Phase 1 Testing of a Homebuilt[1]

Brian P. Lee, Ph. D., P.E.
Kent, WA

Abstract

This paper describes the Phase 1 testing done on a homebuilt experimental F.8L Falco which was meticulously crafted over a period of 32 years only to have the builder pass away before the first testing could begin. Federal aviation regulations require that each experimental amateur built airplane be shown to be controllable throughout its normal range of speeds and throughout all the maneuvers to be executed, and that it has no hazardous operating characteristics or design features. From initial inspections of airframe, engine, and instruments through first flight, envelope expansion, handling qualities evaluation, and performance measurements, the paper describes some of the challenges involved in ensuring a safe airplane in the absence of the builder. The quality of the design and execution of the build were such that the 40-hour test program was completed in less than 7 days. The airplane was pronounced Grand Champion at Oshkosh in 2016.

Introduction

The man

Bill Roerig was a high school industrial arts teacher following his service in WWII being trained in radar operations. He was one of the founders of what is now Fox Valley Technical College in Oshkosh, WI.


Figure 1 Bill Roerig and his F.8L Falco during final assembly

Bill began building his airplane in 1982, shortly before his retirement from teaching. In 1983, Bill became involved with the then-new EAA Air Academy, a summer aviation immersion camp for high school students in Oshkosh, WI. It was through Air Academy that Bill met the author in 1986. Each year during the Air Academy the staff would undertake a pilgrimage to Appleton, WI, where Bill's shop was located in order to check on progress of the Falco project. So the author had the privilege of some 30 years of amazement at the outstanding craftsmanship that went into this particular airplane. Along the way, of course, many conversations took place regarding design and build details, from balancing of the control

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surfaces against flutter to brake line material to mechanical clearances for control linkages, to validating the twist in the wing.

Bill undertook this project purely to prove to himself that he could build the whole thing all by himself. The wood work, the metal work, the composite cowling and gear doors, the electrical work, even the painting and upholstery was done by Bill, mostly working by himself. He made his own oleo struts from scratch, per the drawings. The fuel tanks were fabricated by hand (the stiffening beads formed by placing the aluminum between dies that Bill made from hard maple, taken to the basement, and Bill jacked the house up on top of the dies to force the dies together). He then welded the tanks himself. He carved the Falco logo into the stainless steel brake pedals, and into the insert in the top of the stick. The landing gear retraction mechanism is a lead-screw arrangement with all three actuators driven via bevel gears by one motor. Bill cut the Acme threads on the lead screws (two right-handed and one left-handed) himself with dies he made himself, then he built a pattern and cast his own aluminum transmission housing to hold the gears and the motor. The system works well.

The airplane

Italian designer Stelio Frati's F.8L began life in the 1950's. The first flight of the prototype was in 1955. Constructed entirely of wood, the airframe matured through a couple of very brief limited production runs (it was a certified production airplane in Italy). When the design was brought to the US in 1978, the drawings were re-drawn with the help of David Thurston, and marketed as an Experimental Amateur-Built airplane. Drawings were made available, and many major assemblies were available as kits (spars, laminated fuselage frames, ribs, gear, engine mounts, canopies, etc.) Of course, Bill did not partake in those opportunities, except the plexiglass canopy, which he did not blow himself.

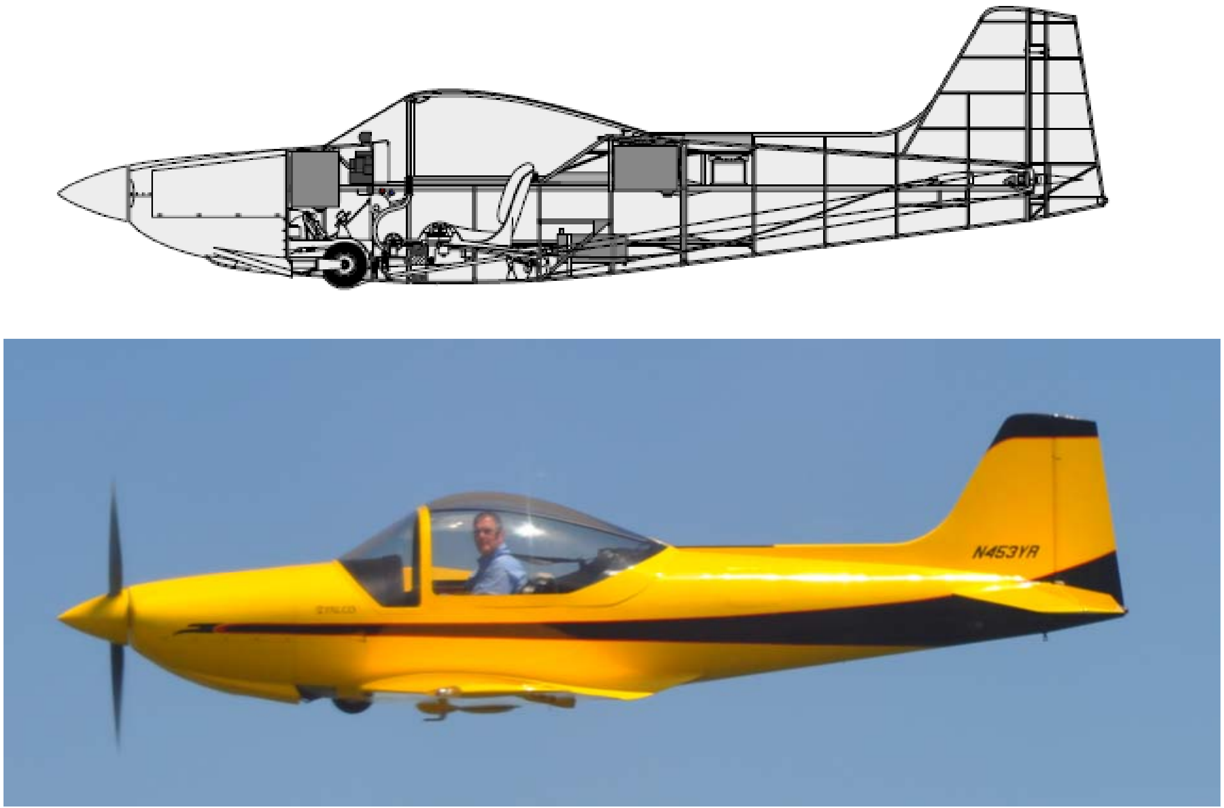

Figure 2. Stelio Frati’s F.8L Flaco

The Falco is a 2 seat aircraft, with side-by-side seating for pilot and passenger with an option for a 3rd seat in the large baggage compartment aft of the pilot and passenger seats. Landing gear is fully retractable via electric motor driving lead screws all connected via bevel gears in the transmission between the seats. Although some builders have installed 180 hp Lycoming engines, the airplane was designed for 160 hp. At 2100 lbs gross weight, the airplane has a wing loading of 19.53 lb/ft^2 and a power loading of 13.12 lbs/hp. Flight controls are conventional center sticks with cables and pushrods connecting to the aerodynamic surfaces. There are two fuel tanks: one forward of the instrument panel, one aft of the baggage compartment, roughly 20 gallons each.

