



Airframe Noise Research Update

David P. Lockard

Acoustics TWG Meeting, Oct 15-16, 2014



Wake / Flap Side-Edge Interaction Noise Experiment

Florence Hutcheson, Tom Brooks, Dan Stead

Quiet Performance

Fixed-Wing Project

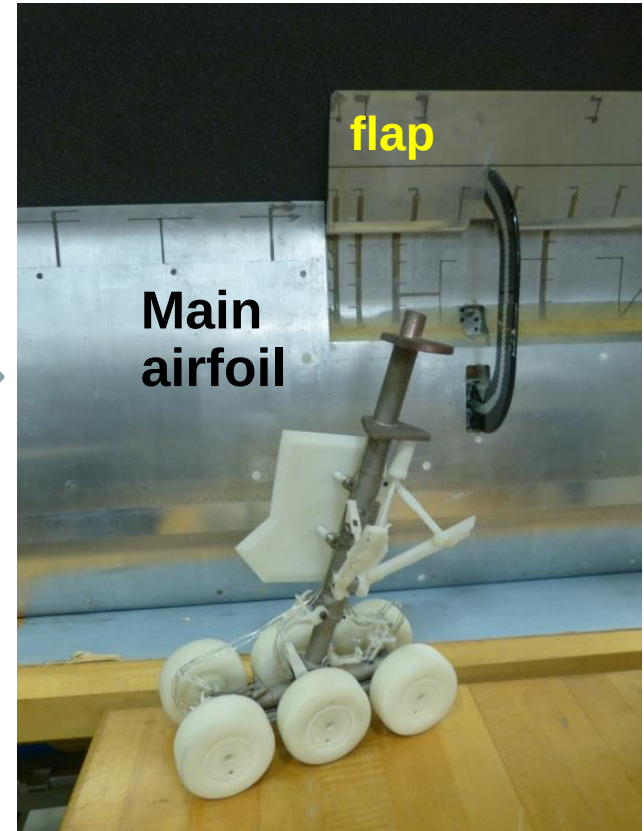
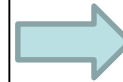
Acoustics TWG Meeting, Oct. 15-16, 2014

Wake / Flap Side Edge Interaction Noise Experiment

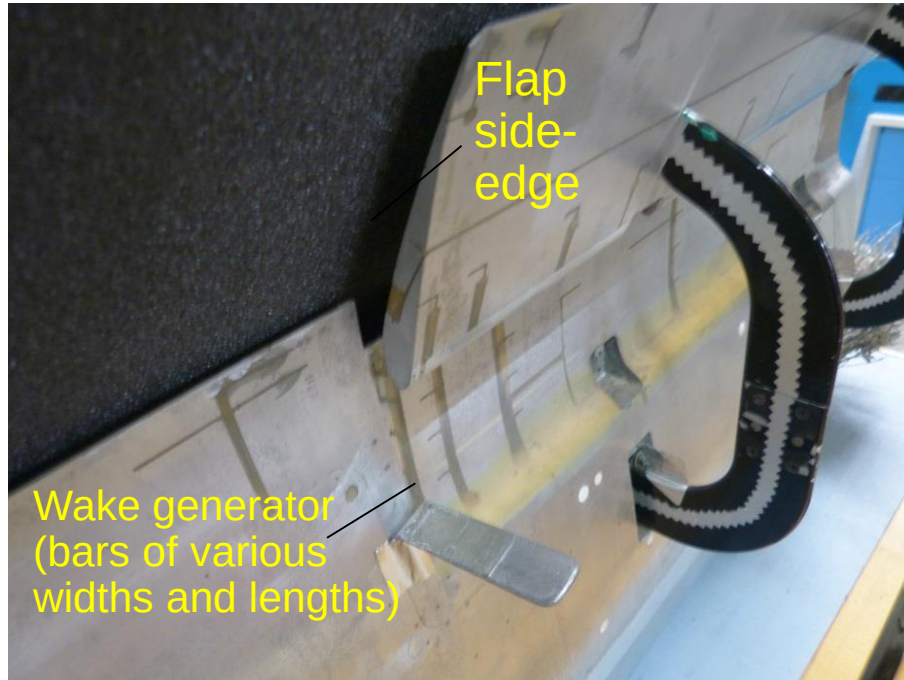
- Objective: Examine effect of interaction of wake with flap side edge on radiated noise, particularly noise sensitivity to wake generator placement and geometry
- Problem relevant to landing gear wake/ flap interaction noise

Test Model

- NACA 63₂-215 main element airfoil (16" chord and 36" span) with a half-span Fowler flap
- Assembly of existing high-fidelity LG model with wing/flap model requires major modifications to both test models

