

Spatial Information System for Pico-Satellite Communication with Remote Monitoring Sensors

PHILIP-KPAE, F.O¹, J. J. Biebuma²

1,2. Department of Electronic and Telecommunication Engineering, Faculty of Engineering, University of Port Harcourt, Nigeria

Abstract: *Pico-Satellite is one of the miniaturized and or small satellite system in recent time with about 0.1kg to 1kg in weight. It use for satellite communication and wireless by linked to a base station, in this research, report, a more detailed description of accessing and visualizing the spatial content of the data log of the P-Sat system is given. In addition to that, visualization is with respect to time and within the boundaries. The spatial content in the data log which is also known as the weather parameters is captured using the Temperature and Relative Humidity Sensors accordingly. The CSV file format, XML and HTML is the used to convert the raw data in the data log into readable plain text. The Pico-Satellite system made of Structure which houses the electronic subsystem including the onboard computer has a direct link to the Xbee Transmitter. The data in the data log is sent via Wireless Communication technology to the Xbee Receiver at the base station with a base station Computer having the spatial information for pico-satellite software is installed. In conclusion, this is geared towards achieving results that is spelt out in the Objectives set for this research. The research is done at the Calabar Airport where the software facilities is. The data received is then fully analyzed accordingly. The Experimental results in this research shows the Geo-fencing outcome and variation of Pressure, Temperature and Relative Humidity with real time and Altitude.*

Keywords: Comma Separated Version, HTML, Geo-fencing, Monitoring Sensor, Pico-Satellite, Pressure, Relative Humidity, Temperature, XML.

1. Introduction

1.1 Background of the Study

Advances in satellite communication technology have contributed to development of Pico satellite (p-sat) which is being used in fields such as prediction and for the field of environmental and atmospheric parameters (Gulfar, 2009). Lately, several organizations have designed and implemented a version of P-Sat called Can Satellite. The Can Sat is used for the capturing of atmospheric data along with some Spatial coordinates with respect to the Can Sat location (Quarshie, 2013). As at the Calabar International Airport, the particular type of P-Sat used is the Radiosonde Weather Balloon (RWB), it is applied in capturing the environmental parameters around the airport area.

Over the years, there has been progress in the plan and subsequent evolution of P-Sat by Engineers. This singular act has made the availability of p-sat technology common in the global securities industry. As a consequence, a larger number of p-sat otherwise known as CubeSat was developed by CubeSat-class programs in the Surrey University, University of Stanford, Hawaii Space Flight Laboratory, Corporation of Aerospace and Angstrom Aerospace located at Sweden and other facilities that is charged with the duty of such advanced system design and development (Bordetsky, 2010).

The increasing demand of CubeSat Pico-Satellites across the globe has increased the number of organizations as there are over 20 of such organizations in the macrocosm that is responsible for the development, evaluation and possible launching of the CubeSat Pico-Satellites yearly (Puig-Suari, 2011). The academic world is not the only one that benefits from Pico-Sat innovation, the Pico-Sat integration experiment is a major benefactor, CubeSat technology used by security agencies for finding, tagging and tracking

enhancement and for sharing data worldwide with proper networking and control operations scenarios (Turin, 2008). Over the years the satellite systems have involved huge funds from government and personnel thus making it expensive. Nonetheless, with P-Sat emergence, the monetary value of developing satellites has drastically lost weight. The purpose and goal of the larger satellites are achievable with the advent of Pico-Sat. Furthermore aerospace engineering training in universities has changed from theory study to practical work. (Kelly, 2007).

Notwithstanding the advantages in the advent of the P-Sat in remote monitoring-Sat systems, available software have limited capabilities to access and visualize the spatial content of this data logs of P-Sat systems. This capability limits the Geo-location functionality application to image data content along a base map.

Furthermore, because of the mechanisms used to launch P-Sat for example, the balloon and others drone, the data capture from any given region always include data from location beyond the areas to gain access to by that given region (Akinode, 2013). Hence, in some of these cases a spatial base search engine and geo-fencing technique is made available to play a pivotal role as in extracting data pertaining to the specific geo-fenced area. Unfortunately, these technical functionalities are lacking in the remote monitoring software of P-Sat being used.

1.2 Statement of the Problem

Common challenges for the remote monitoring software of Pico Satellite systems include the following:

- 1) Limited ability of the pico-satellite system at the Calabar Airport to access and visualize the spatial content data log of Pico satellite systems;
- 2) The capabilities of the Pico satellite systems limit in the use of Geo-location functionality to visualize data content in real time, on a base map; and

- 3) The data captured from any given region always include data from locations beyond the boundaries of that given region due to the launch mechanism for the Pico satellite such as balloons and un-manned aerial vehicle (UAVs) drones.

1.3 Research Questions

Established on the problems stated above, this study hopes to offer responses to the following research questions?

- 1) In what ways is a spatial data-base processing of Pico Satellite data log needed in the remote monitoring unit of the Pico Satellite?
- 2) How can it be analytically used to determine the distance between points and bearing based on their GPS coordinates (longitude and latitude)?
- 3) What approach will be required to extract data captured within a given geographical area?
- 4) How can it be analytically used to specify the points within and outside a Geo – fencing polygon region giving its GPS co-ordinates.
- 5) What approach will be needed in developing a third party web map application for visualizing the Pico Satellite data log on a map based on their spatial information content?

1.4 Objectives of the work

The aims of the research are as follows:

- 1) To produce a more versatile spatial information system that will be compatible with Pico satellite remote monitoring software;
- 2) To develop a Geo-fencing mechanism for extracting Pico satellite data for any defined geographical region or area;

1.5 Scope of the Research

This research work is focused and centered on remote monitoring software for a Pico Satellite: The Radiosonde Meteorological Weather Balloon used at the Calabar International Airport and at Uyo.

1.6 Limitation of the Research

- 1) The research may not be compatible with the remote monitoring software of other P-Sat.
- 2) Given that the satellite considered does not capture pictures and video content, the whole research work did not include visualizations of images and video.

2. Review of Literature

2.1 Satellite Communication

Satellites are the greatest needs of communication engineering, micro-gravity research and for academic purposes. This development has made the study of space more interesting and easier. Over the past years countries like Russia, America, Germany, Japan and other first world countries have explored the space to a great extent. Globalization of world affairs which includes monitoring and businesses looks increasingly united and at the same time divided as spy activities is carried out by each country or the other on each other via Satellite communication technology not excluding organizational spy activities. This busy global activity has necessitated the design and development of artificial satellite whose advantage is not limited to a reduced Satellite system with limited resources and of course less cost effective (Rysanek, 2002). Satellites are semi-independent computer-controlled systems. Satellite subsystems is designed to carry out many tasks, which includes power generation, thermal control, telemetry, attitude control and orbit control (NASA, 2010).



Figure 2: GPS Satellite (NASA 2010)

Etymologically, it is derived from the Latin word “satellitem” or “satelles” meaning an attendant, one who is constantly hovering around and attending to a “Master” or big man (Etymology Dictionary). Satellites are launched

into space to do a specific job, thus they perform specific Function(s). The type of satellite that is launched to monitor cloud patterns for a weather station will be different than a satellite launched to send television signals across Canada.

The satellite must be designed specifically to fulfill its function.

- 1) Anti-Satellite weapons/"Killer Satellites" are satellites, designed for destruction enemies' warheads, satellites, and other space objects.
- 2) Astronomical satellites are satellites used for the observations of distant planets, galaxies, and other outer space objects.
- 3) Biosatellites are satellites designed to carry living organisms, generally for scientific experimentation.
- 4) Communications satellites are satellites stationed in space for the purpose of telecommunications. Modern communications satellites typically use geosynchronous orbits, Low Earth orbits.
- 5) Miniaturized satellites are satellites of unusually low masses and small sizes.[17] New classifications are used to categorize these satellites: minisatellite (500–100 kg), microsatellite (below 100 kg), nanosatellite (< 10 kg).
- 6) Navigational satellites are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracies on the order of a few meters in real time.
- 7) Reconnaissance satellites are Earth observation satellite or Communications satellite deployed for military or intelligence applications. Very little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.
- 8) Earth observation satellites are satellites intended for non-military uses such as environmental monitoring, meteorology, map making etc.
- 9) Tether satellites are satellites which are connected to another satellite by a thin cable called a tether.
- 10) Weather satellites are primarily used to monitor Earth's weather and Climate.
- 11) Recovery satellites are satellites that provide a recovery of reconnaissance, Biological, space-production and other payloads from orbit to Earth.
- 12) Manned spacecraft (spaceships) are large satellites able to put humans into (and beyond) an orbit, and return them to Earth.

Satellite communication system like any other electronic system are a self-contained communication system with the ability to transmit and receive signals, especially data captures from the Global Positioning System (GPS) from space station to the ground station (Earth Base) via sky wave (Fortescure, 1991). One major criteria to be considered in the Satellite design and development is the ability of any such satellite to withstand increasing shock

that may arise during launching of the satellites into orbit which could be approximately 28,100km (17,500 miles) per hour and an unfriendly space environment with increase radiation and very high temperature due to its closeness to the sun, having an operational life span of about 20 years (Bourmeester, 2010). Satellites should be light taking into consideration the cost of launching a single satellite. There are two components that determine the launch of satellite, they are cost and weight and are equally hooked on each other. Based on that, the satellite should be smaller, lighter and be made of materials that are durable to meet the challenges and the test of time (Barza, 2006). Due to its importance in world activities, its operation should be reliable either 100 percent in the space station without being maintained nor repaired.

Satellites communication engineering provides a universal communications link between several points across the globe (Bourmeester, 2010). However, domestic and international networks take credit on the use of satellite high technology irrespective of the subscriber's geographical location, this is achievable due to its suppleness and cost efficiency (Barza, 2006). One very important limitation of wire and wireless communication links is its inability to be channeled across different continents of the world and oceans including some remote areas (Fortescure, 1991). Satellite machinery is invariably the best solution of communication across continents oceans and those remote areas as it use sky wave propagation in connectivity. It covers a large landmass where other communication channels like aluminum, copper wire and fiber optics could be very expensive to run (Kalman, 2008).

2.2 Overview of Pico-Satellites

The acronym "Pico" from the Spanish word means 'small quantity'. Pico-Satellite or "PicoSat" as it is often called is simply a name given to the artificial satellite system that has a damp mass ranging from 0.1 and 1 kg (Nmea, 2008). Existing design and development of such satellites may have several Pico-Satellites working together. In some cases, pico-satellites designs needs bigger satellite to serve as link between ground controllers or launching and docking with the picosats. CubeSat design that is approximately 1 kg in mass, is a typical model of bigger Pico-Satellite (or minimum NanoSat) (Tsitras, 2012).

Picosats is growing in popularity due to its simplicity in design and development as an alternative for 'Do It Yourself (DIY)' kit builders. Pico-Satellites are available in commercial quantity between the ranges of 0.1–1 kilogram (Linger, 2002). This has led to the launch of many Pico-Satellites recently precisely between 1999-2012 as shown in Figure 2.1

Amount of launched Pico-Satellites

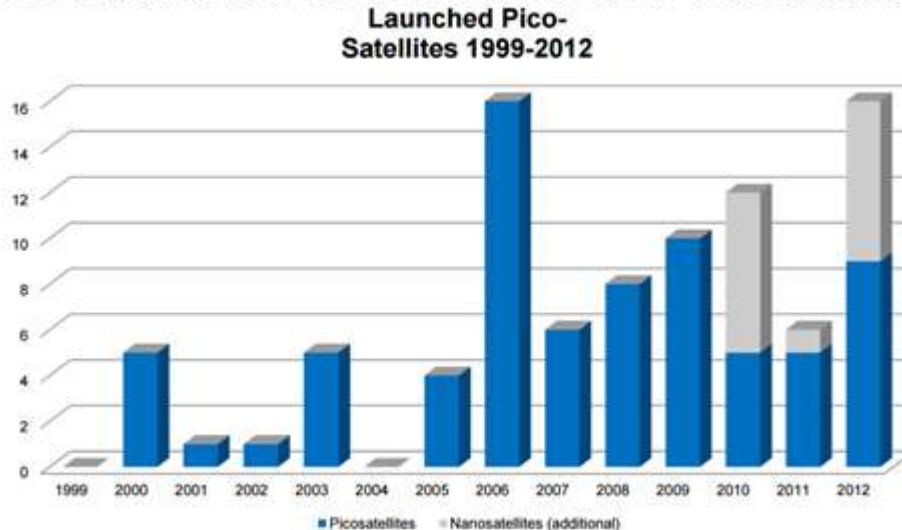


Figure 2.1: Launched Pico-Satellite 1999-2012 (Rysanek, 2002)

p-Sat is usually applied in many areas especially in the maritime sector, for enabling findings exchanged tagged object, tracked object and as well as global information, shearing solutions that relates to emerging network-controlled Maritime Introduction Operation (MIO) sceneries. It also helps in tracking and tagging Weapons of Mass Destruction (WMD) materials via Sea Line of Communications (SLOCs).

Pico-Satellite research is an excellent avenue for hands-on experience, allowing engineers and scientists to learn, and experiment on subsystems. Since the design is of lower difficulty as well as reduced cost effects in terms of market values, it however implies that this platform is better off than micro or large satellite in other to carry out some experiment in a subsystem and budding innovations. The Pico-Satellite project, though faced with challenges as is every space endeavor, has advanced and successfully achieved its aims and objective of functional on-board data handling subsystem and communication subsystem. At this stage the engineers and scientists are capable of demonstrating a secure communication channel, allowing tele-command and telemetry transmission (Quarshie, 2013).

2.3 Classification of miniaturized or Small Satellite (Wet Mass < 500 kg)

Small satellite systems may provide a low-cost and readily deployable solution for disaster detection and monitoring.

