Acoustic Principles and Noise Metrics

Acoustic Principles and Noise Metrics

- **Sound can be described in terms of its amplitude (pressure) and frequency (pitch)**
  - **Amplitude – a direct measure of the magnitude of sound without consideration for other factors that may influence the perception of it**
  - **Frequency – expressed as a Hertz (Hz) or cycles per second**

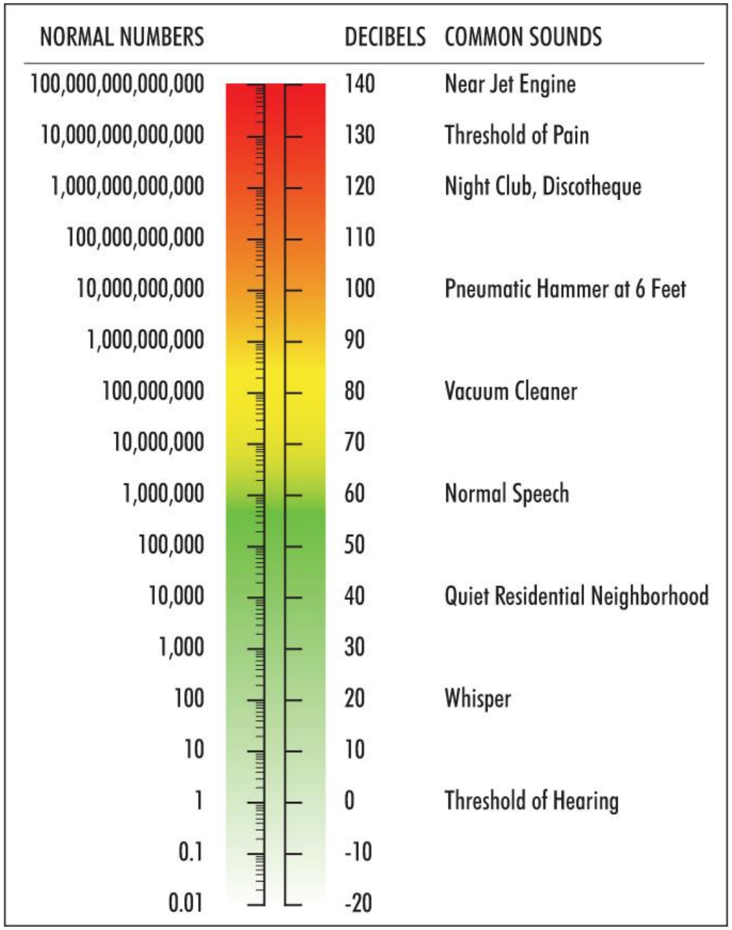
Acoustic Principles and Noise Metrics

- **Amplitude**
  - **Sound pressure ranges are very large, therefore they are expressed on a logarithmic scale**
  - **Logarithmic scale compresses the wide range in sound pressures to a more useable range**
  - **Standard unit of measurement is the decibel (dB)**

Acoustic Principles and Noise Metrics

- **Amplitude – continued**
  - **A sound level of 70 dB has 10 times the acoustic energy as a level of 60 dB, while a sound level of 80 dB has 100 times the acoustic energy as a level of 60 dB**
  - **A sound 10 dB higher than another is usually judged to be twice as loud**

Acoustic Principles and Noise Metrics



The Decibel Scale

Acoustic Principles and Noise Metrics

- Decibel Mathematics (logarithmic)

70 dB + 70 dB = 73 dB

70 dB + 50 dB = 70 dB

70 dB x 10 = 80 dB

70 dB x 100 = 90 dB

Acoustic Principles and Noise Metrics

- **Frequency**
  - Normal audible frequency range for young adults is 20 Hz to 20,000 Hz
  - Frequency range for aircraft noise is between 50 Hz and 5,000 Hz
  - The human ear is not equally sensitive to all frequencies

Acoustic Principles and Noise Metrics

- **Noise is unwanted sound**
  - **What is music to my ears may be noise to you**
  - **By its very nature noise is subjective**
  - **We measure or model sound levels and relate them to social surveys to assess the potential for annoyance**

