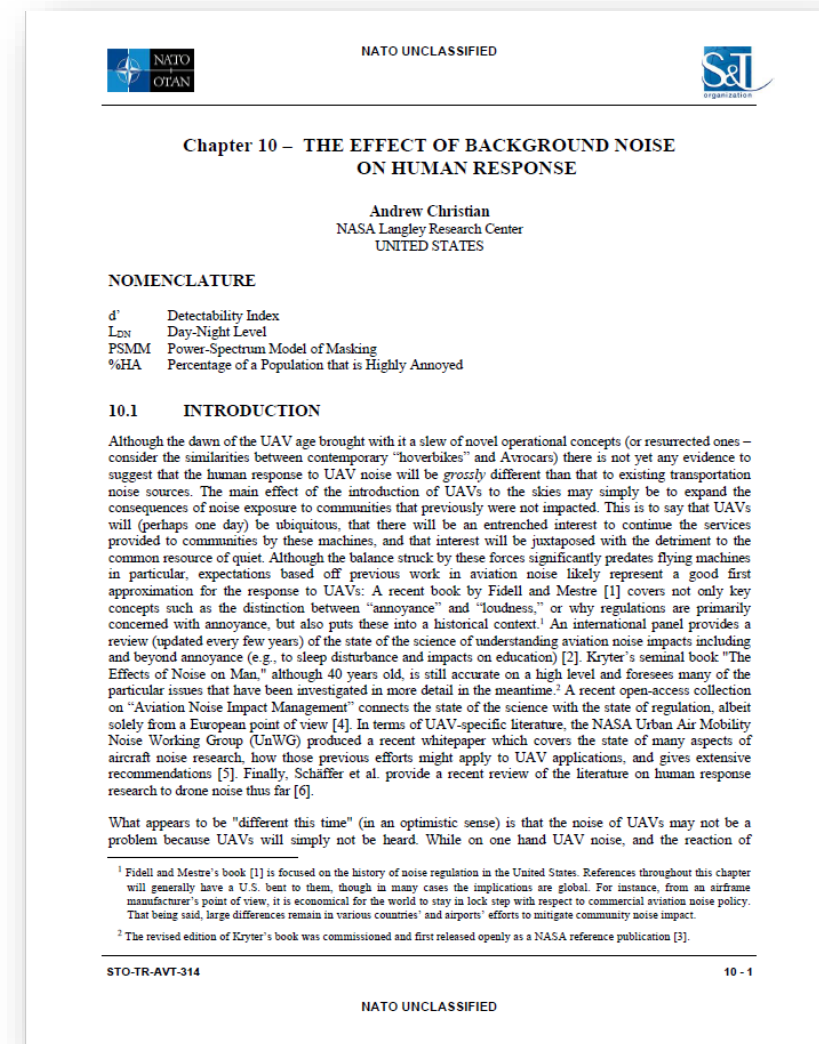
- In the largest sense, nothing that has been learned so far about UAV noise makes us think that human response will be *mechanistically* different from the response to other sounds.
 - For instance, as UAVs get louder, or as their numbers increase, they will be more annoying.
 - The incorporation of a background noise effect should be seen as augmentation, rather than replacement for current practice.



What (Might Be) Different This Time?