They are classified as follows:

- 1) Mini satellite 100 – 500 kg;
- 2) Micro satellite 10 – 100 kg;
- 3) Nano Satellite 1 – 10 kg;
- 4) Pico Satellite 0.1 – 1 kg;
- 5) Femto Satellite < 100 g;

2.4 Typical CanSat –/ Radiosonde Weather Balloon

The p-sat used at the Calabar airport is in form of a balloon used for the determination of upper level atmospheric weather conditions, gathers the available data at that level

and sends it back to the base station by means of a transmitter (Anyaeibunam, 2014). The balloon is made up of rubber like material known as latex, It is of high flexibility, and is able to produce the lift required by itself. The Radiosonde weather balloon filled with either helium gas or hydrogen gas (Fortescue, 1991). Helium gas happens to be globally used to inflate the balloons; this is because it is denser than air thereby ensuring operational capability of the balloons (Fortescue, 1991). Several types exist, with specific functions. Another smaller type is the pilot weather balloon otherwise known as smaller air craft. It is been monitored visually especially when it is ascending; its main application is that it provides information on speed and the direction associated to wind (Schmidt et al., 2008). Ceiling weather balloon another model whose functional ability is to determine the altitude regarding cloud basis (Fortescue, 1991). However, the teardrop model is the most advanced, where the gas content of the balloon influences its ascent rate.

The radiosonde is the unit of measurement of a weather balloon, the measurement is done separately throughout the process: this unit of the equipment is normally attached to the lower side of the string so that it enables easy measurement of the required parameters, such as determining the concentration of the ozone. Two possible ways in the weather balloon could extract the temperature information, air pressure and wind specification is either to record or transmit data during ascension, or it starts measurement when it gets to required predictable altitude (Anyaeibunam, 2014). Special radars, different types of sensors and multifaceted satellite systems are used in modern technologies to ascertain weather conditions while the application of a weather balloon is simply a complementary method of aggregating the level of information (Ecbrecht, 2002). Weather balloons carries all kinds of gear high up purposely to get a prescribed quantity in which the atmospheric pressure is, including temperature and humidity; every data that is collected then transferred to the collection center known as weather center. Notably, weather balloons are extraordinarily very useful in acquiring information relating wind actions and inactions; thus, radar

and navigation equipment of the GPS type is then used to track the weather balloon. The workability of the mechanisms is such that, the weather balloons are attractively captivating to viewers who may be seeing it for the first time as it ascends into the atmosphere.

Weather balloons, without any obstruction reaches about 39.5 kilometers (24.9 miles) high or more than that, depending on the quality of materials as well as the content primarily of gas. However, there is a limit to which the weather balloons can reach due to the diminishing pressure as an influential factor, it can expand to a point whereby it gets to its maximum inflation and possibly disintegrate. Under this situations the measurement gear gets lost. To determine atmospheric weather condition at higher altitudes, scientist relies mainly on rocket sound and observation of satellites.

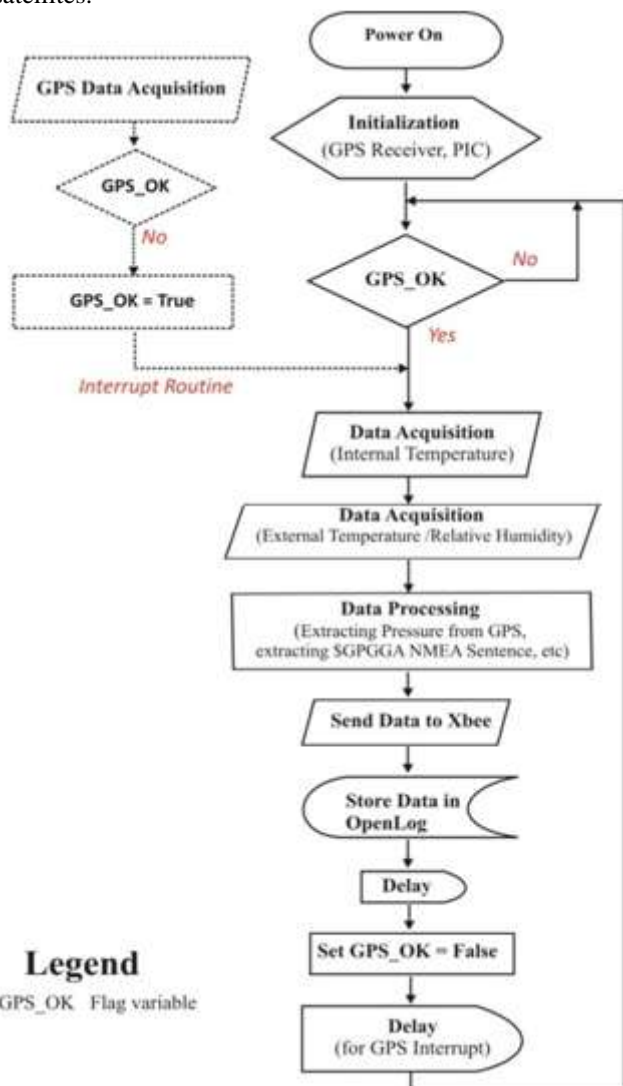


Figure 2.2: CanSat flow Chat Diagram

2.5 Component of a Pico Satellite

The p-Sat is designed based on the following subsystems; they includes a system that accumulates information (data) from the sensors, Data processing system, system that Communicates with the ground station; and system that Controls the P-Sat (CanSat).

A typical Pico-Sat (CanSat) system is subdivided into two main subsystems vital to its functionality: the Structure and the Electronic subsystem.

2.5.1 Structure

Protection of the electronic components and durability of the electronic subsystems should be based on proper packaging of CanSat. The communication module should be reliable so that the communication between the can-sate and ground station should be effective to;

- 1) Guide against damage to the electronic components as a result of the influence of hash weather conditions.
- 2) Reduce the dissipation of heat within and outside the CanSat; and
- 3) Enhance the complete validity between the Pico-Satellite and the communication module used at ground station.

2.5.2 Electronics Subsystem

The primary purpose of the design of the Electronics subsystem of the CanSat is for monitoring and for pressure acquisition, relative humidity, GPS information, and the temperature surrounding the environment and also the “satellite position” all for the purpose of successful transmission of same data to the ground station. Four units such as Electrical Power supply; Microcontroller; Sensors; and Communication module are used to actualize the requirement of the satellite system. (Akinode and Alawode, 2013).

2.5.3 Communication Module

The functionality of the Can Satellite is primarily based on the communication module. The main purpose of the communication module is to convey data and for the “satellite” controllability. This is implemented using the wireless (radio) module together with ground station and the microcontroller embedded with the satellite system (Salami, 2006)). In summary, the goals of the communication module is given bellow;

- 1) Reliability in data transmission;
- 2) Effectiveness in “satellite” controls; and
- 3) Ability to autonomously detect and recover fast after having some communication problems (Selva, 2012).

The communication protocols employed by some component of CanSat are listed as follows: National Marine Electronics Association (NMEA 0183) protocol, RS-232 protocol, Inter-Integrated Circuit (I2C) protocol and 802.15.4/ZigBee protocol.

2.5.3.1 The NMEA 0183 Protocol (National Marine Electronics Association)

This is a combination of electrical specification as well as data specification just for the purpose of enhancing the communication between the marine electronics instrument like the echo sounder, the sonars, the anemometer, the gyrocompass, the autopilot, the GPS receivers as well as other instruments (Anyaeibunam, 2014)). This standard (NMEA 0183) employs simple ASCII and a protocol called “serial communications protocol (SCP)”. The SCP specifies the procedures by which data can be transmitted in which, it is possibly expressed as a "sentence" from one "talker" to multiple "listeners" at an instant of time. That means that a talker can may be unidirectional in conversation with

approximately an unlimited listeners using intermediate expanders and as well as multiplexers and multiple sensors to a single computer port (Schaffner, 2002).

2.5.3.2 RS232 Protocol

RS-232 is a practical standard interfacing protocol that is approved by Electronic Industries Association (EIA) for the purpose of connecting serial devices. In other words, RS-232 is a long time established standard protocol that is best described as the physical interface between a protocol for a relatively low-speed serial data communication and Data Terminal Equipment (DTE) as well as Data Circuit-Terminating Equipment (DCE). The interfacing device is popularly known as DCE, an acronym for Data Communication Equipment. This criterion specifies the electrical characteristics and signals timing, what signals is to be communicated, and the sizes and pin-out of the connectors used (Quarshie, (2013).

2.5.3.3 Inter-Integrated Circuit (I²C) Protocol

Inter-Integrated Circuit (I²C) also known as I-square-C, or IIC is a multi-master serial single-ended computer bus was invented by the Philips semiconductor division, it is known today as NXP Semiconductors. The application of NXP includes; the attachment of low-speed peripherals to motherboards, embedded systems, cell phones and other digital electronic devices (Nwajiobi, 2012).

The inter-integrated circuits (I²C) utilizes two distinct dual-directional open-drain lines, as in Serial Data Line (SDA) and Serial Clock Link (SCL), pulled up with resistors. Allowable voltages is +3.3 V and +5 V, although not limited to systems with other voltage values within the allowable range. The I²C designreference either 7-bits and/or a 10-bits address space (based on the device used). Common IIC bus speeds are both the 100 Kbit/s standard mode as well as the 10 Kbit/s low-speed mode, but randomly low clock frequencies can also be allowed. Recent revisions of IIC has the capability of hosting good number of host devices (nodes) and runs as fast as 400 Kbit/seconds in a Faster approach (mode), 1 Mbit/s Faster mode plus (Fm⁺), and 3.4 Mbit/seconds High Speed mode (Hsm). Such speed modes are widely employed in an embedded systems other on a personal computers (PCs) (Salami, 2006).

A bus device depends largely on four modes of operations.

Even as most devices uses one role and two modes. Namely;

- 1) Master Transmit — the master node that sends data to a slave node;
- 2) Master Receive — the master node that receives data from a slave node;
- 3) Slave Transmit — the slave node that sends data to a master node; and
- 4) Slave Receive — the slave node receives data from master node.

The master transmits is said to be in a master mode initially only if it sends a start bit and a seven-bit address of the slave that it intends to link/communicate, which is eventually trailed by a single bit that represents that it is to write zero (0) command to the slave or to read one (1) command that emanates from the slave. Acknowledged (ACK) bit for active low for the address signifies that the slave thus exist on the bus. At that point, the master continues either in

transmit mode or receive mode based on read bit or write bit it sends. Likewise the slave is made to continue its role as a complementary mode with respect to reception or transmission of the required data. For proper functionality of this subsystem, the address together with the data bytes sends most significant bit initially.

Nonetheless, if the master intends to transmit/write a message to the slave, then it repetitively sends a byte while the slave sends an Acknowledged (ACK) bit. Hence, the master is said to be in a transmitting mode while the slave is at the same time said to be in receiving mode. If the master intends to receive/read a message from the slave then it repetitively receives a byte while the slave sends an Acknowledged (ACK) bit. Hence, the master is said to be in a receiving mode while the slave is at the same time said to be in transmitting mode.

The master is either expected to end transmission with “STOP bit”, or sends a “START bit” if it intends to regain control of the bus in case of retransfer of another bit. (a "combined message").

2.5.3.4 802.15.4/ZigBee Protocol

Institute of Electronics and Electrical Engineers (IEEE) standard 802.15.4 is a standard offers a fundamental lower network layers of a wireless personal area network (WPAN) which is focused on low-cost and low-speed communication availability amid embedded devices (Farison, 2010).

A 10-metre communication range has a transfer rate of 250,000 bit/s conceived framework. Tradeoffs favors a radically embedded devices that has a lower power supplies, though not only one layer, but other physical layers. Transfer rates of as low as of 20 and 40 Kbit/s was defined at the initially time, afterword a 100 Kbit/s rates is being added to the current revision.

Lower speed rates is however considered as a result of the effect of the power used up. The main identifiable features of the IEEE 802.15.4 with the WPANs is the achievement of extremely low process of manufacturing and cost of operation and the simplicity associated with the technology, with no sacrifices in its suppleness or generalization.

The ZigBee is preferably the most extensively used development to the 802.15.4 standard, it is also referred to as ZigBee Alliance Standard. This association sustains, supports, and improves in the research and development of more advanced and sophisticated protocols that stands the test of time and for advance and sophisticated applications. These improvements consist of validation with usable points (nodes), security codes for unauthorized access, and a data paths and sending capability that enables mesh configuration. ZigBee is popularly used in wireless sensor networks most especially in a mesh network (Farison, 2010).

2.5.5 Microcontroller Subsystem.

The CanSat gets all its signals from the sensors that makes up the complete unit. This is achieved with the help of the microcontroller subunit. It is there not be out of place to describe the microcontroller as the heart-beat of the CanSat. After which, the microcontroller then sends the required

signals to all other subunits including the ground station via the wireless module. However, to actualize maximum compatibility and seamless interfacing of the pico-satellites spatial information system with different Pico-satellites remote monitoring units, the data captured from the Radiosonde Weather Balloon Pico-satellite are been exported in Comma Separated Version (CSV) file format. Another file format such as the Extensible Markup Language (XML) can also be used. Particularly useful for web-based applications is the Extensible Markup Language format (Gregorio and Bernardi, 2003).

Microcontroller Subsystem goals includes:

- 1) Data collection from the sensors used in the system;
- 2) Data processing/handling;
- 3) Inter system communication including the ground station; and
- 4) Satellite control.

2.6 Common Interfaces of Radiosonde Weather Balloon and the Ground Station.

The remote wireless monitoring unit (RWMU) is the connection unit between the Radiosonde Weather Balloon

(RWB) and the ground station. Its primary function is to retrieve the raw data every 1 seconds from the RWB and send it back to the base station for processing. The links is made possible by:

- 1) Interfacing the electronic unit and the microcontroller unit in the satellite communication system.
- 2) Interfacing the wireless module and the available sensors that makes up the entire system.
- 3) The Remote wireless monitoring Sensor for the Data Capturing as in the case of the radiosonde weather balloon (RWB).

