CATNLF Flight Test Data and the Need for ELISE Design

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Transition Modeling Discussion Group – June 2023

Outline

- Background / Motivation
- Method
- Results
- Next Steps

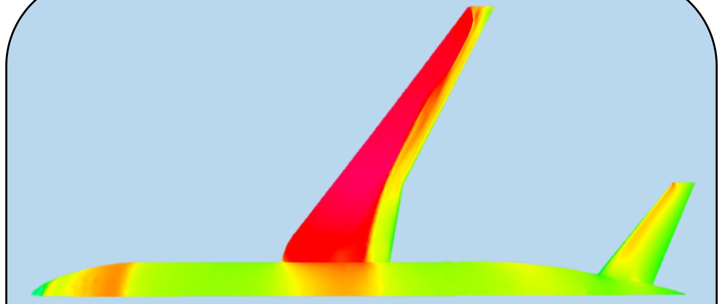
CATNLF Concept Development

NASA Laminar Flow Design Method

Crossflow Attenuated NLF (CATNLF) design method changes the shape of the wing airfoils to obtain pressure distributions that delay transition by damping crossflow instabilities

Computational Study

2014 – 2017



Goal: To develop technology
Reference: AIAA 2016-4326

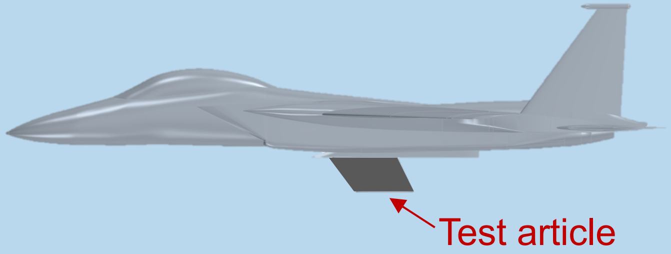
Wind Tunnel Test

2017– 2019

Goal: To confirm computations
References: AIAA 2017-3058, AIAA 2019-3292

Flight Test

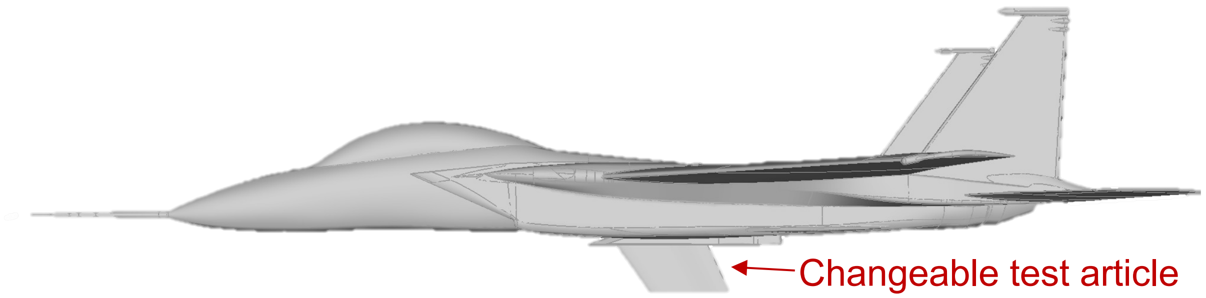
2019 – Present



Goal: To advance technology
Reference: AIAA 2021-0173

CATNLF Flight Test Series

Series of flight tests under an F-15 using the Centerline Instrumented Pylon (CLIP)

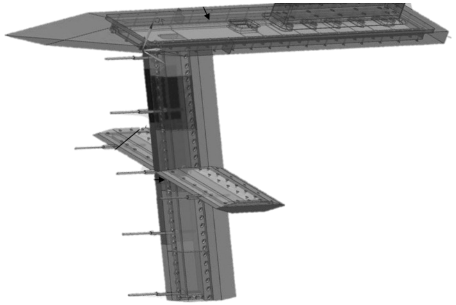


AFRC F-15 CLIP Flight Test Bed

Flight 1: ReHEAT Experiment

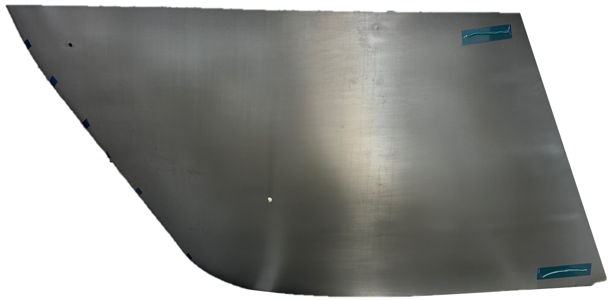
Goal: Test carbon-based heating layer for improved flow visualization
Status: Successfully completed 2020*

