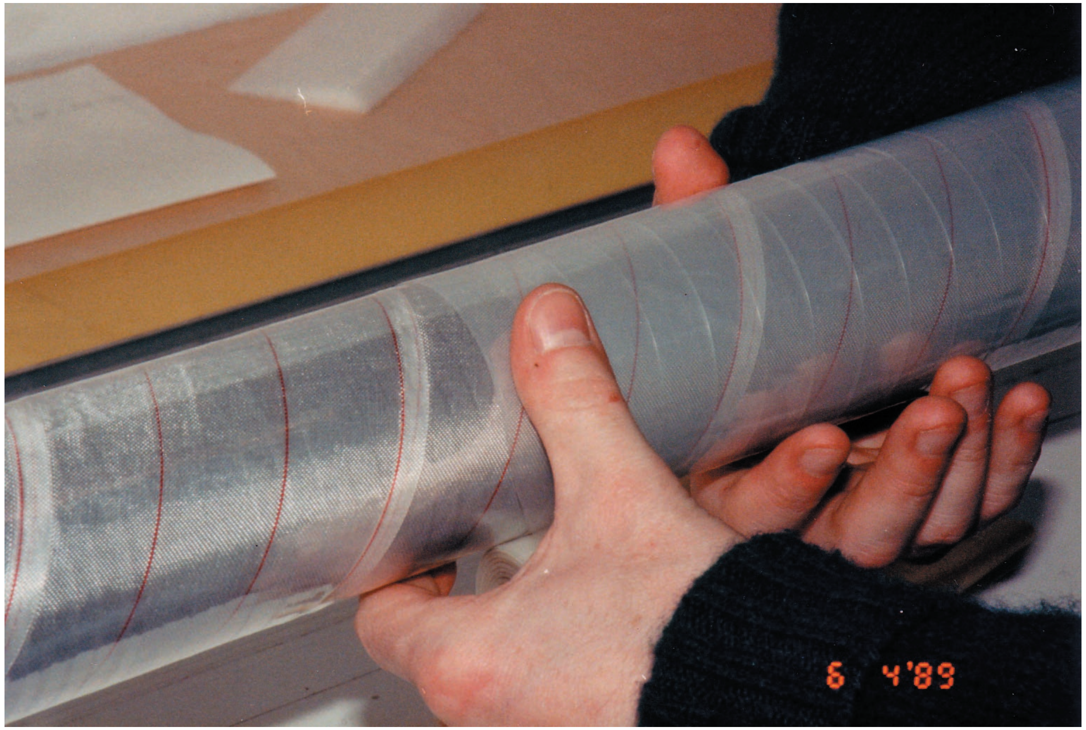
Some useful knowledge from the past
Some knowledge for the future

Airglow flying at Lasham in 2025. Photograph Barney Harle

Cutting CFRP pre preg and wrapping it onto the mandrel

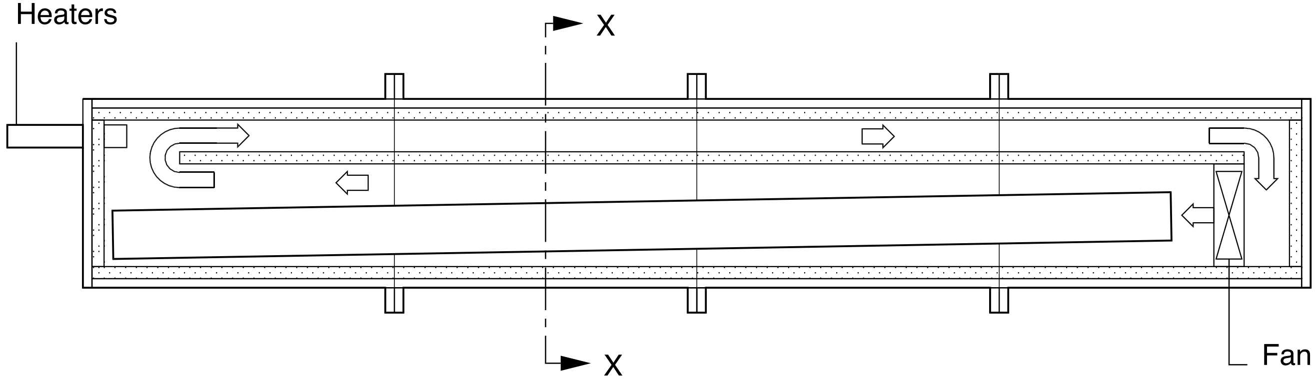
A “How to make CFRP tubes” guide can be downloaded from: https://www.humanpoweredflight.co.uk

Photogaphs Mark McIntyre

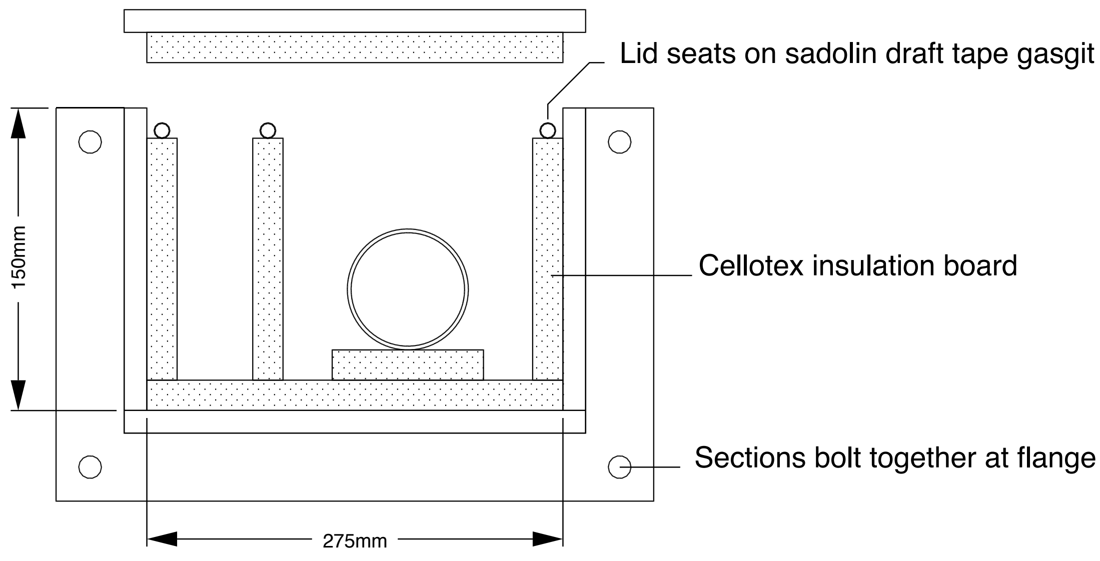


The picture above shows the un-cured CFRP tube wrapped in peel ply and over wrapped in heat shrink tape. First a layer of low shrink tape and then a layer of high shrink tape. The picture on the right shows the oven used to cure CFRP for Airglow. The red box is a home made temperature controller. I would now buy an industrial PID controller. The fan (an oil cooling fan from my brother in laws old fishing boat engine is driven by an external motor.) The idea was to circulate the air and to keep it at an even temperature. There are other was to make an oven - see the following drawings.
Photogaphs Mark McIntyre

Schematic of the oven used to cure CFRP tubes for Airglow



SECTION X-X



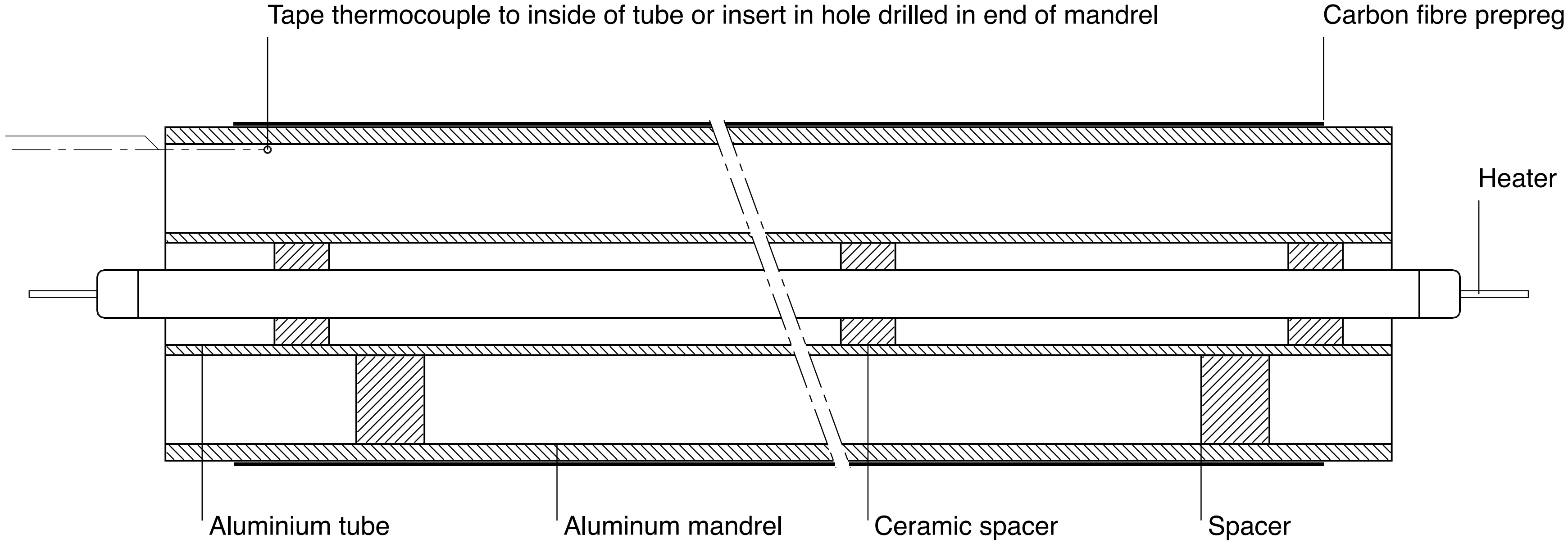
The oven is built from 12mm plywood lined with 25mm Cellotex 'RR' aluminium foil faced insulation board.

