

Basic Aircraft Noise Terminology

- **What are “Sound” and “Noise”?**
 - Sound Pressure Level
 - Decibel
 - A-Weighted Decibel
- **Single Event Metrics**
 - Maximum A-Weighted Sound Level, L_{max}
 - Sound Exposure Level, SEL
 - Single Event Noise Equivalent Level, SENEL
- **Cumulative Exposure Metrics**
 - Equivalent Sound Level, L_{eq}
 - Day-Night Average Sound Level, DNL
 - Community Equivalent Sound Level, CNEL
- **Other Metrics**

Definition of Noise

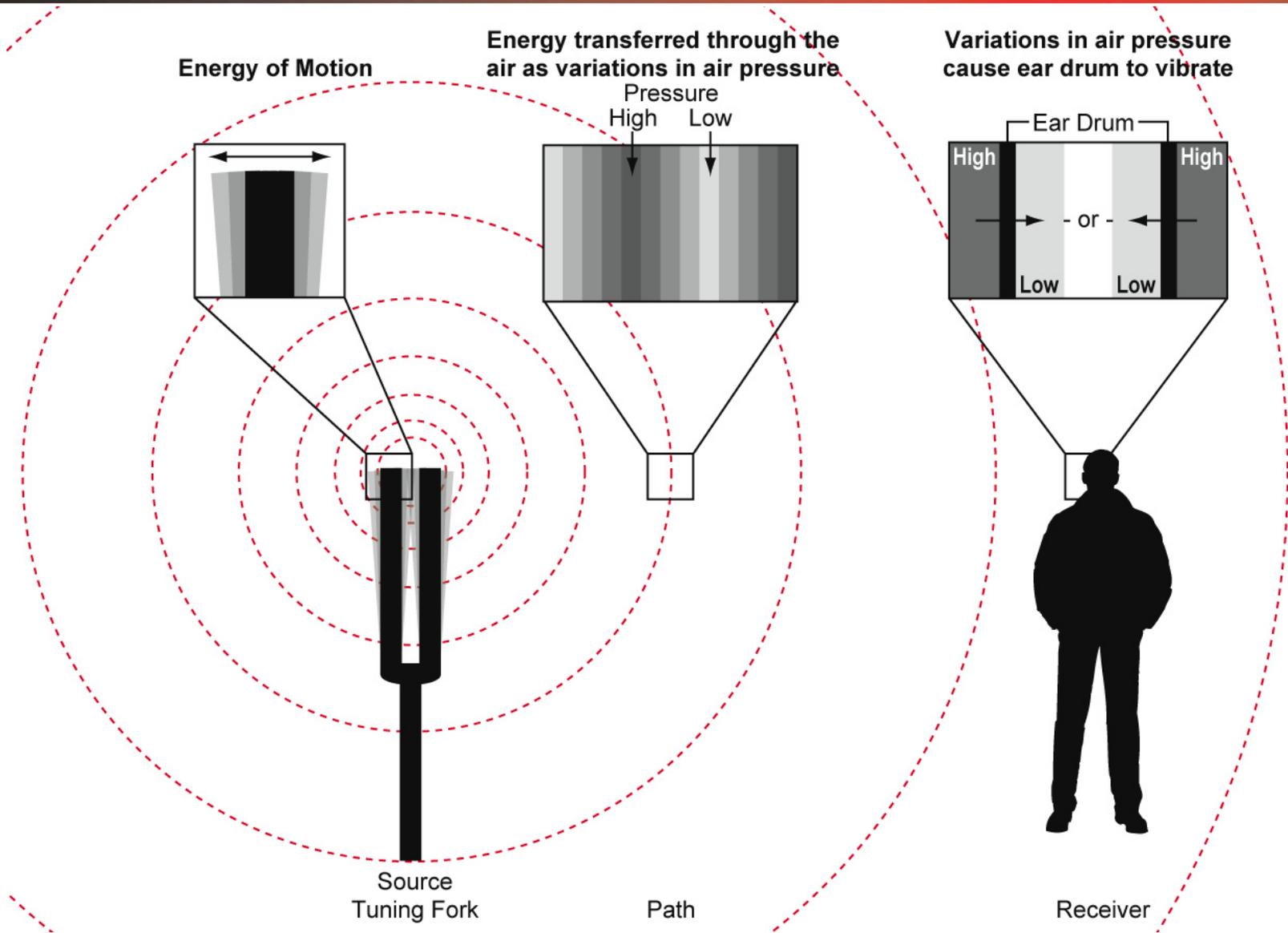
www.hmmh.com

- **Noise** is “unwanted sound”
 - A *subjective* quantity
- **Sound** is any pressure variation a human ear can detect
 - An *objective* quantity
- We relate sound levels to noise by considering *effects*
 - Annoyance
 - Speech interference
 - Sleep disruption

Sound Pressure:

Variations in air pressure that travel from source to receiver

www.hmmh.com



The Decibel Scale

www.hmmh.com

- We use a *logarithmic* scale – decibels – to express sound levels and noise levels
- The decibel scale matches the way our ear and brain “auditory system” interprets sound pressures
 - *We “hear” in decibels.*
- We can hear sound pressures over a HUGE range
 - 0.000,000,003 to 0.003 pounds per square inch (psi) – the threshold of hearing to the threshold of pain
- The decibel compresses this to a smaller range
 - 0 to 140 dB

