Escola Secundária João de Deus, Faro

Project CanSat 2016

Team CanRover

- Work done by:

➔ Daniel Santos

➔ Hernani Sousa

➔ Inês Duarte

➔ João Costa

➔ Jonas Rodrigues

➔ Marta Barros

Teacher : Vitor Guerreiro

1. Introduction

The 2016 CanSat competition is an educational project organized in Portugal by Centro AeroEspaço of Torres Vedras Flying Club and Ciência Viva – National Agency for the Scientific and Technological Culture.

The CanSat is an operational model of a micro-satellite in which all systems are assembled in a volume that fits inside a soda can. The model is launched by a rocket up to a height of 1000 meters and during its descend a scientific experiment of data collecting is conducted until the satellite's safe landing.

This competition is an initiative of the European Space Agency (ESA), that promotes both teamwork and a practical application of knowledge acquired in school subjects such as physics, mathematics and informatics.

The CanRover team is a team of six members, composed by Daniel Santos, Hernâni Sousa, Inês Duarte, João Costa and Jonas Rodrigues, from Escola Secundária João de Deus in Faro that has applied to the 2016 Portugal CanSat Project.

The CanRover (CanSat) will collect data from several atmospheric elements and, following its landing, it will move along a predefined trajectory.

The main objective of the CanRover is to serve as a prototype to a future recon mission of a planet, in which a satellite must be able to provide enough data to characterize the atmosphere – temperature, pressure and humidity – as well as the surface – surface relief and magnetic field – of the new planet.

The project has two missions, a primary mission and a secondary mission. The primary mission is to measure temperature and atmospheric pressure during its fall with the aid of sensors and a parachute. The secondary mission is divided in two stages. The first stage involves the measures obtained during the fall whereas the second stage is related with the trajectory of the CanRover on the ground. During the fall, the CanRover will calculate air humidity (using the same sensor that measures temperature), latitude, longitude, and time using a GPS system. With the aid of an accelerometer, it will also gather information about the magnetic field, direction, and inclination; furthermore it will register altimetry variations using a precision altimeter. Along the predefined surface journey all these elements continue to be measured, and the altimeter will provide information to delineate the topography of the area. Data collection is made every second.

The journey of the CanRover can be followed in Google Maps, with this project it will be possible to characterize the atmosphere when it comes to temperature, pressure and humidity and also collect information about the Earth's magnetic field and the surface where the CanRover lands.

2. Description of the project

2.1. The CanRover

The CanRover will be built according to the dimensions stipulated by CanSat (115 millimetres high and 66 mm de diameter), with the wheels being set in each end. The wheels will have 65,01mm in diameter and a width of 10,04mm and ground contact surface made of 12 blades (or grousers) made of a rubberized material, as it can be seen in Figure 1. The shape of the wheels was chosen having in mind the grip in irregular terrains and also the ability to overcome a larger number of possible obstacles in its path, which is much greater when compared to the traditional wheel shape. The material chosen was rubber since it is important to have a material that is able to deform and absorb energy during the landing impact.

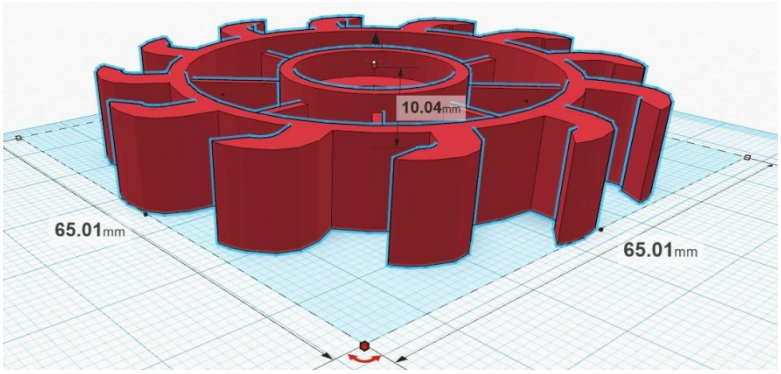


Figure 1 – Schematics of the Wheels of the CanRover, projected in THINKERCAD ®.

