Core/Combustor Noise – Research Overview

Lennart S. Hultgren, NASA Glenn Research Center, Cleveland, OH 44135

Presented at the Acoustics Technical Working Group Meeting
Hampton, Virginia, April 11-12, 2017

Summary

Contributions from the combustor to the overall propulsion noise of civilian transport aircraft are starting to become important due to turbofan design trends and advances in mitigation of other noise sources. Future propulsion systems for ultra-efficient commercial air vehicles are projected to be of increasingly higher bypass ratio 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.

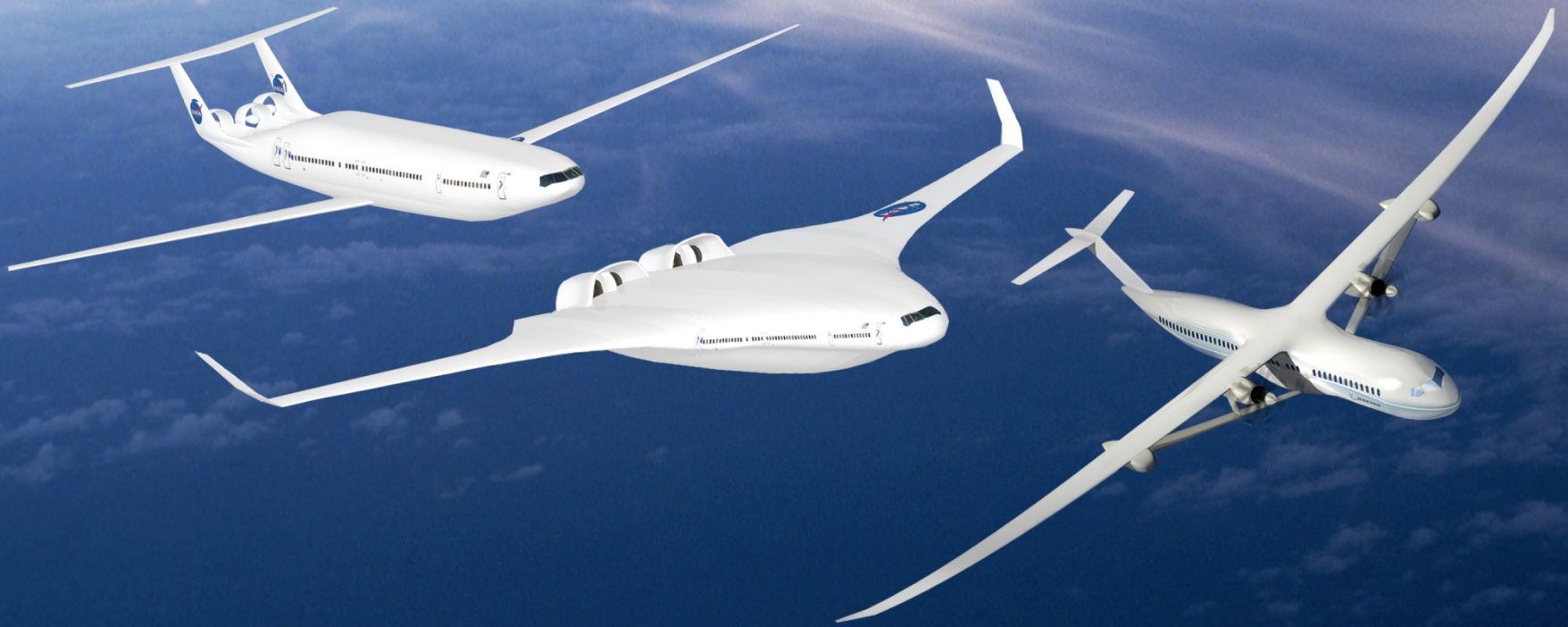
National Aeronautics and Space Administration

