Geographic aspects are constructed and analyzed using navigation canister-sized satellite.

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Abstract

For tiny satellites, a novel and automated navigation, guidance, and control system is created, examined, modelled, and tested in this work. This system serves as the main on-board control unit for a flying vehicle, as is well known. It is made up of a number of hardware components, including different sets of sensors and electronics based on the kind of vehicle, as well as system software algorithms. The study focuses on tiny satellites, which are increasingly being employed as key instruments for a variety of deep space and low Earth missions. Sensors and the Extended Kalman Filter filtering method used by the Navigation subsystem have been explained. The satellite's state vector is estimated by this subsystem. The Extended Kalman Filter filtering method and sensors used in the Navigation subsystem have been explained. The satellite's state vector estimations are provided by this subsystem. The GPS receiver, accelerometer, and gyro—all of which are regarded as Inertial Measurement Unit (IMU) component subsystems are presumed to be part of this car's navigation subsystem. The satellite's actuators, which are thought to comprise a number of micro-thrusters, receive guiding orders from the guidance subsystem. Control orders for actuation torque increments are provided by the Control subsystem. Two examples have been provided to show the effectiveness of the suggested GNC system. The satellite is directed to align itself with its intended location in the first case. In order to get a desired attitude, the satellite is directed to execute two successive rotational operations in the second example: de tumbling and reorientation. Numerous charts and a qualitative examination of the connections between the satellite's condition and guiding parameters serve to demonstrate the numerical simulation parameters and their outcomes. There **is** an appendix containing the required formulae and figures, as well as a list of references.

Keywords:

1. Introductions

In order to conduct attitude manoeuvres utilizing micro-thrusters, the project aims to create, design, and integrate the Navigation, Guidance, and Control (GNC) functions into a special framework that may be used **on** board a satellite. The study's goals are to: 1) create the guidance scheme by combining a PD controller with a fourth-order polynomial law; 2) integrate this scheme with navigation and control functions for particular maneuvers; and 3) show how the resulting GNC system can execute an attitude maneuver. The technological method involves developing the guiding function using the current PD control rules and integrating it with navigation and control features to create a framework that can receive measurement data and provide real-time guidance instructions. The functionality of this framework serves as the foundation for the implementation of the suggested GNC system designs and software algorithms. Small satellites and other traditional spacecraft may quickly reorient themselves into desired locations or avoid obstacles by using micro-thrusters. When used in conjunction with an automated GNC system, this can lessen the requirement for human input for basic maneuvers and satellite orientation maintenance. This thesis demonstrates how to orient and maintain the angular position of a satellite in a circular orbit using a basic GNC system.

2. Literature review

A clamped free flexible beam and a stiff center hub make up the satellite non-linear model. Conflicting goal functions, such as time and energy, can be optimized using the multi-objective technique. Consequently, a trade-off solution (non-dominated solutions) can be found. These solutions become available to the designer for **a** posterior choice of an individual solution to be implemented. Both the design space (Pareto set) and the objective functions space (Pareto front) contain representations of the non-dominated solutions.

[1] This study considers the nonlinear relative attitude dynamic and kinematic equations represented by relative angular velocity and relative quaternion, respectively. In order to develop an output feedback controller, the lead filter is used to create a virtual angular velocity signal. The Lyapunov approach is used to demonstrate the closed-loop system's stability. The L2-gain disturbance attenuation theory is used to enhance the planned controller while taking the external disturbance into account. To validate the suggested controllers, numerical simulations are performed. [2]. The simulation results of the attitude estimation with various noise statistics on the star data are shown. The results of this approach are also compared with the gyro-aided system in the accuracy of the attitude estimation process. The results show that the concept presented in the paper does work and that the accuracy would meet a large variety of satellite mission requirements. The major result of this research is the realization of a space-capable stellar attitude determination system which does not require a rate gyro package. [3] Nanosatellites designed for in-situ measurements will be spin-stabilized and equipped with a complement of particles and field instruments. Nanosatellites intended for remote measurements will be three-axis stabilized and equipped with imaging and radio wave instruments. Key technologies under development include: advanced, miniaturized chemical

