



# NASA Junction-Flow Experiment: Results and Future Plans

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This work was supported by NASA's Transformational Tools and Technologies (TTT)  
project of the Transformative Aeronautics Concepts Program

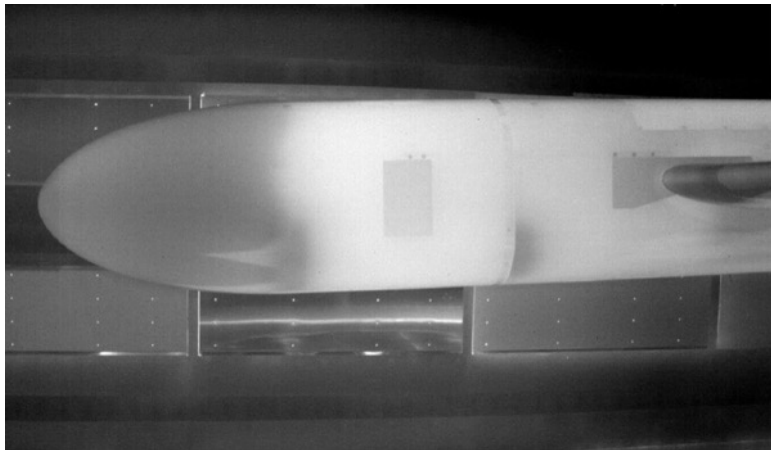


# Specific Objectives

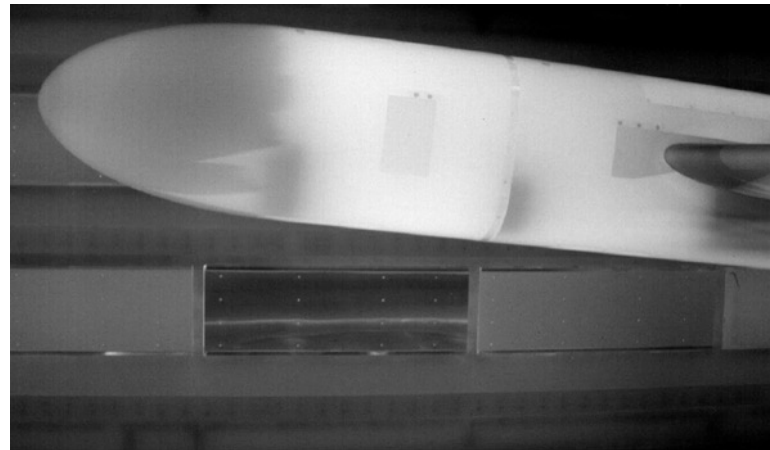
- Perform flow-field measurements via internally mounted laser Doppler velocimetry (LDV) systems
  - Mean velocities, Reynolds stresses, and velocity triple products
  - Measurements in the trailing-edge corner region of wing-fuselage junction
  - Measurements in the leading-edge region of the wing-fuselage junction
  - Measurements on the fuselage, upstream of the wing-fuselage junction
- Measure dynamic pressures at selected locations on the wings and fuselage of the model
- Characterize boundary-layer transition on the model via infrared imaging
- Visualize surface topology of separated corner flow via oil-flow

# Infrared Images of Port Side of Fuselage

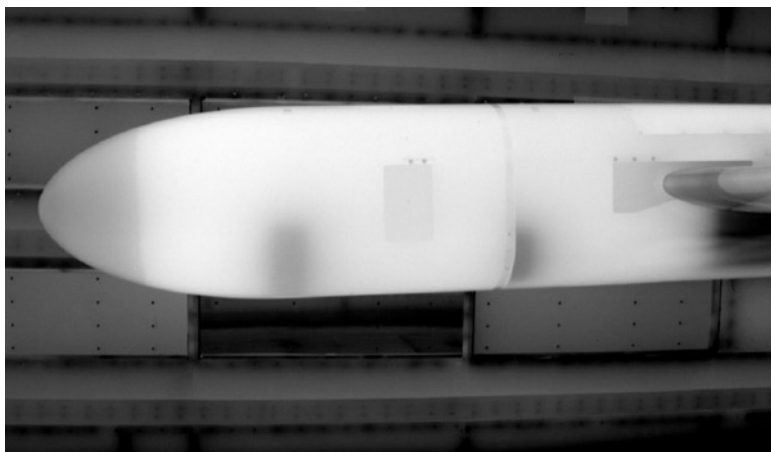
Baseline (without trip dots),  $\alpha = -2.5^\circ$



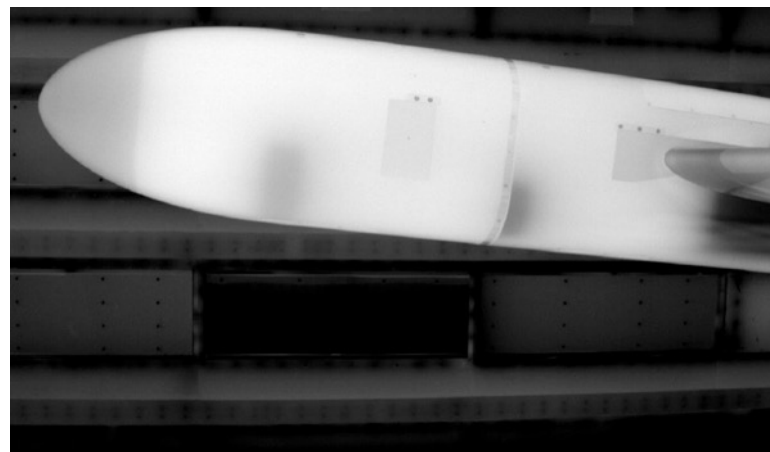
Baseline (without trip dots),  $\alpha = 5^\circ$