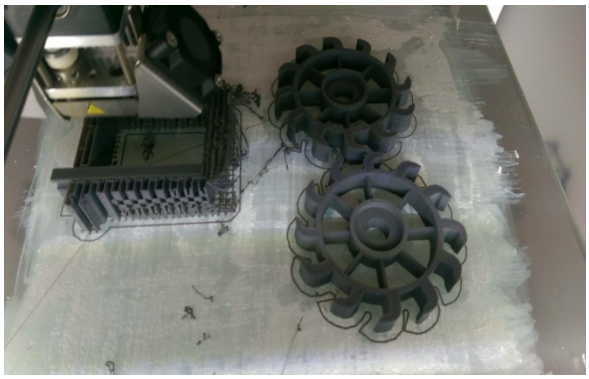


Figure 2 – Construction of the chassis and wheel casts on a 3D printer.

The disposition of the CanRover components is illustrated in Figure 3. The servos will be placed in the lower part of the chassis along with the batteries. Thus the centre of gravity of the chassis will be as low as possible making the CanRover more stable. The arduino will be set above this together with all the necessary sensors.

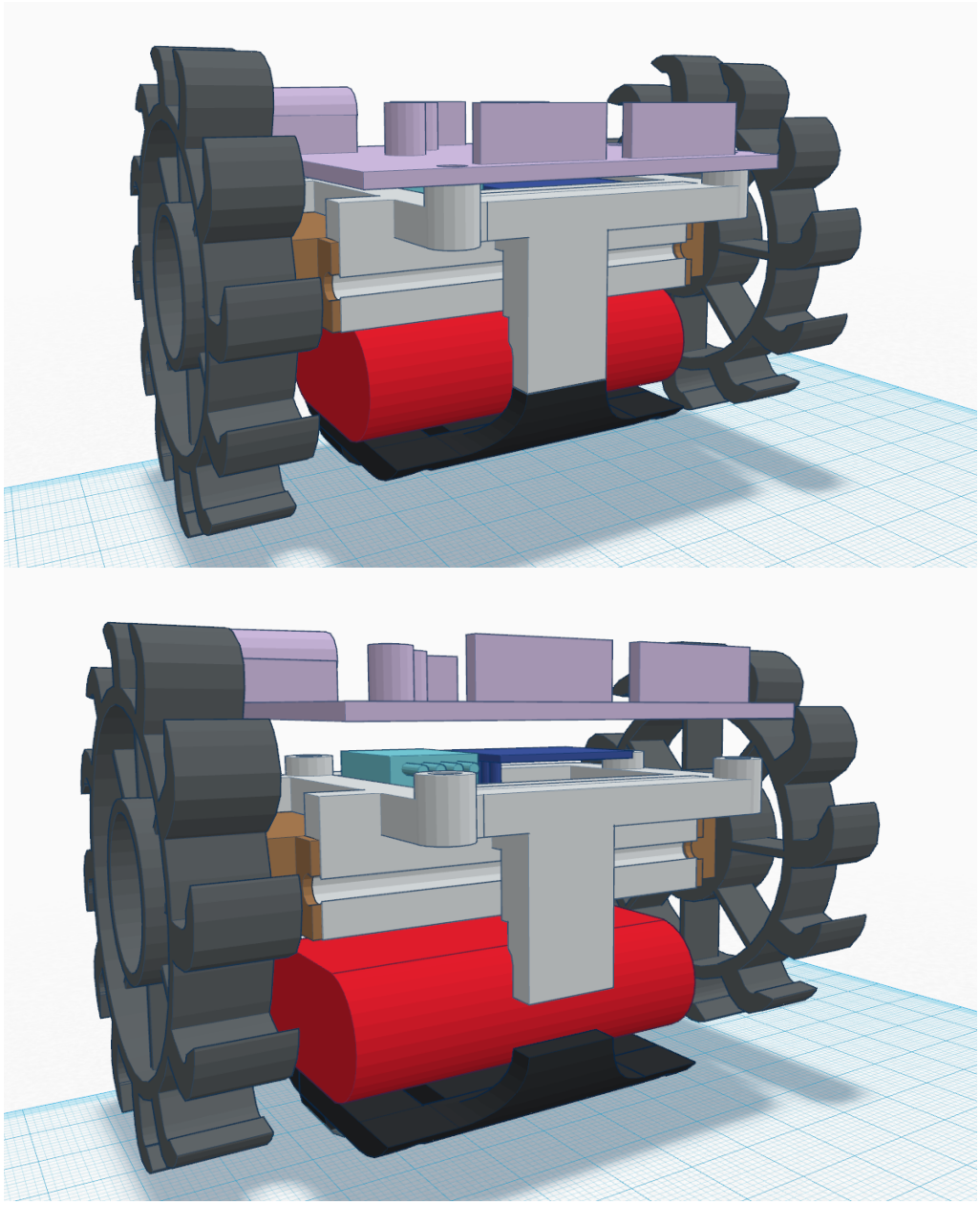


Figure 3 – 3D representation of the CanRover and its components, projected in THINKERCAD ®

- -Arduino UNO (Rev3)
- -wheels
- - Battery and stabilizer holder
- -Chassis
- -Continuous rotation servos
- -DHT 22
- -CMPS 11
- -Battery 500 mAh/ 11.1v

A plastic structure will be made in order to keep all the systems together, and then wrapped in compact foam. In this way, the support system of all the components of the CanRover (plastic structure and compact foam) will have a significantly low mass and at the same time it will help to absorb energy during the landing impact.

2.2. Parachute

2.2.1. Theoretical Introduction

