NASA / GE Aviation Collaborative Partnership Research in Ultra High Bypass Cycle Propulsion Concepts

Abstract

Current collaborative research with General Electric Aviation on Open Rotor propulsion as part of the Subsonic Fixed Wing Project Ultra High Bypass Engine Partnership Element is discussed. The Subsonic Fixed Wing Project goals are reviewed, as well as their relative technology level compared to previous NASA noise program goals. The current Open Rotor propulsion research activity at NASA and GE are discussed including the contributions each entity bring toward the research project, and technical plans and objectives. GE Open Rotor propulsion technology and business plans currently and toward the future are also discussed, including the role the NASA SFW UHB partnership plays toward achieving those goals.

NASA / GE Aviation Collaborative Partnership Research in Ultra High Bypass Cycle Propulsion Concepts

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Fundamental Aeronautics Program

2nd Annual Meeting

Atlanta, GA

October 7-9, 2008

NASA / P&W UHB Partnership Research

- ***Objective***
  - Develop noise reduction, emission reduction and performance improvement technologies for the Ultra High Bypass engine cycle, then demonstrate and validate their potential in full scale applications
- NASA has a strong and successful history of developing aircraft propulsion improvement technologies with Industry/OGA/Academia partners

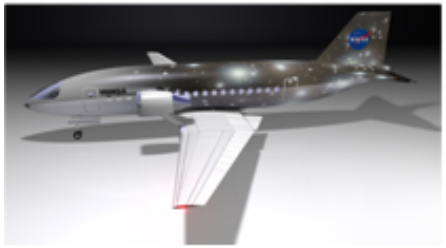
NASA / GE UHB Partnership Research

- Today, increasing fuel prices and tighter environmental regulations along with aggressive SFW goals for future aircraft requires refining, improving and demonstrating the combined effectiveness of previous noise reduction and performance enhancing technologies

CORNERS OF THE TRADE SPACE	N+1 (2015 EIS) Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020 IOC) Generation Unconventional Hybrid Wing Body (relative to B777/GE90)	N+3 (2030-2035 EIS) Generation Advanced Aircraft Concepts (relative to user defined reference)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)	55 LDN (dB) at average airport boundary
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts

** An additional reduction of 10 percent may be possible through improved operational capability
* Concepts that enable optimal use of runways at mutiple airports within the metropolitan areas
EIS = Entry Into Service; IOC = Initial Operating Capability

N+1 Conventional



N+2 Hybrid Wing/Body

N+3 Generation

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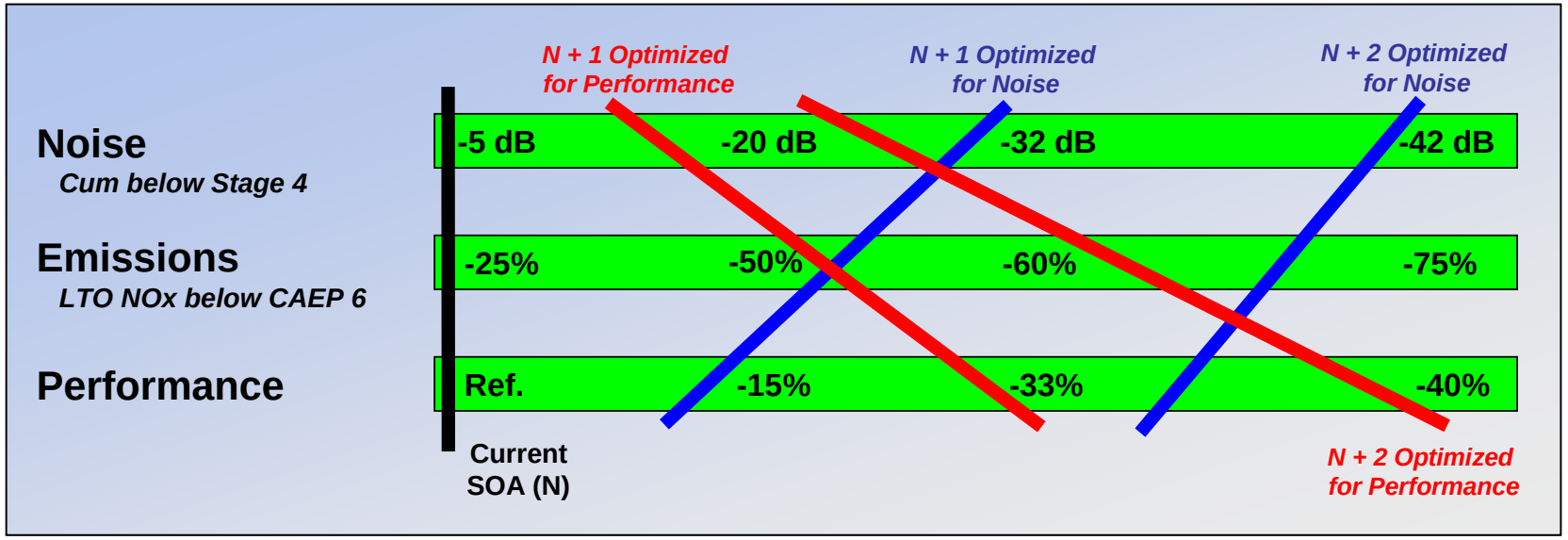
- However, *limited goals trading* is possible to address specific requirements



