

Collaborative Research on the Ultra High Bypass Ratio Engine Cycle to Reduce Noise, Emissions, and Fuel Consumption

Presentation Abstract

A pictorial history of NASA development of advanced engine technologies for reducing environmental emissions and increasing performance from the 1970s to present is presented. The goals of the Subsonic Fixed Wing Program portion of the NASA Fundamental Aeronautics Program are addressed, along with the areas of investigation currently being pursued by the Ultra High Bypass Partnership Element of the Subsonic Fixed Wing Program to meet the goals. Ultra High Bypass cycle research collaboration successes with Pratt & Whitney are presented.



Collaborative Research on the Ultra High Bypass Ratio Engine Cycle to Reduce Noise, Emissions, and Fuel Consumption

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Integration Validation Partnership Element,
Subsonic Fixed Wing Project*



SFW UHB Partnership Element

➤ Objective

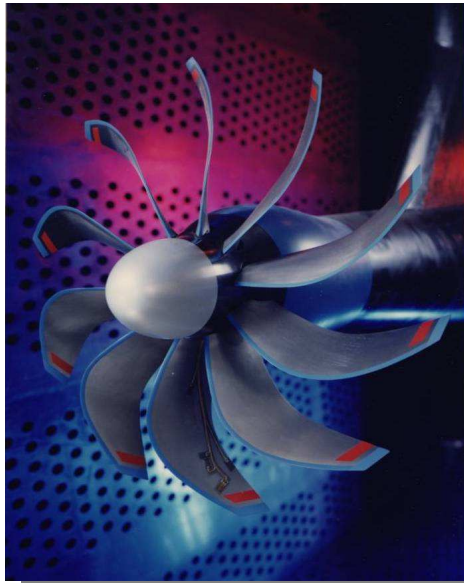
- Develop noise reduction, emission reduction and performance improvement technologies for the Ultra High Bypass engine cycle, then demonstrate and validate their potential in full scale applications
- NASA has a strong history of aircraft propulsion improvement technology development with Industry Partners



Strong History of Technology Development

➤ 1970s

- Single Rotation Propfans (Hamilton Standard/UTRC)
 - Significant fuel burn improvement over then current turbofans



*SR-5 Fan in NASA
Glenn 8'x6' Wind Tunnel*

*Large Advanced Propeller
Full Scale Static Test*



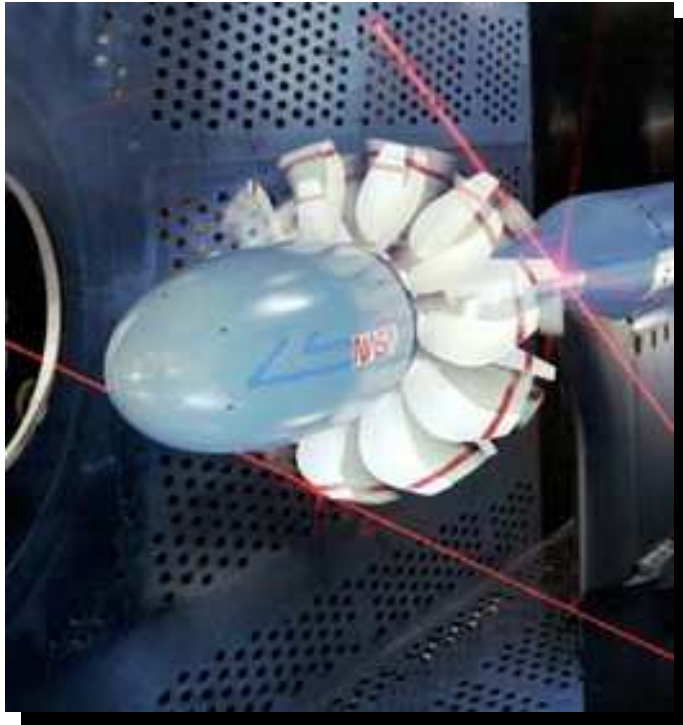
Propeller Test Assessment Aircraft Demo



Strong History of Technology Development

➤ 1980s

- Counter Rotation Propfans (GE)
 - Reduced installation effects, improved efficiency



*Counter Rotation Propeller in
NASA Glenn 8'x6' Wind Tunnel*

GE Unducted Fan / Boeing 727 Flight Demo





Strong History of Technology Development

➤ 1990s

- Ultra High Bypass Engine Cycle (P&W)
 - Reduced noise and fuel burn with conventional appearance