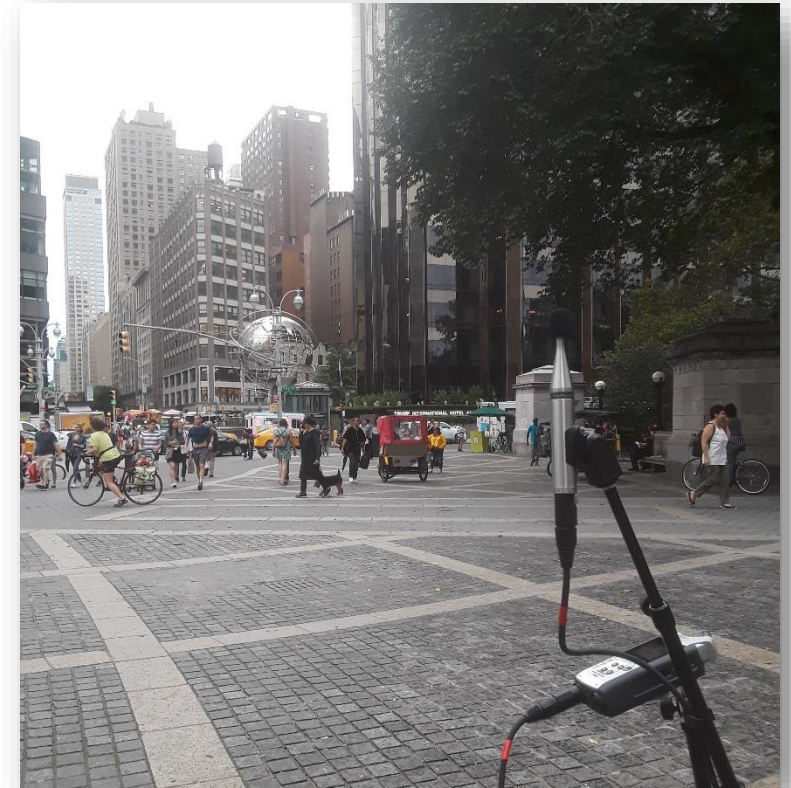
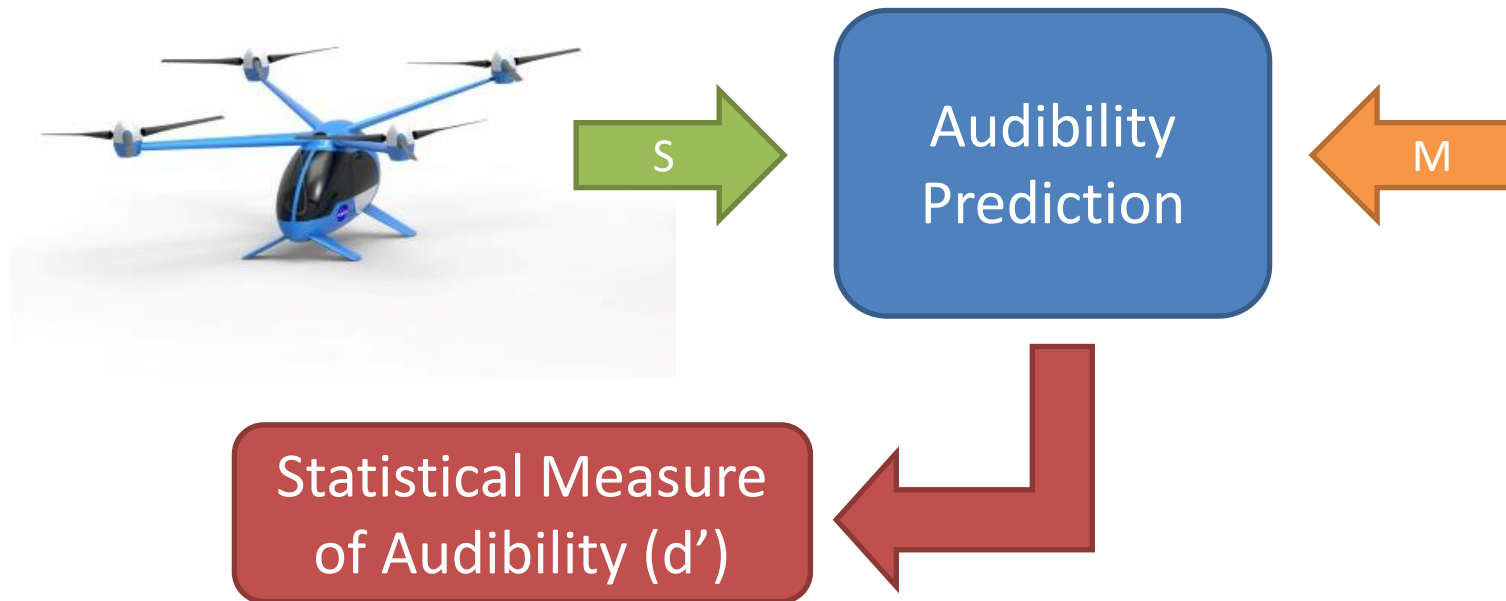


