Comparison of Measured and Simulated Acoustic Signatures for a Full-Scale Aircraft with and without Airframe Noise Abatement

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Validation of Full-Scale Airframe Noise Simulations

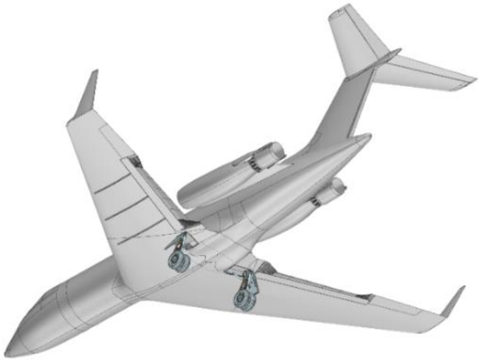
❑ Goals

- Extend application of simulation-based airframe noise prediction to full-scale, complete aircraft with extreme geometric detail
- Evaluate aeroacoustic performance of main landing gear (MLG) noise reduction (NR) and Adaptive Compliant Trailing Edge (ACTE) technologies on a G-III aircraft
- Use extensive airframe noise flight test data to benchmark/validate simulation results
- Assess capabilities and shortcomings of selected computational methodology

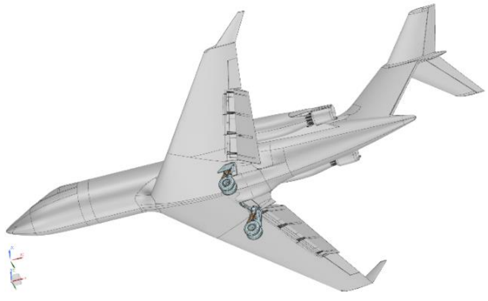
❑ Test Aircraft

- SubsoniC Research Aircraft Testbed (SCRAT/804)
  - ➢ ACTE flaps without and with MLG fairings
- Baseline G-III aircraft (808)
  - ➢ Flown in baseline configuration (Fowler flaps, no gear treatments)

NASA 804 (SCRAT)

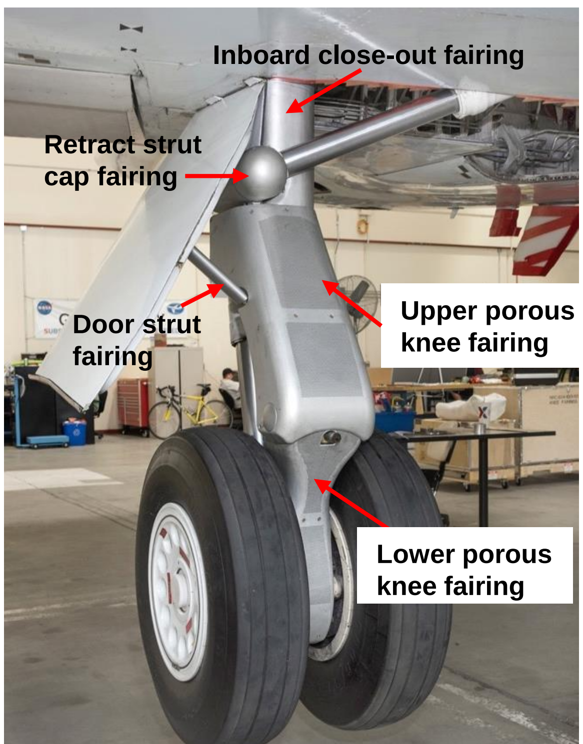


NASA 808

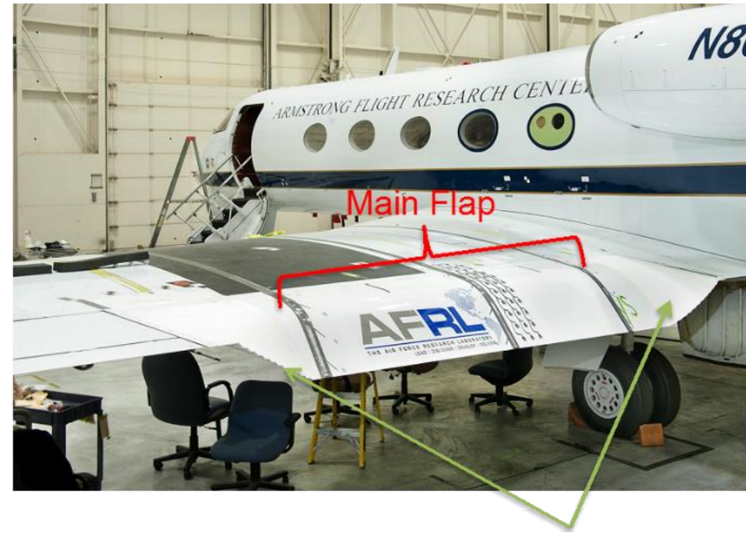


Simulated NR Technologies

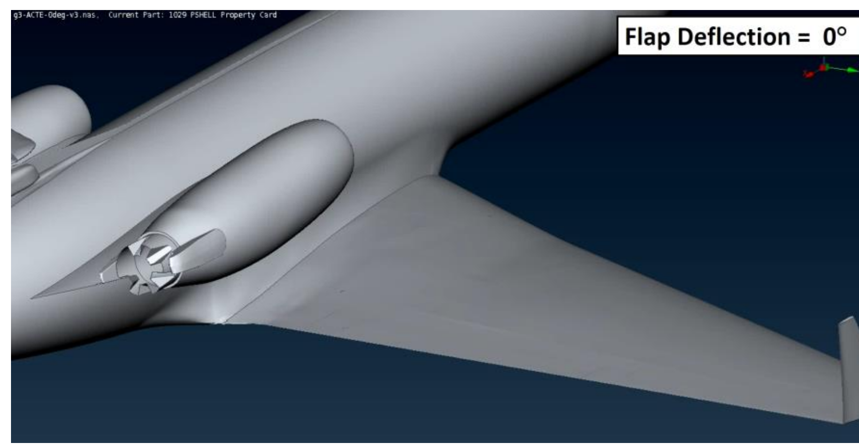
- **Adaptive Compliant Trailing Edge (ACTE)**
  - Technology developed jointly by the U. S. Air Force Research Laboratory (AFRL), FlexSys, Inc., and the NASA ERA project
    - Eliminates flap side edges and bracket assemblies
- **MLG NR Technologies**
  - MLG fairings
    - Total of 11,332 drilled holes of D = 0.080" (2mm)



MLG fairings



Transition surfaces



ACTE flap

Data Sets Used for Simulation Benchmarking

- **First flight test (Aug. – Oct. 2016)**
  - Evaluated aeroacoustic performance of ACTE technology
    - Microphone array and in-flight steady surface pressure measurements
    - Preliminary acoustic measurements for baseline configurations
- **Second flight test (Aug. – Oct. 2017)**
  - Evaluated acoustic performance of MLG and cavity NR concepts with ACTE flaps
    - Microphone array and in-flight steady surface pressure measurements
    - Additional acoustic measurements of the baseline configurations
- **Nominal speed of 150 kts**
- **Engines set at "ground idle"**

