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

Igor Timofeev, Neel Le Penru

TEAM IMPULSE

CanSats in Europe

Second Interim 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 will fulfil the primary mission of measuring temperature and pressure and relaying these over a radio telemetry link. It will also measure and transmit relative humidity; this, in tandem with the temperature reading, will permit experimental determination of the dew point. 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.

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 CanSat ought to be resistant to water, since if the CanSat lands on wet grass then there is the potential for damage to electronics.

Progress Synopsis

On submission of the previous report, some electronics issues had been encountered; these have now been overcome, and the prototyping effort is proceeding according to plan. It appears likely that a working electronic and mechanical prototype will be obtained by the end of term, as scheduled; regrettably, certain sections of the software are running behind, and so only a skeletal firmware will be running on the prototype. The funding of the project appears strong and on target at present; outreach is proceeding well. Please see individual sections for further information.

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 is to write an article for the Newbury Electronics blog, which is seen by a number of customers; it is also expecting to be mentioned on St Paul's School's website.

We also have a YouTube channel:
https://www.youtube.com/channel/UCwkEleLGbYMSZ6twPv3DrAQ

Videos of talks will be uploaded here.

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 £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.

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.

Expected Costings

Section	Expected Cost	Approx amount spent to date
Outreach (incl website costs)	£50	£30
Hardware	£100	£30
Electronic components	£250	£175
PCB Manufacture	£0	£0
Misc	£100	£0
Total	£500	£250

Of these, the cost of the final CanSat, including components, is likely to be significantly under £200, bearing in mind the following costings:

Section	**Cost**
Electronics	£80
Hardware	£40
Misc	£30
Total	**£150**

Mechanical Design

The current issue that is being addressed the chassis' inability to surmount objects head on. When the Mark 1 Chassis hit an object either head on or from the side it would stop and become trapped. This was due to the fact that the wheels, when kept stationary, forced the body to turn instead effectively rendering the design immobile on rough terrain.

Chassis Mark 2

It was decided, after several team meetings, that a more space efficient and stable design could be created by changing the shape of the central body from a circle of diameter 58mm to a flat bottomed circle of diameter 66mm, with 7.5mm taken off from the bottom and replaced with a stationary strut that would ground itself wherever possible. This change took place following several considerations:

1. In order to mount the parachute release system and PCB, flat surfaces would be required; this meant that not only would the redesign facilitate mounting but reduce wasted space in the can.
2. The flat base would allow simpler distribution of weight as it was known that the chassis strut would produce a moment, and thus keep it upright on flat planes and cause it to detour around rougher terrain as it would naturally spin away from an incline or decline in its path.
3. Due to the weighting of the chassis and the tensile strength of 2mm copper rods, the design could be kept within the specifications of 66mm diameter but in practice the central part would bend towards the ground thus allowing the strut a few millimetres more depth over the wheels.

Testing

Two working chassis prototypes have been assembled and partially tested.

Rough Terrain

On rough terrain the new prototype functioned well, catering without problem for small undulations in the ground. Grade 140 emery paper was added to the wheels to give them more grip and increase its net velocity thus giving it a higher momentum and allowing it to skim over undulations more easily.

On one occasion during testing however, when dropped it landed in such a way that the strut prevented movement by lifting the wheels slightly off the ground. The small pits on either side further reduced the purchase the wheels got and it took over 30 seconds for the design to rectify itself (due to the wind it blew to one side and allowed one wheel to turn). This suggests an extensible strut that can be released on or after impact is required to ensure this does not occur on the day.

Smooth Planes

On smooth planes the design kept upright without fail and moved quite quickly and smoothly. However due to a slight imbalance in weight and the lack of adhesive holding the wheel securely (this would be used on the real design) it had a tendency to stray to the right slightly. This can be easily rectified and will be fixed by the final design. Fortunately, it does indicate the concept of using a strut is viable and works well on smooth planes.

Inclined Planes

On an incline the design performed poorly. It tackled the incline head on and collided then pushing itself away by means of the strut and tackling it again at a slightly different angle. Though this works as a means of bypassing inclines, on a board of 200mm and height 25mm, it took 13 seconds to free itself. Furthermore it then wandered in a completely different direction, which is not entirely satisfactory.

