Aerodynamic Flight-Test Results for the Adaptive Compliant Trailing Edge

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Outline

- Introduction
- Flight Test Approach
- Investigation Methods
- Flight Test Results
- Conclusions

Introduction

- Adaptive Compliant Trailing Edge (ACTE) effort was a joint project with NASA's Environmentally Responsible Aviation (ERA) project and U.S. Air Force Research Laboratory (AFRL)
- The ACTE technology has the potential to reduce aircraft weight, improve aerodynamic efficiency, and reduce airframe noise
- NASA GIII airplane was modified, removing trailing edge flaps, along with flight and ground spoilers, and installing seamless compliant flaps
- Flaps were fixed at specific flap deflections, ranging from -2 degrees (trailing edge up) to 30 degrees (trailing edge down) and only adjustable on the ground
- A series of flights was flown to obtain aerodynamic and structural data for the modified GIII airplane with the ACTE flaps installed

GIII SubsoniC Research Aircraft Testbed

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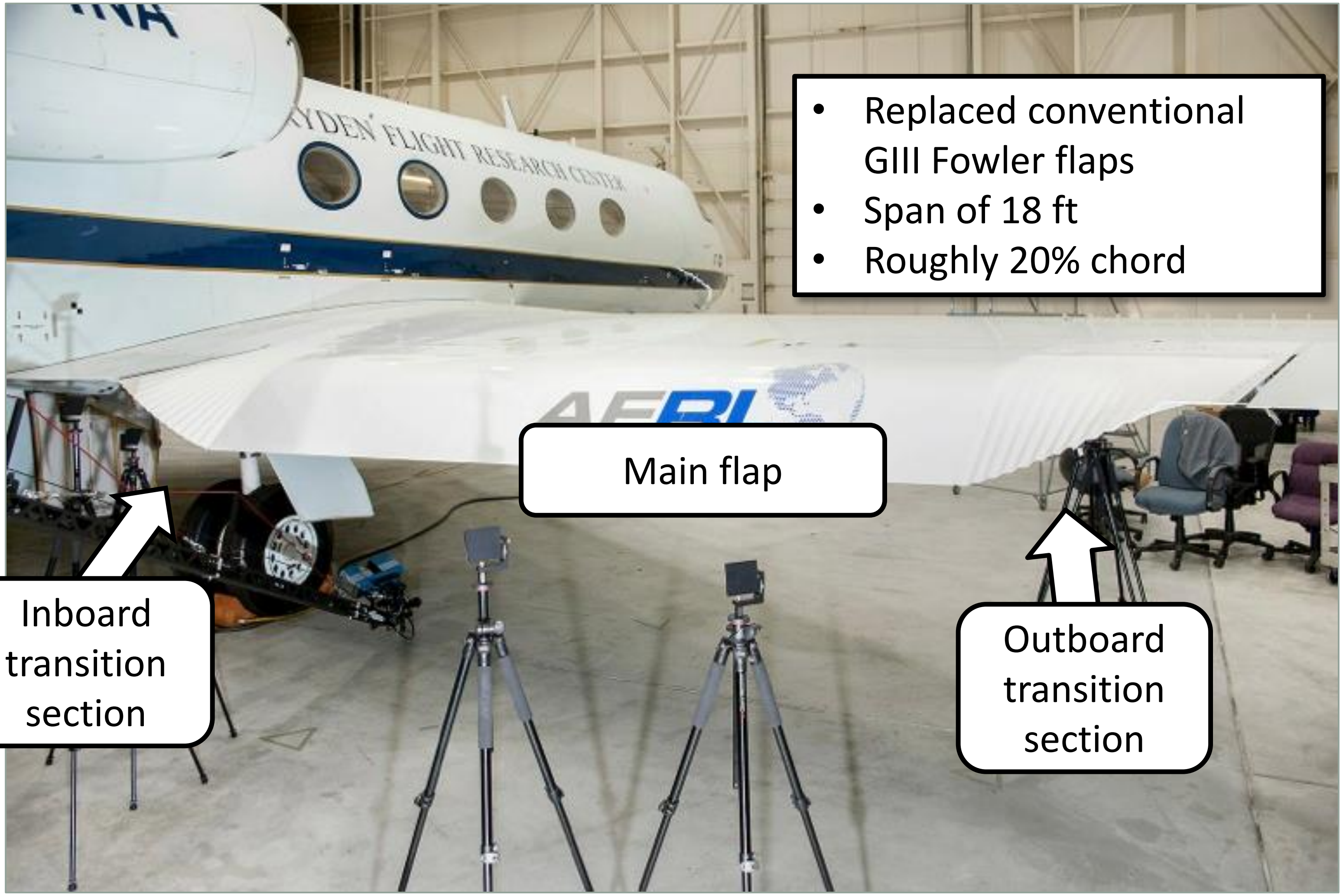
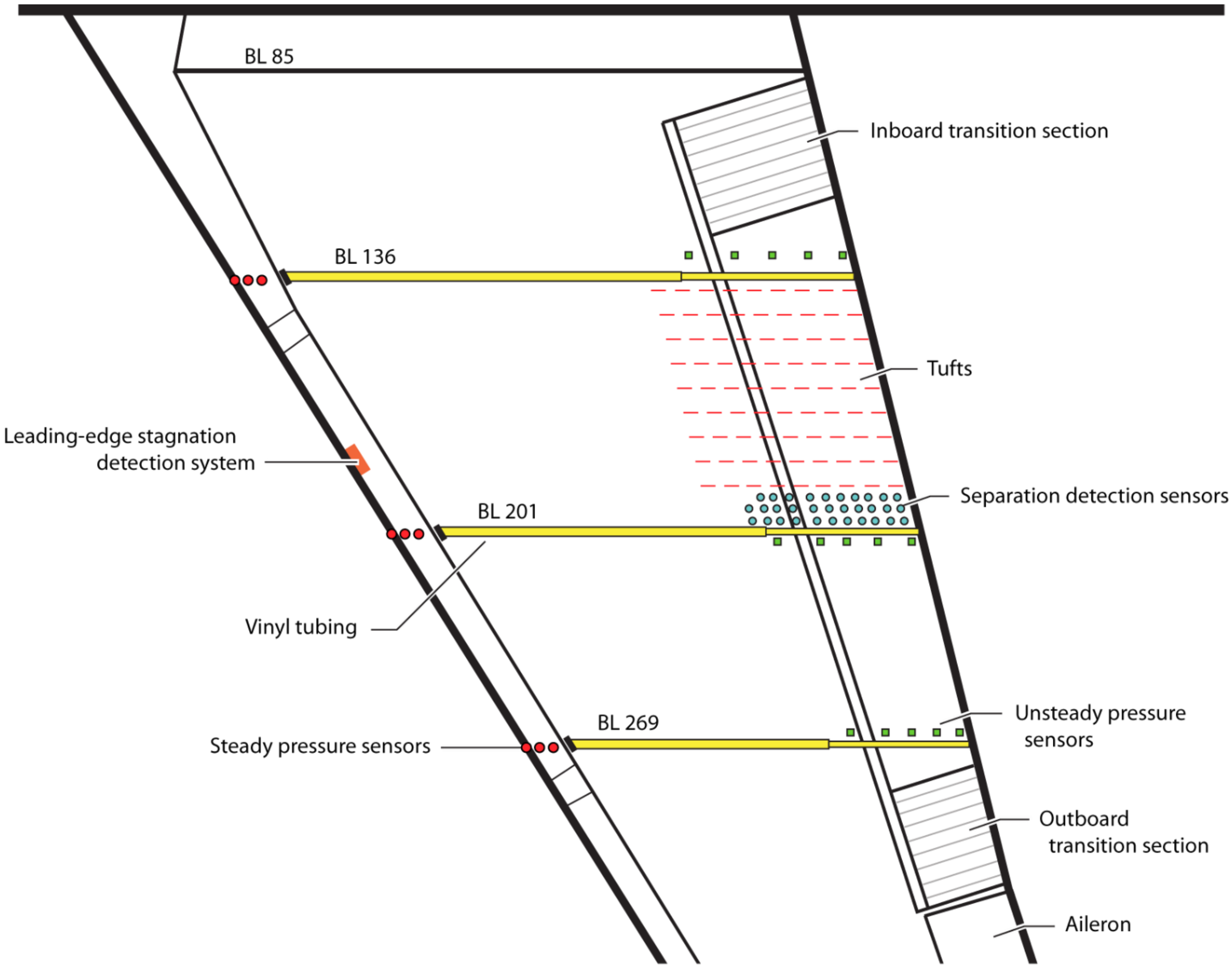
- GIII Airplane Information:
  - Service Ceiling: 45,000 ft
  - Max Speed: 340 KCAS, Mach 0.85
  - Zero Fuel Weight: 38,000 lb, Max Takeoff Weight: 69,700 lb
  - 75 ft wingspan
- Standard Research Instrumentation:
  - Pitot-static and total temperature parameters
  - Flow angle vanes
  - Embedded GPS/INS (EGI) unit
  - Surface position measurements
- ACTE Research Instrumentation:
  - Structural sensors, including strain gages, fiber optics strain sensing, accelerometers
  - Aerodynamic sensors, including steady and unsteady pressures, a leading-edge stagnation sensing system, separation detection sensors, and tufts

