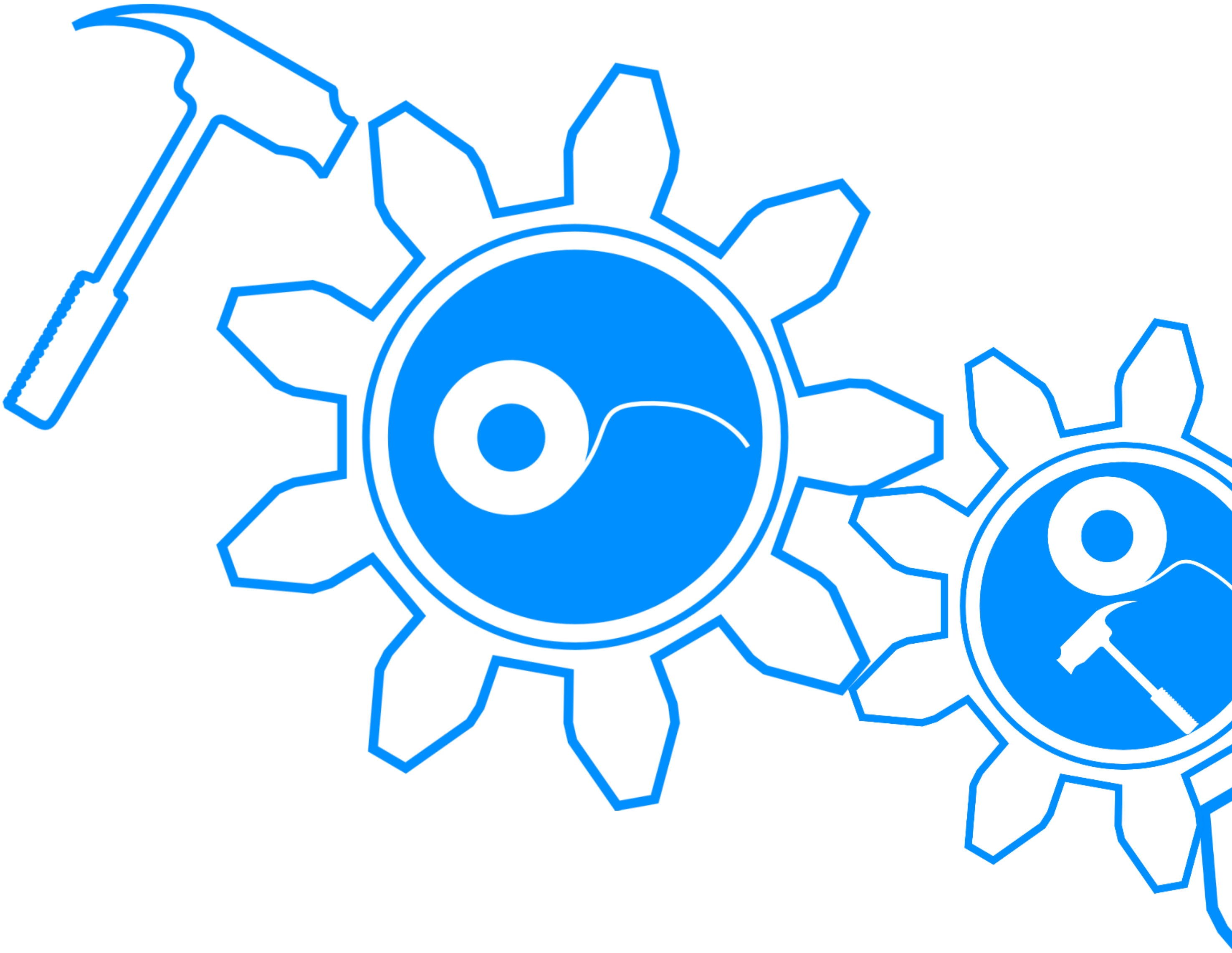


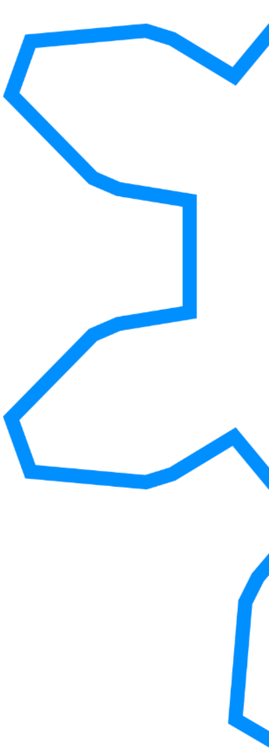
William Eustace, Euan Baines, Yuki de Pourbaix, Alex Forey, Hugo Cheema-Grubb, James Crompton,

Igor Timofeev, Neel Le Penru

TEAM IMPULSE

CanSats in Europe

Final Report



Contents

Team Members

William Eustace

William is the team leader and hence shoulders most of the organisational responsibilities. He coordinates all the different parts of the team and is head of the team's finances and acquisition.

Euan Baines

Euan is responsible for the core programming to control the components mounted on the board while working with Alex & William to improve the website. He is also deputy team leader, assisting William with administration and paperwork.

Yuki de Pourbaix

Yuki is head of design and development of the CanSat external and internal structures, as well as manufacturing of the chassis and mounting of components within the can.

Neel Le Penru

Neel is in charge of designing the parachute release system and determining the necessary dimensions of this parachute.

Alex Forey

Alex is a main contributor to the CanSat software development, as well as being the head of peripheral software development.

James Crompton

James is the head of electronics and works with William to improve structural efficiency of the board.

Hugo Cheema-Grubb

Hugo heads up the outreach program and, collaborating with the team as a whole, organises outreach events; he is also in charge of contacting several companies in order to discuss any potential interest they may have in the programme.

Igor Timofeev

Igor is designing and implementing the primary control loop for the rover; he is experienced in C/C++ and advanced in mathematics. For the latter reason, he is likely to take charge of the data analysis during and after the flight.

