



2019 DART Source-Diagnostic Test Results Update

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Motivation/Introduction

Experimental Setup

- Sensor Arrangement

- Data Acquisition

Modal Decomposition Results

- Circumferential ITP Array Example Results

- Sideline 61-Microphone Array Example Results

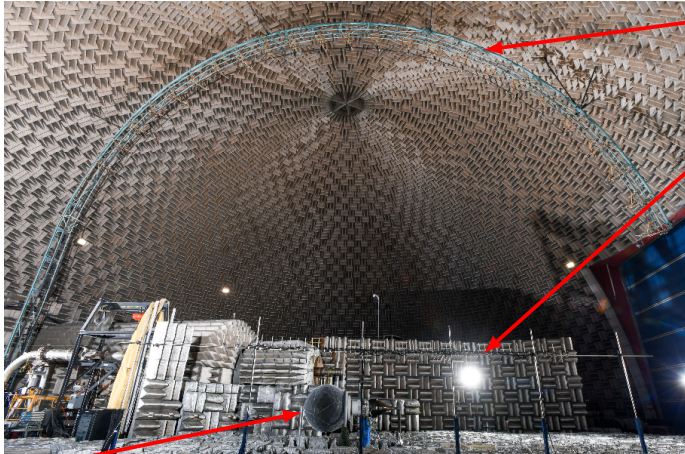
- Farfield 24-Microphone Array Example Results

- Circumferential ITP Array Example Results

Summary

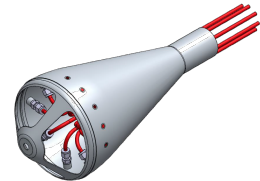
- Core/Combustor-Noise Source and Mitigation Research
- Continuation of 2017 Baseline DART Core/Combustor-Noise Test
 - Boyle et al AIAA Paper 2018-3281
 - Boyle et al ASME Paper GT2020-14194 (for Turbo Expo 2020)
- NASA GRC DGEN Aeropropulsion Research Turbofan (DART)
 - DGEN 380 — 500 lbf thrust class turbofan engine
 - Small, but relevant for aeroacoustic research
- Aero-Acoustic Propulsion Laboratory (AAPL) — Anechoic Facility
- Overall more extensive acoustic instrumentation
 - Circumferential ITP array at core-nozzle exit
 - Sideline and farfield (overhead) microphone arrays
 - Simultaneous high-data-rate acoustic measurements (93 channels)

Experimental Setup — Overview



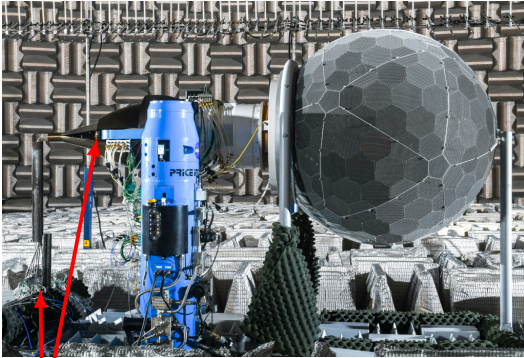
DART and Microphone Arrays in AAPL (Anechoic) Facility

- Overhead Farfield 24-Microphone Array
- 61-Microphone Sideline Array
- 8-ITP Circumferential Array