Described in the popular press as “Sensuous to behold, delightful to handle, fast, frisky, frolicsome, and just the tiniest bit feisty” (Ref 1), the airplane lives up to each of those descriptors, and is the second most-popular type on the EAA’s Grand Champion list (second only to the classic Hatz biplane). Widely regarded as challenging to build well, the design is a very good performer. The Falco demonstrates stall speeds of around 60 mph, and a V_{NE} of 240 mph, for an impressive speed range of 4. The airplane is designed for aerobatics with a maximum load factor of +6 g’s and a minimum of -3 g’s.

In addition, the airplane design is quite well documented, with the US distributor producing both a Flight Manual (Ref 2) and a Testing Manual (Ref 3). Both of these are well written and professionally published.

Figure3. Falco Construction Details

When FAA inspector Ray Peterson signed the airworthiness certificate for this example, he noted “I was so impressed with the detail, I almost didn’t see the airplane.”.

The challenge

Three weeks after Bill watched Ray Peterson sign the airworthiness certificate, Bill passed away. He did not get to see his masterpiece fly.

Bill’s two sons are mechanically savvy with long experience in competition automobile racing at a very high level, but they have virtually no aeronautical experience, are not pilots, and didn’t hang around with their dad’s pilot friends. During the build, Bill did not let them help with the project, because he had set out to demonstrate to himself that he could do it himself. As a result, Bill’s family only knew that the airplane was “dads project”, it was high-tech, fragile (compared to their 7000 hp top fuel dragster), and very expensive (like the car). There were several boxes of files in the hangar, but the family was largely unfamiliar with what might be in them.

Some twenty years earlier, Bill had asked the author if he would be willing to do the first flight (OF COURSE!), but his enthusiasm waxed and waned, being concerned that someone might get hurt in his creation. After his passing, although the same concern was shared by the family, they understood that the airplane would be more marketable if it were tested before being offered for sale.

The promise made to Bill's sons was 1) that the Phase 1 testing would be done safely; and 2) that the airplane would be safe for the next owner when the testing was completed. In addition, since the family was paying for the fuel, much care was taken that this was not just a joyride in someone else's airplane. Testing is serious business, and on this occasion, it was also a mission.

A big part of the challenge involved the fact that the airplane (and the family) was in Appleton, Wisconsin, while the author was in suburban Seattle. Further, while the family would pay for fuel, the planning, the testing and the analysis was done as a favor. This was a volunteer effort done at a distance, so time with the airplane was very precious.

Planning

The author is no stranger to experimental flight testing, having taken formal courses in flight testing, benefitting from the experience and expertise of Ralph Kimberlin and Don Ward and Tom Strganac, having spent a career working with professional test pilots who trained and taught at the great military institutions at Edwards (USAF TPS), Patuxent River (USN TPS), Boscombe Down (ETPS), Istres (EPNER), and Zhukovsky (Gromov FRI), and having spent nearly 40 years flying as flight crew on experimental transport aircraft. Climbing into experimental airplanes and evaluating them in flight is sometimes almost a day-to-day event. Nevertheless, taking the responsibility for planning and execution of a safe test program as a one-man job is very different. In an industrial environment, there are consummate professionals to look after literally every technical discipline during every phase of the project. In the case of a homebuilt, it's typically up to just one person to make sure it's right. There was some relief in knowing that the fundamental design was of very high quality and well proven. There was also relief in being quite familiar with both the builder and the build process itself, having witnessed it personally. Nevertheless, the continuous focus on the evaluation of details was pervasive and consuming. Detailed planning and the rigorous use of checklists for everything helped to maintain the focus.

There is plenty of literature available to provide background and detail specifics for conducting a safe and efficient flight test campaign (e.g. Ref 4-9). These were reviewed as a refresher. In addition, having access to professional test pilots proved to be a big help, and much advice was garnered via conversation with professional colleagues. In particular, the best practices of reference 10 were quite useful as a final evaluation of the test plan, to identify anything not already covered.

Specific to the Falco, there are very good reference documents (Ref 2, 3).

Test cards were written in advance. The plan was that these defined the sequence. If there was a need to explore some problem, a decision was made whether the issue would interfere with the planned testing: if no, we would proceed. If yes, we would not, until the issue was resolved.

Instrumentation

Aside from basic flight and engine instruments, the airplane was not instrumented. Cockpit instruments, and a hand-held force gage were available. Testing was supported, though, with use of an MP-3 recorder which had a remote microphone. The microphone was inserted into the ear-cup of the headset, and would record everything heard in the headset: radio calls, intercom, engine noise. As long as the pilot remembered to talk to himself, data could be recorded this way. This was a significant help when things in the cockpit got busy, allowing transcription of the data later onto the test cards. In fact, this was found to work better than transmitting to the ground crew, because it did not involve a different radio frequency, didn't involve pressing the push-to-talk switch, did not risk missing an ATC call. The set-up used is illustrated in Figure 4.

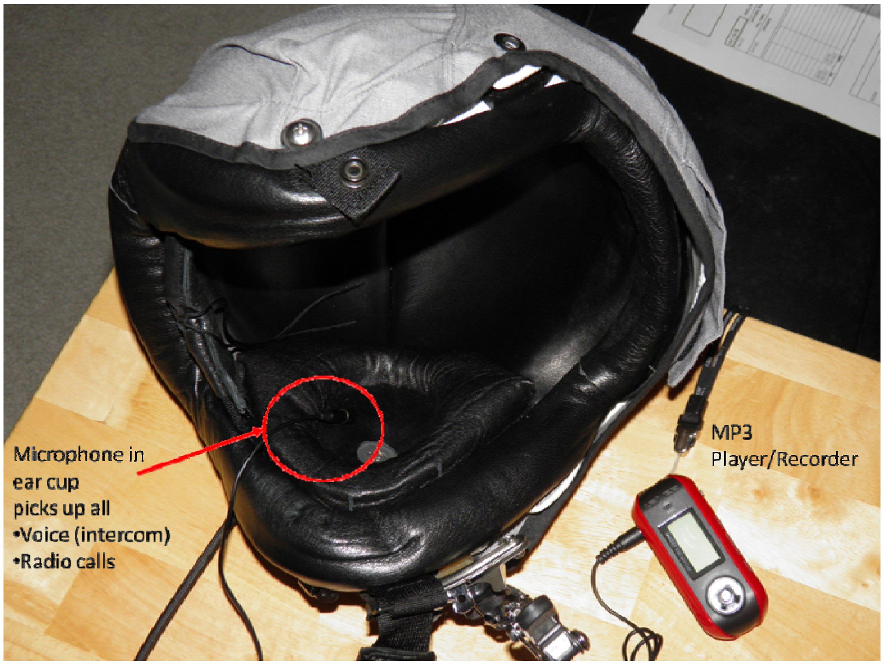

Figure 4. Audio recording as instrumentation

Personal Safety

Despite some very warm days, the pilot used a Nomex flight suit and Nomex gloves for all of the envelope expansion flights (it's an airplane built of wood, after all). Although both a seat-pack parachute and helmet were available, some test-fitting in the cockpit revealed that either the parachute or the helmet would have to go. It was decided to use the helmet and delete the parachute. The helmet was seen to provide more protection from more dangers than the parachute. Even then, the seat cushion was deleted and the pilot sat on the plywood seat pan. This was acceptable for a couple of hours at a time, but became uncomfortable for longer periods. Also, because of the lack of a parachute, the airplane was not spun, nor were flutter evaluations done at V_{NE}. Nor are they recommended in the kit manufacturer's publications. There is an extensive discussion of the characteristics in each of those regimes in the Flight Test Guide (Ref. 3), which describes the characteristics of the design in detail and points out that this testing is not conducted for individual examples of manufactured airplanes, either. It is recognized that the homebuilding process is significantly different from that in under an FAA production certification.

