Aerodynamics of the Q-200/Tri-Q-200:
Part 3 – Analysis of flying Q's

Part 3 (of 3) of a follow-up to my 2009 study discussing Q-2 decalage (Q-Talk 138). This study focuses on aerodynamic computer modeling of the Q-2 tandem wing configuration and comparison of those models with flying aircraft. -- Jay Scheevel, Grand Junction, Colorado

Introduction

The aerodynamic modeling methods and assumptions in this Q-200/Tri-Q200 study are covered in Part 1. Part 2 discusses the flight envelope, including takeoff and landing, by employing the models to generalize about the flight behavior both in and out of ground effect. This part (Part 3) makes extensive use of flight videos gathered from the internet in order to do an evaluation of the Q-200 and Tri-Q200 flight behavior in actual flight conditions, and then to compare those flights with the modeling results from Part 2 of this study. The modeling results compare very favorably with the actual flight video evaluations and also shed light on the dynamic/transient behavior of the Q-200 and Tri-Q200 designs including variability between individual aircraft and the aircraft response to techniques of various pilots.

As one might expect, landing and take-off behaviors differ between Q-200 and Tri-Q200 primarily because the Tri-Q200 must rotate in order to take off, whereas the conventional Q-2/Q-200 takes off essentially from a 3 point stance. However, observations from videos also show there are substantial differences between the two variants in cruise flight apparently resulting from aerodynamic forces induced by the landing gear design of the Tri-Q200. The first part of the discussion will review the Q-200, followed by a discussion of the Tri-Q200.

The modeling from Part 2 is strictly for equilibrium conditions, meaning constant alpha and airspeed. but the videos of actual flights include periods of dynamic or transient conditions in addition to equilibrium ones. The non-equilibrium (dynamic) portions of the flight videos are instructive, especially during takeoff, but my analysis necessarily recognizes that these conditions depart from the modeling assumptions. Discussion of dynamic flight conditions is speculative, but may add qualitative insight.

The Q-200 Flight Envelope Model

Figure 1 is the same as one discussed in Part 2. The graph contains a series of colored curves which represent the equilibrium flight conditions for calibrated models of the Q-200. Each colored curve represents the flight profile for a different decalage. Any point on a colored curve represents an equilibrium flight condition where forces on both canard and wing (lift, drag and moments) combine with non-wing drag moments to result in stable flight. The aircraft gross weight (900 pounds) is applied as a vertical force located at the fuselage station (FS) and water level (WL) corresponding to the center of gravity (CG) of the aircraft. Each colored curve represents all possible combinations of airspeed and alpha (~AOA) for that decalage and the loading condition. The vertical axis of the graph is alpha. The horizontal axis is airspeed (CAS). The yellow stars on this graph represent the estimated alpha/CAS combinations for flight tests in the prototype QAC Q-200 N81QA and plot on top of the yellow curve corresponding to the javafoil-based model results for decalage of minus 1. The measurements are from Michael Huffman's 1983 report on the QAC prototype Q-200 N81QA. Flight tests were conducted at a weight of ~900 pounds and CG of FS 44" based on description of loading used for flight tests. All reported data was collected during flight out of ground effect.

Figure 2 is the equivalent of Figure 1, but is the model response when in ground effect. The yellow stars shown on this figure are the same as those in Figure 1 (measure out of ground effect). The difference between the yellow curve and the yellow stars shows the significant impact of flight into ground effect. This is most apparent at low airspeeds where alpha values are significantly reduced from those when flying out of ground effect. Maximum achievable alpha at pitch buck in ground effect is less than 7 degrees, whereas out of ground effect it is near 10 degrees for the modeled CG and gross weight.

Use of videos to evaluate Q-200 Flight Behavoir

In this part of the study we evaluate two currently flying Q-200's through the use of posted internet videos. The first of these is Mike Dwyer's Q-200 (N3QP). N3QP has several decades and more than 1000 hours of flight time. Dwyer's videos are recorded in Florida (near sea level), so provide very useful standard atmospheric condition comparisons to modeling results. The second flying Q-200 was built and flown by Sanjay Dahll. Dahll's plane (N102SD) has been flying for close to 4 years and has an estimated 150+ hours. It is flown in Michigan (ground elevation 600-700 feet above sea level).

