

Active Separation Control at NASA Langley Research Center: A Tribute to Avraham 'Avi' Seifert



LaTunia Pack Melton

Flow Physics and Control Branch
NASA Langley Research Center (LaRC)
AIAA SciTech Forum and Exhibit

January 6 – 10, 2025

Scientific and Technical Information (STI) preparation funded by the Airframe Technologies Subproject of Advanced Air Transport Technology Project (AATT)

Active Separation Control at NASA Langley Research Center: A Tribute to Avraham 'Avi' Seifert





Seifert CV Excerpt: Langley Research Center (LaRC)

- **1996 – 1999 National Research Council, Research Associate at NASA LaRC**
 - Researcher: Design, construction, conduction and data analysis of active flow control (AFC) experiments
 - Control of flow separation at high Reynolds numbers and compressible speeds over airfoils and generic configurations in two- and three-dimensional flows.
 - Conduction of experiment in cryogenic, high-pressure wind tunnel
 - Fundamental aspects of active flow control
 - Active control of jet spreading and vectoring
 - Participation in CFD code validation for active flow control
 - Development of active flow control actuators (also in cooperation with others).
 - Participation in the development of closed-loop control methodology for active separation control
- Supervised Students:
 - 1997 – 2000 L.G. Pack, NASA Langley & George Washington University, M.Sc
 - "Periodic Excitation for Jet Vectoring"

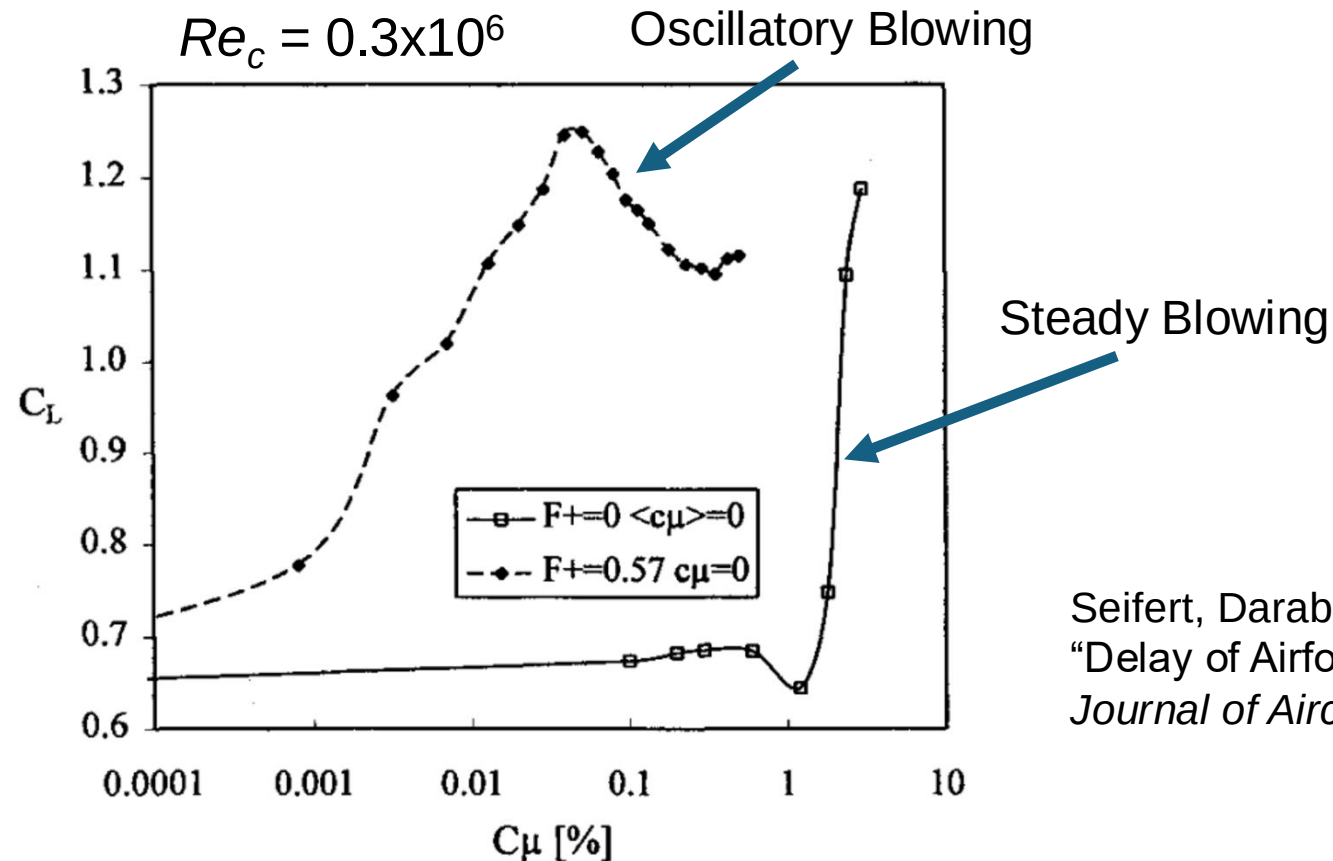


Seifert CV Excerpt: Langley Research Center (LaRC)

- **1996 – 1999 National Research Council, Research Associate at NASA LaRC**
 - Researcher: Design, construction, conduction and data analysis of active flow control (AFC) experiments
 - Control of flow separation at high Reynolds numbers and compressible speeds over airfoils and generic configurations in two- and three-dimensional flows.
 - Conduction of experiment in cryogenic, high-pressure wind tunnel
 - Fundamental aspects of active flow control
 - Active control of jet spreading and vectoring
 - Participation in CFD code validation for active flow control
 - Development of active flow control actuators (also in cooperation with others).
 - Participation in the development of closed-loop control methodology for active separation control
- Supervised Students:
 - 1997 – 2000 L.G. Pack, NASA Langley & George Washington University, M.Sc
 - "Periodic Excitation for Jet Vectoring"