All simulations performed with Exa's PowerFLOW®

- **Initial Simulations**
  - Mostly performed prior to first flight test
  - Conducted at medium spatial resolution
    - Grid sizes 3×10^9 to 4×10^9 voxels
    - M = 0.228, AOA = 6º, Re = 10.5×10^6 (MAC)
  - Used to optimize design of MLG fairings prior to PDR and CDR
  - Used as "blind test" to assess predictive capability of computational approach
    - Pressures on aircraft solid surface used in FWH propagation
    - Farfield noise spectra computed for single microphone at array center
- **Post 1st Flight Simulations**
  - Conducted at fine spatial resolution
    - M = 0.228, Re = 10.5×10^6 (MAC)
    - Aircraft AOAs matched flight test data
    - Pressures on aircraft solid and permeable surfaces used in FWH propagation
    - Integrated farfield noise spectra computed from synthetic array data
  - Simulations ongoing for various configurations

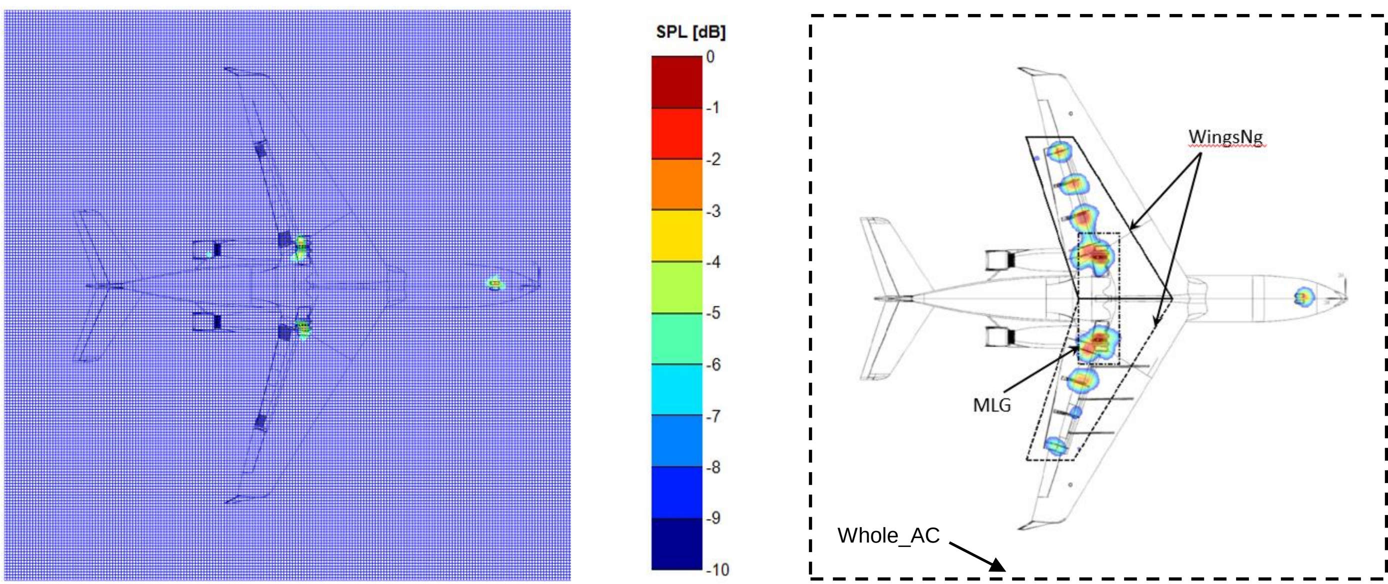
Array Data Processing

❑ **Flight Test**

- Based on time-domain CLEAN technique in AVEC's phased array software suite
- 0.5 s record corresponding to ±50 ft from array center (90º, overhead)
- Data corrected for temperature and relative humidity (lossless state)
- Scaled to an altitude of 394 ft (120 m) based on spherical spreading for pressure ($p'^2 \sim 1/r^2$)

❑ **Simulations**

- Based on frequency-domain CLEAN technique in AVEC's phased array software suite
- Approx. 1.5 s record for 90º (overhead)
- No atmospheric attenuation needed
- Scaled to an altitude of 394 ft (120 m) based on spherical spreading for pressure ($p'^2 \sim 1/r^2$)



Fine Grid, 201x201, 6 in. resolution

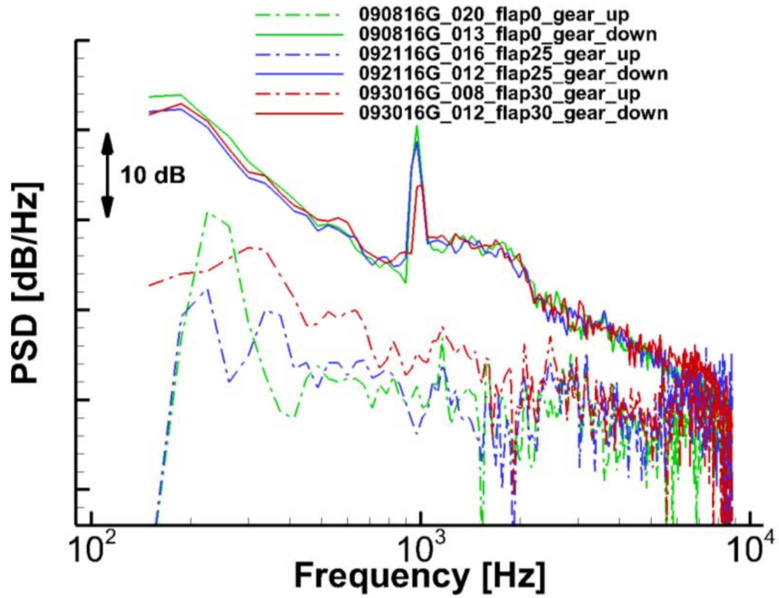
Integration regions for farfield noise spectra

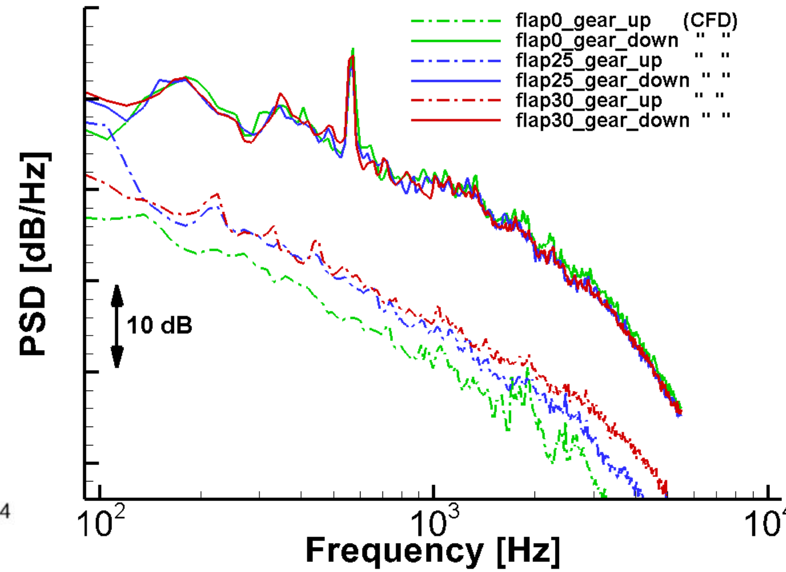
Beamform map for 808 aircraft: Fowler flap 39º, landing gear deployed

