



Structural Aspects of Airframe Noise Reduction Devices

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Airframe Noise Reduction

Subsonic Fixed Wing

Technical Working Group Meeting

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Acknowledgements



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Aeroacoustics

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Materials & Structures

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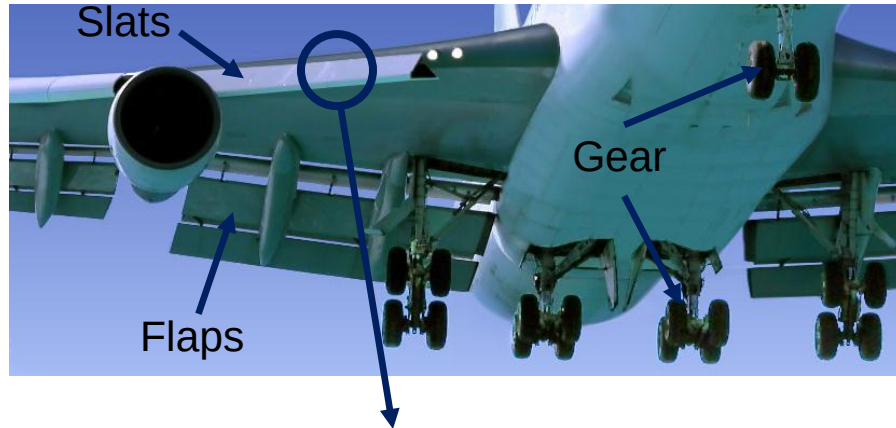
Airframe Noise Mitigation Concepts



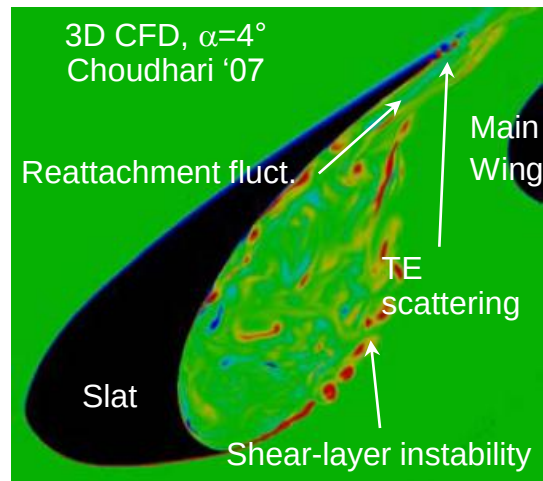
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Airframe noise sources



Wing Leading Edge Cross Section



Background

- Airframe noise comparable to engine noise during approach
- Slats & flaps are major contributors

- Characteristics
- Multi-element airfoil increases lift
- Unsteady flow creates noise
- Challenge: Reduce airframe noise w/o aero compromise (cruise or landing)

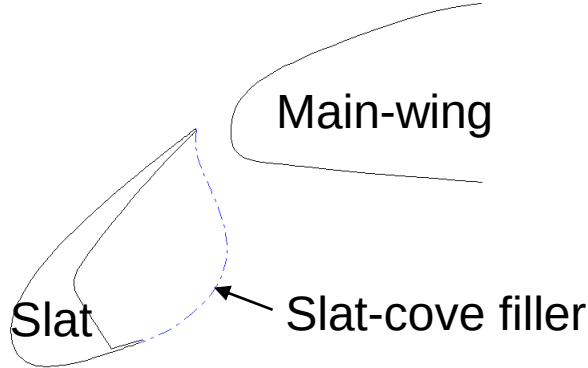
Superelastic SMA Slat-Cove Filler (SCF)



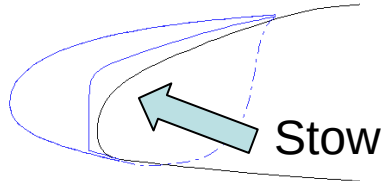
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Landing



Cruise



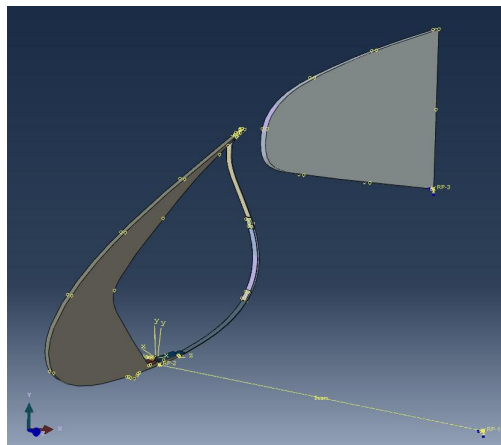
Objective:

- Guide gap flow
- Auxiliary flexible structure

Requirements:

- Highly deformable
- Load bearing
- Simple and lightweight
- Failsafe

Computational model



Approach: Employ superelastic shape memory alloy (SMA) material

- Deploys/retracts with slat
- Moderate noise reduction, 3-4 dB
- Straightforward implementation

Monolithic SMA Slat-Cove Filler



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Monolithic SMA SCF Bench-Top Demo @ 75% Scale

- Parametric study and analysis validation
- Actuation and aerodynamic loads under evaluation



