JAIN DEEMED-TO-BE UNIVERSITY | FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Aerospace Engineering

JGI Global Campus, Jakkasandra Post, Kanakapura Taluk, Ramanagara District, Pin Code: 562 112

2022-2023

Research and Entrepreneurship Project

Report on

"DESIGN AND DEVELOPMENT OF FLIGHT COMPUTER FOR HIGH-POWERED ROCKETRY"

Submitted in partial fulfilment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

AEROSPACE ENGINEERING

Submitted by

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CERTIFICATE

This is to certify that the project work titled **“DESIGN AND DEVELOPMENT OF FLIGHT COMPUTER FOR HIGH POWERED ROCKETRY”** is carried out by **Sourav Ghosh (20BTRAS033), Tenzin Wangmo (20BTRAS063), Tshering Gyeltshen (20BTRAS064), Tandin Dorji (20BTRAN045),** bonafide students of Bachelor of Technology at the Faculty of Engineering & Technology, Jain (Deemed-to-be) University, Bangalore in partial fulfilment for the award of degree in Bachelor of Technology in Aerospace/Aeronautical Engineering, during the year **2022-2023**.

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Date: 6 December 2022

DECLARATION

We, **Sourav Ghosh (20BTRAS033), Tenzin Wangmo (20BTRAS063), Tshering Gyeltshen (20BTRAS064), Tandin Dorji (20BTRAN045),** are students of **FIFTH** semester **B.Tech** in **Aerospace Engineering**, at Faculty of Engineering & Technology, **JAIN** (**Deemed-to-be University)**, hereby declare that the PCL titled **"DESIGN AND DEVELOPMENT OF FLIGHT COMPUTER FOR HIGH POWERED ROCKETRY"** has been carried out by us and submitted in partial fulfilment for the award of degree in **Bachelor of Technology in Aerospace Engineering** during the academic year **2022-2023**. Further, the matter presented in the project has not been submitted previously by anybody for the award of any degree or any diploma to any other University, to the best of our knowledge and faith.

Signature

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Signature of Students

Abstract

High Powered Rocketry involves launching sub-orbital rockets to higher altitudes. They are usually done to perform scientific experiments in the atmosphere or for testing of new equipments. On board computers play a critical role in the flight. They are tasked with collecting flight data, transmitting back to the ground station, to manoeuvre the rocket and for deployment of parachute and payload. Through this project, we aim to design and fabricate a flight computer capable of controlling a sounding rocket up to an altitude of 100 km, which is designated as the Karman line, the known boundary between Earth's atmosphere and outer space.

Keywords: Embedded Systems, High Powered Rocketry, Flight Computer, Guidance and Control, Telemetry.

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1. Introduction

High Powered Rocketry involves launching sub-orbital rockets to high altitudes. It is usually done to perform scientific experiments in the higher altitudes or to collect data or to test new equipment. The most recent HPR launches include India's Skyroot Aerospace's **Vikram-S**, which launched up to an altitude of 89 km, ISRO's **Rohini RH200** which reached up to an altitude of 70 km.

Flight computers have been used in rockets since over half a decade now. They were first used in the **Jupiter C** launch vehicle, and over 60 years later, we are seeing unprecedented rise in the use of technology for flight control. Some of the important functions a flight computer performs involve collection of flight data, transmission of the data to ground stations, flight control, payload deployment, tracking of location, active stabilization, and in some cases, parachute deployment.

The Intercollegiate Rocket Engineering Competition (IREC) is massive competition involving over 150 university teams and 1000 students from various backgrounds launching rockets up to an altitude of 30,000 ft. Innovation in the design of On-Board Computers have been observed there, and efforts are being made to surpass the same year by year. This project aims to develop a more efficient and optimized design for enhanced performance up to the Karman line, which is at an altitude of 100 km, and is the line designated as the border between Earth's atmosphere and outer space.

Fig-1 Skyroot Vikram-S

Components used in the design are COTS (Commercial-Off-the-shelf), while the PCB (Printed Circuit Board) is SRAD (Student Researched and Developed). Most of the components are mostly to be acquired from STMicroelectronics, a well-known semi-conductor manufacturing company, while the rest will be acquired from local hardware stores and other well-known manufacturers.

2. Literature review

Negahban, Sirus (2019) designed a flight computer for IREC 2019. The paper specified the components used in his system and also analyzed the performance of the entire system.

Kahe, G. (2017) designed a computer with a dual-redundant architecture. The system was redundant such that there are two independent systems for computation of data, while both the systems received data from the same set of sensors.

Wright, D. (2013) specified some guidance and control techniques used in development of sounding rockets.

NASA's Sounding Rocket User Handbook provides a good overview behind the operations and design of a sounding rocket.

3. Aim and Objectives

The main aim of this project is to design a Flight Computer for High Powered Rockets.

