LOWER ATMOSPHERIC SATELLITE FOR ENVIRONMENTAL PARAMETERS MEASUREMENT

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Abstract : In the past couple of decades, there is rapid growth in the field of satellite technology. In order to get familiar with the space technology, a model, small and light weight satellite having power system, sensing elements and telecommunication system into its minimal volume that can perform some of the basic tasks that artificial satellites can do, is being developed. This paper presents design and development of an advanced level mini-satellite which will going to be launched to an altitude of about 100 to 1000 m using a balloon mechanism from ground level. Such mini-satellite systems proposes an automatic environmental parameters measuring system by a model satellite using Arduino board, which may help to measure atmospheric parameters like temperature, humidity, pressure, acceleration and Wi-Fi communication module to communicate with the ground station PC as its primary operation and secondary operation is the altitude calculations based on pressure data were especially interesting. Hence, with the use of this system, it is possible to implement a low cost technique to measure environmental parameters.

IndexTerms - Arduino board, Atmospheric parameters, IoT, Satellite system, artificial rain.

I. INTRODUCTION

Aerospace is the place where this specific combination of science and engineering emerges. It is not only interesting for scientists and for engineering students too. Hence the Lower Atmospheric Satellite for Environmental Parameters Measurement (LASEP) is a type mini model satellite payload used to provide knowledge about space technology. It is similar to the technology used in miniaturized satellites. Neither such mini-satellite has ever left the atmosphere, nor orbited the Earth. A LASEP is a simulation of a real satellite, integrated within the small square box which is made of aluminium metal and it contains major subsystems found in a satellite, such as power, sensing elements and a telecommunication system, in this minimal volume.

It is the needed to develop a mini model satellite having the data acquisition system which consists of temperature, humidity, pressure and accelerometer sensors which are used as to measure parameters of the atmosphere like temperature, humidity, pressure and acceleration respectively and send it to the ground station as its primary operation. Secondary operation for the system is the altitude calculations based on pressure data which is especially interesting. Since it was found that, a reduction in descent speed, which was caused by the increase in air density on descent. Hence this mini-satellite will be sent in sky at height in range of 100m to 1000m by using various launching methods. All this measured data is compared with ideal parameters which are already stored at ground station. One of the most important aspect of the LASEP is, this system totally based on the internet of things (IoT) by using Wi-Fi module. Information about atmosphere like temperature, humidity, pressure graphs are plotted on IoT. The LASEP is a combination of hardware and software. Hardware part consists of Arduino processor, temperature, pressure, humidity and accelerometer sensors, stepper motor, solar panels for power system. Where software part consist of Arduino Integrated Development Environment (IDE).

This paper has an introduction in first section is followed by the related work of the topic. Third section describes the implementations completed in same area. Fourth section provides information about results obtained from the developed system where fifth part briefly concludes the work.

II. RELATED WORK

Cihan, *et al.*[1] developed a mini model satellite that measures pressure, the temperature and its location. It was the first step to study and reach the space and its technology. This micro-satellite had various capabilities after adding electronic equipments, sensors and GPS. This micro-satellite measures temperature, pressure and location data and sent it to the central database. These capabilities provided with the sensors and GPS which were ready made. The sensed data was tracked by GPS, which exact location of the satellite in the space. The data collected by satellite was sent to the central database with the help of radio receiver which was installed to RF module to have a connection with the micro-satellite. The system was built up with the configuration as cylindrical body and tri-pod landing system with 200 mm in height, 81 mm in diameter and in weight. This project included electronic equipment, sensors, ground station, batteries for energy needs, camera and microcontroller for mobility and memory for data storage units. So, it indicates inexpensive equipment to model a satellite and gain experience. Normally the general satellite launched by a rocket, but in this project a mini-satellite was thrown from the top of a building. It landed with a help of a parachute which was also designed for this mission. While free-falling it records data to its memory. The drawback of this designed system was, it depends heavily on the software. Software control processor, sensor and receiver-transmitter for communication were developed in C language. As a micro-controller had small size of memory (about 64 KB), it needs an external memory device to store the software program and measured data, it was resulting in bulky and heavy system. Authors had mentioned theoretical aspects of the system without implementation.

