HASP Student Payload Application for 2023

Payload Title: LunaSat Testbed

Institution: University of Colorado Boulder

Payload Class: SMALL

Submit Date: 1/6/23

Project Abstract:

We wish to use HASP to increase Technology Readiness Level (TRL) for the lunar technology of the Great Lunar Expedition for Everyone (GLEE) mission. GLEE's mission statement is to land hundreds of LunaSats programmed by students all around the world on the surface of the Moon to collect data and study the lunar environment. WhenBuffsFly aims to improve the Technology Readiness Level of LunaSats by testing the capability, survivability, and accuracy in a near-space environment in early September, launching from Ft. Sumner, New Mexico, as part of the HASP platform.

We plan to run the temperature, magnetometer, and accelerometer sensors and run two pairs of LunaSats for at least 6 hours. Then perform radio frequency (RF) between three pairs of LunaSats. In addition, we plan to observe the changes in the LunaSats' temperature sensor and then compare those temperature readings to a temperature sensor that is not part of the LunaSat but on the HASP payload.

Team Name: WhenBuffsFly

Team or Project Website:

	Student Leader Contact Information:	Faculty Advisor Contact Information:
Name:	Elsa Carreras	Veronica Corral Flores
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Telephone:	720-665-7387	303-492-1243

The signature below indicates that the student lead and faculty advisor have read and understood the HASP CFP and Student Payload Interface manual, commit to providing the required HASP deliverables by the indicated due dates and agree to respond to HASP management inquiries in a timely manner.

Commitment Signature:	Elsa Carreras	

Flight Hazard Certification Checklist

NASA has identified several classes of material as hazardous to personnel and/or flight systems. This checklist identifies these documented risks. Applying flight groups are required to acknowledge if the payload will include any of the hazards included on the list below. Simply place an (x) in the appropriate field for each hazard classification. Note: Certain classifications are explicitly banned from HASP and the remaining hazards will require additional paperwork and certifications. If you intend to include one of the hazards, you must include detailed documentation in section 3.8 of the application as required by the HASP Call for Payloads.

This certification must be signed by both the team faculty advisor and the student team lead and included in your application immediately following the cover sheet form.

Hazardous Materials List

Classification	Included on Payload	Not Included on Payload
RF transmitters	X	
High Voltage		X
Lasers (Class 1, 2, and 3R only) Fully Enclosed		X
Intentionally Dropped Components		X
Liquid Chemicals		X
Cryogenic Materials		X
Radioactive Material		X
Pressure Vessels		X
Pyrotechnics		X
Magnets less than 1 Gauss*		X
UV Light		X
Biological Samples		X
Non-Rechargeable Batteries		X
Rechargeable Batteries		X
High intensity light source		X

* Magnets greater than 1 gauss are banned.

Student Team Leader Signature: Elsa Carrerad

Faculty Advisor Signature: ______________________________

Table of Contents

1. Payload Description

The Great Lunar Expedition for Everyone (GLEE) is one of the current projects at the Colorado Space Grant Consortium (COSGC) in which they plan on launching small, post-it note sized spacecraft, known as LunaSats, to the surface of the Moon. The team is working on reducing the footprint of the LunaSat, and upgrading its components for increased accuracy, memory storage, and operability. WhenBuffsFly is a payload designed to test these LunaSats with the goal of raising their technology readiness level. These tests include running various sensors located on the LunaSats including a temperature sensor, magnetometer, accelerometer, thermopile, and capacitive sensor. These sensors will be running during specific time intervals in flight in which we will determine how long the LunaSats can run in a near-space environment. We will also test the radio frequency (RF) communication of the LunaSats in an array as well as individual communication from the LunaSats to the flight computer. Testing will occur in three environments; an exterior environment exposed to the near-space conditions, an insulated interior compartment that will regulate operational temperature as well as housing our in-flight computer, and a non-insulated interior compartment. Our flight on the HASP platform will aid us in obtaining data to support the progress of the GLEE mission.

