Fall Design Report

EGEE-4810: Senior Design 1

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1. Abstract

The purpose of this project is to develop a payload for NASA's Student Launch competition, in conjunction with Cedarville's mechanical engineering senior design project for NASA's Student Launch. It will involve developing an independent electrical system to fit within the rocket and developing firmware for a microcontroller to gather and communicate data via a radio transmitter and antenna.

2. Introduction and Background

For the past three years, Cedarville University has participated in the NASA Student Launch competition. Within the competition, several universities compete to design a rocket containing a payload to accomplish a set of goals set by NASA. Teams are scored based on how well they achieve each goal, their implementation, and their documentation and presentations given to NASA. Historically, the payload team has also developed the avionics systems onboard the rocket; however, this year the team will focus solely on making the payload, which will be self-sufficient and independent of rocket systems, although the team may also aid the mechanical engineering team with avionics or other electrical systems should the need arise.

This year's payload objective is to take several different measurements, either in flight or on the ground after landing, and transmit them over radio to a NASA receiver. NASA requires the team to pick at least three measurements from eight different options. The payload is also required to contain four human-like figures, called STEMnauts, which may be used fictionally to determine astronaut survivability and other rocket conditions which can be broadcast to NASA.

3. Objectives, Specifications, and Requirements

NASA has provided several objectives and constraints for this year's payload, but they have also incorporated much freedom in the design of the payload, provided it meets governmental regulations and adheres to the intent of the challenge. As the team is split by role rather than objective, all team members are responsible for all objectives. The requirements outlined by NASA in their 2024-2025 Student Launch Handbook (SLH) are summarized below:

- A minimum of three of the following, and a maximum of eight, must be transmitted to NASA upon landing:
    - Landing site temperature
    - Apogee reached
    - Battery status
    - Orientation of STEMnauts
    - Time of landing
    - Maximum landing
    - Landing velocity and G-forces sustained

- Calculated STEMnaut survivability

4. Constraints

NASA has provided constraints in the SLH for the design of the payload, and they are as follows:

- The data to be transmitted to NASA shall be communicated no later than March 17, 2025.
- The payload may not protrude more than a quarter inch before apogee.
- The payload shall transmit on the 2-meter band, at the NASA provided frequency (given later) at the time of landing, and at a maximum of 5 watts.
- The payload’s transmission shall not occur prior to landing.
- The payload shall have sufficient power to function after idling on the launch pad for three hours.

The mechanical engineering team has also provided constraints for the payload to ensure that it fits within the rocket and works well with their design. These constraints are soft requirements, however, and can be worked out and extended if necessary. These are the constraints provided by the mechanical engineering team:

- The payload shall not exceed 3.9 inches in diameter.
- The payload shall not exceed eight inches in length.
    - Some extra components may be placed above the payload (such as an antenna or STEMnauts) extending into the nosecone, which will not count towards the eight-inch maximum length; however, they must be fully contained in the nosecone.
- The payload shall not exceed three-fourths of a kilogram.
- The payload shall not interface nor interfere with the avionics system.
- The payload’s radial center of mass shall be within one-half inch of the center of the rocket.
- The payload should be as close to the given weight and length constraints as possible.
- The payload should be easily removable from the rocket.

The team will also keep the project cost under $1000 for all parts, including the ones already owned by the university.