Therefore new ways of correcting this problem will be investigated and the solutions incorporated into the 3rd revision of the chassis.

Negative Gradient Planes

On a gradual negative incline the chassis proved exceptionally successful, it kept itself almost perpendicular to the plane on which it was travelling and did not spin aimlessly. Though this is currently successful, the team is also considering reducing the speed at which it traverses these negative inclines as it makes it much more likely to fall into a pit and thus force it to tackle an incline.

On steep downward slopes (more than 45°), it span, and skidded rather than traversing the plane. Though it is felt unlikely that the design will face such steep negative inclines on the day (especially on smooth planes), the third revision of the chassis will attempt to resolve the issue.

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 prototypes; it was held together by friction fit only) withstood the tests successfully.

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. This will be achieved using a system, which has yet to be fully designed or built, involving a metal tab, which will be the termination of all of the parachute cord, which will penetrate the CanSat housing on one side, to be held in place by a sturdy, sprung pin system. This will be shock resistant but will be capable of being released by a linear servo motor controlled by the main microprocessor; these motors are available with masses of as little as 1.5 grams.

Electronics

Any project such as this requires complicated electronics internally. These electronics must be relatively robust, both physically and in terms of noise, due to the stresses of launch and landing. These sections are being tested at completion and will be tested extensively before launch.

Power Supply

The power supply section is critical to the entire project, since its failure could prejudice the safe operation of the whole CanSat. The devices must all be supplied with a safe operational voltage throughout the discharge of the power source. In order to achieve a light weight and compact solution, the highest density charge storage device available to the project has been selected, in the form of a lithium polymer (LiPo) battery. This is a very powerful battery chemistry, but suffers the downside of being dangerous if overcharged, over-discharged or short-circuited. Fortunately, Sparkfun Electronics sell a LiPo battery which includes over-volt and over-current protection, and has an under-voltage cut-out. Were a battery which did not incorporate these features to be used, the board would need to implement a low-voltage cut off at around 2.6V; this could have been achieved using an arrangement of junction and field effect transistors coupled with a simple resistor network and a Zener diode, or an operational amplifier. Alternatively, a dedicated power management IC could have been used. This circuit is relatively easily modified to add hysteresis, which would be advisable in case of transient current peaks, either during RF transmit periods or motor stalls. Since the battery incorporates this circuitry in its packaging, the board area used by the power supply stage may be reduced.

The LiPo is a single cell battery rated at 2000mAh, which will provide an output voltage peaking at 3.7V when fully charged, and cutting off at 2.7V, when fully discharged. All of the electronics use CMOS logic levels, however it is believed that the voltage tolerance of these components (generally down to 3V, with standard CMOS rating down to 2.7V; operation cannot be assured at this voltage, however), and since a healthy reserve of charge in the battery is anticipated, bearing in mind the typical discharge curve of a LiPo, this is not expected to present an issue. For this reason, an ultra LDO voltage regulator was used in the power supply for the electronics, which provides a steady 3.3V at voltages almost down to 3.3V, and has very little voltage drop even below this. It has a rated brownout voltage below 2.7V.

For the motors, however, a higher voltage (5V) is required, which is generated by a switching boost regulator, which uses high-speed switching of the input voltage to produce back EMF in an inductor. This output is then smoothed by capacitors, and filtered to DC using a diode.

In both power supply sections, ceramic capacitors have been used. These have been selected according to the manufacturers' recommendations with regard to dielectric (e.g. X7R is specified for a number of components) and other properties, as anything deviating from these is known to increase the likelihood of unstable oscillation, a phenomenon which must be avoided in voltage regulators.

Microcontroller

Since a standard advanced microcontroller requires a significant amount of supporting circuitry both for regular operation and for reflashing, the decision has been taken to use a microprocessor board, in the form of a "Teensy 3.1," which is a board of small dimensions which includes all of the equipment required for programming over micro-USB of the included Freescale MK20DX56, which is a highly capable ARM Cortex M0 based chip. The manufacturers of the Teensy, PJRC, make available a piece of software which permits the production and flashing of .HEX files from standard Arduino code; this opens up the wide range of Arduino libraries to the developers. This is done over USB, which avoids the need for specialist hardware. The board is mounted to the main PCB using headers, and may be considered a black box system from the perspective of electronics design. It should be noted, however, that it may produce a certain degree of electronic noise (as microprocessors often do); to this end, a ground plane has been inserted between it and the radio module, which is mounted on the other side. For the current, prototyping boards, the decision has been taken to mount the board using stackable headers rather than the normal variety; this means that the Teensy can easily be removed, whether it is damaged or the board it is mounted on is superseded. This mounting system has been tested successfully.

