Designing for a Slope Allrounder

Insight into the thought processes behind a balanced design.

James Hammond

Typhoon 2M (80″) showing its versatility.

In this article I'm going to go through the basic thinking and outline design process for my Typhoon 2M — still a popular choice and now holding the record as the most produced moulded 2m slope allrounder ever. While you, the reader may not have the skills or maybe lack the right facilities to make your own all-moulded glider, and indeed it's a lot easier these days to just buy one; I hope that this article will help to give you an insight into the thought processes behind the design procedure. — JH

What Do We Want From a Multi-Purpose Slope Allrounder?

Zzzz…cool man, got to be cool looking…I need cool slick looks from my baby…oh boy, I need blistering fast…yeah…whistling fast…I need TOTALLY aerobatic…I need DS…I need STRONG, dude…got to have strong…yeah… getting there…got to be really light to for those really light breezes…Whoa… what time is it?

Damn, is it that time already? But…what a nice dream…

Unfortunately, however hard we try, our dream will remain just that, a dream — a slick looking sloper that does everything really well, in fact to the max, will never happen. But at least, if we are smart, we can actually fulfill large parts of the dream, push back the limitations a bit and turn them into reality. And that can be a lot of fun.

Let's Get Down to It…Decisions, Decisions…

Realistically the very first thing we have to decide before we set out our list of requirements is wingspan: big or small? We all have different spaces and indeed different priorities — it's sometimes a teeny bit difficult to convince 'she who must be obeyed' (SWMBO) to leave the kids at home so you can go fly your stonking 150" allrounder.

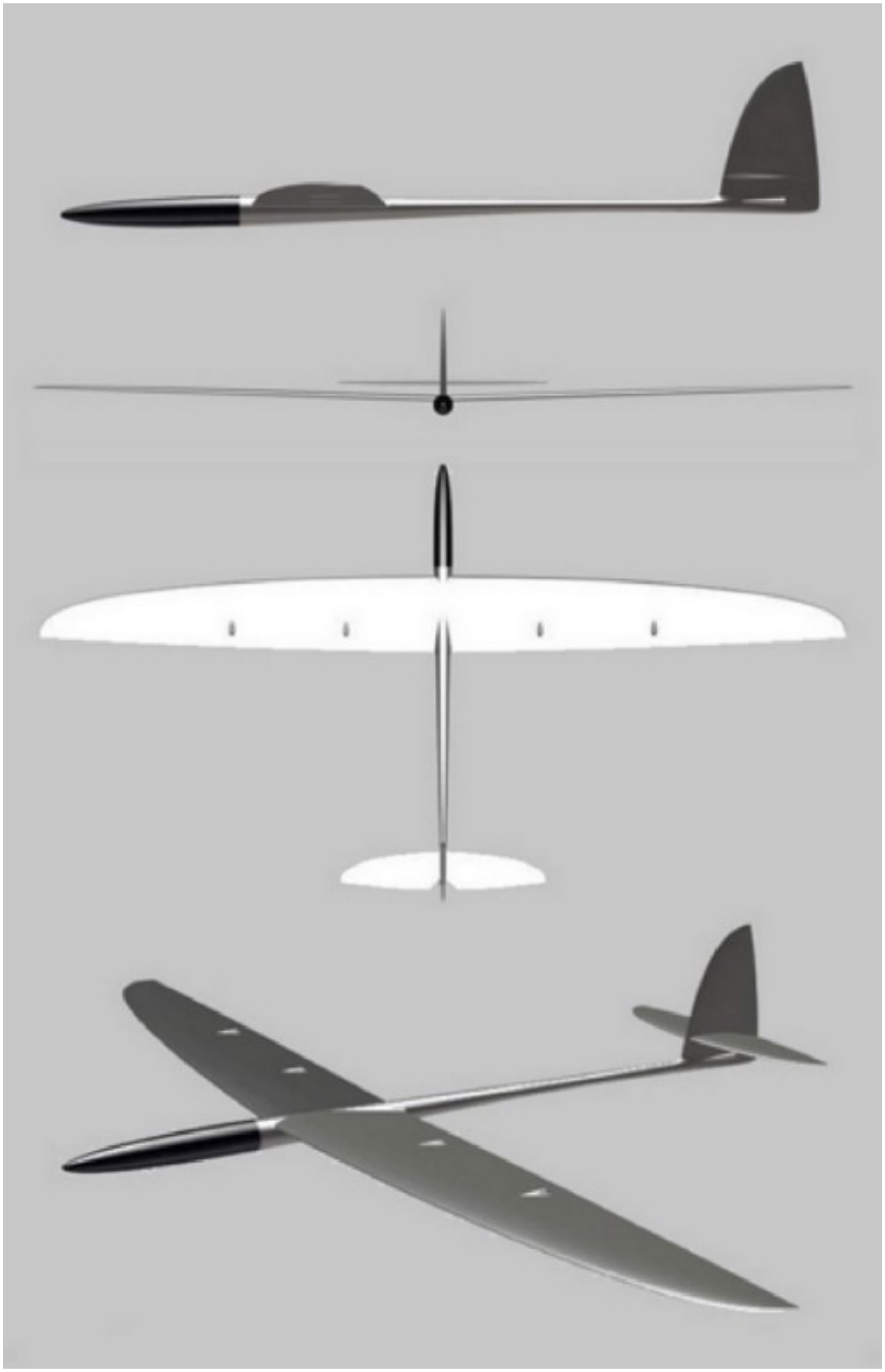

Figure 1: For reference a review of the Typhoon by ace flyer and world champion, Pierre Rondel can be found on his excellent website.

