My Approach to Rubber Scale Flying

By Don DeLoach

This article was originally published in the FAC Newsletter in 2012. Don has updated it here. Much of this wisdom is useful whether you're flying scale or not..

In Free Flight as in most sports the *competitor* wins the event--not the tennis racquet, skis, or race car. The model is just a tool to that end. In our hobby (especially mass launches) the “best” or lightest model seldom wins. That said, I’m not going to try to convince you that building light isn’t generally a good thing. If you’re good at it and your models are strong enough to survive the rigors of contest flying, keep doing it. Lighter models generally have more duration capability, especially in ideal, light/no-wind conditions. But I believe that the mantra of "adding lightness" is ultimately a crutch. What most modelers should focus on first is improving foundational skills such as their understanding of trim/stability, and mastering their winding techniques.

My Models

All of the mass launch models I took to Geneseo in 2012 in are near the middle of the pack in terms of wing loading. Some are actually a bit heavier than the “big guns”. I consider them “all-weather” airplanes. Here are the data:

F4U Corsair	39g	22.5”	Original except enlarged Drela Peanut fuselage Tvo = .65. Dihedral up to the bottom of the canopy, seems adequate. Very stable. 12g x 4 str 3/32” & 2 str 1/8”.
Cessna CR-2	49g	22”	Reduced from 24” Rees plan, original wing and slightly enlarged stab, 10” prop. A spectacular, forgiving design. 16g x 6 str x 1/8”. Will take 8 in.-oz. safely.
Bristol Scout	53g	21”	Enlarged from 1970s Micro-X peanut plan. 35% C.G.,very stable. But also heavy! 11.5g x 4 str 3/32” & 2 str 1/8”. 8.5” prop, carved.
DH.94	27g	23-7/8”	Enlarged from the great Mike Nassise plan, stab enlarged 10%. 8" plastic prop cut down from 9". 7.5g x 2 str 1/8” + 2str 3/32”.
F4F Wildcat	48g	22-3/4”	Enlarged (121%) from the 19” Stahl plan TVo = .62. A real pig at nearly 2 ounces! But it somehow does 80 seconds. 14 g x 4 str 1/8” + 2 str 3/32”.

Props and Rubber

For my 21-24” birds I aim for a prop diameter of 40% of the wingspan. This is a bit arbitrary but seems to work. All but one of my models have carved props in the pitch/diameter (P/D) range of 1.15 to 1.30. The less drag on the ship the higher P/D you can safely use, but I never exceed 1.3. The DH.94 is the only scale model I currently fly with a plastic prop, a 9” blue Peck prop cut down to about 8”.

Too many guys ask obsess about prop P/D or rubber motor length/cross sections without remembering that the two are integrated. That is, for a given airplane every prop has an ideal rubber motor and every rubber motor has an ideal prop. Finding the right combination is first step toward optimizing your flight times.

Some guys (Wally Farrell and Tom Nallen II come to mind) get spectacular results with plastic props, which I consider generally inferior to carved props. They are able to do this because they optimizes their motors to their props. Conversely, Wally or Tom could probably not put one of my carved props on one of his airplanes and expect to not have to change the rubber motor to match it. Again: the prop and the rubber have to be matched.

Dispelling the Myths

“Set CG at 25-30%”. We’ve all heard that one, but it is often a trap for mediocre performance in FF scale. There’s a simple antidote to this: the Bill McCombs Tail Volume Coefficient/Starting C.G. formulae. As soon as I started calculating TVo and C.G. position my understanding of FF trim and stability was changed forever. My models were easier to trim, held their trim better, were less prone to crash, and were able to handle more power. All these factors lead to better (longer) flying models, and more contest success.

TVo = stab area/wing area x tail moment arm/wing average chord

C.G. (%) = 16 + [TVo x 36]

Bill was one of my early mentors and a Princeton-educated Senior engineer for Vought Aircraft. What is TVo? Put simply it is the measure of a horizontal tail’s *effectiveness* as a function of its tail moment arm (length from wing LE to stab LE) and wing average chord. TVo is hugely important, because it explains why a “scale model with a 25% stab” is too vague. A 25% stab on a P-51 Mustang…or a Pilatus Porter? The two airplanes have vastly different moments that result in very different tail effectiveness. One may need a C.G. at 29% while the other needs to balance at 47%. This C.G. difference greatly affects flight trim and behavior.

The *magic* TVo number I have found (through much trial and error) for FF scale is 0.65. When plugged into the McCombs C.G. formula this results in a C.G. of 38%--well aft of the clichéd one-quarter to one-third point.

With a 0.65 TVo almost any scale model can be made to fly well with not a lot of fuss (assuming good fundamentals like warp-free and well-aligned surfaces, adequate dihedral, proper fin area and methodical trimming in calm weather). With TVo less than 0.65 most scale models become quite harder to trim for competitive flight times.

