Priestley College Q03 Report 2016.

Team Members:

- *Tom Hotston -Team Captain*
- *James Ross -Fuselage Construction*
- *Alex Clark -Wing Construction*
- *John Mellor –Electronics*
- *Matthew Lilley -Technical Drawer*
- *Luke James -Fuselage Construction*
- *Mr Arthur Griffiths (WMFC) - Team Mentor*

Executive Summary

The flying of the **Ekranoplan** model proved to be challenging despite us basing the design on an existing working model. There have been many adjustments made to counteract issues that arose in test flights. The first issue we encountered was that the aircraft did not have enough elevation, so in order to fix this we increased the area of the front wing and added an automatic elevator to control the pitch. We then found that this issue disappeared. However, the craft continued to veer to the left. Upon inspection, we found that this was caused by the torque produced by the single motor we had on our aircraft. This issue did not occur on the model we based ours on, because it had two contra-rotating engines which nullified the torque's effect. To resolve this we added auto stabilisation for the yaw. This proved to be successful in subsequent test flights. When we test flew it again another issue cropped up; this time we found that the craft rolled the left when it was in the air. This was due to a lack of control of roll and we resolved the issue by adding ailerons to the back of the wings. These were also controlled by the auto-stabilisation mechanism.

The next issue we faced was that there was too much fuselage side area forward of the Centre of Gravity (CoG) and that the aircraft persisted to rotate about the centre of gravity. This issue did not occur on the full size model ours is based on because the fuselage side area was much smaller. Our solution to this issue was to decrease the forward side area of the craft and adding a fin to the back of the fuselage.

During test flying we encountered many issues. This resulted in the aircraft taking a substantial amount of damage. This caused us to have to rethink a lot of design decisions we had made, and change this for other things. Some damage was caused to the **Ekranoplan** in the process but regardless of this it allowed us to see errors in the design and modify those errors.

The Project

After the success of our model – "Piranha" - in last year's BMFA Electric Challenge (Quantity) event, the students of Priestley College decided to take on a more demanding and challenging design of aircraft. We decided to design and build a ground effect aircraft known as an **Ekranoplan**, which utilises the ground effect to produce more lift and therefore enables the aircraft to carry more balls at a lower altitude. Using a Japanese design as the basis for our project, we produced a scale model of a working aircraft. This we felt would help point us in the right direction for an aircraft none of us had encountered before. Incentivised by the innovation prize, we thought it best for us to jump head first into the challenge and to produce a craft the likes of which has never been seen before at Elvington. With the recent availability of auto-stabilisation radio equipment such as the Spektrum AS3X we have been able to produce a machine that works in tandem with the pilot for an overall improved outcome. **Ekranoplans** are famously challenging to pilot, so the auto-stabilisation systems help in our attempts to be competitive in the challenge.

Using a tandem wing design which utilises the ground wind effect enables us to carry much larger loads than last year due to greatly increased lift, thus allowing us to increase the capacity from 30 balls to a maximum of 60. With a new greater capacity we believe that our design is capable of a podium placing in the competition, and hopefully a victory.

Victory can only be achieved by making the most of each team member's skills and allowing each of us to contribute as much as we can to help better the team. To achieve this we allocated team roles according to each member's strengths; Tom is the most experienced member of the team, so we allocated team captaincy to him. His role was to oversee progress and to record results of test flights and experiments. This helped us to learn from mistakes and further improve the design of the aircraft. Since the craft is an experimental design, this role was integral to our success in this challenge.

Alex was tasked with the construction of the wings as he is also an experienced member of the team and is the most capable with construction. Clearly, the aircraft would not fly without wings. This role was also crucial. John is an A2 electronics student and therefore fits his role as electronics manager perfectly. Within our design there is a heavy emphasis on electronic systems and control and so the correct calibration of the circuitry is required for a successful flight. Matthew is a keen draughtsman and frequently practices his scale drawing skills, he is meticulous with accuracy in his work and therefore is ideal for his role in the team. His drawings act as the basis for the whole design of the aircraft; everything is based on his designs. Luke and James were the only members to not feature in last year's team and so brought a new dynamic to the project. Not only bringing enthusiasm, they both have skills in construction and therefore suit their roles well. They have proven to be capable in their field and are relied upon to produce a sturdy and strong model.