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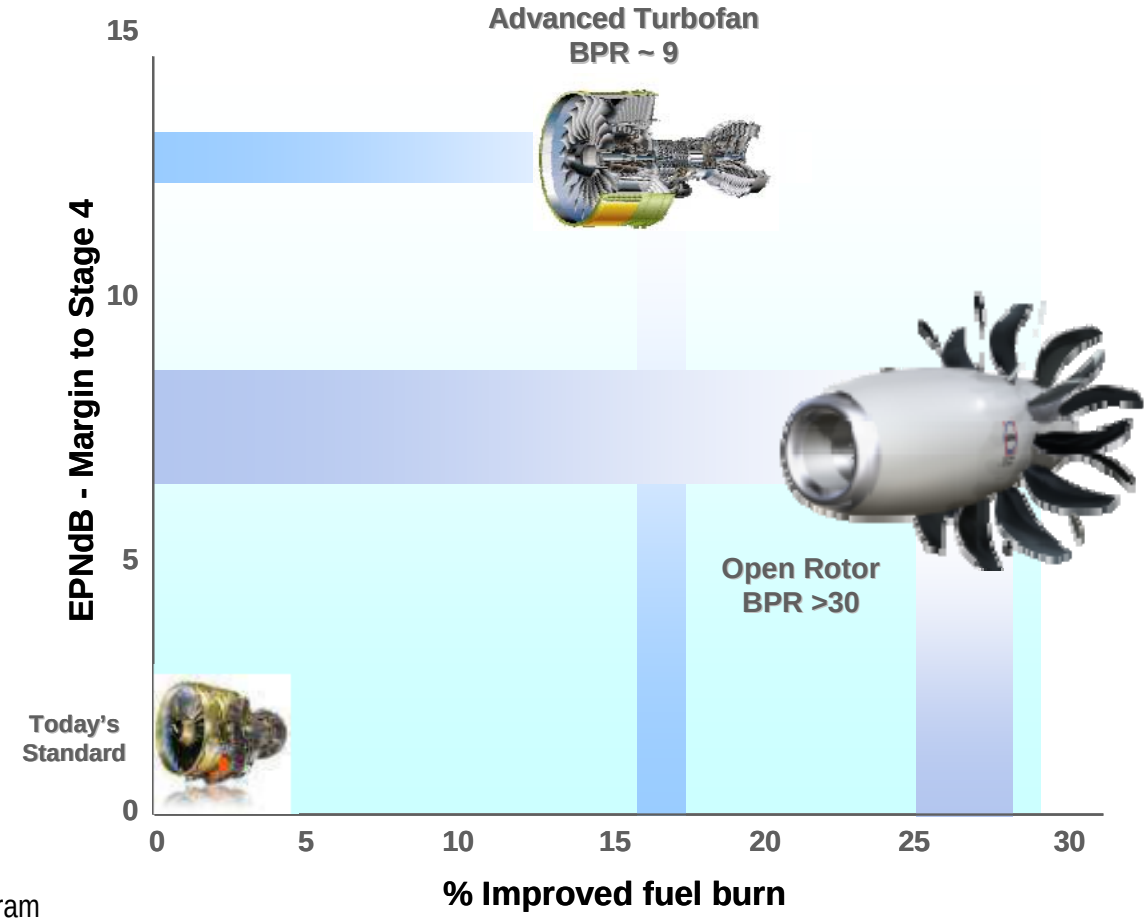
- *Meeting SFW Goals Requires Evaluating Game-Changing Architectures*
  - Open Rotor Technology has potential for significant performance improvement, but with noise goal challenges



