Long Builds & Short Flights

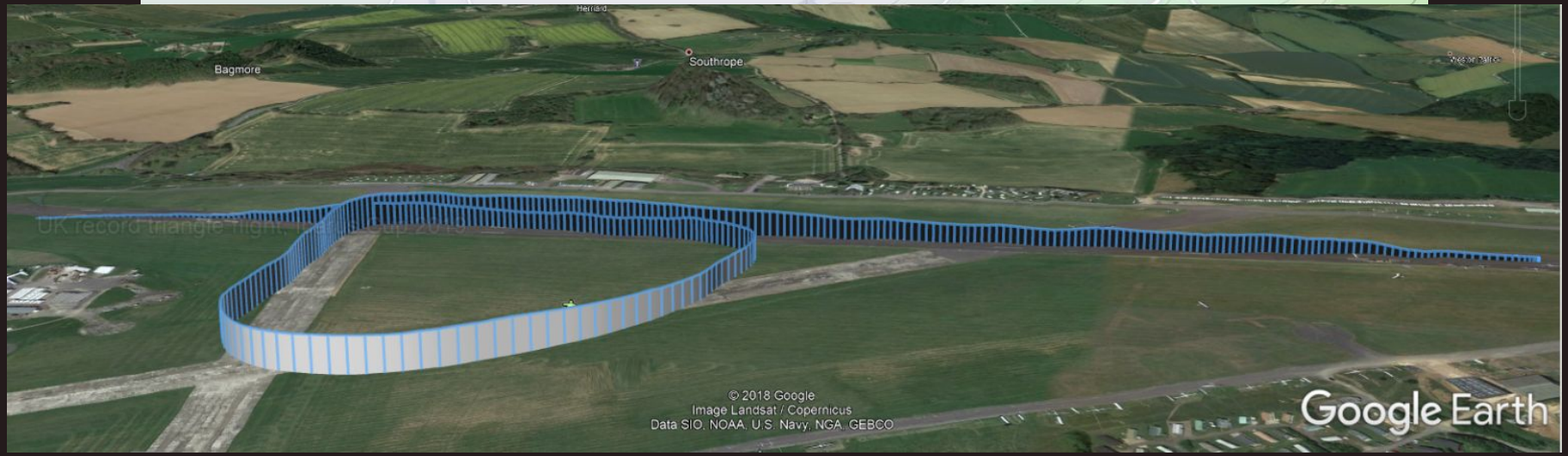
My experience of flying and constructing Human Powered Aircraft

Overview - two parts:

- My time as an Aerocycle team Pilot
  - Some notable flights
  - What it takes for training
- Building my own HPA
  - My build goals, challenges and success so far

Feel free to ask questions as we go along!


New Inn Copse
East Com
180 m
180 m


Bagmore
Southrope
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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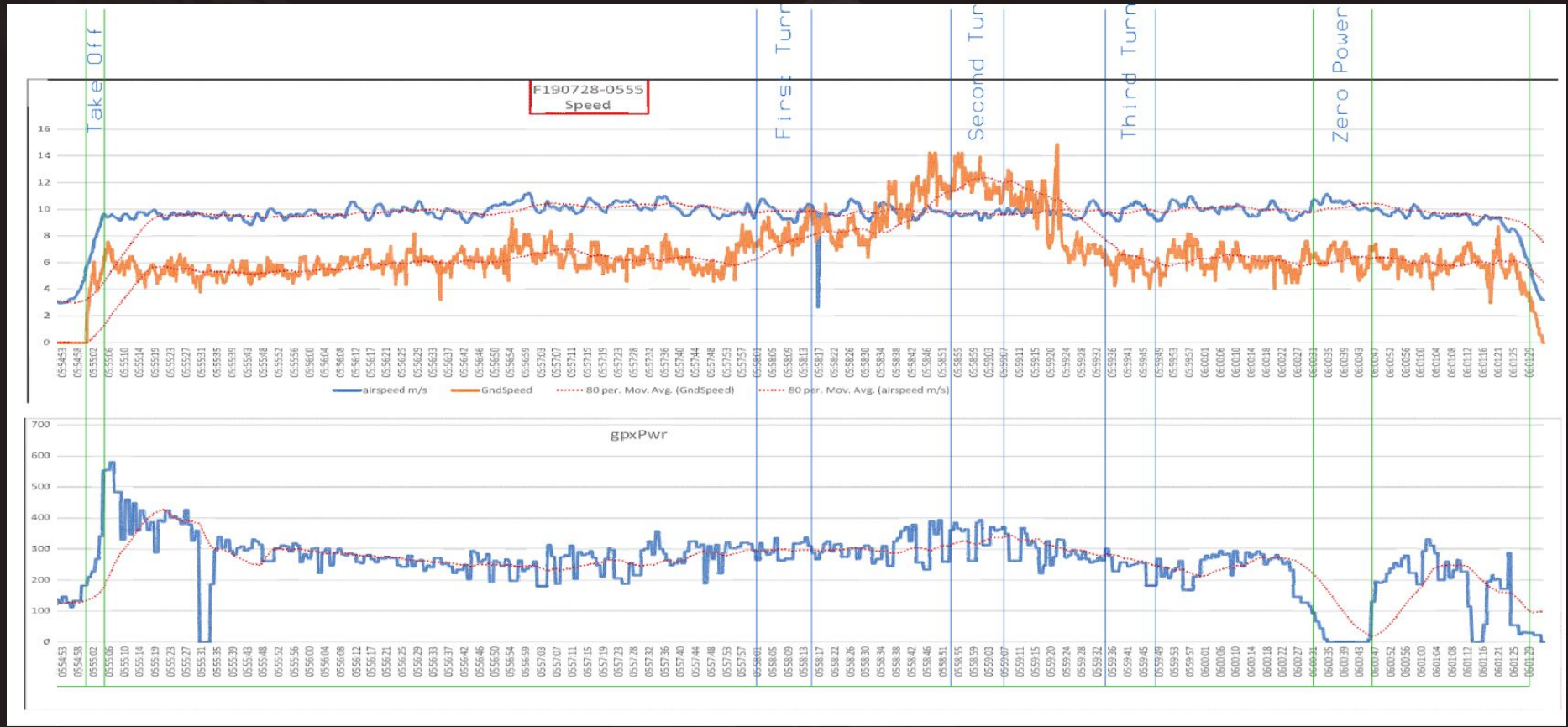
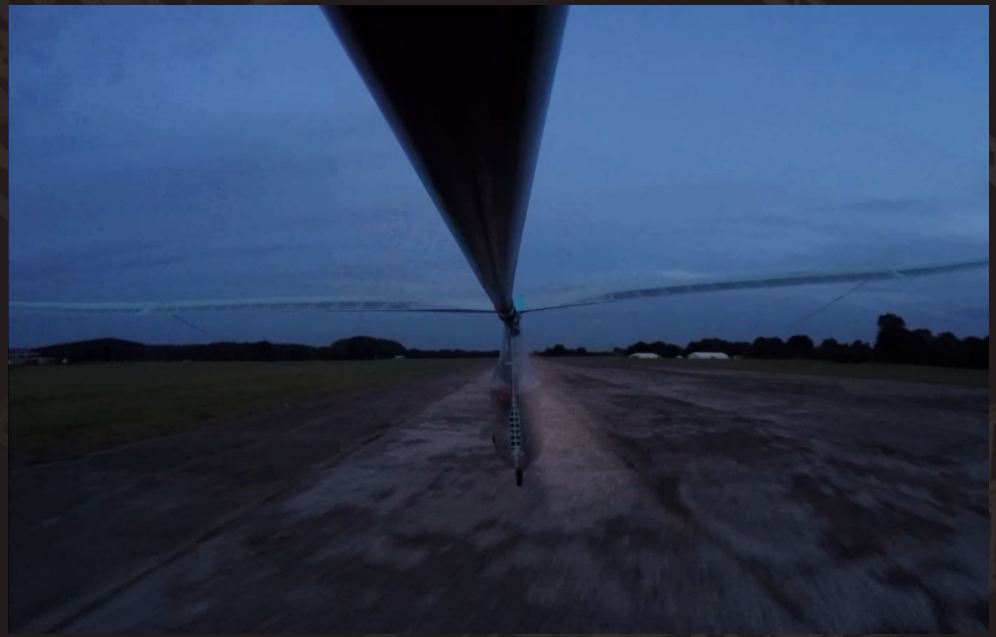