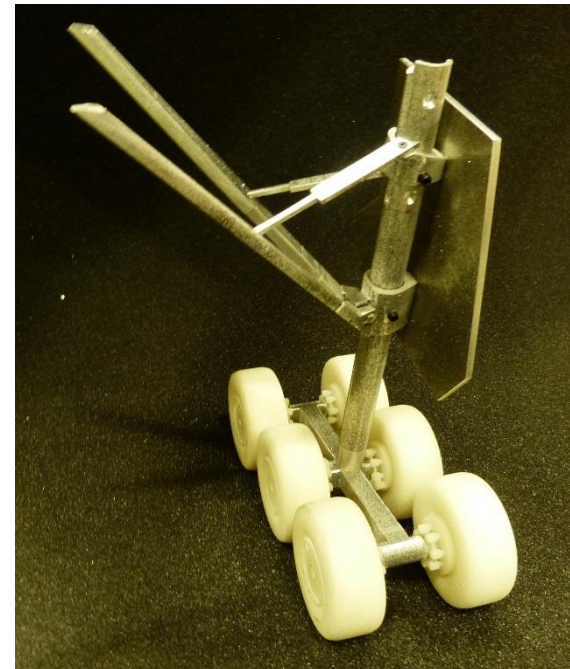


Test Model – Wake Generators

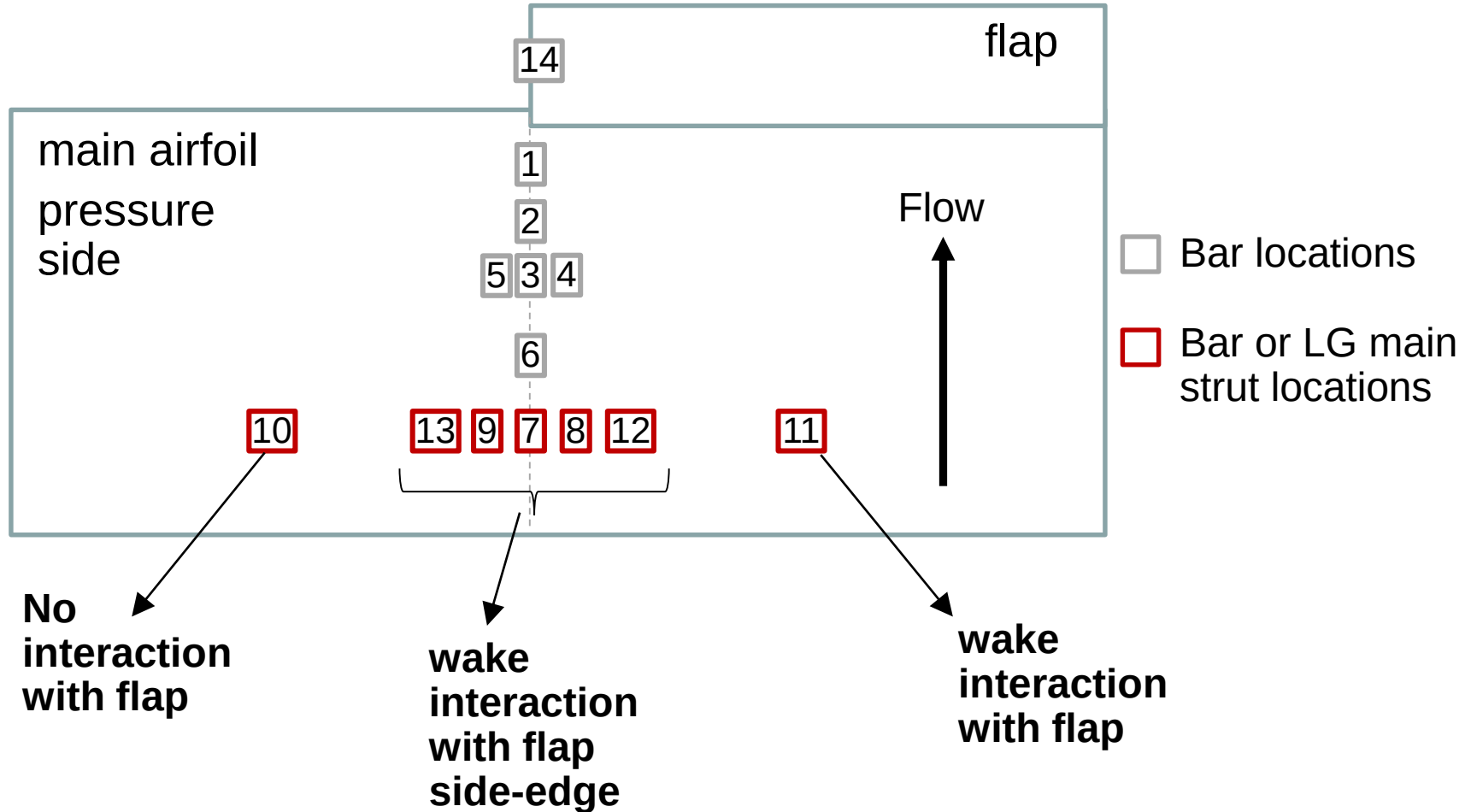


Initial study to examine interaction noise with wake from simple bluff body geometry.

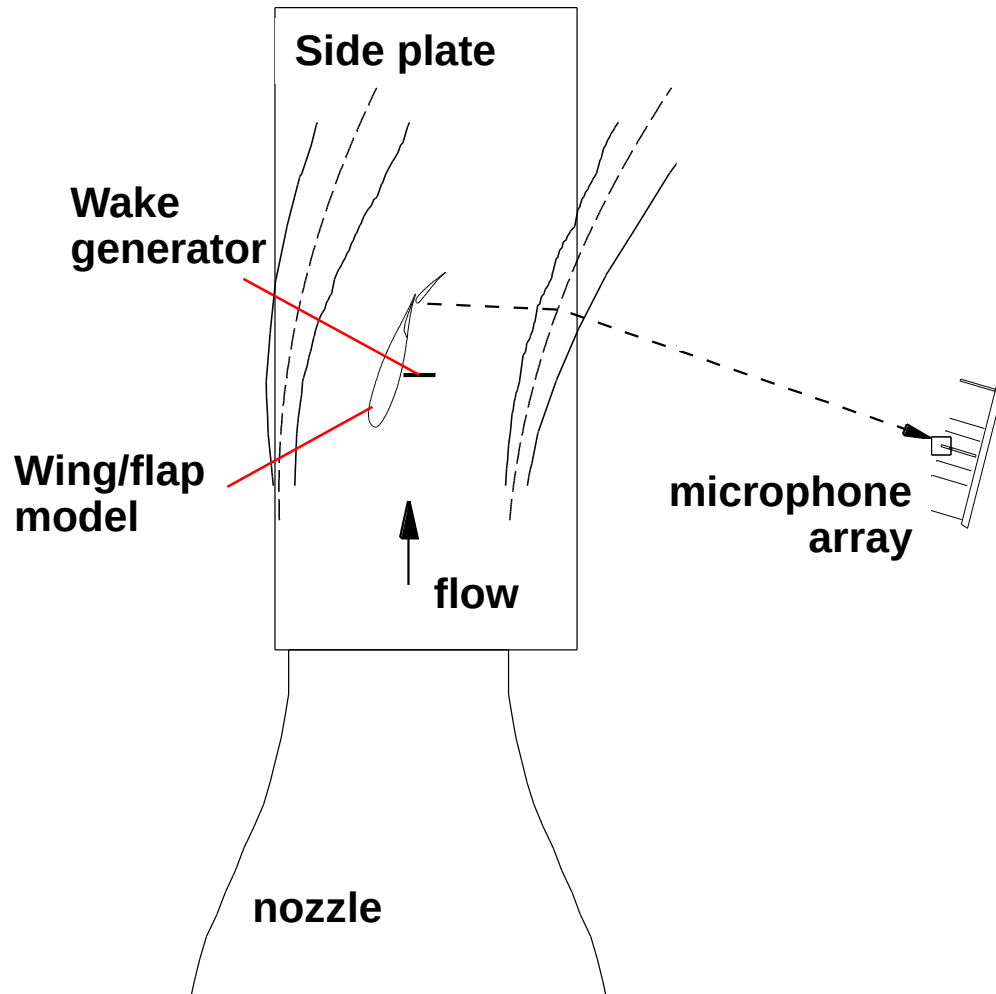
As well as wake from simplified LG model (with simple attachment to wing model).



Wake Generator Placement



Acoustics Experiment (on-going)



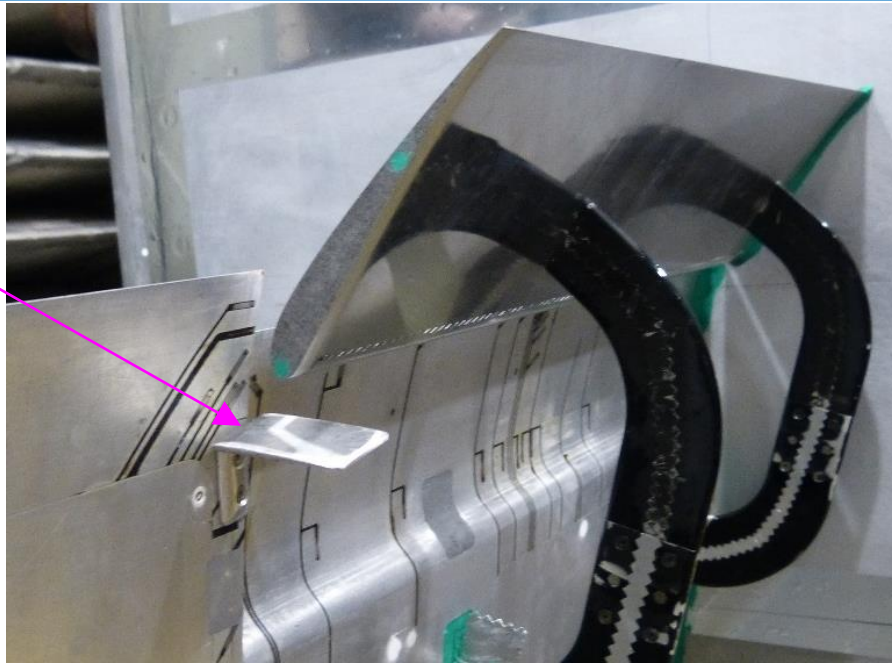
- Conducted in LaRC Quiet Flow Facility
- Main airfoil AOA: 16°
- Flap AOA: 29° and 39°
- $0.09 \leq \text{Mach} \leq 0.17$
- Microphone array fixed on model pressure side in mid-span plane.

