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Trimming from the Ground Up
By Dean Pappas

YOU LEARN a lot from watching what happens at the flying field on a Sunday afternoon and even more from the beginners. You learn what the basic flying skills really are and, most important, you see the beginners struggling with their trainers' shortcomings.

Is your trainer a well-behaved goldfish or a dangerous shark? It doesn't take that much effort to turn one into the other.

In all fairness, even the best of these designs are often built (or assembled from ARF kits) by inexperienced enthusiasts. It would be almost impossible for it to be any other way!

So much hard-earned experience goes into building a well-behaved RC airplane, more goes into installing the mechanical and electronic systems, and even more goes into adjusting or trimming for best flight performance. The purpose of this "From the Ground Up" installment is to make it easier to gather that knowledge and experience.

When I refer to "best flight performance," I don't mean making your trainer perform like a P-51; I mean getting your model to perform its intended "mission" as well as it was designed to. For a trainer that mission is to be well behaved, predictable, and have solid control, especially during takeoff and landing.

The mission of sport and Scale airplanes is similar to the following—with some additions, depending on the type of model. It would be good for a Scale airplane to be well behaved while performing any maneuver that is typical of the prototype. For the sport flier it would be nice if the airplane's predictable behavior helped him or her "look good" while enjoying the sport.

On the other hand, many airplanes have what we often call a "personality." That's code for "It ain't quite right but I'll live with it."

Sometimes experienced fliers do not even realize they're living with a model's undesirable quirks; either their skills are good enough to cover for it or maybe they have never had their hands on a dead-honest airplane. It can be an eye-opening experience! Students don't have those skills yet, and they have no basis for comparison at all; and that can be a problem.

That, in a nutshell, is why we are here: to learn that you don't have to live with it. We can make it better and your flying will benefit at all skill levels, from beginner to highly competent. Most important, as a student your learning curve can be shortened if your airplane is working with you rather than against you.

The Kinds of Problems to Be Fixed: Your Model's "Personality Problems": The list of common trim problems is not that long. It doesn't have to be because any problem can make flying your

airplane difficult. Multiple problems usually add up to more than the sum of the individual parts. There is often more than one cause for a particular problem, and we must figure out where to attack.

1) Poor aileron control response (especially at low airspeed) and directional trim that changes at different airspeeds make accurate flying difficult. These two problems can make it unnecessarily hard to learn to land.

It's tough enough for a student to learn left from right while on the landing approach, but if the airplane tends to deviate to one side and then the control you use for correction becomes sluggish, you have the beginnings of a panic situation. This is supposed to be fun, and we just don't need panic situations!

2) A tendency to veer off in one direction (usually the left) when climbing or when full power is applied adds an unnecessary workload during takeoff. Combine this with poor aileron control response, and you have another potentially unsafe combination.

3) If your airplane drastically changes pitch trim with changes in throttle and airspeed (meaning it's either climbing or diving without elevator input), it's a problem that can lead to a loss of airspeed and control at the wrong time. This can combine with both of the preceding to create even bigger problems.

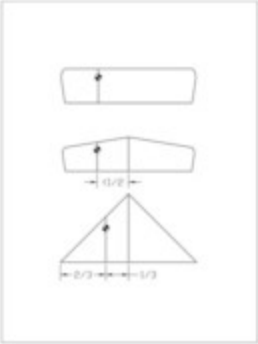
The trick in checking the balance point by hand is to place a thumb under the wing at the same place on both sides. For low-wing airplanes, do the same upside-down. A piece of tape, on both sides at the CG location shown on the plans, helps you place your thumbs evenly. Zachary Pappas photo.

Depending on the airplane's mission, we often intentionally set it up to climb with full throttle (but not too steeply), to maintain level flight at cruise power (maybe a bit more than half throttle), and to finally descend at a gentle glide slope (with enough airspeed for good control) at a fast idle.