Motor Drivers

The motor driver initially selected was the Allegro A3901, because it provided a highly suitable drive system of appropriate current ratings inside a very compact package; it uses a DFN package. A board was ordered and largely assembled, which would have used this chip, however it was discovered to be near-impossible to solder by hand due to the lack of leads; although they extend onto the side, which suggested drag soldering was possible, the combination of a rapid prototyping board (no solder resist) and the fine pin spacing meant it was impossible to solder reliably despite the very thin soldering iron tip and solder used. For this reason, an alternative component has been sourced, and board design is in progress using the Texas Instruments DRV8833-PWPR, which is a much more solderable HTSSOP-16 package. This has been successfully tested.

Sensors

The primary mission requires detection of temperature and pressure; this is achieved through a MEAS-Spec MS5637 chip, which uses a 4-pin QFN package with simple I2C interface to convey temperature and pressure data. This will be mounted on the board inside the CanSat chassis; to obtain external air temperature, a secondary sensor will be needed. This is incorporated in the second sensor, which is an IST HYT-271 hygrometer/temperature sensor, which also uses a 4-pin I2C/power interface and has an SIL design permitting it to be soldered to directly; this will be mounted in a position such that it has access to the air outside. This will give external air temperature and relative humidity. Both of these have been tested and operate as expected. From these data, the dew point of the air will be calculated. The I2C bus is operated at the standard frequency of100kHz. 10K pull-up resistors have been used, since these are specified by the MS5637 datasheet; the standard pull-up size is 4K7 but 10K has been successfully tested with both I2C devices being used.

GPS

The GPS module to be used is the GP-635T, which may be run at 3.3V and has an integrated antenna; it uses up to 50 channels and has a sensitivity of -161dBm. It is based on the UBlox 6 chipset. It communicates using the standard NMEA protocol over TTL serial; this makes it convenient for use with the microcontroller (Teensy), since this has three hardware serial ports available for the user. The GP-635T module has not yet been acquired, however since it uses the standard NMEA protocol, testing thus far has been conducted with a GY-GPS6MU1, which is also based on the UBlox 6 (specifically the NEO-6M variant), and also uses the NMEA protocol over TTL serial; to all intents and purposes it is equivalent. It is heavier and larger than the GP-635T, which is the reason for selecting the latter for the final CanSat. The GY-GPS6MU1 has been tested, achieving reported HDOP (horizontal deviation of precision) in the open of less than three metres with a small patch antenna. This performance level is more than adequate, and this module will be used as a contingency plan.

Communications

Since a large link budget is required for a relatively low power input, Semtech Inc's LoRa technology was selected; the team has been assigned a frequency in the 433MHz band, so the Hope RF RFM98W will be used, which is a 16x16mm SMD module which handles transmission, reception, and can perform cyclic redundancy checks to a user-selectable bit length; this is likely to be used in order to ensure the continuity of transmitted data. LoRa is largely based on spread spectrum technology; Team Impulse has been assigned a frequency of 434.70MHz. The nearest teams are on 434.52MHz and 434.88MHz respectively. This is an 18kHz gap, which suggests that, bandwidth being distributed equally, the maximum allowable bandwidth for Team Impulse transmissions is 18kHz. This is at the bottom end of the LoRa bandwidth range, and is both legally permissible (see Ofcom "Short Range Devices Information Sheet") and clearly within the defined channel width. Since it is the closest appropriate setting, 15.6kHz will be used as the bandwidth.