Sample Data

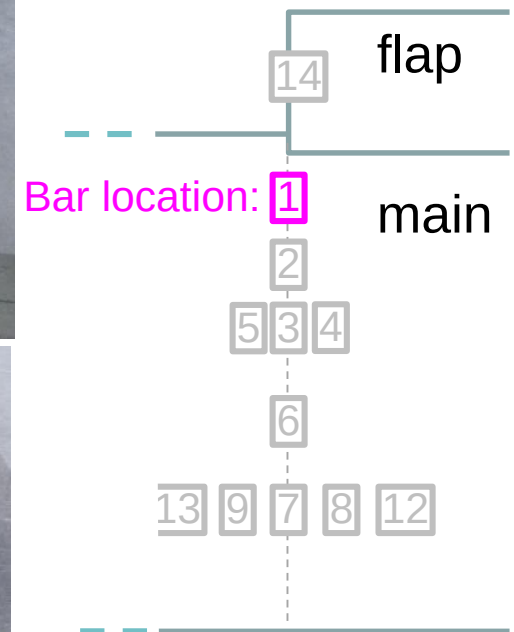
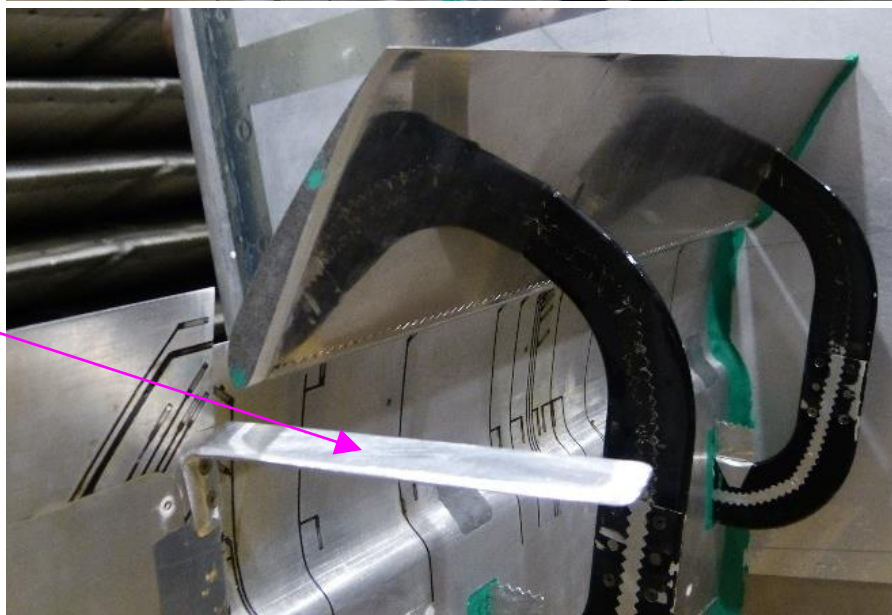
(auto-spectra from single microphone in phased array)

Effect of Bar Length

Short bar
(2"high x1"wide)

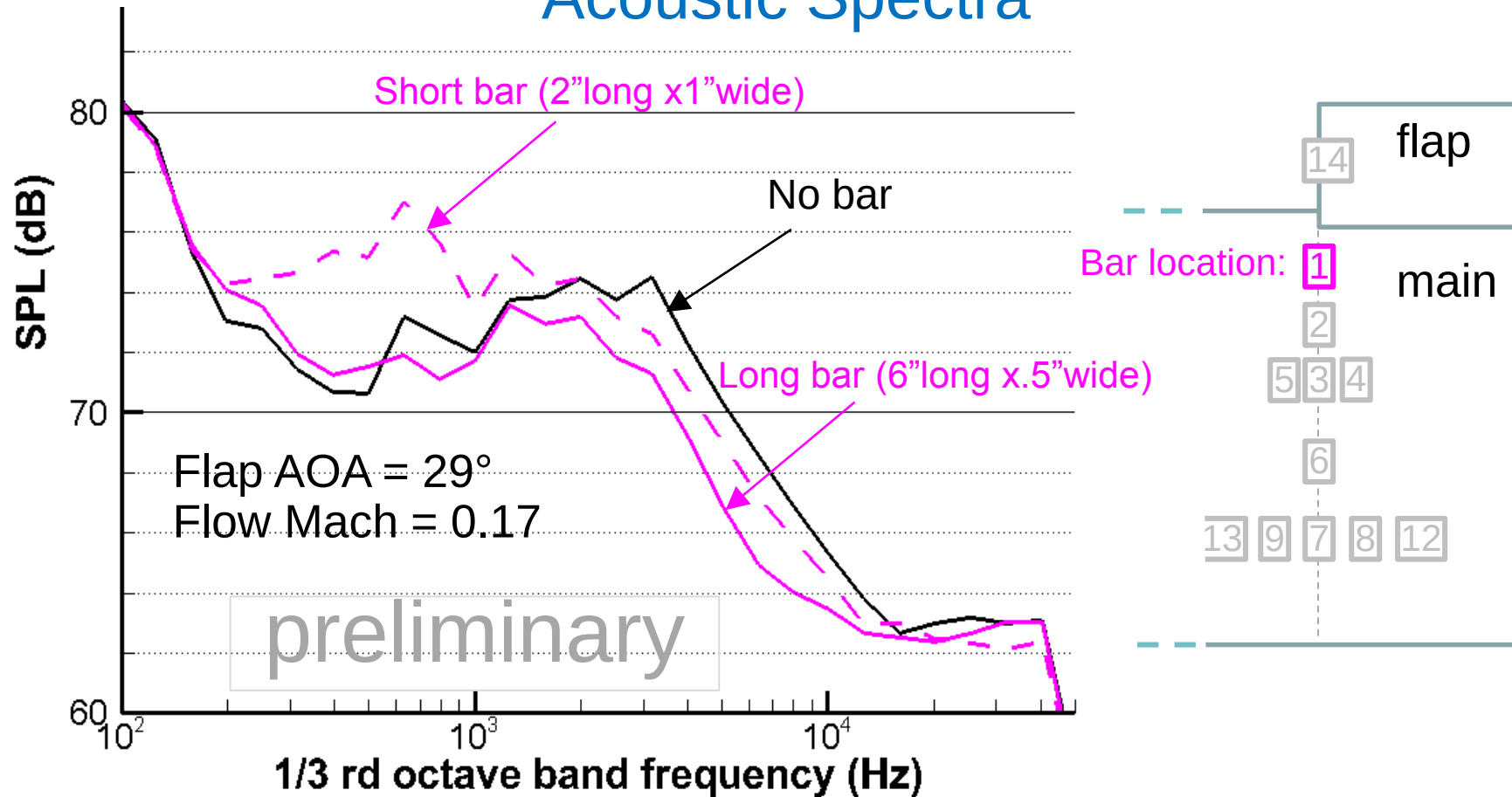


Long bar
(6"high x.8"wide)



