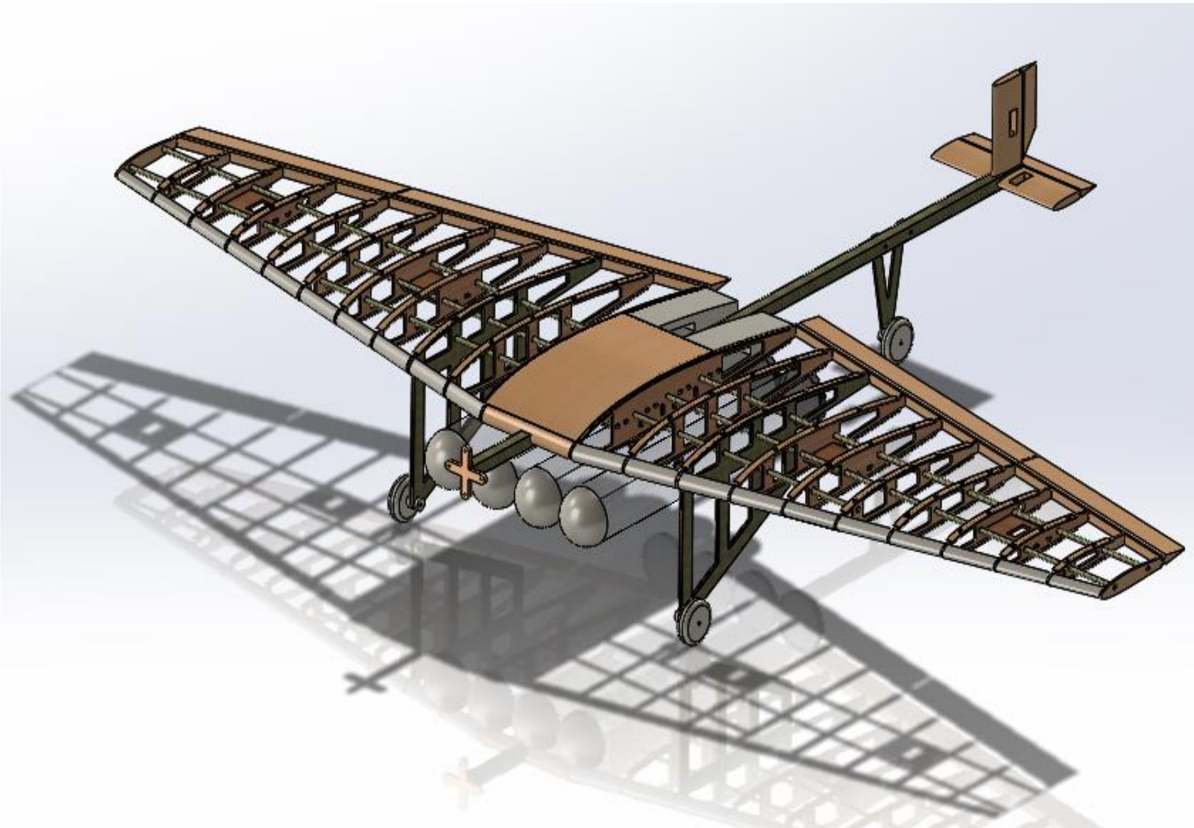


BMFA VOLUME LIFT CHALLENGE RC AIRCRAFT

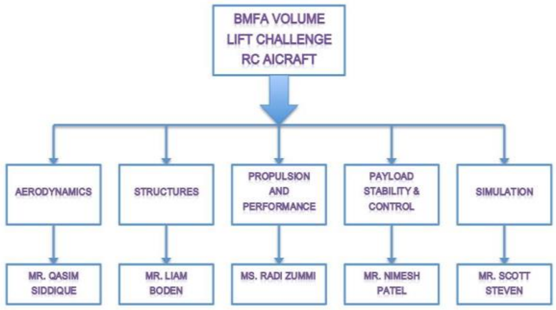
Scott Steven, Nimesh Patel, Qasim Siddique, Radi Zummi and Liam Boden.

