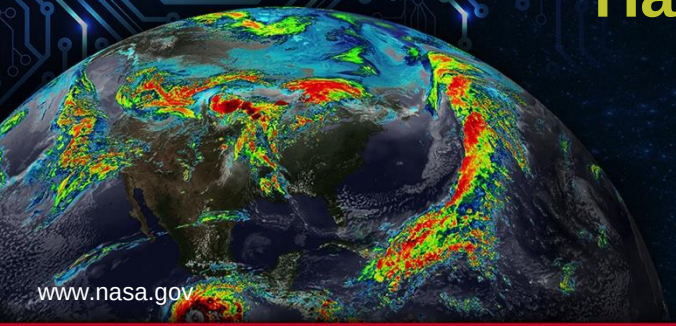
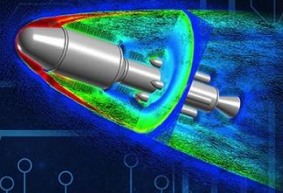
National Aeronautics and Space Administration

A Synergistic Use of Flight/Ground Testing and Simulations: An Airframe Noise Perspective

Mehdi R. Khorrami
Computational AeroSciences Branch
NASA Langley Research Center

Hampton, May 14-15, 2015





Background

- **An important goal of NASA is to significantly reduce the environmental impact of civil transport noise**
  - The Environmentally Responsible Aviation (ERA) project aims to develop the enabling capabilities/technologies that will allow prediction/reduction of aircraft noise
- **Aircraft noise is comprised of two primary components**
  - Propulsion (engine) noise and airframe noise
- **Airframe noise is most prominent during approach to landing**
  - landing gear
  - slotted slats
  - flap and slat side edges
  - flap and slat tracks
  - spoilers
  - component (e.g., gear-flap) interaction

Ref.: Dobrzynski, W., "Almost 40 Years of Airframe Noise Research: What Did We Achieve?" *J. or Aircraft*, Vol. 47, No. 2, March-April 2010

NASA-Gulfstream Partnership

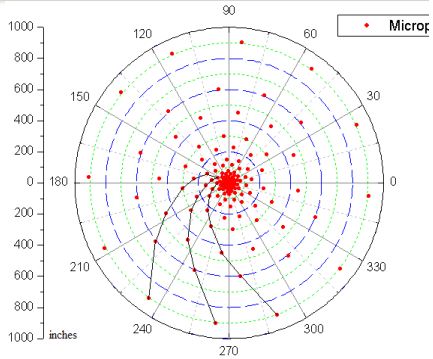
Objectives

- Mitigate radiated **airframe noise** during aircraft landing
- Develop effective noise reduction (NR) concepts applicable to current and future generations of civil transport

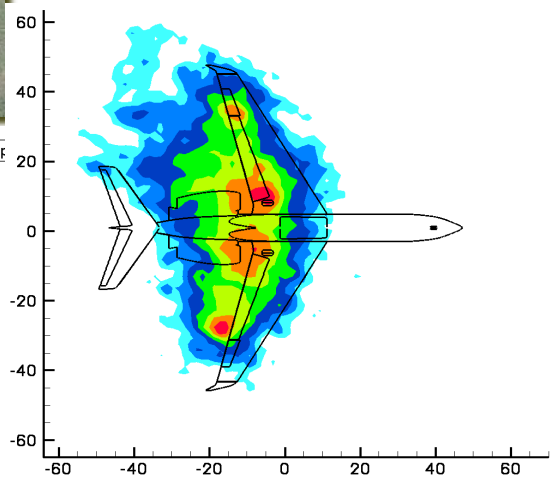
Execution Plan

- Utilize **flight tests**, **wind-tunnel experiments**, and **computational simulations** to:
  - » Better understand the principles of airframe noise generation
  - » Improve airframe noise prediction tools
  - » **Develop efficient noise reduction concepts**
- Evaluate the most promising noise reduction concepts in a realistic environment (full scale flight test)

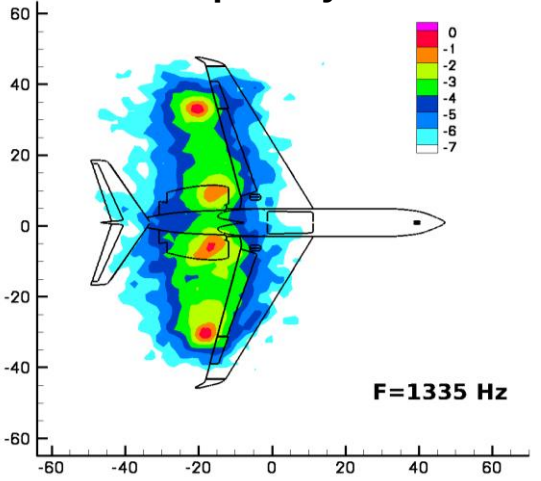
NASA-Gulfstream Airframe Noise Flight (2006)



