Project Documentation

OREGON STATE UNIVERSITY
2021-2022 NASA USLI TEAM

Team: USLI Payload and Avionics

May 2, 2022

Timothy Lee Grant
Ryan Bohl
Chien Hua Nicholas Lin
Jordan Hendricks
Jack Little

1 Overview

1.1 Executive Summary

Our project involves a rocket launched from the center of a virtual grid that is 5000ft by 5000ft in length, divided into 400 sections that are 250ft by 250ft. The goal of our project is to locate the final landing section of the rocket body after being launched to an altitude of 4500ft without the use of Global Positioning System (GPS). The payload is allowed to eject from the rocket at apogee, and detach from the rocket at an altitude of 500ft. It may contain any devices and sensors that can be fit inside of the size constraints of the rocket body. Sensors and other devices are also allowed to remain on the rocket the entire launch.

The final outcome of this project will be in two parts. The first is a system capable of locating the rocket body without the use of GPS. The second is a system capable of performing the avionics for the vehicle. The method for which the rocket body is found is at our team's discretion; the only sensory devices that are prohibited are GPS and anything that could have the potential to cause harm.

Members of this project will be a part of the University Student Launch Initiative (USLI), a multidisciplinary team with members from the Mechanical Engineering (ME) capstone, Computer Science (CS) capstone, and the Electrical and Computer Engineering (ECE) capstone classes at Oregon State University (OSU) [1]. The launch vehicle and payload are to be designed and constructed each year; previous years may aid in potential design decisions as well as provide feedback on design decisions. USLI is associated with the American Institute of Aeronautics and Astrospace (AIAA), which at Oregon State University is composed of eight separate teams. These teams function independently, but will occasionally come together for social, recruiting, or launch events. Oregon State University's AIAA is also associated with the Oregon Rocketry club (OROC), a public club with members across the state who help schedule launch fields and provide necessary support for launches. Additionally, AIAA and USLI members are associated with the National Association of Rocketry (NAR), where members can become registered and certified to launch vehicles with various levels of motors.

1.2 Team Communications and Protocols Standard

Protocol	*Standard*
Online Communications	All team members are active in the discord group created for this project. This has been designated as the default platform for communication. In addition, there is a group text chat and all members have each other's emails, which enables extra points of contact in the case of discord not being checked. The team has decided that there should only be one person to contact the project manager, because this will allow for more streamlined coordination between our group as a whole and the project manager. As a team, it is our responsibility to ensure that the team lead, Jack, understands any information we would like to convey to the project manager, then he can send an email that includes the rest of the team.
Scheduled Meetings	The payload team will be meeting every Monday afternoon at 6pm in Rogers Hall. In addition the University Student Launch Initiative (USLI) team will be meeting every Tuesday at 6pm Merryfield Hall or virtually over Zoom if in-person attendance is not possible. This will be an opportunity for all of the different teams that comprise the USLI group to ensure proper communications and expectations. There are additional meeting times scheduled as needed in Merryfield Hall for completing hands-on work.
Design Assessment and Approval Process	During the course of this project all ideas are welcome at all times; each idea will be given a fair assessment of how it fits the project requirements and would affect the direction of the project given financial, time, and logistical constraints. Since this project is multidisciplinary, members of the other capstone teams, ME and CS, can review proposed ideas to ensure that it is feasible in their respective fields and provide feedback. Potential ideas will also have to be reviewed by representatives of the other technical subteams in USLI, structures and Areo/Recovery, to ensure clear communication for integration and flight.

Quality of Work Expectations	Quality of work is set high for this project; team members must remain diligent in their work and submit work by stated/requested deadlines. Team members are expected to support other members throughout the project providing assistance, support, and ideas. If a team member submits work that is below the level expected for this project, the team member will be provided feedback and asked to redo their work on that section.
Dispute Resolution	In the case of a dispute among team members, the parties will settle issues via a conversation. If the issue is centered around an idea or concept for the project, the conversation will be settled by a majority vote and reviewed by the necessary parties associated with USLI. In the case of a personal issue between members, the issue will attempt to be resolved between members; the payload subteam lead has volunteered to act as a mediator if necessary. In extreme cases, communication with course TA's, professors, and OmBuds staff may be initiated regarding the issue.
Meeting Guidelines	Meetings will occur regularly during scheduled times. There will be three regularly scheduled meetings: Payload General, Payload Electrical, USLI General. In addition to the three regularly scheduled meetings, other meetings can and will be scheduled as necessary as one of the final points during any meeting. Communication about any additional meetings and reminders will be provided though either Slack, Discord, or emails.
Coding Practices	All code written will contain well documented code, such that a person familiar with the programming language will be able to understand the functionality of the code written.
Setback Resolution	Each member of the team will be transparent with their progress on their work. Setbacks or unexpected difficulties will be notified to the group shortly after they are identified. Group members will not attach shame to the individual who brings up their difficulty, but instead appreciate the individual's initiative to bring the issue to the group before the problem becomes unsolvable. Then the group will work together as a team to help solve the issue that has arisen.

Project Partner Communications	Jack Little will be the point of contact with the project partner. The team will bring concerns, updates, and questions to Jack who will then bring those questions to the project partner. Communications will take place using email or in person communication.

Table 1: Team Communication Protocols

Meeting Type	Date/Time
Payload General	Mondays 6:00 PM
Payload Electrical	Mondays 7:00 PM
USLI General	Tuesdays 6:00 PM

Table 2: General Meeting Time

Team Member	Student Email	Student Role
Jack Little	Littleja@oregonstate.edu	Team lead/liaison, Technical Researcher
Timothy Grant	Grantti@oregonstate.edu	IMU expert, Time of Flight implementation
Ryan Bohl	Bohlr@oregonstate.edu	Hardware Assembly, PCB designer, video editor
Nicholas Lin	Linch@oregonstate.edu	Nick, Team Communicator, Avionics Expert. Safety Officer
Jordan Hendricks	Hendrjor@oregonstate.edu	Power Supply, Video Editor

Table 3: Team Member Name and Oregon State Email

1.3 Gap Analysis

This project is important because it explores creative ways to solve the complex issue of locating multiple objects without the use of GPS. A direct application is if one desires to land equipment on the surface of a distant planet that does not already have a GPS satellite infrastructure. This project will assist in the ability of exploring new locations which will allow us to become more knowledgeable about the universe and generally benefit humanity.

Our solution will have the ability to be used in the situation where any satellites would encounter some type of malfunction, such as during an attack or outage. If this were to happen, the ability to determine the location of objects in relation to the surrounding environment would be important. In addition, our design would cut back on the reliance on a single technology, allowing for a stronger, more robust system that is resistant to outages. Specifically, our system would be self contained and not rely on satellites or technologies of that nature.

The main customer of the design would initially be government agencies. Most locations on Earth have access to GPS services, therefore the majority of benefit that this project would provide is on celestial bodies. Currently, not many non-governmental organizations are actively pursuing methods locating objects in areas where GPS is unable to reach. But as more private companies start to move into the aerospace industry, the importance of this project will increase to encompass non-governmental organizations as well.

1.4 Proposed Timeline

October:

- The month of October will be dedicated to sensor and design testing
- The Proposal draft is due on OCT 25th for review by mentor
- The Proposal will be complete on OCT 29th and submitted to National Aeronautics and Space Administration (NASA)

November:

- The month of November will be dedicated to senor and design testing
- Teams will split into two sub teams in preparation for the subscale test flights. Timothy and Ryan will work to create a working IMU that is able to capture and store data. Jack, Nick, and Jordan will work on drone designs that are able to *deploy* mid flight.
- By the end of this month a rough design will be determined

December:

- Subscale launches will occur during this month allowing flight testing of sensors

January:

- The Critical Design Review (CDR) is due on Jan 3rd, locking in our design with NASA
- Continuing designing and construction of the payload
- Continue subscale test flights

February:

- Have a majority of the payload blocks designed and any needed sensors, Printed Circuit Board (PCBs), and microcontrollers be ordered and shipped
- Continue subscale test flights

March:

- Construct Final version of the payload to be integrated into the rocket body
- Flight Readiness Review (FRR) is due MAR 7th confirming that our rocket will be able to fly safely
- Fly rocket as a part of the USLI competition, for record (if not done in april)

April:

- Launch final demonstration flight in Brothers Oregon to compete in the NASA student launch competition

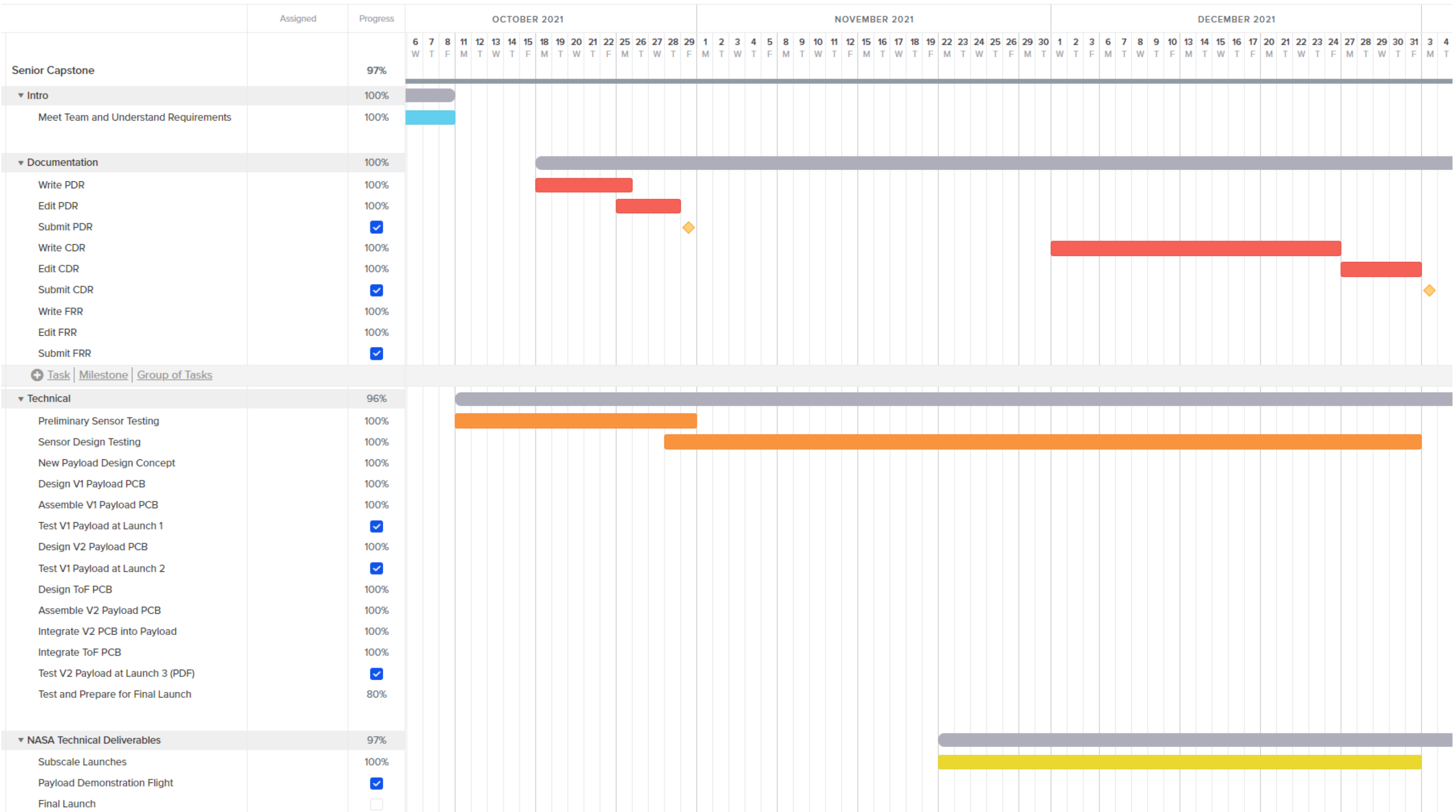


Figure 1: Team USLI Project Timeline I

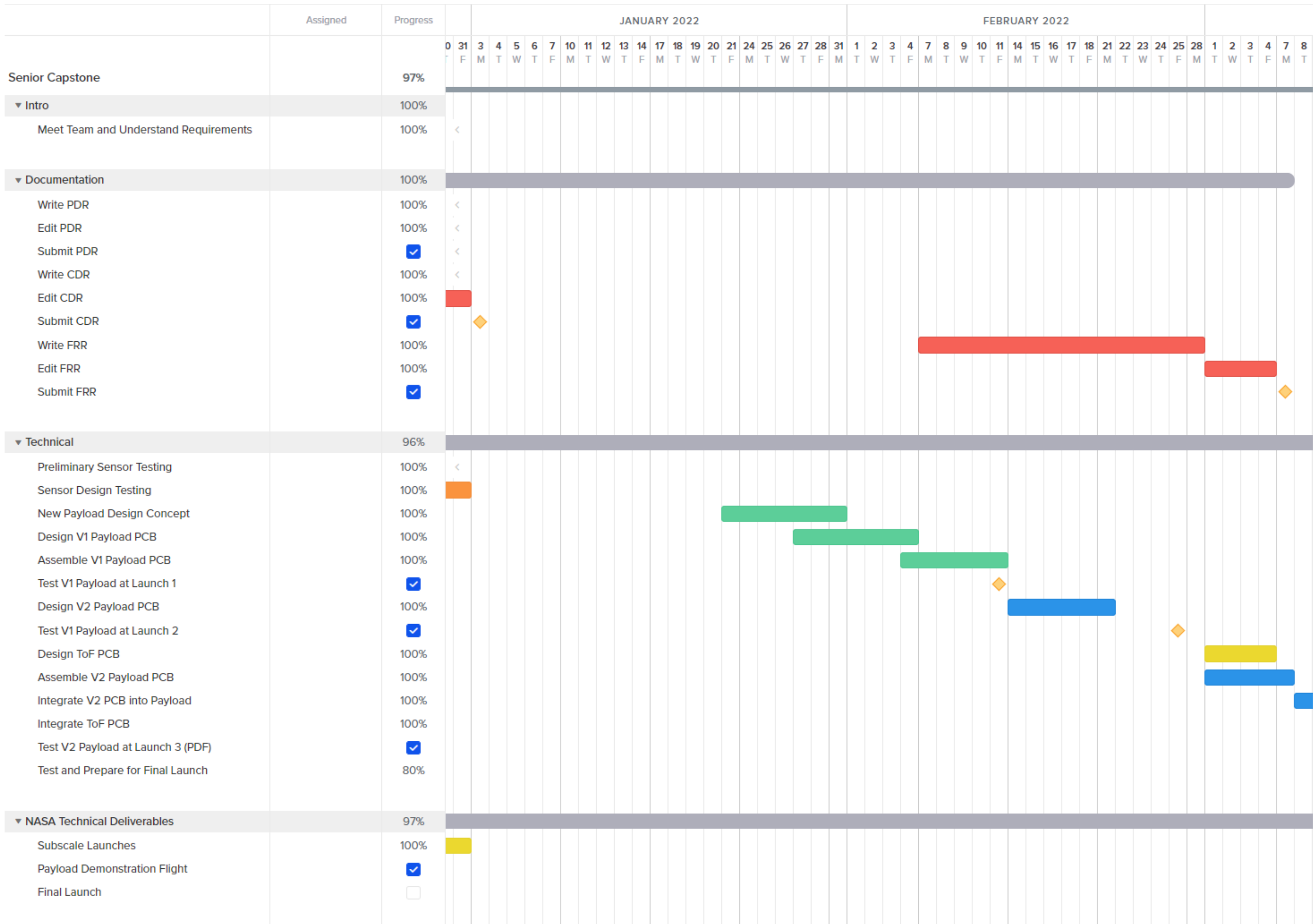


Figure 2: Team USLI Project Timeline II

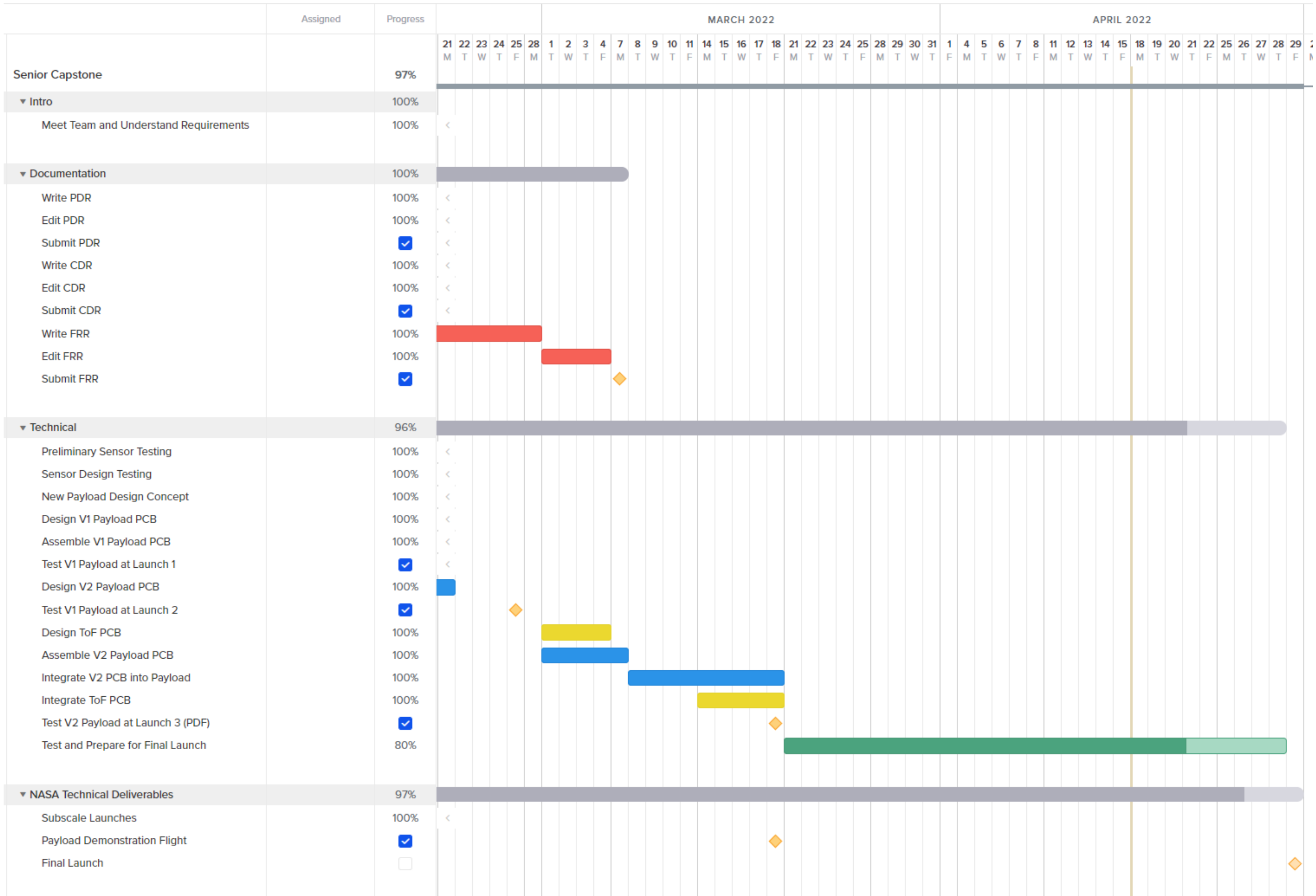


Figure 3: Team USLI Project Timeline III

1.5 References and File Links

1.5.1 References (IEEE)

Government Publication

[1] National Aeronautics and Space Administration, *2022 NASA Student Launch Handbook and Request for Proposal*. Washington, DC: Office of Headquarters Operations, 2021.

1.5.2 File Links

1.6 Revision Table

Date	What Was Done
10/21/2021	Timothy Grant: Initial Draft Creation
	Jack Little: Initial Draft Creation
	Jordan Hendricks: Initial Draft Creation
	Ryan Bohl: Initial Draft Creation
	Nicholas Lin: Initial Draft Creation
10/28/2021	Jack Little made revisions and additions to Executive Summary, Team Communication, References, and Revisions Table.
11/09/2021	Jack Little made changes to Executive Summary
11/11/2021	Timothy Grant: Added paragraph to Gap Analysis. Added event to timeline.
	Ryan Bohl: Revised executive summary
	Jack Little: revised document, incorporating feedback
	Jordan Hendricks: Added the remainder of the visual timeline
18 Nov,2021	Jack Little made corrections to References section
27, Nov, 2021	Timothy Grant made changes to the format of the Protocol/Standards, and added some new standards

Table 4: Team USLI Project Timeline II

2 Requirements Impacts and Risks

2.1 Graded Requirements

Requirement 2.1.1

Project Requirement: The project will have both a main location method and a redundant secondary location method.

Engineering Requirement: The final project will have at least 2 means of locating the rocket body in relation to the launch site, on a 20 by 20 grid of 250ft squares. The only technology forbidden in this process is GPS.

Verification Method:

1) Does the system have two means of determining the rocket body’s location?
2) Does the system know when to switch to the redundant method?
3) Does the system output a grid number between 1 and 400?
4) Does the main location system work in a controlled environment? Steps to do so below
5) Does the redundant location system work in a controlled environment? Steps to do so below
6) If yes to steps 1 through 5 then the requirement has been met. Documentation of such will be included in the verification section, section 5.

Requirement 2.1.2

Project Requirement: The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged. [1]

Engineering Requirement: The final project will remain powered for a minimum of 120 minutes, and operate normally, without a need to change batteries or recharge.

Verification Method:

1) Systems that remain powered during the entire launch will be powered in an idle state on a test bench for a minimum of two hours.
2) During the two hours current and voltage measurements will be taken.
3) Does the system have enough power to continue normal operation after the two hours?
4) If yes to steps 1 through 3 then the requirement is met. Documentation of such will be included in the verification section, section 5.

Requirement 2.1.3

Project Requirement: Electronic components should be secured in a way to ensure components cannot come loose or break during the rocket and payloads flight.

Engineering Requirement: The final project will use PCBs to make wired connections between components. Any wired connections from PCBs will be secured either with a screw terminal or a soldered connection. The final project will not include the following: breadboards, protoboard, copper clad boards.

Verification Method:

1) Does the final project contain any of the following: breadboards, protoboards, or copper clad boards?
2) Are all connections between components made via a PCB?
3) Are any wires from PCBs secured with either a screw terminal or a soldered connection?
4) If yes to step 1 through 3 then the requirement is met. Documentation of such will be included in the verification section, section 5.

Requirement 2.1.4

Project Requirement: The final project will include a functional Avionics unit.

Engineering Requirement: The final project will include an avionics unit that can eject parachutes at 4700 feet and 700 feet. It will also include altimeters and a GPS unit to track position.

Verification Method:

5) In a test bench is the avionics unit capable of:
    a) Collecting GPS data?
    b) Wrirelessly Communicating GPS data?
    c) Igniting e-matches at an altitude of 4700 feet or similar conditions?
    d) Igniting e-matches at an altitude of 700 feet or similar conditions?
6) Are altimeters independently powered?
7) If yes to step 1 and 2 then the requirement is met. Documentation of such will be included in the verification section, section 5.

Requirement 2.1.5

Project Requirement: The Electrical Engineering Subteam will work with the USLI team to complete the Preliminary Design Review.

Engineering Requirement: The final project will include a Preliminary Design Review that will be submitted no later than 01 November, 2021. The rough draft of the document will be due in the week prior for review by our mentor before submission to NASA.

Verification Method:

1) Within the month following the document submission to NASA the Project Partner and or USLI team lead will send email confirmation of document submission.
2) A copy of the email, time table of hours put into the document, and link to the document will be included in the Verification section, section 5.

Requirement 2.1.6

Project Requirement: The Electrical Engineering Subteam will work with the USLI team to complete the Critical Design Review.

Engineering Requirement: The final project will include a Critical Design Review that will be submitted no later than 03 January, 2022. The rough draft of the document will be due in the week prior for review by our mentor before submission to NASA.

Verification Method:

1) Within the month following the document submission to NASA the Project Partner and or USLI team lead will send email confirmation of document submission.
2) A copy of the email, time table of hours put into the document, and link to the document will be included in the Verification section, section 5.

Requirement 2.1.7

Project Requirement: The payload will need to be able to fit within the rocket and have a fixed weight to ensure proper stability of the rocket.

Engineering Requirement: The final payload project will not exceed the size, volume, and weight restraints of 5.25” x 15” cylinder and 10 lbs.

Verification Method:

1) Is the height of the overall payload less than 15 inches?
2) Is the diameter of the overall payload less than or equal to 5.25 inches?
3) Is the total weight of the payload less than or equal to 10lbs?
4) If yes to steps 1 through 3 the requirement is met. Documentation of such will be included in the verification section, section 5.

Requirement 2.1.8

Project Requirement: All members of the Electrical Engineering subteam will become NAR level 1 certified.

Engineering Requirement: All members of the USLI Payload/Avionics team will be at least NAR level 1 certified by or before 31 March 2022.

Verification Method:

1) Scanned copies of each member's NAR level 1 certificate paperwork and or NAR membership card will be included in the verification section, section 5.
2) NAR paperwork includes the date that each member earns their NAR certification, confirming that all members earned their certifications on or before 31 March 2022. This information will be organized in a table in the verification section, section 5.

2.2 UnGraded Requirements

Requirement 2.2.1

Project Requirement: The payload should be accurate up to 1 grid square away or within 250 square feet.

Engineering Requirement: The final project will determine the coordinates of the launch vehicle to an accuracy of at least 250 feet.

Verification Method:

1) In a controlled environment, have the payload determine the location of the rocket body, with all points being known. I.e. the position of the drone, home station, and rocket body are known.
2) Record the estimated position of the drone and rocket body, as found by the payload.
3) Repeat 3 to 5 times.
4) Repeat steps 1-3 with 2 to 3 different sets of positions for the drone and rocket.
5) Is the average difference between the known positions and measured positions greater than 250?
6) If yes to step 5 the requirement is met. Documentation of such will be included in the verification section, section 5.

Requirement 2.2.2

Project Requirement: The Electrical Engineering Subteam will work with the USLI team to complete the Flight Readiness Review.

Engineering Requirement: The final project will include a Flight Readiness Review that will be submitted no later than 07 March, 2022. The rough draft of the document will be due in the week prior for review by our mentor before submission to NASA.

Verification Method:

1) Within the month following the document submission to NASA the Project Partner and or USLI team lead will send email confirmation of document submission.
2) A copy of the email, time table of hours put into the document, and link to the document will be included in the Verification section, section 5.

Requirement 2.2.3

Project Requirement: Electrical systems need to be able to communicate within the entirety of the launch field.

Engineering Requirement: The final project will be capable of sending data and communicating at distances at a minimum of 2000 feet.

Verification Method:

1) In a controlled environment, set one transceiver at a known location and another 2000 feet away
2) Begin sending data between the transceivers. After a transmission is received the far away transceiver will move an additional 50 feet away.
3) Once the transmissions are unable to be received, record that distance as the maximum transmission distance.
4) If the maximum transmission distance is greater than 2000 feet the requirement is met. Documentation of such will be included in the verification section, section 5.

2.2 Impacts

2.2.1 Introduction

The purpose of the following assessment is to provide to the reader an honest and unbiased evaluation of the consequences that this project may cause or may perpetuate. With any assessment, it is important to recognize that the author does bring biases, regardless of the care in which the author attempts to mitigate those biases. The author, as is the reader, are subject to personal biases, cultural biases, political and many other biases.

This assessment will go over the safety concerns that need to be taken into account when dealing with a full scale rocket. Then it will explore the cultural and social implications that the project and the organization which the project is working with perpetuate. The next section will examine the environmental concerns which can be foreseen, and finally the economic concerns will also be addressed.

While some of the problems brought up in this document will not be able to be fully addressed or solved in the scope of this project, other problems can be mitigated. For those issues that can not be solved in the duration of this project, conscious effort should be made in addressing and acknowledging these issues so that going forward into the future, we will be better equipped to make positive changes and to stand up for a more equitable and just society overall. This document will detail those attempts in which the author and the team intend on following to lead to a more ethical society.

2.2.2 Public Health, Safety, and Welfare Impacts

When dealing with a rocket, there will always be safety concerns that need to be taken into consideration. Rockets are essentially a projectile with a bomb. If proper safety precautions are not observed, the rocket propellant could ignite in an incorrect time. This needs to be taken very seriously because if such a situation occurs, there is a possibility of loss of human life. In order to reduce the risk of accidental discharge of rocket ignition, only certified individuals will have access to the rocket when there is a possibility that the rocket could ignite. It will be the responsibility of all members of the USLI team to ensure that we follow the safety rules that are in place.

Another danger when working with rockets is that of the trajectory with which the rocket might take. This includes the planned trajectory and the situation of a failure occurring during the flight. It is important to launch in a location where the rocket will only land in a location where people are not located. In addition the path of the rocket can not be in an airspace where airplanes could collide with the rocket on its flight. The FAA (Federal Aviation Administration) has safety guidelines which must be followed regarding large amature rockets. The rocket that we will be launching qualifies as a large amature rocket because it weighs over 4lbs. Therefore, we must follow the proper guidelines outlined in the FAA's rules [2]. In accordance with FAA regulation, the team will ensure that all detachable sections of the rocket contain a working GPS module. In addition, all launches will be supervised by a NAR certified Range Safety Officer. The Range Safety Officer will ensure that the launch has been cleared for approval and all guidelines are being followed.

Our project utilizes RF communications. According to the law, anyone is allowed to use the bandwidth for frequencies of 900MHz, 2.4GHz, and 5.8GHz [3], [4], [5]. These frequencies are extremely noisy due to the very fact that anyone is allowed to use these frequencies. It will be necessary to use frequencies outside the public use bandwidth inorder to perform the required operations of our project. Therefore our group will need to adhere to the FCC's rules regarding responsible usage of restricted frequency bandwidths. The FCC has established specific bandwidths that are available to people who have an amature radio license. In order to get an amature radio license, a test will need to be taken. Once at least one person in the group has an amature radio license, this will allow us to broadcast within the amature radio bandwidth as long as that member is present for the operations.

2.2.3 Cultural and Social Impacts

NASA, as with most engineering companies and organizations, suffers from a diversity problem. On the NASA webpage, there is a breakdown of racial demographics at NASA. NASA's workforce consists of 72% white or Caucasian [6]. This information was not broken down into which positions are held by which groups. It is possible that many of the higher prestige jobs are held by a skewed distribution that excludes minorities and other disadvantaged peoples. After digging through the NASA Equal Employment Opportunity Strategic Plan for FY 2017-19 documentation that NASA releases, the inclination was correct. In fact, only 1.3 percent of NASA's SL and ST (Senior Level and Scientific) positions are held by Black and African American [7].

But beyond the racial demographics, there was no mention on the NASA official webpage of the percentage of the workforce that was women. According to the Washington Post, the number of NASA employees is shockingly low, only 16 percent of Scientific Senior Positions were occupied by women [8]. NASA must take this problem seriously and be proactive in the promotion of women in their organization. NASA should set an example to other tech and science organizations of how to run a successful organization with strong representation of women in key scientific and technical positions. Ways in which the members of the team can work to close this gender discrepancy is to participate in events that do outreach to people who are interested in going into science or engineering. In addition to participating in events that encourage girls to go into engineering, it is necessary for the group to regularly reflect on their actions to determine if the way in which the project is being conducted is conducive to an inclusive environment and would be able to be integrated in a mixed gender setting. Even though the group is composed of all male identifying members, it is important that at all times in the project the members of the group behave in a manner that would feel comfortable to all groups of people. By acting in such a manner, it enforces a habit of a standard of conduct that must always be observed in a professional environment.

2.2.4 Environmental Impacts

The rocket propellant will use a chemical called Ammonium perchlorate composite. According to the National Library of Medicine, Ammonium perchlorate has been shown to have effects on the reproductive functions of mice, but no such results have been observed in humans [9]. With this in mind, the chemical should not be put into waterways where fish or other organisms can ingest it.

The creation of this project will require a large amount of gas. Because the rocket is only allowed to be tested in Brothers Oregon, it will be required to drive there regularly. The method of transportation that will need to be used to get to our destination is cars, but cars are one of the least efficient methods of travel (only behind taxis) [10]. With a large group, consisting not just of this project's capstone group, but of the entire USLI club, needing to travel so often, it is hugely important to think about the carbon emissions that will be released while testing the rocket. Some ways to lessen the amount of CO2 released in the process of testing are to carpool whenever feasible, and do as much testing as possible in a single trip.

2.2.5 Economic Factors

NASA is an enormous organization which receives 23.2 Billion dollars per year from the Federal Government [11]. The natural question arises as to why so much money should be allocated to an organization whose mission is to explore other worlds, when our own country is riddled with inequalities. The natural ethical question arises, should this money be allocated towards space exploration, when instead this money could go to help rectify the failing infrastructure in minority dominated areas? This is not necessarily a problem with NASA, but a part of a much larger systematic problem that places less value on minority groups and therefore allocates less money towards infrastructure within those communities. NASA is a part of the United States Government, but the problem arises one layer above. Money allocated towards NASA does not mean that money will not be allocated towards other causes. The much larger problem is that money is not being allocated towards those other causes. Congress allocates money to be spent by the United State government. It is extremely important to continue to advocate for changes for more resources allocated towards disadvantaged groups instead of trying to decrease the resources allocated towards scientific organizations such as NASA. The United States has a massive economy of 20 Trillion dollars per year, and spends 6.6 trillion dollars per year [12], [13]. When comparing the total federal spending to the amount that the entire organization of NASA receives, the amount is less than one percent.

Group members are able to make a positive contribution to the fair distribution of wealth by advocating politically for changes in federal spending, and by working on projects that will have the greatest positive impact on disadvantaged groups in the future. Members can also make a positive change in the future by donating to causes that are deemed to be worthy. Consideration in the current moment, will allow greater perspective to which organizations we would like to donate our time and money towards in the future. As responsible global citizens, it is important for us to constantly be aware of problems that are facing people outside of our social circles.

2.2.6 Conclusion:

This project will help NASA to test different methods of locating multiple objects in relationship to each other without the use of GPS. This will further develop the mission of exploring astrological bodies. The ultimate goal to which NASA is working towards is a worthwhile one, that has many positive impacts for all people on the Earth, but the path along the way to accomplishing these goals is also extremely important. NASA should work towards ensuring that a more balanced gender workforce is employed in the organization and that upper level management and scientific positions are occupied by people who more accurately represent the population of America. It is the responsibility of all people who work at NASA and who work with NASA (which includes our organization of USLI) to work towards those goals of equity and representation.

This project does not contribute significantly to environmental problems, but as with all activity the way we once lived is becoming a less and less viable way of living going forward into the future. It will become increasingly important to think of all the ways that we are contributing towards climate change in order to try to reduce and eventually eliminate those practices.

The most pressing aspect of the project that needs active attention is that of safety. A rocket can be a very dangerous device and needs to be dealt with in the utmost care. There are regulations in place to ensure the safety of all those involved with rocketry, it is the team’s responsibility to adhere to all of those regulations. In addition, there are other regulations that do not directly put lives at risk, but do interfere with the wellbeing of the society, these include the frequencies at which the team broadcasts the RF communications. These communications, if broadcasted at the incorrect frequency could cause other organizations, such as the military, to receive noisy signals, thereby decreasing their ability to have effective communication with each other. All safety concerns as well as risks to the overall health of the society must be taken into consideration. This will be done by taking care to follow all laws and regulations that have been reestablished for the receptive practices.

2.2.7 Suggestions:

1. Only certified members will have access to the rocket when the engine is loaded into the rocket.
2. Follow all FAA regulations (such as GPS present on all detachable rocket components, clearing airplane flight paths, ect)
3. Obtain amature radio license, follow courtesy protocol while broadcasting within the amature radio bandwidth.
4. Participate in events that encourage young people (especially girls)
5. Practice an inclusive culture within the project process.
6. Carpool when available to cut down on CO_2 emissions.

7. Be mindful of economic disparities, and keep in mind organizations and projects that work to fight against those inequities.

2.2.8 Revision Table:

Date	Action Taken
18 Oct, 2021	Timothy Grant: Initial creation of document
25 Oct, 2021	Timothy Grant: Added content for Environmental Impacts
28 Oct, 2021	Timothy Grant: Added content for Cultural/Social Factors and Economic Impacts
29 Oct, 2021	Timothy Grant: Revised content for the Cultural/Social Factors
31 Oct, 2021	Timothy Grant: Finished document for Rough Draft
23 Nov, 2021	Timothy Grant: In accordance with Professor Cate's comments, added examples of FAA rules that the team will observe during launch and building of the rocket.
23 Nov, 2021	Timothy Grant: In accordance with Professor Cate's comments, changed vocabulary in the Introduction section to be more action orientated. Also deleted the paragraph which was found to be repetitive in the Introduction section.
31 Nov, 2021	Timothy Grant: In accordance with Professor Cate's comments, added a paragraph outlining some suggestions that can be taken in the future to work to mitigate problems listed in the Economic section. This paragraph replaced a paragraph that I deleted because it was focused on personal economic implications as opposed to global/societal.
2 Dec, 2021	Timothy Grant: In accordance with Professor Cate's comments, added a numbered list for recommendations in the conclusion section.
2 Dec, 2021	Timothy Grant: In accordance with Professor Cate's comments, fixed References indentation.
2 Dec, 2021	Timothy Grant: In accordance with Professor Cate's comments, added content to the Social/Cultural section to give more suggestions to developers on ways to create a more inclusive work environment.
16 April, 2022	Timothy Grant: Minor spelling changes

2.3 Risks

Risk ID	Risk Description	Risk category	Risk prob-ability	Risk impact	Performance indicator	Responsible party	Action Plan
R1	Disagreement of Implementation	Interpersonal	45%	Medium	Communication levels among groupmates, respect level between groupmates	Jack	Keep goal in mind
R2	Battery Performance Affected by Weather	Environmental	40%	Medium	Weather, battery type	Nick	Using Li-po battery, and have a backup battery
R3	Crash Landing, rocket damage	Public safety	30%	High	Ejection mechanism	Aero Recovery Team	Check parachute system
R4	Components Delaying	Technology	30%	High	Port closures	Ryan	Check Lead times, have alternative options
R5	Remote Courses affecting work	Political	30%	Medium	Student's and faculty decisions, COVID-19 spikes, local or federal change of policy	Brittany--USLI representative	Use remote skills gained during Junior Design
R6	Covid-19 Global Virus outbreak	Environmental	20%	High	New Case Data, immediate sickness	Safety Team	All team member wear mask at all time and required to be vaccinated

R7	Sharp item get into eyes	Environmental	20%	Medium	Materials, Safety goggle	Safety Team	Team member will be wearing safety goggles during the vehicle assembling
R8	Car accident	Environmental	10%	High	Driver’s physical and mental status, Weather.	Jack	OSRT who’s driving at the time will rest for at least 8 hours before the trip
R9	Fire injury, damage	Environmental	10%	High	Smoke, alarms, system failure	Safety Team,	Fire Extinguisher
R10	Sharp material injury during build	Environmental	10%	Low	Materials	Structure team members	OSRT team members will wear protection at all times. Included, long sleeves, close toe shoes, gloves etc…

Table 5: Risk Register Table

2.4 Reference and File Links

2.4.1 References (IEEE)

[1] National Aeronautics and Space Administration, *2022 NASA Student Launch Handbook and Request for Proposal*. Washington, DC: Office of Headquarters Operations, 2021.

[2] Everything Old is New Again: From Amateur Rockets to Drones, Everything Old is New Again: From Amateur Rockets to Drones. Washington, DC: Office of Headquarters Operations, 2018. https://www.faa.gov/about/history/milestones/media/amateur_rocketry.pdf

[3] NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION OFFICE OF SPECTRUM MANAGEMENT, FEDERAL SPECTRUM USE SUMMARY 614-902 MHz. Washington, DC: Office of Headquarters Operations, JUNE 21, 2010. https://www.ntia.doc.gov/files/ntia/publications/compendium/0614.00-0902.00_01SEP14.pdf

[4] NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION OFFICE OF SPECTRUM MANAGEMENT, FEDERAL SPECTRUM USE SUMMARY 2400-2417 MHz. Washington, DC: Office of Headquarters Operations, JUNE 21, 2010. https://www.ntia.doc.gov/files/ntia/publications/compendium/2400.00-2417.00_01SEP14.pdf

[5] NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION OFFICE OF SPECTRUM MANAGEMENT, FEDERAL SPECTRUM USE SUMMARY 30 MHz – 3000 GHz. Washington, DC: Office of Headquarters Operations, JUNE 21, 2010. https://www.ntia.doc.gov/files/ntia/publications/spectrum_use_summary_master-07142014.pdf

[6] National Aeronautics and Space Administration, FY 2020 Report. Washington, DC: Office of Headquarters Operations, 2020. https://www.nasa.gov/offices/odeo/workforce-data

[7] National Aeronautics and Space Administration, NASA EQUAL EMPLOYMENT OPPORTUNITY STRATEGIC PLAN FOR FY 17-19 AND FY 17 ANNUAL REPORT. Washington, DC: Office of Headquarters Operations, 2020. https://www.nasa.gov/sites/default/files/atoms/files/fy_2018_nasa_md-715_report_508.pdf (page 3)

[8] Christian Davenport. “At NASA, 2019 was the year of the woman, yet women still are a big minority at the space agency.” The Washington Post. (retrieved Date Accessed). https://www.washingtonpost.com/technology/2019/11/26/nasa-was-year-woman-yet-women-still-are-big-minority-space-agency/ (accessed Oct. 25, 2021).

[9] *Ammonium perchlorate (Compound), National Library of Medicine, 2005 to 2021*. [Online]. Available: https://pubchem.ncbi.nlm.nih.gov/compound/Ammonium-perchlorate#section=Toxicity (section 11.1.1)

[10] Jocelyn Timperley. “How our daily travel harms the planet.” BBC.com. (retrieved Date Accessed). https://www.bbc.com/future/article/20200317-climate-change-cut-carbon-emissions-from-your-commute (accessed Oct. 27, 2021).

[11] “NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FY 2021 SPENDING PLAN FOR APPROPRIATIONS PURSUANT TO P.L. 116-260,” NASA, U.S.A, June 2021. Accessed: Oct 25, 2021. [Online]. Available: https://www.nasa.gov/sites/default/files/atoms/files/updated_fy_2021_spend_plan_june_2021.pdf

[12] The World Bank, “GDP (current US$) - United States | Data,” 2020. [Online]. Available: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=US. [Accessed: Oct. 22, 2021].

[13] “The Federal Budget in Fiscal Year 2020: An Infographic.” Congressional Budget Office. https://www.cbo.gov/publication/57170 (accessed Oct. 23, 2021).

2.4.2 File Links

- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Flight Readiness Review (FRR)

- Include PLAR document after rocket launch

2.5 Revision Table

Date	What Was Done
22 Oct, 2021	Timothy Grant: Create Initial Outline and create rough draft of content in sections.
25 Oct, 2021	Jack Little: Wrote design requirements
28 Oct, 2021	Timothy Grant: Added initial risk assessment table
	Nicholas Lin: Added initial risk assessment table
	Jordan Hendricks: Added initial risk assessment table
	Ryan Bohl: Added initial risk assessment table
	Jack Little: Added initial risk assessment table
11 Nov, 2021	Timothy Grant: Added text to engineering requirements, slight revisions to wording in risk table
	Ryan Bohl: Revised risk table, revised Revision Table
	Jack little: Re-formatted engineering requirements, reformatted revision table, linked PDR
	Nicholas Lin: revised non-technical engineering requirements.
	Jordan Hendricks: Verified accuracy, proof read, and changed awkwardly worded sentences.
18 Nov,2021	Jack Little: Made corrections to References section
24 Nov, 2021	Jack Little: Reformatted the Requirements section, added project partner requirements, refined verification methods, and added to references section.

