Proposal for Cedarville's

NASA Student Launch Payload

EGEE-4810 Senior Design Project: Project Elijah

Project Proposal Presented by

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Due

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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. 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, though 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, 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 and Constraints

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. 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

- 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.

4. Deliverables

The team will deliver a completed payload assembly to the engineering faculty for our final grade, which follows the constraints outlined above. The payload assembly will be self-sufficient and only mechanically attached to the rocket. It will be capable of successfully transmitting information gathered from at least three different sensors from a distance of up to 2,500 feet away from the receiver. If time permits, and the payload is functional, the team will also explore designing, refining, and assembling printed circuit boards (PCBs) to be used within the payload, rather than multiple separate electrical components.

The team will also ensure clear communication through documentation to Cedarville University's engineering faculty via three documents and three presentations. These deliverables are as follows:

- This formal project proposal (due September 13, 2024).
- A class presentation (on November 4, 2024).
- A fall semester faculty presentation (on December 3, 2024).
- A fall semester final design report (due December 13, 2024).
- A spring semester faculty presentation (in April 2025).
- A spring semester final project report (due April 2025).

Additionally, NASA requires several documents to be submitted, as outlined in the SLH. These documents will be completed in coordination with the mechanical engineering team. An accompanying presentation to NASA is required in conjunction with these documents, which will be presented by the team CEO, Rebekah, along with two members of the mechanical engineering team. These are the documents required by NASA:

- A preliminary design report (due September 11, 2024).
- A critical design report (due January 8, 2025).
- A flight readiness review (due March 17, 2025).
- A post-launch assessment review (due within fourteen days of the final rocket launch).

All deliverable submissions to NASA and Cedarville University will contain relevant technical documents to clearly convey the team's design.

5. Development Strategy

The goal of the ECE team is to produce high quality work which consistently functions as expected while also meeting the expectations of NASA, Cedarville University faculty, and the mechanical engineering team. The payload system mainly consists of two steps, data collection and data transmission. The data collection will be performed by a series of sensors connected to a microcontroller (a Raspberry Pi 2040) which will perform calculations on the data and store it. Since the payload will be detached from the avionics system, the sensor information gathered will also be used to detect flight phases to determine when to start collecting data and when to transmit. The radio transmitter will also be connected to the microcontroller and an antenna within the rocket's nosecone. The payload will include a MicroSD card reader, which will have the collected flight data written to it which can be analyzed after a payload test or flight for debugging purposes.

Transmission of data is imperative to the competition, so functional radio transmission is one of the team's first priorities. To determine which data to transmit, the team has ordered the data which can be transmitted to NASA in order of feasibility. It is the team's goal to ensure consistent collection of the first four data measurements and consistent transmission of the data by performing incremental testing of data collection and transmission during development. If the team determines by the end of the first semester that it would be feasible to transmit more data measurements, the team will continue down the list. The three data measurements listed as “Tentative” would require no additional sensors to be added to the payload; only additional software would be required. The team must communicate to NASA the data intended to be transmitted by March 17, 2025. The order of feasibility determined can be found below in Table 5.1. Figure 5.1 provides a high-level architectural overview of the planned components and their interactions.

Table 5.1. Order of Data Measurement Feasibility

Priority	Objective	Expected?
1	Temperature of Landing Site	Yes
2	Apogee Reached	Yes
3	Orientation of On-Board STEMnauts	Yes
4	Time of Landing	Yes
5	Calculated STEMnaut Crew Survivability	Tentative
6	Landing Velocity, G-Forces Sustained	Tentative
7	Maximum Velocity	Tentative
8	Battery Check / Power Status	No