NASA / GE UHB Partnership Research

➢ *2008 Highlights*

- Space Act Agreement signed August 2008 to initiate collaborative research into Open Rotor propulsion concepts
  - NASA and GE will conduct cooperative research on initial Open Rotor concepts to determine noise and performance characteristics in NASA Glenn 9'x15' and 8'x6' wind tunnels starting in early 2009

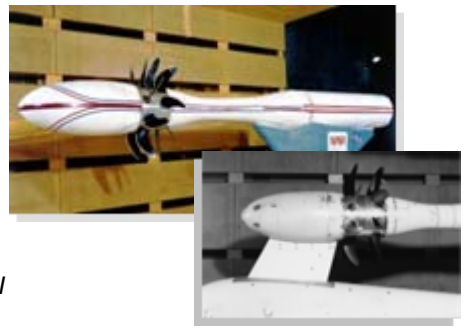
GE Open Rotor Concept

NASA / GE UHB Partnership Research

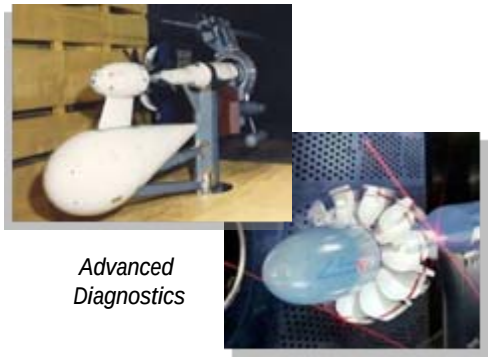
Leveraging the NASA / GE UDF® Experience and UHB Partnership

Climb/Cruise in Glenn 8'x6' Wind Tunnel

Approach/Takeoff in Glenn 9'x15' Wind Tunnel



Installation Effects



Advanced Diagnostics

Counter-rotation Blade Profiles

- Extensive 1980s collaborative testing experience of counter-rotation, open rotor concepts by NASA and GE, resulting in substantial experimental database to guide new activity
- Improved Computational Aeroacoustics developed by NASA/GE/Universities to evaluate new open rotor concepts
- Improved design and system analysis tools to screen potential candidates and minimize scale model test configurations
- Utilize proven NASA test facilities, improved diagnostic testing techniques and existing scale model test articles
- Build on GE expertise in composite construction and advanced core technology to achieve full Open Rotor potential

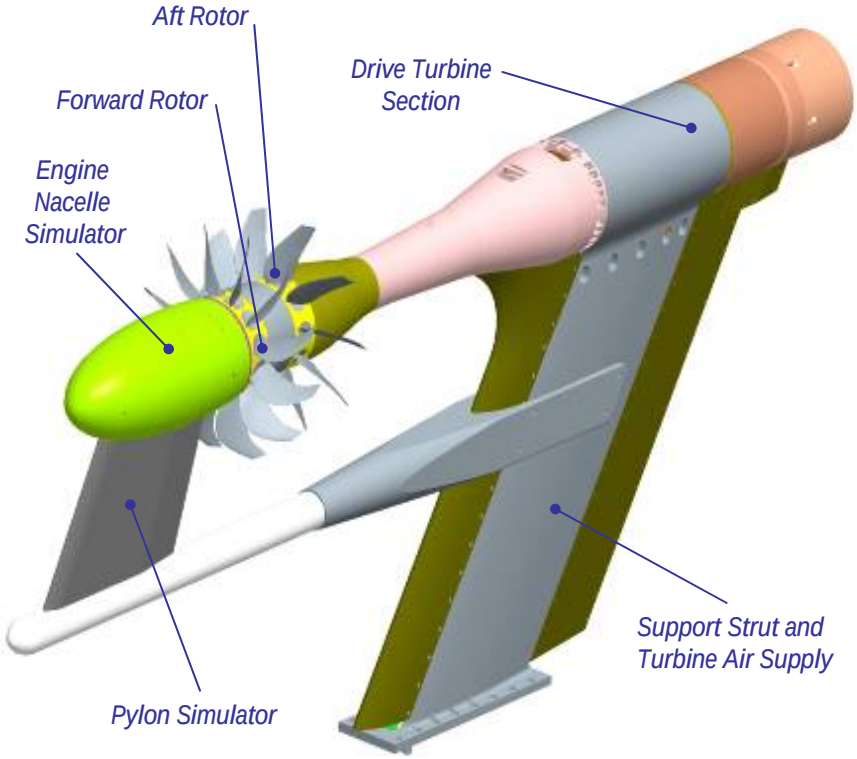
NASA / GE Partnership for the Open Rotor Test Program

