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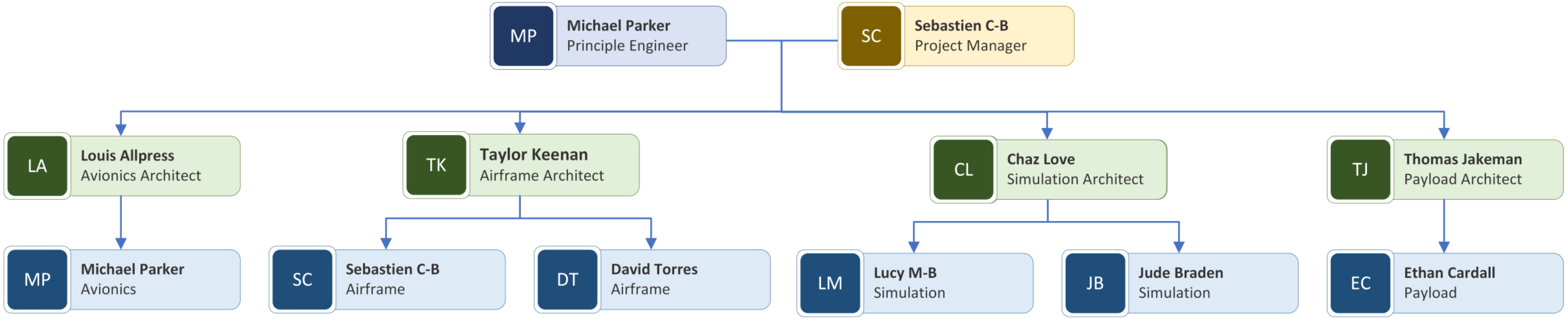
Initial Product proposal

Group 4 – The Quad-Morants

Team Structure



Problem Statement

- **What is the problem? -** Dr Green, from the School of Environmental Sciences at UOL, would like to obtain data regarding the population of Cormorant nests on Puffin Island, located just off the coast of Anglesey.
- The aim of gathering this data is to answer three questions:
  1. How many cormorant nests are there on Puffin Island in the summer breeding season?
  2. Where are the cormorant nests on Puffin Island?
  3. How does the number of cormorant nests on Puffin Island change during the summer?

- **How will this be achieved? -** A UAV is required which can take pictures with a ground sampling of 0.82 pixel/cm at a distance of 30m. The vehicle must be waterproof and easy to fly

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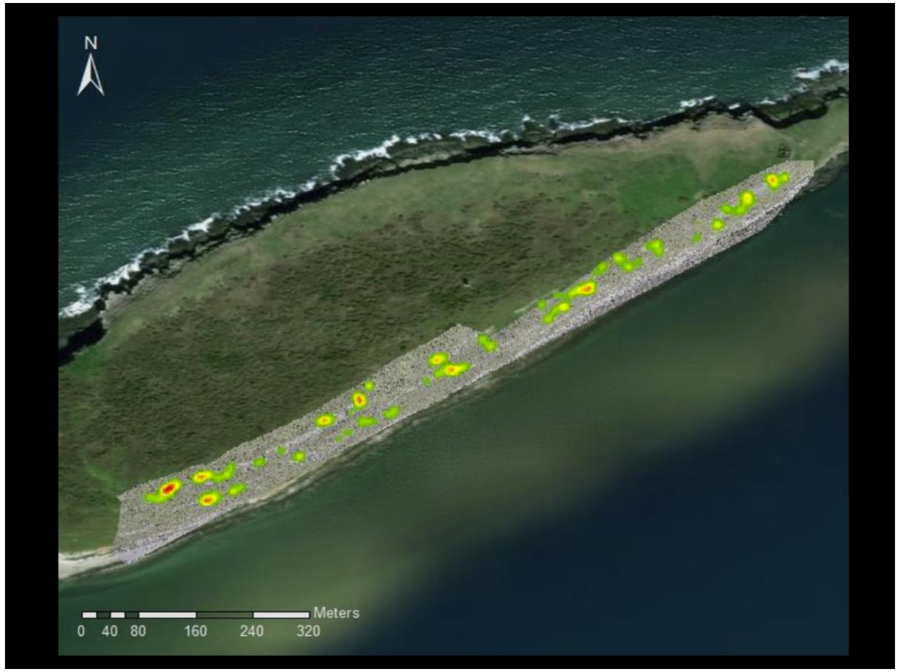
Previous Work



First Attempt with BBC (2018):

- Used a DJI Inspire 1 with a 15mm lens
- 30m altitude
- 830 images with around a %70 overlap
- GSD of 0.43in/pixel

Not a bad attempt but problematic:

- Poor planning
- Missing areas
- Inconsistent image quality

Other work in the field:

- The Nature Conservancy team of Colorado used drones to map and analyze Cottonwood trees in fire affected areas
- A UAV was used to monitor crocodiles in Nepal, flying 46km at an altitude of 80m along the Babai River

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Key customer Requirements

ID	Requirement
CR.1	The product SHALL be able to capture images of the nesting locations
CR.2	The product WILL be able to capture video recording
CR.3	The product SHALL have a camera angle that accounts for the aspect of the site
CR.4	The products camera SHOULD have a GSD of ~0.82cm/pixel
CR.5	The product SHALL be collapsible/ packable
CR.6	The product SHALL be water resistant
CR.7	The product SHOULD come with free software
CR.8	The development and final product SHALL not exceed the budget of £800

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Quadcopter v Fixed-Wing

	Advantages	Disadvantages
Quadcopter	• Easier to control • More stable for recon (clearer photos) • More compact for transportation • Easier for gimble attachment	• Susceptible to wind disturbances • Requires more power • Shorter flight periods
Fixed Wing	• Greater endurance and speed • Longer flight times • Quieter • Higher payload	• Needs take-off distance • More expensive • Harder to land

We opted for a quadcopter design as the advantages of this are more suited to our requirements.

