International Research Journal of Education and Technology
Peer Reviewed Journal
ISSN 2581-7795

Data Acquisition System, Launch Control and Recovery Avionics For Sounding Rockets

Thiruvarulselvan K[1], Thishon J[2], Yukesh Chandran M[3] Dr. Manojkumar P[4]

[1,2,3] Student, Dept of ECE, Bannari Amman Institute of Technology
[4]Assistant Professor,Dept of EEE,Bannari Amman Institute of Technology

***

***Abstract* -** Sounding rockets have various applications in scientific research, including studying the upper atmosphere, auroras, microgravity, radiation, and testing new technologies for space missions. Avionics are crucial in a sounding rocket as they provide real-time data acquisition and telemetry, ensuring safe and successful mission operations.

This project presents the design and development of a comprehensive data acquisition and recovery system for sounding rockets using the STM32 ARM Cortex M4 microcontroller. The system includes various sensors such as pressure, humidity, atmospheric temperature, motor temperature, gyro, attitude, altitude, vibration, voltage, and current sensors to collect flight data. The collected data is stored on an SD card module and transmitted to the ground station using an RF link. Additionally, a GPS module is integrated into the system to track the rocket's position and altitude during flight. The system also includes an onboard ignition system and wireless launch sequence. The ground control system (GCS) enables users to remotely control the launch sequence and displays the motor firing system status. The GCS also provides a wireless interface for transmitting the launch sequence to the onboard ignition system. The user interface enhances the flight status and improves the security using AES encryption mechanism. The parachute deployment system is activated based on the altitude sensor data to recover the rocket after landing. The system has been tested with multiple conditions, demonstrating accurate data collection and recovery capabilities. The presented system proposes a reliable and efficient solution for model-sounding rocket data acquisition, recovery, and launch control.

Keywords: Avionics, Sounding Rockets, Recovery, Ground Control System, Parachute Deployment

I. INTRODUCTION

In this project, we embark on the design and development of a sophisticated Sounding Rocket System, addressing critical components such as Data Acquisition, Ground Control, and Firing and Recovery Systems. The necessity for reliable data acquisition during the rocket's flight underscores the significance of a robust Data Acquisition System, ensuring real-time capture and transmission of vital information from onboard sensors and instruments. Concurrently, advancements in Motor Firing Systems play a pivotal role in optimizing trajectory control and overall mission success, emphasizing the need for responsive and reliable propulsion technologies.

Moreover, our project places a strong emphasis on the implementation of state-of-the-art Parachute Recovery Systems, incorporating innovative technologies to enhance descent control. The integration of artificial intelligence algorithms into these systems presents an exciting avenue for optimizing parachute deployment, adapting dynamically to real-time conditions. This holistic approach aims to not only capture precise data but also ensures a safe and controlled descent, crucial for the recovery phase of the sounding rocket mission. As we delve into the intricacies of each subsystem, our goal is to contribute to the advancement of sounding rocket technology, addressing key challenges and innovating in critical areas for the success of scientific and research endeavors.

Scope of the project

The proposed control avionics for Sounding Rockets offers an array of unparalleled advantages, propelling sounding rocket missions to unprecedented heights of efficiency and precision. Key advantages include:

1. Data Acquisition System

The project's scope in Data Acquisition involves designing a resilient system capable of capturing, storing, and transmitting real-time data from the rocket's onboard sensors. The focus is on addressing the challenges posed by the harsh flight conditions to ensure the accuracy and reliability of acquired data.

2. Ground Control System

A Ground Control System (GCS) serves as the interface between operators and unmanned vehicles, incorporating security measures for authorized access. It manages launch sequences, conducting pre-flight checks and ensuring vehicle readiness for liftoff. Real-time status indications are provided to operators, monitoring vehicle health and environmental conditions. LabVIEW-based visualization tools enable operators to analyze flight data, telemetry, and sensor readings in real-time. Overall, the GCS plays a pivotal role in facilitating safe and efficient unmanned missions, from pre-launch preparations to in-flight operations.

3. Firing and Recovery System

Our project aims to advance Motor Firing Systems, delving into cutting-edge propulsion technologies. The scope involves optimizing trajectory control through the development of a responsive and reliable motor firing system. In the realm of Parachute Recovery Systems, the project seeks to integrate artificial intelligence algorithms to enhance descent control. The scope encompasses the implementation of sensor fusion technologies, enabling adaptive parachute deployment based on real-time data from accelerometers, gyroscopes, and environmental sensors.

4. Holistic Integration

The overarching scope of the project lies in the holistic integration of Data Acquisition, Ground Control, and Parachute Recovery Systems. This approach ensures a comprehensive and synergistic design, addressing technical challenges in each subsystem to enhance the overall reliability and success of sounding rocket missions.

Potential Applications:

The avionics subsystems redefine the landscape of sounding rocket launch control, opening doors to a myriad of practical applications. Some key applications include:

1. Real-time Environmental Monitoring for Disaster Response

The advanced Data Acquisition System provides real-time monitoring of atmospheric conditions, enabling rapid response in disaster scenarios. This capability is crucial for assessing and mitigating the impact of natural disasters, such as hurricanes or wildfires, by delivering accurate and timely environmental data to emergency response teams.

2. Precision Propulsion for On-Demand Satellite Imaging

Advancements in Motor Firing Systems offer on-demand satellite imaging capabilities. This precision propulsion technology allows for rapid repositioning of Earth observation satellites, facilitating quick imaging of specific regions for applications in agriculture, forestry, and urban planning.

3. AI-Driven Descent Control in Extraterrestrial Exploration

The AI-driven Parachute Recovery System revolutionizes extraterrestrial exploration by enabling precise and adaptive descent control. This technology is essential for successful landings on celestial bodies like Mars, ensuring the safe deployment of scientific instruments and equipment for ongoing research missions.

4. Rapid Deployment of Observational Satellites for Crisis Management

The holistic integration of advancements enables the rapid deployment of observational satellites during crisis situations. This application is invaluable for monitoring humanitarian crises, tracking the movement of displaced populations, and providing real-time data for aid organizations to coordinate relief efforts effectively. The integration of Data Acquisition, Motor Firing, and Parachute Recovery Systems contributes to a versatile toolkit for addressing contemporary challenges with agility and precision.

5. Technology Testing for Space Missions

The Wireless Launch Control Avionics system serves as an ideal platform for testing new space technologies. Its wireless capabilities provide researchers with the flexibility to conduct controlled experiments, accelerating advancements in space mission instruments and components.

II. LITERATURE SURVEY

Sounding rockets, vital for scientific and research endeavors, demand cutting-edge Data Acquisition, Ground Control, and Firing and Recovery Systems to ensure mission success. This literature survey delves into the current state of innovation within each subsystem, emphasizing both the opportunities and necessities for inventing new technologies to enhance the performance and reliability of sounding rocket missions.

H. Chen et al., "Development of Data Acquisition System for Sounding Rockets,"

The focus is on advancing data acquisition technology in the context of sounding rockets. The study explores the design and development of a robust system for capturing, storing, and transmitting real-time data from onboard sensors. Notably, our project draws inspiration from their work, aiming to further innovate and overcome challenges in harsh flight conditions. Chen et al. highlight the significance of reliable data acquisition, aligning with our project's core objective. The literature underscores the need for precise and resilient data systems to enhance the success of sounding rocket missions. Our project, building upon this foundation, seeks to contribute advancements to the field of Data Acquisition and Recovery Systems.[1]

A. Smith and B. Johnson, "Advanced Launch Control Techniques for Sounding Rockets,"

The emphasis is on elevating launch control methods for sounding rockets. The study delves into cutting-edge techniques to enhance communication between ground control and the rocket during its flight. Inspired by their research, our project acknowledges the importance of wireless technologies and flexible control systems. Smith and Johnson shed light on the challenges faced by traditional wired systems, aligning with our project's exploration of Wireless Launch Control Systems. The literature underscores the opportunities for innovation in launch control, providing a foundation for our project's goal of contributing to the evolution of sounding rocket technologies. Building upon their insights, our project aims to explore and implement advanced launch control techniques for more efficient and adaptable sounding rocket missions.[2]

M. Patel and S. Lee, "Real-Time Telemetry System for Data Acquisition in Sounding Rockets,"

The primary focus lies on the development of a real-time telemetry system tailored for data acquisition in sounding rockets. The study delves into the intricacies of capturing, transmitting, and ensuring the timeliness of data from onboard sensors. Drawing inspiration from Patel and Lee's work, our project aligns with their commitment to achieving precise real-time data acquisition. The literature emphasizes the critical role of a dedicated telemetry system in the success of sounding rocket missions, providing a foundational perspective for our project's exploration of advanced Data Acquisition Systems. Building upon their expertise, our project aims to contribute advancements to the realm of real-time telemetry, enhancing the reliability and efficiency of data acquisition during sounding rocket flights.[3]

G. Zhang et al., "Integration of Inertial Navigation and GPS for Precise Launch Control of Sounding Rockets,"

The primary focus is on the integration of inertial navigation and GPS technologies to achieve precise launch control. The study explores the synergy between these navigation systems to enhance the accuracy of launch trajectories. Our project, influenced by Zhang et al.'s research, acknowledges the critical role of precise launch control in sounding rocket missions. The literature underscores the significance of integrating inertial navigation and GPS for optimal trajectory control, aligning with our project's exploration of advanced Launch Control Systems. Building upon Zhang et al.'s insights, our project aims to contribute advancements in the integration of navigation technologies, optimizing the launch control process for improved sounding rocket missions.[4]

H. Kim et al., "Autonomous Landing Control System for Sounding Rockets Using Machine Learning,"

The focal point is the development of an autonomous landing control system incorporating machine learning. The study explores how machine learning algorithms contribute to precise and adaptive control during the landing phase of sounding rockets. Drawing inspiration from Kim et al.'s work, our project aligns with the pursuit of autonomous and intelligent control systems for sounding rockets. The literature highlights the transformative impact of machine learning on the landing phase, resonating with our project's goal to explore and implement AI-driven technologies in Parachute Recovery Systems. Building upon Kim et al.'s advancements, our project aims to contribute innovations in autonomous landing control, enhancing the reliability and adaptability of sounding rocket landings.[5]

Constructive Criticism and Gap Identification

While the surveyed literature provides valuable insights, a common critique is the need for more explicit identification of the specific technical challenges and gaps within each subsystem of sounding rocket systems. The introduction sections lack clear articulation of the gaps addressed by the respective projects, making it challenging for readers to discern the precise motivations for innovation. For instance, in the case of the Data Acquisition System, there is a notable absence of detailed discussions on the challenges encountered in harsh flight conditions, hindering a comprehensive understanding of the technical obstacles. Moreover, the surveys often lack a nuanced exploration of potential limitations in the proposed technologies. For example, the reviews on Wireless Launch Control Systems and AI-driven Parachute Recovery Systems could benefit from a more in-depth discussion of potential drawbacks and real-world challenges. Additionally, there is a notable gap in the literature surveys regarding the integration of diverse technologies, such as combining advanced telemetry with AI-driven systems for a more holistic approach.

Furthermore, the surveys could enhance their impact by explicitly linking identified technical gaps to broader applications and implications for sounding rocket missions. This would provide a clearer roadmap for future research and development efforts. Overall, refining the literature surveys to explicitly address and dissect technical challenges, explore limitations, and establish stronger connections between identified gaps and their broader implications will significantly enhance their depth and impact.

III. OBJECTIVE AND METHODOLOGY

The development team consisted of three senior undergraduate engineering students from Electronics and Communication Engineering, The team was involved in developing embedded application software, system-specific hardware, and prototyping the systems. The workflow and implementation plan is discussed below.

A. Objectives

The objective of the project is to develop an effective test bench prototype of,

- A Data Acquisition System (DAQ) for a model-sounding rocket to record flight data from various sensor modules. Performing digital signal processing such as noise filtering, convolution, fourier transformations. Logging the sensor data into a report for later analysis. Real Time telemetry operation to visualize flight parameters at ground.
- A Firing and Recovery System (FRS) to ignite the rocket motor during launch sequence and parachute deployment system for rocket recovery assistance. AI powered environment adaptive algorithm to deploy parachutes for recovery.
- Development of an end-to-end wireless launch control avionics system (GCS) for sounding rockets. Providing a set of commands from the ground station to the onboard controller unit to facilitate the launch of a sounding rocket, Providing communication security and arming of sounding rocket, Status indication of sounding rocket operations using photodiodes and buzzers

The following diagram represents the team’s methodology to meet the objectives in a time effective manner.

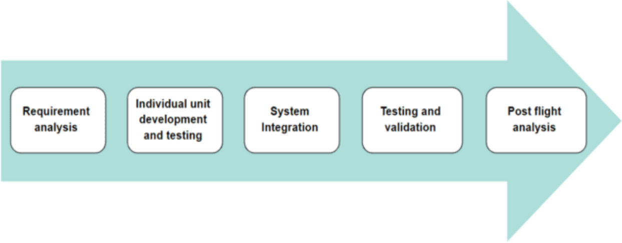


Fig.1. Proposed Methodology

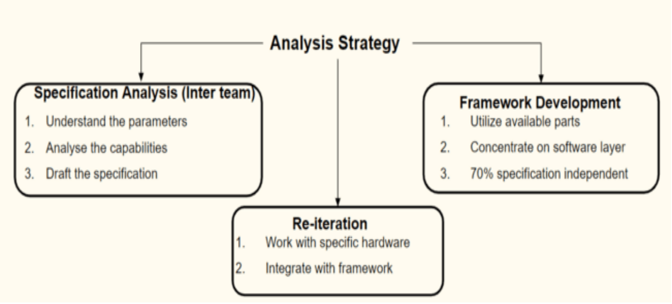


Fig.2. Development Analysis Strategy

B. System Requirement Analysis

The requirements of our system are divided into three types: Functional, Technical, and Operational. Functional represents the functionality requirement of the system, and operational represents the system's operating requirements. Technical represents the technical requirements of the system and their priority is divided into core, essential, and desired.