Multi-Piece SMA Slat-Cove Filler

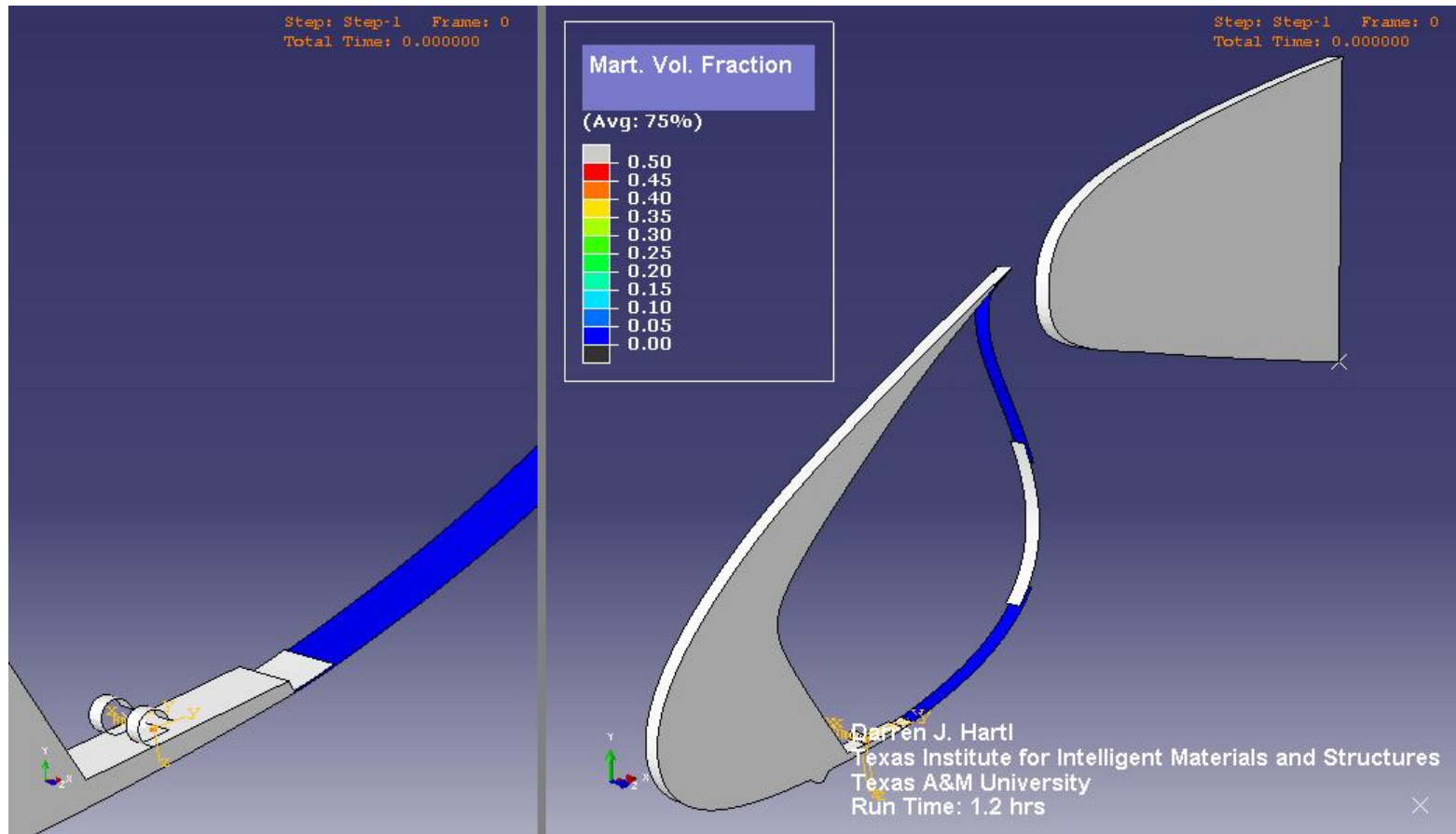


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Simulation of Multi-piece SMA SCF Retraction

- Large deformation, contact, nonlinear materials
- Facilitate parametric study and optimization



Shape Memory Polymer Composite SCF



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Objective:

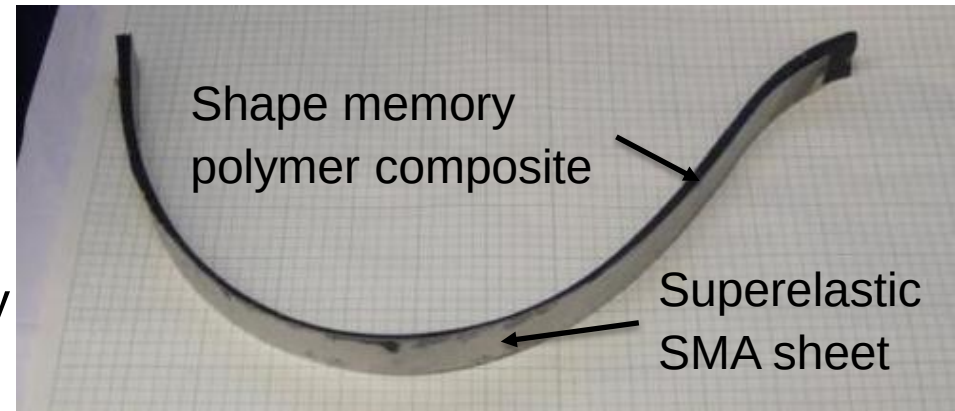
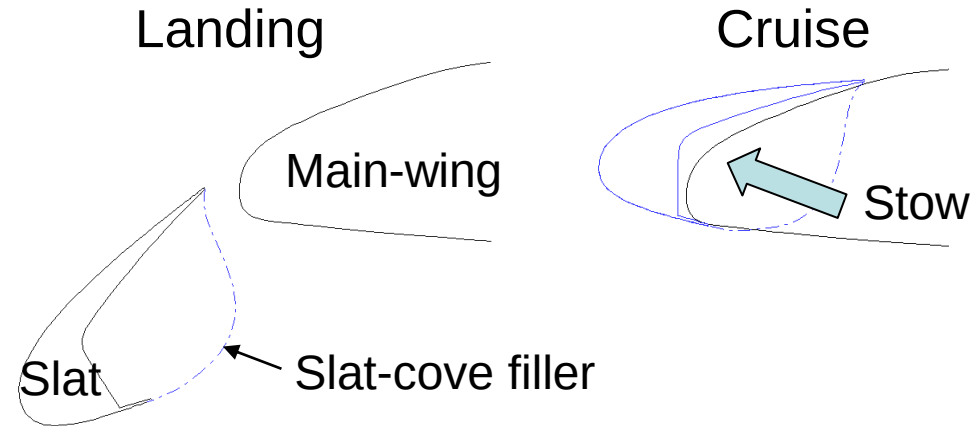
- Guide gap flow
- Auxiliary flexible structure
- Further reduce force to stow

Additional Requirements:

- Spatial addressability

Approach:

- Novel variable stiffness material - shape memory polymer with conductive filler
- Laminate with SMA foil for elasticity and durability



