Boeing CLEEN Phase III Program Update

FAA CLEEN Consortium – Industry Day

Jennifer Kolden

November 8, 2023

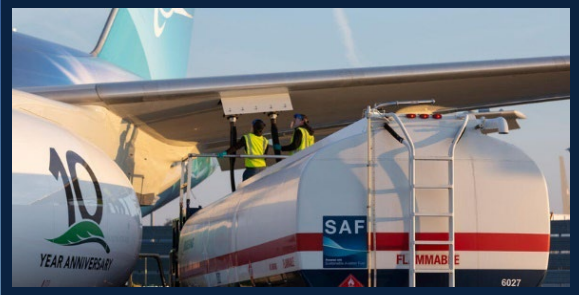
Decarbonizing Aerospace

SUSTAINABLE AEROSPACE TOGETHER

FLEET RENEWAL

OPERATIONAL EFFICIENCY

RENEWABLE ENERGY



ADVANCED TECHNOLOGY

Carbon Offsetting and Reduction Scheme for International Aviation

MEET CASCADE

The Boeing Cascade Climate Impact Model, or “Cascade” is a dynamic modeling tool that quantifies the power of aviation’s major strategies to cut emissions. Within the tool, you can explore different decarbonization pathways and even forecast how each can impact aviation emissions through 2050.

EXPLORE CASCADE

Boeing Program
CLEEN Phase III

Quiet High-Lift

"Reducing Airframe Noise"

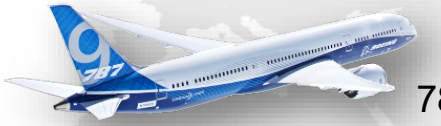
"Enabling Quieter, Advanced Propulsion"

Quiet Landing Gear

Next Generation Inlet

737 MAX

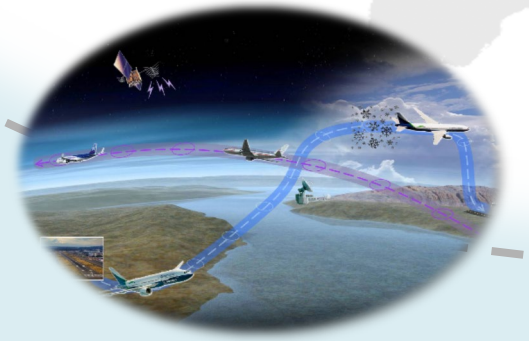
eco Demonstrator PROGRAM



787

"Improving How the Airplane is Operated"

Intelligent Operations



Sustainable Aviation Fuels

"Accelerating SAF Uptake to meet CO2 goals"