Core/Combustor Noise – Research Overview

…. *Research in Support of Ultra-Efficient Commercial Vehicles*

Lennart S. Hultgren
NASA Glenn Research Center
Cleveland, OH 44135

NASA/GRC Team Members
Devin K. Boyle
Brenda S. Henderson
Lennart S. Hultgren



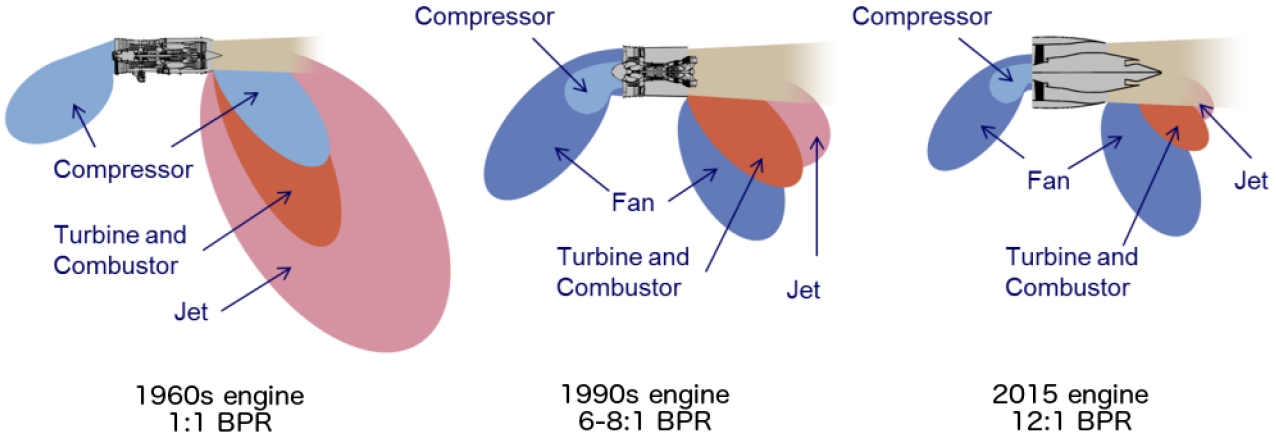
Acoustics Technical Working Group
Hampton, VA, April 11-12, 2017

www.nasa.gov

NASA Advanced Air Vehicles Program
Advanced Air Transport Technology Project
Aircraft Noise Reduction Subproject

PROPULSION-NOISE SOURCES

… Relative Strengths Changing with Engine Evolution



- Core Noise Likely Becoming More Important in Future
  - in particular combustor noise
  - turbofan design trends, engine cycle changes and noise-mitigation advances are expected to reduce the other propulsion noise sources
- Potential Impact of Emerging Lean Combustor Designs
  - combustor noise-source structure changes?
  - could increase combustor-noise component

Applicability Of Current Core-Noise Prediction Tools To Emerging N+3 Designs Is Unknown

