



NASA Airframe Noise Reduction and Prediction: ARM Flight Tests and Companion Simulations

Mehdi R. Khorrami
Computational AeroSciences Branch
NASA Langley Research Center

25th AIAA/CEAS Aeroacoustics Conference
Delft, Netherlands

May 20-23, 2019

NASA Acoustic Research Measurements Flight Tests



❑ ARM-I (Aug. – Oct. 2016)

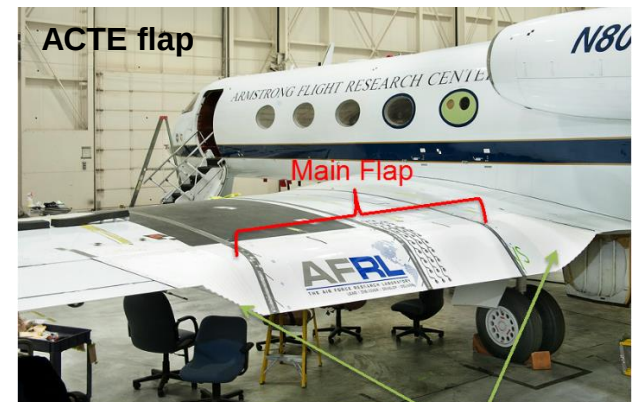
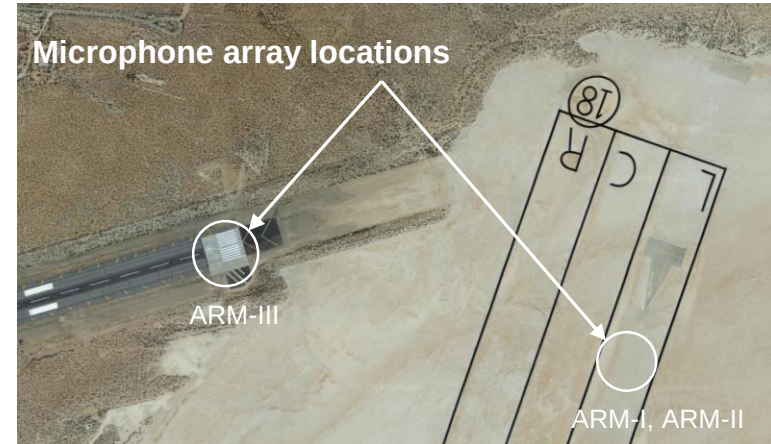
- Conducted on a lakebed at Edwards AFB, CA (Mojave Desert)
- Evaluated aeroacoustic performance of Adaptive Compliant Trailing Edge (ACTE)

❑ ARM-II (Aug. – Oct. 2017)

- Conducted on a lakebed at Edwards AFB
- Evaluated acoustic performance of main landing gear (MLG) and cavity noise reduction (NR) concepts on G-III aircraft in combination with ACTE
 - Accurate evaluation of gear technologies without contamination from flap noise

❑ ARM-III (March – May 2018)

- Conducted on an inactive runway at Edwards AFB
- Acquired baseline noise data for G-III aircraft
- Evaluated acoustic performance of MLG and cavity NR concepts on G-III with Fowler flaps
 - Evaluation of NR capability of gear technologies for conventional flaps



❑ **Overall, 47 flights and $\approx$ 1,100 passes over array (>90% good)**

□ Goals

- Conduct aeroacoustic measurements of the baseline (unmodified) G-III aircraft
- Evaluate aeroacoustic performance of MLG and cavity NR technologies on a G-III aircraft with Fowler flaps
- Gear NR technologies evaluated individually (component level) and in combination
- Acquire aeroacoustic data for benchmarking the predictive capability of high-fidelity airframe noise simulations

□ MLG Fairings and Gear Cavity Treatments



Main landing gear fairings



Chevron / foam Cavity Treatment



Mesh Cavity Treatment

NASA Gulfstream G-III Test Aircraft



❑ Subsonic Research Aircraft Testbed (SCRAT), also known by its tail number as “804”

- Highly instrumented testbed
- Three spanwise strips of steady pressure ports
- Recording of aircraft parameters (e.g., true airspeed, AOA, engine settings)
- Recording of aircraft position (GPS)



❑ Second G-III aircraft “808”