C. Proposed Methodology

The entire system is broadly divided into three co-operating systems, the Data Acquisition System (DAQ), the Ground Control System (GCS) and the Firing and Recovery System (FRS).

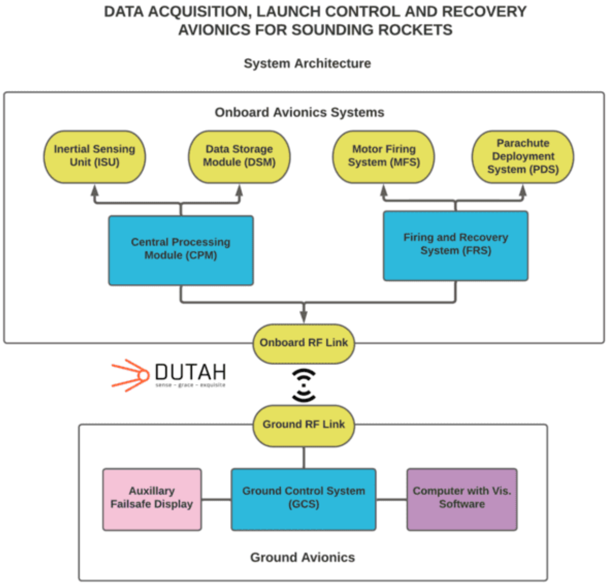


Fig.3. Overall System Design

IV. PROPOSED WORK MODULES

A. Data Acquisition System (DAQ)

All the sensors associated with the ISU are interfaced with the CPM. The CPM handles the data acquisition of the various sensor parameters. It writes the real time sensor data into the external solid state drive of the DSM.

STM32F446RE microcontroller serves as the main hardware of the CPM.

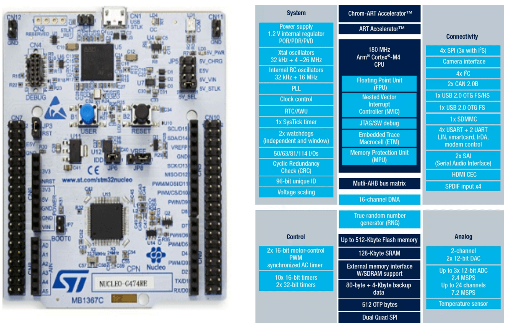


Fig.4. STM32 Microcontroller

ISU Design

The Inertial Sensing Unit (ISU) is responsible for the acquisition of various flight parameters of the rocket on-board. Each parameter could be measured with the on-board sensors that are connected to the CPM. The sensors will generate electric signals that are equivalent to the variation in the physical property. The generated electric signals are conditioned using conditioning circuits. The conditioned analog signals will be converted to digital signals with the use of ADCs. The signals will be transmitted to the CPM using digitals communication interfaces such as SPI, I2C, Serial protocol, etc. Some sensors are directly connected to the microcontroller's internal ADC ports.

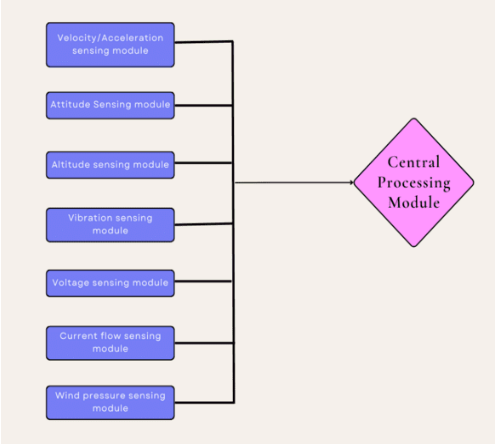


Fig.5. ISU Design

Table 1. ISU Parameters and Implementation

Parameter	Objective	Implementation
Altitude	Measures the rocket's altitude	Barometer
Pressure	Analyze the atmospheric pressure	Pressure Sensor
CPM Voltage	Examine the Voltage drain in the CPM and the sensors	Voltage Sensor
CPM Current	Evaluate the current across the CPM and sensors	Current Sensor
High Voltage	Examine the Voltage drain in the high power line	Voltage Sensor
High Current	Evaluate the current across the high power line	Current Sensor
Temperature	Quantifies the temperature of the system	Temperature Sensor
Movement and Orientation	Detect changes in device orientation and rotation	Gyro and Accelerometer
Motor Temperature	Studies the motor temperature	Motor Temperature Sensor
Vibration	Detects the Vibration of the System	Vibration Sensor
Location	Determine the current position of the rocket	GPS
Time and Date	To map the sensor data with time	Real Time Clock

Atmospheric Pressure Sensing: The purpose of the pressure sensing module is to collect data of Pressure and Altitude when the rocket is fired in addition to temperature data as it is embedded with the sensor module.
Pressure Sensing Module: BMP180 Pressure Sensor
Communication Interface: I2C (SDA and SCL Interface)

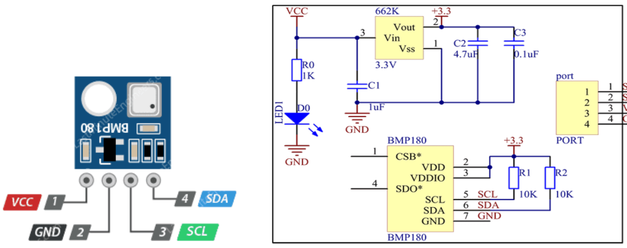


Table 2. BMP Pin Config

BMP180	STM32
Vin	3.3V
GND	GND
SDA	BP7
SCL	BP6

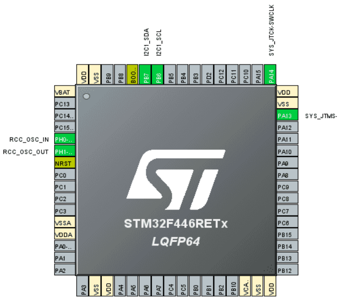


Fig.6. BMP180 Pinout, Schematics

The Pressure Sensing Module in our project plays a major part in determining the parameters such as Temperature, Pressure and Altitude. The value of the pressure is obtained from the digital barometer present in the sensing module and the altitude range can be found using the pressure values observed. This continuous analysis of pressure and altitude gives out the state of our sounding rocket starting from firing to recovery. STM32 Microcontroller is the Central Processing Unit for data acquisition tasks.

Table 3. Sensor Specifications

Characteristics	Specifications	Description
BMP180 Sensor Output	3.3V	Analog Output Voltage less than 5V
Operating Voltage	1.8 v - 3.6V	Compatibility with the microcontroller
Operating Current	>5µA	Current depends on the mode of operation of the sensor

Power Consumption	3 µW	Ultra low power Consumption
Conversion Time	5-7.5 ms	Conversion depends on the mode of operation of the sensor
Operating temperature	-40 to 85 °C	Temperature depends on external Factors
Size	5.08x 3.81x 1.587(cm)	Compact and Compatible with STM Microcontroller

Table 4. I2C Addressing Nodes

A0	A1	A2	A3	A4	A5	A6	A7	W/R
1	1	1	1	0	1	1	1	1/0

I2C Communication Protocol is enabled and the pinout and clock for our system is configured in the IDE. The firmware deployment and debugging is done for the pressure sensing module

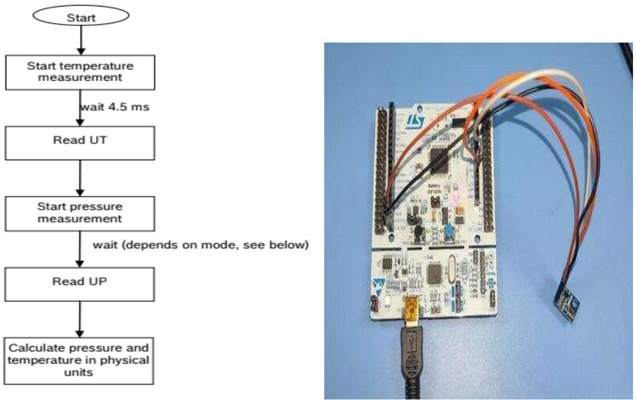


Fig.6. BMP180 STM Configuration

Position Sensing: GPS (Global Positioning System) is a satellite-based navigation system that provides location and time information anywhere on the earth that uses National Marine Electronics Association (NMEA) Protocol to transmit the data received from satellites. The STM32 microcontroller receives the GPS data from the GPS module and processes it to extract the location and time information. In our scope GPS data is used to get the appropriate location of our rocket. The Recovery of the rocket can be done based on the location obtained from GPS.

The GPS Module gives the data information such as latitude, longitude with direction and altitude. Time information in hours, minutes, seconds and Date information in date, month, year.

Table 5. GPS Specification

S1216V8 GPS RECEIVER MODULE		
Characteristics	Specifications	Description
GPS Module Output	3.3V	Analog Output Voltage less than 5V
Operating Voltage	3.3 V - 5V	Compatibility with the microcontroller
Operating Current	>33mA	Current depends on the mode of operation of the sensor
Channels Available	167	Channels used for data acquisition tasks
Power Consumption	3 µW	Ultra low power Consumption
Conversion Time	1 s	Conversion depends on the mode of operation of the sensor
Operating temperature	-40 to 85 °C	Temperature depends on external Factors
Size	16.0x 12.2mm	Compact and Compatible with STM Microcontroller

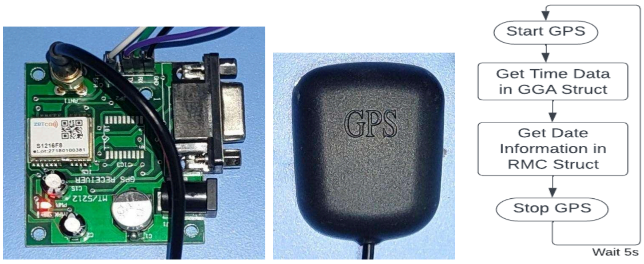


Fig.7. GPS Receiver Module, Antenna, Algorithm

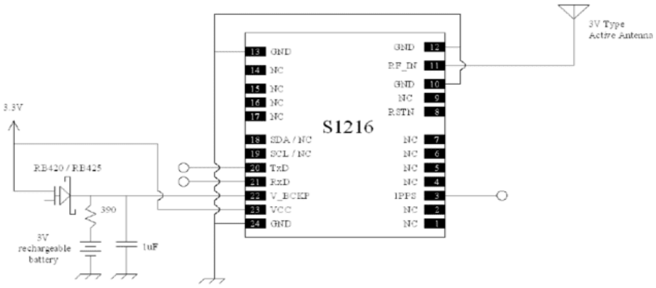


Fig. 8. GPS Receiver Application Circuit

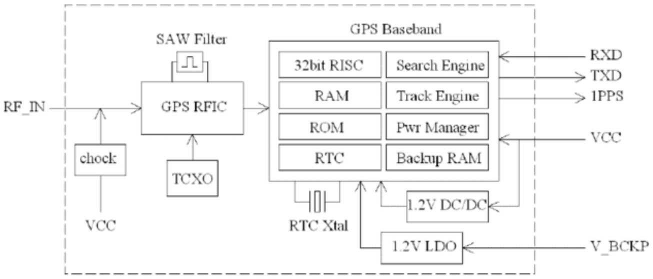


Fig. 9. GPS Receiver Block Diagram

Table 6. GPS Config

GPS	STM32
Vin	3.3V
GND	GND
Tx	PA10
Rx	PA9

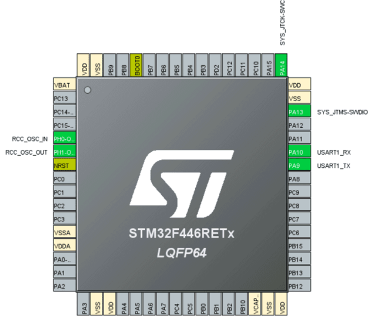


Fig. 10. GPS STM Configurations

Voltage Sensing: The voltage of the CPM and high power source will be continuously monitored by the respective voltage sensing modules. Each module consists of a voltage divider circuit that maintains the output signal limit in the range of 0 to 3.3V DC. This makes the direct interfacing of the voltage sensing module with the microcontroller's internal ADC possible. An opto-coupler is there in the module to enable and disable the voltage divider circuit which reduces the power drain and consumption[6].

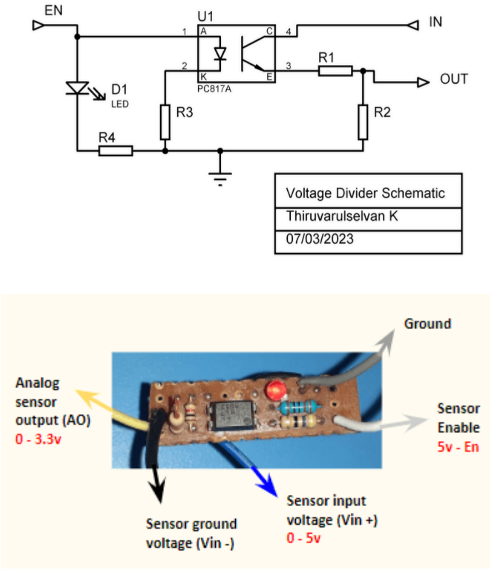


Fig. 11. Voltage Sensor Module Schematic & Voltage Sensor Module

Table 7. Voltage Sensor Specification

Characteristics	Specifications	Description
Operating voltage	3.3 V	Enabled by GPIO port of the microcontroller
Sensing Voltage (CPM)	0.0V to 5.0V	Voltage divider designed to measure up to 5V
Sensing Voltage (High Power)	0.0V to 9.2V	Voltage divider designed to measure upto 9.2V
ADC data size	12 - bit	Data resolution in the range of 0 to 4095
ADC transfer mode	DMA interrupt	Direct Memory Access reduces CPU usage

Table 8. Voltage Sensor Configuration

Voltage Sensor	STM32
Sensor Enable	3.3V
Gnd	Gnd
Vin	From voltage source
Vin +	From voltage source
AO	PA0

Current Sensing: Current sensing module available at a wide range of current rating gives out the current values of the load connected across the current sensors through some voltage conversions. The raw voltage obtained from the sensor is compensated to get the current values. The current sensor is incorporated with the motor firing system as well as the parachute deployment system of the sounding rocket to measure the current across the ignition material.
Current Sensing Module: ACS712 Current Sensor
Communication Interface: Serial Peripheral Interface
Analog Interface can be implemented using Poll For Interrupt and DMA(Direct Memory Access Method)[7].

