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Original Article

Connecting the Dots: CubeSat Communication for Emergency Response Services

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Abstract - *The novel idea in this paper is to design a small-sized satellite to establish a communication channel between the victims who need emergency services and emergency services respond. Basic communication systems like GSM connectivity fail due to the destruction of GSM towers, network congestion, power supply cut-off, etc., in emergency situations. The HAM radio devices, satellite phones, and radio frequencies operated devices are not available to the victim for communicating with emergency response services, which leads to epidemic and even death. In such a situation, the Wi-Fi connectivity system is provided in disaster conditions so that victims can easily communicate with the emergency response services using easily available smartphones. Along with the method, the usage of such a communication channel in CubeSAT at a frequency of 2.4 GHz is suggested and constructed. In this case, the CubeSAT was deployed 600 meters above sea level. Since there is less congestion, we have decided to use the suggested 2.4 GHz frequency for our investigation. With this channel, victims can send SOS messages by selecting the type of disaster, location, and what needs they require.*

***Keywords** – ADCS, COTS, CubeSAT, GSM, HAB.*

1. Introduction

Numerous scientific and technological advancements brought about by overcoming the difficulties of working in space have benefited Earthly society in a number of areas, including consumer goods, energy and the environment, transportation, public safety, health and medicine, information technology, and industrial productivity. NASA satellites offer a scientific viewpoint on earth's interrelated systems and how the globe reacts to changes brought about by both natural and man-made factors. CubeSATS are compact, standardized spacecraft used for a range of space-based activities, such as technology demos, scientific research, and naturally occurring calamities.

In an emergency situation, people are stuck in a disaster or a blackout zone and need help. In such a situation, a message using their mobile phones, laptops, or tablets to the nearest ground station is required. In order to construct larger satellites for larger payloads, CubeSATs can be created by combining numerous tiny components [1]. CubeSATs are significantly more adaptable thanks to retractable antennas and solar cells. A device known as a Poly-Pico Satellite Orbital Deployed [2], or P-POD for short, launches CubeSAT into space. As a secondary payload, the basic P-POD can fit on nearly any rocket and can accommodate three CubeSat. Since their introduction by CalPoly and Stanford in 1999, more than 100 CubeSat have been launched into space [3]. To reduce space debris, the Low Earth Orbit (LEO) satellite is usually placed at a distance of 160 to 2000 kilometers from the sea level and falls back to earth in a few weeks or months. CubeSAT is a solution to establish the connection between a blackout zone and other zones underconnectivity. This will not only solve the connectivity problem but also aid in faster reaching out to people who have been hit by disasters and help to pare down losses. Transmission of these messages will use a particular frequency. The connected ground station will retransmit the message to CubeSAT, and CubeSAT will communicate help messages to the emergency responders.

2. Literature Survey

ITA CubeSAT, the AESP-14, has been designed with the special. Additionally, this work demonstrates the use of computational techniques for static and modal structural analysis to forecast the structural response to the launch environment [4]. The ability of INPE to produce major CubeSat structures is also explored and demonstrated through the use of reverse engineering on a Commercial Off-The-Shelf

(COTS) construction. The analysis's findings demonstrated that, at typical launch environment levels, the structure's maximum stresses are reached far below the limitations of the material utilized.

The first experimental remote sensing satellite that India produced was called Bhaskara-1. [5] The image of Bhaskara-I in Figure 1 was launched on June 7, 1979, from Kapustin Yar using the Intercosmos launch vehicle, weighing 444 kg at launch. It was positioned at an inclination of 50.7° with an orbital Perigee and Apogee of 394 km and 399 km, respectively.

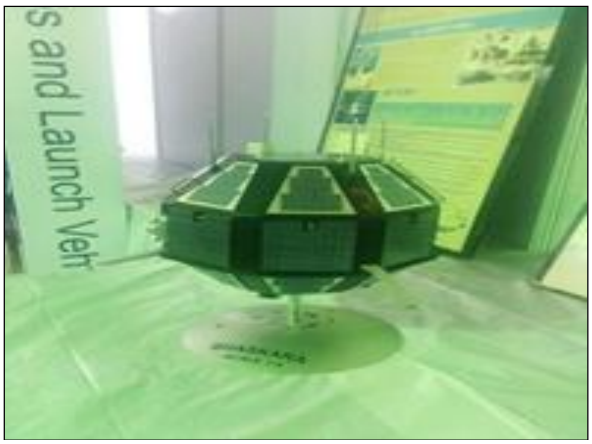


Fig. 1 Scale model of Bhaskara [6]

The satellite consisted of two television cameras that captured geology, forestry, and hydrology data in the visible (600nm) and near-infrared (800nm) wavelengths. Satellite Microwave Radiometer (SAMIR) is used for research on water vapour, liquid water content in the atmosphere, ocean status, etc., and it operates at Scale Model Of Bhaskara 19 and 22 GHz [6].

This satellite uses a two-band TV camera system (0.54 to 0.66 µm) and near-infrared (0.75 to 0.85 µm) to conduct earth observation studies for meteorological, hydrological, and forestry data. This satellite uses a two-band TV camera system (0.54 to 0.66 µm) and near-infrared (0.75 to 0.85 µm) to conduct earth observation studies for meteorology, hydrology, and forestry.

Additionally, a three-chain radiometer that operates at microwave frequencies will be used to research the ocean's surface. Additionally, it advances the techniques for gathering, analysing, and disseminating data, establishing remote sensing satellite management of the planet's natural resources.

In Figure 2, the USSR launched Aryabhata, India's first satellite, into a near-Earth orbit on April 19, 1975. India's ability to develop satellite technology internally was demonstrated by the satellite's launch. Three scientific experiments were also carried out on the satellite. In addition to demonstrating India's capability, the satellite launch produced skilled scientists and engineers who were instrumental in successfully launching India's first lunar mission, Chandrayaan-I. Aryabhatta also covered the development, design, and operational characteristics of India's first scientific satellite onboard antenna system [7].