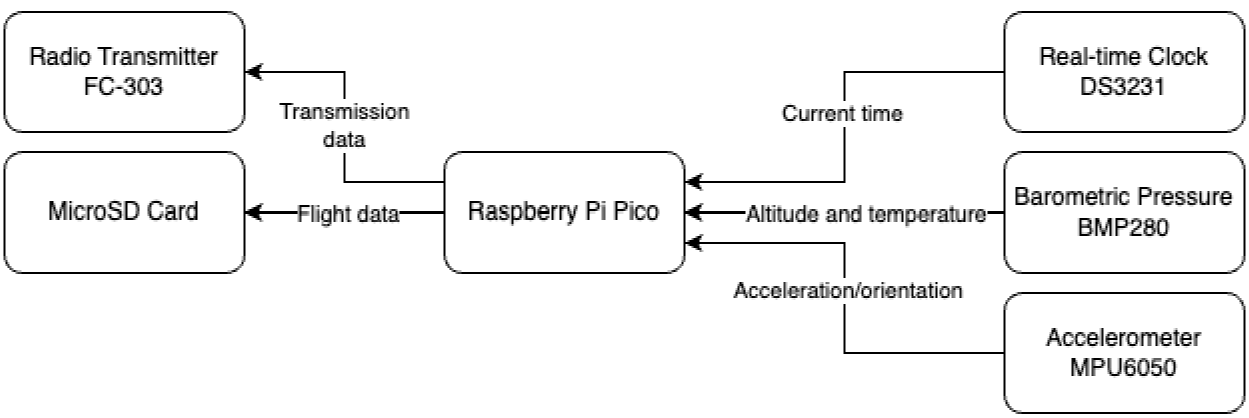

Figure 5.1. High-Level System Architecture

6. Testing Plan

Testing is done incrementally during development. In general, we intend to test payload data collection capabilities locally, and then simulate landing conditions deploying the payload within other model rockets, subjecting it to mechanical impact, or dropping it from heights to replicate the stresses experienced during landing and flight. The payload should survive such impacts, and these tests can be used to gather data for event detection, such as launch or landing detection. The team also has specific goals for each process and sensors which we will use for testing. A system will be considered functional when test conditions are met. These conditions can be found below in Table 6.1.

Table 6.1. Test Plan and Conditions

Test Description	**Expected Result**	**Test Procedure**	**Passing Result**
Time Functionality	Clock retains real-world time	Print out the current time to debug console after several power cycles	Ensure real-world time is kept after power cycles within +/-1 second within thirty seconds after power on
Accelerometer Functionality	Accelerometer tracks payload motion	Turn payload container across all axes while printing the calculated rotation to the debug console	Ensure the rotation calculated is +/-5 degrees of the measured rotation
Barometer Functionality	Barometer can be used to calculate true altitude ASL and AGL	Print out calculated altitude continuously to debug console; monitor altitude while up and down stairs	Ensure altitude is computed properly to +/-10 feet when compared to other reporting devices
Temperature Functionality	Temperature is accurate to current temperature	Move through different environments, within enclosed spaces, and during long-running times	Ensure temperature settles within one second with less than +/- 1°C of error
Transmission	Radio transmission can be read from up to 2,500 feet away	Transmit information out on the intramural fields and walk around, and change directions, and go behind small obstacles	Data is fully transmitted and received on the FTM-300DR from up to 2,500 feet away in every direction and without line of sight, especially when pointing directly at the receiver
MicroSD Data	The MicroSD card has flight history data which can be reviewed	Run the payload through the same test scenarios above while collecting data onto a MicroSD card	The test scenario data matches the data received from signals, and the data is uncorrupted

7. Budget Considerations

The following budget provided in Table 7.1 indicates the supplies that the team anticipates needing for the project. This includes both items that are already in inventory as well as other products that the team plans to purchase. Several of the critical parts listed have a quantity of "3" assigned; this is because the team is operating under the assumption that each pre-competition launch or durability test could result in the destruction of some or all of the components.

Table 7.1. Proposed Budget

Item Type	Part	Quantity	Unit Cost	Total Cost	Already Owned
Radio	FCC Ham Radio License	2	$ 35.00	$ 70.00	No
Radio	YAESU FTM-300DR	1	$ 379.95	$ 379.95	No
Radio	FC-303 Data Radio Transmitter	3	$ 30.00	$ 90.00	No
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	DS3231 Real Time Clock (3-pack)	1	$ 7.99	$ 7.99	Yes
Sensor	BMP280 Barometer & Thermometer (10-pack)	1	$ 7.99	$ 7.99	Yes
Sensor	MPU6050 Gyroscope & Accelerometer (3-pack)	1	$ 9.99	$ 9.99	Yes
Battery	2200mAh 3S LIPO Battery (2-pack)	1	$ 28.99	$ 28.99	Yes
Memory	W25Q64 Flash Memory Module (5-pack)	1	$ 7.99	$ 7.99	No
Memory	Micro SD-Card Reader (10-pack)	1	$ 8.89	$ 8.89	Yes
Memory	Micro SD-Card 32GB (5-pack)	1	$ 29.94	$ 29.94	Yes
PCB	PCB Manufacturing per Version	2	$ 40.00	$ 80.00	No
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:	**$ 916.70**	
			Actual:	**$ 737.91**	