With trip dots,  $\alpha = -2.5^\circ$

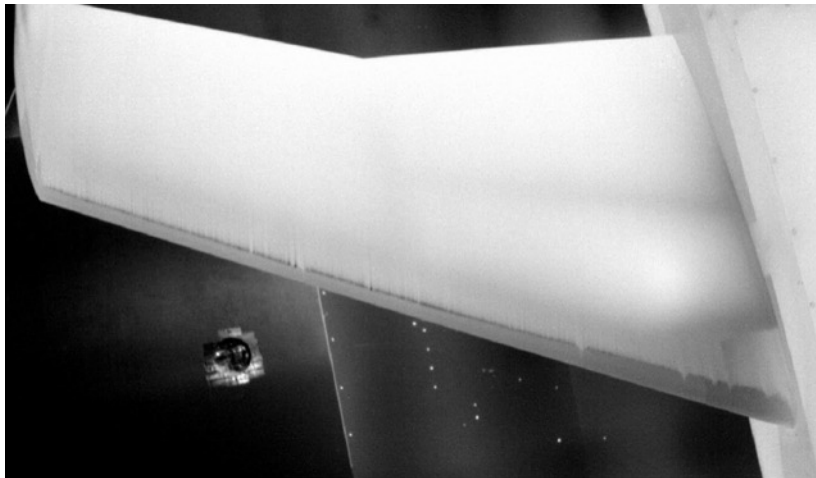


With trip dots,  $\alpha = 5^\circ$

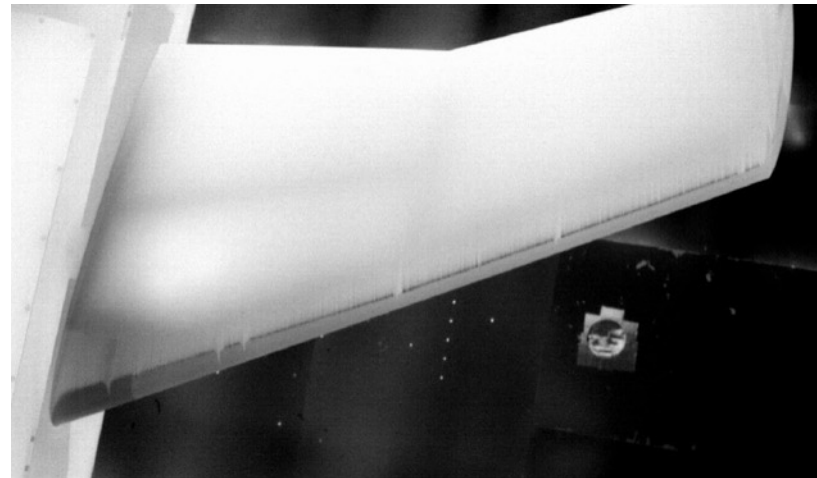


# Infrared Images of F6 Wing Upper Surface Baseline (Without Trip Dots), $\alpha = 5^\circ$

Starboard Wing



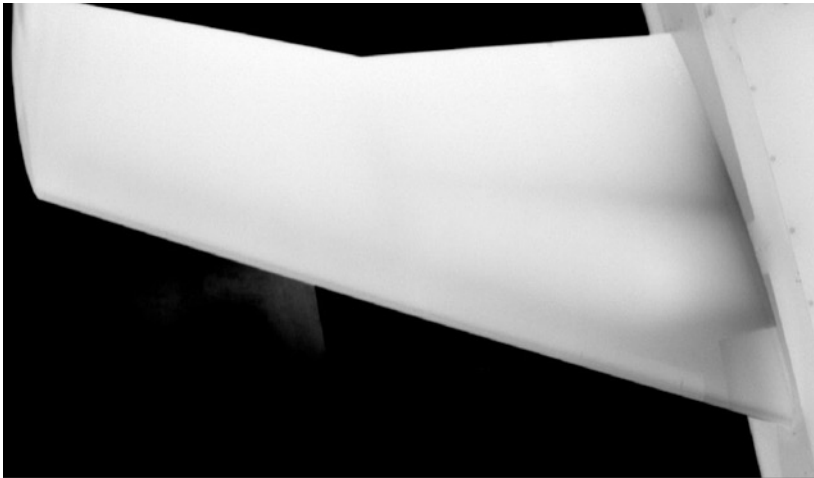
Port Wing





# Infrared Images of F6 Wing Upper Surface With Trip Dots, $\alpha = 5^\circ$

Starboard Wing

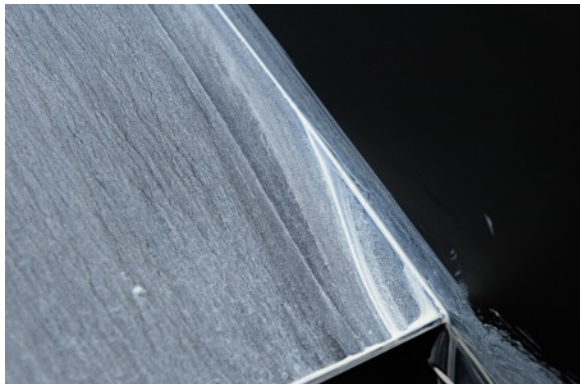


Port Wing

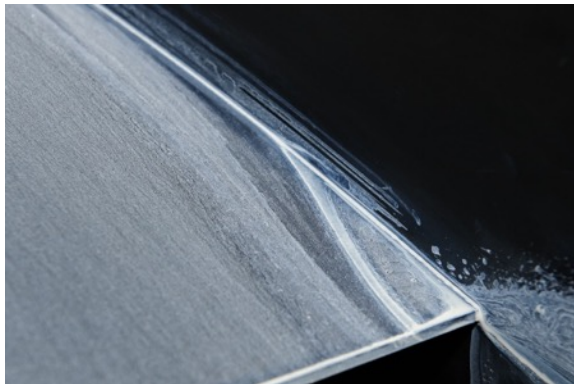


# Oil-Flow Visualization of Corner Separation

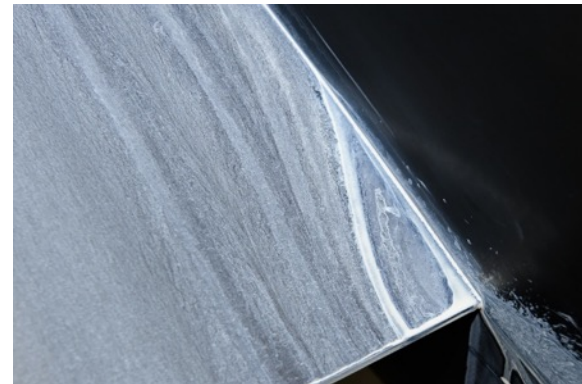
$\alpha = -2.5^\circ$



$\alpha = 0^\circ$



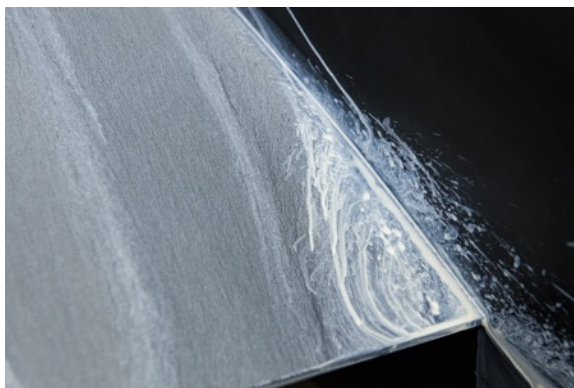
$\alpha = 2.5^\circ$



$\alpha = 5^\circ$

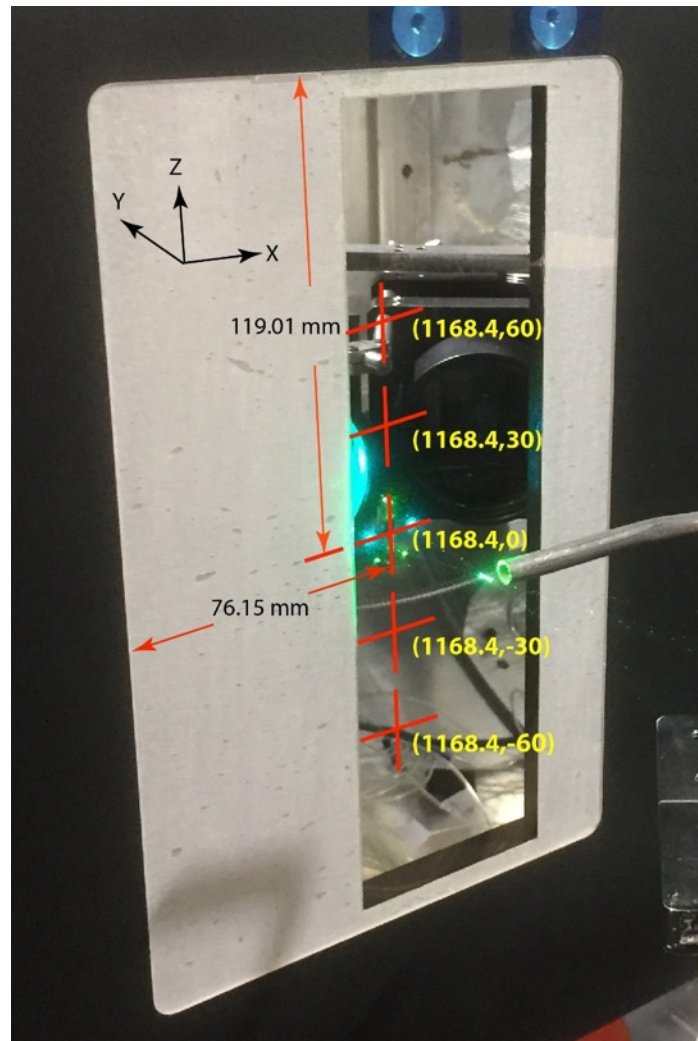


$\alpha = 10^\circ$



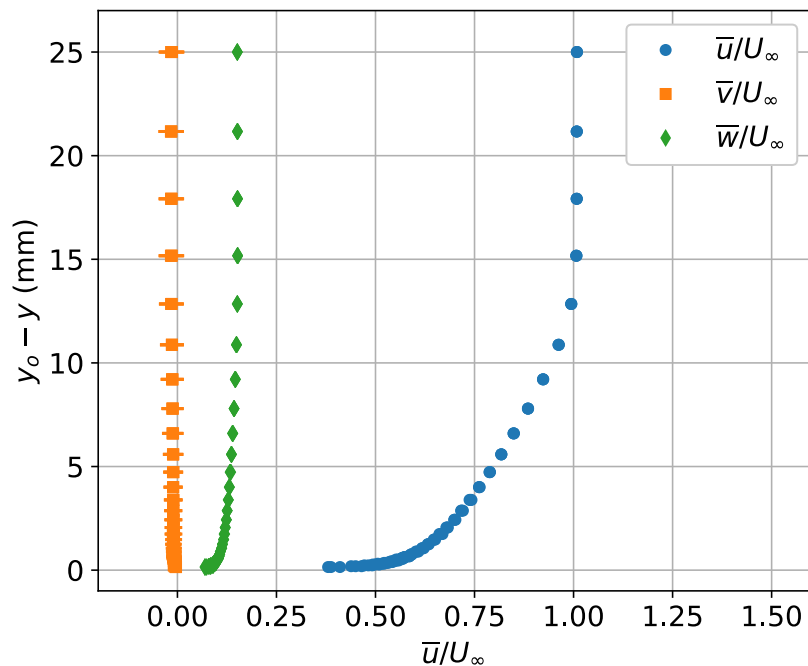
| $\alpha(^{\circ})$ | $\ell$ (mm) | $w$ (mm) |
|--------------------|-------------|----------|
| -2.5               | 81          | 22       |
| 0                  | 89          | 29.5     |
| 2.5                | 104         | 38       |
| 5                  | 118.5       | 42.5     |
| 10                 | 152         | 54       |

# LDV – Fuselage Nose-Section Surveys

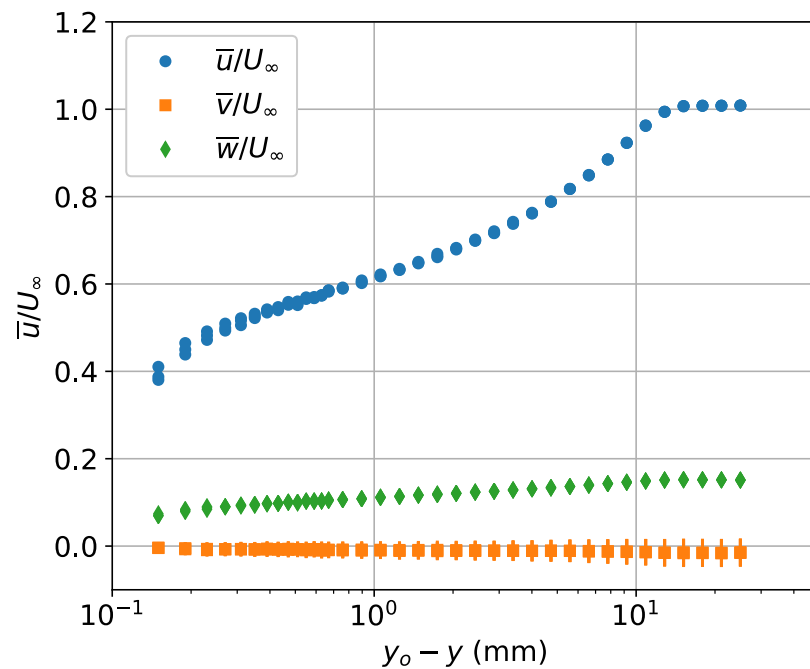


# LDV Data – Fuselage Nose, $\alpha = 5^\circ$ , $z = 0$ mm

Mean velocity  
(linear scale)

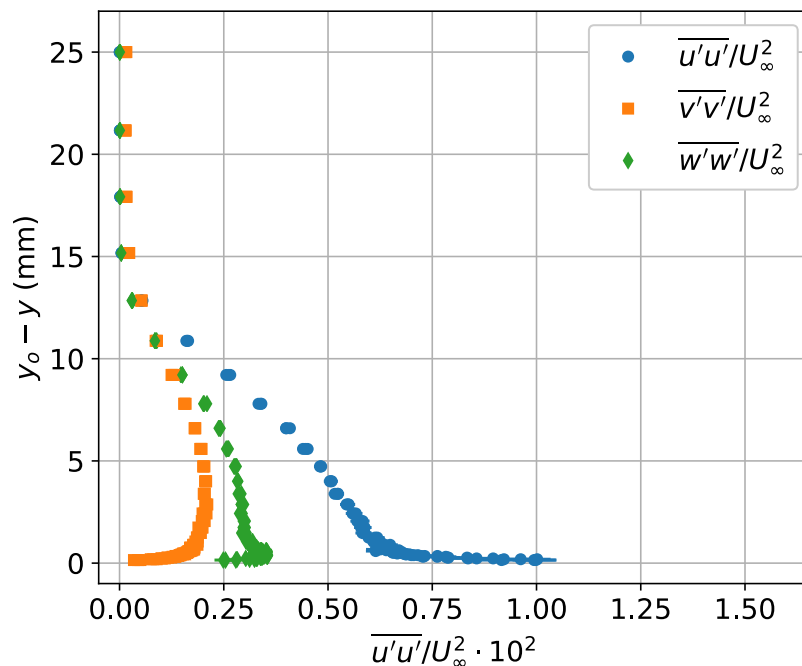


Mean velocity  
(semilog scale)

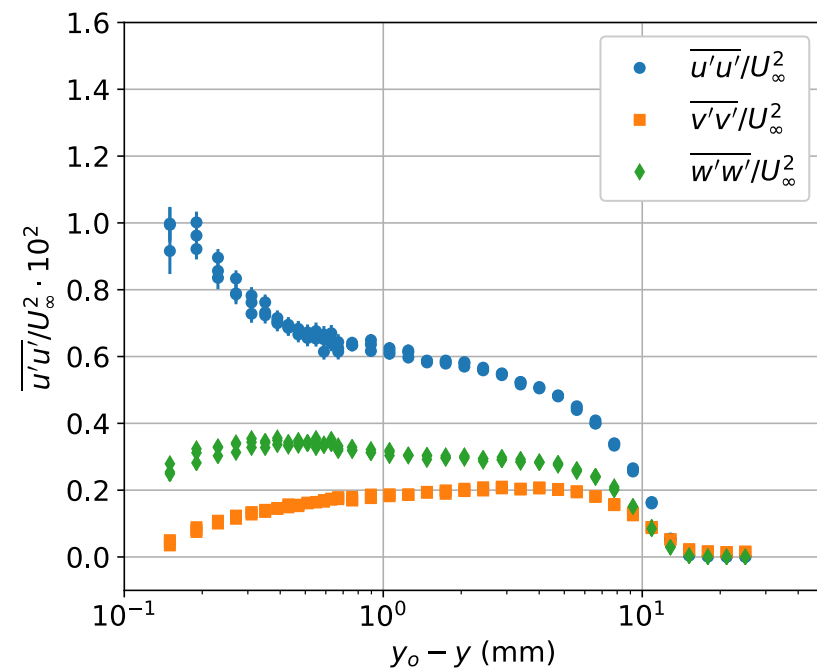


# LDV Data – Fuselage Nose, $\alpha = 5^\circ$ , $z = 0$ mm

Reynolds normal stress  
(linear scale)