Shape Memory Polymer Composite SCF

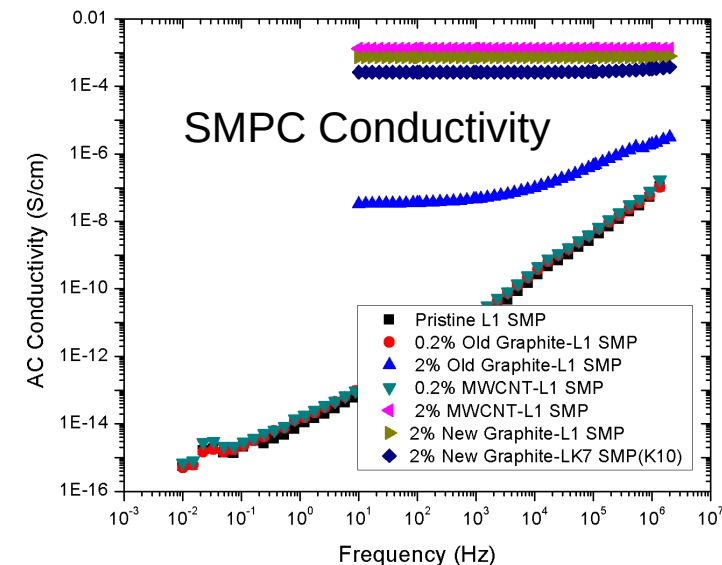
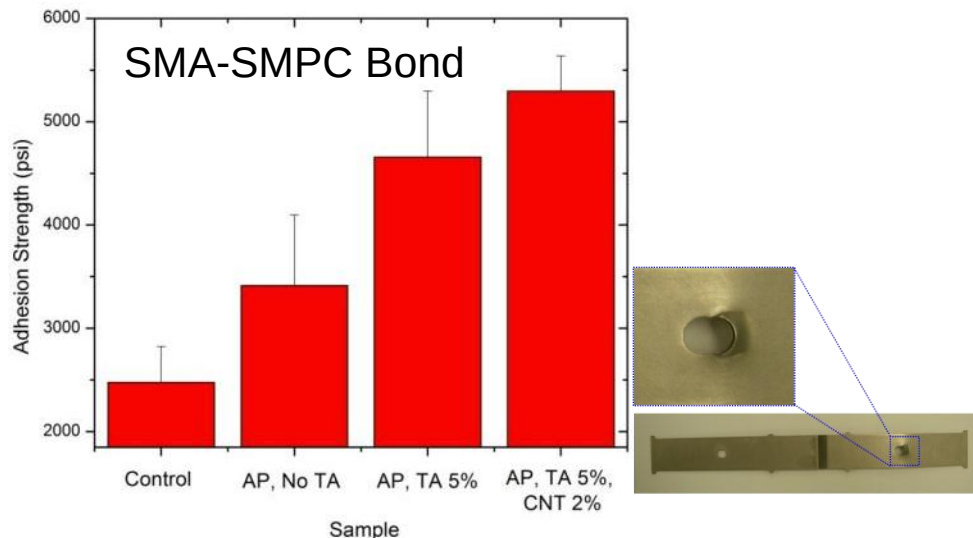
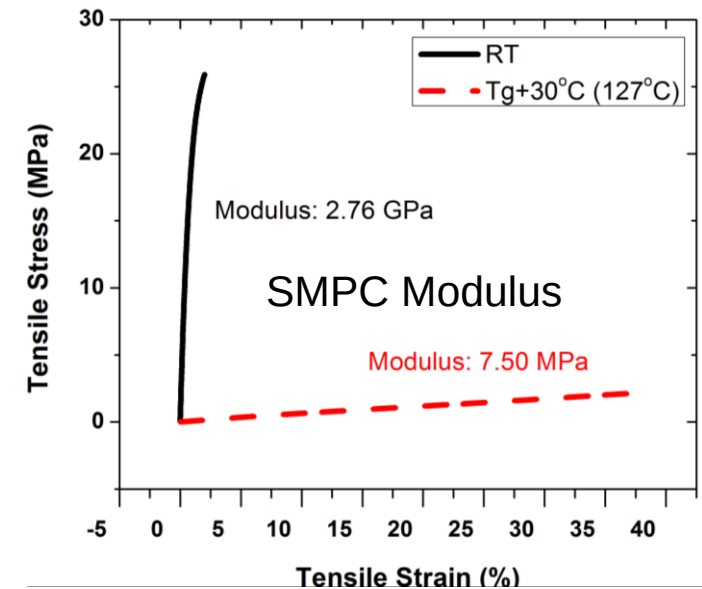


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Progress:

- Large modulus change (~ 3 GPa to ~ 2 MPa)
- High electrical conductivity ($\sim 10^{-3}$ S/cm)
- Shape set of SMA foil
- Bonding of SMA to SMPC
- Segmentation of electrode demo



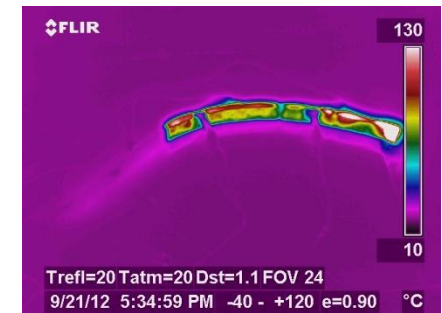
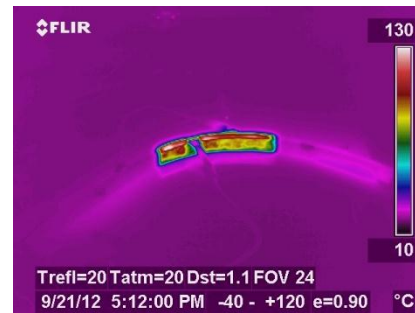
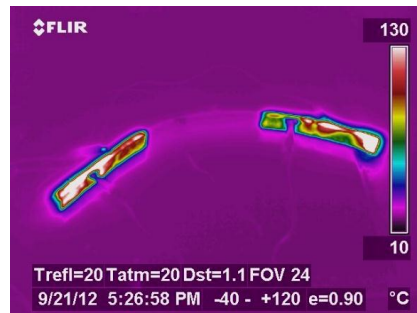
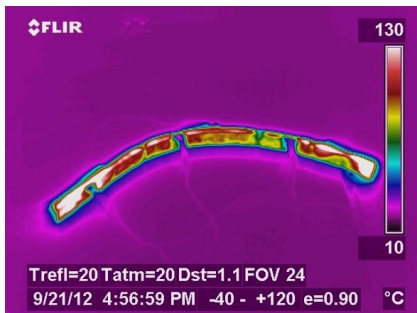
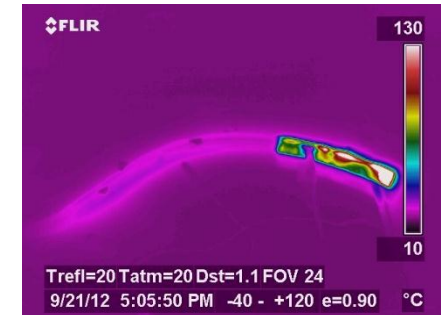
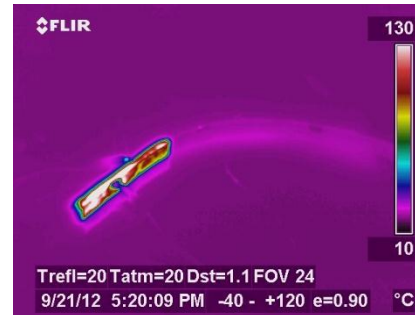
Shape Memory Polymer Composite SCF



