

# Perceptual attributes of eVTOL noise noticeability and blend with reference to the ambient

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Spring 2021 ATWG

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- **How aircraft noise and the ambient has been characterized in lab studies**
- **How noise impacts are characterized in noise ordinances, regulations with reference to the ambient**
- **How reaction to signals in the ambient are measured by social surveys in terms of annoyance**
- **An alternative means of measuring eVTOL noise in lab studies so that we can estimate *acceptance* rather than *annoyance***
- ***??? Is there a delta offset between annoyance & acceptance (for a given parameter) that could relax requirements for noise emission***

*ambient = shorthand for “typical background noise in a community”*

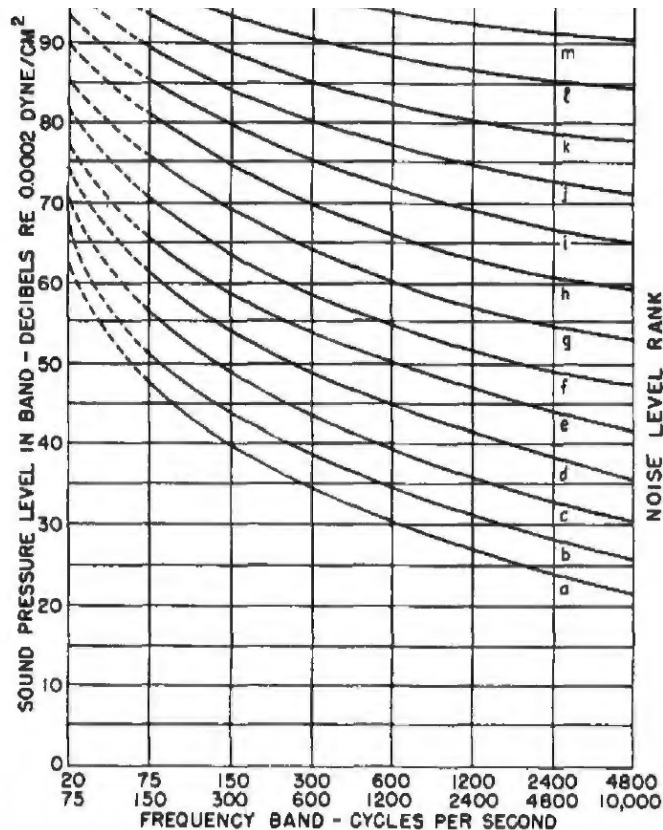
- Underlying assumption of the role of background noise in acceptance of a novel sound source: articulated by Stevens, Rosenblith and Bolt- 1955

## A Community's Reaction to Noise: Can It Be Forecast?

K. N. STEVENS, W. A. ROSENBLITH, AND R. H. BOLT

BOLT BERANEK AND NEWMAN INC.

*The composite noise rating may make it possible to assess the community's reaction even before the noise is turned on.*

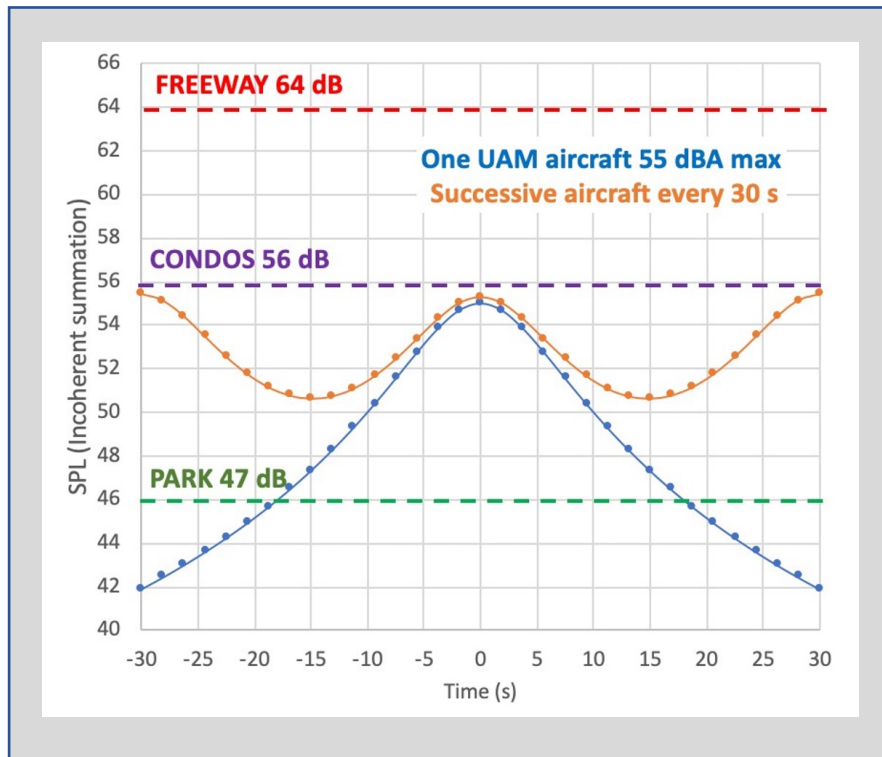


It may happen, for example, that the noise from a particular source is masked by the background noise in one community but is much more intense than the background noise in another community. The two communities will respond quite differently to these two stimulus situations. In a sense, *the background noise level plays the role of a reference level with which the noise under consideration is compared.*

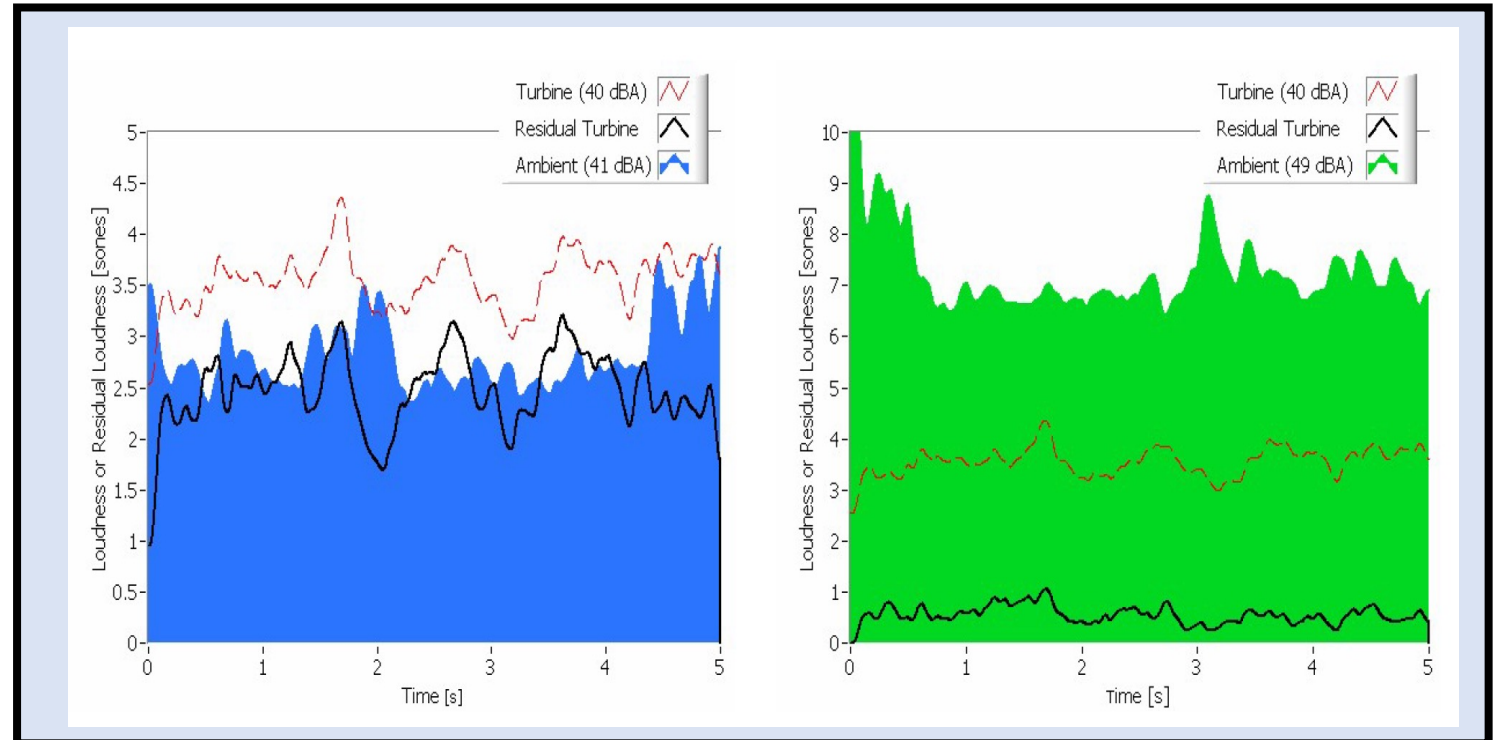
## ➤ Ambient environmental noise, masking and partial loudness