The Aryabhatta Mission's goals included designing and building a satellite in-country and assessing how well it performed in orbit; being able to conduct a number of intricate operations on the satellite while it was in orbit; setting up the ground stations needed to communicate with it; and testing the ability to build, test, and validate complex space craft systems [8].

Fig. 2 Scale model of Arya Bhatta [8]

This paper aims to aid the successful transmission of details of emergency situations and blackout zones during disasters in a region to emergency responders in another region on earth. This includes the study of satellites for this particular application, which is necessary for emergency victims.

A proposed CubeSAT is designed as a small satellite with a 10 centimeter cube and weighs 1 kilogram. That's about 4 inches and 2 pounds [8]. Concerning the above satellite, it is encouraged that a small and lightweight CubeSAT be designed to apply emergency response.

Therefore, the paper is organized as follows: Section 1 introduces CubeSAT, followed by the design methodology for CubeSAT in Section 2. Section 3 includes the Electronic Circuitry and Rotor Assembly along with the antenna design for CubeSAT. The prototype of CubeSAT is explained in Section 4, and Power distribution and calculation in CubeSAT are explained in Section 5. Finally, in Section 6, the Helium Balloon is explained along with the power budget for the satellite. The paper ends with an analysis of the results and a conclusion.

3. Design Methodology of CubeSAT

The First structural part of the CubeSAT started with the Ground station. The CubeSAT with the helium balloon [9, 10] is used to hang up in the space design, which is explained here. The block diagram of the ground station is shown in Figure 3. Ground Station in this method is used to track the satellite in orbit around the earth, which helps to establish communication with the satellites. The ground station is made up of four parts.

- Electronic circuitry and Rotor assembly
- Helical antenna
- Yagi-Uda antenna.
- Ground base station

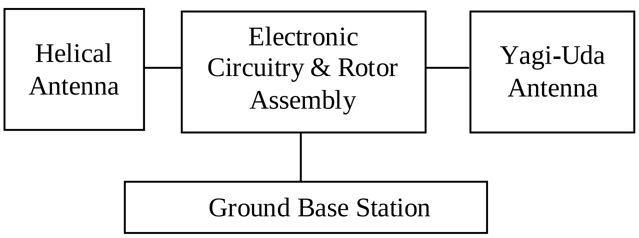


Fig. 3 Block diagram of ground station (used in CubeSat)

This whole system has a design with a maximum height of 9 feet and a minimum height of around 5 feet. The ground station antenna is 4.5 feet wide. The whole system is fully rotational, which helps to make continuous high-gain communication links with the satellite in orbit around the earth.

3.1. Electronic Circuitry and Rotor Assembly

As shown in Figure 3, the block of the ground station is the main body of the whole system of the CubeSAT. This block consists of the onboard microcontroller unit of Atmel's ATmega328p with 16Mhz external clock frequency. This controller is assembled and mounted on the PCB with two bipolar stepper motor controllers. The stepper motor controllers are A9488. This electronic circuitry is powered by a 9V, 500mA SMPS circuit.

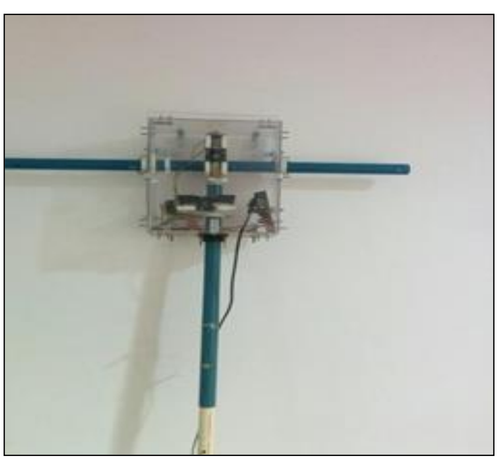


Fig. 4 Electronic circuitry & rotor assembly

The microcontroller unit is serially connected to the ground station computer system (For this purpose, here is the use of RPi 3 b+). This whole antenna rotates only when it starts receiving signals from the satellite. And as soon as the antenna starts receiving the signals from the satellite, the system starts tracking the satellite. [11, 12] To stay in contact with the satellite, the ground station moves the antenna. This is called electronic circuitry and rotor assembly, as shown in Figure 4.

3.2. Helical Antenna

Another part of the ground station is the helical antenna, which tracks satellites. This antenna is also preferred most of the time for receiving signals because of its structure. The helical antenna can easily capture vertically polarized, horizontally polarized and circularly polarized signals. The helical antenna used in this project is an 8 loop antenna with a pitch of 150 mm, loop radius of 115 mm and height of 1350 mm made of GI wire for signal reception and a GI wire mesh for reflection. The structure is supported by 3 pipes on which the wire is wound [13]. The antenna is connected to the receiver of the ground station computer via a channel connector. The image of the helical antenna is shown in Figure 5.

Fig. 5 Helical antenna

3.3. Yagi-Uda Antenna

The next part of the ground station is the Yagi–Uda antenna, as shown in Figure 6. The Yagi Uda antenna is used to transmit signals from the source. This antenna is also used widely for radio wave reception. This antenna works in end-fire array mode. [14] The Yagi Uda antenna used in the ground station is made for the frequency band of Very High Frequency (VHF). This antenna transmits at a frequency of 588 MHz. This antenna is made of 1 dipole reflector, 1 folded dipole, which is used as a feeder and 9 directors. By synthesizing the generalized chains and kinematic chains with the necessary numbers of links and joints, respectively, all possible generalized chains with the same number of links (N) and joints (J) as the initial generalized chain are produced. The Yagi- Uda antenna image is displayed below [15].

Fig. 6 Designed Yagi-Uda antenna for 2.4 GHz frequency

3.4. Ground Station Base and Test Code

The Ground station base is made up of 3 Iron rods connected in a pyramidal form. The fully assembled Ground Station antenna is shown in Figure 7.

Fig. 7 Ground base station

The ground station antenna system connects the pitch and yaw control motors [16]. The shafts are coupled with the bipolar stepper motor shaft. The microcontroller controls the motors.

The ATmega328p is a microcontroller that is serial to the computer of the ground station. For establishing communication between victims and emergency services, the pseudo-code is generated for communication as shown below.

