Radio Control Scale Aerobatics

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posted courtesy of Peter Goldsmith & Model Aviation (approved by Rod Kurek)

What if, from the very beginning, you learned to fly RC with the radio upside down? Then, two years later, someone said you needed to turn it over and fly right side up? It'd probably be pretty tough because you learned all of the habits the wrong way. Flying a plane that's not fully trimmed is just about as bad. You get into the habit of correcting for poor flying characteristics and end up chasing the plane around the sky during the whole flight. Then when you move to a new plane you have to start over and learn how to compensate for the new plane's different set of problems all over again.

In a conversation with top-rated TOC pilot Peter Goldsmith at this year's Nationals, Pete noted that it didn't look like many of the planes were trimmed well. Some of the pilots, even in the top classes, were chasing their planes around the sky rather than flying the maneuvers. Peter was excited to do something about that problem and I asked if he would write something for this SA column. He graciously agreed. I think this is one of the most important topics that you could get from this column. Peter's approach is systematic, comprehensive and complete. In this first of two installments, Peter covers subjects related to trimming the physical airframe. In the next SA column he'll review how to set up your radio to compensate for poor flight characteristics using a variety of mixing techniques. Tear these pages out of this magazine and put them in a notebook or your flight box. If you follow these steps in the proper sequence you're guaranteed to have a better flying plane than your competitors who didn't!

Peter Goldsmith was born and raised in Sydney, Australia, and began flying radio control at eleven years old. He still remembers his first radio transmitter called a "Bionic Baby", a two-channel dry cell system that his mother bought for him in Singapore. Young Pete had two weeks before his mother arrived home with the new radio so he put that time to good use and designed and built his first RC aircraft. Growing up, Peter says, he would design and build his own planes out of necessity. So, from the very beginning, he was a designer. Peter's first love in RC has been sailplanes and soaring. He loved doing aerobatics with them and through an evolution of events decided to try F3A. His first contest was in 1978. Peter competed on an Australian National level in Pattern up until he came to the U.S. in 2000, and was the Australian National champ from '95 until 2000. During that time he was also a member of the Australian National team for the World Championships making the finals in three of the five Worlds and was awarded Oceanic Champion three times. In Scale Aerobatics, Pete has multiple top-level performances at the Masters and won it in '01. He has placed second in the AMA Nationals three times and won the Freestyle National Championship in '02. Peter competed in the Tournament of Champions from 1992 until it's end in '02. He is currently the JR Team Manager and continues to compete at the very top level. One of the most telling aspects about Peter's RC career is that he has always flown and competed with his own designs, scratch built, and trimmed based on his 25+ years of experience.

Peter Goldsmith: Competing in this year's Don Lowe Masters I was inspired by the raw talent in pilots half my age -- I was honored to place 7th! I began thinking about all the help I had received over the years and felt driven to give back to the new pilots of the aerobatic community, as had been done with me many years ago. Earlier in the same year in a discussion with Mike Hurley at this year's Nats, I shared with him how passionate I am to share my life's aerobatic knowledge, and he invited me to write something about trimming and mixing.

A properly trimmed model can reduce your workload in an aerobatic sequence by an enormous amount. I judged at the Nationals this year and thoroughly enjoyed the experience. I was impressed with the skills, especially in the lower classes, displayed by pilots but noticed most of them trying to fly around a poor trim setup. It drove me crazy to watch! I remember bouncing out of my judging chair and saying to Mike, "boy, I need to help these people!" So here are some thoughts from my own 25 years of experience and involvement with people who shared their thoughts on trimming with me.

First, an observation. There is no such thing as a perfectly trimmed model. Our goal is to reduce our workload in flight when flying sequences. Even if we could get our model perfectly trimmed, we would need perfect flying conditions to benefit from the perfect set-up!