- **Auditory masking** describes how eVTOL noise is partially or completely obscured by the ambient
- **Partial loudness** describes how the judgment of the loudness a particular sound (e.g., an eVTOL) is affected when heard simultaneously in the presence of another sound (e.g., the ambient), as a function of time.

eVTOL incoherent summation, 100 mph, 1000 ft



Nelson (2007) wind turbine data



## ➤ Limitations of prior studies of combined aircraft and ambient noise:

### Veridical ambient simulation requires:

- spatial auditory cues (due to binaural masking level difference, movement trajectory)
- realistic masking spectrum
- cognitive cue to establish sense of place (“soundscape”)

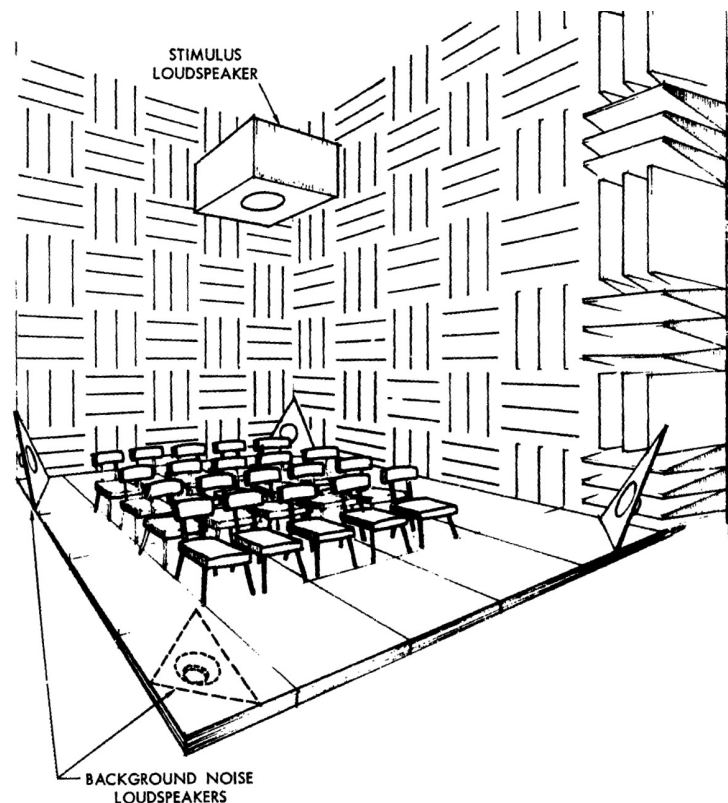


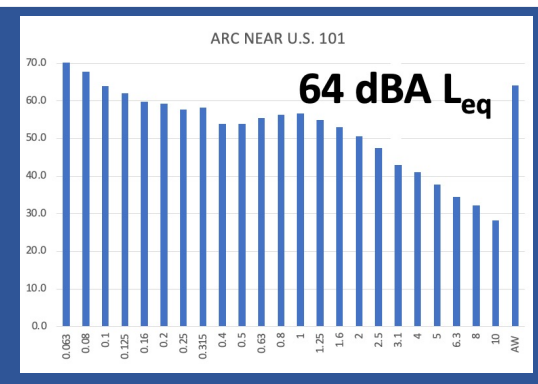
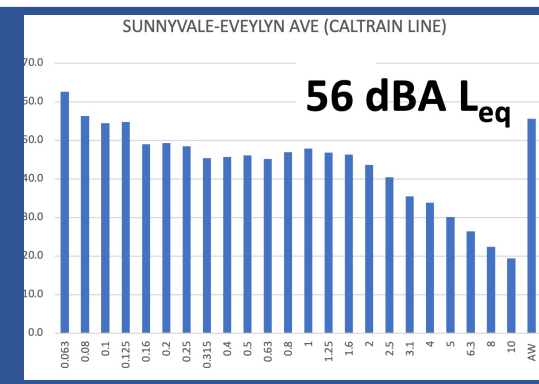
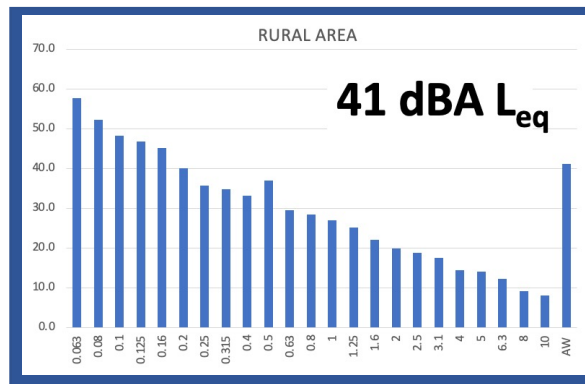
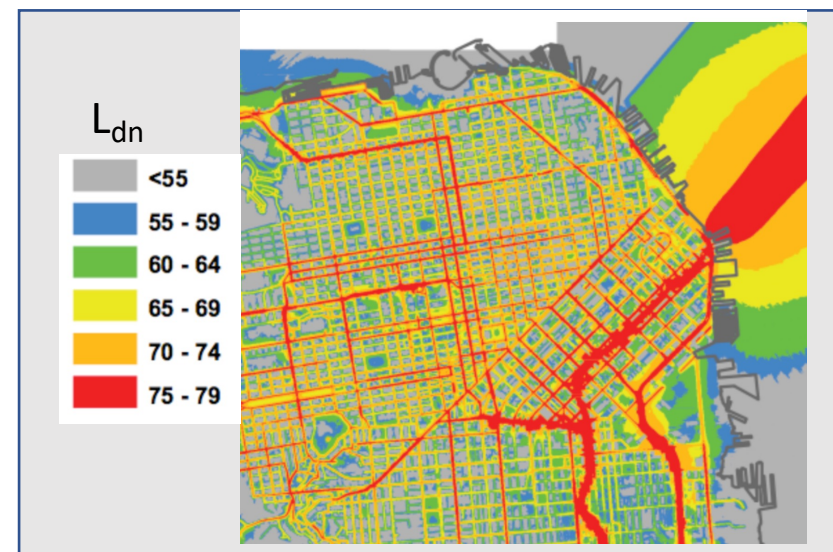
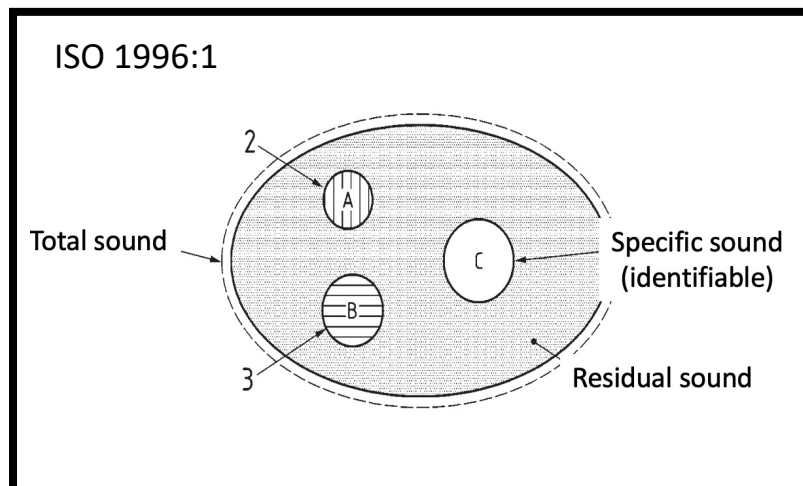
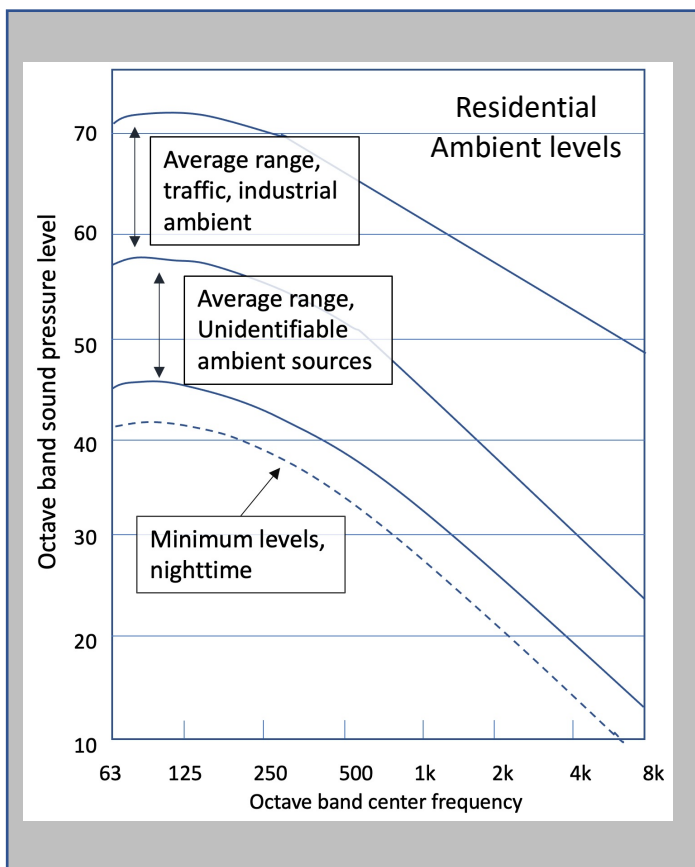
FIGURE 5. ANECHOIC CHAMBER FACILITY FOR DURATION AND BACKGROUND LEVEL TESTS

Pearsons (1966)

- **No ambient** included in forming **noy** aircraft noise scale
  - *Kryter (1959)*
- **Spatial audio cues** not included
  - *Namba and Kuwano (1980)*
- **Uncontrolled** existing ambient outdoors
  - *Bishop (1966)*
- **Noise generator** used as an ambient proxy
  - *Berglund et al. (1975)*
- **Indoor environment simulated** via low-pass noise filtering
  - *Powell and Rice (1975)*