This test code sets the rotation angle of the antennas by rotating the stepper motors [17]. The motor takes 200 Steps to rotate fully. The rotation of the antennas is limited from 0^0 to 180^0 with respect to the horizontal plane 0^0 to $+180^0$ with respect to the vertical plane, and 0^0 to -180^0 with respect to the vertical plane. Different rotation directions need to be used to avoid any kind of full rotation. Following is the algorithm for stepper motor control

```
START
DEFINE stepPin1 = 7
DEFINE dirPin1 = 6
DEFINE stepPin2 = 10
DEFINE dirPin2 = A0
DEFINE numSteps = 400
DEFINE stepDelay = 1000

FUNCTION setup ()
   SET pinMode(stepPin1, OUTPUT)
   SET pinMode(dirPin1, OUTPUT)
   SET pinMode(stepPin2, OUTPUT)
   SET pinMode (dirPin2, OUTPUT)
END FUNCTION

 FUNCTION move Motor(stepPin, dirPin, steps,
 direction)
   SET digitalWrite(dirPin, direction)
   FOR x FROM 0 TO steps
   SET digitalWrite(stepPin, HIGH)
   WAIT stepDelay microseconds
   SET digitalWrite(stepPin, LOW)
   WAIT stepDelay microseconds
  END FOR
END FUNCTION
FUNCTION loop()
 CALL moveMotor(stepPin1, dirPin1, numSteps, HIGH)
 WAIT 1000 milliseconds
 CALL moveMotor(stepPin1, dirPin1, numSteps, LOW)
 WAIT 500 milliseconds
 CALL moveMotor(stepPin2, dirPin2, numSteps, 255)
// Forward
 WAIT 1000 milliseconds
 CALL moveMotor(stepPin2, dirPin2, numSteps, 0)
// Backward
 WAIT 500 milliseconds
  END FUNCTION
 END
```

4. Rotor Assembly Parts

Axis bushings and gears are essential components in mechanical systems, particularly machinery and automotive applications [18]. Axis gear spacing refers to the distance between adjacent gears mounted on parallel shafts within a gear train. "Axis side hold" typically refers to a mechanical feature or characteristic related to the way an axis (or axle) is secured or held in place within mechanical assemblies [19]. An azimuth axis pillar mount typically refers to a specific type of mounting system used in astronomical telescopes or other devices that require azimuthal (horizontal) rotation. Ball bearing rings are essential components in ball bearings that are used to reduce rotational friction between moving parts. High-speed turbo machinery frequently uses ball bearings, essential to the rotor dynamic behavior. The sensor holder is made of a ceramic material whose coefficient of thermal expansion is as close to that of the sensor material as is practical to reduce thermal strains. The sensor and contacting pads placed on the front plate of the sensor holder are connected via wire-bonded connections [20]. To complete the electrical circuit, the internal signal cables of the camera are soldered to these contacting pads. Ceramic paste can be applied to the contacting pads and bond wires to protect them from mechanical loads.

5. Prototype of CubeSAT

As a prototype, the CubeSAT is made up of the MDF board. This CubeSAT will be launched soon with the help of High Altitude Balloon (HAB). The CubeSAT consists of one RPi processor having 1.2 GHz ARM Cortex A53, with 1GB RAM, which is sufficient to run Java script program (code).

CubeSAT also consists of the 12V LiPo, 2200 mAH battery and 5V, 3000mAH LiPo battery for individual purposes. CubeSAT also has an external Yagi-Uda antenna connected to the internal communication board, which provides the communication channel at 2.4GHz. This antenna has been tested on the ground, providing a communication range of 2km. The internally connected modules on the sides of the CubeSAT are as follows as shown in Figure 8.

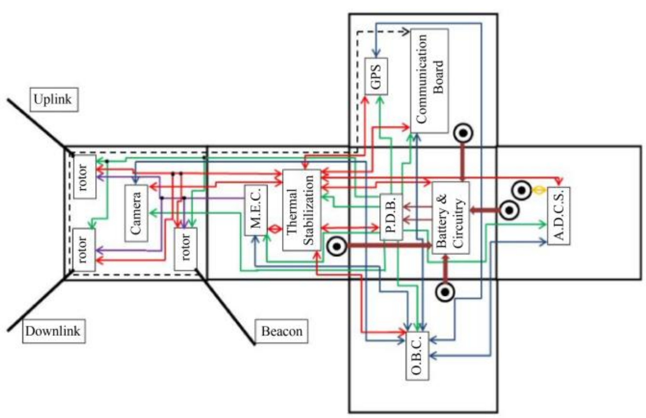


Fig. 8 Internal Connections of CubeSAT

The main component of the CubeSAT, i.e., an onboard computer, is monitoring and controlling the entire internal circuitry. As shown in Figure 8, the camera, M.E.C., thermal stabilization, battery circuitry, P.D.B., GPS, Communication board and ADCS are connected to the On board Computer. The O.B.C. directly controls the Camera while the rotor assembly is connected to the M.E.C., which is connected serially to On Board Computer. P.D.B. controls the current supply of the whole circuitry.

The whole circuitry is powered by a LiPo battery rating of 11.1 V, 2200 mAh. The communication board is responsible for generating the beacon signals and uplink signals, which are sent to the ground station located near emergency response services.

The thermal stabilization unit monitors and controls the internal temperature of the CubeSAT, and this has to be done to avoid any kind of extremely sudden temperature changes, which can lead to damage to the electronic components and abnormal behavior. GPS is used to locate the CubeSAT in its orbit. ADCS is used to determine and control the attitude of CubeSAT. The reference of bus connections is given in Figure 8.

Side A consists of Battery connectors and circuits, which work as power distribution in CubeSAT. Side B has no mounted components on it. Side C consists of two LiPo batteries; one is 5V, 3000 mAH to power Raspberry Pi, and the second one is 12V, 2200mAh. Side D consists of a communication board. Side E consists of Raspberry Pi, which works as the brain of the CubeSAT. Side F has an antenna mounted on it from the outside and internally, and two L-shaped latches support it. The CubeSAT is a prototype that was made by the team and tested. CubeSAT is made of the MDF board.