1.1 Payload Scientific / Technical Background

As the expansion of the space industry takes place, so does the need for data across planetary bodies such as the Moon. Our payload, WhenBuffsFly, plans to test lunar technology known as LunaSats in order to support our adjacent GLEE project by raising the technology readiness level (TRL). Our experiment will include radio frequency communication verification, multiple sensors' capability, and the survivability of the LunaSat's components to determine the overall operability of the spacecraft in a near-space environment.

The primary objective of our mission is to support the advancement of the GLEE mission. The project is currently at a TRL of level 6 in which the prototype LunaSat on the ground functions correctly. We are seeking to raise the level to level 7 by demonstrating the technology in a near-space environment. In order to raise the TRL, the technology will be tested for capability, survivability, and accuracy of the LunaSats components and sensors as a system. The temperature, accelerometer, and magnetometer sensors will be run together to determine if the combination can survive in a near-space environment. Additionally, along with the LunaSat sensors, we want to verify that the radio frequency communication components are operational when exposed to the temperature changes during flight, especially those sustained when in near-space. At launch, we will initiate the assignments for pair 2 and 4, in which the LunaSats will be running for a minimum of 6 hours to test if the LunaSats can both survive and accurately collect data for long periods of time. Once the flight reaches hour 3, the RF testing will commence for pairs 1, 3, and 5 in order to verify that each LunaSat can successfully communicate with the flight computer. Directly after the individual RF tests, on hour 4, LunaSats pairs 1, 3, and 5 will shift from individual communication to communication in an array. As all of the RF tests conclude, those three same LunaSat pairs will begin collecting data with their respective sensors (Table 1). For the remainder of flight, all LunaSat pairs will continue to run the sensors they were assigned. The time intervals for each testing window is shown in Figure 1.

Hour 0
- Begin running LunaSat pairs 1 and 4 with all sensors active.

Hour 3
- Begin RF testing between the central computer and pairs 2, 3, and 5 individually.

Hour 4
- Begin RF testing with pairs 2, 3, and 5 in array communicating to each other.

Hour 5
- Begin sensor assignments on pairs 2, 3, and 5.

Hour 6+
- Continue running pair assignments until end of flight.

Figure 1: In-Flight Testing Timeline

After the completion of the mission, we hope to achieve multiple objectives relating to the capabilities, survivability, and accuracy of the LunaSats. Primarily, we are seeking to validate the operation of the temperature, magnetometer, and accelerometer sensors onboard the LunaSat and obtain data throughout the entirety of flight. By the end of the mission, we want to see all sensors running on two different LunaSat pairs, one on the exterior of the payload, and one interior of the payload. We hope to have successful RF communication both in array and between each assigned pair to the central computer. Throughout flight, the exterior mounted LunaSats will experience a wide range of temperatures in which we want to see successful operation. Our final objective will compare the temperature sensors on the LunaSats to an additional temperature indicator to determine the accuracy of the LunaSat sensors. The data we will collect from the experiment and its tests will help us raise the TRL of LunaSats to level 7.

1.1.1 Mission Statement

WhenBuffsFly is aimed at improving the Technology Readiness Level of LunaSats by testing the capability, survivability, and accuracy in a near-space environment in early September, launching from Ft. Sumner, New Mexico as part of the HASP platform.

1.1.2 Mission Background and Justification

WhenBuffsFly is focused on testing the operational effectiveness of LunaSats, a sticky note sized spacecraft. These LunaSats are part of a separate COSGC project, known as GLEE. GLEE's mission is to deploy five hundred of these spacecraft to the surface of the Moon to collect local and distributed science, based on the student teams that those LunaSats are assigned to [1]. The goal of the project is to make lunar science more accessible to the public by offering student groups the ability to control these LunaSats. The data collected by these spacecraft will be utilized to characterize magnetic fields, detect movement, and measure regolith characteristics at many points on the surface simultaneously. Currently, the GLEE project is at a technology readiness level (TRL) of six, in which the technology has been tested on the ground. However, our goal with this payload's experiment is to raise the TRL to level seven in which the technology must be demonstrated in a space environment. Our experiment will characterize the capability, survivability, and accuracy of the LunaSats sensors and components. These components will be pushed to their limits to gather experimental data to aid GLEE in LunaSat upgrades, as well as establishing a baseline for operations in space.

