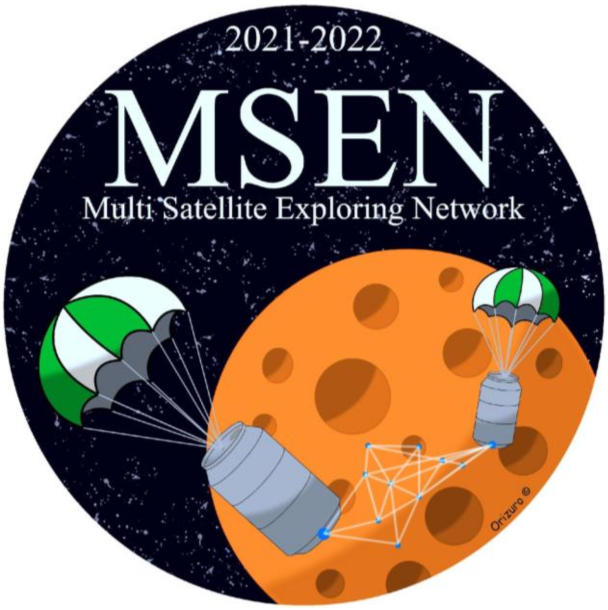

MSEN Final Report

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1. Team organisation and roles

Our team consists of seven members, one teacher (Miguel Neta) and six students (Mateus Cantante, Gonçalo Silva, Rafael Jacinto, Rodrigo Madeira, Alexandre Plotean and Octavian Popuiac).

All students study at the same class of the area of science and technology having Mateus, Rodrigo, Gonçalo and Alexandre being 17 years old with the rest of the members being 18 years old.

In order to obtain better performance the group was initially divided into 4 main areas: the modelling team (Gonçalo and Rodrigo), the Arduino programming team (Octavian and Mateus), the secondary mission programming team (Alexandre and Rafael) and the recovery team (Mateus), having later added the communication team (Rafael) and changed the roles of some members in order to take advantage of the areas where each one was more efficient.

In the end Rafael was responsible for the project coordination, the communication manager and the welding manager of the team.

Alexandre was responsible for all the programming of the project besides being responsible for the 3D printing and also did the calculus as well the construction of the parachute.

Rodrigo performed the functions of making this final document besides being the editor and responsible for the subtitles of the team's introduction video.

Octavian besides assisting Alexandre in programming was responsible for the social networks and the dissemination of the project.

Gonçalo made 3D models of the project's components and also made this document.

2. Description of the project

2.1 Project Summary

Our project consists of an effective way to carry out an exploration of a planet in aspects such as: relief, climate, meteorology and even the interior of the planet. This is all possible due to the possibility of covering a location with numerous sensors depending on the mission goals.

These *Seeds* modules communicate the data with the *Flower* and subsequently send them to Earth with help of the *Dandelion* satellite.

The *Seeds* can be equipped with various sensors ranging from temperature and humidity (which will be used in this competition) but they can also be equipped with sensors for humidity, radiation, movement, gas composition… etc.

In addition to receiving data from the *seeds*, the *Flower* can be equipped with sensors such as seismographs, augers, soil composition analysers, etc.

The positions between them can be calculated with the time it takes for a radio wave to go back and forth between two modules.

The *Dandelion* carrying several *Flowers* can launch them to the desired study locations, broadening the area of study in addition to offering the opportunity to cross-reference data offering possibilities such as studying the interior of the planet.

2.2 Expected results

It is intended to recover the pressure and temperature data as well as the request-response time between the modules in order to later create a map of relative positions.

The pressure and temperature data will be collected by the sensors given by the CanSat kit and then sent to the *Flower*. The time will be measured when the *Flower* sends a data request to each *Seed* which will be summarised by transmitting a specific symbol associated to each *Seed,* and when it sends the data it counts the time that this operation took. Because we are using the Arduino's internal clock the precision obtained is no more than 1×10^{-6} seconds, which is not enough for an efficient distance measurement trough radio wave.