Some scale subjects with longish tail moments and/or larger stabs can have even larger TVos, which is a very good thing. If you can achieve TVo = 0.75 without making the stab look excessively large (remember, these *are* scale models!) by all means, do it. This TVo yields a C.G. of 43%, meaning you can put in a very long motor often with little or no nose ballast. You'll also have a model with less need for downthrust and decalage.

Can a Model Have Too Much Stability?
Yes! The most common example in FAC circles is too much longitudinal (pitch) stability. This model is going require a lot of nose weight to balance, will need more decalage, and as a result will need much more down thrust to control the power burst than a properly-C.G.ed model. I see lots of these models at FAC contests. They fly fine in cruise mode but they can't take advantage of the last 30-50% of the available torque without looping or requiring gross amounts of cruise-killing down thrust. Many of these models could be rebalanced at 35-40% of root chord, and they'd require less nose weight, less down thrust, and they'd fly significantly longer because they'd be able to handle more power and climb more steeply.

How Much Decalage/Incidence?
Forget about measuring this. Just calculate the TVo and starting C.G., balance on the bench with a motor installed, then start your trimming. Test glides over tall grass will reveal what is needed. Once the model is gliding safely over a short distance I take it to a steeper hill and let it glide longer. Some type of easily adjustable stab LE or TE is a big time-saver. I use 0-80 nylon screws under each TE on a "split" stab rotating on .040 carbon rod.

Positive Incidence in the Wing or Negative in the Stab?
This is a rabbit trail that just leads to confusion. I have models with 0 degrees of wing incidence that fly as good as models with 3 degrees wing incidence. All that matters is the *relative* angles of the wing and stab—known as *decalage*. In a typical FF scale model with TVo between 0.65 and 0.75 *decalage* is going to be about 2-3 degrees, but that's trivial because you're not ever going to actually measure it. Just set the C.G. per the TVo, start your test glides, and tweak the stab or wing angle until you get a floating glide. That's it. From this point you know you have a model with adequate pitch stability with C.G. in the right place that is safe to start power-trimming. You should not need to trim anything but the thrust angles from this point on.

Rubber and Torque
Every rubber motor of a given cross-section has a failure torque. Let's call it T_{fail}. That's the point at which a motor is going to break, regardless of the number of turns or whether or not the motor is broken-in.

T.85 is the highest torque you should ever expect to wind a given motor without about a 30% chance of failure. Note that this does not assume your model can safely fly at T.85, though. This does assume the motor is well lubed, properly stretch wound and free of nicks or imperfections.

T.75 is an even more conservative number you may want to keep in mind, since we are talking about scale models with fragile fuselages.

Figure 1. Torque Chart for post-2008 Tan Super Sport (total width expressed in eighths of an inch)

eighths	Tfail	T.85	T.75	notes

2	3.0	2.5	2.2	
3	5.0	4.2	3.7	4 x 3/32" or 6 x 1/8"
3.5	6.0	5.1	4.5	2 x 1/8" + 2 x 3/32"
4	7.0	6.0	5.3	
4.5	8.5	7.0	6.4	6 x 3/32"
5	10.0	8.5	7.5	4 x 3/32" + 2 x 1/8"
5.5	11.5	9.8	8.6	4 x 1/8" + 2 x 3/32"
6	13.0	11	9.7	8 x 3/32" or 4 x 3/16"
7	16	13.6	12.0	4 x 1/8" + 4 x 3/32"
7.5	17	15	13	10 x 3/32"
8	19	16	14	
9	23	19	17	12 x 3/32" or 6 x 3/16"
10	26	22	20	
10.5	28	24	21	14 x 3/32"
12	34	29	26	16 x 3/32" or 8 x 3/16"
13.5	40	34	30	18 x 3/32"
14	42	36	32	
15	46	40	35	20 x 3/32" or 10 x 3/16"
16	51	44	38	
16.25	51	45	38	22 x 3/32"
18	59	49	44	24 x 3/32" or 12 x 3/16"
20	69	59	52	
22	78	67	59	
24	88	75	66	32 x 3/32" or 16 x 3/16"
26	98	84	74	
28	110	92	83	
30	120	101	90	

The most important number for FF scale is the maximum torque that a given model *can safely fly with*, called T_{safe}. Note that with scale models (marginal wing dihedral, relatively small stability margins in all axes) T_{safe} is only found through trial and error flight testing (and diligent record-keeping). Every model I fly has a T_{safe} that I'm careful to never exceed. Obviously, do your T_{safe} testing over tall grass in calm weather.