- Flown in its baseline (Fowler flaps, no gear treatments) configuration
- Except for recording of GPS data, no other instrumentation onboard
- Indicated airspeed (IAS) called out by pilots
- Acoustic data used only for preliminary assessment of baseline noise levels



Ground and Flight Operations



❑ Phased microphone array

- Composed of 185 hardened, weatherproof, temperature-compensated sensors
- Ground and aerial sources allowed tracking of microphone response and array health during long deployments

Humphreys, W. M., Lockard, D. P., Khorrami, M. R., and McSwain, R., "Evaluation of Methods for In-Situ Calibration of Field-Deployable Microphone Phased Arrays," AIAA Paper 2017-4176, June 2017.

Baumann, E. and Waggoner, E., "Flight and Ground Operations in Support of Airframe Noise Reduction Tests," AIAA Paper 20182970, June 2018.



Array deployed on an inactive runway



Microphone health monitoring

Ground and Flight Operations



□ Certification microphones

- Three Pole-mounted B&K4939 ¼" free-field microphones
 - Two aligned with the flight path and one positioned sideline
 - Pre- and post-flight calibration of the microphones
- Measurements to supplement phased array data as aircraft certification was not the intended goal
 - Background noise and local weather less than desirable
- Unique opportunity to extend simulation benchmarking to EPNL type data

Ravetta, P. A., Wisda, D. M., Khorrami, M. R., and Van de Ven, T., "Assessment of Airframe Noise Reduction Technologies based on EPNL from Flight Tests," Paper to be presented at the 25th AIAA/CEAS Aeroacoustics Conference in Delft, The Netherlands, May 2019.



Upstream of phased array



Downstream of phased array



Starboard side of phased array

Pole-mounted microphone locations

Flight Pattern for Passes Over Array



- All passes with engine at “ground idle”
- Typical pass completion time: 4.5 – 5.5 min
- Data processed in near real-time for select freqs.
 - Data quality assessed before next pass

Flight Track

Test Airplane



Flight Intercept

3 pole-mounted certification microphones

Runway

Phased Array
185 Microphones

Altitude at array center

350 ± 50 feet

Lateral Deviation

± 35 feet

KCAS Variation

$\pm 5\%$ of avg. airspeed

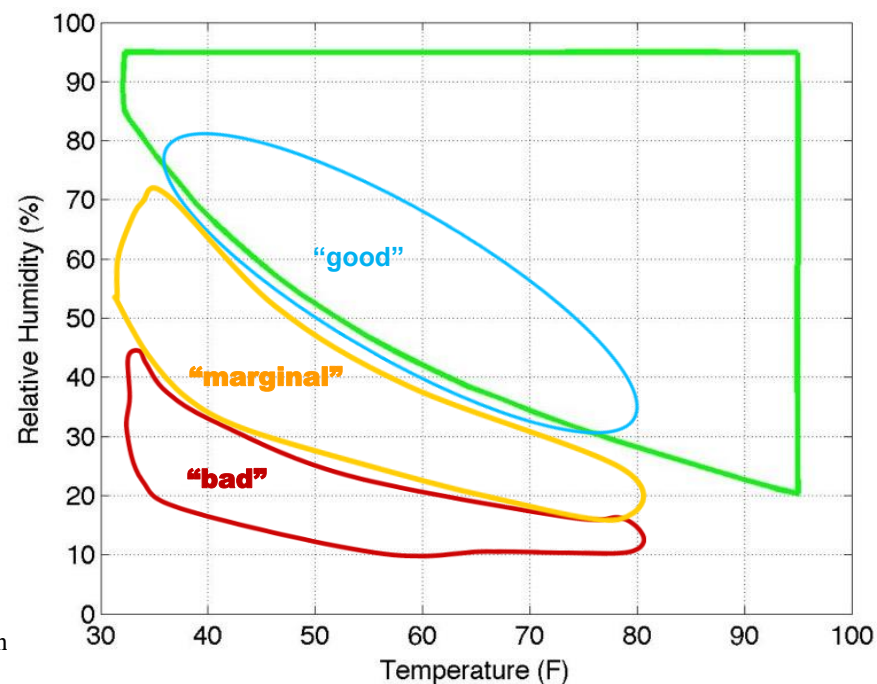
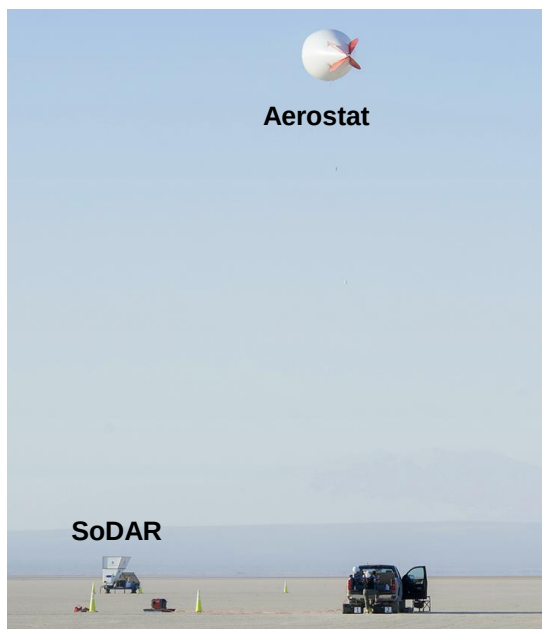
Acquire Data