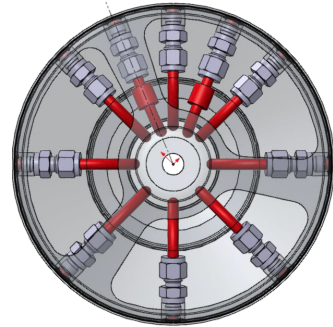


ITP-Instrumented
Core-Nozzle Centerbody

Experimental Setup — 8-ITP Circumferential Array



DART with Instrumented Tailcone

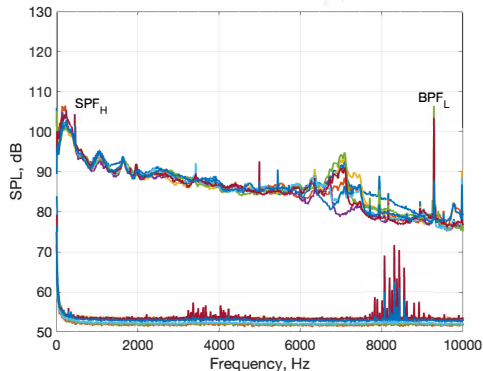


Instrumentation, Downstream View

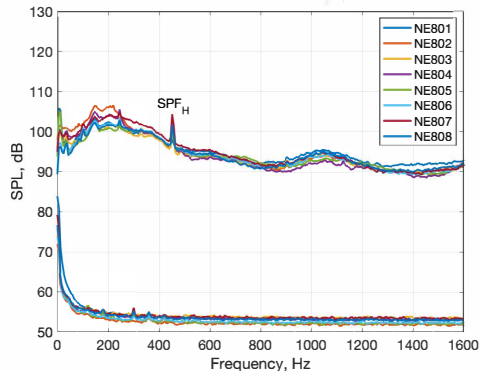
- Circumferential ITP Array at Core-Nozzle Exit — 45° Spacing
- Eight 5-psi Differential Pressure Transducers — Two Additional Ports

- Simultaneous High-Data-Rate Acoustic Measurements
 - Typically: 93 channels at 100 kHz sampling rate, 60 s duration
 - National Instruments™ 24-bit ADC System — LabVIEW controlled
- Select Mean-Line Data Recorded by Engine Data System at 1 Hz
 - Ambient conditions
 - Turbofan engine station data
 - Engine performance parameters
- FADEC/ECU in Automatic Mode
 - Holds RPM extremely steady at each engine operational point
 - Acoustic test points for sequential engine-power settings — idle to max
 - Typically: 33%, 50%, 60%, 70%, 80%, 90%, and MaxPower(T_{amb})

Core-Nozzle-Exit Circumferential-Array SPL Results



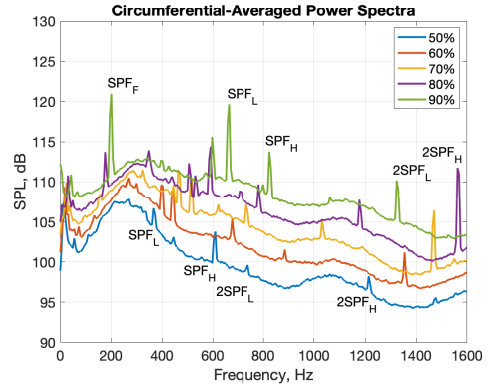
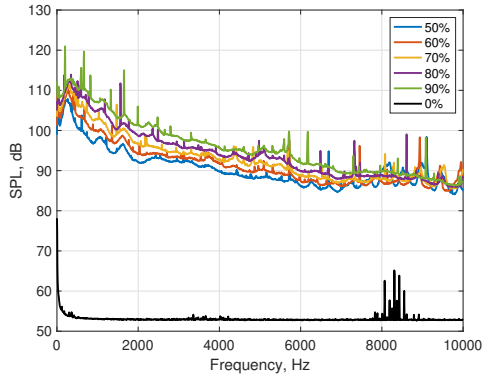
Narrowband SPL — Idle (33%) and Background



Lower Frequencies

- In General, Excellent Signal-to-Noise Ratio, S/N
- Electronic (?) Noise Around 8 kHz Somewhat Worse Than in 2017 Test

Core-Nozzle-Exit Circumferential-Averaged PS Results

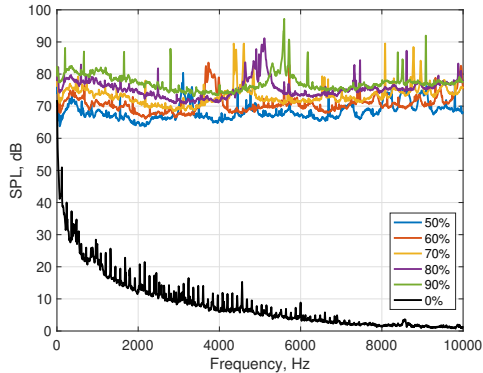


Narrowband SPL, 50%–90% $NFAN_c$ and Background

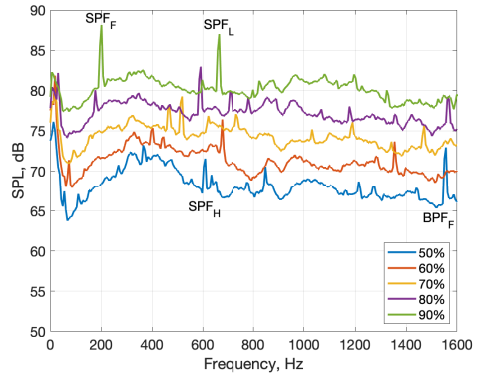
Lower Frequencies

- SPL Based on Circumferentially-Averaged Power Spectra
- Shaft-Passing-Frequency Tones and Harmonics Visible in Spectra