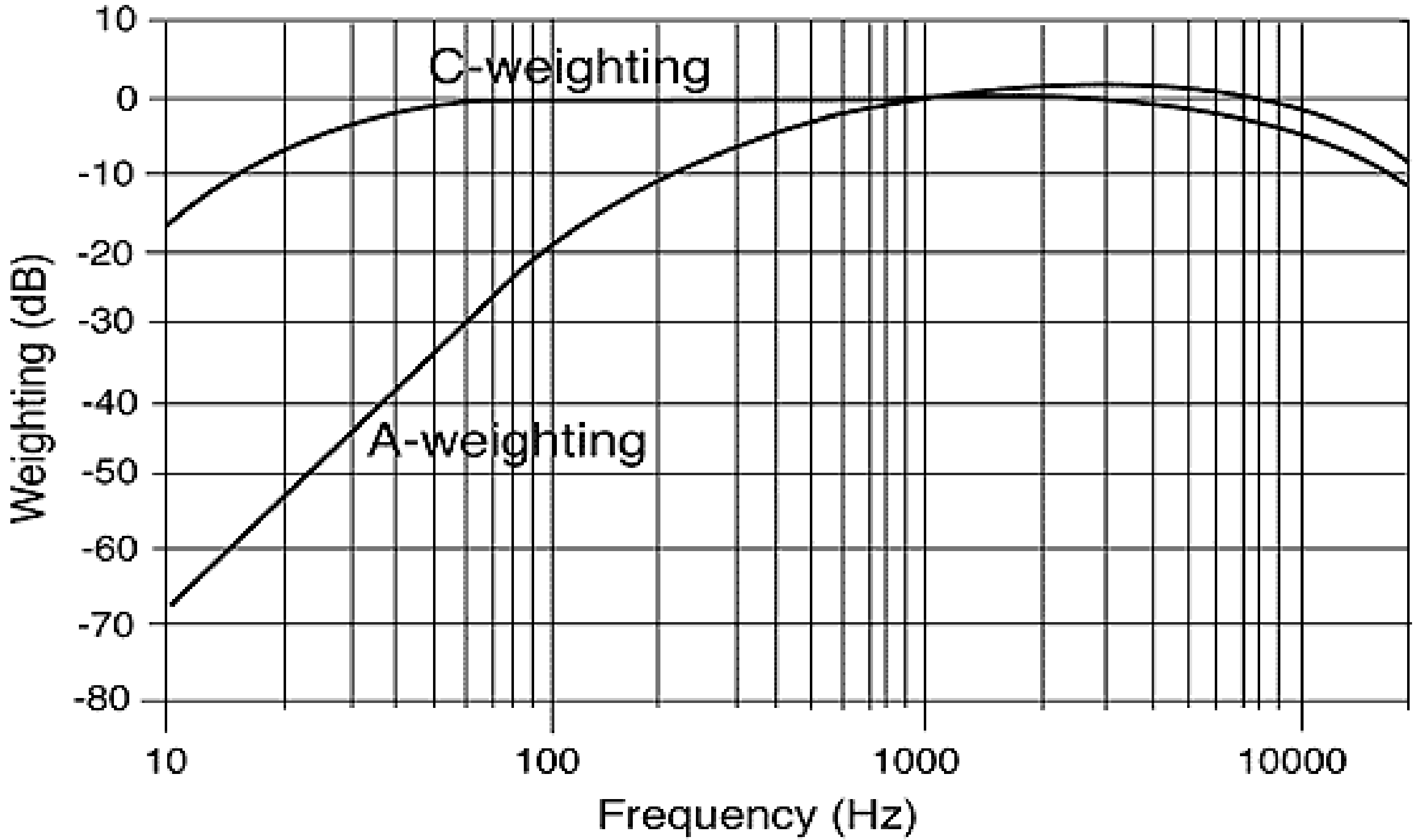
Acoustic Principles and Noise Metrics

- **Noise metrics used in aircraft noise assessments are based upon the following frequency weighting scales:**
  - **Frequency-weighted contours (dBA and dBC)**
  - **Perceived Noise Level**

Acoustic Principles and Noise Metrics

- **Frequency-weighted contours**
  - **dBA approximates the sensitivity of the human ear**
  - **dBC is used for low frequency noise**

Acoustic Principles and Noise Metrics



Acoustic Principles and Noise Metrics

- **Perceived Noise Level**
  - **Originally developed for assessment of aircraft noise**
  - **EPNL is still used for aircraft certification**

Acoustic Principles and Noise Metrics

- Single Event Metrics
  - Frequency-weighted metrics (dBA)
  - Maximum Noise Level (Lmax)
  - Sound Exposure Level (SEL)
- Cumulative Metrics
  - Equivalent Noise Level (LEQ)
  - Day-Night Noise Level (DNL)

Acoustic Principles and Noise Metrics

- **Frequency-Weighted Metrics (dBA)**
  - **To simplify measurement and computation of sound loudness levels, frequency weighted networks have obtained wide acceptance**
  - **A-weighting (dBA) has become the most prominent of these scales**
  - **Replicates the way we hear sounds**

Acoustic Principles and Noise Metrics

- **Frequency-Weighted Metrics (dBA)**
  - **Shows good correlation with community response and is easily measured**
  - **Most aircraft noise studies are based upon the dBA scale**
  - **14 CFR Part 150 requires the use of A-weighting**

