Interference Effects of a Flow-Through Nacelle on a Slotted, Natural-Laminar-Flow Wing

David Palmer – University of Tennessee, Knoxville
Advisor – Dr. Jim Coder, University of Tennessee, Knoxville

Abstract

Overset grid methods are used to analyze the influence of a low fan pressure ratio flow-through nacelle on a slotted, natural-laminar-flow (SNLF) semi-infinite wing. Since SNLF airfoils are a transformational technology, unconventional configurations are investigated to illuminate how nacelle position affects the laminar flow on the SNLF wing. Flow-through studies are a precursor to powered on engine integration where a thrust-drag bookkeeping method will be implemented.

Research Questions

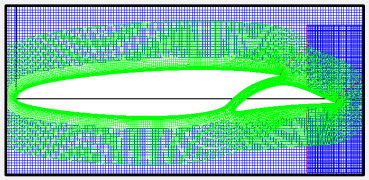
1. How does a flow-through nacelle influence laminar flow over a SNLF wing at cruise conditions?
2. Which engine position minimizes interference drag at cruise conditions?

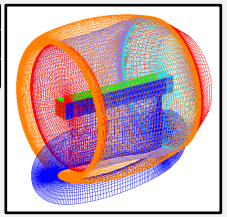
Methodology

An axisymmetric nacelle grid and SNLF airfoil grid were created using the overset grid software Chimera Grid Tools 2.1. The 2D airfoil was stretched in the plane normal direction to create a semi-infinite wing with constant chord.

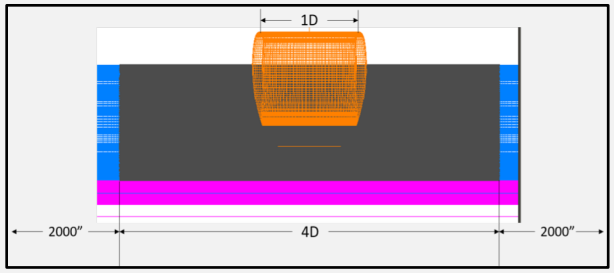
Flight Conditions	
C_L =	0.35
M =	0.745
Alt =	44000 ft

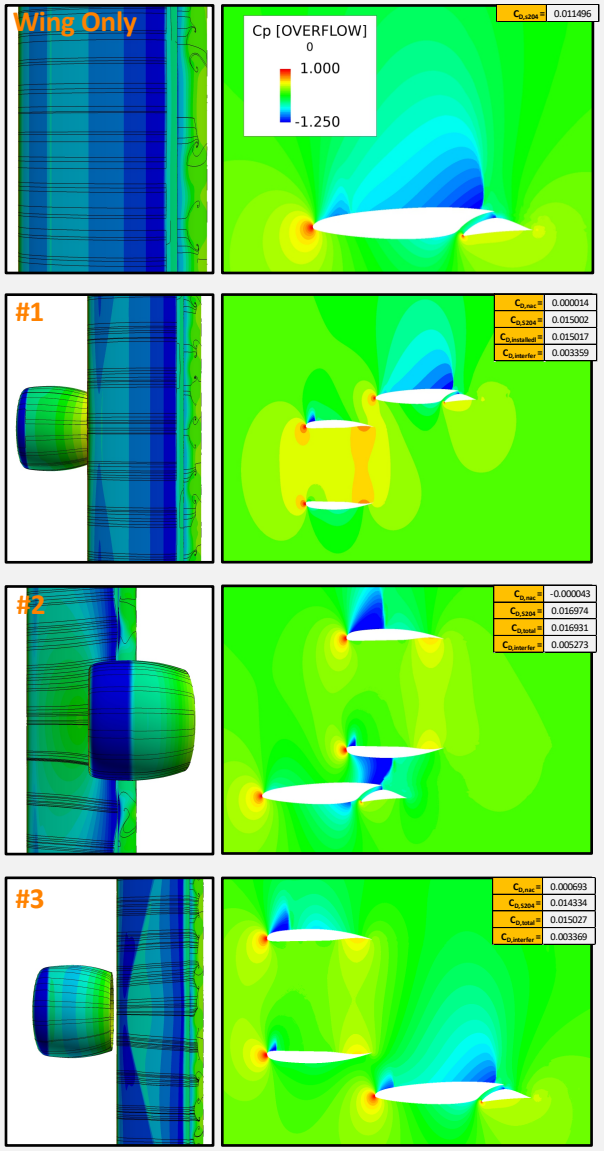
Geometry	
Nacelle Diameter =	77 in
Wing Chord =	110 in

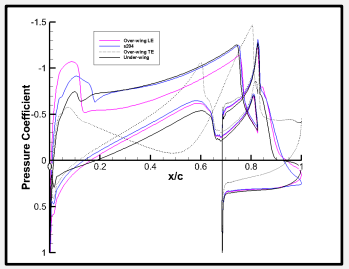




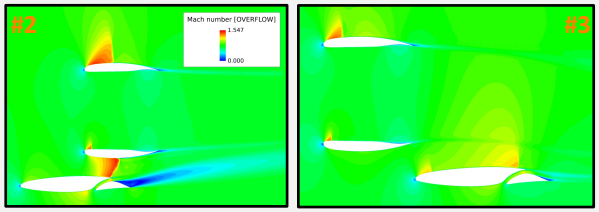
Above: near-body, plug, and flow-through nacelle grids
Left: s204 wing near-body grid with aft element refinement block
Below: geometry layout used for flow-through study







Leading edge shockwaves result in pressure jumps for all configurations while a additional late shockwave in position #2 leads to separation



Left: A Strong shockwave created by accelerated flow through the gap between the wing and nacelle leads to separation of the aft element of the wing.
Right: There's no strong shock wave, and later separation on the aft element leading to reduced interference drag compared to position #2.

Future Work

Three general nacelle configurations were simulated to assess the impact on laminar flow over a semi-infinite SNLF wing. Qualitative results give some insight into future powered-on engine studies:

- Trailing edge over-wing positions result in increased drag caused by a strong shock near the trailing edge of the SNLF wing. The nacelle must be further downstream of the wing to mitigate this nozzle-like effect from the nacelle and the wing.
- Streamlines on the surface of the wing show that the leading edge nacelles delayed separation while the trailing edge nacelle created earlier separation.
- A powered-on nacelle must be implemented to further examine the potential for minimizing interference drag.

Acknowledgements

This material is based upon work supported by the National Aeronautics and Space Administration (NASA) under cooperative agreement award number NNX17AJ95A. The work was performed under the University Leadership Initiative (ULI) at the University of Tennessee, Knoxville for the "Advanced Aerodynamic Design Center for Ultra-Efficient Commercial Vehicles." Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of NASA."