



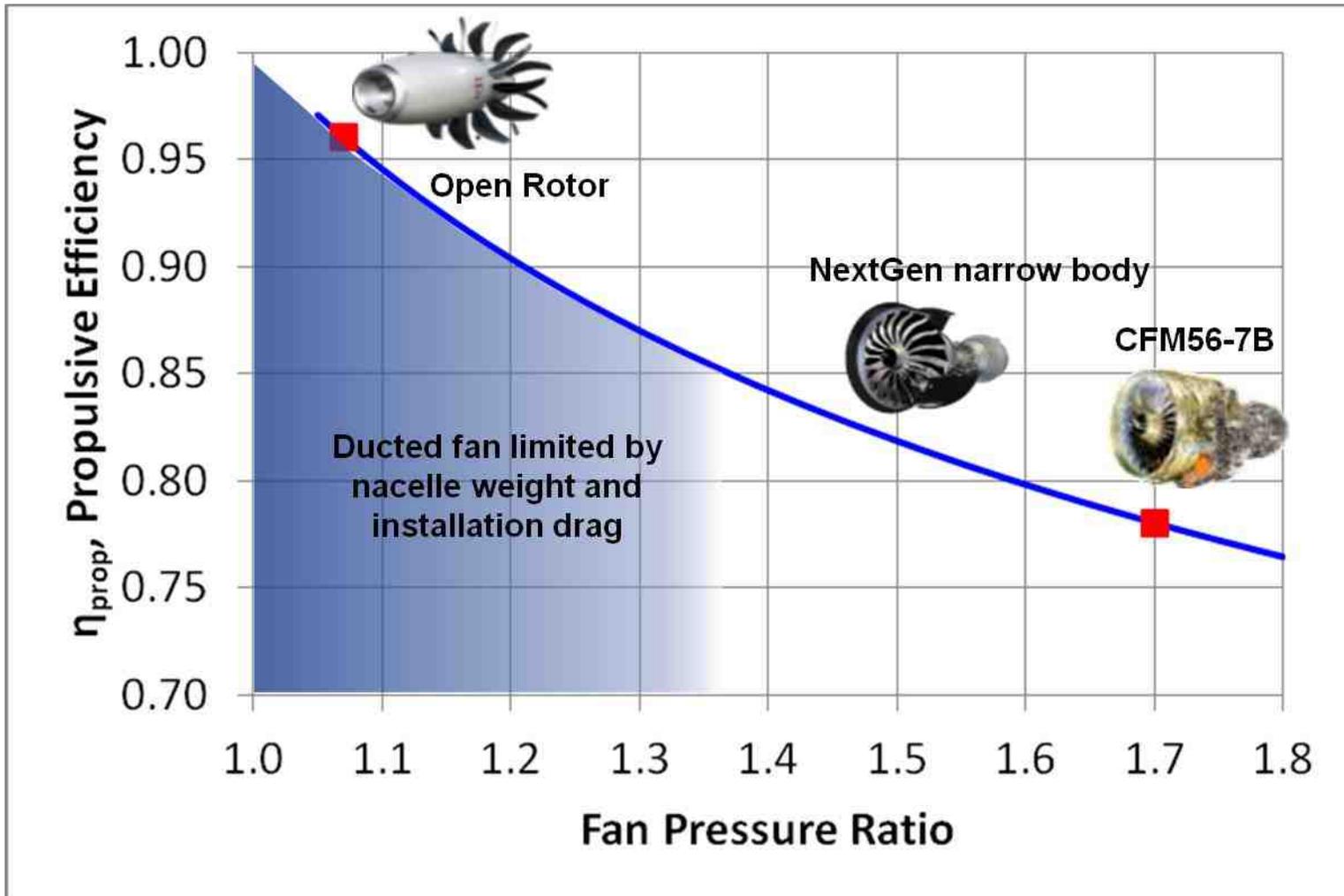
# PROGRESS IN OPEN ROTOR RESEARCH: A U.S. PERSPECTIVE

GT2015-42203

Dale E. Van Zante  
NASA Glenn Research Center

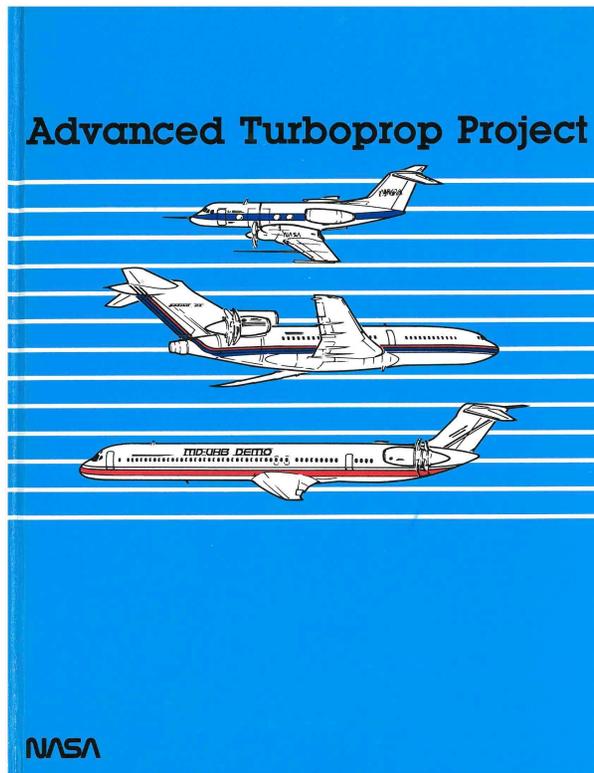


# Motivation

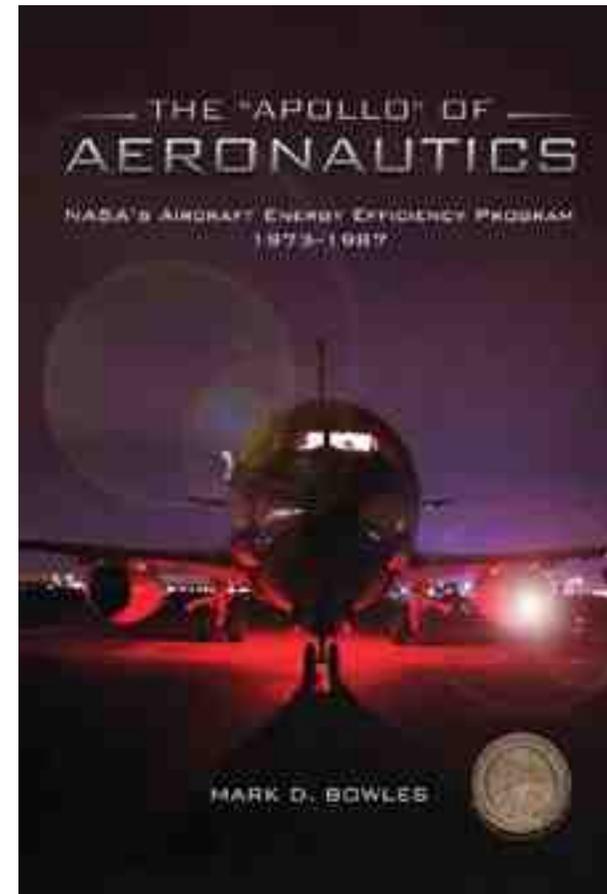