With the aid of a High Altitude Balloon (HAB), this CubeSAT was launched. To operate the Javascript application (code), the CubeSAT has a single Raspberry Pi CPU with a 1.2 GHz ARM Cortex A53 and 1GB of RAM. For personal use, CubeSAT also includes a 12V LiPo, 2200 mAh battery and a 5V, 3000 mAh LiPo battery. Additionally, the internal communication board of CubeSAT is coupled to an external Yagi-Uda antenna, which supplies the 2.4 GHz communication channel. According to ground testing, this antenna has a 2-kilometer communication range. Figure 9 displays the CubeSAT's internally connected modules on its sides.

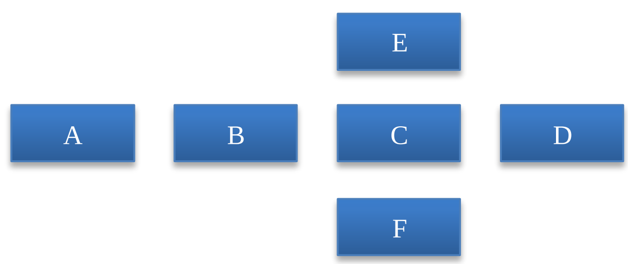


Fig. 9 Sides of CubeSAT prototype

The camera unit will be the Gom Space Nano Cam C1U, a high-performing camera system, along with a rotor specially designed for CubeSAT, as shown in Figures 12(a) and (b), respectively. It is a 3-megapixel, 1/2" (4:3) format color CMOS sensor with 2048 x 1536 pixels, capable of data processing and saving images onboard the camera system, shown in Figure 12(b). This camera will be used for earth observations only. This camera unit will be connected to the Onboard computer system to transmit the saved images to the earth in JPEG format, BMP format, or raw file.

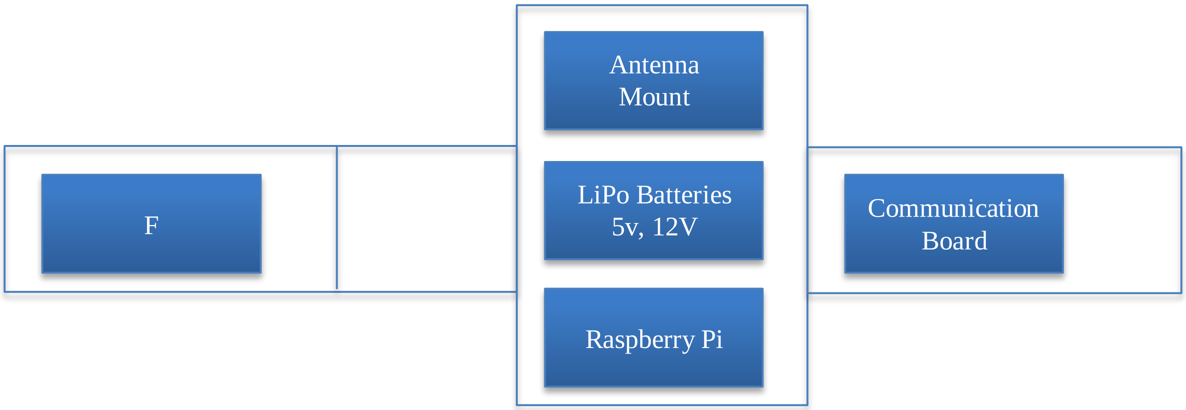


Fig. 10 Components used in CubeSAT Prototype

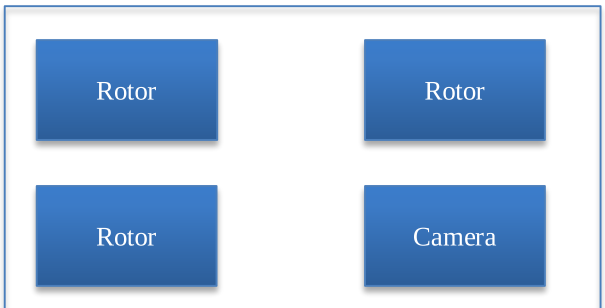


Fig. 11 Rotor unit in Side A

Fig. 12(a) Geared rotor, and (b) GOM space Nano Cam C1U.

This site contains 3 rotor units, which will help to deploy the antenna in the desired position. The 5V DC motor will be used in this rotor unit, as shown in Figure 12(a). These motors will be controlled by 2 units of L293D H-bridge ICs of Microcontroller assembly in serial configuration with the onboard computer. The motor will first get coupled with the gears, followed by antenna coupling.

Antennas on this side are Beacon Antenna, Uplink Antenna and Downlink Antenna. Beacon will be used to send beacon signals to the earth's ground station, and Uplink and Downlink antennas will be used to trans-receive the data from CubeSAT to earth and vice versa Side B has no mounted components on it. The Microcontroller Electronic Circuit (MEC) will consist of a microcontroller unit named Atmel's Atmega 328p (QFP) with an externally supplied crystal frequency of 16MHz. This unit will help in rotating the antennas connected to the rotors in the desired position. The PWM signal output from the microcontroller assembly will drive the rotor assembly. The programming will be in C++ language for microcontroller assembly. This unit will work in slave mode and will be connected to the master onboard computer. The onboard computer will give the instructions to the MEC according to the requirements.

The thermal stabilization unit will monitor and control the internal temperatures of the CubeSAT and will also monitor the external temperatures for any drastic variations. The Thermal Stabilizer will keep the components working in any external temperature range of -215 degrees Celsius to 155 degrees Celsius at Low Earth Orbit (LEO). This unit will use a coolant to flow around the components and circuits. This coolant will flow from a complex mesh of copper tubes, as shown in Figure 12(c). The coolant that will be used is yet to be finalized, but finalizing the use of Nitrogen in its liquid form is final.

Fig. 12(c) Copper tubes

Side C consists of two LiPo batteries; one is 5V, 3000 mAH to power Raspberry Pi, and the second one is 12V, 2200mAh.

