Core/Combustor-Noise Update

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Summary

Future propulsion systems for ultra-efficient commercial air vehicles are projected to be of increasingly higher bypass ratios resulting from larger fans combined with much smaller cores, with ultra-clean burning fuel-flexible combustors. Unless effective noise-reduction strategies are developed, combustor noise is likely to become a prominent contributor to overall airport community noise in the future. This presentation gives a brief overview of the NASA outlook on pertinent issues and far-term research needs as well as current and planned research in the core/combustor-noise area. The research described herein is aligned with the NASA Ultra-Efficient Commercial Transport strategic thrust and is supported by the NASA Advanced Air Vehicle Program, Advanced Air Transport Technology Project, under the Aircraft Noise Reduction Subproject.

The overarching goal of the Advanced Air Transport Technology (AATT) Project is to explore and develop technologies and concepts to revolutionize the energy efficiency and environmental compatibility of fixed wing transport aircrafts. These technological solutions are critical in reducing the impact of aviation on the environment even as this industry and the corresponding global transportation system continue to grow.

National Aeronautics and Space Administration
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NASA Advanced Vehicles Program
Advanced Air Transport Technology Project
Aircraft Noise Reduction Subproject

NASA CORE/COMBUSTOR-NOISE RESEARCH

…. Effort in Support of Ultra-Efficient Commercial Vehicles

Problem: Core Noise is an Emerging Issue

1) Turbofan Design Trends, Engine-Cycle Changes and Reduction of Other Propulsion-Noise Sources
2) Lean-Combustor Designs Could Increase Noise

Objective: Significantly Reduce Airport-Community Noise

1) Improve Engineering Models for Prediction
2) Enable Mitigation Strategies at Early Design Stage

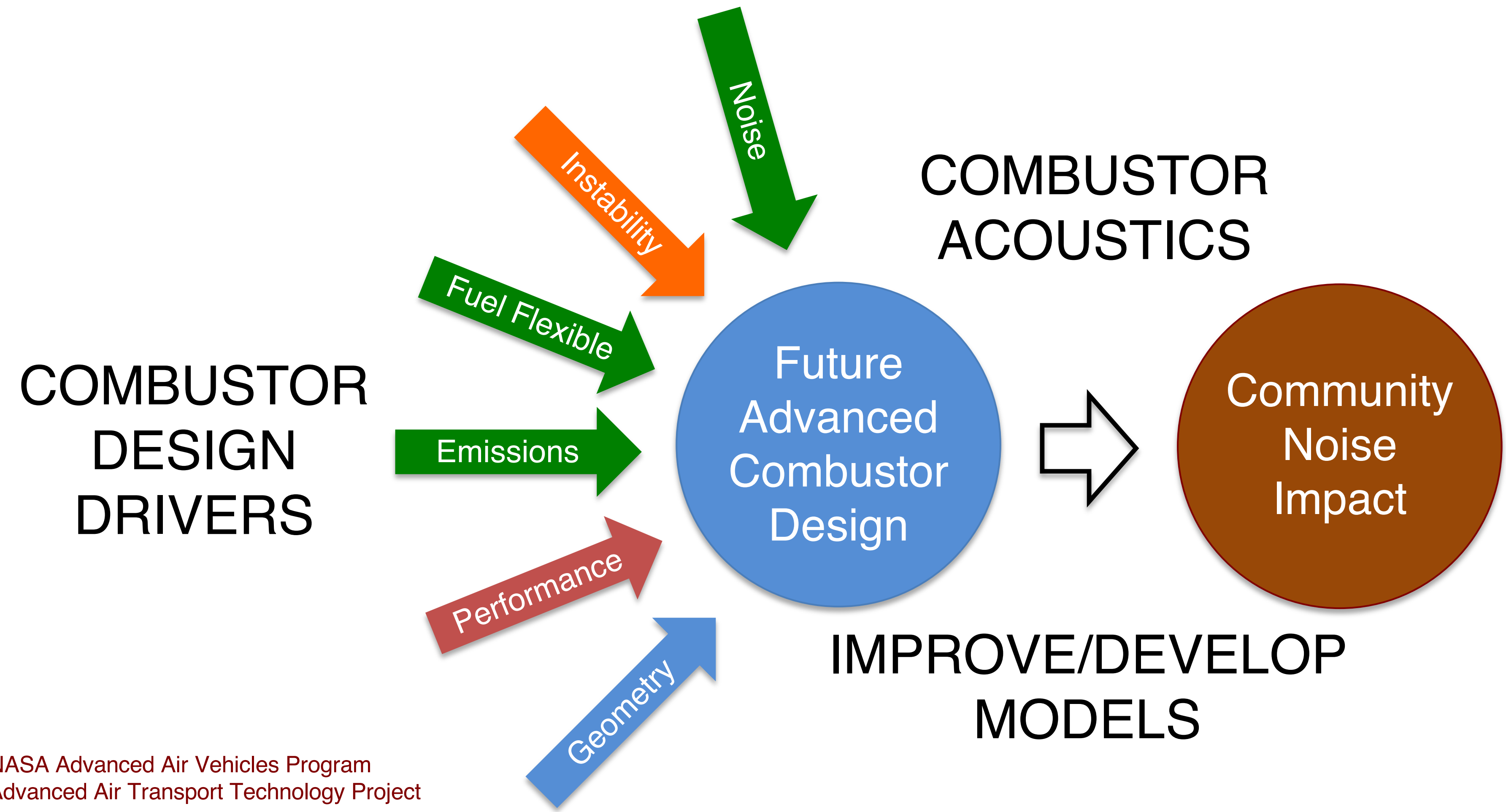
Approach: NRA Activities and In-House Research