1. Design Philosophy

The design philosophy for the UAV has been to create an aircraft that has a low structural weight in order to maximise the aircrafts performance in terms of payload capability and performance characteristics, in preparation for the BMFA volume lift challenge 2016.

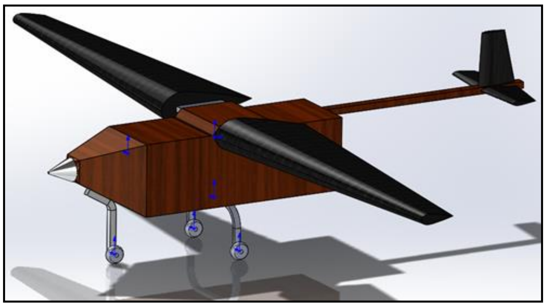
2. Team Roles

The task of designing and analysing the aircraft has been split into five areas which where each undertaken by one student, with an additional role of piloting the aircraft been addressed to an external source, a BMFA B Rated Pilot. These areas are as follows:



3. Conceptual Design

After evaluating and thoroughly examining the BMFA rules, a preliminary set of specification was issued to the group, a set of design requirements were created. There was no limit placed on the wing size, however, with majority of the electric propulsion elements specified by the BMFA, only thing left was to choose the optimal propeller and to test the full propulsion System. Multiple designs for the payload compartment were needed to be generated.



Once the team had decided upon the design requirements for the aircraft, they translated to the aircraft having high lift and manoeuvrability, performance with minimum weight. Other areas were easy installation of battery and servos and also a high load and unload speed of the payload.

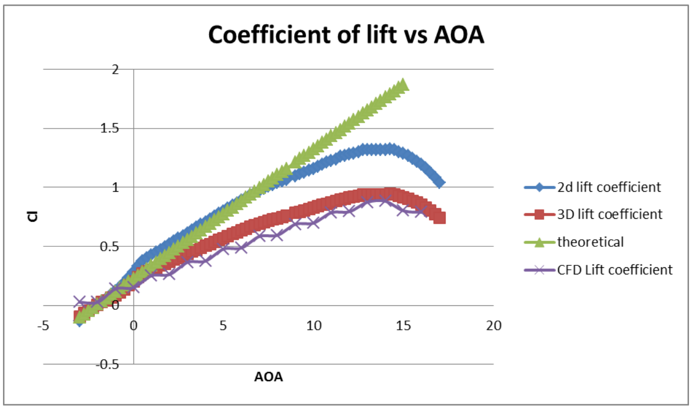
4. Configuration

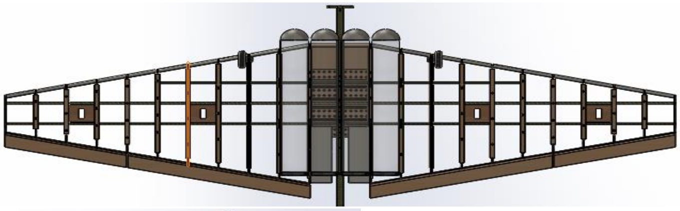
The aircraft configuration taken by the team is a non-traditional design where the fuselage is merely a strut with the main landing gear as part of the main wing structure. With such configuration, the designed payload compartment, comprising of four tubes, been layered side by side with each having eight tennis balls each.

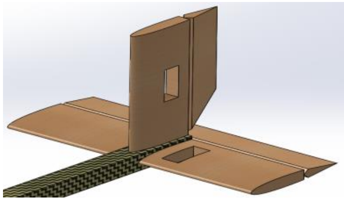
Wing Structure

A tapered wing was chosen, having a low cambered aerofoil (been NACA 2412) so as to achieve high lift performance and ease of construction. The aircraft tail and fin being made as a straight wing with a flat plate cross section for simplicity, shaped at Leading and Trailing edges.

