CFD Simulations of Landing and Takeoff CRM High-Lift Configurations

Veer N. Vatsa
NASA Langley Research Center, Hampton, VA

John C. Lin, Latunia P. Melton, and David P. Lockard
NASA Langley Research Center, Hampton, VA

Ryan Ferris
Dassault Systemes, Simulia Corp., Long Beach, CA 90802

2021 AIAA AVIATION Forum

2-6 August 2021

Objectives

- Verify the accuracy of CFD solutions for landing configuration of high-lift version of the NASA Common Research Model (CRM-HL) over a broad angle-of-attack range
  - **Examine the effect of a nacelle chine on flow characteristics**
- Use CFD simulations to explore the feasibility of using a localized flap gap blowing (LFGB) active flow control (AFC) concept to enhance performance of the CRM-HL model in takeoff configuration
  - **Assess the effect of LFGB on the flow characteristics of CRM-HL at nominal takeoff conditions**

CRM-HL Landing Configuration in NASA 14x22 Wind Tunnel (WT)

Test Configuration

10% scale WT model

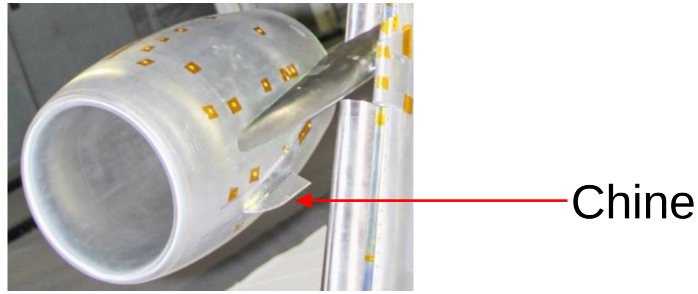
Semispan = 115.675 inches

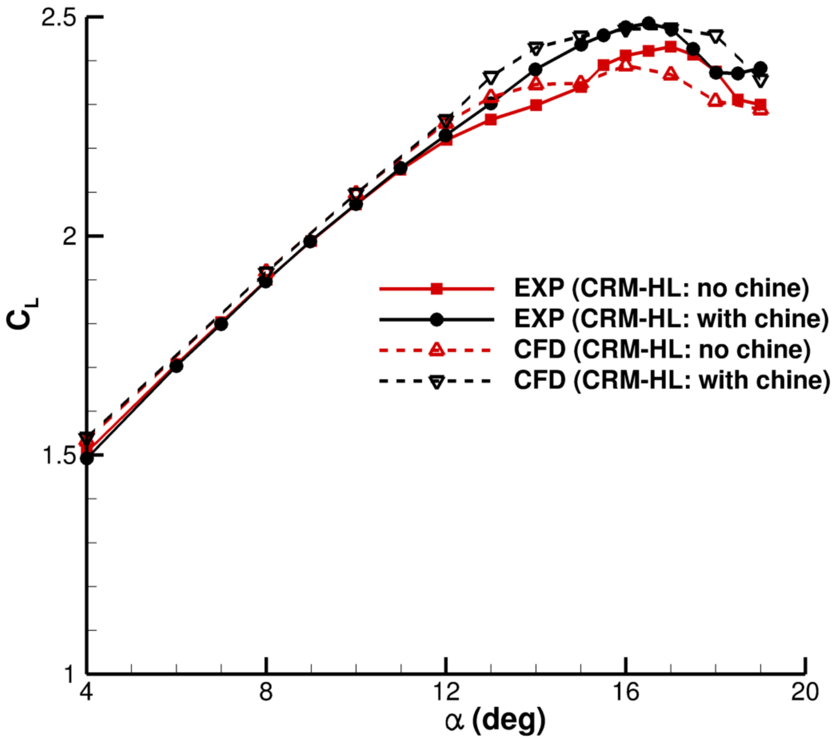
Chord = 27.58 inches at a span of 46.875 inches

Governing Equations/Numerical Approach

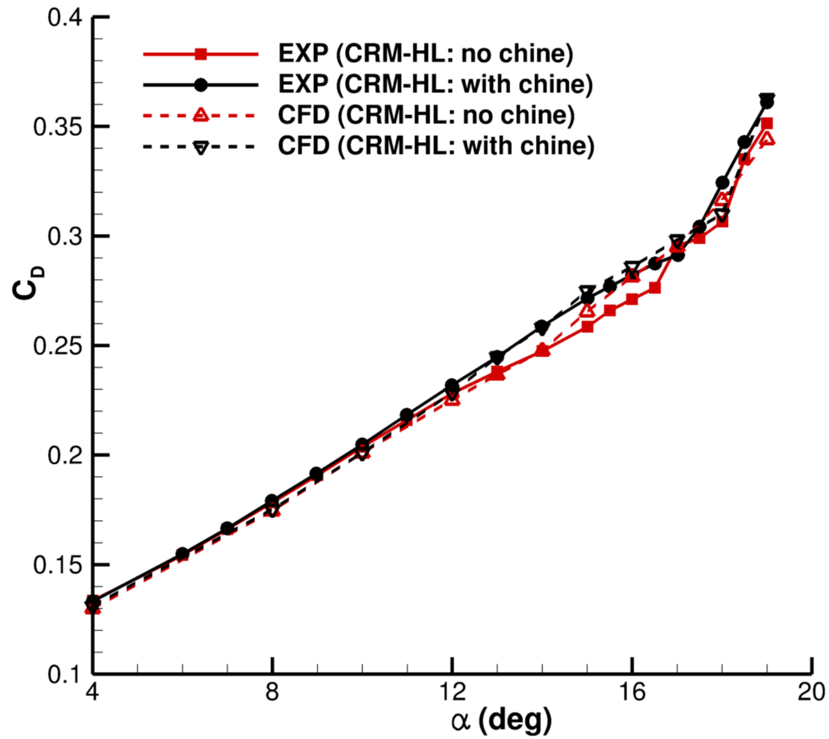
- Flowfield simulated with a Lattice Boltzmann model (LBM) based CFD code
- Hybrid turbulence model using wall functions
- Solver: PowerFLOW® v6-2019, particle tracking method
  - Solution advanced in time using explicit time-marching scheme
- Boundary Conditions
  - Inviscid flow at top and side walls
  - Viscous flow at tunnel floor and exposed model surfaces
  - Total pressure & temperature at feed tube inlets