- Optimistically, it is possible that the noise of UAVs may not be a problem because UAVs will simply not be heard.
 - We now have to be concerned with *both* the sound of the aircraft in isolation, *and* the natural or artificial ambient.
 - Without the presence of the ambient, an observer might change either their attitude (to be annoyed), or their behavior (to complain).



The Problem of Audibility

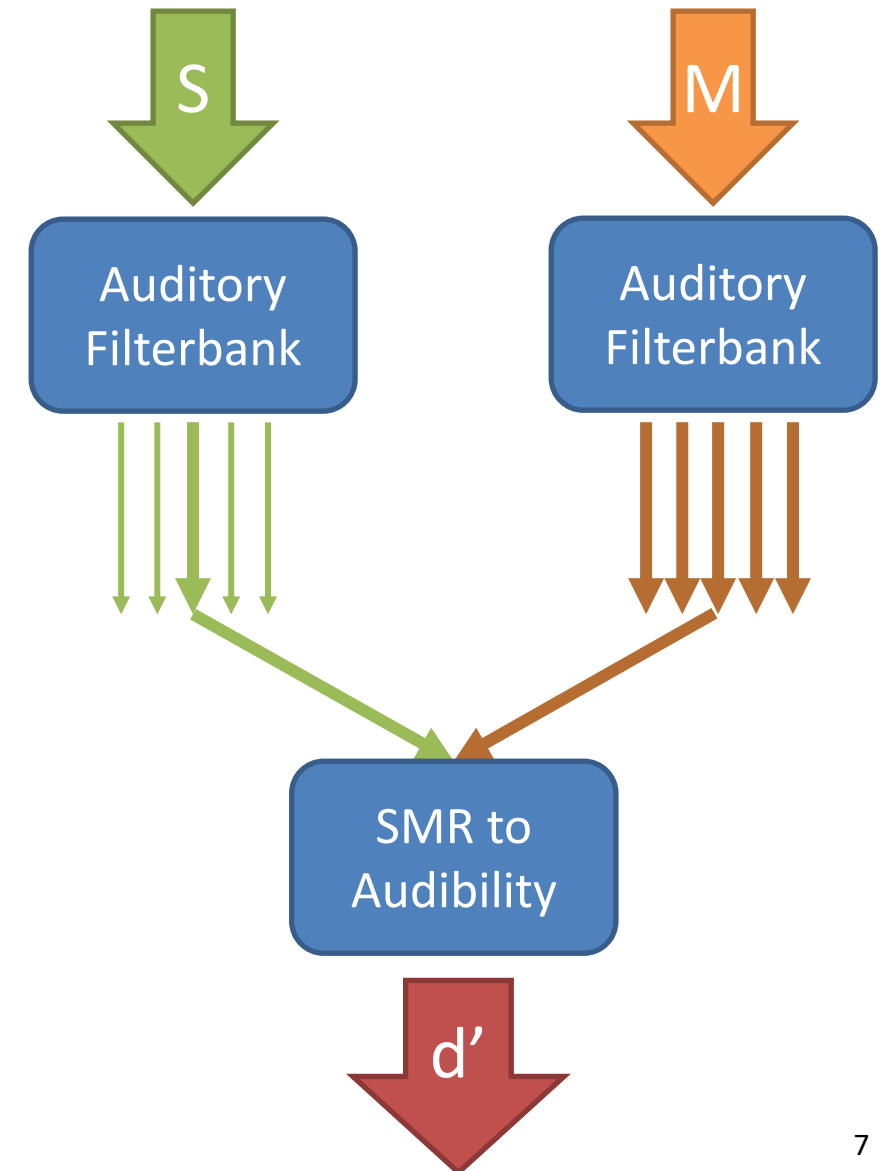
- Generally, what we want to do is predict how likely it was that a listener heard a ***signal*** in the presence of a ***masker***.
 - If the signal is inaudible, we say that it was ***masked***.





