

# **Pushrods, Servos and Control Linkages**

## **By Troy Newman**

### **Step One: Choosing the Servo**

Servo choices are central to any thought about linkages. I was told once that you can never have enough servo for the job. Many factors play a role in servo selection.

Speed is good, but more critical for us in pattern modeling are power (torque) and centering or precision. Many of the servos on the market today have plenty of power, but their centering leaves something to be desired. Digital servos are best at centering, as a general rule. However, some brands just don't center as well as others.

### **Linkage Matters**

We sometimes spend lots of money to get the latest and greatest digital servo and then throw a piece of music wire at the linkage, with a Z-bend in it and a sloppy, oversized servo wheel hole. When you buy the right servo for the task, you need to consider the linkage that connects your fingers via radio waves to the aileron, rudder, elevator, and throttle. Linkages need to be stiff, and friction free. You need the connections to be tight and free of any slop.

Next is a look at the geometry involved in how the radio and servos work. These principles are critical to good linkage setup.

Stiff lines and slop-free connections are important. There are many products offered on the market as pushrods. I'd recommend at least a 4-40 pushrod for use in pattern models. This would include Dubro's 4-40 metal pushrods. They're the cheapest and they work. They're not the lightest but they'll move the surface without breaking or failing under the loads we apply.

On the other hand, weight's a big factor. Dubro 4-40 pushrods tend to get heavy. And since pattern flyers are always looking to save weight, the carbon fiber pushrod systems work the best. They're stiffer, lighter, and easier to deal with than old metal rods.

The most readily available carbon fiber rods are made by Central Hobbies. These have titanium ends and are very light and stiff. Remember: the pushrods are your connection between fingers and control surface. So I choose Central Hobbies' carbon fiber pushrods. They're easy to use, and I've never had one fail. In fact, I've never heard of one failing or breaking, when it was correctly assembled.

To check for slop or bend in a particular linkage, turn the radio on with that servo connected and then apply a small amount of force to the control surface. Wiggle the control back and forth, watching both the servo and linkage. There'll almost always be something in terms of gear slop or some give. You'll want to minimize this as much as possible. Nylon-gearred servos are one solution for gear slop. Likewise, a rigid servo tray or mounting rails are important.

### **Step Two: Clevis Links and Ball Links**

I want to deal with aileron linkages to start with. The goal here is to have a "friction free" connection that has no slop. The old method of connecting a Dubro clevis to a plastic twist-on horn tab works well. However, we're dealing with a plane that produces vibration. We're dealing with a model that we plan to fly a lot. And we want it to handle flight #50 as well as it handled flight #5.

The older style linkage is just as good on day #1 as the more costly BB linkage stuff. It's on day #50 that you'll see the holes start to wear. The clevis pin can wear and break in cold weather. The worst case is you lose your model. Best case is the model doesn't fly as well as it can without the linkage slop. I ran such linkages for years and was always fighting them to keep things tight.

You may even get sick of fixing the problem so you convince yourself it can go another 5 flights without repair. Then you fool yourself in actually believing the slop isn't hurting anything. I did that. I thought I wasn't good enough to feel the differences. I wasn't being very critical of my model's performance. A side benefit of improving your flying skills is the ability to recognize when the model just isn't right. Of course, if you've never flown one that's properly adjusted, you have no point of reference.

I'd be willing to bet money that 95% of the pattern models out there today can be improved. Life is so much easier when we take care of the problems.

This belief is one reason I use **MK Ball Bearing clevis links**. These things are bullet proof. I put over 3000 flights on one model — all with the original pushrods and clevis links. They were just as tight on flight #3000 as they had been on flight #1. So I'm sold. They're not cheap but they're worth the extra to me. Not having to change out clevis links means one less thing to maintain on the model. I don't spend time re-trimming the model. I don't spend time in the shop (and not flying) installing new clevises. I don't worry about a linkage failure that will cost me the plane.

I use the MKD0810 (2mm). I use this with the Central Hobbies 2mm Titanium Pushrod Ends. They work great. The pin of the clevis is actually a 2mm bolt and I stick a hex nut on the backside for safety. You can use whatever you like, but I haven't found anything else as smooth or durable as the MK clevis links.