Effect of Angle of Attack (α) Variation on Force Coefficients for CRM-HL Landing Configuration



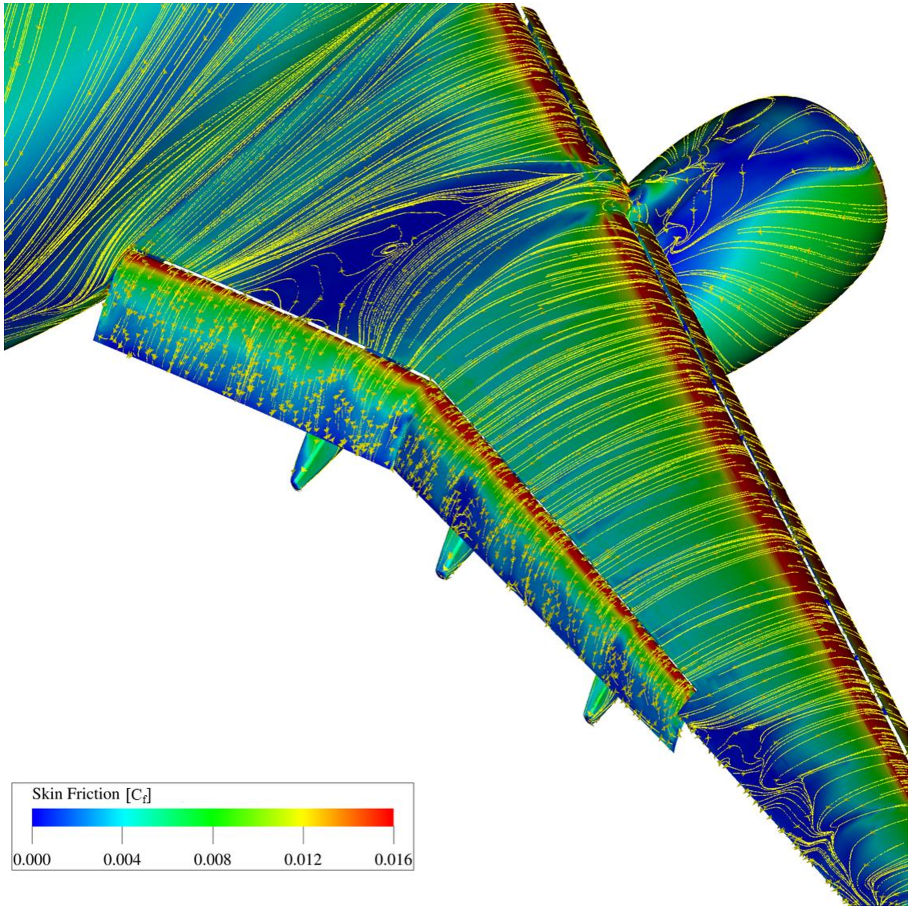


Lift Coefficient

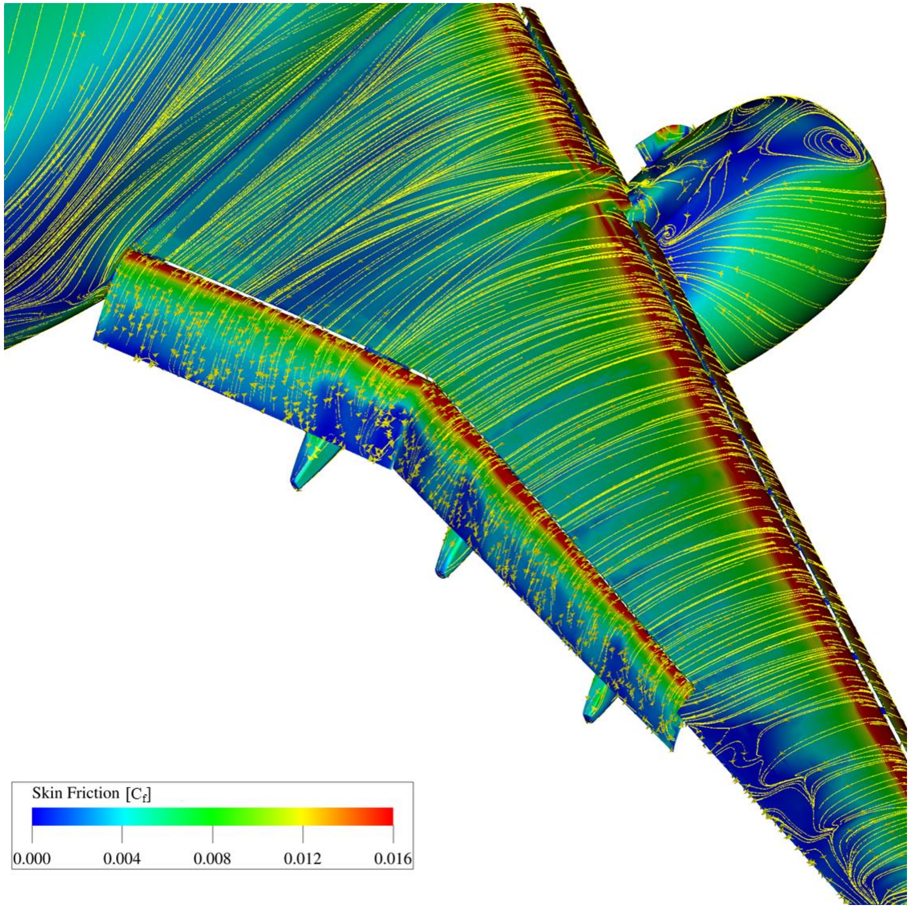


Drag Coefficient

Effect of Chine on Surface Streamlines
(Landing Configuration, α=16°)