Brief Overview

Proposal

The CanSat's primary mission is to measure temperature and pressure and relay these over a radio telemetry link. It will also measure and transmit relative humidity; this, in tandem with the temperature reading, will be used to calculate dew point: this is an important metric for pilots of light aircraft, is a factor in the risk of asthma attacks and illustrates the team's ability to add sensors to the device to perform monitoring additional to that of the primary mission. The secondary mission selected is that of a 'comeback CanSat' - the ability to travel on the ground as a partially autonomous rover. This will involve GPS location data being relayed to base and used on-board.

The CanSat is designed around the secondary role, and hence the design must sacrifice space that would otherwise be used for electronics in favour of extra ground clearance and larger wheels.

In order for the rover to reach the ground safely, the parachute will be designed to reduce the descent rate to an acceptable level. The parachute must also be released upon landing to avoid unnecessary drag on the rover as it moves along the ground.

Progress Synopsis

As planned, a working prototype was produced by the end of the Autumn Term; however, progress this year has been somewhat slower due to high academic workloads for all involved. The failure of a critical piece of CNC equipment for a long period significantly restricted the team's ability to manufacture the chassis to the design previously employed, so an alternative design which may be manufactured mostly without CNC machining has been produced and manufactured. It has been found to be adequate for the tasks involved. The electronics have been completed and found functional. The software and firmware is still to be finalised but almost all components now work to within specification.

Outreach

A significant amount of effort has been expended on outreach. The team has developed a website (http://teamimpul.se) to assist in this. A dedicated, shortened domain name has been secured, since this is easier to remember and more likely to be accessed and thus to make an impact. A files area has now been added to this, which ensures that reports and bulletins issued by the team are clearly made available to the public. All source code and designs are shared openly on GitHub under the organisation 'Team Impulse' (https://github.com/team-impulse/), as part of the outreach plan involves returning effort to a helpful community. The licence in question is a modified version of the MIT licence, the only modification being to forbid other entries in this year's CanSats in Europe competition from using the licensed material without written permission from Team Impulse. A bulletin was issued on Monday 8/12/14, and the decision has been taken to issue bulletins once every few weeks until the launch, if there is anything to report, since this has the twin benefits of providing an easy reference point regarding other project sections for team members and making more information accessible to the public.

William, Euan and Yuki gave a talk to the school's Engineering Society recently, in which they demonstrated the experimental approximation of coefficient of drag (as described in the Parachute section of this report) and took questions. This talk clearly succeeded in its goal of outreach, insofar as it attracted a new member, Igor Timofeev, who had recently joined the school and so had not been part of the initial team.

As another section of the outreach effort, a team Twitter account (@TeamImpulseSPS) has been created, which permits the provision of regular updates to people wishing to subscribe to them. PCBTrain, who are now sponsoring the team (see below), have retweeted some of the team's Tweets to their numerous followers. The team has also submitted an article for the PCBTrain blog, which is likely to be published in the run-up to the competition.

Funding

Sources

Newbury Electronics (PCBTrain) has agreed to sponsor the team by the provision of free PCBs, which significantly reduces the cost of the overall project by allowing us to reduce the cost of PCBs significantly; it may also be possible to have the cost of PCBs already ordered reimbursed; this would mean a total saving of up to £250 over the budgeted cost. The team has also approached Sparkfun and Google for sponsorship; no reply has been received, but further approaches to other electronics suppliers are intended before Christmas. It is purely a question of reducing overall cost now, since budgetary constraints are unlikely to be a significant issue bearing in mind the PCBTrain sponsorship.

St Paul's has fielded numerous CanSat teams in previous years, all of whom have used various pieces of electronics with potential for reuse; Team Impulse is using several of these, which might otherwise sit unused, which brings down the cost of the project quite significantly.

The team also conducted a cake sale in school; this was organised collaboratively with the beginners' CanSat team from St Paul's, Team Colossus, and raised more than £280. Of this, since the clearances for the cake sale were obtained by Team Colossus and since they provided around 60% of the food, Team Impulse is to receive approximately £90 (roughly 1/3 of the proceeds), which, covering costs, leaves around £75 to contribute to the project.

Two members of the team are Arkwright Scholars; this scholarship includes £200 annually to be given to the school for investment in projects as deemed suitable. This money is likely to be included in the CanSat budget. As a secondary matter, the school is willing to sponsor the project directly to the sum of a few hundred pounds should it become necessary; this money comes from the Engineering department budget. Although the CanSat module currently under construction is only a prototype, the cost of manufacture of the final product is anticipated to be significantly less, for the following reasons:

- Since a surplus of the SMD components required was purchased, in order to allow for errors in assembly resulting in the loss of a component, no more components are anticipated for the electronics; this saves on both shipping and component expenses.
- The PCB manufacture is sponsored.
- The materials for the chassis and wheels are stocked by the school's workshop, and so are available at very low cost.

Costings

Section	Expected Cost	Approx. amount spent to date
Outreach (incl. website costs)	£50	£40
Hardware	£100	£40
Electronic components	£300	£120
PCB Manufacture	£0	£0
Misc.	£100	£50
Total	£560	£260

For more detailed costings, please see Appendix A

Mechanical Design

Initially, the design consisted of a series of copper struts supporting multiple ultralight plywood rings, which formed the perimeter of the CanSat. This left a large cavity into which the electronics systems and batteries could be placed; however, during the spring term, a critical period for chassis manufacture, the school's laser cutter was out of commission for some weeks. This mandated a redesign, since plywood struts of the thickness required could not be cut accurately by hand.

Chassis designs were optimised to be as compact and strong as possible. Since the chassis is significantly below the specified mass, reducing chassis mass is now secondary to strength goals - a lightweight CanSat is useless if it breaks upon impact. Building on the success of the copper strut idea, the new design has a fixed aluminium plate onto which all the electronics can be mounted, with an aluminium “lid” stretching most of the way along the top part. Although this produces a large amount of unusable space below the axles, this is necessary in order to provide the ground clearance necessary for operation on long grass.

In order to ensure that there are no short-circuits as a result of the new all-metal shell design, the exposed areas have been insulated using duct tape; although not the obvious choice for insulation, it has a thickness great enough to reduce the risk of damage on landing. Extra internal space that is now available due to the decreased volume of the CanSat's shell has been used for batteries.

