Boeing CLEEN II program update

Consortium Public Session
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CLEEN II Technology Demonstrations Discussion Topics

Program Overview

Technology Benefits

Compact Nacelle Status Update

Discussion

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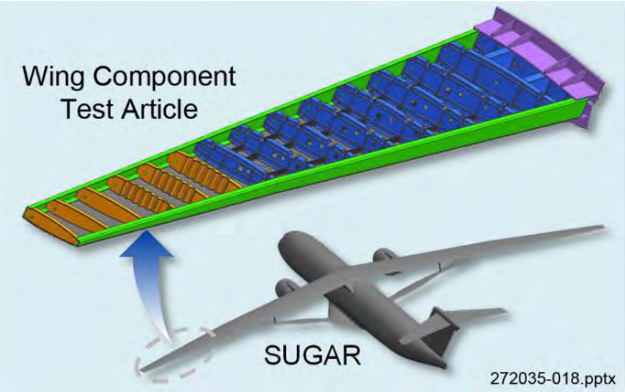
CLEEN II Technology Demonstrations

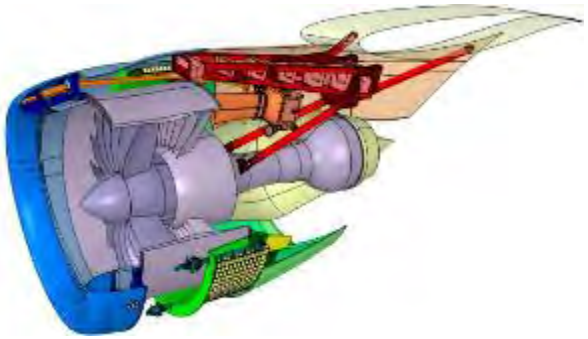
Structurally Efficient Wing

- Demonstrate 14 wing structure technologies that improve structural efficiency and reduce weight through a structural ground test



Compact Nacelle

- Demonstrate aerodynamic performance of a short inlet in crosswind through ground testing
- Demonstrate noise reduction of improvements to a thrust reverser duct through flight demonstration



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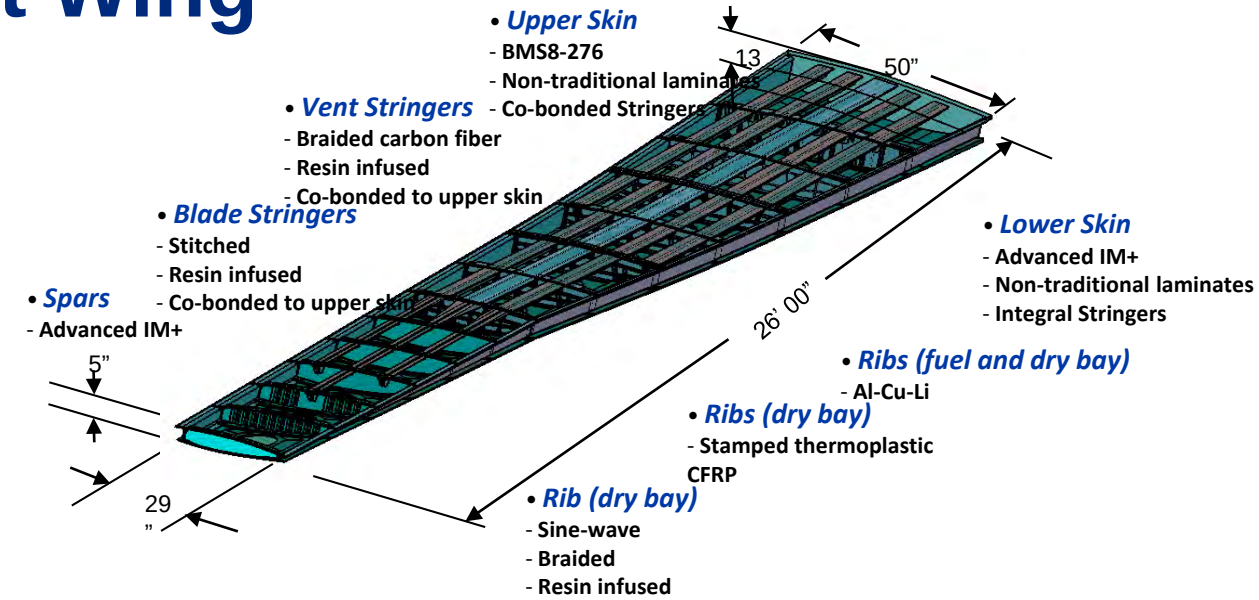
CLEEN II Technology Demonstrations
Boeing Structurally Efficient Wing