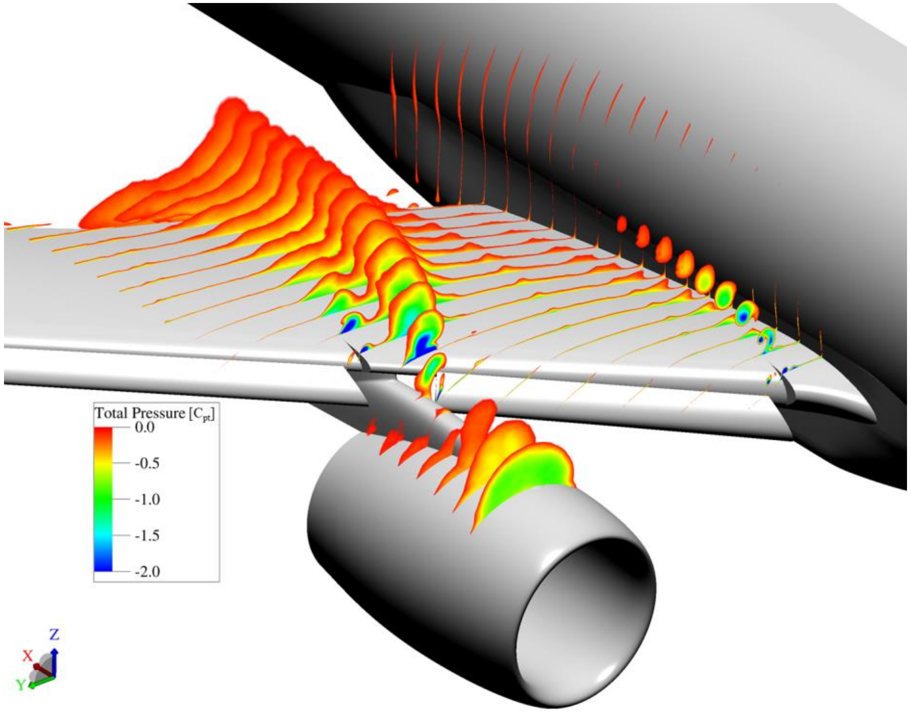


No chine

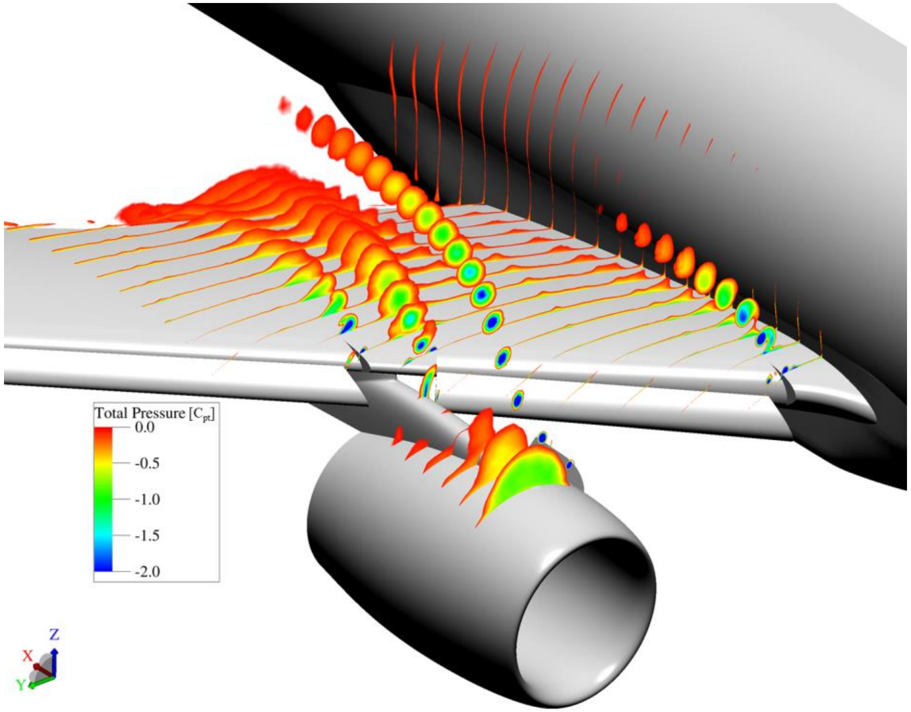


With chine

Effect of Chine on Off-surface Flow
(Landing Configuration, α=16°)