Motivation: Active Separation Control Using Periodic Excitation

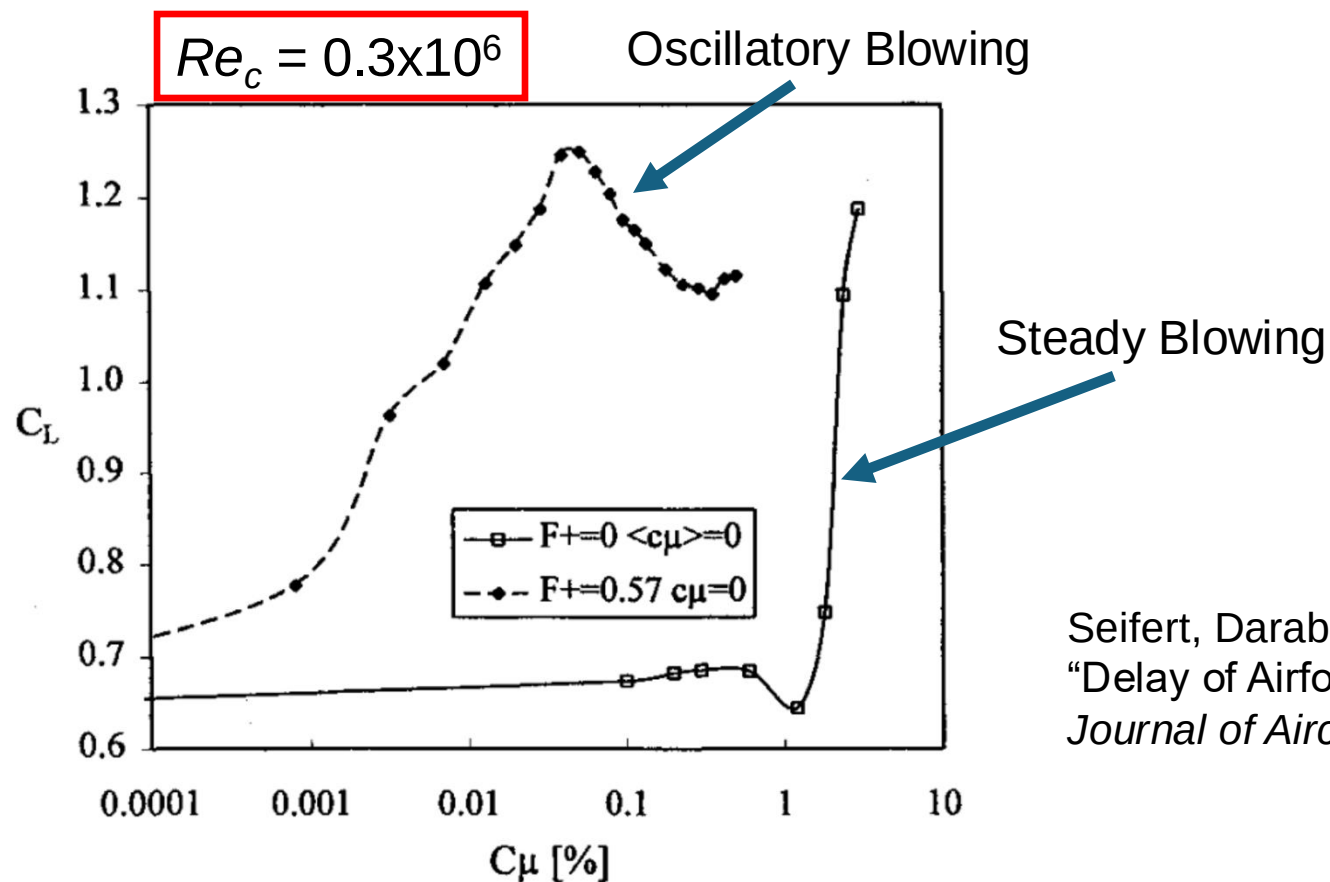
Seifert et al. demonstrated that periodic excitation is as effective as steady blowing and *can be* more efficient in terms of momentum at controlling separation



Seifert, Darabi & Wygnanski
 "Delay of Airfoil Stall by Periodic Excitation"
Journal of Aircraft, Vol. 3, No. 4, July – August 1996

Motivation: Active Separation Control Using Periodic Excitation

Seifert et al. demonstrated that periodic excitation is as effective as steady blowing and *can be* more efficient in terms of momentum at controlling separation



Seifert, Darabi & Wygnanski
 "Delay of Airfoil Stall by Periodic Excitation"
Journal of Aircraft, Vol. 3, No. 4, July – August 1996

Actuation Approach

Spanwise uniform excitation introduced thru narrow two-dimensional slots

Frequency: $F^+ \approx 1$; fx_{sep}/U_∞

Amplitude: Momentum coefficient, $C_\mu = (c_\mu ; \langle c_\mu \rangle)$

Orientation: Nearly tangential

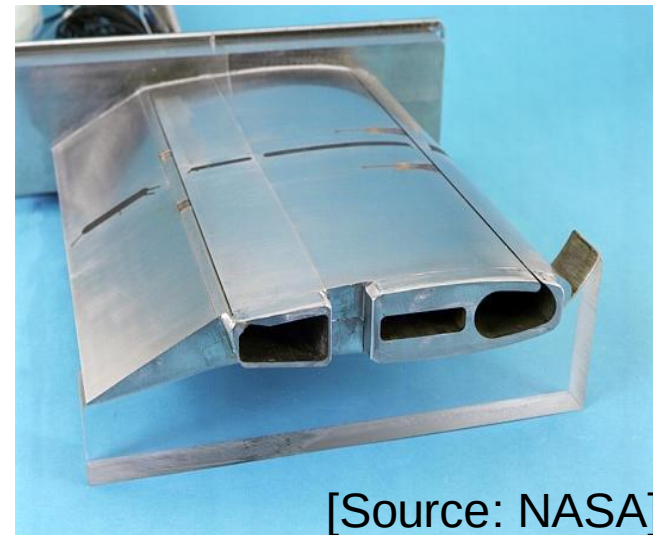
Location: Upstream, near natural separation

