NASA/GE Collaboration on Open Rotors - High Speed Testing

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 for the 8x6 SWT high speed testing is presented as well as future scheduled testing which includes the FAA/CLEEN test entry. The tunnel blockage and propeller thrust calibration configurations are shown.

National Aeronautics and Space Administration

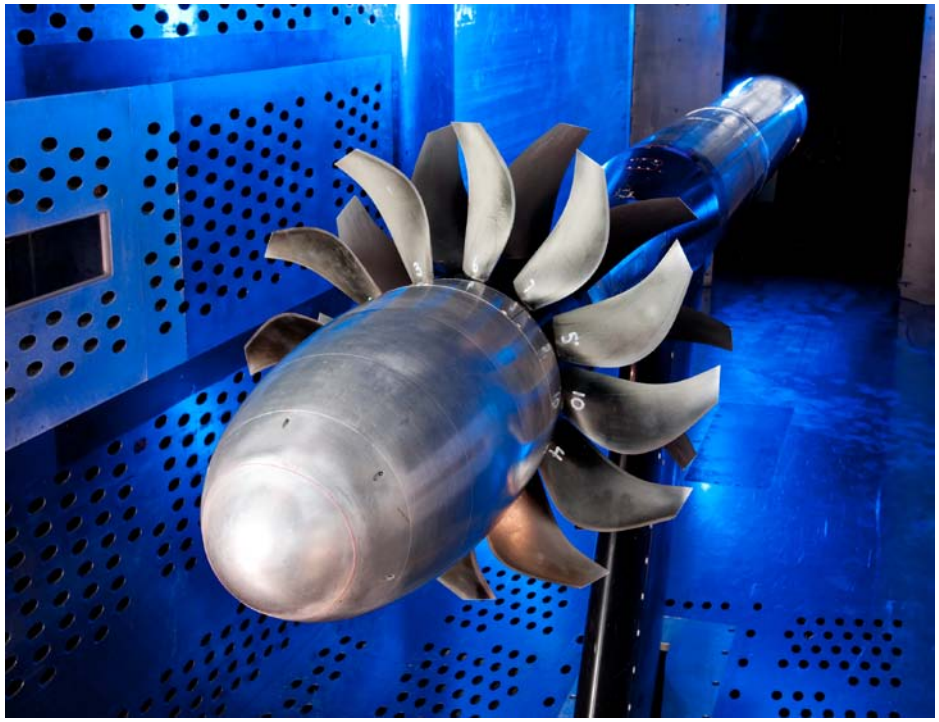
NASA/GE Collaboration on Open Rotors - High Speed testing

Dale Van Zante
Project Engineer for Propulsion
Environmentally Responsible Aviation
Integrated Systems Research Program

Acoustics Technical Working Group
April 21-22, 2011

Outline

- ERA Goals/Program Structure
- The Open Rotor test program
- High-speed testing
  - Blockage calibration
  - Thrust calibration
  - Acoustic plate
- Test status
- Summary



8x6 installation with Historical Baseline blade set
NASA C-2011-611

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

NASA's Subsonic Transport System Level Metrics

Sumarizing the potential technology payoff …

…. Innovative technology for dramatically reducing noise, emissions and fuel burn

CORNERS OF THE TRADE SPACE	N+1 = 2015*** Technology Benefits Relative To a Single Aisle Reference Configuration	N+2 = 2020*** Technology Benefits Relative To a Large Twin Aisle Reference Configuration	N+3 = 2025*** Technology Benefits
Noise (cum below Stage 4)	-32 dB	-42 dB	-71 dB
LTO NO_x Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%	-50%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

***Technology Readiness Level for key technologies = 4-6. ERA will undertake a time phased approach, TRL 6 by 2015 for "long-pole" technologies
** RECENTLY UPDATED. Additional gains may be possible through operational improvements
* Concepts that enable optimal use of runways at multiple airports within the metropolitan area

ERA Project Leadership Team

Environmentally Responsible Aviation (ERA) Project

1.0 Project Management
- Project Manager (PM): Fayette S. Collier
- Deputy PM: Gaudy Bezos-O'Connor
- Chief Technologist: Anthony Washburn
- Chief Engineer: Mark Mangelsdorf

