Systems Engineering for the PRANDTL-D 3c Aircraft

Author: James G Larson
Mentors: Albion H Bowers, Oscar J Murillo, and Dave E Berger

Photo: NASA Photo Lab

Abstract

The purpose of the Preliminary Research in AerodyNamic Design to Lower Drag (PRANDTL-D) project is to show that birds fly using a "bell" shaped spanload rather than using an elliptical shaped spanload and to demonstrate the extensive benefits of this alternative spanload. This validation is done by flying a research glider with a twenty five foot wingspan that collects a range of parameters in flight. To ensure the data collection computers and suite of sensors work together and mesh well with the aircraft, systems engineering principles are applied. Needs for new one-off parts require a systems engineering approach as all the criteria of the plane, such as aerodynamics, structures, and avionics, must be taken into account when making decisions. The result of this approach were effective solutions that had a minimal negative impact on other systems that were not related to the original problem.

Introduction

The PRANDTL-D 3c aircraft carries an Electronic Pressure Management (EPM) system that protrudes from the avionics bay and disrupts the laminar air flowing around the aircraft. Without some sort of shell or fairing, this parasitic drag could negatively affect the aerodynamic data collected. The fairing must be closely derived from the original airfoils of the aircraft to best retain the flying characteristics of the aircraft.

