Boeing CLEEN II Program Update
Compact Nacelle (CN)

Consortium Plenary Session
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Compact Nacelle – Motivation

General Engine Characteristics
- 2025 EIS
- Geared Low Pressure Ratio Fan
- Bypass Ratio of 12 to 14
- Large Fan, Small Core
- Core Mounted Accessories

Nacelle Technologies Required
- PAI Optimization
- Short Inlet (0.4 L/D or less)
- Advanced T/R Configuration
- Improved Acoustic Solutions
  - Advanced Manufacturing
  - New High-temp materials
  - Advanced Bleed Systems
Compact Nacelle - Overview

**Short Inlet Aerodynamics Ground Test**

Ground Testing  Reporting

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
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- 2017: Ground Testing
- 2018: Reporting
- 2019: Flight Demonstration (RR FTB)
- 2020: Final Report

**Aft Duct Acoustics noise reduction**

Rolls-Royce

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Compact Nacelle (CN) - Short Inlet

Anticipated Benefits:

Cumulative predicted impact over 20 years:

- Enables advanced engines with 2025 EIS
  - 14%-16% reduction in fuel consumption on 125-seat and larger aircraft yielding ~400M tons of fuel saved
  - CO2 production avoidance of ~1200 M tons
- Achieve 1% Block Fuel savings through weight and drag reductions

Objectives:

- Measure effects of inlet flow distortion at the fan face in cross wind.
- Validate Short Inlet design tools for transition to Boeing’s next development program.

Work Statement:

Conduct ground crosswind test of a Boeing Short inlet installed on a Trent 1000 engine in collaboration with Rolls-Royce at their Stennis, Mississippi test facility.

Accomplishments since project launch:

✓ Project Launched – Apr ‘17
✓ Short Inlet delivered to Stennis – Apr ‘17
✓ Kickoff Meeting / Test Plan review – Jul ‘17
✓ Block 1 testing completed – Aug ‘17
✓ Baseline Inlet delivered to Stennis – Dec ‘17
✓ Block 2 TRR completed – Dec ‘17
✓ Block 2 testing completed – Mar ’18
✓ Final Briefing – Sep ‘18
✓ Limited Rights Report – Oct ‘18
✓ Public Report – Nov ’18
✓ Program End – Nov ’18
Compact Nacelle (CN) – Aft Acoustics

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 2020 ecoDemonstrator

Accomplishments/Plan:

- Surplus Hardware Obtained – 1Q ‘19
- Concepts developed – 2Q ‘19
- Interim Project Phase Launched – Jul ‘19
- ATP – Oct ’19
- PDR – Oct ’19
- H/W on Dock at Boeing Field – Q2 ‘20
- ecoD 2020 Flight Test – Q3 ’20
- Limited Rights Flight Test Report – Q3 ‘20
- Public Test Report – Q3 ‘20
- Program End – Q4 ‘20
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**
Accomplishments

- Acquired T/R Hardware, shipped to Charleston, SC
- Completed conceptual designs & airplane level sensitivity analyses (for Aft fan tones & broadband)
- Generated moldlines for acoustics fairings
- Completed CFD, CDUCT Attenuation analysis
- Developed Draft test plan for 2020 ecoDemonstrator
- Completed Preliminary Design Review – Oct ‘19
Next Steps

• **Thrust Reverser Prototype Design Complete** – Q1 ‘20

• **Safe-to-Fly Approval** – Q1 ‘20

• **Final Test Plans** – Q1 ‘20

• **Hardware on Dock Boeing Field** – Q2 ‘20

• **ecoD 2020 Flight Test** – Q3 ’20

• **Limited Rights Flight Test Report** – Q3 ‘20

• **Public Test Report** – Q3 ‘20

• **Program End** – Sep ‘20
Summary

- Short Inlet Ground Test was successfully completed in 2018, achieving TRL 6.
- Rolls-Royce will use the Boeing Short Inlet to conduct a Flight demonstration on their FTB (under RR CLEEN II contract).
- A project to implement improvements to nacelle aft duct acoustics was launched earlier this year.
- This new project leverages existing hardware to save costs.
- Preliminary design of the acoustic improvements is complete.
- The experimental prototype hardware will be flown on the Boeing 2020 ecoDemonstrator.
- Results from this project will inform current and future nacelle designs and contributes to the FAA’s CLEEN II goal of reducing aircraft and community noise exposure.
## Acronyms

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ATP</td>
<td>Authority To Proceed</td>
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<tr>
<td>CDUCT</td>
<td>Boeing ducted fan noise propagation code</td>
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<td>CFD</td>
<td>Computational Fluid Dynamics</td>
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<td>CN</td>
<td>Compact Nacelle</td>
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<tr>
<td>DDR</td>
<td>Detailed Design Review</td>
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<tr>
<td>EIS</td>
<td>Entry Into Service</td>
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<td>EPNdB</td>
<td>Effective Perceived Noise, Decibels</td>
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<td>H/W</td>
<td>Hardware</td>
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<td>Kickoff</td>
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<tr>
<td>L/D</td>
<td>Length to Diameter ratio</td>
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<td>LHS</td>
<td>Left Hand Side</td>
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<td>O/D</td>
<td>On Dock</td>
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<td>OGV</td>
<td>Outlet Guide Vanes</td>
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<td>PAI</td>
<td>Propulsion Airframe Integration</td>
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<td>Preliminary Design Review</td>
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<td>System Requirements Review</td>
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<td>Thrust Reverser</td>
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<td>UHB</td>
<td>Ultra High Bypass</td>
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Thank you