

# Pratt & Whitney

A United Technologies Company



**The PurePower<sup>®</sup>  
GTF<sup>™</sup> Engine**  
**Geared for  
the future.  
Transforming  
aviation today.**

**P&W CLEEN TECHNOLOGY DEMONSTRATORS**  
**CLEEN I: ULTRA-HIGH BYPASS RATIO**  
**CLEEN II: HIGH PERFORMANCE CORE**

# CLEEN TECHNOLOGY DEMONSTRATORS

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Topics for Discussion

Program Overview

UHB Technology Status

HPT Technology Status

HPC Technology Status

Discussion

*E195-E2 Flight*



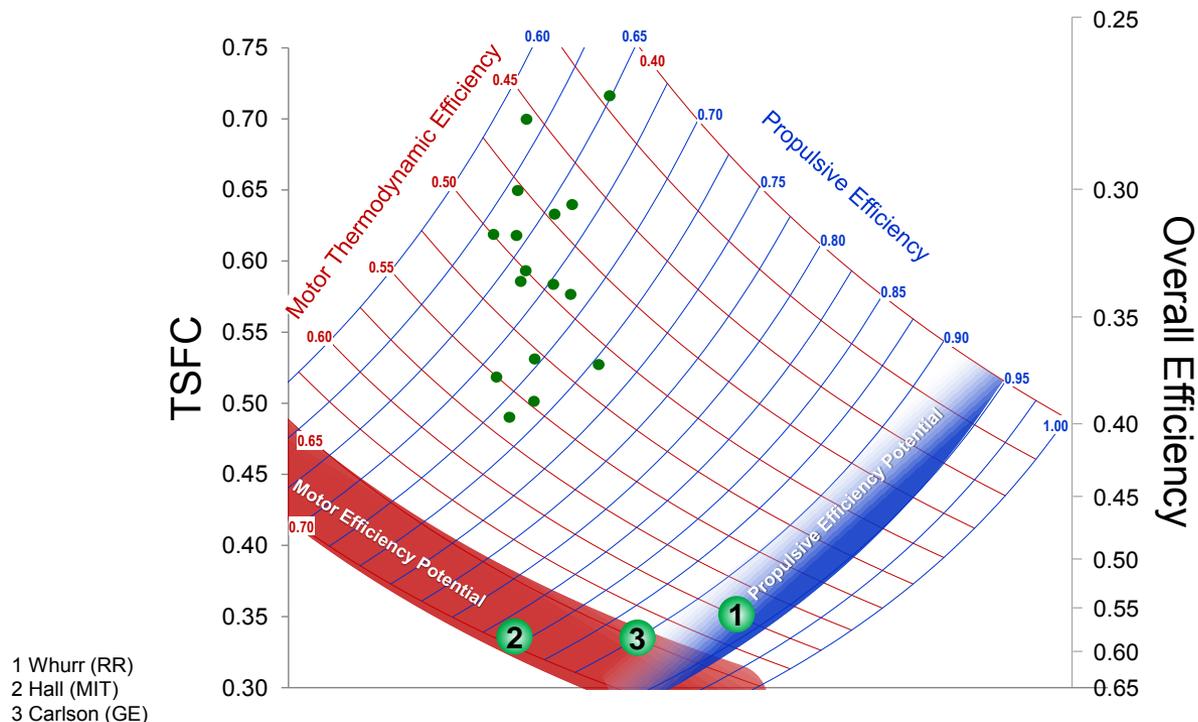
Photo credit: Embraer

# CLEEN TECHNOLOGY DEMONSTRATORS

## Entering A New Era of Engine Architecture

Improved propulsive efficiency enabled by PurePower<sup>®</sup> Geared Turbofan<sup>™</sup> architecture

