

Appendix A: Project Proposal Form

Team letter:	Ganges	Name of person elected as team leader:	Ben Rowlinson
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Responsibilities

Name	Design responsibility
Ben Rowlinson	Integration, Cargo Acquisition, Data-logging, Power Management, Team Leader
Lawrence Gray	Chassis design, Control Processing, Integration, Financing
Joseph Hindmarsh	Gyroscope/Accelerometer interface, Cargo Acquisition, Integration, Liaisons
Joel Trickey	Communications, Telemetry, Encryption, Secretary
Mohammed Ibrahim	Human Interface, Air-to-Ground Communications, Telemetry, Documentation

Overall Design Summary

To fulfil the brief effectively the UAV must:

- Have a high maximum cargo weight to UAV weight ratio (cargo-UAV ratio)
- Produce a stable flight-path
- Have adequate battery life to transport the cargo then return to the base-station.
- Safely and quickly disarm the motors when commanded

We can afford a reasonable cargo-UAV ratio using 4 brushless DC motors. For stability, a microcontroller receiving feedback from a gyroscope-accelerometer module, forms a PID controller. This controller system devolves much of the responsibility for stability from the pilot. A second on-board microcontroller handles communications with the ground to relieve strain on the control system. Log data is written to an on-board SD card and transmitted back to ground. The pilot communicates with the UAV using X-Y joystick potentiometers and a microcontroller, which translate the pilot's commands to the desired Throttle, Pitch, Roll, and Yaw values. Switches disarm the motors, enable changes to PID gains, or activate the servo-controlled cargo acquisition mechanism.

Specification

- x4 2205 2300kV brushless DC motor
- Arming system for the motors to ensure safety compliance
- 5030 ABS Propellers – 5 inches diameter, 3 inches up per rev
- Motor Speed controlled by 1-2ms PWM Electronic Speed Controllers (ESCs) – I_{MAX} : 20A
- Powered by 3 Cell 11.1V 1550mAh LiPo Battery – I_{MAX} : 45A (Continuously) 90A (Burst)
- RF modules operated using SPI interface
- On-board file logging to SD card – Same data as telemetry
- Gyroscope and Accelerometer (MPU6050) - with in-built Digital Motion Processing (DMP) and an I²C interface, at 100 samples/s
- Servo used for cargo acquisition – Controlled by PWM, located underneath the chassis, carrying cargo using a hook.
- Laser-cut acrylic chassis, assembled using acrylic glue
- I-style design for easier weight distribution and more carrying capacity
- Reprogram the PID controller on the fly by changing k values wirelessly for faster tuning
- Interfaced with the pilot using two X-Y joystick potentiometers, a bank of function switches, and a microcontroller
- RFM12B-S2 ISM band modules for both uplink and downlink - using an SPI interface
- Sharp GP2Y0A41SK0F IR sensor provides altitude sensing for telemetry, with accuracy from 15cm to 100cm

Module Design Proposals

Names of people involved:	Lawrence, Ben, Joe
Title of Module:	Control Module

The Control Module is responsible for the main functions of the device, running the main PID control loop and interfacing with the gyroscope and accelerometer. The program loop is designed to be short enough to allow regular updating of motor speeds through PWM control of the ESCs. The base for this module is the ATMEGA32u4 of the Arduino Leonardo, chosen for the wide availability of sensor interface libraries and four 16-bit timers to allow graduation in motor speeds for fine control of the device. This will interface with the Communications module through the UART protocol to receive the user input and will return the motor speed and device orientation for logging and telemetry. The ESCs isolate the high current power circuitry of the motors from the low current micro-controller, taking in low current PWM with a maximum 10% duty cycle and providing the four motors with a PWM signal at much higher currents.

Names of people involved:	Ben, Joe
Title of Module:	Sensing Module

The sensing capabilities of the system is based around the MPU6050 gyroscope/accelerometer IMU, a Sharp GP2Y0A41SK0F infra-red proximity sensor and battery level sensor. The IMU and IR sensor were provided by the team, as they can be acquired for minimal cost elsewhere (China). The MPU6050 has an on-board DMP which will be used to relieve load on the Arduino by converting the raw data (rotational velocity) from the gyroscope into angles for yaw, pitch and roll on chip. This data is sent over an I²C bus ready for use in the stabilisation algorithm. The Infra-red sensor will be mounted on the base of the drone to detect low flight altitudes. The output of this sensor is an analogue voltage which will be fed into an ADC on the on-board Il Matto, as this data is not necessary for stable flight. A potential divider will reduce the battery voltage for ADC measurement, to be included in the telemetry readout.