F190728-0555
Speed
Take Off
First Turn
Second Turn
Third Turn
Zero Power
airspeed m/s
GndSpeed
80 per. Mov. Avg. (GndSpeed)
80 per. Mov. Avg. (airspeed m/s)
gpxPwr

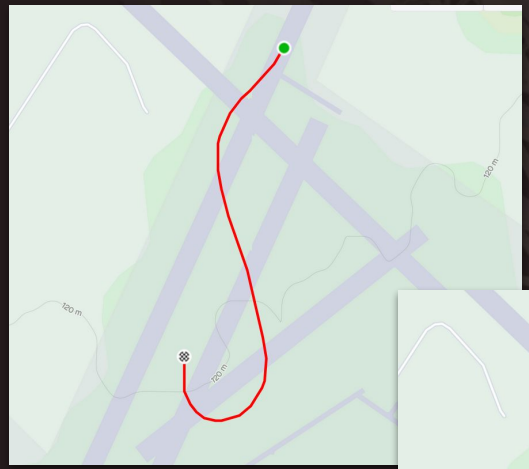
Some more notable flights

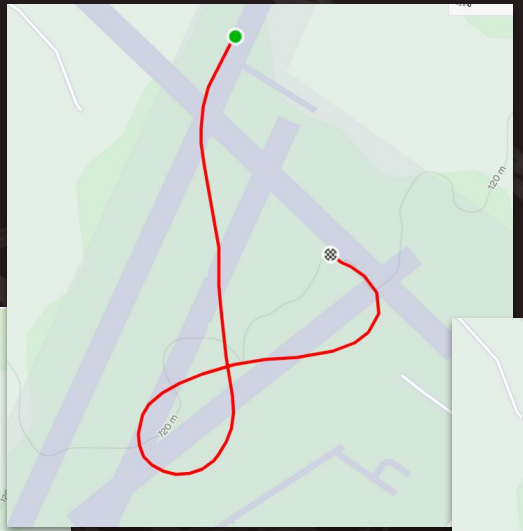
Night Flying! -

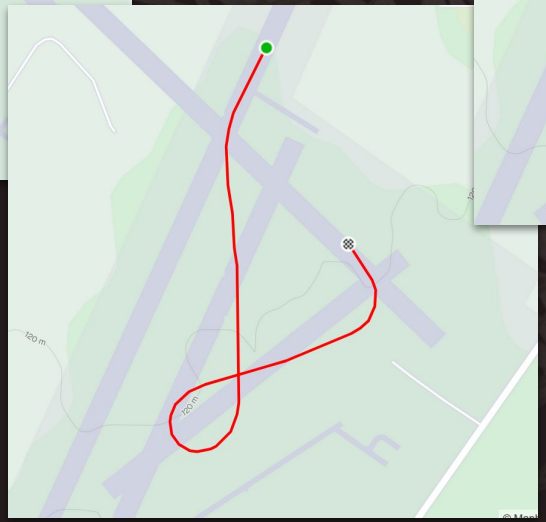


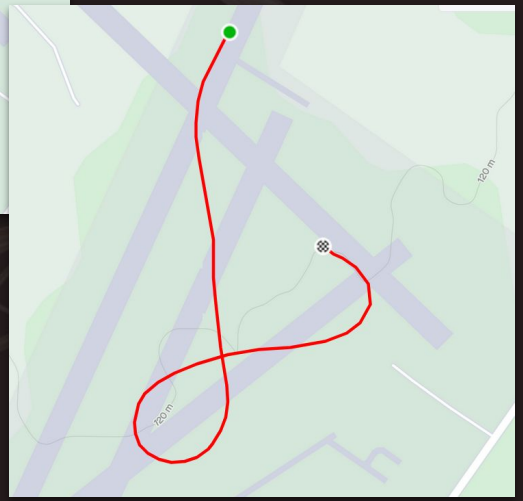
AKA, the quickest way back to the hanger and on to the bar