NASA COMBUSTOR-NOISE APPROACH

…. Better Physical Understanding And Engineering Models

Need: Understand Implications of Lean Combustor Design

1) Core-Noise Physics
2) Effective Noise-Reduction Techniques

Goal: Impact Design Process by Ultimately Developing

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

Means: NRA Activities and In-House Research

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

Significantly Reduce Impact of Airport Community Noise

NASA COMBUSTOR-NOISE RESEARCH

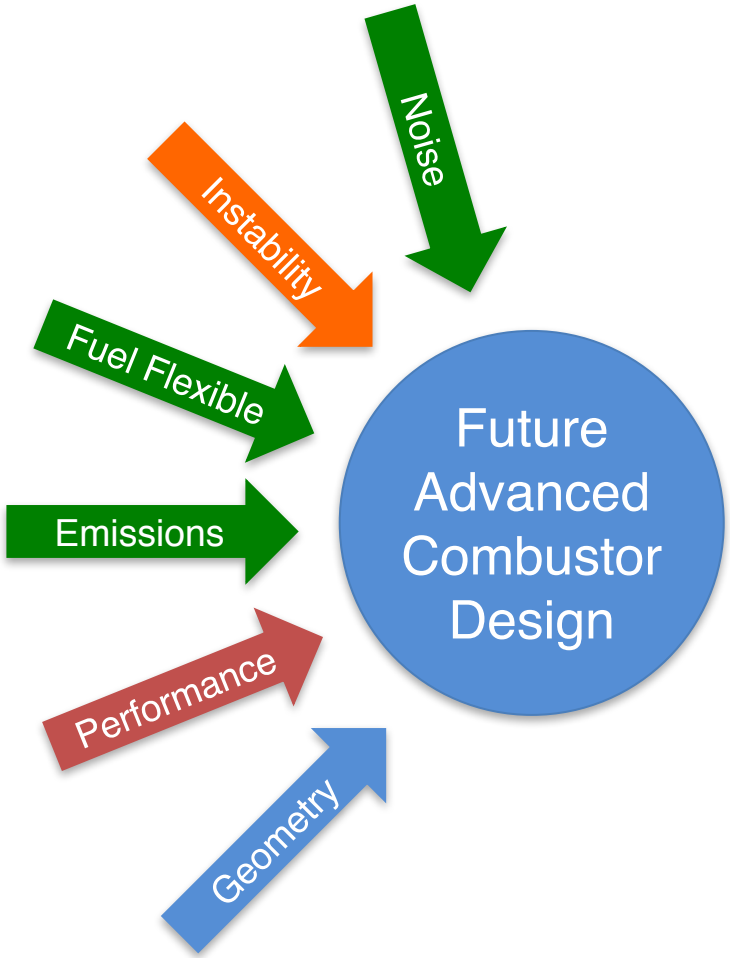
…. Better Physical Understanding And Engineering Models

NOISE-SOURCE CHARACTERIZATION

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

COMBUSTOR-DESIGN TRENDS

…. Combustor Design Drivers & Potential Impact on Combustor Acoustics



Several Axial Source Regions Possibly With Different Scaling Laws

Balance Between Direct And Indirect Combustor Noise Could Change

Community Noise Impact

?

Frequency Range & Peak

Active/Passive Combustion-instability Control Strategy Could Increase Noise Levels Even In The Absence Of Instability

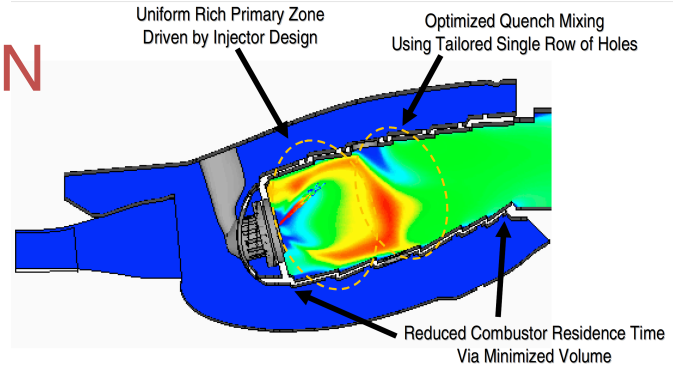
Can Current Combustor-Noise Scaling Laws Be Extended to N+3 Conditions?

UTRC NRA RIG TEST – PI: Duane McCormick

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

Rich Quench Lean

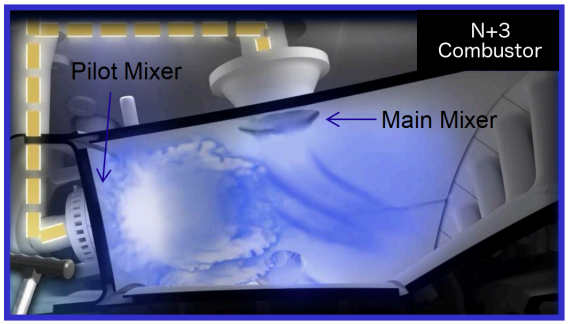
N



TALON Family – RQL

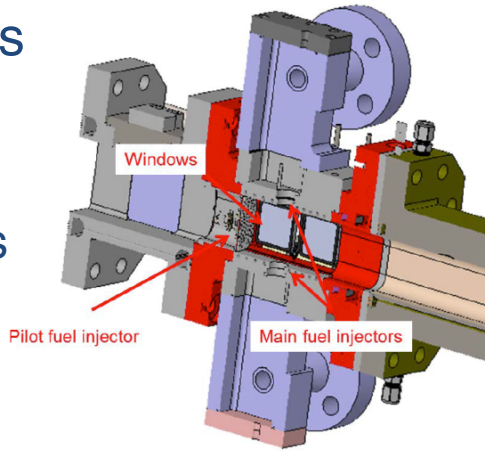
Axially Controlled Stoichiometry (ACS)