Efrén *et al.*[2] developed the first step for developing a nanosatellite, the fundamental mission of the system was the collection of telemetry data in the Veracruz-Boca del Rio (a satellite development organisation in South Africa), with special emphasis on measuring air pollutants, the typical measured variables are temperature, relative air pressure, relative humidity, the development of the system architecture consists of a flight segment and ground station, which shows data through a desktop interface variables measured in real time and stored for later analysis. Authors tried to simulate the real satellite in the space, which took the volume of a soda tin of 355ml. As a result, the challenge of introducing all the systems that takes part in a satellite, such as the power subsystems, communication and sensors, linked to the correct working of the system. Its deployment in the air by a rocket of short distance, a balloon, an airplane with a radio control or from a high building, and its recovery after the launch, was the result of entire designed system. This process or experiment had high impact on the building of the significant knowledge, so this experiment allows researcher the testing of theory by direct implementation. But the developer used the RF transmitter and RF receiver for data exchange purpose. This traditional method of data exchange requires antenna system which needs a heavy programming for efficient transmission and reception of data and a large size metallic antenna too which directly increases the weight of system.

Mustafa *et al.*[3] presented, designed and implemented a PC based ground station for a nanosatellite. The ground station was developed from scratch by a programming language C#. And it was platform-free therefore it may operate with any mini-model satellite having different brand microcontrollers. The users may track several parameters and sent control commands simultaneously. For designing ground station, author used microcontroller, GPS sensor, XBEE RF modem and shield, and a pressure sensor on experimental conditions. But author had just calculated the pressure from the environment and location of designed rover using GPS sensor. Also a XBEE system was used by author for making communication between the ground station and rover, but this XBEE system had very short coverage area.

Sultan *et al.*[4] designed and manufactured a model satellite named Vecihi that was able to perform some of the basic tasks that artificial satellites can perform. It had design constraints about budget, dimensions and weight; and having subsystems like: sensors, storage module, wireless transmission, control, and optional imaging subsystems. Sensors consist of pressure, temperature and direction. All the data acquired with sensors and had stored in a Micro SD storage device with an appropriate format and had to be sent to a ground station for processing. Here the model satellite started recording from separation, and keeps recording until landing. After landing, the satellite would be located with the help of buzzer device attached to it. For experimental purpose, the author implemented all subsystems in small 30g weighted cylindrical container. The electronics components used in nanosatellite were AtMega processor, temperature and pressure sensor, XBEE and SD card. But the experiment stores the acquired data first and until connect storage device the data was not accessible.

III. SYSTEM DESCRIPTION

The main aim of designing the mini model satellite system is to increase the knowledge about space technology. Other systems may propose for the same reason. Different types of sensors like temperature, humidity, pressure, etc. will be deployed in small, lightweight, nanosatellite. These sensors will read the actual parameters from the environment. These random analog values will be first combined with the help of a Arduino processor and then transmit this data to the ground station. The processor will transmit these values to the base station via traditional transmitter-receiver or by IoT. It will capture the real time values of sensor readings and send it for data analysis. The entire telemetry system for nanosatellite is divided into two parts those are transmission system and reception system.

The system can be send vertically upward using a balloon mechanism and during the descend, satellite starts collecting the data like temperature, pressure, humidity, acceleration from the surrounding atmosphere and environment. The temperature was measured by LM-35, pressure by BMP-180, humidity was measured by DHT-22 and acceleration by GY-61 sensors. At the same time Arduino processor used in the satellite collects the environmental data from respective sensors and send it to the ground station with the help of Wi-Fi module interfaced with the Arduino. This Wi-Fi module contains in built TCP/IP protocol which assigns a specific IP address to it. This IP address is registered on ThingSpeak IoT. So by connecting PC to the internet, such collected environmental data is directly accessible to the user.

Then according to requirement of user, the graphs of temperature, pressure, humidity, acceleration are plotted. The data collected by sensors of the mini-model satellite is used to draw the graphs. These graphs are directly potted on the ThingSpeak IoT.