Air is circulated by a fan driven by an external electric motor.

Heating is provided by two 1500 Watt 'hot air guns' controlled by a PID on/off temperature controller.

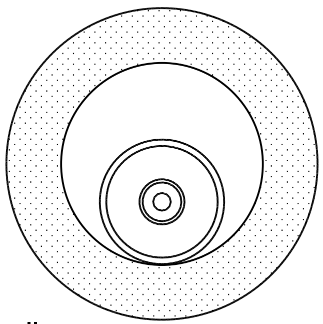
- Cellotex 'RR' insulation board is available from insulation suppliers.
- The oven was built in 4 2m sections that bolt together.
- The curing temperature of the pre-preg was 120 degrees C.

Schematic of a simple oven for curing CFRP tubes



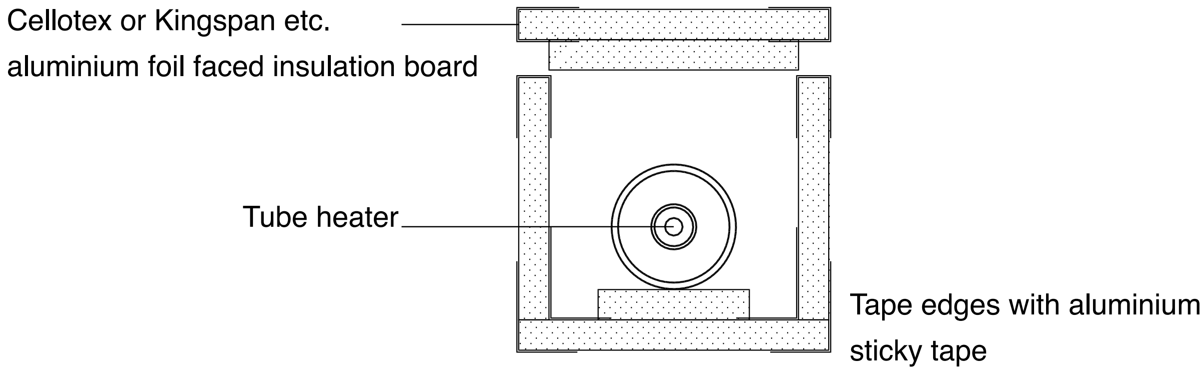
The heater element is made from two unwound oven heater elements joined end to end.
Note. These heater elements can be bought straight.
The heater element is put inside an aluminium tube to make it easy to remove the heater from the mandrel and so that the aluminium tube acts as a heat defuser.

SECTION ON TUBE IN ROCKWOOL PIPE INSULATION TUBE

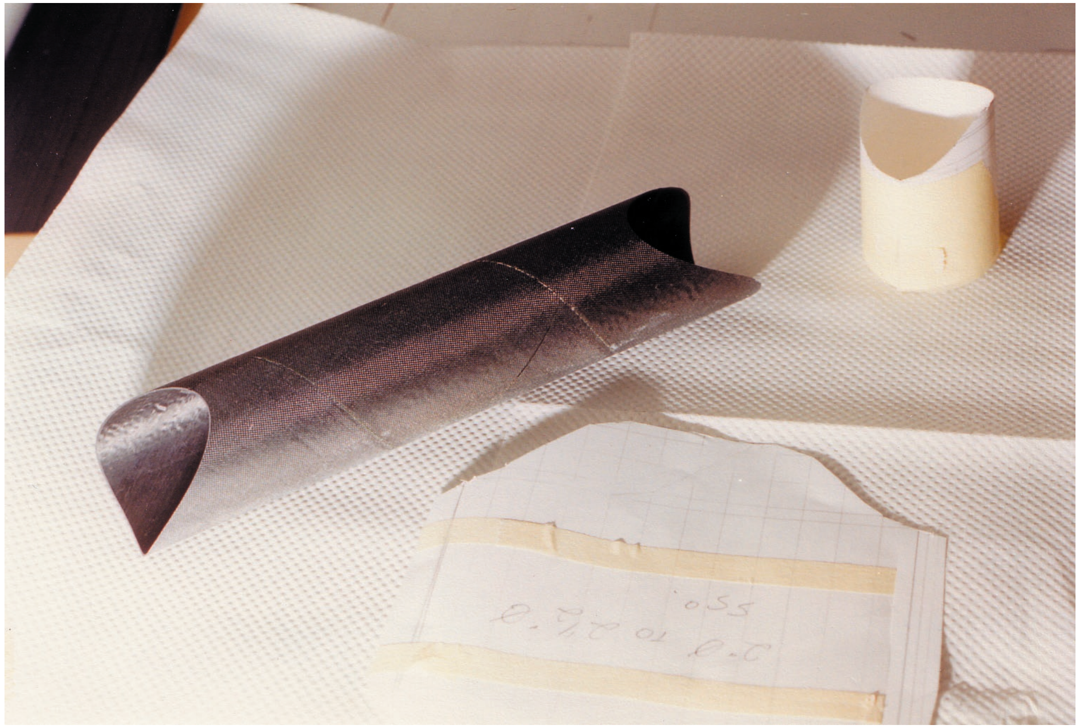


A PID temperature controller is used to regulate the oven temperature

SECTION ON TUBE IN INSULATED BOX



Jochan Hanne extracting one of the tip spars for Velair from the mandrel using a Tirfer, a tree, and a car. This did not work because of the builders preference for light cars. What did work was using (and bending) two strong trees. Photograph Peer Frank

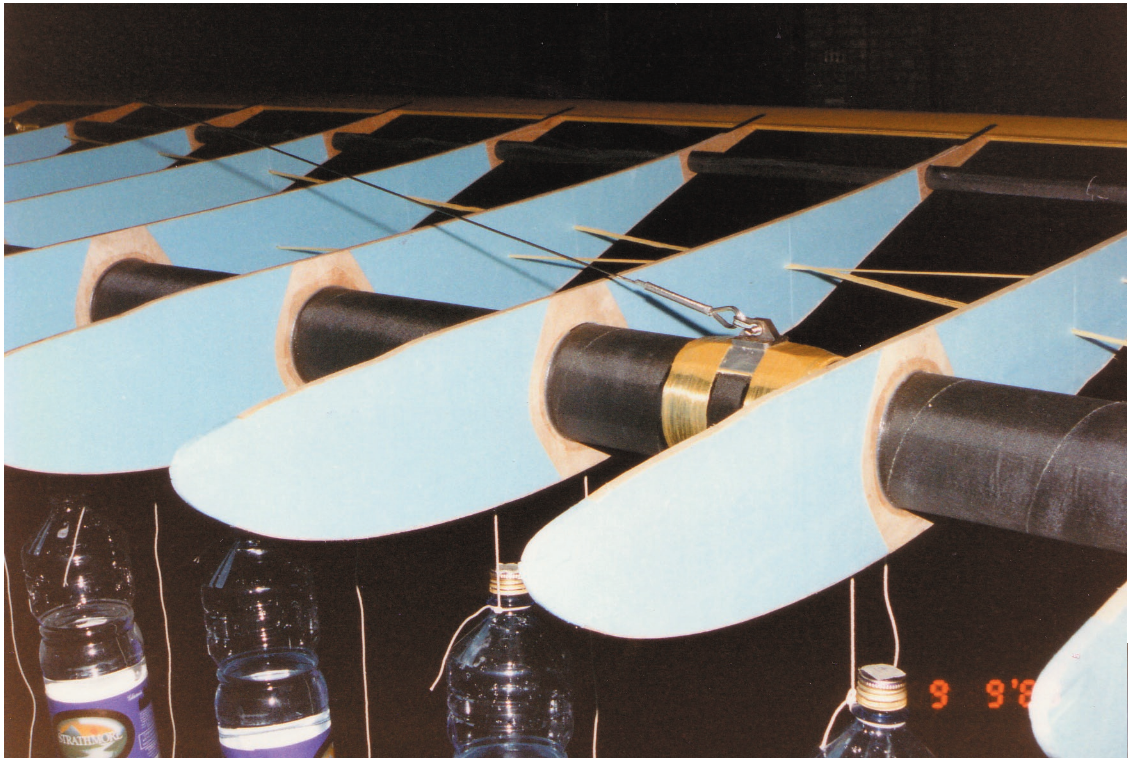


A tube being cut to fit. We made paper templates of the tube intersection to eliminate trial and error. Soon after this picture was taken a computer program was written to plot the intersections