The sensors used in the system is seen in the CanSat Specification and Description Language (SDL) diagram shown in figure 2.3. The following measurement are made:

- 1) Temperature of the internal, using TMP102;
- 2) Temperature of the external, using sensor HIH6130;
- 3) Relative Humidity, also using HIH6130; and
- 4) The GPS supplies the raw data/information relating to the latitude, UTC Time, Longitude, Satellites Used, Altitude,

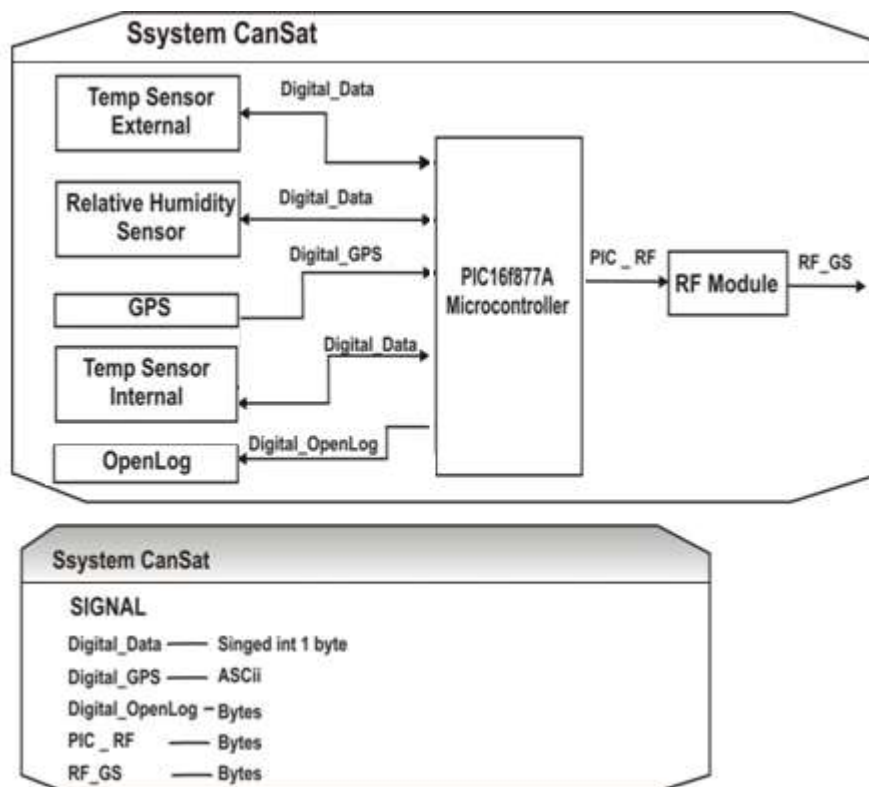


Figure 2.3: CanSat Specification and Description Language (SDL) Diagram

2.6.1 Temperature Sensors

As shown in Fig. 2.3, two temperature sensors are connected to the CanSat. They are; internal Temperature sensor and the external temperature sensor. The interfacing both temperature sensors and microcontroller is based on two-wire serial interface I²Cs. The I²C protocol permits interconnectivity of 128 different usable devices of using two bus lines that is bi-directional, one for Serial Clock (SCL) and the other for Serial Data (SD). It is a master slave kind type operation whereby the microcontroller is in the master mode while the temperature sensors is in the slave mode.

All the address packets that is transmitted via the I²C bus is a 9 bits long address, it consists of 7 address bits, the READ/WRITE control bit and the acknowledge bit. Accordingly, if a READ/WRITE bit is set, a read operation is expected; if not, a write operation is executed. The most significant bit (MSB) is first transmitted.

All data packets transmitted via I²C bus is a 9 bits long data, it also consists of a single data byte and the Acknowledge (ACK) bit. During data transfer, the master node is employed to generate the clock as well as a START and STOP conditions, while the receiver node assume the

responsibility to acknowledge the reception. The MSB is first transmitted.

2.6.2 Relative Humidity Sensor

The relative humidity is measured also by the Honeywell Humidcon (HIH6130) sensor. Separate commands are issued to the device to take temperature of the exterior readings and relative humidity readings.

2.6.3 The Global Positioning System (GPS)

The Global Positioning System (GPS) is as satellite based navigational system, practically used for locating positions anywhere on earth surface. It is best described as a network of many satellites that continuously transmit information continuously in real time. The GPS is also used for précised location identification on earth surface by taking measurement of the distance of the location on earth surface from satellites system(s). Design and operational activities in the United State by the United State Department of Defense. The design of GPS consists of the following components like satellites system, control station, monitoring station, and one or more receiver(s). GPS receivers' takes information wirelessly from satellites and users triangulation to calculate one or more user's precise location. GPS systems birth was in the early 1970's, twenty four (24) satellites orbits at high altitude (11,000 miles) first satellites launched in 1978. It becomes fully operational in April 1995.

There are basic Navigational information made available by the GPS units, these are: current position: coordinate (latitude & longitude), direction to specified way point, distance to specified waypoint, current speed taken, and the direction of travel.

The EM406 GPS is linked with the USART port transmission (Tx Pin) in the microcontroller. The GPS sends data as long as 8 bit format, either 1 start bit, and/or 1 stop bit in 4.8 kilo baud rate (4800 baud rate) every second (Nylund, 2008)). The data is been read from the USART port and have it processed before it sent to the ground station.

2.6.4 Open Log

The Open Log is used as a backup device in case of communication failure between the payload unit of the system and the ground station. Open Log runs at 3.3 to 5 V at 9600 bps by default. The baud rate is configured from 300 bps to 1000 Kbps. I modified the configuration file to work specifically at a serial speed of 4800, but it is also reconfigured through a software commands.

The micro SD card can be of any size from 64 Megabytes to 16 Gigabytes. Before using Open Log we format the card to FAT 32 file format using windows. Once the Open Log is powered, it will create a configuration file called CONFIG.TXT as in figure 2.4 shown below.

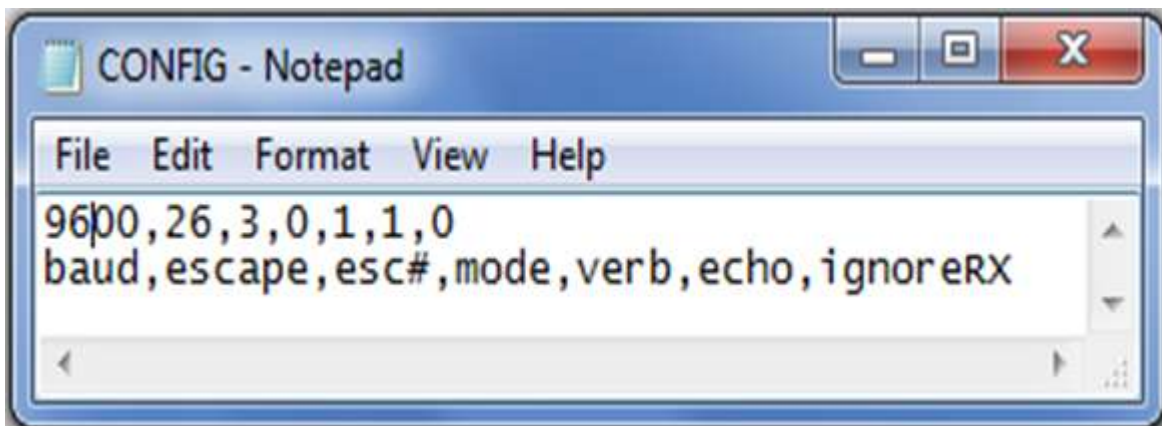


Figure 2.4: Open Log Configuration File

From the figure above, the default baud rate is 9600, mode of communication is 1 - data logging mode. Changing the baud rate means changing its configuration file to 4800 and save the changes with notepad. When the device is powered, it will read the new baud rate and start communicating with it.

2.7 Spatial Data Based Management System (SDBMS)

In the various fields of the SDBMS, there is always need to manage the geometric, the geographic, or the spatial data, that is the data which is directly related to the space parameters for possible monitoring (Schaffner, 2002). The need to organize and manage large data has resulted in the building of database and its associated software. For instance, a two-dimensional perception of the earth surface – which has to do with geographical space and the man-made space just like the Very Large Scale Integration (VLSI)

design layout, a human brain which contains volume of natural ideas. The management of data in a relational database systems has always been the focal point of researchers. Ever then there have been significant improvement till date. However, database is defined as the collection of large interrelated information stored in a computer system (Solheim at el, 1999). Data found in database are characterized by its large volume and also persistence such that can survive in an unexpected software or hardware disappointment (Solheim at el, 1999). Managing and controlling access to database in a system has giving rise to what can be best describe as “database management system (DBMS)”. DBMS is the deliberate collection of software that manages and at the same time controls accessed to any data that is stored in a database system.

Terms that offers support like pictorial database system, image database system, geometric database system,

geographical database system, or spatial database system have been associated to database system. The terms “pictorial” and “image” databasesystems arose from the singular fact that the data been managed are captured initially in a form known as digital raster images (e.g. remote sensing data captured by satellites). The “spatial database system” became popular through conferences and bi-annual “ Large Spatial Databases (SSD) symposium” held since 1989 (Klofes and Anderson, 2008), and as a result it has to do with database that contains set of objects in geographical space given no attention to images and/or pictures in space. Indeed, objects in geographical space with identity and a well-defined extents and locations and relationships are dealt with differently from raster images with specific requirements and technicality. Therefore, spatial database systems and image databasesystems has to be clearly differentiated from each other base on the data requirement. The former has to do with spatial data while the later has to do with images. (Kelly, 2007). The image database systems (IDBS) has to do with analytical techniques to extracting objects in geographical space from images present in space, and at the same time offers some spatial database functions. It has the capacity to storing, manipulating and also retrieving raster images as discrete entities based on the IDBS design and development.

The DBMS performs the function listed below;

- 1) Defining a database i.e. specifying the data types, structure, and constraints to be considered;
- 2) Constructing database systems i.e. storing the data itself into persistence storage;
- 3) Manipulating the database;
- 4) Querying a database other to retrieve detailed data;
- 5) Updating the database;
- 6) To offer Spatial Data Types (SDTs) in the required model as well as to issue query language; and
- 7) Its support spatial data types (SDTs) to implementing and to provide spatial indexing and well-organized algorithms for the purpose of spatial joining.

To achieve the above functions, different modeling techniques exist to represent specific data for storage. The modelling techniques includes an object – oriented database model, a relational database model, a spatial database modeling techniques, a temporal database model and a spatiotemporal database model.

2.7.1 Object Oriented Database

Objects-oriented database systems were born in the 1980s from the merger of two technologies: database systems and object-oriented programming languages (Long, (2012). Data about entities in object oriented database is stored in an object which is identified by an object identifier. The type of object in this model specifies the properties or attributes that the object is made up of. Any Set of objects that has the same attributes are simply referred to as collections (Long and Rogers, 2002). That means, any object-oriented database is a set of collections.

2.7.2 Relational Database

It relies on a single structure, i.e. the table or relation. As such, it is represented as both entities and relationships via tables. A relational database stores data in tables, known as

relations. Each table made up of rows, (also called tuples) and columns, (also known as i.e. attributes or fields) (NASA, 2010). A row is a collection data about an exact entity. Thus a relational database is that which stores set of tables.

2.7.3 A Temporal Database

A Temporal database is that which stores data relating to real-time instances. It has a facility to offer temporal data varieties and can also store information that relates to past, present and future time (Schilling and Brieb, 2006). It is however a modelling techniques designed to provide extraordinary support in handling data types with a temporal component part like time (Tsitas, 2012). In this database, objects can assume different numerical values at different times. According to JiYONG Zhang, temporal DBMS manages time-referenced data and the time is associated with the database entities (Tsitas, 2012). It finds great application in finances such as banking sector, record-keeping such as personnel and inventory management, scheduling such as project management in a smart sheet.

2.8 Geo-information Integration Overview

Spatial data, also known as geographic information, is data that identifies location and its boundaries and features (Akinode and Alawode, 2013). Spatial data can reference to natural, constructed or even abstract objects. Geographical information system (GIS) is a system that stores manages and presents spatial data (Zeiger at el, 2006 ; Schmidt and Zeiger 2006). Typical usage of GIS software is for example logistics, resources or asset management, urban planning and marketing applications. Spatial data inside GIS is stored in coordinate system which references particular place. Other attributes can be linked to location to store other parameters about spatial information as its appearance, boundary or any other feature.

The area of GIS is rather new-the first pioneer period can be identified spans from 1950s to 1970s in United States of America and The United Kingdom. Second phase of GIS can be traced from early 1970s to early 1980s when governments funded research activities and role of the individual started to diminish. From 1980s to 1990s GIS industry has grown with emergence of personal computers and workstations (Zeiger at el, 2006; Schmidt and Zeiger 2006). By 21st century the evolution in other information technology areas and usage of internet has caused GIS industry to consolidate to some extent and begin standardization projects to provide better guidelines for GIS vendors.

2.8.1 Geographical Information System (GIS)

Geographical locations is a fundamental reference point in the physical world. Among the core capabilities of GIS, mapping is the visualization of location-based data that is the recognizable function that a GIS systems can performed. A GIS is the integrated collection of computer software and data used to view and manage information connected with specific locations, analyze spatial relationships, and model spatial processes (Shilling and Garcia, 2009). GIS as a computer system, is capable of assembling geographically referenced information, storing it and as well as

manipulating and subsequently, put-on-view the geographically referenced information (Puig-Suari and Heidt, 2011). GIS provides electronic exemplification of information commonly known as spatial data, about Earth's natural features and the earth's features influenced by man. The above mentioned Earth's features are normally quantified in location by recording their coordinate parameters that describes the positions of these features on a map or earth through its coordinate systems. The Earth's features can also be separated into different layers where each layer contains facts about common feature or group of features.

Different application of GIS are capable of creating different layers. A GIS also attributes data, which is a descriptive information of a given map features. The attribute data is however placed in a separate database different from the graphics data but links to each other to help in describing the relationship between attribute information and the spatial data respectively (Schilling, 2013). The technological advancement in the GIS device can integrate database operations like query and analytical statistics, visualization and analytical geographic that is obtainable by a map. Over the years, GIS programs are utilized in geographical information processing from many sources and integrate same to map project. The GIS can use a many data capturing methods such as aerial photograph, remote sensing data, and GPS collection or from a printed map. Data comes in variety of formats such as DBF, CSV, and Excel tables and Open Database Connectivity (ODBC) connections requires data in Oracle, SQL, and MS Access tables. GIS is of dissimilar possible formats for GIS data and data that requires conversion to a supported format. The requirement for getting data into a GIS format is assigning geographic coordinate that identifies where the data ought to be represented on given map (Kalman and Berkenostock, 2008).

