Bearhawk 20 Minute Flight Test

In the summer of 2022 I had the pleasure of meeting Mujahid Abdulrahim of the University of Missouri at Kansas City (UMKC). He was at USAF TPS working on a project for USAF TPS for the summer. He introduced me to his “20 Minute Flight Test” program that he had put together as a way to collect flight test data on various general aviation aircraft. These data could be used to better understand the capabilities of different aircraft types and to provide interesting projects for his students at UMKC. Of course, there is suspicion that this is just a clever way to convince other pilots to take him flying in their airplane, an idea that I fully support and wonder why I didn’t think of it.

To support the 20 Minute Flight Test, Mujahid had a strap-on instrumentation system and two GoPro cameras. Since the Bearhawk was equipped with its own instrumentation system, this report is written to record the results (including maneuvers that I never got around to measuring before) and to provide truth data for Mujahid to compare his results against.

Since I am writing this report mostly for myself and Mujahid, and nobody is paying me to do it, I am dispensing with the usual fancy editing of plots and just going with the basic default products out of Excel. I’m not even spending time to remove the “Chart Title” from the plots that were just slapped together.

Profile Description

The profile starts on the ground with an interview of the pilot. The pilot is asked the following questions:

1. How long have you been flying?
2. How much total time have you flown? How many hours in this aircraft?
3. Why do you fly this aircraft?
4. What is your typical flight mission(s)?
5. What is one (or more) of your favorite aspects about this aircraft?
6. What is something you would like to improve about this aircraft?
7. What is the most interesting airplane that you have flown?

Photographs are taken at eight locations radially around the aircraft, as well as of the wing airfoil, dihedral, wing control surfaces, tail control surfaces, and the instrument panel. This being a modern flight test program, photographic data include a pre-mission selfie with the airplane and a post-mission selfie.

The data logger was strapped onto the left wing strut, and provided insight for materials needed to make a better universal mount. A GoPro camera was mounted to the right wing strut. I can’t remember if a GoPro was mounted in the cabin. Normally this would be set up to record the cabin audio, but in this case was not because the appropriate connection cord was in Missouri while the airplane was in California.

The flight profile consisted of

1. Normal takeoff
2. Climb at maximum angle of climb (V_x), maximum rate of climb (V_y), and cruise climb
3. Level Acceleration, slowing from cruise speed to minimum level flight speed, then accelerating to maximum speed
4. Control response, consisting of doublets in pitch, yaw, and roll
5. Turn response, consisting of a 90 degree right turn, followed immediately by a 90 degree left turn, and a 360 deg steep turn
6. Stalls in the cruise configuration, power off; in the landing configuration, power off; and in the cruise configuration, power on
7. An optional maneuver at the pilot’s discretion that is unique to the aircraft or shows off some special capability
8. Normal landing.

Is it really 20 minutes?

This flight was flown on 2 August 2022 from Rosamond Skypark (L00). Takeoff was at 1035L, and the last maneuver (stalls) was completed at 1103, for a total elapsed time of 28 minutes. No effort was made to fly the profile super efficiently, and breaks were taken as required to allow the engine to cool down to acceptable temperatures. The entire mission lasted for 1.0 hour, but this included additional time for Mujahid to try his own hand at flying the airplane.

Instrumentation

The Bearhawk instrumentation included a Dynon D10A EFIS, which recorded air data, attitudes, lateral acceleration, and yaw rate from internal sensors at a rate of 1 Hz. The D10A also recorded GPS location and speed data as provided by the Garmin GNS 480. The D10A clock was synced to GPS time by way of the GPS data messages.

Engine data, including manifold pressure, RPM, outside air temperature, cylinder head temperatures, exhaust gas temperatures, voltage, and amperage were recorded in the EDM 930 at a rate of 0.5 Hz (every 2 seconds). The EDM 930 clock was synced to GPS time immediately before the flight.

Takeoff

Takeoff Conditions:
Gross weight: 2375 lbs
Wind: minimal cross wind, no significant headwind
Temperature: 90 deg F (yes, at 1035L)
Initial Altitude: 2534 ft

All altitudes were recorded with local altimeter set. The local altimeter setting was not recorded. (Bad FTE technique) The altitude reported was estimated to be within 100 feet of pressure altitude. The field elevation was 2415 feet. The takeoff altitude was recorded at 2534 feet. The difference was suspected to be from a calibration error in the Dynon altimeter, which is known to vary relative to the round dial altimeter. Additionally, the source for the altimeter setting on the local CTAF was known to give a measured altitude higher than the known field elevation. However, the differences between the measured altitude and the actual pressure altitude were assumed to have minimal effect on the aircraft performance.

Measured Data:
Rotate Speed: 60 KIAS
Liftoff Speed: 75 KIAS
Time from brake release to liftoff: 20 sec
Time from rotate to liftoff: 4 seconds

Calculated Data:
Density Altitude: 5049 feet
Liftoff true airspeed: 80.85 KTAS
Takeoff ground roll distance assuming a constant acceleration: 1364 feet
Takeoff ground roll distance from latitude/longitude of start point and liftoff point: 1335 feet

The takeoff distances measured by two different techniques are very close to each other (within 29 feet, about 2 per cent), lending credibility to the result.

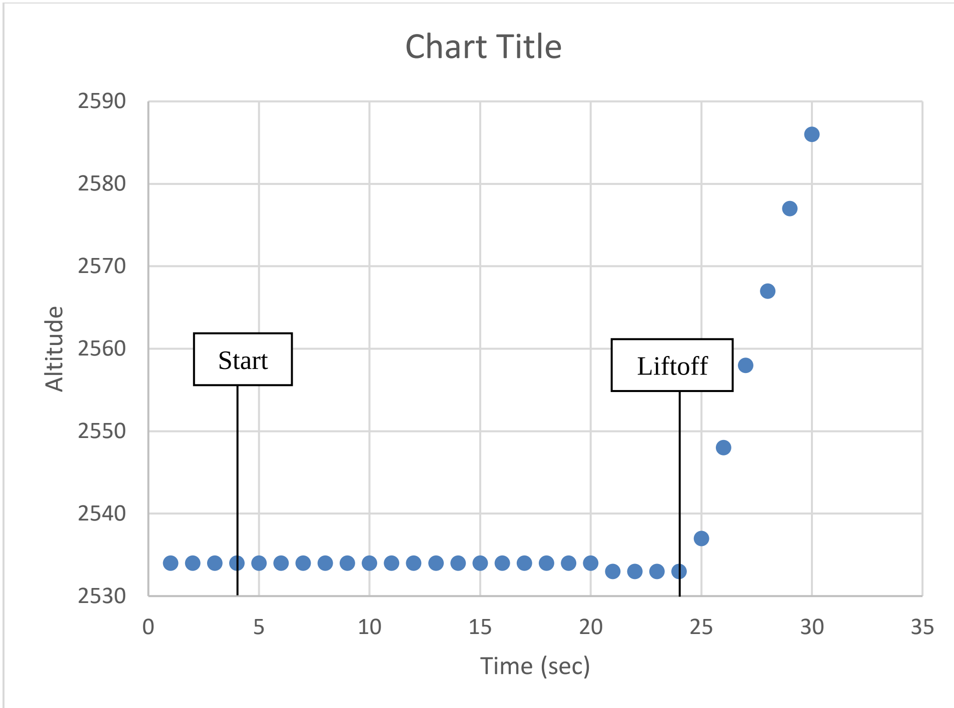

Figure 1. Takeoff Altitude

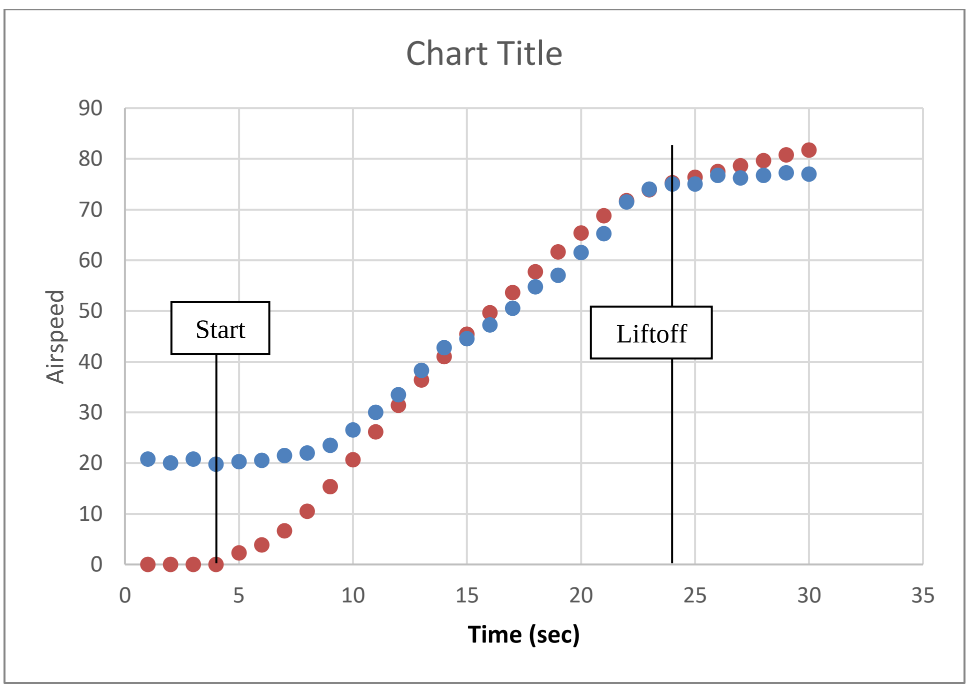

Figure 2. Takeoff Airspeed (Blue KIAS, Brown GPS GS)

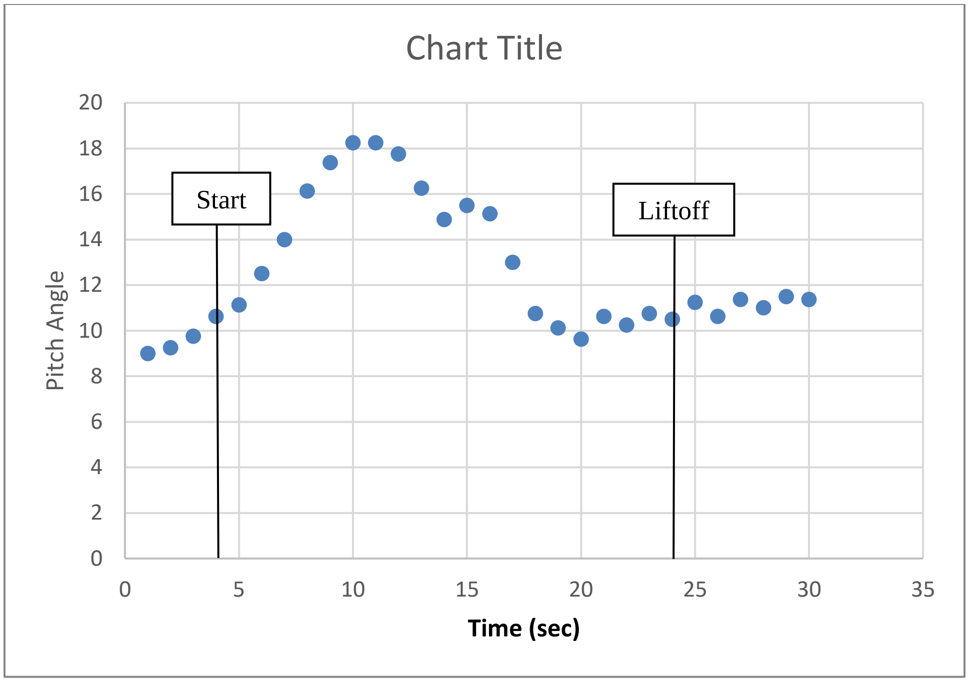

Figure 3. Takeoff Measured Pitch Attitude

The measured pitch attitude was not reliable during the takeoff acceleration. It should start out around 10 degrees, reduce to close to zero when the tail is raised, then stabilize around 11 degrees for the climbout. The data as recorded indicate that the pitch attitude increased to 18 degrees, which would mean the airplane was standing on the tailwheel with the main gear several feet in the air, which is clearly not what happened during the takeoff roll.