Some of the videos prepared by Dwyer for flights in N3QP include strip-type speed and altitude data synchronized with the video (using Dashcam), these numbers are informative for analysis of all phases of flight. Dahll's videos for N102SD do not include speed or altitude data, but like other videos used here, unique runway markings can be identified and distances between those markings can be measured accurately using Google earth. Then interval-timing of these markings on the real-time video allows ground speed to be computed during the take-off. Airspeed (CAS) from groundspeed can be estimated based on assumptions of atmospheric conditions during takeoff and flight. This includes consideration of density altitude and wind conditions.

Using specific angular relationships between airframe features, as seen from the camera point of view (POV), an angular scale can be constructed and then superimposed on the video frame capture images. By comparison of this scale to the distant horizon, the alpha angle during any phase of level flight can be estimated.

Combined with the visually measured alpha values, and in some cases with video observations of elevator and reflexor configurations, meaningful comparisons with the Javafoil models from Part 2 can be made.

Q-200 Flight Characteristics - N3QP

Several photographs of N3QP are available online. Views from the side have very little parallax so allow for measurement of the decalage angle of the aircraft by observation of the wing and canard sections viewed from the side (N3QP decalage has not yet been hand measured). Figure 3 shows side views of N3QP wings. These photos have been overlain with the appropriate template for the wing section which were digitized from QAC plans. The angle listed is that of the section template's level line when matched to the photo. The aircraft is sitting empty on a reasonably level surface. The canard has a 10 degree angle and the main wing has a 9 degree angle, meaning that N3QP has a decalage angle of minus 1, essentially the same as the QAC prototype, N81QA.

Figure 4 shows a screen capture view from a N3QP video. The image is from a point of view (POV) in the cockpit very near the seatback bulkhead. Superimposed on this view is a calibrated angular scale. When compared to the distant horizon, the alpha is indicated on the scale. The topography is very flat in this part of Florida, so the distant horizon is flat and clear in this shot. This view demonstrates that the alpha is 7 degrees when the aircraft is loaded. The speed of the aircraft when taxiing and also when this shot was taken, is near take off speed (65 mph). At this point the plane still has all wheels on the runway, but is about to lift off.

Figure 5 shows N3QP, just prior to take off on a different flight, however the view in this video was from a camera mounted near the end of the left canard with a view of the bottom surface of the canard. Figure 5 has a clear view of the edge of the runway which serves as a horizontal reference. The lower surface of the right canard root permits a visual alignment of the QAC template, the comparison of this template's level line to the horizon reinforces the observation that takeoff alpha in ground effect is about 7 degrees. Also, this view allows the measurement of the elevator deflection that is applied at the moment of takeoff (17 degrees elevator).

Figure 6 is taken from the cockpit view, showing N3QP just after takeoff at a speed of 74 mph. The horizon against the angular scale reveals that alpha is now 6.5 degrees, still in ground effect.

Figure 7 is the view from below the canard revealing that the elevator setting is at 10 degrees, while the aircraft is still in ground effect just after takeoff at 74 mph.

Figure 8 is the modeled flight configuration summary in ground effect. The plot shows combinations of airspeed, alpha and elevator configurations that result in stable level flight of the Q-200 when in ground effect. The two yellow stars represent the near take off and very early flight behavior of N3QP from Figures 4 through 7. The stars plot above to the model decalage curve of minus 1 (yellow). The stars are nearly half way between decalage minus 1 and minus 2 model curves. Since decalage is apparently minus 1 for N3QP, the stars would be expected to plot on the yellow curve, but they come in slightly high to this. This could be the result of several factors including the use of up aileron reflexor setting during takeoff, or a more rearward CG than 44" FS that was used for the model. Neither of these conditions could be confirmed from the videos. That said, the measured flight characteristics at takeoff for N3QP are close enough to the expected values for decalage of minus 1 to allow us to call the model a good proxy for the flight behavior of N3QP while taking off and flying in ground effect.

Figure 9 through 12 show sequential shots from the cockpit camera at different phases of the same flight but out of ground effect. The alphas and airspeeds are shown on the figures. Figure 13 is the graph of airspeed vs. alpha for the model Q-200 out of ground effect. On this graph, the airspeed/alpha observations from Figures 9 through 12 are plotted as yellow stars. The yellow stars track close to the yellow minus 1 decalage curve, which is consistent with the expected flight behavior of N3QP based on its minus 1 degree decalage.

