Pratt & Whitney – FAA CLEEEN III Consortium

Industry Day / Public Session

May 3rd 2023

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CLEEN III: Fan Module Technologies Development &
TALON® X+ Combustor Module Enhancements
693KA9-21-T-00005

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Pratt & Whitney - World Leader

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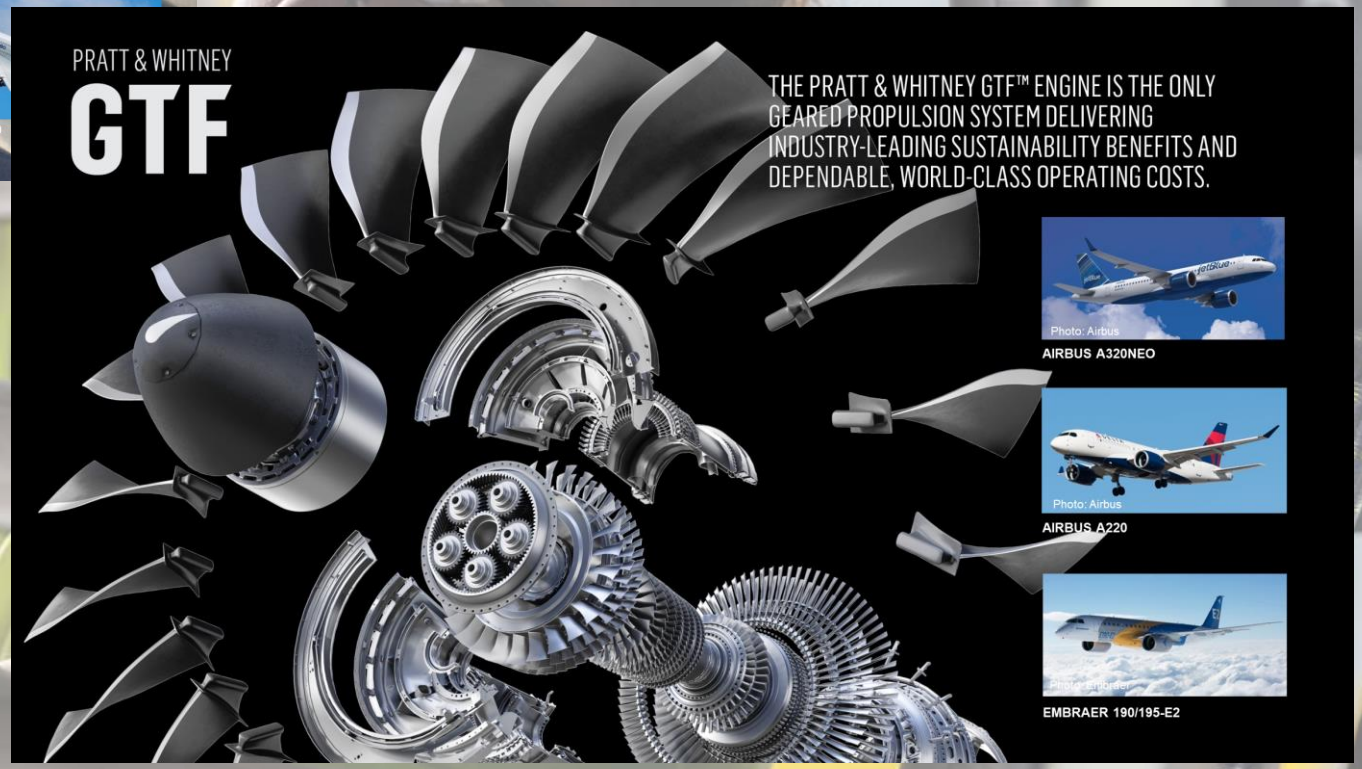
2050 Commitment to NET Zero Emissions