1.1.3 Mission Objectives

1. Validate the operation of the temperature, magnetometer, and accelerometer sensors onboard three pairs of LunaSats and obtain data for at least 6 hours.
2. Run all sensors simultaneously on two pairs of LunaSats for at least 6 hours.
3. Three pairs of LunaSats will communicate using RF in an array with each other as well as communicate with the onboard central computer.
4. Observe LunaSat operation throughout the temperature changes that they sustain throughout flight.
5. Compare the readings of the LunaSat temperature sensors to that of an additional onboard temperature indicator.

1.1.4 Scientific Relevance to the HASP Platform

The objective of this experiment is to raise the TRL of CU's GLEE LunaSat from a TRL 6 to a TRL 7. As a TRL 6 technology, we have demonstrated the functioning of the prototype GLEE LunaSat on the ground. The HASP platform will allow us to achieve TRL 7, demonstrating the functioning of the LunaSat in a near-space environment. This aligns directly with one of the focuses of HASP, improving a system TRL. Extended access to the near-space environment provided by HASP will allow us to expose our LunaSat prototypes to combined endurance, thermal, radiation, and other flight stresses which we could not otherwise recreate in one test. Testing the performance of the LunaSat sensors during the flight will improve the TRL of the LunaSat, by either confirming that the system is able to function in a space environment and provide accurate data, or exposing unforeseen issues with the LunaSat.

1.2 Payload Systems and Principle of Operation

The payload has two major systems, mechanical/structures, as well as electrical. The mechanical system is composed of the payload structure and its two compartments, insulated and non-insulated. The electrical system includes the HASP central power supply, voltage regulator, flight computer, and the LunaSats being tested.

Table 1: LunaSat Pair Assignments

Pair Number	LunaSat Number	Location	Insulated/ Non-Insulated	Sensors Running	Additional Tests
1	1a, 1b	Exterior	Non-Insulated	Temperature, Magnetometer, Accelerometer, Capacitive Sensor, Thermopile	Solar panel voltage observation
2	2a, 2b	Exterior	Non-Insulated	Temperature, Accelerometer, Magnetometer	Radio Frequency communications in array and to onboard computer
3	3a, 3b	Interior	Non-insulated	Temperature, Accelerometer, Magnetometer	Radio Frequency communications in array and to onboard computer
4	4a, 4b	Interior	Insulated	Temperature, Magnetometer, Accelerometer, Capacitive Sensor, Thermopile	n/a
5	5a, 5b	Interior	Insulated	Temperature, Accelerometer, Magnetometer	Radio Frequency communications in array and to onboard computer

