Jet Engine Noise Reduction

Presented By
Greg Kurtz
Brad Walsh

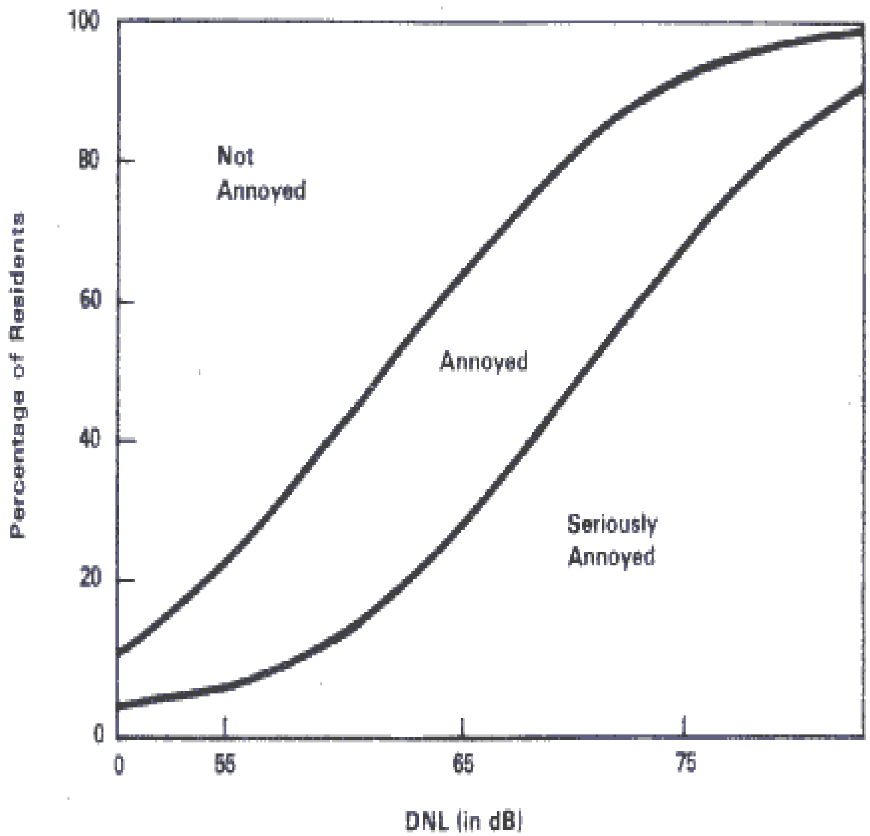
Overview

- Problems Caused by excessive noise
- History of Noise control
- FAA noise regulations
- Sources of Jet engine noise
- Methods of Reducing Jet Engine noise
- Acoustic properties

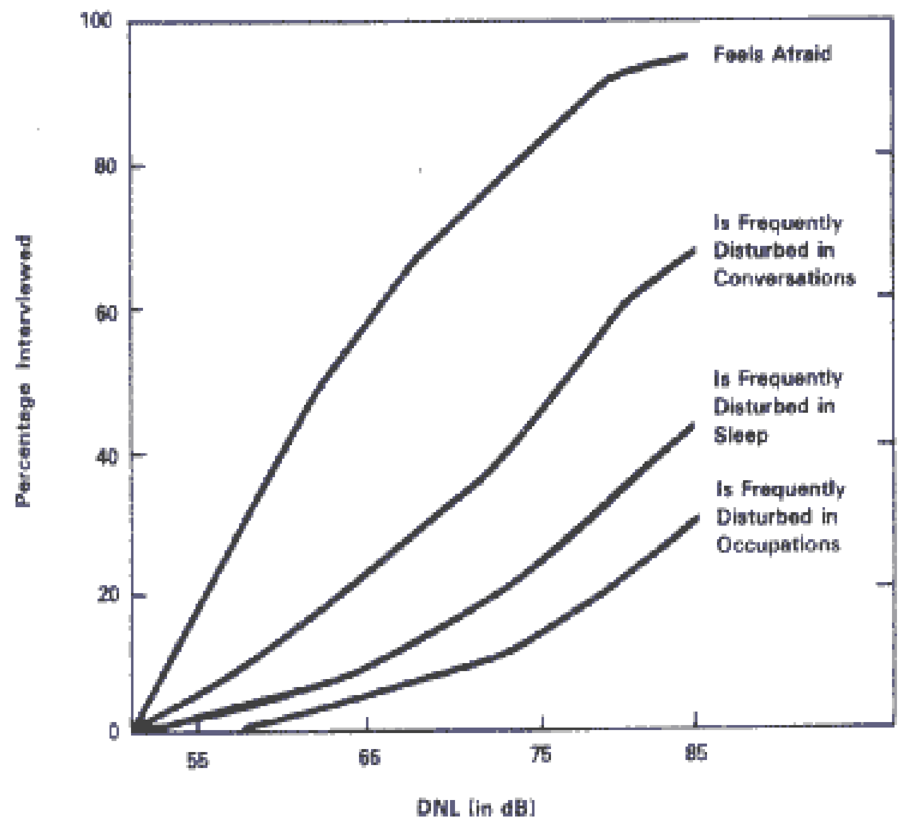
Environmental Effects of Noise

- Some Wildlife animals are effected
- Annoyance
- Hearing Loss
- Sleep interference
- Attention Span
- Real Estate Values