In the Dynon D10A, the pitch angle is derived by an unknown software algorithm from rates and accelerations. It is not provided by a spinning mass gyro. This system is sufficient in a non-accelerating or very low accelerating reference frame. Experience has shown it to be sufficient as a pitch reference for IFR flight. Apparently large accelerations mess it up. These large accelerations occur while on the ground, when the pilot's eyes are watching outside and pitch information is not needed.

Best Angle of Climb

Conditions:
Gross Weight: 2375 lbs
Altitude: 4200 feet
Density Altitude: 6711 feet
Manifold Air Pressure (MAP): Wide Open Throttle (WOT) 24.4 in Hg
RPM: 2400 (climb RPM)
Mixture: Full Rich

Based on "Bearhawk N6786E #164 Limited Performance Evaluation" the target speed for Best Angle of Climb was expected to be 65 KIAS. The existing Matlab model predicted a Rate of Climb (ROC) of 1036 feet per minute (fpm).

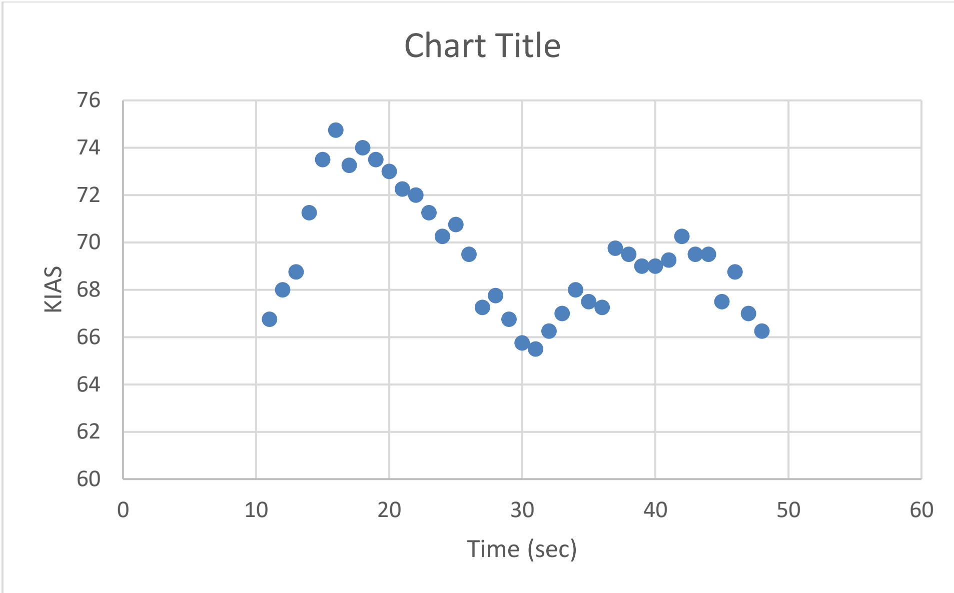

Figure 4. Best Angle of Climb Airspeed

Figure 4 shows that the airspeed somewhat stabilized around 68 KIAS from 30 seconds to 48 seconds. This was slightly faster than the aim airspeed of 65 KIAS, which again might arise because of minor differences between the round dial airspeed indicator that was used to fly the maneuver and the D10A which was used to record the data.

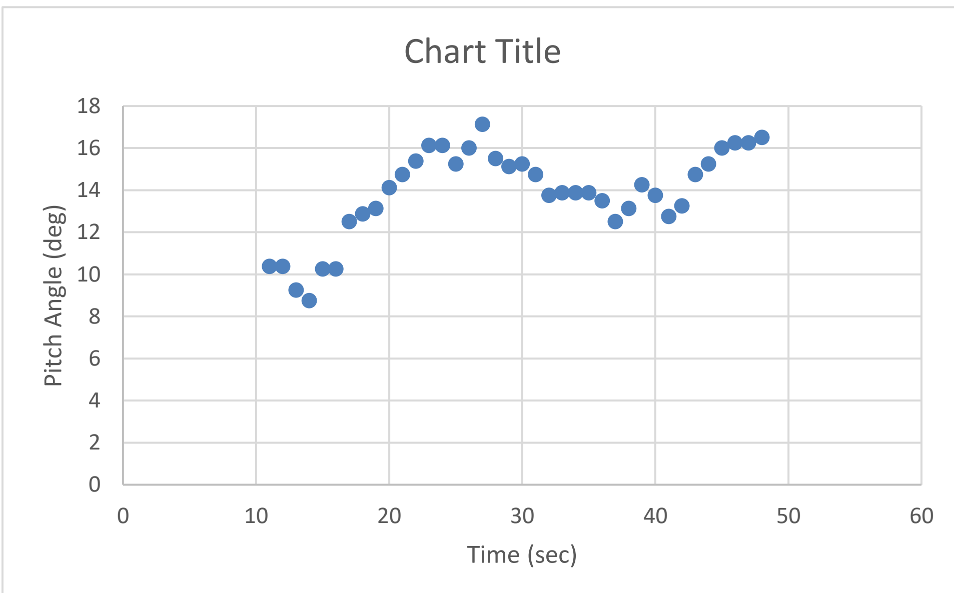

Figure 5. Best Angle of Climb Pitch Attitude

Figure 5 shows a measured pitch attitude of around 15 degrees, which is higher than the pitch attitude on the ground in the three point stance of about 10 degrees. Thus, the nose feels very high to the pilot, and the horizon is not visible over the nose, but only on the sides of the nose. At this high pitch attitude, the attitude indicator becomes more useful for maintaining the pitch attitude than viewing the horizon.

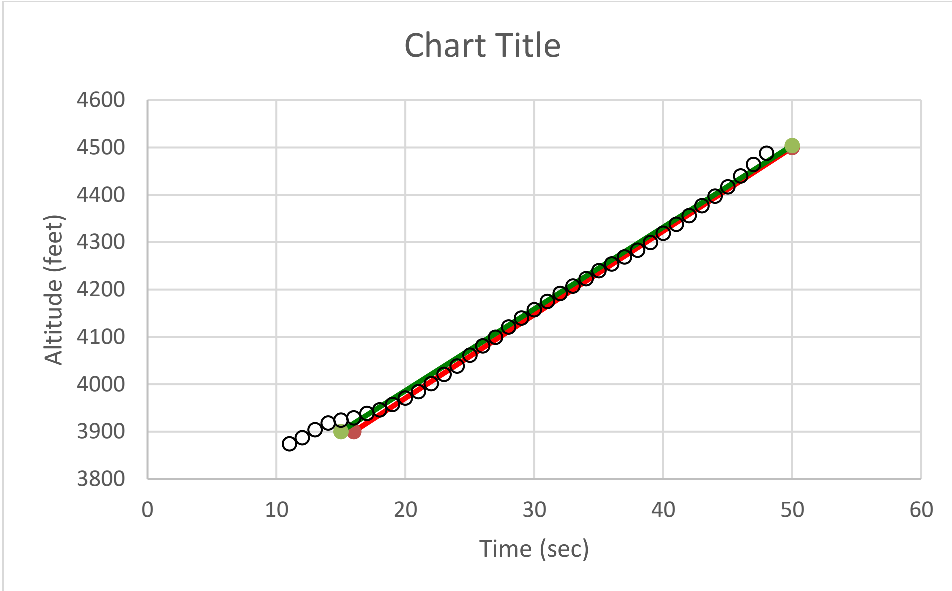

Figure 6. Determining Rate of Climb from Altitude Change with Time

Figure 6 shows a red line measuring the Rate of Climb by finding the slope of the Altitude data with Time. This red line measures the Rate of Climb as 1058 fpm. The green line shows the model predicted Rate of Climb of 1036 fpm. The two lines are practically indistinguishable, so the model was considered valid.

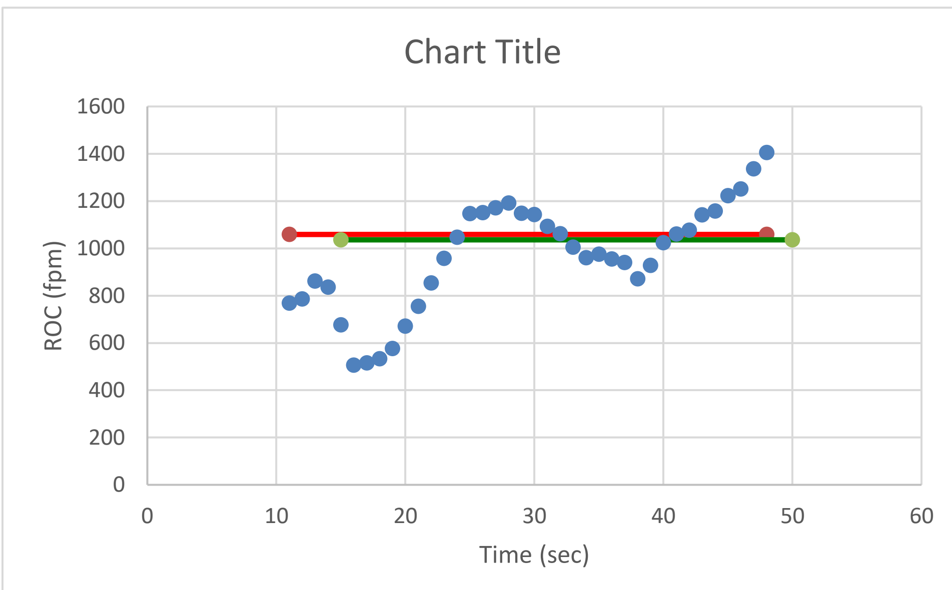

Figure 7. Best Angle of Climb Airspeed Rate of Climb

Figure 7 shows the same information on a plot of Rate of Climb. This Rate of Climb is as reported by the D10A and is not a differentiation of the altitude data. Again, the measured Rate of Climb (1058 fpm) is shown in red, and the model predicted Rate of Climb (1036 fpm) is shown in green.

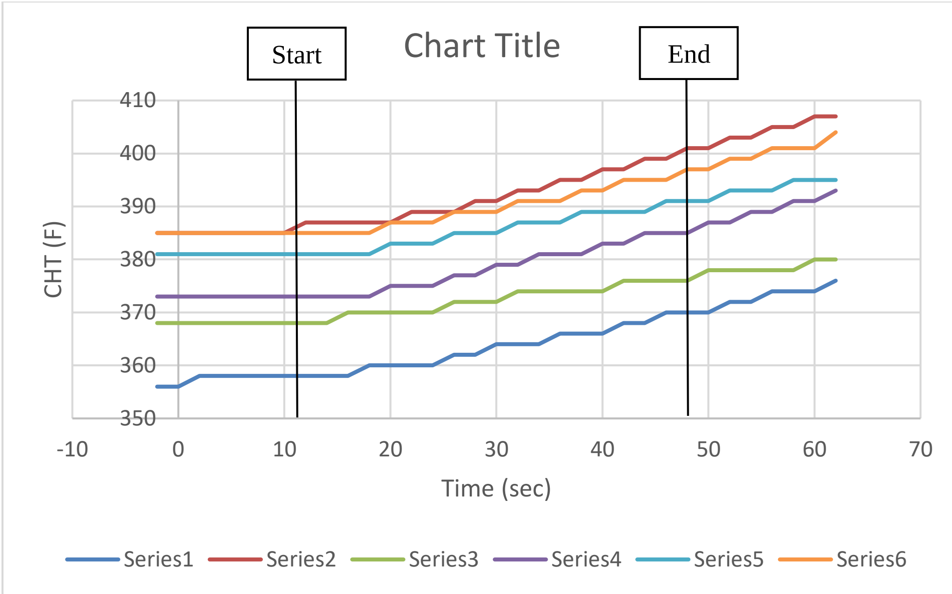

Figure 8. Engine Cylinder Head Temperatures (CHTs) During Best Angle of Climb

In this Bearhawk, climbing at Best Angle of Climb speed for anything more than a few seconds is not recommended. The engine cooling is not sufficient for extended climbing at this low speed. Figure 8 shows that the Cylinder Head Temperatures (CHTs) were acceptable prior to the climb (less than 400 degrees F), but rapidly started to increase during the climb. The CHTs were rapidly climbing toward 435 degrees F with no indication of stabilizing. At 435 degrees F significant measures will be taken by the pilot to prevent temperatures from exceeding 435 degrees F.