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Segmentation of Electrode



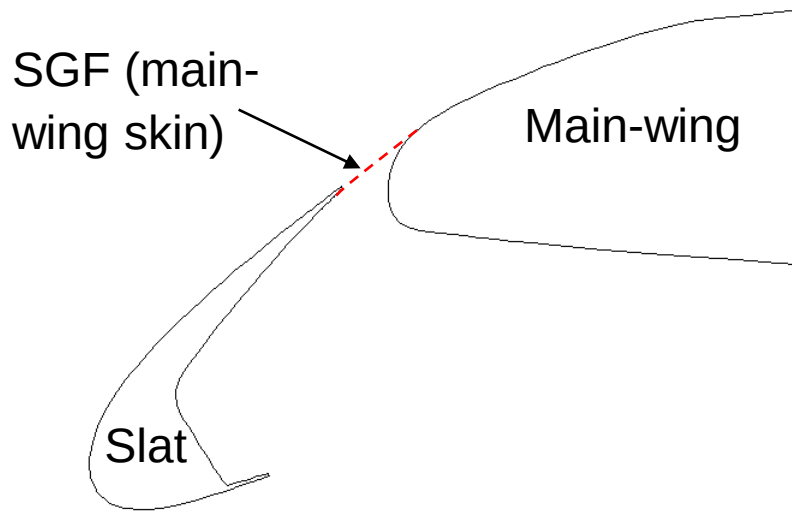
Superelastic SMA Slat-Gap Filler (SGF)



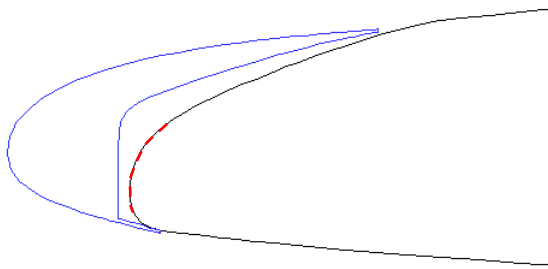
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Typical Landing



Cruise



Objective:

- Block gap flow strategically
- Employ section of main-wing skin

Requirements:

- Failsafe
- Highly deformable
- Load bearing
- Simple and lightweight

Solution: Employ superelastic SMAs

- Excellent noise reduction, 8-10 dB

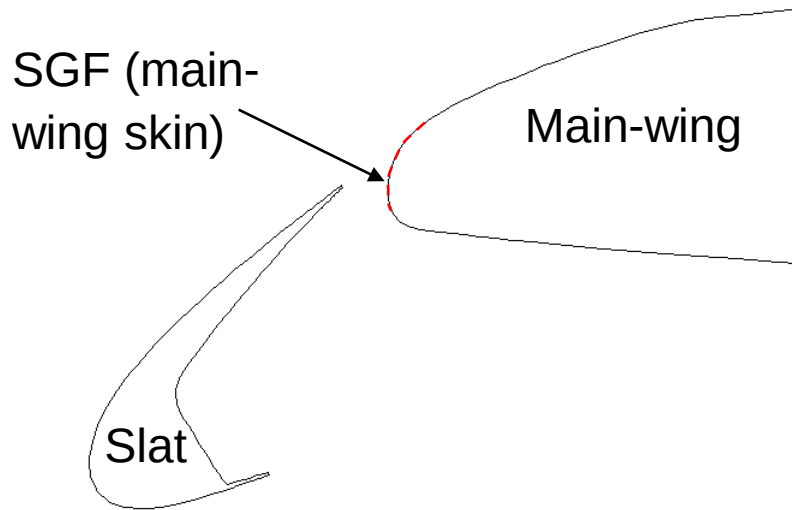
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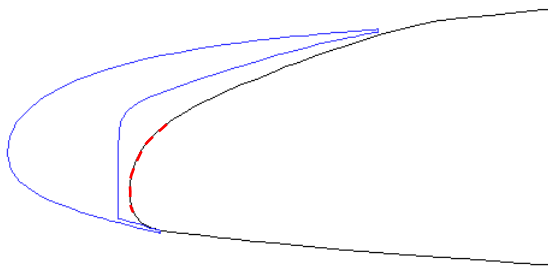
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Atypical Landing



Cruise



Objective:

- Block gap flow strategically
- Employ section of main-wing skin

Requirements:

- Failsafe
- Highly deformable
- Load bearing
- Simple and lightweight

Solution: Employ superelastic SMAs

- Excellent noise reduction, 8-10 dB
- Slat gap opens when necessary
- Deploys/retracts with slat
- Mod. implementation complexity

Superelastic SMA Slat-Gap Filler (SGF)



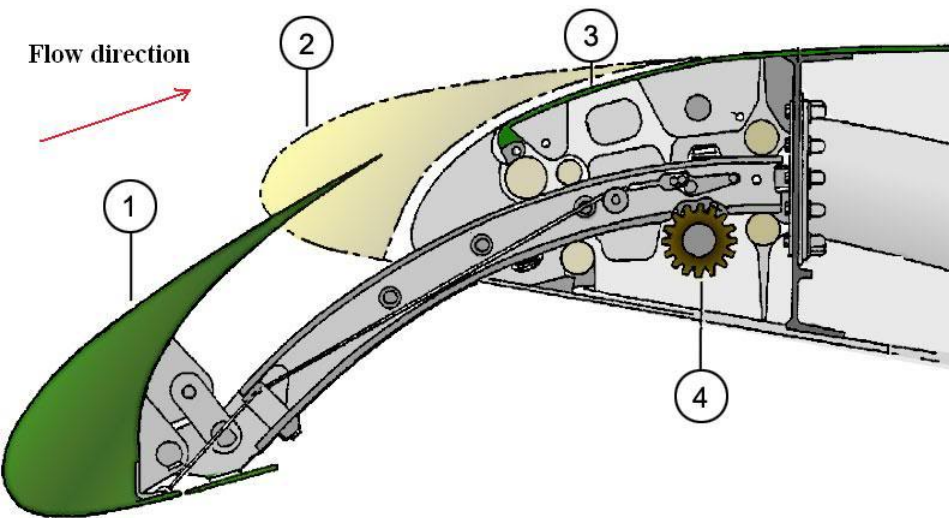
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Slat-Gap Filler Bench-Top Demo @ 75% Scale

