MECH5080M – Team Project

Developing the transmission system of an active stability system of a sounding rocket

MECH5080M Team Project – Individual Report

Improving an active stability system of a sounding rocket

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SCHOOL OF MECHANICAL ENGINEERING

UNIVERSITY OF LEEDS

MECH5080M TEAM PROJECT 45 credits

TITLE OF PROJECT

Developing the transmission system of an active stability system of a sounding rocket

PRESENTED BY

Antoine Durollet

OBJECTIVES OF PROJECT

Develop a transmission system for an active control system, and oversee the flight simulations of the rocket.

IF THE PROJECT IS INDUSTRIALLY LINKED TICK THIS BOX ☒

AND PROVIDE DETAILS BELOW

COMPANY NAME AND ADDRESS:

Airbus Defence and Space

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INDUSTRIAL Mentor:

Theo Gwynn

THIS PROJECT REPORT PRESENTS OUR OWN WORK AND DOES NOT CONTAIN ANY UNACKNOWLEDGED WORK FROM ANY OTHER SOURCES.

SIGNED [signature] DATE 30/04/2024

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Abstract

This paper goes over the research and work that was carried out to develop the transmission system of an active control module for a sounding rocket. The main objective of the report is to detail how the transmission was designed and ensured to be sturdy enough to handle the constraints of a rocket flight. It outlines how the shape of the canards was chosen using both simulations and testing, how the transmission was designed and implemented, and goes over the flight simulations of the rocket and compares them to the data obtained during the flight.

1) Introduction

a. Introduction

The Aptos project was started in 2022 in order to develop an active control system for a sounding rocket. The reason it is needed is because when rockets fly, they tend to point their nose into the wind, this phenomenon is called weathercocking, and causes the rocket to have a lower apogee. To counteract this, a system composed of variable angle aerofoils, called canards, was implemented.

The Aptos project is done in conjunction with the Leeds University Rocketry Association (LURA) and aims to develop an active control system and use the findings to incorporate into the future rockets of LURA. LURA aims to be a pioneer in developing new rocketry technologies and push the current knowledge of rocketry further. To achieve those goals, LURA has set itself the long-term objective of reaching the Karman Line, the arbitrary line where space begins, which is at 100km of altitude. Currently, no UK university team has been able to reach this altitude. The current rocket, the Gryphon II, is aimed to break the current amateur rocketry record, held by the University of Sheffield and set at over 11 km, by going to 13 km. Its successor, the Gryphon III, is planned to reach an altitude of 50 km, the halfway mark to the Karman Line.

b. Background

The previous year's team had designed a transmission system onto which the canards were directly mounted on the servomotors, which caused damage to the servomotors when the rocket landed during their first test flight in April 2023. There was also a problem that the canards could come undone easily and the entire system had to be disassembled to be able to mount the canards back in place. Another problem that existed was that there was a space between the radial holes for the canards and the canards mount points, which ended in the servomotors taking most of the weight of the canards and the loads caused by the rocket flying in the air.

c. Aim

The aim of the project is to work on and improve an already existing active control system for a rocket to implement in the future rockets of the Leeds University Rocketry Association.

d. Objectives

The objectives of the aerodynamics team were to develop a new canard shape, create a new transmission system and oversee the simulations and design the various parts for the test flights.

e. Report Structure

This report will go over each of the objectives and how they are achieved. It will first go over the existing literature for active control systems and canards in rocketry, then will go in depth on how the shape and planform of the canards were selected. After that, it will talk about the transmission system that was implemented and the testing required for it to fly. It will then summarize the results from the launch that was conducted on the 14th of April 2024.

2) Literature Review

To ensure that a rocket will fly straight, it needs to be stable. This is done by creating a rocket such that the centre of pressure is aft of the centre of mass. This is so that the aerodynamic forces acting on the rocket keep it aligned with the airflow. The ratio between the two is called stability calibre [1], and the generally accepted static margin is $SM > 1$. It is achieved by modifying the size of the aft fins and shifting the weight inside the rocket.

A passive stability is not always desired, especially in the case of high-altitude flights. Passively stable rockets tend to weathercock when there is a cross wind, which results in a lower apogee than expected and a larger landing area [2]. For that reason, an active control system is usually preferred for high altitude flights as it controls the dynamic stability of rockets and allows unstable rockets to fly pre-determined trajectories and modify them.

There are different types of active control systems [3], the most known being aerodynamic control surfaces, which are similar to what is currently used on airplanes, gimballed engines, which is seen on the bigger rockets from NASA, ESA and SpaceX. The third type is using canards at the fore of the rocket. The canard method was chosen as the rocket bodies are quite small and the first two systems take too much space near the aft of the rocket, where the motor is.

The aerofoil can have multiple chord shapes [4] [5]. Out of the existing ones, the straight tapered wing was favoured as its shape reduces the vortex on its tip, resulting in a lower drag than a constant chord wing. It is worth noting that a tapered wing is less efficient than an elliptical-shaped wing but is easier to manufacture. It was also decided to have a straight swept aerofoil [5] as the rocket was estimated to have a maximum velocity of 103m/s or M=0.311. Swept wings are more common and see their advantages increase exponentially as the speed gets closer to the speed of sound, at 330m/s.

A four-digit NACA aerofoil was chosen as they usually have a softer stall than higher NACA types. They also have a more gradual increase in drag as the lift increases, meaning that they provide a higher lift to drag ratio [5]. All of this makes NACA four-digit aerofoils more permissive of errors which makes them the better choice for a first design.

The aspect ratio is an important factor to consider when designing an aerofoil. A higher aspect ratio makes the airflow be closer to a 2D airflow, which creates no induced drag meaning that a higher aspect ratio increases the lift coefficient and decreases the drag coefficient [6]. However, a high aspect ratio will also increase the bending stress and will start to have torsion if the aerofoil is too long. They also have slower roll rate and acceleration than aerofoils with smaller aspect ratio [7].

The load transmission is being done by a shear pin. To ensure the pin doesn't shear under a certain load, the bearing stress equation has been used [8]. This takes into account the shape of the pin, as well as the thickness of the plate and the load.

Polylactic acid (PLA), is a thermoplastic acid that is often used in fused deposition modelling (FDM), also know as fused filament fabrication (FFF). PLA is a biodegradable plastic that has a high versatility, is relatively low cost and highly accessible [9]. It's easy accessibility and low cost allows to create multiple versions of a part or system in a relative short time through the use of FFF printers such as the Bambu Lab printers. It is a material that has a low melting point, around 160°, and doesn't shrink much when cooling, its thermal expansion coefficient is around 73 $\mu\text{strain}/°\text{C}$, which allows it to keep the shape of the part accurately [9].

3) Defining the Canards

In order to define the optimal aerofoil, the CFD software XLFR5 was used as it was developed specifically for aerofoils simulation. The aerofoil needed to be symmetrical as it needs to provide no lift when in neutral position while being able to provide lift at both positive and negative angles. A range of NACA aerofoil shape were simulated, from NACA 0010 to NACA 0020.

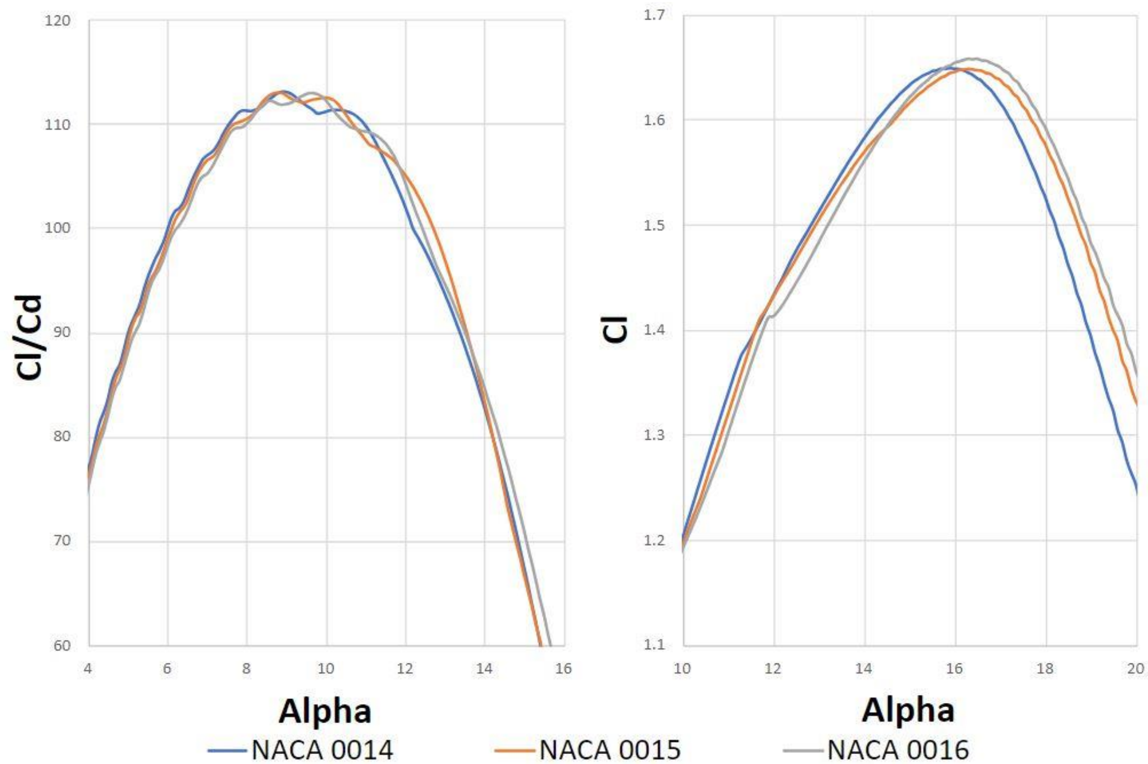


Figure 3.1. CFD Comparison of three NACA Aerofoils

The three best aerofoil shapes were found to be NACA 0014, NACA 0015 and NACA 0016. The latter was chosen due to its slightly higher stall angle and higher coefficient of lift. It can also be seen from the second graph that the stall angle of the canard is at 16.5°.

The planform of the canard was dictated by two main factors. The first one, which required to make the canard larger, being the corrective moment [10] [11] required to steer the rocket in the air without requiring too high of an angle of attack. The second one, which aimed to reduce the size of the canard, was the drag created by the canards, and drives the centre of pressure closer to the centre of mass, making the rocket less stable. To help in this task, an excel spreadsheet was created.

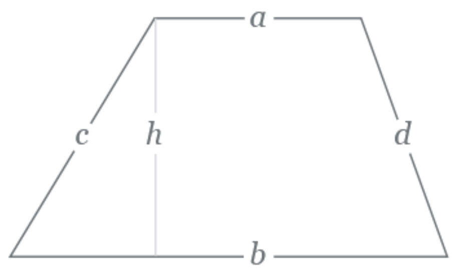


Figure 3.2. Dimensions of a tapered aerofoil

After modifying the different lengths of the canard, the root chord was chosen to be $\mathrm{a} = 80\mathrm{mm}$, the tip chord would be $\mathrm{b} = 50\mathrm{mm}$ and the wingspan would be $\mathrm{h} = 70\mathrm{mm}$. This gives the canards an aspect ratio of 1.077 [7]. This is to ensure that the canards do not experience too much bending stress and break away from the rocket.