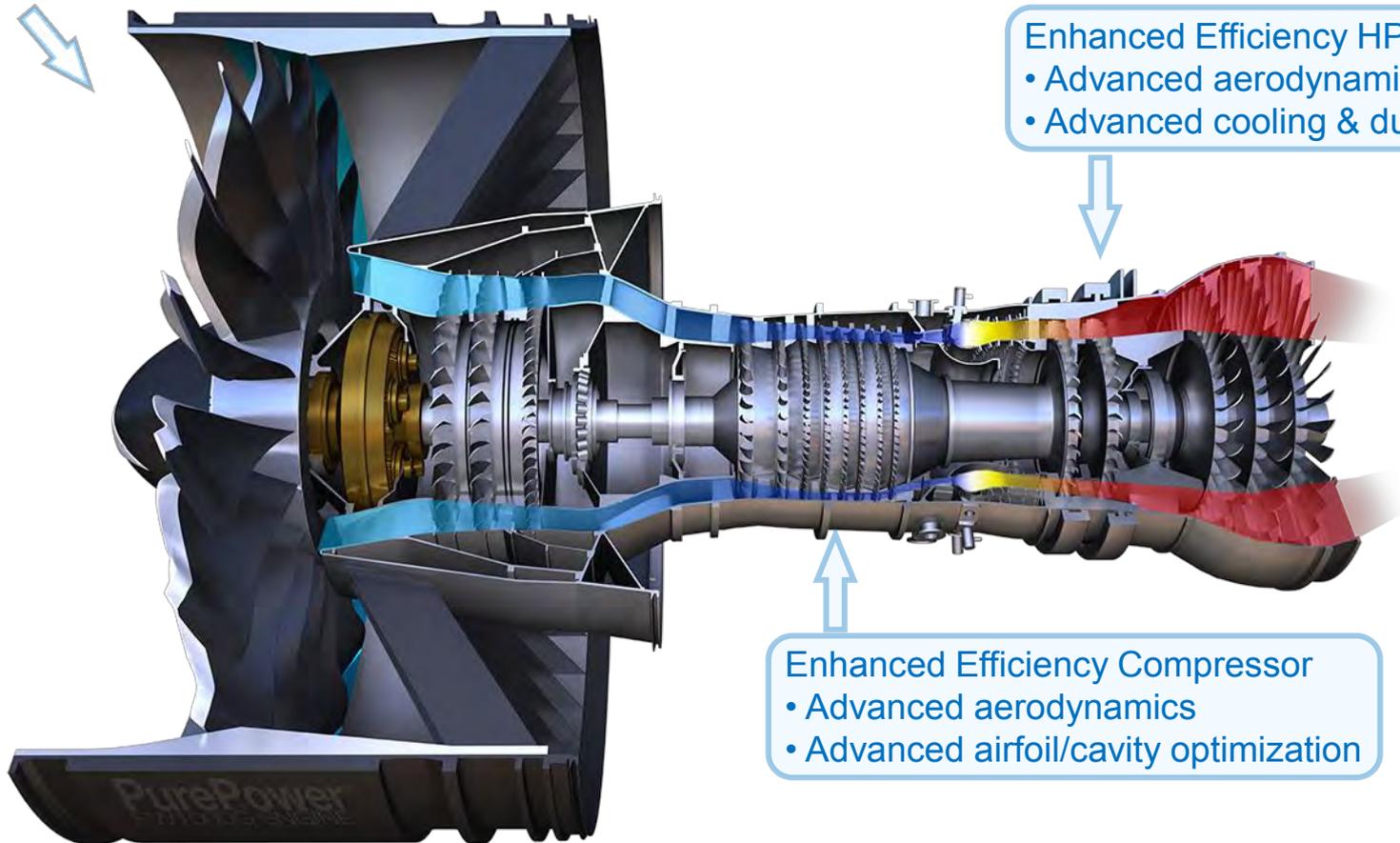
CLEEN I and II efforts enhance performance of GTF system



# CLEEN TECHNOLOGY DEMONSTRATORS

## Core and Propulsor Technologies under Evaluation

Ultra-High Bypass (UHB) Propulsor  
(Short Inlet, Low Pressure-Ratio Fan)



Enhanced Efficiency HPT  
• Advanced aerodynamics  
• Advanced cooling & durability

Enhanced Efficiency Compressor  
• Advanced aerodynamics  
• Advanced airfoil/cavity optimization

# CLEEN TECHNOLOGY DEMONSTRATORS

## Program Schedule

	2015	2016	2017	2018	2019	2020
<p>Photo Credit: NASA</p>  						
<b>UHB Techs.</b>	Fab & Assemb	Rig Test	Fabrication / Assembly	Eng Test		
<b>HPC Techs.</b>		Fabrication/Assembly	Rig Test	Analysis/Redesign	Fabrication / Assembly	Engine Development Program
						
			Photo Credit: MTU			
<b>HPT Techs.</b>		Design	Base Fab	Base Testing	Fab	Testing
						
					Photo Credit: Penn State University	

# CLEEN TECHNOLOGY DEMONSTRATORS

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## Program Overview – Summary Status

Key technology demonstrators running or completed test

HPC rig post test evaluation completed

Post test h/w acceptable

Engine demo planning initiated.