High Reynolds Numbers Separation Control Research

NACA 0015 Airfoil (1996 – 1997)

0.3 Meter Transonic Cryogenic Tunnel (0.3m TCT)

- Leading Edge (LE) Control
- Trailing Edge (TE) Control
- Shock/Boundary Layer Interactions



[Source: NASA]

Wall mounted Hump model (1998 – 1999)

0.3m TCT

- Subsonic Speeds
- Compressible Speeds
- Sweep Effects
- Excitation Location



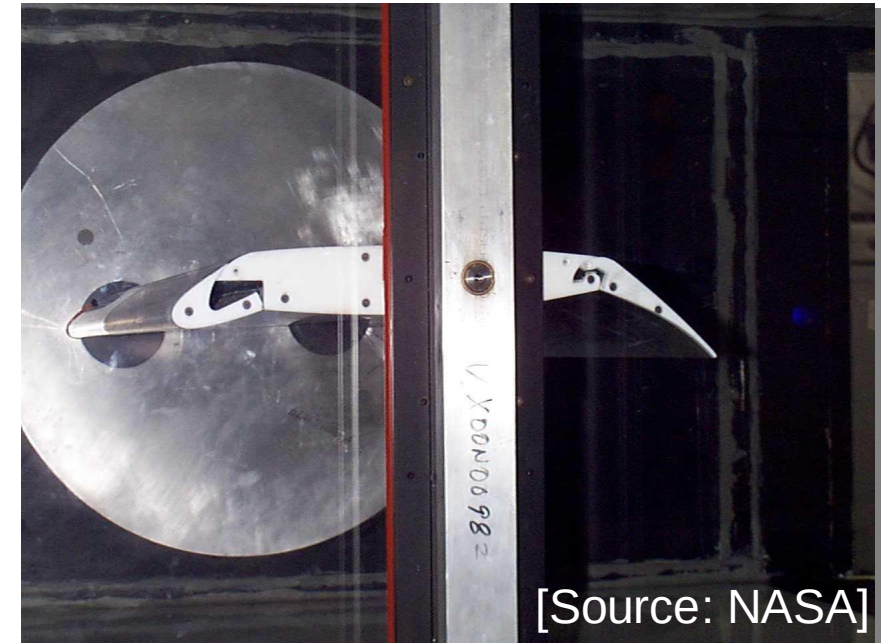
[Source: NASA]

Low Reynolds Numbers Separation Control Research

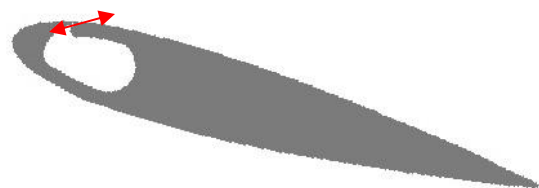
Simplified High-Lift Energy Efficient Transport (EET) Airfoil Model (2000 – 2003)

Basic Aerodynamics Research Tunnel (BART)

- LE Control
- TE Control (flap actuator)
- TE Control (hinge line actuator)
- Combined Control