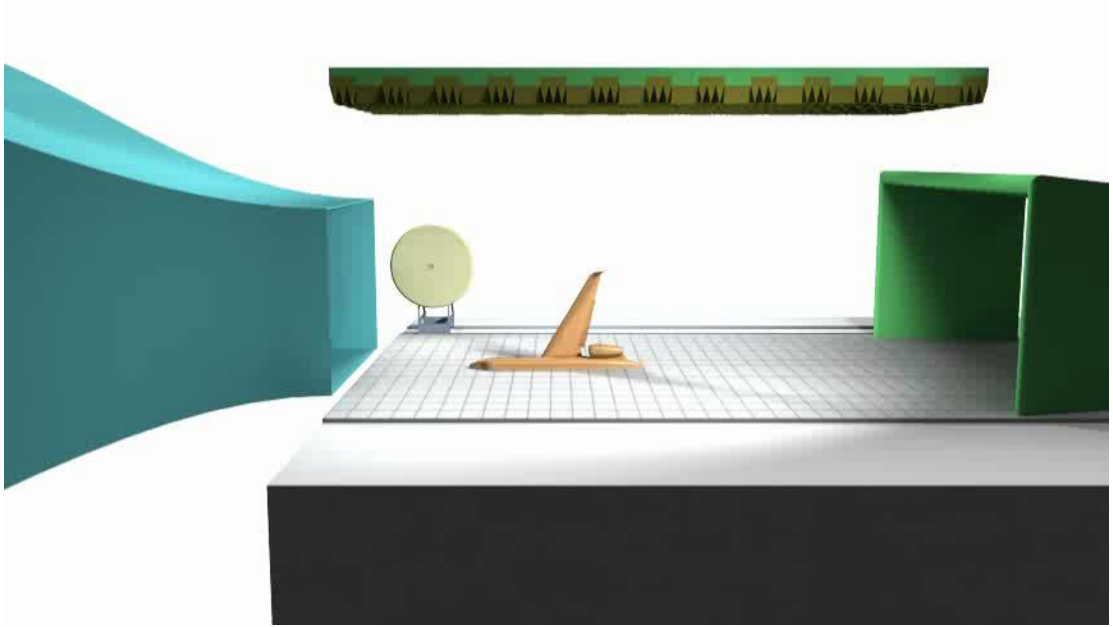
Main Gear and Flaps only



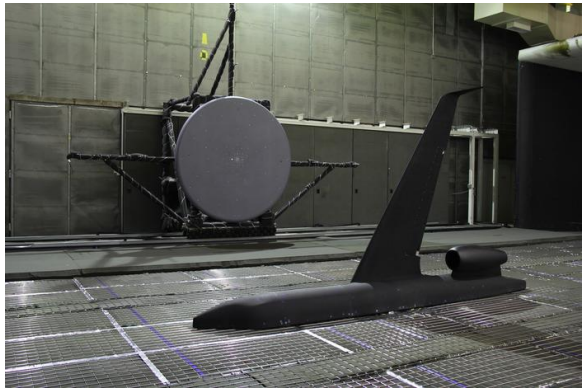
Flaps only



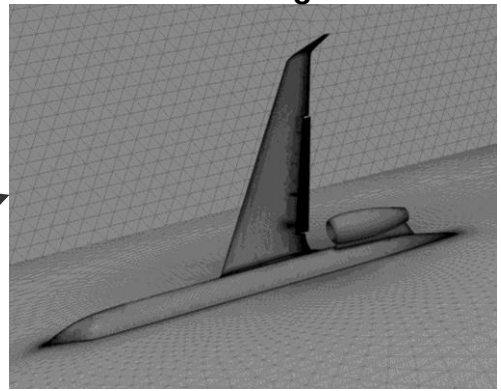
Wind Tunnel Tests and Corresponding Simulations