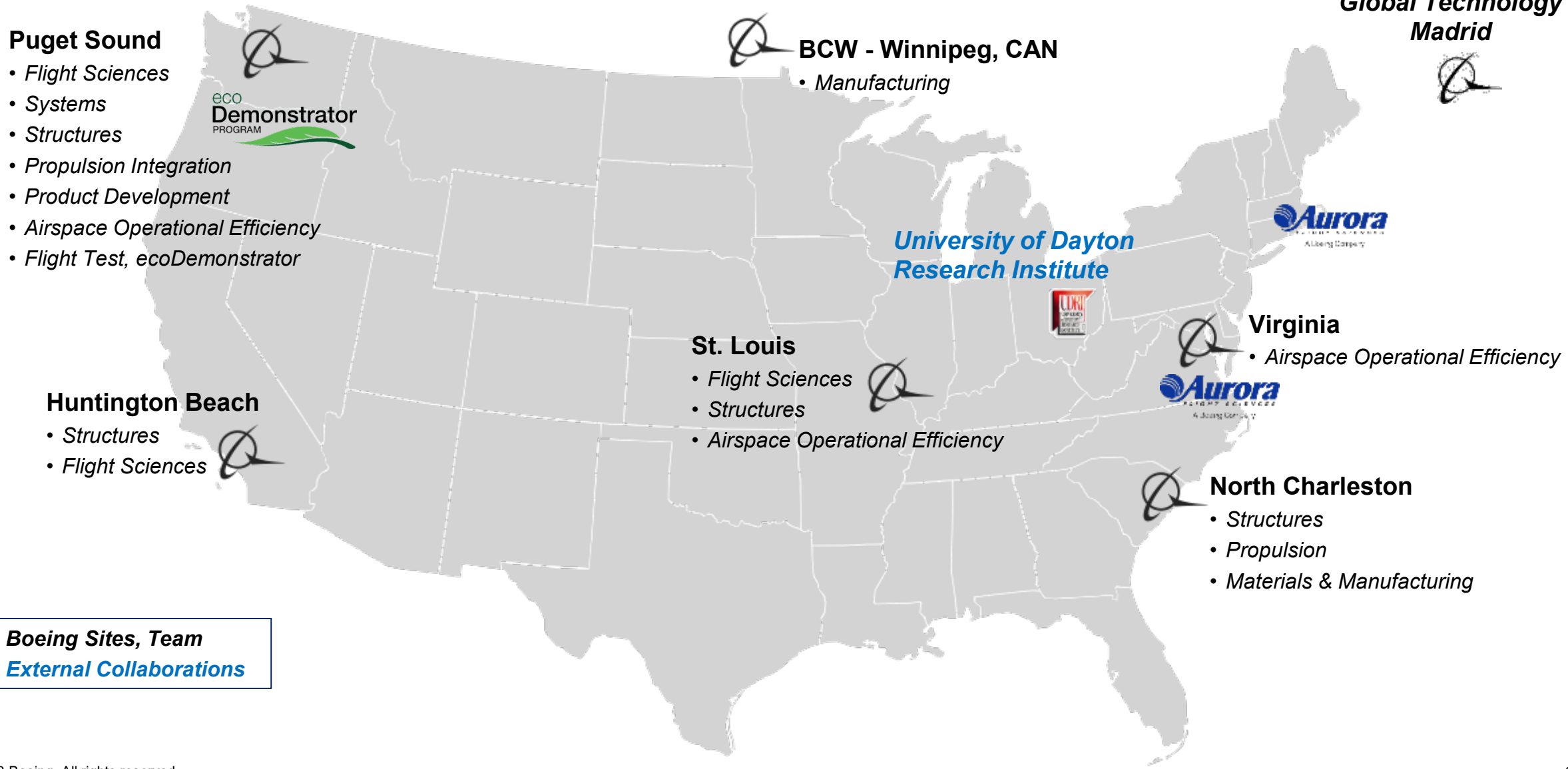
Aurora FLIGHT SCIENCES A Boeing Company

BOEING

NASA

UDRI UNIVERSITY of DAYTON RESEARCH INSTITUTE

Program Team – “Best of Boeing”



Puget Sound
- *Flight Sciences*
- *Systems*
- *Structures*
- *Propulsion Integration*
- *Product Development*
- *Airspace Operational Efficiency*
- *Flight Test, ecoDemonstrator*

BCW - Winnipeg, CAN
- *Manufacturing*

Global Technology Madrid

University of Dayton Research Institute

Virginia
- *Airspace Operational Efficiency*

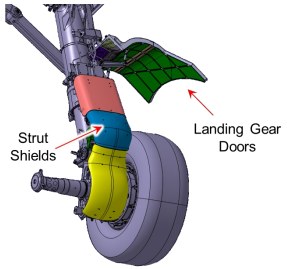
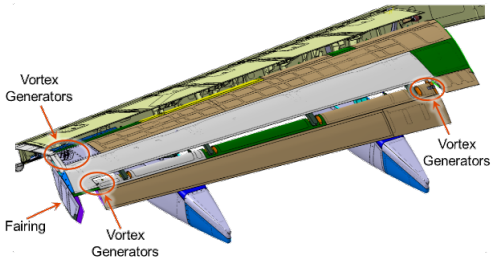
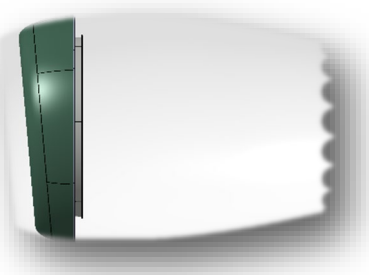
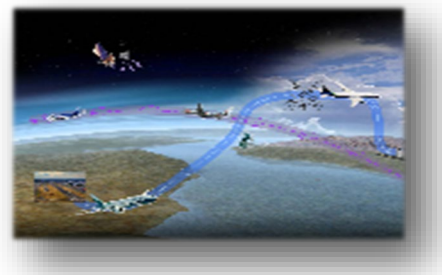
St. Louis
- *Flight Sciences*
- *Structures*
- *Airspace Operational Efficiency*