Best Rate of Climb

Conditions:
Gross Weight: 2375 lbs
Altitude: 4800 feet
Density Altitude: 7319 feet
Manifold Air Pressure (MAP): Wide Open Throttle (WOT) 23.7 in Hg
RPM: 2400 (climb RPM)
Mixture: Full Rich

Based on "Bearhawk N6786E #164 Limited Performance Evaluation" the target speed for Best Rate of Climb was expected to be 75 KIAS. The existing Matlab model predicted a Rate of Climb (ROC) of 1059 feet per minute (fpm).

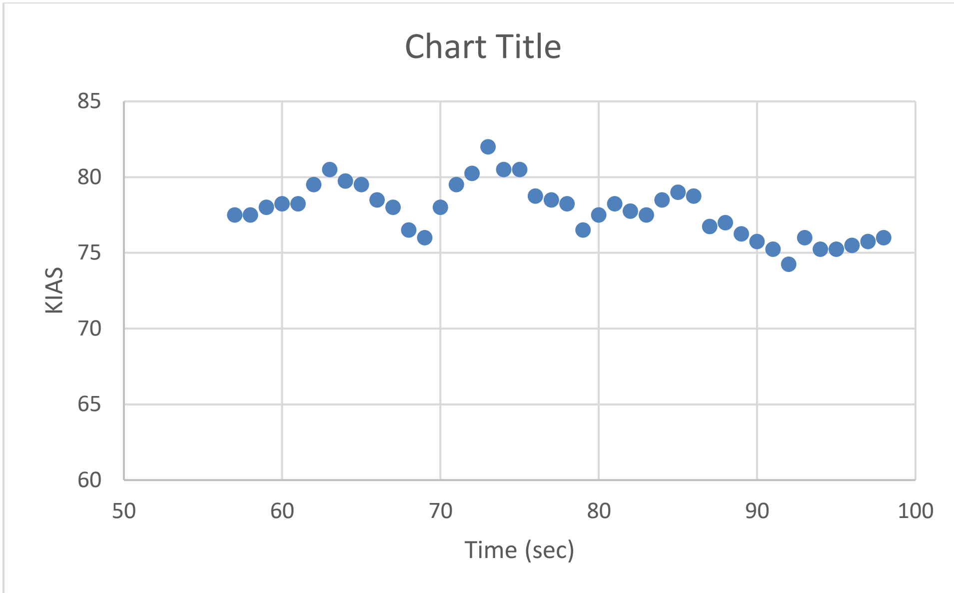

Figure 9. Best Rate of Climb Airspeed

Figure 9 shows that the airspeed somewhat stabilized around 77 KIAS. This was slightly faster than the aim airspeed of 75 KIAS, which again might arise because of minor differences between the round dial airspeed indicator that was used to fly the maneuver and the D10A which was used to record the data.

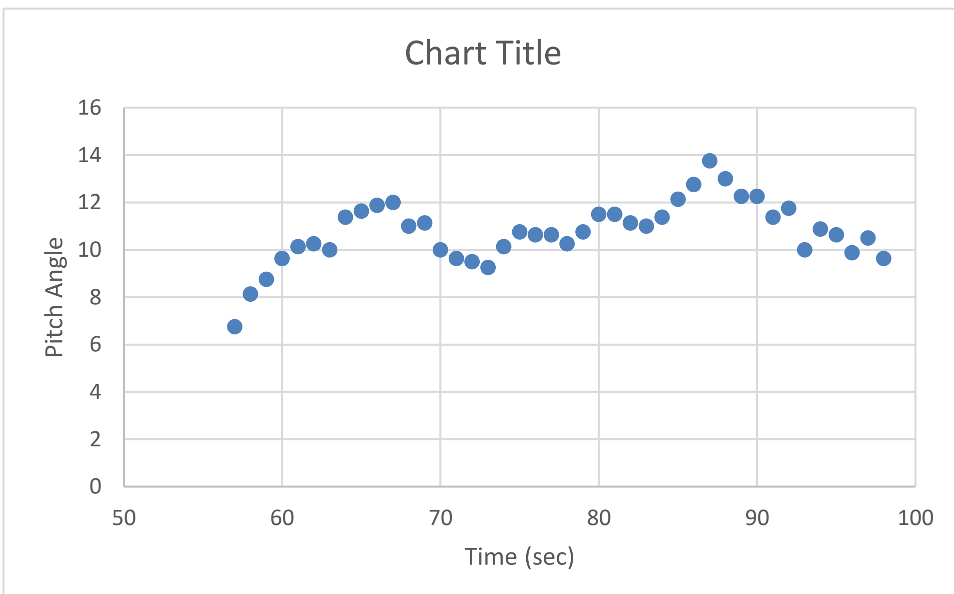

Figure 10. Best Rate of Climb Pitch Attitude

Figure 10 shows a measured pitch attitude of around 11 degrees, which is almost the same as the pitch attitude on the ground in the three point stance of about 10 degrees. The nose still feels high to the pilot, and the horizon is not visible over the nose, but only on the sides of the nose. At this high pitch attitude, the attitude indicator becomes more useful for maintaining the pitch attitude than viewing the horizon.

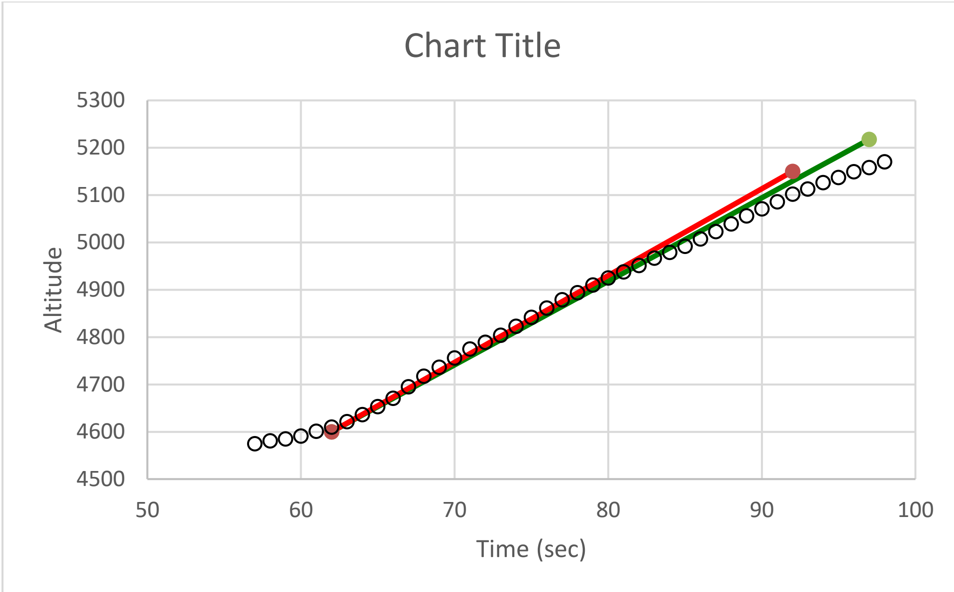

Figure 11. Determining Rate of Climb from Altitude Change with Time

Figure 11 shows a red line measuring the Rate of Climb by finding the slope of the Altitude data with Time. This red line measures the Rate of Climb as 1100 fpm. The green line shows the model predicted Rate of Climb of 1059 fpm. The two lines are practically indistinguishable, so the model was considered valid.

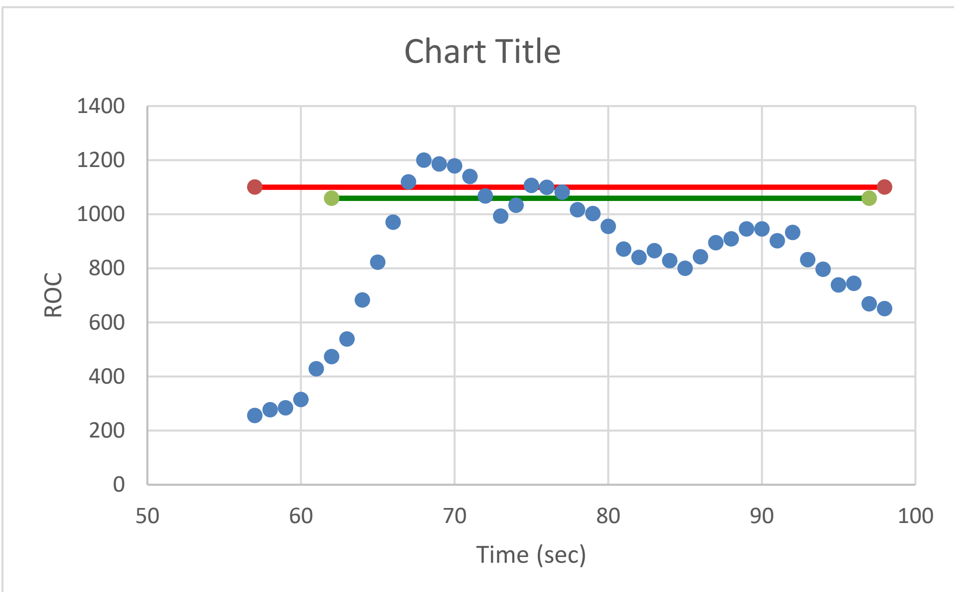

Figure 12. Best Rate of Climb Airspeed Rate of Climb

Figure 12 shows the same information on a plot of Rate of Climb. This Rate of Climb is as reported by the D10A and is not a differentiation of the altitude data. Again, the measured Rate of Climb (1100 fpm) is shown in red, and the model predicted Rate of Climb (1059 fpm) is shown in green.

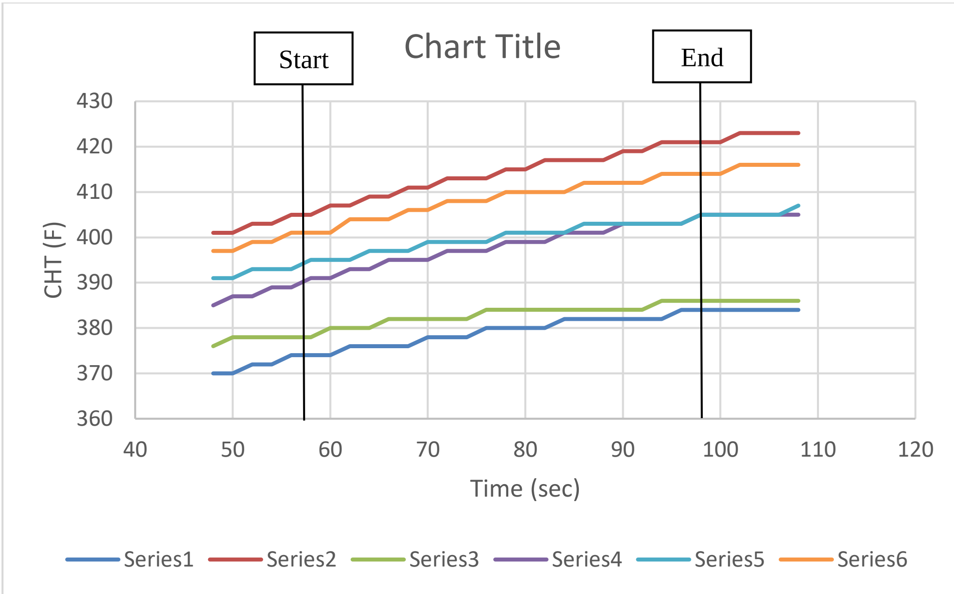

Figure 13. Engine Cylinder Head Temperatures (CHTs) During Best Rate of Climb

In this Bearhawk, climbing at Best Rate of Climb speed for anything more than a few seconds is not recommended. The engine cooling is not sufficient for extended climbing at this low speed. Figure 13 shows the Cylinder Head Temperatures (CHTs) during the Best Rate of Climb test. Temperatures were already elevated from the Best Angle of Climb test done immediately before this test. Even with the slightly higher airspeed, the CHTs continue rapidly climbing toward 435 degrees F with no indication of stabilizing. At 435 degrees F significant measures will be taken by the pilot to prevent temperatures from exceeding 435 degrees F.

