Radio Controlled
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Front cover: Simon Nelson and Russell Conrad head out for the maiden flight of Simon's Syron F3F. This issue of *RCSD* features the design-build-fly article for this aircraft starting on page 4. Canon EOS 450D, ISO 400, 1/1000 sec., f6.3, 76mm

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Contact bsquared@rcsoaringdigest.com
rcsdigest@centurytel.net
http://www.rcsoaringdigest.com
Yahoo! group: RCSoaringDigest
FaceBook: https://www.facebook.com/RCSoaringDigest

In the Air

About the 3-view plans on the back cover

From <http://www.fai.org/fai-record-file/?recordId=16889> and <http://amablog.modelaircraft.org/fai/2013/08/13/new-model-aircraft-international-record-claim/>

Claim number : 16889
Sub-class : F5 Open (Radio Control Flight)
Category: Aeroplane
Group : Electrical Motor Rechargeable Sources
Type of record : Duration: 171
Course/location : Norris Field Liberty, IN (USA)
Performance : 18h 6min 13sec
Pilot : Andre Mellin (USA)
Members : Dave Brown (USA); Joe Mekina (USA)
Date :05.08.2013
Current record : 12 h 36 min 46 sec
(30.07.2008 – Vincent Labrouve, France)

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The details shown above are provisional. When all the evidence required has been received and checked, the exact figures will be established and the record ratified (if appropriate).

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For Joe Mekina's commentary on this duration flight, please see <http://amablog.modelaircraft.org/fai/files/2013/08/We-did-it.pdf>.

Time to build another sailplane!

B²

SYRON F3F

Simon Nelson, simonnelson@vodamail.co.za

First of all, I need to thank all the guys who helped me get this project going. Russell Conrad, for all the pushing to get it built and construction ideas and as always he does all the test launches with my new planes. Russell Brent Conradt and Dudley Le Roux, for all of the composite help and advice. My son Ryan, for helping to build it. Garth Lee, for his encouragement for my designs and who has promised me a mould of the Syron. And last but not least, my wife Heather, who allows me to disappear into the garage for hours and for borrowing kitchen stuff without permission.

This model is scratch built, so you will need to know about epoxy, glass, carbon, radio set up, etc.

I have always wanted to build a large fast slope racer for F3F, but I did not have enough experience building that size and strength. I also did not want to do the same shapes as all the others. I do like the blended wing and fuselage. Also, I have always been keen on very thin airfoils, and for many years built models with very thin sections, a 2 meter (Petrel) a 2.7 meter F5J (Lanier XE) and a very light 2 meter (Lanier) and won a few local comps with them.

After building a slope aerobatic model, the 3.5 meter Flip, and the 2.5 meter version of same, both all glass, carbon and foam, I felt that I knew enough to build stronger and faster and bigger.

The wing core showing the thin section used.

Wings and tail are blue foam, glass and balsa skinned and carbon spars. The carbon spars are 'foam spars' cut from the cores and a carbon sock pulled over them. There are six spars including 2 x wing joiners and 4 x ballast tubes. The six spars blend into two at the tip. When it's done you can stand on it. Yes, I tried.

Fuselage is balsa sides, top and bottom, with added on blue foam wing and tail fairings, and covered in a carbon sock. The whole lot was sprayed with vehicle 2-part paints.

The construction of the wing looks complicated and the list is long, but it's actually easy, just a bit of planning and patience.

<u>Wings and tail</u>

You can do the list below in any sequence. But all of the bits must ready when you put the wing and tail skins in their blocks for setting overnight. All the spars, tubes, etc. will also go in at the same time.

Make sure you have planned it all and you are organized!

Cut the cores, note the trailing edges stick out of the blocks by about 15mm <u>with the skins on</u>, I put on wooden battens top and bottom of the trailing edge and clamp using bull dog clips. This will make sure the trailing edges cure dead straight.

Glue the wing cores / blocks into their panels.

Mark and cut out the spars / joiners and number them.

Cut out and mark the skins.

Glass the skins.

Trim the skins to fit the wings / tail.

On the wing skins, mark and spray glue on the carbon tow (ribbon) spar caps, servo areas and the trailing edge carbon stiffener.

Make up all tubes, joiners for the wings and tail.

Glue on a 3mm carbon rod to the leading edge on the wings only, it will keep the Leading edge ding-proof on landing. It also works well in removing pesky foamies from the slope!

Warning! Please make sure that you know where the servos are going and mark so you are not cutting into the spars.

Hot wire cut the wings and tail in normal manner. Please make sure that the foam blocks are square and true. Take your time here. Please note the dihedral on the wing tips; this was done by marking the tip templates higher up on the block to give you the dihedral. The center section is flat.

Make sure that the wing blocks are all the same thickness as they will be epoxied together to give you a left and right wing "block."

Before cutting, mark all the block ends with vertical lines so it is easier to line up the cores later. Also make sure you mark top, left panel, right panel, etc.!!! Yes, I have made two lefts, but I was much younger then, and I knew everything!

You can see on the templates that there is a hole from root to tip. This is for the servo cables and keeping bacon sandwiches safe.

I cut the cores doing the tops first, then remove the top block, cut out the servo cable holes, then cut the bottom core. To do the servo cable holes, it's done manually, while the cores are weighted down. Drop in the hot wire and let it go down, and then, with your helper, move together and go around the hole. You can now push out the waste and check you have cut it all out.

Epoxy the wing cores and blocks together. Take out the cores and mark the location for the spars and joiners. Put the roots together so they line up perfectly. Slice out the "spars" and number them. See the pictures.

<u>Wing and tail skins</u>

I do not have vacuum bagging stuff, so this is how I do the skins.

You need a piece of glass the size of one wing panel or both. Clean the glass. I also use a very sharp blade to clean away any previous epoxy. Use your normal release agent. Remember dirt marks on the glass will show on the skin.

Cut out and mark 1.5mm balsa skins. Make them about 10mm oversize. You can also use "Airex" from the same composite store. It's 1.5 mm foam, just like balsa, only better.

I used 100g/m^2 cloth on the glass. Smooth it out carefully. Now wet out the glass from the center outwards. Use a spreader and put some effort into it without breaking the glass!! Get rid of all the excess epoxy and make sure it looks all the same wetness.

Warning! With balsa, I do not glue the balsa sheets together!! It leaves a nasty but small ridge. I tape them together with masking tape. Lay the balsa on the foam skin, it will stick nicely; now peel off the masking tape. Make sure you coat the balsa with epoxy well done with a spreader. It seals the balsa against moisture. If you do not do this the skin will warp and you will have ridges all over. Better to use the Airex thin foam sheet as the skin.

I have used 49g/m^2 cloth on the inside and this works very well, but the skin is VERY stiff and is impossible to bend around the leading edge, etc. I had to sand the inside leading edge of the skins down to make it a bit more flexible to go

◀ *The basic wing planform*

▲ *Making up the ballast tubes*

▶ *Separated wing components*

around the leading edge of the cores.

When cured, peel the skins off the glass. You now have a glass smooth skin for the wings and tail. Ok, now trim the skins. I stacked and taped them all together. Yes, make sure you have the sizes all correct before cutting. Mark on the inside of the skins where the carbon spar caps go and for carbon servo reinforcement. Please do top and bottom for the servo, as the servo will sit on the top and the hatch will be cut from the bottom.

You will need to sand the trailing edges to a taper so they are sharp when together. Remember there is a strip of carbon tow in here as well for stiffness.

Spray tack on all the carbon sheets for the servos and tows for the spar caps and trailing edge 20mm wide strip.

When you are ready to put the skins on the cores, you will wet out the carbon on the skins and lay on a 49g/m^2 cloth on top (inside of the skin). This whole wetted out skin is then laid onto the core, and it will easy go around the leading edge and helps to bond the skin, spar caps and spars. Once again, make sure you use a spreader and get rid of the excess.

Wing and tail joiner tubes.

Notes: Why two joiner rods? Because the wing is about 17mm thick at the root and I don’t have fancy moulds to do those nice big square joiners. You will see four ballast tubes in each wing. With lead you will be way over weight, so use aluminum, brass or copper rods for ballast

I used 12 mm ejector pins for the wing joiner x 2, but they are very heavy so I swapped them for 12mm K&S tubing filled with carbon tow and a 4mm steel rod. When carbon breaks, it's clean and final, i.e., you lose a wing and crash! With a steel rod inside it just bends so you can land. I put waxed paper around the steel rods and then slide over some carbon sock to make the wing tubes. I used 15mm copper tube and did the same to make up the tubes for the ballast tubes.

The tail joiners are just aluminum tubes and the inner tubes filled with carbon, no steel rod.

As you can see in the pictures, the cut out "foam spars" are trimmed and the joiner / ballast tube are epoxied to the ends. All the tubes are smaller than the wing and tail roots, so you cyano on balsa sheet top and bottom of the joiner and ballast tubes and sand to shape to fit the thickness of the cores, less 1mm to allow for the thickness of the carbon tow and sock that goes over them.

<u>Wing core assembly</u>

Yes I know that glass and carbon should not really be together because of coefficients of expansion etc., but this is not full-size and the wing is seriously strong as is. The molded Syron will be all carbon.

Plan carefully and use slow epoxy and get someone to help and make sure they know what your procedure is.

On one wing panel, you will have, from top to bottom,

1. Glass skin,
Airex or balsa,
Carbon, spar cap (no. 1), carbon trailing edge strip and square carbon cloth patches for the servos.
50g/m^{2}cloth, over the whole of the inside of the skin.
Foam core

2. Carbon spar cap (no. 2) on top of the spars
Spars, balsa-tube-foam wrapped in carbon sock

3. Carbon spar cap (no. 3) on bottom of the spars
50g/m^2 cloth, over the whole of the inside of the skin.
Foam core

4. Carbon, spar cap (no. 4), and square carbon cloth patches for the servos.
Airex or balsa,
Glass skin,

Note; there is only one carbon strip, 20mm wide, on the <u>trailing edge</u> for stiffness; you can put it on the top or bottom on the skin.

Get ready!

Wing cores ready, all spars cut and numbered and laid out on a table. See picture. Did you check the core and skins fit? Does the skin go around the leading edge OK?

Wing joiners waxed.

Skins ready and marked.

I used my perfectly flat floor to put the blocks on lined up. Make sure you can walk around them freely.

I used old doors with weights (30 Kg cement bags x 5 per panel) on top to "clamp" down the cores when setting. Get all this stuff ready. I also marked out on the floor with masking tape where the cores go, center section gap, etc., etc.

Cut out the inner glass cloth skins. I used a second layer of carbon tow between the joiner / spar tubs and the wing. (See the layout list above, and pictures.) Cut all these to size and tapers.

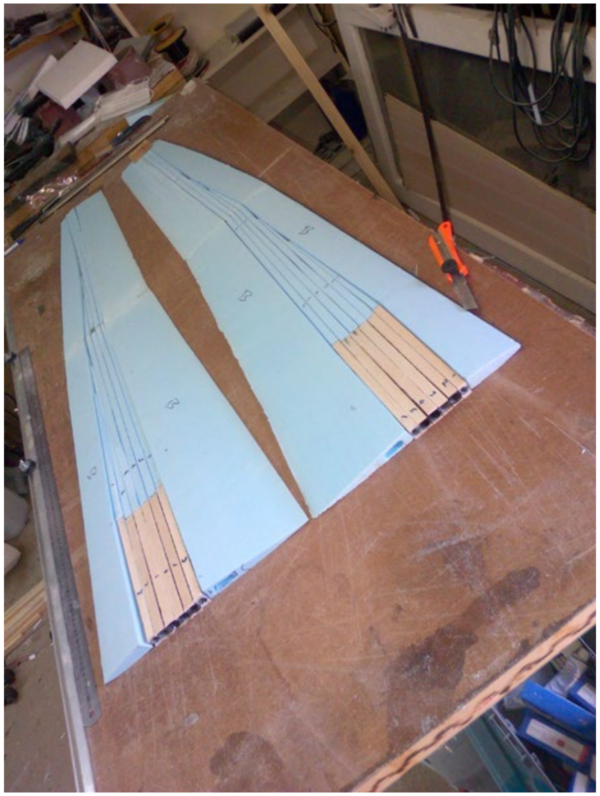
Get a piping bag or squeeze bottle ready with micro balloons to squirt into the leading edge. When the skins are on, you are going to pipe the balloons into the leading edge. It's only a gap of about 4mm or less.

I cut up some hard wood battens, about 15mm square. When the wings / tail are in the blocks and all is done and curing, put on a batten top and bottom of the trailing edge and clamp using bull dog clips, this will make sure the trailing edges cure dead straight.

Epoxy time!

It's a similar process for the tail. We actually did the tail first to get us in the groove as it were!