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Take-Off Location

Location 1: Puffin Island

Benefits:
- Increased flight Range
- Centralised take-off location
- Less restricted operating requirements (visual line of sight)
- Reduced risk of incidents whilst operating drone

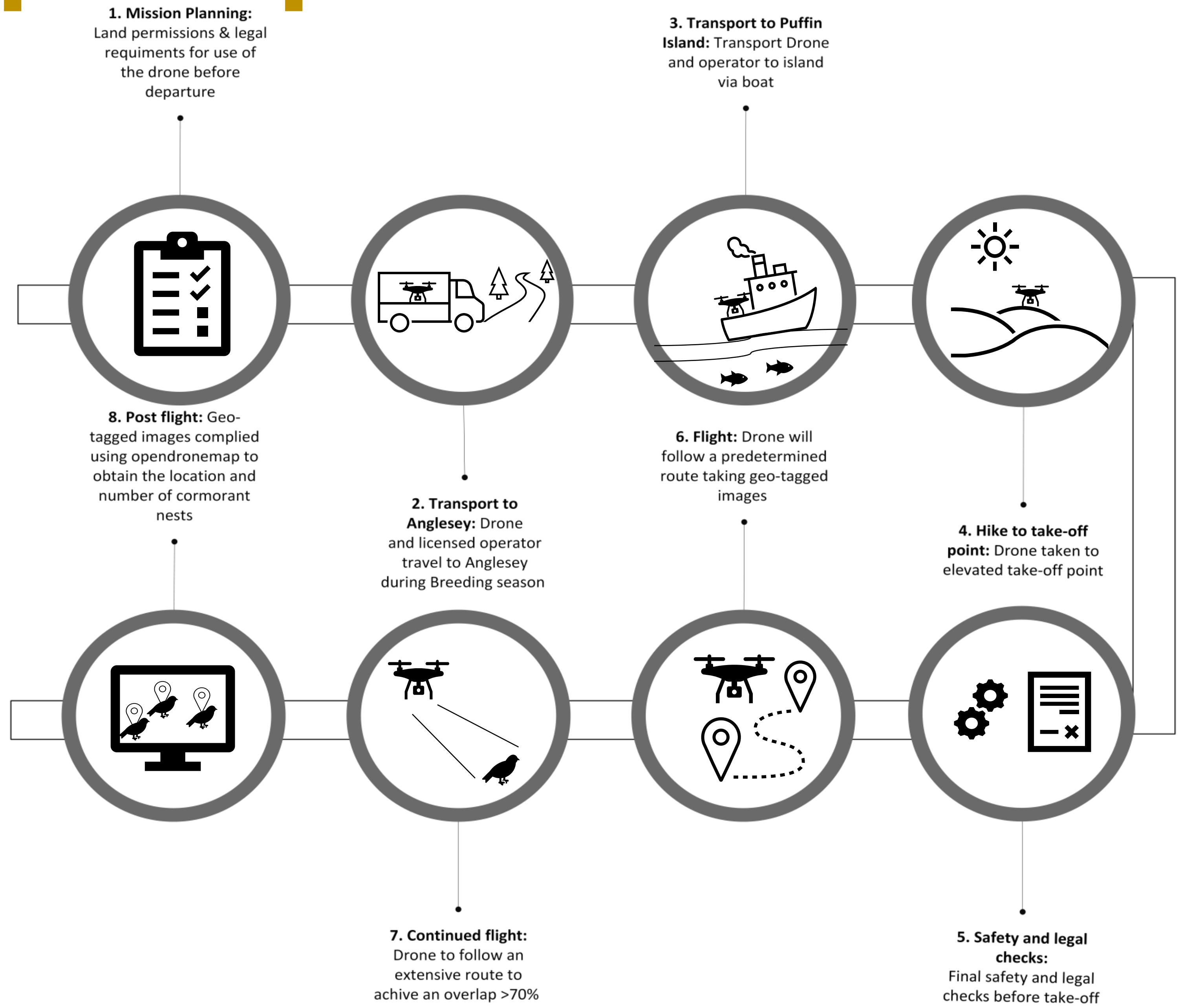
Concerns:
- Makes operations more complex
- Increased risk to persons and wildlife

Location 2: Anglesey

Benefits:
- Less complex operations
- Reduced risk to persons and wildlife

Concerns:
- More restrictive operating requirements (loss of visual line of sight)
- Increased risk whilst operating drone over water/ wind resistance
- Additional flight range needed to complete same level of coverage compared to puffin island launch.