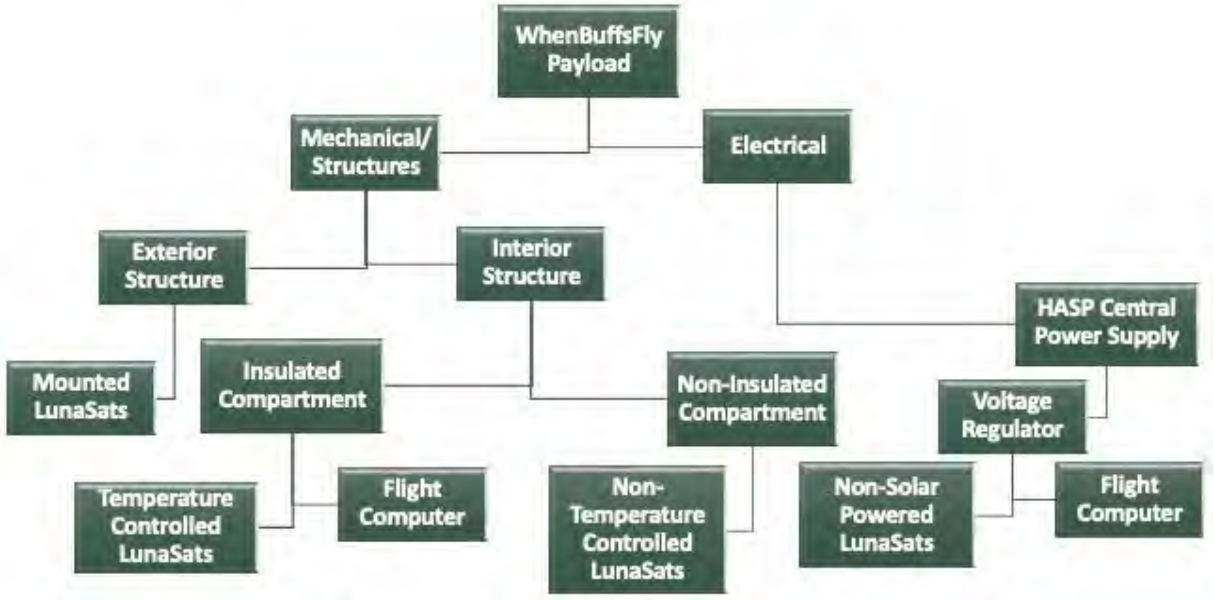


Figure 2: Payload Systems Diagram

1.3 Major System Components

1.3.1 Structure

We propose our payload for HASP to be a basic design of a rectangular box to house LunaSats in different ways. We want to have 3 main sections of the payload. One: inside the box, insulated to make sure that the LunaSats can run to have a ground level. Two: have another section inside the box to house the LunaSats so that they don't get damaged and are not affected by debris in space which is not insulated. Three: have LunaSats mounted on the exterior of the payload but still inlaid to test the durability of them and test the solar panels.

1.3.2 Electrical System

The electrical system's main purpose is data collection, processing, and storage. The main components will be the central computer (a Raspberry Pi Zero [RPi Zero] with a custom designed PCB board connected via wire), and 5 pairs of LunaSats. External power will be provided from the HASP power source and run through a voltage regulator on the PCB via a wired connection. Every LunaSat will be connected to the central computer via a wired connection to the PCB. This wired connection will allow for power and data transfer. While every LunaSat is sending data through this connection, only 4 pairs of the LunaSats will be receiving power through this wired connection. The remaining pair is powered exclusively by solar panels that are built into the LunaSats. All of the data from each LunaSat will be stored locally on a micro-SD card located on the RPi Zero, and specific data sets will be transferred from the RPi Zero to the HASP computer for data downlink via the HASP serial connector.

Additionally, LunaSat pair 2, 3, and 5 are connected in array via RF as well as to the RPi zero via the RPi zero's external RF receiver, which is connected to the RPi via the PCB. The goal of connecting the LunaSats in an RF array is to test this type of RF functionality, which is how the LunaSats will communicate via RF on the surface of the Moon.

1.3.3 LunaSats

The LunaSats were designed by the GLEE team. The HASP team will not make any changes to the boards, and the LunaSats will be treated as off-the-shelf components. The LunaSats measure 6x6 centimeters and contain a solar panel, temperature sensor, thermopile, capacitive sensor, 3-axis accelerometer, and magnetometer. A picture of the front of a LunaSat is shown in Figure 3.

Figure 3: The most recent version of the LunaSat from the GLEE website [2]

1.4 Mechanical and Structural Design

There will be a housing unit for LunaSats inside while having four flush LunaSats on the outside. The housing will be made out of aluminum 6061 which has been used in many different aerospace applications like planes and rockets. Aluminum is a light but strong material. It has a high tensile strength in low temperature environments which is ideal for our payload. We will add a window to one of the faces of the payload body so that RF communication can reach the outside LunaSats because the aluminum will block RF communication. We will need to test the material and RF transceiver to see how big the window must be and the optimal position to place the window.

There will be a section of the inside housing that will be insulated that will hold our main computer and two pairs of LunaSats (see figure 10 in appendix A.2). To better maintain heat on the inside of the payload we will use a white paint that will reflect UV radiation. For the inside of the payload we will add a multi-layer polyester insulation to maintain the right temperature.

The payload body will be mounted on the given PVC plate with a ¼ inch hex bolt with two washers and a nut to connect it. As well as epoxied down to ensure it stays on the plate. This is shown in section 4, figure 8.

To attach the LunaSats to the payload, we will have nylon PCB corner and edge mounts shown in Figure 4. A detailed drawing of the mounting hardware is shown in Figure 11 in Appendix A.2.