4) This next problem is closely related to the preceding problem. If the airplane does not settle into a predictable glide slope when the throttle is reduced, this can add to the pilot's workload during final approach and landing. A proper glide has a predictable sink rate that is just steep enough to maintain adequate airspeed for good control, but it is not so steep or so fast that it makes it hard to get the airplane to settle to the ground in the flare.

The flare is that last portion of the landing, in which up-elevator is added to almost stop the descent rate and bleed off the last bit of excess airspeed. This makes the model touch down in a three-point attitude if it is a tail-dragger or with the main gear first and the nose wheel an inch off the ground in the case of a tricycle-geared model.

If the glide is too shallow, the airplane will mush along with the nose up and with low airspeed, leading to poor directional control authority. This often leads to the problems in item 1. You will often find experienced pilots landing a particular airplane "hot," or fast, every time because the model has a controllability problem at low speed.



Constant-chord wings have an easy-to-find MAC. The balance point is normally one-quarter of the way back, on the MAC. For tapered and swept wings, find the location where half the surface area is inboard and half is outboard. That is the MAC. It is only one-third of the way out from the middle on delta wings.

The Pitch-Control Balancing Act: Predictable control is a balancing act. There is a balance of forces always at work to make the airplane fly straight and level, to climb, and to descend. When the forces are not precisely in balance, the airplane will be changing pitch—either nosing up into a climb or dropping into a dive.

The dominant forces are aerodynamics, gravity, and engine thrust. That's not much of a surprise, is it?

I don't want to give a whole course on aerodynamics here, so this explanation will not be entirely rigorous, but I do want to give you a feel for how these forces juggle so that the kinds of adjustments we make later will make sense.

For almost all "normal" airplanes the horizontal tail holds the tail end of the airplane down. The wing makes lift, and the act of making lift creates a nose-down torque. This is for two reasons, the first of which is that for stable flight (again, for almost all normal airplanes) the CG, or balance point, is in front of the wing's center of lift.

The second reason is that as the wing bends the passing air downward, it can be said to rotate the airflow; therefore, the air imparts an opposite, nose-down rotation to the wing and the airplane to which it is attached. Although it's simplistic to put it this way, the wing pushes down on the passing air and the passing air pushes up on the wing.

Along with this nose-down torque, which is a by-product of making lift, add the nose-up effect of the horizontal-stabilizer incidence angle and the level-flight trim position of the elevator. Ideally the elevator should be straight, as compared to the horizontal stabilizer, but sometimes it is necessary to trim the elevator up or down a bit.

Finally, there is the small nose-down torque caused by the engine downthrust. That effect is changed by the engine's throttle setting; at idle the trim force caused by downthrust is nil, while at full throttle it can be important. This makes downthrust an important part of the pitch-trim balance "see-saw." Look at the diagram showing pitch see-saw and the diagram showing incidence angles and downwash.

There is also a balance of forces in roll or from side to side, but I'll cover that later.

Pitch Trim: In the list of preceding problems, items 3 and 4 were devoted mostly to pitch issues; we'll start there.

First we should tend to a few details of the sort that are best taken care of at home, in the workshop. That's right; trimming (just like charity) begins at home.

To begin with, make sure the balance point, in the fore and aft direction, is where the plans or instructions indicate. If the plans show a range of positions, as they should, shoot for somewhere in the forward half of that range. We call that a "nose-heavy" CG.

The ideal balance point is not a well-defined location for a particular airplane design. It can vary a bit depending on the flying for which your airplane is intended. It also depends on the all-up weight, the size and location of the fuel tank, and small differences in building or assembly.

A quarter of a degree difference in the incidence angle between the wing and horizontal stabilizer in your airplane compared to the designer's can change the ideal CG location. For that reason, most designs show a CG range.

As the CG moves aft from the initial nose-heavy position, the airplane becomes less stable in pitch. This is not necessarily a bad thing; excess stability makes an aircraft more sensitive to airspeed changes and makes it less maneuverable.

On the other hand, if the model is too tail-heavy it tends to have a short life! Instability, or even near-instability, causes many crashes.