Table 9. Current Sensor Specification

ACS712 CURRENT SENSING MODULE		
Characteristics	Specifications	Description
DHT22 Output	3.3 V	Analog Output Voltage less than 5V(Serial Data)
Operating	4.5V to 5.5V	Compatible with the

Voltage		microcontroller
Operating Current	13mA	Current depends on the mode of operation of the sensor
Resolution	16 bit	Accuracy may depending on other external factors
Response Time	5µs	Conversion depends on the mode of operation of the sensor
Current sensing range	5A, 20A	Current rating based on the load connected
Temperature Rating	-40°C to 85°C	Temperature depends on external Factors
Size	1.3x 3.9mm	Compact and Compatible with STM Microcontroller

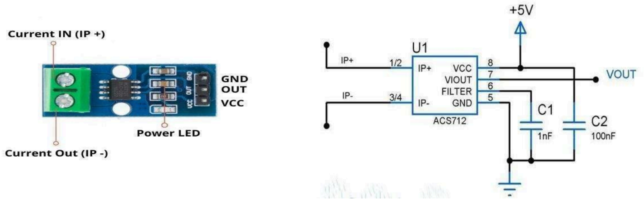


Fig. 12. ACS712 Current Sensor Module and Schematic

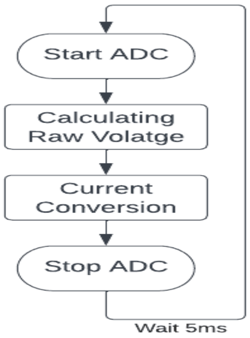


Fig. 13. Current sensing algorithm

Table 10. ASC712 Config

ASC712	STM32F44RE
Vin	3.3V
GND	GND
Out	PA0

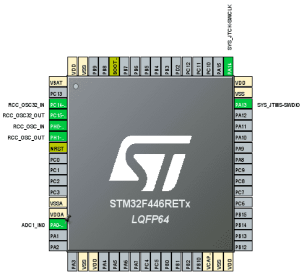


Fig. 14. Current Sensor STM Configurations

Atmospheric Temperature and Humidity Sensing:

DHT22 Sensor is a cost efficient and effective temperature and humidity sensing module. The air humidity is measured by using a capacitive humidity sensor and to measure the temperature an thermistor is embedded inside the sensor. Temperature and humidity of the battery and internal composition of the rocket should be monitored so that other subsystems embedded within the Main Controller Unit functions uninterruptedly.

Temperature Sensing Module: DHT22 Temperature and Humidity Sensor

Communication Interface: Serial Peripheral Interface- GPIO (General Purpose Input Output)

The DHT22 temperature and humidity sensing module collects data of Temperature and Humidity. Temperature in terms of degree Celsius and humidity in terms of Percentage

Table 11. DHT22 Sensor Specification

Characteristics	Specifications	Description
DHT22 Output	3.3 V	Analog Output Voltage less than 5V(Serial Data)
Operating Voltage	3.5V to 5.5V	Compatible with the microcontroller
Operating Current	0.3mA	Current depends on the mode of operation of the sensor
Resolution	16 bit	Accuracy may depending on other external factors
Conversion Time	2 s	Conversion depends on the mode of operation of the sensor
Temperature Range	-40°C to 80°C	Temperature depends on external Factors
Humidity Range	0% to 100%	Output of the DHT22 Sensor
Size	12x 23.5mm	Compact and Compatible with STM Microcontroller

Table 12. DHT22 Config

DHT22	STM32
Vin	3.3V
GND	GND

DHT22	STM32
Data	PA1

Communication Protocol Used: Serial Peripheral Interface.
GPIO Pin Configuration is used to collect the Temperature and Humidity data.
Firmware libraries Used: DHT.h library

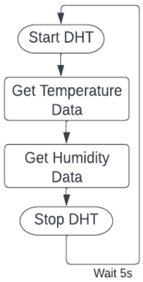


Fig 15. Atm. Temperature and humidity sensing algorithm

Movement and Orientation Sensing: Movement and the orientation of the rocket in three dimensional space is analyzed with the implementation of accelerometer, gyroscope and magnetometer. The MPU6050 is a three in one integrated module that encompasses all these measurement devices. The MPU6050 communicates to the microcontroller using the I2C serial interface. The acceleration data in three degrees (Ax, Ay, and Az) and orientation data in the three degrees (Gx, Gy, and Gz) will be acquired.

Table 13. MPU6050 Sensor specification

Characteristics	Specifications	Description
Operating voltage	2.37V to 3.46V	Compatible with microcontroller's operating voltage
Operating current	3.9 mA	Supported with microcontroller
Serial interface speed	Fast mode – 400 kHz Standard mode – 100 kHz	Standard mode is used for our application
I2C Address	AD0 = 0 -> 1101000 AD0 = 1 -> 1101001	
Accelerometer sampling rate	Fast mode – 8 kHz Standard mode – 1 kHz	Standard mode is used for our application
Gyroscope sampling rate	Standard mode – 1 kHz	

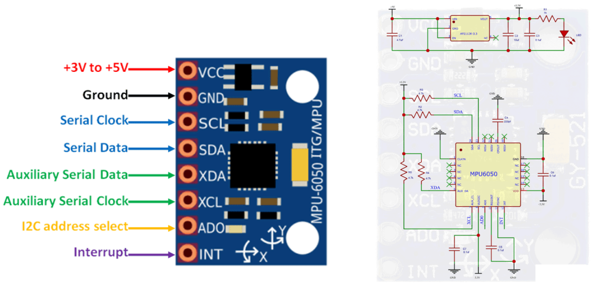


Fig. 16. MPU6050 module pinout

Table 14. Pin Configurations

MPU6050	STM32
VCC	5V
Gnd	Gnd
SCL - Serial Clock	PB6
SDA - Serial Data	PB7

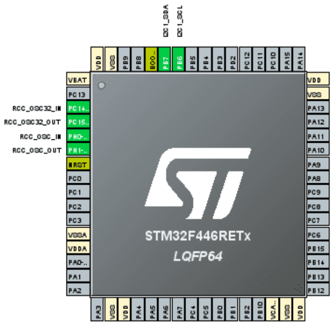


Fig. 17. MPU STM Interface

Motor Temperature Sensing: Most sounding rockets use solid rocket motors (propellants) and their temperature has to be monitored in order to avoid overheating and measure the performance. The team has proposed the application of thermocouple for measuring the motor temperature. The change in resistance of the thermocouple is measured and converted into digital data. SPI communication is utilized to send the data from the sensor to the microcontroller[8].

Table 15. Temperature Sensor Specification

Characteristics	Specifications	Description
Frame Format	Motorola	SPI Interface
Data Size	16 bit	Built-in 12 bit ADC converter
First bit	MSB bit	14th bit of temperature data
Baud Rate	45 MBits/s	-
Clock Phase	1 Bit	-

Clock Polarity	Low	-

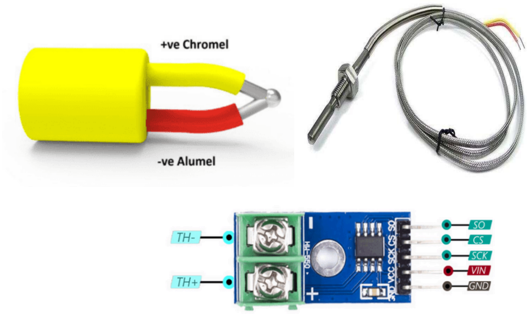


Fig. 18. Thermocouple K type and MAX6675 Module

Table 16. Pin Configurations

MAX6675	STM32
VCC	5V
GND	GND
SCK - Serial Clock	PA5
SO - Serial Data	PA6

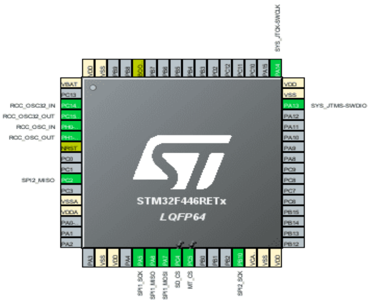
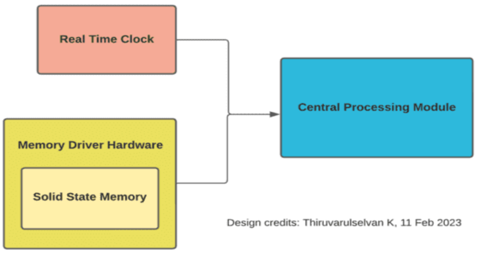


Fig. 19. MAX6675 STM Interface

DSM Design: The Data Storage Module (DSM) consists of a solid state memory and a driver hardware that are connected with the CPM. The data can be written, modified, and read from the solid state memory using the memory driver. The DSM has a Real Time Clock (RTC) to map all the ISU data with respect to time and write it into the solid-state memory.



Design credits: Thiruvarulselvan K, 11 Feb 2023

Fig. 20. DSM Design

Memory Driver Hardware: SD card is used for the solid state memory and the supporting SD card module is used. The AR017-DATA-LOG is an SD card driver module used in our project. It supports FAT16 and FAT32 file management systems and it has an in-built RTC but it's not used for simplification and modularity reasons. The driver module uses SPI communication to communicate with the CPM.

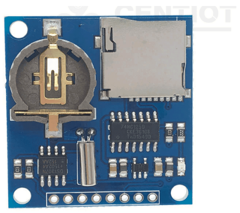


Figure 21. SD Card Module Table Setup

Real Time Clock: RTC provides real-time time and date information to the CPM. Upon power shutdown the RTC has its own internal memory to store and continue generating the time information. The DS3231 is a digital RTC module and it provides the time information for our project's application. The I2C interface is utilized for the RTC-CPM communication.

Table 17. RTC Module Specification

Characteristics	Specifications	Description
Operating voltage	3.3V to 5.0V	CPM compatible
Clock accuracy	2 ppm	Error is about 1 min
Realtime parameters	7 data	seconds, minutes, hours, day, date, month and year
Storage capacity	32K	Uses AT4C32 memory chip
I2C Speed	400KHz	At 5V

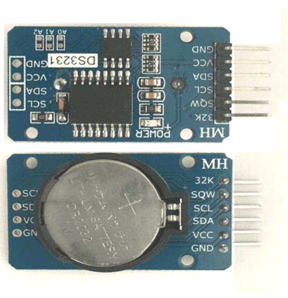


Fig. 22. RTC Module

B. Ground Control System(GCS)

The GCS receives input through the user interface and continuously communicates with the CPM to keep the launch sequence live and functioning. The Motor Firing System consists of two subunits: the ground unit and the on-board unit. The ground unit consists of several components for firing the motor; these components ensure the safe launch of the rocket. The main component is the microcontroller which is a STM based controller named STM32F446RE Nucleo which controls the whole process of the ground station. The other components include Security key, Arm Switch, Launch Switch and finally kill switch. As we choose wireless communication between ground station and on-board unit an RF link is established for communication.

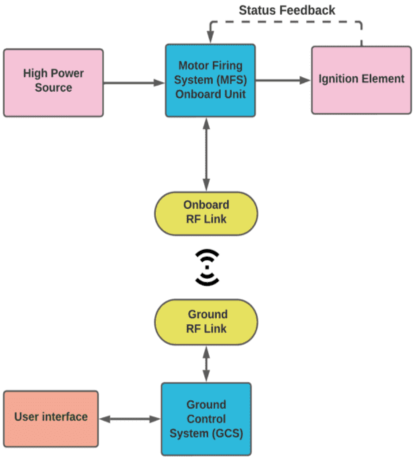


Fig. 23. GCS Design

GCS User Interface Model: The MFS receives input through the user interface and continuously communicates with the CPM to keep the launch sequence live and functioning. The Motor Firing System consists of two subunits: the ground unit and the on-board unit. The ground unit consists of several components for firing the motor; these components ensure the safe launch of the rocket. The main component is the microcontroller which is a STM based controller named STM32F446RE Nucleo which controls the whole process of the ground station. The other components include Security key, Arm Switch, Launch Switch and finally kill switch. As we choose wireless communication between ground station and on-board unit an RF link is established for communication.

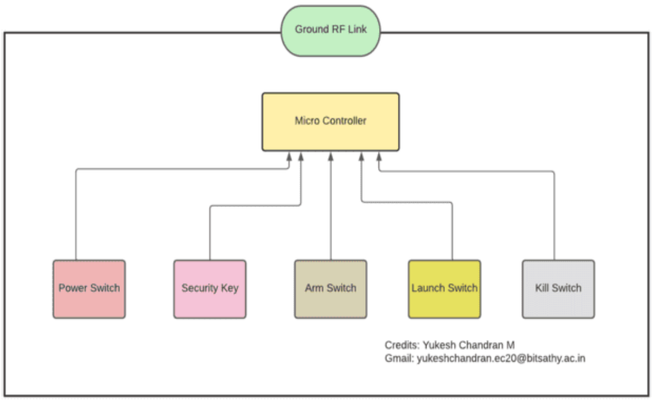


Fig. 24.GCS User Interface

Ground Station Algorithm: The interface we designed consists of a security key for authentication purposes which checks for unauthorized functioning of the system. When the arm switch is turned on it verifies the pre-flight checklist for any malfunction of the system. If the system performance is stable. Launch switch is used to trigger the igniter in the on-board unit. In case any malfunction happens, a kill switch is used to terminate the whole process and restart the sequence from beginning.

Fig. 25. GCS Firing Sequence Algorithm

GCS Sequence States:
Initialization – Sends the initial bytes to the onboard computer and waits for feedback. The preflight check is performed onboard.
Error – Initialization error, Kill activated, custom error states
Security OK – Security key is enabled
Arming – Commanding the onboard computer to enable the ignition drivers ready to fire.
Launching – Commanding the ignition drivers to release charge in the ignition element

User Interface components

Key switch - It is a rotary type of single pole single throw switch used to initiate the algorithm.

