CLEEN II Consortium

Program Update – Public Plenary

GE Aviation

October 28, 2020

Approved for Public Use

GE is aligned with CLEEN goals

FAA Goal Area	CLEEN I Goal 2010 – 2015		CLEEN II Goal 2015-2020	
Noise (cum below Stg 4)	-32 dB		-32 dB	**Advanced Acoustics**
LTO NOx Emissions (Below CAEP/6 @30 OPR)	-60%	**TAPS II**	-75% (-70% rel CAEP/8)	**TAPS III**
Aircraft Fuel Burn (including SAF)	-33%	**Open Rotor** **FMS-ATM** **FMS engine integration**	-40%	**MESTANG I & II** **FMS** **SAF testing**

GE and partner products

Up to -15% FB
vs. CF6-80C2

GEnx (2011)

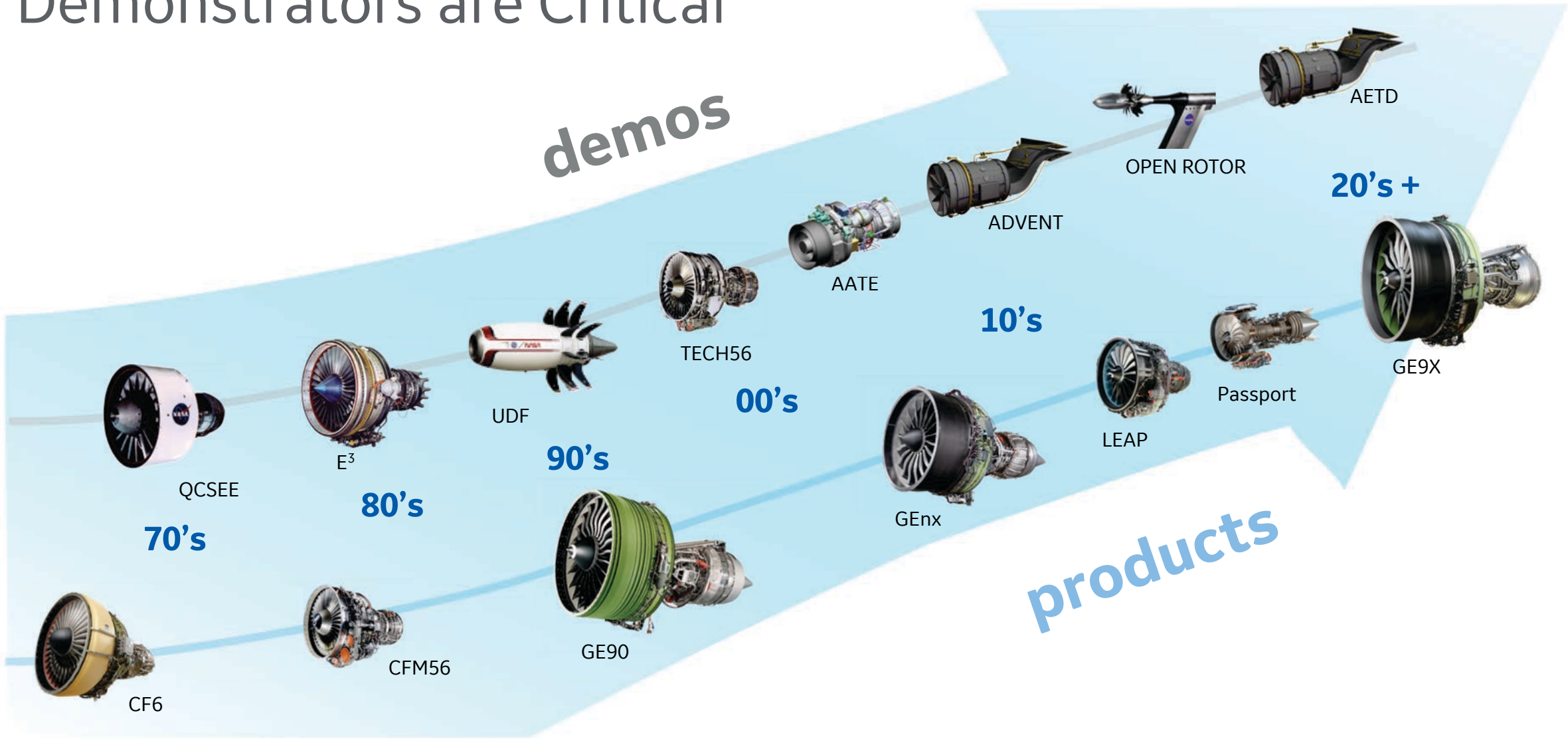
-15% FB
vs. CFM56

CFM* LEAP™ (2016)