Servo and control setup

3D trim and precision trim typically work against each other. What I mean by this is that when pilots set up their new 40% something, they go straight for the big rates; 35°, 40°, and in some cases 50° of throw. Has anybody thought how this can affect the servo resolution? And more importantly the servo power? Most scale aerobatic events allow a separate aircraft for freestyle. Why not have your free aircraft setup specifically for the free event, then have a precision setup for known and unknowns sequences? I know for me personally having a model just for freestyle will be something I aim to do in the future. That's not always a realistic option, so if you're using the same plane for precision and free, bias it toward a precision control setup.

For precision flying I would expect you to be running between 12° and 15° of elevator throw. If you feel you need more than this, check your exponential as it may be too high. Just as a starting point, 35% expo is what I call a linear feel. What I like to have with my expo is when at half stick, I get about 50% of the reaction of full stick, around 35% – 40% expo gives you this with modest control deflections. If I have my stick at full travel, my aircraft will roll around 360° per second; about right for precision. Now when I only move my stick half way, I should be looking for 180° per second. Make sense?

If freestyle/3D flying is your bag, then you're stuck with the downside of long servo arms and will have to pay attention to the servo power delivered in this environment. With my 46% Cap 232, I use 1" servo arms on all surfaces with the exception of rudder which is 1¼". I have 28° on aileron, 32° on elevator and 35° of throw on rudder. For me, this is a good compromise for precision and free flying, but it's biased towards free. With 1" servo arms, and 1½" distance from control horn attachment point to center of hinge line, I'm getting a 1 to 1.5 ratio. More importantly I am maximizing servo power and control geometry. With 1" servo arms my resolution is better, control slop is reduced, and servo wear is greatly reduced. Another bonus is that I don't need as many servos per surface. Give it a try next time you set up your aircraft. You may be surprised. In fact in some cases you may see no difference in control responsiveness by going to 1" servo arms, as with the better geometry you may be reducing any control surface blow back.

One of the biggest challenges I see pilots dealing with is surface blowback. Blow back is when the servos are overpowered by the amount of pressure on a given control surface during full deflection causing the surface to lose holding power and start to push back towards the neutral position. It can also happen when in neutral trying to hold the plane stable or stop it when exiting a maneuver. With blowback, your snaps will be all over the place, both entry and exits. Getting consistent flying is almost impossible. Every time your speed changes your control response will change. Hmm…. I suspect a few lights just went on. Yep, could it be the fact that you're consistently missing your snap exits is due not to your skills, but control blowback?

When setting up your servos, make sure you run the numbers, do the math and figure out just how much power you are delivering to the surface. All servos are rated at inch ounces -- that is, at one inch from the center of the servo. An 8611 is 266 inch oz. on 6 volts. With a 2" servo arm the applied force is reduced to only 133 inch oz., and around 200 inch oz. with a 1½" servo arm. Years ago I was able to measure the forces on my Cap. Believe it or not, the ailerons required well over 30 lbs of force to deflect at 100 mph! Today there are a lot bigger ailerons out there than mine. Please pay attention to this -- it is crucial to consistent flying. If you have to use 1½" servo arms, or 2" servo arms, you will need more servos.

Sequencing.

My concept of sequencing the trimming process is simple. I can't make this point more loud and clear: It is very important to trim your model in the *correct sequence* to make sure each adjustment has no affect on the previous adjustment. There is an intentional order in which I recommend trimming a model; Model balance, Center of Gravity (CG) is number one. You can't move ahead until you have a CG you're happy with. If you change your CG at a later point you will need to start over and check your entire trim setup. Differential, knife edge flight, down line tracking will all be affected by the CG.

Next is dynamic balancing, or "wing tip weight". Then comes thrust angles, then aileron differential, and finally P mixing, knife edge tracking, roll coupling, down line track and so on. Oh, and if you change your propeller, your whole trim setup will change. 'Duh'. Been there? I know I have. Make sure you're trimming with the same propeller you plan to compete with. When I went from a 2 blade to a 3 blade prop on my 46% Hangar 9 Ultimate, I needed 2° more up thrust and 1° more right thrust, plus everything else changed as well -- knife edge tracking, differential, etc… I had to start all over again. The lesson here is to determine what propeller you'll want to use before you start this trim process.