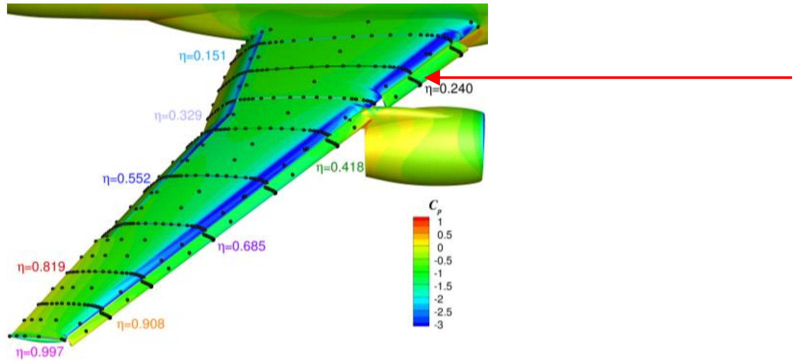


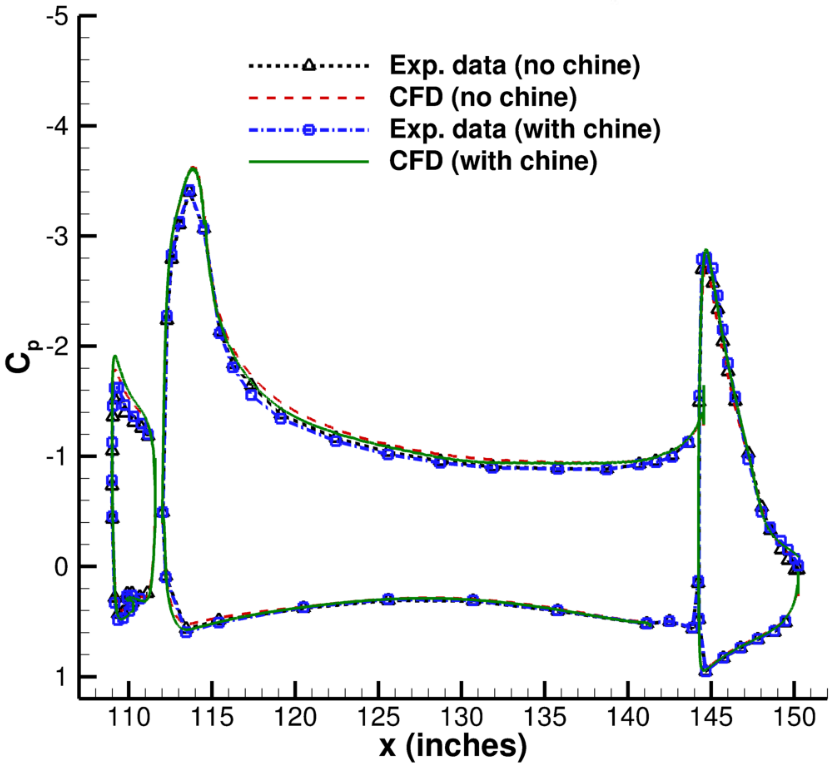
No chine



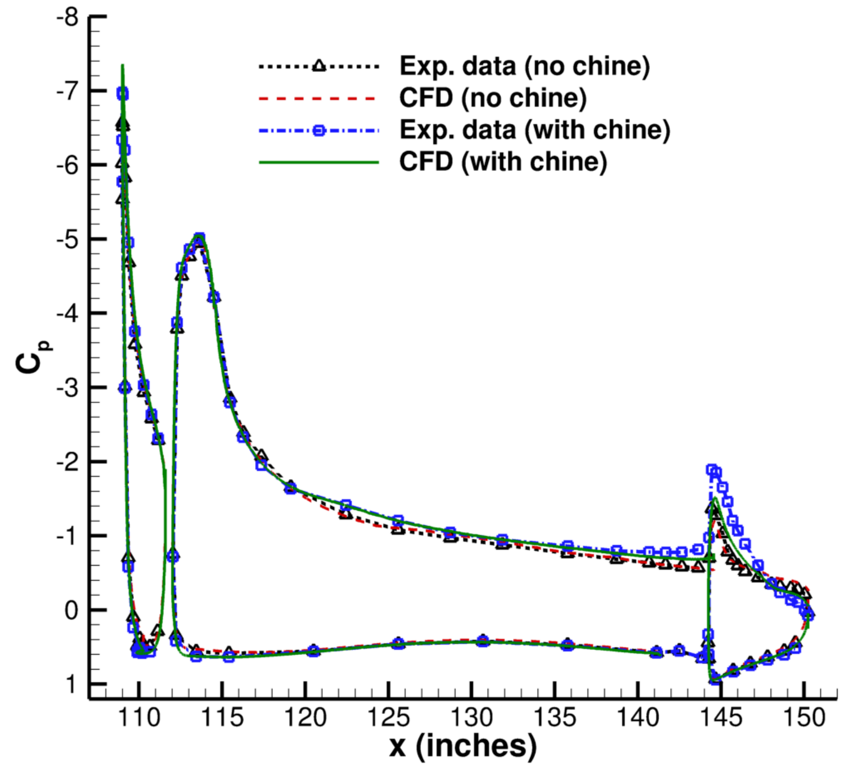
With chine

Effect of Chine on Sectional Surface Pressure Coefficients (Inboard Midspan, η=0.240)