Multiple Figure of 8 Attempts

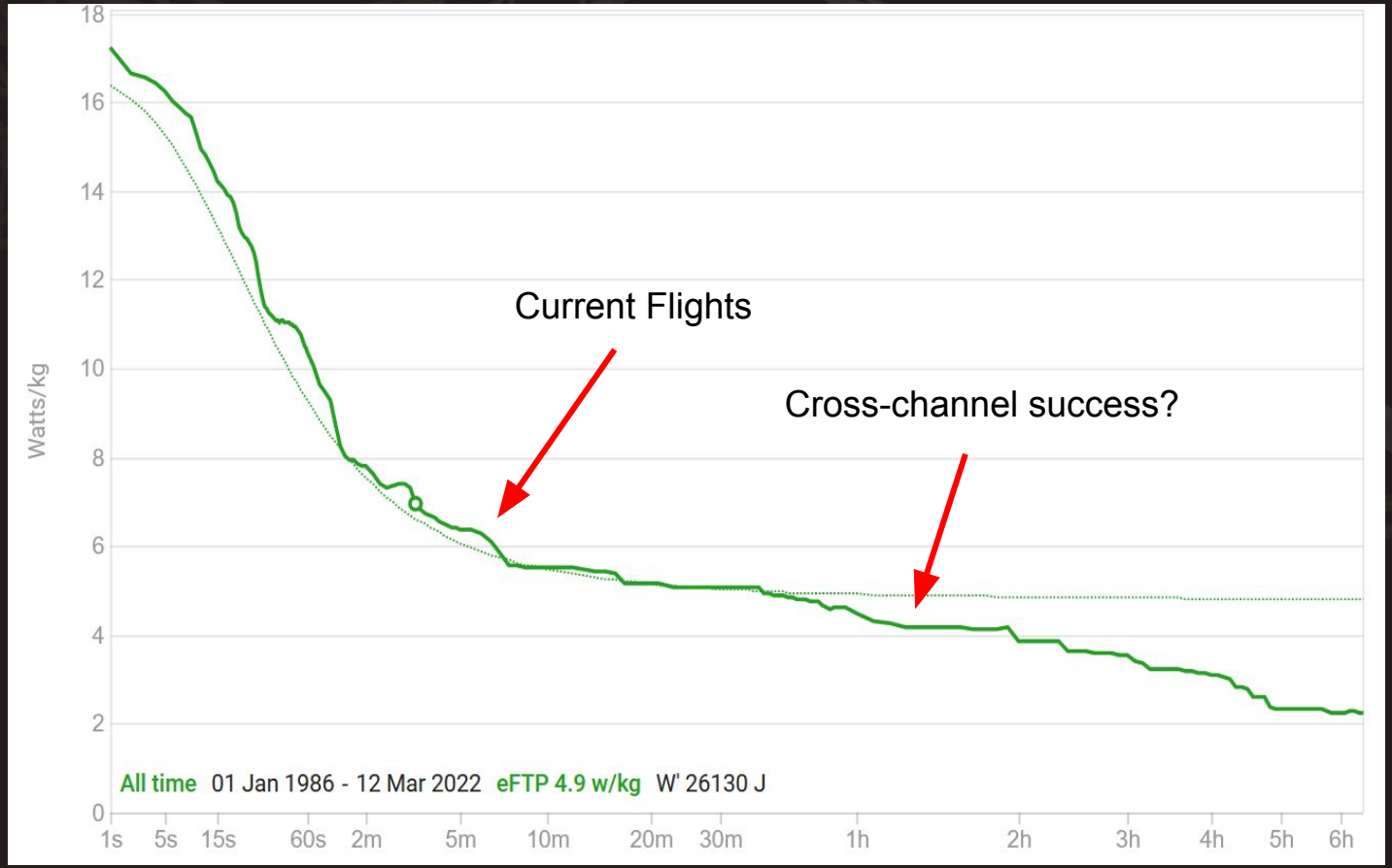








What next? - Pushing the Power Curve



Ramping up my cycle training:

- 8 to 10 hours a week
  - Commuting three or four days a week
  - Evening club rides
  - Indoor training rides
  - Longer weekend rides
  - Road racing and time trialing
  - Hill climbs!
- Improving watts / kg for easier flights

What’s next? - My very own HPA

5 Year plan for design and build - currently just over 1 year in

- Realistic goal to spread time and costs
- Still want to be young, fit and have all my hair by the time I’m done building it!

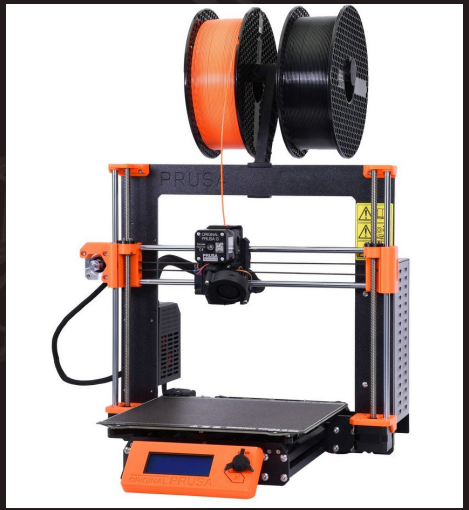
My constraints:

- Space - limited to a few meters
- Cost - use off the shelf parts where possible
- Tools - minimal required machine tools, no mill or lathe available
- Lazy! - don’t like to fettle, sand and adjust parts

Which Technology?

Three possible options for budget CNC type machines:

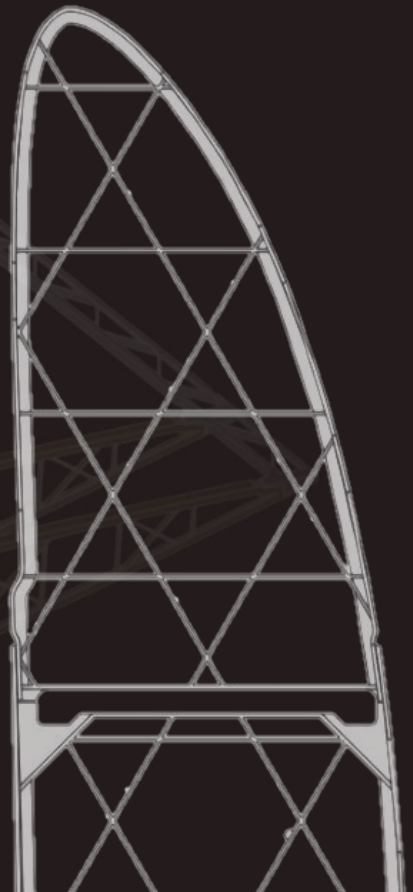
- Laser cutter for foam
- CNC router for foam
- 3D printer



3D printer is the most versatile, but least well proven and has the smallest footprint

Laziness solution - filament 3D Printing

- Variety of materials available - tradeoff of strength, stiffness, cost and weight:
  - PLA - cheap, great for general purpose testing
  - Carbon reinforced nylon - structural
  - LW-PLA - lightweight structure and fairings
- Good general purpose use
  - SUHPAs Lazarus demonstrated good use of 3D printed parts in the drivetrain, tail fittings and propeller blades.
- Can be very selective where you add material and weight to optimise stiffness
- A few downsides still:
  - Potentially costly material, slow for large numbers of parts
  - Limited build area - 210 x 250 x 210 mm



Overall HPA Design

Faster flying ‘sporting’ aircraft suitable for british weather - stick with what I know!

Rugged and tough

Aero is everything!

Hopeful specs -

Span: 22 to 25 m, high aspect wing

Flight speed 9 m/s

Sub 40 kg weight

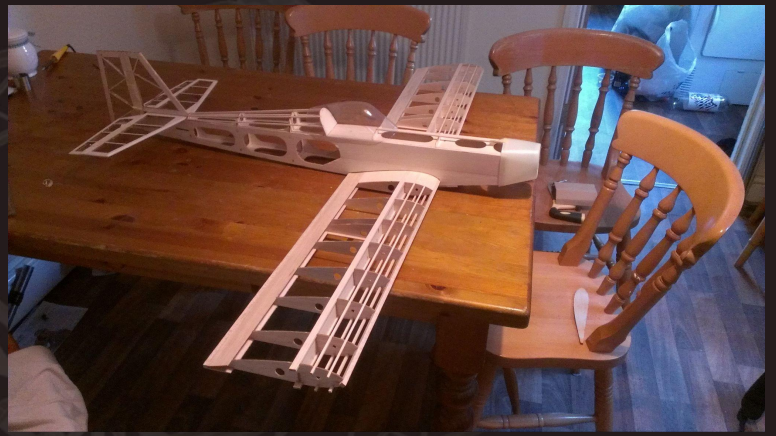
Overall HPA Design

- Tractor prop
- Underslung pod, recumbent position
- Everything faired where possible
- Carbon tubes with printed lugs for joints

Similar to Daedalus or more recently, Betterfly.

How did I get to this?