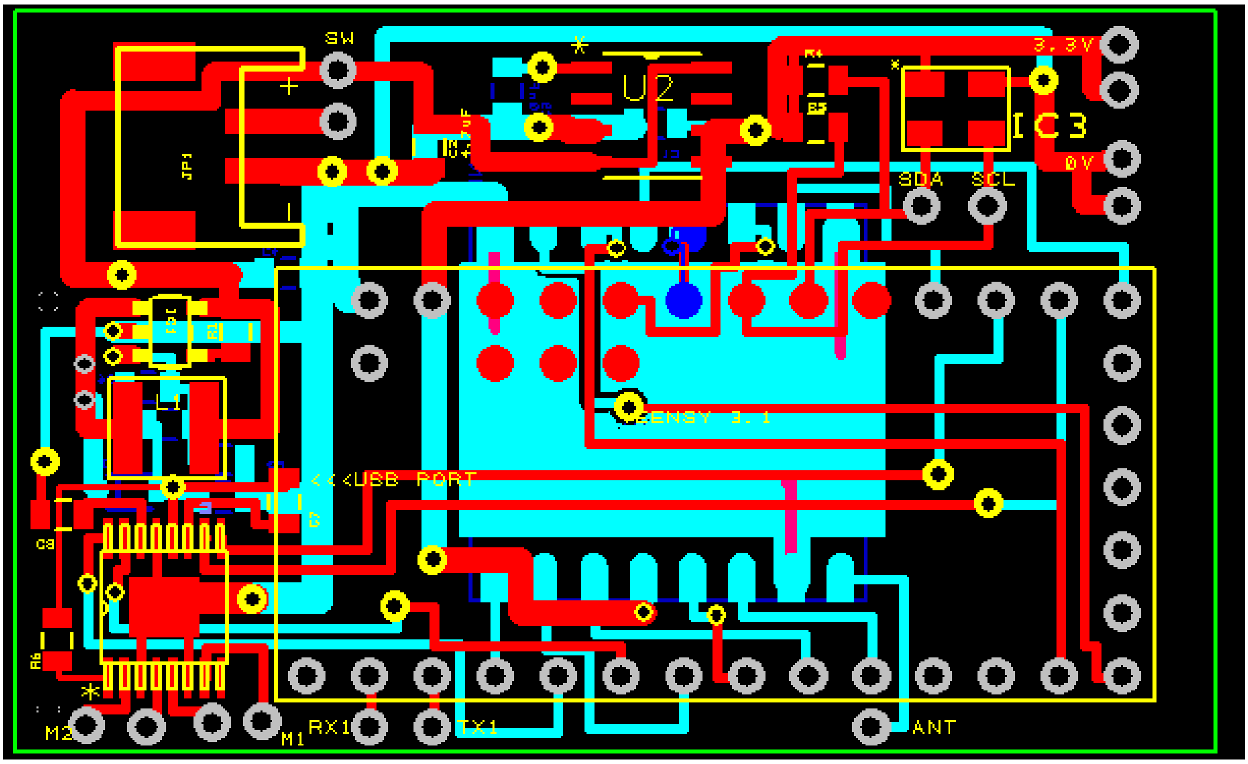
A spreading factor of 6, the lowest possible, will enable a high data rate; according to the LoRa Modem Design Calculator tool provided by SemTech, this will yield a data rate of 836 bits per second, with a link budget of 144dB and a receiver sensitivity of -130dBm. If, during testing, this proves to be unworkable, the spreading factor may be increased at the cost of decreasing data rate. The LoRa modems also provide inbuilt FEC (forwards error correction); the project will use this at a "coding rate" of 3 (on a scale of 1-4) which reduces the packet count and overhead involved compared to setting 4, but maintains good error correction capability, especially useful for dealing with burst interference.

