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DESIGN OF A GROUND STATION FOR A CAN-SIZED SATELLITE.

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Supervisor: Dr. Louis SIBOMANA

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DESIGN OF A GROUND STATION FOR A CAN-SIZED SATELLITE.

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Dedications

We dedicate this project to:

- The almighty God,
- Our parents, brothers, and sisters,
- Our friends,
- Our relatives,
- Our lecturers and classmates,
- All who offered his/her effort to accomplish this task.

Approval and Certification

We affirm that this final year project has been prepared at the University of Rwanda, College of Science and Technology, School of Engineering, Department of Electrical and Electronics Engineering for the honor of Bachelor's degree in Electronics and Telecommunication Engineering under the supervision of Dr. Louis SIBOMANA. We also confirm that to the best of our knowledge, it is our original work. Contributions from other sources have been appropriately acknowledged.

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Abstract

CanSat is a type of small satellite that is easy and cheap to build. Previous works focused on designing and implementation of CanSat but they did not consider a working ground station for its control and monitoring. As such, this project aims to design a CanSat ground station to make the visualization of data easier, faster, and much more enjoyable. Our main objective is to create a working user interface that allows any user with valid credentials to control, monitor, and access different functionalities of the CanSat. The designed Ground station graphical user interface (GS_GUI) interacts with the CanSat to visualize and display the data coming from the CanSat. Examples of measurements of environmental variables or data to be collected include temperature, humidity, atmospheric pressure, and altitude. The results of extracted data from the CanSat are visualized or displayed by the ground station graphical user interface (GS_GUI) using a chart presentation in form of graphs to make it more readable and understandable. The graphs clearly show the magnitudes of each type of measurement in various taken possibilities with their units. The development of the (GS_GUI) is written in Python programming language together with Hypertext Markup Language (HTML) and Cascading Styling Sheet.

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List of Abbreviations

ABC: Atanasoff berry computer

BMP: Barometric Pressure

C&DH: Command and Data Handling

CanSat _RWA: Cansized satellite in Rwanda

CST: College of Science and Technology

GAA: Get All Altitude

GAG_2: Get All Gyroscope

GAH: Get All Humidity

GAP_1: Get All Global Positioning Satellite

GAS: Get All Snap

GAT: Get All Temperature

GCA: Get Current Altitude

GCG_1: Get Current Global Positioning Satellite

GCG_2: Get Current Gyroscope

GCH: Get Current Humidity

GCT: Get Current Temperature

GPA: Get Previous Altitude

GPG_2: Get Previous Gyroscope

GPH: Get Previous Humidity

GPP_1: Get Previous Global Positioning Satellite

GPRS: Get Previous Recent Snap

GPS: Global Positioning Satellite

GPT: Get Previous Temperature

GRS: Get Recent Snap

GS: ground station

GS_GUI: Ground Station Graphical User Interface

GS_UI: Ground Station user interface

GUI: graphical user interface

HKD: Housekeeping data

MPU: Microcomputer

RF: Radio Frequency

RX: Receiver

TS: Take Snap

TTC&M: Tracking, Telemetry, Command, and Monitoring

TX: Transmitter

UI: user interface.

Chapter I: Introduction

1.1 Project Background

Rwanda has embarked on a journey to become a leading nation in innovation and technology in Africa and has decided to establish and enhance the advancement of technology as a way that leads to economic growth. This led to the motivation of students choosing to learn science and other technology-related fields, and the number of students exploring different technology concepts grew and hence some choose to explore satellite communication as their field of interest including CanSat.

CanSat as it is shortly written stands for a can-sized satellite which is a type of small satellite where all components of satellite functions are housed inside a can-sized like structure [1]. This type of satellite was introduced by Professor Bob Twiggs of Space Development Laboratory of Stanford University at the time; it was in November 1998 at the University Space Systems Symposium (USSS) held in Hawaii. The main advantage of the CanSat is its small size and its affordability in terms of building. This makes it easy for students and others to acquire basic knowledge and to experience different challenges in building a satellite [1]. The main function for intended CanSat is used as a learning tool for engineering students and other people wanting to explore the satellite communication field, but this doesn't limit it, the CanSat can also be used for other different things like remote sensing and many more.

The data generated by CanSat is usually transmitted to the ground station in real-time by Radio Frequency (RF) communication or is recorded in the memory of CanSat so that it can be retrieved after landing of CanSat. And hence the need for a satellite ground station.

Previous work embraced on the design of a CanSat prototype, but they lacked a working ground station to control and command the CanSat. The ground station also serves as a hub to upload and store the satellite recorded data. In addition, the ground station involves a working graphical user interface (GUI) which acts as the interface for the ground station.

1.2 Project Objectives

1.2.1 Main Objective

The main objective of our project is to design a ground station for the CanSat. The ground station (GS) is made of a GUI which interacts with the CanSat and provides a way of communication between CanSat and GS.

1.2.2 Specific Objectives

The project's specific objective is to create different functionalities that compose the ground station. The main functionalities include data handling components like data collection and data display functionalities. Command related functions like command adding, command removing, and other more functionality like viewing all commands and addition of another CanSat or satellite by pasting Application programming interface.

1.3 Scope of the Project

During the project, we planned to create a ground station user interface (GS_GUI) which is easily used and manipulated by anyone with the necessary skills especially engineering students. Students can alter functionalities in accordance with how they wish it to fit, by respecting the rules governing the GUI uses of course. GUI is dedicated to all students who wish to use this interface in his/her daily studies and get a better understanding of different concepts in the satellite communication field. The project involves different stages, the first stage is to create the GS_GUI, and then the second step is to integrate the GUI and the CanSat. Due to time available, we only developed a GS_GUI with basic UI functionalities like FILE, DATA, HELP, and settings.

1.4 Research Methodology

To conduct our project the following methods and techniques were used:

1.4.1 Methods

1.4.1.1 Documentation

This method refers to using books, websites, and journals for literature review and searching information related to GS_GUI creation and the CanSat in general.

1.4.1.2 Design and testing method

We test and run the ground station in Windows and Debian os but the GS_GUI can also be run on different Operating System (os) which is compatible with python 3.0.

1.4.2 Tools

We used different tools in the GS_GUI creation, the GUI was created using Python in general with some HTML. The codes were written using different Python IDEs like Anaconda and visual studio code editor.

1.5 Expected results

With the GS_GUI, we can visualize different data such as temperature, humidity, pressure, accelerometer, images, and videos acquired from CanSat on the dashboard running on the ground station for a telemetry mission.

Chapter II: Literature Review

2.1 CanSat technology

2.1.1 Introduction to CanSat technology

A CanSat is a simulation of a real satellite, integrated within the volume and shape of soft drinks can [1]. The challenge for the students is to fit all the major subsystems found in a satellite, such as power, sensors, and a communication system, into this small volume as illustrated in Figure 1. The CanSat is launched up in the sky by a rocket similarly some people use a balloon to reach an altitude that can be estimated to one kilometer, then its mission initiates. This involves carrying out a scientific experiment of accomplishment of a safe landing and analyzing the data collected [1]. Through the CanSat project, experiencing all the phases of a real space project, from selecting the mission objectives, designing their CanSat, integrating the components, testing the system, preparing for launch, and analyzing the scientific data gained. By doing this, students get familiar to learn the process that is typical of real-life scientific and technical professions, attain and strengthen fundamental technology and programming related perceptions.