Huntington Beach
- *Structures*
- *Flight Sciences*

North Charleston
- *Structures*
- *Propulsion*
- *Materials & Manufacturing*

- ***Boeing Sites, Team***
- ***External Collaborations***

Projects & Benefits

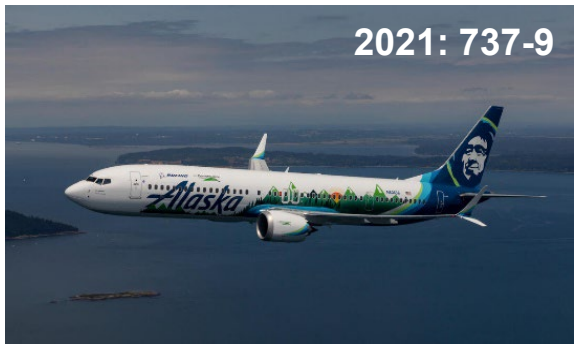
	Quiet Landing Gear	Quiet High-Lift	Next Generation Inlet	Intelligent Operations	Sustainable Aviation Fuels
Technology					
	• Acoustically Treated Main Gear Doors • Perforated Strut Shields	• Outboard Flap Side Edge Fairings • Outboard Flap Vortex Generators	• New Structural Architecture • New Ice Protection System • Maximize Acoustic Treated Area	• Noise-Optimized Flight Paths • Leverages Existing Capabilities	• Higher Performing Blends • Drop-in Compatibility • Support Scale-up
Impact	Reduce Community Noise	Reduce Community Noise	Enable New Engines, Reduce Community Noise, Fuel Burn	Reduce Community Noise, Fuel Burn	Reduce Fuel Burn, Emissions
Airframe Benefits / Metrics	Up to 0.5 EPNdB	Up to 0.5 EPNdB	1.5 EPNdB 2.0% Block Fuel	3-5 peak dBA 2% Take-off Block Fuel 5% Approach Block Fuel	2%-3% Block Fuel
Projected Fleet Impact	Reduce 65 dB community noise contours	Reduce 65 dB community noise contours	Community Noise, 82M Metric ton, CO2 reduction	Community Noise, 28M Metric ton, CO2 reduction	2950M Metric ton, CO2 reduction
Transition	2030 , 2035 Retrofit	2030 , 2035 Retrofit	2030 (partial) , 2035	2030 , 2035 Retrofit	2030 , 2035 Retrofit

Technology Transition

- Boeing Product Development leveraging CLEEN III technologies
  - New Products and Retrofit
  - Acoustic lining designs
  - Low speed / high lift configuration
  - Nacelle acoustics and ice protection system
  - Advanced lower noise landing gear and flap systems
- Refine/Validate noise prediction tools and design practices
- Provide near-term capabilities/services aligned with FAA NextGen and DataComm
- Mature fuel system component readiness to enable low aromatic fuels – SAF compatibility

CLEEN Phase III Technologies aligned with Product Strategies and Sustainability Vision

EcoDemonstrator Program History ~ 250 projects



eco Demonstrator PROGRAM

CLEEN Phase III Program leverages successfully proven ecoDemonstrator Program

Program Timeline

Today

ATP | 737 Flight Demo | 787 Flight Demo | Final Report

2021 | 2022 | 2023 | 2024 | 2025 | 2026

- Quiet Landing Gear
- Quiet High Lift
- Intelligent Operations
- Sustainable Aviation Fuels *(Pending Fuel Availability)*

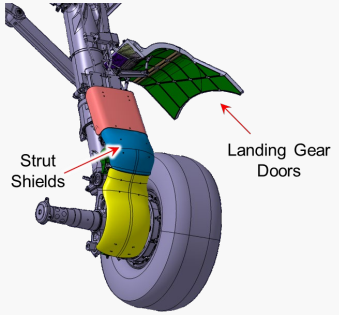
Design | Fab / Assembly | Flight | Analysis / Reporting

- Next Generation Inlet
- Intelligent Operations

Design | Fab / Assembly | Flight | Analysis / Reporting

Quiet Landing Gear (QLG)

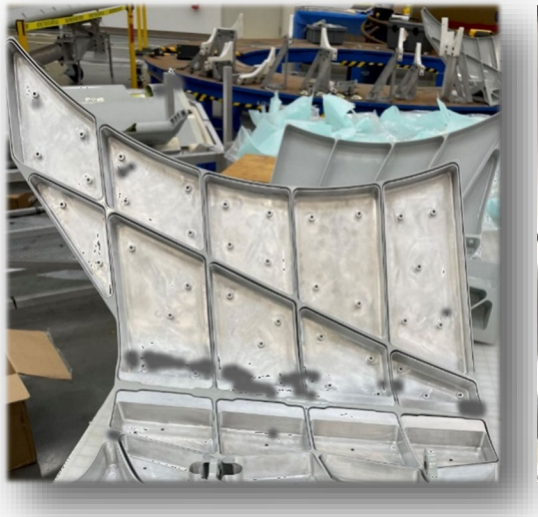
Objective: Develop landing gear (airframe) technologies to reduce aircraft noise at approach



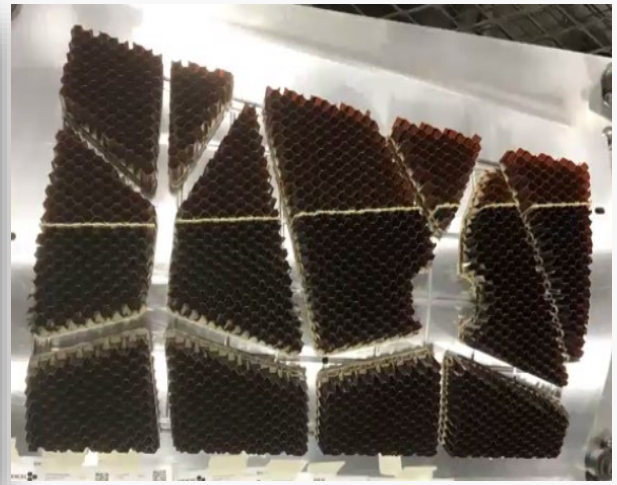
Accomplishments:

(May – Nov)

Conceptual Design → Preliminary Design → Detailed Design → Fabrication Assembly → Flight Testing → Reporting

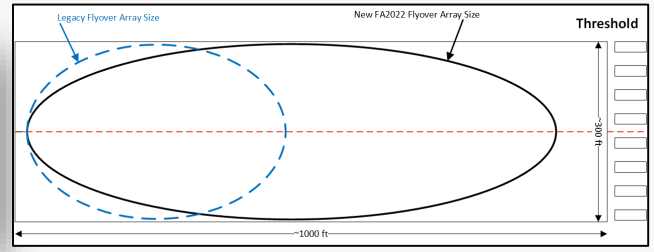


Door Inserts
Fabrication & Fit-Check



Acoustic Core
Fabrication

Acoustic Face sheet
Fabrication



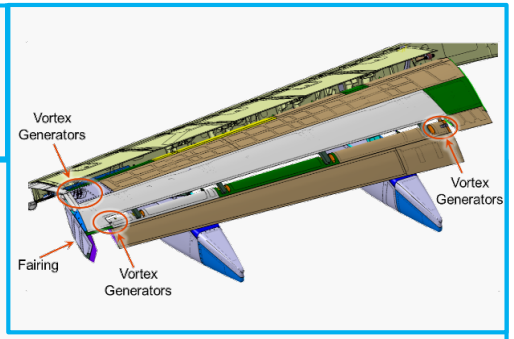
New Phased Array
Fabrication

Lookahead:

Complete Fabrication & Assembly – 1Q24
Flight Testing – 2Q24

Quiet High Lift (QHL)

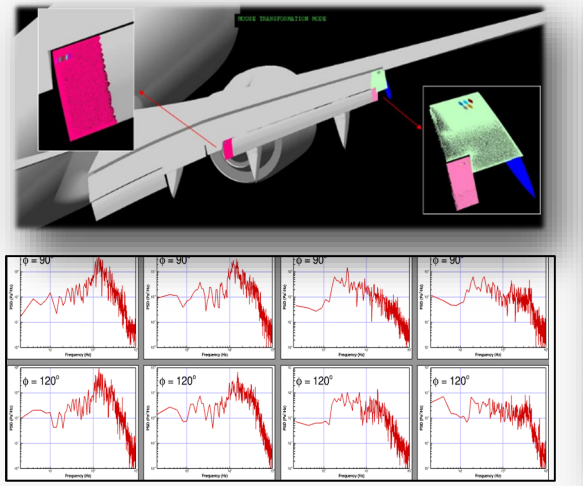
Objective: Develop outboard flap (airframe) technologies to reduce aircraft noise at approach



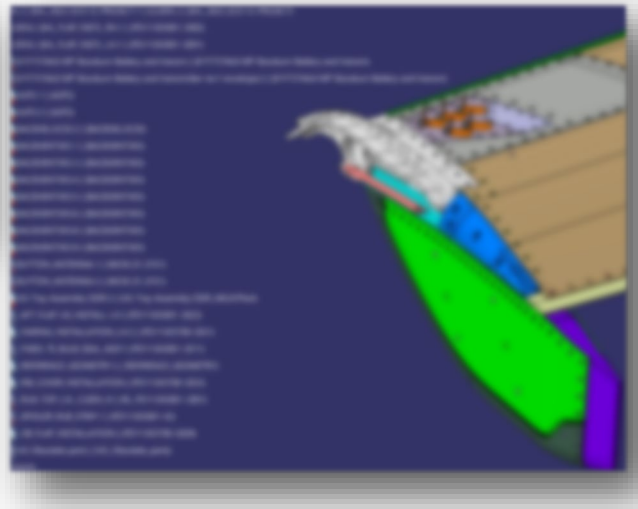
Accomplishments:

(May – Nov)

Conceptual Design → Preliminary Design → Detailed Design → Fabrication Assembly → Flight Testing → Reporting

