Sirius and the skyscraper fuselage

3 metre soarer based on Graupner

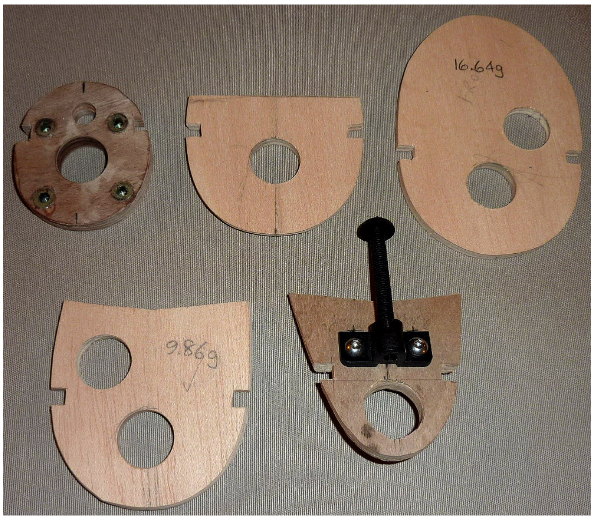
Cirrus wings and tailplanes

Last edit 21 June 2018

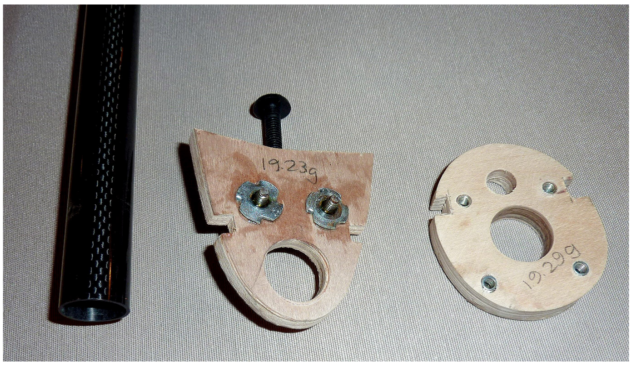
I decided to build a new motorised fuselage for 40 year-old 3 m Graupner Cirrus glider wings and tailplanes. It is a credit to the quality of the original kit that all were sound and true after years of storage. I fitted ailerons and airbrakes and covered them with Hobby King film.

I decided to use a 20 mm round carbon fibre tube for the tailboom. I bought one that was made with epoxy resin rather than polyester so it would glue well with epoxy. It turned out to be exactly the correct length for the complete fuselage and was only 92 g.

This set me thinking about not cutting it but taking it right through forward to the motor bulkhead. I decided to use 6mm liteply formers. I love liteply! The only exception was the motor bulkhead, which I laminated from four layers of 3 mm birch ply. The five formers weighed a pleasing 48 g in total including t-nuts, threaded inserts and wing mounting bracket. The fuselage has a semi-scale curved pod at the front planked with 3mm balsa and then glassed using 24 or 48 g/m^2 cloth and Eze-Kote polyester resin. I couldn't use carbon fibre cloth as it would screen the receiver. Any minor damage to the shell can easily be repaired.

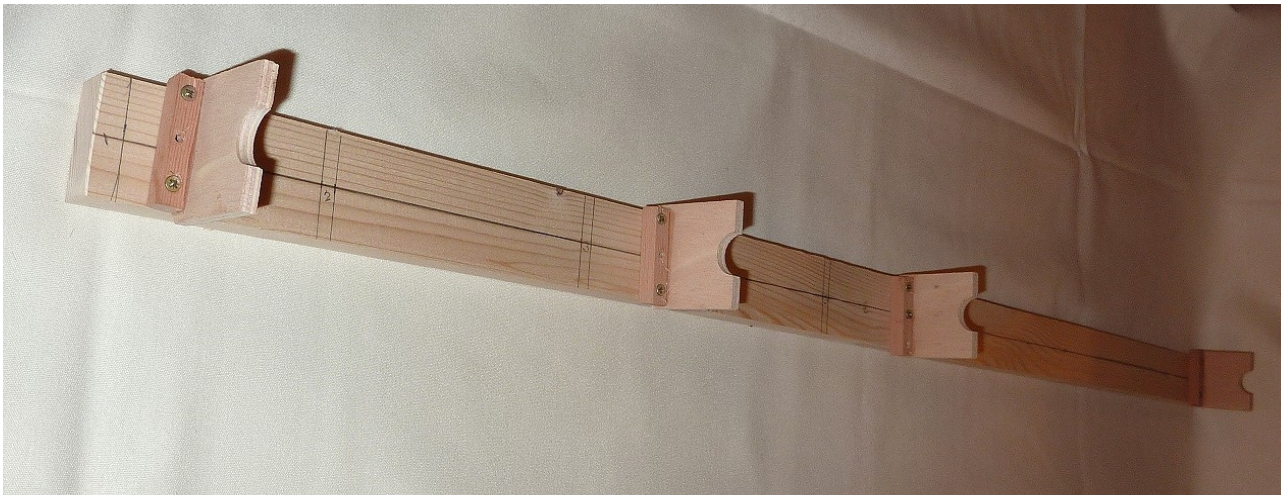


Formers



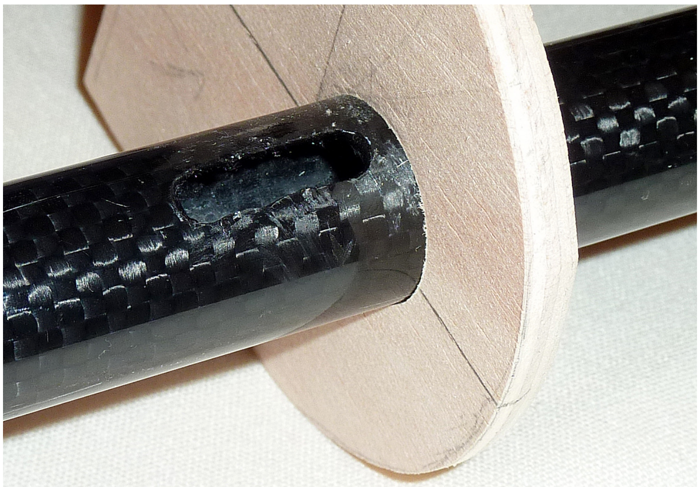
Formers and tube

I drew the formers on 1.5 mm card and cut them out to check that the curves would look good. I then traced them onto the 6 mm liteply and cut them using a Makita jigsaw with a fine blade, followed by sanding to exact shape with a belt sander lying on its side. I cut the 20 mm holes using a diamond holesaw in a bench drill press. I tested the shapes again for flow on a 20 mm wood dowel. I didn't want to scratch the polished surface of the carbon fibre by moving the formers around. I built a jig with cross markings to ensure lateral true and marks at top-dead-centre on each former to get them vertical.



The jig

One difficult decision was where to cut a hole in the tube for the servo leads which would go from the receiver to micro servos in the tail for the elevator and rudder. It will be a stress-raiser of course but I reasoned that a 5 mm smooth rounded slot cut in the side with a diamond holesaw in a bench drill press should only cause horizontal weakening that the longerons and the ply plate for the radio gear would correct. If I had any residual doubts I could sleeve it with epoxied 1 mm ply. I didn't need to. I smoothed the inside edges of the slot with a dribble of epoxy in case the carbon fibres wore the insulation away and shorted the wires.

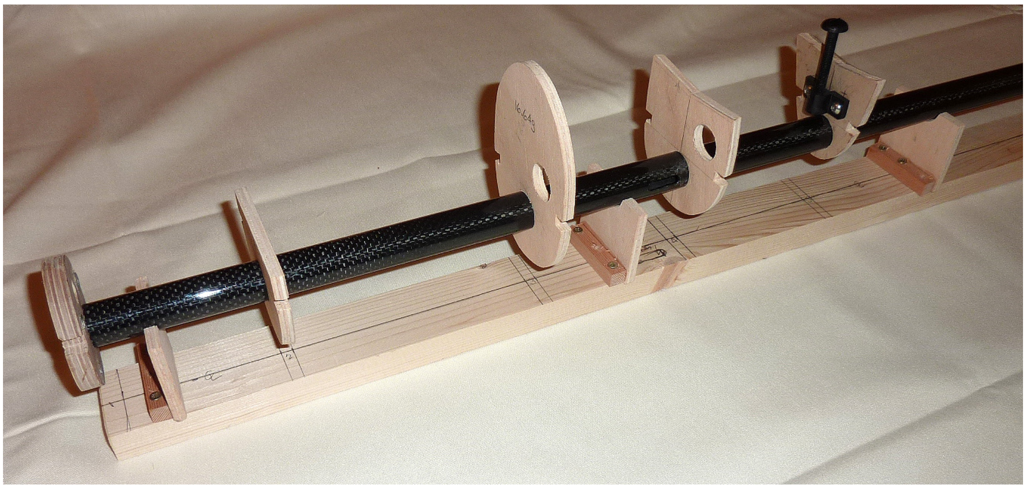


Servo wire slot

At the rear I drilled holes top and bottom, with another holesaw, for a 6 mm carbon fibre tube leading edge for the fin. I left the tube unglued until all the formers were in place so the bottom could drop onto the datum line on the jig to check that the formers were aligned with the fin.

