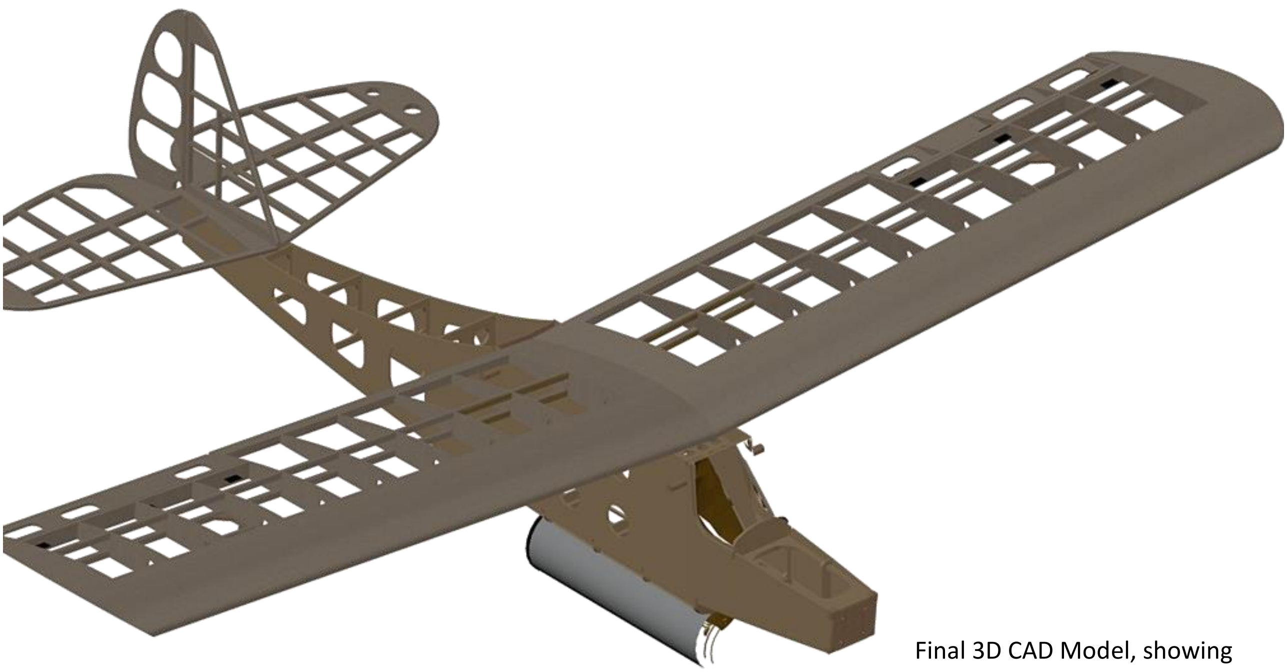
University of South Wales

Team No. Q.01

BMFA Payload Challenge - “Quantity”

June 2016

Design Report



Final 3D CAD Model, showing bare airframe

This will be the first year The University of South Wales has competed in the BMFA challenge; therefore this year's event will be treated as a "trial run". From the outset the model was designed to be easy to build, with a focus on traditional building methods and materials

This report will highlight the key features and specification of the model.

The team

Ollie – 1st year Civil Engineering (team manager)	Initial design, 2D and 3D CAD, Wing build, report
Dan – 2nd year Aero Engineering	Motor testing, fuselage build, "ground team"
Hayley – 2nd year Aero Engineering	Report, presentation
Pouya - 2nd year Aero Engineering	"ground team"

Prototype

The prototype was a simple model with a limited payload capability. Its 1.5m wingspan represented a good match with the motor and offering good lifting capabilities, whilst being small enough to tackle windy weather. The initial prototype provided an indication of the aerodynamic properties of the aircraft, which allowed implementation of improvements and slight refinements.