Balance

OK, how do I know the correct CG for my model? If in doubt, read your model's instructions; that's usually a good place to start. For precision flying, forward is better, but… too far forward can be a problem. I can't put in writing what is the best feel for each pilot, other than it is a feel thing. I can, however, give you some symptoms of too far back and too far forward, plus some simple tests I use to check.

One of my favorite ways to determine the correct CG is spin entries. If, when entering a spin, your model mushes, and kind of slides into the spin with no real stall visible, you may be too far forward. Another sign of forward is excessive down elevator needed for inverted flight. This is not always the reason but is a sign. Rear CG is probably easier to see for most pilots. Some obvious clues are the model is sensitive in pitch, unpredictable around the stall, or climbs when on an inverted 45° line. Again, CG is mainly about feel. The important thing is to determine your CG before you work on any other aspect of trimming your aircraft. I would recommend at least 10 – 15 flights before making the commitment to where the CG needs to be if it's a new model.

Dynamic Balance

Ok, we're happy with our CG. The next trim step is dynamic balance. This is really only relevant with wing tip weight. Most other axes on a model aircraft are not affected too much by the dynamic effects of high g loads. But the wings are. Just because they both weigh the same and don't carry any aileron trim doesn't mean you can't have a wing weight problem. I have seen a myriad of ways to test for wing weight trim. Loops, pulling to vertical, and so on. My suggestion is to think about the sequencing argument. If you do loops, or pull to a vertical upline, the engine thrust can have an effect. But we

haven't trimmed our thrust angles yet, so how do we check this? Think about it, what could you do to check your wing tip weight in flight that will not be affected by thrust?

Some of you may have figured this out already but what I do is put the model into a vertical dive with the throttle back (minimum of 3 – 4 seconds) and pull a hard corner at the bottom. No matter where your wings are in roll, when you pull to level, the wings must be level. Check this concept with your stick plane. It really doesn't matter where your wings are. As you pull to horizontal flight your wings must be level. If you attempt to pull a hard vertical from horizontal, you must be absolutely sure your wings are perfectly level. I don't know about you guys but I am not that good! If you go from vertical to horizontal, not only will the engine thrust have no effect, but your wings can be anywhere as you're on a vertical down line.

When you pull the corner, the aircraft may be pointing in a different direction than you planned, but that is okay, as long as the wings are level. Now I know when some of you try this experiment you will notice one wing will consistently drop. You may have to add some weight to the opposite wing tip. I was never really sure if my tip weight was correct until I went to this method. Make sure you only use elevator through the corner. Perhaps, just for the trimming process, you can increase the aileron stick tension to ensure that you don't accidentally input a little aileron with the elevator and the elevators track correctly when you pull the stick back. Don't be quick to make a decision! Have patience and have a friend observe the proceedings. Do many pull outs and make absolutely sure before you move on to the next step of trimming.

Thrust angles

OK, guys, it's time to put aside esthetics and get that thrust correct. I sure see a lot of spinners perfectly lining up to the cowl these days. One of the biggest deterrents to adjusting for the correct thrust angles is once the plane is built and you make an adjustment, the spinner won't line up any more. Once again, when building your model, pay attention to the instructions. Chances are somebody has figured it out pretty close. I like to test fly the model before I paint the cowl. Once I am happy with thrust, I can make the appropriate cosmetic changes to complete the model before painting. For all the money you guys spend traveling and time you spend practicing, do put good model trim ahead of esthetics!

Setting up the correct thrust angles is fairly simple. Well, it's simple to identify, harder to adjust. Now that we know our wing tip weight is correct, we should be able to, with confidence, pull to some accurate vertical up lines. Number one issue with this is making sure your wings are level. Don't guess. Be absolutely sure your wings are level before pulling to a vertical. I have seen people add unnecessary right thrust as they were not level when pulling corners, leaving an inside wing down (normal human behavior) and the model would lean to the left. What I like to do is to fly directly overhead, into the wind, where I can clearly see my wings, then pull to a vertical up line. OK, up we go, first 100' is good, next 100' is good, moving through 500', still tracking well, up over 1000' now, still straight. If you working at it, the best you can hope for is around 1000 or so feet – plenty for most figures.