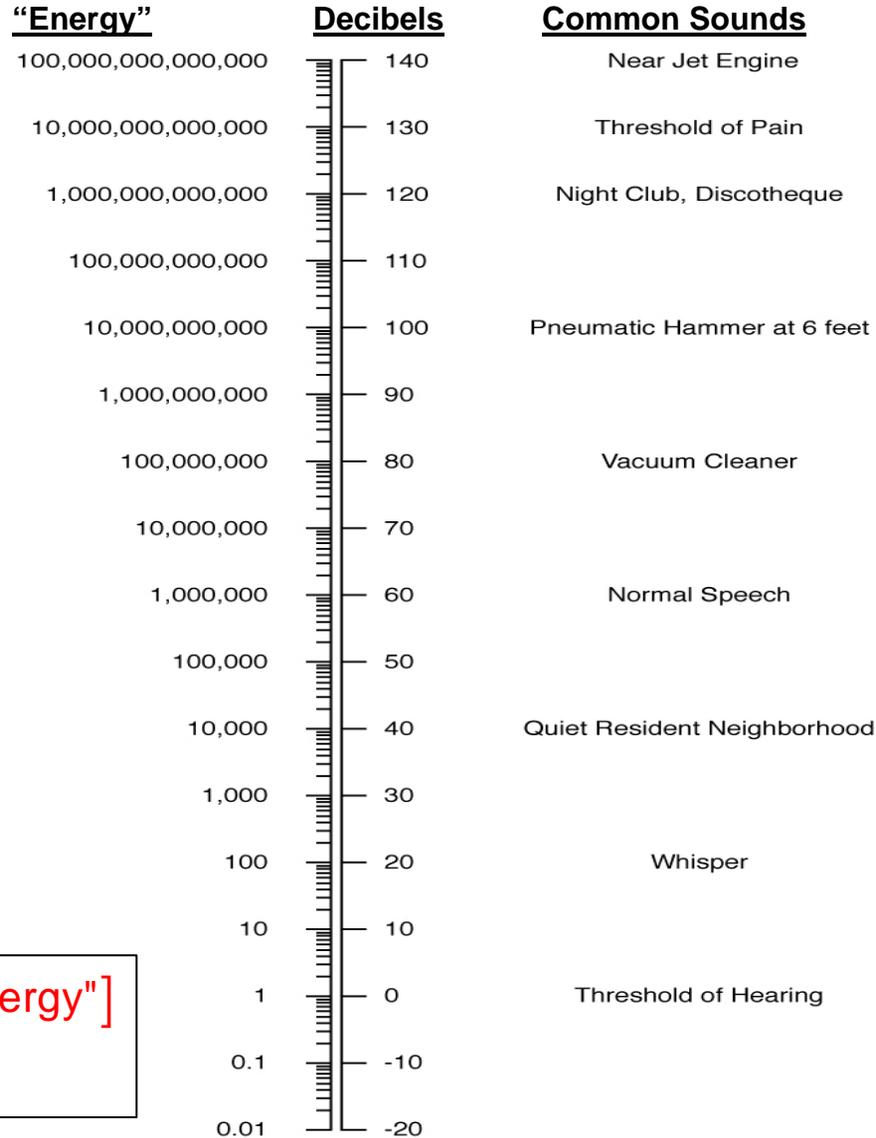
Decibel Changes

www.hmmh.com

- In a laboratory with a direct A:B comparison we can detect about a 1 dB change in sound level
- In a normal environment, a 3 dB change is generally the threshold of detectability
 - Why? Noise fluctuates and distinct A:B comparisons are rare
 - A 3-dB increase represents two times the sound energy
- A change of 6 dB is clearly perceptible in
 - A 6-dB increase requires four times the sound energy
- A change of 10 dB is required before the sound seems twice as loud
 - A 10-dB increase requires ten times the sound energy

Decibels and "Energy"

www.hmmh.com



$$\text{Decibels} = 10 \log["\text{Energy}"]$$

$$"\text{Energy}" = 10^{\text{Decibels}/10}$$

Rise/fall

1dB 5dB 10dB



Wobble

1dB 5dB 10dB



Decibel Addition – *It's not ordinary math!*

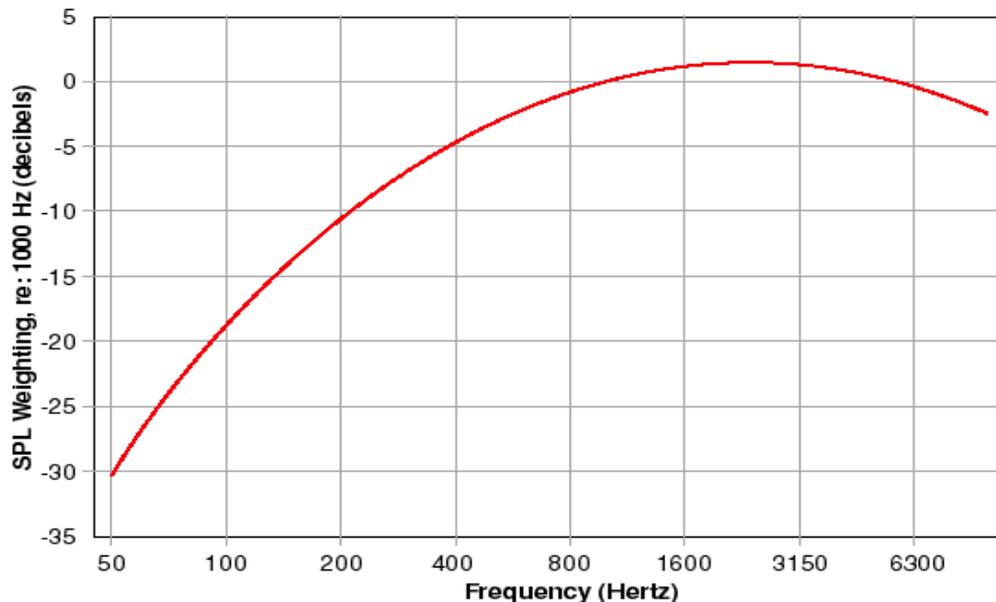
www.hmmh.com

- Decibels are a logarithmic quantity, so...
- Two equal sources:
 - $100 \text{ dB} + 100 \text{ dB} =$ ~~200~~ 103 dB
- Four equal sources:
 - $100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} = 106 \text{ dB}$
- Ten equal sources:
 - $100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} +$
 $100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} + 100 \text{ dB} = 110 \text{ dB}$

A-Weighted Sound Level (dBA)

www.hmmh.com

- The human auditory system is not equally sensitive to all frequencies
- To be a useful environmental analysis tool we need a way to measure sound the same way the ear “hears” it
- The **A-weighted level** achieves this goal

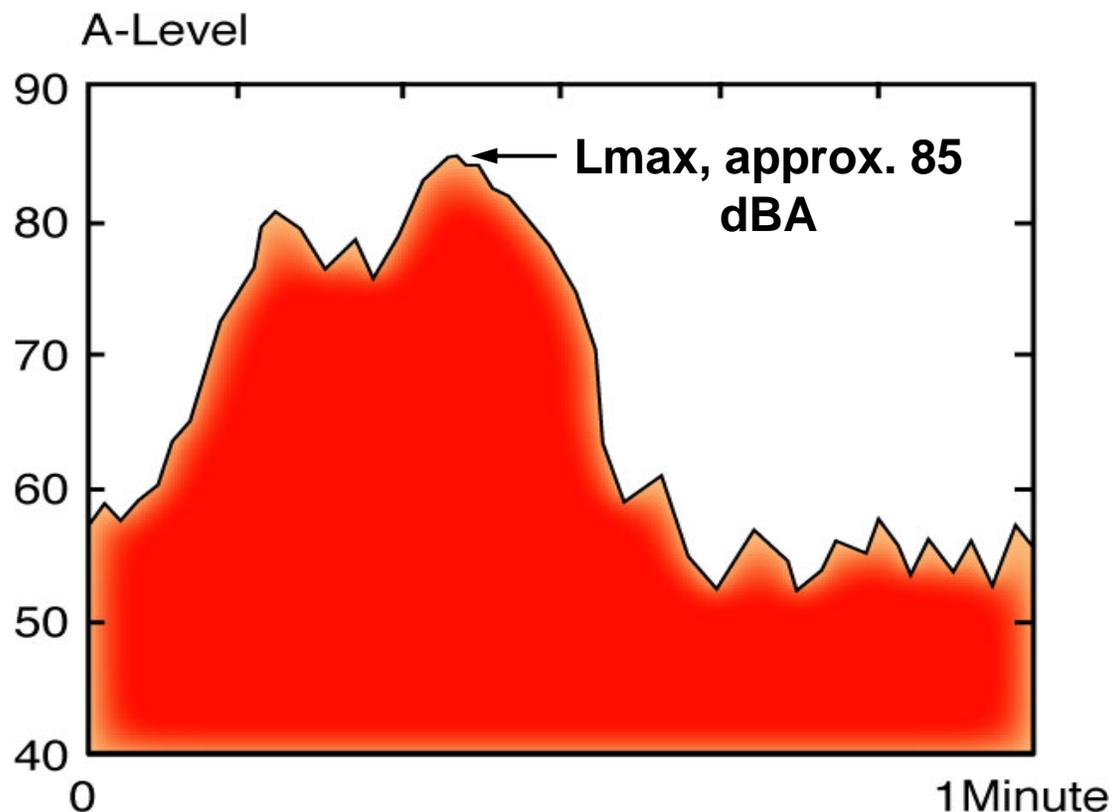


Consistent with EPA's recommendation, the A-weighted level is used by federal, state, and local agencies for environmental noise analyses

Single Event Noise Metrics: Maximum Sound Level (Lmax)

