



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

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Subsonic Fixed Wing Project*



SFW UHB Partnership Element

➤ Objective

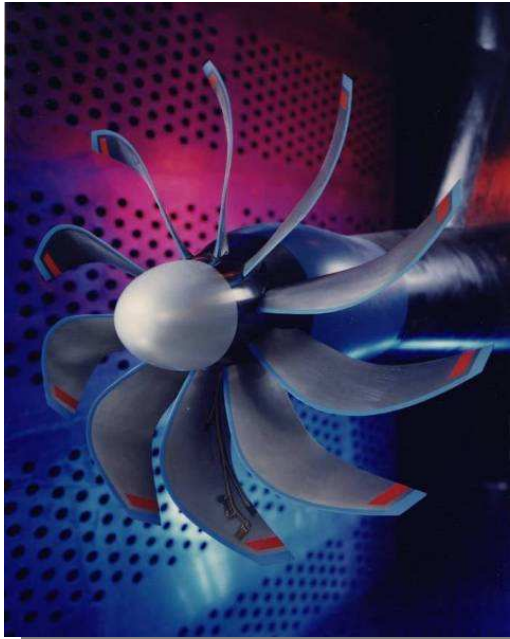
- Develop noise reduction, emission reduction and performance improvement technologies for the Ultra High Bypass engine cycle, then demonstrate and validate their potential in full scale applications
- NASA has a strong history of aircraft propulsion improvement technology development with Industry Partners