Objective

Demonstrate 14 wing structure technologies that improve structural efficiency and reduce weight through a structural ground test



SEW Technologies	Goal Impact	Benefits and Application
• Advancing manufacturing technologies • Advanced pre-preg composites • Resin-infused stitched blade stringers • Resin-infused hat stringers • Advanced alloy metallic ribs • Resin-infused sine wave rib • Stamped thermoplastic ribs • Non-Traditional Laminates • Co-Bonded Stringers	Fuel Burn reduction	Reduce Block Fuel up to 3.5% by saving up to 28% [wing] structural weight relative to 777-200 baseline.

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CLEEN II Technology Demonstrations
Boeing Compact Nacelle – Short Inlet

Objective

- Demonstrate aerodynamic performance of a short inlet in crosswind through ground testing

Compact Nacelle Technologies	Goal Impact	Benefits and Application
Short Inlet	Fuel Burn Reduction	Reduce Block Fuel up to 1.0% through weight and Drag reductions relative to a conventional length inlet. Enable next generation engines for Boeing's next new product

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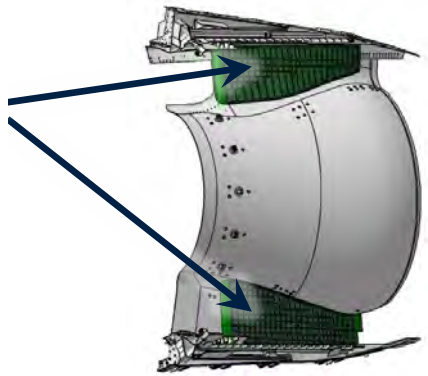
CLEEN II Technology Demonstrations
Boeing Compact Nacelle – Aft Fan Duct Acoustics

Objective

- Demonstrate noise reduction improvements to a thrust reverser duct through flight demonstration

Treated Blocker Doors



Thrust Reverser Inner Wall

Compact Nacelle Technologies	Goal Impact	Benefits and Application
Acoustic improvements to Thrust Reverser Aft Fan Duct: • Increased acoustically treated area • Advanced acoustic liner	Community Noise Reduction	0.4 to 1.2 EPNdB for new aircraft applications 0.2 to 0.6 EPNdB as retrofit potential for some existing models.

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CLEEN II Technology Demonstrations Program Schedule