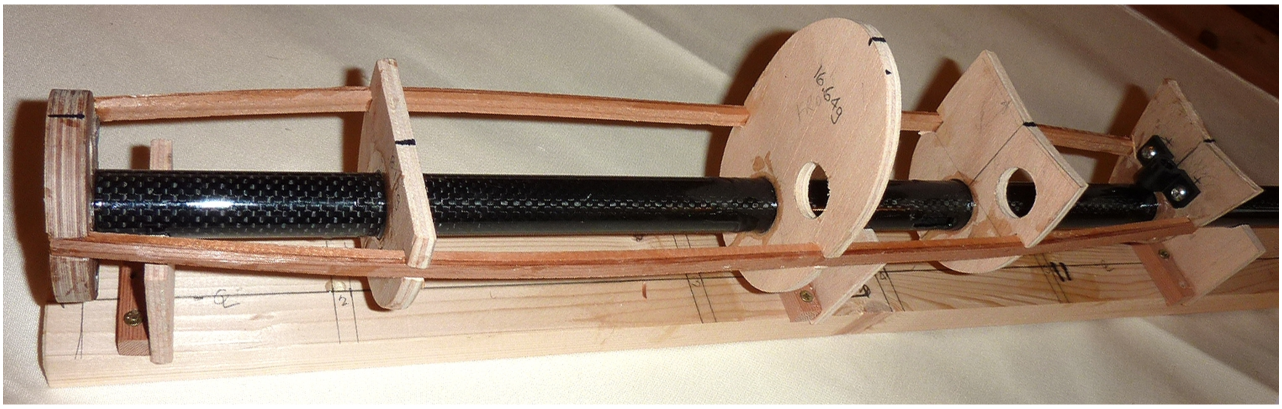
Installing the servo extension wires proved easy. I dropped them in from the tail end until I could see them through the slot then hooked them out with a wire paper clip.

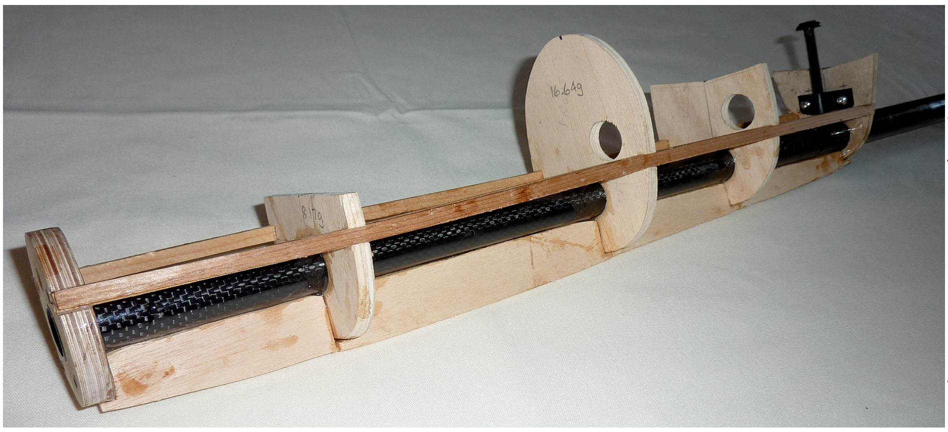
Unglued formers on the jig



I glued the motor former first using a square, as this would determine the motor thrust lines and so had to be exact. After 24 hours, when the two-part epoxy had fully cured, I glued the others. To measure exactly the two parts of the larger quantities of epoxy needed for this I used a disposable cup on a balance. One big advantage of the tube is that angles of attack are easy to measure and set up and the fuselage is certain to be straight in plan view.

Once cured I fitted longerons made of two layers of spruce (6x3 and 6x1.5) to lock the formers in place, glued with white PVA. I will fit the mounting plates for the electronics to them.





To protect the planking when landing, and to stiffen the structure, I shaped and glued in a keel made of 6 mm liteply. It stands 3mm proud of the formers so the planking will be flush.

The fin leading edge is a 6 mm round carbon fibre tube with 0.5 mm walls. The 3 mm liteply insert helps to lock it in place and forms a fin rib. Because this reduced the space inside the main tube I had to install the servo leads before gluing. I wrapped the wires with plumber's PTFE tape to prevent them being glued. It worked a treat.

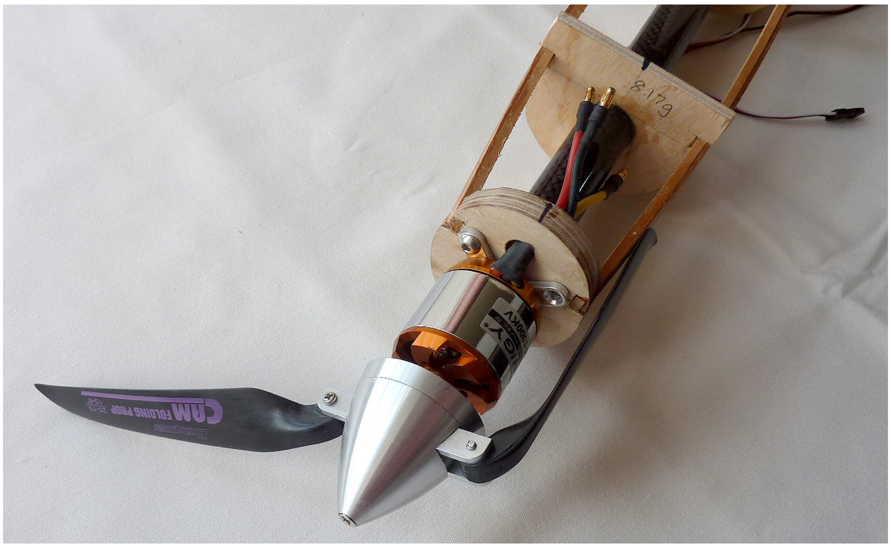
The rear of the fin is a 6 mm square thin-walled carbon fibre tube. I will use round pivot hinges for the rudder glued into holes drilled in the tube.

For a while I puzzled over how to get the fin perfectly aligned. Then I realised that two spruce spars clamped onto the fin uprights and the wing fixing bolt would do the trick. I was pleased and surprised to find that the spruce was straight enough afterwards to be usable.

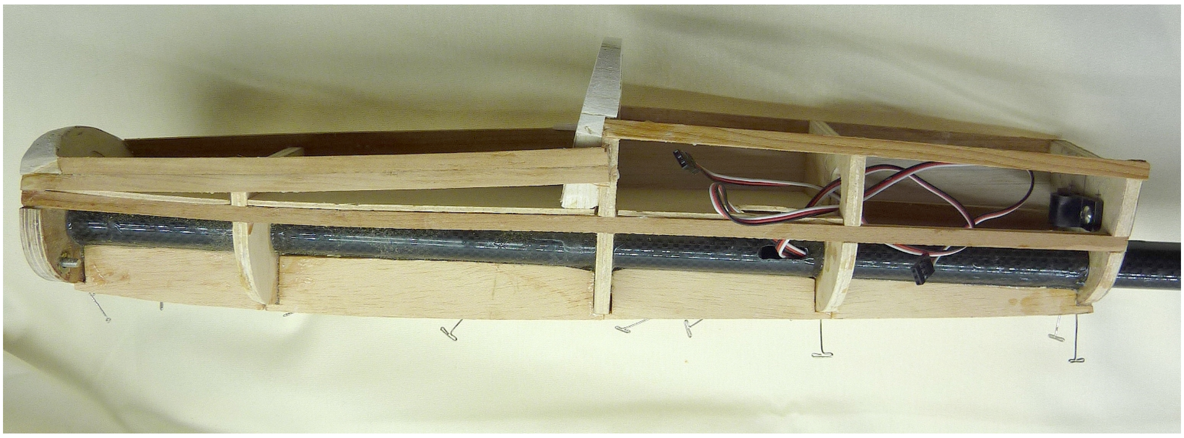
The main tube takes up a fair bit of room in the pod. However the only electronics under the wing are a tiny FrSky X8R receiver and battery voltage, GPS and vario telemetry devices, so there is plenty of room. I put in a sloping plate under the canopy so the battery would be ejected in the event of a sudden stop. In minor bumps it is often the battery that causes damage, which in this case would only be to the canopy. Unfortunately the size of the tube ruled out a retractable wheel. I used an aluminium strip strake instead. I had hoped to use titanium but couldn't find any 6 x 2 mm strip.