Concept of Operations – Puffin Island Launch



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Avionics

Control

- **Flight Controller:** Pixhawk 4 with Autopilot and GPS Module
- **RF Transmission:** Frsky Receiver, 433MHz Telemetry Radio Kit (2 Radio Modules and 2 Aerials)

Software

- ArduPilot
- QGround Control
- OpenDrone Map

Powerplant

- **Propulsion:** T-Motor MN3508 KV700, fitted with 12x4 polymer propeller blades, producing a manufacturer stated 1360g of thrust each.
- **Speed Controller:** Turnigy MultiStar 30A ESC 2~4s
- **Power Distribution Board:** Holybro PM07 5V 3A output 15V input
- **Battery:** Spektrum 5000mAH 30C Battery

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Airframe

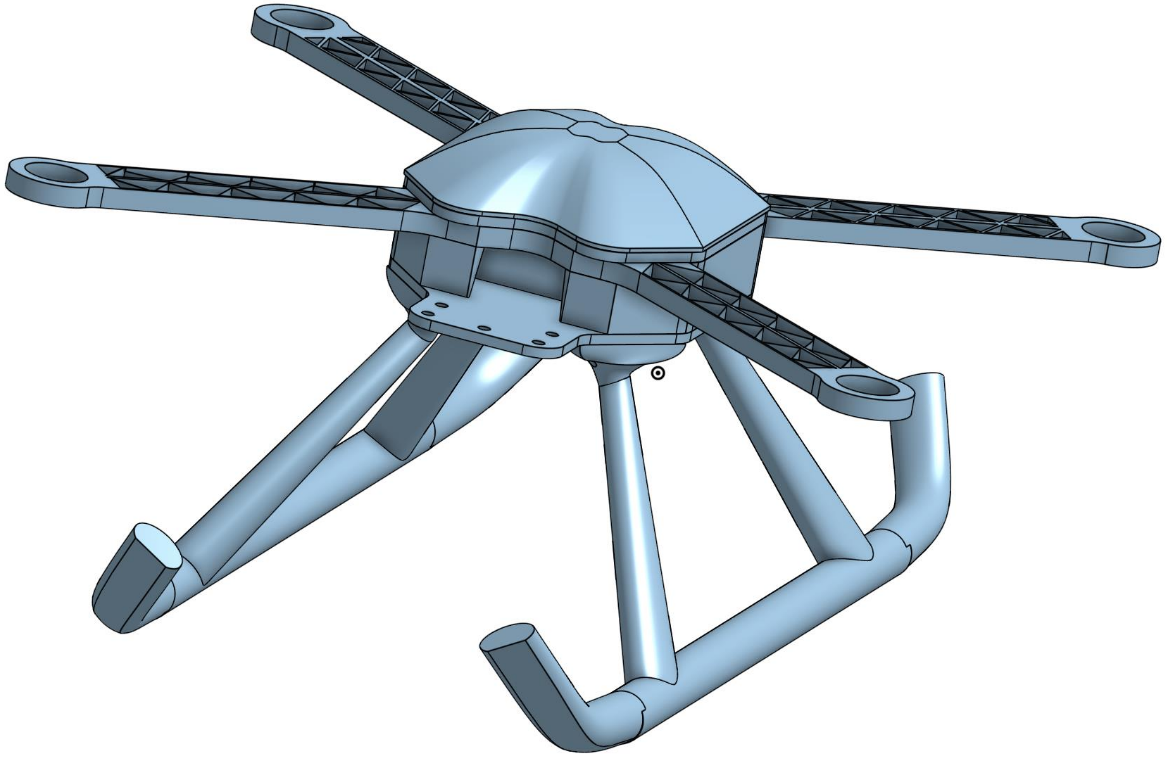
Main Requirements:
- Lightweight.
- Simple and compact.
- Airframe must withstand loads without failure.
- Provide capacity for mission equipment such as payload and avionics.
- Water Resistant.

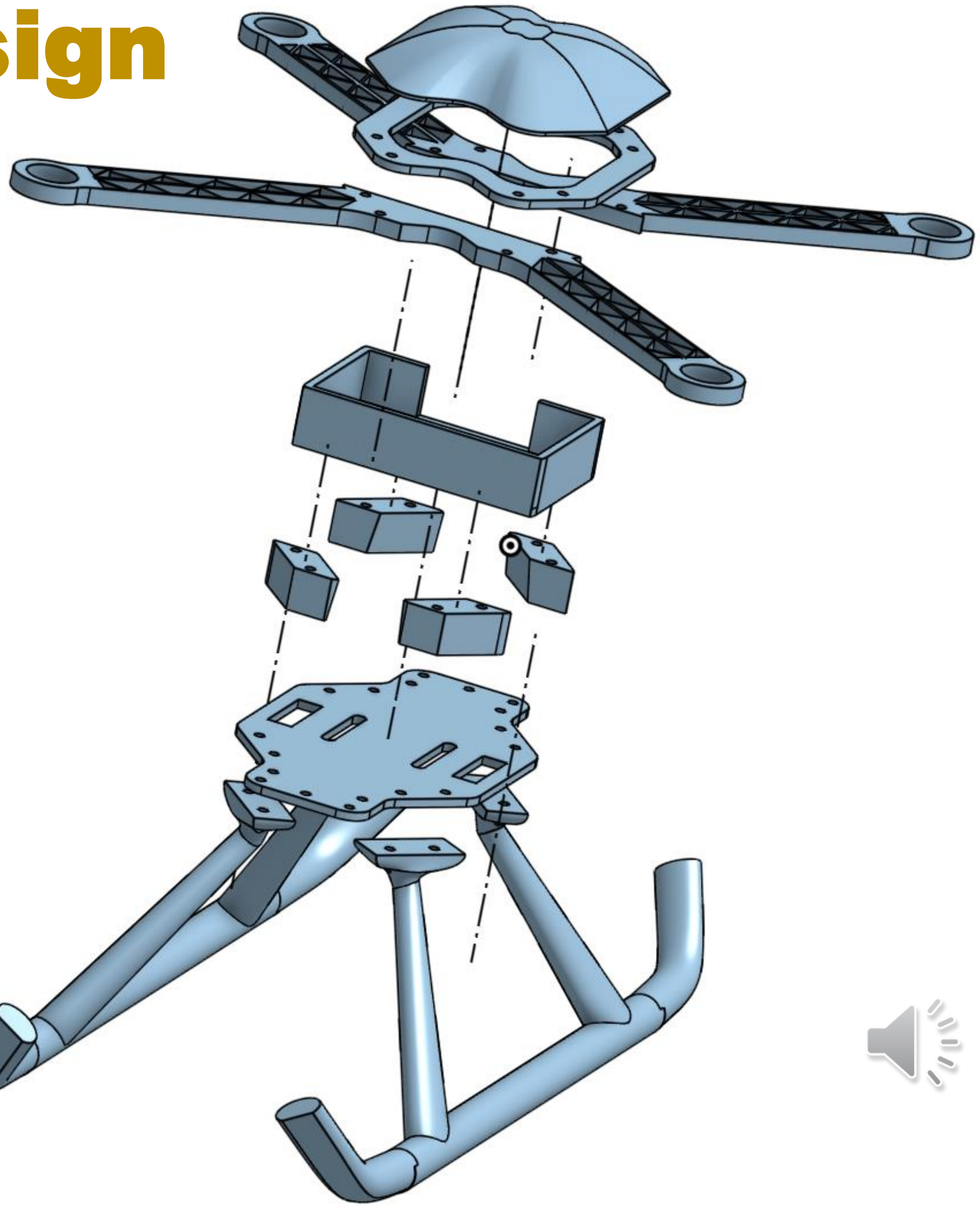
In early design stages, we must determine:
- The required flight envelope for mission.
- The load-bearing capacities of each component.
- A plan to minimize vibrations to maintain image quality.
- Consider environmental conditions for mission.

