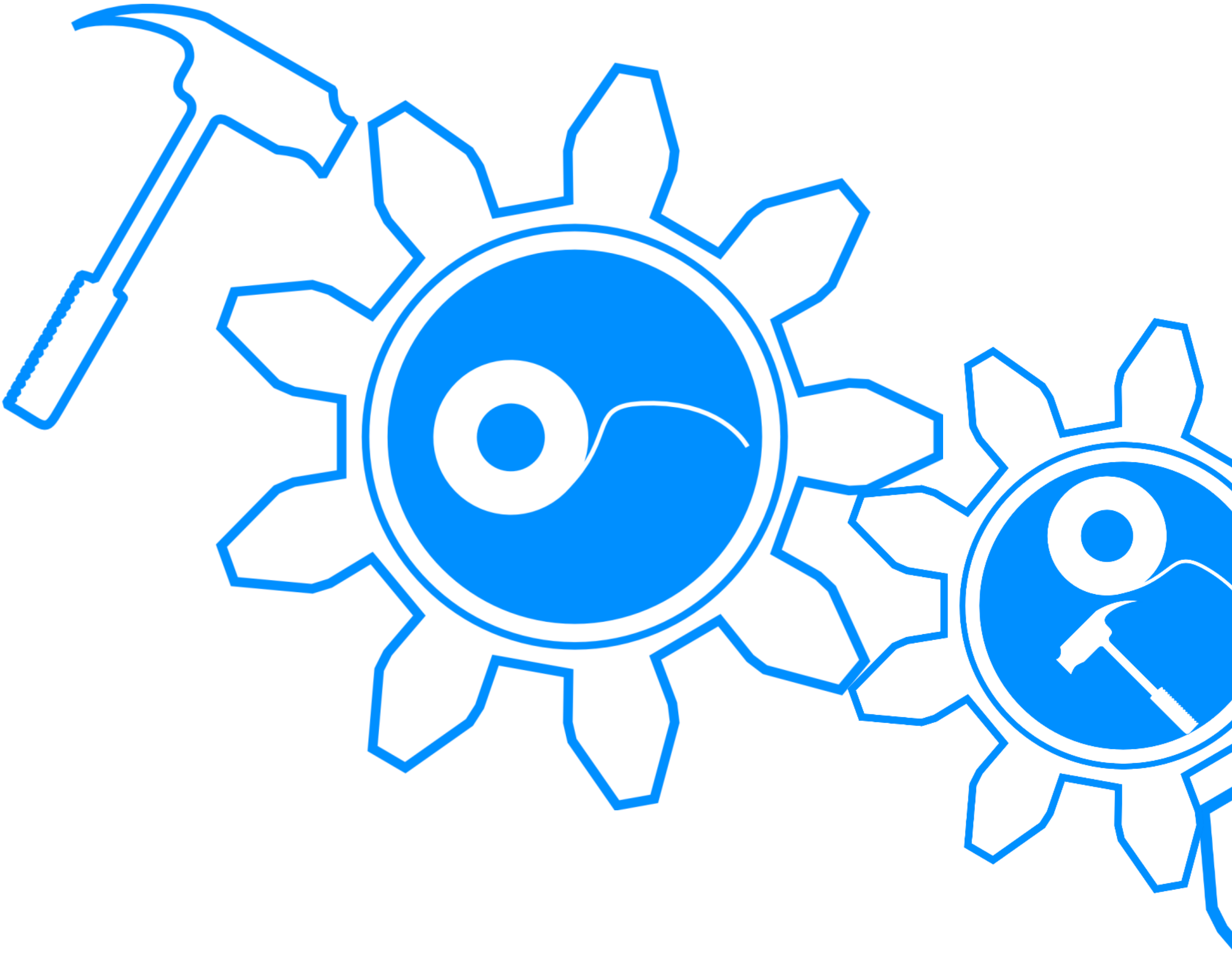


William Eustace, Euan Baines, Yuki de Pourbaix, Alex Forey, Hugo Cheema-Grubb, James Crompton

TEAM IMPULSE

CanSats in Europe

First 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.