Flight Trim

Unlike the experts I have never been able to make my low-wingers fly safely to the right under high power. I find it safer to use the traditional trim scheme of L-straight-R using just enough down thrust to prevent a power stall, and 0-1 degree of right thrust and using prop torque to turn the model left under high power. As the launch torque bleeds off the left circle widens, straightens for a few seconds, then reverses to a right circle at the end of the cruise. When the rubber unwinds completely the gyroscopic forces of the freewheeling prop keep the model circling right. I've found this trim scheme to be very safe if some basic guidelines are followed:

- Wing washout must be equal. This is especially important on low-wings with high taper ratios like Yaks, P-40s, etc. They seem especially sensitive to slight washout differential.
- Rudder trim also seems critical. Rudder is a very speed-sensitive adjustment (it increases its effectiveness with the *square* of airspeed) so it is best to not use any rudder trim if it can be avoided. Keep your rudders dead straight and I believe you'll avoid a lot of trimming problems.
- A common trim problem on L-straight-R low wingers is that they will do a shallow right spiral dive at the end of the motor run. In such cases I've usually found that my wingtip washout was not quite equal, or my rudder not completely straight, or both. It might also be that your propeller has too much blade area or diameter, either of which can increase the right gyroscopic forces enough to create a spiral. Once on a 23" model I was getting a spiral dive in the glide with a 10" prop. I cut the prop down to 9.5" and the glide spiral disappeared.

(*(PFFT Ed. Note: Those who have success in right-right trimming normally have little less washout on the right wing than the left and add a tad more right thrust to compensate. The result is a slight right skid after the initial torque burns off. The deadly spiral dive in glide mode is often a result of L-L trim.)*

Winding to Torque

One of the biggest fallacies in rubber-powered Free Flight is winding to a particular turns count and expecting the same relative power from flight to flight. A real-world example: wind a brand new motor to 1500 turns and note the reading on your torque meter--let's say it is 4.0 inch ounces. Now unwind the motor and let it rest for a few minutes before rewinding. On the second winding to 1500 turns that motor is going to reach only about 3.5 inch-ounces, and this torque yield will only worsen (to perhaps to 3.2-3.4) on the third and subsequent windings. Why? There are volumes of technical articles on this subject in NFFS Symposium books and other sources but the non-technical gist is this: As rubber is repeatedly wound it elongates and softens. This softening is a double-edged sword for our purposes. It enables us to pack more turns in, but it also can mislead us into believing *turns* equals *power*. This is not the case. On this second winding motors need about 110% of the turns of the first winding to equal the torque of the first winding. On third and subsequent windings, as the rubber softens further, motors need 10-15% more turns to equal the first-winding torque.

The Torque Meter

For 21-24" scale models I use a home made torque meter in with a range of 0-12 inch-ounces. One can be made in about an hour and will become an indispensable part of your winding equipment. Go the Pensacola Free Flight Team's website (www.pensacolafreeflight.org) and search for the article on Herb Kothe's torque meter. Calibrate it to inch-ounces per Herb's instructions or to another meter.

There are also commercially available meters. Dennis Tyson in Michigan is planning to manufacture a new meter for the FAC market in the near future. Contact Dennis at dennis.tyson@familychristian.com.

The value of a torque meter should be evident now. When I wind for a mass launch I seldom even count my turns. It much easier and more valuable to have *torque* targets for each of the three rounds. For example at Geneseo 2012 my torque targets in for the three rounds in WWI combat were: 2.0, 3.0, and 4.5 inch-ounces respectively. My notes indicate that the first round was a squeaker—I under-wound, did only 61 seconds, and nearly got eliminated. Next time my round one target on that model will be 2.5 in.-oz.

Another example from last year: originally I was flying my 23" Wildcat on 6 strands 1/8" at 5.5 inch ounces. This was the highest I could wind it without looping or power stalling severely. Since this motor will take 11.0 inch-ounces safely without breaking it was clear that I was under-winding the model and it was still overpowered. So, I dropped the cross section to 5-1/2 eighths (2 loops 1/8" plus one loop of 3/32") keeping the motor weight the same. The result is a just-right climb pattern and excellent cruise with more total turns, and duration in the 80-90 second range—not bad for this heavy and draggy fighter.

How Torque Affects the Flight of Our Models

With a typical rubber scale model (especially low wing racers and fighters) there's not enough wing dihedral to allow all-out flying at near-maximum motor torque without substantial danger. By "danger" I mean a model that can't sustain a fast, steep helical climb without falling off to the left due to propeller torque. With my 23" Corsair this is easy to spot: at 5.5 inch-ounces the model is perfectly safe in the climb and will do about 80 seconds in neutral air. But at 6.0 I discovered that it will do a partial left torque roll/wingover, losing a bunch of altitude on the climb-out. The cure, I found, is to launch it in a slight (20-degree) right bank when I wind it above 5.5. Still, it doesn't get appreciably higher on 6.0 flights versus 5.5, so it'd probably safer to just stick with winding to 5.5.