There are no root ribs for the wing or tail.



◀◀ *Ballast tube assemblies in the wing cores*

◀ *Balsa sheeting ready for application*

▲ *Close-up of wrapped ballast tubes*

They have a glass skins on, see below.

Bottom foam blocks lined up and taped to the floor.

Wet out the carbon and add the 49g/m^2 to the bottom skins and lay out on the blocks.

One wing panel at a time, lay on the "leading edge front."

Add in the extra carbon spar cap on the skin. Wet this carbon out on the table to get all the excess off.

Now, in numbered sequence, carefully take a spar-tube, lay it out on the table with the number marks on the top, reel off but don't cut the carbon sock and wet out using a spreader, slide on the wetted out sock using a snaking action with your hands. it will go on nicely and you can pull it tight to grip the foam and tube blocks. Trim over length. You want the sock to stick out of the tip and root about 10mm for trimming later.

Remember to add in the waxed joiners

Do the same with all the spars on both panels. Don't rush. You should have about five hours before the epoxy gets grumpy. RELAX!

You will have to fiddle to make sure the wing cores-spars line up with your foam block marks. It will all stick together nicely.

Add on the next spar cap.

Add on the trailing edge 20mm wide carbon strip.

Add on the top skins.

Use your wife's best piping bag or soft bottle with a nozzle and run a bead of

▲ Joiners in place, ballast tubes open

▶ *Skinned right wing and right V-tail*

thick micro balloons into the leading edge and around the 3mm leading edge carbon rod. Your wing skins should be touching the rod.

Use strips of masking tape and tape the trailing edges so the skins all line up.

Put on the top blocks and line up with the block marks.

Tape in place.

Weight down.

Walk away and just leave it for a few days!!

When cured, open it all up. Take out the joiners. You did wax them, eh?

Trim the root and tip with a band saw and sandpaper.

Careful with the shards of cured carbon. Ryan will confirm that's it worse than standing on a Lego.

Epoxy on the balsa tip blocks.

When the tip blocks are done, support the wings / tails vertically and cut out two strips of $100g/m^2$ glass cloth and epoxy on to the roots. Root ribs done!

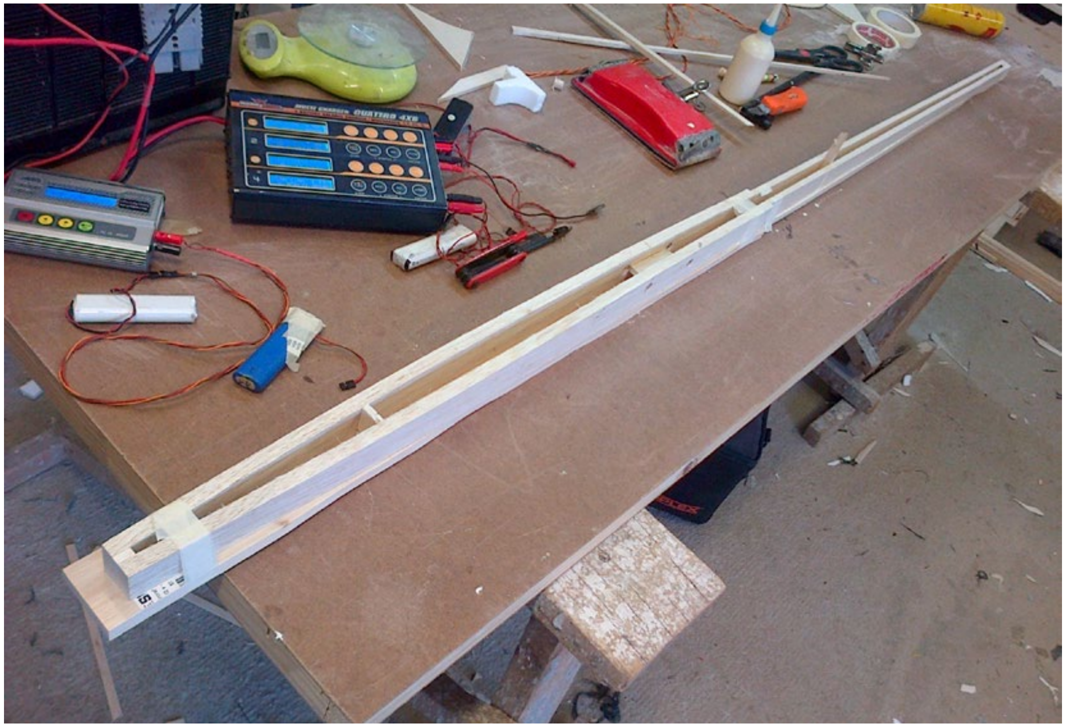
When you sand the tips and roots flush you will notice that the wax on the wing skins will help to get a clean edge.

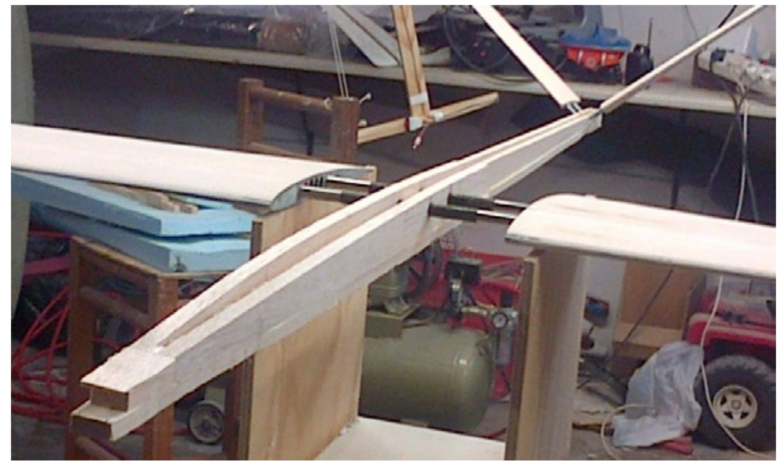
Glass the tips with $49g/m^2$.

With the long cure time of the epoxy, we fiddled with the wing lining up as we had never done anything this involved before. We also did not mark the cores and blocks so we had to use the "Mark I Eyeball" to check all was in order.

<u>Fuselage</u>

It's just 12 mm balsa sides, spliced





▲ The beginnings of fuselage construction

◥ *V-tail mounting*

▶ *Fitting the wing joiners*

together for the length, and balsa sheets top and bottom.

Before you make up the fuselage, please mark out carefully the wing section and joiner tube holes and same with the tail. The incidence of the wing is 1.8 degrees. Tail is at 0 degrees.

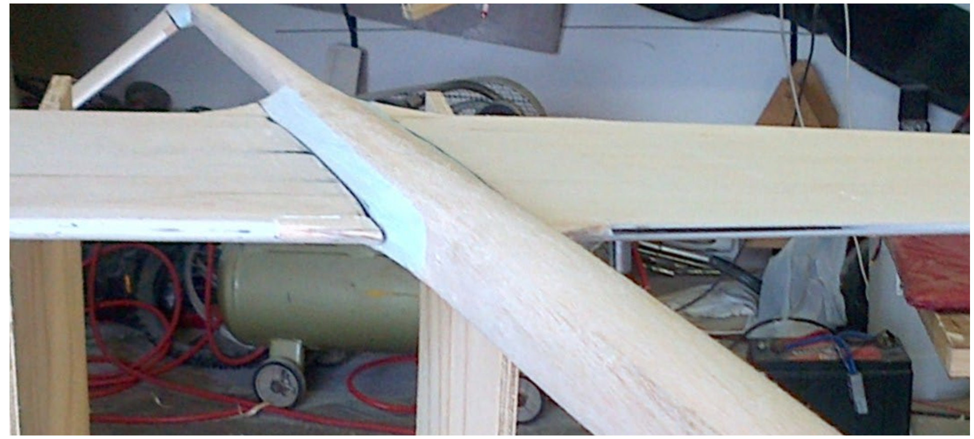
There are no ply doublers, basic stick formers are added in (see the pictures) to separate the center section. Add on the bottom sheeting and then knock out the formers. Add in the wing and tail tubes. Please make sure you get them correct!!!

While the fuselage is open, run in your cables for the tail servos. Then add on the top sheeting.

Here's a trick I have used to "see" where you are sanding the shape of the fuselage so you don't go too far. Paint the inside of the fuselage side sheets with poster paint. A thin coat, you just need a bit of color. It will dry quickly. Do the same with the block-sheets top and bottom before you glue them in to blocks or on the fuselage. You now have a "contour lines' as you sand. Easy!

Fuselage, wing and tail fairings.

I used 0.5 mm carbon sheet cut to the curved blended root shapes for the wings and tail and these are covered with



◀ *Overview of the nearly completed airframe*

▲ *Bottom view of the wing-fuselage fairing*

balsa sheet or block, top and bottom to match up with the wing trailing and leading edges. I rimmed back the leading edge and trailing edge about 5mm to make a "notch" so they can slot in. Make sure they line up with the airfoil shape. Please use carbon in the middle or the edges will chip. Thin ply is hopeless.

Sand the wing and tail fairings to shape. Use light weight filler to blend them in.

Epoxy on the oversize foam fairing blocks on the fuselage and blend to shape to match up the roots of the wings and tails. See the pictures.

Now cover the whole fuselage in a carbon sock. You need to make sure the sock sticks everywhere to the fuselage or it will lift. You need to spray glue the whole fuselage. Now, unfortunately, with the glue on, there is no way you can slip the sock over, so I taped up one end of the sock, turn it inside out and then push this end up against the nose. Then roll it out over the fuselage inside out. I then wet out in the normal manner.

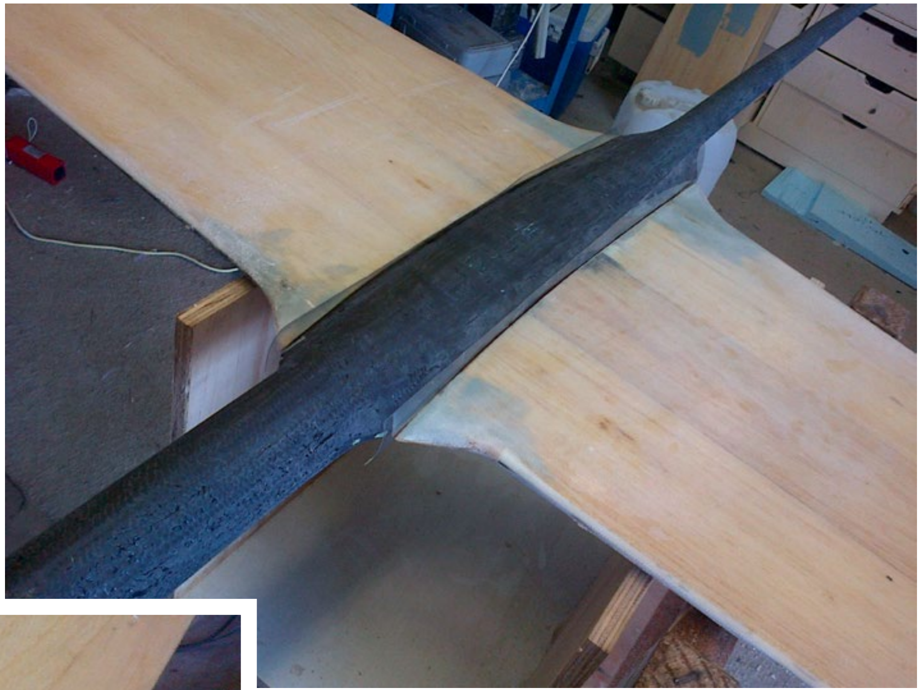
You can use carbon cloth cut to size to cover the fuselage if you want.

OK, now cut out a strip of thick Mylar, (see the pictures) and cut out the joiner holes and wax both sides. Slide on the Mylar and the wings and tail on to the fuselage. You MUST wax the joiners!! Using very light epoxy filler, or you can use a micro balloon mix as well, blend in the wing, tail and fuselage. See the pictures. You can go overboard a bit to make sure it "flows" nicely from the wing to the fuselage. You are going to sand most of it off anyway.

You will need to wiggle the wing to get it to pop off. Be patient and don't stress. It will come off. Crossing your fingers does not help, making sure it is waxed properly does!

Finishing

Note that most of my model wings and tails have "knuckle hinges." I don't like gaps!! Yes, knuckle hinges are more work, but well worth it.



◤ *The well-shaped front end*

▲ *The wing leading edge fairing*

◀ *Mylar aids the final wing-fuselage junction correct*

▲ *Tweaking the V-tail junction*

▲ *Fiberglass root cap*

▲ *Final shaping of the wing root fairing*

Mark carefully top and bottom, the flaps and ailerons, and then cut out using a steel ruler taped to the panel. Many cuts are made to slice through the skin. Same way with the servo covers. Be patient, many cuts and they will come out. Remember, you are cutting through carbon.

