Quiet Spacecraft Cabin Ventilation Fan Development: Motivation and Context

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Abstract

It is important to control acoustical noise aboard crewed space vehicles and space habitats to provide a satisfactory environment for voice communications, alarm audibility, and restful sleep, and to minimize the risk for hearing loss and annoyance. As with most noise control efforts, it is best to control the noise at the source, and for spaceflight vehicles these are typically the fans associated with the Environmental Control and Life Support (ECLS) system. These include air ventilation fans, such as the main air conditioning fan (the 'cabin fan'), intermodule ventilation (IMV) fans, air revitalization fans (for removal of carbon dioxide and trace contaminates), and thermal cooling fans. Thermal cooling pumps that circulate cooling fluid are another significant noise source in spaceflight vehicles, but these are outside of the scope of this paper.

Throughout the history of crewed spaceflight, there have been issues with noise from ECLS ventilation fans. In the Apollo Command Module (CM) the crew would turn off the CM cabin fan once in orbit and use the backup suit-loop fan for ventilation because noise from the cabin fan interfered with communications and was an annoyance. On the Space Shuttle the ventilation system underwent significant redesign, including the addition of ventilation system mufflers, with resulting noise levels that were still too-high for long-duration missions. In the early years of International Space Station (ISS) operations, acoustical noise was one of the top two habitability issues, resulting in significant noise controls (along with significant cost and crew-time impacts) being implemented on-orbit on many fans, with significant noise reductions realized only after replacing noisy fans with fans of a quieter design, funded by the ISS Program.

And, with the spaceflight vehicles and habitats currently being developed, there are again concerns with noise levels from ventilation fans. In the Orion vehicle, additional duct mufflers needed to be added to address the cabin fan noise. The Gateway's Habitation and Logistics Outpost (HALO) module and low-Earth orbit (LEO) Freeflyer habitats are currently working to solve this problem. This will also be an issue for lunar and Mars spaceflight vehicles, space suits, and surface habitats.

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In an effort to address this problem, NASA is working to leverage the technology developed in its Aeronautics Research Mission Directorate (ARMD), specifically at the Glenn Research Center (GRC), to design highly efficient and quiet fans for reducing community noise levels from civilian aircraft. This technology was created over decades of research and development, and was proven to be effective at reducing aircraft noise levels. The current collaboration across NASA Centers, including HQ, GRC, and the Johnson Space Center (JSC) in this area is the first effort at re-purposing these tools, i.e. design codes and techniques, developed for high Reynolds number fans to spaceflight vehicle and habitat, low Reynolds number, fans.

This paper will discuss the need for transfer of aeronautics fan design technology to spaceflight use. This paper will also discuss the potential benefits from this, which are significant, including 1) volume and mass savings from noise controls that are no longer as large or needed at all, 2) reduced system pressure loss from mufflers and silencers (that don't need to be as restrictive) for better ventilation, 3) reduced power draw because of the reduced system pressure loss and the highly efficient fan design, and 4) satisfying spaceflight vehicle acoustic requirements to provide a safe and habitable acoustic environment for astronaut crewmembers. All of these benefits will be crucial for the successful development and operations of future spaceflight vehicles, space suits, and habitats.

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