Annoyance

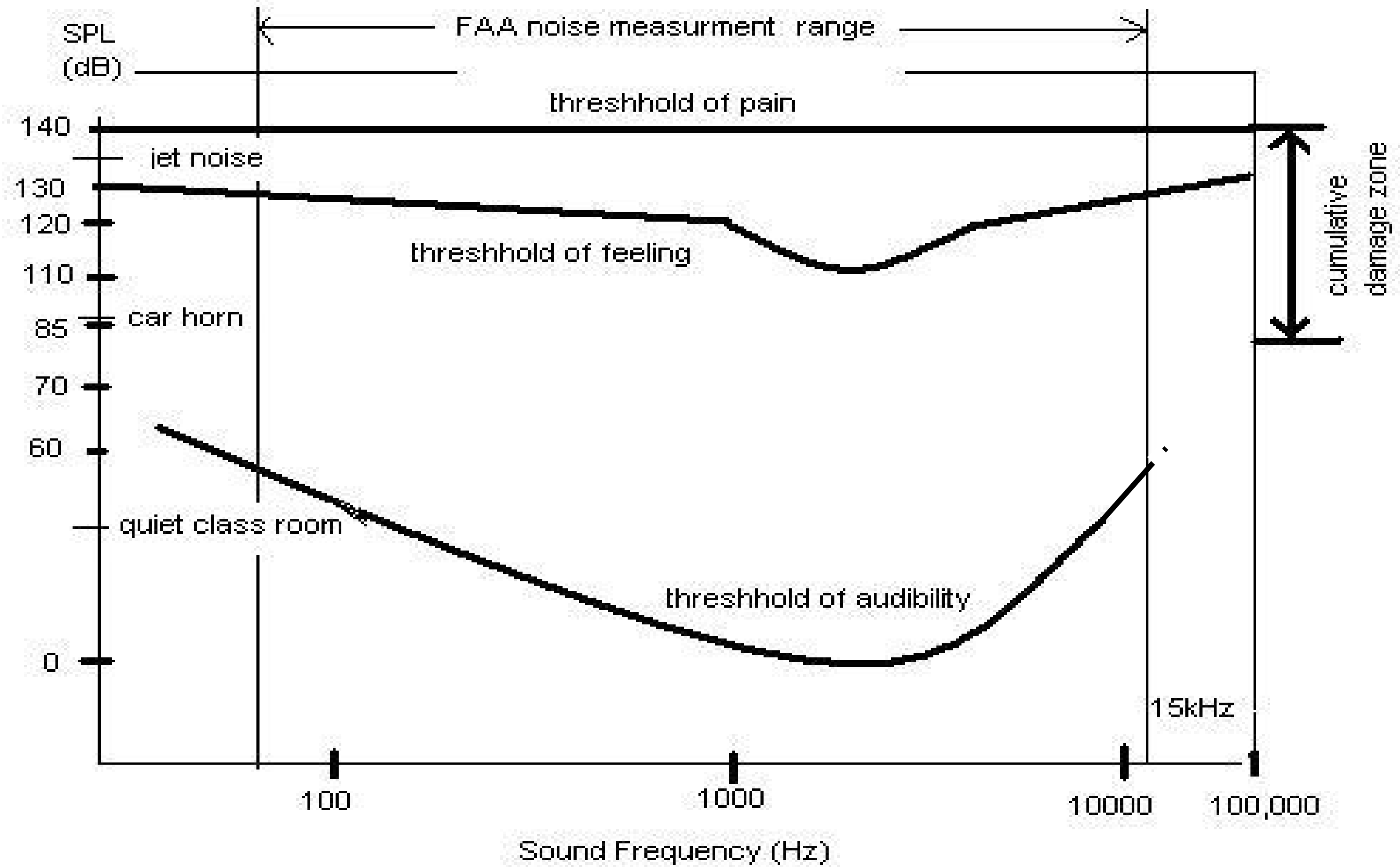


Annoyance Caused by Aircraft Noise in Residential Communities Near Major Airports