Q-200 Flight Characteristics – N102SD

Several videos of Sanjay Dahll's Q-200 (N102SD) have been posted. Two of these are analyzed with two different camera positions represented. The first is one where the camera is mounted to the wheel fairing on the inside with a view of the lower surface of the canard (similar to some of the videos of N3QP), and another where the camera is mounted on the leading edge of the vertical fin with a forward view of the top of the aircraft.

Figures 14 through 18 are a collection of screen captures from the wheel fairing camera position. The QAC canard template is superimposed on the wing root and is aligned with the canard at that location, so serves as a reference to compare to the horizon line, in order to determine alpha. Airspeeds are estimated by either 1. timing reference points passing the cameral on the runway (take off) or 2. assuming the expected modeled airspeeds (in cruise flight).

Figure 14 is a slow taxi. The horizontal reference indicates a taxi alpha of 6 degrees.

Figure 15 is late in the takeoff roll, when elevator is deflected down 5 degrees. Figure 16 is immediately afterwards, when the elevator is quickly deflected to 8 degrees and the plane has just lifted off. After lifting off, the alpha goes rapidly to 7.5 degrees, then settles back in Figure 17 to 5.8 degrees (elevator held at 4 degrees).

Figure 18 is in level cruise at an estimated CAS of 140 mph, alpha of 0.5 and elevator at 2 degrees up (-2).

Figure 19 is shows the scenarios in Figures 15 through 18 as yellow stars plotted on the Javafoil Q-200 model. The takeoff behavior is close to that expected for a decalage angle of minus 2, although the point of corresponding to 7.5 degrees alpha is probably not equilibrium because of dynamic rotation during lift-off. The actual decalage of N102SD has not been measured either physically or from photos. It is apparent that some up aileron reflexor is used during take-off see figure 25. Use of reflexor will cause the Q-200 to fly as if it has a more negative decalage. The models are all based on neutral reflexor.

Figure 20 is the version of the model shown in Figure 19, but when out of ground effect. The takeoff behavior in Figure 19 indicates suggests N102SD decalage is close to minus 2, however if neutral reflexor was used at cruise and up reflexor at takeoff, then the natural decalage of N102SD would be consistently minus 1.

Figures 21 through 27 show a series of flight scenarios for N102SD from a camera position on the vertical fin. The yellow lines on each Figure are marking parallel linear surface features such as taxiway or runway boundaries or runway markings. The crossing point of the extrapolation of two parallel horizontal lines is commonly known as the vanishing point. Because of the geometric law of parallax, the crossing point when viewed from the camera represents a point on the distant horizon. This point can be compared to the superimposed angular scale in the center of the figure in order to read alpha from the red arrow (similar to the analysis that was used to evaluate N3QP). The reason the vanishing point method is used is because the actual horizon is hidden behind the main wing in most of the views from taken from the tail POV. If the horizon is visible, it is used instead.

Figure 21 is slow taxi, confirming 6 degrees taxi alpha.

Figure 22 is early in the takeoff roll. The alpha increases slightly to 6.5 degrees,

Figure 23 and 24 both show late takeoff roll with alpha increasing to 6.7 then 6.9 with down elevator deflection near takeoff speed (~70 mph CAS).

Figure 25 is immediately after lift-off (75+ mph CAS). A rapid elevator deflection that pops the plane into the air dynamically lifts the nose to an alpha of 8.7 once airborne. It immediately settles back (Figure 26) to 5.4 degrees at an estimated CAS of 85 mph CAS.

Figure 27 is at level cruise at an altitude just below cloud base. The alpha is 0.5 with an estimated CAS of 140 mph.

The takeoff sequence in Figures 24, 25 and 26 is plotted on the alpha versus CAS of the model for comparison. Note the rapid rotation shown by the dashed lines shows the trajectory of the sequence. This sequence (excluding the dynamic pitch-up at take-off) suggests the N102SD has a decalage behavior consistent with a value of minus 2 degrees. This is similar to what was indicated by the canard mounted camera POV.

Figure 29 is the same type of plot as in Figure 28, but shows the model results for flight out of ground effect. The scenario from Figure 27, N102SD in cruise flight, is plotted as a yellow star on this Figure. This indicates that the cruise flight is as expected for a decalage value of minus 1. Again, if reflexor was used for takeoff and adjusted to neutral for cruise, the points in Figures 28 and 29 would be consistent with N102SD having a minus 1 decalage. Figures 24 and 25 seem to show that up aileron reflexor is present for takeoff, and Figure 27 appears to show neutral reflexor at cruise. Overall, N102SD is consistent with the model predicted behavior for a decalage angle of minus 1.