*17" Advanced Ducted Propulsor
in NASA Glenn 8'x6' Wind Tunnel*

*22" Advanced Ducted Propulsor
in NASA Glenn 9'x15' Wind Tunnel*



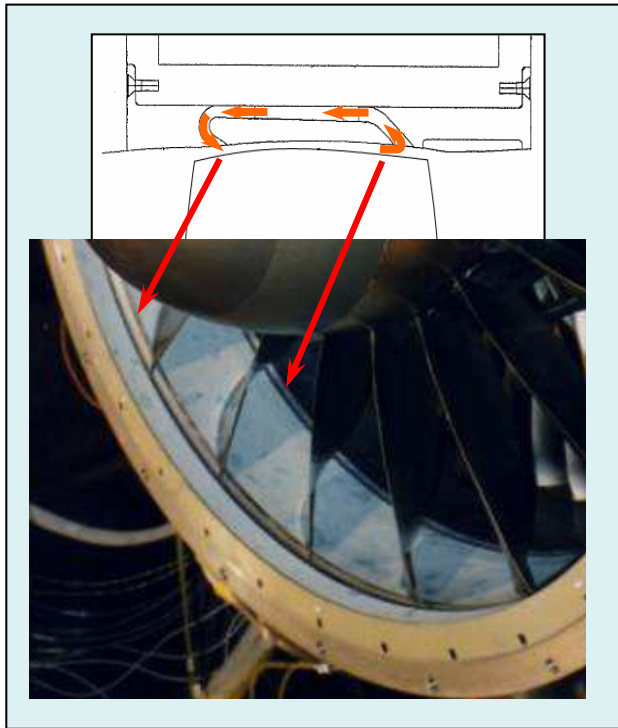


Strong History of Technology Development

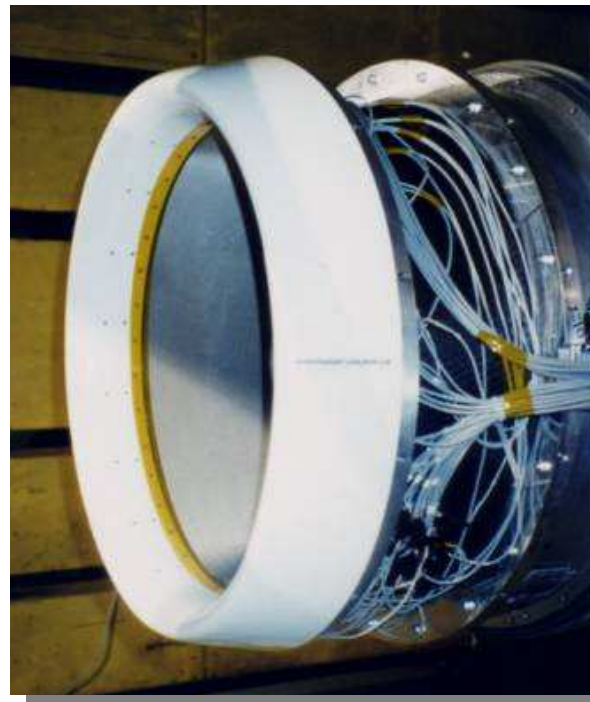
➤ 1990s

- Advanced noise reduction technologies for turbofans

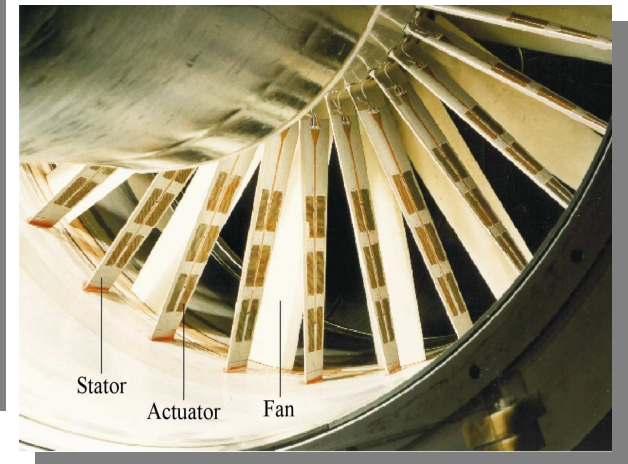
- Fan blade tip flow management (P&W)



- Active/passive liners (Northrup Grumman)



- Active noise control (NASA)





Strong History of Technology Development

➤ 1990s

- Advanced noise reduction technologies for turbofans
 - Increased rotor-stator spacing (Allison)
 - Reduced fan tip speed (P&W)
 - Swept and/or Leaned stator vanes (Allison, Honeywell)



Swept stators



Leaned stators



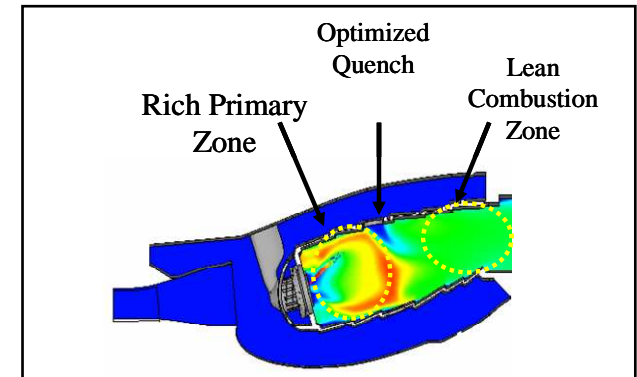
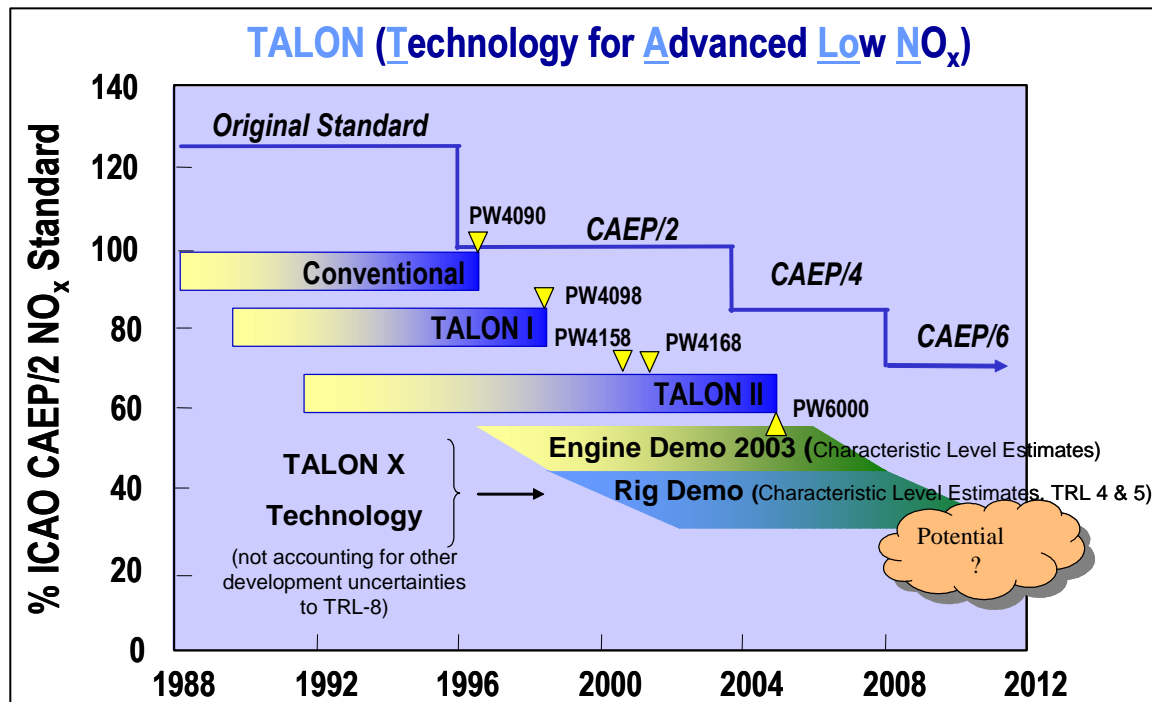
Swept & leaned stators



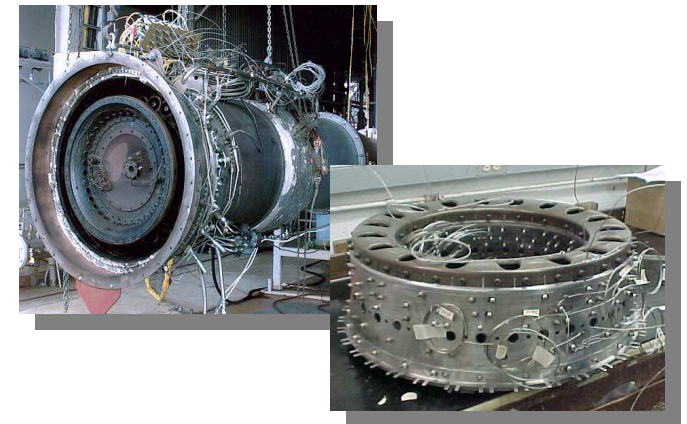
Strong History of Technology Development

➤ 1990s

- Advanced combustors for turbofans



Rich Burn Quick Quench Lean Burn Combustor Concept



Annular Combustor Test Rig



Strong History of Technology Development

➤ 2000s

- Advanced noise reduction technologies for turbofans
 - Chevrons (GE, P&W, Boeing)



Advanced Chevron Test in NASA Glenn AeroAcoustic Propulsion Lab (AAPL)