Masking Model Basics

- Based on the mechanisms of the peripheral auditory system, we can formulate a good set of first steps:
 - Consider the ear as a bank of bandpass auditory filters.
 - The signal and noise are filtered by this bank separately.
 - Compare the power of the signal to that of the masker in each filter.
 - Have a way to relate this ratio to empirical audibility data and create a measure of detectability (d').
- This model can predict a large amount of empirical data for very fundamental experiments.





Issues That Might Impact Detectability

- Researchers have demonstrated the fragility of this approach:
 - The problem is that the filters of the ear are not attached to power detectors, but rather transduction mechanisms that generate a neural firing code.
 - The brain is free to use any information it can gather from the auditory nerve to try to figure out if a sound is there or not.
- Humans can use all kinds of acoustical information to do audibility tasks. Here are some that could impact a UAV-like scenario:

Acoustical aspects:

- ❖ Temporal envelope
- ❖ Spectral envelope
- ❖ Spatial cues

Nonacoustical/cognitive aspects:

- ❖ Object streaming
- ❖ Informational Masking
- ❖ Familiarity...

The DNA Phenomena



- While the prediction of d' (*detectability*) is necessary, the real goal is to be able to predict *annoyance* when detectability is low.
- A moderating factor may be how *noticeable* a sound is. That is, a sound may be perfectly detectable, but can it annoy people if it doesn't capture one's attention (i.e., away from a task or conversation).

Studying how Detection leads to Noticeability leads to Annoyance (DNA) is the subject of current research at NASA.