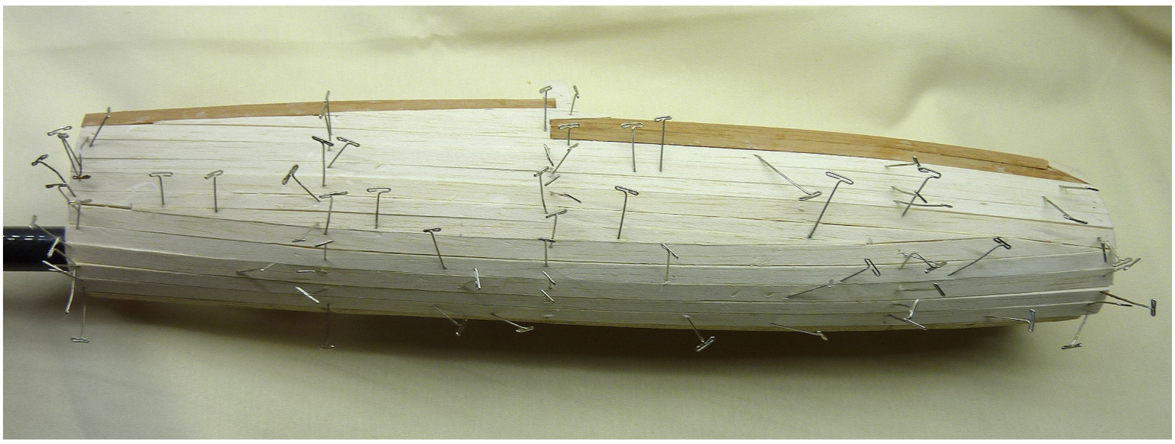
I call this building technique the 'Skyscraper method' for a reason I'll explain later.

Here are the motor and folding propellor mounted on the motor bulkhead.



This series of photographs shows the progress in planking, filling, glassing and sealing with Eze-Kote.

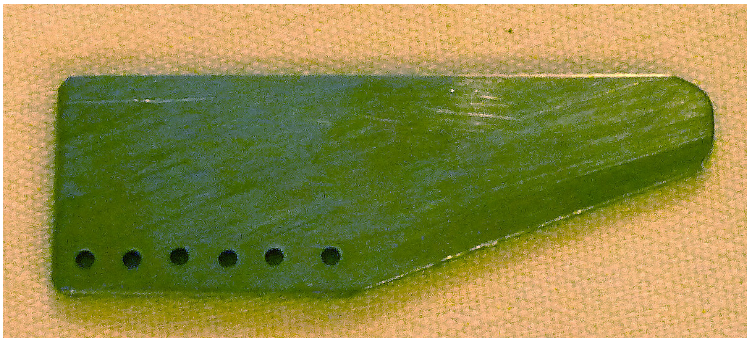




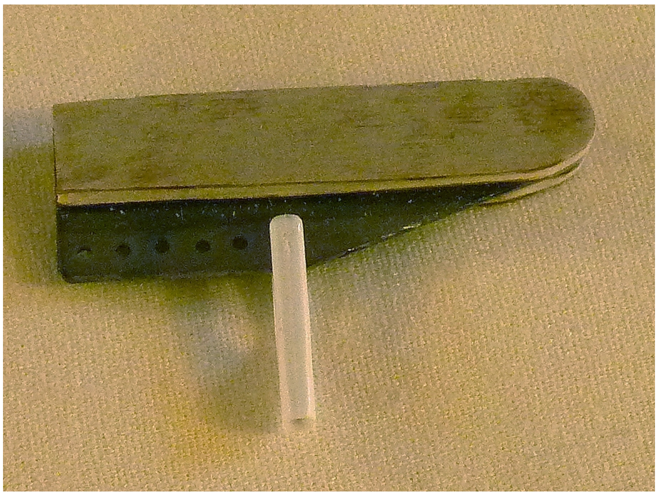
The all-flying tailplane suspension

The Sirius has all-flying tailplanes. This meant I had to find a way of mounting and pivotting them. I decided to install micro servos in the tail for the tailplanes and the rudder.

The bellcrank is the key component. I made it from 1 mm titanium and it weighs 3.4 g. It carries, in 3 mm tubes, the two 2 mm piano wires that plug into the tailplane halves. The holes for the 3 mm brass tubes were drilled when the side cheeks were glued on. The row of 1.5 mm holes is for the clevis on the end of the servo connection. This pushes it from below. I like titanium as it is only twice the density of aluminium but immensely tough and hard enough never to wear. It is about the same as mild steel for cutting and filing though drilling is slightly more difficult due to its springiness and poor conductivity causing heating. Apart from tiny holes, a bench drill press is required but these are cheap now.



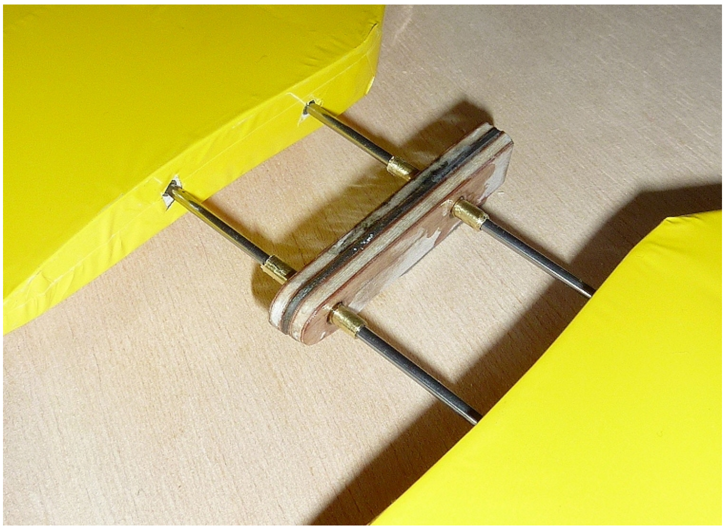
I then laminated some strips for cheeks for the bellcrank and to form a box in which to mount it. I used 1 mm ply on each side of some 2 and 3 mm balsa. This is the bellcrank with the thinner cheeks fitted. The cheeks were sanded, as were the inside surfaces of the box, so they rub smoothly. The rubbing area will give extra stability.



To form the bearings I used two sizes of brass tube. The smaller is 2 mm bore for the tailplane mounting piano wires. This has an outside diameter of 3 mm which is a perfect running fit in 4 mm outside diameter tube. These were glued into the box to form bearings for the bellcrank to pivot. 2 mm is a little small for the wires but this was the size in the original tailplanes. I imagine it was to keep the aft weight down. If I was building new ones I would use larger carbon fibre tubes.

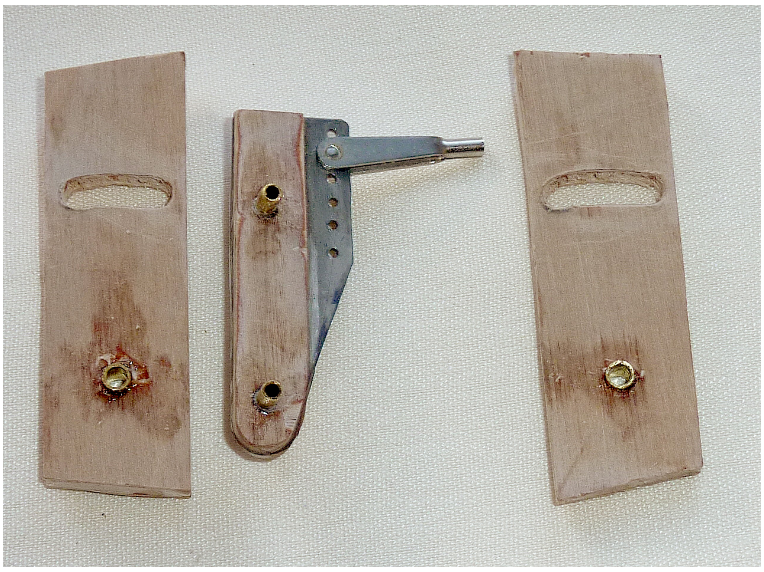
The drilling and assembly order needed careful planning.