Next is the connection on the servo side. I choose ball links, the kind with a bolt through the pivot ball. There are tons of sources for these things. Hangar 9 makes some, Dubro, and others. I started using the NMP Dual Axis Rod Ends because they're super light and easy to use. They will rotate with the servo, and also pivot up and down to a certain degree as the linkage moves. Central Hobbies sells these things as DARE (Dual Axis Rod Ends). I use the 2mm version with titanium pushrod ends.

Again, I use the Dual Axis Rod Ends because there's zero maintenance on them. It's a "put on and forget it" type of item. They don't wear out.

### **Step Three: Geometry of Pattern Plane Linkage**

Geometry is a huge part of linkage setup. We're now dealing with precision setups not 3D. We're talking about using the servo to its maximum efficiency and using the best mechanical advantage possible on our linkages.

First step: You want to choose surface control horns and servo arms that give you only as much throw as you need. If you're only going to fly on 10 degs of aileron travel why set up the linkage for 20 degrees maximum? I never run my flying rates less than about 80%. Yes that means D/R values are around 80% this gives me some wiggle room to get a little more aileron travel, if needed, but still maintain the resolution of my servos. **You want to run the longest control horn on the surface and the smallest servo wheel you can get away with.**

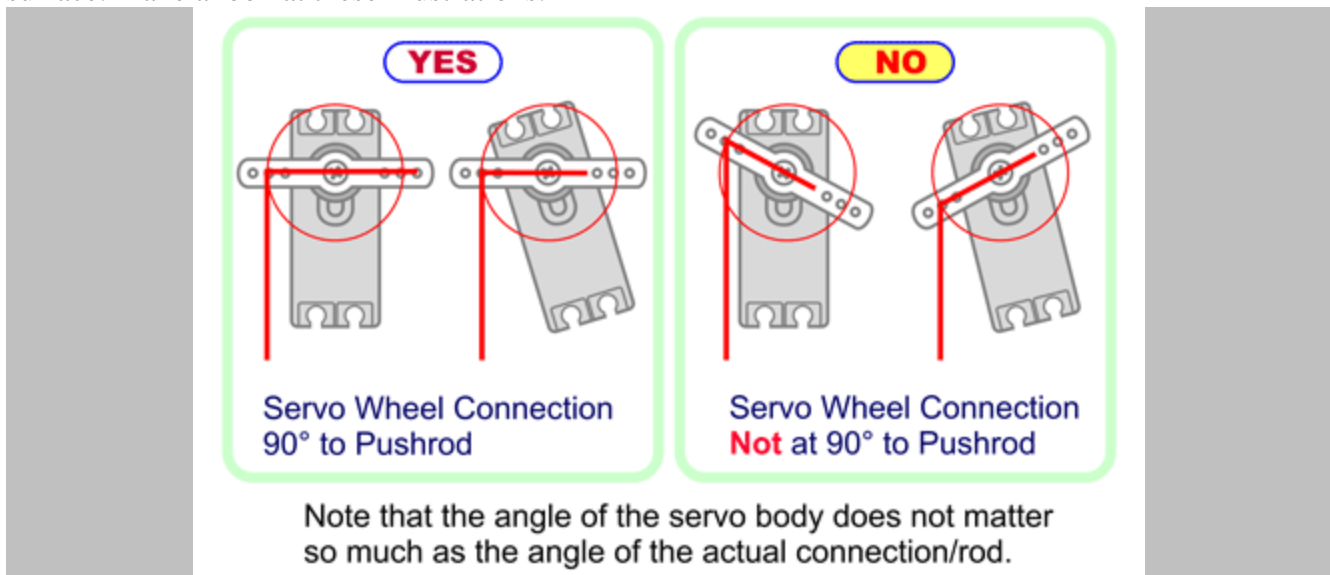
For example, my standard setup is to place the aileron's **control horn clevis "pivot point" at 1-3/8" above hinge line**. And my **servo arms are about 1/2" long**. This gives a better than 2 to 1 advantage to the servo for holding the aileron in the right spot. This leverage helps in loop tracking, rolling, and in getting the plane to lock on and groove.