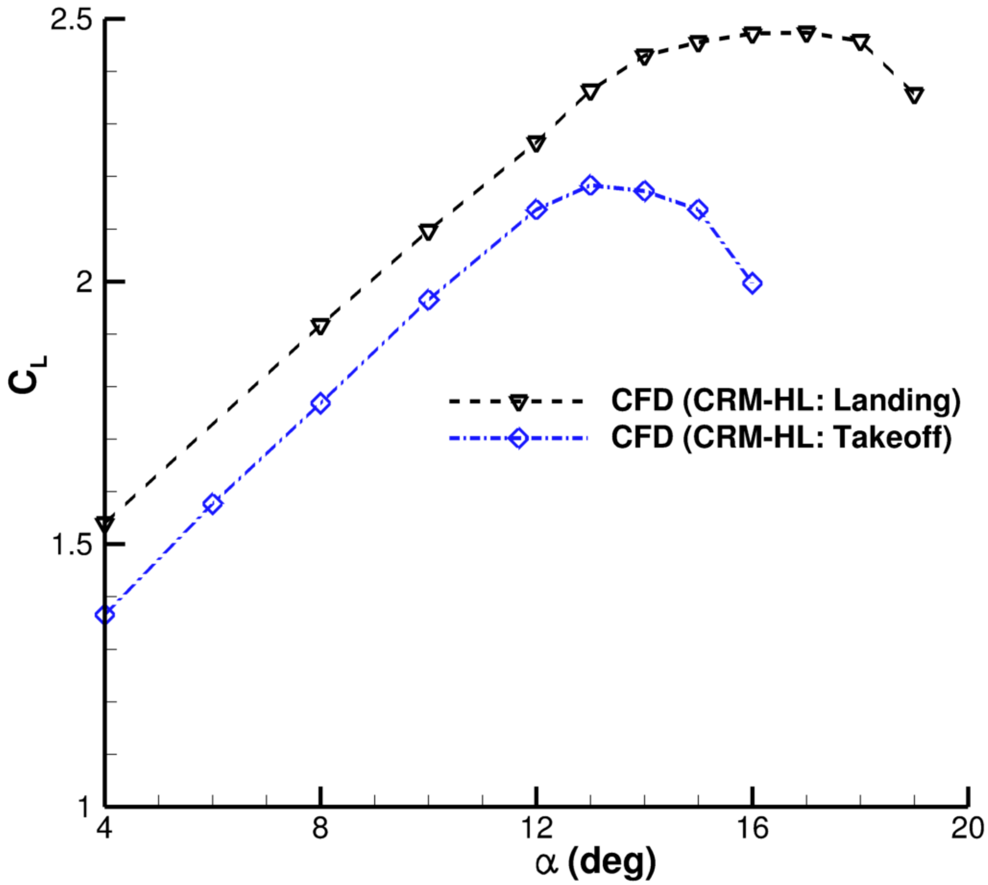


α=8°



α=16°

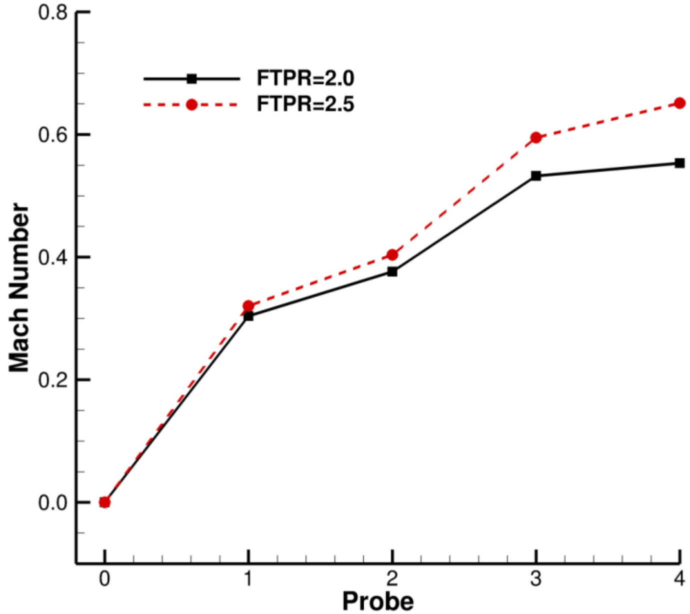
Comparison of Lift Coefficients for CRM-HL Landing and Takeoff Configurations Equipped with Chine



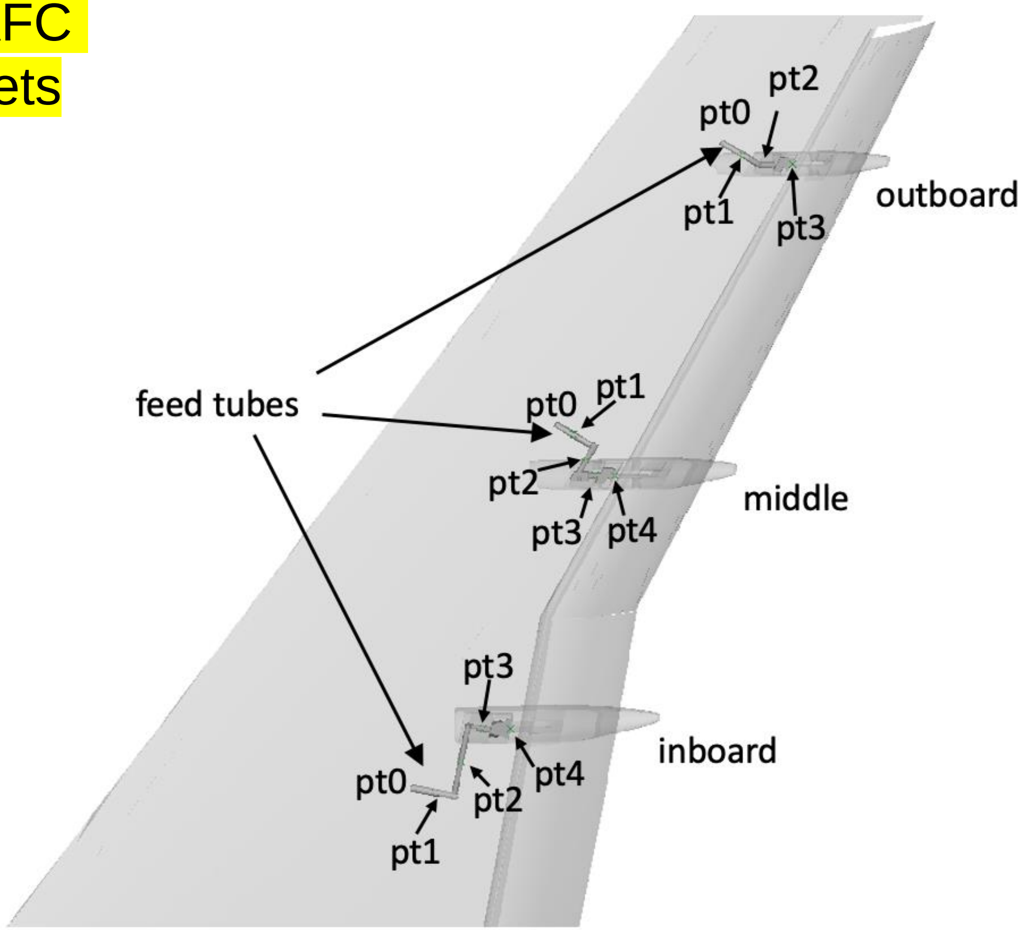
	Landing	Takeoff
Slat deflection	30°	22°
Flap deflection	37°	25°