5. Engineering Design

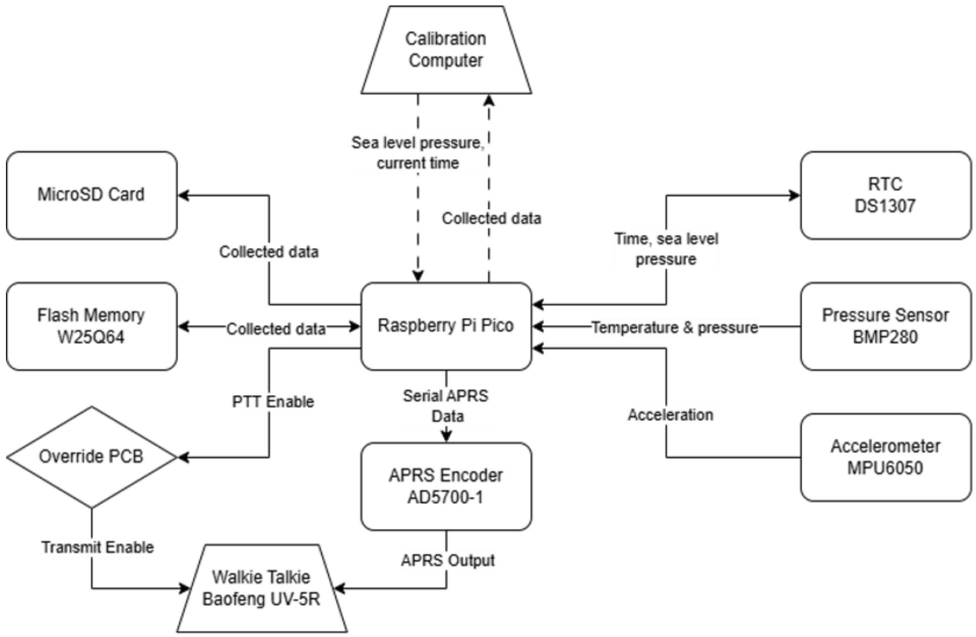

Figure 1: Full System Diagram

5.1 Software Design

The code is written using C++ and the official Pico software development kit (SDK). It operates using two cores: one for data collection (Core 0), and one for data writing (Core 1). Launch will be detected by software, and when the rocket launches, the payload will start collecting data with Core 0, and it will be sent to Core 1. Core 1 will write the data to external flash memory. This will occur continuously until the payload detects landing. After landing, Core 0 will transmit the data to the Baofeng UV-5R, while Core 1 will pull the data from external flash memory and write it to the MicroSD card. We do this to ensure there is no contact loss with the MicroSD card during data transfer (in flight), which could corrupt data.

The payload also required the creation of an auxiliary computer program used to calibrate it with the current time and current air pressure. This calibration computer is a simple terminal program which uses a custom packet based serial protocol and is written in Python. It also is designed for debugging and self-testing.

Currently, the team has data readings from all sensors as well as flash memory. The team is working on communication with the MicroSD card and resolving deadlocks arising from multi-core processing.

5.2 Electrical Design

Once the microcontroller has received the data from the sensors and formatted it into APRS packets, it sends the data to the APRS encoder, which converts the digital bits to APRS tones and sends them to the Baofeng UV-5R HAM radio. The radio then transmits the tones on the 2-meter band.

The current APRS encoder design is that of a voltage divider followed by an analog multiplexer. The goal of this subcircuit is essentially to build a digital-to-analog converter. In order to turn digital 0's and 1's into sine waves at the correct frequencies, the voltage divider supplies four voltages that can be controlled based on the resistor values. The analog multiplexer can select which of these voltages will be output at any given time. The goal is to step the voltage up and down along a rough sine wave. The two select lines come from the microcontroller, so the shape and frequency of the sine wave can be controlled. After this circuit, the output will look like a quantized sine wave, which can then be low pass filtered to give a much better approximation of a true sine wave. This output will be fed into the radio's mic input, which it will then transmit to the receiver via the 2m band.

The Baofeng UV-5R has its own battery pack, so the power requirements for this year's payload are much smaller than they have been for previous years. The team intends to use a 1000 mAh 7.4 V LiPo battery pack because of its compact size and secure connector.

The payload will require two printed circuit boards for each rocket launch. The primary PCB will collect data, store it in memory, and send out APRS data to be broadcast by the transmitter. The secondary PCB acts as an override for the primary PCB, only allowing transmissions to be broadcast during the particular transmission window immediately after landing. This fulfills a NASA constraint which requires us to have redundancy for disabling the transmitter before, during, and after the rocket's flight.