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

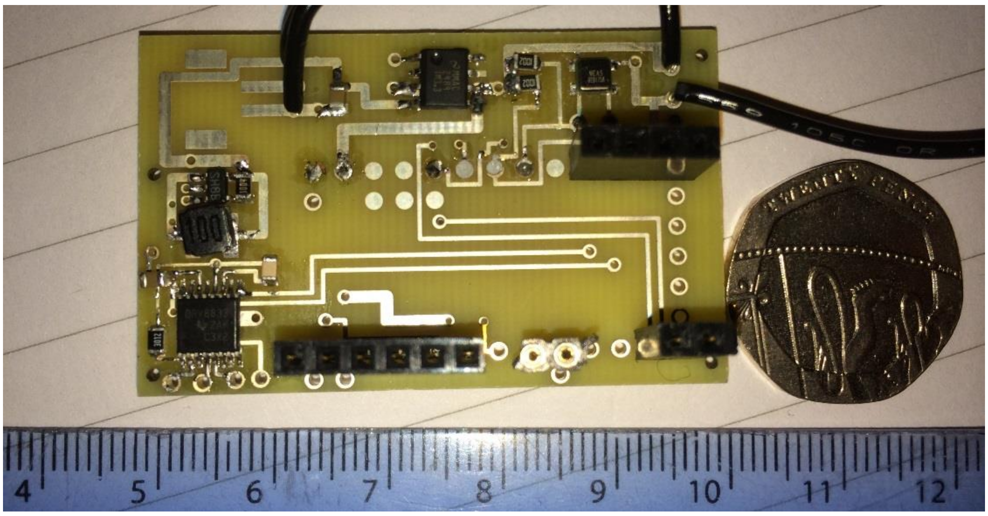
PCB



The printed circuit board has been designed in RS/Allied DesignSpark PCB 6.1. All files are available on the GitHub repository. This is Revision B; the circuit remains largely the same as revision A, with the following changes:

1. Added missing trace from U2 pin 8 to V+. Pulls up sleep pin, to ensure that the device is always active. A piece of wire was required for this on Revision A.
2. Changed motor driver from Allegro A3901 to Texas Instruments DRV8833PWP. This is in a rather easier-to-solder variant of the HTSSOP-16 package.

The board has been assembled by hand; please see below for a photograph which omits the Teensy (since this has been removed temporarily to allow direct access to individual pads).



Software

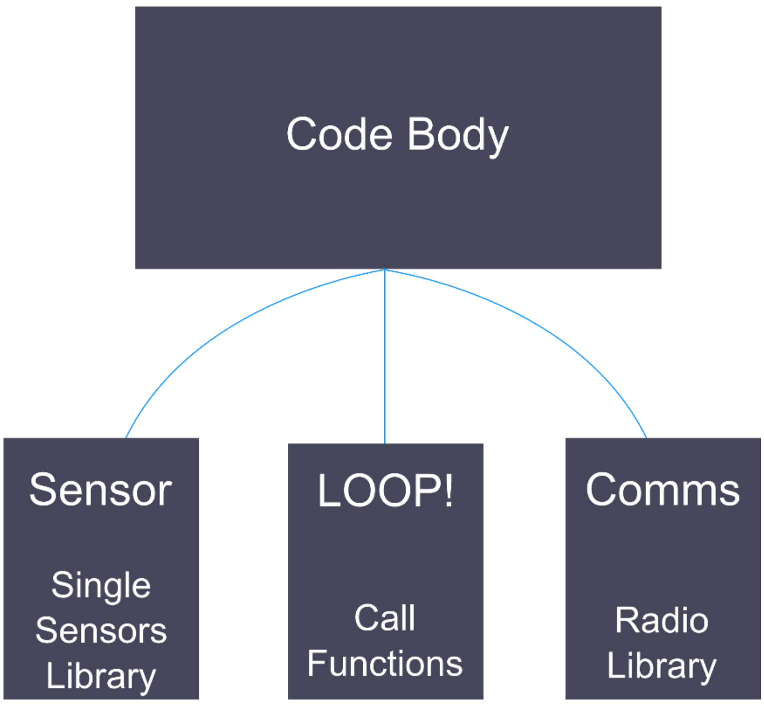
Progress is reasonably strong on software, with the firmware progressing well and work on the base station software to begin in earnest shortly. A number of important decisions regarding the structure of firmware code have been made and are detailed below.

Firmware

The rover firmware is progressing strongly, with three people at work on it; William, Euan and Igor. In order to make the code as readable as possible (which is important bearing in mind that the team intends to check the code manually for possible infinite loops and logical issues before the launch campaign), it has been decided to segment the code into a number of libraries; there will be a 'sensor' library, which will handle all interactions with sensors (excluding GPS) and all calculations on data retrieved from these, and a 'communications' library, which will abstract the radio module interface (and will probably include a function to check for a new packet from the ground). The majority of the code for the sensor library is now written; the MS5637 interface is implemented, as is that for the IST HYT-271. The communications library has yet to be written, because the messaging protocol by which the ground station and rover will communicate has yet to be finalised.

