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 -- VIRTUAL MEETING

MAY 4, 2022

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GTF ADVANTAGE ENGINE

RAPID TRANSITION OF COLLABORATIVELY DEVELOPED TECHS INTO COMMERCIAL FLEET

up to
34K **takeoff thrust**
at sea level
most powerful GTF engine

up to
17% **less fuel and CO_2**
vs. previous generation engines like V2500
most efficient, 100% SAF compatible

mature reliability
with high durability at entry into service

full intermix + interchange
maximum customer flexibility

100% SAF Validation Demonstration (March 2022)

Pratt & Whitney Integrating Customer Needs

LOWER ENGINE CASH OPERATING COST & ENVIRONMENTAL SUSTAINABILITY

20%

Market Drivers, Initiatives & Commitment to Action

Domestic & International pledges

- Fuel
- Maintenance cost
  - Noise
    - Emissions
      - Reliability
        - Sustainability
        - Product Cost
        - Capability

CLEEN Program Goals

Develop and demonstrate (TRL 6-7) certifiable aircraft technology

CORNERS OF THE TRADE SPACE	CLEEN (N+1) (EIS 2015-18) Ref: B737/CFM56-7B	N+2 (2020)* Ref: B777-200/GE-90	N+3 (2025)*
Noise (cum below Stage 4)	-32 dB	-42 dB	-71 dB
LTO NO_x Emissions (Below CAEP 6)	-60%	-75%	better than -75%
Aircraft Fuel Burn	-33%	-50%	better than -70%

* Technology Readiness Level for key technologies = 4-6

Strive to be the best aerospace engine company FOR the world

FOR OUR PRODUCTS

Emissions
Reduce the environmental impacts of our products
Work with our customers to reduce in-service impacts

Sustainable Products
Design, manufacture and service products to minimize impacts
Use Ecodesign to drive product innovation

FOR OUR SITES

Zero Waste
All by-products 100% recycled
Increase efficiency and reduce "non-product" output

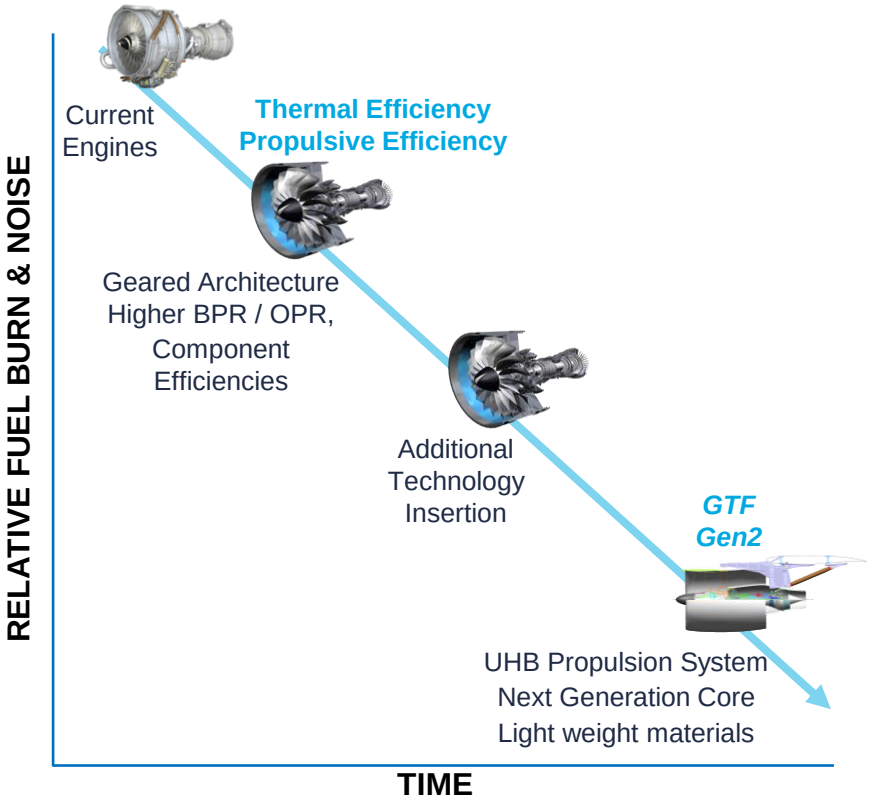
Carbon Neutral
Use only sustainable energy sources
Lower our footprint to avoid future impacts and costs