Airport Logistics

Appleton regional airport (KATW) is a very good place to do testing (Figure 5). It has large runways, relatively little traffic outside of the week of Airventure. It has a tower and fire-rescue facilities. It also has a very tight eye on security. While the condominium hangars are easily accessible from the road, the security is very tight.

Figure 5. Outagamie County Airport, Appleton, Wisconsin

The airport has large blocks of adjacent airspace which are mostly unencumbered (an MOA to the West, Green Bay Class C to the Northeast, and OSH Class D to the South). The Milwalkee FSDO was quite generous in giving us an 80 mile radius for Phase 1 testing, which was more than adequate.

Inspection

The very first step was enlist the aid of the most experienced Falco guy to be found. It happened that there was another (Grand Champion) Falco living with its builder at the author's home airfield. His expertise was enlisted during the initial inspection and envelope expansion activities. (He was coerced into taking time away from work and taken to Appleton at the author's expense. This was well worth the investment.) He was able to explain how to gain access to all of the hidden systems workings, identified the mis-rigged rudder cables, and assisted in understanding the landing gear system wiring issues.

Notwithstanding knowledge that the Falco design is well respected, and that this builder was a superb craftsman, that the author had “witnessed” the construction over 30 years of association with the builder, and that there was a brand new airworthiness certificate in hand, the very first thing to accomplish was a detailed inspection of the airplane. This was done with the aid of a checklist procured from the kit distributor (no longer in business). This checklist was more than 30 pages long and consisted of essentially a very thorough annual condition inspection. One discovery was that even though the airplane had been recently assembled, it had not actually been lubricated. This was accomplished.

The airplane was measured, including control surface deflections, and the stops were verified, one at a time, and recorded. Rudder cable tensions were discovered to be too low, so they were tightened, the rudder re-rigged, and stops confirmed.

The end result of the inspection: one cotter pin was found missing. It was on a gear door, and those were to be removed for the first flights, anyway (at the pilot’s direction).

Weight and Balance data was reviewed. The airplane had been weighed twice in the builder’s last weeks of life. It was discovered that during the first weighing, two digits had been transposed from the scale readings. The empty weight/balance was given a sanity check by gently raising the nose wheel off the ground and estimating the force on the horizontal tail to do that.

It had been decided that the first flights would be flown in the forward third of the kit manufacturer’s recommended CG envelope, and the loading was computed for that WITH 8 gallons of fuel in the aft tank. While it would have been easier to configure the CG by leaving the aft tank empty, the pilot wanted some fuel (in this case about an hour’s worth) available in case for some reason the front tank stopped feeding. Feeding of fuel from both tanks was demonstrated during ground runs.

Landing gear operation was confirmed, many times, both electrically and manually with the airplane on jacks. This airplane’s landing gear wiring configuration did not conform to the wiring diagram in the drawing package. The drawings called for an airspeed switch in the power side of the electric gear motor to prevent inadvertent gear retraction at low speed (i.e. on the ground). This particular airplane did not have this switch, but had instead a weight-on-wheels squat switch. It was determined that no flight testing would be conducted until the team understood completely the operation of the gear, including the meaning of each indicator light. Finally, the gear was retracted and extended using the manual crank both to confirm operation and to visually watch all of the switch functions while the gear was in transit.

Back on the gear, the struts were stiffened from the drawing-specified pressures to the “field used” pressures obtained from the Falco guru. This solved an intermittent blinking gear-down green light on the ground caused by the squat switch making and breaking discovered during taxi.

Gear doors were removed for the first flights. Even though the gear would be left down for the first 2 (at least) flights, the doors were removed to reduce risk of damage in an overspeed event. They would be left off until after first gear retraction tests.

Since at this point, the instruments were not yet marked with range markers a great many post-it-notes with reminders for the pilot were posted all over the instrument panel (Figure 6). In addition to posting these, the pilot spent some considerable cockpit time in the hangar reviewing and annotating the kit manufacturer's checklists, and discussing various possible failure scenarios with the ground crew and the Falco SME.

Figure 6. Temporary Placards

Fuel Calibration

With the help of the entire crew, the airplane was re-located to the fuel farm to both fuel it and to calibrate the fuel system. Knowing that the engine had been run previously, there was unusable fuel in the lines, the gascolator bowl, and in the bottoms of the tanks. The tanks were confirmed empty. Then fuel was added in 2-gallon increments. Each time, the gages were marked (actually, a post-it-note) and at the same time, a dipstick was made and calibrated for each tank (front and back).

First Engine Runs

The engine had been run about 5 minutes, approximately 5 months before the testing began. The philosophy employed was to acknowledge the previous engine run, but to proceed as if it had not taken place (there were no witnesses to that event available at the time of testing). This was not a new or newly-overhauled engine. It was a mid-time Lycoming IO-320 rescued from a Twin Comanche and very carefully pickled until installation. This simplified the testing considerably, as new-engine break-in procedures would not be necessary.

First engine runs were conducted with the aid of checklists provided by the kit manufacturer AND service bulletin material provided by the engine manufacturer.

First engine runs produced some data;

- The engine started easily, ran smoothly.
- The intercom did not work.
- The alternator did not come on line at first.
- The CHT/EGT was inoperative.
- The tachometer calibration was checked with an optical calibration device: Close at idle, but read high at high RPM.

Following these, the cowling was removed for a thorough inspection of the firewall forward. A small oil leak was discovered at the case halves just above the forward main bearing. To confirm the front seal status, the propeller was removed and re-installed. The case bolts were torque to the factory specification (they were found to be out of specification). Other squawks were corrected and more engine runs were conducted to confirm that all had been corrected.

Full Power Run

The small, light weight brakes on the 500x5.00 main wheels on the Falco are not known for being robust. Other Falco owners had reported not being able to hold full power with the brakes. But the test plan called for full power for 3 minutes (because of a (non-Falco) reported incident in which an engine failed at 2:45). The airplane was located so that it could be pointed into the wind for engine cooling but situated so that if it began moving it would be unlikely to hit anything, and it was secured via the main landing gear struts to a car for the run. All systems performed as expected. The engine developed full power and ran well for the duration of the 3 minutes. Temperature extremes were recorded, but did not exceed red line values.