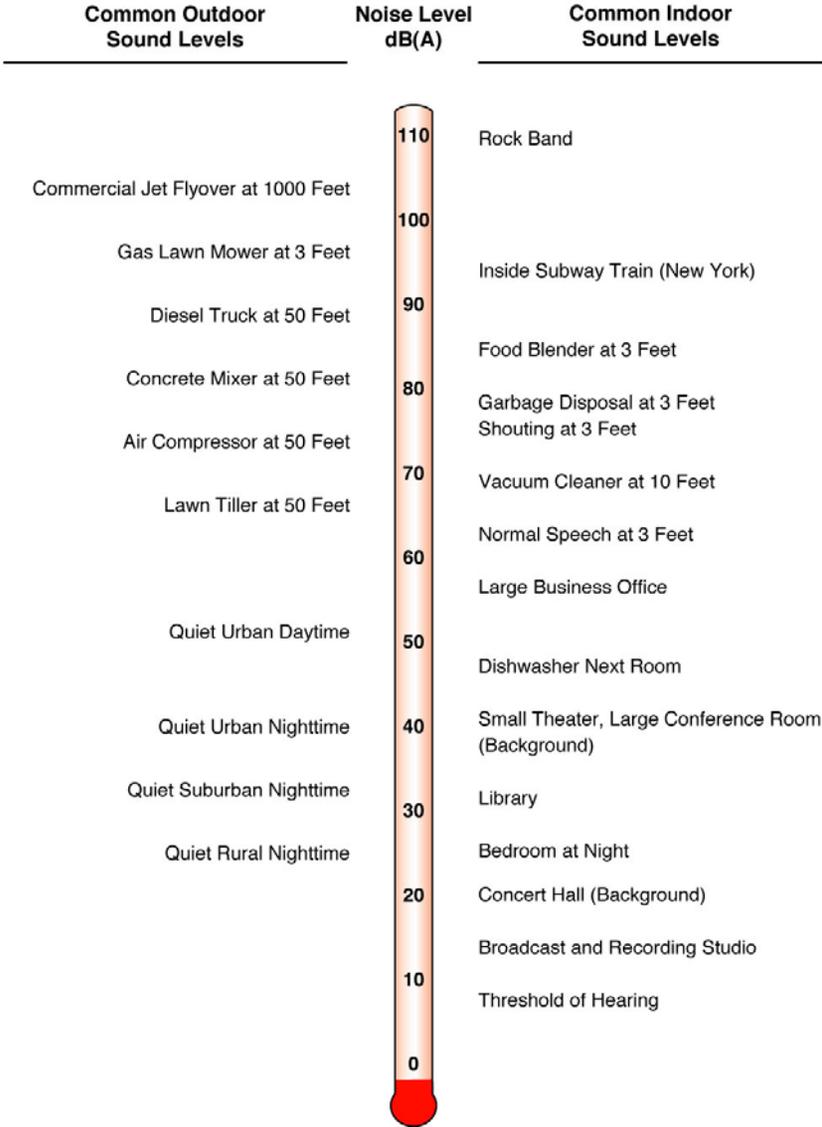
www.hmmh.com

- The simplest way to describe a discrete noise “event” is with its maximum sound level, abbreviated as Lmax
- Accounts only for sound amplitude (dBA)



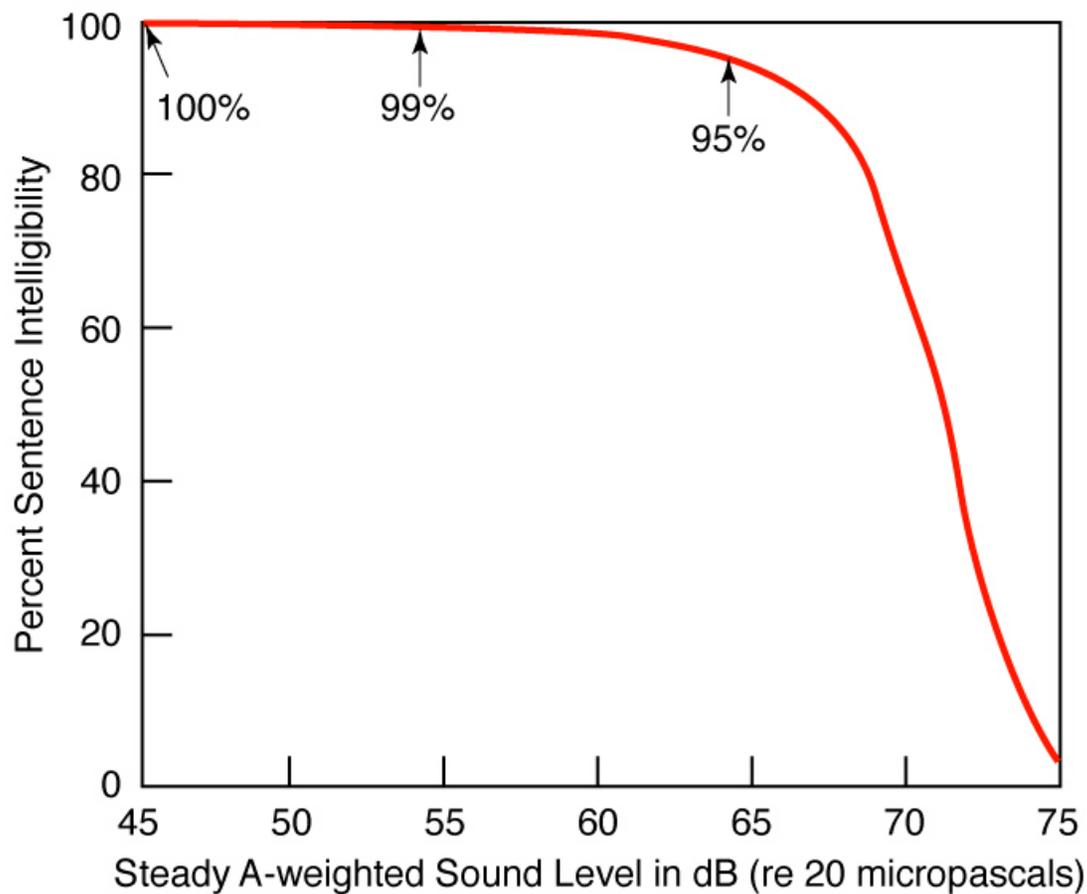
Common Environmental A-weighted Sound Levels, dB

www.hmmh.com



Speech Interference and Lmax

www.hmmh.com



Note: Assumes 300 sabins absorption typical of living rooms and bedrooms and is valid for distances greater than one meter

Source: EPA, 1974

Single Event Noise Metrics: Sound Exposure Level & Single Event Noise Exposure Level (SEL & SENEL)