Face the ailerons and flaps with hard balsa, sand and put on a coat of epoxy. Sand until smooth and blend in nicely with the surface.

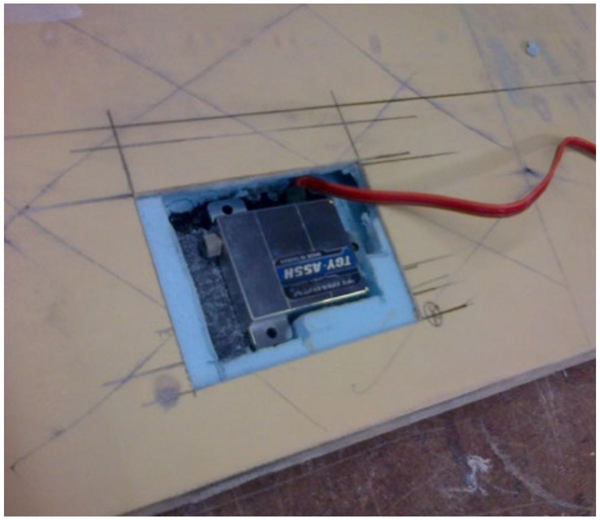
Now use a piece of sandpaper-wrapped dowel and sand the wings and tail hinge areas concave. You need to get the skins to a razor-edged on the hinge line. Trial fit the ailerons, flaps and elevons, etc., and make sure you get a good fit!

▲ *Airframe completed*

▲▶ *V-tail*

▲▼ *Fairings provide for a very smooth wing-fuselage junction*

▲▶ *Fairings provide for a very smooth wing-fuselage junction*



▲ *Wing servo mounting*

▲ *Pushrod fairing*

▲ *Fuselage access hatch*

▲ *"Knuckle" hinges throughout*

▶ *Flap and aileron hinging allows a large amount of deflection*

Glass the concave hinge areas with $49g/m^2$ cloth. This helps as a sub spar and anchors the hinge pins. Give it a light sanding when cured.

Mark out the hinge points on the control surfaces and panels. Make sure they are in the center!! Put a hinge next to the horn area to stop any flexing.

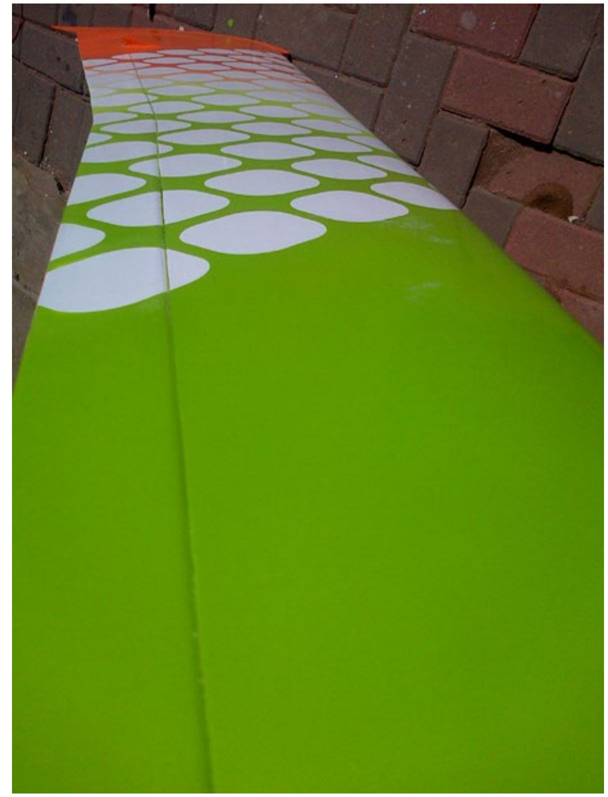
With a small brush wipe a bit of wax on the hinges points. The aileron, flap and elevon pin hinges are epoxied in with a thick mix of micro balloons. I used a small soft plastic bottle with a spout. Push the nozzle in tight to the hinge holes and use a quick squeeze. I do not use a “piping bag” as it will flow all over the place. After you squirt, the bottle sucks it back making it easy to work with.

I glued in the ailerons, flaps and elevons, then painted. I put the controls past the normal limits so the paint goes in the hinge area.

Control horns were made from PC board. Please make sure that all the horns and clevises are a good fit. No play here please!

You will note the servos are way back on the wing because of the wing spar. Make the servo “hatch” at least 20mm bigger all round than the servo. When cut, peel off the cover, then cut out the foam for the servo. You will have a “ledge” all around the servo well that the servo cover will sit on. All the servos are underneath the

▲ *Bottom and top surfaces after application of 2-part automotive paint*



▲ *Upper right wing surface looking from tip to root*

◀ *Wing-fuselage fillet*

▲ *V-tail mounted*

wing. The flap horns come out on the top of the wing, and the aileron horns are underneath. The pushrod fairings are made using a bit of blue foam, sanded to a fairing shape, and then glassed with two layers of 100g/m^2. Then the foam is melted out, the fairing cut and sanded to shape, epoxied in place and blended with filler. The fairing on the aileron is part of the hatch.

The wings and tail skins will have some wax on them that you will need to clean off. My Syron was painted in the normal manner with 2-part paint, undercoat and colour, and then polished.

Check CG, switch on and chuck it.

On my test flight, I did not have a single click of trim, and still have not clicked. The CG was spot on as was the aileron differential. First time ever for me. You know what you are doing with this type of model, so have fun.

Please contact me if you need any help.

Simon and Russell head out for the maiden flight.

http://www.rcsoaringdigest.com/videos/SYRON_DSing_2.mp4

Designer Vortices

A highly conjectural article on how a few wing shapes can minimize vortex drag

The relatively perimeter-driven wingtip vortices of box wings, C-wings, and winglets, versus the more center-driven wingtip vortices of standard monoplane wings

Philip Randolph, amphioxus.philip@gmail.com

Figure 1: Nonplanar wings

Perhaps the definitive article on how a few odd wing shapes can at least slightly reduce vortex drag is by Ilan Kroo, of Stanford: "Nonplanar Wing Concepts for Increased Aircraft Efficiency." Dear reader, that's your homework. Bonus: It's well illustrated.

What I have to add is a conceptual analysis. It will hint at ways to control the strength, character, and location of trailing vortices, and may help in the design process. The goals are three:

• First, to create wingtip/trailing vortices with lower rotational velocities (leeching less kinetic energy). And,

• Second, to create wingtip/trailing vortices with centers in which pressures are less violently lowered than those around planar monoplane wingtips of similar span and load. Trailing vortices are like mini-tornados with low-pressure centers that suck back on a wingtip, making much of vortex drag. Kroo explains that Lockheed's 1980's term for aft-placed winglets that do this is, 'vortex diffuser.'

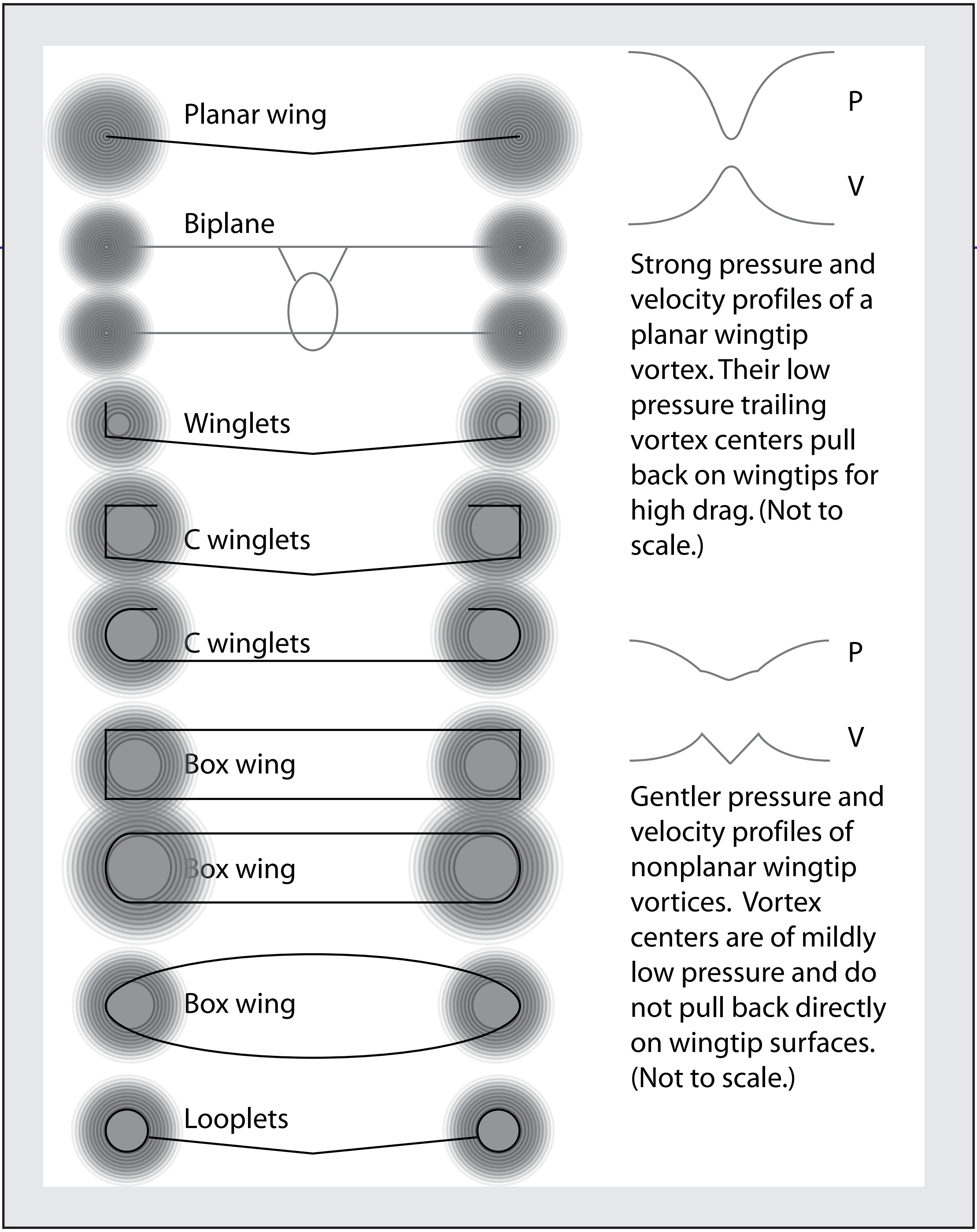
• The third goal is to locate the low-pressure center of the trailing vortex off the wing surface, so that it to some extent pulls back on air rather than on the wing.

Disclaimers:

I have to start with four disclaimers:

First, what happens around oddly shaped wingtips can't be mapped with conjecture. That takes either wind tunnel testing or quite sophisticated computational fluid dynamics. Never the less, I'll try.

Second, even those ubiquitous winglets aren't things that automatically do a good job. Their design requires sophisticated engineering and targeted optimization. Winglets are generally designed for the cruising altitude and cruising speed of a plane. That's where most of the fuel is spent and where



increases in efficiency save the most money. Winglets designed for cruise may or may not be an asset at other speeds and altitudes. In an engineering sense winglets are design fussy. So are most of the 'non-planar' wings.

Third, we can't get rid of wingtip vortices, even by getting rid of wingtips. At least not for wings with load. Wingtip and trailing vortices are part of the great sinking-vortex swirls in which all airplanes fly, as described by Frederick William Lanchester in his 1907 Aerodynamics.

Fourth, I'm about to introduce a few conceptual tools. Each presents an ideal, and so is unrealistic. Bear in mind that real flows around even simple wings are far from ideal. Still, a good concept or two may raise the right questions.

Check the appropriate box to indicate you have read the above disclaimers

⊂⊃ Agree ⊂⊃ Disagree

and continue.

Figure 1: Planar and nonplanar wings and the approximate locations of their wingtip vortex cores. Where the low-pressure core is centered away from a wing's surface it will pull back on air rather than wing, and drag may be reduced.

Velocity and pressure profiles of planar and nonplanar wings are not to scale. Trailing vortex core pressures are lower behind planar wingtips than behind nonplanar wingtips.

What are planar and nonplanar wings? The two forces that create trailing vortices – pressure gradients and sheers.