Low and High Speed Taxi

Initial taxi testing explored ground handling (very tight, with stiff pedal steering forces, but very sensitive to deflection), brake conditioning and operation (we had bled the brakes during the inspection; no issues), and control during full-power acceleration (brisk). This was conducted in cooperation with Tower on the end of a not-well-used taxiway.

High speed runs were made on runway 3/21. The plan was to accelerate to 50 mph to check aerodynamic control surface effectiveness, high speed ground handling, and generally get a better feel for the airplane. Aerodynamic control surface effectiveness was evaluated, except rudder which was by design solidly tied to the nosewheel steering. Although the nosegear was raised off the ground during these taxi tests, no attempt was made to evaluate rudder effectiveness with the nosegear in the air.

At the end of the high speed taxi runs, the airplane had performed well, it was toward evening, the air was cooler, and the wind had died. It was time for the first flight. During “one last walk-around”, when the vertical tail was gently pushed left and right, a “clunk” could be heard. This was isolated to the nosegear. Further investigation revealed that as the bearings had “settled in”, the wheel was able to slide side-to-side on the axle. The airplane would not be flown until this was corrected.

The Falco nosewheel axle is a custom affair in which the axle nut is secured via a setscrew into the fork so tightening the axle nut to constrain the motion would involve either cutting a new slot in the nut for the setscrew or drilling and tapping another hole in the fork. The local Falco guru was consulted to determine the material the fork was made of. He assured the crew that it was 2024 aluminum. The decision was made to drill and tap a new locking location for the setscrew. The wheel was removed, the bearings were cleaned. A new hole was drilled for the new setscrew location – about 1/4 turn tighter. But this was very difficult to drill, and harder to tap. It seems that Bill had not used aluminum, but 4130 steel!

First Flights; Envelope Expansion

Planning for the first flight had begun well prior to even the inspection. The advice garnered from Mike Carriker was:

- Overspeed the takeoff: you want to be comfortably away from the edge of the envelope in the first few moments of the flight.
- Start with an acceptable landing flap – because you might have to land with it (immediately). Expand the speed envelope with that flap setting before changing anything.
- Then go to a better landing flap – for the same reason – and expand the speed envelope with that flap setting.
- If all is going well, go to flaps up and expand the speed envelope in that configuration.

The decision had already been made that the first flights would be flown with the gear down and the doors removed. That would effectively limit the speed envelope to be evaluated.

The envelope expansion procedure written into the test cards was to

Trim at the selected speed.
Evaluate characteristics:
    Pitch response and stick free/fixed stability
    Roll response and stick free/fixed stability – including gentle turns each direction
    Directional response and stick free/fixed stability
    Steady heading sideslips to full pedal, each direction
    Stick raps in each axis to check high frequency dynamics (up to 210 mph indicted)
    Gentle roller-coaster evaluation of Nz response +/- ~0.5 g
    High frequency dynamics via mild stick raps
Accelerate to +10, decelerate to -10 from the trim speed with elevator alone, evaluate forces and airplane characteristics (buffet, etc.).

The airplane was then re-trimmed to the next speed and the sequence repeated. At this point, the airplane had already been at the next speed but now it’s time to explore the characteristics at the new speed.

In the low speed direction, this was continued until the pilot's comfort level with the characteristics had been reached or the manufacturer's predicted stall speed was approached. This lowest speed evaluated was then multiplied by 1.3 to establish the minimum approach speed for the first landing. There was no intention to stall the airplane on the first flight, and in fact, that did not happen. There was, however, a very distinct change in the character of the stick forces below 70 mph. The stick became quite "mushy", the force gradients were significantly lower than at higher speeds, the deflections for the same airplane response became significantly larger.

In the high speed direction, the landing gear limit speed was used as a never-exceed speed for this early testing (gear remained down). To remind the pilot, a piece of tape was placed on the airspeed indicator at the placard speed. In addition, the gear handle was taped in the down position so the pilot would NOT be tempted to touch it.

Prior arrangements were made with Appleton Tower for the first flight. The plan was to climb through the Class D airspace, but to remain directly over the airport for the duration of the flight. The ground team was instructed to remind the pilot to record engine parameters regularly during the flight.

The purpose of a first flight is to:

- Make sure the engine continues to run; and
- The flight controls and other systems operate properly until
- A safe landing is made; and
- The airplane can be inspected again.

The purpose of the second flight is to make sure that the first flight was not a fluke. Then the testing can continue.

All planned test conditions on the first flight were completed per the test card, including evaluations at all flap configurations. The second flight was a repeat of the first. The only anomaly noted was that full pedal sideslips with left pedal produced significant, large amplitude, low-frequency buffeting. No indication of departure was present, just lots of large-amplitude buffeting. It was repeatable, only appearing at very near full pedal and it existed at all flap settings and power settings with gear down. This phenomenon did not appear with right pedal nor with gear up. The condition was noted for further investigation later.

Qualitative results included:

- Longitudinal
    - Controls VERY smooth and precise
    - Trim quite effective and useful to ~80 mph
    - No adverse characteristics from 80 mph to V_{LE}
    - Longitudinal stick gets very soft below 70 mph
    - Positive stability throughout.
- Lateral-Directional

- Controls VERY smooth and precise
- Roll mode time constant is VERY short, very precise, no ratchet tendencies
- Requires Right rudder in level flight
- Left wing heavy: ~10 deg/sec roll rate stick free, forces light, easily manageable; can be held with rudder, but requires significant deflection
- Positive stability observed throughout.

Final approach was deliberately longer than normal; the landing was really quite easy.

First Gear Retraction

First gear retraction was on Flight 3. Gear doors remained off. The point of this flight was to ensure that the landing gear mechanism worked properly under flight loads (of course it was checked and re-checked in the hangar on jacks).

A secondary goal for this flight was to expand the speed envelope once the gear was up. This evaluation used the same procedures as were used on the first flight, and stopped at the top of the green arc (not wanting to expand toward V_{NE} until the gear doors were re-installed).

A chase airplane was used for this flight, with the experienced Falco guru as an observer in the chase airplane. It was important to be able to examine the gear cycle, the gear in place in the wells.   The gear was cycled 3 times, photos were taken (see Figure 7), and the chase was left for the speed envelope expansion evaluations.

Figure 7. Flight 3, First Gear Retraction

High Speed Evaluations

Once the gear doors were re-installed and verified on jacks and operation in-flight, the speed envelope was expanded to the V_{NE} of 240 mph. Max level speed was observed to be 205 mph indicated, so speeds above that required descending flight. Again, the characteristics were evaluated using the same sequence as during initial speed expansion with the exception that the stick raps were omitted above

210 mph (the pilot was not wearing a parachute, it is a proven design with known close attention to the control surface balancing during construction, and no adverse characteristics seen to that point).

