Daniel Sampaio Secondary School, Sobreda

Team Argos Final Report

MátiSat

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1. Team organization and roles

1.1. Distribution and assignment of tasks

From the outset of the project, tasks were distributed according to each team member's strengths and personal interests. To ensure efficiency and focus, we created dedicated sub-teams within the group, all working collaboratively toward the same goal:

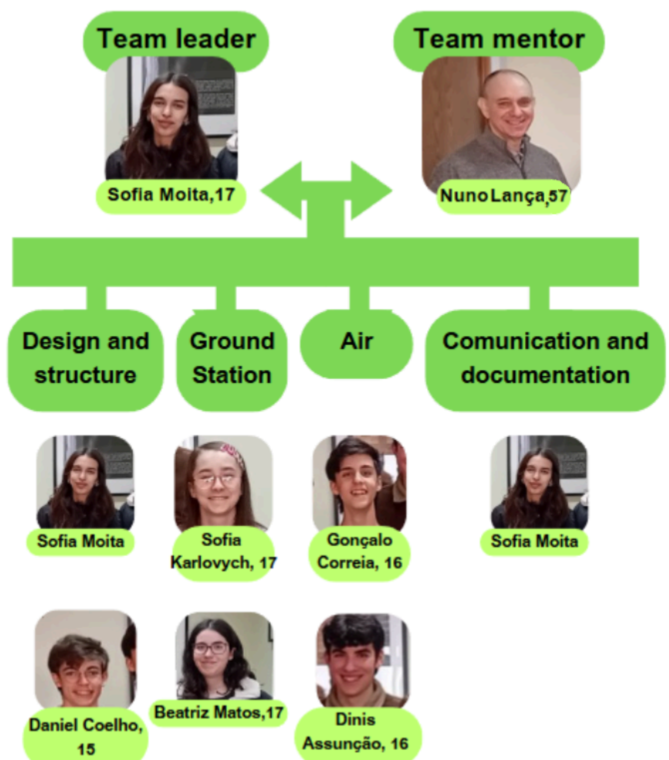
a) Design and Structure Team: Responsible for the development of the cansat's 3D structure and physical assembly. This team handled both the digital modeling and the hands-on construction of the satellite.

b) Ground Station Team: Tasked with ensuring the proper operation of the Ground Station interface, including the reception, display, and storage of telemetry data.

c) Air Team: In charge of programming and configuring all onboard systems. This team also developed the communication protocols to ensure that data was transmitted reliably to the Ground Station.

d) Communication and Documentation Team: Responsible for maintaining clear communication across all team members and ensuring a consistent work pace. They also oversaw the creation and quality of all required documentation for the competition.

1.2. Organization chart



Picture 1: Organization Chart

2. Description of the project

2.1. Project summary

Global satellite systems provide valuable large-scale and long-term data but they often lack the spatial resolution and sampling frequency necessary to detect fine changes in local ecosystems, especially in small areas or during periods of frequent cloud cover. By capturing Normalized Difference Vegetation Index (NDVI) data from a low-altitude platform like a cansat, we can obtain high-resolution, near-real-time insights into the health of local vegetation. This localized perspective is essential for validating satellite observations, supporting precision agriculture, and enabling early detection of environmental stress factors at the ground level.

Primary mission

The goal of the primary mission is to measure air temperature and atmospheric pressure during the flight of the cansat (MátiSat) and transmit this data in real time to the Ground Station, at a minimum rate of once per second. To meet these requirements, we selected the BMP280 barometric sensor. This sensor is adequate since we had chosen the Raspberry Pi Zero as our onboard microprocessor and Python as our programming environment. The BMP280 offered good library support and compatibility. Additionally, the version of the sensor provided by Seeed was ideal for our hardware configuration, as it connects directly to the I^2C port available on the Grove HAT for Raspberry Pi Zero that we used in the cansat.

Secondary mission

For the secondary mission, our objective is to map the NDVI and assess the health of vegetation in the area overflown by the cansat. This is achieved by: capturing ground images in both near-infrared (NIR) and visible light (VIS); tagging each measurement with GPS location data; processing the images to generate pixel-by-pixel NDVI maps. To accomplish this, we equipped the cansat with two Raspberry Module 3 cameras (one standard and one NoIR) and a GPS module, as described below.

