Status of NASA's Bio-inspired Broadband Acoustic Absorber

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Virtual Acoustics Technical Working Group Meeting
April 7, 2020
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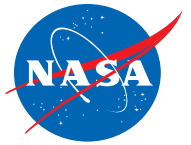
Status of NASA's Bio-inspired Broadband Acoustic Absorber

Outline

- Team, Mission, and Vision
- Context
- Challenge
- Inspiration
- Concept overview
- Opportunities
- Conclusion
- References

Status of NASA's Bio-inspired Broadband Acoustic Absorber



NASA Glenn Team

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Ed Envia, Acoustics Branch

Jeffrey Severino, LERCIP Intern, Acoustics Branch

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Martha Brown, Aeroacoustics Branch

NASA Project Management Team

Funding provided by

NASA's Advanced Air Transport Technology (AATT) Project

Jim Heidmann, Project Manager

Tony Nerone, Novel Propulsion Airframe Integration (NPAI) Subproject Manager

Cliff Brown, NPAI Technical Lead

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Team, Mission, and Vision

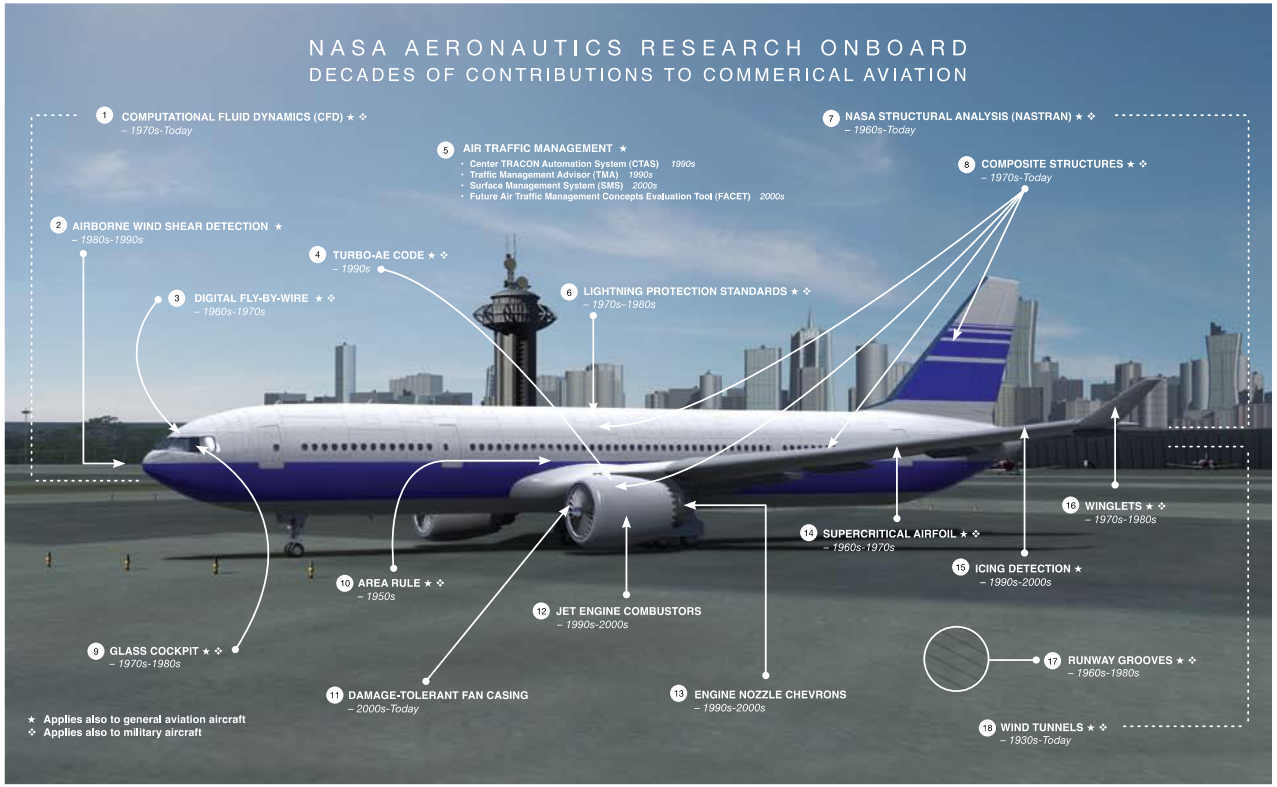
- We are explorers, inventors, and mentors who are trying to increase the peace and quiet in the world by finding ways to reduce airplane engine noise pollution.
- Our mission is to help create safer, cleaner and quieter aircraft and to inform our peers and the public through our research and outreach.
- Our vision is to help create a more peaceful world by bringing out the best in each other through curiosity, creativity, competition, collaboration, communication, and compassion.

At AIAA SciTech 2020, MIT's Danielle Wood reminded us to ask: How might we work towards reaching the United Nation's Sustainable Development Goals? (Reference 1)

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Team, Mission, and Vision

- Acoustic absorbers are used onboard an aircraft in many places within the engine, fuselage, ventilation systems.
- Today, we are maturing a recently-patented bio-inspired broadband acoustic absorber and providing opportunities for many industries to commercialize it.
- Technology and expertise developed for aviation noise reduction can have spinoff use in space exploration missions and for a variety of industrial and consumer uses here on Earth.

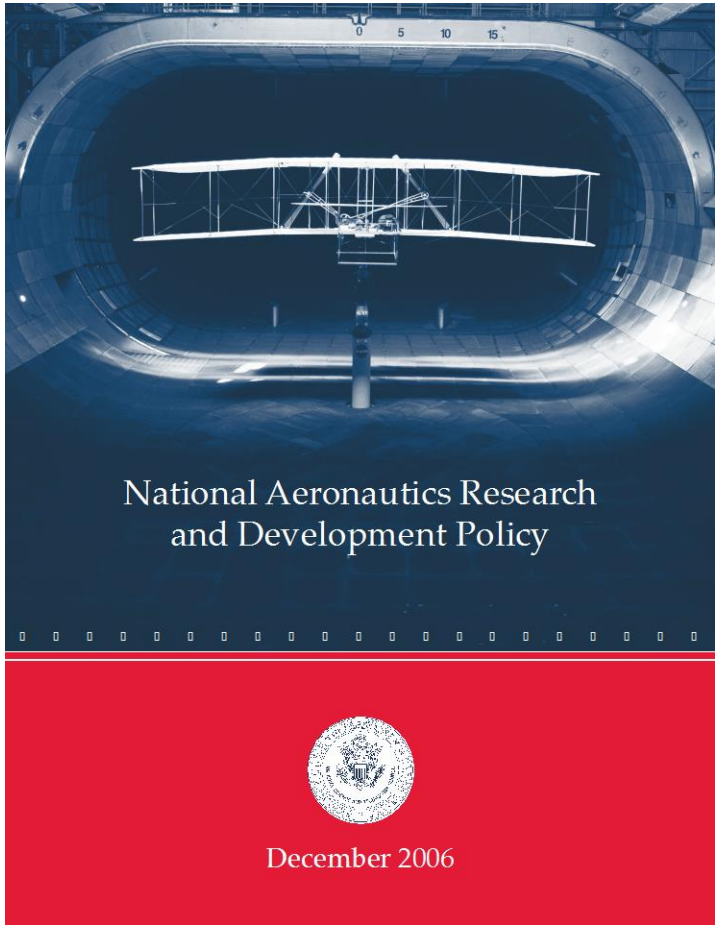


Reference 2

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Context

- We are just one of NASA's many aeronautics research teams.
- If you want to find out more about the the unique role NASA plays within the global aeronautics research community, you can turn to the first National Aeronautics Research and Development Policy.