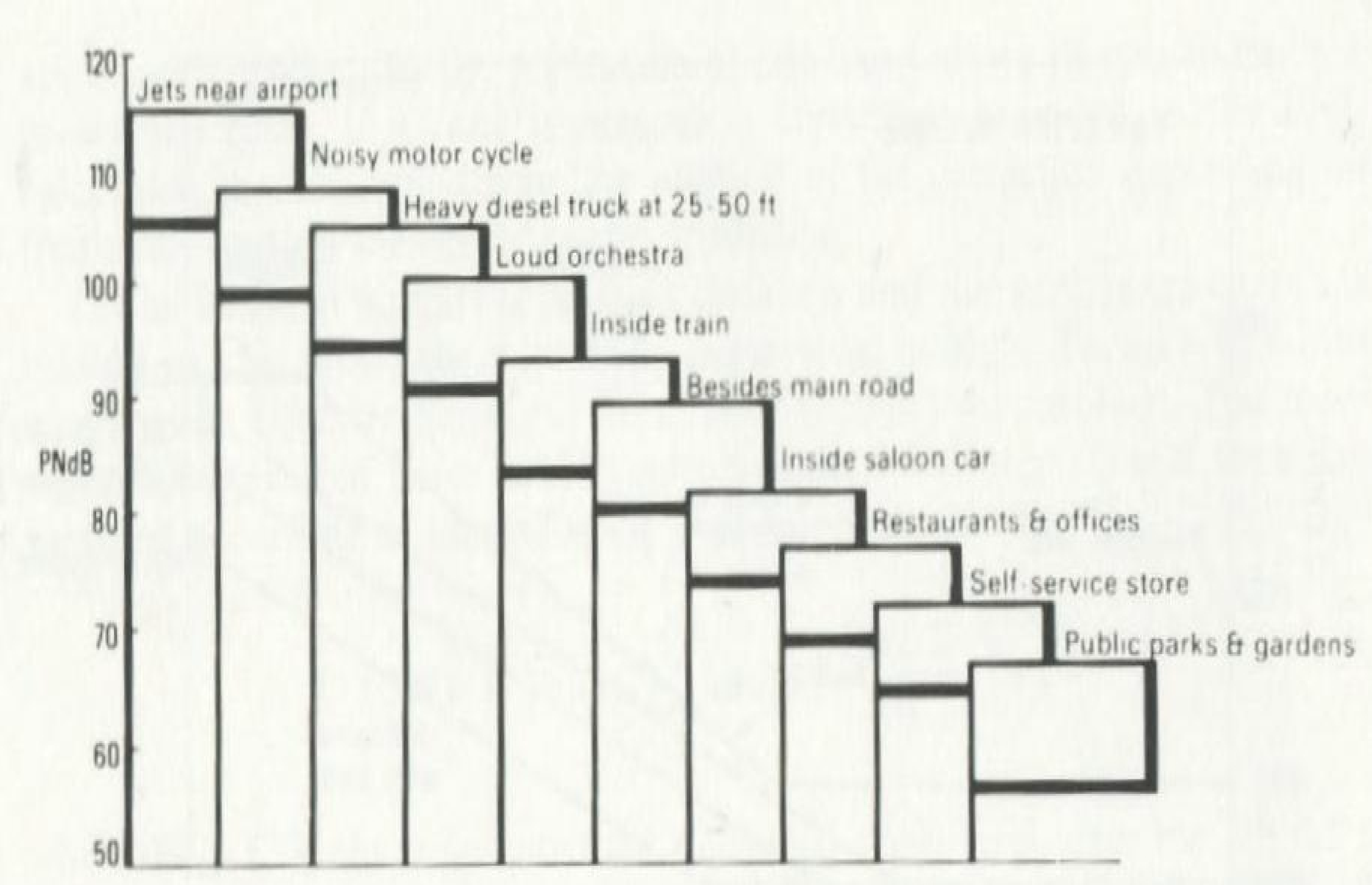


Community Response to Aircraft Noise-Netherlands Survey

Human Ear Range of Pressure and Frequency Response



Reference Decibel Levels



Effects of Noise Regulations

- Since 1976 the number of people exposed to Jet noise above 65 dB has dropped from 7 million to 500,000.
- Flight paths have been established away from highly populated areas
- Buildings near airports such as homes, schools and businesses are being acoustically insulated

History of Jet Noise

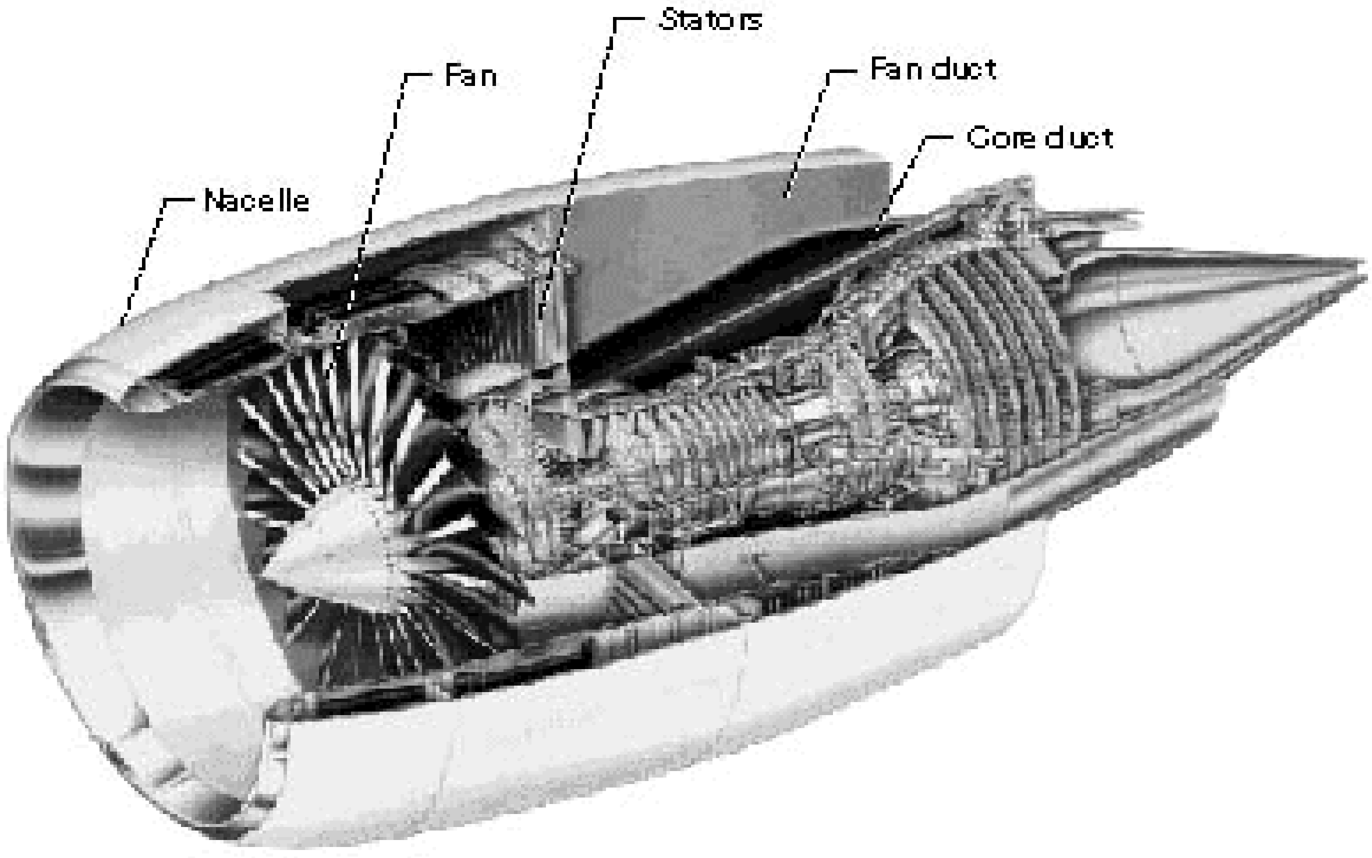
- Commercial Jets in 1960's were 6x louder than those of today
- Lighthill and Goldstein were two biggest players in acoustic theory developement
- Low bypass-ratio jets were later replaced with high bypass ratio jets
  - Low bypass-ratio jets produce higher exit velocities