As an airplane gets close to tail-heavy, the first sign is that elevator control gets touchy. When a model is set up at the aft end of its CG range, the elevator control will usually be more powerful. But if it gets jumpy, or the airplane feels as though the elevator trim is inconsistent, you are flirting with tail-heaviness.

For more advanced sport airplanes with semisymmetrical or symmetrical airfoils, an important factor in where the CG belongs is inverted flight. If it takes too much down-elevator to fly inverted, the model is likely nose-heavy. If it takes no down-elevator, or even climbs sometimes, it is definitely tail-heavy. A jumpy elevator is a sign of near-disastrous tail-heaviness.

If your airplane always seems to run out of elevator authority when it comes time to flare for landing, it could be a sign of nose-heaviness. That is not the only reason for this problem, but I'm mentioning it at this point for completeness' sake.

Checking the CG: To find the balance point, you need to hang the airplane from somewhere above its three-dimensional CG. All that really means is that if your airplane has a high or shoulder-mounted wing, you can hold it up using one finger on each hand under the wing. If you have a low-wing airplane, you may find it easier to do this with the model upside-down. A photo illustrates this technique.

Make sure to place both fingers the same distance back on each wing panel, and move back and forth until the airplane hangs level. A typical safe starting point for almost any airplane is if the CG is placed at 25% of the mean aerodynamic wing chord (MAC). The farthest back the CG usually gets on a typical trainer is 33%, or one-third, of the MAC.

Flying wing and tailless models typically fly with the CG at 15%-20% of the MAC. On a constant-chord wing, the 25% point is exactly one-quarter of the way back from the LE to the TE. Most trainers are designed with constant-chord wings.

Once you have found the starting balance point, move equipment if necessary to make the airplane balance properly.

When the balance point is incorrect, the first thing that typically gets moved is the battery pack for the radio. Most often the battery has to be moved forward under the tank to move the balance forward. If that isn't enough, you may even consider using a heavier, larger-capacity battery. After all, nickel and cadmium are useful heavy metals, and lead is just dead weight.

If you must add nose weight, place it as far forward as practical so that less is necessary. The weights that mount to the crankshaft are not generally recommended.

If, on the other hand, your airplane is nose-heavy to start with, it is slightly easier to move the battery and receiver aft. The receiver is relatively fragile in a crash and expensive compared to the battery, so keep the receiver behind the battery! If you must add tail weight, place it as far aft as you can, on the fuselage, because less will be necessary.

One more thing: take a good look at your airplane to make sure the wing and stabilizer are mounted exactly as described on the plans. You are looking for incorrect incidence angles, which could force you to counteract them with excessive amounts of elevator deflection.

Oh yes, one more thing. Make sure the elevator trim on the transmitter is centered and the elevator control surface is straight. That will require a control-linkage adjustment. You don't want to run out of trim-lever movement because you didn't set the elevator straight to begin with. That goes for all the other control surfaces too!

Going Flying: Most trainers are designed to climb at full throttle and fly in level cruise at a power setting just above half throttle without having to change the elevator trim. On takeoff your test pilot will take this into account and wait until the airplane is throttled back to cruise power before making any fine elevator-trim adjustments for level flight.

Now, the importance of knowing that the elevator was straight with the trim lever centered will become apparent. As you first put trim into the airplane, you already have some idea of what you are dealing with. Does it need up or down from the ideal, and roughly how much?

That's better than waiting until after landing to look and see that all that furious wiggling of the transmitter trim lever was just to get things straight!

Pitch Flight Testing: Now that the airplane is trimmed for level cruise, let's do a couple simple tests. Smoothly advance the throttle to full. Without making elevator corrections, but still keeping the wings level with minimal, smooth aileron control inputs, watch the climb that results.

Is the climb too shallow and fast? This might be ideal for an advanced sport airplane, but for a trainer you want a solid climb with adequate airspeed.

Is the climb too steep? Watch to see if the climb is so steep that the airspeed has decayed.