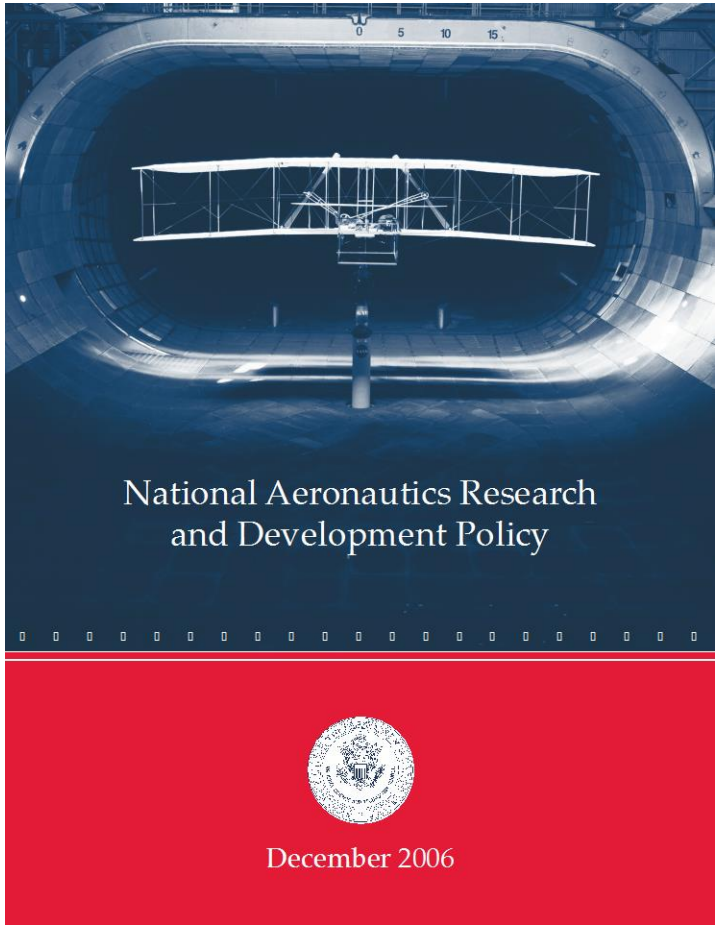


Reference 3

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Context

- NASA performs experiments and analyzes components and systems. We use concept aircraft to guide our imaginations collectively. Our most promising concepts coalesce into flight tests of experimental aircraft. Some of this technology is commercialized.
- Through all this work, NASA also helps to develop the workforce and theory and tools that are needed to produce and operate safer and cleaner and quieter aircraft.
- Noise pollution has been experienced from the beginning of powered flight.



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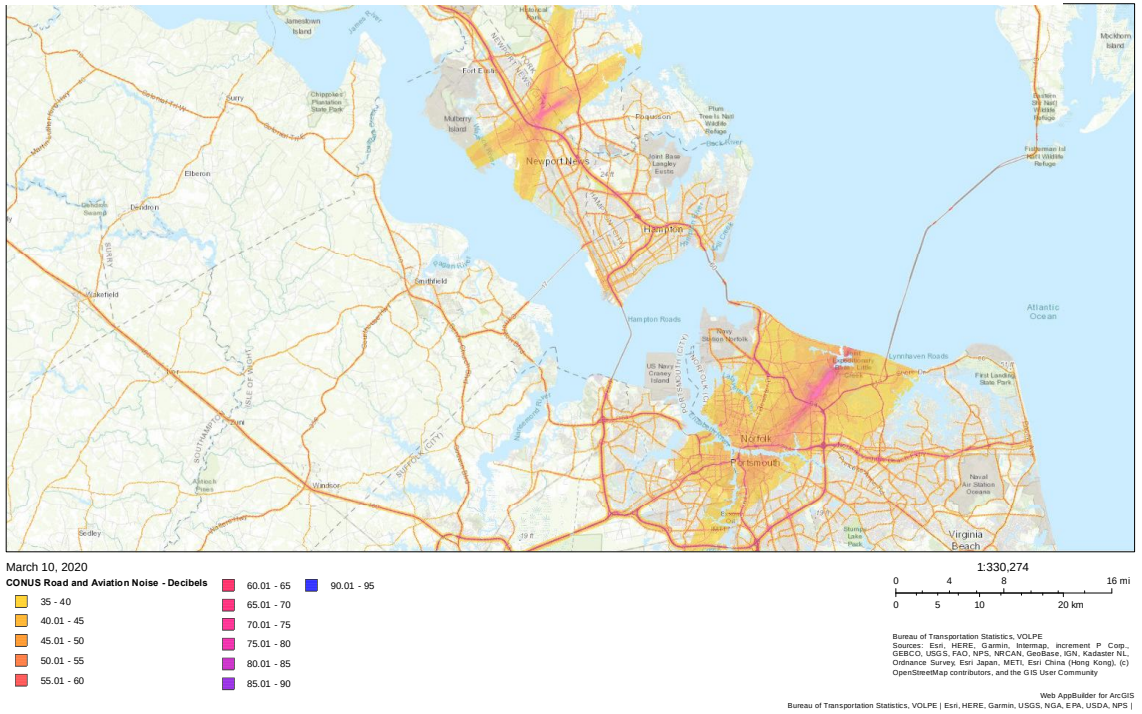
Context

- Noise pollution from aircraft remains with us today.
- Airplanes are a dominant source of noise pollution in the world.
- Since the 1960's, the number of vehicles on land, sea, and air in the United States has roughly tripled.
- Aircraft noise is concentrated near our airports and is audible for nearly everyone living in the US—in addition to the crew and passengers of each aircraft.
- You can explore the soundscape in your neighborhood using the online National Transportation Noise Map.