PSU HPT START facility upgrade shakedown completed

Baseline turbine test in process

Technology hardware casting drawings released

UHB engine demonstrator testing complete

150+ hours/250+ cycles of ground testing

Aero performance, mechanical, acoustic characteristics confirmed

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## HPC Technology Status Maturation Strategy

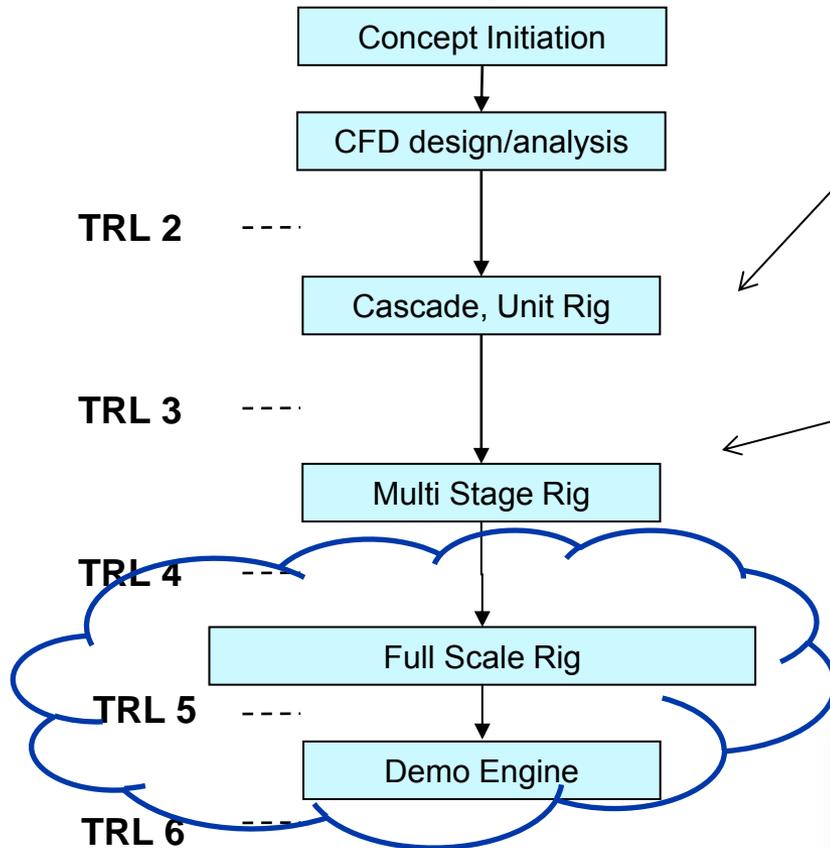


Photo Credit NRC Canada

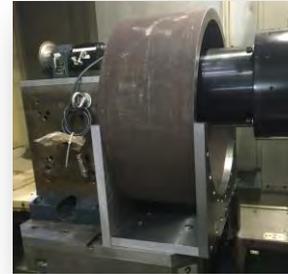


Photo Credit: MTU



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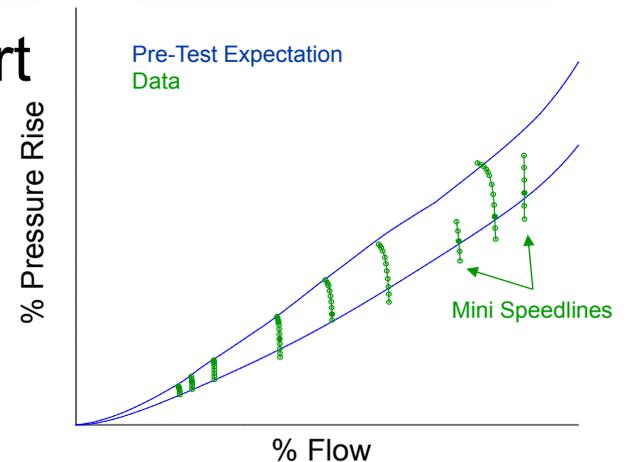
## HPC Technology – Near Term Milestones Achieved