Planar wings are approximately flat when viewed from ahead. We can ignore a bit of dihedral or polyhedral. Planar-wing wingtip vortices are formed by two forces: First is the pressure gradient up around the wingtip, from raised below to lowered above. That creates and centers the vortex. Second is the sheer between inboard downwash and outboard upwash. This sheer can be severe. It adds to the rotational velocities of the wingtip vortex. (A sheer without the curving pressure gradient would not necessarily make a vortex.) The sheer helps the pressure gradient around the end of the wing create a very-high-rotational-velocity center, which centrifuges the trailing vortex's low-pressure center. And the vortex center is in the same horizontal plane as the wing, usually right at the wingtip. Thus it impacts directly on the wing, dragging it back and ruining pressure energy recovery

Nonplanar wings include wings with winglets, C-wings, box wings, and ring wings. As always, the pressure gradient up around wingtips is determined by span loading and load distribution. Planar and nonplanar wings with similar spans, loads, and load distributions will have similar total pressure differences up around wingtips. But the pressure gradient up around a non-planar wingtip will be longer in path and less intense. That's the first of a few advantages of some non-planar wings. Second, the vortex will be perimeter driven, making a lower-velocity rotational center. And third, the low-pressure center of the trailing vortex will probably not be on a wing surface.

planar elliptical lift distribution wings. And that can reduce drag.

A perimeter driven vortex has a less violent center than vortices which have a sheer right at their center, as at the end of a standard (planar) monoplane wing. It's a good place to start. But that's all. The flows around nonplanar wingtips are complex. What happens in the middle of their vortices is more complex.

Planar wings are approximately flat when viewed from ahead

Nonplanar wings include wings with winglets, C-wings, box wings, and ring wings

Parenthetical note: Kroo observes that winglets add the equivalent of about 45% of their height to span.

Perimeter-driven vortices versus center-driven vortices

The conceptual tool we'll add is a contrast between perimeter-driven vortices and center-driven vortices. Wingtip and trailing vortices are always a mix. But some nonplanar and bell-shaped lift distribution wings trail vortices more perimeter driven than standard

A center-driven vortex is like what you see when you look in your blender. Or like what you see when you use a drill-bit paint stirrer in a can of paint. The deep funnel at the center of the whirlpool indicates high rotational velocities and very low pressures close to the middle. Rotational velocity slows to zero at the edges of the can. Its profile is that of a tornado spout.

A real-world, perimeter driven vortex: You attach your five-gallon bucket of white paint, partially full, to a potter's wheel. You step on the pedal. Initially the bucket spins faster than the paint, but soon all equalizes. All points in the paint rotate with the same angular velocity. If the paint suddenly solidified, its internal movement would not change. It has also formed a whirlpool pattern, but its center is merely a dimple. Pressures at the centers of perimeter driven vortices are not as low as pressures at the center of center-driven vortices.

A planar wingtip's vortex is more mixed. The sheer between inboard downwash and outboard pressure gradient upwash makes a vortex which is partly center-driven. The pressure gradient around the wingtip is strongest close to the wingtip, but also exists further out. The centrifuging is strongest close to the wingtip.

So the wingtip vortex doesn't have the zero-pressures and infinite velocities of an ideal vortex at its center. But it's closer to ideal vortex velocities and pressure gradients than a more perimeter-driven vortex.

Disclaimer #5: Blender and paint-stirring examples are weak analogies for what happens around wingtips. Vortices created by stirring water or paint are from viscosity. Around wingtips, the vortex forming forces are from pressure gradients and sheers. Viscosity is too minor a force to directly affect wingtip vortex creation. But effective viscosity, from turbulent mixing of flow momentums, is stronger and is important in trailing vortices.

> different shapes of wing (planar or non-planar) and different load distributions apply different patterns of the forces that create wingtip and trailing vortices

More tools: A Lanchester sinking vortex. Load distributions. Downwash. Sheers. Perimeter-driven vortices versus center-driven vortices.

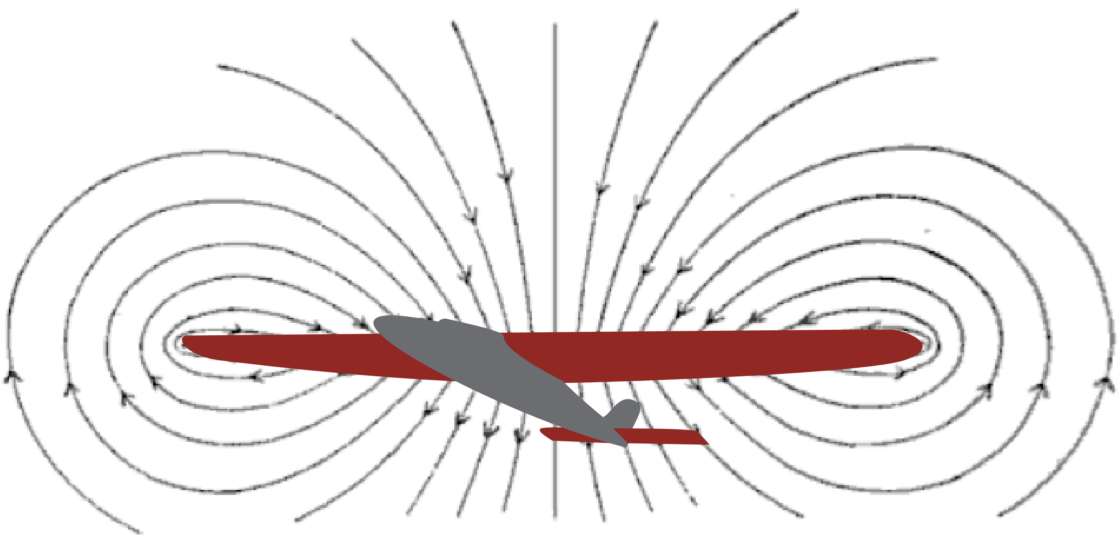
The strength, character, and location of a trailing vortex is determined by a number of forces. When asked, "Which forces?" on your multiple-choice exam, please answer "e – all of the above." That is, wingtip flows are complex. But we can get an idea.

Basically, different shapes of wing (planar or non-planar) and different load distributions apply different patterns of the forces that create wingtip and trailing vortices. The resulting vortices can vary in pressure profile and positioning of the vortex core. Trailing vortices with lower pressure cores suck back on a wing harder than those with more gently lowered pressures at their cores.

Lanchester's sinking vortex: All are similar in that a loaded wing always flies within Lanchester's sinking vortex pattern. The difference between upwash volumes ahead of the wing and sheet downwash aft is net downwash. Even though a subsonic wing flies into upwash, on the average, inboard of wingtips it pushes air down. That makes air swirl up around wingtips. So wingtip vortices are inescapable, but the pattern of forces and velocities that create them can be engineered. Thus wingtip vortices can be designed.

Figure 2: Lanchester's sinking vortex

Lift distributions: Choosing wing lift distributions and span loading is a traditional means of minimizing vortex



Lanchester's acceleration field, the result of the plane's sink, is in gray, and makes the wingtip vortices.

Figure 2: Lanchester's sinking vortex. All wings fly within air that on the average, inboard of their wingtips, is sinking. Air outboard of wingtips is displaced up. All wings fly within this great swirling pattern. But its pressure and velocity profiles can be designed.

drag. It has usually been enough to say what works rather than why it works. For a given span and wing area an elliptical load distribution produces minimum vortex drag. If the optimization target is to carry the same load while maintaining the same root bending moment but minimizing wing weight a bell-shaped lift distribution (BSLD) will be optimal. Traditionally these approaches aren't described as means of designing the trailing vortex, but that is also what they do.

Compared to an elliptical lift distribution a bell-shaped lift distribution puts the pressure forces and the downwash momentums that help form trailing vortices further from wingtips. That makes a trailing vortex that is more perimeter driven than the trailing vortices behind an elliptical wing's wingtips. BSLD wings also have lower downwash velocities near wingtips, making less sheer with air rising outboard of wingtips.

Wings with bell-shaped lift distribution have formative pressures further from wingtips. Thus they are more perimeter driven than wings with elliptical load distributions.

Downwash patterns and sheers: An elliptical lift distribution creates even downwash velocities across the span of the wing. Sheers between an elliptically loaded planar wing's downwash and outboard upwash are severe. The high velocity sheer between downwash inboard and upwash outboard plus the pressures up around wingtips make a wingtip vortex that is fairly center-driven. The result is a trailing vortex with a very-low-pressure center which pulls back on the wing, and very high central velocities carrying kinetic energy into wake.

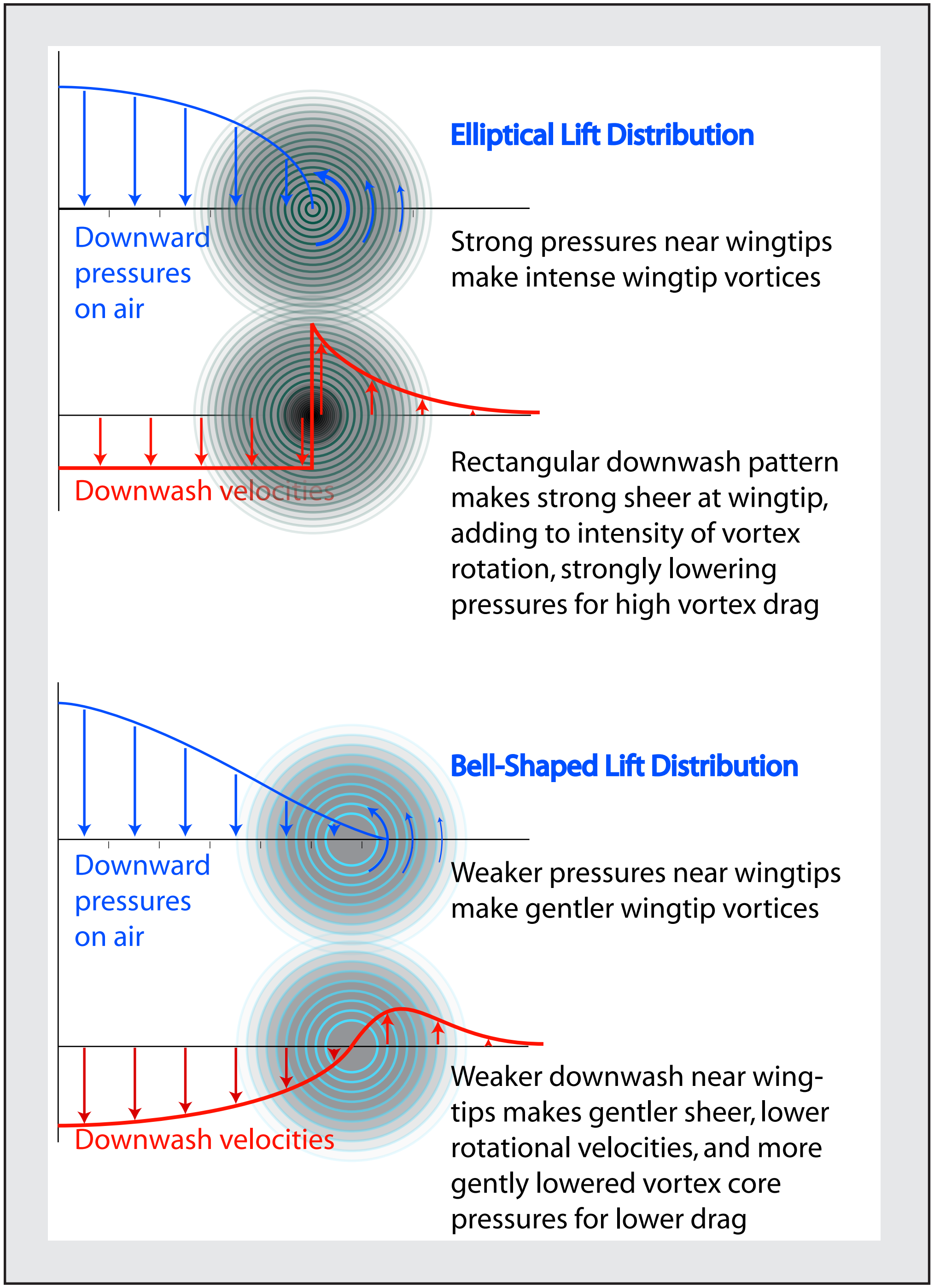


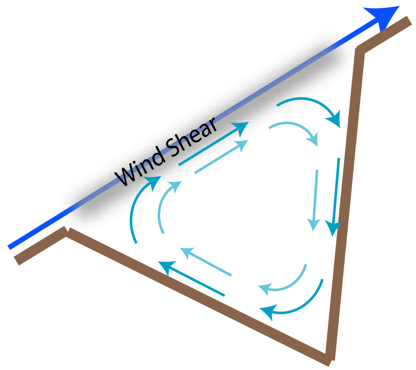
Figure 3: The pressure downwash velocity patterns of bell-shaped and elliptical lift distributions

Given roughly equal span and span loading, compared to center-driven vortices perimeter-driven vortices develop much gentler pressure and velocity profiles.

