AFLONEXT FINAL CONFERENCE

Active Buffet Flow Control on Wing Trailing Edge

AFLoNext

2ND GENERATION ACTIVE WING

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ACTIVE BUFFET FLOW CONTROL ON WING TRAILING EDGE

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Outline

\ Motivation / Objectives

\ Benchmark of CFD Simulation Capabilities

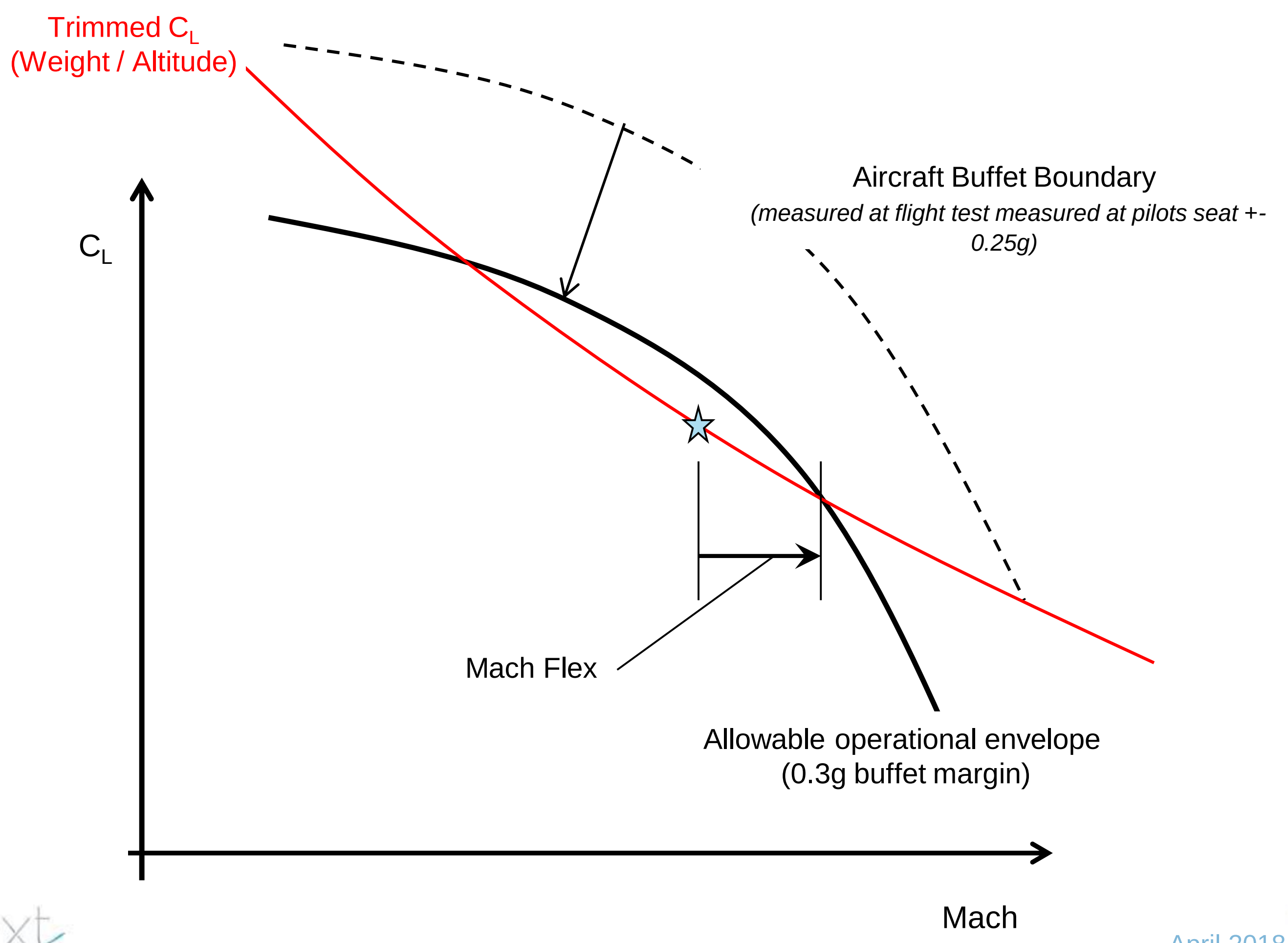
\ Design of Mini-TED devices for Buffet Control