Cruise Climb

Conditions:
Gross Weight: 2375 lbs
Altitude: 5500 feet
Density Altitude: 7988 feet
Manifold Air Pressure (MAP): Wide Open Throttle (WOT) 23.3 in Hg
RPM: 2400 (climb RPM)
Mixture: Full Rich

Based on experience, the target speed for a Cruise Climb was 100 KIAS. At this condition, the existing Matlab model predicted a Rate of Climb of 699 fpm. After the Best Rate of Climb test, the throttle was reduced and level flight was maintained long enough for the CHTs to cool back to acceptable values (below 400 degrees F).

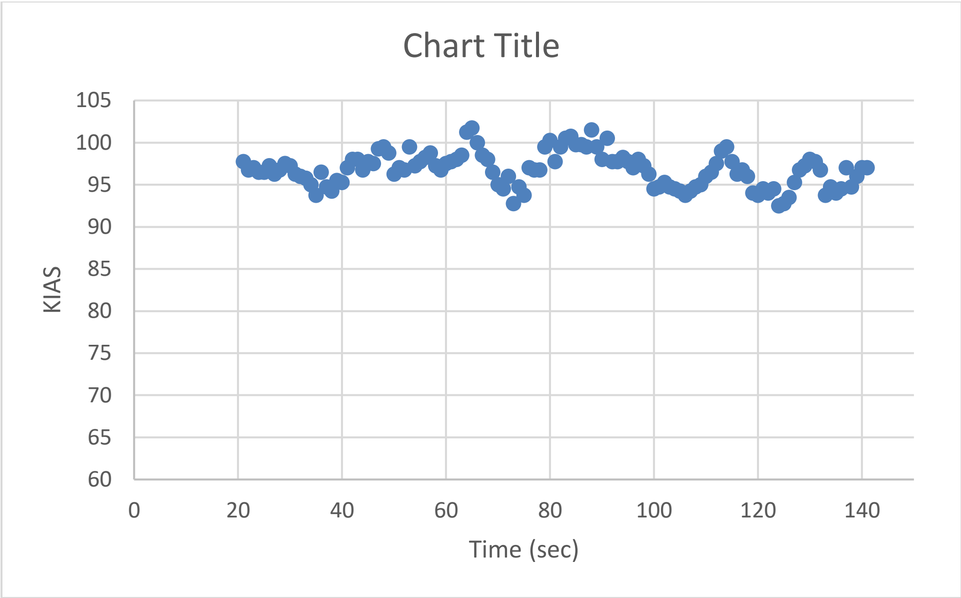

Figure 14. Cruise Climb Airspeed

Figure 14 shows that the airspeed somewhat stabilized around 98 KIAS, which was close to the aim of 100 KIAS. Again, this might arise because of minor differences between the round dial airspeed indicator that was used to fly the maneuver and the D10A which was used to record the data. Then again, it could be simply because the Test Pilot didn't do any better.

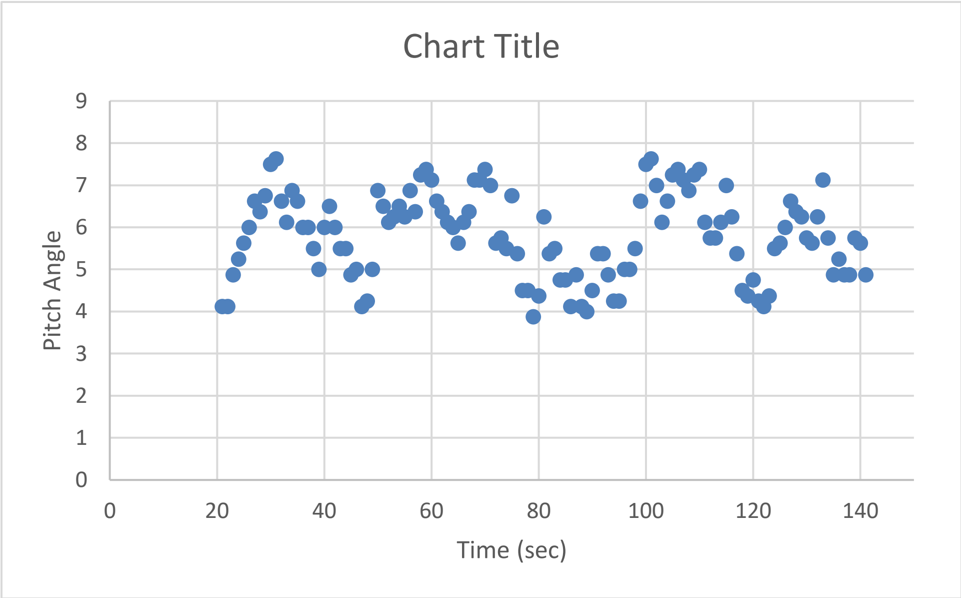

Figure 15. Cruise Climb Pitch Attitude

Figure 15 shows a measured pitch attitude of around 6 degrees. At this attitude, the top of the cowling is conveniently aligned with the horizon, which makes it easy to maintain the cruise climb attitude while still looking outside.

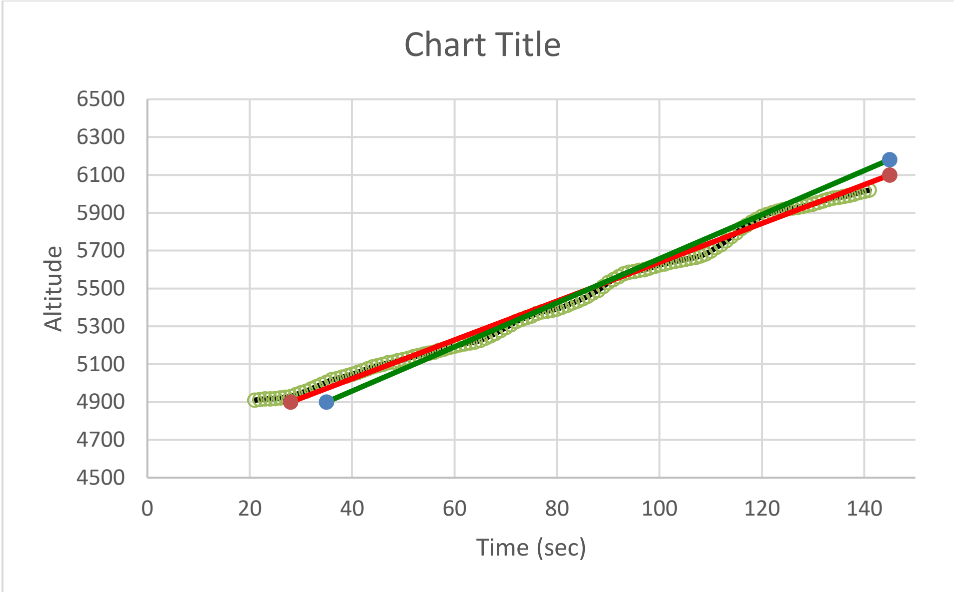

Figure 16. Determining Cruise Climb Rate of Climb from Altitude Change with Time

Figure 16 shows a red line measuring the Rate of Climb by finding the slope of the Altitude data with Time. This red line measures the Rate of Climb as 615 fpm. The green line shows the model predicted Rate of Climb of 699 fpm. The two lines are very close, so the model was considered valid.

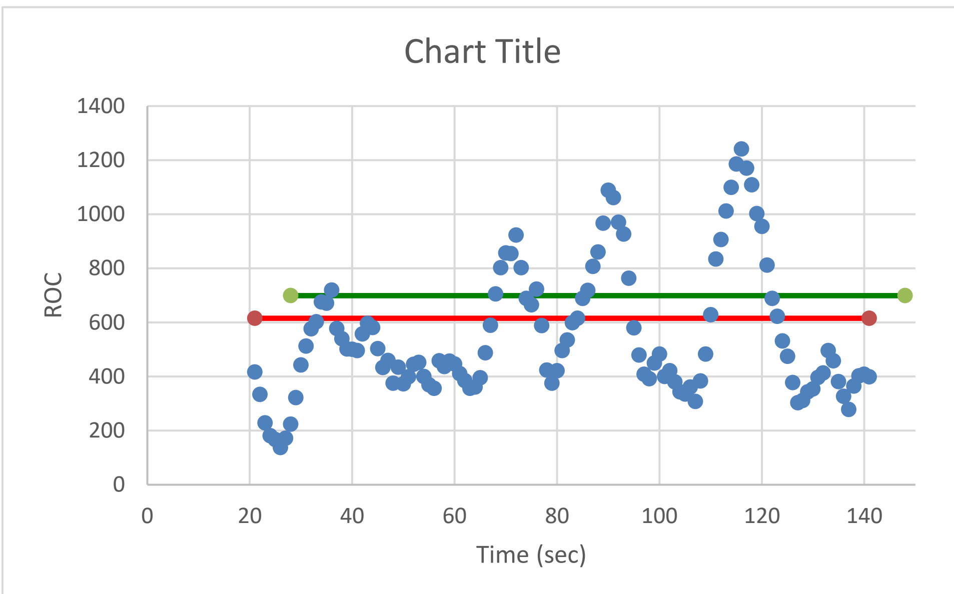

Figure 17. Cruise Climb Airspeed Rate of Climb

Figure 17 shows the same information on a plot of Rate of Climb. This Rate of Climb is as reported by the D10A and is not a differentiation of the altitude data. Again, the measured Rate of Climb (615 fpm) is shown in red, and the model predicted Rate of Climb (699 fpm) is shown in green.

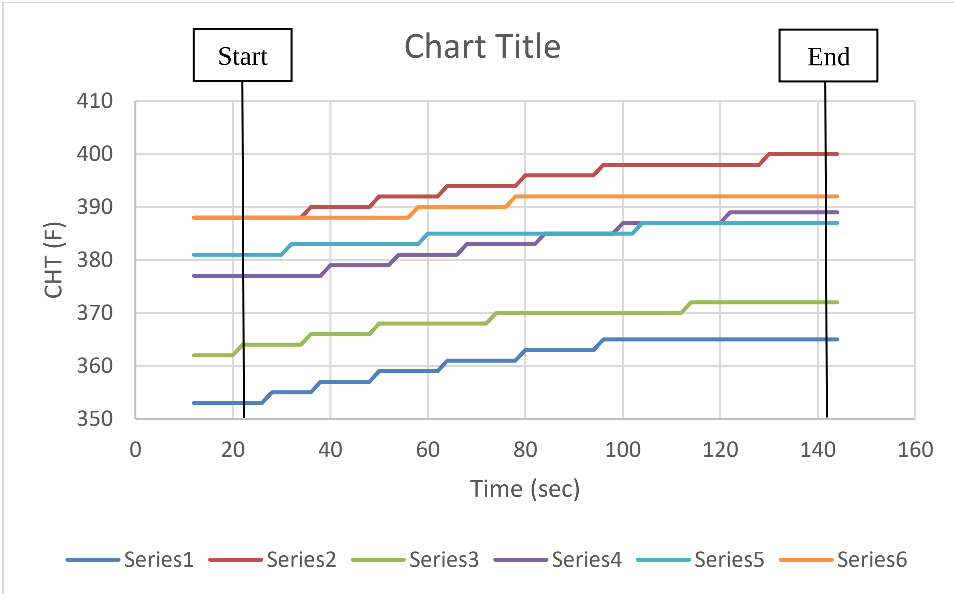

Figure 18. Engine Cylinder Head Temperatures (CHTs) During Cruise Climb

The cruise climb is preferred because of the ability to better manage engine temperatures. Figure 18 shows a rise in CHTs similar to Figure 8, but Figure 18 is over a time scale three times as long. Hence, temperatures are rising at a slower rate and closer to stabilizing, such that overheating is much less of a concern.

