# YOKE OR THROTTLE

## WHAT CONTROLS AN AIRPLANE'S GLIDEPATH?

AOPA Flight Training Magazine: May 5, 1998 By Ed Kolano

Me: How about letting me write an article about controlling the flight path angle on final approach?

Editor: You mean whether power or elevator controls airspeed or glideslope?
Me: Yeah.

Editor: No.

Me: No?

Editor: It's been done, re-done, and done again, and it makes pilots angry.

Me: But I can write a completely non-controversial, practical treatment that wouldn't upset people.

Editor: No hate mail? No irate readers telling me I don't know what I'm talking about, even though you wrote it? Completely non-controversial?

Me: Would I lie to you?

Editor: Okay.

I've flown a few final approaches where everything was perfect and I didn't have to touch a thing. The power setting and trim were right on, and the wind cooperated. Airspeed was perfect and the airplane tracked the glideslope all the way down the approach. All I had to do was revel in my luck. If skill had played a part in these rare approaches, I would have had more of them in the past 22 years, and at least one wouldn't have happened on a solo flight.

On an approach to landing, skill enters the picture when the airplane deviates from the desired flight path. A little too much power, not enough back-yoke, not trimmed properly, or maybe that rare occurrence - wind at the airport - are all suspects in the final approach flight path mystery. Flight path control is a continuous series of corrections that results in progressively smaller deviations so the airplane arrives exactly where it should, in position to land.

The pilot's goal is to be on glideslope, or flight path angle for visual approaches, and on the recommended approach airspeed. In the airplanes most of us fly, we have two tools to control flight path and airspeed once we set the landing configuration (landing flaps, trim set, and, if applicable, gear down) - the yoke and the throttle.

**What Does Throttle Control?**

Throttle controls power. More throttle causes the engine to produce more power and vice versa. The propeller uses that power to create the thrust that pulls the airplane forward.

Power is the rate of energy change. For this discussion, an airplane in flight has two kinds of energy. Kinetic energy is associated with the airplane's speed, and potential energy depends on how high the airplane is flying. Changing the power setting affects one or both of these types of energy. The larger the power change, the quicker the change in the airplane's energy state.

Let's say we're flying straight and level at a constant airspeed and power setting. Then we add some throttle. If we keep the airspeed from changing, the airplane climbs. We've prevented a change in kinetic energy by keeping the airspeed constant and the airplane builds potential energy by climbing. The rate of climb depends on how much power we added.

It works the same way on final approach. If we start from a stabilized condition with a specific airspeed and rate of descent, adding power - and maintaining the same airspeed - results in a reduced rate of descent. Add enough power and the descent transitions to a climb. If we reduce power instead, the rate of descent increases. So it appears we can control the airplane's rate of descent by adjusting the power and maintaining a constant airspeed.

Let's return to straight and level flight. We'll add power, but this time we'll hold the altitude constant. Because we're preventing any change in potential energy, kinetic energy must change, which means the airplane accelerates.

Back on final approach, we can hold a constant rate of descent when we change the power. Again, when we add power an energy change must occur somewhere, so the airspeed increases. It appears we can control airspeed by adjusting the power and maintaining a constant rate of descent.

**What Does Yoke Control?**

The yoke is connected to the airplane's elevator, so that's what it controls. The elevator's deflection angle determines the airplane's angle of attack. Angle of attack (AOA) is the pitch angle between the relative wind and some fixed longitudinal reference on the airplane, usually the wing's chord line. The elevator doesn't really elevate anything except the AOA.

When you pull the yoke back, the airplane pitches nose-up because the elevator is commanding a new AOA. When the wing reaches its new AOA, the pitching stops and the airplane flies at this new AOA.

Lift and drag change as the AOA changes. With the drag change comes an airspeed change. This is how the yoke controls the airplane's airspeed.

If we pull the yoke back slightly in level flight and with a constant power setting, the airplane pitches up slightly then settles onto a new AOA at a slower airspeed. Even though we haven't touched the throttle, the airplane is probably climbing because it needs less power for level flight at the slower airspeed. The excess power causes a climb.