Tri-Q200 Flight Envelope Model

As noted in Part 2 of this study, the Tri-Q200 configuration behaves differently than the Q-200. For takeoff this is because of the obvious fact that the Tri-Q200 must rotate to a higher alpha in order to take off. What is not so obvious is that the Tri-Q200 also differs from the Q-200 in all phases of flight because of significant aerodynamic contributions of the main gear as compared to the standard gear on the Q-200 taildragger. The variations between the two gear styles is caused by drag moment differences and also by significant de-lifting forces induced by the landing gear shape. The flight behavior of the Tri-Q200 requires a unique model that incorporates these differences. Part 2 explains the Tri-Q200 modeling results in detail. We use the Tri-Q200 model from Part 2 in order to compare to actual flying Tri-Q200's discussed below.

Tri-Q200 Flight Characteristics – N625JM

Jerry Marstall's Tri-Q200 (N625JM) was one aircraft that has been measured for the the 2009 decalage study and has been flying as a Tri-Q200 for many years. N625JM has decalage angle of +0.85. The loaded taxi alpha was measured to be 4.5 degrees. Knowledge of these parameters allow for specific comparison to the Tri-Q200 model. Also very informative is the camera position mounted just below the rudder on bottom of the fuselage which gives a full view of the main wing, canard and landing gear. Airspeed during takeoff was determined by timing runway markings, and cruise airspeed is estimated.

Figure 30 shows N625JM in stationary taxi position with alpha at 4.5 degrees. The yellow line marks the horizon (aligns with 4.5 degrees on the scale). In addition, a horizontal orange line marks a unique registration point on the main wheel fairing. This is used to determine the flex of the gear leg. The red line connects registration points on both ends of the canard. This red line is used to determine the flex of the canard. The black line connects registration points on the tips of the main wing and is used to determine the flex of the main wing. The various superimposed scales are used to quantify the various measurements.

Figure 31 shows N625JM late in the takeoff roll at an estimated 65 mph CAS. Note that the aerodynamic forces prior to this moment have pitched the aircraft forward slightly to 3.1 degrees.

Figure 32 shows N625JM later in the takeoff roll with estimated CAS of 70. In the video, the main wheels can be seen bouncing slightly as they momentarily depart the runway. The nose wheel is still firmly in contact with the runway.

Fig, 33 is similar to Figure 32 with slightly higher airspeed with estimated CAS of 74. This is where a large elevator deflection causes the nose wheel to lift and nose to rotate upward.

Figure 34 shows mains off the ground with nose wheel lifted and reaching the top of the rotation with estimated CAS of 78 and alpha of 6.5 degrees. This is a dynamic condition, and soon after this, while flying in ground effect, the nose rotates quickly downward again.

Figure 35 shows the bottom of the nose down movement while accelerating in ground effect. The nose reaches a minimum of 2.8 degrees at a CAS of 90 mph.

Figure 36 shows a stabilized alpha of 3.5 while still accelerating and starting to depart ground effect at CAS of 100 mph.

Figure 37 shows a level cruise at 135 mph CAS and alpha of 2.2 degrees.

Figure 38 plots yellow stars for N625JM on top of the plot of zero decalage Javafoil model for the Tri-Q200. The stars show the configurations captured in Figures 31-37. The taxi angle is below the stable flight envelope for zero decalage at low airspeeds. The low taxi angle of 4.5 to 5 degrees requires that a significant elevator deflection must be used at take-off in order to cause the aircraft to rotate to an attitude that will cause all wheels to lift off the runway. This rotation appears to occur around 70-74 mph CAS as shown in Figure 33. The nose high attitude achieved dynamically at lift off is recovered while still in ground effect as the plane accelerates at a much lower alpha. The Javafoil model is insufficient to model this dynamic behavior, so the dashed line on Figure 38 is used to represent the progressive history of the take-off shown in the video. The left most yellow star, corresponds to near level, stable flight and this point/star is also shown in Figure 39. Figure 39 shows the model behavior out of ground effect. The two stars in Figure 39 are the flight configurations for N625JM shown in Figures 36 and 37. The left most star in Figure 39 is the only one that is completely out of ground effect. From this analysis, it appears that N625JM flies as if it has a decalage of approximately -0.75. This is expected if reflexor is deployed with significant trailing edge up at a sufficient angle, and it appears that this is the case from the video.