Current FAA Goals

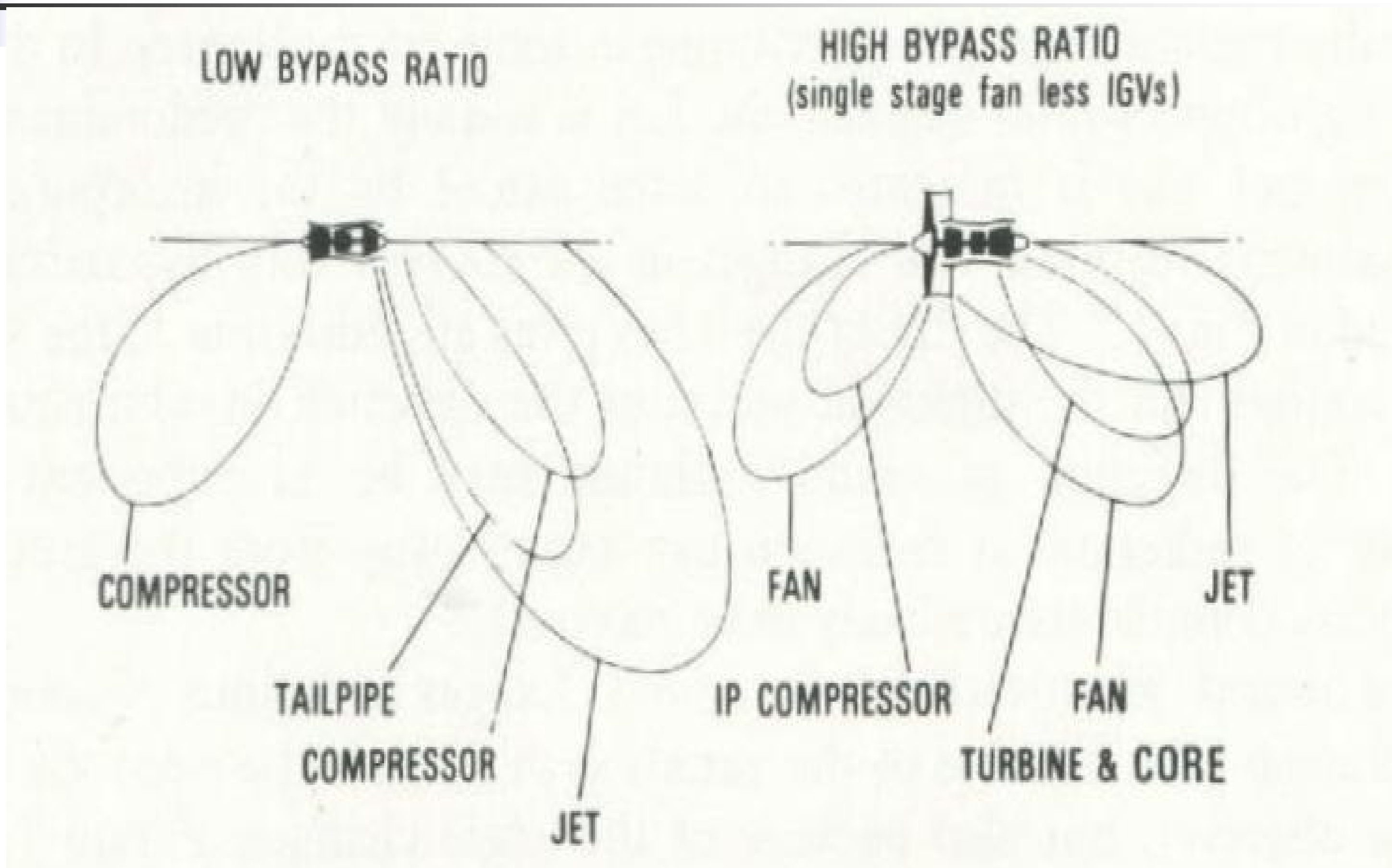
- Continue to reduce aircraft noise at the source (phase out stage 1 and 2 aircraft)
- Use new technology to mitigate noise impact
- Encourage compatible use of land and discourage incompatible usage around airports
- Look further into the design of flight paths around highly populated areas
- Provide special consideration for national parks and reserves
- Ensure strong financial support for noise control project