Table 6: Revision Table

3. Top-Level Architecture

3.1 Block Diagram

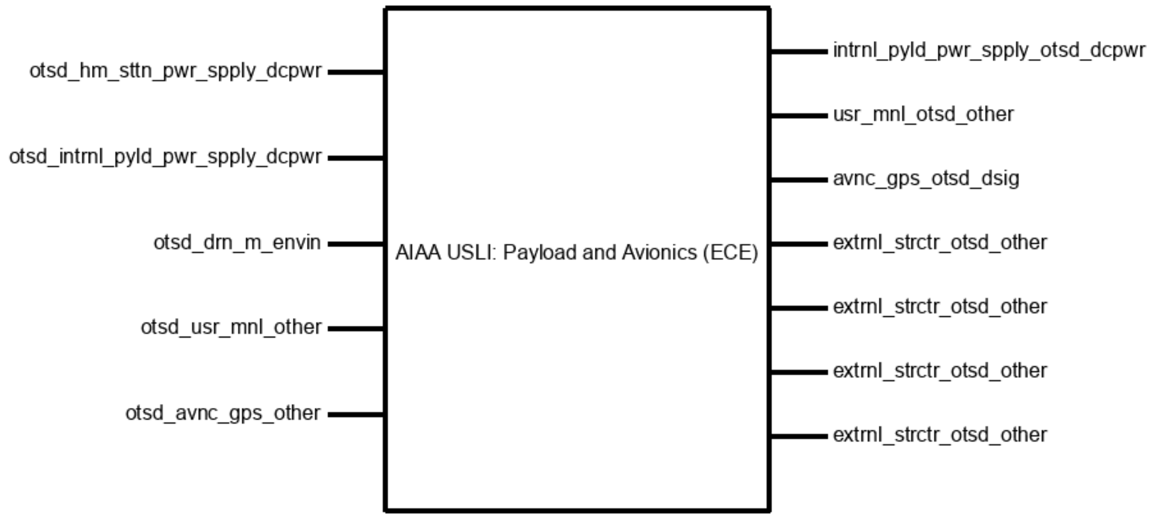


Figure 4: Top Level Diagram for The Payload and Avionics System

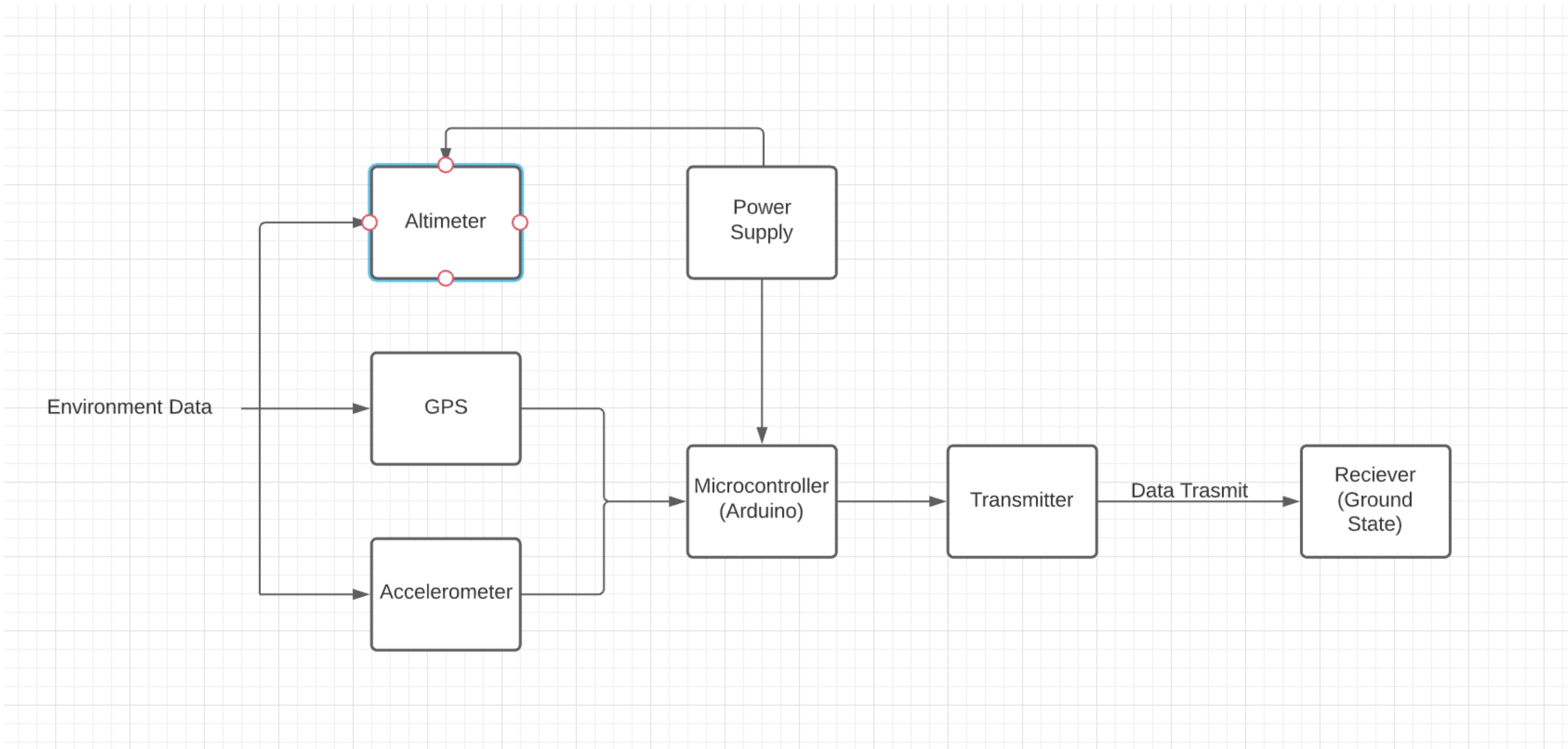


Figure 5: Block Diagram For Avionics System

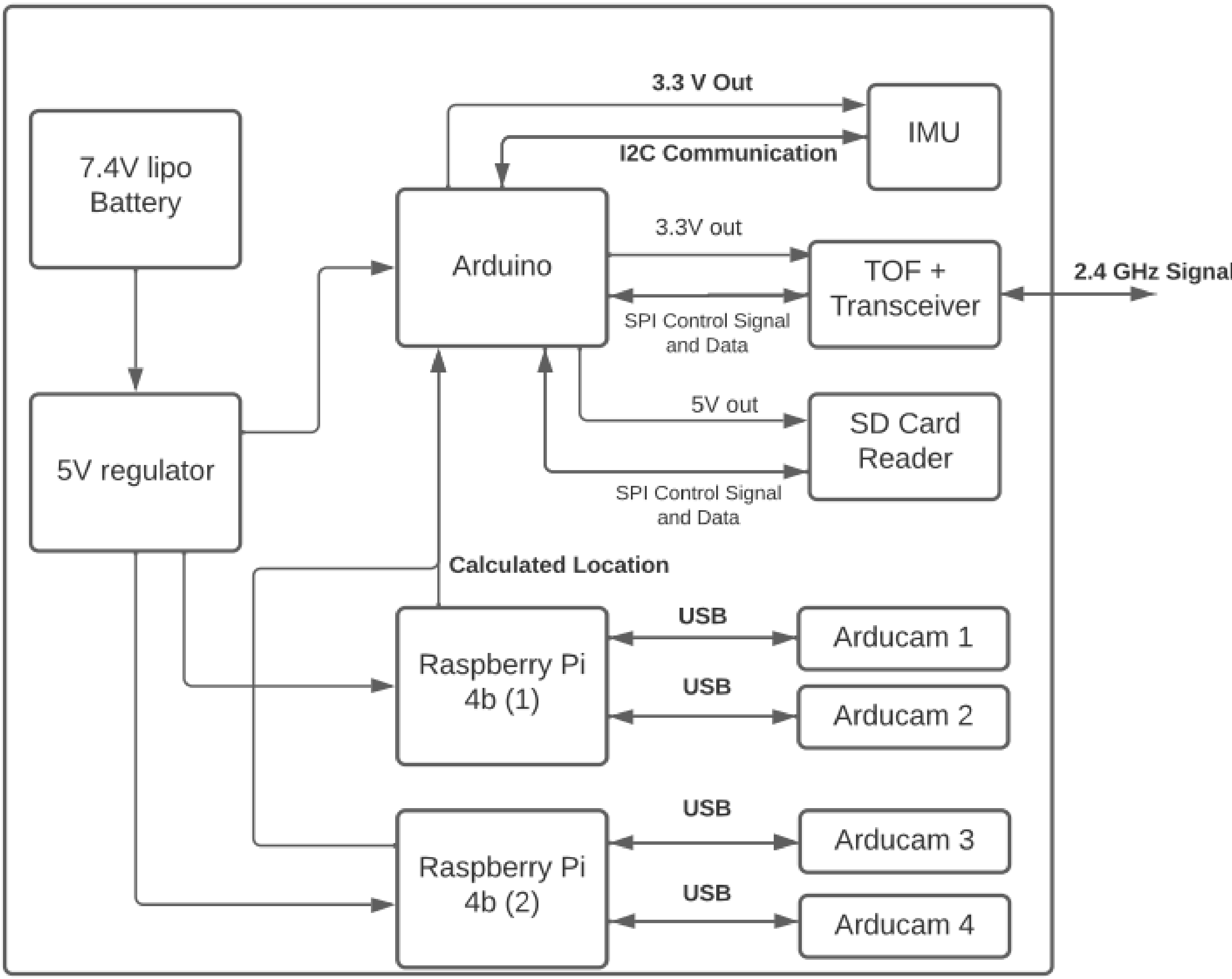


Figure 6: Block Diagram for the Internal Payload

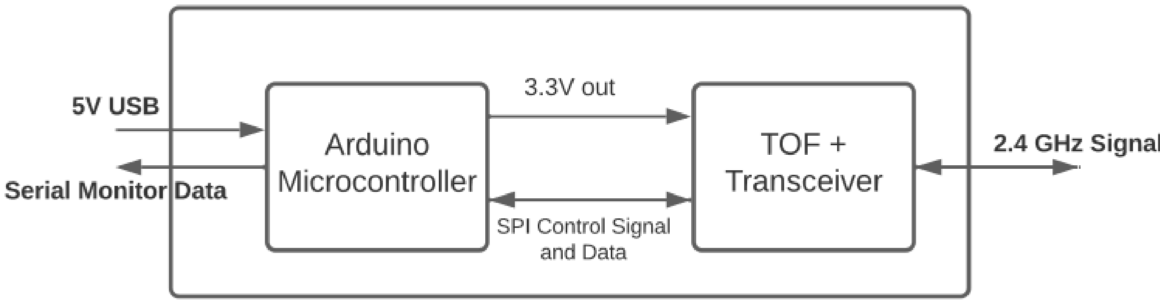


Figure 7: Block Diagram for the Home Station System

3.2 Block Descriptions

This page generates the contents of Section 3.2. Based on your project document, you will want to update formatting to match. The table shows the current complete list of blocks in the student portal for your project. This output can be helpful for summarizing your current project state and looking for discrepancies in the system architecture. This page is not guaranteed to be visible to users who are not students of ECE44x.

The table below can be 'Copy and Pasted' into Google Sheets, Excel, MS Word, and a variety of other tools.

Name	Description
Drone IMU Champion: Timothy Grant	*An IMU is a device that takes in acceleration data in the X Y and Z direction, angular velocity in the X Y and Z direction, and the magnetic field of the Earth in the X Y and Z direction. The task of this block is to take in the data that is coming in from the environment into the IMU and to then translate that data into something useful that can then be used by other blocks to accomplish the various tasks required. This IMU will be placed onto a drone. The task that will be required for the IMU is to be able to determine the orientation that the drone is in. This will be done by the use of the gyroscope data. As the drone tilts, the tilt can be measured by the gyroscope as an angular velocity. But there is a problem by simply adding up the angular velocities. Imagine a scenario in which the device is tilted in the positive X direction 90 degrees, then along the device's positive Z direction 90 degrees, then finally it in the negative Y direction 90 degrees. The device will now be flat again, but if the technique of adding up the total angular velocities is used, then the final orientation will be +90 in the X, +90 in the Z, and -90 in the Y. The problem lies in that the device's coordinate frame is different from the reference frame. Therefore when multiple rotations are applied together the orientation will lose its bearing. To fix these issues there is an idea called a rotation matrix. A rotation matrix is a mathematical representation of the projections each axis has on the reference frame. This method can be used to apply rotations to a frame*

	which is changing relative to the reference frame. There exists a different mathematical concept called quaternions. Quaternions use rotation matrices but are a layer abstracted and are therefore easier to work with. Luckily the IMU that this block works with has the ability to obtain the four quaternion values and feed those four values to the software. This block makes use of this functionality to determine the pitch and roll of the device, and thereby creating a PWM signal to be sent to the motor controller based on the orientation of the devices in order to keep the drone stable.
Home Station Power Supply Champion: Ryan Bohl	*This block is the custom power supply that will take in DC power from a lipo battery to provide 5v and 3.3v outputs. The main purpose of this block is to supply power to every device that will be used at the home station (launch site) during a rocket launch. Through the use of an Arduino's voltage regulator, this home station power supply will supply 3.3 volts to a transceiver that communicates with the rocket's transceiver to control payload behavior at different points during flight. Additionally this block provides 5v power to the custom designed time of flight sensor, which pings a signal to determine the distance of the rocket. Voltage is also supplied to an arduino nano microcontroller that sends control signals to the time of flight sensors and transceivers. The arduino will have female pins so that jumper wires can be connected to other devices as desired in the development process. In conclusion this block takes in power from a battery up to 15 volts and supplies the operating voltage to all components present at the home station*
Internal Payload Power Supply Champion: Jordan Hendricks	*This block takes in a voltage and steps the voltage down to levels which can power the interfacing components. The internal power supply is responsible for providing the correct voltage and current to the Arduino Nano microcontroller and the SD card reader. The other components on the system to be powered include an IMU and XBee3 Radiofrequency module. These modules require 3.3 Volts and will be connected to the 3.3 Volt pin on the Arduino. Each of these components are expected to have low current draw and should be able to be powered with one power supply.*

Home Station Power Supply Champion: Ryan Bohl	*This block is the custom power supply that will take in DC power from either a battery or laptop USB and steps it down to 5 volts. This home station power supply will supply 5 volts to a transceiver that communicates with the transceiver on the payload. Additionally it provides power to the time of flight sensor. Finally, the output voltage is also supplied to microcontrollers that send control signals to the time of flight sensors and transceivers. In conclusion this block takes in power from a laptop or a battery up to 15 volts and supplies the operating voltage to all components present at the home station*
Drone ToF Champion: Jack Little	*This system will be able to measure the time of flight of a Radio Frequency (RF) signal and use that measurement to determine the distance from the sensor to a specific relay. The system is run on a 30MHz crystal oscillator and counts the cycles before the signals return. The system is required to be as small and lightweight as possible, and will likely be integrated onto the Drone PCB. This specific Time of flight sensor does not act as a relay to the other systems. The maximum accuracy of this system with the specified clock speed is roughly 10 meters. These measurements will be used to find the position of two points in space relative to this module.*
Avionics PCB Champion: Nicholas Lin	*The PCB (Printed Circuit Board) will be designed specific for the Avionic system. The PCB will be designed to connect to the Arduino Uno, and the components that is required for the Avionic system, which included GPS, Transceivers (Transmitter will be the one that is build on the PCB, and the receiver will be at the ground station)*
Home Station Enclosure Champion: Timothy Grant	*The home station enclosure will be where the electronic components for the home station are located. The home station will contain a PCB with an Arduino Nano attached onto the PCB. Above the Arduino Nano will be the Time of Flight PCB. The Time of Flight PCB will have an antenna with a flexible wire attached to it. The enclosure will need to be sturdy enough to ensure that rouged handling of the enclosure will not cause it to break. It should also provide a method for keeping all of the electronics in place, such that the enclosure can be orientated in any way and the electronics will still be secure. This is important because*

	although the home enclosure will not move much while in operation, the home enclosure will need to be moved into place and therefore should be durable to normal handling. The home station enclosure will need to be able to fully enclose all of the components mentioned above. The PCB will be secured into the bottom of the home station enclosure to ensure that the electronics are fixed into place and do not slide around. The method of securing the PCB to the bottom enclosure will be to use ledges at the bottom of the enclosure which the PCB will be able to slide into. A hole will need to be placed at the top of the enclosure to allow the antenna to be able to be placed through the enclosure and be exposed to the open. In order to keep the antenna in place, the home station enclosure will make use of a keyhole, in which a notch, located at the base of the antenna (seen in Figure 10) will fit into a keyhole inside of the hole in the enclosure. This will allow the antenna to be stable in the enclosure and not fall down due to gravity. There will also need to be another hole located where the USB port to the Arduino Nano is located. The home station electronics will be powered and communicate through a laptop located at the home station, therefore it is necessary that a USB connector be able to be connected to the Arduino while all electronics are enclosed.
External Structure Champion: Jordan Hendricks	*This block is an external structure that will offer the team valuable data for the CS team. The external structure will be a 10ft by 10ft wood frame that will hold a 10ft by 7.5ft piece of colored fabric. Since the rocket will have cameras on-board which will be looking for a structure at a distance, this block will give an ideal case giving a large surface area of color. This structure will be useful in two testing cases: both with a drone and with the rocket. The drone can be flown out to distances defined by the rocket simulations and take pictures of the structure. The CS team will use these images to filter out colors other than the one on the structure using hue, saturation and value (HSV) techniques. Another test case will be with the rocket which will use its four cameras taking pictures on descent. This will help the team determine the size of structure that will need to be created so that the rocket can 'see' it at various distances. While this is only one side of the overall structure, it can be replicated 3 more times to make a cube.*

Universal Time of Flight PCB Champion: Ryan Bohl	*This block is a PCB that contains all of the hardware components specific to the time of flight sensor, as well as an Arduino Nano footprint that will allow the PCB to be connected either on top or beneath the microcontroller. By connecting this PCB to an Arduino, the Semtech SX1280 transceiver can be configured so that it can send and receive desired messages. Once configured by the software team, this transceiver will also have the ability to send and receive time of flight signals, and this functionality will be used during the rocket's flight to determine its distance from the home station. This same PCB will be implemented at the home station and on the rocket. Both implementations of the PCB will be connected to Arduinos that will control their behavior so that they may send and receive data to each other as desired.*
User Manual Champion: Jack Little	*The user manual will be able to aid anyone in the setup, use, and understanding of the overall payload system. The user manual is composed of sections for general overview, setup and pre-flight testing, integration, pre-launch configuration and check, post flight analysis, and troubleshooting. The user manual is written in a way that can be understood and followed by adults with at least some level of technical understanding; having a greater technical understanding should add to using the user manual.*
Avionic GPS Champion: Nicholas Lin	*The purpose of the GPS design is to satisfy the requirement of NASA, to recover the rocket after the launch. It is important for the Avionics system to get GPS (Global Positioning System) data from the GPS module and send the data back to the base station by using the transceiver system. The transceiver system was combine with two devices, the transmitter and the receiver. The transmitter will be assemble on the rocket, and the receiver will be located at the base station on the ground.The Avionic system can be broken into three components, the transceiver, the GPS breakout board, and the micro-controller, Arduino Uno. For the choice of the GPS, the team decided to choose the Adafruit Ultimate GPS Breakout board v3. The GPS will be connect to the Arduino Uno with GPIO pins, then collect the data and process the information through the micro controller, and then send the data back to the base station.*

3.3 Interface Definitions

Name	Properties
otsd_hm_sttn_pwr_spply_dcpwr	• ***Inominal:*** *1 A* • ***Ipeak:*** *1.5 A* • ***Vmax:*** *15 Volts* • ***Vmin:*** *8 Volts*
otsd_intrnl_pyld_pwr_spply_dcpwr	• ***Inominal:*** *120mA* • ***Ipeak:*** *1.3A* • ***Vmax:*** *9.5V* • ***Vmin:*** *8.5V* • ***Vnominal:*** *9V*
otsd_drn_m_envin	• ***Electromagnetic:*** *Magnetic vector field of the Earth measured in Micro Teslas* • ***Other:*** *Angular velocity around the z-axis measured in degrees per second* • ***Other:*** *Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the x-axis* • ***Other:*** *Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the y-axis* • ***Other:*** *Angular velocity around the y-axis measured in degrees per second* • ***Other:*** *Angular velocity around the x-axis measured in degrees per second* • ***Other:*** *Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the z-axis*

otsd_usr_mnl_other	• ***Other:*** *The user manual will provide a minimum of 5 sources.* • ***Other:*** *The user manual will be formatted in IEEE.* • ***Other:*** *The user manual will provide sufficient detail in all sections. Those sections are: general overview, setup and pre-flight testing, integration, pre-launch configuration and check, post flight analysis, and troubleshooting.*
otsd_avnc_gps_other	• ***Other:*** *World location (Longitude)* • ***Other:*** *GPS signal* • ***Other:*** *World location (Latitude)*
intrnl_pyld_pwr_spply_otsd_dcpwr	• ***Inominal:*** *112mA* • ***Ipeak:*** *219mA* • ***Vmax:*** *5.2V* • ***Vmin:*** *4.8V* • ***Vnominal:*** *5V*
usr_mnl_otsd_other	• ***Other:*** *The user manual will provide a troubleshooting section for solving some of the system issues that may arise, and include a minimum to 5 potential issues.* • ***Other:*** *The user manual will provide a step by step guide on setting up and integrating the payload into the rocket body, and should contain enough detail to follow steps correctly.* • ***Other:*** *The User Manual should provide detailed instructions in a minimum of two ways. I.e. a description, lists, and or images.*

avnc_gps_otsd_dsig	• ***Other:*** *Real time stamp* • ***Other:*** *Location Data (Latitude)* • ***Other:*** *Location Data (Longitude)*
extrnl_strctr_otsd_other	• ***Other:*** *The external structure will display at least a 10ft by 7ft piece of fabric for testing.*
extrnl_strctr_otsd_other	• ***Other:*** *The external structure will be at least 10ft in width.*
extrnl_strctr_otsd_other	• ***Other:*** *The external structure will be at least 10ft in height.*
extrnl_strctr_otsd_other	• ***Other:*** *The structure will offer a size to distance ratio of at least 0.005 for both dimensions and occupy at least 0.005% of the frame at 1,200 feet.*

3.4 References and File Links

3.4.1 References (IEEE)

This reference is a link to the datasheet of a Simple Switcher Voltage Regulator by Texas Instruments. The regulator outputs high current and is available in many different output voltage values:

"LM2576xx Series SIMPLE SWITCHER® 3-A Step-Down Voltage Regulator." Texas Instruments, Jun-1999.

3.4.2 File Links

3.5 Revision Table

Date	What Was Done
18 Nov, 2021	Jack Little created initial section draft
19 Nov, 2021	Jack Little Added diagrams, interface definitions, and block descriptions.
2 Dec, 2021	Ryan Bohl revised block descriptions and interface definitions for blocks he owns based on feedback received.
	Jack Little created new block diagrams and revised the block descriptions and interface definitions for blocks he owns based on feedback received.
	Nicholas Lin: Update the Avionics system block description. Added Inormal, Imax. Created and added the top level block diagram for the Avionics system.
	Timothy Grant updated Vmin, Vnominal, Inominal, Imin, Imax on the interfaces that connected with power supply. Deleted redundant sentences in the descriptions of the block diagram.
	Jordan Hendricks - Updated the tables for interface definitions and block

	diagrams. Updated the interface definitions for which I am responsible for.

4 Block Validations

4.1 Home Station Power Supply

4.1.1 Home Station Power Supply Block Description

The champion of this block is Ryan Bohl. This block is the custom power supply that will take in DC power from a lipo battery to provide 5v and 3.3v outputs. The main purpose of this block is to supply power to every device that will be used at the home station (launch site) during a rocket launch. Through the use of an Arduino's voltage regulator, this home station power supply will supply 3.3 volts to a transceiver that communicates with the rocket’s transceiver to control payload behavior at different points during flight. Additionally this block provides 5v power to the custom designed time of flight sensor, which pings a signal to determine the distance of the rocket. Voltage is also supplied to an arduino nano microcontroller that sends control signals to the time of flight sensors and transceivers. The arduino will have female pins so that jumper wires can be connected to other devices as desired in the development process. In conclusion this block takes in power from a battery up to 15 volts and supplies the operating voltage to all components present at the home station

4.1.2 Block Design

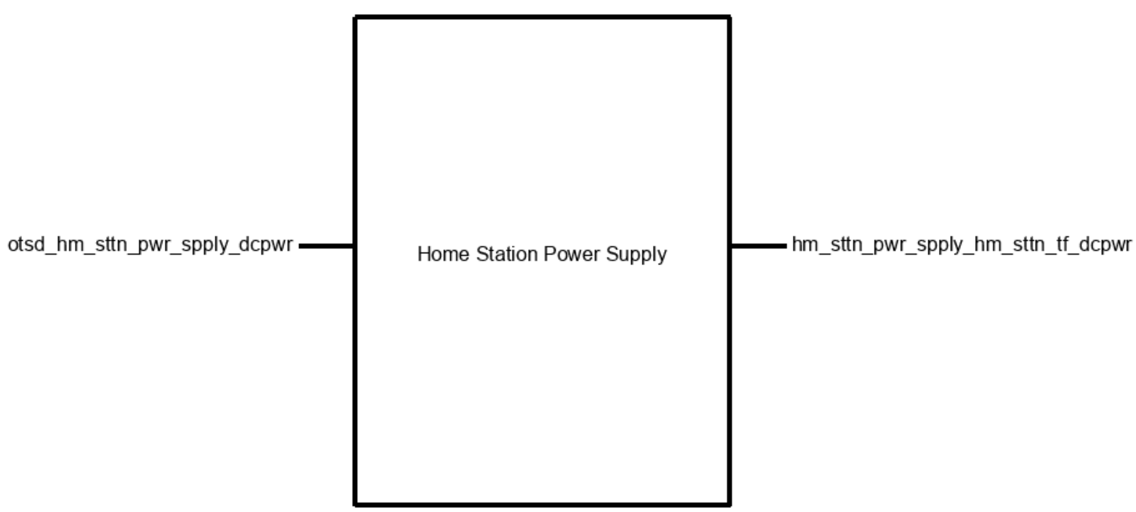


Figure __: Top Level Block Diagram

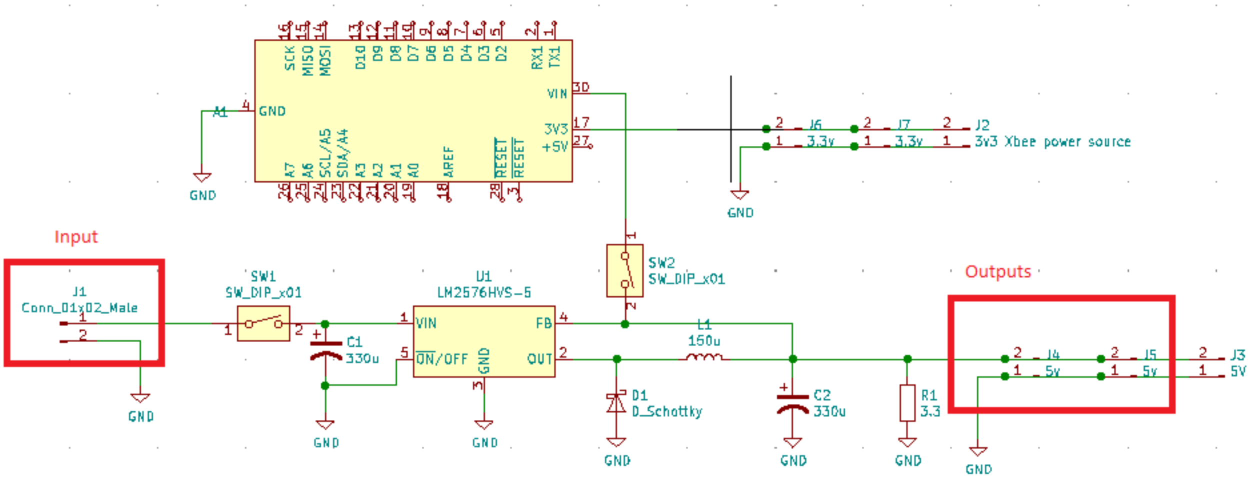
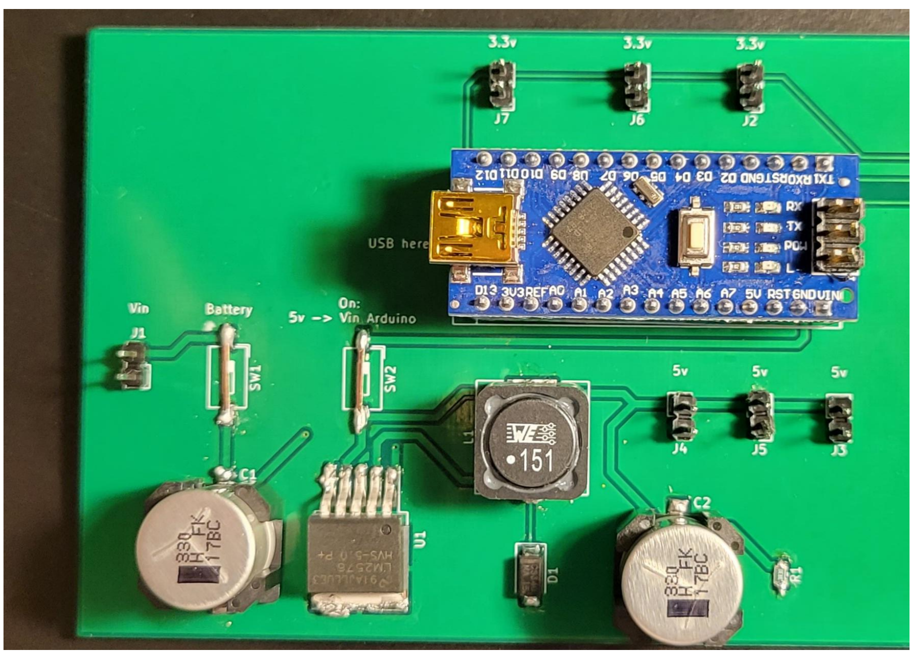


Figure __: Home Station Power Supply Schematic



The left two voltage input pins will connect to a Lipo battery that will range between 7 to 15 volts. This voltage will be regulated by the circuitry down to 5 volts. This section of the circuit is based on the recommended application circuit for the LM2576 IC [1]. The 5V will be sent to the TOF system block. The arduino Nano will be supplied 5v through either a laptop USB connection or through the regulated output. For USB power, there will be a USB connection to the arduino and SW2 will be set to disconnect from the other 5V rail. For a non USB supply, the USB must be disconnected from the arduino and SW2 will connect to the Vin pin to the 5V output. Regardless of how the arduino is powered, It has an on-board regulator that will work to supply 3.3V as desired by the XBee transmitter [2]. This is a standard interface, so it will not be tested, and the XBee transmitter is a commercial device that will be programmed by CS students. In the PCB image, the switches that were ordered were rated for only 25 mA, so they were removed and the PCB was configured to draw power immediately from a connected battery and that the Arduino will be powered from the 5v voltage regulator output.

4.1.3 Block General Validation

This block works to power everything that is used at the home station. This is crucial because there are transmitters that are used to control rocket ejections and the behavior of the overall payload. For instance, FAA regulations require that the payload drone can begin operating only after it has descended below 400 feet during the launch [3]. The user at the home station will send a signal to the drone payload to begin stabilizing using the XBee transmitter, which in turn will have its power supplied by this block. This block powers the Time of flight sensor as well, which is one of the three main devices used in determining the rocket's distance from the launch site, which is the main goal of the project. Every item within this block has been thoroughly considered, and they are all necessary to power the devices that will allow the user to locate the rocket's final landing location.

A stand alone lipo battery will be used as the input voltage for this block, as it will reduce the power consumption from laptop batteries. At the final launch site, the user will not be able to recharge electronic devices as usual since it is located in a field, so laptop batteries must be preserved for avionics operations. The different switches in the schematic allow the user to toggle if the arduino is powered from a laptop or from the input voltage. There are currently six sets of output pins that allow a 3.3v or 5v output. These multiple outputs are included for development purposes as many devices have these operating voltages, and more devices may be connected during testing. The arduino nano was chosen to be included in the block because it has an on-board 3.3v regulator, a small footprint, and because it can be programmed to interface with connected devices using its I/O pins. This block was designed to supply power to every necessary device, while leaving room for more devices to be tested and implemented.

4.1.4 Block Interface Validation

Otsd_hm_sttn_pwr_spply_dcpwr: Input

Inominal: 1 Amps	The battery will supply 1 amps	USLI has batteries that are rated for 5 amp hours [4]
Ipeak: 1.5 Amps	The battery will not supply more than 1.5 amps	The LM2576 will not draw more than 1.5 amps [1]
Vmax: 15 Volts	This design mirrors the tech demo design that had an input voltage with 15v vmax	The lipo batteries that are currently owned by USLI operate at less than 15 volts
Vmin: 8 volts	This design mirrors the tech demo design that had an input voltage with 8v vmin	The lipo batteries that are currently owned by USLI operate at more than 8 volts

Hm_sttn_pwr_spply_hm_sttn_tf_dcpwr: Output

Inominal: 1.2 Amps	This design mirrors the tech demo design that had an output current with 1.2 A Inominal	The time of flight sensor will operate at 1.2 amps during operation
Ipeak: 2 Amps	It is not expected for this system to deliver more than 2 amps	The custom time of flight PCB will not draw more than 2 amps
Vmax: 5.3 Volts	This design mirrors the tech demo design that had an output voltage with 5.3v vmax	5v output voltage described in page 5 of IM2576xx datasheet [1]
Vmin: 4.7 Volts	This design mirrors the tech demo design that had an output voltage with 4.7v vmin	5v output voltage described in page 5 of IM2576xx datasheet [1]
Vnominal: 5 volts	The time of flight block is designed to operate at 5 volts	5v output voltage described in page 5 of IM2576xx datasheet [1]

4.1.5 Block Testing Process

1. Verify there is no battery input voltage, and connect the USB from your computer to the arduino
2. With a multimeter, verify that the 3.3v pin on the arduino outputs 3.3v. You can connect the negative multimeter probe to the shielded USB connection
3. Disconnect the USB from the arduino. With the multimeter, verify that the input voltage (preferably a benchtop power supply) is between 8 and 15 volts and connect it to the J1 pins. Turn both switches in the circuit on.
4. With a multimeter, verify that the 5v output pins actually output 5 volts. You can connect the negative multimeter probe to the shielded USB connection
5. Vary the input voltage to test all values in the 8 to 15 volt range and verify that the output stays between 4.7 to 5.3 volts
6. Connect the positive terminal of the 5v output to the positive terminal of an adjustable load using the multimeter in current sensing mode. Connect the negative terminal of the adjustable load directly to the ground in the 5v connector using a jumper wire.
7. Vary the input voltage from 8 to 15v volts and verify that the block outputs a standard 1.2 amps and never more than 2 amps. Repeat the input voltage sweep and with the benchtop power supply, verify that the current delivered is 1 amp, and that it never goes above 1.5 amps
8. If the previous steps are completed and everything is in the correct range, then the block will function as intended.

4.1.6. References and File Links

[1] “Lm2576.pdf SymLink - semiconductor company | ti.com.” [Online]. Available: https://www.ti.com/lit/ds/symlink/lm2576.pdf. [Accessed: 08-Jan-2022].

[2] “Digi xbee 3 zigbee 3 RF module,” Zigbee 3 RF Module | Digi XBee 3 Zigbee 3.0 | Digi International. [Online]. Available: https://www.digi.com/products/embedded-systems/digi-xbee/rf-modules/2-4-ghz-rf-modules/xbee3-zigbee-3#specifications. [Accessed: 08-Jan-2022].

[3] “Airspace 101 – Rules of the Sky,” Airspace 101 – rules of the sky, 30-Aug-2021. [Online]. Available: https://www.faa.gov/uas/recreational_fliers/where_can_i_fly/airspace_101/. [Accessed: 20-Jan-2022].

[4] “Amazon.com: Goldbat 11.1V 5000mah 3s 50c LIPO RC battery ...” [Online]. Available: https://www.amazon.com/GOLDBAT-5000mAh-Battery-Connector-Traxxas/dp/B07PK16WB2. [Accessed: 20-Jan-2022].

4.1.7. Revision Table

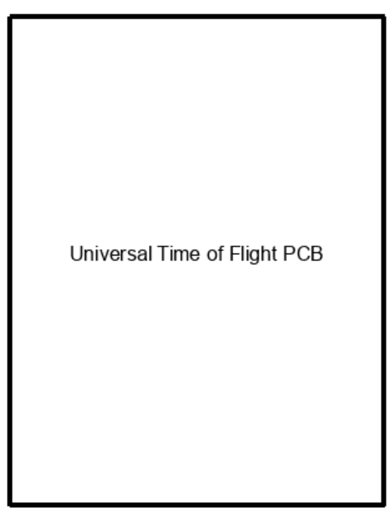
1/6/22	Ryan Bohl: Document Created, Added to sections 4.1.1 4.1.2
1/7/22	Ryan Bohl: Added information to other sections, submitted draft for review
1/19/22	Ryan Bohl: Added content and revised every section based on received feedback
1/21/22	Ryan Bohl: Assembled block, revised document, and submitted for grading

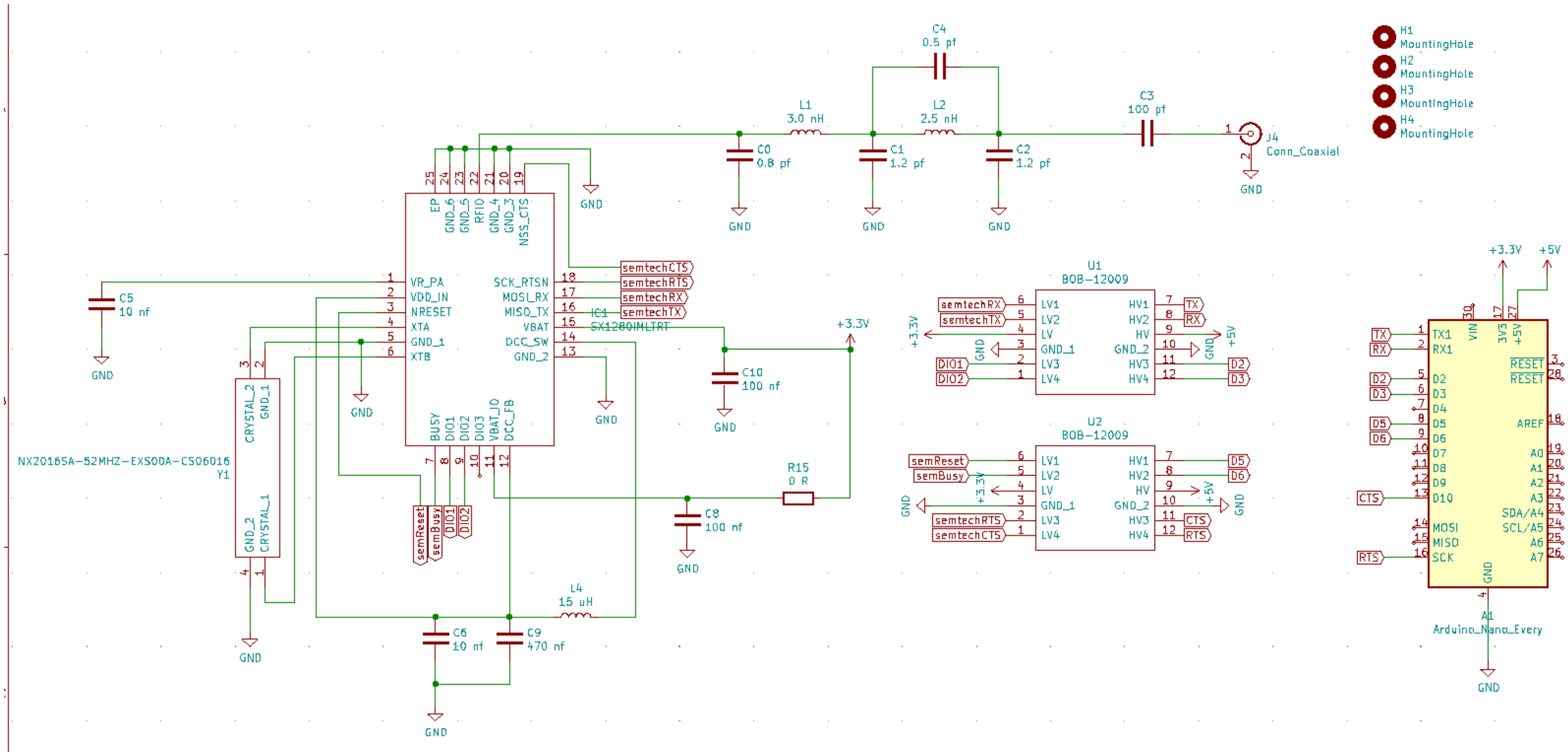
4.2 Universal Time of Flight

4.2.1 Universal Time of flight PCB Block Description

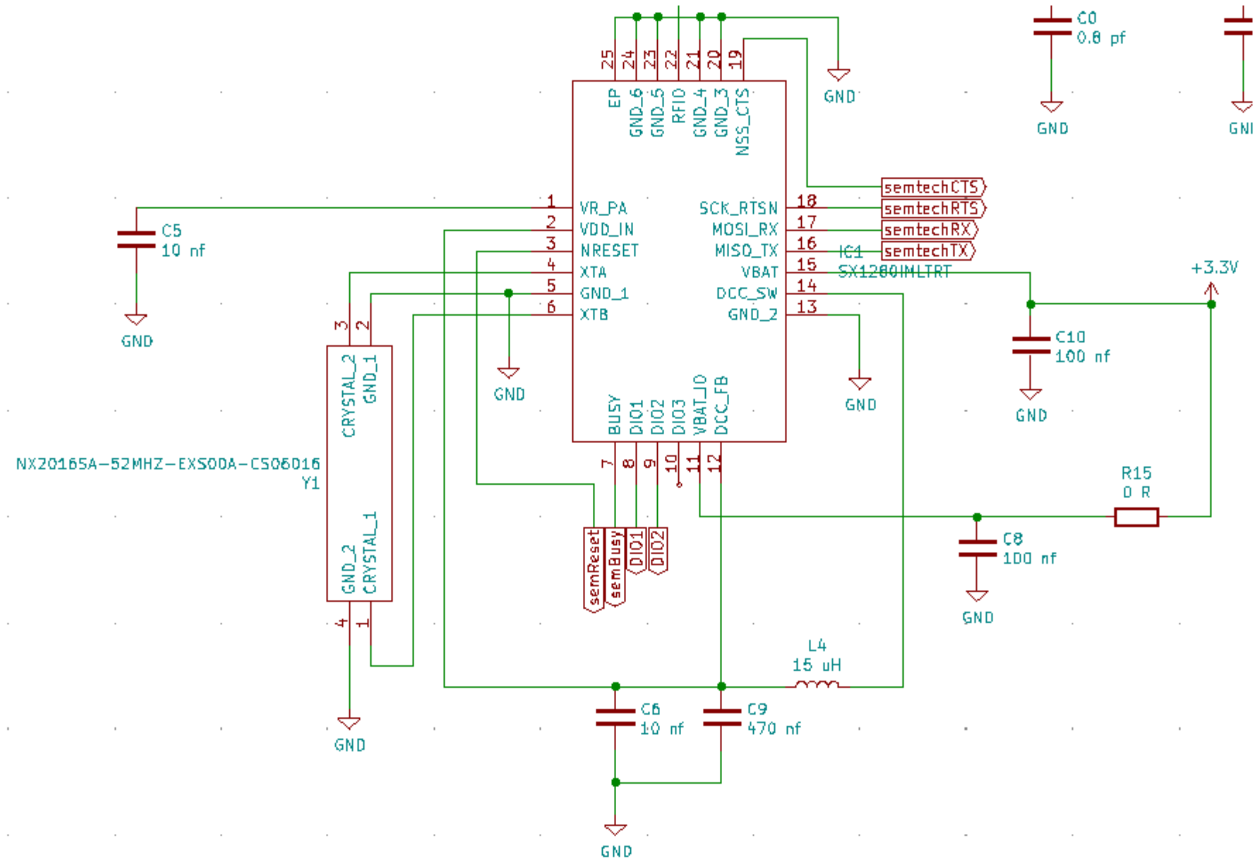
The champion of this block is Ryan Bohl. This block is a PCB that contains all of the hardware components specific to the time of flight sensor, as well as an Arduino Nano footprint that will allow the PCB to be connected either on top or beneath the microcontroller. By connecting this PCB to an Arduino, the Semtech SX1280 transceiver can be configured so that it can send and receive desired messages. Additionally, this transceiver has the ability to send and receive time of flight signals, and this functionality will be used during the rocket's flight to determine its distance from the home station. This same PCB will be implemented at the home station and on the rocket. Both implementations of the PCB will be connected to Arduinos that will control their behavior so that they may send and receive data to each other as desired.