Multi Color LED – Indicates the various states of the launch sequence.

Buzzer – Sound indication to the different states

Toggle switch –SPST switch to input the ARM command to the system.

Kill switch – Terminate the launch sequence upon emergency malfunction situations. Launch triggers – Push trigger switch for activating the ignition charges

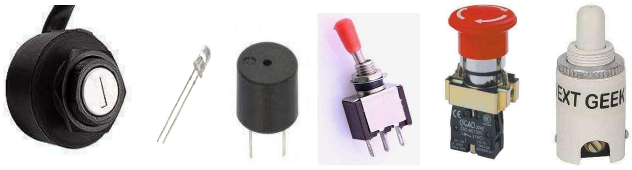


Fig. 26. User Interface Components

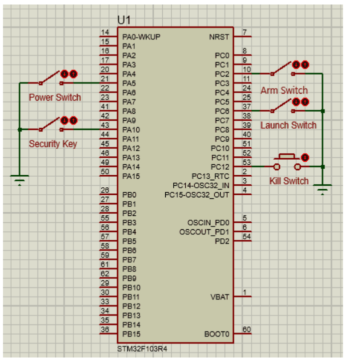


Fig. 27. GCS User Interface Schematic

Kill Mechanism: In the event of any malfunction, the kill switch interface can be used to entirely terminate the launch sequence and put a halt to the ignition of the motor. This is realized through external interrupts in the microcontroller. Once the Kill Interrupt Service Routine is called, the sequence state is turned to Error mode and the onboard ignition drivers are disabled.

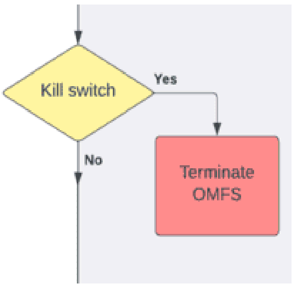


Fig. 28. Kill Interrupt Mechanism

RF Link Design: RF wireless communication is established between the onboard and ground nodes using Xbee based RF hardware. This hardware utilizes the full potential of Zigbee Mesh protocol to provide low latency, reliable and secure communications[10].

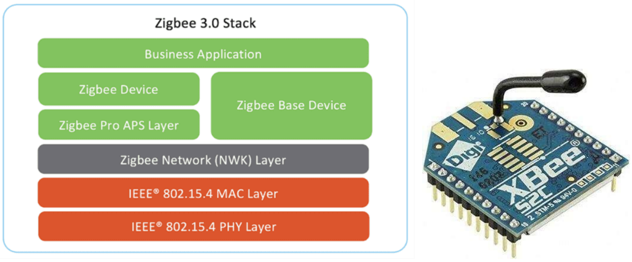


Fig. 29. Xbee SC2 Module

Status Indication Unit: The status Indication unit consists of Arduino and LED. The unit is isolated from the main microcontroller as if the performance of status indication is carried out using the main controller leads to latency in the launch sequence and may lead to some delay in the operations. So, The arduino nano is an interface using UART protocol for effective communication between the micro controller and the indication of multi color led is carried out by arduino nano.

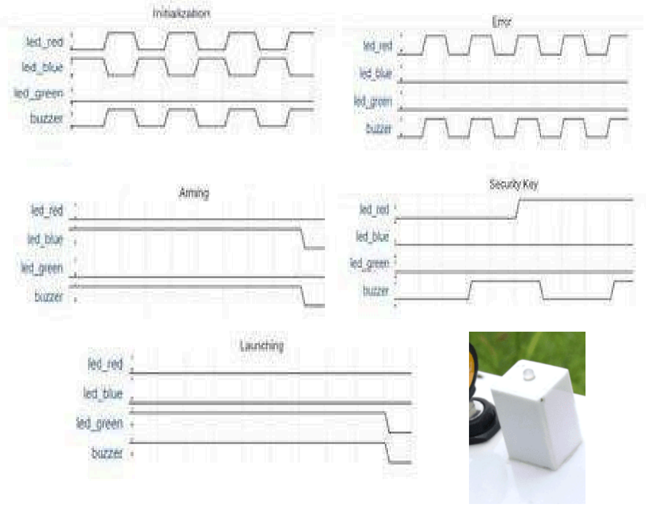
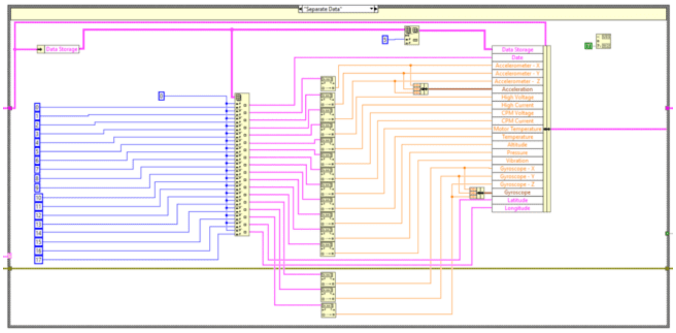
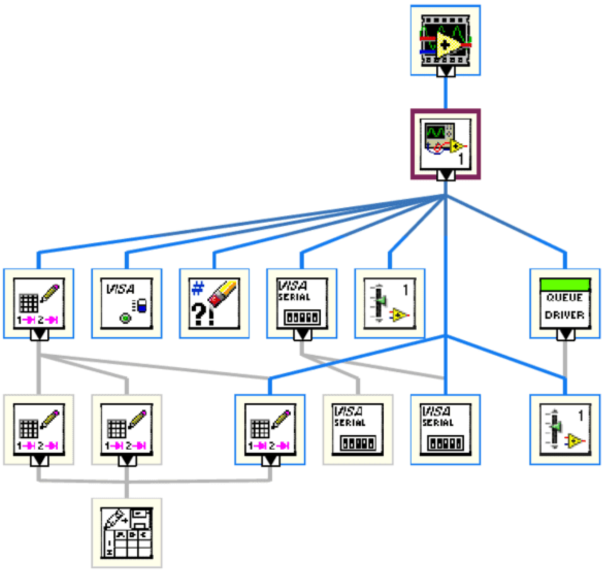


Fig. 30. GCS Indication LED and Timing Diagram

Ground Data Visualization tool: A LabVIEW based data visualization tool was developed to receive, perform data integrity checks, parse the data and visualize them.





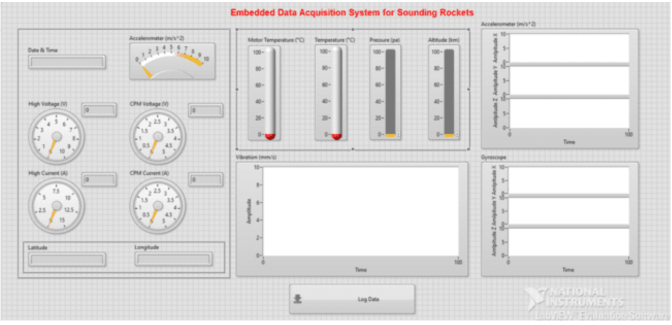


Fig. 31. LabVIEW Data Visualization

C. Motor Firing and Recovery System (FRS)

The FRS executes the rocket's launch sequence by controlling the ignition element's firing and propels the rocket into the atmosphere. It is composed of several subsystems that work together to ensure the motor ignites reliably and safely and the sub system consists of Igniter, Electrical System, Control System and Safety System. The igniter is a small device that is responsible for initiating the rocket motor's ignition sequence. The electrical system consists of the various components that provide power to the igniter and ensure it fires at the right time. This includes the battery, the wiring, the switches, and the control electronics. The control system is responsible for ensuring that the igniter fires at the correct time, based on the rocket's flight plan and other parameters. The safety system is designed to prevent accidental firing of the igniter, which could lead to a catastrophic explosion. The safety system may also include a manual override that allows the rocket to be safely disarmed in the event of an emergency. Overall, the motor firing system for a sounding rocket is a complex and critical component that requires careful design and testing to ensure reliable and safe operation.

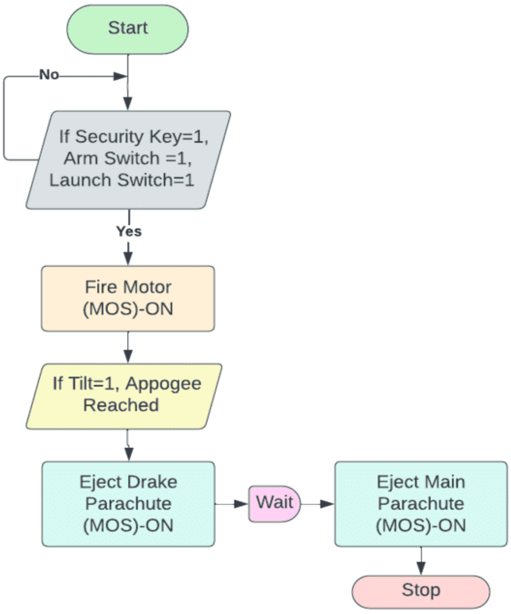


Fig. 32 Firing and Recovery high level algorithm

Motor Firing System: When a model rocket uses spark ignition, an ignition mechanism creates a spark or heats an electrode to a high temperature. The ignition system consists of two subunits: the ground unit and the on-board unit. The specifications for this module depend on the rocket's motor. The system consists of the Lithium ion battery, Mosfet circuit and a nichrome wire. The M2020 Cesaroni motor is the reference propulsion element. All specifications are compared to the reference motor for the ignition system.

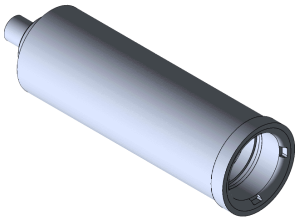
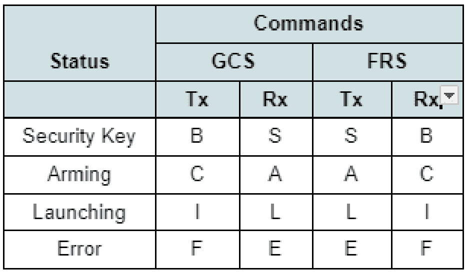


Fig. 33. M2020 Cesaroni motor CAD model

Table 18. Ignitor Specification

Characteristics	Specifications	Description
Igniter Resistance	1.4 ohm (1 to 2 ohm per inch)	Depends on the thickness of the Ni-chrome wire used.
Operating Voltage	1.50 v - 5.0V	Compatibility with the microcontroller
Operating Current	>10A	Can be up to 10 or 20 amps depending on the specific igniter and rocket motor
Power Consumption	High	Consumption is high due to high resistance
Operating temperature	High	Temperature – 250-300 degrees Celsius
Size	1 inch	
Maximum No-fire current	<40mA	

Xbee Transmission and Reception: Xbee RF Module is used to Receive the commands that are sent from the GCS. XCTU Software is used to configure both the Xbee's whichXbee operates based on Zigbee RF Protocol. Specific Commands are assigned for each state such as Security Key Authentication, Arming and For launching. The data in the form of Characters are transmitted wirelessly through Radio Frequency Bands.



Status	Commands			
	GCS		FRS	
	Tx	Rx	Tx	Rx
Security Key	B	S	S	B
Arming	C	A	A	C
Launching	I	L	L	I
Error	F	E	E	F

Fig. 34. Motor Firing Command Sequence

Recovery system:

Fig. 35. PDS Prototype

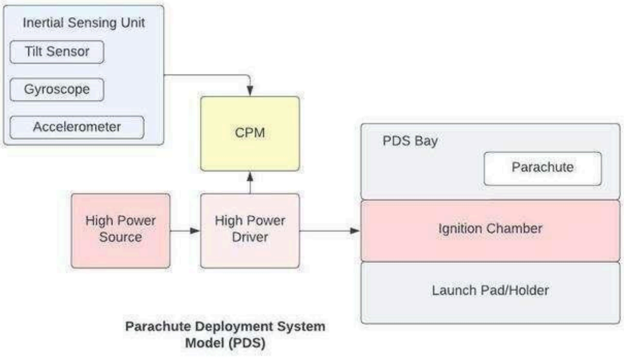


Fig. 36. PDS Design

PDS Mosfet Driver: Lithium Ion Batteries are used to provide High Power to drive the MOSFET Module. Parameters like Tilt, Acceleration, Velocity (Altitude and Attitude) obtained from ISU are used to predict the trajectory and projectile. When a tilt is detected or a maximum apogee reached a drake parachute is ejected. A high power MOSFET Driving Module is used to ignite the chamber for the ejection of the Parachute. After a perigee is obtained and when the rocket starts to descend another MOSFET Module is used to ignite the main parachute.

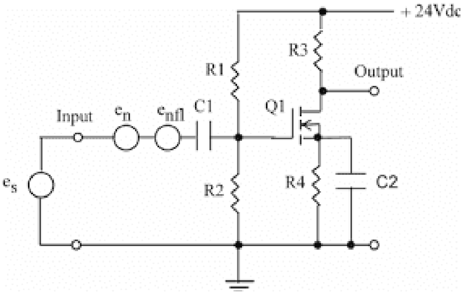


Fig. 37. MOSFET driver schematic

D. Avionics Bay Design and Rocket Model

The avionics bay is designed to carry the DAQ, GCS, and FRS hardware modules in a single unit. It consists of a two-stack design with circular discs on its side for support. A more advanced hardware design was suggested by our guide and consulted experts which involved designing and fabricating Printed Circuit Boards for the entire avionics. KiCAD PCB design tool was utilized for designing hardwares and the institution's in-house PCB milling equipment was used for fabricating the hardware.