Business Team
- Deputy PM Business: Timothy Warner
- Lead Resource Analyst:
- ARC Resource Analyst: Delphina Turner
- DFRC Resource Analyst: Sarah Samples
- GRC Resource Analyst: Lisa Ferenc
- Risk Manager: Jon Kilgore
- Schedule Analyst: Daniel Healey
- Configuration & Data Mgmt: Pamela Banks
- NRA Manager: Sherri Yokum
- AVC NRA Task Manager: Joseph Piotrowski

2.0 Airframe Technology
- Sub-Project Manager: Pamela Davis
- Sub-Project Engineer: Heather Maliska

2.1 Lightweight Structures
- Element Lead: Dawn Jegley

2.2 Flight Dynamics and Control
- Element Lead: Timothy Risch

2.3 Drag Reduction
- Element Lead: Rudy King

2.4 Noise Reduction
- Element Lead: Medhi Khorrami

3.0 Propulsion Technology
- Sub-Project Manager: Ken Suder
- Sub-Project Engineer: Dale Van Zante

3.1 Combustor Technology
- Element Lead: Chi-Ming Lee

3.2 Propulsor Technology
- Element Lead: Brian Fite

3.3 Core Technology
- Element Lead: James Heidmann

4.0 Vehicle Systems Integration
- Sub-Project Manager: Hamilton Fernandez
- Sub-Project Engineer: Russel Thomas

4.1 Systems Analysis
- Element Lead: Craig Nickol

4.2 Propulsion Airframe Integration
- Element Lead: Steve Smith

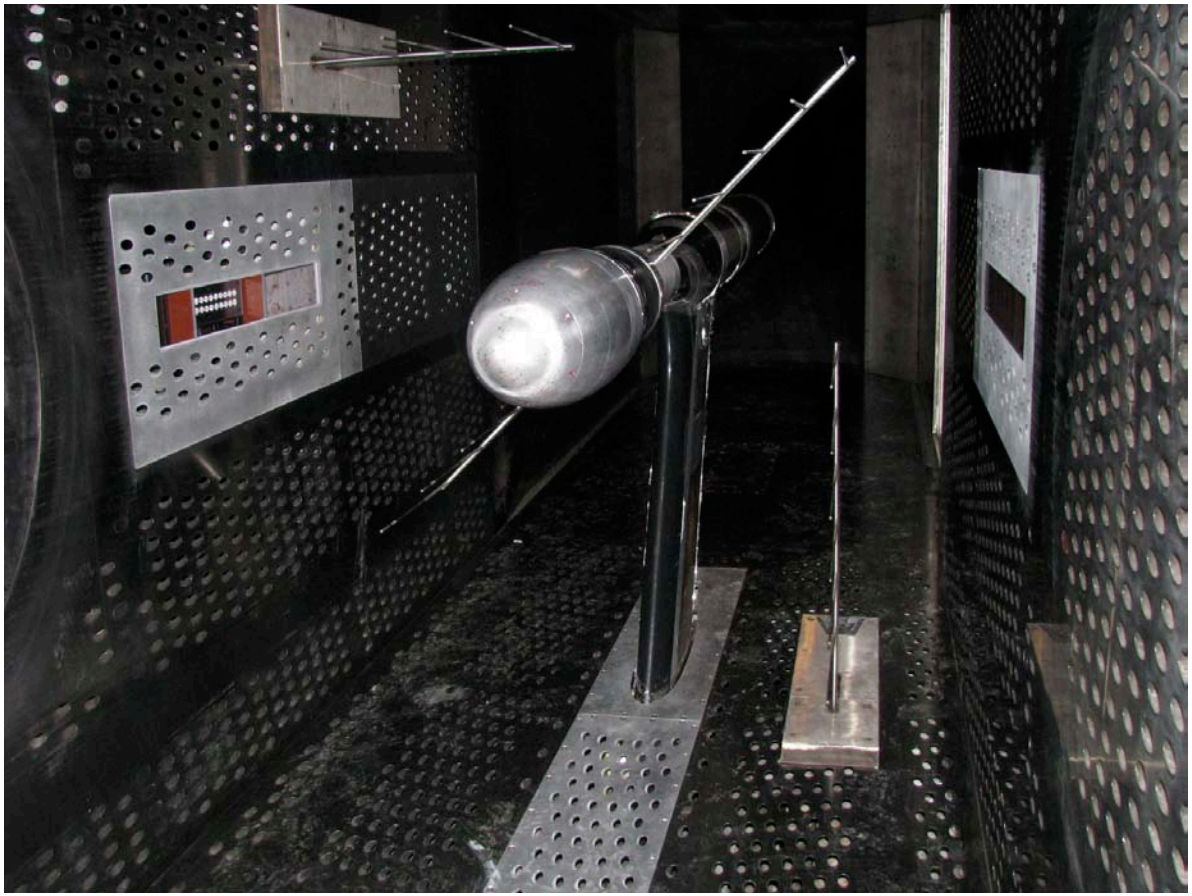
4.3 Propulsion Airframe Aeroacoustics
- Element Lead: Russ Thomas