propulsion systems; miniaturized sensors; highly integrated, compact electronics; autonomous onboard and ground operations; miniaturized onboard orbit determination methods; onboard RF communications capable of transmitting data to Earth from significant distances; lightweight and efficient solar array panels; lightweight, high-output battery cells; a miniaturized heat transport system; lightweight yet strong composite materials for nano-satellite and deployer-ship structures; and simple, reusable ground systems.[4] The micro-Newton variable thrust control technology and the thrust noise of the drag-free satellite platform are reviewed in this work. Firstly, the research status of micro-Newton scale variable thrust control technology and its applications to drag-free satellite platforms are introduced. Then, the noise problem is analyzed in detail, and its solution is theoretically investigated in three aspects: “cross-basin flow problem,” “control problem,” and “system instability and multiple-coupled problem.” Finally, a systematic overview is presented, and the corresponding suggested directions of research are discussed. This work provides detailed understanding and support for realizing low-noise variable thrust control in the next generation of drag-free satellites. [5] The thesis presents a fabrication process for these thrusters, employing an anodic bonded silicon-glass wafer stack with a capped microfluidic channel. Fabrication was executed at the EKL lab, using a simplified manufacturing process that is detailed within the report. Post-fabrication, the thrusters underwent mechanical and electrical characterization. The results indicate incremental improvements in both design performance and manufacturability. The new VLM design yielded a 15% increase in thrust efficiency, while the new LPM assembly reduced the occupied volume by 30% [6].The CanSat was launched by the facilities of ISRO-INSPACe-INDIA by a launch vehicle rocket, which achieved a height of 800m. The mission requirements were to measure physical parameters like temperature, air quality, altitude, humidity, position data, orientation data, battery status and health, barometric pressure, latitude, longitude, power data and system status using mechanical actuators and electronic sensors. Mission states are sent to the ground station right from the satellite with the reference level as ground. The real-time data packets are received and decrypted at the ground station and the laptop of the ground station, graphically visualizes the data obtained. The flight pattern obtained was limited to a plane that covers an area of 25X25 m by the help of NAVIC.The paper covers designs as well as the recently tested CanSat. [7] We derive **a** two-degree internal model control structure of ADRC, which is used for robust stability verification. Search programs determine the parameters that satisfy system stability and the performance requirement. The design technique has shown to be robust to the perturbation of the system and good performance in disturbance suppressing. To check the design of the controller, an overall simulation is preformed, and the results confirm that the controller is able to meet the system requirements. [8]

2.Problem statement

The goal of this mission is to build a CanSat that weighs less than 0.700 kg (+/-.050 kg) and has dimensions no more than 0.125 m in diameter and 0.310 m in height using parts made in India. On the ground station, each data field must be displayed using a real-time user interface or piece of software. In the event of a telemetry link failure, CANSAT must additionally capture the data and store it to an onboard SD card. The CANSAT structure should be built to survive launches that accelerate by 15 Gs and **shocks** by 30 Gs. To prevent disassembling CANSATs on the launch pad, the CANSAT must include an external power switch with an indication light or sound for turning on or off. The CANSAT has to have enough battery life to last for up to two hours while waiting on the launch pad, in addition to extra time for flight operations. Each team must construct and run its own ground station. Every piece of telemetry must be shown in real time throughout launch and descent. All telemetry presentations must be made in engineering units (meters, metres per second, Celsius, etc.). Teams must plot data in real-time while in flight. The ground station must be mobile in order for the crew to be situated at the operational site along the flight line and move to a different place as necessary in the case of a distant landing location to detect the CANSAT.

3.Airframe Design

Aluminium male standoffs and perforated aluminum sheets are used to construct the fuselage. Onboard computers, electronics, and computers make up the fuselage. Batteries and a descent control system are also put within the container. Table 1 illustrates the CanSat's geometric properties. Table 2 provides the weights of the CanSat components. CanSat's overall weight shouldn't be more than 0.700 kg. The Top Stage, First Stage, Second Stage, and Last Stage are the four phases that make up CanSat.

Table 2. Geometric Characteristics Of CansSat.