Sideline 61-Microphone-Array Example Result



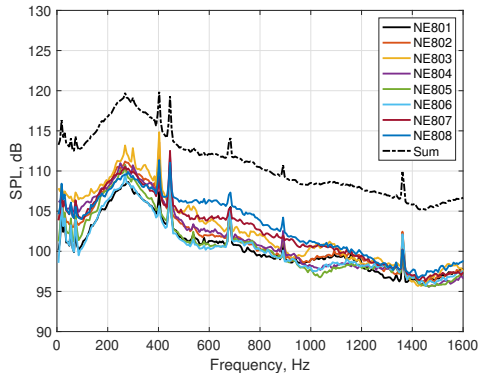
Narrowband SPL, 50%–90% NFAN_c and Background



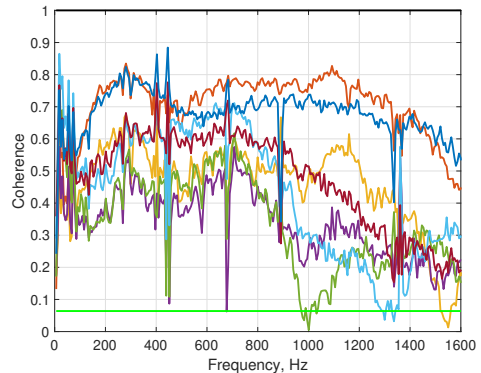
Lower Frequencies

- Microphone at 121° Polar Angle — Various Power Levels
- Shaft Frequencies Also Detectable in Sideline Spectra

ITP Array Mode Decomposition – Coherence

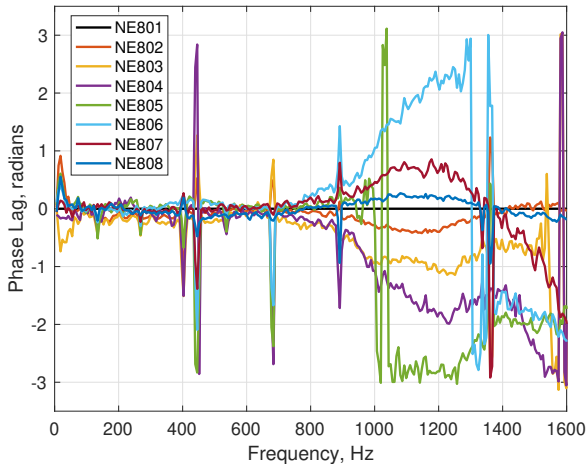


ITP Narrowband SPL — 60% N_{Lc} and Sum



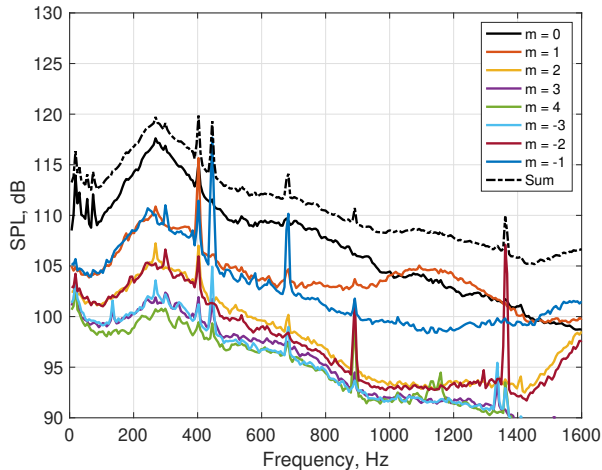
Coherence Spectra, NE801 Reference

- Sum of SPL is Total Signal To Which Energy in All Modes Contributes
- Statistically Significant Signal Coherence for Most of Relevant Range



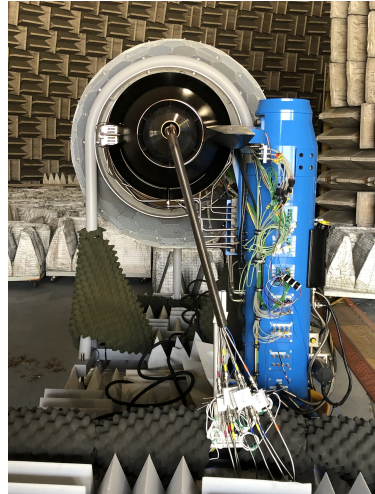
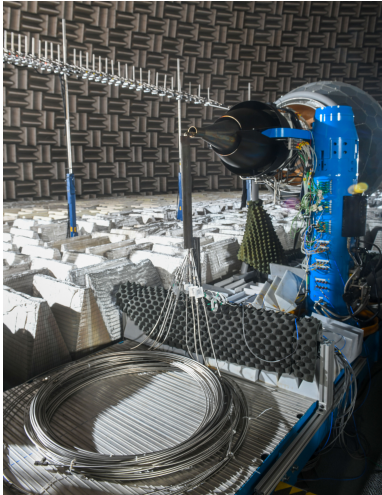
- Phase Lag is Nearly Zero Until First Mode Cut On (~ 800 Hz)
- Rapid Phase Variations are Non-Physical
- After First Azimuthal Mode ($m = \pm 1$) Cut-On Phase Lag Diverges
- Sensor Pairs Respond Asymmetrically for Same Circumferential Distance From NE801 (ref)