4.2.2 Block Design

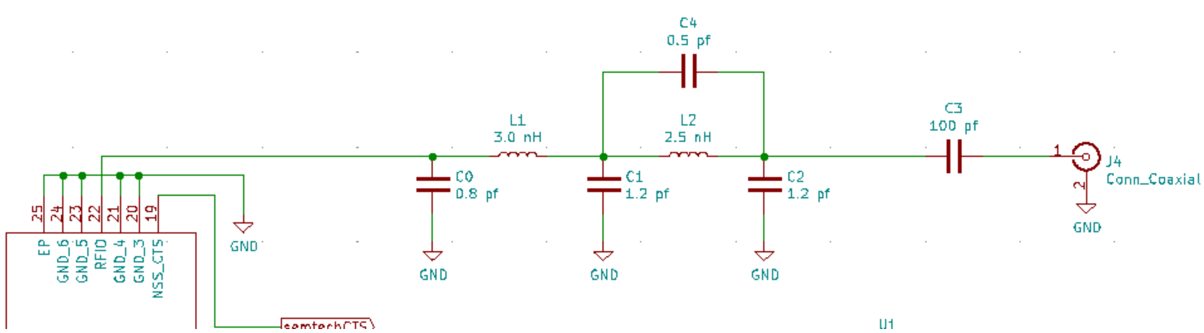




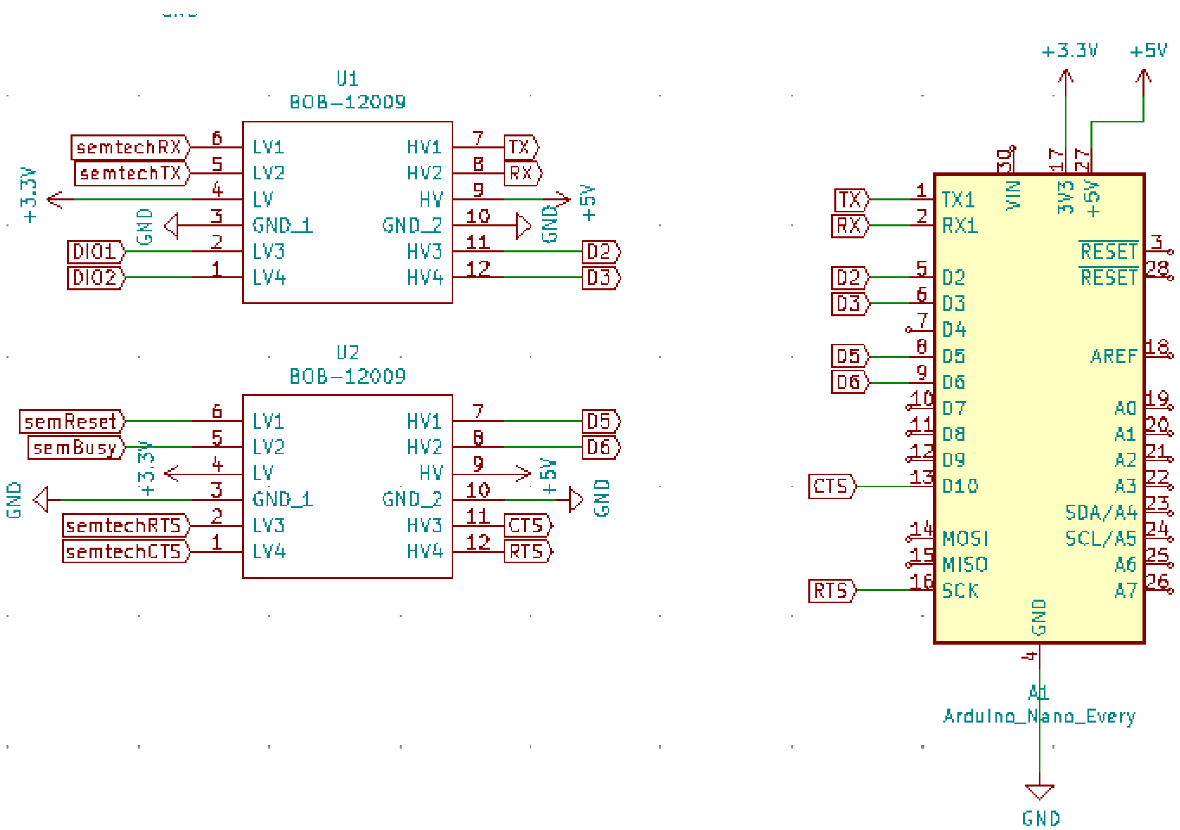
Full Schematic



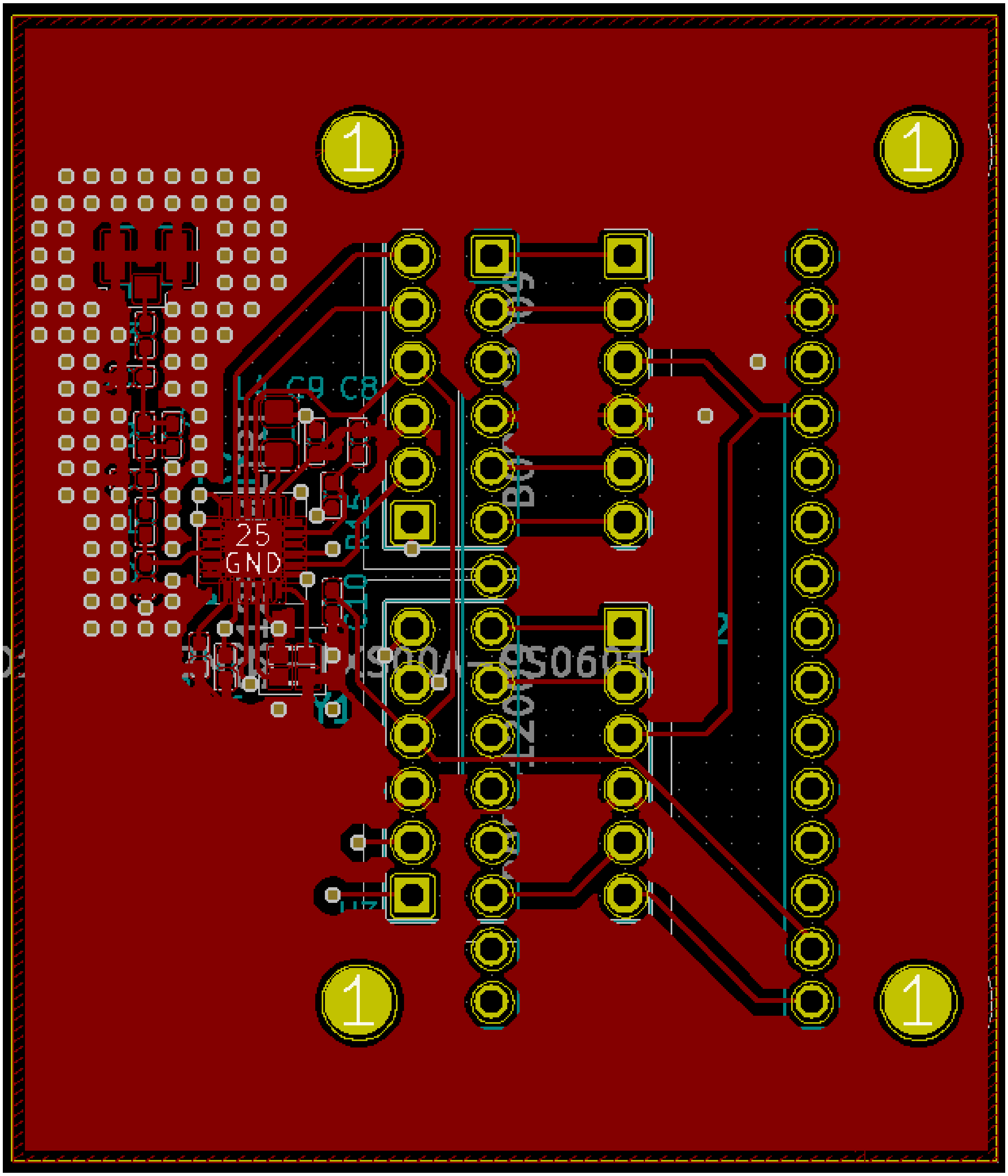
SX1280 connections



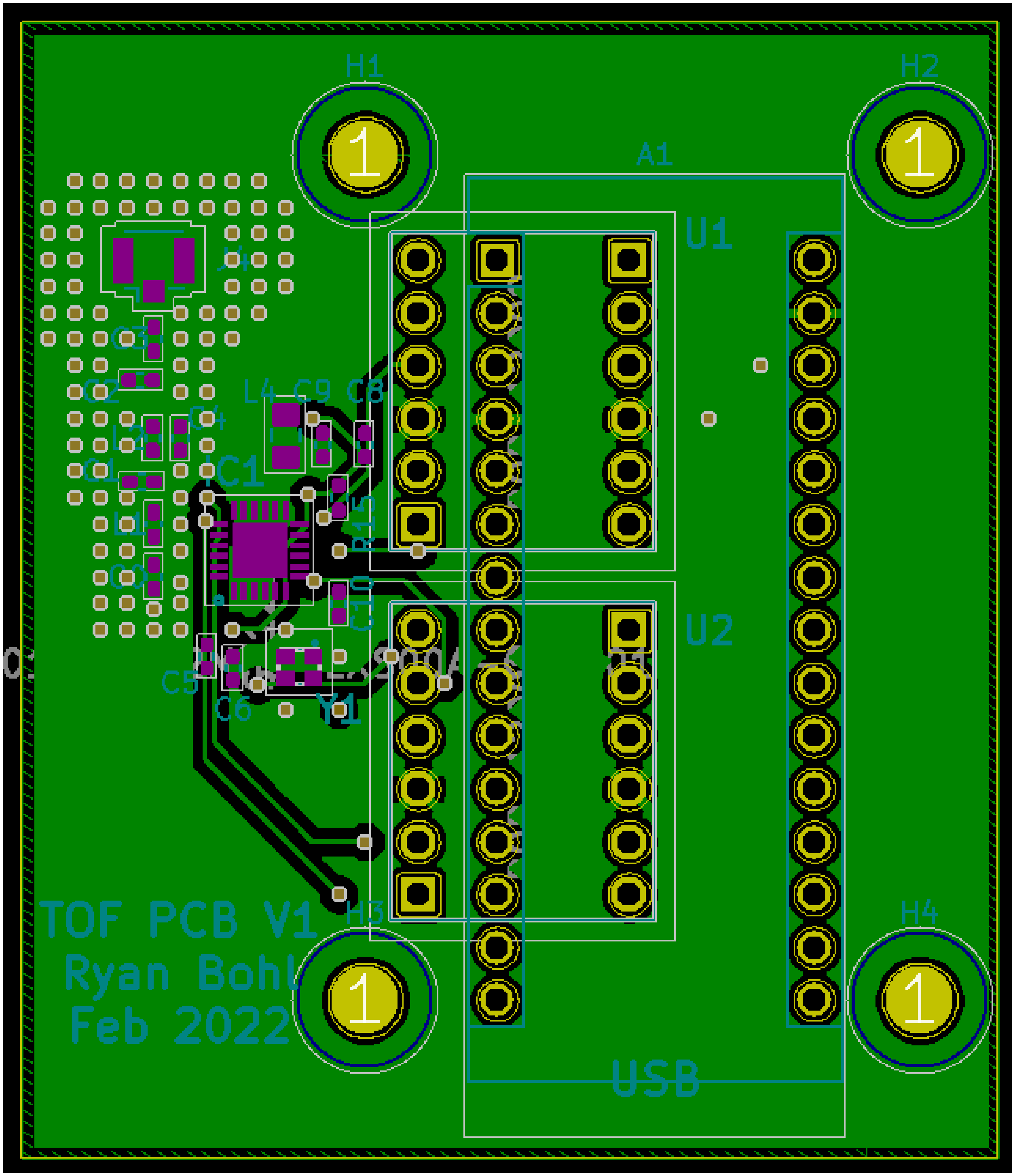
Antenna, filter, and RF pin



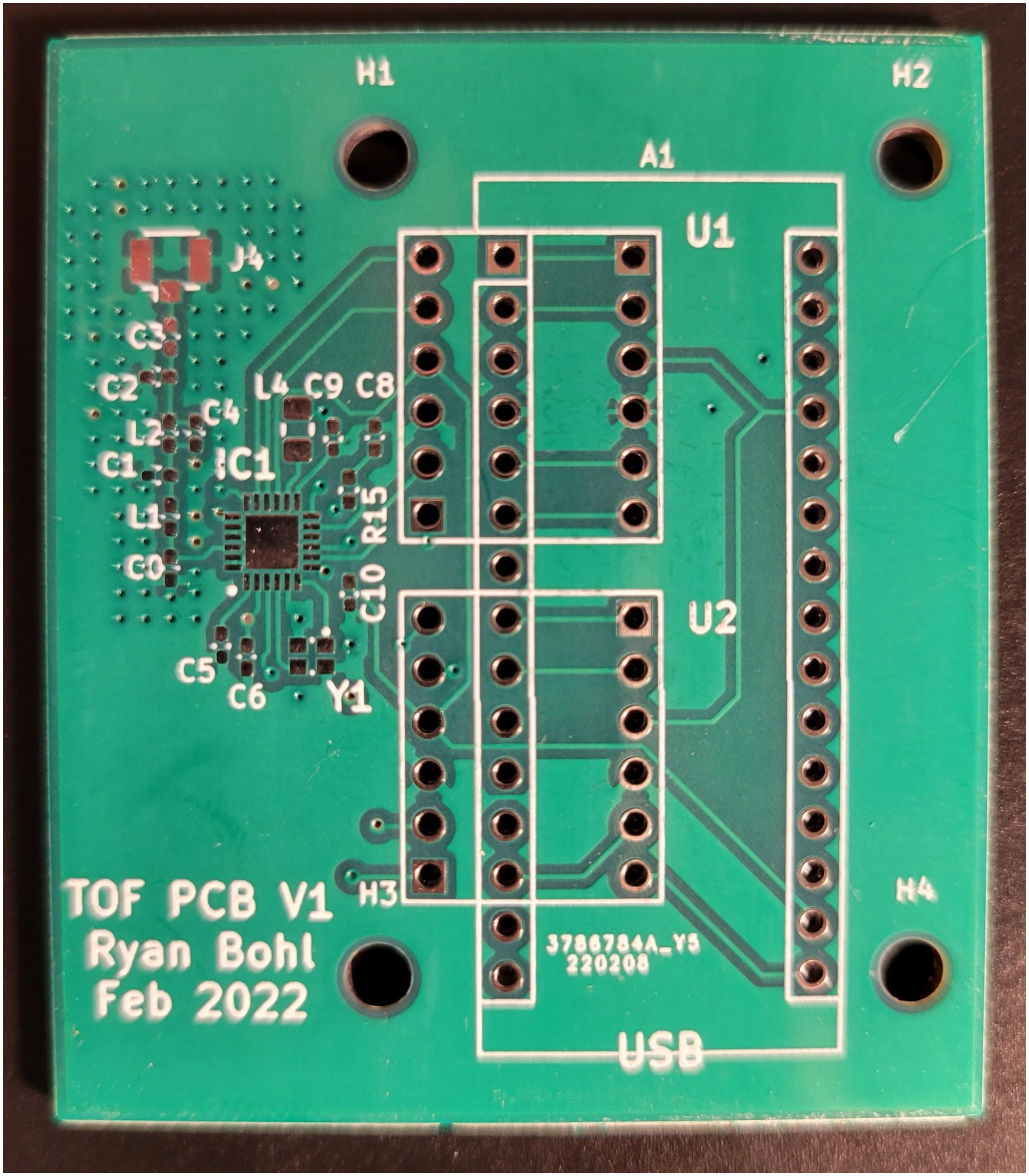
Logic level converters and arduino connection



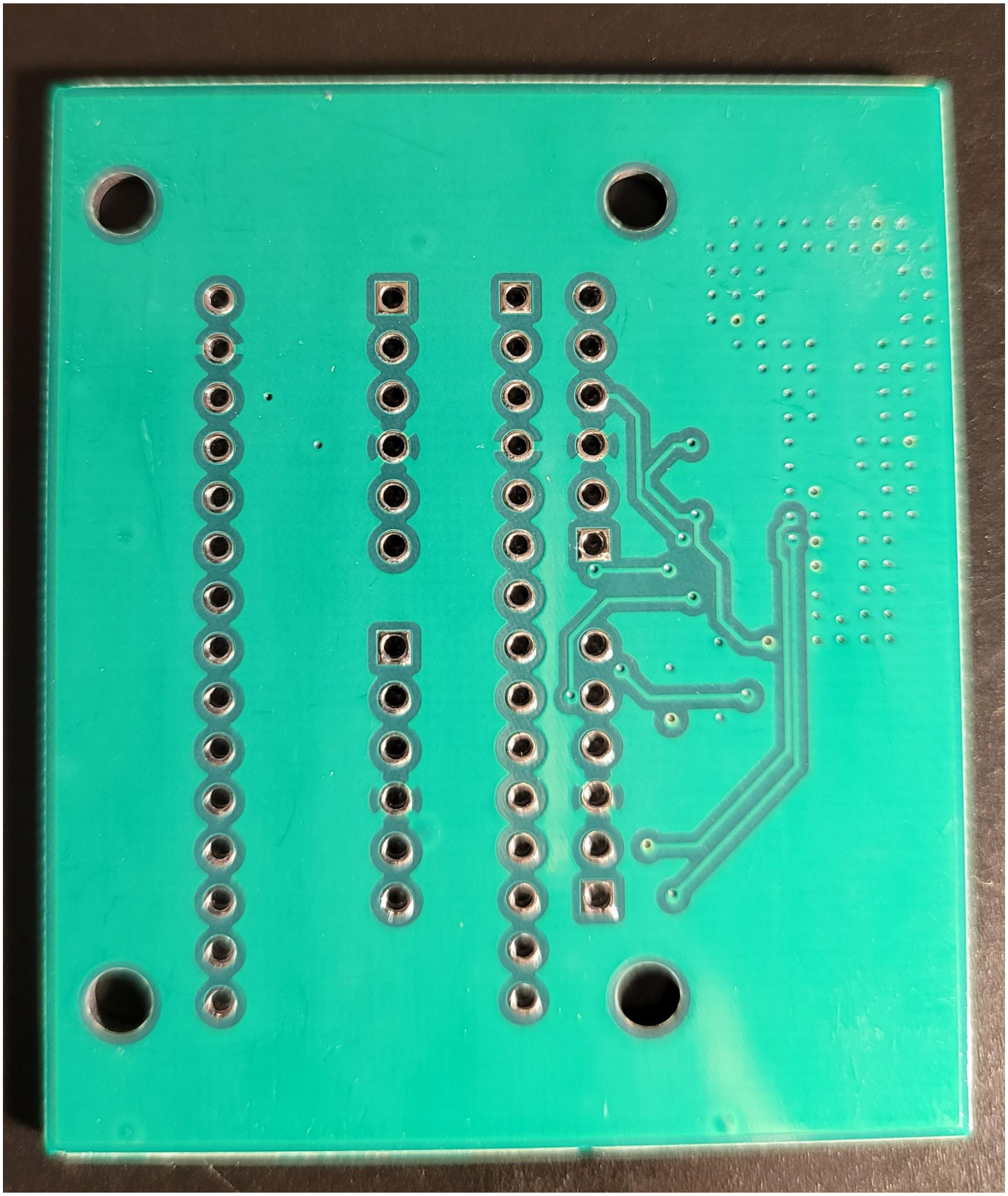
Top layer



Bottom Layer



Bare PCB Top Side



Bare PCB bottom side

The PCB contains many vias around the antenna port and filter as specified in the datasheet. The PCB contains 2 logic level converters (U1, U2) which convert the arduino's 5v digital pins to 3.3v for the SX 1280. 4 mount holes are included for stability. The arduino and logic level converter pins must be placed on opposite sides of the PCB.

TOF BOM (1 Unit)

Reference	Description	Unit Price	Total Price	Link
U1	TOF	$6.60	$6.60	Link
R15	0 Ω Thick Film Resistor ±1%, 1/16W	$0.10	$0.10	Link
C0	0.8 pF Multilayer ceramic capacitors C0G ± 0.1 pF, 50 V	$0.10	$0.10	Link
C1, C2	1.2 pF Multilayer ceramic capacitors C0G ± 0.1 pF, 50 V	$0.04	$0.07	Link
C3	100 pF Multilayer ceramic capacitors C0G ± 5%, 50 V	$0.03	$0.03	Link
C4	0.5 pF Multilayer ceramic capacitors C0G ± 0.05 pF, 50 V	$0.15	$0.15	Link
C5, C6	10 nF Multilayer ceramic capacitors X7R ± 10%, 25 V	$0.02	$0.04	Link
C8, C10	100 nF Multilayer ceramic capacitors X7R ± 10%, 16	$0.02	$0.04	Link
C9	470 nF Multilayer ceramic capacitors X5R ± 10%, 10 V	$0.10	$0.10	Link
L1	3.0 nH Wire-wound Inductor ± 0.1 nH	$0.26	$0.26	Link
L2	2.5 nH Wire-wound Inductor ± 0.2 nH	$0.26	$0.26	Link
L4	15 µH MLZ2012 Multilayer Shielded Inductor ± 5%	$0.07	$0.07	Link
Q1	52.000 MHz Crystal unit, NDK Ref: EXS00A-CS07103,	$0.78	$0.78	Link
J4	U.FL connector	$6.99	$6.99	Link
U1, U2	Logic Level Converters	$2.99	$5.98	Link
Total Price			$21.57	

4.2.3 Block General Validation

The central component of this block is the SX1280 transceiver, which offers long range communication at 2.4 GHz [1]. This is important as it will be used to communicate with a rocket that could reach 2500 feet in distance. The datasheet for this block provides great detail for how to design a PCB including what size of components to use, and this was referenced heavily in the design process. This block is crucial to the overall design of the project as it determines the magnitude of the distance between the rocket and the home station. The overall landing position of the rocket will be calculated based on polar coordinates, and this block accomplishes the distance aspect of that calculation. The ranged mode described in the datasheet will be what is used for time of flight communication, while LoRa 2.4 GHz will be used to transfer data, such as the final, calculated landing location. These modes can be switched by configuring registers through UART during operation. This PCB will be located on both the home station and the internal rocket payload, and they will be controlled independently and autonomously through arduino code. Because there are many pin connections to the Arduino Nano and because this circuit will be implemented multiple times, it was necessary for a PCB to be designed that utilizes the Arduino Nano footprint. The small form factor of the PCB will also allow it to be easily implemented inside the rocket.

The SX1280 contains SPI/UART pins, and It is through these pins that the IC's registers can be configured to change transmitting or receiving behavior, as well as change its sensitivity, bandwidth, power, timeouts, and data rate settings. The SX1280 will be powered by the arduino's 3.3v supply. The arduino is also connected to 2 of the 3 configurable digital I/O pins which can be used based on datasheet instructions. Currently the application of these DIO pins is unknown in terms of our project, but having two of them connected may be important for future development. The SX 1280 also has a busy pin which indicates when the transceiver is currently sending, receiving, or is busy with other operations. This pin will be polled and if it outputs low, a new operation can be performed. There is a reset pin connected that is active low. If the module is having issues this pin can be utilized during operation to reset the system.

The schematic above contains a 52 MHz crystal oscillator (Y1) that is used as a reference to increase the accuracy of the distance calculation. There is an antenna connector (J4) that connects to a IPEX/U.FL antenna that will be the focal point in sending/receiving signals. There is an RLC filter between the antenna and transceiver pin that is based on the application circuit included in the datasheet. Finally, there are two logic level converters that allow the arduino's 5v pins to interface with the SX1280s 3.3v pins. Every component has a purpose in the overall design and allows flexible use of the SX1280 as testing continues.

4.2.4 Block Interface Validation

This block has no specified interfaces as it is a PCB module.

4.2.5 Block Testing Process

Numbered steps of what will be accomplished during block checkoff

1. Connect two individual Time of flight PCBs to the corresponding pins on arduino Nanos, and plug these arduinos into two separate laptops.
2. Flash the sender code onto one of the arduinos, and the receiver code onto the other.
3. After the arduinos are flashed, open the serial monitors within the Arduino IDE on each laptop and follow the prompts to begin sending and receiving data.
4. Make note of the message being transmitted. It will include a randomly generated number to ensure that it is a unique message. On the receiver arduino, verify that the received message matches what was transmitted.
5. Following the serial monitor instructions, configure the arduinos to swap modes so that the original receiver will now transmit a new message to the other arduino which is now a receiver. Repeat step 4.
6. After the transceiver functionality has been demonstrated, the serial monitor will prompt the user to press a key to enter time of flight mode on both serial monitors.
7. The current distance between sensors will be displayed in the serial monitor. Verify that this value changes corresponding to distance. Note: This sensor has an accuracy of roughly +/- 10 feet due to the nature of how distance is measured involving an oscillator. A total range of at least 100 feet should be allotted for this test, preferably outdoors.

4.2.6. References and File Links

[1] "Ds SX1280-1 v3.2 - mouser.com," Mar-2020. [Online]. Available: https://www.mouser.com/datasheet/2/761/Semtech_04152020_DS_SX1280-1_V3.2-1832709.pdf. [Accessed: 04-Feb-2022].

Arduino sketches will be provided here once finalized.

4.2.7. Revision Table

2/1/22	Ryan Bohl: Document Created, Began work on all sections
2/4/22	Ryan Bohl: Finished original draft, submitted for review
2/16/22	Ryan Bohl: Added and modified content in first 3 sections according to design changes and feedback
2/18/22	Ryan Bohl: Proofread document and submitted

4.3 Drone IMU

4.3.1 Drone IMU Description

An IMU is a device that takes in acceleration data in the X Y and Z direction, angular velocity in the X Y and Z direction, and the magnetic field of the Earth in the X Y and Z direction. The task of this block is to take in the data that is coming in from the environment into the IMU and to then translate that data into something useful that can then be used by other blocks to accomplish the various tasks required. This IMU will be placed onto a drone. Therefore, one of the main tasks that will be required for the IMU is to be able to determine the orientation that the drone is in. This will be done by the use of the gyroscope data. As the drone tilts, the tilt can be measured by the gyroscope as an angular velocity. This angular velocity can be translated into a matrix that represents what orientation in 3D space the drone is located. Using this data, the drone will be able to increase or decrease the motors to allow the drone to remain level to the ground. There are two problems with using a gyroscope to determine the orientation of the drone. The first problem is that the program that integrates the angular velocity needs an initial starting orientation. Normally this would be accomplished by the use of the magnetometer to find absolute north, but NASA has set a requirement that our system should not use any magnetometer data. All data that comes into the block from the magnetometer will be immediately discarded. Therefore, data will need to come into the block from the vision processing unit. This data will give the current orientation of the drone. Due to drift of the gyroscopes, the orientation will need to be periodically updated from the vision processing unit. Acceleration will also be detected by the IMU. Acceleration must be double integrated in order to get the positional displacement. This means that there will be a large amount of error that will be introduced into the system. This problem is inherent to the device and will need other means outside of the block to rectify.

4.3.2 Design

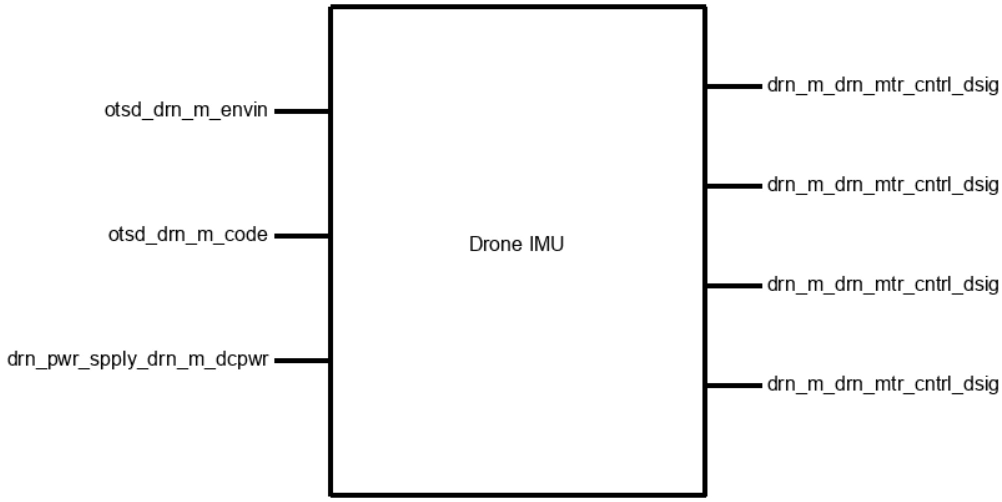


Figure 4.3.2.1: Black Box Diagram

Figure 4.3.2.1 shows the black box diagram of the IMU system. The computer vision will feed into the system a positional matrix depicting the current orientation of the device. The power supply will supply the system with voltage and current. The output signal will be a PWM signal going to the 4 motor controller, to determine the RPM of the drone's motors.

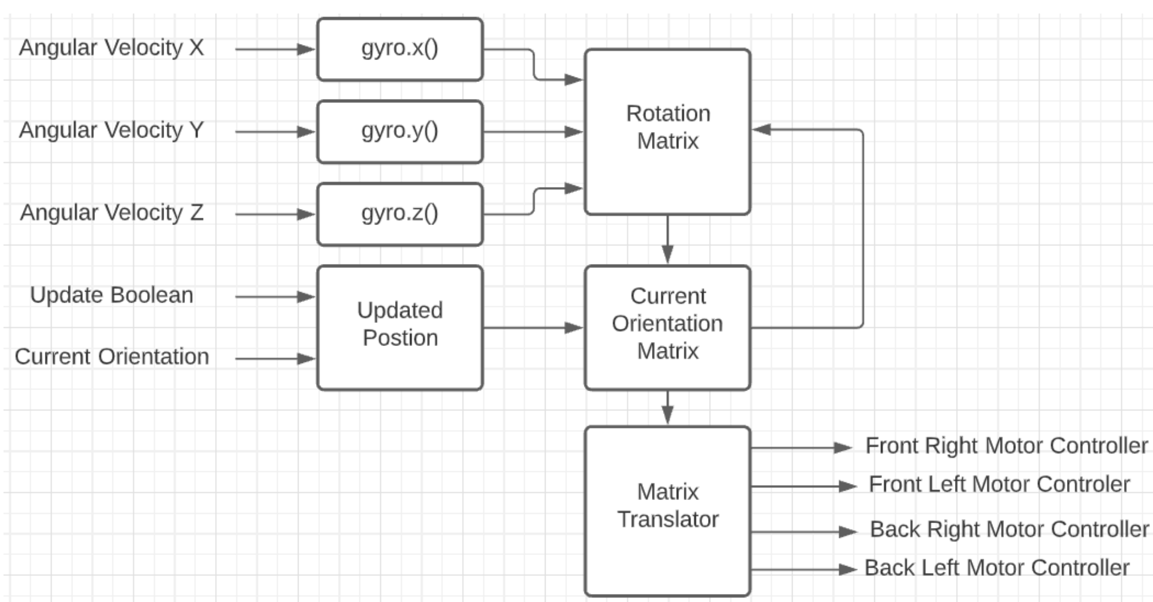


Figure 4.3.2.2: Code Data Flow Chart

Figure 4.3.2.2 is a more detailed depiction of how the data in the system will flow. The IMU will communicate with the Arduino by passing gyroscope data around the x y and z axes. With this data, the Arduino will create a rotation matrix and constantly update the current orientation matrix based on the rotations which the IMU is reporting. If a signal for an positional update is given, the current orientation matrix is updated with the vision processing's most current orientation matrix. Based on the orientation matrix, a PWM signal is created and sent to the 4 motor controllers.

```
Initialize orientation matrix

while True:
   start timer

   if (Vision Processing Ready)
        Update orientation matrix

   gyro = pull gyro data from IMU
   thetaX = gyro.x / time difference
   thetaY = gyro.y / time difference
   thetaZ = gyro.z / time difference

   RotationMatrix = createRotationMatrix(thetaX, thetaY, thetaZ)

   currientOrientation = currientOrientation * rotationMatrix

   right = -currientOrientation(y projection onto z-axis)
   left = currientOrientation(y projection onto z-axis)
   up = currientOrientation(x projection onto z-axis)
   down = -currientOrientation(y projection onto z-axis)

   analogWrite(pin6, right + back)
   analogWrite(pin8, right + up)
   analogWrite(pin9, left + back)
   analogWrite(pin12, left + up)
```

Figure 4.3.2.3: Pseudocode

The pseudocode depicted in Figure 4.3.2.3 shows the basic functionality and methodology of the software portion of the block.

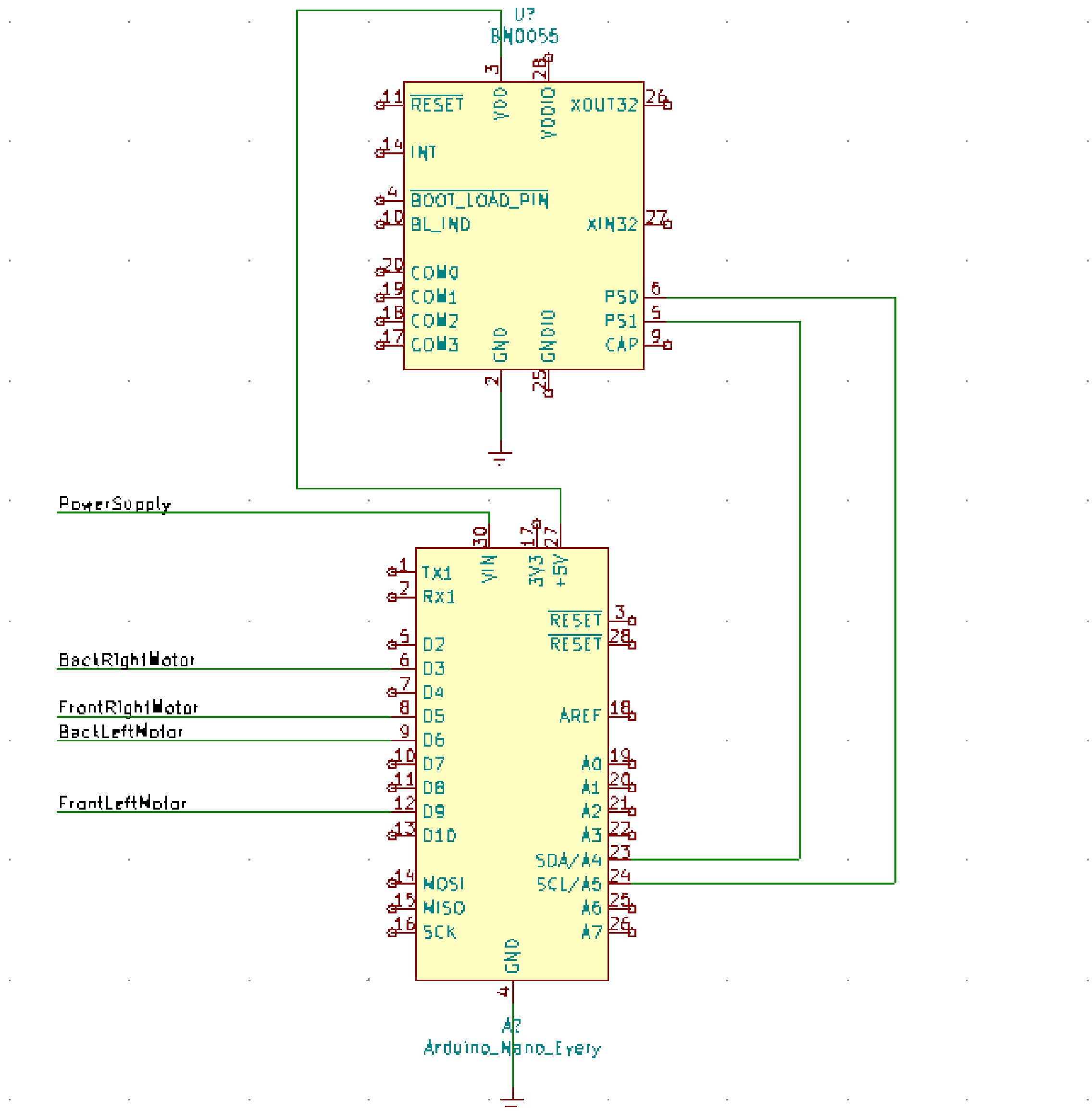


Figure 4.3.2.4: Wiring Diagram

Figure 4.3.2.14 shows the wiring diagram which connects the Arduino to the power supply, motor controller, and the BNO055.

4.3.3. General Validation

The IMU which was selected was the BNO055. The reason that this particular device was selected was due to availability of supplies. The original device selected was an ‘AltIMU-10 v5’. But there were issues with getting this specific IMU device in a timely manner, therefore a different device was selected which has similar characteristics. The BNO055 cost 30 dollars, which is a reasonable price for an IMU. This IMU will not be an expendable component. The only time in which it will be required to replace this component is in the event of a crash. Due to the predicted infrequent occurrence of this event, it is acceptable to use a slightly more expensive device for an increase in functionality.

The Arduino nano was selected due to size constraints. Because the entirety of the project will need to be able to fit within the body of a rocket, size is the most important factor to consider when making design decisions. The Arduino nano is the smallest Arduino platform which still has all of the functionality which is required to be able to complete the task. The Arduino nano has enough I/O pins to support the PWM signal to each of the motor controllers on the drone. The reason for the selection of the Arduino platform instead of other devices is that I and the rest of my team are most familiar with Arduino and RaspberryPi. Arduino was selected over RaspberryPi because of the speed at which the processing could take place. The RaspberryPi has an operating system which is over the microcontroller, whereas Arduino interacts directly with the hardware; thereby allowing the Arduino to be able to process much faster than is possible with the RaspberryPi.

4.3.4 Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details <u>for this block</u> above meet or exceed each property?**

otsd_drn_m_envin : Input

Electromagnetic: Magnetic vector field of the Earth measured in Micro Teslas	The magnetometer reads the value of the Earth's magnetic field. The Earth produces a magnetic field which comes from the geological activity present in the planet. The fields run along the longitude of the Earth. This information can be read in by a magnetometer.	"3.6 Output data" (page 30) states that the unit which the magnetometer on the BNO055 measures in is Micro Teslas.[2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf
Other: Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the z-axis	The accelerometer measures acceleration in the units of m/s^2. The accelerometer which is orientated to detect acceleration in the z-axis will capture the acceleration which the z-axis is experiencing.	"3.6 Output data" (page 30) states that the units in which the accelerometer on the BNO055 measures is in units of m/s^2. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf

Other: Angular velocity around the z-axis measured in degrees per second	A gyroscope is able to measure the angular velocity that the device is rotating. The gyroscope which is orientated to detect angular velocity around the z-axis will capture the angular velocity which occurs around the z-axis.	“3.6 Output data” (page 30) states that the units that the gyroscope measures in are in units of degrees per second. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf
Other: Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the x-axis	The accelerometer measures acceleration in the units of m/s^2. The accelerometer which is orientated to detect acceleration in the x-axis will capture the acceleration which the x-axis is experiencing.	“3.6 Output data” (page 30) states that the units in which the accelerometer on the BNO055 measures is in units of m/s^2. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf
Other: Force being applied to IMU (causing acceleration) measured in m/(s^2) applied to the y-axis	The accelerometer measures acceleration in the units of m/s^2. The accelerometer which is orientated to detect acceleration in the y-axis will capture the acceleration which the y-axis is experiencing.	“3.6 Output data” (page 30) states that the units in which the accelerometer on the BNO055 measures is in units of m/s^2. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf
Other: Angular velocity around the y-axis measured in degrees per second	A gyroscope is able to measure the angular velocity that the device is rotating. The gyroscope which is orientated to detect angular velocity around the y-axis will capture the angular velocity which occurs around the y-axis.	“3.6 Output data” (page 30) states that the units that the gyroscope measures in are in units of degrees per second. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf
Other: Angular velocity around the x-axis measured in degrees per second	A gyroscope is able to measure the angular velocity that the device is rotating. The gyroscope which is orientated to detect angular velocity around the x-axis will capture the angular velocity which occurs around the x-axis.	“3.6 Output data” (page 30) states that the units that the gyroscope measures in are in units of degrees per second. [2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf

otsd_drn_m_code : Input

Other: Receive device orientation along device's Z-axis	The Vision Processing unit will determine the angle of rotation from North. This value will be put into the format of a rotation matrix in the form of rotation from the reference basis. A rotation matrix is a convenient way to format an orientation.	The current orientation matrix which the IMU block uses is in the form of a rotation matrix, therefore in order to ‘update’ the matrix to the Vision Processing’s orientation, by changing the current orientation matrix to be the rotation matrix which is provided by the Vision Processing block, this will allow the IMU block to start applying the angular velocity to the updated position provided by the Vision Processing unit.
Other: Receive device orientation along device's X-axis	The Vision Processing unit will determine the angle of rotation from North. This value will be put into the format of a rotation matrix in the form of rotation from the reference basis. A rotation matrix is a convenient way to format an orientation.	The current orientation matrix which the IMU block uses is in the form of a rotation matrix, therefore in order to ‘update’ the matrix to the Vision Processing’s orientation, by changing the current orientation matrix to be the rotation matrix which is provided by the Vision Processing block, this will allow the IMU block to start applying the angular velocity to the updated position provided by the Vision Processing unit.
Other: Signal which changes boolean value to inform program ready to be updated	A boolean value will be updated when the vision processing unit is able to determine an orientation. A boolean value will be able to inform the program that an updated orientation is ready to be implemented.	Boolean value will be set to true when the vision processing block has an updated orientation. The boolean value will be set in the vision processing section of the program. An ‘if statement’ will check if this boolean value has been set to true.

Other: Receive device orientation along device's Y-axis	The Vision Processing unit will determine the angle of rotation from North. This value will be put into the format of a rotation matrix in the form of rotation from the reference basis. A rotation matrix is a convenient way to format an orientation.	The current orientation matrix which the IMU block uses is in the form of a rotation matrix, therefore in order to ‘update’ the matrix to the Vision Processing’s orientation, by changing the current orientation matrix to be the rotation matrix which is provided by the Vision Processing block, this will allow the IMU block to start applying the angular velocity to the updated position provided by the Vision Processing unit.

drn_pwr_spply_drn_m_dcpwr : Input

Inominal: 19 mA	The current drawn from an Arduino is 19 mA.	Current will be based off of the voltage and the resistance present in the system. The voltage will be held constant at 5V nominal, so if the normal operating current of an Arduino is 19mA, then as more resistance is introduced into the system in the form of the IMU, the current will fall, causing 19mA to be the maximum normal operating current which the system will use.[1]
Ipeak: 25 mA	A value of 25mA was selected because at no point should the system require more than 25 mA.	As was described in the Inominal section, the current will decrease as the resistance of the system increases. The normal operating current of the Arduino is 19mA, so the system with added resistance should never exceed this maximum current value of 24mA.
Vmax: 7V	A value of 7 volts was selected because this value is under the absolute maximum voltage	“29.1 Absolute Maximum Ratings” (page 308) specifies a maximum operating voltage of

	which the Arduino nano is able to operate at. This ensures that the Arduino will remain protected at all times during operation.	13V. Because the Arduino nano will power the IMU, as long as the Arduino is functioning, the Arduino will be able to supply enough power to the IMU.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vmin: 4.5V	The normal operating voltage which the Arduino normally takes through Vin is 5 volts, but through testing it was determined that a voltage of 4.5 volts was also acceptable.	A voltage of 4.5volts was applied to the Vin of the Arduino and with this voltage the Arduino was able to function and was also able to power the IMU. The entire system functioned at this voltage.
Vnominal: 5V	The normal operating voltage that the Arduino normally takes through Vin is 5 volts. This is why 5 volts was selected as the Vnominal.	Both 7V and 4.5V were tested on the system and the system was able to function. 5V is between these two values and should also function. In addition, a test was also done at specifically 5V and the system was able to function as expected.

drn_m_drn_mtr_cntrl_dsig : Output

Logic-Level: Active High	An active high or active low standard could have been chosen. A decision needed to be made and active high was chosen having no advantage or disadvantage either way.	"18.7.3 Fast PWM Mode" (page 156) Determining the input to the analogWrite function in the software will determine the PWM signal which is generated by the Output Compare (OC). By providing an input to the analogWrite function with the convention of higher number as more ON, this will produce a PWM signal that is active high.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A

		-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Max Frequency: 1000Hz	A value of 1000Hz was selected because out of all of the output pins, the highest frequency possible was 980Hz.	Pin 6 has the highest frequency of 980Hz. The other pins have a frequency of 480Hz.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Other: Signal Type: PWM	A PWM signal was selected so that the motor controller would be able to not only have data on which direction the device is tilted, but also to be able to know an approximation of how much the device is tilted in a particular direction.	A PWM signal was successfully produced using the analogWrite function in the Arduino library.
Vmax: 5.5V	A logic high is defined as 5V. Therefore a value of 5.5V was selected to allow for slight variation of the ON signal.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vmin: 0V	Logic low is represented as 0 Volts.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare

		is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vnominal: 0V	Because the device will "normally" be in the balanced position, the default voltage for the output signal will be 0V. When the device is tilted in an orientation to necessitate motor correction, the PWM signal will then turn on.	When the device is powered on and lays flat on the table, the LED lights are turned completely off. There is 0 volts on the output under "normal conditions" during tests.

drn_m_drn_mtr_cntrl_dsig : Output

Logic-Level: Active High	An active high or active low standard could have been chosen. A decision needed to be made and active high was chosen having no advantage or disadvantage either way.	"18.7.3 Fast PWM Mode" (page 156) Determining the input to the analogWrite function in the software will determine the PWM signal which is generated by the Output Compare (OC). By providing an input to the analogWrite function with the convention of higher number as more ON, this will produce a PWM signal that is active high.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Max Frequency: 1000Hz	A value of 1000Hz was selected because out of all of the output pins, the highest frequency possible was 980Hz.	Pin 6 has the highest frequency of 980Hz. The other pins have a frequency of 480Hz.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Other: Signal Type: PWM	A PWM signal was selected so that the motor controller would	A PWM signal was successfully produced using the analogWrite

	be able to not only have data on which direction the device is tilted, but also to be able to know an approximation of how much the device is tilted in a particular direction.	function in the Arduino library.
Vmax: 5.5V	A logic high is defined as 5V. Therefore a value of 5.5V was selected to allow for slight variation of the ON signal.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vmin: 0V	Logic low is represented as 0 Volts.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf

Vnominal: 0V	Because the device will "normally" be in the balanced position, the default voltage for the output signal will be 0V. When the device is tilted in an orientation to necessitate motor correction, the PWM signal will then turn on.	When the device is powered on and lays flat on the table, the LED lights are turned completely off. There is 0 volts on the output under "normal conditions" during tests.

drn_m_drn_mtr_cntrl_dsig : Output

Logic-Level: Active High	An active high or active low standard could have been chosen. A decision needed to be made and active high was chosen having no advantage or disadvantage either way.	"18.7.3 Fast PWM Mode" (page 156) Determining the input to the analogWrite function in the software will determine the PWM signal which is generated by the Output Compare (OC). By providing an input to the analogWrite function with the convention of higher number as more ON, this will produce a PWM signal that is active high.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Max Frequency: 1000Hz	A value of 1000Hz was selected because out of all of the output pins, the highest frequency possible was 980Hz.	Pin 6 has the highest frequency of 980Hz. The other pins have a frequency of 480Hz.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Other: Signal Type: PWM	A PWM signal was selected so that the motor controller would be able to not only have data on which direction the device is tilted, but also to be able to know an approximation of how much the device is tilted in a particular direction.	A PWM signal was successfully produced using the analogWrite function in the Arduino library.