\ Evaluation at Aircraft Level

\ Lessons Learnt

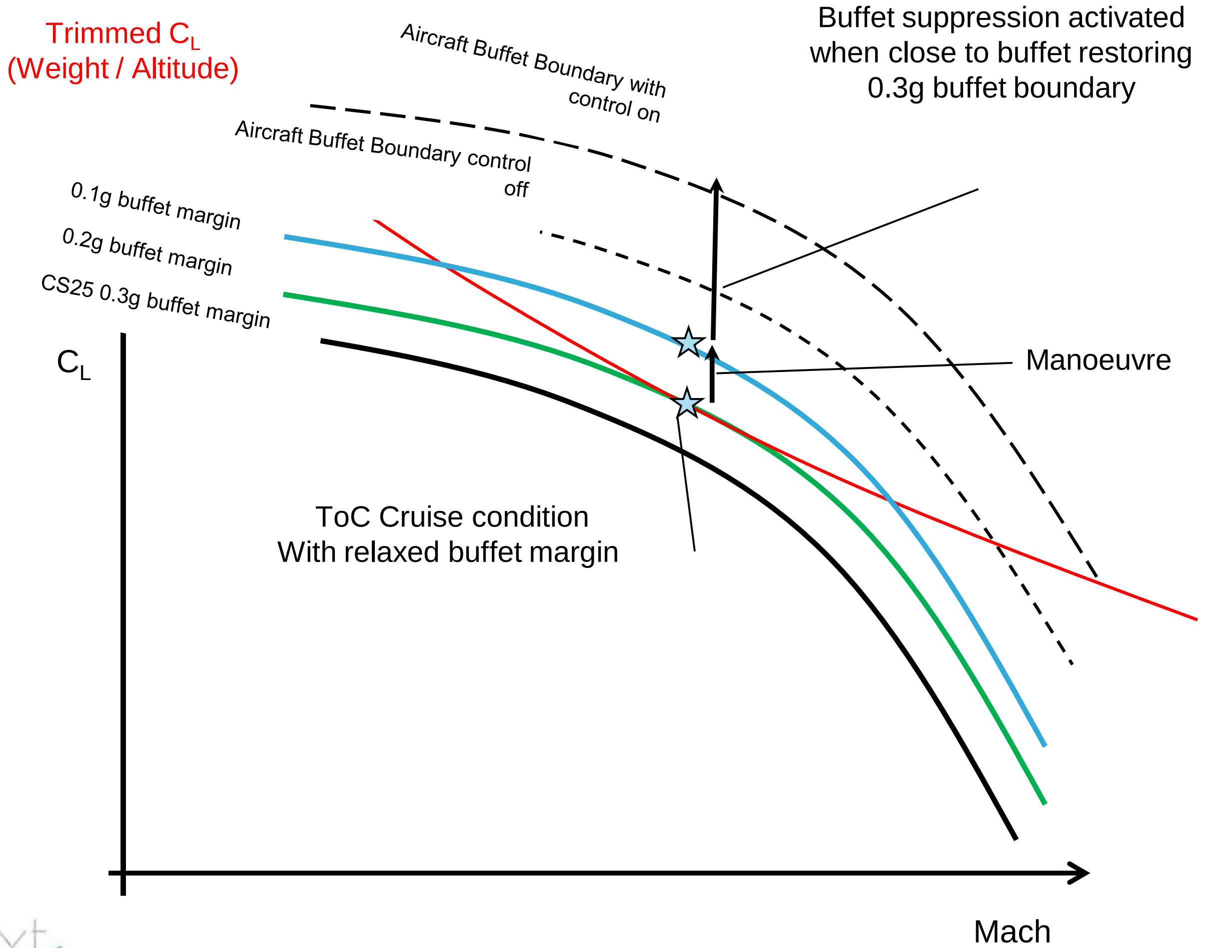
Motivation

Potential of Buffet Control



Motivation

Potential of Buffet Control



Objectives

Predict the performance of different control devices

Identify the most promising application (buffet control?)

Perform parametric study to find more efficient configurations

Optimisation w.r.t. a specific objective (max lift/efficiency?)

Benchmark of CFD Simulation Capabilities

Prerequisite for design:

\ validated design environment

\ common baseline

Validation process:

\ definition of benchmark experiments for comparison

\ case studies by contributors

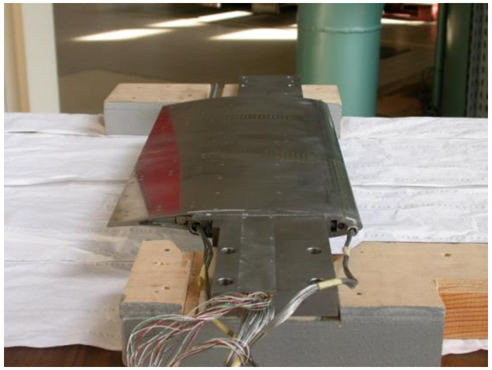
\ cross-comparison of results

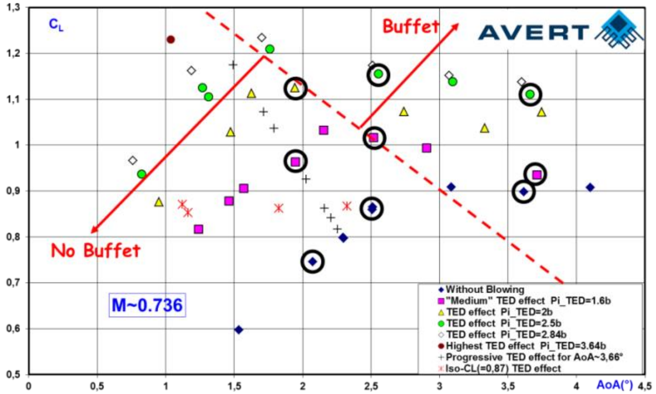
\ derivation of lessons learnt

Benchmark of CFD Simulation Capabilities

Benchmark Experiments used AFLoNext:

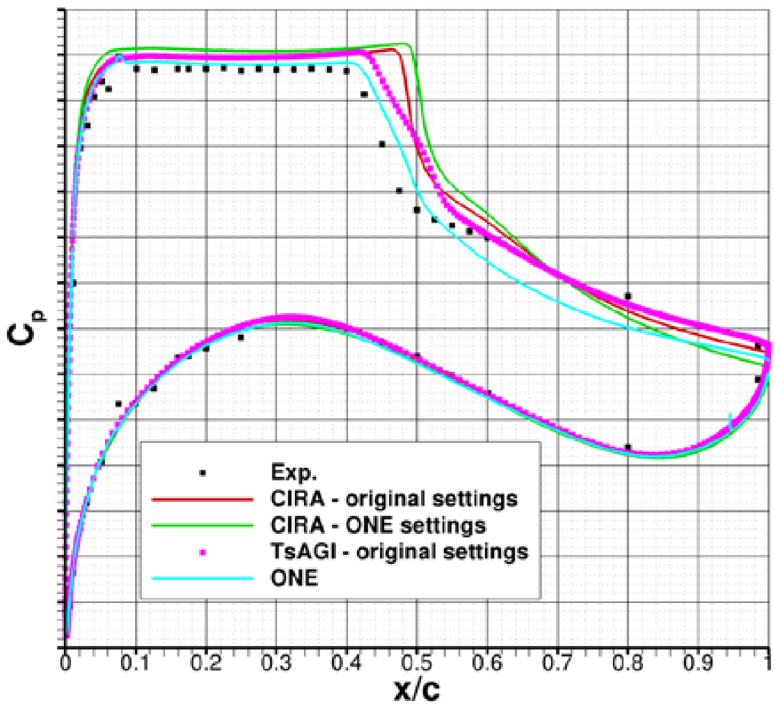
- buffet flow control experiments conducted within the AVERT project (EU 5th Framework)
  - 2D airfoil experiments performed at VZLU
  - 3D half-model experiments performed at ONERA
- selected test case
  - transonic flow with/without buffet
- data for comparison
  - steady/unsteady pressure and aerodynamic coefficients



