FAA CLEEN

November 2012

Agenda

- Geared Turbofan™ Engine Development & Certification Status
- FAA CLEEN Technologies
- Alternative Fuel Evaluation
- FAA CLEEN Program Status

GTF Development & Certification Status

Customers Want:

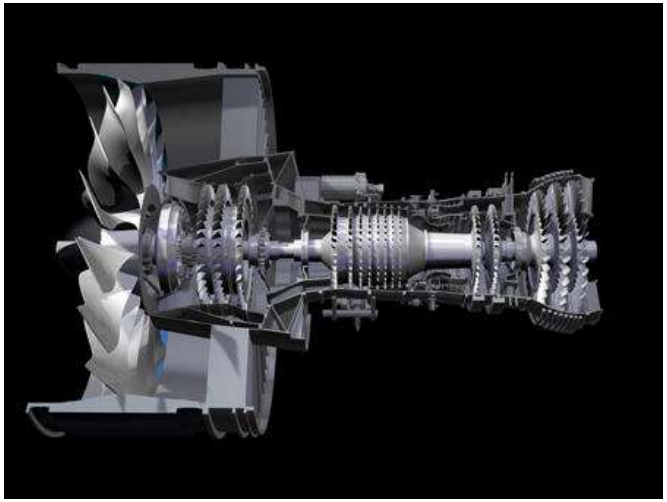
Lower Engine Cash Operating Cost

Cost drivers

- Fuel
- Maintenance cost
- Noise
- Emissions
- Reliability

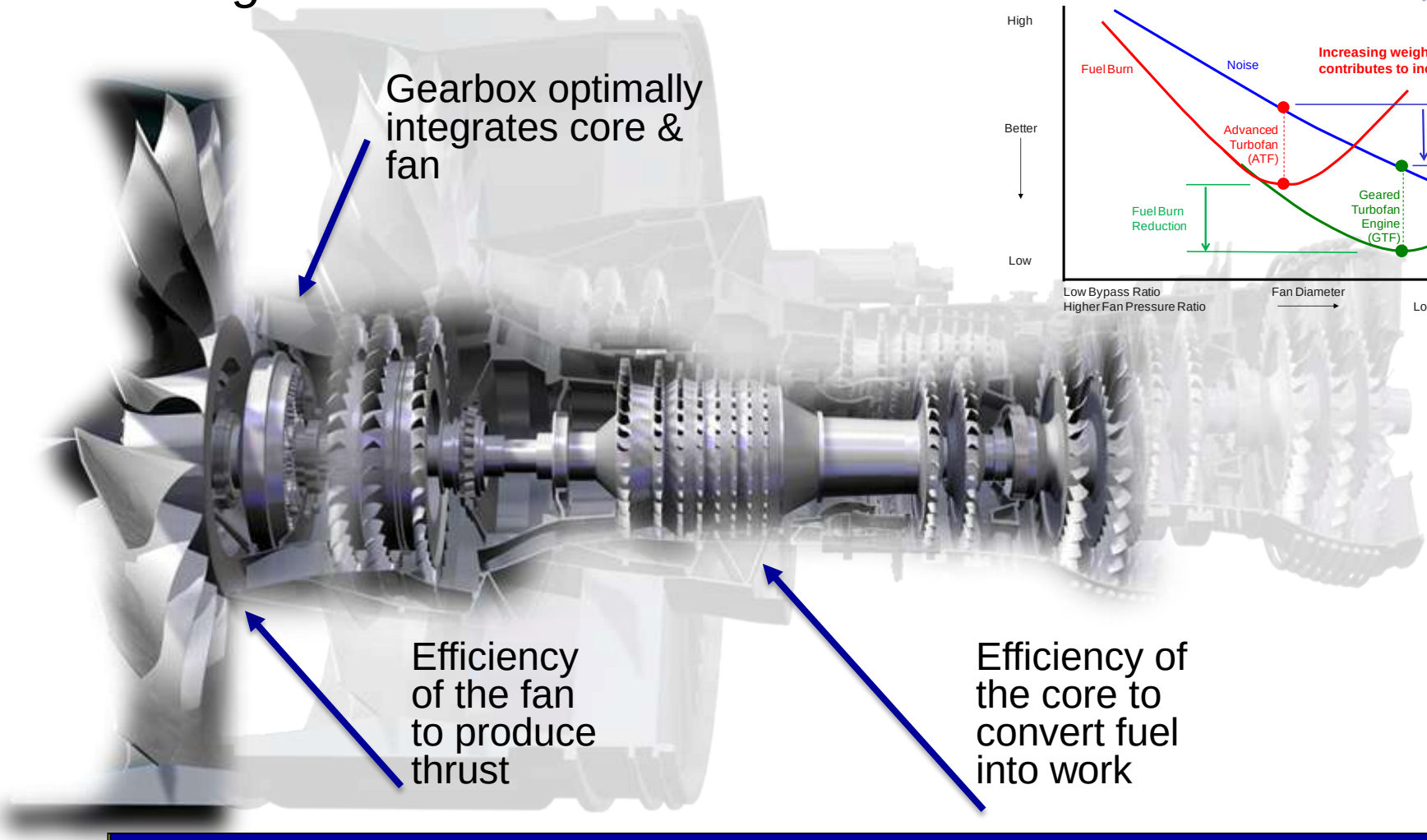
Solution

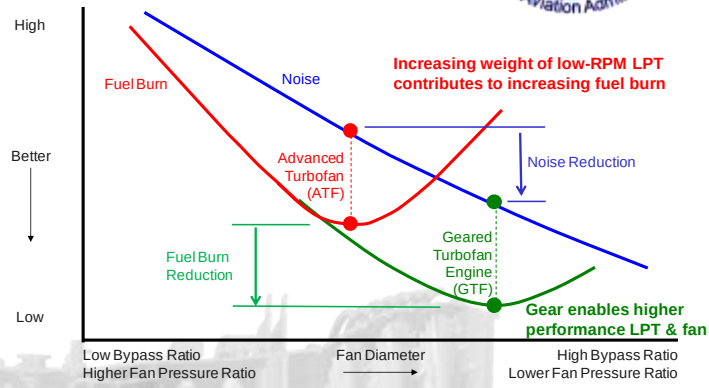
Geared Turbofan (GTF)



