Appendix A: Project Proposal Form

Team letter:	Y	Name of person elected as team leader:	Peter Xuanuan Chai

Responsibilities

Lab pair no.	Name	Design responsibility
A1	**Peter Chai**	**Team leader, administration work, RF transmitter, wifi live camera link.**
	Adrian Wilzcynski	**PID control on master Arduino, I2C interface between arduinos.**
I25	**Nabeel Kabour**	**Bluetooth interfacing with comms Arduino, RF receiver design and implementation, automation for wall detection.**
I26	**Lewis Smith**	**RF transmitter design, Bluetooth testing, administration work.**
D11	**Brittanny Barrett**	**Frame design and construction, electronic integration with chassis.**
F18	**Robert Cockell**	**Automation for landing and altitude detection. Hook design and synthesis.**

Overall Design Summary

We are intending to design a 40cmx40cm, quad rotor, arduino controlled aerial drone.
This design will produce approximately 3.6Kg of maximum thrust, with 4x2300kv motors, 4x25A ESCs, and 6inch propeller blades. Our design is aimed to produce the greated mass lifted to drone mass as possible. With very powerful motors drawing much current, what we may have compromised is a substantial flight time, but it will be enough for several trips.

The drone will feature 2 Arduinos (pro-micro/Nano). One will execute the PID control to the motors, using feedback from the gyroscope and accelerometer on the MPU-6050 module. The other Arduino will manage the communications between our remote control via an RF NRF24L01+ module, and will also send feedback data to the user by using a HC05 Bluetooth module. We can also send controls to the communications Arduino via Bluetooth by using an android app “Bluetooth Electronics” by kewl. The two Arduinos will communicate to each other via an I2C protocol.

As for our design for the frame, it will be 3D printed using PLA plastic in a dual layer form with a mesh in between for additional strength. The electronics will be centred on the drone along with the 3700mAh battery.

The hooking mechanism will be a telescopic lever that drops a metal three pronged hook as the drone takes off.

Additional features may include:
Live video feed, using Rasp-Pi Zero W
Automatic safety protocols using Ultrasound/IR sensors on the sides of the drone to stay away from walls.
Also automatic landing in case of low battery by using ultrasound sensors to detect altitude.

Module Design Proposals

Names of people involved:	Robert Cockell, Adrian Wilzcynski
Title of Module:	Master Control Arduino

The purpose of the control module is to take the commands passed over the communications and pass the correct values to the motors to fulfil the commands. To achieve this, our module will use a PID control loop (Proportional Integral Derivative) to remove the error between the measured values from the on-board instruments (an accelerometer and gyroscope) and the desired values passed over control. The module will be run from an Arduino Nano, because an Arduino Nano is small, light and efficient and cheap.

The control module should have:

- A loop frequency of no less than 250 Hz. This will ensure that the drone control loop will be fast enough to respond to variations while keeping the drone airborne.
- A PID basis. This is because PID control provides faster stabilisation times than P or PD control, and easy to program on the software we are using.
- The ability to hold the quad-copter steady upon receiving the command to do so, and hold steady as long as the command is maintained.
- Physical communication using the I2C protocol with the communications module.
- Feedback from additional devices (a barometer, IR proximity sensors) from which the drone can assume control. For example, should an IR proximity sensor detect a wall in front of the drone, the drone will stop rather than crash into the wall.
- Set commands which allow the drone to perform certain actions automatically, without any more data from the user. For example, under a certain command the drone might land by itself. This, and the previous point, should use a second Arduino to process the data so that the loop frequency is not compromised by the calculations. This second Arduino should be the same one used for communications.

Names of people involved:	Nabeel Kabour
Title of Module:	Communications Arduino

The quad copter is controlled using an android app which uses communicates with a Bluetooth module which sends serial data to an Arduino. Bluetooth was chosen as a communication protocol as it provides simple interface using a mobile app, which is also very customizable, and allows for multiple methods for sending data, and allows for displaying received data in recognizable ways. The baud rate of the Bluetooth communication is 9600, and this is pre-set in the app. The Arduino receives control information in the form of serial data in the form of packets (ex. @LX120Y130!), which are decoded and processed then sent to another Arduino which deals with the stabilization of the quad over I2C. I2C was chosen for the communication between the two Arduinos as it only requires 2 connections, and because the master Arduino (the one used for control) requests the data to be sent from the slave Arduino, which means communication only takes place when necessary. Another motive to use I2C is that the master Arduino communicates with the accelerometer/gyroscope using I2C.

Names of people involved:	Britanny Barrett
Title of Module:	Chassis

For our drone design, a few considerations must be made in regards to the frame that we design. The overall mass must be considered, due to the additional load that the rotors incur when producing thrust. To properly fit with other modules, the mass of the frame must be constrained to a reasonable ratio, and all modules must fall under the maximum thrust to mass ratio. This is the most important consideration to make when building the frame.