CRM-HL Takeoff Configuration with Localized Flap Gap Blowing (LFGB)

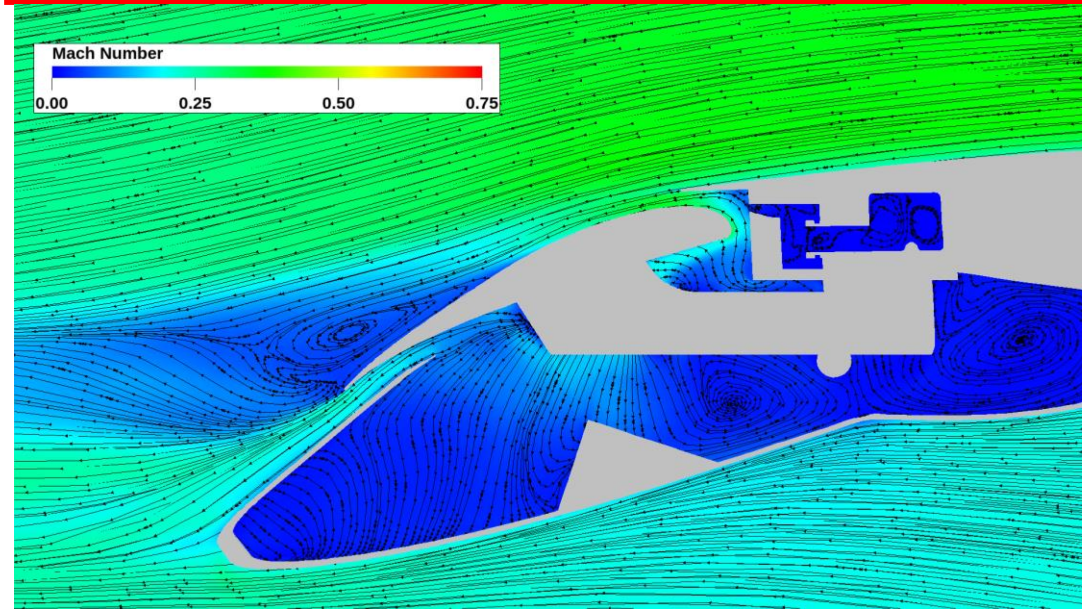
Compressed air blown through AFC actuators aligned with flap brackets



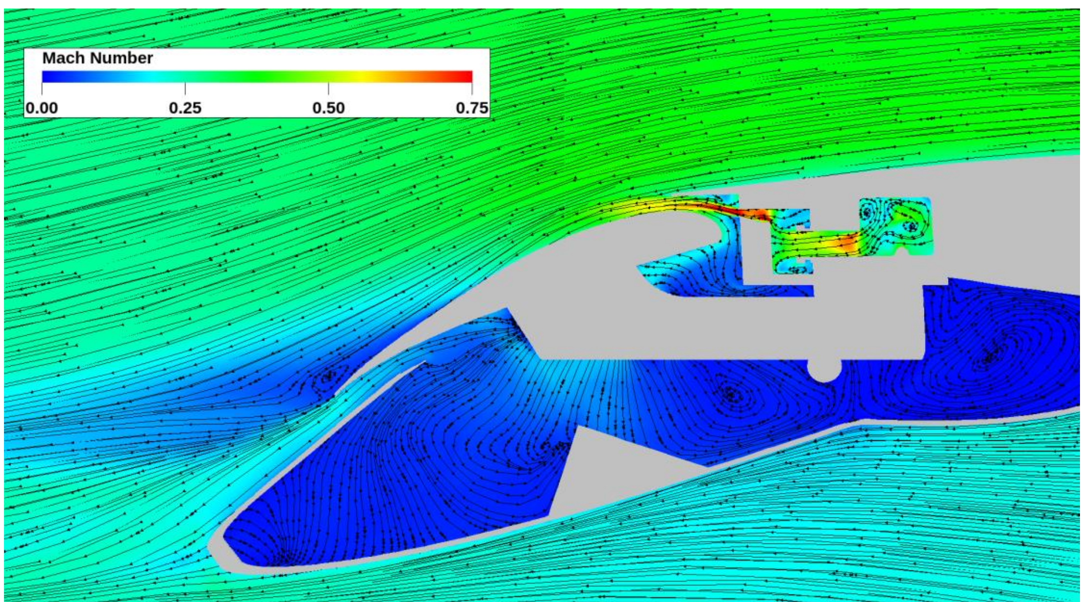
Middle actuator



Effect of LFGB on Off-surface Flowfield
(Midsection, α=8°)