Airframe Concept:
- Water-tight Hub connecting motor arms and housing core electronics and payload.
- Hub must be light, and weight evenly distributed for stability.
- Motor arms hold the DC motors and propellers which generate lift.
- Arms must be strong and durable.
- Landing rails provide positioning and clearance for camera.
- Landing rails must absorb landing impact.

Requirement ID	Description
LR.3	The maximum take-off mass MUST be less than 25kg.
CR.3	The product SHALL have a camera angle that accounts for the aspect of the site.
CR.5	The product SHALL be collapsible/packable.
CR.6	The product SHALL be water resistant.
DR.1	The motor arms SHALL withstand bending moments by a factor of safety of 1.5x the ultimate tensile strength.

Airframe Conceptual Design





Airframe Design

We must evaluate several components and their function, the materials and the rationale for their use, the manufacturing method for each component and a detailed plan of the building process.

The Hub

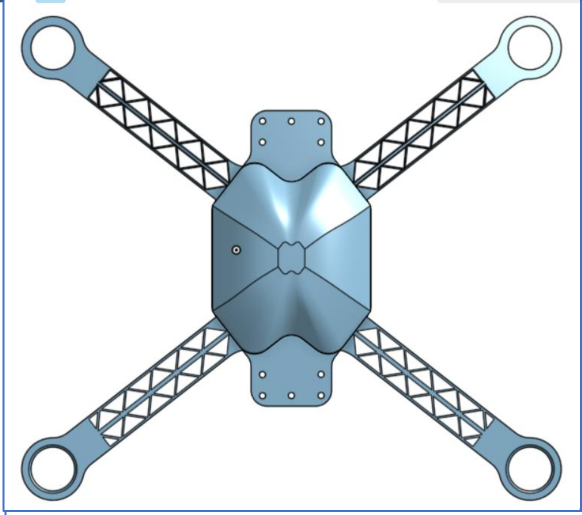
- Consisting of two robust carbon fibre plates & acrylic box to accommodate the avionics internally.
- External mounting point to attach the gimbal underneath the drone.
- Hub must withstand torsional and bending loads from motor arms.
- 3D printed dome to seal internal payload.

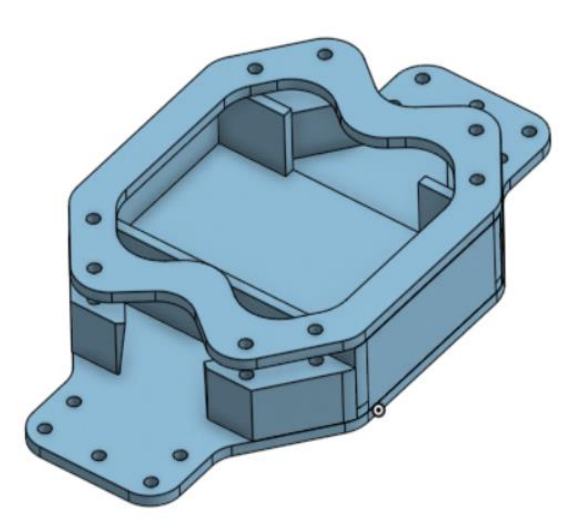
Motor Arm

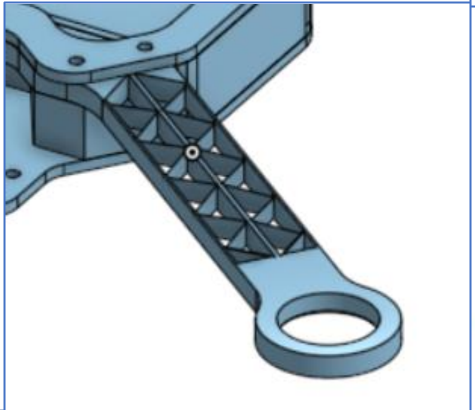
- Carbon fibre truss configuration allowing reduced weight without compromising structural integrity.
- Motor produces bending moments and motor arm must resist bending loads.
- Prevent exposure of wiring to water.
- Current model doesn't include foldable arms, in process of adding a horizontal hinge to make the Quad-morant portable.