-10% FB
vs. GE90-115B

GE9X (2021)

Demonstrators are Critical



Demonstrators play a foundational role in development of new products

You have to prove it in flight....

GE9X certified on September 25th, 2020

Delivering lower fuel burn, NOx emissions and noise

Lower fuel burn, NOx and noise

10%
LOWER
Specific fuel consumption
versus GE90-115B

>55%
MARGIN
CAEP 8 NOx

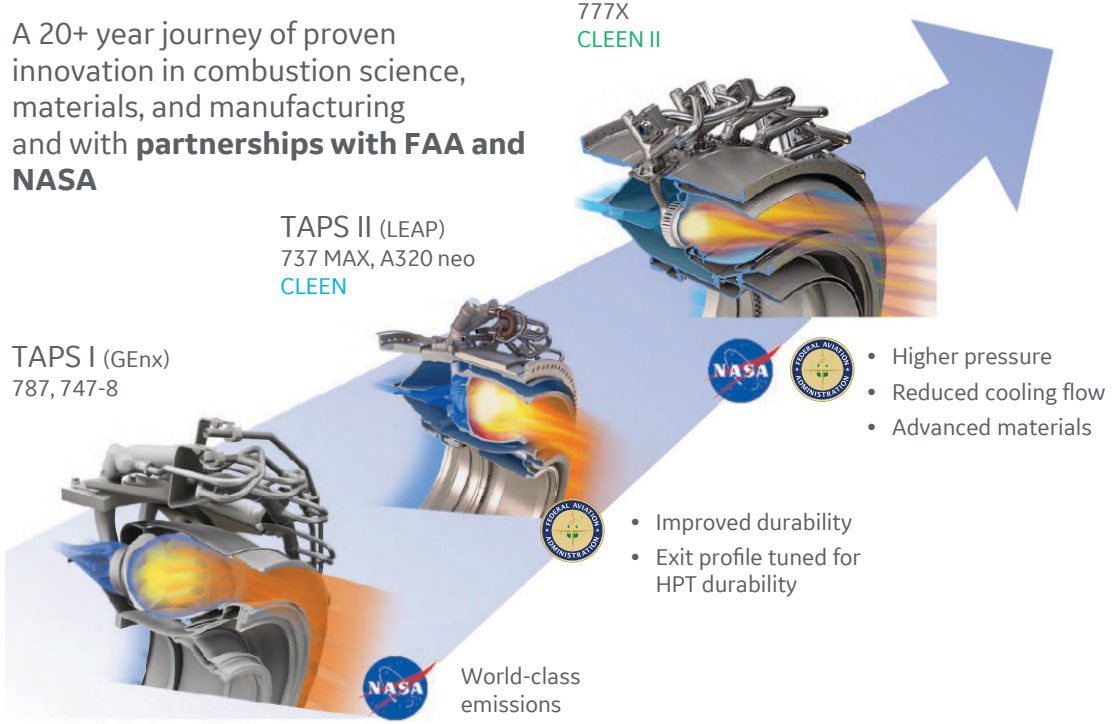
105k
LBS. THRUST
multiple applications

Quietest
GE Engine
in terms of pounds of thrust per decibel

Further evolution in TAPS combustor

GE TAPS III Combustor
Combustion technology

A 20+ year journey of proven innovation in combustion science, materials, and manufacturing and with **partnerships with FAA and NASA**