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P&W Future Strategic Growth

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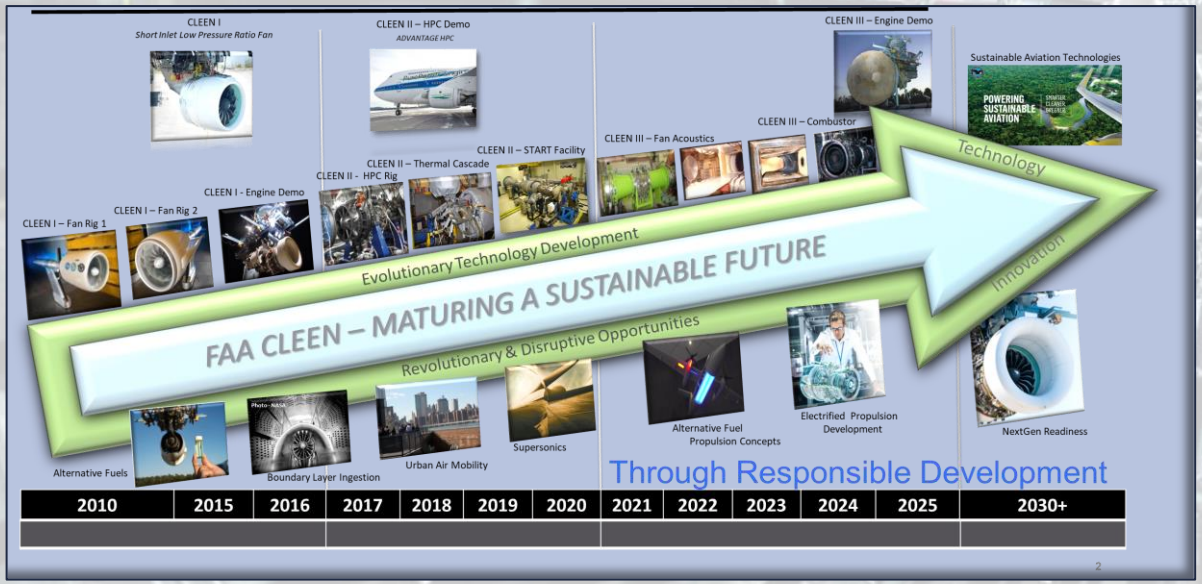
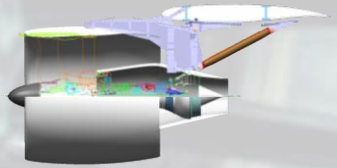
RELATIVE FUEL BURN & NOISE

Current Engines

Geared Architecture
Higher BPR / OPR,
Component Efficiencies

Thermal & Propulsive Efficiency





GTF-Gen2

UHB Propulsion System
Next Generation Core,
Light weight materials,
Sustainable Advantages

INNOVATION & TECHNOLOGY

CLEEN Drives Contributions To Aviation

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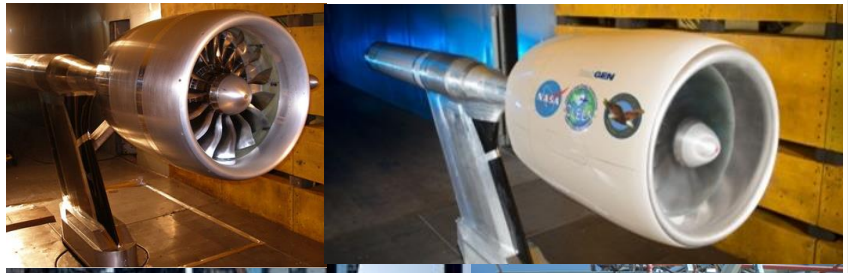
CLEEN I