2015	2016	2017	2018	2019	2020	2021

Structurally Efficient Wing

Design → Coupon, Subcomponent Tests → NIAR / L/N Test & Reporting

TRL 3 — TRL 4 — TRL 5 — TRL 6

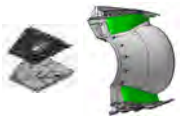
Compact Nacelle - Short Inlet

Rolls-Royce

Prototype Development → Ground Testing → Reporting → Support to Flight Test

TRL 4 — TRL 5 — TRL 6

Compact Nacelle – Aft Duct Acoustics



eco Demonstrator PROGRAM

Concept Dev → Prototype Dev → FT & Reporting

TRL 4 — TRL 5 — TRL 6 — TRL 7

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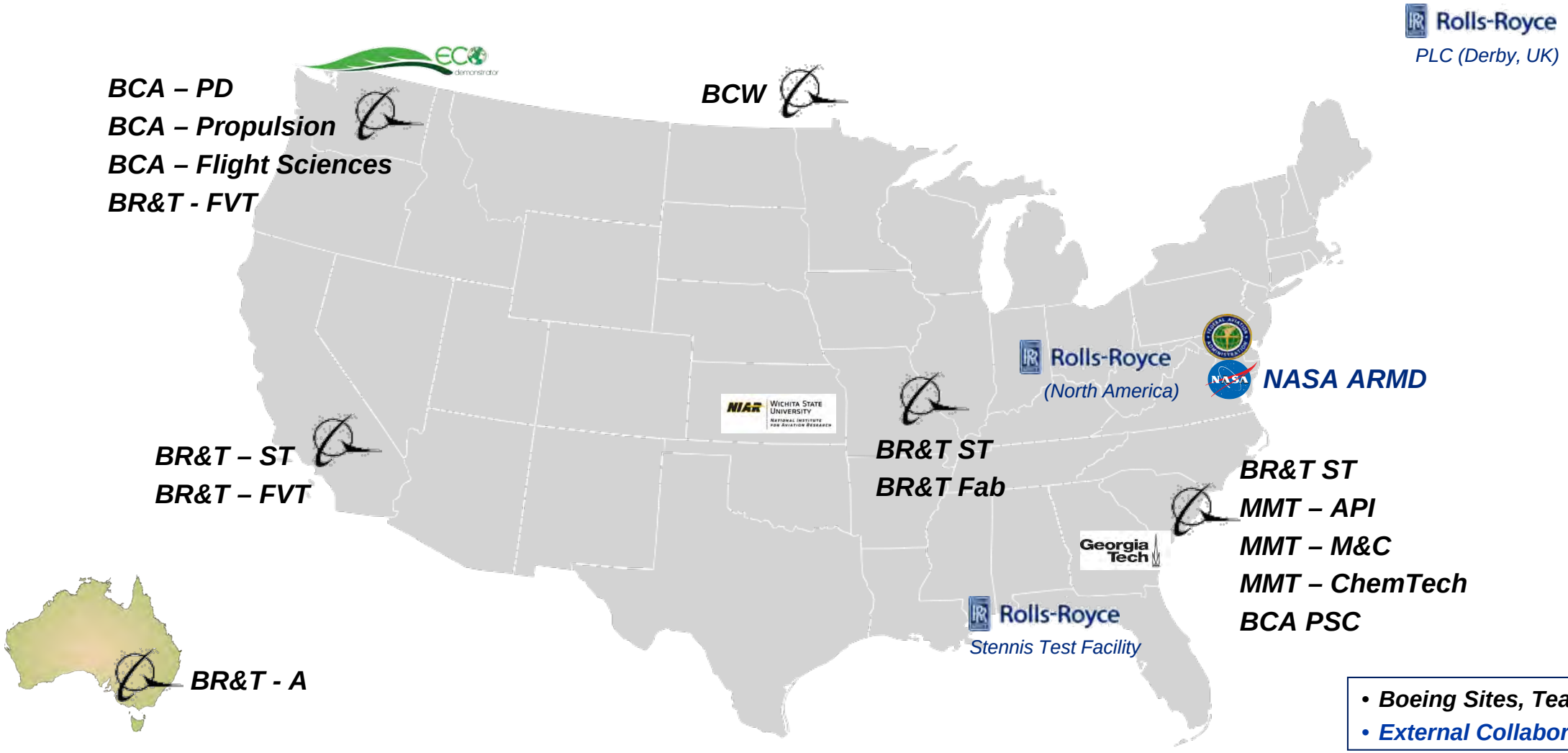
CLEEN II Technology Demonstrations Contributing Teams / Sites / Partners



- Boeing Sites, Teams
- External Collaborations

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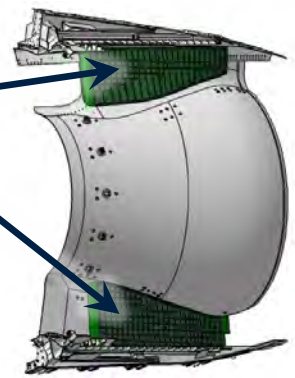
Compact Nacelle (CN) – Aft Fan Duct Acoustics

Treated Blocker Doors



Anticipated Benefits:

- *0.4 to 1.2 EPNdB for future applications to UHB-configured aircraft entering service in the 2025 time frame*
- *0.2 to 0.6 EPNdB as retrofit potential for some existing models.*

Objectives:

- *Develop acoustic treatment concepts for aft duct of compact nacelle architectures*
- *Validate design concepts through flight demonstration for transition to new and existing products*

Work Statement:

- *Develop prototype TR hardware*
- *Conduct flight demonstration on the Boeing 737 Max 9 ecoDemonstrator*