While the longitudinal control forces stiffened with speed as expected, they stayed quite comfortable at high speeds. Lateral stick forces got significantly stiffer above 170 mph. Directional control was very, very crisp at high speeds. The airplane was held at V_{NE} long enough to conduct the qualitative evaluation, with moderate stick forces. Longitudinal trim limits were exceeded above about 210 mph, so the dives required holding speed with forward stick. Stick free characteristics were not evaluated at V_{NE}, but the evaluation at this speed was terminated with an approximate 2-g pull. Characteristics during the deceleration were quite normal.

Airspeed Calibration

Much has been written about calibration of pitot-static systems (e.g. Refs 4-9). Numerous techniques have been used including surveyed speed courses, tower fly-bys, and use of calibrated chase-aircraft. But the advent of GPS and a little bit of math makes this task almost trivial. It does require precision flying and relatively calm (not turbulent) air, but the analysis is made easy with the help of Kevin Horton's excellent and well documented software (Ref 12).

The airspeed calibration was conducted after the envelope expansion was complete and the gear doors were installed so the final aero configuration was stable. The first attempt was found to be contaminated by rough air, and the data was not all consistent. Smooth air the next morning produced better results, shown in Figure 8.

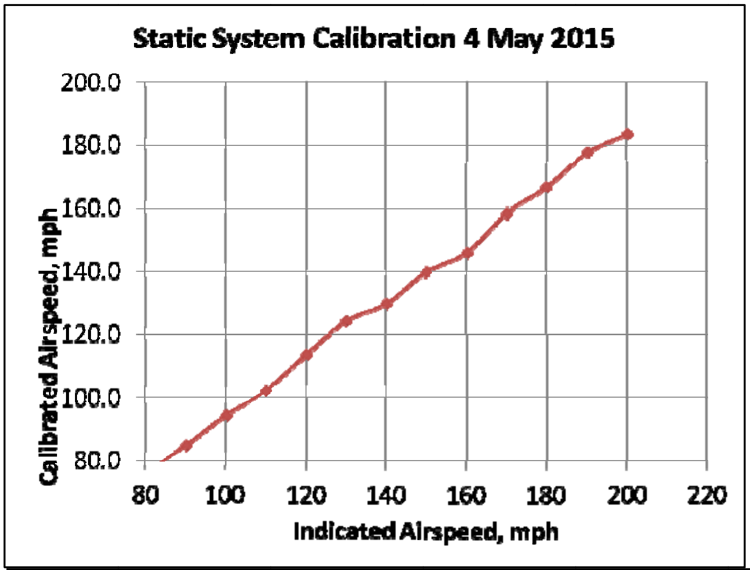

Figure 8. N453YR Airspeed Calibration Results

CG Expansion

Keeping in mind the fact that the physics of a conventional reversible control airplane will provide stick force per V (Static Stability) and stick force per g (Maneuver Stability) as linear functions of CG, the expansion of the CG envelope proceeded as guided by measured stability. Theory teaches that static stability will go to zero before maneuver stability would, nevertheless, both were measured.

The Falco has 2 fuel tanks, one ahead of the instrument panel, and one behind the cockpit. In addition, the pilot and passenger are both aft of the nominal forward CG, so seat loading is also available for controlling CG. Since Bill never installed tie-downs in the baggage compartment, no ballast was used there. Ballast used was in the form of river rock, obtained from a local landscaping store. Each bag was weighed, marked, and the necessary ballast was loaded into the right seat (up to 300 pounds at one point). Great care was taken to ensure that the ballast was firmly contained and would not interfere with the flight controls (Figure 9).

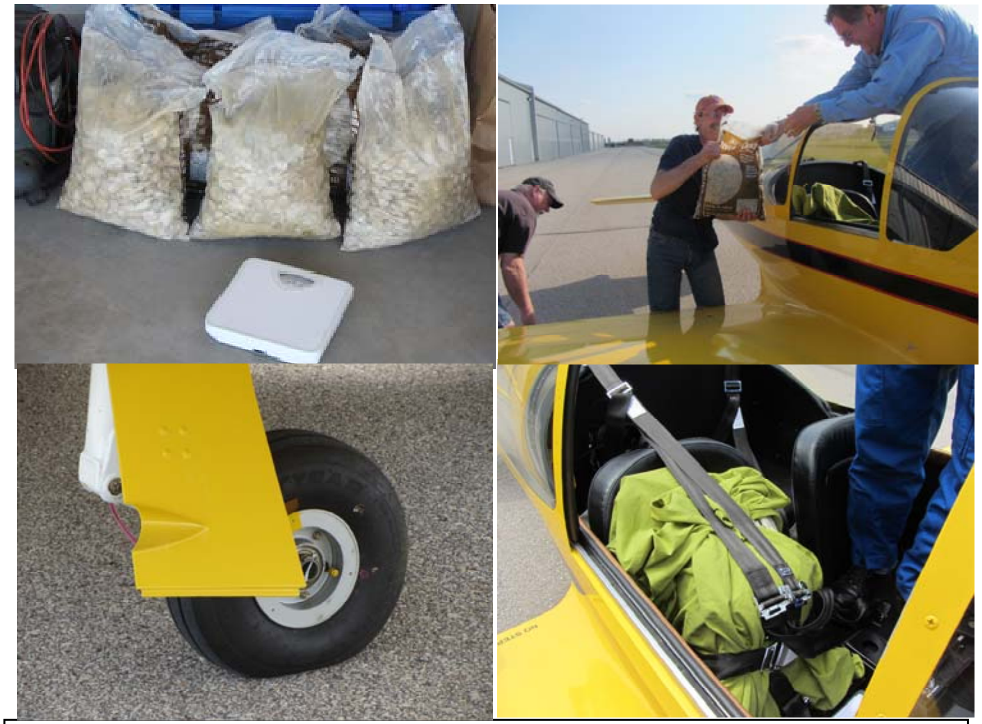

Figure 9. Ballasting to Control CG

Static Stability was measured by measuring the stick force required to stabilize on a speed 30 mph faster and 30 mph slower than the trim speed. Maneuver Stability was measured by measuring the stick force to hold 2 g's (1-g incremental) in a level 60 degree bank turn. Sometimes this took several times around the turn to get the condition stabilized and the force gage on the stick while monitoring for traffic, etc., but the technique worked, as illustrated in Figure 10.

Figure 10. Measuring Static and Maneuver

It should be noted that the static friction in the control system was well below the hand-held force gage's ability to measure it – very, very low friction.

Following the measurements at the nominal CG used for the envelope expansion, the CG was moved aft and the measurements repeated. Extrapolation of those trends predicted close to zero stability at the kit manufacturer's aft limit, so a third set of measurements were taken prior to flying at the aft limit. The results of these measurements are shown in Figure 11.