The estimated lift force required to provide the desired corrective moment is 103.565 N for a cross windspeed of 10m/s. This force generates a pitching moment of 0.483 Nm about the canard.

To confirm the results from the simulations, a wind tunnel test was carried out using the wind tunnel of the ESTACA engineering school.

4) Transmission System

Due to issues that arose in the first version of the transmission system, it was decided to create a second version. The first idea was to have a bearing put in place to help alleviate the servomotor, and the second was to prevent the forces caused by the ground acting on the canards when the rocket lands to reach the servomotors. Figure 2 shows how the previous system attached the canards to the servomotors, while Figure 4 shows the new system that was designed to answer the issues that were met in the first design.

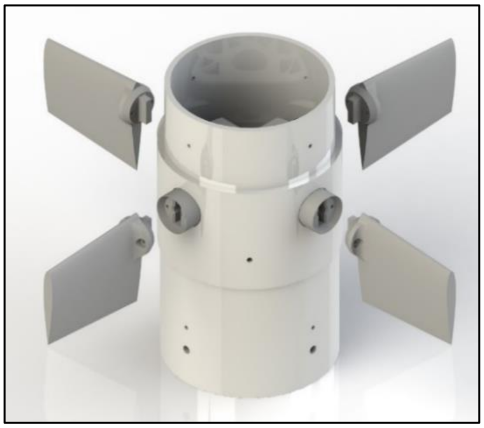


Figure 4.1. Previous Aptos Module Transmission System

To solve the first problem, it was first envisioned to use ball bearings. However, because of their thickness it prevented the canards to be connected to the servomotors. This meant that the other choice was then decided to use brass bushings, which was chosen.

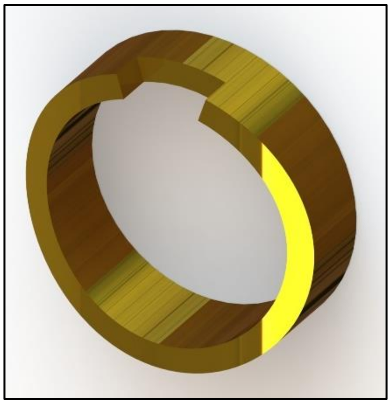


Figure 4.2. Brass Bushing

To prevent the canard from moving past its stall point, which would reduce in a sharp decline in lift, and hence rotational moment, a slot has been cut into the bushing to limit the range to +/-15°.

To reduce the drag created by it, they were also filed down to the outer diameter of the rocket as closely as possible.

The second issue was solved by redesigning the whole transmission. To begin, a shaft was designed to be mounted on the servomotor using 4 centering pins and a bolt to secure it in place.

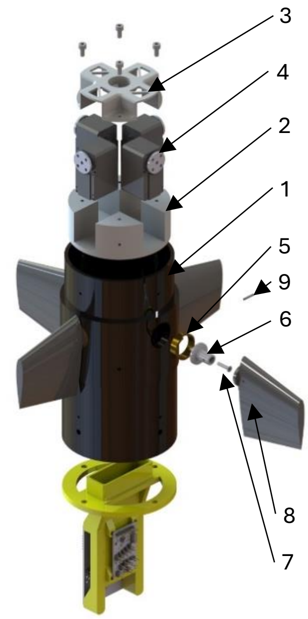


Figure 3.2. Exploded View of the Aptos Module

The attachment point of the canard to the shaft was set so that it would be fore of the centre of pressure. This is so that if the shear pins broke, the canards would automatically come to their neutral position with an angle of attack of 0°. This is so they will not create any lift and modify the roll, pitch or yaw angle of the rocket.

To assemble the transmission system, the servomotors (4) are mounted into a 3D printed bed (2) and are secured in place with the 3D printed lid (3). This sub-assembly is then slid inside the Aptos module (1). Once it is in place,, the shaft (6) is connected to the servomotor, and secured in place using a bolt (7). The canard (8) is then mounted on top of the shaft and connected to it using the shear pin (9). The brass bushing (5) has been glued prior to the assembly to take the brunt of the axial load from the canards, and to ensure that the frictional losses are kept to a minimum.

Once the shaft is installed on the servomotor, the canard can be mounted on it and is secured in place using a shear pin made of anycubic resin [12]. The shear pin is design to transfer the load from the servomotor to the canard and break when the rocket lands on one of the canards, so that it does not damage the servomotor.

Anycubic resin was chosen as the tolerances in the canard and shaft are low to prevent the canard from moving on its own. By using anycubic, a flexible material, it allows to insert the pin without breaking the part while locking the mechanism in place.

The dimensions of the pin were calculated by estimating the impact force the canards will undergo.

$$F_{impact} = ma_{impact} = m\frac{v_{impact}^2}{d_{impact}}$$

Where the mass of the rocket is 8.392kg, its ground hit velocity is 5.67m/s and the estimated duration of impact is 0.3m due to the soft nature of the ground and the crops that would soften the landing.

Once this was found, the torque this force generates about the canard is:

$$T_{impact} = F_{impact} * d$$

Where the distance is the length from the aft of the canard to the centre point of the shaft hole.

From this, the force acting on the shear pin can be calculated using the torque.

$$F_{shear} = \frac{T}{d_{pin}}$$

After finding the forces going through the shear pin, the bearing stress the pin will undergo was calculated.

$$B_t = \frac{F_{shear}}{t_{plate} * D_{pin}}$$

The bearing stress generated when the rocket lands is estimated to be 1.179 GPa. The flexural strength of the material is 50-60 MPa according to the manufacturer [9], which would result in a breaking torque of 1.162Nm This means that the shear pin should break when the rocket lands. However, as the maximum torque the servomotors should produce is 0.48 Nm, which is comparable to a stress of 11.364 MPa, the shear pin should manage to transfer the load to the canards without breaking, and break upon landing.

The servomotors that were used in the previous year had to be changed. This was decided during a meeting with the United Kingdom Rocketry Association (UKRA), the governing body of amateur rocketry, where the transmission mechanism of the servomotor was discussed. The previous servomotors, the Herkulex DRS-0101 [13], uses plastic gears, and they felt more comfortable with a servomotor that uses metal gears. As the rest of the system was already designed and had started manufacturing, it had to follow the electronical requirements of the previous servomotor. Specifically it had to have an UART protocol communication system, and a rated .current of 7.4V, while having a stall torque equivalent or higher to it. The dimensions of the new servomotors also had to be as close as possible to that of the previous ones to fit inside the Aptos module. After establishing those requirements, a suitable servomotor was researched and selected. The chosen servomotor selected by both the avionics and aerodynamics team was the STS 3215 [14]. This servomotor uses copper gears, has a stall torque of 19 kg.cm, or 1.9 Nm, which is higher than the Herkulex-0101, and uses an asynchronous serial communication protocol.

5) Testing

The wind tunnel testing was carried out at the ESTACA engineering school in France [15] as there were problems with the wind tunnel in the University of Leeds. In addition, the wind tunnel at the ESTACA can go to 40m/s [16], whereas the wind tunnel at the University of Leeds can go to 12m/s. The wind tunnel that was used utilizes a force balance system, similar to the one used at the University of Leeds. It was carried out using 3D printed canards and by having a set of two canards mounted on both sides of the mount block to provide symmetrical lift and drag forces. A total of four different sets of canards were created, all at different angles of attack ranging from 0 to 15° with a 5° deflection between them. They were printed with the leading edge facing down. This was done to minimize the amount of supports while not making it too fragile during printing.

Each canard jig was tested three times, and the results were combined to have an average of the values given. The tests consisted of having a jig installed and the windspeed were gradually increased in increments of 5 until it reached the maximum velocity of 40m/s.

Figure 5.1.1. Wind Tunnel of the ESTACA

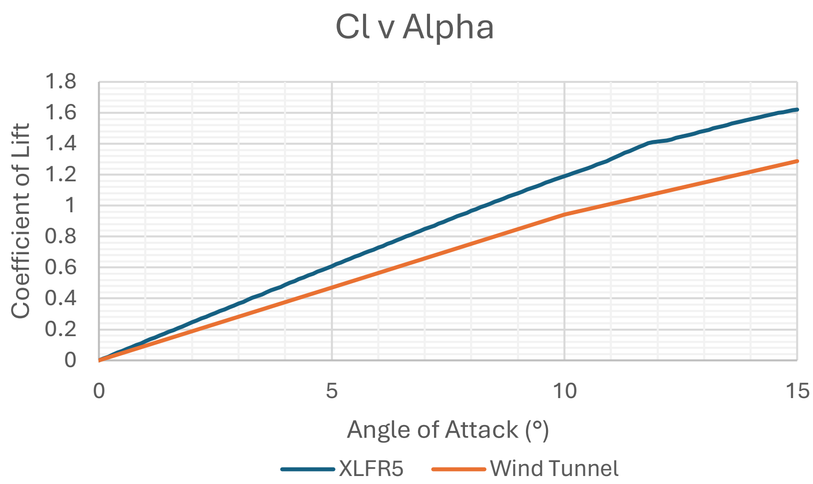


Figure 5.2. Comparison of the Cl between the simulations and Wind Tunnel

The coefficient of lift generated by the aerofoil is lower than the simulated one, with a maximum discrepancy of 25.850% when the angle of attack is at 15°. The measured coefficient of lift is lower than the simulated one.

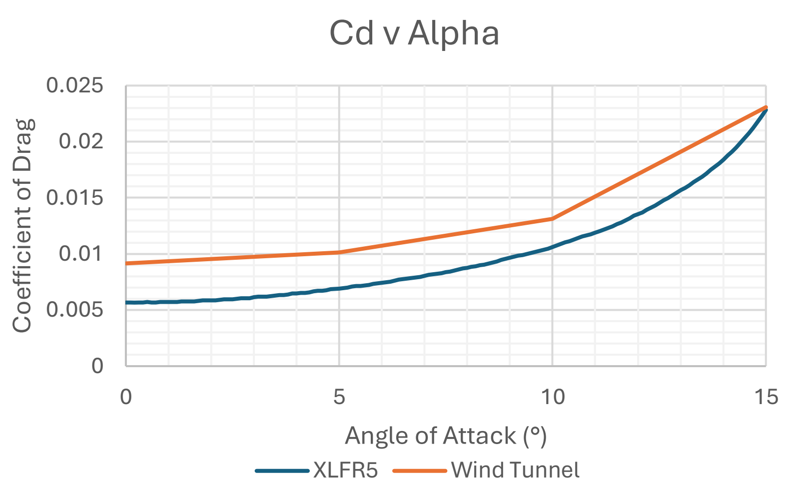


Figure 5.3. Comparison of the Cd between the simulations and Wind Tunnel

It can be seen that the coefficient of drag between the simulations and the wind tunnel testing has the highest discrepancy at 37.872%, when the angle of attack is 0°.

When the wind tunnel is run at 40m/s [16], the lift force's slope starts decreasing starting at 10° while the drag force increases exponentially. This can be explained as the angle of attack gets closer to the stall point of the canard.

The differences between the simulations and the wind tunnel testing may be caused by the print orientation, and print quality which was set at fine where the nozzle diameter is 0.4mm. The combination of both could cause disruptions in the airflow, ending in a lower lift coefficient and higher drag coefficient as the shape of the aerofoil is not exactly the same.