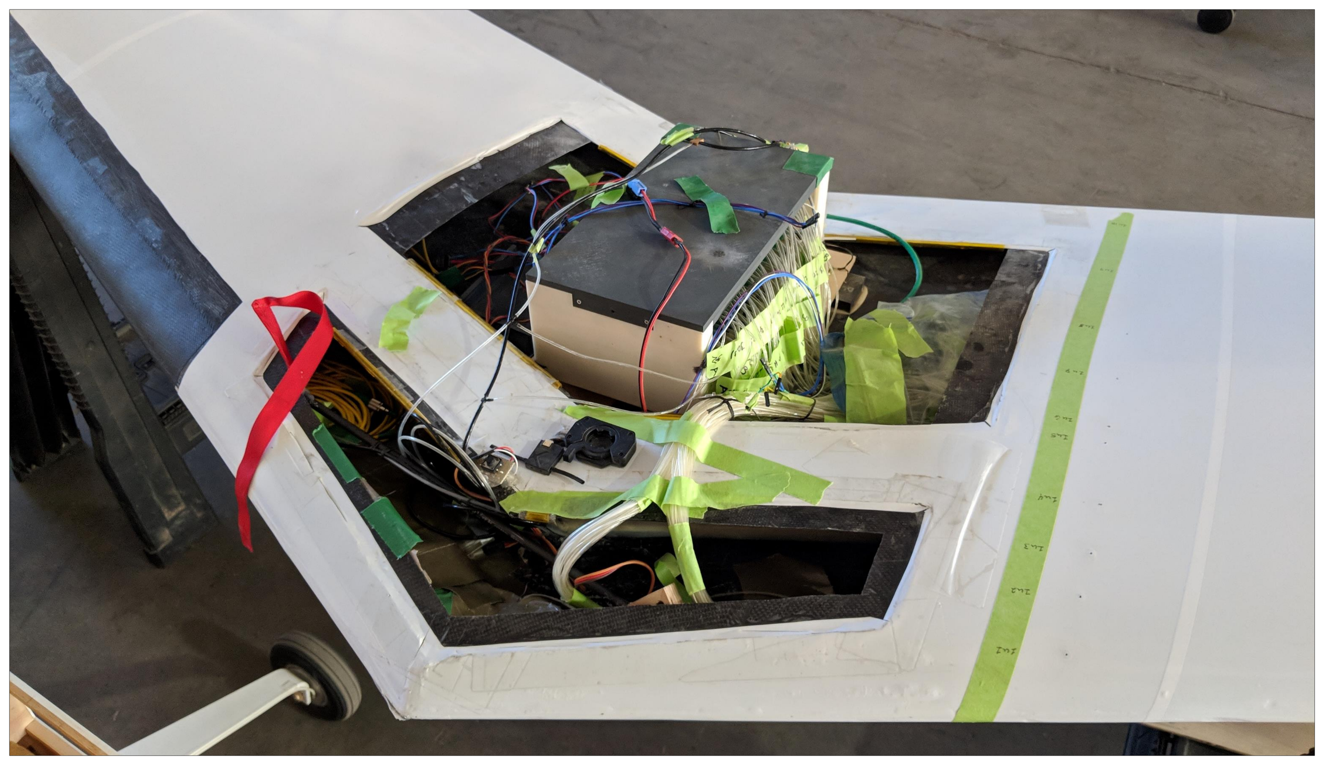

Figure 1: The EPM system shown in mounted position

Meanwhile, the original pitot tube was a possible area of improvement on the aircraft. A new air data probe was presented as an effective upgrade that had positive qualities where the original pitot tube was lacking. It provided a solid mounting point, a method to well define its orientation, and it included alpha and beta vanes which measure the aircraft's attitude. Both of these upgrades support the main objectives of the research program by eliminating negative aspects and providing more parameters with which the science team can use.

Method

The original airfoils and their corresponding span locations were obtained to begin the design process of the fairing. With the airfoil coordinates imported into Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA), the top half of the airfoil coordinates were scaled by a constant factor in both X and Y direction. After exporting the modified airfoil coordinates to SolidWorks (Dassault Systèmes, Vélizy-Villacoublay, France), guide lines were added to the airfoil sections and a solid surface was made.

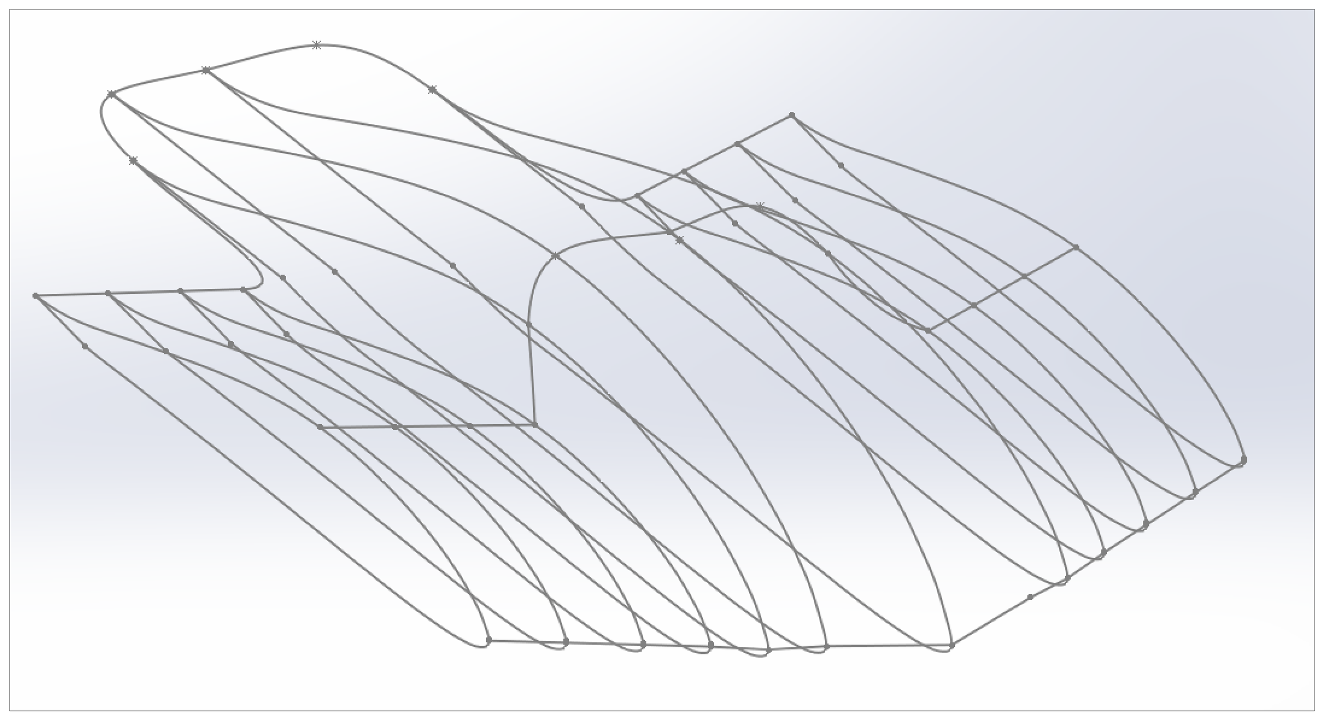

Figure 2: The airfoils and guidelines with which the fairing was created

After the fairing had been created by an outside fabricator, light hand-modifications had to be made to complete the design. These modifications were done fairly easily due to the fiberglass material which is quite workable. The front lip was heated and molded around the aircraft's shape, two National Advisory Committee for Aeronautics (NACA) ducts were cut out (one in the front and one in the back) to provide cooling air to the avionics, and the underside of the fairing was sealed to complete the loop of the airfoil. The fairing is mounted with packaging tape as this mounting method allows for easy access to the avionics bay.