Weather Measurements and Restrictions



- ❑ Atmospheric conditions near the array site (up to 550 ft) measured with Aerostat and SoDAR
- ❑ Global weather report and initial Aerostat data used to reach a “fly” or “no-fly” decision
- ❑ Atmospheric measurements obtained every hour once flights began

Wind Limitations	
Wind Speed	13 kts maximum
	10 kts average
Cross Wind Speed	9 kts maximum
	6 kts average



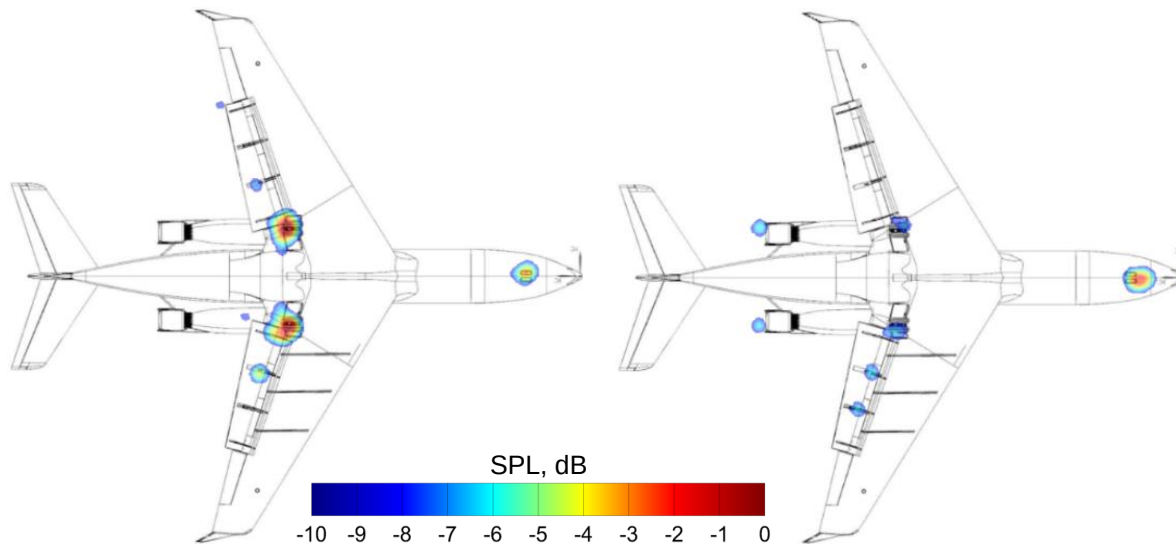
Lockard, D. P. and Bestul, K. A., “The Impact of Local Meteorological Conditions on Airframe Noise Flight Test Data,” AIAA Paper 2018-2971, June 2018.