- **Community noise survey data** referenced to **long-term ambient measurements**
  - $L_{dn}$  (DNL) or 24 hr  $L_{aeq}$ 
    - *Lim et al. (2008)*
    - *Fields (1998)*

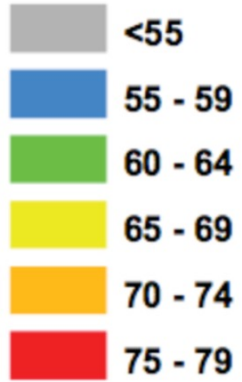
# ➤ Ambient environmental noise: acoustical engineering definitions

- “what remains after a noise source being investigated is turned off” (Morfey)
- “all-encompassing noise associated with a given environment at a specified time, being usually a composite of sound from many sources at many directions, near and far; no particular sound is dominant” (Harris, Schomer)
- “the lowest sound level repeating itself during a minimum ten-minute period” (S.F Noise Ordinance)



# EXEMPLAR URBAN RESIDENTIAL NOISE ORDINANCE (SAN FRANCISCO)

## Day-Night Noise Level (Ldn)



sf-noise-map.png 2,098x906 pixels



## Noise ordinances reflect an averaged level, NOT a noise dose

### EXTERIOR NOISE LIMITS

(Levels Not To Be Exceeded More Than 30 Minutes In Any Hour)

Receiving Land Use Category	Time Period	Noise Level (dBA)		
		Noise Zone Classification (1)		
		Rural Suburban	Suburban	Urban
One & Two Family Residential	10 pm- 7 am	40	45	50
	7 am-10 pm	50	55	60
Multiple Dwelling Residential Public Space	10 pm- 7 am	45	50	55
	7 am-10 pm	50	55	60
Limited Commercial Some Multiple Dwellings	10 pm- 7 am	55		
	7 am-10 pm	60		
Commercial	10 pm- 7 am	60		
	7 am-10 pm	65		
Light Industrial Heavy Industrial	Any Time	70		
	Any Time	75		