- ✓ Complete post test hardware assessment

Over 200 parts/assemblies evaluated and documented



- ✓ Complete data assessment & test report



# CLEEN TECHNOLOGY DEMONSTRATORS

## HPC Technology – Data Assessment & Next Steps

Data assessment completed

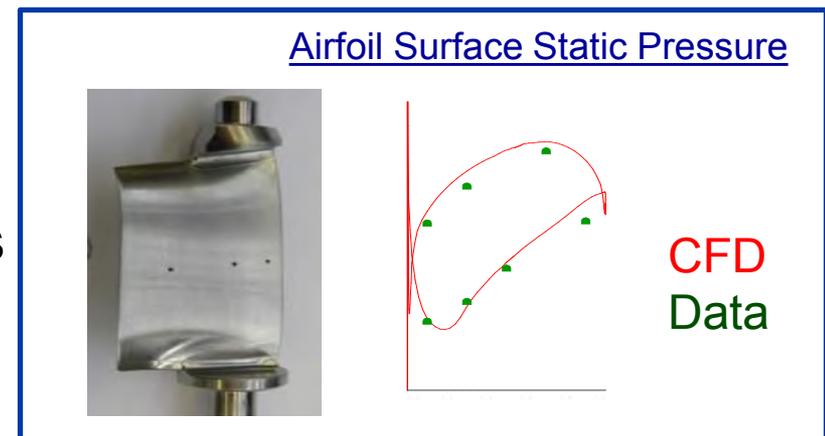
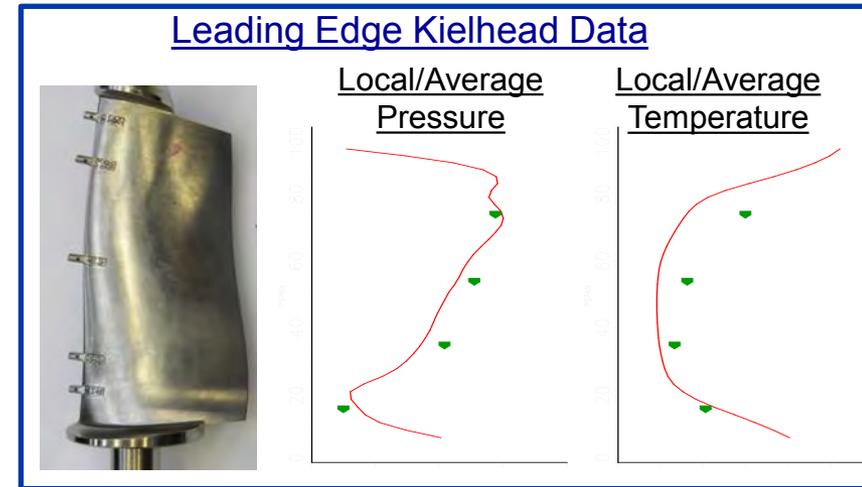
Improved GTF HPC achieved

Extensive instrumentation enables detailed HPC understanding

Comprehensive sensitivities study completed

Results comparable to CFD predictions

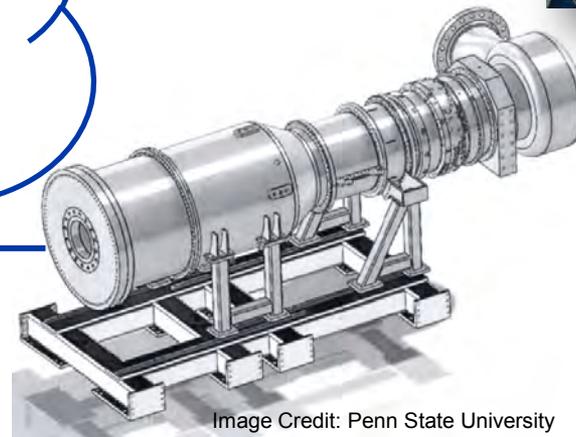
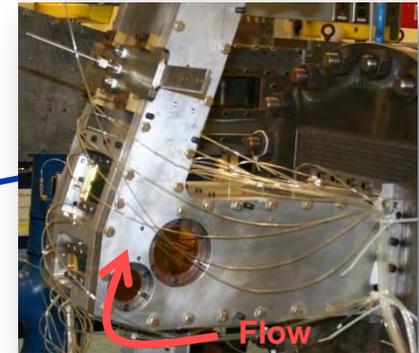
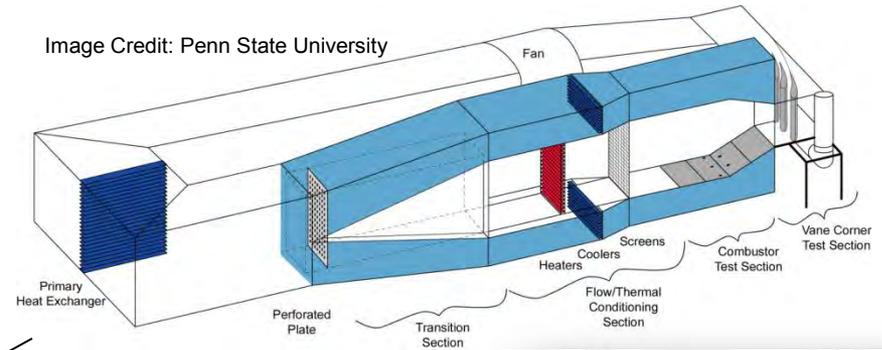
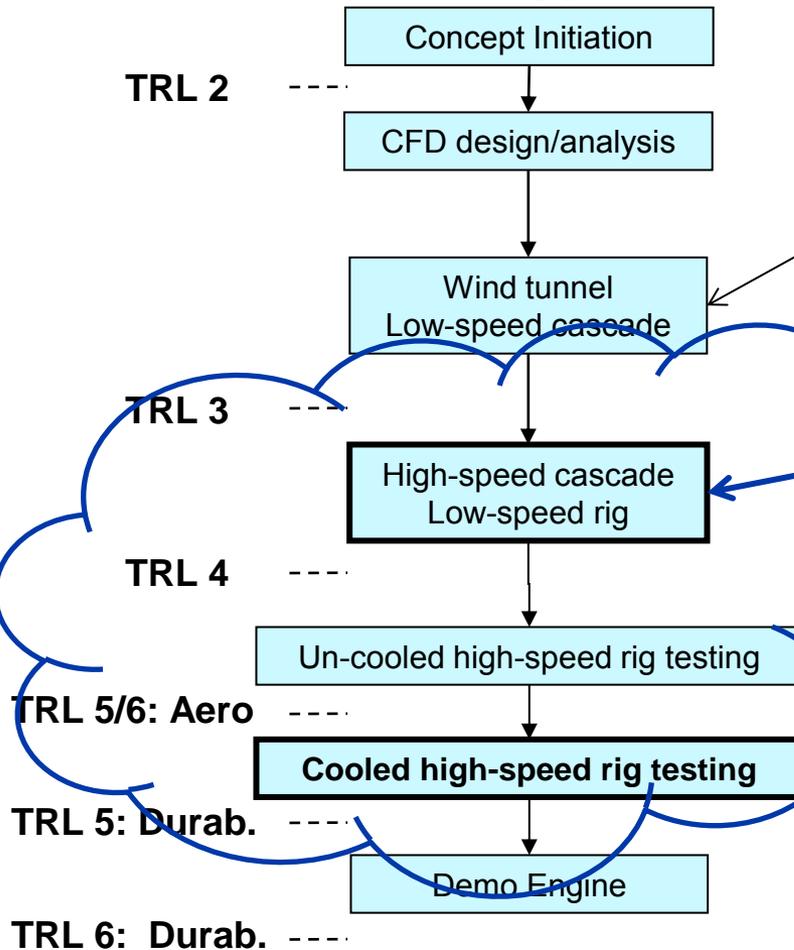
Demo engine planning initiated