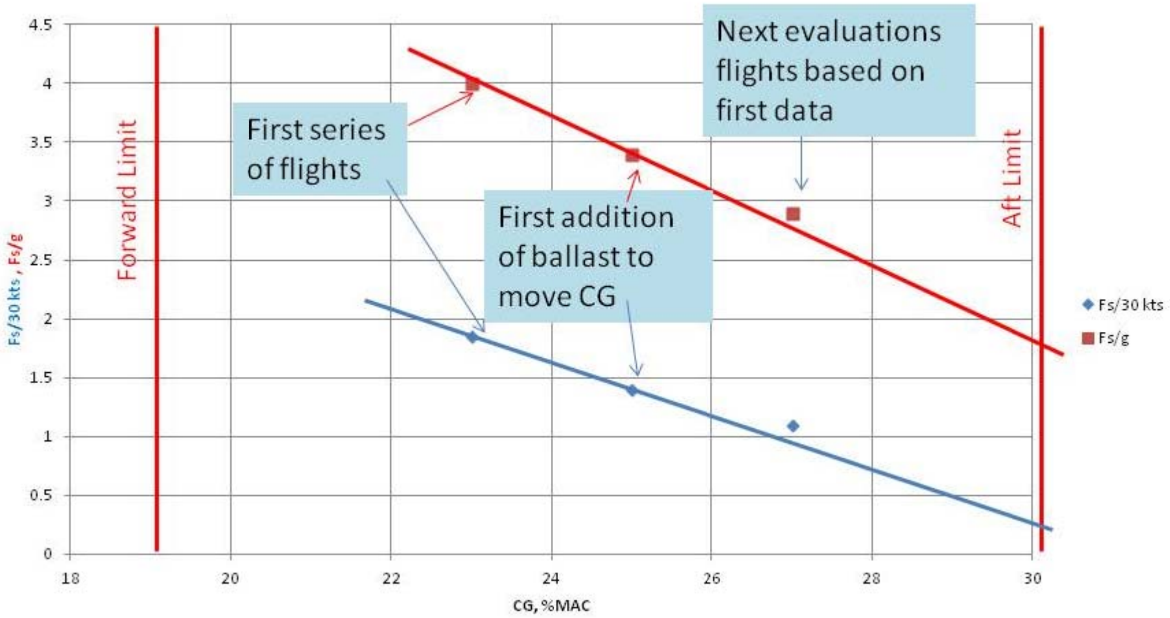

Figure 11. Static and Maneuver Stability Results

Stall Testing

During the low-speed envelope expansion testing on the first flight, the stick forces were seen to have a significantly lower gradient with both speed and load factor below 70 mph. The stick got decidedly "sloppy" below 70. Even though the drawings call for an 11 inch long triangular stall strip to be located on the inboard wing leading edge, the builder had omitted this detail. He did this on the advice of another builder who claimed that it didn't do much (except provide stall warning buffet) and besides, it looked "ugly". Because of these two items, stall testing was approached very cautiously and with lots of recovery altitude. The initial stalls were done before the final trim tabs were installed, so the stalls were done in a slightly asymmetric aerodynamic configuration and initially at Forward CG.

The speed at the break was close to the predicted stall speed for each flap deflection. Gear position did not seem to change the stall speed appreciably.

The airplane was seen to stall quite abruptly, with a very hard break to the left and a positive and abrupt pitch down. For the same reasons as the very short roll mode time constant (lack of lateral inertia), the roll was very abrupt. Pitch response at the stall was also abrupt, and always nose-down, although in those very early stalls, the nose-down motion was aided by the pilot's very fast recovery control inputs. Stick force at the stall break was very low, perhaps a couple of pounds, but was not measured.

Subsequent discussion with other Falco pilots indicated that a left break is not uncommon when flying solo – because of the load asymmetry.

Stalls were conducted in level flight and in turning flight in all flap and gear combinations and with power varied from idle to takeoff power. One Flaps 40 stall demonstrated a stick snatch in the direction of the lateral break – an indication of asymmetric stall progression onto the ailerons. At takeoff power, one stall broke to the Right.

As the CG envelope was expanded, the stalls were repeated at Aft CG. Lateral characteristics were unchanged from the forward CG cases. Longitudinal stick forces were lighter, but still positive. For the final check, the stall recovery was effected by simply releasing the stick as opposed to making a nose-down input. Recovery was positive.

Stalls were repeated with 300 pounds of ballast in the right seat. The break to the left was softened somewhat, and the speeds were slightly faster (as expected), but otherwise, characteristics were as discovered earlier.

Finally, after installing the trim tabs (wedges on the left side of the rudder and lower surface of right aileron), the stall series was repeated again to confirm that the tabs did not appreciably alter the characteristics. They did not.

Asymmetric Sideslip Characteristics

The asymmetric buffeting at full pedal was "re-discovered" in a crosswind landing (crosswind from the right at 16 knots) on Flight 13. This was after successfully demonstrating crosswind characteristics (wind from the left the previous day), so it came as a bit of a surprise (although it should not have – it was discovered and noted on Flight 1!).

Near the end of the test campaign, when a suitable chase airplane became available, the asymmetric buffet condition discovered on the first flight and reminded during crosswind landings was investigated more fully. Recall that during sideslip testing on the first flight, full pedal to the left produced significant buffet, while full pedal to the right did not. The angles of sideslip (derived from change in heading) were not significantly different. There was no tendency to depart in either direction.

Since the anomaly was only seen with Left pedal, the right side of the vertical tail and rudder were tufted (a quick trip to the local needlework store – black yarn on a yellow airplane worked well). As can be seen in Figure12, there is no tendency for separation on the convex side of the vertical tail (rudder deflected away from the camera in this image), even thought the chase pilot reported the tips of the horizontal moving ~2 inches during the buffeting. Again, the buffeting was only observed with gear down, all flap settings, nominal power at approach airspeeds.

Figure 12. No tendency for separation on the convex side of the vertical tail

On the next flight, the other side of the vertical tail was tufted in the same way. The results are shown in Figure 13, the concave side of the vertical tail (rudder deflected towards the camera). The vertical tail and rudder is completely separated. That this condition might show up and present asymmetrically as it did is confirmed by Hoerner and Borst (Ref. 13) in their discussion of propeller slipstream effects on single engine airplanes.

Figure13. Separation on concave Side of Vertical Tail

Since there was no tendency to depart in the full pedal condition, the buffeting was seen as a nuisance feature, certainly not good for the structure over long periods of time, and not good for the pilots' comfort level. The decision was made to insert a shim in the rudder stop mechanism, to limit rudder deflection to the left. The size of the shim was selected to limit the sideslip to just below the large separation (and associated buffeting) condition. This was found to be not particularly limiting in terms of sideslip or crosswind capability.

Performance Testing

Performance testing is sometimes described as "boring". Perhaps that's because there is a smaller perceived element of danger involved, the flights are generally away from the edges of the flight envelope, and the test conditions are not particularly dynamic. This testing in a single-pilot environment, though, is very intense and the fact that there are lots of test conditions which require significant concentrated precision in flying makes this testing very demanding on the pilot. Despite the "lore" of low danger, the low speed end of the climb tests, during which the airplane is flown at full power very close to the power-off stall speed, at +/- 1 mph holding +/- 1 degree of heading makes one understand just how important it is for the engine to continue producing full power.

