T662 Infrared Thermography Results: Transition on the Wing Leading-Edge Extension

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Background & Objectives

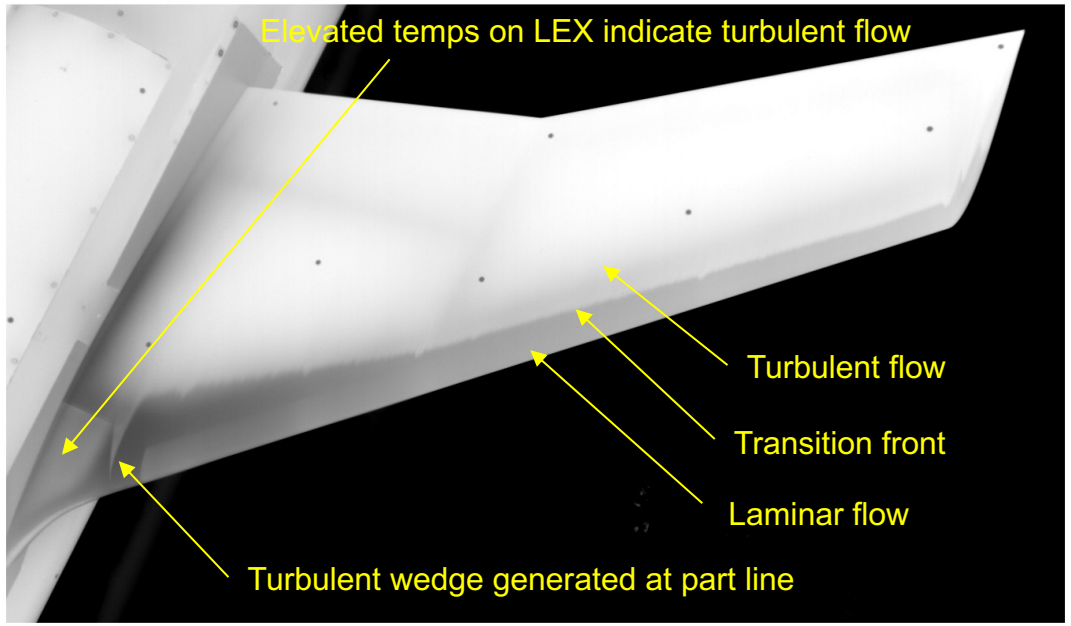
- During Test 662, IR thermography was used to measure the natural laminar-turbulent transition location on the juncture-flow model configured with the symmetric-wing geometry and a leading-edge extension (LEX)
  - Global images of the upper/lower wing surfaces and the fuselage were obtained
  - Detailed results are reported and discussed in AIAA Paper 2023-0441
- For subsequent turbulent-flow measurements during Test 662, IR thermography was also used to verify that turbulent flow was achieved on the model surfaces with trip-dot arrays
  - A row of trip dots was placed on the fuselage to fix the transition location
  - Rows of trip dots were placed on the upper & lower wing surfaces to fix the transition location at a percentage of the local chord length
- Question: what is the state of the boundary layer on the LEX?
  - Look at IR images with and without trip dots to help elucidate the boundary-layer state on the LEX