Nick Weston with one of the internal bulkheads that stabilise the thin walled tube against buckling
Photogaphs Mark McIntyre

Mark McIntyre adding x-bracing of Kevlar tow. The structure that carries the in-plane loads is made up from 3/4″ CFRP tubes and Kevlar bracing

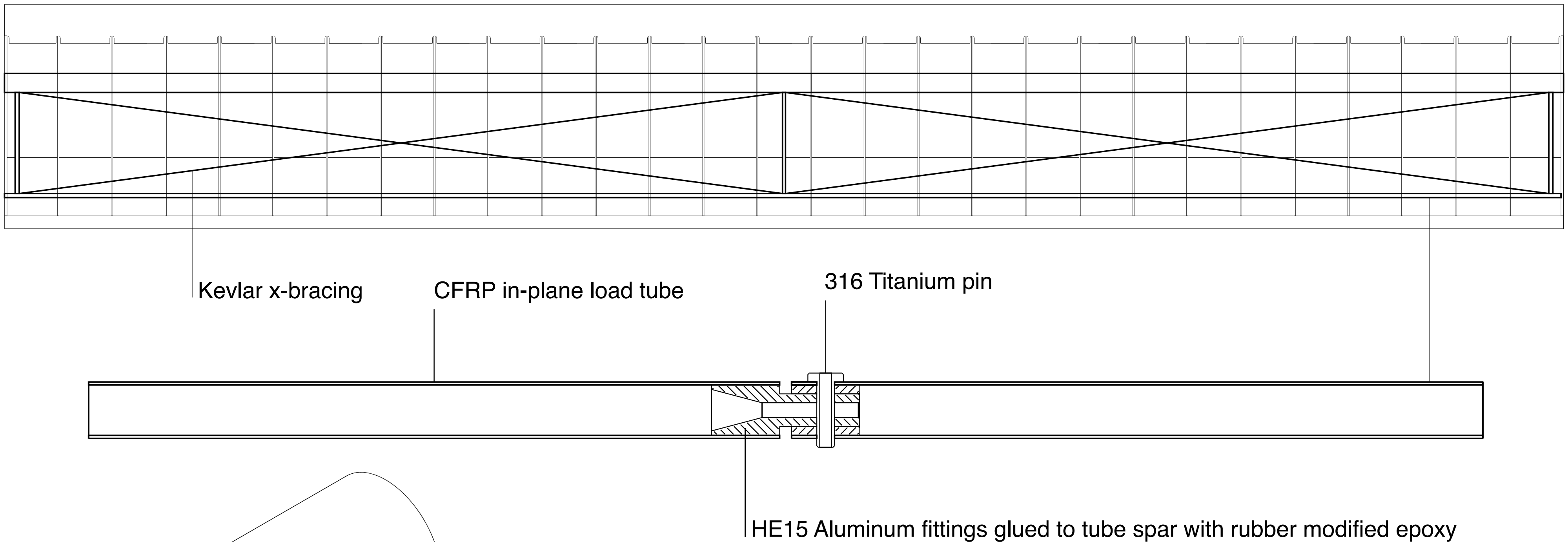
Mark McIntyre and Bryan Gostlow working on the wing
Photographs John McIntyre

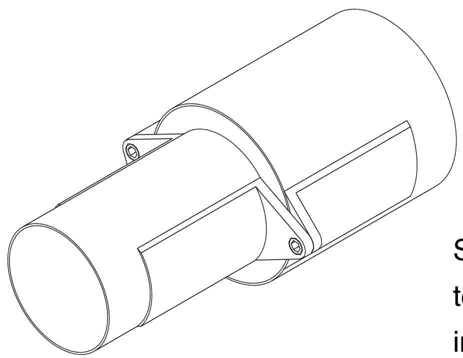


The lift wire attach fitting
Photogaph Mark McIntyre

The wing being load tested. We started at 1g and worked up to 2g. The wing is suspended upside down at an angle of attack corresponding to a lift coefficient of 1.1 so that the wing structure is also carrying the correct in-plane load. Photogaph Mark McIntyre.

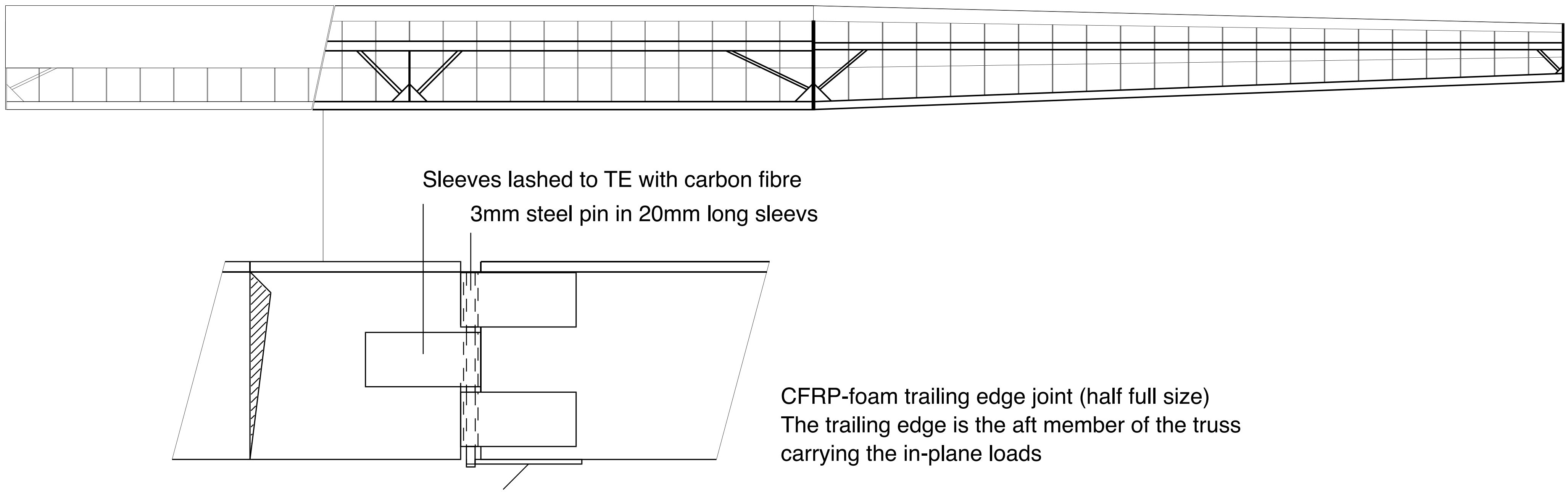
The structure carrying in-plane loads in the wing of Airglow





Sketch of aluminum compression and torque transfer fittings at the joint inboard of the lift wire attachment

The structure carrying in-plane loads in the wing of Velair



Testing the tail boom and tails on Duxford runway. Photograph John McIntyre.

Test, test, test, every component before flying because the damage a failures does can be limited to one component whereas a failure during test flight will probably be catastrophic.

The first flight July 1989
Photograph Rodney Tibbs

Reverse engineering the Bird Man House Phantom HPA

All photographs are from x.com/Handlayup

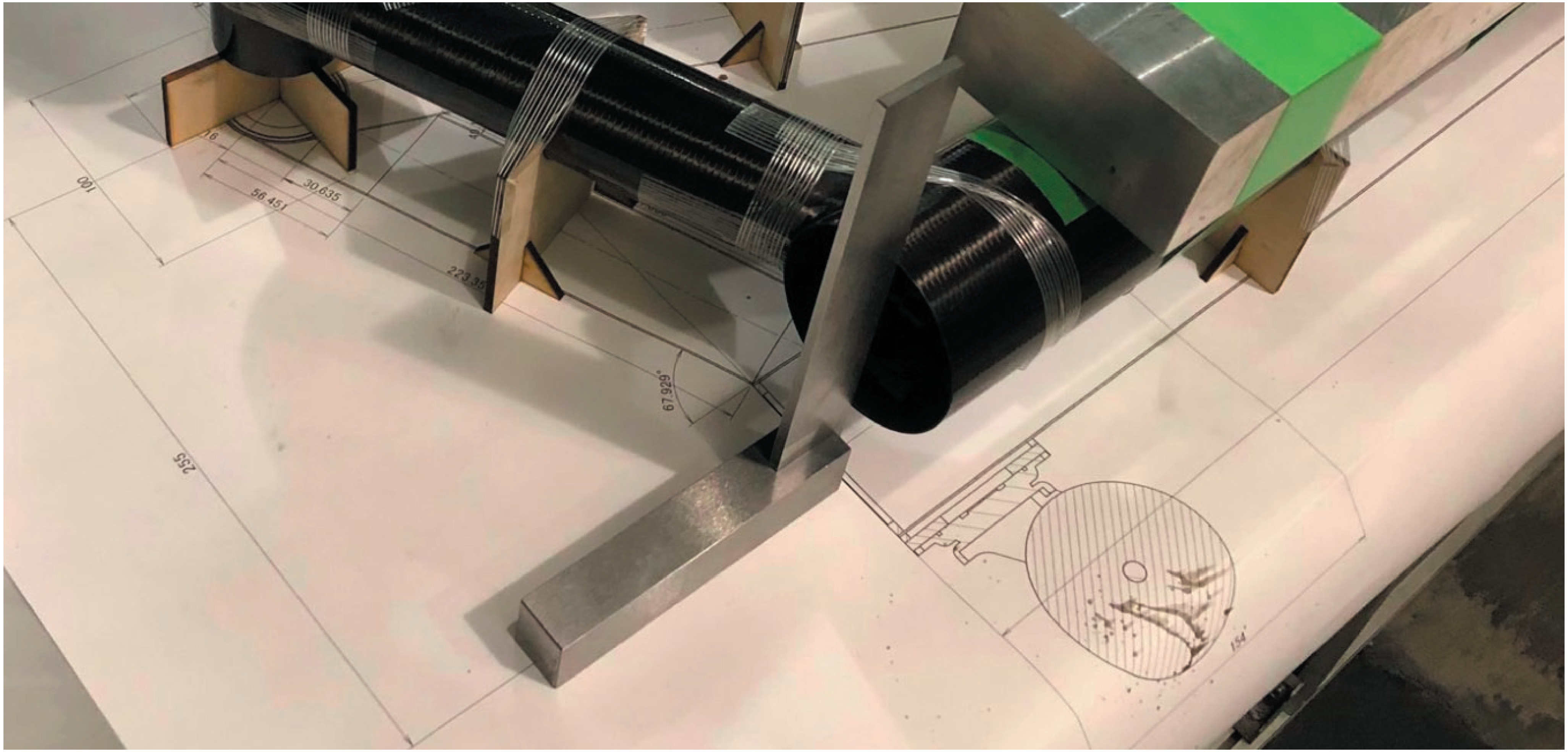
Why reverse engineer the Phantom?