The parachute is connected to the central part of the CanRover with a solenoid. The chosen parachute model is a circular parachute as this model does not need a trajectory control system during descent. We chose a model with apex as a way to avoid oscillatory movements in order to reduce turbulence. A swivel was placed between the can and the parachute to minimize the CanRover rotation during the descent. We also chose a net parachute instead of a cord model, the advantages are that the CanRover will not be entangled and the opening of the parachute is guaranteed. There is also an even distribution of forces. To ensure parachute resistance at 1000N and 20G, we chose ripstop nylon and 4 nylon straps (3/8) type 3, a nylon net and also a nylon sewing line. The colour will be fluorescent orange in order to follow the application requirements. The parachute was sewn in a professional equipment, Syko.

Near the ground, the solenoid will release the parachute letting the CanRover in freefall to avoid entanglement so that it can then start its surface mission of collecting data about the topography outline and the Earth's magnetic field.

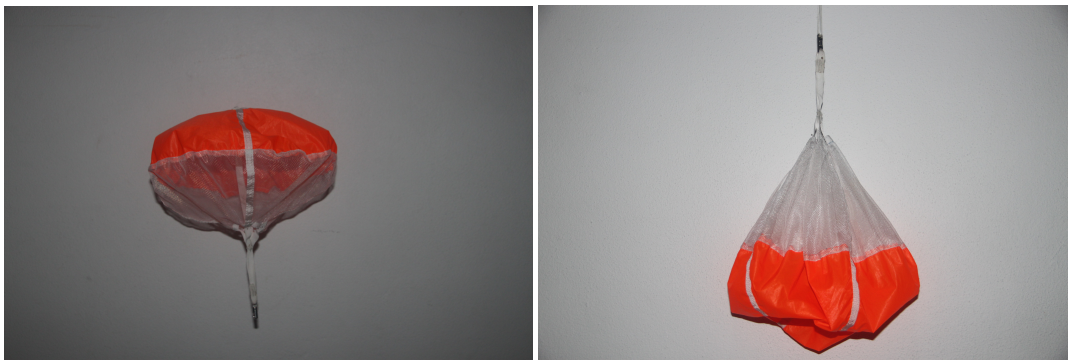


Figure 4 – Finished parachute.