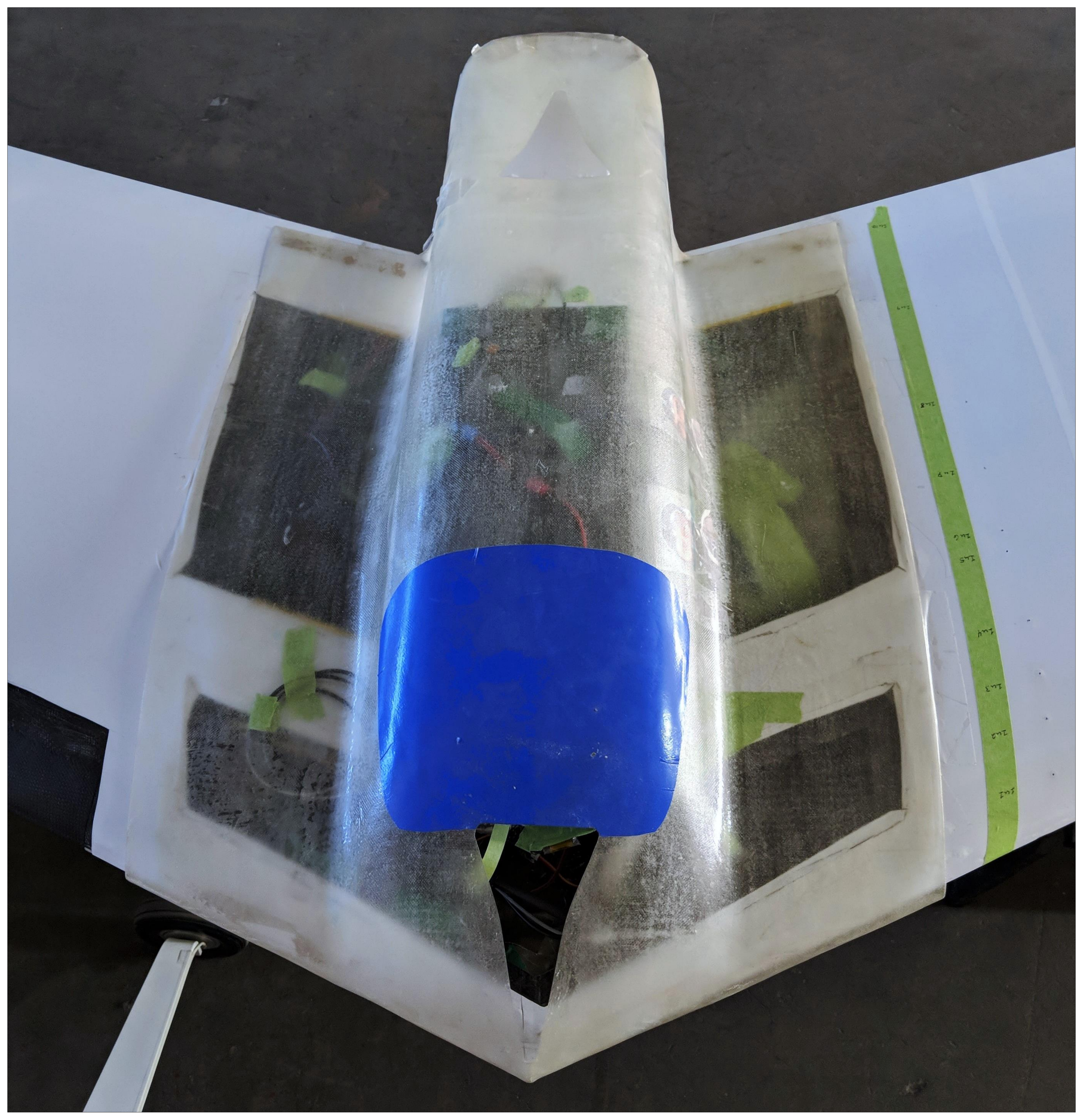

Figure 3: The fairing with its two NACA ducts

The new air data probe required a new mount as well as a calibration of the potentiometers that provide the angle of attack and angle of sideslip measurements. To accurately determine the linear model of the potentiometers, a rate table was used to set predefined angles of the air data probe. The vanes, with small weights on the ends, moved to various angles and then outputted the corresponding voltages to a desktop computer which logged the data. Two different tests were run on each vane: one of ordered two degree steps from zero degrees to plus or minus twenty degrees and one of randomized angles in the range from positive ten to minus thirty degrees.