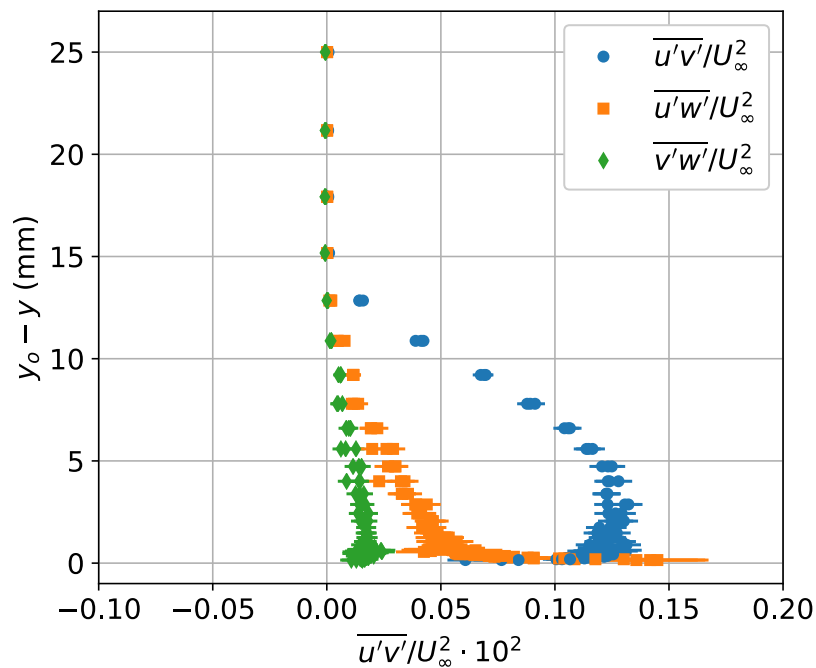
Reynolds normal stress  
(semilog scale)



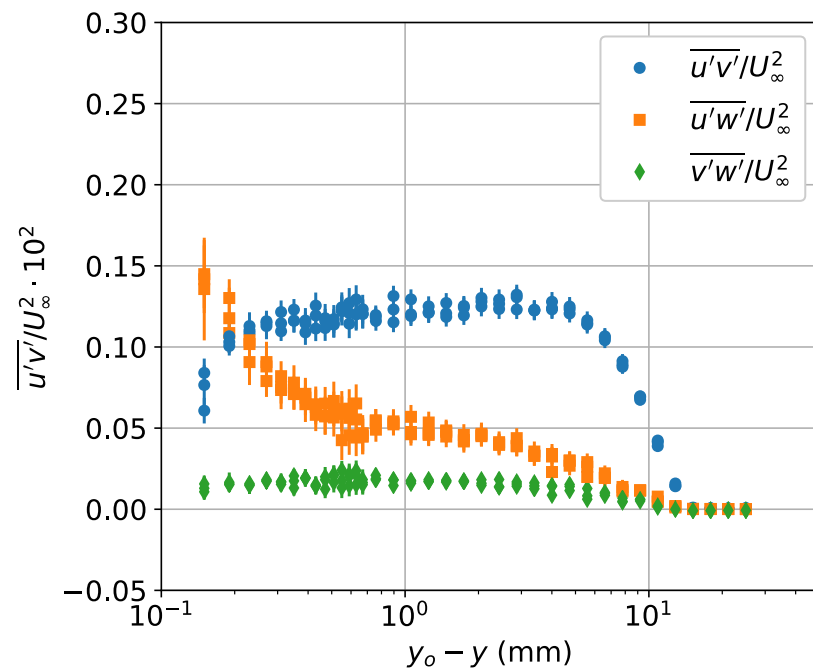


# LDV Data – Fuselage Nose, $\alpha = 5^\circ$ , $z = 0$ mm

Reynolds shear stress  
(linear scale)

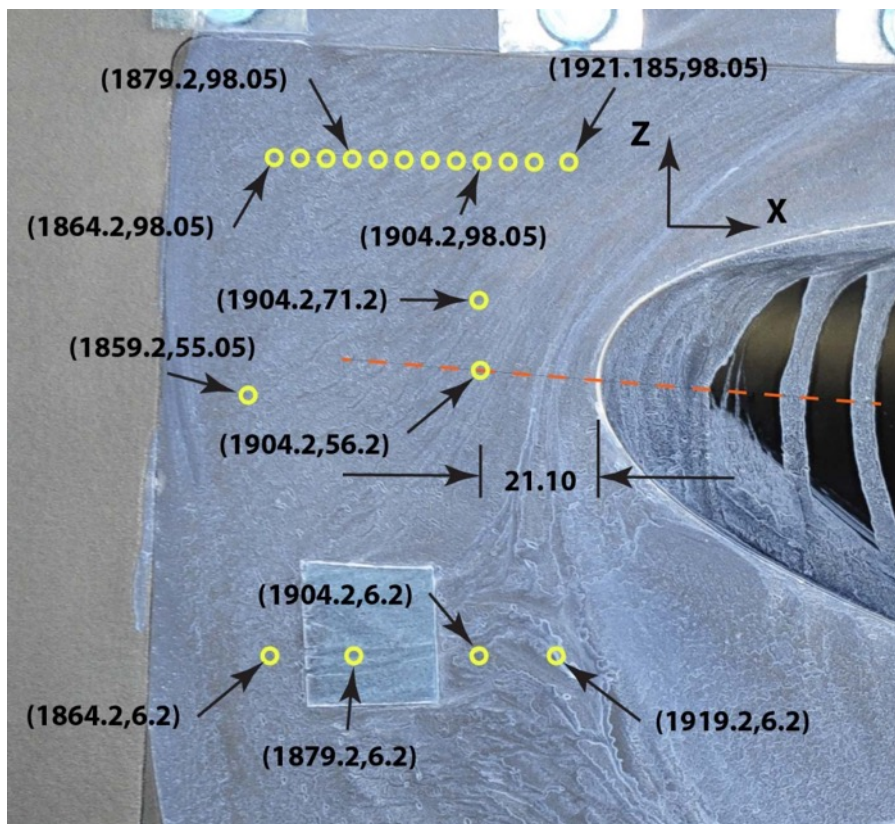


Reynolds shear stress  
(semilog scale)

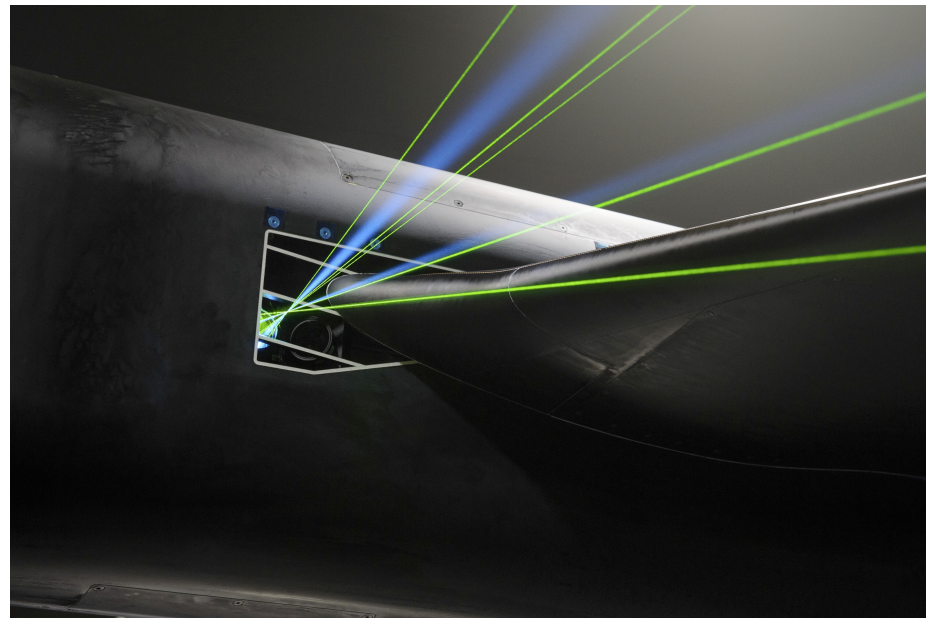


# LDV – Wing Leading-Edge Surveys, $\alpha = 5^\circ$

## LDV measurement locations



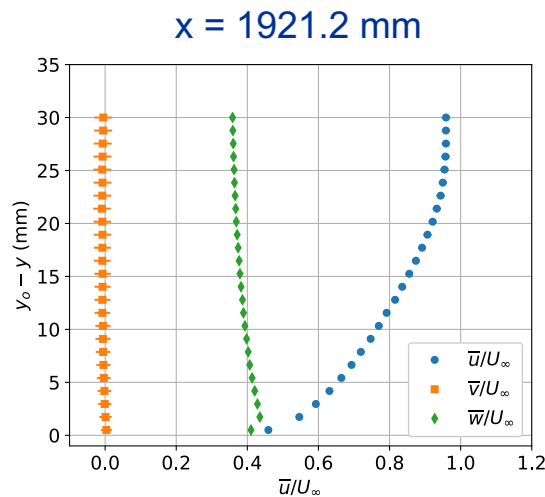
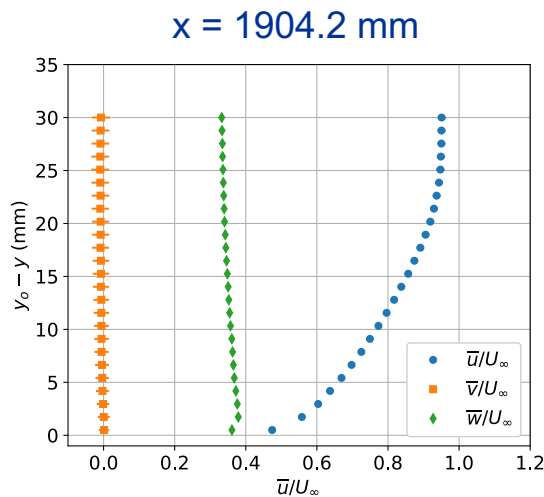
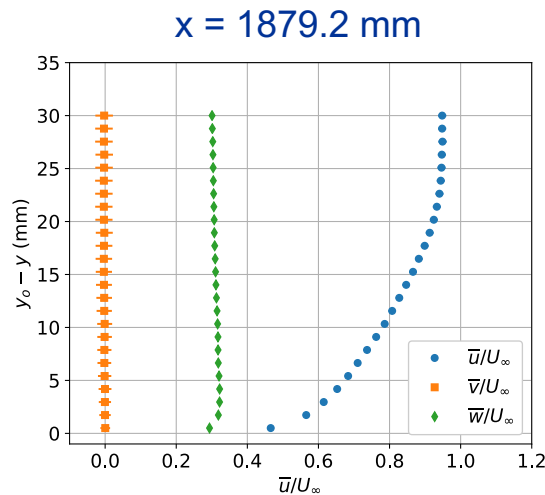
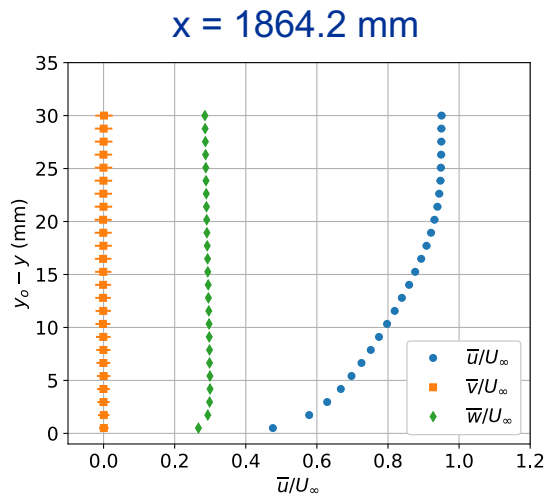
## LDV system positioned at the wing leading-edge window