All this with the objective of creating a map of relative positions where the data obtained by the sensors will be associated with a certain space, being therefore able to create observations about climate and meteorology and their variations.

3. Changes to initial project, if applicable

There have been many changes to the project since it began such as:

- Initially we would have used a humidity sensor to complement the data already collected by the other sensors (pressure and temperature) due to the lack of certainty of the time needed until the sensor arrives and is ready to be tested we chose to not risk and cancelled that idea.
- Initially we were also supposed to use a board that consisted of a stopwatch that measured time in nanoseconds in order to get more accurate data, but due to the lack of information regarding the operation with the board and not finding anyone that has worked with it we decided to not take the risk and use the functions micros, regarding its less accuracy in favour to actually show something.

4. Project sub categories:

4.1 Design overview

The *Seed* 3 will be released at an altitude of about 1 kilometre while the others (*Seed* 1 and *Seed* 2) will stay at ground, localised within 150 meters of the *Flower* due the error on the system, which will allow triangulation of the modules, beyond also demonstrating how the network works in this competition.

We will be using temperature and pressure sensors for collecting data.

Our project has its main scientific objective as creating an alternative positioning network to a global position system network, since this last one wouldn't exist in foreign planets.

The MSEN's secondary mission is to create such a network between the modules in this case the *Flower* and the 3 *Seeds*, but for it to be possible it will be required in each Arduino circuits one antenna on the *Seeds* which creates the possibility for *Flower* to *Seed* and *Seed* to *Seed* communications.

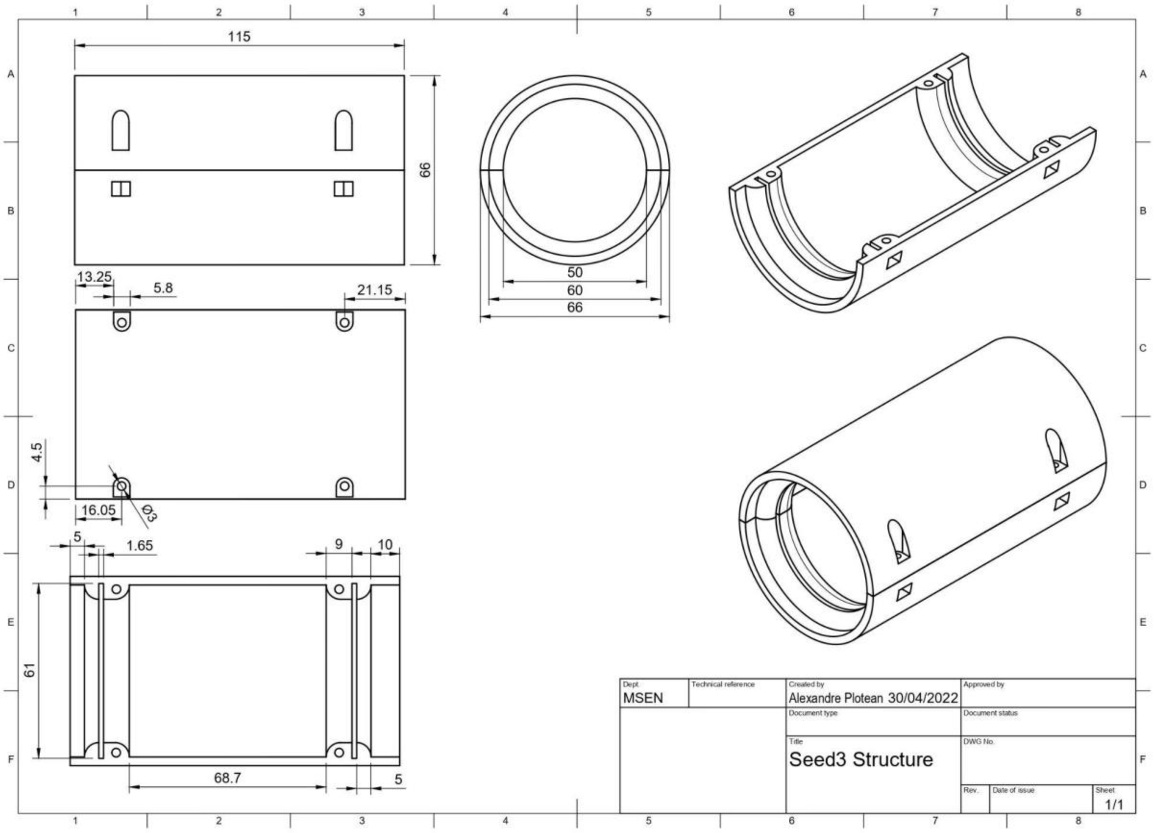
In the *Flower* there will be 3 communications channels and a another one for localization.