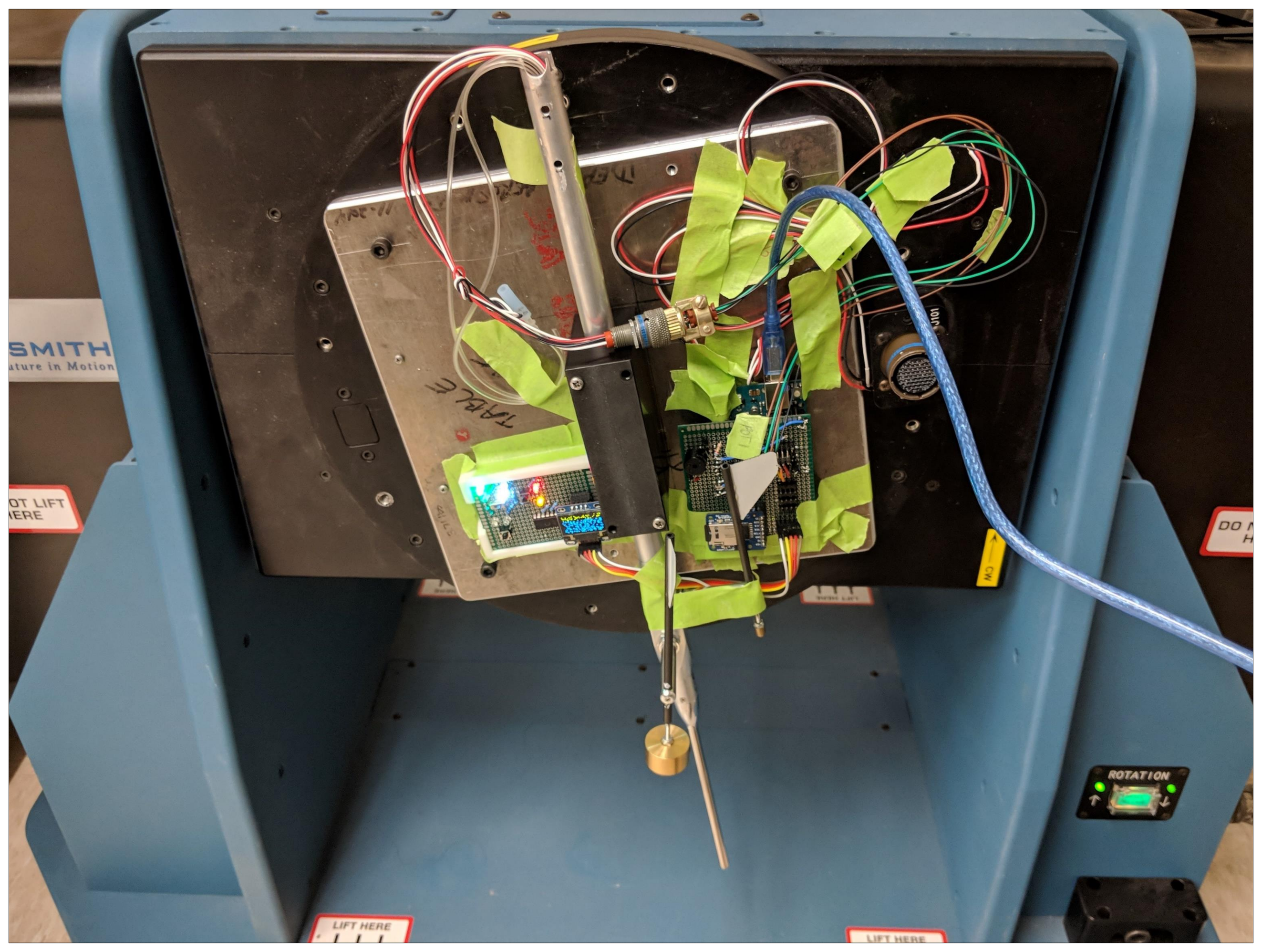

Figure 4: The air data probe and the data acquisition computer on the rate table

Results

In its 20+ flights, the fairing has performed nominally without greatly affecting either the handling of the aircraft nor the aerodynamics. The new air data probe, along with the data acquisition computer that logs the data, is a notable upgrade from what was prior. The calibration has shown that the potentiometers can measure an angle to within approximately half a degree error range.

