NASA / Pratt & Whitney Collaborative Partnership Research in Ultra High Bypass Cycle Propulsion Concepts

Abstract

Current collaborative research with Pratt & Whitney on Ultra High Bypass Engine Cycle noise, performance and emissions improvements 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. Progress toward achieving the Subsonic Fixed Wing Project goals over the 2008 fiscal year by the UHB Partnership in this area of research are reviewed. The current research activity in Ultra High Bypass Engine Cycle technology, specifically the Pratt & Whitney Geared Turbofan, at NASA and Pratt & Whitney are discussed including the contributions each entity bring toward the research project, and technical plans and objectives. Pratt & Whitney Geared Turbofan current and future technology and business plans are also discussed, including the role the NASA SFW UHB partnership plays toward achieving those goals.

NASA / Pratt & Whitney Collaborative Partnership Research in Ultra High Bypass Cycle Propulsion Concepts

Chris Hughes
Subsonic Fixed Wing Project

Wes Lord
Siamak Masoudi
Pratt & Whitney

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

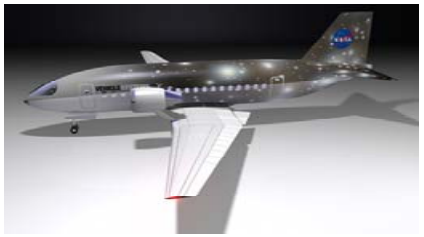
NASA / P&W UHB Partnership Research

- 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

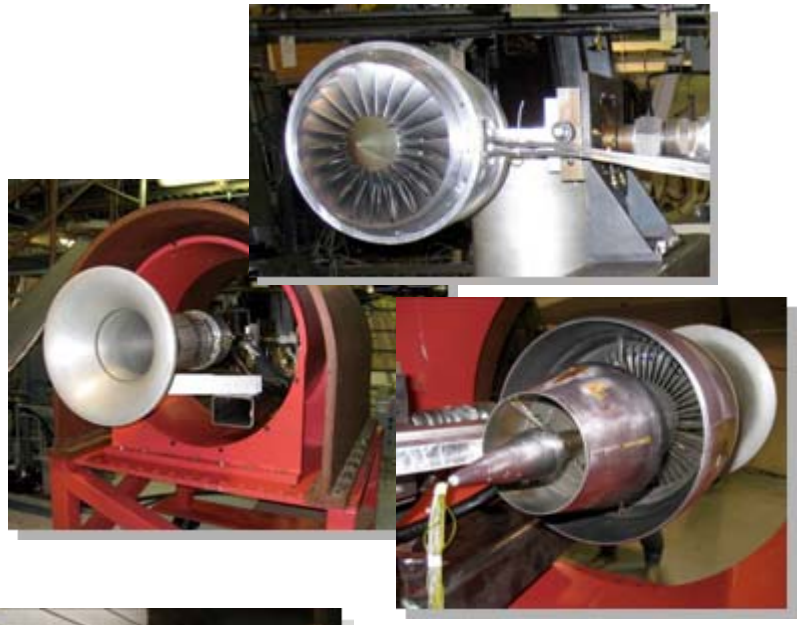
N+3 Generation

?

NASA / P&W UHB Partnership Research

➢ *2008 Highlights*

- P&W / NASA Nacelle/Wing Interaction Test
  - Highly successful collaboration between Government / Industry Partners and three NASA centers
  - Entire test schedule, from first coordination meeting to final test run, performed in just 11 months; less than half the time normally allotted
  - Effort included design and fabrication of completely new half-span model
  - 8.9” turbine powered simulator (TPS) manufactured in 1994 completely refurbished including new control system, quality tested and performance fan mapped with five different fan nozzles of varying area
  - Test data provided confidence in design for nacelle-wing integration at BPR = 12