Strong History of Technology Development

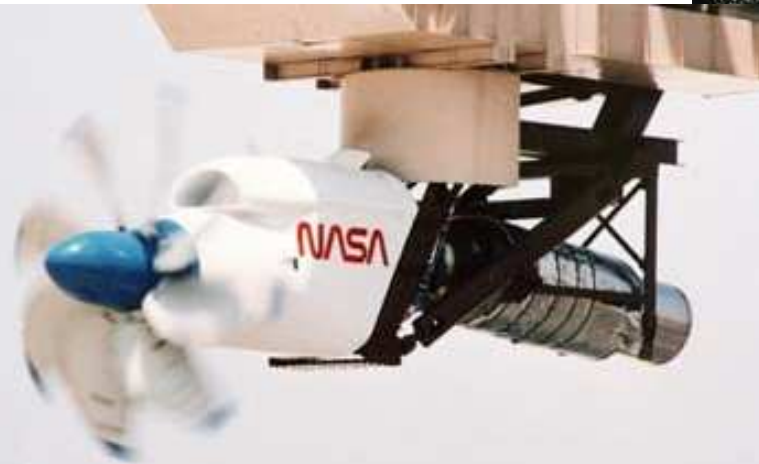
➤ 1970s

- 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*



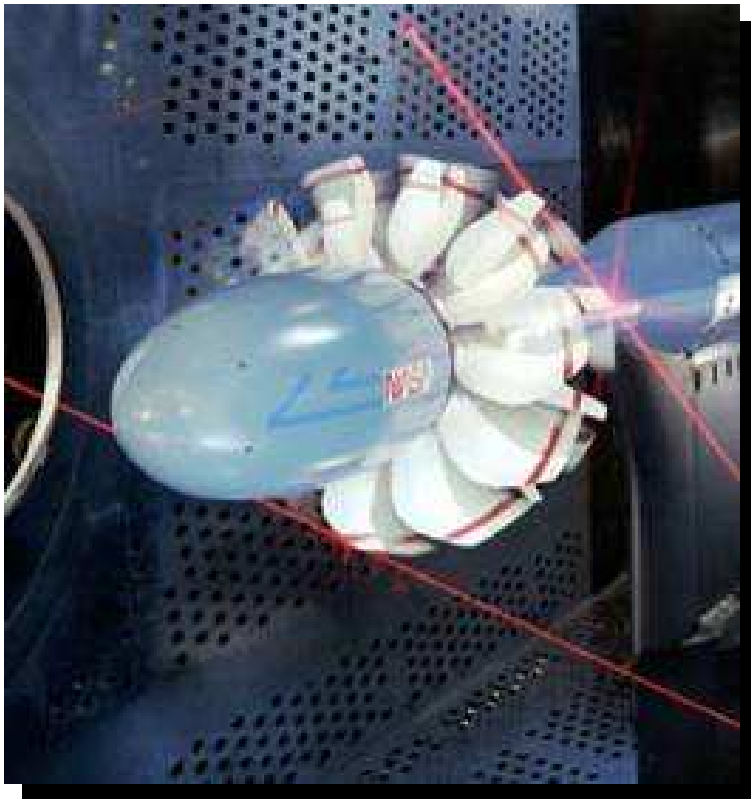
Propeller Test Assessment Aircraft Demo



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*



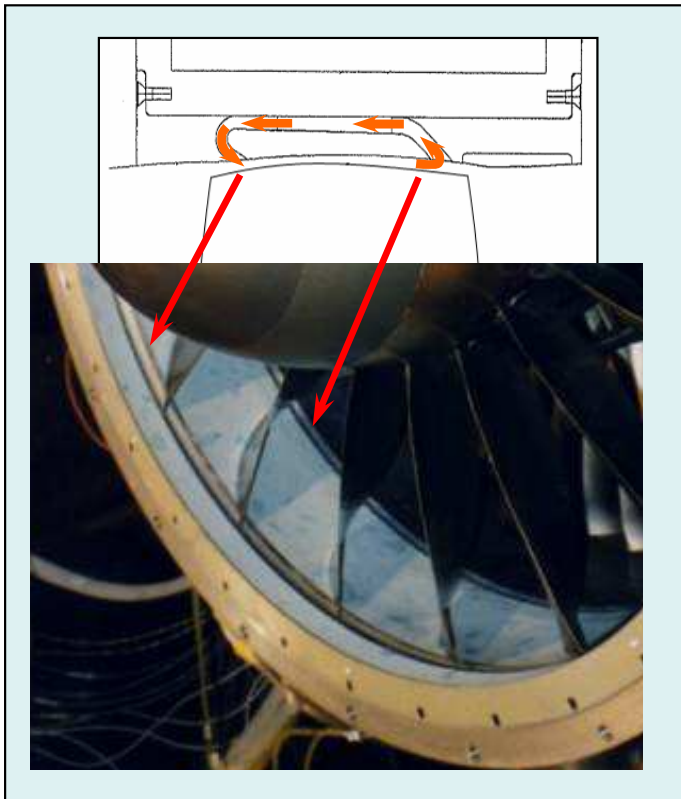


Strong History of Technology Development

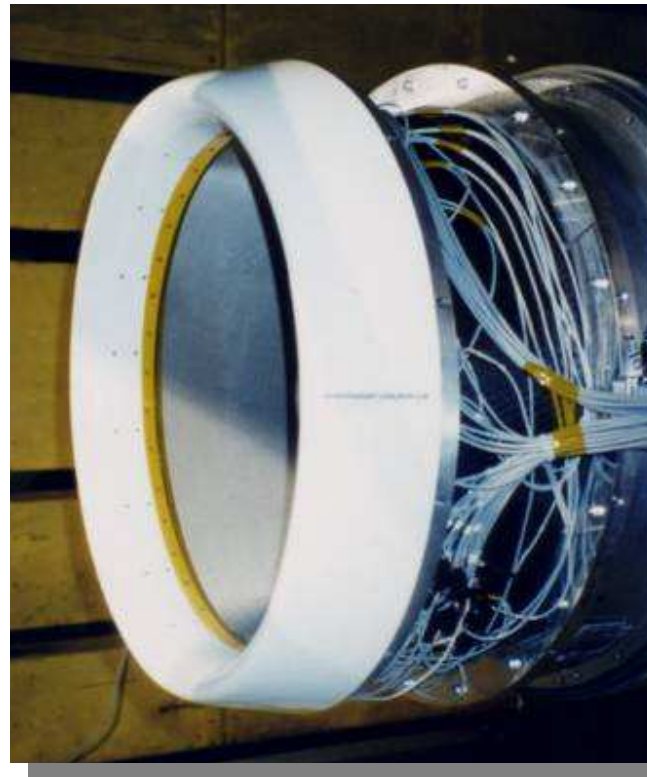
➤ 1990s

- Advanced noise reduction technologies for turbofans

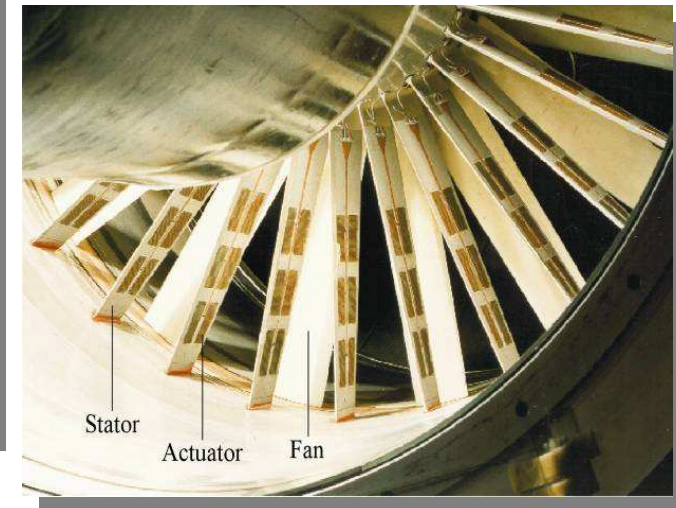
- Fan blade tip flow management (P&W)



- 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



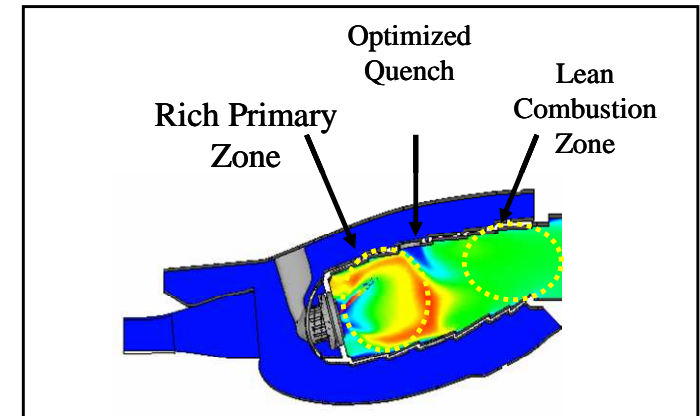
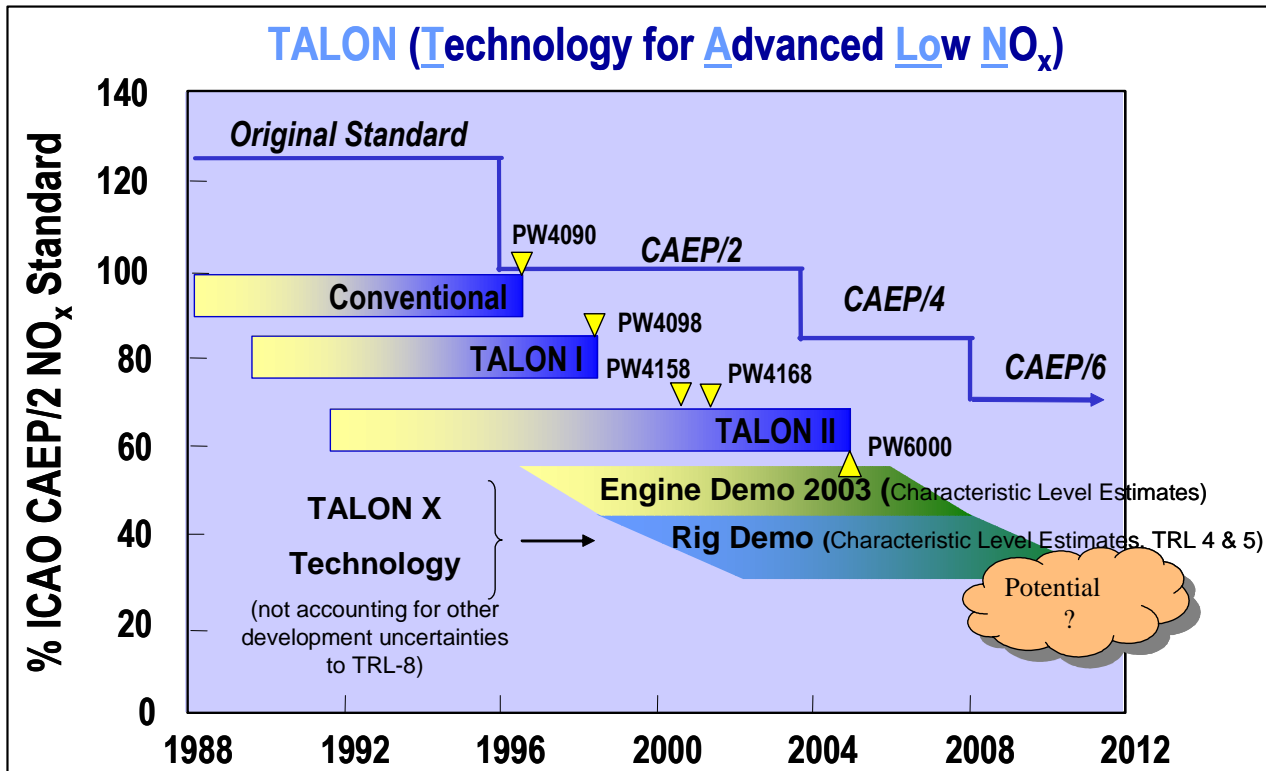
Swept & leaned stators



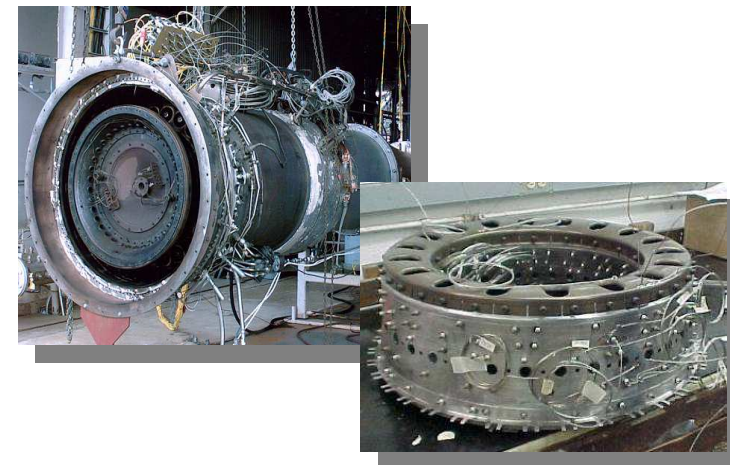
Strong History of Technology Development

