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Infrared Images of Boundary Layer Transition on the D8 Transport Configuration in the LaRC 14- by 22-Foot Subsonic Tunnel

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Presentation Outline

Introduction

The purpose of this study is to non-intrusively detect the location of laminar to turbulent boundary layer transition on a D8 transport model in the LaRC 14'x22' Subsonic Tunnel.

Goal

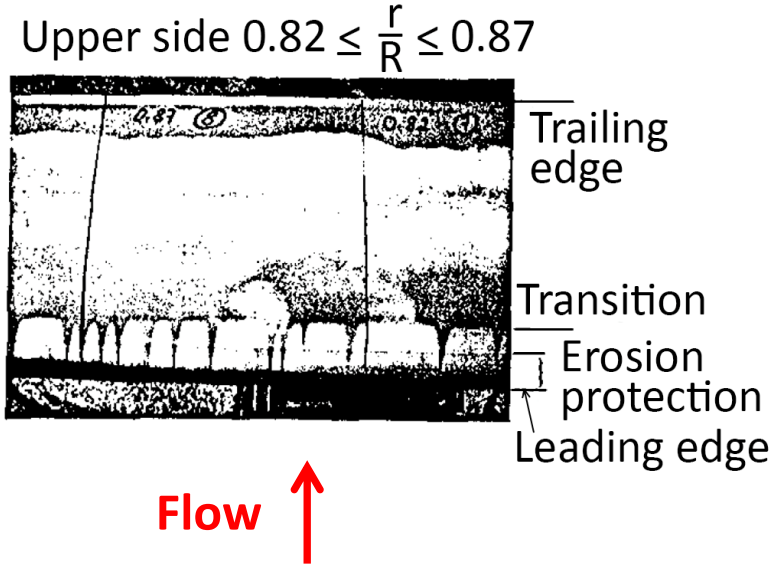
- Determine the effectiveness of trip tape applied around the nose of the model, and along the leading edge of the wings, for different flow conditions

Study Impact

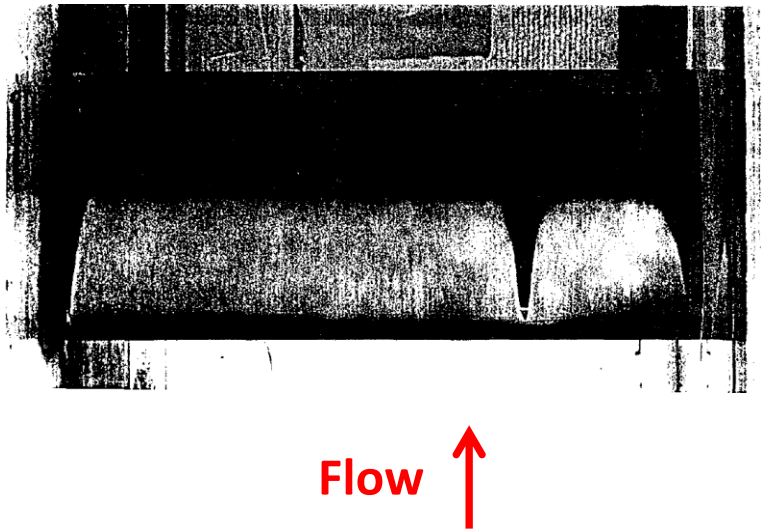
- Infrared thermography provides a non-intrusive technique to compare the expected and observed boundary layer transition locations for the given flow conditions and implemented boundary layer trip mechanism
- In subsonic flows, the surface of the model quickly reaches an equilibrium temperature in regions with both laminar and turbulent boundary layers, so infrared thermography images must be recorded at the correct time to observe transition
- Infrared radiation from the model also can demonstrate other flow phenomena over the surface of the wind tunnel model in addition to boundary layer transition

Historical Perspective – Sublimation Techniques

Acenaphthene on a helicopter rotor blade (Körner et al., AIAA 87-0085)



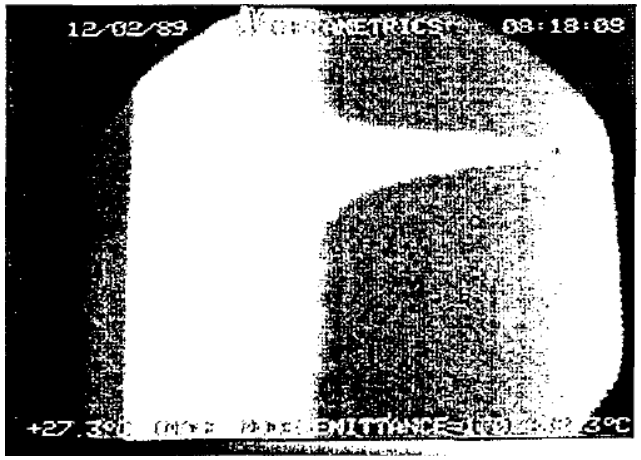
Napthalene on a wooden model at low angle of attack (Crowder, AIAA 90-1450)



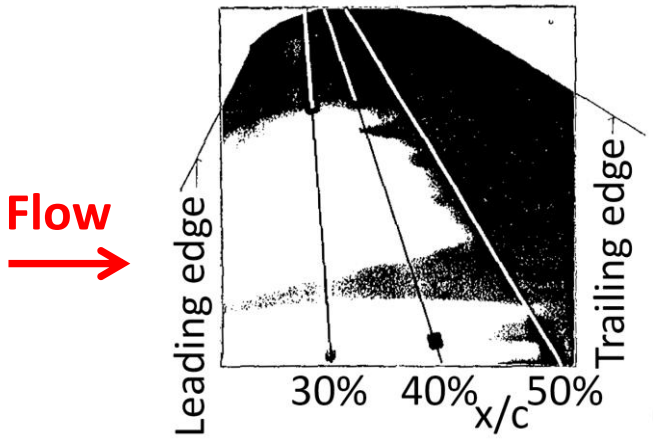
Boundary layer transition studies used to require a coating of a sublimating material, such as acenaphthene or naphthalene, on the surface of models or flight vehicles. This sublimating technique only yields one transition image per application of the coating.

Historical Perspective – Infrared Radiation (IR)

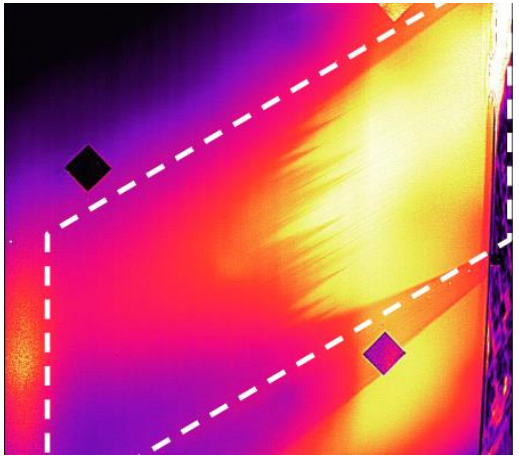
IR image of transition on a wooden model at low angle of attack (Crowder, AIAA 90-1450)



IR visualization of transition in flight (Körner et al., AIAA 87-0085)



ExaminIR processed IR image of an airfoil (Crawford et al., AIAA 2014-1411)



The current capability of IR imaging for the purpose of transition studies is vastly improved in terms of temperature and spatial resolution.

Experimental Facility

14- by 22-Foot Subsonic Tunnel

MIT D8 Model Installed in Test Section

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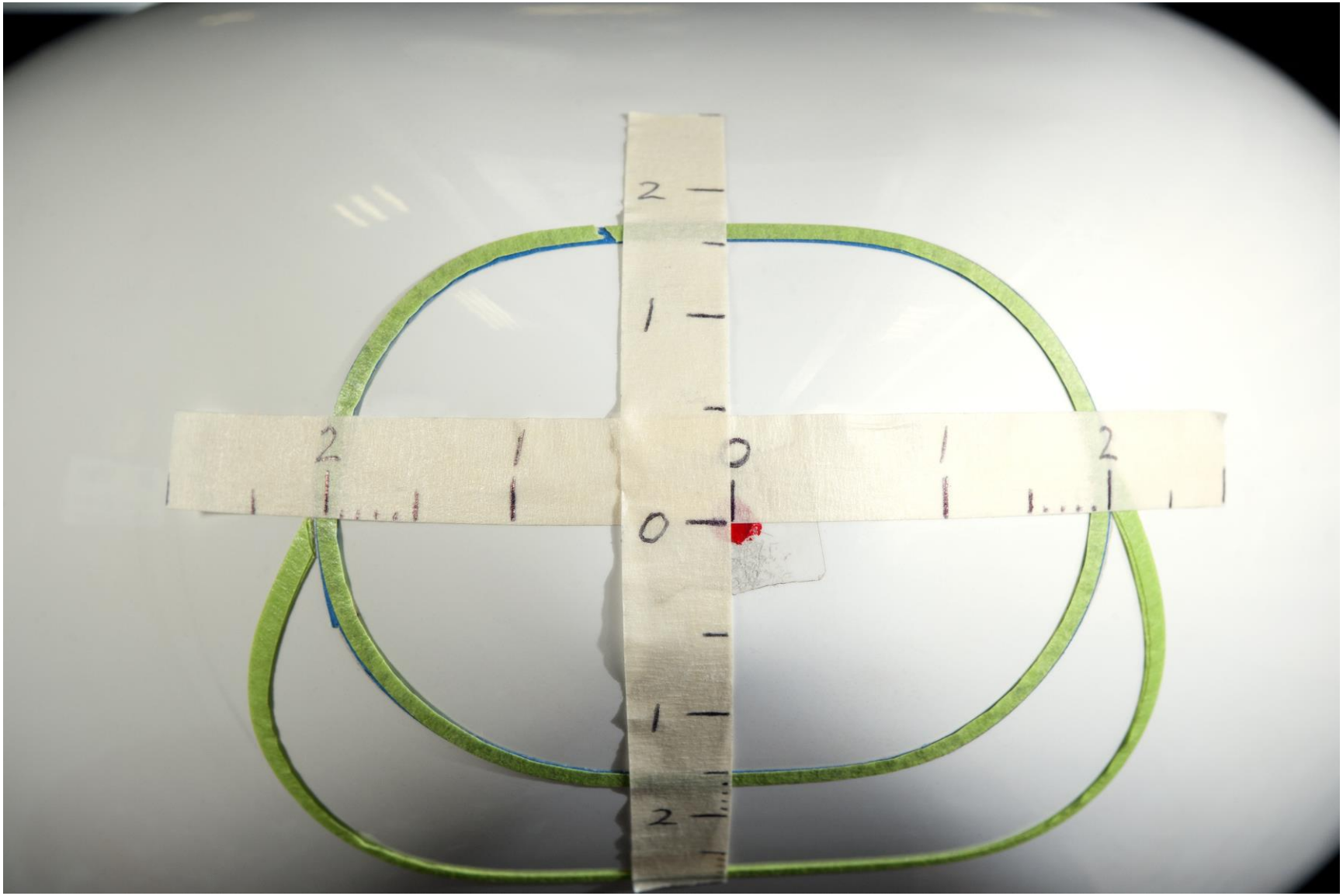
Trip Tape at Fuselage Nose



