Introduction

Figure 1. Turbojet Engine from 1950s Era, from Reference 3.

Turbojet engine noise sources include the compressor, turbine, combustor, and the exhaust jet.

The jet noise is significantly reduced in high-bypass-ratio turbofan engines, but the fan noise is an additional noise source.

Furthermore, the airframe itself is a noise source.
<table>
<thead>
<tr>
<th>Source</th>
<th>Discrete Tones</th>
<th>Broadband Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan</td>
<td>Tones at various frequencies, whine and whistle</td>
<td>Yes</td>
</tr>
<tr>
<td>Compressor</td>
<td>High frequency tones</td>
<td>Yes</td>
</tr>
<tr>
<td>Combustor</td>
<td>No</td>
<td>Low frequency noise</td>
</tr>
<tr>
<td>Turbine</td>
<td>High frequency tones</td>
<td>High frequency noise</td>
</tr>
<tr>
<td>Jet</td>
<td>No</td>
<td>Low frequency noise, rumble and roar</td>
</tr>
</tbody>
</table>

**Variables**

- $P$ is the acoustic pressure
- $I$ is the intensity
- $W$ is the radiated power
- $\rho$ is the mean density of the gas
- $C$ is the speed of sound in the gas
- $U$ is the flow velocity in the source region
- $L$ is a length scale of flow in the source region
- $M$ is the Mach number
- $A$ is the exhaust nozzle area

**Lighthill’s Scaling Formulas**

Consider a high-speed, subsonic, turbulent air jet.

![Diagram showing parameters for Jet Noise](image)

**Figure 2. Parameters for Jet Noise**
The acoustic pressure $P$ is

$$P \propto \frac{\rho U^4}{c^2} \left( \frac{L}{x} \right) \quad (1)$$

The intensity $I$ is

$$I \propto \frac{p^2}{\rho c} \quad (2)$$

$$I \propto \frac{\rho U^8}{c^5} \left( \frac{L}{x} \right)^2 \quad (3)$$

The radiated power $W$ is the intensity integrated over a spherical surface of radius $x$. Essentially, this is the same as multiplying the intensity by the surface area of the sphere.

Thus, the radiated sound power $W$ is

$$W \propto \frac{\rho L^2 U^8}{c^5} = \rho L^2 U^3 M^5 \quad (4)$$

Note that $L^2$ is proportional to the exhaust nozzle area $A$.

References