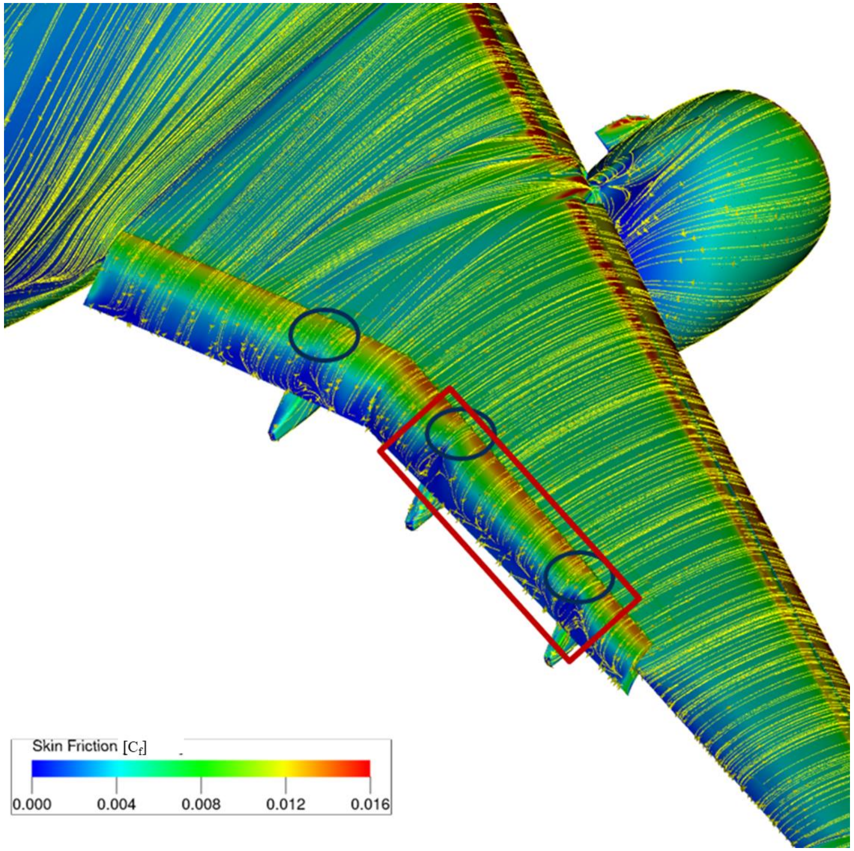


AFC-OFF

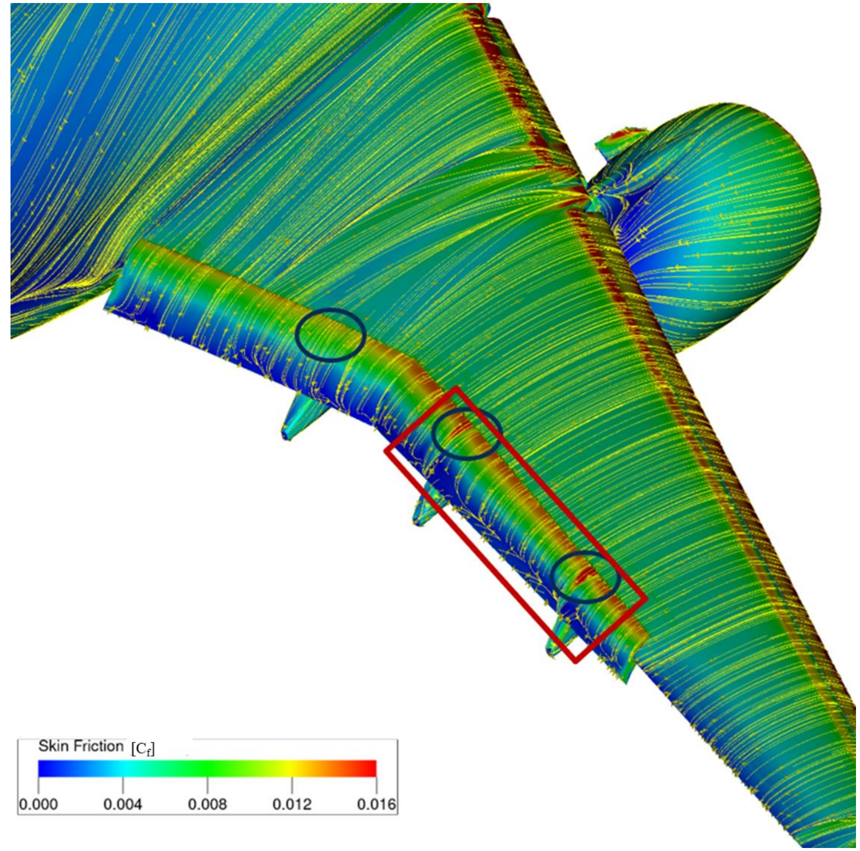


AFC: FTPR=2.5

Simulated Surface Streamlines: Global View
(Effect of AFC on Surface Separation, α=8°)