➤ 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

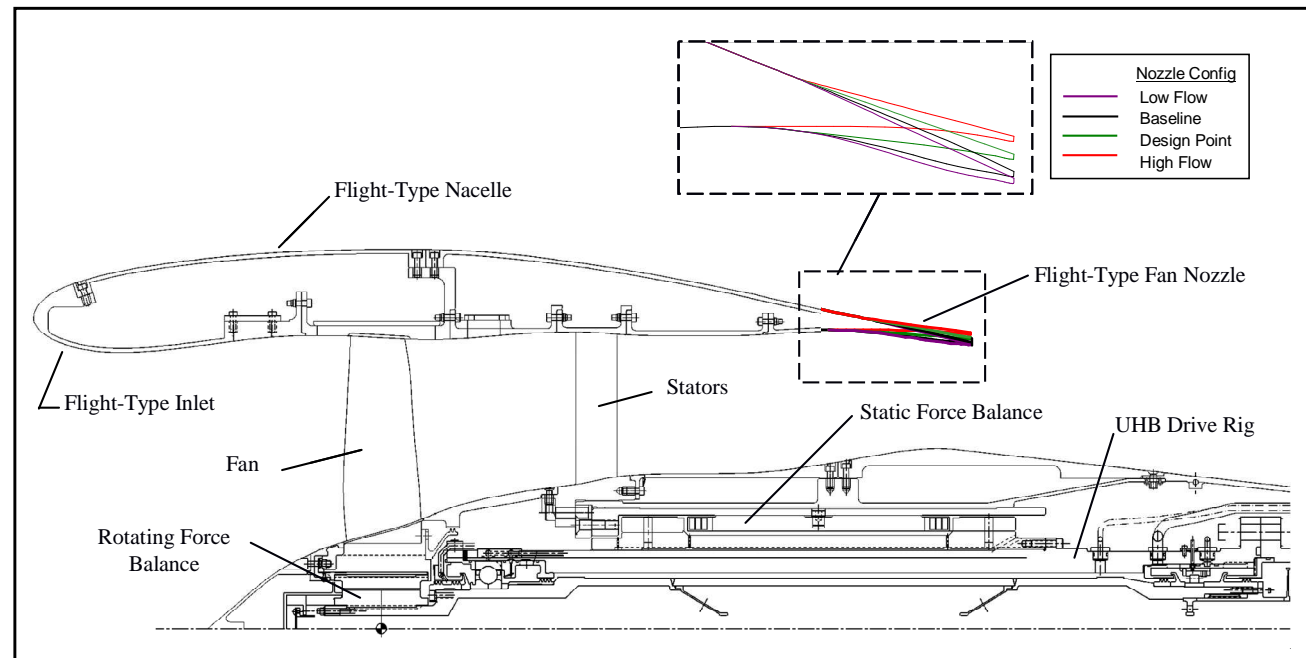
➤ 2000s

- Advanced noise reduction technologies for turbofans

— Highly forward swept fan blade (Honeywell)



— Variable Area Fan Nozzle (NASA)

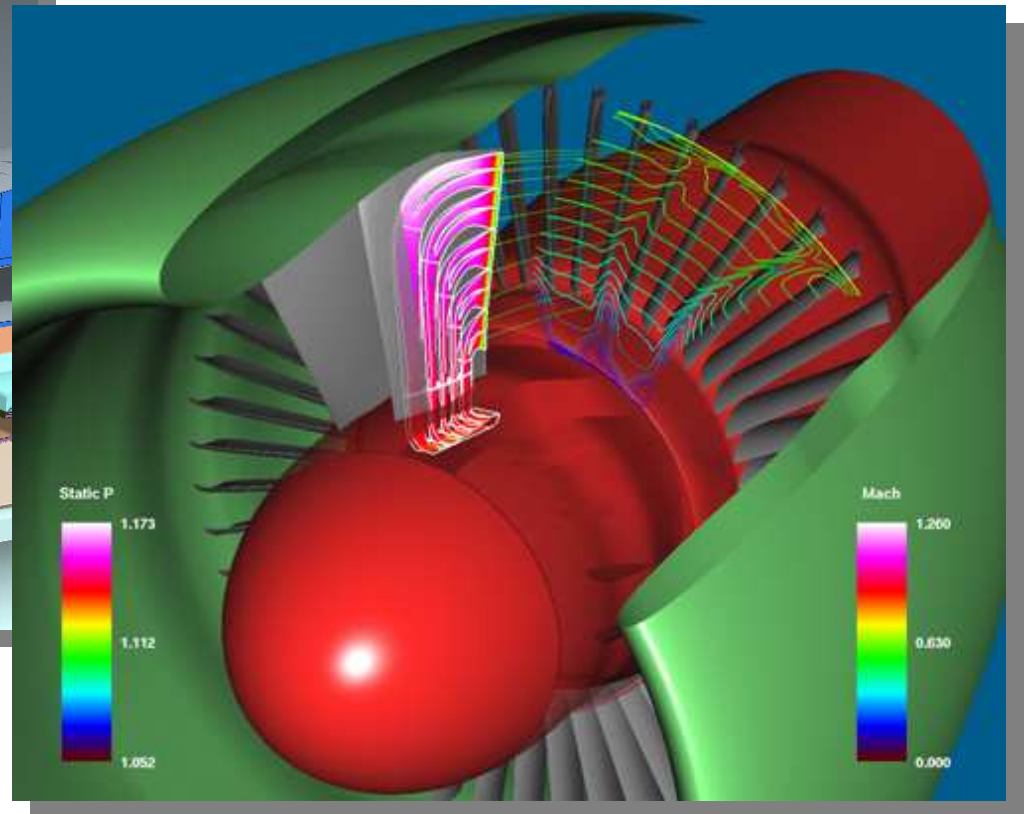
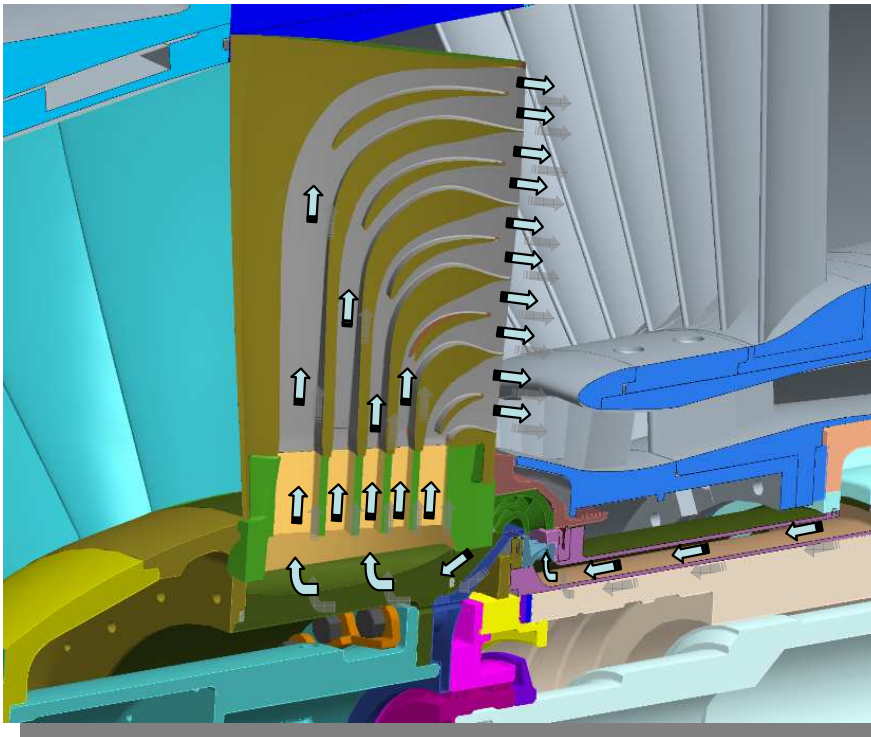