Forces on Flight Surfaces – Tri-Q200 N625JM

As previously discussed, Figures 30-37 have a number of reference lines and scales superimposed in addition to the scale used to measure alpha. The additional lines and scales are used to measure the deflections of: 1.Nose gear, 2.Main gear, 3.Main wing, and 4.Canard, throughout all phases of flight. Because of the tail mount of the camera, all of these deflections can be measured. To calibrate these deflections, I assume that force vs. deflection function is linear (a simplification, but useful for comparitive analysis in this case). The specific spring constants can be estimated for each of the 4 components to give an estimate of loads in pounds of force. The measurements are taken prior to take-off, during take-off and during flight. The results reveal how the Tri-Q200 configuration of N625JM uniquely responds to flight loads.

Figure 40 shows a graph of the loads estimated from measured flex of each component. The spring constants are determined by known loading conditions on the ground. When N625JM is stationary, the load on both wings is zero. Of course the wing has weight, so deflects downward under that load, but that weight of the wing is part of the gross weight, not a flight force. We only want to measure airflow induced loads, so we designate stationary flex as zero. The main gear and nose gear are fully loaded when stationary, supporting the entire gross weight of the plane. Similarly, the main gear becomes fully UN-loaded at the moment of takeoff. So, at takeoff the entire weight of the aircraft is borne by the flying surfaces. The weight on the ground is estimated at around 900 pounds. The deflection of the main and nose gear and main gear is caused by loads that are determined by moment arms with respect to CG. With a CG of about 45" FS (estimated for N625JM for this video), the load on the main gear is about 700 lbs. and that on the nose gear about 200 lbs. The spring constant for the gear leg is determined by measuring the difference in deflection while stationary (fully loaded) compared to that at the moment of takeoff (unloaded). What was unexpected, prior to this study is that as the aircraft accelerates after takeoff, the main gear continues to deflect further downward revealing that the gear leg is experiencing a negative (de-lifting) force caused by airflow. By applying the spring constant calibrated to the loaded gear condition, the main gear experiences a downward force in cruise flight of about 200 pounds (as shown by the green curve in Figure 40). The orange curve in Figure 40 shows the combined load of both Canard and Main wing. Because of the de-lifting force on the main gear leg, the other lifting surfaces must counter to provide about 1100 pounds of lift (900 lbs GW plus 200 lbs of negative lift on the gear leg). The models for the Tri-Q200 from Part 2 include a de-lifting gear leg and somewhat predicted this effect, but the magnitude of effect is revealed by the calibrated video. Since the de-lifting gear leg is located behind the CG of the aircraft, the Tri-Q200 necessarily flies at a higher alpha than the Q-200 taildragger. Both the main wing and canard need to provide more lift to compensate for the downward force from the gear leg. At cruise of CAS 135 mph the measurements show that the main wing is providing 400 lbs. of lift and the canard is providing about 700 pounds of lift. N625JM trues out slightly above 2 degrees alpha in level flight at cruise. In this same flight configuration, the Q-200 flies close to zero alpha at similar airspeeds. The purple curve in Figure 40 shows the sum of all measured forces at all airspeeds. This curve should be flat and exactly equal to the gross weight of 900 lbs to be in equilibrium. It is pretty close to flat, but varies during the rotation and take-off phase because of dynamic variations in loads caused by the transient conditions during takeoff that are shown in Figure 38.

The primary point of Figure 40 is to show that, because of the de-lifting force of the main gear leg, the wing and canard must effectively provide 200 pounds additional lifting force so as to cancel the gear leg. The cause is the misalignment of the gear leg airfoil with respect to the streamlines. The gear leg has a negative effective angle of attack at all alphas according to the modeling of streamlines. In addition to the negative lift, the leg is contributing significant associated induced drag which adds to both the form and parasite drag components of the leg. Also, because the wings must provide additional lift to cancel the negative lift of the gear leg, their induced drag is higher than it would be if it were only carrying the gross weight of the plane. The Q-200's original design has demonstrated, when "on the step" (alphas approaching zero), that the main wing in its minimum drag orientation and provides little or no lift thereby reducing its induced drag to near zero. In this case the canard is providing all the required lift and induced drag is minimized because of the fact that the induced drag is being generated by only half of the total wing area (canard only, no main wing induced drag). On the other hand, the impact of the Tri-Q200 main gear is to cause the higher total drag on all surfaces and to significantly lower cruise speed of the Tri-Q200 in comparison to its Q-200 taildragger cousin.