The overall dimensions should also be considered, such that stability is offered when regulating the rotor speeds as part of the control system, but that unnecessary space is not taken. If the rotors are too close to one another, small changes in rotor speed may result in destabilization. The overall size of the design should be large enough to encapsulate all parts, and provide stability. It should be no more large, to avoid adding mass to the system.

Strength is another consideration to make. It's expected during the prototyping phase, and during erroneous flight, that the drone may crash land. As a result, the frame could be damaged. There are several methods we can employ to reduce the damage. By having separate modules for the frame, replacement is made much easier when damage does occur. The type of material should also be considered. As we have 3D Printing as an option, PLA will be used in the first instance due to its ease of printing. ABS would be a better option as it is less brittle, and also less dense than PLA.

The overall structure of the drone should be built to fit certain specifications. A mesh type design can be used to remove the unnecessary mass from the drone, without reducing strength between joints. Connection points must be offered to prevent any of the electronics coming loose, due to the forces of acceleration and gravity experienced by the drone. A dual layer body can be used to encapsulate the electronics in the centre of the frame. Rotor cages should be used to avoid potential injury. And the battery must be taken into special consideration in its positioning, as lithium polymer batteries are flammable when subject to sudden damage.

Cost Estimates

Mechanical Parts:
4x EMAX RS2205 2300KV RACESPEC COOLING SERIES MOTOR £51.79
4x 6by4.5 Propellers £2.30

Electronic Parts:
4x CHAOS BLHELI_S DSHOT ESC £27.96
2x Arduino Nano £7.38
1x MPU-6050 £4.99
1x HC05 £4.50
1x NRF24L01+ £1.00
1x RF Transmitter

Up to £2 for wires/other cheap electronic components

Power:
1x 3700mAh 3S 25C LiPo Battery £19.99

Frame:
1x PLA Drone Chassis £5
1x Hook mechanism £1

Human Resources:
6x 50hrs of developing testing etc £22,500
work force constructing £20/hour

Other costs:
Conformance testing £2000
Repair/service/rent etc £100k

Hardware cost of 1 Unit: £127.91

External Costs: £124,500 (human resource + other cost)

Say it takes 0.1hrs to manufacturer a unit (assuming made in bulk). So we have £2 labour costs per unit made.

Thus ***total cost of 1 unit will be £129.91***. We will set the ***market price to be £190***.

Profit margin per unit is £60.09.

We would need to sell about ***<u>2,071 units</u>*** to be able to make a profit if we divide the external costs by the profit per unit.

However, when actually manufacturing, we will use wholesale components and perhaps hire a manufacturer to produce it for us. With the incurred costs of hiring a manufacturer for mass production but much cheaper components and materials, we would estimate the cost of 1 drone to be about £50. If we sell that at a lower price per unit, say £150, we will only need to sell 1,245 units to be profitable. Because of the lower selling price, we can sell a larger quantity more rapidly, helping us produce a profit in a much shorter time.

Prototyping and Construction Method

When constructing the prototype drone, we must complete a number of tasks in order to test a fully working unit. Generally, each of the separate modules must be tested individually before being brought into the main build.

We will build a frame consisting of four main arms and a body, using a 3D printer to construct each of the elements. The electronics will be housed in the body, and the motors for the propellers will be on the end of each arm. The frame itself is relatively arbitrary for testing. Once we are certain that the electronics are adequately held in place, we can complete the building of the entire frame.

Electronic components are available in modules where available, such as the Control Arduino. This allows prototyping to be completed more easily, as there is no need to design our own circuit boards. However, there are some aspects of circuitry that can't be made with simple interlink between modules. These parts will be attached to perfboard, which will allow for fast construction of electronics, and debugging during the construction phase.

When testing the stabilizing behaviour of the drone, tests will be completed on each of the units that contribute to working rotor function before being integrated into the build. First, the gyroscope/accelerometer will be tested with the Arduino in order to verify that the two modules are communicating. By moving the sensors about, we can verify that the data is behaving correctly. The Arduino can then be connected to electronic speed controllers, which will regulate the speed of the motors/propellers. Code will then be implemented that allows the feedback of the gyroscope to modulate the motor speed. The propellers will be held down to the workbench at this point, as they should be safely tested before being implemented into the frame. Once we have verified that the motors compensate for the position of the gyroscope, we can consider the system complete, pending stabilization testing.

We are then able to connect the second Arduino, which handles the Bluetooth communications. After uploading the code and connecting this Arduino into the circuit, we can test whether commands we send are capable of changing the motor speeds as expected.