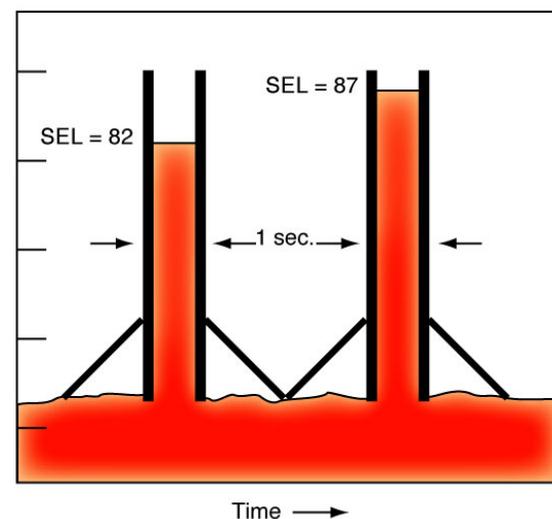
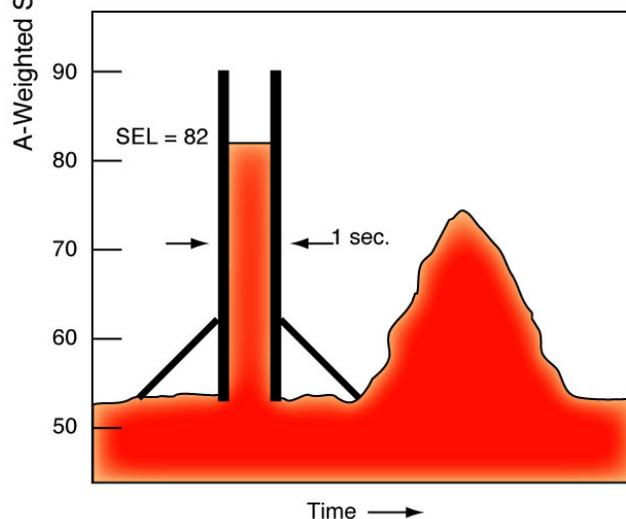
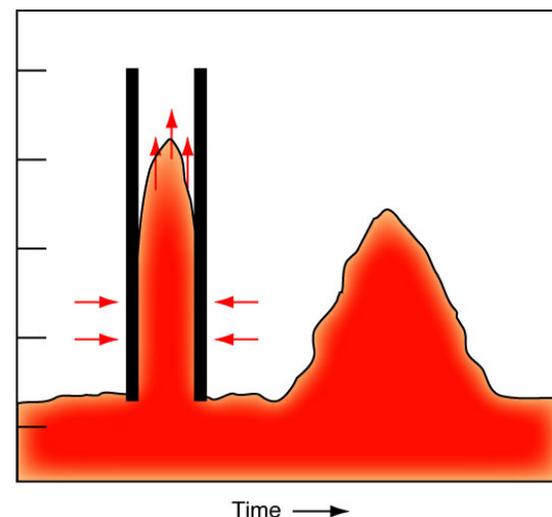
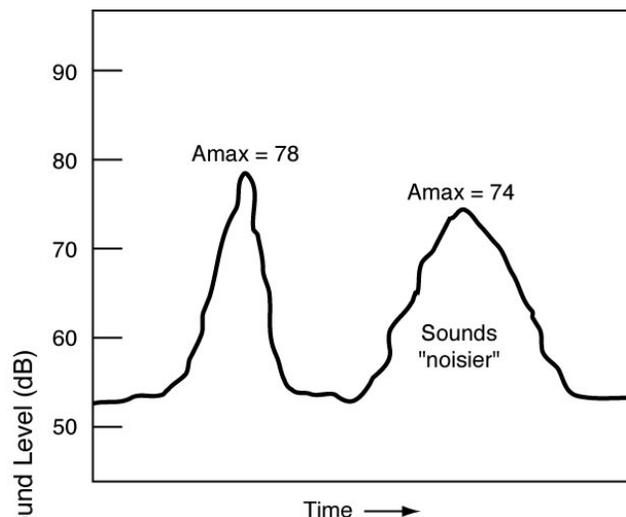
www.hmmh.com

- Two events may have the same L_{max} , but very different overall noise exposures, because of duration
- **Sound Exposure Level (SEL)** is a measure of the total “noisiness” of an event, that takes duration into account
- **Single Event Noise Exposure Level (SENEL)** is the SEL for a defined noise threshold level
 - As long as SENEL is measured for the period when the level is within 10 dB of the L_{max} , it will be essentially the same as SEL
 - We usually measure SENEL in a real-world environment

So what exactly do SEL and SENEL represent?

www.hmmh.com

- The one-second long *steady* level that contains as much energy as the *varying* level over full event
- Note: an event with a higher L_{max} can have a lower SEL than a longer event
- Correlates to awakenings