Vmax: 5.5V	A logic high is defined as 5V. Therefore a value of 5.5V was selected to allow for slight variation of the ON signal.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vmin: 0V	Logic low is represented as 0 Volts.	"18.7.3 Fast PWM Mode" Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on "15.6 Compare Match Output Unit" (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vnominal: 0V	Because the device will "normally" be in the balanced position, the default voltage for the output signal will be 0V. When the device is tilted in an orientation to necessitate motor correction, the PWM signal will then turn on.	When the device is powered on and lays flat on the table, the LED lights are turned completely off. There is 0 volts on the output under "normal conditions" during tests.

drn_m_drn_mtr_cntrl_dsig : Output

Logic-Level: Active High	An active high or active low standard could have been chosen. A decision needed to be made and active high was chosen having no advantage or disadvantage either way.	“18.7.3 Fast PWM Mode” (page 156) Determining the input to the analogWrite function in the software will determine the PWM signal which is generated by the Output Compare (OC). By providing an input to the analogWrite function with the convention of higher number as more ON, this will produce a PWM signal that is active high.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Max Frequency: 1000Hz	A value of 1000Hz was selected because out of all of the output pins, the highest frequency possible was 980Hz.	Pin 6 has the highest frequency of 980Hz. The other pins have a frequency of 480Hz.[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Other: Signal Type: PWM	A PWM signal was selected so that the motor controller would be able to not only have data on which direction the device is tilted, but also to be able to know an approximation of how much the device is tilted in a particular direction.	A PWM signal was successfully produced using the analogWrite function in the Arduino library.
Vmax: 5.5V	A logic high is defined as 5V. Therefore a value of 5.5V was selected to allow for slight variation of the ON signal.	“18.7.3 Fast PWM Mode” Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on “15.6 Compare Match Output Unit”

		(page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vmin: 0V	Logic low is represented as 0 Volts.	“18.7.3 Fast PWM Mode” Figure 18-6 (page 156) Shows a diagram of high and low output from the PWM signal. The OCnx is the output of the PWM signal and is shown in either the ON or the OFF state. Then on “15.6 Compare Match Output Unit” (page 106), the Output Compare is a logic 1 or a logic 0. http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf
Vnominal: 0V	Because the device will “normally” be in the balanced position, the default voltage for the output signal will be 0V. When the device is tilted in an orientation to necessitate motor correction, the PWM signal will then turn on.	When the device is powered on and lays flat on the table, the LED lights are turned completely off. There is 0 volts on the output under “normal conditions” during tests.

4.3.5 Verification Plan

1. Pull magnetometer data from IMU and print to screen. Thus verifying input of Earth’s magnetic field.
2. Orient IMU along the x, y, and z axis directly towards Earth’s ground, such that Earth’s gravitational field is fully in the direction of the x, y, and then z axis. Print value onto screen to show full 9.8 m/s^2 appears in each x, y, and z.
3. Rotate IMU around the x, y, and z axis. Print values received from gyroscope onto screen. Show increase of angular velocity as rotation is faster, show decrease of angular velocity as rotation is slower.
4. Simulate input in the form of float value which indicates degrees of rotation from the standard basis in the x direction.

5. Simulate input in the form of float value which indicates degrees of rotation from the standard basis in the y direction.
6. Simulate input in the form of float value which indicates degrees of rotation from the standard basis in the z direction.
7. Attach an input to the Arduino which will toggle a boolean value in the program during run time. Verify that position is updated.
8. Attach power supply to the system with a voltage of 7 Volts. Move orientation of IMU, observe LED to verify system still functioning.
9. Attach power supply to the system with a voltage of 4.5 Volts. Move orientation of IMU, observe LED to verify system still functioning.
10. Mesure 25mA input
11. Show normal operation at 19mA
12. Attach power supply to the system with a voltage of 5 Volts. Move orientation of IMU, observe LED to verify system still functioning.
13. Move device in orientation as to show increase in output trigger. LED used as indicators will increase in intensity indicating logic level high.
14. Attach oscilloscope to output. Move device as to stimulate different output conditions. Verify output signal never goes above 490Hz.
15. Use oscilloscope to take snapshot of output waveform. Verify PWM signal.
16. Use oscilloscope to take snapshot of output waveform. Verify high of no larger than 5.5V on waveform.
17. Use oscilloscope to take snapshot of output waveform. Verify low of 0V on waveform.
18. Use oscilloscope to take snapshot of output waveform. Verify “normal operating output” of 0V on waveform.
19. Repeat steps 13-18 for all 4 LED pins.

4.3.6 References and File Links

[1] http://ww1.microchip.com/downloads/en/DeviceDoc/ATmega48A-PA-88A-PA-168A-PA-328-P-DS-DS40002061A.pdf [Accessed: 15-Jan-2022].

[2] https://cdn-shop.adafruit.com/datasheets/BST_BNO055_DS000_12.pdf [Accessed: 15-Jan-2022].

4.3.7 Revision Table

3 January, 2022	Timothy Lee Grant: Initial creation of document.
	Timothy Lee Grant: Wrote initial draft of Validation Plan section and Interface Validation Section.
4 January, 2022	Timothy Lee Grant: Added input of the vision processing unit that will tell the direction of North, and also added output which will be sent to the

	drone motor control unit. Changes are necessary to a functioning system.
5 January, 2022	Timothy Lee Grant: Created flow chart
	Timothy Lee Grant: Created black box diagram
6 January, 2022	Timothy Lee Grant: Added steps in verification process
	Timothy Lee Grant: Added data sheet references
7 January, 2022	Timothy Lee Grant: Added steps in verification process
	Timothy Lee Grant: Added content to "Why is this interface this value?" section and "Why do you know that your design details for this block above meet or exceed each property?" section.
	Timothy Lee Grant: Added description to block diagrams (Figure 1 and 2)
8 January, 2022	Timothy Lee Grant: Added content to the "Why do you know that your design details for this block above meet or exceed each property?" section.
15 January, 2022	Timothy Lee Grant: Created new interface section to reflect updated concept and fix errors present in previous rough draft assignment.
19 January, 2022	Timothy Lee Grant: Created new flow chart and copied block diagram from Senior Design Webpage
20 January, 2022	Timothy Lee Grant: In accordance with Professor Don's review suggestion, added schematic wiring diagram.
	Timothy Lee Grant: In accordance with Jordan Hendricks' review suggestion, added a sentence in the description section which clearly states that this data will be used to control the motors of the drone to maintain stability.
	Timothy Lee Grant: In accordance with Professor Don's review suggestion, rewrote the Verification Plan as to provide a numbered list instead of paragraph form. And in accordance with Jordan Hendricks' review suggestion, broke up the acceleration verification plan into the 3 different axes.
21 January, 2022	Timothy Lee Grant: After experimentation in the lab, values changed for input voltages, currents, and output voltages and frequencies.

4.4 Home Station Enclosure

4.4.1 Home Station Enclosure Description

The home station enclosure will be where the electronic components for the home station are located. The home station will contain a PCB with an Arduino Nano attached onto the PCB. Above the Arduino Nano will be the Time of Flight PCB. The Time of Flight PCB will have an antenna with a flexible wire attached to it. The enclosure will need to be sturdy enough to ensure that rouged handling of the enclosure will not cause it to break. It should also provide a method for keeping all of the electronics in place, such that the enclosure can be orientated in any way and the electronics will still be secure. This is important because although the home enclosure will not move much while in operation, the home enclosure will need to be moved into place and therefore should be durable to normal handling.

The home station enclosure will need to be able to fully enclose all of the components mentioned above. The PCB will be secured into the bottom of the home station enclosure to ensure that the electronics are fixed into place and do not slide around. The method of securing the PCB to the bottom enclosure will be to use ledges at the bottom of the enclosure which the PCB will be able to slide into. A hole will need to be placed at the top of the enclosure to allow the antenna to be able to be placed through the enclosure and be exposed to the open. In order to keep the antenna in place, the home station enclosure will make use of a keyhole, in which a notch, located at the base of the antenna (seen in Figure 10) will fit into a keyhole inside of the hole in the enclosure. This will allow the antenna to be stable in the enclosure and not fall down due to gravity. There will also need to be another hole located where the USB port to the Arduino Nano is located. The home station electronics will be powered and communicate through a laptop located at the home station, therefore it is necessary that a USB connector be able to be connected to the Arduino while all electronics are enclosed.

4.4.2 Design

Figure 4.4.2.1

Figure 4.4.2.1 is the block diagram for the home station enclosure. Because the enclosure block does not interact with the outside world or interact with any of the blocks in the project, there are no interfaces. Figure 4.4.2.1 shows that this block does not have any interfaces. The enclosure will house the electronics which are at the home station.

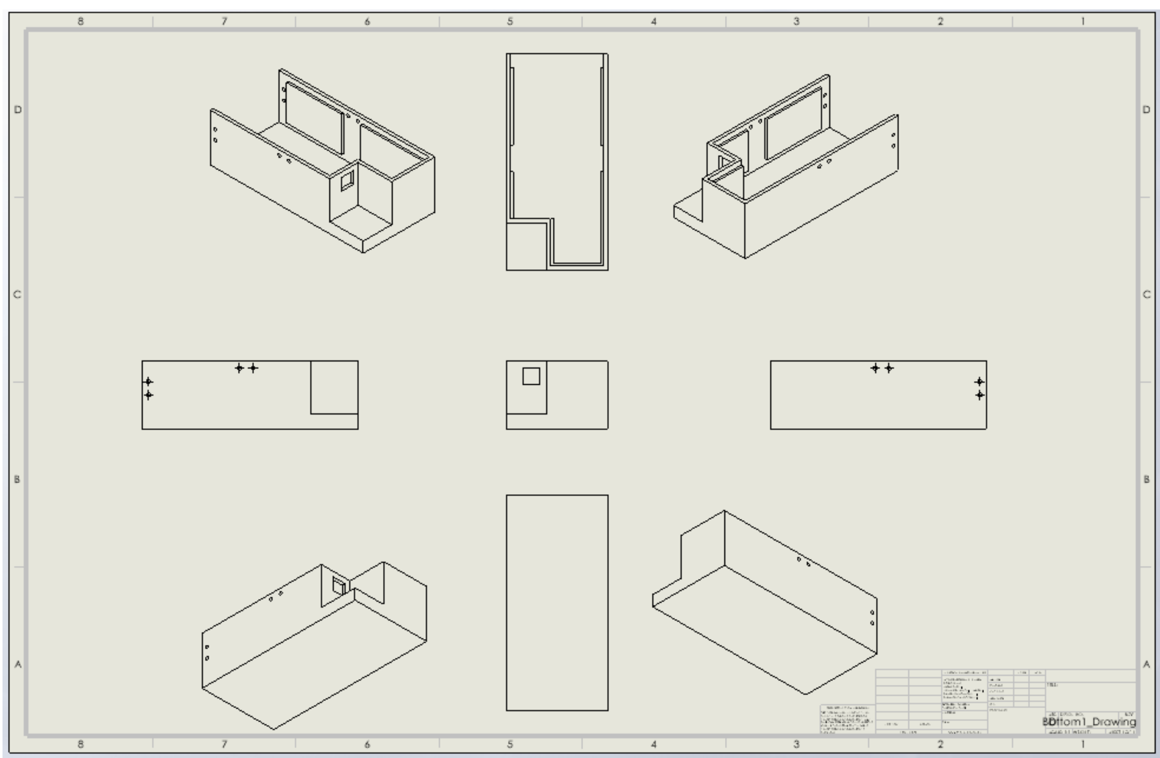


Figure 4.4.2.2

Figure 4.4.2.2 shows a schematic drawing of the bottom enclosure. Notice the cut out which allows access to the USB port on the Arduino. Also notice the ledges which the top enclosure will rest upon. The holes in the side of the enclosure will fasten the top to the bottom.

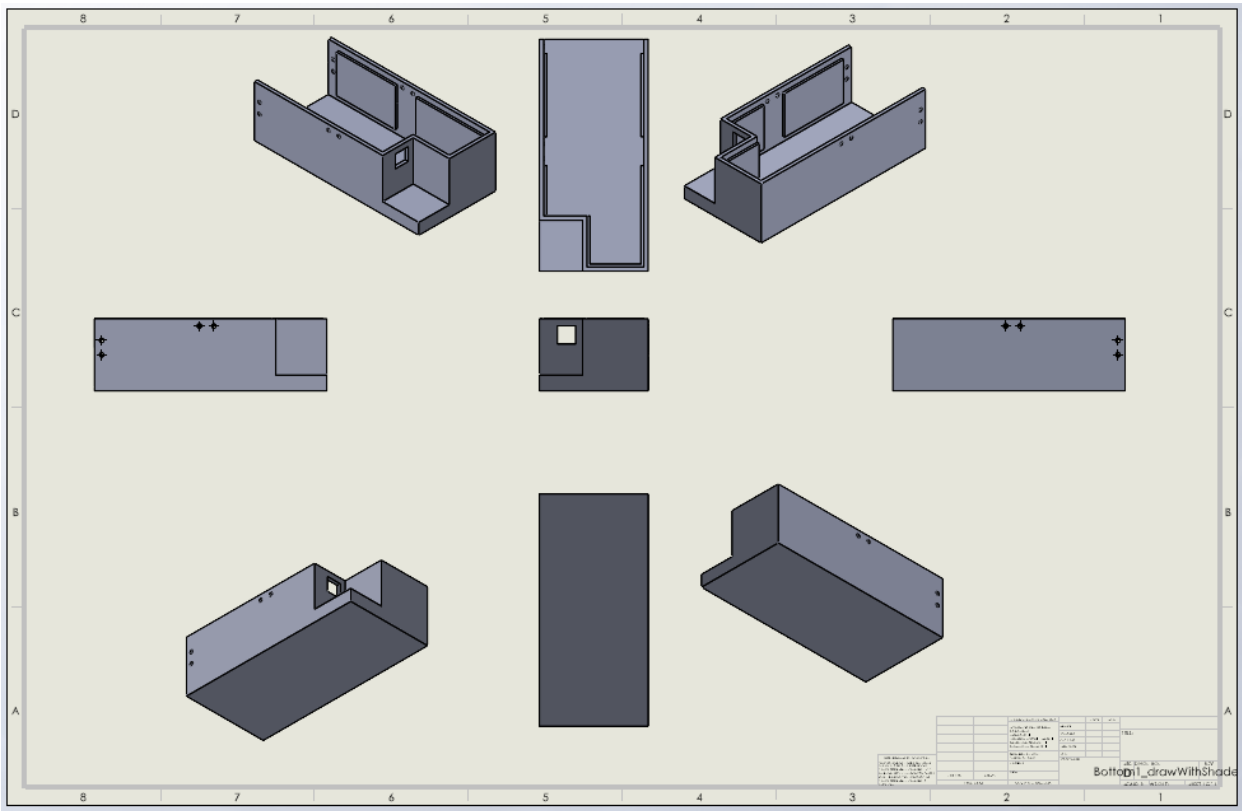


Figure 4.4.2.3

Figure 4.4.2.3 provides a shaded view of the bottom of the enclosure. This allows for better depth perception and analysis of the enclosure for the reader.

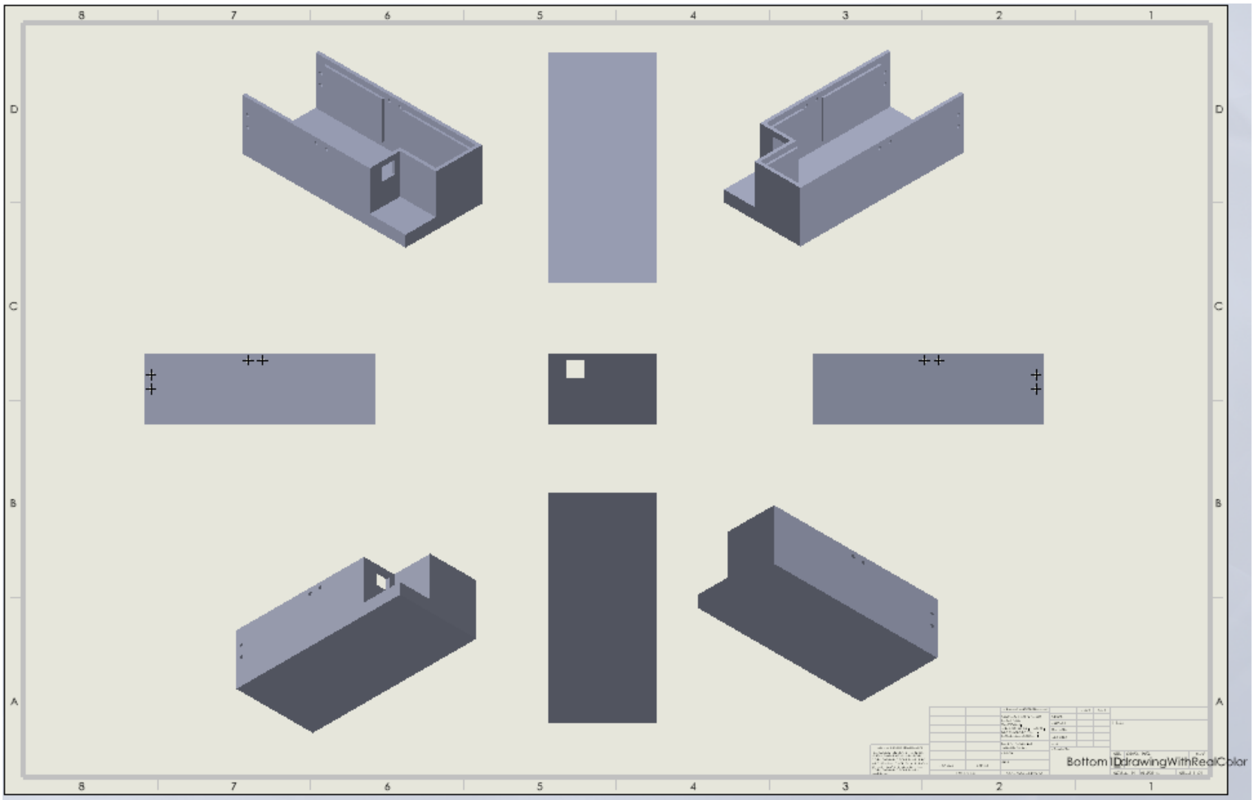


Figure 4.4.2.4

Figure 4.4.2.4 shows the rendered color of the bottom enclosure to further depict the enclosure.

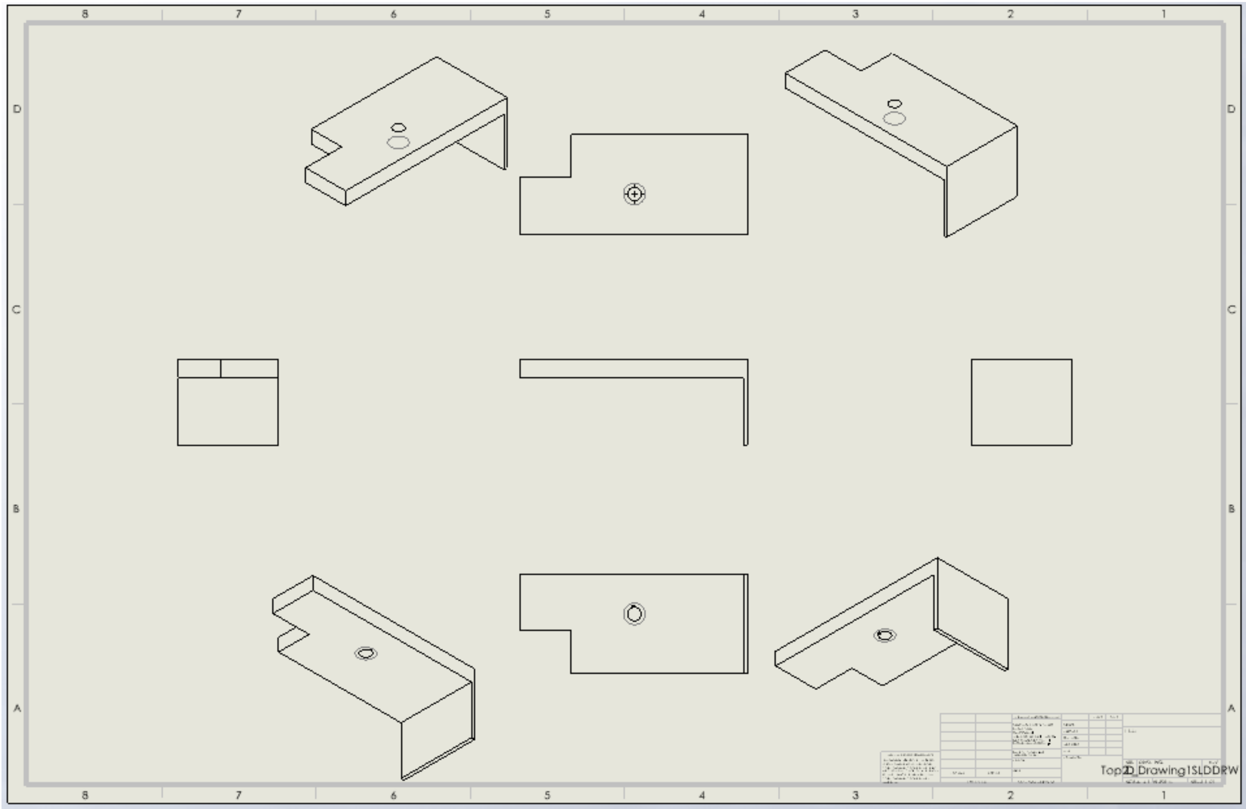


Figure 4.4.2.5

Figure 4.4.2.5 shows the top enclosure. This is the part which will fit on top of the bottom enclosure. Notice the hole which is present, allows for the antenna to be placed through the top enclosure. From this diagram, the keyhole in which the antenna will rest on is not clearly visible, but can be seen in Figure 9.

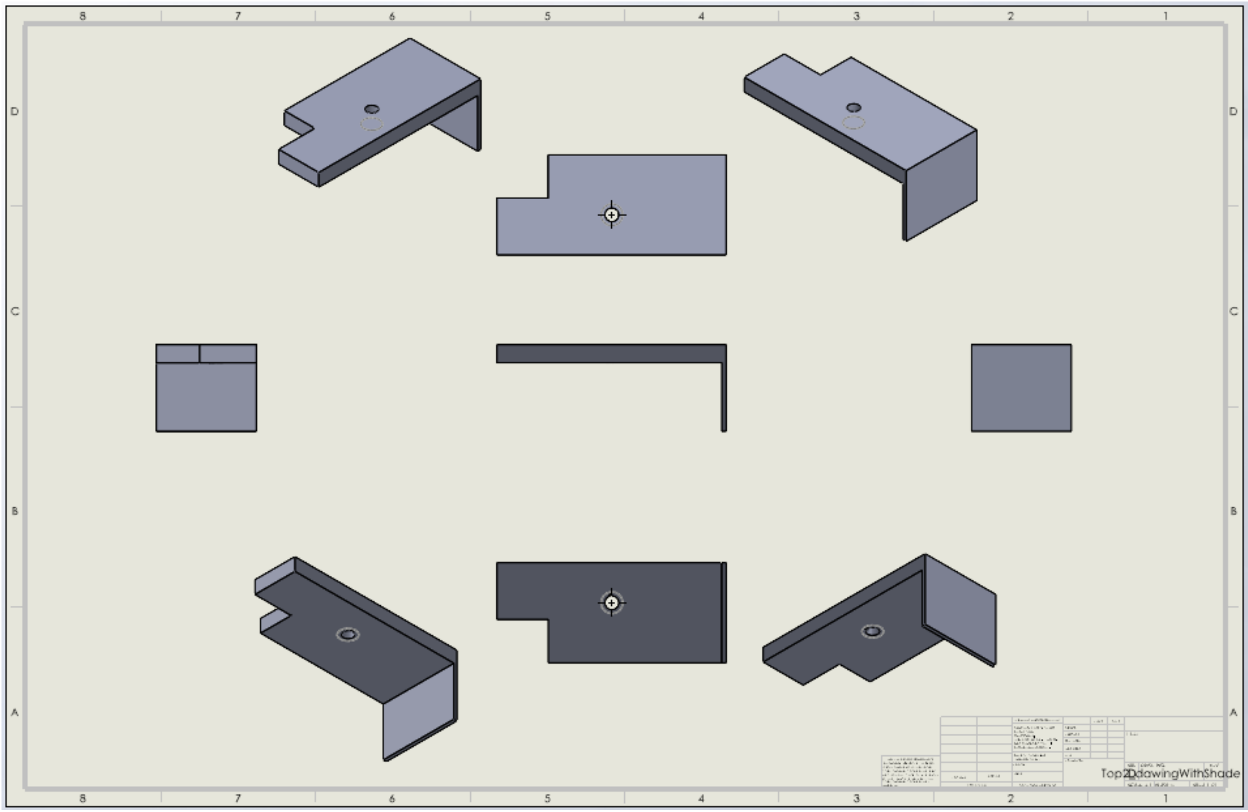


Figure 4.4.2.6

Figure 4.4.2.6 provides a shaded view of the top enclosure. This allows for better depth perception and analysis of the enclosure for the reader.

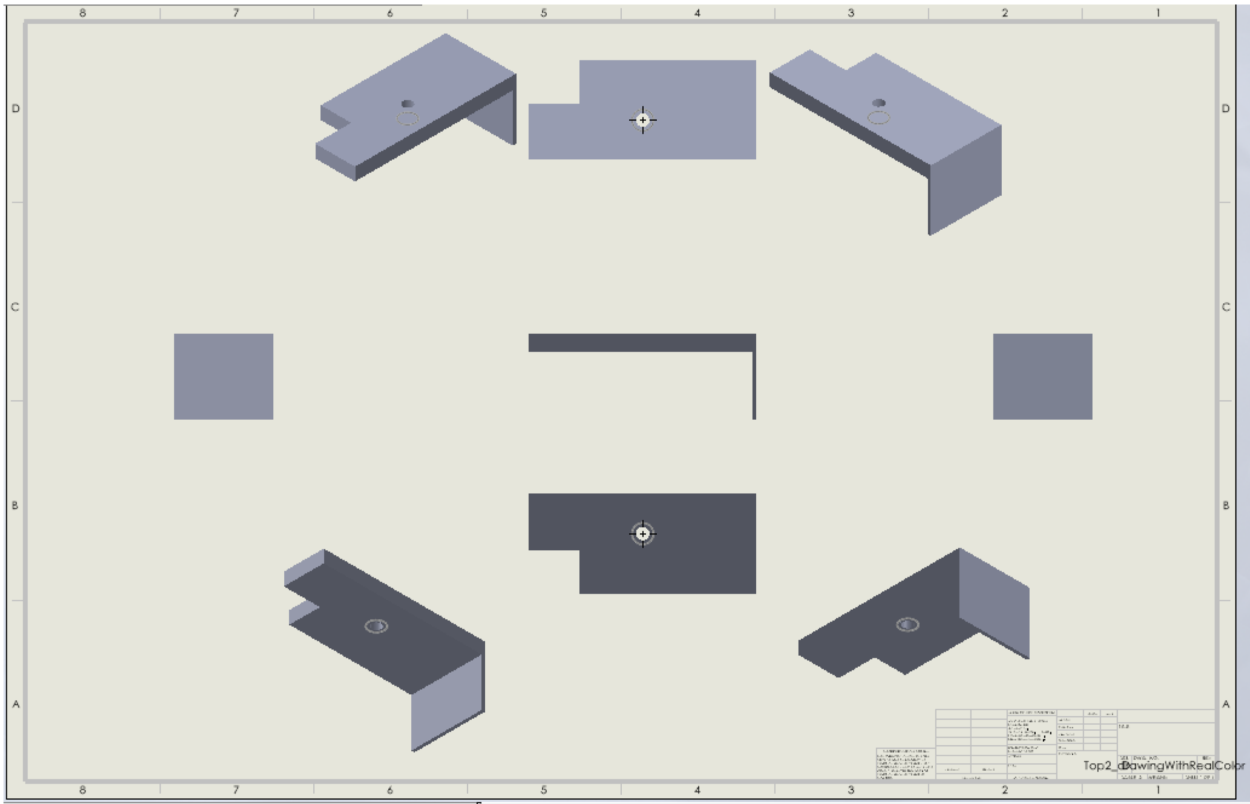


Figure 4.4.2.7

Figure 4.4.2.7 shows the rendered color of the top enclosure to further depict the enclosure.

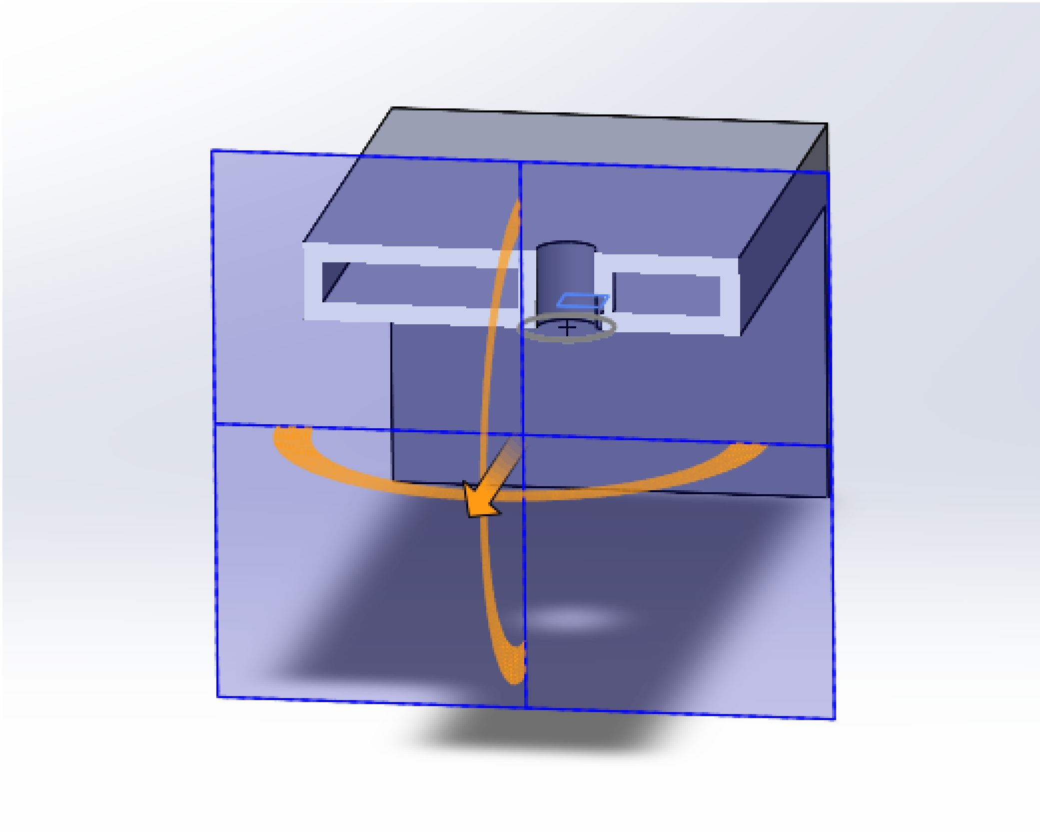


Figure 4.4.2.8

Figure 4.4.2.8 shows the hollow nature of the top enclosure. The top needs to have a larger thickness because the keyhole which the antenna will rest on needs to be encompassed within the top of the top enclosure. In order to reduce weight, material used, and print time, a method of creating a hollow structure was employed.

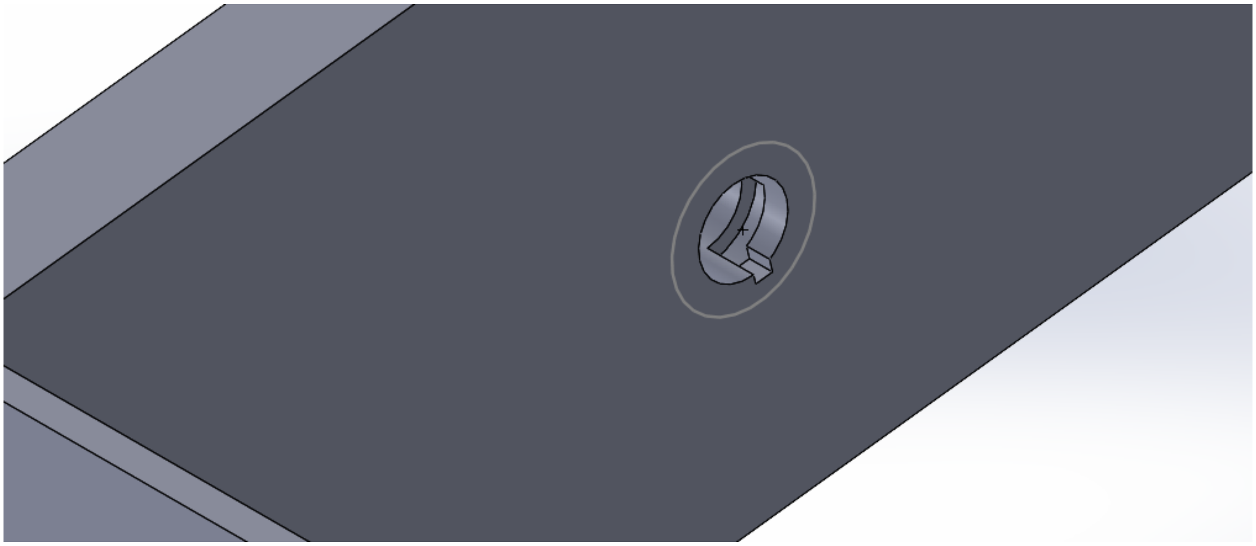


Figure 4.4.2.9

Figure 4.4.2.9 depicts the keyhole which will be used to allow the antenna to rest inside of the top of the top enclosure. The notch on the antenna will fit inside of the upward cut out, then by turning the antenna, the antenna will be secured against gravity.

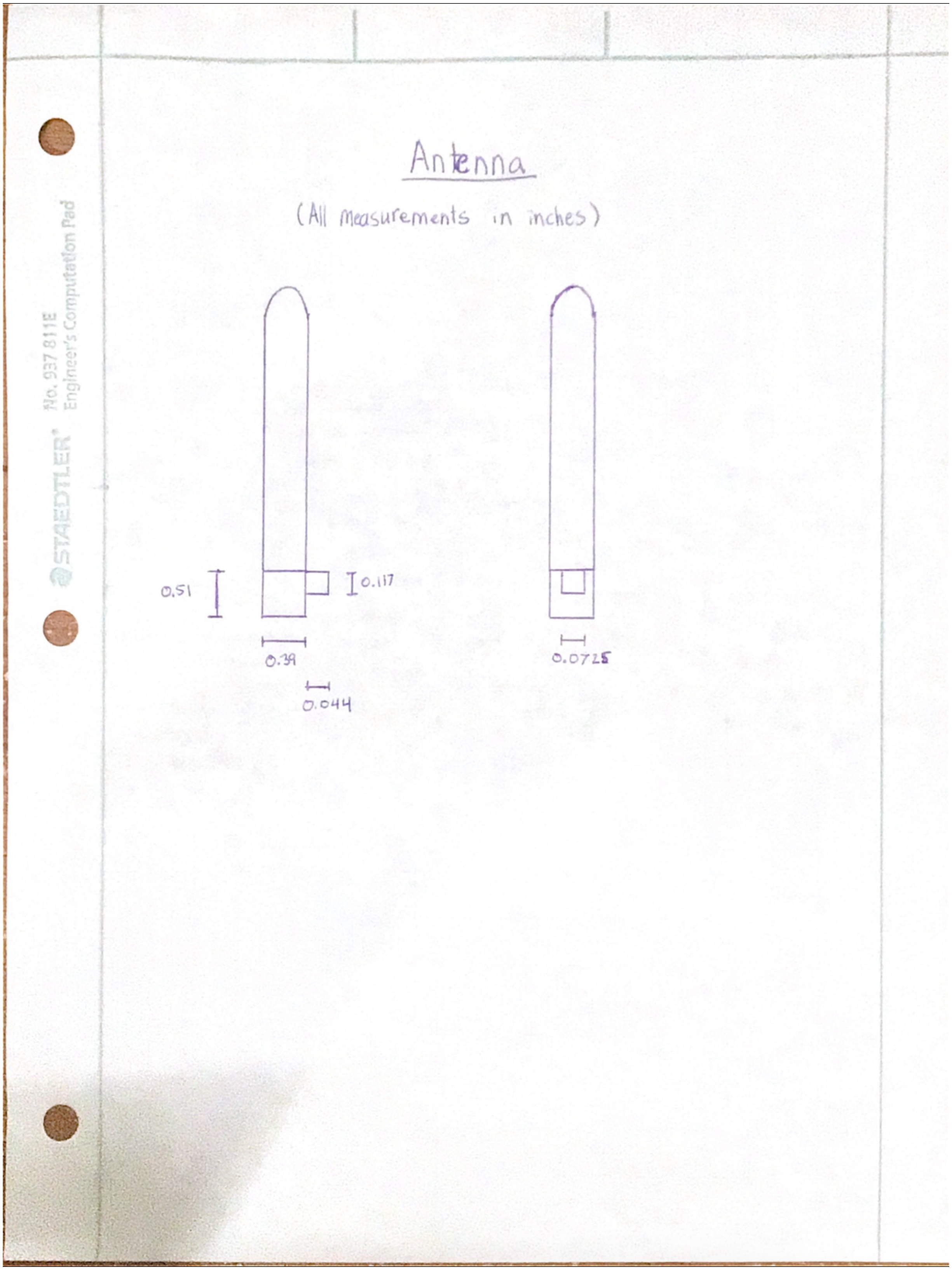


Figure 4.4.2.10

Figure 4.4.2.10 shows the measurements for the antenna. Special attention was shown to the base of the antenna because this is the location where the enclosure will be latched into place with the help of a keyhole. The lip on the top of the base will slide into position by being twisted, this will allow the antenna to be placed into the enclosure and not fall down due to gravity. The antenna has a smaller diameter than the base of the antenna, therefore the antenna will be able to be placed through the hole in the enclosure and the base will be latched into place.

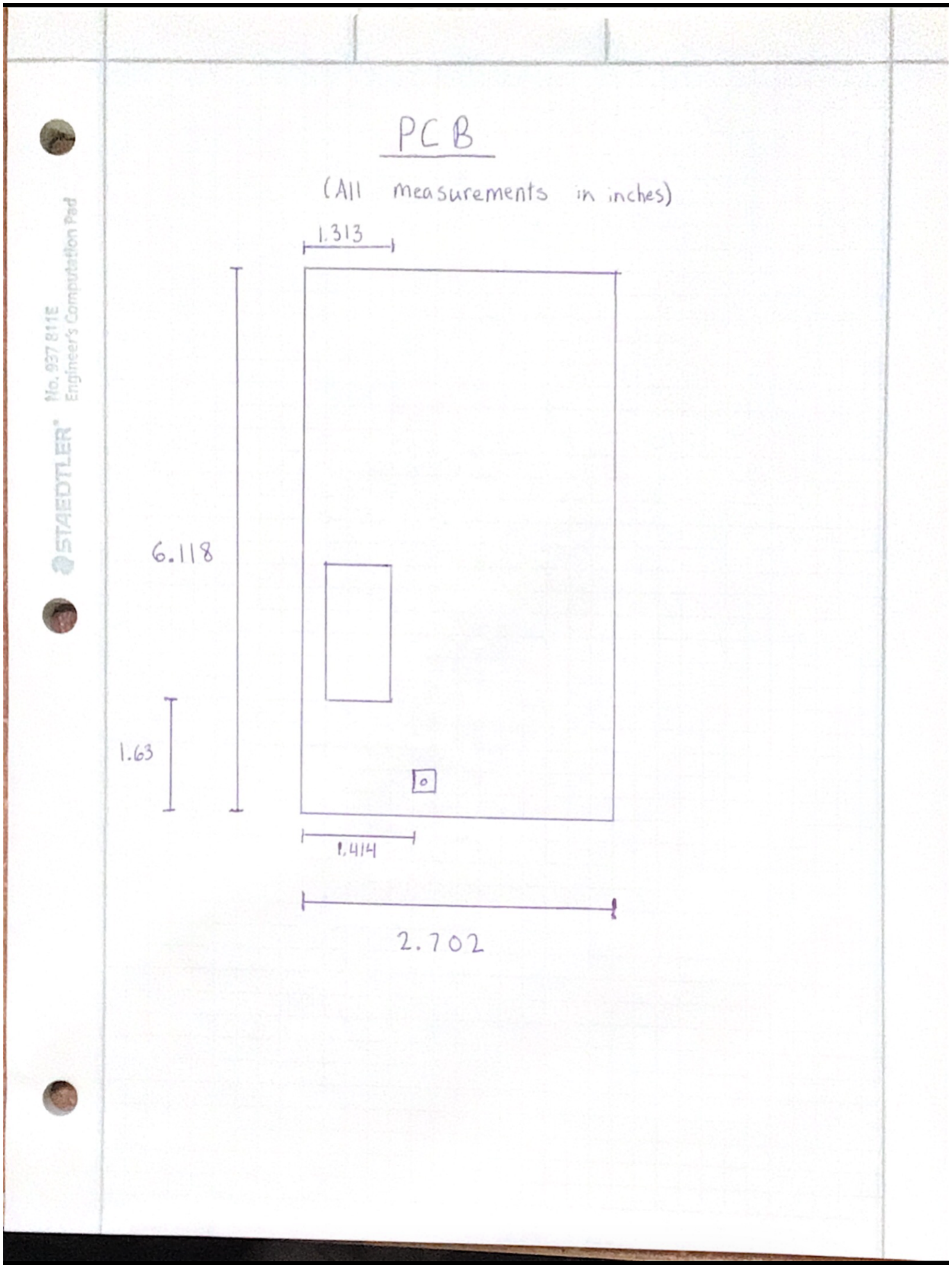


Figure 4.4.2.11

Figure 4.4.2.11 shows the measurements for the PCB and the locations on the PCB for the Arduino.

Figure 4.4.2.12

Figure 4.4.2.12 shows the PCB from which measurements were taken. It also shows the antenna from which measurements for the diameter of the base was taken.

4.4.3 General Validation

The block will be built with 3D printed technology. There are multiple reasons for selecting the enclosure to be 3D printed as opposed to other methods of building, such as wooden construction. The first reason is that our team's secondary goal is not only to produce a project that is functional, but also to be able to produce a project that impresses NASA. Members of our group have mentioned that NASA likes to see projects that incorporate 3D printing. By 3D printing more components of our project, this will enable our team an increased chance of scoring points in the NASA competition. The second reason for going with a 3D printed design is because 3D printing is quickly becoming an industry standard that I have never had the opportunity to get exposure to. By 3D printing this enclosure, it will allow me to gain valuable experience in a field that I have never worked with before. The final and most important reason for the selection for 3D printed design is that 3D printing allows for much more complex shapes and will allow for precise placement of features exactly where they are needed. This is extremely helpful because many of the features which are going to be placed in the home station enclosure need to be in specific locations for example the Arduino needs to be in the correct location as to allow for the USB port to be accessible from the outside of the enclosure this requires a hole in the enclosure at the exact location in which the USB port on the Arduino will be.

The design will make use of the CAD software Solidworks. The reason for selecting Solidworks for cad design is that solid works represents the industry standard for CAD and is therefore the most logical selection for modeling the enclosure. Solidworks has a massive amount of information available on the Internet to help people get started with Solidworks. This will come in handy because as a beginner there will be many questions that arise and using and using industry standard software will allow greater clarity in finding helpful information.

The purpose of the enclosure is to protect the PCB, therefore the walls of the enclosure need to be thick enough to be rugged against normal daily handling, but also not so thick that the enclosure becomes too heavy or wastes material. By searching 3D printing forums and taking an average of the recommended wall length, a result of 0.12in was decided. This number was confirmed to be a reasonable thickness by asking the mechanical engineers who have extensive experience working with 3D printed projects.

Another decision which needed to be made was the tolerance which would be allowed for the PCB. The enclosure needs to fit the PCB snug enough to prevent the PCB from rattling around inside, but the tolerance can not be too small because there is a risk that the enclosure will not be able to fit the PCB. The printer which will be used in the manufacturing of the enclosure has a resolution of 0.04mm. This is more than enough resolution for the purpose of securing the PBC. But just because the printer has a resolution which is quite small, this does not mean that the printer will place the material so precisely. Therefore it was decided to add a tolerance of 0.0625in. This will allow for some wiggle room while the PCB is being inserted and taken out of the enclosure, but not enough room as to allow for the PCB to rattle inside the enclosure.