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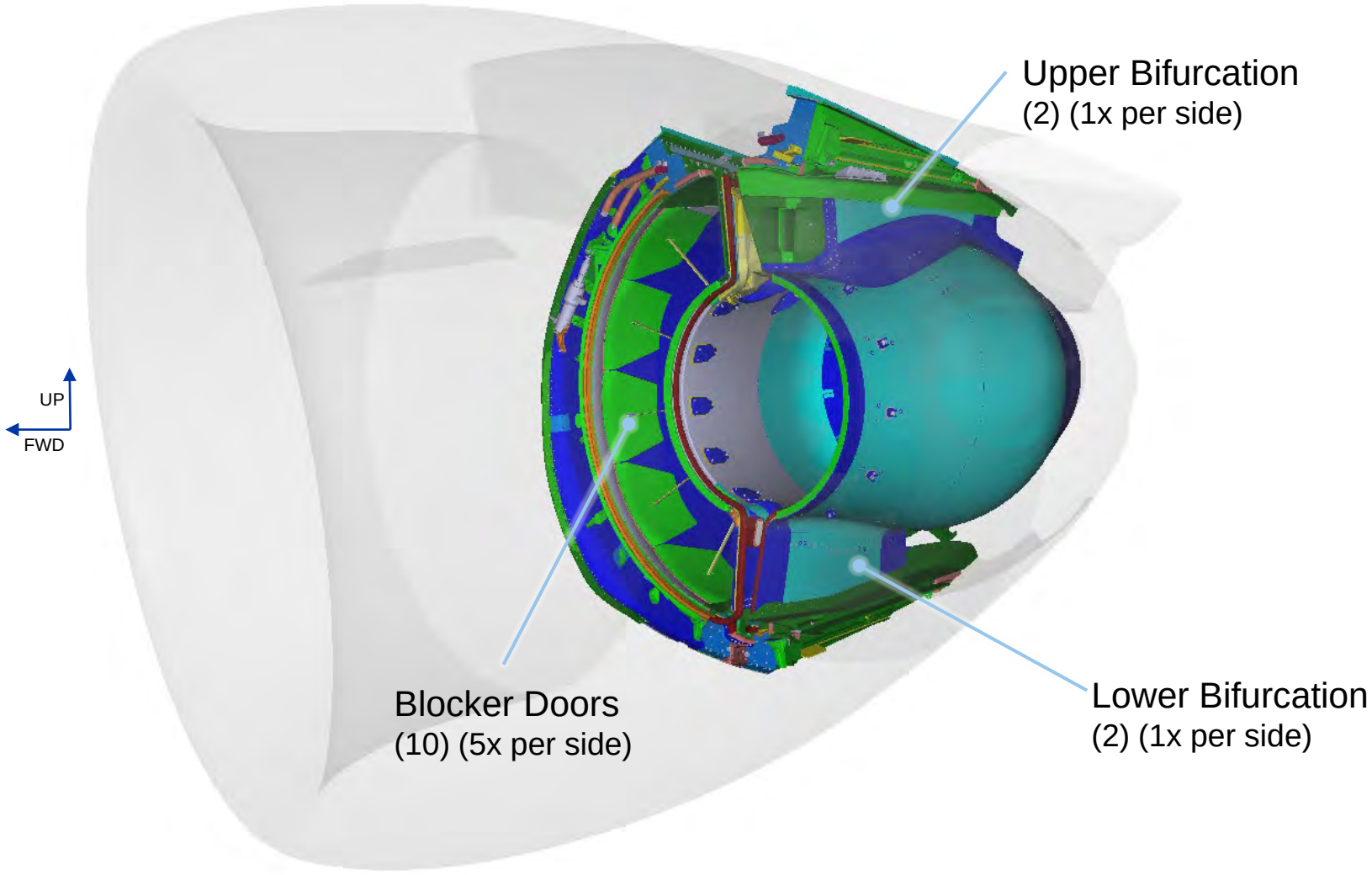
Thrust Reverser Walk Around



Silhouette of Engine shown for reference

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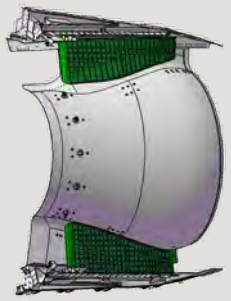
Compact Nacelle (CN) – Aft Fan Duct Acoustics Advanced Acoustic Treatment

