Boeing CLEEN Phase III Program Update

Consortium Plenary Session

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November 3, 2021

Approved for Public Release

Sustainability Approach

We have organized our sustainability efforts around four key pillars: People, Products & Services, Operations and Communities. We have defined key sustainability priorities based on stakeholder interests. Our key stakeholders include our communities, customers, current and future employees, the flying public, investors, regulators and suppliers.

PEOPLE

Our story starts with our people. We commit to advancing a collaborative, inclusive and globally diverse culture that creates unique careers in aerospace.

PRODUCTS & SERVICES

We innovate for a better tomorrow. We demonstrate an unwavering commitment to safety, quality and integrity and instill best practices in all that we do.

OPERATIONS

It's not just what we do — it's also how we do it. We operate sustainably and engage transparently on behalf of our customers and stakeholders.

COMMUNITIES

Our communities matter to us. We focus on global partnerships and programs that inspire our future through education, honor our heroes and strengthen our homes.

Sustainability Priorities

We have defined key sustainability priorities and aligned them with responsible and inclusive business practices to enable a positive global impact.

- Climate Action
- Employee Safety & Well-Being
- Environmentally Responsible Operations
- Equity, Diversity & Inclusion
- Product & Services Safety & Quality
- Community Engagement
- Education & Skill Development
- Economic Performance
- Ethical Business Practices
- Responsible Supply Chain Practices
- Data Privacy & Information Security

COMPANY HIGHLIGHTS

Boeing protects, connects and explores our world and beyond. As a leading global aerospace company, Boeing develops, manufactures and services commercial airplanes, defense products and space systems for customers in more than 150 countries.

2020 Revenue	2020 10-Year Served Market Outlook	2020 Employment
$58B	$8.5T	141K

Boeing's H-47 Chinook helicopter is an advanced, battle-tested heavy-lift helicopter supporting cargo and troop transport, humanitarian and special operations missions for defense forces around the world.

FAA CLEEN: A Key Part of Boeing's Sustainability Portfolio

CLEEN I

2010	2011	2012	2013	2014	2015

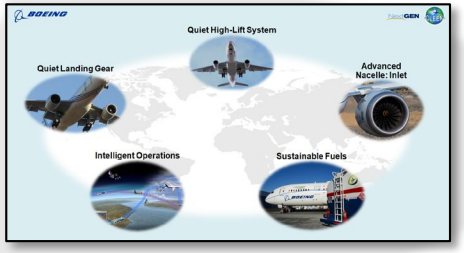
Adaptive Trailing Edge (ATE)
Ceramic Matrix Composite (CMC) Nozzle
Biofuel Blend Chemistry Testing

CLEEN II

2015	2016	2017	2018	2019	2020	2021

Structurally Efficient Wing (SEW)
Compact Nacelle – Short Inlet
Compact Nacelle T/R Acoustics
D-8 Fuselage Composite Fab Demo (AFS)

CLEEN III



2021	2022	2023	2024	2025	2026

Quiet Landing Gear
Quiet High-Lift
Advanced Inlet
Intelligent Operations
Sustainable Aviation Fuels

Active Technology Projects
Completed Technology Projects

CLEEN Phase III Scope

Quiet High-Lift System

"Reducing Airframe Noise"

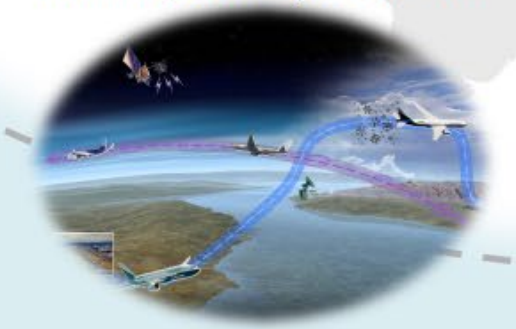
"Enabling Quieter, Advanced Propulsion"

Quiet Landing Gear

Advanced Nacelle: Inlet

"Improving How the Airplane is Operated"

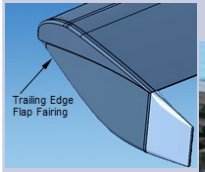
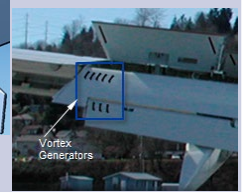
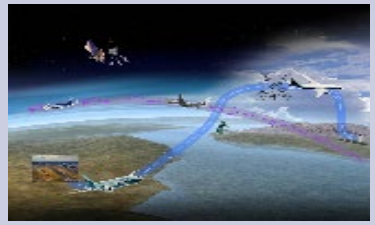
Intelligent Operations



