Basic Aircraft Noise Terminology

HARRIS MILLER MILLER & HANSON INC.

Topics

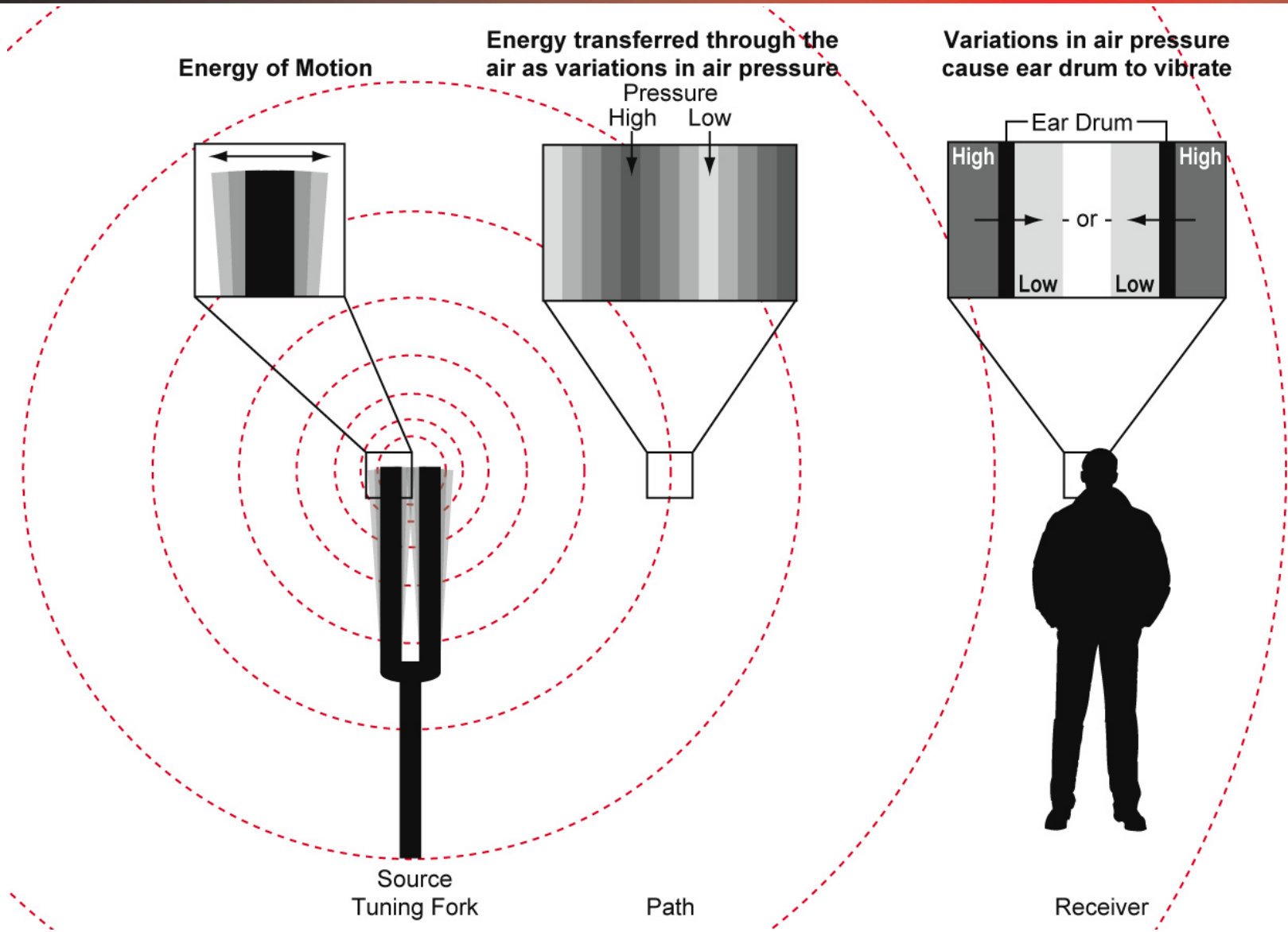
- **What are “Sound” and “Noise”?**
  - Sound Pressure Level
  - Decibel
  - A-Weighted Decibel
- **Single Event Metrics**
  - Maximum A-Weighted Sound Level, Lmax
  - Sound Exposure Level, SEL
  - Single Event Noise Equivalent Level, SENEL
- **Cumulative Exposure Metrics**
  - Equivalent Sound Level,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

Definition of Noise

- ***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



The Decibel Scale

- **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

- **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”

“Energy”	Decibels	Common Sounds
100,000,000,000,000	140	Near Jet Engine
10,000,000,000,000	130	Threshold of Pain
1,000,000,000,000	120	Night Club, Discotheque
100,000,000,000	110	
10,000,000,000	100	Pneumatic Hammer at 6 feet
1,000,000,000	90	
100,000,000	80	Vacuum Cleaner
10,000,000	70	
1,000,000	60	Normal Speech
100,000	50	
10,000	40	Quiet Resident Neighborhood
1,000	30	
100	20	Whisper
10	10	
1	0	Threshold of Hearing
0.1	-10	
0.01	-20	

$$\text{Decibels} = 10 \text{ Log}\left["\text{Energy}"\right]$$

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

Rise/fall

1dB 5dB 10dB

Wobble

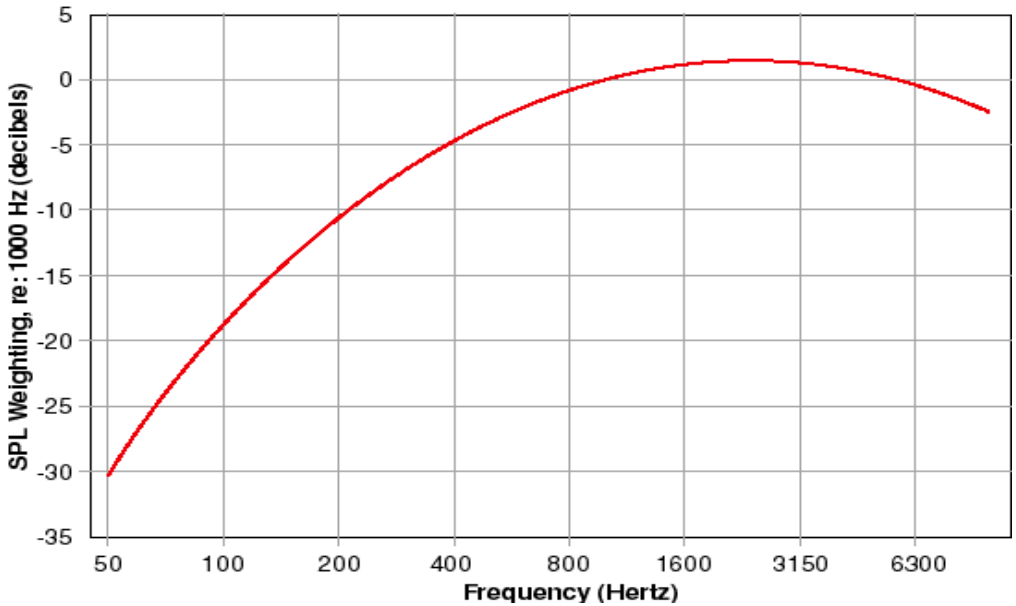
1dB 5dB 10dB

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

- **Decibels are a logarithmic quantity, so…**
- **Two equal sources:**
  - 100 dB + 100 dB = ~~200~~ 103 dB
- **Four equal sources:**
  - 100 dB + 100 dB + 100 dB + 100 dB = 106 dB
- **Ten equal sources:**
  - 100 dB + 100 dB + 100 dB + 100 dB + 100 dB +
    100 dB + 100 dB + 100 dB + 100 dB + 100 dB = 110 dB