Region		Improvement
Bifurcations		Increased acoustic yield Maximized full-depth treatment
Blocker Doors		Increased acoustic yield Advanced treatment concept

Experimental TR incorporates advanced acoustic treatment concepts

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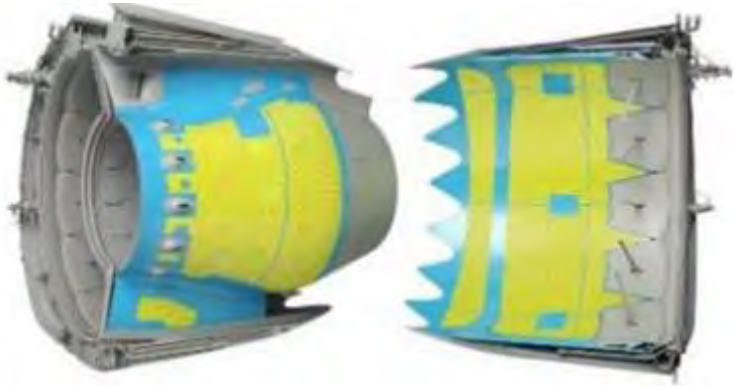
Compact Nacelle (CN) – Aft Fan Duct Acoustics Advanced Acoustic Treatment

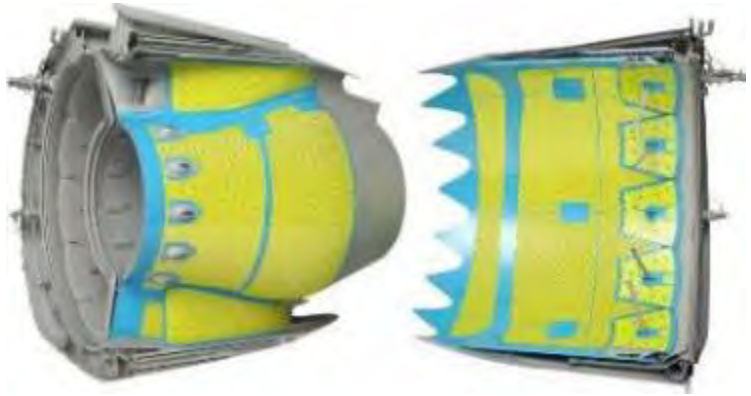
Acoustically Treated
Untreated

Region	Production	Experimental
Bifurcations	5%	60%
Inner Wall	60%	70%
Blocker Doors	0%	70%
TOTAL	50%	70%