Propulsive Efficiency




Low Pressure Ratio Fan – Short Inlet Development

Novel Architecture Potential

Propulsion Metric Benefits

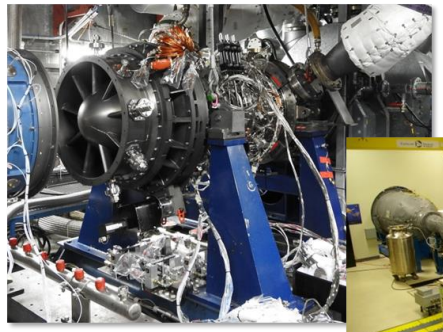
1.5% Fuel Burn Reduction

~30,000 gallons of fuel potential per year / plane

*A320 Neo, 2.0 hr flights, 3100 annual flight hours

CLEEN II

Thermally Efficiency



High Compressor Aero Efficiency Airfoils

High Pressure Turbine Aero/Thermal Efficiency
PSU START Facility

Engine / Airframe Level

1.4% Fuel Burn Reduction

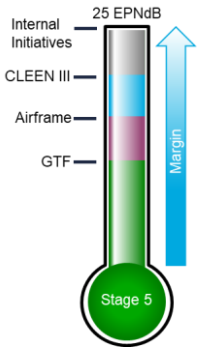
Fleet Level

29,000 gallons of fuel saved per year per plane*

*A320NEO, 2.0 hour flights, 3,100 annual flight hours

CLEEN III

Sustainability



Fuel Burn 0.8 %

NOx / nVPM 5% / 10%

EPNdB (stg 5) **3**

2010 — 2017 — 2015 — 2020 — 2021 — 2026

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Pratt & Whitney's CLEEN III Technologies

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Program Development

Today

Program Milestones

Technology Maturation

Studies / Concept Initiation & Optimization | PDR | DDR | Mfr & Assy | Engine Demonstration 6 | Report