➢ *Test Objectives*

- Produce a shareable open-rotor design and geometry to use as technology baseline
- Investigate performance and noise including installation and AOA effects across a potential flight operating envelope
- Generate open, shareable database of test results as a Historical Baseline Open Rotor configuration to aid prediction code development and verification by Government/Industry/Academia

➢ *Plan*

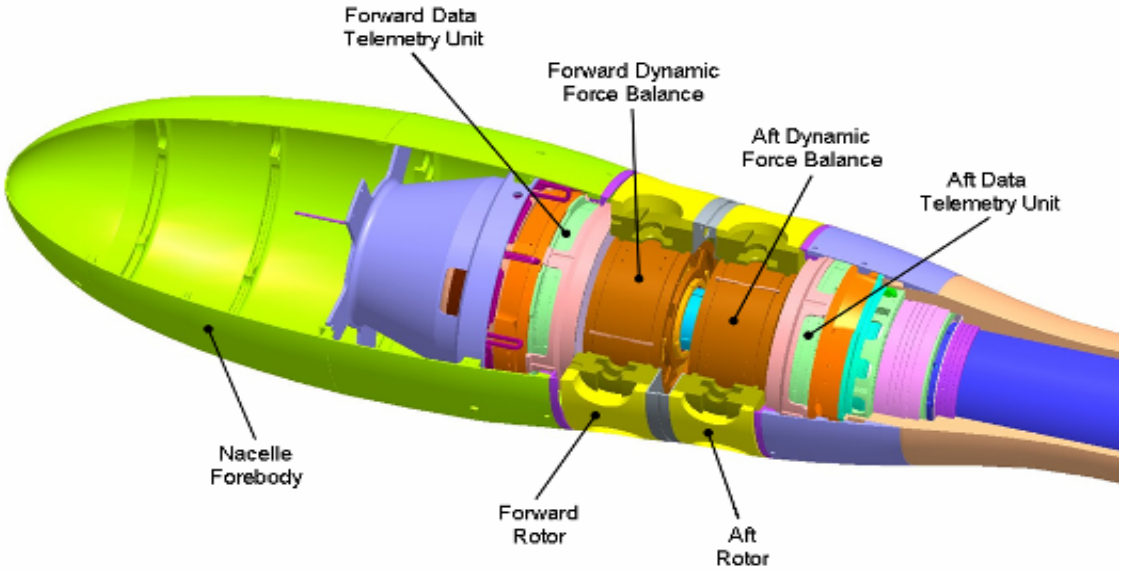
- NASA will refurbish, modernize and make operational 1980s counter-rotation Open Rotor Propulsion Rig
- GE will design and fabricate 1980s-based open rotor fan
- Low-speed performance, acoustics, flow diagnostics, AOA and installation effects will be investigated in NASA Glenn 9'x15' LSWT
- High-speed performance and near-field acoustics will be investigated in NASA Glenn 8'x6' SWT



NASA Glenn Open Rotor Propulsion Rig

NASA / GE Partnership for the Open Rotor Test Program

- *NASA Glenn Open Rotor Propulsion Rig*
  - Two independently controlled, counter-rotating shafts
  - Each shaft capable of delivering up to 750 shp at maximum speed of 10,000 rpm
  - Two-component rotating force balances measure up to 400 lbs thrust and 500 ft-lbs torque per rotor
  - State-of-the-art digital telemetry units transmit data from each rotor to base system for transfer and storage on facility data system
  - Up to 12 strain gages per rotor available for monitoring fan blade dynamics
  - All subsystems (speed control, lubrication, air supply) are new, state-of-the-art designs