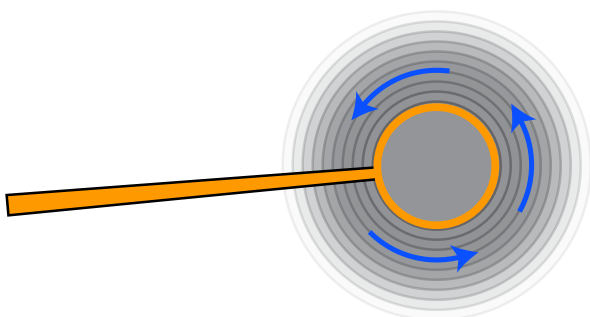
Perimeter-driven vortices versus sheer-driven cavity flows

My initial thoughts as I read Kroo's online paper used 'sheer-driven cavity flows.' I pictured the longer path air must take around a C-wingtip to get from below to above. I imagined that C-shaped path as then accelerating the air inside it into a perimeter driven swirl. Where such a perimeter flow does take place it would probably not do so. Typically a 'sheer-driven cavity flow' is caused by viscosity and turbulence along one side of a cavity. Wingtip vortices are caused by pressure gradients. Unlike the thick paint in our paint can, viscosity is too minor a force to have significant influence on wingtip vortex formation.

Figure 3: Pressures and sheers of elliptical and bell-shaped lift distributions. Elliptical wings have a rectangular downwash velocity pattern, making stronger sheers at wingtips than BSLD wings. Pressure and velocity profiles are not to scale. For a further discussion of BSLD and wing twist, see Bill Kuhlman's excellent five-part series "Twist Distributions for Swept Wings." <http://www.b2streamlines.com/winglinks.html>



Classic Shear-Driven Cavity Flow.
Velocities are highest near the perimeter



If a looplet could restrict upward velocities to outside its perimeter the low viscosity of air might not allow even sheer-driven cavity rotation to develop in the vortex center untill well behind the wing. That would make very low vortex drag. It is unlikely that any wingtip could make such a simple flow

And for C-wings or box wings that's a good thing. The relatively un-rotationally accelerated trailing vortex centers would not have greatly lowered pressures. But it is always more complex than such a simple analysis. There are the local pressure forces and momentums created by the C-wing airfoils and all the other formative pressures, momentums, and sheers.

Regardless of how a wingtip vortex is formed, once its air becomes trailing vortex, it is 'perimeter-slowed.' It's like if your five-gallon bucket was filled with water and you suddenly stopped the potter's wheel. The whirlpool shape would persist for a while, until viscous sheer friction with the bucket slowed it. In a trailing vortex, the friction with the surrounding still air is via turbulence, mixing of momentums, effective viscosity.

Figure 4: Sheer-driven cavity flows

For planar and non-planar wings of equivalent span and load, we can compare wingtip vortices. We'll find that the comparatively center-driven vortex center of a planar wing has lower pressures and higher velocities than the somewhat more perimeter-driven vortex center of a C-wing or a box wing. Winglets are somewhere in between.

Figure 4: Sheer driven cavity flows are one type of perimeter-driven cavity flow. Because air has such low viscosity, even if flows up around a C winglet or box wing are 'perimeter' velocities, they may not swirl the center of a wingtip vortex. That would result in fairly gently lowered pressures in the center of the trailing vortex. Actual flows around nonplanar wingtips aren't that simple.

Fall 2013
Cumberland Soar-for-Fun

Pete Carr WW3O, wb3bqo@yahoo.com

The Fall trip to Old Knobbly Hill was November 9th and 10th. This outing is unique in soaring because of the great location and the gathering of enormous sailplanes. Jim Dolly owns the site and has continued to upgrade the location and access so that the cargo trailers and their scale contents can make the journey up the road without problems.

Normally Jim hosts the event with four days of soaring which start on Friday and end on Monday. The idea is to offer enough days that a couple of them will be favored by good weather. It was that way this time as Saturday was fairly calm winds and shirt-sleeve temperatures while Sunday was 40 degrees and winds over 40 knots.

Saturday was perfect for aerotow and the tugs didn't get a break all day. The sailplanes were slightly smaller than last spring with 14 to 16 foot spans as the norm. The notable ships of the session were the L-13 Blaniks that are ARFs from Horizon Hobbies. They are 165 inch span, 22 pounds and sport a Red Bull decal that is eye-popping. The price for this ship is right at $1000 and the workmanship is truly excellent. There were several of these planes on the field and I wondered about the problem of flying two at the same time. It would be hard to tell them apart if flown in the same lift! The comments from pilots were that the Blanik tows very easily, shows lift well and is a dream to land.

The majority of tow tug duties were done by a Piper Cub with a really strong engine. Its climb rate was the same whether it was towing a 4 meter sailplane or a SkyBench Big Bird. Later in the day a pair of smaller electric Piper Cubs with boonie wheels were brought out to play. These were Carbon-Z Cubs from Horizon Hobbies with 84 inch span, weighing 8 pounds with 17 ounce wing loading. Again, the workmanship of these ARFs was quite excellent and they flew great. They would make a fine tow tug for smaller sailplanes up to about 12 foot span and weighing 8-10 pounds. The big tires were not needed on the short-cut grass of the field but they could easily tow from taller, thicker grass.

As mentioned before, Saturdays air was calm with only light thermal lift. Later in the afternoon the valley started working and larger gliders got good altitude off the field. There were a good variety of bungee launched ships along with electrics so the sky was full of traffic.

Title page: The Cub tows a Blanik off the short grass of the field. Pilots were getting 10 or 12 tows during the day and the practice showed. The light winds also helped make for stress free launches.

Sunday was another story entirely. A weather front moved through over night and shifted winds from the south to the west. The sky was mostly sunny but winds into the hill were 30 to 40 knots and very gusty. Where the big ships flew on Saturday it was all small ones on Sunday. One ship in particular peaked my interest. It was a 1.5 meter span ship with wingerons. Each wing panel would rotate around the wing rod to serve as both ailerons and elevator. Servos in the fuselage with ball links were hooked to each wing and computer mixing allowed the controls to operate.

As many readers will remember, the edge of the field toward the valley is lined with short trees and generates considerable low level turbulence. For that reason Sundays aerobatic fleet was launched from bungee cords that shot them over the trees and into the smoother air. The Wingeron equipped sailplane had such a launch and that must have been one very stout piece of bungee rubber! It bent the wing rod and almost jammed the steering of the ship. The pilot was able to land the ship with minor damage and was stunned to find the heavy steel wing rod bent! That will give you some idea of the conditions of Sunday on the hill.

Jim Dolly had the propane heaters and the coffee pot going in the building so a good grouping of spectators gathered inside to watch to action and the carnage. There were also snacks and a light lunch served so no one went away hungry.

The site also had a frequency pin board for fellows who fly 72 MHz gear. The ham bands are also there so I used three pins on Saturday. As time goes by the old frequencies are used less and less so I suppose the pins will go away at some time in the future. The pager transmitters on the west side of the valley had always played havoc with parts of the 72 MHz band so maybe that's a good thing. Still, there were some nice old radios on the field doing a fantastic job for their pilots.

Evidently Jim hosts events in the Spring and Summer in addition to the November fun. It pays to check the High Point Aviation web site occasionally for dates and information of upcoming events.

Resources:

<http://www.horizonhobby.com>; web site for Horizon Hobbies for the Blanik and Cub.

<http://www.highpoint-aviation.org>; web site for the soaring club.

jdolly@atlanticbb.net; Jim Dolly's email address.

The Piper Super Cub tow tug sits in the sunshine. With its tinted cockpit glass it's hard to tell this Cub from the full sized aircraft.

The Piper Super Cub tow tug sits at idle waiting for a sailplane to hook up. This ship was also from Horizon Hobbies and had a really big engine.

Above: The L-13 Blanik sits on an assembly cradle in the early sunshine. The Red Bull decal really makes the ship stand out.

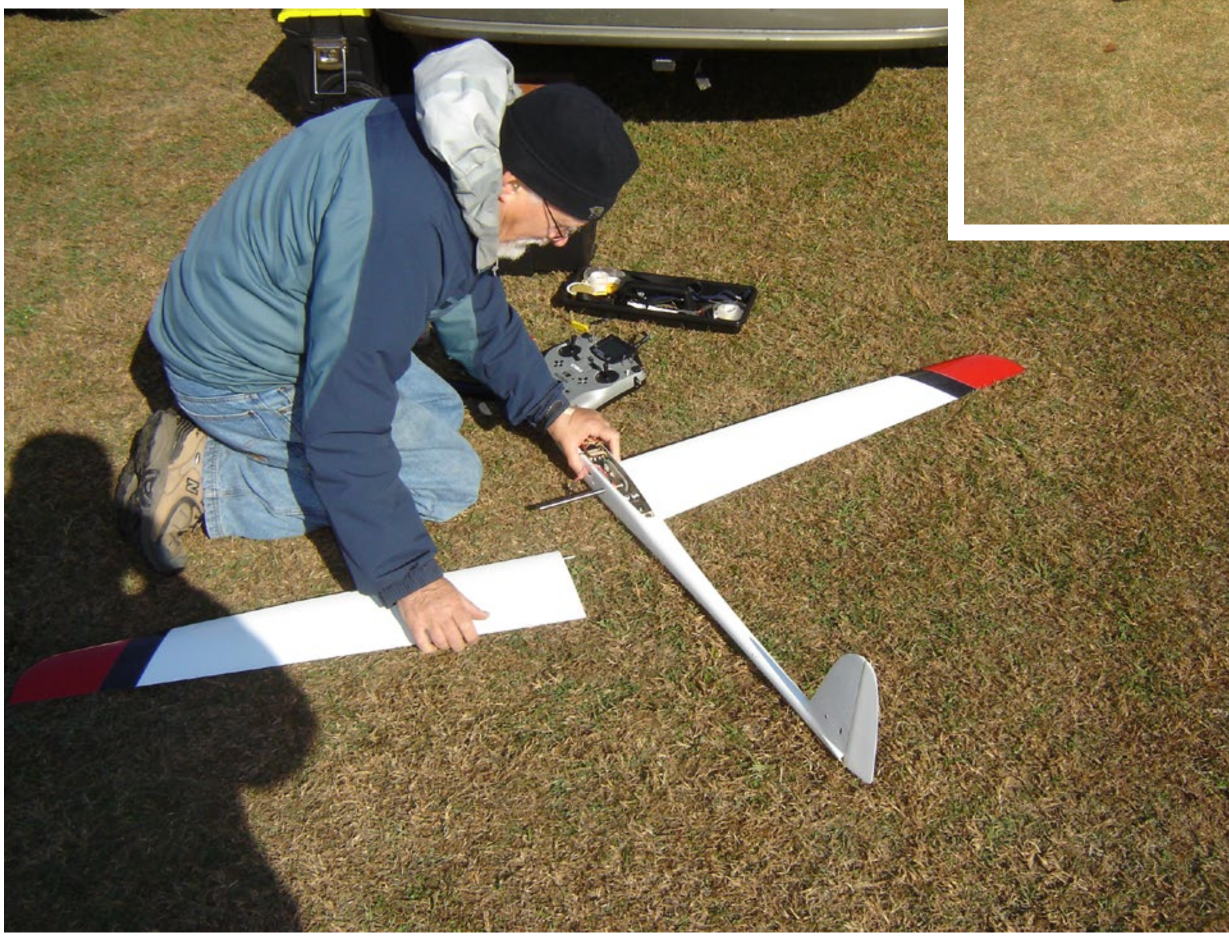
Below: This is the cockpit of another Blanik. Batteries and receiver share the forward location with the pilot. The hinges on the canopy make it easy to access the radio.

Above: The Horizon Hobbies Blanik has enormous flaps which are a great help on landing. Spoilers are also added and can be mixed with flaps or used separately.

Below: This gives a good reference of the size of the Blanik. At 22 pounds it can be a handful to hold.

*A small slope ship is launched from a bungee line into the Sunday gale.
The day was a big difference from the warm air and light winds of Saturday.*

A pilot gets ready for another trip to the lift. The small flying wings did really well in the extreme conditions. I also liked the license plate on his SUV, SOARNTZ!



This slope ship was equipped with wingeron steering. Servos in the fuselage controlled each wing panel. The panels rotated around the massive steel wing rod. Here the pilot tries to free the bent rod which had partially jammed the steering.

This Vee-tail ship towed very well behind the Cub. It was the only Vee-tail on the field Saturday so was noteworthy. It handled the turbulence of the tow without a problem.

This Schweitzer sailplane has a full cockpit and tinted canopy. I was especially impressed with the hinges on the rudder which are identical to the real 'ship. It towed beautifully and worked lift just like its full size counterpart.