Climb Pitch Attitudes

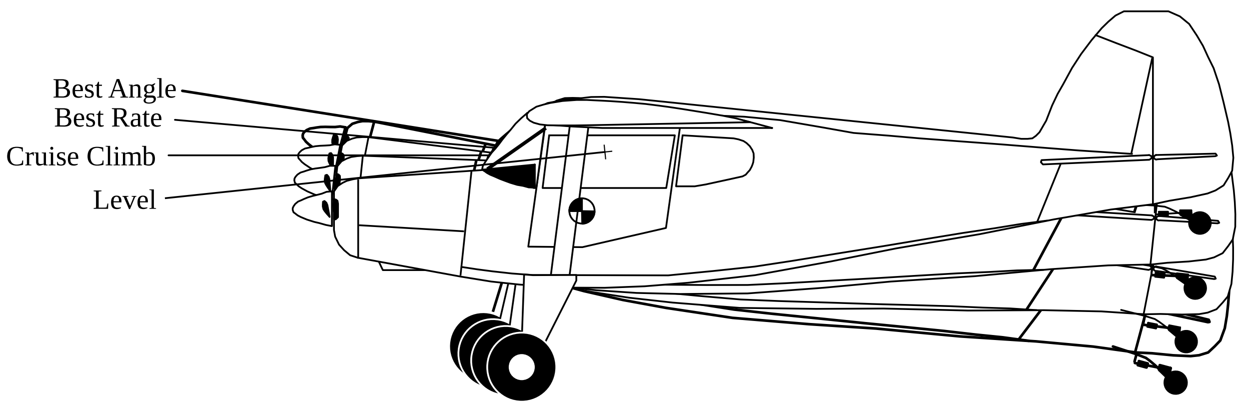

Figure 19. Climb Pitch Attitudes

Figure 19 shows the relative pitch attitudes called out in the previous pages. The fuselage side view is shown, along with a line representing the sightline from the pilot's eye position to the top of the cowling. In the Best Angle of Climb and Best Rate of Climb attitudes, this sight line is above level, meaning that the horizon in hidden from view behind the cowling. In the Cruise Climb attitude, the sight line is essentially level, representing the horizon lined up with the top of the cowling. In the level flight attitude, the sight line is below the horizon, representing a view of the terrain ahead.

Level Accel

Conditions:
Gross Weight: 2375 lbs
Altitude: 6200 feet
Manifold Air Pressure (MAP): Wide Open Throttle (WOT) 22.5 in Hg
RPM: 2400 (climb RPM)
Mixture: Full Rich

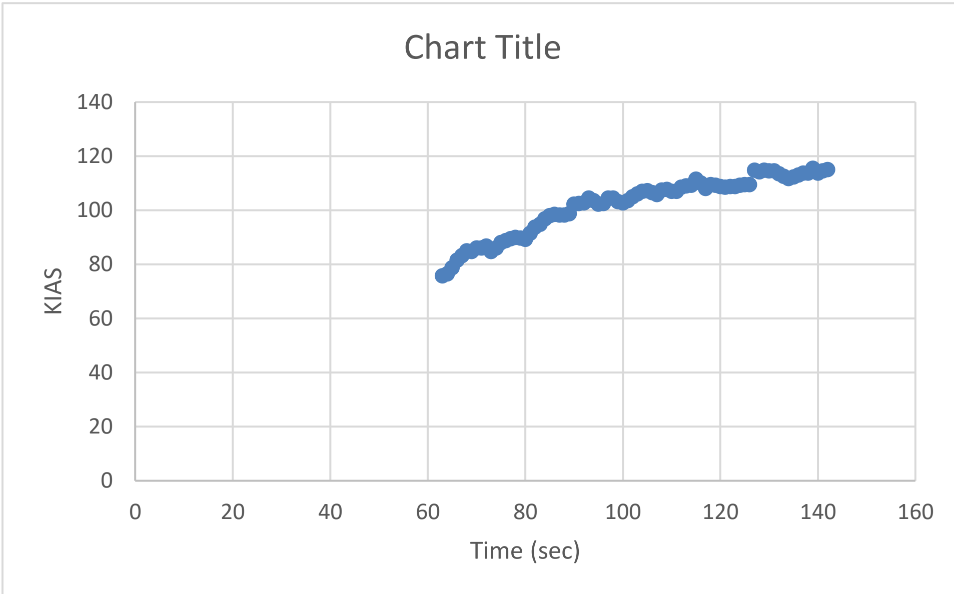

Figure 20. Level Acceleration Indicated Airspeed

A Level Acceleration was performed from 75 KIAS to 115 KIAS at wide open throttle with climb RPM (2400) set.

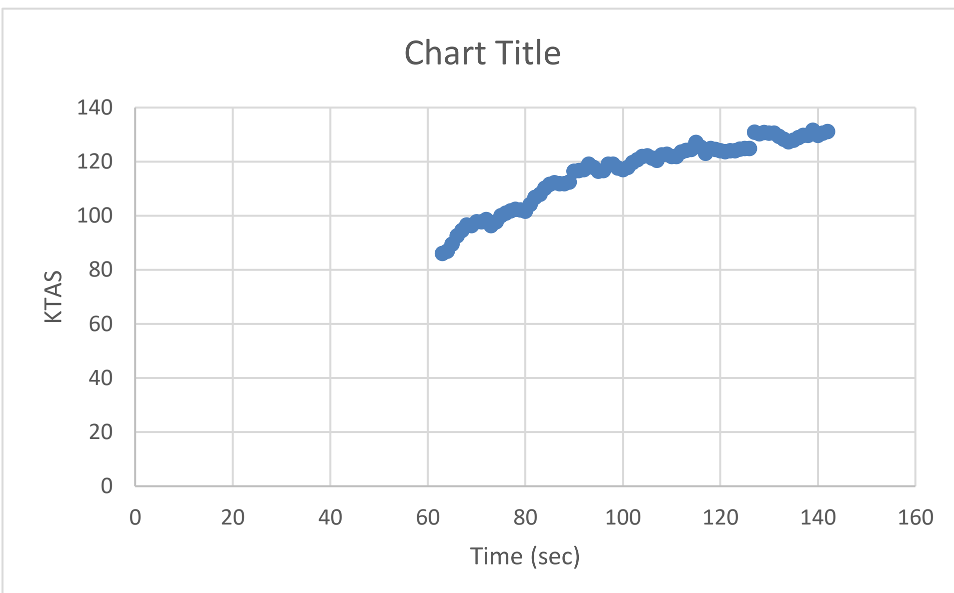

Figure 21. Level Acceleration True Airspeed

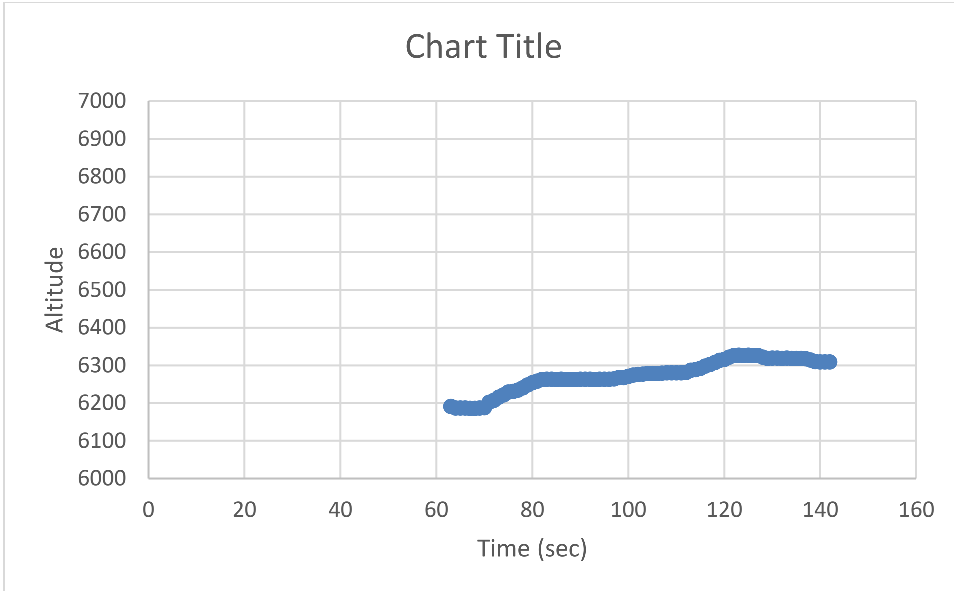

Figure 22. Level Acceleration Altitude

During this level acceleration, an altitude gain of a little over 100 feet was seen. Not quite as good as we like from our TPS students, but reasonably acceptable.

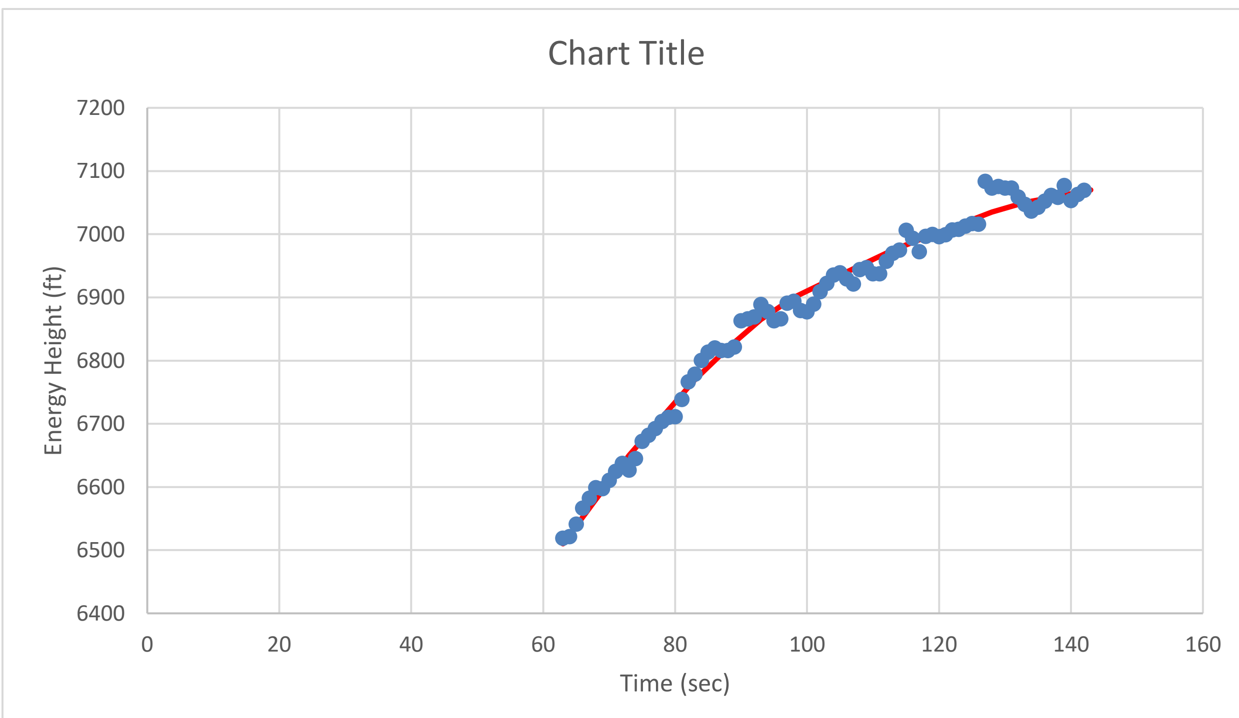

Figure 23. Level Acceleration Energy Height

Figure 23 shows the Energy Height of the Bearhawk throughout the Level Acceleration. Energy Height is given by

$$E_s = h + \frac{V_t^2}{2g}$$

Using Energy Height to find Specific Excess Power incorporates both changes in altitude and airspeed. Figure 23 shows a fairing in red under the blue data points.