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

The project is progressing broadly as planned, with some minor setbacks in Electronics resulting in the need for a second revision of the board to be ordered. For a detailed outlook, please see the ‘Progress’ section at the end of this report.

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. 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.

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.

The School holds an annual Societies Fair, to give new entrants an idea of what extracurricular activities they may expect over the coming years; the team exhibited at this, and spoke to a large number of Year 9 students, many of whom signed up to SPS Space, the school's aerospace society, under which CanSat is run. A number of these congregate every Friday lunchtime to participate in various projects, for example projects relating to high-altitude ballooning, and on one such Friday recently, William gave a 15 minute presentation detailing both the CanSats in Europe programme and the Team Impulse entry. An opportunity was then presented for questions to be asked.

Further outreach is planned; a school assembly to certain lower years is likely to be undertaken in the next few weeks, when it can be arranged, and the team intends to publish a short press release to the local press shortly. Updates will continue to be posted to Twitter and to the website.

Funding

Sources

Sponsorship applications have been made to Newbury Electronics, which is a firm based in Berkshire manufacturing PCBs on a small scale basis, and to Sparkfun, a large electronics supply firm in America. The results of this are still awaited, however it is believed that even if sponsorship is refused, the project will still be able to proceed on existing funding, which is outlined below. Further sponsorship applications, likely to firms including Google, are in the pipeline and will be made shortly; these are likely to be delayed until the result of the existing sponsorship requests is known.

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. This funding alone adds up to more than the maximum budget permitted under the CanSat regulations, and so it is believed that no issue will arise.

Expected Costings

Section	Expected Cost	Approx amount spent to date
Outreach (incl website costs)	£50	£30
Hardware	£100	£20
Electronic components	£250	£160
PCB Manufacture	£200	£45
Misc	£100	£0
Total	£700	£250

Hardware

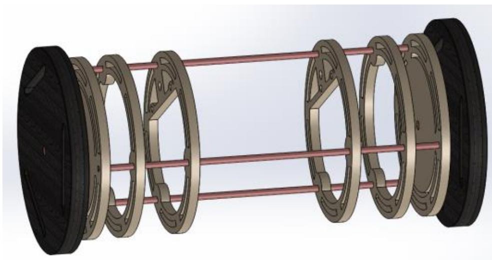
Currently, the Cansat's hardware is the most advanced part of the build. Multiple CAD renders have already been developed, and Yuki has selectively tested the chassis of the build having considered plastics, metal and wood; it was decided through stress testing, both virtual and physical, to use plywood and either copper or aluminium in the final design. With data on the weaknesses and strengths of the design, the hardware team has begun to refine it in order to fulfil the given criteria to the best of the team's combined abilities.

The requirements taken into account at every stage of testing and concept design are as follows:

- It must fit into a can of dimensions 66mm Diameter and 115mm length.
- It must weigh 370g including batteries and must be able to resist a force of up to 3.7N on impact.

The process adopted in order to optimise the design involves a great deal of CAD work using Solidworks, in which each part is designed and tested individually, before a test of the assembly as a whole to ascertain any weaknesses in the design.

Materials are chosen based on three factors of descending importance: tensile strength, mass per unit volume and price. In doing so the team has researched each material and used the information to run more accurate tests in order to ensure the final design will be as efficient as possible.



Although the testing itself is done entirely virtually at first, the results are then used to decide upon which material to use in physical tests. In this way costs are minimised, along with material wastage. This also allows more realistic tests to be run in the physics laboratory where its mass is accurately measured, and then pressure applied to ensure it meets the required benchmark. If it fails to do so, changes are made to the virtual design until it is significantly stronger than theoretically necessary and repeat the process.

The testing process will become steadily more aggressive as the design progresses into its final stages in order to cater for unexpectedly rough conditions on the day. Currently several drop tests from ascending heights onto grass and concrete have been performed, as well as the application of a vertical impact force of 10N, which occurred without the chassis noticeably weakening. The aim is to ensure the final design keeps to this benchmark.