2.2.2. Mathematical equations

The base equations for the construction of the parachute were the following:

$$A_p = \frac{2mg}{\rho C_d v^2}$$

$$A_\circ = \pi r^2$$

$$A_p = A_\circ \Leftrightarrow \frac{2mg}{\rho C_d v^2} = \pi r^2 \Leftrightarrow r = \sqrt{\frac{2gm}{\rho C_d v^2 \pi}}$$

$$r = \sqrt{\frac{2 \times 0{,}350 \times 9{,}81}{1{,}225 \times 0{,}75 \times 8{,}5^2 \times \pi}} \approx 0{,}1815m$$

$$r_f = 0{,}1815 + 0{,}008 = 0{,}1895m$$

in which A_p is the parachute area, and A_o is the circle area; as the shape of the parachute is a circle, one can deduct the radius, r, however since it was necessary to create a cast for the production of the parachute, the radius was increased by 8mm for the parachute seams, r_f.

The apex area (A_a) must be around 4% of the total parachute area, therefore:

$$A_p = \frac{2gm}{\rho C_d v^2}$$

$$A_p = \frac{2 \times 9{,}81 \times 0{,}350}{1{,}225 \times 0{,}75 \times 8{,}5^2} \approx 0{,}103m^2$$

$$A_a = 0{,}04 A_p$$

$$A_a \approx 0{,}04 \times 0{,}103 \approx 4{,}138 \times 10^{-3} m^2$$

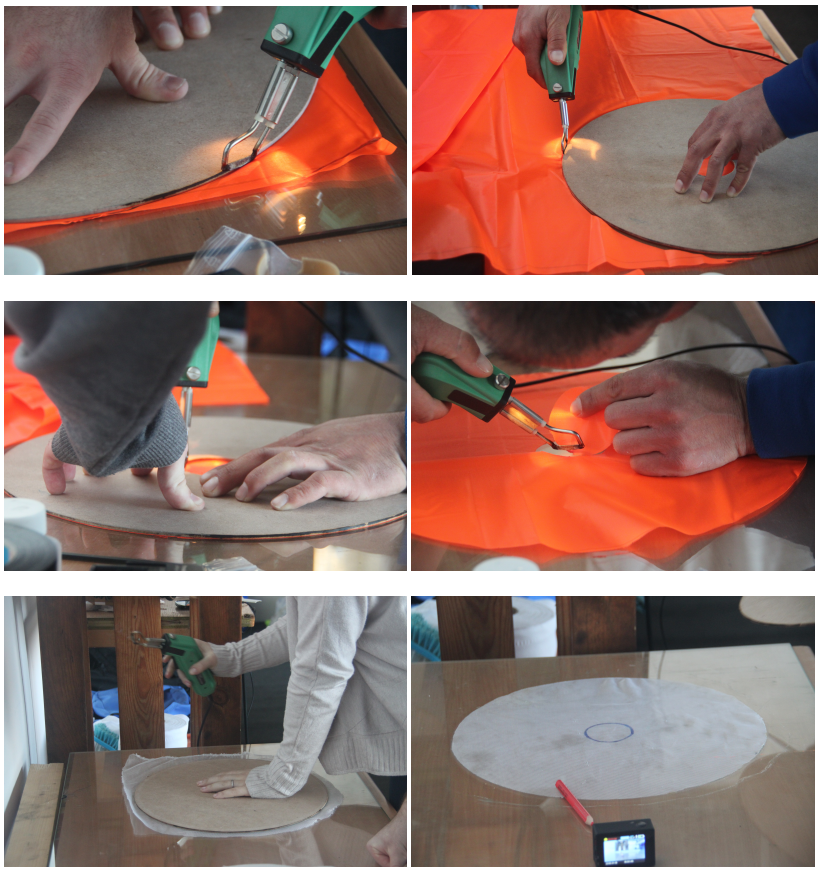
$$A_a = \pi r^2 \Leftrightarrow 4{,}138 \times 10^{-3} = \pi r^2 \Leftrightarrow r = \sqrt{\frac{4{,}138 \times 10^{-3}}{\pi}} \Leftrightarrow r = 0{,}036m$$

In all calculations, we considered g as gravity acceleration, 9,81 ms^{-2} at sea level, ρ as air density at sea level, 1,225 kgm^{-3}, Cd the parachute traction coefficient, 0,75, and v the parachute descent speed, 8,5 ms^{-1}.