Experimental Setup

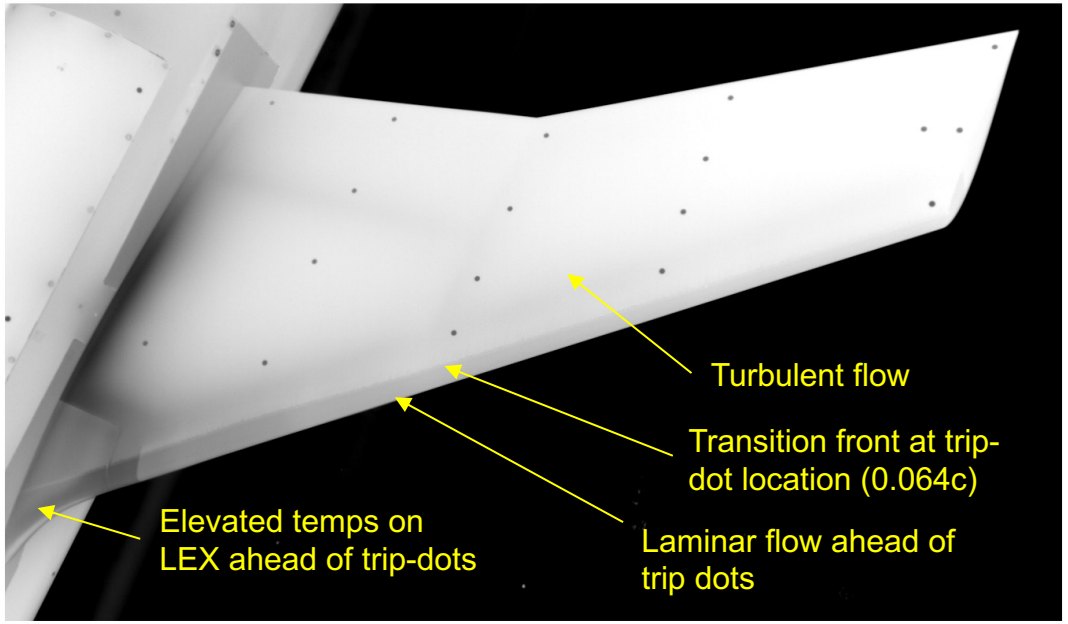
- IR camera details
  - Indium Antimonide (InSb) detector that provides temperature measurements in the MWIR range (3-5 μm)
  - Detector resolution of 1344 x 784 pixels with a pixel pitch of 14 μm
  - Noise equivalent temperature difference of the detector was less than 25 mK
  - Cameras were fitted with 25 mm, f/4.0 lenses for a wide-angle view of the wing upper surfaces
- IR cameras were placed in the tunnel test section ceiling behind circular cutouts that provided views of the port and starboard upper wing surfaces
- Adjustments to IR image exposure and contrast were made during post processing
- The juncture-flow model was painted with a flat black polyurethane paint
  - Provides a low-emissivity surface for the IR thermography and low reflections from IR sources in the test section
  - Provides a modest level of insulation from the aluminum surface of the model (nevertheless, the internal structure of the model is revealed in the IR images, since local heat conduction is influenced by the internal model structure)