Flight 2: Flow Rake Experiment



Goal: Quantify flow environment underneath F-15
Status: First flight June 2023

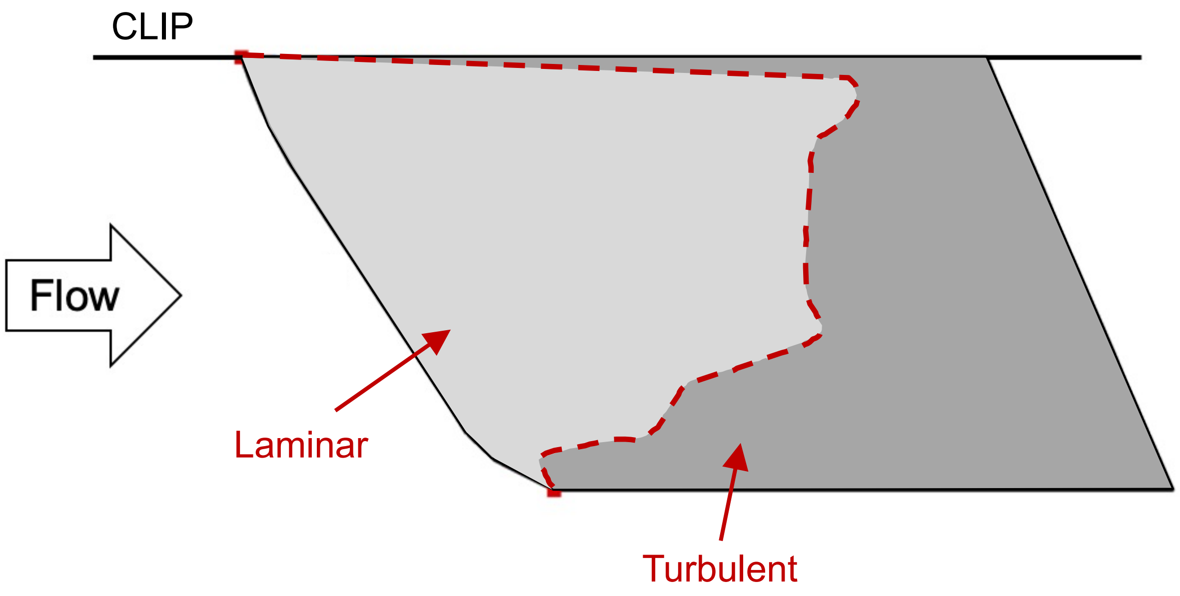
Flight 3: CATNLF Experiment



Goal: Test CATNLF concept in flight environment
Status: First flight September 2023

*Reference: AIAA 2020-3089

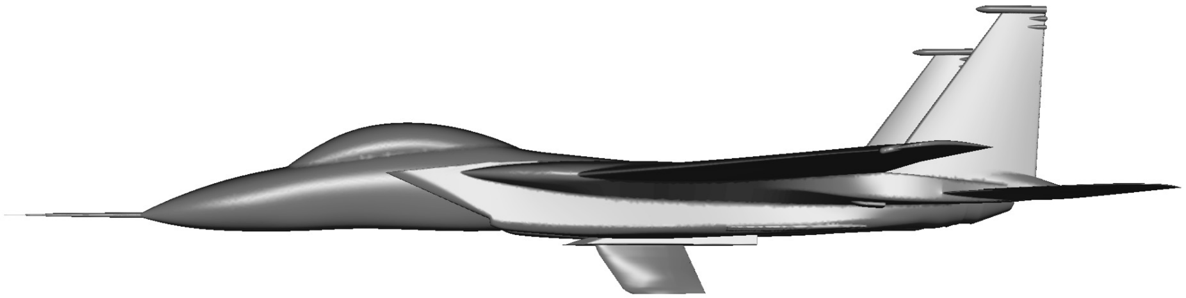
CATNLF Test Article Design



Key Geometry Parameters and Design Conditions	
Mean Aerodynamic Chord (MAC)	5.9 ft
Span	3.3 ft
Leading-Edge Sweep	35 deg
Mach	0.85
Re_{MAC}	31 million
Section Lift Coefficient	0.50