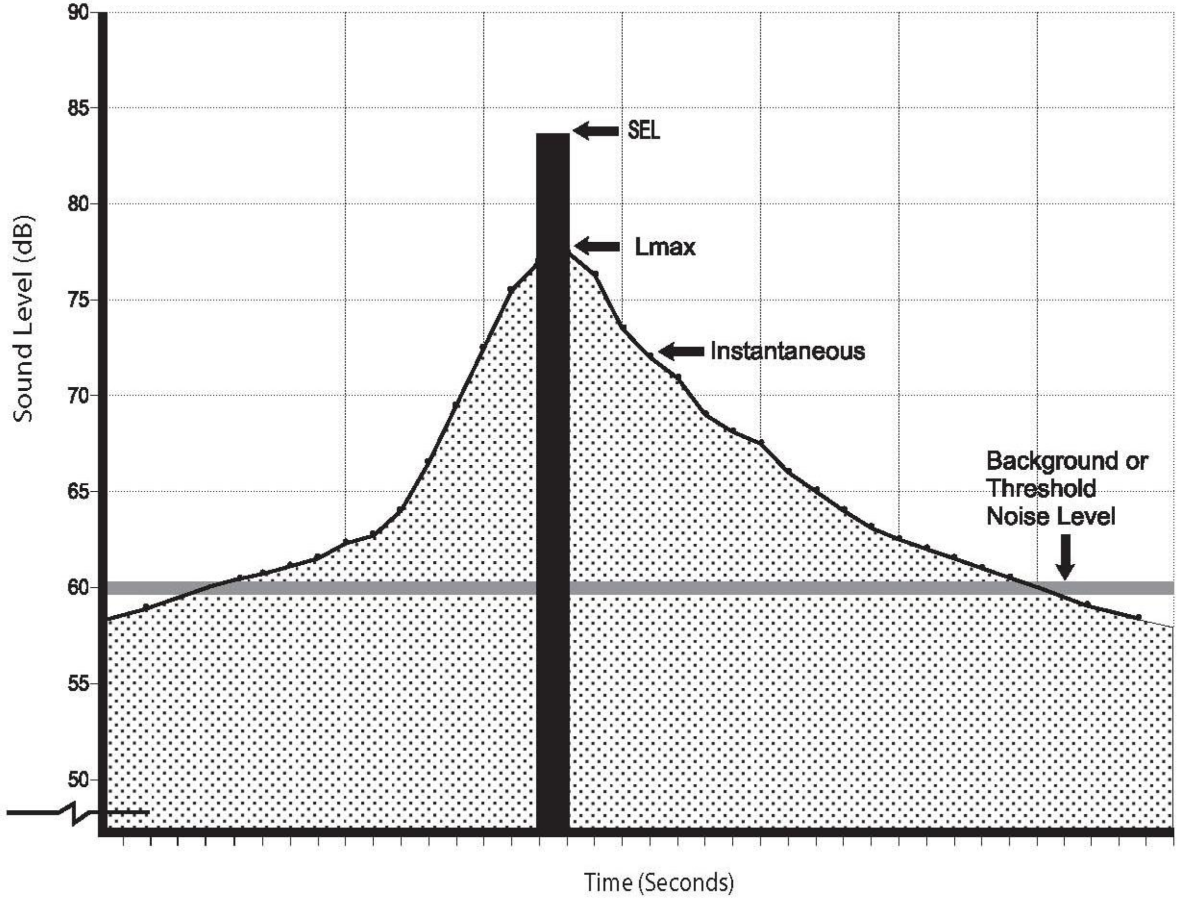
Acoustic Principles and Noise Metrics

- **Maximum Noise Level (Lmax)**
  - **Highest noise level reached during a noise event**
  - **Lmax achieved when aircraft is at its closest point (typically, directly overhead)**
  - **Generally, it is this metric that people instantaneously respond to when an aircraft flyover occurs**

Acoustic Principles and Noise Metrics

- **Sound Exposure Level (SEL)**
  - **Another metric for aircraft flyovers**
  - **Computed from dBA sound levels**
  - **Integration of all the acoustic energy contained within the event**

Instantaneous Level, Lmax, SEL, Background Level



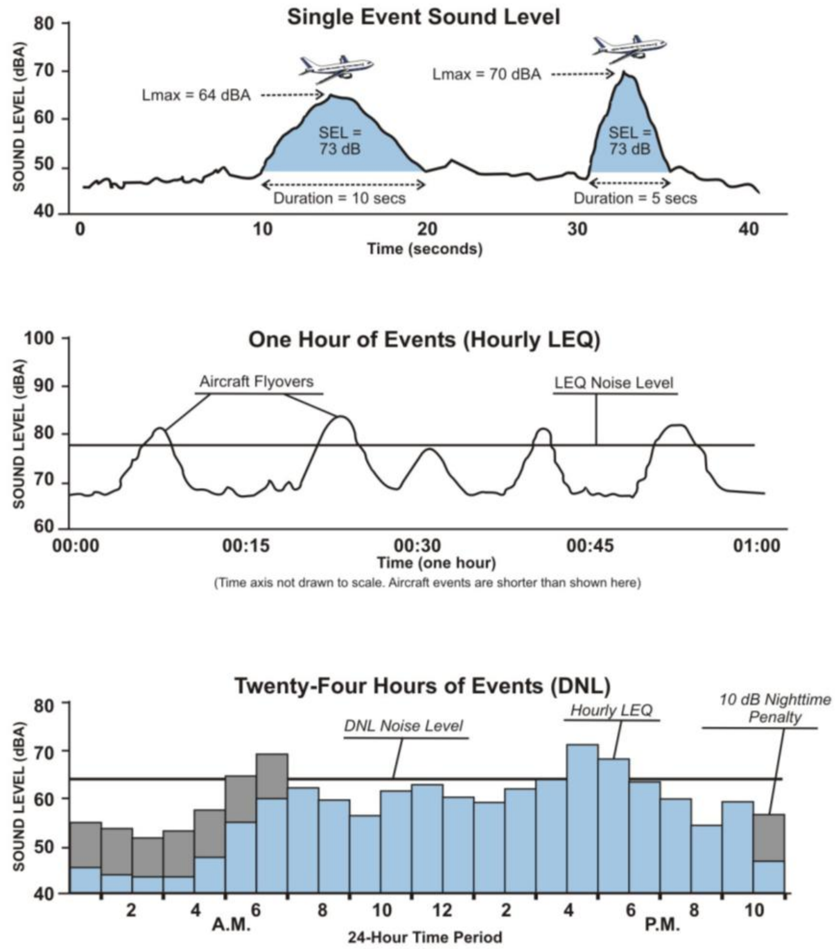
Acoustic Principles and Noise Metrics

- **Equivalent Noise Level (LEQ)**
  - “Energy” average noise level during the time period of a sample
  - Based on the observation that the potential for a noise to “impact” is dependent on the total acoustical energy content
  - Can be measured for any time period, but typically measured in 15 minutes, 1 hour, and 24 hours