Component/Assembly	Mass[gm]
Overall CanSat Mass	518.00
Descent System’s Total Mass	50.00
Camera System Total Mass	66.54
Electronic System Total Mass	305.00
System Structure Total Mass	41.00

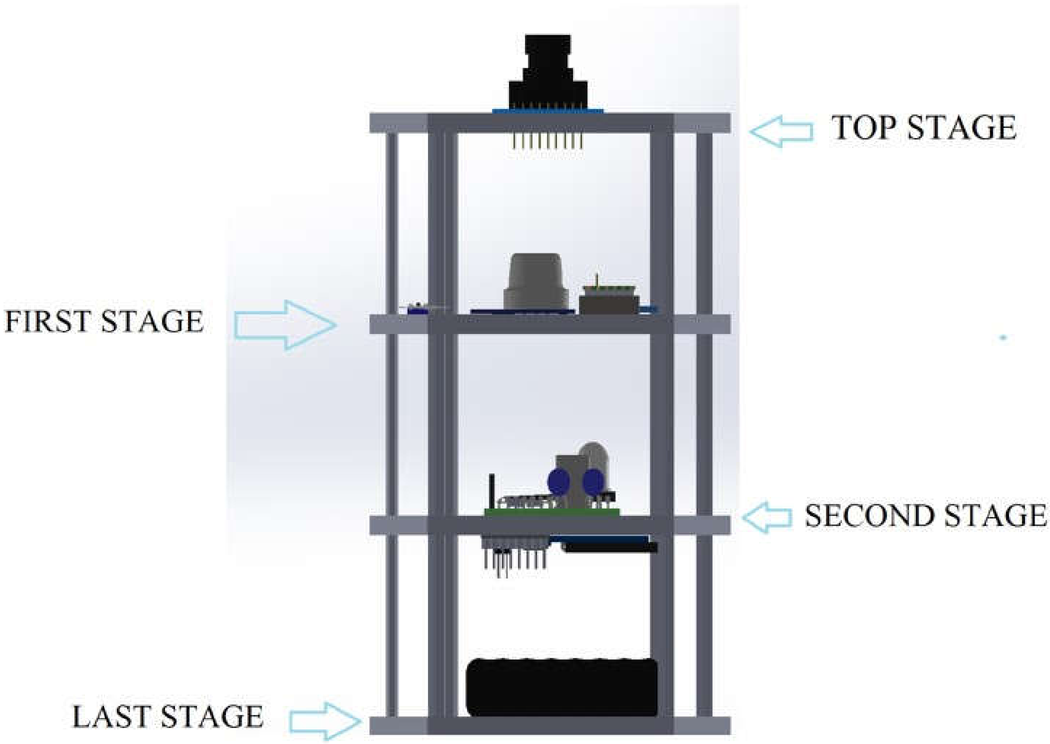

Fig. 1. Total 18 Male standoffs are used in hexagonal shape. Male standoffs are made up of aluminium alloy. Male standoffs have a dimension of 5*5*50 mm. All the Male standoffs are connected to chassis. Total 4 chassis are used in the payload.

This paper goes into detail about the simulations that have been run for a complete GNC system for a small satellite in a circular orbit. The current simulations show that it is possible for this system to maintain control and orient itself using micro-thrusters in a desired position with minimal input from external sources. In particular, this study applies a polynomial guidance function in conjunction with navigation and control functions to create a closed-loop system. While the navigation used is the standard navigation function with an EKF filter with IMU and GPS sensors, the guidance portion of the GNC system is something that has yet to be fully explored. With the integrated on-board guidance and navigation, the PD controller is capable of achieving its goals in the simulations. The real-time targeting has been considered for the first time as part of the proposed on-board attitude guidance. The target state included the Euler angles and angular rates. This is the main reason for considering the proposed guidance as the"target-relative attitude guidance". This allows us to create a real time on-board attitude guidance using the polynomial method developed by Klumpp for a translational motion of Apollo landers. However, such a method has been shown to be currently limited in its scope. The simulations were conducted for the purposes of de-tumbling and reorientation. As a result, the results from these simulations show that the guidance has a similarity with a bang-bang controller.