ITP Array Mode Decomposition – Mode Contributions

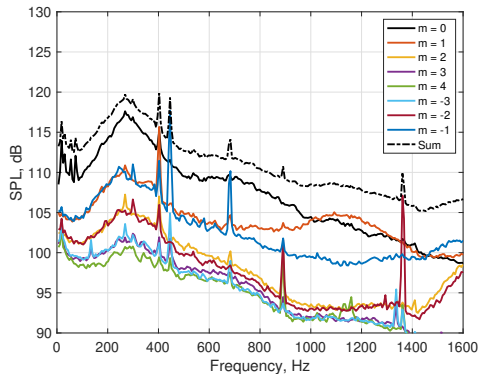


- Plane Wave Mode Dominates Low Frequency Core Noise
- First Azimuthal Mode Cut-On Estimated at About 800 Hz
- $m = \pm 1$ Mode Content Unexpectedly Asymmetrical
- Plane Wave Mode No Longer Dominant Above $\sim 1,000$ Hz

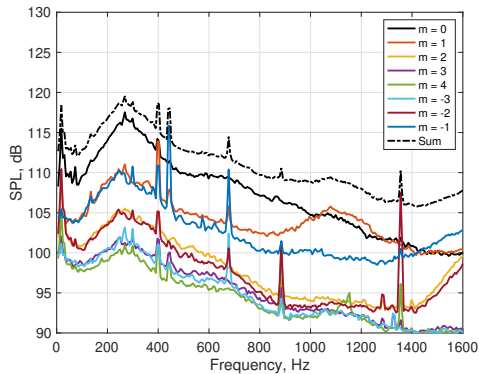
ITP Array Mode Decomposition – Effect of Clocking



ITP Array Mode Decomposition – Clocking



ITP SPL — 60% N_{LC} Clocked

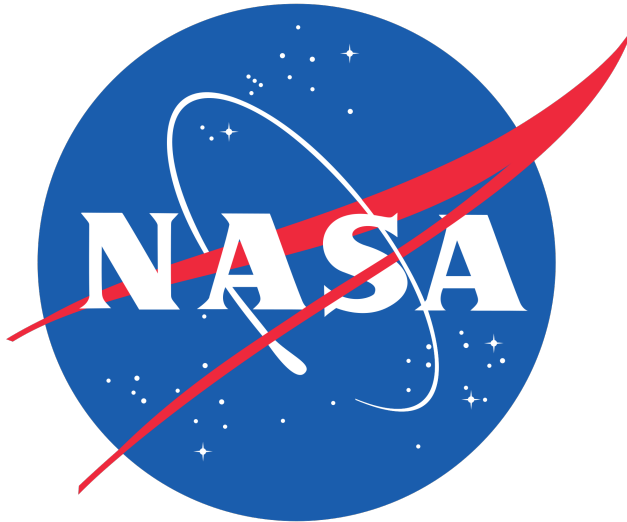


ITP SPL — 60% N_{LC} Standard

- Sensor Locations Rotated 22.5° Counterclockwise
- Similar Behavior Among Modes for Both Positions

- DART Source-Diagnostic Test Completed — Aug 2019
 - Continuation of 2017 Baseline DART Core/Combustor-Noise Test
 - Propagation of First Azimuthal Mode Suspected from 2017 Data and Observed in 2019 Test
- More Extensive Acoustic Instrumentation
 - Up to 93 Channels of High-Data-Rate Simultaneous Data
 - Circumferential ITP array at core-nozzle exit
 - Sideline and farfield (overhead) microphone arrays
 - Various Configurations
- Detailed Analysis of Data Ongoing
 - Papers Submitted to ASME Turbo Expo and AIAA Aviation 2020

Questions?



Backup–Tailcone Images