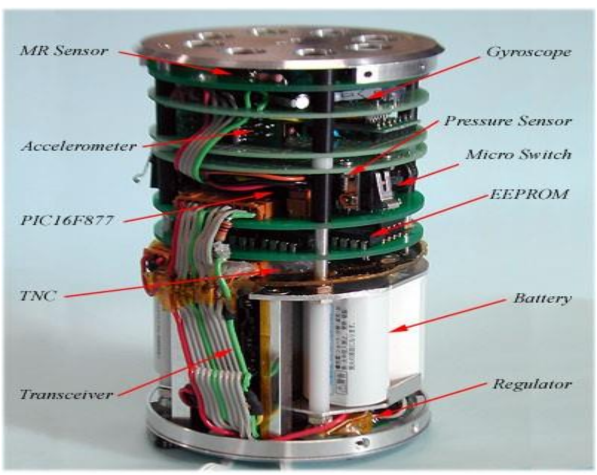


Figure 1.A typical CanSat image like the one built [2]

2.1.2 Relationship between CanSat and Satellite

CanSat is considered "a very small and simple satellite", and has a similar function with satellites and operates away from the human operators. This fact makes the education based on CanSat very suitable as a first step in training towards real satellite development [3]. On the other hand, CanSat is different from real satellites in several aspects such as size, equipment on board, methods of launching, and distance of operation or altitude. The following are common features between CanSat and a real satellite.

2.1.2.1 System Configuration

Both satellite and can-sat have C&DH system (Command and Data Handling or information management system), mission subsystem, power subsystem, communication subsystem, structure, and mechanical subsystems, thermal subsystem, and attitude or orbit control subsystem [3]. The only differences are that can-sat usually does not require thermal control though a satellite needs it, it also may not need a communication system because acquired data can be retrieved after landing the can-sat.

2.1.2.2 Non-repairable system

Both CanSat and real satellites are "non-repairable systems"; they cannot be repaired once they are released from a rocket or dropped from a balloon [3]. This feature makes the development of satellites an extremely difficult problem and such difficulties and how we can prepare the countermeasures can be learned and trained even in the CanSat project. The important concept here is to make the system “robust to disturbances and fault tolerant”, whose mechanisms should be implemented in the design and verified by tests even in CanSat.

2.1.2.3 Importance of Ground Station

As CanSat and satellites should remotely be operated, training on system development of a ground station as well as ground operation is very important for both. The first step of the ground operation is that the human operators on the ground understand the current status of the satellite. To do so, telemetry should be designed, i.e., what should be downlinked to the ground station. As the communication speed from satellite to the ground is limited, the information to be downlinked should be carefully selected. And the downlinked data should be displayed on the screen so that human operators easily grasp what happens in the satellite. And sometimes a quick uplink command should be generated, verified, and uplinked to the satellite with the help of a ground station computer. These cycles can also be learned in a CanSat project, though the ground station for CanSat is much simpler than ground stations for satellites [2].

2.1.2.4 Development process

Satellite development usually takes a phased approach, including conceptual design with BBM (Breadboard Model) development, PDR (Preliminary Design Review), detailed design with EM (Engineering Model) development, CDR (Critical Design Review), PFM (Proto-Flight Model) development and pre-launch operation [2]. This process can also be simulated to some extent in the CanSat project. High-level project management is required for both.

2.1.2.5 Launch environment

When CanSat is launched by a rocket, similar environments including acceleration, vibration, and shock as real satellite cases are exerted on CanSat, and how to make the system tolerant against such environments can be trained in CanSat. Vibration or shock tests are required for CanSat in this case, and how to do such tests and how to make feedback from the test results can also be learned. On the other hand, some points are different between CanSat and satellites, and some are points are favorable for CanSat, as compared with real satellites. Some of these points are missions that can be performed in CanSat are a subset of missions to be done in satellites, thermal subsystem, is usually not required for CanSat [3].

2.1.3 Related Works on CanSat

Many researchers and organizations involved in promoting space education and public awareness have introduced the use of CanSat as an affordable way [4]. Different competitions on CanSat have been introduced, to allow and facilitate students to explore CanSat technology [4]. The major issue with different CanSat projects is that different scholars tend to work on CanSat alone, many don't bother working on the ground station implementation and ground station (GS) as the second major part of any CanSat project. Scholars use online alternatives to monitor and control the CanSat, but this approach is not adequate. Online alternatives are not reliable and don't provide a straightforward way to control the CanSat. The GS_GUI we created gives a straightforward solution to all of the stated problems. Which is why we worked on it. In the below subsections are some of the major CanSat related works.

2.1.3.1 Can-sat mission and system

The concept of can-sat mission examples and achieved mission, is the determination significance of the success of the mission, is crucial that the installed equipment in the mission subsystem to operate as envisioned, so it is necessary that all the subsystems perfectly support the mission [3].

2.1.3.2 Vecihi Can-Sat Model

The vecihi CanSat model is of great use in describing any CanSat associated work. It was developed in 2003 to promote innovative solutions and improve current solutions in space education in general through CanSat technology in particular [4]. The main mission of this satellite was to deploy a payload from a launcher and have it land safely using aero-braking techniques that are not based on parachutes or streamers. Another mandatory need was to acquire and transmit data continuously between the ground station and the model satellite as well as to protect the payload, a large hen's egg that is located inside.

2.1.4 Electrical Architecture

In this subsection, we discuss the main electrical architecture of a CanSat as part of CanSat by referring precisely to the vecihi CanSat's model as example. The vecihi CanSat model consist of two divisions in its electrical architecture which are:

Electrical diagram: this part needs an electrical system for flight control, communication, and landing on a mission. The electrical architecture consists of sensors, microcontrollers, motors and drivers, battery, memory card, and other circuits, which all need to be powered by 7.4 v and 6400mAh current capacity [4].

Ardupilot: the chosen controller for the can-sat is Ardupilot Mega APM2. The APM2 is more durable and stable than handmade cards. All needed data are used to balance and decide to run actuators from APM2 includes an accelerometer, gyroscope, parameter, temperature sensor, magnetometer, logic level converter, ATMEGA2560 Microprocessor, and a voltage regulator. The APM2 has a 16MHz clock speed. The GPS and the memory card can be easily integrated with the corresponding electrical diagram [4].

2.1.4 CanSat Equipment's

2.1.4.1Sensors

The part of sensors inside CanSat, for the most part, the same as in satellite, is to identify CanSat's stats such as electric voltage, the temperature of main devices, and attitude. Whereas, a sensor can act as a mission payload such as a camera [5].

Sensors are generally categorized into three types:

1. Sensors which estimates the measures a reference object or quantity. For instance, determination of the direction of the sun using a solar sensor.
2. Sensors that evaluate the conditions of their operations. Temperature sensors, gyroscope (gyro) sensors are examples of these types of sensors [5].

Position sensor

A position sensor is a device to measure the position of anybody. Position sensors can be linear, angular, or multi-axis [6]. The main position sensor used in satellites is the Global Position System, which is a satellite-based navigation system that was developed by the U. S. Department of Defense in the early 1970s [7]. It provides continuous positioning and timing information anywhere in the world under a weather condition, the sensor used is GPS. It is the abbreviation of Global Positioning Satellite, which is a constellation made up of 24 satellites surrounding the earth with the purpose of terrestrial surveying, and latitude, longitude and altitude can be determined [8]. Moreover, it helps us locate the CanSat once it is launched in the atmosphere.

2.1.4.2 Camera

The visionary sensor is used to capture the image while the satellite is in space. It is crucial to select and purchase a product that realizes a required high resolution and high processing speed or using FPGA, every image is taken every ten seconds, then it is relatively easy to use serial communication to transmit and save images [9].

2.1.4.3 Gyroscope

A gyroscope is used to measure the angular velocity of the flying object like can-Sat or Anybody axis in degrees per seconds [9]. This sensor is used in a variety of role such as:

- Flight path stabilization
- Autopilot feedback
- Sensor or platform stabilization
- Navigation.

2.1.4.4 Accelerometer

An accelerometer measures large acceleration caused by the launch of can-sat, separation from the rocket, and deployment of parachute [9]. Accelerometers are available in many forms; they can be raw sensing elements, packages transducers, or a sensor system or instrument, incorporating features such as totalizing, local or remote display, and data recording. There are different types of accelerometers; the most common types of accelerometers are piezoelectric, capacitance, null-balance, and resonance, piezo-resistive, and magnetic induction [9].