At the current rate of progress the expectation is to have a completed a fully functional primary prototype before 2015 on which further tests may be performed before building the final model.

The current design involves wheels of diameter 66mm on each end of the can and a central strut extended from the chassis for balance. Several different methods of making it mobile were considered, but the team decided upon this particular design due to its efficient use of the space allowed. Other designs, including treads or internal weights were unreliable on inspection or took too much space in the final design. While going through the design phase, the team considered the option of using wheels that could be compacted but would then spring out on impact. Foam wheels are the current optimum solution as they would act as good shock absorbers and could be compacted within the can reducing the need for ground clearance within the 66mm diameter. This is an idea still under test which may be put into practice in the final design.

Parachute System Design

The parachute retardation force is dependent upon the shape and size of the parachute, which has yet to be confirmed; it is currently believed that a circular shape would prove easiest in deployment, 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.

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, however testing will be undertaken before launch.

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 very dangerous if overcharged, over-discharged or short-circuited. Fortunately, Sparkfun sell a LiPo battery which includes over-volt and over-current protection, and has an under-voltage cutout. 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 space used both on the board and in general.

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 (6V) is required, which is generated by a switching boost regulator, which uses high-speed switching of the input voltage to produce back EMF in the conductor. This output is then smoothed by capacitors, and filtered to be unipolar using a diode.

In both power supply sections, ceramic capacitors have been used. These have been selected according to the manufacturers' recommendations, as anything deviating from these is known to increase the likelihood of oscillation, a phenomenon which must be avoided in this circuit.

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. 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.

Motor Drivers

The motor driver initially chosen 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 pin spacing; each pin is separated from the next by 0.3mm, which turned out to be impossible to solder 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 is considered appropriate for hand assembly.