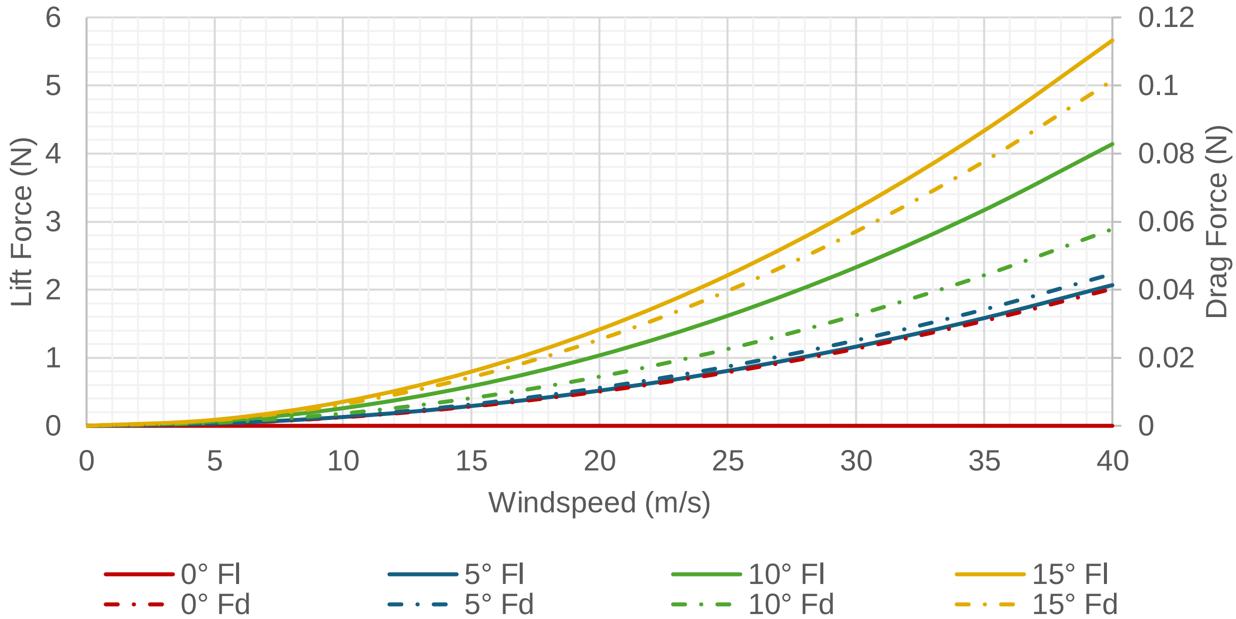


Figure 5.4. Comparison of the different AoA at different windspeeds

As the windspeed increases, the lift and drag force increase exponentially. It can be noted that at higher angles of attack, the lift force increases at a higher rate than the drag force. This means that as the angle of attack increases, the more efficient it becomes, until it reaches its stall point.

During the first assembly of the system, the servomotors were told to move past the 15° limit to see what would happen, and the shear pins broke. This ensured that they would break when the servomotors were moving past the +/-15° range the bushings allow.

6) Test Flight

The Pathfinder rocket was flown on the 14th of April 2024 with the Aptos module installed. The UKRA, gave their approval to fly the rocket with the system enabled.

The flight simulations of the Pathfinder rocket were carried out with different windspeeds. As the position of the canards cannot be changed throughout the flight, they have been set at a 0° angle of attack for all windspeeds. The apogee is estimated at 462m above ground level, and the rocket has a passive stability of 1.81cal.

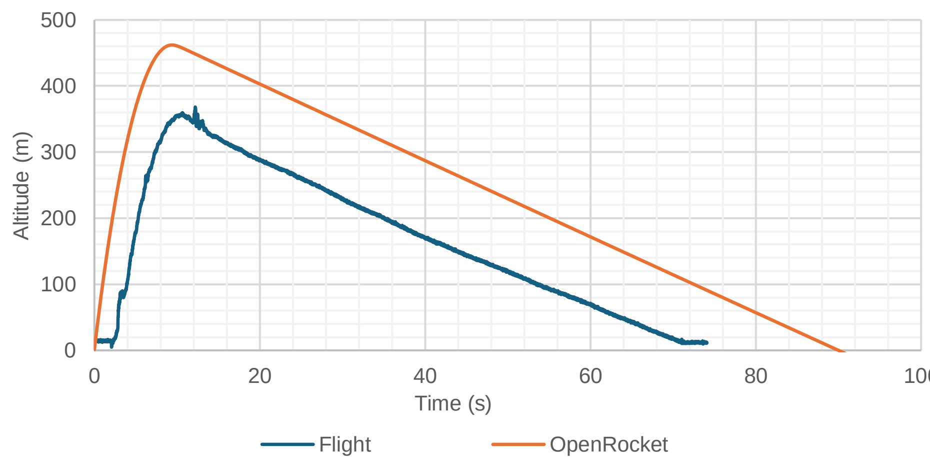


Figure 6.1. Comparison of the OpenRocket model and flight data

Figure 6.2. Aptos module after landing

The rocket flew to an altitude of 354m above ground according to the flight computer onboard. After the rocket landed and was recovered, it was noted that there was no damage to the canards and the shear pins did not shear. This could be because the calculations were taken with a high margin of security to prevent the pins from shearing during flight, which would cause the canards to fall off and prevent the trajectory to be corrected. This would also cause debris to fall which might hit and injure someone. As a secondary measure, the shear pins were glued in place to have a redundancy in case of one or multiple shear pins broke.

This discrepancy between the OpenRocket simulations and the flight data that was recovered could be caused by the software not being designed for active stability systems.

In order to simulate the aerofoils, a set of fins resembling as close as possible the shape of the canards was added to the Aptos module. However, they do not represent the real shape of the canards. The fins are also passive, meaning that they have a set cant that cannot be modified during the flight.

After gathering and comparing the data between OpenRocket and the flight, more simulations were run by setting the cant of the canards at different angles and it did not seem to impact the flight except in one case, where the canards are all set at the same angle, which creates roll and makes the rocket more stable, allowing it to reach a higher apogee.

7) Conclusion

a. Conclusion

The previous year team's system was functional but had some issues that had to be addressed. Primarily, the canards were mounted directly on the servomotors, which would cause damage to the servomotors when the rocket landed. Also, it had a tendency to easily undo itself, which would be a problem if it happened when the rocket was in flight. Another issue that existed was that to allow the canards to rotate freely, they were designed to not touch the bores. This forced the servomotors to hold the weight of the canards, as well as the aerodynamic forces acting on them, which causes them to get damaged faster. For these reasons, it was decided to review the whole system.

The canards were simulated using a CFD software designed for aerofoils, called XLFR5, and the results between last year and this year were compared. The entire canard was redesigned to produce more lift while having as little impact on the drag as possible. This resulted in a canard with a very low aspect ratio to minimize the bending moment. Once this was done, a model was made of the canard and was sent to the ESTACA engineering school in France to undergo wind tunnel testing at different angles of attack. The results of the simulations and tests have been compared and it came up that the lift generated in the wind tunnel was lower than the expected one from the simulations, while it produced higher drag forces. This could be caused by the printing parameters of the parts. Due to this, the orientation of the canards was modified so that they would be printed from the tip to the chord. This was done so that the print layers would help guide the airflow and not disrupt it.

The differences between the simulated and actual flights could be coming from inaccuracies from the software as it is not made to simulate aerofoils in that way.

The revised transmission system, being a first prototype, is designed to transfer a higher torque than is required. This was done to ensure that it did not break away during flight which would cause the rocket's trajectory to not be modified, and to prevent debris from falling off. However, as there was still a risk of them breaking off as they were not tested, it was decided to use superglue to hold them in place and reduce the chance of the canards from falling. The brass bushings that were designed were cut by hand, and therefore have a high tolerance in the slot.

b. Future Work

The next steps of the projects would be to improve on the transmission system, by preventing the canards from detaching in case of the pin breaks. Further wind tunnel testing could be carried out at higher speeds to better match the expected maximum speeds.

Future work should also focus on creating a mathematical model of the aerofoil to help the development of future canards, as well as increase the accuracy of the simulations, or even begin a software that is able to simulate the flightpath of rockets using active control.

8) References

[1] N. Hall, “Rocket Stability,” NASA, 2023. [Online]. Available: https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/rocket-stability/. [Accessed 05 12 2023].

[2] A. Bierig, S. Lorenz and H. Spangenberg, “Development of the Aerodynamic Control System for the Hypersonic Experiment SHEFEX II,” ResearchGate, 2013. [Online]. Available: https://www.researchgate.net/publication/259898649_Development_of_the_Aerodynamic_Control_System_for_the_Hypersonic_Flight_Experiment_SHEFEX_II . [Accessed 5 11 2023].

[3] M. Bellis, “Rocket Stability and Flight Control Systems,” ThoughtCo, 2019. [Online]. Available: https://www.thoughtco.com/rocket-stability-and-flight-control-systems-4070617#:~:text=Active%20control%20systems%20included%20vanes,their%20location%20on%20the%20rocket. [Accessed 15 10 2023].

[4] T. Benson, “Wing Area,” NASA, [Online]. Available: https://www.grc.nasa.gov/WWW/k-12/VirtualAero/BottleRocket/airplane/area.html. [Accessed 20 10 2023].

[5] G. Dimitriadis, “Aircraft Design,” [Online]. Available: http://www.ltas-cm3.ulg.ac.be/AERO0023-1/ConceptionAeroAerodynamisme.pdf. [Accessed 15 10 2023].

[6] C. L.J., Aerodynamics, 1975.

[7] D. O. Dommasch, S. S. Sherby and T. F. Connolly, Airplane Aerodynamics, Pitman Publishing Corporation, 1961.

[8] G. E. Maddux, L. A. Vorst, F. J. Giessler and T. Moritz, “Stress Analysis Manual,” US Department of COmmerce, 1986. [Online]. Available: https://apps.dtic.mil/sti/pdfs/AD0759199.pdf. [Accessed 13 12 2023].

[9] Ansys, *Granta Edupack,* 2022.

[10] Apogee Rockets, “Basics of Dynamic Flight Analysis (Part 2),” 2007. [Online]. Available: https://www.apogeerockets.com/education/downloads/Newsletter193.pdf. [Accessed 17 10 2023].

[11] Elsevier Inc, “Appendix C2 - Design of Canard Aircraft,” 2013. [Online]. Available: https://booksite.elsevier.com/9780123973085/content/APP-C2-DESIGN_OF_CANARD_AIRCRAFT.pdf. [Accessed 23 10 2023].

[12] Anycubic, “Tough Resin,” Anycubic, [Online]. Available: https://uk.anycubic.com/products/uv-tough-resin?variant=44184648941853.

[13] Robotshop, “Herkulex DRS-0101 Smart Robot Servo,” Herkulex, [Online]. Available: https://uk.robotshop.com/products/herkulex-drs-0101-robot-servo. [Accessed 10 11 2023].

[14] FeeTech, “7.4V 19kg.cm Magnetic Encoding,” FeeTech, [Online]. Available: https://www.feetechrc.com/74v-19-kgcm-plastic-case-metal-tooth-magnetic-code-double-axis-ttl-series-steering-gear.html. [Accessed 15 11 2023].

[15] ESTACA, “ESTACA,” ESTACA, [Online]. Available: https://www.estaca.fr/en/. [Accessed 03 02 2024].

