



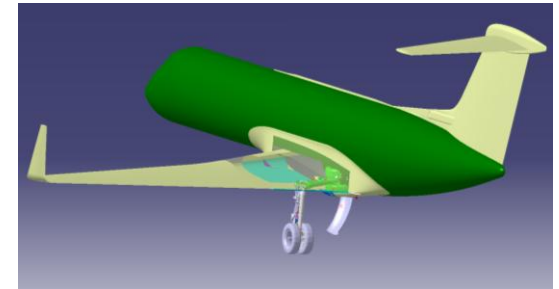
ERA Airframe Noise Research

David P. Lockard
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NASA-Gulfstream Partnership on Airframe Noise:

G550 Semi-Span Model Testing

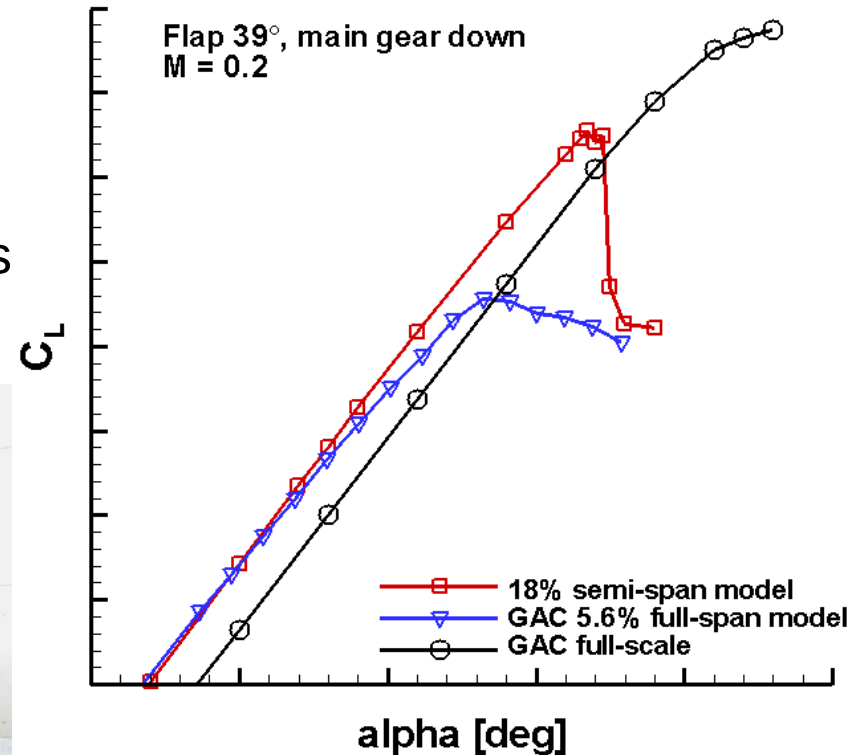
- High-fidelity model
 - 18% of full-scale
 - Geometric details captured
- Heavily instrumented
- Multiple entries in NASA 14'x22' tunnel
 - Closed wall: Aerodynamic measurements
 - Open wall: Aero & acoustic measurements
- Test bed for noise reduction concept development
 - Flap-side edges
 - Main gear
 - Gear - Flap interaction