A-Weighted Sound Level (dBA)

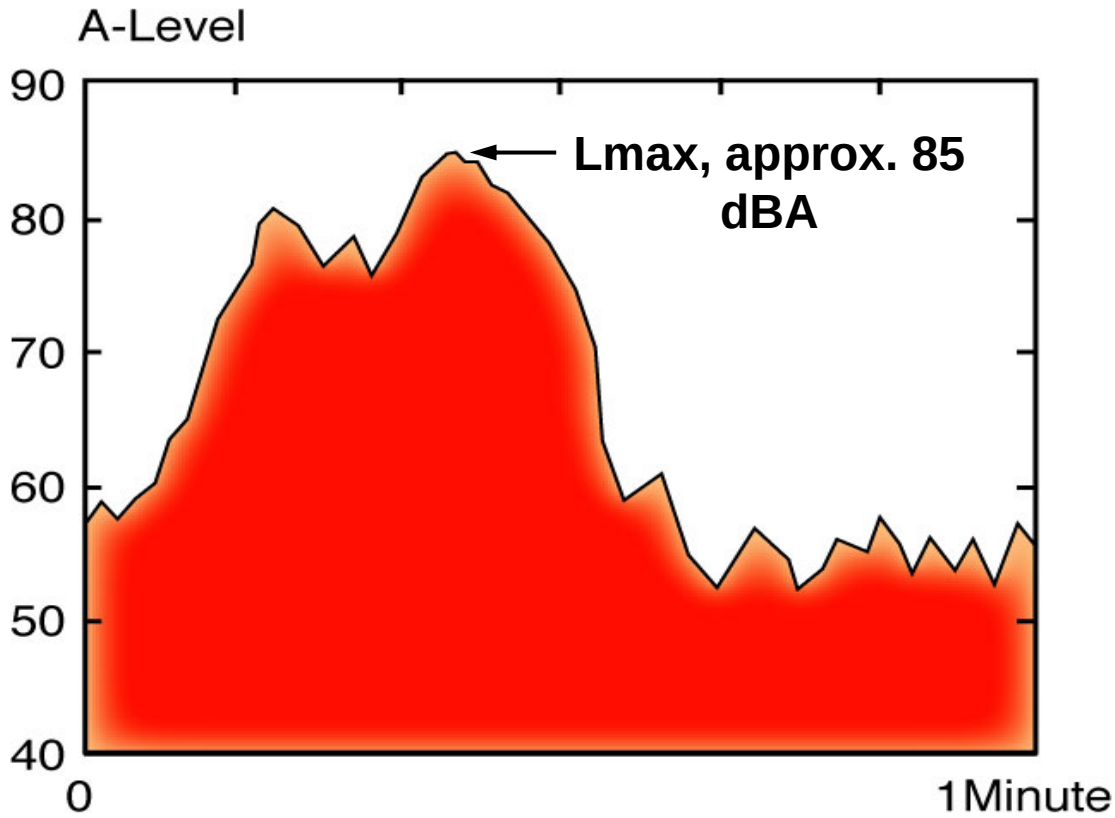
- The human auditory system is not equally sensitive to all frequencies
- To be a useful environmental analysis tool we need a way to measure sound the same way the ear "hears" it
- The **A-weighted level** achieves this goal



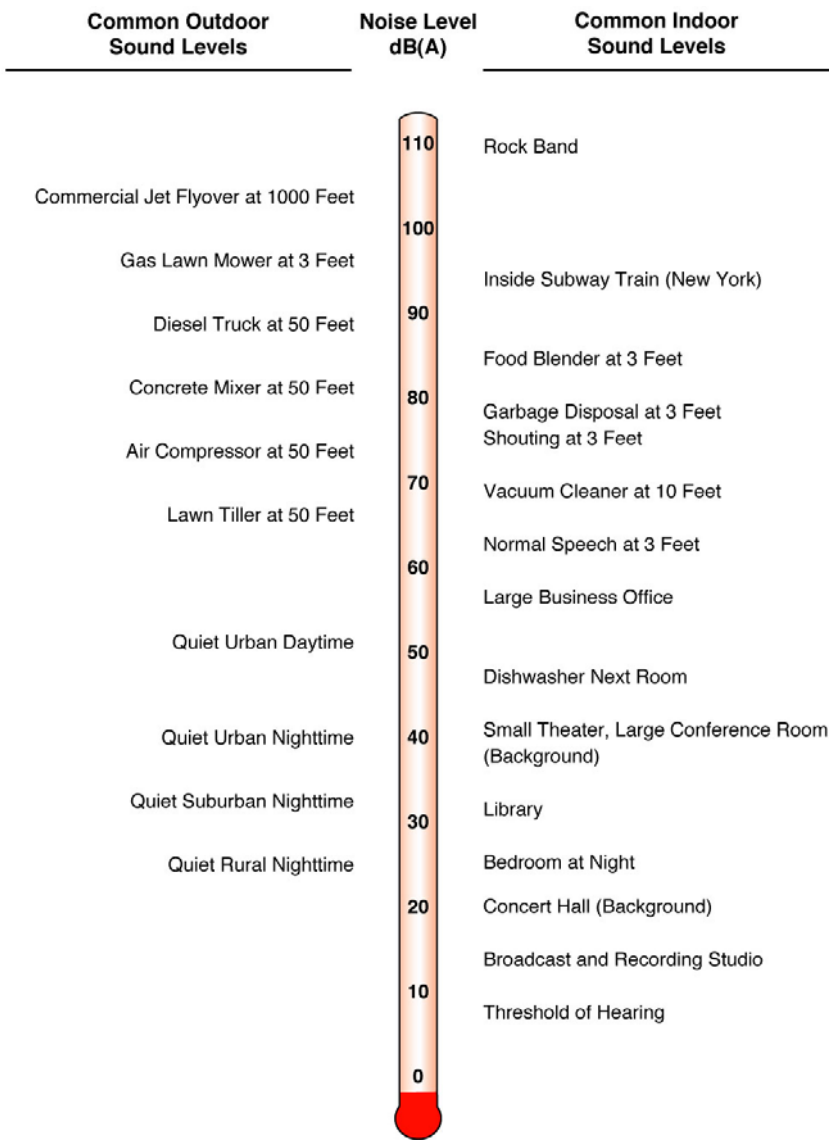
Consistent with EPA's recommendation, the A-weighted level is used by federal, state, and local agencies for environmental noise analyses