For almost any model aircraft, there is a truism in that the larger it is, the better it will fly and this ‘kinda’ rule also applies to our slope soarers. For pretty much every slope soarer type — and in this series we will be dealing with aerobatic, allrounders, high performance competition types, and alpine soarers — at the correct weight for the type, the bigger the model is, the easier it will be to fly, and the better it will perform the tasks we demand of it — at either end of the design envelope. Though more convenient, possibly less expensive, and certainly easier to transport and store, smaller models are twitchier and more sensitive, and really demand a lot more skill overall to fly well, so it's best not to think too tiny.

> *Takeaway: Big is better than small, so it's best to go as big as we can. But do consider other factors of influence.*

But Hmmm...How Big Is Good For Me?

An average allrounder is the kind of ship that breaks down pretty small with the fuselage normally representing the longest component. If designed conveniently small, when disassembled it could maybe be kept (hidden) in the car most of the time, and flown when the opportunity presents, or maybe could easily be stored in a bag like a set of golf clubs and then quickly put into the trunk with other models in our fleet. Probably for most of us, the width of a standard car trunk, back seat or maybe car windowsill are the most convenient reference measurements for deciding size. This means we need a model with something between 72″ (1.8m) at the small end and 100″ (2.5m), with the sweet spot at 80″ (2m) span… so this is where I started back in 2008, when considering the Typhoon 2M model

> *Takeaway: For the size of the model, try to consider what's a happy medium between performance and convenience for you.*

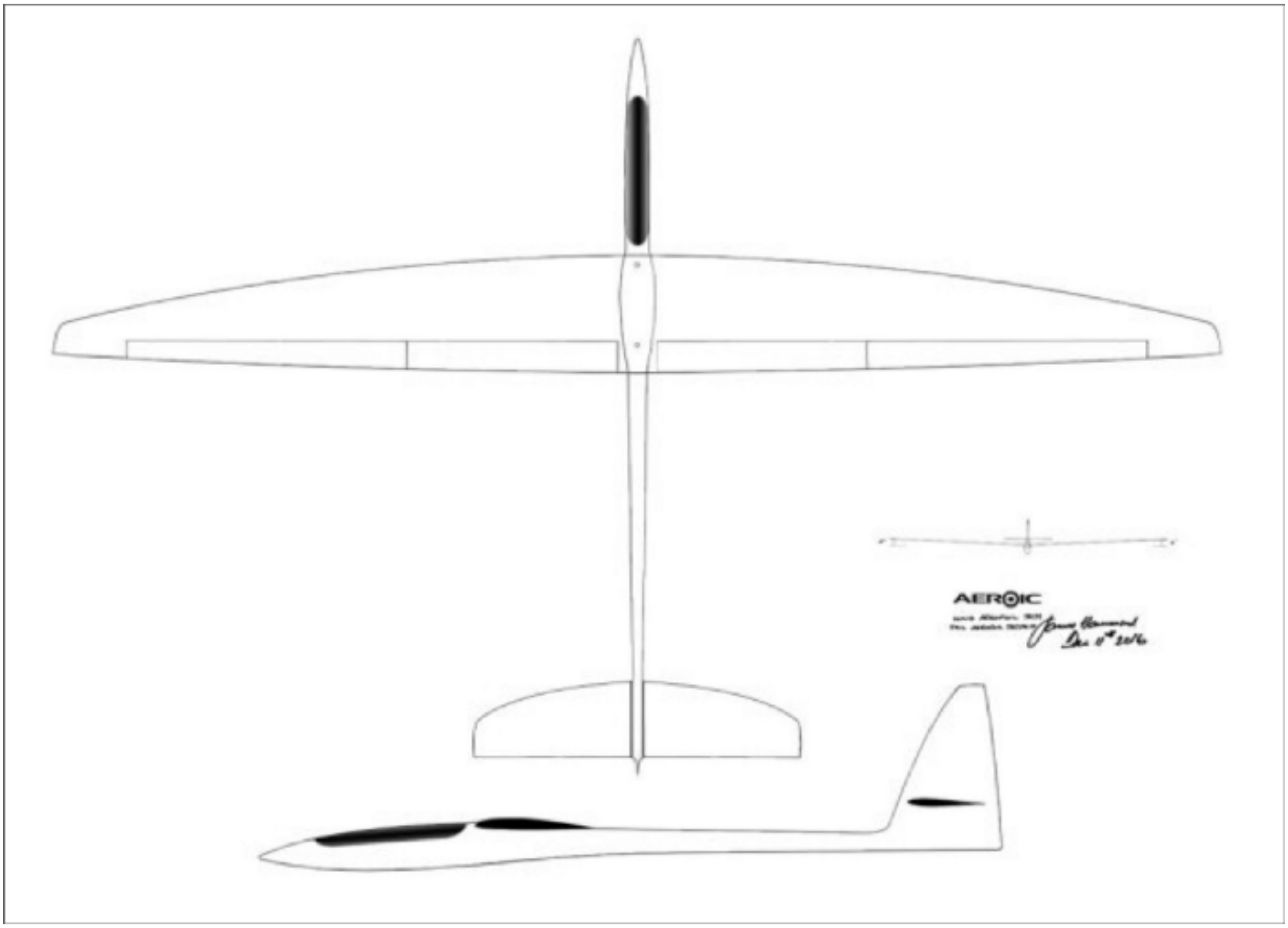

Figure 2: Sessanta 60″ (1.5m) — a smaller allrounder — this time with correct aileron extent.