Blind Test Comparison

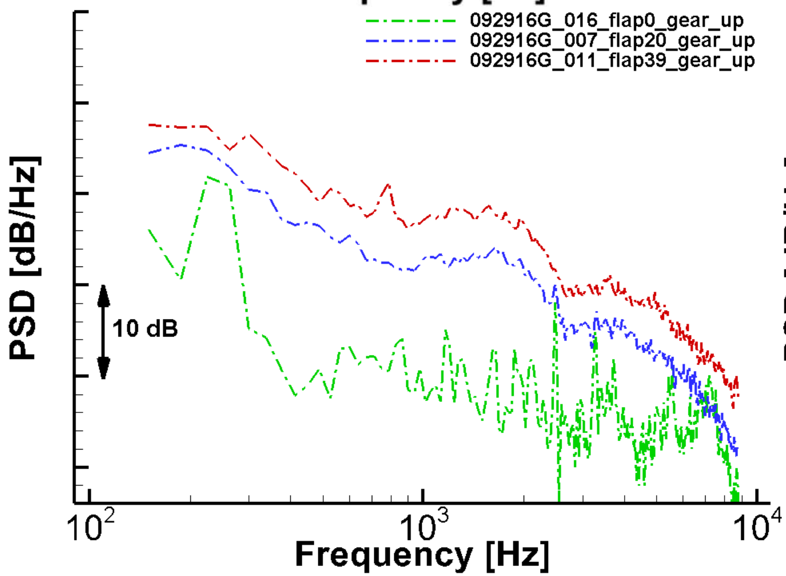
Flight test (integrated) | **Simulations (array center position)**

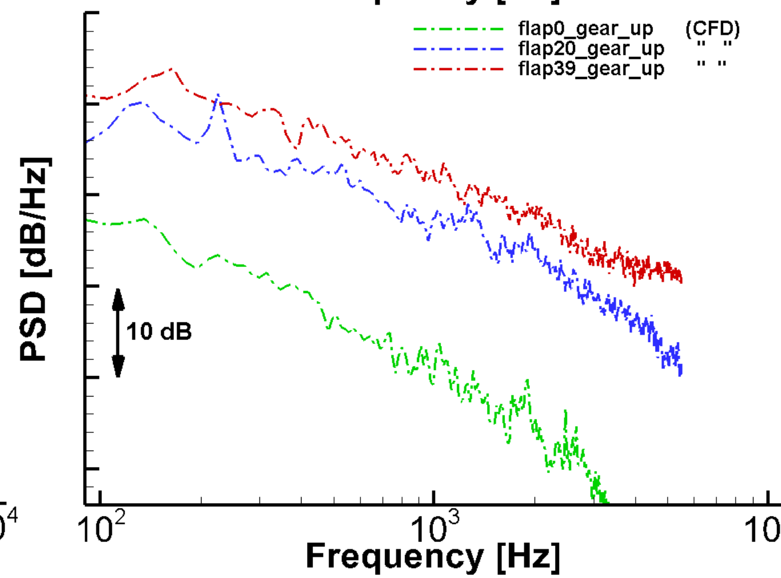
ACTE flap, gear effects





Fowler flap deflection effects

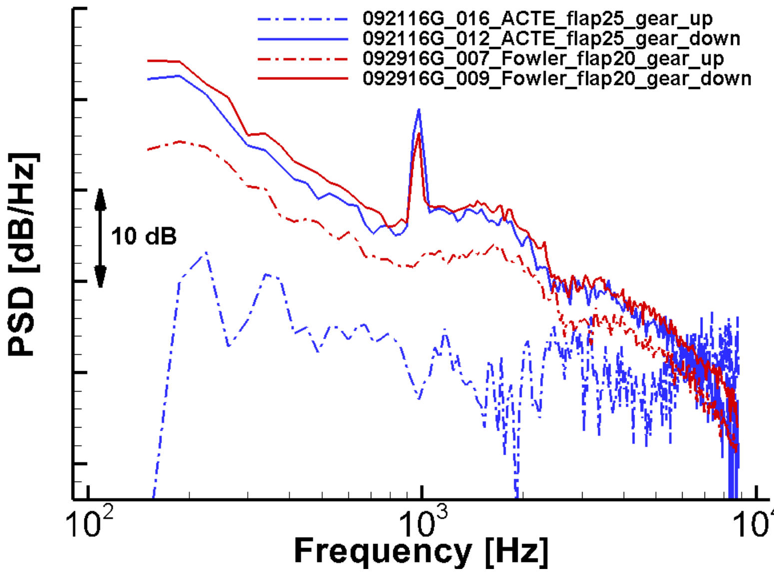


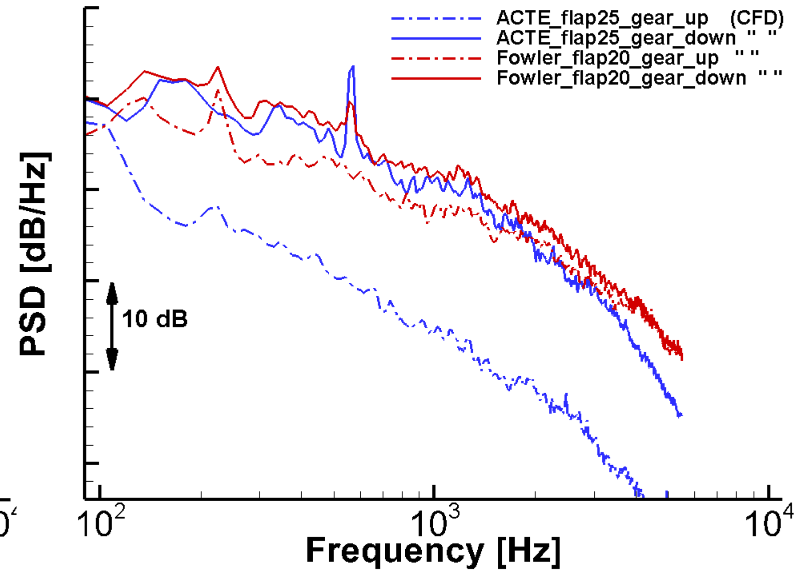


Blind Test Comparison

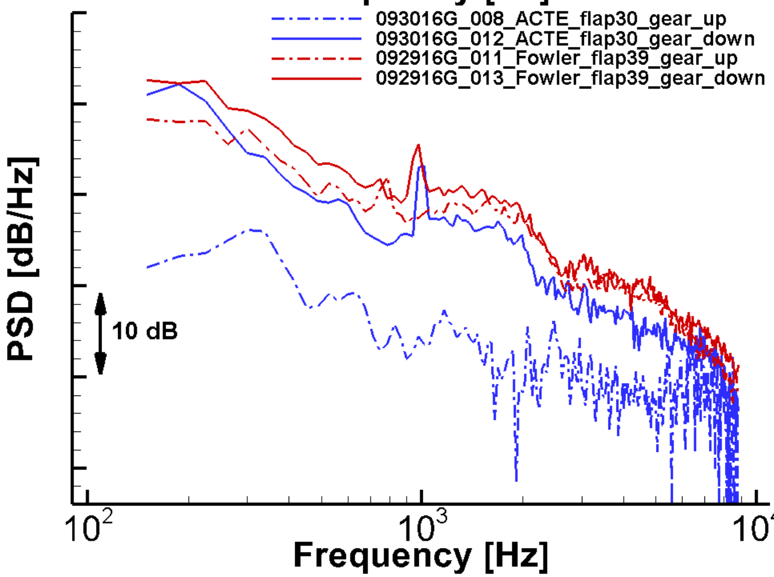
Flight test (integrated) | **Simulations (array center position)**