N+3



UTRC HPHT-Rig – Base-Line and Advanced Design Combustor

- Detailed Unsteady Multi-point Heat-Release And Pressure
- Modern (N) and Future Advanced (N+3) Conditions
- Expected Outcomes:
  - Scaling Principles to Extend Reduced-Order Models
  - Validation of Future High-Fidelity Prediction Tools
  - Validation of Optical Techniques at N+3 Conditions



NASA COMBUSTOR-NOISE RESEARCH

…. Better Physical Understanding And Engineering Models

DIAGNOSTICS & MITIGATION

- Source-Separation Methods

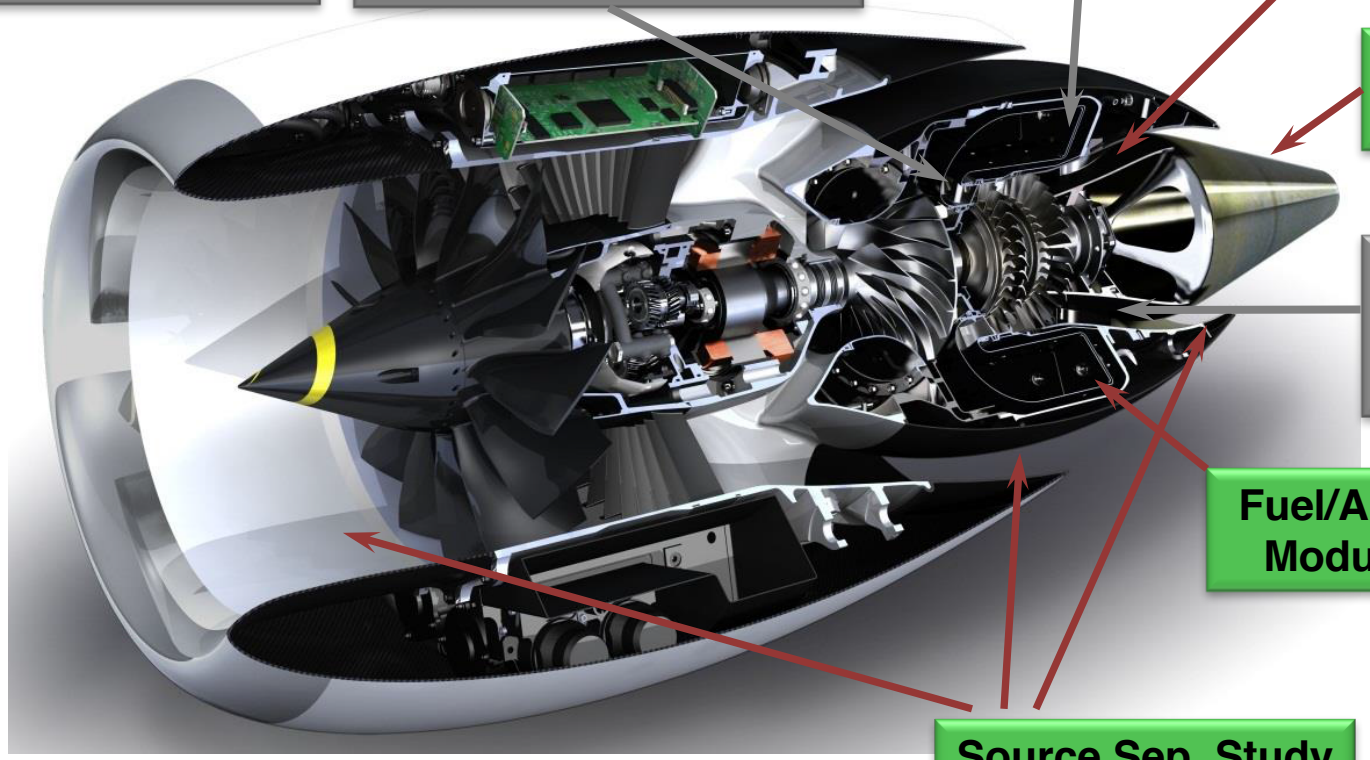
Thank You Dan Sutliff And Facilities Team

