Boeing CLEEN Phase III Program Update

Consortium Plenary Session

Jennifer Kolden

November 16, 2022

Boeing's Innovation Landscape

Supporting innovative product development

Boeing Commercial Airplanes

Product Development

Aurora Flight Sciences, A Boeing Company

SKYGRID, A Boeing, SparkCognition Company.

wisk

BOEING ANALYTX

IT&DA

Boeing Global Services

Boeing Research & Technology

BOEING AVIONX

Disruptive Computing & Networks

ae HORIZONX

HRL LABORATORIES

Boeing Defense, Space & Security

Phantom Works

Boeing Research & Technology (BR&T)

What is the future of flight?

Integrated Vehicle Systems

- Advanced Structural Design
- Aerosciences
- Analysis, Certification & Qualification
- Guidance, Navigation, Control & Autonomy
- Integrated Vehicle Technologies
- Propulsion
- Structural Integration & Verification
- Product Analysis & Teardown
- Systems Integration
- Applied Math

Can We Build It?

Materials & Manufacturing Technology

- Additive Manufacturing
- Advanced Production & Inspection
- Automated Paint & Seal
- Chemical Technologies
- Composite Demonstrators – Wing & Fuselage
- Composites, Metals & Ceramics
- Enterprise Automation & Safety Standardization
- Future / Smart Factory
- Robotic Wing & Fuselage Assembly

Is It Smart?

Mission Systems & Autonomy

- Autonomy
- Artificial Intelligence
- Data Analytics
- Advanced Electronics
- Cyber Security
- Advanced Computing
- Communications
- Network Technology
- AvionX Engineering

Can We Productionize It?

Enterprise Production System Engineering

- Production Engineering
- Industrial Engineering
- Manufacturing Technology Integration
- Materials, Processes & Physics
- Production Process Capability Improvements
- Production Critical Services
- Production Asset Management

Boeing Program
CLEEN Phase III

Quiet High-Lift

"Reducing Airframe Noise"

"Enabling Quieter, Advanced Propulsion"

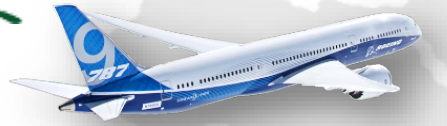
Quiet Landing Gear

Next Generation Inlet

737 MAX 10

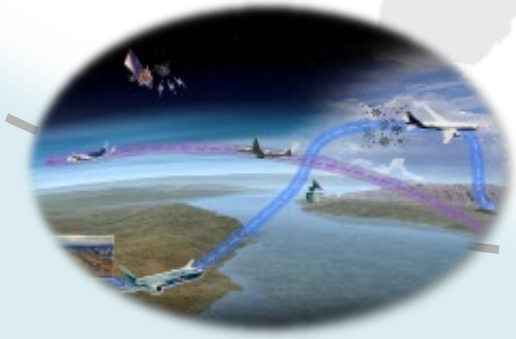
eco Demonstrator PROGRAM

787 9 (RR)



"Improving How the Airplane is Operated"