1) Partnerships with Industry/Universities through NRAs
2) In-House Research: Diagnostics and Noise Reduction – DGEN Aeropropulsion Research Testbed (DART)

Significance: Core/Combustor Noise Must Be Addressed to Ensure Noise Limits for Far-Term Concept Aircraft

NOISE-SOURCE CHARACTERIZATION

- Core-Noise Physics – Better Understanding of Sources
- Understand Impact of Evolving Combustor Technology



UTRC NRA HPHT-RIG TEST – PI: Duane McCormick

…. Acoustics of Future Low-Emissions Combustion Technology (Oct 2016)

- Acoustics of Modern (N) and Future Advanced (N+3) Combustors
- Detailed Unsteady Multi-Point Heat-Release And Pressure
- Leverage Combustion/Emissions NRA Effort at UTRC

N+3 Development Contract (OEM Design)

NNC14CA30C
Fuel-Flexible Combustor for High-OPR, Low-Emissions, Compact-Core N+3 Propulsor

N+3 Acoustics Contract

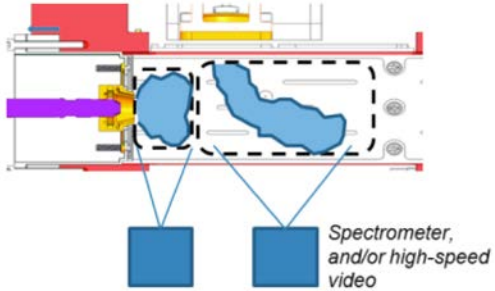
NNC16CA39C
- Design Modifications for N Combustor Rig
- Obtain UHR Field and Unsteady Pressures
- Statistically Characterize Acoustic Sources
- Examine and Extend Legacy Scaling Laws
- Measure Unsteady Temperatures

- Benefit from Hardware Development
- Contribute FEA Acoustic Rig Model –> Combustor-Dynamics Studies
- Expected Outcomes:
  - Scaling Principles to Extend Reduced-Order Models
  - Validation of Future High-Fidelity Prediction Tools
  - Validation of Optical Techniques at N+3 Conditions