# LDV Data – Wing LE, $\alpha = 5^\circ$ , $z = 98.05$ mm

## Mean Velocity Profiles

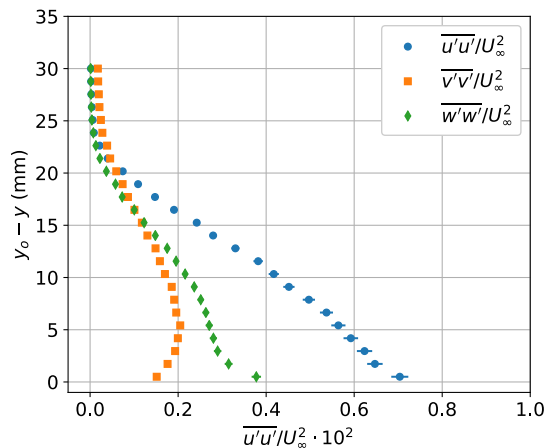




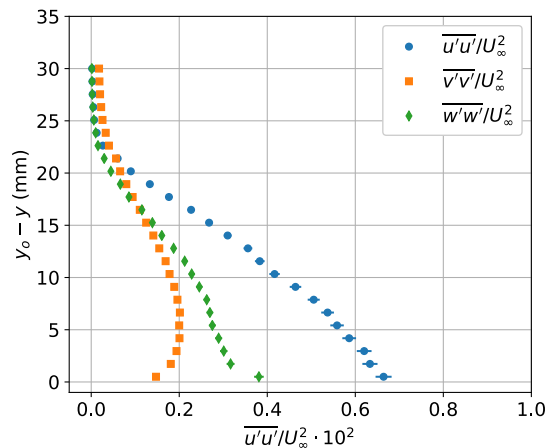
# LDV Data – Wing LE, $\alpha = 5^\circ$ , $z = 98.05$ mm

## Reynolds Normal Stress Profiles

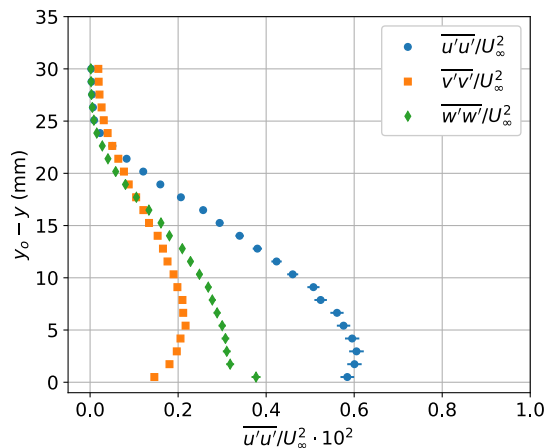
$x = 1864.2$  mm



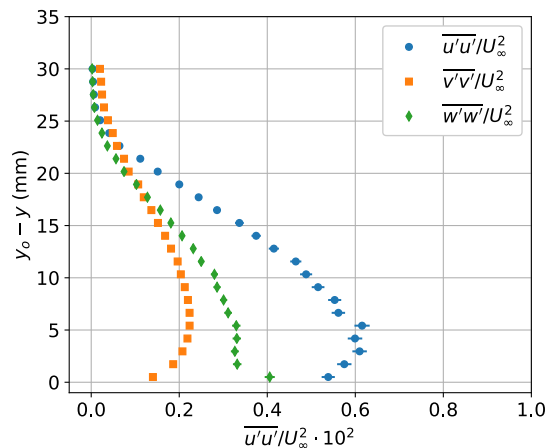
$x = 1879.2$  mm



$x = 1904.2$  mm



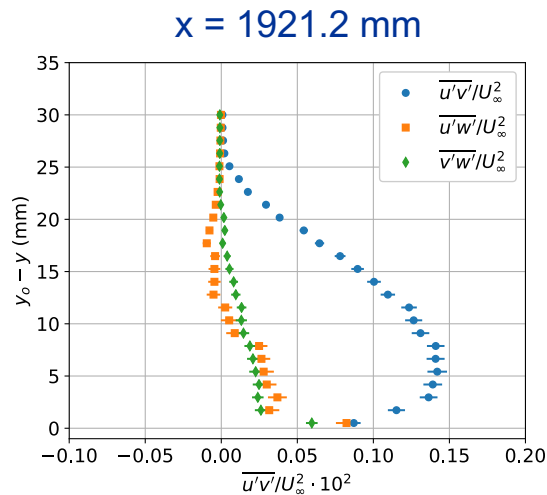
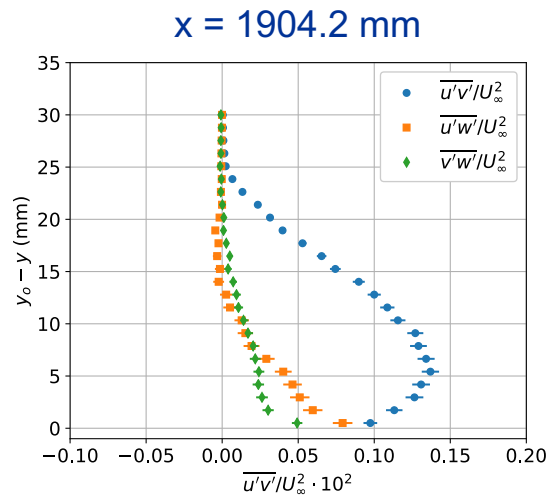
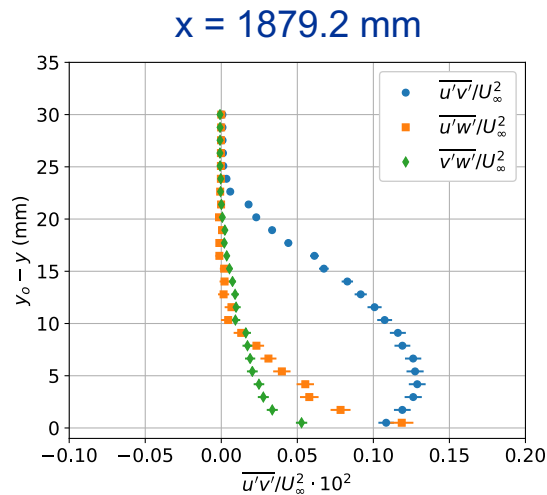
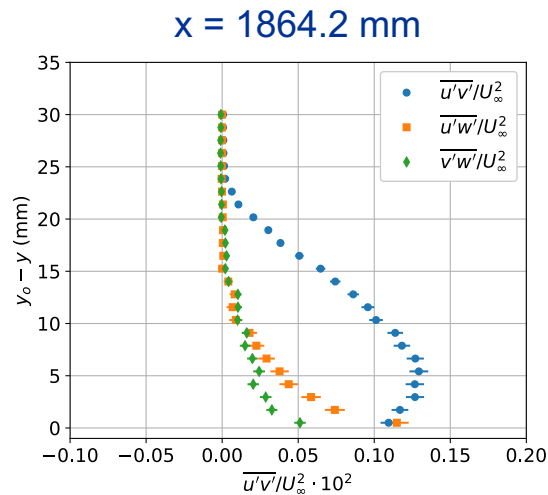
$x = 1921.2$  mm