[16] ESTACA, “Ressources,” ESTACA, [Online]. Available: https://www.estaca.fr/en/research/laboratory/mechanics/ressources/. [Accessed 03 02 2024].

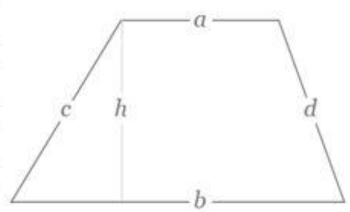
9) Appendix

Inputs		
Max Speed	133	m/s
C1	276	
Windspeec	10	m/s
a	0.05	m
b	0.08	m
h	0.07	m
Rho	1.225	kg/m3
Mu	0.0000181	
Cm	0.15	0

Geometrical Inputs/Outputs		
	cm	m
Cg	77	0.77
Cp	57	0.57
Cg-Cp	20	0.2
Area		0.00455

Dynamic Outputs		
Velocity Magnitude	133.37541	m/s
Wind AoA	0.075046764	Rad
Mcor	20.71290675	Nm
Lift Req	103.5645338	N
Cl Req	1.050413482	
Re	586741.272	
Pitching Moment	0.483363264	Nm
	0.049272504	Kgm
	4.927250397	Kgcm
AoA to Reach Cl	8.8°	
Max AoA	15°	

$$C_m = \frac{M}{qSc}$$



Appendix 1.Table for determining the canard shape

Inputs				
apogee	507	m		
distance_apt-aft	1.445	m		
distance_canard_servo	0.048	m		
Ground hit velocity	5.67	m/s		
Weight	9.176	kg		
Gravity	9.81	m/s^2		
t_coll_est	0.1	s		
d_impact	0.3	m		
length_half-shear-pin	6.26	mm	0.00626	m
thickness_canard	1.76	mm	0.00176	m
D_pin	2	mm	0.002	m
D_servo	24	mm	0.024	m

Landing Inputs		
E_kin	147.4992	J
F_impact_	520.2792	N
F_impact_	425.8765	

Forces acting on APT Module		
E_pot	130.0739	J
v_impact	5.324556	m/s
F_impact_	484.2216	N
T_impact	20.44207	Nm

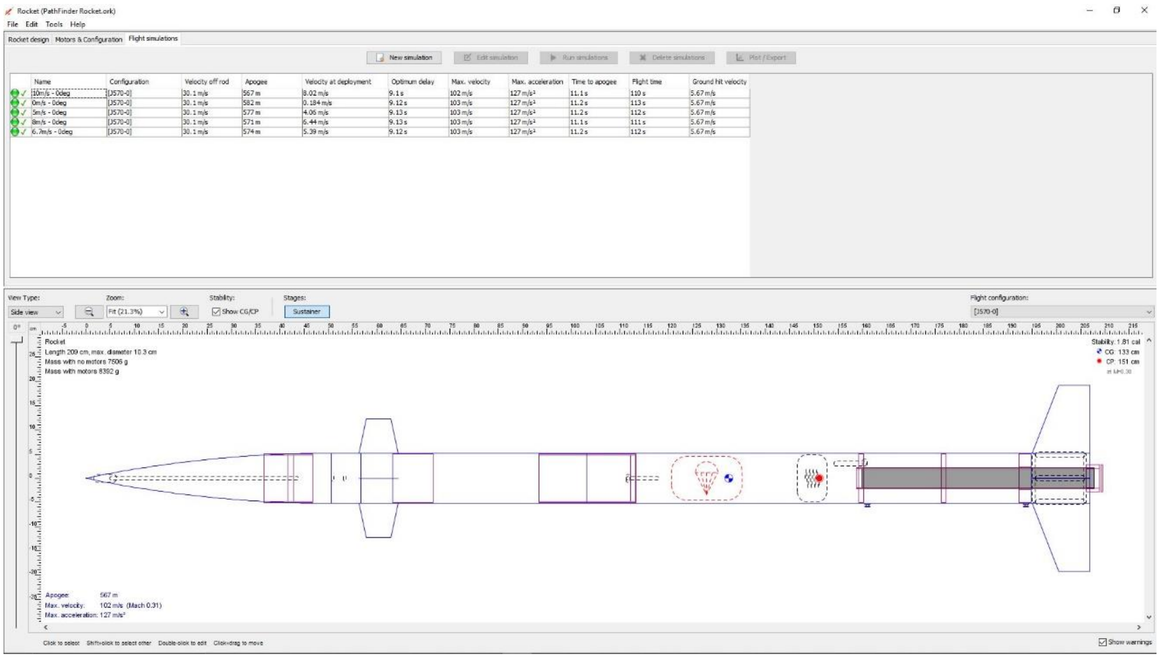
Shear on Impact from simulation		
T_impact	23.242636	Nm
F_pin	**3265.506**	**N**
Bearing_Stress	**927.701**	**MPa**

Shear from Servo		
Torque	**0.48**	**Nm**
F_pin	**40.000**	**N**
Bearing_S	**11.364**	**MPa**

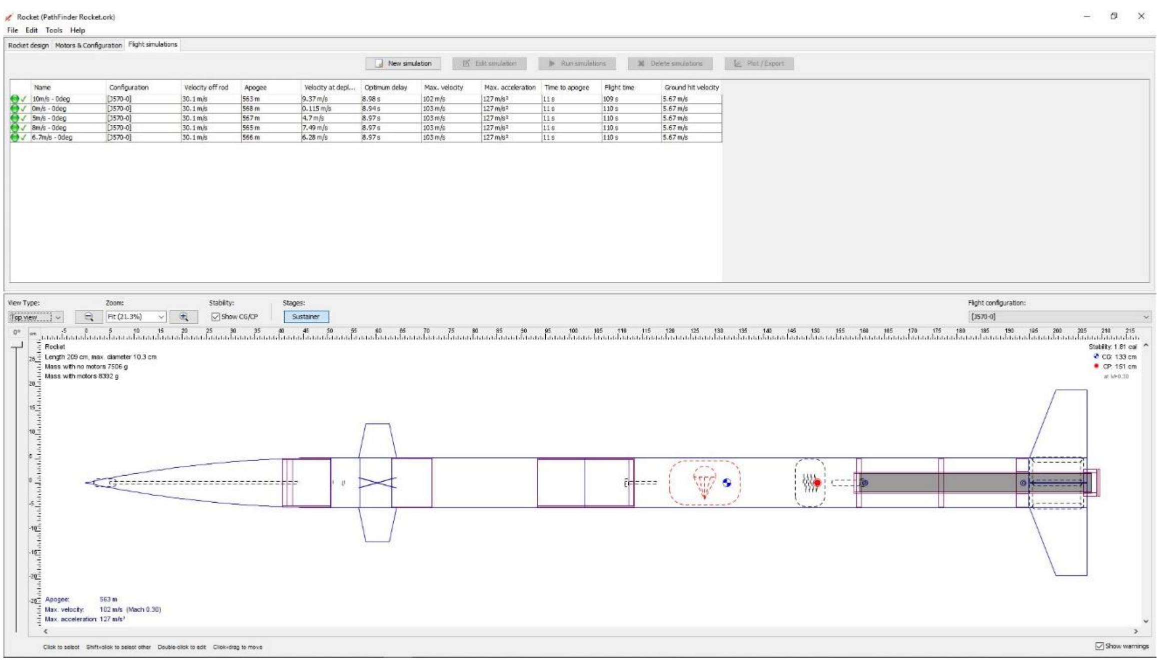
Material		
Anycubic Resin		
Yield Strength	55	Mpa
Tensile Strength	55	MPa
Max Force	**96.8**	**N**
Max Torque	**1.1616**	**Nm**

Flight Data			
Height	Time	Fall Speed	
314.612	13.263	5.27704437	m/s
24.802	68.182		

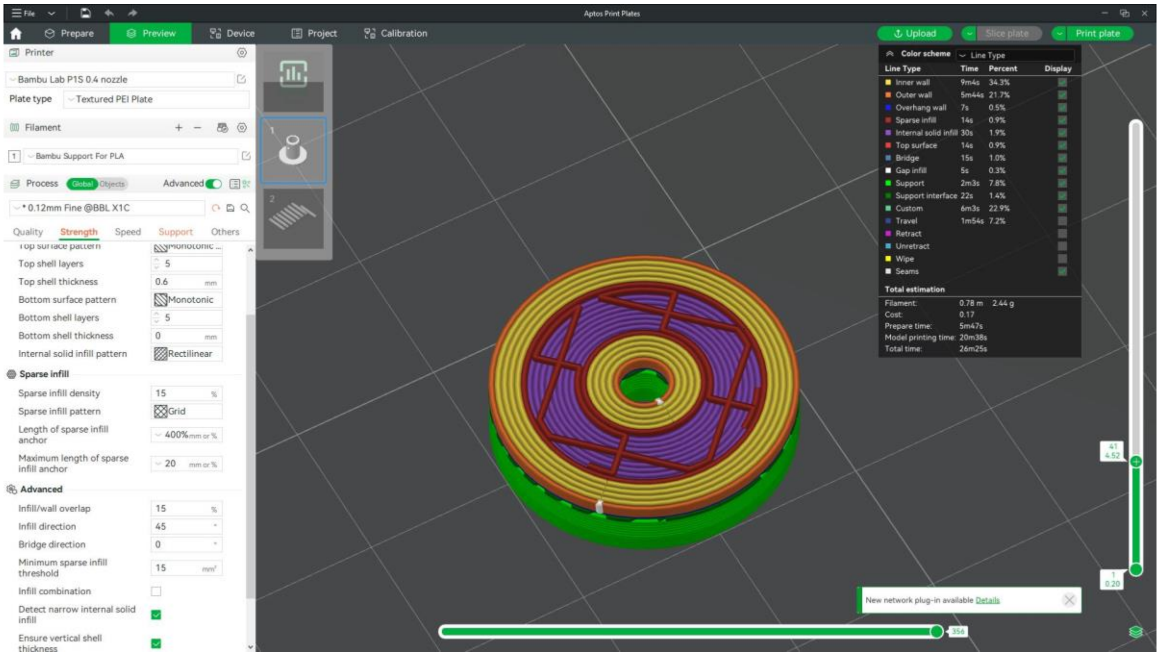
Appendix 2.Table for determining the Shear pin dimensions