Sample Microphone Array Results



□ 804 Aircraft

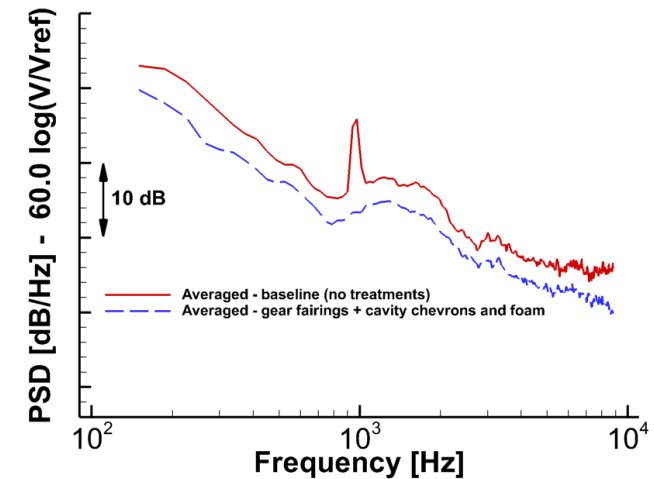
- Fowler (baseline) flaps deflected 20°, landing gear deployed
- Frequency: 2,000 Hz



Baseline main gear

MLG fairings + cavity chevrons and foam

Beamform maps



Integrated farfield spectra

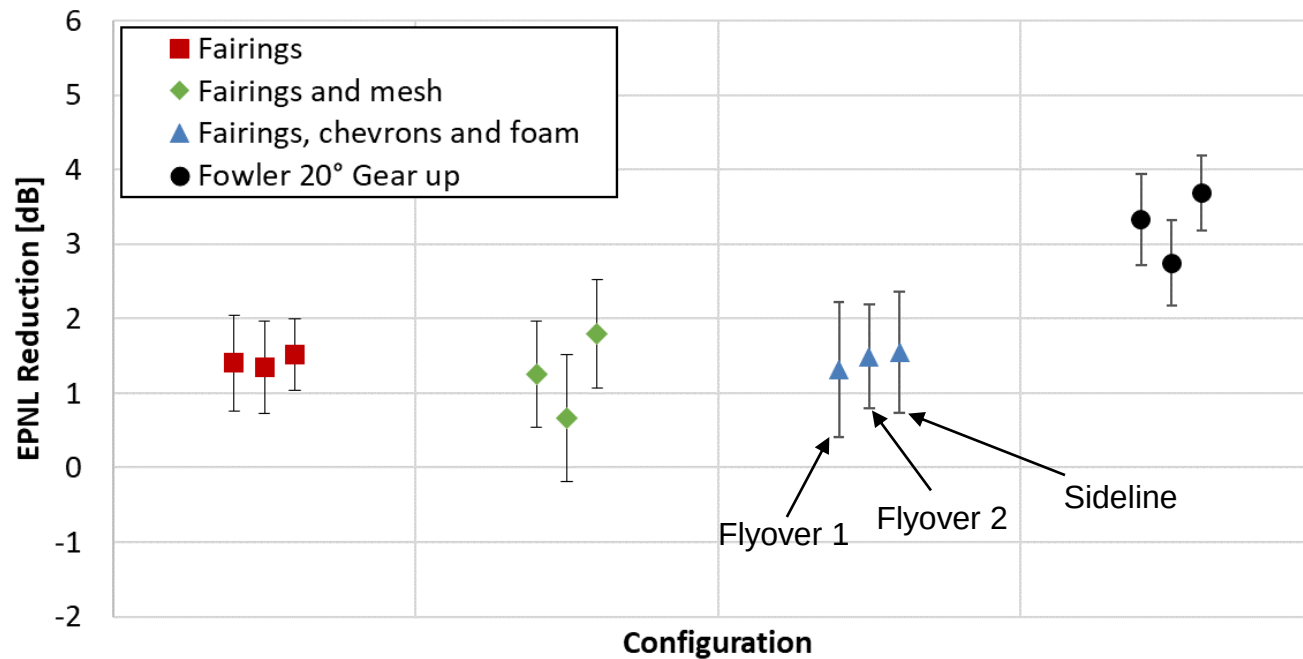
Khorrami, M. R., Lockard, D. P., Humphreys, W. M., and Ravetta, P. A., "Flight-Test Evaluation of Landing gear Noise Reduction Technologies," Paper to be presented at the AIAA/CEAS Aeroacoustics Conference in Delft, Netherlands, May 2019.