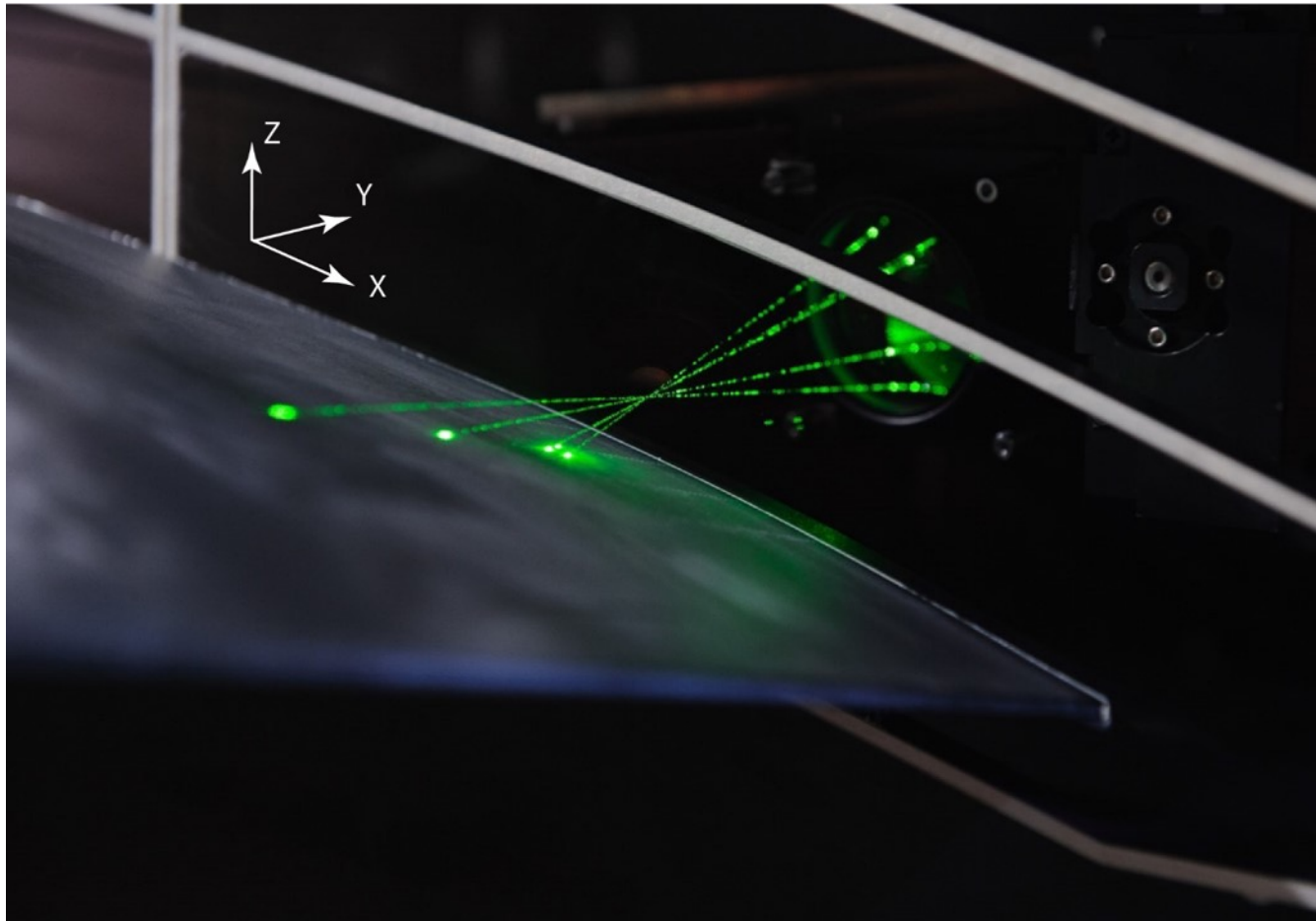


# LDV Data – Wing LE, $\alpha = 5^\circ$ , $z = 98.05$ mm

## Reynolds Shear Stress Profiles

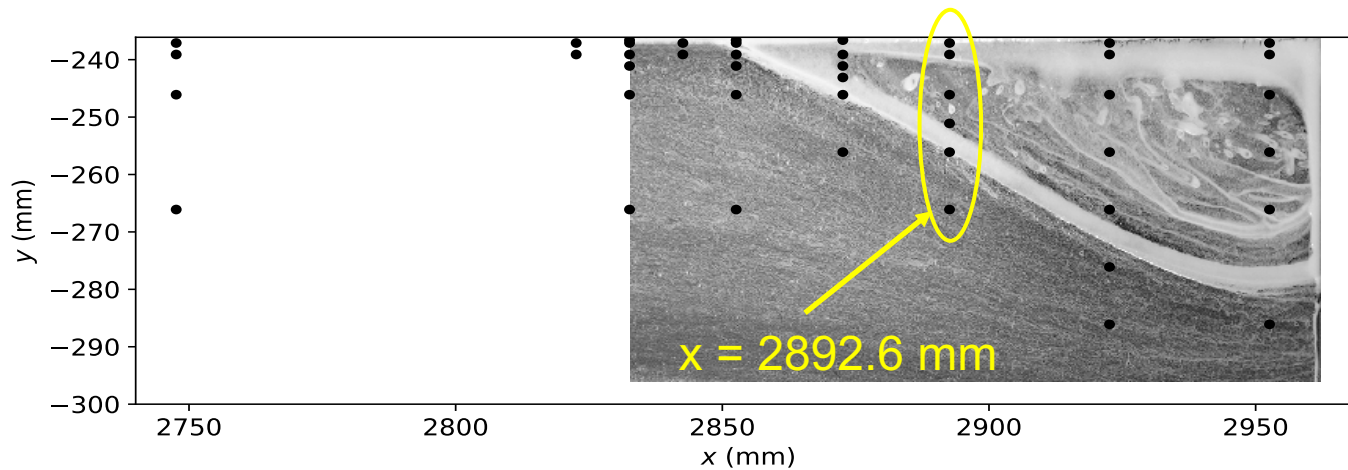


# LDV – Wing Trailing-Edge Surveys, $\alpha = 5^\circ$



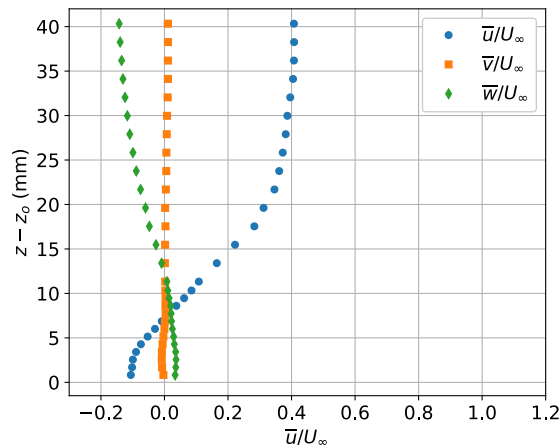
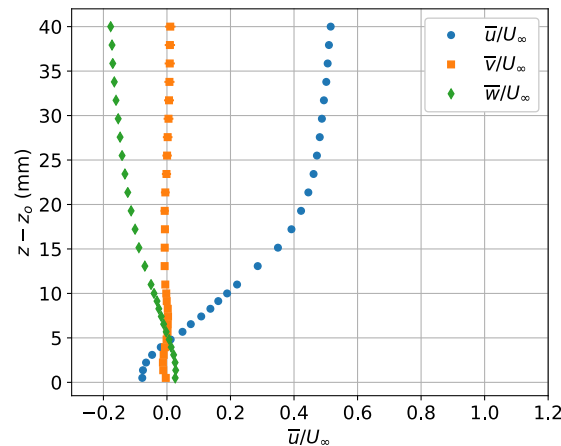
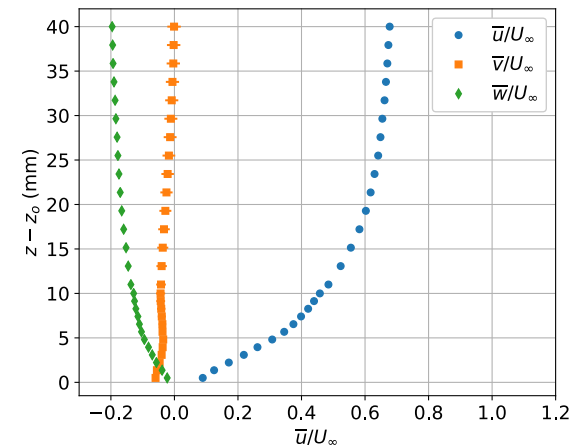
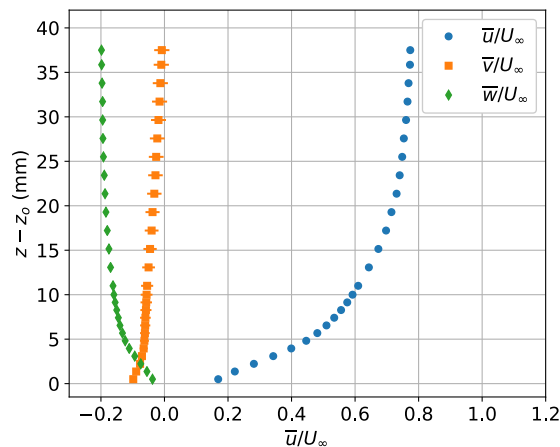
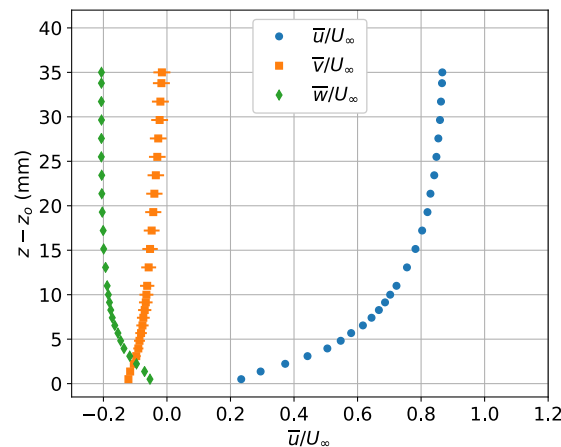
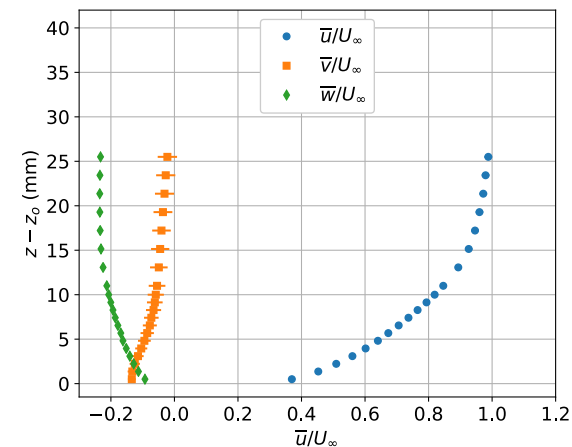
LDV system installed at the  
wing trailing edge

# LDV – Wing Trailing-Edge Surveys, $\alpha = 5^\circ$



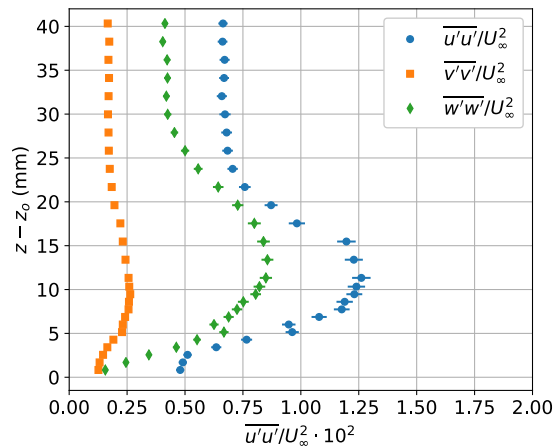
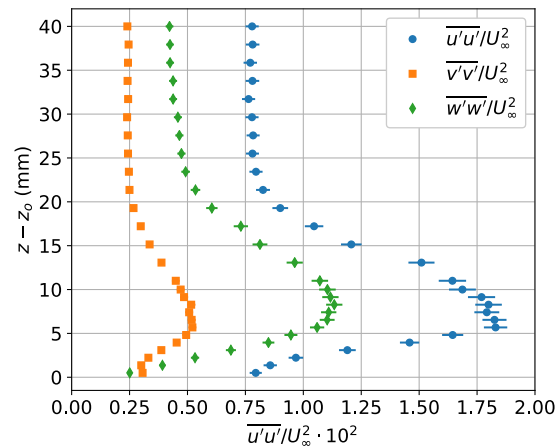
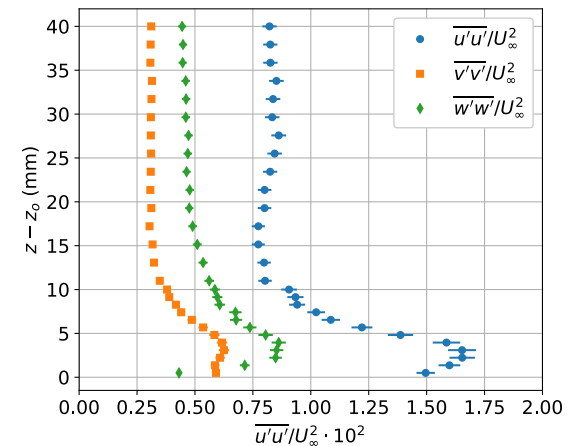
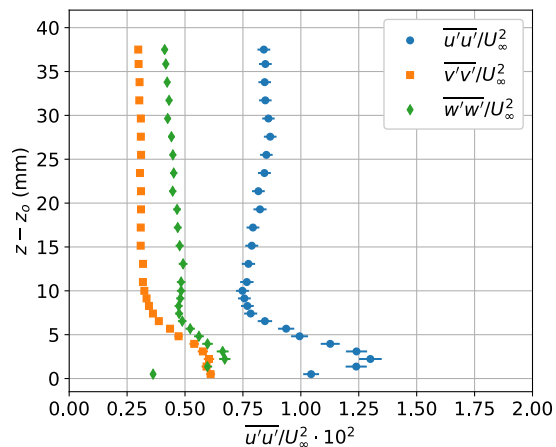
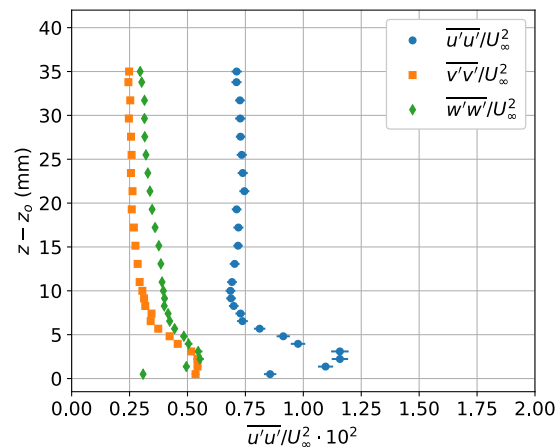
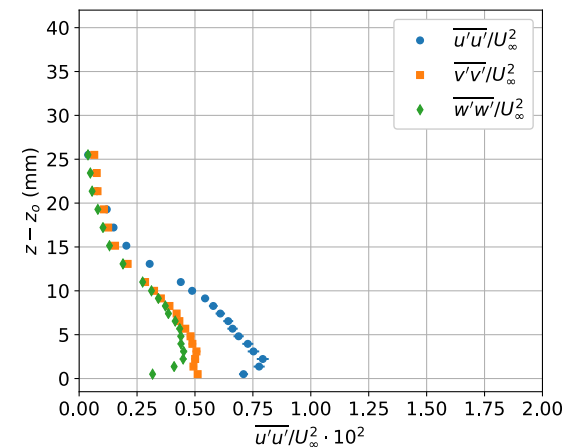
# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm

## Mean Velocity Profiles

 $y_o - y = 1$  mm $y_o - y = 3$  mm $y_o - y = 10$  mm $y_o - y = 15$  mm $y_o - y = 20$  mm $y_o - y = 30$  mm

