Pushing the Envelope

By Will Fox CFI, TC, FA – November 2014

I had an interesting thing happen to me in the Pegazair the other day. I got a chance to get up close and personal with flutter. The Peg was loaded with camping gear for my trip to Negrito. I was close to my gross weight and my CG was located farther back then normal, but still well within the maximum limit. I was giving a ride to a friend of my daughter before leaving on the trip. We had been flying over the Sangre de Cristo mountains and were descending through 10,500 feet for the Santa Fe airport at about 120 mph indicated, when the controller asked me to go direct to the numbers at best speed for traffic considerations. I dropped the nose a bit, picked up some more speed, and re-trimmed the aircraft. I noticed that the trim was considerably farther forward than normal and attributed it to the aft CG. In fact, it was more forward than it ever had been before, but I didn't realize it at the time. The speed began to increase, and suddenly the stick began to oscillate rapidly for and aft as the nose began pitching up and down.

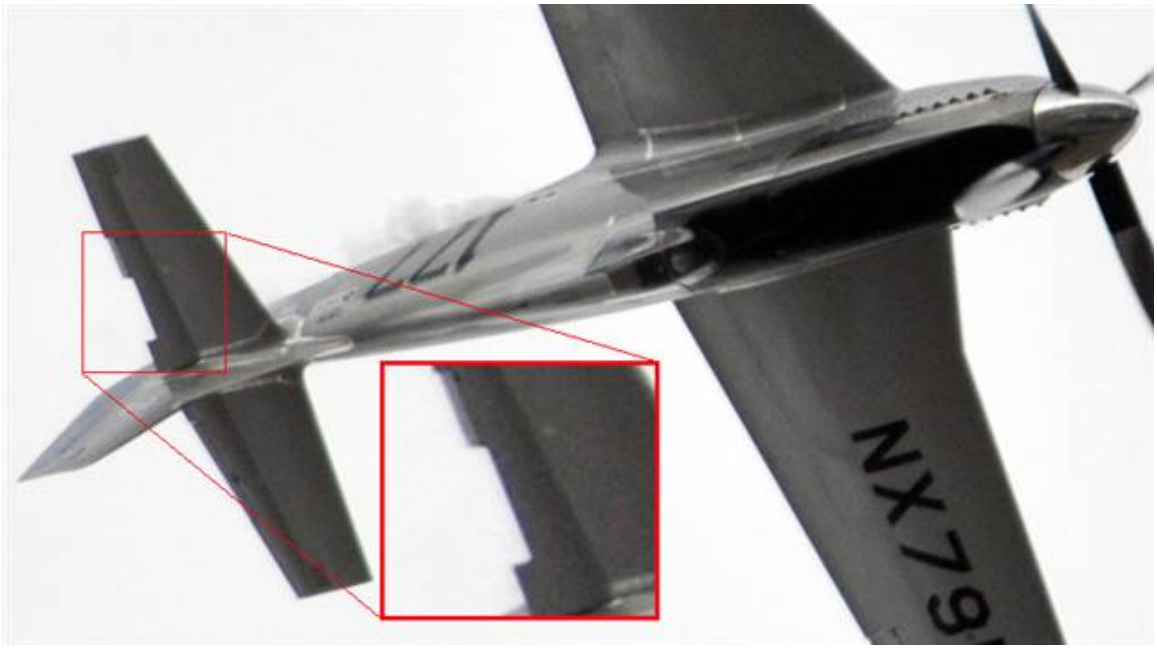

Figure 1. This is a picture of a highly modified P-51 called the Galloping Ghost, at the Reno Air Races shortly after one of the elevator trim tabs separated due to flutter resulting in a horrific accident.

I didn't realize it at the time, but I had just pushed the flight envelope of the Pegazair beyond the range that I had previously tested it to. That's when you go from being pilot to test pilot. It is not a pleasant experience when it happens to you and you are not prepared. In fact it can be a fatal experience, as was the case when the Galloping Ghost shown in Figure 1, a highly modified P-51 race

planet, crashed at the Reno air races after losing a trim tab due to flutter.

I often get calls from pilots wanting to expand the envelope of their aircraft by increasing their gross weight, or by installing a larger engine or different propeller to go faster. I try to help them, because this is one of the great freedoms we enjoy with experimental aircraft. It is the freedom to change and improve our aircraft as we see fit. However along with great freedom, comes great responsibility. And in this case, that is the responsibility to thoroughly test the aircraft throughout its operating range after you make modifications to it, to assure that it is safe.