I used to be a big user of aluminum servo arms, and the linkage was really pretty. Well, pretty doesn't always cut the mustard. I like the aluminum servo arms because they're stiff and don't flex. But they don't need to be 1.5" long. I use the connection hole in the arm that's only 1/2" from the servo's center of rotation. A note if you choose to use plastic arms and wheels with the servos: Use the round wheels. They're the stiffest with the least amount of flex.

Mechanical advantage is the king now on my models. The result has been models that fly better. And they continue to fly better because gear slop and pot wear are minimized by a good mechanical linkage. Lots of guys who set up a 1 to 1 ratio on the linkages find it really tough to maintain them. Not to mention the fact that you just don't need that much travel on the surfaces. If you're setting your dual rates down around 50-60%, you're giving up resolution on your servo.

Make sure your linkage is symmetrical.

Lots of people who'll make sure the pushrods are parallel to the servo case still neglect to look at the symmetry of the linkage. Always make sure the pushrod is connected to the servo wheel or horn at the spot that forms a right angle between the servo arm and the pushrod when connected to the control surface. Take a look at these illustrations.



The two linkages with pushrods at 90° angles to the servo wheels (image on the left) are correct. In the image on the right, the servos with the pushrods attached at points higher or lower than a 90° angle are not correct.

How do you get the servo arm and the linkage to look right, like pictures on the left above?

First, you must totally disregard the location of the control surface to be connected. It need not be centered or inline with airfoil as of yet. You need only to have the linkage connected in order to get the pushrod to come off the wheel at the proper angle, as shown in the diagrams. Notice the servo can be mounted at an odd angle as long as the pushrod is at a true right angle to the arm. Notice the angle formed by the line through the center of the arc's rotation and that of the pushrod. This angle should

remain at 90° when we're dealing with small travels like those on pattern models. When going to larger 3D models we may need to change our geometry a little bit. But similar principals will still apply.

Returning to the question above, how do you get it this way? My servo wheels don't give me a hole that sits at this 90° angle location. So how do I fix it?

There are two ways to get the geometry correct. First of all, there's an odd number of splines or "teeth" on servo output shafts. What does this mean for you and me? **Well, if you rotate the servo wheel 180°, to use the other side of the wheel, you'll move ½ tooth in terms of the angle. This'll help get it closer.**

The next step is accomplished by sub-trim. In fact, this is what sub-trim is for. You all thought sub-trim was a TX's way of keeping a trim setting so that your trim tabs were in center, and the surfaces were aligned with the wing? **WRONG.** Many guys use sub trim this way, but until you get into really good linkage geometry sub trim can actually serve to make your linkage worse instead of better. The key here is to use as little sub trim as possible. As in Zero is good. 80% is bad. But sub trim the servo so that you get the geometry shown in the pictures. After that you don't touch sub trim again.

Next thing is to mechanically adjust your pushrods' length to get the control surface centered. I use 2mm threading because this is a very fine thread. It allows a very fine adjustment on the clevis and ball links. Remember when I mentioned 4-40 hardware? Well, 40 threads per inch is what the 40 stands for, or 0.025 inch per full turn of the clevis. A 2-56 thread is 0.0179 inch per full turn of a clevis. The 2mm threads are even finer than this. Since we're trying to narrow it down to ½ turns of the clevis, 2mm threading produces less than 9 thousandths (0.009") length change per ½ turn on the clevis. This makes fine-tuning the linkage easier and more accurate.

#### **Step Four: Adjusting Servo Travel**

Once you have your linkages set up as shown in the picture, and your control surface centered, it's time to set your ATV's, travel adjust volume, or end point adjustments. JR calls this travel adjust and Futaba calls it ATV. I'm referring to Futaba 9Z and JR 10X systems right now. I know many of you guys are using 8 and 9 channel systems. They'll have the same functions but sometimes refer to them differently. Now ATV does not refer to the rates you fly on. ATV's are the physical end points of a servo's travel.