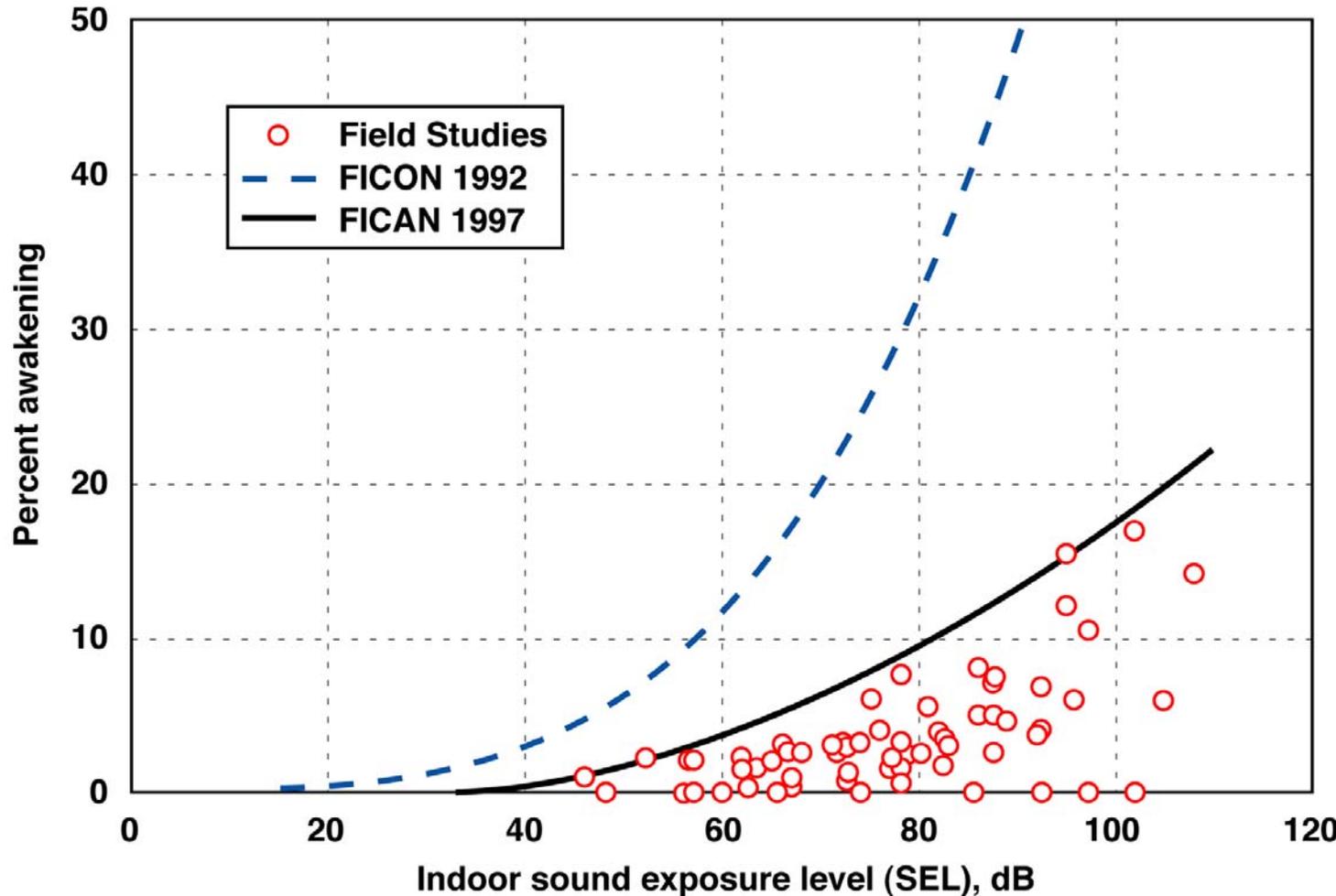


SEL (SENEL) Correlates to Awakenings

www.hmmh.com

ANSI 12.9-2000/Part 6

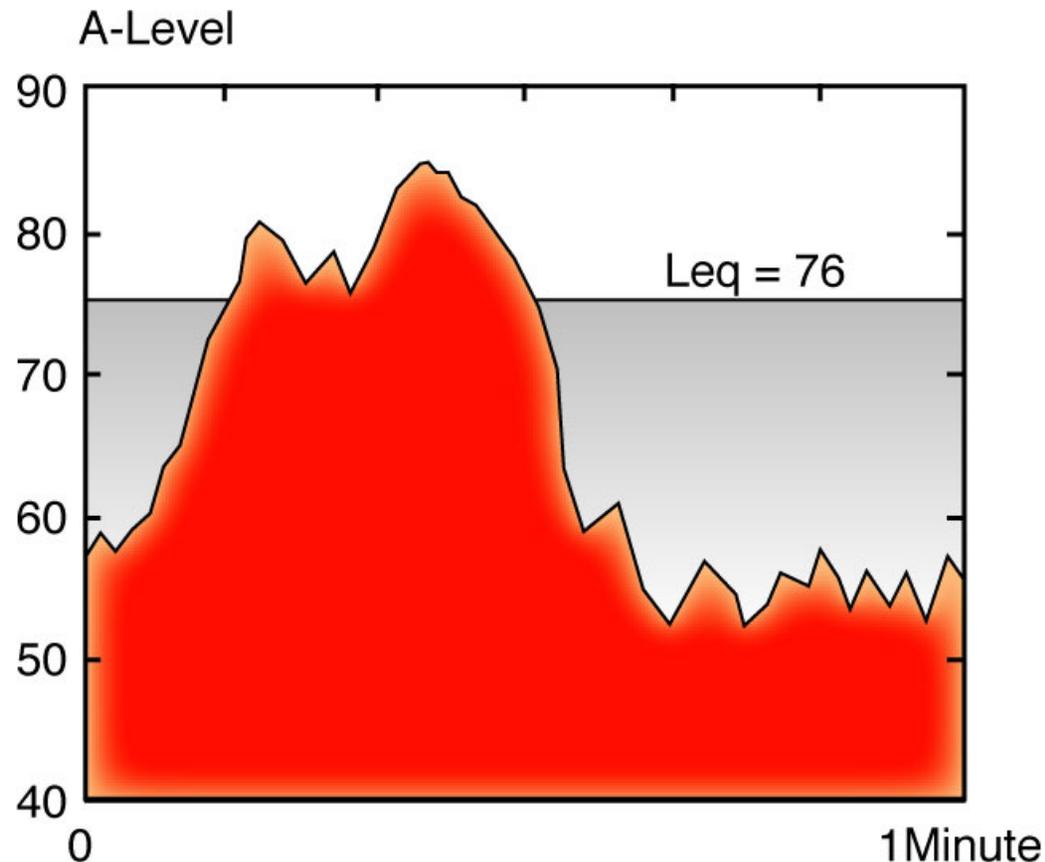
Methods for estimation of awakenings associated with aircraft noise events heard in homes



Cumulative Exposure over Time: Equivalent Sound Level (Leq)

www.hmmh.com

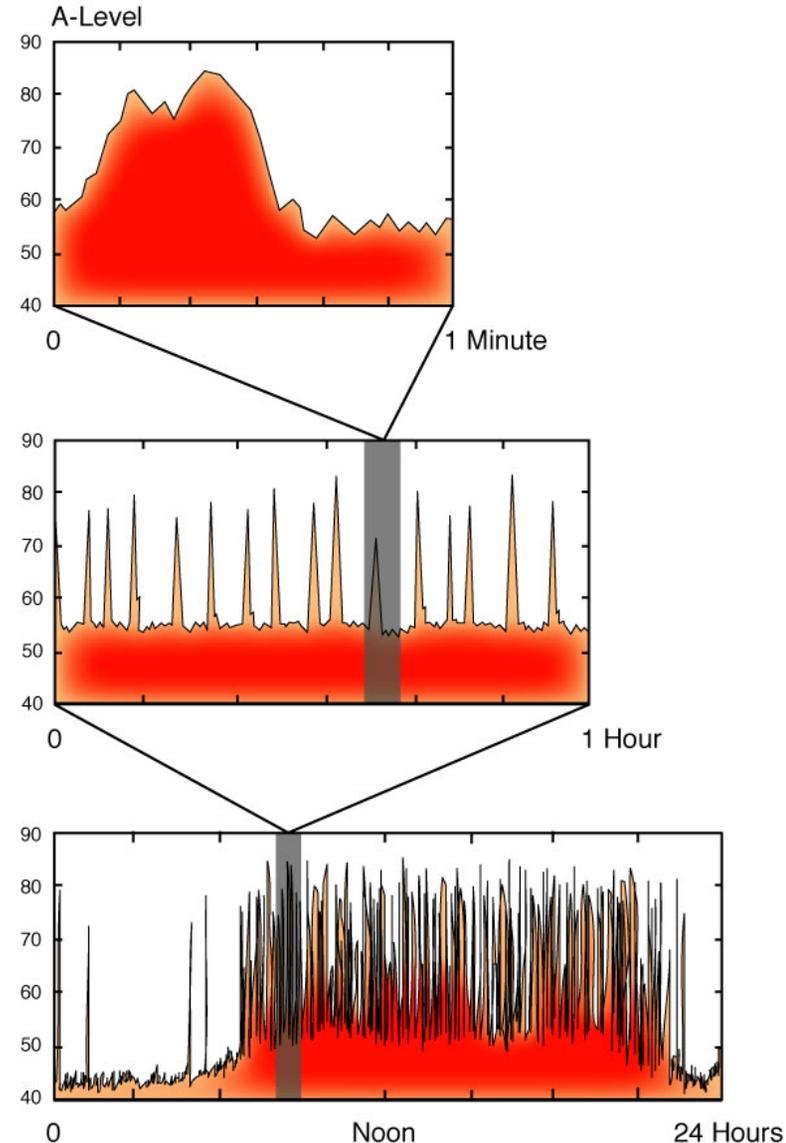
- Leq is the constant sound level that contains the same amount of energy as the time-varying sound level over the same time period
- Unlike SEL, Leq is not “squeezed” into one second
- Leq represents the energy “averaged” level
- Leq can be expressed for any time interval



Cumulative Exposure over Time: Day-Night Average Sound Level (DNL or Ldn)