Both libraries will be controlled by a main loop (the Arduino environment is designed for a cyclic executive program structure) which will also take charge of navigation and motor control. The GPS will be interfaced with over serial, with the data read into a TinyGPS++ (an open source GPS library) object; this avoids writing complicated and hard-to-debug code to decode NMEA sentences and keep track of the resulting data. The outline of the rover firmware brief is to produce something which follows at least the broad principles of critical software design: making the code easy to review and ensuring that it is reviewed. It should be noted, however, that owing to time and budgetary constraints the team does not intend to apply so-called "formal methods" to the program as a whole, although some mathematical proofs of the navigation and motor control algorithm may be produced.

This diagram illustrates the broad structure of the rover firmware:



Software

The base station software development is still at the concept stage; unfortunately, time constraints on the people involved have meant that this section, which has the potential to be very time consuming, is still only in its initial phases. The firm decision has now been made, however, to implement the system using C# and GTK#, a .NET/Mono binding for the popular GTK+ framework. The specifications are as follows:

1. The software should have a map display showing the current rover position.
2. The software should display the current rover co-ordinates, both in degrees, minutes, and seconds format and in OS grid reference format.
3. 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. RSSID).
4. 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.
5. The software should calculate dew point and display it.
6. The software should provide any appropriate telemetry information (possibly battery voltage; internal can temperature (from MS5637)).
7. The software should provide an interface to enter waypoints for the rover to navigate to.
8. The software should provide an interface to permit manual control of the rover.
9. The software should log all data in an appropriate file format.
10. The software should interface with the local base station Arduino over USB Serial.

The maps are likely to be taken from OpenStreetMap or another such open source map vendor; they are likely to be served through a local HTTP tile server with some formatting applied.

Progress

The project overall is progressing according to plan. Some software delays have occurred, as the last report suggested was possible; the lack of availability of hardware at an early stage hindered development of software in parallel. It seems likely, however, that the software will be completed well before the launch deadline, and indeed before the documentation report is due in early February. This will give us the planned month of testing before launch.

As a result of the funding gained from the cake sale and from the PCBTrain sponsorship, there is no issue with regard to finances.