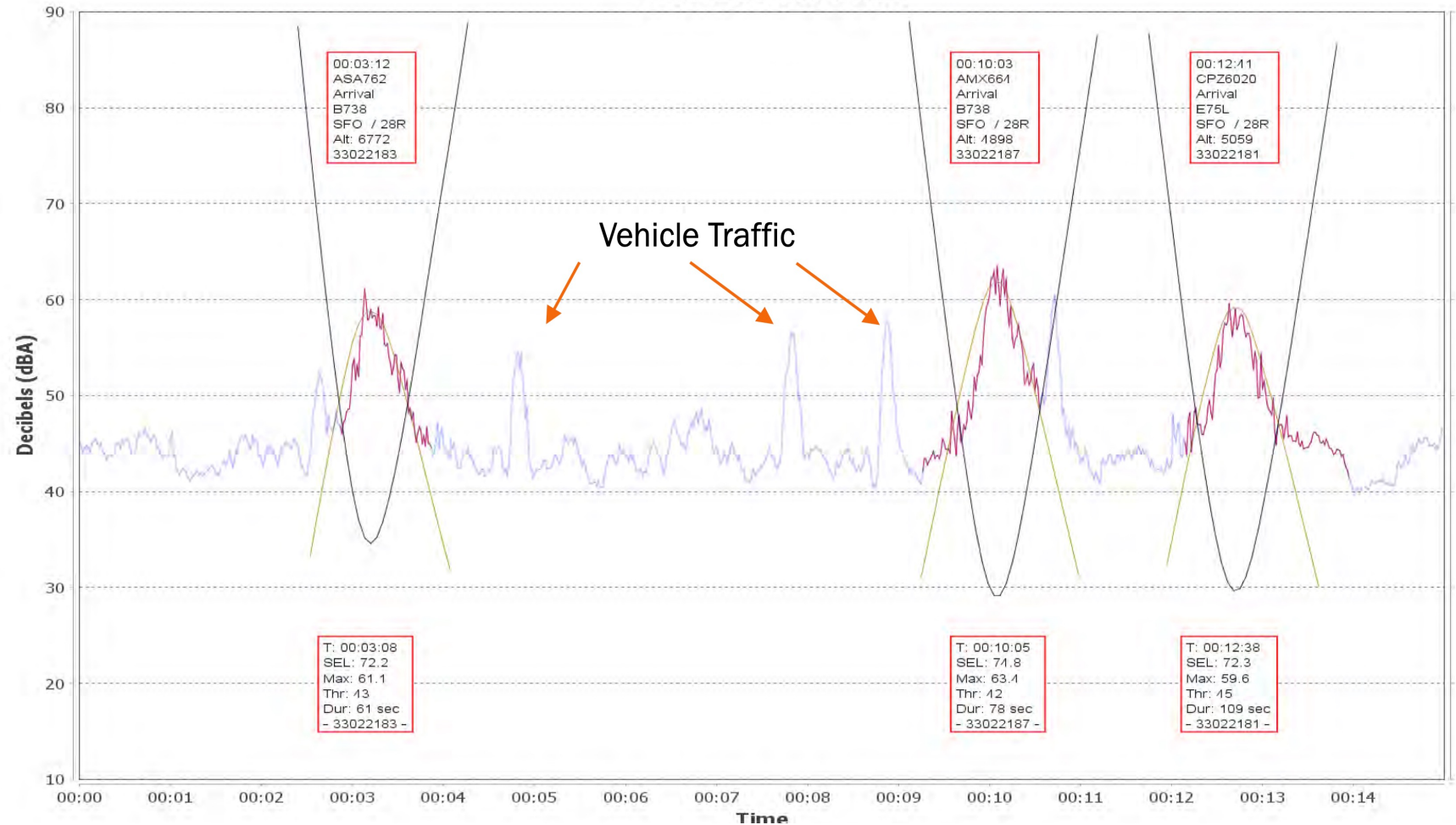


**Ldn 60 = normally acceptable**, residential land use: “primarily applied where outdoor use is a major consideration (e.g., backyards in single-family housing developments, and recreational areas in multiple family housing projects”

**Ldn >60-75 = conditionally acceptable**; noise reduction-insulation required



**No person shall produce, suffer or allow to be produced by any machine, animal or device, or any combination of same, on residential property, a noise level more than 6dB above the local ambient at any point outside of the property plane (40 dBA floor, Lmin, 6 minutes). Daytime exception 8am-8pm, M-F:70 dBA at a distance of 25 feet.**



**BART (Bay Area Rapid Transit) CRITERIA FOR OPERATIONAL NOISE FROM TRAINS**  
**dBA MAX VALUES:**

	Single Family – Multi Family
I <u>Low Density Residential:</u> urban residential, open space park, suburban residential or quiet recreation area. No nearby highways or boulevards	70 – 75
II <u>Average Residential:</u> urban residential, quiet apartments and hotels, open space, suburban residential, or occupied outdoor areas near busy streets	75
III <u>High Density Residential:</u> urban residential, average semi-residential/commercial areas, parks, museum, and non-commercial public building areas	75 - 80
IV <u>Commercial:</u> areas with office buildings, retail stores, etc., primarily daytime occupancy. Central Business Districts	80
V <u>Industrial/Highway:</u> areas or Freeway and Highway Corridors.	80 - 85
<i>Special Receptors</i>	
“Quiet” Outdoor Recreation Areas	70



Albany, CA (former “key route” rail car line ~1903-1958)

## ISO/TS 15666

### Acoustics – Assessment of noise annoyance by means of social and socio-acoustic surveys

*retrospective judgment; memory*

Unipolar scales (neutral-negative)

#### A.4 Unipolar scales (neutral-negative)

From many previous surveys, it has been found that reactions to transportation noise are overwhelmingly either negative or neutral. Therefore the questions should use unipolar scales that extend from a negative pole (extremely annoyed) to a neutral position (not at all annoyed), but not to a positive pole (extremely enjoyable).

Thinking about the last (12 months or so), when you are here at home,

##### **verbal rating scale**

how much does noise from (noise source) bother, disturb or annoy you?

- Not at all?
- Slightly?
- Moderately?
- Very?
- Extremely?

##### **0-to-10 opinion scale**

what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by (source) noise?

## Laboratory studies

Sneddon, Pearsons and Fidell (2003) :

### Laboratory study of the noticeability and annoyance of low signal-to-noise ratio sounds

“Noticeability is the ability of an audible signal to attract the attention of an individual engaged in an activity other than listening for such a sound”