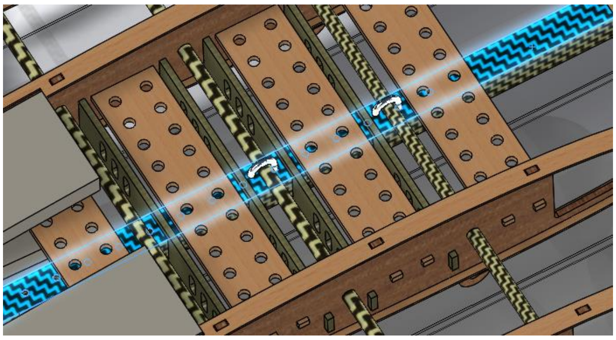
	Wing	horizontal tail	vertical tail
area	$0.48m^2$	$0.078m^2$	$0.031m^2$
span	1.6	$0.56m$	$0.22m$
chord length	Root-0.45 tip-0.15	0.14m	0.14m
Aspect ratio	5.8	4	1.5
Taper ratio	0.3	0	0







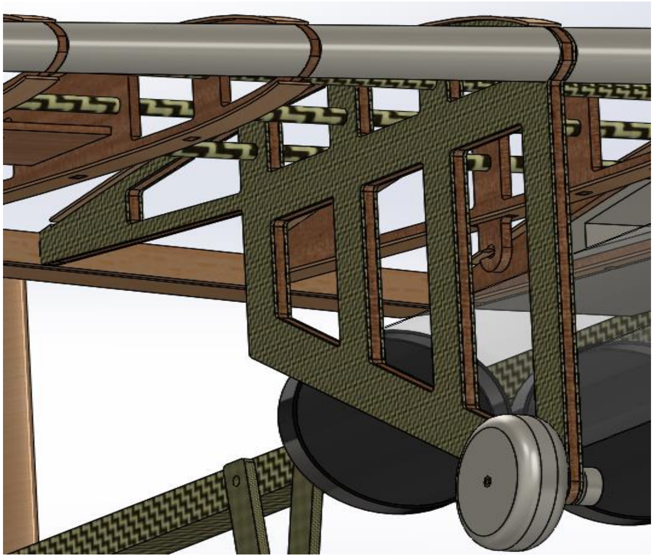
a. Structures



The aircrafts structure has been designed in a manner that allows for the main section of the fuselage and the wing to be detached from the main fuselage strut and tail section as shown. This is achieved by having the main section of the fuselage and wings mounted to the support strut through a series of mounting brackets that are free to move up and down the support strut and located using two custom locating pins. Finally a removable engine mounting bracket allows the wing/ fuselage section to be removed. This idea initially came about in order to aid in the transportability of the aircraft. Multiple holes in the support strut has also been added so that the centre of gravity can be easily adjusted by locating the main section of the fuselage and wing in different locations.

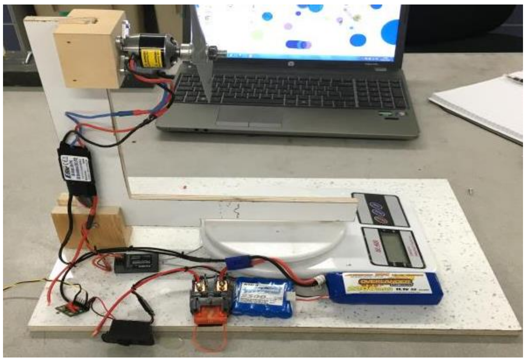
5. Advanced structural techniques and materials

A range of materials including carbon composite material has been selected to form part of the structure of the aircraft. All components are drawn on Solid Works CAD program, and Laser Cut, or 3D Printed. Carbon fibre has been selected for the wing mounting plates and for the wing spars. In terms of the landing gear carbon fibre composite coated plywood was selected. This was selected in order to produce a structure that was both relatively easy to manufacture while increasing the structural integrity of the component over that of an equivalently dimensioned plywood only design.



6. Propulsion Unit

The propulsion system was finalised by investigating the performance of various motor-propeller matches and comparing the results obtained through theoretical evaluation, experiment and simulation (MATLAB).



Propeller (Diameter x pitch) in inches	Thrust (kg)	Thrust (N)
9" x 7.5"	1.054	10.34
10" x 7"	1.160	11.38
11" x 6"	1.360	13.34

A thrust rig was built (figure on the right).

Thrust produced by different propellers tested is listed in table.