TPS model testing at Glenn 8’x6’ wind tunnel

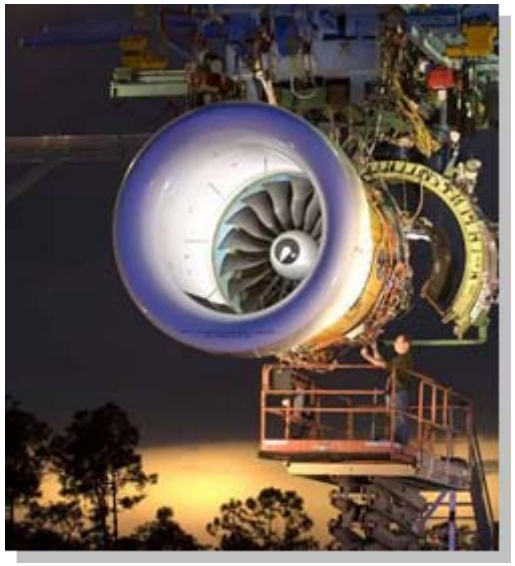
Half-span model test in Ames 11’ wind tunnel

NASA / P&W UHB Partnership Research

➢ *2008 Highlights*

- Geared Turbofan Demonstrator Engine
  - Successful ground demonstration of Geared Turbofan concept completed May 2008
    - Fan performance verified, acoustic characteristics within expectations
  - Successful ground demonstration of F-T based Alternative Fuel completed in January 2008
    - Significantly reduced particulate levels measured compared with JP fuel and with negligible impact on engine performance
- Future Collaboration
  - Space Act Agreement negotiations initiated for continued research collaboration into next generation Geared Turbofan starting with system analysis and design studies in 2009