Strong History of Technology Development

➤ 2000s

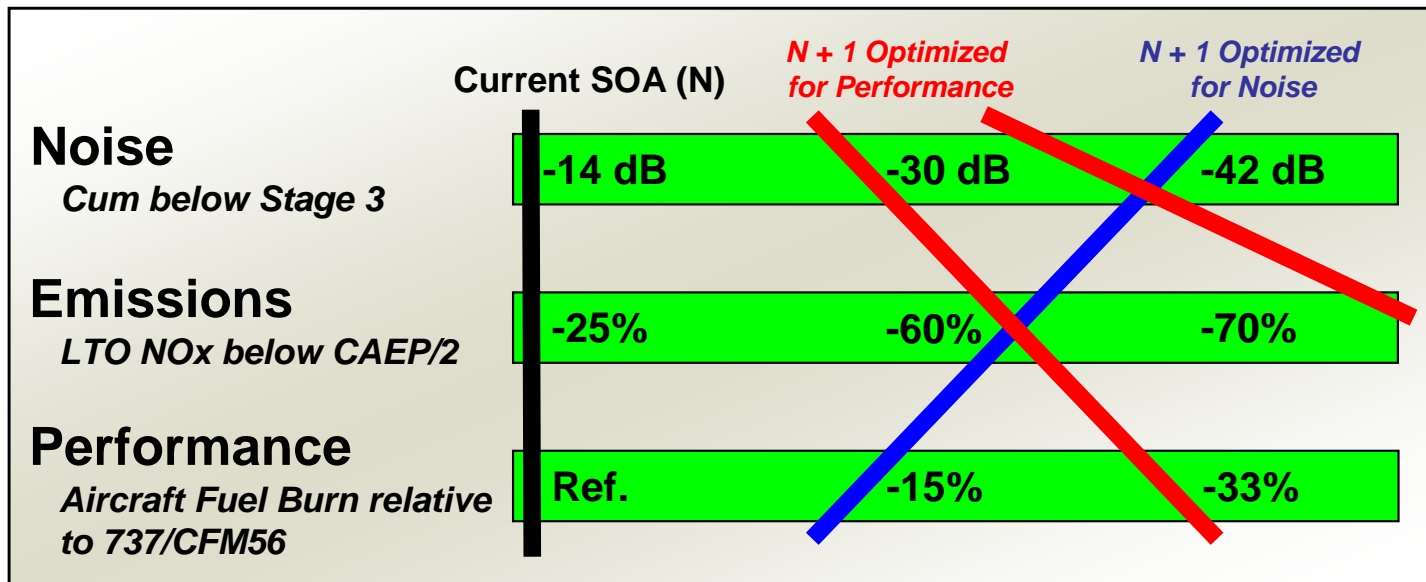
- Advanced noise reduction technologies for turbofans
 - Fan trailing edge blowing (NASA)





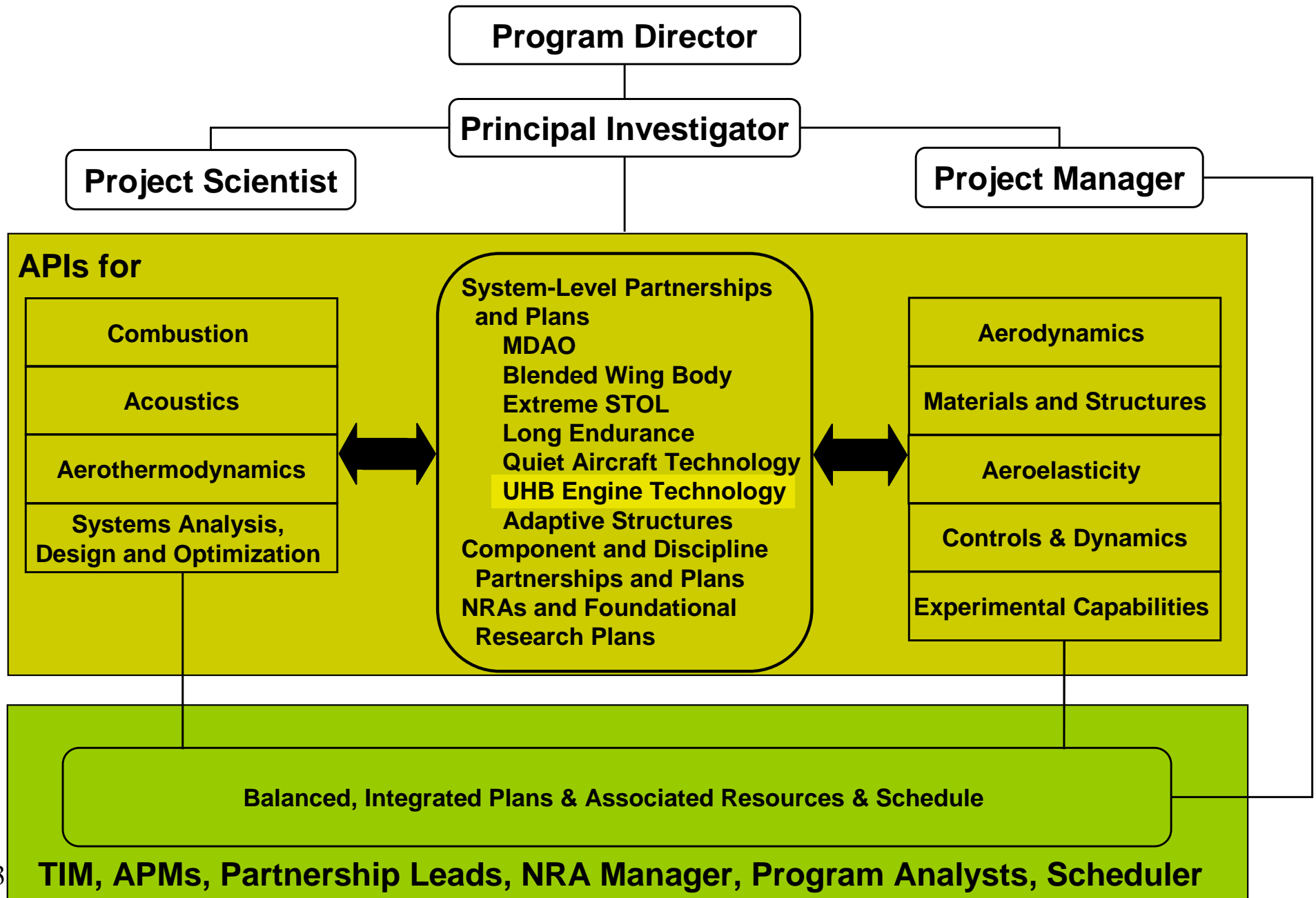
Today's Challenges

- 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



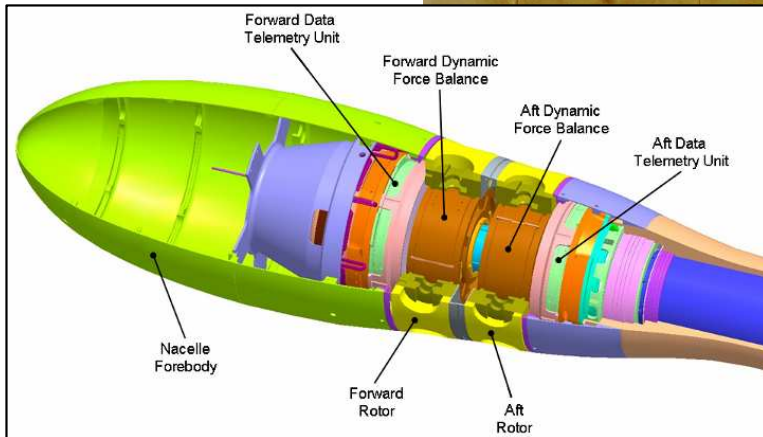
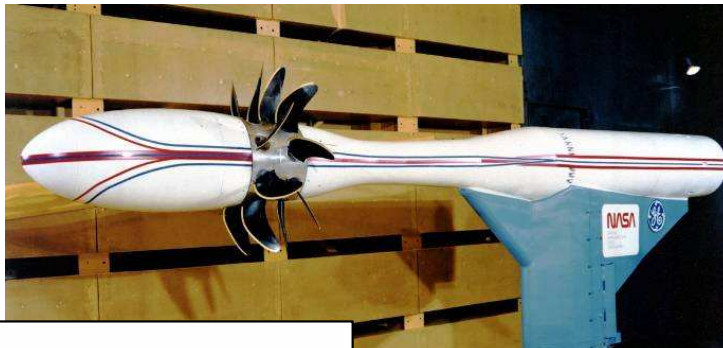