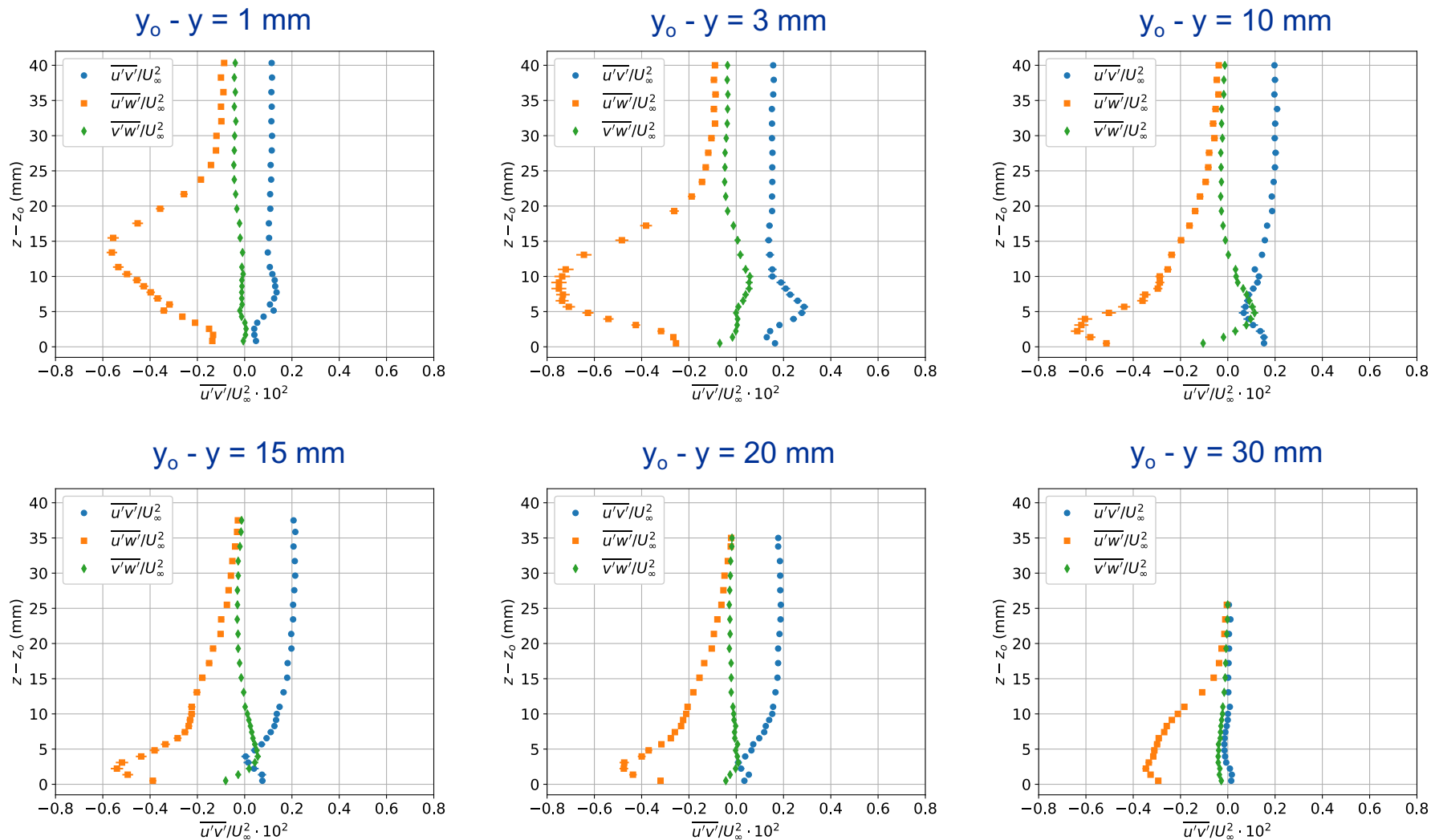
# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm

## Reynolds Normal Stress Profiles

 $y_o - y = 1$  mm $y_o - y = 3$  mm $y_o - y = 10$  mm $y_o - y = 15$  mm $y_o - y = 20$  mm $y_o - y = 30$  mm

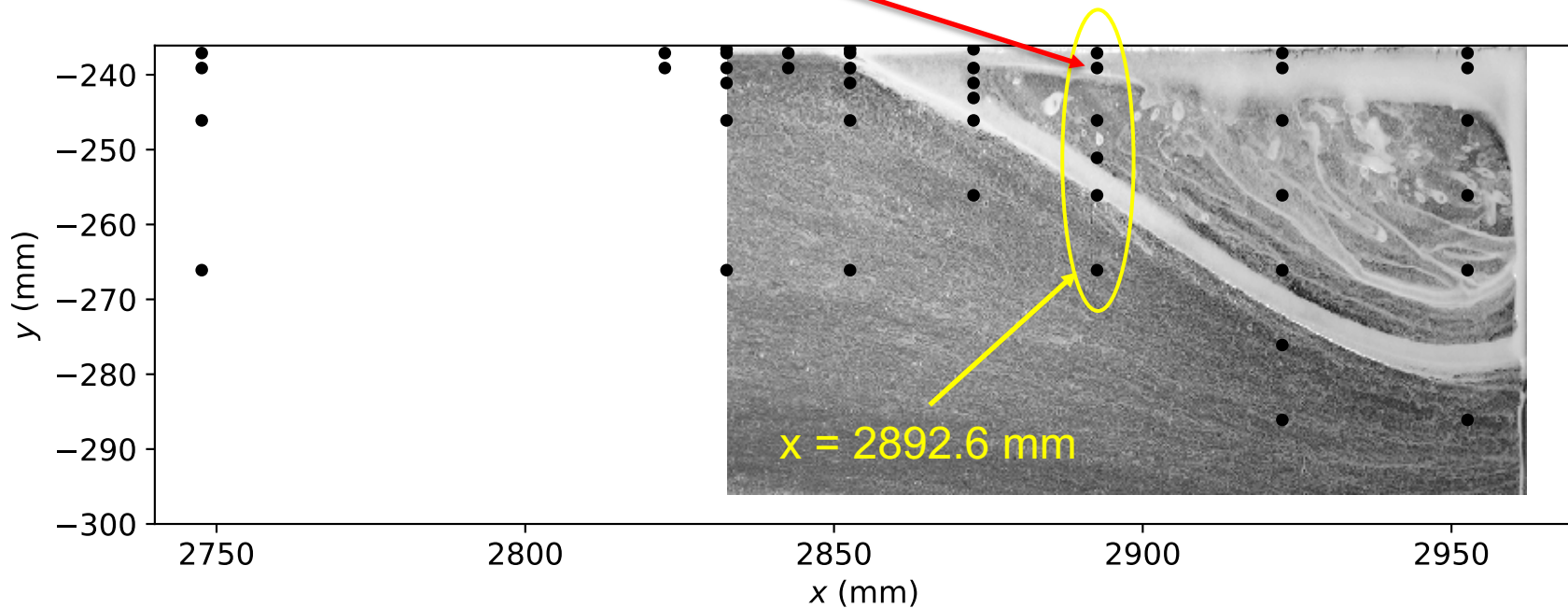
# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm

## Reynolds Shear Stress Profiles



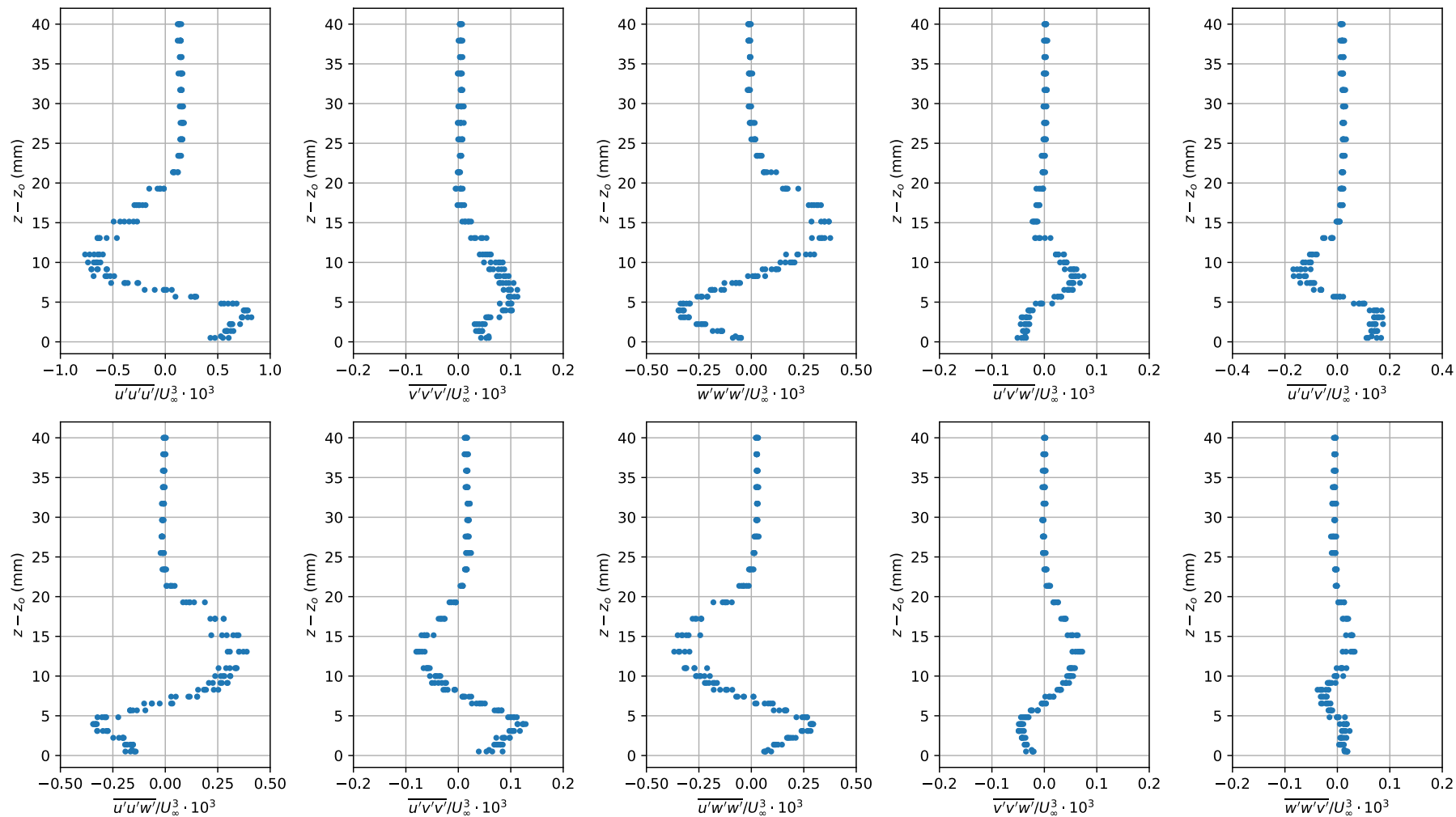
# LDV – Wing Trailing-Edge Surveys, $\alpha = 5^\circ$