So Now We Know How Big It Will Be, What Do We Actually Want From the Model — Or at Least What Can We Realistically Expect?

Remembering how I was gathering my thoughts for the Typhoon design back in 2008, I listed my own parameters in probable order of desirability:

Flying parameters: fast, pretty aerobatic, got to fly well in a wide range of conditions, is easy to fly, is easy to land, and looks good. For the most part all of these are functions of aerofoil choice, and wing planform/aspect ratio arrangement.

Static parameters: good looking! Strong, and durable enough to survive some of my less than ideal arrivals, has standard size ballast capability, is easy to install the radio, is easy to transport, assemble and disassemble, and the cost will not involve limb amputation. These tend to be related to the construction design i.e. what materials and how they will be used, though to a lesser extent the actual shape of the model and the radio access will also have some influence.

One good thing about your own moulded model is that you can change the materials and the quantities used at will, to make a gossamer-light model through to a stonking DS Blaster and anything in between, all using the same mould set. But we also need to remember that more material means more resin which means more weight. Also, its often not the amount of material you use that has the greatest effect, but which kind, and how you use it.

> *Takeaway: With your own moulded model you have complete control over weight and strength.*

Wannahaves

Has standard size ballast capability, is easy to install the radio, is easy to transport, assemble and disassemble, and the cost (don't tell SWMBO!) will not involve limb amputation. Well that's quite a lot of wants and needs, but actually pretty achievable. So, let's kick off with the wing design as this is easily the most important part of an allrounder, or in fact any slope soarer. First of all, we need an aerofoil:

Choosing an Aerofoil

Uh oh — now we could be back to making lists again. Here I may be able to save some time. I have designed at least four very successful allrounder slope models between 80″ (2M) and 100″ (2.5M) and I can tell you pretty much what we need, and why: What's required is a semi symmetrical section (Not flat bottomed) with a thickness of between 7.5% and 8.5% — this is the sweet spot. Why? because at this thickness the camber line of the section will have a good curve, which will create enough lift to carry ballast if needed, and it will be quite aerobatic. At this thickness range the section can deal with a large variety of model weights, yet its thin enough to be low drag, while still being thick enough to be structurally viable and capable of withstanding high aerodynamic loads. There is no point going below a thickness 7.5% because there will be little or no advantage on a slope soarer, and even possibly a loss of performance due to the wings having to be strengthened and made heavier to compensate for the lack of structure. By the same token there is no point in going over 8.5% as the extra lift is simply not needed, while the drag on a smaller 2M model escalates pretty fast with thicker sections. Last but not least. Any modern aerofoil with a decent alpha performance does not need any rigging angle. Repeat: Any modern aerofoil with a decent alpha performance does not need any rigging angle.

> *Takeaway: Choose a nice proportioned aerofoil between 7.5% and 8.5% to get the best overall performance from your model.*

> *Takeaway: Don't design your model with any rigging angle — it will destroy the performance.*

> *Takeaway: Sections like the RG15, MH32, JH25, and JH35, fit the bill.*

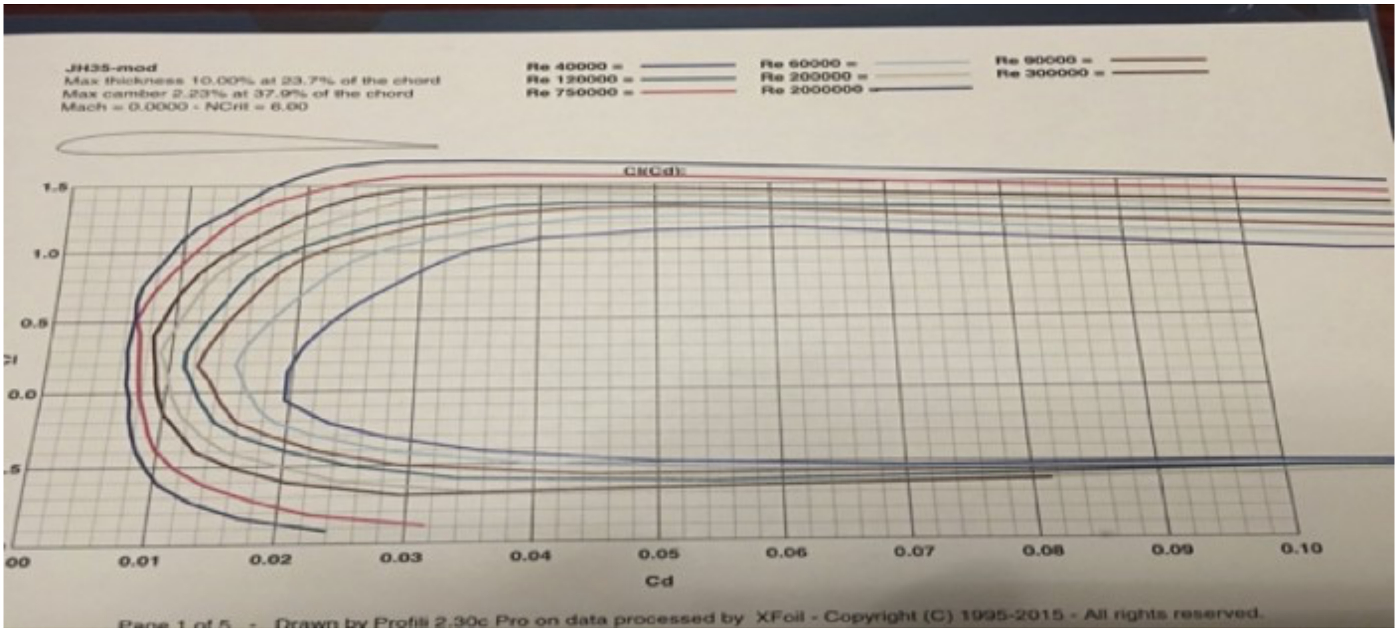

Photo 3: A set of L/D curves for the JH35 Alpine soaring section.