Names of people involved:	Joel, Mohammed
Title of Module:	Communications Module

The Communications module is based around the ATMEGA644p microcontroller on an Il Matto board. It functions as the main communications hub of the system, interfacing with the RFM12B-S2 transceivers over SPI. This provides the uplink and downlink to the base station and controller. It will perform some basic processing of the instructions from the controller, passing them through to the control module to create a new set-point for the Control Module. This interfacing with the Control Module will be done over UART, and will receive in return logging data from the IMU. This logging data will be periodically written to an SD card sharing the SPI bus, and transmitted back to the base station as telemetry information. The communications microcontroller will also be responsible for controlling the servo-powered cargo hook through a PWM data signal.

Names of people involved:	Joel, Mohammed
Title of Module:	Ground Control Module

The Base Station of the system is formed around the core of another Il Matto ATMEGA644p board. It will take input from the user through a combination of joysticks and buttons on the HID (Human Interface Device) controller. The joysticks contain dual X-Y potentiometers, which will be directed into the ADCs of the Il Matto to extract values. There will also be a UART connection to a host PC to be able to update PID constant values without needing to reprogram the Control Module, as well as to make the display of telemetry and debug information easier to implement and use. The base station will be connected to a RFM12B-S2 radio transceiver module over an SPI bus to allow it to communicate with the quadcopter wirelessly while in flight.

Names of people involved:	Lawrence
Title of Module:	Chassis Design Module

The chassis will be built from 5mm acrylic chosen for its rigidity and wide availability. As the chassis will be produced using a laser cutter, triangle cut-outs add little to the complexity of manufacture and provide valuable weight savings without compromising too much structural integrity.

Propeller diameters of 5-6 inches mean that the motors have to be positioned away from the main body of the vehicle. To avoid excessive weight, the motors will be mounted on struts in an I-shape, keeping the additional weight low whilst allowing the propellers sufficient clearance.

A twin-tier design leaves plenty of space for the battery in its fireproof bag whilst maintaining accessibility for the rest of the electronics for inspections and light maintenance purposes. The feet of the chassis form a separate I-shaped structure to reinforce the motor struts and improve the rigidity of the chassis. The servo mount for the hook is located on this structure to provide support and enable the hook to be stowed out of the way for landing procedures.

Cost Estimates

Costing:

Development:

Unmanned Tech: £79.03
Other components:
 Arduino Leonardo: £18.50
 Micro Servo Motor: £7.70
 Gyroscope: £1.50
 Misc. components + boards: £8
 Transceiver: £5.65
 Atmel atMega644p chip x 2: £12.62
 A2 acrylic sheet: £10.55
TOTAL: £143.55

Production:

Unmanned Tech: £79.03
Other components:
 Arduino Leonardo: £12.49
 Micro Servo Motor: £2
 Gyroscope: £1.50
 Misc. components + boards: £4
 Transceiver: £5.09
 Atmel atMega644p chip x 2: £8.04
 A2 acrylic sheet: £8
 2 hours of construction cost (£20 per hour): £40
TOTAL: £160.15

A skilled worker will first laser cut the frame and glue it together which should take 30 minutes. They then must program all the microcontrollers and calibrate the ECSs, this should take another 30 minutes. The circuits should take 20 minutes to connect and mount. Finally, the last 40 minutes will be spent on testing and verifying that everything is in a working order.

Project hours per person:

Over a span of 2 weeks of designing and testing an estimate of total 88 hours (based on current work time)

Total of 440 man hours: (guess split of those hours)
160 hours developing software
40 hours board production and building
240 hours total debugging

At £75 per man hour total cost of £33,000
CE mark: £2000
Manufacturing costs: £100,000

Total Development costs and manufacturing costs: £135,143.55

Profit Margin:

To make money if they are being sold at £300 (profit margin of 53% we need to make 965 units (assuming 100% yield) at 90% yield (worst case) we need 1073 units before breaking even

Prototyping and Construction Method

To test the dimensions of the drone we are planning to construct a full-scale model of the chassis using cardboard and glue. We will do this by cutting out cardboard as per our laser-cut design. This will allow us to ensure that the design has enough space for routing wires, identify areas where size can be reduced, and gain a basic knowledge of its structural integrity.