The new metal design should allow the CanSat to survive the maximum force testing predicted could be experienced during landing intact. By using a metal case, we hope to increase the strength of our shell substantially as well as reducing volume. This also serves to increase the mass of the CanSat, which is a serious concern. Even if mass were a concern (or became a concern due to last minute modifications), lightweight components have been used elsewhere and the improvements in spatial efficiency and strength justify the increased mass. The metal design will provide many advantages over a wooden design, relating to the strength of mounting: mount points for the wheels and motors can be more firmly fixed to the chassis, which means that the wheels and motors are far more likely to remain aligned in the event of a heavy landing. Mount points for the struts and parachutes can also be increased in strength, which minimizes the risk of structural failure during parachute deployment, release and landing.

Strut

If the can were to be contained exclusively within the 66mm form factor specified, it would not be able to apply sufficient torque to move while remaining upright. To this end, a strut of length 55mm has been designed to be mounted at the midpoint of the can. This is lightly weighted about half way along in order to increase the permissible turning moment. It is mounted on a sprung pivot, which pushes it outwards when released, meaning that it can be stowed to keep it within the maximum permitted diameter during launch. The end of the strut is engaged in a slot in the left wheel, and upon strut deployment being commanded, that wheel is rotated. This permits the strut to spring out and begin its task of keeping the system upright. The construction of the strut mechanism is yet to be completed and is an area of some concern; however, it is anticipated that it will be completed, albeit with a narrow margin of error, before the competition.

Wheels

Based on testing of several prototype models it was ascertained that the grip and weight of the wheels was insufficient to allow it to progress effectively on inclined or smooth planes. Testing during December revealed that the rover was unable to make progress on long grass, expected at the launch site, because the wheels would not make enough contact with the ground. This led to several developments being tested, resulting in the choice to move from 4mm Plywood to 25mm High Impact Polystyrene Foam. Though this had several major impacts on chassis design, including reducing length available for electronics, in testing it performed significantly better on grass, allowing the CanSat to perform its secondary objective better.

Subsequently, the decision was taken to reduce diameter of the foam part of the wheels to 60mm allowing space for an inbuilt strut release mechanism that alleviated the need for a servo motor for deployment. This in turn saved space on the Printed Circuit Board and mounting copper plate, increasing space available.

In order to mount the wheels securely it was necessary to cut a plastic internal case on which to stick the motor axle and foam. This plastic had to be of minimal thickness in order not to reduce space for components further, while being brittle enough to keep shape under weak tension from changes in the plane and yet pliable enough to withstand initial impact with the ground. For these reasons it was decided to use 1mm acrylic cut on the laser cutter to ensure maximum efficiency and accuracy.

In order to manufacture the wheels to the specified dimensions, the laser cutter was discounted as an option due to its inability to cut materials of more than 12mm thickness. Though the option to cut three layers of 10mm and stick them together was considered, it too was discounted following a discussion of strength and burning/melting of the edges between each layer. As such, the wheels were manufactured by hand using a bandsaw, hot wire cutter, belt sander and pillar drill. Once assembled it was decided that the use of double sided sticky tape was preferable to a stronger adhesive such as Araldite or an alternative epoxy glue on the grounds that it would prevent an uneven finish and would reduce the thickness of the layer added, reducing the chance of going past the maximum specified diameter (66mm) or height (115mm).

Parachute System Design

The parachute retardation force is dependent upon the shape and size of the parachute, which is still unconfirmed; it is currently believed that a circular shape would prove easiest in deployment and manufacture, but from the point of view of attachment, a square would be significantly easier, because only four lines would be needed to hold it in the shape it is intended to assume, while with the circular parachute a larger number would be needed. The tests performed thus far have been with a polygonal parachute which approximates a circle.

Sizing

Bearing in mind that $v = \sqrt{\frac{2W}{\rho \cdot C_D \cdot S}}$ where v is the speed of descent in m/s, W is the weight of the object as a whole, ρ = 1.225 $\mathrm{kg/m^3}$ and S is the area of the parachute, a parachute size can be calculated for a chosen descent speed; sources indicate that a reasonable drag coefficient for a round parachute being 0.75. This suggests that a parachute of about 15cm diameter would be sufficient.

A test was undertaken in which the prototype chassis, suspended beneath a parachute left from a previous mission of approximately 15cm ‘projected’ diameter, was dropped from a height of approximately 4 metres, the resulting drop recorded at 120 frames per second (high-speed video). This was then analysed frame-by-frame to determine the acceleration at a given stage and thence to approximate the coefficient of drag; the result of this experiment was a C_d of 0.79. This would imply a final descent velocity (i.e. terminal velocity) of 10.4 m/s, which satisfies the regulations with an appropriate margin for error. The prototype chassis (which was not assembled in the same way as subsequent revisions; it was held together by friction fit only) withstood the tests successfully.

A parachute of approximately this diameter is currently under test after some delays in its production; the current results suggest that an expansion to 20cm diameter will be necessary since there are some inevitable inefficiencies induced by the initial parachute deployment.

Release

On landing, the parachute will need to be released, in order to ensure that it does not become tangled in the wheels or snagged on land obstacles. The system to perform this function, which has now been built and tested, involves a copper mount point with a pair of holes in it; a copper tab is inserted into this and a pin placed through the middle. This pin is connected to a 1.5g linear servo motor, which is controlled by the microcontroller. The pin is then withdrawn on command from the base station, permitting the parachute to move away from the chassis.

Electronics

The electronic system is critical to the performance of the CanSat; it is by far the most complicated of the systems involved. A component list may be obtained on the Team Impulse GitHub account, as may a printed circuit board design. Please see Appendix A for a parts list. A brief overview of the systems involved with the project is given below:

Drive System

The motors selected have been used by a previous St Paul's CanSat team with success; they are small motors rated to run off approximately 5V and come with an integrated metal gearbox; this is very robust and has been found highly resistant to gear stripping. The motor speed is nominally 11,500 rev min^{-1} and they are rated for a torque of 2.3 kg cm. This is significantly in excess of what is anticipated for the project. They also have a remarkably low current draw; although the nominal draw is 60mA with 90mA max current draw, they have been found to have a lower current draw than this, especially under light load conditions: a current draw of under 50mA under light load has been recorded for both motors, at 5V. Their light weight and small size makes them very well suited to this CanSat project.