Here are some polars for the JH35, a more "lifty" aerofoil that I designed to give low drag with high response to control inputs, but this time more with Alpine Soaring in mind. For this section, lift has been given priority over out and out speed, yet its still surprisingly fast. I have used this 'foil on only one of my larger 3.2/3.7M span models so far, and it is surprisingly fast, very well behaved, highly responsive to control inputs, thermals exceptionally well and also slows down safely." More about this one the next article.

Note the Double Cusped (undercambered and 'overcambered') configuration with its nice CL/CD curve with no drag bucket, and also the nice lift curve with little effect on the drag.

Figure 4: Profile of JH25 — an open source 8.25% thick section specifically designed for better control response.

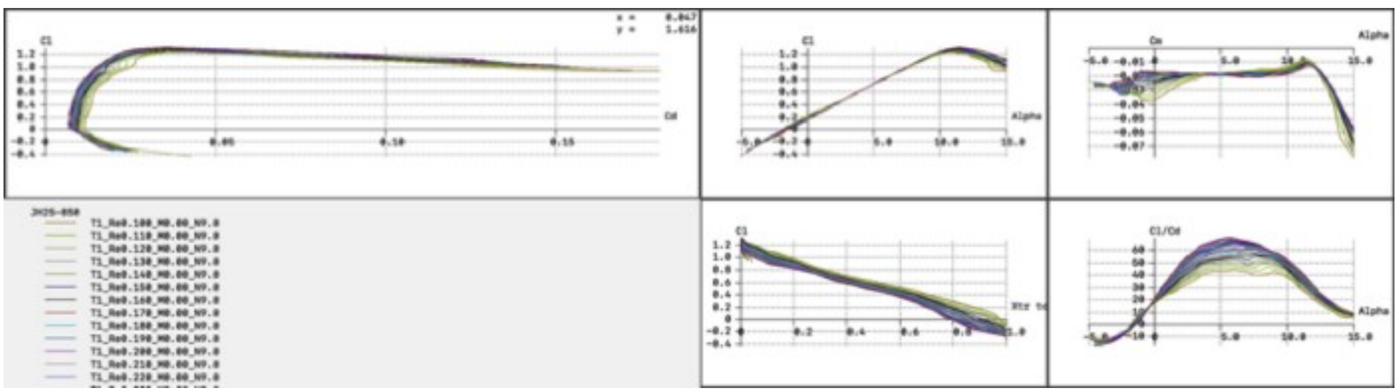

Figure 5: JH 25 polars.

Now for a design point that in my experience is far more important even than the aerofoil section.

The Wing Planform

We all know that we need lift to make our model fly, and we probably know that lift can easily be swapped for speed. Logically though, we don't need a lot of lift out near the wing tips, but we do need more lift closer to the fuselage. In an ideal situation we need to have an elliptical lift pattern span-wise across the entire wing with the most lift close to the fuselage and the least amount at the wingtips. So why not just make the wing elliptical — a true beautiful ellipse just like the WWII Spitfire? Yummy!

Well it turns out that a true ellipse might be great for the lift — at least in theory — but it's actually not so good for model flying qualities. What tends to happen with a true ellipse, is that the Mean Aerodynamic Chord (MAC) and the Centre of Gravity (CG) can find themselves too close together, which can lead to instability and a tendency for the wing to stall if even mildly provoked.

> *Takeaway: Ideally, we want a nice elliptical lift pattern.*

> *Takeaway: It's best to try to modify the ellipse to separate the MAC and the CG as much as possible.*

> *Takeaway: We don't want the problems that true elliptical tips bring.*

Photo 6: Forza 2M shows its plan view in a fast turn.

The other problem with our true ellipse planform idea, is that if carried out to the end of the wings, the air can't find a good way to leave, and then complex and unstable vortices tend to form which can lead to stall propagation. The reason for this is that the air — let's say the isobars since we can divide them into waves by pressure — have to be directed to where WE want them to go and not left to their own devices.