ACTE Flaps



- Replaced conventional GIII Fowler flaps
- Span of 18 ft
- Roughly 20% chord

ACTE Aerodynamic Instrumentation

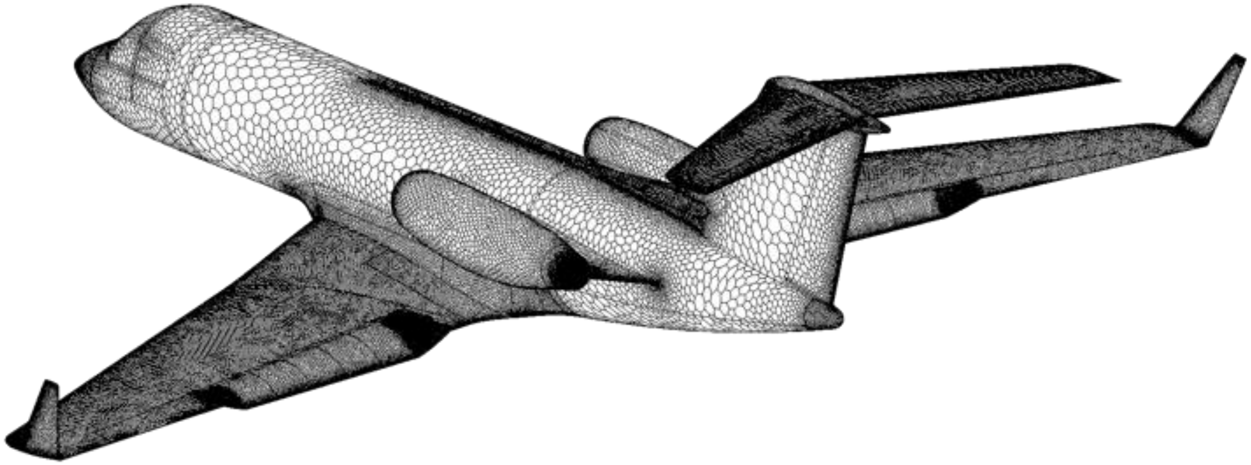


Flight Test Approach

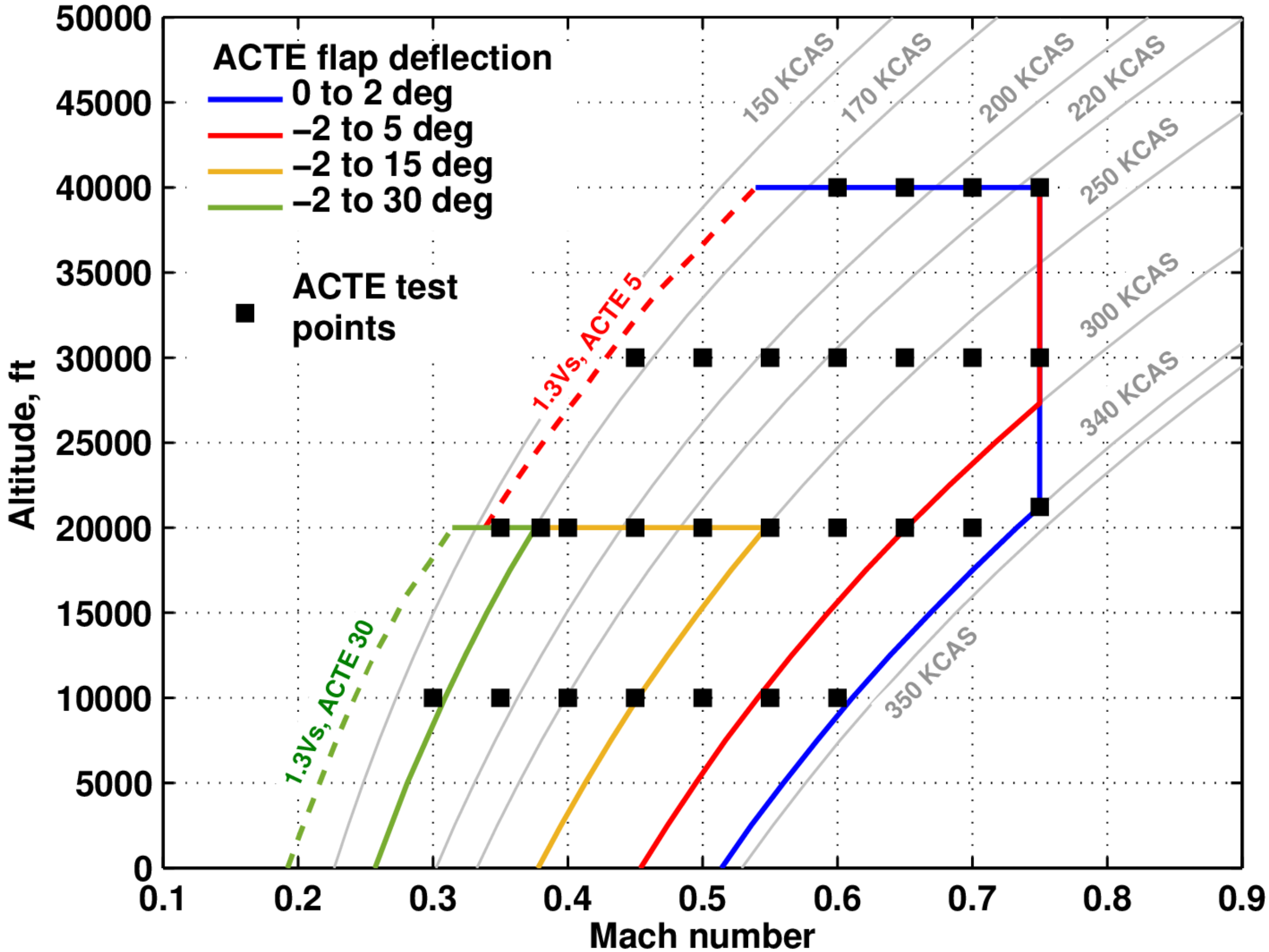
- Prior to ACTE modifications, baseline flights, including some with the flight spoilers disabled, were completed and used to update existing aerodynamic models for the GIII airplane
- CFD analyses were performed with Star-CCM+ code over the planned flight range of flap deflections and flight conditions
- CFD results were used to create an aerodynamic model, investigate effects of the flaps on stall speed and evaluate potential loss of aileron effectiveness
- An aerodynamic model of the force and moment effects of the ACTE flaps was created from predictive tools and incorporated into a 6-DOF flight simulation
- Flights were performed with the ACTE flaps installed, starting with 0 degree flap deflection
- The flight envelope for each flap deflection was cleared, then incrementally increased for the next set of flights