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## HPT Technology Status

### Maturation Strategy



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## HPT Technology – Near Term Milestones Status

- ✓ Complete PSU START rig hardware fabrication/assembly and initiate facility shakedown
  - Upgraded hardware delivered & rig assembled
  - Facility shakedown complete, testing started
  
- ✓ Complete design for technology blade for PSU START rig and release purchase orders
  - Casting purchase orders placed
  
- ✓ Complete UTRC cascade fabrication & conduct baseline airfoil testing
  - Detailed design complete
  - Baseline test start in July

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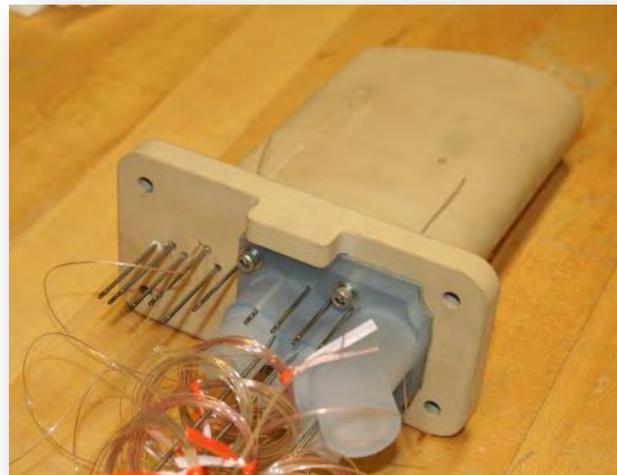
## HPT Technology Status – Cascade Testing

Cascade rig special test equipment design completed

Guidewalls, windows, camera integration

Aero / thermal concept detailed design complete

Baseline blade hardware fabrication initiated



*Single element cascade airfoil*

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## HPT Technology Status – High Speed Rig Testing

Facility upgrade complete – full span, multi-stage, cooling capable

Increased capability, enhanced instrumentation & controls



All Photo and Image Credits: Penn State University

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## HPT Technology Status – High Speed Rig Testing

Rig assembled and shake down complete

Baseline turbine testing imminent



All Photo and Image Credits: Penn State University

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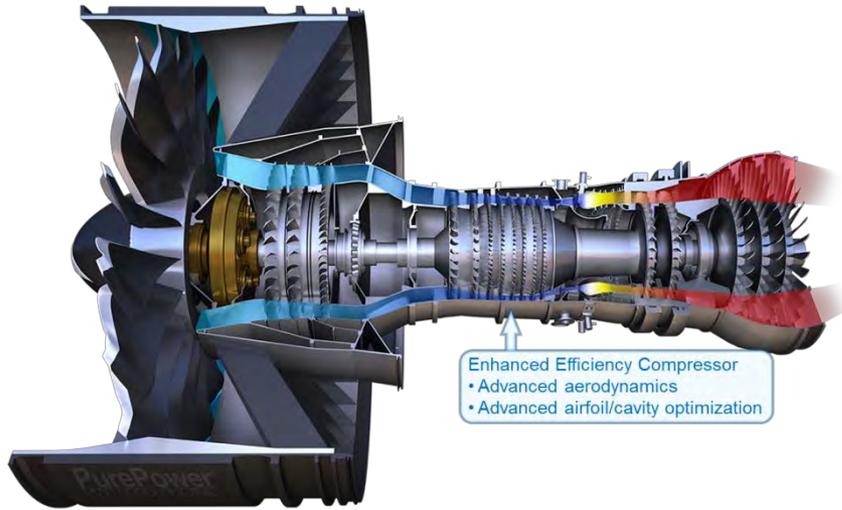
## HPT Technology – Near Term Milestones

