Space Hardware Acoustic Mitigation

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ASEN 5519 Space Payload Design
University of Colorado, Boulder
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Current AFRL Work in Spacecraft Acoustic/Vibration Protection

VALPE II – Vibro-Acoustic Launch Protection Experiment – 2
Launched on a Terrier-Orion sounding rocket out of Wallops.
http://www.vs.afrl.af.mil/Factsheets/VALPE.html
Some Acoustic Definitions/Facts:

**Human hearing**: 20 Hz - 20,000 Hz  
**Human Speech**: 500 - 1000 Hz.  
**Effective disruptive noise range**: 63 to 8000 Hz

**Sound Pressure Level, SPL**: 
\[ \text{dB} = 20 \times \log \left( \frac{P}{P_{\text{ref}}} \right) \]

- \( P_{\text{ref}} = 0 \text{ dB} = 20 \mu\text{Pascal} \) (audible threshold for humans)

<table>
<thead>
<tr>
<th>Sound Pressure</th>
<th>dB</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 \mu Pa</td>
<td>0 dB</td>
<td>Threshold of human hearing</td>
</tr>
<tr>
<td>200 \mu Pa</td>
<td>20 dB</td>
<td>Forest (15 dB typ.)</td>
</tr>
<tr>
<td>2000 \mu Pa</td>
<td>40 dB</td>
<td>Library (35 dB typ.)</td>
</tr>
<tr>
<td>20,000 \mu Pa</td>
<td>60 dB</td>
<td>Office (65 dB typ.)</td>
</tr>
<tr>
<td>200,000 \mu Pa</td>
<td>80 dB</td>
<td></td>
</tr>
<tr>
<td>2,000,000 \mu Pa</td>
<td>= 100 dB</td>
<td>Pain (130 dB)</td>
</tr>
<tr>
<td>20,000,000 \mu Pa</td>
<td>= 120 dB</td>
<td></td>
</tr>
</tbody>
</table>
Below ~200Hz, and above 8000 Hz, the ear does not perceive “loudness” as well.
Shuttle Noise (SPL) limits for payloads in Middeck

![Graph showing noise levels in different frequency bands.]

<table>
<thead>
<tr>
<th>FREQ. BAND</th>
<th>63</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
<th>O.A.</th>
<th>A-wtd</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIMIT</td>
<td>64</td>
<td>56</td>
<td>55</td>
<td>51</td>
<td>52</td>
<td>53</td>
<td>48</td>
<td>44</td>
<td>66</td>
<td>58</td>
</tr>
</tbody>
</table>

FIGURE 4.7.3.1-2 PAYLOAD GENERATED ACOUSTIC NOISE (AFTER APRIL 1, 1994)
Acoustic Hardware Problem: Cooling Fans

<table>
<thead>
<tr>
<th>Fan Type</th>
<th>Noise (broad band)</th>
<th>Blade passing tone</th>
<th>Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrifugal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airfoil blades</td>
<td>Lowest</td>
<td>Moderate</td>
<td>Very efficient</td>
</tr>
<tr>
<td>Backward Inclined Blades</td>
<td>Lower</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Forward Inclined Blades</td>
<td>Moderate</td>
<td>Lowest</td>
<td>Low pressure drop applications</td>
</tr>
<tr>
<td>Radial Blades</td>
<td>High</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Axial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vane</td>
<td>Higher than centrifugal</td>
<td>Can be high, depends on flow obstructions</td>
<td>Very efficient</td>
</tr>
<tr>
<td>Tube</td>
<td>More than vane</td>
<td>Highest</td>
<td></td>
</tr>
<tr>
<td><strong>Propeller</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“Propeller” type is generally used for space/electronic hardware.

Noise levels are generally distributed over the entire frequency spectrum.

CENTER FREQUENCY – Hz

<table>
<thead>
<tr>
<th>dB re 10^-12 watt and 1 cfm at 1 inch ftp</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
</tr>
<tr>
<td>51</td>
</tr>
</tbody>
</table>
Cooling Fan Speed: Noise Effects

- If the speed of a fan is reduced by 20%, the decibel level will reduce by 5 dB.

- Fans that run at peak efficiency tend to be quieter.
Cooling Fan Flow Issues

Low noise fan designs (what we’re interested in) are sensitive to inlet and outlet flow disturbances:

- Brackets
- Capacitors
- Transformers
- Cables
- Finger guards
- Filter assemblies
- Walls or panels, fins

- Sharp angled flow paths are ill-advised.
Noise Solutions: Passive Control

Types: foam, dampers, insulation, isolation

- inexpensive
- reliable
- “dumb” (install and forget)

Cooling Fan Passive Solutions

Mounting Isolation, $5.00

Rubber Grommets:

Flow Gasket, $9.00
Cooling Fan Passive Solutions
Specifically Designed Cooling fans with:
• Bearing vibe isolation
• Mounting isolation
• “Smoother” Airflow designs

$40.00

Zalman CNPS7000A-AICU

XPCGEAR.COM
Noise Solutions: 
Active Noise Control (ANC)

Types: sensors/actuators (mics/speakers)
- expensive compared to passive
- possibly less reliable than passive
- useful when passive not applicable or not capable
- can be more effective than passive
- “smart” (adjustable, adaptable)
Active Noise Control (ANC)

The VERY Basics:

![Diagram of ANC system]

Active Control in a Duct System:

Hull, Radcliffe, Et al.
ANC Demo Example

http://www.val.me.vt.edu/
(Virginia Tech, Vibro-Acoustic Lab)

ANC_demo.exe
Questions