Current Areas of Investigation Under SFW UHB

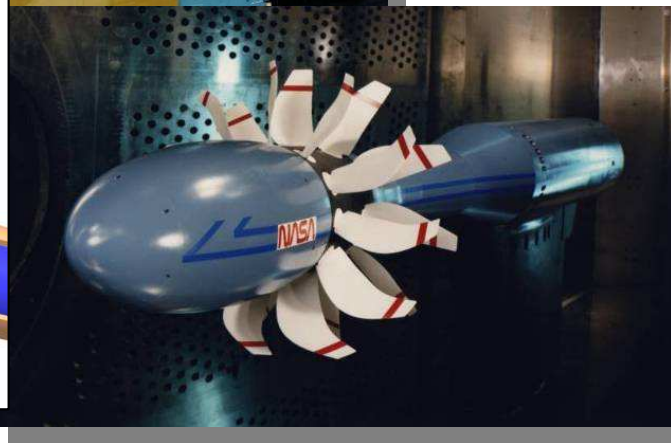
➤ Performance

- 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*



*NASA Open Rotor Propulsion Rig,
Aft Pusher Configuration*



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



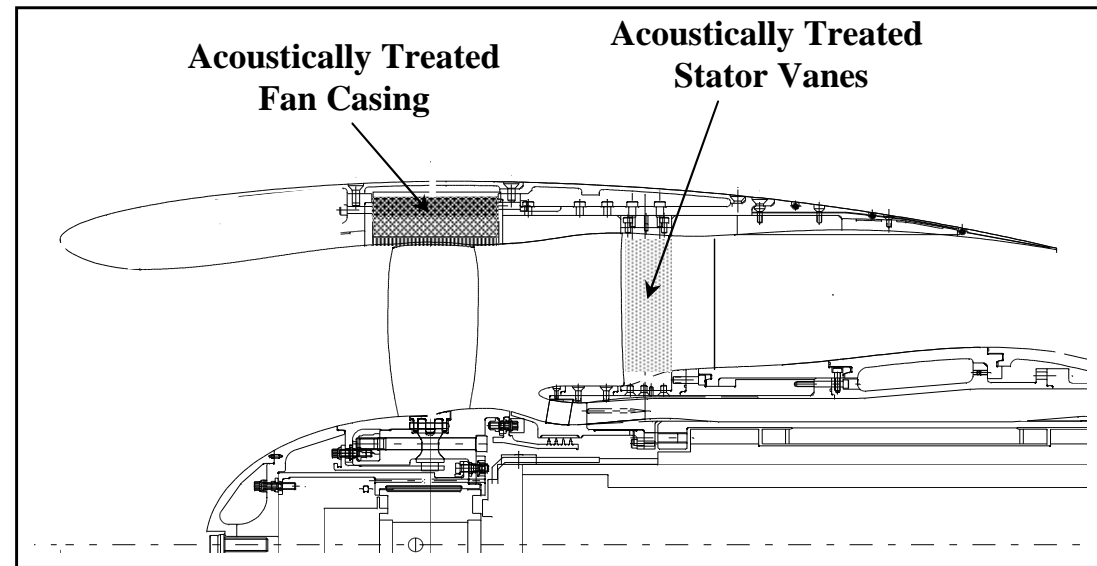
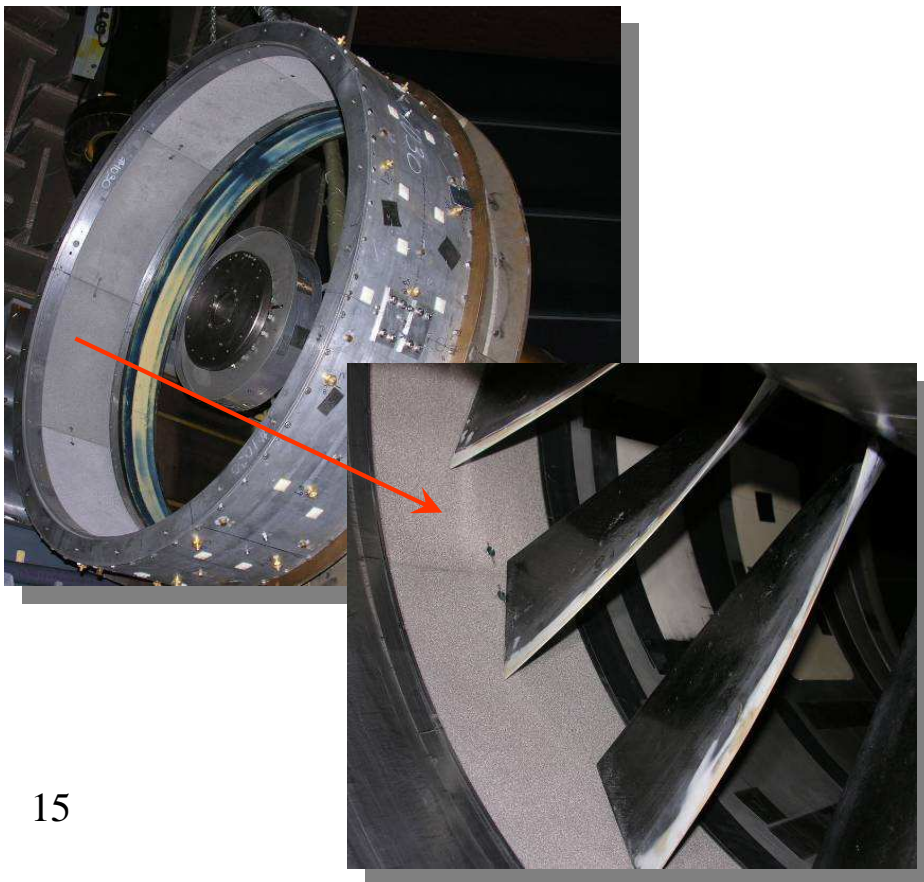
*Propulsion/Airframe
Integration Aerodynamics
Test in NASA Ames
11' Wind Tunnel*



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

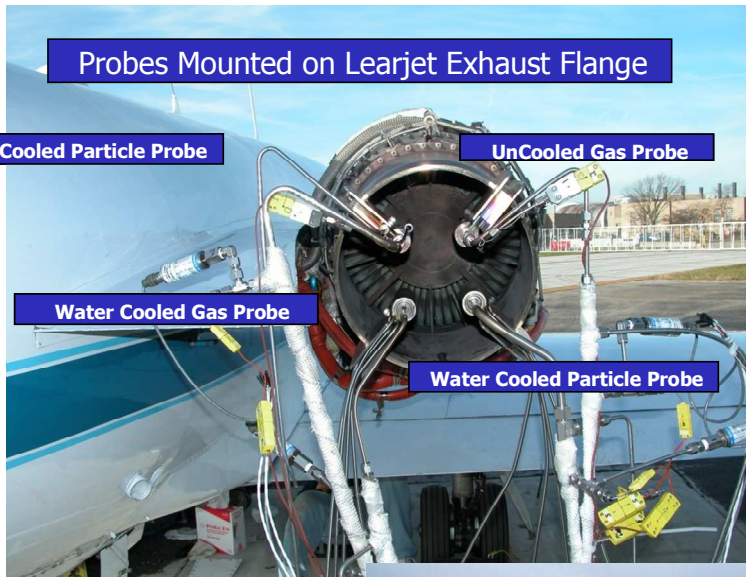
Over-The-Rotor Fan Casing Treatment Test in NASA Glenn Active Noise Control Facility (ANCF)



