Acting on Lessons Learned: A NASA Glenn Acoustics Branch Perspective

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Abstract

Lessons learned from the International Space Station have indicated that early attention to acoustics will be key to achieving safer, more productive environments for new long duration missions. Fans are known to be dominant noise sources, and reducing fan noise poses challenges for fan manufacturers and systems engineers. The NASA Glenn Acoustics Branch has considered ways in which expertise and capabilities traditionally used to understand and mitigate aircraft engine noise can be used to address small fan noise issues in Exploration and Information Technology applications. Many could benefit if NASA can capture what is known about small fan aero and acoustic performance in a "Guide for the Design, Selection, and Installation of Fans for Spaceflight Applications." A draft outline for this document will be offered as a useful starting point for brainstorming ideas for the various smaller, near-term research projects that would need to be addressed first.

Glenn Research Center at Lewis Field

Quiet, Efficient Fans for Spaceflight Workshop

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"When I look at the Great Pyramid the marvel there for me is not the stonework as much as the level of organization that these ancient Egyptians had of getting their society to pull together in such a way that they not only had blocks of stone but bread on the table."

Roger Hopkins, stonemason
Nova, "This Old Pyramid"

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Overview

- Timeline
- Lessons Learned
- Fan Applications:
  - Aeronautics, Space, Info Technology
- Benefits/Concerns
- Suggested Long Term Goal
- Suggested Near Term Goals
- Workshop Objectives

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Timeline

2005: "How can NASA Glenn expertise and capabilities used to understand and mitigate aircraft engine noise be used more broadly?"

2006: Began identifying fan noise issues in Exploration and Information Technology communities
Conducted preliminary tests on small fans at Glenn
Results shared at InterNoise 2006
Proposals submitted to Exploration Technology Development Program ranked high on overguide funding list

2007: Exploration Technology Development Program provided funding for project planning--detailing fan technology needs

2008: Activities include: workshop, investigation of spaceflight fan requirements, collection and review of fan technology proposals, preparation of recommendations to Exploration Technology Development Program for FY09 project plans

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Fan Applications: Aeronautics

Aircraft engine fan design goals:

- efficiency
- durability
- low noise
- reduced cost

The technological evolution of aircraft engine fans is driven by the use of 3D computational methods and experimental measurements.

Rolls-Royce Trent 1000 fan for the A380

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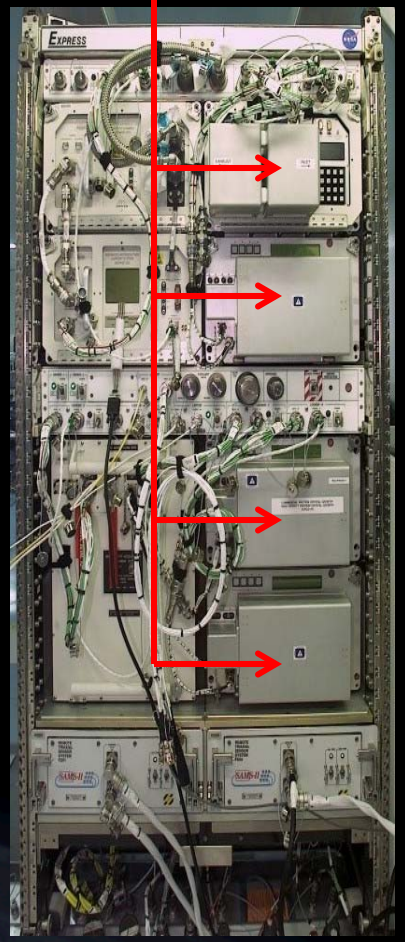
Fan Applications: Space

- A variety of fans are used onboard exploration vehicles: payload cooling, cabin ventilation, suit ventilation
- Historically, not enough attention given to acoustics early in the design cycle of spaceflight fan systems
- Mufflers and enclosures often used for noise control, or waivers issued for systems not meeting noise emissions requirements