US Department of Transportation
National Transportation Noise Map:
Road and Aviation Noise Near Hampton, VA



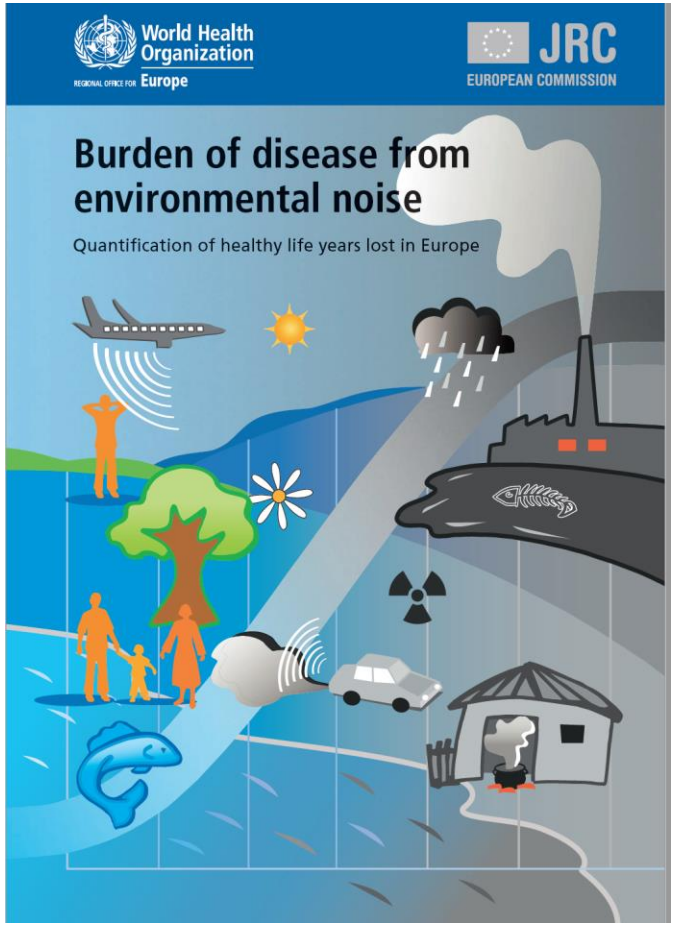
References 4, 9

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Context

- Noise isn't a just a nuisance. Noise is associated with many serious public health problems worldwide including hearing loss, cardiovascular disease, and cognitive and learning impairment.

- The World Health Organization is one group trying to quantify the way that aviation noise pollution impacts human health and provide guidance for policymakers.



Reference 5

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Context

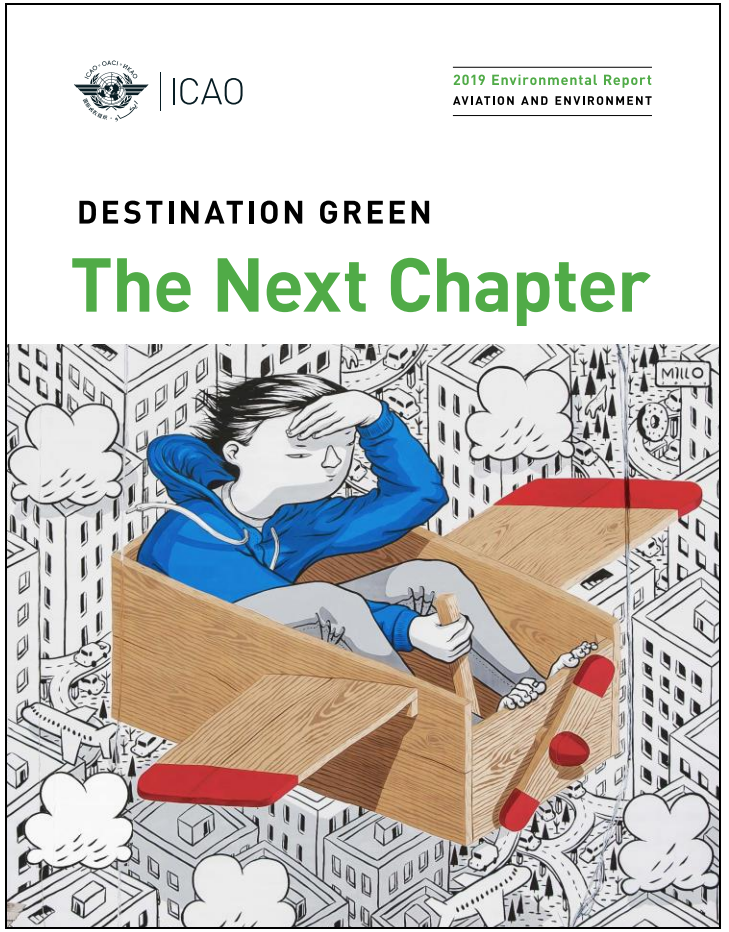
- NASA also helps the aviation community to learn by receiving, processing, and analyzing voluntarily submitted incidence reports with the Aviation Safety Reporting System. A variety of noise related issues is included in this database.
- "Confidential reporting systems have the means to answer the question why—why a system failed, why a human erred."
- We neither succeed or fail alone. We cannot see our own blind spots, and we rely on diversity of thought and inclusion to create a culture of safety, openness, and continuous improvement.

Reference 6

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Context

- In response, we've created the conditions for international cooperation and competition using regulations to drive us to produce and operate safer, cleaner, and quieter aircraft.
- The International Civil Aviation Organization (ICAO), a specialized agency of the United Nations, works with members from around the world to establish consensus-based standards and recommended practices and policies.
- Noise and other environmental impacts of aircraft are the focus of the Committee on Aviation Environmental Protection (CAEP) within the ICAO .
- NASA participates in an advisory role in the ICAO.
- More about this aspect of our work can be found in the ICAO Environmental Report on Aviation and the Environment. (**Ref. 7**)



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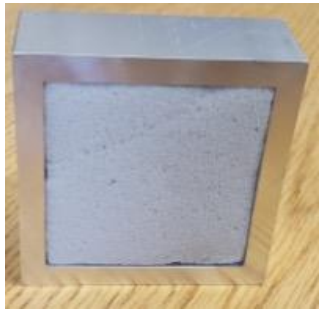
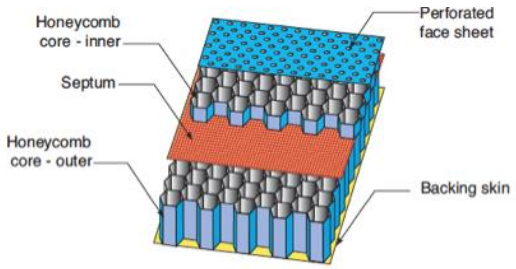
Challenge