18% Scale Gulfstream Aircraft Model

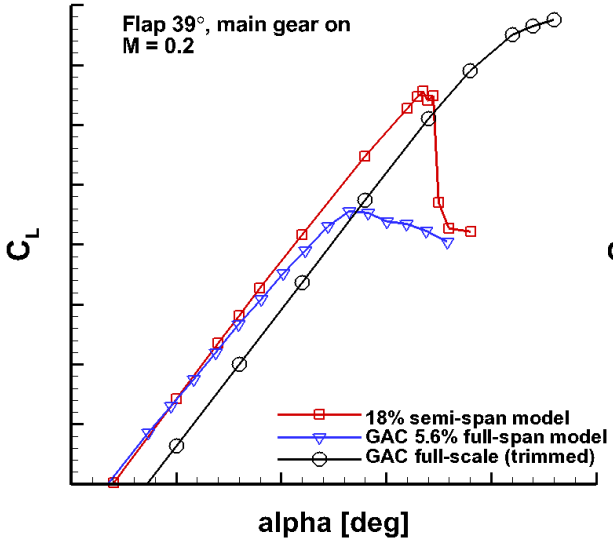


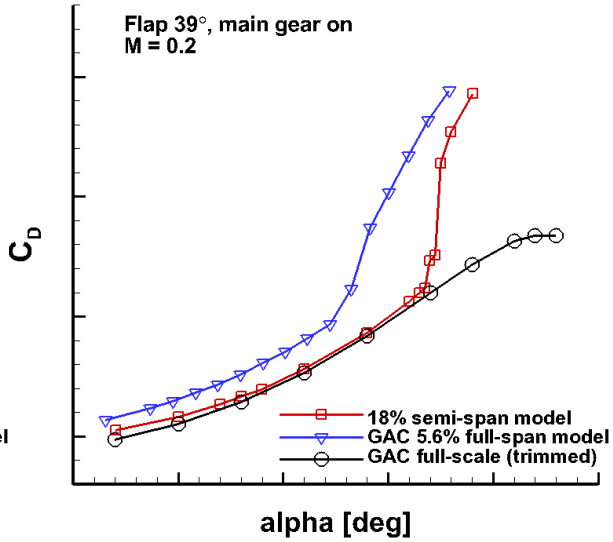
Simulated Configuration

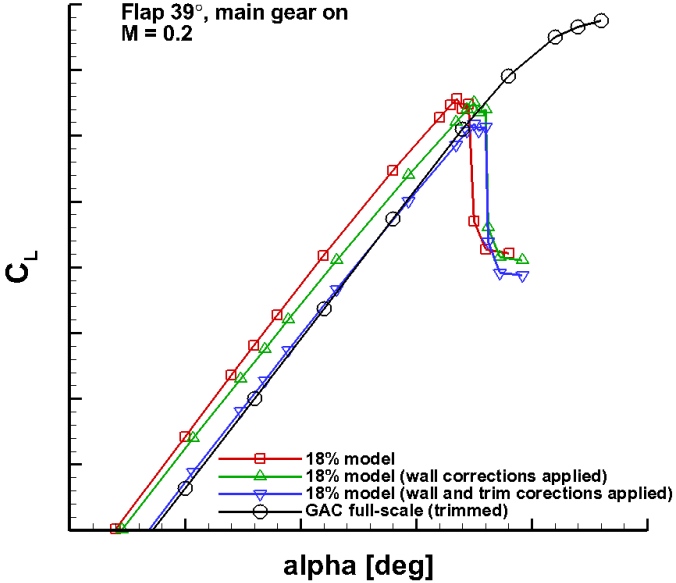


- NASA Langley FUN3D and Exa Corporation Codes
- Executed on NASA Pleiades supercomputer
- Animations by NAS Visualization Group

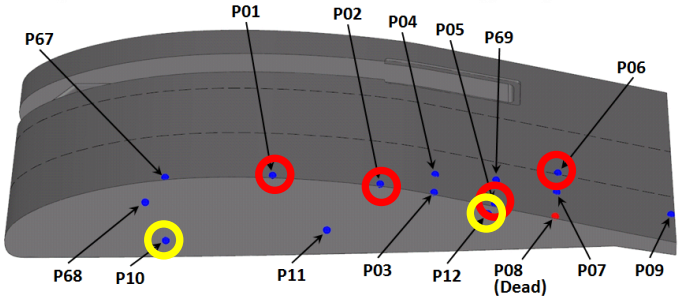
Global Forces (Lift and Drag Coefficients)