Acoustic Principles and Noise Metrics

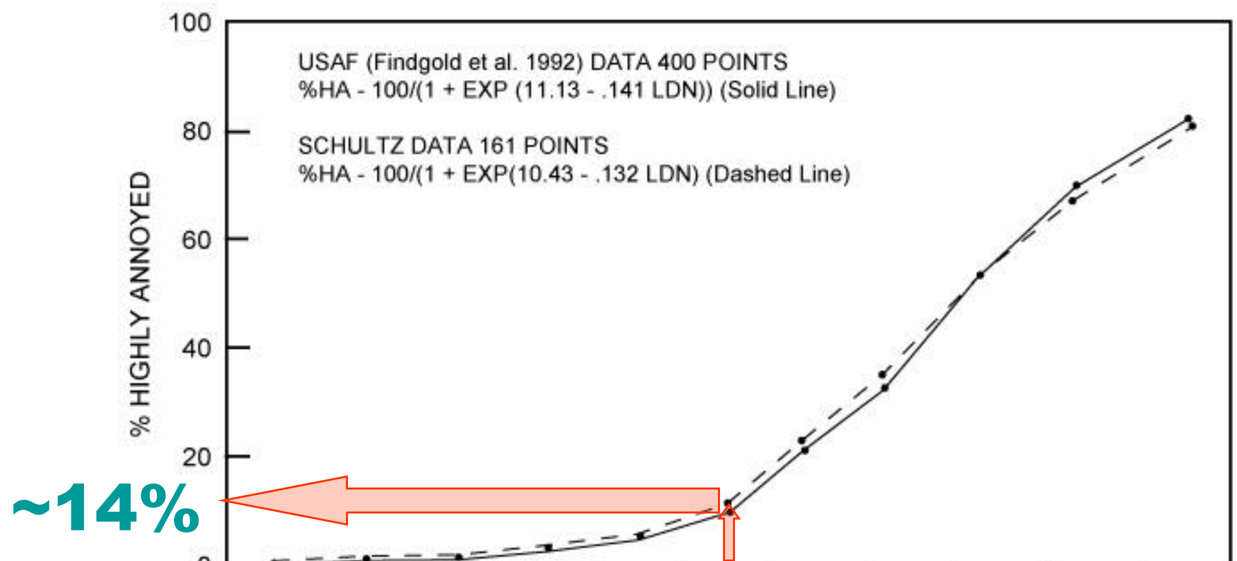
- **Day-Night Noise Level (DNL)**
  - 24-hour time weighted energy average noise level based on dBA
  - Noise occurring between 10 p.m. to 7 a.m. is penalized by 10 dB
  - Penalty was selected to account for the higher sensitivity to noise in the nighttime
  - Penalty also accounts for the expected further decrease in background levels that typically occur in the nighttime
  - FAA specifies DNL for airport noise assessment
  - Environmental Protection Agency (EPA) specifies DNL for community noise and airport noise assessment

Acoustic Principles and Noise Metrics



Acoustic Principles and Noise Metrics

Comparison of Schultz Data (1978) and USAF Data (1992) on Annoyance



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

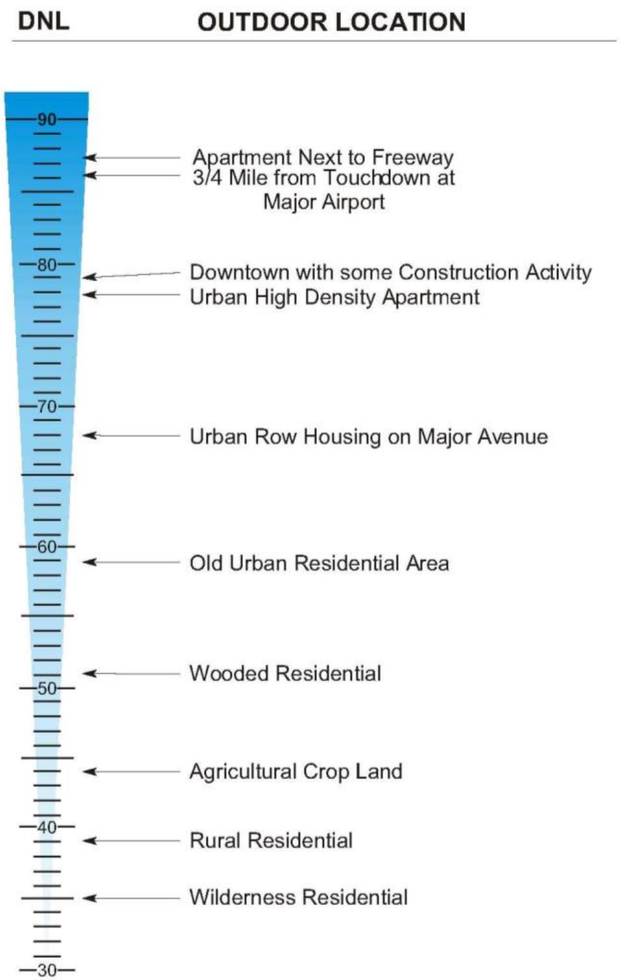
Source: (USAF, 1992)