There will be multiple holes in the enclosure. One of the holes will need to be placed in a location to allow for the access of a USB connector to the port of the Arduino Nano which will be located on the PCB inside of the enclosure. In addition, there will need to be holes to allow for attachment of the top and bottom pieces of the enclosure. The other hole that will need to be present on the enclosure is the top will need to have a hole from which the antenna is able to be pulled through and rest inside without falling out. The antenna has a lip which can be used to hold the antenna into place inside of the hole. This will require a circular cut out inside of the hole of the enclosure to act as a keyhole. Because the top layer will need to be able to encompass the size of the keyhole, this means that the top layer will need to be thicker than the selected thickness value of the walls. In order to keep the weight and material usage down, the technique of constructing a hollow wall will be used.

The room in which the USLI team meets to build the rocket, has 3D printers available to use. These are the printers which will be used to print the enclosure. In total, the enclosure should be able to be printed in a single day. There are some possibilities which would cause the print to take multiple days, such as if the printer gets jammed during the printing process, but under normal printing conditions, the construction should be finished in a day.

4.4.4 Interface Validation

Enclosures and PCB blocks leave this section blank.

4.4.5 Verification Plan

If PCB and other components are completed:

1. Place PCB with Arduino and Time of Flight sensor into PCB layout in enclosure. Show that PCB length and width fit.
2. With PCB, Arduino, and Time of Flight sensor in PCB layout, show that USB port is accessible from outside of the enclosure.
3. Place antenna into antenna hole. Show antenna is able to fit through the hole and rest inside of the keyhole.
4. Show that the antenna and PCB are able to fit within the enclosure at the same time.
5. Show that the enclosure is able to close up without conflicting with any of the devices inside of the enclosure.
6. Lightly shake (which is consistent with motion experienced during walking) enclosure with electronics inside. Ensure that electronics remain in place.

OR, if components are not yet completed:

1. Measure width of PCB layout in enclosure. Show PCB layout width matches agreed upon width for the PCB design.
2. Measure length of PCB layout in enclosure. Show PCB layout width matches agreed upon length for the PCB design.
3. Measure height of enclosure at location which contains the PCB stacked with an Arduino and Time of Flight PBC. Show that no point in this location is below minimum agreed upon value for the stack.
4. Measure height of enclosure at location which contains the PCB only. Show that no point in this location is below minimum agreed upon value for the PCB.
5. Measure the location of hole for USB communication with Arduino. Show that this is in the agreed upon location for the USB port.
6. Measure diameter of antenna hole on enclosure. Show that this diameter is larger than the base of the antenna selected for Time of Flight.
7. Show that the enclosure is able to close up without conflicting with any of the volumes outlined in steps 1-6.
8. Lightly shake (which is consistent with motion experienced during walking) enclosure. Ensure that the enclosure is able to remain intact.

4.4.6 References and File Links

https://my.solidworks.com/solidworks/guide/SOLIDWORKS_Introduction_EN.pdf

4.4.7 Revision Table

1 February, 2022	Timothy Grant: Initial creation of document
2 February, 2022	Timothy Grant: Filled out verification plan.
	Timothy Grant: Added Solidworks to references
3 February, 2022	Timothy Grant: Wrote General Validation section.
4 February, 2022	Timothy Grant: Added measurements (figure 1, 2, 3, 4) to document.
	Timothy Grant: Rewrote initial Description section.
16 February, 2022	Timothy Grant: In accordance with Dennis Kichatov’s suggestion, added content to the introduction section.
	Timothy Grant: In accordance with Dennis Kichatov’s suggestion, added shake test to the verification section.

	Timothy Grant: In accordance with Dennis Kichatov's suggestion, added time of construction to general validation section.
17 February, 2022	Timothy Grant: Added SolidWork figures (figures 2 - 9)
18 February, 2022	Timothy Grant: Replaced old diagrams of the measurements of PCB and Antenna with newer, more professional versions of the measurements (figures 10 and 11).
	Timothy Grant: Added content to general validation section to more accurately describe the functionality of enclosure usage.
	Timothy Grant: Fixed grammatical errors in preparation for submission of document.

4.5 External Structure

4.5.1 External Structure Description

This block is an external structure that will offer the team valuable data for the CS team. The external structure will be a 10ft by 10ft wood frame that will hold a 10ft by 7.5ft piece of colored fabric. Since the rocket will have cameras on-board which will be looking for a structure at a distance, this block will give an ideal case giving a large surface area of color. This structure will be useful in two testing cases: both with a drone and with the rocket. The drone can be flown out to distances defined by the rocket simulations and take pictures of the structure. The CS team will use these images to filter out colors other than the one on the structure using hue, saturation and value (HSV) techniques. Another test case will be with the rocket which will use its four cameras taking pictures on descent. This will help the team determine the size of structure that will need to be created so that the rocket can 'see' it at various distances. While this is only one side of the overall structure, it can be replicated 3 more times to make a cube.

4.5.2 Design

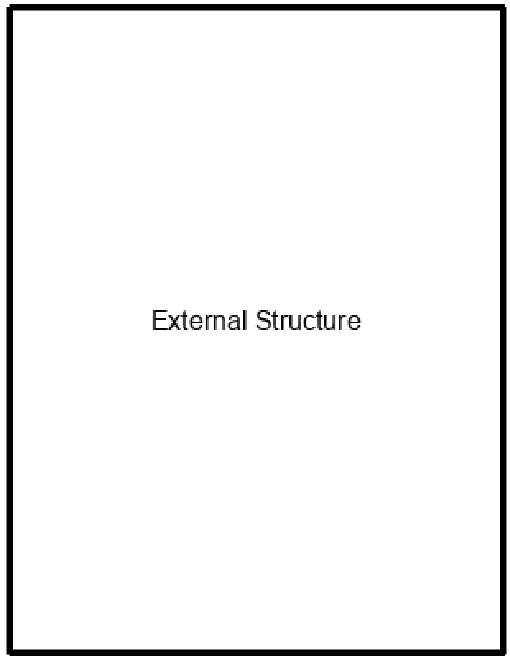


Figure 4.5.2.1: External Structure Black Box

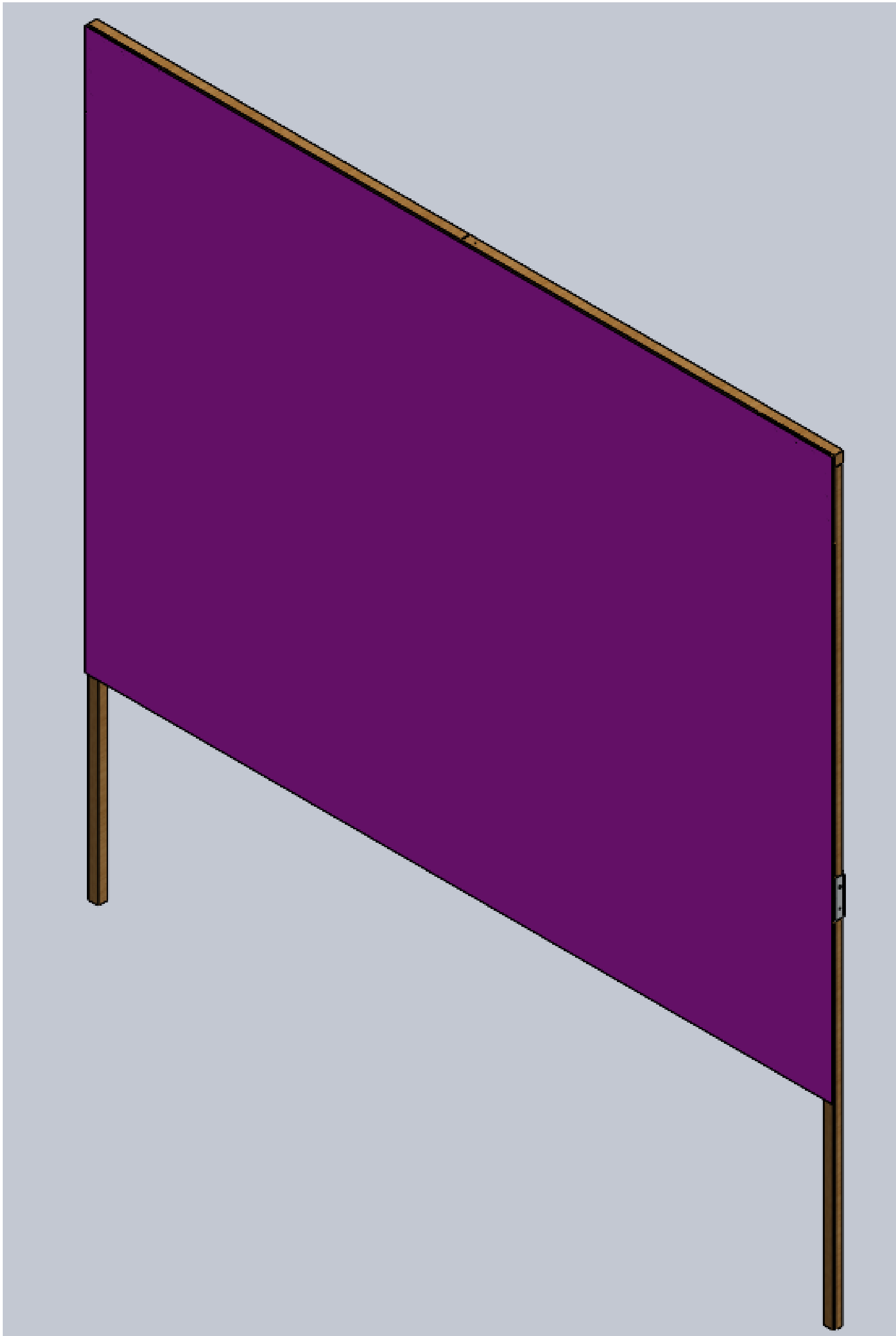


Figure 4.5.2.2: Full Assembly

Figure 4.5.2.3: Frame Only

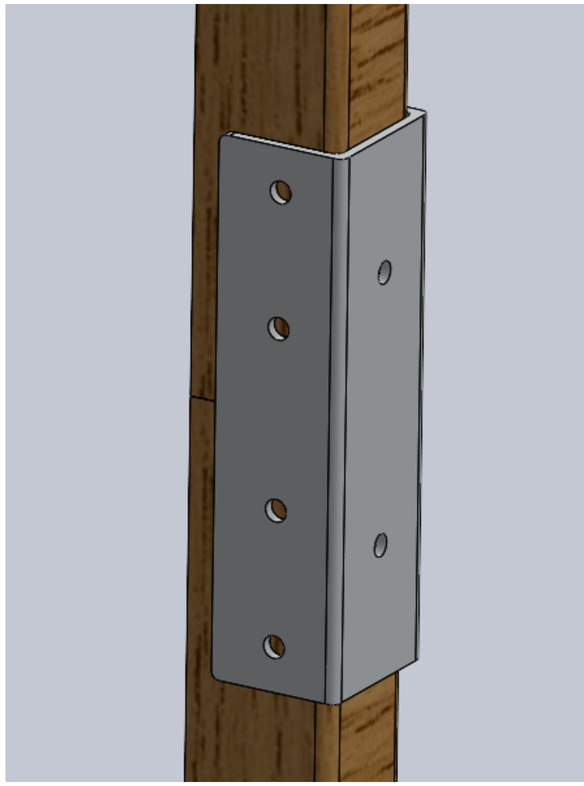


Figure 4.5.2.4: Joint

Figure 4.5.2.5: Frame Corner

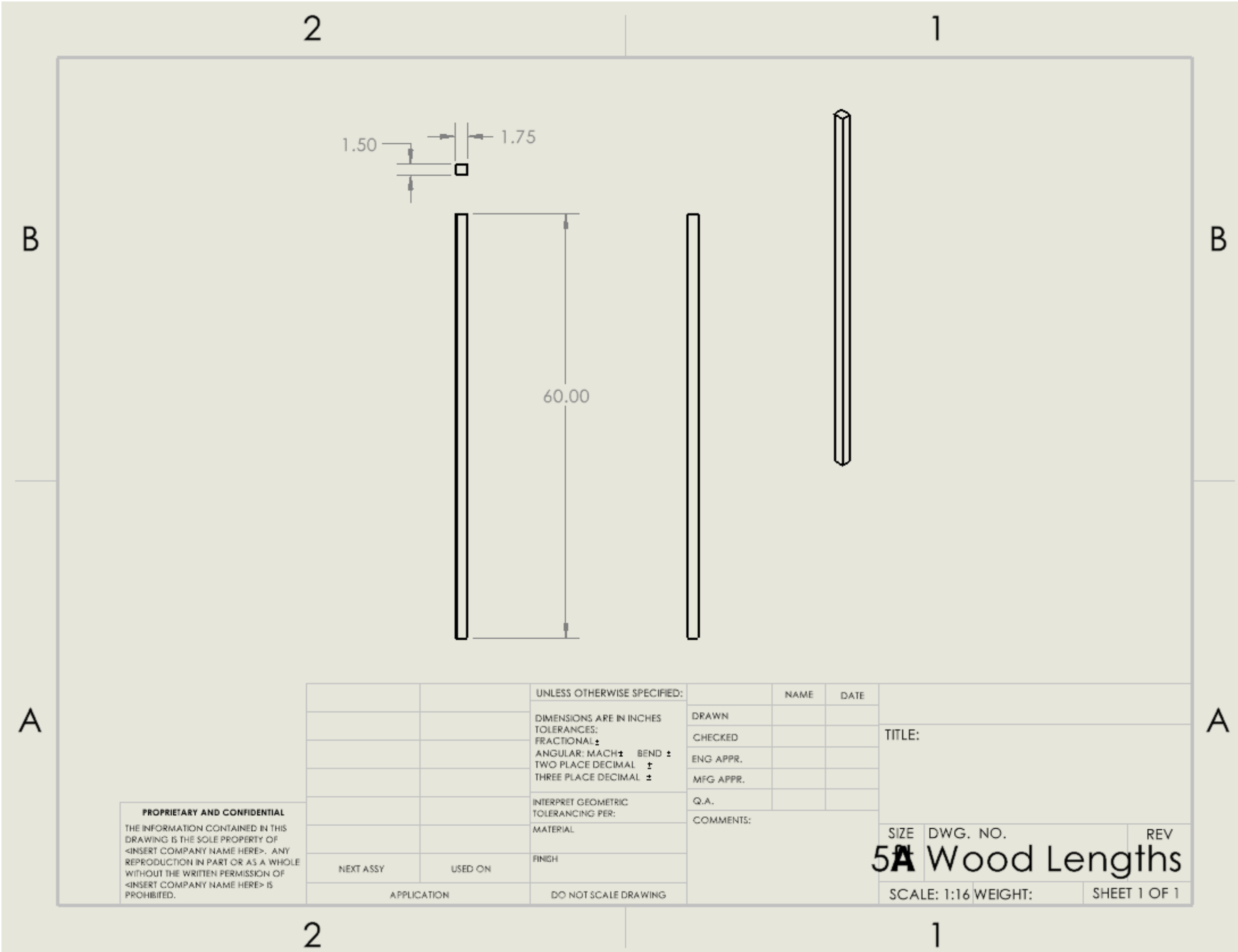


Figure 4.5.2.6: 5ft Wood Lengths Drawing

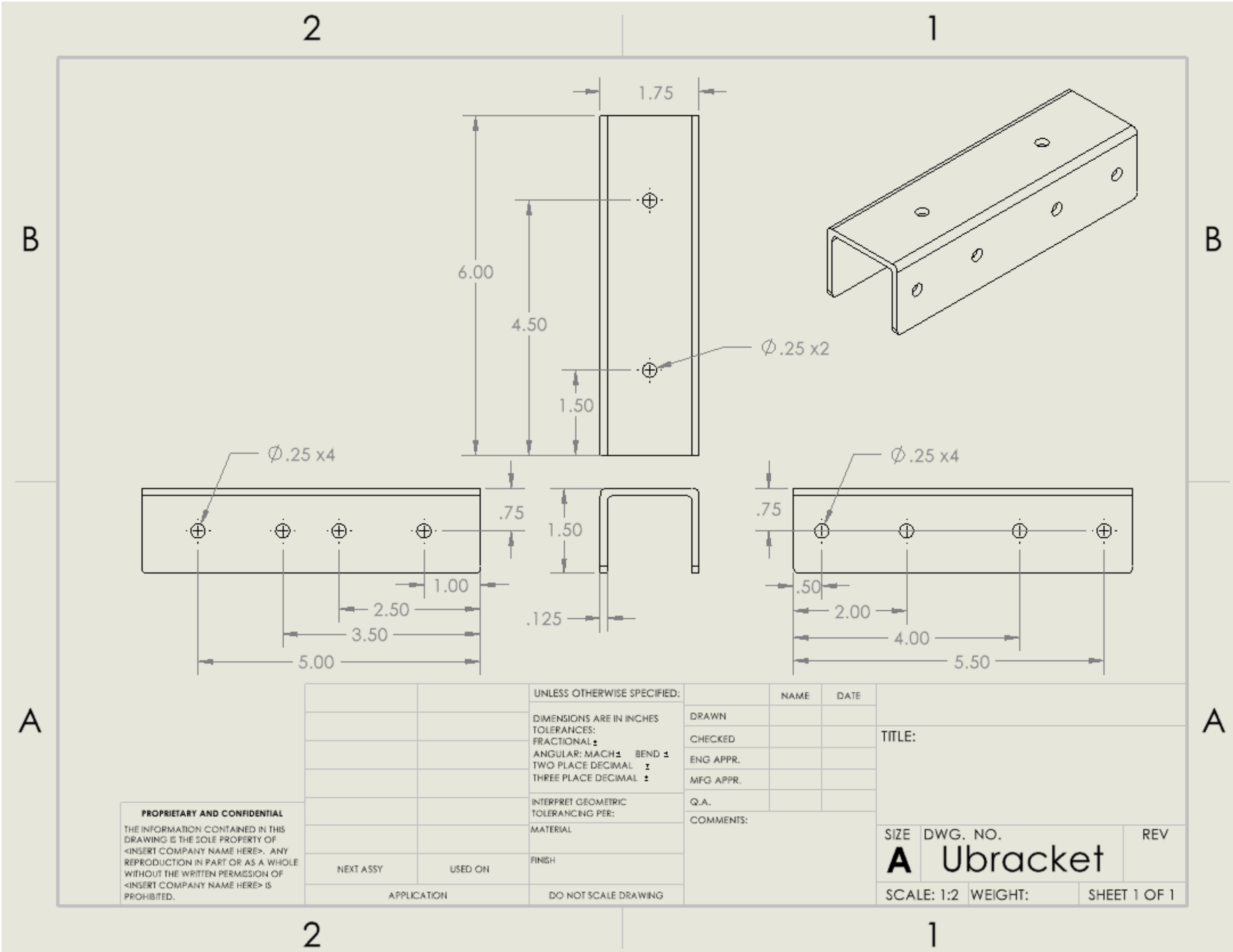


Figure 4.5.2.7: Metal U-Bracket Drawing

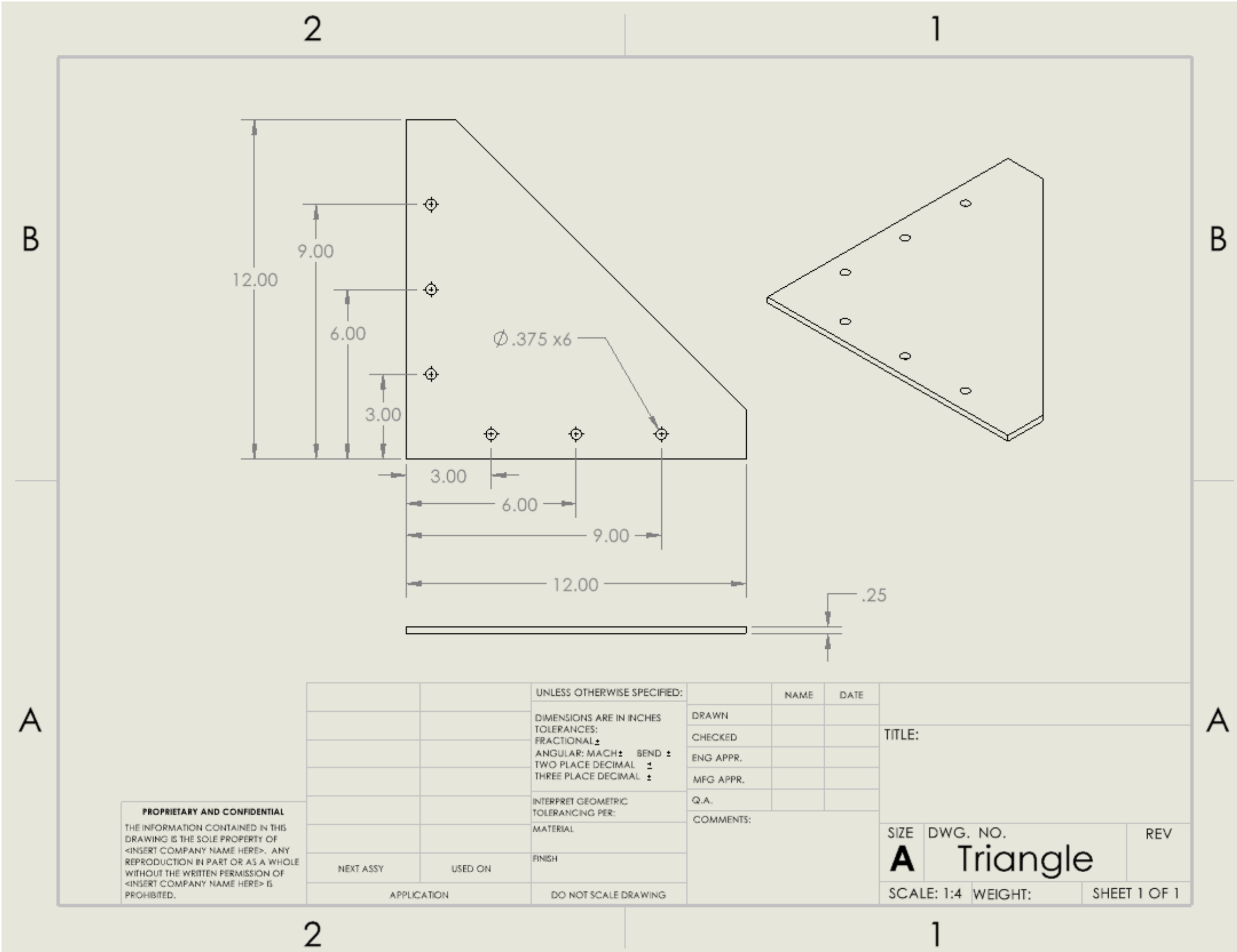


Figure 4.5.2.8: Wood Triangle Drawing

Item	Quantity	Cost Per Unit
10ft 2x4 Wood Beam	2	$8.09
Metal U-Bracket	3	$1.67
2x2ft 0.5”in Plywood	1	$7.85
Screws	30	$0.09
Staples	20	$0.002
13x7.5ft Tablecloth Fabric	1	$19.99

Figure 4.5.2.9: External Structure BOM

4.5.3 General Validation

The external frame is designed to be an ideal testing rig that allows the team to test and hold a large piece of brightly colored fabric. The idea behind this is, the final structure will have 4 sides with 4 different bright colors. When the rocket sees this large structure, it will be able to use the colors it sees to get an approximate angle from the origin. This structure will enable the team to test whether a large, 10x7.5 ft piece of fabric can be seen at distances up to 1200ft away. This is the most likely distance the rocket will travel away from the origin based on the rocket simulations done by the structures team.

The total cost for the external structure is $43.67 which is relatively inexpensive for a frame structure like this one. If we made 4 sides of the structure, the price would be around $175. The data that this will provide to the CS team is invaluable because it provides a large area of bright color in the photos. This will result in more pixels in each image at every distance. The CS team will be able to refine their image processing techniques to find the color and locate the structure when they have more pixels to work with.

4.5.4 Interface Validation

Interface Property	Why is this interface this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?

extrnl_strctr_otsd_other : Output

Other: The external structure will be at least 10ft in height.	This is 10ft in height for ease of manufacturing such that same length of beams can be used for width and height	The structure was designed and built with two lengths of 5ft 1x2s stacked end to end which gives 10 ft in height.

extrnl_strctr_otsd_other : Output

Other: The external structure will be at least 10ft in width.	The space allotted by the NASA competition is 10x10ft minimum and 20x20ft maximum. This is designed to test whether this size is feasible if we are constrained to the minimum.	The structure was designed and built with two lengths of 5ft 1x2s stacked end to end which gives 10 ft in width.

extrnl_strctr_otsd_other : Output

Other: The external structure will display at least a 10ft by 7ft piece of fabric for testing.	The fabric used was only available in specified sizes, most of which were long rectangular pieces.	The fabric displayed was 10ft in width by 7.5ft in height

extrnl_strctr_otsd_other : Output

Other: The structure will offer a size to distance ratio of at least 0.005 for both dimensions and occupy at least 0.005% of the frame at 1,200 feet.	This will offer at least 125 pixels of “color” to work with.	Using the drone, there were over 400 pixels seen at 1200 feet. Using a derived formula, there will be at around 146 pixels of ‘color’ captured with the rocket’s camera at 1200 feet.

4.5.5 Verification Plan

1) Testing the external structure

a) Gather all materials for the structure
b) Use the CAD as a reference to build the frame
c) Attach the fabric to the outside of the frame using staples ensuring that it is relatively taut and flat
d) Test by flying a drone to distances specified by the rocket simulations (600, 1200, and 2200 feet). Take images of the structure at these distances at various different heights (100, 150, 200 feet).
e) Test by holding the structure up during a rocket launch and rotate to face the rocket as it descends.

4.5.6 References

https://photo.stackexchange.com/questions/90059/how-to-calculate-the-size-of-object-in-pixels-knowing-the-camera-properties-and

4.5.7 Revision Table

Date	What was done
2/18/2022	Added part drawings
2/18/2022	Revised the verification plan adding more specifics
2/17/2022	Inserted new black box diagram
1/17/2022	Removed interfaces
2/4/2022	Jordan Hendricks added more figures and began work on all sections.
2/4/2022	Jordan Hendricks added design images and BOM
2/4/2022	Document Created

4.6 Internal Payload Power Supply

4.6.1 Description

This block takes in a voltage and steps the voltage down to levels which can power the interfacing components. The internal power supply is responsible for providing the correct voltage and current to the Arduino Nano microcontroller and the SD card reader. The other components on the system to be powered include an IMU and XBee3 Radiofrequency module. These modules require 3.3 Volts and will be connected to the 3.3 Volt pin on the Arduino. Each of these components are expected to have low current draw and should be able to be powered with one power supply.

4.6.2 Design

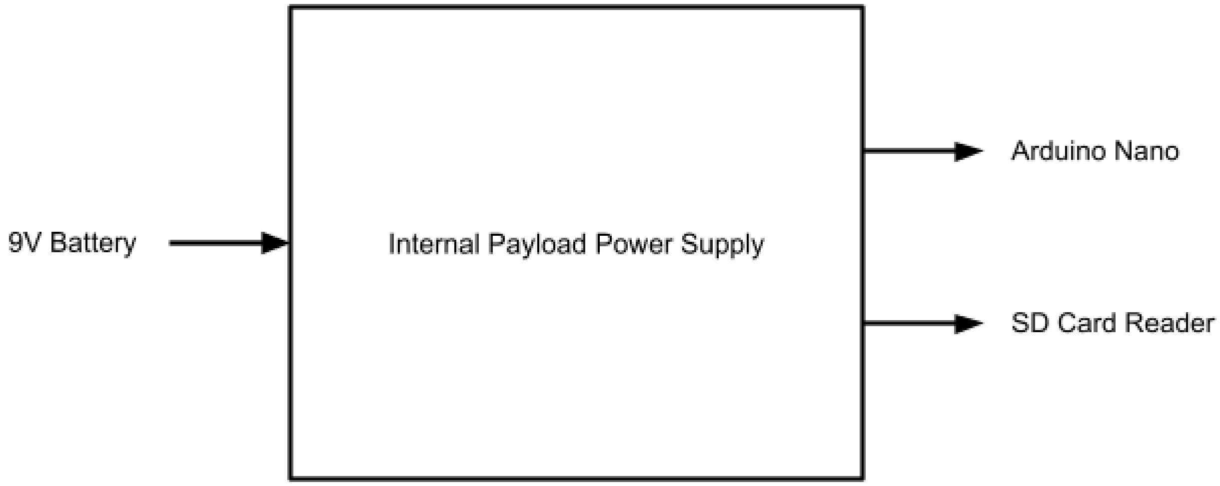


Figure 4.6.2.1: Internal Payload Power Supply Black Box

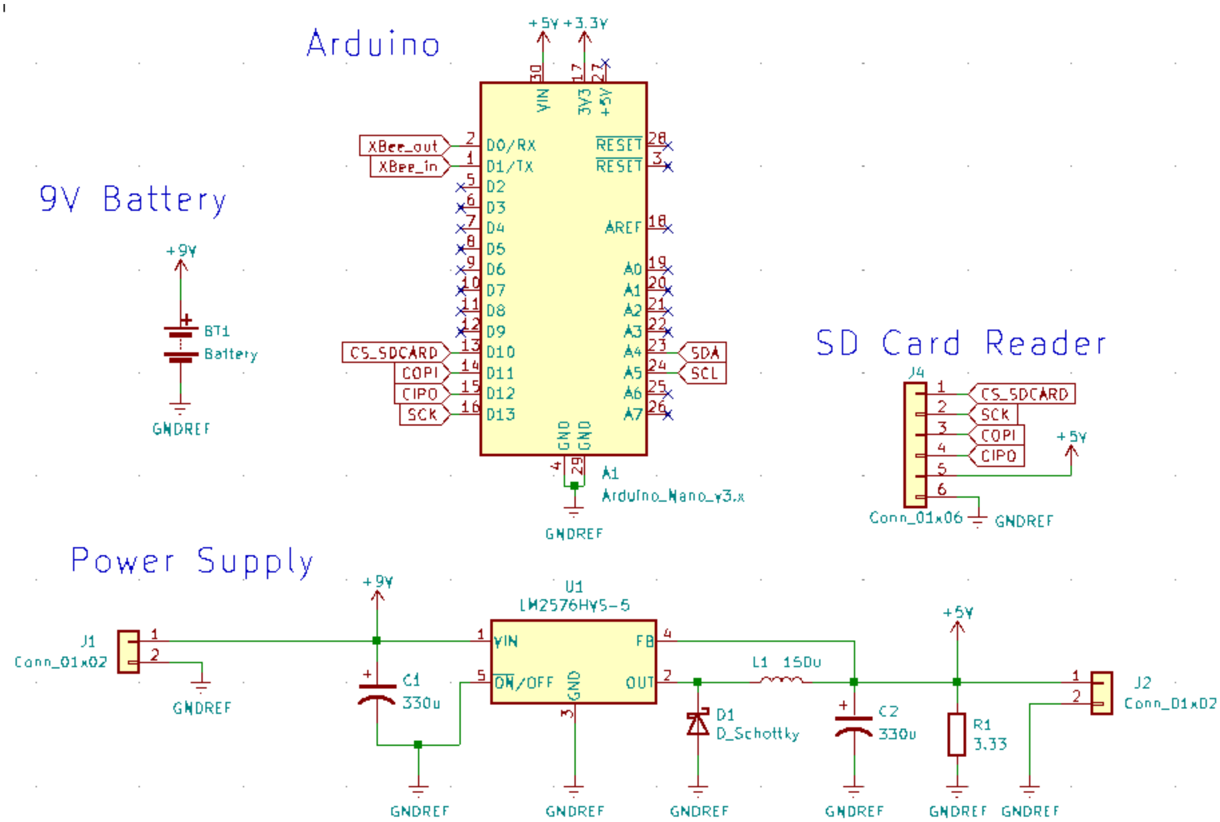


Figure 4.6.2.2: Internal Payload Power Supply Schematic

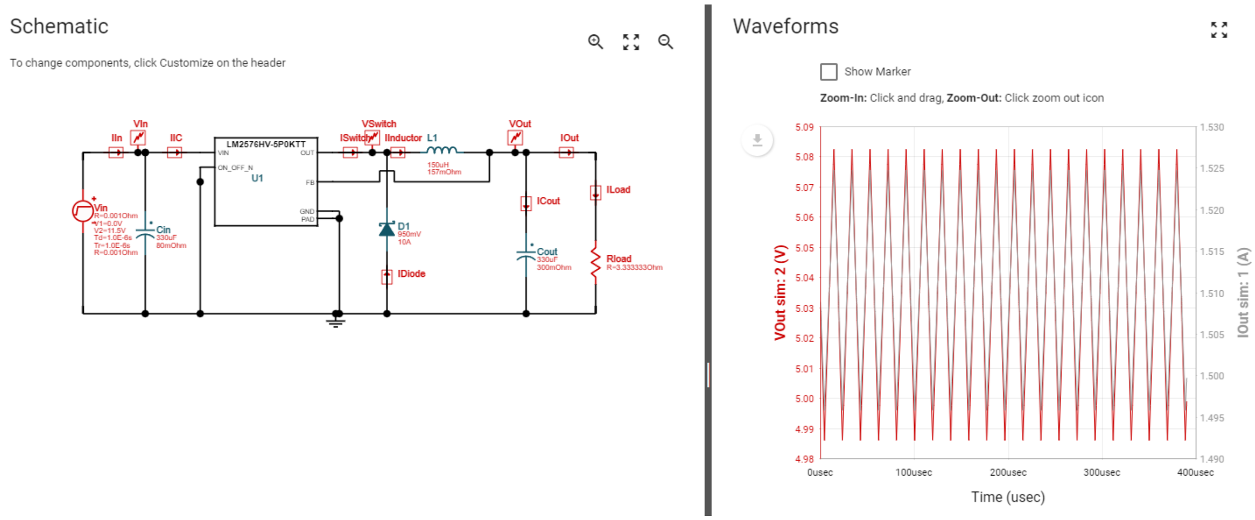


Figure 4.6.2.3: Internal Payload Power Supply Simulation

Reference Designators	Manufacturer	Mfg Part Number	Description / Value / Case Code (in) / Tolerance	Cost Per Unit
U1	Texas Instruments	LM2576HVS-5.0/NOPB	LM2576HVS-5 Voltage Regulator	$9.24
D1	Central Semiconductor	CMSH3-40MA TR13 PBFREE	Diode for Voltage Step Down circuit	$0.67
C1, C2	Panasonic	EEV-FK1H331V	CAP ELEC330uF 50V 20%	$2.19
R1	Vishay	TNPW08053R30DEEA	RES 3.3OHM 1/8 W 0805 SMD 0.05%	$0.54
L1	Coilcraft	MSS1583-154KED	INDUCTOR FIX 150uH 3.9A	$1.08
	JLCPCB		Power supply PCB	$3.00

Figure 4.6.2.4: Internal Payload Power Supply BOM

4.6.3 General Validation

The internal payload's power supply is designed to output 5 volts and up to 1.5 Amps of current. The Arduino Nano requires 5 volts of regulated input voltage and 19mA of peak current. The SD card reader requires 200mA of peak current. With this in mind, the Texas Instruments LM2576 chip is more than capable of powering the Arduino and SD card reader. Once the Arduino has a regulated input, the IMU and XBee3 RF module can be powered from the 3.3 volt pin on the Arduino. This is due to the fact that the Arduino has an onboard buck converter.

The total cost for the power supply and PCB is $16.72 which is relatively inexpensive. The internal payload needs a reliable power source to keep the Arduino on throughout the rocket launch. The PCB will experience rapid acceleration so, implementing SMD components will eliminate possibilities of components coming loose during lift off. All parts of the power supply are in-stock, and have been ordered in advance. The physical size of the power supply is small due to the fact that there are few components required for the design. All components were chosen with their maximum allowed voltage and current in mind so that they have a safety factor in the case of a power surge.

4.6.4 Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details <u>for this block</u> above meet or exceed each property?**

intrnl_pyld_pwr_spply_intrnl_pyld_arduino_nano_dcpwr : Output

Inominal: 12mA	This nominal current drawn by the Arduino when powered by the PCB is around 12mA.	When the arduino was powered in testing, the digital multimeter read around 12mA. The power supply is capable of outputting 1.3A in testing and 1.5A in simulation results with a small, 3.3Ω resistor.
Ipeak: 19 mA	The peak current that is drawn from the Arduino is 19mA. (Tech Specs table, [3])	The power supply is capable of outputting 1.3A in testing and 1.5A in simulation results with a small, 3.3Ω resistor.

Vmax: 5.2V	The maximum voltage output of the power supply should be around 5.2V.	For the LM2576: Max voltage output is 5.2V. (Electrical Characteristics table, [1] pg. 5)
Vmin: 4.8V	The minimum voltage output of the power supply should be around 4.8V.	For the LM2576: Min voltage output is 4.8V. (Electrical Characteristics table, [1] pg. 5)
Vnominal: 5V	The power supply should output 5V nominal.	For the LM2576: Typical voltage output is 5V. (Electrical Characteristics table, [1] pg. 5)

intrnl_pyld_pwr_spply_intrnl_pyld_SD_card_reader_dcpwr : Output

Inominal: 100mA	This nominal current drawn by the SD card reader when powered by the power supply is around 100mA. (Features Section, [3])	The power supply is capable of outputting 1.3A in testing and 1.5A in simulation results with a small, 3.3Ω resistor.
Ipeak: 200mA	The peak current that is drawn from the SD card reader is 200mA (Features Section, [3]).	The power supply is capable of outputting 1.3A in testing and 1.5A in simulation results with a small, 3.3Ω resistor.
Vmax: 5.2V	The maximum voltage output of the power supply should be around 5.2V.	For the LM2576: Max voltage output is 5.2V. (Electrical Characteristics table, [1] pg. 5)
Vmin: 4.8V	The minimum voltage output of the power supply should be around 4.8V.	For the LM2576: Min voltage output is 4.8V. (Electrical Characteristics table, [1] pg. 5)
Vnominal: 5V	The power supply should output 5V nominal.	For the LM2576: Typical voltage output is 5V. (Electrical Characteristics table, [1] pg. 5)

intrnl_pyld_battery_intrnl_pyld_pwr_spply_dcpwr : Input

Inominal: 120mA	This nominal current drawn by the SD card reader and Arduino Nano combined is around 112mA.	The battery is capable of outputting 1.3A in testing.
Ipeak: 1.3A	The peak current that is drawn from the SD card reader and Arduino combined is 220mA (Features Section, [3]).	The battery is capable of outputting 1.3A in testing.
Vmax: 9.5V	The maximum voltage output of the battery if fully charged is 9.5V.	For the battery: Max voltage output is 9.6V from testing
Vmin: 8.5V	The minimum voltage output of the battery if it is not fully charged is 8.5V	For the battery: Min voltage output is 8.2V from testing
Vnominal: 9V	The battery should output 9V.	For the battery: Typical voltage output is 9V. (Electrical Characteristics table, [4] pg. 1)

4.6.5 Verification Plan

1) Testing power supply output

a) Connect the 9 Volt battery to the power supply
b) Use a digital multimeter on the output pins to determine the current and voltage
c) Verify that the voltage at the output is close to 5 volts nominal with no load.
d) Verify that the current draws 12mA when connected to the Arduino Nano. This is done by connecting the digital multimeter in series with the Arduino Nano when power is applied.
e) Verify that the current draws 100mA when connected to the SD card reader. This is done by connecting the digital multimeter in series with the Arduino Nano when power is applied.
f) Ensure that the voltage remains near 5V with both loads (Arduino Nano and SD card reader) connected.

2) Testing power supply input

a) Use a digital multimeter on the output terminals of the battery to determine the voltage is close to 9V

4.6.6 References

[1] “LM2576xx Series SIMPLE SWITCHER® 3-A Step-Down Voltage Regulator.” Texas Instruments, Dallas, Jun-1999. https://www.ti.com/general/docs/suppproductinfo.tsp?distId=26&gotoUrl=http%3A%2F%2F www.ti.com%2Flit%2Fgpn%2Flm2576hv

[2] “Micro SD TF Card Memory Shield Module,” *ElectroPeak Store*. [Online]. Available: https://electropeak.com/micro-sd-tf-card-adapter-module. [Accessed: 22-Jan-2022].

[3] “Arduino Nano,” Arduino Online Shop. [Online]. Available: https://store-usa.arduino.cc/products/arduino-nano/. [Accessed: 22-Jan-2022].

[4] “Alkaline-Manganese Dioxide Battery MN1604.” Duracell Batteries, Bethel https://www.duracell.com/wp-content/uploads/2016/03/MN1604_US_CT1.pdf

4.6.7 Revision Table

Date	What was done
1/21/2022	Jordan Hendricks added more detailed instructions to the verification plan
1/21/2022	Jordan Hendricks added more references for the Arduino and SD Card
1/21/2022	Jordan Hendricks added more another interface and updated the section’s details
1/7/2022	Jordan Hendricks added more figures and began work on all sections.
1/7/2022	Jordan Hendricks added design schematic and BOM
1/6/2022	Document Created

4.7 Avionics GPS

4.7.1 Avionics GPS Description

The purpose of the GPS design is to satisfy the requirement of NASA, to recover the rocket after the launch. It is important for the Avionics system to get GPS (Global Positioning System) data from the GPS module and send the data back to the base station by using the transceiver system. The transceiver system was combined with two devices, the transmitter and the receiver. The transmitter will be assembled on the rocket, and the receiver will be located at the base station on the ground.The Avionic system can be broken into three components, the transceiver, the GPS breakout board, and the microcontroller, Arduino Uno. For the choice of the GPS, the team decided to choose the Adafruit Ultimate GPS Breakout board v3. The GPS will be connected to the Arduino Uno with GPIO pins, then collect the data and process the information through the microcontroller, and then send the data back to the base station.