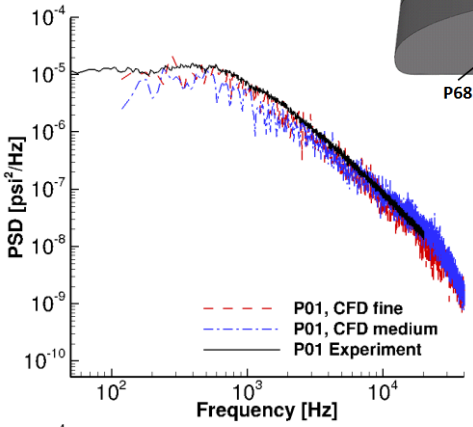


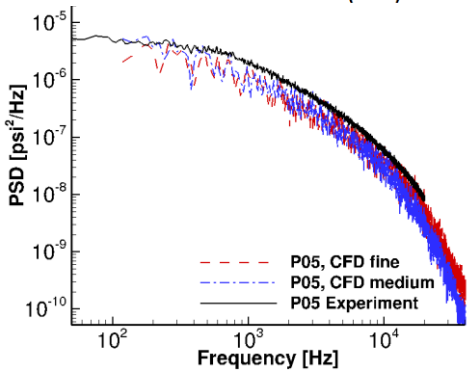


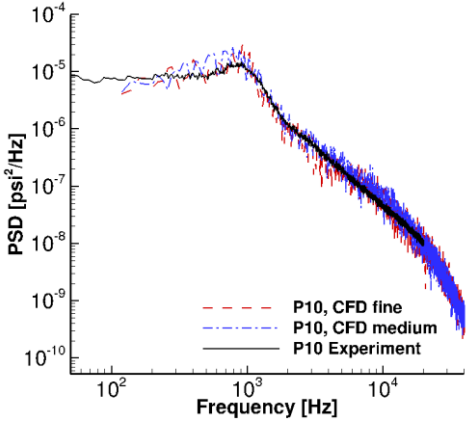


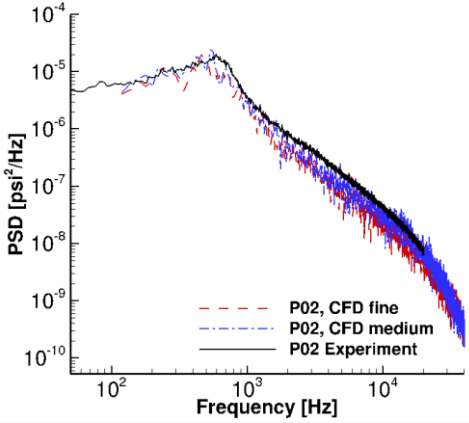
Unsteady Surface Pressures at Flap Inboard Edge Power Spectral Density (Main Gear on)

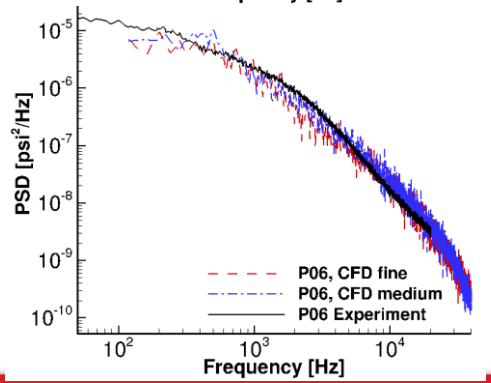


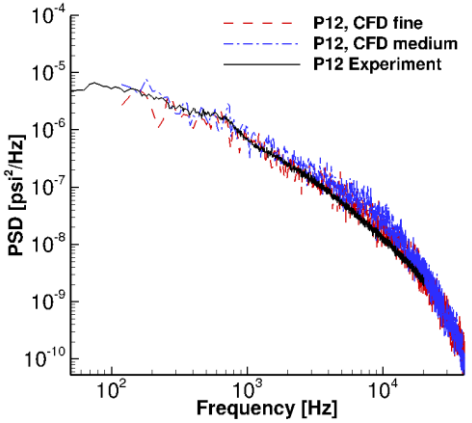






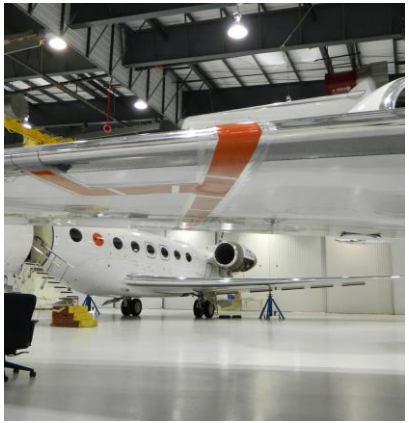




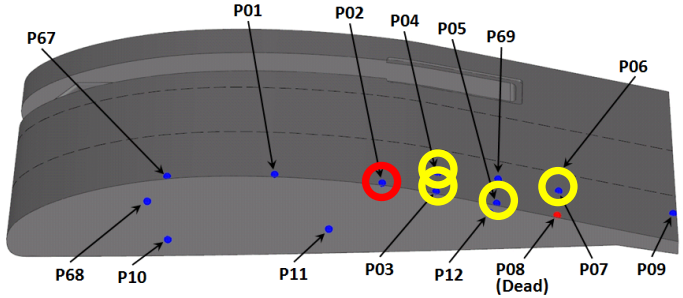


Aerodynamic Flight Test (Gulfstream)