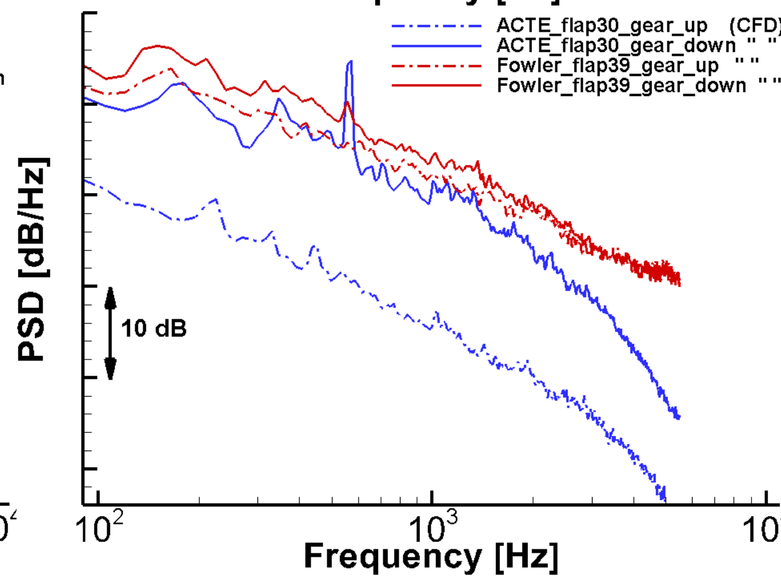
Fowler 20º vs. ACTE 25º





Fowler 39º vs. ACTE 30º



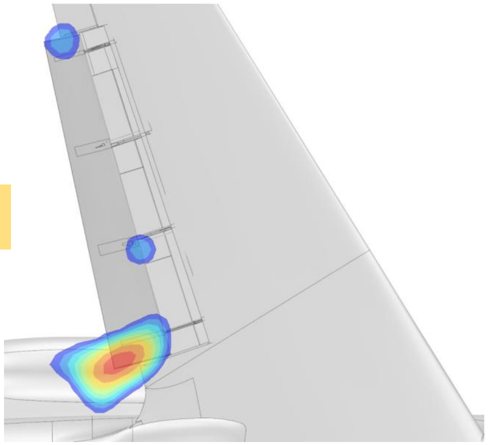


Measured vs. Simulated Beamform Maps

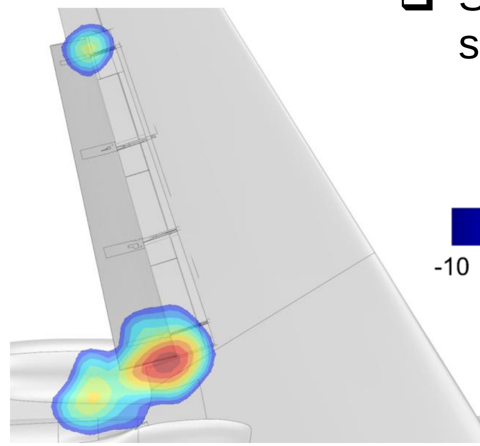
808 aircraft (Fowler flap 39º, landing gear retracted)