1 Mark and drill the positions of both bellcrank holes using 3 mm twist drill in a drill press.
2 Connect a servo with a tester. Put the bellcrank on 3 mm drill as pivot.
3 Find the servo horn and bellcrank holes to give ±15º on full servo deflection.
4 Make sure the chosen bellcrank hole suits the metal clevis. Open up if necessary.
5 Cut two pieces of 2 mm piano wire of the correct length for tailplanes.
6 Glue 3 mm tubes in front and rear bellcrank holes with these wires in and the tailplanes connected.
7 Measure the distance from the rear of the fin leading edge to the front bellcrank hole.
8 Drill front holes in box sides using 4 mm holesaw using this dimension.
9 Glue in 4 mm brass bushes with 3 mm tube in place to line them up exactly.
10 Cut the rear arcs in the box sides using 5 mm holesaw and a 3 mm drill in the front holes as pivot.
11 Smooth bellcrank sides and relevant sides of box sides.
12 Cut front and rear box spacers out of laminate to give slight clearance.
13 Test clearance under pressure from clamps.
14 Assemble box around bellcrank.

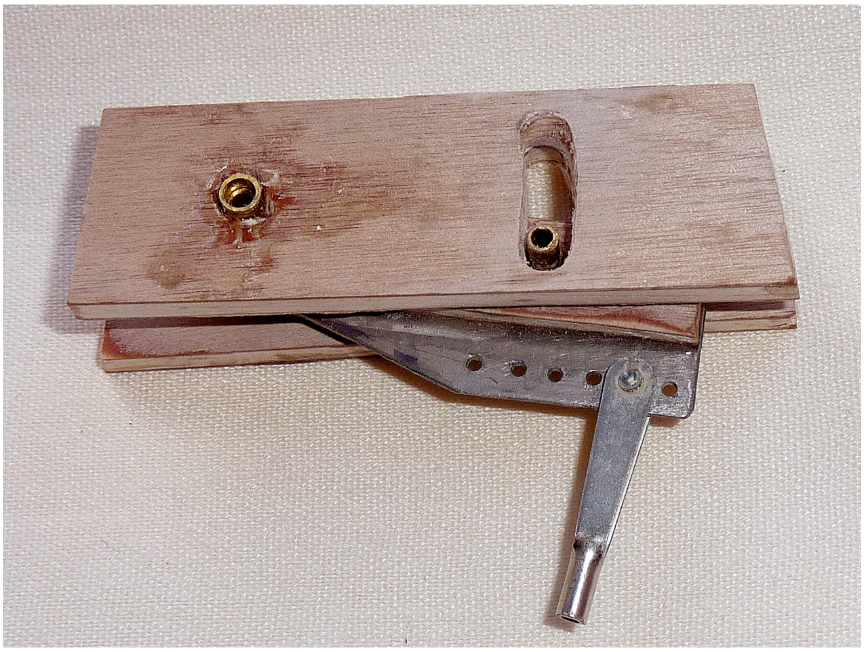


Bellcrank with tubes

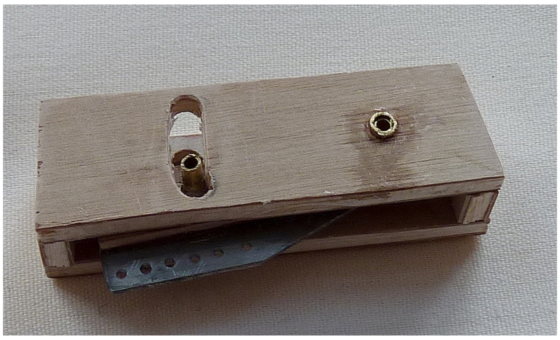
Box parts



Box - loose assembled

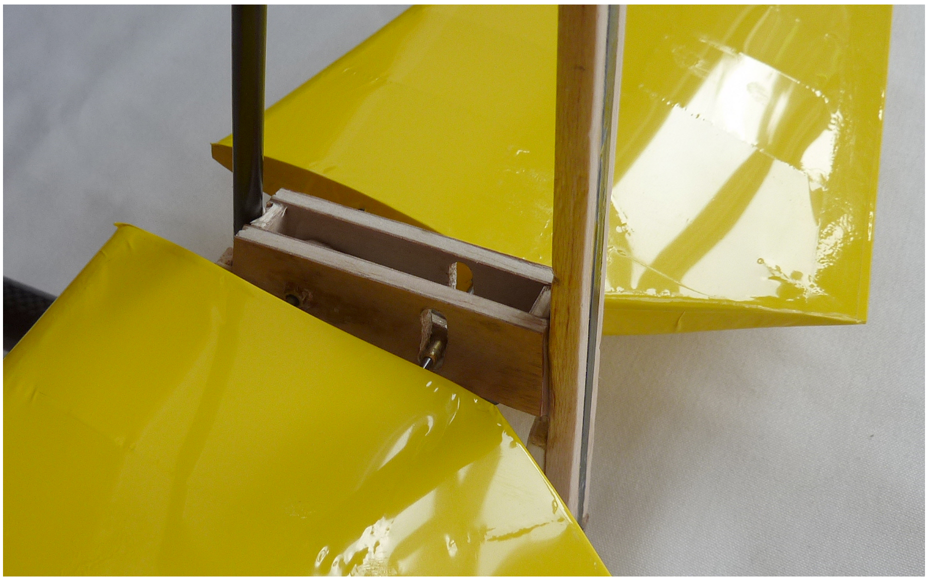


Box complete.

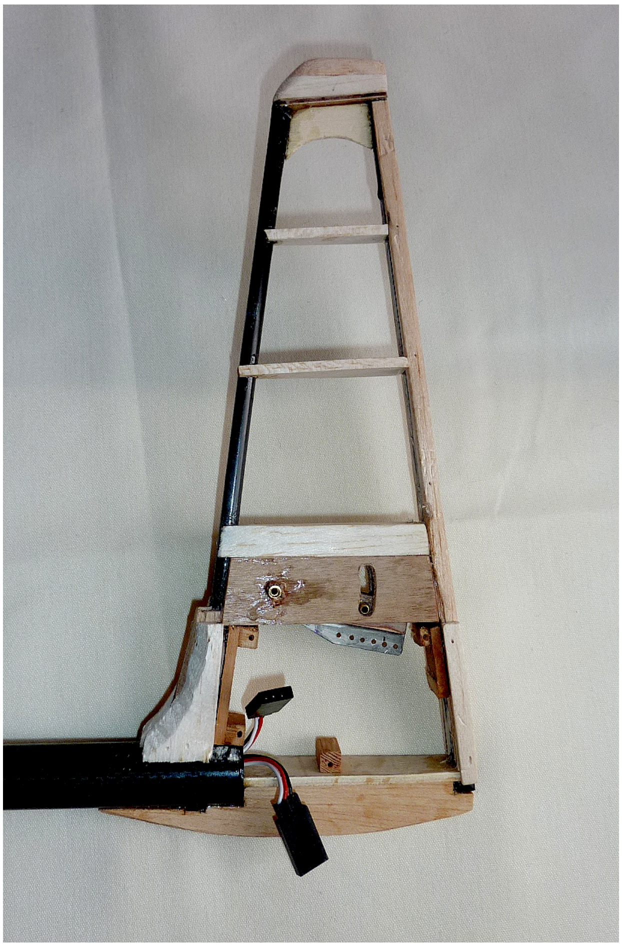


Weight without clevis 11.9 g.