IR Camera Mounted in Side Wall

Long wavelength FLIR SC 3000 IR Camera
Spectral responsivity: 8-9µm
Temperature resolution of 20mK at 30°C
Spatial resolution of 320x240 pixels

Outside the tunnel, camera aimed at the model from the side wall

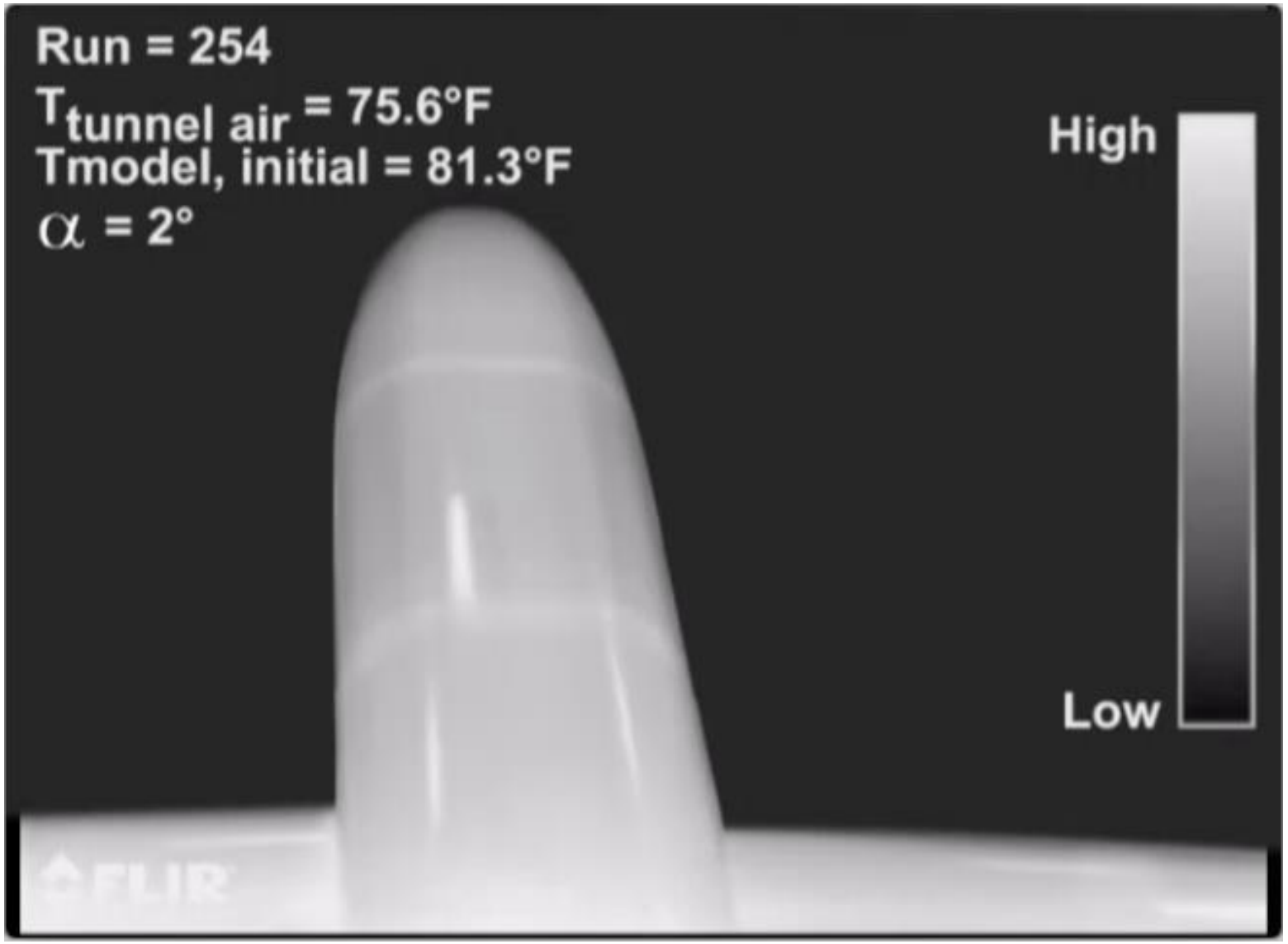
Inside the tunnel, metal blank with hole replaced a pane of glass in tunnel side wall

IR Camera Mounted on top of Ceiling

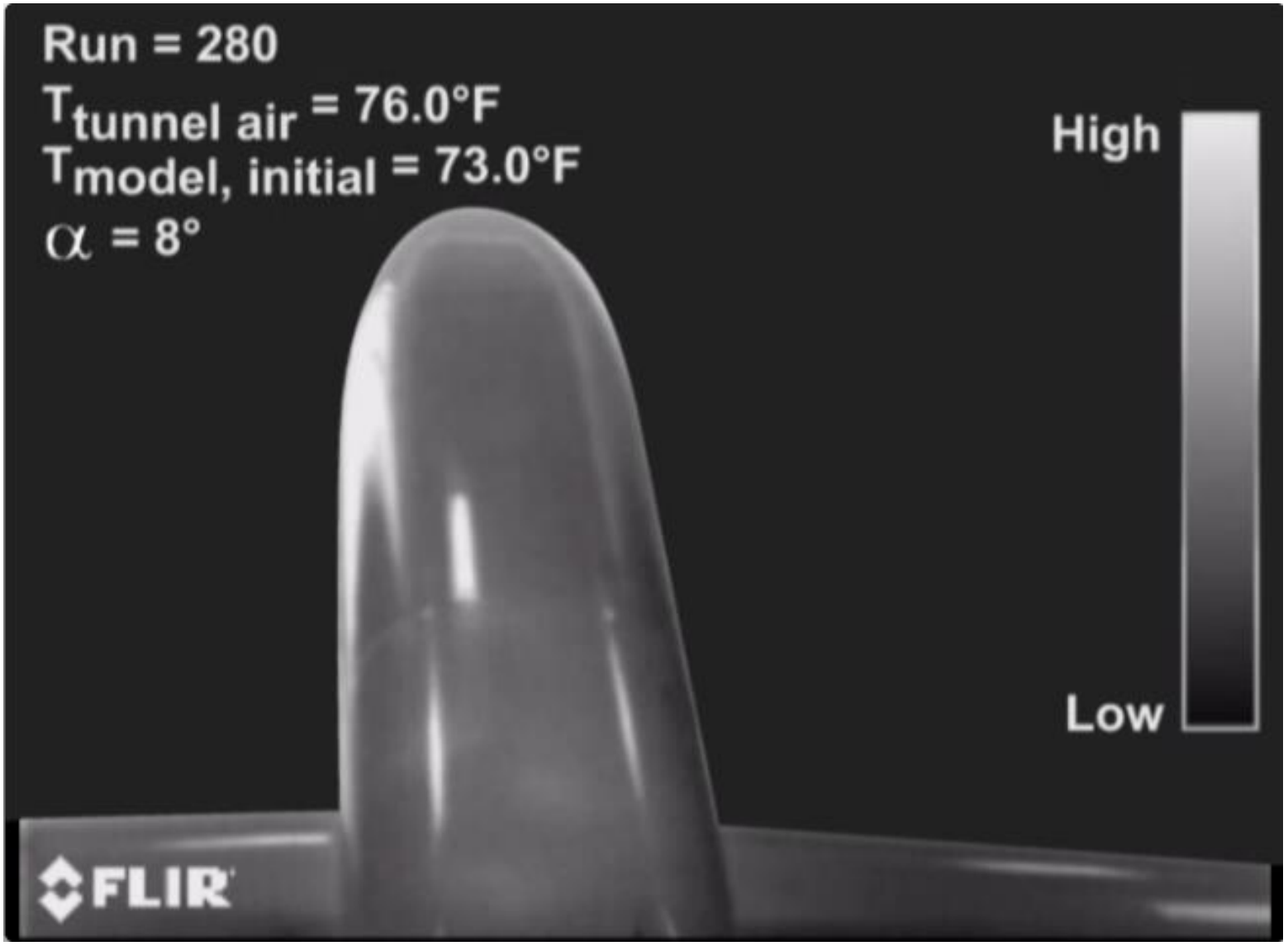
Top view, camera aimed at the model from the ceiling