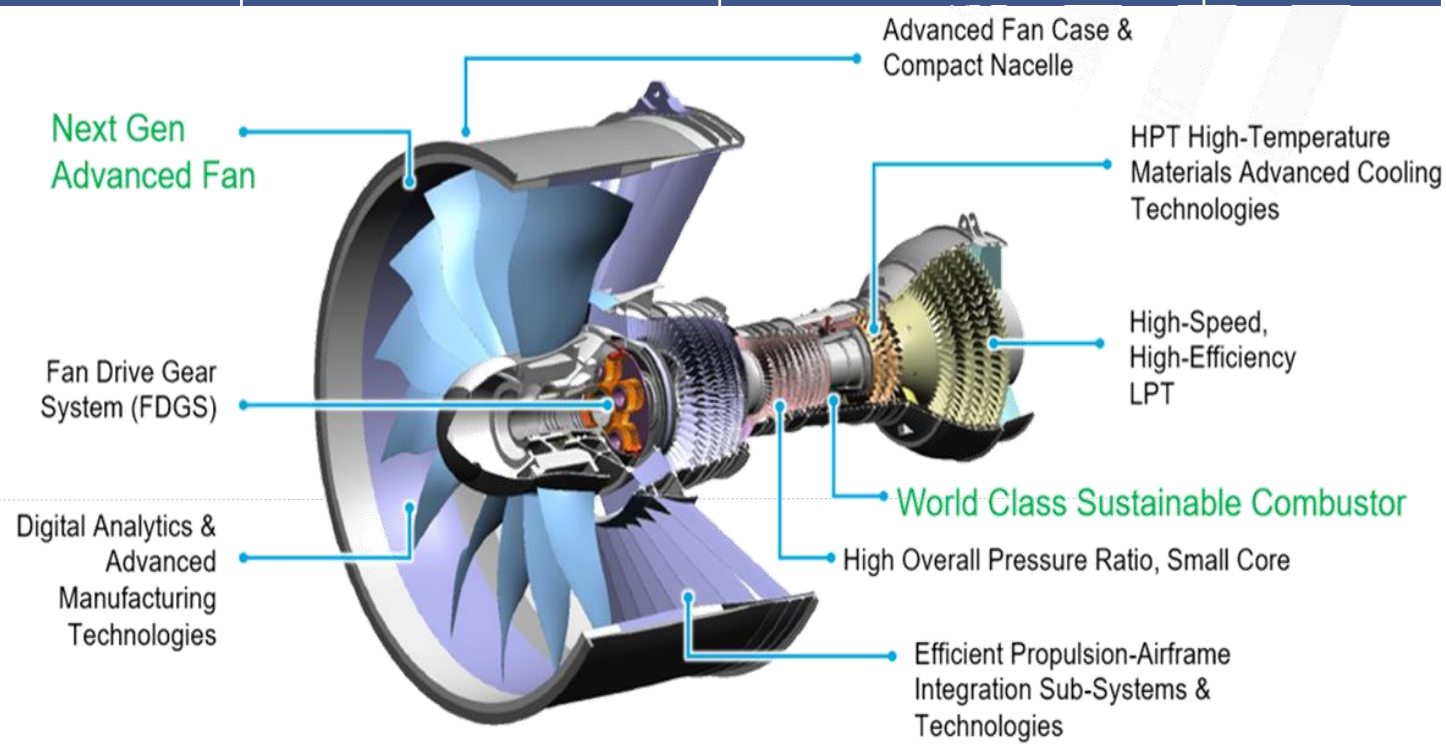
2021	2022	2023	2024	2025	2026

Fan Technologies

- Additively Manufactured Acoustic Liners
- Low-Loss Intra-Stage Liners
- Low-Count / Low-Noise Guide Vanes

Combustor Technologies

- Noise Robust Swirler
- Low Pattern Factor Combustor
- Floatwall+



Fan Module - Accomplishments

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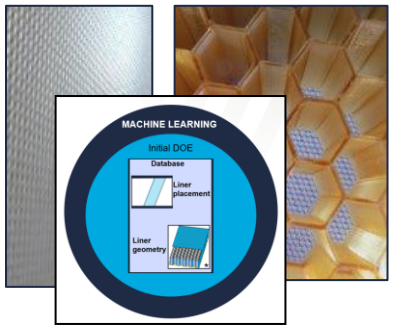
Today

Studies / Concept Initiation & Optimization	PDR	DDR	Mfr & Assy	Engine Demonstration 6	Report

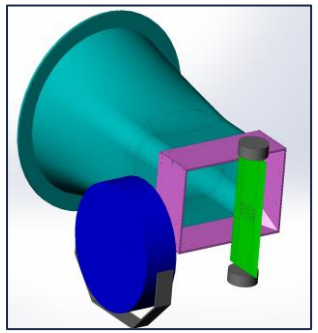
2021	2022	2023	2024	2025	2026

- **Additively Manufactured Acoustic Liners** 4
- **Low-Loss Intra-Stage Liners**
- **Low-Count / Low-Noise Guide Vanes**

- **Wind Tunnel Testing** 5



Advanced MFG & Machine Learning



Acoustic Tunnel & Grazing Flow

Additively Manufactured (AM) Acoustic Liners

- ✓ Attained polymer AM fabrication knowledge for challenging acoustic part treatment
- ✓ Polymer AM materials have been down-selected and their manufacturing processes identified
- ✓ Polymer AM flat panels have been drag and impedance tested

Low-Loss Intra-Stage Liners & Low-Count / Low-Noise Guide Vanes

- ✓ Compact liner impedance testing has progressed with a new configuration currently under evaluation.
- ✓ Conceptual hardware design trades have been evaluated
- ✓ Demonstrator engine designs have been formulated
- ✓ Machine Learning framework has been established and is being utilized
- ✓ New aero performance architectures that will compliment acoustic treatment objectives have been identified

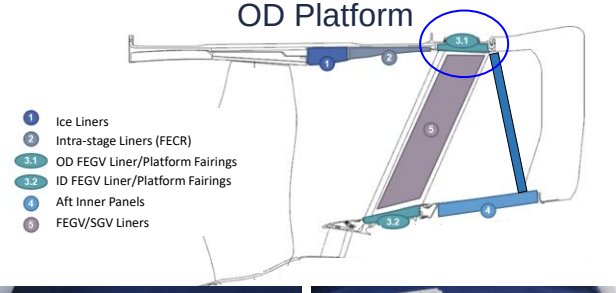
Fan Module – Next 6-Months

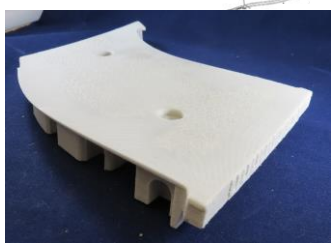
- Execute the system demonstration engine preliminary design
- Continue validation of Machine Learning w/ integration of favorable noise reduction predictions
- Develop new aero performance architectures complimenting acoustic treatment objectives
- Continue wind tunnel drag and impedance testing with the curved acoustic treatment panel on the guide vanes
- Advance manufacturing readiness of the curved polymer AM panels
- Place orders for long-lead material and hardware purchases