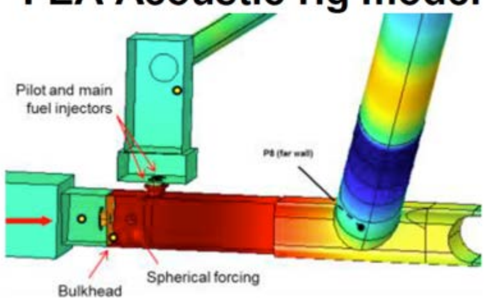
UTRC NRA HPHT-RIG TEST – PI: Duane McCormick

…. Acoustics of Future Low-Emissions Combustion Technology (Oct 2016)

Chemiluminescence of UHR field



FEA Acoustic rig model



Combine UHR Data and Finite-Element-Analysis Acoustic Model

UHR

Modes

Convolve UHR Data with Green's Function → Acoustic Power

- ❑ FEA Acoustic Model Complete
- ❑ Test Hardware Manufactured

Imaging Window Hardware

N-Configuration Dilution Jets

T4 TDLAS Flange

Unlimited-Rights Figures Provided by
United Technologies Research Center

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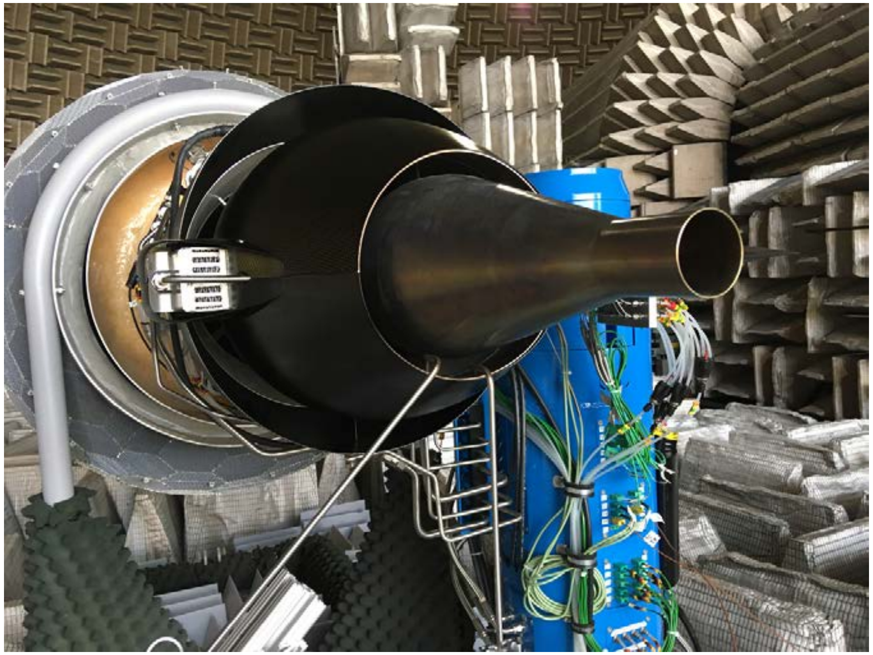
DIAGNOSTICS & MITIGATION

- Develop/Evaluate Measurement and Mitigation Techniques
- Utilizes Cost-Efficient NASA DART Platform – TRL < 6