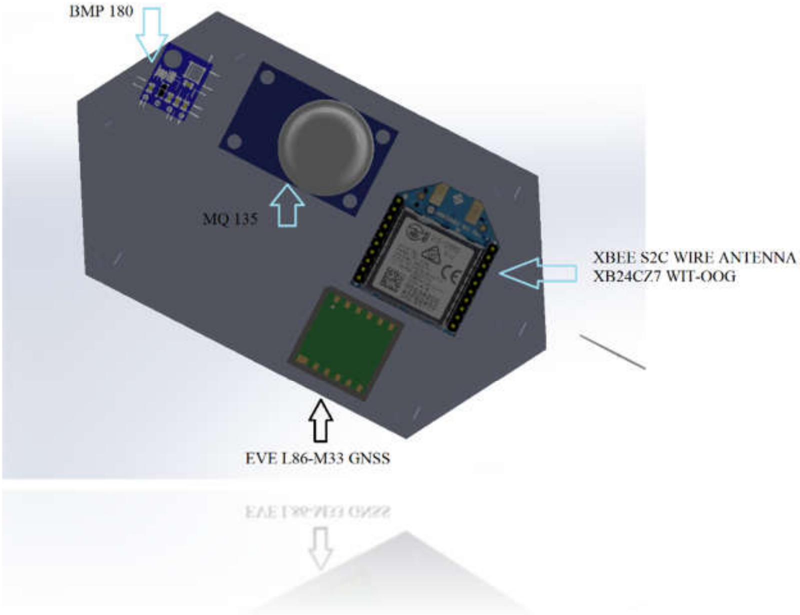

Fig. 2. 1st stage has a total of 5 sensors mounted on it in a systematic way such that : Maximum space is occupied; No overlapping of any sensor ;Proper connection of jumper wires.

Fig. 3. Total length of the chassis is 85 mm and height of 60mm.

4.Electronic System Design

The electrical system is heavily dependant on the programmed. Sensors, receiver-transmitters, and software control processors were developed using the C programming language. The electrical and power system is made up of a wide variety of sensors and other parts [9]. Our

CanSat's sensors gather vital information including barometric pressure, temperature, GPS, longitude, latitude, and battery life

4.1.Sensor subsystem design

Our system of sensing modules includes sensors for temperature, air quality, pressure, elevation, GNSS, pitch and roll, voltage level, and an extra camera module.A number of the sensors, including temperature, pressure, and altitude, are merged into a single sensor or component to lighten and lower the cost of the CanSat.

4.2.Block diagram

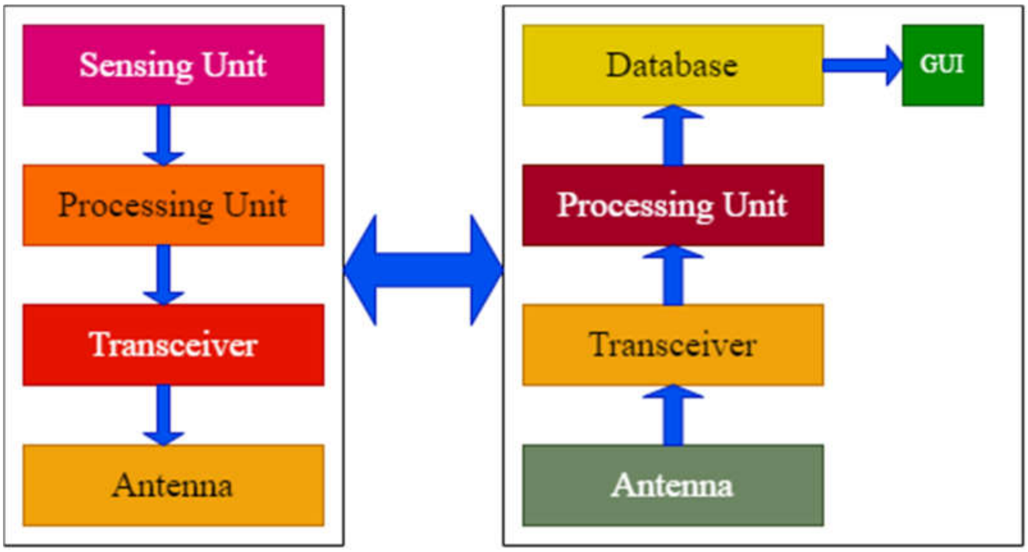

Fig.4. Block diagram

The data transferred between pressure, temperature, altitude, acceleration, humidity, coordinate, and other variables contains information. The electrical architecture of these satellites often consists of an RF module, a CPU, GPS, micro servos, and a variety of sensors. The information is also provided to the ground control station via the RF module after being analysed by sensors depending on the tools and equipment used to execute the task. For complex tasks to be managed in the air, a microprocessor is necessary. The software included inside the microprocessor aids in providing a peek of the processes going on within the satellite [6]. The four steps of CanSat's operating procedures are as follows: The data is processed by the processing unit, which also generates a binary stream that is sent to the transceiver for 10 Hz communication. The first level involves sensor units gathering and addressing relevant data from their immediate physical environment, such as temperature and barometric pressure. The transceiver transmits the data in the 2.4 GHz frequency spectrum at a data rate of 250 KBPS using an antenna.