- Because it represents the state of the art in terms of a high speed low power long range aircraft
- Because as one member of the BHPFC said, we need to stop building Airglow and we need to reduce the frontal area of our fuselages
- Because in 2023 it flew 69.68 km with a power input of 184 W, 3.2-3.4 W/kg

Wing spar	CFRP D-box cantilever spar	
Propeller location	Mid pusher	
Cockpit structure	Cantilever beam	
Wingspan	25 m	
Length	6.7 m	
Empty weight	Design:	21 kg
	Actual:	23 kg
Wing area	14 m^2 assuming a design C_L of 1.0	
Design speed	10 m/s	

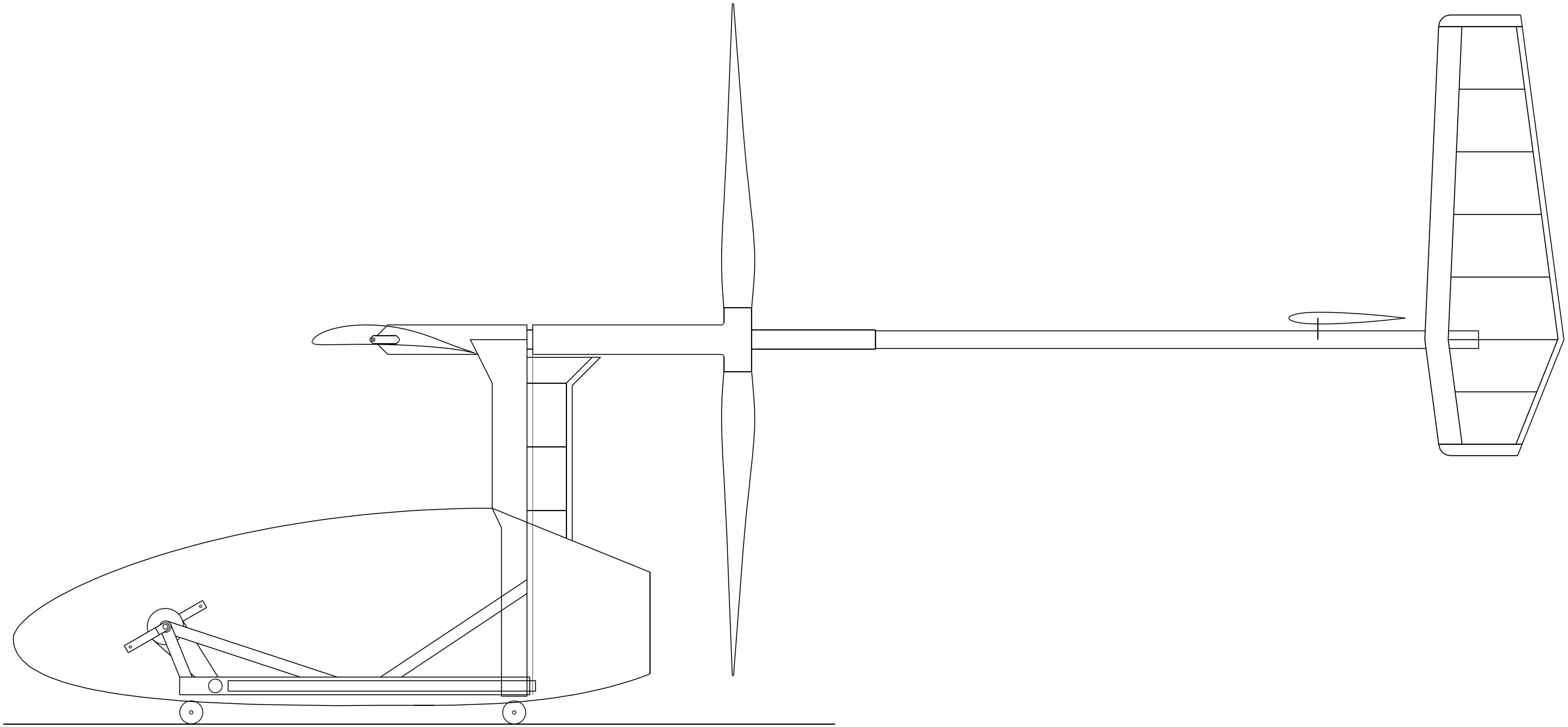
- Though there are no plans for the aircraft (that I know of) there is quite a lot of information contained in the photographs of the aircraft's build. Combining this with knowledge of structures it is possible to create drawings that are useful, although not exact. For example the gearbox drawing was made with the photographs for reference and the constraints imposed by the diameter of the tube it fits inside. The rest is only a useful guess.

- My intention is not to suggest that an exact copy should be made but to draw attention to features of the design that are an improvement on what we are doing here at the present time.

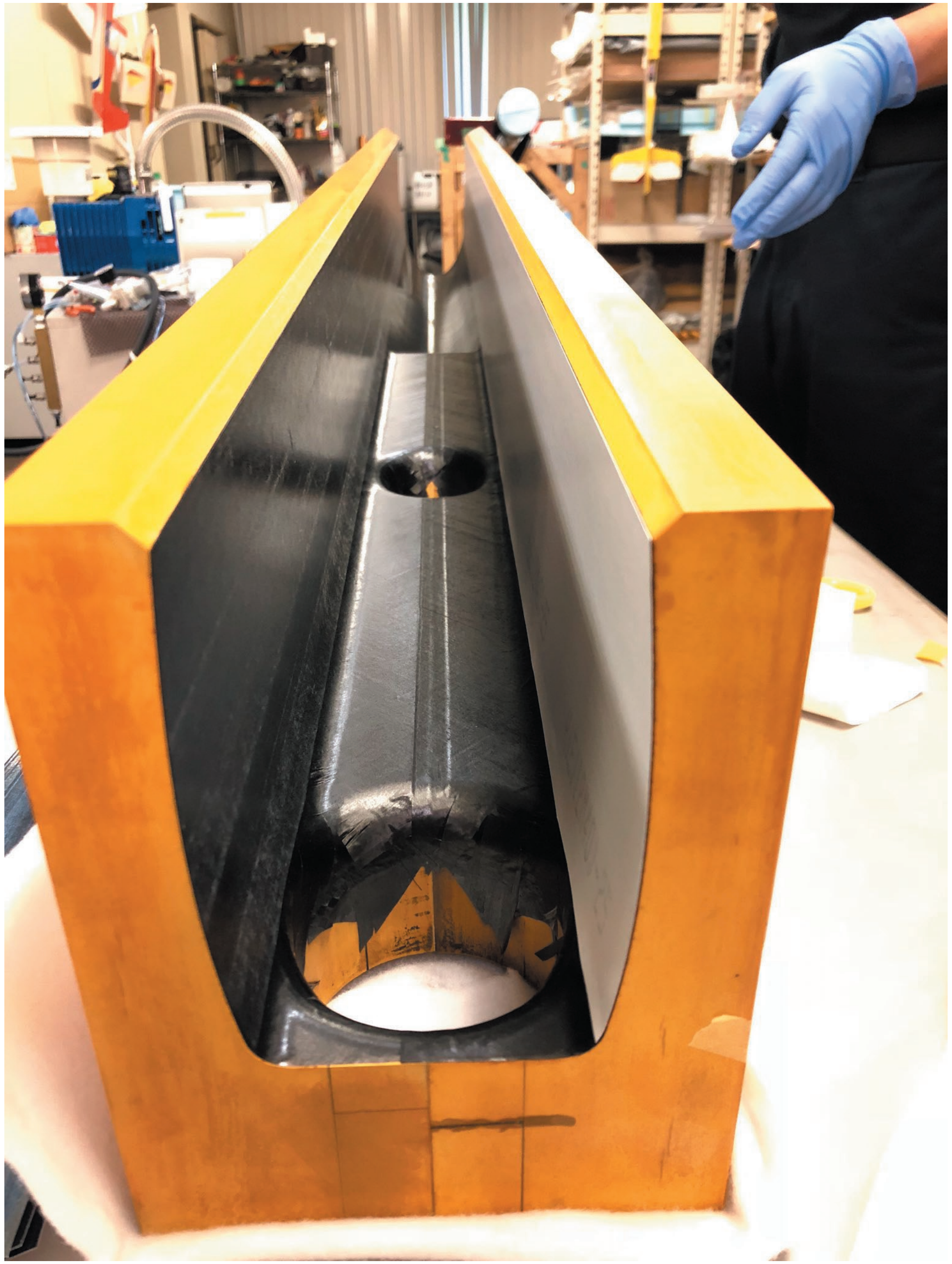


This picture shows the kind of detailed information that can be seen in the photographs, which can be used to construct a reasonably accurate plan.