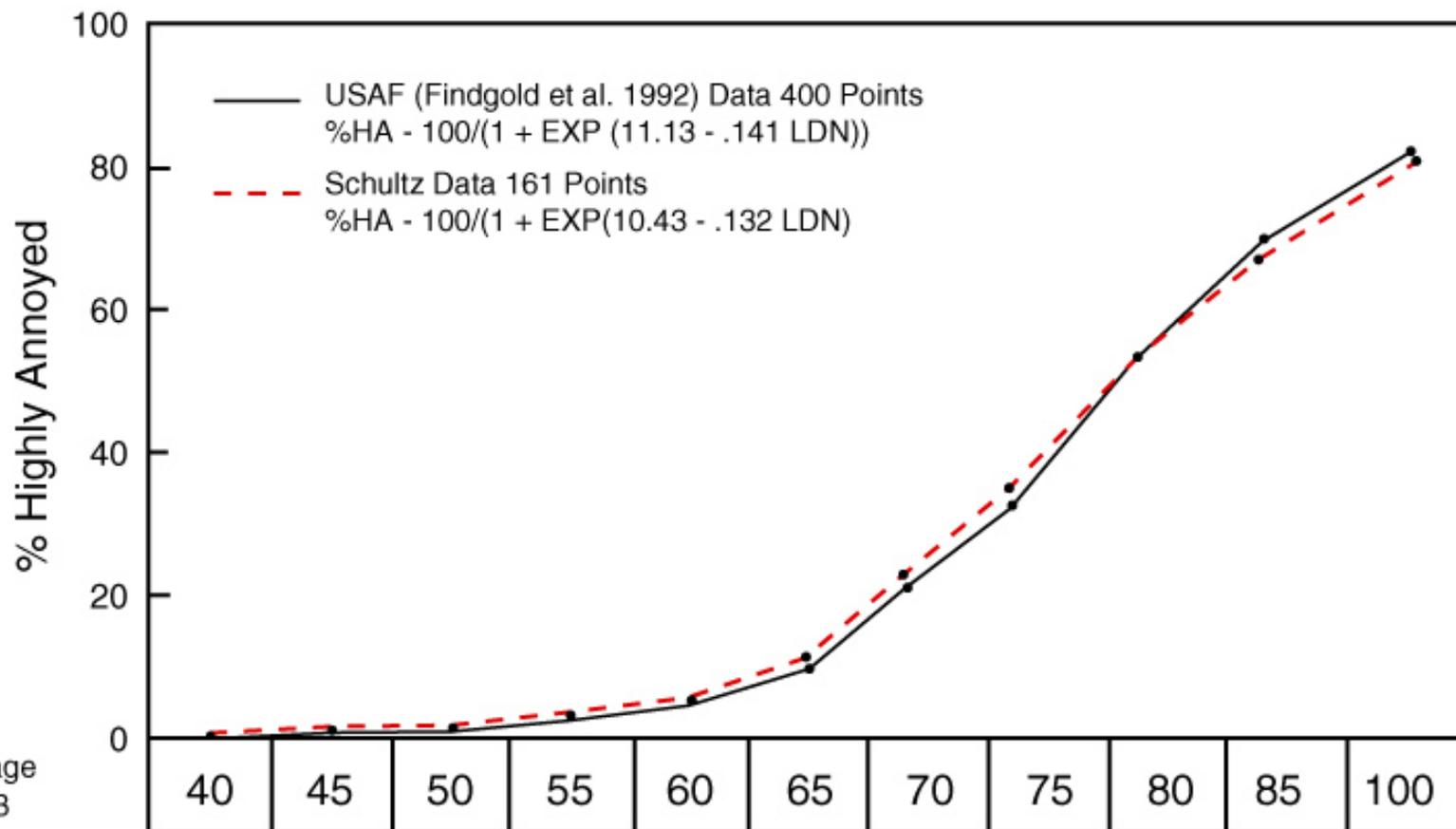
www.hmmh.com

- A way to describe a 24-hour noise dose
- Noise between 10 pm and 7 am is factored up by 10 dB
- For aircraft noise, the night “penalty” is equivalent to counting each night event 10 times
- EPA recommends use of DNL
- Correlates well to community annoyance



Cumulative Exposure over Time: Day-Night Average Sound Level (DNL or Ldn)

www.hmmh.com



Day - Night Average Sound Level in dB

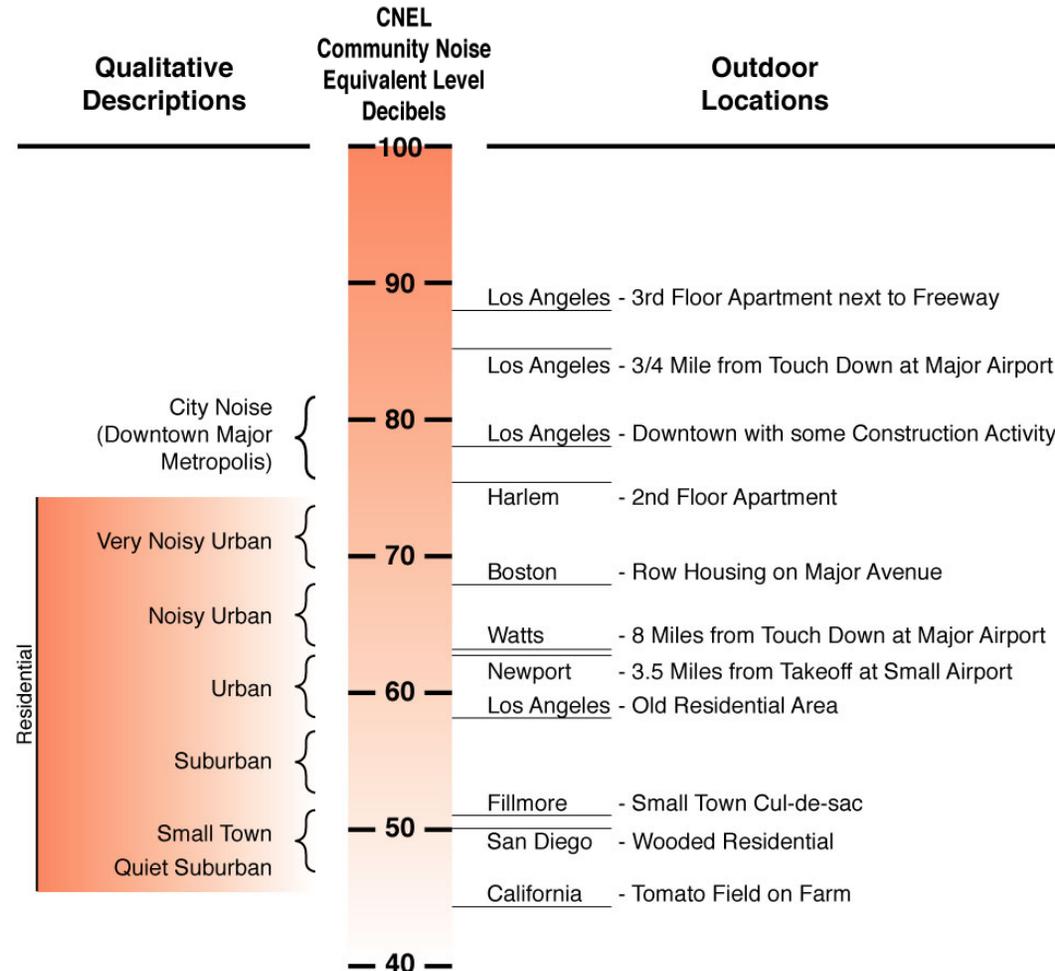
Calculated % HA Points

USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Cumulative Exposure over Time: Community Noise Equivalent Level (CNEL)

www.hmmh.com

- California uses CNEL, a slightly more refined cumulative exposure metric than DNL
- CNEL is similar to DNL, but considers three time periods:
 - Day: 7 am – 7 pm: No weighting or penalty
 - Evening: 7 – 10 pm: 3 times weighting (approx. 4.8 dB penalty)
 - Night: 10 pm – 7 am: 10 times weighting (10 dB penalty)



Interpreting changes in CNEL or DNL

www.hmmh.com

- **0 - 2 dB change in level**
 - May be noticeable
 - Abatement may be beneficial
- **2 - 5 dB change in level**
 - Generally noticeable
 - Abatement should be beneficial
- **Over 5 dB change in level**
 - A change in community reaction is likely
 - Abatement definitely beneficial
- **FAA considers a 1.5 dB the minimum *significant* change where cumulative exposure is above 65 CNEL or DNL**

A given cumulative exposure level (CNEL or DNL) can be come from many different combination of noise events