GTF Demonstrator Engine ground test

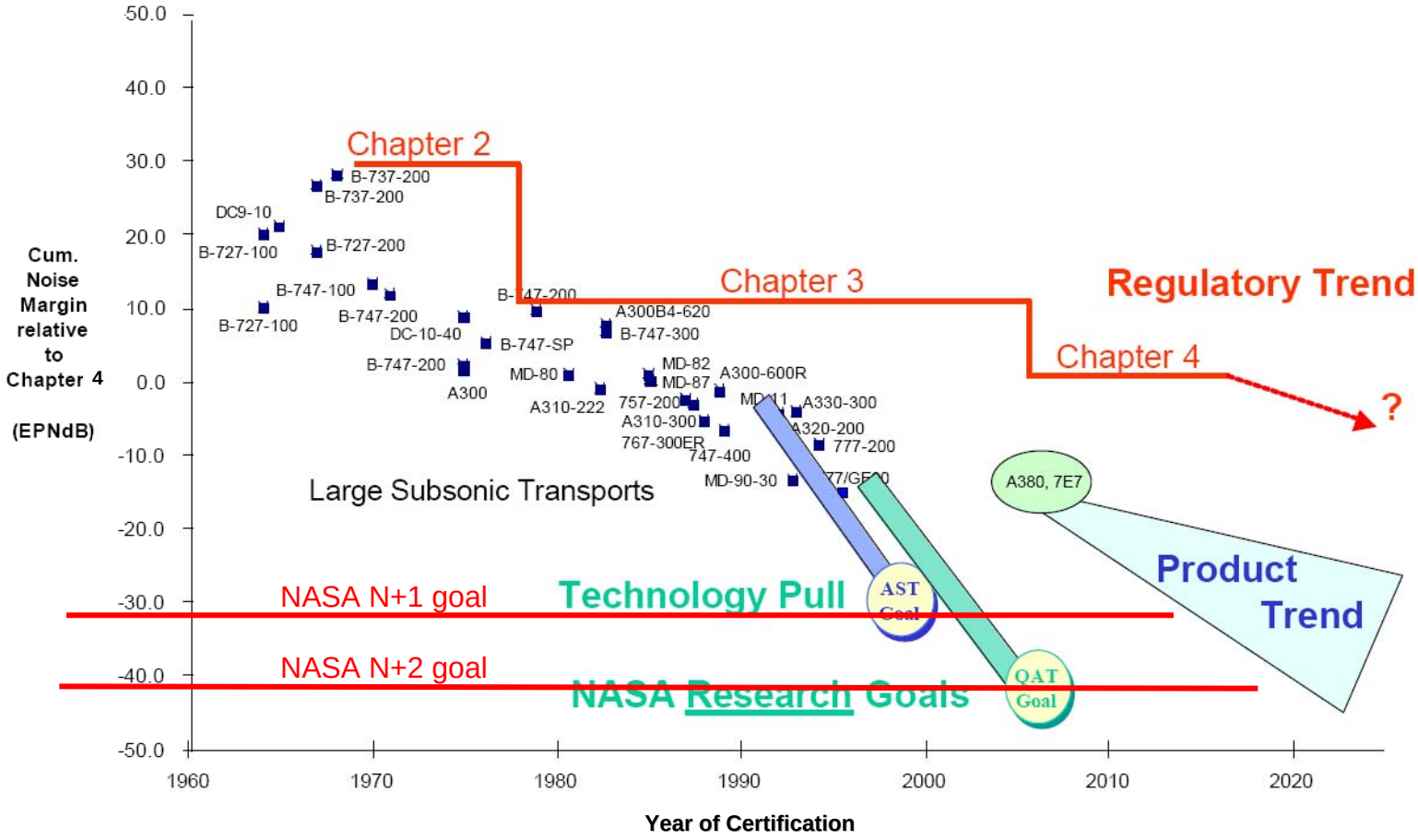


GTF / Alternative Fuels test

NASA / P&W UHB Partnership Research

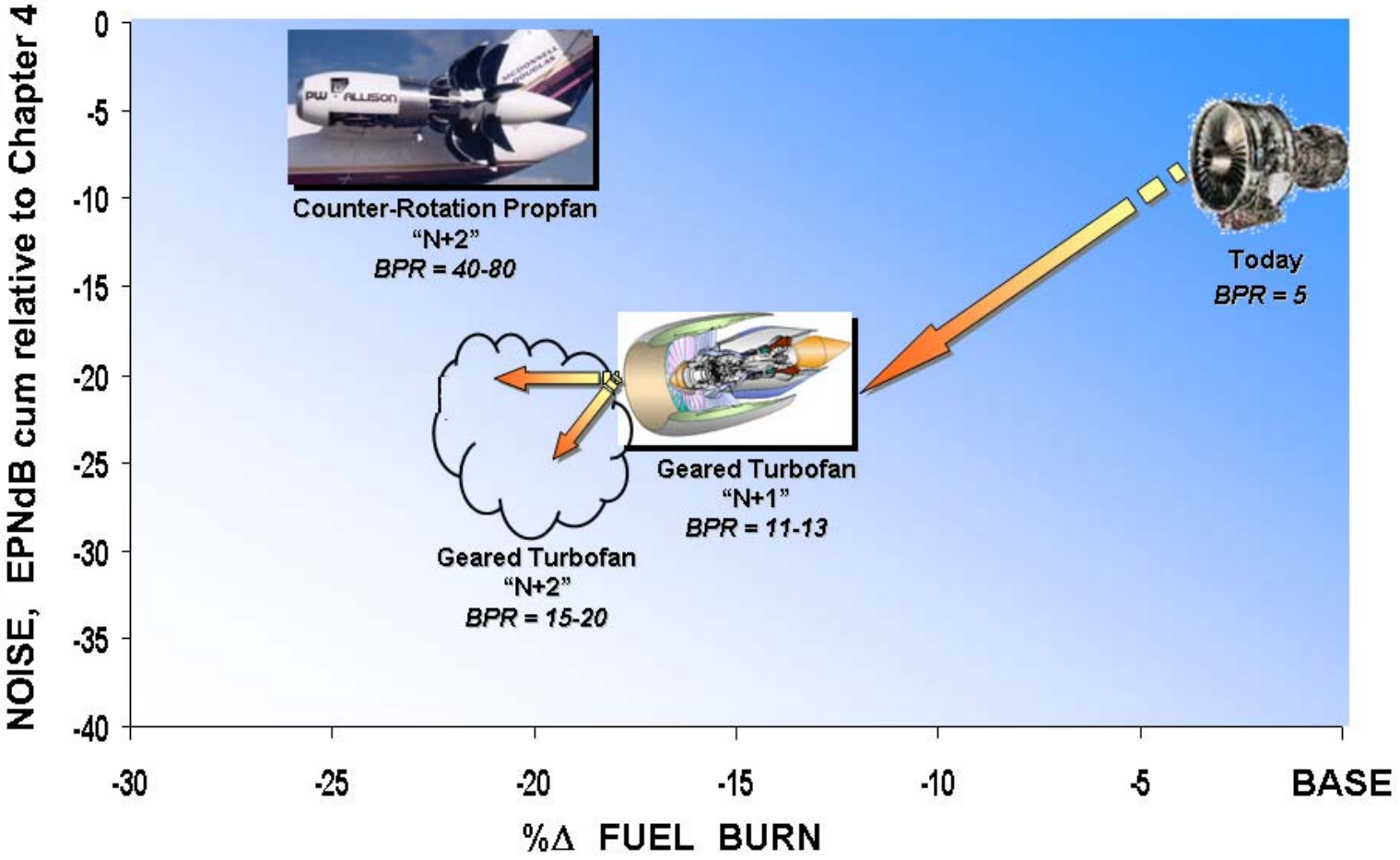
➢ *Future*

- *Environmental regulations, especially noise, continue to challenge new aircraft designs*