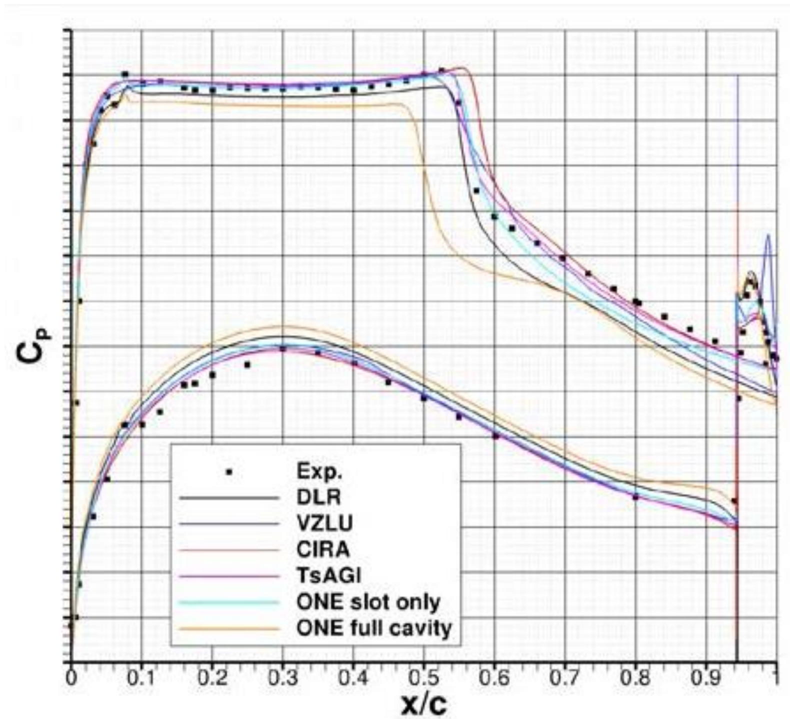


Benchmark of CFD Simulation Capabilities

2D CFD simulation validation



high AoA, no AFC



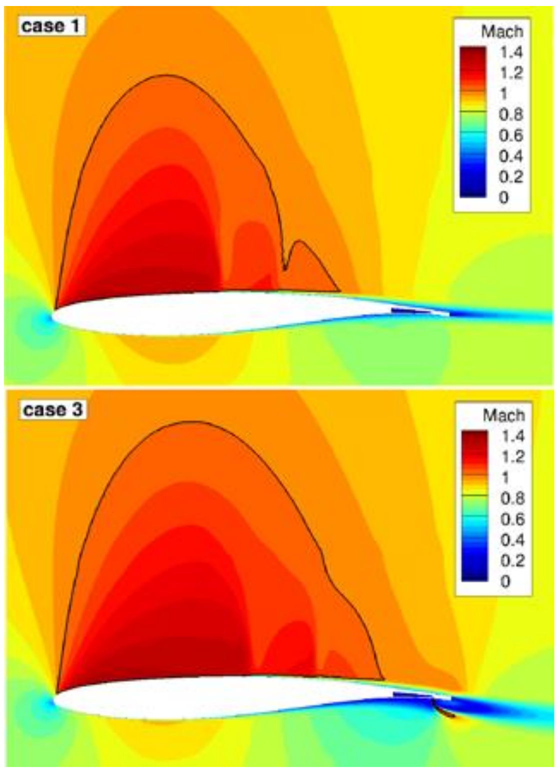
med AoA, with AFC

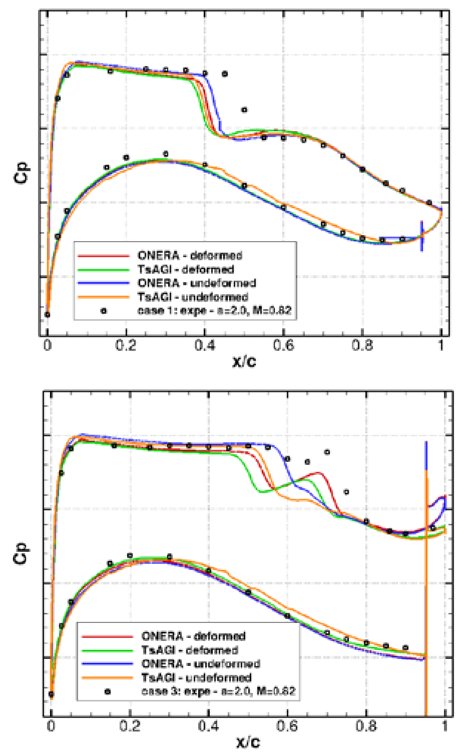
Benchmark of CFD Simulation Capabilities

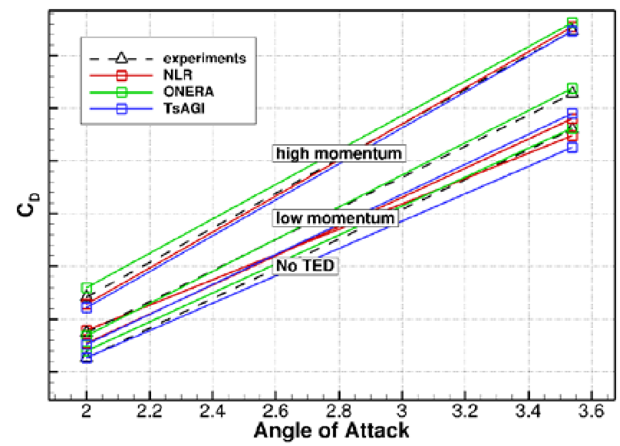
3D CFD simulation validation

no AFC

with AFC



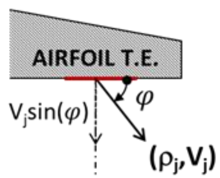




Design of Mini-TED devices for Buffet Control

Design problem

- **Design parameters object of investigation:**
  1. Jet mass-flow rate coefficient: $0.2\% \leq C_{\dot{m}} \leq 0.8\%$ (ref. = 0.43%)
  2. Jet inclination angle: $10° \leq \varphi \leq 170°$ (ref. = 90°)
  3. Slot position: $90\% \leq \left(\frac{x}{c}\right)_{T.E.}^{slot} \leq 98\%$ (ref. = 94.5%)
  4. Slot size: $0.1\% \leq \frac{l_{slot}}{c} \leq 0.5\%$ (ref. = 0.25%)