The instrument panel and pilot of this Moswey 4 were about the nicest on the field. There's a good deal of time and thought that produces workmanship like that.

This is another example of a detailed cockpit. The stick moves with the ailerons and elevator and the pilots hand seems to be doing the steering. The instrument panel is a work of art.

The Moswey 4 wing was covered with fiberglass that was detailed to resemble the texture of cloth covering. It's yellow color showed up very nicely against the deep blue of the Saturday sky.

A Fox aerobatic sailplane has a full cockpit and some serious carbon fiber cloth behind the pilot. While smaller than the average scale ship, the Fox towed really well and managed to work the light lift.

The hat, straps and parachute on this pilot were amazing in their details.
I especially like the port side vent window which is open.

Al Robinson's

Albatross

Al Robinson, arobins1@comcast.net

I thought I'd send a few photos of our latest 'wing, "Albatross." The Albatross weighs 2 lbs. 14 oz. and is powered by three cells with an MPi 2800kV motor direct drive.

We test flew it on Monday, October 14th, and there are a few issues but nothing major and we didn't crash it. Always a plus with your son watching.

Like all tailless aircraft, it's very pretty in flight and hard for old eyes with bifocals to track, but it's fun and climbs out great.

Stack sawn ribs, laminated trailing edge, and I ripped some white pine in the saw for the spars. This one will get a folding prop some time in the future, and I'm probably going to build another one to tweak the design a little more.

The captioned photos on the following pages provide additional details.

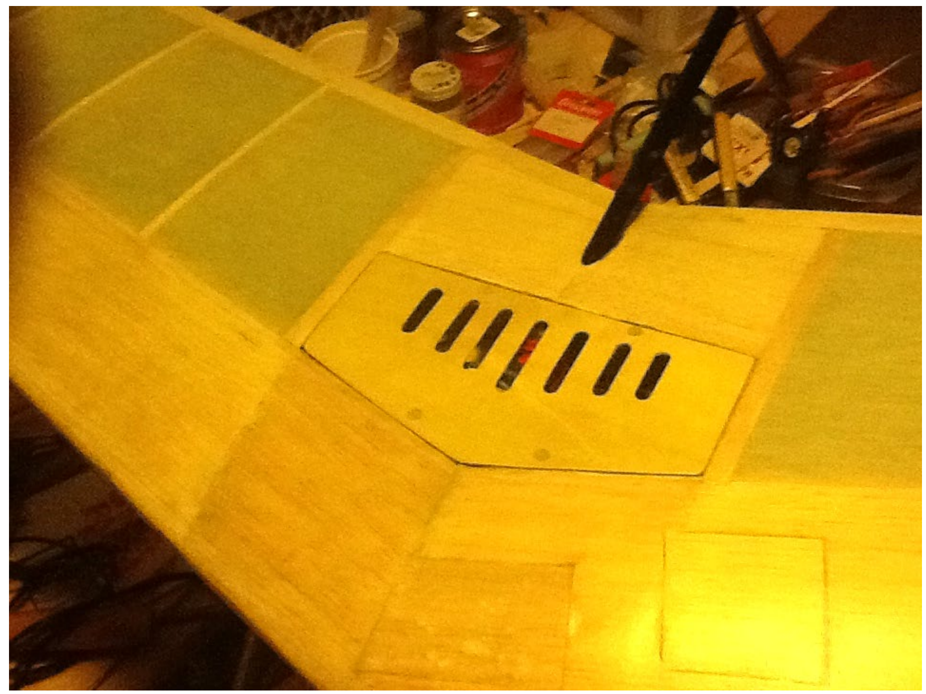
Al with his Albatross. Nice mid-October flying weather.

The extended drive is home-made. I used .125" music wire running in UHMW bushings and turned a chunk of 6061T-6 for the mount and prop driver. The shaft log is a piece of scrap tubing from a paraglider. MPi 2800kV motor turns a 7X4 direct drive at 21K and if Albatross hangs, we will put roller bearings in the shaft log when the bushings wear out, but this was a budget build with parts that we had or could make.

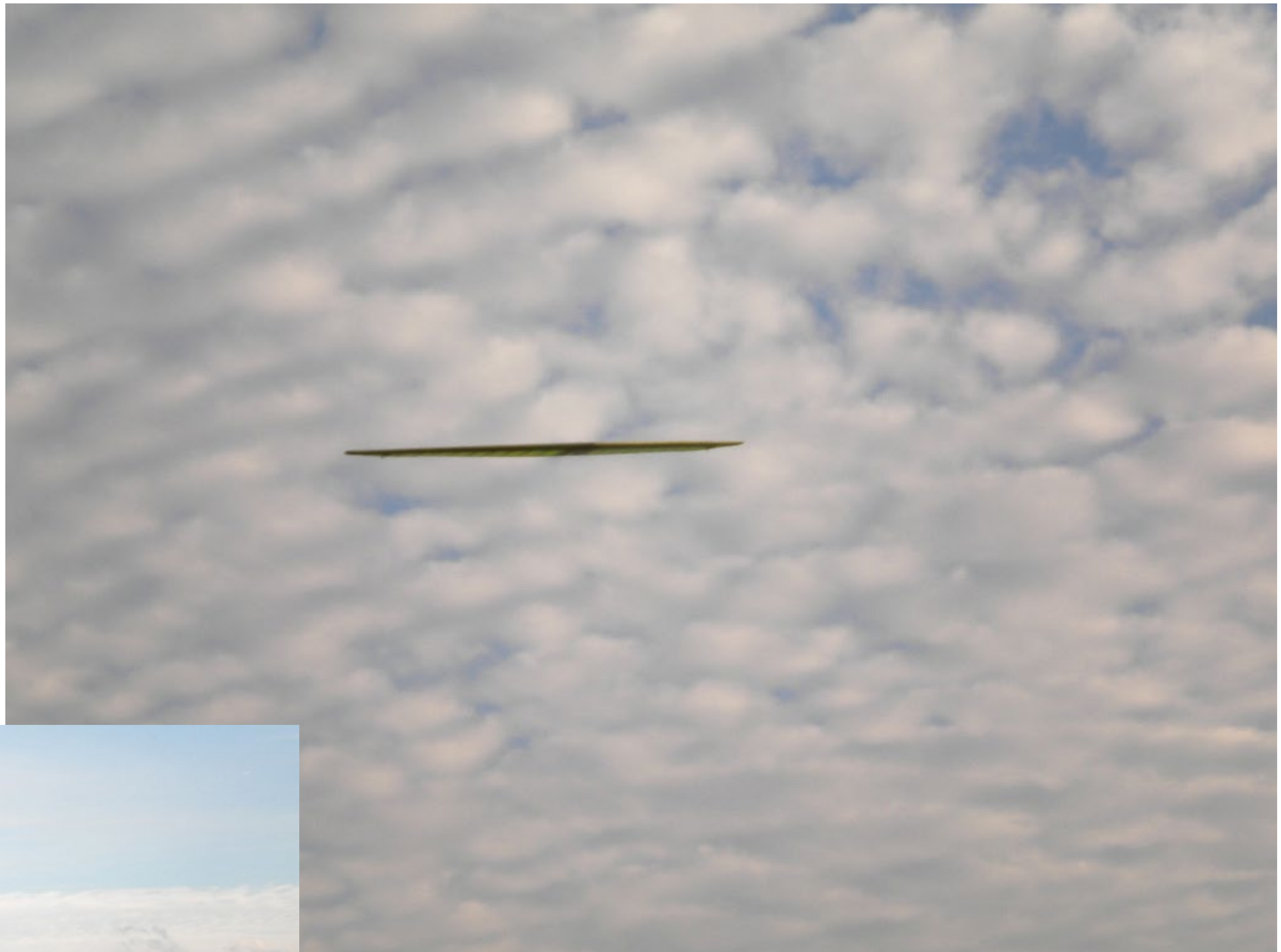
Elevon servo with pushrod mock up.. The elliptical elevons give it an "Old Timer" look that I wanted... something like maybe Frank Zaic at Jetco would have designed. There was no intent to build something high performance, this one's just for fun but I'm really surprised how well it flies. She's quite the floater and has an outstanding rate of climb. I'm waiting on the new metal gear servos to get here so we can test some more. These servos were too small and I knew it, but again... they were on hand.. I'll put skids near the pushrods to protect the new servos. Before it's all over with I'm probably going to build another one to tweak the design a little more.

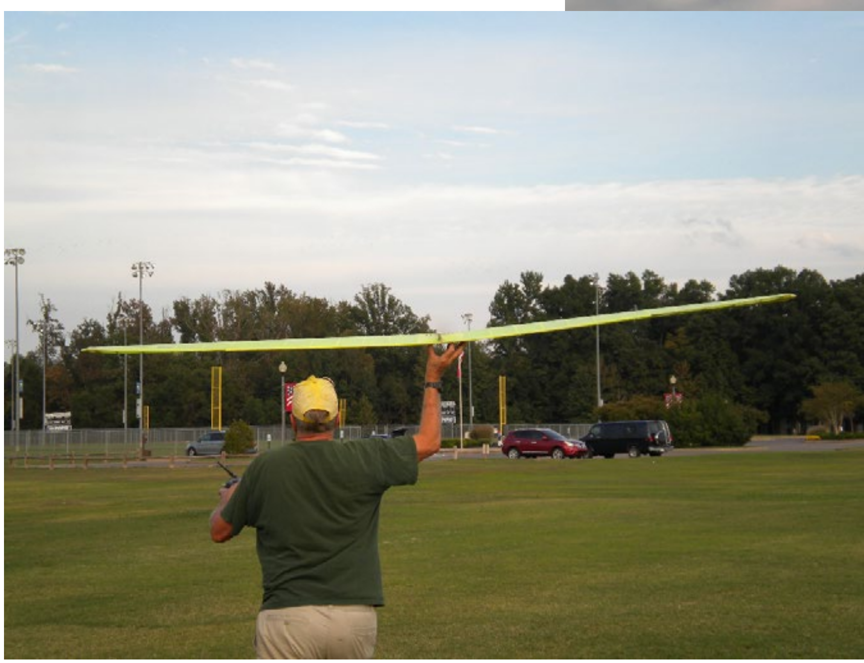
Above: Battery box on the lower skin.. 2100mah... Overkill but we had the batteries on hand and it needed the weight.

Upper right: Albatross was our first try with Polyspan. Love it. Super easy to use and it works like Polyfiber on the big stuff we cover. This pic is the first brush coat of CAB with the fluorescent dye. Supposed to be yellow but it looks green to me. Three more spray coats and it looks nice plus it’s really light. Needs stripes. Like all ’wings, it’s so easy to get disoriented.



Right: Center section closed out. The square patch? A moment of carelessness before it was covered. I flipped the wing over on the work bench and a tube of Titebond punched a hole in the “D” box... Arrrgh! It gets a folding prop later.



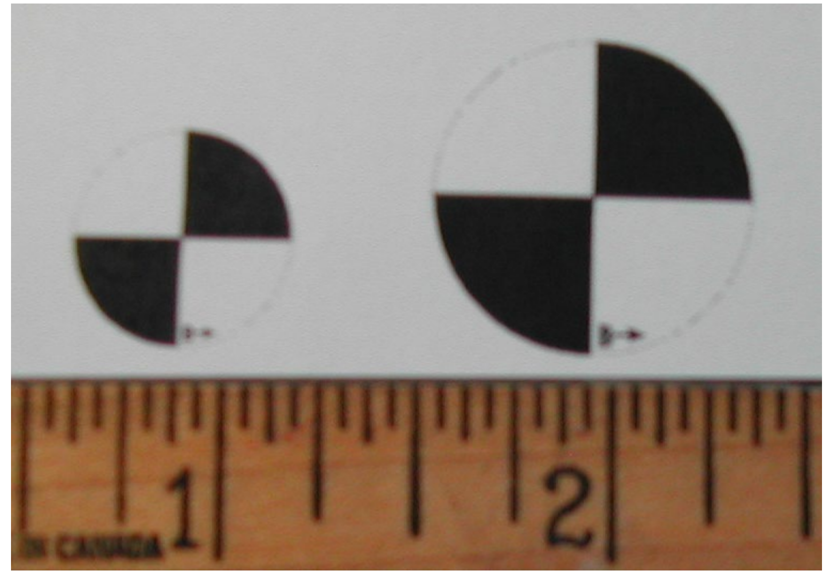


Left: Launching the Albatross. This 'ship has an outstanding rate of climb.

Above: Like all tailless aircraft, it's very pretty in flight and hard for old eyes with bifocals to track, but it's fun to fly.