The FAA requires a 40 hour test phase for homebuilt aircraft for good reason. It saves lives. It is during this phase of testing that you are supposed to explore the flight and ground handling characteristics of your aircraft and make sure it is safe to operate from one end of the envelope to the other. Honestly, this is really difficult to do in only 40 hours of testing. Aircraft companies spend hundreds to thousands of hours doing this for certified aircraft. What we homebuilders often do instead, is explore a subset of the envelope that we feel competent and comfortable with and stay away from the part of the envelope that we don't think we will operate in or are uncomfortable with. For example, not many homebuilders explore the spin characteristics of their aircraft to make sure that the aircraft is recoverable, or dive it to maximum speed to make sure that it is stable and does not come apart, because they don't plan to operate in this part of the envelope. Similarly, few homebuilders test their aircraft at both ends of the CG range to make sure that it performs as expected. How many of us test the aircraft at the maximum forward CG limit and gross weight to make sure that we can still flare it for landing or something on the landing gear doesn't break on a hard landing? How about testing at the rear CG limit and gross weight to make sure that we can get the nose down in a stall, or that the controls aren't so sensitive that it is impossible to fly? Not many I wager. The reason we can usually get away without a thorough test program is that we rely heavily upon the fact that the aircraft designer and kit manufacturer did this for us and that we are building the aircraft exactly as they did, so it will perform the same. This is not a bad approach as long as we don't start modifying the aircraft. However when we decide to use a different engine, or increase the gross weight, for example, all bets are off, and we need to acknowledge the responsibility to once again become a test pilot and fully test the envelope of operation. I didn't test the full envelope when I installed a larger engine on my Peg and increased the gross weight, and that was why I was experiencing elevator flutter with an innocent and trusting passenger sitting right next to me.

When the flutter started, at first all I could do was hang on to the stick for dear life because it took me a second or two to realize what was happening. I immediately reduced power and began to level the aircraft. The oscillation did not stop. I reduced the power even more and pitched the aircraft up, and the oscillation slowed and then thankfully stopped. My heart was pounding as I flew

straight and level and tried to understand what had just happened and what we should do next. I decided that since the aircraft appeared to be undamaged and controllable, and we were already on our approach into Santa Fe, that we should just continue on and land. I reassured my passenger, who hadn't said a word throughout the whole experience, that the aircraft had never done that before, but that it was fine and we would soon be landing in Santa Fe. I didn't know if the aircraft was fine, but I didn't know what else to say at the moment. We landed in Santa Fe uneventfully and when my passenger got out, she told me that was one of the most interesting flights she had ever had. I looked at her in amazement. My daughter April came up and as she and her friend said their goodbyes, I began to look over the aircraft for damage. After her friend left, April joined me and I explained what happened. Together we began looking for damage and what might have caused the flutter. We inspected the elevator and pitch control system and could see no signs of excess play or damage. April was the first to notice that the wire that activates the trim tab was bent between the arm on the tab and the conduit clamped to the horizontal stabilizer. It is normally straight as shown in Figure 2, but now appeared to be bent at almost a 90 degree angle. This explained the elevator flutter.