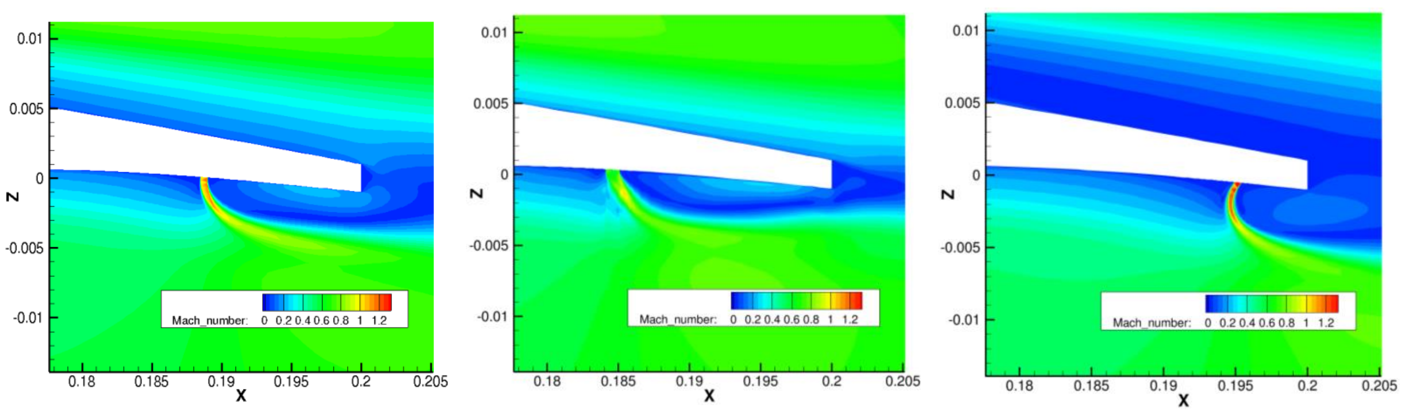
- BASELINE configuration has no blowing
- REFERENCE AFC is fluidic Gurney with reference (AVERT) values of design parameters, and C_μ = 1.12%.

1. **Optimizations for maximum lift:** objective = $C_l(\alpha=0.9°) + C_l(\alpha=3.4°)$
2. **Optimization for maximum lift-over-drag** ratio (E): objective = $E(\alpha=0.9°) + E(\alpha=3.4°)$

Design of Mini-TED devices for Buffet Control

Optimization result

	REF-AFC	OPT-AFC		
		MAX-LIFT	MAX-EFFICIENCY	
MASS-FLOW RATE COEFFICIENT	0.43	0.37	0.30	%
JET INCLINATION ANGLE	90	124.5	85.5	deg
SLOT T.E. POSITION	94.5	97.7	92.5	% chord
SLOT SIZE	0.25	0.24	0.48	% chord

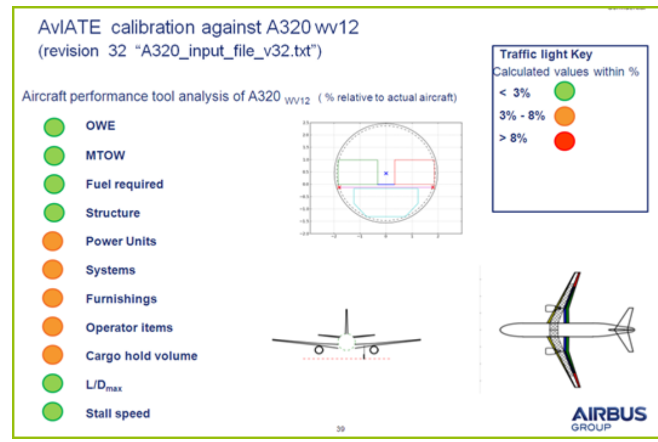


AoA = 1.9°

Evaluation at Aircraft Level

Scope of assessment study

- Wing design space investigated with AvIATE (rapid low order methodology)
- Single aisle use case.
- Wing planform constants: sweep, thickness, crank
- Wing planform variables: span, taper
- Study limited to *aerodynamic* buffet onset
- Wing span loadings are calculated assuming that the Centre of Lift remains constant for C_L range of interest*.
- Assumes buffet is initiated when local sectional C_l exceeds a specified value (function of Mach, sweep, thickness & design philosophy)