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4.3.Ground control station

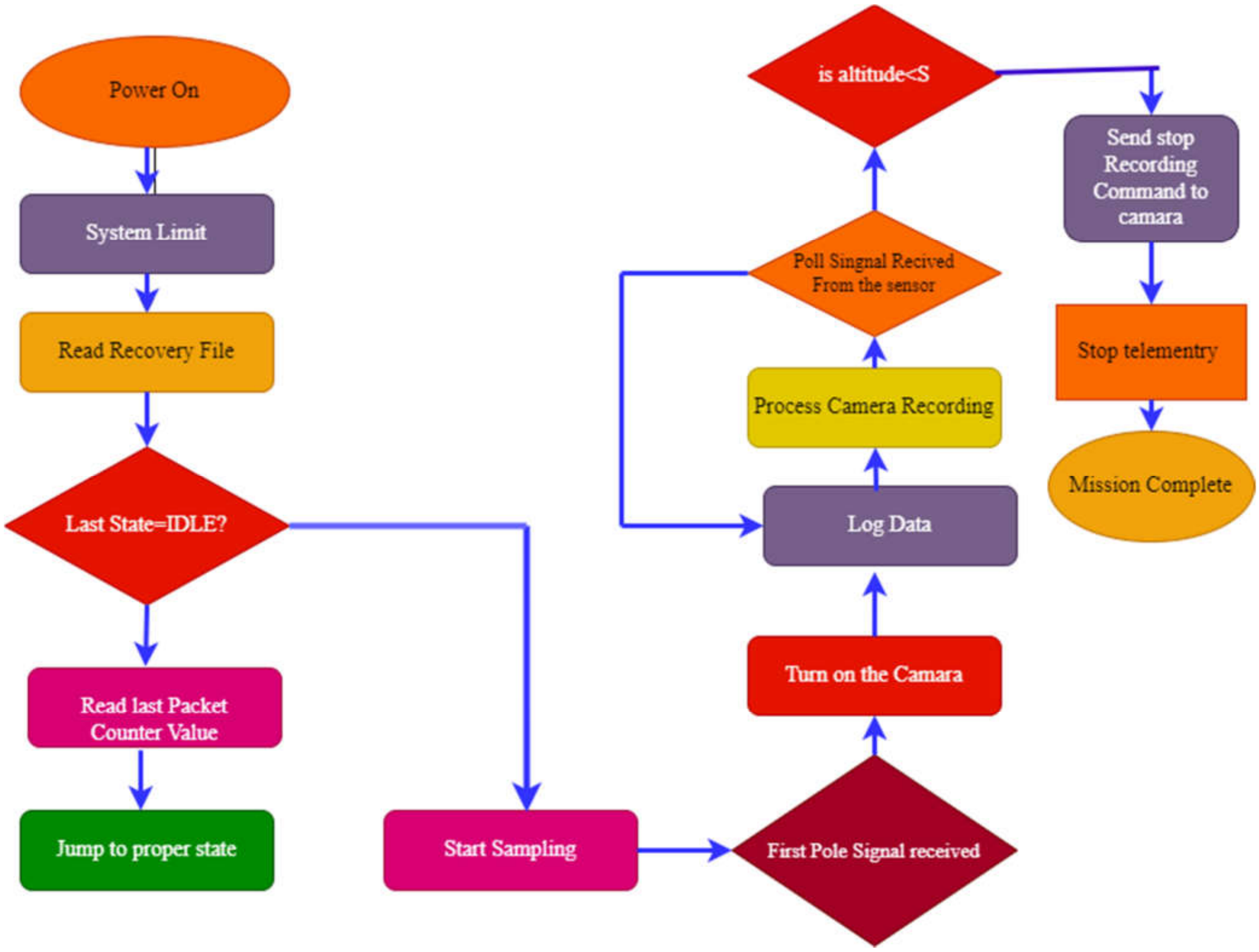


Fig. 5. Payload FSW state diagram

GCS is essentially a land-based control station that enables the user to control Unmanned Aerial Vehicles (UAVs), such as satellites and drones (in our instance), etc. One of the most important aspects of CANSAT is the layout of the ground control station GUI. For this research, a wide range of programming languages and development environments—including MATLAB, Java, and LabView—are examined. Visual Studio was chosen as the foundation for creating the ground station GUI because it is an approachable programming environment [2]. The GCS interface allows the ground station operator to transmit calibration commands for the barometer sensor and row/pitch angles (from the pitch sensor). The GCS Operator may also provide a command to set the time. Simulated data file will be loaded. The operator will issue an activation command after broadcasting to activate the simulation mode, at which point the ground station will begin receiving consecutive values from the csv file at a frequency of 1 Hz. The GCS also transmits the order to disable simulation mode.