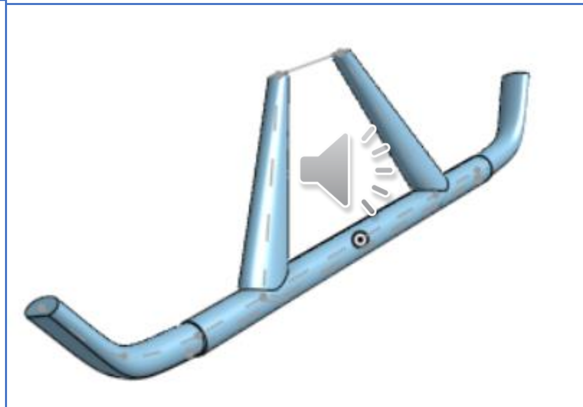
Landing legs

- Experience mainly axial loads from landing impulse.
- Rail configuration which distributes landing impact over larger area and reducing risk of tipping.

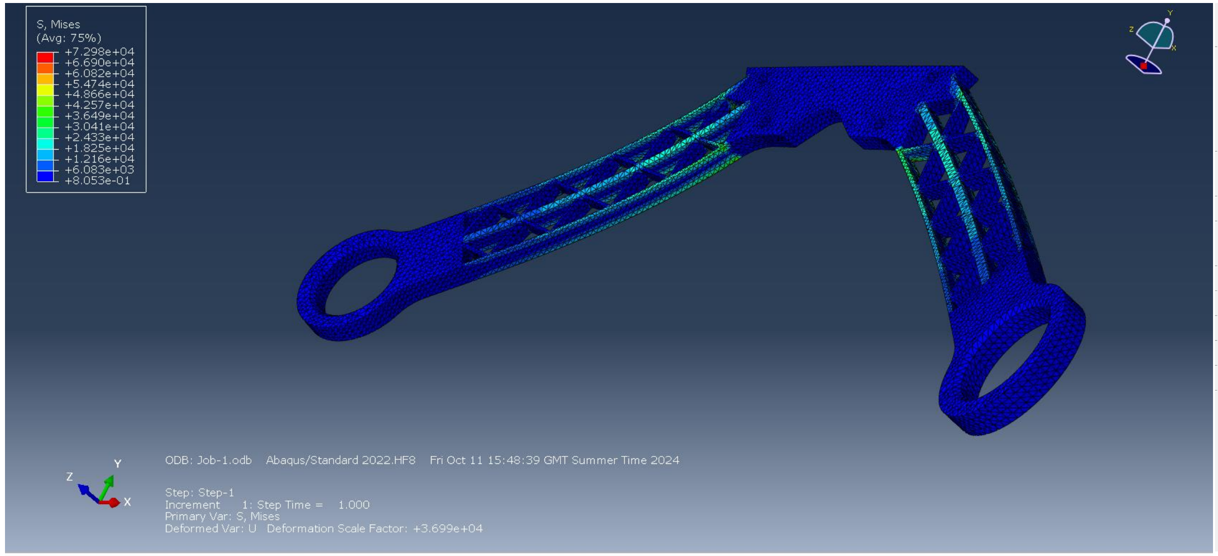


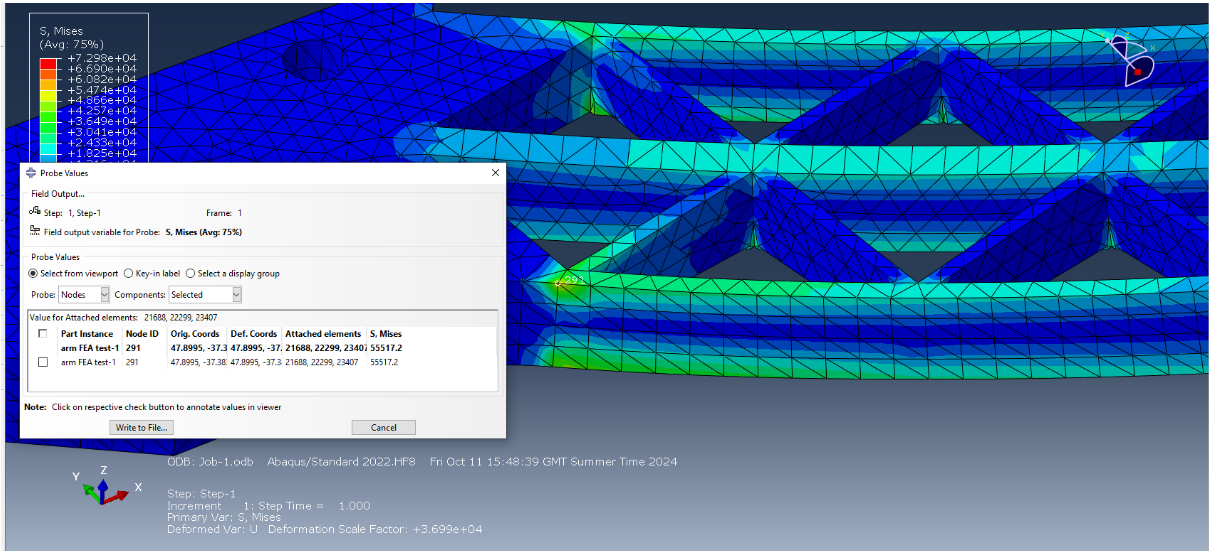






Test Finite Element Analysis





We have liaised with a member of the workshop team to enquire about manufacturing techniques. The Arms can be manufactured several ways. Whether its water jet cut or milled (if its aluminium)

For this test, the chosen material was aluminium 6061. For preliminary testing in future. The Elastic limit and yield limit of the material is needed to measure the loading required to plastically deform and break the arms.