Climb and Glide Testing

Climb and glide performance testing was conducted to ascertain the best angle and rate of climb speeds and the best glide and minimum sink speeds. The testing was conducted perpendicular to the prevailing wind (which of course, first required determining the wind at test time), and involved climbing and descending through a 1000 foot block, timed with a stopwatch. This was a busy challenge to do single-pilot with only hand-held instrumentation. Each test point was flown twice on back-to-back flights with the airplane loaded to a heavy-weight forward CG condition: once starting at the high speed end of the block, and once starting at the low speed end of the block, to account for the fuel burn during the testing. Climb results are shown in Figure 14.

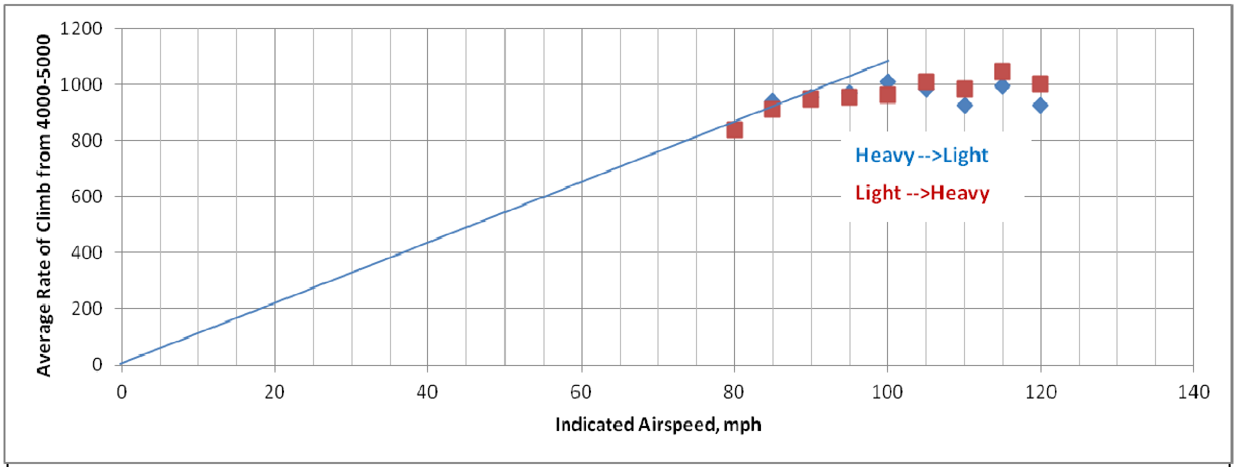

Figure 14. Climb Performance

Power off glide test results were obtained during the same flights. Results for speed for best glide and speed for minimum sink were determined from the same data, taken in the same way as the climb data. Power off glide test results are shown in Figure 15.

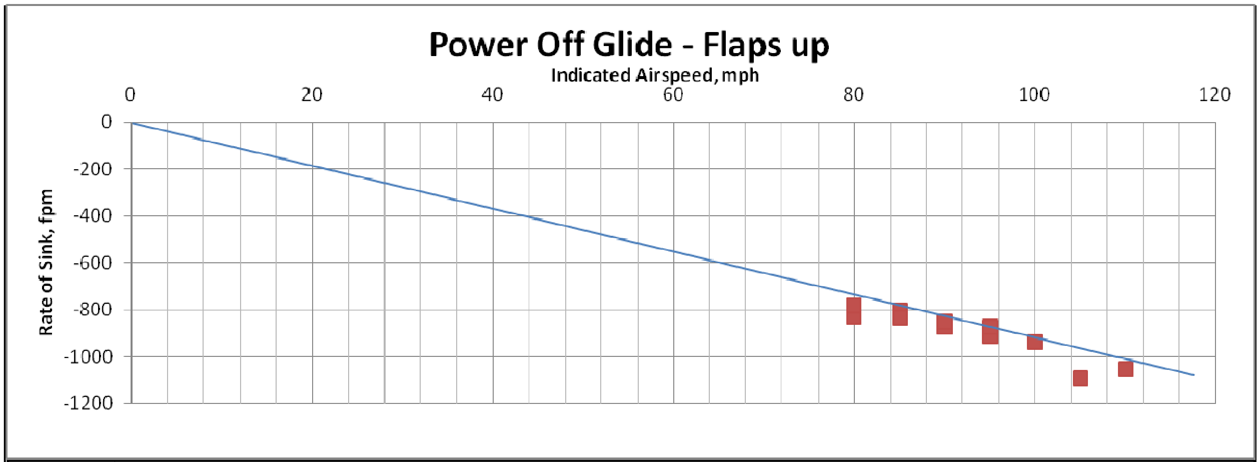

Figure 15. Power Off Glide Performance

Takeoff and Landing Performance

There is a large benefit to conducting testing at an airport with ample runways oriented 90 degrees to each other. During the course of the test period, when winds were favorable, crosswind characteristics were evaluated by simply using the “other” runway. Well into the test period, after some comfort with the airplane characteristics was gained, deliberate attempts were made in crosswind conditions. Takeoffs were demonstrated in 20G27 knots (tower winds). Crosswind takeoff characteristics were completely normal. On the first takeoff attempt, there was some lateral deviation after nosewheel liftoff but before the main gear unstuck. This was less than 10 feet, and disappeared on subsequent attempts as the pilot learned how much rudder to use as the nosewheel lifted off and how much wing-down to use in transitioning to the slip just at main gear liftoff.

Landings were demonstrated with crosswind components of 16 knots (tower winds). The first attempt with wind from the right generated the same buffeting noted on the first flight envelope expansion during the de-crab maneuver, at just a few feed off the runway. This was a surprise, although it should not have been.

Takeoff and landing distance testing was conducted late in the program (after significant familiarity with the airplane characteristics was in hand), and on an opportune day when the wind was calm. Airport personnel were consulted to ascertain distances from the threshold to various landmarks (taxiways, distances between runway lights, etc.) that could be used for estimating distances. These are shown in Figure 16.