**(“...the level at which an audible sound is recognized as intrusive”)**

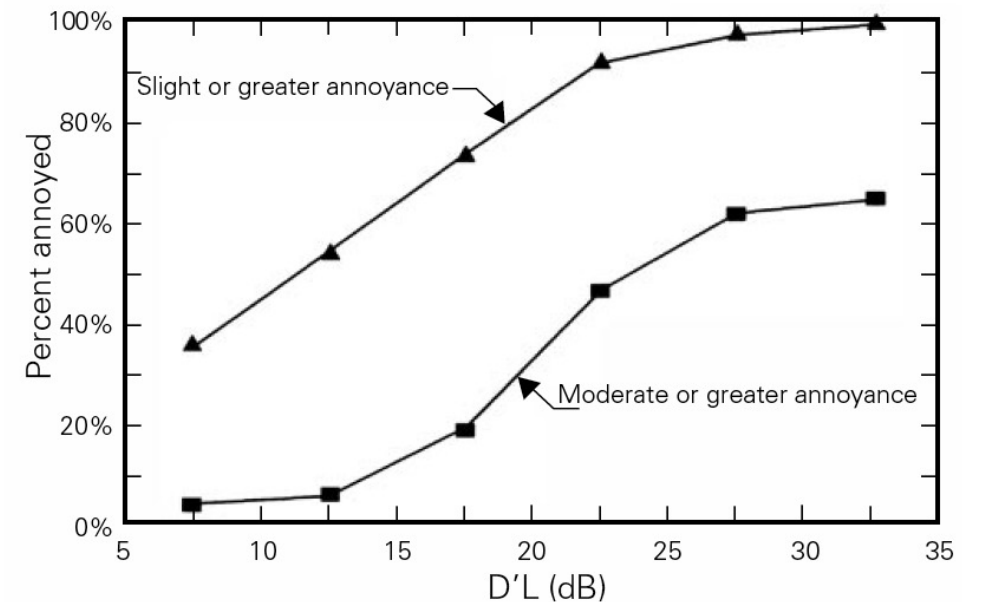
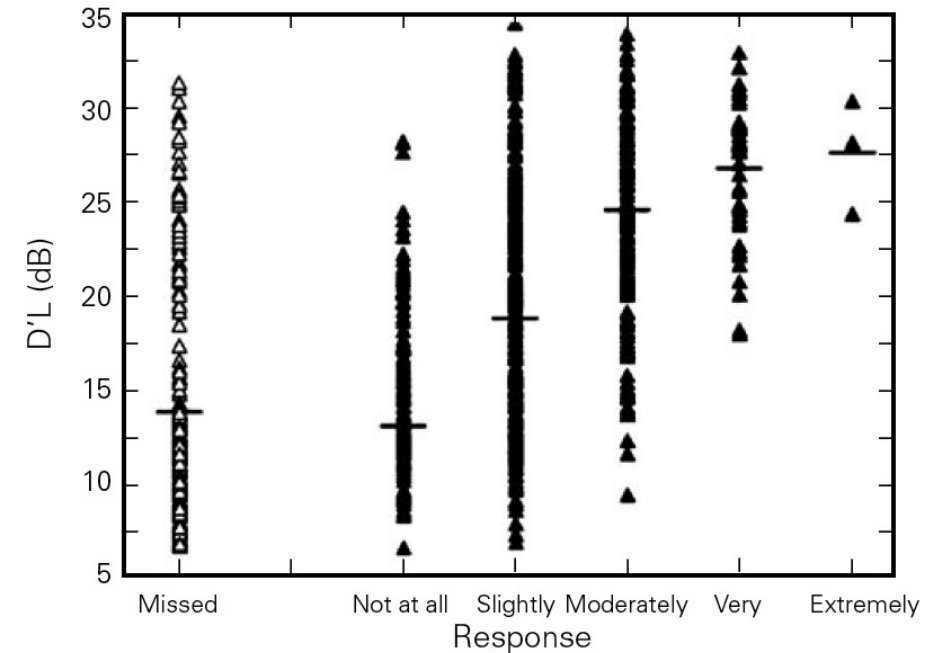
When a sound was **noticed**, its annoyance was rated on a 5-point scale.

Results:

$d' L 6$  ( $d' 4$ ) = detection when focused, 95% HR, 1 % FAR

$d' L 11$  = level for 50 % signals to be noticed

$d' L 16$  = level to command attention when distracted



# HUMAN DETECTION TO AIRCRAFT NOISE: "DETECTION" NPS STUDIES ca. 1980s-1990s

NPOA Report No. 93-1

BBN Report No. 7197

## EVALUATION OF THE EFFECTIVENESS OF SFAR 50-2 IN RESTORING NATURAL QUIET TO GRAND CANYON NATIONAL PARK

FINAL REPORT

Sanford Fidell, Karl Pearsons, and Mathew Sneddon

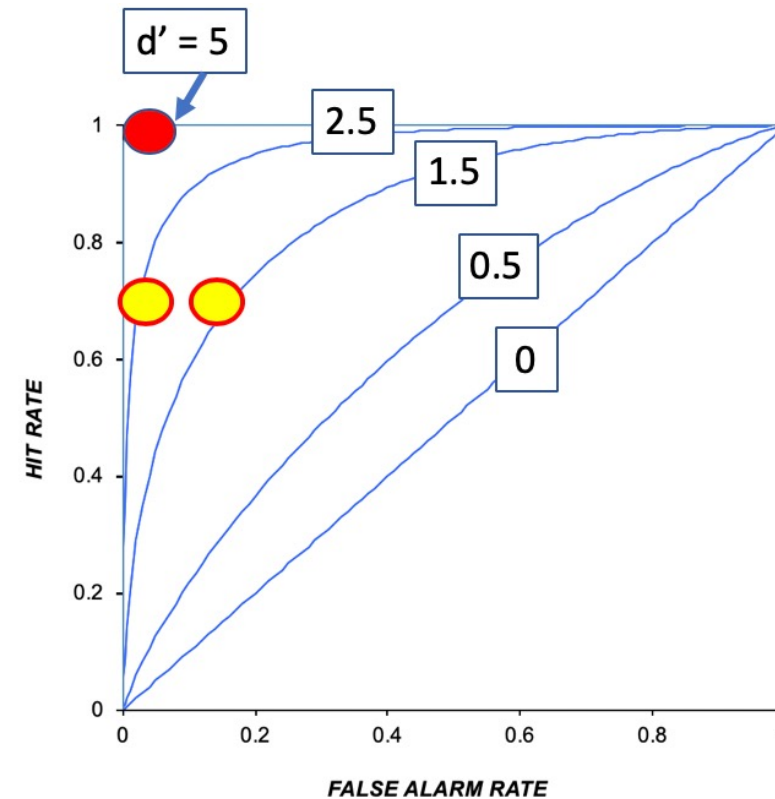
## METHODOLOGY FOR THE MEASUREMENT AND ANALYSIS OF AIRCRAFT SOUND LEVELS WITHIN NATIONAL PARKS

*National Park Service*

Final Report  
March 1989

Paul H. Dunholter, P.E.  
Vincent E. Mestre, P.E.  
Roswell A. Harris, Ph.D., P.E.  
Louis F. Cohn, Ph.D., P.E.

"[In] low sound level settings, the **loudness** of the sound may play a less prominent role .... **signal detection or audibility** appears to be the **most important factor** in predicting annoyance."