If we were flying the original level flight condition at a slow speed, the airplane might have been operating on the back side of the power curve. In this case the new, slower airspeed would be accompanied by a descent instead of a climb. In either case the airplane is flying slower than it was at the original AOA.

If we were flying down the glide path, moving the yoke forward or aft causes the airplane to accelerate or decelerate, just as it does in level flight. The rate of descent changes because of the power excess or deficit, just as it does in level flight. So while we can use the yoke to control airspeed, doing so also changes the rate of descent if we don't change the power setting.

**A Little Deeper**

If power is constant, Figure 1 shows the relationship between airspeed and rate of descent. The airplane is in a rate of descent no matter what airspeed it's flying because the power setting is low, as it would be for final approach.

If we use the yoke to change our airspeed, this "moves" the airplane along the curve. For example, let's push the yoke forward, so the airplane accelerates from 60 to 80 knots (Point A to B in Figure 1). Notice the rate of descent increases from 300 to 500 fpm. Every airspeed change made with the yoke alone results in a rate of descent change.

Now let's see what happens when we change the power. Figure 2 shows three nearly identical curves. Each curve represents a different power setting for the same airplane. Naturally the higher power settings result in a lower rate of descent, so the higher the power setting, the higher its curve appears on the graph.

We'll start with the airplane on final approach at Point A. If we add power - but keep the airspeed constant - the airplane moves from one curve to a higher one (A to B). The additional power has reduced our rate of descent, but our airspeed hasn't changed.

Let's go back to Point A. This time we'll maintain our descent rate when we add power. The higher power setting still means the airplane moves to a higher curve, but our prohibition on changing the rate of descent means the airplane accelerates from A to C.

It appears that by using throttle only, we can control either rate of descent or airspeed. Realistically, we would need an accompanying yoke input to maintain the constant airspeed or rate of descent because changing the power setting usually causes the airplane to pitch nose-up or nose-down.

## Flight Path Angle

So far we've explored the effects of yoke and throttle manipulation on airspeed and rate of descent, but the more pressing issue on final approach is flight path angle (FPA). VASI (visual approach slope indicator) and the ILS glideslope needle are two pilot references for FPA, not rate of descent. Let's now take a look at how the yoke and throttle effect changes in FPA.

FPA is the angle below horizontal the airplane is flying, and it can be depicted in a speed triangle as shown in Figure 3a for a no-wind situation. The airplane's true airspeed is along its flight path, and its rate of descent is the vertical segment. The horizontal segment is the horizontal component of the airplane's speed, but we don't need to deal with it here. There's a simple rule of geometry that tells us the angle between the horizontal speed component and the flight path component is the same as the FPA.

Compare the speed triangle in Figure 3b with 3a. Notice the rate of descent (length of the rate of descent arrow) is less in 3b than in 3a, but the FPA is steeper. This important observation means it's possible to reduce our rate of descent but end up coming down at a steeper angle - and short of the runway.

Need to be convinced? Figure 4 is a composite plot of rate of descent and FPA versus airspeed for a Cessna 172 with full flaps and idle power. Let's say the pilot is flying at 65 knots. If the pilot attempts to correct for being below glideslope by pulling back on the yoke and decelerating to slightly below 60 knots, the FPA becomes steeper. The pilot may initially believe he's made the correct adjustment because the rate of descent decreases. Eventually, however, he'll notice that the situation has become worse as the airplane drops even lower below the glideslope.

Both the flight path speed and the rate of descent determine the FPA. Whether the FPA becomes steeper or shallower following an airspeed change depends on the associated rate of descent change. The small airspeed range between 57 and 63 knots in the example represents the back side of the flight path stability curve (FPA vs Airspeed) where things appear backward. On the back side, flying slower results in a steeper FPA, and flying faster results in a shallower FPA.

My Cessna 172 pilot operating handbook recommends 65 to 75 mph (59 to 67 knots, after applying pitot-static error corrections) for a full-flap final approach speed. Half of this airspeed range is on the back side of the flight path stability curve, according to our data.

