The Effects of Step Excrescences on Swept-Wing Boundary-Layer Transition
Doctoral Dissertation Defense

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Abstract
The immense fuel savings and environmental benefits of reducing aircraft skin-friction drag through laminar flow is well known. However, obtaining substantial laminar flow on an aircraft in an operational environment has proven to be a difficult challenge due to surface imperfections. One controllable imperfection is a 2-D step through requiring certain manufacturing tolerances between adjacent wing panels. This research aims at giving designers more realistic manufacturing tolerances for a typical, swept-wing transport aircraft.

A 30° swept-wing model with a movable leading-edge extending to $x/c = 0.15$ is used in the flight environment and in a low-disturbance wind-tunnel to study the effect of 2-D step excrescences in a three-dimensional boundary layer. Pressure measurements are compared with computational results, infrared thermography is used to globally detect boundary-layer transition, and hotwire measurements provide details of the boundary-layer profiles in the vicinity of the steps. An analysis of the results is provided including comparisons of both the wind tunnel and flight environment, and from experimental studies of an unswept model of similar 2-D pressure gradient. The crossflow instability is believed to dominate the transition process up to the critical step height, while the shear-layer instability dominates after the critical step height. Also, the addition of leading-edge sweep with a similar 2-D pressure gradient substantially lowers the local Reynolds-based critical step height for forward-facing steps, while it is similar for the aft-facing steps. However, a substantial increase in the overly-tight conventional laminar-flow tolerances can be made confidently.