Quad Chart and Supporting Document Grading Rubric.

The final grade will be a combination of the 5-7 minute quad chart presentation and the details in the 2-4 page supporting document. The quad chart should follow the provided template and contain enough details to quickly answer questions during the allotted time. Use the supporting document to give terse, concise answers to the following questions. (The supporting document is limited to 4 pages of content, appendices are not counted in the page limit.) The supporting document should be used in support of the quad chart, do not restate figures, equations, etc. in the supporting document but reference them from the quad chart and/or the provided equation sheet. The intent of the supporting document together with the quad chart is to allow for a stand-alone report of your findings for this lab assignment. You may address the following items in either the quad chart presentation, the supporting document, or both. The recommended items to address while speaking to the quad chart are provided in *italics*.

Advice:

- It is important that the figures are legible and professional, the MATLAB settings for plot width, marker size, legend, axis, etc. will likely need to be adjusted in order for this to be accomplished.
- Answer qualitative questions (such as 'how well does…') with quantitative analysis to show your technical understanding. For example, the answer to a question like, "*How well does your experimental airfoil data match the NACA provided data?*" should not be "*Good*." but rather the answer should be something like *"The experimental data of lift vs normalized chord has a similar linear trend to the NACA data (a slope of 0.5 compared to 0.55) with the largest deviations at the low flow speeds (approximately 25% and 35% deviation respectively). These deviations are likely attributed to the uncertainty of the measurement devices at low speeds as the NACA trend line resides within the uncertainty bounds of the estimate."*
- To conserve document space organize the answers to the following questions by referring to the section and the number. For example: *A.1: This is the response to the question about providing a brief summary of the theory and procedures. Of course the response shouldn't be a restatement of the question itself because one objective of this assignment is to produce short, terse, concise technical writing to which this particular sentence is not a good example. This sentence is a better example of concise writing.*
- The appendices should be used to house extensive information such as MATLAB code or full derivations that can be referenced in the main body of writing. The contents of the appendix should supplement the work but not essential for the narrative. You should refer to the lab assignment and equation sheet to help condense your writing.
- The equation sheet will contain an itemized list of equations from the lab assignment. Please reference the equations according to the assigned number for ease of grading. Additional equations should be added after the provided equations.

Contents and grading breakdown. The final grade will be a combination of the quad chart and supporting document with the breakdown of point indicated by (N):

______/(10) **Airspeed Calculation and Airspeed Model (section A):**

1. Provide a brief summary of the theory and procedures that you went through to compute the airspeed. (2-3 sentences)
2. *(Quad Chart) Include and discuss plots comparing the Airspeed results for both measurement configurations: (1) pitot-static probe and (2) static ring or Venturi tube; and both measurement devices: (1) U-tube Manometer and (2) pressure transducer.* (2-3 sentences)
3. How does the accuracy of the U-tube manometer compare to the pressure transducer? (1-2 sentences)
4. Provide a mathematical model that relates the desired speed to the input control voltage for the wind tunnel. (1 sentence)

______/(10) **Airspeed Measurement Uncertainty (section B):**

1. Quantify the uncertainty and its trends versus the airspeed. *Include on the quad chart and discuss uncertainty as error bars on the plot of velocity versus control input voltage from above*. (1-2 sentences)
2. Draw conclusions on the largest sources of uncertainty and how you could improve the system accuracy. (2-3 sentences)
3. Does the U-tube manometer provide a more or worse accurate measure of the velocity? (1 sentence)

______/(10) **Boundary Layer Influence (section C):**

1. Provide a brief summary of the theory and procedures that went through to compute the boundary layer. (2-3 sentences)
2. *(Quad chart) Plot the boundary layer measurements. Do you observe any noticeable trends?* (1-2 sentences)
3. Quantify the boundary layer thickness from your measurements. How does your measured thickness compare to your theoretical prediction? (2-3 sentences)
4. Do you think the boundary layer is laminar or turbulent? (1-2 sentences)
5. Did you see an appreciable change in the centerline wind tunnel airspeed? If so quantify how much. How does that change compare to what you expected from your prediction? (2-3 sentences)

______/ (10) **Post-processing and Calculation of Force Coefficients (section D):**

1. Discuss how your team post-processed raw measurements of the surface pressure coefficients, and integrated the lift coefficient. Briefly explain your procedure (provide reference equations as necessary in the appendices to conserve space. Utilize the provided equation sheet as desired.), provide well commented MATLAB code in the appendices and reference as needed. (2-3 sentences)
2. What are the major sources of uncertainty in the lift and pressure drag calculations? Place additional equations necessary to answer this question in the appendices and reference them accordingly. (2-3 sentences)
3. In your opinion, how accurate was the estimate of the trailing edge pressure coefficient? (1-2 sentences)