Referring to Figure 4, flying faster always increases the rate of descent and steepens the FPA, while flying slower (but never slower than 63 knots) always decreases the rate of descent and shallows the FPA. The implication here is FPA adjustments can be made intuitively with the yoke alone as long as the airplane is on the front side of the flight path stability curve. In Figure 4, 63 knots is at the apex of the front and back sides of the flight path stability curve. Yoke-only FPA corrections on the back side would require non-intuitive control inputs. If the airplane were below glideslope and on the back side of the curve, the pilot would have to push the yoke forward and allow the airplane to accelerate to achieve a shallower FPA.

Had our pilot opted to control his FPA with power, the corrective throttle adjustments would have been intuitive on both the front and back sides. Changing power settings has the same effect on the flight path stability curve as it does on the rate of descent curve. Adding power shifts the curve upward on the plot, and vice versa. A power addition with airspeed held constant shallows the FPA while reducing the rate of descent; a power reduction causes a steeper FPA and increased rate of descent

**Enter the Real World**

At this point it may seem like power should be used to control the FPA. Well, we have a few more layers of this onion to peel before we're ready to draw conclusions. Pilots can use power for precise FPA control. Navy carrier pilots use this technique, and on the list of precision approaches and landings, carrier landings are at the top. But this technique is driven by other factors such as the extremely tight AOA tolerance at touch down for arresting hook engagement.

For the rest of us who flare when we land and don't have 20,000 pounds of thrust at our disposal, power might not be the FPA control of choice. It takes time for a power change to take effect on the FPA. This delay can lead pilots to think that their correction isn't enough, and they might be inclined to make another power change before the first one has taken effect. This can lead to chasing the FPA from above and below all the way down final.

Our tolerance for this delay decreases as the airplane proceeds down the glideslope and gets closer to the ground. The time available to sort things out is running short, and we may demand quicker corrections, which means larger power changes. We can opt to avoid power changes after a certain point on the approach, but this can place the airplane in a position where the only safe option is to go around, which is always the safest way to "fix" a less-than-perfect approach.

Adding to this sense of urgency is the apparent sensitivity of the FPA indicators. Small altitude changes result in larger FPA changes the closer the airplane gets to the threshold, so the ILS needle and visual FPA indicators (such as VASI) appear to be more active.

Making FPA adjustments with the yoke can offer a few advantages, assuming the airplane remains on the front side of the flight path stability curve. Yoke inputs move the airplane's nose in the direction the pilot wants. If the plane is above the glideslope, the pilot pushes the yoke, and the nose immediately lowers. This immediate feedback may reassure the impatient pilot that he's made the proper correction.

Monitoring the magnitude of the correction may be easier with yoke corrections than with throttle corrections. With the yoke the pilot can establish a new pitch attitude and keep close control of it by referencing the attitude indicator. Monitoring power changes takes the pilot's eyes away from the primary scan to the manifold pressure or RPM gauge. These indicators may take a second or two to stabilize at the new setting.

Besides the immediate yoke-correction response of the nose moving, the delayed response of increased rate of descent and steeper FPA associated with the faster airspeed is also in the proper direction. In short, controlling the FPA with the yoke generally works faster than using the throttle.

Controlling FPA with the yoke raises the question of airspeed, because with this technique an airspeed change is necessary to change the FPA. How much excess airspeed can you accept as you enter the flare? Do you have enough runway to dissipate those extra knots? If your yoke corrections result in a slower-than-desired airspeed, is the airplane now on the back side? Are the flight controls less effective at the slower speed? Can you accept the reduced stall margin? Is there enough airspeed to execute the flare and arrest the rate of descent prior to touch down?

**A Hands-on Look**

Years ago, while I was preparing for my airline transport pilot certificate at Air Desert Pacific, I began flying ILS approaches in a twin-engine Piper Seneca. I flew them the way I flew Marine Corps jets - throttle for FPA and stick for AOA. This worked okay when the airplane was on the upper part of the glideslope, but it caused problems closer to the runway.

When I had enough time to be patient for my glideslope corrections to take effect, small throttle adjustments produced smooth, controlled changes in FPA. Closer to decision height I didn't have that much time so I had to supplement my throttle changes with yoke inputs. It didn't work very well, particularly during single-engine approaches under the hood.