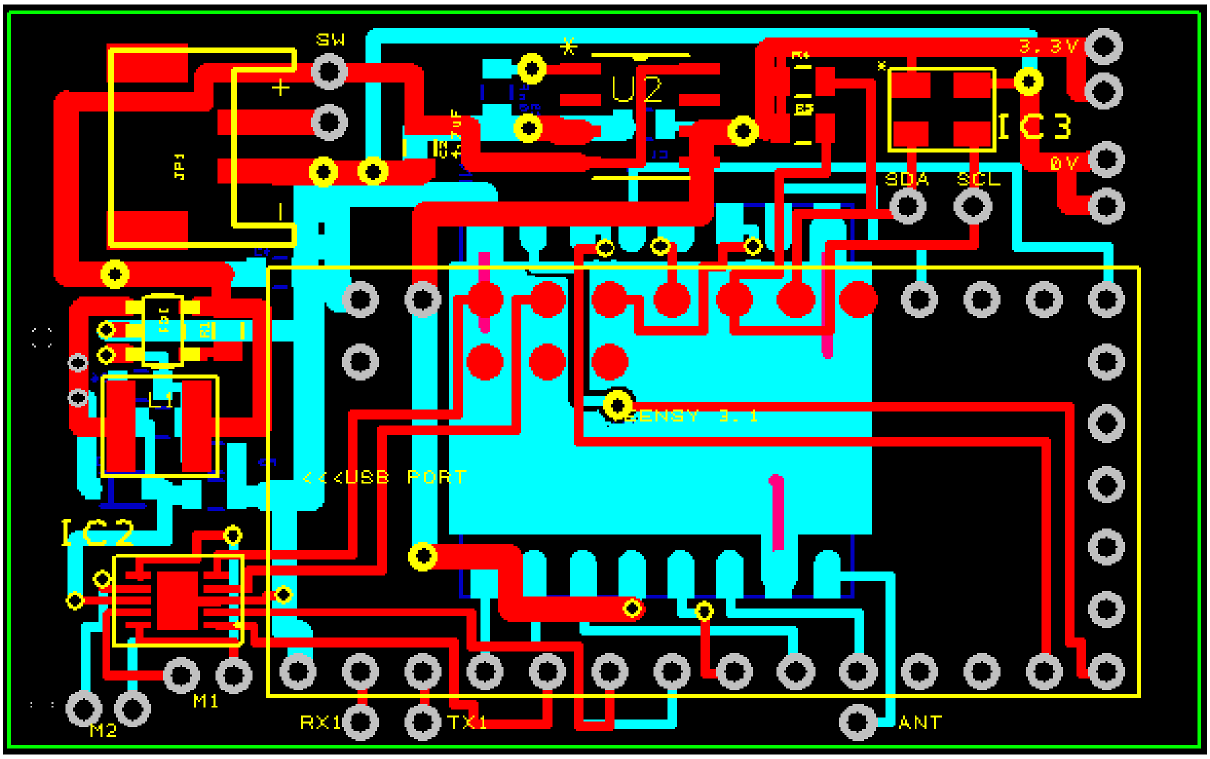
Sensors

The primary mission requires detection of temperature and pressure; this is achieved through a Swiss-made 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.

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.

PCB



This is a top-down view of the PCB, before the replacement of the A3901 motor driver (the accompanying redesign is yet to be completed). The motor driver is “IC2” on the left, the Teensy is the relatively large board in the middle with a number of through-hole pads, and on the other side in blue the ground plane and pads for the radio module may be seen. The pressure sensor is “IC3” at the top right, and both “IC1” and “U2” are power supply chips. The rest of the circuitry is ancillary to these functions. Blue tracks are on the bottom layer and red ones on the top; the green line round the edge is the board outline (dimensions 48.6x30.0mm) and the yellow boxes on the diagram show silkscreen outlines. Pads are represented in the usual fashion. The design was accomplished using DesignSpark PCB. Since issues with the motor driver prevented the board from being fully assembled, no photograph of the assembled board has been included in this report, however other functions have been established.

Software

Little progress has been made on programming, since the electronics manufacture stages are still incomplete and therefore no code may be run, however module code sections have been written and the team anticipates using a number of open-source libraries, which should reduce significantly the amount of original code which needs to be written. Unfortunately, the I2C devices to be used (HYT-271 and MS5637) do not have existing code libraries. The GPS uses a simple NMEA data stream, which is standard; the open source and widely used Arduino library TinyGPS++ includes the capability of finding a bearing and range to a specified set of co-ordinates; this will be of use for the navigation section of the project. The LoRa modules use an SPI interface, for which documentation and sample code in PIC C is available. Other users have written code for the Arduino which uses this chip, which is useful because it helps to highlight any particular issues encountered when using the RFM-98W with the Arduino.

With regard to the base station software, the likely configuration will be a simple combination of Arduino and LoRa module plugged into a computer, which will interface with the LoRa module over USB serial and thus communicate with the rover. This will most likely be written for Mono/.NET in Visual C#, however this remains susceptible to change.

Version control of all software is being undertaken with GitHub, and the team intends to use pull requests where possible and appropriate to ensure that all code is checked by a second team member before being committed to the code base. It is hoped that this will reduce the possibility of errors in code which are not syntactic (ie which are not picked up by the compiler).

Progress

The project has been progressing broadly speaking according to plan, as has been indicated by each section; the key areas of concern at present are electronics and software, since these are the least complete of the sections. It is still felt that these are on course to produce a prototype by Christmas, as originally intended. The plan will then be to produce a final model over the Spring term, beginning intensive testing in February and completing it in time for final launch preparations.

With regard to funding, no budget over-run appears likely, while it appears likely that sponsorship will be obtained to cover a portion of it and thus create a larger safety margin.

Risk and Mitigation Thereof

The greatest threat to the successful completion of the project on time at present is a serious issue with electronics, however this is relatively easily mitigated; the current timeframe permits several revisions of boards to be produced and tested, and it is believed that a second revision of the existing board should be produced and operative in a test environment by mid-November. This level of prior planning will permit a major change to the design should it become necessary.

The other significant threat is hardware; if there are issues with the design, this sector can take some time to incorporate them, despite rapid CAM. The only solution to this is extensive CAD and simulation to determine potential failure points, combined with a broad examination of the design when the likely usage is taken into consideration.

Gannt Chart

This Gannt chart shows the plan for progression of the project during the coming half term.