Bottom view, showing location of removed pane of glass in tunnel ceiling

Turbulent regions cooler than laminar regions



Turbulent regions warmer than laminar regions



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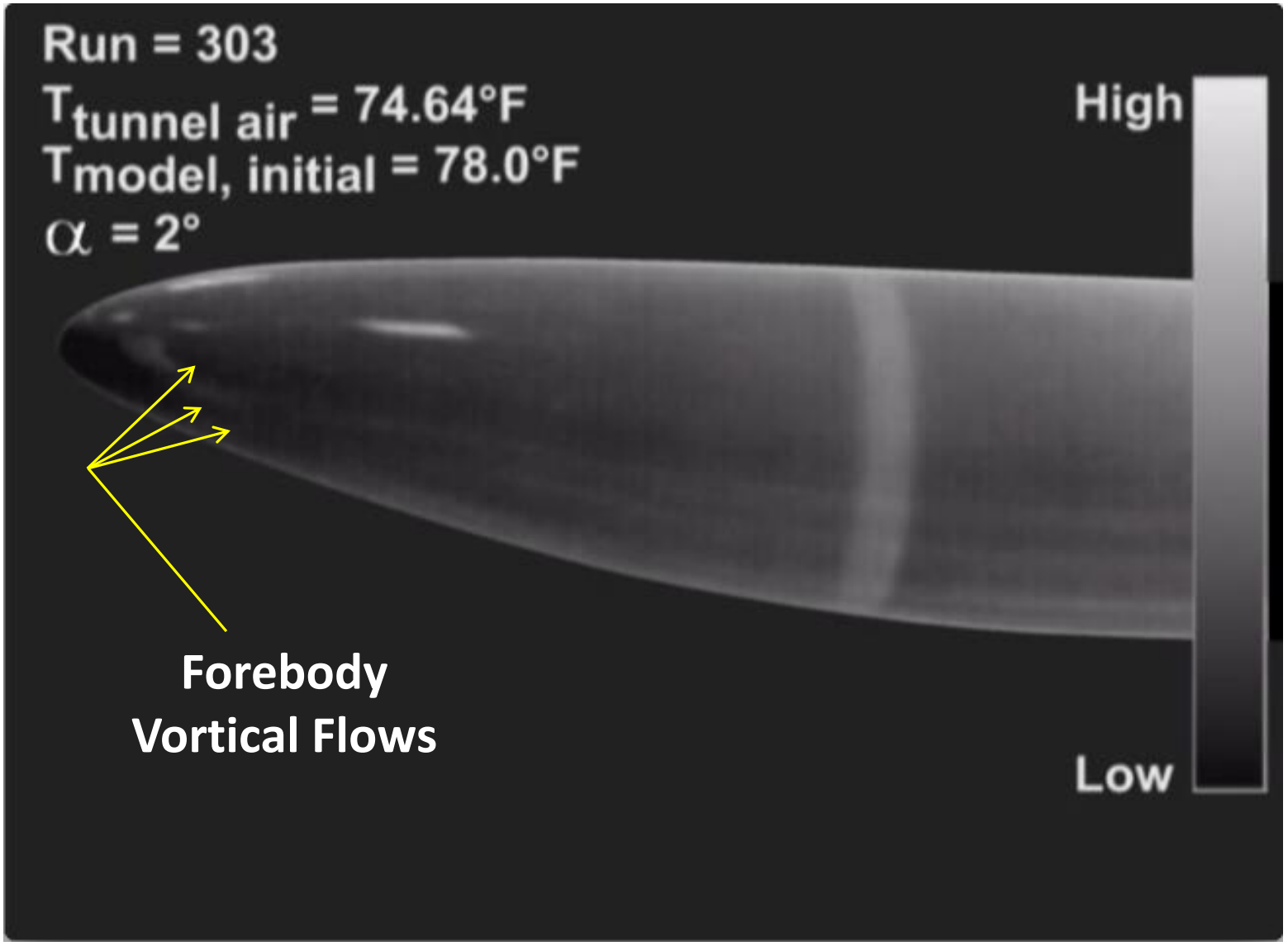

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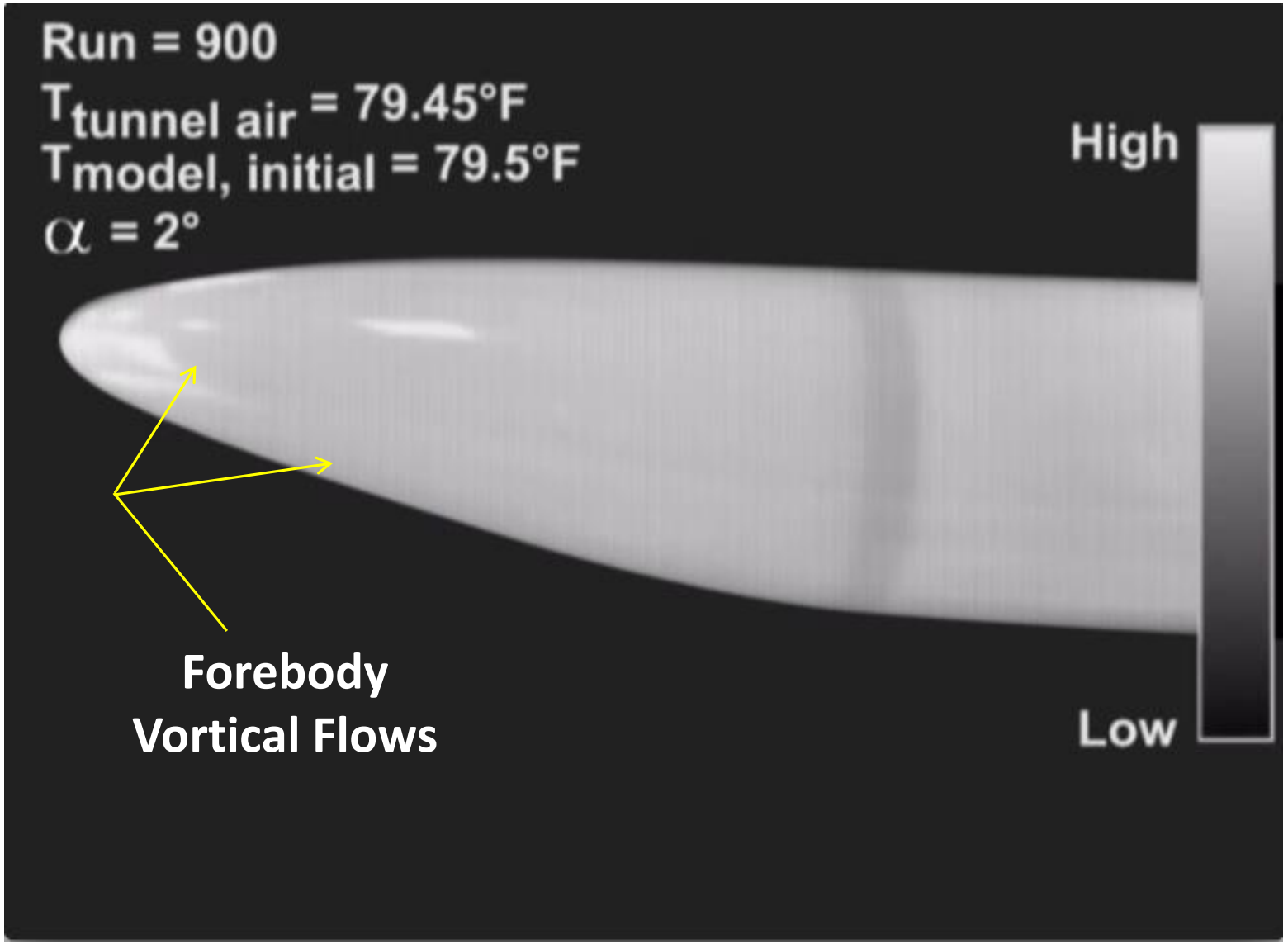

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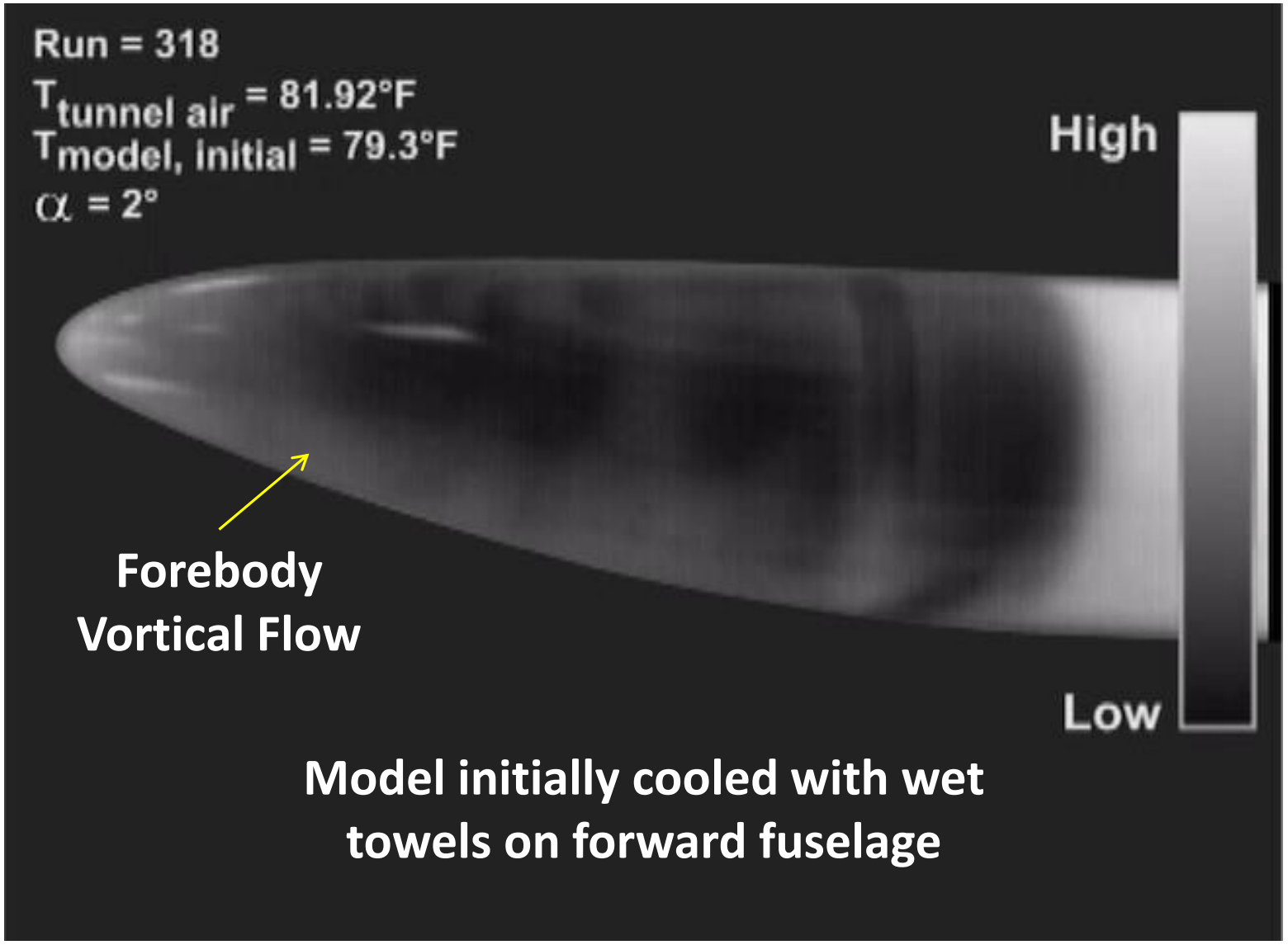