G550 First Entry in Langley 14x22 Tunnel



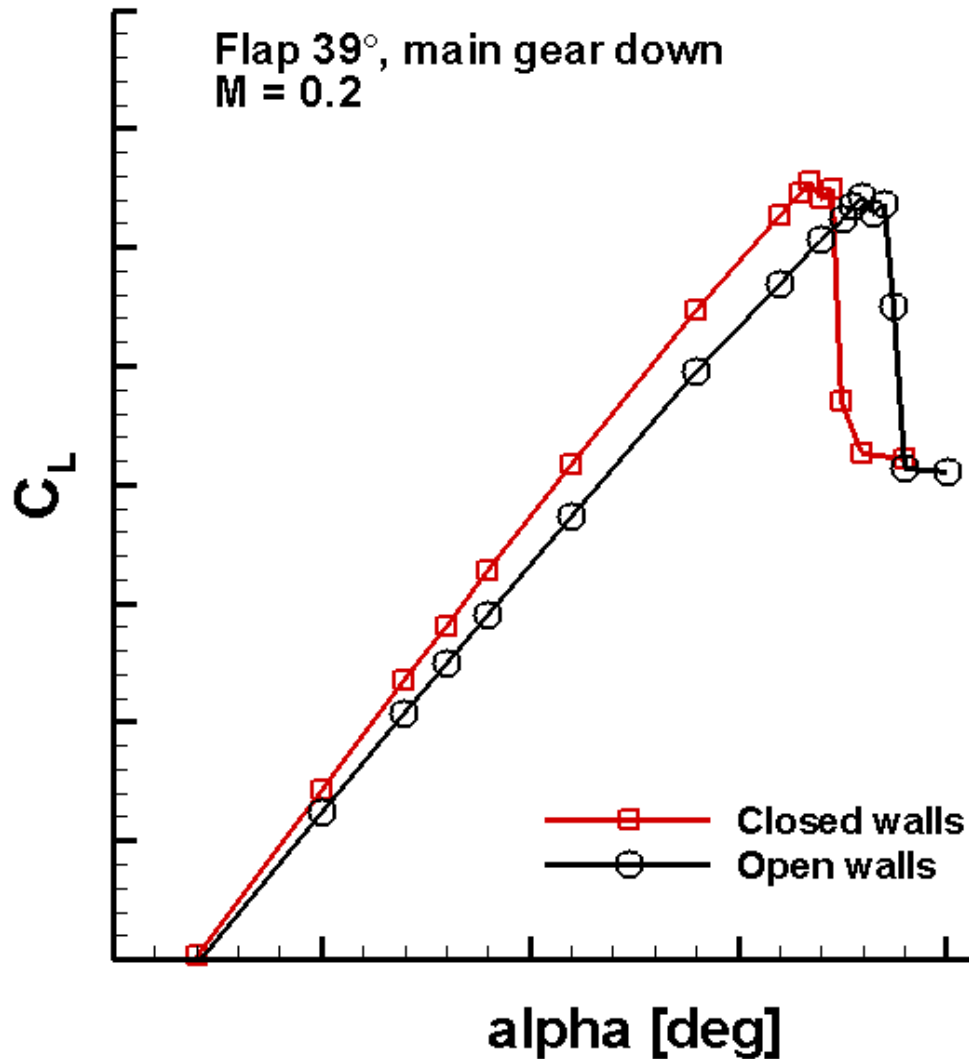
- Aerodynamic testing from 10-13-10 to 11-18-10
- First entry was focused on
 - Global forces (Lift and drag)
 - Steady / unsteady surface pressures
 - Overall aerodynamic characteristics C_L