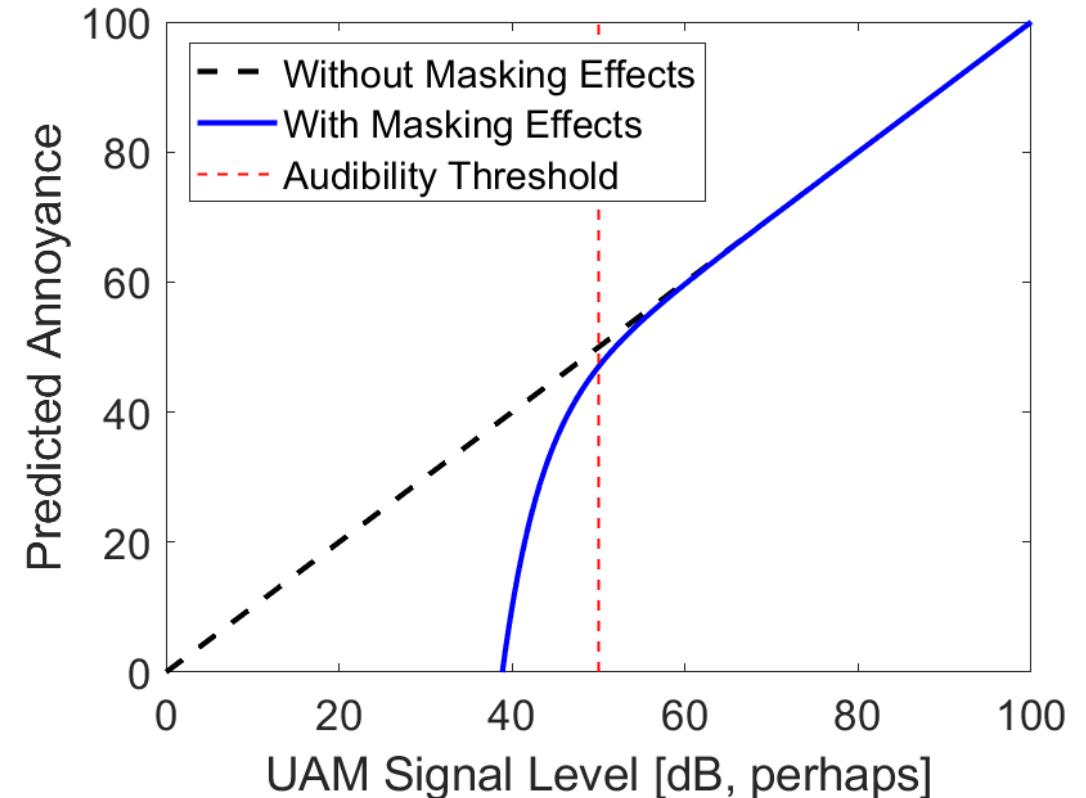
The State of Research

- The report contains an extensive (though not exhaustive) review of literature regarding the link between masking and annoyance.
 - Inclusive of work beyond aircraft noise literature: wind-turbine noise, electric-vehicle noise and road-traffic noise in general, alarm design, more fundamental psychoacoustics, etc.
- An important takeaway is that models used to explain psychoacoustic test results found thusfar have not been made in a way that is *extensible* beyond the results of those tests.



The Link Between Detection and Annoyance

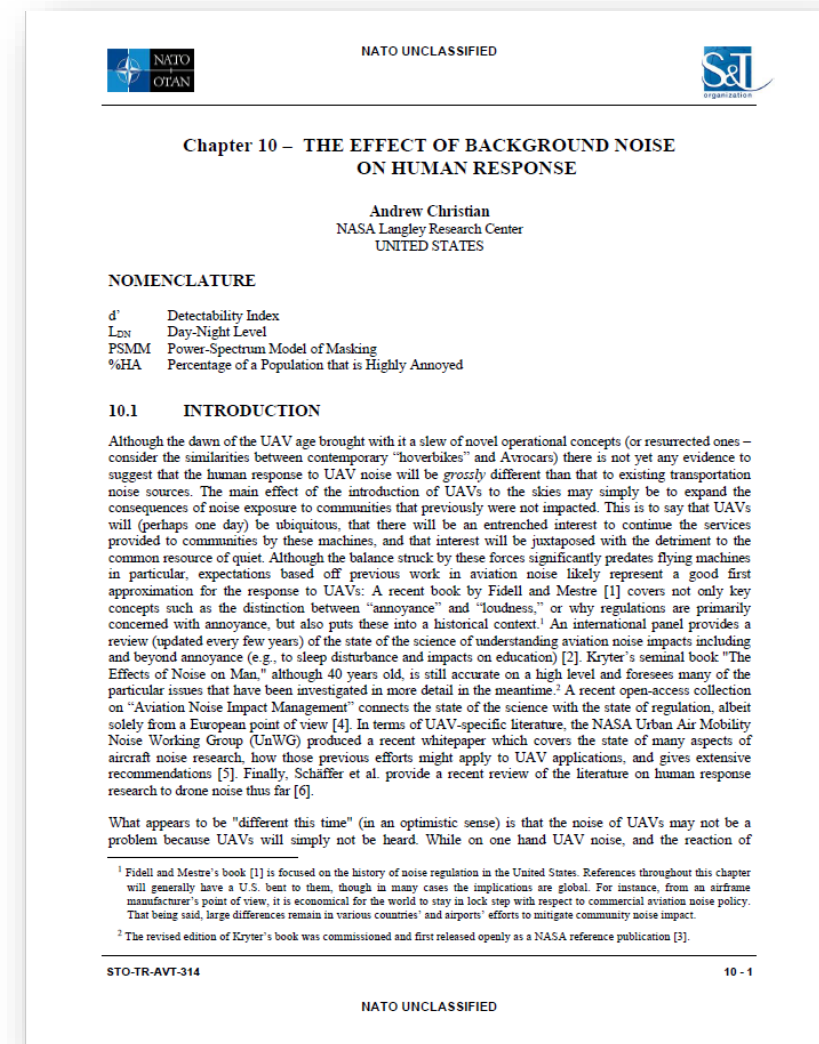
- Coarsely, two rules of thumb emerge from the literature:
 - When sources of noise are sufficiently prominent over the ambient, there is no strong effect of the ambient level on annoyance.
 - When sources of noise get close to the ambient, annoyance is impacted.
- These two concepts can be operationalized into the curve shown schematically at right.