Natural and forced transition on wings

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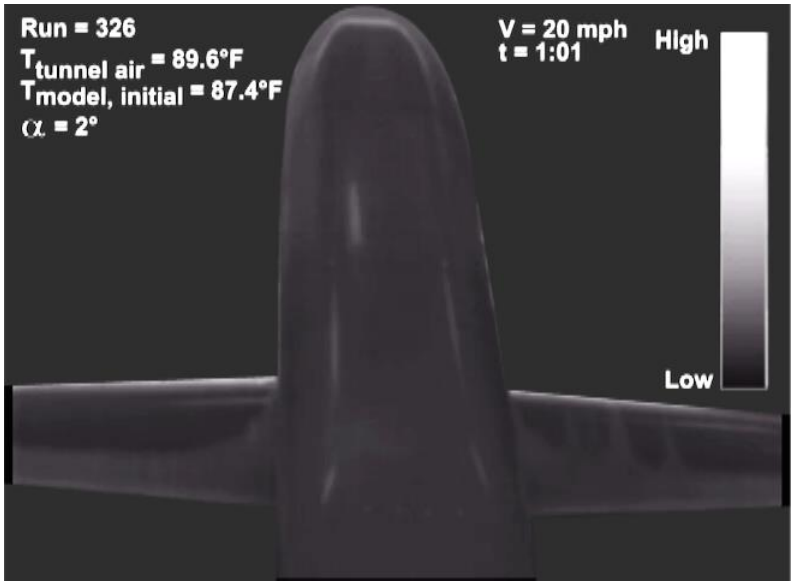
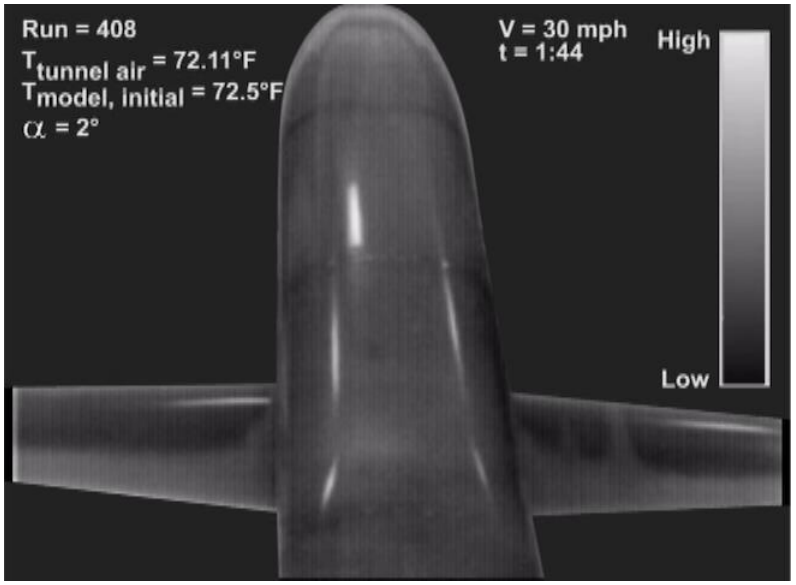
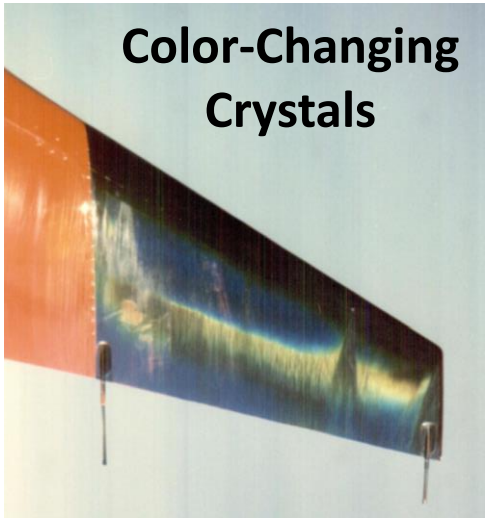
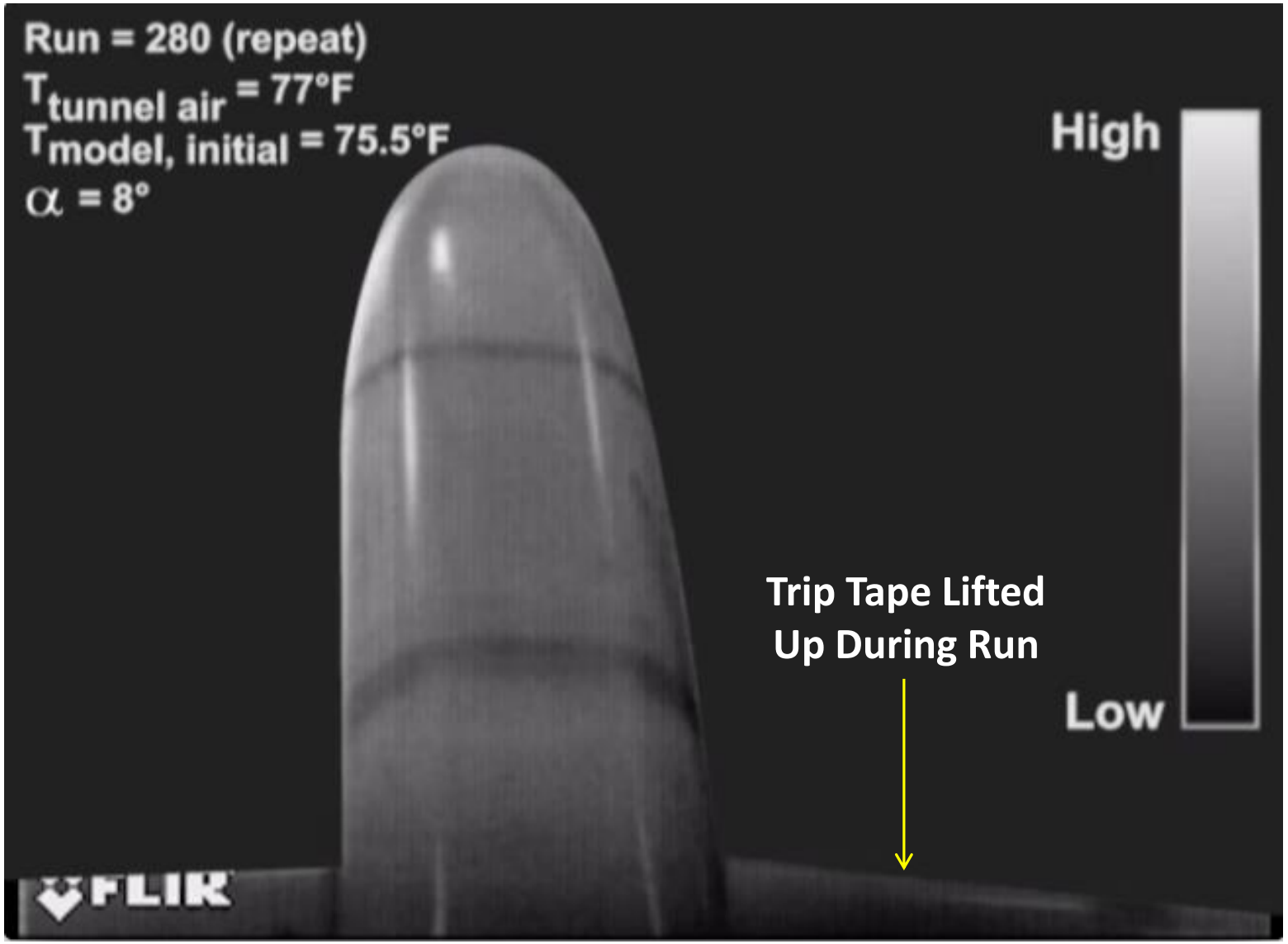




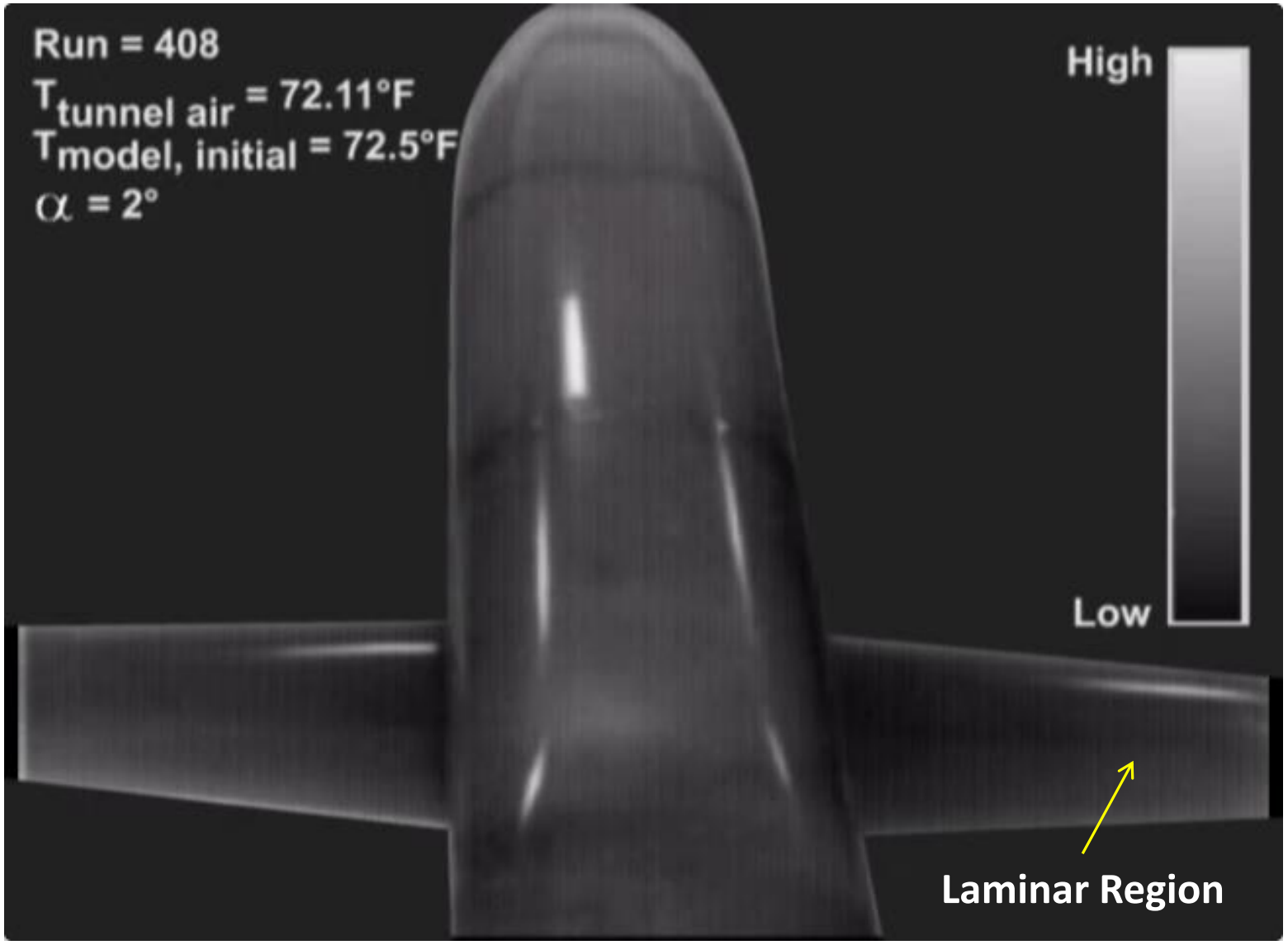
IR cameras provide the capability to non-intrusively observe natural and forced transition that previously was measured by more elaborate techniques such as coating the vehicle or model with either color-changing crystals or a sublimating material.