Has aileron control become sloppy?

Is it difficult to promptly correct the wind's effects? If so, that is a sign that the airspeed is too low because of the steepness of the climb. In that case, you can do one of two things: make the airplane less speed sensitive by moving the CG aft and adding down-elevator trim or add more downthrust. If the airplane climbs too shallow, you would do the opposite.

How do you decide whether to change the engine downthrust or the balance of aerodynamic trim and balance point? Maybe you should use a combination of the two. You need more information, and to get it we use the low-throttle glide test.

For the low-throttle test, set up a straight and level pass, parallel to the runway and roughly 100 feet up. Trim for cruise power level flight and with your hand off the elevator stick, quickly reduce the power to maybe one or two "clicks" above a dead idle just before the airplane passes you.

This is the throttle setting that most of us use for the all-important final approach. Near the threshold of the runway, the engine is slowed to low idle.

Watch the glide slope that results, again keeping the wings level but making no elevator corrections. Does the model settle into a nice glide angle or does it come down like a space shuttle?

Maybe the glide slope is too shallow and the airplane wallows along in a near stall; that is, with the airspeed too low. In that case the directional control will get sloppy too; the ailerons may get sluggish or the airplane will slowly drift off to one side even though it was trimmed for straight and level flight.

Sometimes poor aileron control manifests itself as what feels like a time lag between when the aileron control is applied and when the model actually starts to roll in the desired direction. It will get better if you push the nose down a tiny bit. That's another hint that the glide slope is too shallow.

Now that you've done both tests, it's time to assemble what you have observed and make a change to the setup. If the model has insufficient downthrust, the elevator would have to be trimmed level or slightly down for level flight compared to where it would be with the correct downthrust. Alternatively, the airplane would have to be nose-heavy. See the pitch see-saw diagram.

If the airplane needs more downthrust, at full power it will climb too steeply because the nose-up engine thrust is great. It will also glide too steeply when the nose-up engine thrust is missing and the down-trim or nose-heaviness takes over.

It is also possible that the airplane climbs too steeply under full power and glides okay or a little steep if the model is nose-heavy. That means it is overly stable in pitch and responds to the added airspeed by trying to climb too much.

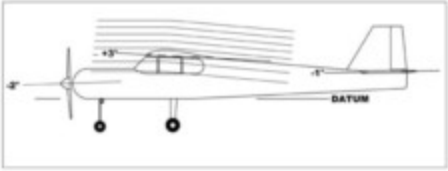
How can you tell if this is the case? If the elevator is trimmed up for level flight, even a bit, this is a hint that the airplane is nose-heavy and the aerodynamic trim was necessary to counteract it.

Which Pitch Adjustment to Make?

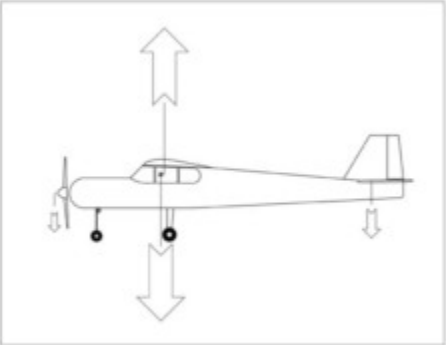
• If the climb or glide is too steep and the elevator trim is up.

The trick in telling the difference between nose-heaviness and insufficient downthrust in a model that climbs too steeply under full power is to look at the elevator trim. If the airplane carries up-trim, move the CG back approximately one-quarter inch, retrim for cruise power level flight, and do the full-throttle climb and low-throttle glide tests again.

If the elevator trim is still up compared to the stabilizer, move the CG back another quarter inch and retrim again until the elevator trim is level or close. If the climb and glide are acceptable, even though there is a bit of elevator trim, it is okay to stop there. Even a bit of down-trim is okay. After all, we are interested in results.