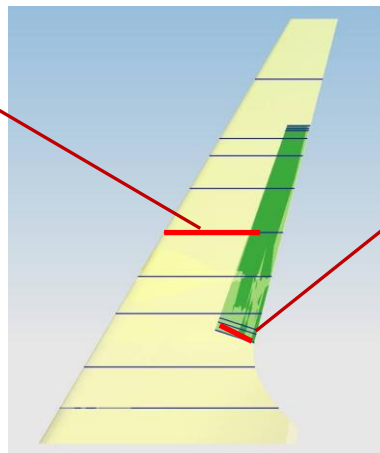
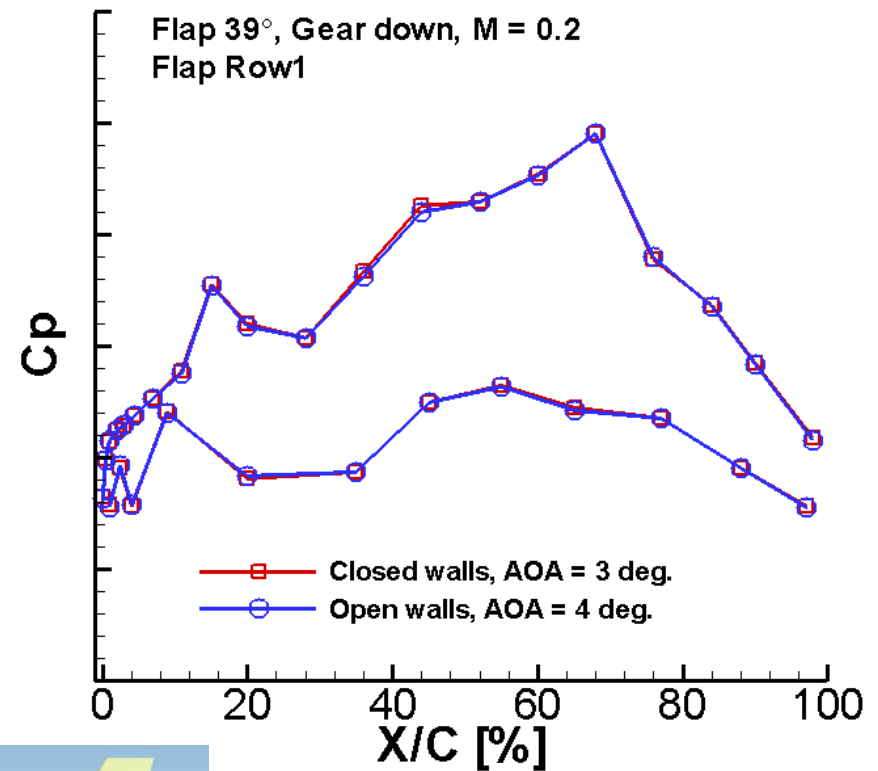
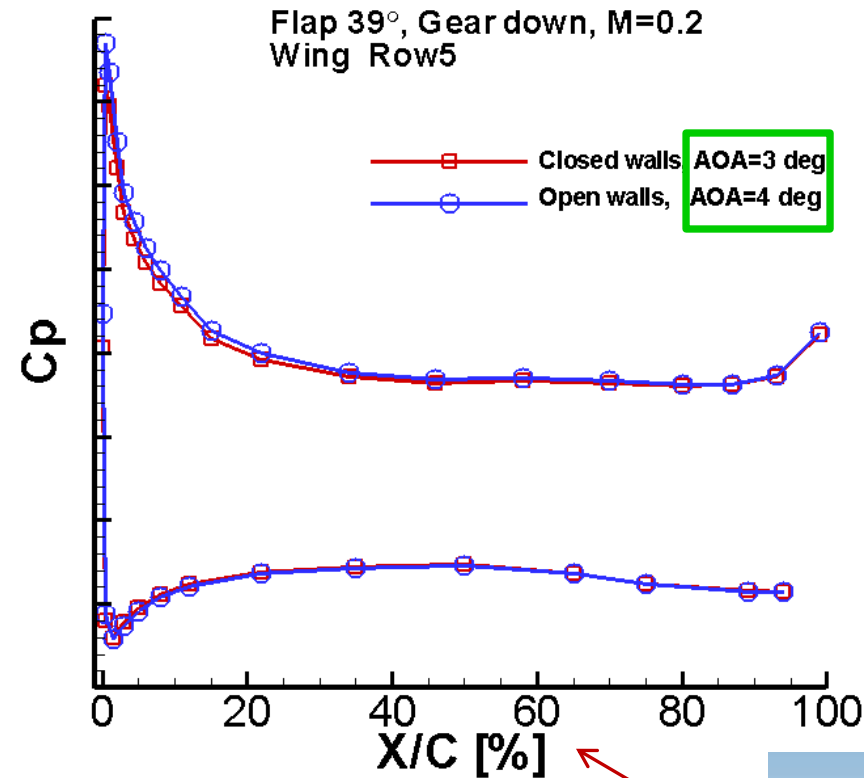
Closed Walls vs Open Walls: Aerodynamics 1