- Use NASA/GRC DART Facility † – Now In Shakedown

† *Facility for TRL < 6 concept and technique development work*

DART/DGEN CORE-NOISE RESEARCH CONCEPTS

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



Update core-noise prediction tools

High-temperature measurement capability

Injector modification

Hot-Section Liner Development

Tail cone Resonators

Turbine blade/vane variations

Fuel/Air Ratio Modulation

Source Sep. Study

DGEN380 Turbofan Engine

Phase 1: Year 1-3

Phase 2: Year 4-6

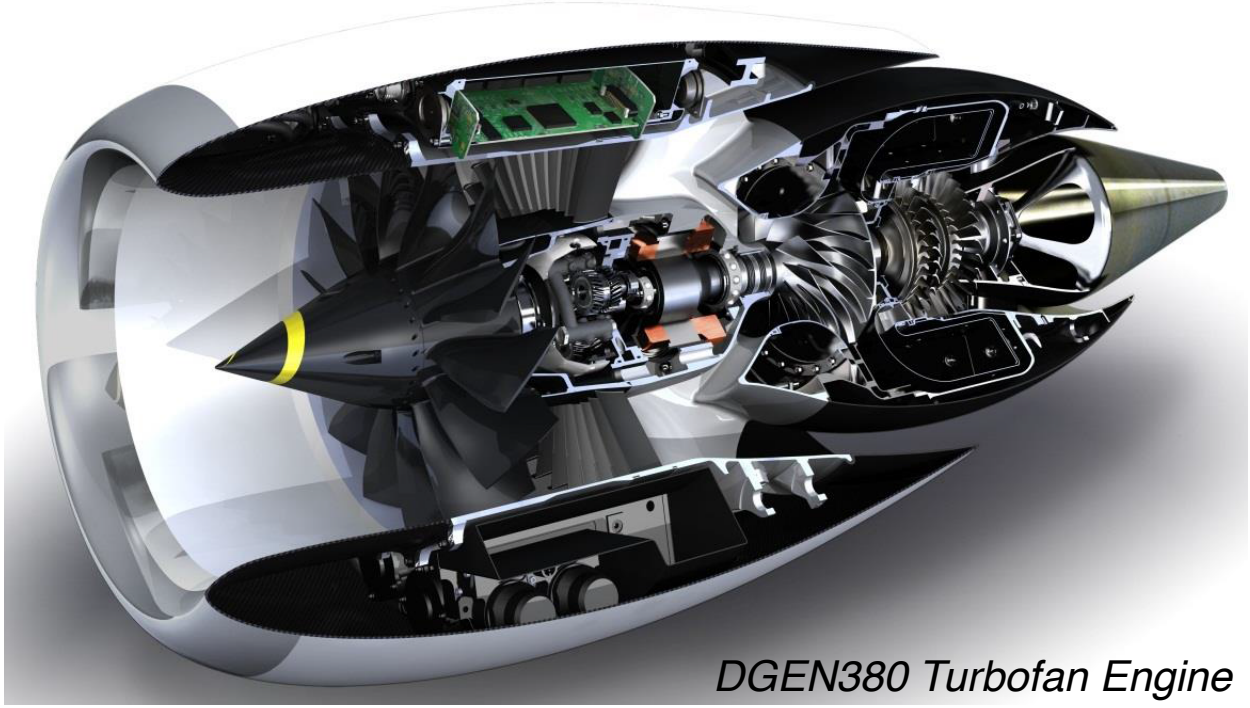
DART/DGEN CORE-NOISE RESEARCH EXAMPLE

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

Baseline Combustor Noise Measurements → **Benchtop Semi-Infinite Tube** → **Core-Nozzle Circumferential Array Measurements**

