NOISE CONTROL IN HABITABLE SPACE VEHICLES AND ENCLOSURES

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Third IAASS International Space Safety Conference
21-23 October 2008

Motivation

Acoustics is a top priority safety and habitability issue in present and future space vehicles and enclosures.

High acoustic levels may cause: **Physiological symptoms**	• Temporary or permanent hearing loss • Auditory pain • Headaches • Discomfort • Strain in the vocal cords • Fatigue
Excessive noise (undesirable sound) may result in: **Psychological effects**	• Irritability • Inability to concentrate • Decrease in productivity • Annoyance • Errors in judgment • Distraction
and other negative effects	• Inability to sleep or sleep well • Inability to communicate • Decrease intelligibility • Degrade crew performance and operations • Inability to hear alarms or other auditory cues

Purpose

The purpose of this work is to discuss the importance of a noise control plan in the design, development and manufacturing process of habitable space enclosures to ensure that the crews are provided a safe, comfortable, and operationally acceptable environment.

Outline

- Introduction
- Noise Control Plan
- Noise Control Plan Applications
- Conclusions and Recommendations

Noise Control Plan

A noise control plan is necessary to define and layout the plans and efforts needed to achieve compliance with the acoustic requirements

The noise control plan should be implemented in the early design phase and include:

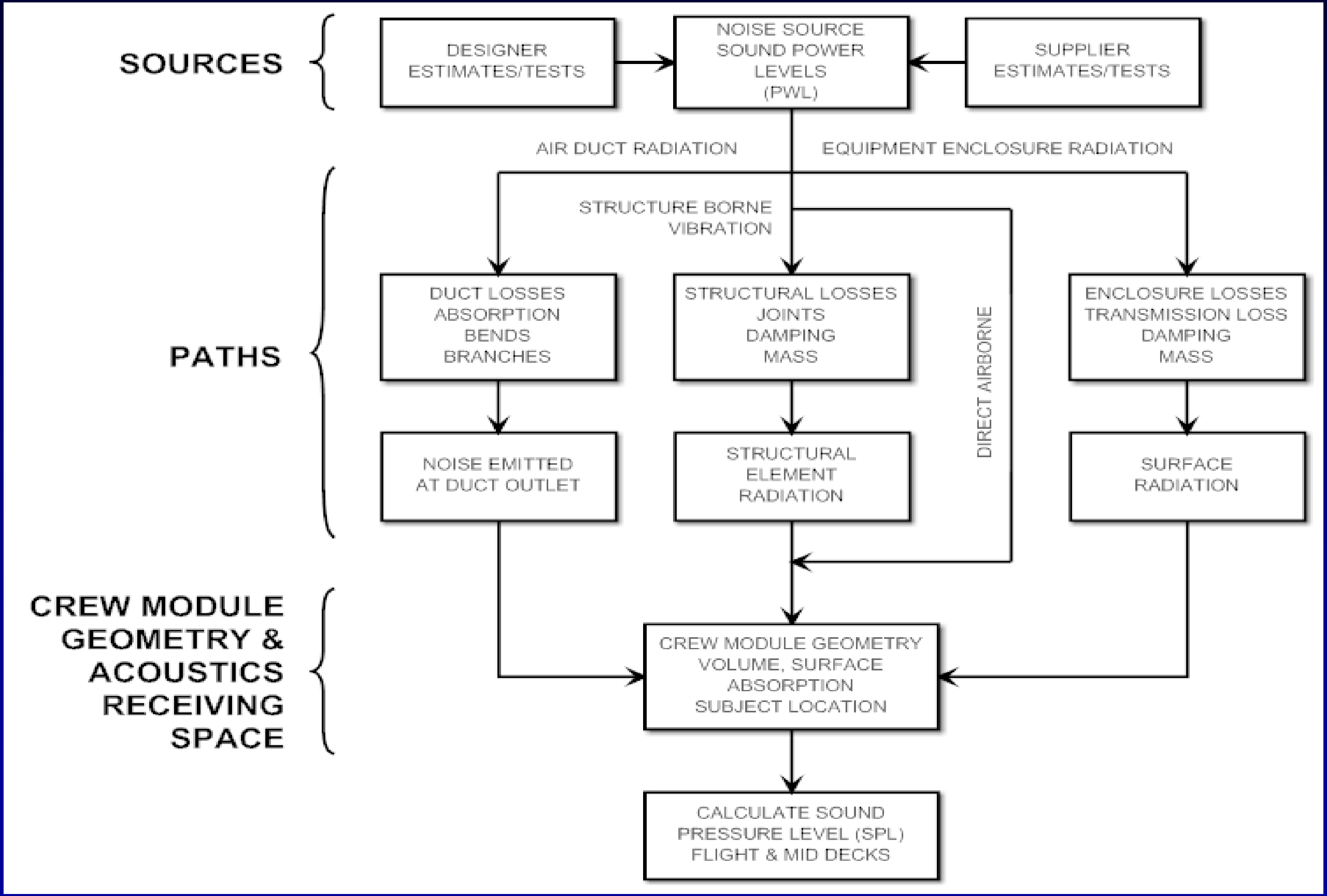
- The overall noise control strategy
- The supporting acoustic analysis approach
- The testing and verification procedures for the system and hardware components