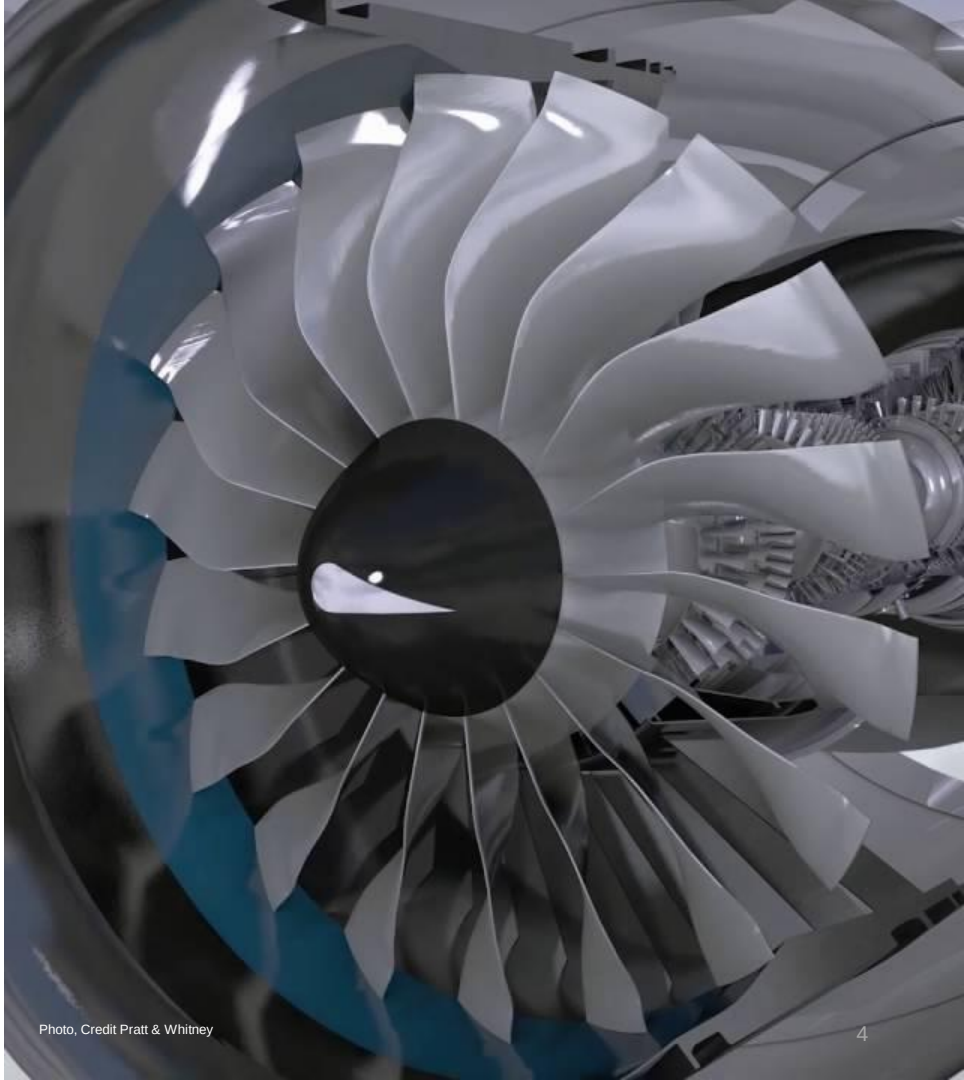
FOR OUR PEOPLE

Influence
Be a force for positive change
Support and engage employees and communities in building a better future