Projection of Noise reduction

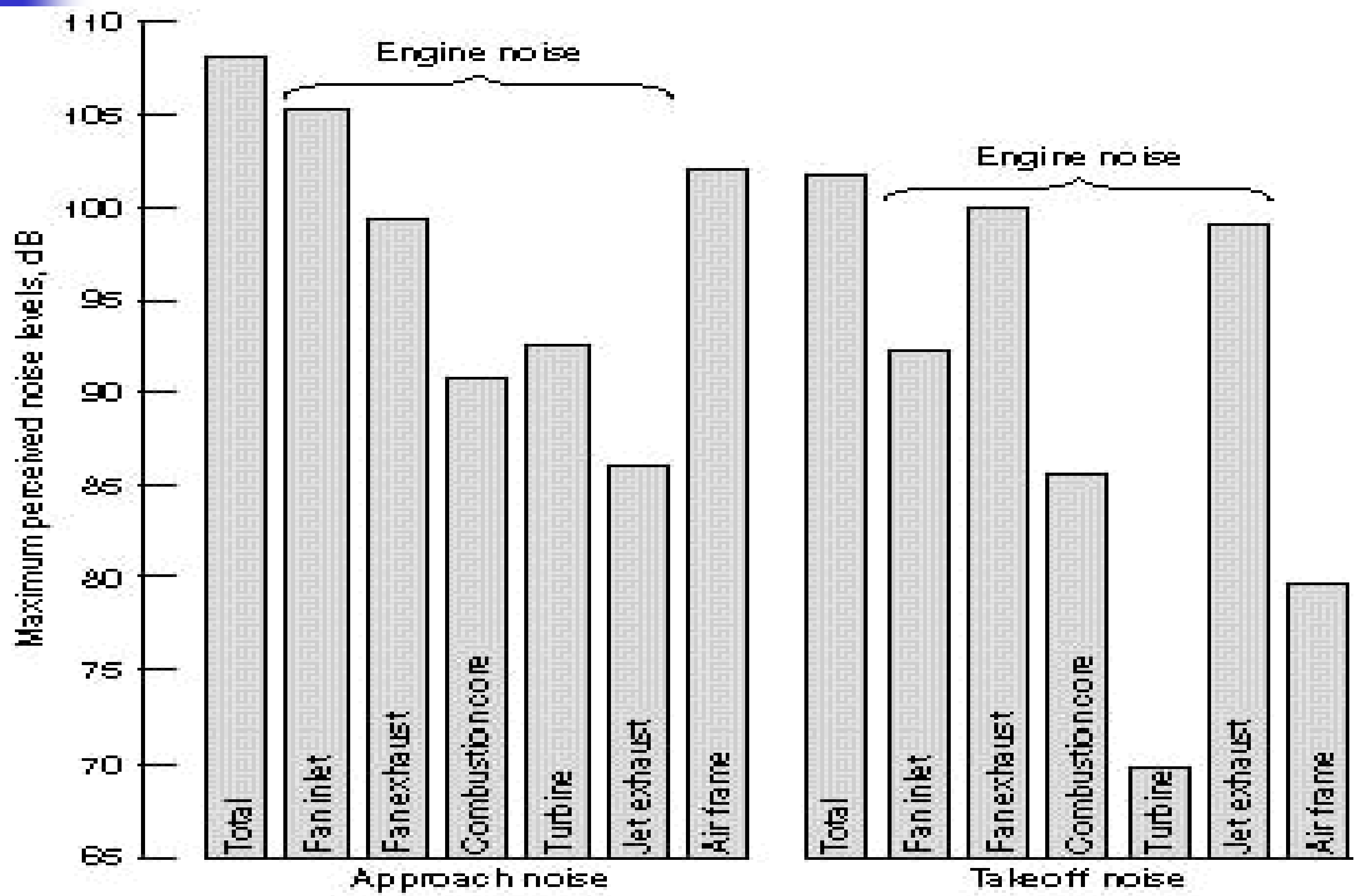
Noise Source Components



Comparing High and Low Bypass Ratio Noise



Jet Engine Noise Source Levels

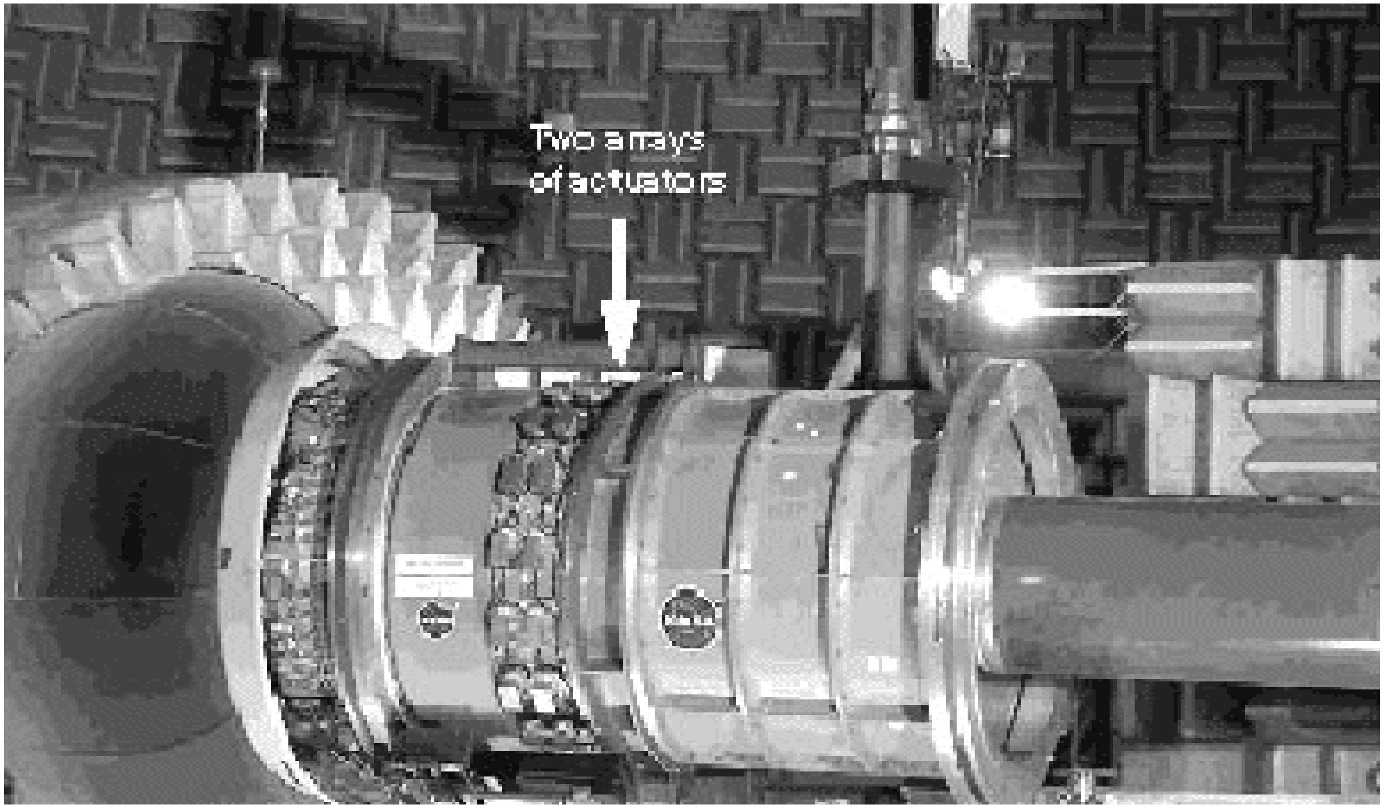


Methods of Noise Reduction

- Active Control
  - Active Noise Control Fan
- Jet Nozzles
- Thrust of engines and number of engines
- Lift and drag exerted on aircraft
- Angle of takeoff and decent
- Location of Engines
  - Mount engines on top of wing