Speed will have a huge affect on your thrust angle on a vertical up line. Entry speed, compared to speed under load after climbing to 100', will be as much as 30 – 40mph slower. My goal is to trim as best I can for the first 1000'. If I go for 2000' then I typically end up with too much right thrust at the start of the climb and not enough at the finish. Play the numbers, look at the figures we fly and set your model up accordingly.

Here's a great little tip for making the adjustments. Let's say, after many pull ups you really need more right thrust. As you pass through 500' you can clearly see your model drifting to the left. Here is the

cool tip; apply some right rudder trim, and continue to apply it until it tracks straight. Bring the plane in to land and check your rudder deflection. Use a protractor to see how many degrees of rudder you required for a straight vertical. What ever it is, divide it by 2 and that will be what you need to add to your right thrust. For example, if you have 2° of right rudder, you will need to add 1° more of right thrust. It works both ways. If you need left rudder (too much right thrust) you can use the same equation.

Part 2,
Differential

Aileron differential is one of the most important aspects of model trim. With the multiple point rolls on both up and down lines in today's modern patterns, poor differential can be a real headache. The good news is it's pretty easy to detect and adjust for axial rolls. You'll remember from last time that at this stage of the game, knowing that our CG, thrust, and wing weight is correct, we can proceed with our differential setup.

Aileron differential is required when the drag of the down-going aileron does not mach the up-going aileron. If your ailerons are not working in unison, then your vertical rolls will look like a mess. A quick diversion….Make absolutely sure you are not getting surface blowback. You will never get your differential correct if you are. It's easy to check for blowback. Push to a vertical downline and roll to the right, stop rolling for a second, then roll again. The roll rate should be the same. If it is slowing then your surfaces are not reaching their intended throws. Another way to check is if your up line roll rate is faster than your down. Do what needs to be done. Either increase your servo power, or improve your geometry, by reducing the servo arm radius, and/or increasing the distance the control horn pickup is from the hinge line. Or, if you have lots of cash, add more servos. Whatever path you take, you can't afford to have surface blowback as your flying will never be consistent.

Okay, where was I? Yes, how do we know when to add differential? First of all, make sure you have a way to electronically adjust your aileron travel individually. Most modern radios have a differential program. I have used both the ATV function or the differential function and both work well. Checking for differential problems is pretty simple. I have used this method for years and it works. I want you to use the same technique as before when checking for the thrust. Fly directly overhead and away from you. This time only pull to a 45° upline, making sure you are either directly into the wind, or directly down wind. Now, using full aileron deflection, roll to the right. If the aircraft, "walks to the right", then you have too much down travel on your ailerons. If, when you roll to the right, the model "walks" to the left you have too much up travel in your ailerons. Repeat this process to the left as well until you are satisfied that your model is tracking true in the roll axis.

As with the thrust angles, don't expect your model to continue to roll for 5000' on a string. It just can't be done. As per previous recommendations, go for the majority situation. There are not that many 5000' up and down lines. Fortunately. With the correct differential on your model, you will be amazed how easy it is to do hesitations on lines. Another benefit is in point rolls on a horizontal line. Your rudder will now have an even feel on both sides, as your model will not be barreling in the rolls.

Mixing

You will notice this topic is the last in the sequence but for many people it's where they go first! I get phone calls all the time from excited pilots. "Pete, I just test flew my new Edge; it only has 8% aileron mix and 4% knife edge mixing." Boy, I think, they sure got to the details of trimming their model faster than I can. If you stick to the correct trim sequence you may be ready only after 10 – 20 flights to work on the mixing to fine tune your model.