2.8.1.1 Types

The wide availability of GPS-enabled devices, Combined with recent advances in the mobile components of server-based GIS technology, makes GIS even more useful for organization such as the university community. Based on its usefulness and mode of application, there is no clear defined demarcation between the various types of GIS since they overlap as such, Puig-Suari, & Heidt, in 2011 classified GIS into the following:

- 1) Four-dimensional GIS- they are designed practically for three dimensional space GIS and additional one for time using spatiotemporal referencing.
- 2) Multimedia/hypermedia based GIS – this device allows user to have access to a wide range of geo-referenced multimedia related data (e.g. simulations, sound and video) by selection of a geo-referenced image based map. This map serves as primary index to multimedia data in a multimedia geo-referenced systems.
- 3) Virtual Reality based GIS – it was developed to allow for creating, manipulating and exploiting a geo-referenced virtual surroundings.
- 4) Web-based GIS – it enable users to have a Widespread access to the internet facilities for various forms of exploitations and environmental issues

2.8.1.2 GIS Subsystem

Geographical information system is made up of four distinct components: Data Input, Data Storage and Retrieval, Data Manipulation and Analysis, and Data Reporting. The data input takes in different types of data/information provided by the user. The collected data is stored in the GIS and retrieved from the GIS for possible update from time to time as the need arises. The information is then used to analyzing different types of layers already stored in the system. Finally, reports are produced in form graphic map, with different visual themes for analysis. (Akinode and Alawode, 2013).

2.8.1.3 The Data Input Subsystem

This Input subsystem enable users of the GIS device to capture, to collect, and to transform space data types to its digital equivalent. This input data is derived from hard copy maps, aerial photography and varieties of remotely sensed images as well as reports, point data samples of survey documentation. The collected data is a space data types which describes attributes like related and absolute location of geographical features and attribute data that describes the space features. Such features can either be quantitative, qualitative or both quantitative and qualitative in nature. Tabular information can also be called attribute information.

2.8.1.4 The Data Storage and Retrieval Subsystem

The data storage and retrieval subsystem of a Geographical information system is one the most needed. It organizes the collected data and attribute them in a pattern that allows for quick retrieval for editing by users for analytical concerns. It also allows for continual updates to be carried out accurately on the database systems. In effect, it utilizes the DBMS for maintaining the tabular data in the system. Data editing capabilities in Geographical information system (GIS) subsystem includes: Collaborative editing of space information and as well as tabular information. Addition, manipulation, modification, and deleting of both spatial features and attributes information are the capabilities of this subsystem. It is also capable of editing selected features in batches while in the processing mode. The Data retrieval and querying involved is based on the peculiar development embedded in the DBMS as it is interfaced to the required software.

2.8.1.5 The Data Manipulation/Analysis Subsystem.

This is the hearth of the GIS system. It is users friendly as it allows users to generate derived information based on users' ability to define the required information to be executed with spatial and attribute procedures. The manipulation function includes geometric transformations, map projection transformations and coordinate transformation while the analysis functions include retrieval, reclassification, and generalization and connectivity functions.

2.8.1.6 Data Output/Display Subsystem

With this subsystem, users can generate graphic displays in the form of maps, and attribute reports that represents the derived information. The results of analysis is then sent to the client for further evaluation and possible implementation of the outputted and displayed analyzed result. Other graphics parameters and maps are then generated for viewers to read and interpret the results and simulations of events

and report to appropriate authorities for immediate action where necessary.

2.8.1.7 Web Application

Web application is defined as software which can be accessed through a web browser over a network such as the internet. Web application is any software application that depends on the web system (web server, network, Hyper Text Transmission Protocol (HTTP), browser) for its correct execution and uses website as its interface. Web applications query the server content and dynamically generate relevant web documents to serve client surfacing the website (Akinode, 2013).

A website is manifested through the web pages or it is a collection of documents written in Hyper Text Markup Language (HTML) language. These web pages can be displayed through the browser such as the internet explorer, opera and Mozilla Firefox. Web site can be static site or dynamic web site (Koyal and Baumann, 2007). Static web site is written by the author and the code is interpreted by browser when a user goes through the site. A dynamic website is defined as a website with its content regenerated as a result of visiting and reloading by users at any time. A dynamic web page is stored on the web server with no actual data but has a template for HTML code and query. When a user accesses the page, the query is executed and an HTML page containing the data is generated.

The World Wide Web (www) consists of server and client computer and end-to-end connection between the server and client is through a protocol called hypertext transfer protocol. Web server which is used in web application is a program that accepts processes and responds to the diverse request from web browser providing the request through Hyper Text Transmission Protocols (HTTP or HTTPS) protocols.

2.9. Geo-fencing

Objects in motion such as automobiles, satellites, humans etc. are monitored by a device known as Geo-fencing

device tracked by Global positioning systems (GPS) (Dana, 1997). The already tracked objects "geographical coordinates" are repeatedly sent to the control room, through mobile network. A set of geographical coordinates is then used in constituting virtual borderline/boundary (geo-fence) around a geographic area. The primary purpose of the system is to find-out if the object that is tracked which is the Pico-satellite is located within the geo-fenced area or not. If the tracked object eventually crosses the geo-fence area, a signal is sent to an embedded alarm system for an alert to be generated. This technology can also allow the detection of space closeness between tracked Pico-satellites and a specified geo-fenced area.

2.9.1. Geo-Fencing application.

Geo-fencing finds its application in many fields that relate to object monitoring including human. Areas like Transportation, security, etc. are not left out as it has seen significant progress from the geo-fence technology.

Transports & Logistics:

The Transport & Logistics sector uses geo-fencing to provide improved and flexible secured services to their clients/customers. In this sector, vehicles with goods to be delivered are made to get to its destination and customers facilities even as they are tracked with the help of the geo-fence technology. The customers' facilities are referred to as points of interests (POI). Vehicle movement with its content get to its destination under serious monitoring due to the fact that it's been tracked in relation to the POI which happens to be within the geo-fence area. When the vehicle is close to its destination, an alert is generated and sent to the POI.

2.9.2 Geo-fencing Techniques

Many geo-fencing techniques have been designed and developed over the years to meet diverse human needs including intrusion detection, mobile assets monitoring, human monitoring within a geo-fence area, vehicular movement monitoring etc. (Gulfar, 2009). Nevertheless, the main technique is presented in this research work.

A. Geo-fenced Area

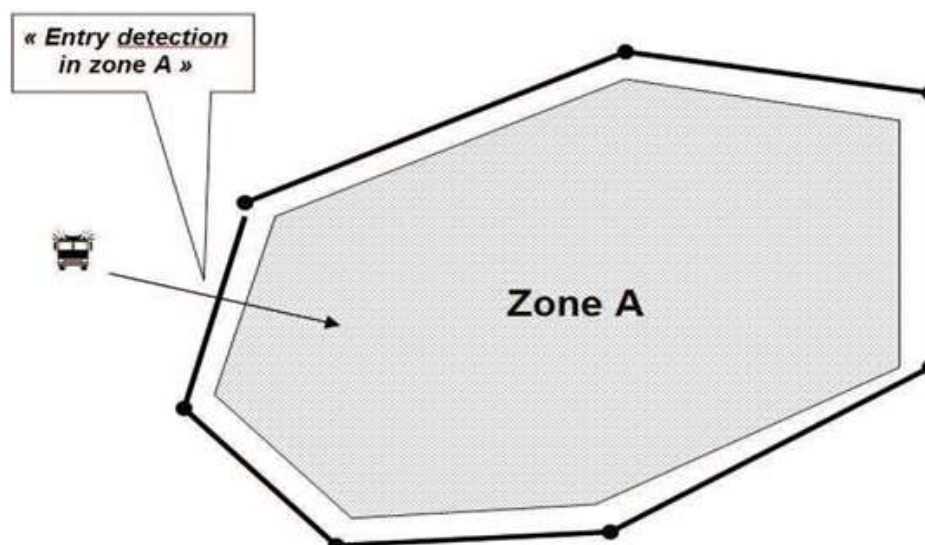


Figure 2.5: Showing a Typical Geo-fenced Area

The method used in this research provides what is called “automatic monitoring” of any object in motion, either the moving object is within or outside a geo-fenced area. Alarm is been generated as soon as a moving object is found around (i.e. entering or exiting) the boundary. The geo-fenced area could range from 10m to as many kilometers (Km) as possible based on the scope of coverage of the system. The geo-fence shape is a simple geometric figure, (i.e. a square, a rectangle, a trapezium, a polygon etc.). Coordinates from any distinctive points of the shape is required to describe the geo-fence perimeter. The coordinates is sent to the calculation algorithm, together with the comprehensive nature of the geo-fence, which then permits computation of alerts.

2.9.3 Geo-referencing

The method of aligning data geographically to geographical coordinate system for the purpose viewing, querying, and analyzing with other geographical data is called geo-referencing according to (Baumann, 2007). Geo-referencing also involves shifting process, rotating process, scaling process, skewing process, and in some areas warping process, rubber-sheeting process, or ortho-rectifying process of the data (Kayal, 2007).

Geo-referencing has to do with defining location of a physical space and it is very important in making aerial and satellite image suitable for mapping (Toorian and Diaz, 2008). It simplifies how the GPS locations with direct relationship to various data position relates to image and real locations in real time. Different projecting system employs different mappings. Different methods are contained in the tools use by the geo-referencing equipment to associate and join the maps with no or least alteration (Quarshie, 2013). Applying this methodology, data that is gotten from the observers or surveyors is allocated a reference point from the topographic maps that is made available. Note: That as many chart/map projection system has almost different application for perfection. Distortion occurs for different features when projecting curved earth surfaces mostly on a flat earth surface. Spherical coordinates or in other words latitude and longitude is the best method for locating any point on the earth surface for nautical and aeronautical navigation purpose (Quarshie, 2013). Another method adopted for the Location of any points on a large-scale maps and earth navigation is with the Cartesian-style plane coordinates methodology. Earth’s surface can be best treated as plane by a large-scale maps (looking at a simplified geometrical shape and calculation) than complex sphere. Earth curvature is most important with a well-constructed large-scale maps like the topographic map.

2.9.4 Geo-location

Satellite geo-location is the method concomitant with the location of the origin of any form/kind of signal that appears on a given satellite communication channel (Salami, 2006). Satellite geo-location, is a process that is employed to improve the negative effect of various forms of interference that may occur in satellites communication probably due to the type of channel used during communication process. However, the interfering signal may be as a result of human

error, system/equipment failure and sometime as a result of deliberate signal jamming. What is important at this point is to identify the actual source and the location of the unwanted (interference) signal so as to carry out the mitigation process

2.9.5 Geo-coding

The geo-coding is a method of allocating latitude and longitude to a point, to provide geographical coordinates related to an address for it to accurately be placed in already existing map (Bordetsky, 2010). When information is presented in a record format, geo-coding enables the record to be mapped, displaying the required information of the geographical location. Geo-coding, can also be defined as the process of locating any point(s) on the Earth’s surface from alphanumeric addressing data associated to real time events (Anyaeibunam, 2014). It is the critical and complex process of accurately placing locations, points of interest on maps. Geo-coding is being performed for the purpose of establishing any location with respect to real world events or phenomenon – even though the area located is an approximated location. Indications of the actual location are to be gathered from the address that is linked with the event or phenomenon (Quarshie, 2013).

The geo-coding process includes the treatment of semi structured alphanumeric addresses of events (which we call parsing), the generation of a correspondence between the structured address and the addressing database (matching), and the actual assignment of coordinates to the event (locating). To perform the parsing, matching, and locating tasks, it requires that the geo-coding process needs to have access to a database where information regarding the addressing system is stored. This research is focused on the collection test locations of the coordinate (latitude and longitude)

3. Research Methodology

3.1 Research Method

Empirical research method is used along with analytical approach in this work. The empirical research contains the development of a common interface for the remote monitoring units of the pico-satellite called the Radiosunde Weather Balloon (RWB), in two different locations; namely, the Calabar airport and the Uyo airport. The Radiosunde Weather Balloon is a commercial off the shelf pico-satellite used at the Calabar Airport to capture the environmental parameters around and above the airport region.

To further improve the spatial data analytically with a particular reference to the pico-satellite data in its log, mathematical models were developed for geo-fencing the pico-satellite data based on its Global Positioning System (GPS) data content. As a result, a web-based spatial information system (WBSIS) is developed with regards to its related mathematical models. The WBSIS is developed using Modified Waterfall Software Development (MWSD) shown in figure 3.1.

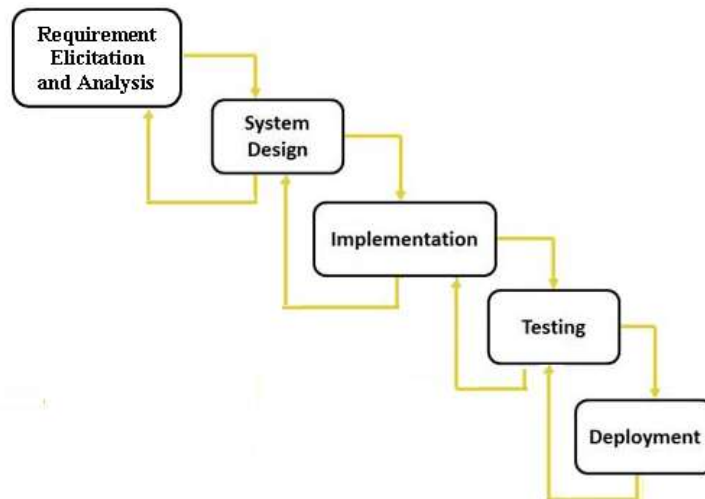


Figure 3.1: The Modified Waterfall Software Development (MWSD) Methodology.

The chronological stages in the MWSD methodology are:

- (i) Requirement Elicitation and Analysis: The requirements associated to this system is developed and captured in stages and as well as documented in the required specification documents;
- (ii) System Design: Defines the systems general architecture as well as a detailed and descriptive system design;
- (iii) Implementation: The system development is in a smaller functional units in the first instance and then integrates after the testing stage is been carried out;
- (iv) Integration/Testing stages: At this stage, all the different functional units developed at the implementation stage is then joined as a single system immediately after the testing of the individual units. Post integration test is also conducted to eliminate any type of fault and possible failures as a result of its operation; and
- (v) System Deployment: At this stage, the system is developed and released for use.

3.2 The Functional Decomposition of the Pico Satellite Spatial Information System.

The p-sat spatial information system is organized under the following major sub-modules:

- (i) Extraction of The Pico-Satellite Data logs;
- (ii) Geo-Fencing of Pico-Satellites Data;
- (iii) Path Profile for Pico-Satellites Surveillance;
- (iv) Map Visualization of the Pico-Satellites Trajectory; and
- (v) Map based-Direction Search.

3.3 Extraction of the P-Sat Data Logs

3.3.1 Interfacing with the RWB in Uyo Airport

Figure 3.2, shows the atmospheric data captured by the RWB and collected via an antenna known as “Remote Monitoring Wireless Unit (RMWU)” attached to the laptop at the earth base station.