- Approx. 52% of surface area has laminar flow at design condition with maximum transition Reynolds number of approximately 24 million
- Laminar flow inboard is shock-limited transition and outboard is Tollmien-Schlicting transition
- Test article instrumented with static and dynamic pressure ports, thermocouples, accelerometers, and internal electrical wires for resistive heating layer

Challenge with Public Release of Flight Test Data



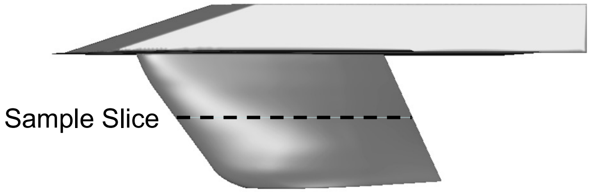
CATNLF Test Article in Flight Configuration

CATNLF Test Article in Isolated Configuration

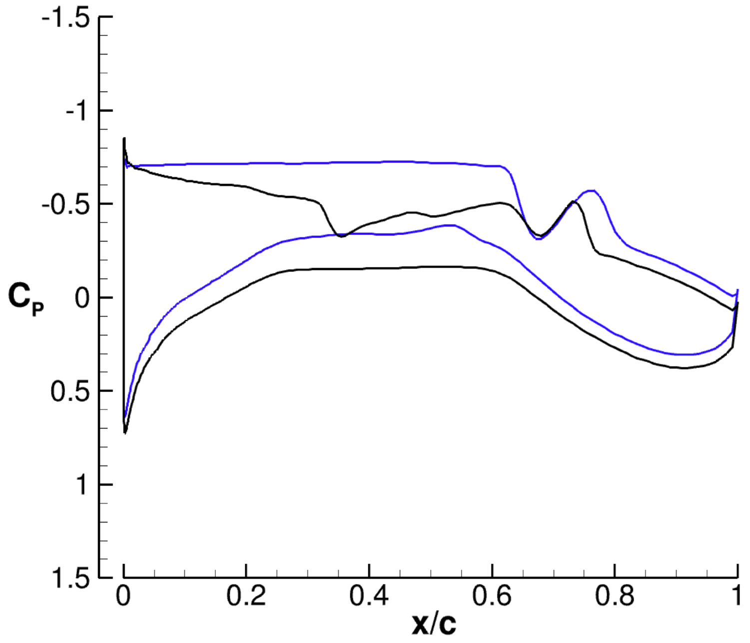
- Proposed plans to release the CATNLF flight test data to community for transition studies
- CATNLF test article was designed in the Flight Configuration to account for interference from the F-15, but the F-15 is not a publicly-releasable geometry
- Aerodynamic and transition characteristics of the test article are significantly altered in the Isolated Configuration because of missing F-15 interference effects

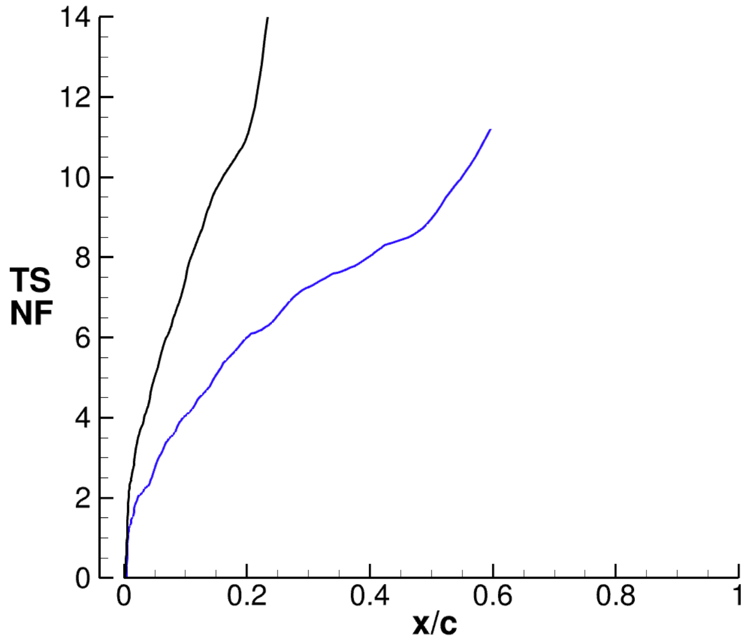
Influence of Aircraft on CATNLF Test Article