The designs for both printed circuit boards were created using the EasyEDA software. The primary PCB has been designed, manufactured, soldered, and tested for functionality, including correct power delivery and full communication with sensors. It is shown with the microcontroller and sensors below in Figure 2. The override PCB has been designed completely and will be sent out to be manufactured soon. Its design is shown below in Figure 3.

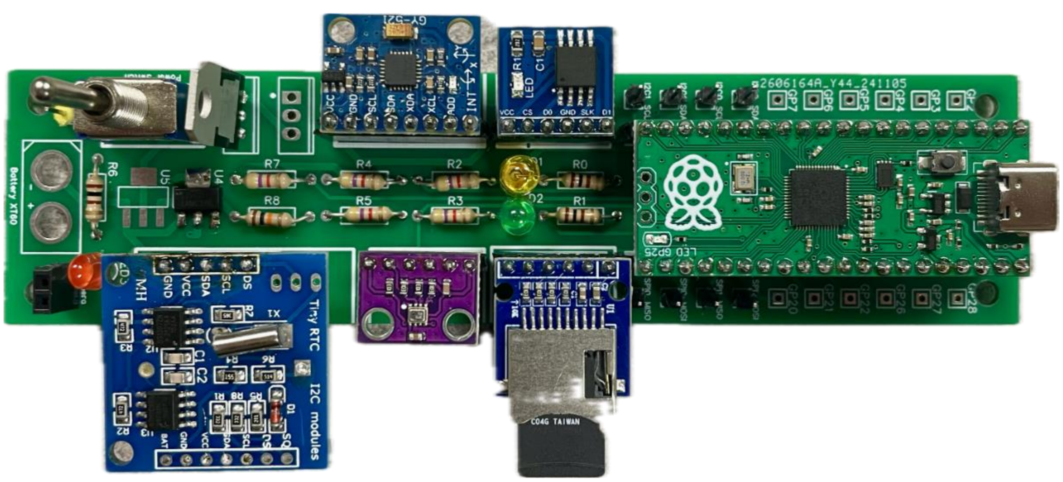

Figure 2: Primary PCB

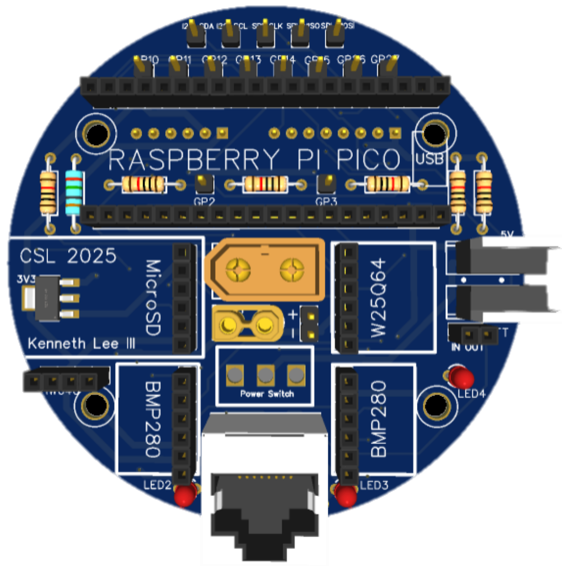

Figure 3: Override PCB

5.3 Mechanical Design

The current payload design can be seen below in Figure 4. The main body of the payload is 3D printed with PLA+ because rapid prototyping is very important for being able to make design changes quickly. The 3D printed payload is a cylinder with two opposing inset faces. The PCB for the primary circuit will be mounted to one side while the PCB for the override circuit will be mounted to the other side; these will both be mounted with standoffs which bolt into heat-set inserts embedded in the PLA+. Below the smaller override PCB will sit the four LEGO minifigures representing STEMnauts. Between the two inset faces of the cylinder is a cavity into which the batteries powering both of the PCB circuits will be placed. Beneath the battery cavity is another cavity accessible from the bottom, which can be used to add more mass to the payload if the chief mechanical engineer determines that more mass is needed near the front of the rocket. Two thin convex shields made of thin polycarbonate or another translucent material will slide up from the bottom of the payload and cover all circuitry and STEMnauts.