On ailerons we want to start with this matched, meaning we want to the control surface throw to be same amount up and down on the ailerons. You'll need a good way to measure the angle of deflection. CRC Throw Meters work and are quick and easy. I find that the more accurately I can measure (and repeat the measurements) the easier this becomes. If you can't see 1-3% of ATV change then your measurement device is not accurate enough. I use a set of pointers I got from Tony Frackowiak that are about 7" long.

We want the angles to be the same: 10° up and 10° down. Don't worry about differential yet. If you set it up in ATV then all your flying rates will track. 80% of the throw on dual rates will still give equal values up and down for both high rate and low rate. The only difference being that the low rate is 80% of the high or, in this example, 8°. ATV settings are independent for each servo. So the aileron servo plugged into the aileron channel will have its own end points, and the flaperon servo plugged in as Aileron #2 has its own end points, too.

We also want our ATV values to be as high as possible. I know the JR 10X goes to 150% The Futaba 9Z goes to 140%. I usually setup my ATV values at about 120% as a minimum. Then I adjust to get the same 10 degs of travel (or whatever the goal deflection is) both up and down. This is done in ATV.

Example: my Supreme's right aileron ATV is set at 125% up and 122% down. The left Aileron servo is 118% up and 123% down. These numbers will change slightly if I change out aileron servos.

Basically, the different values are a way to correct for differences in linkage angles, lengths, or a servo's electronic differences. We're talking 1024 steps in a roughly 120° arc. This means that each step is about 0.12° of rotation. That's a very small difference when you're only talking about a ½" long servo arm.

You'll want to get these ATV values to be as close to the same number as possible, given that the ailerons are actually moving to the same deflection angle. So make the mechanical changes to your linkage. Adjust the height of your control horn connections to get the travels to matched as much as possible. The radio is for fine-tuning, not for correcting mechanical errors.

If you have more than a 10-15% deviation in your ATV values, you need to improve geometry mechanically. You may not be at the proper connecting point on your servo arm/wheel, as described above. Or your control horn clevis connection may not be over the hinge line. Or you have some funny angles playing tricks on your linkage. Square everything up and re-do it.

Getting the servo travel and linkage right is important because once you fly the model, you'll tweak the rates you fly on. You don't want to adjust 65% right aileron and 75% left aileron to get the model to roll the same each way. The radio can mask or correct such problems, but it's so much better to make the corrections mechanically.

Also, when your model needs differential, you'll want to increase differential in logical numbers that you don't need to measure at the field. Simply add 5% differential and you know that the down travel on our example aileron is now moving 9.5°. If you set up your ATV's to electronically correct all the minor deviations then these deviations will magnify and your model will roll fine on high rates but when going to low rate it wobbles and the differential is off. I've seen this happen. I've also watched guys try to adjust the D/R values all over the place to make the travels the same. Then they add in expo values, and it drives the system nuts. You need a BASE and that base is the ATV value, the end point of the servos travel.

### **Step Five: Setting the Rates**

Next task is the rates you fly on. The JR 10X has the advantage here. It has 3 rates automatically built in. Just put the switch in the position you want and adjust the percentage you want. Expo is also set on the same screen. The rates are all even multiples once the BASE ATV or end point adjustments have been set as accurately as possible. So the rates would be about 80% (or 8°) of travel, according to our example.

Futaba 9Z series radios uses a different method for setting the rates. It has a dual rate (D/R) function screen that controls a single rate. This is called your dual rate. When the switch is on for this rate to be active, you're on it. Expo values are also set in this screen. This is under the D/R option in the condition menu of the 9Z series. The 9Z also has a function called AFR or adjustable function rate. This functions basically the same as "high rate" on most dual rate setups. Most people set this AFR as the high rate and it's best to do this. The AFR can give your high rate actually a little more travel than your ATV allows. But with your ATV's up over 120% extending your AFR over 100% can actually

drive your servo to its physical limits rather than the limits of your control surface. This can be a bad thing and can damage the servo or the linkage if it's over travels.

