Edinburgh Napier University

Team A

BMFA – Payload Challenge 2 Quantity

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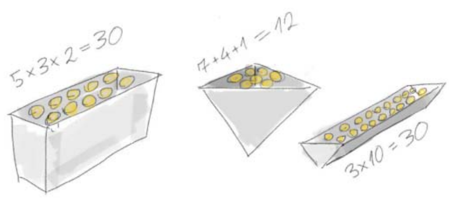
Product Design Specification Fuselage

Initial PDS: Fuselage		IssueNr: 1
Categories	Specifications	Author: Christopher Wild
Payload	20-40 tennis balls	
Weight (unloaded)	<1.5 kg (variable of lift of aerofoil section)	
Weight (loaded)	<1.5kg + 1.17 kg - 2.35 kg (variable of number of tennis balls) + electrical components	
Size	Dependent on tennis ball container + space for electrical components	
Materials	Lightweight/water repellent	
Budget	<£350 (minus costs for additional airplane components)	
Wheels	> 3	
Ergonomics	Access to tennis ball container / access to electrical components / space for cables	
Shape	Minimising drag	
Transport	Modular design for disassembly of components	
Time scale	3 Months	
Legal	BMFA payload challenge rule book	
Structural	Withstand heavy landings and twisting of wing attachment	
Attachments	Wing, tail plane, propeller and wheel attachments, minimising use of screws and parts	

Payload container concepts



The concepts were supposed to provide space for around 30 tennis balls at a size that visually would match the expectations on how the airplane could look like.

Concept selection

Evaluation Matrix: Payload Container			
Criteria	Rectangular box	Triangle based pyramid	Triangular prism
Payload	+	-	+
Ergonomics	+	+	-
Aerodynamics	N	-	+
Attachments	+	-	N
Packaging factor	N	+	N
Loading/unloading	+	+	-
∑ +	4	3	2
∑ -	0	3	2
∑ N	2	0	2

The rectangular box proved to be suitable for quick loading and unloading with a slot that allowed quick handling. Compared to the triangle based pyramid, the packaging factor was not as high and it also could not match the aerodynamic advantages of the prism but provided a good compact solution. Attachments for the wing could be close to each other, which would improve stiffness and part count.

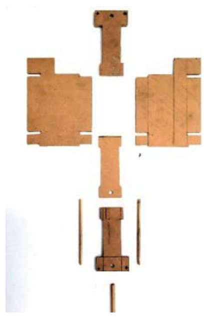
Revised PDS*

Revised PDS: Fuselage			IssueNr: 2
Categories	Specifications	Author:	Christopher Wild
Payload	30 Tennis balls		
Weight (unloaded)	>1.5 kg		
Weight of load	1.74 kg + electrical components		
Size	34.3cm*20.58cm*13.72cm + space for electrical components and wing/wheel attachments		

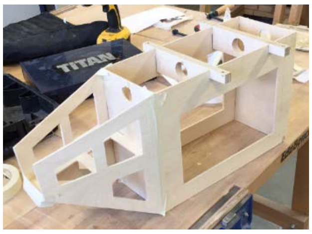
*This PDS only shows revised points, all other constrains given in the previous one are still valid.

Configuration/Embodiment design

For the embodiment design a prototype was made to get a clearer image of the spatial constrains, manufacture and assembly methods. The rails at the side were intended to be used for wing attachments. The rod was thought to go all the way back to tail plane. Moreover, it served as central structural core that carries all main components.



As a resulting decision a carbon fibre rod was chosen to serve as a modular core, for the box, wing attachments and tail plane.