**Low FPR systems for reduced fuel burn at acceptable noise levels.**

# Overviews



**NASA SP-495, 1988**

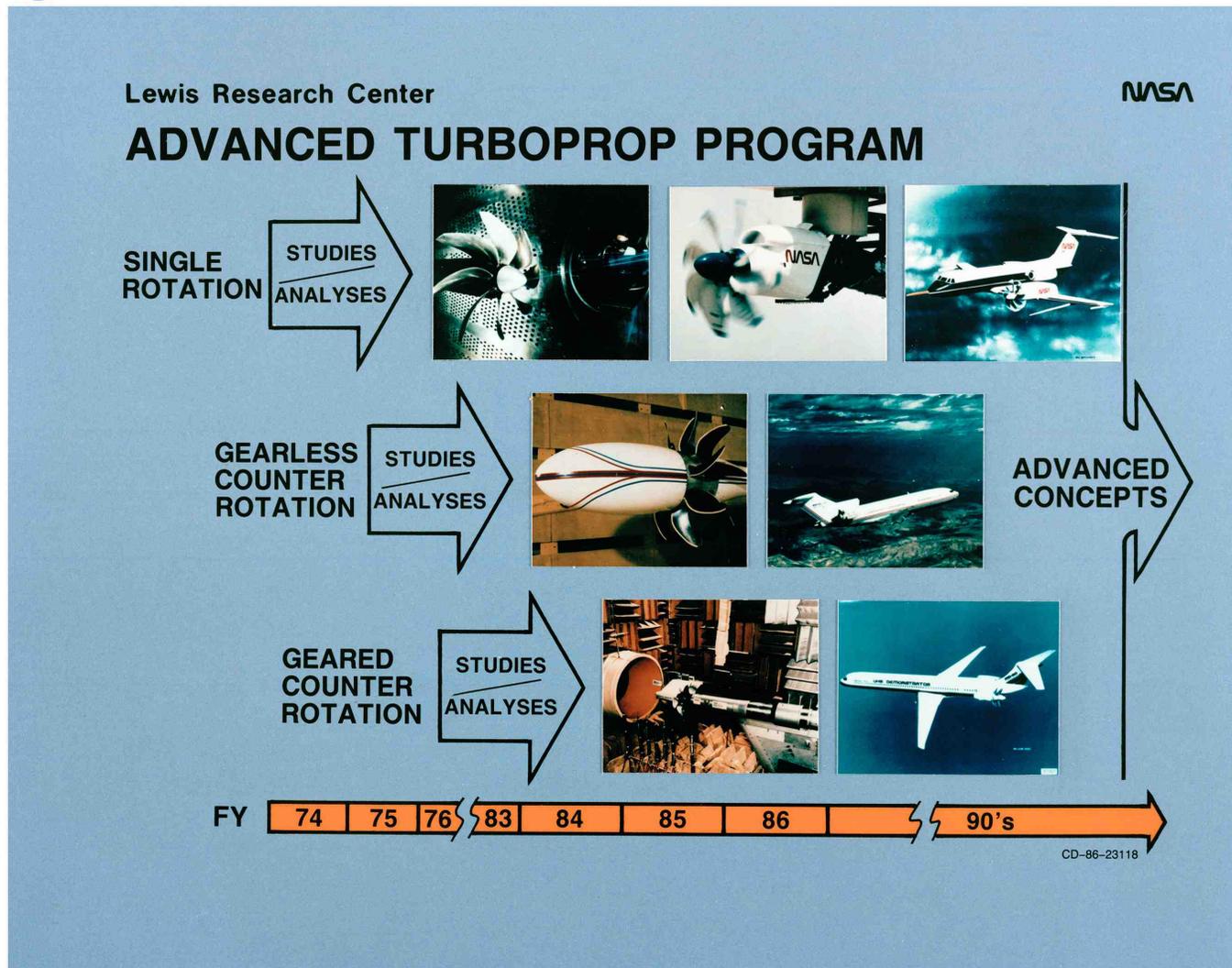


**NASA SP-2009-574 , 2010**

# Advanced Turboprop Program (ATP)



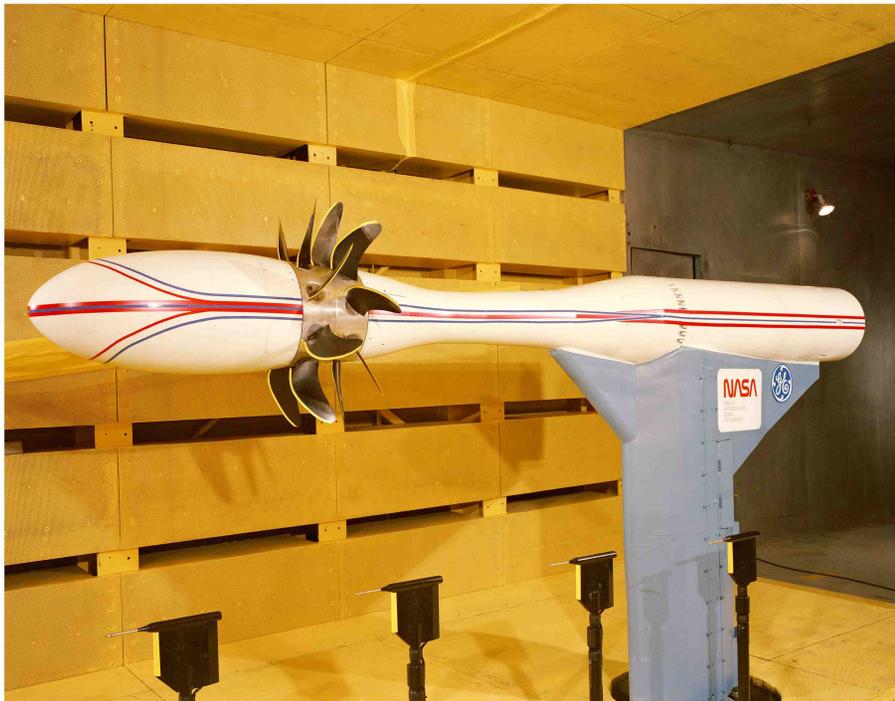