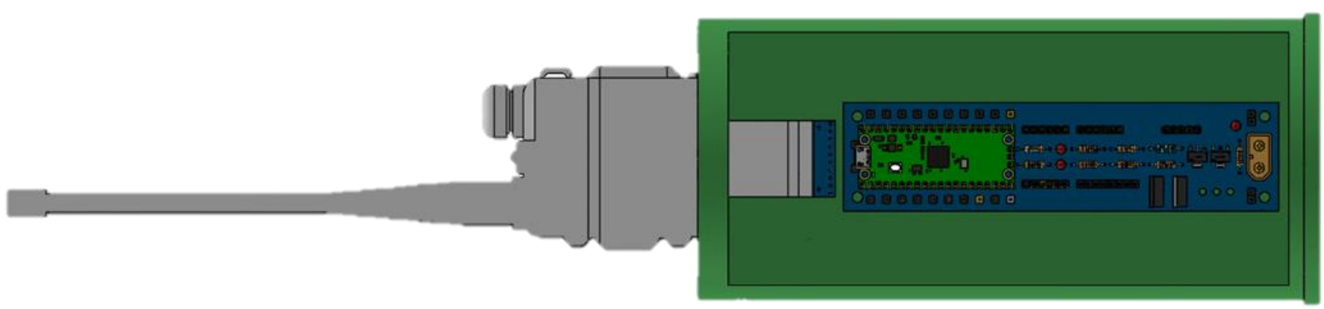

Figure 4: Current Payload Design

The first iteration of this design has already been 3D printed and is usable as a prototype for impact testing as well as adjusting dimensional tolerances.

6. Summary and Conclusion

In conclusion, our team has not only put together a rigorous engineering design but has also taken significant steps into manufacturing, testing, and validating the design. The software environment setup has been completed and all individual sensor and memory interfaces have been validated. The overall circuit design has been confirmed by testing with the primary PCB and testing with radio transmissions is underway. The transmitter override system is not only solved by our secondary PCB, but this PCB can also be used as a controller in the airbrakes portion of the rocket. The CAD assembly of our payload has not only been approved by the chief mechanical engineer, but has also been manufactured for testing.

7. Appendix

7.1 Personal Contributions

CEO: Rebekah Porter

Responsibilities include circuit design and electronics assembly. Specific accomplishments this semester include design of the radio transmission circuitry, design of the voltage divider and analog multiplexer circuity, and presentation of the Preliminary Design Review (PDR) to NASA as the electrical engineering lead alongside the mechanical engineering lead and overall team lead.

CFO: Kenneth Lee III

Responsibilities include project budget management, PCB and CAD design, and APRS transmission testing. Specific accomplishments include 3D printing first payload prototype as well as designing, soldering, and testing the primary PCB.

CTO: Arkin Solomon

Responsibilities include software design and development. Specific accomplishments this semester include implementing multicore processing and achieving communication and control between the sensors, microcontroller, and flash memory.