Initially, we will utilise the breadboards on the Il Mattos to allow quick and easy testing and prototyping of various systems. Such systems include the IR sensors interfacing with the microcontroller and the controller (joysticks, buttons etc.) with the Il Matto on the ground. Once the tests are successful we will permanently connect the modules, without breadboards.

To make the debug process easier and more efficient, various sub-systems will be tested in isolation (starting with the most critical parts: Motor Control, Gyroscope, Ground-to-Air communications) before being gradually integrated together.

Firstly, we will test communications between the Il Matto and the Arduino on the UAV as well as the PWM from the Arduino to the ESCs. Once these functionalities have been fully verified, and any issues have been corrected, these systems can be combined. Similarly, the HID controller and the Il Matto on the ground will be prototyped, tested, then linked directly to the Il Matto on the drone. We can then introduce the wireless radio communications between ground and air. Finally, the less crucial components (SD card logging, cargo acquisition servo, computer interface) will be added into the system, provided critical tasks have been completed.

After prototyping has been completed, we will construct the chassis. This involves using the ECS Makerspace facilities to laser cut 5mm acrylic as per the outline we will have created and using acrylic glue (Dichloromethane) to hold the pieces together. Tabs in the design will allow perpendicular parts to be fitted together, and to be constructed initially without glue. As we are planning a two-tiered design, the top layer will not be constructed until the components on the bottom tier (Il Matto, Arduino) have been successfully fitted. The chassis' design will enable components to be easily accessible and make construction easier by leaving plenty of space for access.

Double sided sticky tape will be used to attach most of the various components to the chassis to allow for good fastening and straight-forward re-positioning of the components. One exception is the motors; these will be attached using the provided screws, through holes in the motor pads of the chassis.

The ESCs will be mounted underneath the second tier, with power distribution achieved by soldering onto stripboard. The gyroscope will be placed in the centre of the drone for the most stable platform, and will be connected to the Arduino using flying leads. The pin header on the breakout board will be flipped by de-soldering and re-soldering on the other side to allow access to the headers without changing the orientation.

The servo for cargo acquisition will be accommodated on the bottom side of the drone through a gap in the acrylic. The acquisition mechanism will be a small hook which is deployed by the servo motor.

The Pilot will actuate two X-Y Potentiometers which are read into 4 separate ADC channels. This will be mounted on a stripboard circuit. We can test this design simply by running an ADC on one channel and transmitting the results over the FTDI cable into the PuTTY terminal, then extrapolate.

We will only be using pre-made surface mount packages with breakout boards, as this eases the prototyping process .

Planned Project Activities

Activity	Initials	Fri am	Fri pm	Mon am	Mon pm	Tue	Wed	Thu	Fri am	Fri pm	Mon am	Mon pm
Testing RFM12B-S2 modules using II Matto	JT	x	x									
Testing RFM12B-S2 modules using II Matto	MI	x	x									
Sending ADC values using RFM12B-S2	MI			x	x							
Reading Gyro data over I2C to Arduino	JH	x	x									
Testing encryption system for Communications	JT		x	x								
Assembling and testing SD card interface	BR	x	x									
Testing PID controller using gyro and servo	LG	x	x	x	x							
Manufacture and Assembly of the Chassis	LG	x	x	x	x							
Manufacture and Assembly of the Chassis	BR	x	x	x	x							
Integrating PID controller with external desired throttle	BR				x	x	x					
Test data rate of the Gyro	JH	x	x	x								
Test IR sensor over a range of distances	BR			x	x							
Add Servo interface capability	JH			x	x							
Write/Test UI for real-time PID tuning	MI							x				
Write/Test ESCs and motors	LG					x	x					
Test two-way communications	JT				x	x						
Tune communications code for optimal data transfer	JT						x	x				
Test piloting system – XY pots and switches	MI				x	x						

Tune PID controller	BR								x	x	x	x
Tune PID controller	LG								x	x	x	x
Read in battery voltage	BR					x						
Power distribution for ESCs	BR					x						
Testing Serial communications between Arduino and II Matto	JH					x						

This is a preliminary estimate for the time schedule. Not all people have jobs at all times yet.