Sample Certification Microphone Results



□ 804 Aircraft

- Fowler (baseline) flaps deflected 20°, gear deployed



Ravetta, P. A., Wisda, D. M., Khorrami, M. R., and Van de Ven, T., "Assessment of Airframe Noise Reduction Technologies based on EPNL from Flight Tests," Paper to be presented at the 25th AIAA/CEAS Aeroacoustics Conference in Delft, The Netherlands, May 2019.



Companion Simulation Campaign

Simulated Full-Scale Aircraft – ACTE vs. Baseline

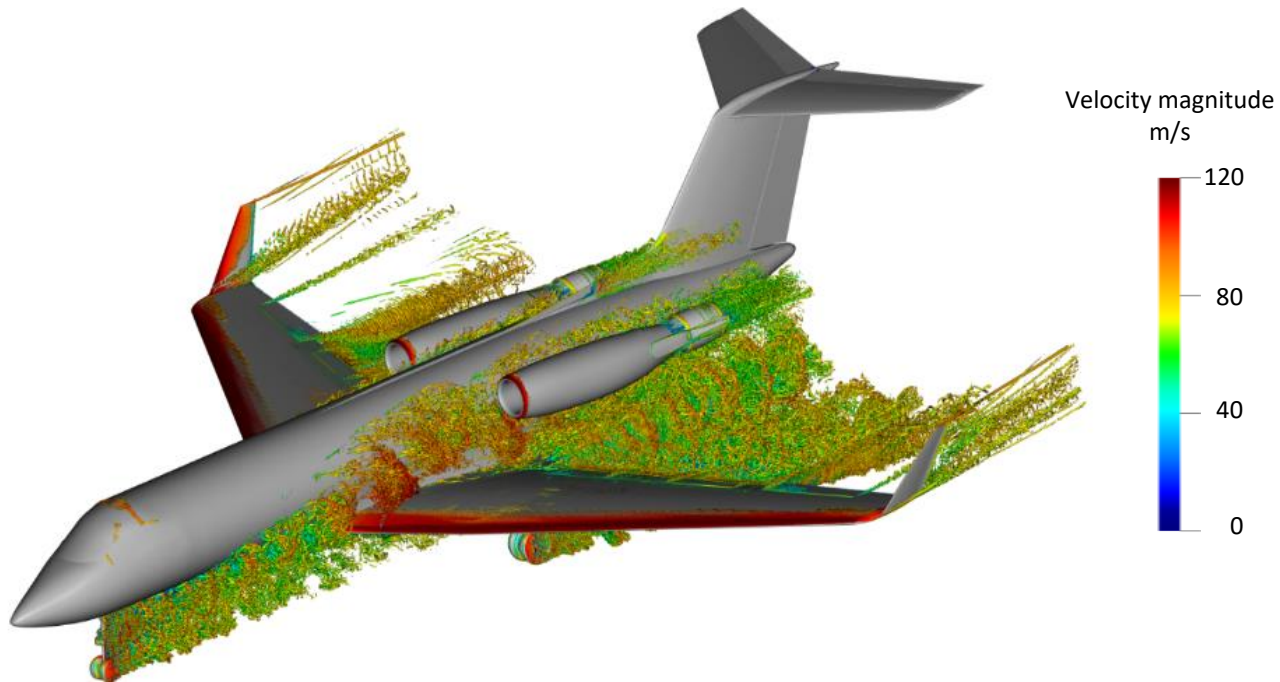


Vorticity Field Based on λ_2 Criterion



□ G-III Aircraft

- Fowler (baseline) flaps deflected 20°, landing gear deployed



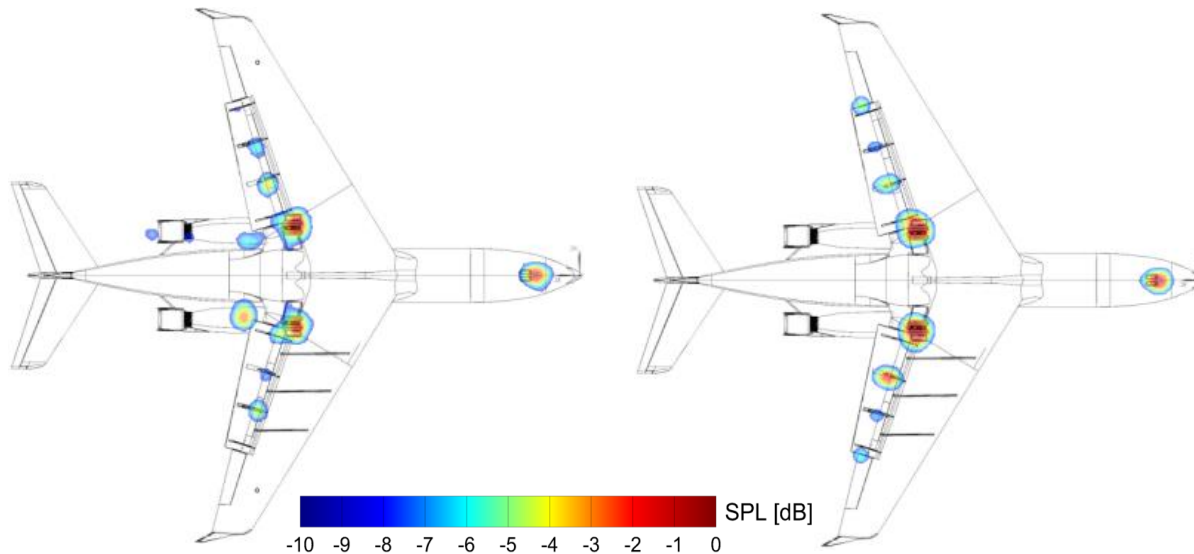
Duda, B., Ferris, R. J., and Khorrami, M. R., “Simulation-Based Assessment of a Full-Scale Installed Quiet Landing Gear/Airframe Noise,”
Paper to be presented at the AIAA/CEAS Aeroacoustics Conference in Delft, Netherlands, May 2019.

Sample Measured vs. Simulated Results



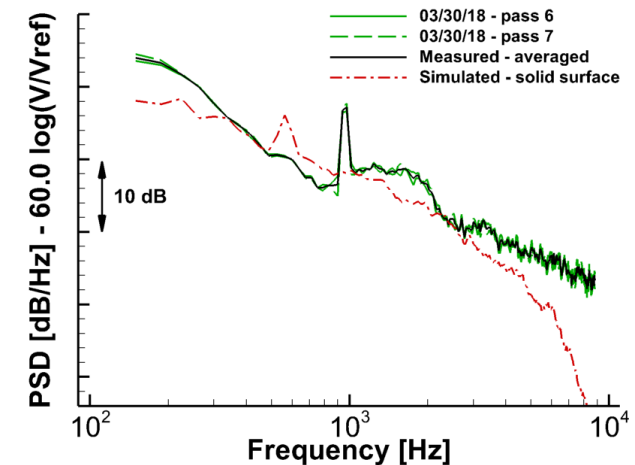
❑ 804 Aircraft

- Fowler (baseline) flaps deflected 20°, gear deployed
- Frequency: 2,240 Hz
- SPL in 1/12th octave band



**Measured
(03/30/18 – pass 6)**

Simulated



Integrated farfield spectra

Khorrami, M. R., Ravetta, P. A., Lockard, D. P., Duda, B., and Ferris, R., “Measured and Simulated Acoustic Signature of a Full-Scale Aircraft with Airframe Noise Reduction Technology Installed,” Paper to be presented at the AIAA/CEAS Aeroacoustics Conference in Delft, Netherlands, May 2019.

Summary



- ❑ Flight tests to evaluate flap and main landing gear (MLG) noise reduction (NR) technologies on NASA G-III aircraft were successfully completed
 - Aeroacoustic performance of ACTE technology was evaluated during ARM-I (2016)
 - Acoustic performance of MLG and cavity NR technologies with ACTE flaps installed was assessed during ARM-II (2017)
 - Acoustic performance of MLG and cavity NR technologies with conventional (Fowler) flaps was tested during ARM-III (2018)
- ❑ Extensive acoustic measurements of baseline G-III aircraft during approach with/without landing gear noise reduction technologies were obtained
- ❑ A comprehensive companion campaign on full-scale, high-fidelity, simulation-based airframe noise prediction was successfully executed
- ❑ In-depth analyses of ARM-III flight test and simulated data will be presented in this session