Figure 1 show the block diagram of LASEP where all sensors like temperature, humidity, pressure and accelerometer are connected to the Arduino. This system not just collects these environmental parameters but also transmitting this captured information to the ground station. Instead of using traditional transmitter and receiver system, this mini-satellite is using IoT to transmit the data to ground station. Arduino collects the data form sensors and send it to the ground station by using Wi-Fi module. Also, images captured by surveillance camera were transmitted to ground station on real time. So the ground station acquires the detailed data about the environmental parameters like temperature, humidity, pressure and acceleration. This ground station catches the current status of environmental parameters using IoT via a Wi-Fi module used in the system. This information will be stored on the Cloud and can be used on the PC anywhere and anytime, as and when extracted. Based on this information, the authorities can initiate immediate action like where to perform experiment of artificial rain or not. This entire system is divided into two subparts i.e. mini-satellite and base station. All sensors were continuously monitoring the environmental parameters, so the data originating from sensors is processed and collected by Arduino (ATmega328P) processor. The specific choice of processor is due to the facts that, as compared to the other data possessors used in existing system; Arduino board is a low cost and easily available with flexible interfacing capability.

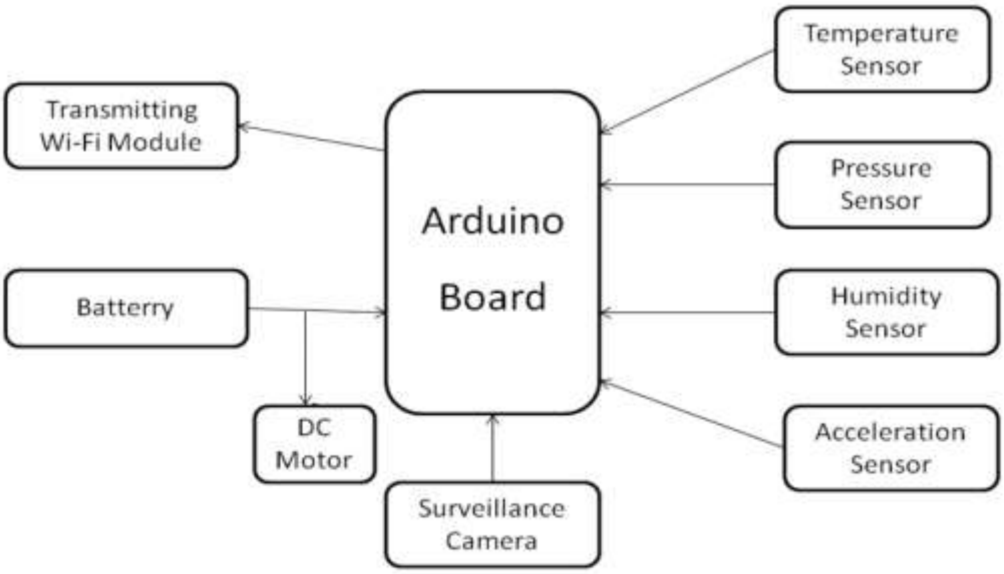


figure 1 constructional block diagram of lower atmospheric satellite for environmental parameters measurement (LASEP)

"Arduino" and its appropriate development environment were used to write the code. The "Arduino" processor is chosen to build the LASEP system because it has comparatively easy programming language and absolutely adequate for this kind of mission. The baud rate of the transmission to the ground station was 115200. This baud rate was high enough to ensure a well-functioning data transmission, but did not destabilize the transmitter Wi-Fi module.