Figure 3.2: The Pico Satellite and Its Remote Wireless Monitoring Unit (RWMU)

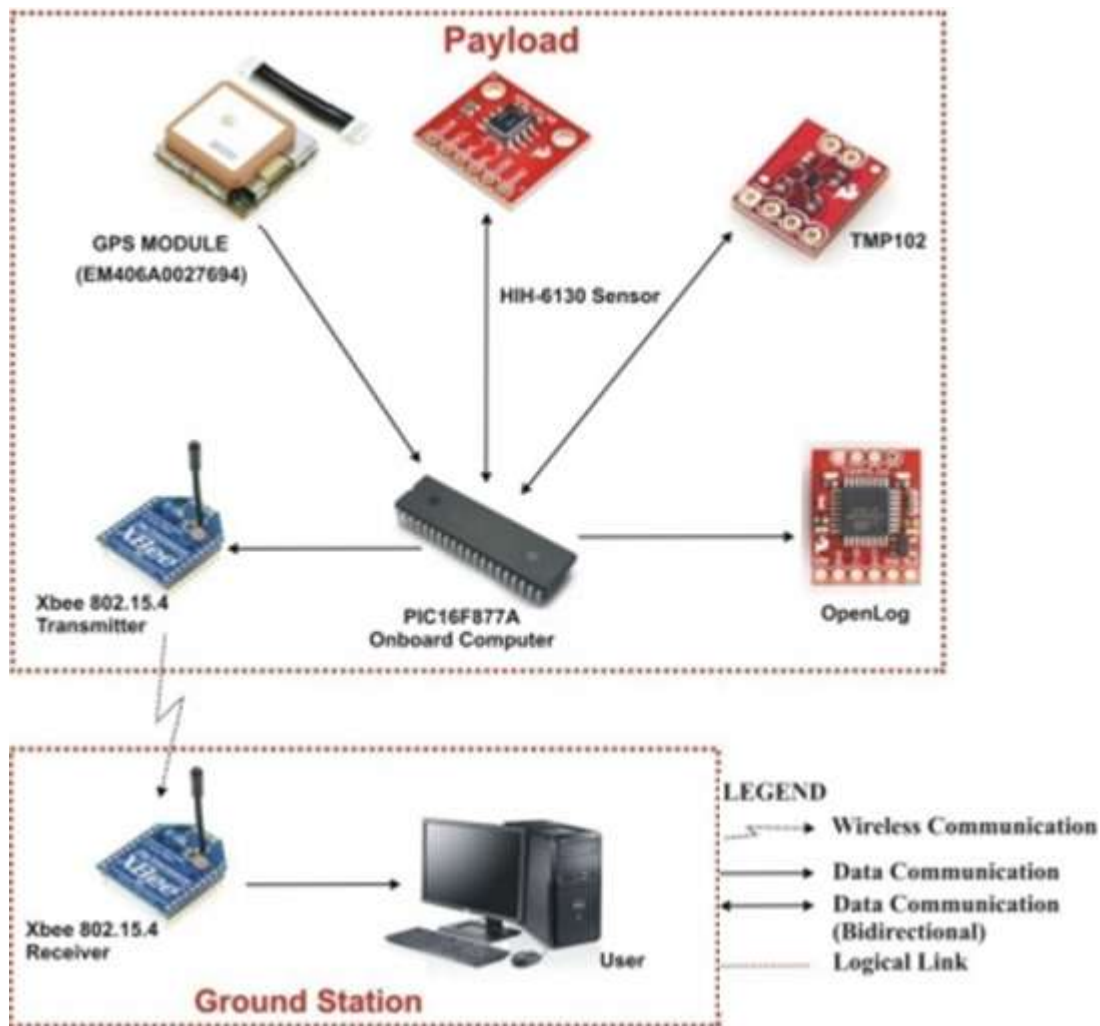


Figure 3.2.1: Schematic of the architecture of the pico-satellite system.

The RMWU receives data from the RWB every 7 seconds. The data set captured every 7 seconds includes the: Longitude, Latitude, altitude, the temperature in the atmosphere, the pressure in the atmosphere, and the atmospheric humidity. The data set are viewed in real-time

in a tabular format shown in table 3.1. At the same time, the data sets captured every 7 seconds are stored in the RWMU's database. Each data set is stored as one unique record.

Table 3.1: The tabular format for the real-time data set captured every 7 seconds from the RWB in Uyo Airport in Akwa Ibom State, Nigeria.

TOF (S)	UTC Time	Latitude (N)	Longitude (E)	WGS84	Altitude (M)	Pressure (KPa)	RH (%)	Int Temp (°C)	Ext Temp (°C)
7	173431	5.022929	7.586055	17.8	61.1	100.5931	77.18	28.62	28.79
14	173439	5.022917	7.586052	17.8	62	100.5824	77.18	28.62	28.79
21	173447	5.022915	7.586052	17.8	62	100.5824	77.18	28.62	28.79
28	173539.22	5.022948	7.586065	17.8	37	100.8813	75.92	28.75	28.97
35	173551	5.022913	7.586045	17.8	61	100.5944	75.92	28.75	28.97
42	173559	5.022912	7.586044	17.8	60.5	100.6003	75.92	28.75	28.97
49	173606	5.022909	7.586046	17.8	60.9	100.5955	75.92	28.81	28.97
56	173614	5.022904	7.586047	17.8	62.3	100.5788	75.92	28.81	28.97
63	173622	5.022896	7.586049	17.8	62.8	100.5728	75.92	28.81	28.97
70	173630	5.022888	7.586053	17.8	62.7	100.574	75.92	28.81	28.97
77	173637	5.022891	7.586056	17.8	64.7	100.5501	75.92	28.87	28.97
84	173645	5.022888	7.586057	17.8	68.9	100.5	75.92	28.87	28.97
91	173653	5.022865	7.586059	17.8	73.5	100.4451	75.92	28.87	28.97
98	173701	5.022846	7.586062	17.8	73.5	100.4451	75.92	28.87	28.97
105	173708	5.022812	7.586065	17.8	70.5	100.4809	75.92	28.87	28.97
112	173716	5.022792	7.586062	17.8	67.6	100.5155	75.92	28.87	28.97
119	173724	5.022845	7.586059	17.8	67.4	100.518	75.92	28.87	28.97
126	173731	5.022829	7.586062	17.8	67.3	100.5191	75.92	28.87	28.97
133	173739	5.022849	7.586065	17.8	70.5	100.4809	75.92	28.93	28.97

147	173755	5.022877	7.586059	17.8	70	100.4869	75.92	28.93	28.97
154	173810	5.022888	7.586065	17.8	71.6	100.4678	75.92	28.93	28.97
161	173818	5.022884	7.586065	17.8	70.6	100.4797	75.92	28.93	28.97
168	173826	5.022882	7.586062	17.8	69.8	100.4892	75.92	28.93	28.97
189	173853	5.022874	7.586064	17.8	67	100.5227	75.92	29.06	28.97
196	173900	5.022875	7.586062	17.8	68	100.5108	75.92	29.06	28.97
203	173908	5.022876	7.586062	17.8	69	100.4988	75.92	29.06	28.97
210	173916	5.022881	7.586061	17.8	69.9	100.488	75.92	29.06	28.97
217	174023.56	5.022903	7.58613	17.8	84.6	100.3128	75.92	30.56	28.97
224	174036	5.022907	7.586057	17.8	75.4	100.4225	74.79	29.93	29.08
231	174043	5.022907	7.586055	17.8	73.9	100.4404	74.79	29.81	29.08
238	174051	5.022912	7.586059	17.8	73.1	100.4499	74.79	29.75	29.08
245	174059	5.022913	7.586057	17.8	74.8	100.4296	74.79	29.68	29.08
252	174107	5.022904	7.586057	17.8	76	100.4153	74.79	29.62	29.08
266	174122	5.022906	7.586057	17.8	75.7	100.4189	74.79	29.56	29.08
273	174130	5.022898	7.586057	17.8	75.2	100.4249	74.79	29.5	29.08
280	174138	5.022892	7.586059	17.8	75.2	100.4249	74.79	29.62	29.08
287	175141.48	5.022865	7.586064	17.8	76.5	101.325	74.79	29.43	29.08
294	180240.22	5.022954	7.586097	17.8	87.9	100.2735	75.54	30.87	29.87
301	180252	5.022893	7.586069	17.8	77.2	100.401	81.02	30.56	29.24
308	180300	5.022894	7.586074	17.8	79.3	100.376	81.02	30.56	29.24
315	180315.58	5.022888	7.586006	17.8	65.8	100.537	81.02	30.5	29.24
322	180334.32	5.022844	7.586115	17.8	90.2	100.2461	75.89	30.5	29.02
329	180346	5.022899	7.586053	17.8	74	100.4392	75.91	30.5	28.86
336	180354	5.022903	7.586057	17.8	73.9	100.4404	75.91	30.5	28.86
343	180402	5.022903	7.586065	17.8	76.1	100.4141	75.91	30.5	28.86
350	180410	5.022940	7.586065	17.8	75.9	100.4165	75.91	30.5	28.86
357	180417	5.022898	7.586065	17.8	76.2	100.4129	75.91	30.5	28.86
364	180425	5.022897	7.586062	17.8	75.9	100.4165	75.91	30.5	28.86
371	180433	5.022895	7.586062	17.8	75.8	100.4177	75.91	30.5	28.86
378	180441	5.022892	7.586064	17.8	75.7	100.4189	75.91	30.5	28.86
385	180448	5.022889	7.586064	17.8	75.6	100.4201	75.91	30.5	28.86
392	180456	5.022881	7.586065	17.8	76.7	100.407	75.91	30.5	28.86

In order to realize compatibility and seamless interfacing of the pico-satellites spatial information system with different pico-satellites remote monitoring units, the data captured from the RWB pico-satellite are exported in Comma Separated Version (CSV) file format. Another file format used is the Extensible Markup Language (XML) file format. The XML file format is particularly useful for web-based applications.

3.3.2 Interfacing with the Radiosonde Weather Balloon (RWB) at the Calabar Airport

The atmospheric data captured by the Radiosonde Weather Balloon (RWB) at Calabar Airport is collected at the base

station in Calabar Airport. The RWMU receives data from the Radiosonde Weather Balloon (RWB) every 1 second. The data set captured every 1 second includes; Longitude, Latitude, altitude, atmospheric temperature, atmospheric pressure, and the humidity. The data set are viewed in real-time in a tabular format of Table 3.3. At the same time, the data set captured every 1 second are stored in the RWMU's database where each data set is stored as one unique record. Again, the data captured from the RWB p-sat are exported in Comma Separated Version (CSV) file format. To process the data contained in the spatial information system, another file format that is used is the Extensible Markup Language (XML) file format.

Table 3.2: The tabular format for the real-time data set captured every 1 second from the Radiosonde Weather Balloon (RWB) at Calabar Airport

TOF (S)	UTC Time	Latitude (N)	Longitude (E)	Elevation [m]	Wsp [kn]	Altitude (m)	Pressure (hPa)	RH (%)	Temp (°C)
0	114531	4.967115	8.347173	5	3	0	1006.8	80	28
1	114535	4.967121	8.347174	82	2.9	5.9	1006.1	89	28.18
2	114544	4.967128	8.347176	83	2.7	11.8	1005.5	97	28.36
3	114549	4.967134	8.347177	83	2.6	17.7	1004.8	100	28.54
4	114553	4.967141	8.347178	83	2.4	23.6	1004.2	99	28.72
5	114559	4.967147	8.347179	83	2.3	29.5	1003.5	99	28.9
6	114605	4.967154	8.34718	83	2.2	35.4	1002.8	98	29.08
7	114612	4.96716	8.347181	83	2	41.3	1002.2	98	29.25
8	114620	4.967167	8.347182	83	1.9	47.2	1001.5	97	29.29
9	114631	4.967173	8.347184	83	1.7	53.2	1000.9	97	29.2
10	114637	4.96718	8.347185	83	1.6	59.1	1000.2	96	29.1

11	114644	4.967186	8.347186	83	1.6	65	999.6	96	29.01
12	114646	4.967193	8.347187	83	1.7	70.9	998.9	95	28.92
13	114653	4.967199	8.347188	83	1.9	76.8	998.2	95	28.83
14	114701	4.967206	8.347189	83	2	82.7	997.6	94	28.73
15	114709	4.967212	8.347191	83	2.2	88.6	996.9	94	28.64
16	114715	4.967211	8.347205	83	2.3	94.5	996.3	93	28.55
17	114724	4.96721	8.347223	83	2.5	100.4	995.6	93	28.45
18	114732	4.967208	8.347241	83	2.7	106.3	995	92	28.36
19	114738	4.967206	8.347258	83	2.9	112.2	994.3	91	28.27
20	114753	4.967204	8.347276	83	3.1	118.1	993.6	91	28.17
21	114808	4.967202	8.347294	82	3.3	124	993	90	28.08
22	114817	4.9672	8.347311	82	3.5	129.9	992.3	90	27.99
23	114825	4.967198	8.347329	82	3.7	135.8	991.7	89	27.9
24	114843	4.967196	8.347347	81	3.9	141.7	991	89	27.83
25	114900	4.967194	8.347364	81	4.1	147.6	990.4	88	27.76
26	114909	4.967192	8.347382	81	4.3	153.5	989.7	88	27.69
27	114916	4.96719	8.347399	81	4.5	159.4	989.1	87	27.62
28	115020	4.967188	8.347417	80	4.8	165.3	988.4	87	27.55
29	115032	4.967186	8.347435	80	5	171.2	987.8	86	27.48
30	115043	4.967184	8.347452	80	5.2	177.1	987.1	86	27.41
31	115051	4.967182	8.34747	80	5.1	183	986.5	85	27.34
32	115059	4.96718	8.347488	79	5	188.9	985.8	85	27.27
33	115107	4.967178	8.347505	79	4.8	194.8	985.2	84	27.2
34	115121	4.967176	8.347523	79	4.7	200.7	984.5	84	27.13
35	115130	4.967175	8.34754	79	4.6	206.6	983.9	83	27.06
36	115139	4.967173	8.347558	79	4.5	212.5	983.2	83	26.99
37	115143	4.967171	8.347576	78	4.4	218.4	982.6	82	26.92
38	120230	4.967169	8.347593	78	4.3	224.3	981.9	82	26.85
39	120252	4.967167	8.347611	78	4.2	230.2	981.3	81	26.8
40	120300	4.967165	8.347629	78	4.2	236.1	980.6	81	26.74
41	120315	4.967163	8.347646	78	4.1	242	980	80	26.69
42	120332	4.967161	8.347664	78	4.1	247.8	979.3	80	26.63
43	120345	4.967159	8.347681	77	4	253.7	978.7	79	26.58
44	120354	4.967157	8.347699	77	4	259.6	978	79	26.53
45	120403	4.967151	8.347715	77	4	265.5	977.4	78	26.47
46	120411	4.967137	8.347729	77	4	271.4	976.7	78	26.42
47	120418	4.967123	8.347742	77	4	277.1	976.1	77	26.37

3.4 Geo-Fencing of Pico-Satellites Data

In some cases, it is expedient to extract data captured within a given geographic area. The geo-fencing techniques employ a feature in related software programs that uses the GPS or radio frequency identification (RFID) to define its

geographical confines otherwise known as boundaries. In this research, the GPS spatial data component of the p-sat data log are used to extract those data which the pico-satellites captured within a specific geographic area defined using geo-fencing technology. Fig 3.3 shows the process flowchart used in geo-fencing of the p-sat data.