First commercial delivery on Boeing 777



Boeing Quiet Technology Demonstrator 2 Test Bed



Boeing 787 Test Flight





Strong History of Technology Development

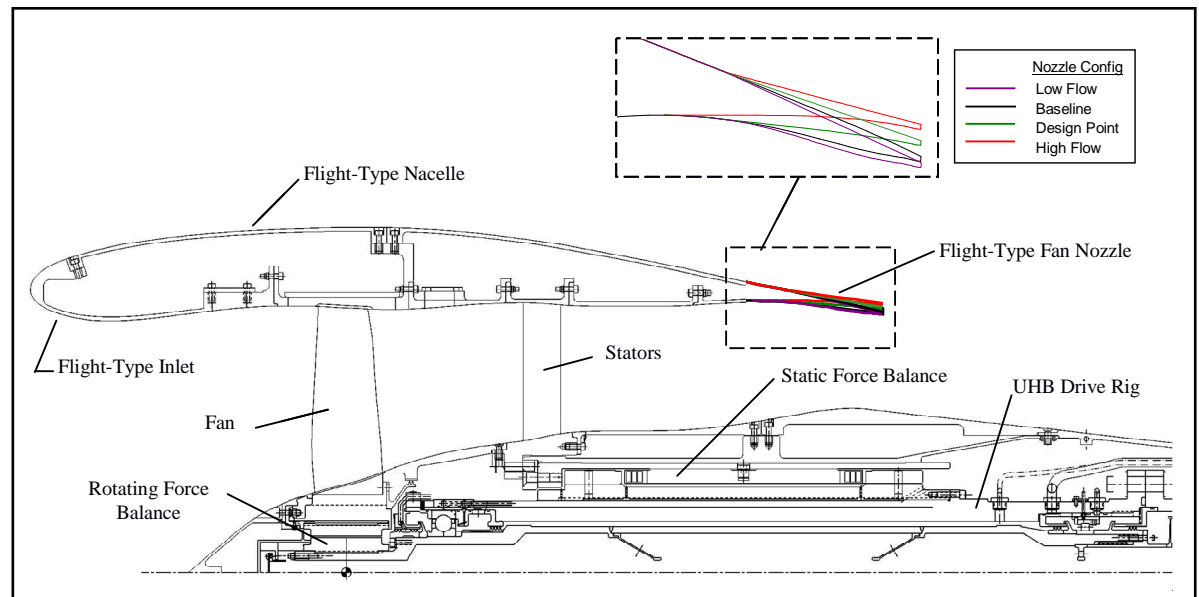
➤ 2000s

- Advanced noise reduction technologies for turbofans

– Highly forward swept fan blade (Honeywell)



– Variable Area Fan Nozzle (NASA)

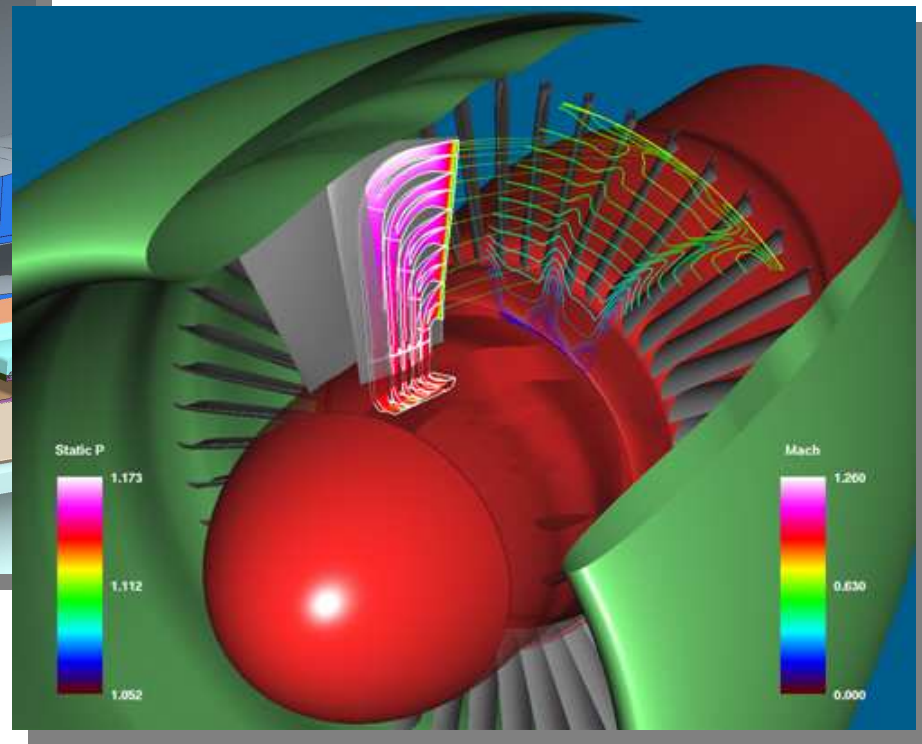
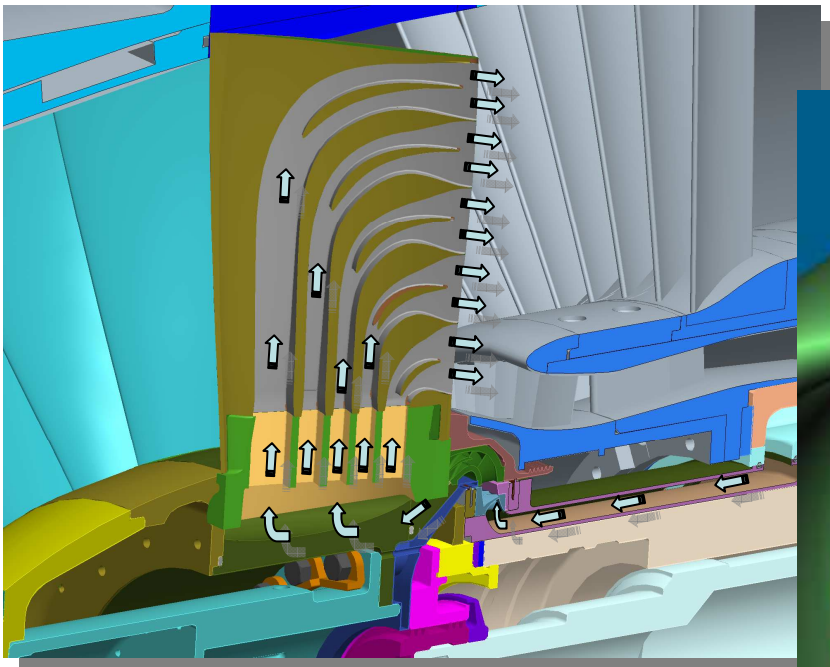




Strong History of Technology Development

➤ 2000s

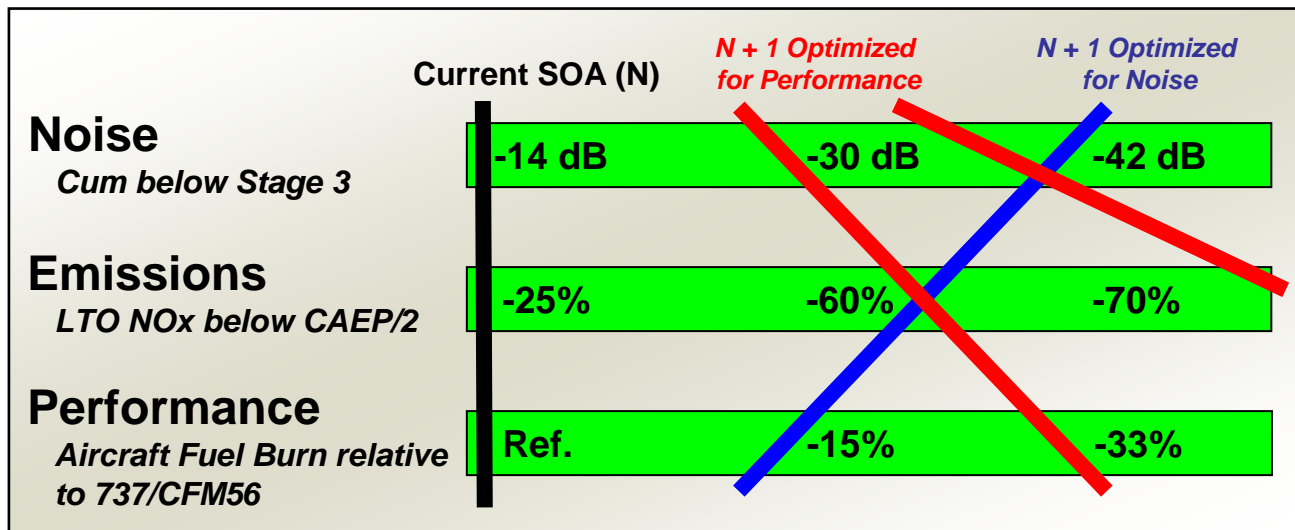
- Advanced noise reduction technologies for turbofans
 - Fan trailing edge blowing (NASA)