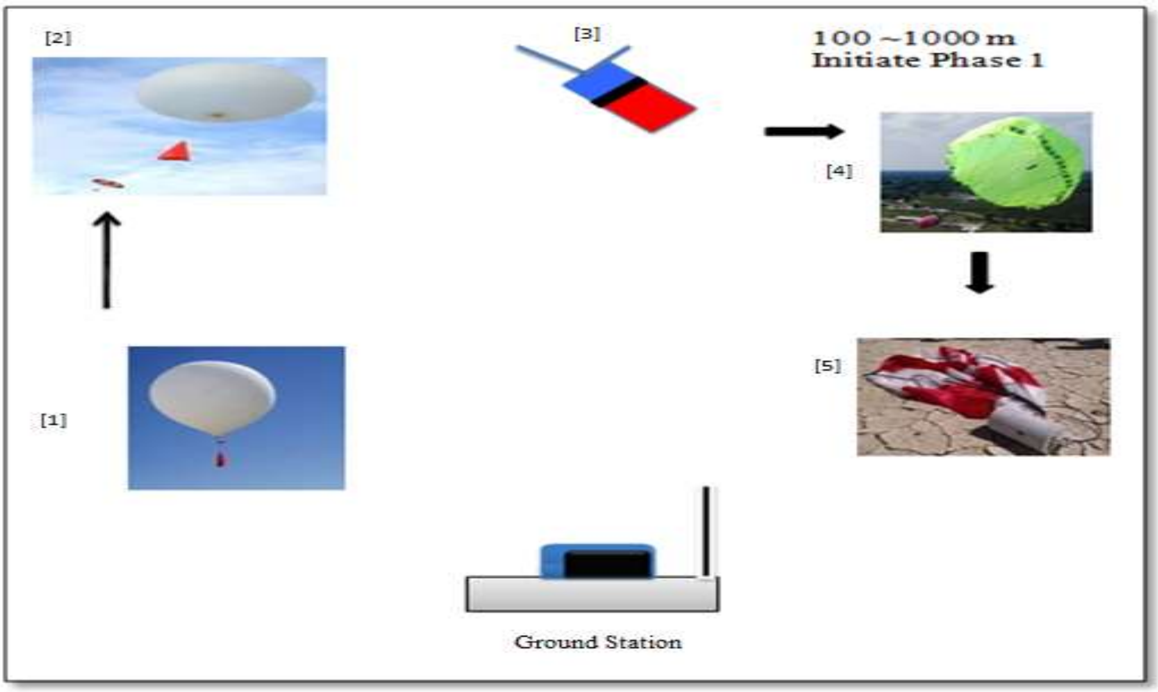


figure 2 balloon launching mechanism for lower atmospheric satellite for environmental parameters measurement (LASEP) to send it at altitude from ground adapted from (www.cansatcompetition.com)

Figure 2 show the balloon launching mechanism used to send the rover at altitude from the Earth surface at stage 1. This balloon is made up of thin, light-weight, durable rubber. But to send it in the sky, it is filled with the hydrogen or helium gas. These gases are used because these are lighter gases than air so these are tend to move in upward direction naturally.

When the rover reaches the desired altitude, by using the burst separation mechanism, balloon and rover get separated this is shown at stage 2 and 3. Then with the help of parachute, the rover starts its landing journey same at stage 4. Out of Hydrogen and Helium gases, Helium gas is used in balloon, because it is an inert gas where hydrogen is highly explosive in nature.

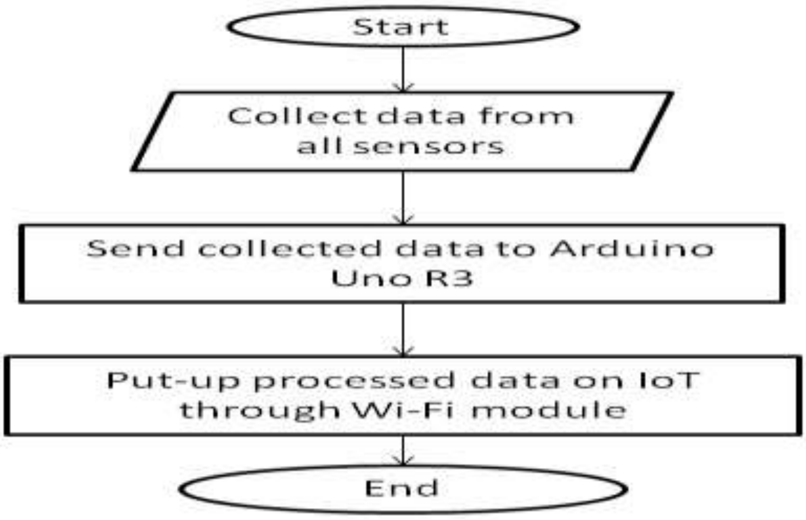


figure 3 working flow chart of lower atmospheric satellite for environmental parameters measurement (LASEP)

Figure 3 shows the working of LASEP where the captured sensors data was forwarded to Arduino processor. The processor converts the data in digital form so that the communicator Wi-Fi module can send it to the ground station with the help of internet of things. This Wi-Fi module put all the captured sensor data to the website associated with it. Then the user at ground station can access the data through a remote login.