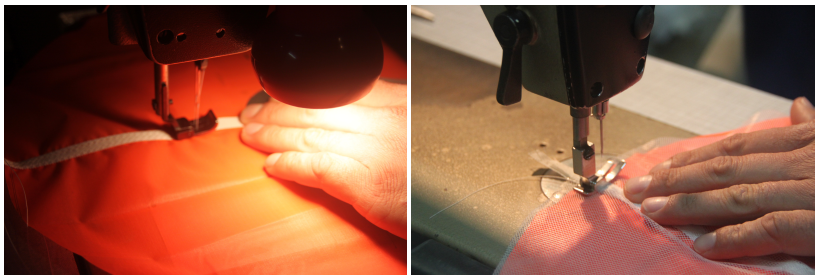
2.2.3. Construction and testing of the parachute

With the materials supplied by SkyDive Algarve it was possible to build the parachute. Therefore, these steps were followed:

1- With the assistance of a previously designed mold in slim wood, the ripstop nylon tissue and the net were cut with a hot knife.



2. Two nylon tapes were sewed to the net.



3. Finaly, the tissue and the net were sewed. The parachute was built in-side-out so that the stiches were placed on the inside increasing its resistence.

2.2.4. Parachute Tests

Five tests were conducted with the parachute, two of them on the 18th of January, in the Óasis building in Faro, at a height of 48 meters, reaching medium velocities of 8,6 m/s and 9m/s.

On the following day, the team travelled to SkyDive Algarve, in Portimão, to test it at higher altitudes, 1000 feet (305 meters), obtaining an average velocity of 10,8 m/s in the first drop. Afterwards the length of the central tape of the parachute was adjusted in order to decrease the average fall velocity to approximately 9,9 m/s. It was adjusted one final time to obtain an average fall velocity of 9,28 m/s, approximately the initially expected 9m/s.

It wasn't possible to test the 20G or the 1000N, as the school didn't have the technical and logistical assets to do so, nor was it possible to test with other entities. Other than that, the use of the tissue as a support surface that would allow an even distribution of forces on the parachute, a net and tape instead of a cord parachute configuration.

2.2. Missions

The Project has two missions. All the data collected in the two missions will be transmitted via radio signal to the computer of the team in land.

The primary mission is to measure the temperature and the atmospheric pressure during the aproximately 120 seconds fall of the CanRover.

The secondary mission is divided in two stages. During the first stage a Temperature and Relative Air Humidity sensor will measure the air humidity to enable a more complete reading of the atmosphere. Simultaneously, latitude, longitude and time will be measure with a GPS, and the direction and inclination of the CanRover will be obtained with a three axis accelerometer. In this way, the movement of the CanRover will be monitored defining its trajectory in Google Maps (through API - Aplication Programming Interface) and its tridimensional orientation. Finally, to obtain a more comprehensive characterization, an altimeter will be used to measure the magnetic field and possible altitude variations on the surface.

The second stage has the main objective of characterizing the ground surface and will take place after the landing. Temperature, humidity and pressure will no longer be registered but the readings on latitude, longitude, time, CanRover direction and inclination, and magnetic field will continue,

nonetheless with different objectives. In this stage, just before landing, the parachute is released so that the CanRover does not get entangled, after landing, the CanRover initiates its predetermined trajectory on the ground. With the GPS and the altimeter, the CanRover will measure surface relief. Magnetic field variations are still being monitored but now along the surface journey. Throughout this mission the data collected on the surface will be transmitted to an application specifically created for this purpose that will use Google Maps API as a way to provide real time location of the device. After completing the data collection, the buzzer is activated and all sensors are turned off, with the exception of the GPS system.