- Design completed and components procured
- Bench-top model fabricated & assembled
- Simulation under development for parametric study and optimization
- Actuation loads and aerodynamic loads under investigation

Typical Slat Mechanism



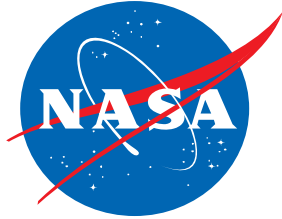
Model Mechanism Demo



Future Plans



- Optimize slat-cove filler designs
- Demonstrate active shape memory polymer composite SCF
- Optimize slat-gap filler design



Trailing-Edge Flap Side-Edge Noise

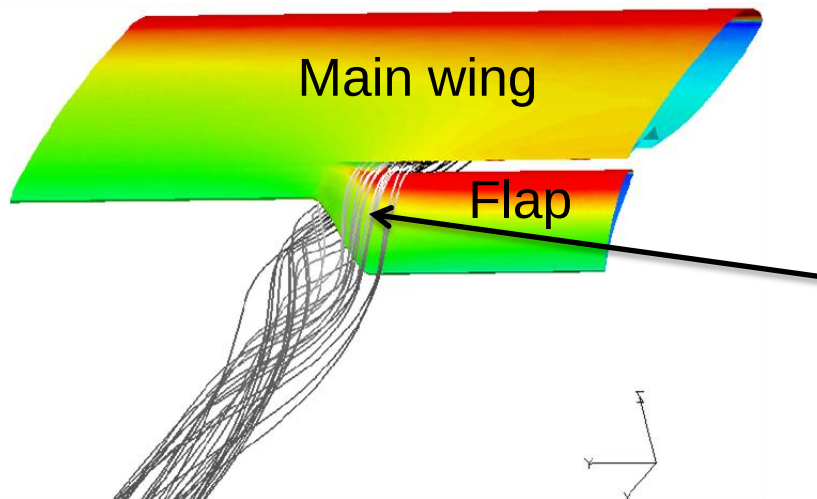
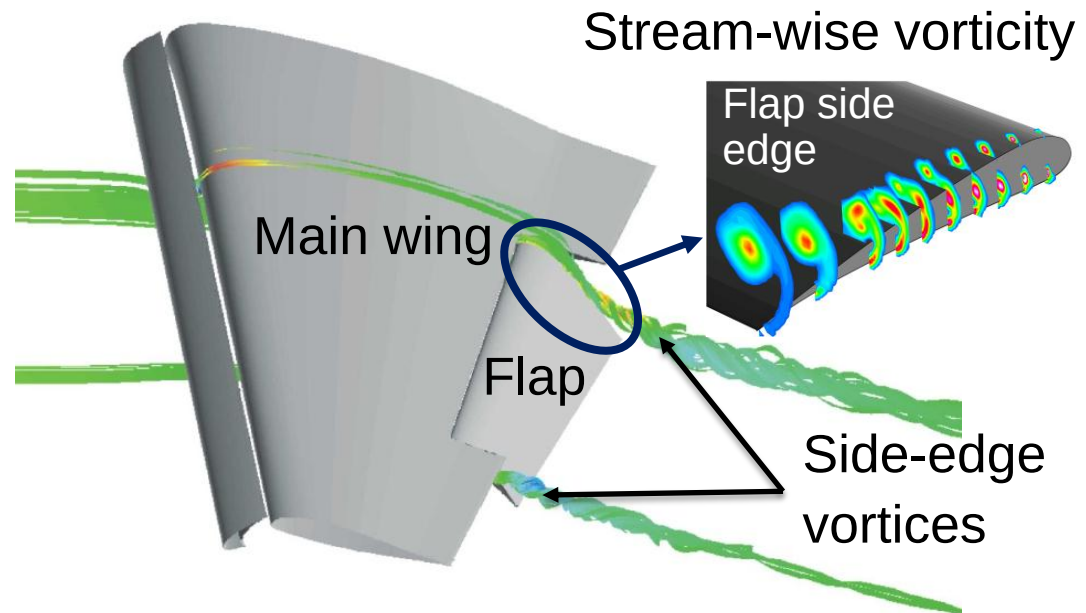


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Noise Production Mechanisms

- Vortex instability
- Shear layer instability



Notional Solutions

- Flow-resistive elements – porous edges, brushes
- Fence
- Conformal link – delay vortex roll-up
 - Large deformation/motion
 - Subtends significant flap span
 - Heavily loaded – must sustain lift

FLEXSEL: G550 Model for 14x22 Test



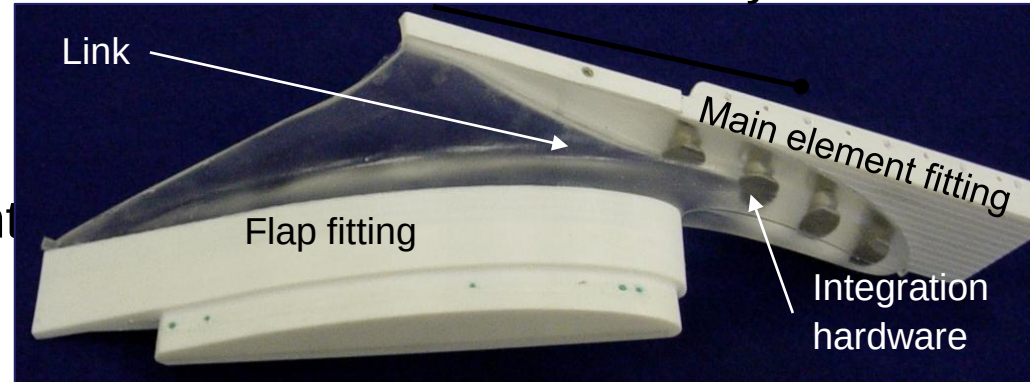
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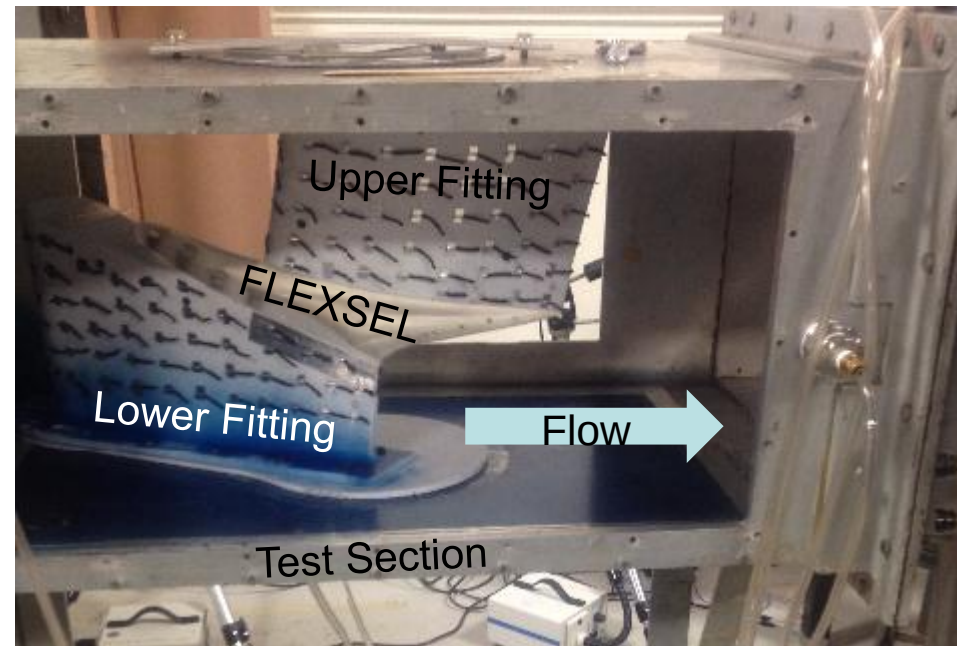
Static Model Progress