A drawing of the Bird Man House Phantom HPA fuselage



Scale 1:25



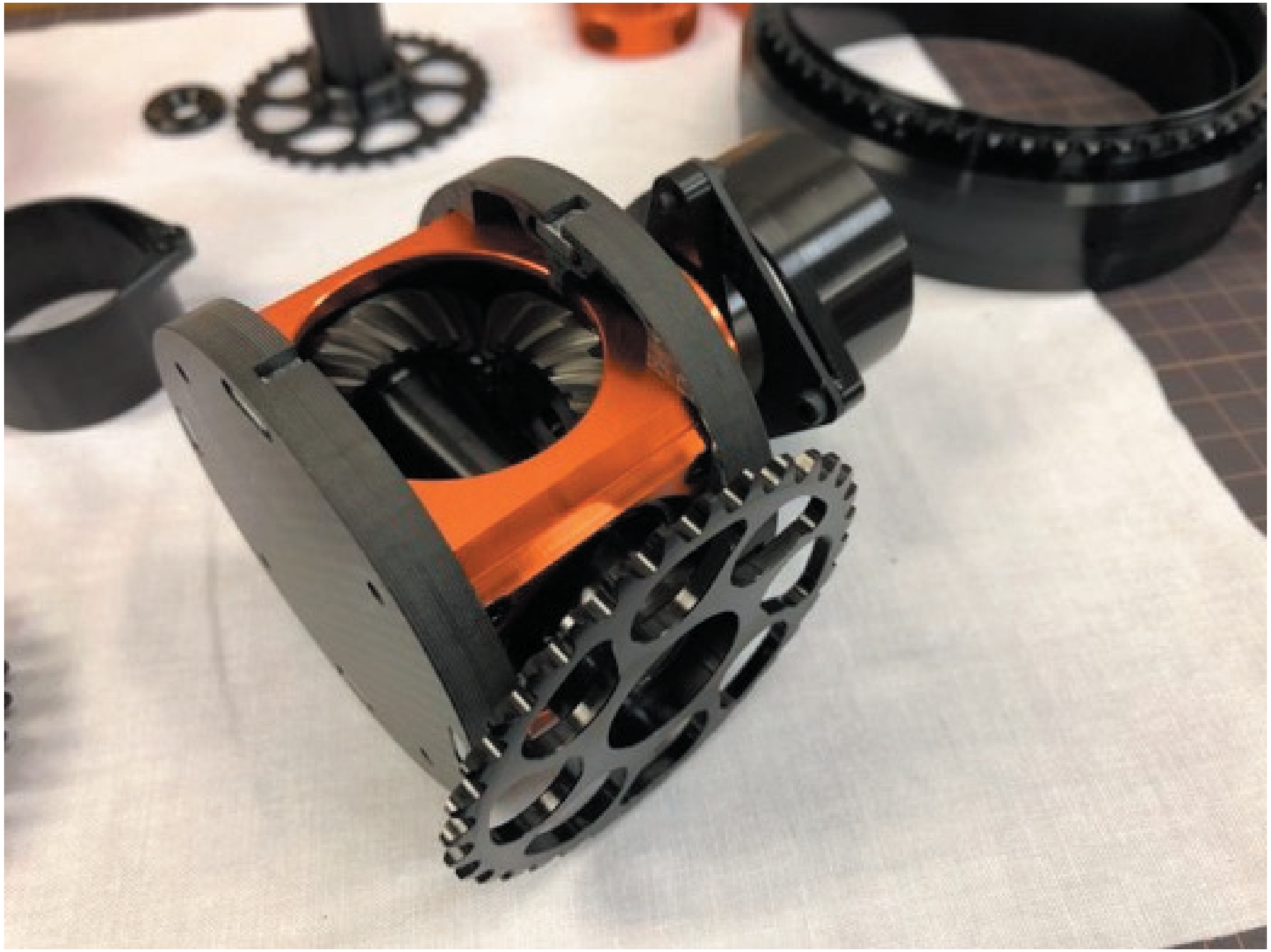
The front half of the main fuselage tube in the mould

The back of the main fuselage tube showing internal bulkheads. It is a sandwich of (estimated) 6 mm thick Rohacell and CFRP. It is bonded to the front half.

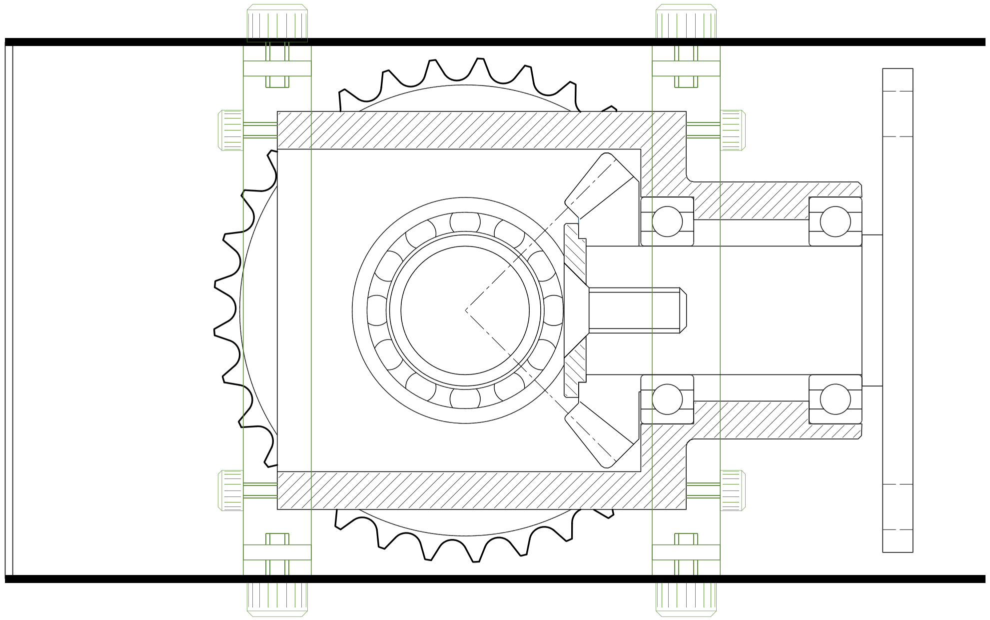
The assembled fuselarge frame

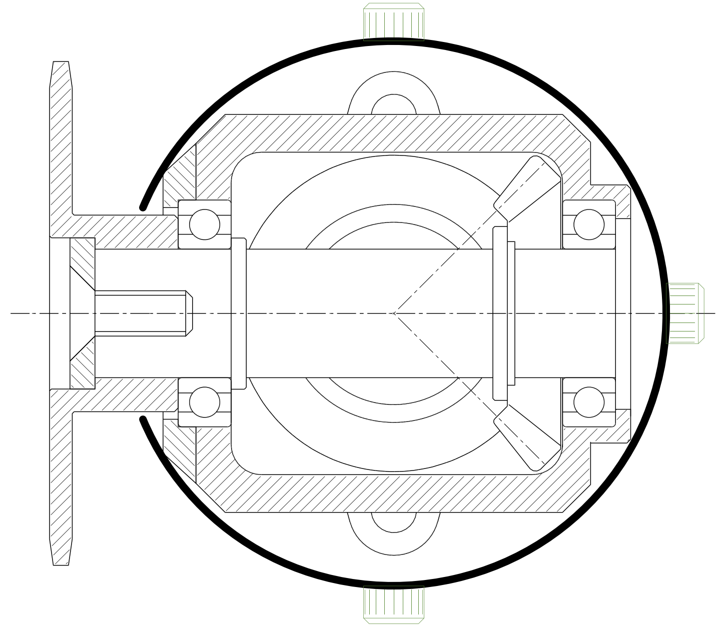
The fuselage viewed from the back looking forwards showing the chain tensioner and control cables