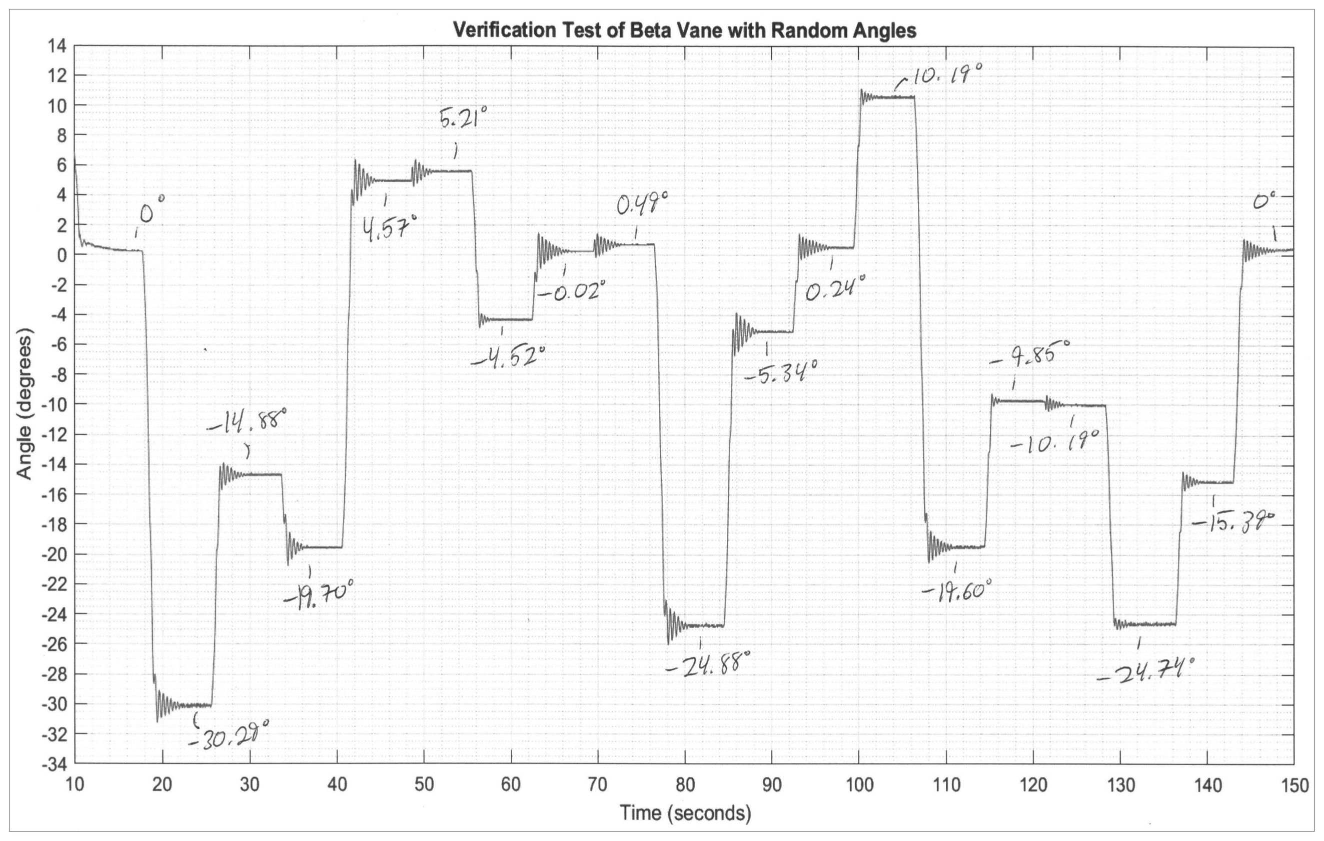

Figure 5: One of the validation tests using the data acquisition computer to log the data Labeled by hand to show the actual angle as determined by the rate table

Discussion

Before the fairing was made by the manufacturer, there was a discussion about where to use carbon fiber or fiber glass for the fairing. Carbon fiber would have been a more rigid material but ultimately it was agreed to use fiberglass as carbon blocks the radio frequency (RF) signal that is used by the radio controller. One downfall of the fairing is the small hazard it creates during landing. If the pilot flares too much, too close to the ground, the tail of the fairing could strike and create an uncertain scenario. One possible scenario is that the tape is pulled up and there is no meaningful damage. Another, more unfortunate scenario would be that a tail strike could cause the plane to pivot into the nose. However, due to the relatively large weight of the aircraft and the extensive experience of the pilot, this second scenario is unlikely.