Single Event Noise Metrics: Maximum Sound Level (Lmax)

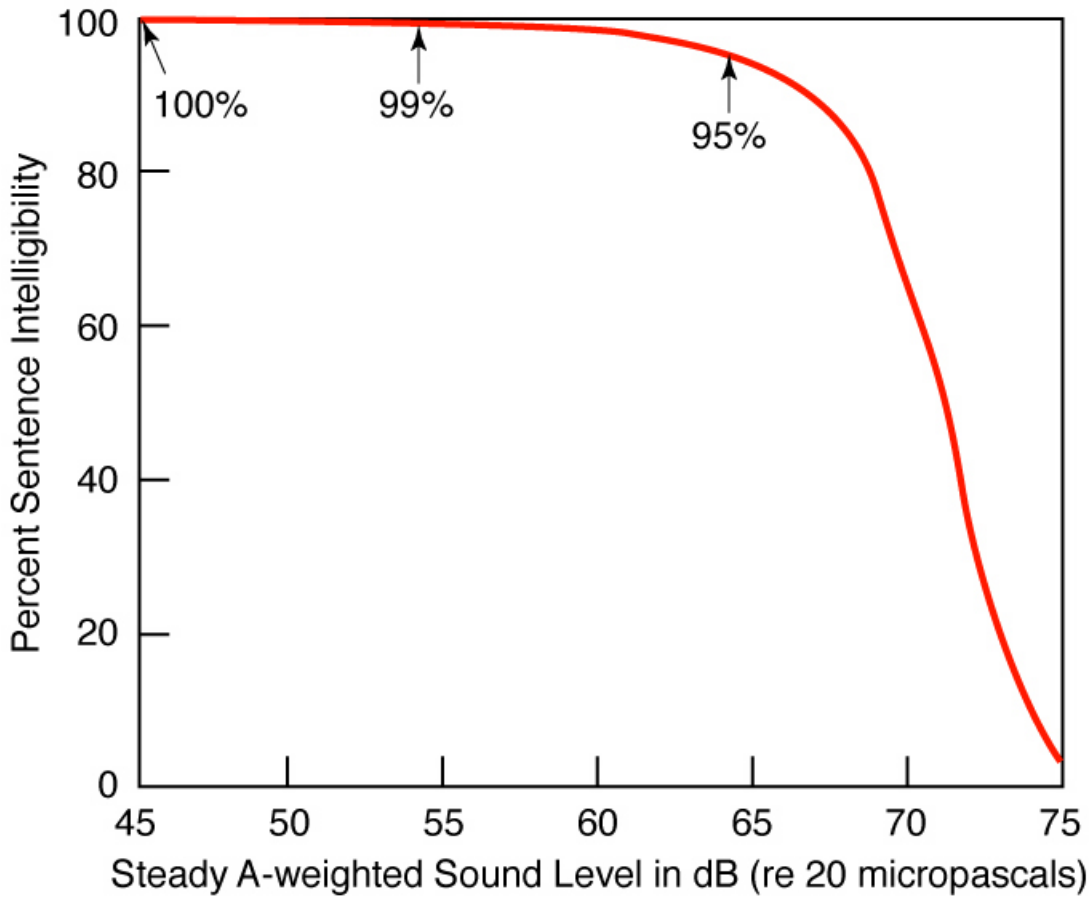
- The simplest way to describe a discrete noise “event” is with its maximum sound level, abbreviated as Lmax
- Accounts only for sound amplitude (dBA)



Common Environmental A-weighted Sound Levels, dB



Speech Interference and Lmax



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

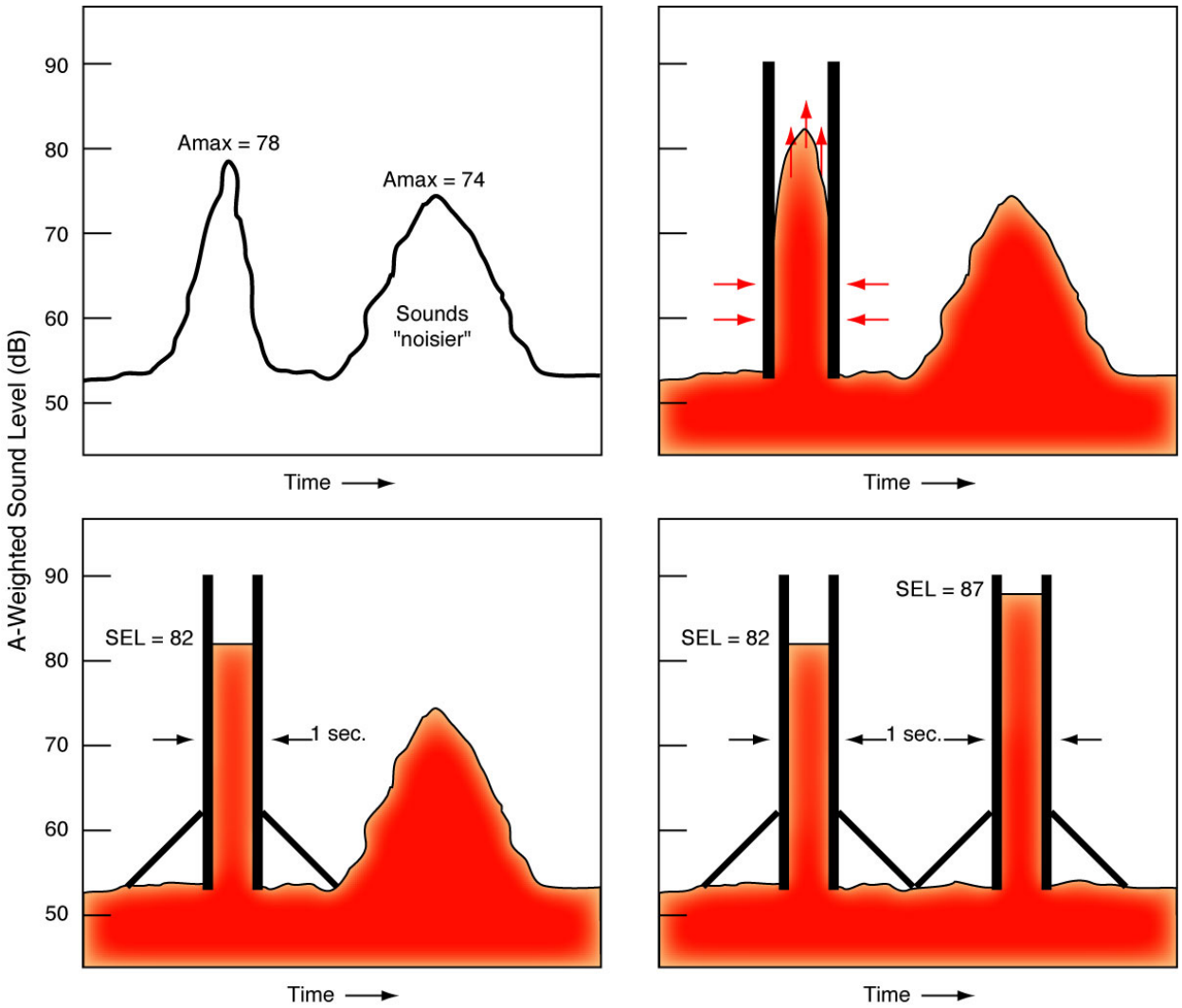
Source: EPA, 1974

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

- **Two events may have the same Lmax, 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 Lmax, it will be essentially the same as SEL
  - We usually measure SENEL in a real-world environment