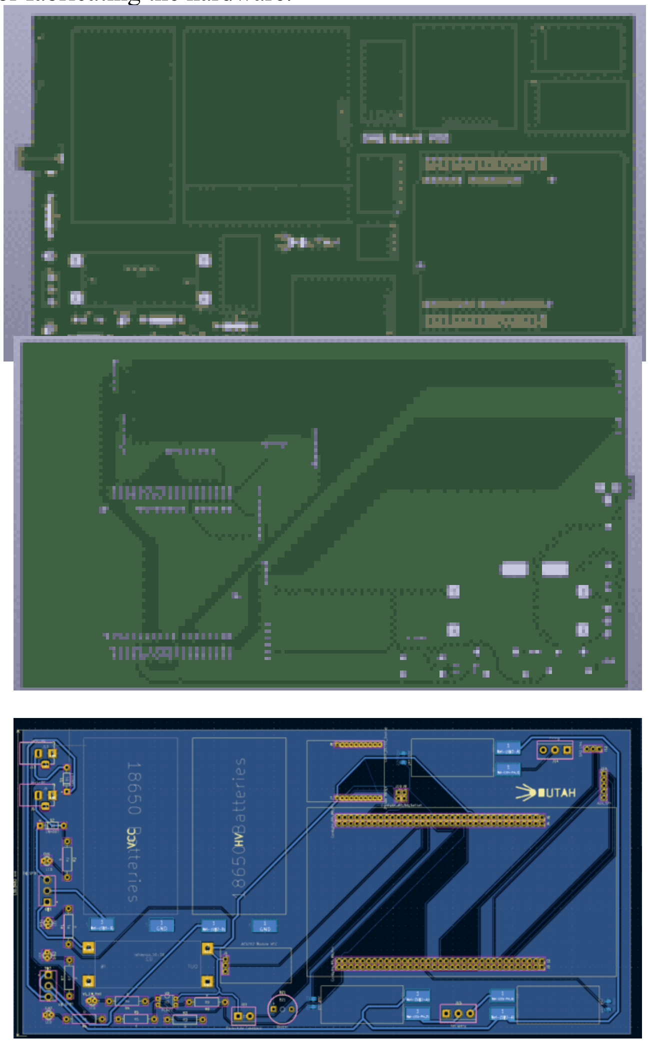
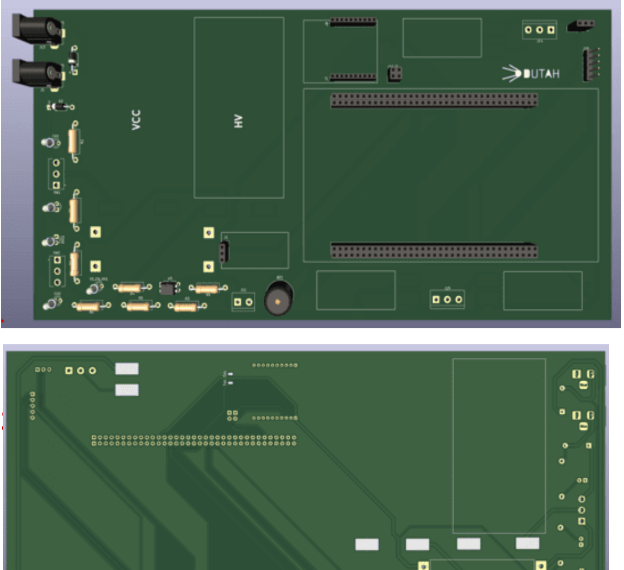


Fig. 38. DAQ unit PCB design



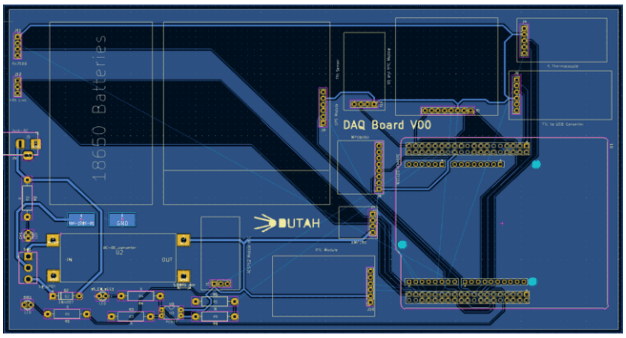
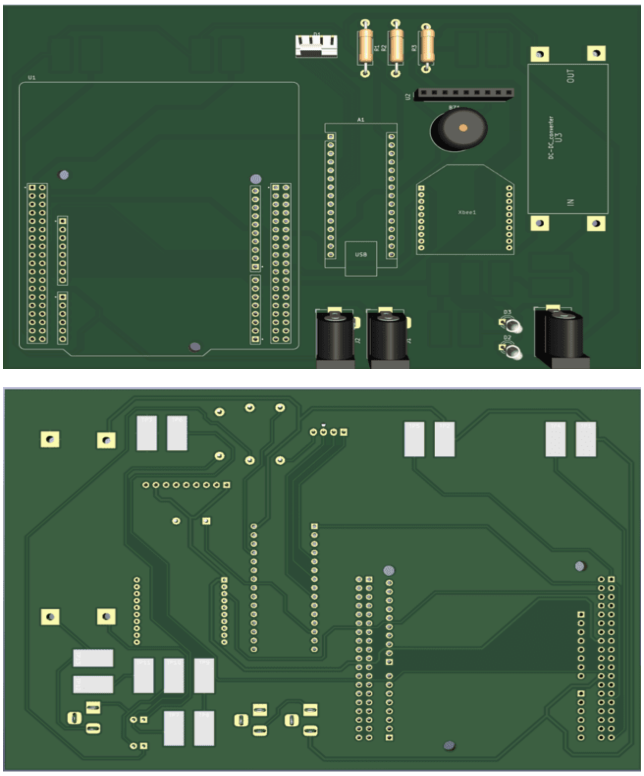


Fig. 39. FRS unit PCB design



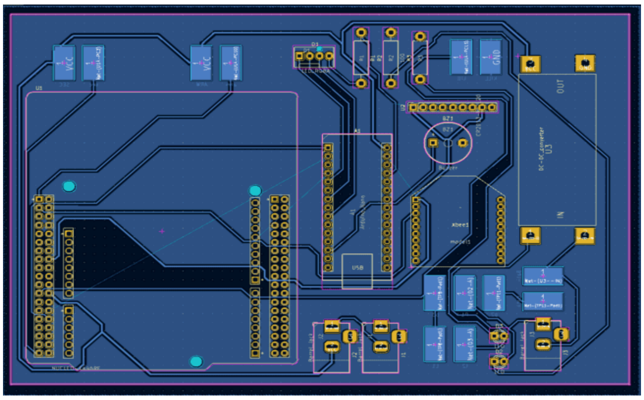


Fig. 40. GCS unit PCB design

V. RESULTS AND DISCUSSION

The working of every module is tested and validated for the accuracy and truthfulness of the data and feedback obtained from the subsystems by standardized procedures. The finalized results and inferences are obtained for continuous refinement.

A. DAQ - System Functionality Validation

Atmospheric Pressure Sensing

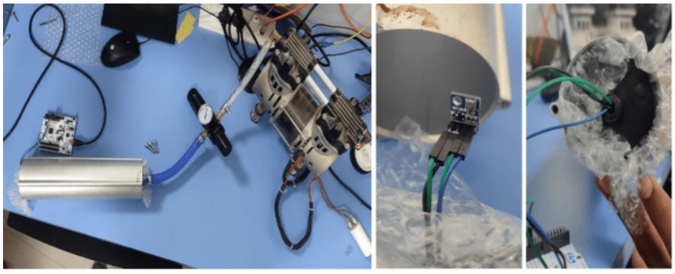


Fig. 41. Pressure Sensor Testing

Table 19. Pressure Sensor Observations

Barometer Test							
Process	**Test Case**	**Inference**	**Status**	**Remarks**	**Test data**	**Assigned to**	**Date of test**
BMP180 Barometric Pressure Sensor	Temperature	Considerable Change when temperature changed	Success	A little difference in Temperature than ideal value	https://drive.google.com/drive/folders/19QBS70N4IUW0LbEuv8fyV-u54PgVzFUI	Thishon J	2/28/2023
	Pressure	Considerable Change on Testing with increased pressure	Success	Variations in other degrees due to imperfection in testing		Thishon J	2/28/2023
	Altitude	Considerable change when moved to different location	Success	Variations in other degrees due to imperfection in testing		Thishon J	3/28/2023

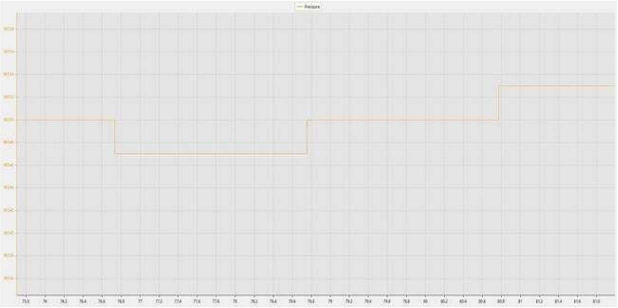


Fig. 42. Variation of Pressure With respect to time

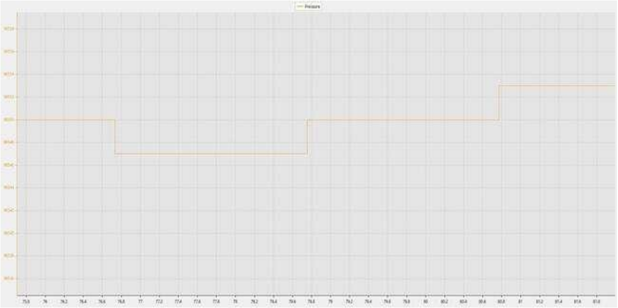
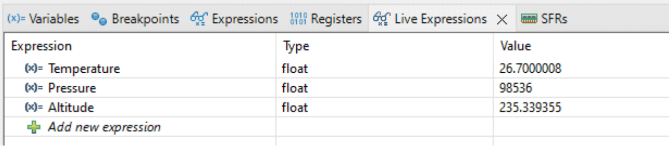


Fig. 43. Variation of Temperature With respect to time

Fig. 44. Variation of Altitude With respect to time



Expression	Type	Value
(x)= Temperature	float	26.7000008
(x)= Pressure	float	98536
(x)= Altitude	float	235.339355
Add new expression		

Fig. 45. Inference obtained from live expression in Cube IDE

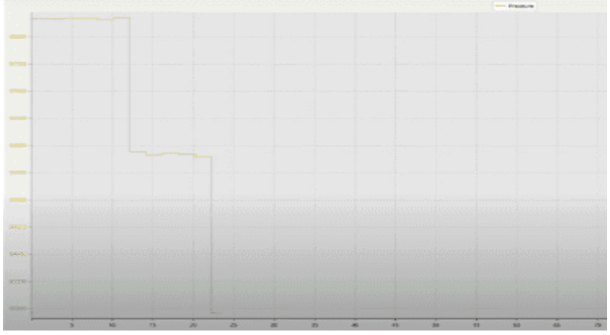


Fig. 46. When pressure reduced using compressor

Fig. 47. When pressure increased using compressor

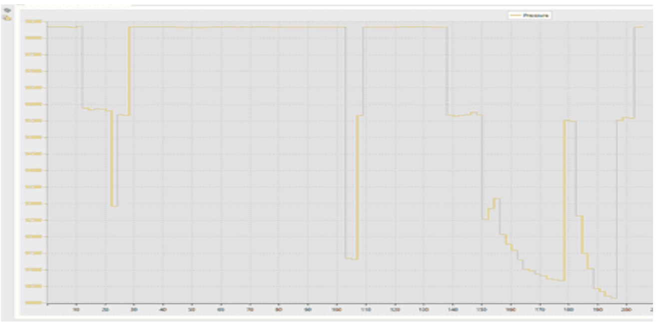
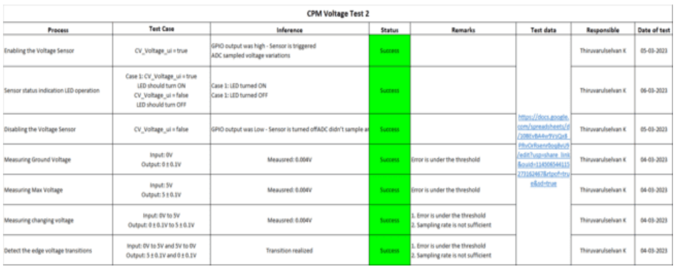


Fig. 48. Variation in Temperature

Temperature Sensing

Table 20. Temperature Sensor Observations



CPM Voltage Test 2							
Process	**Test Case**	**Inference**	**Status**	**Remarks**	**Test data**	**Responsible**	**Date of test**
Enabling the Voltage Sensor	CV_Voltage_ui = true	GPIO output was high - Sensor is triggered ADC sampled voltage variations	Success		https://docs.google.com/spreadsheets/d/[illegible]	Thiruvarulselvan K	05-03-2023
Sensor status indication LED operation	Case 1: CV_Voltage_ui = true LED should turn ON CV_Voltage_ui = false LED should turn OFF	Case 1: LED turned ON Case 1: LED turned OFF	Success			Thiruvarulselvan K	06-03-2023
Disabling the Voltage Sensor	CV_Voltage_ui = false	GPIO output was Low - Sensor is turned offADC didn't sample a	Success			Thiruvarulselvan K	05-03-2023
Measuring Ground Voltage	Input: 0V Output: 0 ± 0.1V	Meausred: 0.004V	Success	Error is under the threshold		Thiruvarulselvan K	04-03-2023
Measuring Max Voltage	Input: 5V Output: 5 ± 0.1V	Meausred: 0.004V	Success	Error is under the threshold		Thiruvarulselvan K	04-03-2023
Measuring changing voltage	Input: 0V to 5V Output: 0 ± 0.1V to 5 ± 0.1V	Meausred: 0.004V	Success	1. Error is under the threshold 2. Sampling rate is not sufficient		Thiruvarulselvan K	04-03-2023
Detect the edge voltage transitions	Input: 0V to 5V and 5V to 0V Output: 5 ± 0.1V and 0 ± 0.1V	Transition realized	Success	1. Error is under the threshold 2. Sampling rate is not sufficient		Thiruvarulselvan K	04-03-2023