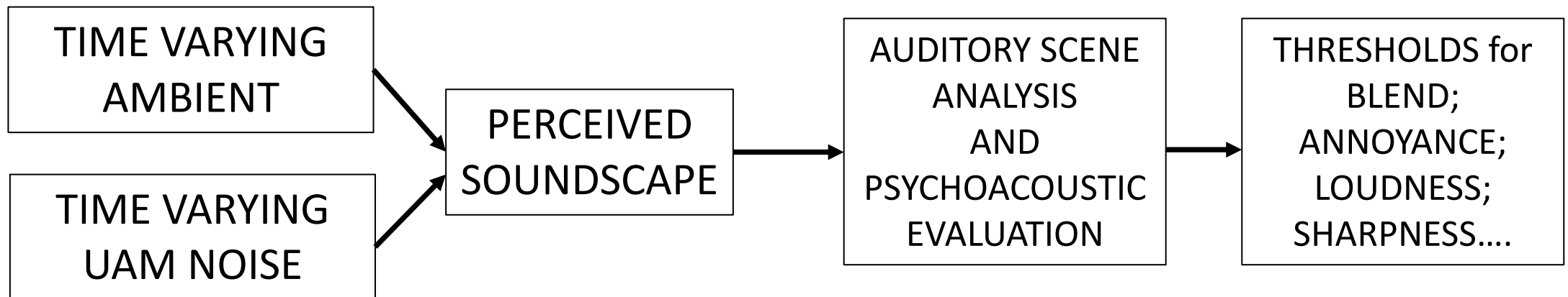


# BLEND “THRESHOLD” (compared to detection or annoyance)

**Q:** What would be an **ideal characteristic** for aircraft noise?

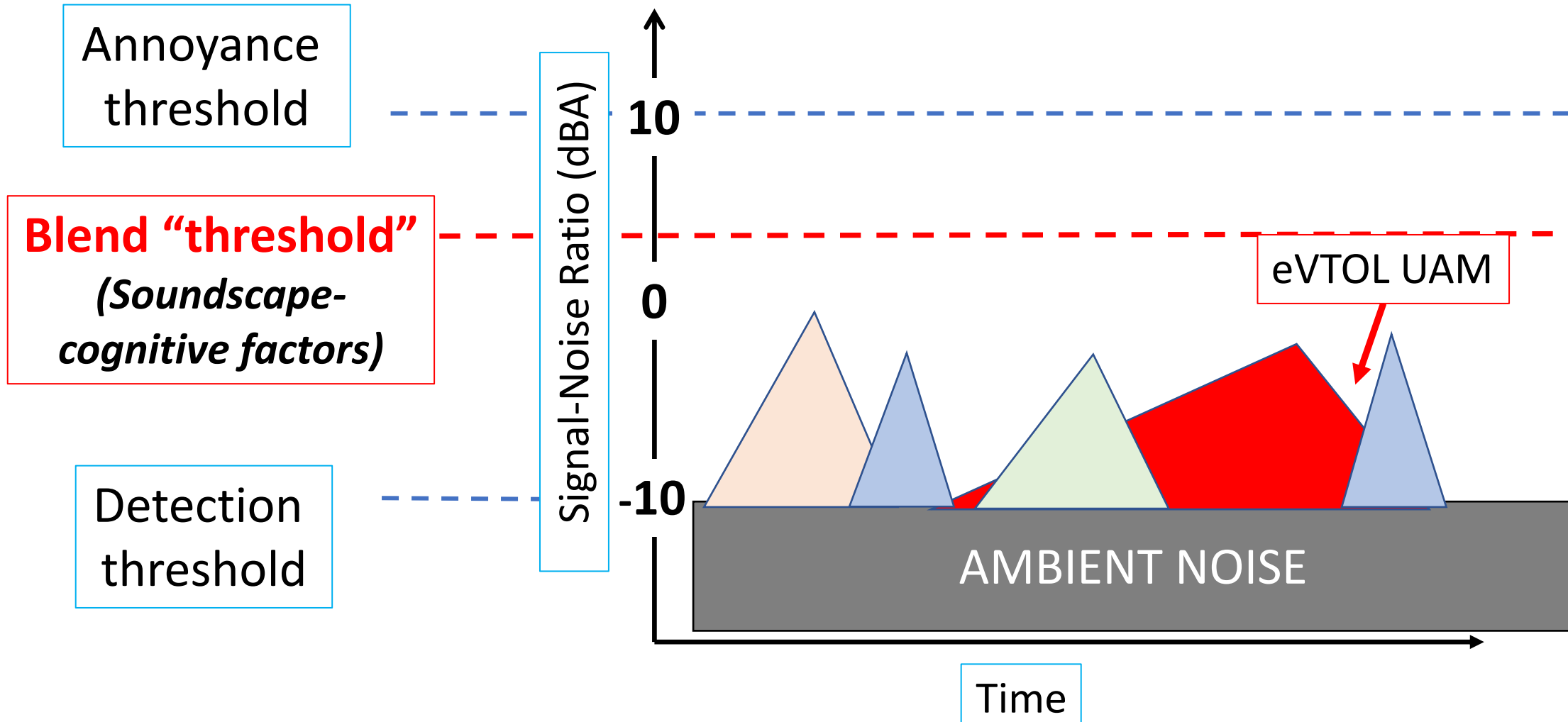
**A:** The noise **blends** into the ambient **soundscape**

- The **blend threshold** is a subjective rating concept representing all attributes of a sound that cause it to not **dominate** over the ambient
- We can predict a blend threshold **objectively** via **auditory scene analysis** and **subjectively** via psychoacoustic evaluation using auralization



- **BLEND METRIC:** Signal-Noise region where UAM noise **does not dominate** other ambient sound sources

• *Blend metric is a practical compromise between **detection** and **annoyance***

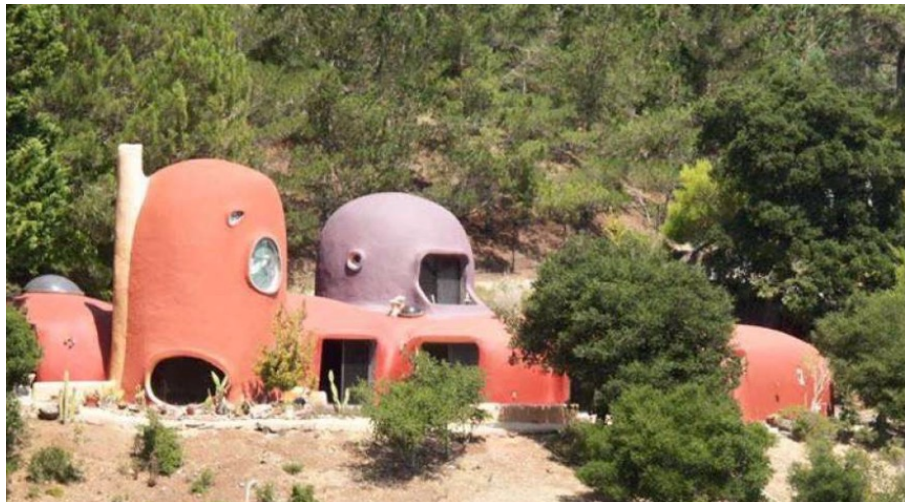
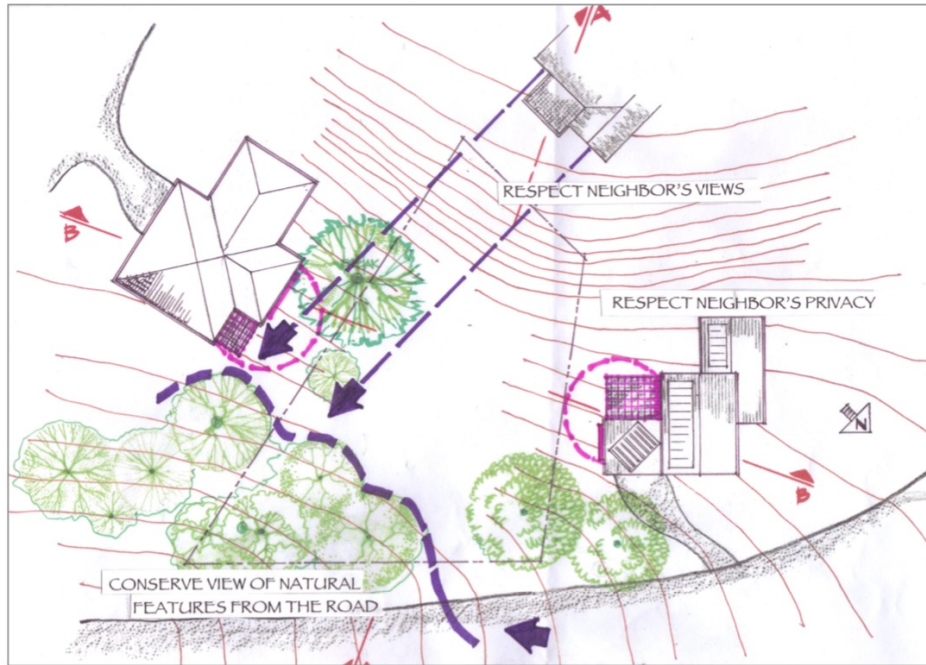