"Accelerating SAF Uptake to meet CO_2 goals"

Sustainable Fuels

Boeing CLEEN Phase III – Projects & Benefits

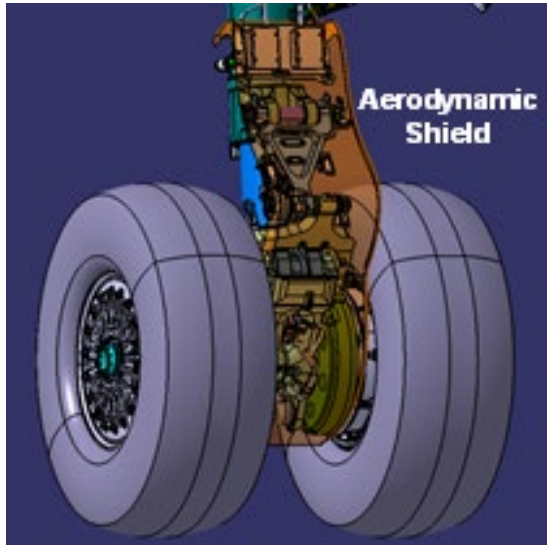
	Quiet Landing Gear	Quiet High-Lift	Next Generation Inlet	Intelligent Operations	Sustainable Aviation Fuels
Technology		 			
	• Acoustically treated main gear door(s) • Perforated strut shield	• Outboard flap TE fairings • TE vortex generators	• New Structural Architecture • New Ice Protection System • Maximize acoustic treated area	• R/T noise-optimized flight paths • Integrate into ATC and A/C systems	• 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% T/O , 5% APP	2%-3% SFC
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 , BGS EFB	2030 , 2035 Retrofit

Quiet Landing Gear (QLG) Project

Motivation:
Reduce aircraft noise at approach = a leading source of community complaints

Objective:
Develop landing gear (airframe) noise reduction technology
- Acoustically treated main gear doors ➔ absorb impinging noise & minimize reflections to the ground
- Perforated shield in front of brake lines ➔ reduce flow-structure interaction & wake turbulence

Work Statement:
Design/analysis/optimization via CFD/CAA tools & learnings from noise/aero testing
Full-scale prototype hardware fabrication & integration with existing landing gear design
Flight demonstration on Boeing 2023 ecoDemonstrator
Assessment of airframe/airplane noise reduction and system level modeling



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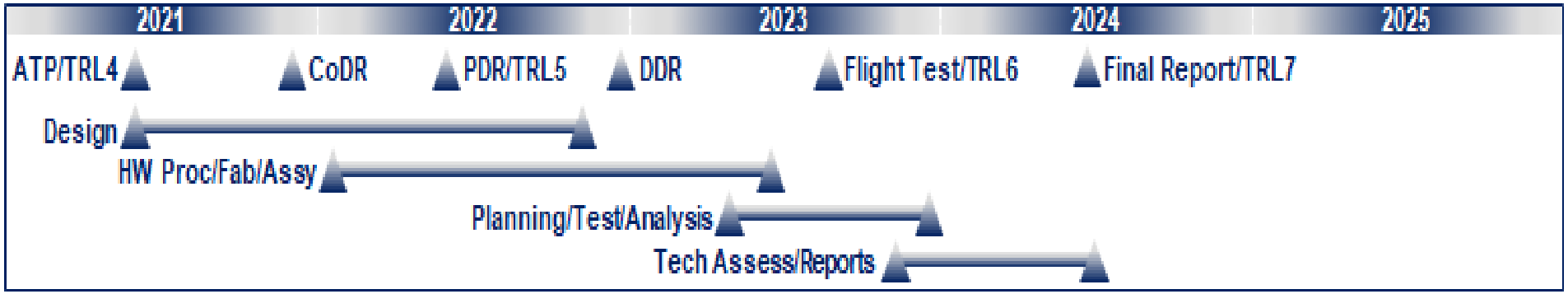
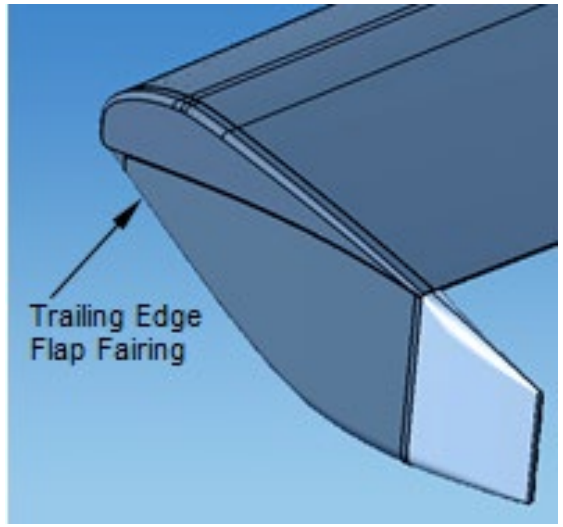