Current Areas of Investigation Under SFW UHB

➤ Emissions

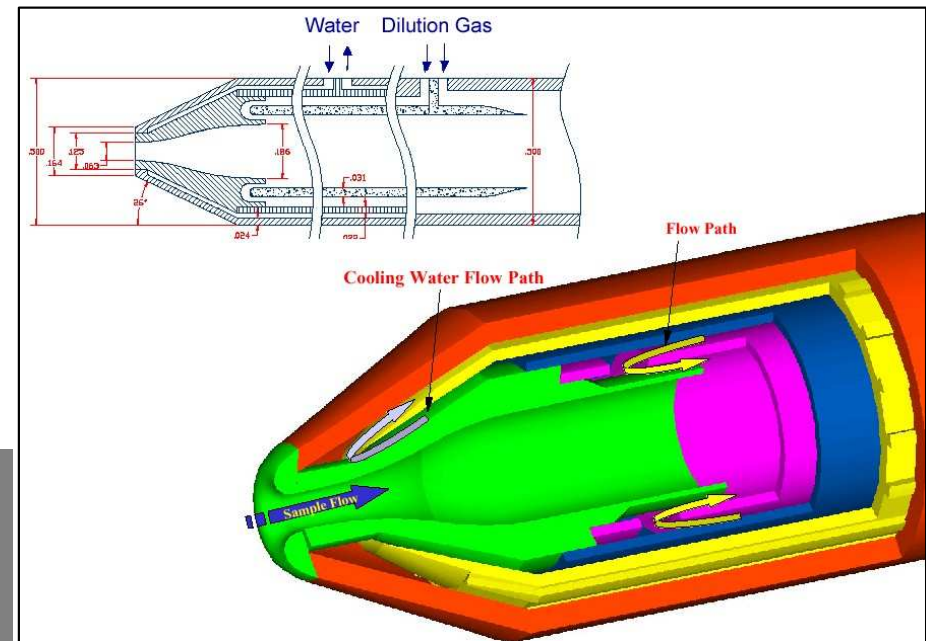
- Alternative Fuels
- Advanced Emissions Measurement Instrumentation Technology