Complete UTRC cascade fabrication & conduct baseline and technology airfoil testing

Complete PSU START rig baseline turbine test and integrate exit traverse

Complete technology blade castings for PSU START rig

# Compressor Aero-Efficiency Techs.



## Benefits:

- Improved thermal efficiency
  - ~ 0.8 – 1.0% fuel burn reduction

## Risks/Mitigations

- Achievement of performance and operability targets
  - Utilize multi-stage rigs for early validation
  - Execute redesign, if needed, and utilize lower-level rigs for progressive validation before engine demo

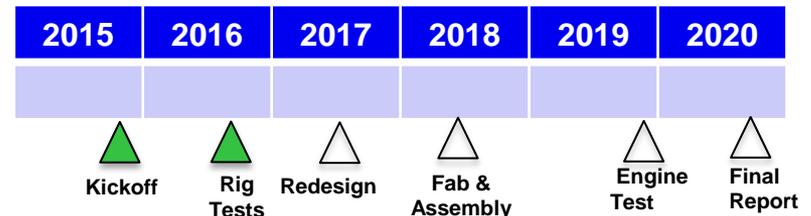
**Objectives:** *Demonstrate improved high pressure compressor efficiency via advanced aerodynamic airfoil optimization*

**Work Statement:** Continue the TRL advancement of compressor aero-efficiency technologies via detailed design, fabrication, full-scale rig tests, and engine validation.

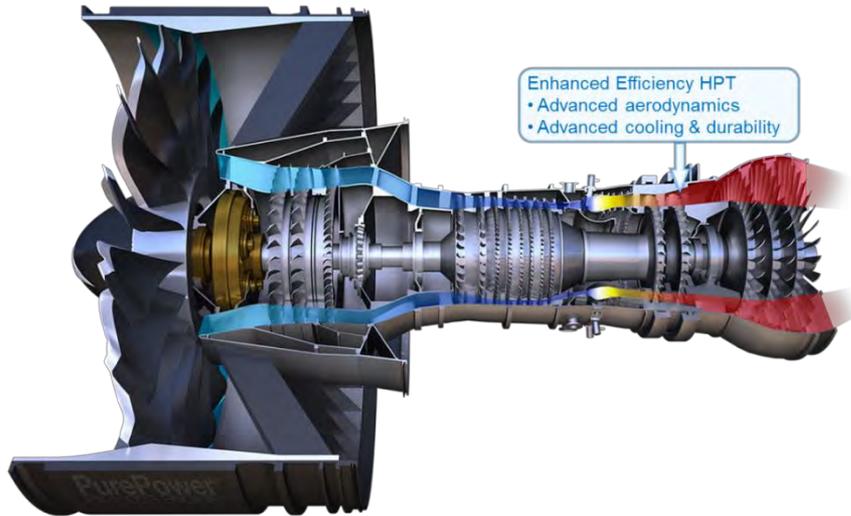
## Prior Accomplishments:

- Completed post test h/w assessment
- Completed rig results analysis

## Schedule & Planned Milestones:



# Turbine Aero-Efficiency & Durability



## Benefits:

- Improved thermal efficiency
  - ~ 0.8 – 1.0% fuel burn reduction

## Risks/Mitigations

- Technology interaction prevents assessment of contribution of individual items
  - Execute additional rig trials to isolate
- Testing compromised due to assembly delays
  - Procure additional rig hardware for assembly

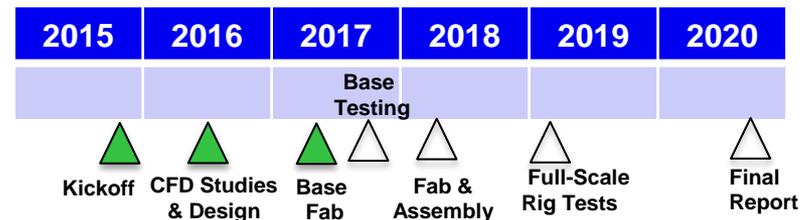
**Objectives:** *Demonstrate improved high pressure turbine efficiency via advanced aerodynamic airfoil and durability optimization*

**Work Statement:** Continue the TRL advancement of turbine aero-efficiency and durability technologies via CFD studies, detailed design, fabrication, and full-scale rig tests.