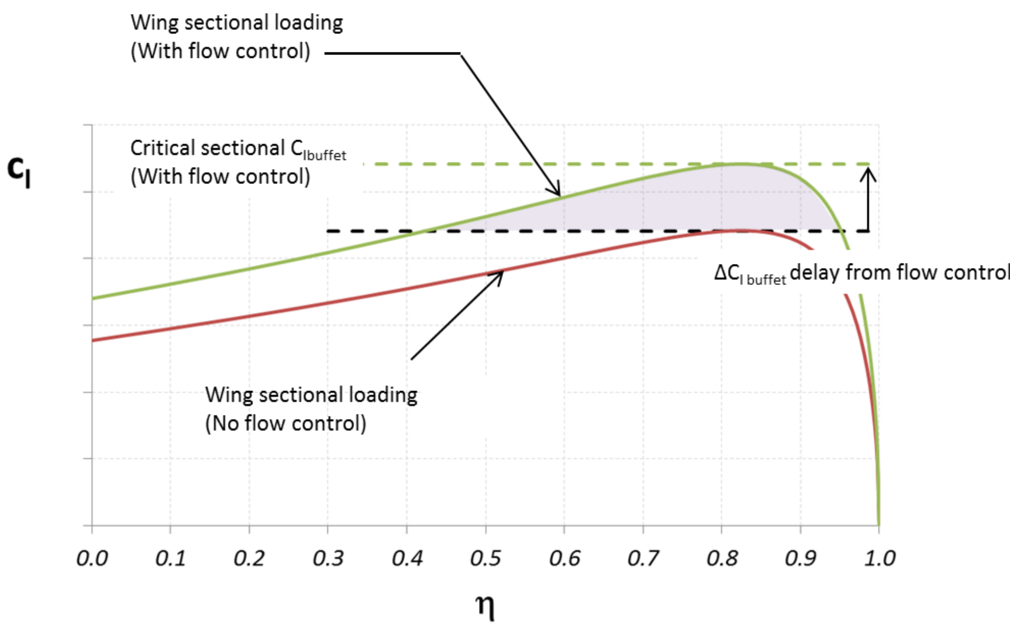


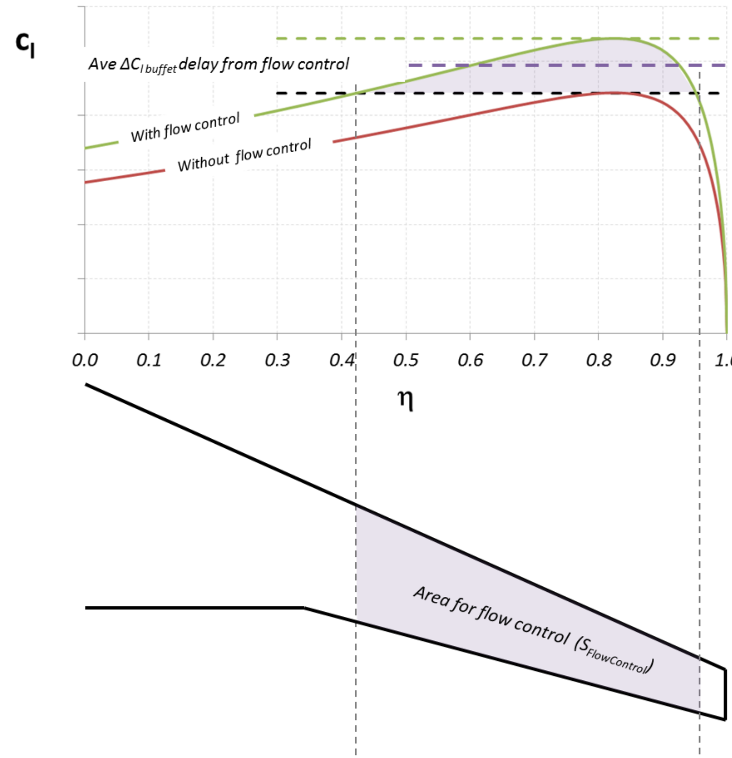
AviATE Tool Adapted for Buffet Study

*Wing deformations tend to bring CoL inboard for increased CL, but for rigid wing analysis CoL migrates outboard for increased CL