Figure 4: Approximate location of corner/edge mounts for the LunaSats.

The mechanical stresses that we will have on the payload will be compression on the main structure, tension on the bolts used for mounting, and possible bending and torsion on the whole payload. This will be mitigated by using a cross hitch pattern that will strengthen the walls of the payload and also decrease the weight of the payload. Using ¼ inch stainless steel bolts that will allow for a higher stress so the payload doesn't get ripped off. The main stress on the payload will be at the joints so we will use bolts and epoxy to ensure that the payload remains together.

1.5 Electrical Design

Electrical Overview

We will convert the 30V of unregulated power that HASP provides into the right voltages for all of the LunaSats, our central computer, and any external components we are using. To do this, we will design a PCB that will have all of the components that we need, including a 5V voltage regulator that will convert the 30V of HASP power into the 5V that our central computer runs off of.

The computer we are using is the Raspberry Pi Zero (RPi Zero). It runs on 3.3V but has a voltage regulator built into its circuitry to convert an input voltage of 5V into the 3.3V it requires. The RPi Zero is an ideal choice for our computer because it consumes minimal current (max of about 140mA during boot up with peripherals connected) and while it doesn't have much processing power, all we need it to do is store all of our flight data from each of the LunaSats (which we will do using the RPi Zero's built-in micro-SD card reader) and to transmit the data we would like to downlink in real time to the main HASP computer using the serial connector. Since the RPi Zero only has a I2C output pin and cannot interface directly with a RS-232 serial connection, we will add to the PCB a component that will allow us to convert the I2C output from the RPi Zero to a RS-232 serial connection to connect to the HASP serial connector.

The PCB will be the main component of our electronics. Not only will it hold the voltage regulator needed for the computer and the I2C to RS-232 converter, it will also be designed to give us enough connections for all of the LunaSats. Due to the limited number of I/O ports of the RPi Zero, the PCB will connect to and transfer data from each of the LunaSats to the computer. This data will have information about which LunaSat it is coming from and a timestamp. The timestamp will be handled by a real time clock module (since the RPi Zero does not have one) also mounted on the PCB (DS1307 RTC from SparkFun). While the PCB will transfer data from all 10 of the LunaSats to the computer, it will only provide power to the 8 LunaSats that are connected to HASP power. The remaining 2 LunaSats will be powered by the solar panels only, and will not be given power through the PCB. To power the HASP-powered LunaSats, the RPi Zero has a 3.3V output pin we will use. Thus the 8 HASP-powered LunaSats will be powered by the RPi Zero, and this means we don’t need a second voltage regulator as all of the LunaSats run on 3.3V.

We are also planning on connecting an external Semtech SX1272 RF transceiver to the RPi Zero (it will be mounted on the PCB), which is the same transceiver that is built into the LunaSats. This will allow us to test the LunaSat RF capabilities by sending data from LunaSat to LunaSat as well as from LunaSat to the central computer. This transceiver runs between 860 MHz and 1020 MHz. All of our LunaSats and the transceiver on our computer will be running at 915 MHz. Figure 5 gives a layout of the power/data transfer between our components.