2.3. Electric Scheme

As it can be seen in Figure 4 the sensors and the GPS are connected to a UNO Arduino microcontroller powered by a LIPO 11.1v battery with a 500mAh capacity.

The altimeter will be the MPL3115A-2 and the accelerometer will be the CMPS11, and they will be connected to the microcontroller by a I2C bus, with the aid of two resistances of 4,7 kohm, as seen in the schematics. The GPS model, Ultimate GPS Breakout, will be connected to the Arduino by serial communication with the microcontroller UART. The temperature and humidity sensor, DHT22, will be connected to the digital input of the microcontroller. The parachute release solenoid and the buzzer are connected to the digital output of the Arduino.

The energy consumption of the sensors and servos of the CanRover are represented in table 1. The solenoid consumption is disregarded once it will only be active during the parachute release.

The temperature and humidity sensor will only perform readings during the descent, which lasts approximately 120 seconds, being turned off immediately after landing for the ground course, therefore its energy consumption is not relevant for the 3 hours of power up required by the regulations.

The GPS, altimeter and accelerometer will be active during the descent (2minutes) and during the ground trajectory (13 minutes), after which only the energy consumption of the GPS system will be relevant for the 3 hours of power consumption required by the regulations. The battery chosen for the project has a capacity of 500 mAh, since, according to Table 1, the total energy consumption of the system is approximately 429 mA. Hence, there is a safety margin of 71 mAh that can compensate for any power surges created by the servos due to steep topography variations.

Sensors and Servos	Arduino Connection	Power (V)	Consumption (mAh)	5V (mAh)	3V	Utilization in hours	Stand by period (h)
Solenoid5V ZHO 0420	Digital output	5	300			0	0
Humidity and Temperature sensor DHT22	Serial	5	5	2,5		0,03	0
Adafruit Ultimate GPS Breakout	Serial	5	25	25		0,25	3
Altimeter MPL 3115A2	I2C	3,3	2		2	0,25	0
Accelerometer CMPS11	I2C	3,3	25		25	0,25	0
Buzzer 5V	Digital output	5	35	35		0	3
Transmitter							3
Servos		6,6	500			0,22	0
		TOTAL Consumption		***62,5***	***27***	**123,15**	**306**
		Arduino Limits (mA)		**800**	**50**		**429,15**