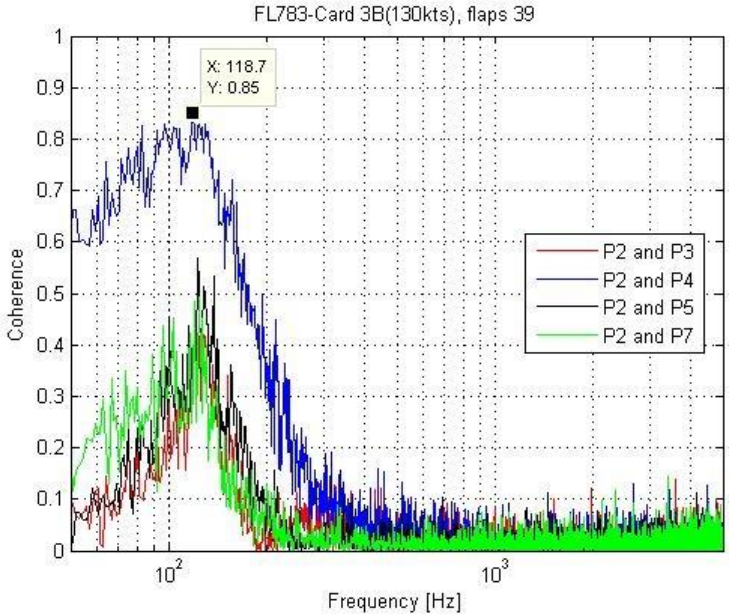
- Flight test performed during March 2013
- Acquired data was used to address:
  - Reynolds number effects
  - Geometric fidelity effects
  - Installation effects
- Critical aircraft components instrumented
  - Pressure belt on wing (steady pressures)
  - Flap (steady and unsteady pressures)
  - Main and nose landing gear (unsteady pressures)
  - Pressure transducers identical as those used on 18% scale model



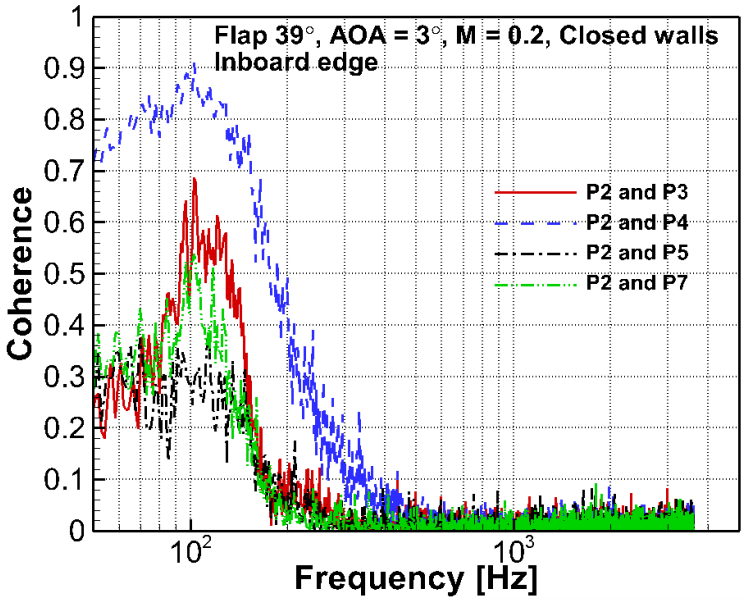
Unsteady Surface Pressures at Flap Inboard Edge Coherence Data (Main Gear Up)