Although we won't show the first communication channel in competition its purpose would be for the *Flower* to *Dandelion* satellite.

The second one is for the data collected by the sensors of the *Seeds* to be sent to the *Flower*.

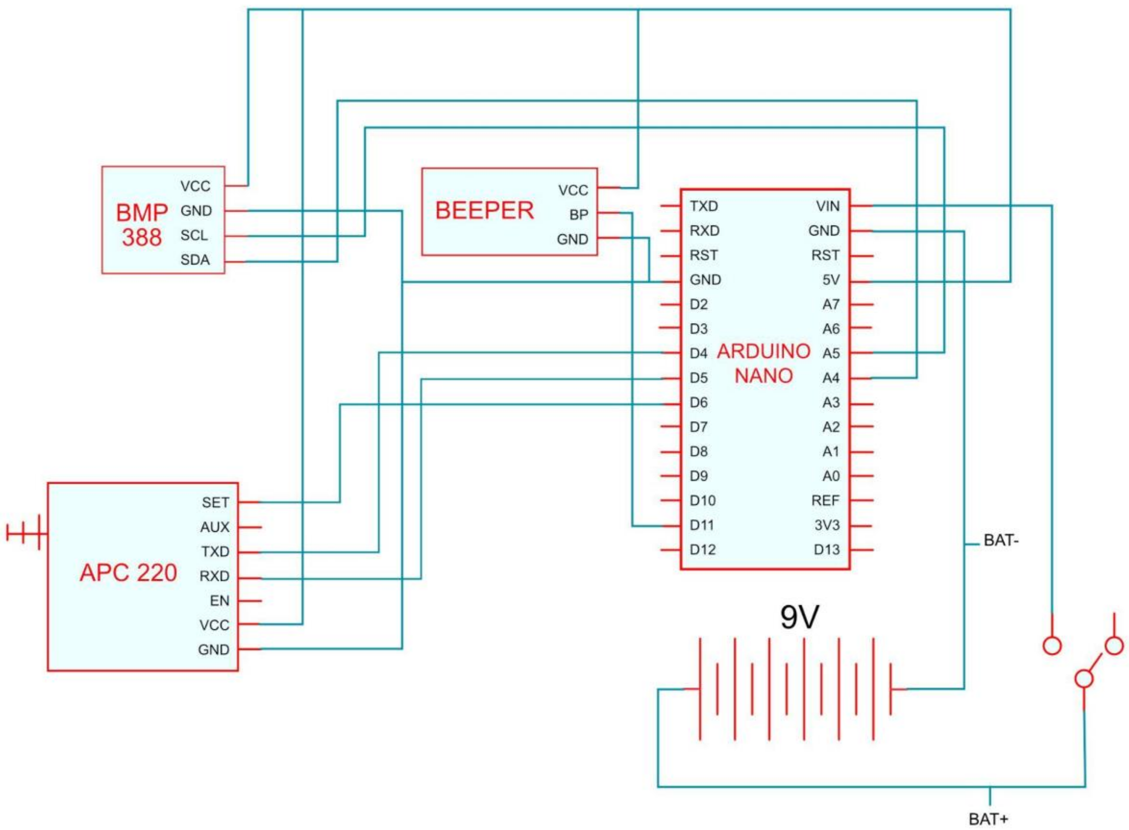
The third one, the location channel, is to send short radio signals from the *Flower* to the *Seeds* and *Seed* to *Seed* which will be re-sent back to the to the one who sent the first sign although in a different frequency as to not create interferences. By determining the time that the signals took to return back, and repeating this process, the *Flowers* defines the distances between each of the modules and triangulates the relative positions of the *Seeds*.