Material	Mass Dens [kg/m3]	Youngs Modulus [MPa]	Poissons ratio
PVC	1300-1450	2.4-4.1	0.4
CFRP	1600	69-150	0.15
Aluminium 6061	2500-2900	68-82	0.334
Stainless steel	7600-8100	190-210	0.27-0.31

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Initial Weight Estimation

For the initial weight estimation it was taking into account different quadcopter masses from similar type of mission to have an idea of the challenges that could be affecting our project in terms of weight.

The weights of similar quadcopters were in a range from 0.7 kilos up to more than 20 kilos depending on different devices and sizes that compose:

-Airframe
-Avionics
-Payload

For the project, the requirements needed to be met for the Initial Weight Estimation are:

Requirement ID	Description
LR.3	The maximum take-off mass MUST be less than 20kg

Initial Weight Estimation

In the case of *Quad Morants*, the initial weight takes into consideration the research of the different essential parts carried out by each team (Airframe, Avionics and Payload) to develop an estimation:

	Parts	Weight (g)
Avionics	Brain (Pixhawk 4/ w gps)	50
	Power distribution board (PM07)	36
	Motor brushless (x4) (T-Motor MN 3508 KV 700)	400
	Motor blades (x4) (T-Motor 12inch)	60
	ESC (x4) (30A)	120
	Receiver (FRsky)	15
Payload	Camera (Sony Alpha a5000)	269
	Gimble	350
Battery		700
Empty	Airframe	1553.55
Total Weight		3553.55

Weight estimation of the different components of the quadcopter

Simulation

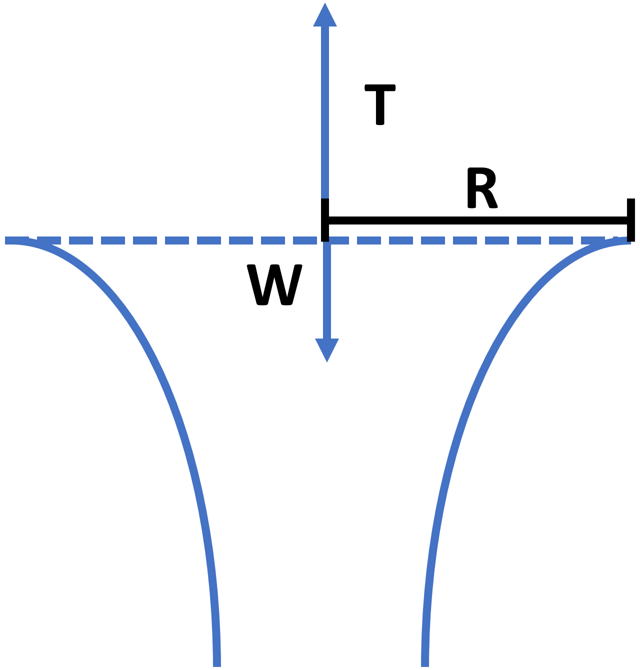
Why use simulation?

- Cost and time effectiveness
- Accurate numerical results
- Sustainability

MATLAB	SIMULINK
Estimates of thrust and power required from the initial mass	Allows simulation of the 4 rotors rather than the 1 from momentum theory
To analyse data outputted from Simulink in a timely and neat manner	Allows rotors to be accurately tuned (PID controllers)
	Stability can be modelled and tested (add wind disturbances into simulation)

Initial Momentum Theory

Total Weight (N)	Total Thrust (N)	Factor of Safety
35	73	$\frac{73}{35} = 2$



Assumptions:

- Figure of Merit = 0.6
- ISA Sea Level Density = 1.225 kg/m^3

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Payload - Camera

Resources Provided
- Sony α5000 and SELP 1650 Lens
- Battery and Media

Requirements
- 70% image overlap
- Resolution: Suggested approximately 0.82cm/pixel
- Recording Height of 30 meters

Ground Sampling Distance (GSD):

Dependent Values:
- Flight Height – 30m
- Sensor Width – 23.2mm
- Focal Length – 50 mm
- Image width – 5456 pixels

Sony α5000 SELP 1650 Lens Specification

Part	Specification
Sensor Size	23.2 x 15.4 mm
Number of effective pixels	20.1 MP
Number of total pixels	20.4 MP
Approximate Image Resolution	5456 x 3632
Focal Length	50 mm
Size	109.6 x 62.8 x 35.7 mm
Total Weight	385 g
Battery Life	420 Shots or 150-minute continuous recording (Approximate)

$$GSD = \frac{Flight\ Height\ * Sensor\ Height}{Focal\ Length\ * Image\ Width} = 0.255\ cm/pixel$$