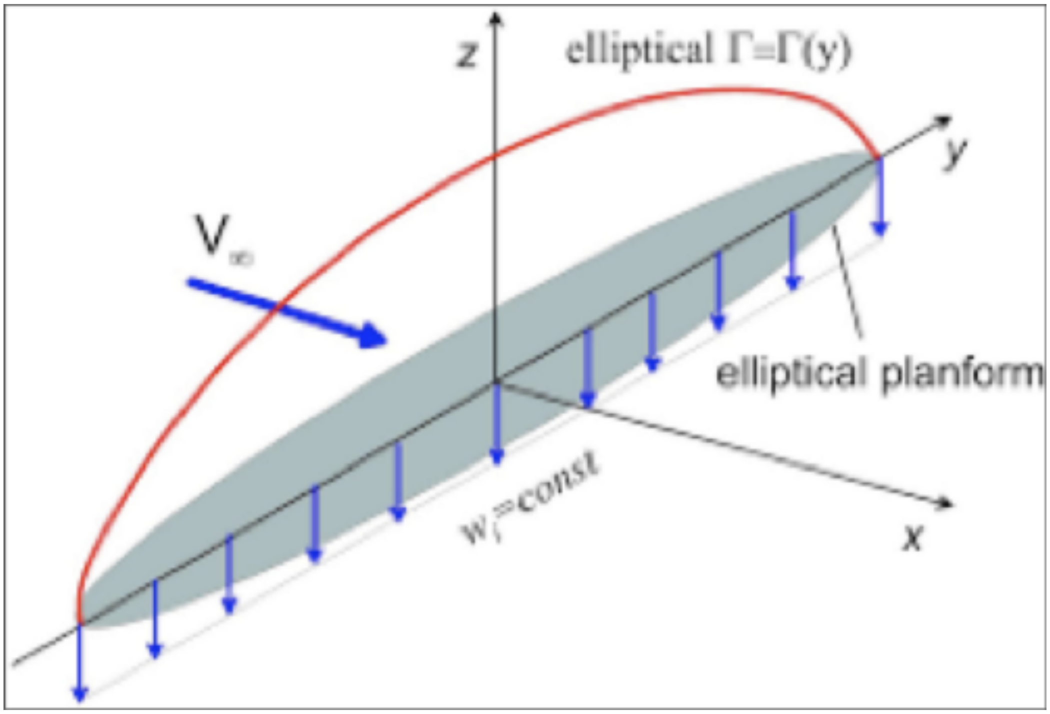

Figure 7: Elliptical lift distribution diagram — note that if the wing really was the same shape as the drawing, then the ends of the red lift curve would be doing some rather strange and unwelcome things.

Remember — the isobars will always find the path of least resistance, which is mostly the shortest path and that can vary a lot with the attitude and speed of the model. This is the seed of the dreaded tip stall, plague of many an otherwise well-designed model, and cause of many heart attacks as its completely unpredictable.

Why Is This so Dangerous?

Wrongly designed tips: Thing is that if the vortices just happen to be departing in the wrong ways — which as they are disorganized is very likely to happen — then this could propagate a stall as the boundary layer becomes suddenly detached from the wing following the path of a vortex. This then starts a stall which rips up the wing and kills all the lift on that wing immediately — but not on the other wing which will mean complete and instantaneous loss of control.

> *Takeaway: tips that are wrongly designed are the*

> *most common cause of the tip stall and should be avoided at all costs.*

Dangerous Liaisons...err, Ailerons

Wrongly designed ailerons: ailerons that end too near the tips on fast slopers, or with too much chord will not give you more control, or if they do you won't notice it. These are not often thought about as stall inducers, but are really dangerous as they can cause stalling if applied in the wrong volume, and/or at the wrong time. This is another phenomenon that often leads to the dreaded tip stall, and it always seems to happen when we are not expecting it — like in a high-speed turn, or when its least recoverable — like on landing.

> *Takeaway: The tip stall can happen at high or low speed.*

Photo 8: A Schwing 2M rests between flights in sunny California.

Actually, there are four kinds of tip stall possibility to be really careful of when designing:

1. *Wrong wing chord profile:* Too much wing area (Chord) too near the tip can cause a stall, as sometimes too much lift is being generated at one time, on one wing only, especially when the wings are travelling at different speeds such as in a turn. The difference in lift is often enough to induce a stall.
2. *MAC and CG too close together:* You could say that the MAC is where the main characteristics of the wing can be seen. It's the centre of lift averaged out over the entire span. So maybe you could imagine it as a kind of inverted pivot point where the hanging wing would go to positive or negative angles. As the CG is also the pivot point of mass balance then if we have MAC and CG too close together they can, and will influence each other, often in an unwanted manner.
3. *Badly designed tips:* In this case the departure of the span-wise flow at

the end of the wing is random and can be stall inducing.

4. *Aileron induced departure:* The outer edges of the ailerons is where we have the least control. Far away from the roll axis — the fuselage — they can however become dangerous as there is the tendency is to give more control inputs, or possibly more control throw than is needed. The ends of the wing are where we have the highest possibility to have unplanned departures from our intended flight path, so it's best to disturb the airflow in that area as little as possible.

Hmmm…thinking…A nasty bag of problems, especially as I want to do aerobatics as well as high speed and thermal flying. Ho hum…so what to do?

Photo 9: Smiles all round after a successful Schwing 80 maiden — Tick Point, California. Stars of the show are myself — the slim handsome dude with the model, Wayne Flower in the foreground — owner of Aloft Hobbies and chief test pilot that day, and ace flyer Bruce Anderson who probably has more of my designs that anyone else on the planet. (image: Julia Liu)

Compromised or ‘Clipped’ Elliptical Wing Design

My thinking process: I know that I really want an elliptical lift pattern, and since I can use CNC (or even carving if I’m good enough) to make the wing master, then I can really have whatever wing shape takes my fancy — within the constraints of the wing span and chord size. But I also know that a true ellipse that extends to the tips will bring problems, plus I know that the pesky chord distribution might also have an effect too. Aileron size and span problems are OK because I can deal with them after the model is made.

Thinking cap on, and the answer comes. Pondering “control” I know I need to control the chord size to limit it to what is needed to put the lift in the right places. I also need to control what happens at the tips, and not let those random elliptical vortices whistle (yes, they do) every which way they feel like and possibly start a tip stall.