Noise Control Strategy

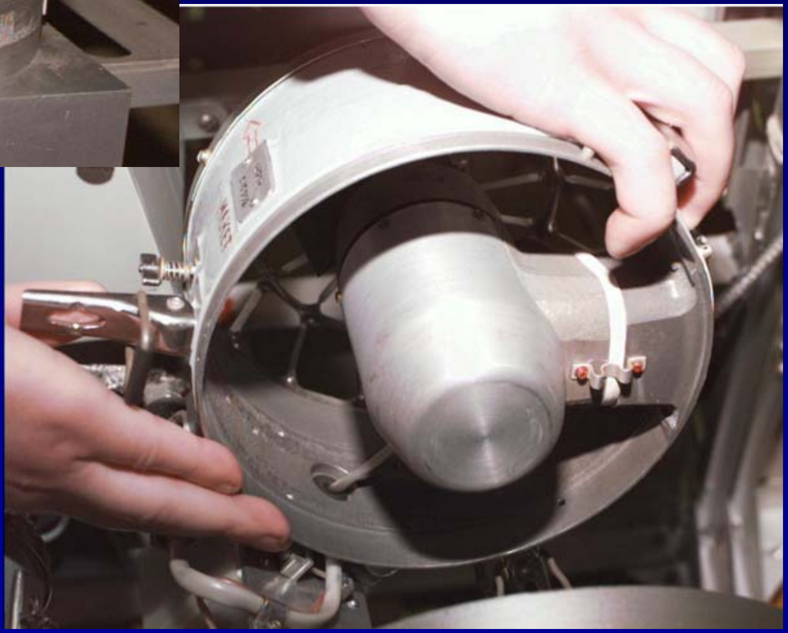
Noise control is the application of designs and technology necessary to limit the noise at the source, along its path, and at the receiver location to acceptable levels

- Noise sources
  - Select noise sources that are quiet by design
  - Quiet the selected design or source hardware
- Noise paths
  - Air borne
  - Structure borne
  - Enclosure radiated
- Noise at the receiver
  - Low frequencies (location dependent)
  - High frequencies (reverberation time, absorption)

Space Shuttle Continuous Noise Strategy



ISS Air Filtration Inlet Fans Source



- Two encased fans
- Two blades each
- Rotations per Minute: 3000 RPM
- Diameter: 0.17 m
- Inlet dimensions: ~ 0.55 m x 0.23 m
- Inflow area: 0.0186 m^2