GE CLEEN II Technologies Overview

CLEEN Technology Name	Goal Impact	Benefits and Application	Status
Advanced Acoustics	Noise	Up to 3 EPNdB cum with neutral fuel burn impact	Active
MESTANG I	Fuel burn	Up to 3% benefit for single-aisle aircraft	Completed
MESTANG II	Fuel burn	Additional fuel burn benefits 1-2%	Active
Sustainable Aviation Fuels	Alternative Fuels	Advance SAF approvals and evaluation tools	Completed
FMS	Fuel burn	Up to 4% benefit, 1.0% fleetwide average	Completed
TAPS III –Technology	Emissions	35% reduction relative to CAEP/8 (55 OPR)	Completed

More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG II)

Fabian Isaza

MESTANG Technology Overview

Next-gen Commercial Aircraft will need a “more-electric” power system to realize practical fuel savings and/or mission capability

Project objectives:

- Advance kV-Class DC primary power system feasibility through lab demonstration
- MW-Class Flight Altitude Generator
- Demonstration with MW-Class SiC converter (NASA SLIM)
- TRL6 demonstrator at GE EPISCenter and NASA’s NEAT Facility
- Demonstrate fuel burn benefit (1-2%) over ± 270V MESTANG Power System

NASA’s NEAT Facility

Customer objectives:

More Electric Systems and Technologies for Aircraft in the Next Generation (MESTANG), is an integrated aircraft power system designed to support future “more-electric” aircraft architectures that reduce fuel burn by up to 3% for single-aisle aircraft while improving performance at equivalent cost

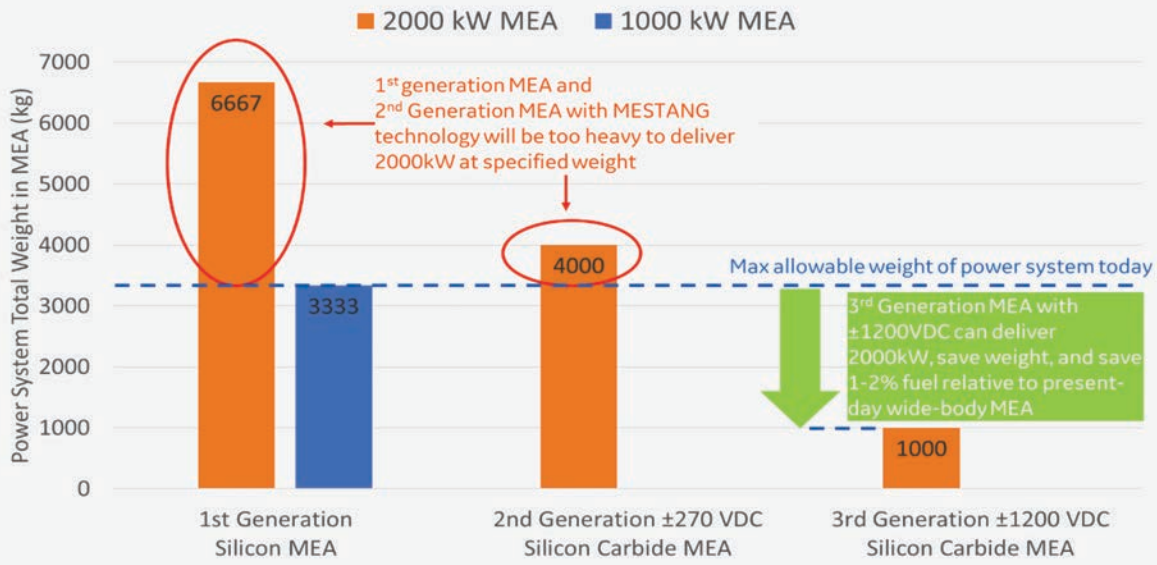
kV/MW Class Generator Benefits

System Weight

kV-Class components enable High Power Density:

- 6+ kW/kg Generators
- 10+ kW/kg Converters
- 2+ kW/kg Power Generation System

B787 Widebody Power System Baseline



Fuel Burn

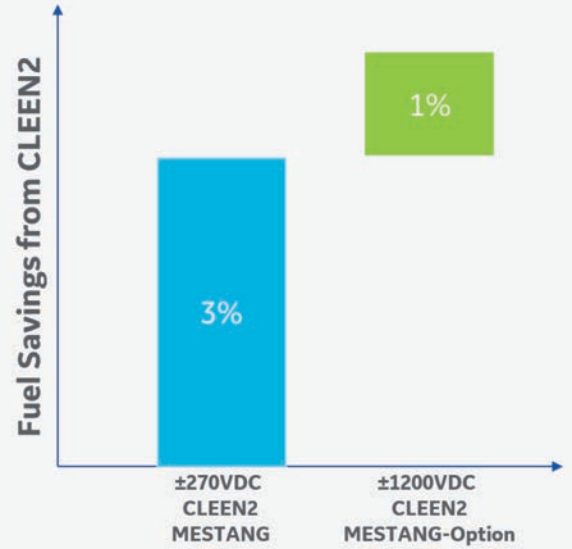
For Widebody aircraft, kV-Class components power density enable fuel burn benefits:

- 1-2% over MESTANG
- 2-3% over 1st Gen MEA

Assumes 4000nm mission

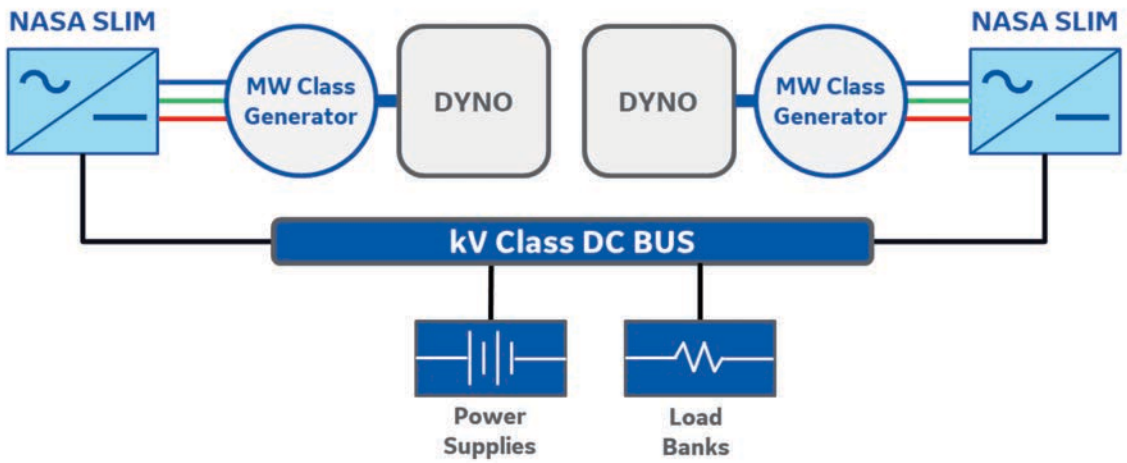
Add'l Opportunities:

- Bleed less
- Electric start
- ECS and actuation
- eTaxi
- System optimization



High Voltage Power System enables weight and system optimization

Project Technology: kV/ MW Class Generator



Anticipated Benefits:

- Up to 3% Fuel burn (Weight + Optimization)
- Higher power density…
  - >2kW/kg Power Generation System
- High efficiency power distribution
- Optimization of electrical system

Objectives:

- TRL6 for high voltage and high-power generator
- Specific Power system density >2 kW/kg
- Additional fuel burn benefits of 1-2% over MESTANG

Work Statement:

- Design and test of altitude flight high voltage and high-power generator

Accomplishments/ Milestones:

• Test Facility preparation	Complete
• Generator Assembly	Complete
• Safe return to test	Complete
• Installation & test readiness	Oct 2020
• Test Initiation	Nov 2020

Schedule:

4Q 19	1Q/2Q 20	3Q 20	4Q20-2021
Design Complete ✓	Manufacture Gen Assembly ✓	Safe return to test activities ✓	Component System Test

Low Pressure Ratio (LPR) Advanced Acoustics

Tim Depuy

Advanced Acoustics Project and CLEEN Goals

"Certifiable aircraft technology that reduces noise levels relative to the FAA's Stage 4 noise standard and/or reduces the noise contour area in absolute terms"