So, putting those together I come out with an elliptical shape but with the rear (trailing edges) pulled back to make the rear curve flatter, and the front part (leading edges) more bowed — so that should sort out the MAC Vs CG problem very nicely, but I’ll still keep my elliptical lift pattern. For the tips I’ll just cut them off and give a more focused and controlled point for the isobars to depart in a more organized manner. A bit like sweeping the wings back on the straight-edged model, I know I am going to give up a bit of pitch and roll maneuverability, but I’ll gain stability and control, and best of all limit the tip stall possibilities.

Example (photo 10) of a non-elliptical ‘legacy’ wing planform on the left, and one of my more modern stretched ellipse designs on the right. i.e. Left side design has too much chord in the wrong places, not enough MAC Vs CG variation, has badly designed tips, plus the ailerons are too close to the ends. Flying slowly, this type of planform might be OK, but as the speed goes up, the problems will show.

Photo 10: Legacy vs more modern wing planforms.

Here is an example (figure 11) of the original Stormbird 2M with pretty much all the features discussed so far. This is the original Stormbird 2M drawing before rendering into CAD. Designed in 2015, this model was really my first excursion into the "dangerous" wing shapes that I now carry in all of my designs. Note the long fuselage — this gives a little more leverage, but also allows the model to be made in 2.5m (100") form as an alternative — hence the Forza 100 was born.

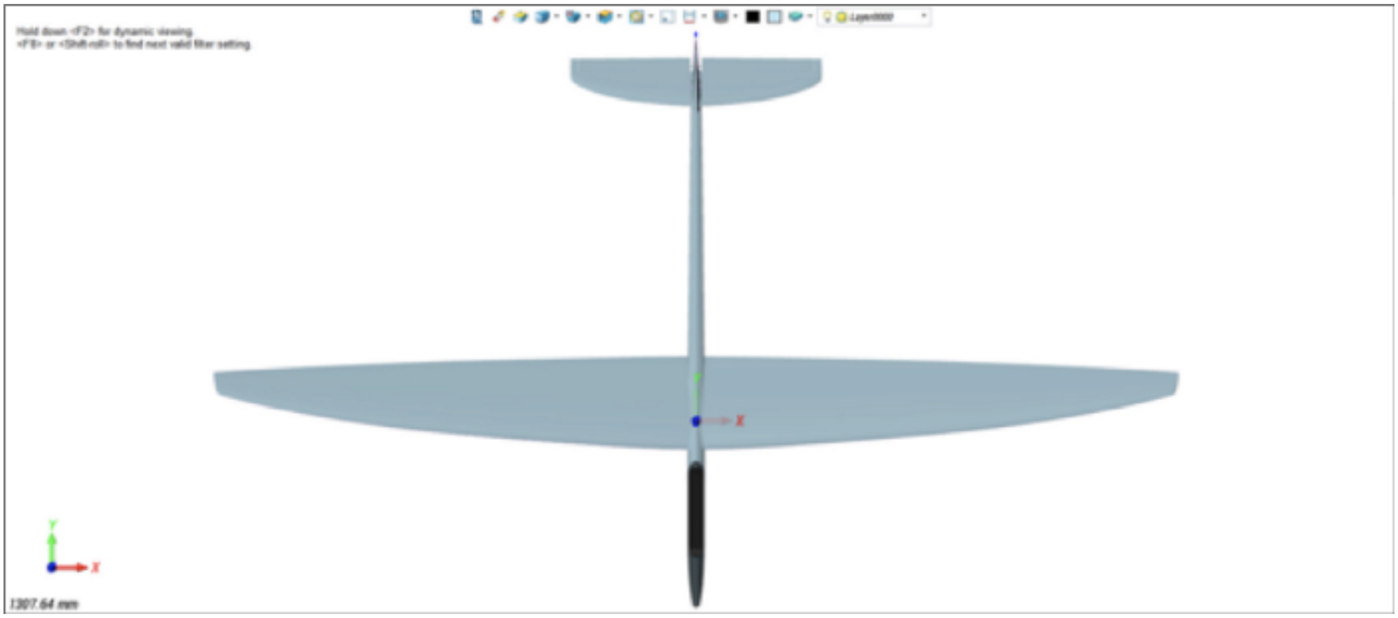

Figure 11: Stormbird 2M plan view — note the 'dangerous' wing shape.

> *Takeaway: Many people when they first saw this new wing shape, believed it to be a tip stall nightmare, and said so quite volubly. Well, it has proved to be exactly the opposite. High speed or low speed tip stalls are very, very, rare with this model and also for its larger and smaller brothers with a similar wing shape, thus proving the design philosophy.*

Now How About the Tail Feathers?

V-Tail good points: fashionable, less pieces/joints so theoretically less drag, can be helpful in stabilizing the model in strong winds, less chance of landing damage.

V-Tail bad points: loss of much of the rudder control, less control effectiveness overall, little or no drag advantage in practice as the inputs need to be greater for the same responses, not so good for nice aerobatics as the control forces can be in the wrong directions.

X-Tail good points: better overall control, with little or no actual difference in drag, decidedly better for nice aerobatics.

X-Tail bad points: not fashionable, more pieces so theoretically more drag, more risk of landing damage.

The choice is up to you. I have done both types with success, but if I was asked which is better for an allrounder, I'd go for the X-Tail every time due to the more open and detailed flight envelope that it allows.

> *Takeaway: Both X-Tail and V-Tail have tradeoffs — which one is better for you?*

Photo 12: Schwing looking nice over the Australian Southern Ocean. (image: Adam Fisher)

Secondary considerations are the stabilizer aerofoil to be used, the area and whether to go for an all moving tail (AMT) or a conventional elevator setup.