- Integrated Mechanical & Electrical Engineering Degree at the University of Bath
- Building RC model aircraft on the shared dining room table led to being part of the Aerocycle build team in summer 2013 and 2014 - helping to build the wings and then the following year the fuselage of Aerocycle 301

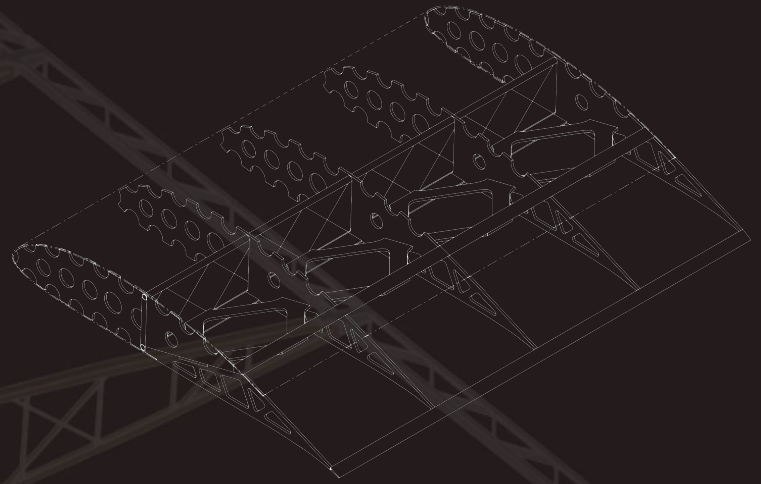


- Currently employed as a product design engineer - use lots of CAD, rapid prototyping, prototype assembly for design of mechanical and electronic components

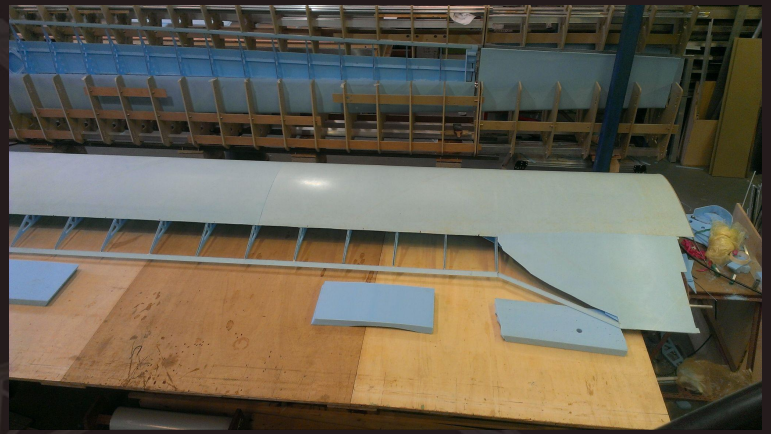
Current HPA Build methods

Wing Construction

- Inside out or outside in?



Aerocycle Wing build, 2013:



Repeating the above in a garden shed?

~~Stealing~~ Innovating the best parts from both construction methods:

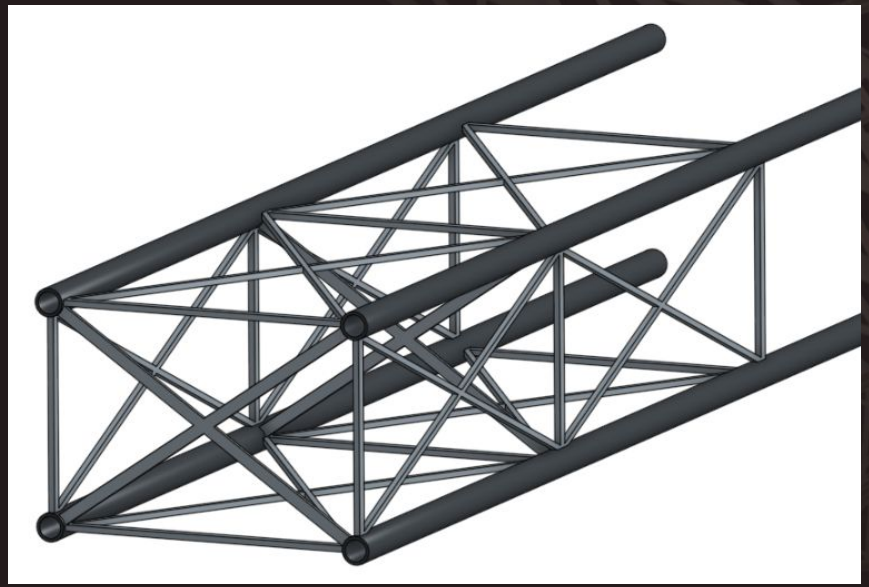
- Building the secondary wing structure around the spar
- Using off the shelf pultruded carbon tube where possible
- Getting a CNC machine to do all the hard work for me

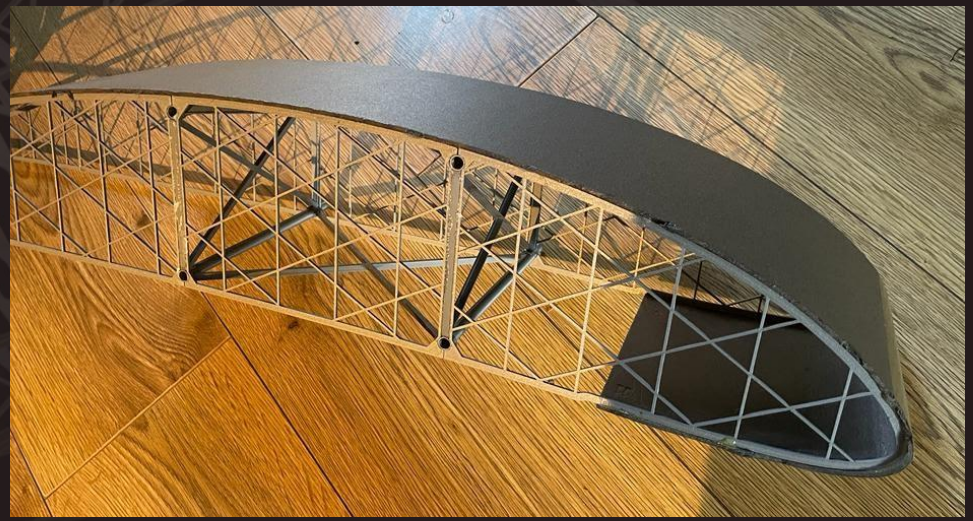
Focus on the right materials, construction methods and assembly technique first - detailed structural analysis can come later with help from much smarter individuals than myself!