2.1.4.5 Barometer

The barometer measures the atmospheric pressure during the mission, it is used to estimate the altitude of can-sat from the measurement atmospheric pressure, as complementary navigation aids, and they are used for restricting the growth of errors in the vertical channel of an inertia navigation system [10]. The sensor used MBP 280.

2.1.4.6 Micro SD Shield Card

For our CanSat-Micro SD is used to keep the record of received data. Therefore, when data are received first they are temporary stored on the CanSat micro SD before displaying them on the CanSat ground station. It helps us to minimize or avoid any incidence which might lead to the missing of data or to maximize the amount of data to be recorded in a given amount of time for a specific area.

2.1.4.7 Data transmission and reception system

These are the two segments of a subsystem communication design that are responsible for transmitting and receiving data. This is achieved by communication between the ground station and the CanSat with the help of the uplinking commands from the ground station to the CanSat and the downlink of data or information including both house-keeping data and mission data from the CanSat to the ground station. The commands uplinked from the ground station are received via the receiving wire as analog signals, a modem is used to convert the analog signal uplinked and after sent to the microcomputer which is used in the interpretation of those commands to recognize the transmitted data from the ground station. The microcomputer handles the data interpreted and pass on to the remaining part of the subsystems [11].

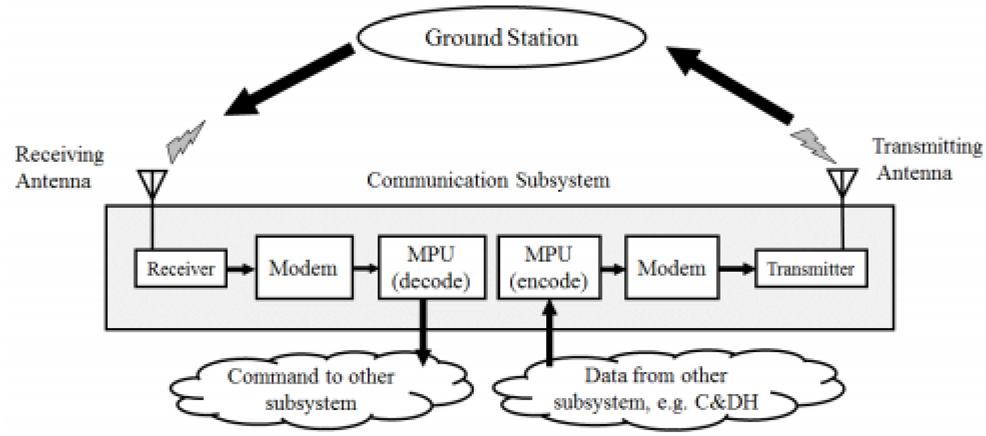


Figure 2. Illustration of Data transmission and receiving systems [11].

As shown in Figure 2, the receiving segment is made up of 4 subparts which are the receiving antenna to collect the transmitted signals, receiver (RX), modem for the conversion of signals, and (MPU) decode appliances like microcomputer. The Transmitting segment is also made up of 4 subparts which are the transmitting antenna for transmitting the signals, transmitter (TX), modem, and encoding appliances [12].

2.1.5 CanSat applications

Satellites are used extensively for a variety of communication applications as a result of some well-recognized benefits. These derive from the basic physics of the system, the most important of which is that a satellite can see a substantial amount of geography at one time. Also, satellites employ microwave radio signals and thereby benefit from the freedom and mobility of wireless connections. Several advantages are interrelated, while others become more important as the technology and applications evolve. The point of these benefits is that satellite communication can represent a powerful medium when the developer of the system or service plays to its strengths. Satellite TV networks (which deliver programming directly to subscribers by satellite), national department store chains (which use VSAT networks to overcome the limitations of poor or fragmented terrestrial data communication networks), and ocean shipping lines (which demand reliable ship-to-shore communication) depend on satellites as their life’s blood. If you can find that kind of connection through satellite technology, then you have a powerful bond on which to build and extend a business or strategic opportunity [12]. Moreover, CanSat provides an affordable opportunity for educators and students to acquire basic knowledge of space engineering and to experience the engineering challenges in building a satellite.

Build a small payload that can fit inside a standard drink can (350 ml) or a little larger size. The CanSats are easily launched using a rocket or balloon and released in the air. Using a parachute, the CanSat is slowly descended back to the ground as it performs its designated mission, i.e., taking pictures and transmitting telemetry. The data generated in CanSat is usually sent to the ground station in real-time by RF communication or is recorded in the memory of the CanSat so that it can be retrieved after landing [12].

2.2 CanSat Ground Station

2 .2.1 Introduction to CanSat Ground Station

A satellite communications system is broadly divided into two segments: a ground segment and a space segment [12]. The space segment refers to the satellite orbiting or the CanSat structure in our case and the ground station control facility called the Tracking, Telemetry, Command, and Monitoring (TTC&M). The other segment is the different stations that receive the transmitted signal. Those include the Very Small Antenna Terminal (VSATs) and other ground stations.

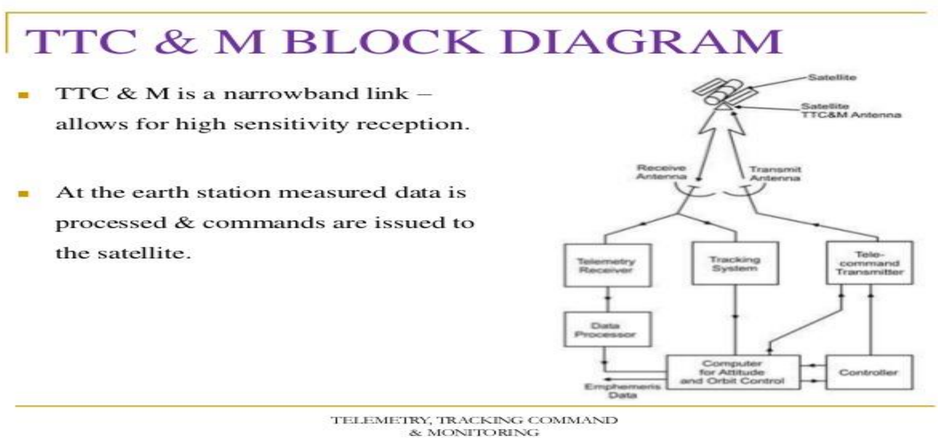


Figure 3. TTC&M block diagram interpretation [13].

The GS is merely a GUI specifically made to interface with the satellite and in our case the CanSat. A graphical user interface (GUI) is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with in-built controls like pushbuttons, list boxes, sliders, menus, and so forth. The GUI should behave understandably and predictably so that a user knows what to expect when he or she acts. For example, when a mouse click occurs on a pushbutton, the GUI should initiate the action described on the label of the button. Figure 4 illustrates a typical GS user interface [14]. A graphical user interface provides the user with a familiar environment in which to work. This environment contains push buttons, toggle buttons, lists, menus, text boxes, and so forth, all of which are already familiar to the user so that he or she can concentrate on using the application rather than on the mechanics involved in doing things.

Figure 4. Image showing a typical example of a certain GS GUI interface [14].

2.2.1.2 *GS_GUI features*

The CanSat is made mainly by the GS_GUI. All the CanSat GS subsystems are embedded in the GS_GUI and act as GUI functionalities. The CanSat GS act as the Telemetry, Tracking, and Commanding and Monitoring (TTCM) subsystem. In general, satellite gets data through sensors.

The Telemetry subsystem present in the satellite sends this data to the earth station. Therefore, the TTCM subsystem is very much necessary for any communication satellite to operate it successfully. The Telemetry subsystem handles the transmitted data from the CanSat, the Tracking subsystem keeps track of the satellite position, and the commanding subsystem adjusts the altitude and orbit of the CanSat and lastly comes the monitoring subsystem which handles the CanSat monitoring. The GS_GUI is made of different functionalities, the main ones being FILE, DATA, SETTINGS, and HELP. The other main functionality is the command prompt on the foot of the GS_GUI interface which allows the user to interact with the CanSat through commands. The GS_GUI is built using python, especially using Tkinter which is a python module created in 1991, it is written in C. Tkinter allows the creation of good GUI and it interfaces with different systems including Windows, Linux, Mac os and many more[15]. The GS_GUI also includes different components written in other languages like the HELP submenu which is written in HTML and CSS. Both HTML and CSS are markup languages used in many projects, especially in web development. The GS_GUI can be run on different systems with python 3.0 and above.