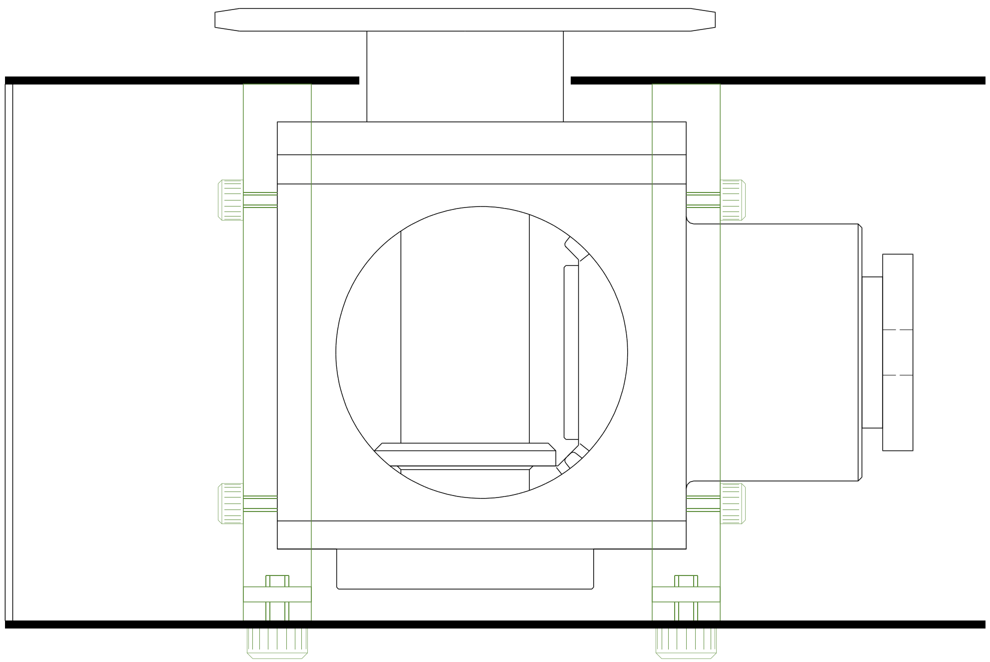
The chain drive linking the pedals to the gearbox



Assembled gearbox. It is mounted in the lower fuselage tube with CNC machined CFRP disks and captive nuts. The chain rings for the pusher prop shaft and drive shaft are visible in the background.







Birdman House Phantom gearbox

The gearbox fits inside the lower tube which is 2.75" = 69.85mm diameter.
It is supported on CFRP disks that are bolted to the fuselage tube with captive captive nuts held in slots in the CFRP disks.

The bevel gears are from KHK, see https://khkgears2.net/catalog6/
The part number is MMSG-20R J 17 and MMSG-20L J 17 (mod 2)
They are fitted to the shafts with keys
The ball races are all 17 mm I.D. x 30 mm O.D. x 7 mm thick
This drawing is full size when printed on A4 paper

Calculating the forces generated by spiral bevel gears

Spiral gears are (slightly) more efficient than straight cut bevel gears but generate axial forces which either push the gears apart or pull them together. It is necessary to calculate the direction of this force to ensure the gears are being pushed apart so the gears are not damaged. Both the axial and tangential forces must be calculated to size the bearings that support the gear shafts.

Notes

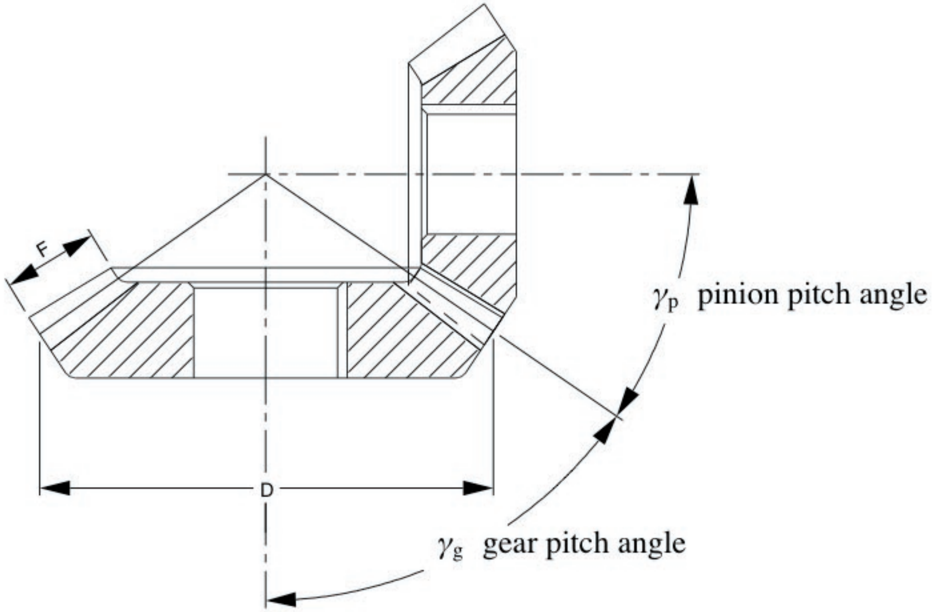
Since only right hand gears with left hand pinions are available, so the other two possibilities are not calculated.

- Choose the solution that gives: separating forces on both gears

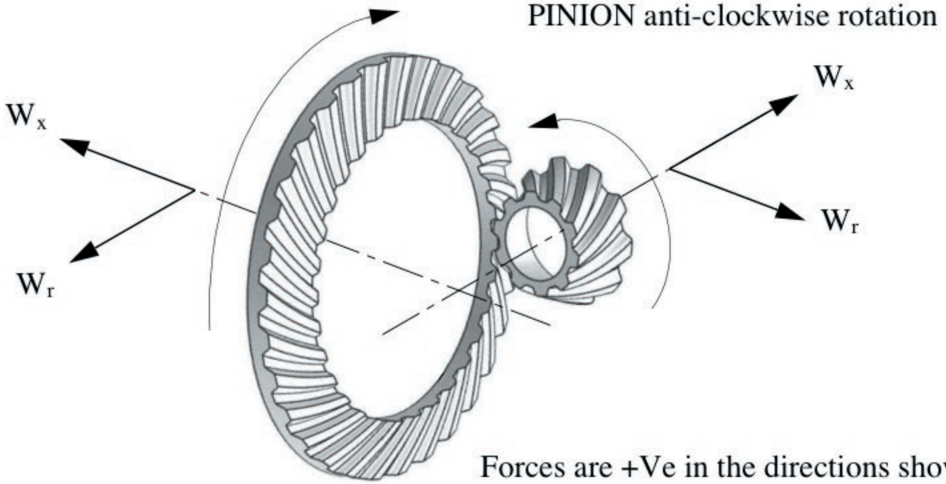
- Gear radial forces: - indicates attracting force, + indicates separating force
- Gear axial forces: + indicates direction of thrust away from cone centre, - indicates the direction of thrust towards cone centre
- The rotation direction is viewed from the front of the gear/pinion (same side to teeth)

- The gear is driving right hand
- The pinion is driven left hand
- Rotation direction viewed from the back of the gear/pinion (opposite side to teeth)
- Radial force on gear is equal to the axial force on the pinion
- Radial force on pinion is equal to the axial force on the gear

Calculating the forces in a spiral bevel gearbox



ψ	pressure angle
γ	pitch angle
γ_g	gear pitch angle
γ_p	pinion pitch angle
φ	spiral angle
T	torque
D	pitch diameter
F	face width
W_t	tangential force
W_r	radial force
W_x	end thrust
dmg	mean gear diameter = $D - F \sin\gamma$