F = 630 Hz

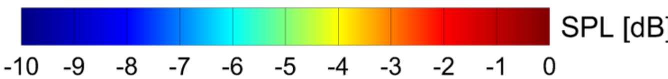
Flight test



Simulation

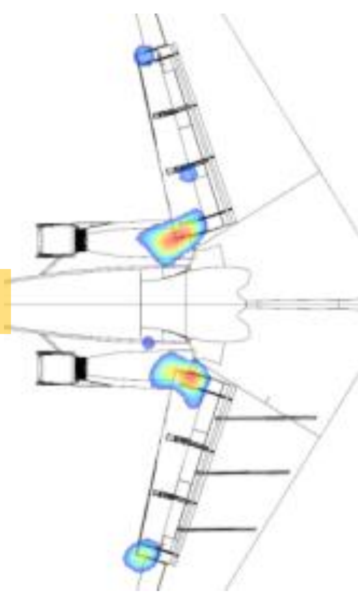


- ❑ Synthetic results used FWH solid surface

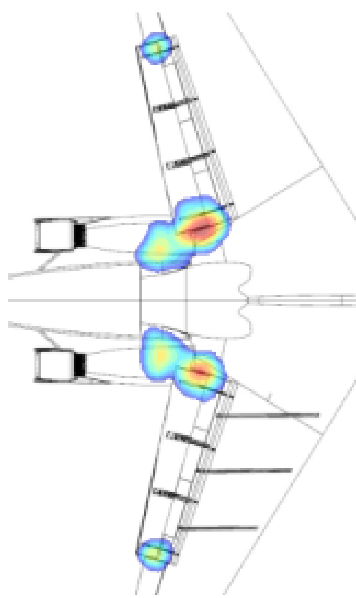


F = 630 Hz

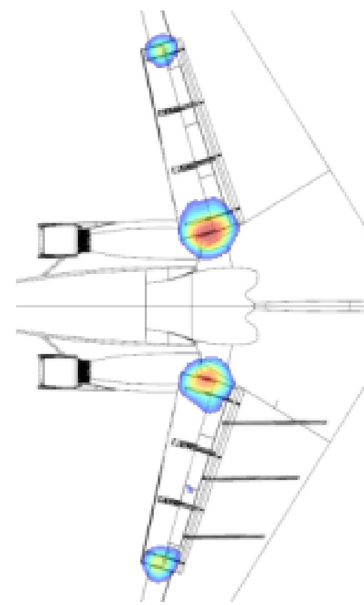
Flight test



Simulation with nacelles



Simulation without nacelles



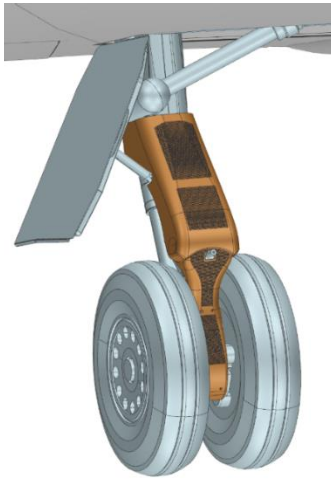
Fine-Resolution Simulation Dataset

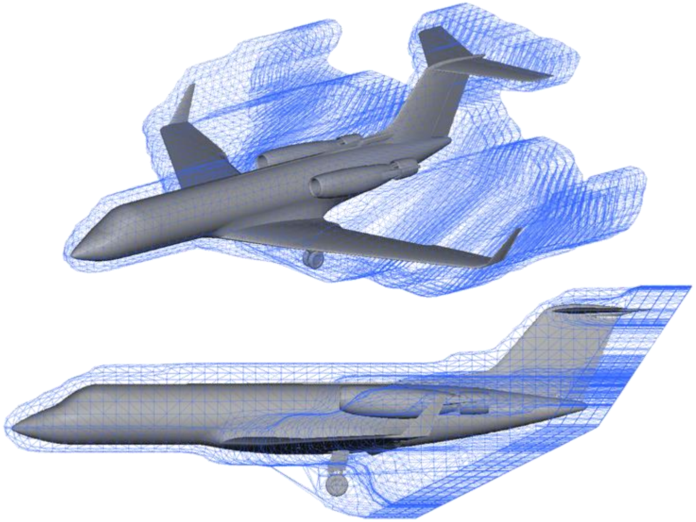
- ❑ Simulation of several key configurations for 804 (ACTE flap) and 808 (Fowler flap) aircraft ongoing
- ❑ For 804 aircraft (ACTE flap), conditions for specific passes (mainly AOA) were matched
- ❑ Three fine-resolution simulations completed
  - Fowler flap 20º, MLG deployed (808 aircraft)
  - ACTE flap 25º, MLG deployed without fairings
  - ACTE flap 25º, MLG deployed with fairings
- ❑ Performance of ACTE flap and MLG fairings compared with noise reduction levels from flight tests

- ❑ In addition to solid, added a permeable surface with multiple endcaps
  - Grid size increased from 7B to 17B voxels
  - Substantial increase in computational resources and file sizes
  - Volume size enclosed by permeable surface limited frequency resolution to < 2 kHz

