# British Model Flying Association Quantity Challenge 2016

## Queen's University Belfast

## School of Mechanical and Aerospace

## Team QUBAir

Reference No: Q-11 Queen's 1

# Contents

# 1. Introduction

This report presents a summary of the design process utilised by Team QUBAir, from Queen’s University Belfast, during the design of the RC model aircraft, the ‘Ark’.

## 1.1 Team Organisation

In order to achieve the team’s goals a motto was devised, encompassing the team philosophy, to: *“Plan Early, Build Early, Fly Early…Crash Early”*

Team roles were discussed and allocated based on each individual’s preference and skill set, however all engineers partook in manufacturing. The team’s organisation is presented in Figure 1.1 below.

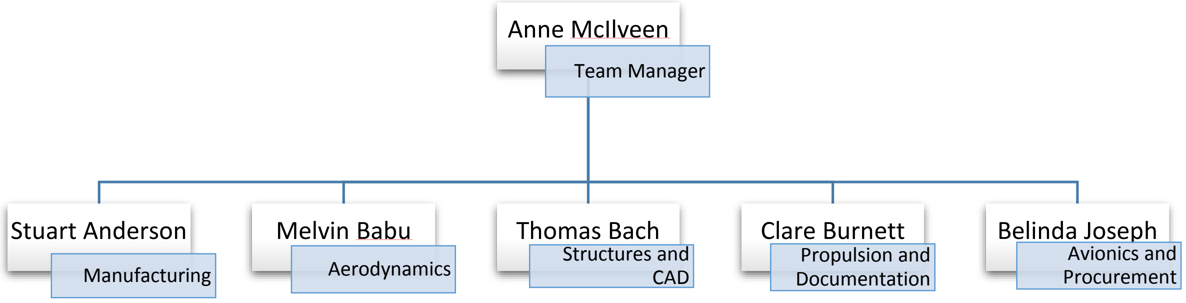

***Figure 1.1:*** *Team Organogram*

# 2. Conceptual Design

## 2.1 Requirements

Systems Engineering was used to decompose the BMFA regulations into functional and physical aircraft requirements. Throughout the design process the requirements were used to verify components, ensuring every decision could be traced back to initial requirements.

Optimal scoring analysis was also carried out, analysing past years BMFA results and performances. Using this information, the number of tennis balls required to win the competition was estimated. Weather conditions at Elvington Airfield were also analysed to ensure the design of the aircraft is strong enough to perform in adverse conditions.

### 2.2 Configuration Selection

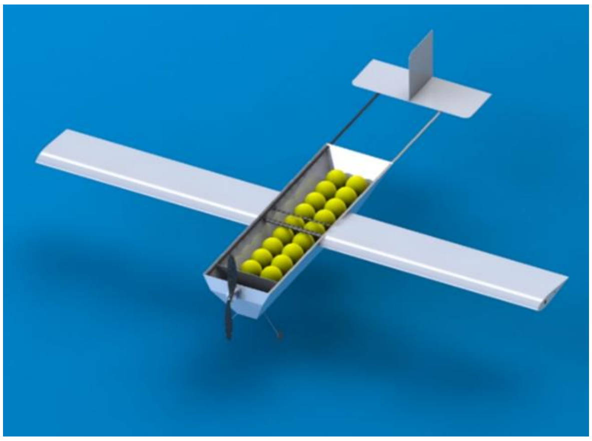

***Figure 2.2:*** *Conceptual Solidworks Model*

Functional and physical matrices of alternatives were created using the requirements analysis. From these, 5 alternative concepts were selected and compared against a set of selection criteria (including aspects such as empty weight and payload capacity) using Pugh Matrix analysis.

A combination of the two best performing concepts were combined to form the 'Ark'. Key conceptual design features included: a distinct trapezoidal fuselage cross section to enable easy payload entry and force the balls into an organised structure (Figure 2.2), with a split wing keeping the cargo area clear for payload loading and unloading, used with a twin boom conventional tail and tail dragger landing gear configuration.

## 3. Preliminary Design

### 3.1 Aerofoil Selection

Using the requirements and performance analysis a constraint diagram was generated, providing initial wing sizing and power requirement data. A wide variety of aerofoils were considered. The aerofoil's lift curve slopes and drag polars were compared, with final selection based on a set of selection criteria (Table 3.1). As a result, the Clark Y (smoothed) was selected. Figure 3.1 presents the corresponding aerofoil and wing lift curve slope.

***Table 3.1:*** *Aerofoil Selection Criteria and Results*

| Selection Criteria | Optimal Aerofoil | Corresponding Parameter |
|---|---|---|
| Highest Stall Angle | Clark Y (Smoothed) | 15.5° |
| Highest $C_{L\,MAX}$ | Selig 1223 | 2.28 |
| Highest $(C_L/C_D)_{MAX}$ | Clark Y (Smoothed) | 92 |

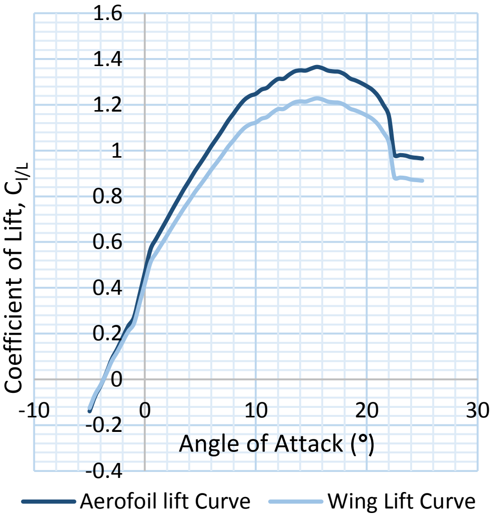

***Figure 3.1:*** *Wing and aerofoil lift curves*

## 4. Detailed Design

### 4.1 Wing Design

As it can be easily cut using a hot wire cutter a rectangular, EPS (expanded polystyrene) wing planform was selected. Utilising the removal of the wingspan limit, the Ark's wingspan is 1.75m, allowing for increased payload capacity. Wing incidence was carefully set to avoid stall, with an incidence of 2 degrees selected. This, in tandem with a tail-dragger landing configuration provides a short-take off distance. For loading purposes, the wing passes through the fuselage and is connected in the centre. The high-mounted wing position also aids with lateral stability. The removable design also aids with ease of transportation. Two carbon fibre spars run through the wing, connected by a sandwich structure with two aluminium caps, to carry shear forces. To verify the spar and connection concept the structure also underwent testing. The wing connection is presented in Figure 4.1.