By the way, JR has a similar function called "trace rate." Once your ATV values or travel adjust on the JR is set and paired for equal deflection, the trace rate can be dialed up and down to produce slightly more or less throw, globally, affecting all the rates. Both AFR and trace rate settings affect all the servos mixed into the function. For example, AFR on the aileron channel will affect both ailerons. Of course, there's no need to adjust the AFR of the flap channel, since it would only affect the flap functions, and we don't use these with pattern models.

### **Last Step: Testing Your Linkage**

So how do you decide if you need better control linkages? Look at your radio settings. If the D/R values that you are flying on are less than 80% for ailerons then you can improve your linkage and get more mechanical advantage for your servo.

Ever wonder why the big 40% models use so many servos on each aileron? It isn't that the size of the aileron and the force required to move the aileron demands three or four 200+oz servos. More often than not, the linkages are set up so poorly that multiple large servos are required to maintain precision. The pilot will feel the blow back of the surface.

We can feel this too on our pattern models, but it's much less pronounced. Our surfaces are smaller and we put over-kill power on them. The end result is that they still deflect under load. It's just less deflection. Proper linkage alignment helps more than over-kill servos.

The big models are being flown on 10-15° of aileron throw for precision, but they need the linkage to put out 45° of travel for the 3D stuff. They have to double the servo power in order to have enough leverage to hold things precise down at 40-50% D/R values. In Pattern flying we're not going for 3D, so we want to maximize the mechanical leverage. This makes the model fly better. It minimizes the minor slop in gear sets and pot wear, and it gives us maximum resolution in our radio.

You want to use all the radio to help you out, instead of simply trying to mix out errors. The radio is best used to adjust minor differences to produce symmetry when making changes or setting up special mixes for things like knife-edge maneuvers.

Maximize your linkages and your model will loop track better. It will groove better, and it will roll more axially. All of this and your model will fly more consistently. Then when you go to a new flying field or different elevation, like the NATS, your model will only need a couple of tweaks on the rates and you'll be just as trimmed as when you left home!



## Part 2:

### Gaining More Control

In **Part 1**, we discussed uses for sub-trim and adjusting the ATV or endpoint travel volume to optimize your linkages. Remember the key to what we want to accomplish: Servo resolution!

We often spend lots of money on TX's and servos, yet many of us set the dual rates at 40%. Just because your ATV is up over 100% doesn't mean that it's okay to set your D/R at 40%. You're giving up resolution on the servos.

Today's servos are very fast, so we don't need to optimize the linkage for speed. We need precision linkages and servos. Centering is only part of the equation but precisions throughout the servo's travel will help all aspects. If you're using less than 80% on your flying rates (whether that's D/R or not) then you're not using the radio or the servo to maximum resolution. If you're not using a rate above 80% for specific purposes in the pattern then you need to get longer control horns on the surface and/or smaller (as in shorter) servo wheels or arms.

We also want "square" linkages—meaning the servo is at its neutral point when the pushrod is 90° to the servo arm ([as shown in the drawings in Linkages Part 1](#)). In Part 1, we use sub trim to set the servo arm in the right location and then we mechanically adjust the length of the pushrods to center the control surface. This is setting the pushrod connection point at a right angle (90°) to the servo's rotation. This gives symmetry to the servos travel and prevents building differential into the linkage.

### Rudder

Since we most likely use pull-pull on rudders, let's discuss some problems commonly seen with rudder linkages. Too often, the control horn on the rudder isn't positioned right. The pivot point of the clevis on the rudder needs to be over the hinge line. If it isn't, there are several things you can do.

#### Adjusting the Pivot Point

**Option 1** A 6-32 bolt can be bent forward on both sides to get the pivot point over the hinge line.

**Option 2** You can use an offset style control horn to locate the pivot over the hinge line.

**Option 3** If you don't set the pivot point over the hinge line at the rudder, then you'll need to offset the connection points at the servo—back in the direction of the rudder in order to compensate. It'll need to match the distance you're off at the rudder.

Any of the above will work.

## Point of the Pivot

It's critical for proper rudder response to either adjust it at the servo or at the rudder horns. See the pictures below for an idea of what I'm talking about.