Each member is crucial in helping to produce a final working model. All team members have demonstrated this by contributing ideas to group discussion. When faced with issues, we worked through them as a team and considered ideas from everyone to help produce a solution.

Calculations:

1. *Number of balls to be carried = 60*
2. *At 65g per ball, total mass to be carried =* $60 \times 65 = 3900\ g$
3. *Model mass from previous year (2015) = 2300g*
4. *Total mass including airframe and power system = 6200g*
5. *Design wing loading = 80g* dm^{-2}
6. $Total\ wing\ area = \frac{Model\ mass}{wing\ loading} = \frac{6200}{80} = 77.5\ dm^2$
7. *Scale wing area based on full size = 60* dm^2
8. **Ekranoplans** will carry twice the wing loading of a conventional aircraft
9. $Actual\ wing\ loading = Total\ wing\ area = \frac{Model\ mass}{wing\ loading}$
10. $\frac{6200}{60} = 103.3\ g\ dm^{-2}$
11. This mean that the wing area will provide the necessary lift for the designed aircraft.

To find size of canard

1. From an aeronautical reference book* ideal canard size = 20% of the wing area.
2. 60 x 0.2=12 dm^2
3. From the scale the wing area would be 4.75 dm^2
4. This could cause problems in pitch.

CoG calculation

1. $CoG\ Position\ = \frac{Average\ Cord}{6} + \frac{3 \times Canard\ Area\ \times Canard\ moment\ Area}{8\ \times Wing\ Area}$
2. $CoG\ Position = \frac{6}{6} + \frac{3\ \times 4.75\ \times 5.9}{8\ \times 60} = 1.17dm$
3. CoG position is $117mm$ behind wing leading edge.

*RC scale aircraft by Gordon Whitehead. Published by "Radio modeller" 1980

Stability

Pitch - To control pitch of the model a large elevator is used, giving a proportionate amount of movement to control the pitch appropriately. **Ekranoplans** are harder to fly because of ground effect. We decided to use auto stabilisation so that pitch would automatically keep the model constantly above the ground. This is controlled by the AS3X controller.

Yaw - A fully moving canard was used to control aircraft yaw. The AS3X controller counteracts the model moving in the wrong direction.

Roll - Roll is dihedral. Roll may be controlled by two ailerons on the edges of the wings. Due to it being a high wing model, this gives greater control of the roll. To solve unwanted roll, we added AS3X control.

All of this coupled with the tandem wing allows for greater stability in ground effect.

Construction:

Wing - The wing is a NACA3A09 wing with 1% reflex that had to have multi method construction. The wing was split into two halves, enabling us to fit more balls inside the main frame of the model. To keep the wings together and withstand great pressure, they were held by a 0.75mm ply main spar, with an aluminium joiner that had dimensions of 20mm x 2mm, which added strength and stability in the wings.

A lightweight film was used to cover the wings, so as to keep the weight across the wings at a minimum. This resulted in the model not having to carry any extra weight around. Lessons learned from last year told us that the angle of attack, which is the angle between the chord line of the wing and the vector representing the relative motion between the aircraft and the atmosphere, was 4 degrees. This was found to provide an optimal amount of lift for the aircraft to leave the ground. To reduce leakage and disrupt air flow, the top hinged ailerons were sealed with tape. To help control the pitch and also to control the lift of the aircraft, a balsa canard was fitted to the front of the aircraft to help give it more stability in flight.

Fuselage - The sheet sides are made from balsa, and form the main beam of the fuselage. This design makes for a large compartment for the cargo, of between 40-60 balls. The undercarriage is attached to the two (separate) wings, using the spar as reinforcement.

Test Flights

All test flights were recorded on video to enable progress to be recorded and to analyse any failures. After each unsuccessful test flight, the team would study the video on a frame by frame basis to agree to the modifications required. The process was assisted by our experienced mentor from **Warrington Model Flying Club. (WMFC)**

Test Flight 1 (February 2016)

The model was in its original set up. The fully tilting canard was controlled by a helicopter heading hold gyroscope. The rotating canard was used for yaw control via the aileron channel on the radio. The steerable nose leg was controlled from the rudder channel on the radio.