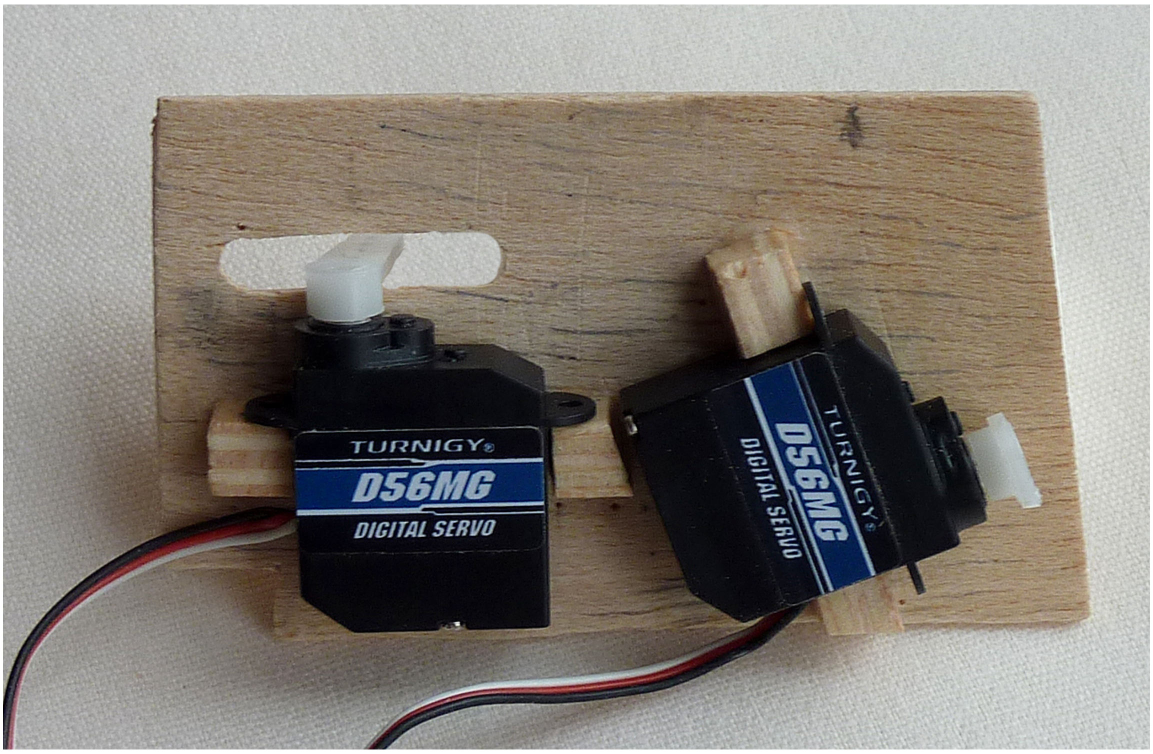
Box installed in fin
with tailplanes

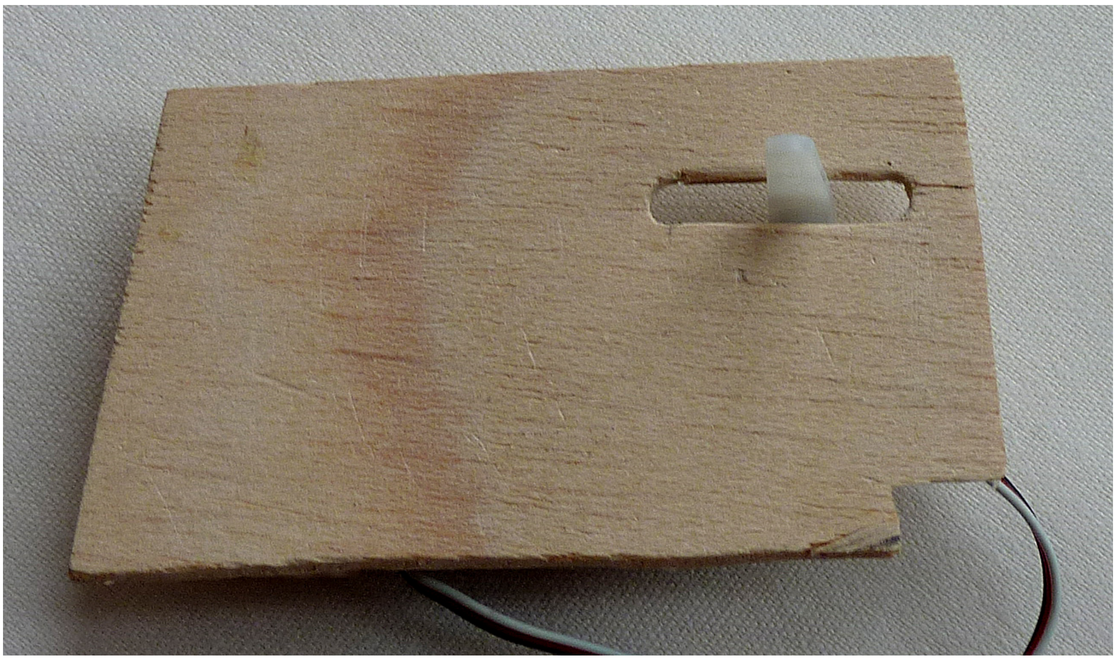


The bosses for the sideplates screws have
been added

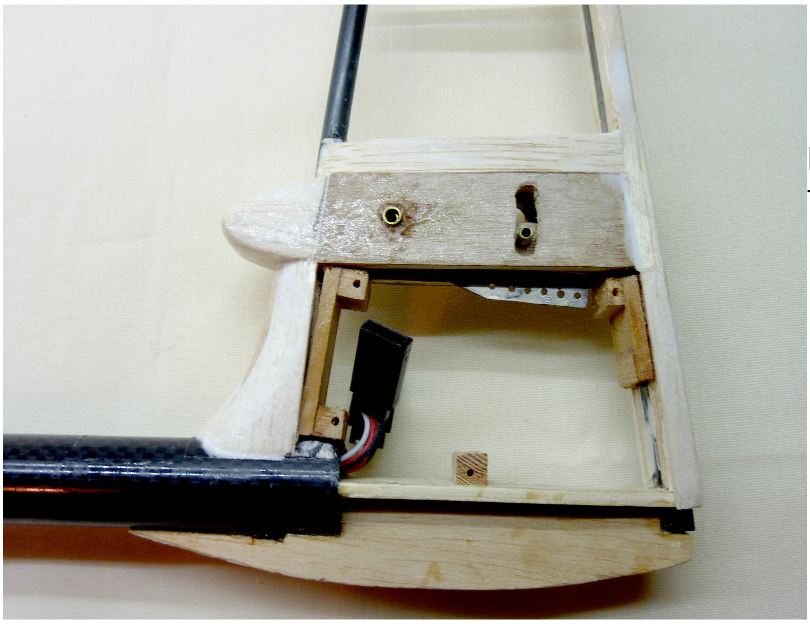


The two servos go into a box under the bellcrank box. Here is one side – the mounting plate. The servos are metal geared and quite powerful for their size. They are fixed with the normal screws. The deflection needed for the tailplanes will be small . Airspeeds will not be high so more important is the ability of the servo to hold the tailplanes steady, and the metal gears, and short, carefully drilled, connections should be more than good enough. After filling and sanding, the two sides are now covered with black Hobby King film.

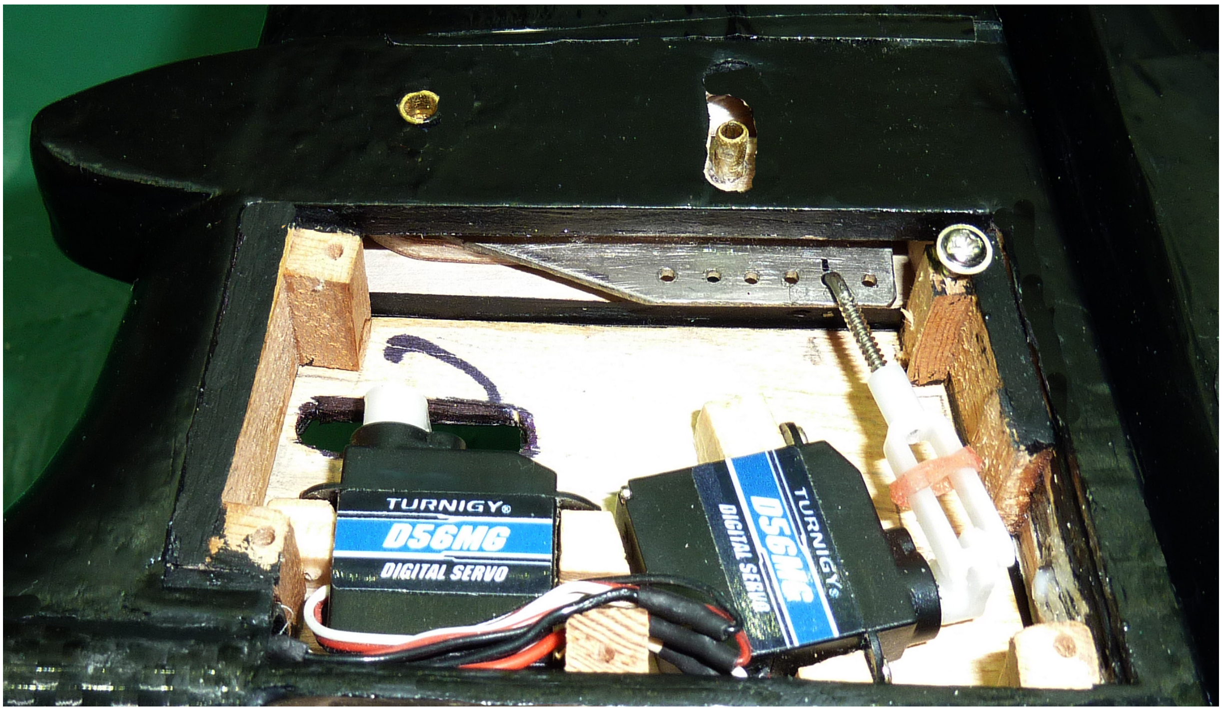




This is the fin with shaped fairings, filled, coated with Eze-Kote and sanded. The area under the fin will be left unfinished until the model is complete. Lead might need to be added. A balsa fairing will then be added and painted.