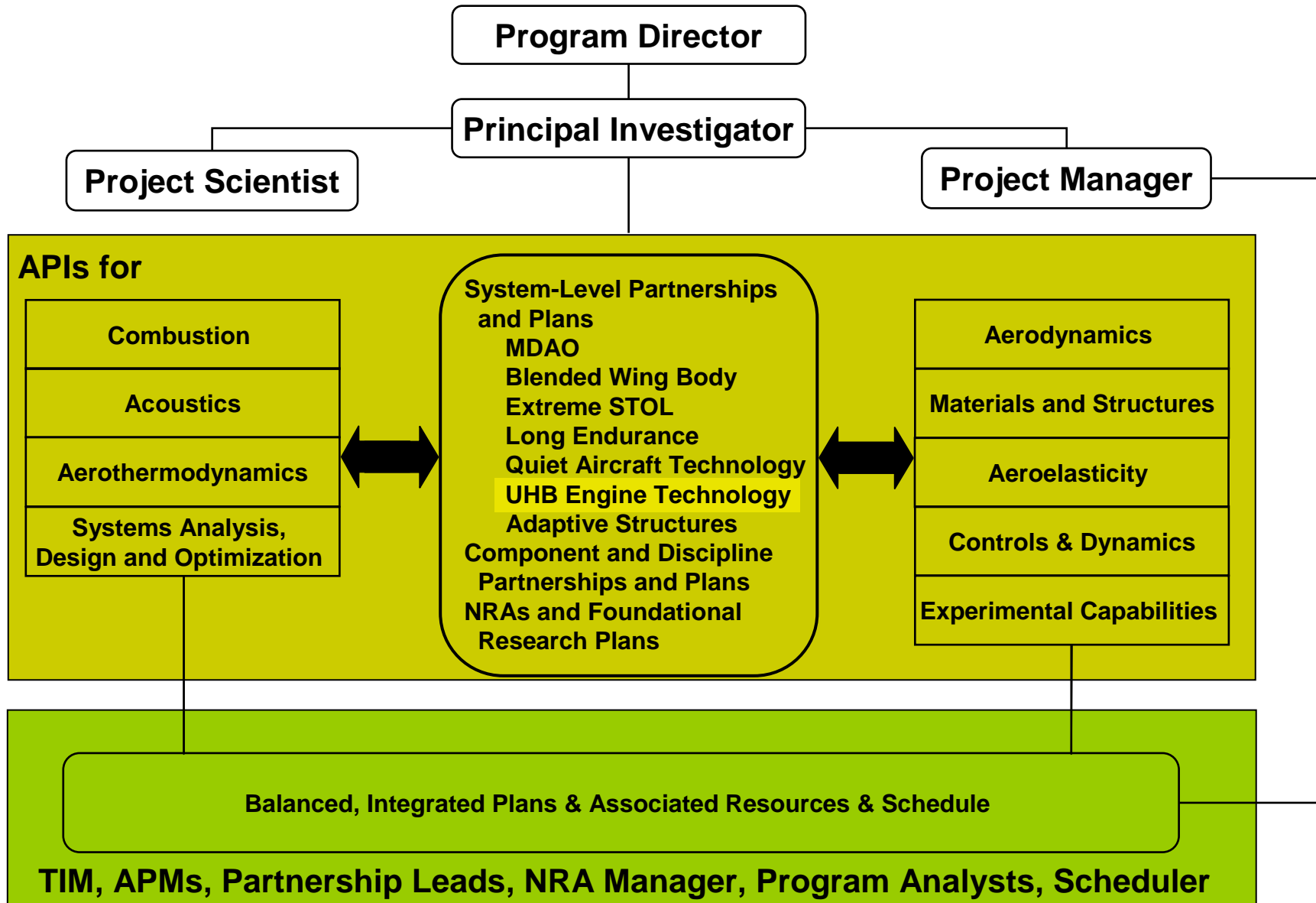
Today's Challenges

- Refining and improving on previous noise reduction and performance improvement technologies and demonstrating their combined effectiveness is necessary to meet the aggressive SFW goals for "N + 1" aircraft
 - Noise: -42 cum below Stage 3
 - Emissions: -70% LTO NOx below CAEP/2
 - Performance: -33% Fuel Burn below B737/CFM56
- However, goals trading may be possible in certain applications





SFW Project Organization



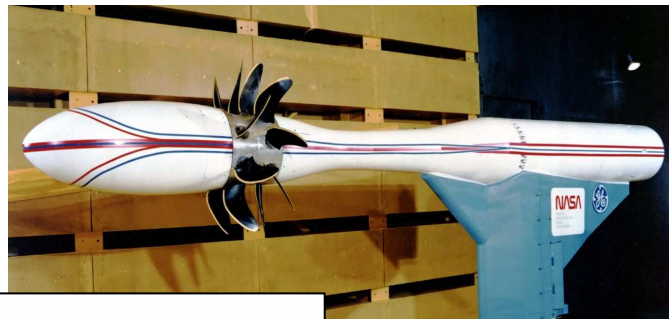


Current Areas of Investigation Under SFW UHB

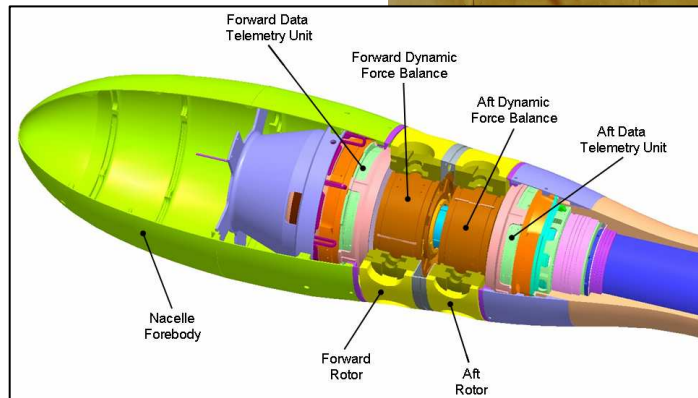
➤ Performance

- Nacelle/Airframe Integration Aerodynamics
- Counter Rotation Fans (Bypass Ratio >30)
 - NASA Glenn drive rig being refurbished now