Risk Management

The D4 exercise is intensive, having demanding requirements yet running over a very short period of time. Successful project management requires management (i.e. planning) of risks. On the right hand side of this form, you should identify the predominant risks to your project, and the controls that you are going to put in place to minimise/mitigate them. Some things you may want to consider are illness of a team member(s), disruption to lab access, broken/faulty components, etc.

All members of your team should sign below to indicate that you have read the [Risk Assessment form](#), taking particular note of items 20 and 21. If you can identify any additional risks to your health and safety that are specific to your design, then you should add corresponding entries to the [Risk Assessment form](#) and attach a copy to this project proposal form. If they are satisfied with your additions, a member of academic staff will sign this form during your first laboratory session on 3rd March 2017. In any case, You should also be aware of the regulations that govern the flight of UAVs in the UK – you can see summaries of these [here](#) and [here](#).

Evaluating risk

Likelihood

		1 Remote	2 Unlikely	3 Possible	4 Likely	5 Certain
Severity	1 Trivial	1	2	3	4	5
	2 Minor	2	4	6	8	10
	3 Lost time	3	6	9	12	15
	4 Major	4	8	12	16	20
	5 Fatal	5	10	15	20	25

International Register of Certified Auditors (IRCA), "A History of Risk",
<http://www.irca.org/Global/Images/technical/inform/issue%2024/24-SAsbury-Figure1.jpg>

Hazard	Severity	Likelihood	Risk	Control	Controlled Severity	Controlled Likelihood	Controlled Risk
Components are damaged/broken through misuse	3	4	12	Comply with ESD handling guidelines. Confirm correct wiring with datasheet before applying power. Turn off power before rewiring. Order a spare of key components, if budget permits.	2	2	4
Ground control User interface may interfere with transmission of joystick controls	3	4	12	Implement interrupts-conditional statements methodology to prevent UI from blocking the transmission of joystick values for a significant amount of time, ensuring smooth ground control.	2	1	2
Mishandling of the ESC	4	3	12	Ensure we comply with ESC's handling guidelines. Confirm correct wiring of the ESC's before applying power. Make sure each ECS is calibrated to control the motors with the given control signals.	3	2	6
Lack of protection from Propellers	3	5	15	Make sure that the motors are not running when a team member is close to them. Considerations are	2	2	4

				made to the chassis design to include blade guards.			
Improper use of battery and charger	4	3	12	Read the online resources and spec sheets to properly utilise the battery to deliver the adequate power needed to run all four motors. Ensure the battery is charged for an adequate amount of time. Use any relevant measurement tools (eg. DMMs) for checking the voltages and currents between the supply to the ESCs to the Motors.	2	2	4
Losing wireless communications from the Human operator	4	4	16	Need to implement a solution for countering the problem of receiving data from other transmitters operating in the same channel/ band. In terms of other drones receiving our transmitted data we are considering the implementation of identification in the transmitted packet so that the data received by other drones becomes redundant. More importantly if, due to technical issues with the transceiver modules, the communication link stops working, we will implement an emergency landing feature to the drone to help ensure the drones safety.	2	2	4
Non-availability of members during certain weekends	3	4	12	We have 2 sub teams, one for control of motors and sensors and the other for communication between the base station and drone. These teams consist of 2 team members who should be aware of their sub team member's work, and the team leader who is aware of all the work being undertaken by the team. This establishes complete understanding of the sub-systems for and for the sake of integration. This will allow other members to handle work required in case of absences.	1	2	2
The chassis could break or deform	4	2	8	We will laser cut an extra set of chassis parts in case one of the parts gets deformed or is completely broken. This allows us to replace parts quickly and easily.	2	1	2

Team member	I have read the Risk Assessment form and I agree to the described operating procedure
Ben Rowlinson	
Lawrence Gray	
Joel Trickey	
Joseph Hindmarsh	
Mohammed Ibrahim	