4.4.Navigation control algorithm

Two control algorithms were created to safeguard CanSat's orientation. The following describes how flight control orientation works:
• The first and second stage parachutes' system stabilizes the CanSat after it separates from the rocket.
• A mechanical gyroscope is employed to orient CanSat.

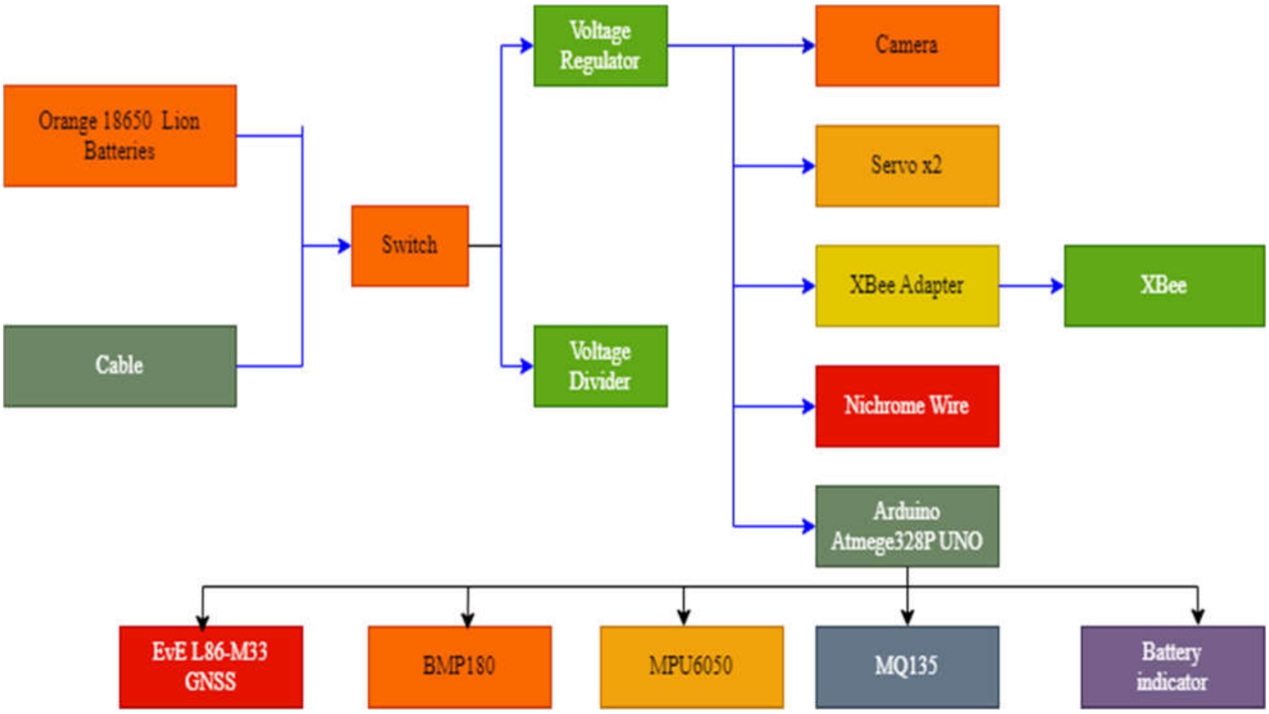
5.Hardware Development

5.1. PCB board

Multiple-storied PCBs must be designed due to a space constraint. A GPS board, sensor board, camera board, and control board were all made as independent PCB's circuit board with the required circuitry, a voltage regulator, a voltage divider, and an Arduino CPU.
A temperature and barometric pressure sensor (BMP180) were put on the sensor board.
Connectors were used to create the connection between the controlling unit and the GPS module.

5.2.Frame and decent control system design.

Aluminum was used in the creation of the hexagonal body, which measures 85 mm by 60 mm by 150 mm. The chassis and male standoff can easily sustain a shock of 30G. In parachute design, a dual deployment system was employed. It was divided into two phases: parachute in two stages: first and second. Rip stop nylon is the material used for the primary parachutes, which are fastened together at the top stage of the frame with the aid of fuse wire. There are a total of four secondary parachutes attached to the frame, each of which is made up of rip stop nylon and has its string fixed at the first and second stage chassis and curled up to the male standoffs of the extreme ends.