Forces, or torques, that contribute to pitch trim are in perfect balance anytime the model is flying level, climbing at a constant rate, or gliding downward at a constant rate. Any imbalance means the model is changing pitch angle. The engine downthrust, the lift of the wing, the weight of the airplane, and the tail downforce all sit on the pitch see-saw.



If you have to move the CG back far enough that down-elevator trim becomes necessary to achieve trim for cruise power level flight, you really should move the CG forward the last step and start to add downthrust.

• If the climb or glide is too steep and the elevator trim is near neutral.

If the airplane had no noticeable up-trim to begin with, add downthrust, retrim for cruise power level flight, and do the climb and glide tests again.

Of course it is possible that your model needs both adjustments. Start by moving the CG back to get rid of excess up-trim. If the climb is still too steep, add downthrust.

• If things don't behave.

If at any point in this process you move the CG back and the model gets touchy in pitch, you need to stop and check the CG location. Your airplane is almost certainly tail-heavy. Move the CG forward to the last location where the elevator control felt predictable.

It's rare that an RC sport model or trainer ever needs the CG to be placed more than one-third of the way back on the MAC and, as I mentioned earlier, a normal CG is closer to one-

quarter of the MAC. If you have stumbled onto tail-heaviness using this method, you need to put the CG back at a position where the elevator control was predictable.

If the airplane still needs a great deal of elevator trim to fly level, you should look at changing the wing incidence. If it needs a lot of up-trim, shim the LE of the wing up on a high-wing airplane. If the model needs a lot of down-trim, shim the TE of the wing up.

When you change the wing incidence, small steps such as 1/16 inch are best. If more than one adjustment is necessary, so be it, but drastic adjustments can have unpredictable consequences.

Again, the goal is to get the model to trim in cruise power level flight with the elevator closely lined up with the stabilizer. Any remaining problem with a steep climb and glide is almost certainly because you need more downthrust.

• If the climb or glide is too steep and the elevator trim is down.

The likely cause for this is that the wing and/or stabilizer incidences are wrong. The wing and stabilizer incidence angles are creating a strong nose-up tendency, which gets even more powerful at high airspeed.

You either need negative (TE up) incidence in the wing or positive (LE up) incidence in the stabilizer. The wing is usually easier to change. This is a sign of a model that has excessive pitch stability and excess horsepower.

Trainers are intentionally quite stable, but such designs do not tolerate overpowering well. In this case the cure is not to have less power, but to put the airplane in “low gear” with a propeller that limits the top airspeed.

A larger-diameter, low-pitch propeller or a three-blade propeller with the same diameter and lower pitch will help limit the excess speed while harnessing the same horsepower. This airspeed-limitation trick is typically useful if the full-power climb is too steep.

Another way of reducing this problem is to trail both ailerons up approximately 1/32 inch. I will not go into this at length right now, but it will come up later in the section about improving roll control on airplanes with flat-bottom airfoils.

The Opposite Situation:

• If the climb or glide is too shallow and the elevator trim is down—even a bit.

If the model climbs well, or even a bit shallow, at full throttle and then glides nicely or a bit shallow, you want the airplane to change trim with airspeed more than it already does.

Look at the elevator trim to tell whether or not you should reduce the downthrust or push the CG forward. If the elevator is trimmed down, move the CG forward, retrim for cruise power level flight, and redo the full-throttle and low-throttle tests. Continue making adjustments until the elevator trim is level, or at least close to level with the stabilizer.

You may start by moving the CG forward to get rid of the down-elevator trim, and then reduce the downthrust once the elevator trim in cruise power level flight is zeroed out.

• If the climb or glide is too shallow and the elevator trim is level, or even a bit up.

If the elevator was not trimmed down, the CG position is not the issue. Reduce the downthrust.

That about covers basic pitch trim. Next month I will share a method of checking downthrust that is more appropriate for high-performance sport models and airplanes that are intended to be flown fast rather than slow, such as trainers. Then we will test for and adjust right thrust.

Until then, remember that your equipment should be set up to work with you—not against you!

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