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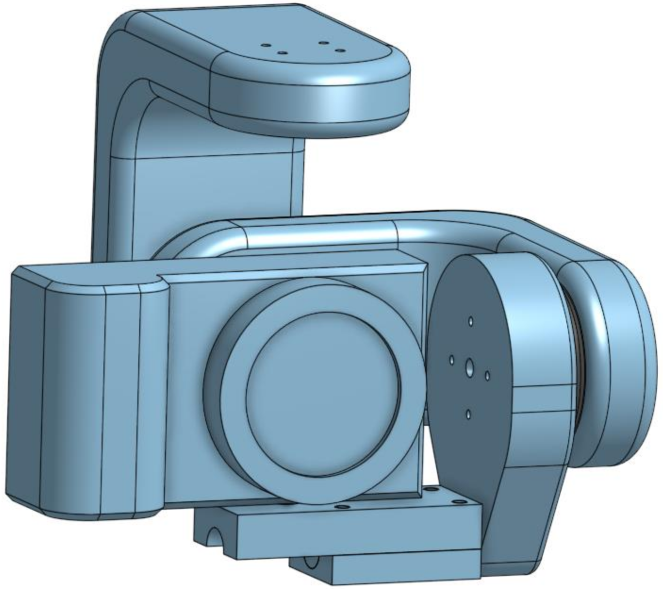
Payload - Gimbal

Type	Advantages	Disadvantages
No Gimbal	Reduces costs significantly	Fixed camera position Unstable camera during flight
2 Axis	Light Not as expensive as 3 axis Stable photos when in forward flight	Unstable footage when drone is moving from left to right (no yaw axis for camera)
3 Axis	Most stable option for camera to obtain footage	Expensive Heaviest option



Based on the table, we have opted for the 2 Axis gimbal as it minimizes weight and costs, while still providing the ability for stable footage/ images in the pitch and roll axis.

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Verification Cross Reference Matrix

ID	Requirement Description	Responsibility	Verification Method						Success Criteria
			I	R	S	D	PT	FT	
Legal Requirements									
LR.1	The product MUST not fly beneath 30m minimum altitude from puffin island	Simulation, Avionics	x						Fences have been setup for the products flight plan to stop the drone from flying outside these bounds.
LR.2	The product MUST not fly above 120m from the closest point to the earths surface (note: this is not just including vertical height)	Simulation, Avionics	x						Fences have been setup for the products flight plan to stop the drone from flying outside these bounds.
LR.3	The maximum take-off mass MUST be less than 20kg	Airframe	x						An inspection will be made prior to flight to make sure weight limits haven't been exceeded
LR.4	Pilot flying MUST maintain Visual line of sight during operation							x	Ensure there's a professional flying the product at all times
LR.5	The product MUST not drop any material during flight	ALL	x						No mechanism included in the design that will allow that to happen
Customer Requirements									
CR.1	The product SHALL be able to capture images nesting locations	Payload, Simulation				x		x	Demonstration will show remote activation of the camera shutter, The file will be saved to a microsd card.
CR.2	The product WILL be able to capture video recording	Payload				x			Demonstration will show remote activation of the recording, The file will be saved to a microsd card.
CR.3	The product SHALL have a camera angle that accounts for the aspect of the site	Payload, Airframe		x		x			The review and the demonstration will show a clear aspect with no obstructions to the view
CR.4	The products camera SHOULD have a GSD of ~0.82cm/pixel	Payload			x			x	Pixels will be counted on a test target at 30 meters away using the camera to see if the resolution will meet 0.82cm/pixel.
CR.5	The product SHALL be collapsible/ packable	Airframe							The drone will be have collapsing arms and fit in the boot of a typical sudan
CR.6	The product SHALL be water resistant	Airframe					x		Water submergence test will be carried out with the structure without the avionics inside. A dummy payload will be inside to test saturation.
CR.7	The product SHOULD come with free software	Avionics				x			A demonstration will display the free software in use
CR.8	The development and final product SHALL not exceed the budget of £800	ALL	x						A Budget breakdown and analysis will pass gate review phases across project completion. Along with a final inspection before FTRR
Design Requirements									
DR.1	Motor arms SHALL withstand bending moments by a factor of safety of 1.5x the Ultimate tensile strength	Airframe			x		x		Motor arm deflection test will validate finite element test results on von mises criteria.