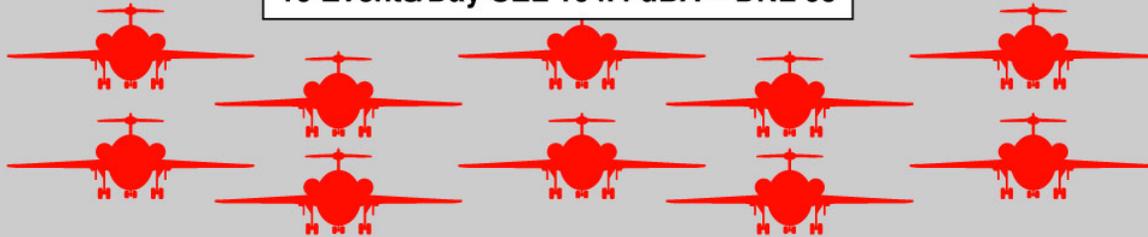
www.hmmh.com

Identical DNL Levels

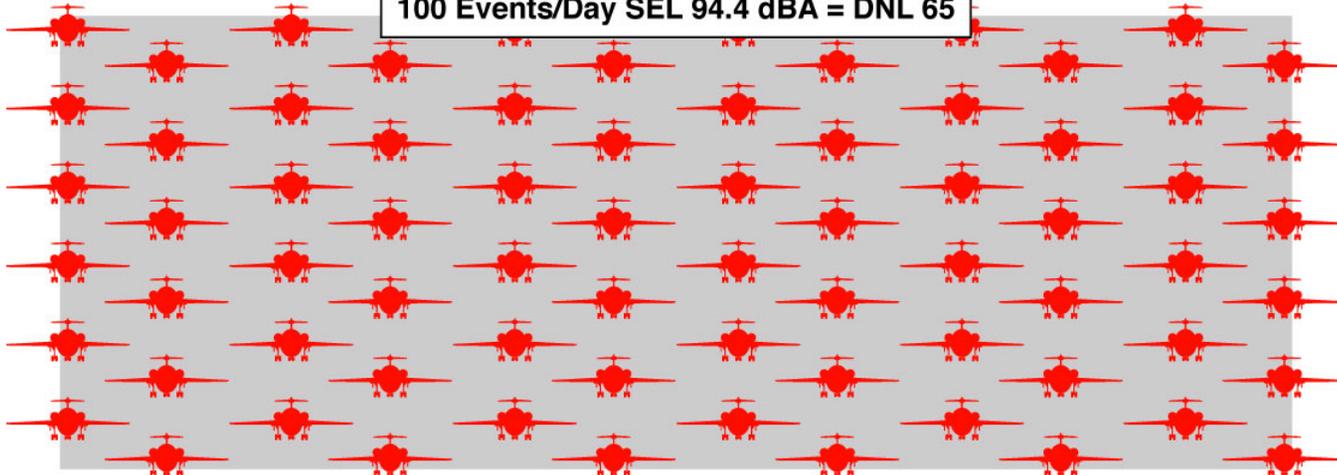
1 Event/Day SEL 114.4 dBA = DNL 65



10 Events/Day SEL 104.4 dBA = DNL 65



100 Events/Day SEL 94.4 dBA = DNL 65



Other Metrics

www.hmmh.com

- **Time above threshold (TA)**
- **Non A-weighted metrics (e.g., C-weighting)**
- **Metrics including pure-tone corrections (e.g., Effective Perceived Noise Level, EPNL)**
- **Many, many others**

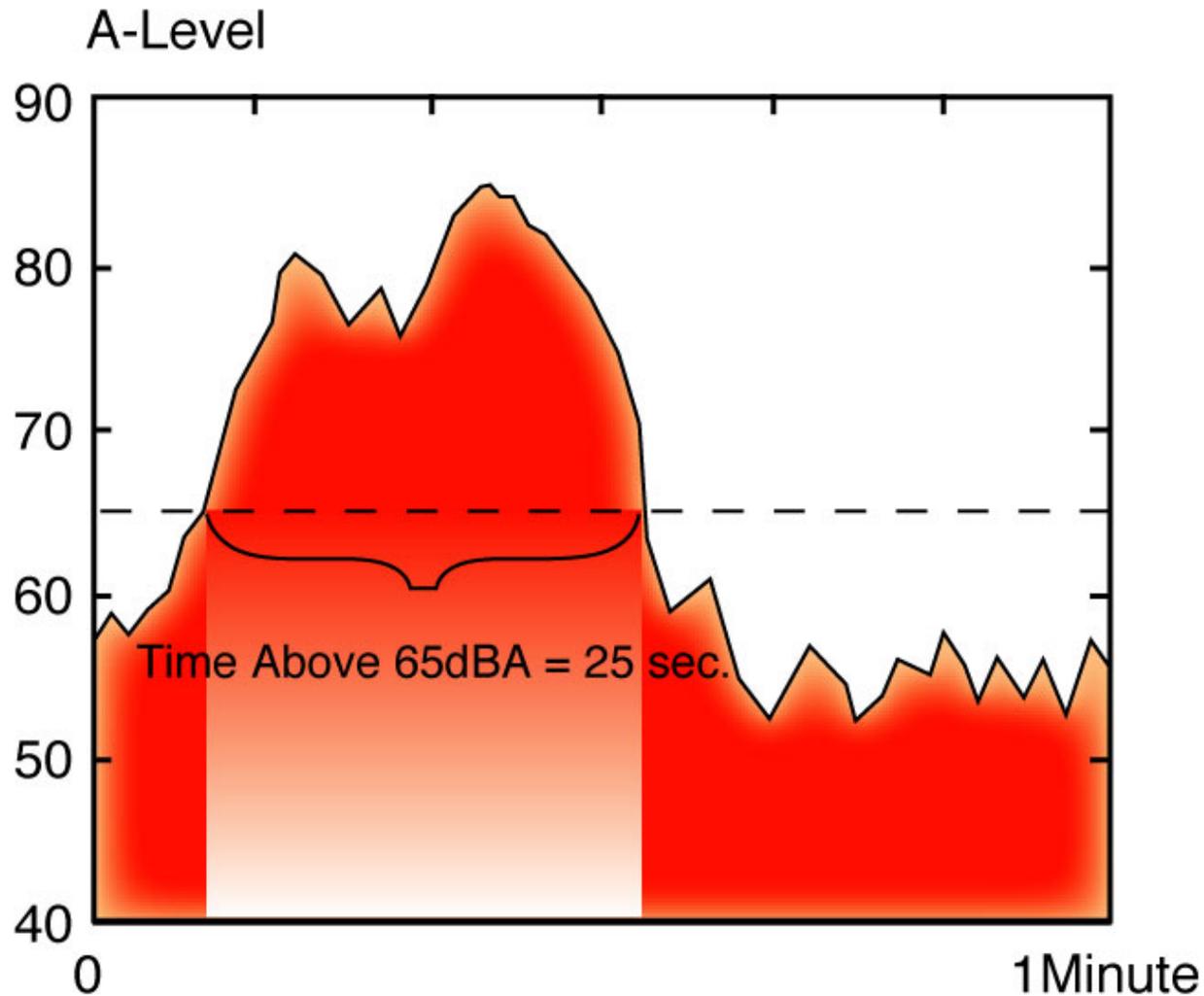
Time Above a Threshold Level (TA)

www.hmmh.com

- **The amount of time the sound level exceeds a threshold of interest (such as outdoor speech interference)**
 - For a noise event
 - For time interval
 - *So TA is both a single event and cumulative metric*
- **Weaknesses:**
 - Accounts only for duration – does not consider level
 - Two events can have the same TA but one can have a much higher L_{max} or SEL / SENEL
 - TA is an unreliable means for assessing human reaction, because the noise level is important to us

Time Above a Threshold Level (TA)