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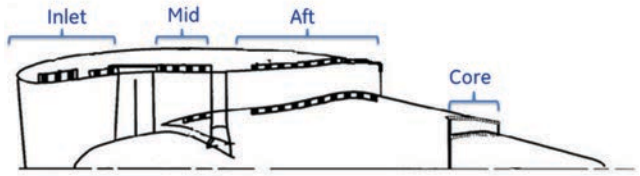
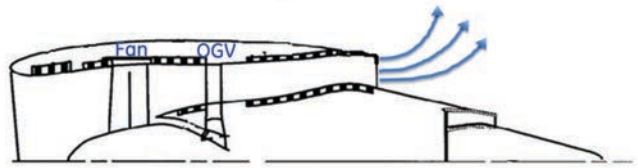
Focused on reducing noise levels through development of *Novel Liners* and *Fan Source Strength Reduction* without impact to fuel burn and emissions

Project Technology:

Novel Liners



Fan Source Strength Reduction



Anticipated Benefits:

- Improved Acoustic liner benefit re: Single degree freedom Liners,
- Target ~ 2EPNdB Cum, Neutral Performance.

- Improved Fan Noise Source Strength Reduction re: LEAP.
- Target ~ 1 EPNdB Cum, Neutral Performance.

Objectives:

- To Develop Novel Acoustic Liners.
- To Develop Fan Source Strength Reduction Concepts.

Work Statement:

Design, Develop, Fabricate and Test Novel Acoustic Liner.

Aeroacoustic Design and Testing of Fan noise source strength reduction concepts.

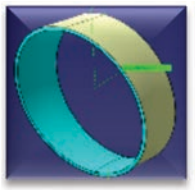
Accomplishments/ Milestones:

- Developed several novel liner cores
- Tested several liners with at NASA's Grazing Flow Impedance Tube facility
- Downselected to a specific liner design
- Completed large demo panel

Fan Noise Source Reduction

- Completed Fan Source Strength Reduction design reviews
- Started manufacture of subscale hardware to validate acoustic benefit and performance.

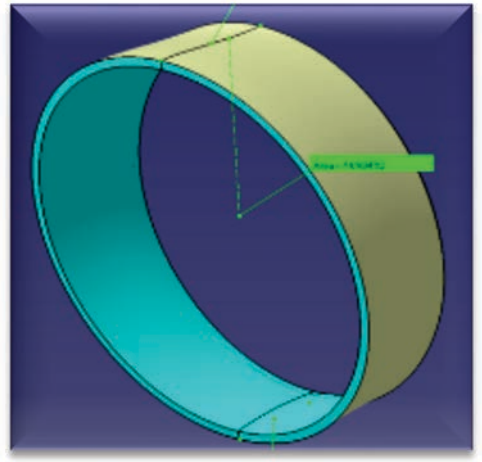
Project Schedule

Technology	Earlier	FY 2018	FY 2019	FY 2020
1. Novel Acoustic Liner Technology	Concepts Developed and Tested in Normal Impedance Tube	Grazing Flow Test Rig Round 1	Grazing Flow Test Rig Round 2	Large scale samples
Test part geometry	<5" X 5" 	2.5" X 21"	2.5 X 21" 	
TRL/MRL		3/3	4/4	4/4
2. Fan Noise Source Strength Reduction	Down Select and Identify Source Strength Reduction Concepts	Preliminary Design of one Aeroacoustic fan Source Strength Reduction Design	Pretest Prediction & Final Reviews	Hardware Manufacture for Wind Tunnel UPS test 
TRL			3	3

Summary and Next Steps

Novel Liners

- Completed Grazing Flow tests
- Optimized a full-scale design based on test and model results
- Manufacturing a large sample sector panel



Fan Source Strength Reduction

- All design reviews complete
- Subscale test hardware being manufactured

Thank you for your support…

In an unprecedented time, the CLEEN program is critical for sustained aviation growth

NextGen component technology maturation supports environmental protection

Technology demonstrators are foundational… leading to certification of products

GE is aligned with FAA's energy, emissions, and noise reduction goals

GE is looking forward to great continued partnership