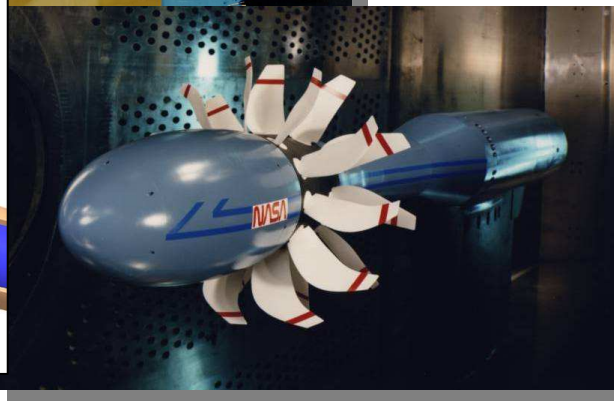
*Approach/Takeoff Testing
in NASA Glenn
9'x15' Wind Tunnel*



*Propulsion/Airframe
Integration Aerodynamics
Test in NASA Ames
11' Wind Tunnel*



*NASA Open Rotor Propulsion Rig,
Aft Pusher Configuration*



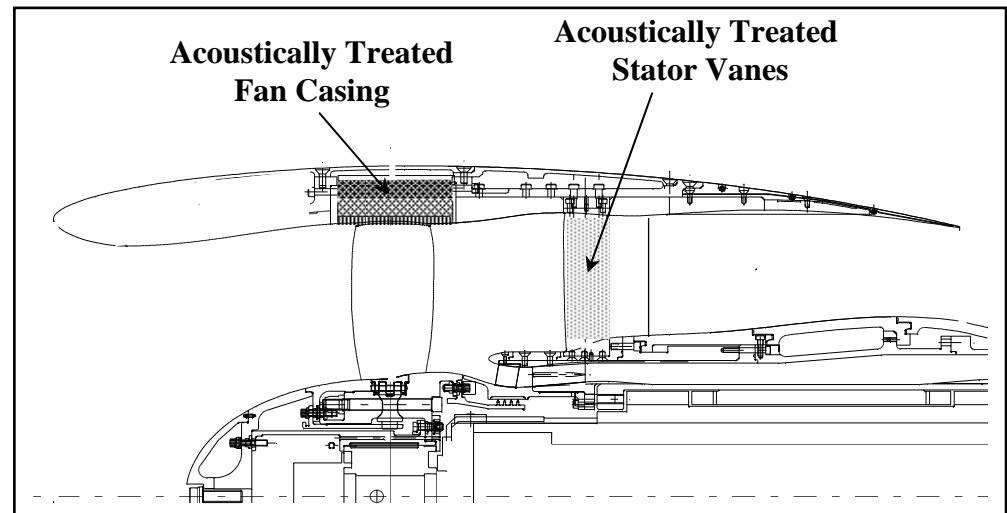
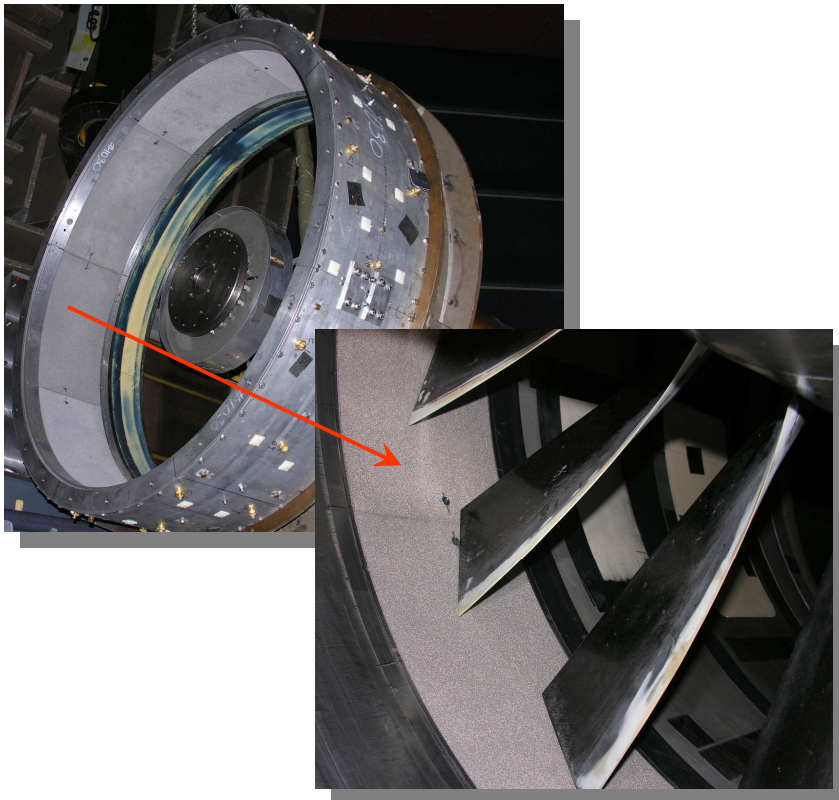
*Climb/Cruise Testing in
NASA Glenn 8'x6' Wind Tunnel*



Current Areas of Investigation Under SFW UHB

➤ Noise Reduction

- Acoustically Treated Fan Casing (“Over-The-Rotor”) – Foam metal behind porous rub strip
- Acoustically Treated Stator Vanes (“Soft Vanes”)



Over-The-Rotor and Soft Vanes designs in 22" Advanced Ducted Propulsor model

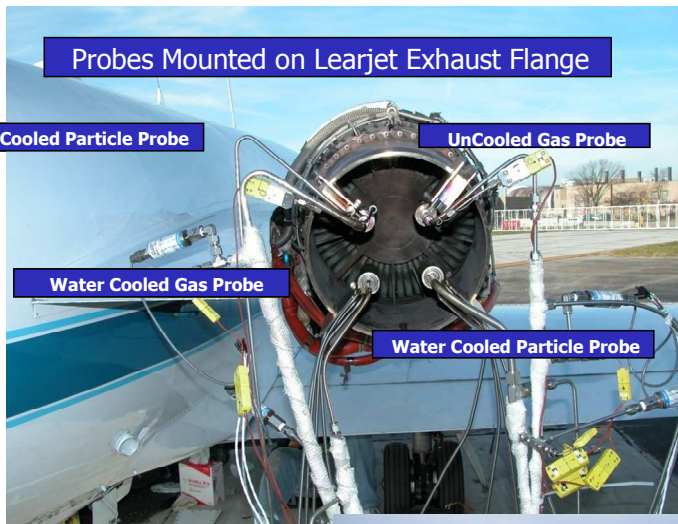
Over-The-Rotor Fan Casing Treatment Test in NASA Glenn Active Noise Control Facility (ANCF)



Current Areas of Investigation Under SFW UHB

➤ Emissions

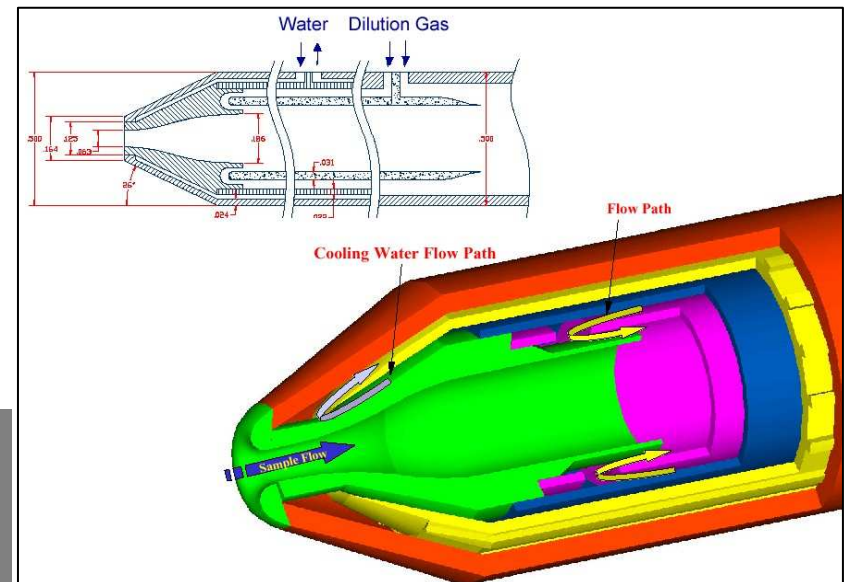
- Alternative Fuels
- Advanced Emissions Measurement Instrumentation Technology