Flight test, GAC

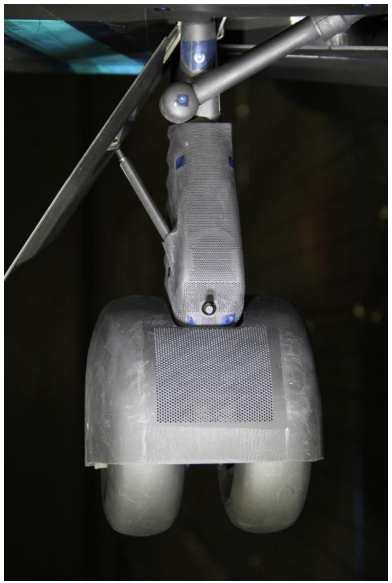


14x22 test, NASA



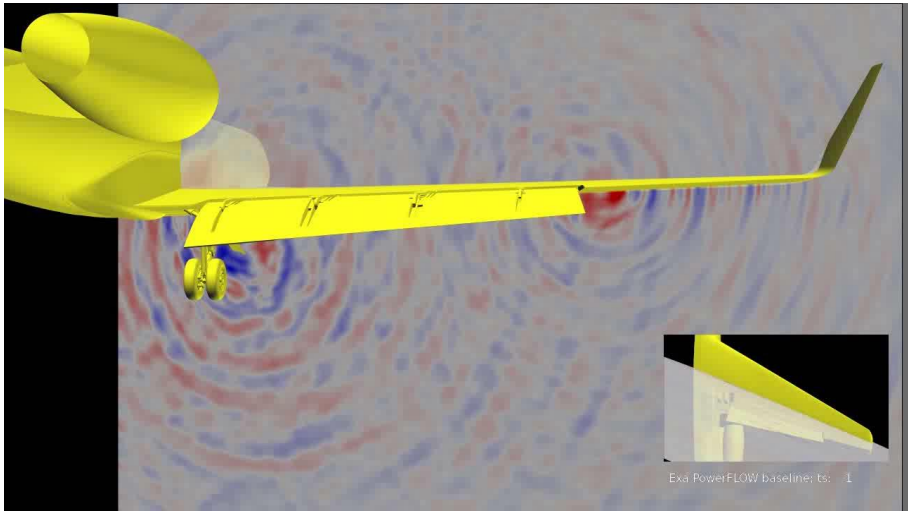
Low Noise Flap and Landing Gear

- Targets noise generated at aircraft flap tips and landing gear
- Circular and non-circular metallic fins (flaps) and porous fairings (gear)
- Effectiveness of concepts was validated/evaluated via simulations and testing

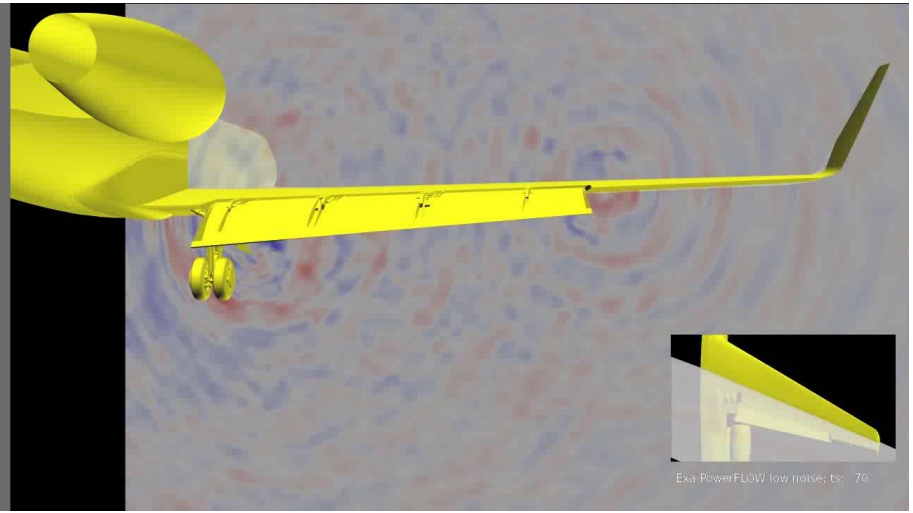


Baseline Comparison with Low Noise Case (Far View of Radiated Acoustic Field)