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The CanSat was successfully executed. It came with a unique GUI. Indian students may research for a fair price with the help of the CanSat project, and anybody who wants to construct a satellite based on comparable ideas can work on such a version to progress the field. The primary goal was to make it convenient and affordable for Indian students, and it was successful. Future work signify will be creating a cheap long-range RF communication module and a cheap launch rocket so that students may launch from greater heights and gather a broader range of data.

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6.2 Navigations

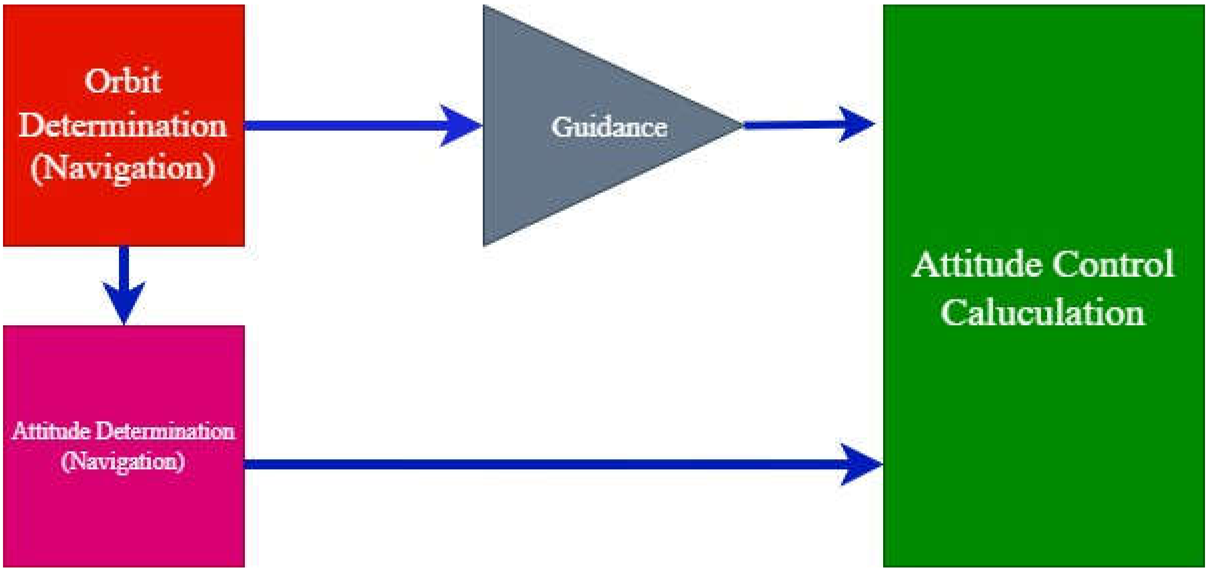

Fig:7 the attitude control processing, the target attitude of the satellite needs to be calculated.

The target attitude and rotational rate, as well as their precision, depend on the mission objectives. There are a variety of target attitude definitions based on the mission objectives. Attitude determination and control is usually discussed relative to the inertial coordinate system. There are several different types of pointing controls as below: Inertial Pointing Mode Spacecraft attitude is controlled in the way that it is fixed to a certain direction of the inertial coordinate system. It is often used for star observation. Nadir Pointing Mode Spacecraft attitude is controlled in the way that a certain axis keeps pointing to the Earth (or a certain celestial body) center direction. It is often used for Earth surface observation in a scanning mode. The target attitude rotates with time based on the relative position of the Earth and the satellite. Ground Target Pointing Mode– Spacecraft attitude is controlled in the way that a certain axis keeps pointing to a certain target object on the Earth's surface. It is often used for Earth observation in a pointing mode, or high speed communication between the target ground station.