4.2 Mechanical/structural system



We opted to 3D print the CanSat (*Seed* 3) structure using PLA filament and in addition we also tried to print with bright colours filaments but we ultimately couldn't do it due to the lack of access to those colours.

4.3 Electrical system



4.4 Software system

Our project software can be divided in four sections:

- the code for the *Seeds*;
- the code for the *Flower*;
- the code that will transform the text file into an Excel file;
- the code that will read the Excel file and create the final map.

The code for the *Seeds* is responsible for the data collection and transmission to the *Flower.*

The code for the *Flower* will work as the head of the network system by sending the commands for the triangulation of the *Seeds*. The same code will allow the *Flower* to collect data from the sensors.

4.5 Recovery system and strategies

From the most diverse controlled fall systems used available to us the parachute was chosen due to its easy conception, being tested and used more regularly while also having a big success rate.

Our parachute will have an octagonal shape and will count with 8 support points in a way to better distribute the force caused by the opening of the parachute securing the safety of the *Seeds*.

Although through our secondary mission we will obtain the modules positions this system has an error distance and therefore the implementation of a beeper in the *Seed* 3 (the one that will fly) was chosen in order to make it even easier to recover.

4.6 Ground support equipment

In the ground we will have 3 modules, one *Flower* and two *Seeds*. In this exemplification we will have the *Flower* and the two *Seeds* that will be two CanSat modules and both will be at similar distance from the *Flower.*

The *Flower* will be responsible for obtaining the times, calculating the distances, receiving the data from the other module (pressure, temperature, and timings) while the two *Seeds* in this case will have the main function of being two of the four points used in the triangulation in addition to recording and sending sensor data (pressure and temperature).

In addition, we will have two tripods to support the two *Seeds* at similar distance.

4.7 Operational concept

In the pre-launch phase it will be necessary to mount the two *Seeds* that remain on the ground using two tripods, these ones although continuously sending information due to the restrictions for the CanSat (*Seed* 3) to receive its information once a second, we will use a directional antenna on *Flower,* most likely we will not have their information during the flight. After the launch the data collected in a text file will be converted to an Excel file via a Python program allowing easy access to build graphics and from that same file the map will be built.

5. CanSat testing

We tested the network stability by turning some off the *Seeds* to simulate the contact loss with the same but due to the hard access to open areas we couldn't fully test the reach, in addition to these tests we also carried out a falling test for the parachute which ended up not having a good enough altitude to give conclusive results.

6. Innovation

The application of the positioning system (like GPS) in other planets is not viable due to the fact that at least 4 satellites need to be in plain sight of the modules and they are considerably large, heavy and expensive therefore hindering the innovation in space exploration by excluding the possibility that in addition to obtaining all possible data through sensors and data processing we can have the exact location (in our case approximately) of the modules (satellites).

Given that with the absence of a solution to this problem the MSEN team comes to present our project that aims to create a network of small dimension satellites that in addition to obtaining data such as temperature and pressure (main mission) we can also obtain the relative positions of the various modules.

The *Seeds* can be equipped with any sensor.

Our project creates a basis to expand to any project presented in the competition, since our project is modular and the information itself can different, being even possible to mix projects for a large scale study of a planet.

7. Acquired skills

The skills we essentially acquired were programming in C and Python as the respective terms and libraries that would allow us to collect and transmit data wireless (in this case radiofrequency).

Additionally, it was necessary to learn 3D modelling, welding, cable stretching and the established connections by cable within the modules (Arduino, sensors and antennas).