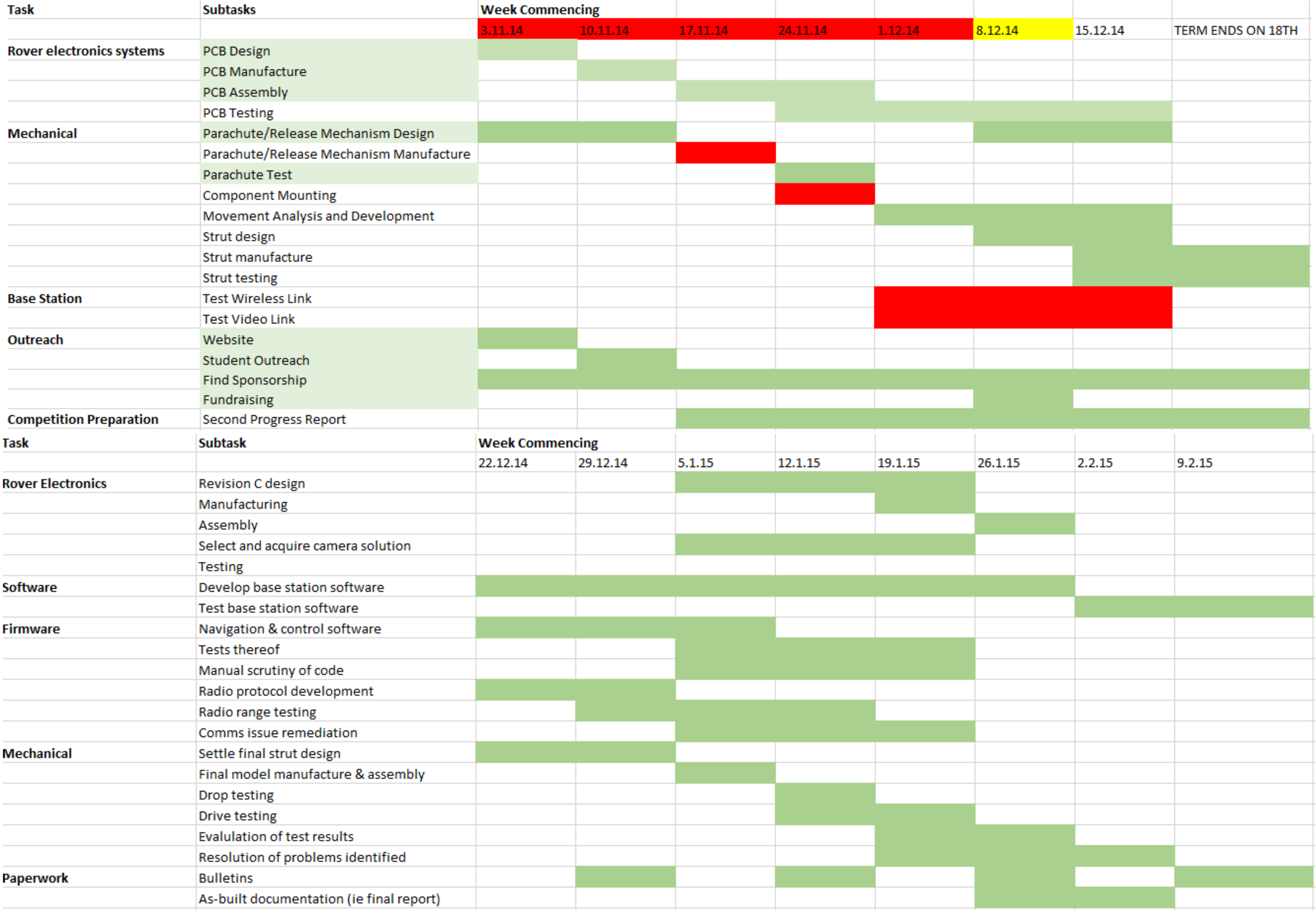
Risk and Mitigation Thereof

Risk	Mitigation
Team Members being unable to work due to illness or other reasons.	During the current stage of the process, the illness of team members has been easily mitigated. It is possible for the team to share the workload (albeit to different extents depending on each team member's specialisation). Further, to ensure that everyone in the team is aware of progress and targets across all departments there are regular team meetings, including ones over Skype conference calls, allowing team members who might not be present at to update and listen to the others. Looking further ahead to issues due to illness during events and the eventual launch, it will be down to the remaining team to do all they can given their overall knowledge of the project's different aspects.
Issues with the arrival of parts such as late arrival or damage.	This is best mitigated by having a clear plan of what parts are required well before they are needed for use such that there is time for parts to arrive even with delays. Similarly, this allows parts to be replaced if they arrive damaged. To produce such plans again requires team cooperation, enabled primarily by meetings online and in person. The team also tries to order from reliable sources which are popular or have been used in the past by other team members or previous teams.
Malfunction of electronic components	The electronics prototyping stages began at the dawn of the project and with the aid of several revisions, the team will ensure that the board is thoroughly tested by the time of the launch.
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 created multiple chassis designs that allow a fair amount of space for the components, easing air circulation.

Delays in software production.	The software has so far and will require rigorous testing. Once again, delays in software can be mitigated by planning far ahead. Issues with software will need to be eradicated or worked around, thus requiring very active team cooperation. Software and hardware will increasingly need to work together.
Delays in construction.	This will be 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.	A working prototype is being produced at present; this will be maintained in working order after production of the final rover begins, in order that they may both be taken to the competition. Thus, if one is destroyed shortly before the competition, it will be a significant disadvantage but will not necessarily result in mission failure.

Gantt Chart

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



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**.

Secondary mission:

The CanSat should:

1. Be capable of movement over smooth ground and rough grass, including inclines of at least 35% on a solid surface.
2. Be capable of navigating directly to a set of co-ordinates transmitted to it.
3. Be capable of following manual commands transmitted to it.

4. Be capable of travelling a minimum of 500m on a suitable surface, given sufficient time.
5. Relay relative humidity to the ground station at least once every five seconds.
6. Have ground software able to calculate approximate dew point.

Desirable Specifications:

It would be desirable for the CanSat to:

1. Record video of its journey;
2. Stream this video back to the base station.
3. Be capable of easy disassembly for maintenance purposes.