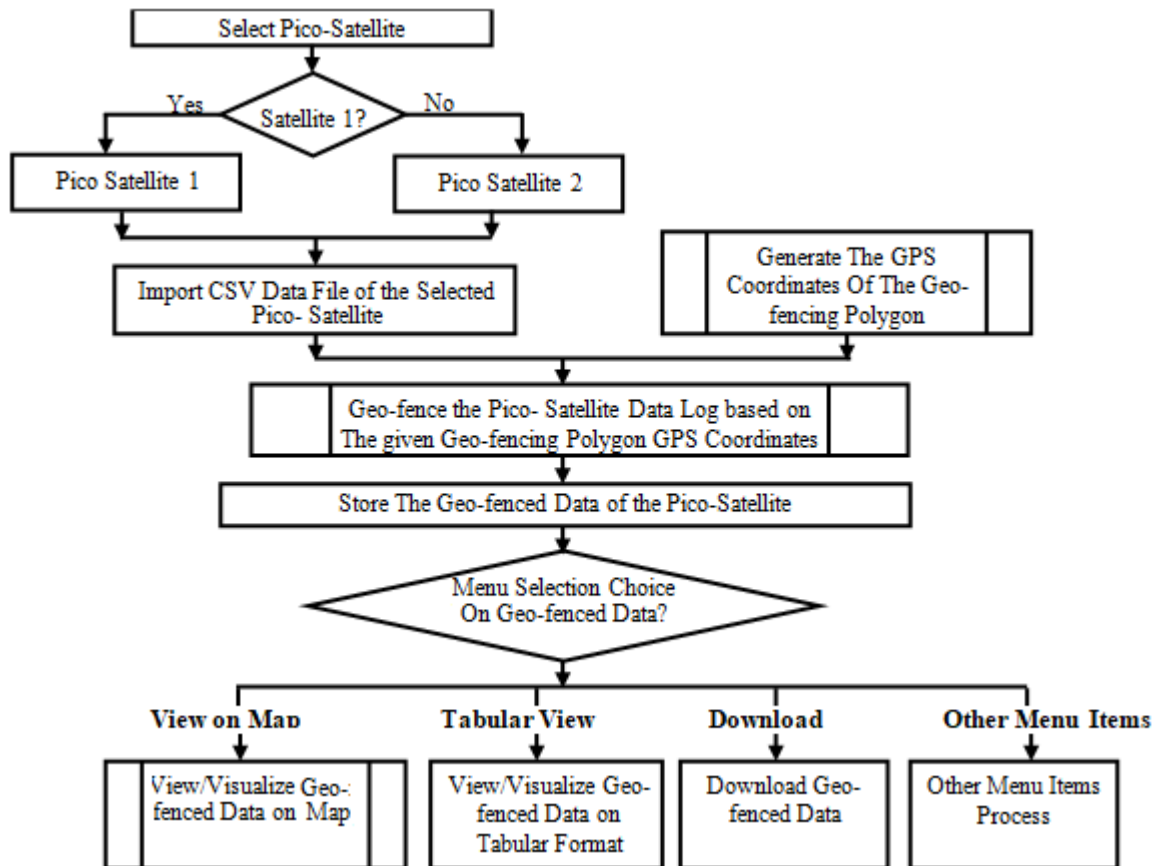


Figure 3.3: The Process Flowchart for Geo-Fencing The Pico-Satellites Data Log.

However, generating the Global Positioning System (GPS) coordinates relating to the geo-fencing polygon, it is required that, a third-party Google map application is developed. The geo-fencing polygon web-map application enables the user to:

- (i) View specific geographical area on Google map;
- (ii) Extract the boundary points of the GPS coordinates of specific geographical area as the user clicks on the boundary points of the geographical area on Google map;
- (iii) Eliminate the geo-fenced area boundaries of the required polygon by polyline;

- (iv) Generates the GPS coordinates of the vertices in the geo-fenced area (polygon).

Fig 3.4 is the practical diagram showing the various output in the geo-fencing polygon web-map application for a geo-fencing Polygon with 7 Vertices (that is, 7 GPS Coordinates). The geo-fencing longitude and latitude which is the polygon's coordinates of the Global Positioning System are then used to extract only those data records in the Pico-satellite's data log that their GPS coordinates fall within the geo-fencing polygon's GPS coordinates.

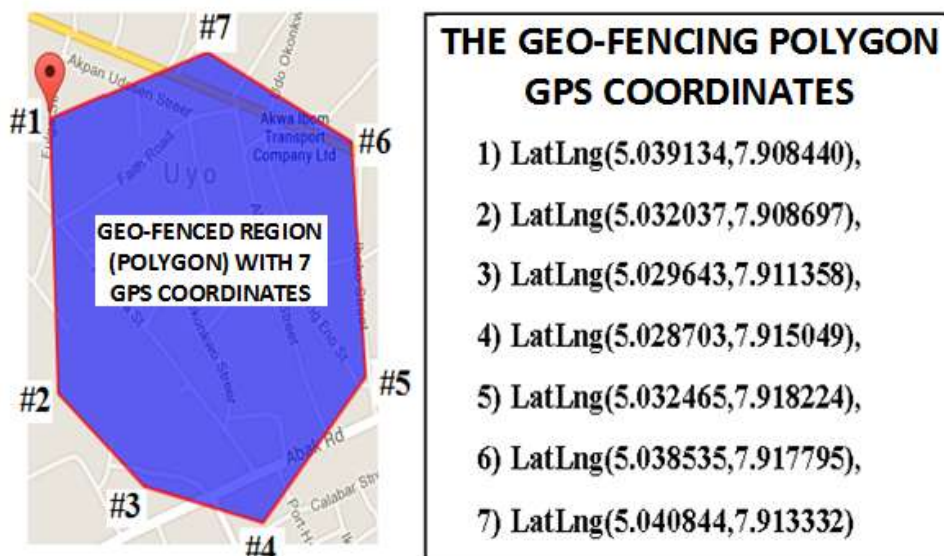


Figure 3.4: The Schematic Diagram of the Output of the Geo-Fencing Polygon Web-Map

Application for A Geo-Fencing Polygon with 7 Vertices (that is, 7 GPS Coordinates)

The geo-fenced data is available for download, for viewing online in tabular format and for viewing on a Google map using another third-party map mashup web-application developed as part of this research.

Fig 3.5 is the schematic diagram of the architecture for the map visualization of the pico-satellite data log. The map visualization tool is also used to picture the geo-fenced data output. The map visualization tool requires internal third-party Google map mashup application and internal third-party map DBMS as well as interfaced data file for interacting with the external Google Map Server via the Google map's Application Program Interface (API).

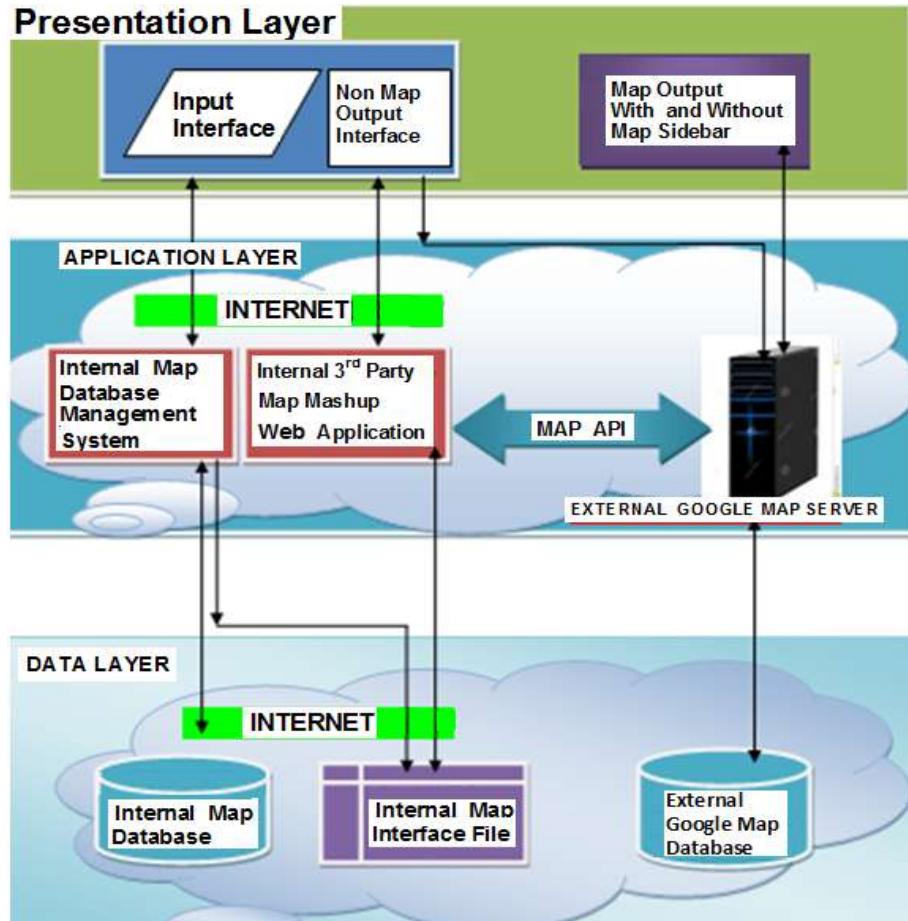


Figure 3.5: The Architecture of the Map Visualization of Pico-Satellite Data. <https://www.googlemapsapi.com> (Retrieved 12/06/2017).

Fig 3.5, shows how to render the map output on a Google base map, the Google Map Server extracts data from both the external Google Map Database and also from the internally generated map interfacing data file provided in this research.

3.5 Path Profiling of Pico-Satellites Data

Path profile is defined as a graphical of representing physical features of a (geographic) path in the vertical plane containing both endpoints of the path, showing the Earth surface as well as trees, buildings, and other features that

may cause obstruction in the path. Path profile is very essential when the pico-satellite launching commences with remotely controlled unmanned aerial vehicles (UAV) otherwise called drone. Fig 3.6 shows the schematic diagram with respect to path profile output. The path profiling application is a third-party Google map web application that generates the elevation along the geographic path defined by a sequence of GPS coordinates. The third-party Google map path profiling web application is also developed as path of this research. It uses similar three tier architecture as shown in Fig 3.5.

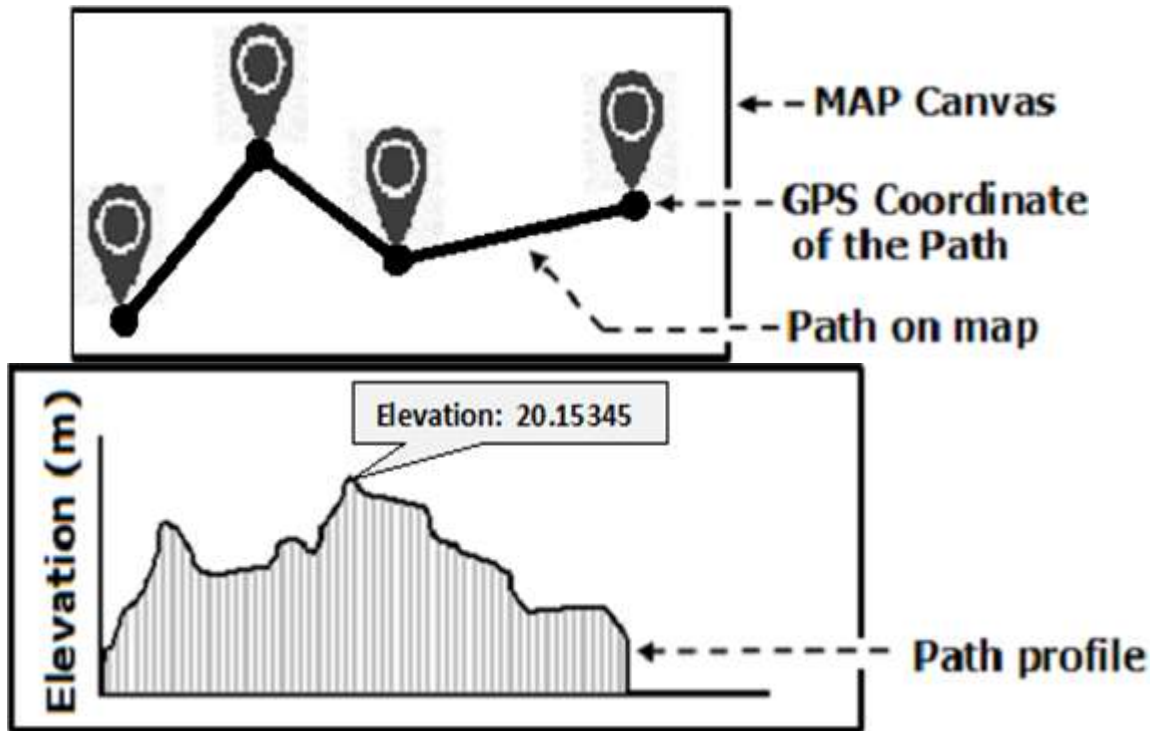


Figure 3.6: The Schematic Diagram of the Path Profile Output

3.6 Map Visualization of the Pico-Satellites Trajectory

This functionality uses the pico-satellite's GPS coordinates to trace the trajectory of the pico-satellite. It is implemented using a third-party Google map, mashup application that draws polyline on a Google map based on the values of GPS coordinates stored in an XML file format. It uses similar three tier architecture as shown in Fig 3.5.