The objectives to be achieved through the flight computer include:

- To record flight parameters at suitable frequency.
- To send data to ground via telemetry systems.
- To store flight data.
- To deploy payload and parachute and appropriate time and altitudes.
- To actively stabilize the rocket.

4. Methodology

Based on the problem statement, firstly a suitable computing architecture is developed for the rocket. Several factors such as redundancy, availability and cost is considered before the necessary parts are chosen. Necessary EDA files are then designed for the respective parts, which are then connected in a circuit using an EDA software. For this project, Autodesk EAGLE was used due to its simple User Interface and availability of libraries for several components. Other such EDA softwares may include Altium, Proteus, KiCAD, EasyEDA and many more.

Further steps would involve design of the PCB (Printed Circuit Board) via the EDA software. Several iterations of the design may be done to optimise the same. Once finalized, the board is then manufactured by manufacturers such as JLCPCB or PCBWay or SeeedStudio, all based in China. The board may also be manufactured by local vendors depending upon the quality. Simultaneously, the necessary ICs maybe ordered. Once the board and the ICs are received, a prototype is assembled by soldering the latter into the former. Most of the components are surface-mount (SMD), hence they need to be soldered in the appropriate manner. Once done, the necessary flight validation tests may be performed.

5. Components List

The following components have been used in the first iteration of the design.

Sl no	Component Type	Model Name
1	Microcontroller	ATSAMD21
2	Pressure sensor	MPL3115A2
3	IMU	BNO055
4	GPS	NEO-M8N
5	SPI Flash Chip	SST25PF020B-80-4C-SAE
6	Telemetry	CC1200/CC1120/XBEE Pro S3B

The following components have been used in the second iteration of the design.

Sl no	Component Type	Model Name
1	Microcontroller	STM32F7/H7
2	Pressure sensor	LPS22DFTR
3	Accelerometer, Gyroscope	LSM6DSOTR
4	IMU	H3LIS100DL
5	GPS	NEO-M8N
6	SPI Flash Chip	SST25PF020B-80-4C-SAE
7	Telemetry	CC1200/CC1120/XBEE Pro S3B

The rationale behind the choice of components include manufacturer lead time, cost and availability of resources in the form of literature or schematics. Most of the components are manufactured by STMicroelectronics, a global leader in semi-conductor manufacturing. Several components are also manufactured by Mouser Electronics, Microchip Technologies and several other local manufacturers. The project aims to maximise the usage of Made in India products.

6. Design

EDA designs have been done as follows.