The first test was carried out indoors in the sports hall. The power was gradually increased until eventually the rear of the craft became airborne with the nose wheel still on the ground. At this point it would spin around within its own length and stop. The test was terminated when the model hit the gym wall, destroying the canard.

Test Flight 2 (Mk2 model, March 2016)

The model was modified to incorporate a non-tilting canard with a conventional elevator, as per the full size craft. The angle of attack was set at plus (+) 6 degrees as is the full size craft. The radio was changed to Spectrum AS3X to allow heading hold and damping gain to be used on the canard elevator. The test was carried out at WMFC flying site from grass. After two attempts the model became airborne then rolled to the left and crashed. The model had been difficult to steer on the ground. There was extensive damage to the canard and the fuselage.

Test Flight 3 (Mk3 model, March 2016)

The radio was reprogrammed to couple the nose wheel and the canard steering on the rudder stick. The test was carried out on the car park at Priestley College. Fast taxi run up and down the carpark proved that the steering was much better. On one run the aircraft became airborne, as the power was removed the craft rolled to the left and crashed resulting in severe damage.

Test Flight 4 (Mk 4 model, April 2016)

It was observed on the video footage that on all test flights the model rolled to the left when it became airborne. The full size aircraft that the design was based upon makes a point of stressing this when the ground effect roll control is not required. The team discussed this point and realised that the full sized aircraft has 2 engines with contra rotating propellers, thus having no torque reaction. Our model only has one engine and thus has a torque reaction, causing the left roll on take-off. Ailerons were added controlled by the spectrum AS3X radio, and the aileron channel on the transmitter.

The test was carried out at a local airfield (Stretton) on a concrete taxiway. The model was very difficult to steer at speed due to the control being too sensitive. The AS3X control was switched on to the steering channel enabling faster runs to be made. On each run when take-off speed was reached, the model spun in its own length and stopped. There was no damage on this occasion.

Test Flight 5 (Mk 5 model, April 2016)

When the model was designed, it was assumed that it would follow the canard, as a supermarket trolley does when being pulled. Examining the video of the test flights revealed that rotation was taking place about the centre of gravity. Further examination showed that the model had a large amount of side area forward of the COG, whereas the full size craft has very little. The decision was taken to add a fin and reduce the cargo bay frontal area by tapering downwards towards the nose.

The test was carried out at a local airfield. On the first run, the model became airborne and flew for several hundred metres in stable flight. Upon reducing power to land, the nose rose vertically and the model climbed to a height of approximately 30 metres before crashing to the runway suffering considerable damage.

Test flight 6 (Mk 6 model), 6/5/16

The video of test flight 5 taken with the model flying shows the canard elevator raised by the AS3X system, giving down force. When power was reduced, the lack of slipstream reduced the down force, allowing the nose to rise. The canard was reduced from six degrees to three degrees.

The testing of the craft at a local airfield resulted in a successful take off. The nose lifted again as power was removed, the model landed hard but little damage was caused.

Test Flight 7(Mk 7 model)

Yet to be undertaken as of 9/5/16. From previous test flights it was agreed to reduce the canard angle to Zero degrees.

Acknowledgements.

This will be the third year that the college has entered the BMFA quantity challenge. The team agreed post selection that they wanted to design, build and test an innovative, out of the ordinary model aircraft. Through the various incarnations of the **Ekranoplan** the team has had to learn a lot of basic aeronautical principles. The design has been inherently challenging, not to say frustrating. The lows of seeing the **Ekranoplan** become uncontrollable despite a sophisticated stabilising system have been matched by the highs of designing and building an aesthetically interesting aircraft.

The team would like to put on record its appreciation to **Mr Arthur Griffiths (Warrington MFC)** for his wise advice, technical skills, patience and tenacity. We would also like to thank **Priestley College** for funding the project and providing the facilities. We would also wish to put on record our thanks to the **BMFA** for setting such a difficult challenge.