$$Torque,\ T = \frac{60\ power}{2\pi\ rpm}$$

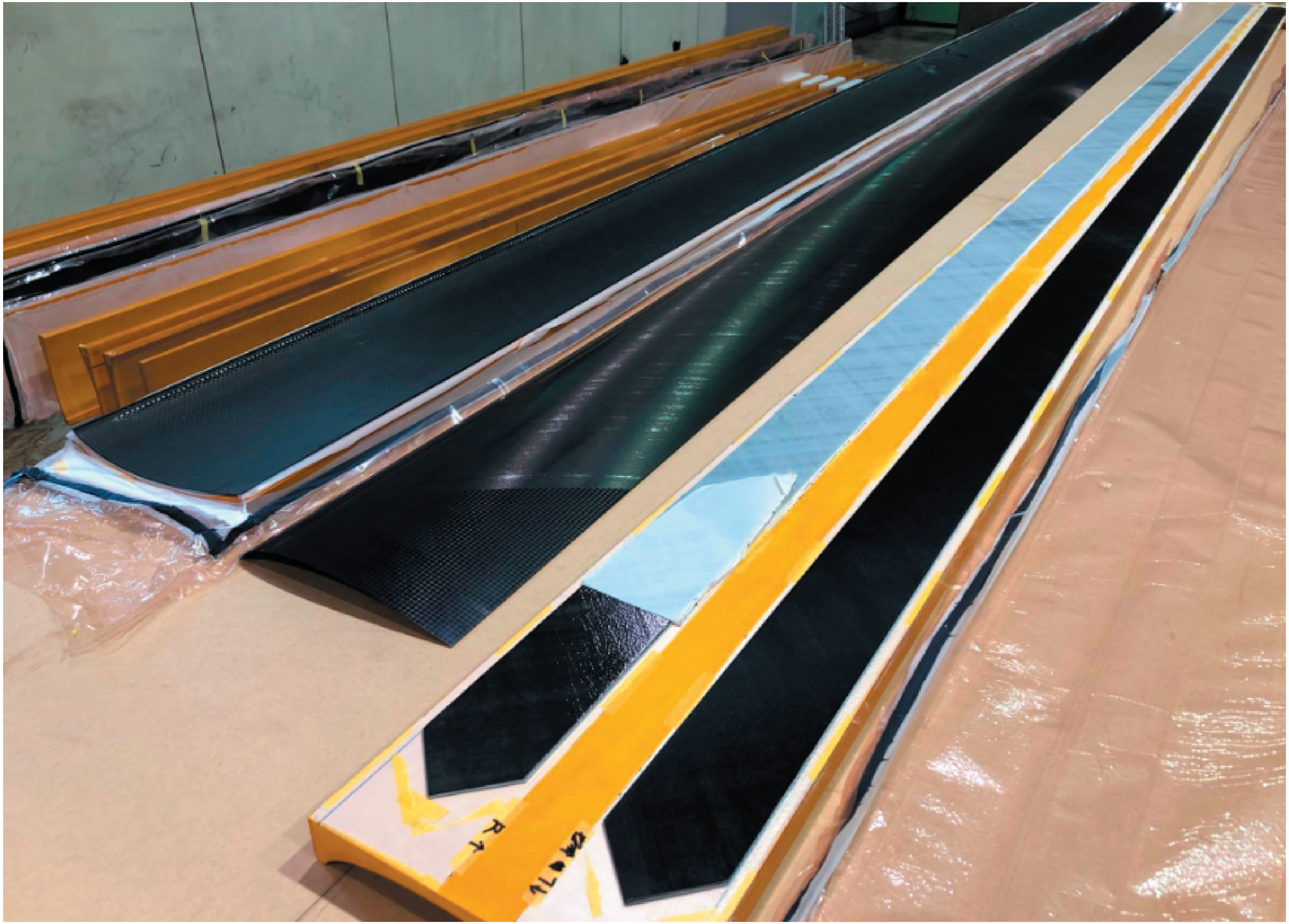
$$Tangential\ force,\ W_t = \frac{2T}{D - F\sin\gamma}$$

$$End\ thrust,\ W_x = W_t\left[\frac{\tan\psi\sin\gamma}{\cos\varphi} \pm \tan\varphi\cos\gamma\right]$$

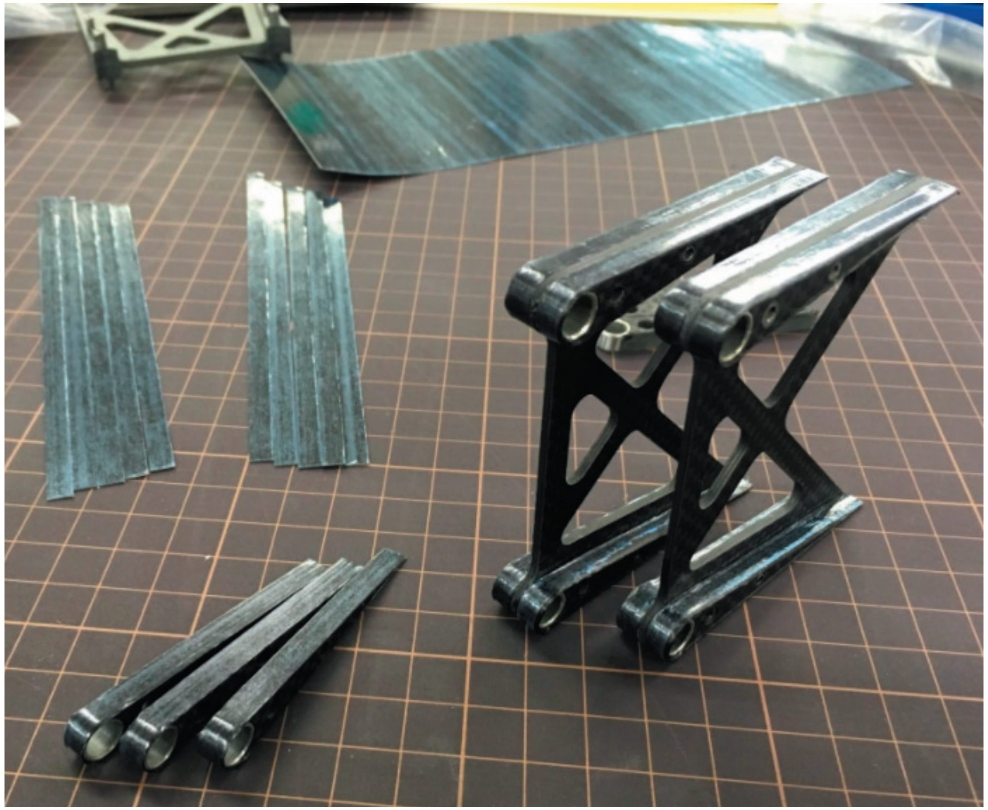
$$Radial\ force,\ W_r = W_t\left[\frac{\tan\psi\cos\gamma}{\cos\varphi} \pm \tan\varphi\sin\gamma\right]$$