- Baseline design developed
- Mechanical tests – tensile, planar, lap-shear, subcomponent
- Hardware developed by rapid prototyping
- Tested in small tunnel

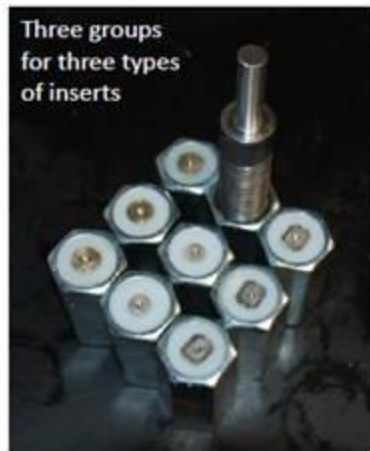
FLEXSEL Assembly



Risk-Reduction Test



Subcomponent Tests



FLEXSEL: Bench-top Articulating Model



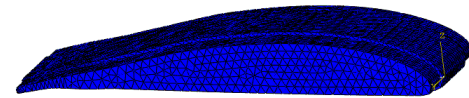
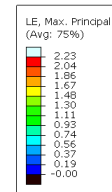
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Link Simulation

Mechanized Model Progress

- Hyperelastic material models
- Link modeling
- Subcomponent tests modeling
- Issues – very large deformation, distortion, adhesion, contact
- Optimize for min. weight/force with acceptable shape
 - Foam core
 - Stress-free intermediate shape
 - Scaling trends
 - Optimized fitting and integration hardware



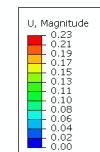
Step: Step-1 Frame: 0
Total Time: 0.000000



Displacement U1=1, in BC2, and U3 = rotational constraint imposed by analytic fu
ODB: Response.odb Abaqus/Standard 6.11-1 Wed Mar 21 13:17:18 Eastern Daylight Time 2012

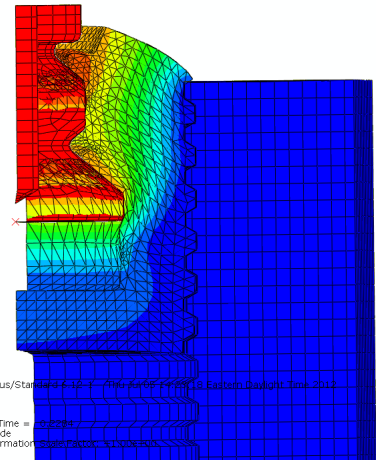
Step: Step-1, Nonlinear Analysis
Increment 0: Step Time = 0.000
Primary Var: LE, Max. Principal
Deformed Var: U Deformation Scale Factor: +1.00e+00

Subcomponent Simulation



ODB: Resp.odb Abaqus/Standard 6.11-1 Wed Mar 21 13:17:18 Eastern Daylight Time 2012

Step: Step-1
Increment 72: Step Time = 0.000
Primary Var: U, Magnitude
Deformed Var: U Deformation Scale Factor: +1.00e+00