Intelligent Operations



Sustainable Aviation Fuels

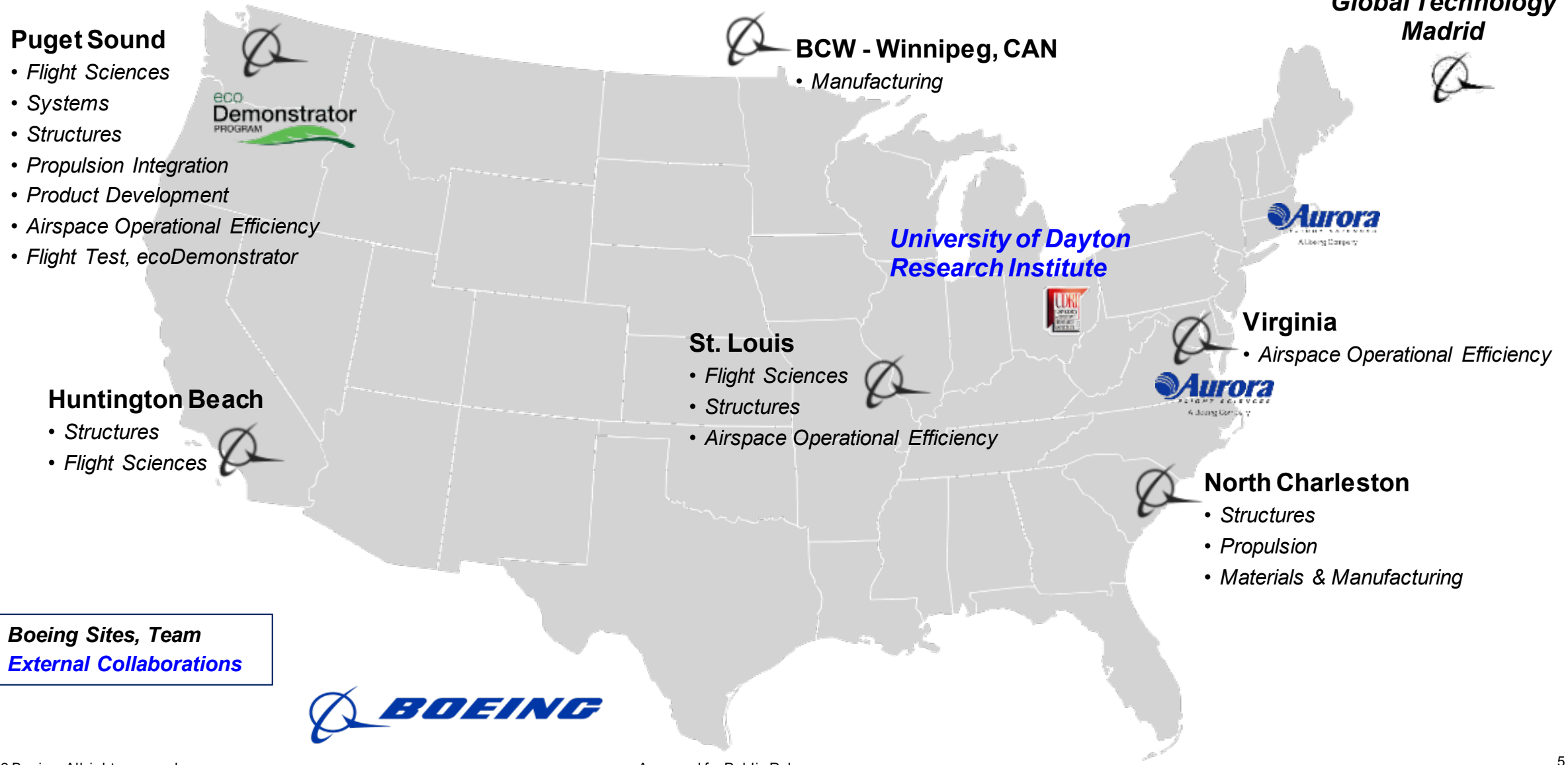
"Accelerating SAF Uptake to meet CO2 goals"

Aurora FLIGHT SCIENCES A Boeing Company

BOEING

UDRI University of Dayton Research Institute

Program Team – "Best of Boeing" & Industry Partners



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*

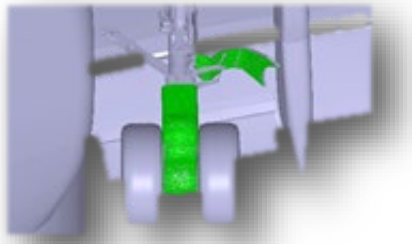
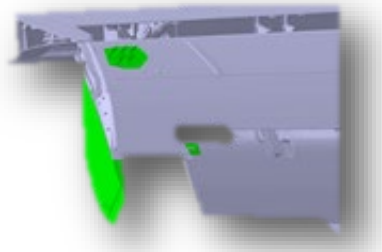
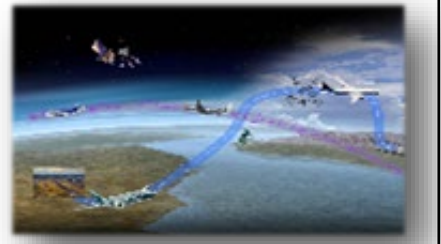
St. Louis
- *Flight Sciences*
- *Structures*
- *Airspace Operational Efficiency*

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 Door • Perforated Strut Shield	 • Outboard Flap Trailing Edge Fairings • Flap Trailing Edge 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	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
  - Structural configuration of wing flaps and landing gear door
  - Nacelle acoustics and ice protection
- Refine/Validate noise prediction tools and design practices
- Provide near-term capabilities/services aligned with FAA NextGen and DataComm
- Address long term compatibility of fuel systems components exposed to low aromatic fuels