FAA's Guideline

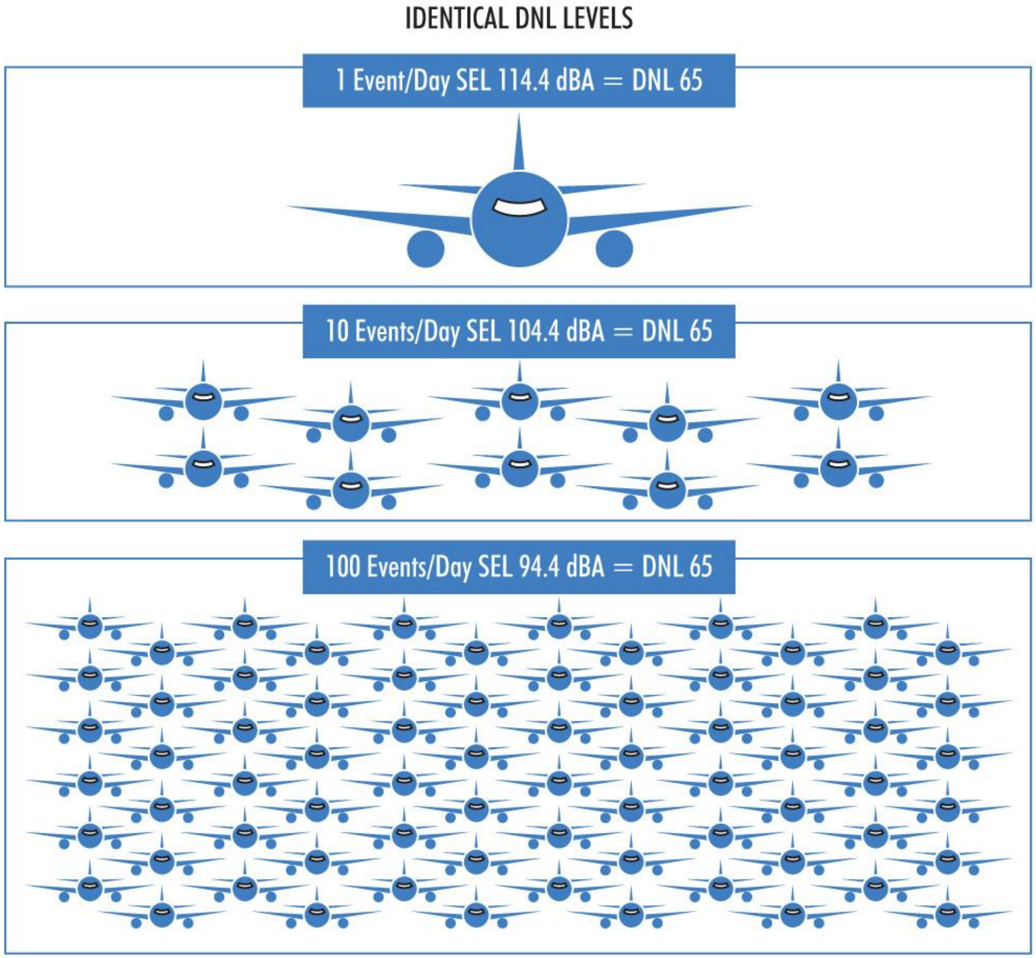
ESA Study Team

THE PORT AUTHORITY OF NY & NJ

Acoustic Principles and Noise Metrics



Acoustic Principles and Noise Metrics



Acoustic Principles and Noise Metrics

- It takes a 3 dB change in the sound level from a source for most people to notice a difference
- A 10 dB increase or decrease is typically perceived as doubling or halving of the loudness, respectively
- Doubling or halving of the distance from the source the receiver equates to +/- 6 dB sound level change

Acoustic Principles and Noise Metrics

- **A doubling or halving the airport operations equates to a +/- 3 dB change in DNL**

- **Using DNL, one nighttime flight will be equivalent to 10 flights during the day**

- **People are more sensitive to changes in noise exposure than the absolute noise level**

Aircraft Noise Assessment 101

Aircraft Noise Assessment 101

- Mathematical models are used everyday to depict a variety of real life conditions such as:
  - Bridge loading, aerodynamic performance, fuel economy, computer animation
- Model accuracy is a function of the modeling algorithms, the empirical databases, and user sophistication
- When used properly, aircraft noise models have proven to be highly accurate

Aircraft Noise Assessment 101

- Modeling tools quantify aircraft noise exposure in the vicinity of airports
- Commonly used aircraft noise modeling tools
  - FAA's Integrated Noise Model (INM)
  - FAA's Noise Integrated Routing System (NIRS)
  - US Air Force's NOISEMAP
  - Aviation Environmental Design Tool (AEDT) 2B*
- Two screening models are also used to assess the need for more detailed modeling
  - The Area Equivalent Method (AEM)
  - The Air Traffic Noise Screening (ATNS)