Figure 5. Ground station Graphical user interface (GS_GUI) with different functionalities

2.2.2 Python for GS_GUI creation

Python is a widely-used general-purpose, high-level programming language. It was initially designed by Guido van Rossum in 1991 and developed by Python Software Foundation. It was mainly developed for emphasis on code readability, and its syntax allows programmers to express concepts in fewer lines of code. The language was released in 1991. When it was released, it used a lot fewer codes to express the concepts, when we compare it with Java, C++ & C. Its design philosophy is quite good too. Its main objective is to provide code readability and advanced developer productivity. When it was released it had more than enough capability to provide classes with inheritance, several core data types, exception handling, and functions. Instead of having all its usefulness built into its center, Python was outlined to be exceedingly extensible. This compact measured quality has made it especially prevalent as an implies of including programmable interfacing to existing applications. Van Rossum's vision of a little center dialect with an expansive standard library and effectively extensible translator stemmed from his dissatisfactions with ABC, which upheld the inverse approach [16].

2.2.3 Advantages of using python in GS_GUI creation

Python's design philosophy emphasizes code readability with its notable use of significant whitespace. Its language construct and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects. Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly, procedural), object-oriented, and functional programming. Python is often described as a "batteries included" language due to its comprehensive standard library [16].It compromises a particularly wide selection of tools for tasks such as scientific computing, graphical user interface (GUI) design, database programming, Web site construction, and signal processing. The language is platform-independent with most programs running on Linux, Microsoft Windows, or MAC OS virtually unchanged [17].There are many high-level languages. However, Python is a powerful programming language for handling engineering and scientific computational tasks efficiently and one of the easiest languages to learn and use, while at the same time being very powerful: It is one of the most used languages by highly productive professional programmers. Also, Python is a free language! If you have your computer, you can download it from the Internet. Python provides several different options for writing GUI based programs. The most used is Tkinter modules which is the one we used also. Tkinter‘s greatest strength is ubiquity and simplicity. As a learning tool, Tkinter has some features that are unique among GUI toolkit [18].

2.3 Designing the GS_GUI

The user interface is the primary method by which users interact with CanSat. It consists of a series of forms and components that trigger a series of events “hidden” from the user [19]. The GUI design must incorporate the usability design principles and the programming basics needed in the control, monitoring, and command of the CanSat. The goal of an interface design is to create a GS interface that is easy to use and resourceful.

Chapter III: METHODOLOGY

3.1 Introduction

This section discusses different procedures and techniques used for the study of the project.

3.2 Methods

For our project, we used various tools such as documentation comprising books, articles, journals, websites, and discussions between supervisor and colleagues.

3.2.1 Documentation

Through documentation method we embraced how to program a ground station associated works, read books about CanSat, and other books which enlightens us how to address collection of data. Furthermore, through reading we learned some of the basic functionalities that a given ground station needs in order to perform well. The web has driven us to accumulate and identify requirements for the best of planning and achieving this project.

This approach of documentation using books, articles, journals, and websites has helped us to know supplementary desired information needed to accomplish this project. It also did provide an overview of the previous work related to the design and implementation of the CanSat ground station and gives us the latest details, problems encountered, and possible ways to overcome them without harming or affecting our project.

3.3 System development

3.3.1 Tools used in the GS_GUI design

The success of a good CanSat project depends on how the CanSat GS_GUI is designed. To create a good GUI there are some of the main tools you need to deliver a good, easy to use, and enjoyable GS_GUI, here are the tools you need:

Computer: we need a computer to run GS_interface. The computer acts as the hubs which allow the user to interact with the GS_GUI and hence interact with the CanSat.

Compatible OS: In the GUI design you also need an OS that is compatible with your GUI following how you wish to design your GUI and the necessary programming tools you wish to use.

Programming languages: we also need one or more programming languages, programming languages allow us to create codes that specify how different components of a GUI should interact with the user, in our case the CanSat GS user. In our case, we used mainly Python and a little bit of HTML and CSS.

IDE (integrated development environment): the IDE provides the platform on which we can write and run our GS_GUI basic source codes. The IDE used in our project was Anaconda mainly and a little bit of Visual studio code.

Version control and version control hub: we also used Git and Github to share codes remotely with one of our supervisors MR.Gedeon MUHAWENAYO.

Chapter IV: DESIGN OF GROUNDSTATION OF CANSAT

4.1 Description

In this subsection, we define and comprehend all procedures, approaches, or techniques, and tools used for the design and implementation of the CanSat Ground station. With the use of flowcharts and block diagrams, we elaborate well the process and methods involved in the better performance of our project. It also provides the expectable result and discussion are presented as pictures (screenshots).

4.2 Development of Ground station

For better communication similar to the satellite, CanSat needs a ground station to downlink the CanSat data extracted or collected. However, concerning the intentions of the CanSat, it is seen that it is wished-for academic purposes. This ground station is needed so that the generated data recorded in the CanSat memory or micro SD shield and card is recovered after the landing of a CanSat or so that those data can be sent to the ground station in real-time by an RF communication to be visualized and analyzed [20].

For our project, we built a ground station which is the finest simpler and lucid ground station compared to that of a satellite so that the operators and regulators understand the latest status of a CanSat and this is one of the main reason why telemetry is needed to fully recognize the downlinked data on the ground station [20].

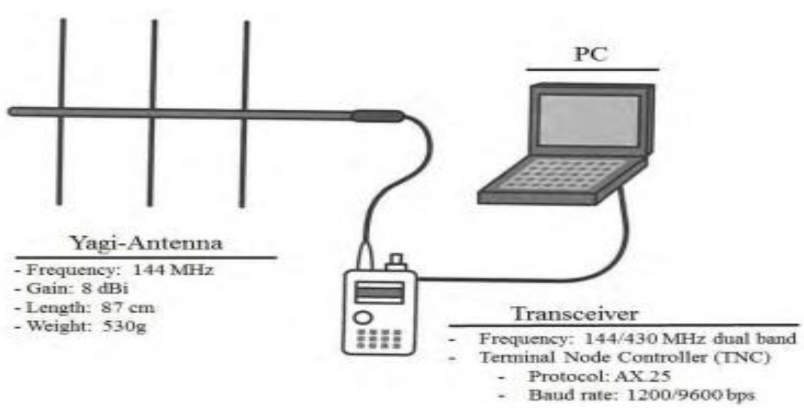


Figure 6. Ground station [20].

4.2.1 The main GUI Homepage

The graphical user interface collects and presents data from the CanSat. The CanSat data is collected from the physical world, artificial environment, and its surroundings or the environment in general, this allows users to interact with their devices with the help of the CanSat extracted data. In addition, the GS_GUI gives permission and access to the user to modify and change the commands to be used by the CanSat ground station that is to mean that the user can add or remove the commands as to his/her wish. The graphical user interface GS_GUI we created is an interface through which a user interacts with electronic devices such as computers, hand-held devices, and other appliances. The GS_GUI has different icons, menus, and another visual indicator (graphics) representations to display information and related user controls [21]. The ground station, GS_GUI with data collected are visualized or displayed using a chart presentation in form of graphs to make it more readable and understandable.