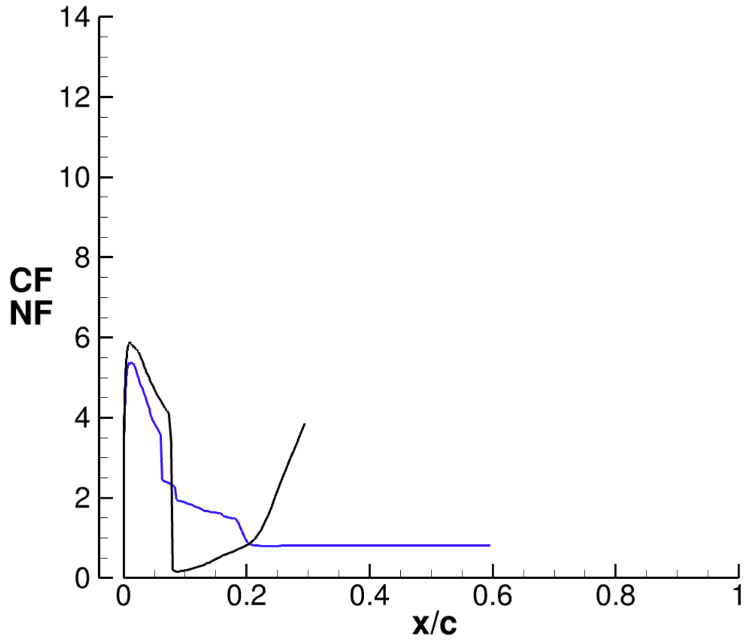
Goals of releasing flight test data include evaluating computational transition methods, but changes in CATNLF test article character without the F-15 complicate that objective