Flap 39° , main gear down
 $M = 0.2$



Closed Walls vs Open Walls: Aerodynamics 2

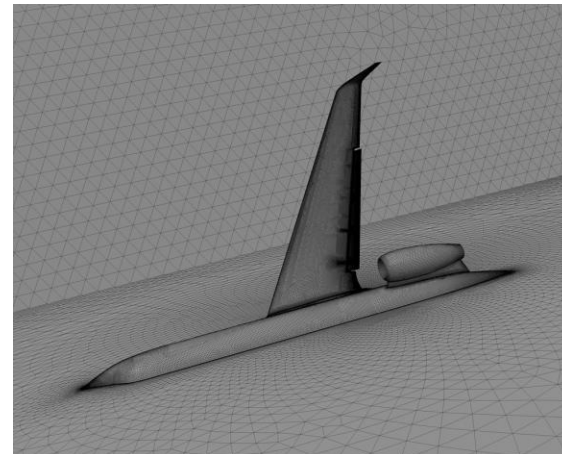
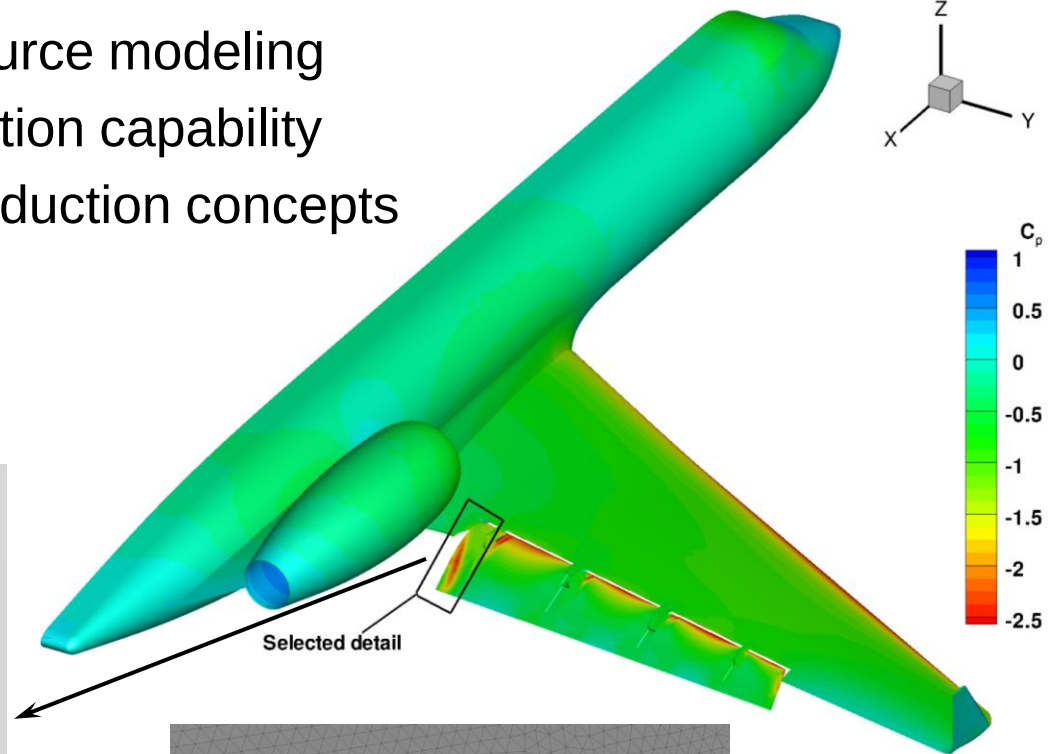
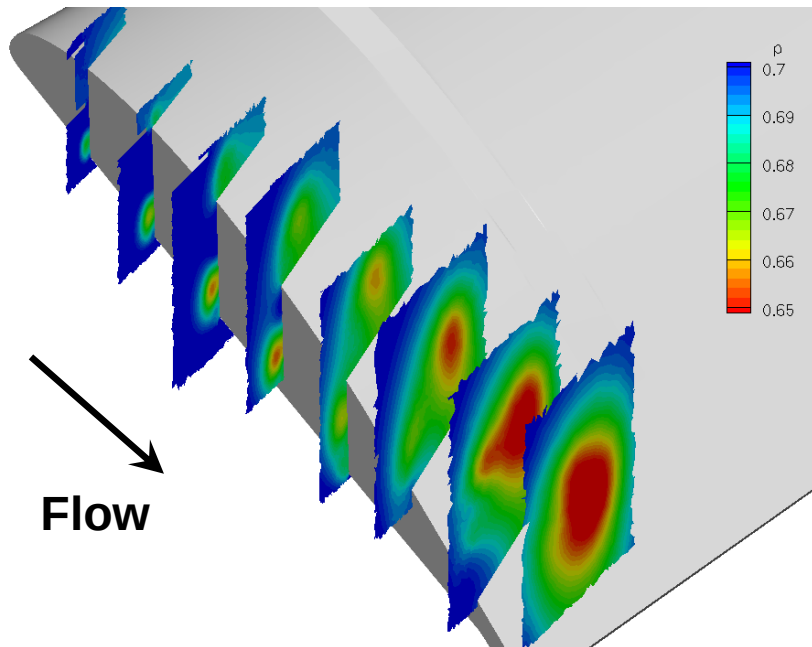