Star-CCM+ Vehicle Aerodynamics

- Unstructured Navier-Stokes solver
- Full airplane was modeled
- Operating engines were modeled using flow conditions from 1-D engine model
- 35 million finite volume cells
- SST K-Omega turbulence model used with an all y+ wall treatment
- 19 prism layers were used within a normal distance of approximately 1.8 inches from the wall



ACTE Flight Envelope



Investigation Methods

- Vehicle Aerodynamics
  - 2-1-1 maneuvers performed in-flight
  - Parameter estimation using equation error and output error techniques
- Sectional Pressures
  - Constant airspeed and altitude "steady-state" maneuvers were flown
  - Pressures were averaged over 5-second time spans with minimal change in Mach, altitude, and angle of attack
  - Pressure coefficients and sectional lift coefficients were calculated
- Pitot-Static System
  - Level acceleration and deceleration maneuvers were performed at various altitudes
  - Meteorological data was combined with differential GPS to produce correction curves

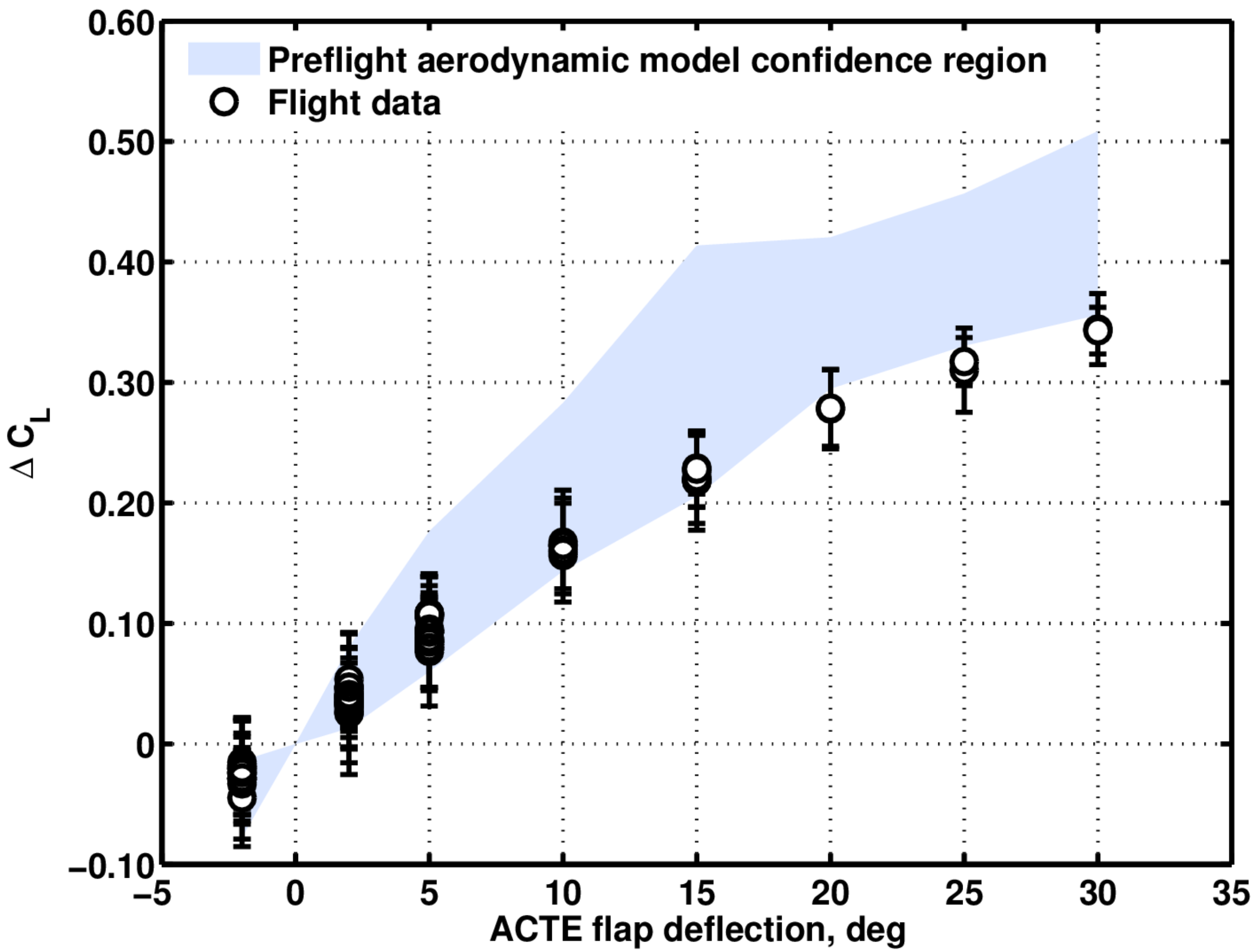
Flight Test Results

- All flight test objectives were met
- A total of 23 ACTE flights were completed
- The flight tests successfully cleared the planned envelope and captured aerodynamic and structural data
- Results in the areas of vehicle aerodynamics, sectional pressures, and effects on the pitot-static system will be discussed