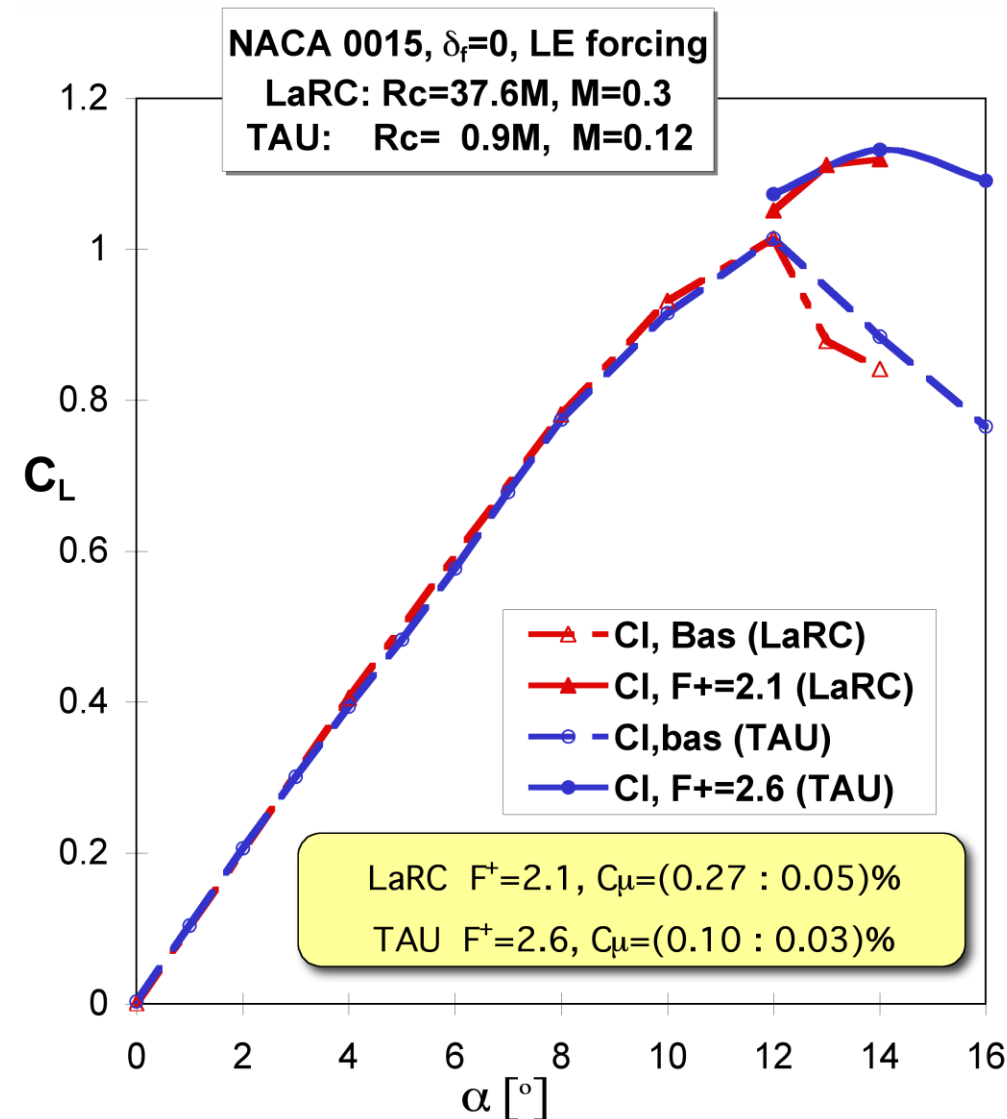


High Reynolds Number Results: LE Control NACA 0015 Airfoil



Leading Edge (LE) Control

- Increased $C_{l,max}$
- Milder stall
- Prevention of hysteresis



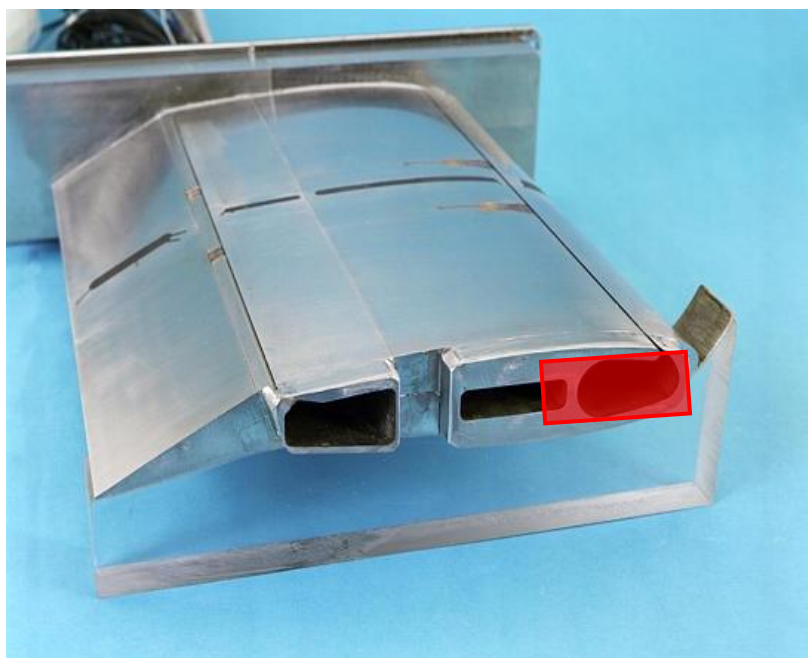
* Results normalized by $C_{l, max}$ with AFC off