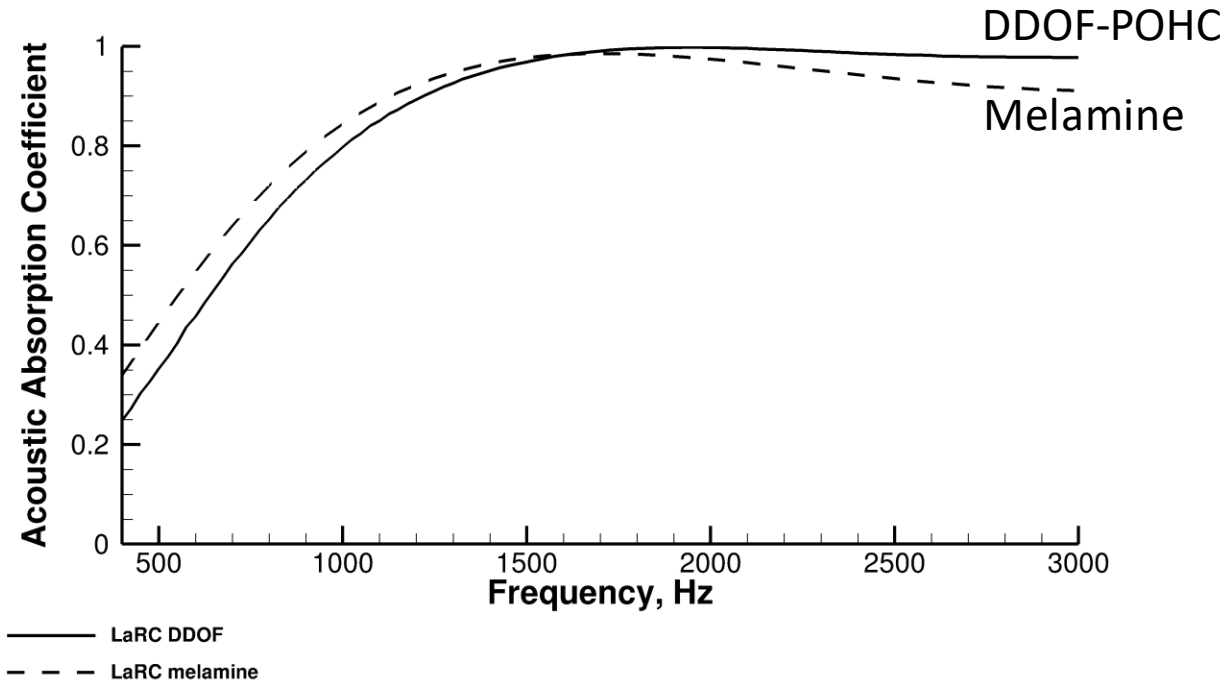
In general, it has been difficult to absorb sounds below 1000 Hz with commercially available structures that are thin and lightweight, especially in applications when the absorber is exposed to harsh environmental conditions, such as high temperatures, high-speed airflow, and sprays of liquid and solid debris.



Melamine



Double Degree of Freedom Perforate Over Honeycomb



Reference 8, 9

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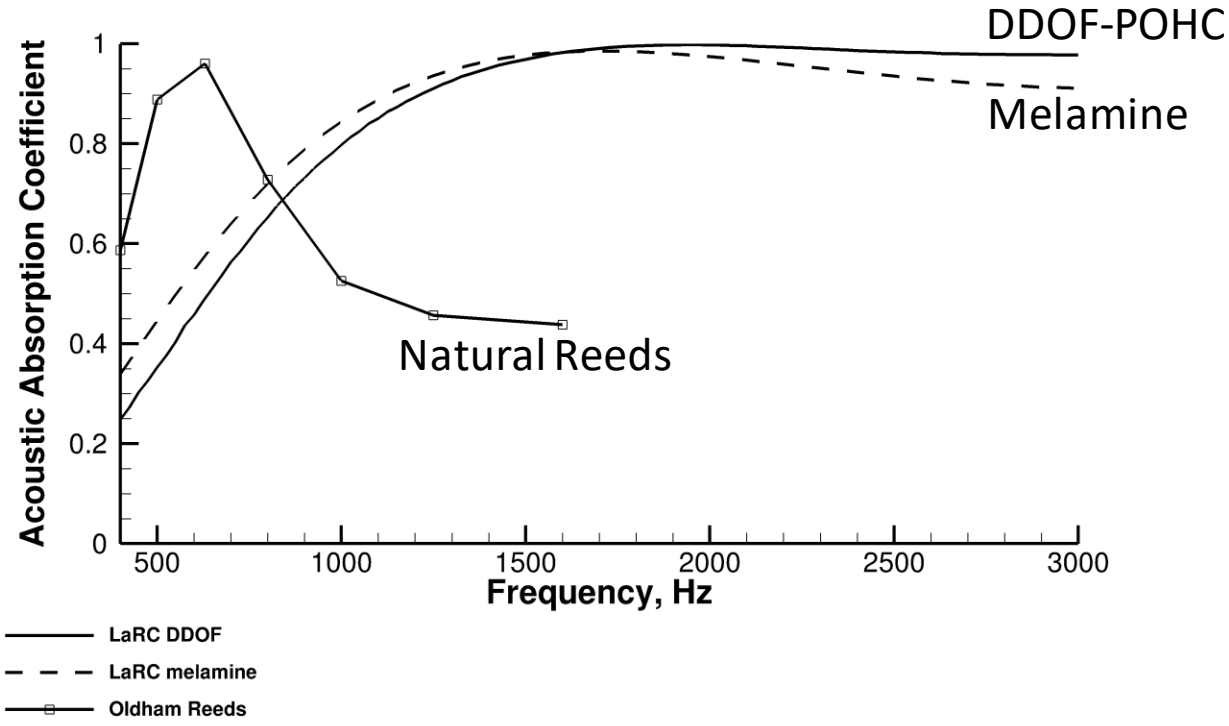
Inspiration

We were first inspired by published experiments of the acoustic absorption of natural reeds.



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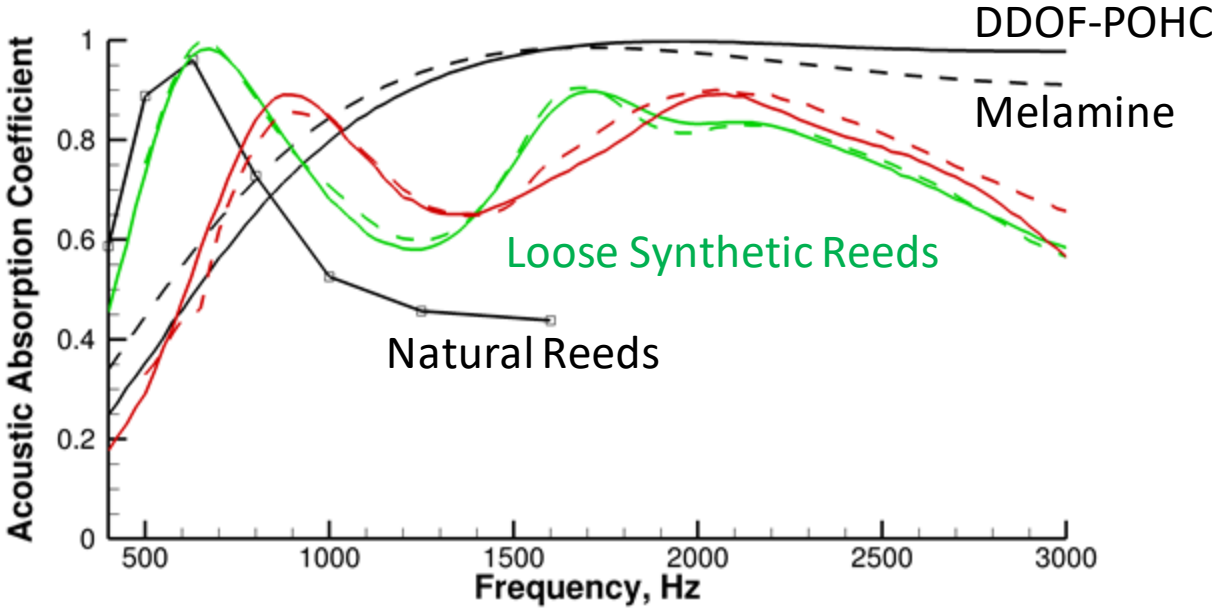
Concept Overview

- We reproduced the acoustic test of natural reeds.
- Then we designed, 3D printed, and tested plastic prototypes that resembled natural reeds.
- Good absorption between 400 and 3,000 Hz, and particularly good absorption below 1,000 Hz, was observed for these 2" thick samples.