- Normally in lab studies involving the sensory evaluation of sound, assessors (subjects) are either “non-expert” or “highly trained”
  - “Non-experts” : affective studies (e.g., noise survey)
  - “Experts” : studies using trained panels or “experienced” listeners (e.g., semantic differential ratings; consensus vocabulary)
- For eVTOL noise studies, it is possible to train subjects to use a specific criteria in ratings, using minimal training for consistency.
- “Blend” is a criteria defined as when a newly introduced sound is no more significant than any other sound source in the existing ambient.
- The condition of “inevitable change” is introduced: “what would be acceptable, based on the existing ambient soundscape”

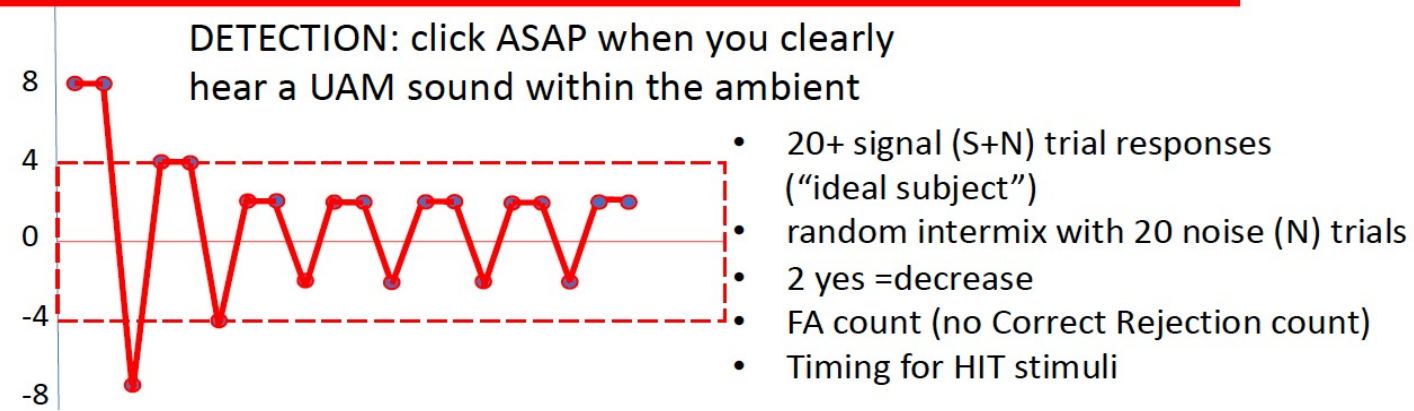
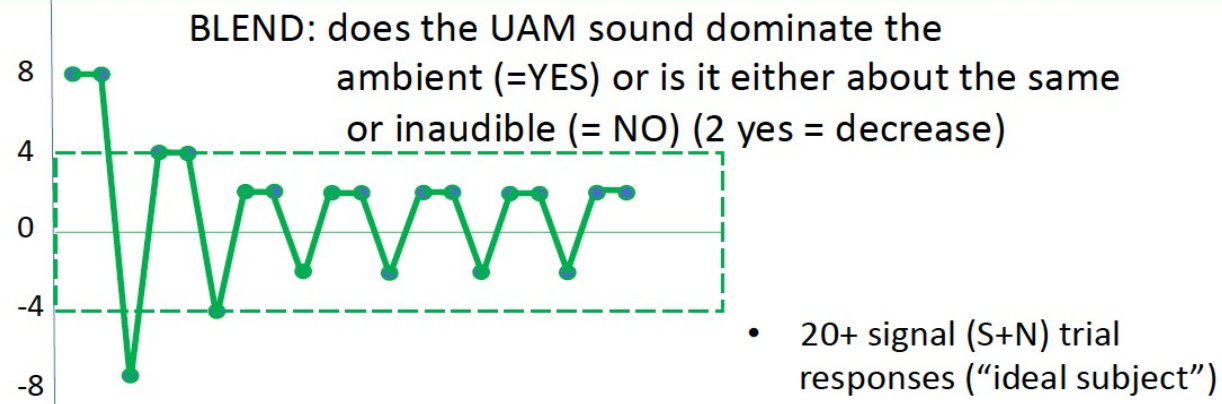
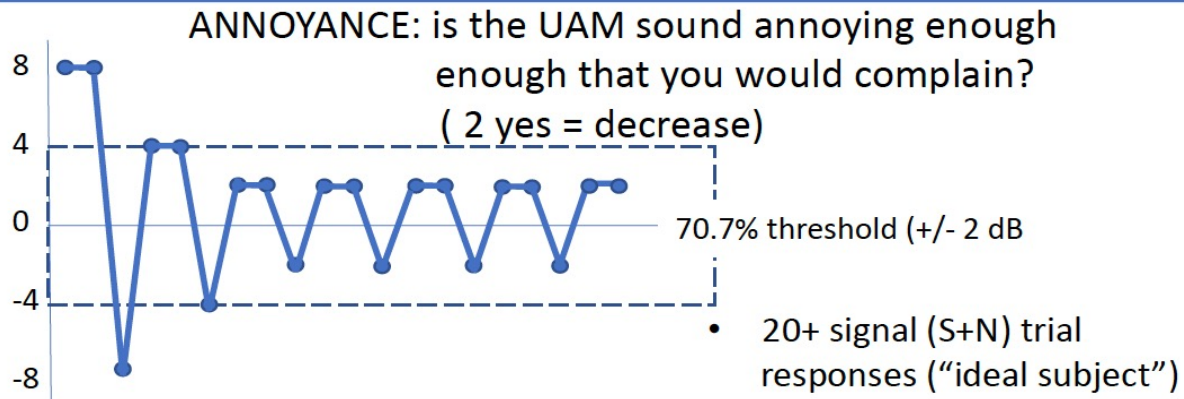


# Architectural review boards: visual blend

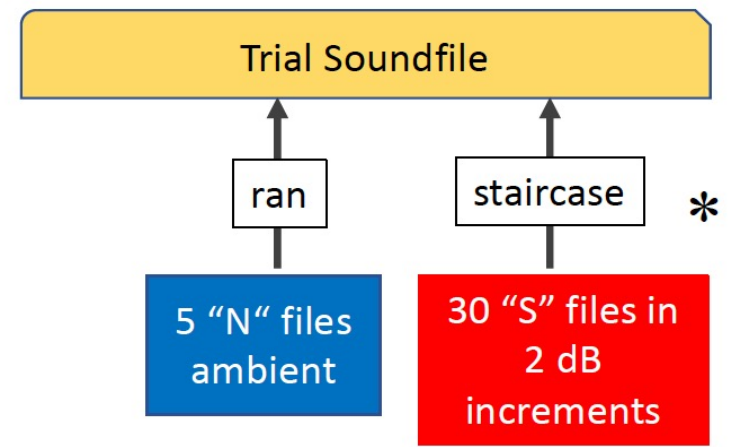
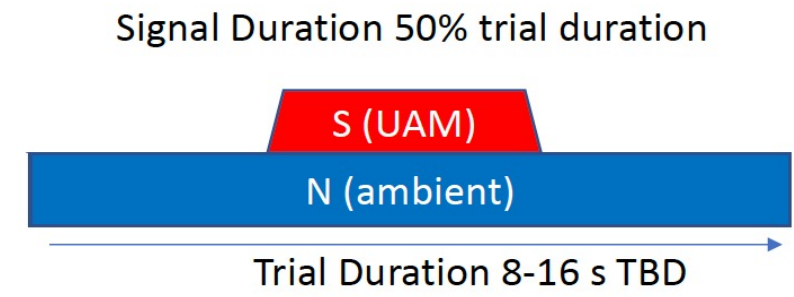
## Small Lot - Off Site Considerations