Payload Configuration

The preliminary prototype could only carry 5 tennis balls (which required removal of the wing to add 2 of the balls), which was not ideal. However, the wing provided plenty of lift which highlighted the potential for increasing the loading capability. The prototype revealed the requirement to explore the loading method to make the reloading process quick and efficient during the competition. This involved adding an extra former and increasing the internal fuselage width to 75mm, thus increasing the clearance for the tennis balls.

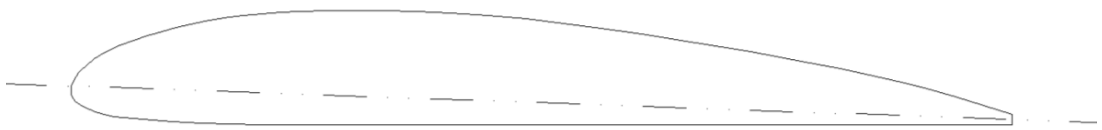
The majority (8 of 10 balls) of the payload is held directly beneath the wing, with the remaining 2 balls just behind the wing. This allows for variation of the payload, without having to greatly re-trim or balance the model. The design of the fuselage means one large payload compartment was not possible, as the relatively weak litepy sides need support to prevent bending. Therefore, the payload was split into 5 sections, with 2 balls in each, stacked vertically. Whilst this may restrict the balls during transfer, it does prevent in-flight movement of the payload.

A removable access hatch (retained with Velcro) is used for quick access to the internal payload. Attached to this hatch is an external "bomb", allowing the possibility to add a further 4 balls. Note that only one container will be used during the competition, to comply with rule Q.7.1

Wing design

The wing uses a Clark-Y section, a fairly out-dated design which is used extensively in model aircraft. This section was also popular in full size aircraft, such as the **Monocoupe 90A**. The Clark-y provides good lift, at the cost of a large amount of drag. Its flying characteristics (e.g. stalling) are predictable; whilst it's flat lower section allows the wing to be built on a flat board.

The wing is built predominantly from balsa wood. The main spar, its webs and the D-Box sheeting provide the majority of the strength, despite only being balsa. The 2 rear spars add rigidity to the wing. The D-box sheeting also prevents sagging of the covering between the ribs, which would otherwise cause unnecessary drag.



Initial flight tests of the prototype suggested the wing incidence was far too much (with an angle of attack of 6˚). Hence, the wing is mounted with its bottom section flat. Being a cambered section, this angle doesn't represent the angle of attack, which is actually 2˚.

Lots of dihedral has been used to increase the models stability, the wing having 10˚ of dihedral (65mm under each tip).

The wing tip shape will affect the wing tip vortex, and therefore the aerodynamic nature of the wing. Winglets are a good example, these induce high amounts of drag as a result of their shape, but are commonly used to increase the advantageous aspect ratio and lift/drag ratio without altering the physical length of the wing, (which would increase the materials bill and add extra weight). Wing tip devices use pressure gradients, the diffusion pressure promotes movement from the higher to lower region, and these in turn create vortices from the movement of air around the wing and the wing tip. Winglets present structural issues, and are very vulnerable - often at risk of damage when landing

However a slightly upswept wing tip has been added to the wing of the final model. This takes inspiration from the Hoerner wing tip, where the lower section of the wing sweeps up to meet the top section at a sharp angle. This arrangement is sometimes used on model aircraft, such as the Veron Cardinal.

3D CAD modelling suggested a lower amount of drag on a Hoerner tip, than one with no tip; however in practice there was no dramatic improvement of the model as a result of adding wing tips - the model is small, with huge amounts of drag being produced elsewhere.

During flight tests of the prototype, it was very difficult to turn the model. It suffered with adverse yaw, caused by the drag induced by the downward-deflected aileron. This made the model yaw the opposite way. This is common with sailplanes and is often resolved by using differential ailerons (more up deflection than down), which is utilised in the final model.

It was agreed that the biggest cause was the full length ailerons, and their large hinge gap. Now the model has ailerons only at the tips, but their chord has been increased, to reduce the amount of

Picture - http://www.derbyaeroclub.com/Wingtips.html deflection required to obtain the same amount of aileron authority. This in turn reduces the hinge gap and therefore helps to reduce the unwanted drag.