Gas & Particulate Probe Design Testing



Probe Sample Line Evaluation



Advanced Particulate Probe Design

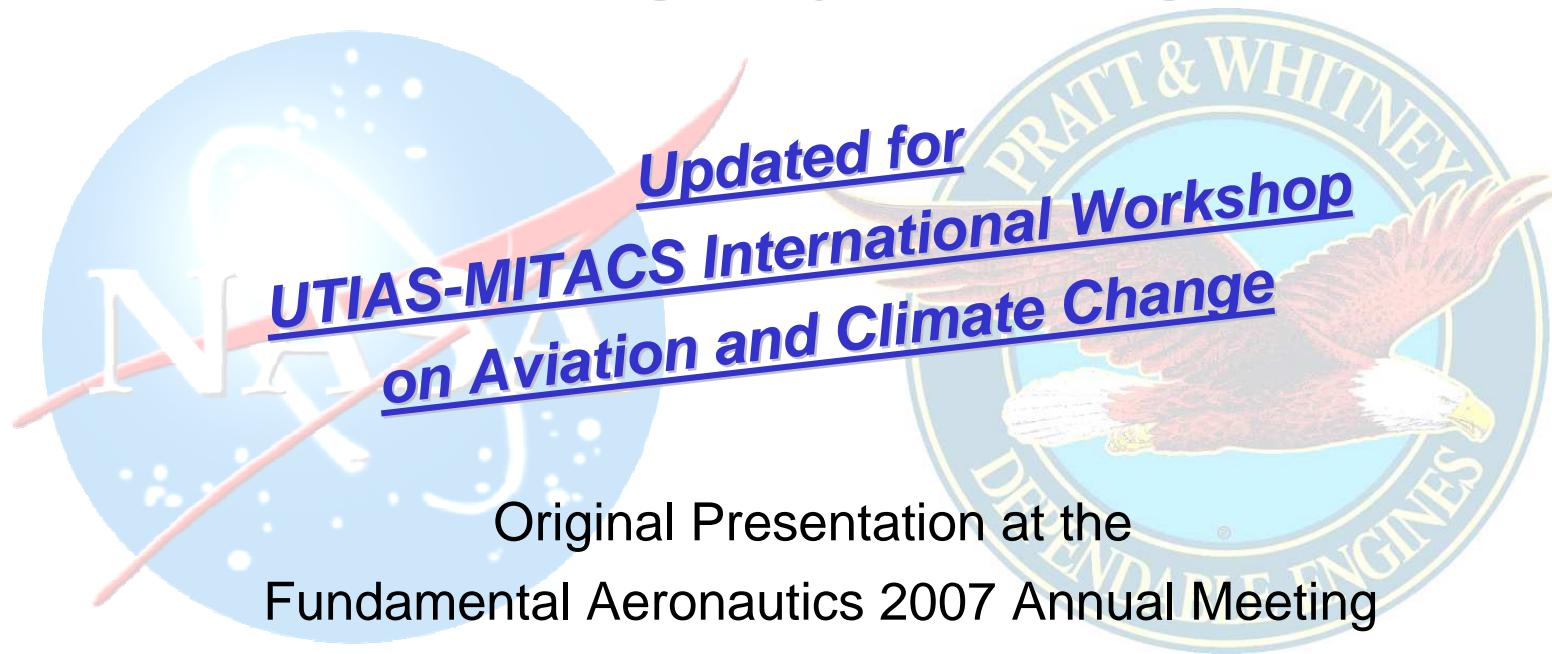


SFW UHB Partnership Element

- *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



Updated for
UTIAS-MITACS International Workshop
on Aviation and Climate Change

Original Presentation at the
Fundamental Aeronautics 2007 Annual Meeting

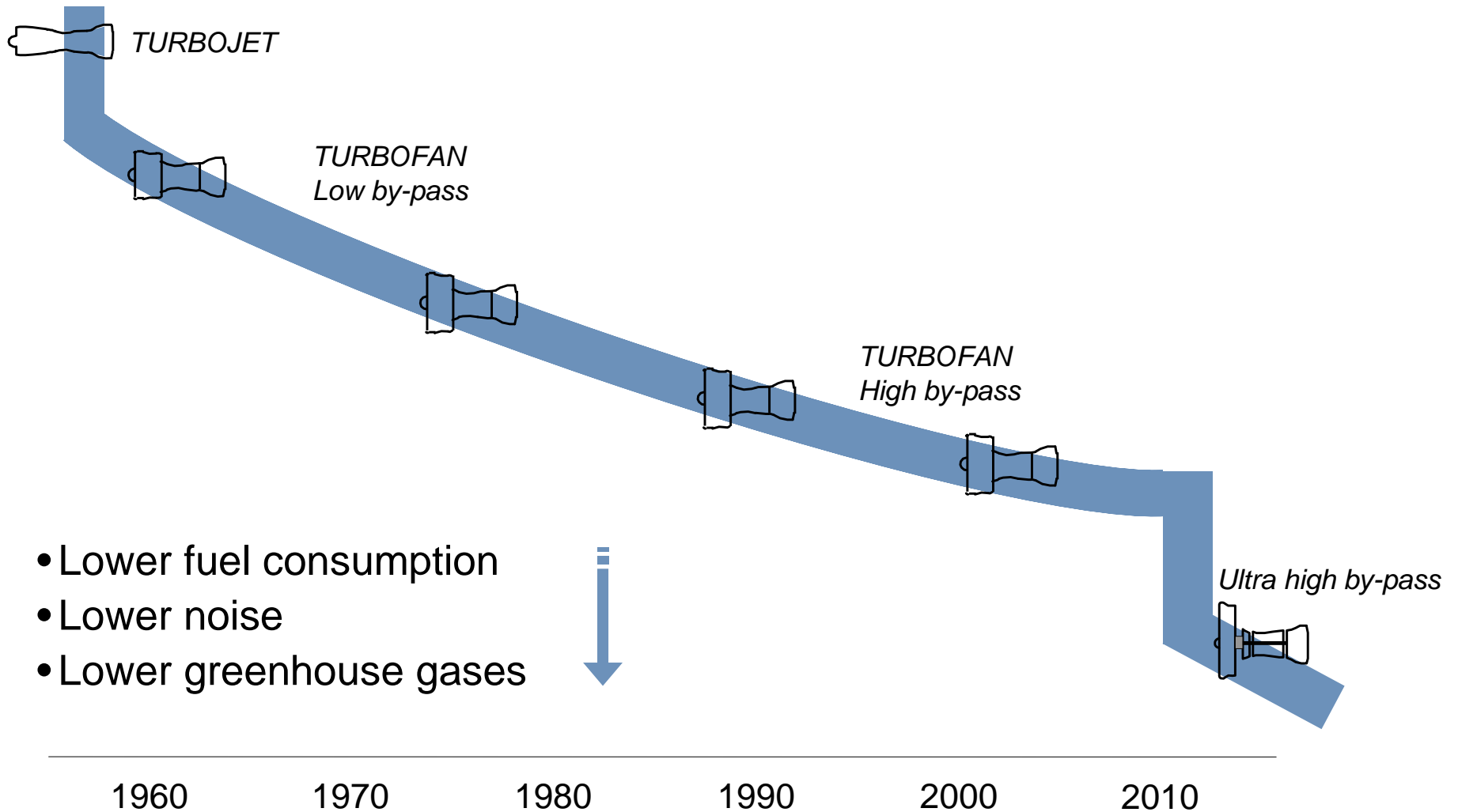
by

Jeff Schweitzer

Manager, Pratt & Whitney Advanced Commercial Engine Programs

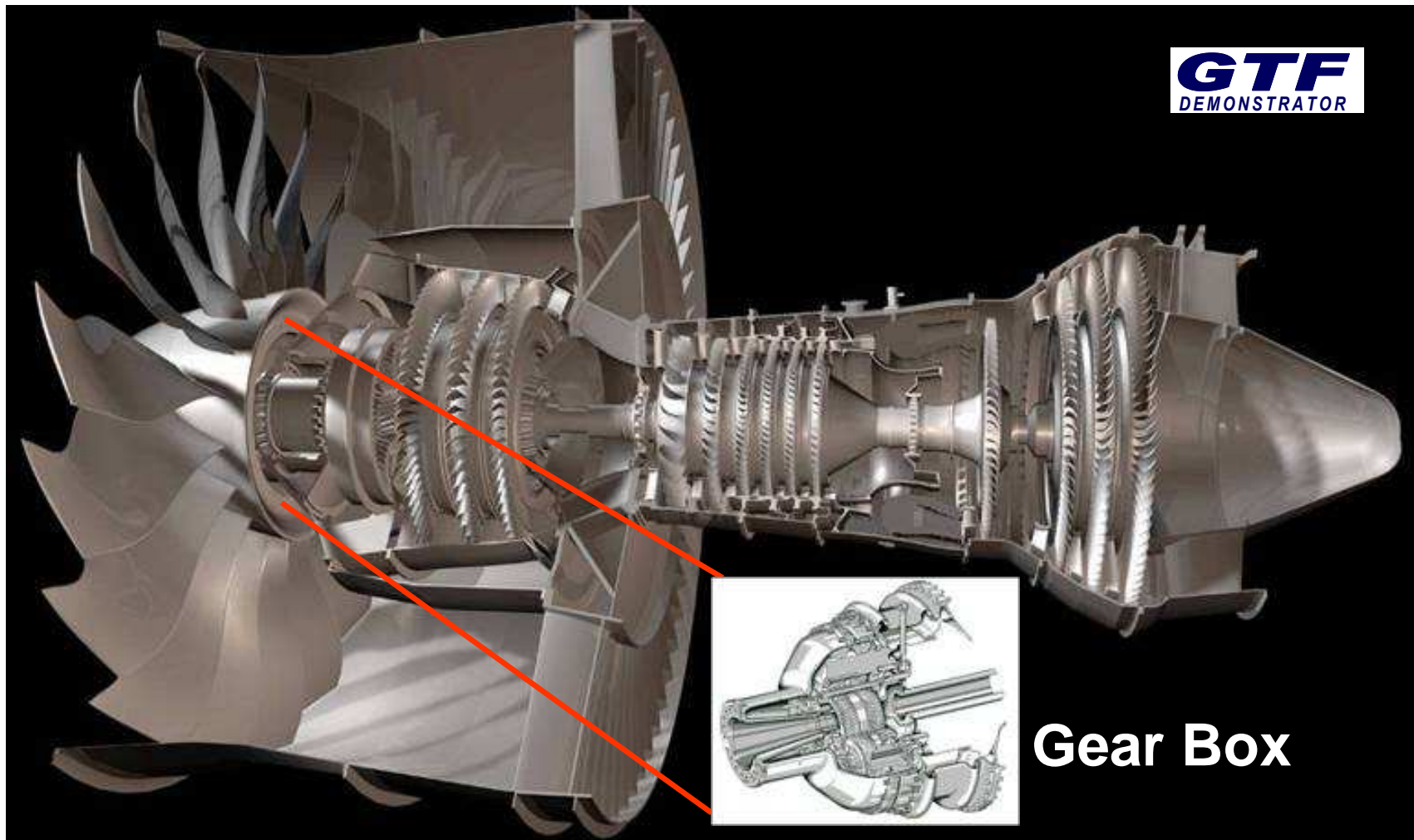
Ultra High Bypass Enables a Step-Change in Propulsion