NASA / GE UHB Partnership Research

➢ *Future*

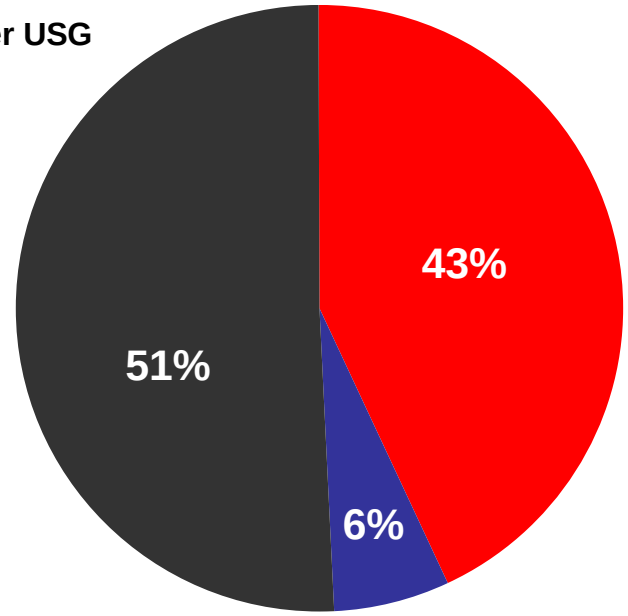
- Through a NASA / GE partnership collaboration, both partners can leverage their experience, expertise, facilities and resources to conduct research on Open Rotor Propulsion concepts for the next generation of advanced aircraft designs and investigate their viability as a new, game-changing aircraft propulsion technology in a environmentally-conscious world