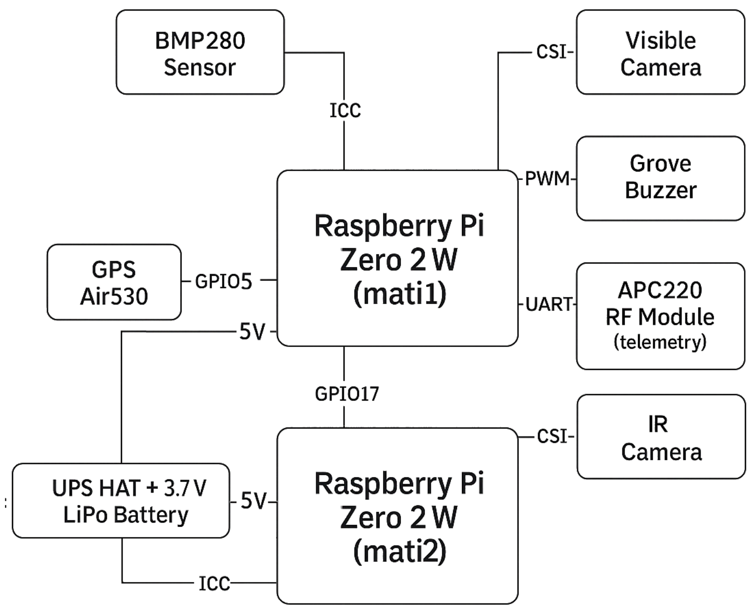
2.2. Expected results

To fulfill the objectives of our scientific mission, we plan to capture images in NIR using a NoIR camera with a suitable optical filter, and combine them with images taken in VIS, with particular emphasis on the red band. This dual-band imaging approach enables the calculation of the NDVI. If the mission proceeds as planned, we will obtain a comprehensive dataset of the overflown area, including: air temperature, atmospheric pressure, estimated altitude (derived from both barometric and GPS data), GPS coordinates, synchronized images in NIR and VIS bands. This dataset will allow us to not only analyze the flight path and environmental conditions during descent but also generate NDVI maps that can help assess the condition of the local vegetation.

2.3. Project details

The secondary mission strongly influenced our choices regarding electronic components and their placement within the limited cansat volume. Two cameras were installed on the bottom face, oriented downward for Earth observation. At the top, we placed the GPS antenna, the RF antenna, and the main power switch. The BMP280 sensor was placed close to the outer surface to ensure accurate pressure and temperature readings. We made the micro-USB port of the UPS module easily accessible and designed the housing in a way that allows direct access to the RF module, for frequency adjustments. The entire process of optimizing component placement was carried out in Autodesk Fusion 360, using accurate 3D models of each module obtained from repositories such as GrabCAD and the open library of OnShape users. This iterative design process underwent four major revisions, during which 3D printing was consistently used to test component placement, ensure mechanical compatibility, and optimize the use of internal space. One of the biggest challenges was positioning the battery, due to the modular nature of the electronics, not as optimized as a PCB designed for this purpose, and the physical limitations imposed by connectors and cable routing. Despite this, we achieved a compact and stable internal layout that ensures both functionality and ease of maintenance.

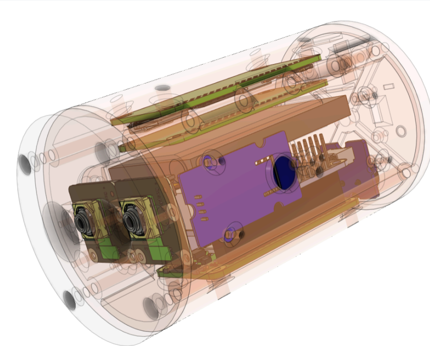
Design overview



Picture 2: Máti design overview.

Mechanical Design

The structure of the cansat was designed in accordance with the competition regulations, respecting the specified dimensions of 115 mm in height and 66 mm in diameter. The total weight was carefully managed to fall within the required range of 300 to 350 g. The central section of our cansat has both Raspberry Pi Zero microprocessors and the LiPo battery. Surrounding this core are the Grove BMP280 sensor, the Grove GPS (Air530) module, the Grove buzzer, and the APC220 RF module.



Picture 3: Máti internal components.

At the bottom of the cansat, in the lower section, are the two Raspberry Camera Module 3 units, as shown in the picture above. Both cameras are mounted side by side and oriented downward to ensure a clear view of the ground. This configuration minimizes parallax, which is essential for accurately aligning and merging the NIR and VIS images during post-processing. The final version is made up of two halves that hinge on each other.

Four 120 mm long M3 threaded rods with caps/nuts hold the entire structure together.