Trip tape problem identified



Laminar region behind removed trip tape



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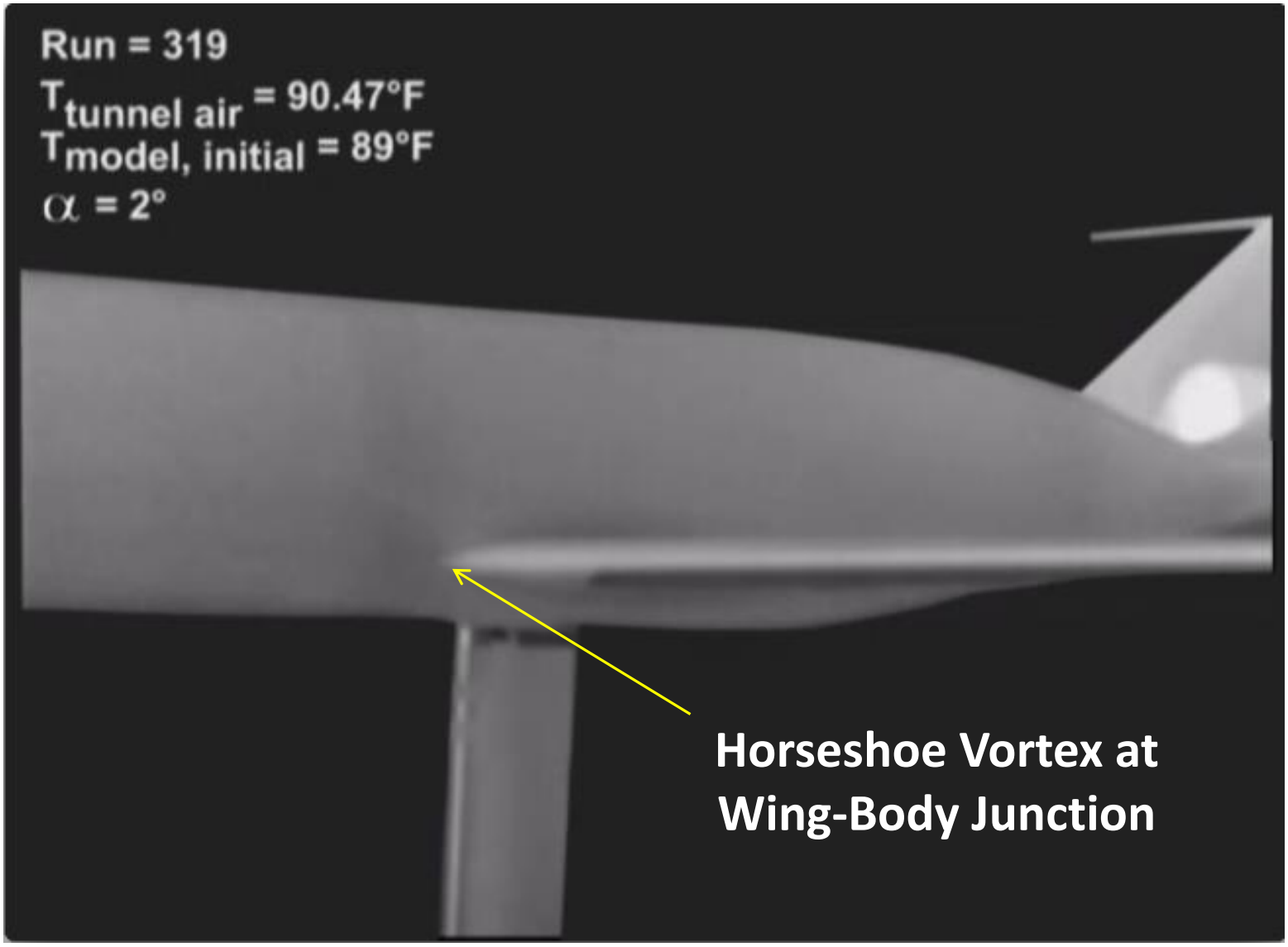

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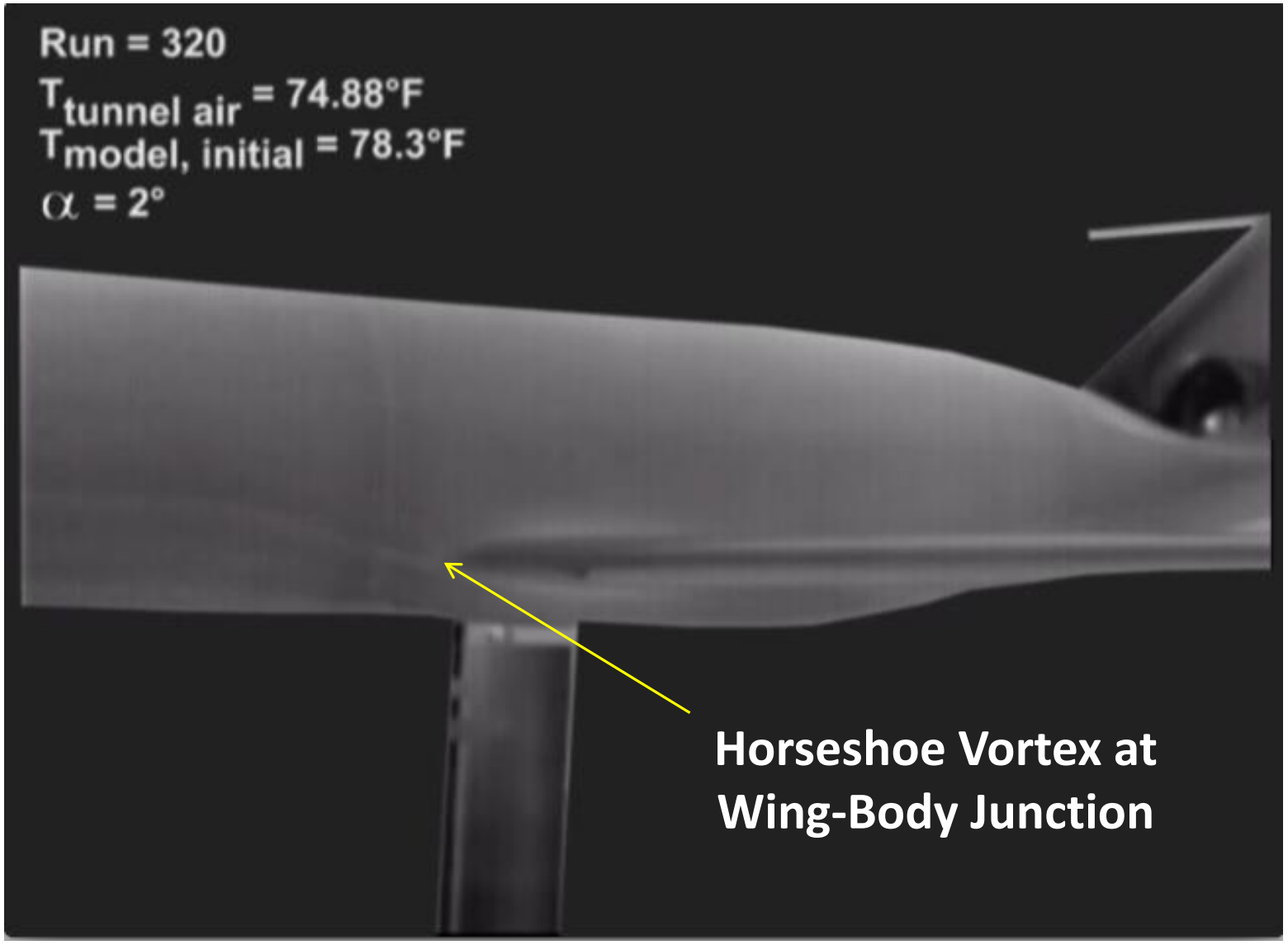
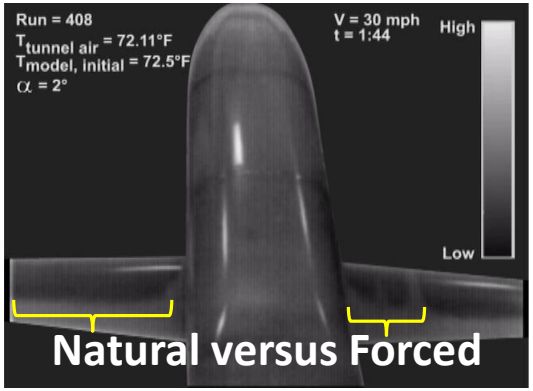
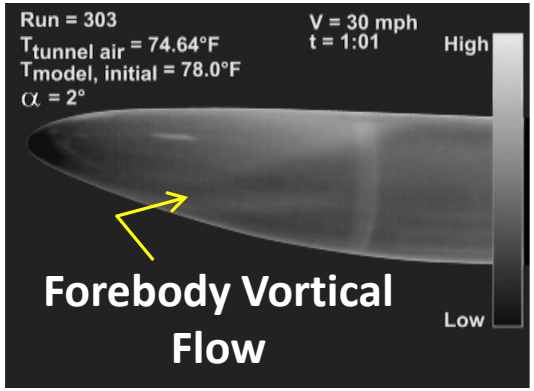


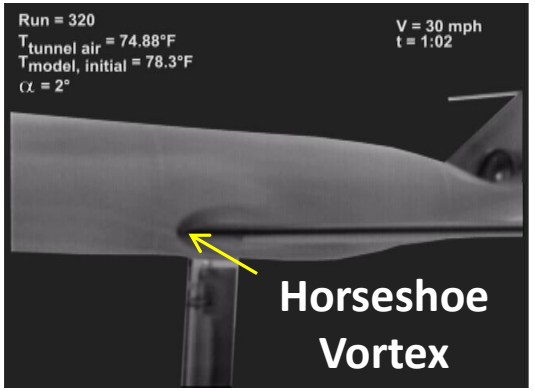
Conclusion – Lessons Learned

- A sufficient temperature difference between the wind tunnel air and the model surface showed the location of boundary layer transition
- Boundary layer transition was visible regardless of whether the wind tunnel air or the model surface was cooler
- Flow characteristics such as a wing root horseshoe vortex or the presence of forebody vortical flows were visualized with IR data
- Active temperature control of the model or the air would enhance the usefulness of IR images, but is not necessary to observe boundary layer transition

Questions?