RCSD

CENTER OF GRAVITY ADJUSTER



Louis Cimon, louiscimon@sympatico.ca

I have been designing, building and flying RC sailplanes for many years. Most sailplanes I have built were plagued by the same problem: heavy tail necessitating adding ballast weight in the nose to obtain proper center of gravity (CG). I designed many sailplanes and I reduced this problem by designing lighter tails and longer noses thus necessitating less ballast weight in the nose. It sometimes produced funny looking planes and was inappropriate for building scale planes.

For sure, it is a plague to add nose ballast to a finely built HLG…

By chance, two years ago, I met a very humble and shy Slovenian scientist, Sioul Nomic Ph.D. who works for a classified Canadian government "skunk works." This guy gave me access to a by-product of his research (unclassified because his employer failed to recognize potential applications of his discovery). Dr Nomic is an internationally recognized specialist of gravitic nano particles (GNP). His research gave way to flexible and paper thin sheets of GNP. Those small sheets of GNP, properly polarized and molecularly aligned particles have some particularly interesting properties, one of which is that they can alter the CG of objects while adding virtually no weight. We temporarily named those sheets Center of Gravity Adjusters (CGAs). (The name will eventually be changed for a flashier one for marketing.)

On the left side of the above photograph is a 2 meter sized CGA on the right a 3 meter sized one.

How does it work? I admit that I don't have a refined understanding of the physics of CGAs. Let's simply say that they affect gravity to a small extent. The scientifically minded will find research publications in many specialized magazines. They are easily used: you simply glue one CGA on each side of the fuselage right where you wish the CG (exactly as it appears on the airplane's plan). Be advised that CGAs are polarized so it is important to put the appropriate CGA on the appropriate side: right CGA on right side of the fuselage, left CGA on left side, otherwise funny things can happen… will happen.

When properly used, CGAs will maintain the CG at the exact position they are placed. This means that they will even compensate for ballast that is improperly centered (within a pretty good but limited range). Dr Nomic pretends that CGAs are not affected by temperature. So far we did not observe changes while flying from -20^{o}F to +110^{o}F.

CGAs are easily and cheaply produced even in small quantities. They are very lightweight (less than 1/10 gram by pair for 3 meters size CGAs), non toxic, environmentally friendly, bio-degradable, foam compatible, CA friendly, epoxy friendly, polyester covering friendly, and etcetera friendly.

Durability is very good. After two years of regular usage, we can measure a very small loss of efficiency with very sensitive lab equipment, but this loss has no practical observable effect on our sailplanes.

They can be covered with tape, Monokote or paint as long as it is not opaque. By the way, CGAs are very slightly less effective in low light conditions. (Dr. Nomic is certain to correct this bug, but in my opinion this is not a practical problem in RC sailplane applications). I don't understand why, but they maintain their effectiveness when used inside an opaque fuselage…

This Sophisticated Lady was made 5 ounces lighter by using a pair of CGAs. The natural CG of this plane without CGAs is 1.5 inch aft.

So far we have experimented with CGAs on 60 inch flying wings, HLGs, 2 meter and 3 meter sailplanes. There is a loss of efficiency on heavier planes, but Dr Nomic is confident to make them work for sailplanes up to 9 meter size in the near future and eventually for very heavy objects.

Our experimentations gave way to interesting uses for RC sailplanes. When used on the bottom of the fuselage — right and left CGA glued one over the other, adding to it's CG adjusting effect — it acts to augment stability.

When they are placed on either side of the center of the wing (top and bottom), specially modified CGAs produce aerobatic flying sailplanes that track very well. We flew Boomerang-type flying wings in various wind conditions and experimented with pretty heavy ballast and believe me, those flying wings were much funnier to fly. Those CGAs were able to compensate for uncentered ballast (almost 8 ounces, 2 inches forward) and those Boomerangs flew very well, especially inverted.

My homemade Boomerang flying wing type slope soaring glider used a pair of those modified CGAs that compensated for placed ballast.

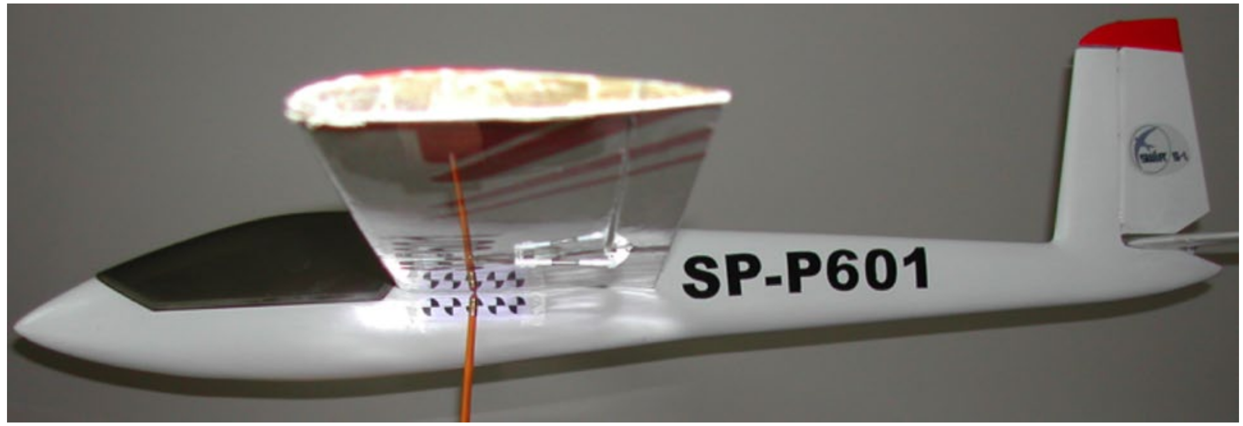
We are also experimenting with eCGAs. Those can modify their characteristics when a very low power electric current is applied. We think that we will be able to modify, in flight, the characteristics of our planes that are related to their CG on 3 axis (more on this in a future paper).

The use and placement of CGAs are open to imagination and experimentation. When they will be easily available, I am certain, we will witness very creative and interesting uses.

The use of CGAs require some basic precautions. Make sure CGAs are well glued to the plane. If only one of the CGA falls off, the plane becomes a bit unbalanced right left and has a tendency to turn in the opposite direction of the remaining CGA but the plane is still easily controllable. If the pair falls off simultaneously, the plane reverts to it's natural CG and that can be disastrous. For safety and cosmetic reasons, I prefer gluing CGAs inside of the fuselage.

CGAs are non toxic but their ingestion may cause light dizziness, particularly to gravitic sensitive people or animals. If ingested, simply drink 8 oz of 3.25% milk accompanied with 20 M&Ms. It is recommended to rapidly consult a doctor just to be on the safe side. Do not apply on living creatures (animal or vegetable). By the way, some applied researches on animals are going on. There is a research that is testing how CGA affects cats' ability to fall on their paws (be assured that no cats were harmed in this research). I think this research has a good chance to win or at least be nominee at Improbable Research Noble Prize Ceremony. More serious scientists are doing promising research with CGA to help people with equilibrium disabilities. Just think of all those elderly people that fall each year.

Dr. Nomic is in the process of patenting his discovery and intends to make his patent royalty free (like Open Source Code in computer programming).



This configuration of CGA significantly increased the longitudinal stability of my 2 meter scale Swift's small stabilizer.

For sure, Nomic's employer has been shortsighted. Just think of the possibilities, more so as Dr. Nomic is confident to make cheap CGAs usable for much heavier loads: heavy trucks, full sized airplanes, even heavy freighter ships and supertankers. On the sports side, just think of the possibilities in surfing, kayaking, skiing, snowboarding, skating, etc.

Leisure, architecture, transportation and industry will eventually be affected by the implementation of CGAs.

For us RC airplane aficionados, CGAs for 3 meter and smaller planes should be available at most hobby shops for next flying season (around April 1st 2014).

I will keep you posted on developments.

Tom's Tips

A Collapsible Multi-Stand

Tom Broeski, T&G Innovations LLC, tom@adesigner.com

The stand keeps the planes off the wet ground and away from the clodhoppers who like to step on wing tips. This stand is great for getting the planes under your rain shelter and still leaving room for people.

Materials:

(2) Pieces 1/2" plywood (Oak or Birch is nice)

(2) 3/4" x 2" x 16" to 20" solid wood, basically a 1" x 2" (I used Poplar)

(4) 3/8" x 2" hardwood dowels.

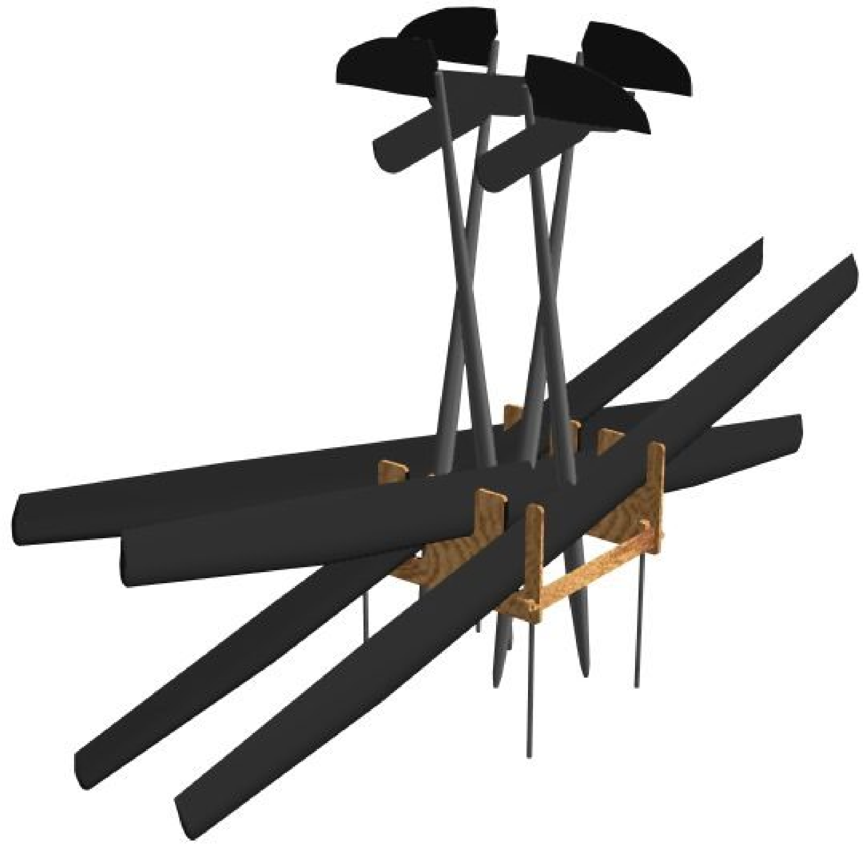
(4) 3/8" x 23" steel rods, sharpened a bit on one end

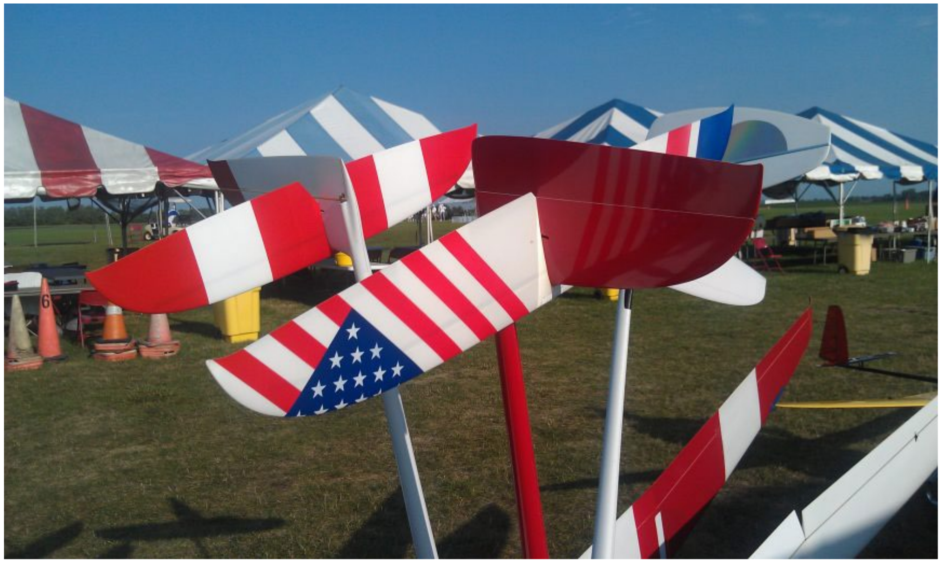
20 ft of 1/2" Velcro loop, or foam insulation, felt or something soft

I used an Aquila XC, an AVA and two Icon 2s to figure out the spacing. It has worked for everything I've tried so far.

For convenience, I've included my pattern.

You will need to taper the dowels to allow them to slide in and tighten the stretchers.