## Prior Accomplishments:

- Completed cascade detailed design
- Completed rig upgrade design and fabrication
- Initiated baseline rig testing

## Schedule & Planned Milestones:



# CLEEN TECHNOLOGY DEMONSTRATORS

## UHB Engine Demo (CLEEN I)

Leverage propulsor technology & acoustic performance

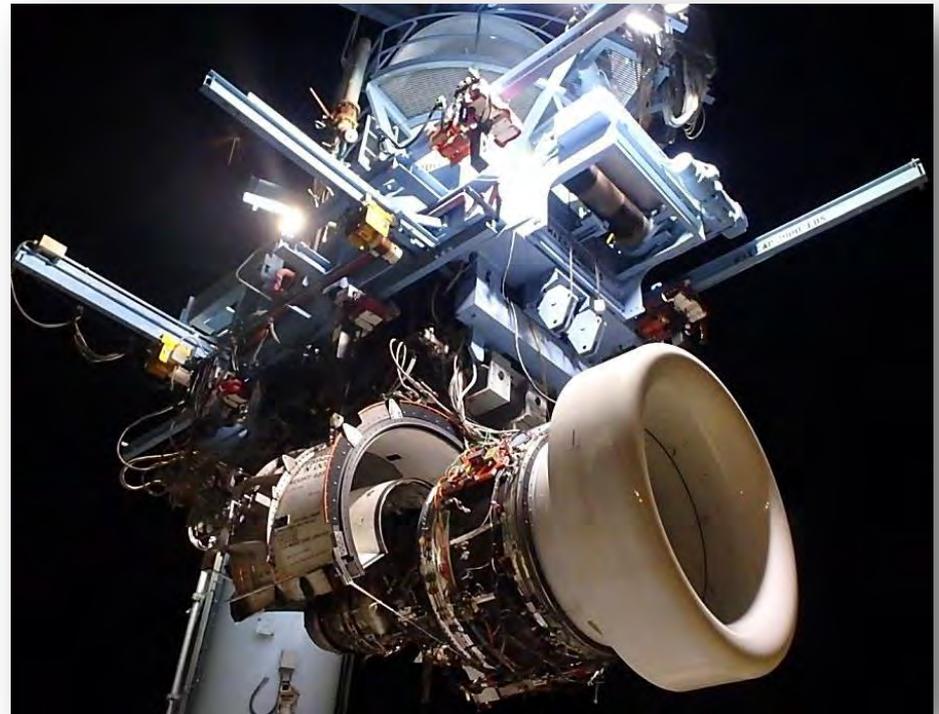
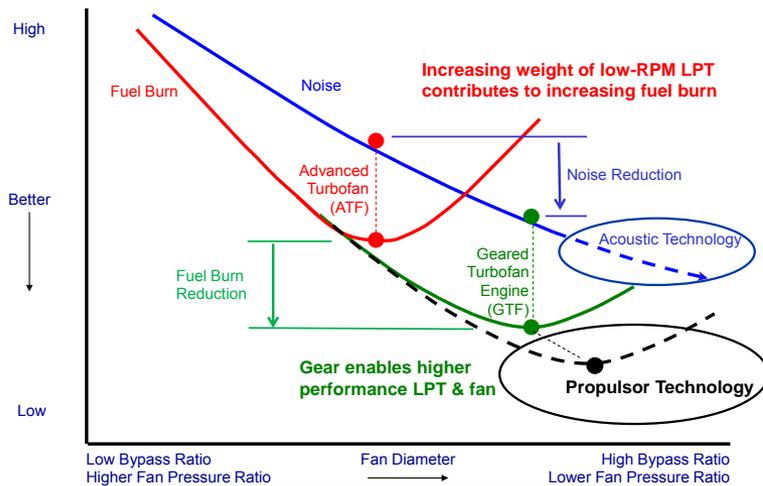


Photo Credit: NASA

# CLEEN TECHNOLOGY DEMONSTRATORS

## UHB Engine Demo (CLEEN I)

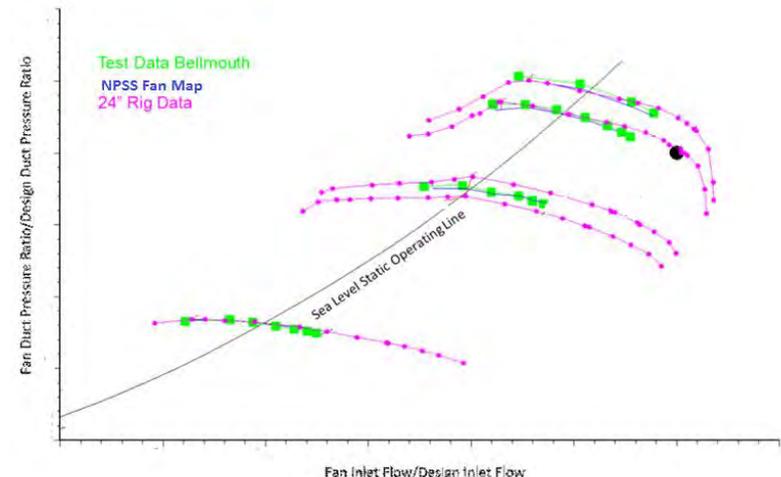
Generation 2 GTF propulsor technology successfully engine tested