## 4.2 Fuselage Design

After a material selection process was carried out, 3mm birch ply was selected for the fuselage. Each member in the truss was sized to distribute the wing loads, impact forces from the landing gear and motor vibrational loads. The load paths are shown in Figure 4.2 below (blue and red lines) and the landing gear locations are indicated using green circles. The fuselage walls are connected using a series of interlocking teeth, bonded with epoxy. Two carbon fibre booms also run through the fuselage longitudinally, adding torsional stiffness.

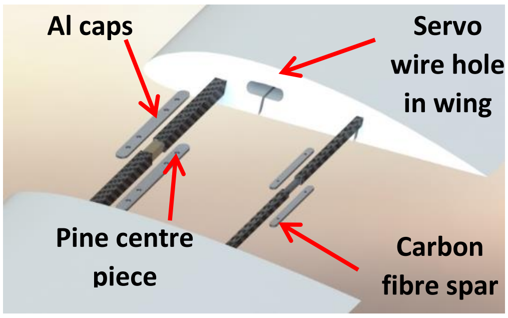

***Figure 4.1:*** *Wing Connection*

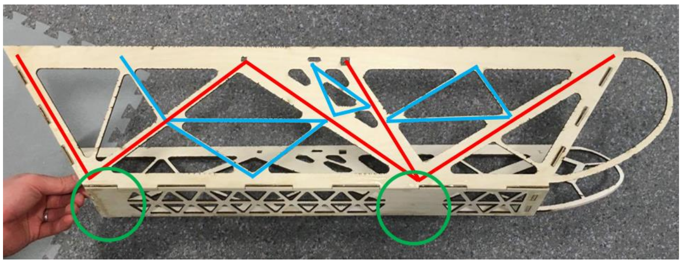

***Figure 4.2:*** *Fuselage structure and load paths*

## 4.3 Landing Gear

***Figure 4.3:*** *Landing gear configuration*

The tail dragger configuration provides an increased angle of incidence, increasing lift and reducing take-off distance. The main landing gear is fabricated from woven carbon fibre and attached using two M6 screws. Smoothed wedges are located on either side of the gear, preventing it from tearing from the fuselage during a crash landing. A torsion spring tail skid was designed for the rear gear, reducing the drag and weight incurred using a conventional wheel design. It is mounted to the fuselage using ply doubler plates and inserts.

### 4.4 Tail Design

The tail is made from balsa, fabricated in several parts using a laser cutter and joined using a zig zag web. Thus facilitating procurement and manufacturing constraints, as shown in Figure 4.4. The tail is attached to the two longitudinal booms using angled foam mounting brackets.

### 4.5 Avionics and Stability

Throughout the design process, components were weighed and the data inputted into the CAD model, providing a means of predicting the aircraft’s centre of gravity. The majority of the avionics components are located in the aircraft’s aerodynamic foam nose (Figure 4.5). The battery is placed in the fuselage for cooling and stability purposes. The motor is mounted to a carbon fibre reinforced MDF block using four aluminium tubes. This provides the required minimum distance of 100 mm between the fuse and propeller.

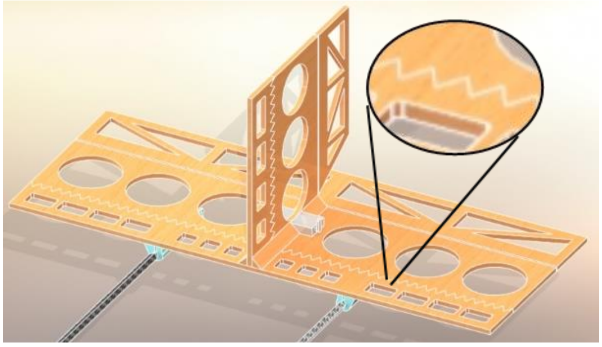

***Figure 4.4:*** *Tail zigzag web*

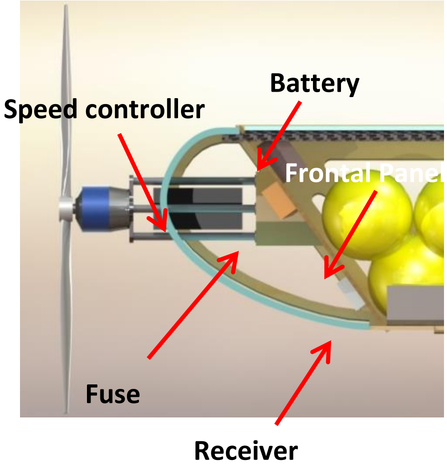

***Figure 4.5:*** *Avionics compartment*

### 4.6 Propulsion

To determine the optimum propeller choice, balance thrust and fulfil battery endurance requirements, experimental propeller testing and QPROP analysis were carried out. Simulated laps were run, with motor RPM recorded to map throttle depreciation over time. The optimum propeller was found to be a 12x6’’ and so is utilised on the “Ark”.