Noise Comparison of Aerospace Vehicles

By Ben Goldman

HAI Heli Expo 2020
Anaheim Convention Center
29 January 2020
### Noise components

#### Noise Sources:
- **Propulsion**
  - Thickness
- **Loading**
- **Volume**
- **Powertrain**

<table>
<thead>
<tr>
<th>Propeller Airplane</th>
<th>Jet Airplane</th>
<th>Helicopter</th>
<th>eVTOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Propeller Airplane" /></td>
<td><img src="image" alt="Jet Airplane" /></td>
<td><img src="image" alt="Helicopter" /></td>
<td><img src="image" alt="eVTOL" /></td>
</tr>
</tbody>
</table>

### Thickness Noise
- Contributes primarily in-plane
- Dominates noise at high tip speeds
  - Reason for helicopter’s long detection range

- **eVTOL will have low thickness noise by employing:**
  - low tip speeds in hover
  - ultra-low tip speeds in cruise
Noise components

- Noise Sources:
  - Propulsion
    - Thickness
    - Loading
  - Volume
  - Powertrain

Loading Noise
- Types:
  1. Unsteady loading noise
  2. Broadband noise
  3. Blade-vortex interaction (BVI) noise
- Contributes primarily normal to the prop plane

Low disc-loading will contribute to eVTOL being quieter than both airplanes and helicopters.
- Broadband noise is better absorbed by the atmosphere.
- Airplane Mode avoids BVI altogether, avoidable in Heli Mode.
### Noise components

<table>
<thead>
<tr>
<th>Propeller Airplane</th>
<th>Jet Airplane</th>
<th>Helicopter</th>
<th>eVTOL</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Propeller Airplane" /></td>
<td><img src="image2.png" alt="Jet Airplane" /></td>
<td><img src="image3.png" alt="Helicopter" /></td>
<td><img src="image4.png" alt="eVTOL" /></td>
</tr>
</tbody>
</table>

#### Noise Sources:
- **Propulsion**
  - Thickness
  - Loading
  - Volume
- **Powertrain**

#### Volume Noise
- Fluid shear in jet exhaust
- High-speed impulsive noise in helicopters
- Composed of high-frequency noise
  - Highly annoying (when present)

- eVTOL employing propellers for propulsion will not generate significant levels of quadrupole noise.
Powertrain Noise

- Modern commercial aircraft generate power using either:
  - Piston engines (Internal combustion)
  - Gas turbine engines (Continuous combustion)
- These engine types are noisy and expensive to quiet down.

- eVTOL use quiet electric motors which do not generate powertrain noise.
Psychoacoustic Tailoring

- To describe noise fully requires more than just the absolute level.
  - The countless metrics and measures acousticians refer to suggests as much:
    - PNL, PNLT, EPNL, SEL, LEQ, loudness, Zwicker loudness, harshness, etc.

- Compared to current aircraft, **eVTOL** can and must be:
  - Perceptually more quiet
  - Perceptually more pleasant to the listener

- Employing multiple, independent propellers / rotors gives designers flexibility to tailor the noise.
Summary

- eVTOL aircraft (can) be significantly more quiet than existing aircraft thanks to:
  - Reduced tip speeds
  - Lower thrust requirements in cruise
  - Optimal directivity in cruise (airplane, not helicopter)
  - Avoidance of BVI
  - Absence of quadrupole noise
  - Absence of powertrain noise
  - Psychoacoustic tailoring

The ((Quiet)) Electric VTOL Revolution is upon us! Did you hear it coming?