Flight tested

Simulated

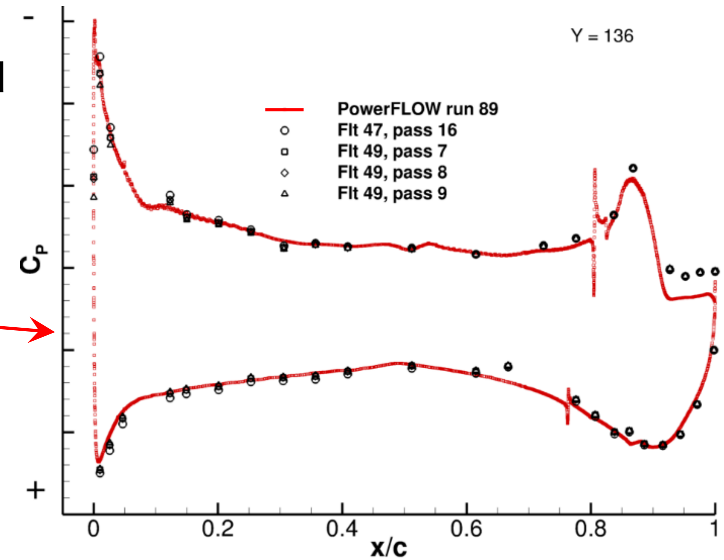


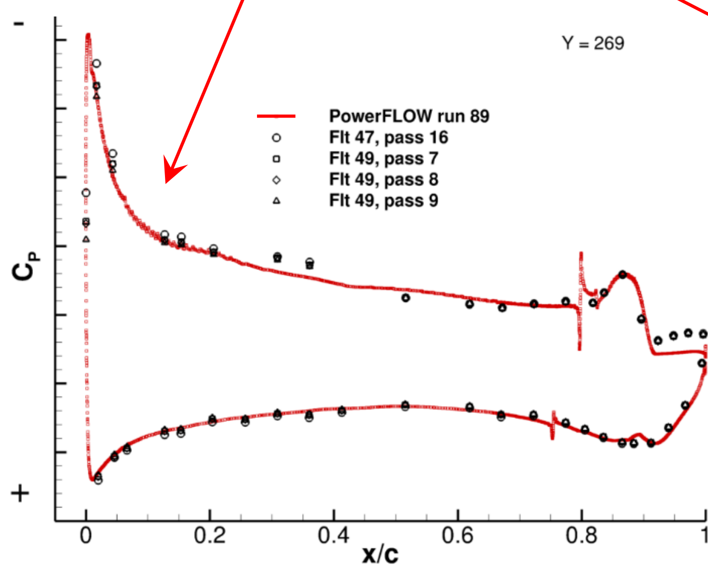


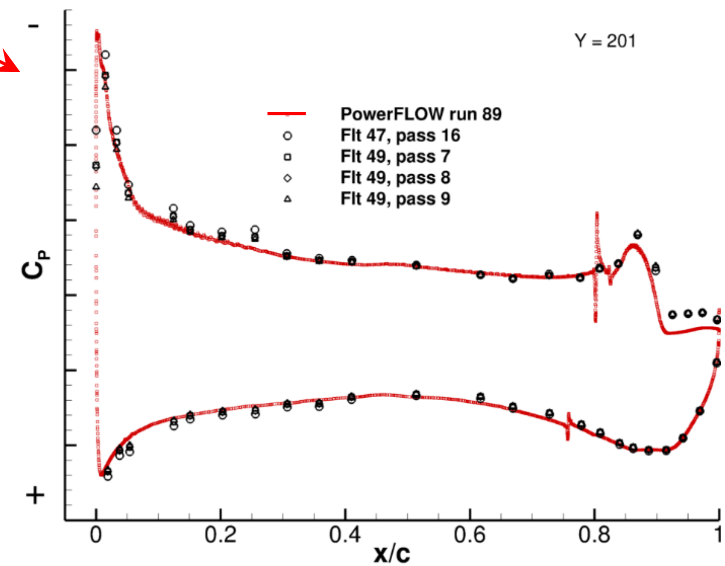
Aerodynamic Comparison

❑ Steady surface pressure

- ACTE flap 25º, landing gear deployed and retracted

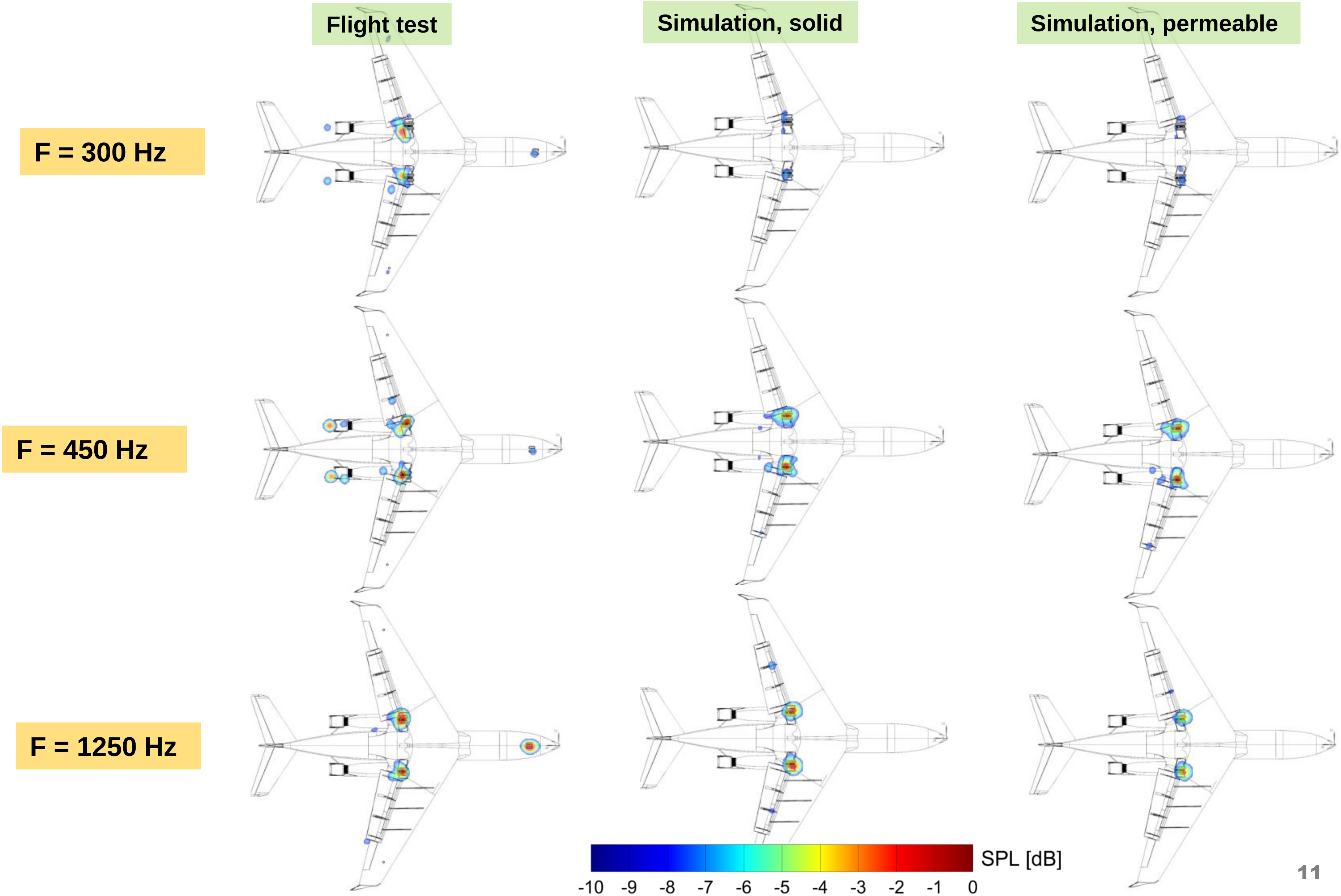






Measured vs. Simulated Beamform Maps

808 aircraft (Fowler flap 20º, landing gear deployed)