The world has changed in just 3 years …

Airline direct cash operating costs

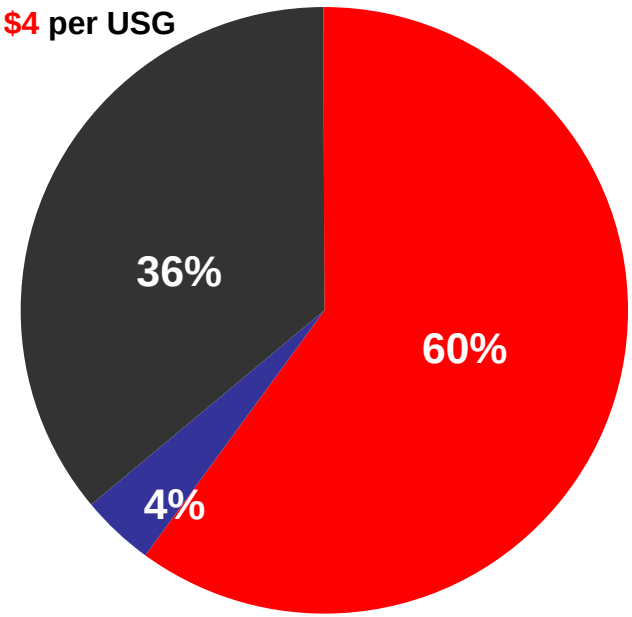
2005

$2 per USG



2008

$4 per USG

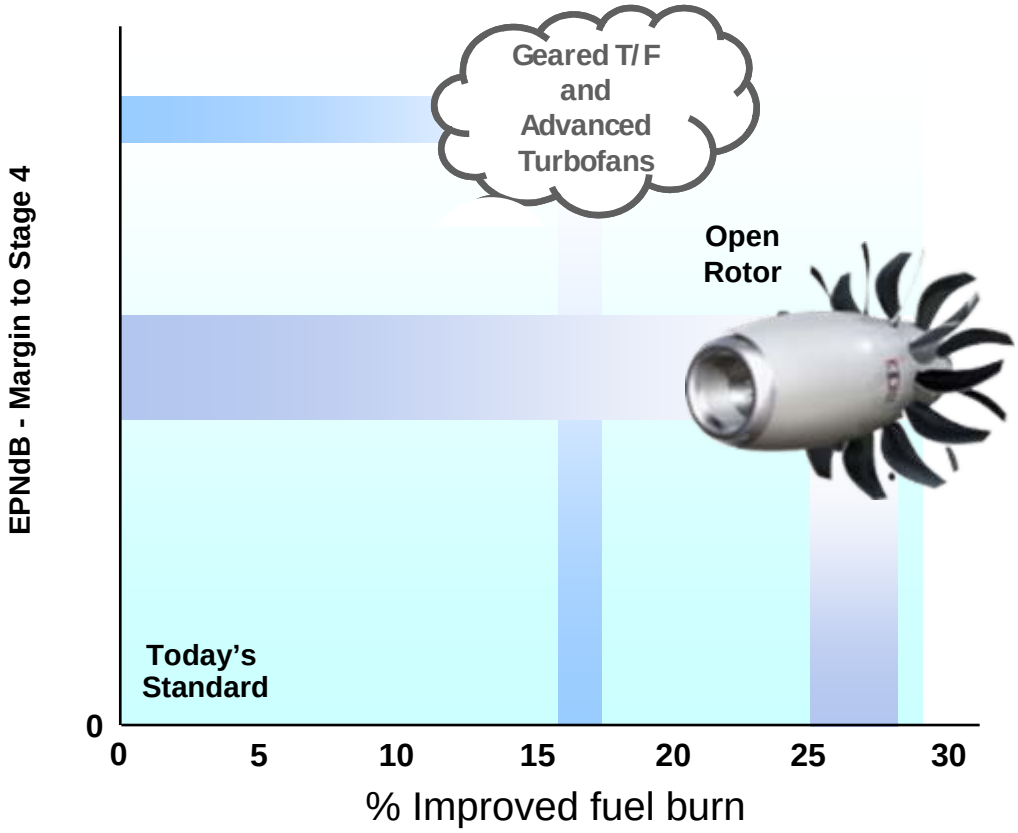


- Fuel Cost
- Engine maintenance
- All Other

Generic single-aisle aircraft (160 passengers)
800 nautical mile range
Source: Internal analysis

Open Rotor key enabling technologies

10% better fuel burn potential … with challenges



- Noise
- Maintenance
- Installation

Open Rotor Technology Challenges

- Noise
  - Current acoustic goal of Stage 4 – 10 dB for configuration to get balanced solution for noise/fuel burn
- Maintenance
  - Costs need to be inline with current generation of turbofans
- Installation
  - Large effective fan diameter requires careful integration with airframe
- Overall
  - Determine best solution meeting noise, fuel burn, maintenance and weight constraints

Leveraging the UDF® Experience

- Ground and flight tests in 1987 & ’88

  … featured at Farnborough Air Show 1988
- Demonstrated tremendous potential for fuel burn improvement