Owning Our Future

Strategy For Future Growth



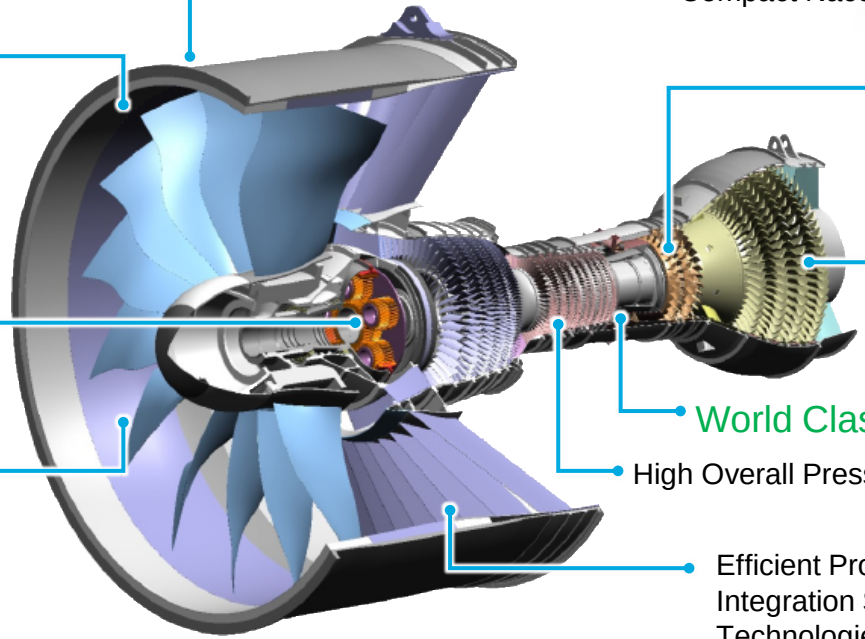


Photo, Credit Pratt & Whitney

Future Generation GTF Engine

INSPIRED BY EXPERIENCE, SUSTAINABILITY & COLLABORATIVE INNOVATION

CLEEN III INITIATIVES HELP ENHANCE FUTURE ENVIRONMENTAL PRODUCT OFFERINGS



Advanced Fan Case & Compact Nacelle

Next Gen Advanced Fan

HPT High-Temperature Materials Advanced Cooling Technologies

High-Speed, High-Efficiency LPT

Fan Drive Gear System (FDGS)

World Class Sustainable Combustor

Digital Analytics & Advanced Manufacturing Technologies

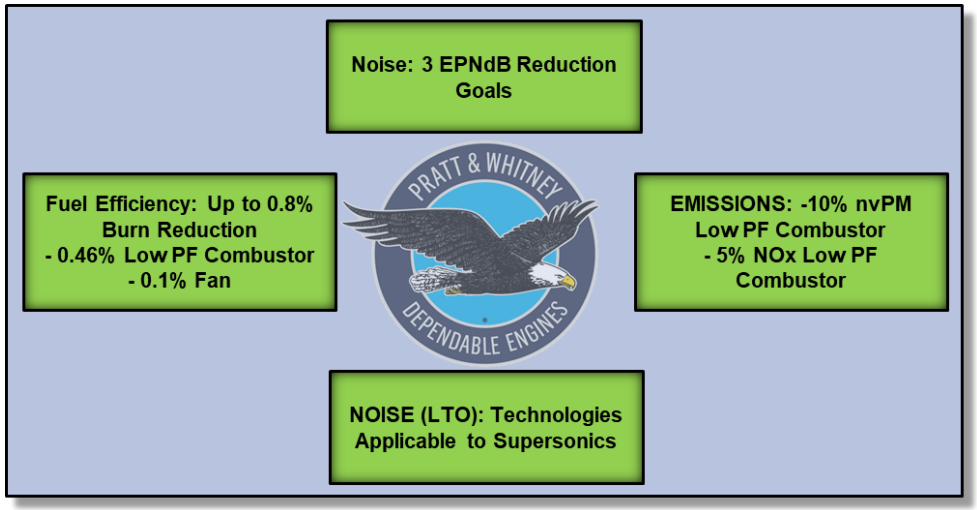
High Overall Pressure Ratio, Small Core

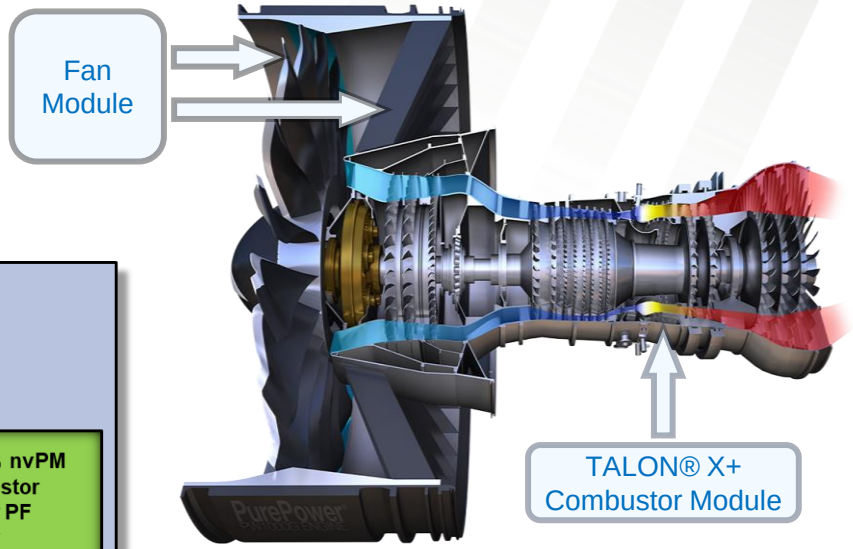
Efficient Propulsion-Airframe Integration Sub-Systems & Technologies