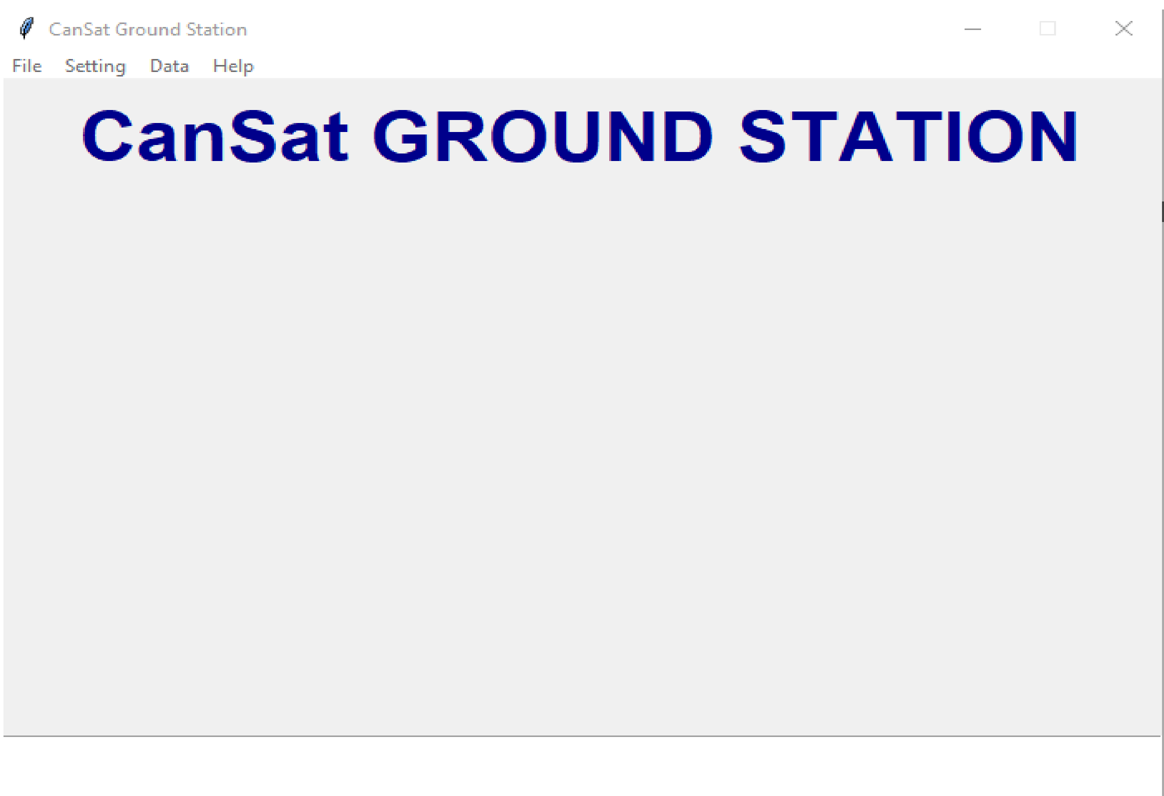


Figure 7.CanSat Ground station Homepage

Figure 7 represents the main welcoming screen of the ground station, this is the first page you see when you run the GS program, and the main importance of the homepage is displays to the user different functionalities of the GS_GUI. We wrote the homepage source code in python.

4.2.2 Ground station GUI features and functionalities

GS_GUI is made of different features and functionalities. These are sets of functions that allow the GS_GUI to perform various tasks assigned by the user. It facilitates the visualization of data, addition, and removal of data, and to provide user guides of this GS_GUI.

Much of the GS_GUI features and functionalities were built using python, but they are other features that were built using other languages like Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS).

Figure 8.File functionality

Figure 8 shows the different features and functionaries of the GS_GUI.

Various functionalities which are in our ground station include:

1. **File functionality**: it is used to create new file, open the file and show us the recent files that have been opened and also give us some examples. It also helps us to quit the program if we want to exit.
2. **Settings functionality**: allow users to set commands according to their wishes by adding, removing and viewing different types of commands.
3. **Data functionality**: help us to visualize the collected data and be analyzed independently.
4. **Help functionality:** provides assistance to the use of the GS_GUI.

4.2.2.1 File functionality

The file functionality is a section on GS_GUI that gives access to file functions. For instance, from the file functionality, you can access the NEW, OPEN, RECENT, EXAMPLE, and QUIT properties.

All of the file functionalities elements was built using python, especially using the python module for GUI creation called Tkinter.

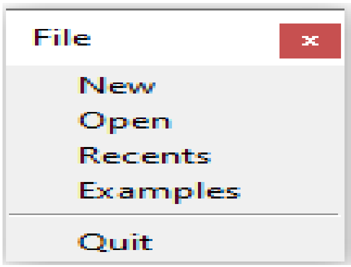


Figure 9. File functionalities screenshot.

As illustrated in the figure 9, the file functionality is composed of the following properties or elements:

- **New**
  It is responsible to provide a new GUI homepage different from the old one that the user had been using.

- **Open**
  It helps us to open other data collected by the CanSat so that they can be displayed in the CanSat ground station. Data can be presented and analyzed according to the desired information. An example of the type of data that can be presented here is images. Most of the image extensions such as PNG, JPEG are supported.

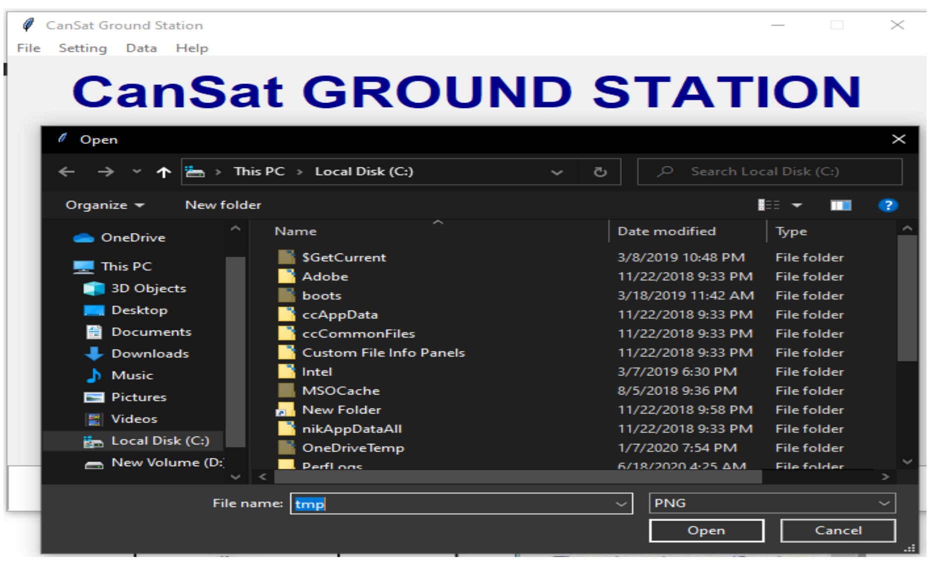


Figure 10.open new sub functionality

- **Recent**
  It shows recent activity or history of the actions that have taken place on the ground station. This helps when you forget to record the presented data.

- **Exampl**e
  It provides the previously done example of how you can use it easily by providing samples.
- **Quit**
  When you are done using the ground station you can quit or exit the GUI to concentrate on the analyzing process.

4.2.2.2 Settings functionality

The settings functionality is used to set the manner or adjust the environment, surrounding the ground station (GS) according to the user's needs. Settings can add, remove, and view all commands. All commands are deeply explained in the help functionality.

Commands are a set of orders subjected to the CanSat to perform a specific task. For better communication between the ground station and the CanSat, commands must be used to direct duty to be done. Besides, commands act like a control mechanism where a signal can initialize a device with help of the commands. For our project, we classify commands into two parts:

Mission command

These are the commands that change the attitude, the working status, and the turn on/off of on-board equipment of the CanSat. Types of data to be extracted here are images with the aid of the camera mounted on the CanSat. Below are the commands which are going to help in the operation of the CanSat.

Camera Command	**Command initials**
Take_snap	ts
get_recent_snap	grs
get_previous_recent_snap	gprs
get_all_snap	gas

Table 1.Mission command and its initials

Housekeeping data command (HKD Command)

These are commands which are responsible for the wellbeing status and working appropriately of the CanSat. With these commands we deal with various types of data such as altitude, humidity, temperature measurement and altitude.