High Reynolds Number Results: TE Control NACA 0015 Airfoil

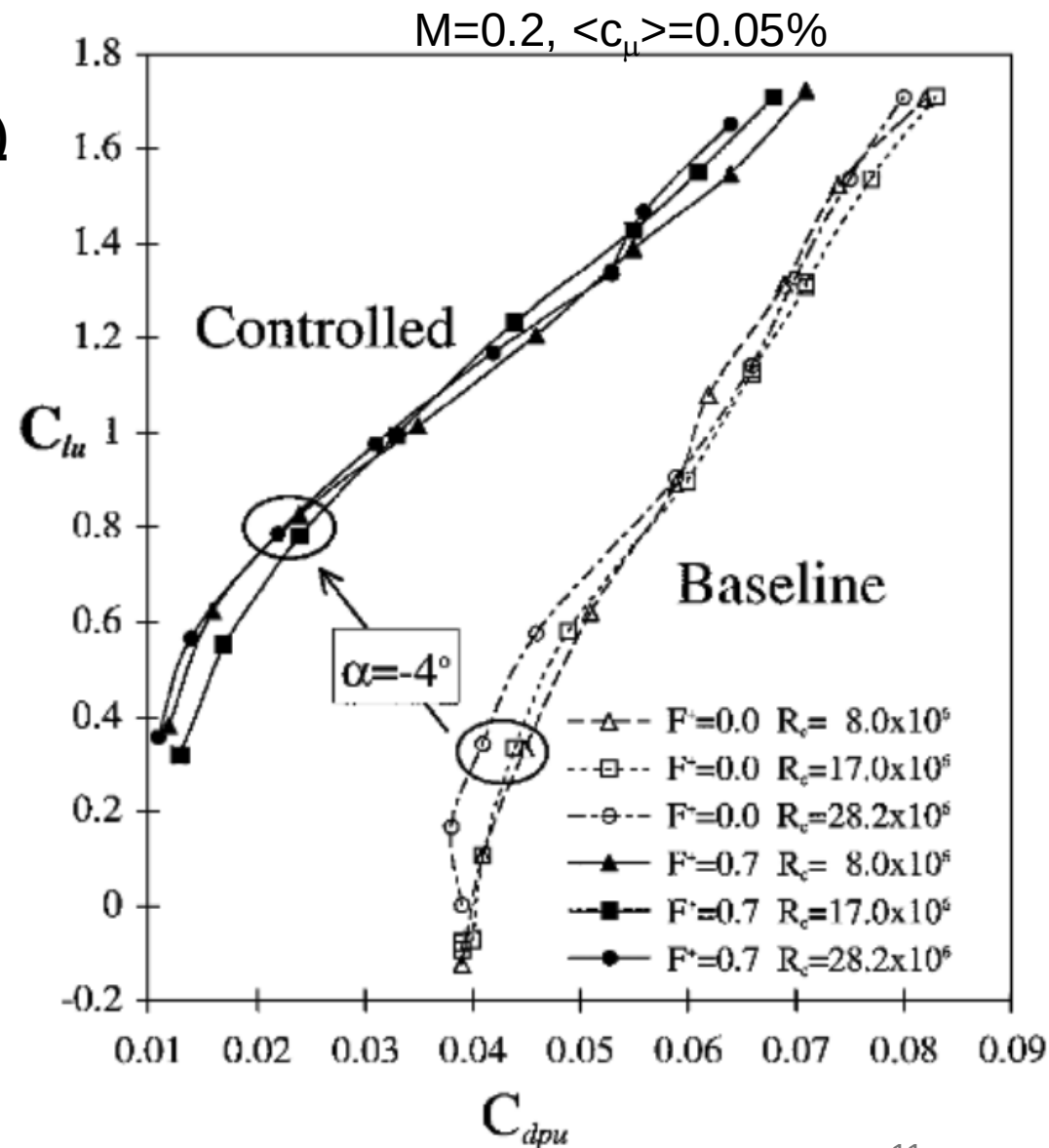


TE Control (Takeoff & Landing)

- 30-50% Drag reduction
- 20-70% Lift increase



$$\delta_{\text{flap}} = 20^\circ$$



Wall Mounted Hump Model (1998 – 1999)



[Source: NASA]

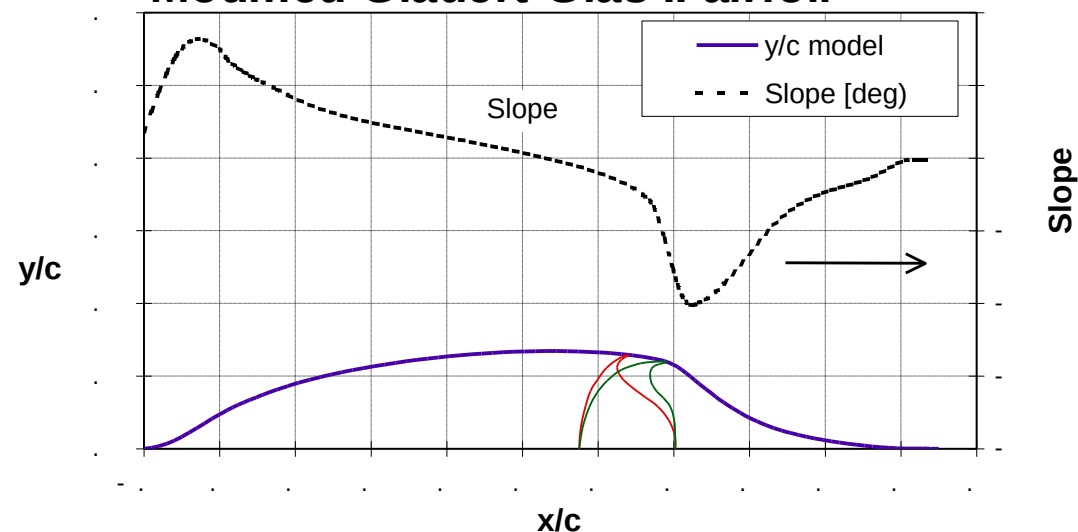
Purpose

- CFD design tools for unsteady BLC
- Comprehensive database for CFD tool validation
- Improve understanding of controlling separated flows at flight Reynolds numbers