Detail of the servo box and all-flying tail suspension.



This shows the servos fitted into place and connected up. I removed the connectors, soldered the wires, and covered them with heat shrink. This saved both space and weight. Connecting to the bellcrank was a tricky little job. I tried all combinations of clevis and rod and in the end settled for the KISS (Keep It Simple - Stupid) approach. The wire in the bellcrank has a double bend like this: ┌┘. The other end is a simple plastic clevis.

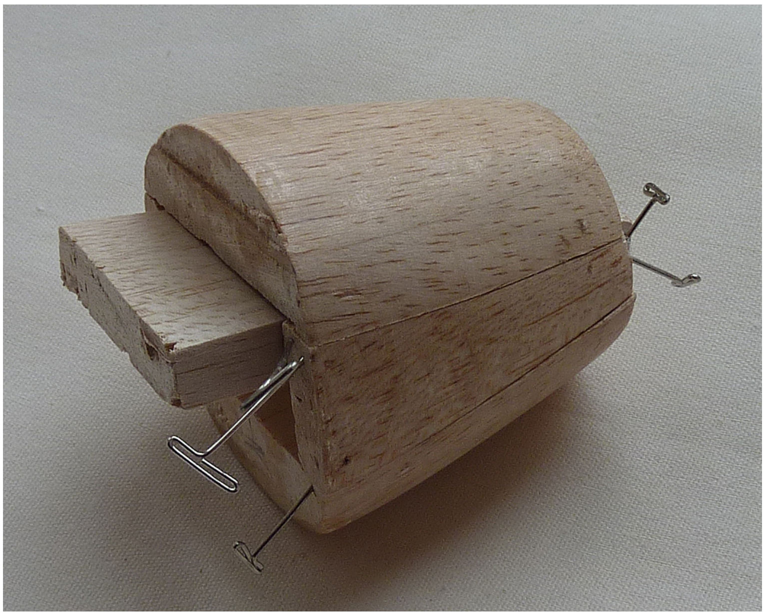
The geometry isn't perfect but I can adjust that with differential throws in the transmitter if needed. On the elevator servo horn I used the hole nearest the centre. I had to, as the full horn fouled the other sideplate and I had to trim it. Full throw, tested with the transmitter not the servo tester, gave a linear movement of 5mm in each direction. On the second from last hole of the bellcrank this gave 6° movement ($\tan^{-1}$ (5/45)), which is just about right. If it proves not to be enough I can move to a bellcrank hole nearer the pivot.

Making the glass fibre cowl

The cowl needed to be elliptical tapering to circular at the spinner. I thought I would make a re-usable male mould out of balsa. The tapering sides would slide out releasing the tapering top and bottom parts. There would be a central key, which would push the parts outwards and would be removed first. I would shape the balsa mould then tightly cover it with cling film as a release agent. The cowl's inside finish wouldn't matter. If it went badly wrong and I couldn't slide the parts out I'd have to chew them out. However I hoped the mould would be re-usable.

The first question was a geometric one. For a given circle radius how thick would the sheet balsa have to be to allow the box shape to be trimmed into a circle? Dredging Euclid out of my brain I calculated the thickness to be 0.28 of the radius. If you calculate thickness using about a third of the radius then there would be margin for strength. Size the wood for the worst case which is the largest circular cross-section and the rest should be fine. Obviously square-ish shapes could make do with thinner wood. In the end, however, I decided to have two layers of 10 mm balsa top and bottom and a single layer for the sides. I made it several millimetres too long to allow for trimming rough edges.

All went to plan. I shaped the male mould and gave it two sanded coats of Eze-Kote to aid release. With a new scalpel blade I sliced the sides and tops apart. Note the taper to the back. I then pinned them back together with the key as shown here.



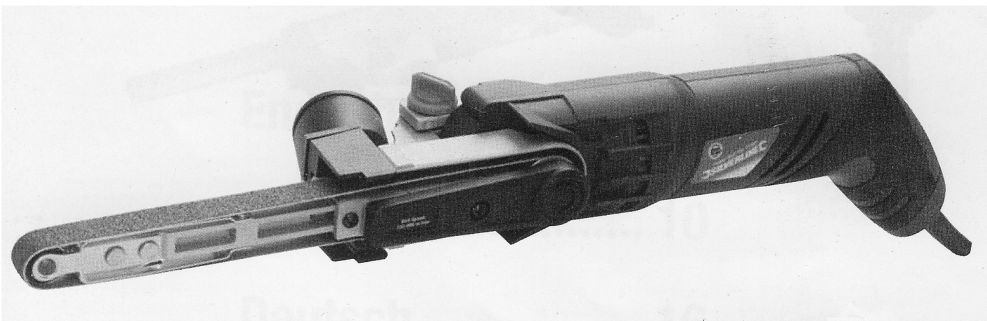
I stretched kitchen clingfilm over the mould with overlap at the edges to avoid sticking. I gave the clingfilm two sanded coats of Eze-Kote, then one layer of 48 g/m^2 glass cloth. This was followed by two more sanded coats of Eze-Kote. I then trimmed the edges with the scalpel, pulled out the key and tried to spring the other parts apart. I only needed to prise one or two parts with a blade, otherwise it all fell apart easily.

First layers of glass removed from the mould.

The resulting moulded cowl was much too flexible. I think Eze-Kote, being a single-part polyester resin, is less rigid than epoxy when cured, so I reassembled the mould parts and wrapped them in some more clingfilm to avoid adhesion at the edges. I applied two more layers of 48 g/m^2 glass with several more coats of Eze-Kote, sanded between. This felt rigid enough but I decided to glue in ply annular shapes to make the ends even more rigid and to aid mounting on the fuselage. I made the ply out of four cross-laminations of 1mm birch ply glued with PVA.

After sanding some more I felt the surface still wasn't smooth enough. I decided to apply several coats of primer with the airbrush. Still not good enough

Then I bought a great new tool, called a belt file. It's a Silverline one and cost £28.50 on eBay. I gave the cowl a real bashing with it on the slowest speed setting using a 120 grit belt. Then when I was happy that it was reasonably flat I applied some more glass, 24 g/m^2 this time, and coats of Eze-Kote.



The next step was to glue in the ply end-plates and trim the fibreglass to length. The plates made the whole thing very rigid. Here is the completed cowl prior to painting. The rear view shows that the cowl is locked in position by the cutouts for the motor mount. I used a diamond holesaw to cut the hole in the front as that would be visible when the spinner was off.

I puzzled over how to fix the cowl to the fuselage. I considered screws but access was difficult both from front and back. I decided to go for two pairs of neodymium magnets.

Even after cellulose filler, sprayed primer and top coats of acrylic, the final result wasn't perfectly smooth. The next will be better after lessons learned. However I proved that the method worked.

Final weight before painting was 13.2 g and 14.6 after.

Making the fibreglass canopy

Having learned the techniques from the Sirius cowl it was time to make a canopy for the same model. As it is a scalish model the front pod, and hence canopy, is quite large.

This time I decided to use release wax and possibly release agent on a polished male mould rather than cling film. As the canopy is open at the bottom there was no need to make a collapsible mould.

First step was to make the mould. I laminated a rectangular blank from several sheets of 10mm balsa glued with white PVA. I then sanded it to the correct length using a belt sander on its side. This was so I could fit it in place and mark the curved edges on three sides: bottom, front and back.