GTF Engine Expands Design Space

Paradigm Shift for Reduced Fuel Burn and Noise

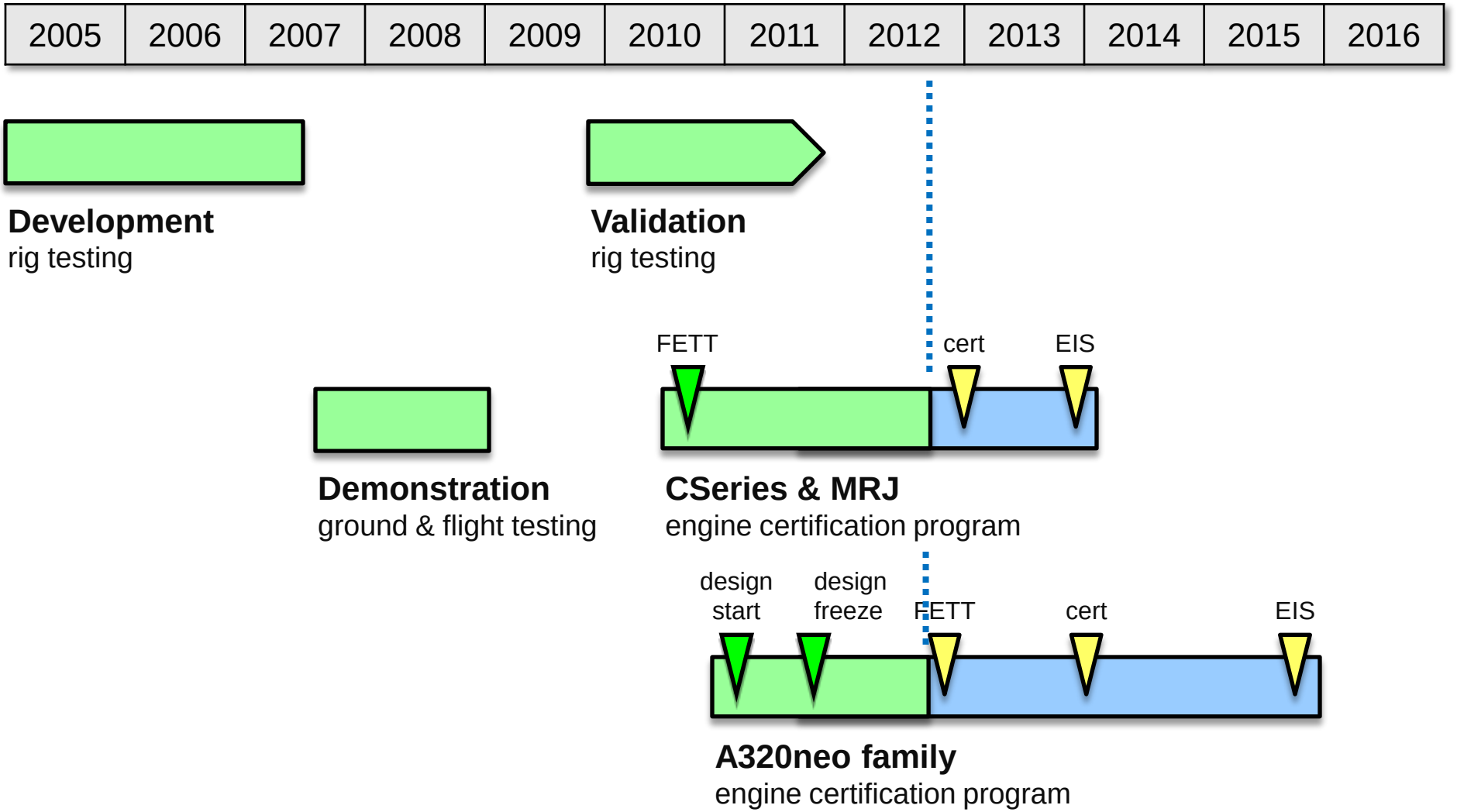




Fuel Efficiency ≈ propulsive efficiency x thermal efficiency

PW1000G Engine Development Schedule

Mature Engine Family

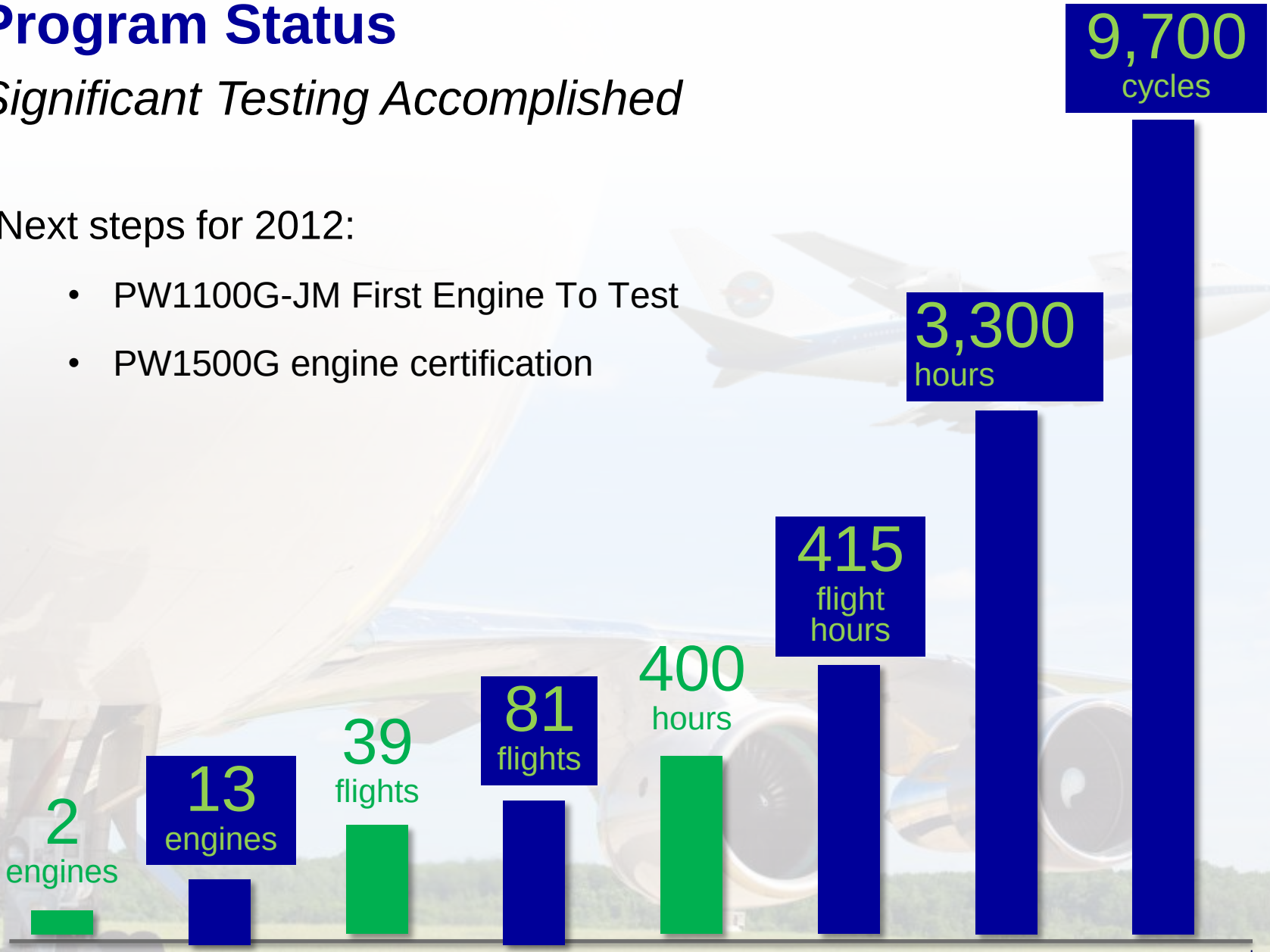


Program Status

Significant Testing Accomplished

Next steps for 2012:

- PW1100G-JM First Engine To Test
- PW1500G engine certification



graph not to scale

PW1500G Program Status

Extensive Testing Conducted to Date

9 engines in test program:

- 6 engines tested or at test
- 3 engines in build

✓ Bird strike testing

✓ 1000 endurance missions test

✓ HPC thermal evaluation

✓ 2nd flight test engine program completed

On track for 2012 certification

PW1500G flight test

PW1500G ground test prep

PW1200G Program Status

- Block I testing completed all objectives
- Successful flight test campaign
- Supporting aircraft rig development for risk reduction
- Aligning engine certification with aircraft certification

PW1200G flight test

PW1200G ground test

Excellent test program to date

PW1100G-JM Program Status

Engine for Airbus A320 Family of Aircraft

- Leveraging PW1200G and PW1500G experience
- Excellent design progress
- Last bolt ceremony held on October 26 (West Palm Beach)

On track for First Engine To Test in 2012

PurePower PW1500G Benefits

	PW1500G	CLEEN Goals
Fuel Burn	>15%	33%*
Noise	Stage 4 – 20 dB	Stage 4 – 32 dB*
NOx	CAEP6 – 50%	CAEP6 – 60%