Effect of Bar Length: Short vs Long

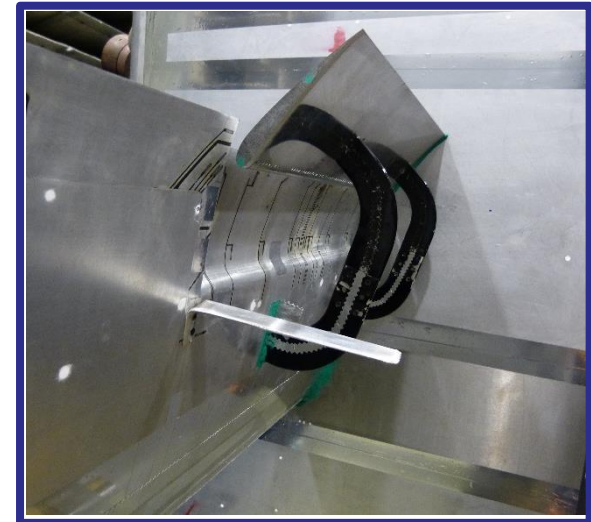
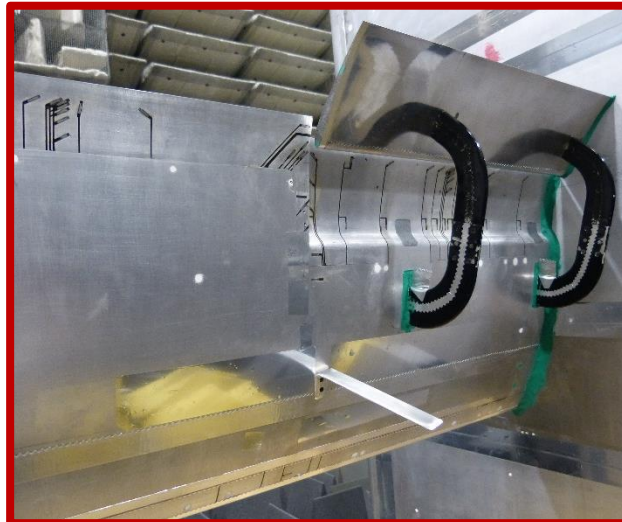
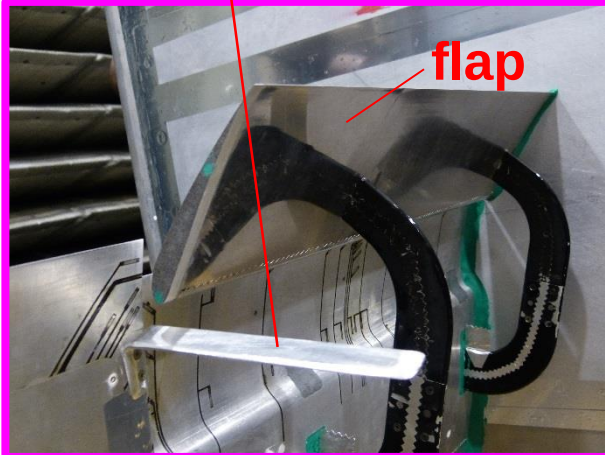
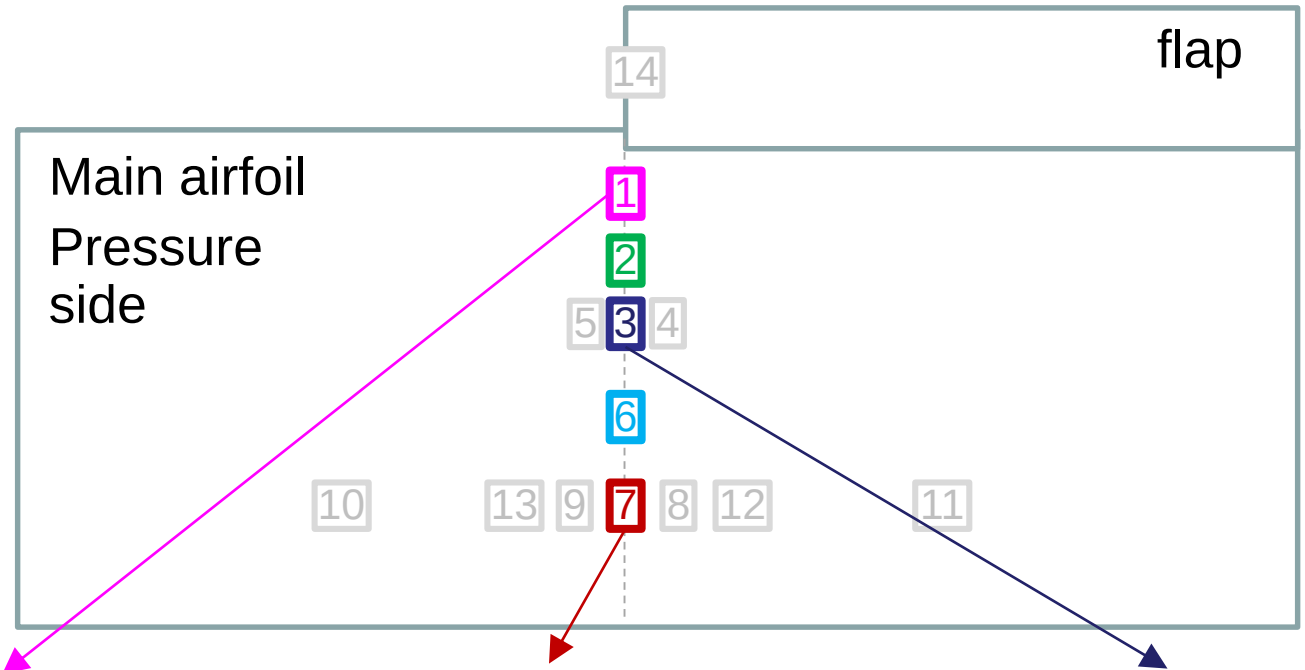
Acoustic Spectra



- Interaction noise sensitive to wake generator geometry.
- Long bar just upstream of flap side edge leads to **up to 4 dB decrease in noise above 500 Hz** (only 0.5-1 dB increase between 200-500 Hz). Similar benefits at other speeds.