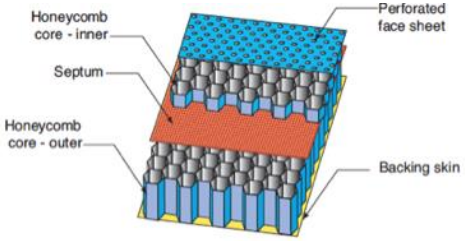
Natural Reeds

Loose Synthetic

Fixed Synthetic

Melamine

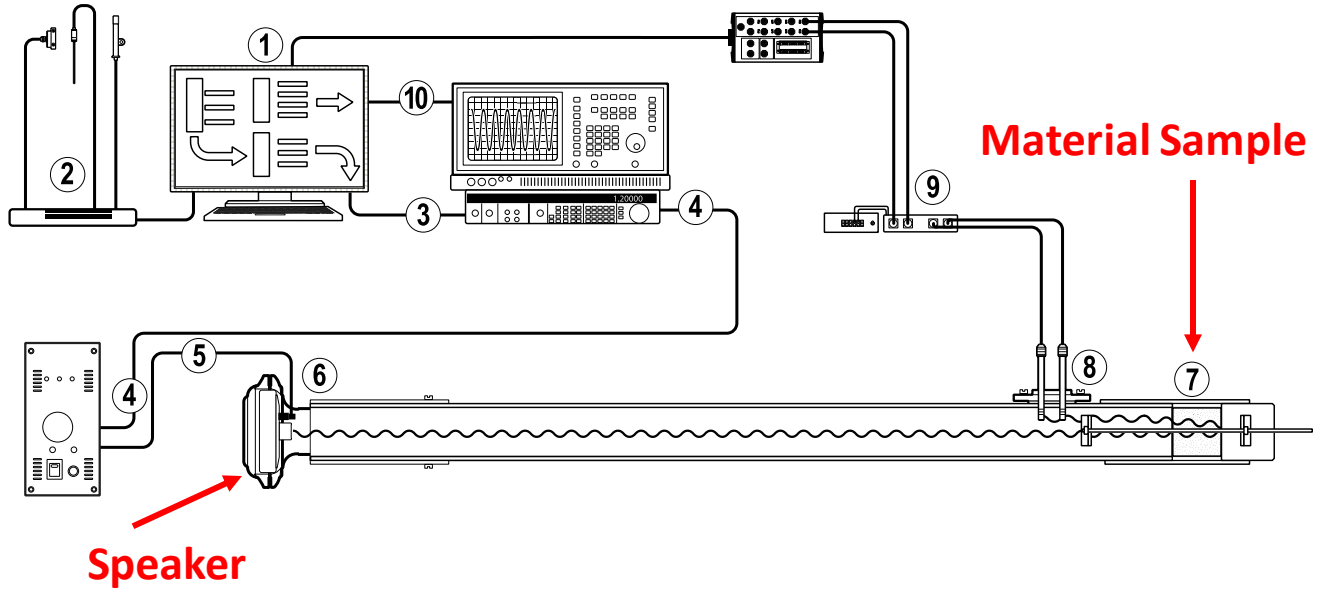
DDOF-POHC



Status of NASA's Bio-inspired Broadband Acoustic Absorber

Concept Overview

- The first acoustic tests of the bio-inspired acoustic absorbers were performed in the NASA GRC and LaRC normal incidence impedance tubes.
- Sample thicknesses varied from 1" to 6", all with a 2" x 2" square cross-section.



NASA GRC Normal Incidence Impedance Tube
2" x 2" Square Cross-section
400-3000 Hz Testing Range

Natural Reeds

Loose Synthetic

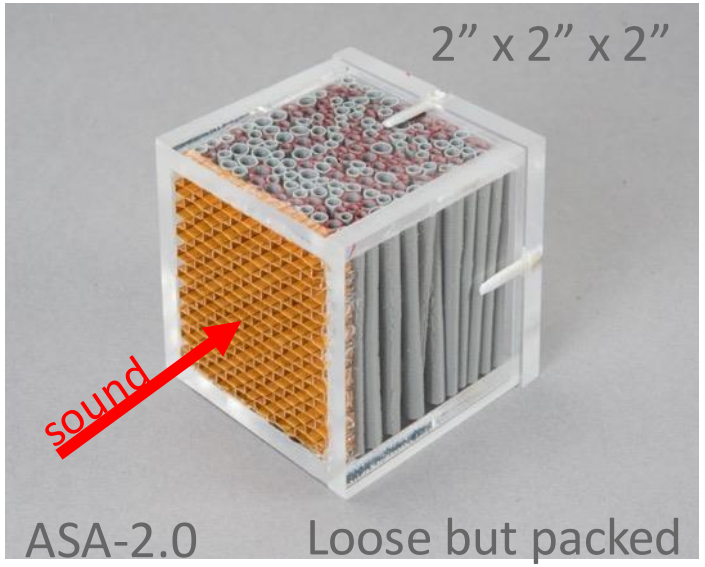
Fixed Synthetic

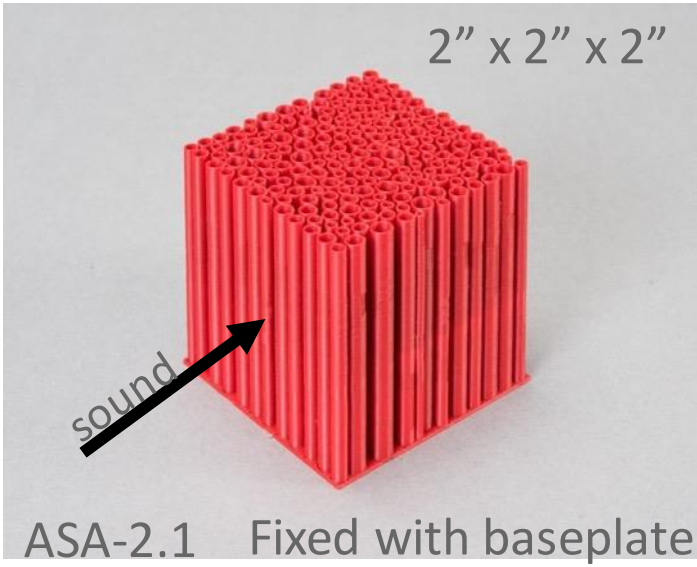
Status of NASA's Bio-inspired Broadband Acoustic Absorber