Further Contents



- The report also contains:
 - A review of regulation and policy wrt. the role that ambient sound has played in community response.
 - Recommendations for future research into the DNA linkage, and what researchers/industry/regulators may expect as models become available.
 - A brief review of military applications of similar hearing models.

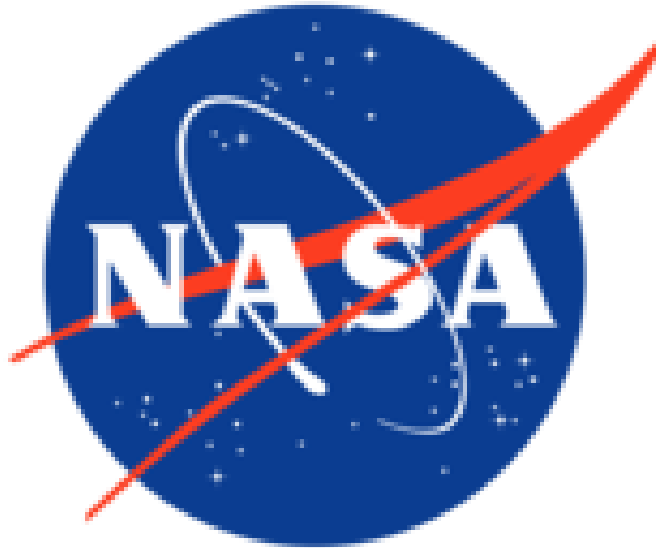


The Outlook



- In the end, the outlook for the incorporation of the effect of masking into the assessment of annoyance for UAVs can be hypothesized:
 - In research applications, the ability to understand the interplay of masking and annoyance will be *essential*, as it has been already in the wind-turbine and electric-vehicle industries.
 - In commercial/industrial applications (from the point of view of the vehicle designers and operators), the ability to understand how the noise of their vehicles will interplay with the soundscapes that they will operate in will likely represent a competitive advantage.
 - In regulatory applications, detectability is least likely to find use due to its fragility, complexity, and the steep data requirements relative to today's metrics.

Questions?



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Regulation and Policy

- Historically, it is simple to say that the role of the ambient has been ignored for most of the history of aircraft noise regulation and policy.
 - There are proposals for noise metrics that can be found in the literature, but none have ever become widely utilized.
 - The NPS represents a very rare counterexample.
- For UAVs, at least early on, proponents of the technology believed that since these vehicles were so different from conventional aircraft, new rules would have to be created to govern their use
 - Ultimately, this turned out not to be the case, and hence, UAV regulations thus far have not incorporated the effects of masking.
 - Community engagement has proven to be more important for pilot industries than consideration of ambient noise levels.



Recommendations and Conclusions

- The following recommendations are defended given the information presented in the chapter:
 - Models need to be further developed for application to UAV noise in the presence of masking.
 - Laboratory psychoacoustic testing of detectability/noticeability/annoyance is necessary to generate data for model development and validation.
 - Initial community reaction test campaigns for UAV missions should be prepared to bring to bear whatever tools there are for the recording and evaluation of existing soundscapes.
 - Industry and researchers should be open to adopting tools for the assessment of masking effects, especially in the case that they see unexpected community response in the presence of background noise.