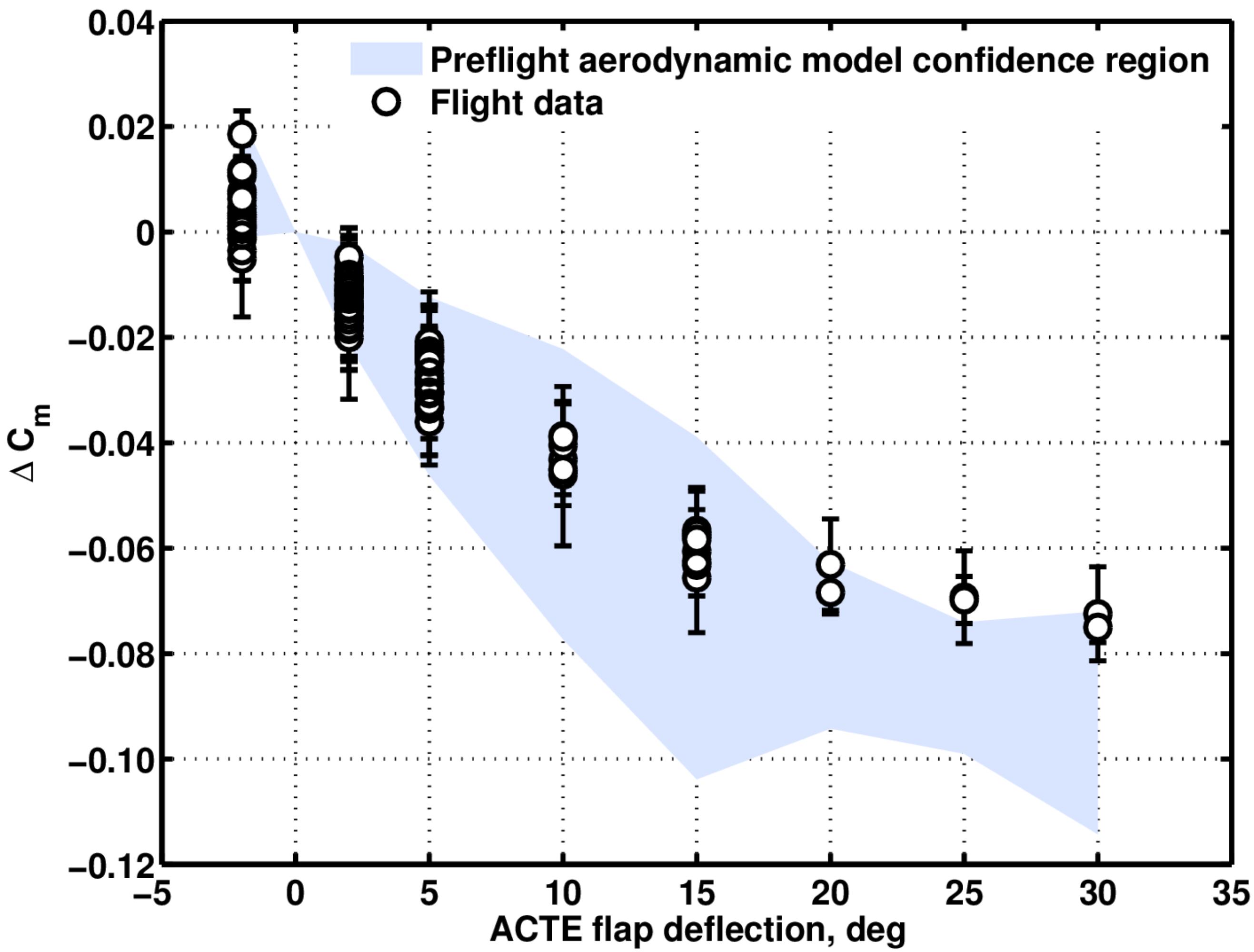
Vehicle Aerodynamics Results

- The ACTE flaps affected airplane lift and pitching moment
- No significant effects to other stability and control derivatives
- The preflight ACTE aerodynamic model over-predicted lift due to the ACTE flap for flap deflections above 10 degrees
- Pitching moment due to ACTE flap was better predicted, but still over-predicted for flap deflections above 20 degrees
- ΔC_L and ΔC_m trends with Mach number were captured reasonably well by the preflight model