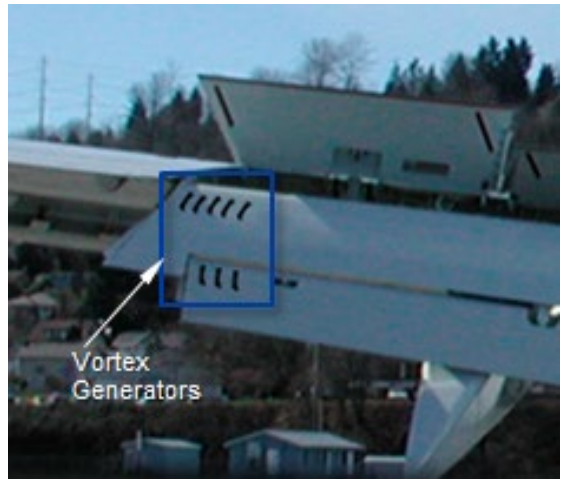
Quiet High-Lift (QHL) Project

Motivation:
Reduce aircraft noise at approach = a leading source of community complaints

Objective:
Develop outboard trailing edge flap (airframe) noise reduction technology
- Static fairing ➔ modify flow around edge and reduce radiated noise
- Vortex Generators (VGs) ➔ modify and control flow around edge and reduce radiated noise

Work Statement:
Design/analysis/optimization via CFD/CAA tools & learnings from noise/aero testing
Full-scale prototype hardware fabrication & integration with existing high-lift design
Flight demonstration on Boeing 2023 ecoDemonstrator
Assessment of airframe/airplane noise reduction and system level modeling





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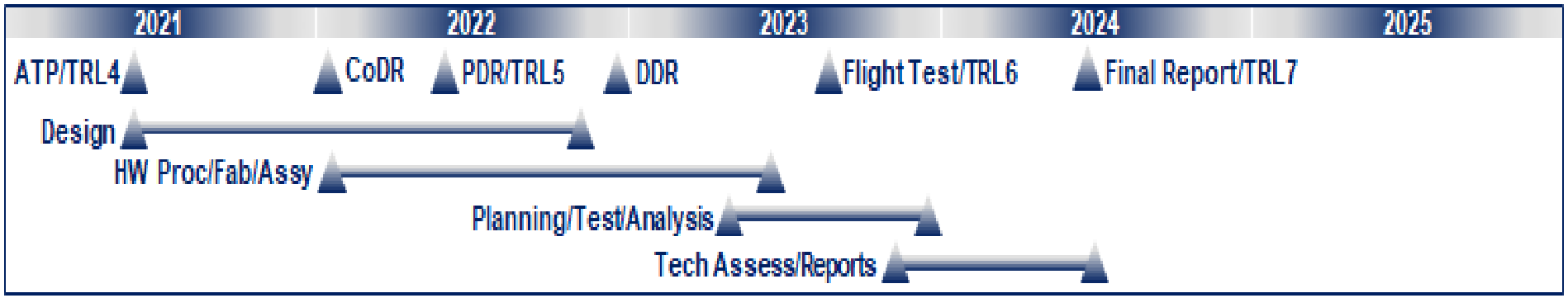
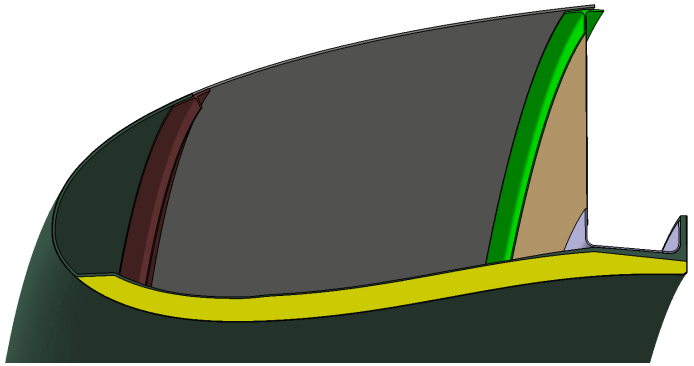