Approach

- Effect of excitation location
- Effect of sweep
- Effect of compressibility

Modified Glauert-Glas II airfoil



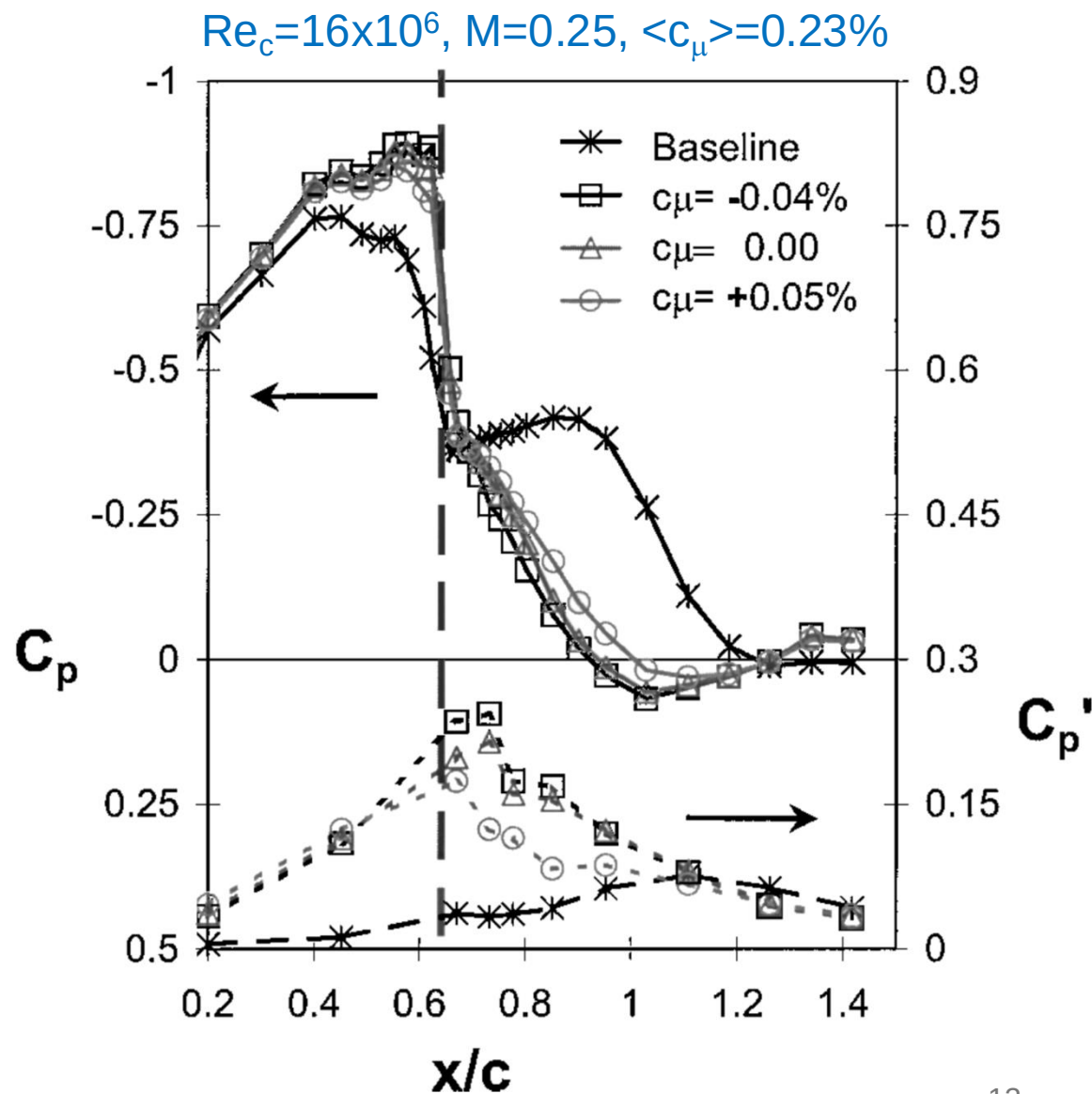
Two slot locations: $x/c = 0.59$ and $x/c = 0.65$

Wall Mounted Hump Model (1998 – 1999)

Hump Model installed in the NASA 0.3-m TCT



[Source: NASA]

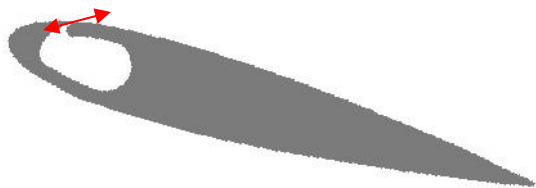


Wall Mounted Hump Model (2004 – 2024)

- Low Reynolds number Hump model fabricated by NASA
 - Slight geometric differences between “Cryo” Hump and low Reynolds number model
 - Cost
 - Optical access (off body measurements)
- Test Case 3 for CFDVAL 2004
 - https://turbmodels.larc.nasa.gov/Other_exp_Data/cfdval2004_exp.html
- Hump model used by NASA and others for the following:
 - AFC actuator development/evaluation
 - Measurement technique development

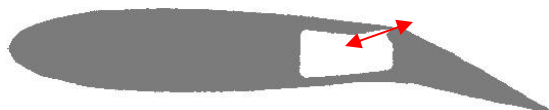
Simplified High-Lift Research (2000 – 2003)

NACA 0015



LE Control

- Increased $C_{l,max}$
- Milder stall
- Prevention of hysteresis



TE Control (Takeoff & Landing)

- 30-50% Drag reduction
- 20-70% Lift increase

Boeing System Study

- 2.6% reduction in part count
- 3.3% reduction in cruise drag
- Integration of AFC at conceptual design yields larger benefits

McLean et al, "Study of the Application of Separation Control by Unsteady Excitation to Civil Transport Aircraft", NASA/CR 1999-20938, 1999

System Study-Recommendations

Additional research required....

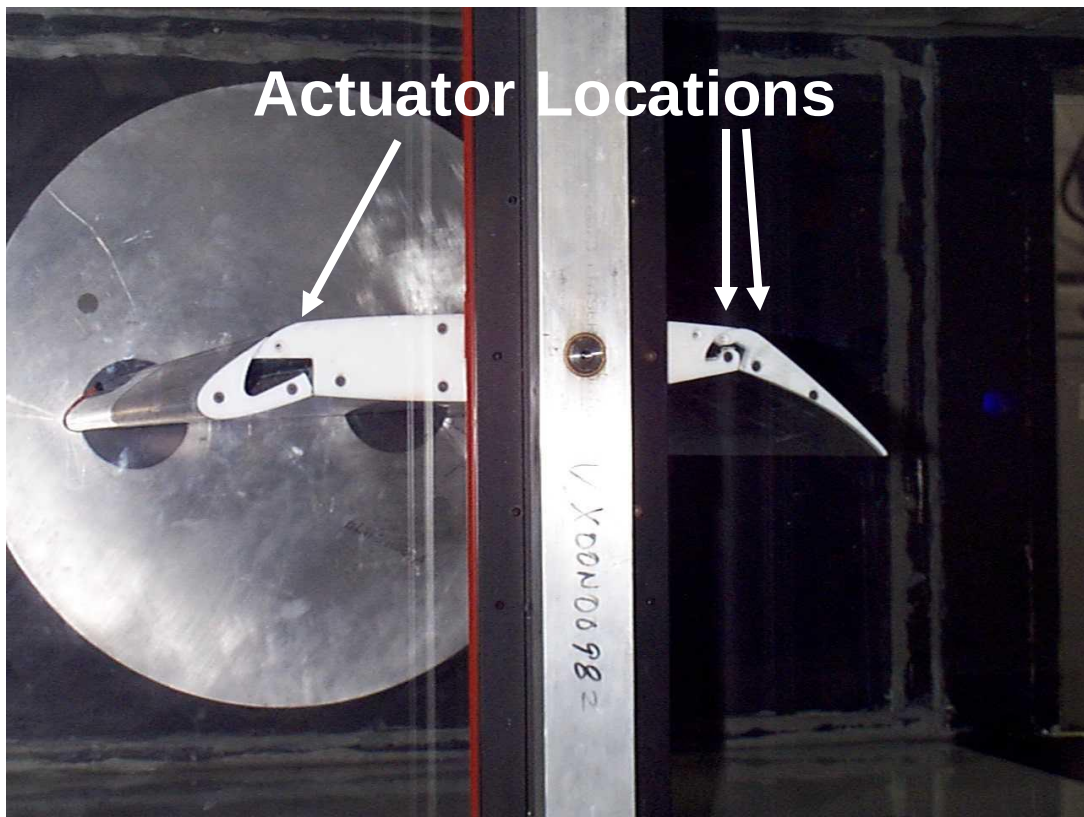
- TE Flap AFC with $\delta_f > 20^\circ$
- Combined LE and TE AFC

