Aircraft Noise Reduction Subproject Overview

Aircraft Noise Reduction Subproject
Advanced Air Transport Technology Project

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Acoustics Technical Working Group Meeting
April 19-20, 2016
NASA LaRC, Hampton, VA
Outline

• Background/Motivation
  • Objective
  • Technical Areas
  • Benefit/Pay-off

• Noise Reduction Concepts
  • Quiet High Lift
  • Multi-Degree of Freedom (MDOF) Liners
  • Additional Noise Reduction Concepts
  • System Noise Assessments

• Concluding Remarks and Future Plans
NASA Subsonic Transport System-Level Metrics

Strategic Focus

1. Energy Efficiency
2. Environmental Compatibility

<table>
<thead>
<tr>
<th>TECHNOLOGY BENEFITS*</th>
<th>TECHNOLOGY GENERATIONS</th>
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<tbody>
<tr>
<td>Noise (cum margin rel. to Stage 4)</td>
<td>-32 dB</td>
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<tr>
<td>LTO NOx Emissions (rel. to CAEP 6)</td>
<td>-60%</td>
</tr>
<tr>
<td>Cruise NOx Emissions (rel. to 2005 best in class)</td>
<td>-55%</td>
</tr>
<tr>
<td>Aircraft Fuel/Energy Consumption (rel. to 2005 best in class)</td>
<td>-33%</td>
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N+3 values are referenced to a 737-800 with CFM56-7B engines

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines. N+2 values are referenced to a 777-200 with GE90 engines.
** CO2 emission benefits dependent on life-cycle CO2e per MJ for fuel and/or energy source used
† ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

Research addressing revolutionary far-term goals with opportunities for near-term impact
Aircraft Noise Reduction (ANR) Technologies

Objective
Explore and develop aero-structural-acoustic technologies to directly reduce perceived community noise without impacting performance

Technical Areas and Approaches
Acoustic Liners and Duct Propagation
— Advanced, low-drag liner concepts
Airframe Noise
— Flap/Slat and landing gear noise reduction
Propulsion Noise
— Fan and core noise reduction
Propulsion Airframe Aeroacoustics (PAA)
— Installation effects on perceived noise

Benefit/Pay-off
Component noise reduction with minimal impact on weight and performance
— Direct contribution to Ultra-Efficient Commercial Vehicles Strategic Thrust
— Liner and non-active-flow-control high-lift system technology may have early insertion potential
Aircraft Noise Reduction Technical Areas

- **Airframe**
  - Lifting components
  - Landing components

- **Propulsion**
  - Propulsor
  - Core (combustor & turbine)

- **Propulsion/Airframe Aeroacoustics (PAA)**
  - Installation Effects on Noise Sources
  - Shielding/Scattering

**System Noise Impact Assessments**

Advanced Air Transport Technology Project
Advanced Air Vehicles Program
Quiet High-Lift

Aero-Structural-Acoustic High-Lift System Test (14x22)

- CHL/CRM: Open geometry high-lift configuration based on the high-speed CRM
- Testbed for slat, flap side-edge, and landing gear noise reduction technology
  - SCF and SGF will be tested in the 14x22 in FY18
  - Modified slats fabricated using realistic materials, but non-articulating

LE Slat Noise (3D CFD, $\alpha=5.5^\circ$)

Slat Cove Filler (SCF)

Slat Gap Filler (SGF)

Conventional High-Lift (CHL)
Common Research Model (CRM)
Quiet High-Lift

CHL/CRM V2.0 Wind Tunnel Model

- 6.25% scale model of a section at mid-span of the CRM outboard slat
- Lift and drag measurements at various angles of attack and flow speeds
- Deployable slat and flap via embedded actuators
- Study fluid-structure interaction (FSI) of slat treatment during articulation
- Risk reduction for 14x22 test and beyond
  - Validation of computational models and overall design process
MDOF Liner Concept