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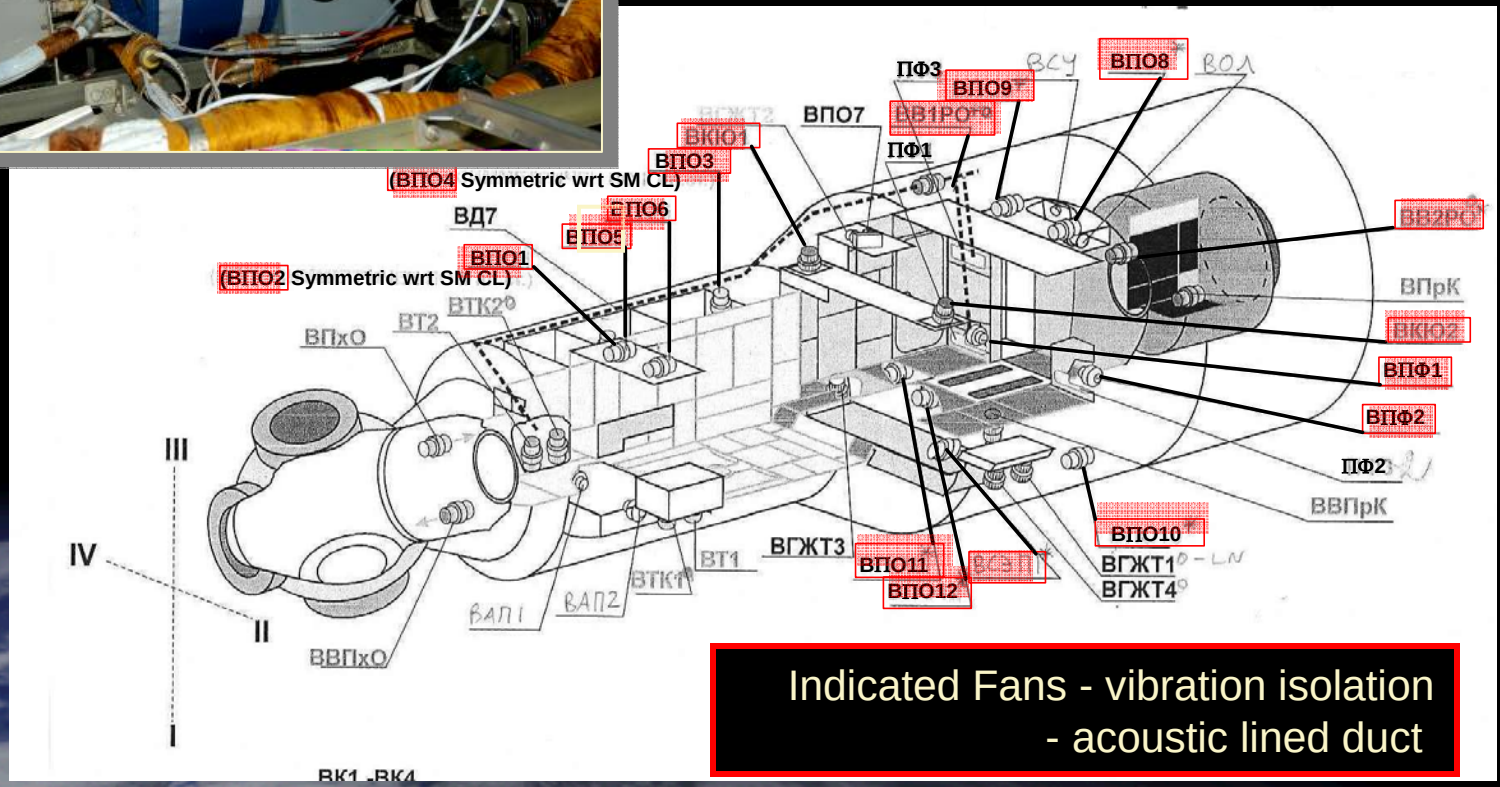
International Space Station
Service Module
Ventilation System



Indicated Fans - vibration isolation
- acoustic lined duct

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Fan Noise Issues in Information Technology (IT) Applications

- The IT industry is working ‘green computing’ initiatives to reduce both power consumption and noise.
- Cooling for high density servers uses fans similar in flow and pressure rise to some in spaceflight applications. Performance and acoustic verification methods don’t exist for this class of fans.
- Improvements in aero, acoustics, and design methods could transfer to IT industry applications.

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"A summary of lessons learned in the ISS are as follows:

- noise requirements for programs need to be well founded
- full-up system limits and limits for hardware types should be specified [sic]
- acoustics needs to be dealt with early in the design process
- acoustics requirements need to be treated seriously as requirements, not goals
- complicated hardware systems like modules and payload racks, need to implement acoustical noise control plans that layout items such as identification and rating of all noise sources, proposed development and verification testing
- an appropriate level of consulting, design support, and oversight needs to be applied
- common testing and verification needs to be applied for all ISS modules
- a small team of experienced personnel, such as the NASA acoustics team, has numerous advantages and benefits to the ISS."