Power

The power supply stages are critical with regard to maintaining stability in the entire electronic system; the radio, GPS, sensors and microcontroller must all be supplied with a smoothed 3.3V, while the servo motor and motors must be provided with 5V; both 3.3V and 5V rails have adequate hysteresis to avoid brownouts when voltage is supplied at expected levels.

The system is powered by a lithium-polymer battery with a nominal capacity of 1000mAh; this would be expected to give a battery life significantly greater than the specified three hours, bearing in mind that the motors will not be operating before landing. See below for details of battery testing.

Lithium-ion and Lithium-polymer batteries use a very sensitive chemistry and are easily damaged by overcharging or over-discharging. Excessive current flow due to short circuits can cause overheating and damage. They also have potentially dangerous failure modes, which, if sufficiently damaged, can involve rapidly starting fires and explosions. In order to avoid these issues, the LiPo used is one with integrated protection circuits, which do not allow charging past a maximum rated voltage of 4.2V or discharge below a minimum operating voltage of 2.7V. In addition, it includes short-circuit protection.

For the control system, an ultra-low-dropout regulator (LDO) has been used; this is capable of supplying 3.3V whenever the voltage supplied is even fractionally above this voltage and causes minimal voltage drop when the voltage across it drops below this. The motors, meanwhile, require 5V and are powered from a boost converter power supply; this uses a small surface-mount inductor to generate a significantly higher voltage, since when the voltage across an inductor is changed, a significantly higher voltage is generated. Were this switching done at a low (<1 kHz) frequency, it would likely result in poor performance; the regulator used switches at 10 kHz and so avoids this issue. Both regulators are surrounded by several smoothing capacitors; for documentation on these, please see individual datasheets. The capacitor types specified in the datasheets have been used in both cases; this substantially reduces the probability of unstable oscillation, in which a positive feedback loop develops and takes the voltage output outside the specified rate.

Sensors

The sensors used are as follows, with their interfaces:

Meas-Spec MS5637BA—Barometer and temperature sensor (I_2C)

IST HYT-271—digital humidity and temperature sensor (I_2C)

ST Micro LSM303—digital magnetometer (I_2C)

U-blox NEO6M—GPS module (TTL Serial)

All of these sensors operate at 3.3V (CMOS logic levels); this simplifies electronic interfaces by removing the need for level-shifting. The I_2C bus operates at the standard slow rate (which is still commonly used in such embedded electronics) of 100 kHz. It uses external pull-up resistors of 10kΩ, which are slightly larger than the standard value but as recommended by several of the device datasheets.

GPS

The module communicates over TTL serial using the industry standard NMEA protocol; since a hardware serial port is available on the microcontroller, the data may rapidly read in. This, combined with a convenient operating voltage (although still using CMOS logic, some GPS modules operate at 1.8V), makes it well suited to the CanSat project. In addition, one has been used by a previous St Paul's CanSat team, allowing a significant amount of expense to be spared by reuse of a previous module; this also has positive environmental connotations.

Communications

Although the standard CanSat radio modules are well suited to operation under competition conditions, they do not have a very strong link budget bearing in mind their power. This, combined with a lack of built-in error-checking, led to the decision to use the LoRa modulation system developed by Semtech, Inc. This uses a low-bandwidth spread-spectrum system with built-in CRC error checking and forward error correction. All modulation and preamble detection is performed on-chip, while a built-in FIFO buffer permits easy packet handling by comparison to a system in which data is not buffered on-chip, since packet data may be requested and read when the host microcontroller is ready. The FIFO holds 256 bytes of data; this is significantly greater than the longest anticipated packet length for this project.

The radio modules selected are the Hope-RF RFM98W 434MHz units; these use a Semtech SX1278 LoRa chip. The module communicates via SPI. The modules are capable of a 168dBm link budget with receiver sensitivity of -148dBm. The transmit power in use is approximately 10dBm (the UK legal limit) rather than the significantly greater 20dBm possible with these modules. Range tests have been conducted with a Yagi antenna at one end which showed a range of more than 1.5km at this power setting, in open space. There was no significant degradation of SNR over this distance, which suggests that a greater range could be obtained if required.

Motor control

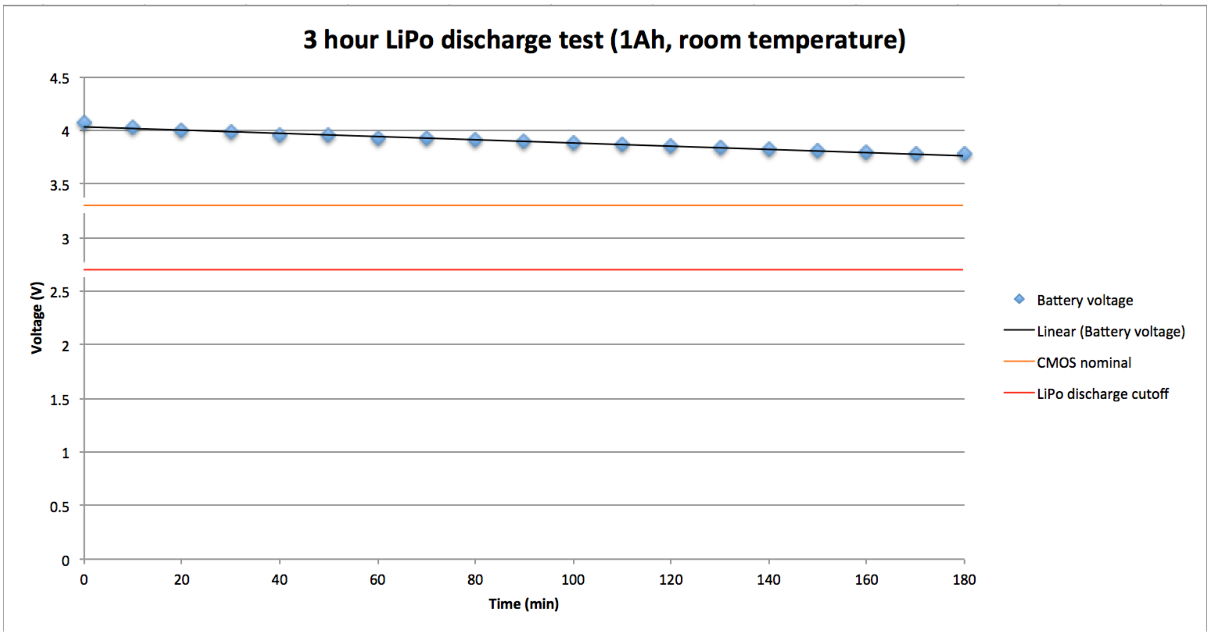
The motor control chip in use is the Texas Instruments DRV-8833 in the PWP/HTSSOP-16 SMD package. This is both possible to solder by hand and amply powerful and efficient for the low-current motors in use.