Measured vs. Simulated Beamform Maps

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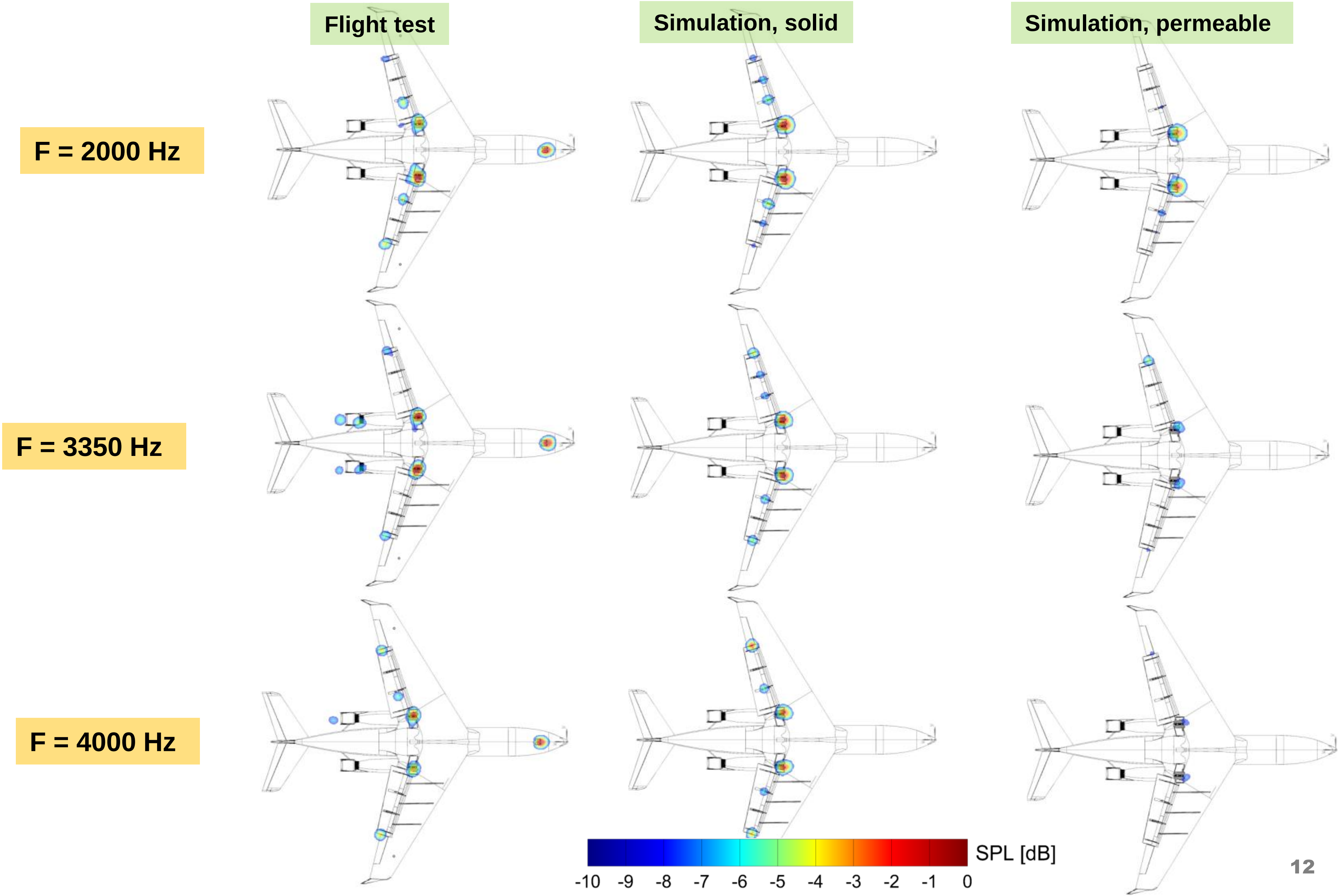
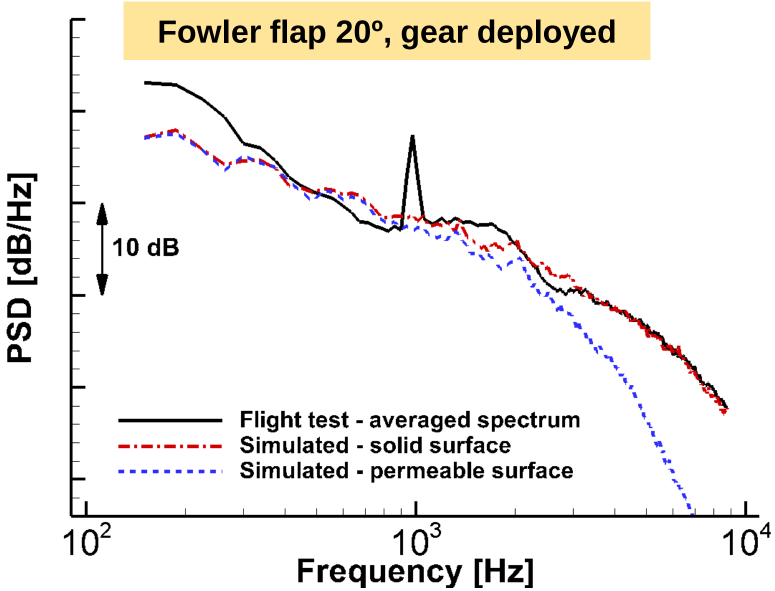
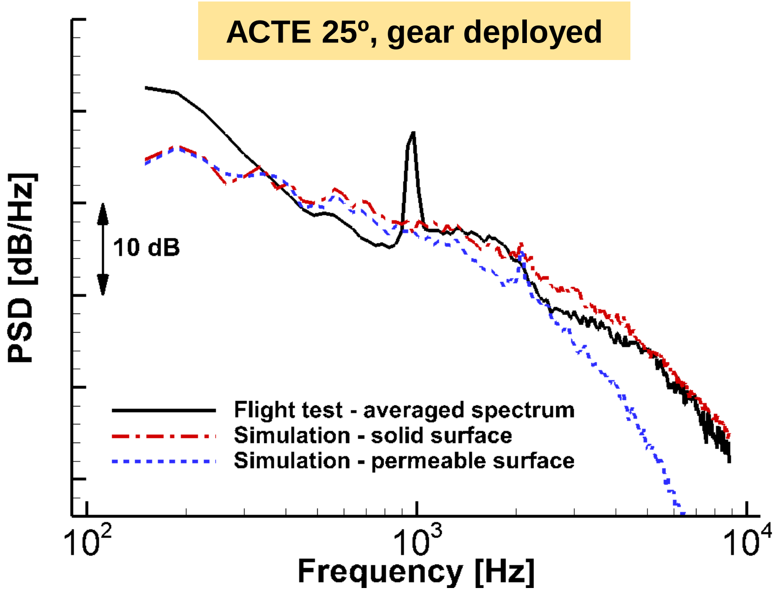
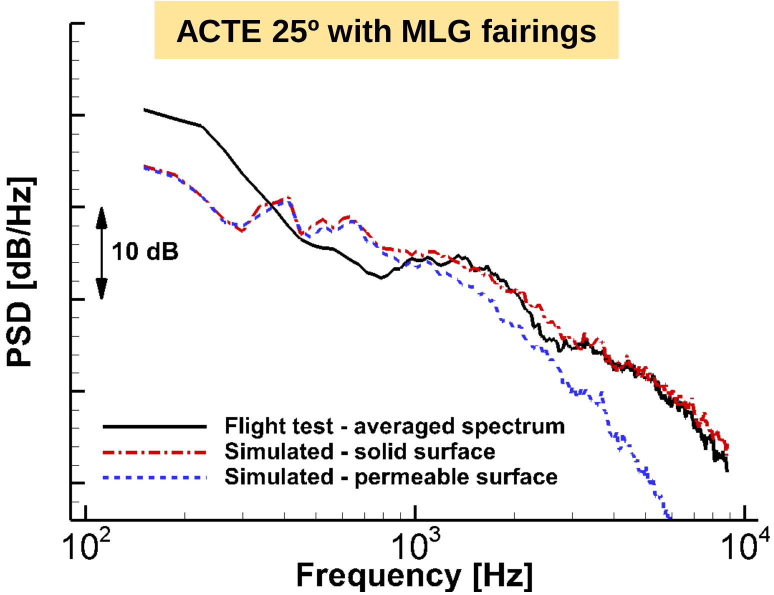


Noise Prediction Trends and Reduction Levels







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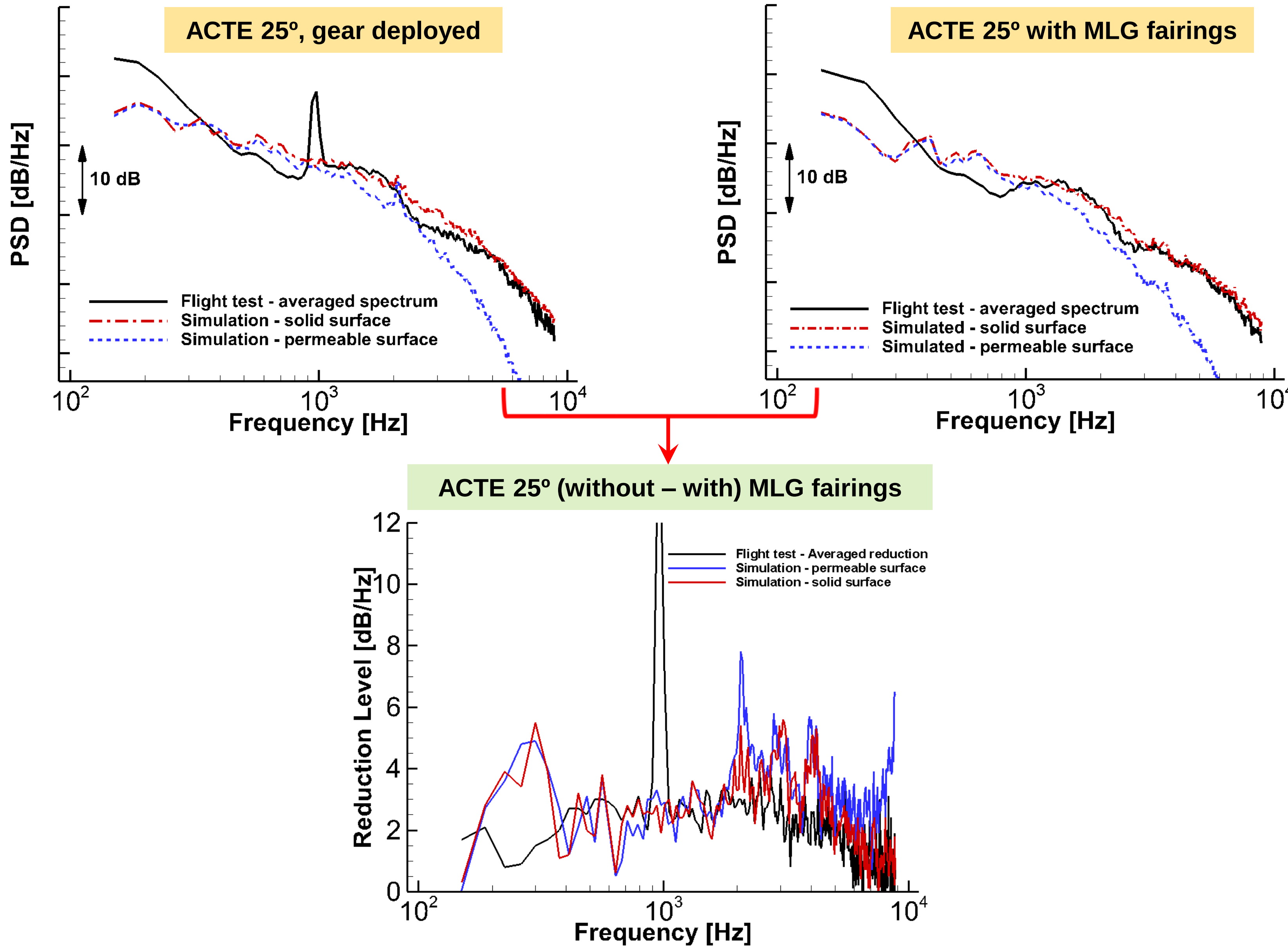