* Aircraft level

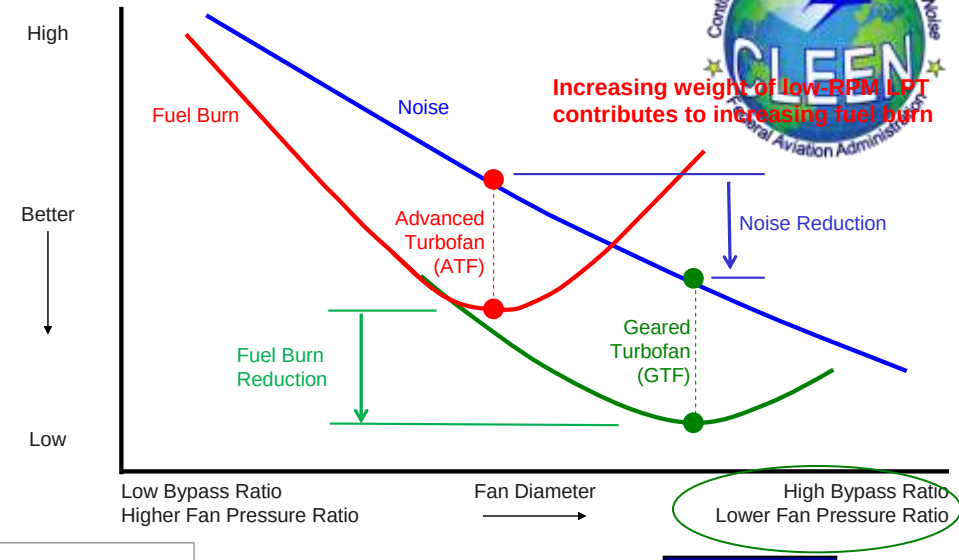
FAA CLEEN Technologies

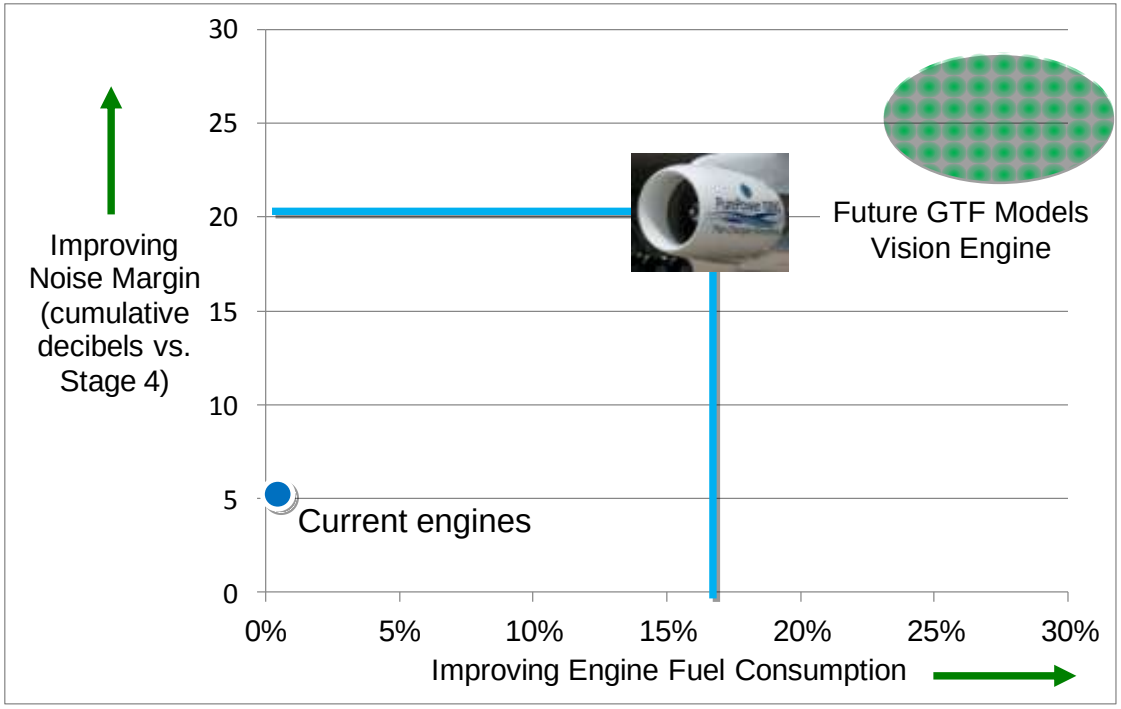
FAA CLEEN Technologies

Company	Technology	Goal Impact	Projected Performance
P&W	Ultra-high bypass ratio Geared Turbofan w/ advanced fan system with reduced weight and drag	Fuel-burn	> 20% reduction
		Emissions	60% reduction in NOx (re: CAEP 6)
		Noise	25 EPNdB reduction (re: Stage 4)

- UHB GTF technologies that leverage the overall GTF system benefits which we anticipate the market will demand in 2020 or beyond.
- Alternate fuel evaluation task initiated in 2012