**Gas & Particulate
Probe Design
Testing**



Probe Sample Line Evaluation



Advanced Particulate Probe Design



SFW UHB Partnership Element

- *While the challenges are big, establishing partnerships with Industry/OGA/Universities to exploit collaborative research opportunities will insure that the noise, emissions and performance goals of the SFW Project are successfully achieved*

Pratt & Whitney

An Overview of Recent Collaboration Research with NASA in Ultra High Bypass Engine Technology



Original Presentation at the
Fundamental Aeronautics 2007 Annual Meeting

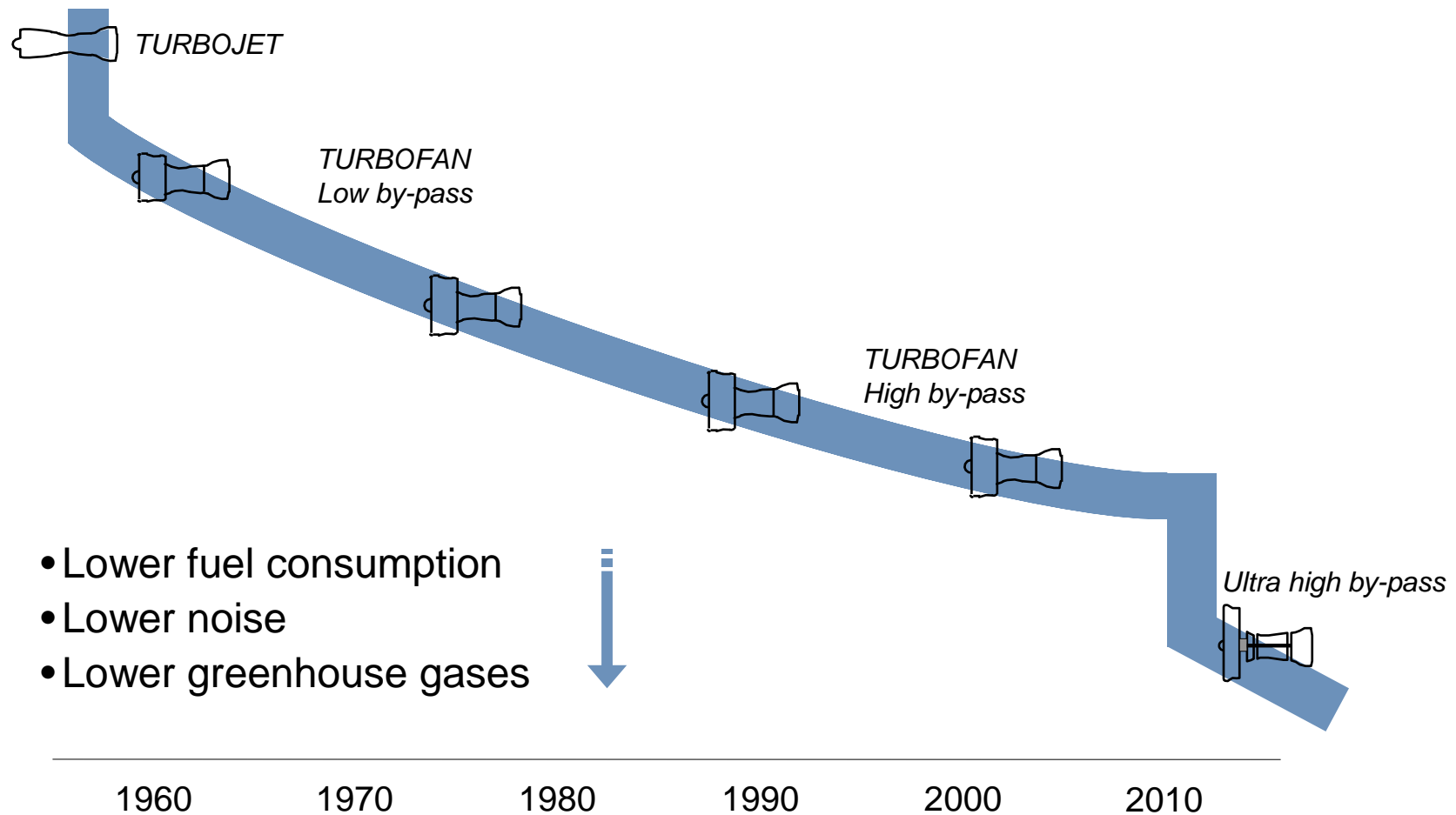
by

Jeff Schweitzer

Manager, Pratt & Whitney Advanced Commercial Engine Programs

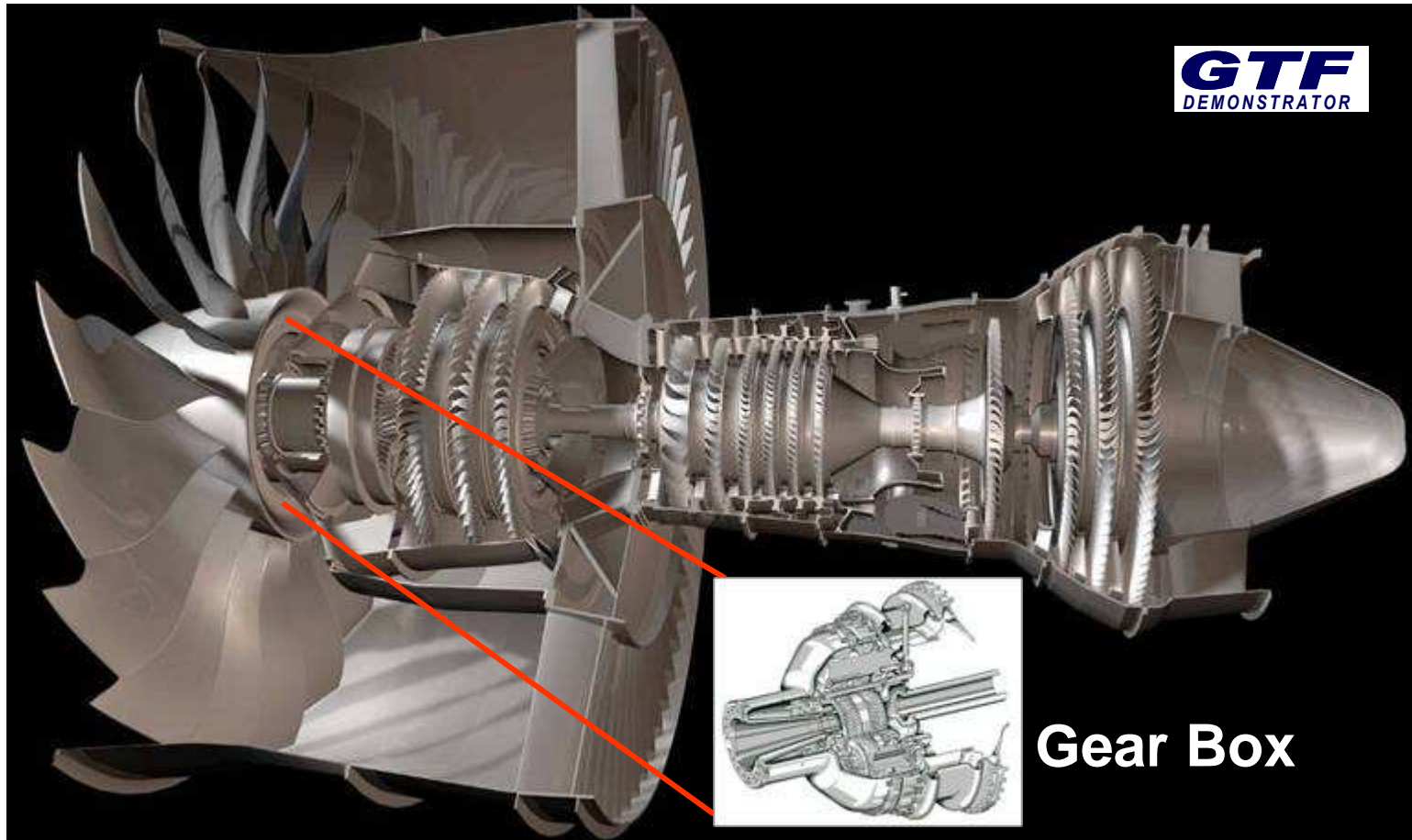
Ultra High Bypass Enables a Step-Change in Propulsion