Table 1 – Consumptions of the CanRover components

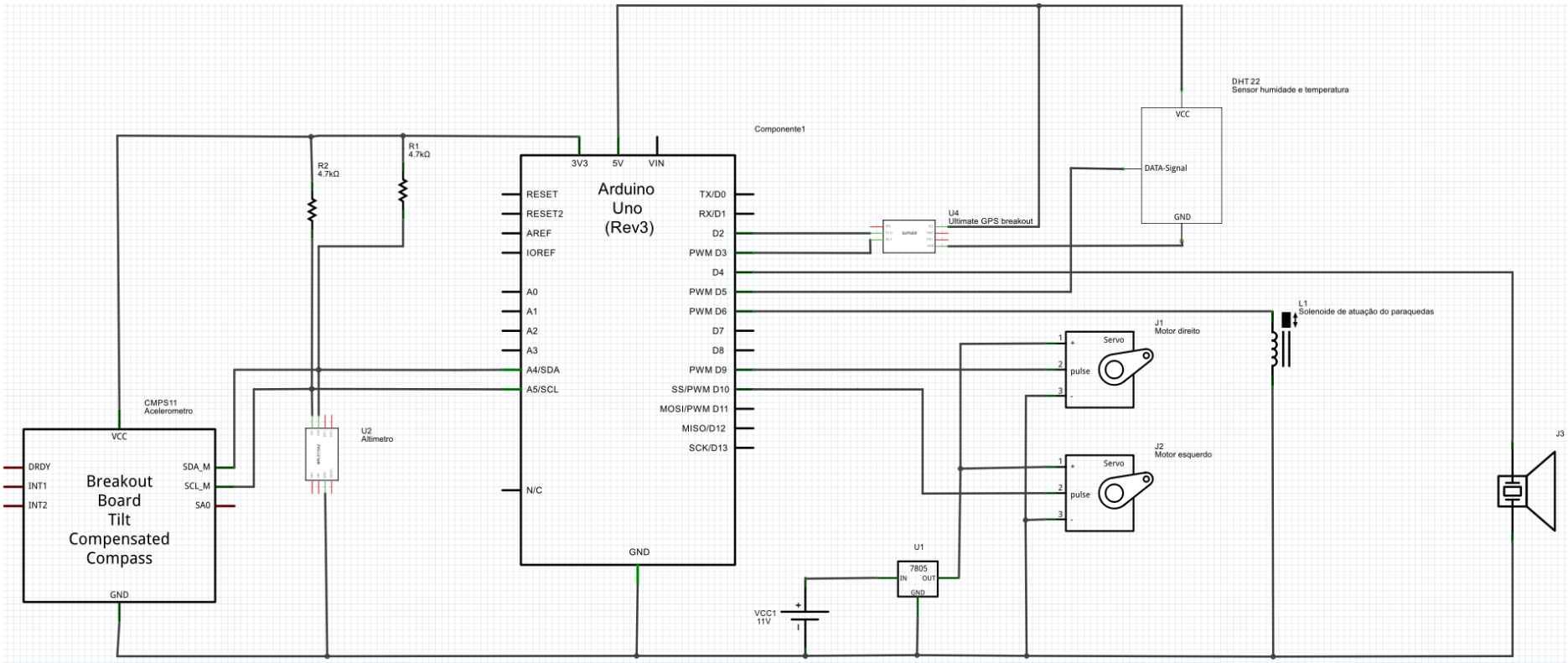


Figure 4 - Electric Scheme

2.5. Recovery systems

As to follow the regulations the CanRover will include a buzzer with sound beeps that can be heard at a distance of over 100 meters, in order to facilitate the recovery of the CanRover. The buzzer will only be activated after the conclusion of surface reading mission. Aside from the sound apparatus, the land team will also receive data (time, longitude, latitude) supplied by the GPS system aboard the CanRover via radio signals in real time, the data, with the aid of the Google Maps API will track the movement of the CanRover. So using the information given by the GPS the team will proceed to the landing area and once there it should be possible to hear the buzzer sound to locate the CanRover and retrieve it.

3. Making the Project known

3.1. Sponsors

The following companies have sponsored and supported this:

- SkyDive Algarve

http://www.skydivealgarve.com/ - they have contributed with technical and professional knowledge for the parachute production, supplied the material for the assembly and testing of the parachute.

SKYDIVE ALGARVE

- English 21

http://www.english21.pt/ - They have contributed with technical and professional knowledge for the English language elements during the application process.

ENG21SH ENSINO DE INGLÊS

Several sponsorship requests were sent to companies such as Banco Santander Totta, Caixa Geral de Depósitos, Intelmatis, Grupo Rolear, Algardata, Visualforma and Brimarel, which are still pending for approval.

3.2. Publicity

To inform about the different stages of the Project, the objectives, vídeos, images, sponsors and news, the contacts are the following:

- Web page : http://canrover.com
- Facebook: https://www.facebook.com/canrover2016
- Youtube: https://www.youtube.com/channel/UCxHwfGr7fw8NpD0EuZHeIxg
- School page: http://aejdfaro.pt/

4. Budget

On Table 2 and 3, the costs related to the Project are shown.