NASA GRC AAPL Facility



Semi-infinite-tube probes at core-nozzle exit 6 and 7 o'clock positions

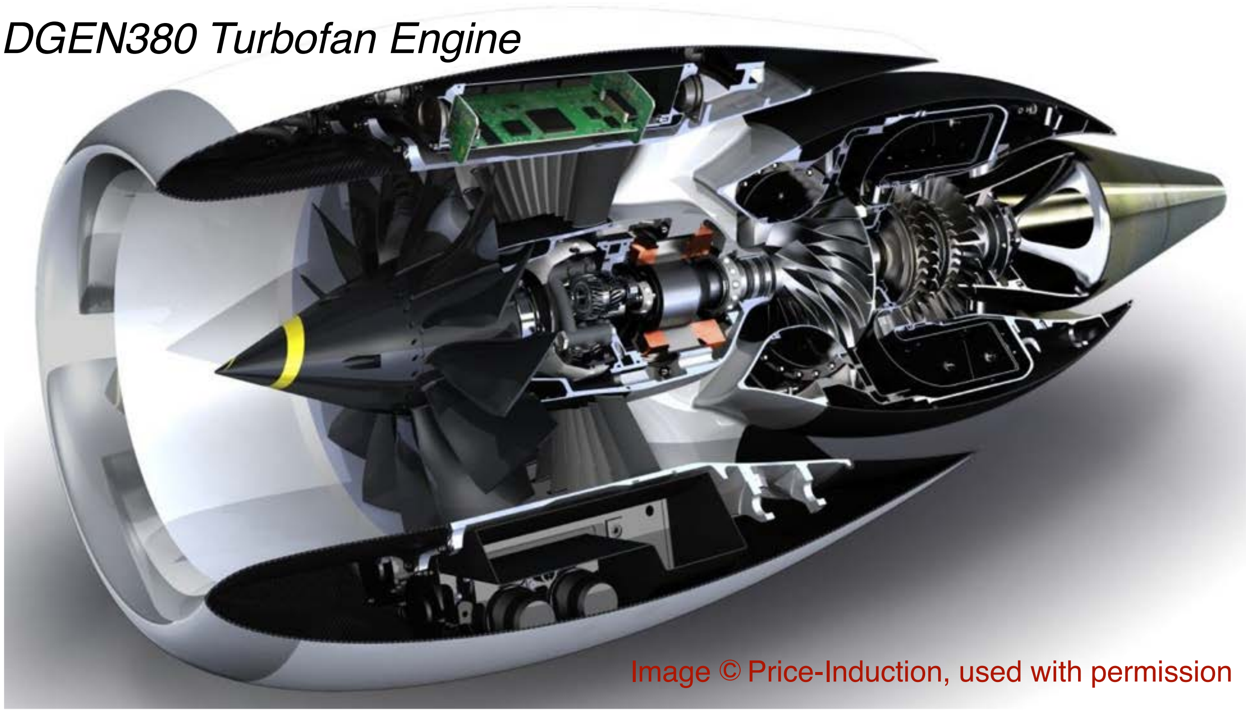
- Not a Turbofan-Development Effort

DART/DGEN CORE-NOISE RESEARCH PATH

…. Development/Evaluation of Measurement and Noise-Mitigation Techniques

Baseline Combustor Noise Measurements → FY17 → **Instrumentation Refinements** → FY18 → **Core-Nozzle Circumferential Array Measurements** → FY19 → **Design Tailpipe for Liner Testing** → **Hot-Liner Testing Circumferential and Axial Array**

DGEN380 Turbofan Engine



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Source Separation Techniques

Determine Noise-Source Structure

Update Core-Noise Prediction Tools

Validate Liner-Design Tools for Hot Conditions

NASA COMBUSTOR-NOISE RESEARCH SUMMARY

…. Better Physical Understanding And Engineering Models

NOISE-SOURCE CHARACTERIZATION

- Core-Noise Physics – Better Understanding of Sources
- Changes with Evolving Combustor Technology

DIAGNOSTICS & MITIGATION

- Use NASA/GRC DART Facility – Baseline Test FY17
- Source-Separation Methods & Mitigation Techniques