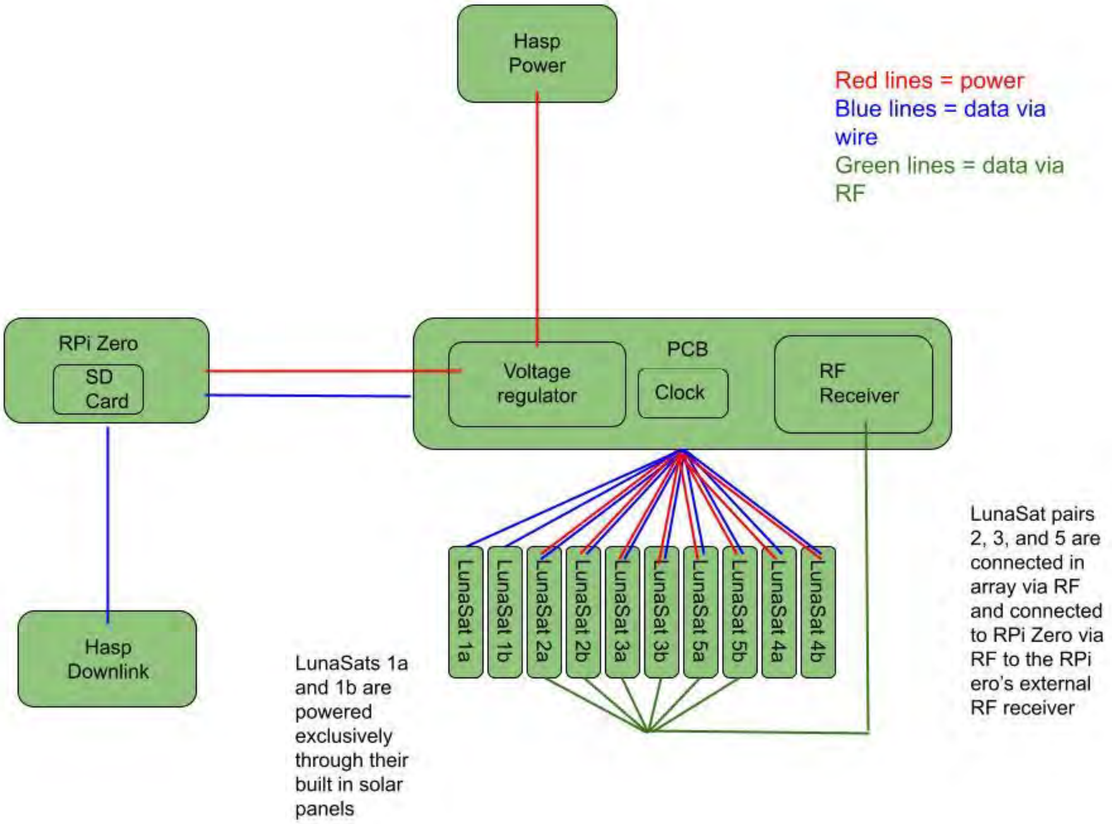


Figure 5: Power/Data Transfer Block Diagram

Data Acquisition:

Data acquisition will consist of 5 pairs of LunaSats (10 total). The pairs of LunaSats will be mounted inside and outside of the structure, measuring varying data. Power supply specifications for each pair are noted in Table 2.

Table 2: Data Acquisition Power Source

Pair Number	Power Source
1	Solar only
2	HASP power supply
3	HASP power supply
4	HASP power supply
5	HASP power supply

The PCB will transfer the data from the LunaSats to the central computer, and the central computer will transfer the data sets we would like to downlink to the HASP computer via the HASP serial connector. The central computer also has a built-in micro-SD card reader we will use to store all of our flight data. We estimate that (the worst-case scenario) a full data packet from our lunasats will be around 840 bytes. Sampling data every half-second for the maximum flight time of a total 24 hours, this will give us approximately 145 MB of space taken up by all of our packets throughout the flight. We plan on using a 32 GB micro-SD card which is cheap and, judging by the worst-case storage, will give us more than enough storage headroom to make sure we can store all of our flight data.

1.6 Thermal Control Plan

When looking at the combined specifications of all of the components of our LunaSats we find that we need to keep components within a temperature range between 0 and 70 degrees Celsius for operation and within a range of -40 degrees Celsius and 90 degrees Celsius for survival (Table 3). The top end of these ranges isn't much of a concern as measurements from previous HASP flights show temperatures peaking around 40 degrees Celsius, in addition, white paint will be applied to the exterior of the payload, reflecting away any unwanted solar radiation. On the other end of the spectrum small payloads on that previous flight recorded temperatures lower than -60 degrees Celsius which would not only prevent certain components from operating but would also fall outside of survival ranges risking damage to parts of the LunaSat. The enclosed part of the payload will include a heating element that will turn on when the interior temperature reading drops to 0 degrees Celsius, in addition to this the inner payload will be heavily insulated with a multi layer polyester, trapping the heat from the heating element and guaranteeing that those LunaSats on the inside will not experience temperatures outside their given operational ranges. For exterior LunaSats we want to test the limits of the devices acknowledging the risk that may be posed to various components as temperatures on the Moon will also exceed the ranges listed in table 3.