Evaluation at Aircraft Level

Process methodology





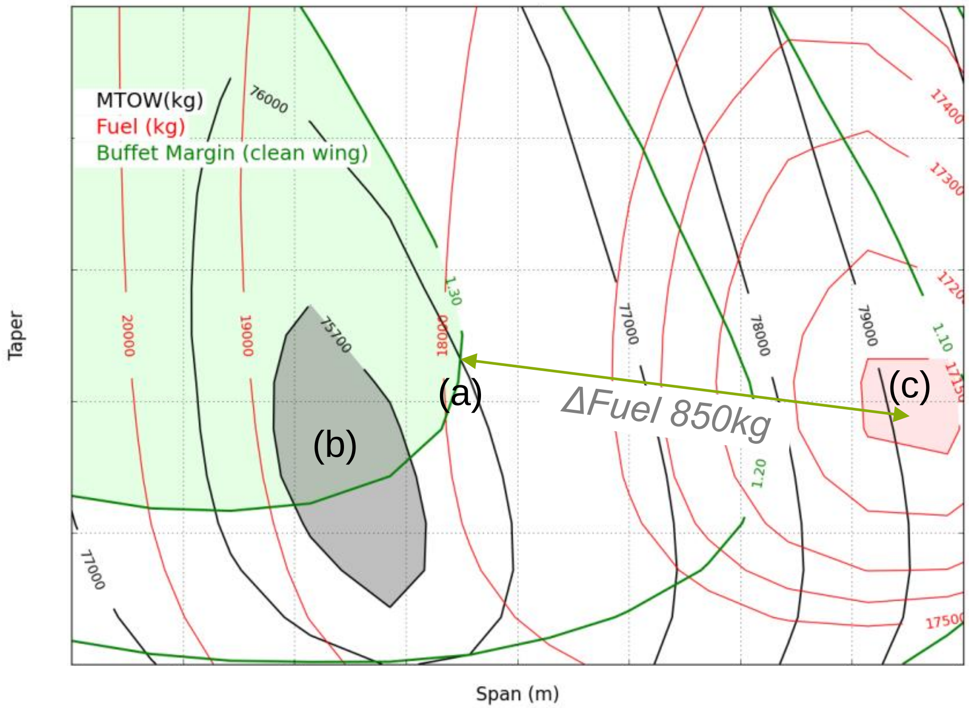
\Flow control effectiveness from 2D simulations allows $C_{l\ buffet}$ to be increased

\Average $C_{l\ buffet}$ and area of wing requiring buffet suppression calculated to determine the mass flow the system must deliver.

Evaluation at Aircraft Level

Potential of buffet onset AFC with const. wing area

Aircraft Without Buffet Control



Single aisle use case.

Mission fuel:

"(a)" 0.3g buffet margin

"(b)" min. MTOW

"(c)" min. mission fuel

\ 4.7% fuel saving if we can recover 0.15g÷0.2g margin to buffet

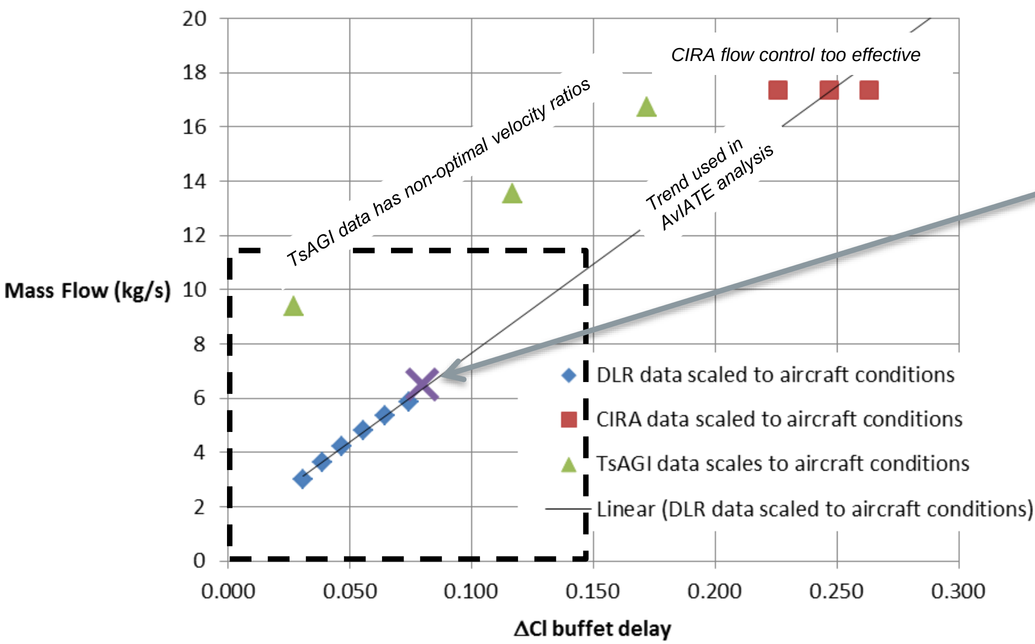
Evaluation at Aircraft Level

Buffet control mass flow requirements

\ Data received from 2D CFD simulations scaled to aircraft conditions

\ Wing planforms assessed need buffet delay up to DCl 0.15

Flow control mass flow scaled to aircraft conditions



Example:

\ ΔC_{lave} buffet delay ≈ 0.08

\ $S_{FlowControl}$ ≈ 40m2

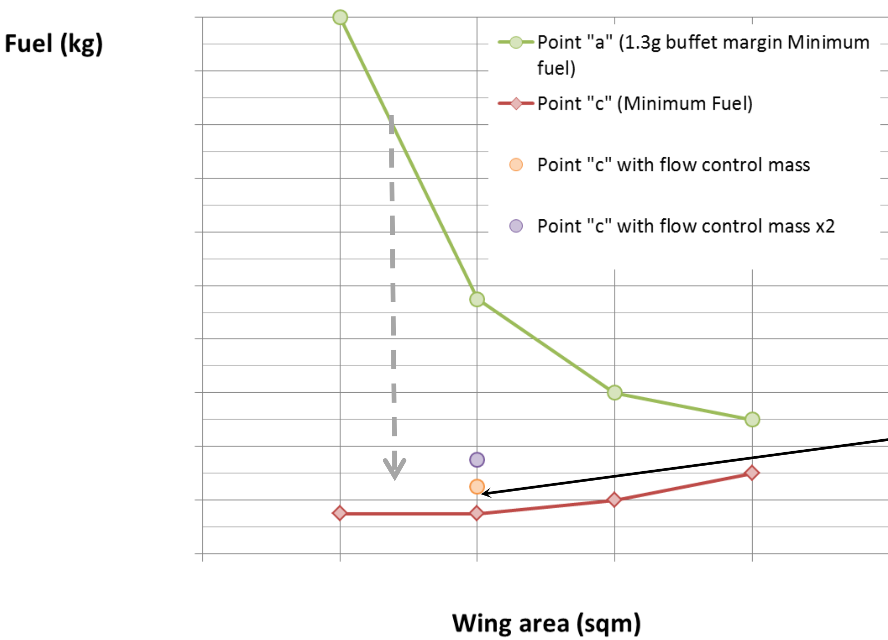
\ Mass flow ≈ 6.5 kg/s

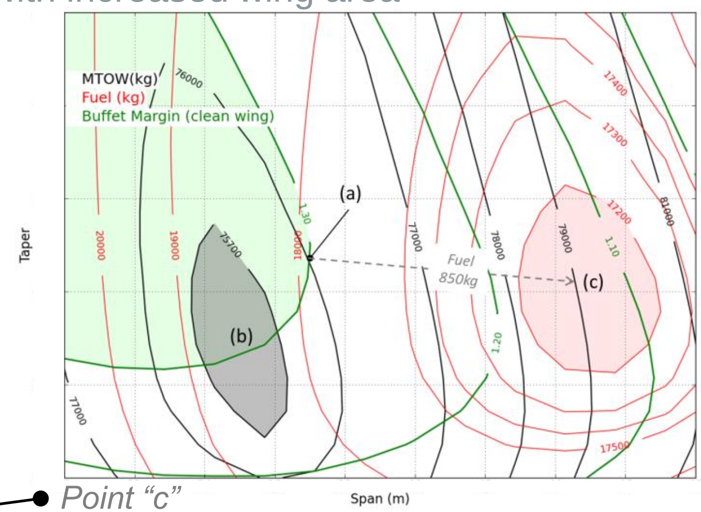
\ Pressure Ratio ≈ 2.1

Evaluation at Aircraft Level

Potential benefits of buffet suppression flow control

- Mass flow & systems mass estimates integrated with AvIATE to derive mass ‘snowball’ effects
- Accounting for system mass system reduces the **fuel benefit** to **4.2%** for the design wing area.
- Largest flow control benefit from small highly loaded wings
- Benefit decreases rapidly with increased wing area
- Benefit of high span wings largely achieved with increased wing area





Point “c”

Mass Flow ≈ 7kg/s, PR ≈ 2.5

Flow Control system Mass ≈ 300kg

Flow Control Power ≈ 700kW

ΔSFC ≈ +5.5%, ΔFuel Flow ≈ 135kg/h

Not accounted for as the system operates momentarily

Lessons Learnt

Benchmark of CFD Simulation Capabilities

\ CFD methods capable to predict buffet onset

\ CFD methods capable to predict effect of AFC on buffet onset

\ *AFloNext experience: deviations in CFD smaller than uncertainties from experiment*

Design of Mini-TED devices for Buffet Control

\ **lift increases** are obtained with a smaller slot closer to the trailing edge; a lower mass-flow rate can be used if the jet inclination is increased beyond 90°

\ **efficiency increases** are obtained with a larger slot more distant from the trailing edge, blowing with a lower mass-flow rate almost normally to the wing surface

Evaluation at Aircraft Level

\ **4.2% mission fuel reduction** by extending buffet margin on single-aisle aircraft size wing

\ fuel reduction potential decreases with wing size

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