Blue = Flight Configuration
Black = Isolated Configuration





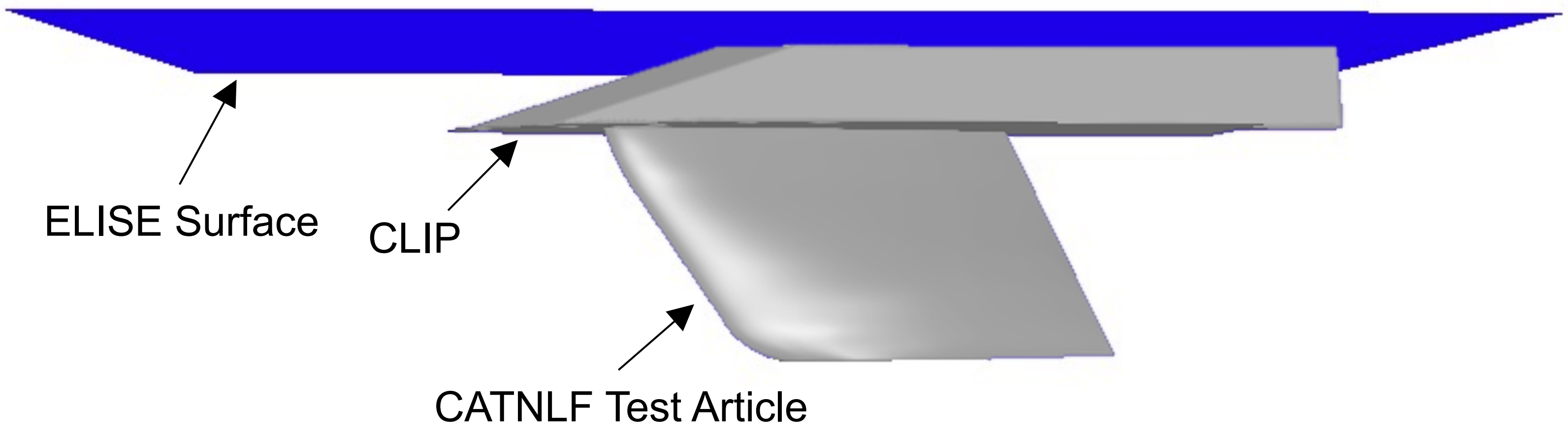


TS = Tollmien-Schlicting; CF = Crossflow; NF = N-Factor

ELISE Design Method

<u>Equivalent Loading via Interference Surface Effects (ELISE)</u>

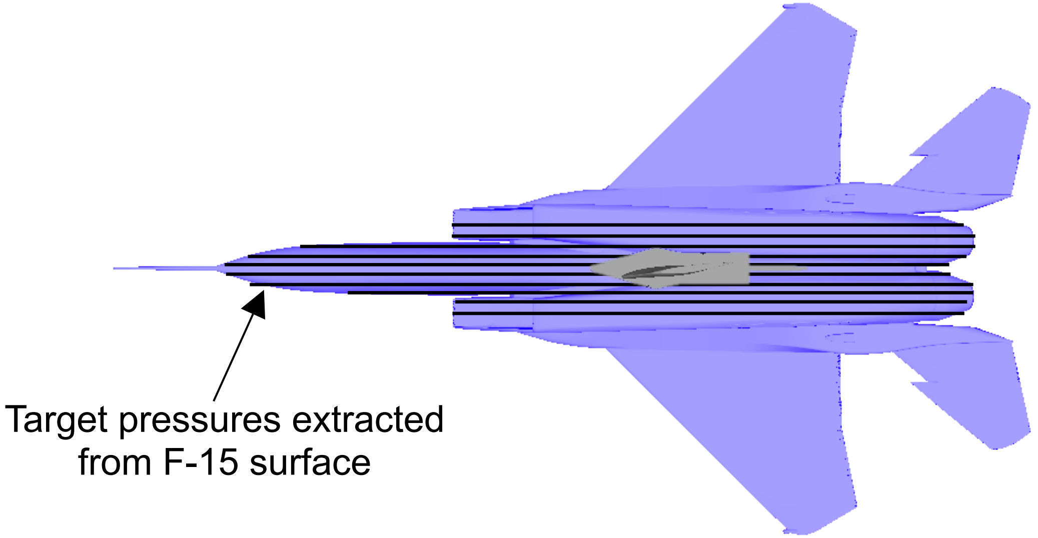
Design method that creates a surface that produces the same interference effects seen on the CATNLF test article in flight

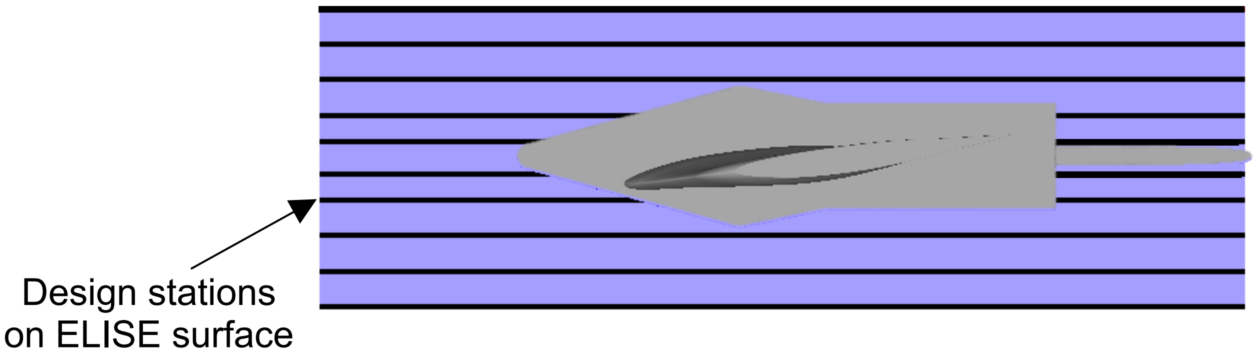


ELISE Design Method

Design Setup:

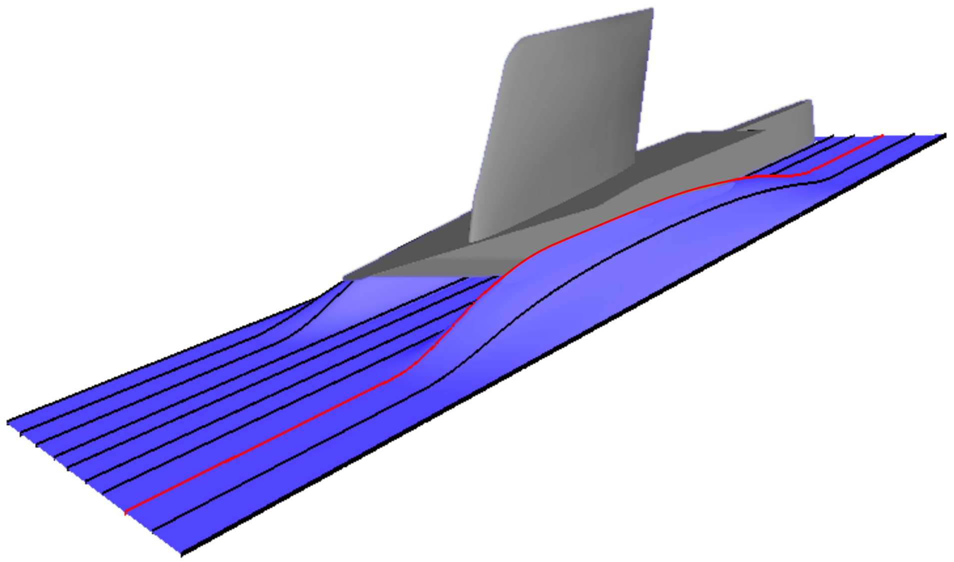
- Test article and CLIP geometry are fixed
- ELISE surface is an inviscid flat box around base of CLIP
- CDISC is used to alter the shape of the ELISE surface to match target pressures
- Target pressures are extracted from the underside surface of the F-15 in the Flight Configuration grid