Triple products at  $y=3$  mm

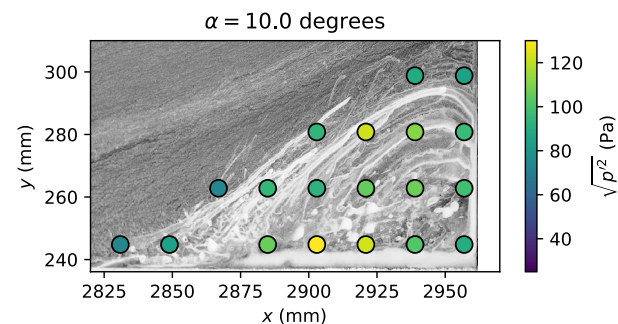
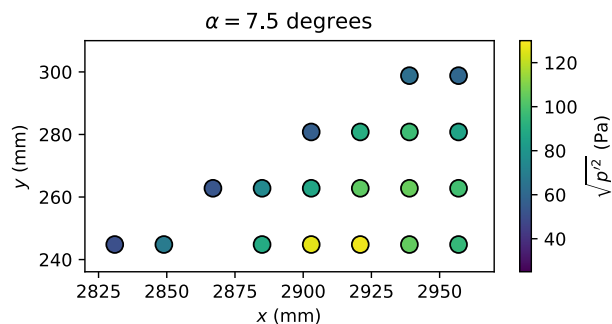
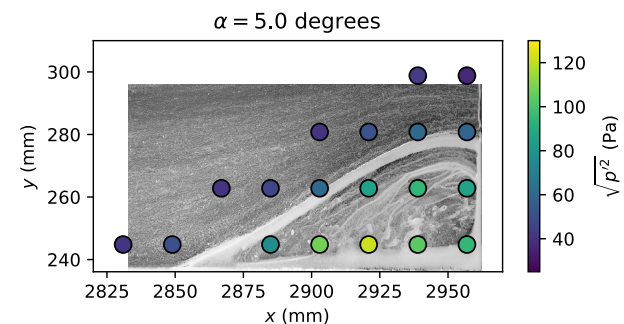
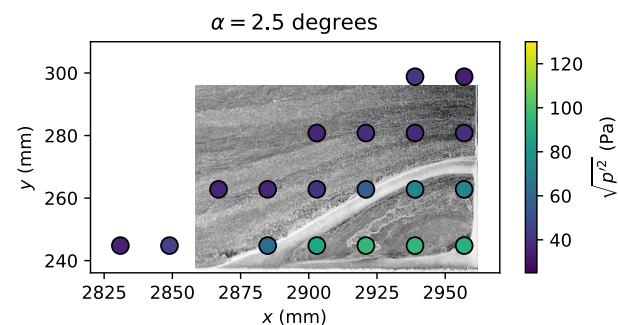
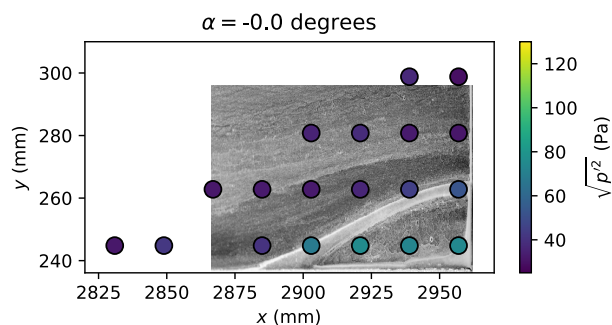
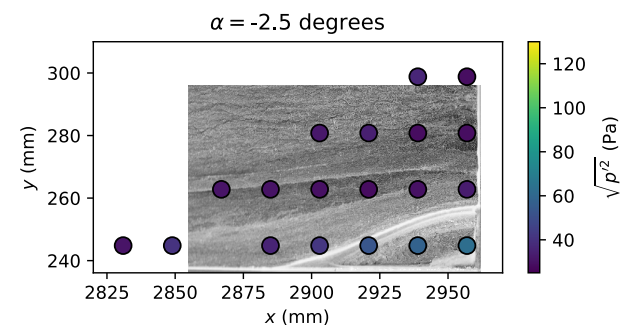
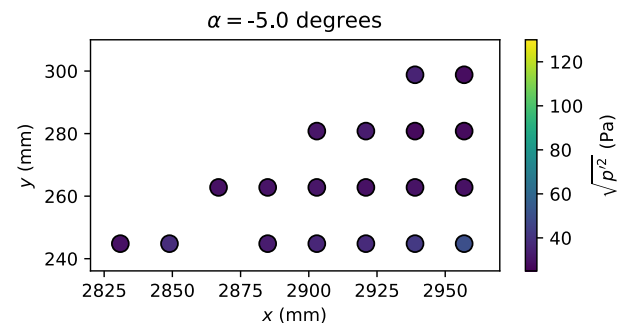
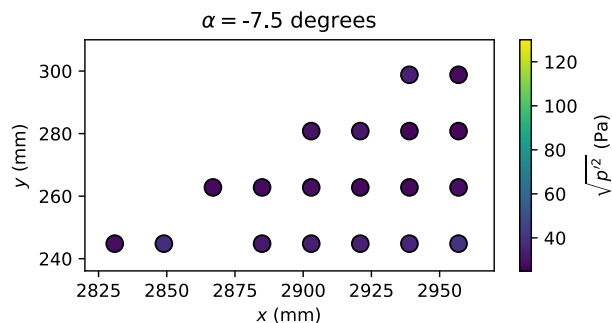
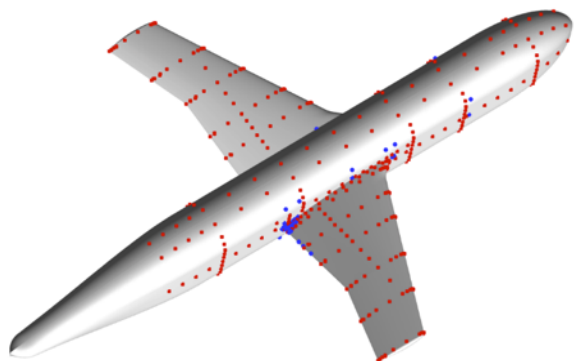




# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm, $y_o - y = 3$ mm, Velocity Triple Product Profiles

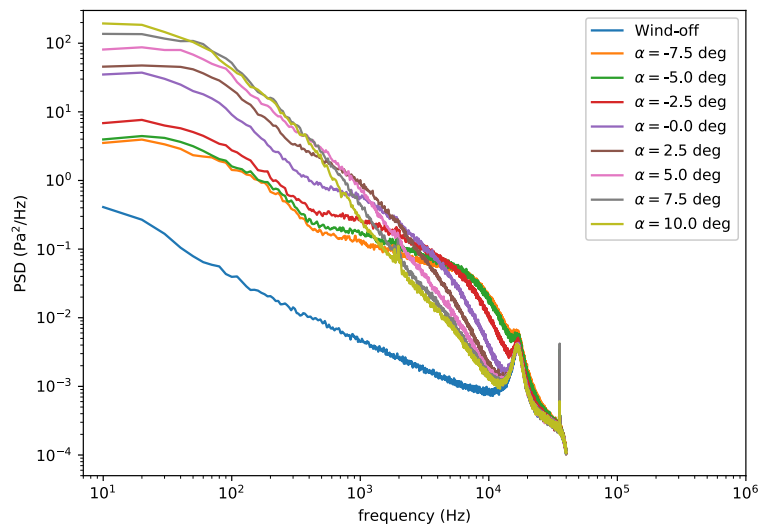


# Broadband RMS Pressures

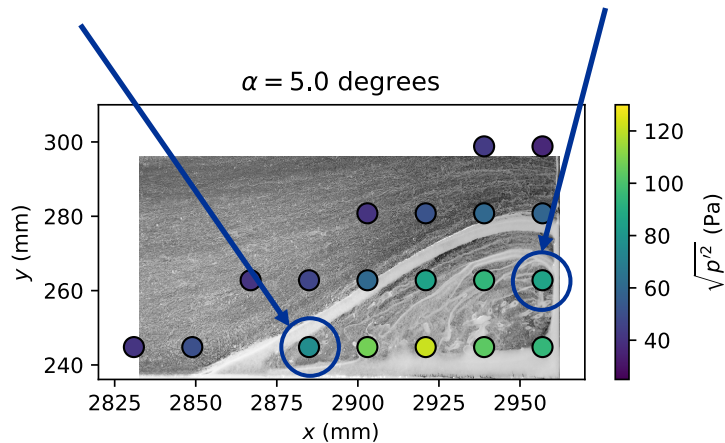
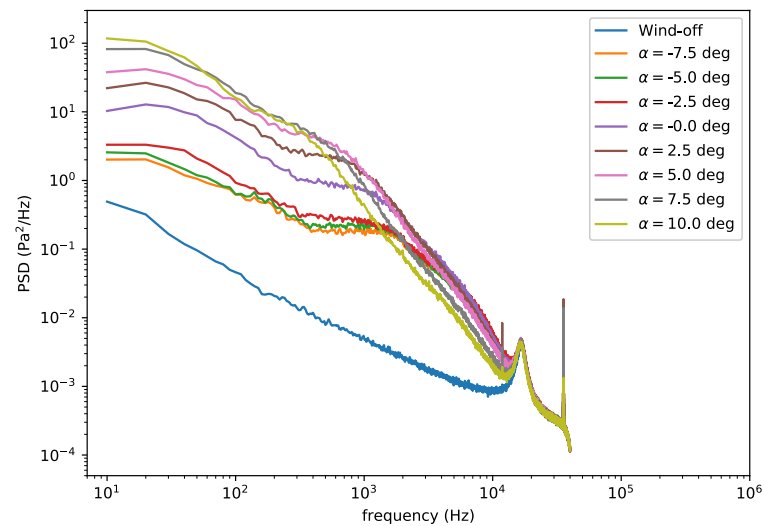


# Power Spectral Densities of Unsteady Pressures

$x = 2902.94 \text{ mm}$ ,  $y = 244.81 \text{ mm}$



$x = 2956.94 \text{ mm}$ ,  $y = 262.79 \text{ mm}$





# Future Plans

- Next 14X22-ft WT entry (6 wks, January 2020) - Perform further experiments on the F6 wing/fuselage with leading-edge extension
  - Use PIV to examine areas on the model that LDV cannot reach
  - Use PIV to find regions of interest for LDV measurements
  - Perform repeat LDV measurements for comparison to previous test results
  - Perform repeat oil-flow viz
  - Will not use IR and dynamic pressures
  - Additional AOA = 7.5 degrees (requires use of oil-flow viz)
- Possible Subsequent 14X22-ft WT entry (8 wks, 2021?) – Explore new wing geometry
  - Install NACA 0015 wing for examination of incipient separation
  - Option to examine the effect of longer fuselage nose (24-inch extension)
  - Will require use of IR, oil-flow, mean and fuselage dynamic pressures
- Add new data to online data base (website)



# Summary

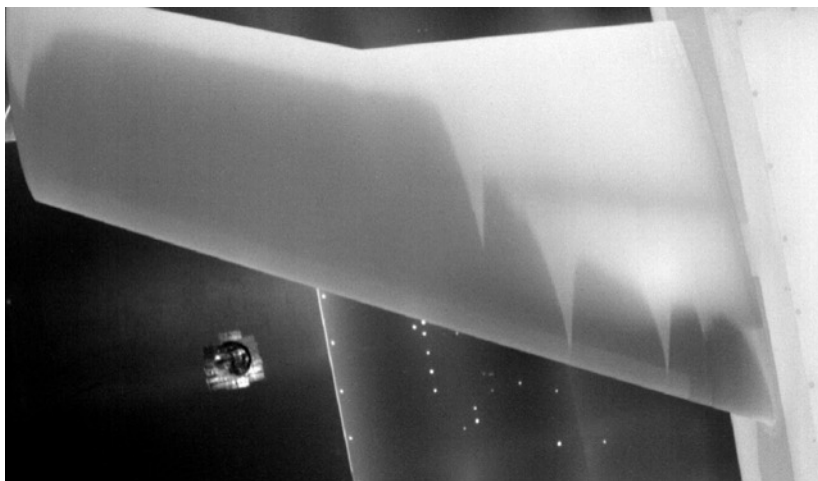
- Presented an initial report on the results of a CFD validation experiment on a full-span wing-fuselage junction model
- Goal is to provide a publicly-available high-quality flow field and surface data set with quantified boundary conditions, geometry, and measurement uncertainties
- Data set will be suitable for use by the CFD community and will help CFD professionals improve their ability to predict turbulent separated corner flows