4.7.2 Design

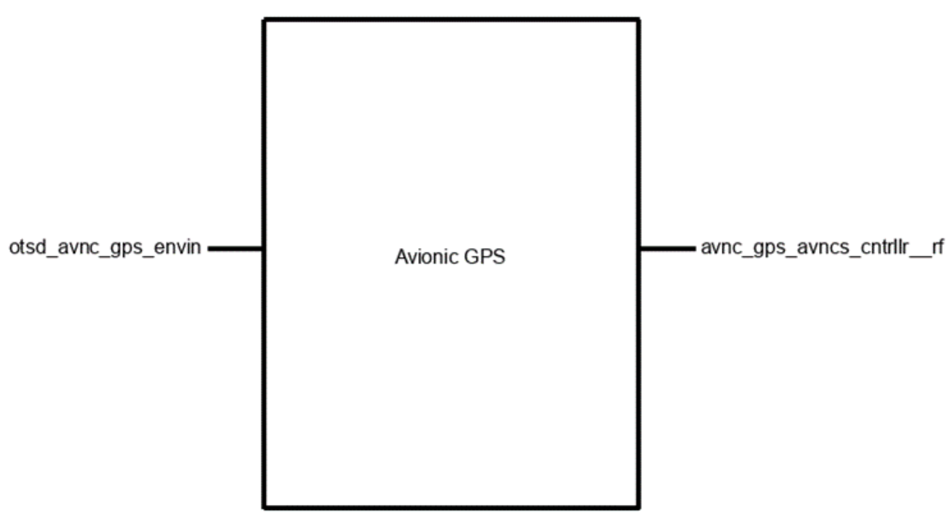


Figure 4.7.2.1: Block Box Diagram

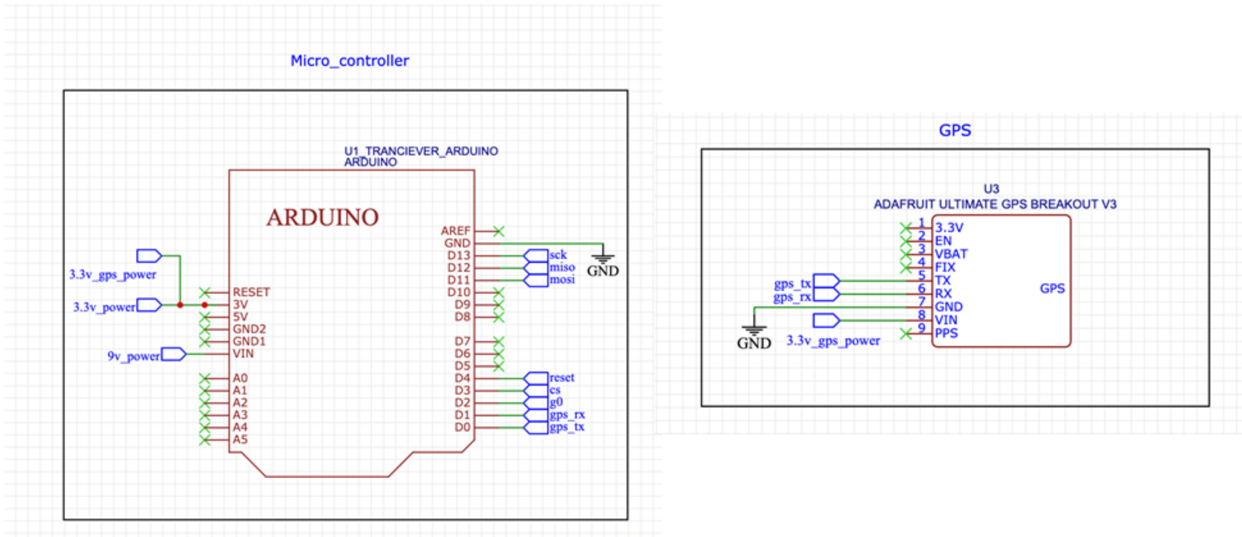


Figure 4.7.2.2: Schematic of The Connection Between GPS and The Micro-Controller

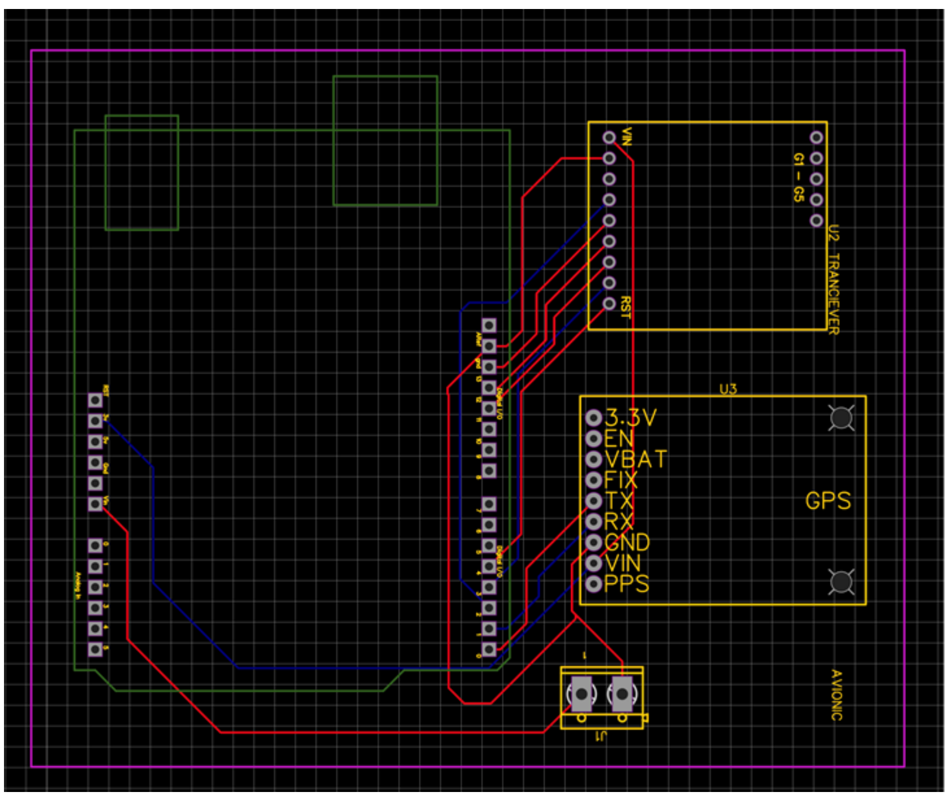


Figure 4.7.2.3: The Place of GPS Breakout Board on The PCB Schematic

4.7.3 General Validation

The Global Positioning System (GPS) is one of the many features that is built in the Avionic System. The purpose of the GPS function is to help recover the rocket after the launch. The Avionic system will get the GPS coordinate and send the location data of the rocket back to the base station on the ground by using the transceiver function. With the help of the GPS data, the team can more easily find where the rocket landed in order to find the rocket quicker and recover the rocket faster. The GPS information included longitude and latitude. For the design of the GPS, the team decided to use Adafruit Ultimate GPS Breakout Board as the module, and connect to the microcontroller, Arduino Uno through

4.7.4 Interface Validation

Interface Property	**Why is this interface this value?**	**Why do you know that your design details <u>for this block</u> above meet or exceed each property?**

otsd_avnc_gps_envin: input

Satellites	The Satellites is needed for the GPS to collect the data	According to the Datasheet, the GPS is using, Satellites: 22 tracking, 66 searching (Module specs, [1], pg.8)
Vmin = 3.0	The minimum voltage to power the GPS breakout board should be around 3.0V.	According to the Datasheet, the Vmin is 3.0V (Module specs, [1], pg.8)
Vmax = 5.5	The maximum voltage to power the GPS breakout board should be around 5.5V.	According to the Datasheet, the Vmax is 5.5V (Module specs, [1], pg.8)

avnc_gps_avncs_cntrllr__rf: output

Message: GPS data(Longitude)	This is the GPS data that is needed for the system	According to the Datasheet, the Longitude information is provided (Module specs, [1], pg.17)

Message: GPS data (Latitude)	This is the GPS data that is needed for the system	According to the Datasheet, the Latitude information is provided (Module specs, [1], pg.17)

4.7.5 Verification Plan

Turn on the Arduino and the GPS breakout board

1. The Adafruit Ultimate GPS Breakout Board needs to be assembled and connected to the Arduino Uno.
2. The Arduino Uno needs to connect to the power in order to power the entire system. The GPS Breakout Board will be powered by the Arduino.
3. Verify that the power is turned on, which the LED light on the Arduino Uno will be ON.
4. Verify that the power is turned on, and load the Avionic GPS code onto the Arduino Uno. To Verify that the code is successfully uploaded, the terminal will print “Done uploading”.

Verify GPS system

1. Turn on the serial monitor in the software.
2. Verify that the GPS system is working, Longitude and Latitude of GPS data should be printed on the serial monitor.

4.7.6 References

[1] “Adafruit Ultimate GPS - Adafruit Industries.” [Online]. Available: https://cdn-learn.adafruit.com/downloads/pdf/adafruit-ultimate-gps.pdf. [Accessed: 4-Feb-2022].

4.7.7 Revision Table

Date	What was done
02/04/22	Nicholas Lin: Create the initial Avionic PCB Block Validation template and content
02/18/22	Nicholas Lin: Added detail and finalize the update of each sections

4.8 Avionics PCB

4.8.1 Avionics PCB Description

The PCB (Printed Circuit Board) will be designed specific for the Avionic system. The PCB will be designed to connect to the Arduino Uno, and the components that is required for the Avionic system, which included GPS, Transceivers (Transmitter will be the one that is build on the PCB, and the receiver will be at the ground station)

4.8.2 Design

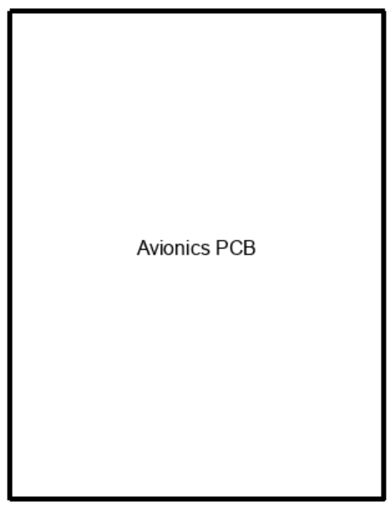


Figure 4.8.2.1: Block Box Diagram

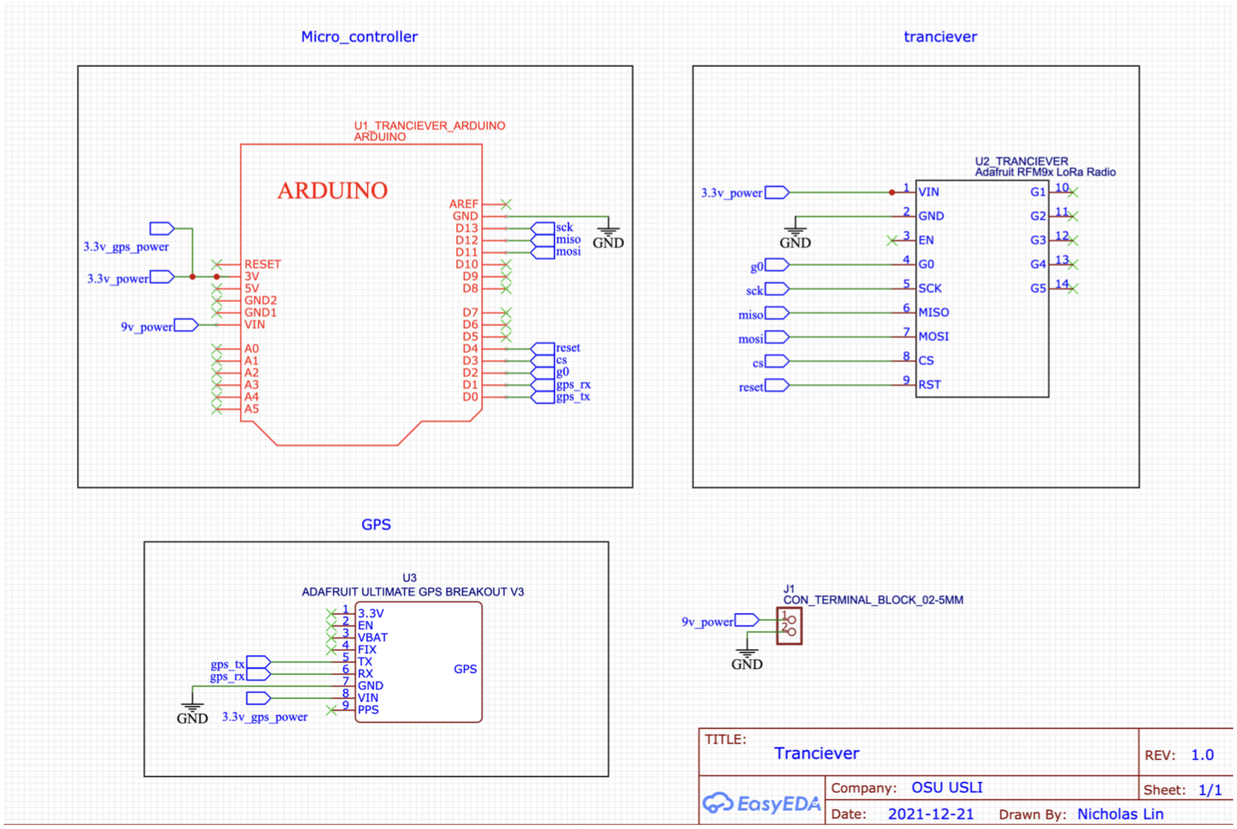


Figure 4.8.2.2: Schematic of The Avionic PCB

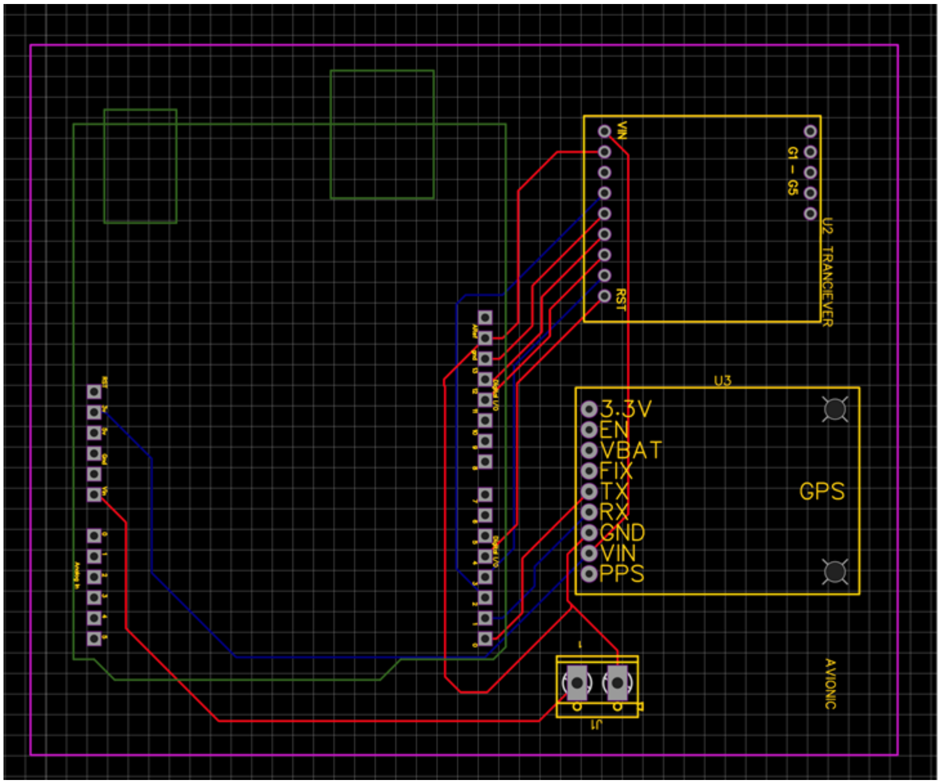


Figure 4.8.2.3: The PCB Schematic

4.8.3 General Validation

The purpose of the PCB (Printed circuit boards) design is to make sure that the system does not have open wire. Which will prevent circuit shortage, and ensure that the tracks of the circuit are correct from one point to another. In this case, the PCB is designed according to the needs of the Avionic system. Avionic system will get the GPS coordinate and send the data that was captured back to the ground station by using the transceiver. In the design, Adafruit LoRa Radio FeatherWing - RFM95W will be used as the transceiver. Adafruit Ultimate GPS will be the module board that is used as GPS. Last but not least the microcontroller used to operate the system is Arduino Uno.

4.8.4 Interface Validation

No interface for the PCB block

4.8.5 Verification Plan

1. The PCB needs to have a complete schematic design with all the required components. For this case, the Avionic system will include a GPS, Transceiver, Arduino Uno Micro- controller, and a DC power terminal.

2. The PCB needs to have a complete layout design with all the required components which included GPS, Transceiver, Arduino Uno Microcontroller, and a DC power terminal.

3. The BOM of the PCB needs to be approved by the mechanical team of USLI

4. The PCB needs to be ordered. To verify that the PCB is being order, screenshot of order detail and invoice will be required

4.8.6 References

[1] "The full Arduino Uno Pinout Guide [including diagram]," circuito.io blog, 18-Nov-2018. [Online]. Available: https://www.circuito.io/blog/arduino-uno-pinout/. [Accessed: 08-Jan-2022].

[2] L. Ada, "Radio Featherwing," Adafruit Learning System. [Online]. Available: https:// learn.adafruit.com/radio-featherwing/using-the-rfm-9x-radio. [Accessed: 07-Jan-2022].

4.8.7 Revision Table

Date	What was done
01/07/22	Nicholas Lin: Create the initial Avionic PCB Block Validation template
01/08/22	Nicholas Lin: Add concept for section 2, 3, 4, 5, 6, 7

4.9 Drone Time of Flight

4.9.1 Drone Time of Flight Description

This system will be able to measure the time of flight of a Radio Frequency (RF) signal and use that measurement to determine the distance from the sensor to a specific relay. The system is run on a 30MHz crystal oscillator and counts the cycles before the signals return. The system is required to be as small and lightweight as possible, and will likely be integrated onto the Drone PCB. This specific Time of flight sensor does not act as a relay to the other systems. The maximum accuracy of this system with the specified clock speed is roughly 10 meters. These measurements will be used to find the position of two points in space relative to this module.

The current stage of the design does not provide a direct connection between any specific pin on either the Arduino or the transceivers, rather the design has all I/O connections being made via male header pins. This is to provide the Computer Science team the ability to test a variety of programs involving the transceivers and not limit the pin selection on any device. Later revisions may specify the specific pins being used on the Arduino and transceivers, making the system more durable and reliable.

4.9.2 Design

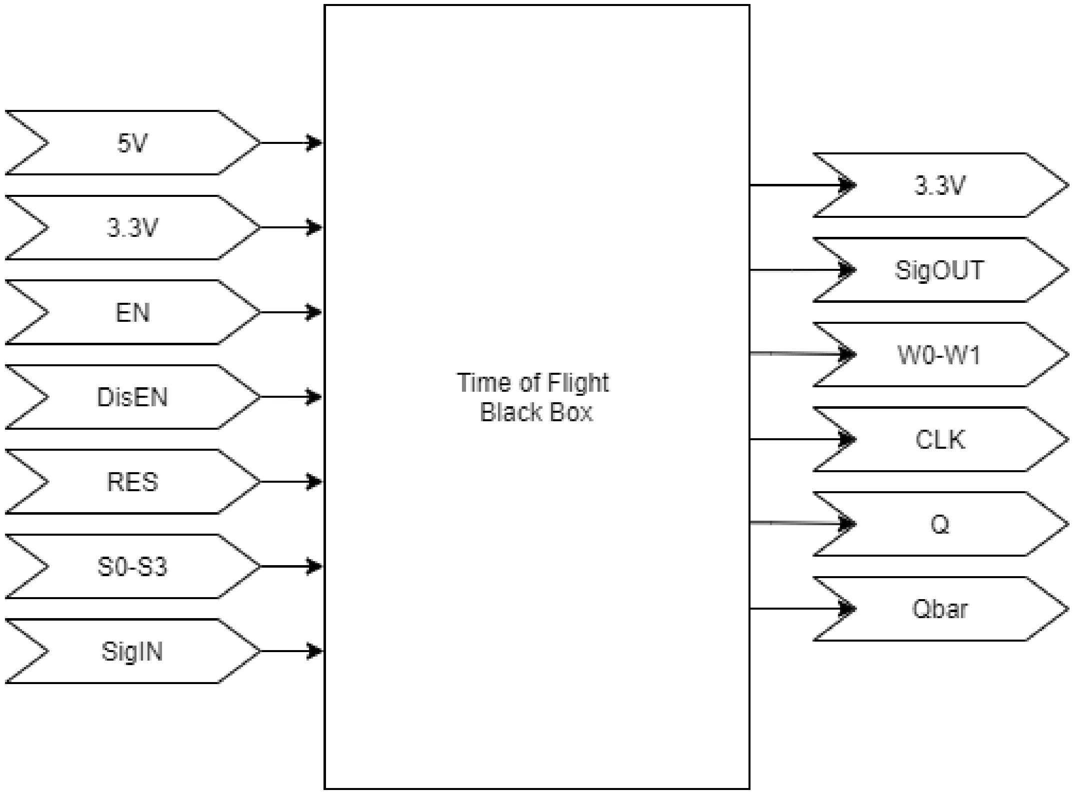


Figure 4.9.2.1: Time of Flight Module Black Box.

The black box diagram, figure 1, provides a surface level overview of I/O detailing which interfaces are inputs and which are outputs. The S0-S3 and W0-W1 interfaces are groups of 4 and 2 pins, respectively; these interfaces are in reference to the design's multiplexer. The 5V input is used within the module and is not needed for the transceivers; the 3.3V input is passed through a decoupling capacitor and then outputted to the transcievers. The interfaces to Q and Qbar in reference to the modules SR-latch and are present to provide the CS with extra data as needed. The flow chart of the time of flight module, figure 2, breaks down part of the theory behind the time of flight module and how it intends to operate.

The block diagram, figure 3, and schematic, figure 4, do not include the specific pinouts for the microcontroller or transceivers to maximize the designs flexibility with software. Whether the transceivers will operate using SPI or UART is still undecided; leaving pinouts ambiguous will provide the CS team members the opportunity to determine which method is best and can be cemented at a later stage of development.

The DM7437N is used to construct an SR-latch which is used to enable and disable the on board clock. The feed of multiple signals is processed by the SN7414, Schmitt Trigger, to create both more accurate signals from the clock and for the transceivers. The 74HC4040 has the ability to count cycles at a maximum frequency of 90MHz; the system operates well below that making it a reliable option.

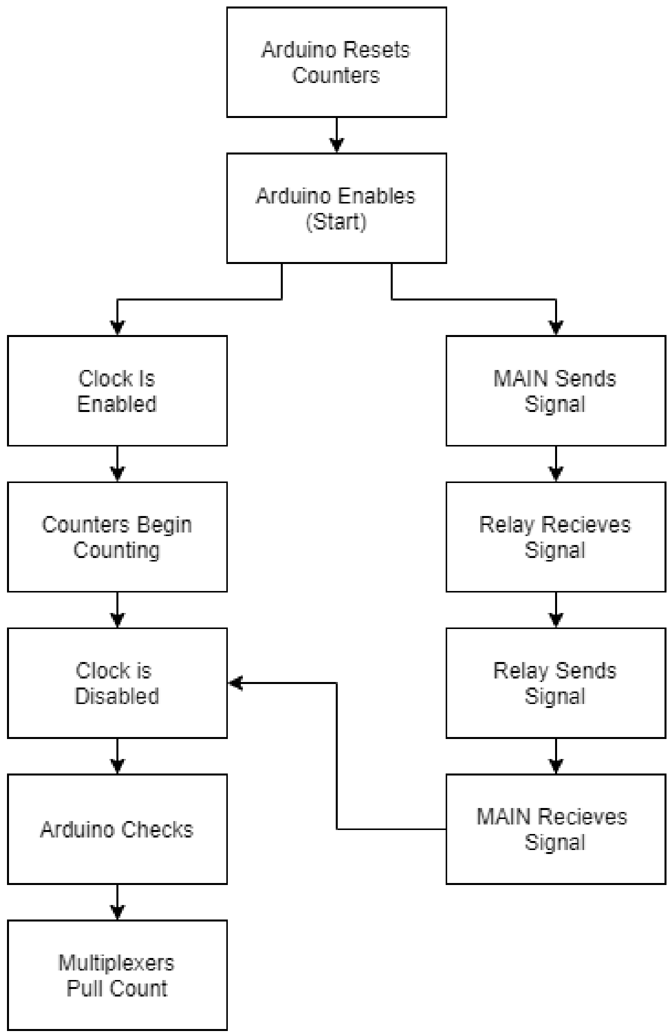


Figure 4.9.2.2: FlowChart of Time of Flight Module Steps.

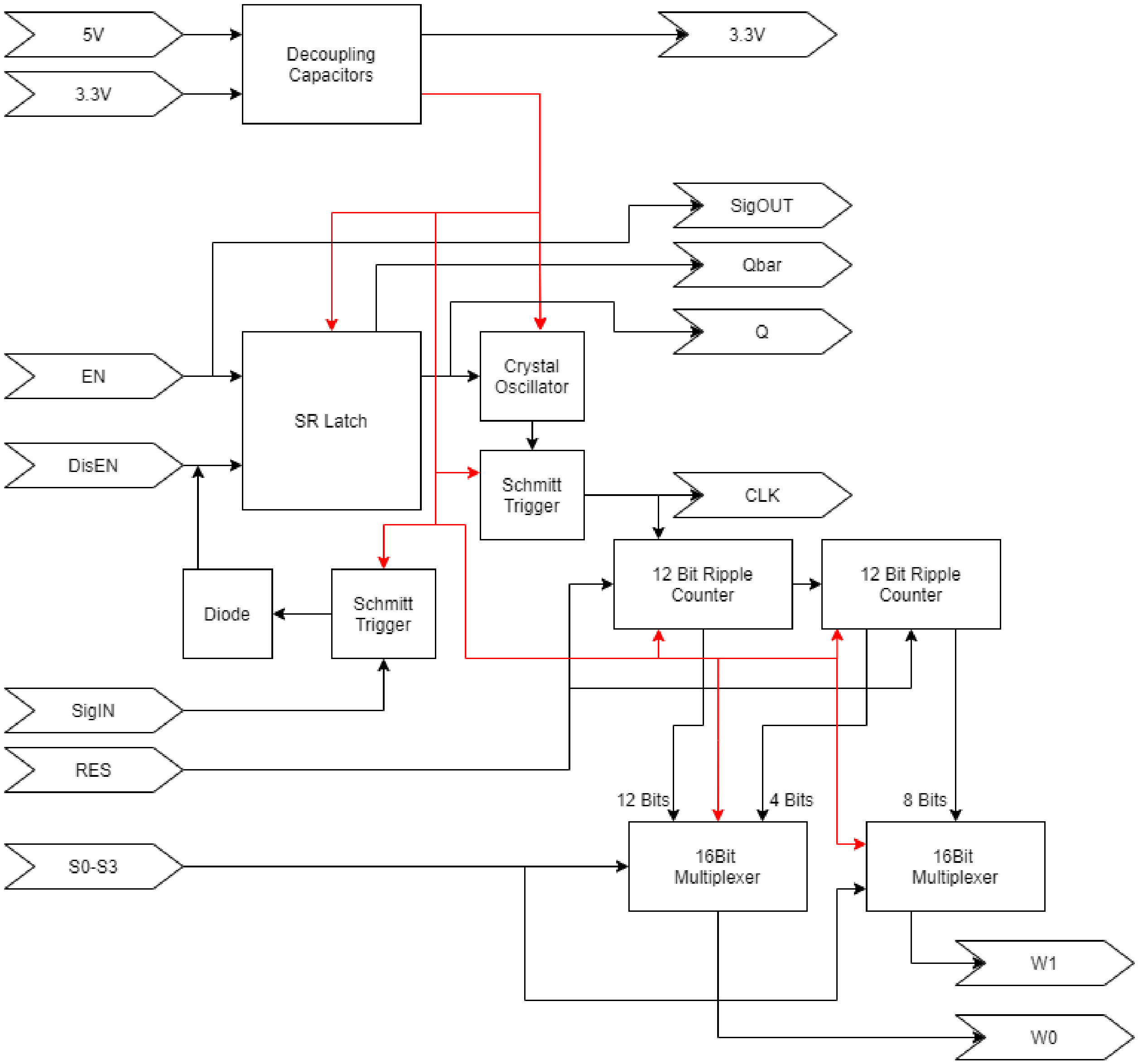


Figure 4.9.2.3: Time of Flight Module Block Diagram. A black line is a normal connection. A red line is a 5V line drawn from the input.

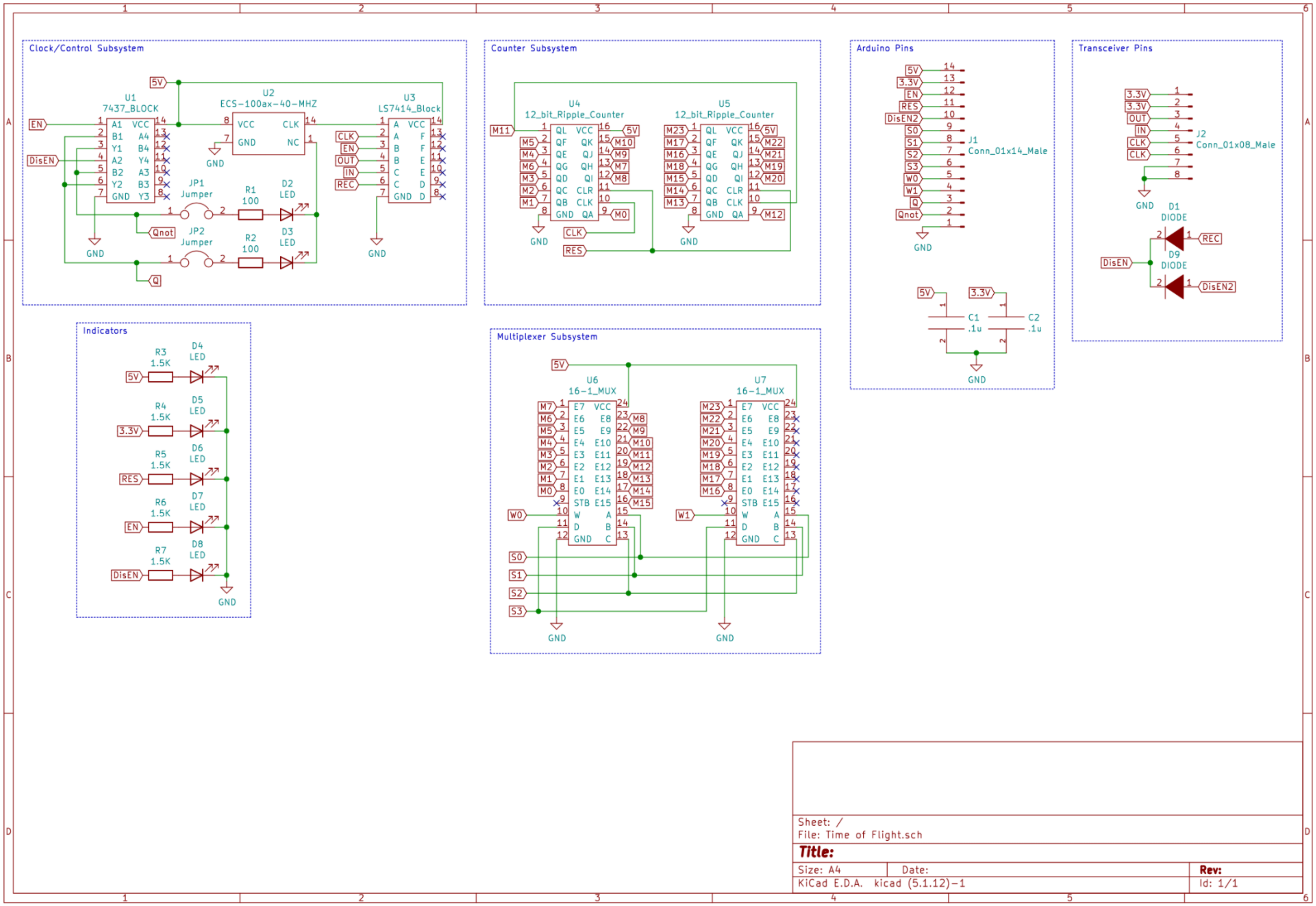


Figure 4.9.2.4: Time of Flight Module Schematic

Part Designater	Part Number/Value	Technical Name	Datasheet Link	Order Link	Quantity
R1, R2	100 Ohm	Resistor	link	https://resi.store/products/117/	2
R3, R4, R5, R6, R7	1.5K Ohm	Resistor	link	https://resi.store/products/145/	5
C1, C2	.1u	Capacitor	link	https://resi.store/products/270/	2
D1, D9	1N4148	Diode	link	https://resi.store/products/461/	2
D2, D3, D4, D5, D6, D7, D8	Red LED, 5mm	Light Emitting Diode	link	https://resi.store/products/331/	7
U1	DM7437N	NAND Gates	link	https://resi.store/products/724/	1
U4, U5	74HC4040	12 bit Ripple Counter	link	https://resi.store/products/614/	2
U6, U7	DM74150	16 Bit Multiplexer	link	https://resi.store/products/640/	2
U2	ECS-100AX-300	30MHz Crystal Oscillator	link	https://resi.store/products/934/	1
U3	SN7414	Schmitt Trigger	link	https://resi.store/products/712/	1
JP1, JP2		shunt/Jumpers	link	https://eecs.oregonstate.edu/education/tekbotSuite/tekbot/pages/publicInventory.php	1
J1, J2,JP1, JP2		Male Header Pins	link	https://resi.store/products/862/	26

Figure 4.9.2.5: Build of Materials for the Time of Flight Module

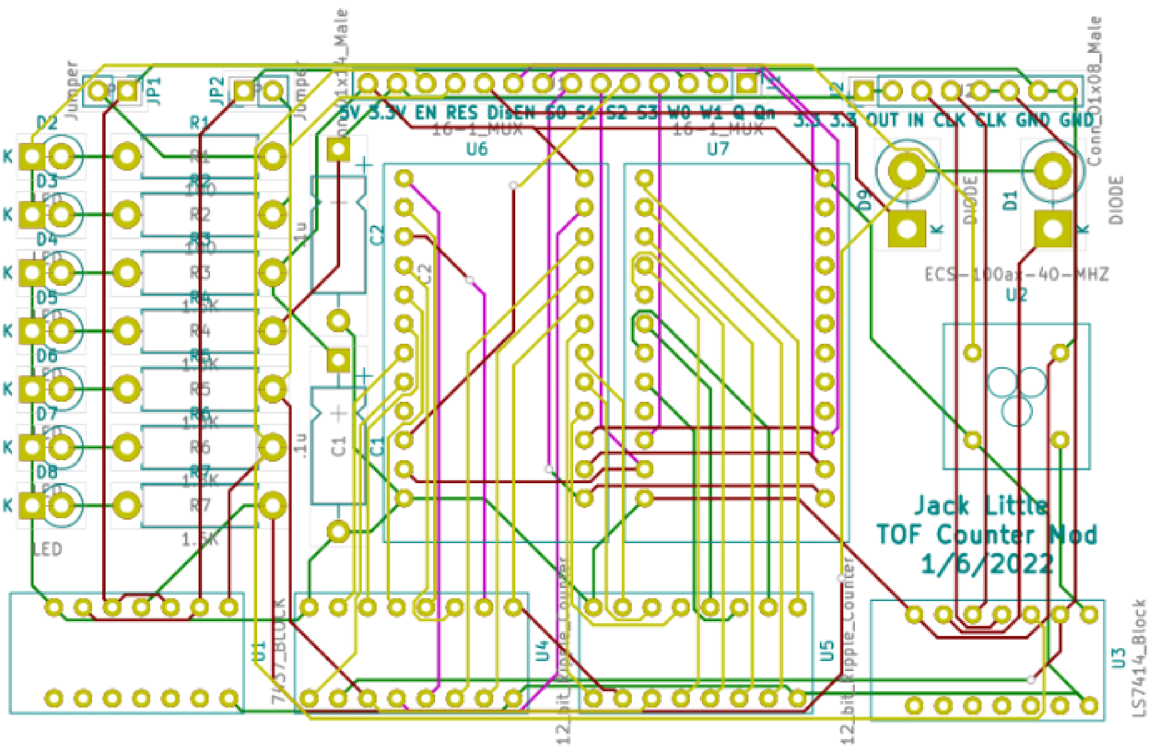


Figure 4.9.2.6: PCB trace outline for Time of Flight Module

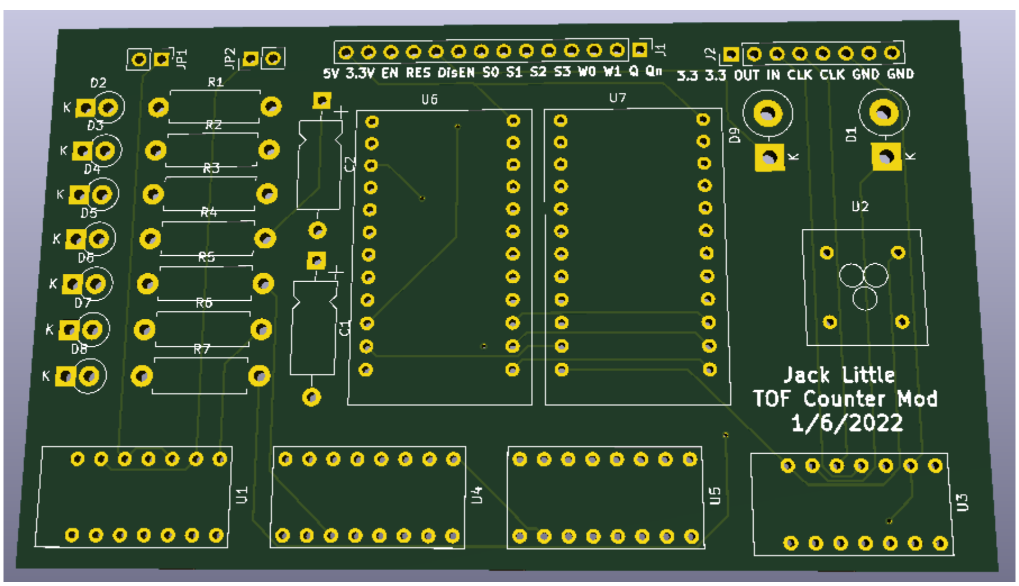


Figure 4.9.2.7: Time of Flight Module PCB

4.9.3 General Validation

The time of flight module is loosely based on the design of Distance Measurement With Radio Waves [1], but altered to interact with a microcontroller rather than an analog interface. The alterations mostly applied to how the system would be enabled, reset, and how data would be collected. The Distance Measurement With Radio Waves had the output going to a series of 8-segment displays which would not work for the system's needs. The output was altered to be processed and collected through a series of multiplexers. The system has the following input pins for the microcontroller: Enable, Disenable, S0-S1, Reset. The system has the following output pins for the microcontroller: W0-W1, Q and Qnot. The system has a pinout for transceivers offering power options as well as a signal IN and signal OUT pin to turn the transceivers on and off.

The module is designed in a way that will simultaneously send a signal out of the module, to a transciever, and enables an onboard clock. The clock input is run into two 12-bit ripple counters in series with each other, and the data from these counters is selected with a 16-1 multiplexer. The on board clock is currently rated for 32MHz meaning that, excluding error, a recorded count should be accurate to within 9.375 meters. The option does exist to get a 66MHz crystal oscillator, which would reduce the margin of error to 4.5 meters. This means that for every excess clock cycle the system would be off by 4.5 to 9.375 meters. Because internal delay is inevitable the system will need to be run long enough to effectively predict the average delay time and remove that from the system to create more viable data.

4.9.4 Interface Validation

Interface Property	Why is this interface, this value?	Why do you know that your design details <u>for this block</u> above meet or exceed each property?
drn_pwr_spply_drn_tf_dcpwr : Input		
Inominal: 30mA		
Ipeak: 40mA		
Vmax: 6V	This is the maximum voltage rating for the drone's on power supply.	This is within the allowed maximum voltage rating for all of the ICs.
Vmin: 4V	This is the minimum voltage rating for the drone's power supply.	This is within the range of voltages for the ICs to operate normally.
Vnominal: 5V	This is the nominal voltage from the drones power supply.	This is the nominal voltage for all of the ICs and oscillators in the system.
drn_pwr_spply_drn_tf_dcpwr : Input		
Inominal: 5 mA		
Ipeak: 10 mA		
Vmax: 5.5V	This is the maximum voltage rating for the drone's on power supply.	This is within the range for the maximum allowed voltage to the transceivers.
Vmin: 2.5V	This is the minimum voltage rating for the drone's power supply.	This is within the range of allowed voltage for the transceivers to operate.
Vnominal: 3.3V	This is the nominal voltage from the drones power supply.	This is the nominal voltage for the transceivers to operate normally.

drn_pcb_drn_tf_dsig : Input		
Fall Time: 3.6ns	This is the fall time of a digital signal generated by an Arduino.	The system uses an arduino as the microcontroller and can handle inputs with a fall time of this scale. This signal is held for a duration long enough to register.
Logic-Level: Active High: Reset counters. Active Low. Nothing.	The reset of the counters can occur as long as the logic level is high. Once its low nothing happens.	This interface is used to reset counters, it only needs to do it occasionally. Having the interface apply when high and do nothing when low helps to ensure the system does not reset when not needed.
Rise Time: 3.6ns	This is the rise time of a digital signal generated by an Arduino	The system uses an arduino as the microcontroller and can handle inputs with a rise time of this scale. This signal is held for a duration long enough to register.
drn_pcb_drn_tf_dsig : Input		
Fall Time: 3.6ns	This is the fall time of a digital signal generated by an Arduino	The system uses an arduino as the microcontroller and can handle inputs with a fall time of this scale. This signal is held for a duration long enough to register and pull the selected value.
Logic-Level: Active highs and low represent a binary value 0-15 to select data from a multiplexer.	The values 0-15 correlate to a 4-bit input that is fed to a 16-bit multiplexer.	
Other: This is a set of four inputs to select data from multiplexers (S0-S3)	There are 24 bits of data contained in multiplexers and to efficiently use the data two 16-bit multiplexers are used needing a 4-bit input.	

Rise Time: 3.6ns	This is the rise time of a digital signal generated by an Arduino	The system uses an arduino as the microcontroller and can handle inputs with a rise time of this scale. This signal is held for a duration long enough to register and pull the selected value.
drn_pcb_drn_tf_dsig : Input		
Fall Time: 3.6ns	This is the fall time of a digital signal generated by an Arduino	The system uses an arduino as the microcontroller and can handle inputs with a fall time of this scale. This signal is held briefly but long enough for this to be negligible.
Logic-Level: Active High: Enable system. Active Low: Nothing		
Rise Time: 3.6ns	This is the rise time of a digital signal generated by an Arduino	The system uses an arduino as the microcontroller and can handle inputs with a rise time of this scale. This signal is held briefly but long enough for this to be negligible.
drn_tf_drn_pcb_dsig : Output		
Fall Time: 3.6ns		
Logic-Level: An active high symbol represents a binary 1 and a logic low represents a binary 0.		
Other: This is two digital signals representing the outputs of the systems multiplxers.		
Rise Time: 3.6ns		

drn_tf_intrnl_pyld_tf_rf : Output		
Datarate: BaudRate 115200		
Messages: A ping request (RF)		
Other: 2.4 GHz		
drn_tf_hm_sttn_tf_rf : Output		
Datarate: BaudRate 115200		
Messages: Ping Request (RF)		
Other: 2.4 GHz		
intrnl_pyld_tf_drn_tf_rf : Input		
Datarate: BaudRate 115200		
Messages: Ping Request return (RF)		
Other: 2.4 GHz		
hm_sttn_tf_drn_tf_rf : Input		
Datarate: BaudRate 115200		
Messages: Ping Request Return (RF)		
Other: 2.4 GHz		

4.9.5 Verification Plan

1) Testing power inputs

a) 5V & 3.3V
   i) Connect the module to an Arduino Nano. The Arduino nano uses an LM1117MPX-5.0 to control the board's 5V supply. The LM1117MPX-5.0 is rated for Vnominal = 5V with a tolerance of .05 V and a current rating of Inominal = 40mA with a tolerance of 40mA; this is well within the acceptable range for the circuit. The 3.3V voltage will also be supplied from an Arduino Nano that uses an FT232R which is rated for Vnominal = 3.3V with a tolerance of .3V, and a maximum current rating of Ipeak = 50mA.
   ii) If the board seems to operate normally with the supplied power then the interface should be deemed acceptable.
   iii) The board also has indicator LEDs that should be illuminated if power is being supplied.
   iv) If parts ii and iii are working accurately then the input is working acceptably.

2) Testing Digital Inputs and Outputs

a) Testing Enable and Reset
   i) The module comes with LEDs that should illuminate when either the Enable or Reset pin is raised High. Using a test code the pins can be turned on or off and should turn on and off.
   ii) Using the systems SR-Latch, which these pins are directly connected to, the Q and Qnot LEDs should be seen illuminating with their respective inputs, Q for Enable and Qnot for Reset.
   iii) If all of the LED indicators are operating accordingly then the inputs are working as expected.
b) Testing S0-S3, and W0-W1
   i) Reset the counters to get clear and accurate data
   ii) To test the effectiveness of the S0-S3 and W0-W1 a program can be used to enable and disable the counters at a known time interval.
   iii) Step through the permutations of S0-S3 and pull the data from W0-W1.
   iv) Convert the pulled data from bits to time. Compare to known interval
   v) If the values are reasonably close together then the interfaces work at selecting and pulling data.

3) Testing Wireless Communication

a) Transceivers
   i) Set up a pair of transceivers to send and receive data on the same channel and frequency, 2.4GHz.
   ii) Enable the system to send and receive data
   iii) Send a Message to a relay; if the system receives a returned signal then the ping request was successful.
   iv) If I, ii, and iii are met then the test is successful.

4.9.6 References

4.9.6.1 IEEE References

[1] "Distance Measurement With Radio Waves," *Instructables*, Jan. 2011. https://www.instructables.com/Distance-measurement-with-radio-waves/ (accessed Jan. 19, 2022).

[2] "pcb design - What is the purpose of a tri-state pin in a Oscillator," *Electrical Engineering Stack Exchange*, Mar. 18AD. https://electronics.stackexchange.com/questions/240643/what-is-the-purpose-of-a-tri-state-pin-in-a-oscillator (accessed Jan. 19, 2022).

4.9.6.2 Reference Links

[1] https://www.instructables.com/Distance-measurement-with-radio-waves/

[2] https://datasheetspdf.com/pdf/248153/NationalSemiconductor/74150/1

[3] https://datasheetspdf.com/pdf/1082133/NationalSemiconductor/DM7437/1

[4] https://pdf1.alldatasheet.es/datasheet-pdf/view/27375/TI/7414.html

[5] https://www.mouser.com/ProductDetail/ECS/ECS-100AX-1966?qs=GxOUx7aO6nxrome5EjDWuA%3D%3D

[6] https://www.digikey.com/en/products/detail/abracon-llc/ACH-32-000MHZ-EK/675372

[7] https://electronics.stackexchange.com/questions/240643/what-is-the-purpose-of-a-tri-state-pin-in-a-oscillator

[8] https://datasheetspdf.com/pdf/903481/NXP/74HC4040/1

[9] https://www.ti.com/lit/ds/symlink/lm1117.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-wwe&ts=1641567604494

[10] https://www.ftdichip.com/old2020/Support/Documents/DataSheets/ICs/DS_FT232R.pdf

4.9.7 Revision Table

Date	What was done
1/4/2022	Jack Little added to the block description, added reference links, created and uploaded diagrams (flowchart, black box, block diagram, schematic)
1/6/2022	Jack Little added more figures and began work on all sections.
1/7/2022	Jack Little added more interfaces and began verification methods
1/19/2022	Jack Little applied peer feedback to block description, general validation, interface verification, references, interface validation
1/20/2022	Jack Little completed interface validation and verification plan

4.10 User Manual

4.10.1 User Manual Description

The user manual will be able to aid anyone in the setup, use, and understanding of the overall payload system. The user manual is composed of sections for general overview, setup and pre-flight testing, integration, pre-launch configuration and check, post flight analysis, and troubleshooting. The user manual is written in a way that can be understood and followed by adults with at least some level of technical understanding; having a greater technical understanding should add to using the user manual.