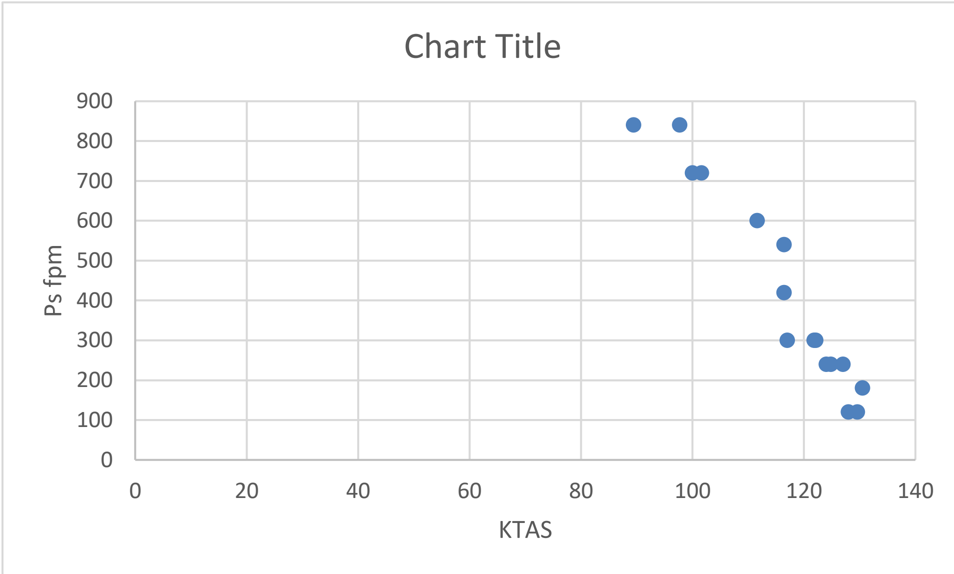

Figure 24. Level Acceleration Specific Excess Power (P_S)

The red fairing in Figure 23 was differentiated to find the Specific Excess Power shown in Figure 24. The fairing was adjusted until it both matched the data reasonably well and produced a Specific Excess Power curve of an expected shape.

An airspeed of 116 KTAS was equivalent to 100 KIAS at this altitude. Entering Figure 24 at 116 KIAS returns a Specific Excess Power of approximately 540 fpm, which compares favorably with the Cruise Climb Rate of Climb of 615 fpm at 700 feet lower.

Control Response

Control response was evaluated at approximately 6500 feet altitude at normal cruise speed, approximately 107 KIAS or 122 KTAS.

Rudder Doublets

Rudder doublets excited the Dutch Roll mode. After controls release, there were three to four overshoots, estimating a damping ratio of about 0.4 to 0.3. The response was more rolly than most gliders, with a Phi to Beta ratio of around 1. There was sufficient lateral stability to be able to pick up a wing (cause a roll) with rudder. This indicated a noticeable dihedral effect, which was expected with a geometric dihedral of 1 degree on each side plus the high wing configuration. The small vertical tail and rudder resulted in relaxed directional stability, which led to the reduced damping. Of interest, this is reminiscent of the relaxed directional stability seen in aircraft of the 1930s, to which this fuselage and vertical tail design is similar.

Elevator Doublet

Initially it was not possible to do a pure pitch doublet. A small pull resulted in the expected increase in pitch angle. However, a small push that was thought to be of the same magnitude resulted in a quicker unload and pitch down than expected. The natural reaction was a second pull to stop the uncomfortable reduction in load factor and pitch rate. Freezing the stick stopped the impending PIO.

On a later flight, a different technique was tried, pushing first, then pulling. This time there was not a feeling of impending PIO. There was movement in the nose with no overshoots. The resulting force of the push and pull was less than what was used before. Trying the same force in a pull-push created the similar results. The problem appeared to be that the airplane was very responsive to pitch inputs. A large pitch input could be made in the pull without being uncomfortable. However, a large pitch input in the push unloaded the load factor faster than expected, thus being uncomfortable.

There was no residual motion following the forced response, showing that the short period was heavily damped.

Aileron Doublet

An aileron doublet caused the expected response in roll. With no coordinating rudder input, the adverse yaw resulting from an aileron doublet excited the Dutch Roll with the same damping results as the rudder doublet.

Turn Response

Turn response was demonstrated at an altitude of approximately 6700 feet at a typical cruise airspeed, around 110 KIAS. No attempt was made to achieve maximum performance in these turns. Bank angles were limited to around 45 degrees (the FAA definition of a steep turn) and roll rates were limited to those typically used in operational flying.

The first turn response demonstrated was a right turn of 90 degrees of heading change, with a rapid turn reversal to a left turn of 90 degrees of heading change. Maneuvers were flown visually to headings marked by roads, with sufficient rudder as required to coordinate the turns.

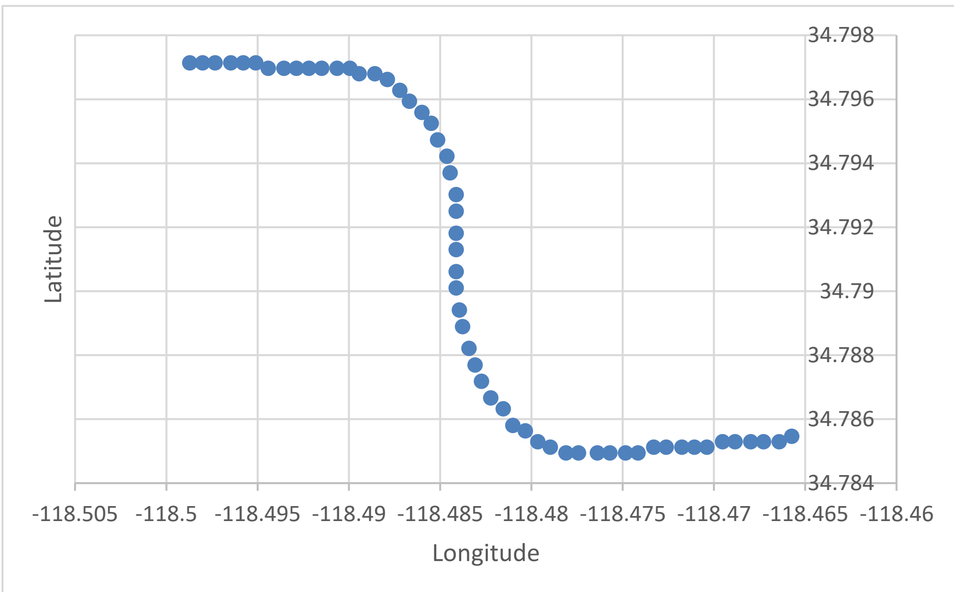

Figure 25. Right 90, Left 90 Ground Track

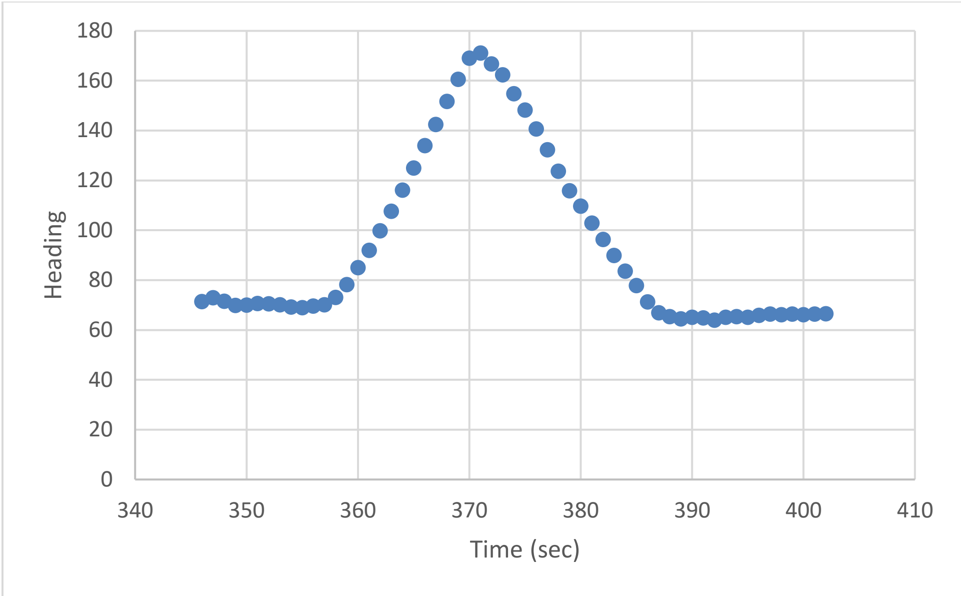

Figure 26. Right 90, Left 90 Heading

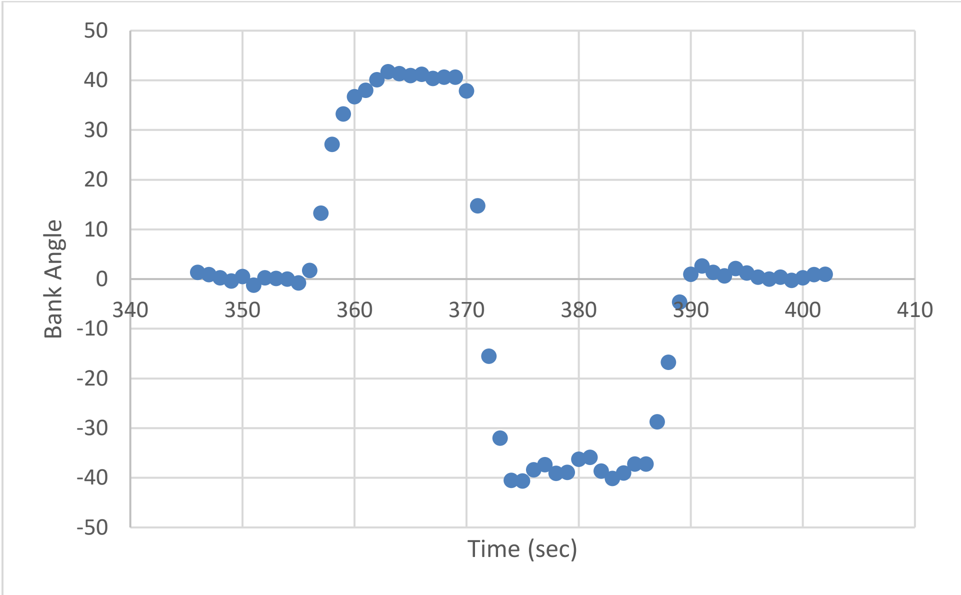

Figure 27. Right 90, Left 90 Bank Angle

Actual bank angles stabilized around 40 degrees. The roll rate during the turn reversal was 27 degrees per second, far more than necessary for anything but the most aggressive maneuvering. This was not the maximum available, as less than full aileron was used.

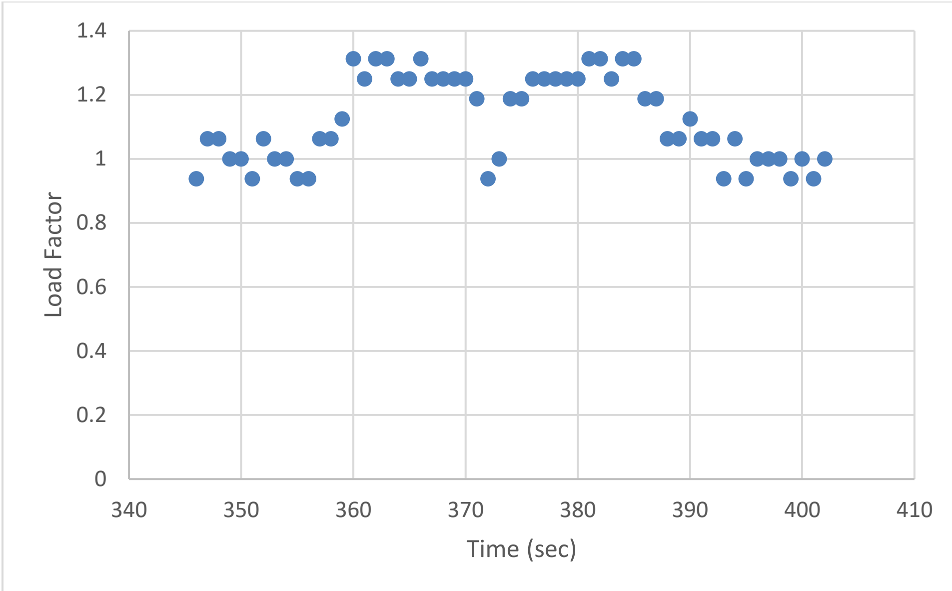

Figure 28. Right 90, Left 90 Load Factor

Load factor during the turns was about 1.3 g, exactly what would be expected for a 40 degree bank level turn.