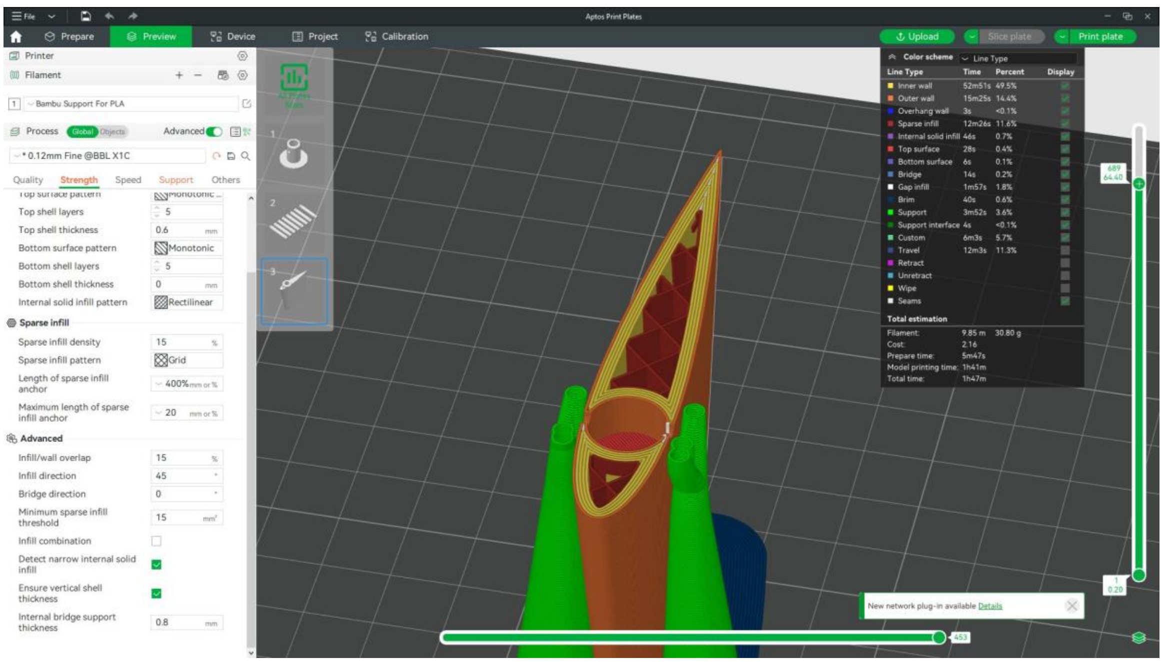
Appendix 3. OpenRocket simulation with the canards at a 0° cant



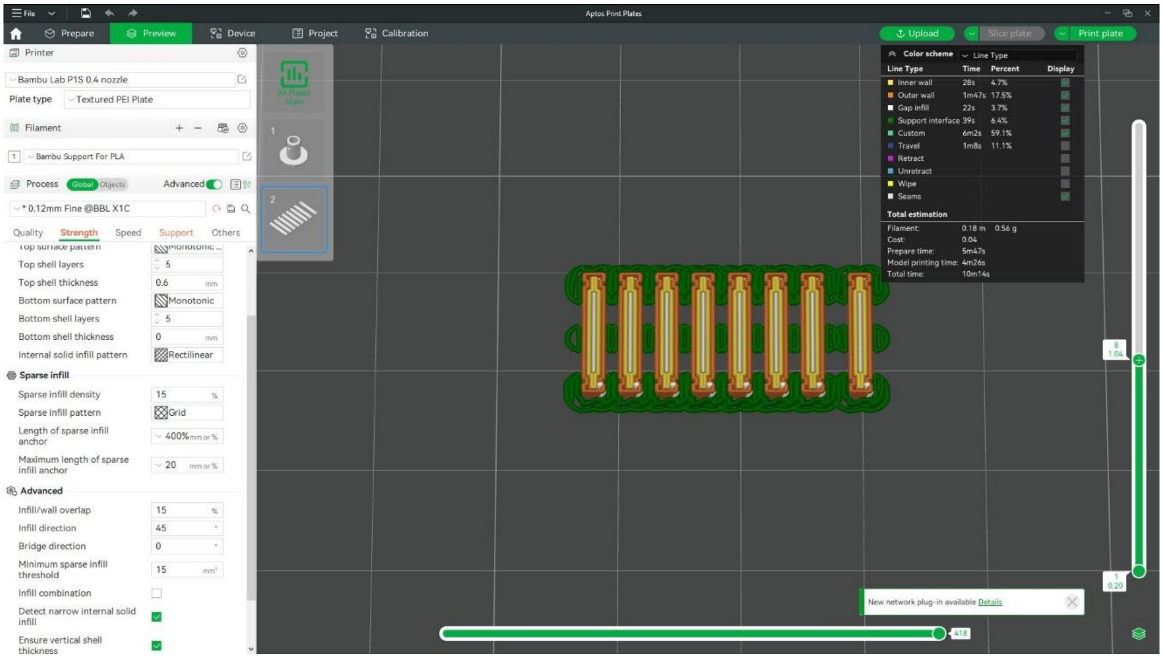
Appendix 4. OpenRocket simulation with the canards at a 15° cant



Appendix 5. Sliced view of the shaft before 3D printing



Appendix 6. Sliced view of the canard before 3D printing



Appendix 7. Sliced view of the shear pins before 3D printing

Appendix 8. Meeting Logs

Meeting number: 1	**Date**: 02/08/23	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine, Dr Jongrae Kim

Agenda

- Introduction to the group project

Progress since last meeting

- Generated the brief

Key notes

- We need to write the initial flight simulations in Python/MATLAB and only after translating to C. The results need to be compared
- Minimum of two people need to check any software developments
- Antoine is in charge of assembly
- Think about the IMU/navigation system that will be used on the rocket

Actions for next meeting

Decide:

- What to achieve for the first launch
- Clear task distribution (create a block diagram for it as well and use it as a tracking system)
- Draft for budget
- Decide who is leading

Supervisor signature

Meeting number: 2	**Date**: 17/10/23	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine

Agenda

- Progress Update
- Decision on leader and submission of ethics form
- Go briefly through the previous work
- Task allocation and create rocket system diagram
- Discuss what would we like to achieve for the first launch
- Check the budget

Progress since last meeting

- Get the information from the previous Aptos group
- Alex Monk did research:
  - We're limited to a 10mW transmitter. We could get an extension to 400mW, but that's not a lot of data. At apogee we can get about 50bytes/s of data

Key notes

Team leader is… Alex Posta. The module leader is required to be informed of this decision by email

Specification:

- Talked about how the general tasks were split, and what to do for the next meeting
- Check document here: https://leeds365-my.sharepoint.com/:w:/r/personal/mn20a2d_leeds_ac_uk/_layouts/15/Doc.aspx?sourcedoc=%7B4A9DAA4B-9BEC-4609-ABE8-D0C9B6BAA0F7%7D&file=Specification.docx&action=default&mobileredirect=true

First launch:

- Flying depends on the weather. Launch sites open back in February, but the weather is pretty unstable then. We should aim for the system to be ready by mid-February but expected to fly in March. (19th February)
- For the launch:
  - Minimum viable avionics system: get the first iteration for PCB and get data

Budget:

- Try to get 2 launches in: one small MRC (mid Feb) and one big one in SARA
- Rough estimate £1500

Actions for next meeting

Task Allocation:

- Fill out the specification document individually. This will be reviewed by the end of the week.
- Estimate the length of each task for addition to the Gantt chart.

- Have a look at the previous CPP and come back to talk about what needs to be changed.
- Talk to Dr Kim,
  - organize a meeting with Airbus (Theo Gwynn)
  - clarify whether we can use last year's data.
- Alex Monk: system diagram and what is needed for the first launch.
- Ollie: think what electronics are needed and include them into budget.
- Sam: check budget for control + redesign control for canards.
- Antoine: check WT and prior simulations for CFD.
- Alex Posta:
  - Submit the ethics form to the module leader (Wassim Taleb).
  - Check the general cost of launches and what is needed for the first launch.

Supervisor signature

Meeting number: 3	**Date**: 20/10/23	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine, Dr Jongrae Kim

Agenda

- Go through actions taken since last meeting
- Check initial:
  - task allocations
  - specifications
  - budget
- Talk through launch schedule
- Any other questions

Progress since last meeting

All:

- Initial task allocation and specification put together
- Initial budget sheet created
- Team lead decided and ethical form submitted
- Each group member did some research on their respective topics
- Chapters put together for the CPP

Key notes

- Bi-weekly meeting starting 3rd November, 12pm Fridays.
- Decision to use STM32 as flight computer.
- For first rocket launch, where canards will not be active, feed target orientation data into the control system, instead of the actual orientation, to check response given an optimal flight. Consider control system response when orientation error is large.
- Add mechanical end stops to the canards.

Actions for next meeting

- Create a Gantt Chart for tasks and send it BEFORE the next meeting. Make sure to structure it to clearly demonstrate tasks dependencies, i.e. which tasks can only be started after another is finished.
- Add hardware & software simulation tasks to task list.
- Create a technical specification / requirements document, and include metrics/methods that demonstrate successful testing/completion.
- Create a design interfaces document showing connections and comms protocols between each section / PCB / chip that will be utilised. Include a complete system diagram.
- The document should also contain the data pipeline, showing data format from sensors, to flight computer, to storage & telemetry.
- Have CPP draft complete by next meeting.
- Create a mass budget estimate and select a target altitude.

Supervisor signature

Jongrae Kim

Meeting number: 4	**Date**: 24/10/23	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine

Agenda

- Progress of Gantt chart
- System Diagram
- CPP section allocation
- Avionics:
  - Obtaining Arduino & Servos for testing
  - Component redundancy & failsafe procedure
  - Arming/initialisation
- Discussion of Spin Can

Progress since last meeting

Antoine:

- Software Learning for CFD Analysis

Oliver:

- Avionics Specification, draw.io diagram and KiCad progression

Alex Monk:

- Telemetry Specification progression

Alex Posta:

- Outline of cpp and gantt chart

Sam:

- Research

Key notes

- Looked through the Gantt Chart and assigned people to all tasks.
- Decision to have two different power sources for avionics/canards.
- Add a relay for the canard? To cut the power. Yes, decided it should be investigated.
- Split the CPP tasks.

Actions for next meeting

- All to go through the Gantt chart and check if all section topics and deadlines are correct
  - Alex Monk – Tuesday
  - Antoine – Wednesday
  - Oliver – Wednesday
  - Alex Posta – Thursday
  - Sam - Thursday

Supervisor signature

Meeting number: 5	**Date**: 31/10/2023	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine

Agenda

- Progress since last
- Gantt Chart
- CPP
- Friday meeting

Progress since last meeting

Alex Monk:

- Picked a frequency for telemetry, leaning towards a SMD transceiver chip

Oliver:

- Schematics are at about 50%, Resources section of CPP mostly completed, more budgeting

Antoine

- Research into different aerofoils, understanding better last year's aerofoil and why it was chosen

Alex Posta:

- Mainly looked at CPP and Gantt chart

Sam:

- CPP, research into control

Key notes

- CPP due at 12 on 8/11/23
- Do a review for the avionics schematics in two weeks
- Alex Monk – preference for C language for ground station interface, putting data into database.
- Gantt chart timing for telemetry doesn't work for the first launch
- Current title of the project doesn't fit with the work we need to do
- Going over objectives and deliverables – each person should do the objectives and deliverables for their section of the project.
- For resources, have small table for costs, if there is a page free then add the full table
- Meeting with airbus
    - Small PowerPoint about LURA and Aptos
    - What can airbus provide knowledge wise?
        - How they process data, data filtering, pipelines, data correction
        - How do they suggest we test the system before flight
        - Suggestions about mounting the canards and linkage to the servos
    - Financial support

Actions for next meeting

- Review the budget by end of Thursday 2/11/23 - ALL
- Move schematics & all files onto the shared OneDrive – ALL
- Get hold of Theo's individual report – Alex Posta
- Review gantt chart timings – Alex Monk
- Have draft of all CPP sections by Friday 3/11/23 – ALL
- Create a more accurate project title that reflects the project
- PowerPoint for airbus meeting – Antoine

Supervisor signature

Meeting number: 6 | **Date**: 03/11/2023 | **Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine, Dr Jongrae Kim, Theo Gwynn

Agenda

- Small PowerPoint about LURA and Aptos
- Ask Airbus
  - If they need anything from us?
  - What can airbus provide knowledge wise?
    - How they process data, data filtering, pipelines, data correction
    - How do they suggest we test the system before flight
    - Suggestions about mounting the canards and linkage to the servos
  - Financial support
- Ask for feedback on CPP and Gantt Chart

Progress since last meeting

- All – work on the CPP

Key notes

- Objectives:
  - Get started on the wind tunnel early as it takes a long time to have it available
  - Need to define success parameters for avionics
  - Need to think of a backup plan in case of things don't work

- Airbus Q&A:
  1) What does Airbus need from us?
     a) Airbus just wants to develop relationship with university and students. Airbus will never be able to use the data. So, we define what we want to do
  2) How they process data, data filtering, pipelines, data correction
     a) Theo will contact someone for that
  3) How do they suggest we test the system before flight
     a) Theo will contact someone for that
  4) Suggestions about mounting the canards and linkage to the servos
     a) Mount the canards to a stronger body. Want to shift and separate the load
  5) Can we be added to the presentations, with the CubeSat project?
     a) Theo will see what he can do
  6) Can we get money?
     a) Probable not directly from Airbus. However, Airbus works with companies that support uni teams. So, Theo will reach out to them
  7) Any advice for LURA in the future?
     a) LURA has done well, but it will be interesting how it goes seeing that Theo Y. is gone

Actions for next meeting

Drop a message to Theo with questions.

