Reestablishing Open Rotor as an Option for Significant Fuel Burn Improvements

A low-noise open rotor system is being tested in collaboration with General Electric and CFM International, a 50/50 joint company between Snecma and GE. Candidate technologies for lower noise will be investigated as well as installation effects such as pylon integration.

Current test status is presented as well as future scheduled testing which includes the FAA/CLEEN test entry. Pre-test predictions show that Open Rotors have the potential for revolutionary fuel burn savings.
Reestablishing Open Rotor as an Option for Significant Fuel Burn Improvements

Dale Van Zante
Open Rotor Technical Lead
Environmentally Responsible Aviation
Integrated Systems Research Program

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www.nasa.gov
Outline

• Why Open Rotor?
• The Open Rotor test program
  • The NASA/GE Collaboration
  • ERA Diagnostics Program
• CFMI projection of modern open rotor performance
• The path forward
• Summary

Testing is supported by the Environmentally Responsible Aviation Project
Data analysis efforts are supported by the Subsonic Fixed Wing Project
Facility support is from the Aeronautics Test Program
Why Open Rotor? Technology Development

- **Base Noise, EPNdB Cum to Stage 4**
  - ERA Airframe Shielding
  - ERA Airframe & Propulsion Techs
  - ERA Advanced Vehicle Studies

- **Current**
  - UHB Gen 1
    - BPR ~ 9-12
    - (TRL 6 ~ 2013 EIS)
  - UHB Gen 2 + NASA NR Techs
    - BPR ~ 15-18
    - (TRL 6 ~ 2020)

- **Open Rotor**
  - BPR > 30
    - (2020)

- **Future Goals**
  - N+2 Goal
  - N+3 Goal

- **Noise Reduction**
  - Silent Aircraft Initiative
  - and SFW N+3 Advanced Vehicle Studies

- **Technology Milestones**
  - 2015
  - 2020
  - 2025
The NASA/GE Collaboration on Open Rotor Testing

• **Objective:** Explore the design space for lower noise while maintaining the high propulsive efficiency from a counter-rotating open rotor system.

• **Approach:** A low-noise open rotor system is being tested in collaboration with General Electric and CFM International, a 50/50 joint company between Snecma and GE. Candidate technologies for lower noise will be investigated as well as installation effects such as pylon integration.

Historical Baseline Blade Set
12 x 10 blade count
Non-proprietary geometry/data
Export controlled
At take-off open rotors have high rotor lift coefficients and strong tip vortices. Front rotor tip vortex interacting with aft rotor blade is a dominant noise source. State of the art CFD is being used to modify the open rotor tip vortex at take-off conditions to reduce the noise generation.

- Modern analytical tools shedding light on open rotor source noise
- Advanced designs showing good promise in aero-acoustic wind tunnel tests
# Test Program Overview

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A detailed aerodynamic performance data set was acquired for all blade sets as well as acoustic measurements at 18 axial locations.

Primary NASA researcher: John Gazzaniga
The ERA Diagnostics Program

The goal is a comprehensive data set that will identify noise sources and enable improved performance and acoustic modeling of open rotor systems.
ERA Diagnostics: Detailed Historical Baseline flowfield measurements

The 3D PIV measurements provide a wealth of information about the blade wakes and vortex track. NASA Researcher: Mark Wernet

The Pressure Sensitive Paint measurements show phase locked static pressure on the surface of the rotating blade. NASA Researcher: Tim Bencic
ERA Diagnostics: Historical Baseline Installation effects (1)

The location of peak noise level in the **phased array** map changes in the presence of the CFMI pylon indicating a change in the relative strength of sources.

NASA Researcher: Gary Podboy
The presence of the CFMI pylon induces distortions into blade rows causing noticeable increase in the levels of the individual rotor harmonics.

NASA Researcher: David Elliott
Strategies in addition to propulsion system noise reduction are needed to meet the N+2 goals. An example is acoustic shielding by tail or wing surfaces.

Within the ERA Diagnostics testing canonical shielding configurations were measured to provide basic acoustic data for model validation.

NASA Researchers: David Stephens and Dave Elliott
NASA Analysis: Ed Envia
ERA Diagnostics: Historical Baseline Acoustic Shielding (2)

Test Matrix

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Short barrier, Forward position

Finite acoustic barrier wall.

Semi-infinite acoustic barrier wall.

~34°  ~67°
The ‘shadow’ of the barrier wall is visible as a 5 dB reduction region in this view from 0.5 kHz to 50 kHz, however the behavior of tones is more complicated.

**Detail from 0.5 kHz to 10 kHz**

A complex pattern of tone constructive and destructive interference is apparent.
Objectives: Aerodynamic performance and near field unsteady pressure measurements at cruise Mach number.

Installation of ORPR into the 8x6 began in December.
Open Rotor based propulsion systems provides revolutionary fuel burn advantages.
The Path Forward

Gen-1 Blade designs

9x15 Low Speed test
ERA Diagnostics test
8x6 High Speed test

NASA System Studies

NASA system studies will help guide future research investment.

FAA CLEEN/NASA/GE Gen-2 blade testing to follow.
• GE Gen-1 Blade designs have demonstrated noise reduction relative to 1980s designs.
• Confirmation of predicted cruise efficiency is pending with the 8x6 test.
• FAA CLEEN/NASA/GE Gen-2 blade testing to follow.
• The ERA Diagnostics testing added design method validation data.
Federal Aviation Administration: CLEEN program