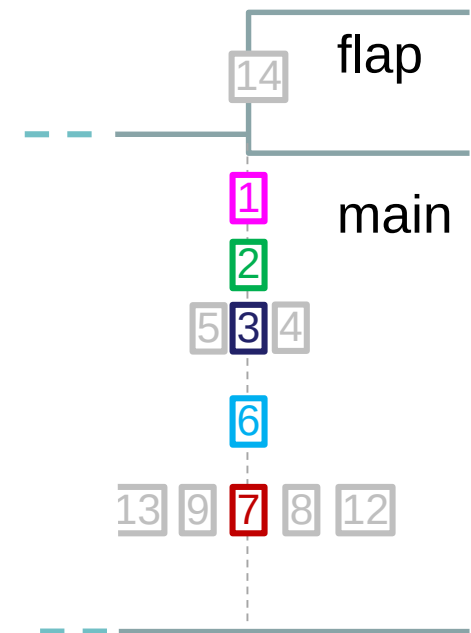
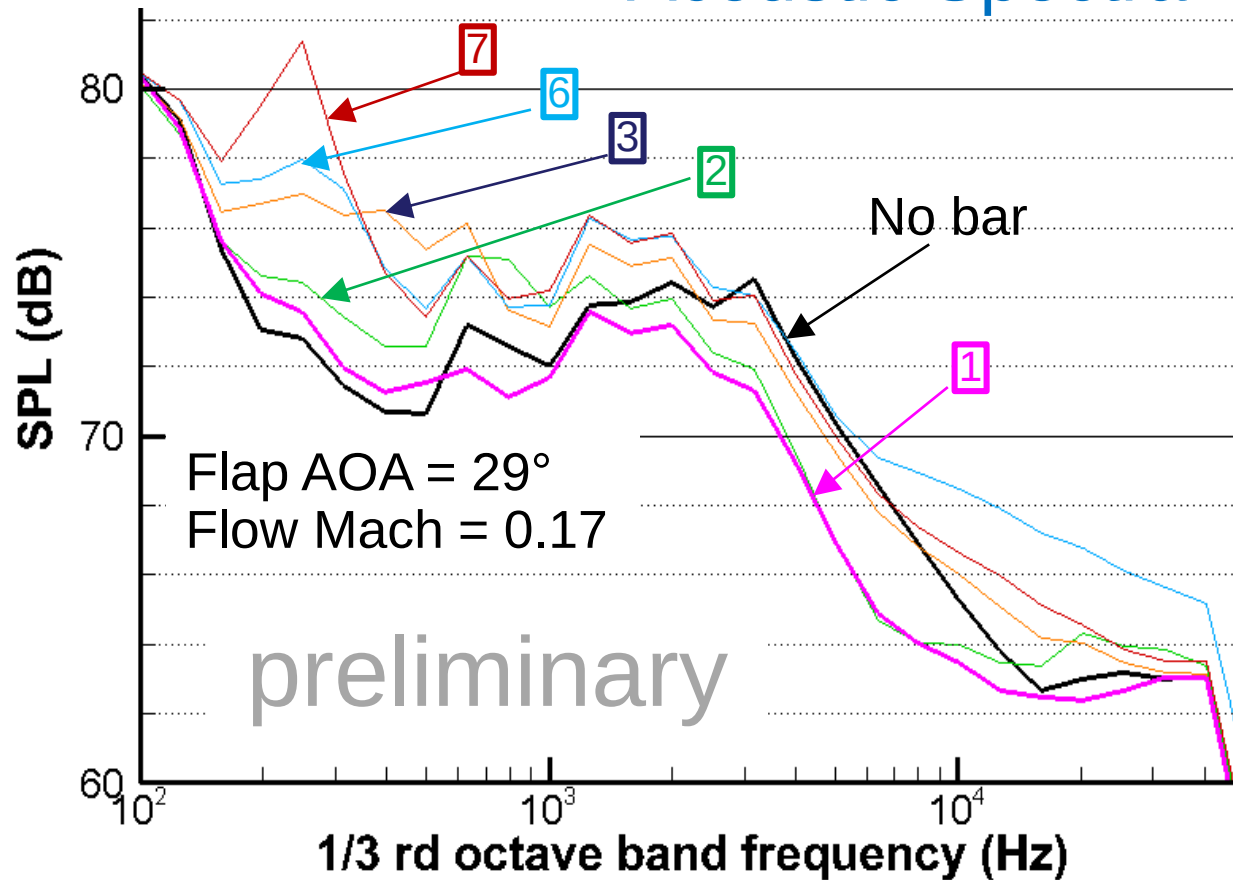
Effect of Streamwise Location

Bar $\approx 6''$ high x
0.5'' wide



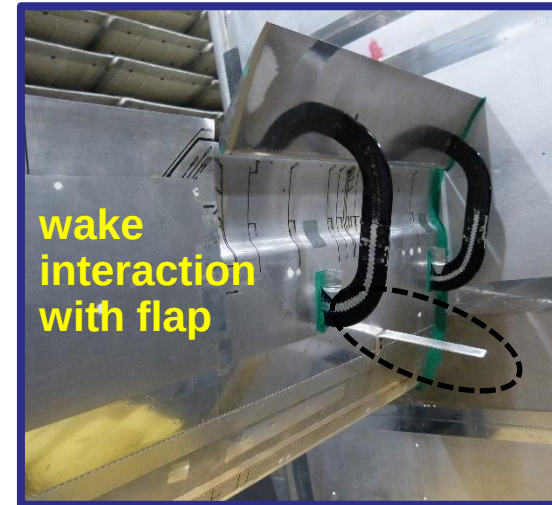
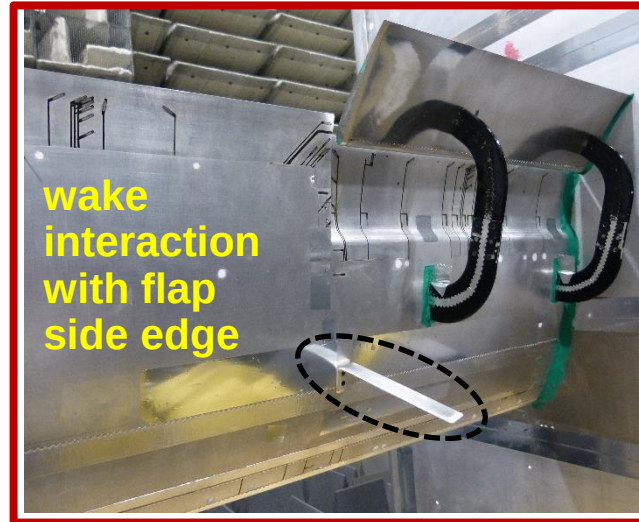
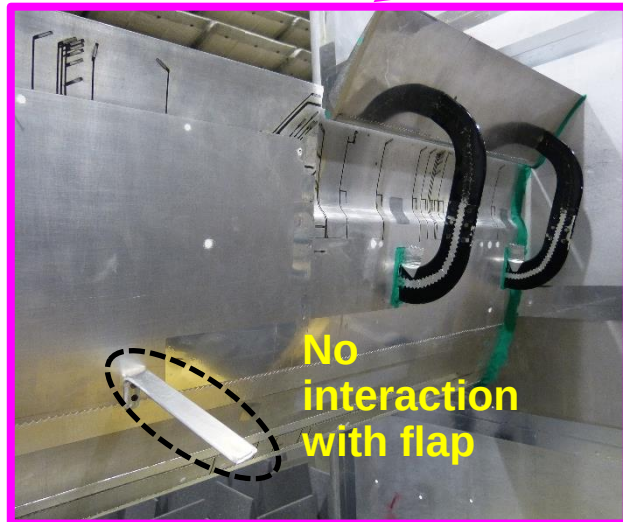
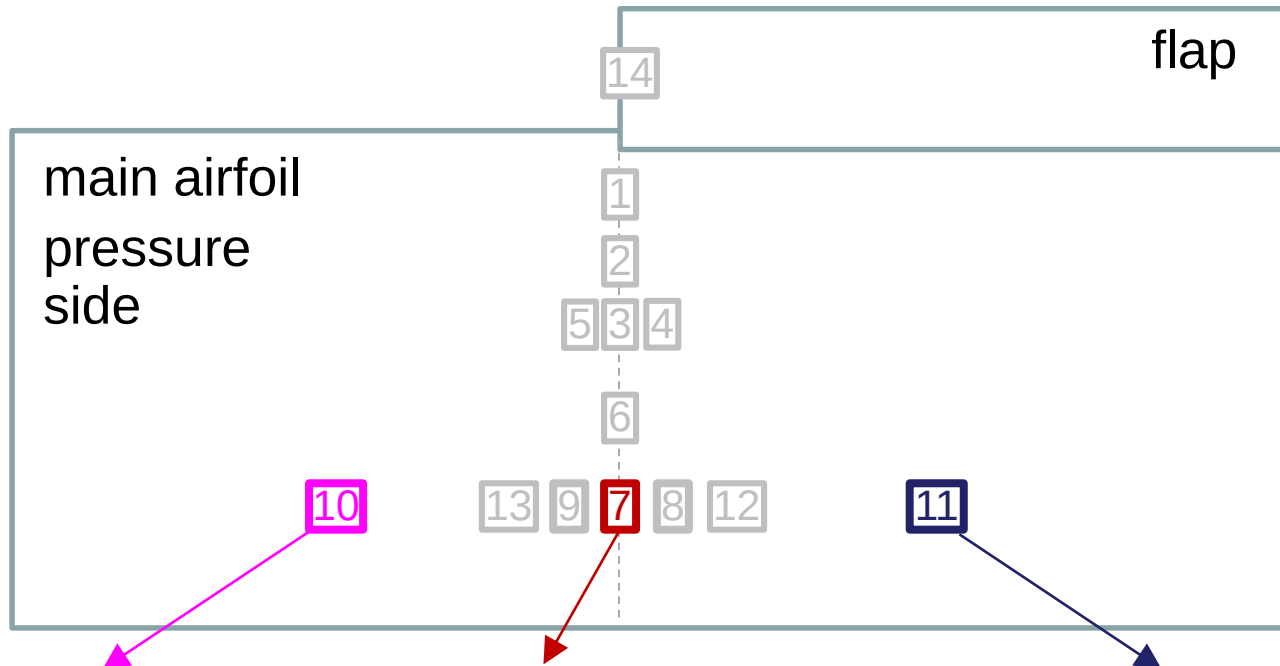
Effect of Streamwise Location: Long Bar