NASA / P&W UHB Partnership Research

➢ *Meeting SFW Goals Requires Evaluating Game-Changing Architectures*



NASA / P&W UHB Partnership Research

- Through partnership and collaboration with NASA, Pratt & Whitney has successfully demonstrated the viability of the Geared Turbofan as the aircraft engine for the next generation of aircraft (“N+1”), using Ultra High Bypass fan technology to address the goals of reducing noise, emissions and fuel burned.

- Continued collaboration between NASA and Pratt & Whitney on an advanced generation of Geared Turbofan will enable engine technology to meet the aggressive SFW goals for more advanced aircraft designs (“N+2” and beyond).

Fundamental Aeronautics Program
2nd Annual Meeting
Atlanta, GA
October 7-9, 2008

Siamak Masoudi
Wes Lord

WHAT'S SHAPING THE INDUSTRY

Focus For Next Generation Airplanes

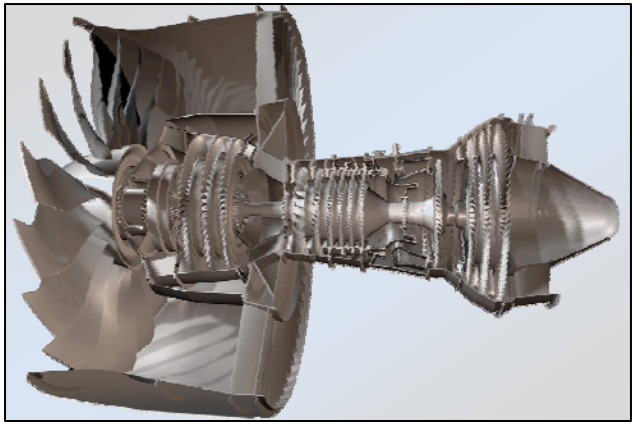
CO_2, a Growing Global Concern & NOx, a Local Air Quality Concern

Noise Impacting our Communities & Airport Expansion

The Rising Cost of Fuel

Geared TurboFan (GTF™)