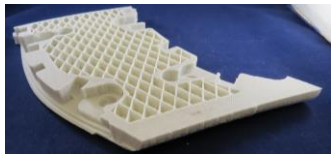
PWSAO

Surrogate Assisted Optimization

OD Platform







OD Platform in AM

Combustor Module - Accomplishments

GO BEYOND

Today

Studies / Concept Initiation & Optimization	PDR	DDR	Mfr & Assy	Engine Demonstration	Report

2021	2022	2023	2024	2025	2026

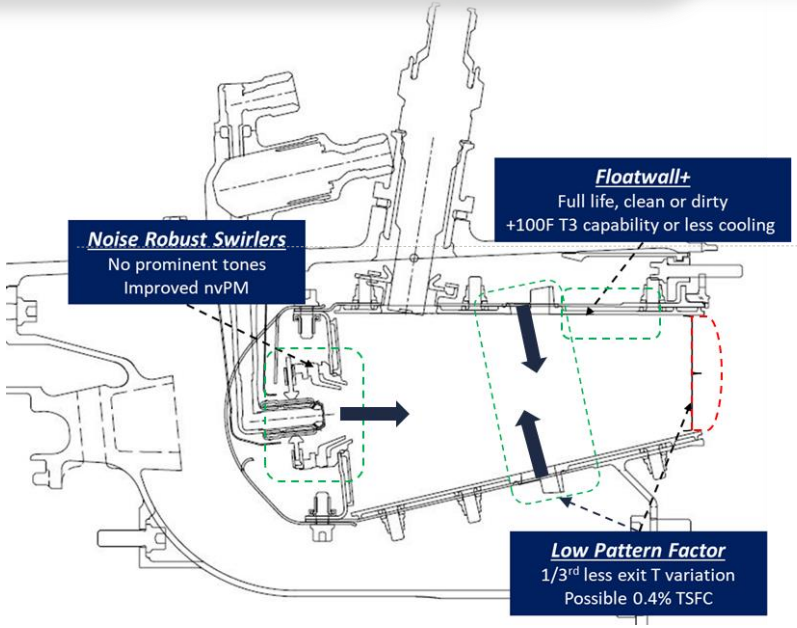
- **Noise Robust Swirler**
- **Low Pattern Factor Combustor**
- **Floatwall+**

4

- **Full Annular Rig Testing**

5

6



Noise Robust Swirler (NRS)

- ✓ Selected NRS concepts for SNR round 2 testing
- ✓ Preliminary downselect of demo swirler configuration

Low Pattern Factor (LPF)

- ✓ Build 2 Pattern Factor Visualization Rig (PFVR) test completed; confirms improvements for quench hole configuration
- ✓ Preliminary downselect of demo quench configuration

Floatwall+ (FW+)

- ✓ Selected rainbow wheel panel configurations for Multi-Sector Full Annular Rig (MS FAR)
- ✓ Preliminary downselect of demo panel configuration

Full Annular Rig / Demo Combustor

- ✓ Kicked off preliminary design for demo combustor configuration

Combustor Module – Next 6-Months

- Noise Robust Swirler (NRS) - Start round 2 SNR testing of NRS concepts to measure tones
- Low Pattern Factor (LPF) - Start Low Cost FAR (LC FAR) combustor test to demonstrate reduced pattern factor
- Floatwall+ (FW+) - Start MS FAR combustor test to measure improved metal temperatures
- Full Annular Rig / Demo Combustor
  - Finalize Integrated Full Annular Rig (FAR) Build 1 combustor configuration
  - Kick off detailed design for demo combustor configuration

Single Sector

Multi-Sector and Full Annular

Thank You.

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