Contrast this typical scale low-winger with an average non-scale duration ship like a Gollywock (C.G. at 90%, huge 45% stab, TVo of 1.80, ample dihedral). Gollywocks (and most other duration ships) have at least twice the dihedral of most scale ships, so they are much better equipped for steep climbs. Take out half of the dihedral on a Gollywock and I believe you've have a very hard time trimming it for anything but a modest climb angle.

How to Wind

Again, there are yawn-inducing volumes written on this subject. Better to avoid the boredom and follow these simple rules:

1. Don't bother with motor break-in for FF scale, especially mass launches. The first two windings prior to the final launch serve as a perfect break-in for the last round, which should be right at T_{safe}.
2. Stretch that rubber *way* out before putting in a single turn! This is essential, and is something I see too few FACers doing. Tan Super Sport fails at about 10x of its relaxed length. You should pull out to four to five times the relaxed length before putting in a single turn.
3. Once you've stretched out begin winding. Fast winding is not bad early in the turns count. Put in about 50% of the anticipated final turns before progressively moving in. Again, this process is critical. Too many guys start moving in too early and too quickly. Start checking the torque meter after every few handle cranks when you're above about 50% turns. Ideally the torque should not be dropping at all as you move in; if it is you are moving in too fast. Let the rubber pull you in.
4. Your last few handle cranks should occur just as your motor hook or O-ring reaches the nose area. Watch your final torque here carefully and slow down a bit more. Sometimes one more handle crank can mean the difference between 5.0 and 5.5 inch-ounces, which can mean the difference between a safe flight and a dangerous one.
5. Studies have shown that wound rubber loses 15% of its total energy in the first 5 minutes after winding. In mass launches this means you shouldn't try to be the first to finish winding. A 10:1 winder is essential.

Summary: Dos and Don'ts

DO
Use a digital 0.1 (or 0.01) gram scale to make up your motors by weight well before a contest. Lubricate, braid and label and bag them by *length for weight*. Example: I use 6 strand 1/8" motors for multiple airplanes. All are 16 grams un-lubed, but some strand out to 34" while others strand to as short as 31" that's a significant difference in cross section (and resultant torque output).

DON'T
Make up motors to solely to length! This is especially true when switching rubber batches. Some batches are thicker than others, which can result in overweight/underweight motors.

DO
Test fly to find the absolute highest torque level your model can safely take. Do this over tall grass when it is calm!

DON'T
Ever wind to a new, uncharted torque number in a mass launch final round, expecting stellar results. If you're close enough to Tmax you might rekit your aircraft in a torque roll/wingover.

DO
Discard old motors often. Rubber is cheap! A typical FAC motor costs 75 cents or less. After 3-4 windings I trash them. As a result I almost never break motors, especially with the great new post-2008 Tan Super Sport.

DON'T
Leave an old motor in your plane for a month or two and expect to not break it quickly at the next contest. Again, rubber is cheap; time spent rebuilding fuselages is not!

DO
Have total confidence that there is no bad rubber anymore! Ever since the switch to a new chemical additive in early 2009, all the Tan Super Sport batches have been consistently excellent. They have high energy return (within 5-10% of the best Tan II), but most importantly for scale flying they are extremely *durable*. At Geneseo 2012 I used May 2009, June

2009 and January 2011 exclusively, not broken-in, and I didn't break a single motor all week (I flew eleven events).

DON'T
Use Tan II anymore in mass launches. It is getting too old and brittle, and this is exacerbated by the warm temperatures (above 80 degrees F) at which we typically fly in summertime. I learned this the hard way at FAC Nats 2010, where I suffered broken Tan II motors in two mass launches on the first day. That was enough to convince me to make the switch to Super Sport permanently.

DO
Use pure silicone oil for lube. It is available at hobby shops as R/C car shock oil. Get the 100-125 weight stuff—about the viscosity of honey. Work it in really well with latex-gloved hands (it is very difficult to wash off). One light application is all you need for the life (3-4 windings) of a typical contest motor. Since switching to this stuff I don't relube anymore, period. Even a motor that has been wound a couple times and looks dry is not. Try it and see for yourself.

DON'T
Use Son of a Gun or Armor-All for rubber lube. It splatters easily and ruins fuselage covering, but most importantly it evaporates readily and is too thin to stay on the rubber without frequent reapplication.

I am no master rubber scale flyer (I enjoy building much more) but I do possess a solid knowledge base when it comes to the fundamentals of rubber power, props and trimming. That said when it comes to mass launches I'm keenly aware that there is a lot of luck involved, namely avoiding mid-airs (I survived two at Geneseo 2012), staying out of crops/trees, and numerous other screw-ups that can and often do arise at the worst possible moments.

I hope this information will help you in your quest to become a better rubber flyer.