8. Division of Responsibility

To distribute team responsibility and satisfy course requirements, our team will operate with the CEO, CFO, and CTO officer roles. Each team member will take on one of these roles. The CEO will be responsible for team management, NASA presentations, planning, and general communications with Cedarville University faculty and the mechanical engineering team leadership. The CFO will be responsible for financial management and communicating with faculty for purchasing necessary equipment. The CTO will be expected to have an in-depth technical knowledge of the payload systems and technical capabilities. Each team member has also been given additional responsibilities for different portions of the payload. Each team member is responsible for knowledge and functionality of their portion as well as the testing and documentation pertaining to it. The entire team, however, will contribute to general testing and general documentation. The team's division is given below:

- Kenneth Lee III (CFO):
  - Housing design and manufacturing
  - PCB design
- Rebekah Porter (CEO):
  - Circuit design
  - Electronics assembly
- Arkin Solomon (CTO):
  - Software design and development

9. Reporting Plan

The team will submit a report each week on the hours worked, progress made, and goals for the following week to the team advisor, Dr. Tuinstra. Additionally, the team will meet each week with the mechanical engineering team to coordinate efforts, communicate progress and needs, and facilitate effective teamwork.

Our team will give two milestone updates to our advisor Dr. Tuinstra. We have set the following objectives for our milestone updates:

- Milestone #1
  - Our PCB daughter board design will be completed and approved by Dr. Kohl.
  - We will have working communication between the microcontroller and each sensor over I2C.
- Milestone #2
  - We will have a completely working PCB daughter board.
  - We will have sent data transmissions from the payload’s transmitter and successfully displayed it from our receiver.
  - We will have a completed CAD model of the entire payload.

Finally, the entire list of our NASA and Cedarville deliverables, as well as our timeline for preparing to meet those deliverables, is layed out in a Gantt chart shown in Table 9.1.

Cedarville University NASA Student Launch 2024-25 Plan

CSL: Project Elijah PROJECT NAME | **8/14/2023** START DATE | **05/03/2024** END DATE

Task	Start Date	End Date	8/12/2024	8/19/2024	8/26/2024	9/2/2024	9/9/2024	9/16/2024	9/23/2024	9/30/2024	10/7/2024	10/14/2024	10/21/2024	10/28/2024	11/4/2024	11/11/2024	11/18/2024	11/25/2024	12/2/2024	12/9/2024	12/16/2024	12/23/2024	12/30/2024	1/6/2025	1/13/2025	1/20/2025	1/27/2025	2/3/2025	2/10/2025	2/17/2025	2/24/2025	3/3/2025	3/10/2025	3/17/2025	3/24/2025	3/31/2025	4/7/2025	4/14/2025	4/21/2025	4/28/2025	5/5/2025	5/12/2025	5/19/2025	5/27/2025
NASA																																												
Student Launch Proposal	8/14/2024	9/11/2024																																										
Preliminary Design Review (PDR)	10/3/2024	10/28/2024																																										
PDR Teleconferences	11/4/2024	11/26/2024																																										
Critical Design Review (CDR)	11/30/2024	1/8/2025																																										
Subscale Flight	10/7/2024	1/8/2025																																										
CDR Teleconferences	1/15/2025	2/6/2025																																										
Team Photos	2/6/2025	2/10/2025																																										
Flight Readiness Review (FRR)	2/6/2025	3/17/2025																																										
Vehicle Demonstration Flight	1/8/2025	3/17/2025																																										
Payload Demonstration Flight	3/17/2025	4/14/2025																																										
FRR Teleconferences	3/24/2025	4/11/2025																																										
Launch Window	4/5/2025	5/4/2025																																										
Post-Launch Assessment Review (PLAR)	4/5/2025	5/28/2025																																										
Cedarville																																												
Senior Design Formal Proposal	9/2/2024	9/13/2024																																										
Milestone #1	9/23/2024	10/3/2024																																										
Project Progress Presentation	10/14/2024	11/4/2024																																										
Milestone #2	11/4/2024	11/14/2024																																										
Final Presentations (Fall)	11/18/2024	12/6/2024																																										
End of Semester Report (Fall)	11/22/2024	12/13/2024																																										
Final Report	1/7/2025	4/11/2025																																										
Final Presentations (Spring)	4/11/2025	4/15/2025																																										