Air Filtration Inlet Fan
Noise Sources

- **Broadband Aerodynamic Noise**
  - Inlet turbulence
  - Blade surface pressure fluctuations
  - Trailing edge vortex shedding
  - Wake behind the supporting strut

- **Discrete Frequency Aerodynamic Noise**
  - Blade Passage Frequency (BPF=RPM*B/60)

- **Structureborne Noise**
  - Rotational frequency (BPF=RPM/60)

Air Filtration Inlet Muffler Receiver

Octave band sound pressure levels did not meet criteria:

Octave Band Frequency [Hz]	250	500	1000	2000	4000	8000
Required Attenuation [dB]	11	11	8	9	4	4

Noise Control Applications

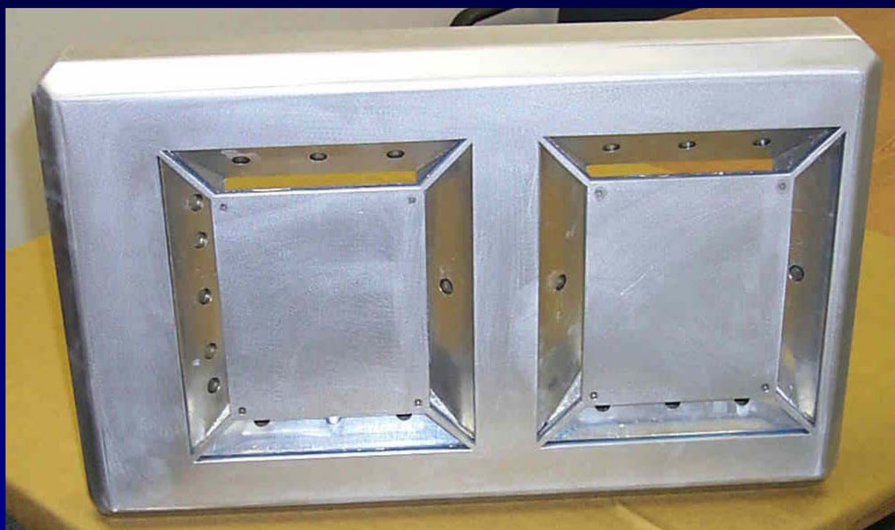
- **Fan Design**
  - Blade
  - Motor/bearing
  - Support strut
- **Air Filtration System Inlet Design**
  - Enclosure/duct (Aerodynamic fairing)
  - Plenum
  - Absorptive lining
- **Muffler Design**

Air Filtration Inlet Muffler Path

Constraints

- Absorption material less than 30% filter area
- Total thickness less than 80 mm
- At least 20 mm between filter and inlet surface