Next Generation Inlet (NGI) Project

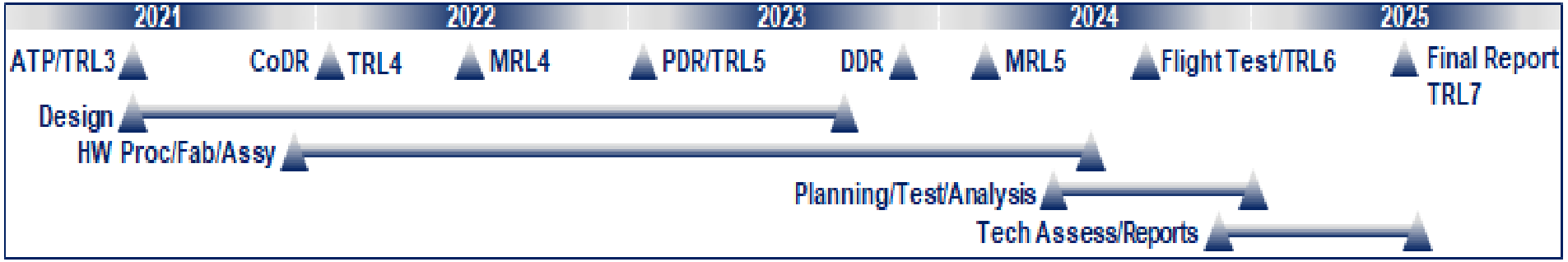
Motivation:
Address reduced-length inlet integration challenges to maximize installed Ultra-High Bypass (UHB) engine performance benefits
Reduce aircraft noise at take-off and approach

Objective:
Develop inlet (engine) noise reduction technology with reduced weight & drag
- Reclaim acoustic area lost by inlet length reduction / expand acoustic treatment into previously unavailable areas
- Novel inlet architectures and engine systems integration



Work Statement:
Design/analysis and leveraging of Rolls-Royce Short Inlet technology maturation
Full-scale prototype hardware fabrication & integration with Trent 1000 engine
Flight demonstration on Boeing 2024 ecoDemonstrator
Assessment of engine/airplane noise reduction and system level modeling

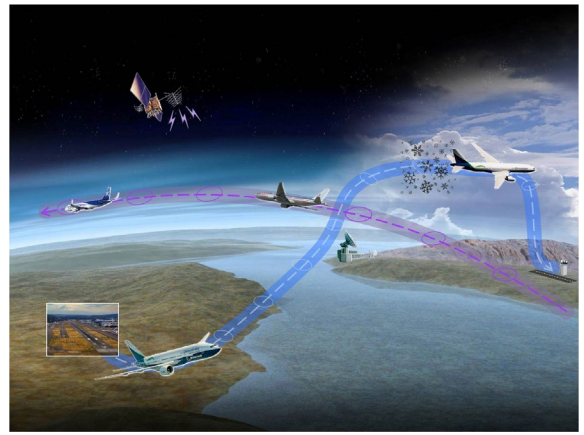
Schedule:



Intelligent Operations (IO) Project

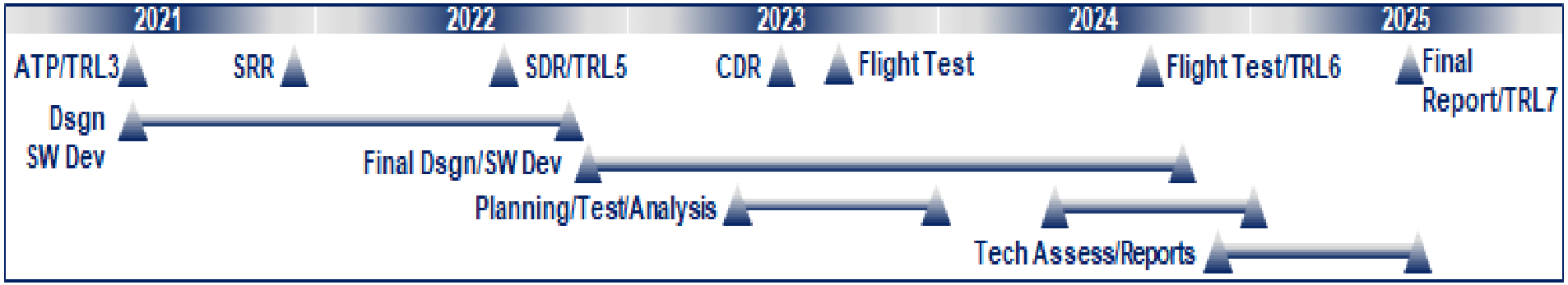
Motivation:
Reduce aircraft operational noise (Dep/Arr) = source of community noise exposure intensified by Precision Based Navigation