Supervisor signature

Jongrae Kim

Meeting number: 7	**Date**: 21/11/2023	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine

Agenda

- Progress Update
- Budget Discussion
- Schematics Review
- Presentation Review
- Task List for next meeting

Progress since last meeting

Antoine:

- Has selected the fin shapes, but has been busy with LURA

Alex Monk:

- Theoretical schematic for the PCB. Implementation in KiCad required

Sam:

- Literature and project research undertaken, but has been busy with LURA

Oliver:

- Didn’t do much. Worked on LEDs, buzzers that we will need. Did some current predictions.

Alex Posta:

- Looked at data bases. Seem to be going for InfluxDB
- Got feedback from Theo

Key notes

- When is the presentation poster deadline?
- Hardware testing should start in beginning of January
- CRC checking was recommended by Theo to check the data. Need to create a protocol that includes CRC checking. He talked about SpaceWire protocol.
- Dave asked about data filtering.
- Theo didn’t answer the question about actuators.

- Budget must be submitted fast. Uni can be slow to approve budget and order stuff for us. Hopefully it’s not the SIPR method.
- Budget:
- Draft PCB to be included

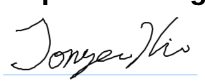
- Look at the schematics on our own, but Ollie gives us an overview of what he has drawn. Will have a review later this week. Has been decided to be on Friday
  Maybe use diodes to prevent reverse current? Drop a message to Arthur about it.
- Need to decide how the internal structure is.

- Need to prepare a ppt for the presentation showcase.

Actions for next meeting

- Antoine:
  - Need to run CFD sims
  - Alex Monk:
  - Need to do draft PCB on KiCAD
  - Create a chat with Theo Gwynn
  - Ollie:
- Want to get schematics done this week
- Alex Posta:
- Ask Dr Kim on Wednesday how to order stuff

Supervisor signature



Meeting number: 8	**Date**: 29/11/2023	**Attendance**: Alex Monk, Alex Posta, Sam, Oliver, Antoine

Agenda

- Updates from everyone
- PowerPoint Presentation
- What to do for next week

Progress since last meeting

Antoine:
- CFD simulations are ready, Ansys took quite some time to run some simulations
- Got the model in a steady state

Alex Monk:
- None

Sam:
- MATLAB legacy, looking into LQR => improve with steady state error

Oliver:
- Completed the schematic, schematic review and started the PCB design

Alex Posta:
- Install MySQL and InfluxDB locally and test them

Key notes

- Go over the PowerPoint for the December showcase

Actions for next meeting

Oliver:
- Finish the PCB and complete BoM
- Generate new PDF with PCB

Alex Monk:
- Have schematics ready and reviewed
- Try to start PCB layout

Sam:
- Fix the file for MATLAB
- Develop the equations for the new canard + steady state error

Antoine:
- Finish CFD simulations for next week

Alex Posta:
- Select a database (MySQL) and start on the server (Flask)

All:
- Work on the PowerPoint

Supervisor signature

Meeting number: 9	**Date**: 06/12/2023	**Attendance**: Alex Monk, Alex Posta, Oliver, Antoine, Dr Jongrae Kim

Agenda

- Order PCB components
- Check the PowerPoint for the presentation

Progress since last meeting

All:

- Have worked on providing information for the PowerPoint

Key notes

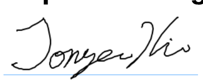
- Model mathematical model of the rocket to feedback into the control when testing
    - How do we model the force relative to speed on the canards
    - Complexity comes from speed => assume air density is constant
    - Velocity changes => torque generated by fin is difficult (this needs implementation in simulator)
    - Then convert the response into fake sensor data

- Review of PowerPoint
    - Too many figures per each slide
    - Too much text on slides

Actions for next meeting

- Everyone to change their sections of the PowerPoint to account for the feedback

Supervisor signature



Meeting number: 10	**Date**: 11/12/2023	**Attendance**: Alex Monk, Alex Posta, Oliver, Antoine, Sam

Agenda

- PowerPoint Project Showcase
- Work during winter
- When we are back

Progress since last meeting

- Work on the Project Showcase PowerPoint

Key notes

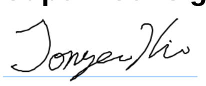
- Split presentation:
  - Introduction: Alex Posta
  - Aims + Objectives: Sam
  - Risk assessment: Alex Monk
  - Previous work: Ollie
  - Design/Update sections: Each one of us should talk about ours
  - Future work and conclusion: Alex Posta

- January:
  - Exams: 17th and 19th of January
  - PCB: After the 19th of January start to assemble
  - Wind Tunnel Testing: after the 22nd of January

Actions for next meeting

- Over Christmas (up util the 27th Dec):
  - Oliver:
    - Flowchart,
    - Look at drivers/logic,
    - Pseudocode for logic
  - Sam:
    - Improve MATLAB controller
  - Antoine:
    - CAD for testing jig
    - start actuators CAD
  - Alex Monk:
    - Initial design for the hardware-in-the-loop testing
    - Basic antenna design
  - Alex Posta:
    - Webserver + UI
    - Look into drivers for firmware

Supervisor signature



Meeting number: 11	**Date**: 12/01/2024	**Attendance**: Alex Monk, Alex Posta, Oliver, Antoine, Sam

Agenda

- Updates over Christmas
- Estimate arrival time for boards and actions
- Define tasks to do over January
- Launch Ops

Progress since last meeting

Antoine:

- Finalized shape and planform of canard

Alex Monk:

- Designed antennas, and ordered driven element planar patch PCBs

Ollie:

- Made a first software flowchart, but is pretty basic

Sam:

- No news, has been working for his exams

Alex Posta:

- Made a webserver for flight data

Key notes

- Parts are still waiting for approval and haven't been ordered yet
- Might want to focus on other tasks as the part arrival date is a big unknown. Lots of software and design to do
- Report is due on 1st May. Ideally, we will fly in the 1st week of April, but if we fly in the 2nd we can start writing it before flying

- Launch Ops:
    - Need to do a lot of testing to have the green light from UKRA. Especially if we want to go to MRC instead of SARA
    - Have flight computer running and have hardware testing done by end of February

Actions for next meeting

- Alex Monk to help Alex Posta for boards
- Ollie to do firmware if the boards do not arrive, and look at MATLAB translation into C with Sam. There's a library in Simulink but need to check it works properly
- Antoine needs to write the wind tunnel procedures and have them ready for after exams. And start doing a draft design of the actuation system
- Check actual data against the simulated data
- Having next meeting on the 26th at 12pm

Supervisor signature

Meeting number: 12	**Date**: 26/01/2024	**Attendance**: Alex Posta, Oliver, Antoine

Agenda

- Updates
- Workshop situation
- General testing procedures
- Wassim project updates
- Revise actions for next week

Progress since last meeting

Antoine:

- Canards are almost ready for testing. Will go to the workshop today to finalize the design and start printing.

Alex Monk:

- Received PCBs and ordered and receive filaments for custom antenna design

Oliver:

- Received PCBs
- Stencil is here! Just need to cut it at G68
- Look into servo drivers

Sam:

- No updates this week due to other commitments

Alex Posta:

- Improve on the web server, drivers for accelerometer/IMU, research hardware in the loop testing

Key notes

- Don't solder in the new workshop. Should be done either in electronics lab or Ollie's house.
- For WT testing, ask Antoine.

For Wassim

- we received 2 examples papers on Minerva
- talk about final report, next Tuesday at 1PM over Teams, anyone can join on the link: https://teams.microsoft.com/l/meetup-join/19%3ameeting_Yjc5NGFlZGUtZmE0MS00NzhiLTk3YTItN2YzNzViMmZkYTIw%40thread.v2/0?context=%7b%22Tid%22%3a%22bdeaeda8-c81d-45ce-863e-5232a535b7cb%22%2c%22Oid%22%3a%22f746f915-85b4-4cee-8456-4848428704d1%22%7d

Actions for next meeting

- Have common work sessions. Can go to the West Teaching Lab. Idea is to work together and talk, not each on their own. Next working session should be after the meeting with Dr Kim Jongrae.
- Have the weekly meetings at 10am/11am on Fridays.

Supervisor signature

Jongrae Kim

Meeting number: 13	**Date**: 02/02/2024	**Attendance**: Alex Posta, Oliver, Sam

Agenda

- Updates
- Airbus conference
- Launch situation
- Revise actions for next week

Progress since last meeting

- Sam:
  - Go through the control and install adds-on
- Oliver:
  - Accelerometer, temp and IMU drivers' updates
  - Servo driver
- Alex Posta:
  - Try to run the MATLAB/Simulink simulation to get the controller into C

Key notes

- Try to run the control on MATLAB and realise there is not documentation in terms of what to install, which file to start

Actions for next meeting

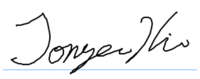
Sam:

- Create a list of Adds-On and documentation (instructions, flow-chart) for the control
- Make sure the algorithm runs as last year

Oliver and Alex Posta:

- Continue working on firmware

Supervisor signature



Meeting number: 14	Date: 09/02/2024	Attendance: Alex Posta, Alex Monk, Antoine Oliver, Sam

Agenda

- Updates
- Look at part lists
- Launch Plan

Progress since last meeting

Sam

- Control: Simulation running, but only with certain OpenRocket data. Filtering and project organisation ongoing

Alex Posta:

- Firmware: Debugging on the flight computer:
    - SPI test and get it to work
    - Read barometer data

Oliver:

- Flight Computer: Board almost completely soldered, no obvious shorts so far

Antoine:

- Mechanical: Transmission design proposed

Key notes

- Servo transmission needs a chamfer, servo needs more secure attachment. Mounting system shouldn't protrude outside rocket body.
    - Suggested larger bearing / bearing removal and having the canard break on impact instead.