Electrical system

The design was centered around the Raspberry Pi Zero 2W - the smallest Raspberry Pi model capable of interfacing with a camera - and the Raspberry Camera Module 3, which offers a good balance of performance and affordability for the mission's requirements. The Seeed Grove Raspberry Pi Zero HAT acts as the central hub for peripheral integration, providing: UART connectivity to the APC220 RF module, I²C connection to the BMP280 sensor, PWM output to the buzzer, serial interface to the GPS module, and several additional GPIO connections. A second Raspberry Pi Zero 2W (mati2) is dedicated to VIS image capture via its own Camera Module 3. The entire system is powered by a Waveshare Raspberry Pi Zero UPS HAT, which manages power delivery from a 2000 mAh LiPo battery. The system is turned ON/OFF via an external two-pole power switch. Power management was a key consideration throughout the design process, particularly due to the requirement that the system operate continuously for at least four hours. The Waveshare UPS module provides stable 5V output from either a micro-USB input or the internal 3.7V LiPo battery. It also supports monitoring of key power metrics via I²C, allowing the secondary Raspberry Pi to track system power status in real time.

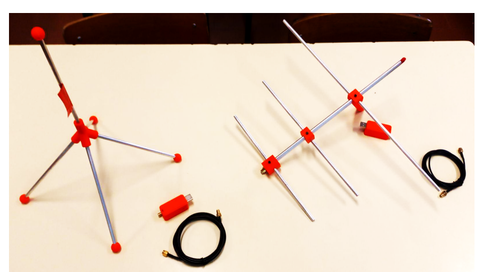
Software development

All hardware modules were initially tested individually using existing Arduino libraries, and later, with the equivalent Python libraries for Raspberry Pi. The integration was gradual: we began testing modules in pairs, increasing complexity step by step, until we were confident that the full system could operate reliably. The Python code for the mati2 unit (secondary Raspberry Pi) was relatively simple to implement. This unit listens for a trigger signal on a specific GPIO pin and then initializes the camera to capture images. The mati1 unit required a more complex implementation and extensive testing. Its main tasks include acquiring sensor data, detecting altitude thresholds, triggering the image capture system, and managing telemetry transmission. The final structure of the telemetry was refined with the valuable guidance of Duarte Cota's work available online.

Ground Station

Our ground station consists of two antennas tuned to 433.350 MHz, in accordance with the specifications provided by the competition organizer:

- A ¼-wave ground plane antenna, built using 6 mm diameter aluminum tubes, with element lengths calculated using an online antenna design tool;
- A Logarithmic Periodic Dipole Antenna (LPDA), also constructed with 6 mm aluminum tubes, following detailed specifications kindly provided by Professor Eduardo Ferreira.



Picture 4: Ground plane ¼ wave (left) and LPDA (right) antennas.

Telemetry is received by two laptops, each connected to an APC220 RF module via USB. Both systems run a custom Python script to record telemetry data in real time, and display it with the *matplotlib* library.

Recovery system

Parachute geometry - The parachute was inspired by a semi-spherical design, divided into 12 parts to closely approximate a hemispherical shape. To enhance stability, a central spill hole was included, with a diameter of approximately 15% of the parachute's overall diameter. This spill hole plays a crucial role in reducing oscillation and ensuring a steady descent by allowing controlled airflow through the canopy. It also helps prevent the parachute from 'puffing' - a phenomenon where trapped air causes the canopy to deform and behave erratically.

Materials - The parachute canopy was constructed from a durable fabric repurposed from an umbrella, chosen for its strength and lightweight properties. Reinforcements were added to the edges, section joints, the central opening, and the spill hole to ensure structural integrity during deployment. For the shroud lines and bridle, we selected a polyamide rope with a 2 mm diameter, rated to withstand up to 900 N. To minimize the risk of line twisting during descent, the shroud lines were kept as short as possible. Additionally, a fishing swivel rated for 280 kg was used to mechanically decouple the parachute from the cansat, further reducing torsion and improving stability.

Dimensions - Our parachute has a diameter of 34 cm and a canopy area of approximately 910 cm² (0,09 m²). The central spill hole, sized at roughly 15% of the parachute's diameter, measures about 5.1 cm in diameter, corresponding to an area of approximately 19,6 cm². Initial calculations, based on descent rate estimates and canopy geometry, suggested a canopy area of around 0,08 m², corresponding to a diameter of approximately 32 cm. However, after performing drop tests, we opted to increase the size slightly to 34 cm in diameter to achieve a more stable descent and improve overall reliability during deployment.

Picture 5: Different aspects of the parachute design.