The data values of temperature (T) in degrees Celsius were obtained from output voltage of sensor by using following equation [4]:

$$\boldsymbol{T = V_o * \frac{5 * 100}{1023}} \quad \ldots (1)$$

where V_o = Output Voltage for all sensors

The pressure values (*P*) can be calculated in hectopascal (hPa) by using following equation [4]:

$$\boldsymbol{P = \left[\frac{\frac{V_o}{1023} + 0.095}{0.009}\right] * 10} \quad \ldots [2]$$

To measures the environmental parameter directly with the help of sensors and Arduino processor was the primary operation of rover. Then the barometric height measurement method was carried out to calculate altitude of satellite from the Earth surface. This method uses the fact that the pressure of the atmosphere decreases, as the altitude increases. In order to measure this phenomenon, a sensor that detects the changes in pressure was integrated (BMP 180). The gathered data allowed to calculate the height given that the pressure at the launch area, which was depending on the weather, was known. At this point it has to be mentioned that this practice is also applied by airplanes in general aviation to determine the height.

With the help of the barometric formula, the corresponding height *h* can be determined using following relationship of pressure *(P)* [1]:

$$\boldsymbol{h = \left[1 - \sqrt[5.255]{\frac{P}{P_0}}\right] * \frac{T_0}{0.0065}} \quad \ldots [3]$$

Where, P_0 and T_0 are pressure and temperature at sea level respectively.

Since they are dependent on the weather, they are not constant but have to be measured before any height determination activity.

Acceleration *(a)* was calculated from accelerometer data as shown in equation [2]:

$$a = [V_o - m] * 0.7 \quad ...[4]$$

Where, m is the neutral point of data.

These calculated data from sensors was appeared on web server which contains temperature, humidity, pressure and acceleration values generated by sensors. So to access this collected information, user needed a PC with the internet connection. To access the data generated by mini-satellite from IoT, user must sign in first on i.e. ThinkSpeak IoT website. Sign in id and password was unique for all the user so that data stored on Cloud can be kept safe and private. After signing in, all the environmental data captured by mini-satellite was available on channel. All the acquired data can be read on the web application with proper graphs and tables. The data that were stored in ground station will be compared with the data that was collected by the satellite after landing.

IV. RESULTS AND DISCUSSION

Initially, to measure environmental parameters, operation of Lower Atmospheric Satellite for Environmental Parameters Measurement was carried out inside a room so as to test the components and data transmission rate. The system was initialize inside a room hence all the initial reading of temperature, humidity, pressure and acceleration captures the same parameters inside a room and then system was moved on roof top of a building having height about 53m which reads environmental data. The operation of system was carried out on three separate days i.e. on 25th, 28th, 31st of May in summer season. All reading were captured at every after 30 min interval. The second test was carried out on terrace of building having height 150m on 28th May and third test was carried out by actually launching a satellite by using a balloon mechanism at an altitude of 300m on 31st May.

	25-May	28-May	31-May
Series 1	42.7	44.6	42.1
Series 2	43	44.9	42.5
Series 3	43.5	45.8	42.9
Series 4	44.8	46	42.5
Series 5	45	46.3	42.8

figure 4 measured environmental temperature by LASEP

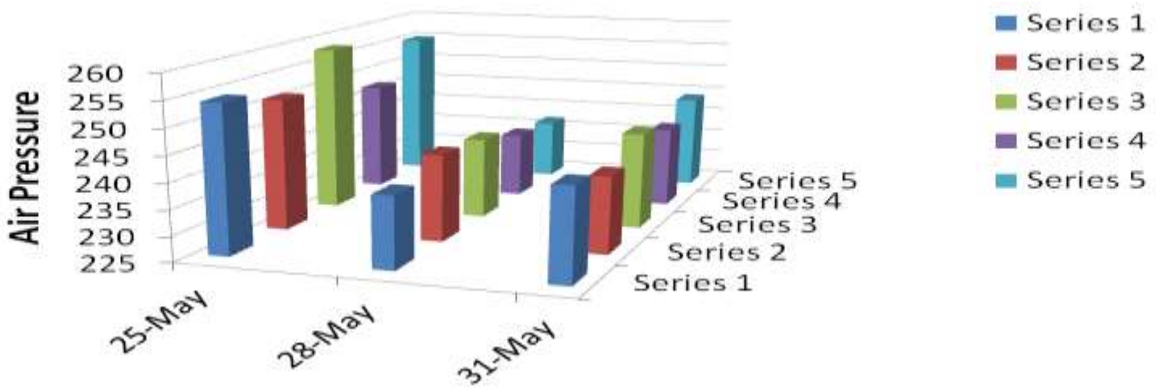
Figure 4 shows environmental temperature data collected by temperature sensor and its graph was plotted on IoT. X-axis represents the day at which reading had been taken and Y- axis represents respective measured temperature. Where Z-axis represents the measured temperature values on each respective day. The table in the Figure 4 represents set of values of temperature measured on three separate days. The first bar i.e. the first reading was indoor reading. The system was initially kept inside house, then moved to the terrace of a building. So this temperature data was collected from altitude about 53m. As the system was inside a room initially, the temperature reading was minimum and as it was moved outside in actual environment, there was gradual increase in temperature. The fourth reading which was collected at 4.20 p.m. was the reading from the terrace it shows approximately constant values for the reading.