CLEEN III Technologies aligned with Product Strategies and Sustainability Vision

Program Timeline

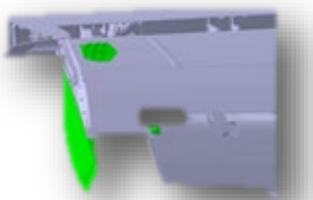
Major Program Elements

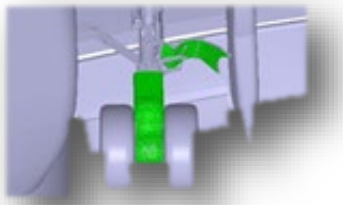
ATP | Today | 737 Flight Demo | 787 Flight Demo | Final Report

2021 | 2022 | 2023 | 2024 | 2025

Technologies

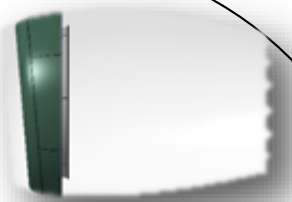
Quiet High-Lift



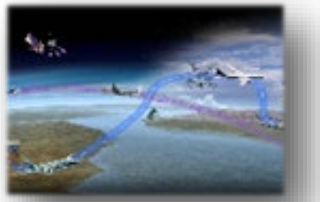


Quiet Landing Gear

Next Generation Inlet

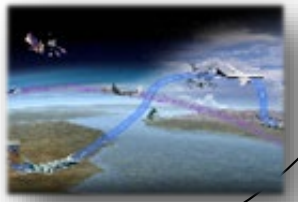


Sustainable Aviation Fuels



Intelligent Operations

Intelligent Operations

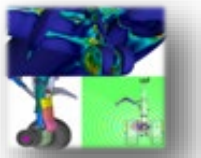


Legend
Noise Reduction
Fuel Burn
Alt Fuel Transition

Quiet Landing Gear (QLG)

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

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

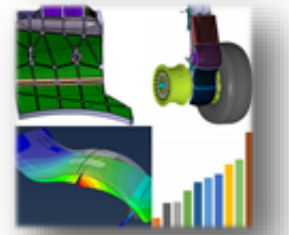


Conceptual Design Review (CoDR) Nov

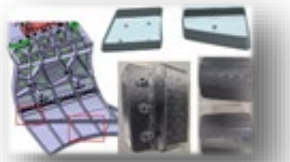
ATP May

ecoD Gate A Oct

2021



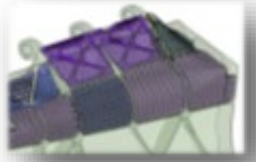
Preliminary Design Review (PDR) Jun



Fab Risk Trials Apr

ecoD Gate B Feb

Gear Rig Trial Aug



Model Based Definition Release Oct

2022

DDR Feb

Build Start Mar

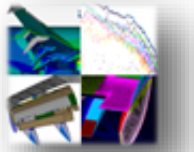
HW Complete Jul

2023

Quiet High-Lift (QHL)

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

Objective:
Develop outboard trailing edge flap (airframe) noise reduction technology to reduce aircraft noise at approach

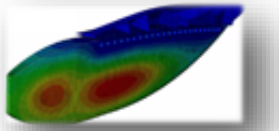


Conceptual Design Review (CoDR) Jan

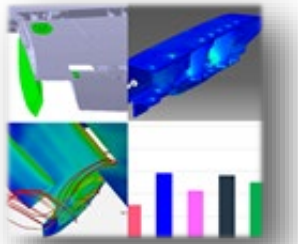
ATP May

ecoD Gate A Oct

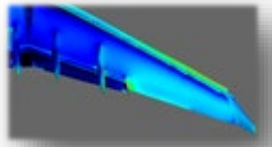
2021 - 2022



Fairing Trades Apr

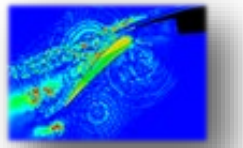


Preliminary Design Review (PDR) Aug



Aero/S&C Opt'n May

ecoD Gate B Feb



CFD/CAA Oct

2022

HW Complete Aug

DDR Mar

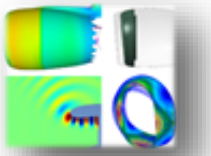
Build Start Apr

2023

Next Generation Inlet (NGI)

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

Objective:
reduction technology with reduced weight & drag to reduce aircraft noise at take-off & approach and address reduced-length inlet integration challenges of UHB engines