The propeller thrust has been theoretically calculated as,

$$T = \rho \frac{\pi\,(0.0254 \text{ x } D)^2}{4}\left[\left(\Omega \text{ x } 0.0254 \text{ x } p \text{ x } \frac{1}{60}\right)^2 - \left(\Omega \text{ x } 0.0254 \text{ x } p \text{ x } \frac{1}{60}\right)V_{a/c}\right]\left(k_1 \frac{D}{p}\right)^{k_2}$$

Where, $V_{a/c}$ = aircraft velocity in m/s, D = propeller diameter in Inches, p = propeller pitch in Inches, K_1 = propeller coefficient constant, K_2 = propeller power factor

The value for K_1 and K_2 has been determined experimentally by the respective propeller production companies and are available in the company's product datasheet.

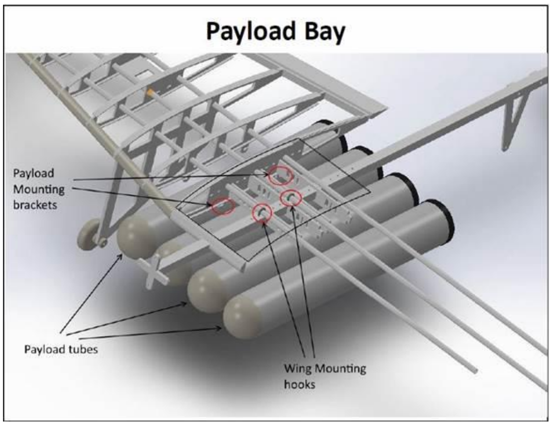
a. Propeller efficiency:

Propeller	Ct	Cp	Cq	Thrust (N)	Power (Watts)
9" x 7.5"	0.05346	0.019724	0.003139	10.21	168.508
10" x 7"	0.064393	0.026074	0.004149	12.30	222.757
11" x 6"	0.075267	0.032949	0.005243	14.38	281.499

Where, C_t is coefficient of thrust, C_p is coefficient of power. Thus the Graupner 11"x6" propeller has been selected.

7. Payload Distribution

For payload compartment several designs were considered. After careful consideration following design was arrived at (Shown below). Consisting of four cylinders made out of very



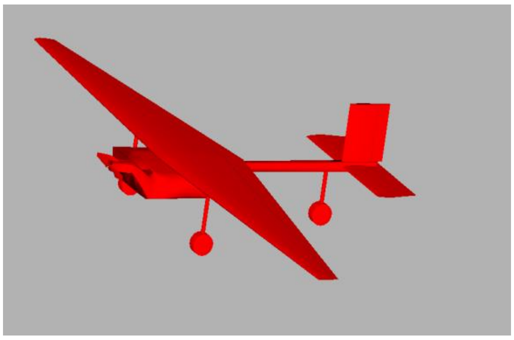
thin glass fibre . It will be mounted directly to fuselage. There is no fuselage in traditional way; it is just square tube made out of carbon fibre. In this way the drag should be kept at minimum to improve the aircraft performance. At initial stage we are aiming for 6 tennis balls in each tube, times 4 tubes = total 24 tennis balls configuration. It can be varied after initial tests either to increase (max 32) or decrease the number of balls. This design allows any multiple of 6 or eight balls to be carried.

Centre of gravity and static margin.

As per current configuration we have centre of gravity location at 230 mm along with x axis from nose to tail. Static margin for control and stability performance 20% MAC. this gives us good room for payload variations, in other words to increase or decrease the number of tennis balls. Wing mounting is designed accordingly so that if needed, wing can be moved forward or rearward to achieve best possible stability and performance configuration. In above picture, the wing mounting, and payload mounting hooks are visible.

8. Practical testing

Practical testing of structure was undertaken on half the wing in order to validate the structural integrity of the design. It was tested to 2.5 × the total predicted aircraft weight (with payload).



Secondly, the aircraft was tested for stability and control in X-Plane Simulation Software. This test revealed that our aircraft needs a slightly bigger wing span, and a much larger tail and fin.

Final aircraft model will have increased geometries in wing, tail and fin. The tail volume coefficient of the amended aircraft will be approximately 0.6 and the fin volume coefficient will be around 0.65.