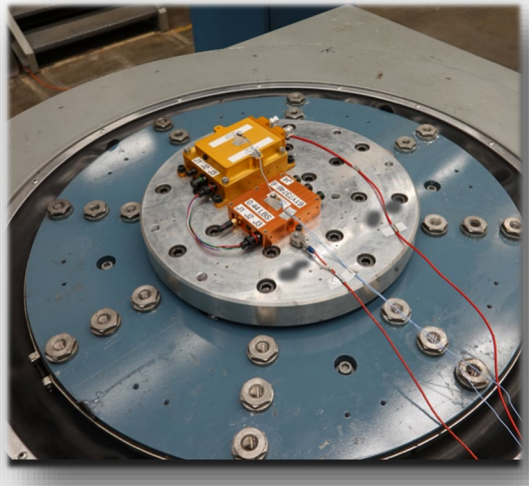


CFD/CAA Predictions



100% MBD Engineering Releases

Flap Disassembly



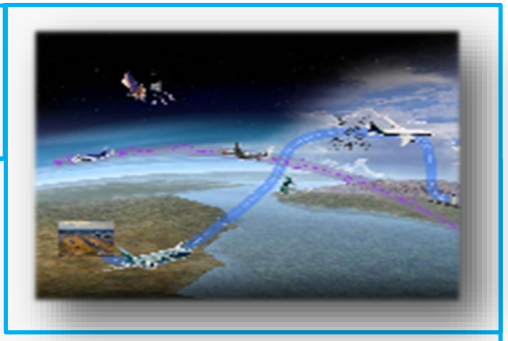
Updated Design Risk Reduction Testing

Lookahead:

Complete Fabrication & Assembly – 1Q24
Flight Testing – 2Q24

Intelligent Operations (IO)

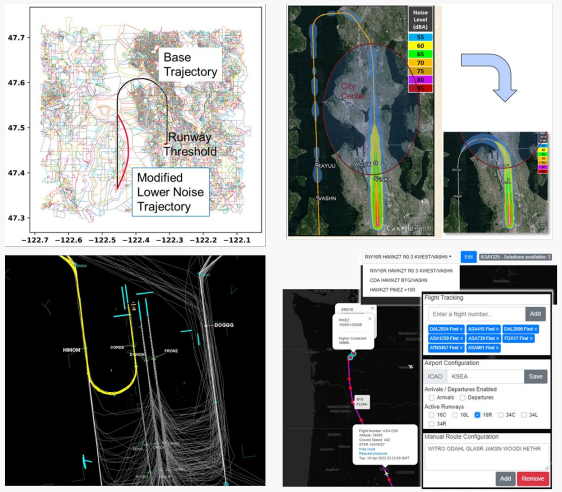
Objective: Develop aircraft operational noise reduction technology to reduce aircraft noise at take-off & approach



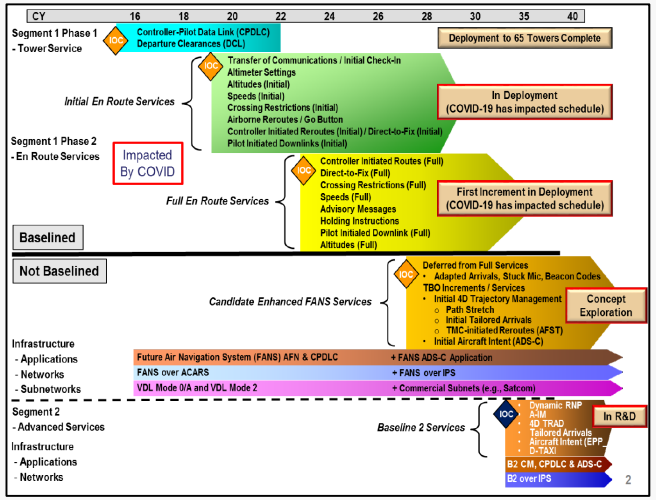
Accomplishments:

(May – Nov)

Initial Design → Design Validation → Testing & Refinement → Flight Testing → Reporting

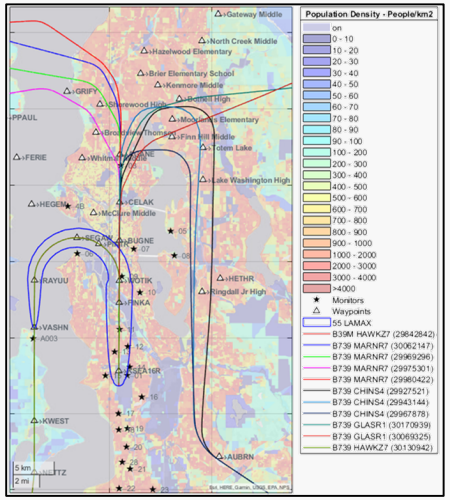


CDR



FAA Data Comm Coordination

Procedure Optimization & Pilot Simulations



Noise Impact Assessments

Lookahead:

Procedures/Systems Updates & Software Development (Drop 3) – 1Q24

Flight Test – 2Q24 & 2Q25

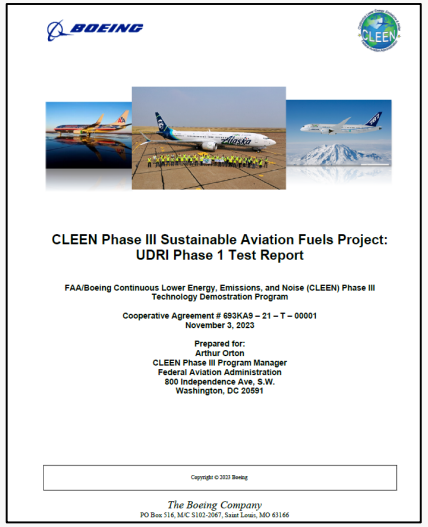
Sustainable Aviation Fuels (SAF)

Objective: Mature fuel system component readiness to enable low aromatic fuels – SAF compatibility

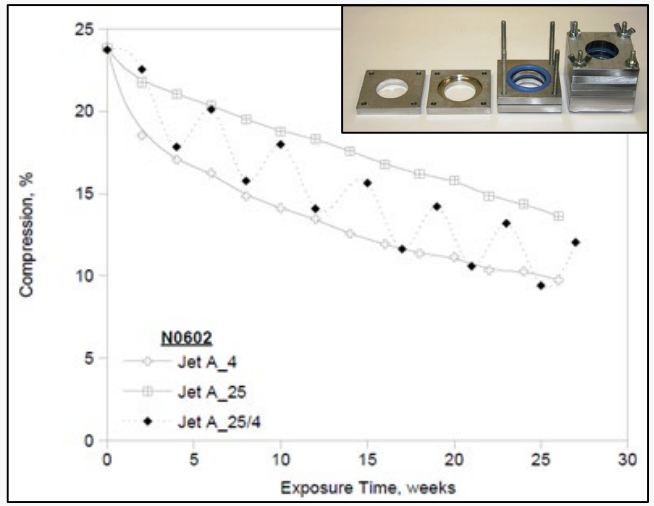
Accomplishments (May – Nov):

(May – Nov)

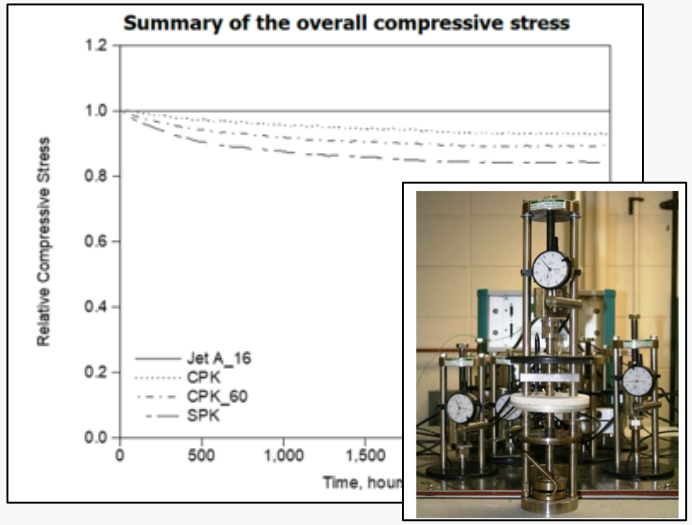
Lab Testing → Flight Testing → Reporting



Phase 1 Test Report
Public Release



Phase 1
Switch Loading



Phase 2
Thermal Cycling

Lookahead:

Complete UDRI Phase 2 Lab Testing – 1Q24

Flight Test – 2Q24 (Pending Fuel Availability)

Program Timeline

ATP | Today | 737 Flight Demo | 787 Flight Demo | Final Report

2021 | 2022 | 2023 | 2024 | 2025 | 2026

- Quiet Landing Gear
- Quiet High Lift
- Intelligent Operations
- Sustainable Aviation Fuels *(Pending Fuel Availability)*

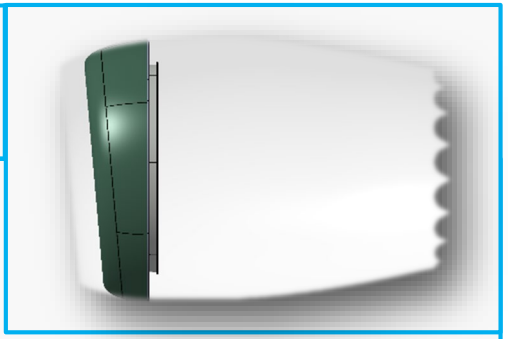
Design → Fab / Assembly → Flight → Analysis / Reporting