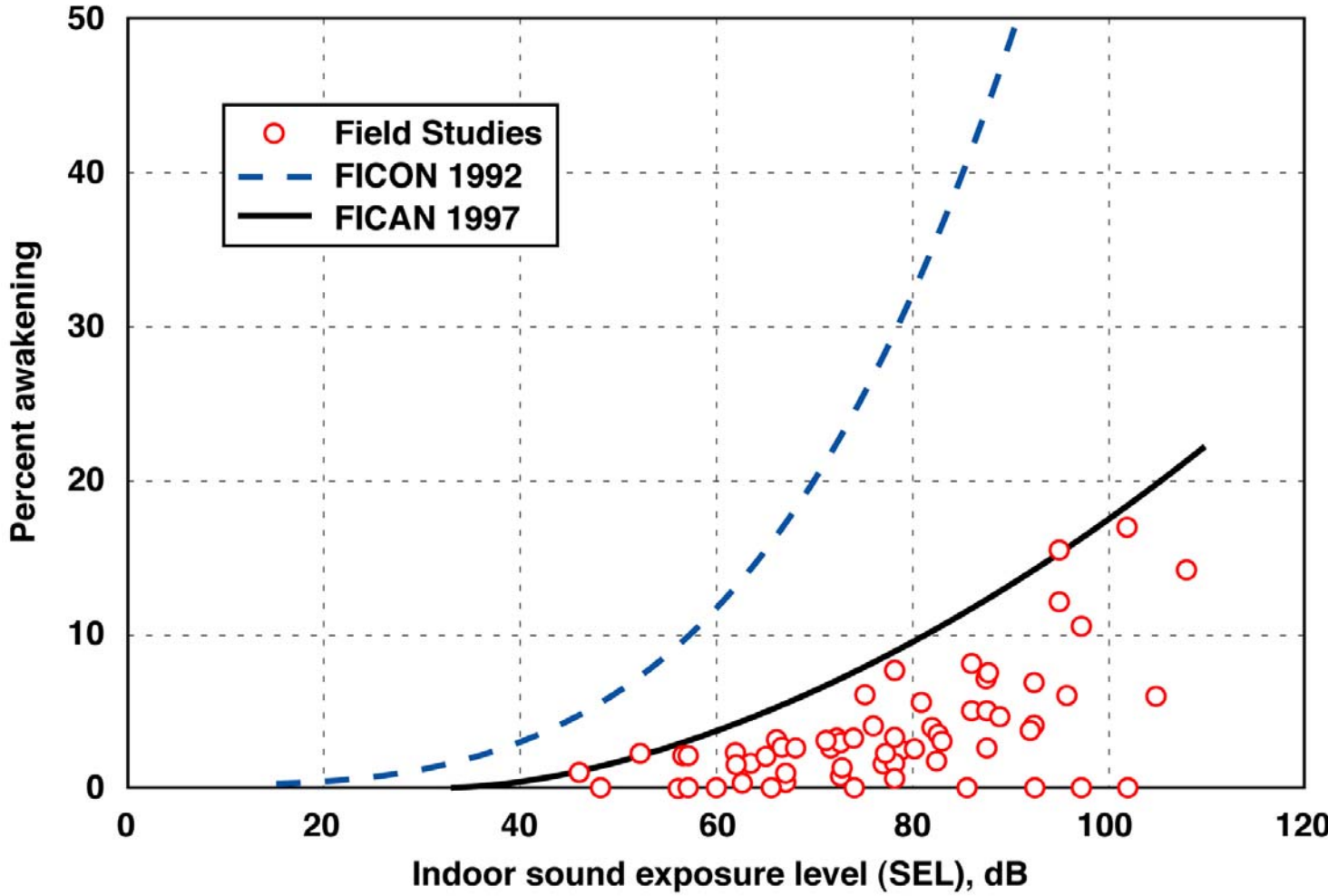
So what exactly do SEL and SENEL represent?

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



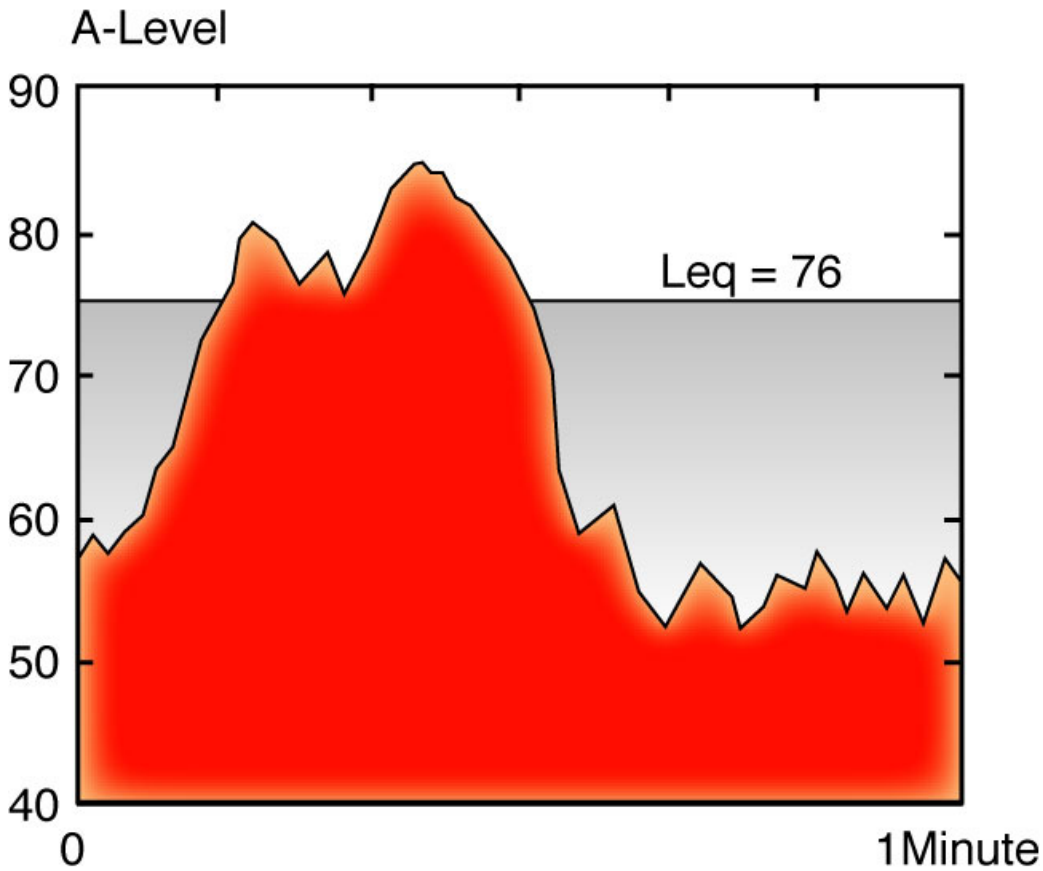
SEL (SENEL) Correlates to Awakenings

ANSI 12.9-2000/Part 6
Methods for estimation of awakenings associated with aircraft noise events heard in homes