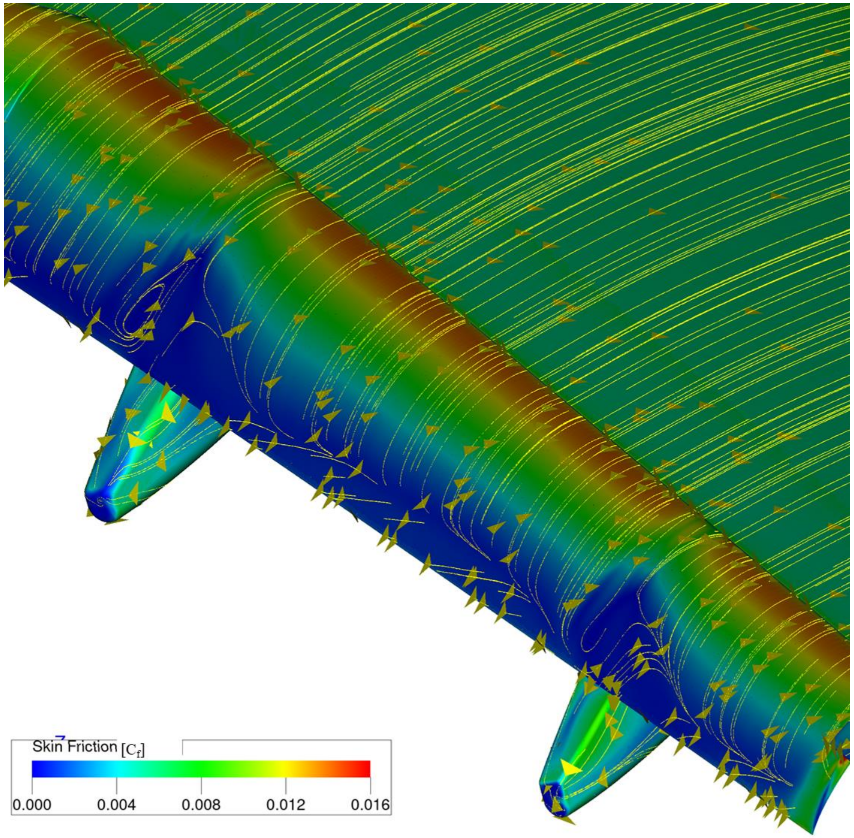


AFC-OFF

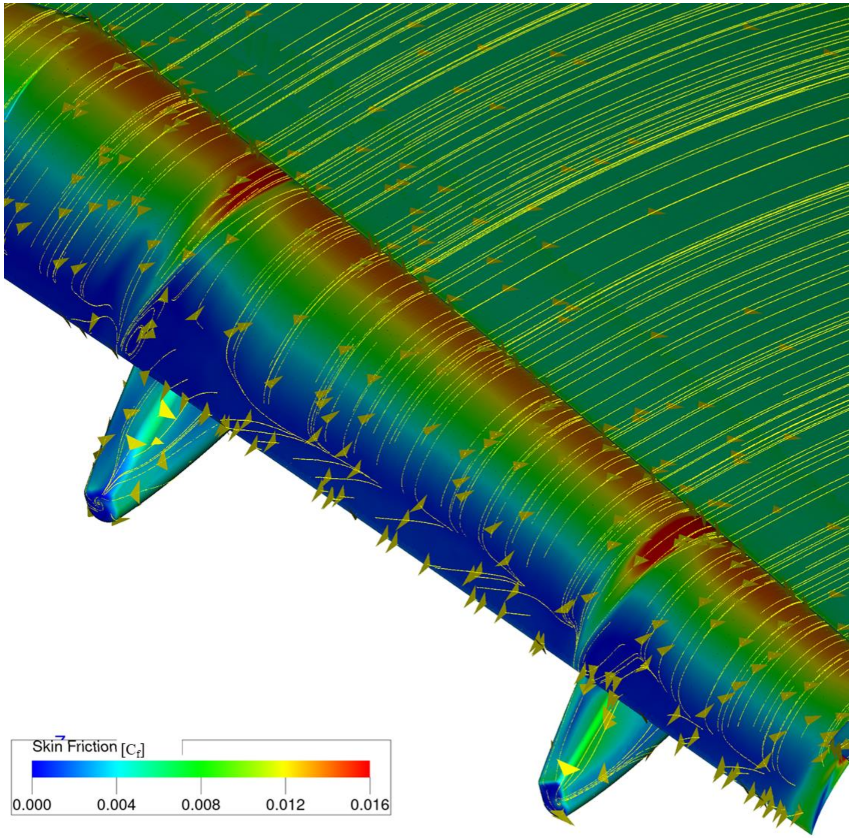


AFC: FTPR=2.5

Simulated Surface Streamlines: Zoomed View
(Effect of AFC on Surface Separation, α=8°)



AFC-OFF



AFC: FTPR=2.5

Concluding Remarks

- PowerFlow code used to compute flow over a broad angle-of-attack (α) range including maximum lift conditions for conventional CRM high-lift landing and takeoff configurations
  - ***Computed C_L and C_D vs. α for landing configuration compared well with experimental data for $\alpha \leq 12°$, maximum lift slightly underpredicted. Effect of chine were captured by simulations***
- CFD simulations performed for CRM takeoff configuration to serve as reference for assessing effect of LFGB on aerodynamic performance
  - ***Effect of LFGB is observed only in the vicinity of blowing jet, minimal effect on global flow field and integrated forces***
  - ***Use of higher mass flow through larger feed tubes and wider AFC nozzles is recommended for LFGB to meet the project goal of obtaining higher lift to drag ratio***

Acknowledgements

- This work was supported by the NASA Advanced Air Vehicles Program through the Advanced Air Transport Technology Project. The authors would like to thank Jared Fell for providing the CAD geometry for CRM-HL embedded with LFGB modules, and to Scott Brynildsen for creating watertight geometry suitable for CFD simulations