Learning the possibilities and operations of the Arduino besides involving the study of electronics, as well the diverse type of parachutes such as their sizes, shapes, all the formulas and mathematical processes required to obtain its characteristics in order to allow the building of this with as little error as possible.

We also were required to learn the many ways of available existing communications as well choose the most safe and suitable for the transmission of data during the competition, it was also necessary to learn the several types of available antennas, their respective ways of operating and concrete goals allowing us to collect enough data to choose the most appropriate for our project, additionally it was equally necessary to deepen our knowledge in mathematics more specifically in geometry as to allow triangulation.

8. Dissemination

The MSEN Project counts with accounts on several social networks (Instagram, Youtube, TikTok). However, the most used was Instagram because it is the network where we have more friends, colleagues and teachers who could help in the dissemination process.

The presentation video is available on all our social media accounts and the school science club with audio in Portuguese and subtitles in English and as mentioned before details such as the evolution of the 3D models built, various images of all the material used, etc. is only available on Instagram as this has since become our main platform.

All in all we got more than 500 views on our presentation video and a few more followers.

We also have a page about our project on the school's science club website with information and the presentation video.

- Youtube: https://www.youtube.com/channel/UCfOC94HmSU80AjIZJQD5sNg
- Tiktok: https://www.tiktok.com/@msen_cansat?lang=en
- Instagram: https://www.instagram.com/cansat.msen/
- CCVnEsla MSEN: http://cc.esla.edu.pt/index.php/atividades/a-decorrer/cansat-msen

9. External support, if applicable

During the course of a project like this it is normal for doubts and complex problems to arise due to several factors such as disagreements with the budget, lack of information about the components, lack of practical knowledge about most of the areas covered in the project, etc.

We asked several institutions and departments for help, but not all of them were willing to help us.

We had collaboration and help from:

- ICT and electronics teachers from our school and near schools, for 3D modelling and 3D printing;
- one member of the RAEGE institution located in Santa Maria in the Azores;
- university teachers of telecommunication at the Universidade do Algarve;
- the Parachute Regiment of the Portuguese Army located in Tancos, Santarém, which provided us with fabric for the construction of the parachute.

10. Budget

For the building of a *Seed* 3 we used the CanSat kit, and a beeper, plus around 100 g of PLA filament.

All the *Seeds* present in the competition have a similar construction as well for the *Flower* since it will not be at scale neither will have total functionality. The Flower and the 1 and 2 *Seeds* were made using old CanSat modules of our school. The antenna also was used in previous projects.

- Kit Workshop Cansat (126,94€): https://www.ptrobotics.com/cansat/7505-kit-workshop-cansat.html
- beeper (1,75€): https://www.castroelectronica.pt/product/modulo-campainha-activa-2pcs-compativel-c-arduino--velleman
- Antena Yagui (21,99€): https://www.castroelectronica.pt/product/antena-digital-tdt-uhf-10-elementos-lte-yagui--televes
- PLA (3,00€): https://shop.beeverycreative.com/product/pla-flashforge-500g/

Total cost: 3 × 126,94€ + 1,75€ + 21,99 + 3,00€ = 407,56€

To allow our participation at the CanSat Portuguese final, our school will rent a transportation (430,00€) and pay the costs of gas and tolls (130,00€).

- https://www.viamichelin.pt/web/Itinerarios?departure=8125%20Quarteira%2C%20Faro%2C%20Portugal&departureTid=city-1888867&arrival=Ponte%20de%20sor&index=0&vehicle=0&type=0&distance=km&currency=EUR&highway=false&toll=false&vignette=false&orc=false&crossing=true&caravan=false&shouldUseTraffic=false&withBreaks=false&break_frequency=7200&coffee_duration=1200&lunch_duration=3600&diner_duration=3600&night_duration=32400&car=hatchback&fuel=petrol&fuelCost=1.955&allowance=0&corridor=&departureDate=&arrivalDate=&fuelConsumption=&shouldUseNewEngine=false