NASA C-1986-9461



# Extensive Wind Tunnel Test program

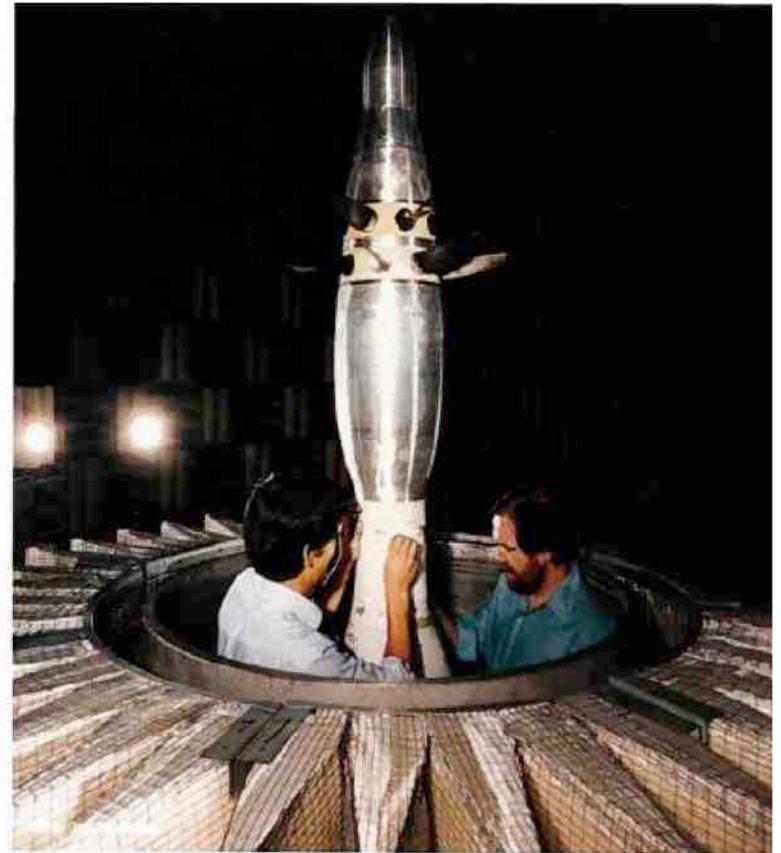


NASA C-1986-7568



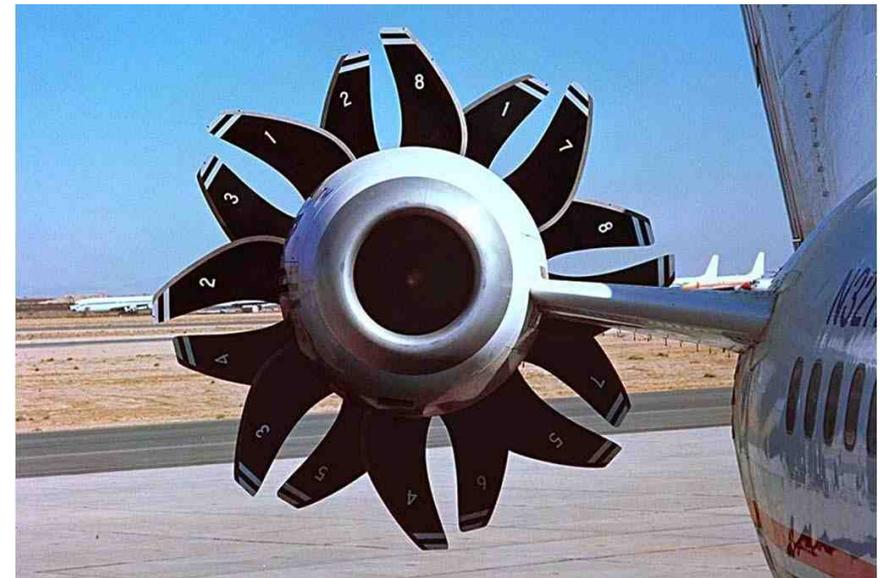
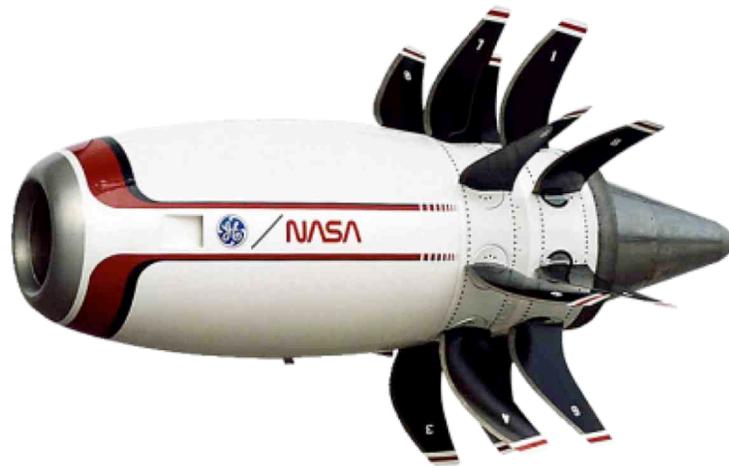
National Aeronautics and Space Administration  
Lewis Research Center