Pratt & Whitney's CLEEN III Technologies

OVERALL PROGRAM GOALS AND OBJECTIVES

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

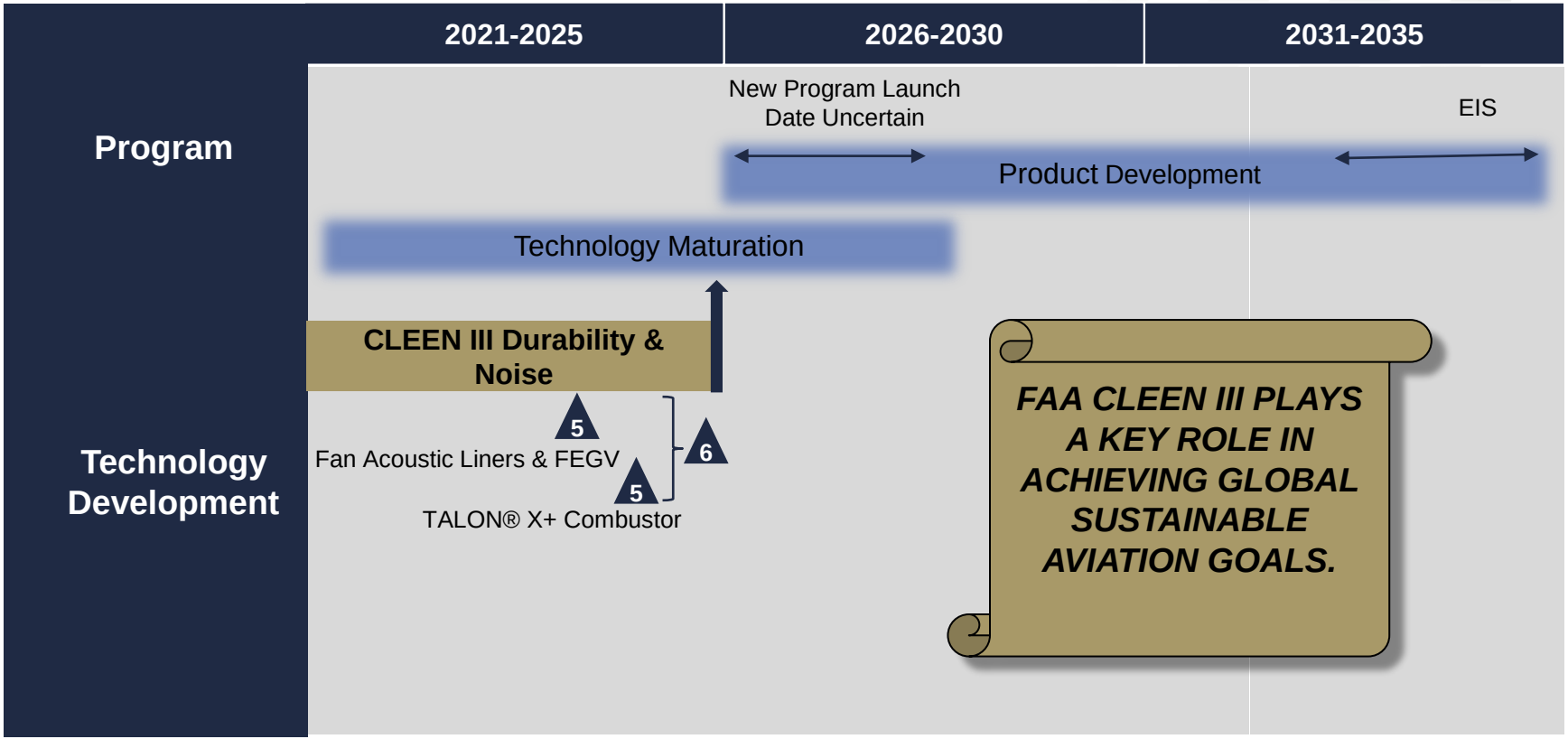




- Noise Robust Swirler
- Low Pattern Factor
- Floatwall+

Pratt & Whitney's CLEEN III Technologies

NEW PRODUCT ROADMAP TIMELINE

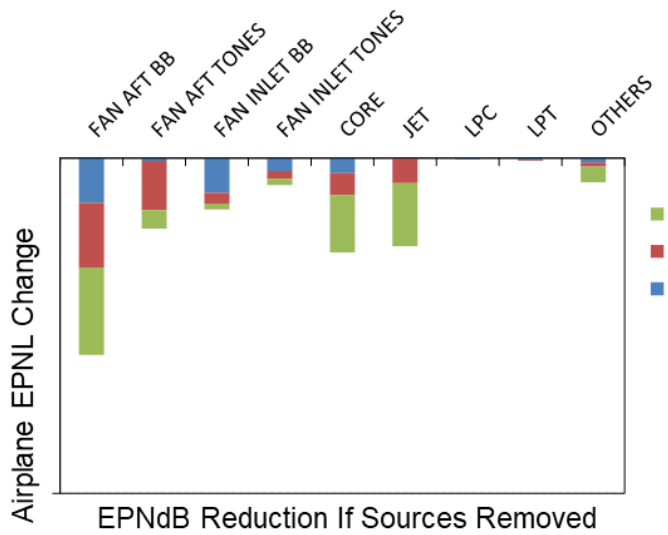


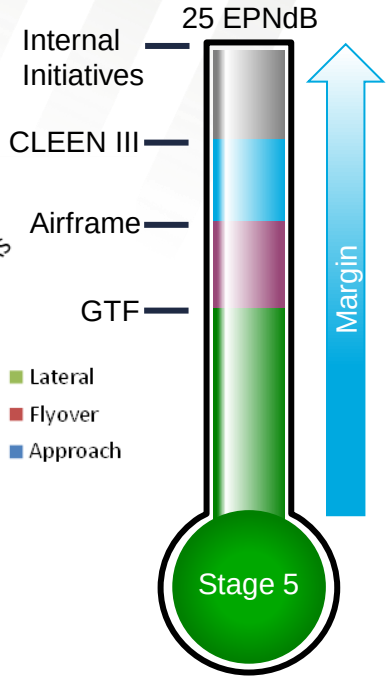
Fan & Combustor Noise Reduction Enable Noise Goals

FAA Goal:
25 EPNdB Cumulative Margin to Stage 5

- ✓ **GTF Noise 12 – 13 EPNdB Margin to Stage 5**

- FAA CLEEN III - 3 EPNdB Noise Reduction Target
  - Focus is on fan and combustor component noise reduction





Pratt & Whitney's CLEEN III Technologies

NEXT GENERATION FAN MODULE

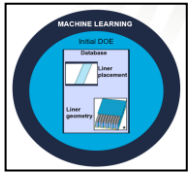
Technologies:

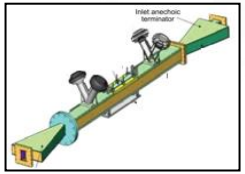
- Additively Manufactured Acoustic Liners
- Low-Loss Intra-Stage Liners
- Low-Count / Low-Noise Guide Vanes

Benefits:

- Improve Liner Effectivity for Noise
- Compact Liner Design Improves Weight
- Low Loss Acoustic Liner Reduces Fuel Burn
- Acoustically Treated FEGVs Targets Source

Photos, Credit Pratt & Whitney





Advanced MFG & Machine Learning → Acoustic Tunnel & Grazing Flow → Engine 2025

Objectives:

Demonstrate Advanced Fan Acoustic Tools & Technologies that will enhance the next Generation GTF.

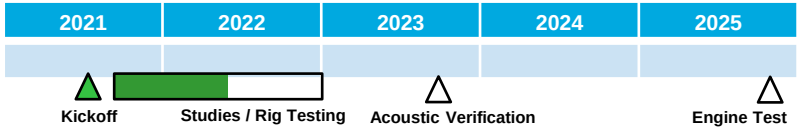
Ahead of us:

- Additive MFG Trials & Quality Sampling
- Automated Machine Learning Trials

Accomplishments:

✓ Machine Learning - Tools Integrated

Schedule & Planned Milestones:



Pratt & Whitney's CLEEN III Technologies

TALON® X+ COMBUSTOR MODULE

Technologies:

Noise Robust Swirler:
- Improves fuel/air uniformity for decreased NOx and nvPM

Floatwall+:
- Reduces cooling air, exit thermals & emissions

Low Pattern Factor Combustor:
- Improved CFD capability for complex flow and geometric variation.