The final model makes use of a radio mix, which feeds in matched rudder when aileron is applied. However, this may be disabled during the flight competition, depending on the pilot's preferences.

Fuselage

The fuselage is very simple, made predominantly from lite-ply. Birch ply is used in high stress areas. After damage to the prototype, it was necessary to ensure the fuselage structure could support the weight of the model (and its payload) and withstand the loads during normal flight (and hard landings), yet also keep the mass of the model as low as possible. Addition of cross grained sheeting to the final model improved rigidity and strength. Lightening of the lite-plywood formers and sides helped to counteract the subsequent weight gain.

The wing and tailplane seats are level; however the motor mounting was an important consideration, involving adjustments for the side and down-thrust forces. The motor is now mounted with 5˚ downthrust and 2˚ right side thrust to counteract the torque of the motor.

A motor cowling and speed controller cover have been fitted, to help with the streamline effect and protect the speed controller.

Undercarriage is from piano wire, with low bounce wheels fitted. Piano wire undercarriages are much easier to make than carbon fibre, and offer a lighter alternative to Duralumin.

Tail Surfaces

A common issue with designing models is finding the correct tail area. Whilst no calculations were made, the general consensus was the tail area of the prototype needed to be increased. Although this does not affect the models lifting capabilities, it was found to be advantageous with respect to stability.

Further improvements to the tail involved an overall simplification of the design and removing the lifting section to make building easier. Research found that lifting section tailplanes have never been mathematically proven according to “Model Aircraft Aerodynamics”, written by Martin Simons.

As per the tail, the fin and rudder were increased in size, to give the model more turning authority.

Final notes, Control and Powertrain

The whole model is covered with Solarfilm, providing a resilient finish with only a minor weight gain. It is also very quick to apply.

Testing of the E-flite motor started, using a purpose-built test jig. Essentially a pivoting L-shape, with the motor mounted horizontally. When the motor was running, the thrust force exerted a downward force on a set of kitchen scales. Doing this with several propellers gave an indication of which propeller to use. The testing gave a general indication that the thrust increased with pitch and diameter, however over 12” it was apparent the motor was bogged-down and was limited to fairly low revs. No readings were taken for current, which is an important factor, considering the 40A fuse. Flight tests of the prototype hinted that torque reaction was an issue, so in-flight testing will most likely determine the final propeller. A wattmeter will also be used in these tests, to ensure the powertrain is not overloaded. After discarding 2 cheap propellers due to poor balance, and three being damaged by fairly minor impacts, APC brand propellers will be used, due to their better resilience, and providing much more thrust, when compared to a cheap propeller at the same speed.

The speed controller is mounted under the fuselage, with air scoops and outlets used to promote good airflow. In an attempt to reduce the motor torque reaction, the “Start up rate” of the speed controller has been changed (to 1 second. The 40A fuse and its holder are held in front of the wing, at 25˚ away from the propeller arc. The mounting is very sturdy, as the fuse is a very tight fit in the holder

The transmitter used is a Hitec Optic 6 sport, with an Optima 6 receiver. 4No. 9 gram servos are used, offering 2.2kg/cm torque (ie, if the servo is fitted with a 1cm long arm, it could lift 2.2kg). As the motor battery will be unplugged frequently during the event, the internal Battery Eliminating Circuit of the speed controller has been disabled, and a separate 4.8v, 2Ah receiver battery is used.

Future modifications

There have been a few major issues with our model, which will be rectified for next year’s event –

- In an aerodynamic sense we aim to improve the model further by making the fuselage and wing shell more sleek, to reduce the overall drag. This would improve the models efficiency, and therefore payload capabilities.
- Redesigning the fuselage would be sensible, for better payload capacity and access.
- More time selecting propellers, giving longer flight times, possibly increasing our flight score
- Further testing into wingtips would be useful, and using a more efficient wing section is essential. Addition of flaps and wheel brakes would also be investigated.

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