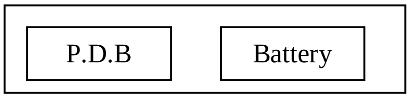


Fig. 13 Power Distribution Board (PDB)

The Power Distribution Board (PDB) unit consists of complex RC circuits to control the current coming from the battery system and various voltage regulator units, as shown in Figure 13.

The PDB unit will manage the power distribution. This unit will comprise RC components, L7805, L7809, and L7812 ICs, as well as a transistor circuit with a Zener diode to regulate the voltage. This PDB will have a supply coming from the battery system. The abbreviation and full-form system block used are given in Table 1.

Table 1. Abbreviation and full form

Abbreviation	Full Form
O.B.C	On Board Computer
M.E.C	Microcontroller Electronic Circuitry
G.P.S	Global Positioning System
P.D.B.	Power Distribution Board
A.D.C.S	Attitude Determination & Control System

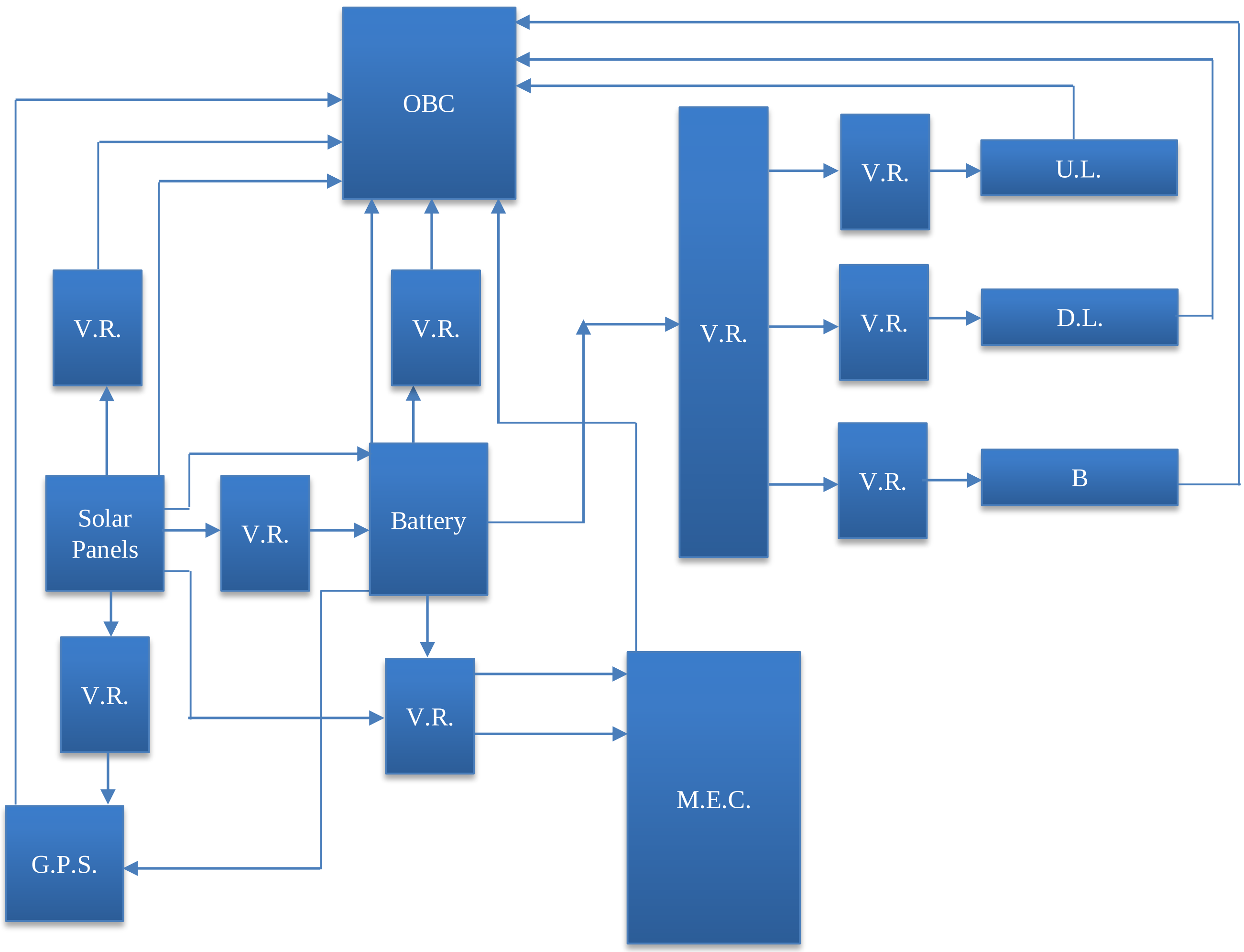


Fig. 14 Circuit diagram for power distribution in CubeSAT

The battery system in the CubeSAT will have a DC-to-DC transformer and an SMPS circuit to stabilize the voltage and current. The battery system will get the input from the solar panels installed on the outer body of the CubeSAT for charging. This system will have a 12V, 2200mah LiPo battery (3 cells), shown in Figure 14.

6. Orbital Calculations

CubeSAT, which will help people to communicate in disaster cases, will be deployed in orbit around the earth. This will make the CubeSAT easily handle many emergency messages coming from people stuck in disasters. There will be a CubeSAT system that will orbit the earth continuously, as shown in Figure 15. This system will make the continuous emergency communication channel available to users. The system consists of multiple CubeSAT because, at Low Earth Orbit, it is not possible for one CubeSAT to stay continuously over the region. This happens because of the universal gravitational phenomena, the force of gravity that is applied by the earth on the objects on the earth's surface and on the celestial bodies like the moon, which are very close to the earth. These phenomena kept satellites in orbit around the earth. Due to this, the orbital velocity of the satellite becomes very large, which causes the satellite to sweep around the earth very fast compared to the earth's rotational velocity at the surface. Due to this, one satellite can't create a continuous communication channel. Hence, multiple satellite system is required.