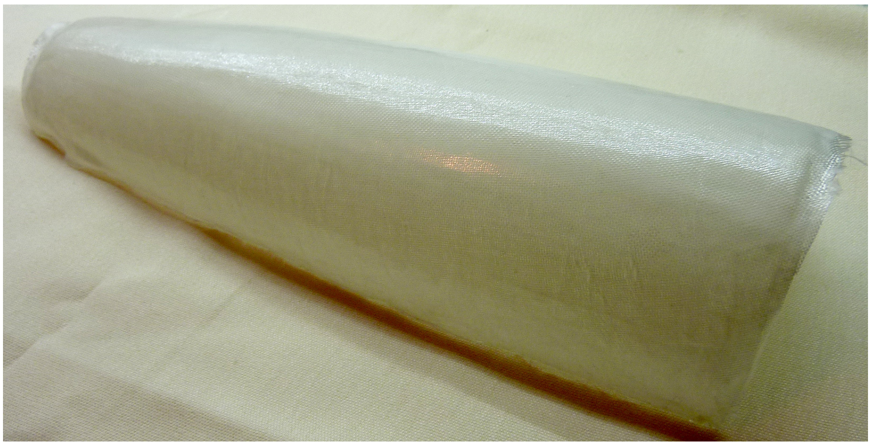
I then planed it down using a David razor plane. Once happy with the overall shape, I switched to sandpaper. One critical matter was how much smaller to make the mould to allow for the thickness of the glass laminations. In the end I reasoned that it was not critical after all as the canopy would be flexible prior to framing and so could be trimmed to fit. Rough measurement on a cowl gave a thickness of a bit under 1mm so I made the mould this much smaller all round except the ends.

Here you can see the rough planed mould in position on the fuselage.

Here is the sanded mould coated with EzeKote and polished. Its outer surface will be on the inside of the canopy so a high polish wasn't needed. The EzeKote layers on the moulding will be sanded to give the outside finish.

Before applying glass to the mould I experimented on some scraps of balsa to discover how many base layers of resin to use and how well the release agents work. I applied two layers of EzeKote to smooth the mould and three coats of mould release wax to each using a paper towel. You don't let the wax dry but clean each coat off with a cloth when wet. Then to one sample I added a single coat of PVA release agent using a soft brush. First time I didn't leave it long enough to dry. It takes an hour at room temperature (20 to 25ºC). It seemed dry but the EzeKote dissolved it when I applied it. I found that wax on its own worked just as well as when I used PVA agent, so I didn't bother with PVA on the canopy mould.

I laminated three layers of 48 g/m2 cloth with one of 24 g/m2 cloth on the top to give a smooth surface. I lost count of the number of EzeKote coats but I'd guess about ten. Each dries quickly so delays are short. It popped off the waxed mould very easily.



EzeKote is not as rigid as normal resin so, though this number of layers gives a fairly stiff shape, it could not be used as a structural component.To stiffen the canopy I framed it with ply and trimmed the ends of the canopy, which were moulded square, to give more realistic sloped ends.

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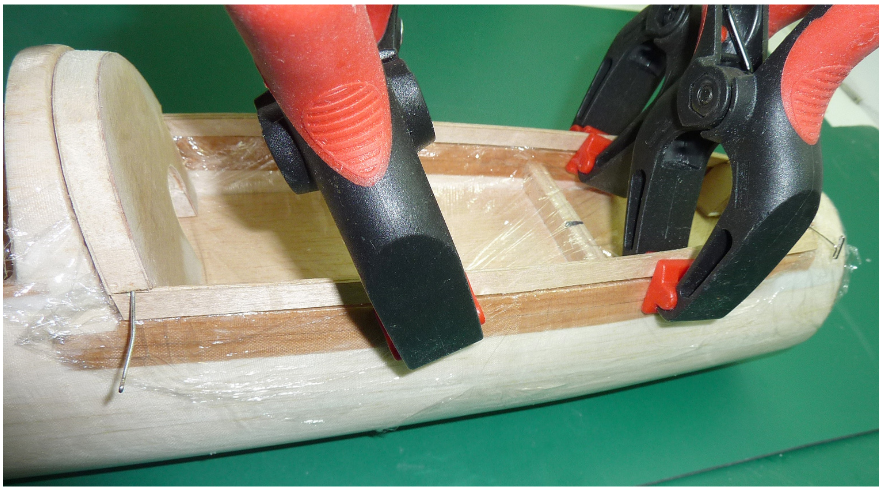
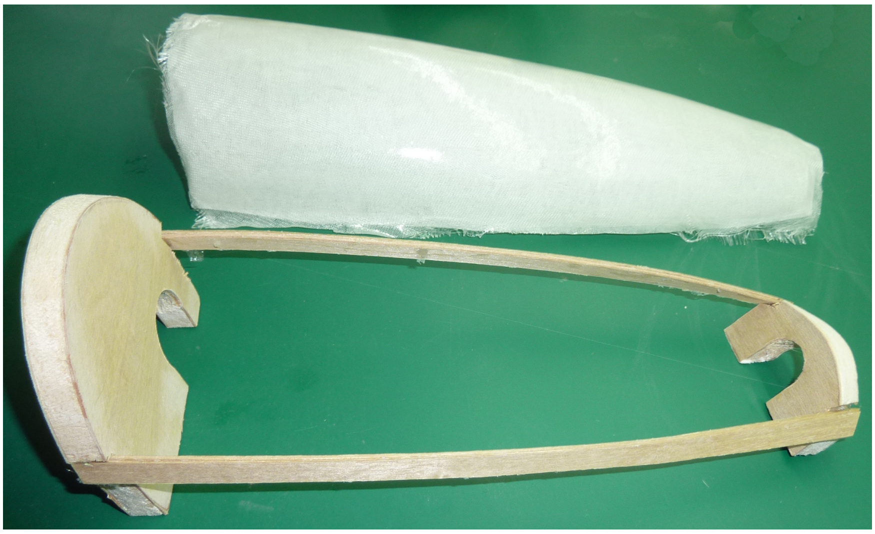
The side frame parts both curve and twist. I tried to use spruce but it was too rigid. I cut strips of 1mm birch ply glued in threes with PVA and clamped in position. I covered the opening with cling film to prevent the new frame sticking.

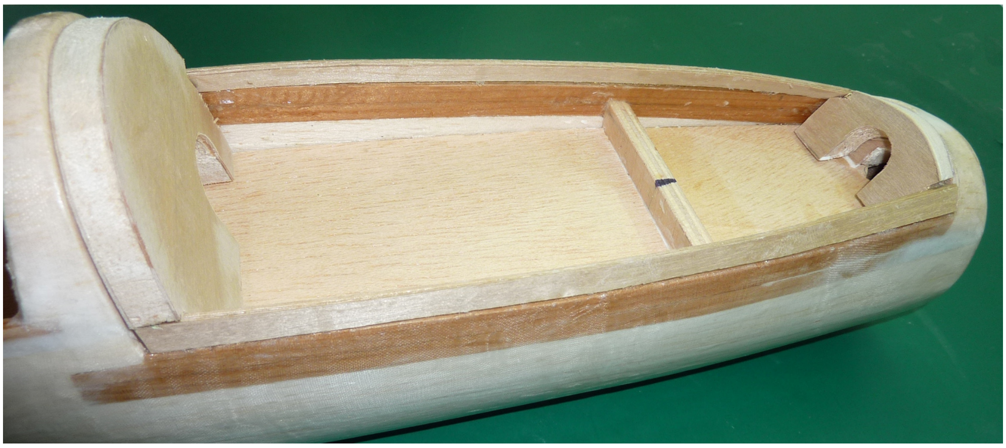


I was delighted that the parts held their shape when unclamped.