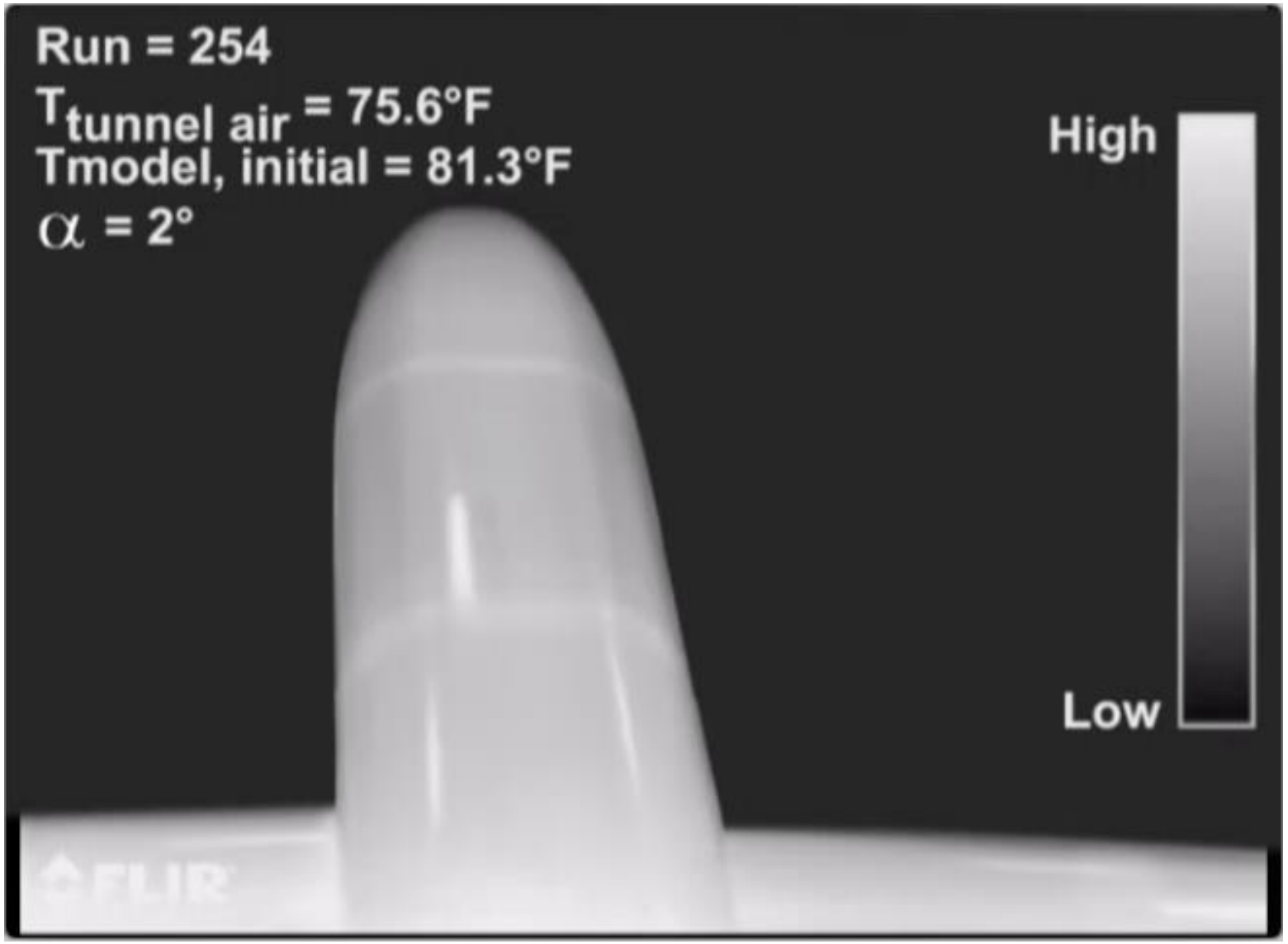






Back-Up Slides

Turbulent regions cooler than laminar regions



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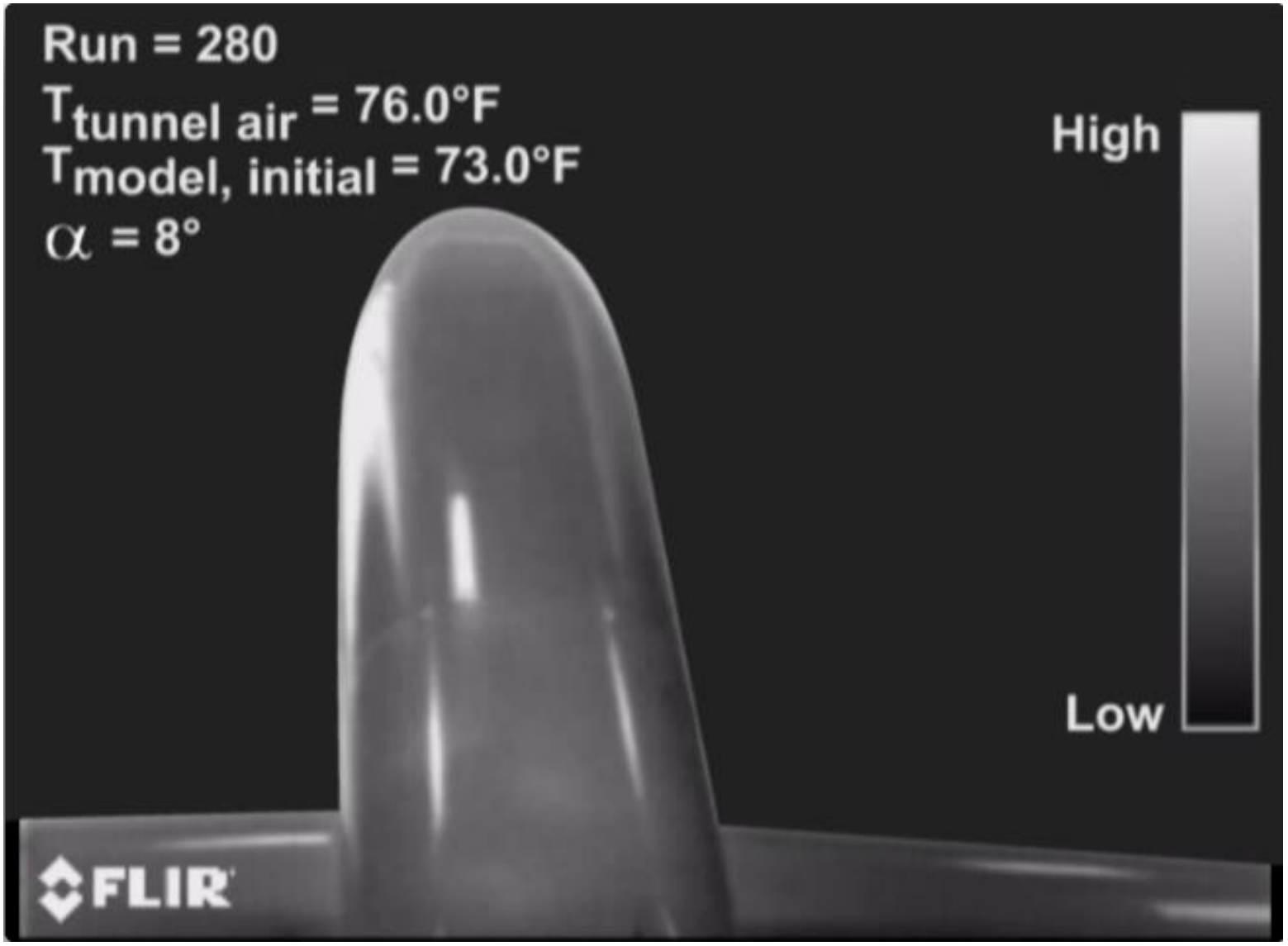

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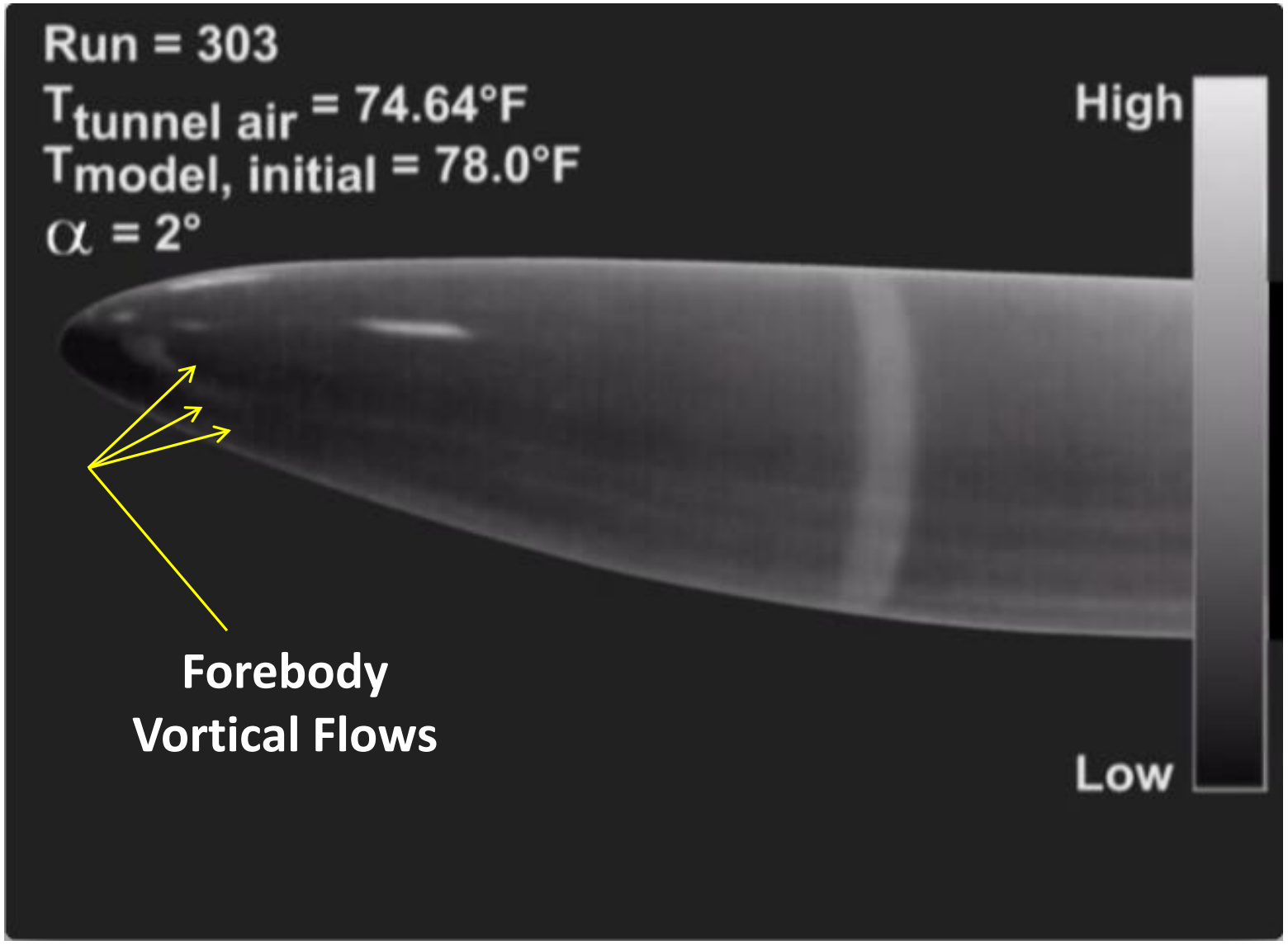