As explained above, mathematical calculations are done to know the orbital speed and the number of satellites required in the orbit. The calculations are mentioned below:

Considering the CubeSAT will be deployed in the low earth orbit, around the earth, at an altitude of 200km from the earth's surface. Taking into consideration the fact of the influence of the gravitational force on the satellite and other celestial bodies near the earth, the following results are acquired from the calculations by applying Newton's laws of motion and Kepler's laws of orbital dynamics:

- The System of the CubeSAT will be deployed in Low Earth Orbit (LEO) at a height of 200 km from the earth's surface.
- 10 such CubeSAT will orbit the earth at the height of 200 km at an orbital inclination of 22o from the equator towards the north. In the CubeSAT system, each CubeSAT will cover a circular area of around 1.2566x1013sq.m for the (radius = 2000 km, diameter=4000km) on the earth's surface.
- The orbital time of each satellite around the earth is 1.4732 hrs, i.e. 5303.67016 seconds, and one satellite will cover INDIA for 529.9672406 seconds.
- The distance between two adjacent satellites revolving around the earth would be approximately 4128.681065 km.
  Constants (or Predefined values) :
  Re= Radius of the earth h=Altitude of the satellite from the surface of the earth
  G= Universal Gravitational constant
  Me=Mass of the Earth
  SAT (T) = 2π(Re+h)1.5/(GMe)0.5
  Re=6371km,
  h=200km,
  G=6.67x10-11 N-m2/kg2,
  Me=5.97x1024 kg

By putting the values in the above equation, the orbital time period is,

T= (2π)(6.571x106)1.5/(6.67x5.97x10-11x1024)0.5
= 5303.676016 s /T
= 5303.670616/3600
= 1.4732 hrs.

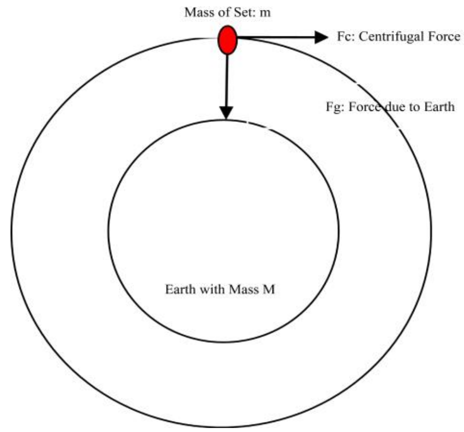


Fig. 15 Orbit of satellite

D angle of the Cone made by the satellite, while covering the above-mentioned area over the earth's surface, will be 'ω'

ω =area/ (Re+h)2 = 1.2566x1013/(6.571x106)^2
= 0.300 steradian = 984.841905 sq. deg.

Number of satellites required to orbit around the earth, 'N'

N= (time required to cover the circumference of the earth at the height of 200km) / (time required to cover the distance of 4000km over the earth's surface at the height of 200km)
N= 5303.676016/529.9672406 = 10.007 ~ 10

Distance between each satellite at the height of 200km above the earth's surface,

X= (Circumference of the circle at the height of 200km)/ (number of satellites)
X= 2π(Re+h)/10 = 41286810.65/10=4128681.065 m
= 4128.681km.

High Altitude Balloons, as shown in Figure 16 are unmanned balloons. They are discharged into the stratosphere and typically reach heights of 60,000 to 120,000 feet (18 to 37 kilometers) and are typically loaded with hydrogen or helium and, infrequently, methane. The High-altitude Balloons are manufactured by latex. Latex is a natural substance found in plants. Plants use the milk-like liquid to defend against herbivorous insects extracted from trees such as maple trees. The extracted liquid is spun and then moulded as a balloon shape. These balloons are of different sizes, starting from 300g to 1500g. The selection of a balloon depends upon the weight of the payload to be sent in near space for various experiments. The Helium gas requirement also changes according to the size of the high-altitude balloon.

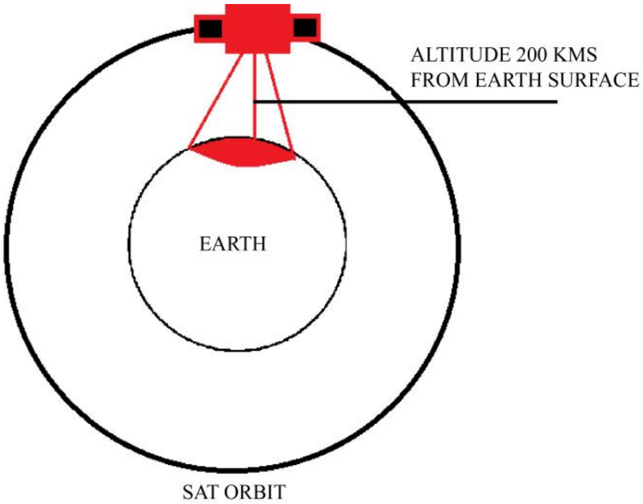


Fig. 16 Altitude of satellite

The most common type of high-altitude balloons with orbital plane inclination is weather balloons, which are sent to the earth's atmosphere with a payload device named radiosonde to obtain information on atmospheric pressure, humidity, and wind speed, as shown in Figures 17(a) and 17(b). The kind of weather balloon called a transponder is designed to stay in earth's orbit for extended periods of time. Nowadays, these high-altitude balloons are used by college students/enthusiasts to establish a communication channel using different frequencies and test them at a very high range so that they can replicate it for the betterment of their future projects. The payload has electronic equipment such as radio transmitters, GPS receivers, and beacon antenna. The use of high-definition cameras for earth imagery is also a common application.

Depending upon the size of the high-altitude balloon, the payload value and amount of helium gas to be filled vary depending on various parameters and require various formulae. The balloon size, payload weight, helium needed, free lift, approximate burst and parachute required for the retrieval of the payload are shown in Table 2.