Stabilizer aerofoil choice is pretty easy: A symmetrical aerofoil of between 7 to 10% is required. I use my JHSYM-10 aerofoil, and recently the JHSYM-9 at a controversial 10% and 9% thickness respectively — more thickness than most people would go for, but there is method in my madness. Through testing the aerofoils **with** elevator movements, I quickly found that the thicker aerofoils actually have less drag and more control response than the thinner ones. This is likely due to the way the air flows around and separates on the thicker section when the elevator is deployed compared to a thinner section where it can have an entirely different separation path.

Stabilizer area choice not a problem either: On a smallish 2m model, if you make something about 17% to 20% of the wing area, you'll be on safe ground. In this range, the Stabilizer will be big enough to be effective, but not needlessly over large.

The third decision is more controversial: to AMT or not to AMT? For control effectiveness I can tell you — through many long hours of wind-tunnel and practical flight testing — that the elevator setup is more effective in every way than the AMT. On the other hand, the elevator type can be a bit trickier to make with its hinges, and to actuate — but I'm assuming that if you do actually get to making a model then this is well within your capability. The AMT works well enough for most people, and is a lot less work. Your choice, but for me it's always the elevator type. The elevator chord should be suitable for the aerofoil section but normally 25% is good.

Stabilizer shape? Follow the wing shape that you have used as much as possible — this is not only for looks, but also effectiveness as the things that we have discussed for the wing shape are all valid for the Stab too.

> *Takeaway: Thinner aerofoils do not necessarily have less drag, and may actually lessen control response.*

> *Takeaway: A tail volume of between 17 to 20% of the wing area will work well.*

> *Takeaway: Elevator setups work better than AMT type.*

> *Takeaway: V-Tail or X-Tail, make the Stabilizer shape similar to the wing shape — the same rules apply.*

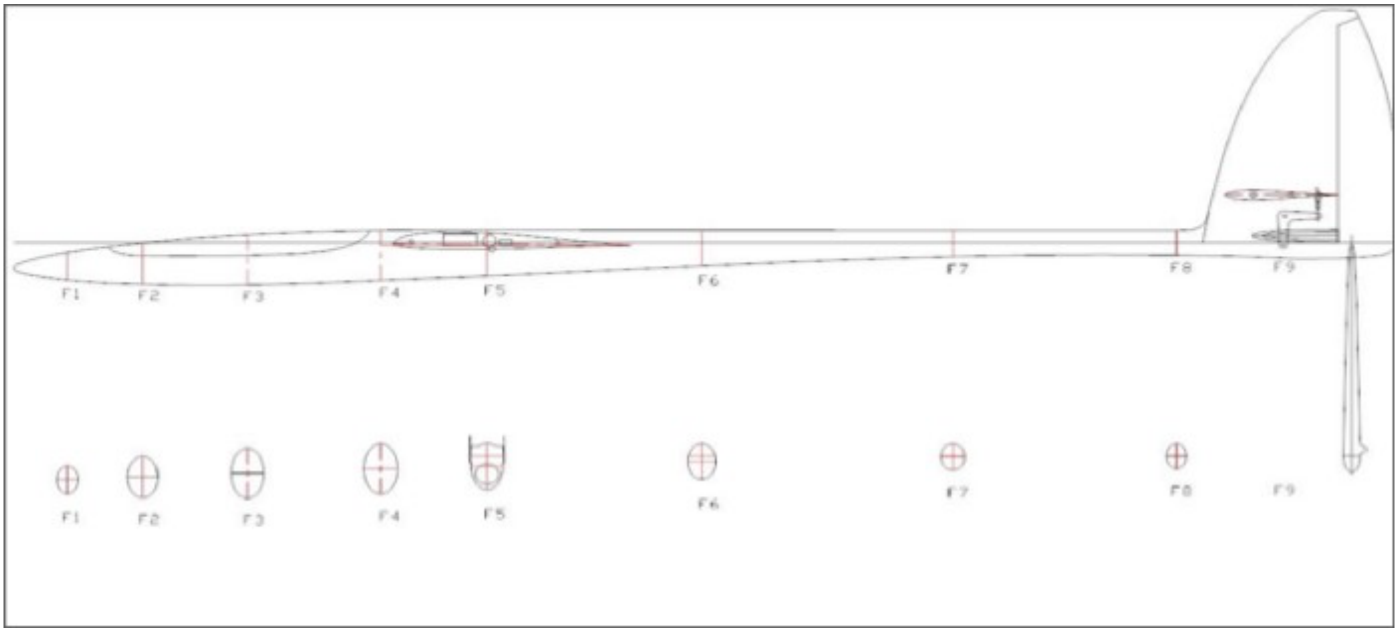

Figure 13: Corsa fuselage drawing — note the downward pointing nose…gives a nice predatory look.

The Fuselage

Finally! I guess the first thing to be considered for the fuselage is the moment arms. By this I mean the distances between the wing and tail, and the wing and nose. Think of these measurements in the same way as levers, but remember the weight considerations too. The longer the lever, which is the distance behind the CG, the easier it is to move the load which is the area in front of the CG. These are pretty critical as if they are too short you will need big control movements to change the pitch and yaw, but too long and they will add unnecessary weight which will need to be counterbalanced by adding weight in the nose.

So here, without going into it too much, I'll give some moment arm references based on my own experience and using the wing root chord as the yardstick:

- Nose moment length to wing leading edge: 1.5 to 1.7 x wing chord
- Tail moment Stabilizer leading edge to wing trailing edge: 2.75 to 2.8 x wing chord.