Acoustic Spectra



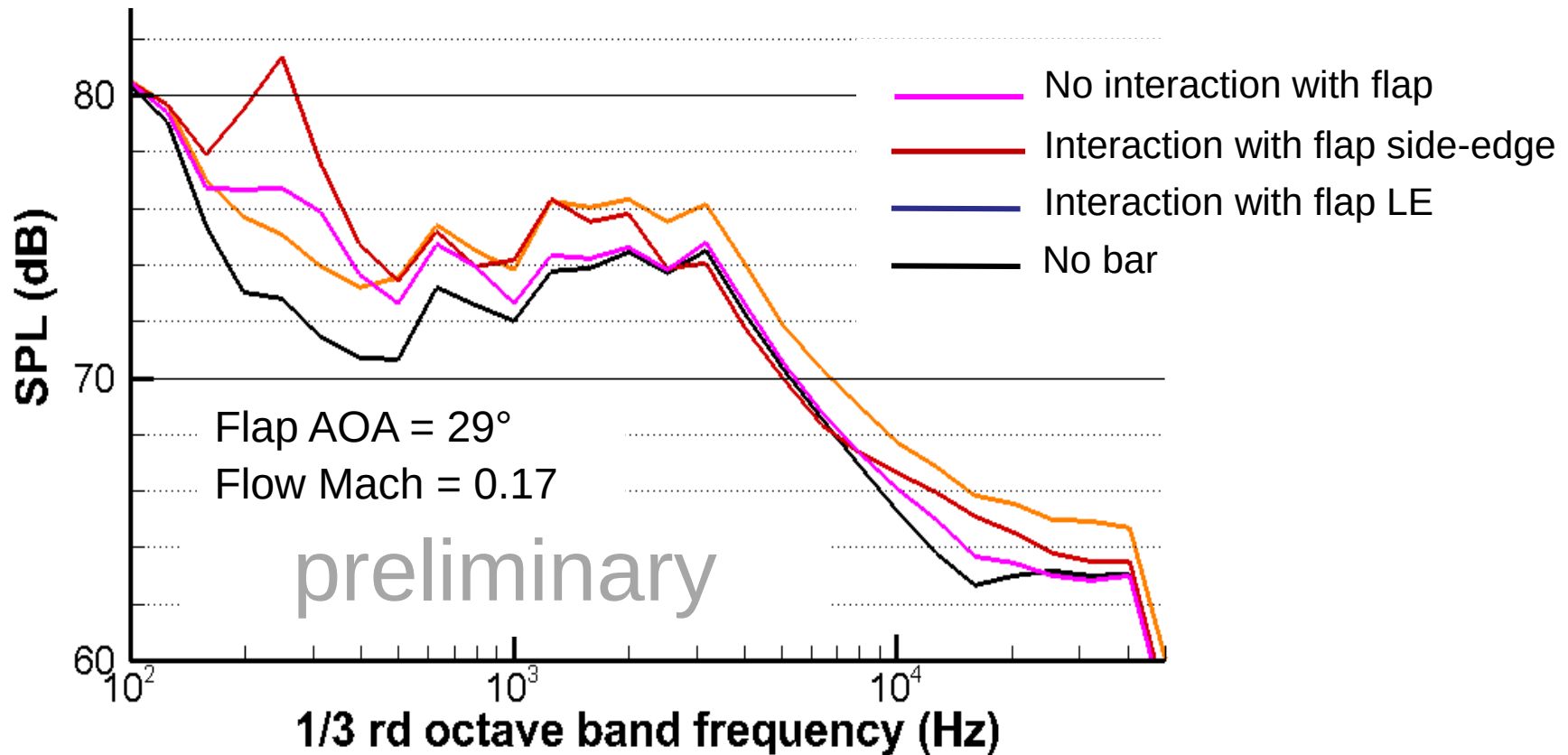
- Low-frequency tone develops as bar is moved upstream
 - Related to shed vortices from the bar impinging on the flap edge

Effect of Spanwise Location



Effect of Spanwise Location: Long Bar

Acoustic Spectra



- Noise from wake interacting with flap side-edge instead of flap LE:
 - Louder tonal content between 200-500Hz (interaction with shed vortices)
 - 2 dB quieter above 2 kHz

Status

- Test is on-going. Currently investigating:
 - Effects of landing gear placement on wake/flap interaction noise
 - Flap side-edge noise reduction potential from wake generators
- Data acquisition to be completed by late October 2014
- Data Analysis to follow