Active Control Fans

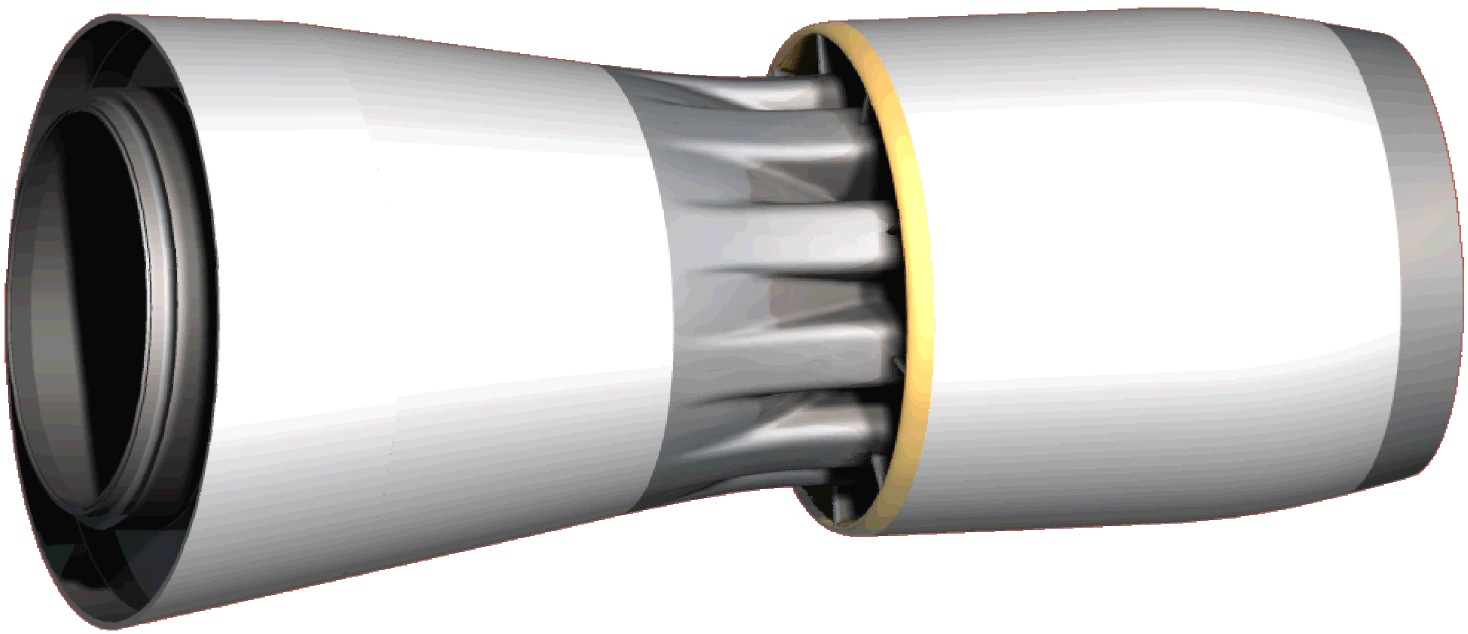
- Glenn Research Center



Active Control Fan performance

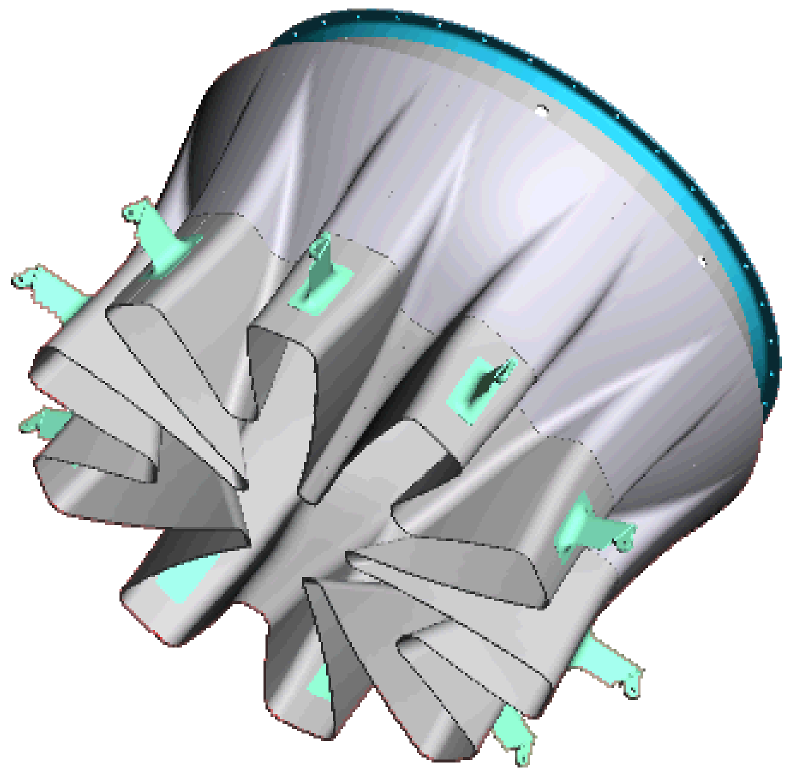
- Goal is to achieve a 6 dB reduction in jet exhaust noise