Corsa 108″ (2.75m) a larger allrounder. Note that on this test flight model the ailerons have been set too close to the tips. Some tape, a ruler, a sharpie pen and hacksaw soon had that sorted!

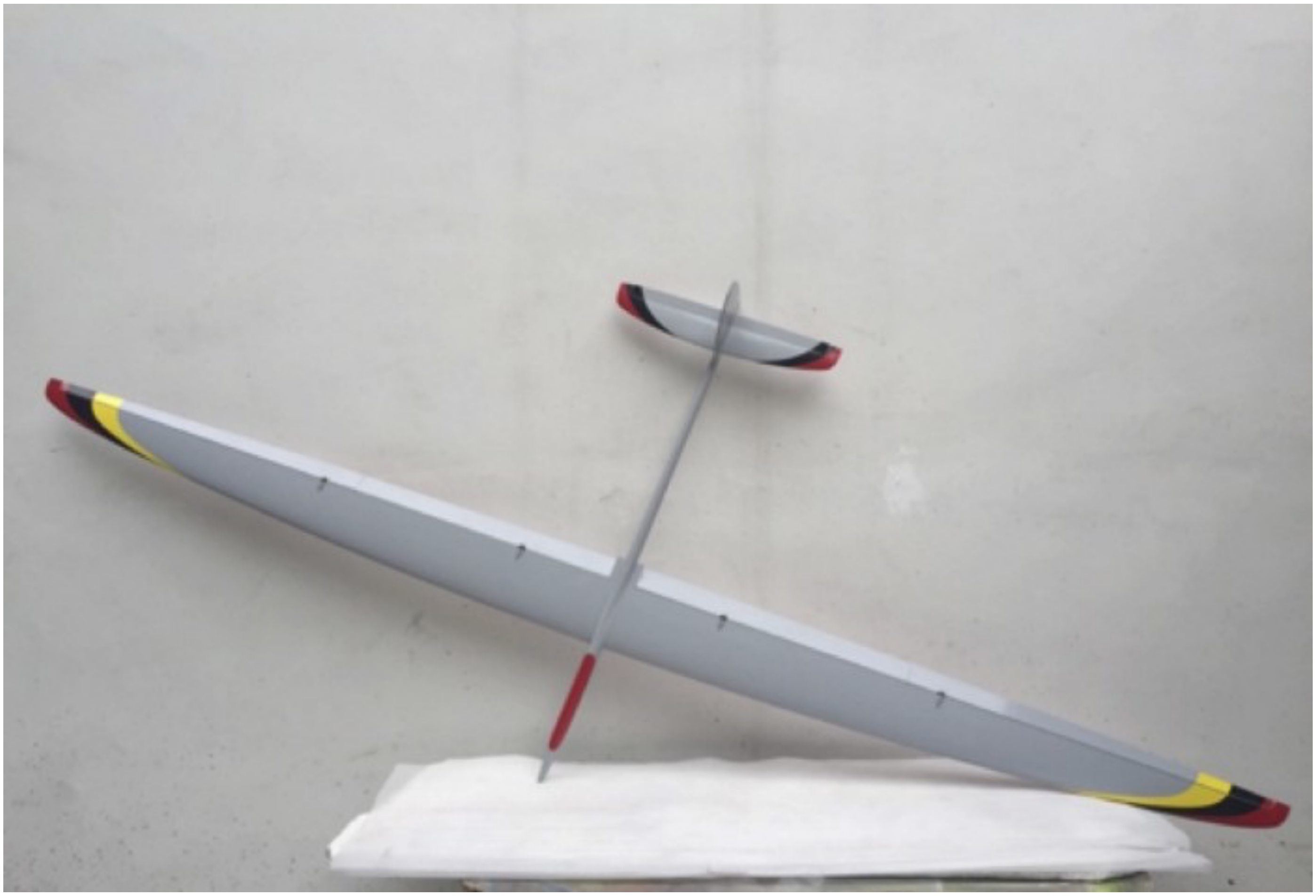

Photo 14: Corsa 108 prototype — not the incorrectly cut ailerons…the hacksaw soon came out…

Fin Size

For an X-Tail a good start point is go to 2 to 2.5 the size of the total horizontal stabilizer area and allow a good-sized rudder. Frankly any aerofoil section can be used from 7 to 10% The reason for the greater volume here is that we are not doing the work of the Horizontal Stabilizer that is working against the MAC and the CG, here we are trying to force large amounts of wing to yaw — which it usually does not want to do. With the advent of smaller, lighter, but super strong servos you may decide to put both of the servos' rudder and elevator in the fin — remember to make the internal fin area large enough plan access hatches.

2.75M Corsa in its OEM guise showing what you can expect of a well-designed slope allrounder, fast, aerobatic and easy to fly. (video:
Composite RC Gliders GmbH*)*

One last parameter for the fuselage: make it look good! Mess about with it — especially the fin which defines the fuselage to a large degree — until you have something that not only looks good, but also has large enough — but not too large — cross sections that will handle landing whiplash — especially before and after the wing positions. The strongest cross section is the round shape.

Overall folks, there is a lot of value to the saying that "if it looks good, it flies good" — especially for allrounder slope soaring models.


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Photo 15 and **Photo 16**: Corsa 108 flies its magic over the Faroe Islands. (images: Jogvan Hansen)

This is the second part of a four part series. Coming up in the May issue of RCSD, author James Hammond provides his take on designing for high performance 3M ships. Don't want to miss it? Best subscribe to our mailing *list! All figures and photos are by the author unless otherwise indicated.*

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