GS GUI Housekeeping data commands

Types of commands	Commands	Command initials
Altitude	get_current_altitude	gca
	get_previous_altitude	gpa
	get_all_altitude	gaa
Temperature	Get_current_temperature	Gct
	get_previous_temperature	Gpt
	get_all_temperature	gat
GPS	get_current_gps_position	gcg_1
	get_previous_gps_position	gpp_1
	get_all_gps_position	gap_1
Gyroscope	get_current_gyroscope_position	gcg_2
	get_previous_gyroscope_position	gpg_2
	get_all_gyroscope_position	gag_2
Humidity	get_current_humidity	gch
	get_previous_humidity	gph
	get_all_humidity	gah

Table 2.Housekeeping data commands and their initials

This setting functionality has other sub functionalities such as:

1. **Add new mission command**

This is the introduction of new mission command by the user which is not in the previously stated commands and find it to be helpful. The user has to enter the full command name followed by the command initials as shown in the figure below.

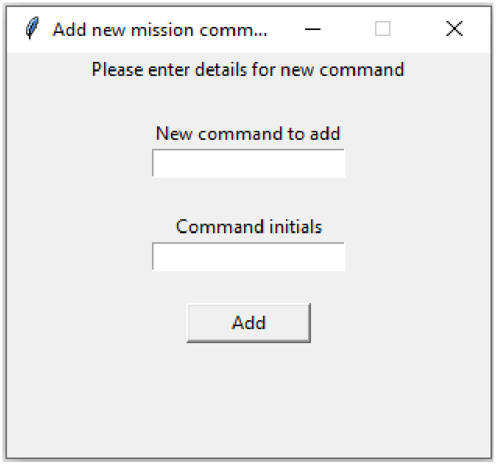


Figure 11. Add new mission command

2. Remove mission command

This is used to eliminate unnecessary or unwanted mission commands and commands which are not used at all. To reject the mission command the user has to enter the full command name followed by the command initials as shown in the figure below.

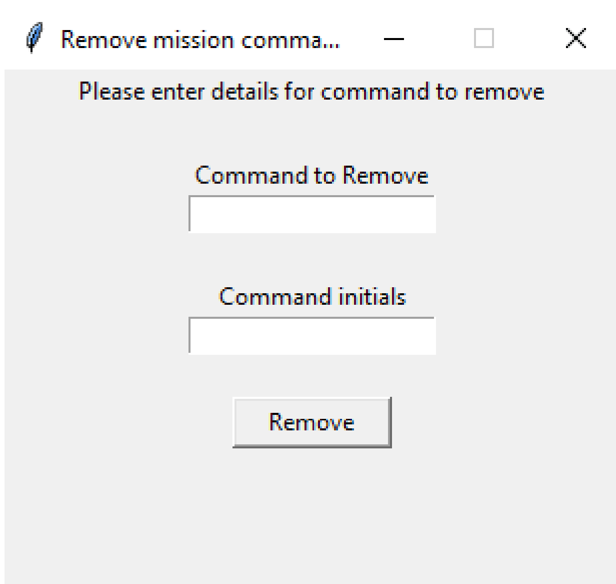


Figure 12. Remove mission command.

Add HKD command

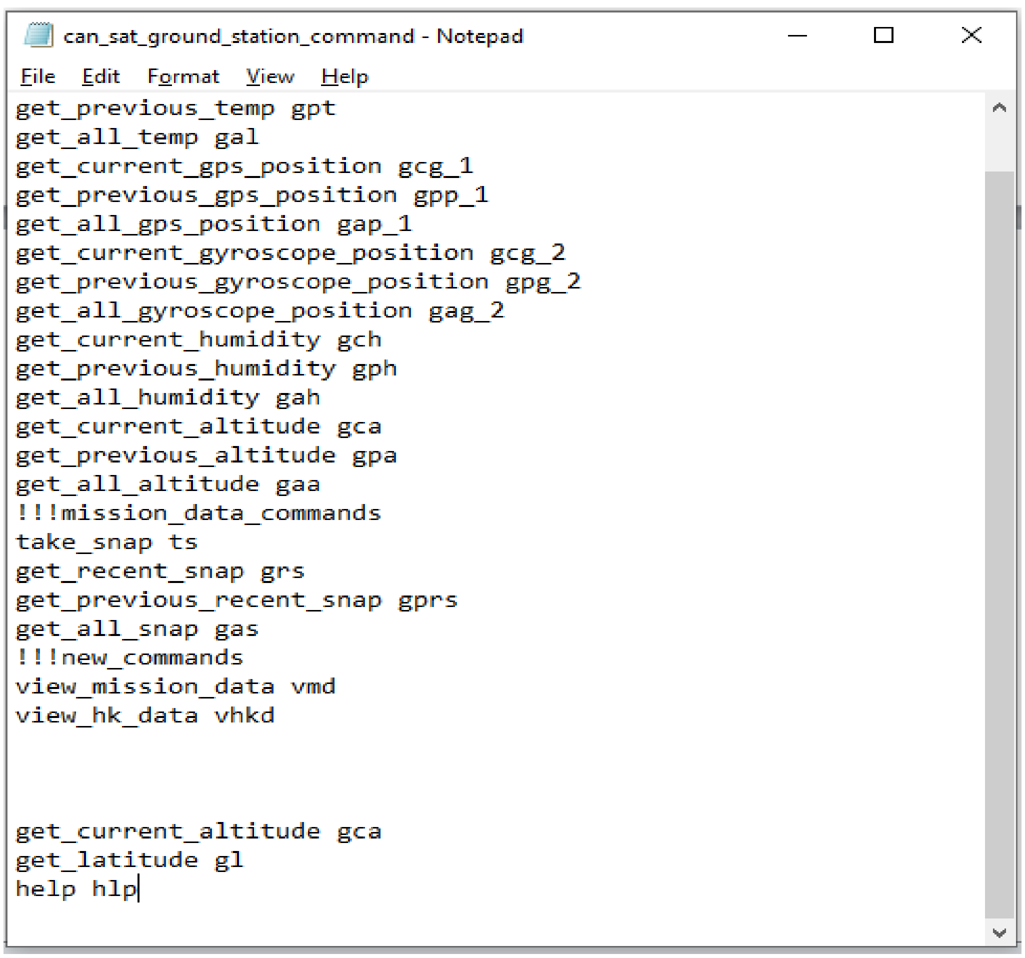
This is the introduction of new mission command by the user which is not in the previously stated commands and finds it to be helpful. The user has to enter the full command name followed by the command initials as shown in figure 11.

Remove HKD command

This is used to eliminate unnecessary or unwanted mission commands and commands which are not used at all. To reject the mission command the user has to enter the full command name followed by the command initials as shown in figure 12.

View all command

This is the display of all command entered in the CanSat ground station and all activity or history of the settings functionality. The added or removed commands both mission and housekeeping data are visible through this view all command sub functionality.


can_sat_ground_station_command - Notepad

File Edit Format View Help

```
get_previous_temp gpt
get_all_temp gal
get_current_gps_position gcg_1
get_previous_gps_position gpp_1
get_all_gps_position gap_1
get_current_gyroscope_position gcg_2
get_previous_gyroscope_position gpg_2
get_all_gyroscope_position gag_2
get_current_humidity gch
get_previous_humidity gph
get_all_humidity gah
get_current_altitude gca
get_previous_altitude gpa
get_all_altitude gaa
!!!mission_data_commands
take_snap ts
get_recent_snap grs
get_previous_recent_snap gprs
get_all_snap gas
!!!new_commands
view_mission_data vmd
view_hk_data vhkd



get_current_altitude gca
get_latitude gl
help hlp
```

Figure 13. View all command

1.2.2.3 Data functionalities

This section helps us visualize the collected data and be analyze independently

For us, we divided data into two parts which are:

- Mission data
  Example: Camera.
- Housekeeping data
  Example: Temperature, Humidity, Altitude , gyroscope , GPS.