4.10.2 Design

The user manual is structured as such,

Section	Description
Table of contents	Lists all sections and subsections as well as the corresponding page numbers. This section provides the user with a quick and simple way to find accurate and correct information.
Overview	This section covers the intended operation of the payload system. The method(s) of the location as well as a breakdown of the various technologies used in the system will be described in detail. The section will not dive into extreme technical detail but provide a necessary level of understanding.
Setup and Pre-Integration Checks	This section provides users with a step-by-step guide for setting up the payload section and testing it prior to integrating it into the full rocket. This section includes subsections covering the initial setup of hardware and software, a subsection for setting up the home station, and a subsection for pre-integration testing of the systems.
Integration	This section will describe the method that the payload system is intended to be integrated into the rocket body. This section will include a subsection for the physical structure and a subsection for the integration method into the overall rocket body. The payload will already be assembled so the physical structure section is a list of

	checks. The integration subsection will contain a list of steps for fitting and securing the payload to the rocket body.
Preflight Checks	This section will cover checks that will be done of the payload section once the integration is complete and the rocket is assembled. There will be no subsections but rather a step by step guide for walking through the checks and what will be expected.
Post-Launch Analysis	This section will cover understanding the information recovered from the launch. The section will have subsections for reading serial port information, removing the payload section from the rocket body, and any other information pertinent to recovering data and shutting down the system.
Troubleshooting	This section will contain a number of various potential issues with the subsystem and include potential solutions. Each subsection, a problem, will be given a description of the problem and what to look for, and the best immediate solution. Solutions are to assume minimal knowledge of the system, and or structural, electrical, or programing knowledge.
References	Lists all references used throughout the creation of the user manual in IEEE format. This section will provide users with a way to find source information that can be used to expand users knowledge of various systems and components.
Glossary	Lists all acronyms and abbreviations used throughout the user manual. This section will allow users to quickly understand the meaning of various acronyms.
Revisions Table	Lists every alteration and edit made to the user manual in the form of a date, who made the edit, and what they did to the user manual.

Link to Doc:
https://docs.google.com/document/d/1UoYcQWLLAC6nMoShKLDDg7XEWgfYLSptB1-bMiDkgvI/edit?usp=sharing

4.10.3 General Validation

The presented design exceeds the needs of the block by providing every section required for the block, as well as others that may provide additional information beneficial to the user. The design describes a number of guides for users to follow that can aid users through all stages of the payload's intended use and operation. Various sections of the block utilize lists and images of the actual system to convene the intended use and operation at a variety of levels. The block does not rely solely on a single method of communication to convene information but rather a variety of text, images, lists, and other various nuances in writing.

The user manual troubleshooting section will contain more than five sections with sufficient information to fix the system with the minimum amount of effort required to quickly and accurately correct the system. The troubleshooting section is necessary because of the extreme conditions the payload will be under and the potential for quick and effective solutions to common problems. This is more than sufficient for the block because it intends to provide users with not only solutions but solutions that may be the best options for the fix, in the case of small errors; larger issues may simply specify the return to the EECS subteam for repairs, and or a direct replacement.

4.10.4 Interface Validation

Interface Property	Why is this interface, this value?	Why do you know that your design details for this block above meet or exceed each property?
otsd_usr_mnl_other : Input		
Other: The user manual will provide a minimum of 5 sources	Thin interface is this value, five references, to provide a minimum threshold for research needed to provide a well styled and thorough user manual.	There are currently four sources for the block that cover sources from various key components to stylistic guides that can act to benefit the overall block as well as other interfaces for the block itself.
Other: The user manual will be formatted in IEEE	The interface is to be styled in IEEE both for its simplicity while writing as well as its relation to the course structure and professionalism it brings.	The design for this interface property is met because during the course of writing and revising the document continual formatting checks will occur and be implemented into the user manual.
Other: The user manual will provide sufficient detail in all sections. Those sections are: general overview, setup and pre-flight testing, integration, pre-launch configuration and check, post flight analysis, and troubleshooting.	The user manual will be sufficient in detail to make it as useful as possible when working with the payload system both in the field and in a controlled environment. Users of the user manual will be able to reliably find and use information without too many hanging questions.	The current design meets this interface property because the current outline of the document contains all of the required subsections as well as other sections that may be beneficial to users.

usr_mnl_otsd_other : Output		
Other: The user manual will provide a troubleshooting section for solving some of the system issues that may arise, and include a minimum to 5 potential issues.	This interface 'value' exists because it may be considered one of the more important sections in the user manual. The section will be able to provide users with reasons and solutions to potentially common issues that may be prevalent in the system during its handling and operation.	The system is likely to have a multitude of different issues. As they occur, or preemptively, plans for the repair or replacement of the issue will be created. This is more than substantial for this interface property.
Other: The user manual will provide a step by step guide on setting up and integrating the payload into the rocket body, and will contain enough detail to follow steps correctly.	This interface is this value to ensure that the user manual contains guides so users will be able to quickly assemble, setup, integrate, test, and disassemble the payload system with minimal confusion.	The design for this block meets this interface property by having lists in all of the appropriate sections of the user manual.
Other: The user manual will provide detailed instructions in a minimum of two ways. I.e. descriptions, lists, images, or other forms.	This interface is this value to attempt to diversify the type of information and create a more substantial type of document that can maximize the amount and quality of information.	The user manual exceeds this interface property because it will contain descriptions, lists, and images that will provide the information in a multitude of ways providing more thorough, quality information.

4.10.5 Verification Plan

1) Sources and formatting
   a) Go to the references section of the user manual and verify the number of references is greater than or equal to five.If there are a minimum of five references the requirement is met.
   b) Walk through the IEEE style manual [1] and verify that all parts of the user manual meet the requirements described by the style manual. If the user manual follows all parts of the IEEE style guide then the requirement is met.
2) Sections and depth
   a) Verify in the user manual's Table of Contents that sections for the general overview, setup and pre-flight testing, integration, pre-launch configuration and check, post flight analysis, and troubleshooting are present. If all sections are present then the requirement is met.
   b) Read through the troubleshooting section and verify the presence of at least 5 potential issues, each with corresponding descriptions and solutions. If there are a minimum of five issues this requirement is met.
   c) Verify that there is a general overview of the system. If the section is present and provides detailed information about the normal operation of the system the requirement is met.
   d) Verify that there are sections for setting up and integrating the system. If these sections exist and provide step-by-step guides on preparing the system for launch.
   e) Ensure that there are a minimum of two methods for showing what is needed and intended by the guide. If so, this requirement is met.

If all parts of 1 and 2, above, are met then the block has been verified as operational and complete.

4.10.6 References

4.10.6.1 IEEE References

[1] "IEEE Editorial Style Manual," University of Chicago Press. Accessed: Feb. 2022. [Online]. Available: https://www.ieee.org/content/dam/ieee-org/ieee/web/org/conferences/style_references_manual.pdf.

[2] U. S. University, "Technical Writing Standards | Engineering Writing Center | College of Engineering," *engineering.usu.edu*. https://engineering.usu.edu/students/ewc/writing-resources/technical-writing-standards (accessed Feb.2022).

[3] "Long Range, Low Power, 2.4 GHz Transceiver with Ranging Capability," Jul. 2019. Accessed: Feb. 05, 2022. [Online]. Available: https://www.tme.eu/Document/1042f35a88b6ee421559d19923804032/SX128x.pdf.

[4] "R-Pi Troubleshooting - eLinux.org," *elinux.org*, Jan. 2020. https://elinux.org/R-Pi_Troubleshooting (accessed Feb. 05, 2022).

4.10.6.2 Reference Links

[1] https://www.ieee.org/content/dam/ieee-org/ieee/web/org/conferences/style_references_manual.pdf

[2] https://engineering.usu.edu/students/ewc/writing-resources/technical-writing-standards

[3] https://www.tme.eu/Document/1042f35a88b6ee421559d19923804032/SX128x.pdf

[4] https://elinux.org/R-Pi_Troubleshooting

4.10.7 Revision Table

Date	What was done
2/3/2022	Jack Little created the outline of the document and began to add minimal substance to the references section.
2/4/2022	Jack Little added substance to the design section, general validation, interface validation, verification plan, and references section.
2/18/2022	Jack Little Applied peer feedback to Description, Design, General Validation, Interface Validation, Verification Plan, References

5 System Verification Evidence

5.1 Universal Constraints

5.1.1

The system may not include a breadboard

No breadboard is used in the final product. All components utilize the PCB designs.

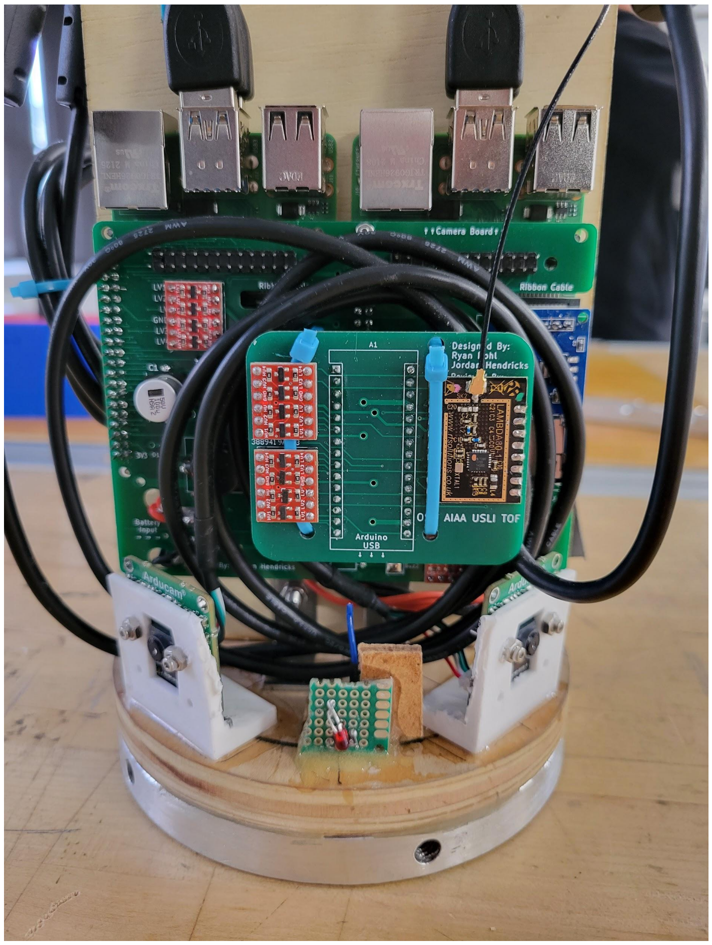


Figure 5.1.1.1

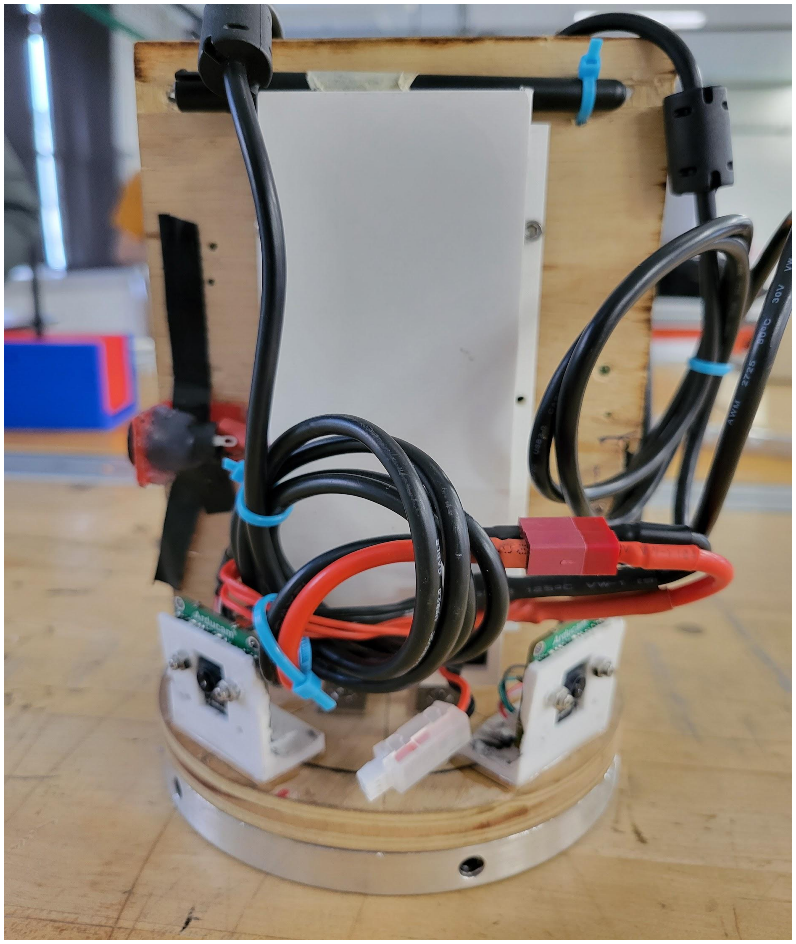


Figure 5.1.1.2

5.1.2

The final system must contain a student designed PCB and a custom Android/PC/Cloud application.

The final system contains two PCBs for the Time of flight system, one for the internal payload, and one for the avionics system. These PCBs were designed to individually contain all of the hardware necessary for successful operation, and adding more PCBs was not necessary. See Figure 5.1.1.1 to see the custom PCB on the internal payload assembly.

Our system uses a Raspberry Pi which has multiple programs that run on it. The Raspberry Pi has an operating system, and therefore the program which runs on a Raspberry Pi fulfills the requirement of an application. The programs were developed by the Computer Science team.

5.1.3

If an enclosure is present, the contents must be ruggedly enclosed/mounted as evaluated by the course instructor.

The enclosure will be designed with SolidWorks and will be printed out with a 3D printing machine. The enclosure will securely hold the PCB inside.

Video Link

5.1.4

If present, all wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors

The only exception to this is the battery connector to the main payload PCB. The reason we did not use a connector for this is because the location is near the edge of the board which limits the possible height of the connector. Battery connectors are larger than standard connectors to allow more current. The location of this on the board is close to the edge and a camera module. We wanted to route the wires on the backside of the board to keep a low profile inside the rocket body and not put stress on the wires. Our current configuration implements a Dean's connector which allows the battery to be easily removed and recharged. The main payload PCB contains header pins that connect all of the custom PCBs to the Arduino and Raspberry Pi 4Bs. The four arducams connect to the Raspberry Pi via USB.

The Home Station contains connectors for connecting the antenna via U.FL and connecting an arduino to a laptop via USB.

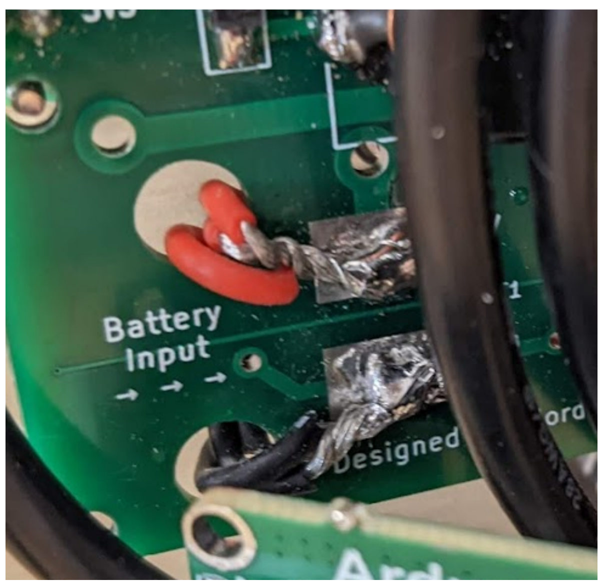


Figure 5.1.4.1 Battery Connection

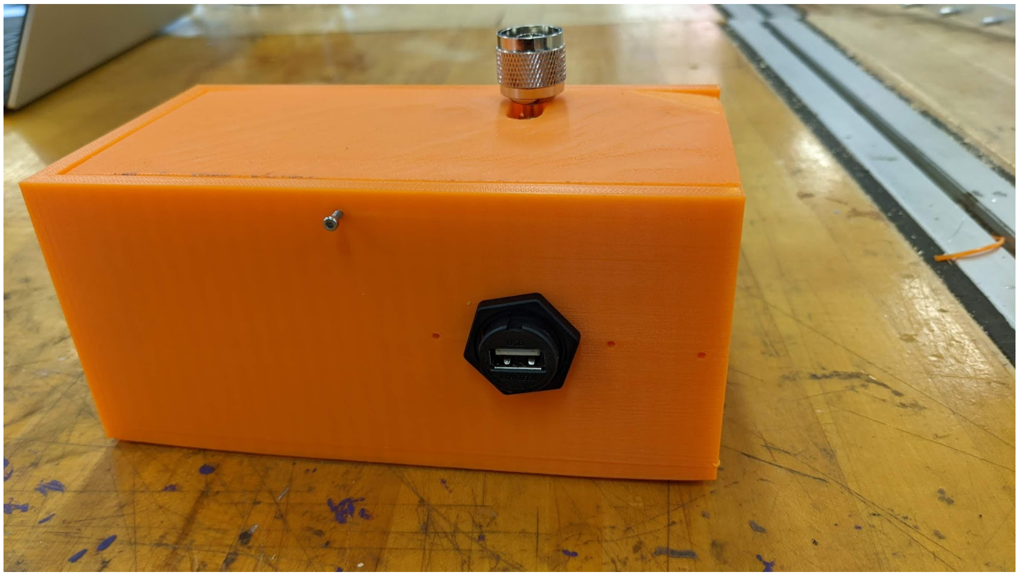


Figure 5.1.4.1: Connections on the outside of the enclosure

5.1.5

All power supplies in the system must be at least 65% efficient

Using WEBENCH TI Power Designer software simulation to model the efficiency of the power supply. The simulation calculates the efficiency to be 83%.

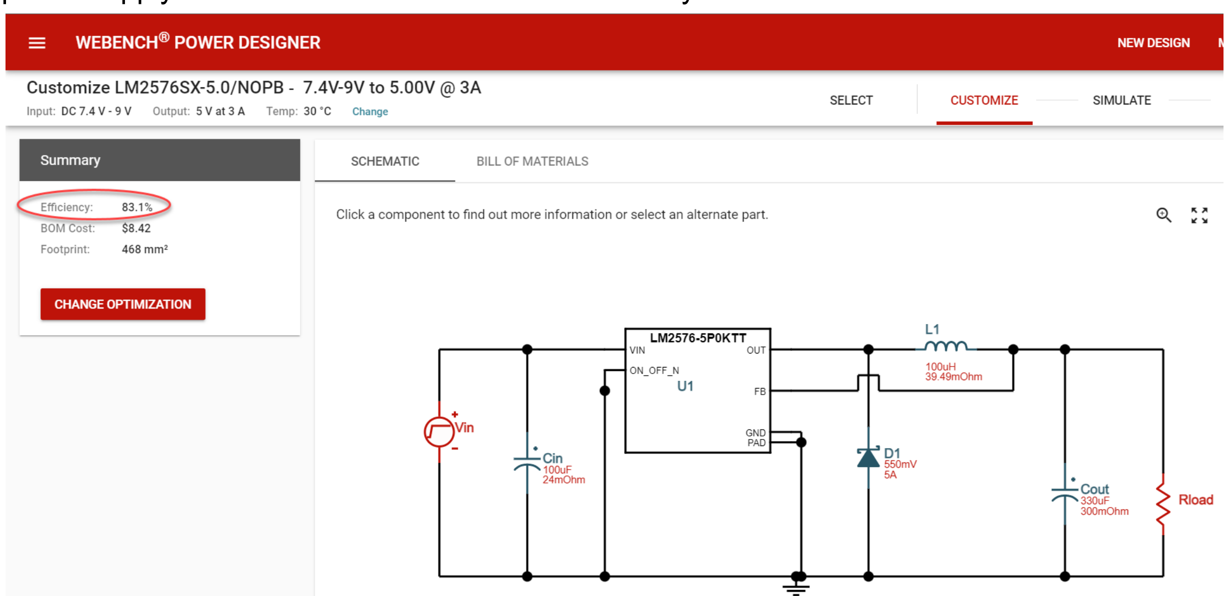


Figure 5.1.5.1: WEBENCH TI Power Designer

5.1.6

The system may be no more than 50% built from purchased modules

This system was built from smaller components (such as Arduinos, RaspberryPis, cameras, ect) which were integrated together to create the entirety of the project. The integration of all of these components can be viewed in Figure 5.1.1.1.

5.2 Preliminary Design Review

5.2.1 Requirement

Engineering Requirement: The final project will include a Preliminary Design Review that will be submitted no later than 01 November, 2021. The rough draft of the document will be due in the week prior for review by our mentor before submission to NASA.

5.2.2 Testing Processes

Verification Method:

1) Within the month following the document submission to NASA the Project Partner and or USLI team lead will send email confirmation of document submission.
2) A copy of the email, time table of hours put into the document, and link to the document will be included in the Verification section, section 5.

5.2.3 Testing Evidence

This section includes the email verifications from our project partner, Brittany Blanksma-Stark, as well as an hours log from the Preliminary Design Review hours logged. The hours log has been filtered to only show ECE Capstone members. The total hours of each team member has been placed into Figure 5.2.3.1. The Preliminary Design Review can be found at the following link, Preliminary Design Review.

Date (Day/Month/Year)	Time in	Time out	Hours	Name
18/10/2021	10:00 AM	10:30 AM	0:30:00	Jordan Hendricks
19/10/2021	11:52 AM	12:28 PM	0:36:00	Timothy Grant
20/10/2021	10:00 AM	12:00 PM	2:00:00	Ryan Bohl
22/10/2021	1:33 PM	2:45 PM	1:12:00	Timothy Grant
23/10/2021	4:50 PM	6:00 PM	1:10:00	Jack Little
24/10/2021	12:20 PM	2:10 PM	1:50:00	Jack Little
24/10/2021	12:45 PM	1:45 PM	1:00:00	Ryan Bohl
24/10/2021	4:30 PM	5:30 PM	1:00:00	Ryan Bohl
24/10/2021	11:00 PM	11:59 PM	0:59:00	Jack Little
24/10/2021	7:30 PM	8:30 PM	1:00:00	Jordan Hendricks
25/10/2022	12:00 AM	1:00 AM	1:00:00	Jordan Hendricks
25/10/2021	12:00 AM	12:50 AM	0:50:00	Jack Little
25/10/2021	10:00 AM	11:00 AM	1:00:00	Timothy Grant
25/10/2021	1:00 PM	1:30 PM	0:30:00	Timothy Grant
25/10/2021	8:30 PM	9:15 PM	0:45:00	Jack Little
25/10/2021	8:30 PM	11:45 PM	3:15:00	Ryan Bohl
25/10/2021	10:30 PM	11:30 PM	1:00:00	Jordan Hendricks
26/10/2021	12:00 AM	12:35 AM	0:35:00	Timothy Grant
26/10/2021	8:15 PM	11:59 PM	3:44:00	Jack Little
26/10/2021	10:00 PM	11:59 PM	1:59:00	Timothy Grant
27/10/2021	12:00 AM	12:53 AM	0:53:00	Timothy Grant
27/10/2021	12:00 AM	2:00 AM	2:00:00	Jack Little
27/10/2021	10:30 AM	11:15 AM	0:45:00	Ryan Bohl
27/10/2021	2:00 PM	3:00 PM	1:00:00	Jack Little
27/10/2021	2:00 PM	7:00 PM	5:00:00	Nick Lin

Figure 5.2.3.1: Hour Log for Preliminary Design Review

Team Member	Total Hours
Jack Little	12:18:00
Jordan Hendricks	3:30:00
Timothy Grant	6:45:00
Ryan Bohl	8:00:00
Nick Lin	5:00:00
Total	35:33:00

Figure 5.2.3.2: Total Hours Logged Per Member and Total Hours

Engineering Requirement verification for team USLI External Inbox x

Lin, Nicholas <linch@oregonstate.edu>
to Donald, Ingrid, Brittany, ECE44X, me, Timothy, Jordan, Ryan

Thu, Nov 11, 2021, 9:57 PM

Dear Don, Ingrid, and the TAs,

The purpose of this email is to verify one of our engineering requirements, *Preliminary Design Review (PDR) will be complete and submitted by November 1st, 2021.* The USLI ECE team has contributed and completed the PDR before the due date (Nov 1st, 2021). In order the verify the engineering requirement, we are having the project partner, Brittany, who is also the team-lead for USLI to reply to this email as verification. The link below is the PDF file for the PDR

PDR: https://drive.google.com/file/d/1fF-wM5k4DeCt8B3aF1HyMHxyVP05Sy9t/view?usp=sharing

Please let us know if there are any further questions or concerns,

Thank you and best regards
- Oregon State University, USLI, Electrical Engineering Team

Oregon State University, USLI - Electrical Engineering Team
Nicholas Lin
Jack Little
Timothy Grant
Ryan Bohl
Jordan Hendricks

Blanksma-Stark, Brittany <blanksmb@oregonstate.edu>
to Nicholas, Donald, Ingrid, ECE44X, me, Timothy, Jordan, Ryan

Hello all,

I am responding to confirm that the USLI Electrical Engineering Team contributed and completed the PDR before the Nov 1st deadline.

Thanks,
Brittany

5.3 Critical Design Review

5.3.1 Requirement

Engineering Requirement: The final project will include a Critical Design Review that will be submitted no later than 03 January, 2022. The rough draft of the document will be due in the week prior for review by our mentor before submission to NASA.

5.3.2 Testing Processes

Verification Method:

3) Within the month following the document submission to NASA the Project Partner and or USLI team lead will send email confirmation of document submission.
4) A copy of the email, time table of hours put into the document, and link to the document will be included in the Verification section, section 5.

5.3.3 Testing Evidence

This section includes the email verifications from our project partner, Brittany Blanksma-Stark, as well as an hours log from the Critical Design Review hours logged. The hours log has been filtered to only show ECE Capstone members. The total hours of each team member has been placed into table 5.3.3.1. The Critical Design Review can be found at the following link, [Critical Design Review.]()

Date (Day/Month/Year)	Time in	Time out	Hours	Name
18/11/2021	3:00 PM	4:30 PM	1:30:00	Jack Little
19/11/2021	12:30 PM	3:00 PM	2:30:00	Jack Little
19/11/2021	4:00 PM	6:45 PM	2:45:00	Jack Little
07/12/2021	10:00 PM	11:00 PM	1:00:00	Jordan Hendricks
09/12/2021	11:30 AM	2:00 PM	2:30:00	Ryan Bohl
09/12/2021	5:00 PM	8:00 PM	3:00:00	Ryan Bohl
09/12/2021	8:30 PM	10:00 PM	1:30:00	Ryan Bohl
11/12/2021	6:30 PM	7:00 PM	0:30:00	Ryan Bohl
11/12/2021	3:00 PM	4:00 PM	1:00:00	Ryan Bohl
12/12/2021	4:30 PM	5:45 PM	1:15:00	Ryan Bohl
13/12/2021	5:00 PM	8:00 PM	3:00:00	Jack Little
13/12/2021	9:00 PM	11:30 PM	2:30:00	Jack Little
14/12/2021	12:00 PM	5:00 PM	5:00:00	Jack Little
16/12/2021	4:00 PM	11:00 PM	7:00:00	Jack Little
17/12/2021	12:00 PM	4:00 PM	4:00:00	Jack Little
27/12/2021	3:00 PM	5:30 PM	2:30:00	Jack Little
27/12/2021	12:00 AM	6:20 PM	6:20:00	Timothy Grant
27/12/2022	12:00 AM	6:00 PM	6:00:00	Jordan Hendricks
27/12/2023	12:00 AM	4:45 PM	4:45:00	Nick Lin

Figure 5.3.3.1: Hour Log for Critical Design Review

Team Member	Total Hours
Jack Little	30:45:00
Jordan Hendricks	7:00:00
Timothy Grant	6:20:00
Ryan Bohl	9:45:00
Nick Lin	4:45:00

Figure 5.3.3.2: Total Hours Logged Per Member and Total Hours

CDR Submission Verification Inbox ×

Grant, Timothy <grantti@oregonstate.edu> Wed, Jan 5, 11:23 PM
to Brittany, me, Nicholas, Jordan, Ryan, Donald, Ingrid, Emory, Rachael

Good Morning Brittany,

One of the requirements that was selected for my group's Senior Design course is to submit the Critical Design Review (CDR) to NASA before 3 January, 2022. The method of verification for this requirement is an email confirmation by the USLI team lead confirming that the CDR was submitted before the deadline. Could you respond to this email confirming the participation of the payload sub-team in the CDR's creation, and that the CDR was submitted before 3 January, 2022?

Thank you,
Timothy Lee Grant

Figure 5.3.3.3: Email Requesting Verification of CDR Participation

Blanksma-Stark, Brittany <blanksmb@oregonstate.edu> Thu, Jan 6, 10:15 AM
to Timothy, me, Nicholas, Jordan, Ryan, Donald, Ingrid, Emory, Rachael

Hello All,

Thanks Timothy for reaching out. This email is to confirm participation of the payload sub-team in the CDR creation. The CDR was submitted before 1/3/22.

Best,
Brittany

Figure 5.3.3.4: Email Verification of CDR Participation from Project Partner

5.4 Size and Weight

5.4.1 Requirement:

Engineering Requirement: The final payload project will not exceed the size, volume, and weight restraints of 5.25" x 15" cylinder and 10 lbs.

5.4.2 Testing Processes

Verification Method:

1) Is the height of the overall payload less than 15 inches?
2) Is the diameter of the overall payload less than or equal to 5.25 inches?
3) Is the total weight of the payload less than or equal to 10lbs?
4) If yes to steps 1 through 3 the requirement is met.

5.4.3 Testing Evidence

[Video Evidence]

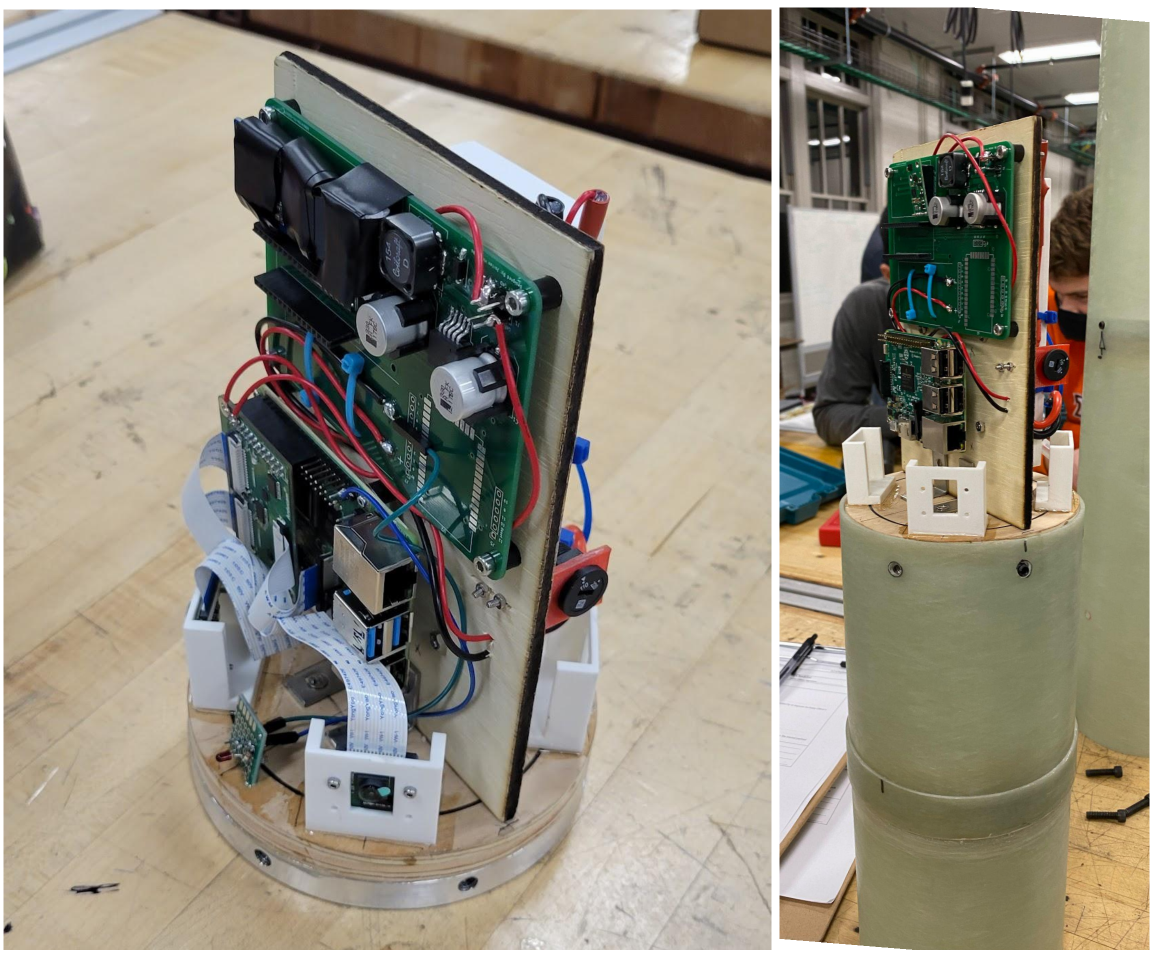


Figure 5.4.3.1: Picture of payload, attached to rocket

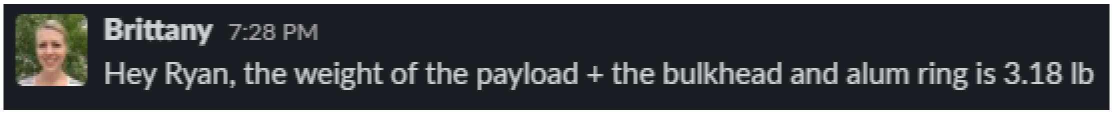


Figure 5.4.3.2: Confirmation of size by project partner

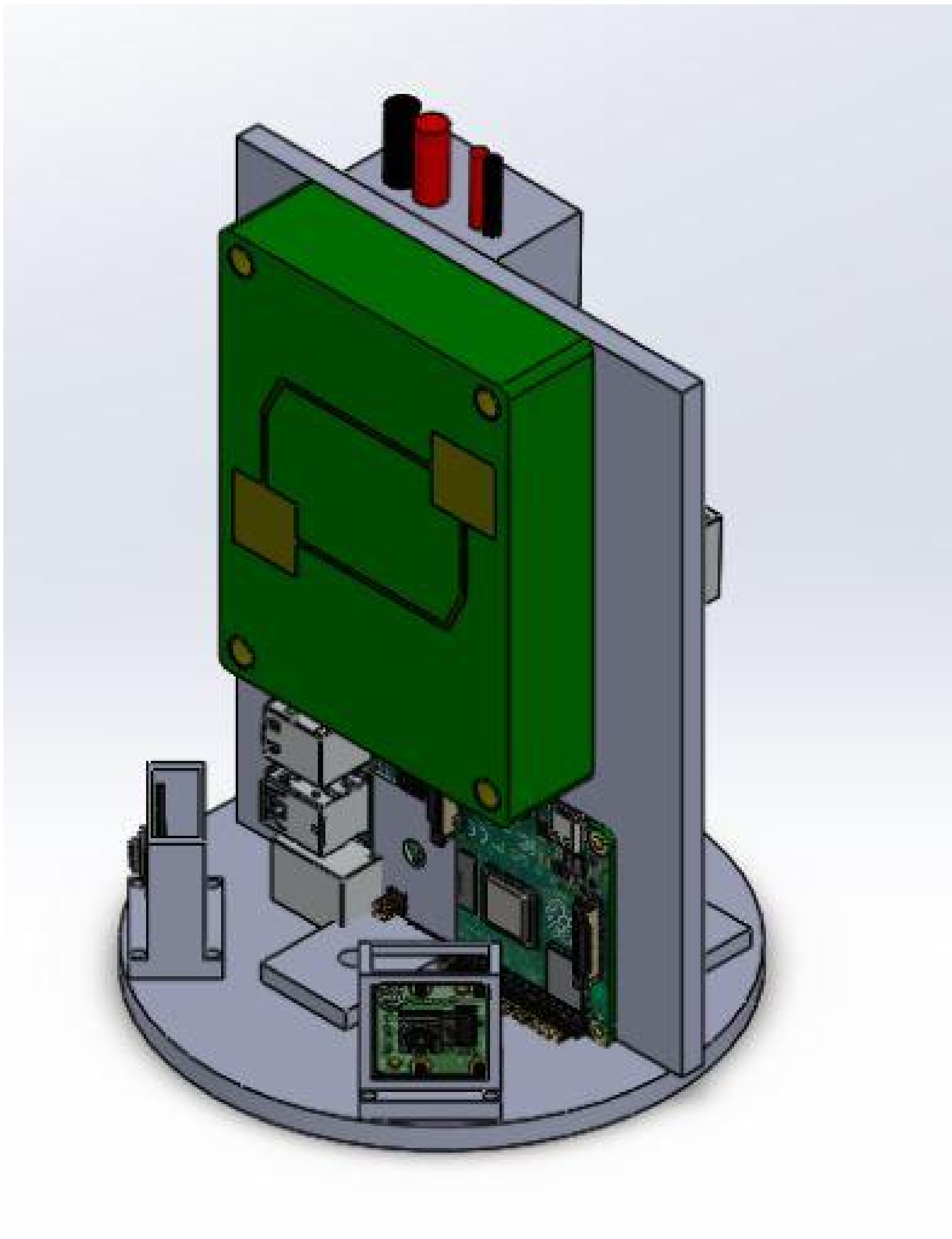


Figure 5.4.3.3: Payload CAD

Figure 5.4.3.4: Launch-ready rocket with payload inside

5.5 Two Methods of Locations

5.5.1 Requirement

Requirement: The final project will have both a primary and backup method of locating the rocket body in relation to the launch site, on a 20 by 20 grid of 250ft squares. The only technology forbidden in this process is GPS.

5.5.2 Testing Processes

Verification Method:

7) Does the system have two means of determining the rocket body's location?
8) Does the system know when to switch to the redundant method?
9) Does the system output a grid number between 1 and 400?
10) Does the main location system work in a controlled environment? Steps to do so below
11) Does the redundant location system work in a controlled environment? Steps to do so below
12) If yes to steps 1 through 5 then the requirement has been met. Documentation of such will be included in the verification section, section 5.

5.5.3 Testing Evidence

Video Evidence

5.6 Remain Launch Ready for 2 Hours

5.6.1 Requirement

Requirement: The final project will remain powered for a minimum of 120 minutes, and operate normally, without a need to change batteries or recharge.

5.6.2 Testing Processes

Verification Method:

5) Systems that remain powered during the entire launch will be powered in an idle state on a test bench for a minimum of two hours.
6) During the two hours current and voltage measurements will be taken.
7) Does the system have enough power to continue normal operation after the two hours?
8) If yes to steps 1 through 3 then the requirement is met. Documentation of such will be included in the verification section, section 5.

5.6.3 Testing Evidence

Video Evidence

5.7 Physically Secured Design

5.7.1 Requirement

Requirement: The final project will use PCBs to make wired connections between components. Any wired connections from PCBs will be secured either with a screw terminal or a soldered connection. The final project will not include the following: breadboards, protoboard, copper clad boards.

5.7.2 Testing Processes

Verification Method:

8) Does the final project contain any of the following: breadboards, protoboards, or copper clad boards?
9) Are all connections between components made via a PCB?
10) Are any wires from PCBs secured with either a screw terminal or a soldered connection?
11) If yes to step 1 through 3 then the requirement is met. Documentation of such will be included in the verification section, section 5.

5.7.3 Testing Evidence

Video Evidence

5.8 Avionics

5.8.1 Requirement

Requirement: The final project will include an avionics unit that can eject parachutes at 4700 feet and 700 feet. It will also include altimeters and a GPS unit to track position

5.8.2 Testing Processes

Verification Method:

12) In a test bench is the avionics unit capable of:
    a) Collecting GPS data?
    b) Wrirelessly Communicating GPS data?
    c) Igniting e-matches at an altitude of 4700 feet or similar conditions?
    d) Igniting e-matches at an altitude of 700 feet or similar conditions?
13) Are altimeters independently powered?
14) If yes to step 1 and 2 then the requirement is met. Documentation of such will be included in the verification section, section 5.

5.7.3 Testing Evidence

Avionics Data

5.9 NAR Certification

5.9.1 Requirement

Requirement: All members of the USLI Payload/Avionics team will be at least NAR level 1 certified by or before 31 March 2022.

5.9.2 Testing Processes

Verification Method:

3) Scanned copies of each member's NAR level 1 certificate paperwork and/or NAR membership card will be included in the verification section, section 5.
4) NAR paperwork includes the date that each member earns their NAR certification, confirming that all members earned their certifications on or before 31 March 2022. This information will be organized in a table in the verification section, section 5.

5.9.3 Testing Evidence

Figure 5.9.3.1

Figure 5.9.3.2

Figure 5.9.3.3

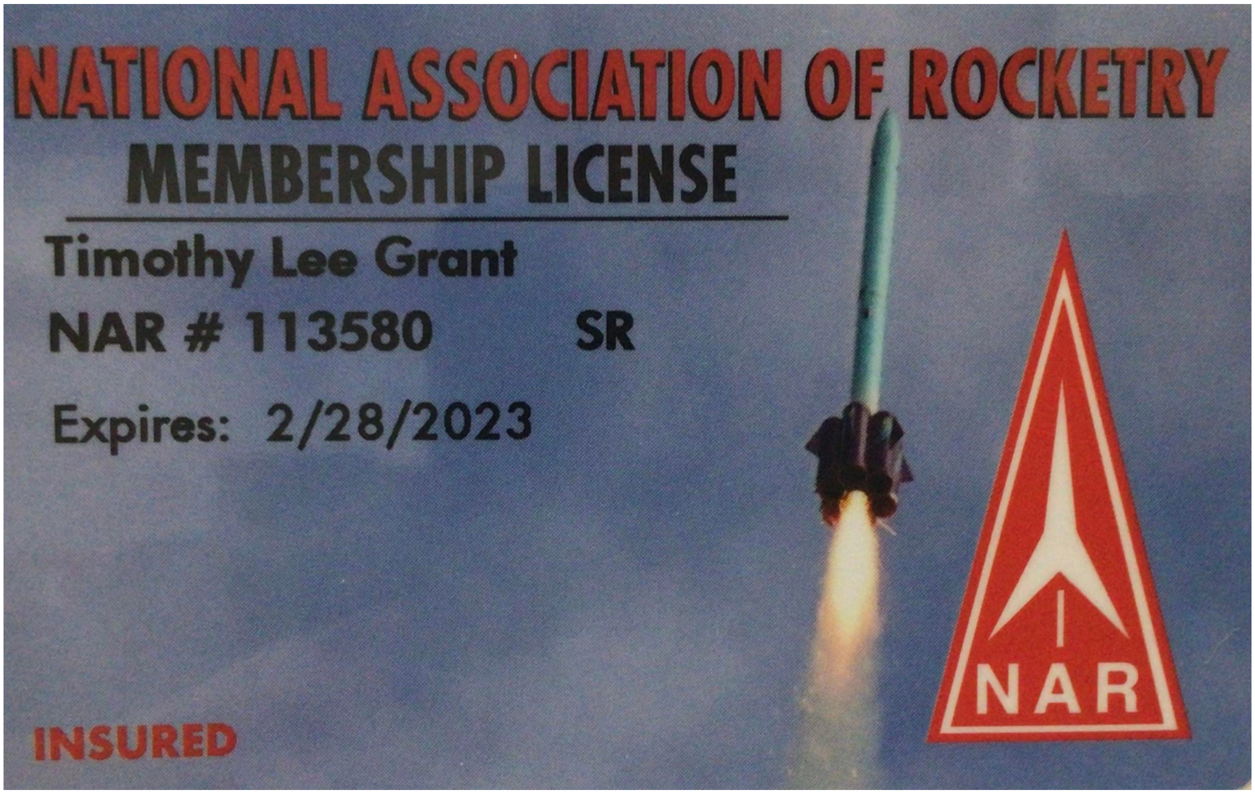
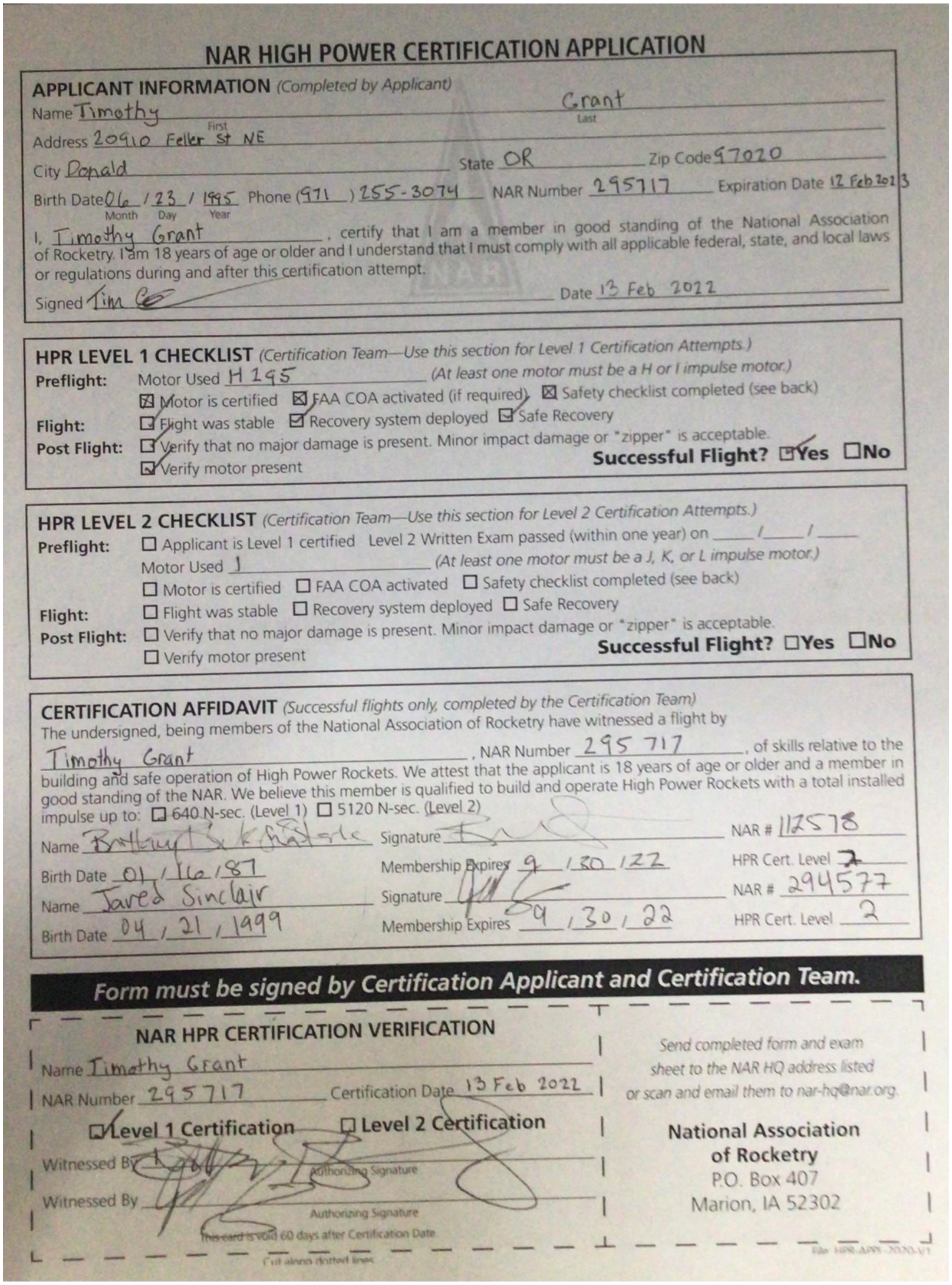

NATIONAL ASSOCIATION OF ROCKETRY
MEMBERSHIP LICENSE
Timothy Lee Grant
NAR # 113580 SR
Expires: 2/28/2023
NAR
INSURED

Figure 5.9.3.4



NAR HIGH POWER CERTIFICATION APPLICATION

APPLICANT INFORMATION *(Completed by Applicant)*

Name Timothy (First) Grant (Last)

Address 20910 Feller St NE

City Donald State OR Zip Code 97020

Birth Date 06 / 23 / 1995 (Month Day Year) Phone (971) 255-3074 NAR Number 295717 Expiration Date 12 Feb 2023

I, Timothy Grant, certify that I am a member in good standing of the National Association of Rocketry. I am 18 years of age or older and I understand that I must comply with all applicable federal, state, and local laws or regulations during and after this certification attempt.