Second operation was performed 12.00 noon at an altitude of 150m. Hence the temperature measured shows high values. Where third operation of LASEP system was carried out at morning 10 a.m. with height of 300m. Hence the results of operation was, temperature was comparatively low at an altitude also for morning period too. Hence it was observed that, temperature varies with respect to time and height.

i.e. $Temperatue \propto \frac{1}{Height}$

This can be explained by concept that, when height increases by 200m, it shows decrease in temperature about 0.7 to 1^{0}C for plane land. This concept changes according to the location e.g. there is 3^{0}C decrease in temperature for every 250m altitude for hilly area. These are the concept related to the environment and hence it is very difficult to predict environment and atmosphere.

Figure 5 shows the environmental pressure data collected by pressure sensor and its graph was plotted on IoT. The X-axis represents the day at which data was collected and Y-axis represents calculated pressure and Z- axis represents set of pressure values measured on each respective day. The value of pressure on first operation of LASEP shows gradual change this was due to the movement of a system from one place to another. On the second and third operation of LASEP the values of pressure were pretend to be constant. This was due to no change in temperature.

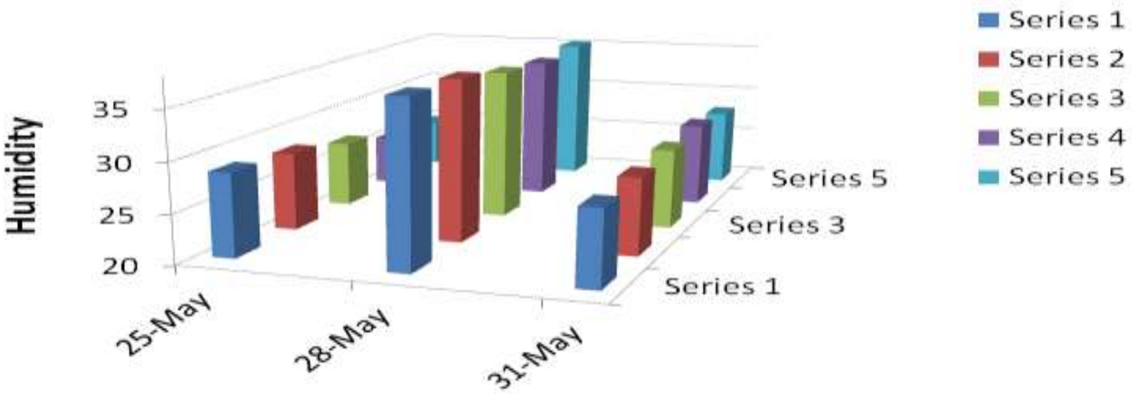


	25-May	28-May	31-May
Series 1	254	239	243
Series 2	251	242	240
Series 3	258	241	244
Series 4	247	238	241
Series 5	255	237	244

figure 5 pressure values measured by LASEP

From Figure 4 and Figure 5 it was observed that as temperature was high, the pressure at same day was respectively low. i.e. $Pressure \propto \frac{1}{Temperature}$

The pressure is inversely proportional to temperature; it means that whenever temperature is high the respective atmospheric pressure will be lesser. Hence the atmospheric pressure change is totally depends on change in atmospheric temperature.