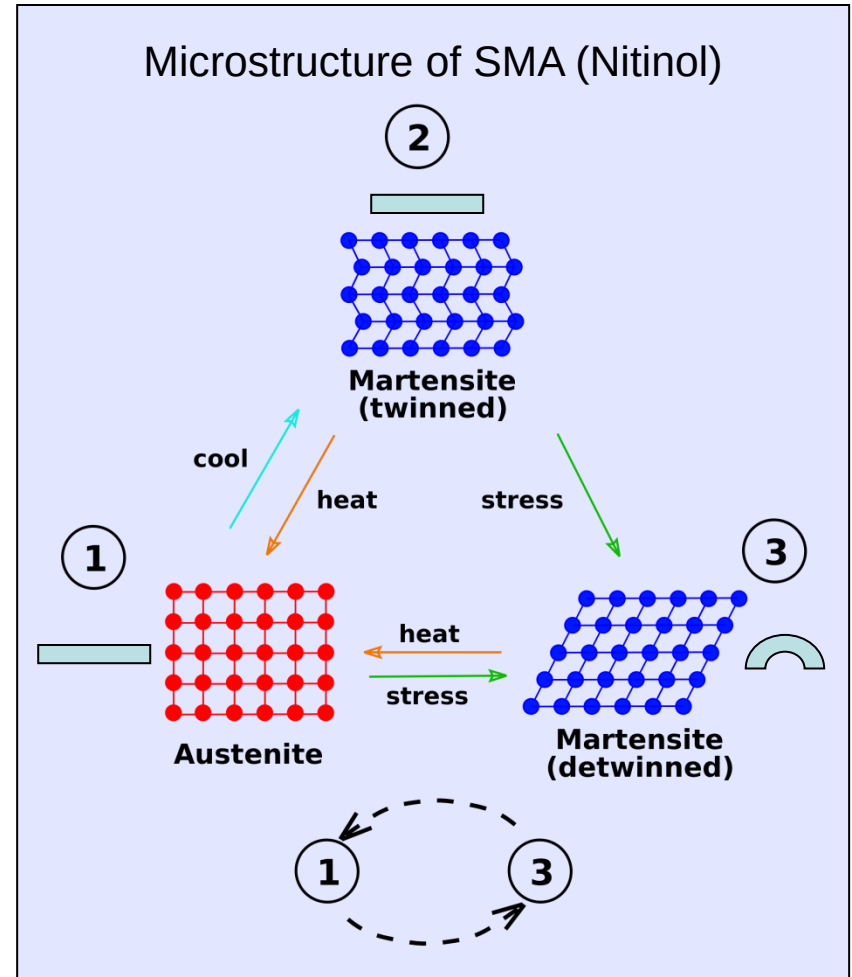
Shape Memory Effect & Superelasticity

Thermoelastic Shape Memory

- Typical service condition 3
- Heat to actuate 1
- Generates deformation and/or stress
- Applications include stiffness control, shape control, release devices, etc.
- Cool to return 3

Superelasticity

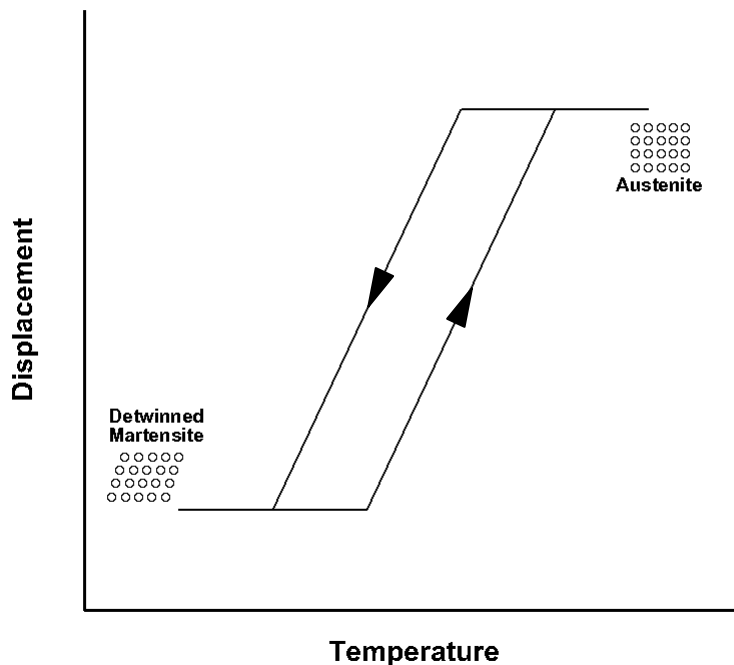
- Typical service condition 1
- Apply stress to 3
- Deformation and work
- Applications include reconfigurable structures and energy storage/dissipation
- Remove stress to 1



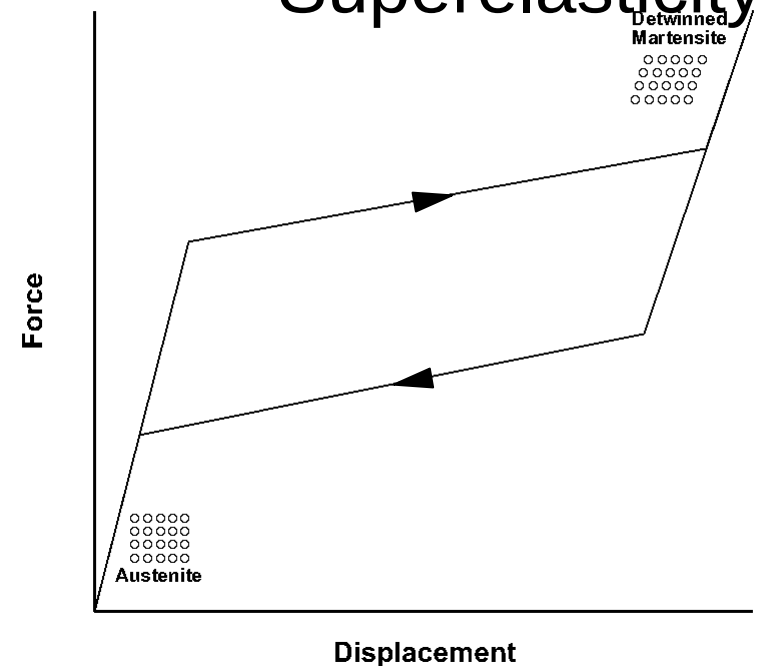
Shape Memory Effect and Superelasticity

- Superelastic material returns to its formed shape after the removal of even relatively high applied strains
 - Takes advantage of a change in underlying crystal structure