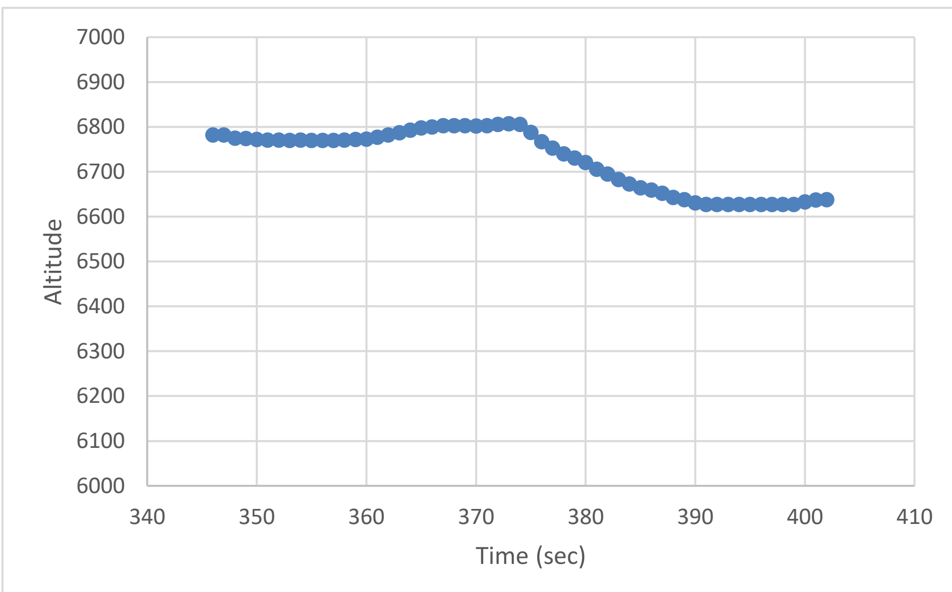

Figure 29. Right 90, Left 90 Altitude

The first 90 degree turn was within a few feet of a level turn. The second 90 degree turn lost about 180 feet during the turn.

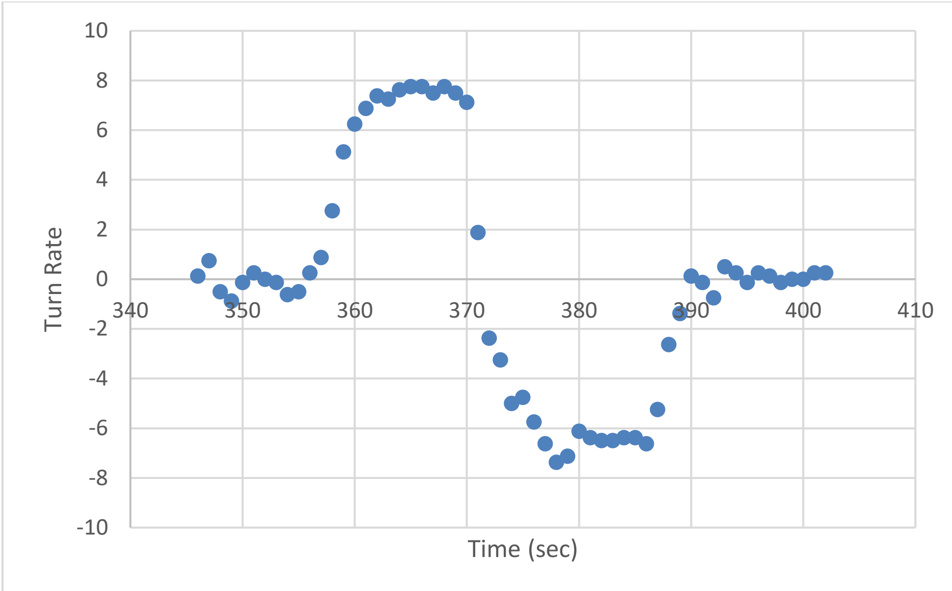

Figure 30. Right 90, Left 90 Turn Rate

The turn rate during the turn was 6 to 8 degrees per second, well in excess of the standard rate turn of 3 degrees per second.

The second turn response demonstrated was a steep turn to the right for a full 360 degrees. Rollout was determined visually by road alignment.

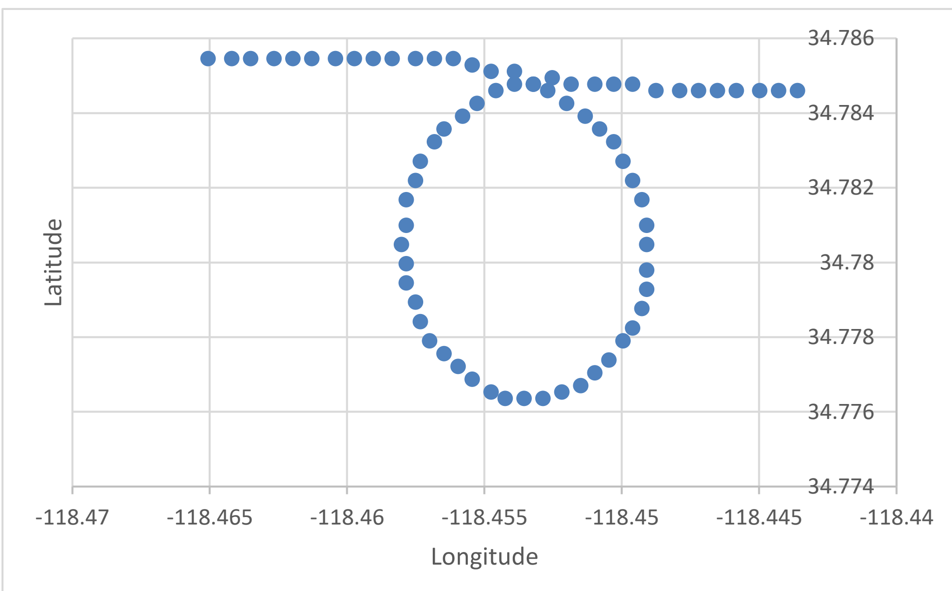

Figure 31. Steep Turn Ground Track

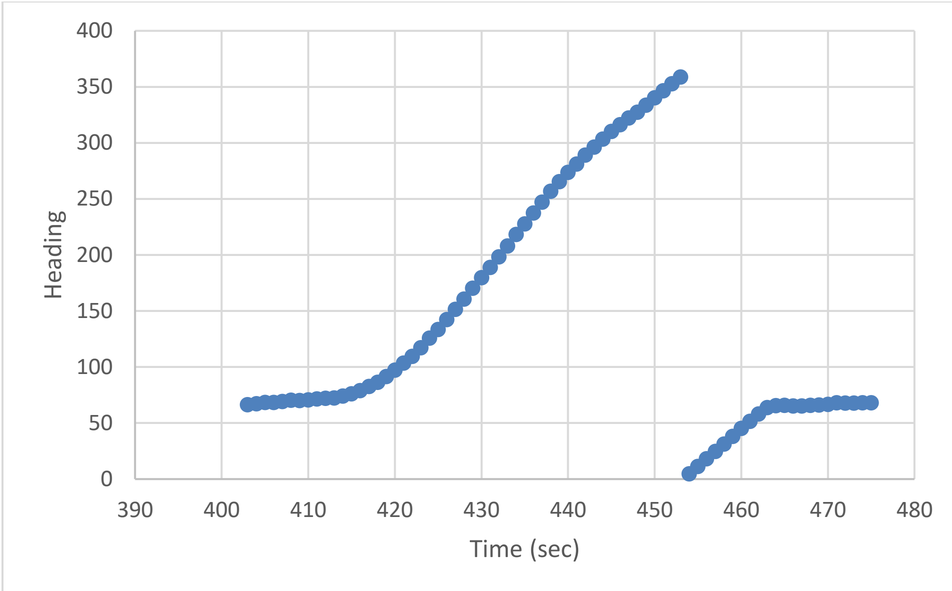

Figure 32. Steep Turn Heading

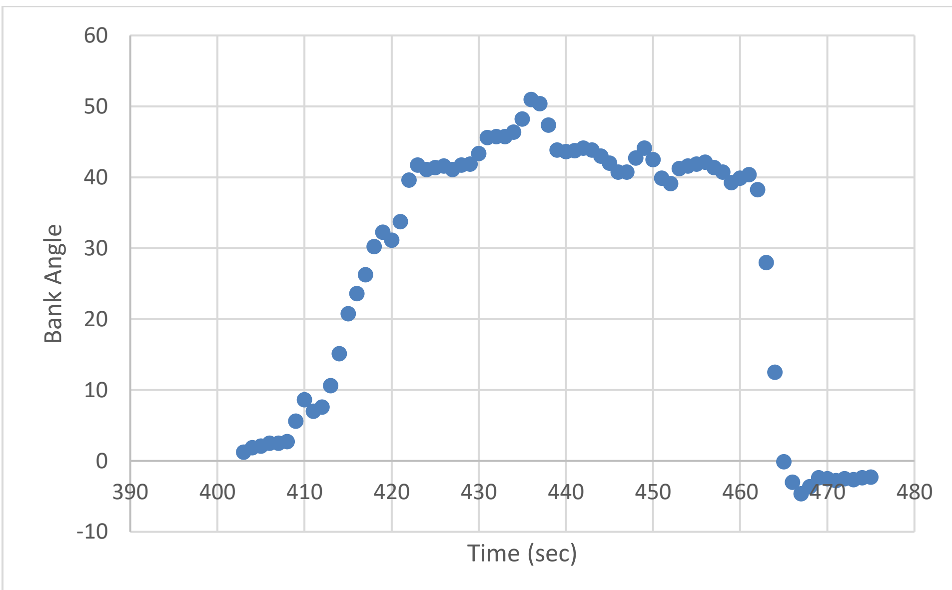

Figure 33. Steep Turn Bank Angle

Bank angle for this turn was around 42 degrees, with one excursion up to 51 degrees.

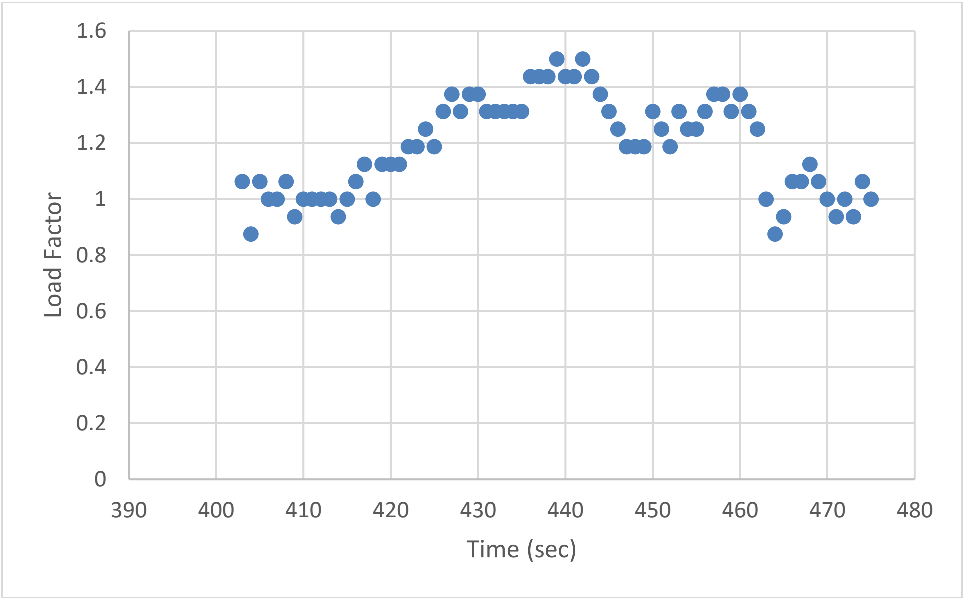

Figure 34. Steep Turn Load Factor

The load factor was again around 1.3.