Baseline Configuration



Low Noise Configuration

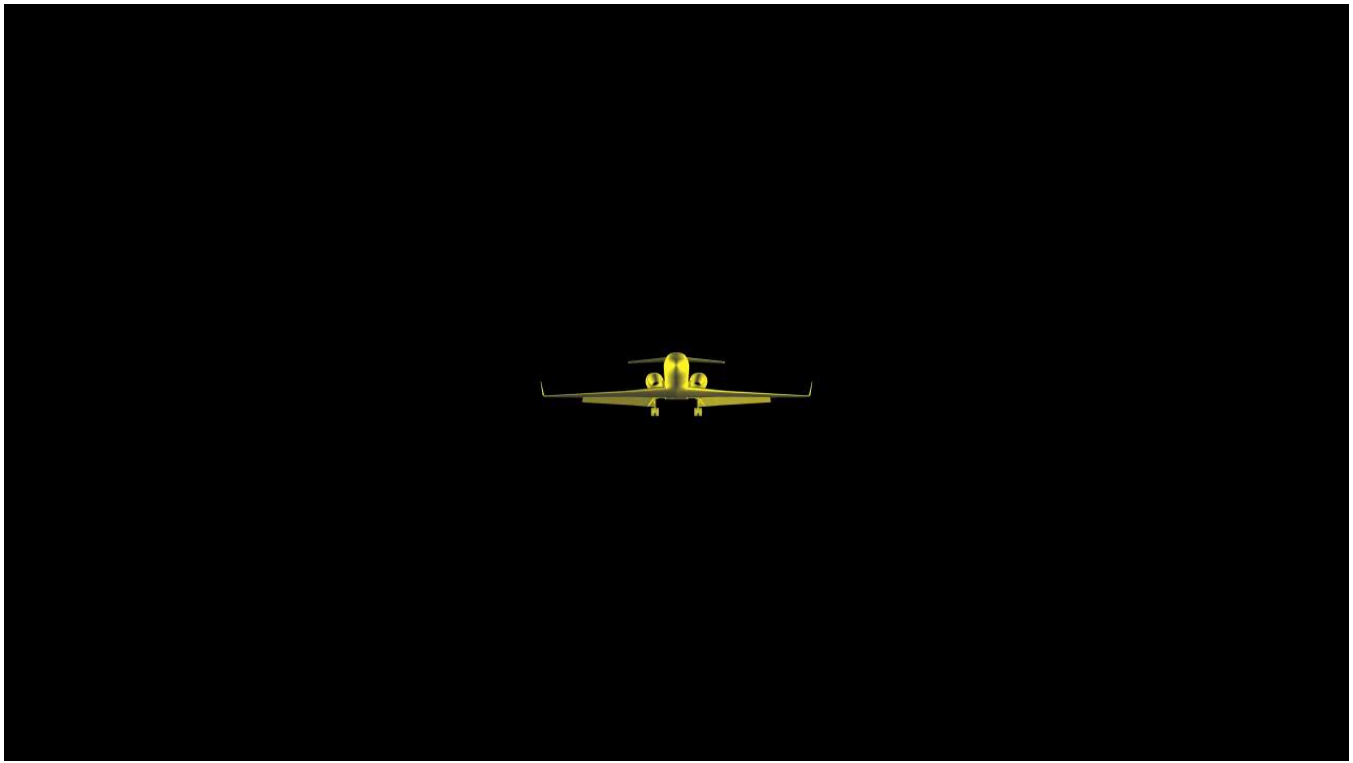


Simulation Characteristics

- As–built 18% scale high-fidelity Gulfstream model
- Re = 3.47 x 10^6 based on MAC
- Solver: Exa Corporation PowerFLOW® (LBM)
- Finest resolution: 3 x 10^9 cells, 4000 cores, 1 x 10^6 CPU hours (NASA Pleiades)

Baseline Full-Scale Aircraft Configuration

Radiated Noise From Full-Scale Aircraft (Baseline)