Thermoelastic SME



Superelasticity



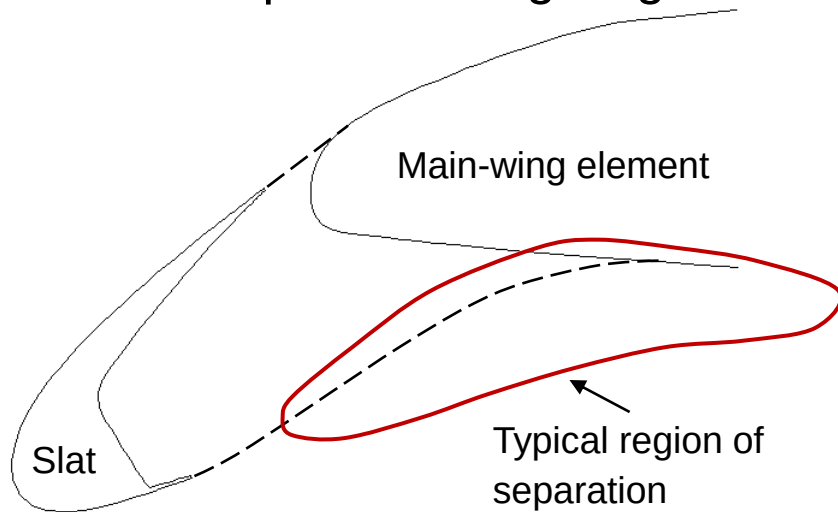
DLE & SGF Aerodynamics



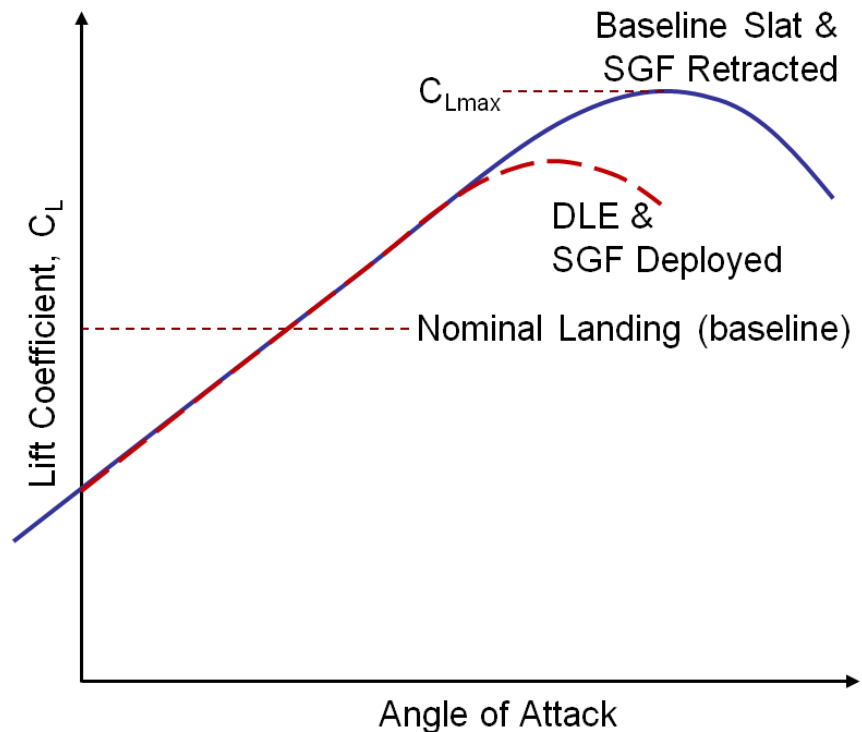
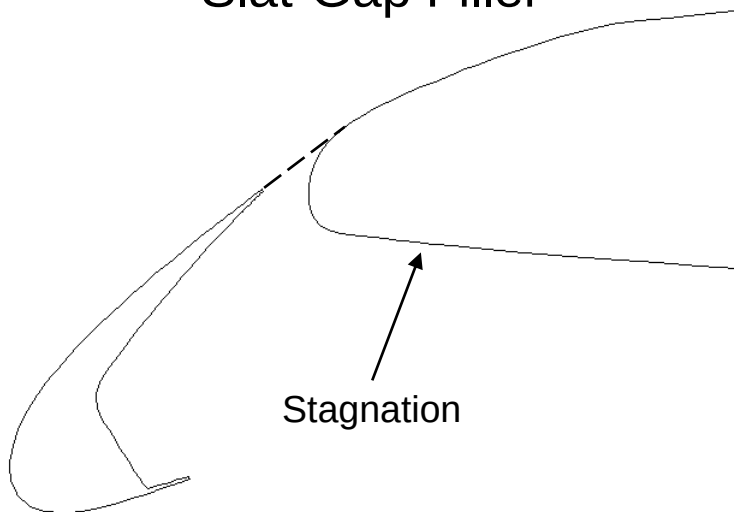
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Drooped Leading Edge



Slat-Gap Filler



- DLE & deployed SGF aerodynamics $\Rightarrow$ aeroacoustics similar
- DLE exhibits deficit in high-lift aero
 - AFC or other prov. required
- SGF achieves baseline high-lift aero via autonomous retraction
- SGF exhibits low complexity & weight

Leading-Edge Noise Sources and Solutions

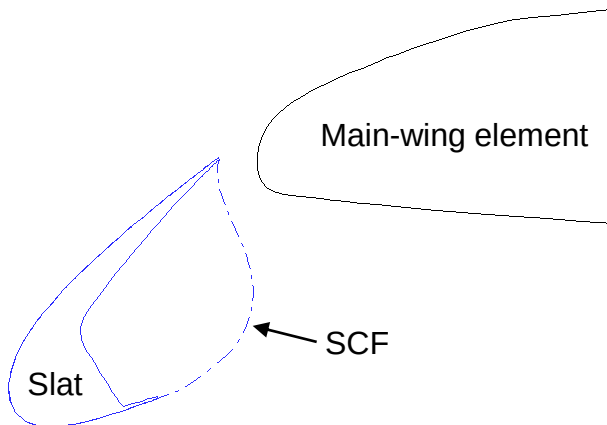


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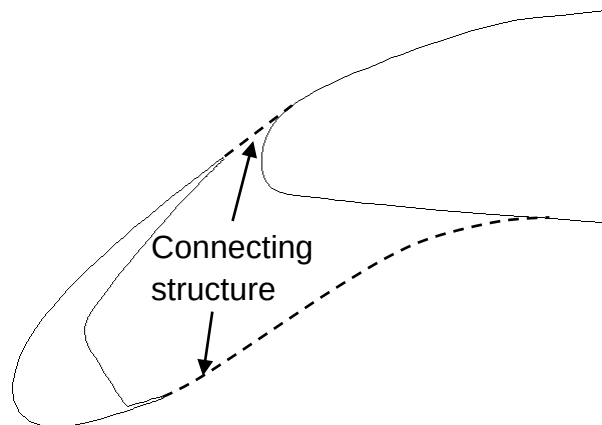
Notional Solutions

Slat-cove filler



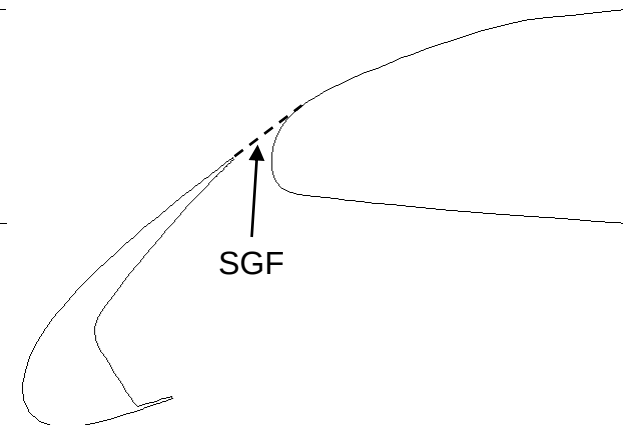
- Moderate noise reduction
- Excellent high-lift
- Low weight/complexity

Drooped leading edge



- Excellent noise reduction
- Compromised high-lift
- High weight/complexity

Slat-gap filler



- Excellent noise reduction
- Excellent high-lift
- Mod. weight/complexity