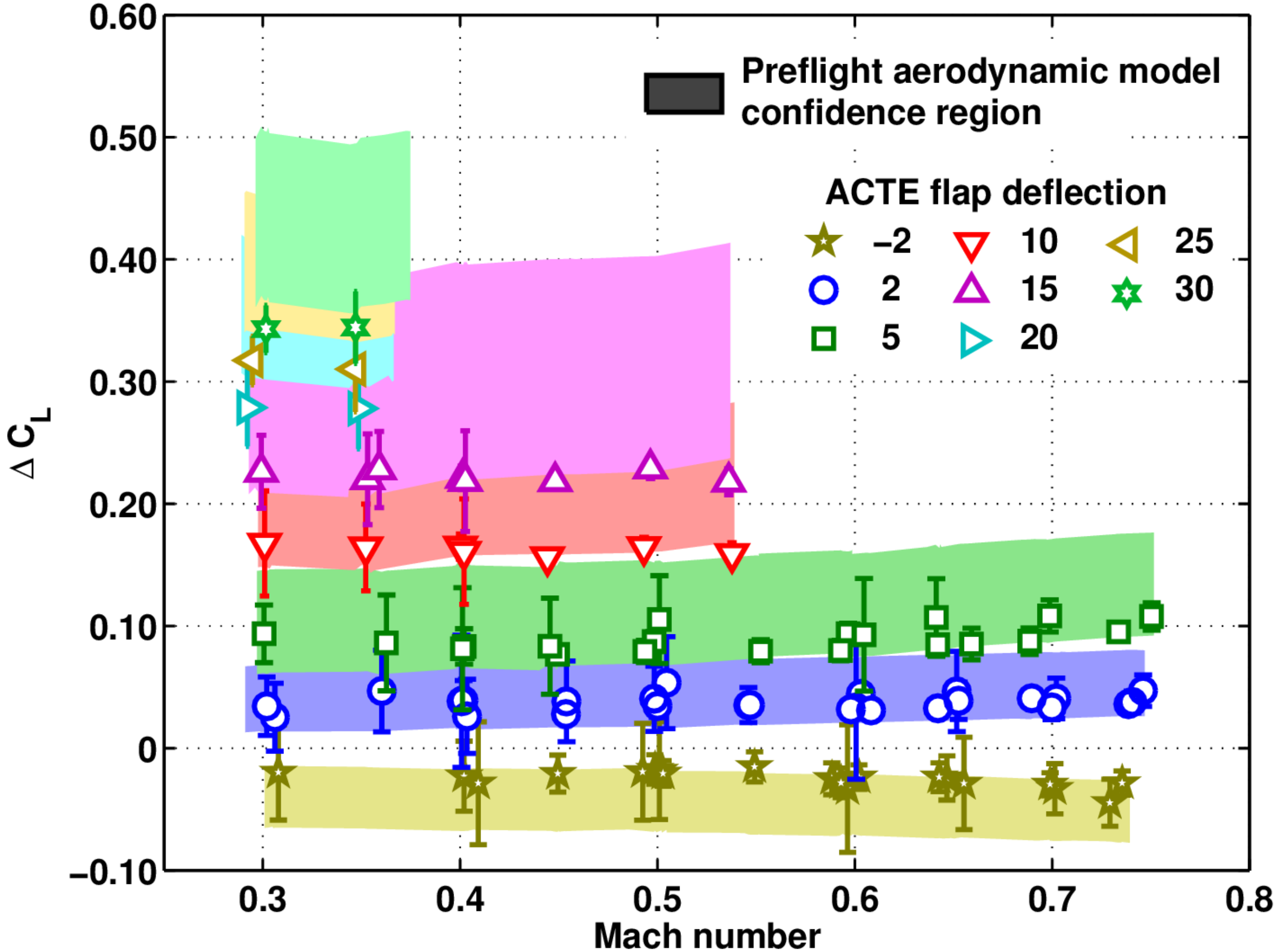
ΔC_L vs. ACTE Flap Deflection



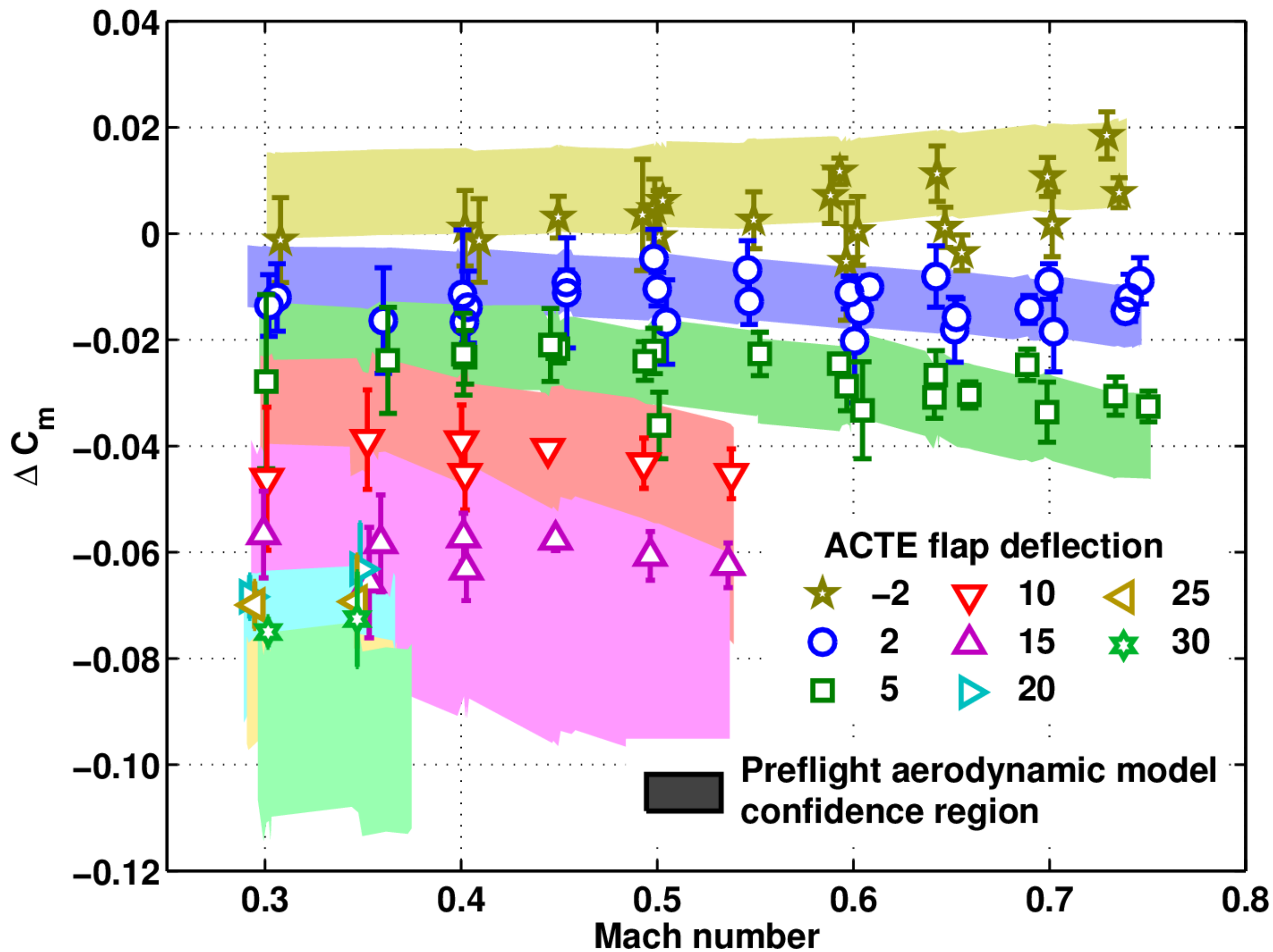
ΔC_m vs. ACTE Flap Deflection



ΔC_L vs. Mach Number



ΔC_m vs. Mach Number

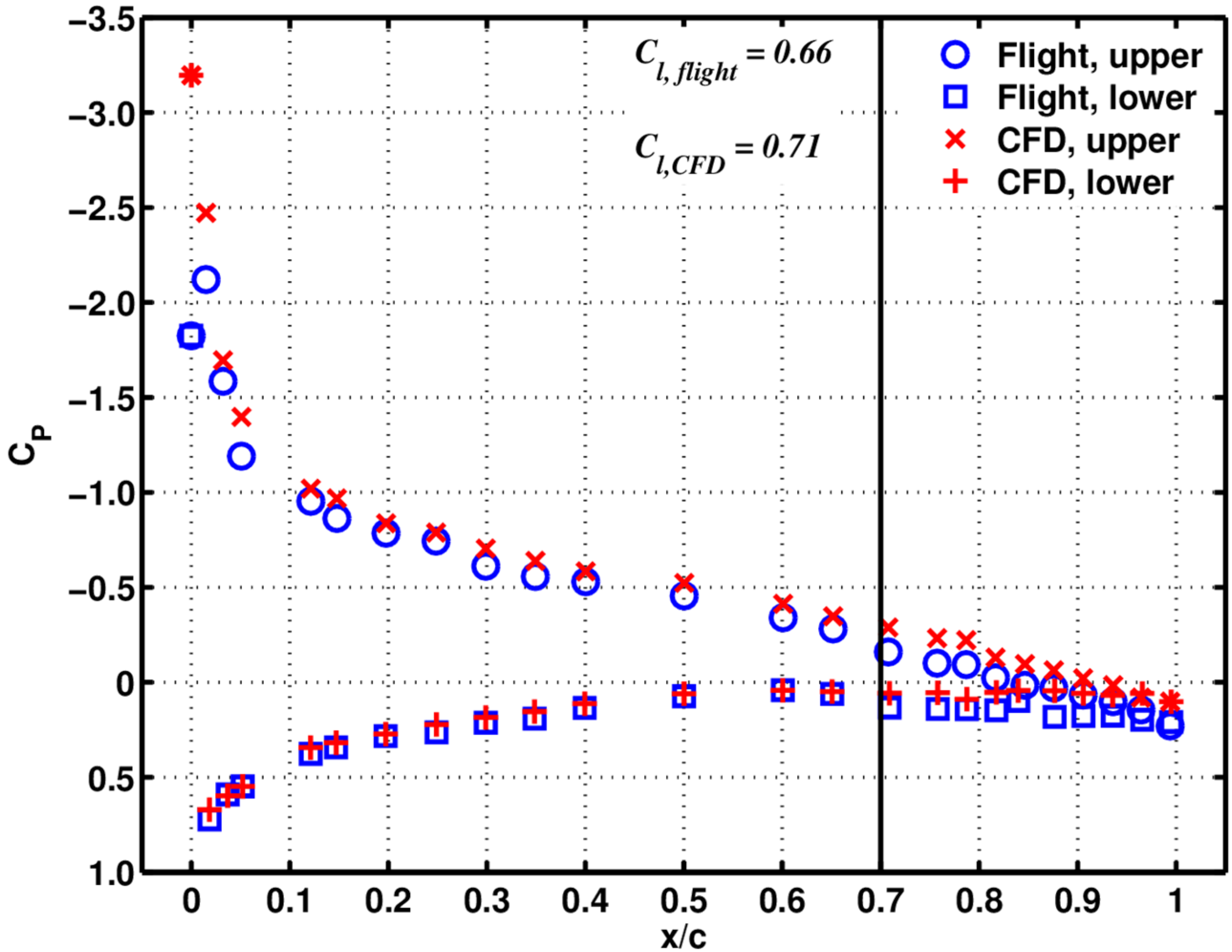


Sectional Pressures Results

- CFD results consistently over-predicted suction over the entire airfoil section (at all three butt lines)
- At high flap deflections, flow separation over the flap was under-predicted by CFD results
- Predictions for flow separation point were most accurate for the inboard pressures and least accurate for the outboard pressures
- Results for sectional lift mirrored overall aerodynamic model trends for lift due to ACTE flap