Evolution in By-Pass Ratio



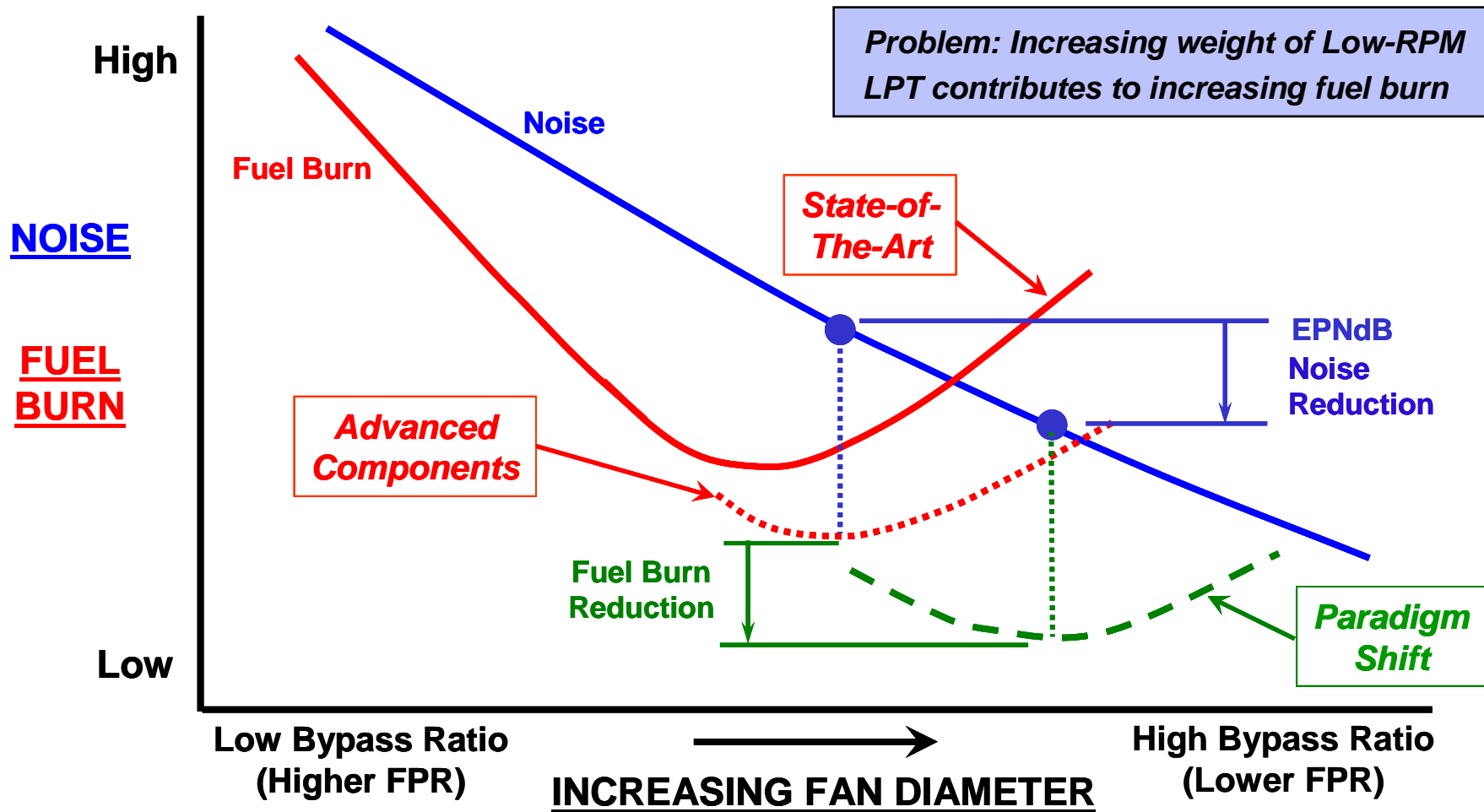
Pratt & Whitney Developing the GTF™

Geared Turbofan (GTF) Engine is Optimized Implementation of UHB



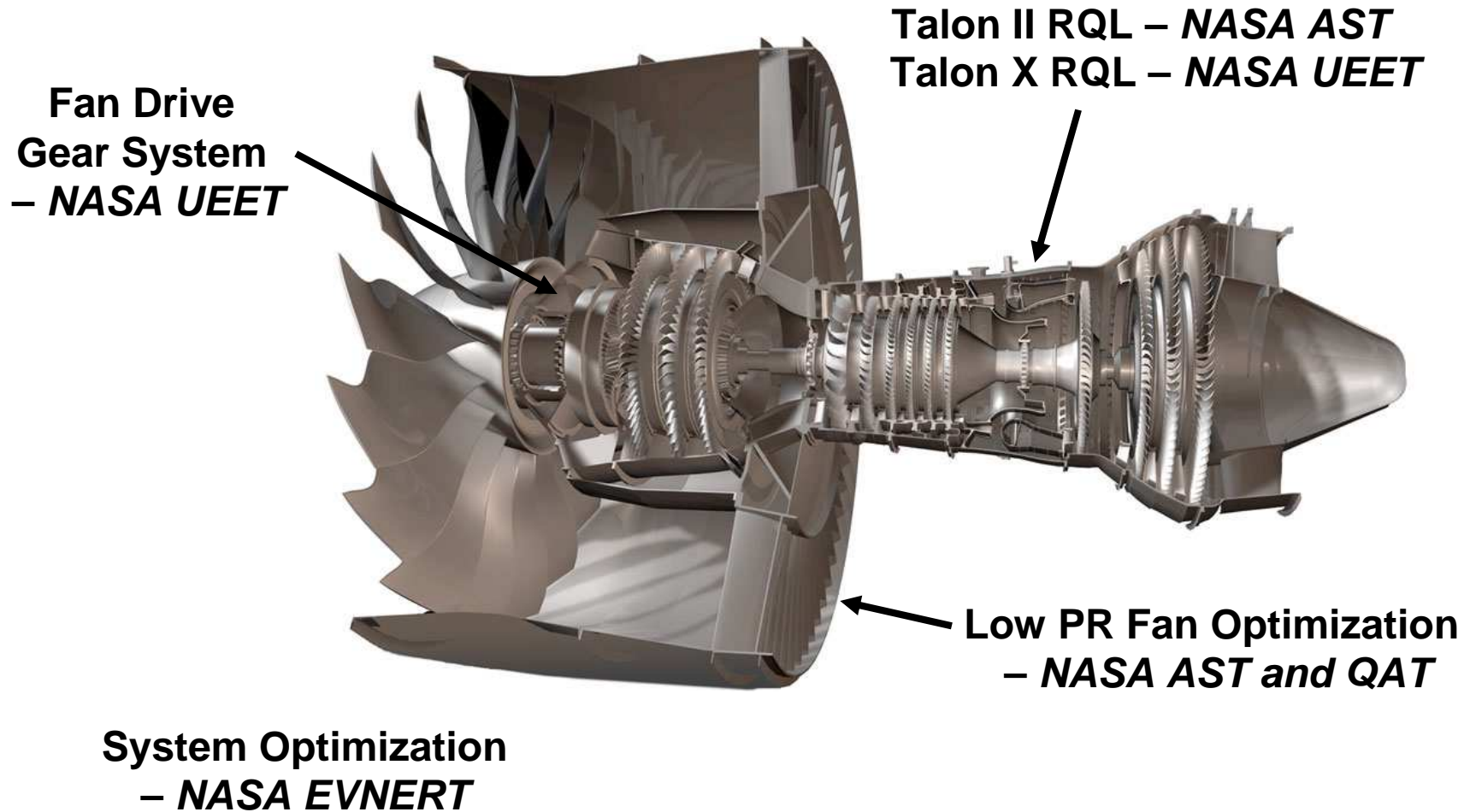
Fundamental Propulsion System Characteristic

GTF allows Paradigm Shift to Reduce Fuel Burn AND Noise



NASA-P&W History of Technology Development

Some Technology Highlights from NASA-P&W Programs



Subscale Rig Demonstrated UHB Fan Performance

Collaborative Test in NASA 9' x 15' Acoustic Wind Tunnel



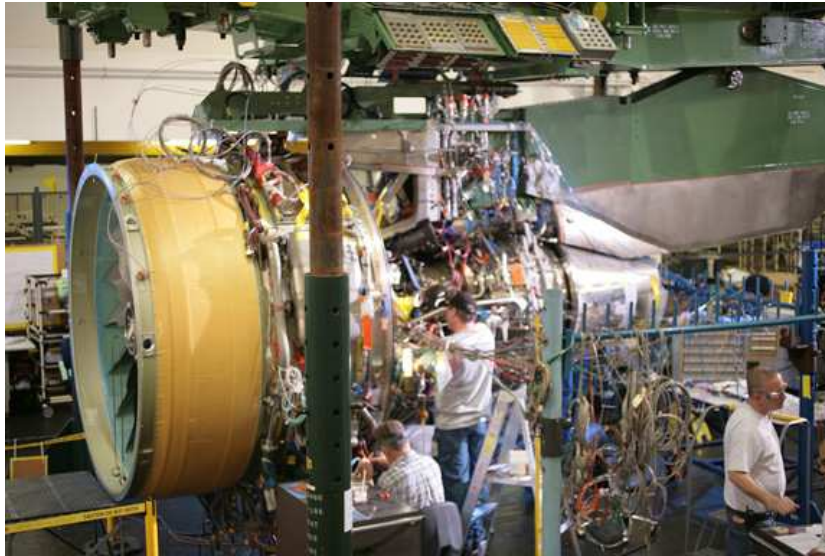
Pratt & Whitney Geared Turbofan Model in Glenn 9'x15' Wind Tunnel

- 22" Subscale Rig Demonstrated:
 - Noise reduction benefits of an advanced (UHB) cycle fan
 - Fan efficiency that exceeded predictions
 - Overall performance advantage of a low PR, low tip speed fan
 - High efficiency fan design translates into decreased noise

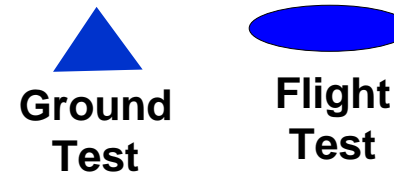
Rig test data used to define fan aerodynamics for GTF Engine Demo Test

Geared Turbofan™ Demonstrator Runs in 2007

Ground Test 2007-2008, Flight Test in 2008



On Track For 2007 Demonstration Testing



Intersection of NASA-P&W Goals

UHB Partnership Objectives from GTF Engine Demo Test

- Evaluate alternative fuels