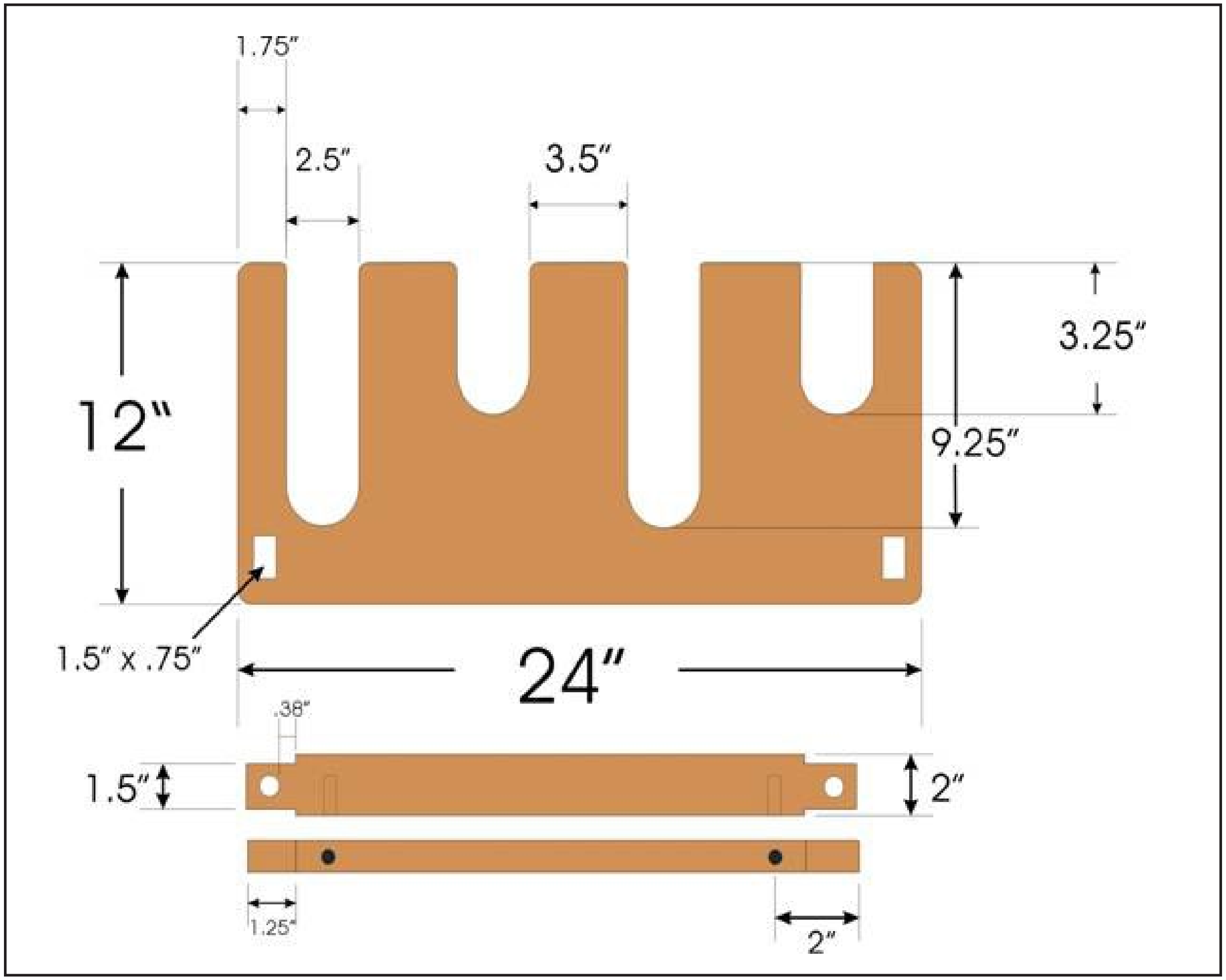


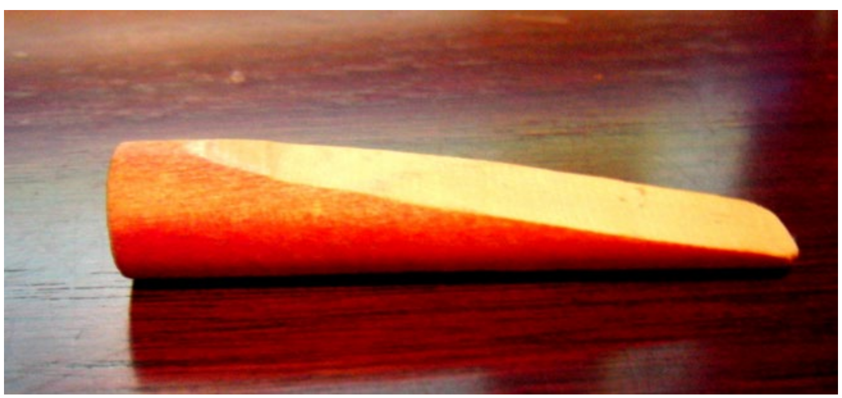


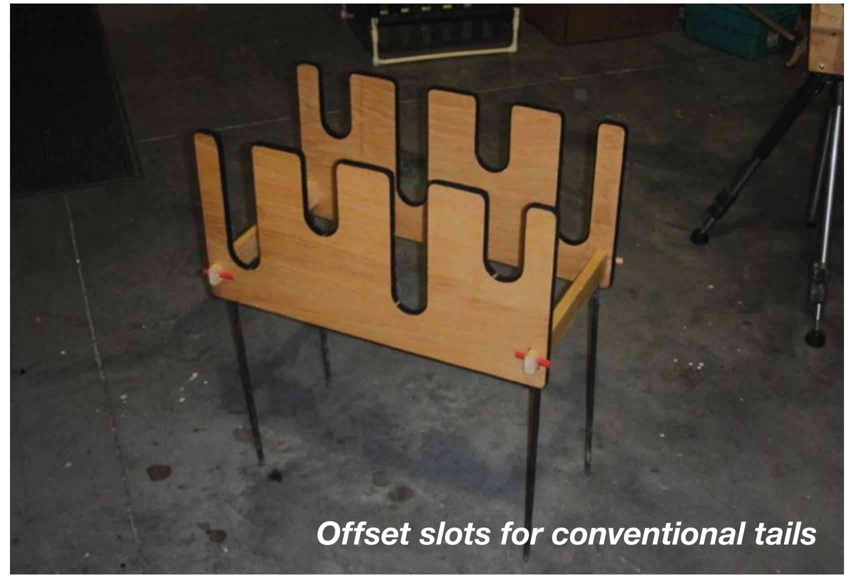
On the field, the Multi-Stand can be configured for either conventional tails or V-tails by turning around one side panel. The cant angle can be adjusted by making shorter and/or longer stretcher bars in the shop. Might be nice to have a couple of lengths made up ahead of time.

The longer the stretchers the less tilt and the further off the ground the plane wing tips will be for the conventional tail version. I use 16" stretchers most of the time. I painted the dowels red to make them easier to find if I drop one. Line the slot edges with foam tape or Velcro loop.

For standard tails, flip the sides so there is a long slot and short slot on opposite sides. For V-tails have the slots will be the same depth on both sides.


1.75"
2.5"
3.5"
3.25"
12"
9.25"
1.5" x .75"
24"
.38"
1.5"
2"
1.25"
2"

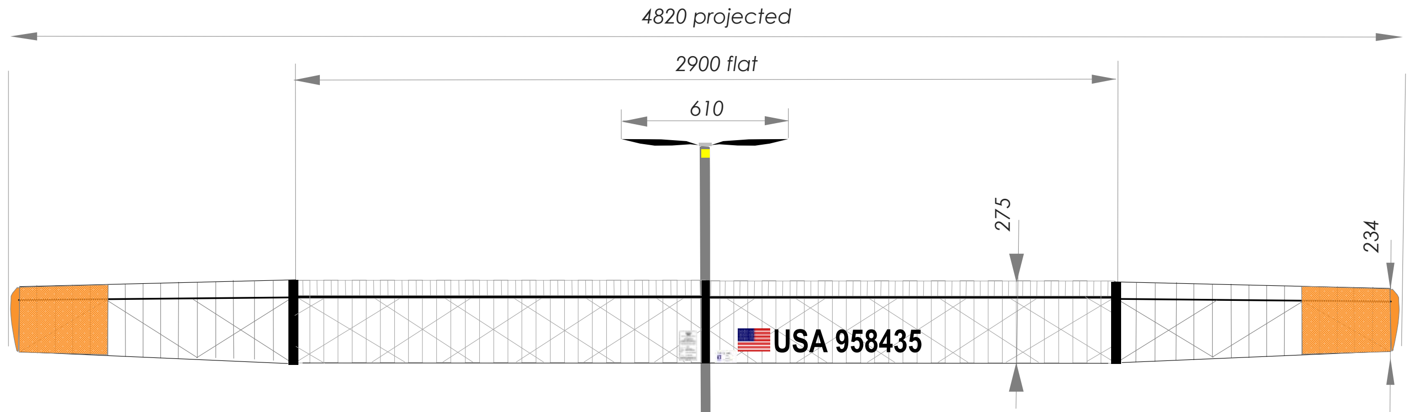




Offset slots for conventional tails

Symmetrical slots for V-tails

World Record Model – Radio Control Electric Duration – F5 # 171
Team members: Andre Mellin, Dave Brown and Joe Mekina
August 04/05, 2013 Norris Field, Liberty Indiana – USA
18 hours – 6 minutes – 13 sec

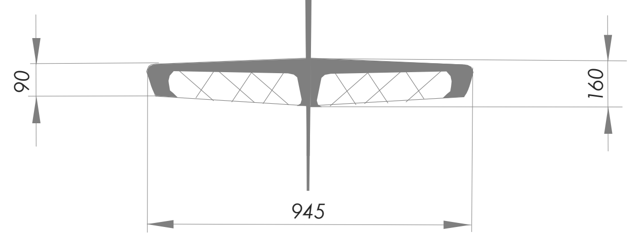


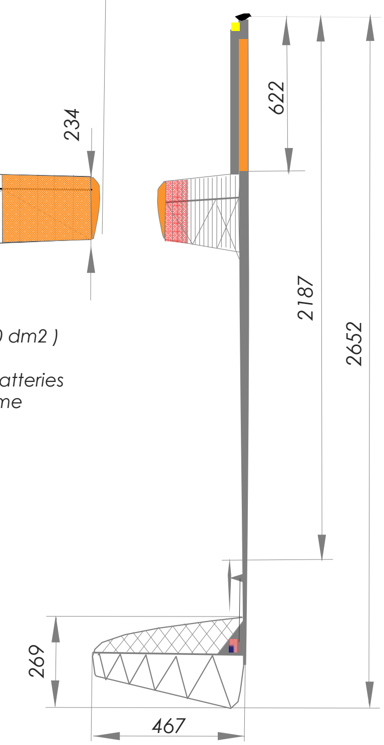
Design Details:

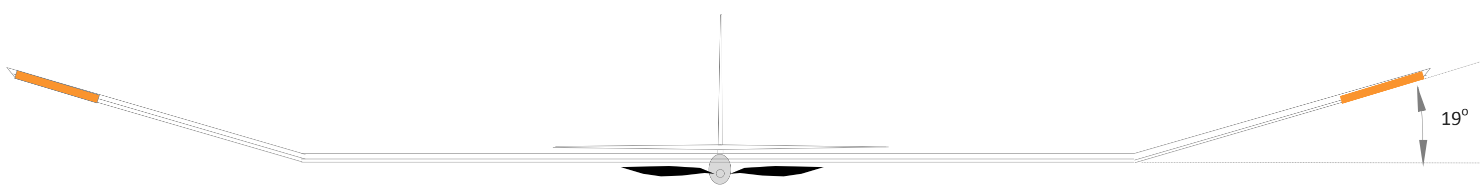
Wing:	*CF and balsa, Mylar Covering*
Fuselage:	*CF*
Motor:	*AXI 2212-34, 8:1 spur gearbox*
Prop:	*610 mm x 620 mm*
Batteries:	*45 Li-Ion Cells, 18650 form factor arranged 5S9P*
Lights:	*LEDs on tips of wing and elevator, 2 on fuselage*
RC:	*SPEKTRUM DX-7, AR9310*
Telemetry:	*SPEKTRUM STI*
ESC:	*CASTLE Phoenix Ice Lite 100*

F5 RC Electric Duration event #171:

Surface Area:	*140.4dm^2 (< 150 dm2)*
Total weight:	*3.950 kg (< 5 kg)*
Power	*Rechargeable batteries*
Motor turning propeller	*> 98% of flight time*







All dimensions in mm unless otherwise noted

<http://amablog.modelaircraft.org/fai/files/2013/08/world-record-model-3-view-2013-08-05.pdf>