Microcontroller

The microcontroller used is a Freescale MK20DX56VLH7, which is a high-end ARM Cortex M0 based microprocessor. Since the package is very difficult to solder directly and because specialist equipment (e.g. JTAG programmer) is required to place the Arduino bootloader onto the chip, a Teensy 3.1 microprocessor board has been used; it is soldered to the board using headers, which reduces space consumed while permitting the device to be replaced in the event of damage without scrapping the entire board. When contrasted to the T-Minus board included in the CanSat kit, the Teensy is significantly smaller (see comparison photograph) and has a higher clock speed (96MHz) with all pins being digital interrupts. This property is very useful for communication with the radio module.

Battery

The specification for the CanSat program specifies a minimum battery life of three hours; a three-hour test was conducted using the production Lithium-Polymer battery with both motors running constantly and radio packets being transmitted every 700ms; the voltage supplied at the end of the three hours was greater than 3.7V (still above the battery's nominal voltage). Bearing in mind the motors are not expected to be running continuously, this result was highly satisfactory and would indicate that the CanSat may be left switched on for significantly longer than three hours without suffering battery exhaustion.



Current

Both with regard to battery life and to temperature, it is of interest to know current draws for individual components. These have been measured using a standard digital multimeter where measured; other values have been drawn from the datasheet or other sources.

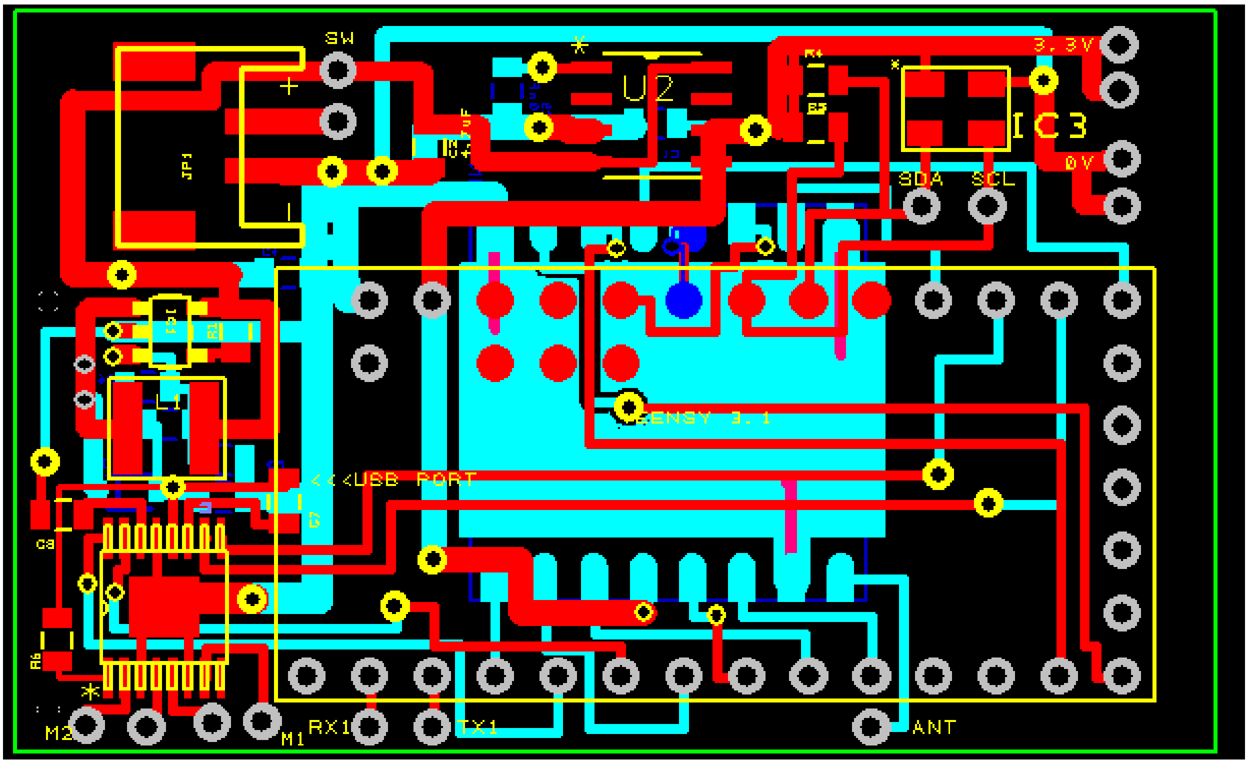
Component	Current draw (ma)	Conditions?	Measured
Teensy 3.1	40.5	Conducting GPS read and processing of data. 3.3V	Y
GY-GPS6MV1	32.0	During satellite acquisition. NB contingency GPS module only. 3.3V	Y
Motors (x2)	63.0	Power measured at 3.3V input – includes power loss across voltage regulators. 5.0V supplied to motors.	Y
MS5637	<0.03	From datasheet – OSR=8192, Vs=3.3V	N
GP-635T	52	Specified during discussion. Normal operation post-acquisition. 3.3V	N