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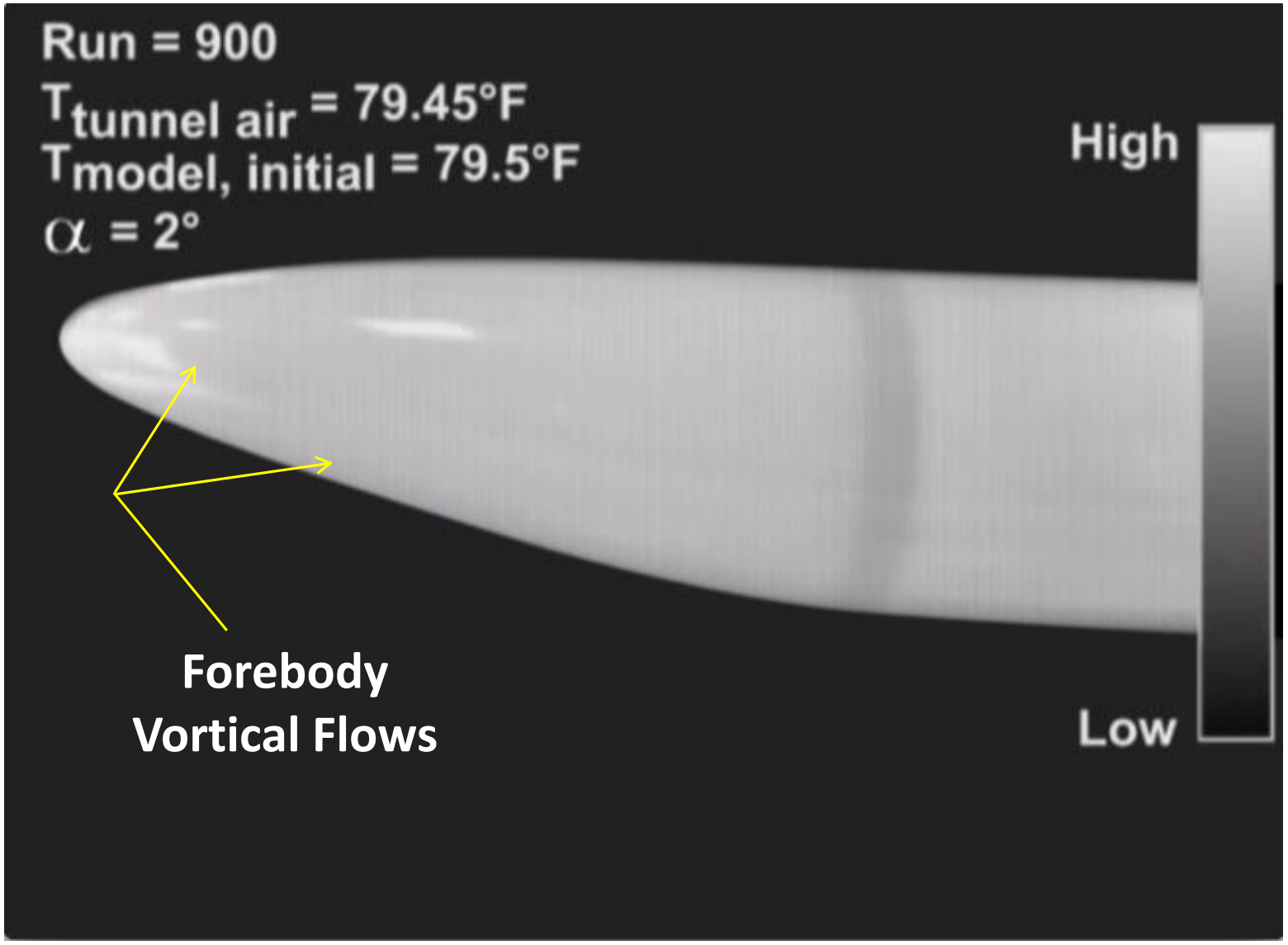

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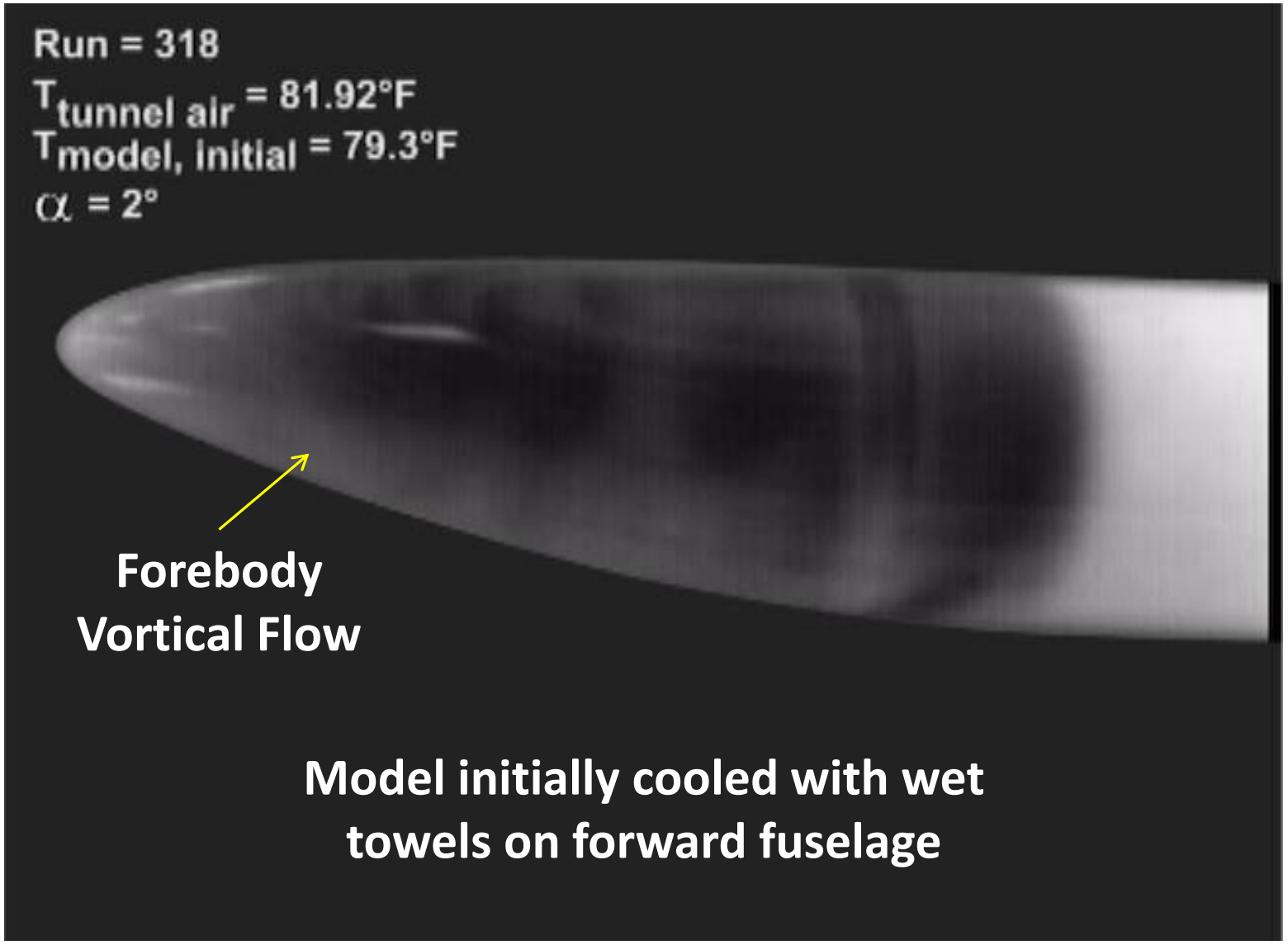