Concept Overview

- An acrylic sample holder with an acoustically transparent honeycomb retainer held the loose synthetic reeds together within the impedance tube.
- Sound waves can travel in between the spaces between the reeds.
- Research is underway to identify physics-based models of acoustic performance:

$$\propto = f(l, w, d, \ldots.)$$

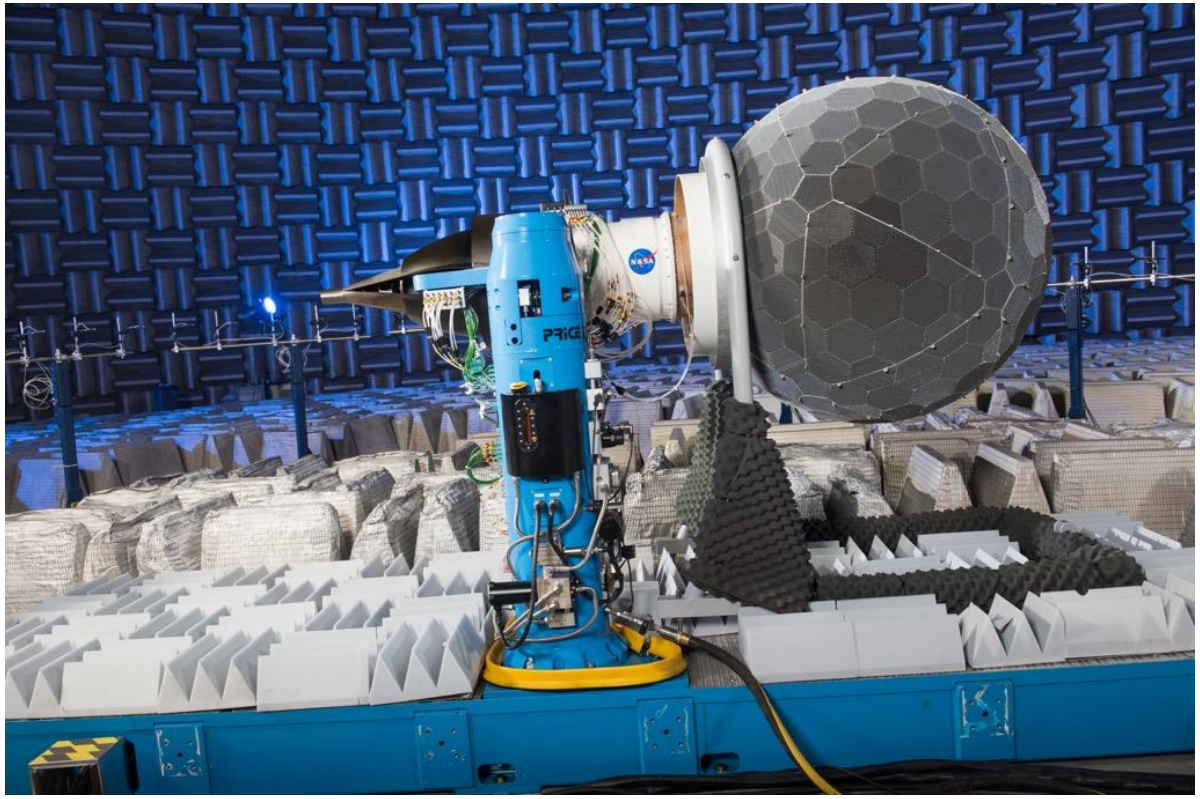




Status of NASA's Bio-inspired Broadband Acoustic Absorber

Concept Overview

- More recently, we have been able to additively manufacture annular prototypes of the bio-inspired acoustic absorber that fit within the DGEN 380 engine inlet.
- It was important to prove that we can design and fabricate the prototypes needed for a wide range of experimental and theoretical work.



NASA GRC DGEN 380 Turbofan Engine in the Aeroacoustic Propulsion Laboratory

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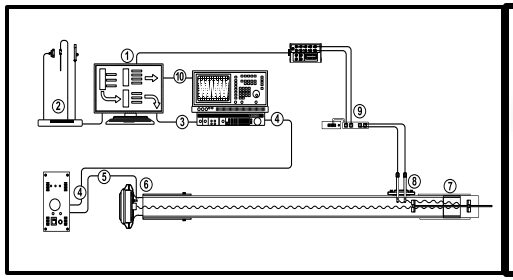
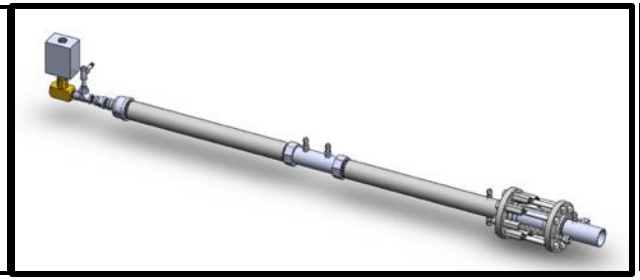
Concept Overview

There are several acoustic tests that can be performed to mature this technology for use on aircraft, ranging from bench tests to flight tests.