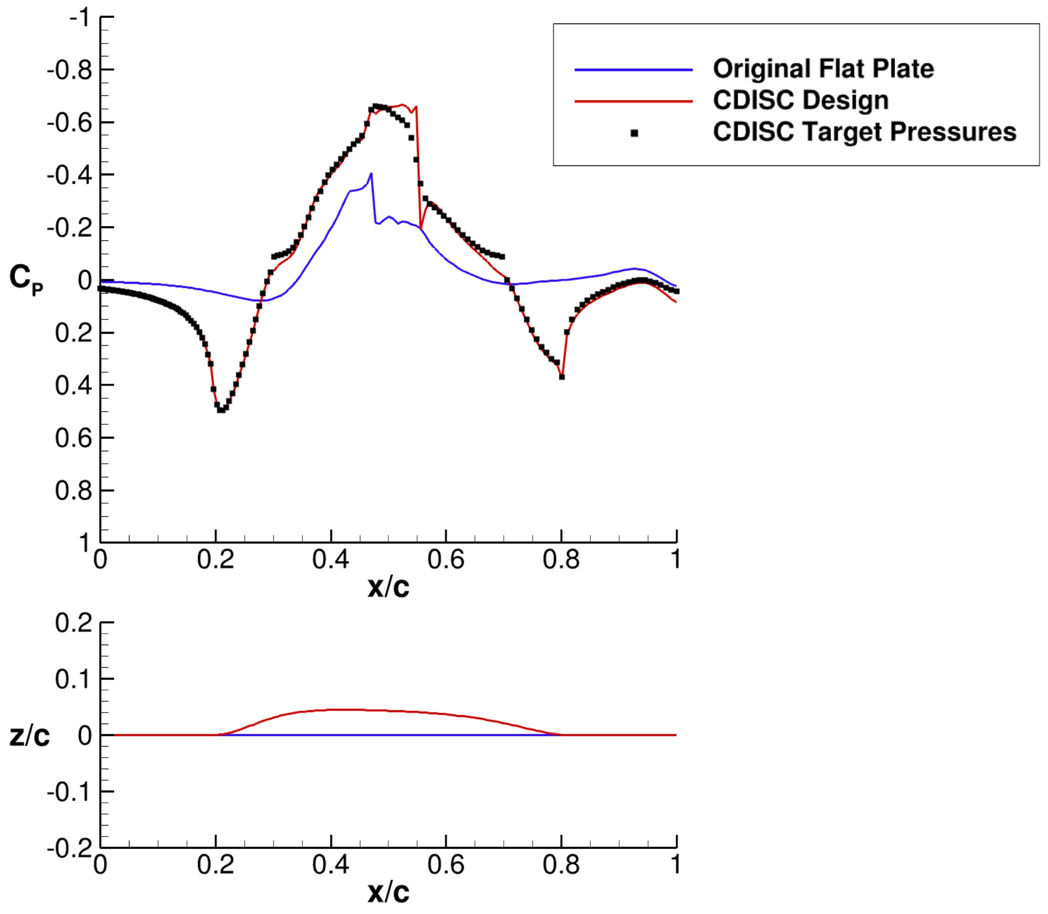


Preliminary Design Results: Surface Geometry

Preliminary results suggest CDISC is successful at altering the ELISE surface geometry to match the target pressures



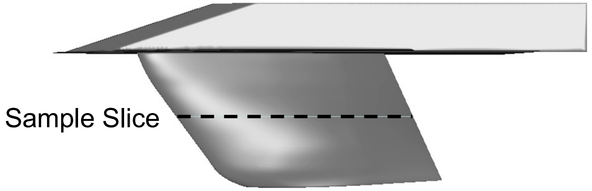
Surface Length	Surface Width	Surface Max Height
21.78 ft	7.00 ft	1.96 ft



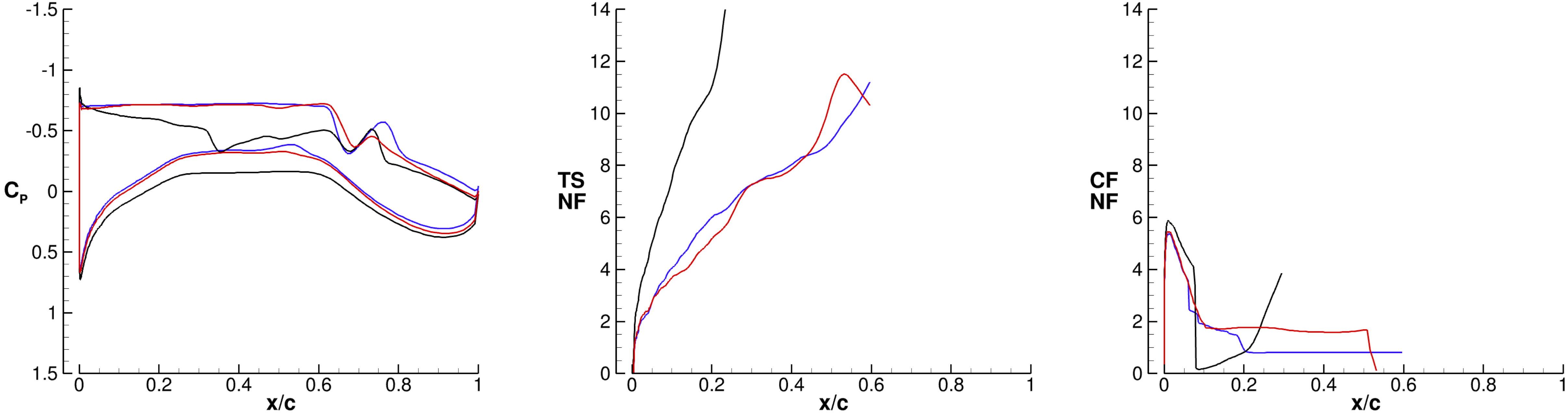
Example design station

Preliminary Design Results: Test Article Pressures

Preliminary results suggest the ELISE method is successful at replicating the interference effects of the F-15 on the CATNLF test article in flight



Blue = Flight Configuration
Black = Isolated Configuration
Red = Isolated Configuration with Designed ELISE Surface



Next Steps

- Finalize design of ELISE surface and assess at off-design conditions
- Current programmatic interest in a follow-on wind tunnel test of the CATNLF test article to evaluate influence of environment on laminar flow characteristics
- Wind tunnel test would require an ELISE surface with additional considerations:
  - Viscous effects on ELISE surface
  - Tunnel wall effects on CATNLF test article
  - Limitations on size due to blockage concerns
- Publication coming SciTech 2024 on ELISE design approach