PCB

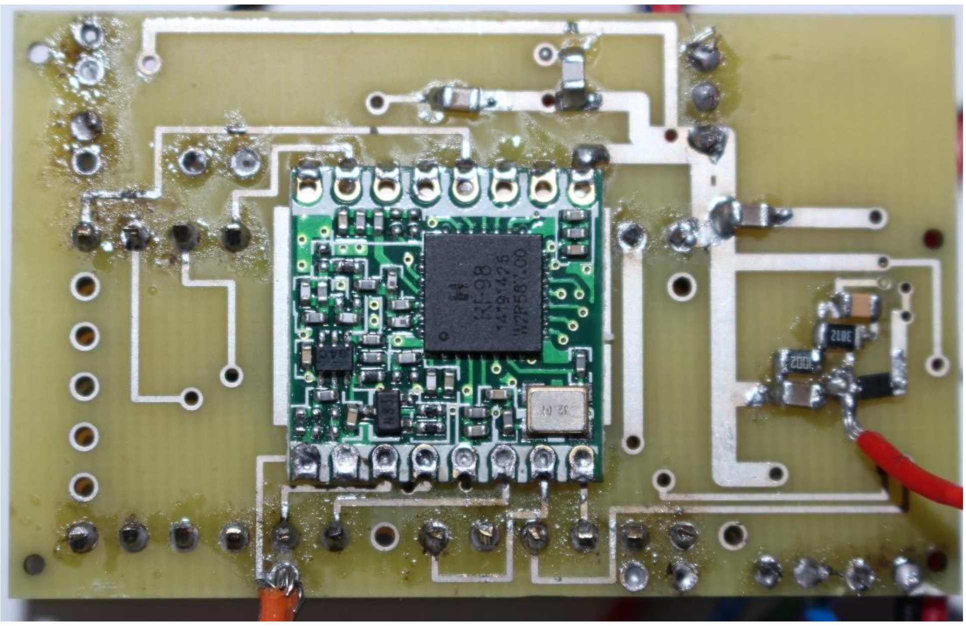
The final printed circuit board is a second revision of the board designed in October to meet the initial specification; it was manufactured by Team Impulse's main sponsor, PCBTrain Ltd, and is a double-layer PCB. Since it was manufactured using PCBTrain's Express service, it does not have a solder mask, but this is not an operational disadvantage.

The board was designed in RS Components' DesignSpark PCB and exported to Gerber format for manufacture.

Below are photographs of each side of the printed circuit board.

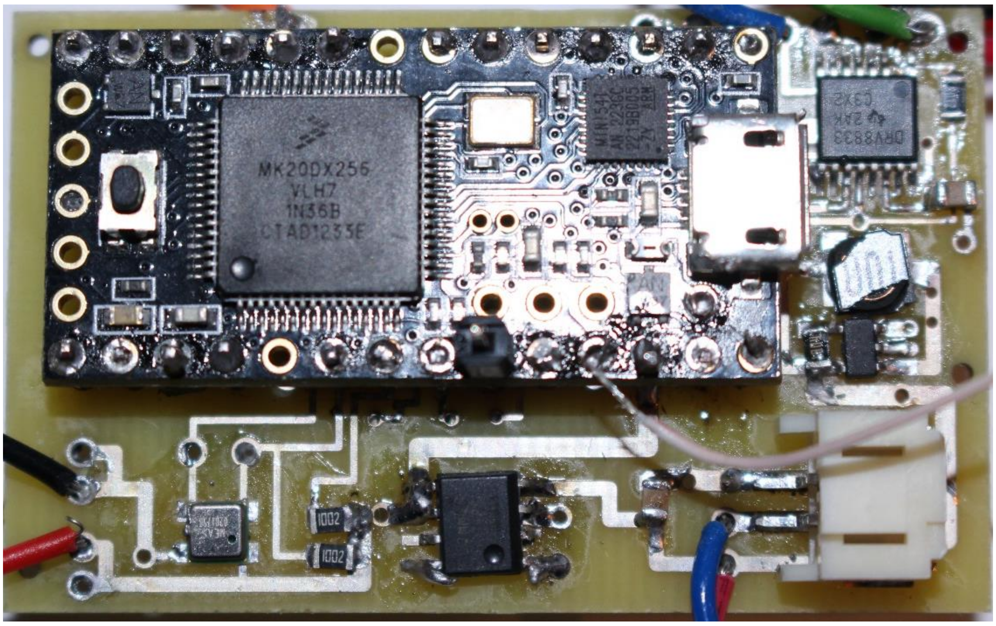


Bottom side:



Note the radio module in the centre of the PCB with the antenna connection (orange wire, bottom left). The red wire on the right side of the photograph is the connection point of the servo motor to the 5V rail.

Top side:



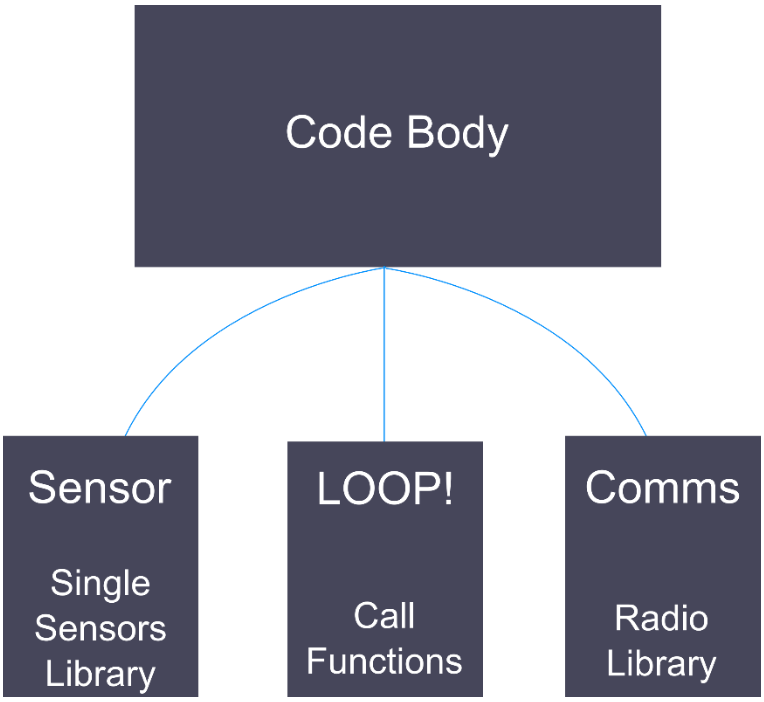
The Teensy dominates this side of the PCB, occupying the top area; on the top right is the motor driver, then the 5V boost converter circuitry below that. The JST connector on the bottom right is the main power feed from the LiPo; the chip at bottom middle is the 3.3V LDO regulator and the silver chip mounted to the left of that is the MS5637. Other sensors are mounted off-board. Motor power lines run from the top right.