**NASA Contra-Rotating Rig in  
9x15 LSWT**



**GE Contra-Rotating Rig in Cell  
41 (from X-Noise 2011)**

Flight Demo occurred in parallel with WT test program

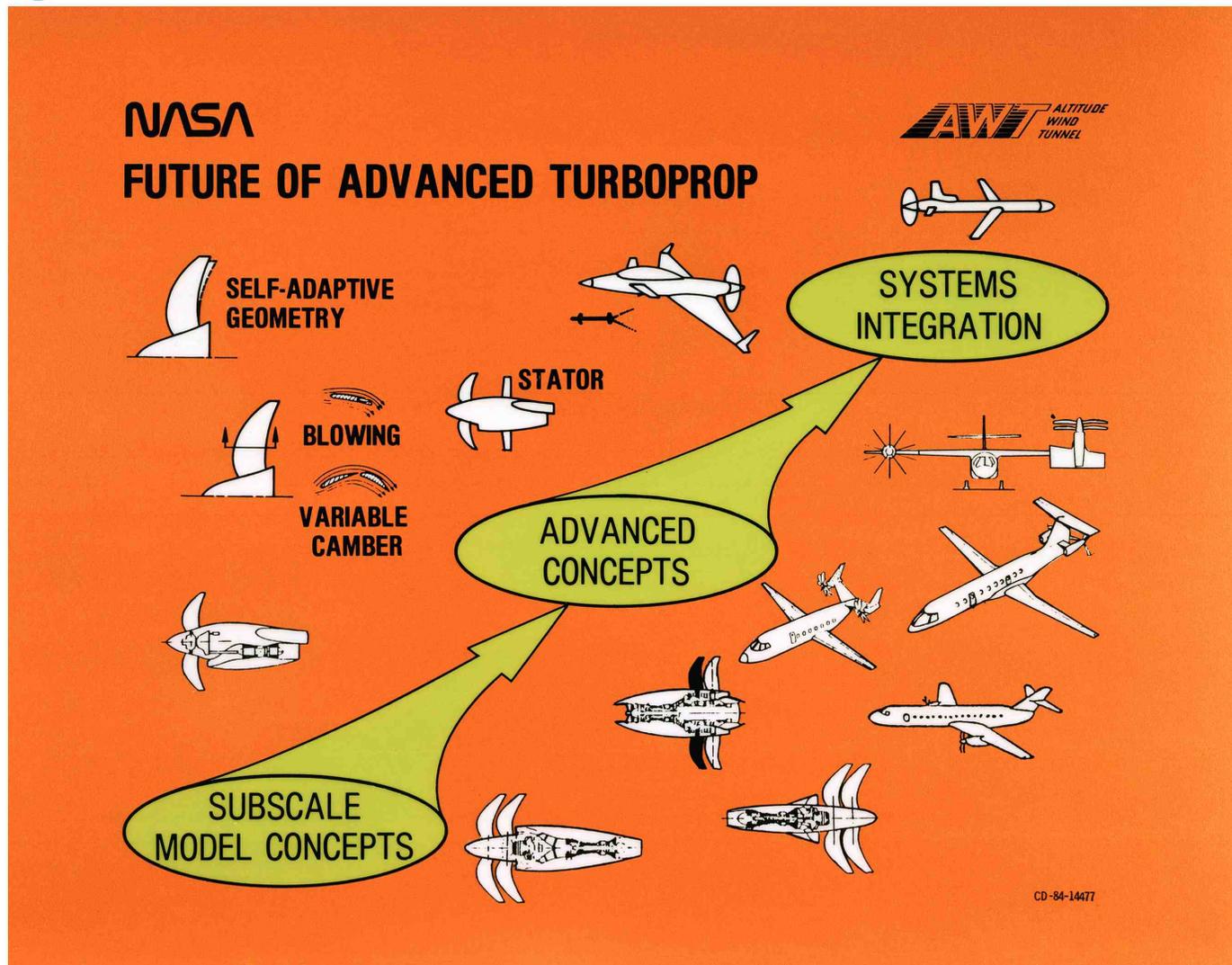


**The UDF™ engine used an early blade design, F7/A7. It had a distinctive look and sound.**

# Advanced Concepts



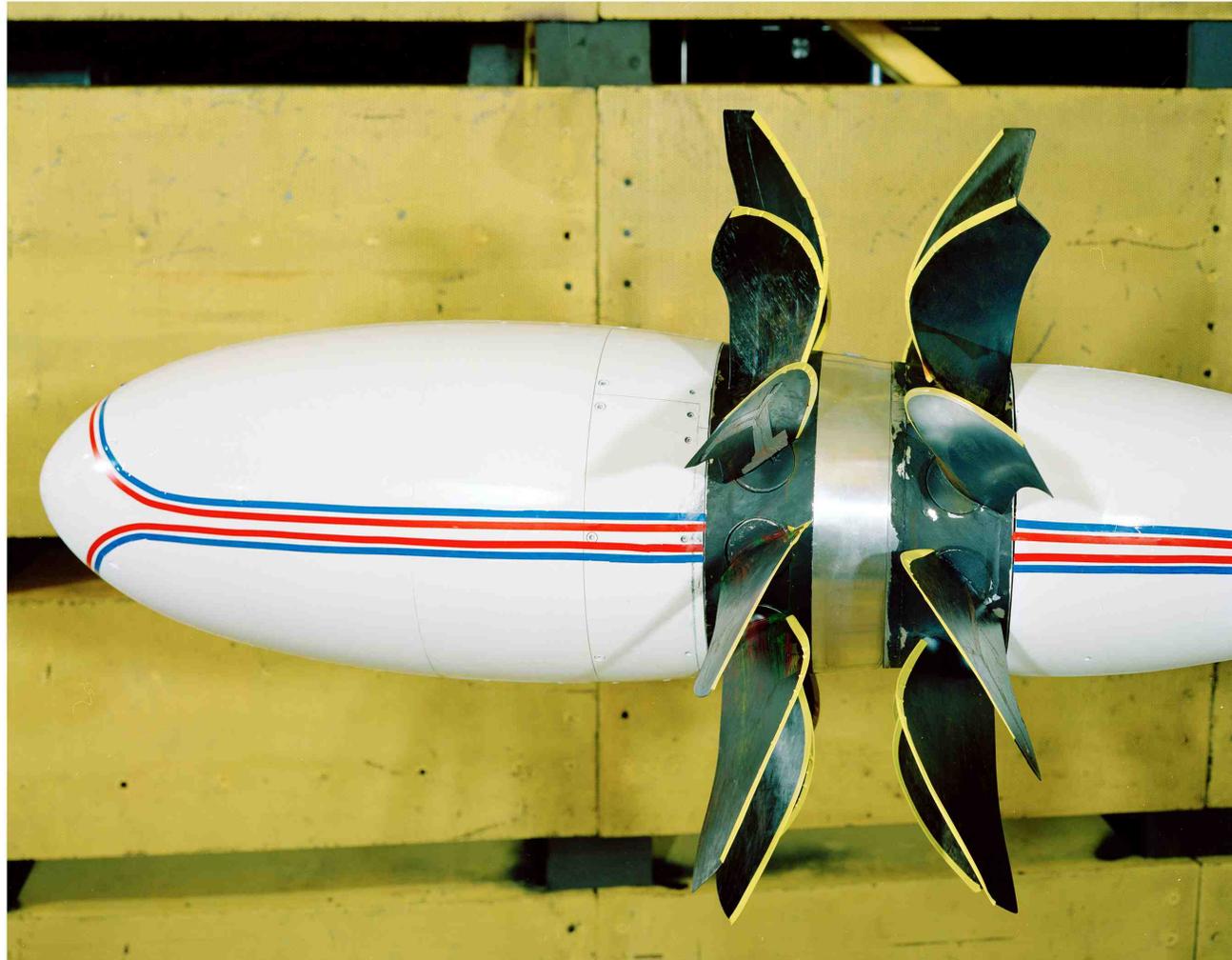
NASA C-1984-1348



# Advanced Concepts: Forward Swept Rotor



 C-1992-5894



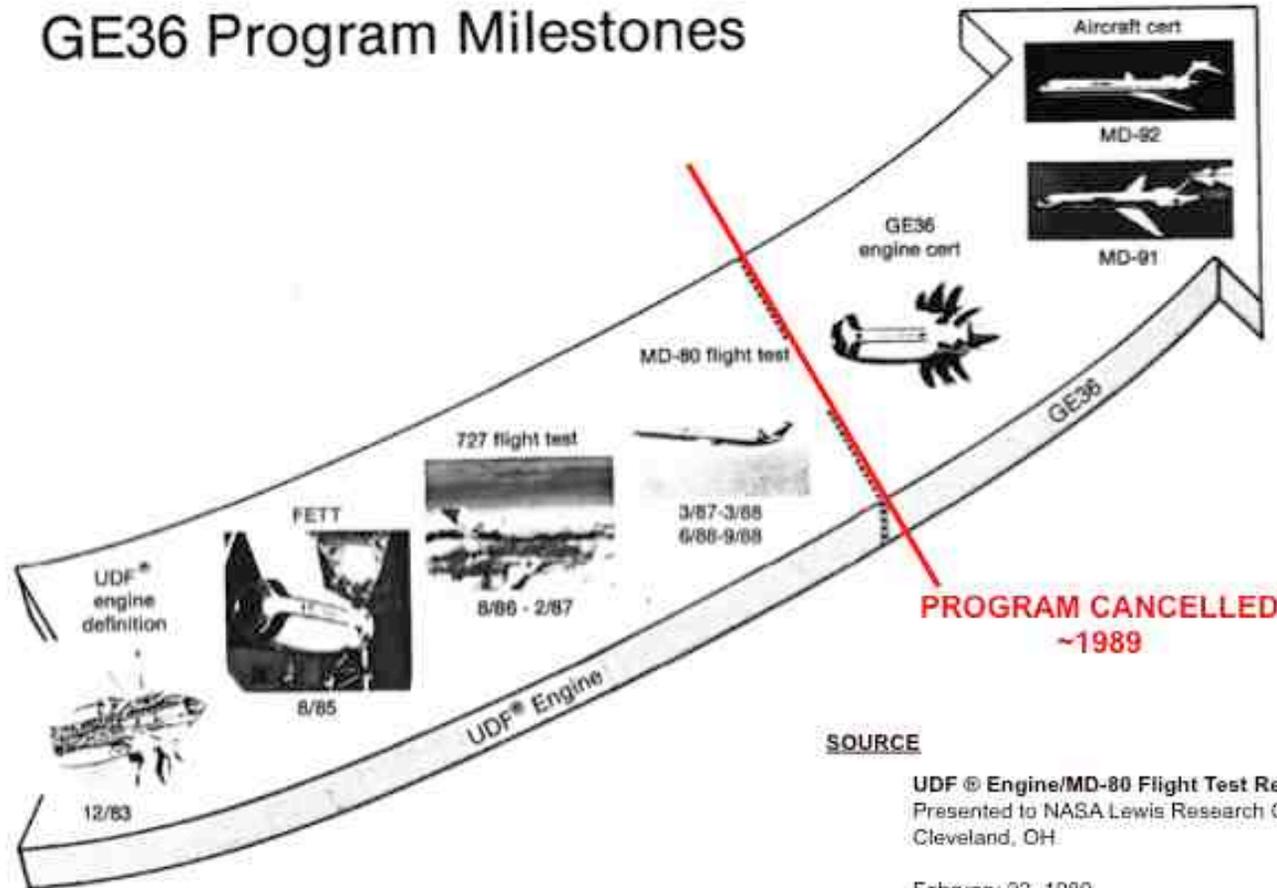
**AIAA-93-0596**

National Aeronautics and Space Administration  
Lewis Research Center

# GE36 Development



## GE36 Program Milestones



X-Noise, March 2011

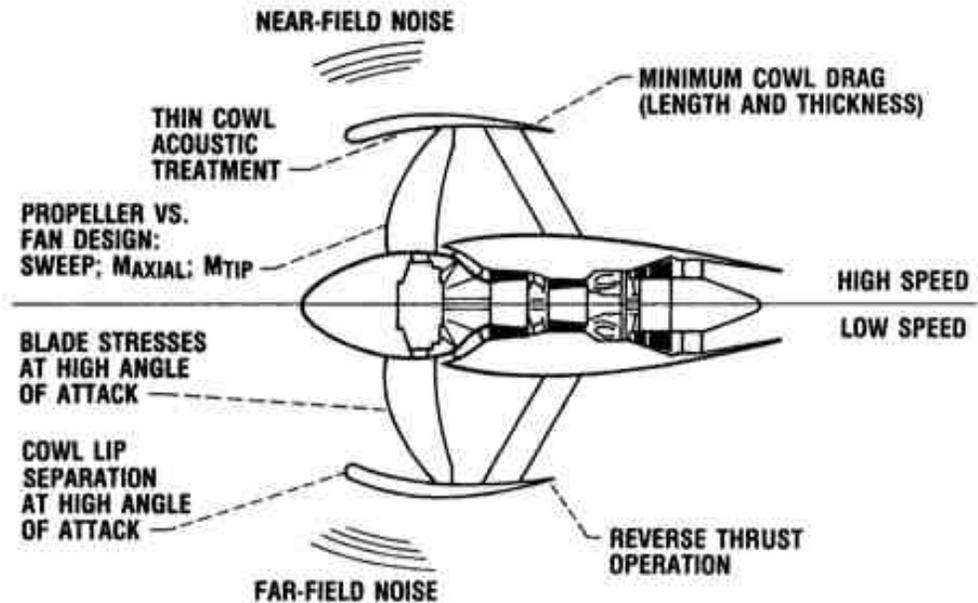
ecomagination  
3/