We can then integrate the electronics into the frame itself. This will allow us to test whether or not the drone can be kept stable. By carefully holding on to the drone at a height, and slowly letting it go while monitoring its behaviour, we can ensure that the drone is able to stabilize itself. At this point, we can experiment with software values for the PID to achieve re-stability from multiple angles of orientation.

Once stability is reached, still carefully monitoring the drone, we will send commands through Bluetooth to slowly move the drone. This will finally ensure that our drone works to specification. We can then move on to testing the behaviour when a weight is being carried by the drone.

Planned Project Activities

Please list the activities that you intend taking place during your laboratory time, and indicate when they should occur, and who will do them. The 'Initials' column must specify only one person. If two people a

Activity	Initial	Fri AM	Fri PM	Mon AM	Mon PM	Tues	Wed	Thurs	Fri AM	Fri PM	Mon AM	Mon PM
PID Control Development. Writing and uploading programs to the control arduino and testing it with a simple micro-server	AW											
Bluetooth communication design and testing. Sending byte packets to and from arduino.	NK											
Frame design/manufacture. 3D design the chassis using CAD, then 3D print it. Then assembly the parts into a complete chassis	BB											
Work on hook design and synthesis. Test hook designs and find ways to fit onto chassis. Fix hook onto chassis.	RC											
RF transmitter synthesis	XC											
RF transmitter design	LS											
RF reciever design and synthesis	NK											
Develop Automation Code for altitude sensing	RC											
Develop Automation Code for a wall sensing	NK											
Automation coding implemented onto control arduino	NK											
Interfacing control and comms module	AW											
Fix mechanical parts onto chassis	XC											
Assembling all electronics onto chassis	BB											
Test, tune and refuel drone until successfully accomplishing milestones.	AW											
Design and implement wifi camera streaming with RPI	XC											
Final trail run with various weights	All											

Risk Management

Hazard	Severity	Likelihood	Risk	Control	Control Severity	Control Likelihood	Control Risk
Risk of hot solder/soldering iron causing burns	3	3	9	Wear eye protection, turn off and put in stand when not in use.	2	2	4
Harmful soldering fumes	2	3	6	Use a fan when soldering	2	1	2
Propellor blade injury	2	2	4	Use protective perimeter around blades in design	2	1	2
Drone flying into you	4	4	16	Stand behind protective netting when testing drone	4	1	4
Short circuiting components	2	3	6	No liquids near drone. Follow ESD handling guidelines	1	2	2
Compenents are damanged/broken through misuse	3	4	12	Comply with ESD handling guidelines. Confirm correct wiring with datasheet before apply power. Order spare compenents.	2	2	4
Insufficiently secured compnents falling off drone during flight	3	3	9	Make sure all components are secured onto drone by tape, glue or screws.	3	2	6
Hot glue gun misuse	4	3	12	Make sure to leave glue gun in stand when not in use.	3	2	6

Team member	**I have read the Risk Assessment form and I agree to the described operating proceedure**
Peter Xuanyuan Chai	
Adrian Wilzcynski	
Britanny Barrett	
Nabeel Kabour	
Lewis Smith	
Robert Cockell	

Appendix D: Design Completion Form

To be completed by the lab supervisor during the time in the lab to record milestones. ***This form is an example and you MUST edit it to identify your own milestones*** *(10-15) that you will attempt to meet during the progression of your design. Think about MILESTONES (what you'll show/deliver) rather than TASKS (what you'll do). You should aim to have a few milestones per subsystem (which probably build on each other), plus a couple of system milestones reflecting system integration. A single copy of this form should be printed, on one sheet of Landscape A4 paper, and brought to each lab session. It will be finalised by 17:00, on Monday 13th March.*

Component of system/Milestone	Supervisor	Time/Date	Comments (all/part/none working; protoboard/constructed)
Bluetooth modules interfaced with arduino			
MPU-6050 gyroscope and accelerometer data received on arduino			
PID control functioning on control Arduino			
RF controller can communicate and control comms arduino			
I2C interface between comms and control arduinos operational			
PID can control the motor drives			
Bluetooth/RF controller can successfully change PID setpoint			
Frame successfully 3D printed and assembled			
Hook successfully constructed and integrated with frame			
Integrated electronic and mechanic components onto chassis			
Drone can achieve controlled flight			
Drone can detect walls/other close surfaces			
Drone can automatically avoid walls			
Wifi live streaming implemented			
Drone can safely land when battery is low			
Drone is capable of lifting a cargo of 1200 g			

Milestones finalised by supervisor: ………………………………………………… Signed ……………………………………………………………… Date

Prototype hardware handed over to: ………………………………………………… Signed ……………………………………………………………… Date

Other items returned to Lab support hatch and checked by: ………………………………………………… Signed ……………………………………………………………… Date