NASA/Honeywell 9x15 Test

Broadband Benefit Demonstrated

- **Sideline OASPL Attenuation at 80% RPM**

  - Acoustic Attenuation, dB (OASPL, 1kHz-25kHz)
  - Frequency, kHz

- **Attenuation Spectra, 80% RPM**

  - Frequency, kHz
  - Attenuation, dB

**Multi-Degree of Freedom (MDOF)**

- Single-Degree of Freedom (SDOF)

**Nacelle Liner**

- Hub Liner – 1
- Hub Liner – 2

**Broadband Benefit Demonstrated**

- NASA MDOF
- Honeywell SDOF
Additional Concepts

- Soft Vane
- Over-The-Rotor Acoustic Treatment

Notable benefits possible: Need further development

- Lean nine-point fuel injector (LDI)
- Swirler

Understand combustor-design change impacts

Advanced Air Transport Technology Project
Advanced Air Vehicles Program
Low-Drag Liner Concepts

Grazing Flow Impedance Tube (GFIT) Test

Objective
- Reduced liner drag for internal/external applications

Technical Areas and Approaches
- Acoustic benefits and improved aerodynamic performance (fuel burn)
Fan Acoustic Casing Treatment

**Objective**
Evaluate fan acoustic casing treatments noise reduction potential of up to TRL 3

**Technical Areas and Approaches**
Series of progressively higher TRL testing
- Normal Incidence Tube Testing (LaRC)
- Low Speed Fan Testing (ANCF, GRC)
- Scaled UHB Fan Testing (W-8, GRC)

Acoustics: In-duct array testing

Aero: Determine aerodynamic impact

**Benefit/Pay-off**
- Benefits up to 4-5dB reduction have been demonstrated in previous testing
**Objective**
Evaluate soft vane broadband noise reduction

**Technical Areas and Approaches**
Series of progressively higher TRL testing
- Generate and characterize noise generated by interaction with upstream turbulence

Acoustics: Improve acoustic benefit

Aero: Quantify and reduce aerodynamic impact

**Benefit/Pay-off**
- Soft vanes have shown a significant noise reduction potential on the Source Diagnostic Test hardware.
- ERA assessments predict potential 1.5 EPNdB system noise reduction
**Objective**
Further validate and improve acoustic scattering prediction capabilities
- Employ well-defined sound source
- Utilize open, generic geometry

**Benefit/Pay-off**
- Establish validation database
- Characterize effect of flow, model wake, and source location

Scattering of sound by an aircraft fuselage
Technical Areas and Approaches
Acoustic scattering test to be performed in QFF
• with 2-D NACA0012 airfoil
• using non-intrusive, laser-induced, monopole source.
• Test repeated at DLR and ONERA

Status: Test preparations are on-going
• Test hardware fabrication is nearly complete.
• Laser and optics set-up needed to meet test requirements has been established.
• Traverse systems for the microphones and laser/optic assembly have been developed and controls integrated in the QFF data acquisition system.
• Data acquisition expected to run May-June.
Technical Areas and Approaches
QFF acoustic scattering test

- 2-D NACA0012 airfoil
- Non-intrusive, monopole source.
- Test repeated at DLR and ONERA

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Propulsion Airframe Aeroacoustics

Source Shielding/Scattering
Acoustically Treated Tail (External Liners)

Jet-Surface Interaction Test (JSIT)

Preliminary Prediction of Shielding Impact

- Conceptual Stage (Initial Feasibility Study)
- No N+2/N+3 Noise Technologies Applied
  - FSC: Improved Shielding Model
  - FSC-A+: Refined Fan Prediction
System Noise Impact Assessment

Overall system noise impacts of various component technologies assessed through periodic system noise studies for baseline and unconventional aircraft configurations.
Concluding Remarks and Future Plans (1/2)

ANR Subproject is well poised within the AATT Project to support Ultra-Efficient Commercial Vehicles Strategic Thrust

- Technical Challenge, TC 3.1, to be concluded in FY18 with results from MDOF Liners and Quiet High-Lift Test in 14x22
- Technical Challenge, TC 3.2, to be formulated and proposed with technical investments to close current predicted noise goal gap with associated impact/benefits to performance goals
  - Acoustic Liners and Duct Propagation: Low-drag advanced liners
  - Airframe Noise: High-lift system/gear interaction
  - Propulsion Noise: Fan and core noise reduction
  - PAA: Installation effects on sources
  - System Noise Impact Assessments

Integrated PAA Test
Concluding Remarks and Future Plans (2/2)

Technical Challenge, TC 3.3, to be formulated and proposed with technical investments in propulsors for FY18-22 within the AATT Project.