Modified Energy Efficient Transport (EET) Model



Model Description

$$\delta_s = 0^\circ \text{ to } -30^\circ \quad \delta_f = 0^\circ \text{ to } 60^\circ$$



Modified EET Model in BART

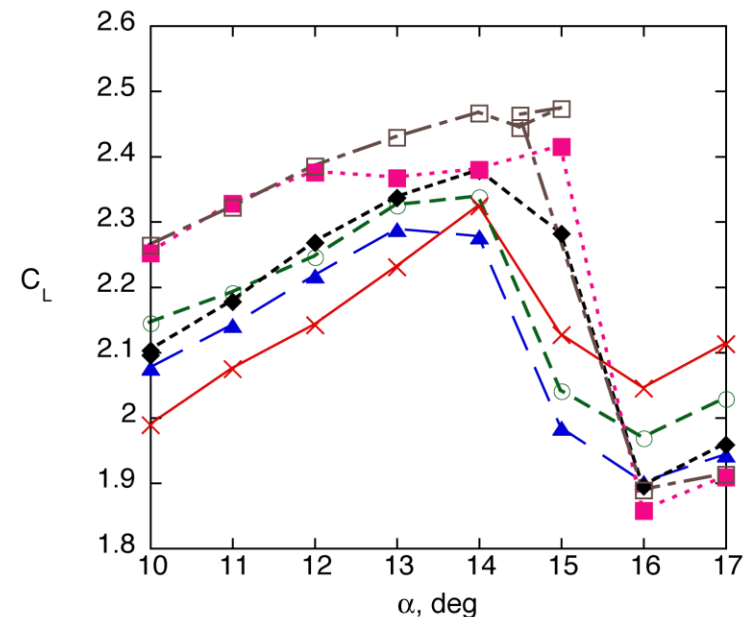
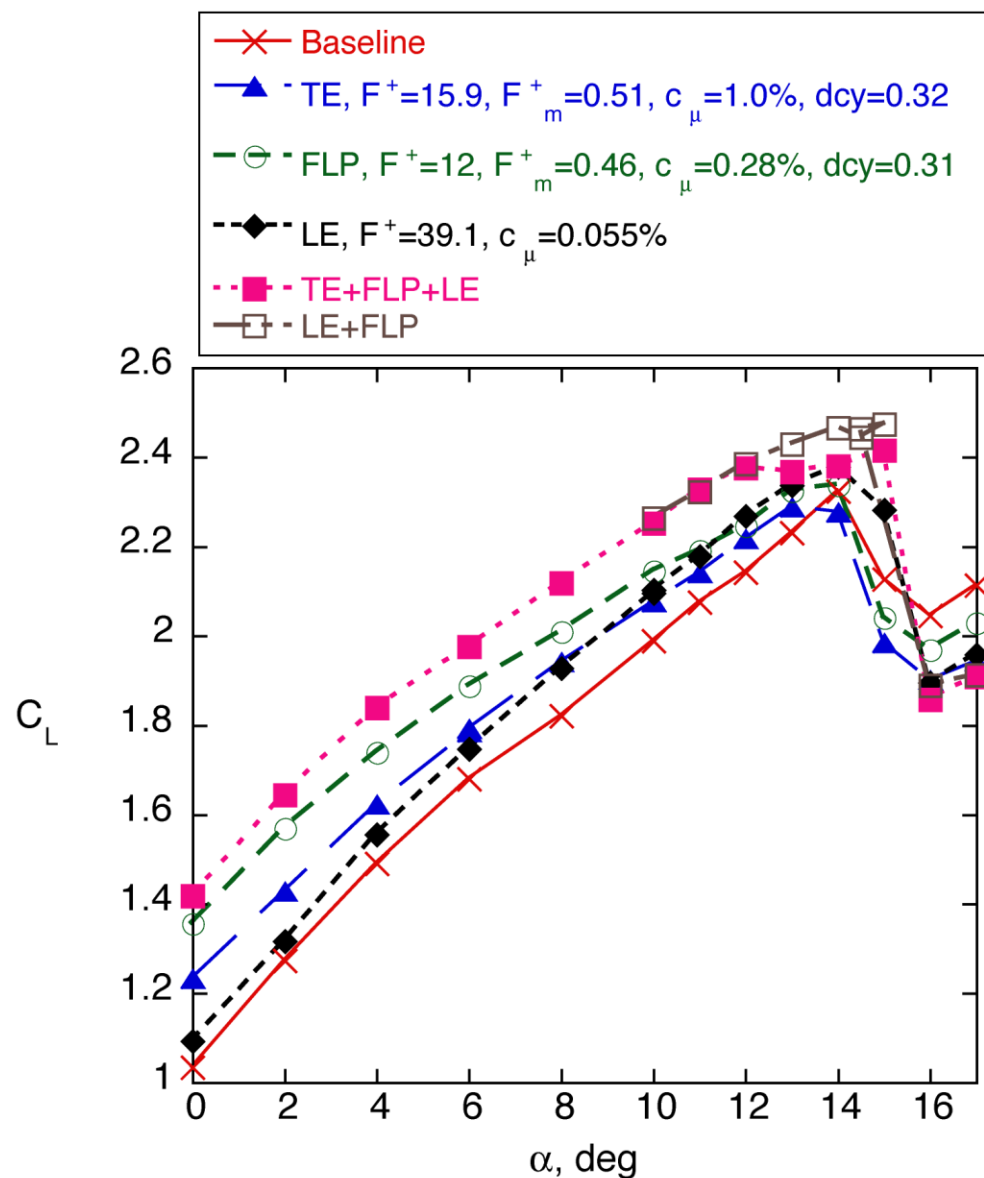
Instrumentation