Lest one argue that N635JM gear leg forces measured in this study are unique or anomalous, there is confirmation of the phenomenon demonstrated on another Tri-Q200 (N585SY) measured for this study. Figures 41, 42 and 43 are screen captures from a video of N585SY. The camera position is on the upper surface of the canard in this video. These figures have two scales superimposed at a position near both the left and right main gear legs. The scales are used to measure the deflection of the each side of the gear leg with respect to the fuselage. Figure 41 is when the plane is stationary so this figure reflects the deflection with the full gross weight supported on the gear. Figure 42 is immediately after takeoff so reflects the deflection when the gear is completely UN-loaded. Figure 43 shows the deflections during level cruise flight. The numbers on the scale are linearly spaced, allowing computation of an appropriate linear spring constant. In Figure 40 at full ground loading, the left gear reads 3.0 and the right gear reads 19.8. In Figure 41 is shown at the moment of takeoff with fully unloaded gear, the left gear reads 5.0 and the right reads 23.0. The difference in the values between Figure 40 and 41 represent complete unloading of approximately 700 pounds of load on the gear (350 lbs. on each side), so the left gear spring calibration amounts to 175 lbs./unit and the right computes to 109.4 lbs./unit. Figure 42 at level cruise shows the left gear at 5.6, and the right gear at 24. Applying the same spring constants to these changes since takeoff reveals the down force on the right gear to be 109.4 lbs. and on the left gear to be 105 lbs. Together, these sum to 214.4 lbs of down-force which is nearly identical to the value measured for N625JM at cruise. These observations confirm that the main gear leg, as designed is capable of applying a negative lift force of approximately 200 ibs. and adding a corresponding amount of induced drag, significantly degrading the potential performance of the Tri-Q200 at higher airspeeds.

Tri-Q200 Flight Characteristics – N625JM

Other flight videos of Jean-Paul Chevallier's Tri-Q200 (N585SY) are taken with a variety of camera positions on the aircraft. These different positions allow an analysis of the flight characteristics from a variety of perspectives for this aircraft. N585SY's decalage was hand measured using the standard tool described in the decalage study and referenced in Part 1 of this study. The decalage of N585SY was determined to be -0.4 degrees and the loaded taxi alpha was measured to be 2.0 degrees. The methods for scaling the value of alpha from screen captures and for the determination of airspeed are identical to or are variants of the methods already described.

Figures 44-47 show a takeoff sequence of shots for N585SY. These are plotted on Figure 49 in comparison with the ground effect zero decalage model of the Tri-Q200. The results plot above the zero decalage curve, but converge closer to the zero decalage curve as the takeoff sequence progresses. Keep in mind that the measured alpha (using the scale on the horizon) may not reflect true alpha if the aircraft is in a climb. This is because when there is a climb involved, the angle of the aircraft relative to the horizon is not the same as the angle of the aircraft relative to the stationary air mass. The angle of the climb must be subtracted from the measured alpha in order to know the true alpha. In flight shown in Figures 44-47, N585SY is climbing out of ground effect as the sequence progresses, but the angular contribution of that climb cannot be determined precisely, so the measured alpha measured will be higher than the true alpha. N585SY has a decalage of -0.4, which would dictate that measured data plot above the zero decalage profile on Figure 49, but the alpha values seem to exceed those expected for a decalage of -0.4. N585SY also has a Legare-style T-tail, which adds an unknown contribution to performance, and whose setting cannot be determined from the videos.

Figure 48 shows the cruise phase flight of N585SY following the takeoff in Figures 44-47. The data from Figure 48 is plotted as a yellow star on Figure 50 (left most star). The data from Figure 47 is also plotted on Figure 50 for comparison, since the flight condition in Figure 47 is also out of ground effect.

Figures 51-56 show the takeoff sequence for N585SY on a different flight than that shown in Figures 44-47. This second takeoff sequence is plotted on Figure 49 as blue stars and a blue dashed line. This second takeoff demonstrates that the pilot's decision of when to rotate for takeoff (at what CAS) will determine a unique path through the dynamic rotation and takeoff sequence, and will affect how much pitch correction must be applied at various points while in ground effect. Once airborne and out of ground effect, there is no significant variation in flight characteristics between flights in the same aircraft. This is demonstrated in Figure 50 by comparing the yellow and blue stars from these two distinct flights.

End of Part 3.