GO BEYOND

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

PRATT & WHITNEY – FAA CLEEN III CONSORTIUM
INDUSTRY DAY / PUBLIC SESSION

NOVEMBER 16TH, 2022

THIS DOCUMENT HAS BEEN PUBLICLY RELEASED.

RAYTHEON TECHNOLOGIES

GO BEYOND

Explore Our Businesses

Collins Aerospace	Pratt & Whitney	Raytheon Intelligence & Space	Raytheon Missiles & Defense


Photo, Credit Raytheon Technologies

67,500 employees

46 countries

100+ years of redefining aerospace

30,000 patents in-force and pending

Redefining aerospace


Photo, Credit Raytheon Technologies

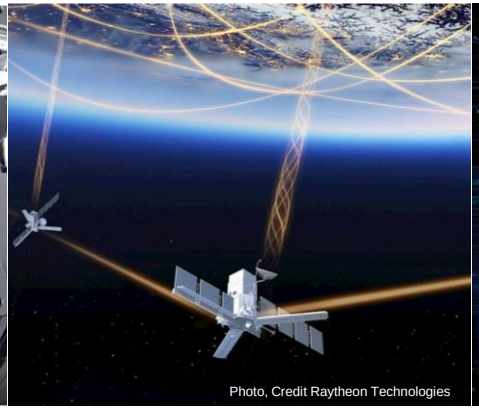
Go beyond

36,000+ employees

40 countries

11,000 commercial engines in service

7,000+ military engines in service


Photo, Credit Raytheon Technologies

34,500 employees

30 countries

66%+ of the world's airspace is managed by our systems

100% of DoD information assurance standards implemented on GPS-OCX, the highest level of cyber protections for any DoD

Any domain, any challenge


Photo, Credit Raytheon Technologies

Proven to perform

29,000 employees

30 countries

17 partner nations for Global Patriot™ Solutions

$300 million investment in GaN technology

World-Class Engineering Teams, Delivering Innovative Solutions

PRATT & WHITNEY - SUSTAINABLE AVIATION

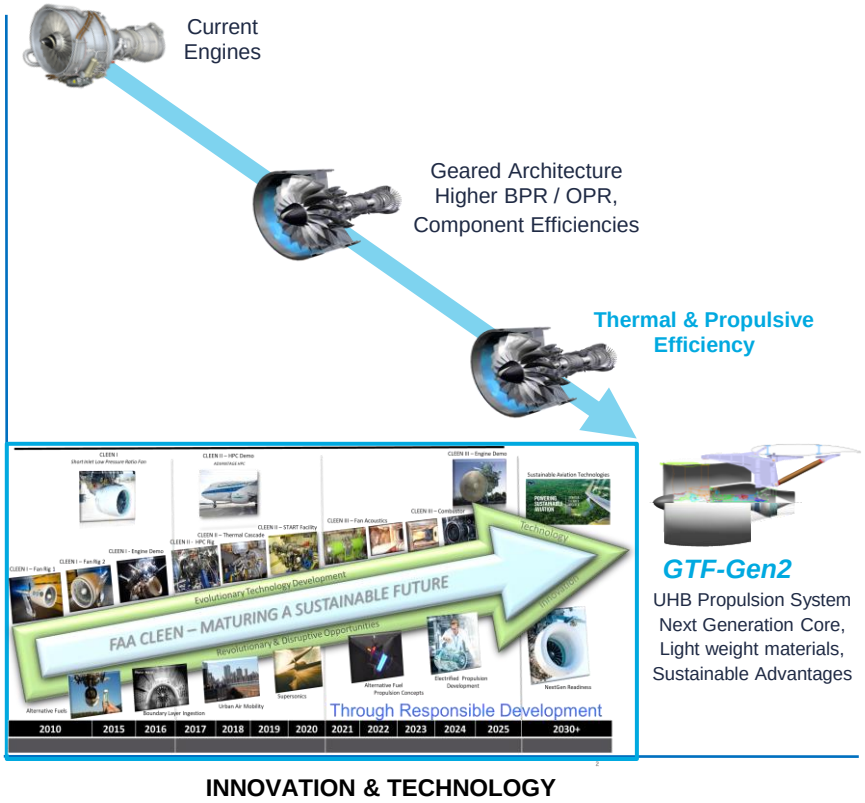
GO BEYOND

Where our Thriving Planet & Human Ambition are in Sync.