Balanced Design Solution for Reduced Fuel Burn – Noise – Emissions

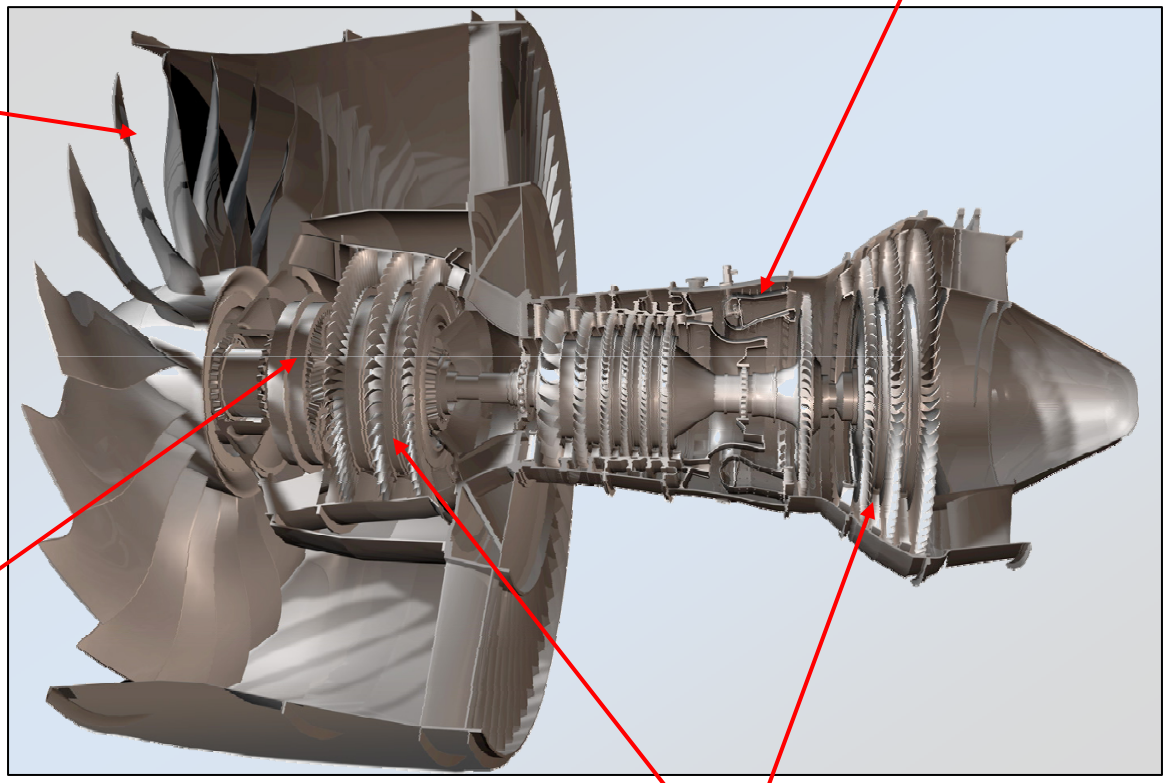


	Projected Based on Demonstrated Technology
NOISE (cum margin to Ch4)	**-20 EPNdB**
LTO NOX (below CAEP 6)	**-60%**
FUEL BURN (relative to 737/CFM56)	**-15%**
MAINTAINANCE COST	**Significant Reduction**

PW-NASA Collaboration Focused on GTF Technology
Key Configuration Elements

Low-Emissions Combustor

Low-PR Fan
Low Tip Speed
BPR ~ 9 - 12



Fan Drive Gear System
5 Planets
Gear Ratio ~ 3

High-Speed Low Spool
Compact LPC, LPT

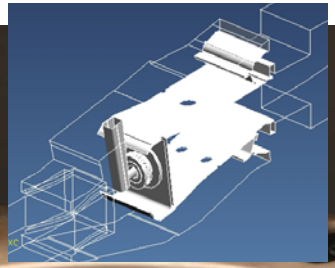
GTF Technology Development in Partnership with NASA

			TRL
UEET, QAT	2001-02	System Architecture/ Technologies Studies	2 - 3
	2003-04	Component Design/ Technology Studies e.g. Low-PR Fan	
EVNERT, SFW	2005-08	Component Scale-Model Technology Tests	4 - 5
	2007-08	Low Spool - Fan - Nacelle Engine Demonstrator Ground Tests	6
	2008	GTF Demo Engine Flight Tests	7

Low-Emissions Combustor Technology

Complete Suite of Analytical and Experimental Tools Key to Success

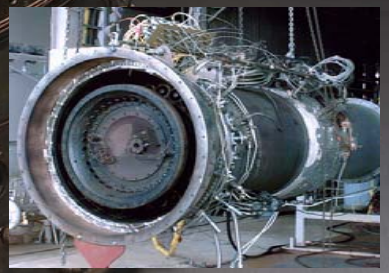
Ignition
Rigs (Vendor)



CFD (P&W)

Annular Rigs (P&W)

Sector Rigs (NASA & UTRC)



1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008

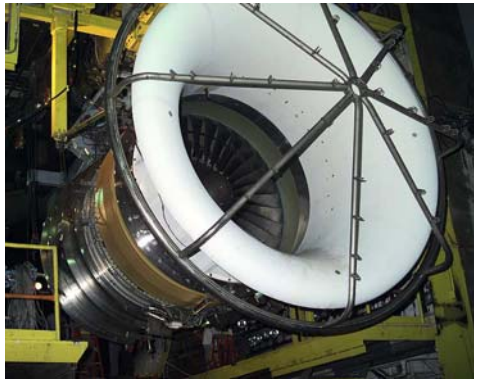
NASA Advanced Subsonic Technology

NASA Ultra Efficient Engine Technology

TALON – Technology for Advanced Low NOx

PW-NASA Partners In Developing Talon Low-NOx Technology

TRL-6 Milestones



Demonstrators

- X861/1 PW4173 TALON II Engine Test ~50% NOx Reduction (CAEP/2)
- JTDP02 PW6000 TALON III Engine Test >60% NOx Reduction (CAEP/2)
- JTDP03 PW6000 TALON X Engine Test >70% NOx Reduction (CAEP/2)