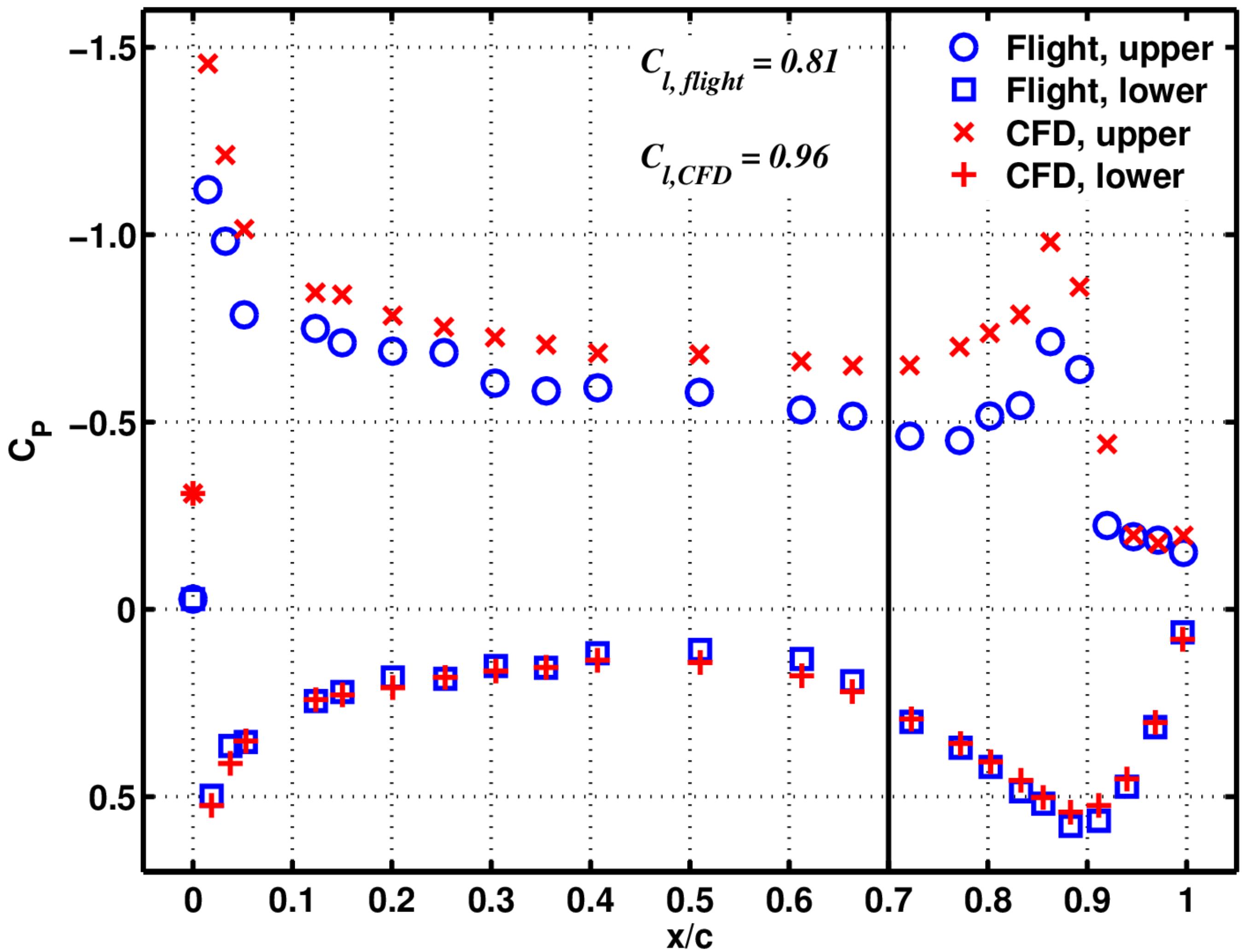
Sectional Pressures

0° ACTE flap at Mach 0.30, 10,000 ft



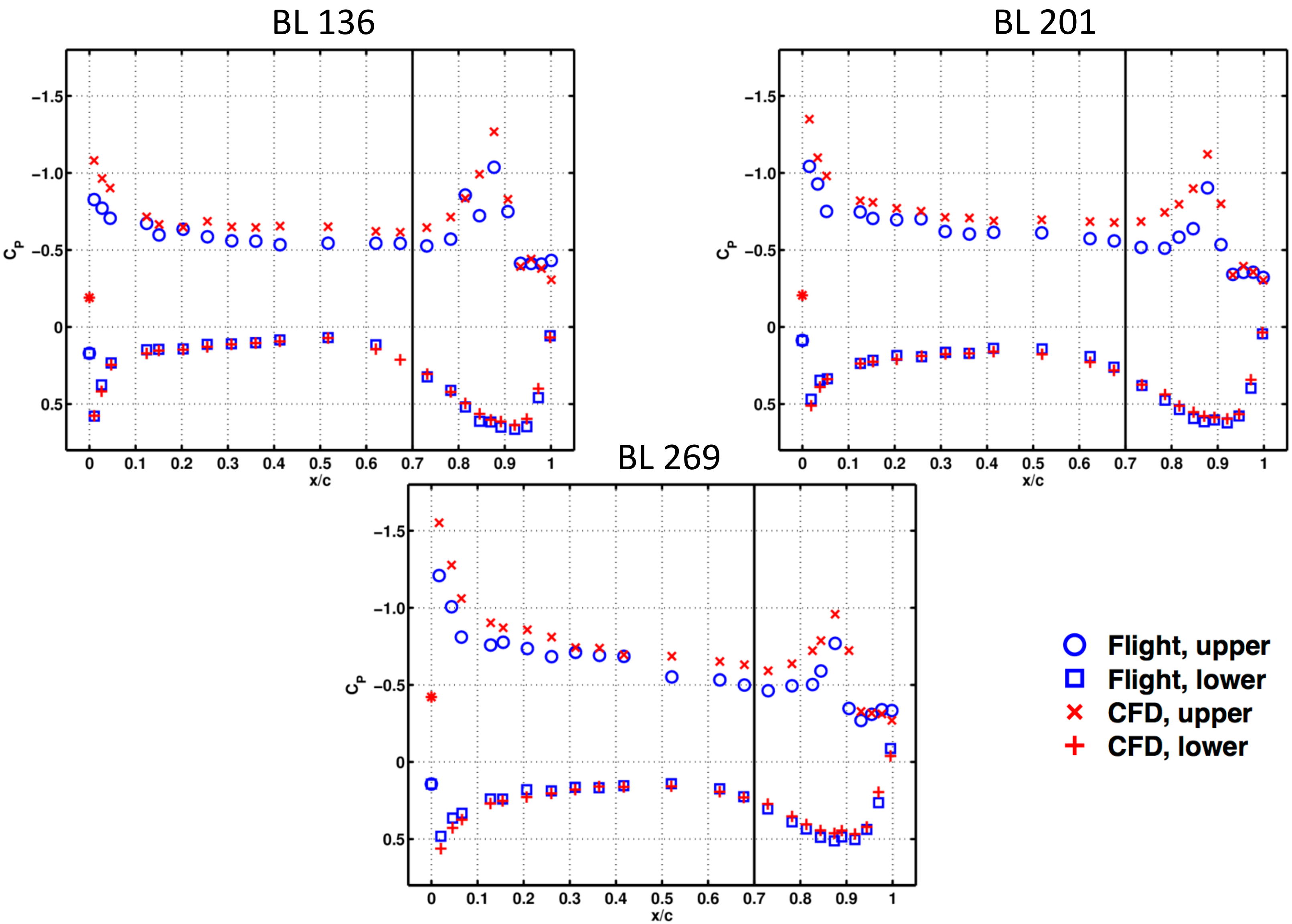
Sectional Pressures

20° ACTE flap at Mach 0.30, 10,000 ft

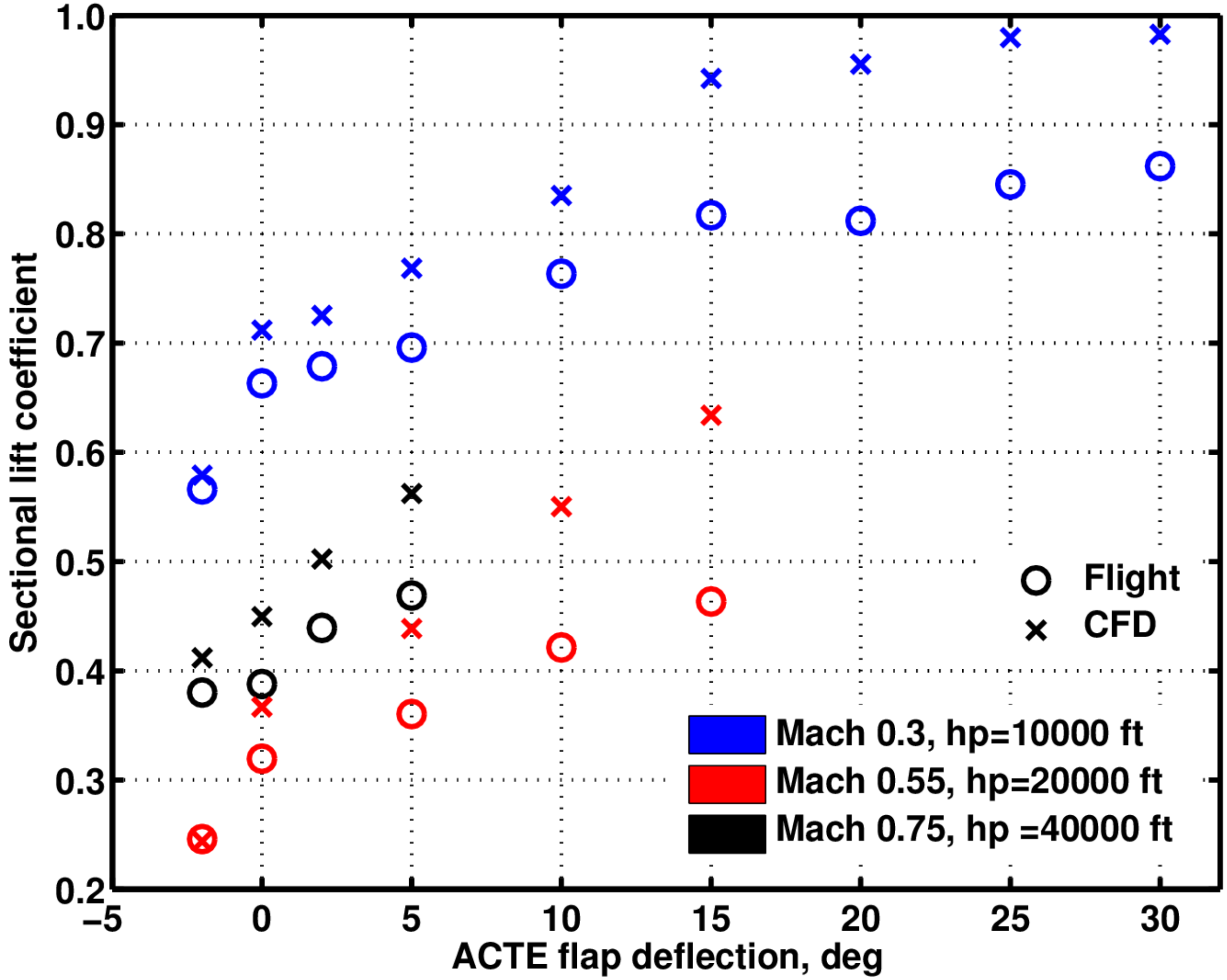


Sectional Pressures

30° ACTE flap at Mach 0.30, 10,000 ft



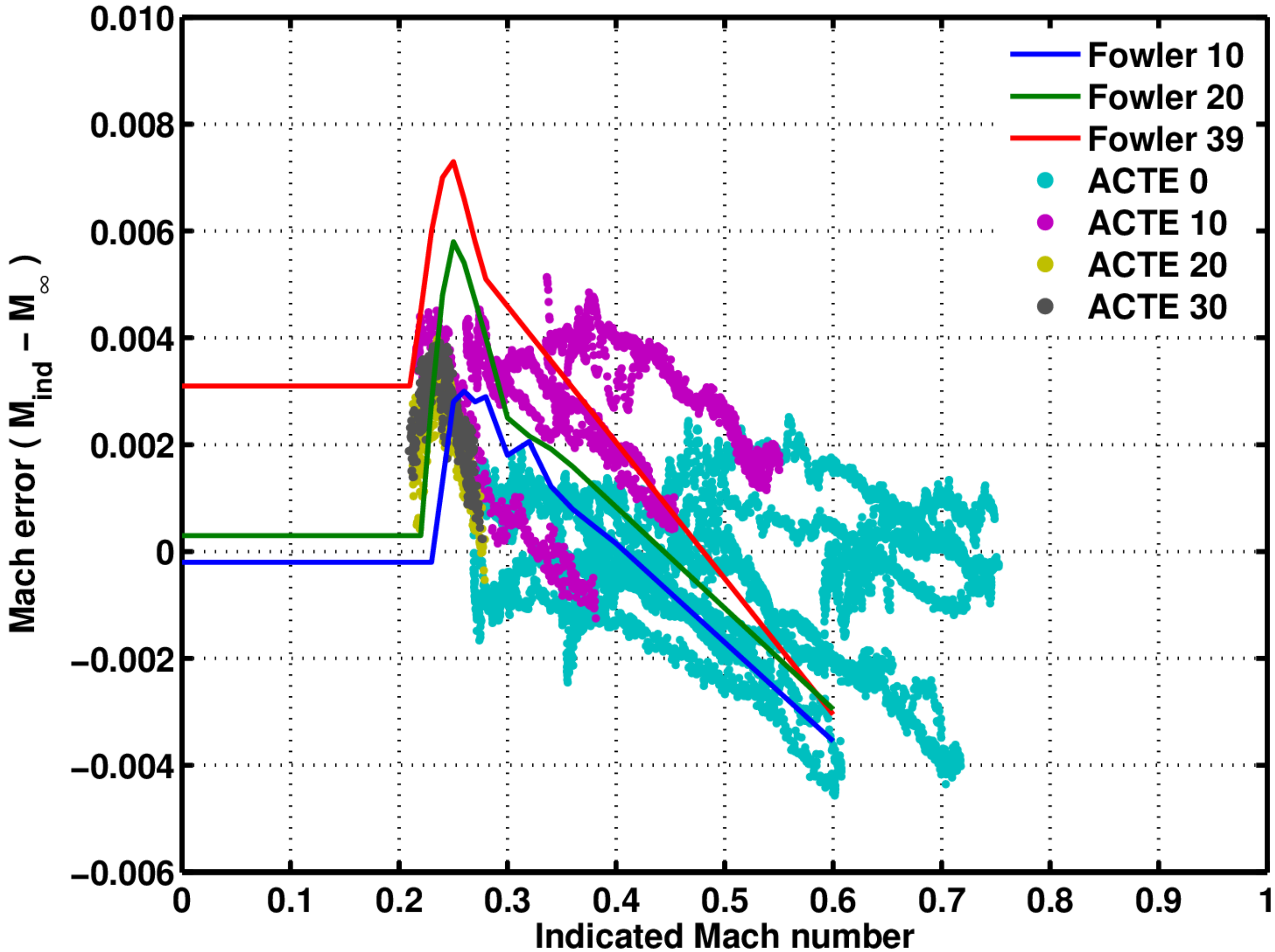
Sectional Lift



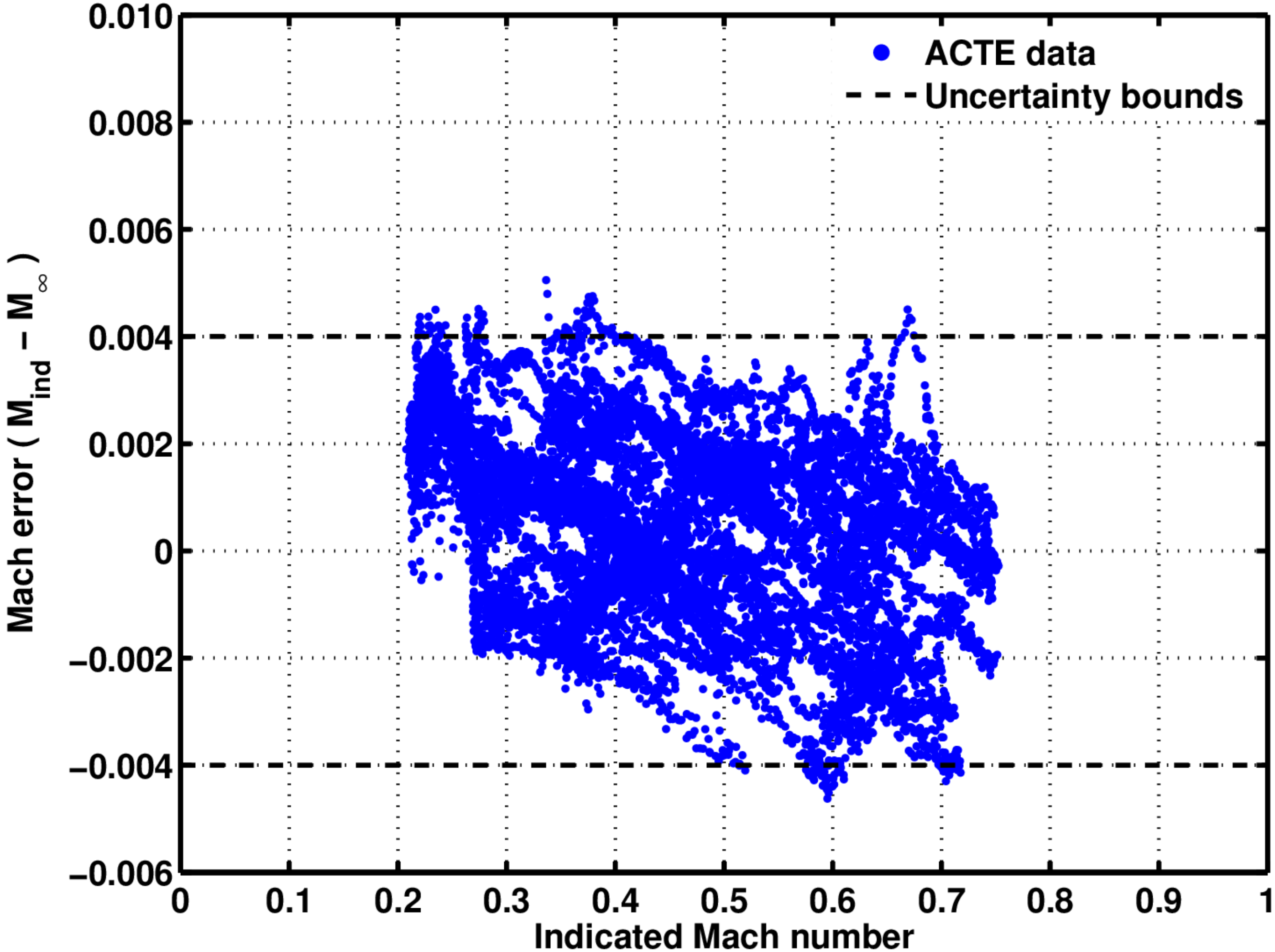
Effects on Pitot-Static System