6.1 Design Iteration 1

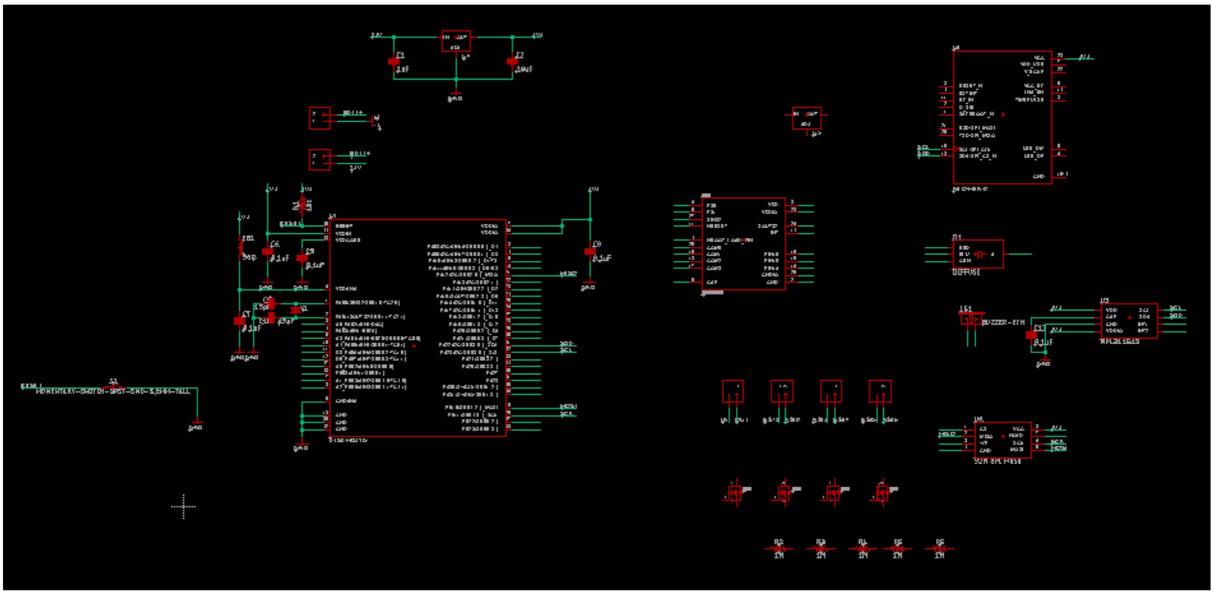

Fig-2 Schematic Iteration 1

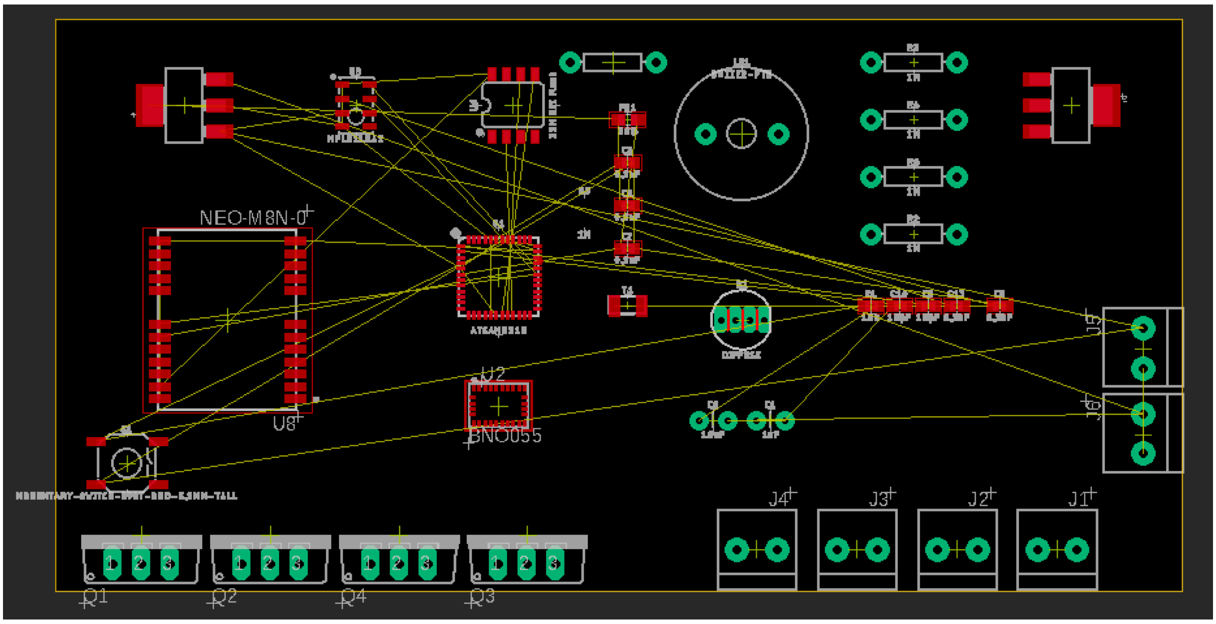

Fig-3 Board Iteration 1

Design Iteration 2 is still under progress, and is stated for finish in January 2023.