Comprehensive aero and acoustic test program...over 2600 test parameters

Performance consistent with pretest predictions and scaled fan rig results

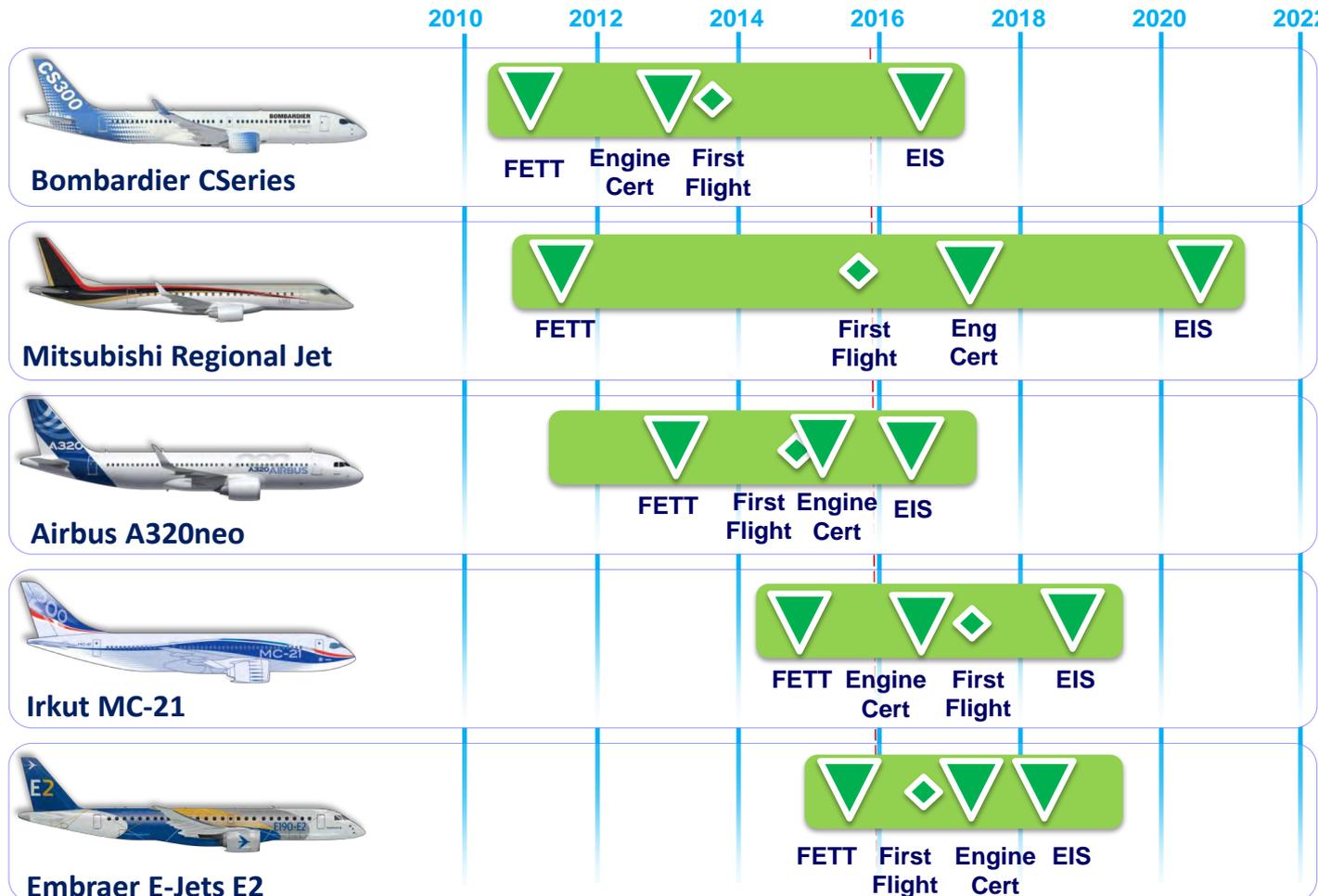
Design space validated

Engine ready for UHB flight demonstration program



# PUREPOWER® GTF ENGINE APPLICATIONS

80+ Customers/8000+ Engine Orders



# CLEEN TECHNOLOGY DEMONSTRATORS

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## Summary

P&W CLEEN programs progressing to plan

Technology delivering improved GTF performance

HPT technology facility upgrades completed

HPC technology rig performance assessment complete



# THANK YOU

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