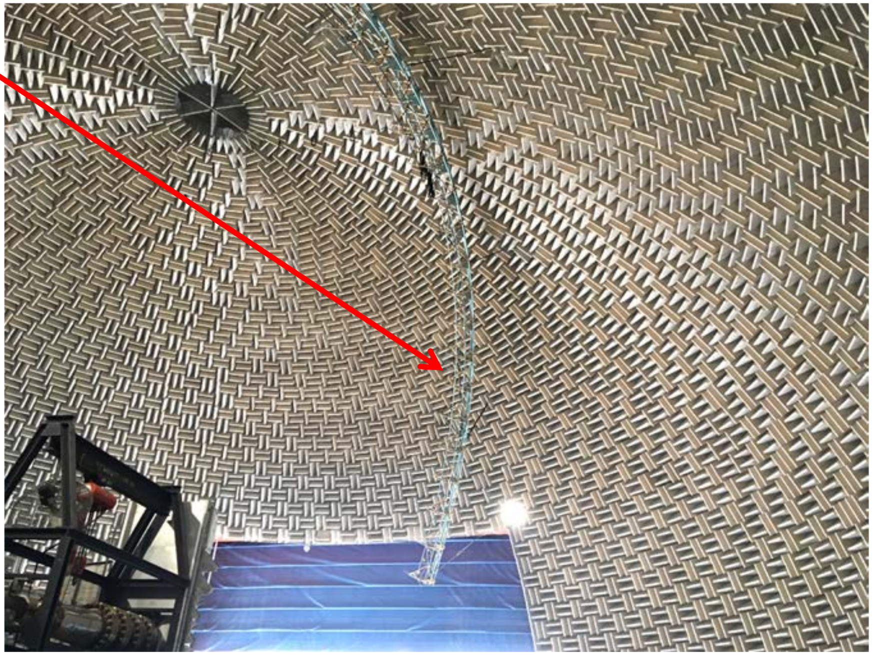
Facility for TRL < 6 concept and technique development work

NASA

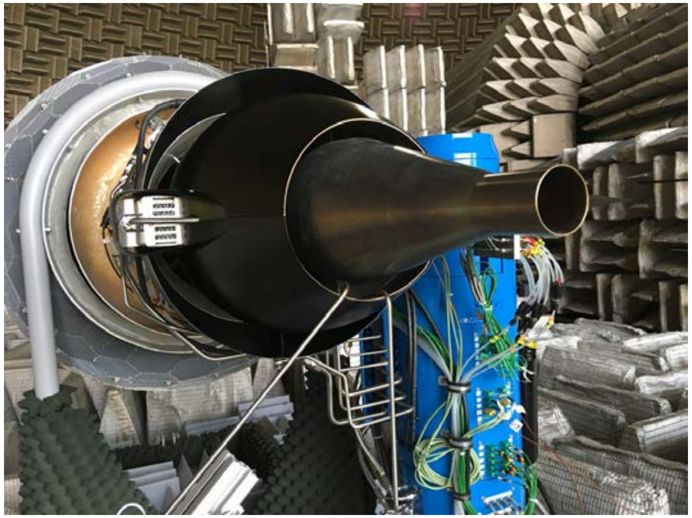
2017 DART Core/Combustor-Noise Test

…. Acoustic Instrumentation Layout in NASA GRC APPL Facility

7 far-field microphones in AAPL overhead array in aft quadrant: polar angles 110º to 140º