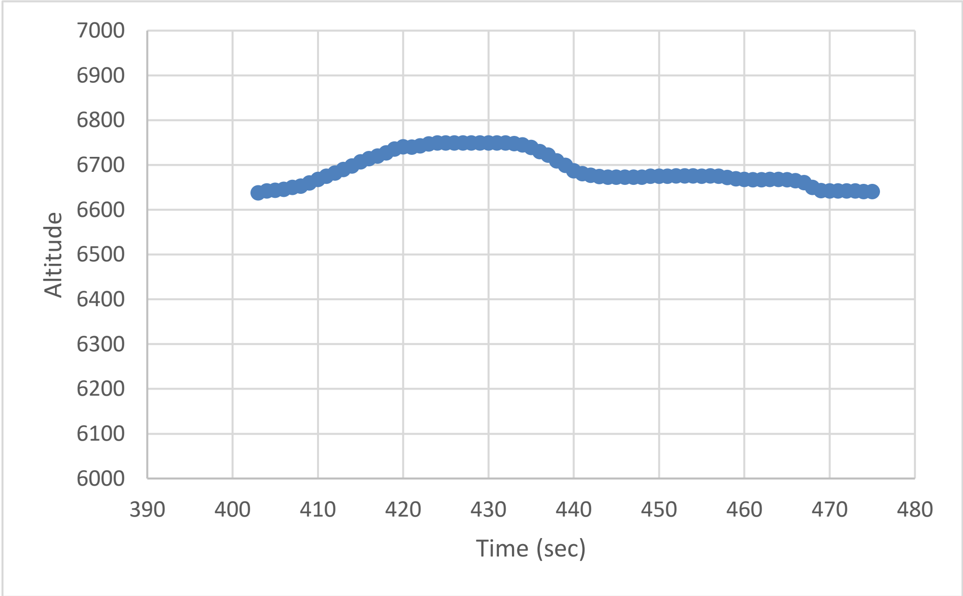

Figure 35. Steep Turn Altitude

Altitude was controlled within 100 feet, giving a good level turn.

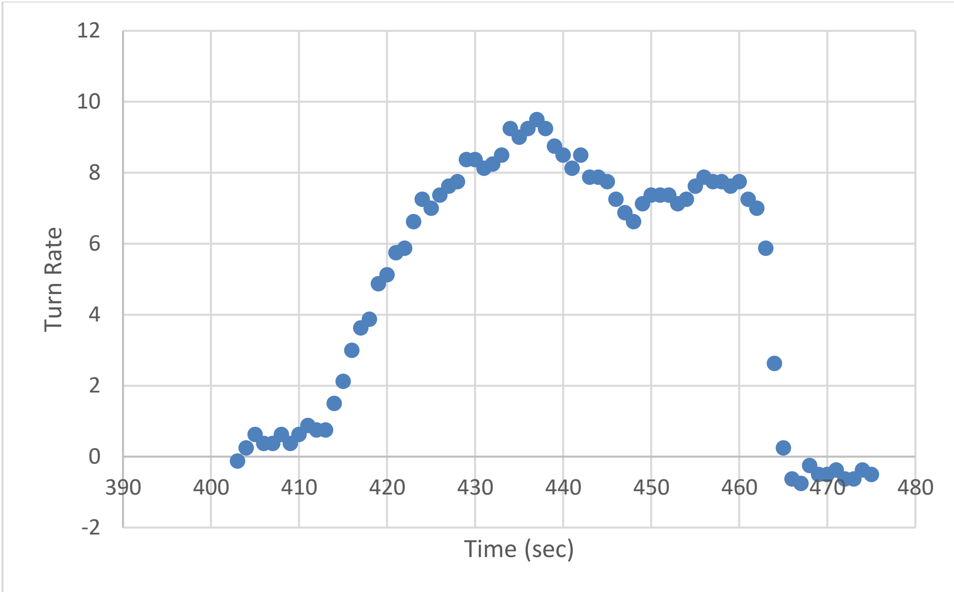

Figure 36. Steep Turn Turn Rate

The turn rate during the turn was 6 to 8 degrees per second, well in excess of the standard rate turn of 3 degrees per second.

Stalls

Stalls were demonstrated by slowing in level flight at approximately 1 knot per second. Stalls were indicated by uncommanded pitch or roll motions. Predicted airspeeds came from previous testing where airspeeds were read from the round dial airspeed indicator. Measured airspeeds for this testing were read from the Dynon D10A recorded data.

One stall was accomplished in the cruise configuration with the flaps up and power idle. Two stalls were accomplished with three notches of flaps (40 degrees) and power idle. Stalls were not accomplished in the cruise configuration with power on. Unlike a trainer aircraft with low excess power, where power on stalls result in a moderate pitch angle, the excess power available in the Bearhawk at stall speeds would result in uncomfortably high pitch angles, higher than the pitch angles seen during the Best Angle of Climb testing. While power on stalls are normally practiced to simulate getting slow after takeoff, the high pitch angle possible in the Bearhawk should warn the pilot that he is doing something wrong long before getting to an actual stall.

Angle of Attack measurements were taken from the Dynon D10A angle of attack instrumentation, which was derived from pressure measurements. For each stall, a higher angle of attack was seen shortly before the stall while slowing than was seen at the actual stall break.

All stalls were very benign, with only small uncommanded motions. Recovery was simple and quick by releasing back stick force. Controllability was never in question.

The lines on the charts mark when the stalls occurred.

Table 1. Stall Testing Results

Configuration	Predicted Airspeed (Round Dial ASI)	Measured Airspeed (Dynon D10A)	AOA at Stall (per cent)	Maximum AOA (per cent)
Flaps Up	51 KIAS	55.5 KIAS	77	86
40 deg Flaps	46 KIAS	51 KIAS	73	84
40 deg Flaps	46 KIAS	51 KIAS	43	82

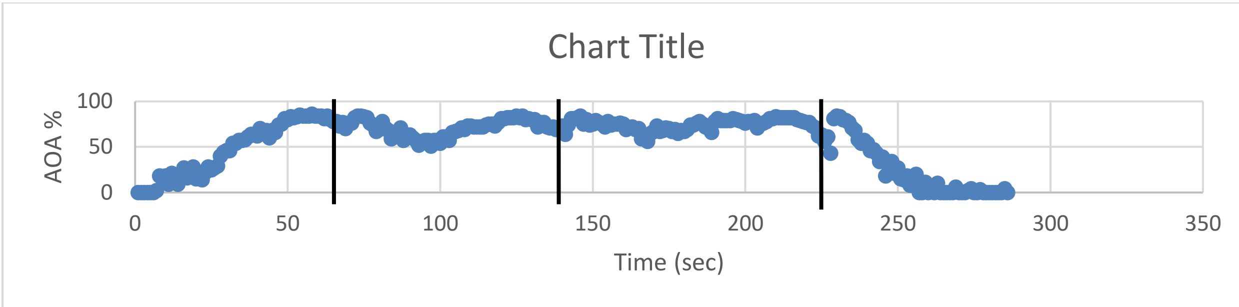

Figure 37. Stall Angle of Attack

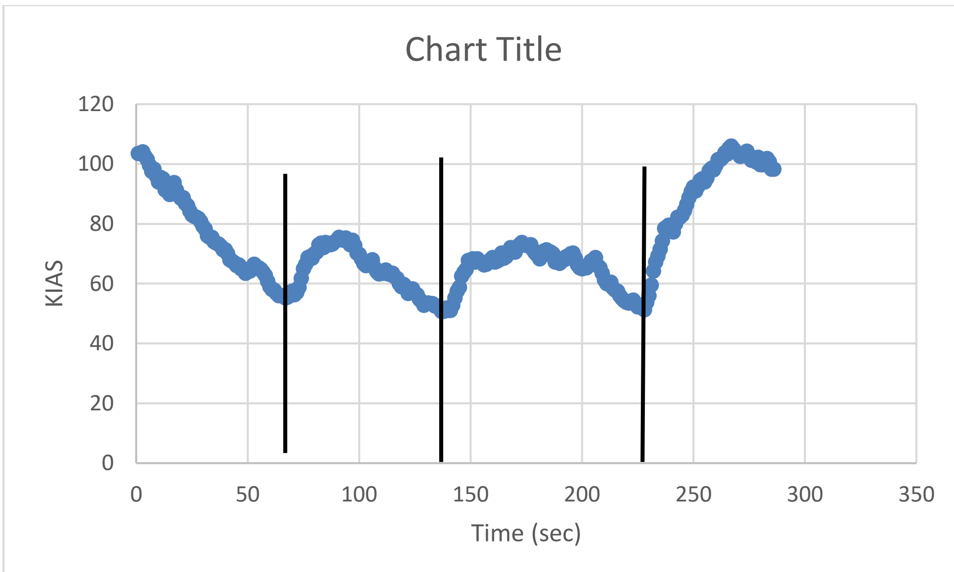

Figure 38. Stall Indicated Airspeed

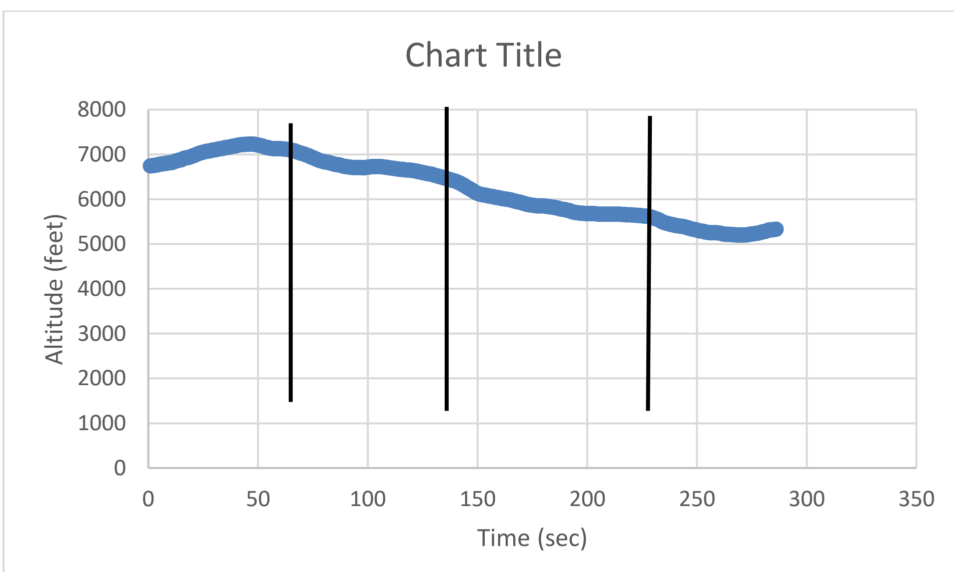

Figure 39. Stall Altitude

Landing

Normal approach airspeed is 60 to 65 KIAS with three notches of flaps (40 degrees), with the preference being toward 60 KIAS, while it typically tends more toward 65 KIAS. Wheel landings are preferred by the pilot simply because of their similarity to glider landings. Touchdown is estimated to occur around 55 KIAS.

Rollout is normally allowed to free roll until approaching the desired runway exit, rather than hard braking to achieve a minimum rollout distance. This prevents needing to use power to taxi off the runway and minimizes wear on the brake pads. With good airspeed control on final, touchdown typically happens within 500 feet past the aim point. Ground roll can easily be limited to 1000 feet with light to moderate braking.

- Russ Erb