**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.**

## Keynote Session

### *New Benchmarks for Gas Turbine and Jet Engine Advancements*



**August Wilhelm Henningsen**  
*Chairman of the Executive Board*  
Lufthansa Technik AG

With Lufthansa since 1979, Mr. Henningsen has overseen various areas of the company, including: the flight operation department; the aircraft-control group; aircraft structure and systems engineering; aircraft cabins and systems; and the overhaul line of the Boeing 737 fleet. With the formation of Lufthansa Technik AG (LHT) in 1993, he took charge of the aircraft components services division of the new company. A member of LHT's Executive Board since 2000, when he was placed in charge of the newly created MRO product and services division, Mr. Henningsen became Chairman of the Executive Board in 2001.



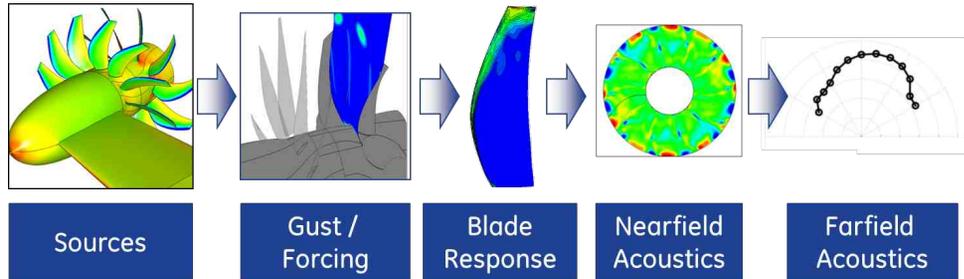
**Master of Ceremonies**  
**ASME TURBO EXPO 2004**  
**Executive Conference Chair**  
**Sigmar Wittig**  
*Chairman of the Executive Board*  
German Aerospace Center (DLR)

**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.

NASA C-2010-3604



National Aeronautics and Space Administration  
Glenn Research Center at Lewis Field

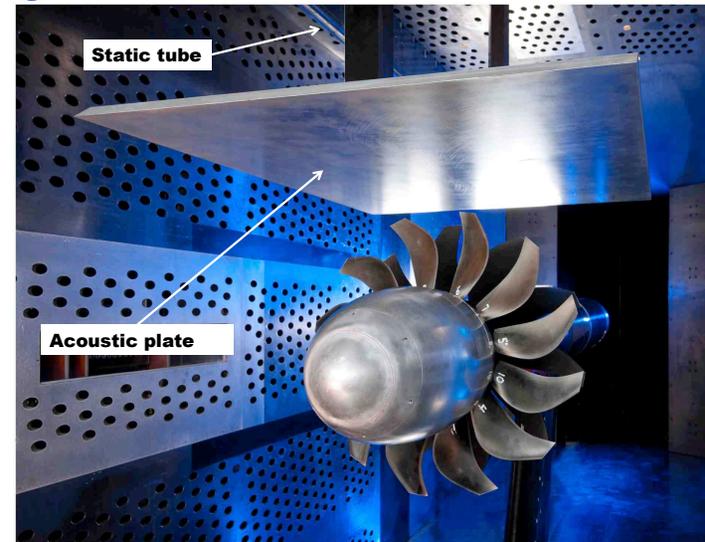


imagination at work



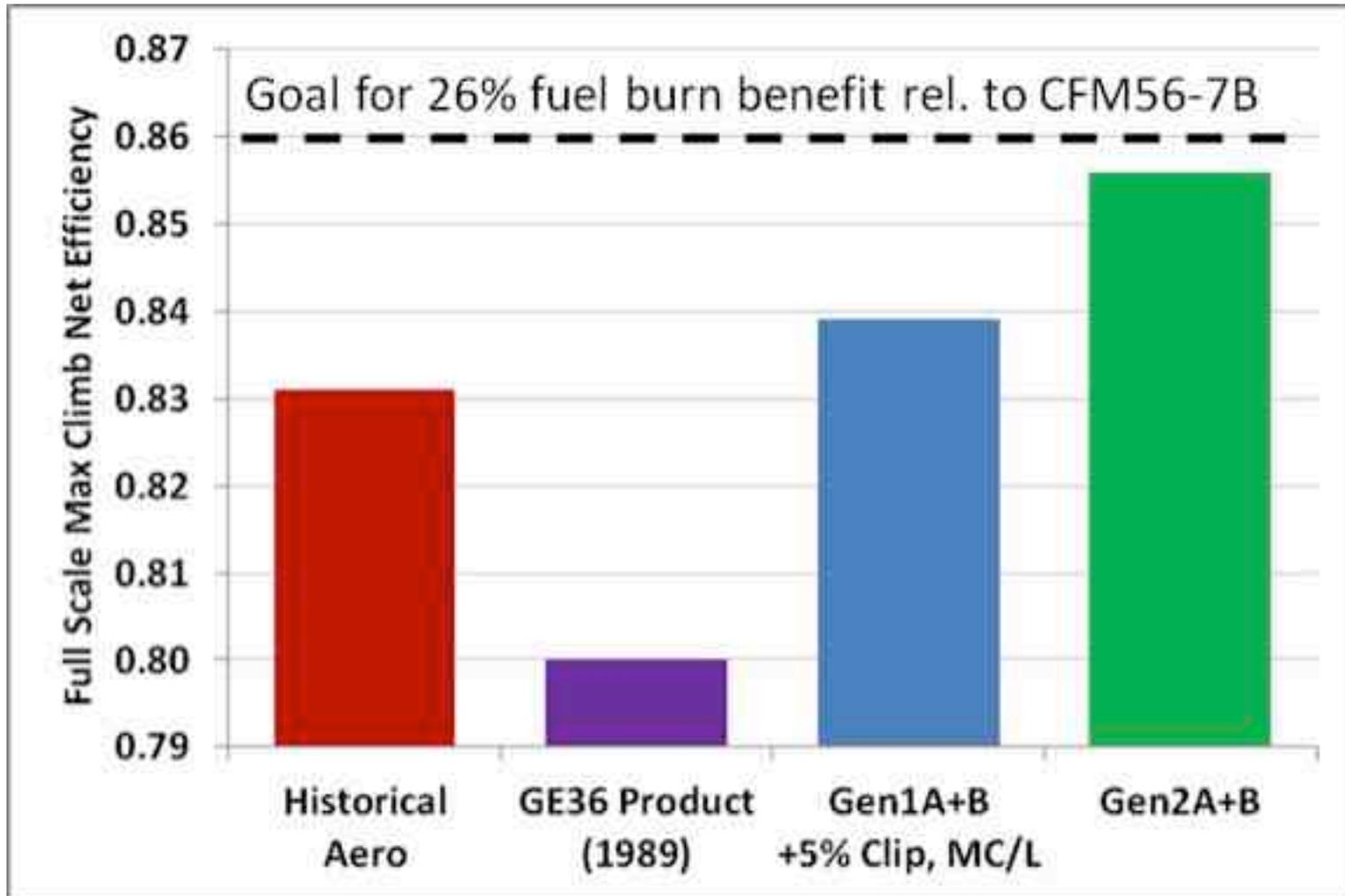
- FAA Continuous Lower Emission, Energy and Noise (CLEEN) Program
- NASA Environmentally Responsible Aviation (ERA)
- NASA Fixed Wing (FW)
- NASA Aeronautics Test Program (ATP)