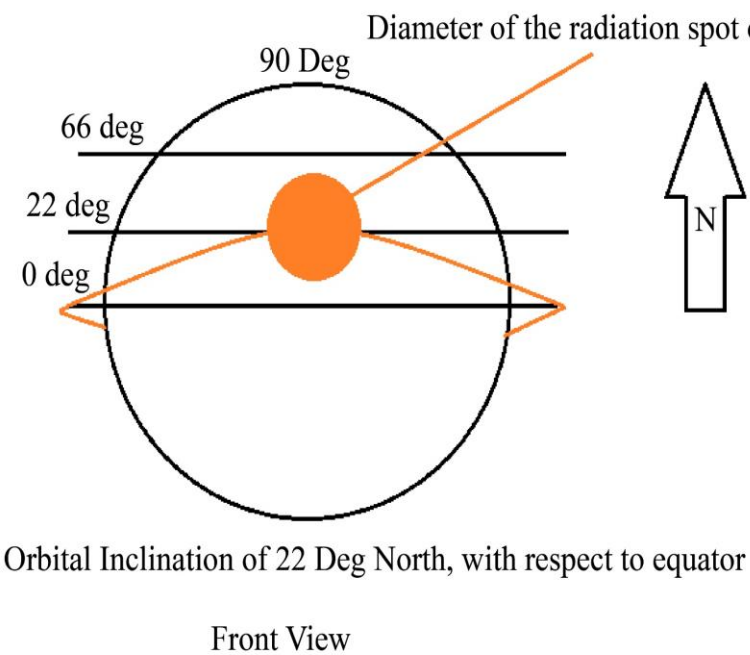
The payload for experimentation is carried out using various electronic equipment. These high-altitude balloons with such payloads are called as Balloon SATs.

Balloon SATs are used for range testing of communication payload, atmospheric analysis, earth imagery, and various research work at college and high school levels.

Calculation of Wind Speed
Velocity of Wind (V) = V_{10} x $(h/h_{10})\alpha$
V_{10} (Velocity of wind at 10m) = 6.67m/s.
h_{10} = 10 m
For h= 600m,

Hellman exponent (α)=0.27
(Unstable air above human-inhabited areas)
V= 6.67 x (600/10)^ 0.27 = 20.147m/s = 72.53km/h
For h=600m, Hellman exponent (α) = 0.34
(Neutral air above human-inhabited areas)

V= 6.67 x (600/10)^0.34 = 26.834m/s = 96.60km/h



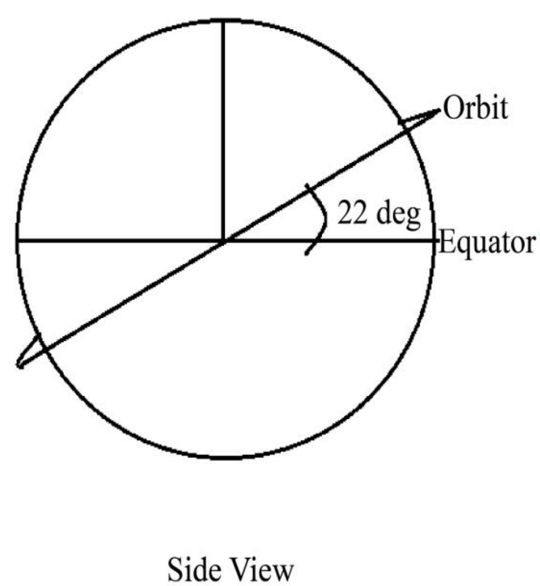


Fig. 17 (a) High altitude balloon **Fig. 17 (b) Orbital plane inclination**

Table 2. Balloon standards

Balloon Size	Payload Weight	Helium Needed	Free Lift	Approx Burst	Parachute Size
300 g	150 g	0.84 cu m	410 g	84,000 ft.	18 inch
500 g	250 g	1.29 cu m	570 g	93,000 ft.	18 inch
800 g	400 g	1.84 cu m	690 g	108,000 ft.	24 inch
1000 g	500 g	2.23 cu m	780 g	112,000 ft.	24 inch
1200 g	600 g	2.62 cu m	890 g	115,000 ft.	24 inch
1500 g	750 g	3.21 cu m	1040 g	117,000 ft.	30 inch

Calculations of Helium
Balloon -1200 g
Gas – Helium
Density of gas – 0.1786 kb/m3
Air Density-1.205
Air density model-7238.3
Burst Diametre-8.63 Payload-1200+1500=2700g
Launch volume-4 m3 approx. Balloon Cd-0.25
Launch Diameter =2*(3*launch volume/4*pi)1/3
=1.9694 m
Area=pi*(launch diameter/2)2 3.0461 m^2
Gross lift=4*(Air density-density of gas)
=4*(1.205-0.1786)
=4.1056 kg Free lift=Gross lift-(2700/1000)
=1.4056 kg
Free lift [N] =1.4056*9.81=13.7839 N
Burst volume = (4*pi/3)*(burst diameter/2)3
=336.5355 m3
Burst volume ratio = (burst volume/Launch volume)
=84.1338
Burst height= -Air density model*ln(1/burst volume ratio)
= - 7238.3*ln(1/84.1338)
Ascent rate = (free lift / (0.5* balloon Cd*airdensity* area))1/2
= (13.7889/(0.5*0.25*1.205*3.0461))1/2
=5.48 m/sec
Time to burst = (burst height/ascent rate)
= (32083.10/5.48) = 97.57 min.

7. Results and Discussion

The ground station antenna testing is done by tracking the NOAA satellites. The tracked satellites are NOAA 15, NOAA 18 and NOAA 19. To set the starting azimuth of the antenna, the software tool named "Orbitron" is used. This software calculates and determines the accurate value of the azimuth and elevation of the satellite, as shown in Figure 18.

The received signals from the NOAA satellites are in the form of pulsed beep sounds. These beep signals are converted into images with the help of the software named "WxtoImg" the received images from the ground station are as shown in Figures 19 and 20.

The ground station, made by the team, successfully tracked the NOAA satellite scheduled on 13/05/2024 at 12:38:28 PM and recorded the images rendered by the software named "WXtoImg". The list of the satellites available for tracking on 13/05/2024 and compared with the other satellites for the frequency is shown in Table 3 with the downlink frequency and time.