Components	Quantities	Price (€)	Brand/model	Supplier	weight (g)	Information
Rotation servo	2	19.86	Micro Servo-MG92B	pt robotics	14	https://www.sparkfun.com/datasheets/Robotics/servo-360_e.pdf
5v solenoid	1	6,46	ZHO 0420	pt robotics	13	http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Robotics/ZHO-420S.pdf
accelerometer	1	33,7	CMPS 11	ptrobotics	10	http://www.robot-electronics.co.uk/htm/cmps11doc.htm
altitude/pressure/temperature sensor	1	16,54	MPL3115A2	ptrobotics	13	http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/Pressure/MPL3115A2.pdf
Board	1	17,35	Freaduino ATmega328	DealExtreme	27	http://www.elecfreaks.com/wiki/index.php?title=Freaduino_UNO
Gps module	1	51,66	Adafruit Ultimate GPS	pt robotics	8,5	https://www.adafruit.com/products/746
humidity/temperature sensor	1	12,93	DHT22	pt robotics	5	https://www.adafruit.com/datasheets/DHT22.pdf
battery	1	8,43	Turnigy nano-tech 500mah 3S Lipo	hobbyking	50	http://www.hobbyking.com/hobbyking/store/uh_viewItem.asp?idProduct=87953
Shipping		10				
Total		150,61			154,5	

Table 2 – CanRover budget .

Components	Quantity	Price (€)	Supplier	Weight (g)
Orange Nylon Ripstop	1,5 m2	22,43	SkyDive Algarve	
Tape 3/8 type 3 200 pounds	2,5 m	15,03	SkyDive Algarve	
Nylon net	1,5 m2	4,97	SkyDive Algarve	
Swivel	1	2,5	SkyDive Algarve	
Nylon cord		5,07	SkyDive Algarve	
Total		50		22

Table 3 – Parachute Budget..

5. Team / Tasks

CanRover is a team with 6 members currently attending the science and technology course in Escola Secundária João de Deus in Faro:

- Daniel Jonas Guerreiro dos Santos, nº13, 12ºE – parachute construction, prototypes construction, CanRover construction and sponsorship requests;

- Hernâni Gonçalves de Sousa, nº19, 12ºE – 3D image production, prototype construction, parachute testing, CanRover conception, parachute calculations, CanRover construction and sponsorship requests;

- Inês Zagalo Varela Ramos Duarte, nº20, 12ºE – report production, parachute testing, parachute calculations, CanRover construction and sponsorship requests;

- João Pedro Viriato Pinto e Costa, nº21, 12ºE – Programming of the CanRover prototype, parachute testing, website development, CanRover construction and sponsorship requests;

- Jonas Gouveia Rodrigues, nº22, 12ºE - Programming of the CanRover prototype, website administration, parachute testing, video edition, CanRover construction and sponsorship requests;

- Marta Raquel Duque Mora Féria Barros, nº27, 12ºE – parachute construction, report production, 3D image production, CanRover construction and sponsorship requests.

5. Coordinators/ Acknowledgements

The authors of this report would like to thanks to Vítor Guerreiro, IT teacher in Escola Secundária João de Deus, for the opportunity given and for the all the means made available by the school. We would also like to thank Duarte Nuno Ramos Duarte, a Marine Geology professor at the Algarve University, José Conduto, electrical engeneer. Furthermor, the authors would like to thank Helder Sousa, SkyDive Algarve, instructor for the help during the construction of the parachute. The authors would also like to thank João Vicente, English teacher, for the support and translation of this report.

6. Conclusions

The parachute was built minding the materials and technical procedures that ensure, in theory the 1000N and 20G resistence, although it wasn't possible to test it.

The parachute will sustain an average fall velocity of 9,28 m/s, with a total mass of 343 grams, fulfilling the application requirements.

A prototype of the CanRover (figure 5) was developed in order to test the locomotion in open spaces, which allowed us to conclude that it was not possible of use a counterbalance due to mass limitations imposed for the application. Therefore it will be adopted a stabilizing system in order to achieve the correct position of the CanRover.

Figure 5- Prototype.