IR Images of Port Wing at α = 5 degrees

Baseline – no trip dots



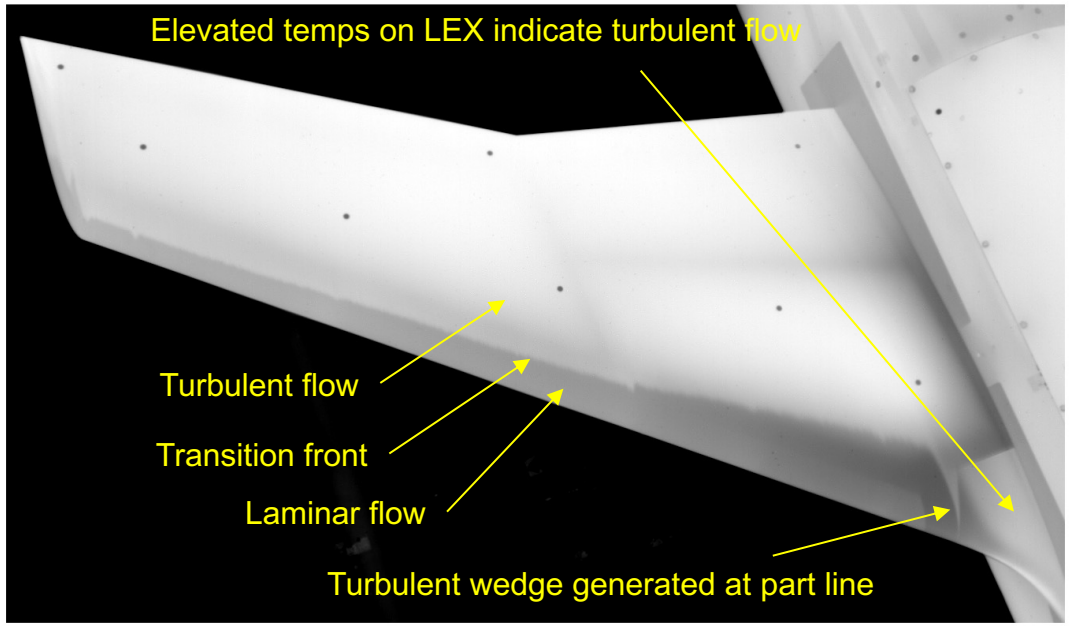
Trip dots applied at 0.064c



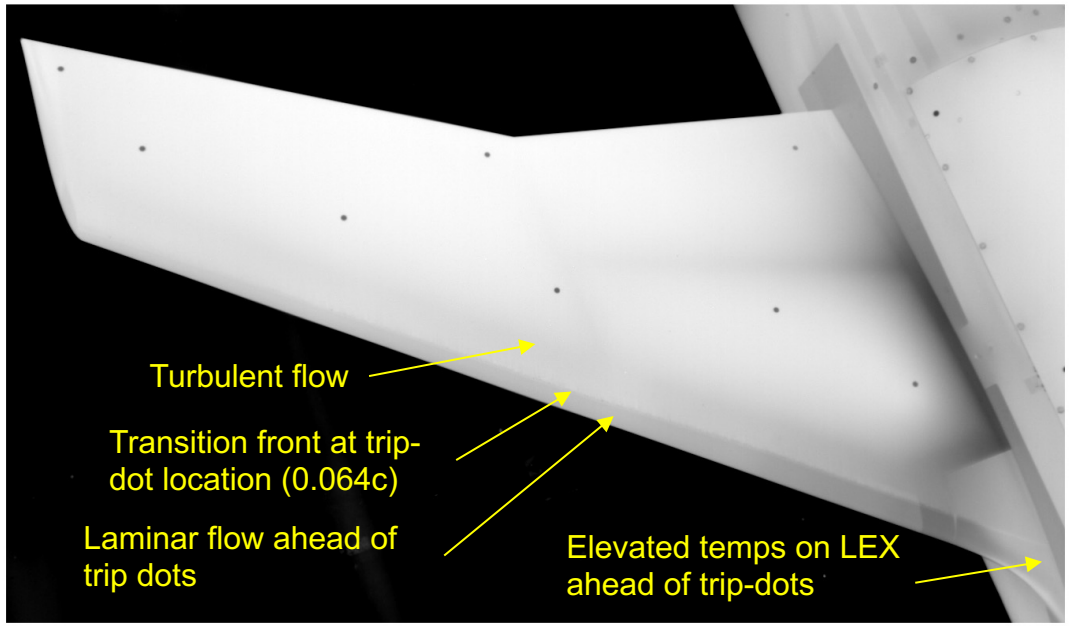
- For these IR images, air temperature was higher than model temperature.
- Lighter tones indicate higher surface temperatures associated with turbulent flow; darker tones indicate lower surface temperatures associated with laminar flow
- For baseline case (no trip dots), elevated temperatures on LEX indicate turbulent flow
- For case with trip dots, elevated temperatures on LEX ahead of trip dots also indicate turbulent flow