*AEDT 2B was released by the FAA on May 29, 2015

Aircraft Noise Assessment 101

- The INM 7.0d has been the FAA-approved model for use in preparing:
  - Noise exposure maps (NEMs) for 14 CFR Part 150 and Part 161 studies
  - Noise elements of environmental assessments (EAs) and environmental impact statements (EISs)
  - Noise elements of airport master plans
- While AEDT 2b was released on May 29, 2015, FAA's policy provides for continued use of the current noise model for a project already underway
- INM 7.0d will be used for the JFK 14 CFR Part 150 NEMs

Aircraft Noise Assessment 101

- **NIRS is approved for use in assessing changes in aircraft noise exposure resulting from changes in air traffic procedures over large geographic areas**
- **NOISEMAP is approved for noise studies involving predominately military aircraft operations**

Aircraft Noise Assessment 101

- **The AEM may be used for screening certain airport improvement projects to see if the change in noise exposure reaches the threshold of significance:**
  - **If there is greater than 17% change in the area of the 65 dB DNL contour a more detailed modeling effort is required**
- **The ATNS may be used for screening modifications to air traffic procedures above 3,000 feet AGL:**
  - **Used to identify potential increases of 5 dB or more in community noise levels**
  - **FAA considers whether there are extraordinary circumstances that warrant preparation of an environmental assessment**

Aircraft Noise Assessment 101

- Aircraft noise modeling tools have many analytical uses:
  - Depicting annual aircraft noise exposure
  - Depicting single-event noise exposure
  - Predicting future aircraft noise exposure
  - Assessing changes in noise impacts resulting from runway configuration changes or new runways
  - Assessing changes in fleet mix and/or number of operations
  - Evaluating operational procedures

Aircraft Noise Assessment 101

Integrated Noise Model

- FAA's standard tool since 1978 for determining the predicted noise impacts around airports
- INM handles fixed wing and rotary wing aircraft and is a state-of-the-art aircraft noise model*
- Model produces noise exposure contours that are used for determining land use compatibility

*AEDT 2B was released by the FAA on May 29, 2015

Aircraft Noise Assessment 101

Integrated Noise Model

- The INM was designed to depict the cumulative 24-hour noise exposure for the annual-average day at an airport
- Primary area of focus is the 65 dB DNL contour
- Annual-average day DNL contours will not always match short-term measured values due variables such as:
  - Runway use
  - Fleet mix
  - Wind and weather conditions
  - Pilot/controller techniques

Aircraft Noise Assessment 101

Integrated Noise Model

- **The INM can also predict noise at a specific location that may be sensitive to noise impacts (school, hospital, noise measurement sites, etc.)**
- **16 predefined noise metrics are supported, including:**
  - **DNL**
  - **Lmax**
  - **Leq**
  - **SEL**