1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008

Service Introductions

- PW4098 Talon I
- PW4158 Talon II
- PW4168 Talon II
- PW6000 Talon II
- NGPF Talon X Product Launch

NASA Advanced Subsonic Technology

NASA Ultra Efficient Engine Technology

TALON – Technology for Advanced Low NOx

Isolated Fan-Nacelle Rig Test for Low-PR Fan

NASA GRC 9x15 Acoustic Wind Tunnel 4Q2006

Scale-Model Fan
22-inch diam

Test Objectives:

- **Fan Performance Map**
- **Efficiency**
- **Flutter or stall boundary**
- **Acoustics**

Test Results:

- **Demonstrated high efficiency and low noise potential for the Low-PR Fan**
- **Rig data used to define fan aero/acoustic design for GTF Engine Demo**

Installed Powered-Nacelle Test

NASA ARC 11ft Wind Tunnel 2Q2008

Half-Span Aircraft Model
BPR ~ 12 Propulsion Simulator
9-in fan diam

Test Objectives:

- **Installation Impact UHB Engine**
- **Flow Diagnostics**
- **Lift, Moment Coeffs**
- **Cruise and High-Lift Wing**

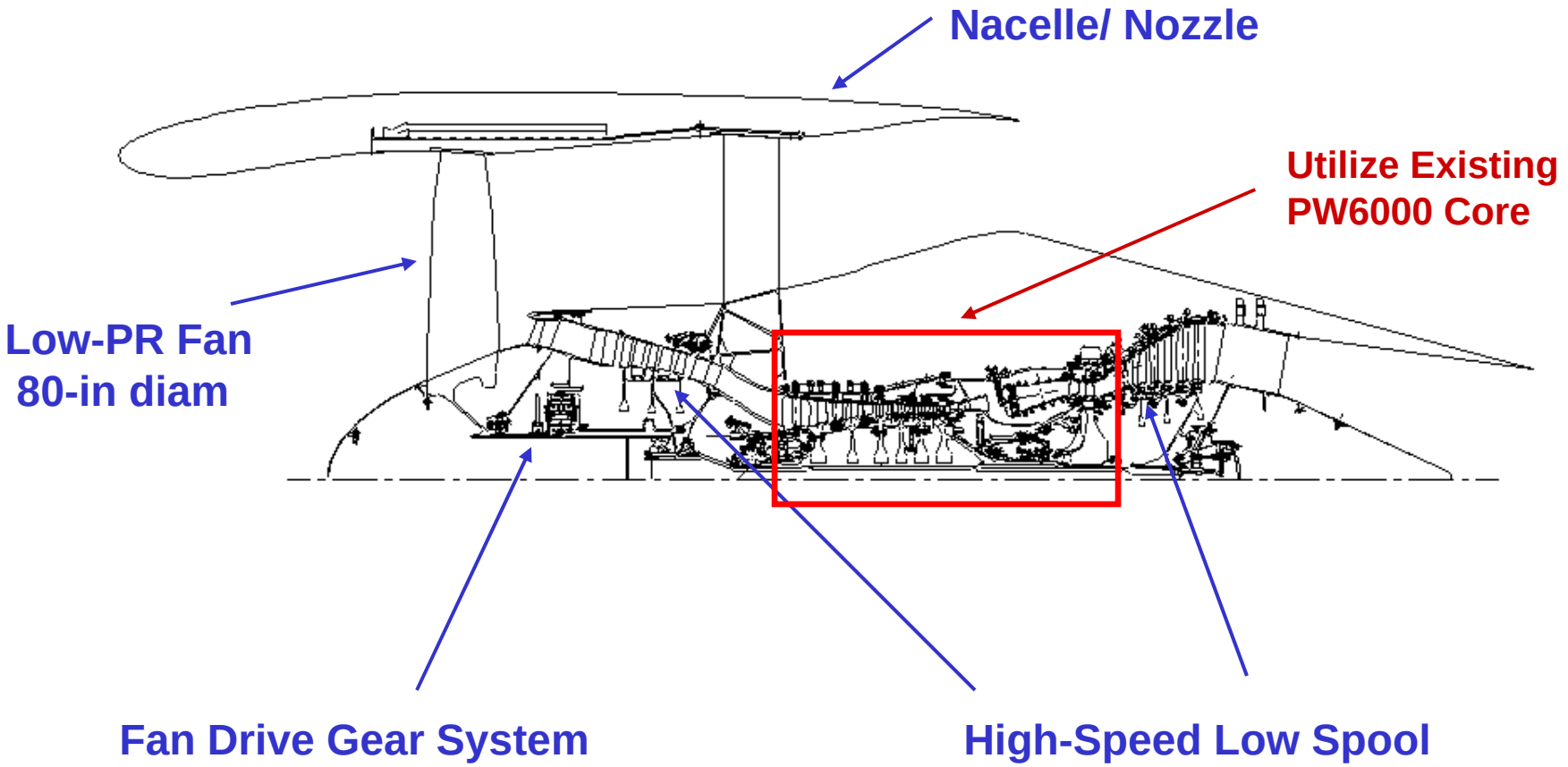
Test Results:

- **No Adverse Impact on Lift for Range of Nacelle Configurations**
- **Baseline for Future Advanced UHB Installation Studies**
- **Data for CFD Code Validation**

GTF Technology Demonstrator Engine

Demo Program Initiated as Joint Effort with NASA under EVNERT

Key Technologies



GTF Demo Engine Ground Test

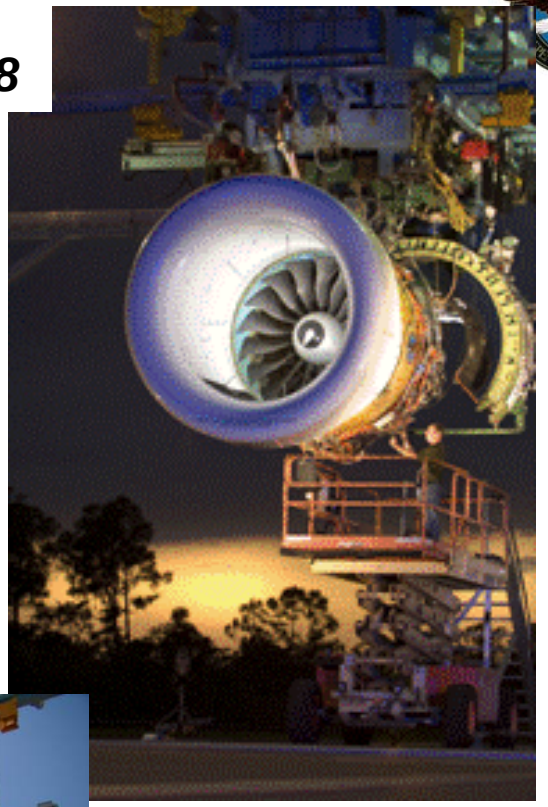
PW C11 Test Stand WPB 4Q2007 – 2Q2008

Test Objectives:

- Performance
- Fan Map
- Acoustics
- Operability/ Transients
- Thermal Management System
- FDGS Vibes Survey
- FADEC Software Checkout

Test Results:

- GTF Component Efficiencies
  -meet or exceed predictions
- FDGS Flawless Operation
- Acoustics Validation of
  Low-Noise System Design



Performance Bellmouth

Flight Inlet

Acoustic Conf w ICD

GTF Demo Engine Flight Testing

PW Plattsburg NY 747SP FTB Aircraft 3Q2008

Airbus A340-600 FTB Aircraft 4Q2008

Test Objectives:

- **Altitude Performance**
- **Operability/ Transients**
- **Thermal Management System**
- **Maneuver Loads/ Stresses**
- **Engine-out Windmill Condition/ Altitude Relight**
- **Acoustics/ Cabin Noise**

Test Results 747SP FTB:

- **12 Flights/ 44 Flight Hours**
- **Met all Objectives for This Phase of Testing**
- **FDGS Stresses/ Vibes Consistent w Ground Test**

Geared TurboFan Product Selection

Mitsubishi Regional Jet (MRJ)

ANA March 28, 2008

Bombardier CSeries

Lufthansa July 13, 2008

PW-NASA Technology Future Direction

- **Advanced Gas Generator**
  High OPR, high thermal efficiency, low emissions

- **2nd generation GTF Technology**
  BPR ~ 15 – 20, improved propulsive efficiency, low noise

- **UHB ducted fan – airframe integration**
  aircraft system level optimization for fuel burn – noise design space