- Next Generation Inlet
- Intelligent Operations

Design → Fab / Assembly → Flight → Analysis / Reporting

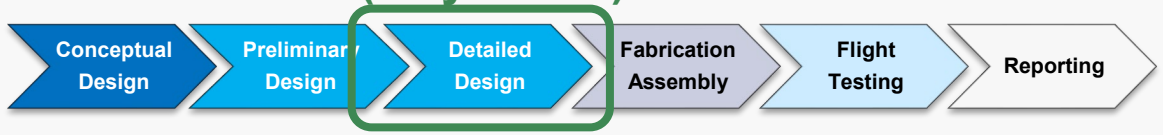
Next Generation Inlet (NGI)

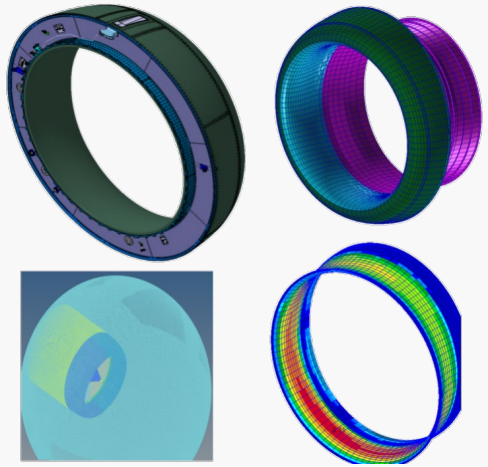
Objective: Develop inlet (engine) technologies to reduce noise at take-off and approach and address reduced-length inlet integration challenges of UHB engines



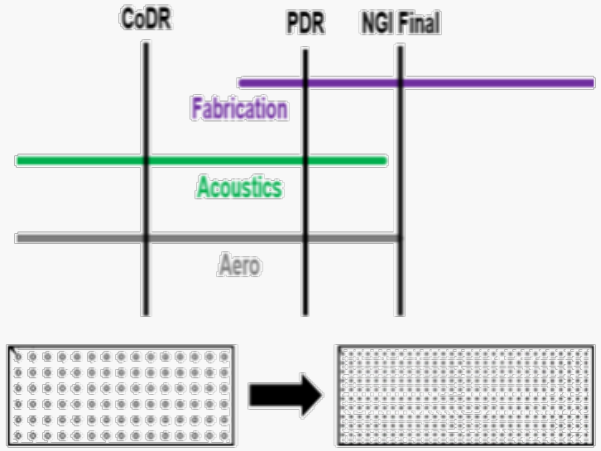
Accomplishments:

(May – Nov)

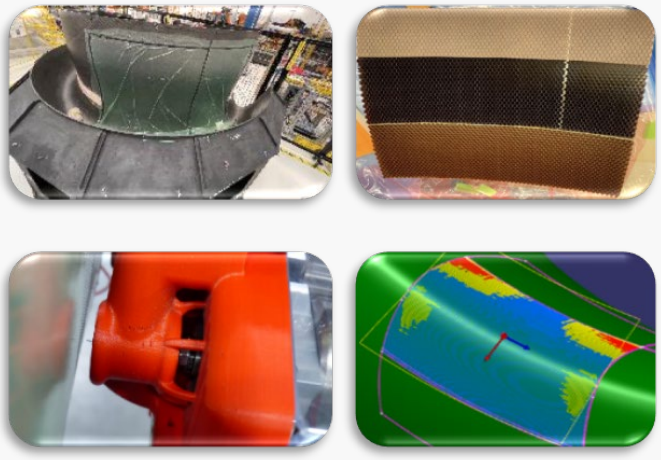




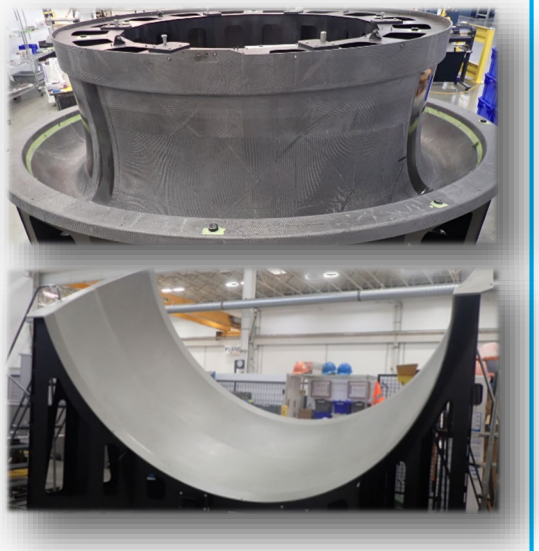
DDR



Acoustic Lining Design Finalized



Manufacturing & Ice Protection System Risk Reduction Trials



Large-Scale Tooling Received

Lookahead:

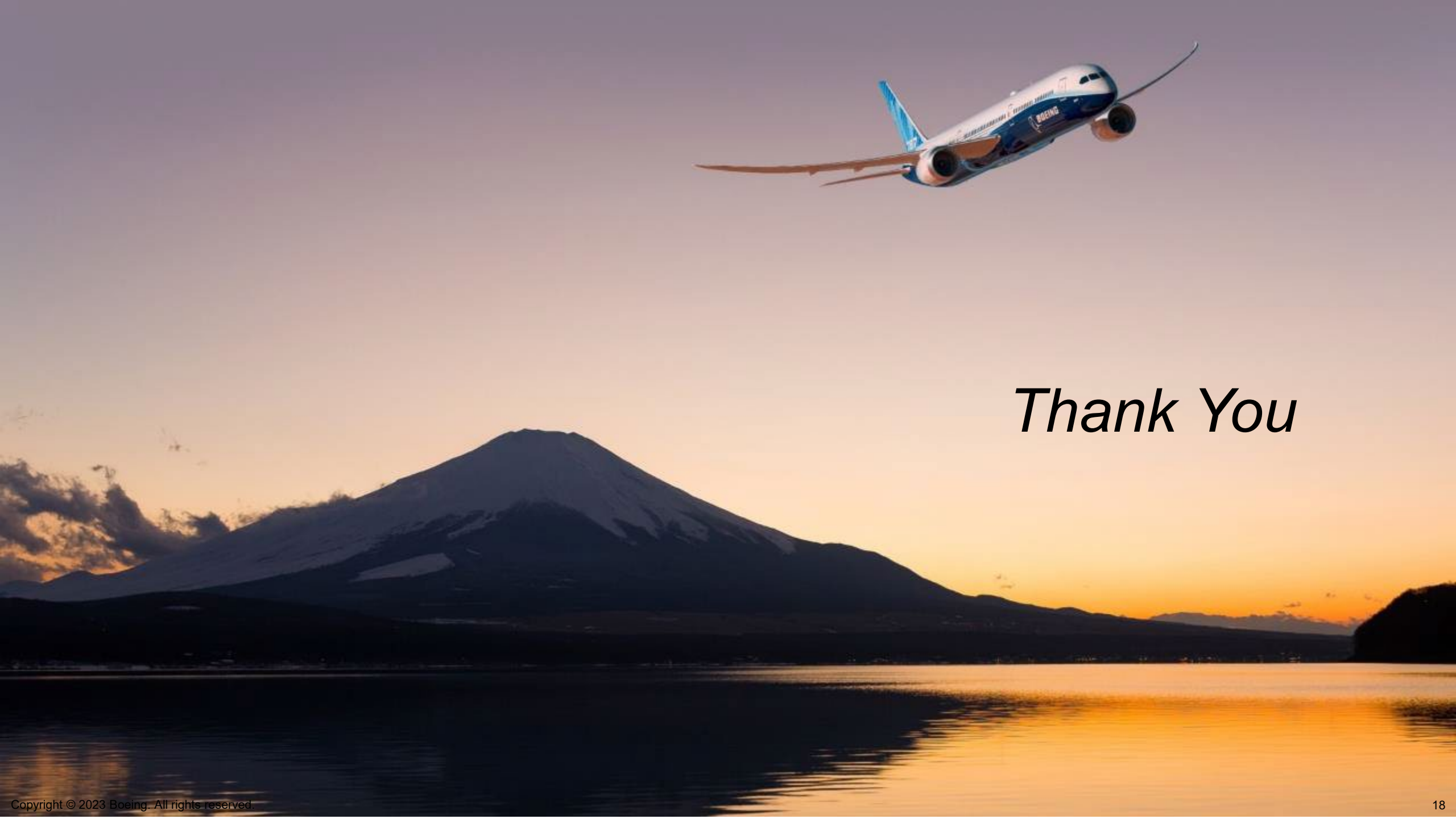
Complete Engineering Releases & MRL5 Assessment – 4Q23

Complete Fabrication & Assembly – 2Q24

Summary & Next Steps

Project	Conceptual Design	Preliminary Design	Detailed Design	Fabrication & Assembly	Flight Testing	Reporting
QLG	✓	✓	✓	In-Work	2Q24	2Q25
QHL	✓	✓	✓	In-Work	2Q24	2Q25
NGI	✓	✓	✓	Started	2Q25	2Q26
IO	✓	✓	✓	NA	2Q24, 2Q25	2Q26
SAF	UDRI Phase 1 Complete / Phase 2 Test – ECD 1Q24				2Q24	1Q25

Projects on-track to meet TPMs that address FAA goals



Thank You

Acronyms

ATP	Authority to Proceed
CAA	Computational Aero-Acoustics
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
dBA	Decibels, A-weighted
DDR	Detailed Design Review
EPNdB	Effective Perceived Noise, Decibels
MBD	Model Based Definition
MRL	Manufacturing Readiness Level
SAF	Sustainable Aviation Fuel
SDR	Software Design Review
SRR	System Requirements Review
UDRI	University of Dayton Research Institute
UHB	Ultra High Bypass
VG	Vortex Generators