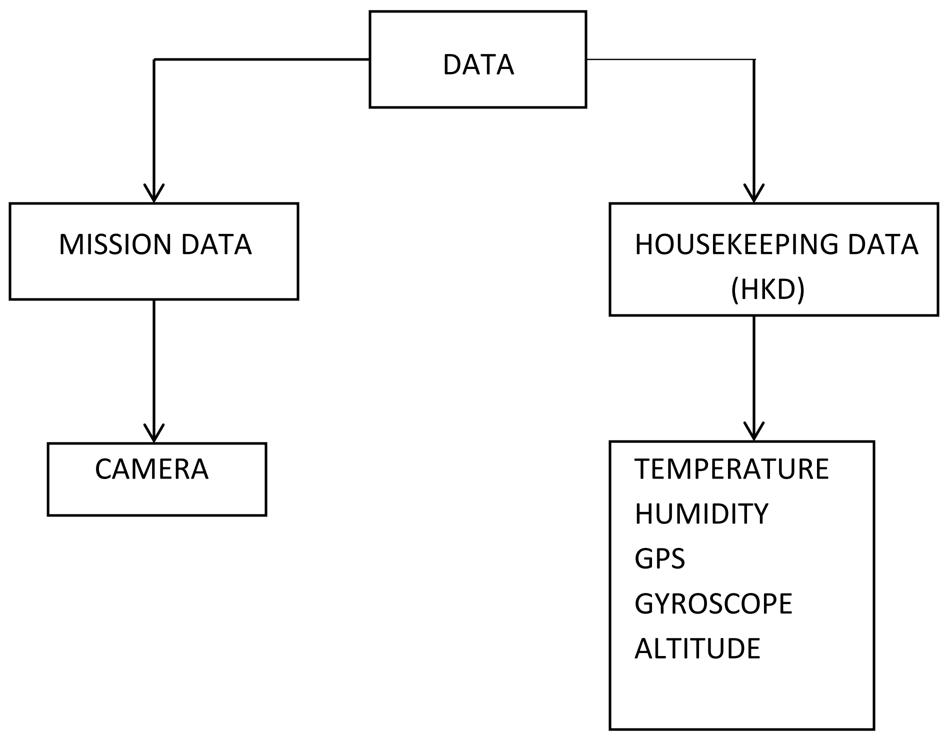


Figure 14. Types of data our CanSat

1.2.2.4 Help functionalities

The help functionality describes and enlightens information about CanSat by explaining the meaning of a CanSat, meaning of ground station, and a note on the graphical user interface and type of programming language used to produce this GUI. It also has a CanSat ground station user guide which also offers rules and steps to be respected or to base on when adding new commands or removing them.

In this help functionality, we specifically used Hypertext Markup Language (HTML) and Cascading style sheets. It is used to provide user guides, information about the CanSat, and report issue of this GS_GUI.

4.3 Testing and Results

After writing and debugging all the codes necessary or needed to run GS_GUI we perfomed the testing. Testing was done to discover bugs and make the GS_GUI easy to use. After testing we can conclude that the GS_GUI was running quite well and it was displaying the expected results. Below are the screenshots of CanSat data we hoped to visualize and display to anyone using the CanSat ground station (GS).

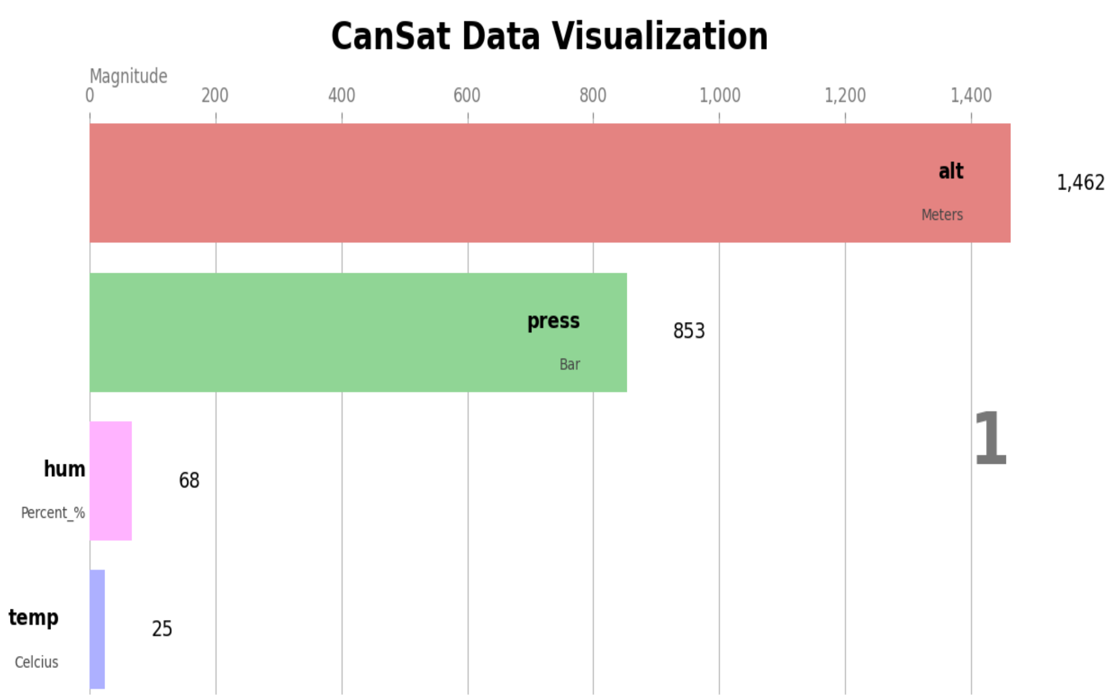


Figure 15. Visualization of collected CanSat data

In Figure 15, clearly shows the measurements of each data with their corresponding unit and magnitude in various ranges. For instance, temperature, humidity, pressure and altitude are abbreviated as temp, hum, press and alt, respectively. The number one (1) shows a set of data collected at the first time and for our case, data had been collected in three different times as it is displayed using animation of the graphs in GS_GUI. Those data are changing with time because the CanSat do not collect data in a single period but it collects more data and then when analyzing it does an average depending on the information collected. With this ground station, we can analyze one type of CanSat data independently depending on the information needed.

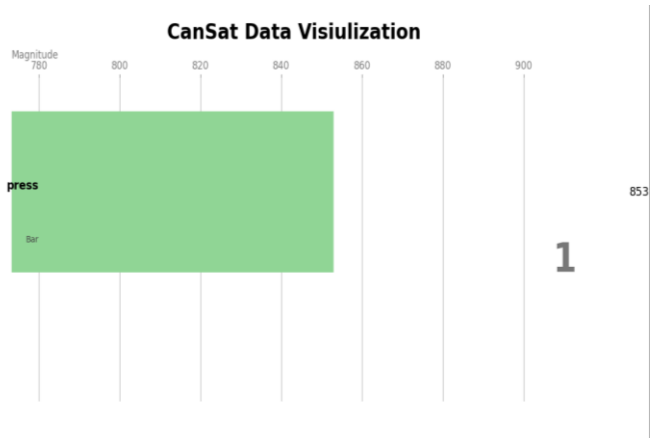


Figure 16. Atmospheric pressure analysis.

The user might choose to search for deep information about the atmospheric pressure thanks to the type of sensor responsible for the collection of atmospheric pressure MBP 280.

From figure15, we showed how to visualize the range of the atmospheric pressure and we selected the pressure row which gave us figure 16 and from there, the magnitude of atmospheric pressure is 853, which is in the range between 842 to 867 of a set of atmospheric pressure collected data.