Objective:
Develop aircraft operational noise reduction technology (reduce noise variability)
- Intelligent operations – noise optimized flight algorithms (real-time inputs of a/c state, weather, geography, ATM)
- CONOPs for rapid arr/dep clearance delivery and regulatory roadmap



Work Statement:
Develop algorithms leveraging net-enabled aircraft and onboard/ground systems inputs
Build CONOPS via integration with Airports and FAA NextGen ATM/Data Comm systems
Flight demonstration on Boeing 2023 & 2024 ecoDemonstrators
Assessment of operational noise reduction, human factors, and system level modeling

Schedule:



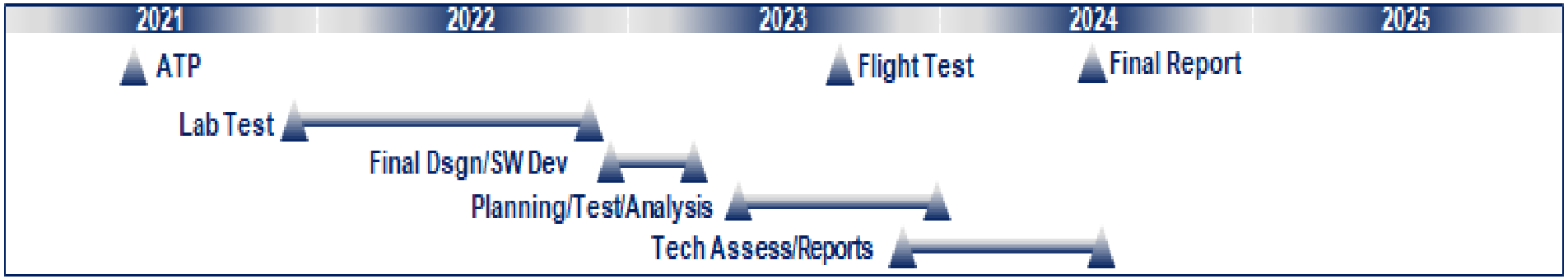
Sustainable Aviation Fuels (SAF) Project

Motivation:
Address long term material compatibility of low aromatic fuels with systems “conditioned” for petroleum fuels (rings/sealants shrink, harden, and fail)

Objective:
Support continued expansion of certified alternative fuel pathways to promote uptake and sustainability
Characterize selected new alternative fuel blends (cycloparaffin SAF blend ratios up to 100%)

Work Statement:
Conduct material compatibility tests w/UDRI (approved NBR materials using petroleum fuels w/range of aromatic concentrations)
Conduct material compatibility testing w/UDRI on cycloparaffin fuel & blends
Large scale fuel production, and flight demonstration on Boeing 2023 ecoDemonstrator
Dissemination of results/findings to broader community

Schedule:



Summary

Five Technology Projects focusing on community noise reduction and Drop-in SAF

- **Quiet Landing Gear**
- **Quiet High-Lift**
- **Next Generation Inlet**
- **Intelligent Operations**
- **Sustainable Aviation Fuels**

Two Flight Test Demonstration Campaigns

- **2023 – 737MAX**
- **2024 – 787**

Next Steps Prior to May ‘22 Consortium

- **Completion of Conceptual Design Phases**
- **Conduct Conceptual Design Review (HW) and System Requirements Review (SW)**
- **Start of Hardware Procurements & Fabrication Planning**
- **Initial Planning for Flight Testing**

Acronyms

A/C	**Aircraft**
APP	**Approach**
ATC	**Air Traffic Control**
ATE	**Adaptive Trailing Edge**
ATP	**Authority to Proceed**
BGS	**Boeing Global Services**
CAA	**Computational Aero-Acoustics**
CDR	**Critical Design Review**
CFD	**Computational Fluid Dynamics**
CMC	**Ceramic Matrix Composite**
CoDR	**Conceptual Design Review**
dBA	**Decibels, A-weighted**
DDR	**Detailed Design Review**
EFB	**Electronic Flight Bag**
EPNdB	**Effective Perceived Noise, Decibels**
HW	**Hardware**
MRL	**Manufacturing Readiness Level**
NBR	Nitrile Butyl Rubber
PDR	**Preliminary Design Review**
R/T	**Real-Time**
SDR	**Systems Design Review**
SEW	**Structurally Efficient Wing**
SFC	**Specific Fuel Consumption**
SRR	**System Requirements Review**
SW	**Software**
TE	**Trailing Edge**
T/O	**Take-Off**
TRL	**Technology Readiness Level**
UDRI	**University of Dayton Research Institute**

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