Streetscape Elevation

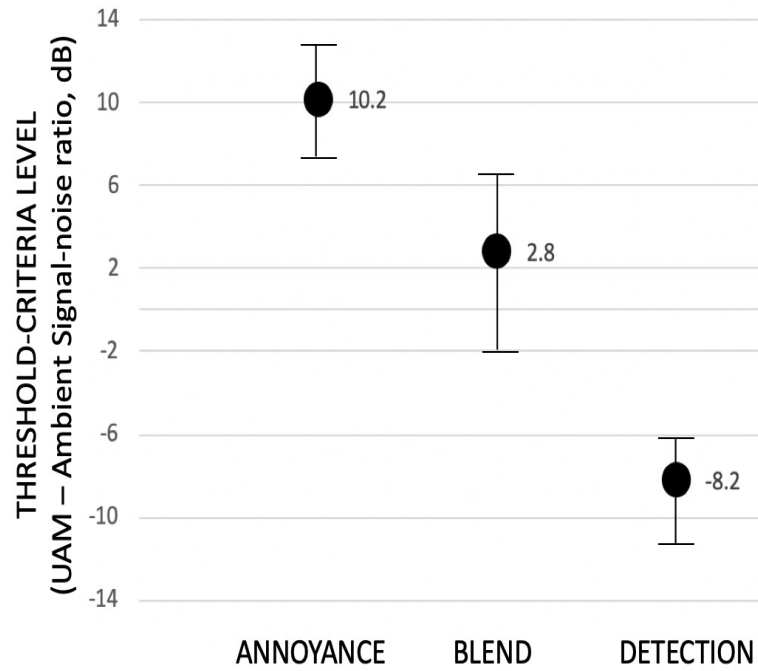


YES or NO responses (single interval, 2AFC)  
70.7% threshold level (2 down, 1 up)

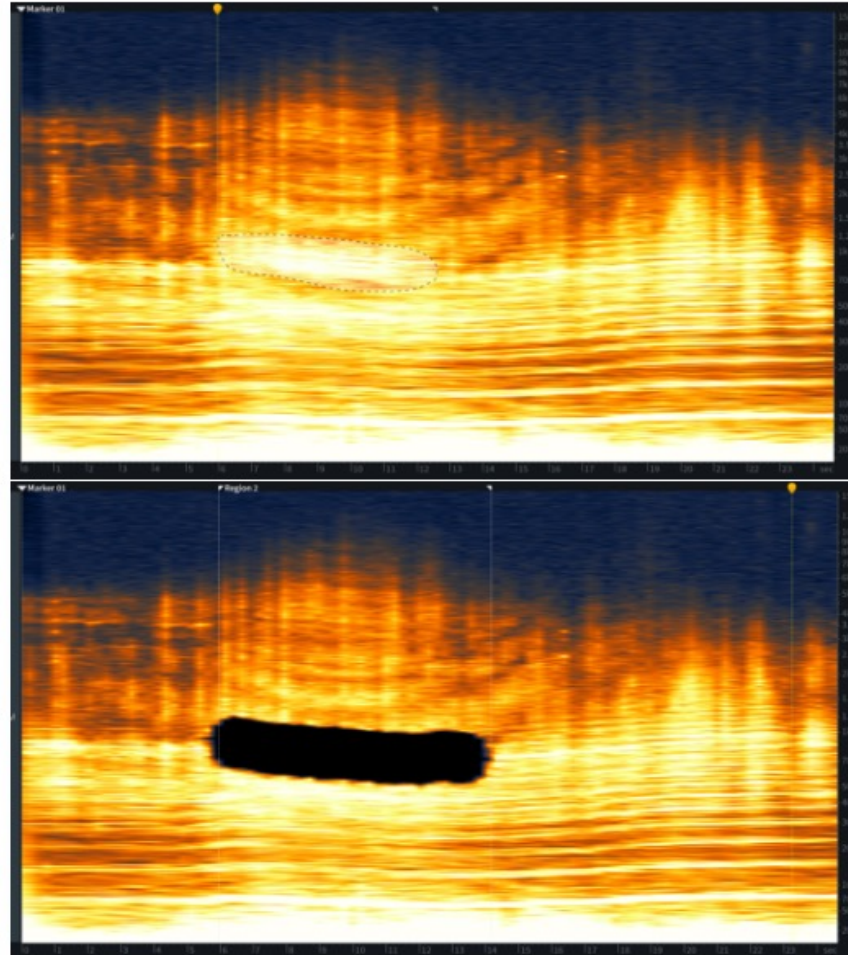


\* Detection trials include N only

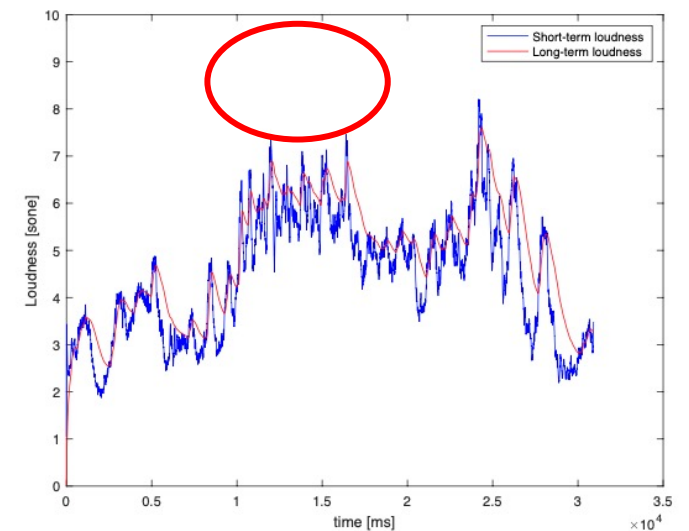
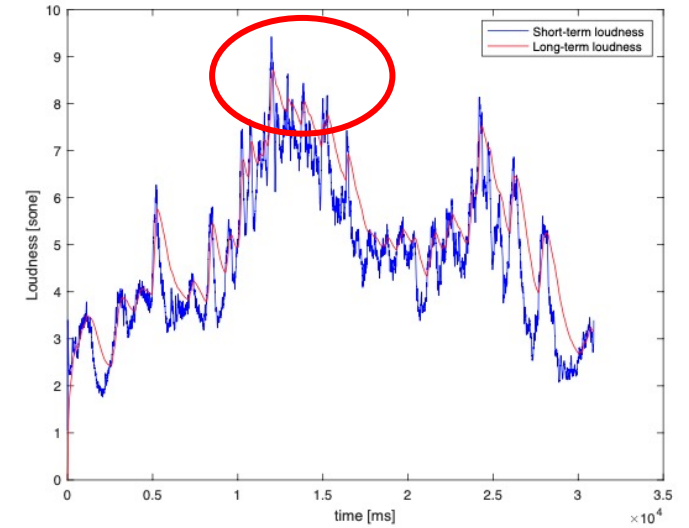
## Judgments as a function of LEVEL (signal-noise ratio) ("informed routing")



## Judgments as a function of TONE ATTENUATION ("informed design")



## Difference in time varying loudness with significant tone attenuated



# Perceptual attributes of eVTOL noise noticeability and blend with reference to the ambient

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