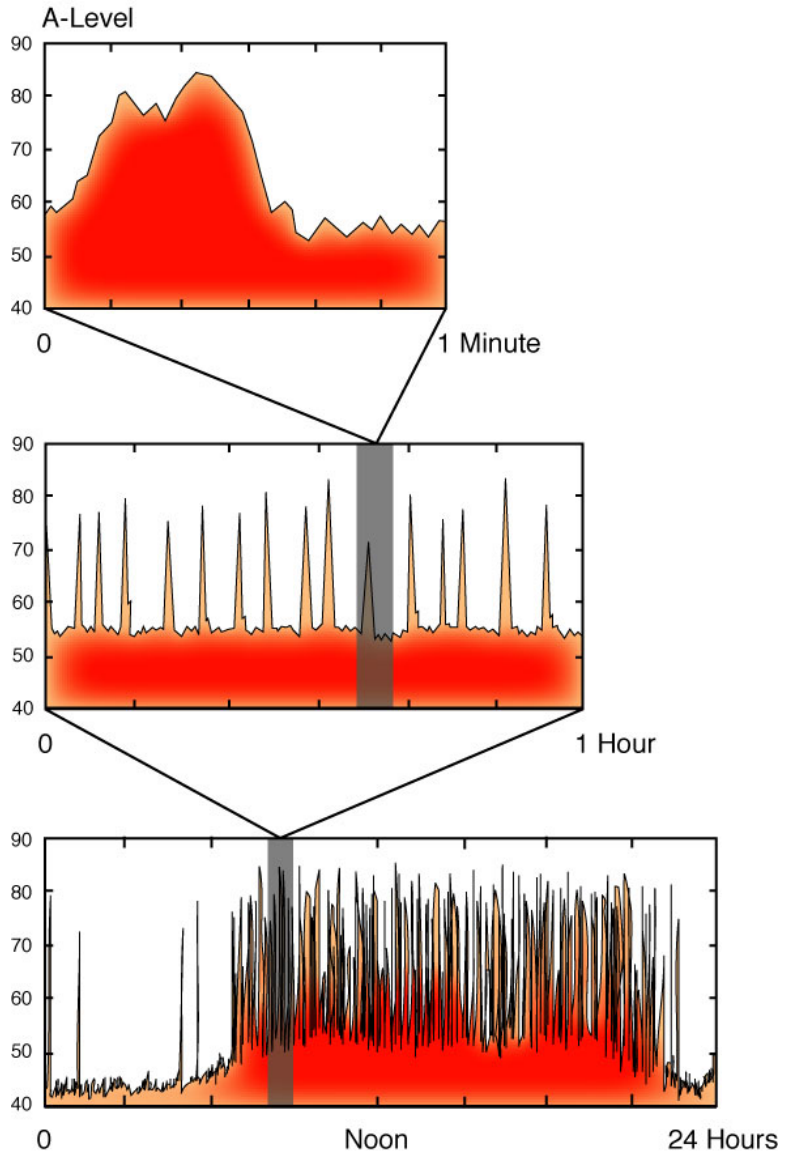
Cumulative Exposure over Time: Equivalent Sound Level (Leq)

- 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

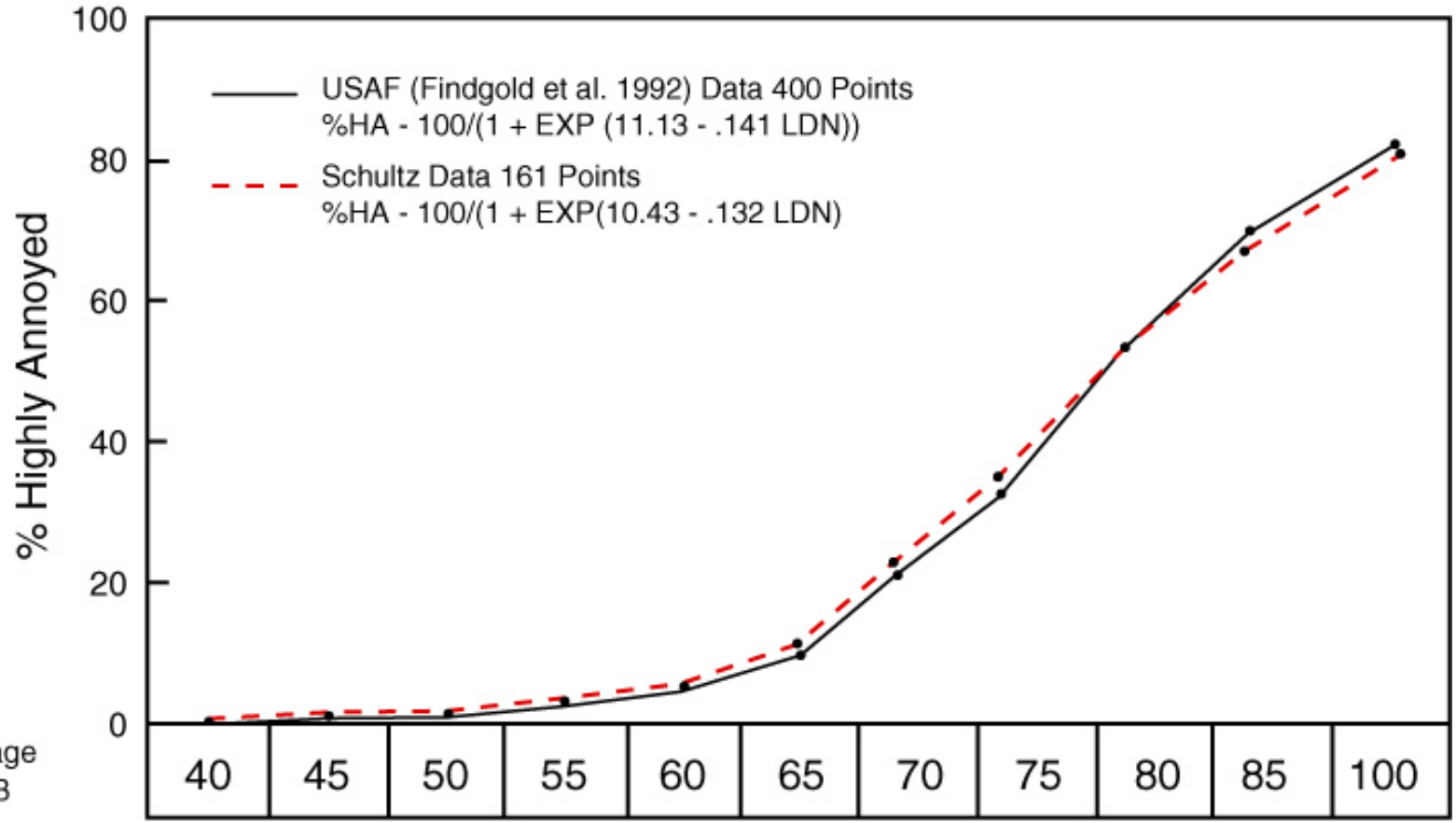


Cumulative Exposure over Time: Day-Night Average Sound Level (DNL or Ldn)

