INTEGRATED PROPULSION SYSTEM NACELLE TECHNOLOGY DEMONSTRATOR
CLEEN II Consortium Public Plenary Session

Presenter: Jeff Anderson
Nov 7th, 2018
Outline

• Company overview
• Elevator Speech
• Case for Action
• Program Summary
• Opportunity Cost
• Nacelle Technologies
• Technology Risks
• Technology Risk Reduction
• Project Schedule
• Past Achievements
• Future Plans (2018)
• Future Plans (2019)
• Summary
Leading provider of high technology systems for the commercial building and aerospace industries

Employs approximately 220,000 people in more than 4,000 locations

Located in approximately 70 countries around the world

2017 net sales of $60B
UTC Aerospace Systems (UTAS) – By the Numbers

Part of the UTC Family of Companies

UTAS Snapshot

- 40,959 Employees
- $14.5B Net Sales
- $2.3B* Adjusted Operating Profit

Our Top 3 Customers in 2016

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
UTC Aerospace Systems – Who We Are!

We design, invent and deliver the MOST ADVANCED AND DIVERSE range of aerospace systems - and solutions - on the market.
Our systems make modern flight possible

WE POWER IT
WE START IT
WE VENTILATE IT
WE CONTROL IT
WE MONITOR IT
WE PROTECT IT
WE LAND IT
WE STOP IT
UTC Aerospace Systems (UTAS) – Business Units

Business Units

Aerostructures

ISR & Space Systems

Interiors, Actuation & Propeller Systems

Landing Systems

Sensors & Integrated Systems

Electric, Environmental & Engine Systems
Key Products and Systems

Nacelle systems
Pylons and fairings
Tailcones

Key Platforms

Airbus Family / A320neo
A350 XWB
Boeing 737NG Family
Boeing 787 Dreamliner

Airbus A220
MRJ
Embraer 170/190
Embraer 175E2/190E2/195E2

UTC Aerospace Systems – Aerostructures

Industry leading independent supplier and integrator of nacelles and pylons, offering complete life cycle design/build/support for large commercial and regional jet customers around the world
Elevator Speech

Aerodynamically and acoustically optimized Inlet and Fan Duct architectures, enabling lower emissions, energy and noise initiatives, aimed at maximizing efficiency of the next generation high bypass ratio propulsion systems for reducing climate impact from aviation.
Case For Action

Legacy ~5:1 BPR or less

Improved technology ~12:1
  Product Introduction 2025

Next Gen. technology ~15:1+
  Entry into Service now 2030+

UTAS CLEEN II technology scope aligned with 2025 Middle of Market

UHBR: Fuel burn benefit

% Delta Fuel burn vs. BPR

Conventional Nacelle

CLEEN II Nacelle

Engine

Legacy 5:1

2025 Improved Tech 12:1

2030+ EIS ≥ 14:1

Bypass Ratio (BPR)

CLEEN II

Clean Fan Duct

FAA CLEEN II acoustic demo

☑ Short Inlet & Clean Fan Duct

☑ Novel acoustics

☑ Advanced manufacturing

☑ Innovative materials

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
Project Technology
Short Inlet & Clean Fan Duct for HBR Engines

Objectives:
• Achieve TRL6 for Clean Fan Duct acoustics
• Achieve TRL5 for HDL & Short Inlet
• Validate anticipated benefits

Work Statement:
• Develop ground test demonstrator
• Do subscale acoustic and kinematic tests to validate models
• Perform full-scale engine ground test
• Use test data & analyses to project aircraft-level benefits

Anticipated Benefits:
• -1.05% fuel burn
• -2.0 EPNdB noise

Risks/Mitigation Plans:
• Acoustic performance/subscale tests, acoustic optimization models
• Load levels & paths, subscale tests, kinematic & stress model correlation
• Manufacturing tooling and assembly
• Test stand integration/work with P&W

Accomplishments:
• Engine platform & test facilities identified
• Acoustic prediction models validated
• Zoned Liner acoustic design optimized
• Bond panel tooling & fixtures ordered
• TR manufacturing location confirmed

Schedule:

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
Opportunity Cost

- Fuel burn and noise improvement technologies are important to UTAS future nacelle product competitiveness
- FAA funding:
  - Accelerates progressions of CLEEN II technologies to TRL6/MRL6
  - Supports allocation of IR&D funds to screen and mature more technologies
  - Promotes awareness of FAA CLEEN goals within company
- Possible negative impacts without FAA funding:
  - Delay introduction of these technologies to the commercial fleet
  - Defer introduction of other fuel burn/noise technologies
  - Unable to offer technologies to 2025 opportunities
Short Inlet Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Goal Impact</th>
<th>Benefits and Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Inlet</td>
<td>Fuel burn</td>
<td>~0.5% reduction.</td>
</tr>
<tr>
<td>Advanced acoustics</td>
<td>Noise reduction</td>
<td>~0.0 EPNdB reduction. (Maintain Acoustics with shorter inlet)</td>
</tr>
</tbody>
</table>

**CLEEN II Short Inlet**
Technology Risks of Short Inlet Architecture

Challenge:
Inlet innovative core development for shorter nacelle aero lines

Risks:

• Acoustic area limitations due to shorter nacelle aero lines
• Manufacturing methods of new and more effective acoustic treatment
• Test limitations – No engine ground test available to validate short inlet
Technology Risks of Short Inlet Architecture

Challenge:
Inlet innovative core development for shorter nacelle aero lines

Risks:

• Acoustic area limitations due to shorter nacelle aero lines

• Manufacturing methods of new and more effective acoustic treatment

• Test limitations – No engine ground test available to validate short inlet
Technology Risk Reduction

- Developing **next generation acoustic core**
  - Analysis shows potential to **improve acoustic** performance by developing unique **non-conventional geometries**
  - **Two** main **candidates** identified

**Concept A**
Large acoustic cavities

**Concept B**
Alternative septum Configuration

Rapid prototyping accelerated down select of acoustic preferred core concepts
Technology Risks of Short Inlet Architecture

Challenge:
Inlet innovative core development for shorter nacelle aero lines

Risks:

- Acoustic area limitations due to shorter nacelle aero lines
- Manufacturing methods of new and more effective acoustic treatment
- Test limitations – No engine ground test available to validate short inlet
Technology Risk Reduction

- Developing manufacturing solutions that enable implementation
  - Utilized rapid prototype fabrication methods to validate acoustic response
  - Selected configurations are targeting equal or better performance than current state-of-the-art DDOF at significantly lower cost

Rapid Prototype → Evaluate → Refine & Iterate

Targeting equal or better performance at significantly lower cost
Technology Risks of Short Inlet Architecture

Risks:

• Acoustic area limitations due to shorter nacelle aero lines
• Manufacturing methods of new and more effective acoustic treatment
• Test limitations – No engine ground test available to validate short inlet

Challenge:
Inlet innovative core development for shorter nacelle aero lines

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
Technology Risk Reduction

- Utilize NASA LaRC CDTR (Curved Duct Test Rig) followed by NASA ANCF (Advanced Noise Control Fan), operated by the University of Notre Dame Turbomachinery Lab, test facilities to validate acoustics.
- CLEEN II Inlet CDTR initial design optimization ongoing
- CLEEN II Acoustic prediction tools will be validated based on CDTR test

Advanced Tailored Acoustic design feasibility verified by test and analysis
# Clean Fan Duct Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Goal Impact</th>
<th>Benefits and Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean fan duct Thrust Reverser</td>
<td>Fuel burn</td>
<td>~0.5% reduction&lt;br&gt;Demo designed for 25,000-40,000 lb thrust-class engines with expected entry into service by 2025</td>
</tr>
<tr>
<td>Advanced tailored acoustics</td>
<td>Noise reduction</td>
<td>~2.0 EPNdB reduction. (Zoned Acoustics &amp; Area Maximization)</td>
</tr>
</tbody>
</table>

- **Zoned/Thin Acoustics & Area Maximization**
- **Low Drag Surface**
- **Fewer Airflow Obstructions**
Technology Risks of Clean Fan Duct T/R

Challenge:
Thrust Reverser design for a maximized acoustic clean fan duct

Risks:

• Acoustic maximization for clean duct aero lines

• Understanding load paths and vibration levels

• Fabrication methods and locations for ground test TR
Technology Risks of Clean Fan Duct T/R

Challenge:
Thrust Reverser design for a maximized acoustic clean fan duct

Risks:

• Acoustic maximization for clean duct aero lines
• Understanding load paths and vibration levels
• Fabrication methods and locations for ground test TR
Technology Risk Reduction

- CLEEN II clean duct demonstrator design configuration finalized
  - Area maximized and zoned liner optimization complete
  - Low drag liner design integrated into zoned liner

Simulated Zoned Liner

Advanced tailored acoustic design finalized
Technology Risks of Clean Fan Duct T/R

Challenge:
Thrust Reverser design for a maximized acoustic clean fan duct

Risks:

• Acoustic maximization for clean duct aero lines
• Understanding load paths and vibration levels
• Fabrication methods and locations for ground test TR
Technology Risk Reduction

• Finalized load set for ground test
  • Critical load cases identified
  • Analysis plan confirmed for major interfaces and bond panels
  • Approach agreed with Chief Engineers

• Completed initial design and sizing iteration
  • Weight target achievable
  • Structural challenge understood

Structural evaluation well underway. Acoustic & low drag objectives achievable
Technology Risks of Clean Fan Duct T/R

Challenge:
Thrust Reverser design for a maximized acoustic clean fan duct

Risks:

• Acoustic maximization for clean duct aero lines
• Understanding load paths and vibration levels
• Fabrication methods and locations for ground test TR
Technology Risk Reduction

- Tooling for bond panel fabrication designed and ordered
  - Supports 2019 build schedule
- Bond panel and Thrust Reverser build locations confirmed
  - Bond panels fabricated in Riverside, California
  - Thrust Reverser assembly in Foley, Alabama

Fabrication plans in place to support 2020 ground test
Project Schedule

Award
Task Plan


Configuration Definition & Systems Traded
Preliminary Design
Conceptual Design
Detailed Design Tool Design & Hardware Fabrication
Test Planning & Engine Assembly
Gmd Test
Analysis & Report

Optimized Design
UTAS Re-scope Proposal
Architecture Freeze
Re-scope Proceed

PDR DDR

HW Build Comp
Engine Assy
Final Report

Completed Milestone
In Work
Planned Milestone

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
Past Achievements

2012 – 2015 IRAD
30+ Short/Clean Duct Configs.

2 Short/Clean Duct Configs.

TR Actuation Integration Workshop

Test Engine/Pylon Integration Workshop

Preliminary Layout

Kick-Off Meeting w/PW and APS

Demo Config. Down Select

Demo Aerolines

Architecture Freeze

Scope Change Proposal

Engine Selected

2016

TRL4 Acoustics

TR Test Rig Design

TRL5 Acoustics

TR Test Rig Fab

Flow Model Design

TR Test Rig Kinematics / Vibration Testing

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
2018 Plans

- Engine Selected
- Clean Duct Conceptual Design
- Preliminary Design & Analysis
- Release Initial Assembly Drawings

- Product Path Definition
- Linkless Blocker Door Configuration Downselect
- Hidden Drag Link Design Layout
- IP Design Space Assessment
- Alternate HDL Concept Down Selected

▲ Completed Milestone △ Planned Milestone
Future Plans (2020)

<table>
<thead>
<tr>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finish assemble CLEEN II test components</td>
<td>Engine Assembly Complete</td>
<td>TRL 6 Engine Ground Test</td>
<td>Final Report</td>
</tr>
<tr>
<td>Vibration Testing Complete</td>
<td>Model &amp; Test Correlation Complete</td>
<td>Dynamic Analyses of Flow Induced Vibration TRL 5 Modeling Complete</td>
<td>Aero Analyses TRL 5 Modeling Complete</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

△ Planned Milestone

© 2018 UTC AEROSPACE SYSTEMS – FOR PUBLIC RELEASE
THIS DOCUMENT DOES NOT CONTAIN ANY EXPORT CONTROLLED TECHNICAL DATA
Summary

• Efforts Aimed at maximizing efficiency of 2025 high bypass ratio propulsion systems

• Technologies applicable for next generation nacelles for Next Generation Single Aisle, New Midsize Airplane, Middle of the Market

• Inlet & T/R architectures support CLEEN II lower energy and noise initiatives

• Selected technologies applicable for performance insertion on current production programs

• Ground Test demonstrator preliminary design & analysis complete. Fabrication locations known and planning ongoing.

• New HDL concept evaluation underway
Thanks!

Any Questions?