3.7 Direction Search on the Pico-Satellites Trajectory

This functionality requires two GPS coordinates as input and then it provides walking or driving direction between those two points. It is implemented using a third-party Google map, mashup application that draws polyline on a Google map based a set of GPS coordinates stored in an XML file format. It uses similar three tier architecture as shown in Fig 3.5.

3.8 Capturing and Conversion of GPS Data Formulas

The Global positioning system (GPS) raw data captured by the pico-satellite from the atmosphere is been converted to various forms using the following formulas:

(i) To convert from degrees minutes seconds (D° M' S'') to Decimal Degree (D° D°)

The following formula is used:

$$D + (M/60) + (S/3600) = D.D^\circ \quad (3.1)$$

Where D is representing decimal, M/60 is representing minute per minute, and S/3600 represent seconds per minute.

From table 3.2, giving a latitude 4.967115 captured as a raw data from the radiosonde weather balloon would be translated to 49° 67' 115" and converted with the following formula as;

$$49 + (49/60) + (115/3600) = 49.84861111^\circ$$

(ii) To convert from degrees minutes seconds (D° M' S'') to decimal minutes (D° M. M'')

The following formula was used;

$$D \text{ and } M + (S/60) = D.M'' \quad (3.2)$$

Where D represent degree format, S/60 represent seconds per minute, and M'' represent decimal minute. Also from table 3.2, giving a latitude of 49° 67' 115" would translate to; 49 and 67 + (115/60) = 49° 68.9166667'

(iii) To convert from decimal degrees (D.D°) to decimal minutes (D M.M')

The following formula was used;

$$\text{Int}(D) = D^\circ$$

$$(D - \text{Int}(d)) * 60 = M.M \quad (3.3)$$

Where Int (D) represent integer degree, M.M represent minute multiply by minute

From the result in equation 3.1 49.84861111 it would translate to; Int (49.8436111) and (49.8486111 – int (49.8486111)) * 60 = 49° 68.9166667'

(iv) To convert from decimal degrees (D.D°) to decimal degrees (D.D°)

The Mathematical models used for the implementation is;

$$\text{Int}(D) = D^\circ$$

$$\text{Int}((D - \text{Int})) * 60 = M'$$

$$(((D - \text{Int})) * 60) - \text{Int}(((D - \text{Int}(D)))) * 60 \quad (3.4)$$

The value in equ. 3.1, 49.84861111 degrees would translate to;

$$\text{Int}(49.84861111) \text{ and } \text{int}(49.848661111 - \text{int}(49.84861111)) * 60 \text{ and } (((49.8486111 - \text{int}(49.8486111)) * 60) - \text{int}(((49.8486111 - \text{int}(45.781111)) * 60))) * 60 = 49^\circ 67.115''$$

3.8.1 Mathematical Analysis for Distance and Bearing Between the Two Points Based on GPS Data.

The distance between two points when the coordinates (longitude & latitude) are giving, will mathematically be expressed according the following phases / stages;

Stage 1: computation of straight-line Euclidean distances of two points that is obtained by boring through Earth; and

Stage 2: conversion of the already computed distance to one that measures along earth surface.

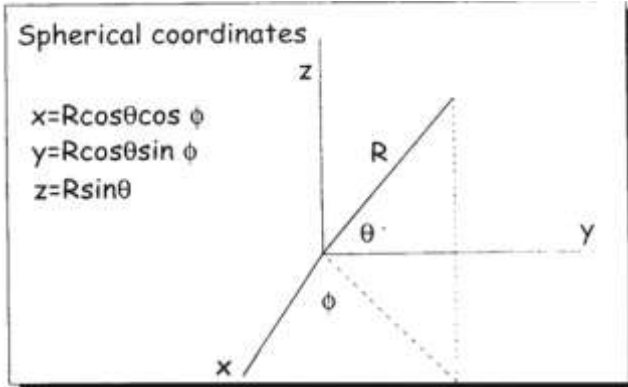


Figure 3.7: Orbicular Coordinates

- (i) The central point is located center of the Earth;
- (ii) The *x*-axis passing through Prime Meridian at 0° longitude;
- (iii) The *xy*-plane consisting of equator of earth, so that positive *z*-axis passes through North Pole.

Where θ = the angle measured in latitude, while angle ϕ is the measure of the longitude, where $0 \leq \phi < 360^\circ$, and $-90^\circ \leq \theta \leq 90^\circ$. The Negative value of θ as shown corresponds to those points of the Hemisphere at the south end while the positive values of θ corresponds to those points of the Hemisphere at the north end accordingly.

The radial distance denoted by the letter R is made to vary as a result of the application of the spherical coordinates; though, in this thesis it is fixed as the average radius of Earth which is approximately equal to 6,378 km. i.e. $R \approx 6,378\text{km}$.

Given that the two points P_a and P_b depends on the latitude-longitude pairs, $P_a(\theta_a, \phi_a)$. In the Cartesian coordinates:

let $P_a = P_a(x_a, y_a, z_a)$

$P_b = P_b(x_b, y_b, z_b)$,

And the variables *x, y, and z* can be computed using the equations given bellow:

$x = R(\cos\theta \cos\phi)$ (3.5)

$y = R(\sin\phi \cos\theta)$ (3.6)

$z = R \sin\theta$ (3.7)

The Euclidean distance *d* between P_a and P_b is given by three-dimensional Pythagoras Theorem:

$d^2 = (x_a - x_b)^2 + (y_a - y_b)^2 + (z_a - z_b)^2$ (3.8)

The entire work will be by evaluating the distance R with regards to the spherical coordinates. Hence by converting

the Cartesian coordinates to its corresponding spherical coordinates, it means;

$$\begin{aligned} d^2/R^2 &= (\cos\theta_a \cos\phi_a - \cos\theta_b \cos\phi_b)^2 \\ &+ (\cos\theta_a \sin\phi_a - \cos\theta_b \sin\phi_b)^2 \\ &+ (\sin\theta_a - \sin\theta_b)^2 \\ &= \cos^2\theta_a \cos^2\phi_a - 2\cos\theta_a \cos\phi_a \cos\theta_b \cos\phi_b \\ &+ \cos^2\theta_b \cos^2\phi_b \\ &+ \cos^2\theta_a \sin^2\phi_a - 2\cos\theta_a \sin\phi_a \cos\theta_b \sin\phi_b + \cos^2\theta_b \sin^2\phi_b \\ &+ \sin^2\theta_a - 2\sin\theta_a \sin\theta_b + \sin^2\theta_b \\ &= 2 - 2\cos\theta_a \cos\theta_b \cos(\phi_a - \phi_b) - 2\sin\theta_a \sin\theta_b \end{aligned}$$

Accordingly, to determine distance *D* along earth surface, Fig. 2 has to be analyzed in thoroughly. From Fig 2, *D* is the length of the arc along the sector.

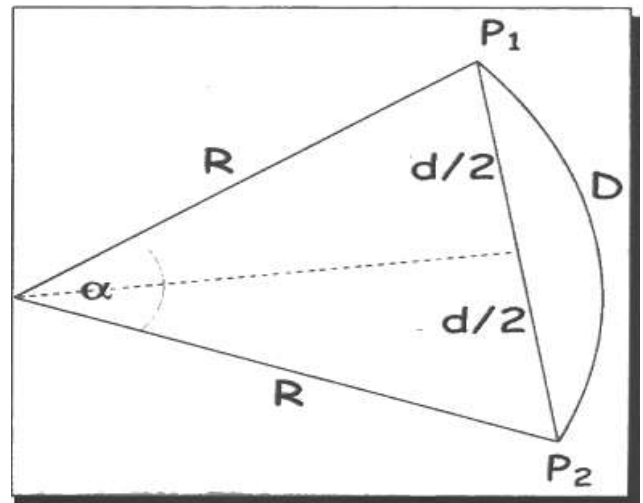


Figure 3.8: Arc Length

From 3.8 above,

Let $\text{Sin}(\alpha/2) = \frac{d}{R}$

We get

$\text{Sin} \alpha = 2 \sin(\alpha/2) \cos(\alpha/2)$

$= \frac{d}{R} \times \sqrt{1 - \left(\frac{d}{2R}\right)^2}$

$= \frac{d}{2R^2} \sqrt{4R^2 - d^2}$

As a result, distance *D* is computed using the equation;

$D = R_\alpha = R \sin^{-1} \left(\frac{d}{2R^2} \sqrt{4R^2 - d^2} \right)$ in terms of *d* and R (3.9)

The Equation 3.9 depicts the haversin equation, which is given as;

$\text{Haversin } B = \sin^2 \left(\frac{B}{2} \right) = \frac{1 - \cos B}{2}$

i.e. $\cos B = 1 - 2 \text{ haversin } B$.

Returning to the formula for *d* above, we continue, feeding in the new notation and represent haversin with letter A:

$$\begin{aligned} d^2/dR^2 &= 2 - 2\cos\theta_a \cos\theta_b \cos(\phi_a - \phi_b) - 2\sin\theta_a \sin\theta_b \\ &= 2 - 2\cos\theta_a \cos\theta_b [1 - 2A(\phi_a - \phi_b)] - \\ &2\sin\theta_a \sin\theta_b \\ &= 2 - 2\cos(\theta_a - \theta_b) + 4\cos\theta_a \cos\theta_b A(\phi_a - \phi_b) \\ &= 4A(\phi_a - \phi_b) + \cos\theta_a \cos\theta_b (\phi_a - \phi_b) \end{aligned}$$

Which says that

$$\left(\frac{d}{2R}\right)^2 = A(\theta_a - \theta_b) + \cos\theta_a \cos\theta_b A(\phi_a - \phi_b)$$

i.e.

$$A\alpha = A(\theta_a - \theta_b) + \cos\theta_a \cos\theta_b A(\phi_a - \phi_b)$$

With reference to Fig 2 above, a more redefined formulae is derived and applied in this work. i.e.

$$\left(\frac{d}{2R}\right)^2 = A(\theta_a - \theta_b) + \cos\theta_a \cos\theta_b A(\phi_a - \phi_b) \cdot \sin^2(\alpha/2)$$

=Aα, meaning that

$$D = R_\alpha = 2R \sin^{-1}(\sqrt{A\alpha}) \quad (3.10)$$

3.8.2 Mathematical Analysis for the Winding Number Algorithm for Point in the Polygon

The winding number mathematically measures the number of times a polygon enclosed a point. The winding number immediately determines whether or not a point lies within the polygon and also determines the directional area of the polygon i.e. in a clockwise or counter clockwise aspect for appropriate analysis.

By a temporal analysis, the winding number associated to polygons, that is called the contour C, about a point x, w, can measure whether C encloses x, and the number times and at what orientation the contour C “winds around” x. In particular,

$$W = \begin{cases} 0, & \text{if } x \text{ is not } 0 \\ n > 0 & \text{if } C \text{ winds around } x \text{ } n \text{ times counterclockwise} \\ n < 0 & \text{if } C \text{ winds around } x \text{ } (-n) \text{ times clockwise} \end{cases}$$

Winding number, W is computed as follows:

$$W = \frac{1}{2\pi i} \int_C \frac{1}{z} dz$$

Where $z = x + iy$

Where W can also be defined as contour integral in the complex plane

Therefore W (winding number) algorithm for point within a polygon is given by:

Input: vertices

v_i where i is any number from 1 to n representing polygon C.

Input: winding number w of polygon C about point x.

0.) Replace each v_i by $(v_i - x)$.

1.) Initialize $w = 0$.

2.) For each vertex v_i (i = 1 to n) in the polygon C:

If $(y_i y_{i+1} < 0)$ then $[\overline{v_i v_{i+1}}$ crosses the x-axis]

$$\text{Sex } r = x_i + \frac{y_i(x_{i+1} - x_i)}{(y_i - y_{i+1})}$$

r is the x-coordinate intersecting between $[\overline{v_i v_{i+1}}$ and x-axis]

If $(r > 0)$ then $[\overline{v_i v_{i+1}}$ crosses positive x-axis]

If $(y_i < 0)$ then $w = w + 1$ else $w = w - 1$

Else if $(y_i = 0)$ and $(x_i > 0)$ then $[v_i$ is on the positive side of/on the x-axis]

If $(y_{i+1} > 0)$ at that point $w = w + 0.5$

else $w = w - 0.5$

Else if $((y_{i+1} = 0)$ and $((x_{i+1} > 0)$ then $[v_{i+1}$ is on the positive x-axis]

If $(y_i < 0)$ then $w = w + 1/2$ else $w = w - 1/2$

3.) Return $w = w$ of C about x

3.8.3 Mathematical Expression for Area of Polygon Based on GPS Data

Applying the surveyor’s formula, the mathematical expression for area of polygon base on its GPS data is given by the equation:

$$A_n = \frac{1}{2} \left\{ r \left| \begin{matrix} \cos\theta & r \cos \frac{2\pi}{n} \\ r \sin\theta & r \sin \frac{2\pi}{n} \end{matrix} \right. + r \left| \begin{matrix} \cos \frac{2\pi}{n} & r \cos \frac{4\pi}{n} \\ \sin \frac{2\pi}{n} & r \sin \frac{4\pi}{n} \end{matrix} \right. + \dots \right. \\ \left. + \dots \left| \begin{matrix} r \cos \frac{(n-1)\pi}{n} & r \cos 2\pi \\ r \sin \frac{2(n-1)\pi}{n} & r \sin 2\pi \end{matrix} \right. \right\} \quad (3.11)$$

$$= \frac{1}{2} r^2 \left\{ \sin \frac{2\pi}{n} + \sin \frac{2\pi}{n} + \dots + \sin \frac{2\pi}{n} \right\}$$

$$= \frac{r^2}{2} \cdot n \sin \frac{2\pi}{n} = \pi r^2 \sin \left(\frac{2\pi}{n} \right)$$

4. Result and Discussion

4.1 The Results

After coding and testing, the web-based spatial software developed for remote monitoring of the Pico satellite at the two locations was hosted locally on a laptop for offline demonstration. In this chapter, some sample screenshots are shown as the result of the work. The screenshots capture various features of system with the data acquired via Pico satellites.