Software

The ‘software’ for the CanSat is split into two parts; firmware and base station software. The former is written in Arduino C, the latter in Python.

Firmware

The final firmware implementation, which has been codenamed ‘Solent Sandfish’ is still to be finalised but currently stands at 428 lines long; it makes use of the easily reviewable structure laid out in previous reports in which a large amount of code is packed into libraries. The custom libraries in use are ‘SensLib’, which handles all sensor communications and processing with the exception of the LSM303 magnetometer and ‘RFMLib’ which handles radio communications; between them, they contain another 417 lines of code. The structure of the overall program is illustrated by the diagram below.



Where a device has a pre-existing library, this has been used instead; a full list of libraries used is given below.

- TinyGPS++ - performs processing of NMEA strings (the format in which GPS data are yielded).
- LSM303 – handles I/O and processing of LSM303 magnetometer data (also calibration).
- SPI – interfaces with the MK20DX56’s hardware SPI (Serial peripheral Interface) bus.
- Wire – interfaces with the MK20DX56’s hardware I_2C (Inter integrated circuit) bus.
- Servo – simplifies the PPM (pulse-position modulation) control of the servo motor in use for parachute release.

The firmware has been checked for errors during the process, by a team member who has not been deeply involved in its development; this continues as the finishing touches (which mainly concern communications protocol) are made. The reasoning for this, a form of delayed pair programming, is that operations which are clearly invalid under certain conditions when viewed by an objective eye may not be obviously unsafe when checked by the person who wrote them initially.

The majority of the firmware has been written by William, with contributions from Igor and Euan.

During testing in December of the initial prototype, it was found that the GPS heading accuracy at the speeds involved was significantly below that expected, to the degree that no autonomous heading control could be obtained at all; this necessitated the addition of a digital compass. This was obtained at no cost, since it had been used in a previous year's CanSat project. Although concerns were raised during initial team discussion of the modification that the motors' magnetic fields would render the magnetometer unusable, it has been found during testing that, by keeping a sufficient distance from them and calibrating it carefully, a heading accuracy which is well within 10° has been obtained.

Base station software

The base station software was initially specified, in the previous interim report, to display a live-updating map and graph, plotting the rover's position and a specified piece of data. Since then, the decision has been taken that to do so much processing of these data during reception is to prejudice program stability: it is critical that the data are logged securely, while data are expected to be graphed at greater length later. Bearing this in mind, the graphing functionality was deemed to be unnecessary and dropped. Upon further examination of the launch site, it was discovered that no maps of RAF Elvington that would be of assistance in selecting co-ordinates exist. For this reason, instead of having a map to permit the placement of waypoints, a text-based interface is being implemented, which will allow the placement of a waypoint, the location of which is either based on an offset from the present rover position or an absolute set of co-ordinates.

The base station software is implemented in Python, using the GTK3 graphical interface development framework. The serial interface with the Teensy on the receiving end uses the pySerial library to read in data. A live-updating display of data-link status and SNR/RSSI of last packet is displayed, along with a counter of the number of packets with failed CRC checks. The raw data coming in from the serial port is also displayed.

The data transmitted over the radio link is exclusively in bytes; since many of the metrics being recorded contain 16 or 32 bit numbers, some bit-shifting must be done. This is to be performed in the base station software; both the raw data and the bit-shifted/processed data are to be logged in CSV files.

The updated specification for the base station is therefore as follows:

1. The software should display the current rover co-ordinates, both in degrees, minutes, and seconds format and in OS grid reference format.

2. The software should display the temperature, pressure and relative humidity readings transmitted from the rover, along with information about the quality of the link (i.e. RSSI).

3. The software should provide a calculation of altitude, possibly based on a barometer on the ground station (hence providing height rather than altitude) or a pressure entered.

4. The software should calculate dew point and display it.

5. The software should provide any appropriate telemetry information (internal can temperature (from MS5637)).

6. The software should provide an interface to enter waypoints for the rover to navigate to.

7. The software should provide an interface to permit manual control of the rover.

8. The software should log all data in an appropriate file format.

9. The software should interface with the local base station Arduino over USB Serial.

Data Processing

In the event of launch delays, it is possible that the team will have very little time to analyse the data produced. The conventional approach would be to use a spreadsheet program such as Microsoft Excel to produce a series of graphs and find correlation factors using a set of custom-built spreadsheets. This is a very time-consuming approach which needs some significant altering to take into account the amount of data produced and which therefore is not ideally suited to a situation in which the team is likely to be tired and time is short. To this end, the decision has been taken to use MATLAB for data analysis.

This will save time and ensure that the data is processed correctly as the script used can be tested in advance. The ability to read a CSV file into a set of data matrices is very useful for a project such as this which will deal in large amounts of such data.

These data will be graphed and used to build a 3D map of the journey with annotated points and readings at those coordinates. Graphs will be produced of all possible pairs (e.g. temperature-relative humidity, temperature-altitude, altitude-time, altitude-dew point) and correlation factors found. The team will then select graphs suitable for presentation from this set and incorporate these into the presentation to the judges. One of the specified mission objectives is to determine whether dew point changes when measured at different altitudes; it is defined as being “at a constant barometric pressure” but since the humidity, a factor in dew point, is likely to vary with altitude, there may be a significant difference. The size of this difference will be determined experimentally during the CanSat’s launch.