Signed Tim G Date 13 Feb 2022

HPR LEVEL 1 CHECKLIST *(Certification Team—Use this section for Level 1 Certification Attempts.)*

Preflight: Motor Used H195 *(At least one motor must be a H or I impulse motor.)*

☒ Motor is certified ☒ FAA COA activated (if required) ☒ Safety checklist completed (see back)

Flight: ☑ Flight was stable ☑ Recovery system deployed ☑ Safe Recovery

Post Flight: ☑ Verify that no major damage is present. Minor impact damage or "zipper" is acceptable.

☒ Verify motor present

Successful Flight? ☑ Yes ☐ No

HPR LEVEL 2 CHECKLIST *(Certification Team—Use this section for Level 2 Certification Attempts.)*

Preflight: ☐ Applicant is Level 1 certified Level 2 Written Exam passed (within one year) on ____ / ____ / ____

Motor Used J *(At least one motor must be a J, K, or L impulse motor.)*

☐ Motor is certified ☐ FAA COA activated ☐ Safety checklist completed (see back)

Flight: ☐ Flight was stable ☐ Recovery system deployed ☐ Safe Recovery

Post Flight: ☐ Verify that no major damage is present. Minor impact damage or "zipper" is acceptable.

☐ Verify motor present

Successful Flight? ☐ Yes ☐ No

CERTIFICATION AFFIDAVIT *(Successful flights only, completed by the Certification Team)*

The undersigned, being members of the National Association of Rocketry have witnessed a flight by Timothy Grant, NAR Number 295 717, of skills relative to the building and safe operation of High Power Rockets. We attest that the applicant is 18 years of age or older and a member in good standing of the NAR. We believe this member is qualified to build and operate High Power Rockets with a total installed impulse up to: ☒ 640 N-sec. (Level 1) ☐ 5120 N-sec. (Level 2)

Name Bethany [illegible] Signature [signature] NAR # 112578

Birth Date 01 / 16 / 87 Membership Expires 9 / 30 / 22 HPR Cert. Level 2

Name Jared Sinclair Signature [signature] NAR # 294577

Birth Date 04 / 21 / 1999 Membership Expires 9 / 30 / 22 HPR Cert. Level 2

Form must be signed by Certification Applicant and Certification Team.

NAR HPR CERTIFICATION VERIFICATION

Name Timothy Grant

NAR Number 295717 Certification Date 13 Feb 2022

☑ **Level 1 Certification** ☐ **Level 2 Certification**

Witnessed By [signature] Authorizing Signature

Witnessed By [signature] Authorizing Signature

This card is void 60 days after Certification Date

Cut along dotted lines

Send completed form and exam sheet to the NAR HQ address listed or scan and email them to nar-hq@nar.org.

National Association of Rocketry
P.O. Box 407
Marion, IA 52302

File: HPR-APP-2020-V1

Figure 5.9.3.5

5.10 References and File Links

5.10.1 References (IEEE)

[1] "3D CAD Design Software," *Solidworks*. [Online]. Available: https://www.solidworks.com/. [Accessed: 06-Mar-2022].

5.10.2 File Links

PDR link:
https://drive.google.com/file/d/1fF-wM5k4DeCt8B3aF1HyMHxyVP05Sy9t/view?usp=sharing

CDR link:
https://drive.google.com/file/d/1zisnLI0EEDN3WarYdbuxwy-jORDxNzas/view?usp=sharing

5.11 Revision Table

Date	What Was Done
3/6/2022	Jordan, Jack, Timothy, Nick, Ryan: Initial create of section
	Timothy Grant: Updated Figure names
4/21/2022	Jordan, Jack, Ryan, and TIm formatted section and added sections 5.4-5.9

6 Project Closing

6.1 Future Recommendations

The project which was assigned to our team was initiated at the beginning of the year, it was not a continuation of any previous projects. Therefore there are plenty of opportunities for improvement on this project.

6.1.1 Technical Recommendations

6.1.1.1

Finer tuning of the IMU, anlong with a higher and more sensitive IMU would result in a more accurate backup location in the case where the main method of estimating location fails. The reason the team opted to use a medium quality IMU was that we were unsure of the feasibility of an IMU to return data of any use, and therefore were hesitant to spend the hefty price which is associated with higher quality IMUs. Choosing the right IMU is important when starting a long term project, and doing more research would have helped accomplish our goals [1]. This year's project serves as a proof of concept for the IMU and can be used as justification for pursuit into higher cost IMU devices.

6.1.1.2

One interesting idea which was brought up in the brainstorming portion of the development process, but ultimately not pursued, was that of a directional signal. The idea was to have a rotating beacon which emits a signal in a specific direction. The signal can be constrained to a direction with material that blocks the frequency which the signal is being transmitted at. As the beacon rotates, the only time in which the payload receives the signal is when the home station beacon is pointed directly at the payload. This concept can be tested with a few different techniques including with a single or double receiver, or a doppler technique [2]. This information can be used to give the angle of the payload. It is possible to use this method to confirm the angle which is given by the vision processing unit, or to override the angle which the vision processing unit gives if this method turns out to be more accurate.

6.1.1.3

Test the transmission technology more thoroughly and possibly use different antennas or devices that allow greater range and higher reliability. The configuration used in the payload this year was not effective beyond local line of sight uses. Testing this more thoroughly would remove a major failure point in next year's launch. Additionally it would be beneficial to test the payloads ability to broadcast to the home station at several launches before the competition event.

6.1.1.4

In order to increase the reliability of the vision processing system, a larger home station base could be utilized. The advantage to increasing the size of the home station base is that the vision processing has more of a chance to capture a clear image of the base while the rocket is descending. In addition a larger home station base would mean that the images which the vision processing unit will have more pixels of the home station base. This will result in an increase in the accuracy of the theta which the vision processing produces to determine the location.

6.1.2 Global impact recommendations

6.1.2.1

Many of the components which were used in this year's project could be reused in next year's project. By reusing components, this would mitigate some of the negative effects of the global shipping system. Because parts need to be assembled from many different locations, a single component requires the utilization of fossil fuels for all of the individual sub-components to be brought together, assembled, then shipped to the final destination. Each step of the way utilizes harmful and ever dwindling resources to achieve, therefore any of the components which can be reused in the next year's version of the project should be. Particular components of interest include Raspberry Pi's and

Arduinos. These micro-controllers are multi-purpose in so far as they only need changes in software to entirely change the purpose of the device. Most projects will need at least one microcontroller, and therefore these are good candidates for reuse.

6.1.2.2

The five members of the ECE team consisted of 100 percent male identifying members. This was a pairing that was out of our control because teams are randomly assigned. But this does indicate the systematic gender disparities which can be found in the engineering department at Oregon State University. In order to make progress towards advancing gender justice, future teams can strive to create a welcoming environment for all members. This can be accomplished in many ways; by constant self-awareness of gendered language, increased levels of professionalism to avoid uncomfortable situations for underrepresented groups, and a constant awareness of how unseen forces negatively impact people different from ourselves [3].

6.1.3 Teamwork recommendations

6.1.3.1

Half way through the project the USLI team decided to change the method in which we conducted our meetings. We changed from a system which simply stated the direction in which each subteam was hoping to go in the coming week to a method where each individual person talked about what was accomplished over the course of the previous week, what we plan to accomplish next week, and what is currently stopping our progress. This method was much more effective because it encouraged constant progress by each member of the team [4]. A poll was taken after the project winded down about this method, and the majority of the people on the team stated that this method was helpful in encouraging them to accomplish tasks over the course of the week.

6.1.3.2

Another method which was implemented halfway through the project was on the subteam weekly meetings was to discuss the exact and specific tasks which needed to be accomplished, then to assign a specific person to the tasks. The payload subteam started by mapping out all of the major tasks which we thought needed to be accomplished over the course of the project, and the rough time period which those tasks needed to be done by. Then we broke those tasks down into smaller tasks until there were many small and manageable tasks for each person to complete every week. We would go through the tasks each week and assign specific tasks to specific people. This method allowed each person to take responsibility for goals which needed to be done [4]. In addition it helped to inspire motivation for the group members because it allowed us to see our efforts in the context of the larger project and how our work was going to accomplish the overall project.

6.2 Project Artifact Summary with Links

Internal Payload PCB:

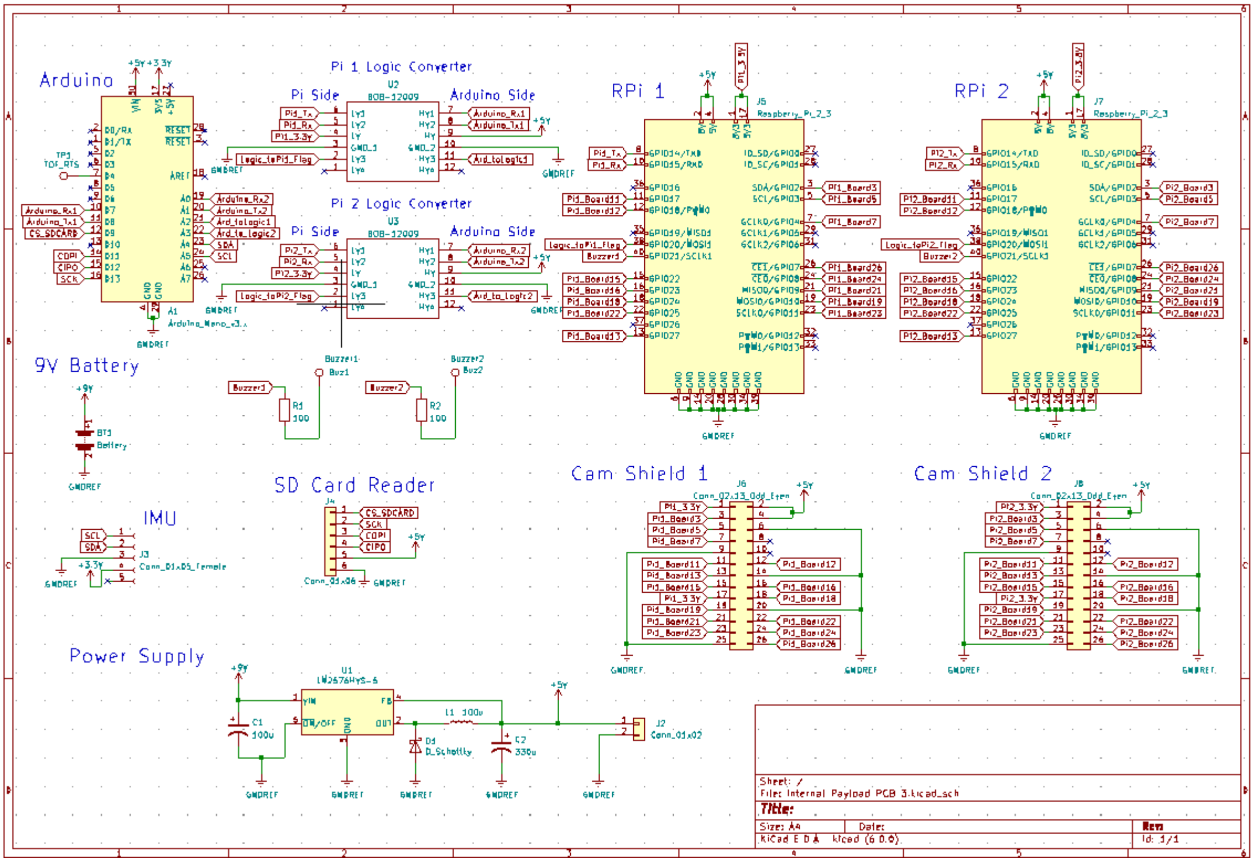


Figure 6.2.1: Internal Payload PCB Schematic

Home Station PCB:

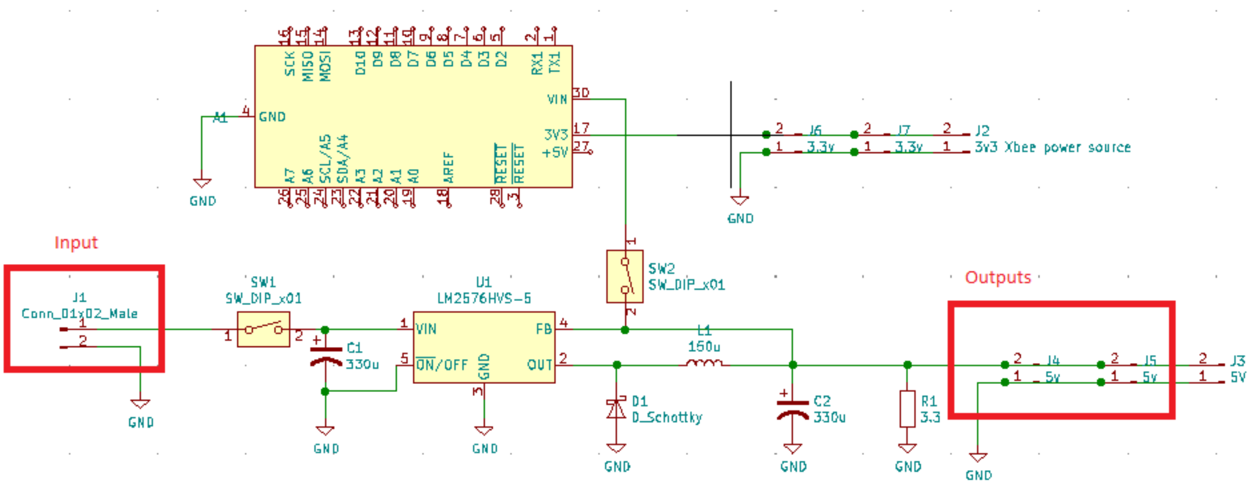


Figure 6.2.2: Home Station PCB Schematic

Time of Flight PCB:

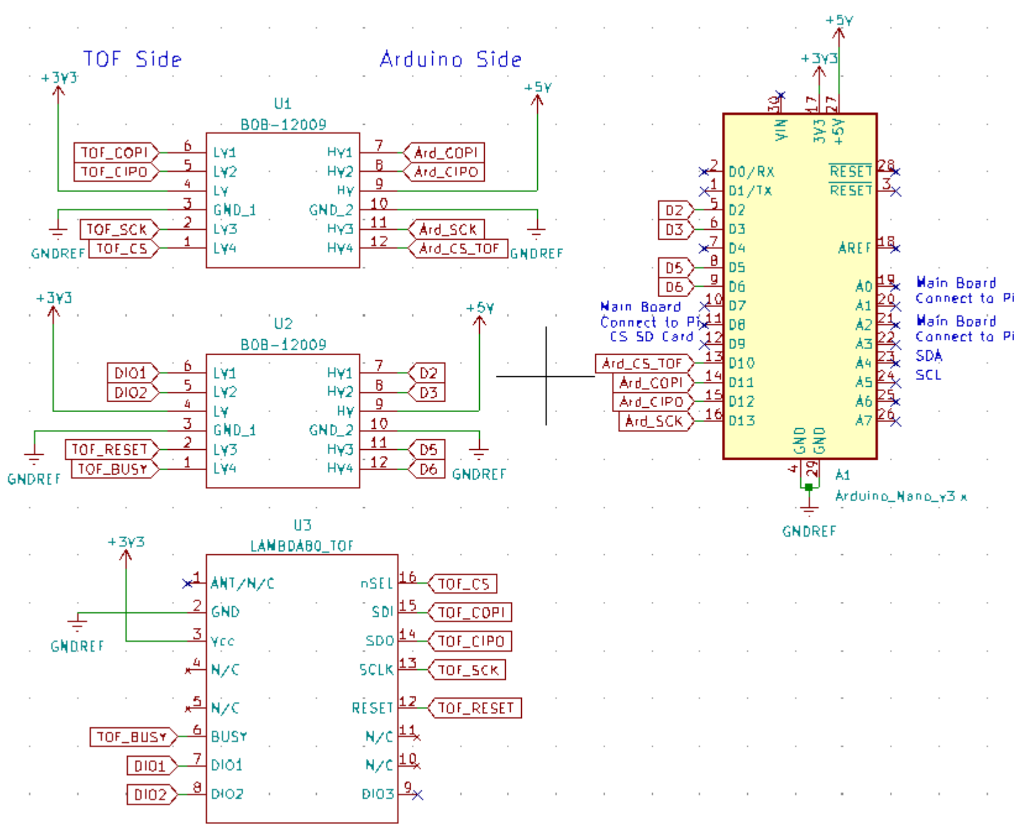


Figure 6.2.3: Time of Flight PCB Schematic

Enclosure Drawings:

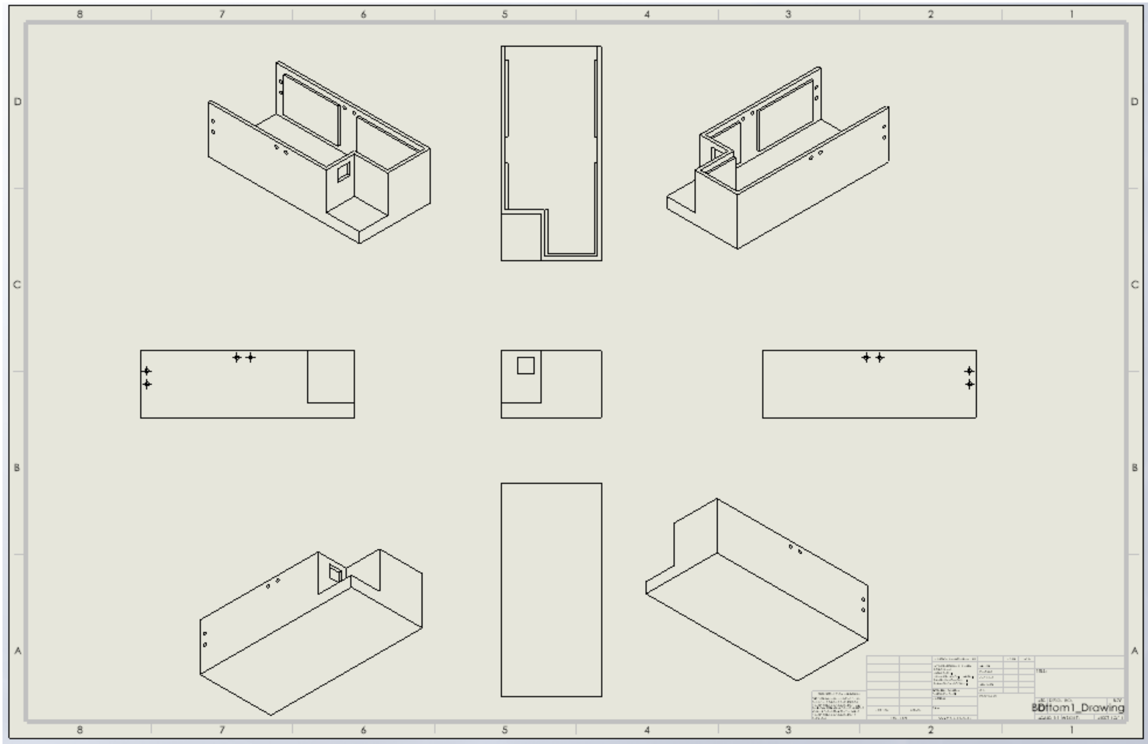


Figure 6.2.4: Enclosure Drawing

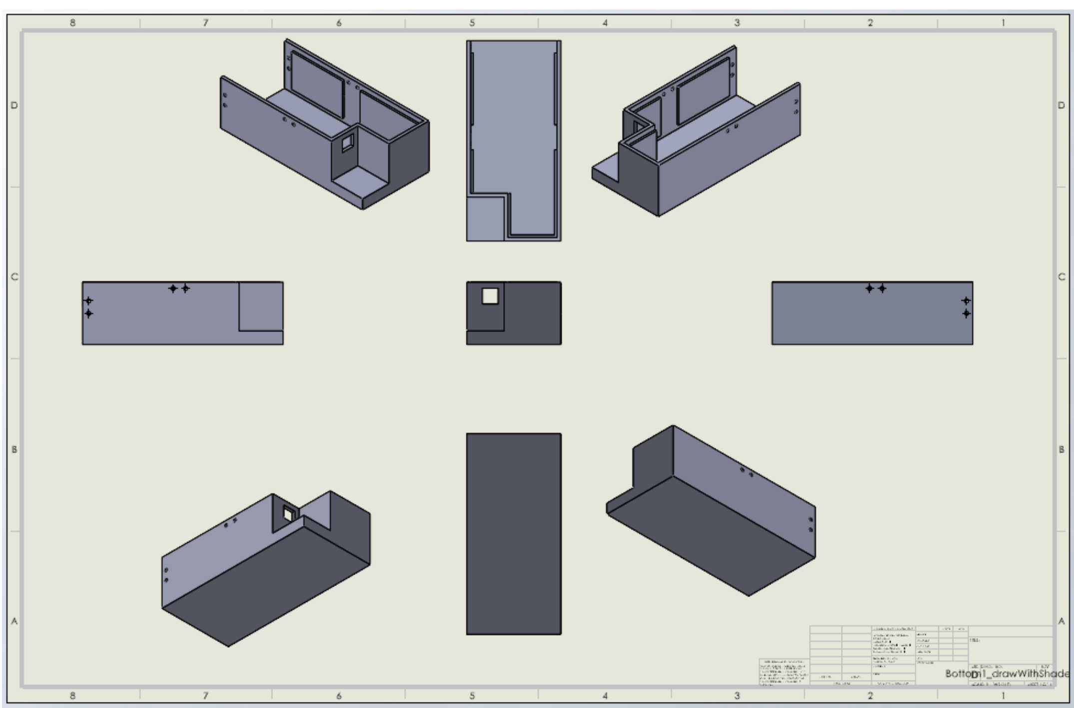


Figure 6.2.5: Enclosure Drawing

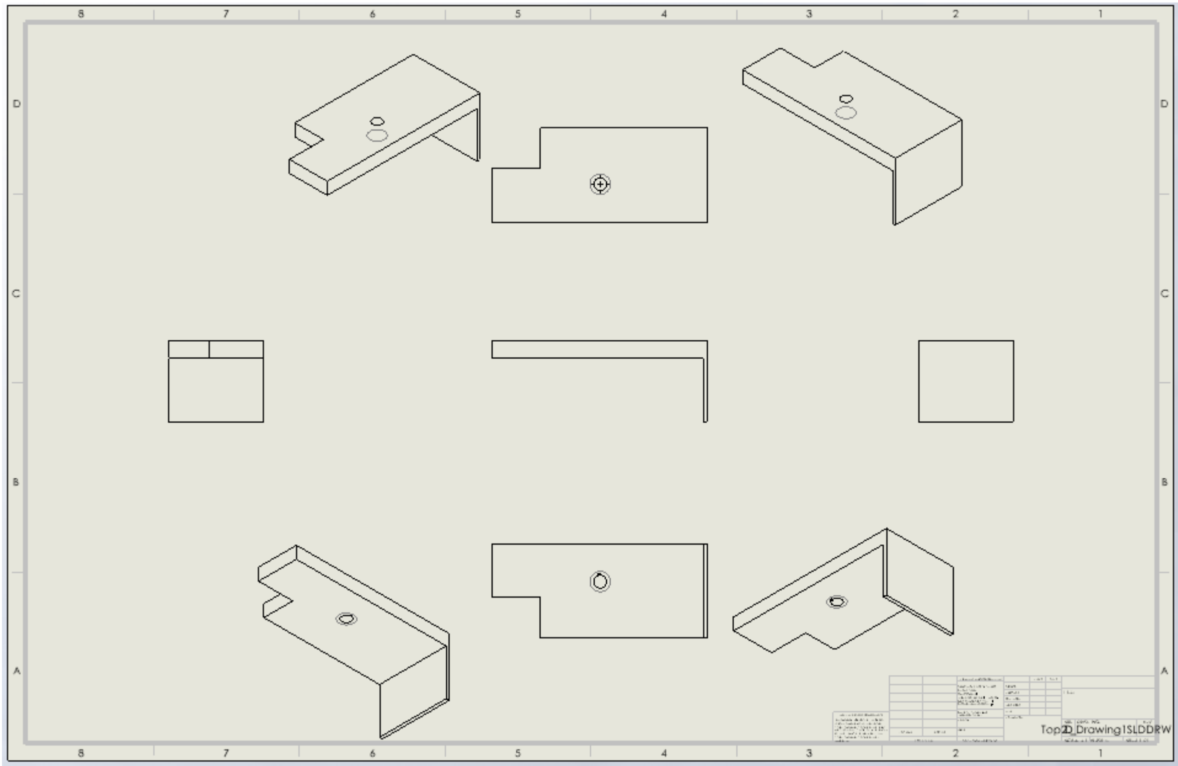


Figure 6.2.6: Enclosure Drawing

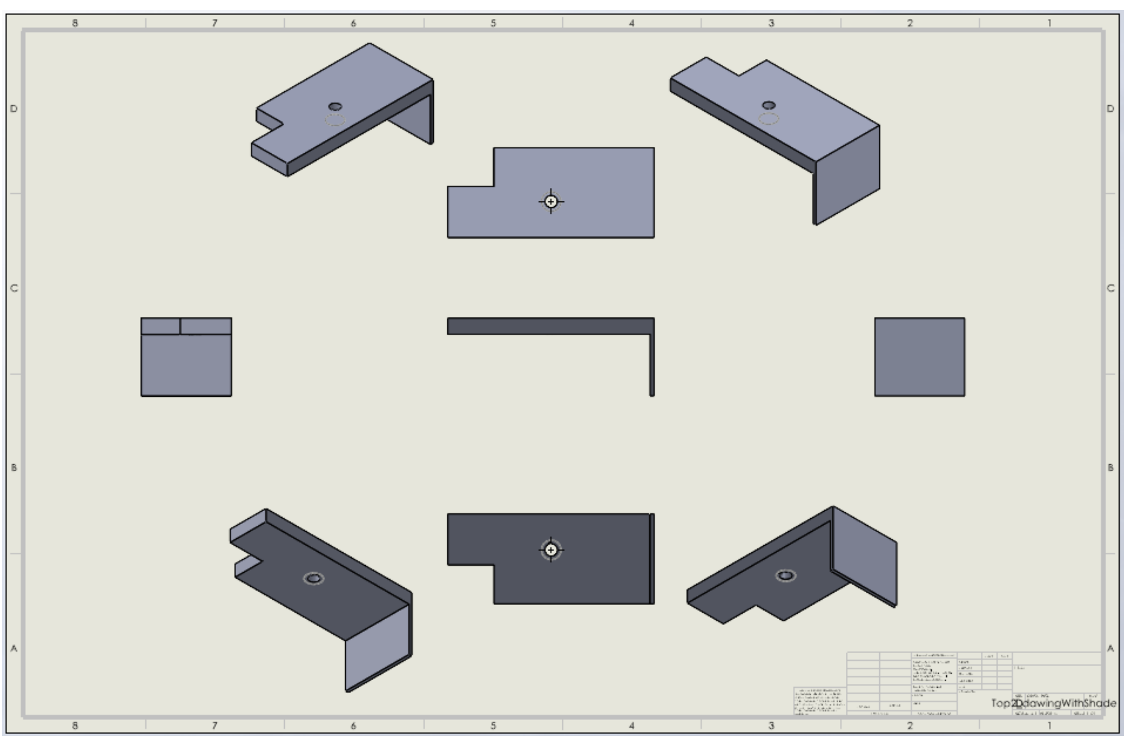


Figure 6.2.7: Enclosure Drawing

Enclosure Drawings:

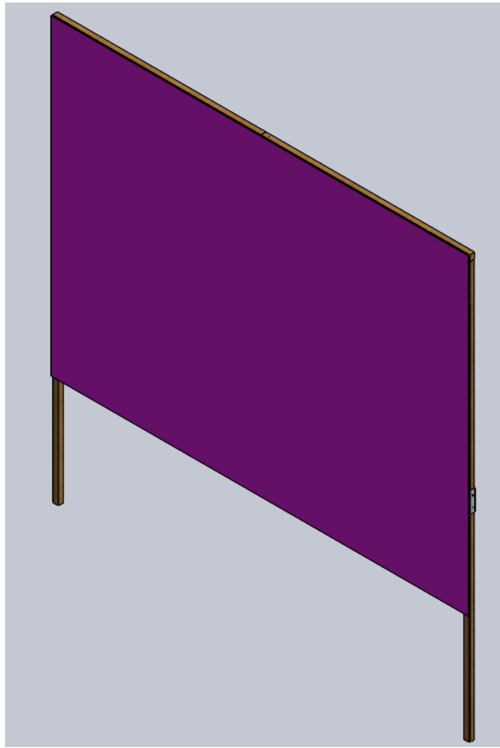


Figure 6.2.8: External Frame

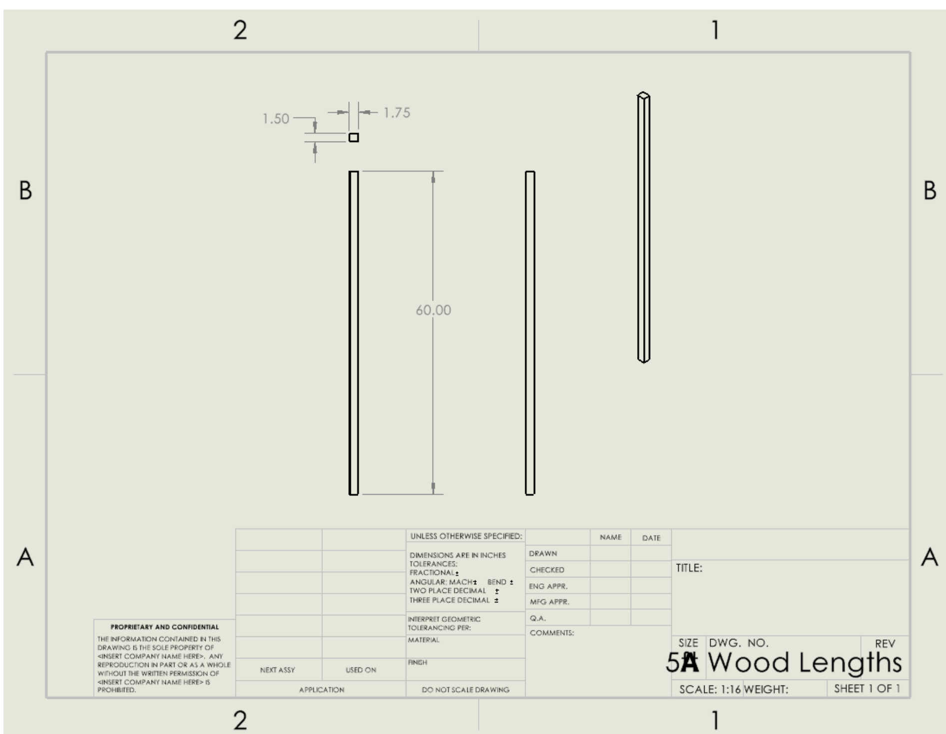


Figure 6.2.9: External Frame Drawing

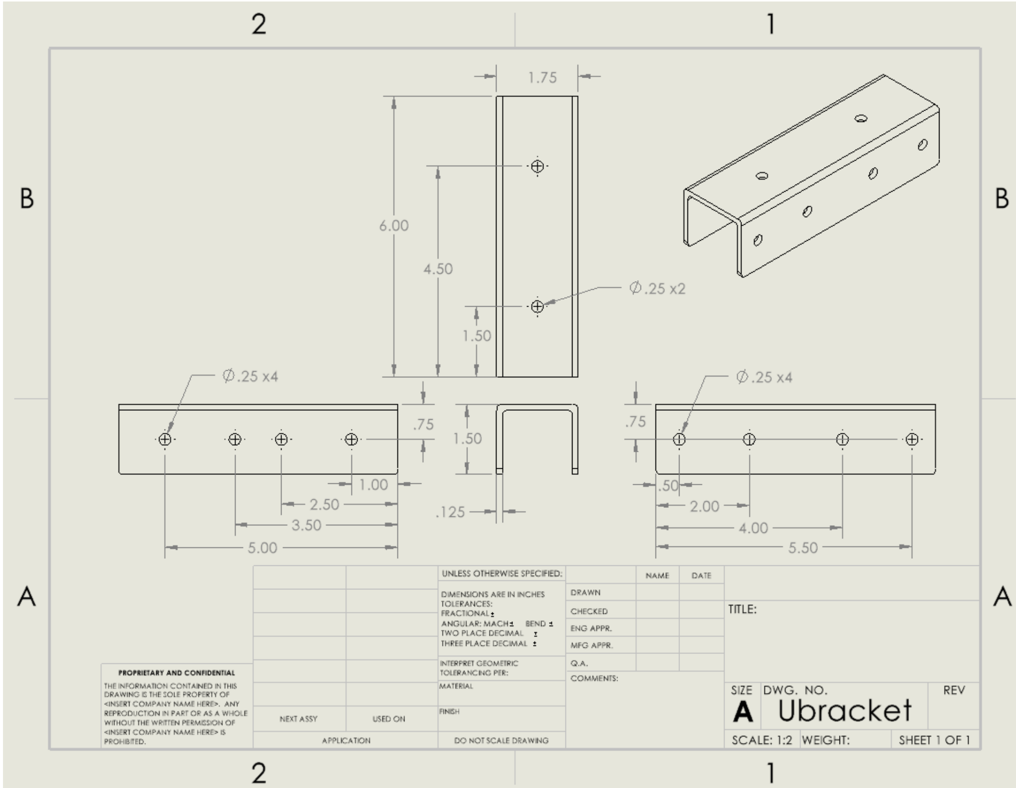


Figure 6.2.10: External Frame Drawing

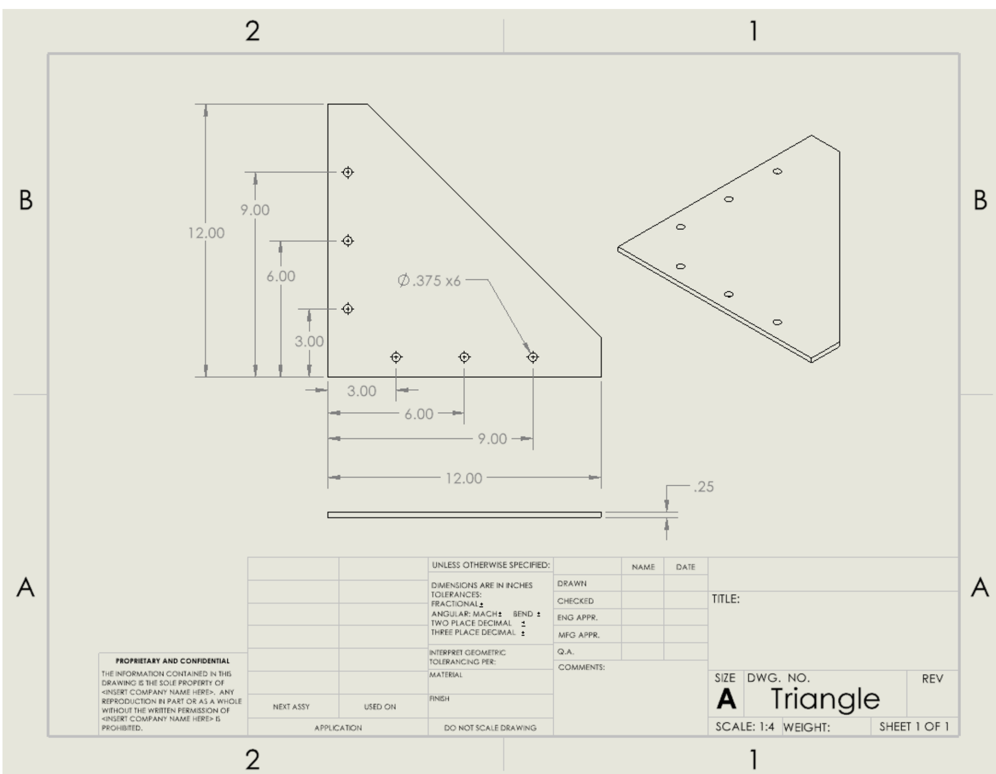


Figure 6.2.11: External Frame Drawing

Avionics:

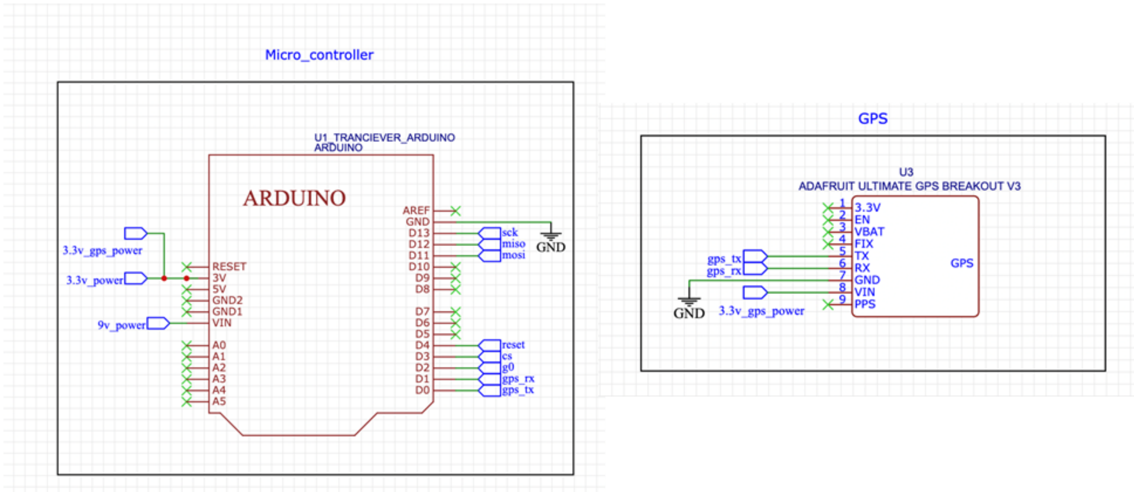


Figure 6.2.12 Avionics GPS Schematic

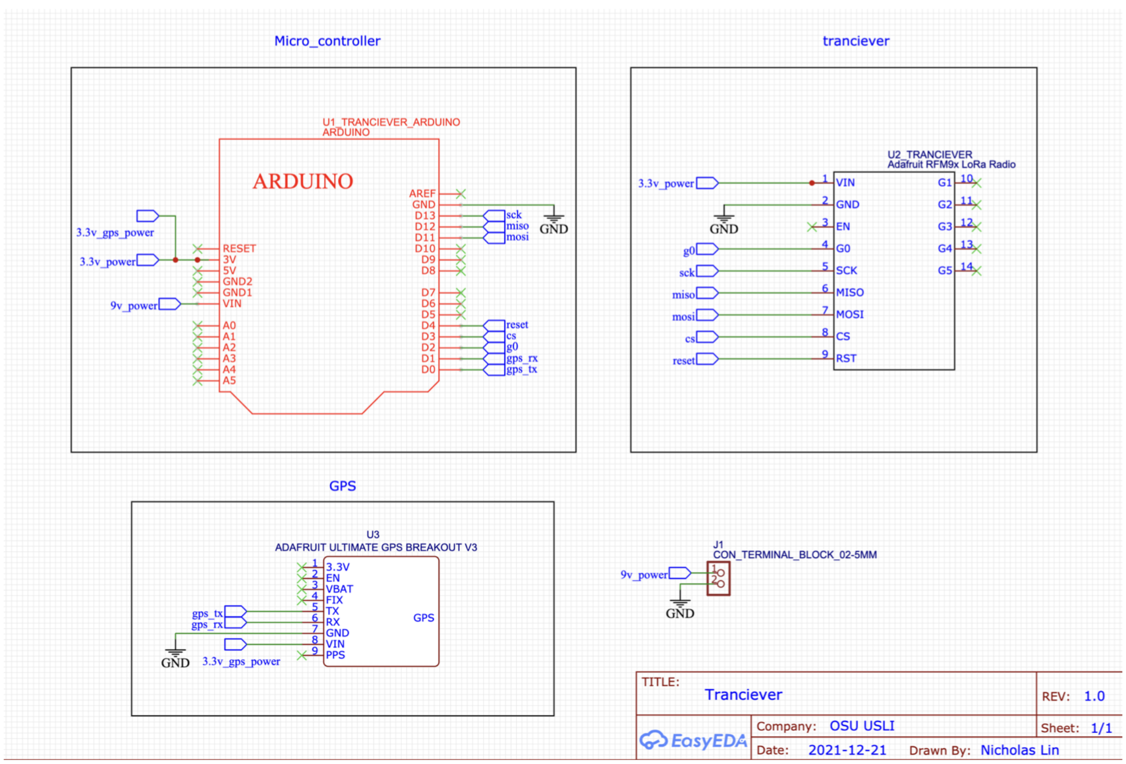


Figure 6.2.13: Avionics PCB Schematic

6.3 Presentation Materials

Project Poster

Weekly Video Updates:

Week 5
Week 6
Week 7
Week 8
Week 10
Week 12
Week 15
Week 22
Week 25

6.4 References

[1] W. Johnson, "How to choose the right inertial sensor for your build," *Inertial Sense*, 21-Feb-2020. [Online]. Available: https://inertialsense.com/choosing-inertial-sensors-your-build/. [Accessed: 05-May-2022].

[2] E. Botha and K. Faul, "An introduction to radio direction finding," *Alaris Antennas*, 04-Nov-2020. [Online]. Available: https://www.alarisantennas.com/blog/an-introduction-to-radio-direction-finding/. [Accessed: 05-May-2022].

[3] "How do we make the field of engineering more diverse?," *Stanford University.* [Online]. Available: https://engineering.stanford.edu/magazine/article/how-do-we-make-field-engineering-more-diverse [Accessed: 05-May-2022].

[4] "The basics of working on teams," *MIT Human Resources*. [Online]. Available: https://hr.mit.edu/learning-topics/teams/articles/basics. [Accessed: 05-May-2022].

6.5 Revision Table

Date	What Was Done
4/19/2022	Timothy Grant: Initial create of section
	Timothy Grant: Created content in sections 6.1.1, 6.1.1.1, 6.1.1.2, 6.1.3.1, 6.1.3.2

4/21/2022	Jack Little Formatted Section
5/5/2022	Timothy Grant, Ryan Bohl: Added global impact recommendations
	Ryan Bohl, Jordan Hendricks: Added presentation materials and project artifact summary figures
	Timothy Grant, Ryan Bohl: Added technical recommendations