Benefits:

- Contributes to the 3 EPNdB Noise Reduction
- >10% nvPM reduction
- > 5% NOx reduction
- 0.46% improvement in engine efficiency
- Improved life combustor liners

Photos, Credit Pratt & Whitney

Single Sector 2021-2022 → Multi-Sector and Full Annular 2023-2024 → Engine 2025

Objectives:

Demonstrate combustor technologies to address core noise, engine efficiency and emissions

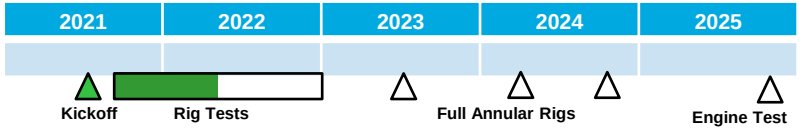
Ahead of us:

Develop the constituent combustor technologies (Noise Robust Swirler, Floatwall+, and Low Pattern Factor Combustor) with CFD and single nozzle rigs, then integrate and test in full annular rigs

Accomplishments:

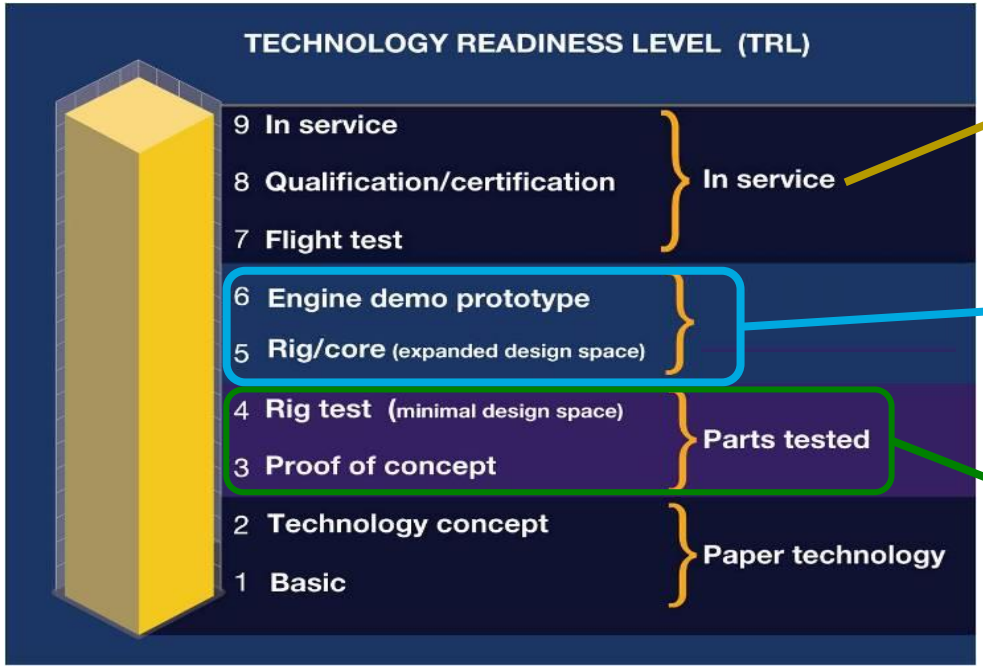
✓ Rig tests and CFD initiated

Schedule & Planned Milestones:



Technology Maturation in CLEEN

TECHNOLOGY DEMONSTRATION WILL FOLLOW PROVEN PROCESS TO VERIFICATION



Photos, Credit Pratt & Whitney

Summary

- PW1100G-JM engine ideal candidate for high bypass ratio technology demonstrator vehicle
  - Mature foundation to build upon to achieve FAA CLEEN III goals with high probability of success.
  - Direct product relevance for both next generation and retrofit opportunities.
- P&W continues early maturity of high bypass ratio fan and combustor technologies through analytics & component rigs, while beginning preparations for engine demonstration
  - The Pratt & Whitney team is progressing on advanced Fan and Compressor learning.
  - Technology maturity on track toward TRL4 milestones.
  - CLEEN III goals remain at the forefront during these early stages of the program development.

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