AAPL overhead array



Semi-infinite-tube probes at core-nozzle exit 6 and 7 o'clock positions

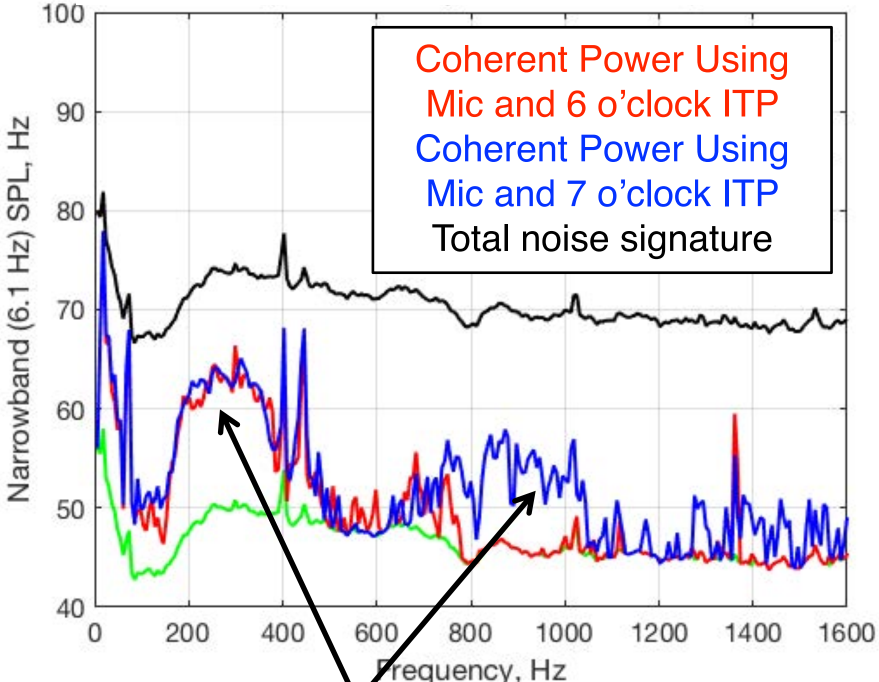
1 mid-field stand-mounted microphone 130º direction, engine-center height, 10 ft distance

Mid-field microphone (left) - Engine (right)

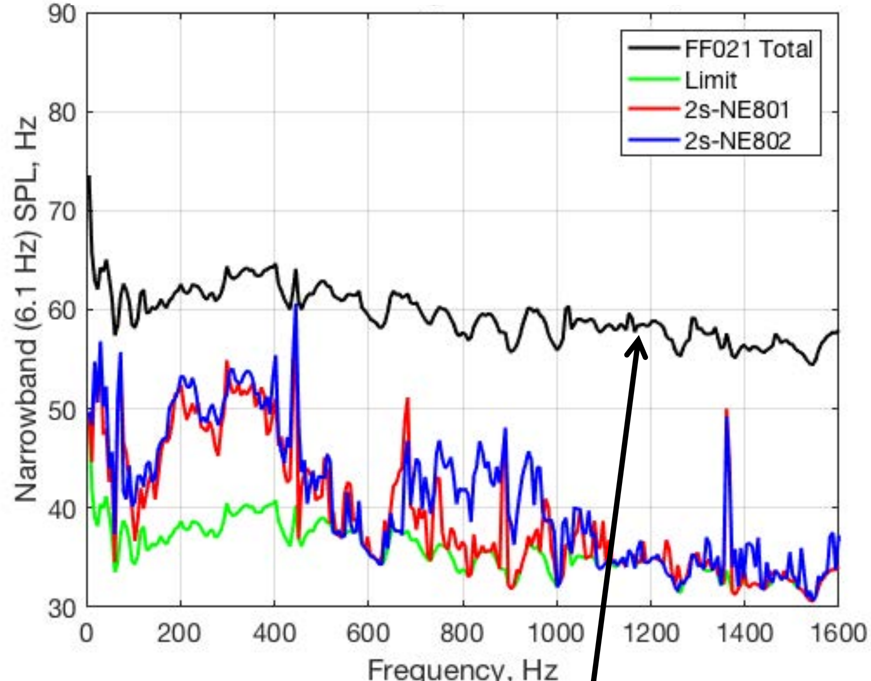
2017 DART Core/Combustor-Noise Test

…. Mid-Field and Far-Field Combustor-Noise Component at 60%

Mid-field (10 ft, 130°) 2-signal coherent output



Far-field (37 ft, 131°) 2-signal coherent output



Broadband combustor-noise component

Total noise signature

Broadband combustor noise ($m = 0$) detected up to about 500 Hz using either ITP

7 o'clock ITP also detects second broadband-noise frequency range ($m = \pm 1$)

Not clear at present why second range not detected by 6 o'clock ITP

NASA