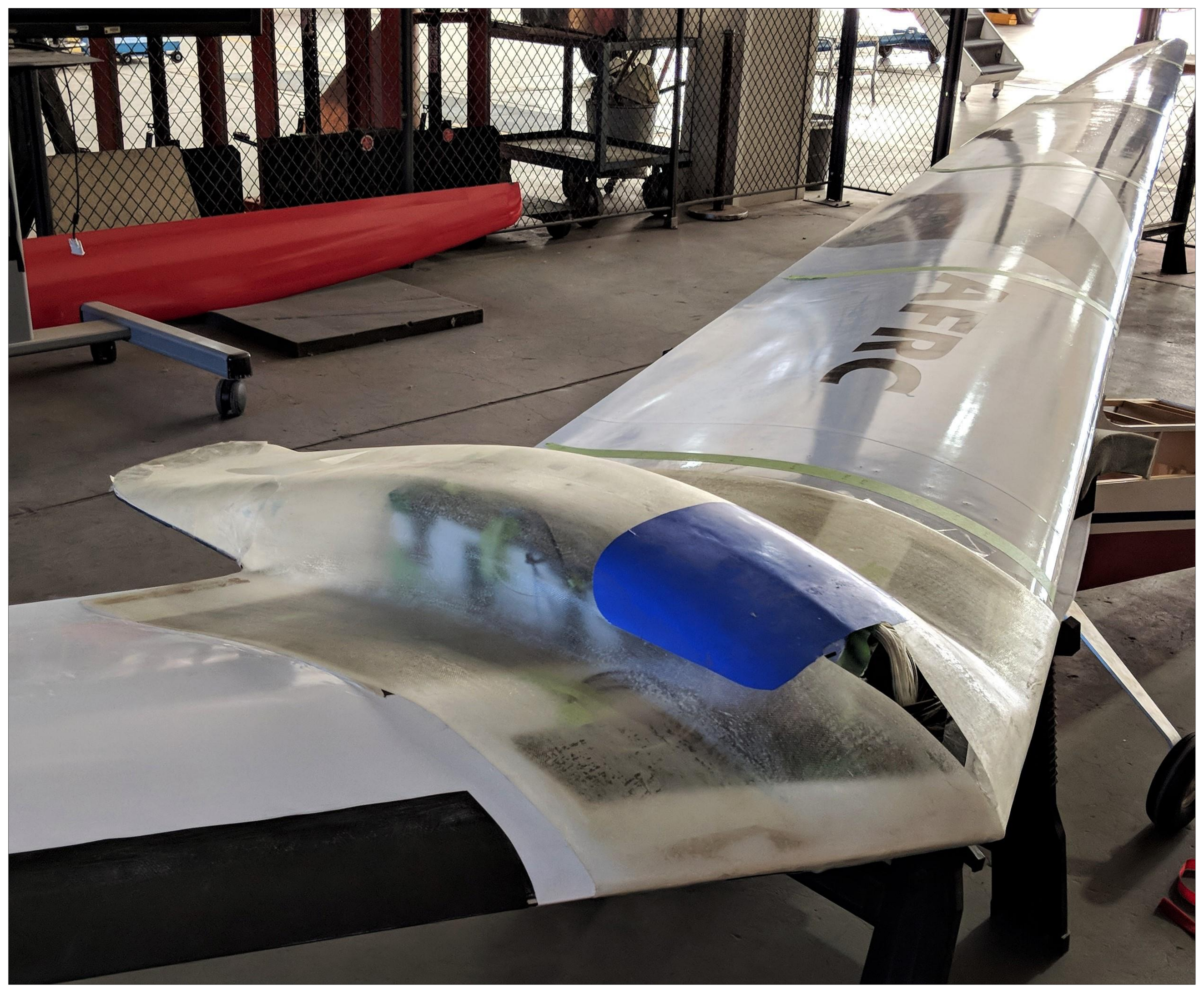

Figure 6: The fairing resting on the aircraft

References and Acknowledgments

Bowers AH, Murillo OJ, et al (2016) On Wings on the Minimum Induced Drag: Spanload Implications for Aircraft and Birds. NASA/TP-2016-219072.

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