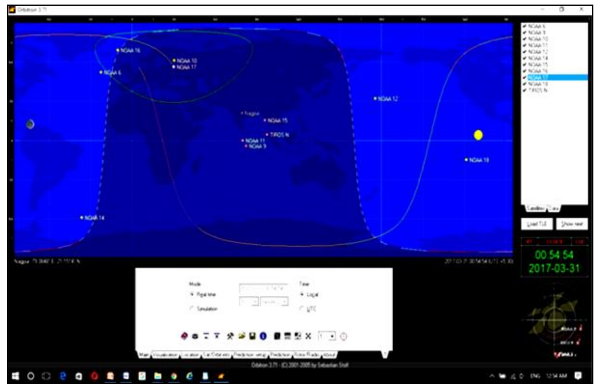


Fig. 18 Azimuth and elevation results of satellite

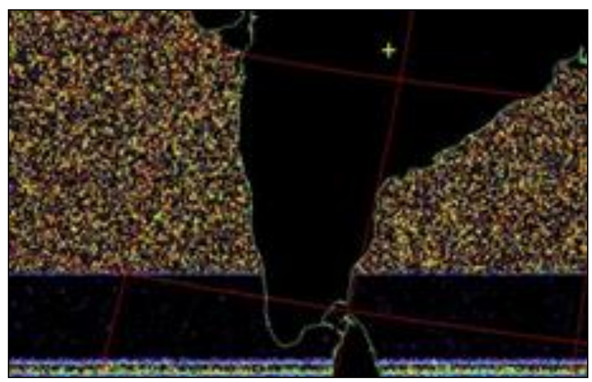


Fig. 19 NOAA Satellite Image of Southern Half of INDIA

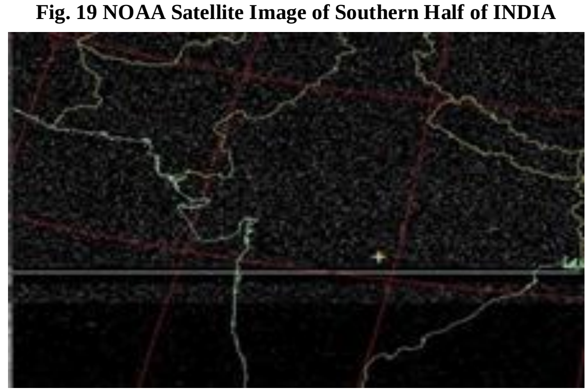


Fig. 20 NOAA Satellite Image Northern Half of INDIA

Table 3. Comparative analysis of satellites that were available to track

Satellite Name	Frequency (MHz)	Time (pm)
NOAA 18	137.9125* (APT) DNLINK: 0000.000 (HRPT)	12:38:28
NOAA 9	136.77	12:45:03
NOAA 15	137.500* APT DNLINK: 1702.500 HRPT	13:25:03
NOAA 11	137.77	13:47:08
TIROS N	137.77	14:07:08
NOAA 9	136.77	14:27:08
NOAA 15	137.500* APT DNLINK: 1702.500 HRPT	15:02:41

As per the requirements to build the satellite, proposed to ISRO, the power distribution in the CubeSAT Circuitry is shown in Table 4.

Table 4. Power Budget and distribution in CubeSAT

Devices	Supply Voltage	Load Current	Power
Beacon Antenna	5v	1A	5W
Uplink Antenna	5v	1A	5W
Downlink Antenna	5v	1A	5W
OBC	5V	480mA	2.4W
GPS	3.6V	100 mA	120mW
ADCS	4.2V	400mA	5W
MEC	5V	240mA x 3=720mA	3.6W

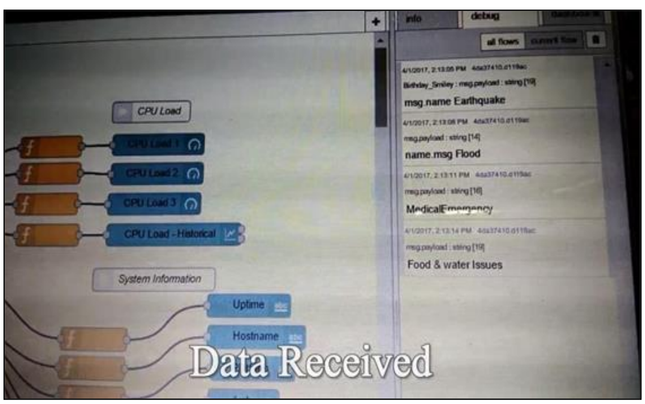


Fig. 21 Data received on the Server shown (Earthquake, Flood, Medical emergency and Food and Water Issues)

As the frequency for the satellite is not yet documented by the Government, but for demonstration purposes, the working frequency used in the CubeSAT prototype is 2.4 GHz. On this frequency, the mobile gets connected easily to the server via CubeSAT, and the server receives the emergency messages, as shown in Figure 21.

8. Conclusion

The whole system of the CubeSAT, ground station, and server can help people stuck in a disaster. The communication does not require any handheld radio devices such as mini HAM radio, satellite phones, etc. Communication can be done just by using the smartphone's Wi-Fi. The channel flow of the nodes at the server can accept the emergency messages in disaster cases in large amounts, and the server is fully functional, i.e. there is no lag in the processing of the emergency messages.

The CubeSAT for communication is built to help people stuck in disasters just by using mobile Wi-Fi. The victim then sends the emergency message to the server from the mobile. The prototype of the CubeSAT has been built and is working perfectly. The prototype frequency used to connect to the server is 2.4GHz. The Server is built on the Node-RED platform. The basic nodes are connected in a flow that can easily accept emergency messages from the user and forward them to the response services. The proposed work of the orbit calculations of the CubeSAT is done by taking the reference from the previously built CubeSAT's such as SWAYAM, STUDSAT, ANUSAT, and PRATHAM. The system of 10 satellites requires making a continuous channel between the ground station and the satellite. The 8-turns helical antenna is built for the purpose of tracking the satellite in orbit, and the 9-element Yagi-Uda antenna is built to transmit the signals from the ground station to the CubeSAT. The internal electronics system needs the development of both the ground station and the CubeSAT. This will help extend the lifetime of the satellite.

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