Muffler Noise Control Application



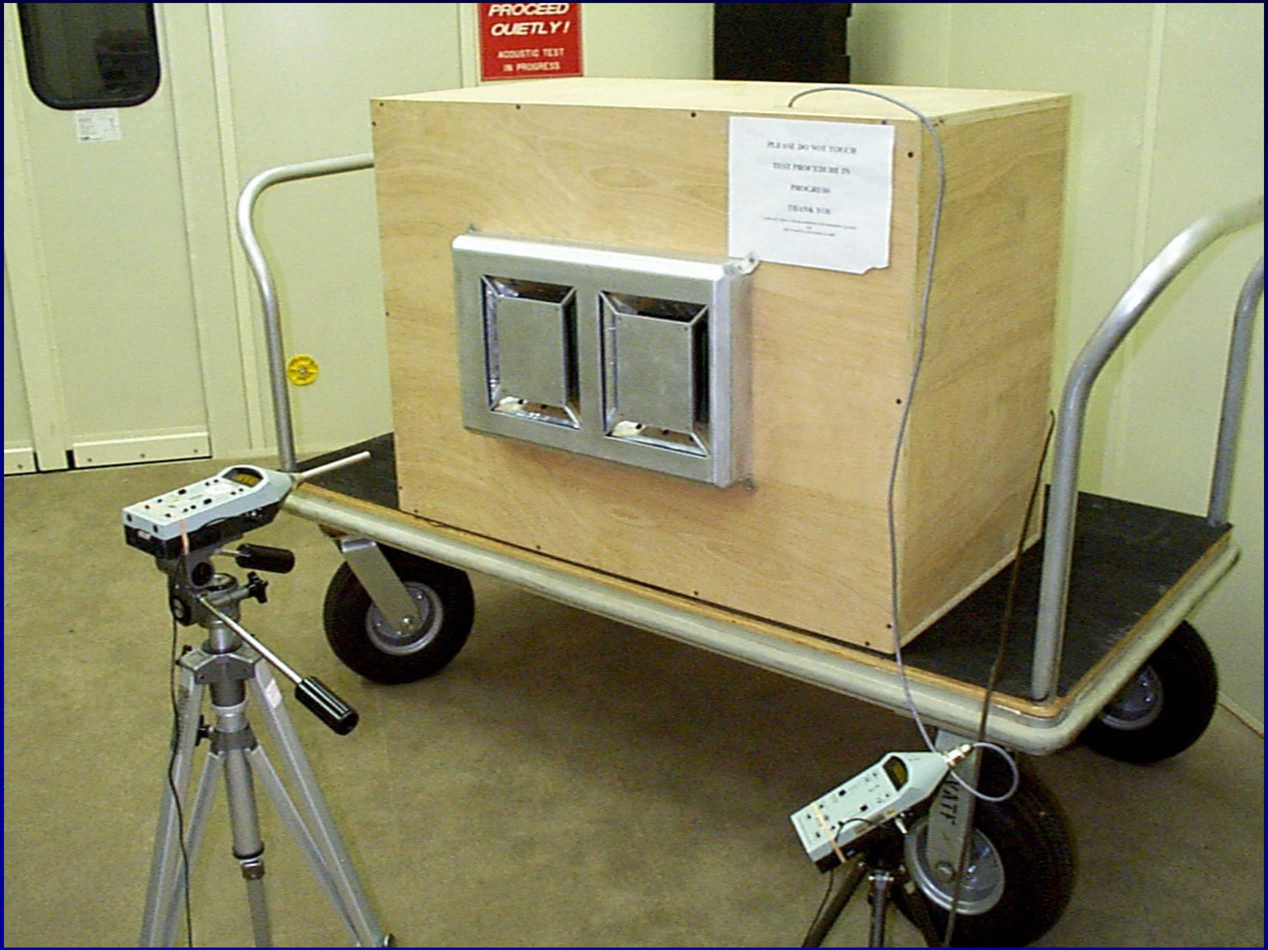
- Same flow inlet area
- Noise barrier

- Structural damping
- Resonator attenuation
- Absorption

Muffler Noise Control Analysis

- Inflow area design
- Sound transmission loss analysis
- Visco-elastic material selection and damping properties
- Helmholtz resonator frequency and attenuation
- Sound absorption material and thickness assessment

Muffler Noise Control Verification



Air Inlet Muffler Noise Control Results

- **Fairing:**
  - Improved airflow
- **Sound Transmission Loss:**
  - 3.18-mm thick aluminum panel
  - Field TL of 19.3 dB (250 Hz) and 25.3 dB (500 Hz)
- **Structural Damping:**
  - Viscoelastic material (1.59 mm) applied to panel
- **Helmholtz Resonators:**
  - Attenuation at peak tonal sound pressure level
- **Absorption Material:**
  - Sound absorption above 1000 Hz

Conclusions and Recommendations

A noise control plan is essential to achieve acoustic compliance and should include:

- Noise control strategy
- Acoustic analysis approach
- Testing and verification plans

To be successful it is recommended that:

- The plan be actively monitored
- Be implemented in the early design phase
- Be supported by management