Hollow CFRP pedal cranks

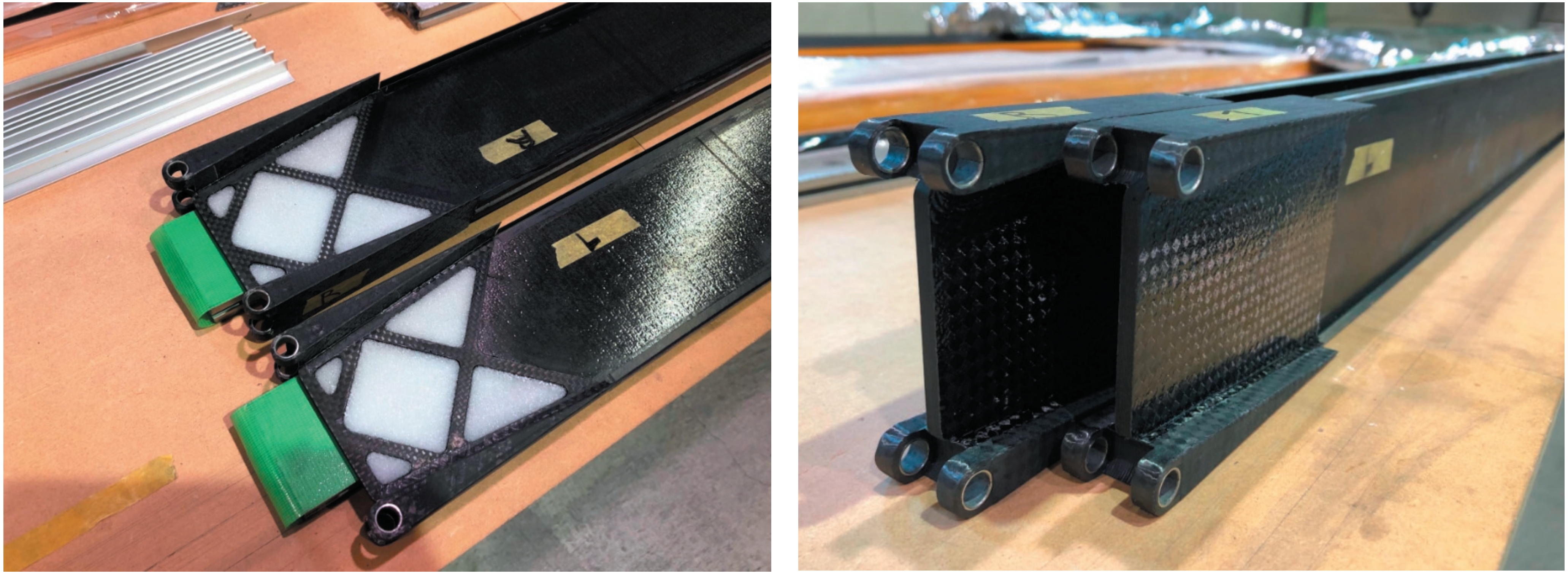
Wing load test to 1.5g



Wing skins and spar webs



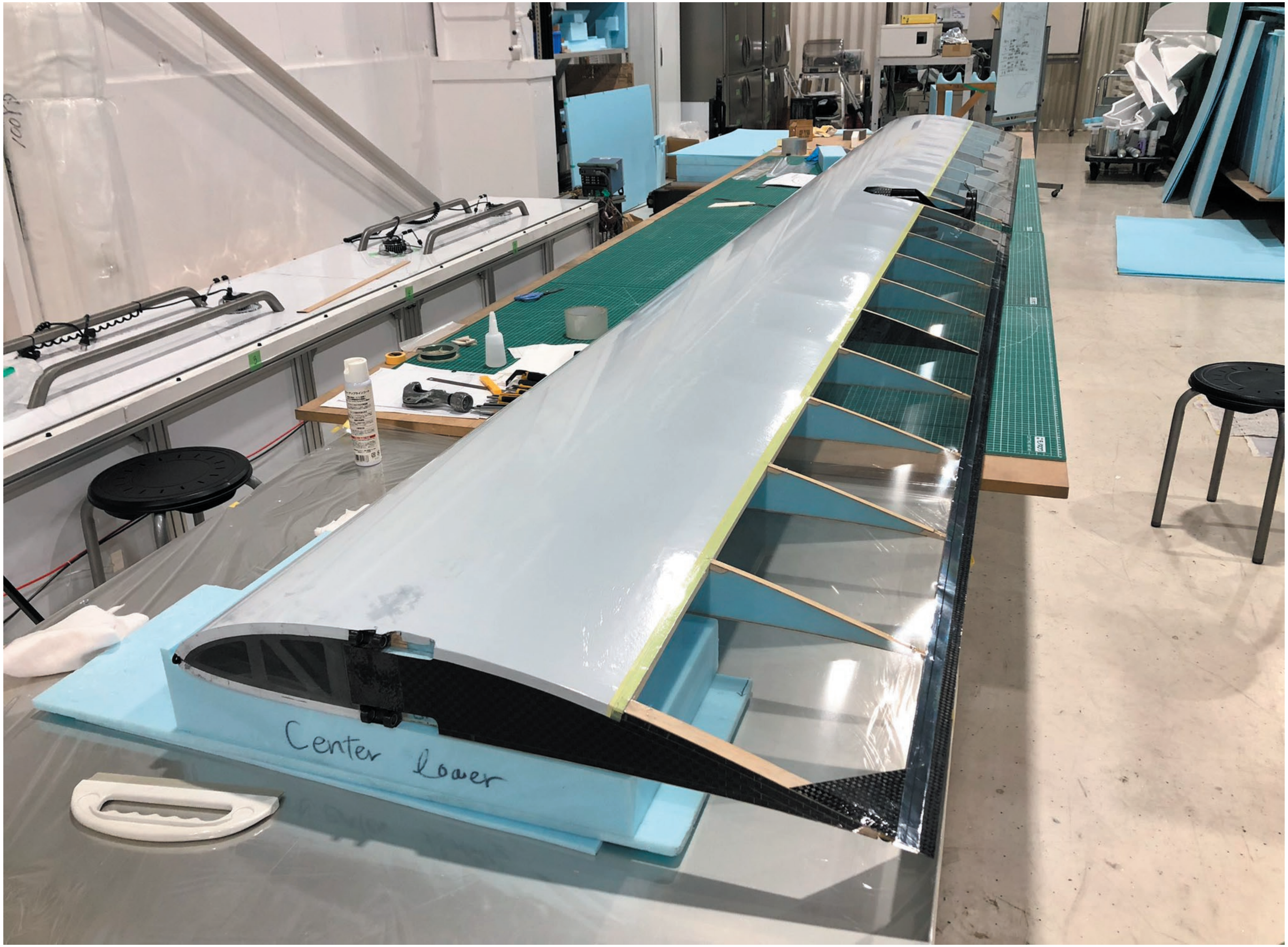
Spar joints. These work like the joints in Musculair II, (I have not seen how the spar in Musculair I was joined, so I do not know if the joins in that were made in the same way), and in Velair 88. We also made and tested such joints for Airglow but decided to use a tube spar because we thought it to be lower risk. These joints as used in the Phantom HPA are the most beautifully engineered I have seen for a pure I-beam spar, though the joints and spar designed by John Edgley for Aerocycle are most elegant, much easier to make, and therefore also worth serious consideration.



Spar joints construction. The holes in the end fittings are filled with Rhoacell foam and the joints reinforced with CFRP cloth

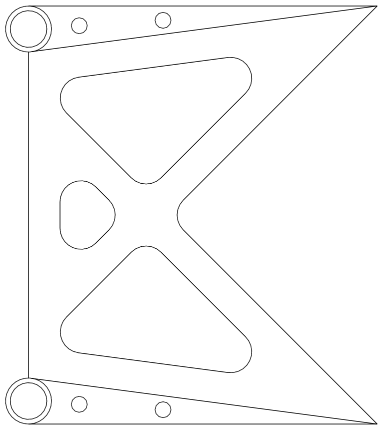
Wing tip panel D-box assembly

It is more efficient to make the wing in three or five panels to reduce the stresses in and the weight of the joins in the I-beam spar. The probe on the attachment faring holds, pitch and yaw vanes, and the airspeed sensor.



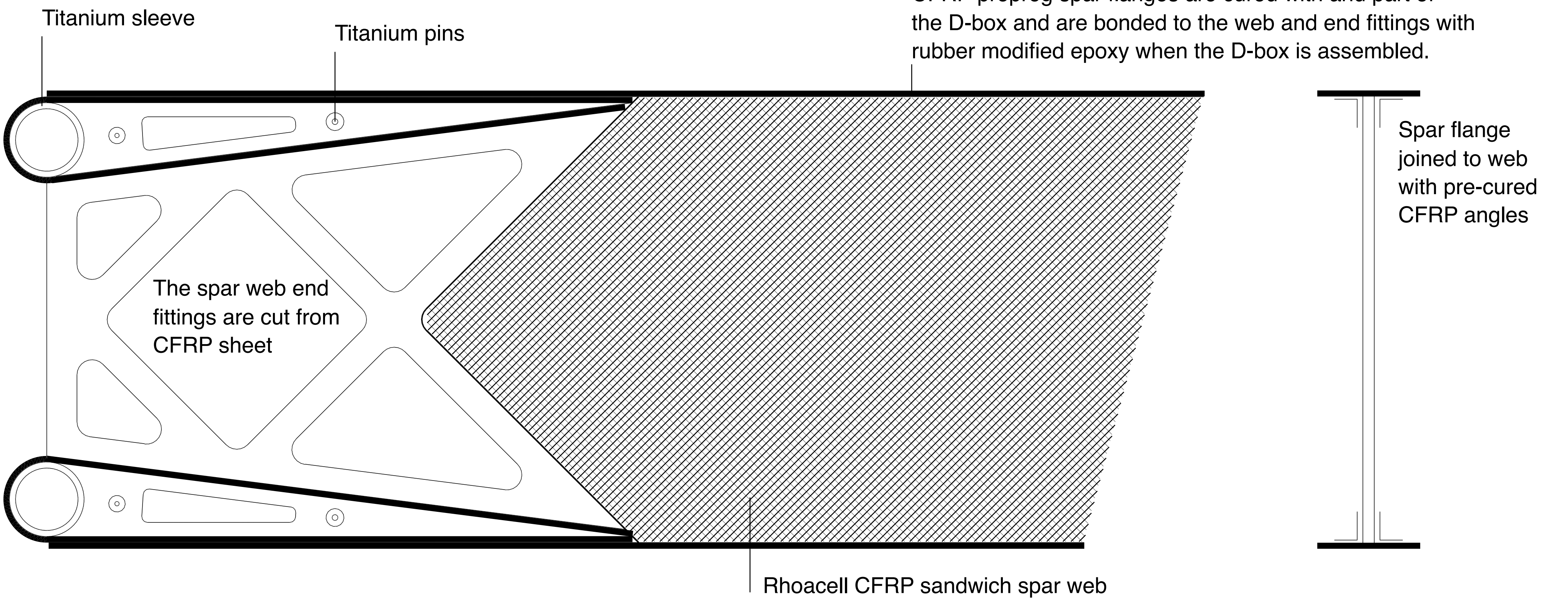
Wing centre panel. The D-box and upper surface (foam) sheet is covered in white plastic to keep the CFRP cool

Birdman House Phoenix wing spar joints



This drawing is not to scale, it was traced from photographs to show only how the spar was constructed you should calculate sizes and pin diameters to suite your aircraft.
The holes in the spar end fittings are filled with Rhoacell and are sandwiched between layers of CFRP cloth vaccum bagged onto it and also onto the spar web to join it to th end fitting.

The tip panal joint end fitting is also shown.



The probe below the wing has, pitch and yaw vanes and an airspeed sensor attached. The point being that the wings lift and drag varies with angle of attack so that monitoring angle of attack is more useful than monitoring airspeed. Monitoring yaw is useful because at zero degrees of yaw drag is minimised. (Think of the yaw string glider pilots attach to their canopies that allows yaw to be monitored.) Whereas when an airspeed indicator is relied upon the speed to fly at to maintain minimum power must be recalculated for each different pilot.

This picture shows another aircraft, the yaw/pitch vanes are however identical on Phantom.

Thoughts and advice

- We could not have constructed Airglow if we did not know how to use a lathe and milling machine, to work wood, and make model aircraft. Value these skills and take every opportunity to learn to make things. It is my opinion that such skills have been catastrophically undervalued in Britain, see The Wolf Report

- Someone asked me what the most difficult things about making Airglow were. Now I have had time to think about this the answers are teaching myself how to design aircraft, writing the computer programs needed to design the aircraft, and learning how to make CFRP tubes

- Proceed cautiously and load test everything before flying

- It is the authors contention that we already have human power aircraft good enough for sport in the form of Aerocycle, the aircraft of Team-F and Phantom so if it were up to me I would award the Aircraft for Sport prize to the first aircraft to fly the Kremer course for the Aircraft for Sport competition without concern about the wind speed constraints of the competition.

- I suggest a modification to the Kremer Marathon competition rules along the lines of the Kremer speed competition. The first aircraft to fly the course at 10 m/s wins a prize, then another prize is awarded each time the speed is increased by 0.5 m/s

Thank you

I will put a copy of this talk on the Human Powered Flight website:
https://www.humanpoweredflight.co.uk/page/downloads