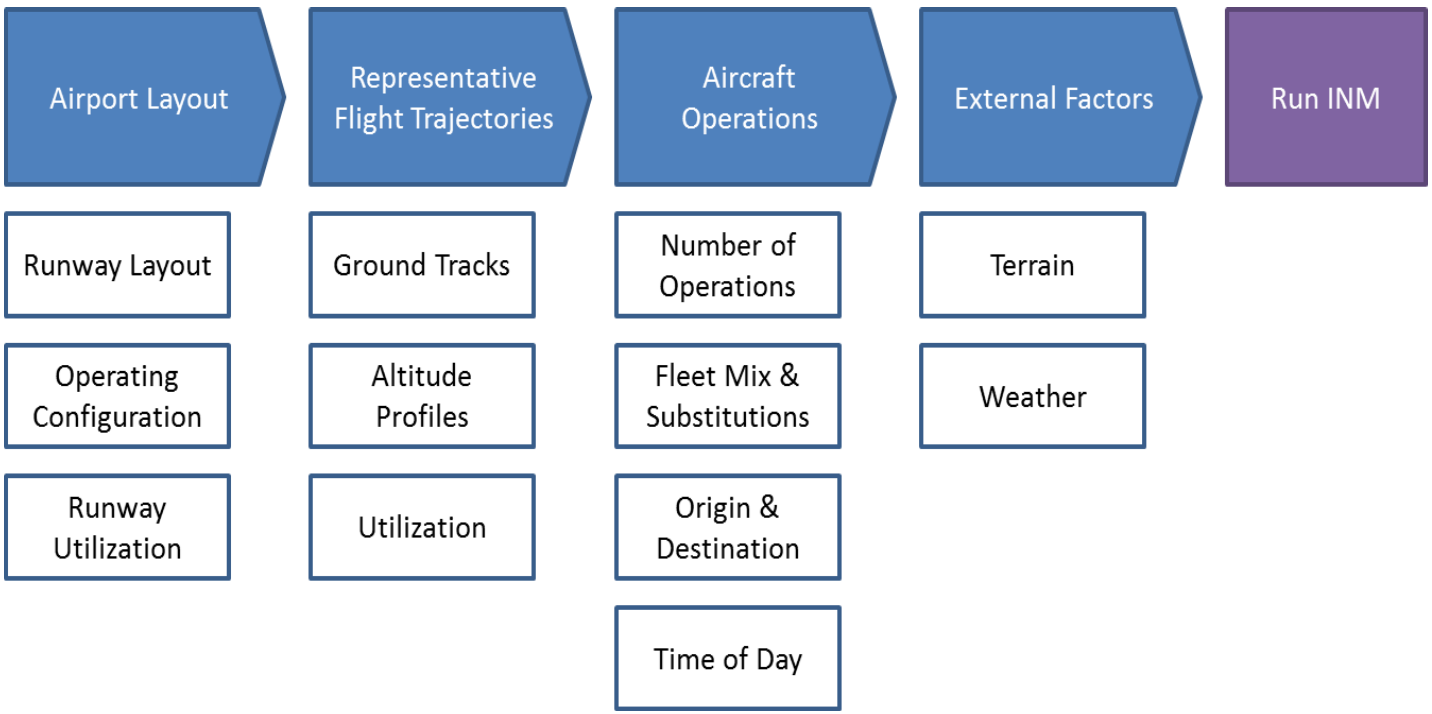
Aircraft Noise Assessment 101

Integrated Noise Model

- The INM has been in use for more than 35 years and has been continually updated to improve its accuracy
- The INM contains an extensive aircraft performance and noise level database derived from actual noise measurements of aircraft in flight
- Results from the INM have been validated on several occasions with overall modeled and measured levels falling within a couple of decibels of each other

Aircraft Noise Assessment 101

Integrated Noise Model: Inputs



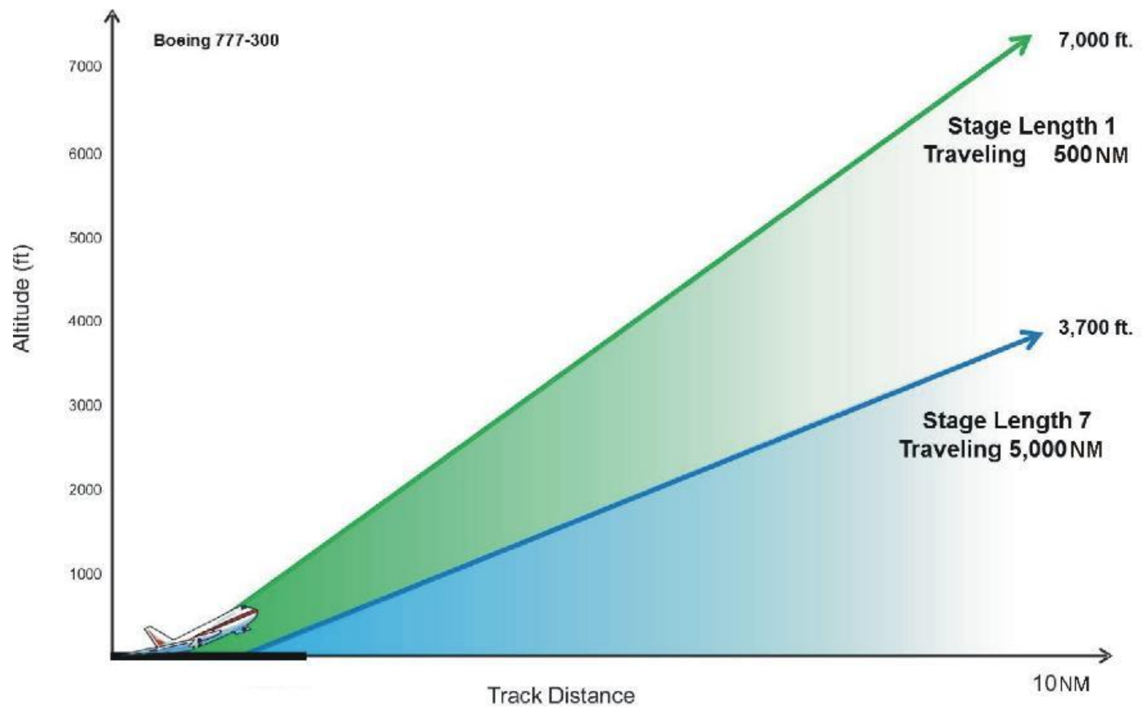
Aircraft Noise Assessment 101

Integrated Noise Model: Computation

- Each aircraft type "flies":
  - off the runways as they are used
  - departure profiles based on aircraft weight, annual-average temperature, and airport altitude
  - the flight tracks as they are used during the year
  - approach profiles as they are flown

Aircraft Noise Assessment 101

Integrated Noise Model: Computation



Aircraft Noise Assessment 101

Integrated Noise Model: Computation

- **INM computes the exposure of each operation:**
  - as it would be measured in the airport environs accounting for the annual-average runway and flight track use
- **The noise exposure of each aircraft operation is:**
  - energy-summed over a user-specified grid to determine the annual-average noise exposure
- **Values of equal noise exposure are connected using "contour lines"**

Aircraft Noise Assessment 101

Integrated Noise Model: Computation

- Sophisticated algorithms use aircraft noise-power-distance curves to calculate noise exposure
- Algorithms are based on guidance documents published by the Society of Automotive Engineers (SAE)
- Primarily SAE-AIR-1845 “Procedure for the Calculation of Airplane Noise in the Vicinity of Airports”