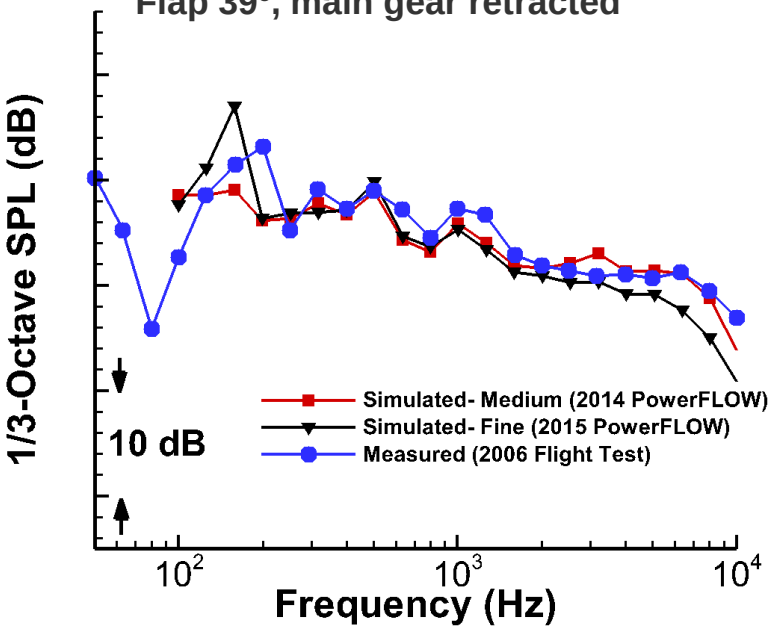


Simulation Characteristics

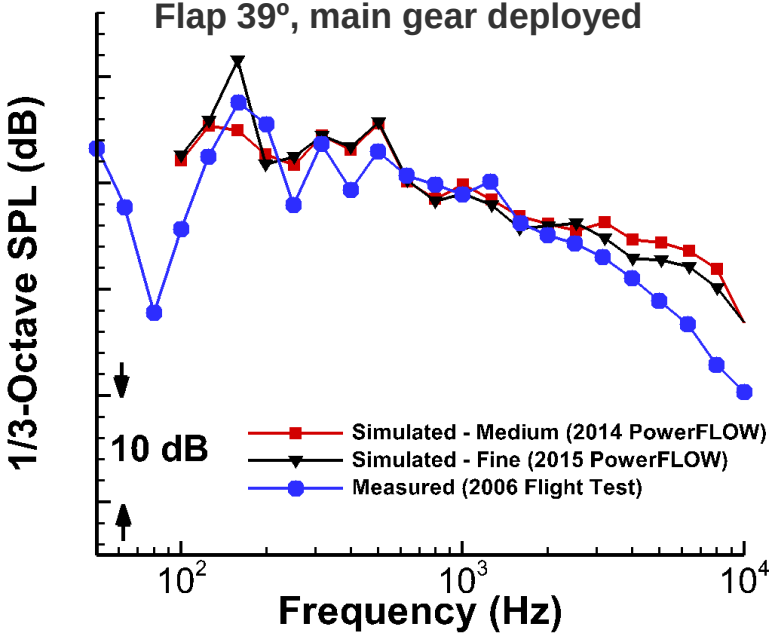
- Full scale Full Gulfstream Aircraft
- Re equivalent to 50% of flight: Re = 10.5×10^6 based on MAC
- Solver: Exa Corporation PowerFLOW® (LBM)
- Finest resolution: 8.4×10^9 cells, 6000 – 12000 cores, 7×10^6 CPU hours (NASA Pleiades), 20 – 25 days per run

NASA-Gulfstream Airframe Noise Flight Test (2006)

Flap 39º, main gear retracted

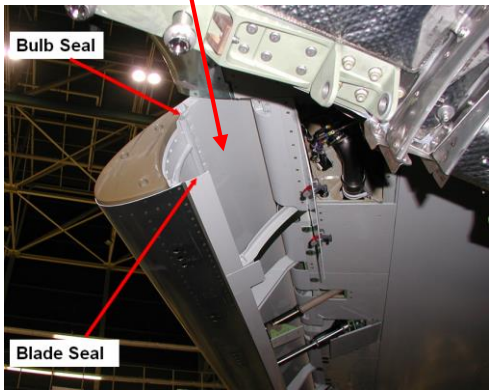


Flap 39º, main gear deployed

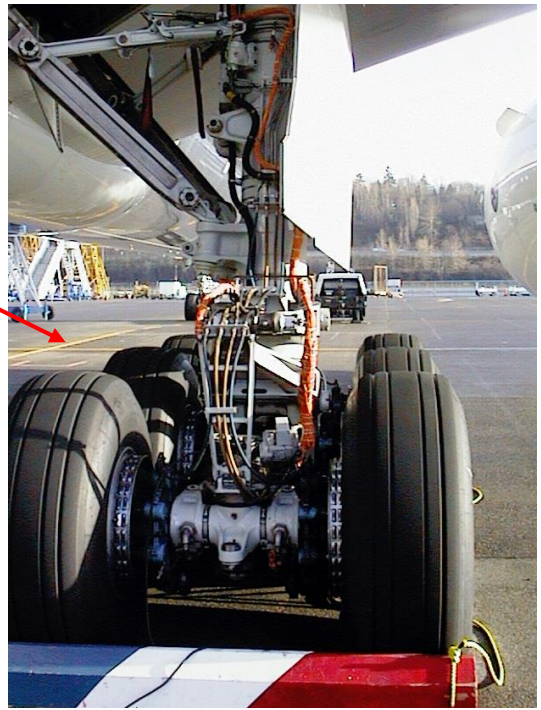


Flyover certification point
Distance of 396 feet from source

Large Civil Transport (Boeing 777)



Boeing 777 leading edge slat



Boeing 777 main landing gear

Backup Slides