- For launch on 10th March:
    - Barometer, accelerometer, IMU data recorded
    - Initial control loop running with no direct output
    - Data saving to NAND Flash
    - Launch with simple antenna design.

Actions for next meeting

- Do a mouser order for missing components

- Alex Posta wants to get accelerometer data reading out on flight computer, will move onto hardware in the loop testing of Ollie's board once MATLAB running

- Need to design a mounting system for flight computer and telemetry board
    - Alex Monk and Ollie need to send Antoine CAD models for boards

Supervisor signature

Meeting number: 15	**Date**: 16/02/2024	**Attendance**: Alex Posta, Antoine, Oliver, Sam

Agenda

- Updates
- Deadlines
- Launch Operations
- Purchasing

Progress since last meeting

- Control: Get the MATLAB script running, implement Kalman filter on the Barometer (input)
- Firmware: None
- Flight Computer:
    - Solder last parts (create soldering procedures) + create updates for future versions
    - Create secondary part order
- Mechanical: Start designing the PCB support for the launch
- Telemetry: None
- Structure for individual report - Ollie

Key notes

- Launch Operations:
    - Had a call with Paul from UKRA to ask if we can launch Pathfinder from MRC
    - He seemed quite positive about it, but had the following requirements:
        - Instead of going thorough TPS (Teams Project Support), we need to create a Facebook chat with him, Andy, Chris and Collin + all Aptos team
        - We need to send them documentation:
            - OpenRocket Simulations, CAD, further details about mechanical spec, servo motor spec (torque, movement, operating range) (list all parts, dimensions in mm)
            - Electronics, Firmware, Control, Telemetry overview
            - Failsafe mechanisms (mechanical, electrical, especially control)
            - Testing procedures
        - They want metal geared servos
        - We need to sign a waver (in case the rocket crashes and produces damage, it will be out fault rather than UKRA)
- For the mechanical side, focus more on the actual Aptos Launch rather than the 10th of March small academy rocket test launch

Actions for next meeting

- Set the general report structure and deadlines – Alex Posta

Supervisor signature

Meeting number: 16	**Date**: 23/02/2024	**Attendance**: Alex Posta, Alex Monk, Antoine, Oliver, Sam

Agenda

- Updates
- Deadlines + Report
- Targets over the next 2 weeks

Progress since last meeting

Antoine:
- Investigating new servos

Alex Monk:
- Use the air holes (drill additional ones) to mount the antenna; started the CAD
- Started soldering components for telemetry
- Written C code to work with transmitter
- CAD the antennas for the Academy rocket

Ollie:
- Firmware updates: SPI, sort out the delay function, system clock, watchdog running, LEDs, buzzer, UART

Alex Posta:
- Check deadlines and documents that need submitting
    - Get the MATLAB code running and start to look into hardware in the loop testing (HIL)
- Get a serial output in MATLAB

Key notes

- Cannot find servo, did not spec any servos
- Check deadlines document:
    - Deadlines.docx
- Plan for the next 2 weeks:
    - Finish Airbus presentation by the 27th of February (Tuesday)
    - Get the Academy rocket ready for the 10th of March
    - Finish poster between 11th - 13th of March

Actions for next meeting

- Friday:
    - Antoine to search workshop, living and Toby's room for servos
    - Alex Posta put PowerPoint together for Airbus
- Sunday:
    - If servos not found, Alex Posta and Antoine spec new servos
    - Antoine should buy academy motor (38mm, some H)
    - Ask Dom to launch it for us

Antoine:
- Send Alex Monk CAD of Academy rocket

Sam:
- Get the MATLAB control working in C

Supervisor signature

Meeting number: 17	**Date**: 01/03/2024	**Attendance**: Alex Posta, Alex Monk, Antoine, Oliver

Agenda

- Airbus brief
- Updates
- Work on the following week

Progress since last meeting

Antoine:

- Look into buying servo motor
- Look into rocket motors

Oliver:

- Code: get the barometer data on Aptos
- Get the IMU to spit data

Alex Monk:

- Nothing this week

Alex Posta:

- Get the accelerometer data (in some form)
- General code flow

Key notes

Airbus:

- The propulsion was nice, we enjoyed the site. Enjoyed some of the talks. Rover arena wasn't very big, but still interesting.
- We are in a good position in terms of project compared to other teams. Quite happy to see our projects

Launch:

- Buy motor from the launch site. Add the I and J motors that we would like to launch with.
- Start the integration loop and write data to NAND Flash.
- Get the telemetry stuff inside the rocket for the small launch inside the rocket and still be approved by UKRA.
- Use PETR Gryphon as the rocket testing platform.

What frequency do we want to run the control to? 5-10 times closed loop bandwidth. 50Hz? They used 50ms time intervals for data reading, 10ms for gain updating.

Actions for next meeting

- We need a mounting solution/firmware development
- To Do:
    - Assembly ready for testing (Wednesday evening)
        - Bracket printed
        - Connection method to the rocket
    - Firmware ready for testing (Wednesday evening)
        - Accelerometer, IMU, barometer data
        - Store and read off NAND/SD card
        - Control converted to C
        - Initial code flow routine
    - Testing of assembly on (Thursday)

Supervisor signature

Meeting number: 18	**Date**: 08/03/2024	**Attendance**: Alex Posta, Sam, Antoine, Oliver, Alex Monk

Agenda

- Updates
- Launch Prep

Progress since last meeting

Antoine:

- Designed the board cage for the first launch
- Tried printing antenna for Alex Monk but had an issue, will try again.

Ollie:

- NAND flash code has been improved and test.
- Code written to get data off in CSV format.

Alex Monk:

- Can see signals showing up from transmitter to receiver. Plans to attach barometer for the launch

Alex Posta:

- Firmware. A lot of updates to the code.
- Overview of the structure and flow.
- Data from barometer and Accelerometer
- Data buffer for the last 50 readings.

Sam:

- Looked at generating C code.

Key notes

First launch will just be logging data not running any control code.

- Software flow is nearly ready for first launch.
- NAND flash is working
- Discussion around the format of input data the control algorithm need.
- Demo of telemetry progress
- Next launch could be April 7th in Cambridge
- Would we want to build up the second PCB
- Possibility of using university drones or Sam's drone to do testing.

Actions for next meeting

Oliver and Alex Posta:

- We need IMU driver complete for the control. Does IMU output angle or angular velocity

Sam:

- Check what is raw data needed in the control
- Conversion between CSV and open rocket data.

Alex Posta:

- Generate new frame array structure

Antoine:

- Print antenna & cage

Alex Monk:

- Details of all tests needed for the telemetry.

All:

- Meeting tomorrow 10am to complete assembly and procedures for the Sunday launch.
- Think about integration between main board and telemetry
- Poster due on Wednesday.

Supervisor signature

Meeting number: 19	**Date**: 08/03/2024	**Attendance**: Alex Posta, Sam, Antoine, Oliver, Alex Monk

Agenda

- Updates
- Launches

Progress since last meeting

Antoine:

- Wind Tunnel testing meeting with Sam. Going to be a few more weeks as they are testing a new equipment. Need to put pressure on Sam to do it asap.

Ollie:

- Will work with Sam to get the code working and changes needed to adapt legacy code to our new boards.
- Gyro data is pretty good.
- Accelerometer on the IMU is working.
- Tried to figure an angle from the axis of gravity. However, it uses the arctan function, which needs floating points that we don't have. Gives an approximate, but not close enough.
- Missing the BME280 and the servo drivers.
- Needs to do servo driver, BME driver and arctan problem.
- Might do low pass filters, but the data we get is good enough.
- Will check if the boards can fit horizontal in Aptos.

Alex Monk:

- Tried to demodulate the signal, but there is a lot of noise. Maybe the data rate is not correct? Not using an impedance match, so might have an impact.
- Need to try using a standard antenna to see if the problem isn't his antenna.
- Once demodulation is done, need to find a way to automatically read the data coming from the antenna. Need to copy the binary code from antenna into a .txt file before decoding by hand.

Alex Posta:

- Has been a bit ill. Poster has been submitted

Sam:

- Looked at the formulas for MATLAB and went over the code from last year to see what needs to be improved. Can't currently do floating points, which could be a problem for gains.
- Will work with Ollie to get the code working and changes needed to adapt legacy code to our new boards.
- Legacy was doing comms using Bluetooth. Getting rid of it and coming with an alternative solution to that.
- Need to work on servo drivers, and update controls from the Legacy.
- Need to implement changes of the updated Pathfinder to the simulations.

Key notes

- Servos are on their way to uni, and bushings are already here, waiting to be picked up.
- Launches:
    - G2 team to do launch on the 14th of April from MRC.
    - Can go to EARS on the 7th to do a test launch, do a small bottle test in the field?
    - Test telemetry in a car?
    - Can put it on a drone and fly it. Sam has a drone. Can test on Sam's commercial drone.
- People will be back before the 14th, but not too sure how long before. Can go to Peak District on the 5th to do testing.

Actions for next meeting

Supervisor signature

Meeting number: 20	**Date**: 08/03/2024	**Attendance**: Alex Posta and M, Sam, Antoine, Oliver, Dr Jongrae Kim

Agenda

- Updates
- Ask questions about report

Progress since last meeting

- See previous table – Meeting on the same day as previous

Key notes

- Next meeting: Friday 3pm

- If we want to reference the work of others, include a footnote with their names. Make sure everything is transparent.

- Pick a literature paper and use the style of that paper, general style. Common mistakes:
  - Define acronyms (even 3D). Define when it first appears
  - Abstract is independent from all the report, define acronyms twice if they appear there
  - When you have formulas, define all variables under the equation. Examples when the variables are. All symbols need to be defined. If they appear after, it is ok
  - For Figures: put AXIS names and UNITS
  - X axis is something… which axis is there? Even put them on the figure. X,y axis. Add legend
  - Use IEEE reference
  - Figure and tables must be refereed in text before they appear
  - If figure is big, put it over two columns
  - Formulas, everything needs to be defined

Arxiv: Contains drafts papers https://arxiv.org/pdf/2311.11372.pdf

SERVOS: Antoine has two, Oliver has two

Actions for next meeting

Supervisor signature

Meeting number: 21	**Date**: 22/03/2024	**Attendance**: Alex Posta, Alex M, Sam, Antoine, Oliver

Agenda

- Updates
- Work to be done for next week

Progress since last meeting

Oliver:

- Managed to make the servos move independently through the board. Need to test the accuracy. The input gives the absolute position. The input is millidegrees. Can set the neutral position as we want, for now it's been set in the middle of the 4000 available values. Needs more testing to know which side is clockwise and anti-clockwise. Can be tested this weekend before Ollie leaves
- Formatted the IMU driver for readability
- Set min and max angle functions. If input a value higher than the max angle, it shouldn't go above the 15°
- Plugging in the servos uses the UART board. Which results in slowing down figuring out which angle it is at

Alex Posta:

- Converted the MATLAB control into C. At the moment it is pure maths, so no problems so far
- Created LQR controller
- Created matrix operations to translate matrices into coordinate systems
- Created a new Simulink model for the loop testing. Using serial blocks. Broke the control loop and added some serial blocks
- Send the roll, pitch and yaw of rocket directly into code

Sam:

- Has not touched the gains. Added filters on the yaw and pitch angle, and added PI controller
- From OpenRocket you can take the pressure rate and plopped that into the Simulink, which is more representative of how the speed of the rocket will be simulated

Antoine:

- Have all the parts ready for the first assembly test

Alex Monk:

- Antenna works better! Still not perfect. Little demo of it
- Have not just noise, but peaks showing the bits. There is a lot of reflection
- However, it's not centred around 433 MHz. It is not calibrated properly
- Also has a demodulator for it

Key notes

- Try to test the module while spinning
- Telemetry needs a better antenna
    - The current one is not good, so going to buy the one he needs on eBay
- Aptos boards don't fit inside the Aptos Module. Mount needs to be redesigned to have it vertical. Can use the old mount that was meant for Petr Griffin (Academy small rocket)
- The gyroscope drifts over time. Can be offset from the get-go by looking at the standard deviation, and also look at the accelerometer data to know where the gravity field is pointing towards

Actions for next meeting

Oliver:

- Verify the servo positions before leaving

Alex Posta:

- Get Ollie’s code working to see the canards moving
- Test the controller on microprocessor, and using the loop in Simulink
- Get floating point to work

Sam:

- Need to check that modifications make sense, and are the correct representation of how it will be simulated. More testing and experiments

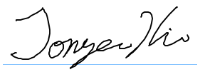
Antoine:

- Need to finish prepping all the parts and assemble them together. Will be done by Sunday morning
- Need to find an alternative for the wind tunnel. (IPSA? Need to ask one of his old teachers.)