Recovery strategy - The GPS data recorded at the Ground Station is expected to help locate the cansat. The cansat is equipped with a buzzer module that is automatically activated once landing is detected—based on a stable altitude reading over a period of one minute. The buzzer emits an intermittent sound continuously until the CanSat is found, helping the team locate it acoustically, even in dense vegetation or rough terrain. This strategy maximizes the chances of successful recovery while keeping power consumption low during flight. The parachute and cansat are coloured with bright orange to help recovery.

Operational Concept

During the pre-launch phase, our team follows a checklist to ensure system readiness. The cansat is fully assembled, with all components tested individually: sensors, cameras, GPS module, radio transmitter, and onboard power supply. The internal storage is verified to ensure enough space for images and telemetry logs.

The system is powered on a few minutes before launch, and telemetry reception is confirmed by the Ground Station. If everything is working as expected, the cansat is ready to be loaded into the rocket. Telemetry is sent to the Ground Station at a fixed rate of 1 Hz, including sensor data, GPS position, and status information.

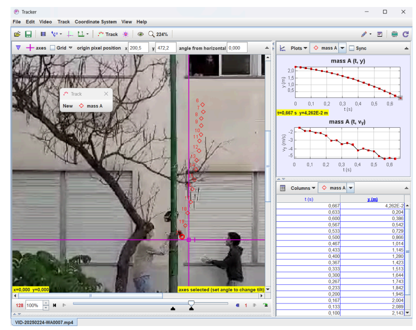
Once launched, the cansat remains inactive in terms of mission logic until it detects a significant increase in altitude - typically above 10 meters. This triggers the start of image capture routines. Photos are taken at regular intervals and stored onboard. Upon landing, based on sustained altitude readings, the cansat deactivates photo capture and activates a buzzer for acoustic location.

3. Cansat Testing

3.1. Testing and Validation

We conducted multiple drop tests using cansat prototypes to evaluate parachute deployment and measure descent speed. These experiments allowed us to fine-tune the parachute design, ensuring stable descent and a sufficiently slow terminal velocity. Terminal speeds were reached quickly and measured around 10 m/s.

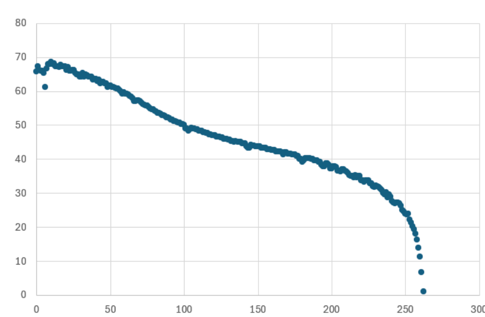
We carried out exhaustive testing of all critical hardware and software components, including: flight control logic and altitude-based state transitions; sensor data acquisition and management; real-time telemetry transmission and logging; image capture and onboard storage procedures; ground station software for data visualization and logging. Simulation and integration tests allowed us to validate the behavior of both hardware and software, reducing the risk of failure during the actual mission launch. For these tests, we used simulated data that closely matched the conditions that we expect to find in Santa Maria.



Picture 6: Drop-test recording for analysis with the Tracker application.

3.2. Power management

Power management was without doubt the most technically demanding aspect of the project. Initial testing indicated that a typical energy consumption for 4 h was around 1400 mAh. With this in mind, we chose a battery capable of delivering 2000 mAh. Throughout the development process, multiple refinements were made to minimize energy consumption while ensuring reliable operation of the mission. These included selectively activating high-consumption components - such as the camera modules, and disabling unnecessary functionalities like the HDMI ports, the Bluetooth service, LED’s, and WIFI connection.

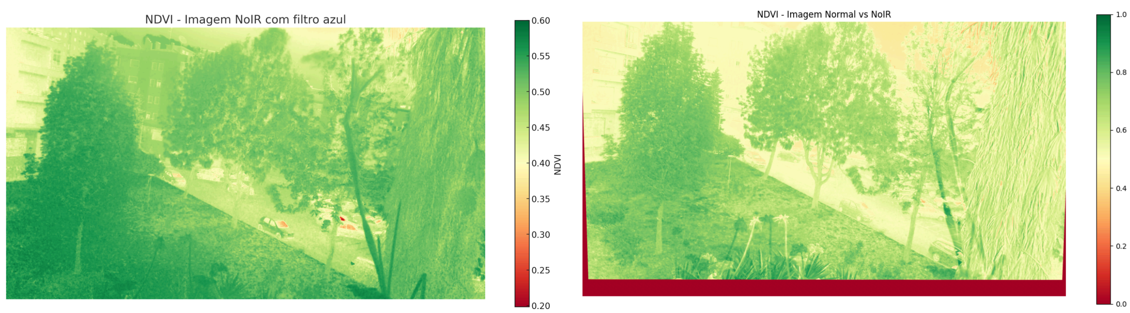


Picture 7: Battery power level recorded over operation time (min) for mati2.