Evolution in By-Pass Ratio



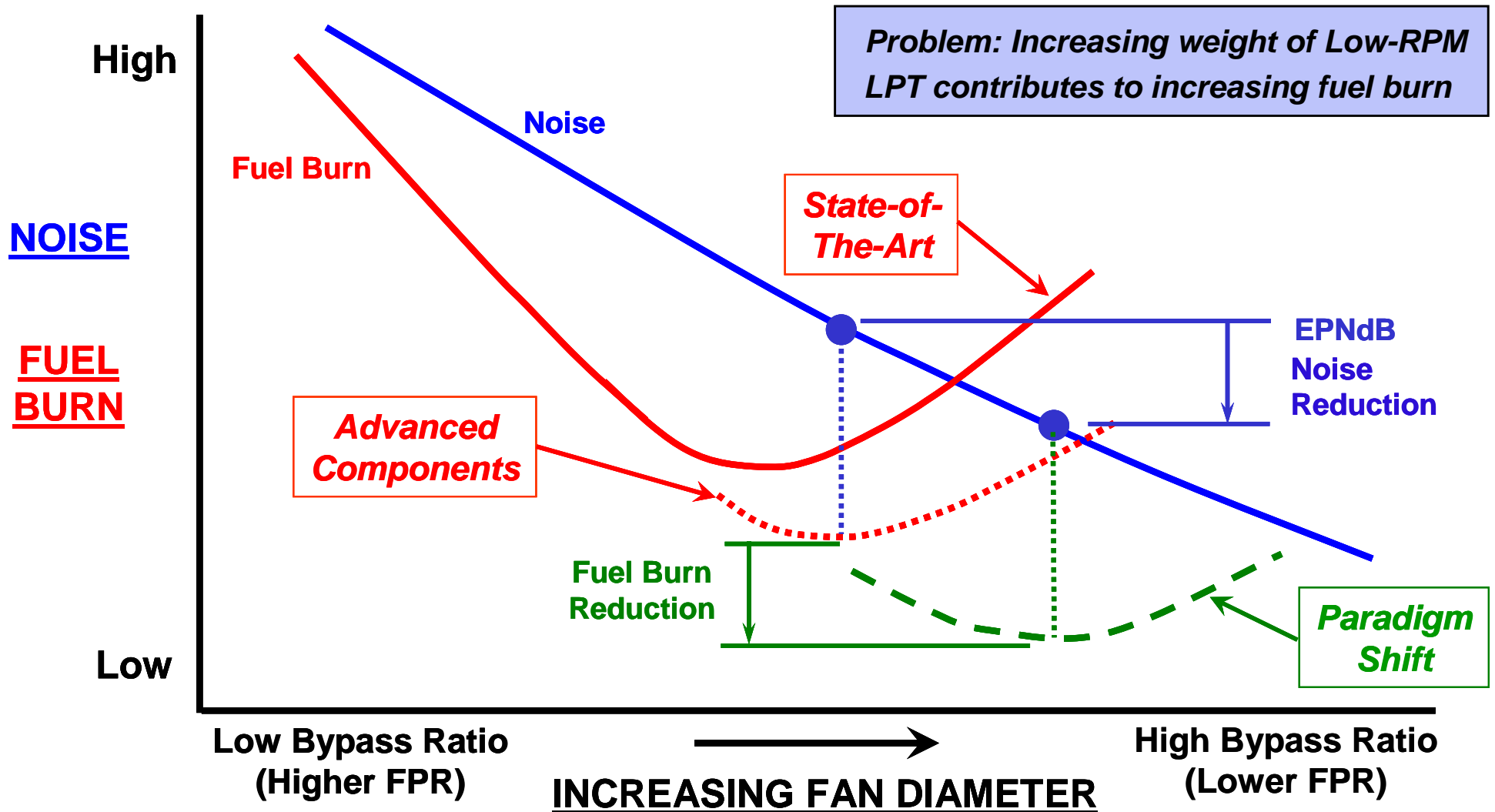
Pratt & Whitney Developing the GTF™

Geared Turbofan (GTF) Engine is Optimized Implementation of UHB



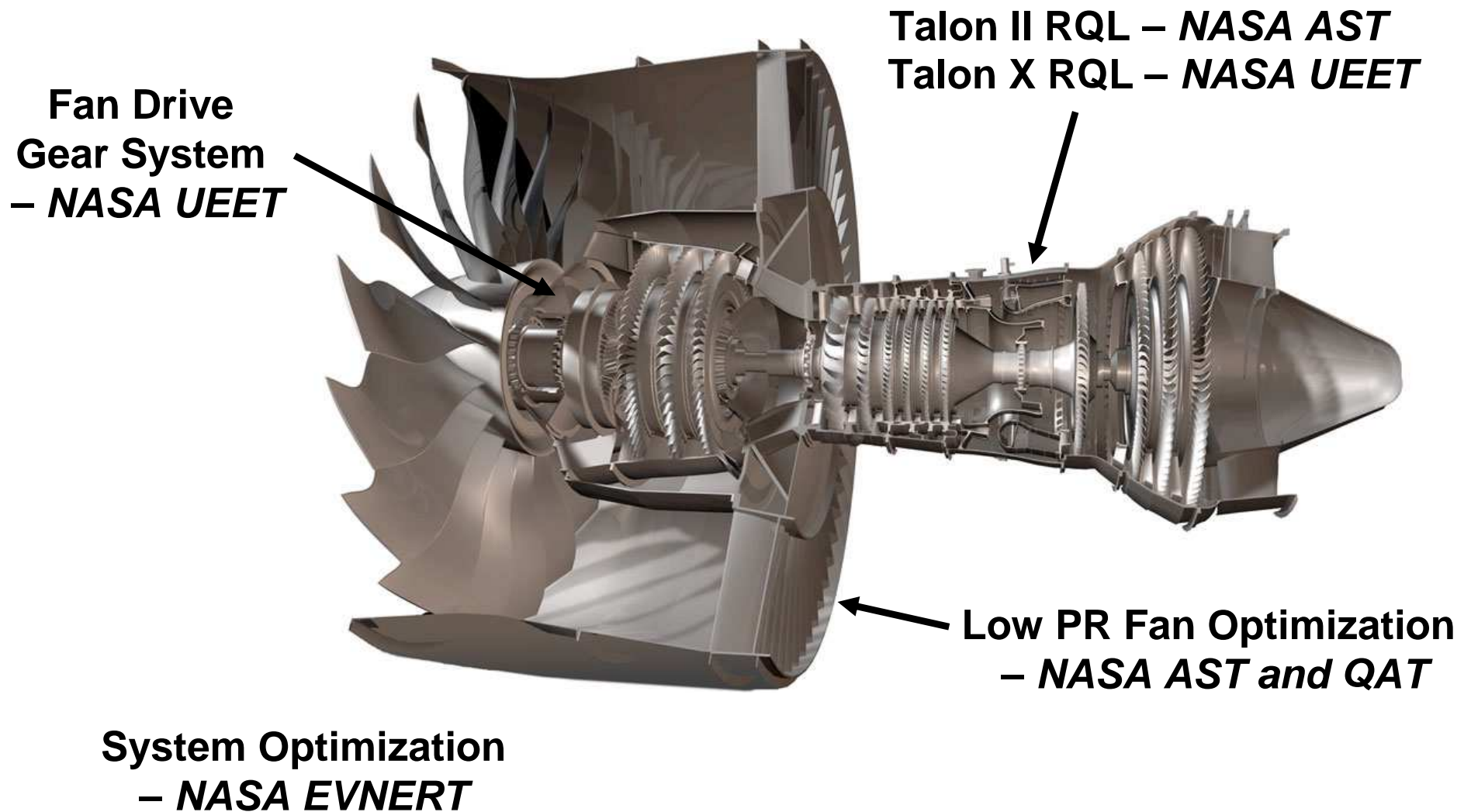
Fundamental Propulsion System Characteristic

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

P&W Ground Test 2007-2008, Flight Test in 2008

- **Phase 1 Ground Test Complete**
 - Engine performance on target
 - Excellent Fan Drive Gear System results
- **Phase 2 Ground Test begun April 2008**
 - Verification of complete flight configuration
- **Flight test in 3Q 2008 using P&W Flying Test Bed aircraft**



Intersection of NASA-P&W Goals

GTF 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



GTF Demo Engine in West Palm Beach

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

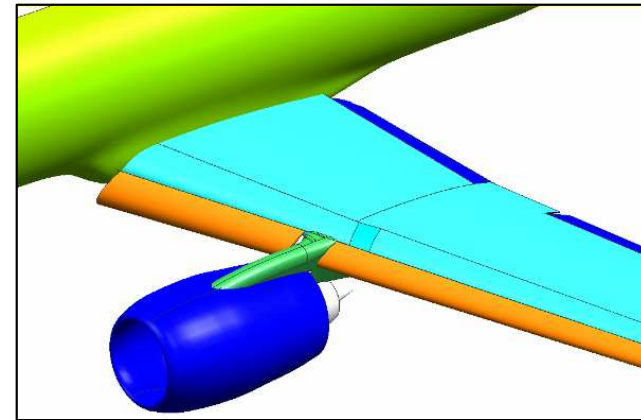


Exhaust Gas Sampling Probes

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



Wing/Nacelle Model

8.6" Fan Simulator

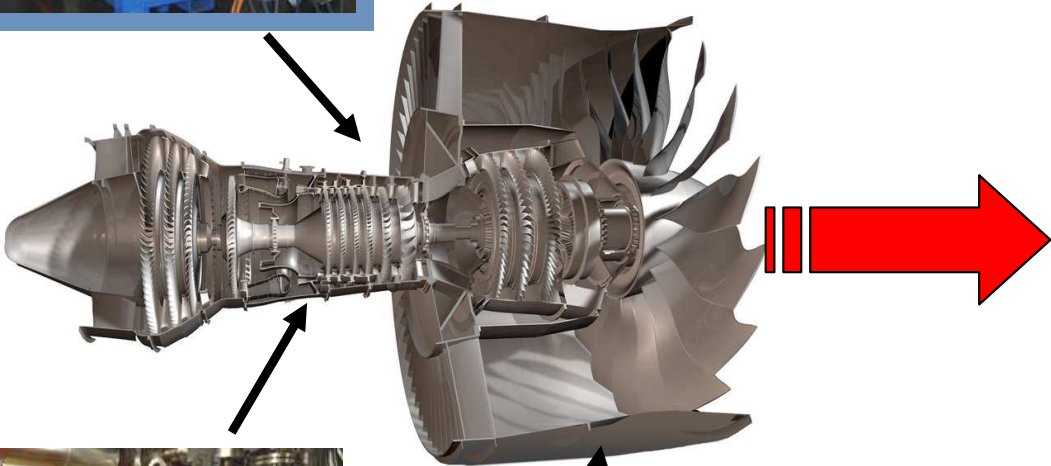


Wing/Nacelle Test Hardware in Ames 11'

Collaborative model test
begun in May 2008 at NASA
Ames 11' Wind Tunnel

P&W Transitioning Technologies Today

Products with a Step Change in Environmental Performance



Mitsubishi Regional Jet (MRJ)



Bombardier CSeries

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