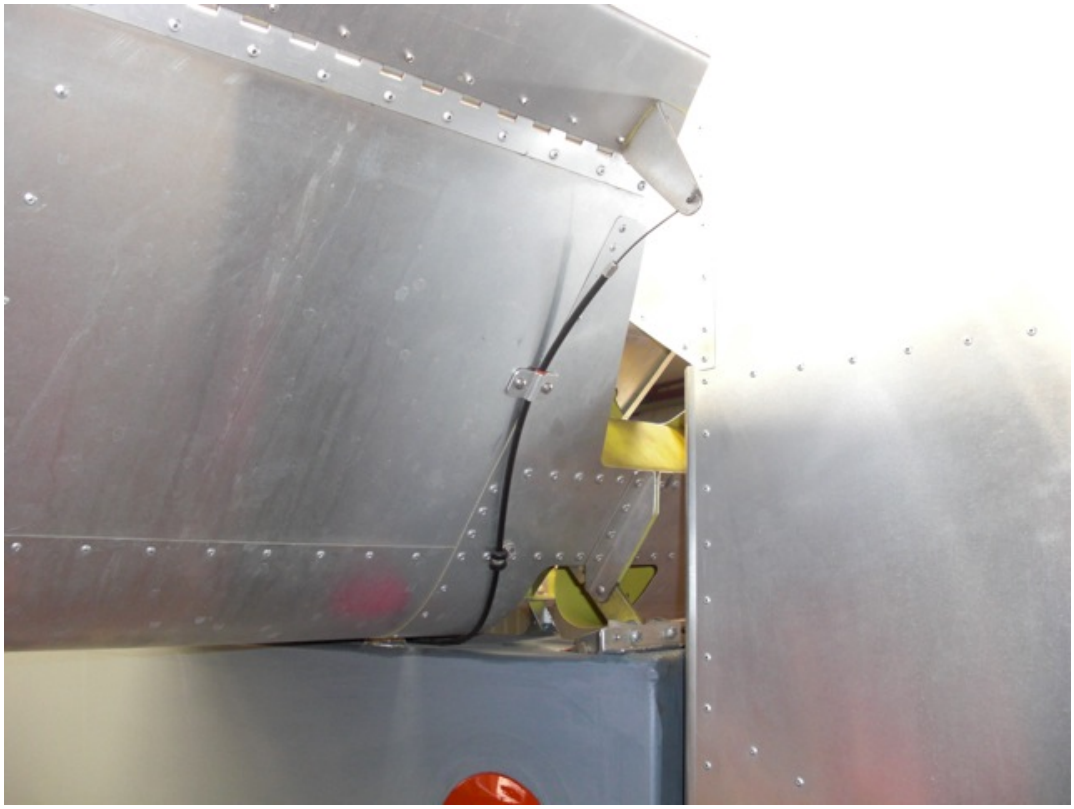

Figure 2. The elevator trim tab on the Pegazair is activated by a push-pull wire attached to an arm on the tab. The wire conduit is anchored to the elevator. The wire should be straight between the conduit and the tab as in this picture. If it is not, it can buckle and produce elevator flutter.

Why did the push-pull cable bend? When I installed the new engine and increased the gross weight, I had done dive testing to much higher speeds then I was flying that day without a problem. I had also flown with a more aft center of gravity and a higher gross weight than I had that day and had had no problems. What I hadn't tested was the combination of these factors, which together, put me in a different part of the flight envelope.

What happened in this situation is that the trim tab was projecting up into the air stream more than it had in any of my previous tests. This combined with the speed caused the 0.060" diameter push-pull wire to buckle under the load. This produced a change in the forces on the elevator. The elevator moved up abruptly causing the aircraft to pitch up. Then the elevator overshot its new trimmed position due to inertia, and the resulting aerodynamic forces began to push it back down resulting in the stick being pushed forward and the pitch starting to decrease. The trim tab has its own inertia of course, and the rapid down movement of the elevator had caused the trim tab to overshoot its neutral position, a sort of snap-the-whip kind of effect. This in turn pushed the elevator down even more. The effects would reverse as the elevator hit the end of the down stroke and start the cycle over. The fact that the push-pull wire had a bend in it and was not rigid, caused it to act as a spring and allow aerodynamics and inertia to dominate its position as opposed to the trim lever in the cockpit. Trim controls should be rigid to work properly, and the bent piano spring wire was anything but rigid.

Now that the mystery was explained, it was time to fix the problem. I straightened the wire and flew back to Los Alamos at a trim speed that put the trim tab in trail with the elevator so that it would have no load on it. Once I was home I ordered a much heavier duty push-pull cable with a 0.090" diameter wire and installed it. I then went out and tested the Pegazair at the same conditions that produced the flutter previously. No flutter. I then slowly increased the speed until I achieved the maximum dive speed and trimmed it there. No Flutter. I later discovered that an updated version of the plans included a heavier trim cable just as I had installed, but I wasn't aware of the change. It is good that the trim push-pull wire did not break. If it had, the elevator oscillation would have been much more severe and could have lead to the failure of the trim tab or elevator completely.

I was extremely fortunate. Flutter is often a very destructive phenomenon. Often the onset is so rapid and destructive that the aircraft structure fails almost immediately resulting in a fatal crash. Take a look at these videos to see flutter in action:

http://www.youtube.com/watch?v=OhwLojNerMU
http://www.youtube.com/watch?v=X2wYvr20nAg
http://www.youtube.com/watch?v=s3-g9B6Fgjs

In my case, my passenger and I both survived unharmed and the aircraft was undamaged. I can only attribute this to the patron saint of aviation, Lady of Loreto, who watches over stupid pilots that need to be more conscientious in their flight testing. Lady Loreto must be pretty busy, given all the folks that I think she must be watching over. So lets give her a break and be meticulous in our testing, and recognize the need for additional testing throughout the envelope when we modify our aircraft. Also take a good hard look at your trim systems and make sure that they are well maintained and rigid. If they get sloppy or fail, life can get very exciting and very short.