By reading battery data from the UPS module via I²C, we were able to monitor the power level in real time. The graph above shows the measured battery percentage over time (in minutes), confirming that our design successfully exceeded the 4-hour operational requirement set by the competition.

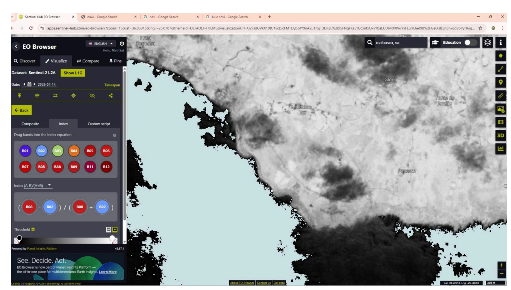
3.3. NDVI Image Processing

Testing has been conducted on the image processing developed to compute the NDVI index. Below are examples of real results obtained during these tests. In the first example, only the image captured by the NoIR camera equipped with a blue filter was used. Despite the limitations of working with a single spectral band, we were able to extract relative vegetation information. In the second example, the full NDVI calculation was performed using the OpenCV (Computer Vision) library, combining synchronized images captured by the NoIR camera and the standard RGB camera. The two images were aligned and processed pixel by pixel, where each pixel corresponds to a specific vegetation index value. These tests allowed us to validate the image alignment algorithms, the NDVI calculation logic, and the robustness of our processing code. The results demonstrate the potential of our dual-camera system to produce meaningful vegetation health maps using low-cost hardware and open-source software tools.



Picture 8: NDVI index images obtained by processing a NIR image (left) and VIS/NIR images (right).

While the dual-camera system is designed to capture real-time images during descent, we also looked into using satellite imagery of Santa Maria island, obtained through the Copernicus EO Browser, as illustrated in the image. Each pixel represents a calculated value based on the infrared band B8, and the blue band, B2.



Picture 9: NDVI index map obtained by processing B2 and B8 bands on Copernicus EO Browser.

4. Innovation

The cansat 'Máti' project distinguishes itself through a high level of system integration, real-time telemetry, and autonomous operation — all developed from the ground up by our team. Working with the Raspberry Pi platform, students had to acquire and apply a wide range of technical and programming skills, often in areas well beyond the typical curriculum. Most team members began with little or no prior experience in embedded systems, electronics, or low-level hardware interfaces. Throughout the project, they encountered and overcame significant technical hurdles, each of which contributed to their growth as problem-solvers and systems thinkers. Among the key technical achievements were: full hardware integration using the Raspberry Pi Zero and Grove sensor modules, managing communication over I²C, PWM, UART, and GPIO interfaces; real-time telemetry transmission via APC220 radio modules in structured JSON format, with robust data logging and live visualization in a custom-built Python ground station; sensor data management combining barometric and GPS readings, with adaptive logic for detecting launch and landing phases; autonomous camera triggering, including synchronization between two onboard Raspberry Pi units to capture both NIR and VIS imagery during flight; energy optimization strategies, such as delaying camera initialization until necessary, to reduce power consumption.

5. Dissemination

We developed an outreach plan using both social media and our school's communication channels. With the goal of reaching the widest possible audience, we launched an Instagram account, a dedicated website, and a GitHub repository to share our progress, technical work, and results. Within our school community, the project will also be featured in the very first edition of Daniel Sampaio's Science Fair, further enhancing the visibility and impact of our efforts. We also reached our local municipality for help and we were featured in the Junta de Freguesia da Charneca de Caparica e Sobreda news. Thanks to these initiatives, we have successfully raised awareness about our project - and we intend to continue sharing our journey, bringing a little bit of science to everyone along the way.

@argosteam_cansat

GitHub https://github.com/team-argos/mati

https://sites.google.com/ae-danielsampaio.pt/argos-team-and-mati-sat

6. External support

Many individuals have contributed to our project along this journey that started in September of 2024, but the core of the support we had came from the teachers that lead the Clube Ciência Viva na Escola - Extremamente Ciência. A local supplier of electronics, Robert Mauser, provided technical and logistical support.

