PROGRESS IN OPEN ROTOR RESEARCH: A U.S. PERSPECTIVE

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Motivation

Low FPR systems for reduced fuel burn at acceptable noise levels.
Overviews

Advanced Turboprop Project

NASA SP-495, 1988

NASA SP-2009-574, 2010
Advanced Turboprop Program (ATP)
Extensive Wind Tunnel Test program

**NASA Contra-Rotating Rig in 9x15 L SWT**

**GE Contra-Rotating Rig in Cell 41 (from X-Noise 2011)**
Flight Demo occurred in parallel with WT test program

The UDF™ engine used an early blade design, F7/A7. It had a distinctive look and sound.
Advanced Concepts
Advanced Concepts: Forward Swept Rotor
The engine development program ended when oil prices dropped.
Legacy of UDF™ work

GE90 Composite Fan Blade  
(geaviation.com)

Low FPR Ducted concepts  
(NASA TM-101361)

Research focus returned to ducted systems.
Lufthansa expressed the desire for lower fuel burn engine technologies.

Similar sentiments are in:
Epilogue: From Shock to Trance “How quickly we forget our history...” Bowles, SP-2009-574
Next Generation Open Rotors

Contemporary design systems enable the simultaneous optimization for both aerodynamics and acoustics.

FAA Continuous Lower Emission, Energy and Noise (CLEEN) Program
NASA Environmentally Responsible Aviation (ERA)
NASA Fixed Wing (FW)
NASA Aeronautics Test Program (ATP)
Aerodynamic results

![Graph showing Full Scale Max Climb Net Efficiency for different categories: Historical Aero, GE36 Product (1989), Gen1A+B (+5% Clip, MC/L), and Gen2A+B. The goal for 26% fuel burn benefit relative to CFM56-7B is indicated by a dashed line at 0.87. The categories are listed below the graph.]

F31/A31
Acoustic results

F31/A31
An assessment of the technology at TRL 4

Advanced UHB Turbofan (BPR ~14)
Fuel burn: 27% lower than ref. vehicle
Noise: 24dB cum margin to Ch4

Gen-2 Open Rotor
Fuel burn: 36% lower than ref. vehicle
Noise: 16.8 dB cum margin to Ch. 4

Revised Gen-1 Open Rotor
Fuel burn: 35% lower than ref. vehicle
Noise: 13.6 dB cum margin to Ch. 4

Initial Gen-1 Open Rotor
Fuel burn: 36% lower than ref. vehicle
Noise: 12.6 dB cum margin to Ch. 4

% Fuel Burn Benefit Relative to 1998 Technology Reference Vehicle

AIAA 2013-3628
What remains to do?

Propulsion Airframe Integration
AoA into rotors
Transonic performance

Technologies for additional noise margin

Technologies to address certification issues
(EASA-ToR-MDM.092, 2011)

Need an airframe designed for use with an Open Rotor.
Summary

- The current generation of Open Rotors is more efficient and significantly quieter than the legacy propfans.
- Challenges to implementation still exist: noise, propulsion-airframe integration, certification.

“The problem is developing a long-term energy plan that does not fluctuate with the changing price of oil and the changing demands of the market.” -- from the Epilogue of SP-2009-574