 - Fischer-Tropsch fuel (50/50 blend)
 - Confirm reduced emissions (particulates)
 - Confirm specific fuel consumption
- Use data to confirm scalability to subscale model fan results. Validate:
 - NASA codes and systems
 - Reduced noise, higher efficiency



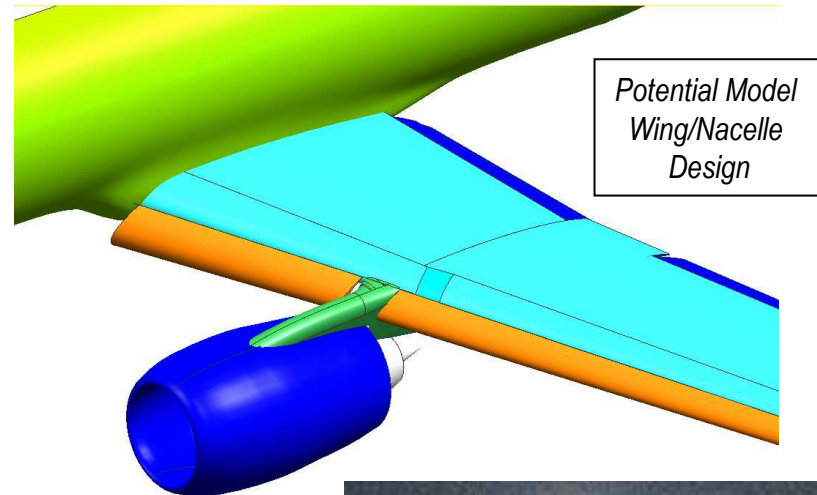
Exhaust Gas Sampling Probes

Collaborative Alternative Fuels test successfully completed February 2008 at P&W Florida facility

UHB Propulsion Integration Study

Wing Interaction Study for UHB Engine Installation

- Large diameter UHB nacelle
- Realistic HB engine simulation
- Drag minimization
- Low PR fan/nozzle installation aerodynamics
- NASA Multi-Disciplinary Analysis and Optimization verification



8.6" Fan Simulator



Collaborative model test
planned for May 2008 at
NASA Ames 11' Wind Tunnel

P&W Transitioning Technologies Today

Products with a Step Change in Environmental Performance



Summary

GTF Activities at P&W Align with many NASA UHB Goals

- NASA-P&W: Tradition of technology successes
- EVNERT and 22" GTF Fan Rig Test demonstrated UHB concepts
- UHB Partnership collaboration opportunities for 2008 and beyond identified
- Anticipate continued collaboration with NASA on research challenges in aeronautics



SFW UHB Partnership Element

Questions