Production



CLEEN II Experimental



Experimental TR has significantly more acoustic area than Production

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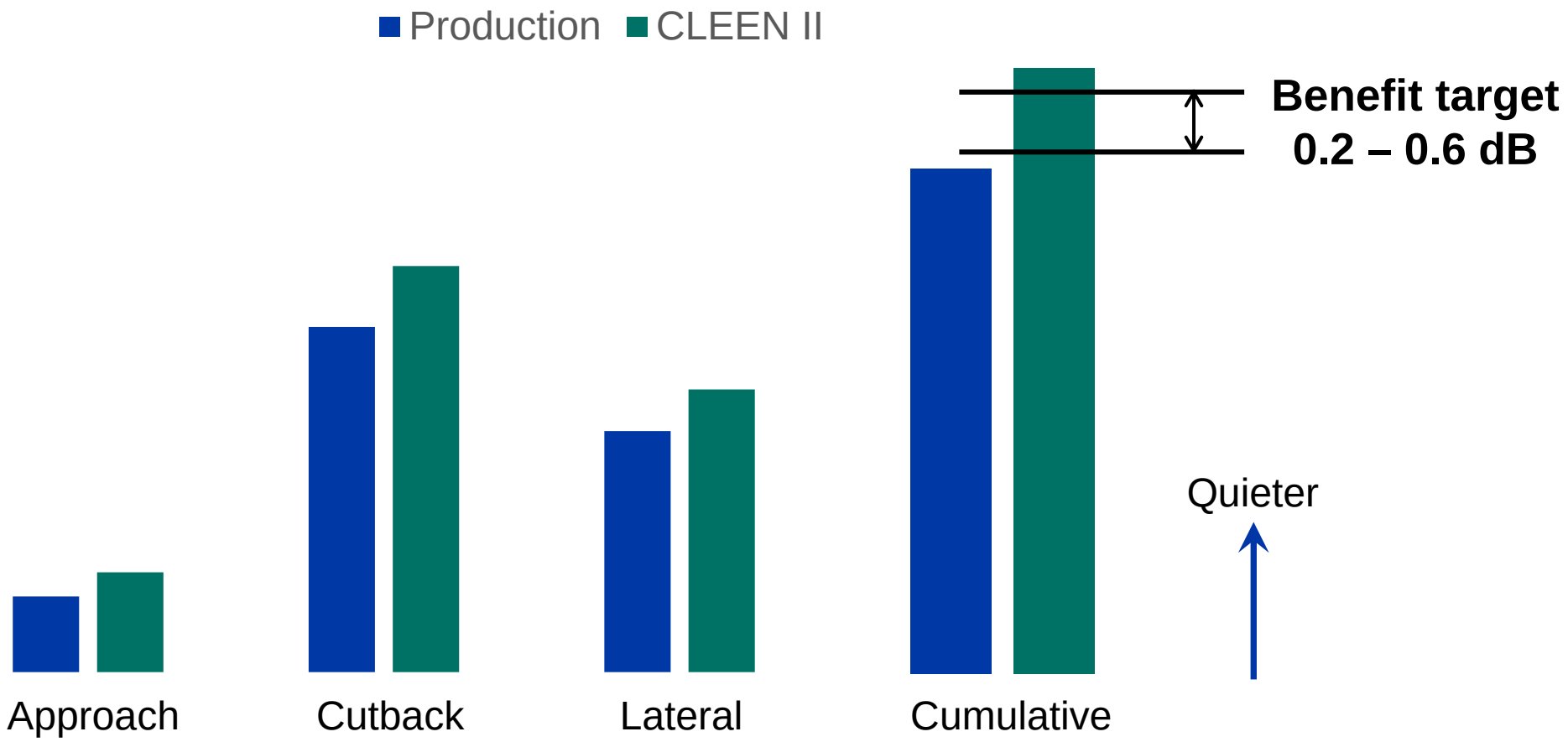
Compact Nacelle (CN) – Aft Fan Duct Acoustics
Airplane Level Pre-Test Prediction



Pre-Test Prediction Exceeds CLEEN II Objectives on Current Aircraft

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Demonstration Approach

- **Leverage existing hardware**
  - An existing TR will be modified and provided for LHS installation
  - TR locked out for ease of manufacture
  - Increase acoustic treated area by 50% to 80% with prototype fairing and treatment on blocker doors
  - All hardware designed and modified by Boeing

- **Collect community noise acoustic flyover data at Moses Lake, WA Grant County Airport.**
  - Using ground based acoustic instrumentation
  - Ground based microphones and 4-ft microphones to be distributed under the flight path
  - Ground based phased array

- **Aircraft level attenuation measurements to be projected to 2025+ EIS engine technologies using analytical predictions**

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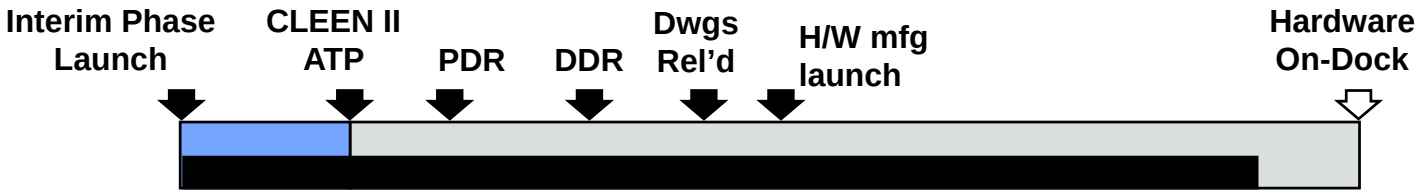
Accomplishments



- ✓ ***Acquired T/R Hardware, shipped to Charleston, SC***
- ✓ ***Completed CFD, CDUCT Attenuation analyses***
- ✓ ***Developed Draft test plan for ecoDemonstrator Flight Test***
- ✓ ***Completed Preliminary Design Review – Oct '19***
- ✓ ***Completed Detailed Design Review – Jan '20***
- ✓ ***All engineering released – Mar '20***
- ✓ ***Hardware production launched – Mar '20***
- ✓ ***Completed Safe-to-Fly Engineering – Apr '20***