7.2 Current Gantt Chart

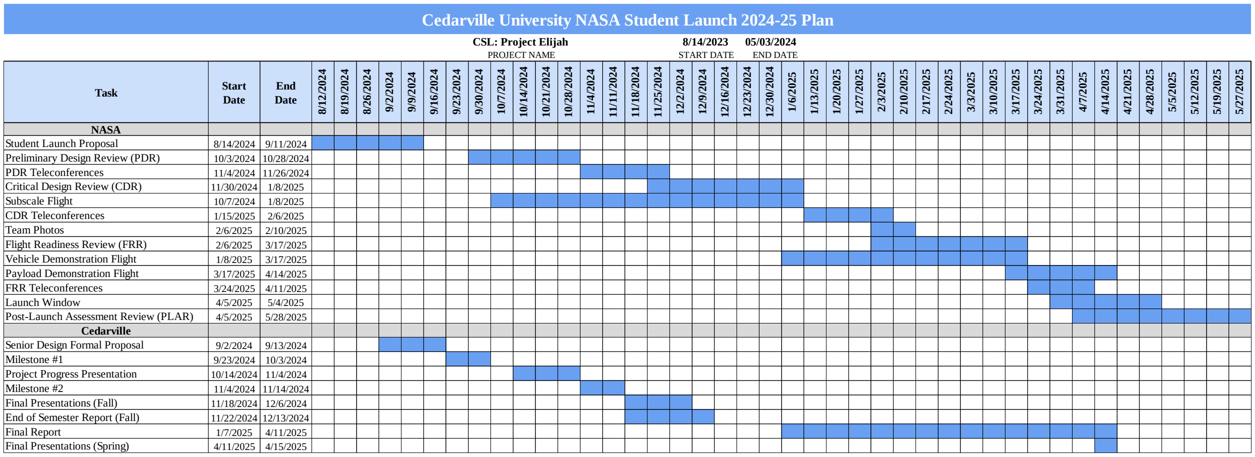

Figure 5: Cedarville Student Launch Payload Team Gantt Chart

7.3 Bill of Materials

Table 1: Cedarville Student Launch Payload Team Procurement List

Item Type	Part	Quantity	Unit Cost	Total Cost	Already Owned	Already Purchased
Radio	FCC Ham Radio License	2	$ 35.00	$ 70.00	No	$ 70.00
Radio	BTECH APRS-K1 PRO	1	$ 34.49	$ 34.49	No	$ 34.49
Radio	UV-5R Ham Radio Transceiver	2	$ 31.69	$ 63.38	No	$ 31.69
Radio	Diamond Antenna Dual-Band HT Antennas RH707	3	$ 29.99	$ 89.97	No	$ -
Microcontroller	Raspberry Pi Pico	3	$ 5.00	$ 15.00	Yes	$ -
Sensor	DS1307 Real Time Clock (3-pack)	1	$ 7.99	$ 7.99	Yes	$ -
Sensor	BMP280 Barometer & Thermometer (10-pack)	1	$ 7.99	$ 7.99	Yes	$ 7.99
Sensor	MPU6050 Gyroscope & Accelerometer (3-pack)	1	$ 9.99	$ 9.99	Yes	$ -
Battery	1000mAh 2S Li-Po Battery (2-pack)	2	$ 22.99	$ 45.98	No	$ -
Memory	W25Q64 Flash Memory Module (5-pack)	1	$ 7.99	$ 7.99	No	$ 7.99
Memory	Micro SD-Card Reader (10-pack)	1	$ 8.89	$ 8.89	Yes	$ 8.89
Memory	Micro SD-Card 32GB (5-pack)	1	$ 29.94	$ 29.94	Yes	$ -
PCB	PCB Manufacturing per Version	2	$ 40.00	$ 80.00	No	$ 25.00
Materials	PLA Filament (1 kg)	2	$ 25.00	$ 50.00	Yes	$ -
Miscellaneous	LEGO STEMnauts	4	$ 5.00	$ 20.00	No	$ -
Miscellaneous	Wires, Connectors, etc.	1	$ 20.00	$ 20.00	Yes	$ -
			Total:	**$561.61**		
			Actual:	**$411.81**		**$ 186.05**

8. Bibliography

[1] “2025 Student Launch Handbook,” NASA, https://www.nasa.gov/wp-content/uploads/2024/08/2025-nasa-sl-handbook.pdf?emrc=f8a406?emrc%3Df8a406.