I've broken down the Program Mix (P-mix) topic into 2 sections. The first is the downline torque offset or throttle offset mixing. Second is the traditional rudder elevator/aileron mixing. Most pilots have a fairly good understanding of the latter, rudder to elevator/aileron, but not many are using throttle offset mixing. I have seen some, but only in the pitch compensation. Pay attention to what your model is doing on a down line, or at reduced throttle (idle) in the roll or yaw axis. One of the side benefits of judging our events is that you see a lot of strange trim situations. I can clearly remember models at the Nationals rolling on down lines, and yawing off axis causing some strange looking down line rolls. It's almost impossible to have perfect trim in roll at all speeds. All you can hope for is to mix in some compensation to help reduce your workload.

Both the yaw and roll axis, in most cases, have a bigger affect on your model tracking on down lines than any other situation. Imagine what the effects of a 5° error on every down line would mean. Over the height of the box you can drift in or out by as much as 150'. The same applies to the roll axis. Ever noticed how hard it is to get your wings level when approaching a pull corner with little time? With your model rolling and yawing at different speeds you will never be consistent. It is hard enough to be absolutely sure if your wings are level, let alone chase an out of trim situation. Good news is that it's fairly easy to compensate for.

Throttle to Aileron Mixing

Let's do the roll axis first. You can do this either of two ways and both work well. In fact, I would suggest you try both to get the best input. Version 1 is to climb to a high altitude, simulating a typical top of the box altitude, and fly directly over your head and into the wind. About 50' - 100' out from yourself, push down. Watch carefully to see if the model is rolling on the down line. Most models will roll slightly to the right as the aileron trim set for full throttle will be too much at low throttle as the torque effects will be greatly reduced.

Okay, I know many of you fly with no aileron trim. That's great but I bet you are carrying trim at reduced throttle. Personally, I have never had a model that hasn't needed a little left aileron mix on low throttle. The second way to check for throttle aileron mix is to fly along at level flight, medium height, and reduce the throttle. Watch carefully and see if your model is rolling; chances are it is. Ever wondered why you always have to lean a little left aileron entering spins, or why your model always falls one way? Perhaps it's because your low power trim is not correct.

Throttle to Rudder Mixing

The second P-mix is the throttle to rudder mix. Again, it's hard to get your model to track correctly in the yaw axis at all speeds. Your only hope is to apply a small amount of "left" rudder on low throttle. To check for this, use the same technique as the throttle to aileron (above). Fly above yourself, directly into the wind and push down in front of yourself and watch carefully. You will be amazed, especially at the start of the down line. If you haven't got any throttle offset to rudder, you are most likely flying around the problem and where I find it most challenging is in figure 9's and vertical and horizontal 8's. Any time you are using elevator and are off on the yaw axis, it's a bad day. I can hear all you guys thinking, yes it's true, your model perhaps could need a little rudder mix on low throttle. Give it a try and you will be amazed.

I know of some fairly experienced modelers that use the same theory but reverse where the mix is. They use little to no right thrust on the engine but have right rudder mixed on full throttle. That works well too, I've been told, but haven't tried it myself. One thing you may want to experiment with in both these scenarios is where the mix is activated. For a low throttle left rudder mix, I like to have the stick offset

start at least above half and let it progress from there as you reduce the throttle. It seems to be the best balance, plus I am not getting a sudden mix input -- it progresses more or less with the speed of the model. This will vary from model to model but try to keep the mix activation well above an idle setting.

Rudder Aileron Mixing

Earlier I made reference to pilots applying programmable mixes in their trim program. Notice that this is the last thing you do. Looking through the sequence, each trim adjustment has complemented the next stage. In most cases, for rudder aileron mix, a linear P-mix is all that is required. What I mean by linear P-mix is that you don't need a progressive value to the mix, i.e. less at the start, more at the ends. The mix will be linear. What causes adverse roll or proverse roll coupled to the rudder is the incorrect dihedral. Most modern designs, with the exception of biplanes, are real close and only require a small amount of rudder aileron mix. Some like to put their model on knife-edge, but I like to just do flat turns, simulating rolling turn inputs.