Alex Monk:

- Get the oscillator going. Take out all the wrong decode/noise data
- Modify the PCBdesign
- Buy a new antenna

Supervisor signature



Meeting number: 22	**Date**: 22/03/2024	**Attendance**: Alex Posta, Alex Monk, Sam, Antoine, Oliver, Dr Kim Jongrae

Agenda

- Updates
- Questions about report

Progress since last meeting

See previous table

Key notes

- Need more specific titles/more details for the chapters. Have to have a specific font and size.
- Do not use webpages as reference unless it is the only source
- Do not use excuses such as “time limitations…”, “budget…”
- We should add a section about the rocket launch

Questions

- Do we need to have the same title?
    - No need for the same title for the individual report. Add the main title it as a subtitle under your individual title

- How do you add and reference code?
    - If you have a code snippet, add it as a figure. You do not need to add a reference to your own code. Make it clear if you took inspiration from somewhere. Add a link to GitHub, we do not have to make it public, add a footnote that says that code is not public and give access key or something

- Table of components with features for each component (all evaluation come from different sources)
    - You basically need to add references for all of those difference. Or, if you reference Mouser in multiple locations, add link to Mouser and say (see price on Mouser)

- If you made modifications, new versions
    - Tell the “story”. In an engineering report, you need to show off all of the process. That is one of the most important points in the report

- Should we use the ECSS standard?
    - Would be good to use standards, find improvements for next phase. We need to explain what those are before we use them. Take all documents as separate

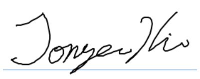
- Is he looking for a specific structure for the chapters?
    - No

- How much can he review our reports? Is it only one page or the whole report?
    - 20% of each report can be send for review. We can approach other academic as well for review.

- Do we need to post it on LinkedIn/post the screenshot of the LinkedIn post?
    - I do not know… maybe required, but not marked. Probably yes.

- How many references is he expecting?
    - 20-30 references. Include majority of them from journal papers. Single space, smaller font.

Supervisor signature



Meeting number: 23	**Date**: 05/04/2024	**Attendance**: Alex Posta, Alex Monk, Sam, Antoine, Oliver

Agenda

- Updates
- Drone and car tests
- Launch Operations

Progress since last meeting

Antoine:

- 3D printed the model of the drone support
- Got the data off the wind tunnel in France
  - Stationary canards with different angles of attack (from 0 degrees to 15 degrees)
  - Increase the wind speeds by increments of 5m/s up to 40m/s
- Redesigned the transmission system of the Aptos module; currently the canards are not attached properly to the servos

Alex Monk:

- Telemetry is not ideal; mostly working in the past as it transmits data; but frequency shifts every time when you turn it on
  - The oscillator was 4MHz instead of 40Mhz
  - A new oscillator was fit, registers are read correctly, but still does not get the frequency right => prob because the voltage input is not stable enough (it is not stable from Teensy/Power Supply/AAA Batteries), you get a drop in voltage when the current is drawn for the transmission => get a circuit to speed up the voltage set
    - Order a voltage regulator and some regulators

Sam:

- Look into Kalman filter between accelerometer and gyroscope to stop the gyro drift in midflight. Keep this for his report

Oliver:

- Further developed the servo driver; got the input as millidegrees
- Initial orientation of the board is worked out using the accelerometer; therefore, board can be initialized on the pad rather than ground
  - Due to the gyroscope reading; initially gyro was calibrated by lying on flat ground, but we cannot do that on a field.
  - Additionally, when rocket is stationary, remove the gyro drift using the acceleration data (if stationary the acceleration should reveal the orientation of the rocket on pad).
- Currently working on the update of the orientation based on accelerometer
- Try to set the servos to the orientation of the board to see if the Euler angles work, some issue with the char pointer

Alex Posta:

- Check the controller code from C that was translate from MATLAB using the hardware: faced multiple issue with the way in which the data was passed from one function to others; the gyroscope data was not calibrating after a time; the servo deflections were not correct angles; look at the servo transmission mechanism->canards are not attached properly
  - Solve the C pass by reference issues in various functions.
  - Got to the point in which the orientation function outputs some Euler angles and they are passed on the controller to receive servo deflections.
  - The servo deflections react to yaw/pitch but did not conclude whether the output is correct or not.
- Change the frameArray structure to reflect the new sensors.
  - FrameArray contains a maximum of 128 bytes
  - Included the majority of the sensors + Euler angle and rates
  - Need to talk to Ollie to confirm that structure is what is needed; Sam also mentioned two additional variables that he needs

Key notes

- For Antoine, try to get a mathematical equation for the canards; would be extremely beneficial for the controller in the future
- For Alex Monk, get a voltage regulator fitted; regulator arrives tomorrow (Amazon), another one comes on Monday (Mouser)
- Sam: give us a csv file of the Euler angle / rates / velocity / altitude
- Alex Posta: get the velocity out of barometer; change the NAND flash

Issues:

- Servo 1 works as long as you use it with ID 1 instead of 101
- For csv printing, do not use the equal sign; talk further about the NAND Flash storing procedure (Alex Posta + Ollie)
- Extra 96 bits available on the NAND Flash: Sam needs two values for Roll and Pitch
- Alex needs SPI1 (for telemetry) in mode 0
- Canard deflections: bump them to int16 and change the orientation to use the struct instead of the chart; store it in millidegrees

Actions for next meeting

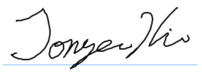
Drone test:

- Try to do a drone test on Wednesday.
    - If system does not look good, do further drone testing the week after the 14th
    - if weather does not improve by Tuesday, decide whether we want to do the launch
- Total payload test: approx. 500g
    - If needed; fly the telemetry assembly separate from the avionics

Tuesday meeting:

- 6:30pm Tuesday; decide what to do this week.

Supervisor signature



Meeting number: 24	**Date**: 19/04/2024	**Attendance**: Oliver, Antoine, Alex Posta

Agenda

- Updates
- Report structure
- Split sections to write for group report
- Next week plan

Progress since last meeting

All:

- **We launched a rocket!!!**
- Attempt a drone test, unsuccessful

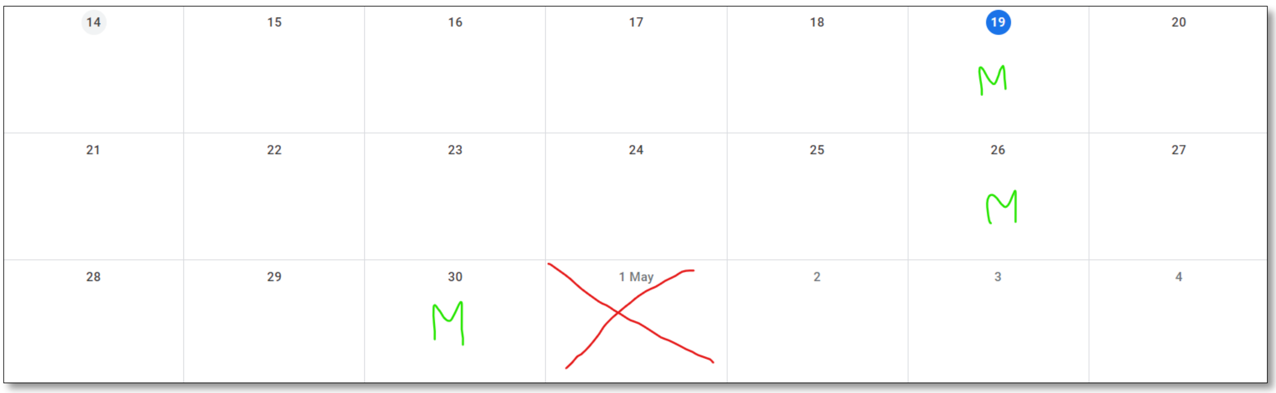
Oliver + Alex Posta:

- Eliminated gyro drift using accelerometer data
- Get the LQR to work when board was setup on the table and then reorientate axis of gyro for vertical velocity
- Optimise code running to get the main at 100Hz and faster
- Redesign flight loop: add buzzers, LEDs, trigger between flight stages slightly differently to make them more consistent
- Update vertical velocity calculation and check for landing using gyro data
- Vacuum chamber testing
- Get data off Flight computer after launch
- Change db and web structure to reflect the new frameArray

Antoine:

- Printed the PCB mount
- Reprint the servo mount, test fit and assembly
- Added slots for bushings and glued them in place
- Ran OpenRocket Simulations with the new weighted parts
- Look at mathematical model of the canards
- Looked at the wind tunnel data

Key notes

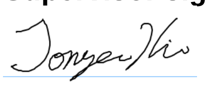


- Less than 2 weeks to submit
- See group word document for section splits
- Do final tests on Monday: run another vacuum test, try to do a drone test. Telemetry?
- Meet on Wednesday, the 24th, to check first draft of all sections for group report; meet at 2pm
- Late long meeting on the 30th of April to submit the group report

Actions for next meeting

- Write report

Supervisor signature



Meeting number: 25	**Date**: 26/04/2024	**Attendance**: Oliver, Antoine, Alex Posta, Alex Monk, Sam

Agenda

- Updates
- Check meeting log
- Report
- Website/LinkedIn

Progress since last meeting

All:

- Work on report

Alex Monk:

- Two more iterations of the transceiver board; amazon oscillator did not oscillate at the correct rate; had to resolder new ones
  - Connect reset pins to incorrect voltage, resolder new board
  - Board goes into transmit mode, regulators work, does calibration and power amplifier
  - Antennas are printers, run tests

Ollie:

- Did a drone test and looked at results, had multiple issues: barometer is affected by prop wash, accelerometer and gyro faced too many vibrations; would be worth adding extra filters
- Found a prone app that works at 100Hz that does accelerometer, gyro and orientation (does quaternions into Euler, exactly as us); match the phone test to the flight computer: Sensor Logger

Alex Posta

- Small test bench for the database ingestion rate

Key notes

- Look through meeting logs and send them for checking

Actions for next meeting

-

Supervisor signature