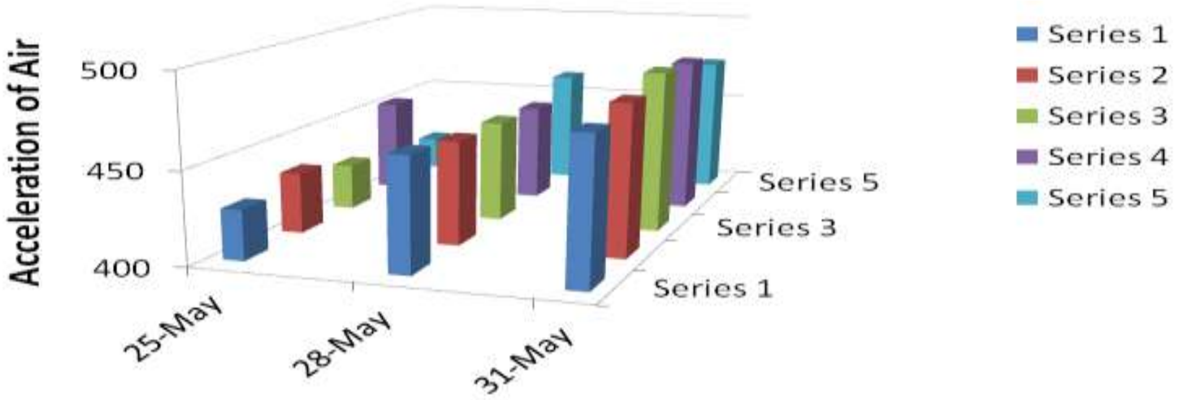


	25-May	28-May	31-May
Series 1	28.5	36.7	27.7
Series 2	28	36.5	27.9
Series 3	26.8	35.4	28.2
Series 4	25.2	34.8	28.6
Series 5	25	35.3	28

figure 6 the humidity sensor output on IoT of LASEP

Figure 6 represents the humidity data. The initial readings of first plot pretend to be high because the data was collected inside the room. These values start decreasing when the system was taken outside. This data was collected in the month of May, hence due to the summer season, humidity was less. On second operation of LASEP, humidity reading was high, this was due to the presence of water storage tank on the top of building. While the third reading represents approximate constant. This was a natural phenomenon.

The raw acceleration data in z-direction shown in Figure 7 was measured by the on-board accelerometers. The X- axis represents the day at which acceleration data was collected and Y-axis represents measured environmental acceleration of air and Z- axis represents set of air acceleration values measured on each respective day. It is clearly visible in the first plot that there was a lot of noise in the data. This was due to the movement of rover i.e. moving the LASEP system from room to the terrace of a building. Eventually, the temperature data was considered preferably during the mission. Conspicuously, the temperature remained stable until LASEP began its descent. But on the second and third operation of a LASEP, the acceleration values were seems to be constant. This signifies air was stable i.e. no movement of air at the time of operation.



	25-May	28-May	31-May
Series 1	427	461	477
Series 2	433	456	481
Series 3	425	455	487
Series 4	451	453	484
Series 5	418	463	475

figure 7 the accelerometer sensor output on IoT of LASEP

Table 1 LASEP components voltage and current consumption

Object	Voltage Required (V)	Current Consumption (mA)
Arduino Board	8.0	3000
Temperature Sensor (LM35)	5.0	0.06
Pressure Sensor (BMP180)	3.3	10.00
Humidity Sensor (DHT22)	5.0	<15.0
Accelerometer (Adafruit GY-61)	3.3	0.35
Wi-Fi Module (ESP-8266.01)	3.3	2000

Current consumption by the system = 4.025A

Table 1 briefly describes the current requirement of components used in LASEP. The most of the power is consumed by the Arduino processor, as it is the only source which provides energy to all the components. Also Wi-Fi module requires high current for its operation as its task was to load the data captured by sensors in LASEP on IoT.

V. CONCLUSION

To measure the environmental parameters like temperature, humidity, pressure and acceleration of air, the system called lower atmospheric satellite for environmental parameters measurement was designed and implemented successfully. The measurement operation was carried out in summer season hence it was clearly indicating that the value of temperature was high above 40^0C. From the operation of satellite, the relationship between temperature and pressure also between temperature and acceleration was studied. These were the concept related to the environment and hence it was very difficult to predict it. Hence all these environmental parameters were calculated to study the change in behavior of environment and this study will help to generate weather prediction report. This study also helps to carry out environmental experiment like artificial rain.

VI. ACKNOWLEDGMENT

I express my gratitude to Mr. Pratap B. Pawar, Department of Electronics and Telecommunication, VJTI for his constant encouragement, co-operation and support during the preparation of this project work. I also thankful to Mr. Pradip Mahajan and Miss. Priyanka R. Pawar for providing strong support, these are responsible and talented personalities I had, to fulfil my technical quires.

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