Progress

The project's mechanical hardware is now nearly complete. The electronics are operative and the software/firmware is nearly complete. There are still many variables which present a risk to the successful completion of the project and the fulfilment of the mission criteria. Details of and solutions to these risks, where such solutions are possible, are presented in the table below. Tasks which remain to be completed are listed in the Gannt chart below that.

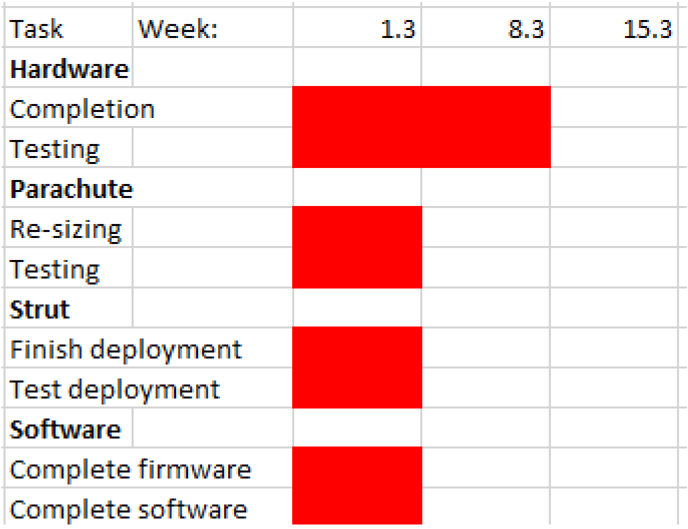
Risk and Mitigation Thereof

Risk	Mitigation
Team Members being unable to work due to illness or other reasons.	The hardware is nearly complete, and all software work can be done from home. Therefore there is no significant threat to the project from this; the work can be carried on by the remaining members of the team provided that communication is able to continue (which, in all foreseeable eventualities, it will be).
Issues with the arrival of parts such as late arrival or damage.	All parts have now arrived and been checked.
Malfunction of electronic components	The electronics are now complete and, although damage to them is entirely possible during testing or transport, spare parts for all components are in stock and will be taken to the competition.
Overheating of electronics once in the CanSat.	One concern was the overheating of components if overly tightly packed into the CanSat. However, the team has deliberately tried to use components that are small (and lightweight), and have allowed air circulation in all chassis designs.
Delays in software production.	The software is well under way and is partially operable already. Beyond the provision of time in team members' personal calendars for further programming work, nothing more can be done at this stage.
Delays in construction.	This is mitigated not only by having a clear plan of what needs to be done but also back up plans should there be issues with the strength of parts or if sections fail during testing. Fortunately there has been progress from the CAD side of the project to testing actual chassis prototypes. The use of CAD/CAM also enables very rapid manufacture.
Issues with hardware and the construction processes.	Testing will be paramount and factored in to the construction plan. The largest issues at present are surrounding the 'strut' or support to prevent the chassis spinning, upon which testing has begun. Further testing and modification will need to focus on ensuring that individual components are strong and light, and that the hardware can cope with the potential conditions during the launch, descent and landing, such that testing must be quite in-depth. Though time consuming, this is the most watertight method of mitigating potential issues during construction and during the CanSat's operation.

Destruction of the final rover during testing or transportation.	The first prototype, which is of limited functionality, is still partially assembled. In an emergency it is possible that this could be used to carry out some of the functions intended for the main rover; it is hoped that, at the very least, the primary mission could be undertaken.

Gannt Chart

This Gannt chart shows the plans for completion of the project:



Task	Week:	1.3	8.3	15.3
Hardware				
Completion		🟥	🟥	
Testing		🟥	🟥	
Parachute				
Re-sizing		🟥		
Testing		🟥		
Strut				
Finish deployment		🟥		
Test deployment		🟥		
Software				
Complete firmware		🟥		
Complete software		🟥		

Mission Criteria

Primary mission:

1. The CanSat should relay ‘dry bulb’ air temperature and barometric air pressure to the ground via radio at least once per second.
2. The CanSat should log data both locally and on the ground; this data should be able to be graphed using standard spreadsheet software or MATLAB.
3. The CanSat should comply with all of the CanSats in Europe guidelines.
4. The CanSat should have a **maximum diameter of 66mm**.
5. The CanSat should have a mass of 370g.

Secondary mission:

The CanSat should:

1. Relay relative humidity to the ground station at least once every five seconds.
2. Have ground software able to calculate approximate dew point.
3. Investigate whether there is a significant change in dew point when measured at altitude (of particular interest to avoid carburettor icing on aircraft).
4. Be capable of movement over smooth ground and grass, including inclines of at least 35% on a solid surface.
5. Be capable of navigating directly to a set of co-ordinates transmitted to it provided that the path to these is viable.
6. Be capable of following manual commands transmitted to it.
7. Be capable of travelling a minimum of 500m on a suitable surface, given sufficient time.

Appendix A

Electronics Parts List and Costings

Part	Cost (£)	Source
LSM303 magnetometer	22.28 (e.g.)	Obtained from previous CanSat at no cost.
Linear Servo	2.54	Obtained from previous CanSat at no cost
GPS	16.14 (e.g.)	Obtained from previous CanSat at no cost
PCB (x3 incl. first revision)	115.42	Obtained from PCBTrain sponsorship at no cost.
MS5637	1.68	Farnell
Teensy 3.1 (x2)	33.98	Cool Components
IST HYT-271	19.06	Rapid Online
RFM98W (x2)	11.98	HAB Supplies
LDO reg	1.86	Farnell
Passives (capacitors)	6 (approx.)	Farnell
Passives (resistors)	6 (approx.)	Farnell
Inductor	0.79	Farnell
Diode	0.08	Farnell
Motors	6.26	eBay
LiPo	10.99	Cool Components
VAT	20 (approx.)	
Total budget spent (electronics)	118.60	

Mechanical Design

Part	Cost (£) (approx.)	Source
Aluminium	10	School supplies
Acrylic	5	School supplies
Copper	10	School supplies
Nuts & bolts	2	School workshop
Tape and adhesives	5	Various
Foam	4	School workshop
Plywood	4	School workshop