Structural Aspects of Airframe Noise Reduction Devices

Travis Turner

Quiet Performance
Fixed-Wing Project

Acoustics Technical Working Group Meeting
October 15-16, 2014

Acknowledgements



Fixed-Wing Project

Langley Research Center

Aeroacoustics

- David Lockard
- Mehdi Khorrami
- Craig Streett

Prototype Development

- George Hilton

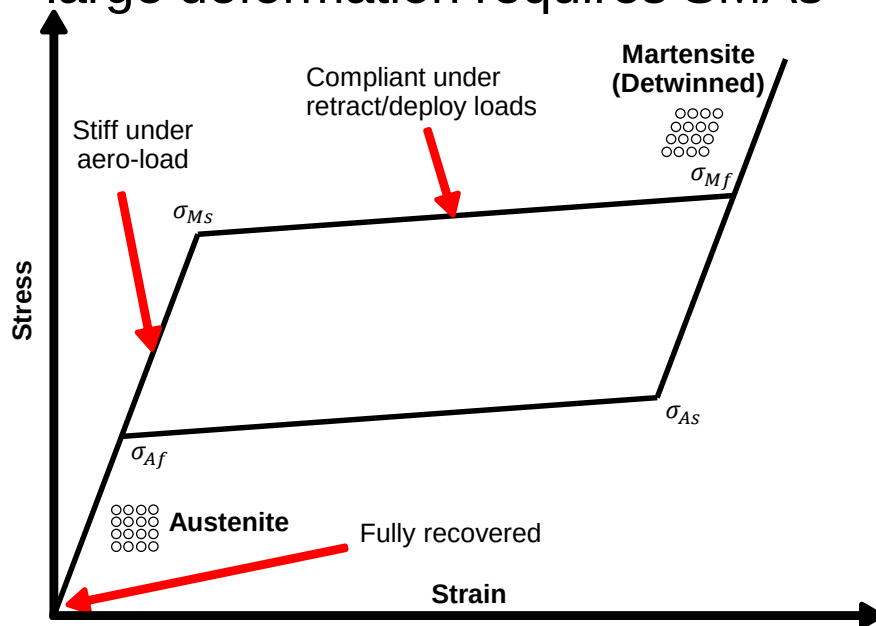
Materials & Structures

- Travis Turner
- Jim Moore
- Reggie Kidd, AMA
- Dave Long, AMA
- Darren Hartl, TAMU
- Will Scholten, TAMU

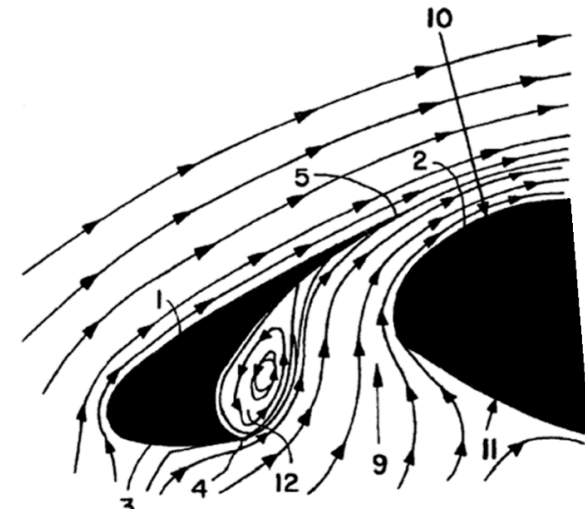
NASA Fixed Wing Project

Superelastic Slat-Cove Filler (SCF)

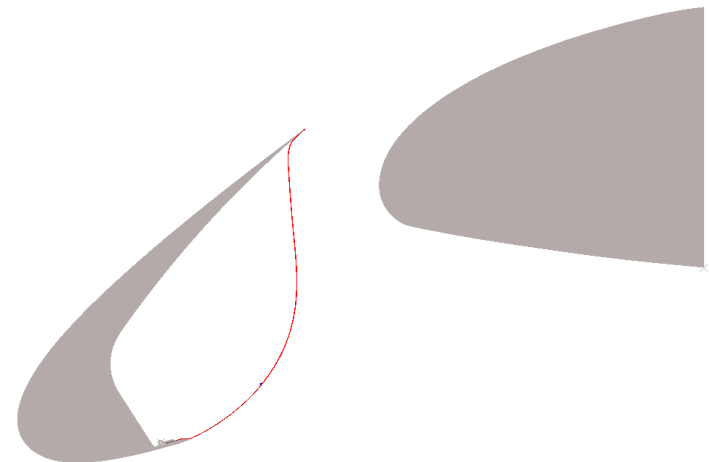
- High-lift devices deployed during approach/landing to improve lift & stall
- Gaps, edges and cavities produce unsteady aerodynamics and noise
- Slat flow is a significant component
- Slat-cove filler (SCF) proposed solution
 - large deformation requires SMAs



SMA Stress-Strain Curve



Flow streamlines in slat region of conventional airfoil



SCF Reconfiguration



Objectives & Approach



Fixed-Wing Project

Langley Research Center

Previous Work

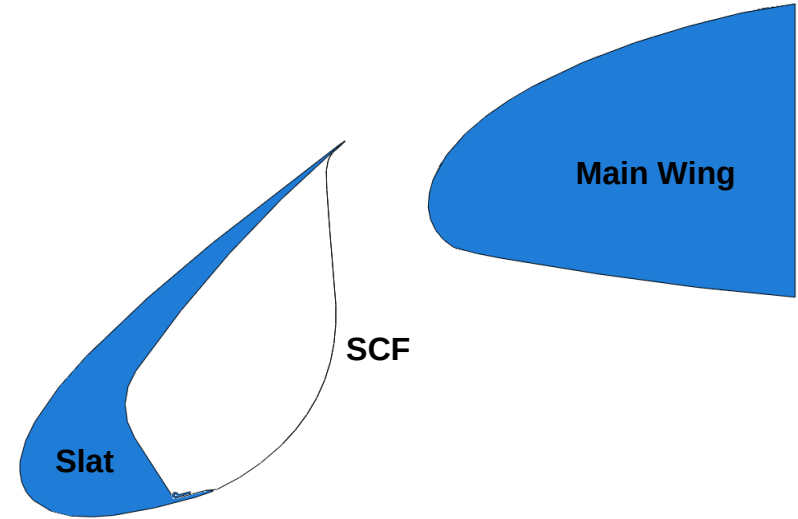
- Monolithic SMA-enabled SCF demonstrated on bench-top model
- Computational design capability demonstrated via Abaqus

Objectives

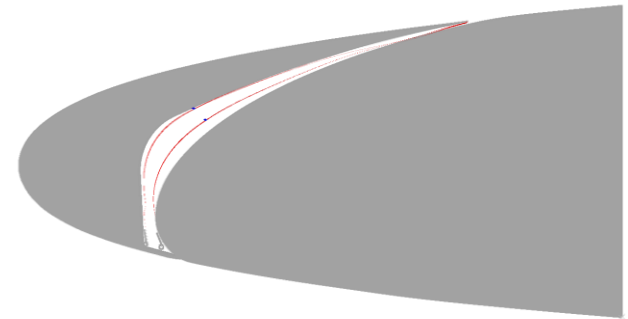
- Develop optimal design capability
- Determine SCF design sensitivity to airframe configuration
- Study 3D and Fluid-Structure Interaction (FSI) effects

Approach

- Modify 30P30N for baseline
- Abaqus FEA and OpenMDAO for DOEs and optimization



Modified 30P30N Slat & SCF Deployed



Modified 30P30N Slat & SCF Retracted



Computational Model



Fixed-Wing Project

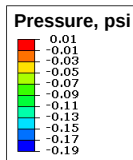
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Finite Element (FE) Model