4.2 The System Modules and Their Screenshots user’s page

n for Pico Satellites

Trajectory	Distance Btw Points	Geofence	Search	Geocode	Graph
Latitude	Longitude	Altitude	Pressure	Humidity	Temperature
5.022929	7.586055	61.099998	100.593102	77.180000	28.620001
5.022917	7.586052	62.000000	100.582397	77.180000	28.620001
5.022915	7.586052	62.000000	100.582397	77.180000	28.620001
5.022948	7.586065	37.000000	100.881302	75.919998	28.750000
5.022913	7.586045	61.000000	100.594398	75.919998	28.750000
5.022913	7.586044	60.500000	100.600304	75.919998	28.750000
5.022909	7.586046	60.900002	100.595497	75.919998	28.809999
5.022904	7.586047	62.299999	100.578796	75.919998	28.809999
5.022896	7.586049	62.799999	100.572800	75.919998	28.809999
5.022888	7.586053	62.700001	100.573997	75.919998	28.809999
5.022891	7.586056	64.699997	100.550102	75.919998	28.870001
5.022880	7.586057	68.900002	100.500000	75.919998	28.870001
5.022865	7.586059	73.500000	100.445099	75.919998	28.870001
5.022846	7.586062	73.500000	100.445099	75.919998	28.870001
5.022813	7.586065	76.500000	100.480904	75.919998	28.870001
5.022792	7.586062	67.599998	100.515503	75.919998	28.870001
5.022800	7.586059	67.400002	100.517998	75.919998	28.870001
5.022829	7.586062	67.300003	100.519096	75.919998	28.870001
5.022849	7.586065	70.500000	100.480904	75.919998	28.930000
5.022870	7.586059	70.000000	100.486900	75.919998	28.930000

Figure 4.1: Screenshot of the home page showing the data log

The screenshot above shows the data acquired via Pico satellites when launched into space. The data contains the raw information of longitude and that of the latitude of the

pico-sat, altitude, the atmospheric humidity, temperature and pressure.

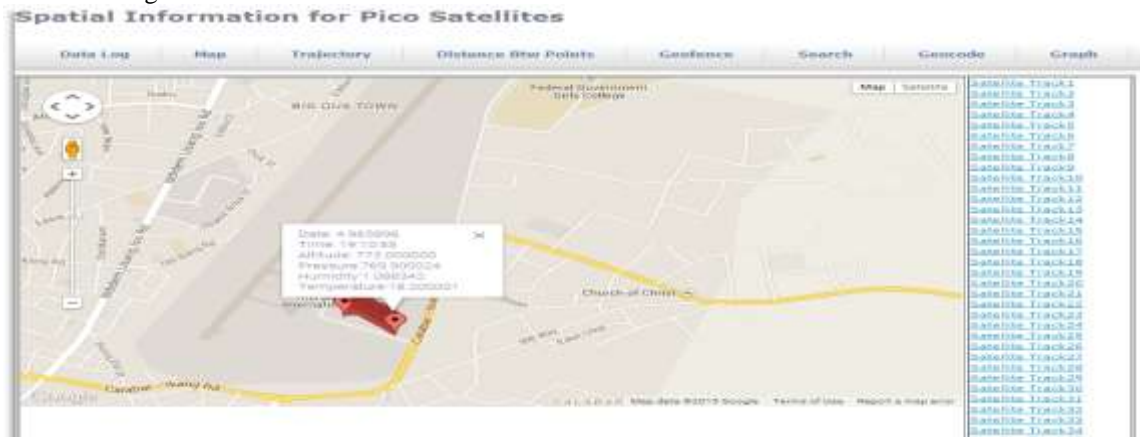


Figure 4.2: Is the screenshot showing location of pico-satellite on Google map

This page show the location of the satellite on the Google map, the info window shows the date and time the data was

obtained with the altitude, pressure, humidity and temperature.

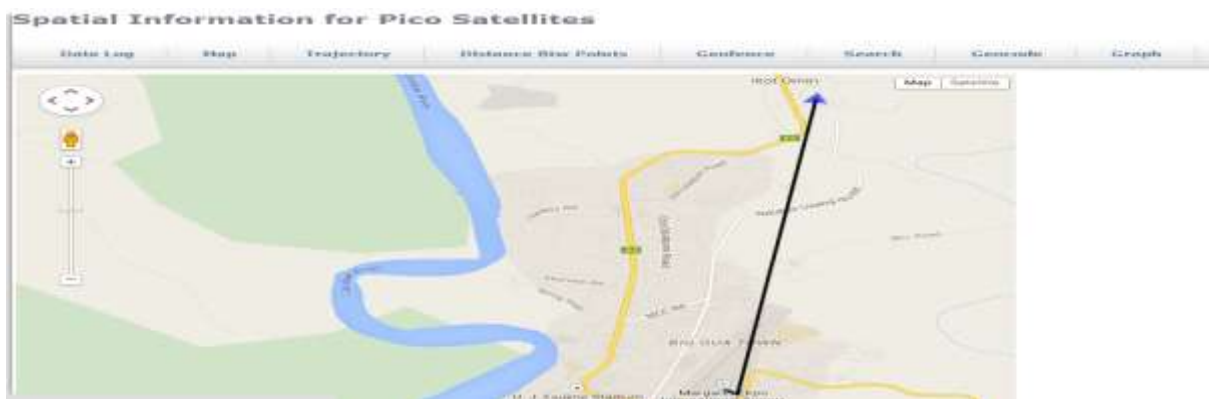


Figure 4.3: Screenshot showing the path (trajectory) of the satellite on the map.

The screenshot show above shows the space path travelled by the satellite. From the screenshot it is observed that, the satellite path began from the airport.



Figure 4.4: The geo-fence region in Calabar

The screen shot above shows the geo-fenced region in Calabar, the satellite is not supposed to travel pass the boundaries of the polygon.



Figure 4.5: The screenshot showing the exact point where the satellite is positioned in the geo-fenced region

From figure 4.5, the satellite position is represented by markers, it is seen that as at 12minutes 43 seconds, the satellite has gone off the geo-fenced region.



Figure 4.6: Geo-fencing screenshot

Figure 4.6 shows a tool used to get the expected coordinates that is used for geo-fencing a region on the map.



Figure 4.7: Screenshot showing the result of calculation of distance that spans amid two points

Figure 4.7 shows how to calculate the distance that spans two points using the coordinates (the latitudes and longitudes). The haversine formula was used to implement this functionality and the distance was given in meters and miles.



Figure 4.8: Screenshot showing how to ascertain the point that exists in the geo-fenced region

The system provides a feasible function to ascertain if a coordinate is inside or outside the geo-fenced region. The Fig 4.8, is the screenshot that shows whether the points is located outside the geo-fenced region while the screenshot in Fig 4.9 shows whether the points is located inside the geo-fenced region.



Figure 4.9: Screenshot showing that a point exists inside the geo-fenced region



Figure 4.10: Screenshot for geo-coding.

In figures 4.10 the screenshots for geo-coding and reverse geo-coding are presented.

4.3 The Graphs

In this section the screenshots for the graphical results from the data obtained from the Pico satellites are shown.



Figure 4.11: Screenshot of a graph showing Pressure, humidity and temperature versus time

The screenshot in figure 4.11 shows the graph of the pressure and humidity against time (seconds). From the graph, it is observed that,

pressure increases as time increases while the humidity and temperature reduces as time progresses.



Figure 4.12: Graph of humidity versus time

In the form of screenshot, Fig 4.12 shows the graph of humidity versus time. From the graph, it is observed that humidity varies with time. I.e. it decreases as the time increases.



Figure 4.13: Graph of pressure versus real time in seconds

The screenshot in figure 4.13 is the graph of pressure versus real time. From the graph, it is observed that pressure increases with real-time, i.e. it increases as the time increases.

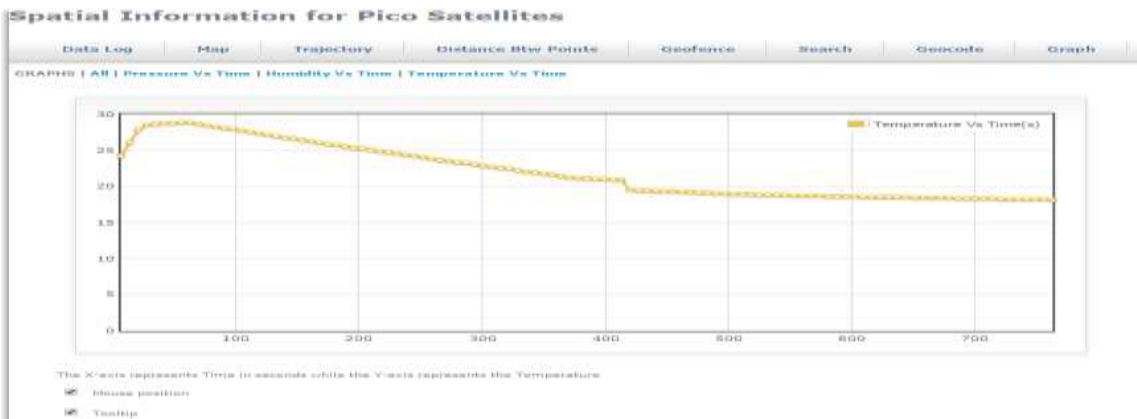


Figure 4.14: Graph of temperature against real time

The screenshot in figure 4.14 shows is the graph of temperature versus real time. From the graph, it observed that temperature decreases with real time. The implication is, the higher you go the cooler it becomes.



Fig 4.15: Screenshot of the graph showing pressure, humidity, temperature against altitude

The screenshot shown in figure 4.15 is the graph of temperature of the atmosphere, the pressure as well as humidity versus altitude (meter). From the graph, it is observed that, pressure is increased with respect to height, while the humidity and temperature reduces as altitude progresses.



Figure 4.16: Screenshot of the graph showing humidity against altitude in meters

The screenshot in Fig 4.16 represents the graph of the humidity versus altitude (meter). From the graph, it observed that humidity decreases as height increases.



Figure 4.17: Screenshot of the graph showing temperature against altitude

The screenshot in Figure 4.17 is the graph of temperature versus altitude (meter). From the graph, it is observed that temperature is made to increase at the start of sensing and

then later it decreases as the height assumes an increase mode.



Figure 4.18: The graph of pressure versus altitude

The screenshot of figure 4.18 shows a linear graph of pressure versus altitude (meter). From the graph, it is observed that it is a linear graph, it implies that pressure increases linearly as the altitude also increases from figure 4.5 the red track line indicates the direction at which the pico satellite moves as it lunches into the various regions of the atmosphere.

4.4 Research Findings

- 1) From the Figures Geo fencing techniques is used at the Calabar Airport. With the P-sate in position, Spatial Information is produced after been captured by the Temperature and Relative Humidity sensors in the payload of the P-sate and sent to the data log through the onboard computer. The compatibility of the spatial information with the p-sate remote monitoring software is achieved.
- 2) The Geo fenced area, in this case is the Calabar airport is developed using the Geo fencing mechanism as shown in Figures 4.7, 4.9, 4.10 which shows the result of calculation of distance that spans between two points, that geo-fenced area exist and geo-coding etc.
- 3) A web based visualization is produced using the Google map technology and the spatial information for pico satellite software editing tools as shown in Fig. 4.2 to 4.10.
- 4) The Relative Humidity (RH) which is the ratio of the amount of water vapour that is present in the air to the saturation point at the same temperature of the geo fenced area is deduced with respect to the coordinated universal time (UTC). The UTC is known as the international standard for civil time and the International. The data is shown in Table 3.2. It varies with the Time after every 1 seconds
- 5) The atmospheric pressure which is the force that is applied over a geographical area divided by the size of the area is shown in Table 3.2. It shows a relative increase as the altitude at different time. The altitude is in other words a hazy air and or the highest degree or point above sea level.

4.5 Contribution to knowledge.

The major contribution to knowledge is the development of spatial information system for pico-satellite communication with remote monitoring sensors.

By knowing the various atmospheric parameters, one can be able to predict the possible outcome of the weather and also forecast the weather. It will go a long way to avert damages to both the persons and properties. For instance, high wind and storm is as a result of high atmospheric pressure, cloudy and gaseous weather could also affect transmitted signal. And so proper prediction and forecasting can lead to a pro-active action and attitude.

Summary, Conclusion and Recommendations

5.1 Summary

In this research empirical and analytical approach is used. The empirical research contains the development of a

common interface for the remote monitoring of two different locations using a pico-satellite called the Radiosonde Weather Balloon (RWB). The Radiosonde Weather Balloon is a commercial off the shelf pico-satellite used at the Calabar Airport and the Uyo Airport to capture the environmental parameters around and above the airports regions. Several graphs and screenshots are generated to show the variations of the atmospheric data captured by the pico-satellite and the geo-fencing region of the GPS coordinates with respect to real time. Modified Waterfall Software Development (MWSD) tool was developed to perform the extraction of the pico-satellite data log and plotting of graphs for the various data captured in the atmosphere by the p-sat was shown with respect to real time.

As such the analysis and software presented in the research are very useful in making it easier for data to be captured in a given region by the use of a geo-fencing technique.

5.2 Conclusion

In this research a web based spatial information system was developed for spatial analysis of the data log of Uyo and Calabar Airports obtained from a Radiosonde Weather Balloon (RWB). The web based spatial information system was developed to be compatible with the data log of the remote monitoring unit of the Pico satellite from two locations. Specifically a Comma Separated Values (CSV) file format was used for interfacing the web based spatial information system (WBSIS) and the Pico satellite remote monitoring unit software.

Furthermore Geofencing technique was used for geofencing the data log of the Pico satellite thereby extracting data captured within any desired geographically area. A third party Google Maps Mashup application was equally used for map based visualisation of the Pico satellites data content. The third party mashup application also includes geocoding and reverse geocoding tools as well as polyline tool for plotting the trajectory of the Pico satellite based on its data log. The application were developed using JAVA Script and PHP scripting languages, MySQL database management system and then hosted locally using Apache web server.

5.3 Recommendations for future studies

The spatial analysis was based on 2D map platform in this case 2D Google map system. As such only the longitude and latitude were considered in the mapping operation. Further work studies are required to provide 3D mapping operation in Google Earth. Such 3D will capture the longitude, latitude, as well as the altitude of the Pico satellite. In addition only Google based map is considered in the present work. Further work is equally required to visualise the data on other online base map service provider

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