FAA CLEEN Technology





FAA CLEEN Demonstrator

+

additional technologies

Alternative Fuel Evaluation

FAA CLEEN – Alternative Fuel

Alternative Fuel Blends For Demonstration Tests

The baseline fuel and fuels to be tested from the three different processes are as follows:

- Baseline Jet A (or Jet A-1) conforming to ASTM D1655
- 30/70 Kior HDCJ/Jet A
- 50/50 Kior HDCJ/HEFA
- 50/50 ARA CH/Jet A
- 100% ARA CH
- 50/50 Byogy/Jet A
- 100% Byogy

Kior Hydrotreated Depolymerized Cellulosic Jet (HDCJ)

- Containing major content by volume of synthetic aromatics

Applied Research Associates (ARA) Catalytic Hydrothermolysis (CH)

- Containing intermediate content by volume synthetic aromatics

Byogy renewables technology

- Ethanol conversion into renewable jet fuel

FAA CLEEN – Alternative Fuel Engine Tests

P&WC Turbofan Engine Model PW615F Selected

- Cessna Citation Mustang currently in production
- 1460lbs thrust, 2-spool turbofan engine
- Reverse flow combustor, dual-channel FADEC
- Test engine and facility available at P&WC

Engine Test Plan

Following tests to be completed for each test fuel

- Engine exhaust emissions (gaseous species)
- Engine exhaust particulates matters (LII & smoke number)
- Engine performance characterization (SFC, Thrust)
- Test points: Ground Idle to Takeoff
- Basic engine operability handling
  - Accel and decel time check
  - Negative fuel spike (Lean blow-out margin)

FAA CLEEN – Alternative Fuel Combustor Rig Tests

P&WC Generic Can Combustor Rig

- P&WC combustor rig located at Laval University, Canada
- Single nozzle can combustor rig design for generic research
- Using representative fuel nozzle (JT15D) and ignitor (PW600)
- Maximum air flow rate of 0.45kg/s (1 lb/sec)
- Cold start capability; fuel and air (+35degC to -40degC)
- Altitude relight (Sea level up to 50Kft or 15kPa)

Combustor Test Plan

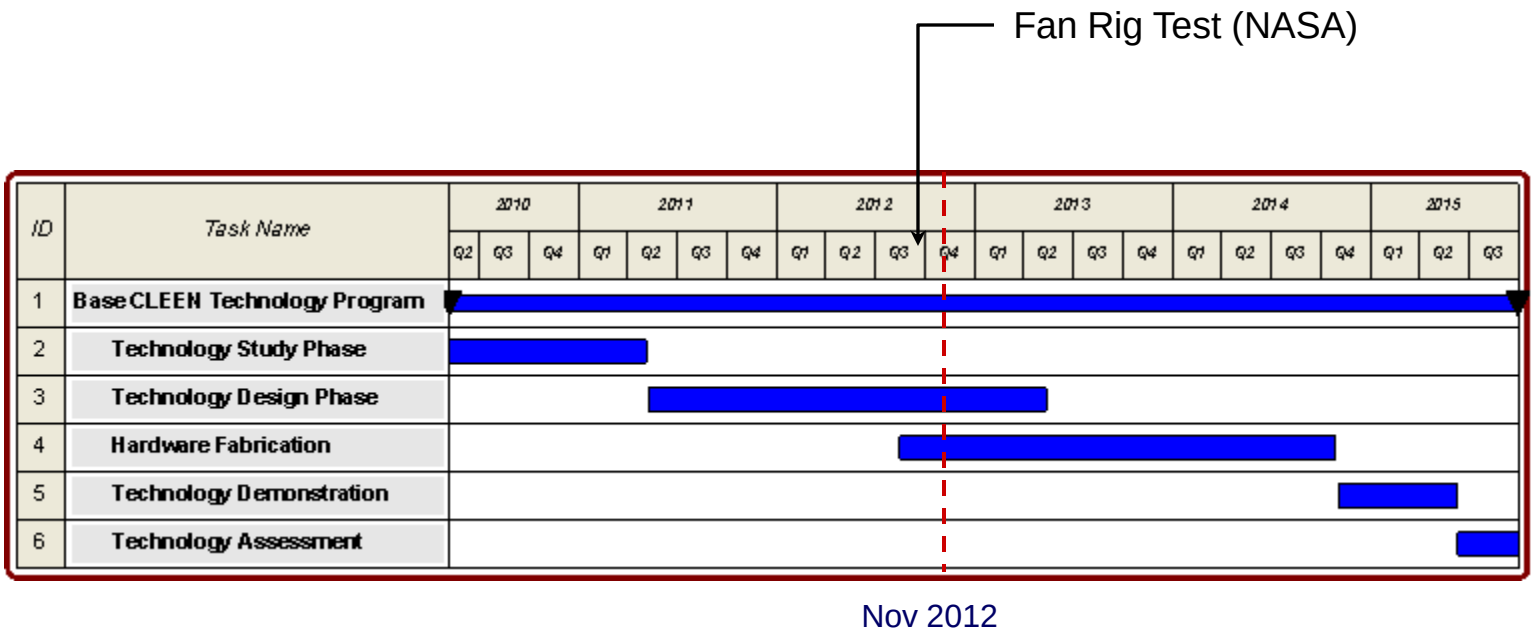
Following tests to be completed for each test fuel