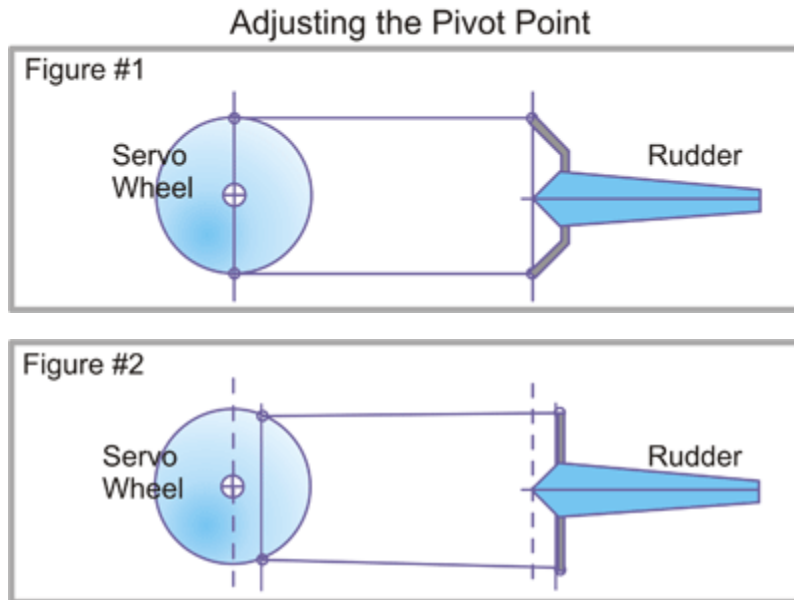


Figure #1 shows the linkage with the pivot over the hinge line. The bolts at the rudder were bent to get this relationship. Notice that the servo wheel pivots are opposite each other on the wheel, at the center of the wheel's rotation.

Figure #2 shows the offset of the pivot points on the rudder back behind the hinge line. Again the servo wheel connections are opposite each other, but they're not at the servo's center of rotation. This setup goes against what we talked about last month but is needed to get the geometry correct for the cables. You see that the connections on the servo wheel are adjusted a distance that's equal to the offset at the rudder horns.

Applying this linkage principle gives a better feel to the rudder, and the cables won't be getting slack or going tight as they come through center. I run my cables extremely tight and I have no problems if the linkage looks like Figure #1 or #2. But if the servo setup is like Figure #1 and the rudder horn is like #2 then your rudder control won't perform as well as it should.

## Control Horns & Mechanical Advantage

I also notice that some guys tend to make the control horns on the rudder as short as possible. This gives up mechanical advantage. As I mentioned last month, long control horns on the surface give us mechanical advantage over the surface. Then we can size the servo arms or wheels to get the required throw. I use rudder horns that measure from 1.5 to 1.75 inch from the center of the rudder's hinge line.

I don't like the pulley type wheels. They are only good if you have a pulley on the rudder side too. I've only seen this done a couple times. It's more of a pain than it's worth. Check Figures #1 and #2 above for proper geometry configurations. With the long control horns on the rudder it means you need to



put a bigger servo wheel on to handle the deflection needed, but the mechanical advantage is given back to the servo.

### **Rules Are Made to be Broken?**

Again, only use dual rates down in the 80% range of what you're flying on. There may be an exception on the rudder though. Sometimes models with highly effective rudders are tough to fly on this high rudder travel. If you're flying such a plane, I'd say you won't need this much throw—not even for stall turns—and you can decrease your travel mechanically. Another solution is to dial the rudder expo up. It's not uncommon for me to run rudder expo up around 60, 70, or 80% on a rudder. You want to avoid the "knee" in the expo curve, but this amount of expo won't hurt anything.

You'll see a better performance from your rudder, and have less of a "spongy" feel, if you give the linkage some attention. Only FAI in the F-03 sequence had a ½ knife-edge loop. So if your model can do knife edge loops with your current rudder setup, I'd bet you can help your rudder response by improving the linkage.

In FAI finals schedules, we do rolling loops and circles that can require high rudder rates. But most guys at the FAI finals level are not still trying to optimize their rudder linkages. These guys already have that figured out. If you get a better linkage then it's easier to "hide" rudder corrections and make them smoother.