NASA C-2011-620



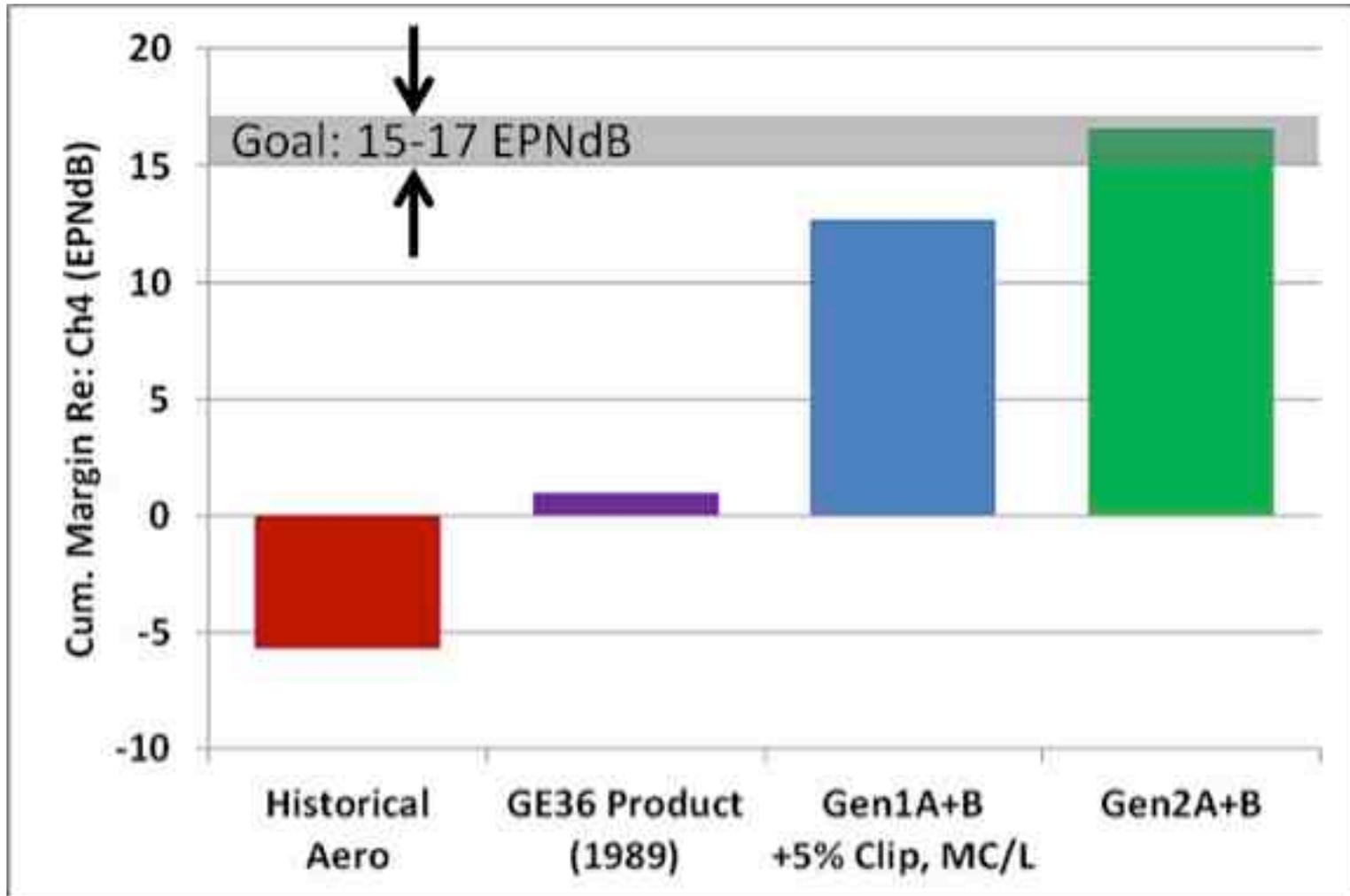
National Aeronautics and Space Administration  
Glenn Research Center at Lewis Field