Rolling turns require more precise mixing than sustained knife-edge flight. In fact, in a contest you don't do much flying on your side at all, but you sure do a lot of rolling turns. So, I like to do the flat turn thing. Doing a simple inside rudder turn to the left, using left rudder, the model should just yaw, with no roll affect. If the roll rolls to the left, then you need to mix 2-5% right aileron to left rudder. My Cap is a little unique as it has adverse roll. When I apply left rudder the model rolls right, so I need left aileron mixed with left rudder. Repeat the process with right rudder. Now what I want you to do is vary the speed in which you do you flat turns. If you find, as you increase your speed, the mix becomes too much, you could be getting surface blowback. Sorry to keep harping about this but it is important. With insufficient rudder power, when you apply a P-mix for roll, or pitch for that matter, the mix value will become too much as the rudder throw reduces due to aerodynamic pressure. I see a few lights going on again. Could this be why you have your mix perfect for knife-edge, but you chase your aircraft all over doing rolling circles?

Rudder elevator mixing

I think about three times in my entire life I had a model that didn't need rudder elevator compensation. As with the previous rudder aileron, start by doing a flat turn to the left and see what happens. If your model pitches down when rudder is applied then mix a small amount of up elevator, or if it pitches up, apply a small amount of down elevator. In some cases, even without blowback, the mix value will not be exactly correct for all throttle settings. Don't panic as with most modern radios suitable for aerobatics you can use what is called a curve mix. This mix allows you to have multiple points along your mix curve to increase or decrease your mix value at different rudder inputs. My Cap is a good example of this. At low rudder throws, I only need 1-2% mix, but as the throw increases I need up to 10%. If I just have a 10% mix it will be too much at small rudder inputs. The curve mix is designed to solve this problem.

Tricks of the Trade

I would like to share a few tricks of the trade to help you with your competition efforts. You probably now have a concept of how much work there is trimming a model. Considering all things equal, you will have a hard time beating a person with the same skills as you with a better trimmed model. It took me 20 years to figure most of this out. Be patient, be observant, and be objective. If your model is not flying right, investigate why. Chances are it's just not trimmed. Even if your models are not perfectly straight, you can trim them. I can almost guarantee my models are at the lower half of building accuracy. They all carry aileron trim and elevator trim. I don't have a nuclear powered building bench, with warp speed laser meters. Nor do I have a 12' x 12', 8" thick granite table to build on.

Don’t feel you have a disadvantage if your model is not perfect. You can trim it pretty well. What makes me laugh is hearing people talk about how straight their wings are, how perfectly their model is trimmed, yet even with a perfectly trimmed model they fly with their inside wing down 5°-10°. If you’re not level in all orientations, vertical and horizontal, both at the top and the bottom of the box, you will have a lot of work on your hands. Probably the biggest progression I’ve made in my flying career was when I learned to fly level. The truth was I didn’t know I wasn’t level!

I started watching other pilots and noticed that everybody flew with their inside wing down, nobody flew level. From that point I went home, made up three flags – red, white, and blue -- and asked my helper to go out and stand under the flight path and keep me level. I think red was for inside wing down, white was for level and blue was for outside wing down. The next month of so was one of the most dramatic learning times of my life. My workload doing maneuvers was reduced immensely. I found myself just waiting for the next input, not my normal 54 inputs all the way up the vertical! I could now pay more attention to corner radius, centering rolls within legs and so on. It was a truly amazing breakthrough. I encourage all of you to investigate flying level.

Finally, many people ask me this question, what’s the best thing they can spend their money and or time on to improve their result at events etc. Should I get a more powerful engine, a better aircraft, what style should I fly, and so on. The simple truth is, all of these things are important but the best thing you can spend your money on is gasoline and oil. Practice. Try to avoid letting your ego be your only motivation. Be objective, be humble, listen, watch, and experiment. That’s what all the TOC and Masters pilots do. Sure, we all have egos, but at some stage of our lives our egos have let us down, we were humbled and forced to listen and be objective. Stay cool and hopefully we can catch up at the next aerobatic event!