- Currently the fan has demonstrated a 3 dB Reduction in fan noise

Noise Reduction Nozzles



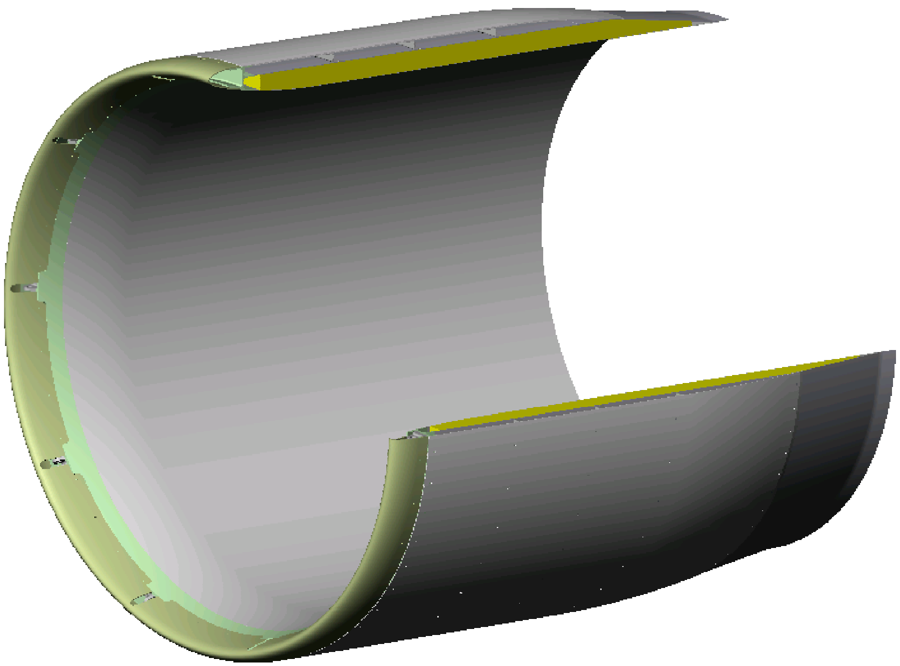
Noise Reduction Nozzles Cont.

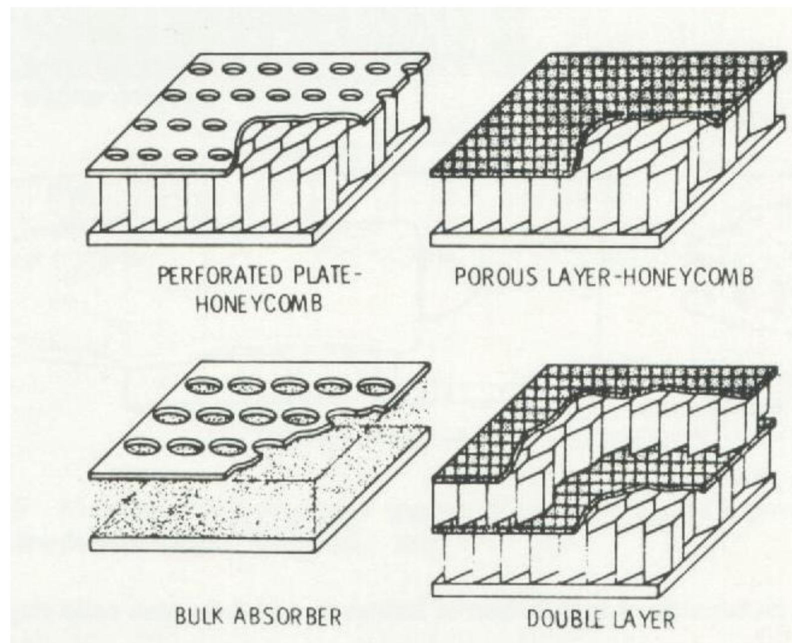
- Choked Mixer Nozzle



Noise Reduction Nozzles Cont.