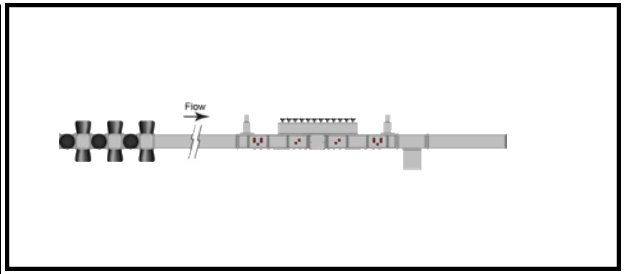
Impedance Tube



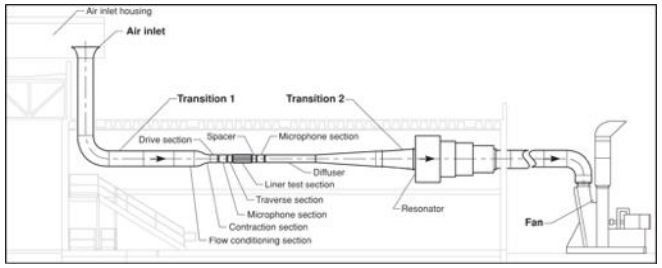
Flow Resitivity Rig

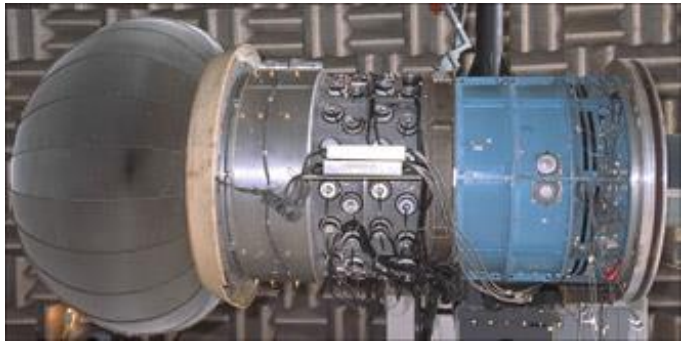


Grazing Flow Incidence Tube



Curved Duct Rig





Advanced Noise Control Fan

DGEN 380

Fan in 9'x15' LSWT

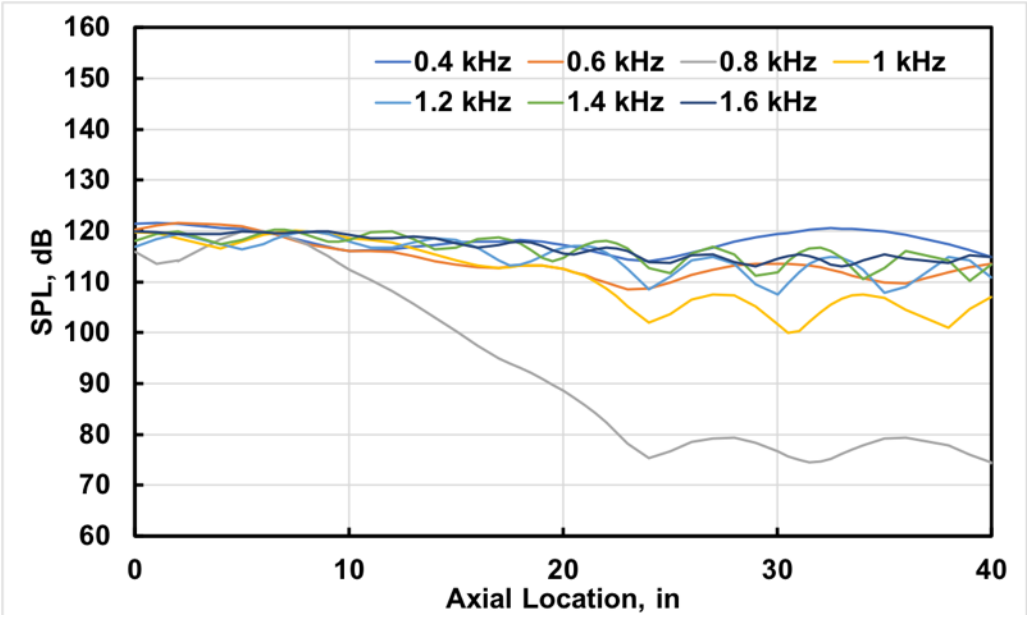
Engine Ground Test

Flight Test—Ref 10

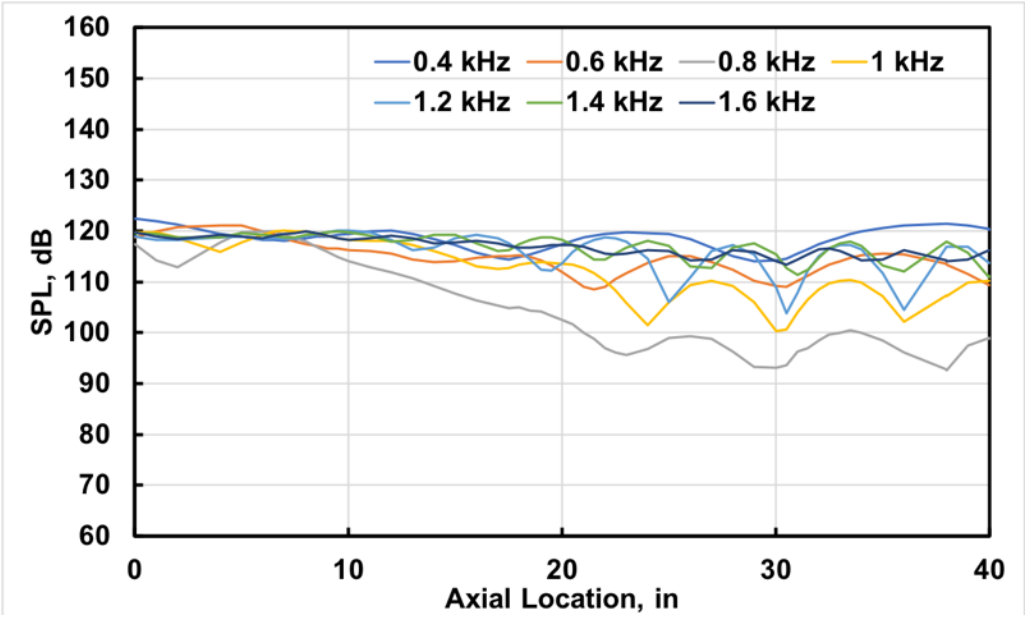
Status of NASA's Bio-inspired Broadband Acoustic Absorber

Concept Overview

Tests were conducted of rectangular samples in the LaRC Grazing Flow Incidence Tube, with and without flow.