4.4 Advanced Vehicle Concepts
- Element Lead: Craig Nickol

Test Program Overview

NASA/GE 9x15 Low Speed Wind Tunnel		**NASA/GE 8x6 High Speed Wind Tunnel**	**NASA/GE/FAA(CLEEN) 8x6/9x15**
GE Gen-1 Blade Designs			GE Gen-2 Blade Designs
Takeoff and Approach Conditions	ERA Diagnostics	Cruise Conditions	TO/Approach and Cruise Conditions
•Aerodynamic performance •**Acoustics** •Hot Film flowfield measurements	•Acoustic phased array •Farfield Acoustics with Pylon •Pressure Sensitive Paint •Stereo Particle Image Velocimetry •Acoustic Shielding	•**Aerodynamic performance** •Near field unsteady pressure	• Aero and acoustic performance of optimized blade designs at low and high speed.

8x6 Tunnel Blockage Calibration



Blockage configuration with wall, floor and rig mounted pitot-static rakes. The corrections are described in AIAA-88-2055 Porous Wind Tunnel Corrections for Counterrotation Propeller Testing.

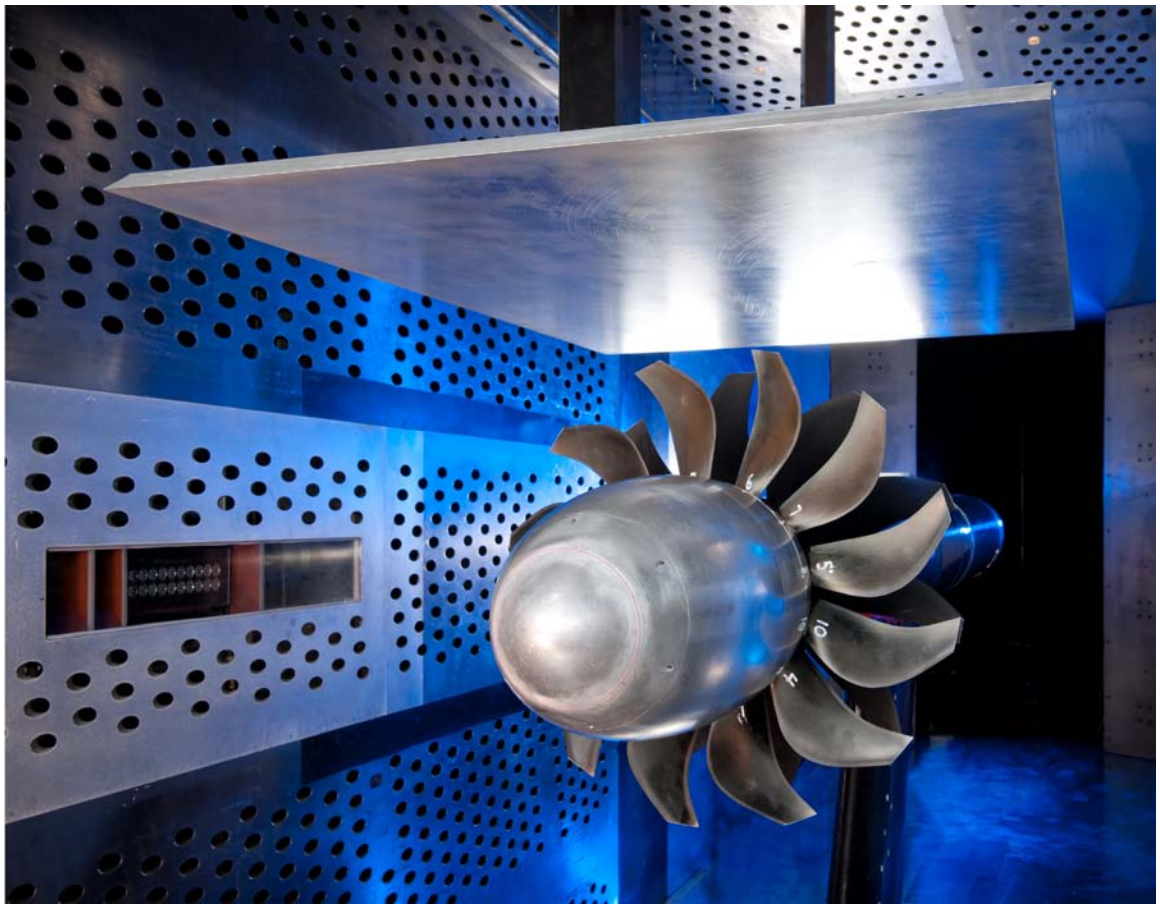
8x6 Tunnel Thrust Calibration

A static tube is used to determine Mach number through test section with propeller thrust.

- 3 rows of 30 statics
- Floor or ceiling mount

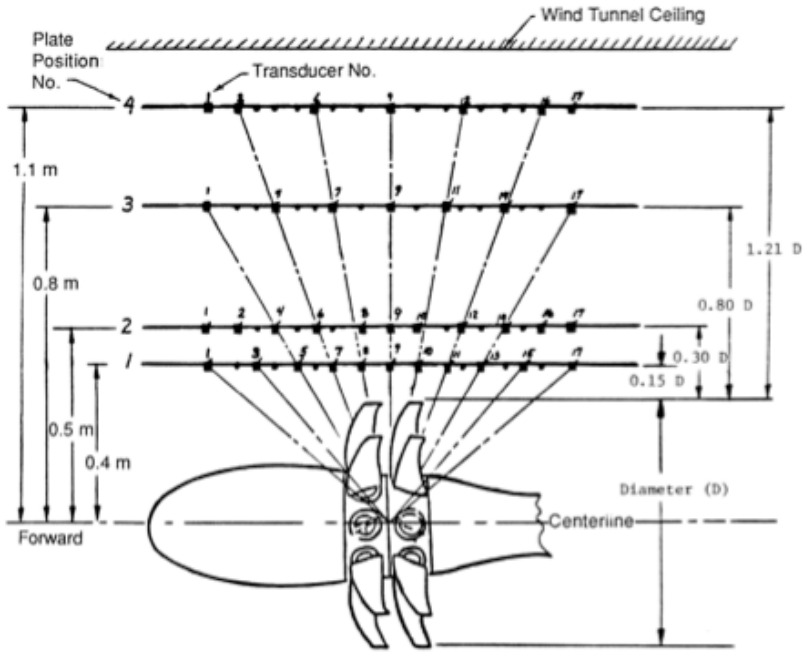
ORPR with Historical Baseline Blade Set
NASA C-2011-625