IR Images of Starboard Wing at α = 5 degrees

Baseline – no trip dots



Trip dots applied at 0.064c



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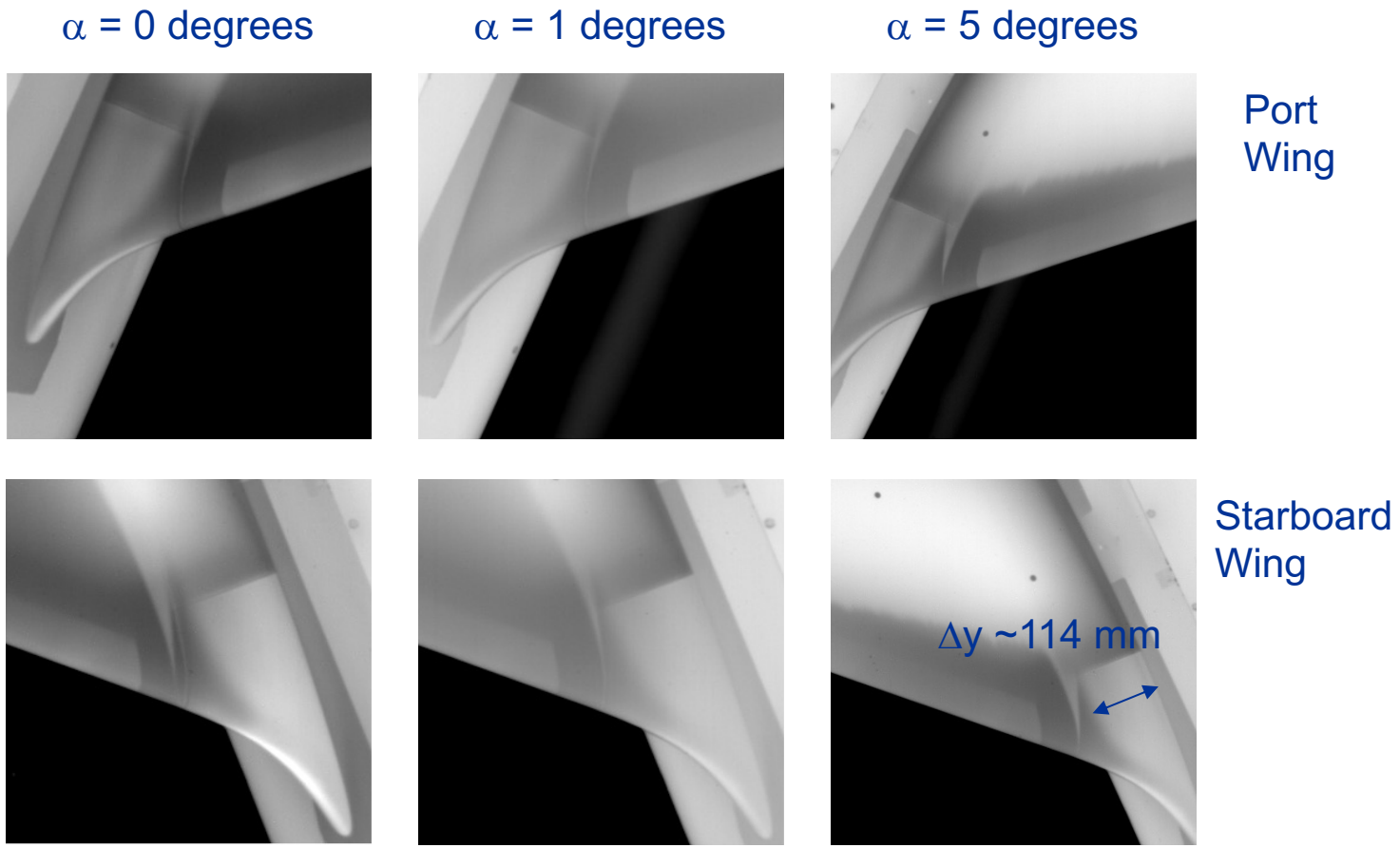
IR images of LEX vs. Angle of Incidence

- Close-up IR images of the LEX for baseline case (no trip dots)
- Elevated temperatures on the LEX of both port and starboard wings indicate turbulent flow
- The source of turbulent flow on the LEX is likely due to attachment-line contamination from the turbulent boundary layer on the fuselage
- Large sweep angle of the LEX and relatively large bluntness produce attachment-line Reynolds number sufficient to sustain turbulent flow
- Moving out along the span, where the sweep angle and LE radius decrease, the attachment line flow appears to relaminarize
- Spanwise extent of turbulent flow on the LEX is approximately $\Delta y \sim 114$ mm for all three angles of incidence (but that does vary somewhat with chordwise position)



Summary

- IR thermography of the symmetric wing upper surface was examined to assess the state of the boundary layer on the leading-edge extension (LEX)
- IR images at three angles of incidence were examined: α = 0, 1, and 5 deg
- In general, the LEX on both the port and starboard wings displays elevated temperatures, indicating a turbulent boundary layer
- The source of the turbulent flow is likely due to attachment-line contamination from the fuselage boundary layer
- Turbulent flow contamination of the LEX is confined to a spanwise region extending Δy ~114 mm from the fuselage surface (although that does vary somewhat with chordwise position)