Source: Jerry R. Goodman, "International Space Station Acoustics," Proceedings from NoiseCon 2003, Inc03_125, (2003).

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Exploration Systems Mission Directorate

Benefits

- Utilizes expertise across NASA centers
- Long term goal can be broken down into smaller, shorter term studies which in themselves can yield useful results
- Addresses ISS lessons learned
- Industrial partners are potential funding sources
- Spinoffs possible to Information Technology industry

Concerns

- Funding and staffing

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Aeronautics Research Mission Directorate

Benefits

- Utilizes expertise and capabilities traditionally used for aircraft engine noise reduction
- Makes broader use of Aeronautics technology
- Some involvement in support of space exploration and tech transfer to non-aero industry may allow us to ramp up efforts in these areas more quickly should political climate change
- Proposed research, as managed by the Exploration Technology Development Program, would be more focused on longer term research and less on solving critical path problems
- Research results may help reduce aircraft cabin fan ventilation noise

Concerns

- Utilizes expertise and capabilities traditionally used for aircraft engine noise reduction
- Research in small fan aero and acoustic performance is not directly related to understanding, predicting and mitigating aircraft engine noise
- Funding and staffing

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Industry

Benefits

- Early involvement with NASA has been shown to be a fruitful path to tech transfer
- AeroAcoustics Research Consortium can be used as a model for allowing competitors to participate and fund pre-competitive research.

Concerns

- Funding and staffing
- Emphasis will be on public dissemination of results

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Proposed Project Summary

Long term goal identified:

We could help NASA and industry if we can capture NASA's expertise in fan acoustic and aerodynamic performance in a "Guide for the Design, Selection, and Installation of Quiet Fans for Spaceflight."

Ideally, this document would highlight experimental and computation tools and methods suitable for small fans, aero and acoustic performance verification methods, as well as advanced diagnostics that could be used to develop the next generation of small quiet fans and noise control devices.

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Model: NASA SP-36 Aerodynamic Design of Axial-Flow Compressors, Irving A. Johnsen and Robert O. Bullock, editors, 1965.

- Report contains 17 chapters representing 21 contributing authors.
- Topics include (among others):
  - Design Requirements
  - System Design
  - Blade Design
  - Off-design performance concerns, operability concerns
  - Experimental Techniques
- Report cites 365 other references.
- Based substantially on a confidential report published in 1956 and declassified in 1958.
- Report continues to be cited today.
- Publicly available from NASA Technical Report Server

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Near Term Possibilities:

- Develop an analysis capability
- Develop a design capability
- Develop a verification capability
- Validate a design or analysis code
- Use or develop advanced diagnostics for noise source identification
- Build a specific quiet fan system
- Develop an active/passive noise control scheme for a specific application
- Incorporate low noise design practices into existing design/analysis methods
- Develop a database
- Select low noise fans for a particular installation
- Quantify installation effects
- Provide design guidance for a fan or a system

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Suggested Outline for Quiet, Efficient Fans for Spaceflight Guide

Fan Design Guidance
- Requirements—aero, acoustic, mechanical, electrical, chemical
- Design and analysis methods and tools
- Recommendations

Aero and Acoustic Performance Testing
- Isolated fan
- Fan subsystem

Aero and Acoustic Advanced Diagnostics
- Isolated fan
- Fan subsystem

Selection Guidance
- Quiet fan database

Installation Guidance
- Noise budgeting
- Effects of installation on fan aero and acoustic performance

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Suggested Outline for Quiet, Efficient Fans for Spaceflight Guide

- Case Studies
  - Atmospheric Revitalization System
    - Requirements
    - Design
    - Selection
    - Installation
    - System Verification testing
  - Suits
    - Requirements
    - Design
    - Selection
    - Installation
    - System Verification testing
  - Payload cooling
    - Requirements
    - Design
    - Selection
    - Installation
    - System Verification testing

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Workshop Objectives

- This workshop is focused on technical information exchange.
- Our workshop will include a moderated discussion of a few areas of fan technology needs suggested by a few of our presenters.
- All attendees are encouraged to submit written proposals for research that addresses fan related aero and acoustic performance needs in your area of expertise.
- Instructions and example given on the workshop website: https://prv.grc.nasa.gov/evt/S9e6/instructions.php
- Submissions from your colleagues are also welcomed.
- Proposals are due to Dale Van Zante/ NASA Glenn Acoustics Branch June 30, 2008