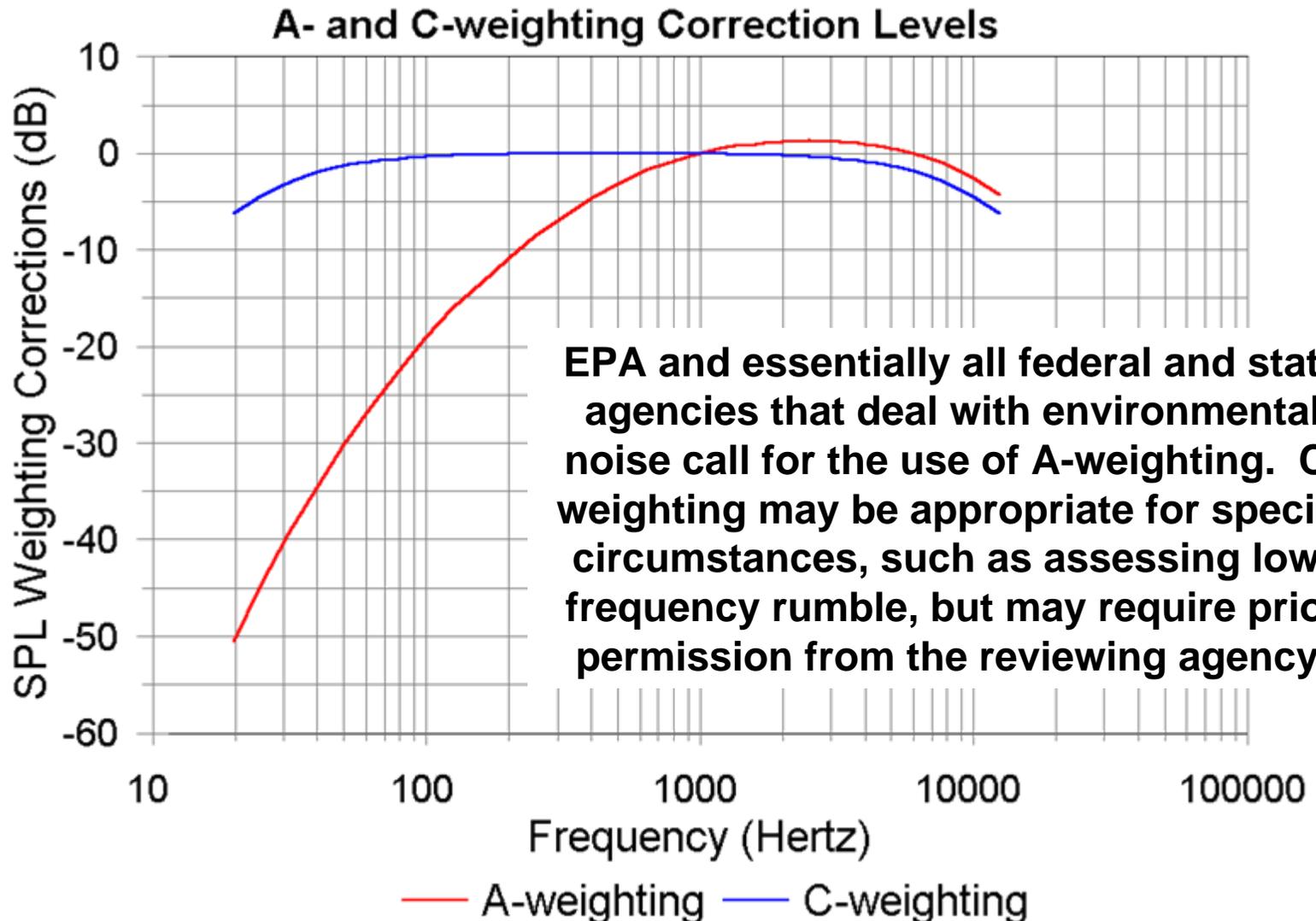
www.hmmh.com



Alternative Frequency Weighting

C-Weighting (dBC) versus A-Weighting (dBA)

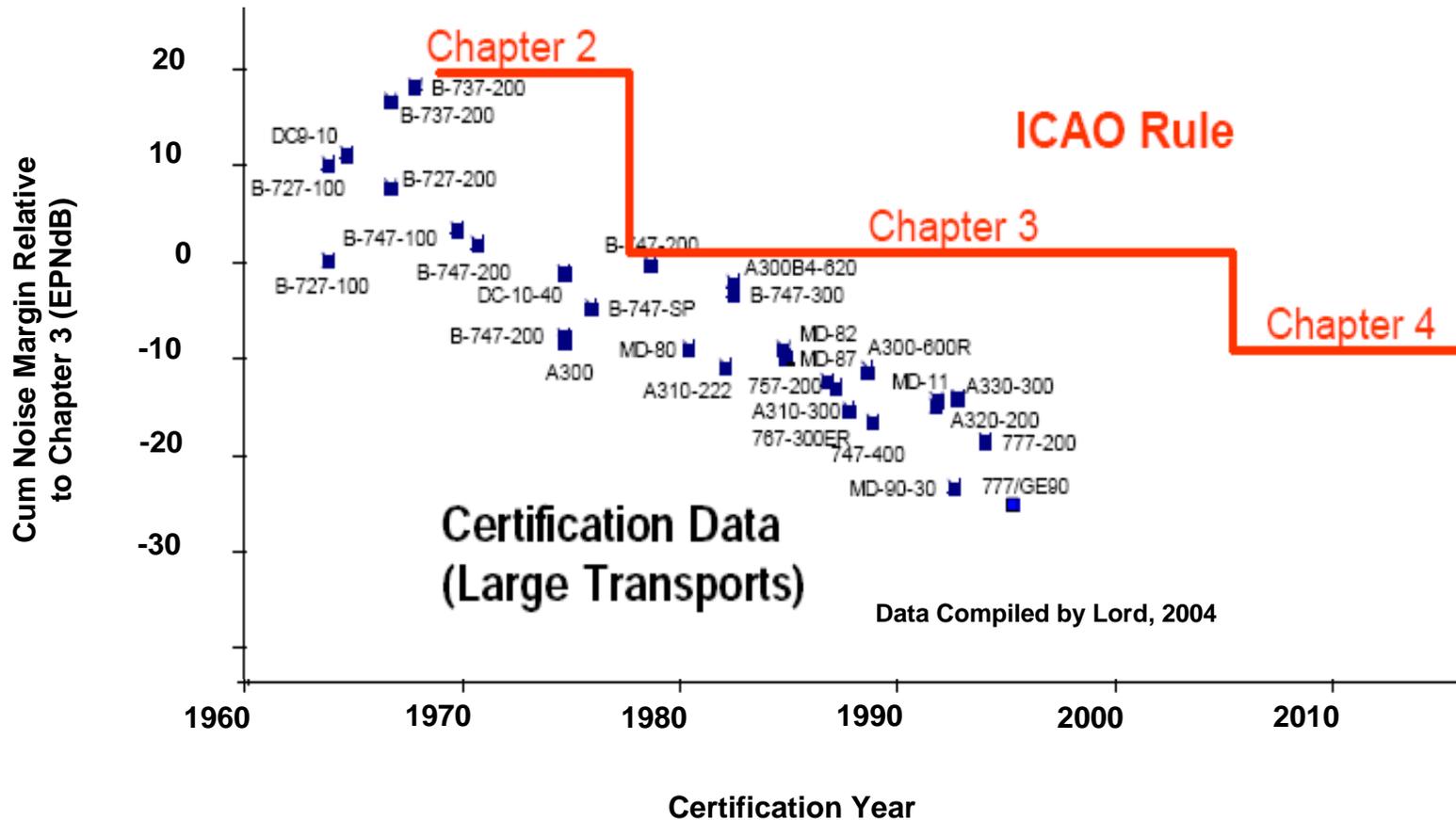
www.hmmh.com



FAA uses EPNL in Aircraft Certification

www.hmmh.com

- Complex measure similar to SEL that also accounts for discrete “pure tones”



Conclusions

- **The decibel is a complex quantity based on sound pressure**
- **A-weighted decibels correlate well with how we hear**
- **Sound / noise levels can be expressed in many ways**
 - Instantaneous maximum (Lmax)
 - Single event noise dose (SEL, SENEL)
 - Short-duration cumulative exposure (Leq)
 - Long-duration cumulative exposure (DNL, CNEL)
- **FAA and EPA use DNL for environmental analyses**
 - California uses the slightly more refined CNEL metric
- **Other metrics are used to address different issues (low frequency noise, certification, etc.)**