- Cold start mapping at seal level constant pressure
- Altitude relight mapping at constant speed (250 knots)

FAA CLEEN Program Status

FAA CLEEN Program Status

Program on Track for Successful Completion



- Technology plan in place
- System studies show no major technical risks
- Test engine identified
- Close monitoring of NASA 22” fan rig

Test Asset Identified – Initial Flight Test Completed

PW1500G Platforms

PW1519G
19,000lbs

PW1521G
21,000lbs

PW1524G
23,300lbs

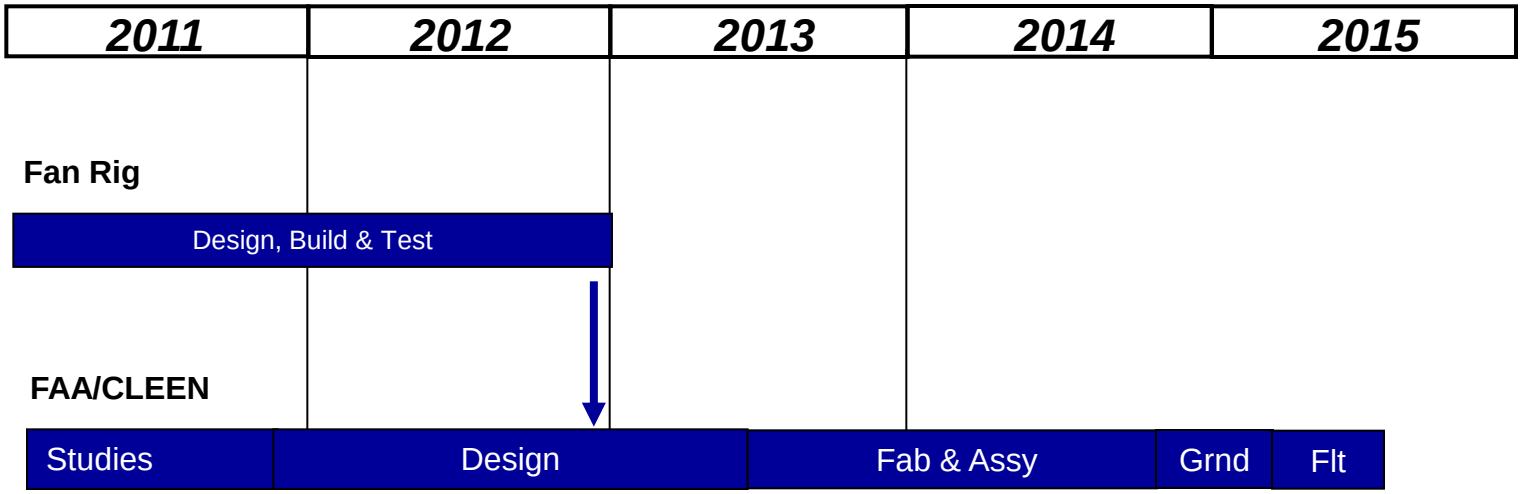
Engine X806

Next test planned - acoustics

22” NASA Fan Rig

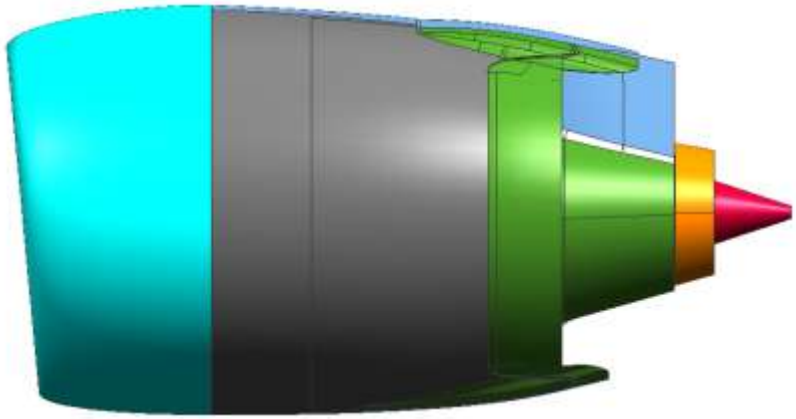
Fan Rig Will Provide Early Learning for CLEEN Technologies

- Complete set of pretest predictions completed
- Fan system performance
- Aeromechanic response
- Operability mapping
- Acoustics



Preliminary Design Nearing Completion

- Fan structural and aero assessments completed
- Nacelle configuration established



Configuration selected that meets all criteria and satisfies FAA CLEEN goals

Preliminary Design Nearing Completion

BOM released

- Critical supplier quotes completed
- Demonstration planning initiated
  - Ground / flight test matrix
  - Instrumentation requirements