imagination at work

GE Composite Expertise

40+ years of experience

TF39

GE36

GE36

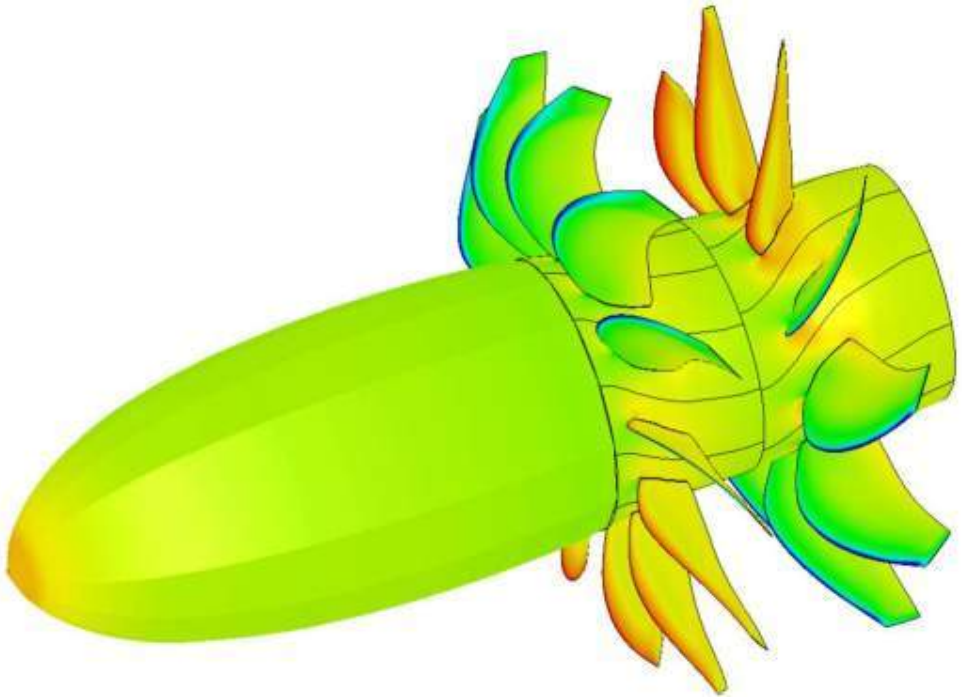
GEnx

GEnx-1B

GE90

Open Rotor Aeroacoustics

- Computation Aeroacoustics (CAA) is being used to guide design studies
  - Developed by NASA, Industry and Academia
- CAA tools allow fewer test configurations and better understanding of noise generation mechanisms
- Scale model hardware defined with new tools



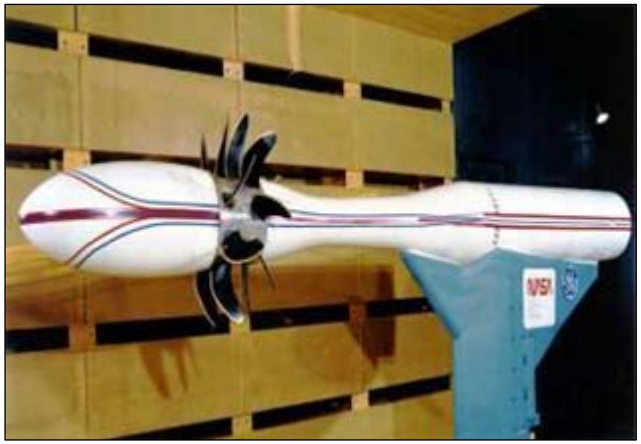
Leveraging Testing Experience at NASA

- NASA ran aeroacoustic and performance testing at GRC as part of collaborative technology development in 1980's
- Acoustic test execution and data acquisition expertise to support development
- Utilize NASA's advanced measurement techniques as needed to understand flow physics and noise generation
- Test data to validate and enhance prediction processes

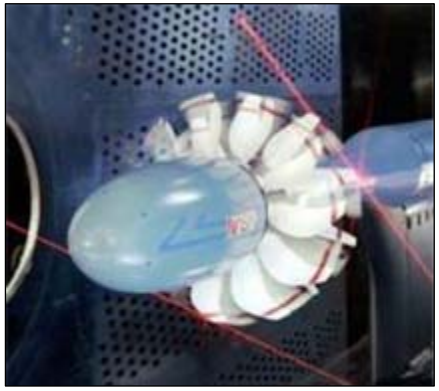
Open rotor scale model test program

- Validate analytical codes
- Evaluate pylon and fuselage interactions

- Low-Speed (NASA 9x15 wind tunnel)
  - Far-field acoustics
  - Aero performance
  - Diagnostic measurements
  - Installed configurations



- High Speed (NASA 8x6 wind tunnel)
  - Aero performance
  - Limited near-field acoustics



Open rotor scale model test data

- "Golden Data Set" – comprehensive, representative baseline blade test results (isolated and installed)
  - Acoustic database
  - Performance data
  - Blade geometry for CFD analysis – New!
- Multiple blade designs to validate codes/explore design space
- Back to back isolated and installed testing for incremental analysis
- Demonstration of acoustic benefits with best performance using advanced diagnostics

How we will get there …

	2008	2009	2010	2011	2012
RTM Fan Blade					
LP Turbine					
HP Compressor					
Combustor					
HP Turbine	 				
Core Engine		 Core 1			
Open Rotor Hardware	 NASA wind tunnel PH 1	 Pitch change mechanism	 NASA wind tunnel PH I1		

It's a much different world …

- Fuel prices at record highs and environmental challenges are accelerating
  - Open rotor architecture offers immediate 10% improvement
- CFM Open Rotor Technology Development
  - Leverages the UDF® past
    - Building on GE's expertise
  - 21st Century design and diagnostic tools
  - Phase I GE/NASA testing in 2009
    - Phase II planned for 2010/2011
  - Significant challenges remain