Companion Computational Simulations



- Provide insight on the nature of noise sources
- Guide physics-based noise source modeling
- Advance airframe noise prediction capability
- Develop and evaluate noise reduction concepts

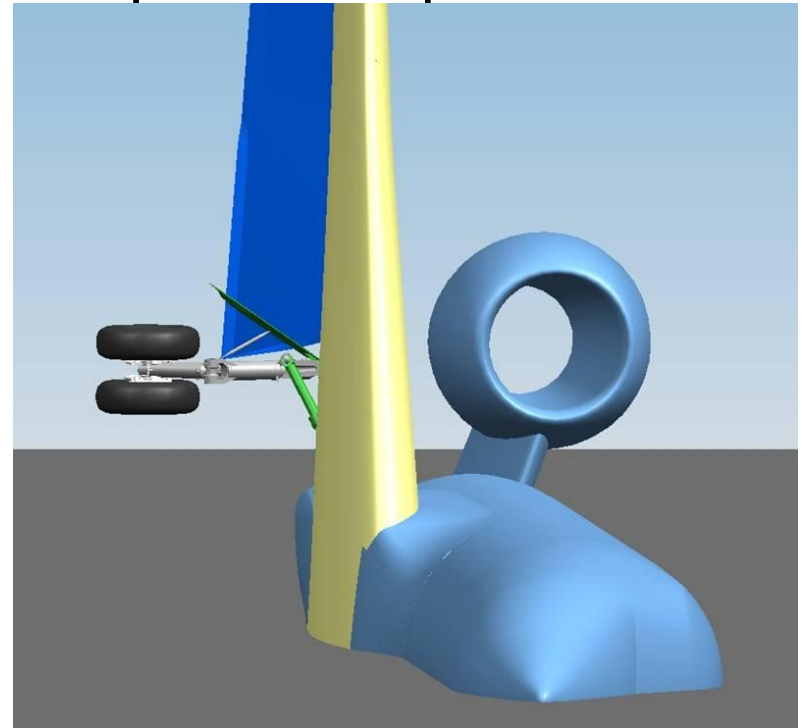
Flap Inboard Edge



G550 Aeroacoustic and PIV Testing



- 2nd and 3rd entries in 2012 are dedicated to
 - Repeat of steady & unsteady surface pressures
 - Repeat of lift and drag
 - Acoustics: Microphone array & free-field microphones
 - Evaluation of noise reduction technologies
 - Off-surface flow: PIV
- Test bed for noise reduction concepts development
 - Flap-side edges
 - Main landing gear
 - Gear-flap interaction



Summary



- An ambitious partnership program focused on airframe noise research has been established and is being executed systematically
- The aim of the partnership effort is to generate/acquire a high-quality airframe noise database that would guide the development of
 - Better noise source models
 - Efficient computational tools with predictive capabilities
 - Viable noise reduction concepts
- Delivery and aerodynamic testing of the 18% semi-span G550 model constitutes the initial critical steps toward achieving these goals



SFW Airframe Noise Research Roadmapping

David P. Lockard

Airframe Noise I

- Nonpropulsive component of aircraft noise
 - Comparable to engine noise when modern aircraft are landing
 - Currently dominated by:
 - Slats
 - Flap edges (including wake interactions)
 - Landing gear
 - Relative levels of the 3 major sources are similar in magnitude but dependent on the specific aircraft
 - Must reduce all 3 to achieve significant noise reduction