Bioliner fabricated from Ultem, 2" thick, Mach = 0

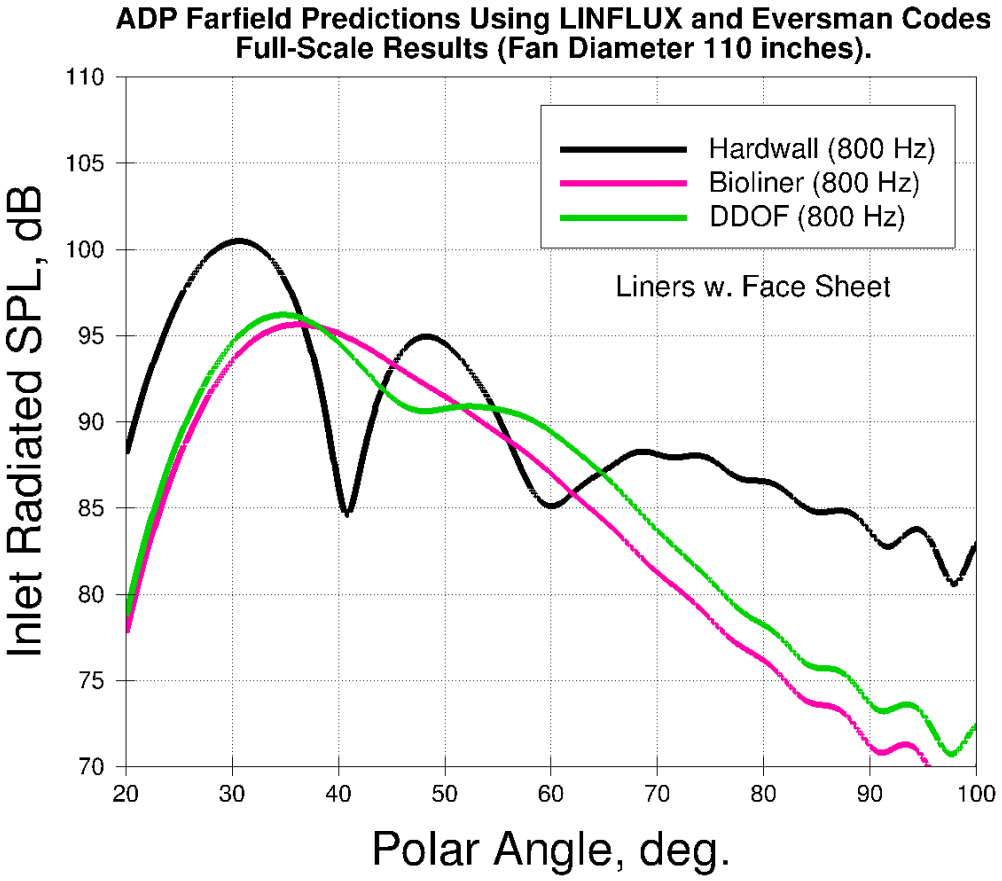


Bioliner fabricated from Ultem, 2" thick, Mach = 0.3

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Concept Overview

- We made a first attempt at predicting the farfield inlet radiated noise for a turbofan model.
- Preliminary results indicate that there is merit to continuing research—that "bioliner" offers noise reduction benefits comparable to state-of-the-art liners at relevant frequencies and inlet angles.
- This is a steppingstone towards other system level estimates needed to determine if this type of liner could offer noise reduction benefits in today's aircraft engines.



Status of NASA's Bio-inspired Broadband Acoustic Absorber

Opportunities

- For aircraft, we are looking especially for multifunctional structures and strong, lightweight high-performance materials.
- A variety of new manufacturing processes can be used to construct prototypes, including the bio-inspired broadband acoustic absorber.
- One idea that I took away from the Additive Manufacturing Short Course at the AIAA SciTech Conference 2020 was that we can create new structures and materials simultaneously with a growing number of additive manufacturing processes. **(Ref. 11)**

Wish list for new structures and materials:

- ✓ absorb unwanted sound
- ❑ to carry a load
- ❑ to insulate
- ❑ to absorb vibrations
- ❑ to generate lift
- ❑ other _____
- ❑ some of the above
- ❑ all of the above

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Opportunities

- We are documenting the results of our prototyping and testing.
- We realize that physics-based models compared to experimental data of the acoustic performance are needed especially for frequencies below 1000 Hz.
- We are grateful for those of you who have learned about our work, performed experiments and published results--like the ones Paul Slaboch and his students at the University of Hartford presented at the last few InterNoise conferences.
- **(References 12,13)**

Broadband acoustic absorbers are generally needed for:

- ❑ current or future aircraft engines
- ❑ aircraft fuselages
- ❑ aerospace ventilation systems
- ❑ automotive applications
- ❑ architectural applications
- ❑ other _____
- ❑ some of the above
- ❑ all of the above

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Opportunities

This technology recently received a patent:

US Patent 10,460,714

Date: October 29, 2019

Title: Broadband Acoustic Absorbers

Inventors: Koch, Jones, Bonacuse, Miller, Johnston, Kuczmarski

Assignee: NASA


US010460714B1

(12) **United States Patent**
Koch et al.

(10) **Patent No.: US 10,460,714 B1**
(45) **Date of Patent: Oct. 29, 2019**

(54) **BROADBAND ACOUSTIC ABSORBERS**

(71) Applicant: **United States of Americas as represented by the Administrator of NASA**, Washington, DC (US)

(72) Inventors: **Lisa Danielle Koch**, Brunswick, OH (US); **Michael G. Jones**, Newport News, VA (US); **Peter J. Bonacuse**, Lakewood, OH (US); **Christopher J. Miller**, Rocky River, OH (US); **J. Chris Johnston**, Cleveland, OH (US); **Maria A. Kuczmarski**, Independence, OH (US)

(73) Assignee: **United States of America as Represented by the Administrator of National Aeronautics and Space Administration**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 286 days.

(21) Appl. No.: **15/425,313**

(22) Filed: **Feb. 6, 2017**

Related U.S. Application Data

(60) Provisional application No. 62/291,755, filed on Feb. 5, 2016, provisional application No. 62/291,765, filed on Feb. 5, 2016.

(51) **Int. Cl.**

G10K 11/172	(2006.01)
G10K 11/02	(2006.01)
G10K 11/04	(2006.01)
G10K 11/168	(2006.01)
G10K 11/16	(2006.01)

(52) **U.S. Cl.**
CPC ***G10K 11/168*** (2013.01)

(58) **Field of Classification Search**
CPC G10K 11/168; G10K 11/172; G10K 11/02; G10K 11/025; G10K 11/04; G10K 11/16; G10K 11/002
See application file for complete search history.

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Primary Examiner — Edgardo San Martin
(74) *Attorney, Agent, or Firm* — Robert H. Earp, III; William M. Johnson

(57) **ABSTRACT**

Broadband acoustic absorbers may be capable providing good absorption performance between 0 and 3,000 Hz, and particularly below 1,000 Hz. Reeds may be incorporated in a single layer, multiple layers, or bundles. Such broadband acoustic absorbers may be applied for acoustic absorption in aircraft, spacecraft, residential and commercial buildings, vehicles, industrial environments, wind tunnels, or any other suitable environment or application where noise reduction is desired.

18 Claims, 38 Drawing Sheets

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Opportunities

- This presents an opportunity to incubate new businesses or new product lines for existing businesses.
- At the very least, licenses document commercialization attempts, and royalties document a commercialization successes.
- You can visit our page on the NASA GRC Technology Transfer Program website:

A Method for Reducing Broadband Noise
https://technology.grc.nasa.gov/patent/LEW-TOPS-109

Status of NASA's Bio-inspired Broadband Acoustic Absorber

Opportunities

Access to intellectual property—our most detailed reports--and federal resources through various programs and partnerships can help bring concepts into service.

Entrepreneurs can submit proposals to the federal government's Small Business Innovation Research Program and the Small Business Technology Transfer Program: **https://www.sbir.gov**

NASA is just one federal organization that provides funding for SBIR/STTR projects. Some SBIR/STTR success stories feature technology licensed from one organization and SBIR/STTR funding from another. Please check solicitations for "acoustics" and "bio-inspired" topic keywords.

Status of NASA's Bio-inspired Broadband Acoustic Absorber

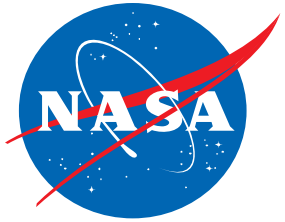
Conclusion

- Bio-inspired Broadband Acoustic Absorber is a promising, recently-patented invention that we can use to increase the peace and quiet in the world through efforts to bring it from concept to service.

- A growing number of experiments have demonstrated that synthetic structures that resemble bundles of natural reeds offer an increase in sound absorption at frequencies below 1000 Hz compared to state-of-the-art commercially available structures of similar thickness, volume, and weight.

Thank you.

We welcome your feedback and questions.



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