Even if I fail, hopefully my ideas might make HPA construction simpler and therefore more feasible to many university teams or individuals around the world

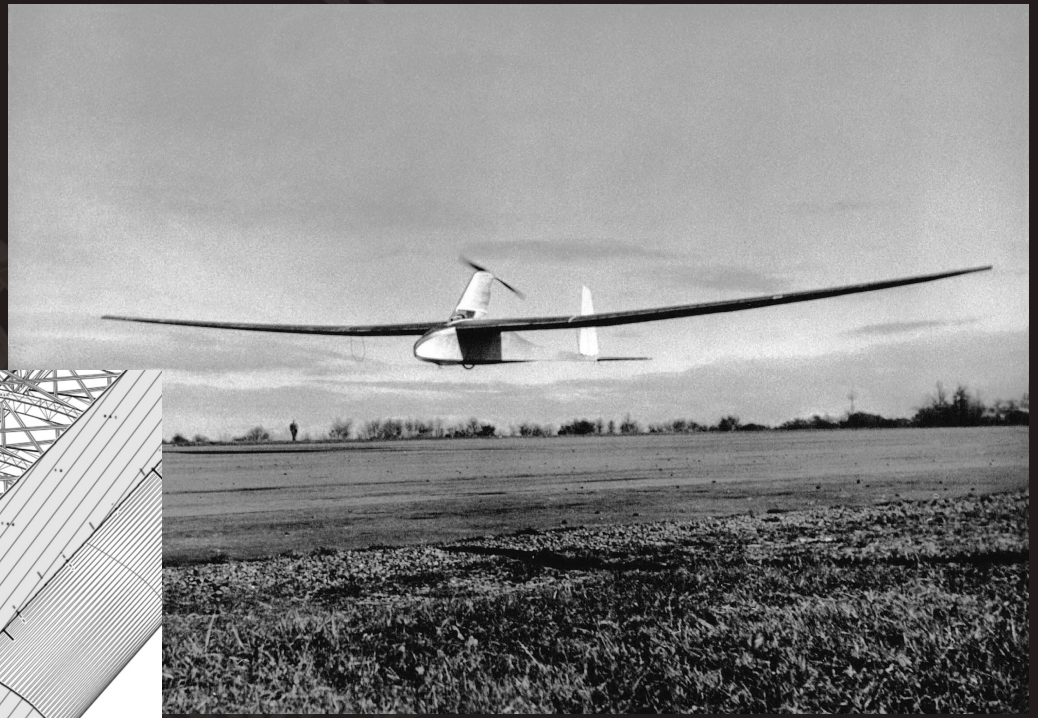
Structural solution - box section spar

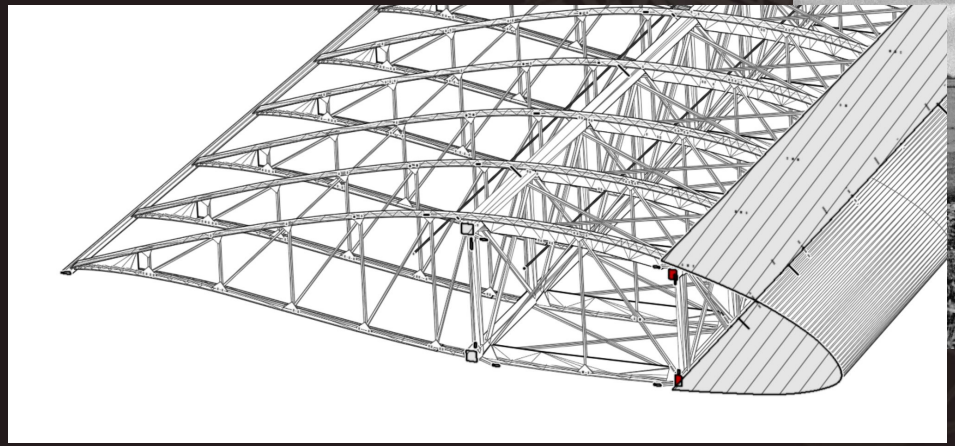
Spent a lot of time trying to come up with a solution - settled on a box spar with four caps, truss like reinforcements to take torsional loads





Turns out I had the same idea as SUMPAC 60 years earlier!





First assembly tests

- With a plan in place, I then built a few test sections using cheap materials to test my construction methods:

Next step:

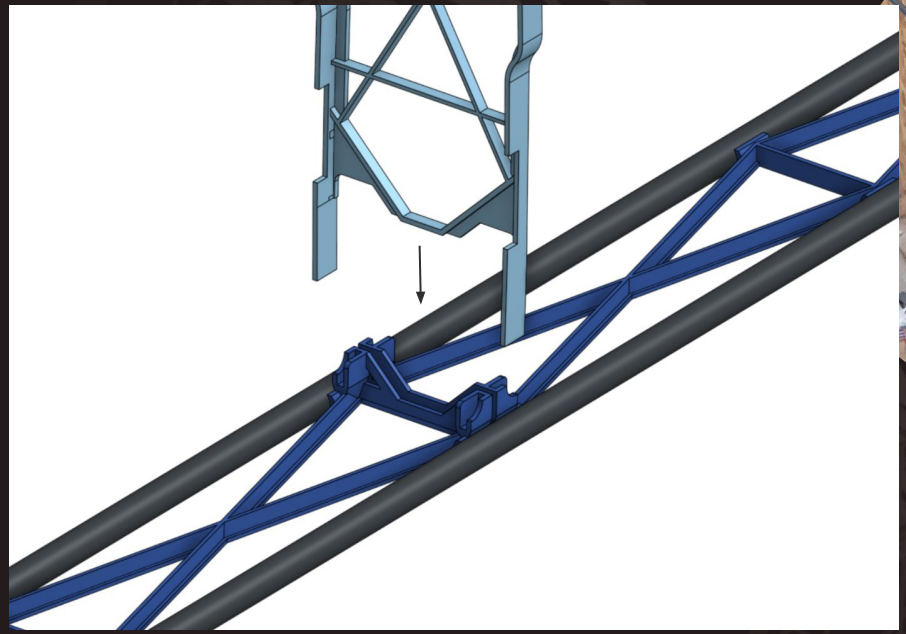
Tail surfaces

Wing Structure Assembly

Start with box section spar - two identical trusses with carbon tube caps:

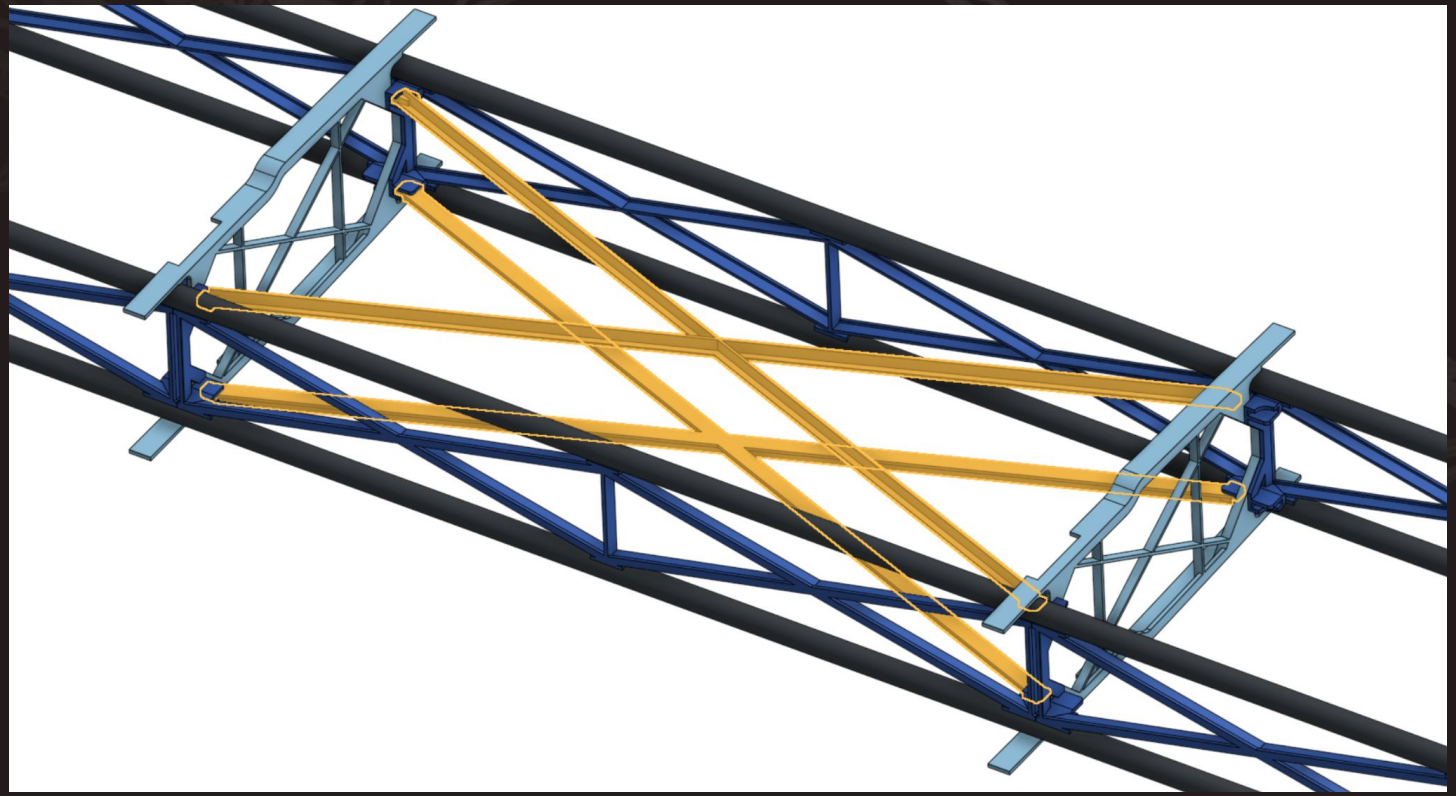
Wing Structure Assembly

Slot center ribs into the truss tabs, followed by the second truss:



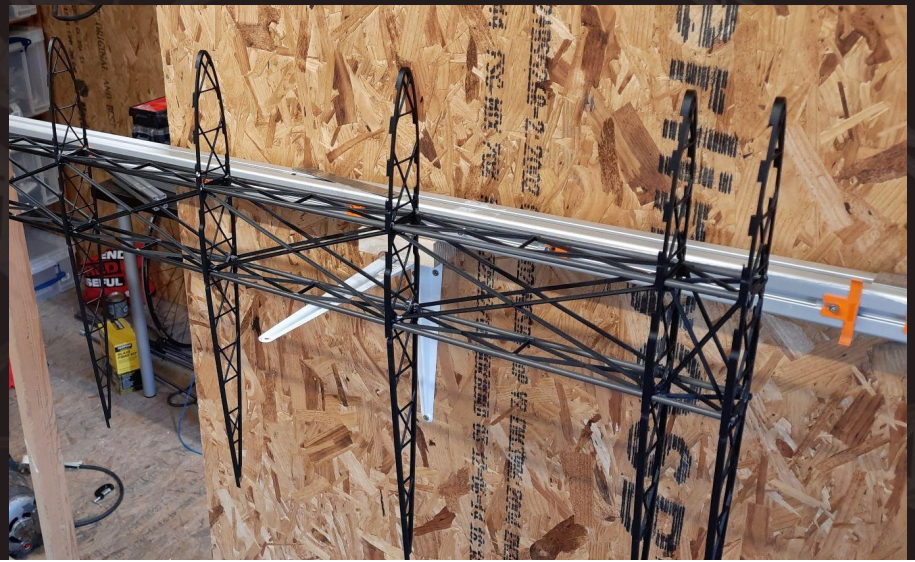
Wing Structure Assembly

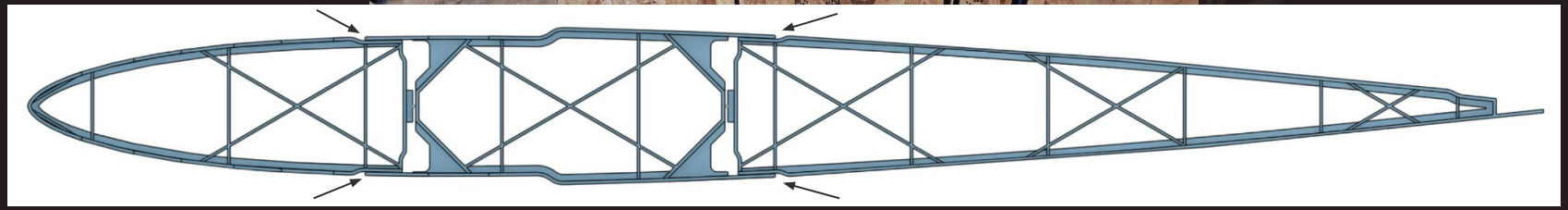
Torsion stiffening webs fitted



Wing Structure Assembly

Fit leading and trailing edge ribs:





Wing Structure Assembly

Fit Trailing Edge:

Wing Structure Assembly

Skinning with Depron:

Wing Structure Assembly

Stiffening the end ribs:

Wing Structure Assembly

Applying the mylar film:

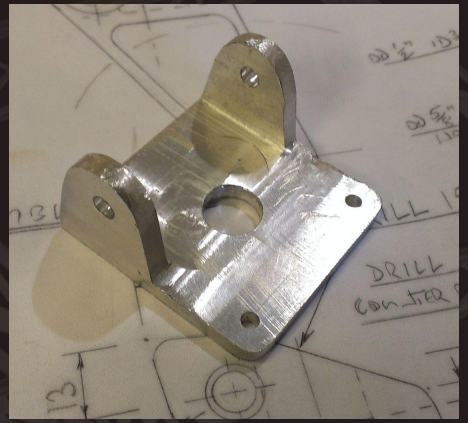
My fuselage experience with Aerocycle 301

Building a new fuselage and tail around the 2013 wing:

- Carbon frame completed
- Fuselage fairing complete

Still plenty to do:

- Fittings for the wing, drivetrain, wheels, and seat



Simplifying the fuselage build process

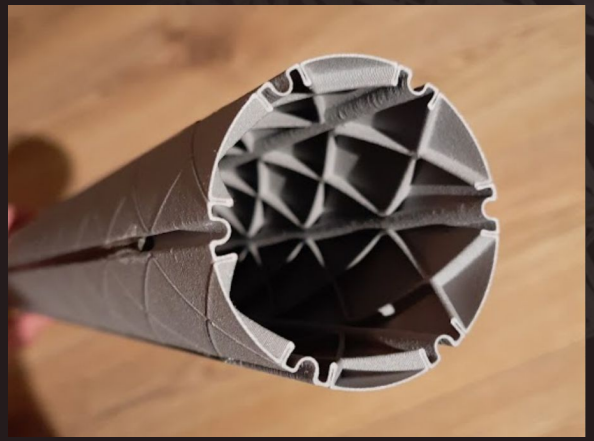
My major obstacles:

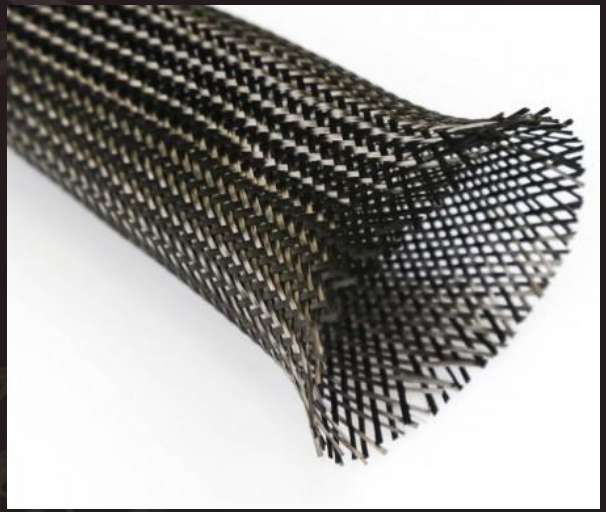
- Custom made carbon tubes - fuselage and tail boom
- One off machined parts - drivetrain & gearbox
- Moulded composite parts - fairings, propellers

How can I use 3D printing to make these parts simpler, cheaper or less labour intensive?

Fuselage tubes and tail booms

A novel homemade tube method using 3D printed cores:





A novel homemade tube method using 3D printed cores:

- Assembled, wrapped and epoxied

Good weight with integrated internal structure:

Simpler Propeller Blades

Blade designs are often specific to a particular aircraft flight speed and diameter

Blades are typically either:

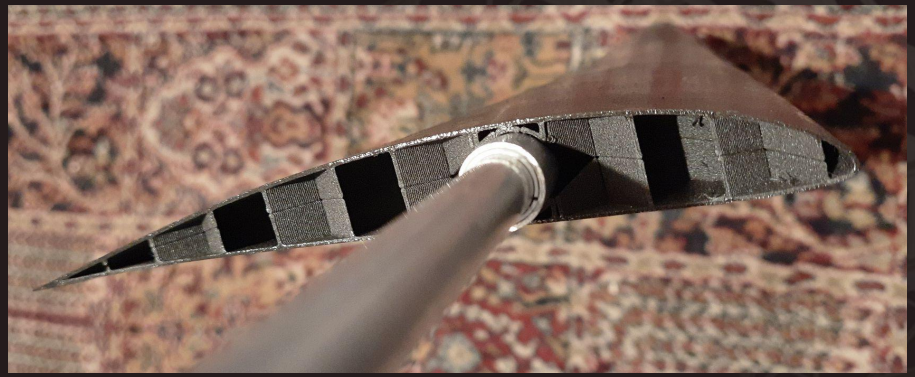
- Made from an expensive mould
- Foam cores skinned with carbon, kevlar, or fiberglass
- Traditional ‘built up’ balsa construction

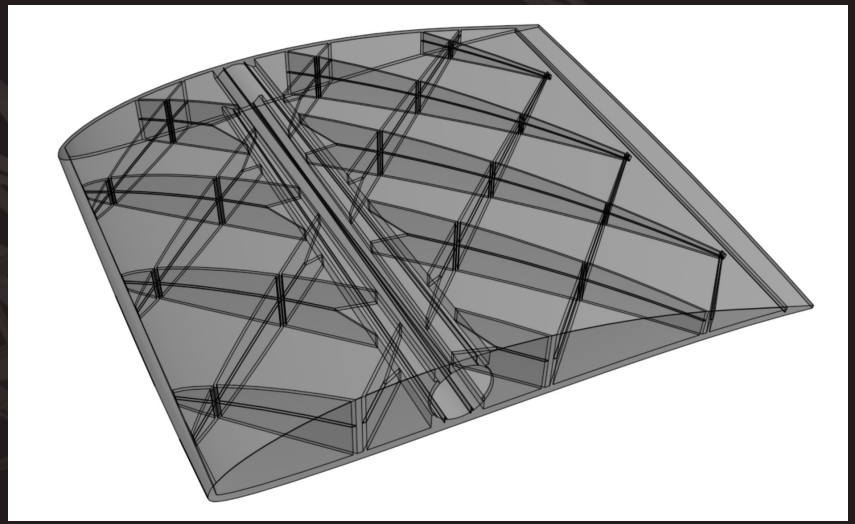
More recently, Charles D’Henin of Lazarus has had success with hollow printed cores and monocoque carbon outer layers

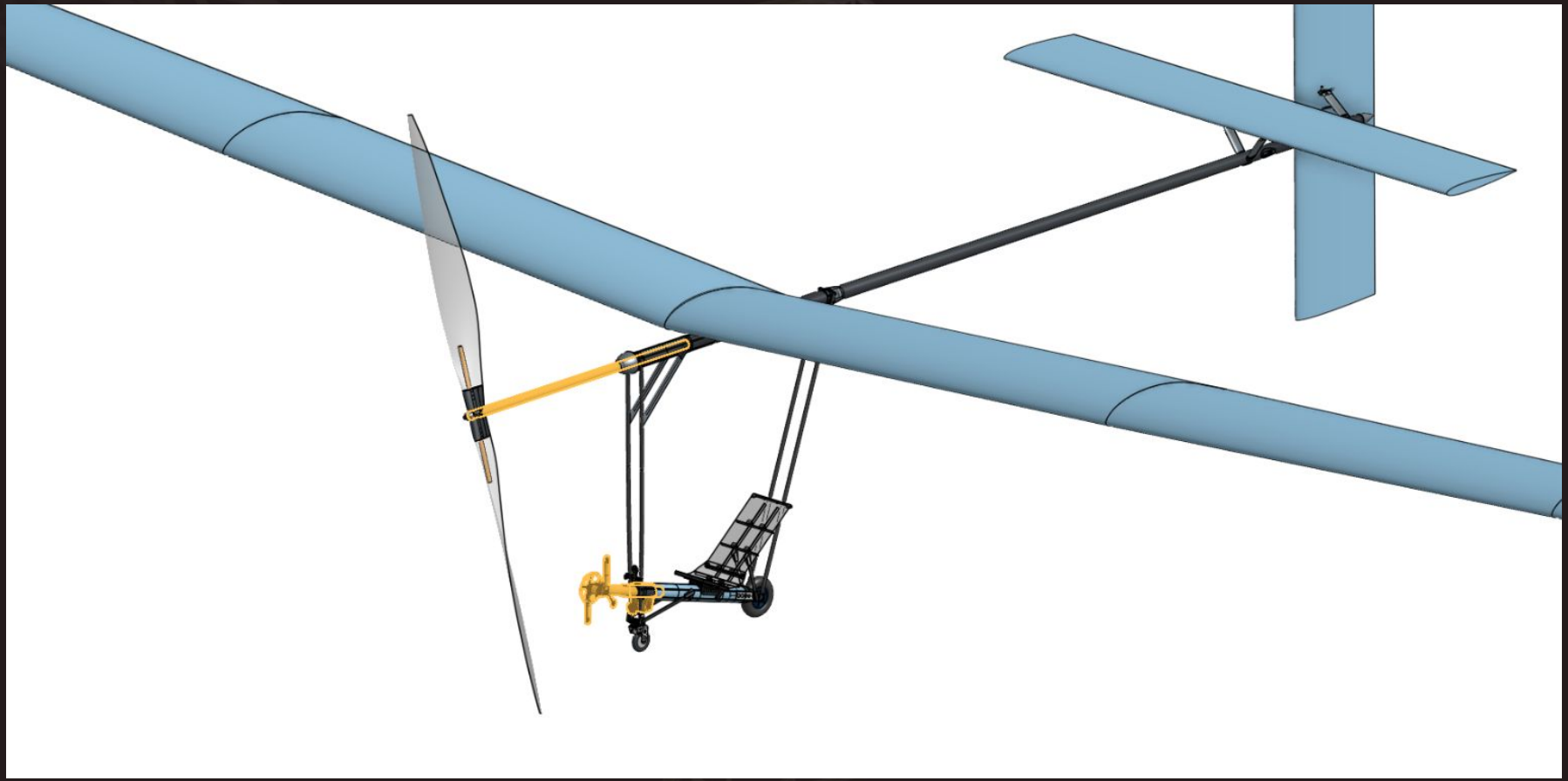
Taking 3D printed blade structure further:

Essentially replicating the solid foam core build method but using printed parts rather than hot wire cut

Parts are printed, built around a spar tube, then thinly skinned with fiberglass cloth

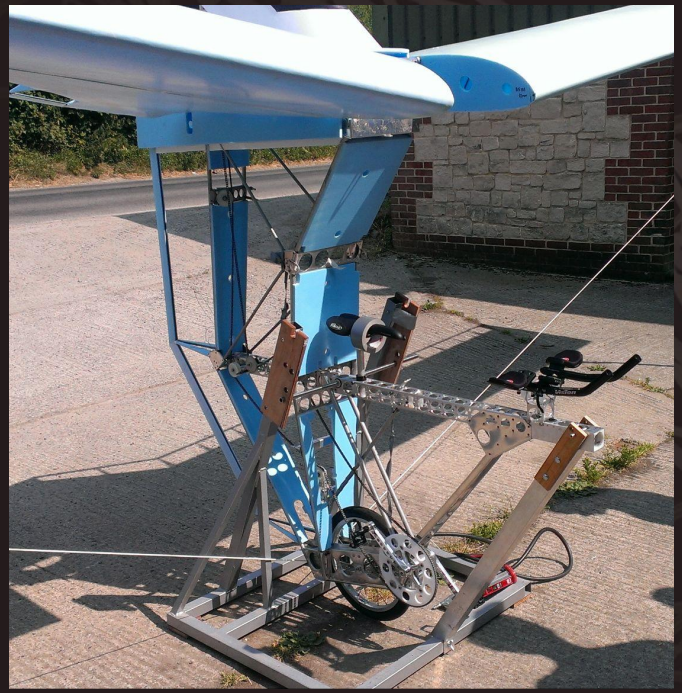






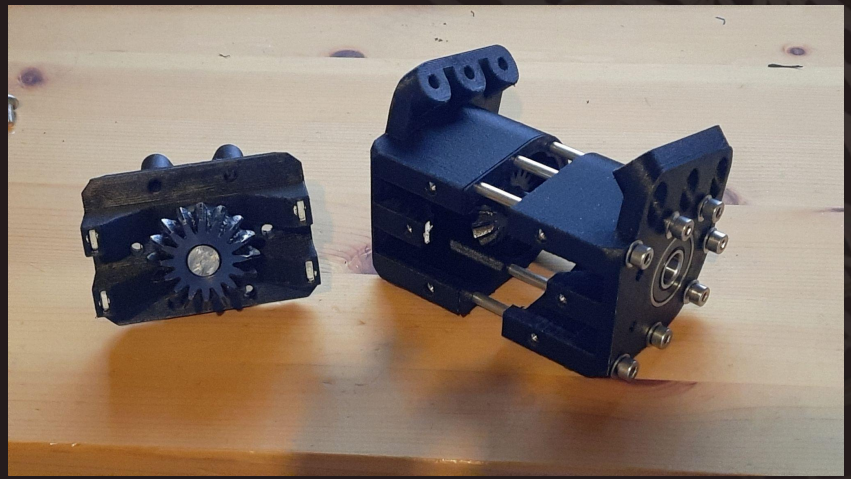
The HPA Drivetrain

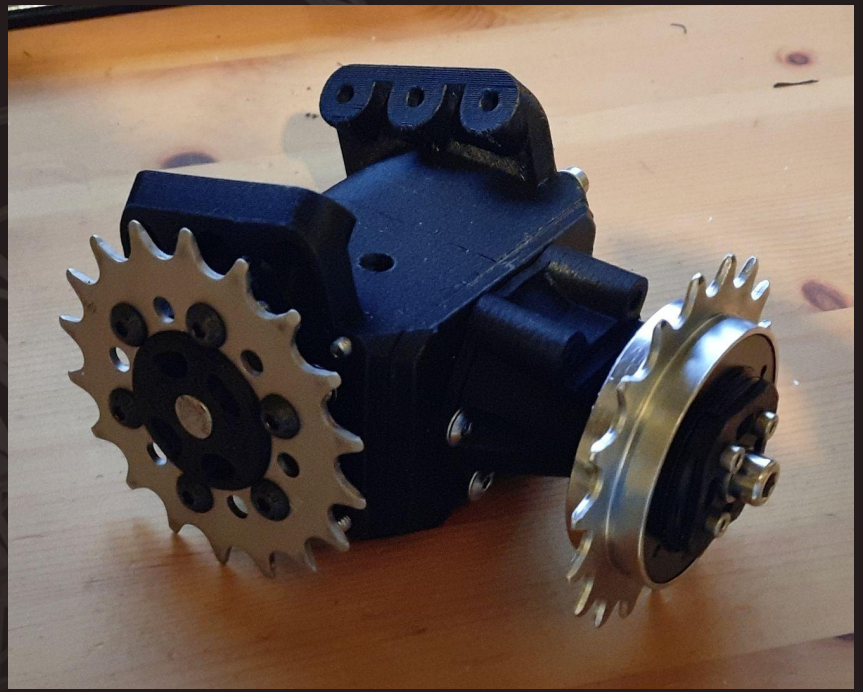
- Gearboxes or twisted chains?



Printed Gearbox

- Small stiff construction
- Standard bevel gears
- Cycling chain, sprockets, freewheel
- Silver steel axles





Fuselage progress so far - aluminium prototype:

Fuselage progress so far - carbon parts:

Conclusions:

Progress is good!

Fuselage should be complete in 2022, perhaps minus fairing

Significant investment required in structural testing of some major wing components - root bending, wing panel joints

More carbon rods!

Thanks for attending!