Airframe Noise II



- Trailing-edge scattering and other secondary sources are estimated to be 8-10 dB weaker than the 3 primary sources of airframe noise



Airframe Noise: Current State of the Art



- Most predictions use semi-empirical models
- Noise reduction development is still primarily done by cut-and-try experimentation
 - Few AFN noise reduction devices have made it onto an airplane
 - Structural aspects, weight, maintenance often limiting factors
- Microphone arrays are employed routinely in experiments
 - Have difficulties with reflections and correlated sources
- Numerical simulations are being used in coordination with experiment to develop and assess noise reduction devices

Airframe Noise: Current State of the Art



- Unsteady numerical simulations are being performed relatively frequently
 - Mostly hybrid RANS/LES
 - Levels are not trusted by industry without corroboration
 - Computations are primarily restricted to components
 - Computer resources are high
- Intermediate-fidelity methods based on steady RANS + CAA or acoustic analogy being developed
- Smart materials and flow control are being developed and assessed for use in noise reduction devices

Potential N+3 Configurations



D8.5 – Double Bubble Configuration



Hybrid Wing Body



Additional N+3 Configurations



Sugar Volt



Truss-Braced Wing



Noise Reduction Technology



- Flap side-edge and slat noise eliminated
 - Fundamental design change
 - Circulation / adaptive flow control
 - Configuration doesn't require a traditional three-element system to achieve high lift
 - Devices quieted using morphing structures
 - Edges / cavities eliminated
- Landing-gear noise reduced
 - Fairings
 - Gear partially embedded in fuselage when propulsion system mounting doesn't require long gear struts
- Operations changed to reduce noise

Near-Term (10 year) Goal



- Eliminating high-lift system and landing-gear noise should achieve 8-10 dB of noise reduction
 - Sufficient reduction in airframe noise to meet N+1 goal
 - Could even meet N+2 goal depending on relative importance of engine/airframe noise



What Advances Are Needed?

Note that some nearer-term activities will not be listed even though they may be important to meet intermediate goals.

Enabling Advances 1



- Microphone array processing advanced to efficiently account for distributed, correlated sources
 - Flow and reflections incorporated
- Benchmark experimental datasets established for flaps, slats, landing gear and integrated systems
 - Includes near-field source and far-field acoustics
- Physics-based prediction
 - Applicable to unconventional configurations
- Integrated aerodynamic, acoustic & structural design of low-noise devices

Enabling Advances 2



- Simulation (unsteady CFD/CAA Hybrid RANS/LES) methodology sufficiently validated to be accepted for routine practice in industry
 - Numerical optimization techniques that guide the development of noise reduction devices
 - Development needs to transition from cut-and-try guided by intuition to optimization guided by mathematics

Enabling Advances 3



- New “devices” for noise reduction
 - Actuators (fluidic, zero mass, plasma)
 - Sound absorbers (liners, compliant surfaces)
 - Fairings
 - Lightweight and stowable
 - Morphing structures
 - Present flow with different shapes dependent on flow conditions
 - Optimal shapes from experimentation / simulation
 - Smart materials developed for the operating conditions / load
 - Low weight and complexity

Enabling Advances from Other Fields



- Operations
 - Speed and path
- Experimental techniques for source interrogation
 - E.g. unsteady pressure sensitive paint
- Improved simulation methodology
 - Efficient algorithms
 - Automated grid generation / refinement
 - Error estimation
 - Turbulence models
 - Hybrid RANS/LES methods

Noise of a Clean Aircraft



- From gliders to commercial planes, trailing-edge noise is dependent on $W V M^2 / (C_L H^2)$