7. Project Timeline

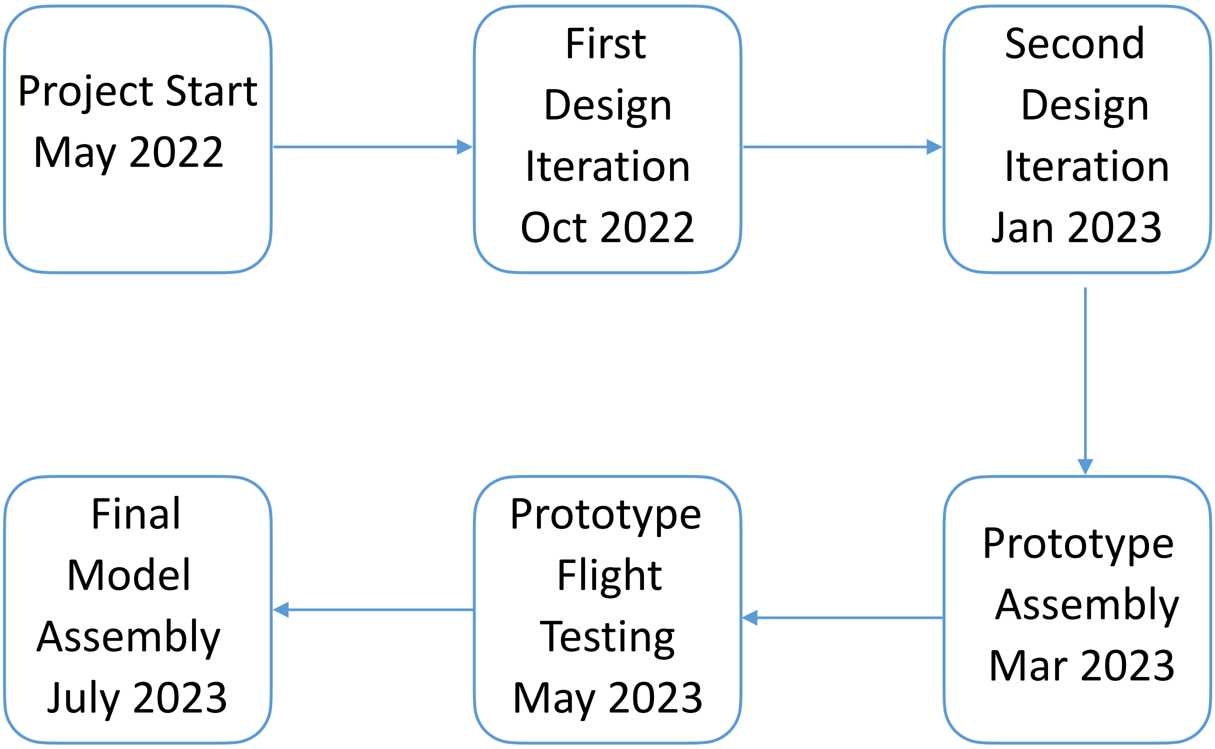

Fig-4 Project Timeline

The project began in May 2022, as a preparation for the Intercollegiate Rocket Engineering Competition 2022. The flight computer is now being developed for HPR launches from July 2023. The first iteration design was completed in October 2022, while the second iteration is set to be completed by January 2023.

8. Budget

8.1 Cost Budget

Cost of sensors and microcontroller.

	Qty	Order Code	Mfr Part No	Your Part No	Line Note	Availability	Unit Price	Line Total
1	1	2393643	STM32F401RBT6			4080	Rs.700.16	Rs.700.16
2	1	2532373	H3LIS100DLTR			8000	Rs.724.14	Rs.724.14
3	1	2980917	LSM6DSOTR			128246	Rs.581.94	Rs.581.94
4	1	3819112	LPS22DFTR			7650	Rs.325.74	Rs.325.74
5	1	2295955	SST25PF020B-80-4C-SAE			1100	Rs.82.34	Rs.82.34
							Sub Total	Rs.2,414.32
							Delivery	Rs.0.00
							GST	Rs.434.58
							Total	Rs.2,848.90

Sort	Product Detail		Description	Quantity	Availability	Unit Price (INR)	Ext. Price (INR)
1		Mouser No: 888-XBP9B-DMSTB002 Mfr. No: XBP9B-DMSTB002 Mfr.: DIGI Customer No: Customer No	Sub-GHz Modules Xbee-Pro 900HP (S3B) DigiMsh 900MHz RPSMA RoHS Compliant QuickView	1	0 Dispatches Now 1 Backordered	₹5,050.06	**₹5,050.06**

Total estimated budget = Rs. 20,000

8.2 Link Budget

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX}$$

Where

P_{RX} - received power (dBm)

G_{TX} - transmitter output power (dBm)

G_{TX} - transmitter antenna gain (dBi)

L_{TX} - transmitter losses (coax, connectors...) (dB)

L_{FS} - path loss, usually free space loss (dB)

L_M - miscellaneous losses (fading margin, body loss, polarization mismatch, other losses, ...) (dB)

G_{RX} - receiver antenna gain (dBi)

L_{RX} - receiver losses (coax, connectors, ...) (dB)

$$L_{FS} = 20\log_{10} r + 20\log_{10} f + 20\log_{10}\left(\frac{4\pi}{c}\right)$$

Where,

r - distance between transmitter and receiver (km)

f - Frequency band (MHz)

c - 299,792,458 m/s

On substituting the respective values after validating the same from the data sheets, we find out that XBEE Pro S3B has a range of over 63 miles, while CC1200 and CC1120 have a range of over 16 miles, while is approximately over 80,000 ft. By increasing the power given to the latter, we can possibly increase the range to over 100,000 ft.

9. Conclusion and Future Work

Millions are spent by Aerospace companies in the area of flight computer development, and also in the area of Guidance, Navigation and Control. They are among the most crucial systems in flight, who are capable of comparing flight parameters and understanding issues pertaining to the flight, subject to which the flight may be aborted. For instance, Firefly Aerospace had several of their launches cancelled because the Flight computer was correctly able to identify issues in flight and aborted the same seconds from lift-off.

Vertical landing is another area under development since almost a decade now. SpaceX and Blue Origin are among the companies who have managed to master the same, while there are several other companies trying to achieve the same in the coming years. It has been found that launching larger rockets for small and micro sized payloads is inefficient, and thus smaller launch vehicles similar to the size of a sounding rocket, called Small Satellite Launch

Vehicles are under development currently. This flight computer may be used in SSLVs, assisting with orbital launches in the future.

10. References

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