- Acoustically Insulated Ejector Shroud





Chevron Jet Exhaust Nozzles

Jet Nozzle performance

- Jet nozzles typically provide a 5 to 10 dB reduction in jet noise
- This is done by mixing exhaust gases with bypass or ambient air prior to exiting the engine.
- The result of mixing is a lower exhaust gas velocity and less turbulence with ambient air

Causes of Sound

- Differences in pressure and velocity with ambient air
  - Obstruction to airflow such as sharp edges, bends in flow, ect.
  - Turbulence from rapid fluctuations in air velocity
  - Boundary layer separation giving random distribution of frequencies and amplitude of sound

Turbulence

- Noise sources that are generated by shear layers in fluid flow are dipoles
  - Dipoles exist in a close stream flow
  - Quadrupoles exist in a free jet boundary
  - Monopoles are produced at 5x the diameter of the jet nozzle
- Monopole’s sound pressure is proportional to r^-1
- This means that for every doubling of distance from the jet nozzle the pressure will be half (or a decrease of 6db).

Turbulence

Acoustic Properties

- Speed of Sound

$$a := \sqrt{\gamma \cdot R \cdot T}$$

- Lighthill's eighth-power law

$$p := \frac{\sqrt{(N \cdot \dot{m} \cdot V)^7}}{r}$$

- Decibel Level

sound pressure level

$$SPL := 20 \cdot \log\left(\frac{p}{p_o}\right)$$

Sound Pressure Level

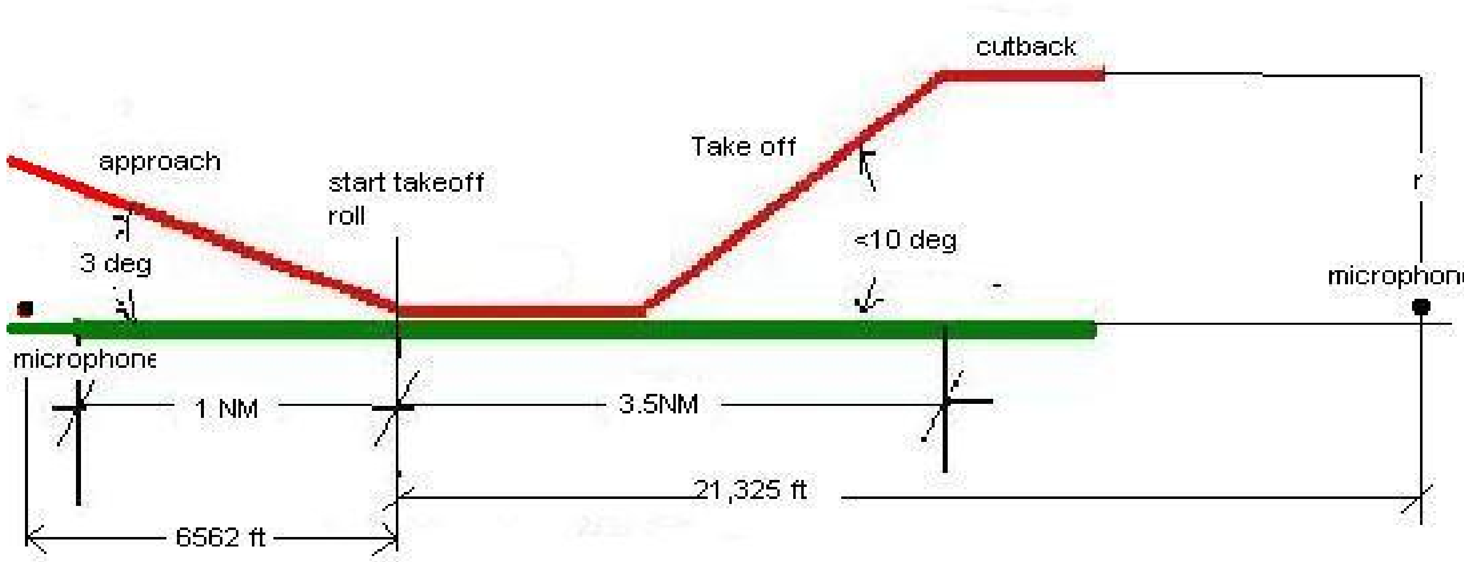
- From the definition of SPL and Lighthill's eighth power rule

$$\mathrm{SPL} := 10\log(N\cdot\dot{m}) + 70\cdot\log(V) - 20\cdot\log(r) + c_1$$

  - N*m total mass flow rate
  - V is jet exhaust velocity
  - r is shortest distance from microphone to flight path

$$\frac{h}{s} = f\left(\left(\frac{T-D}{W}\right)_{TO}\right)$$

Takeoff and Landing Profile



Sound Pressure Level

then

$$\frac{h}{s} := b \cdot \left(\frac{T}{W}\right)^{c}$$

where c is 2.25 for a four engine turbofan aircraft, thus -20log(r) becomes

$$-20 \cdot \log r := \text{constant}_{\ 2} - 45 \cdot \log\left(\frac{T}{W}\right)$$

Sound Pressure Level

introducing lift and drag at the cut back SPL

$$SPL := -40\cdot\log\left(\frac{L}{D}\right) - 40\cdot\log\left(\frac{T}{W}\right)$$

finally

$$SPL := 10\cdot\log(N) + 10\cdot\log(\dot{m}) + 70\cdot\log(V)$$
$$-40\cdot\log\left(\frac{L}{D}\right) - 85\cdot\log\left(\frac{T}{W}\right) + \text{constant}$$

Any Questions ?