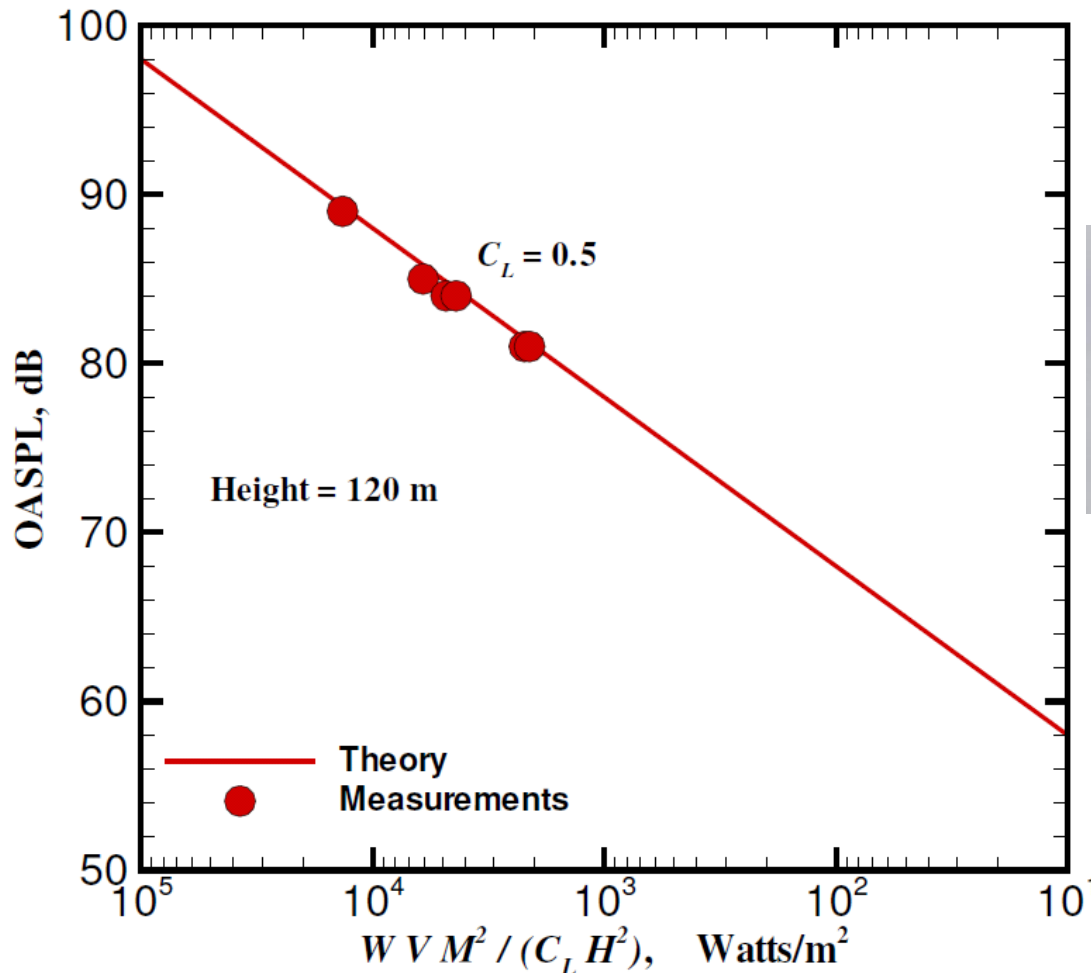
W = Weight

V = Velocity

M = Mach number

C_L = Lift Coefficient

H = Height





Reducing Trailing-Edge Noise

$$\text{Noise} \sim W V M^2 / (C_L H^2)$$

- Reduce the weight of the aircraft
- Decrease speed
- Increase the distance to the ground
 - Higher glide slope
- Technology
 - Brushes
 - Liners / porous surfaces
 - Compliant surface provided by designer materials
 - Serrations



The N+3 Vision

- Advanced configurations and flow control allows low-speed, steep approaches into airports
- Noise is a part of the design phase of an airplane as high-fidelity, unsteady numerical simulations are used to assess design choices
- Discontinuities replaced by smooth transitions
 - Smart or morphing materials being used routinely in noise reduction devices on aircraft
 - Edges treated with compliant surfaces (coatings, porosity)
- Landing gear are made from advanced materials allowing extensive fairings without weight penalties
 - When possible, based on the airplane configuration, landing gear are embedded in the fuselage with only tires exposed



Feedback