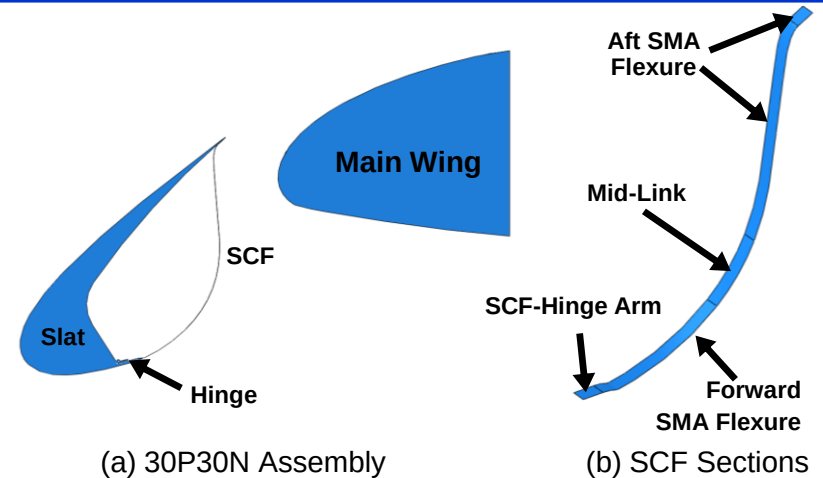
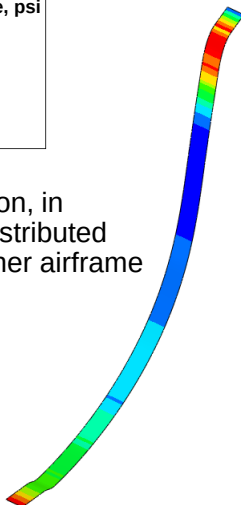
- Slat, main wing & hinge rigid
- SCF deformable
- Datum planes allow parametric study
- Nonlinear materials, large deformation, contact

Loads

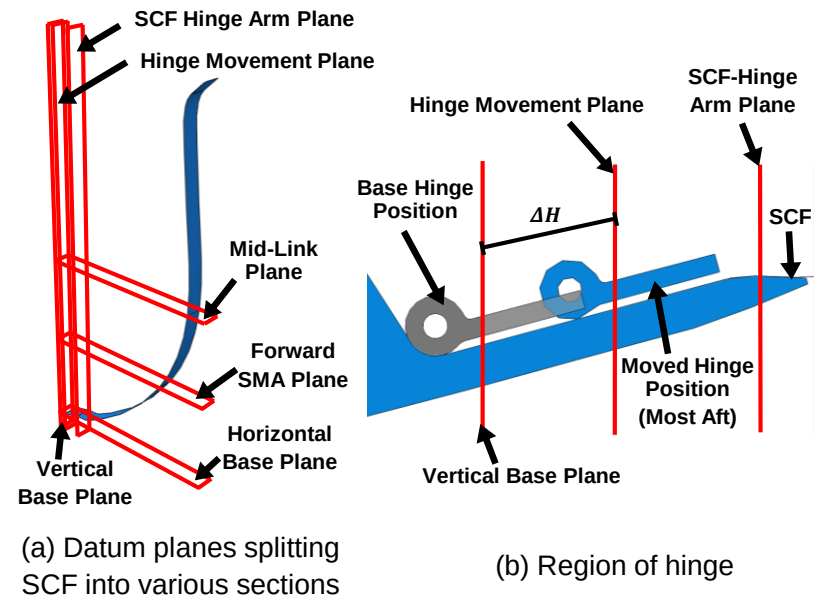
- Aerodynamic – static p distribution
- Retract-deploy kinematics



Nearly all suction, in contrast with distributed pressure on other airframe systems

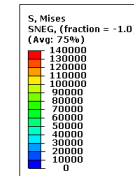
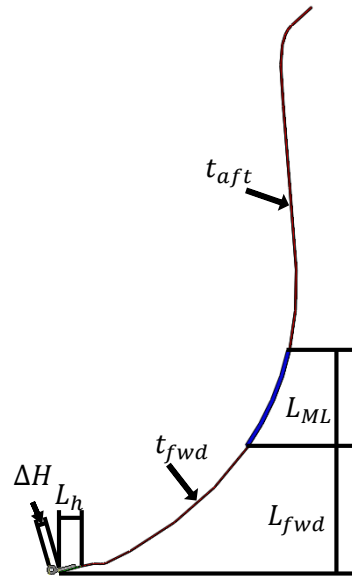


30P30N SCF FEA Model



Datum Planes and Hinge

Design Variables	Range
L_h	0.55-2.0 in
L_{fwd}	2.0-6.0 in
L_{ML}	0.1-6.0 in
t_{fwd}	0.02-0.06 in
t_{aft}	0.02-0.06 in
ΔH	0.0-0.7 in



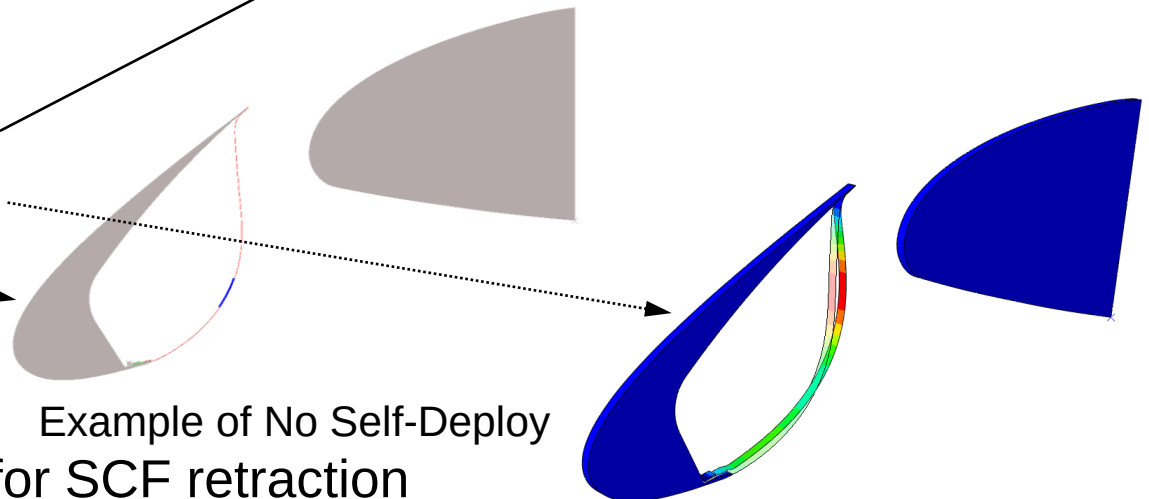
Example of Stress Concentration

Constraints

- Von Mises stress ≤ 100 ksi
- Static aero-deflection ≤ 0.1 "
- SCF must self-deploy

Metric

- Minimize actuator moment for SCF retraction



Example of Large Deflection



Optimization Results



- Both load cases used in optimization
- Algorithm: Non-Sorting Genetic Algorithm II (NSGA2)
- Multi-flexure design with small mid-link
 - Reducing mid-link to minimum shows similar moment profile but failure of displacement constraint
 - Suggests that displacement constraint may be marginal

Design Variable	Optimized Value	Nearest Bound
L_h	0.679 in	0.55 in
L_{fwd}	3.34 in	3.0 in
L_{ML}	0.848 in	4.5 in
t_{fwd}	0.0458 in	0.055 in
t_{aft}	0.0588 in	0.06in
ΔH	0.317 in	0.525 in
Output Parameters	Optimized Value	Nearest Constraint
U_{max}	0.0998 in	0.1 in
σ_{max}^{SMA}	73,300 psi	100,000 psi
Self-Deploy?	Yes	
M_{max}	231 lb-in	

- Assessing CFD options for accuracy and efficiency for Flow-Structure Interaction simulations
 - Models changing forces during deployment/retraction
 - Built in CFD solver in Abaqus inefficient
- Evaluating other materials for SCF
 - Shape Memory Polymer Composite
 - › Softens when current is applied
 - › Excellent SMPC properties & bond to SMA demonstrated
 - › Functioning (deployable and durable) SMPC SCF elusive
 - » Investigating SMA mid-link
- Similar FE analysis proceeding for slat-gap filler