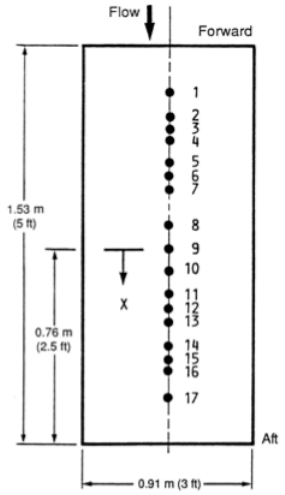
Acoustic Plate Installation



ORPR with Historical Baseline
Blade Set
NASA C-2011-620

NASA/GE Collaboration
8x6 High Speed Wind Tunnel test





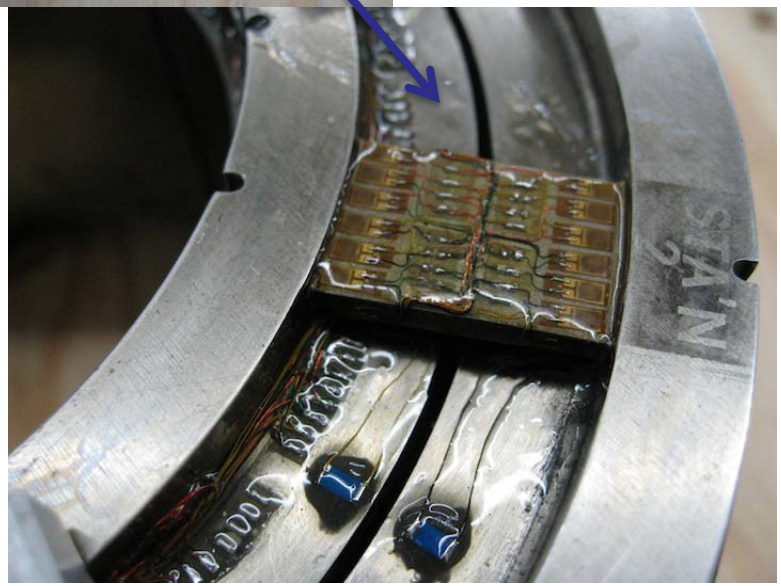
Transducer	Position X	
	cm	in.
1	-46.7	-18.4
2	-38.9	-15.3
3	-34.0	-13.4
4	-29.5	-11.6
5	-23.4	-9.2
6	-18.8	-7.4
7	-14.7	-5.8
8	-7.1	-2.8
9	0	0
10	7.1	2.8
11	14.7	5.8
12	18.8	7.4
13	23.4	9.2
14	29.5	11.6
15	34.0	13.4
16	38.9	15.3
17	46.7	18.4

Objectives: Aerodynamic performance and near field unsteady pressure measurements at cruise Mach number.
P(t) is processed to produce the cross-spectral matrix.
Code by Cliff Brown, Don Braun, David Stephens.

There are 17 Kulite XCL-093 in an axial line down the center of the plate.
(Note: the Kulite numbering is reversed for the current installation. No. 17 is at the forward end of the plate.)

NASA NAS3-24080, Task V Final Report

Test Status



A instrumentation problem with the forward rotor force balance occurred on April 6.
Testing is on hold until the issue can be resolved.

Summary

- The 8x6 tunnel calibration activities were described.
- The cruise efficiency testing is on hold following the forward rotor force balance instrumentation problem.
- Options for the 8x6 test and the FAA CLEEN/NASA/GE Gen-2 blade entry are pending.

8x6 installation with Historical Baseline blade set C-2011-610

Partners

Publications

Elliott, David M., “Initial Investigation of the Acoustics of a Counter Rotating Open Rotor Model With Historical Baseline Blades in a Low Speed Wind Tunnel,” to be presented at AIAA Aeroacoustics Conference, Portland, Oregon, June 2011.

Stephens, David and Envia, Edmane, “Acoustic Shielding for a Model Scale Counter-rotation Open Rotor,” to be presented at AIAA Aeroacoustics Conference, Portland, Oregon, June 2011.

Berton, Jeffery J., “Empennage Noise Shielding Benefits for an Open Rotor Transport,” to be presented at AIAA Aeroacoustics Conference, Portland, Oregon, June 2011.

Hendricks, Eric, “DEVELOPMENT OF AN OPEN ROTOR CYCLE MODEL IN NPSS USING A MULTI-DESIGN POINT APPROACH,” GT2011-46694, to be presented at Turbo Expo 2011, Vancouver, BC, June 2011.

Van Zante, Dale, Gazzaniga, John, Elliott, David, and Woodward, Richard, “An Open Rotor Test Case: F31/A31 Historical Baseline Blade Set,” to be presented at ISABE 2011, Gothenburg, Sweden. September 2011.