My instructor suggested that I use the yoke to control the FPA, then adjust the throttle to correct any airspeed change once I re-established the correct FPA. My FAA examiner was emphatic that this was the only way to fly an ILS. Most glideslope corrections resulted in only a few knots difference in airspeed, allowing a primary concentration on glideslope and a less urgent concern for airspeed.

Preparing for this article I returned to Air Desert Pacific to evaluate both techniques. I flew several ILS approaches in a Mooney M20J, intentionally deviating from glideslope then using the yoke for airspeed and throttle for FPA or throttle for airspeed and yoke for FPA. Approach speed was 90 knots, there was no wind, and I wasn't wearing the hood.

As long as the deviations were small, small throttle adjustments worked fine to control the FPA. Yoke inputs were necessary to maintain the airspeed when I moved the throttle, complicating the task slightly. For example, reducing power when above the glideslope required a slight pull on the yoke to avoid an airspeed increase from the nose-down pitch associated with the power reduction. The result was that I had to pull back on the yoke (until re-trimming) while coming down more steeply.

When glideslope deviations occurred near the bottom of the approach, the delay between throttle adjustment and FPA change was unacceptably long, which meant a missed approach.

Using the yoke for FPA control worked well throughout the approach. I still had the same glideslope sensitivity issue near decision height, but the fact that the airplane responded immediately to my yoke inputs was reassuring. The FAA examiner was right - the airspeed changed only about five knots during the various deviations and corrections. I readily corrected that with a small throttle adjustment.

I achieved the best results by flying the FPA with the yoke and keeping airspeed under control with the throttle. This coordinated yoke and throttle technique is supported in the FAA's Flight Training Handbook, Advisory Circular 61-21A.

Keep in mind other airplanes have different flight path stability characteristics. Airspeed deviations from yoke-control of the FPA may be larger in some airplanes, requiring more aggressive throttle coordination. In others, airspeed deviations may be smaller, allowing yoke-only control for small FPA corrections.

The best advice is to learn your airplane's flight path stability characteristics in a safe environment, away from the ground. Then fly several approaches using variations of the techniques discussed to find out which one works best.

See - completely non-controversial.

*By the way, the editor's address is 201 Main St., Parkville, MO 64152. Editor's note: you can reach Ed Kolano at edkolano@mail.ameritel.net.*

Writing any article requires research. Because "Yoke or Throttle?" has a potential for controversy, doing my practical research where the topic first came to mind seemed to be a good idea, so I returned to Air Desert Pacific (ADP), a Part 141 flight school at Brackett Field (POC) in La Verne, California - about an hour's drive from Los Angeles.

I called ADP President Ari Lapin and asked for his help in the form of an airplane and an experienced CFII. His immediate, enthusiastic support reaffirmed my belief that the ADP slogan, "We'll treat you like family" was indeed a corporate philosophy.

Lapin started ADP in 1987 as a one-airplane flight school with himself as its sole instructor. Today ADP has a staff of 22 full-time flight instructors helping students earn every fixed-wing rating from private pilot through ATP, including multiengine and instructor ratings. ADP's fleet of 29 airplanes includes the Warrior, Archer, Arrow, Mooney, Lance, Seneca, Aztec and Navajo. ADP also uses the larger airplanes for Part 135 operations, offering valuable experience to its appropriately rated staff pilots in addition to the opportunity to build flight time through instruction.

Although an aggressive training program is available, instruction can be tailored to the individual. Every student can essentially set his own pace, helping to ensure a quality education. An average of 30 to 40 students per month fly 30,000 hours annually. The school has its own Frasca 132 multiengine flight training device, which students have unlimited use of during their rating package training. ADP doesn't provide formal classroom training, but instructors use the school's Jeppesen texts and videos to augment their own one-on-one instruction.

When students are ready for the FAA knowledge test, they can take it on one of the three CATS work stations at the school. When it's time for a checkride, ADP maintains a list of five designated examiners in the local area, with an additional dozen available nearby. Perhaps more important is how ADP treats its students. Beyond competitive pricing and ratings packages, ADP picks up every student upon arrival in the L.A. area and arranges a rental car and discounted lodging (hotel, dormitory, and even private homes) for the duration of the student's training.

**Ed Kolano**