Background:

- At the conclusion of ERA, there was still a need for higher TRL, advanced propulsor research.
- The new TC 3.3 is intended to have significant partner cost share and to focus on maturing propulsor technologies for N+3 systems.

Technical investment areas:

- Benchmark low PR fan test case (aero/acoustic/aeromechanic)
- Advanced ducted and/or unducted propulsor systems (To duct or not to duct?)
- Propulsion Airframe Installation/Aeroacoustics for low PR fan systems
Backup Slides
Flight Demo Plan

Hybrid Electric Propulsion Demonstrators

- **Transport Scale**
  - **Ground Test Risk Reduction**
  - **Preliminary Design**
  - **Design & Build**
  - **Flight Test**

- **Small Scale “Build, Fly, Learn”**
  - **Design & Build**
  - **Flight Test**
  - **Preliminary Design**

- **Fully integrated UEST Demonstrator**
  - **Design & Build**
  - **Ground Test Risk Reduction**
  - **Preliminary Design**
  - **Potential Candidates**

- **“Purpose-Built” UEST Demonstrators**
  - **Design & Build**
  - **Flight Test**
  - **Preliminary Design**

**Total Demonstration Cost:** $700M

**Life Cycle Cost:**
- $430M
- $850M
- $400-500M

**FY17** to **FY26**
Aircraft Noise Reduction (ANR)

**AATT TC3.1 (FY18) Fan & High-Lift Noise**
Reduce fan (lateral and flyover) and high-lift system (approach) noise on a component basis by 4 dB with minimal impact on weight and performance (TRL5)

**TC3.1 Investment**
- Acoustic Liners & Duct Propagation – Multi-Degree of Freedom (MDOF)
- Airframe Noise – High-Lift System

**AATT eTC3 Quieter Low-Speed Performance**
Develop, quantify and assess the impact of component noise reduction technologies across the airframe noise, acoustic liner technology, propulsion noise, and propulsion airframe aeroacoustics technical areas. Overall system noise impacts of various component technologies will also be assessed through periodic system noise studies for candidate conventional and unconventional aircraft configurations.

**eTC3 Investment**
- Acoustic Liners & Duct Propagation – Low-Drag Advanced Liners
- Airframe Noise -
- Propulsion Noise
- Propulsion-Airframe Aeroacoustics (PAA)
ANR Research Approach

Example: Single Aisle (SA) - Baseline

Example: Large Twin Aisle (LTA) - Baseline

“dB Math”
2x Source Acoustic Power = 3 dB Increase
10x Source Acoustic Power = 10 dB Increase
ANR Research Approach

Advanced Air Transport Technology Project
Advanced Air Vehicles Program

"dB Math"
2x Source Acoustic Power = 3 dB Increase
10x Source Acoustic Power = 10 dB Increase
Propulsion Noise: Possible Concepts

Over-the-Rotor acoustic treatment fan case

Concepts for Study

Distributed Fans

Counter-Rotating Fans

Shrouded Open Rotor

Graph showing the relationship between fan pressure ratio and propulsive efficiency.
Propulsion Airframe Aeroacoustics

Source Shielding/Scattering
Acoustically Treated Tail (External Liners)

Jet-Surface Interaction Test (JSIT)
NASA systems analysis on the MIT D8.5 configuration - update Sept 2015

- Fast Scattering Code (FSC) for shielding/scattering predictions
- Updated fan and airframe source level predictions

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<tr>
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<th>CUM EPNL Below Stage 4</th>
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<tbody>
<tr>
<td>D8.5-MIT</td>
<td>62.6</td>
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<tr>
<td>D8.5-2015-FSC-A+</td>
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NASA Team: Berton, Burley, Guynn, Nark, Welstead