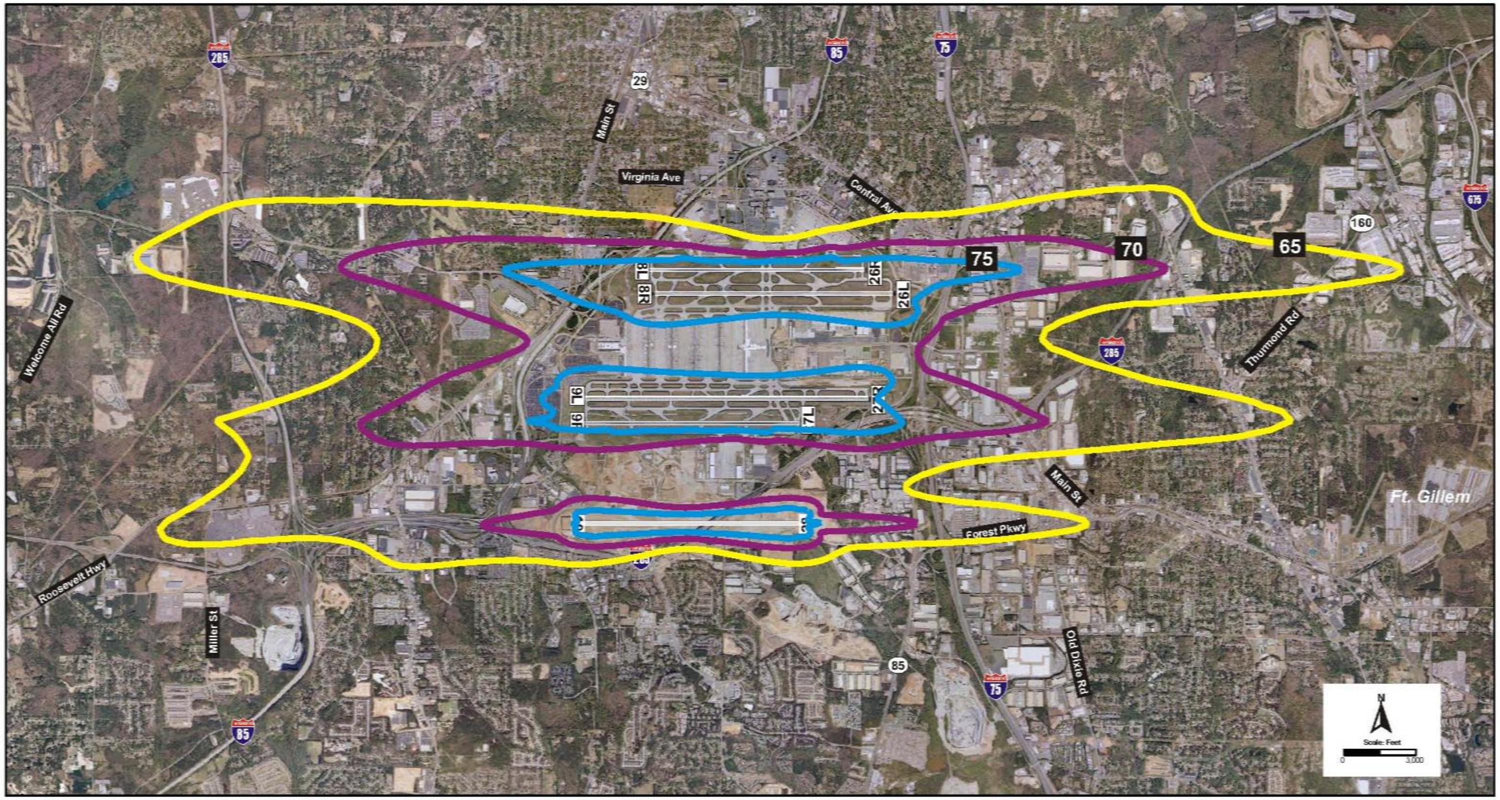
Aircraft Noise Assessment 101

Integrated Noise Model: Output

- Depictions of aircraft noise exposure
  - DNL contours
  - SEL or Lmax contours
  - DNL values across a grid
- Noise levels at specific points
  - home
  - noise monitor
  - school
  - place of worship

Aircraft Noise Assessment 101

Integrated Noise Model: Output



AERIAL SOURCE: GlobeXplorer, January 2004

Aircraft Noise Assessment 101

- Aircraft noise exposure contours are only as good as the people using the noise models

- Improper use of the models can produce inaccurate depictions of aircraft noise exposure

- There is no substitute for experience and depth of knowledge about aircraft operations

Aircraft Noise Assessment 101

- **Noise Exposure Contours**
  - A noise exposure contour identifies areas of equal noise exposure around an airport. Noise exposure contours are similar to contours on topographic maps which show areas of equal elevation
- **Noise Exposure Maps**
  - A noise exposure map is a map showing noise exposure contour lines (or footprints) which identify areas of specific noise levels around an airport. NEMs also include a graphic depiction of geographical features and land uses that surround an airport
- **Noise Compatibility Programs**
  - A noise compatibility program report includes descriptions and a detailed evaluation of noise abatement and noise mitigation options applicable to an airport

Aircraft Noise Assessment 101

- **Noise Abatement Options** are intended to reduce actual aircraft noise levels in noise-sensitive areas by either reducing aircraft noise at the source by using quieter aircraft, shielding noise sensitive areas, or by instituting operational measures, such as changes in aircraft flight tracks or in approach or departure flight profiles

- **Noise Mitigation Options** are intended to reduce the effects of aircraft noise on the receiver. Noise mitigation strategies may include outright property acquisition, acoustical treatment/soundproofing programs, purchase of avigation easements, and land use control measures