  - FTB integration
- Configuration Options
  - Fan Design
  - Nacelle Design
- Evaluate
  - Performance
  - Operability
  - Acoustics

Configuration selected that meets all criteria and satisfies FAA CLEEN goals

FAA CLEEN Vision Engine

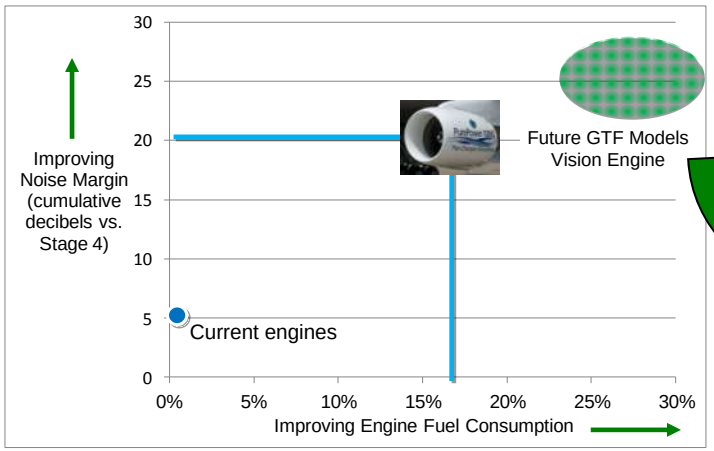
Propulsor
- High Bypass Ratio
- Improved Propulsor Efficiency
- Advanced Fan Drive Gear System

Core (HPC)
- Increased OPR
- Aero efficiency package

Core (HPT)
- Aero Efficiency Package
- Physics Based Design and Lifing Systems

LPT
- Aero Efficiency Package

Combustor
- Enhanced TALON X



Summary

- PW1000G family of engines demonstrating expected benefits of GTF architecture
  - Excellent foundation for achieving FAA CLEEN Goals
- PW1500G engine ideal candidate for high bypass ratio technology demonstrator vehicle
  - FAA CLEEN identified asset completed flight testing
  - In preparation for acoustic testing
- Alternative fuel engine & rig evaluation test plans defined
- Critical CLEEN demonstrator hardware completing preliminary design
  - Supplier procurement in process
- P&W progressing in maturing high bypass ratio technologies through ground & flight testing


PRATT & WHITNEY
DEPENDABLE ENGINES