Based on these findings, detailed drawings and a new prototype were made. The improvements of this prototype included a feasible wing attachment solution. A to scale container for the tennis balls. A separate space for electronical componets located at the front. It also showed, that using plywood for all parts was significantly too heavy. To keep the carbon fibre rod in place and due to a lack of a 30mm drill, the wing attachments had to be remade using a 3D printer. Therefor, new material specifications were added to the PDS

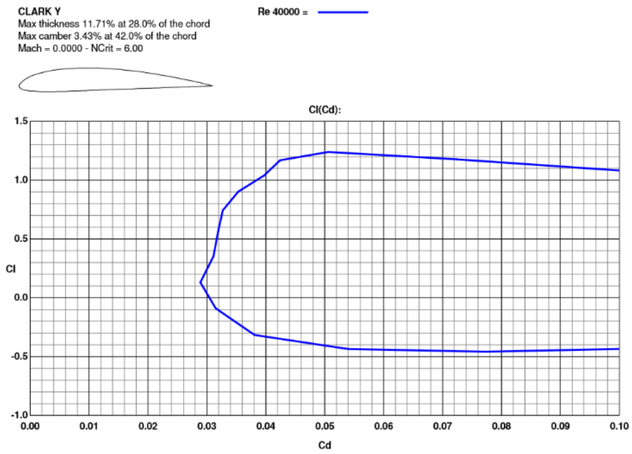
Revised PDS: Fuselage			IssueNr: 3
Categories	Specifications	Author:	Christopher Wild
Materials	Balsa, Plywood, carbon fibre, PLA		

Detailed design

For the detailed design, all components were thoroughly drawn out in cad to ensure fit, meet spatial constraints and to provide a solution to place the wings centre of gravity over the centre of the box. Thus wing attachments were moved further back. The most innovative approach was to use the carbon fibre rod not only as the modular core for the box, wing attachments and tailplane but also to use it to attach the propeller. The whole configuration was designed to allow the carbon fibre rod to be moved back and forth to experimentally determine the right balance. A cage was embedded in the main box to prevent free movement of the tennis balls. The front nose part served to keep the carbon fibre rod in length direction perfectly positioned and included a hole for the cables to connect to the motor.

Manufacture

For manufacture components were cut out of balsa and plywood. Most connections made use of wood clue and only few screws were used for attaching the landing gear. Balsa pieces were added to improve stiffness. As a final step the whole construction was covered in shrink wrap.



Decision Choice for Wing aerofoil

Graph shows the coefficient of lift to coefficient of drag

Working out the area required to lift an optimistic amount of tennis balls. Using the Clark Y aerofoil when the coefficient of lift (C_l) is equal to 1 air speed id 10m/s the lift created it 43N

L = 4kg ~40N   ρ = 1.223kg/m^2 v = 10m/s   s = Wing area (unknown) $C_l = 1$

$$L = \frac{1}{2} \cdot \rho \cdot v^2 \cdot s \cdot C_l$$

$s = 0.65$ m^2

Area of wing

$$s = (2000 \cdot 400) - \left(4 \cdot (100 \ \cdot 600)\right)$$

$$s = 800000 - \left(4 \cdot (6000)\right)$$

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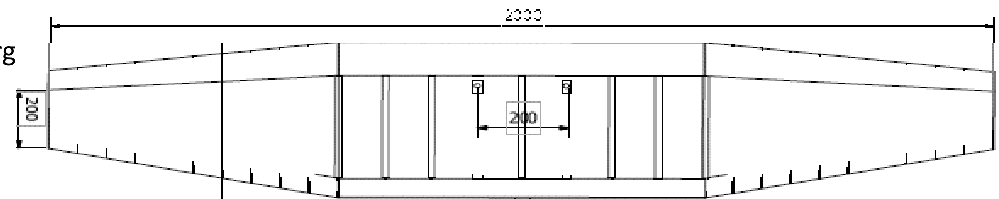