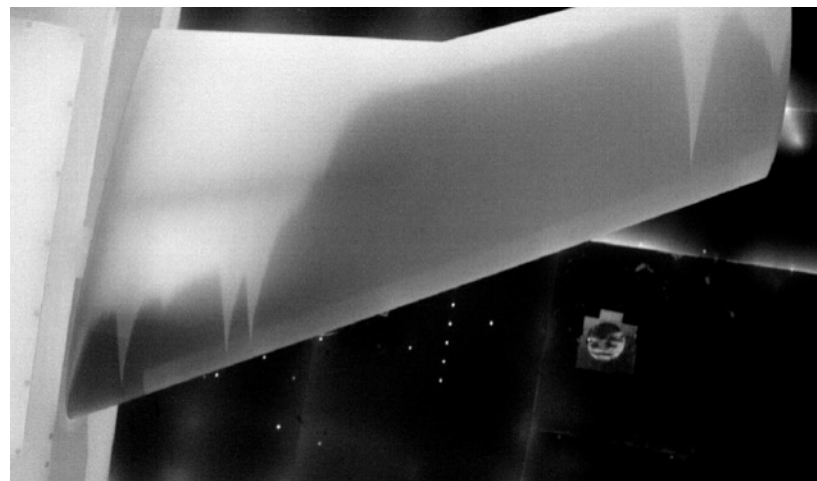
# Background Material

# Infrared Images of F6 Wing Upper Surface Baseline (Without Trip Dots), $\alpha = -2.5^\circ$

Starboard Wing



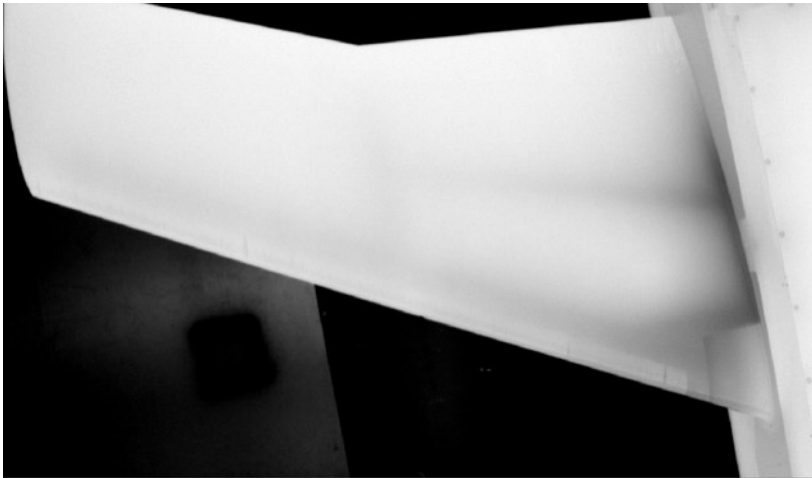
Port Wing





# Infrared Images of F6 Wing Upper Surface With Trip Dots, $\alpha = -2.5^\circ$

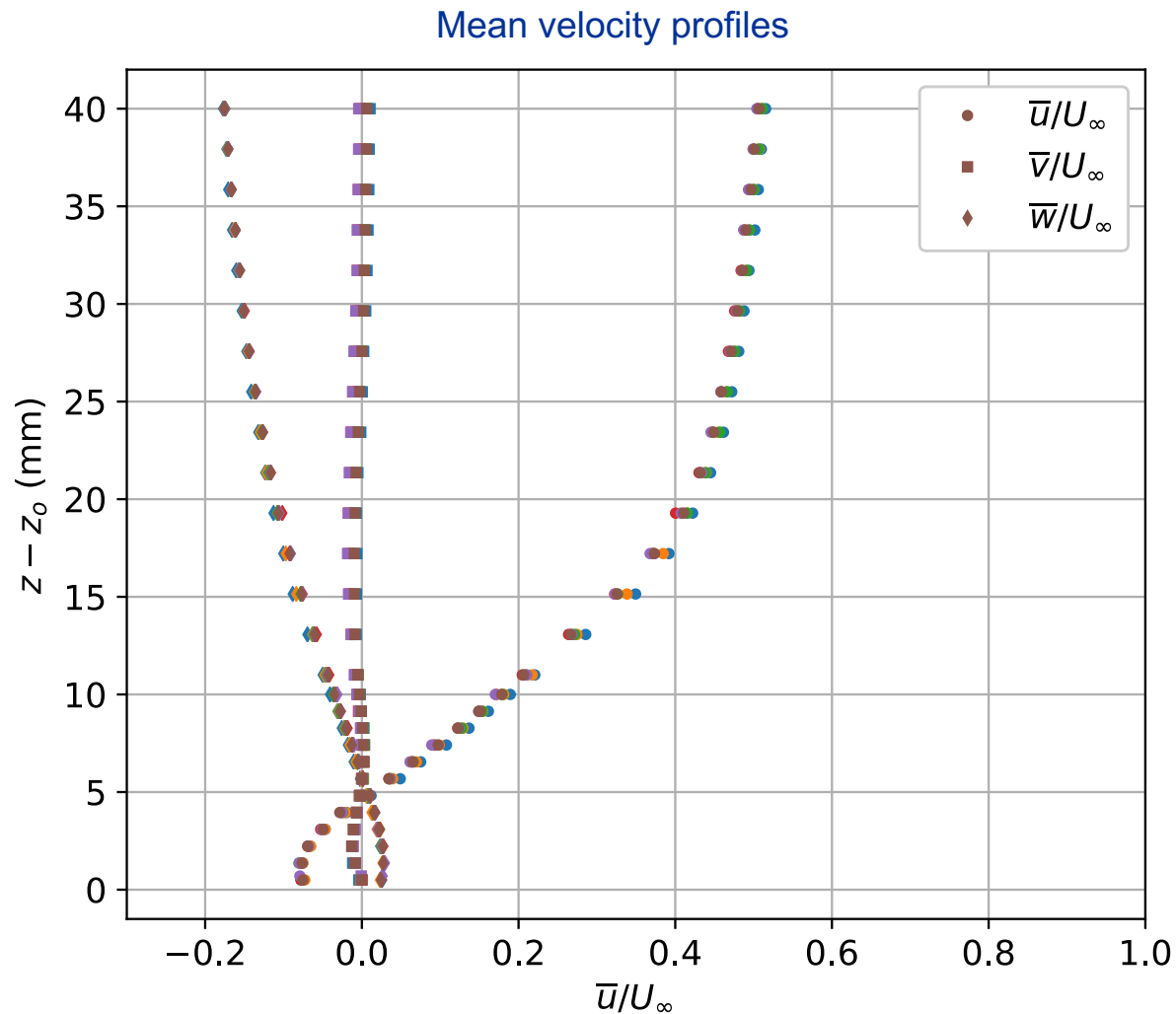
Starboard Wing



Port Wing

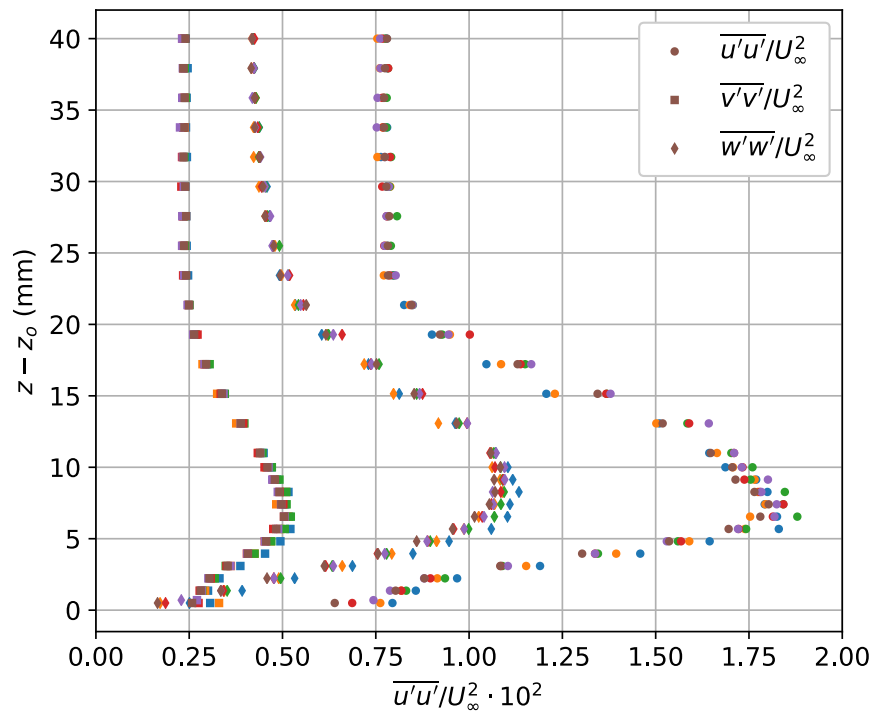


# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm, $y_o - y = 3$ mm, Repeat Profiles

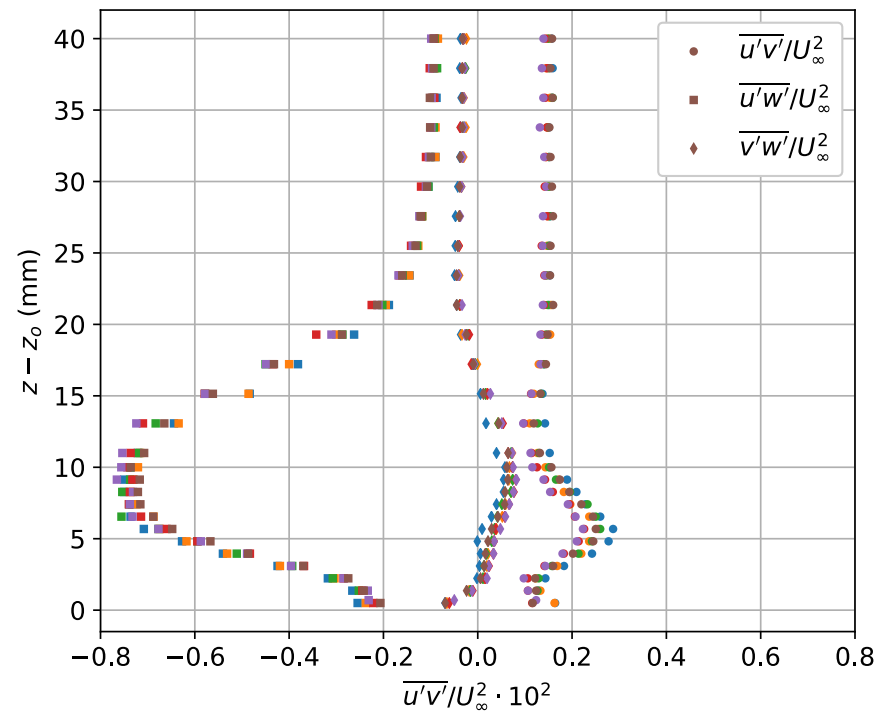


# LDV Data – Wing TE, $\alpha = 5^\circ$ , $x = 2892.6$ mm, $y_o - y = 3$ mm, Repeat Profiles

Reynolds normal stress profiles



Reynolds shear stress profiles





# Summary

- Presented an initial report out on the results of a CFD validation experiment on a full-span wing-fuselage junction model
  - Model geometry exhibits a separated corner-flow region near the wing trailing edge that current RANS models are unable to reliably predict
  - Goal is to provide a publicly-available high-quality flow field and surface data set with quantified boundary conditions, geometry, and measurement uncertainties
- Performed flow-field measurements with internally mounted LDV systems
  - Measurements on the fuselage, near the wing leading-edge, and in wing trailing-edge corner-flow region
  - Measured all three components of mean velocity, all six independent components of Reynolds stress, and all ten independent components of the velocity triple products
- Performed supporting surface-based measurements (IR, oil-flow, mean and dynamic pressures)

Data set will be suitable for use in CFD workshop environments and will help CFD practitioners validate and improve their predictive capabilities for turbulent separated corner flows