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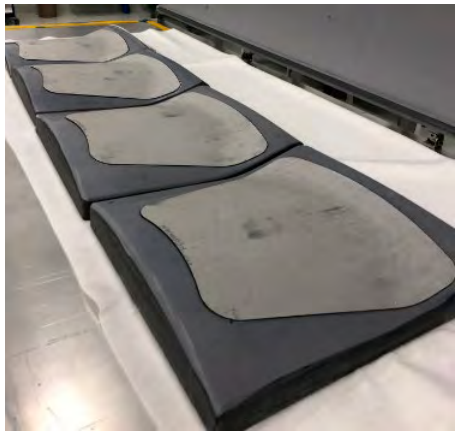
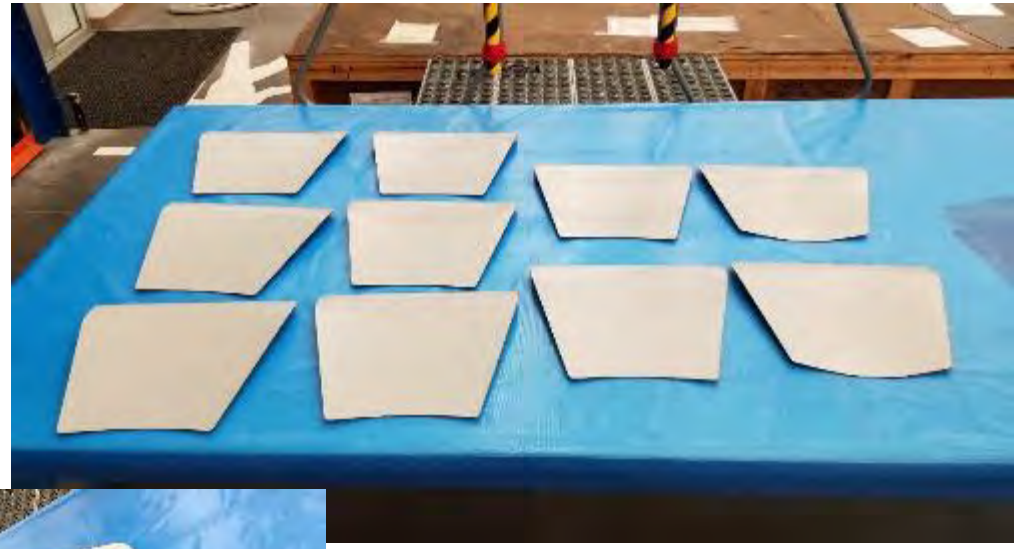
Hardware Build In-Progress