- Despite noticeable effects on the pitot-static system by the standard fowler flaps, airplane pitot-statics were not substantially affected by the ACTE flaps
- Any potential effects of the ACTE flaps fall within the calibration uncertainties of the pitot-static system

Pitot-Static Effects



Pitot-Static Effects



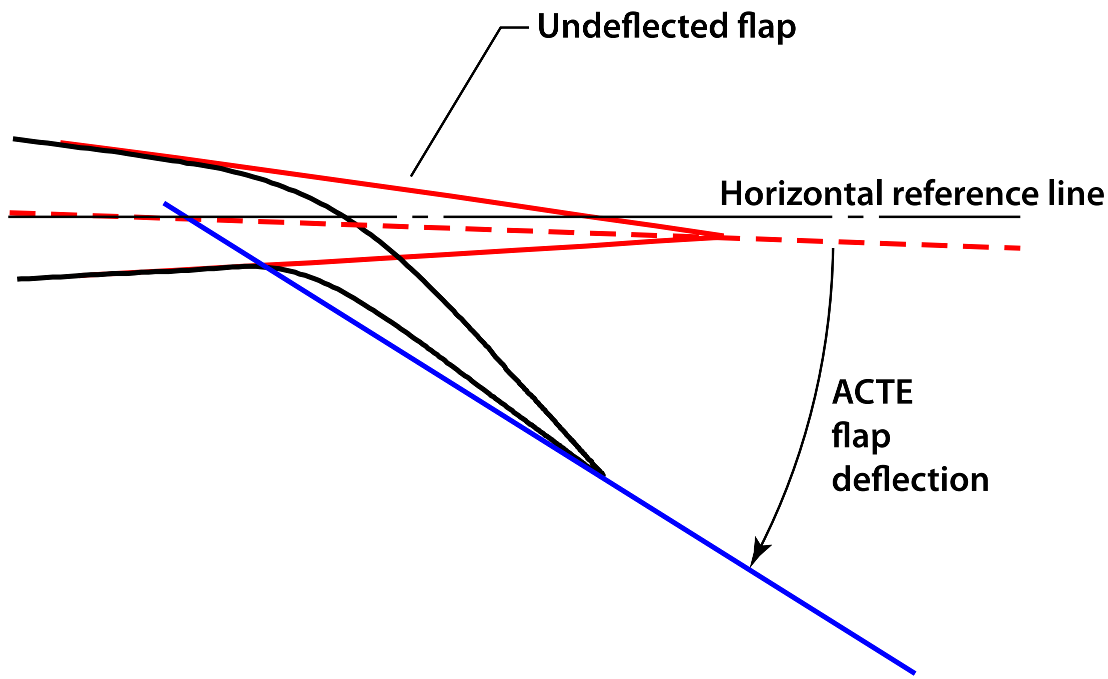
Conclusions

- ACTE flight tests were completed successfully
- Aerodynamic models compared well with flight data at lower ACTE flap deflections, but over-predicted lift at higher flap deflections
- CFD solutions consistently over-predicted suction over the airfoil and under-predicted flow separation over the ACTE flap when compared with flight data
- Airplane pitot-static system was unaffected by ACTE flaps

Questions?

Backup Slides

ACTE Flap Deflection Definition



Sectional Pressures