- 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



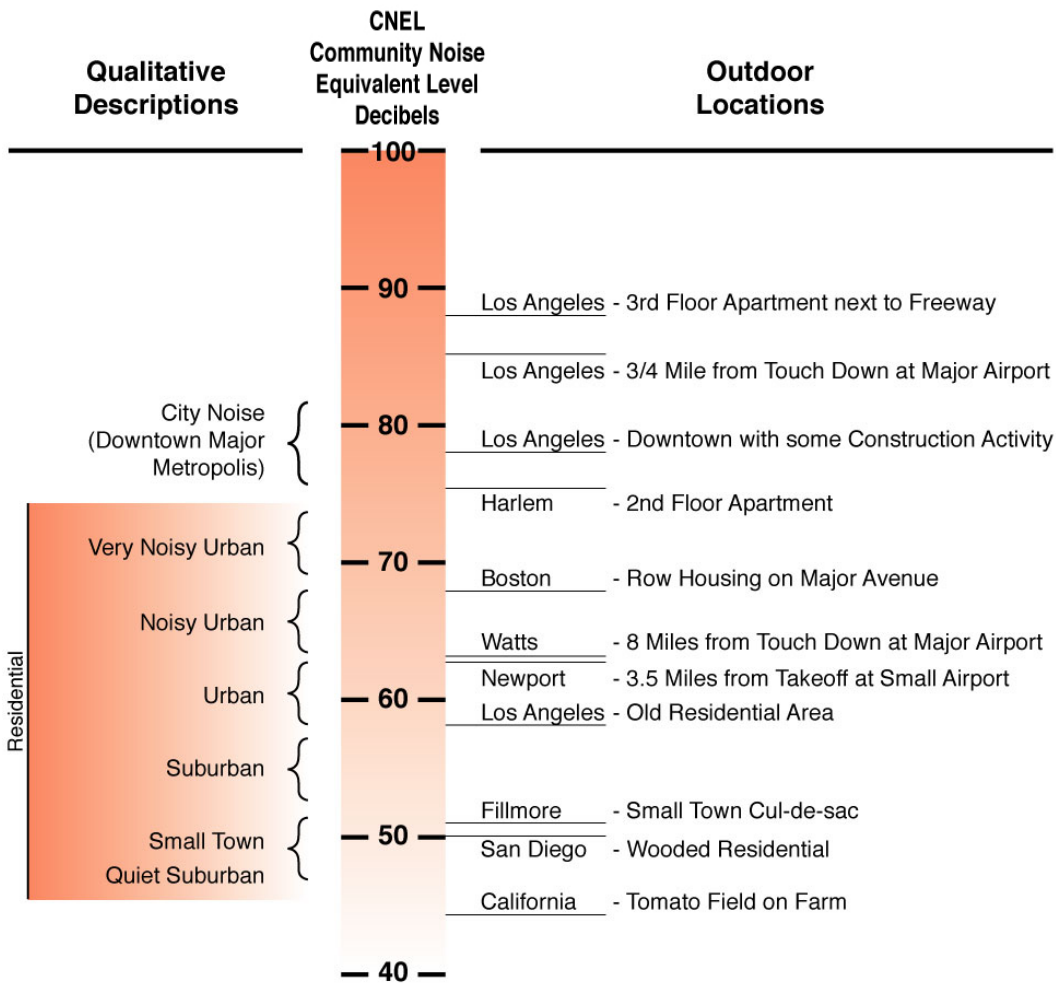
Cumulative Exposure over Time:
Day-Night Average Sound Level (DNL or Ldn)



Day - Night Average Sound Level in dB	40	45	50	55	60	65	70	75	80	85	100
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)

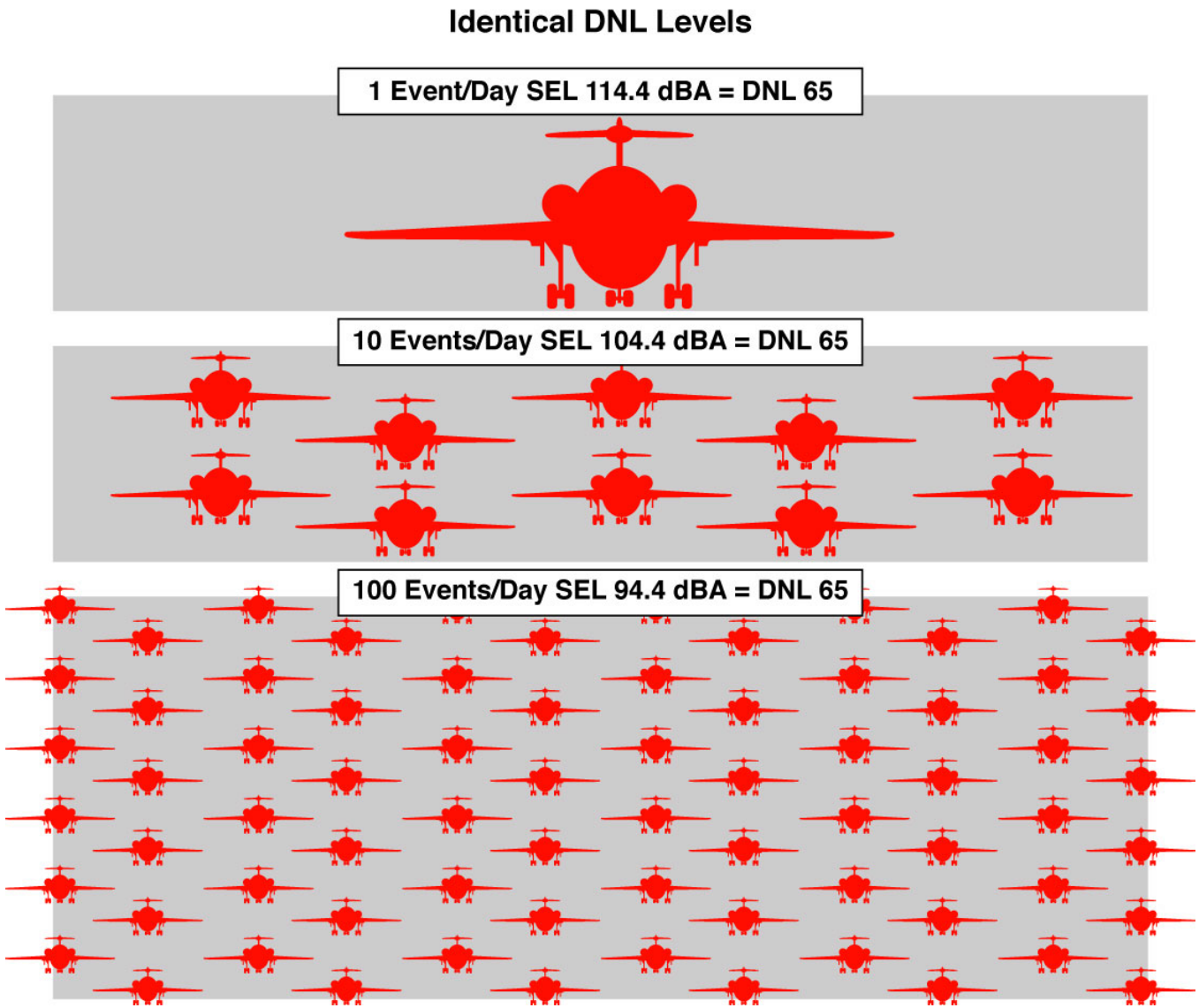
- California uses CNEL, a slightly more refined cumulative exposure metric than DNL
- CNEL is similar to DNL, but considers <u>three</u> time periods:
  - Day: 7 am – 7 pm: No weighting or penalty
  - Evening: 7 – 10 pm: 3 times weighting (approx. 4.8 dB penalty)
  - Night: 10 pm – 7 am: 10 times weighting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