Temperature visualization

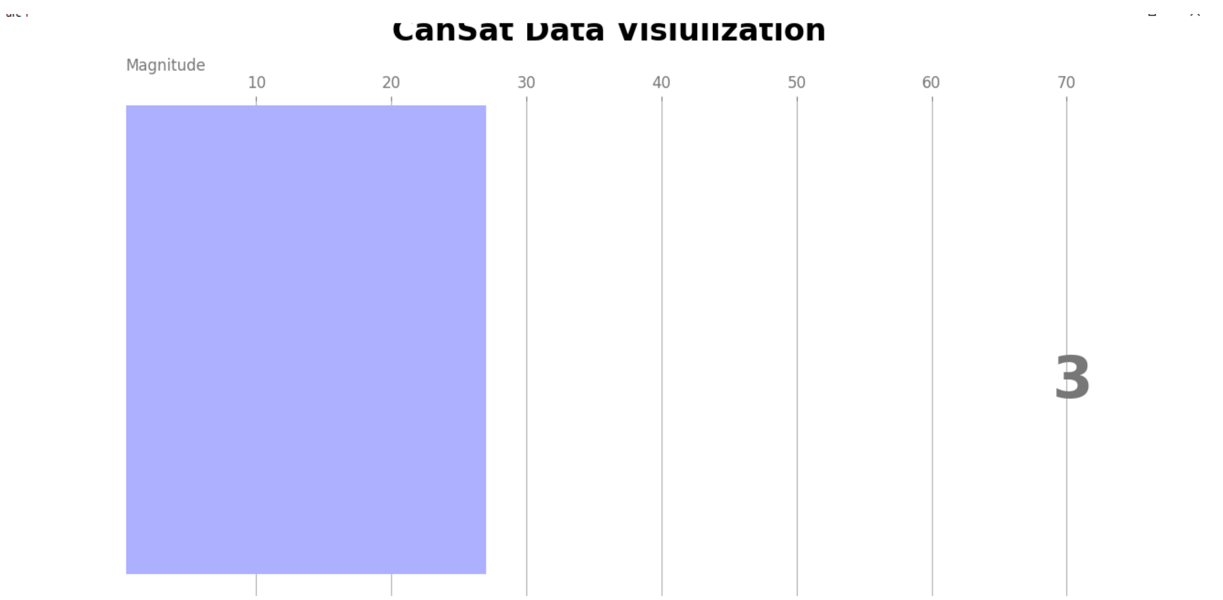


Figure 17. Temperature visualization.

From the figure 17, we got the magnitude of the temperature which was collected by the CanSat, and it was visualized and displayed by the GS_GUI. The temperature was ranging from 25 to 30 degrees Celsius, but from figure 17 the temperature was taken at approximately 27^0c. The number three shows temperature data collected at the third time.

The above screenshots presented, displays the final results a GS_GUI operator sees when he/she wants to visualize any of the data collected by the physical CanSat. The user or the operator gets the data through interacting with the GS_GUI through command prompt. The project source codes are hosted on the Github account and anyone can access and use them in his/her CanSat project. Github account is provided in the appendix.

Chapter V: Conclusion and Recommendation

5.1 Conclusion

The main goal of our project was to create a ground station that interact with the already created CanSat. The designed GS_GUI is easy and flexible for anyone especially engineering students to use. The GS_GUI needed to have basic functionalities so as to visualize and display the collected data from the CanSat. We achieved this goal through sources codes using python language which are part of the GS_GUI program. The project source codes are hosted on the Github account and anyone can access and use them in his/her CanSat project.

The ground station visualize and displays data collected such as temperature, atmospheric pressure, and humidity and these data could be used in environmental management, measurement of climate variation of a region for a specific time, and an education tool for the succeeding generation. The hope is that CanSat GS_GUI created could be used for fellow students and anyone wanting to explore satellite communication technology and the CanSat technology in general.

5.2 Recommendations

They are factors that needs to be taken into considerations by the University of Rwanda, especially students. We recommend that this GS_GUI (source codes are available on the Github repository) be available for engineering students who want to use it in their studies and research. Students should be aware of projects already created to help them. Also, students in the engineering department should not create everything from scratch as they are fellow students who worked on the same projects. Therefore, the University of Rwanda especially the UR-College of Science and Technology (CST) should help in making projects available to students. In addition, further research and exploration is needed so as to improve the CanSat technology in general.

Reference

[1] University Space Engineering Consortium – Japan (UNISEC) November. Can satellite (CanSat).Design manual. 2011. Ver. 1.0.

[2]https://esero.ie/wp-content/uploads/2018/01/CanSat-image-1.jpg.visited on the 20th December 2020.

[3] R.Y Ndayishimiye, G.D Gasiza, E. Nikuzwe, "Design and implementation of can-sized satellite in Rwanda (CanSat_Rwa)," July 2019.

[4] A.kirli, Mahircan Gul, and Celal Tufekci. Model Sat Competition: "Vecihi Can-sat". Published on 2013.

[5] https://en.wikipedia.org/wiki/Sensor: visited on 2020, December 15.

[6] Position sensors. https://en.wikipedia.org/wiki/Position_sensor. [Accessed on 20th May 2020].

[7] University Space Engineering Consortium, Can Sat manual guide: "Can-sat hardware and firmware design". Published in 2014.

[8]Denis Roddy, Satellite communication, fourth ed., McGraw-Hill, published 2006.

[9]"Introduction to Satellite Communication", Bruce R. Elbert, Third Edition. Available from: http://sedighy.ir/wp-content/uploads/2014/10/ebooksclub.org__Introduction_to_Satellite_Communication__Artech_House_Space_Applications_.pdf

[10] ElectronicsWings, MPU6050. Accessed on: Dec 26,2020. [online]. Available:

https://invensense.tdk.com/products/motion-tracking/6-axis/mpu-6050/

[11]Masahiko Y, Communication & Ground station-Department of Aerospace Engineering, College of Science and Technology, Nihon University, Japan. Accessed on: Dec. 26,2020.[online].available: http://www.unisec.jp/cltp/online/7)CLTP4_Communication%20&%20GroundStation.pdf

[12] University Space Engineering Consortium, Can Sat Pico Size artificial satellite:" A Guidebook for building successful can sat project", published 2011.

[13]https://image.slidesharecdn.com/ttcm-170817033932/95/telemetry-tracking-command-monitoring-4-638.jpg?cb=1504502568. Visited on the 20th December 2020.

[14]"Introduction to Graphical User Interface (GUI) MATLAB 6.5", Chapman, Brooks Cole, 2001. Available from: https://ewh.ieee.org/r8/uae/GUI.pdf

[15] “an introduction to GUI programming with Tkinter”, Erik Spence, SciNet HPC Consortium. Available from: http://blog.csit.org.il/UpLoad/FilesUpload/GuiTkinter.pdf

[16]”Hands-on Python Tutorial”,Dr. Andrew N. Harrington, Release 2.0 . Available from: https://homepages.uc.edu/~becktl/Hands-onPythonTutorial.pdf

[17] Noyan, Kinayman, "python for microwave and RF engineers", IEEE microwave magazine IEEE, vol 12, no. 7, 2011.

[18] K. P. Moran, C. Bernal-Cárdenas, M. Curcio, R. Bonett and D. Poshyvanyk, "Machine Learning Based Prototyping of Graphical User Interfaces for Mobile Apps," in IEEE Transactions on Software Engineering.

[19]”the essential guide to user interface design an introduction to gui design principles and techniques”,wilbert o.galitz, third edition.

[20] University Space Engineering Consortium – Japan (UNISEC) November. Can satellite (CanSat). Design manual. 2011. Ver. 1.0.

[21] K. P. Moran, C. Bernal-Cárdenas, M. Curcio, R. Bonett and D. Poshyvanyk, "Machine Learning Based Prototyping of Graphical User Interfaces for Mobile Apps," in IEEE Transactions on Software Engineering.

Appendix

This ground station graphical user interface (GS_GUI) help us to display and visualize data extracted from the CanSat such as temperature measurement, pressure, humidity and altitude and represent them in form of graphs. It was built using different programming languages such as Python together with HTML and CSS.

The Codes used to build this project are found on Github repository below

https://github.com/Gedeon-m-gedus/CanSat_GS.git