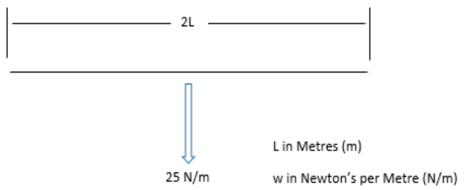
$$s = 776000mm^2$$

$$s = 0.78m^2$$

Manufacture of the wing

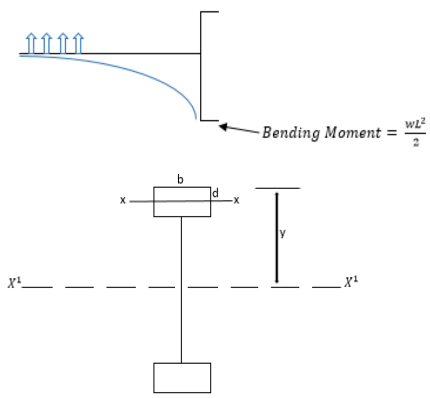
The Clark Y aerofoil has a main advantage in the ease of manufacturing as it has a flat bottom and is not under cambered which means structurally the ribs could be made from balsa and the wrap wouldn't need to be glued to the ribs themselves.

The leading edge (30% of the wing) of the wing was cut from foam using a wooden template of the Clark Y aerofoil and a hot wire, due to size of foam blocks the leading edge was comprised of 4 sections. The ribs were drawn in *Profilli* with slots for a spar on the top and bottom, the two end sections tapered from 400mm to half that size (200mm).



$$Bending\ Moment = \frac{12 \times 1^2}{2}$$

$$Bending\ Moment = 6.25\ Nm$$



$$I_{xx} = \frac{bd^3}{12}$$

$$I_{X^1X^1} = \left(\frac{bd^3}{12} + bdy^2\right) \times 2$$

$$I_{X^1X^1} = \left(\frac{bd^3}{12} + Ay^2\right) \times 2$$

$$I_{X^1X^1} = 2 \times Ay^2$$

$$= 2 \times A \times 0.025^2$$

$$= 0.00125A$$

$$\sigma = \frac{My}{I_{X^1X^1}}$$

$$\sigma = \frac{6.25 \times 0.025}{0.00125A}$$

$$A = 1.45 \times 10^{-6} m^2$$

For the spars calculations were done. Using spruce for the material

The foam sections were glued end to end, the rib slots and the slot for the spar were cut into the foam. Using a combination of adhesives, Mitre Mate, wood glue and cyanoacrylate all the components were glued in place together, for the attachment from wing to fuselage two 3D printed sections were made with 4 holes for nylon screws to be fitted to ensure a strong connection. The trailing edge was then made out of balsa.To add stiffness it was decided to use unidirectional Carbon Fibre placing the orientation of the fibre along the length of the wing. The wing was completed by wrapping in solar film and shrunk to shape.

Tail plane

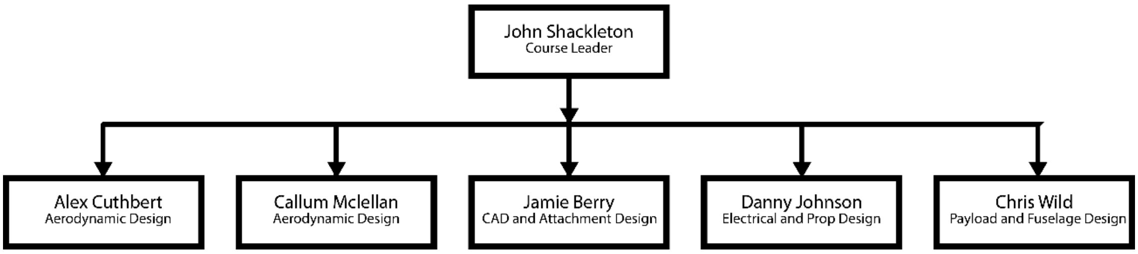
Due to the wing being situated along the top of the fuselage, the airflow would not allow for a traditional style of tailplane. A T-Style tailplane was chosen in order to overcome this. The primary construction of the tailplane consists of a balsa outer shell encasing a foam inner to keep the weight down to a minimum to prevent disruptions to the centre of gravity.

Landing gear

The rear landing gear was attached directly to the rear of the payload container. A single wheel with suspension was fixed to the front to reduce impacts to the plane through heavy landings.

Gearbox

By attaching the gearbox to rod running through the aircraft the torque reaction forces are centred in both x and y axes. The gear ratio is chosen is 3:1. The gearbox housing and gears have been designed for FDM 3D printing.



Team roles and responsibilities