- 79 streamwise pressure taps
- 2 rows of spanwise pressure taps
 $-x/c=0.35, 0.94$
- 48 hot-films
- 31 probe total pressure wake rake
- 9 unsteady pressure transducers

BART Facility

- Test section dimensions
 0.71m H x 1.02m W x 3.05m L
- Max Speed 56 m/s
- Max $Re_c = 1.50 \times 10^6$

LE +TE +TE Flap Control



$Re_c=0.24 \times 10^6$

$\delta_f=20^\circ$

$\delta_s=-25^\circ$

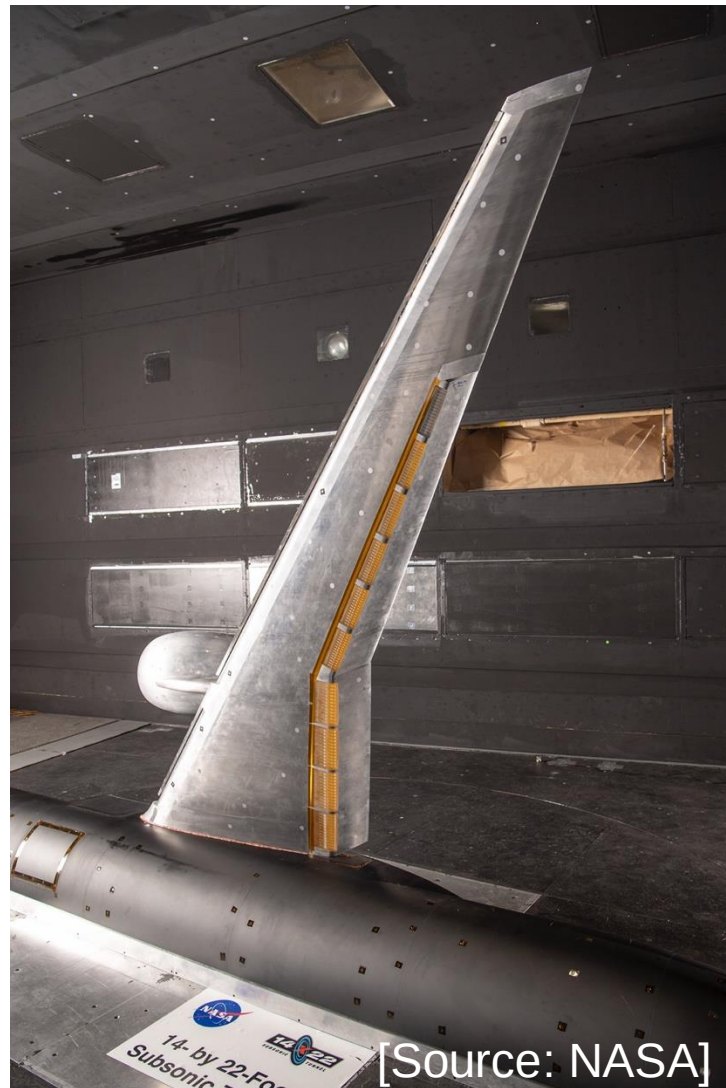
Melton, Yao, Seifert, "Application of Excitation from Multiple Locations on a Simplified High-Lift System", AIAA Paper 2004-2324, 2004

Simplified High-Lift (SHL) Research (2013 – 2020)

Motivated by a potential 3.3 count cruise drag reduction SHL investigated on high-lift Common Research Model (CRM-HL)

CRM-HL Model (relevant open geometry)

- Simple hinged flap augmented by AFC
- Fowler flap
- AFC actuators: [Sweeping jet actuators & steady jet actuators](#)



[Source: NASA]

AFC actuators integrated flap shoulder

Summary

- While at LaRC, Avi Seifert's research included the following:
 - First wind tunnel experiments at flight Reynolds numbers using periodic excitation to control separation
 - First AFC experiments using periodic excitation focused on simplifying high-lift system
 - Development of AFC database for improving CFD tools for unsteady boundary layer control
 - Participation in the development of closed-loop control methodology for active separation control

What I learned

- How to hold a pointer during a presentation
- Gratitude
 - Avi provided steaks for tunnel crew working on Saturday
 - Avi sent an email acknowledging colleagues at LaRC when he was added to Stanford's top 2% scientist