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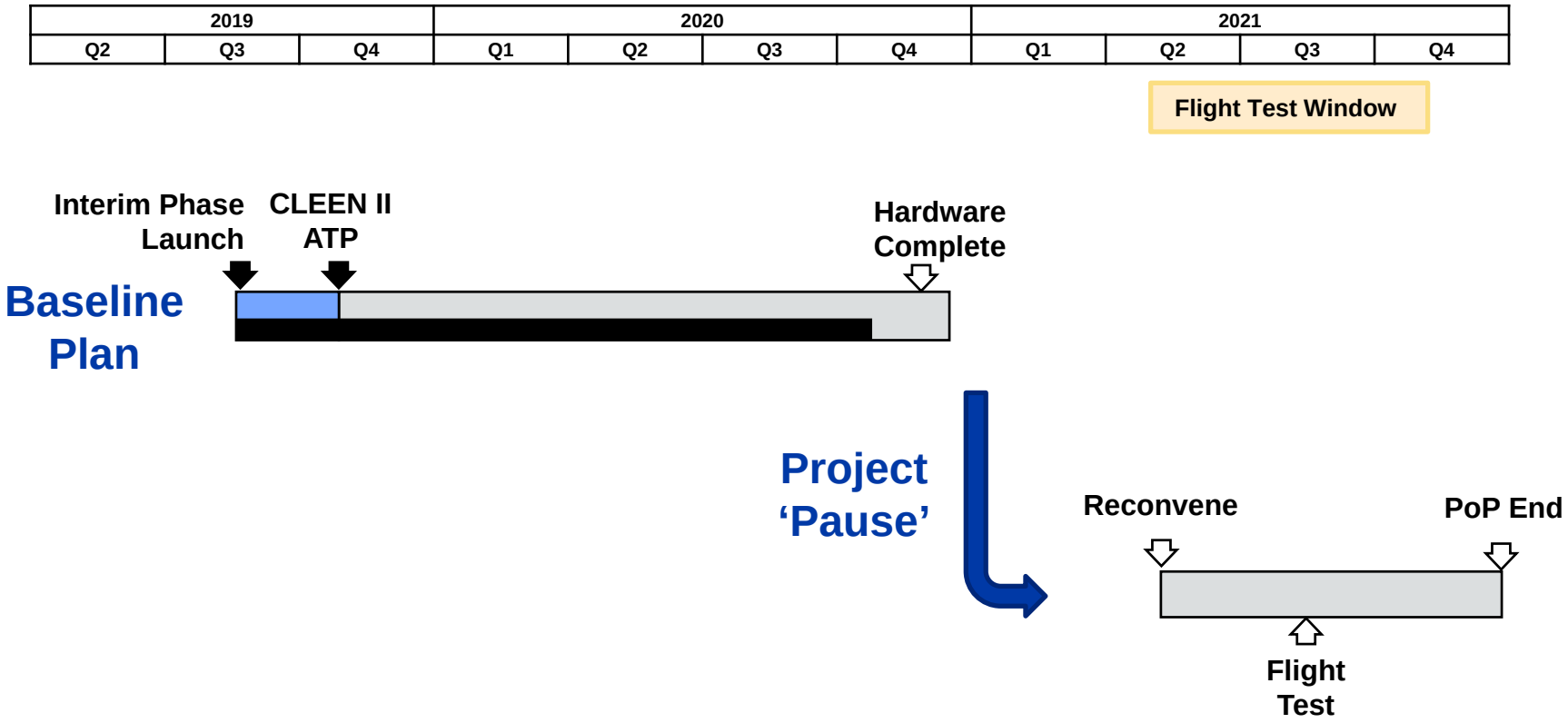
ecoDemonstrator Flight Testing Q3 2021



Acoustic flight test timing is a function of weather window

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Next Steps

- ***Hardware on Dock Boeing Field – Q2 ‘21***
- ***ecoD 737 Max 9 Flight Test – Q3 ‘21***
- ***Limited Rights Flight Test Report – Q4 ‘21***
- ***Public Test Report – Q4 ‘21***

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CLEEN II Technology Demonstrations Summary of Accomplishments

- Boeing's CLEEN II technologies represent some of our high value concepts with a path to certification and implementation.
- Boeing's CLEEN II projects also have linkage to NASA projects and collaborations
- The SEW project was successfully completed in June, achieving TRL6
- The Short Inlet ground test was successfully completed in 2018, achieving TRL6
- The T/R Aft Duct Acoustics prototype hardware fabrication is nearly complete, with a Flight Demonstration planned for a mid 2021 flight test

These projects inform current and future aircraft and nacelle designs and contribute to FAA CLEEN II goals

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Thank you

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Acronyms

ATP	Authority To Proceed
CDUCT	Boeing ducted fan noise propagation code
CFD	Computational Fluid Dynamics
CN	Compact Nacelle
DDR	Detailed Design Review
EIS	Entry Into Service
EPNdB	Effective Perceived Noise, Decibels
H/W	Hardware
K/O	Kickoff
L/D	Length to Diameter ratio
LHS	Left Hand Side
O/D	On Dock
OGV	Outlet Guide Vanes
PAI	Propulsion Airframe Integration
PDR	Preliminary Design Review
RR	Rolls-Royce
S2F	Safe To Fly
SRR	System Requirements Review
T/R	Thrust Reverser
UHB	Ultra High Bypass

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SEW Report Links

SEW Project Final Report – Public Release	FAA KSN Folder Navigation: cleen > cleenii > boeing > Documents > Final Program Reports > Public Releases > SEW > BOEING_SEW_Final_Public_Report_May 2020 released.pdf Link: https://ksn2.faa.gov/apl/aee/cleen/cleenii/boeing/Documents/Final%20Program%20Reports/Public%20Releases/SEW/BOEING_SEW_Final_Public_Report_May%202020%20released.pdf

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