6.3.Block diagram Attitude Determination and Control Process

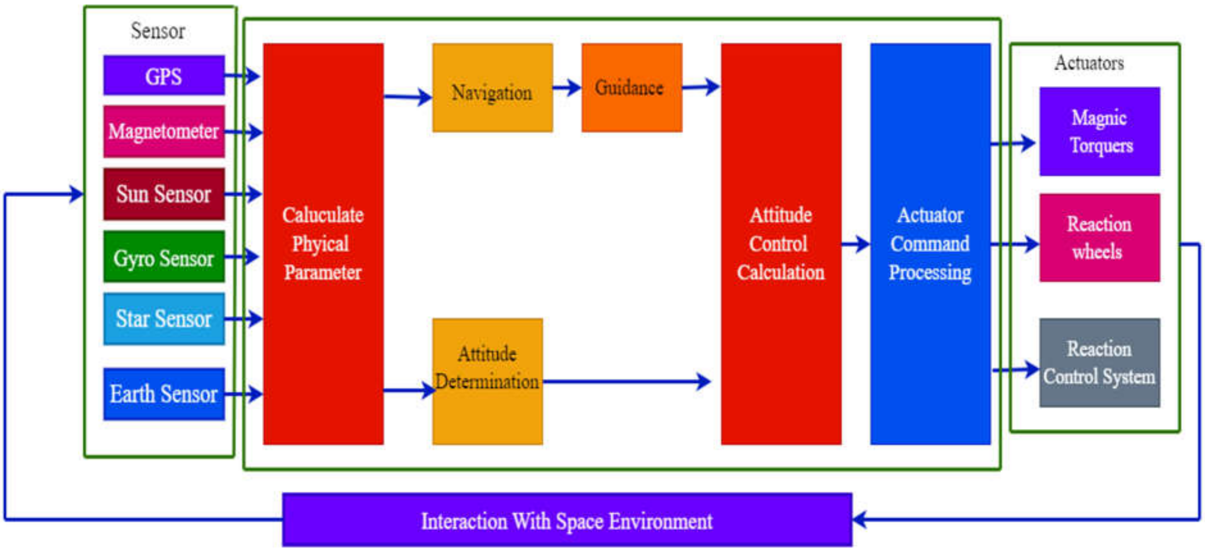

Fig:8 Attitude Determination and Control Process

Attitude determination and control processes can be divided into several steps, executed one after another in a periodical manner continuously. The process consists of processing of sensor data, orbit determination, attitude determination, guidance, attitude control calculation, and the generation of command packets for actuators. Time Information – Time information can be obtained from the GPS receiver or from the on-board RTC. Orbital Position – Orbital Position can be obtained from the GPS receiver, or mathematical integration inside the on-board computer based on the orbital mechanics. TLE (Two Line Element) information can be used. Attitude determination calculations require comparison between the measured physical parameters and estimation with space environmental models. Sun direction Magnetic field direction (Earth rotation) Earth direction.

7. Conclusions

An Introduction to the CubeSat attitude control system is provided. It was explained that the attitude determination and control process consists of several steps, such as navigation, guidance, and control, and that attitude control and orbit control influence each other. Various kinds of attitude control modes and an example of an attitude control system state machine diagram with mode transitions are introduced. Hardware components of the attitude control system were introduced, such as attitude determination sensors, attitude control actuators, and attitude control system computers. Processing tasks of navigation, guidance, and control are described in detail, together with some examples of reference coordinate system definitions and coordinate transformation between inertial coordinate systems and geodetic coordinate Systems. The Mathematical Background of attitude determination and control algorithms was explained including three different kinds of attitude description methods, as well as satellite attitude kinematics, dynamics, and control. Functional verification aspects of the satellite attitude control system were described. Several verification and simulation infrastructures were introduced, and the importance of operational planning of attitude control systems based on the satellite and the space environment simulator was emphasized.

This paper presents detailed simulations of a complete GNC system for a small satellite in a circular orbit. Based on current simulations, this system is capable of maintaining control and orienting itself without external input using micro-thrusters. Combining polynomial guidance with navigation and control creates a closed-loop system. Despite using the standard navigation function with EKF filter and IMU/GPS sensors, the guidance portion of the GNC system has not been fully explored. The PD controller can successfully meet its objectives in the simulations due to the incorporation of integrated on-board guidance and navigation. For the first time, real-time targeting has been incorporated into the suggested on-board attitude guidance. The Euler angles and angular rates were part of the target state. The proposed guidance is primarily regarded as the "target-relative attitude guidance" for this reason. This enables the development of real-time on-board attitude direction utilizing the polynomial approach formulated by Klumpp, specifically for the translational movement of Apollo landers. Nevertheless, this approach has demonstrated its present limitations in terms of scope. The simulations were carried out to achieve de-tumbling and re-orientation. Consequently, the findings obtained from these simulations indicate that the guidance system exhibits similarities to a bang-bang controller.

8.References

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