Design Tailpipe for Liner Testing

Hot-Liner Testing Circumferential and Axial Array



DGEN380 Turbofan Engine

Source Separation Techniques

Determine Noise-Source Structure

Update Core-Noise Prediction Tools

Validate Liner-Design Tools for Hot Conditions

NASA COMBUSTOR-NOISE RESEARCH

…. Better Physical Understanding And Engineering Models

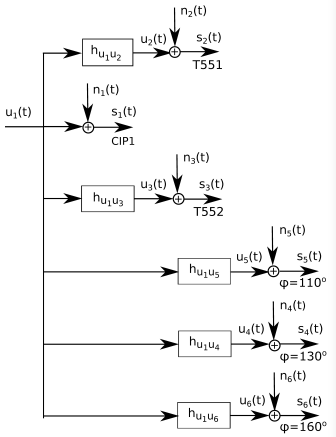
WRAP UP

NASA COMBUSTOR-NOISE RESEARCH ACTIVITIES

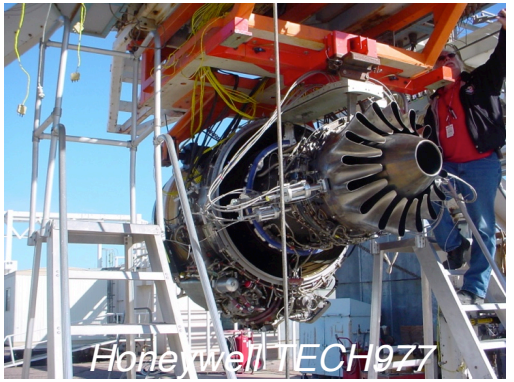
…. In-House and NRA Work

Source-Separation Methods

- Demonstrated presence of TECH977 indirect combustor noise (EVNERT)
- Updated ANOPP GECOR turbine-attenuation factor



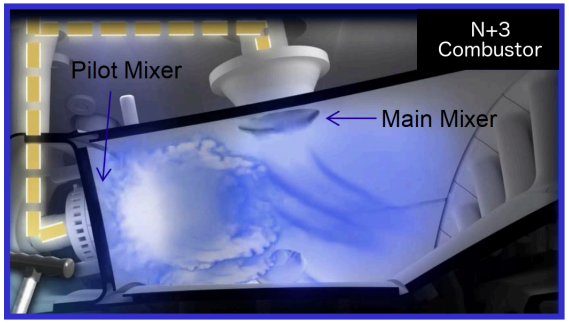
Honeywell NRA (completed 2014)



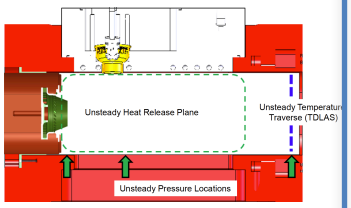
p' & T'

- Noise sources and turbine-transfer function

UTRC NRA (started 2016)

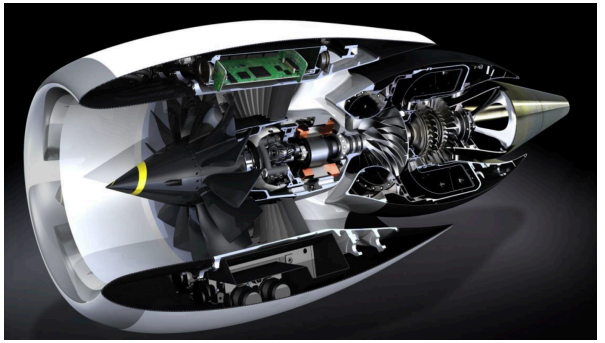


q", p' & T'



- Unsteady measurements characterizing noise sources of advanced low-emissions combustors at realistic N+3 conditions

DART/DGEN (starting 2017)



DGEN380 500 lbf Trust-Class Engine

- Small, modular turbofan engine
- Source diagnostics and mitigation

NASA COMBUSTOR-NOISE RESEARCH SUMMARY

…. Better Physical Understanding And Engineering Models

NOISE-SOURCE CHARACTERIZATION

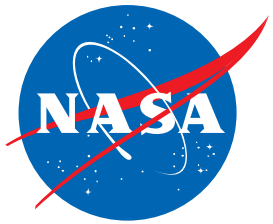
- Core-Noise Physics – Better Understanding of Sources
- Changes with Evolving Combustor Technology

DIAGNOSTICS & MITIGATION

- Use NASA/GRC DART Facility † – Now In Shakedown
- Source-Separation Methods & Mitigation Techniques

---

† *Facility for TRL < 6 concept and technique development work*


NASA