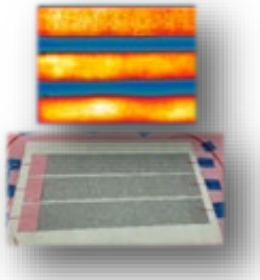


Conceptual Design Review (CoDR) Feb

Surface Reloft Sep

ATP May

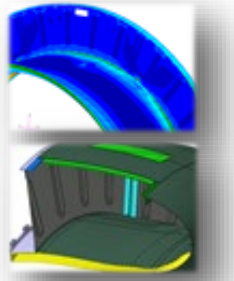
2021 - 2022



Ice Protection System Trials Mar

Curved Inlet Subcomponent Fab Jul

Curved Inlet Composite Tooling Apr



Inlet CAD/FEM Sep

Manufacturing Readiness Assessment Sep

2022

PDR Jan

DDR Sep

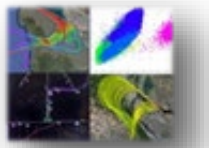
Build Start Oct

2023

Intelligent Operations (IO)

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

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



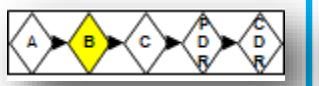
Systems Requirements Review (SRR) Nov

ATP May

ecoD Gate A Oct

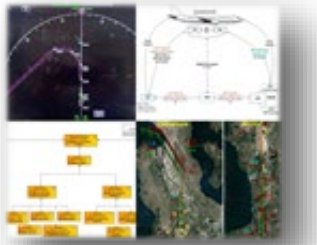
2021

Software Drop 1 & Simulation Mar



ecoD Gate B Feb

Software Architecture Jul



Systems Design Review (SDR) Aug

787 Cab Demo Sep

2022

SW Drop 2 Apr

CDR Jun

2023

Sustainable Aviation Fuels (SAF)

Lab Testing → Flight Testing → Reporting

Objective:
Address long term compatibility of fuel systems materials with low aromatic fuels in order to promote uptake and sustainability

University of Dayton Research Institute (UDRI) Phase 1 BL Test Start
Dec

ATP
May

ecoD Gate A
Oct

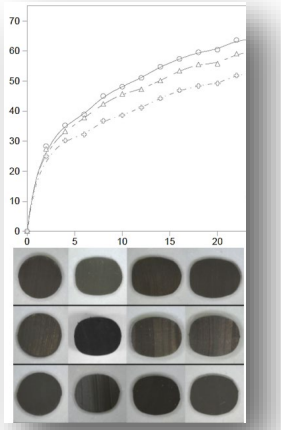
2021

UDRI Phase 1 BL Test Complete
Apr

UDRI Phase 1 Steady-State Test Start
Jan

UDRI Phase 1 Switch-Loading Test Start
Sep

ecoD Gate B
Feb



UDRI Phase 1 Steady-State Test Complete
Oct

2022

UDRI Phase 1 Test Complete
Mar

Phase 1 Report
Apr

UDRI Phase 2 Test Complete
Oct

Phase 2 Report
Dec

2023

Summary & Next Steps

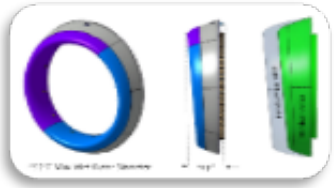
Summary

- CLEEN Phase III aligned with Boeing vision for Sustainable Aerospace
- Under CLEEN Phase III, Boeing is executing 5 projects developing technology to reduce airframe, engine, and flight operational noise, as well as Drop-in SAF
- All but 1 project have completed the Preliminary Design Phase
- All projects on-track to meet noise reduction, fuel burn & Drop-In SAF goals

Next Steps

- Complete Detailed Design Phases & Design Reviews
- Complete Fabrication Planning & Hardware Procurements
- Start Build/Fabrication

Short Inlet Development – CLEEN II



Project Launch

SRR

DDR

RR Short Inlet HW Complete

CLEEN II ATP

HW On Dock at Stennis

Ground Test Block 1

Ground Test Blocks 2/3/4

CLEEN II Final Report (Ground Test)

2022

2015 | 2016 | 2017 | 2018

Tool Calibrations → Reqts & HW Dev → Ground Testing → Reporting → Rolls-Royce FTB

Stennis, MS

Acronyms

ATP	Authority to Proceed
BL	Baseline
CAA	Computational Aero-Acoustics
CAD	Computer Aided Design
CDR	Critical Design Review
CFD	Computational Fluid Dynamics
CoDR	Conceptual Design Review
dBA	Decibels, A-weighted
DDR	Detailed Design Review
EPNdB	Effective Perceived Noise, Decibels
FEM	Finite Element Model
HW	Hardware
Opt'n	Optimization
SAF	Sustainable Aviation Fuel
S&C	Stability and Control
SRR	System Requirements Review
SW	Software
UDRI	University of Dayton Research Institute