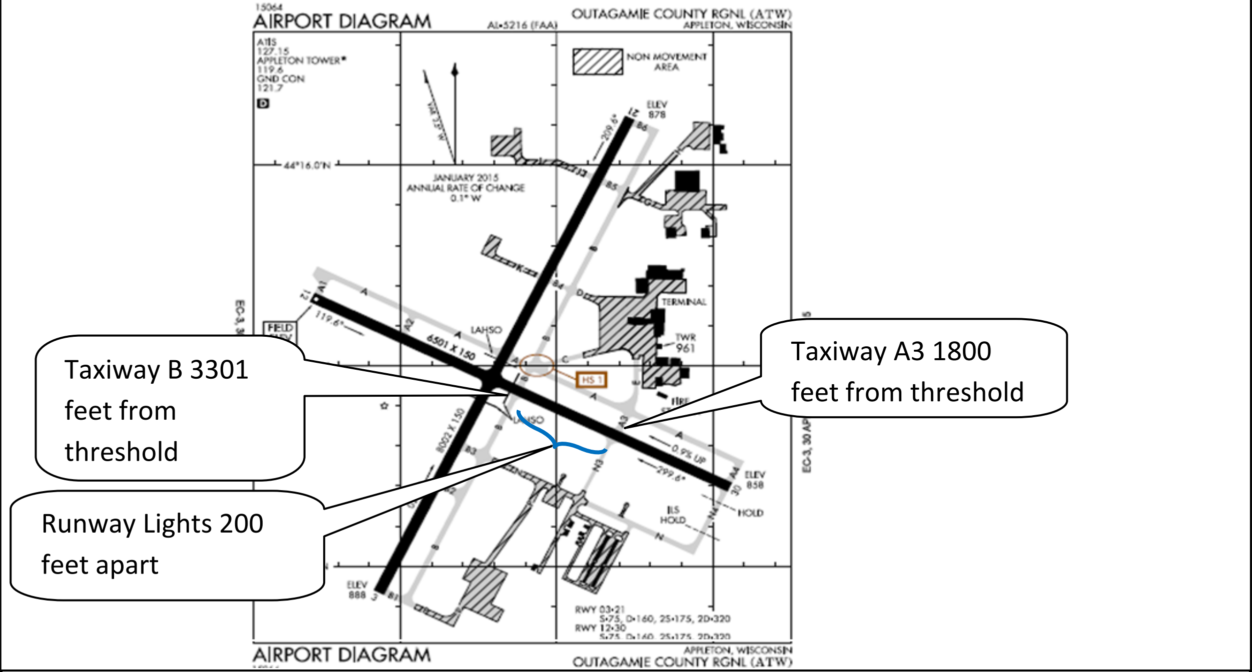

Figure 16. Runway Distance Landmarks

Takeoff distances (liftoff) were straightforward to ascertain, and were always in the vicinity of 1200 feet or about half way down the touchdown zone markings on the runway. The first segment climb gradient and some margin for transition can be added to that for an over-50-foot distance. The 50-foot distance was estimated by identifying runway lights while climbing trough the 50 foot level.

Landing distances first required an estimate of height over the threshold. Of course the PAPI was a good guide, but the recognition that 50 feet is about twice the wingspan, or 4 times the distance from the pilot's eyes to the wing tip was a great aid. The second step was to estimate the touchdown point. A 3 degree glideslope intersects the runway at about the 1000 foot point. From 50 feet over the threshold, touchdown in the first half of the touchdown zone marker was easy. From there, braking without locking the wheels resulted in total landing distances of always less than 2000 feet, and about half the time by 1800 feet.

This testing allowed generation of recommended distances to be recorded for future owners/pilots of this airplane.

At this point, a comment about landing flap setting is appropriate: Much Falco lore specifies landing at 20 degrees flaps, while 40 is available. The available literature suggests that because 40 degrees of flap generates significant drag, it should only be used when landing at very short fields; that a low altitude engine failure will result in landing short of the aim point (maybe even short of the runway). The observation from this testing is that using a flap deflection of 40 degrees does indeed require more power all the way down final approach (about 18 inches of manifold pressure), this is not uncommon when compared to other high performance single engine airplanes – although it is different from many light-wing-loading training airplanes. What 40 degrees of flap deflection does provide on this airplane is a view of the runway over the nose which is not available to 20 degrees of deflection.

Conclusions

The testing described in this paper was conducted under very unique circumstances, on a very tight time schedule necessitated by geographic location. It was conducted safely and without either incident or accident. Nevertheless, much was learned in the experience.

Because this airplane had a non-certified engine/propeller combination, the FAA required a 40 hour phase 1 test period. This experience suggests that regardless of the status of the engine/propeller combination, 40 hours is not too long to accomplish a thorough evaluation. Besides the already-mentioned spin testing and flutter excitations at V_{NE}, cruise fuel flows were not measured during this testing period, either. That testing would require significant additional flight test hours. As it is, the testing described here comprised 40 hours of flying, and took place over the course of less than 7 days.

The next significant learning is that safe and very efficient testing can be conducted given appropriate amount and level of preparation, both before the testing starts and during the test period. Bill’s family was not sure what this engineer/pilot was doing making plots in the back of the hangar after dark, but the next morning everyone knew how many bags of rocks were to be loaded into the airplane and how the fuel should be distributed for the next series of flights. The first oil change was carefully planned to occur on a bad-weather day so as not to impede the progress.

Perhaps the most significant lesson learned is the huge difference between professional testing conducted by a competent industrial organization, and that faced by most homebuilders. The number of technical details and the criticality of those details quickly became apparent in a one-man application. In an industrial setting, it is easy to lose sight of those because everyone involved knows that they are being looked after by consummate professionals. Taking responsibility for everything was certainly an eye opening experience.

It is interesting that people who build their own airplanes will take great care to learn construction techniques, whether it be welding or woodworking or electrical wiring, but very few have ever been exposed to the techniques required to actually evaluate their airplanes. And they don't seem to want to know. Most simply "fly off the time", which is not the point of the regulations. In fact, the FAA requires recording of the key performance parameters (e.g. Vx, Vy, etc.) to be recorded in the airplane logbooks. That would require measuring them.

This represents a huge opportunity for education. In the experience described here, even the "boring" performance testing was realized as very intense stick-and-rudder flying. The recording device helped, but e.g. the climb/glide testing required a significant amount of learning. The ability to maintain airspeed and heading precisely is intense, but it is not the hard part. That comes in deciding how to merge the maneuvers together to both allow recording of the result, resetting the clocks, getting established at the next condition "just in time" to enter the altitude window. This required a certain rhythm during the flight. Sadly, many homebuilders are not interested, they simply want to fly the time off so they can fly out of the flight test area and carry passengers.

Epilogue

When Bill finished painting the airplane in late 2014, his eyesight was failing, and his hands were not as steady as they once were. His sons polished much of the orange-peel and runs out of the paint, at least on the upper surfaces which were most visible. The judges at Oshkosh (of course) noted the imperfections in the paint on the lower surfaces, but nevertheless awarded N453YR "Reserve Grand Champion" for 2015. It's pretty rare for a first time builder to win this kind of honor at OSH the first time.

In 2016, noting the judges' remarks, Bill's sons worked the cosmetic issues on the lower surfaces, and the airplane was awarded Grand Champion in 2016, a sure testament to the quality of the workmanship. Gordon Baxter wrote of the awards presented at OSH in Flying Magazine (Ref. 14): "They sit row on row in their little white dickie-bird caps and the awards go on forever. Do not laugh [at the awards]. May you someday be good enough at whatever you do to have your work judged well at Oshkosh.". After the fly-in in 2016, the airplane was sold to a physician and AME in Kentucky. The good doctor arrived in his Mooney in late August with his son to take the airplane home. When asked if he flew in formation with the Mooney back to Kentucky, he remarked "That was the plan, but I left the Mooney in the dust. When we got home, we compared fuel burns, and mine [in the Falco] was nearly 40% less.".

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