Table 3: Survivable and Operational Temperature Ranges for LunaSat Components

Component	Part Number	Operating Min (°C)	Operating Max (°C)	Survival Min (°C)	Survival Max (°C)	Notes
LunaSat	N/A	0	70	-40	90	Based on the most restrictive temp ranges from the individual components
Solar Panel	SM14K06L-ND	-40	90	-40	90	
Microcontroller	ATMEGA 328	-55	125	-65	150	
PMIC	AEM10941	-40	125	-65	150	
Temperature Sensor	TMP117AIDRVT	-55	150	-65	155	
Magnetometer	MLX90395KDC-BBA-101-RE	-40	125	-40	140	
Thermopile	TPIS 1S 1385	-20	85	-40	100	
555 Timer	NE555P	0	70	-65	150	
Capacitance Sensor	N/A	0	70	-65	150	Abides by 555 timer & microcontroller constraints
Accelerometer	MPU-6050	-40	105	-40	125	
Oscillator	NX2520SA-32.000000MHZ	-10	70	-40	85	

2. Team Structure and Management

2.1 Team Management

General meeting plans:

Full team meeting: The Project Manager will meet with the whole team and talk over the agenda, talk about deadlines, sub-team updates, what sub-teams need help with, what is finished, sub-team decisions, and what to work on next.

Sub-team meeting/Work hours: Team leads will lead these meetings/ work hours. All team members of that team must attend. The total amount of hours should be more than 3 hours for the full team meeting, the sub-team meetings, and work hours.

Executive Meeting: The Project Manager and Systems Engineer meet with Advisors to update them on the progress, gain advice on the project, and discuss the schedule and budget.

Faculty Advisors information:

Veronica Corral Flores email: vcorral@colorado.edu
Mary Hanson email: mary.hanson@colorado.edu

Both Faculty Advisors have been working with the team for one full semester, providing training in the following areas:

- Soldering components into a PCB and troubleshooting issues by de-soldering and finding discontinuity using a multimeter.
- Arduino coding, including digital and analog communication.
- LunaSat use and coding, following more than 10 online modules that include acquiring sensor data and RF communication between LunaSats.
- Systems Engineering by a Systems Engineer working in industry and using the videos from NASA: Systems Engineering for University-level Engineering Projects and Competitions.

This training required two hours per week of in-person work, and students worked either in-person or remote for another 3 hours per week on average. In addition, the Project Manager and the Systems Engineer attended another meeting per week to help them develop leadership skills and learn from more experienced team leads. Advisors also provided support to the team while they crafted this proposal for about 5 weeks.

For the Spring Semester, Advisors will support the team during weekly meetings and sub-team work hours. In addition, Advisors will host Executive weekly meetings to discuss with the Project Manager and Systems Engineer short-term plans for the project, including progress towards milestones, budget and hiring/training needs. Students are required to report their progress and accomplishments every week through a MIC (My Individual Contribution) report, and Advisors are in charge of reading such reports to identify and address any deviation from the tasks and goals of each sub-team. Advisors will devote at least 5 hours per week (each) on supporting and mentoring WhenBluffsFly students.

To support the design and development of the payload in a timely manner, Advisors will schedule a series of internal reviews where the whole team will present their concept, design and progress. The preliminary schedule for the reviews is as follows:

CoDR, Conceptual Design Review - January 26, 2023
PDR, Preliminary Design Review - February 23, 2023
CDR, Critical Design Review - April 20, 2023
FRR, Flight Readiness Review - July 13, 2023

Regarding finances, the WhenBluffsFly team has been assigned a budget of $43,300 as shown in Table 4. Students will receive biweekly payment according to the number of hours worked and reported by them. Travel expenses were calculated based on the number of students available to attend testing & integration and launch. Hardware amount was based on previous projects. Students will make decisions concerning hardware, and will select the best materials and components to build their payload. Advisors will handle finances and will place purchase orders after discussing with students about materials, suppliers, and lead time.