______/ (25) **Airfoil Static Pressure Coefficient Distribution (section E):**

1. (*Quad chart*) *Plot of pressure coefficient, Cp, versus the normalized chord-wise position, x/c, for select different angles of attack of the Clark Y-14 airfoil.* Note: You do not need to plot all of the pressure distributions from the entire class. Furthermore, you should not include plots of data without a discussion of them and purpose for their inclusion.
2. *When properly normalized explain how the pressure distribution varies with airspeed. Are there observable differences? If so why?* (1-2 sentences)
3. *At low angles of attack where the flow is attached, how does the pressure distribution change with Angle of Attack, α?* (1-2 sentences)
4. *Where along the Airfoil chord is there the largest difference in the surface pressures on the top and bottom of the airfoil? What does this tell you about the pitching moment you can expect on a Clark Y-14 airfoil?* (2-3 sentences)
5. *Do you observe any features in the pressure distribution that would indicate the flow has separated at a point on the surface? Additionally, when and where do you observe an adverse pressure gradient across the top surface of the airfoil? How does it change as you increase angle of attack? What does this say about flow separation?* (2-5 sentences)

______/ (25) **Lift and Pressure Drag Coefficients (section F):**

1. *(Quad chart) Plot the composite collection of the sectional lift and pressure drag coefficients (cl, cd) for the Clark Y-14 airfoil versus the angle of attack, α. Include the NACA results from the Technical Report #628.*
2. *How do each the lift and the pressure drag vary with angle of attack? What is the minimum pressure drag and where does that occur? Does the airfoil exhibit a sharp leading edge stall or gradual trailing edge stall? To what variables is this dependent?* (3-5 sentences)
3. *What is the maximum lift coefficient that the airfoil can generate and at what angle of attack does it occur? Does it change with the tunnel velocity?* (2-3 sentences)
4. *What is the lift produced at zero angle of attack; is it zero? If not why and where does the lift equal zero?* (1-2 sentences)
5. *How well do your plots of the lift and drag coefficients match the NACA results? In the linear lift slope region the agreement should be very good, is it? If not, what do you think is the source of this error? Hint, any systematic error/variation you observe may be fundamentally related to the conservation of mass. Can you determine a simple correction factor for the lift? How well does it correct it?* (2-3 sentences)

______/ (10) **Conclusions:** Summarize the key findings. Draw conclusions about your preferred measurement configuration for the wind tunnel airspeed. Why do you prefer this configuration? Did the tunnel wall boundary layers have a significant impact on the centerline airspeed? If so how could you best mitigate its influence in future experiments that you will conduct with the PILOT Wind Tunnel? When you compare your results with the airfoil to those reported in the literature (i.e. the NACA results) what are the key differences and similarities that you see. Draw conclusions about your ability to quantify the lift and drag forces from measurements of the static surface pressure around the Clark Y-14 airfoil. Compare this method for quantifying each the sectional lift and sectional drag coefficients. Was it better for one in particular compared to the other? (1-2 paragraphs)

Specific items to answer using the quad chart presentation:

Windtunnel Airspeed Characterization

1. Discuss plots comparing the Airspeed results for both measurement configurations and uncertainty: (1) pitot-static probe and (2) static ring or Venturi tube; and both measurement devices: (1) U-tube Manometer and (2) pressure transducer.

Boundary Layer

1. Discuss plots of the boundary layer. Do you observe any trends in the boundary layer data? How does your measured thickness compare to your theoretical prediction (laminar or turbulent)?

Airfoil Static Pressure Coefficient Distribution

1. How does the pressure distribution change with angle of attack? Airspeed?
2. Statement of where the largest difference in pressure distribution (between upper and lower surface) exists and the implications the point of greatest pressure distribution has on the pitching moment.
3. Discussion of features in pressure distribution that may insinuate flow has separated (if no features are seen that must be stated).
4. Discussion of adverse pressure gradient on top surface.

Lift and Pressure Drag coefficients

1. Comparison of results to NACA Technical Report #628
2. Discuss how lift varies with angle of attack & What is the maximum angle of attack where lift coefficient is achieved?
3. Discuss how drag varies with angle of attack & At what position does the lowest pressure drag occur?
4. Discuss if the airfoil experience sharp leading edge stall or gradual trailing edge stall, Address which variable this
5. behavior can be attributed to.
6. What angle of attack is the maximum lift coefficient achieved? Does this depend on tunnel airspeed?
7. State what angle of attack in which the lift coefficient is zero.
8. Discuss why lift does not equal zero at a 0 degrees angle of attack
9. Discuss the comparison of results with NACA results. If the lift slope did not match with that of NACA results a correction factor should be identified.