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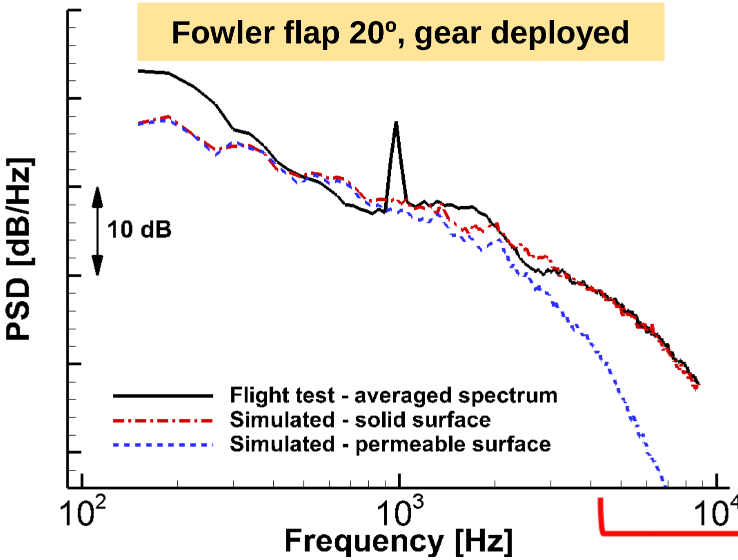

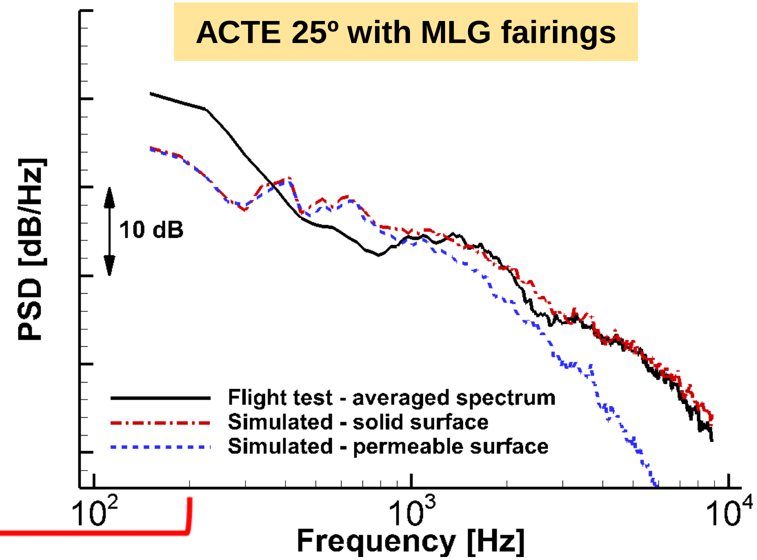

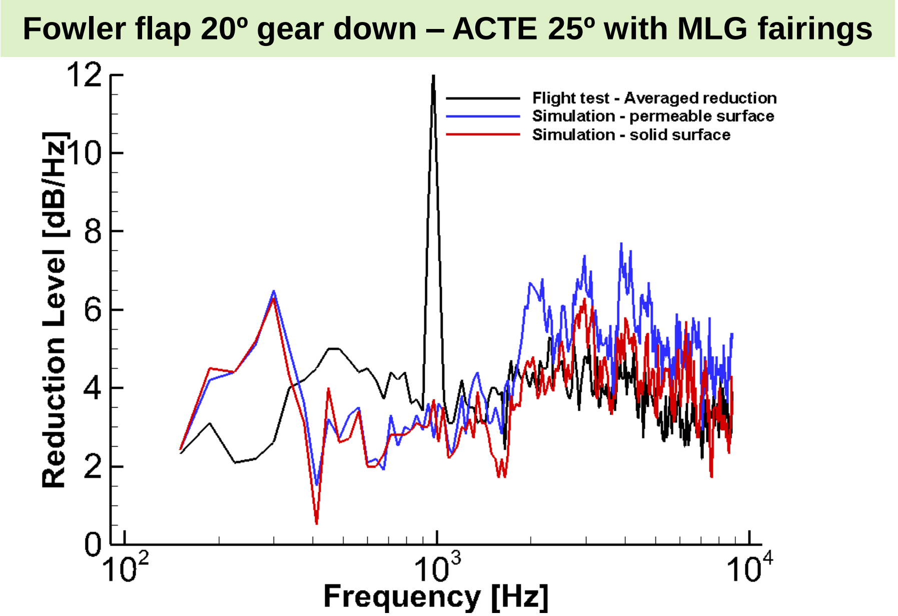

Concluding Remarks

- Aeroacoustic data from NASA 2016 and 2017 flight tests are being used to assess the predictive capability of companion high-fidelity, full-scale airframe noise simulations
- Blind test simulations with medium spatial resolution properly capture all trends observed in the flight test data
- Predicted steady surface pressures for AOAs matching select flight passes are in excellent agreement with in-flight measurements
- Synthetic array data (solid FWH surface) from fine-resolution simulations with actual in-flight conditions are in excellent agreement with measurements for frequencies > 400 Hz
    - Integrated farfield spectra (absolute levels)
    - Acoustic performance of ACTE flap and MLG fairings (differences in levels)
- As currently modeled,
    - Permeable FWH surface results are under-resolved at frequencies > 1.5 kHz
    - MLG cavity noise, which is dominant at frequencies < 400 Hz, was not captured properly
- Additional, ongoing fine-resolution simulations will permit further validation of computational methodology

Backup Slides

Background

- **Issues Facing National Air Transportation System**
  - Steady growth in air traffic
  - Vital role of air transportation system on US and global economies
  - Aircraft noise adversely affects population centers adjacent to major airports
    - By far, primary complaint to FAA
  - For air transportation to maintain its current expansion path, significant gains in aircraft efficiency and emissions reduction must be achieved

- **Aircraft Noise**
  - Propulsive (engine)
  - Airframe
    - Most important during approach
    - Broadband and non-compact
    - Under-carriage and high-lift devices are prominent noise sources
    - Significant reductions in aircraft noise not possible without airframe noise mitigation