# Aerodynamic results



**F31/A31**

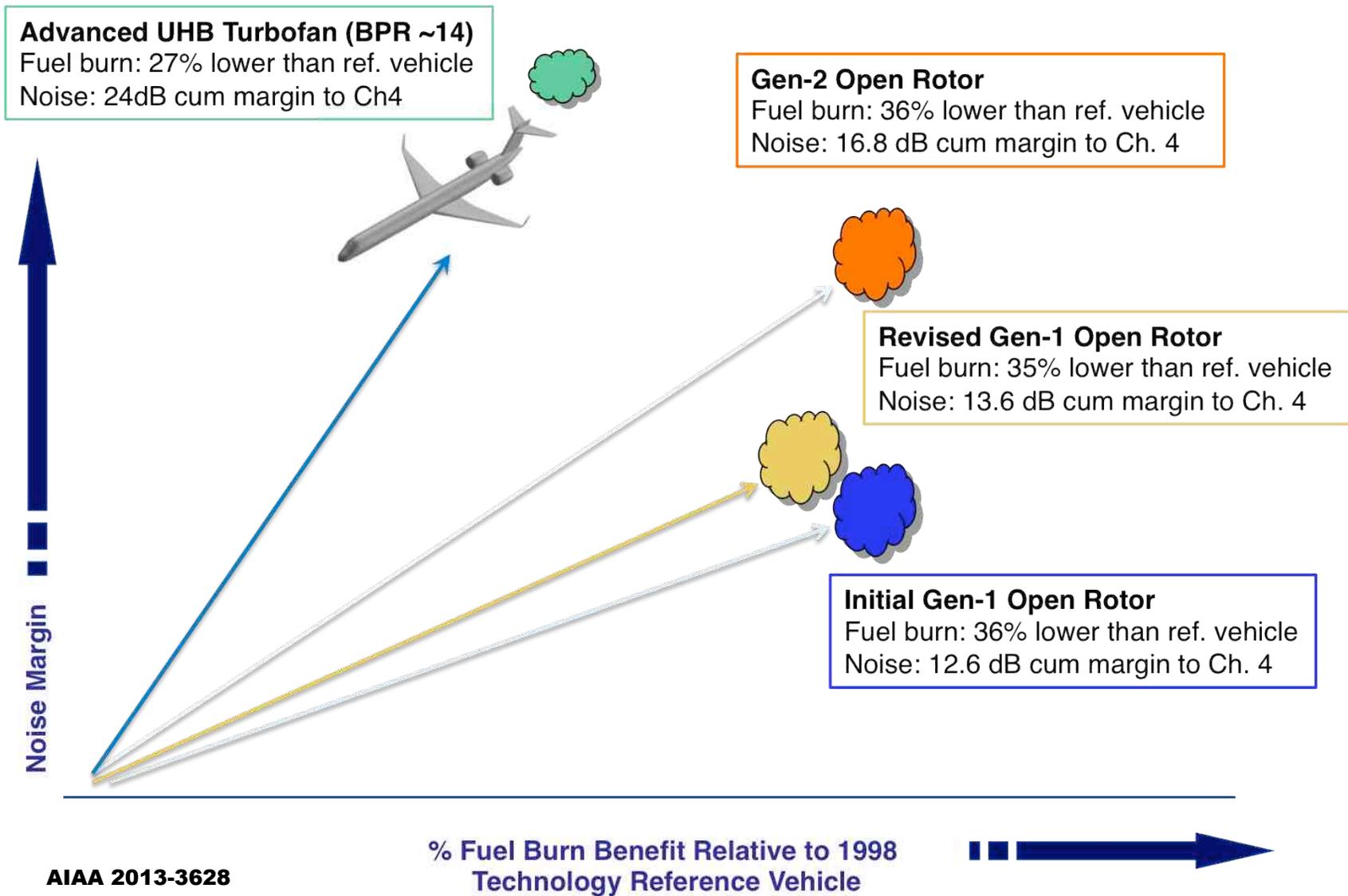
# Acoustic results



**F31/A31**



# An assessment of the technology at TRL 4

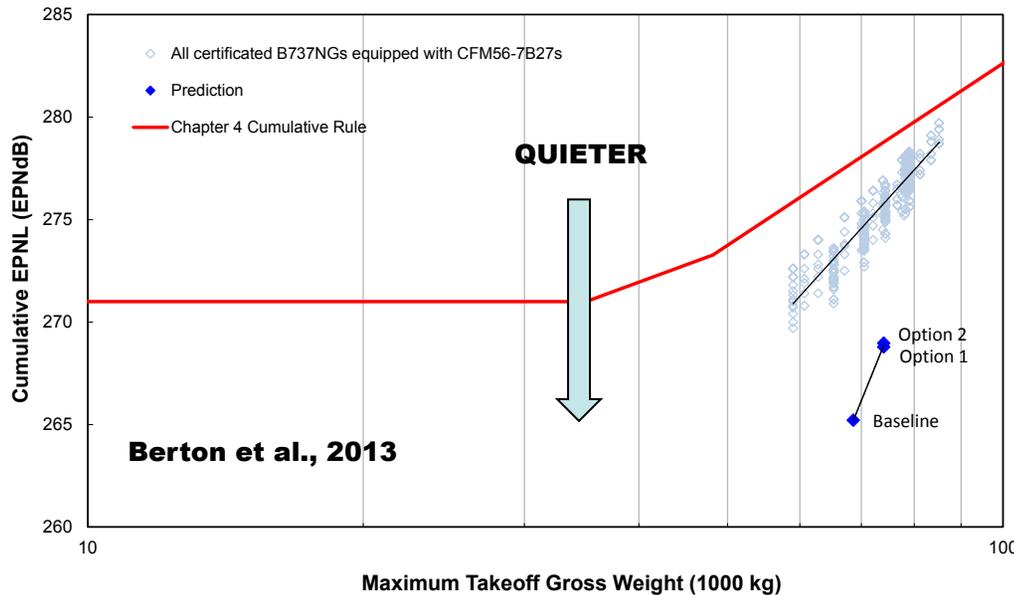
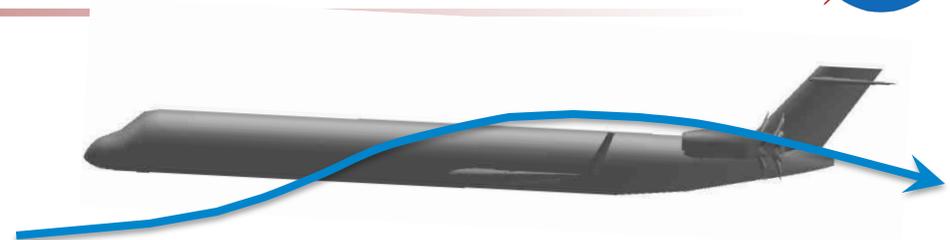


AIAA 2013-3628



# What remains to do?

**Propulsion Airframe Integration**  
**AoA into rotors**  
**Transonic performance**



**Technologies for additional noise margin**

Nov 2014, Edmonton, CA



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

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

# Summary

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- **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