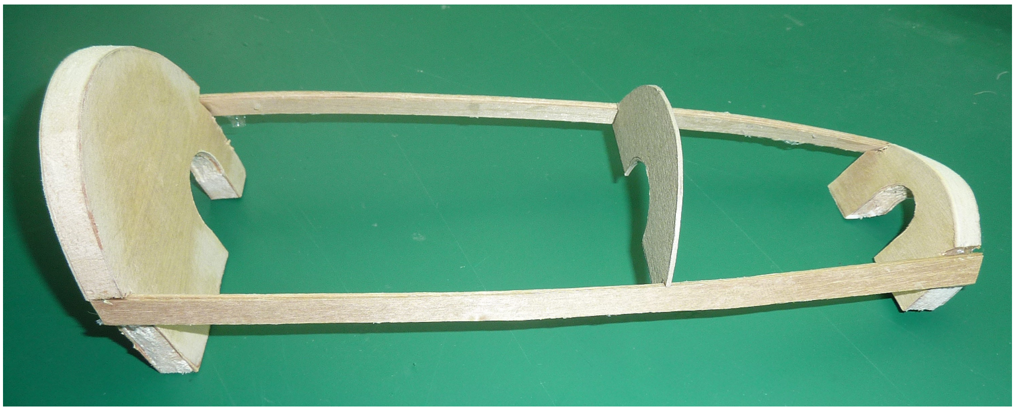
This is the frame after drying.



Frame in place on the fuselage.



Intermediate former being sized using 1.5mm card.



I then air-brushed it with primer and white acrylic to contrast with the black fuselage.

I was pleased with my first major use of carbon fibre. It is light and stiff and does not change shape over time. One disadvantage is that all gluing must be done using epoxy, though possibly thick CA is an alternative. Not being water based, epoxy doesn't get lighter as it dries so you have to be as sparing as possible.

A cylindrical tube works well for a curved fuselage. I must try a square one for a square fuselage. It would make lining up the formers and forming a balsa shell very easy.

Why do I call it the skyscraper method? Such buildings now have a strong central core from which floors and walls are cantilevered. Then the glass is put on the outside. Apart from being rotated by 90 degrees my fuselage design is the same, as it has a very strong core with a light shell covered in glass (fibre).

The wings and tailplanes

Foolishly I didn't keep a photo record of doing the wings and tailplanes. I stripped off the old doped tissue covering using thinner and sanded and filled the frames. I could not get some patches off so relied on sanding those bits.

I modified the ends of the wings to take ailerons as the original was built with rudder and elevator only. I still had the original plans, though they needed some tlc with sellotape, so I made the ailerons the size shown on the plan. I used thin servos in the wings and cut slots in all of the ribs to run the wires through. I replaced the slightly corroded brass tubes in the roots with carbon fibre ones and generally strengthened the area without adding much weight. I installed boxes to take inboard airbrakes and fitted the servoless type as shown in one of the pictures. I used Hobby King shrink covering, which I find light, easy to use and a good shrinker. The low cost is a bonus. One aileron warped and I had to replace it with a laminated one.

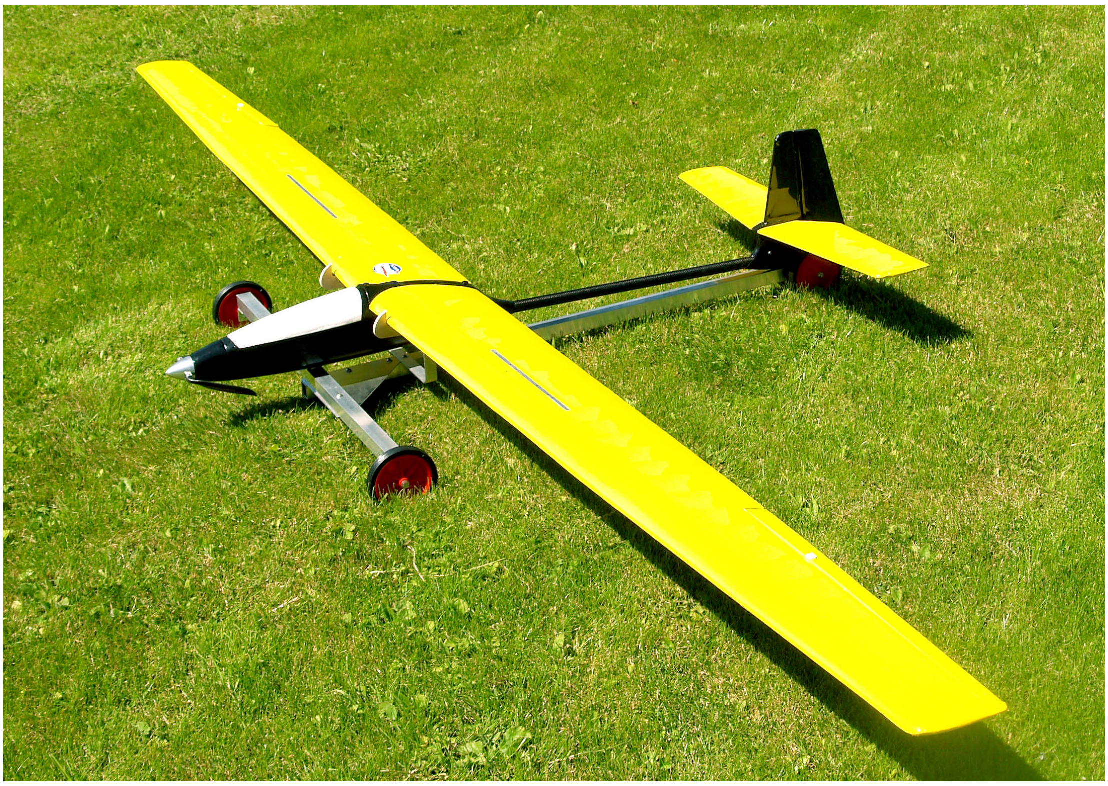
The tailplanes were an easy job. The plastic root ribs were pulled a little out of shape when the covering was heated and shrunk. I had to unstick it from the root ribs, add a filler of balsa and restick the covering. It's not perfect but looks reasonable.

Finished!

At last it's ready for a maiden flight. Ulp! I used to hurl it off hills and tug it into the air with a bungee but have never hand launched under power. Knee trembles.

Launch dolly

I will possibly hand launch once I have the model stably trimmed and have a good idea of the required air speed. Until then I decided to use a lightweight dolly built out of aluminium with 100mm plastic wheels. The main tubes are 25mm square with 1.5mm walls. The front bracer is 1.5mm sheet. It is bolted together with M5 screws and the wheels run on M6 axles. The wings rest on some 6mm liteply supports bolted to 20x3mm aluminium U-shaped frame. I might add a rear support if it proves necessary.



Detail of airbrake

Balancing

I got the balancing stand out (on the website under Inventions). All it needed to be a tiny bit in front of the specified centre of gravity was 15g at the front of the cowl area. Looks like all my efforts to keep the tail light paid off. The servos being in the tail didn't cause a problem.

Lessons learned

1 Collapsible male moulds for fibreglass are quite easy to make out of balsa.

2 Cling film works as a release agent but it is difficult to get it really smooth. It might be easier on a larger or flatter cowl. I experimented with wax release agent on scrap wood. It worked. I also tried adding a layer of PVA paint-on agent as well. It was no better. Provided the parts can be separated any small internal ridges won't matter. I have now tried coating the wood parts on a different mould with three coats of a wax release agent. It worked a treat. The moulded part sprung off easily.

3 It might be possible to achieve moulding rigidity with fewer coats of epoxy or polyester resin. However, making several lots of two-part for a small component would be wasteful. Eze-Kote seems fine on this smallish cowl though. You need to use more layers of glass and resin. I think that the convenience of Eze-Kote makes this worthwhile and the end-plates removed any doubts about rigidity.

4 Don't be afraid to sand fibreglass mouldings aggressively. You can reapply glass and resin. It weighs very little as long as its thin. Keep the sandings off your skin and out of your lungs.

5 Cover the exposed part of the tail boom with a removable film of some kind before starting to glue things. Despite the greatest of care I have put some glue smudges on the polished surface.

6 Provided you are willing to do planking, this is an excellent method for building accurate circular cross-section fuselages, especially when strengthened with glass cloth.

Model data

Weights (g)		
Fuselage with wing mount and radio	847	
Wings	753	
Tailplanes	59	
Battery	229	
Total weight with battery	1888	(original without motor was about 1500g)
Wing area	52 dm^2	
Total area	60 dm^2	
Wing loading	36.3 g/dm^2	
Area loading	31.5 g/dm^2	
Centre of gravity	78 mm back from root leading edge	

Suppliers

Carbon fibre fuselage tube	eBay
Wood	SLEC (of course)
Batteries	Hobby King
Motor	Hobby King
Spinner	??

Propellor blades	??
Covering film	Hobby King
Servos	Hobby King
Air brake	Hobby King I think
Titanium	eBay
Other carbon fibre	eBay
Radio gear	RCLife
Glass cloth	eBay
EZ-Kote	SLEC
Paint and varnish	Hobby King (Vallejo)