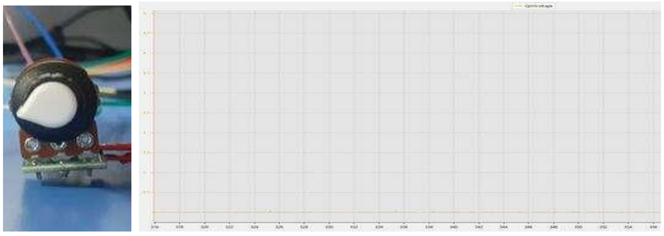


Fig. 49. Measuring ground voltage

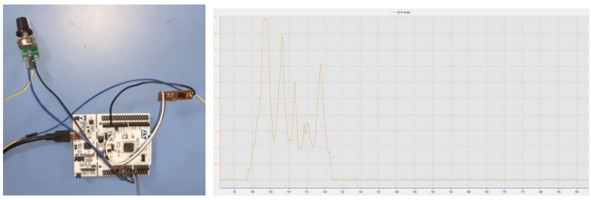


Fig. 50. Measuring voltage transition

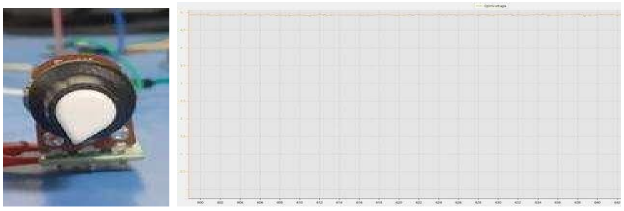


Fig. 51.Measuring maximum voltage

Current sensing:

Table 21. Current Sensor Observations

ACS712 Current Sensor Test							
Process	**Test Case**	**Inference**	**Status**	**Remarks**	**Test data**	**Assigned to**	**Date of test**
ACS712 Current Sensor	Raw Voltage	Considerable Change in Raw Voltage is observed when load connected across sensor	Success	Raw Voltage deviates to few mV	https://drive.google.com/drive/folders/187YgWv7YQLj_9Kkd9P2NY1MuQhrk1ht7	Thishon J	3/8/2023
	Current	Considerable Change in Current Observed when Load connected across the sensor	Success	Current value obtained is of high value need to be conditioned		Thishon J	3/8/2023

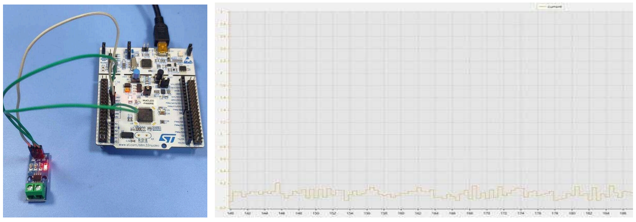


Fig. 52. No load condition

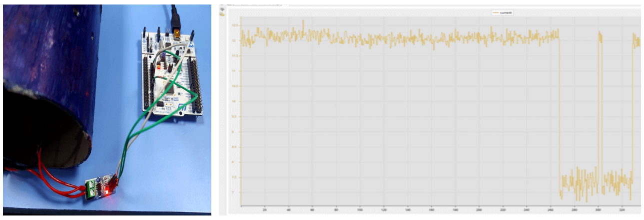


Fig. 53.With load condition

Position sensing:

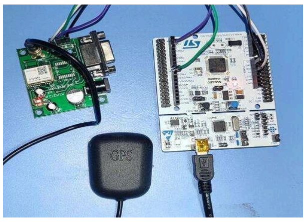
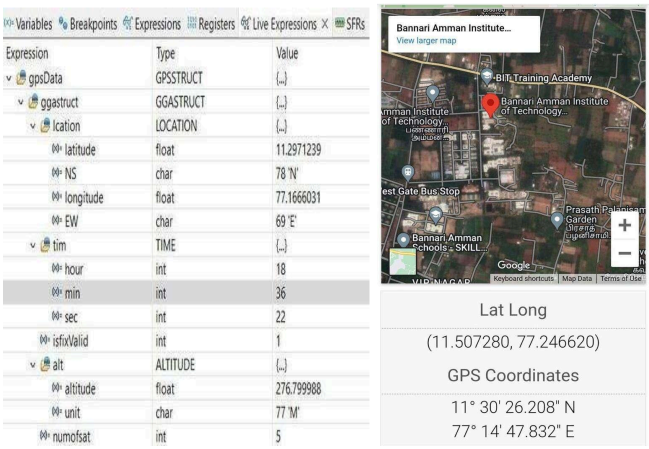


Fig. 54. GPS Test Setup



Expression	Type	Value
gpsData	GPSSTRUCT	{...}
ggastruct	GGASTRUCT	{...}
lcation	LOCATION	{...}
latitude	float	11.2971239
NS	char	78 'N'
longitude	float	77.1666031
EW	char	69 'E'
tim	TIME	{...}
hour	int	18
min	int	36
sec	int	22
isfixValid	int	1
alt	ALTITUDE	{...}
altitude	float	276.799988
unit	char	77 'M'
numofsat	int	5

Lat Long
(11.507280, 77.246620)
GPS Coordinates
11° 30' 26.208" N
77° 14' 47.832" E

Fig. 55. Obtained GPS Parameters

Temperature and Humidity Sensing:

The working of DHT22 Temperature and Humidity Sensing module tested using an DC fan. When the fan is in condition the Temperature and Humidity values get altered. Both temperature and Humidity decrease.

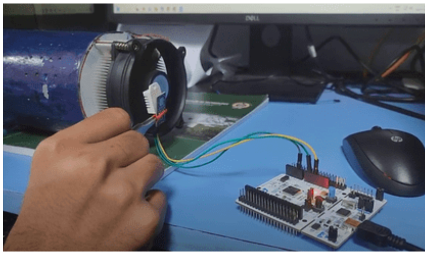


Fig. 56. Workbench Setup for Temperature Sensor Testing

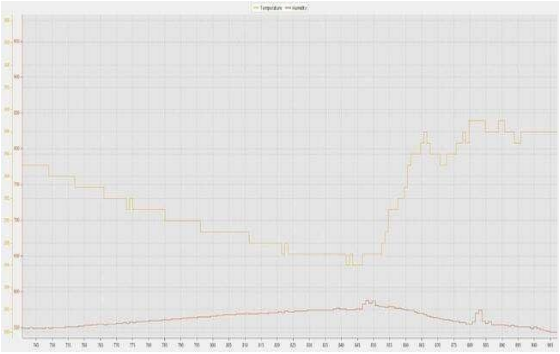


Fig. 57. Variation of Temperature and humidity

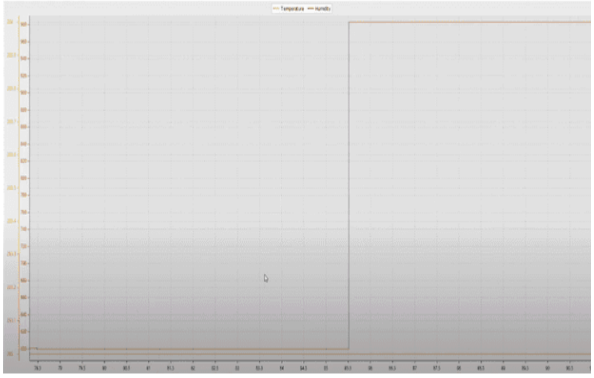


Fig. 58. Variation of Humidity with respect to time

Table 21. DHT22 Sensor Observations

DHT22 Test						
Process	**Test Case**	**Inference**	**Status**	**Remarks**	**Assigned to**	**Date of test**
DHT22 Temperature and Humidity Sensor	Temperature	Considerable Change when temperature changed	Success	A little difference in Temperature than ideal value	Thishon J	3/4/2023
	Humidity	Considerable Change in Humidity Percentage on testing	Success	Humidity value increased to a large extend when exposed to moisture	Thishon J	3/4/2023