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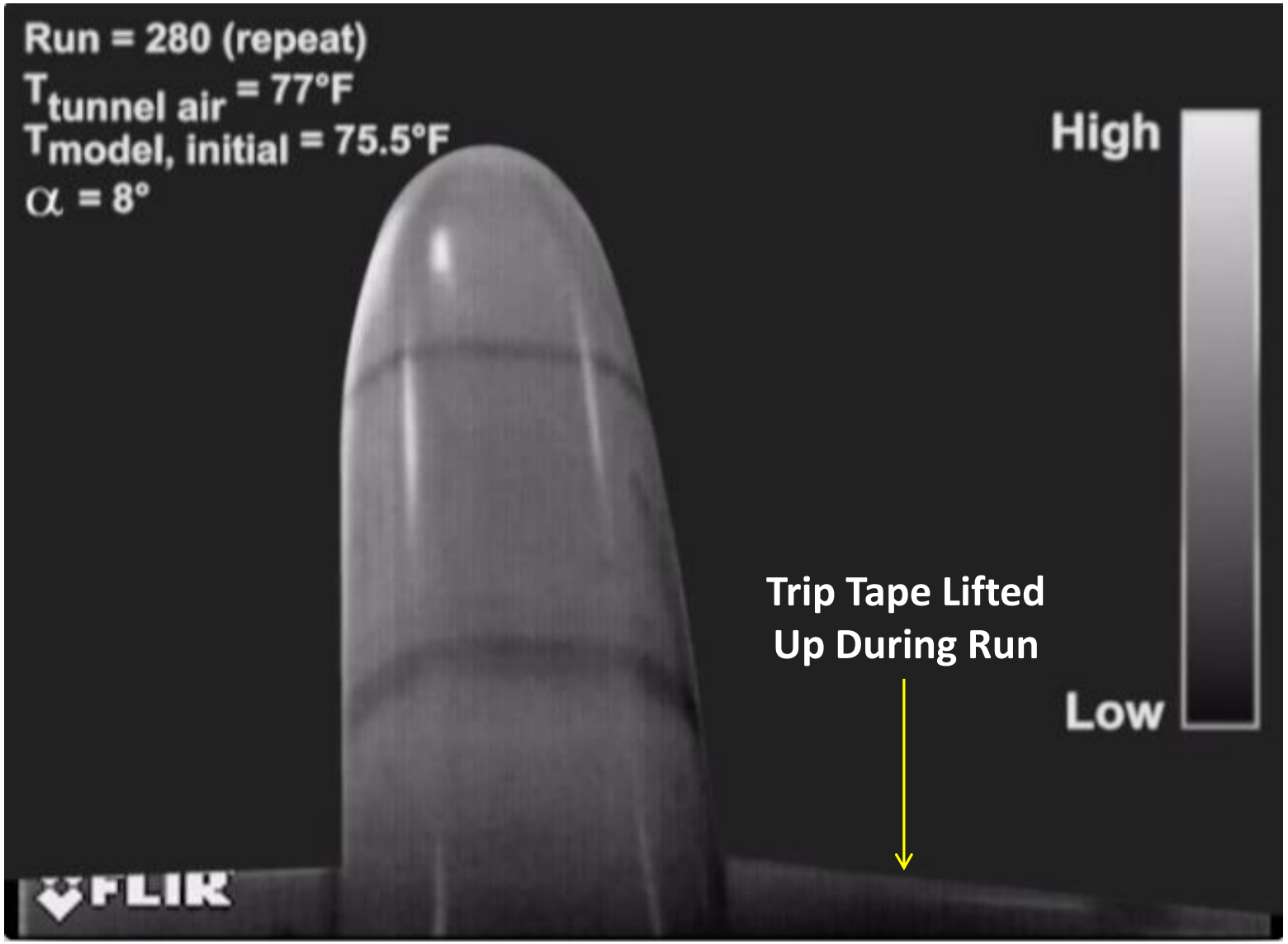

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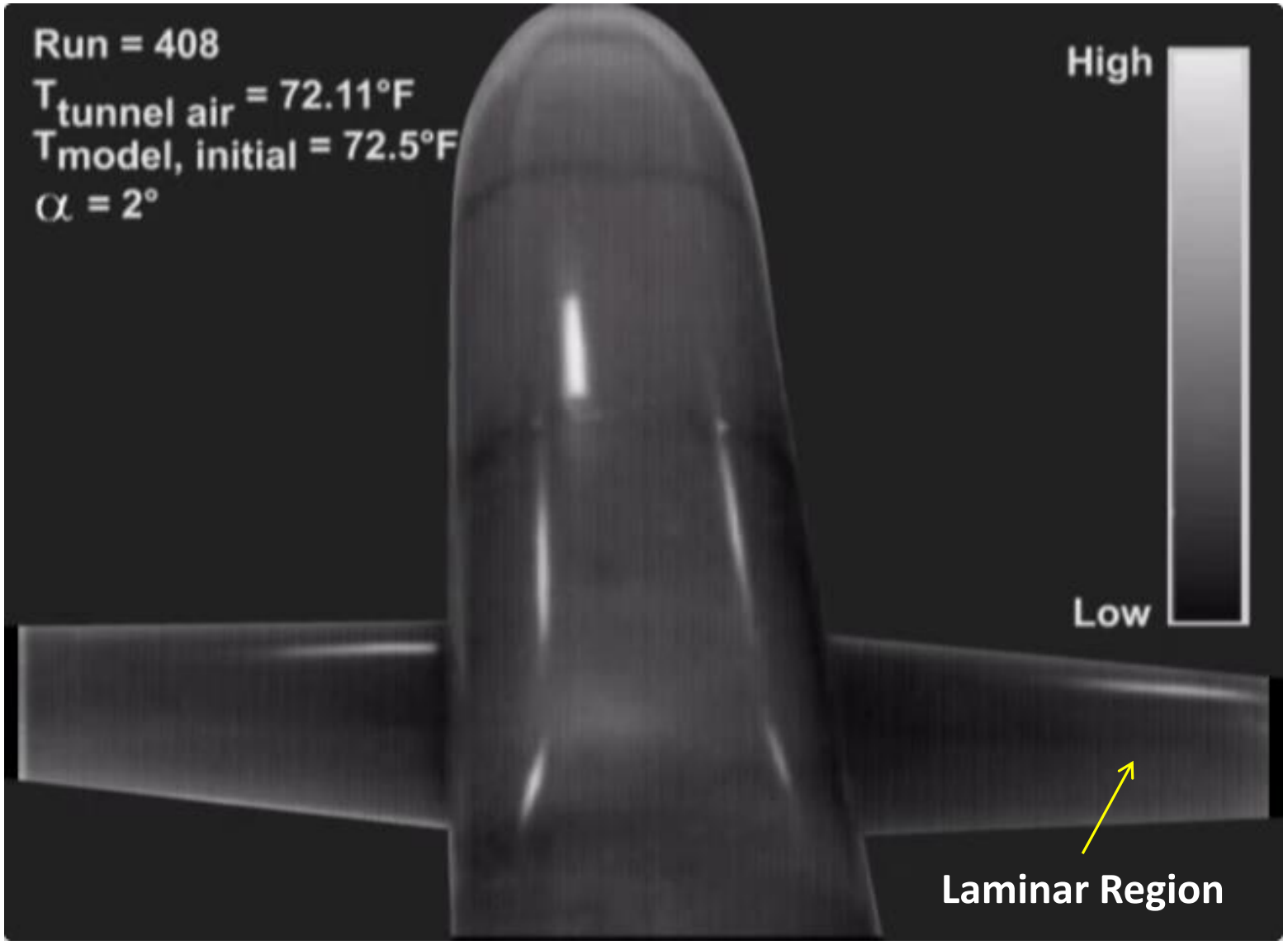

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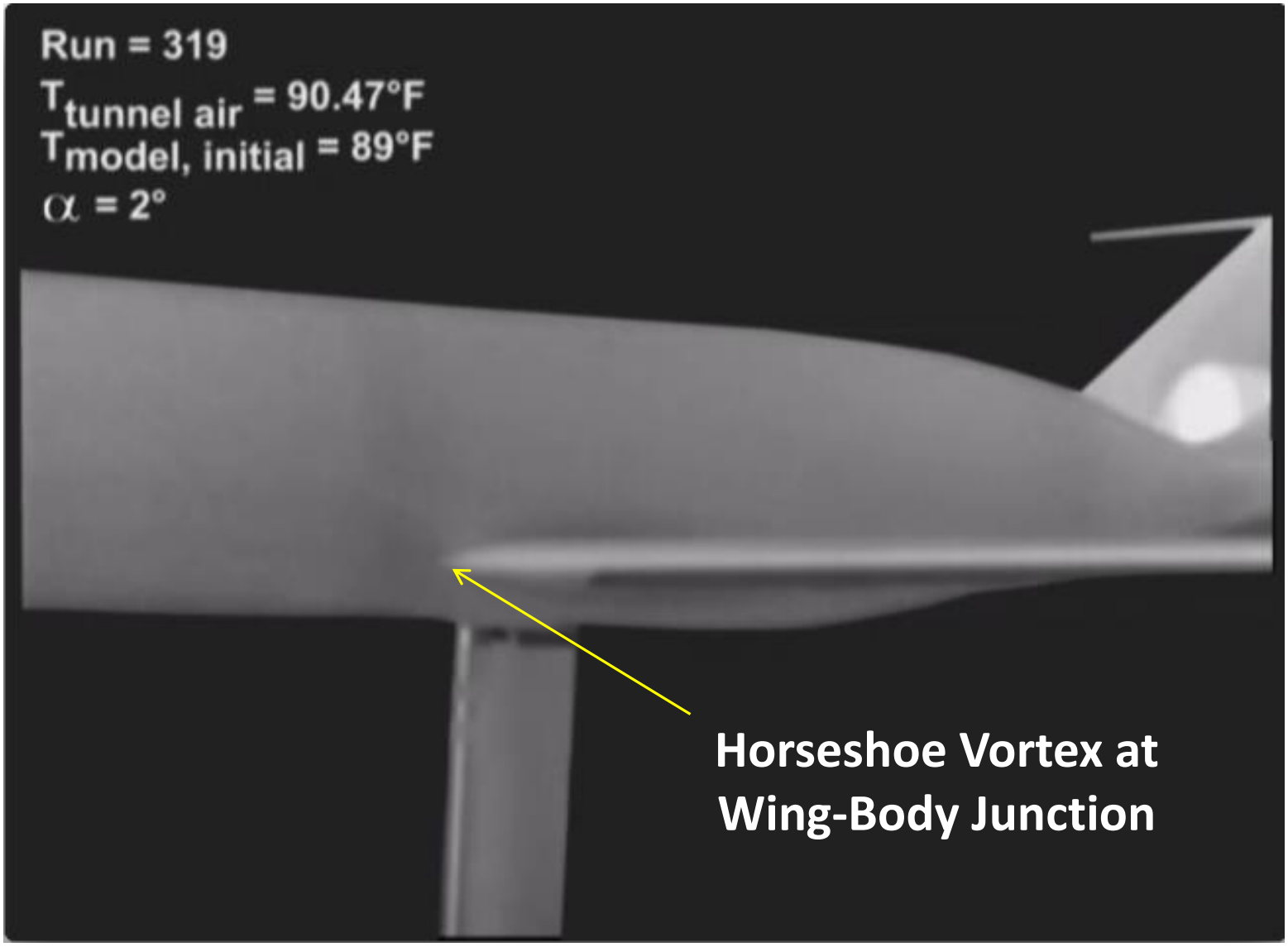

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