Initial Work Breakdown structure

ID	type	At Risk?	Description	Assigned to	Duration	Week	Status	Sign Off
1	Milestone	No	**Conceptual Design**	All	**28 Days**		In Progress	
1.1	Task	No	Backround research	All	1 Day	S1, Week 1	In Progress	
1.2	Task	No	Team Role Selection	All	1 Day	S1, Week 1	Complete	Michael Parker
1.3	Task	No	Requirements Breakdown	All	3 Days	S1, Week 2	Complete	Michael Parker
1.4	Task	No	Platform Selection	All	1 Day	S1, Week 2	Complete	Michael Parker
1.5	Task	Yes	Avionic selection	Louis Allpress	5 Days	S1, Week 2	Complete	Michael Parker
1.6	Task	No	Airframe CAD Concept formulation	Taylor Keenan	9 Days	S1, Week 3	Complete	Michael Parker
1.7	Task	No	Gimbal CAD Conceptual Design Formulation	Thomas Jakeman	9 Days	S1, Week 3	Complete	Michael Parker
1.8	Task	No	Materials research	Sebastien C-B	2 Days	S1, Week 3	Complete	Michael Parker
1.9	Task	No	Material Selection	Taylor Keenan	<1 Day	S1, Week 3	Complete	Michael Parker
1.1	Task	No	Initial Finite element Analysis	Sebastien C-B	2 Days	S1, Week 3	Complete	Michael Parker
1.11	Task	No	Initial Momentum Theory	Chaz Love	4 Days	S1, Week 3	Complete	Michael Parker
1.12	Task	Yes	Budget set	Michael Parker	1 Day	S1, Week 3	Complete	Michael Parker
1.13	Task	No	IPP Presentation	All	12 Days	S1, Week 4	incomplete	
1.14	Milestone	No	IPP Gate Review	All	NA	S1, Week 4	incomplete	
1.15	Task	No	IPP Report	All	7 Days	S1, Week 5	incomplete	
2	Milestone	No	**Preliminary Design**	All	**22 Days**		incomplete	
2.1	Task	Yes	First Propellar Thrust Test	Louis Allpress	<1 Day	S1, Week 4	incomplete	
2.2	Task	Yes	Part order form sent out	Sebastien C-B	1 Day	S1, Week 6	incomplete	
2.3	Task	Yes	Motor Arm Deflection Test	Taylor Keenan	<1 Day	S1, Week 9	incomplete	
3	Milestone	No	**Detail Design**	All	**27 Days**		incomplete	
3.1	Task	No	Sony a5000 camera Inspection	Michael Parker	<1 Day	S1, Week 10	incomplete	
3.2	Task	No	FDR Presentation	All	35 Days	S1, Week 11	incomplete	
3.3	Milestone	No	FDR Gate Review	All	NA	S1, Week 11	incomplete	
3.4	Task	No	FDR Report	All	7 Days	S1, Week 12	incomplete	
4	Milestone	Yes	**Production**	All	**56 Days**		incomplete	
4.1	Task	Yes	PID Control Tune Test	Louis Allpress	<1 Day	S2, Week 3	incomplete	
4.2	Task	No	Ardupilot flight plan inspection	Michael Parker	<1 Day	S2, Week 6	incomplete	
4.3	Task	Yes	Platform GSD Test	Thomas Jakeman	2 Days	S2, Week 7	incomplete	
4.4	Task	No	Final Spending Inspection	Sebastien C-B	<1 Day	S2, Week 8	incomplete	
4.5	Task	No	Final Platform Weight Inspection	Michael Parker	<1 Day	S2, Week 8	incomplete	
4.6	Task	No	FTRR Presentation	All	63 Days	S2, Week 9	incomplete	
4.7	Milestone	No	FTRR Gate Review	All	NA	S2, Week 10	incomplete	
4.8	Task	No	FTRR Report	All	7 Days	S2, Week 11	incomplete	
4.9	Task	Yes	Camera Angle and control Demonstration	Thomas Jakeman	1 Day	S2, Week 11	incomplete	
5	Milestone	Yes	**Flight Test Evaluation**	All	NA	S2, Week 12	incomplete	

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Budget

Total Budget

Component	Quantity	Cost (£)
Pixhawk 4 & Power Management Module & GPS	1	151.00
FRSky S8R Receiver	1	30.95
30A ESC	4	65.00
T-Motor 12x4 Blades	2	65.00
Sony A5100 w/16-50mm Lens	1	399.99
5000mAH Battery 30C	1	50.00
airframe	1	100 (estimate)
3D Printed Gimbal and 2 Motors	1	£100 (Estimate)
Total Cost		£861.94

Total Budget With University discount

Component	Quantity	Cost (£)
Pixhawk 4 & Power Management Module & GPS	1	37.75
~~FRSky S8R Receiver~~	~~1~~	~~30.95~~
30A ESC	4	65.00
T-Motor 12x4 Blades	2	65.00
~~Sony A5100 w/16-50mm Lens~~	~~1~~	~~399.99~~
5000mAH Battery 30C	1	50.00
airframe	1	100 (estimate)
3D Printed Gimbal and 2 Motors	1	£100 (Estimate)
Total Cost		£317.75

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Mitigating Risks

ID	Date raised	Risk Description	Probability	Impact	Severity	Mitigation	Contingency plan	Signed off by
1.1	11/10/2024	Illness of team member	7	3	21	following the WHO guidelines	Redistribute workloads across the whole team to fill in for an ill team mate	Michael Parker
1.2	11/10/2024	Team member Injury	1	4	4	Team members to take care during physical activity	Redistribute the workloads of the affected member	Michael Parker
1.3	11/10/2024	Mentor weekly inavailability	6	2	12	Before scheduled meeting, ensure staff availabilty	arrange for alternate schedule for the affected weeks.	Michael Parker
1.4	11/10/2024	Team member timetable clash	2	3	6	Regularly check calenders	Fill out a progree report for that week and all others	Michael Parker
1.5	11/10/2024	Part Manufacturing error	6	8	48	Order the Parts early.	Reorder the parts or think of alternative solutions to the problem.	Michael Parker
1.6	11/10/2024	Project files save Corruption/overwrite	4	10	40	Have muliple backups of main repository	GitHub has a feature to recover deleted files.	Michael Parker
1.7	12/10/2024	HHTC room availability	6	6	36	leave plenty of University working days to complete the tasks	Use Abaqus Student edition and to a limited 1D beam analysis instead.	Michael Parker
1.8	12/10/2024	3D Printing Availability	8	4	32	Get required 3D printing CAD drawings completed early	Syndey Jones and Harold Cohen On-Campus Libraries offer alternative 3D printers.	Michael Parker
1.9	12/10/2024	Lipo battery explodes	5	10	50	Discharge the Battery to resting charge, place in sandbag	Arrange for a back up Lipo for the TFE .	Michael Parker

Thank You for listening!