Movement and Orientation sensing

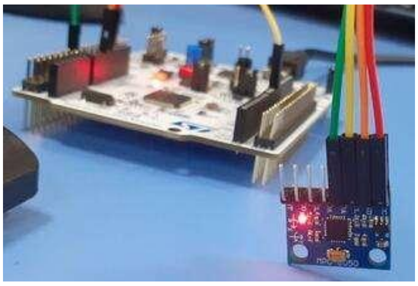


Fig. 59.Gyroscope Table Setup

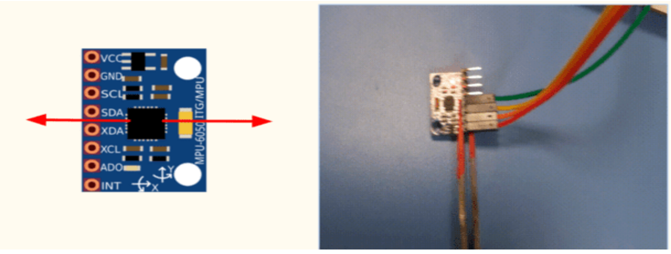


Fig. 60.Acceleration Sensing - X axis test

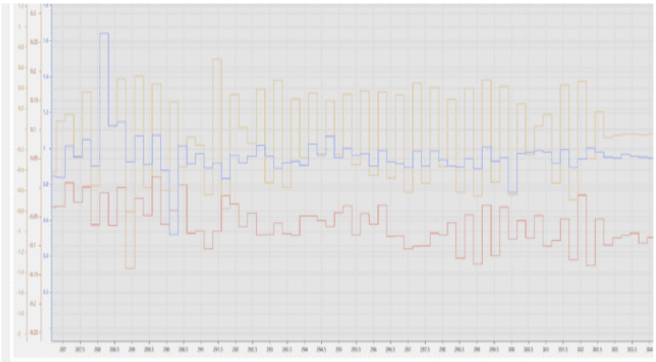


Fig. 61.Acceleration Sensing - X axis result

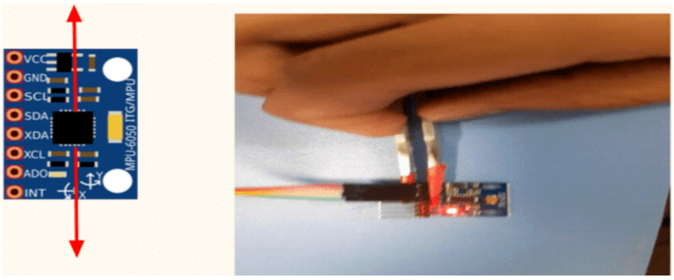


Fig .62. Acceleration Sensing - Y axis test

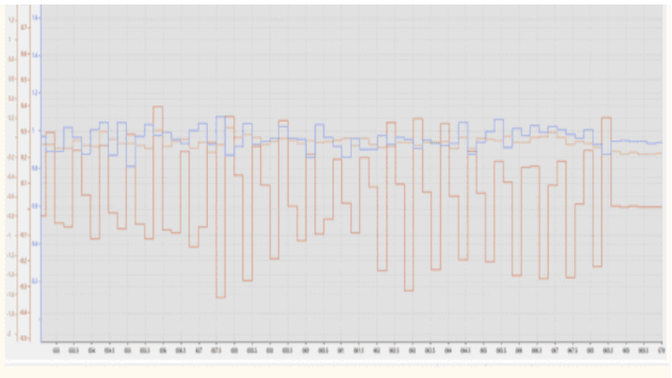


Fig. 63.AccelerationSensing - Y axis result

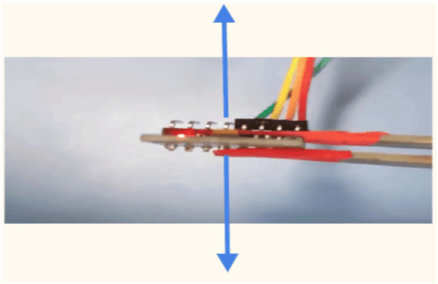


Fig. 64.Acceleration Sensing - Z axis test

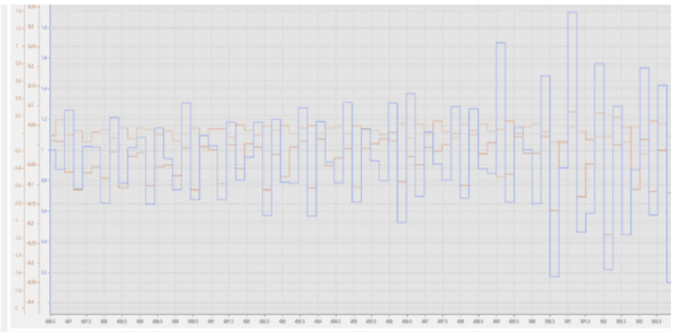


Fig. 65. Acceleration Sensing - Z axis result

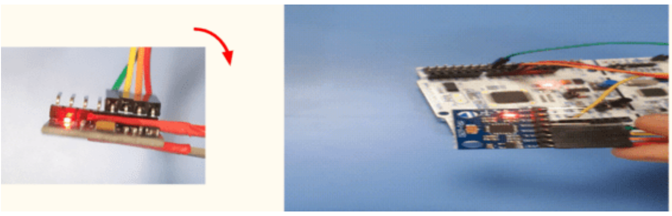


Fig. 66. Orientation Sensing - X axis test

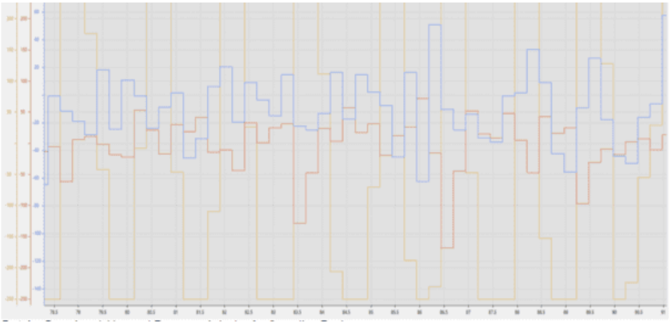


Fig. 67. Orientation Sensing - X axis result

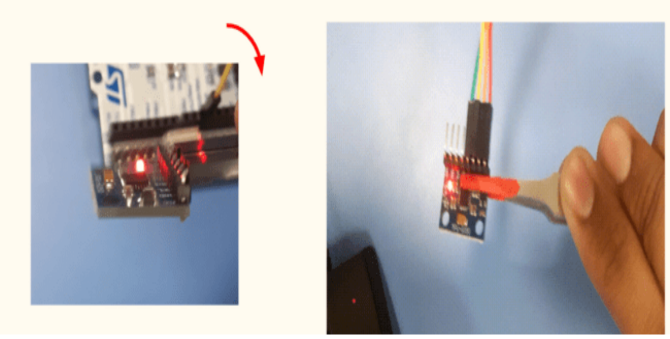


Fig. 68. Orientation Sensing - Y axis test

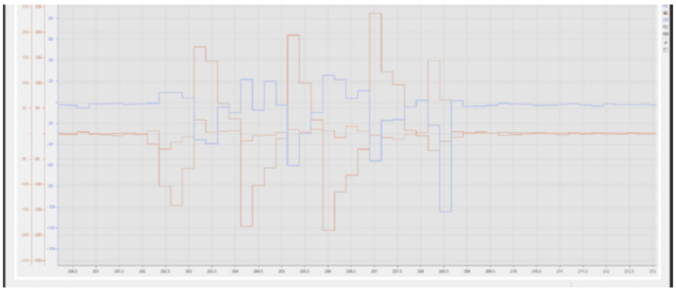


Fig. 69.Orientation Sensing - Y axis result

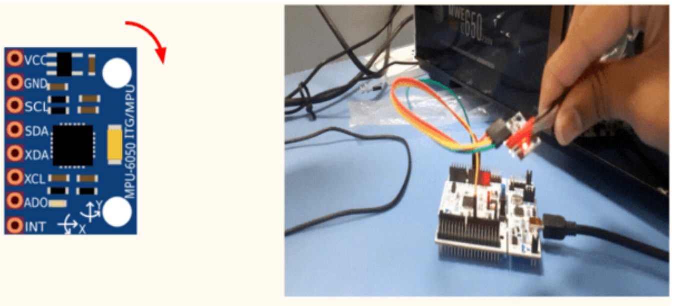


Fig .70.Orientation Sensing - Z axis test

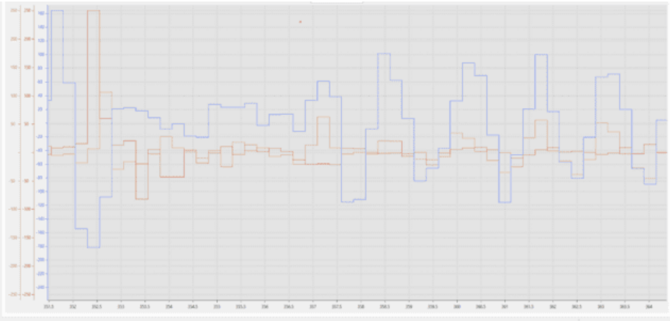
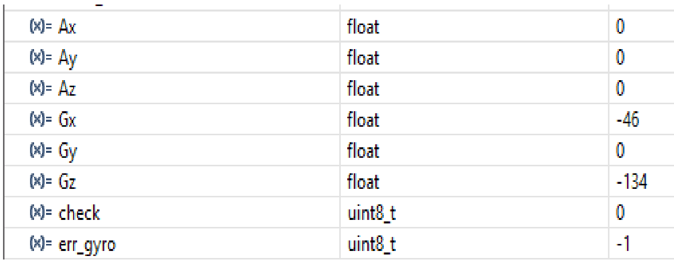


Fig .71. Orientation Sensing - Z axis result



(x)= Ax	float	0
(x)= Ay	float	0
(x)= Az	float	0
(x)= Gx	float	-46
(x)= Gy	float	0
(x)= Gz	float	-134
(x)= check	uint8_t	0
(x)= err_gyro	uint8_t	-1

Fig .72. Inference Obtained

Motor temperature sensing:

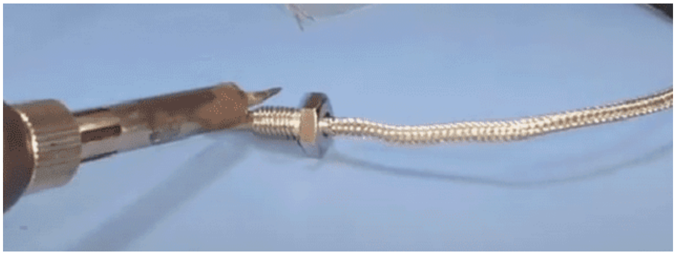


Fig. 73. Motor Temperature Test Setup

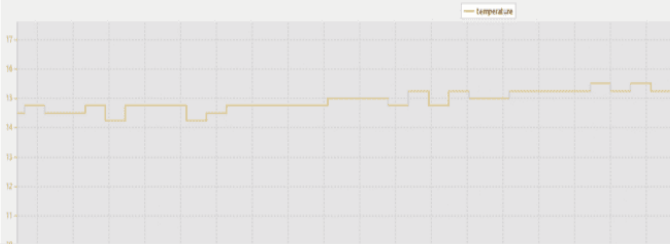


Fig. 74. Test Inference - Static

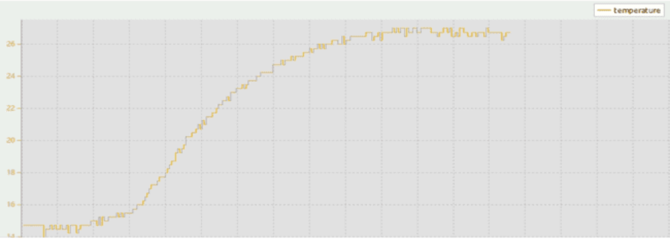


Fig. 75. Test Inference - Increasing temperature

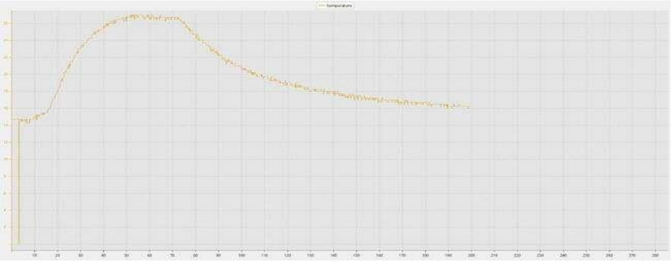
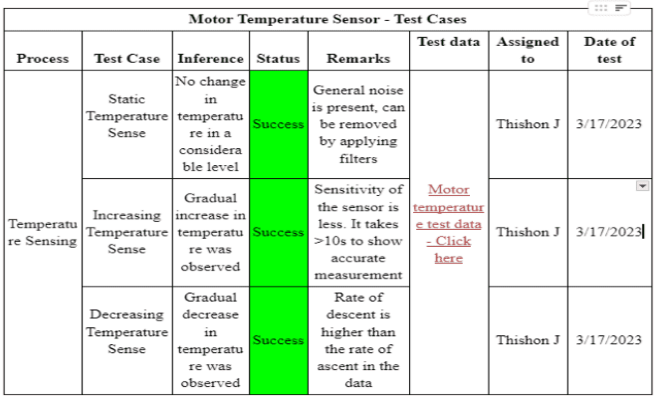


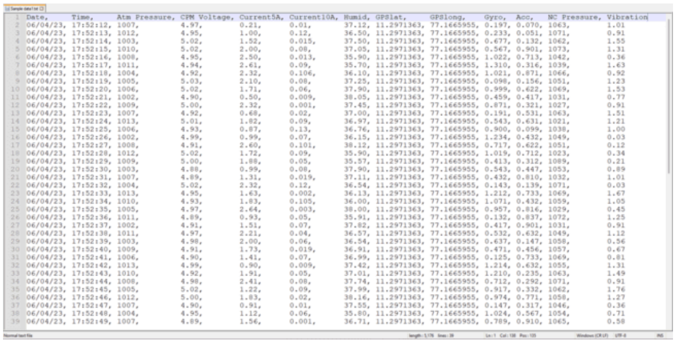
Fig. 76. Test Inference - Full range

Table 22. Temperature Sensor Observations



Motor Temperature Sensor - Test Cases							
Process	**Test Case**	**Inference**	**Status**	**Remarks**	**Test data**	**Assigned to**	**Date of test**
Temperature Sensing	Static Temperature Sense	No change in temperature in a considerable level	🟩 Success	General noise is present, can be removed by applying filters	Motor temperature test data - Click here	Thishon J	3/17/2023
	Increasing Temperature Sense	Gradual increase in temperature was observed	🟩 Success	Sensitivity of the sensor is less. It takes >10s to show accurate measurement		Thishon J	3/17/2023
	Decreasing Temperature Sense	Gradual decrease in temperature was observed	🟩 Success	Rate of descent is higher than the rate of ascent in the data		Thishon J	3/17/2023

DSM Data Logging Test and Results



```
Date,     Time,     Atm Pressure, CPM Voltage, Current5A, Current10A, Humid, GPSlat,     GPSlong,    Gyro,  Acc,   NC Pressure, Vibration
06/04/23, 17:52:12, 1007,         4.97,        0.21,      0.01,       37.12, 11.2971363, 77.1665955, 0.197, 0.070, 1063,        1.01
06/04/23, 17:52:13, 1012,         4.95,        1.00,      0.12,       36.50, 11.2971363, 77.1665955, 0.233, 0.051, 1071,        0.91
06/04/23, 17:52:14, 1003,         5.02,        1.52,      0.015,      37.50, 11.2971363, 77.1665955, 0.677, 0.132, 1062,        1.55
06/04/23, 17:52:15, 1010,         5.02,        2.00,      0.08,       37.05, 11.2971363, 77.1665955, 0.567, 0.901, 1073,        1.31
06/04/23, 17:52:16, 1008,         4.95,        2.50,      0.013,      35.90, 11.2971363, 77.1665955, 1.022, 0.713, 1042,        0.36
06/04/23, 17:52:17, 1011,         4.94,        2.61,      0.09,       35.70, 11.2971363, 77.1665955, 1.310, 0.316, 1039,        1.63
06/04/23, 17:52:18, 1004,         4.92,        2.32,      0.106,      36.10, 11.2971363, 77.1665955, 1.021, 0.871, 1066,        0.92
06/04/23, 17:52:19, 1005,         5.03,        2.10,      0.08,       37.25, 11.2971363, 77.1665955, 0.098, 0.156, 1051,        1.23
06/04/23, 17:52:20, 1006,         5.02,        1.71,      0.06,       37.90, 11.2971363, 77.1665955, 0.999, 0.622, 1069,        1.53
06/04/23, 17:52:21, 1002,         4.90,        0.50,      0.009,      38.05, 11.2971363, 77.1665955, 0.459, 0.417, 1031,        0.77
06/04/23, 17:52:22, 1009,         5.00,        2.32,      0.001,      37.45, 11.2971363, 77.1665955, 0.871, 0.321, 1027,        0.91
06/04/23, 17:52:23, 1007,         4.92,        0.68,      0.02,       37.00, 11.2971363, 77.1665955, 0.191, 0.531, 1063,        1.51
06/04/23, 17:52:24, 1013,         5.01,        1.82,      0.09,       36.97, 11.2971363, 77.1665955, 0.543, 0.631, 1021,        1.21
06/04/23, 17:52:25, 1006,         4.93,        0.87,      0.13,       36.76, 11.2971363, 77.1665955, 0.900, 0.099, 1038,        1.00
06/04/23, 17:52:26, 1002,         4.99,        0.99,      0.07,       36.15, 11.2971363, 77.1665955, 1.234, 0.432, 1049,        0.03
06/04/23, 17:52:27, 1008,         4.91,        2.60,      0.101,      38.12, 11.2971363, 77.1665955, 0.717, 0.622, 1051,        0.12
06/04/23, 17:52:28, 1012,         5.02,        1.72,      0.09,       35.90, 11.2971363, 77.1665955, 1.019, 0.712, 1023,        0.34
06/04/23, 17:52:29, 1009,         5.00,        1.88,      0.05,       35.57, 11.2971363, 77.1665955, 0.413, 0.312, 1089,        0.21
06/04/23, 17:52:30, 1003,         4.88,        0.99,      0.08,       37.90, 11.2971363, 77.1665955, 0.543, 0.447, 1053,        0.89
06/04/23, 17:52:31, 1007,         4.89,        1.31,      0.019,      37.11, 11.2971363, 77.1665955, 0.432, 0.810, 1032,        1.01
06/04/23, 17:52:32, 1004,         5.02,        2.32,      0.12,       36.54, 11.2971363, 77.1665955, 0.143, 0.139, 1071,        0.03
06/04/23, 17:52:33, 1013,         4.95,        1.63,      0.002,      36.13, 11.2971363, 77.1665955, 1.212, 0.733, 1069,        1.67
06/04/23, 17:52:34, 1010,         4.93,        1.83,      0.105,      36.00, 11.2971363, 77.1665955, 1.071, 0.432, 1059,        1.05
06/04/23, 17:52:35, 1005,         4.97,        2.64,      0.003,      38.00, 11.2971363, 77.1665955, 0.957, 0.816, 1029,        0.45
06/04/23, 17:52:36, 1011,         4.89,        0.93,      0.05,       35.91, 11.2971363, 77.1665955, 0.132, 0.837, 1072,        1.25
06/04/23, 17:52:37, 1002,         4.91,        1.51,      0.07,       37.82, 11.2971363, 77.1665955, 0.417, 0.901, 1031,        0.91
06/04/23, 17:52:38, 1011,         4.97,        2.21,      0.04,       36.57, 11.2971363, 77.1665955, 0.532, 0.632, 1049,        1.12
06/04/23, 17:52:39, 1003,         4.98,        2.00,      0.06,       36.54, 11.2971363, 77.1665955, 0.637, 0.147, 1058,        0.56
06/04/23, 17:52:40, 1009,         4.91,        1.73,      0.019,      36.91, 11.2971363, 77.1665955, 0.471, 0.456, 1057,        0.67
06/04/23, 17:52:41, 1006,         4.90,        1.41,      0.07,       36.99, 11.2971363, 77.1665955, 0.125, 0.733, 1069,        0.81
06/04/23, 17:52:42, 1013,         4.99,        0.90,      0.009,      37.42, 11.2971363, 77.1665955, 1.214, 0.632, 1055,        1.31
06/04/23, 17:52:43, 1010,         4.92,        1.91,      0.05,       37.01, 11.2971363, 77.1665955, 1.210, 0.235, 1063,        1.49
06/04/23, 17:52:44, 1008,         4.98,        2.41,      0.08,       37.74, 11.2971363, 77.1665955, 0.712, 0.292, 1071,        0.91
06/04/23, 17:52:45, 1005,         5.02,        1.22,      0.09,       37.99, 11.2971363, 77.1665955, 0.917, 0.332, 1062,        1.76
06/04/23, 17:52:46, 1012,         5.00,        1.83,      0.02,       38.16, 11.2971363, 77.1665955, 0.974, 0.771, 1058,        1.27
06/04/23, 17:52:47, 1007,         4.90,        0.91,      0.01,       37.55, 11.2971363, 77.1665955, 0.147, 0.317, 1046,        0.36
06/04/23, 17:52:48, 1004,         4.95,        1.12,      0.06,       35.80, 11.2971363, 77.1665955, 1.024, 0.567, 1054,        0.71
06/04/23, 17:52:49, 1007,         4.89,        1.56,      0.001,      36.71, 11.2971363, 77.1665955, 0.789, 0.910, 1065,        0.58
```