Interpreting changes in CNEL or DNL

- **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



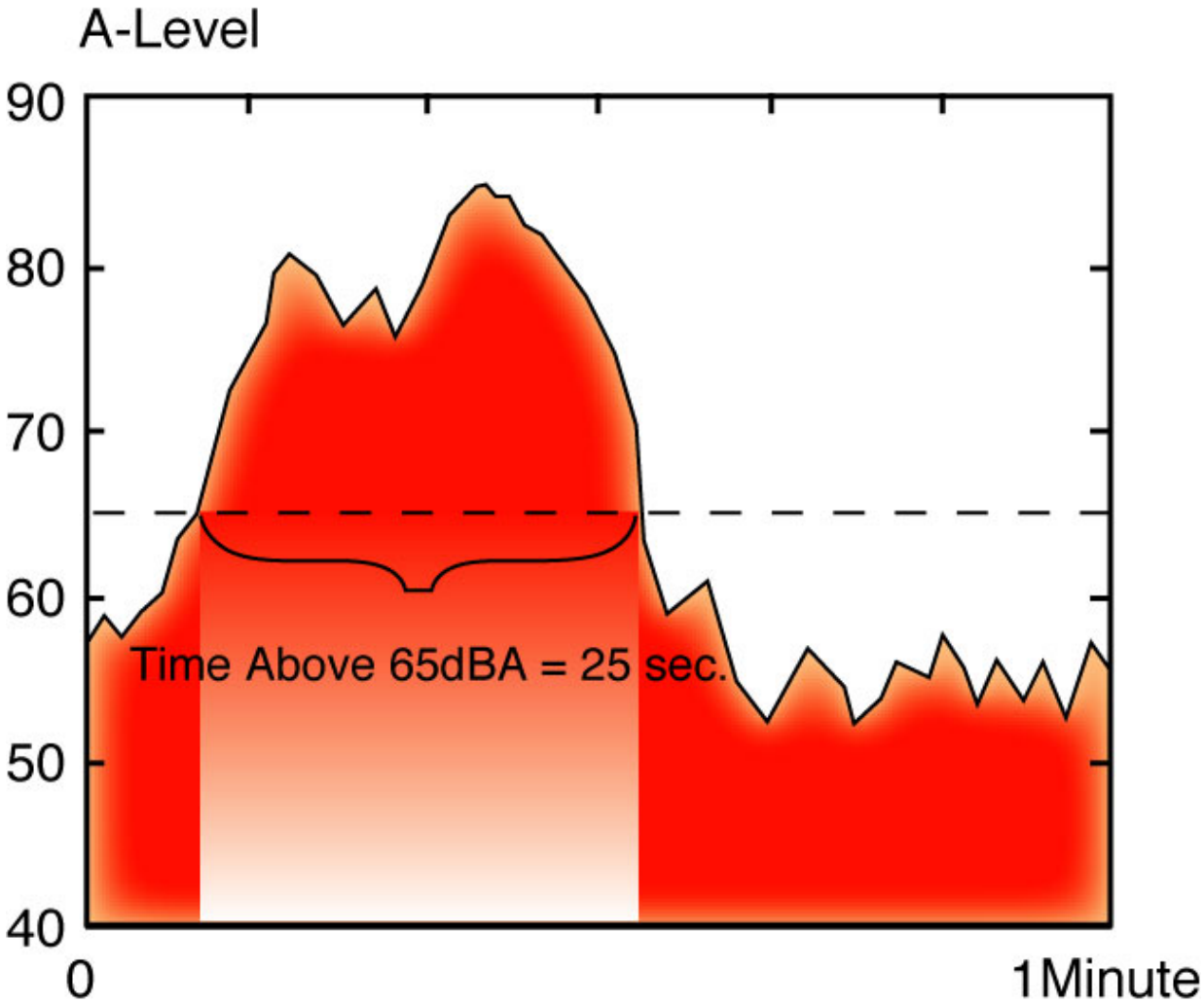
Other Metrics

- 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

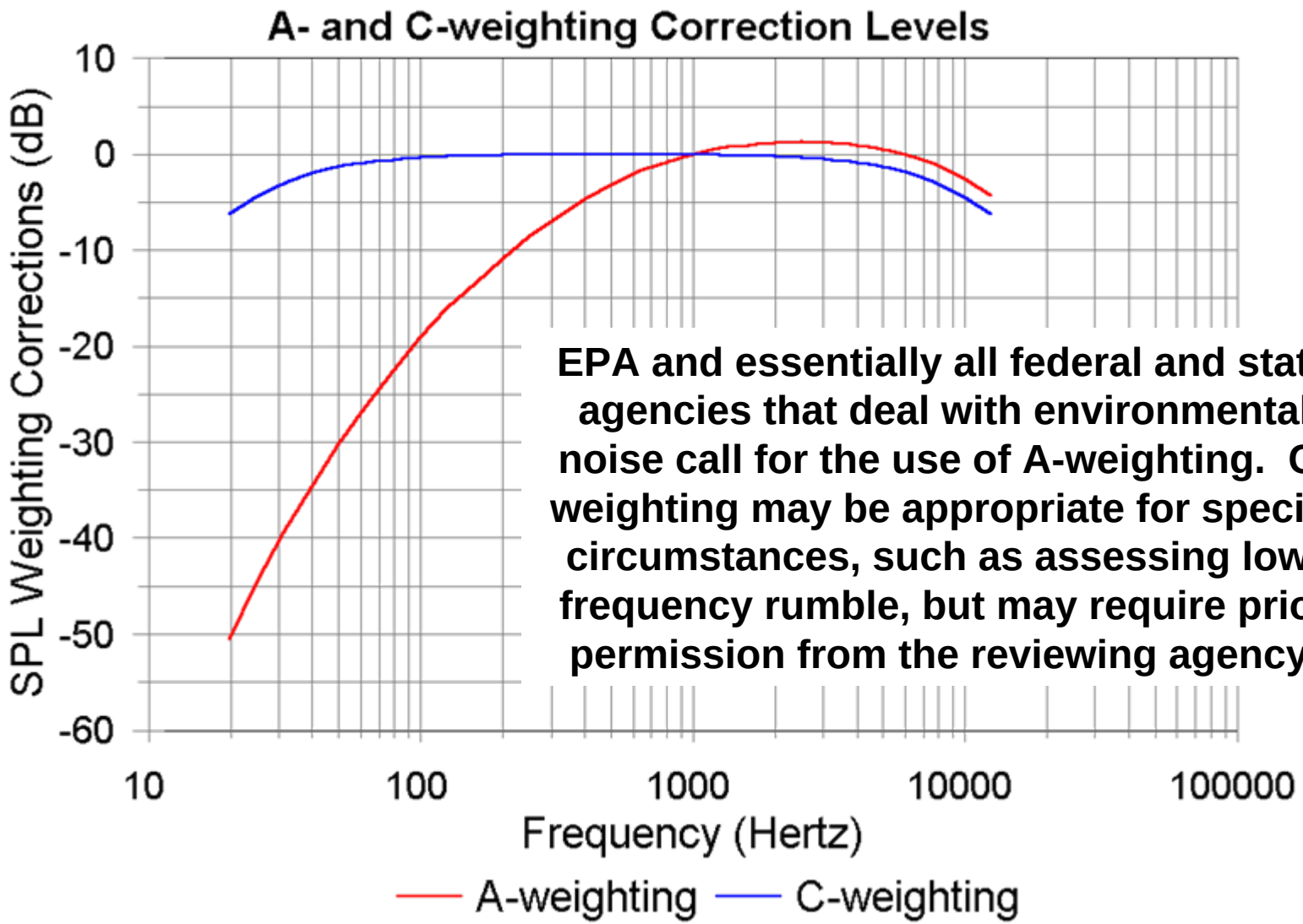
Time Above a Threshold Level (TA)

- **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 Lmax 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)



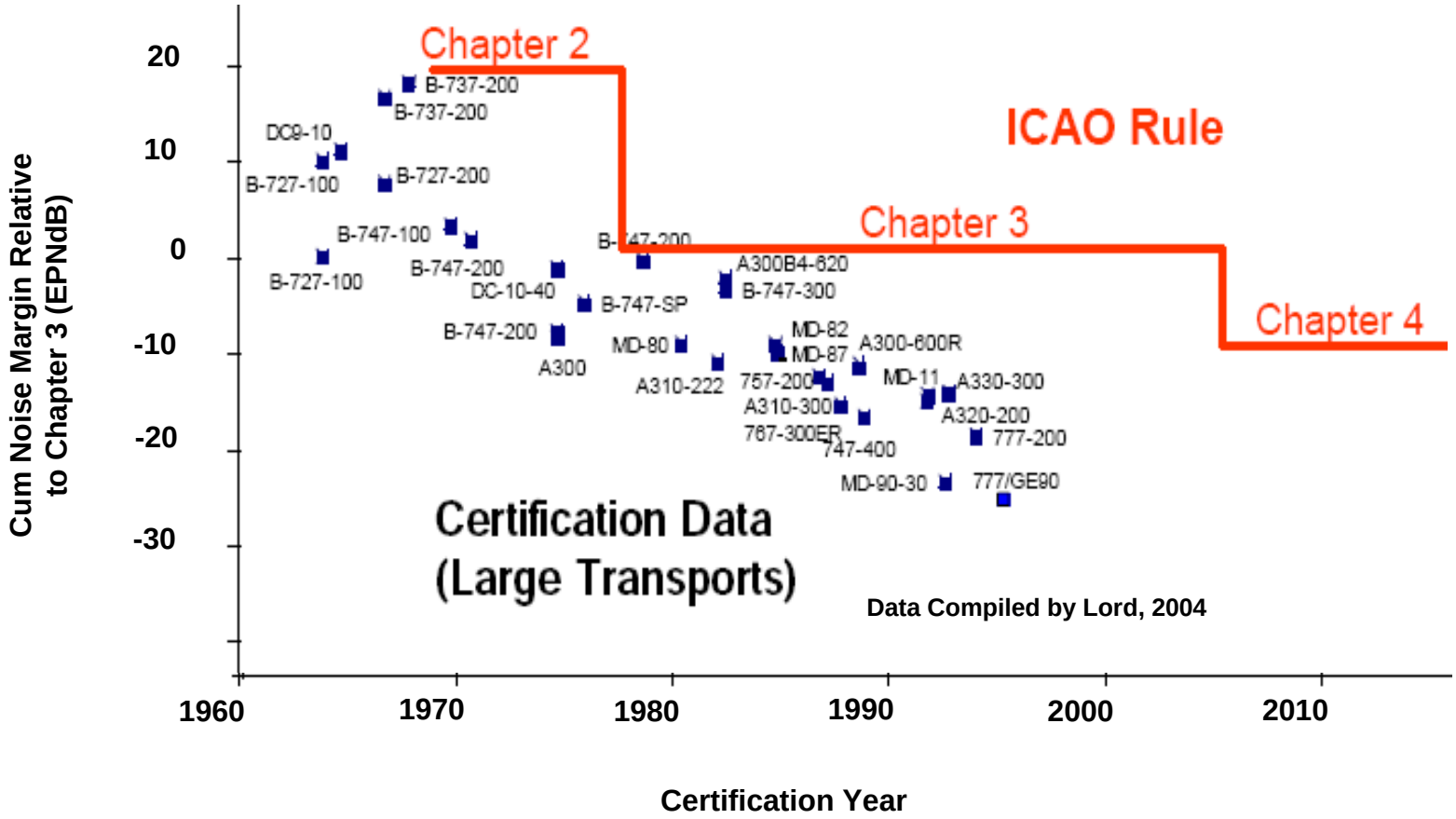
Alternative Frequency Weighting
C-Weighting (dBC) versus A-Weighting (dBA)



EPA and essentially all federal and state agencies that deal with environmental noise call for the use of A-weighting. C-weighting may be appropriate for special circumstances, such as assessing low-frequency rumble, but may require prior permission from the reviewing agency.

FAA uses EPNL in Aircraft Certification

- 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.)**