2050 Commitment to NET Zero Emissions

PRATT & WHITNEY

Future Strategic Growth



GTF-Gen2

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

CLEEN DRIVES CONTRIBUTIONS TO AVIATION

CLEEN I
Propulsive Efficiency

Low Pressure Ratio Fan – Short Inlet Development

Novel Architecture Potential

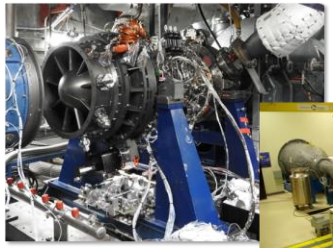
Propulsion Metric Benefits

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

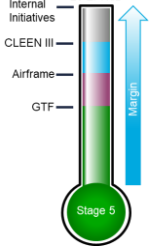
1.4% Fuel Burn Reduction

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

FUTURE GENERATION GTF ENGINE

INSPIRED BY EXPERIENCE - FOCUSED ON SUSTAINABILITY
BECOMING A REALITY THROUGH COLLABORATIVE INNOVATIONS

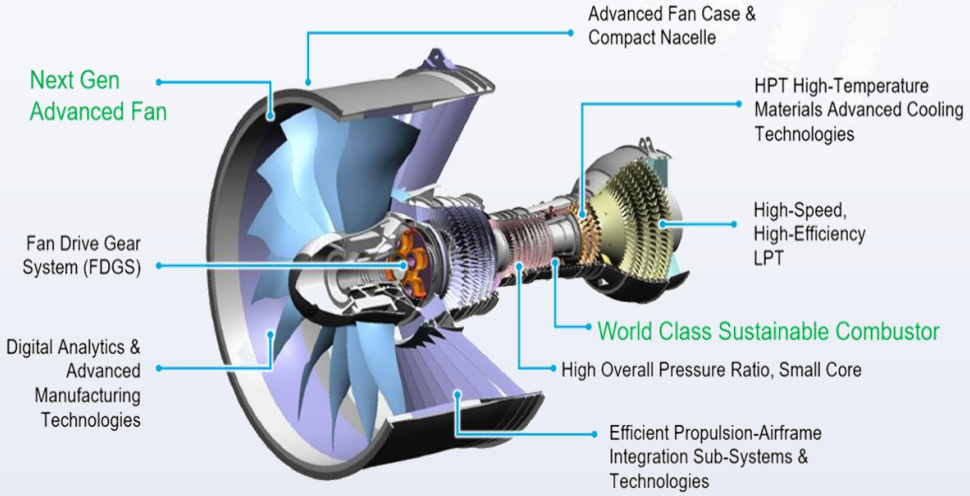
Continuous Lower Energy, Emissions and Noise

- ✓ Strong government-industry collaboration since 2010 facilitating continuous technology advances.
- ✓ Challenging goals, beyond GTF baseline established to make measurable differences on our world.

  0.8% Fuel Burn

  10% nVPM / 5% NOx

  3 EPNdB



FAA Goal:
25 EPNdB Cumulative Margin to Stage 5

PRATT & WHITNEY'S CLEEN III TECHNOLOGIES

NEW PRODUCT ROADMAP TIMELINE

GO BEYOND

▼ Program Milestones
▲ Technology Maturation

Today

Program

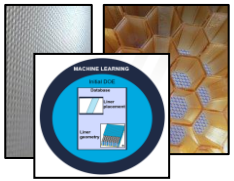
CLEEN III — ▼ PDR — ▼ DDR — Engine Demonstration ▲6 — ▼ Report

2021	2022	2023	2024	2025	2026	2030+

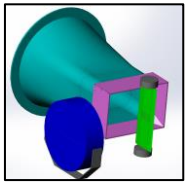
Technology Development

Fan

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



Advanced MFG & Machine Learning



Acoustic Tunnel & Grazing Flow

Wind Tunnel Testing ▲5

Combustor

▲4
Noise Robust Swirler
Low Pattern Factor Combustor
Floatwall+

Single Sector

Multi-Sector and Full Annular

Full Annular Rig Testing ▲5

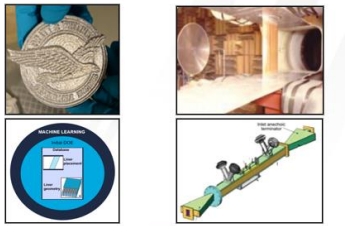
PRATT & WHITNEY'S CLEEN III SUMMARY

Technology Development

Fan

Accomplishments to date:

- ✓ Machine Learning Incorporated and Verified
- ✓ Conceptual Design to demonstrator Concepts
- ✓ Compact Liner Impedance Test completed
- ✓ Additive Materials (AM) selected
- ✓ Manufacturing processes identified
- ✓ Hardware trial parts initiated.
- ✓ Concept hardware evaluated



Advanced MFG & Machine Learning → Acoustic Tunnel & Grazing Flow

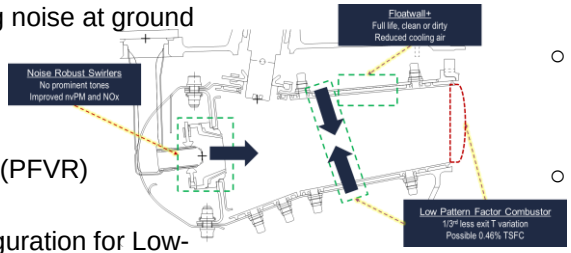
Next 6 month's:

- ○ Advancing MRL with Polymer Trials & Learning
- ○ Validating Automated Machine Learning
- ○ Aero Performance optimized architecture
- ○ Continuing high speed Drag and Impedance Testing
- ○ Initiating system demonstrator concept design.

Combustor

Accomplishments to date:

- ✓ Noise Robust Swirler (NRS)
  - SNR concepts demonstrated reducing noise at ground idle
  - Tool developed for tone capabilities
- ✓ Low Pattern Factor (LPF)
  - Build 1 Pattern factor visualization rig (PFVR) completed
  - Selected improved quench hole configuration for Low-Cost Full Annular Rig (LC FAR)
- ✓ Floatwall+ (FW+)
  - Film effectiveness optimized and selected round 2A panel configurations



Next 6 month's:

- ○ NRS
  - ▪ Select & start round 2 NRS concepts in SNR
- ○ LPF
  - ▪ Start PFVR build 2 testing
  - ▪ Start LC FAR test to demonstrate reduced pattern factor
- ○ FW+
  - ▪ Complete coupon testing at University of Connecticut and Ohio State University
  - ▪ Complete dirt tolerant panel optimization and select round 2B SNR FW+ panel configurations
  - ▪ Select rainbow wheel panel configurations for Multi-Sector Full Annular Rig (MS FAR)

GO BEYOND