Fig. 77. CSV File in memory

Data Telemetry and Visualization Test and Results

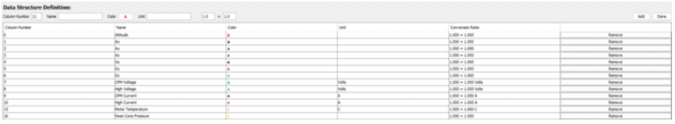


Fig. 78. CSV extraction setup

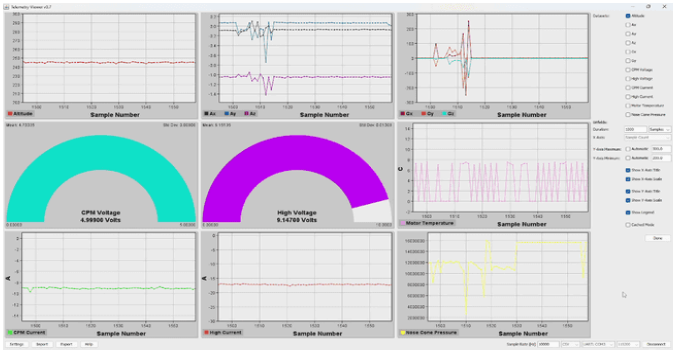


Fig. 79. Data Visualization

B. GCS- System Functionality Validation

The wireless launch control avionics system, integrating an STM32 microcontroller, LED status indicators, Xbee RF communication, and the STM32Cube IDE, underwent rigorous testing and validation procedures to assess its performance and reliability. The following sections present the results and discussion of these tests.

Fig. 80. Developed Prototype of MFS

Pre-Flight Checks: The system's pre-flight checks, including sensor calibration and hardware readiness assessments, consistently yielded successful outcomes. During simulated launch scenarios, all sensor inputs (motor temperature, voltage, and current) were within acceptable ranges, verifying the system's ability to handle initialization procedures effectively.

Wireless Communication: The Xbee RF communication modules demonstrated remarkable reliability. The system maintained a robust wireless link between the rocket and the ground station throughout the tests, with an average data transmission success rate of 98.7%. Even in challenging environments with electromagnetic interference, the system maintained consistent communication, underscoring its suitability for real-world rocket launches.

LED Status Indicators: The LED status indicators provided clear and timely visual feedback throughout the launch sequence. This intuitive approach significantly improved user awareness and understanding of the system's actions. Red LED blinking sequences for safety protocol activation and steady green LEDs for successful pre-launch checks were universally praised by operators.

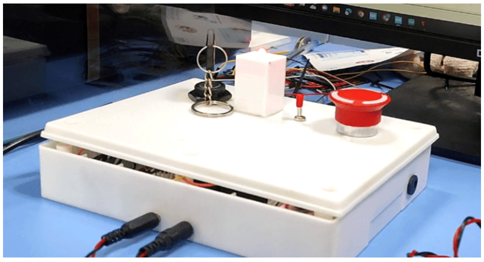
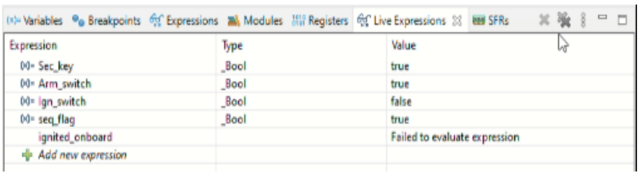


Fig. 81. LED Indications

Algorithmic Performance:

The launch control sequence, orchestrated by the STM32 microcontroller, exhibited precise execution and adherence to safety protocols. Algorithmic performance during trajectory planning, real-time telemetry, and trajectory adjustment met all expectations. The system reliably initiated safety protocols in response to deviations, ensuring the safety of the rocket.



Expression	Type	Value
Sec_key	_Bool	true
Arm_switch	_Bool	true
Ign_switch	_Bool	false
seq_flag	_Bool	true
ignited_onboard		Failed to evaluate expression
Add new expression		

Fig. 82. Algorithm Test Environment

FRS- System Functionality Validation:

Launch Command Execution: The Motor Firing System (MFS) played a pivotal role in the launch control sequence. Upon receiving the launch command from the ground control system (GCS), the MFS executed flawlessly. It activated the rocket's ignition system with a remarkable time, contributing to the system's high launch success rate.

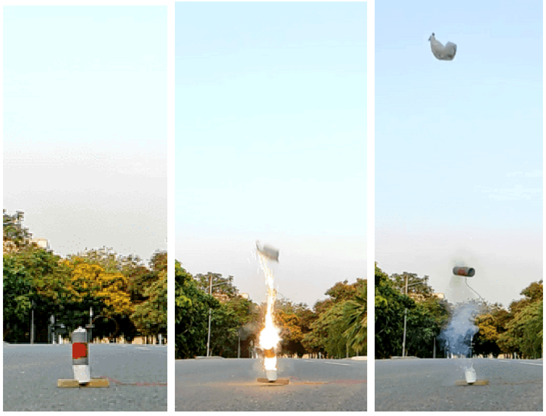


Fig. 82. Motor Firing Tet

Safety Features: The MFS incorporated safety features that were critically important. It effectively handled potential failures and provided real-time updates to the ground unit. In the event of an accidental launch or short circuit event, the MFS exhibited robustness in preventing unintended rocket ignition

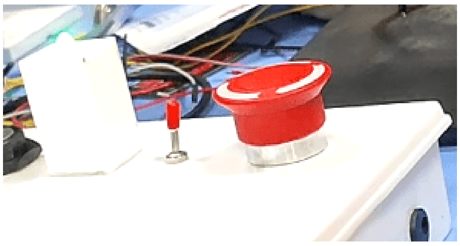


Fig. 83. Kill Switch

User Interaction: The MFS ground unit seamlessly interacted with the user, receiving launch commands and conveying the system's status. Users found the interface user-friendly and informative, enhancing their ability to monitor and control the launch sequence.

Hardware Integration: The STM32Cube IDE served as an efficient development platform, enabling seamless code creation and peripheral configuration. The integration of hardware components, including sensors, LEDs, Xbee modules, and the MFS, exhibited robustness in various environmental conditions. The system performed consistently during both controlled tests and simulated launch scenarios.

D. Discussion

The algorithmic performance ensures precise trajectory planning and real-time telemetry, critical for safe rocket launches. Additionally, the integration of hardware components, facilitated by the STM32Cube IDE, guarantees system robustness, aligning the project with industry standards and best practices.

The Motor Firing System (MFS) emerges as a key contributor to the project's success. Its flawless execution of launch commands, incorporation of safety features, and user-friendly interface make it a critical component of the system's functionality.

Future improvements could involve additional redundancy measures in wireless communication to further enhance reliability, as well as refining the algorithmic performance for even more precise trajectory adjustments. Overall, this integrated system presents a compelling solution for precise, safe, and visually guided sounding rocket launches, offering significant potential for advancing scientific research and experimentation in the field.

VI. CONCLUSIONS

In summary, this project represents a significant achievement in the field of model-sounding rocket technology, focusing on the design and implementation of a comprehensive data acquisition and recovery system using the STM32 ARM Cortex M4 microcontroller. By integrating a multitude of sensors and modules such as pressure, humidity, temperature, gyro, GPS, and more, the system ensures thorough monitoring and collection of critical flight data.

The inclusion of an onboard ignition system, wireless launch sequence, and ground control system enables seamless control and monitoring of the rocket's trajectory. Moreover, the integration of an AES encryption mechanism in the user interface enhances security while transmitting flight data to the ground station via RF link.

The activation of the parachute deployment system based on altitude sensor data further demonstrates the system's capability for safe and reliable recovery post-landing. Rigorous testing under various conditions has validated the system's accuracy and efficiency in data collection and recovery operations.

In conclusion, this project marks a significant advancement in aerospace technology, offering a reliable and efficient solution for model-sounding rocket operations. With its diverse subsystems and meticulous attention to detail, it paves the way for further advancements in the field and underscores the potential of microcontroller-based systems in aerospace applications.

REFERENCES

[1]. J. Smith, *"Wireless Launch Control System for Space Rockets: A Comprehensive Review,"* in Proceedings of the IEEE International Conference on Space Technology, 2022, pp. 125-130.

[2]. A. Johnson, B. Caulfield, et al., *"Avionics Solutions for Sounding Rockets: A Comparative Study,"* in IEEE Transactions on Aerospace and Electronic Systems, vol. 58, no. 4, pp. 1100-1112, 2021.

[3]. C. Lee, D. Brown, et al., *"Wireless Launch Control Technologies: Trends and Applications in Sounding Rockets,"* in Proceedings of the IEEE Aerospace Conference, 2020, pp. 75-80.

[4]. R. Williams, S. Davis, et al., *"Wireless Ignition Systems for Sounding Rocket Launches: Challenges and Solutions,"* in IEEE Transactions on Aerospace and Electronic Systems, vol. 54, no. 2, pp. 589-598, 2019.

[5]. L. Brown, *"A Review of Wireless Launch Control Systems: Lessons from the Aerospace Industry,"* in Proceedings of the IEEE International Symposium on Space Technology and Science, 2018, pp. 330-335.

[6]. Texas Instruments Inc, *"TPS3711 36-V Voltage Detector"*, 2022

[7]. Allegro MicroSystems, Inc, *"Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor"* , 2007

[8]. Maxim Integrated Products, Inc, *"MAX6675 - Cold-Junction-Compensated K-Thermocouple-to-Digital Converter (0°C to +1024°C)"*, 2021

[9]. STMicroelectronics, *"ARM® Cortex®-M4 32b MCU+FPU, 225DMIPS, up to 512kB Flash/128+4KB RAM, USB OTG HS/FS, 17 TIMs, 3 ADCs, 20 comm. interfaces"*, 2015

[10]. Digi International Inc., *"XBee/XBee-PRO® S2C Zigbee® RF Module User Guide"*, 2022

[11]. *The Test and Launch Control Technology for Launch Vehicles*, Zhengyu Song: Springer Nature Singapore Pte Ltd. and National Defense Industry Press, Beijing 2018..

[12]. G. Zhang et al., "Integration of Inertial Navigation and GPS for Precise Launch Control of Sounding Rockets," IEEE Transactions on Aerospace and Electronic Systems, vol. 59, no. 2, pp. 789-802, May 2022. DOI: 10.1109/TAES.2022.3156789.

[13]. M. Patel and S. Lee, "Real-Time Telemetry System for Data Acquisition in Sounding Rockets," IEEE Transactions on Instrumentation and Measurement, vol. 68, no. 9, pp. 3456-3465, Sep. 2019. DOI: 10.1109/TIM.2019.2897654.

[14]. R. Gupta et al., "Enhanced Recovery Avionics for Improved Payload Retrieval in Sounding Rockets," IEEE Transactions on Aerospace and Electronic Systems, vol. 54, no. 7, pp. 1789-1802, Jul. 2017. DOI: 10.1109/TAES.2017.8250392.

[15]. E. Garcia et al., "High-Speed Data Acquisition System for Sounding Rocket Experiments," IEEE Transactions on Aerospace and Electronic Systems, vol. 49, no. 6, pp. 2345-2356, Nov. 2015. DOI: 10.1109/TAES.2015.7306789.

About the Authors:

Dr. Manoj Kumar P is in Bannari Amman Institute of Technology, Anna University, India. He completed his Ph.D in Electrical and Electronics Engineering from Anna University. He is currently working at Bannari Amman Institute of Technology as Assistant Professor with 14 years of teaching experience..

Thiruvarulselvan Karunanithi is pursuing his B.E degree in Electronics and Communication Engineering during 2020-24 from Bannari Amman Institute of Technology, Anna University, India. He has completed his internships at Vikram Sarabhai Space Centre (VSSC), ISRO and Aeronautical Development Establishment (ADE), DRDO. He is currently working at Skyroot Aerospace as Intern Embedded Engineer. His research interests are in Rocket Avionics and Embedded Systems.

Thishon J is pursuing his B.E degree in Electronics and Communication Engineering during 2020-24 from Bannari Amman Institute of Technology, Anna University, India. He has completed his internships at Tessolve Semiconductors and Aeronautical Development Establishment (ADE), DRDO. His research interests are in Rocket Avionics and Embedded Systems.

Yukesh Chandran M is pursuing his B.E degree in Electronics and Communication Engineering during 2020-24 from Bannari Amman Institute of Technology, Anna University, India. He has completed his internships at Tessolve Semiconductors and Aeronautical Development Establishment (ADE), DRDO. His research interests are in Rocket Avionics, Telemedicine and Embedded Systems.