7. Budget

The total cost of the CanSat project amounts to approximately 400€, and so under the 500€ limit. These include communication modules, sensors, cameras, structural elements, and power systems. This cost includes 120€ of the CanSat kit awarded to our team by the organization, of which one APC220 RF module was included in our project. The team sourced components from multiple suppliers and carefully managed the budget to stay within reasonable limits, considering the project's complexity and the goal of building a fully autonomous and scientifically capable payload. The detailed budget can be found here.

Item	Quant.	Unid.	€
APC220 Radio Communication Kit	1	53,00 €	53,00 €
Battery 3.7V 2000mAh Li-Po - 69x41x6.3mm	1	11,01 €	11,01 €
Camera module V3 oficial Raspberry Pi 12MP 76º	1	24,38 €	24,38 €
Camera module V3 oficial Raspberry Pi 12MP 76º NoIR	1	24,38 €	24,38 €

Item	Quant.	Unid.	€
Cansat Nut M5	2	0,05 €	0,10 €
Cansat Screw Eye M5 15x8mm	1	0,31 €	0,31 €
Cansat Serrated Lock Washer M5	1	0,05 €	0,05 €
Cansat Washer M5	1	0,04 €	0,04 €
Cordelette 2mm x 10m orange	1	5,00 €	5,00 €
Flat-Cable for Raspberry pi Zero camera - 15cm	2	3,41 €	6,81 €
Flexible Silicone Tinned Copper Stranded Wire 300V, 28 Gauge, Kit 5 Colors	1	8,44 €	8,44 €
Grove Hat Base for Raspberry Pi Zero	1	8,41 €	8,41 €
Grove Module - Barometer (BMP280)	1	7,56 €	7,56 €
Grove module - Buzzer - Seeed	1	1,60 €	1,60 €
Grove module - GPS (Air530)	1	9,74 €	9,74 €
HY-4P Terminal Block Connector - Male and Female	2	2,81 €	5,62 €
M2 Black Grade 10.9 Steel ISO7380 Button Round Head Screw Bolt, 8mm, 50pcs	1	1,63 €	1,63 €
M2.5 Hex Socket Head Cap Screw 12.9 Carbon steel Allen Screw - 14mm	1	1,83 €	1,83 €
M2.5 Hex Socket Head Cap Screw 12.9 Carbon steel Allen Screw - 50 pcs -20mm	1	2,05 €	2,05 €
M2.5 Threaded inserts - standard 100 pcs - CNC Kitchen	1	9,04 €	9,04 €
M3 Black Carbon Steel Dome Nut Cover DIN1587	1	2,02 €	2,02 €
M3 Black Grade 10.9 Steel ISO7380 Button Round Head Screw Bolt, 6mm, 50pcs	1	1,75 €	1,75 €
M3 Round Black 10.9 Grade Hex Screws - 50pcs - 6mm	1	2,21 €	2,21 €
M3 Stainless steel threaded rod	1	2,99 €	2,99 €
M4 Zinc Plated Carbon Steel Sheep Eye Screw Closed Hook - 50 pcs - 12mm	1	2,97 €	2,97 €
Microcomputer Raspberry Pi Zero 2 WH c/ WiFi + Bluetooth and 40pins conector - Raspberry Pi SC0721	2	19,99 €	39,98 €
SMA male/female cable (RG174) - 1m	1	3,58 €	3,58 €
Solid Swivels for Fishing - 3 pcs - Size 8	1	3,51 €	3,51 €
Ultra-Thin Nylon Parachute Fabric Silicone Coated Ginny Silk Hammock Fabric	2	4,95 €	9,90 €
USB Left & Right Angled Micro 5pin Female to Micro USB Male Data Adapter - 90 Degree	1	3,54 €	3,54 €
Waveshare UPS Hat (C) for Raspberry Pi Zero 5 V Uninterruptible Power Supply Multiple Battery Protection Circuits (Battery Not Included)	1	28,99 €	28,99 €
Kit Workshop Cansat - PTRobotics	1	120,00 €	120,00 €
		Total	402,45 €

8. Acknowledgments

We would like to thank our school, that has helped us throughout the project development and, mainly, the mentor that has accompanied us since the beginning, without whom none of this would have been possible.

Cansat was a dream of ours and this year we managed to make it come true, that, this experience, is something we will be forever grateful for. We would also like to thank our parish council, Costa da Caparica, that was available to share a little bit more of our project with our community, contributing to our success.