Table 4: Budget

Description	Estimated Cost
Student Salaries	$32,000
Travel to Testing & Integration	$4,600
Travel to Launch	$3,700
Hardware	$3,000
TOTAL	$43,300

Finally, Advisors acknowledge all HASP deliverable due dates and expected milestones and will make sure the team works towards the timely completion of such deliverables.

2.2 Team Organization and Roles

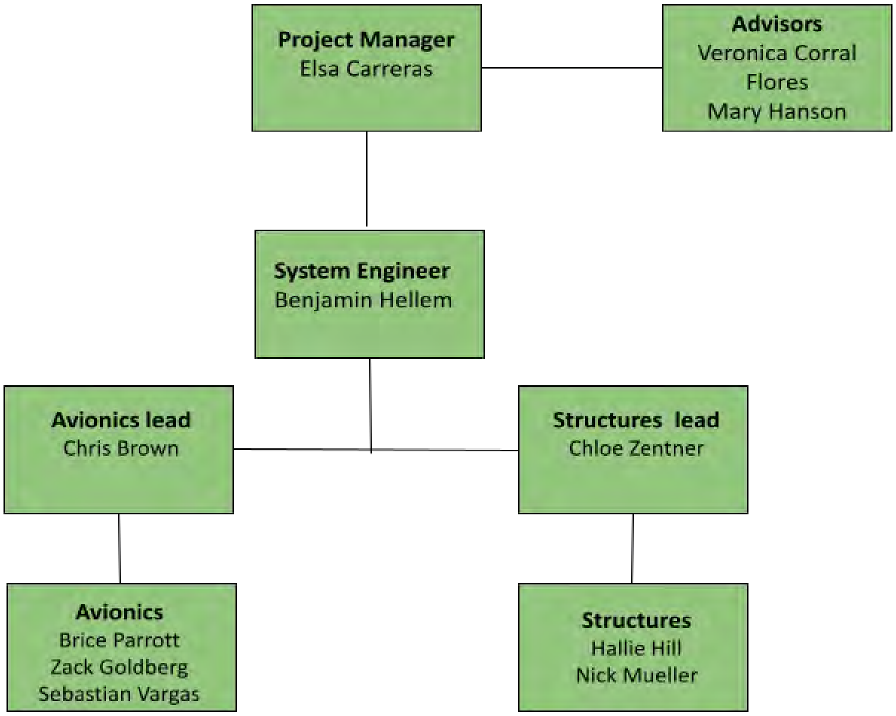


Figure 6: Organization Chart

The Project Manager (PM) will be administering deadlines and will hold executive and standard meetings. PM will additionally be responsible for commutating with HASP, attending teleconferences, and creating monthly status reports.

Systems Engineer will be in charge of creating requirements and ensuring that all the subsystems are working together. They will inspect for any potential risks, and they will manage the Concept of Operations.

Team leads will be responsible for their sub-team and creating expectations with their PM and Systems Engineer. They will lead weekly meetings with their sub-teams and create work hours for their team. Sub-team leads will report updates during the weekly meetings. They will report the issue to the PM and Systems Engineer if any system-level problems occur.

Team Members will be performing assigned activities according to sub-team goals and the overall mission and must document every critical decision, change to parts, and procedures.

Advisors will attend executive meetings with the PM, provide guidance to the students, and attend reviews.

Avionics: Avionics is the combination of the electrical and software subteams. This team is responsible for writing code, designing and creating PCBs (printed circuit board), and designing the electrical system for the project. They will be writing the commands, ground to spacecraft, and telemetry, spacecraft to ground. They need to determine how the system is generating, storing, conditioning, and distributing the power. The avionics subteam is also responsible for the power budget, and making sure the design does not go over this budget. The Avionics subteam is responsible for the creation of the science requirements, which define the project. They will also help with determining how the data will be processed and lead the data analysis.

Structures/Mechanical: The Structures, or Mechanical team will be responsible for the design, creation, and testing of the mechanical structure, or components of the project. Design can be done in a 3D modeling software. The team members will perform different analysis on the model, including, but not limited to thermal analysis and finite element analysis. The team will make and test prototypes before creating the final structure or mechanical components.

Table 5: Contact Information for Team Members and Advisors

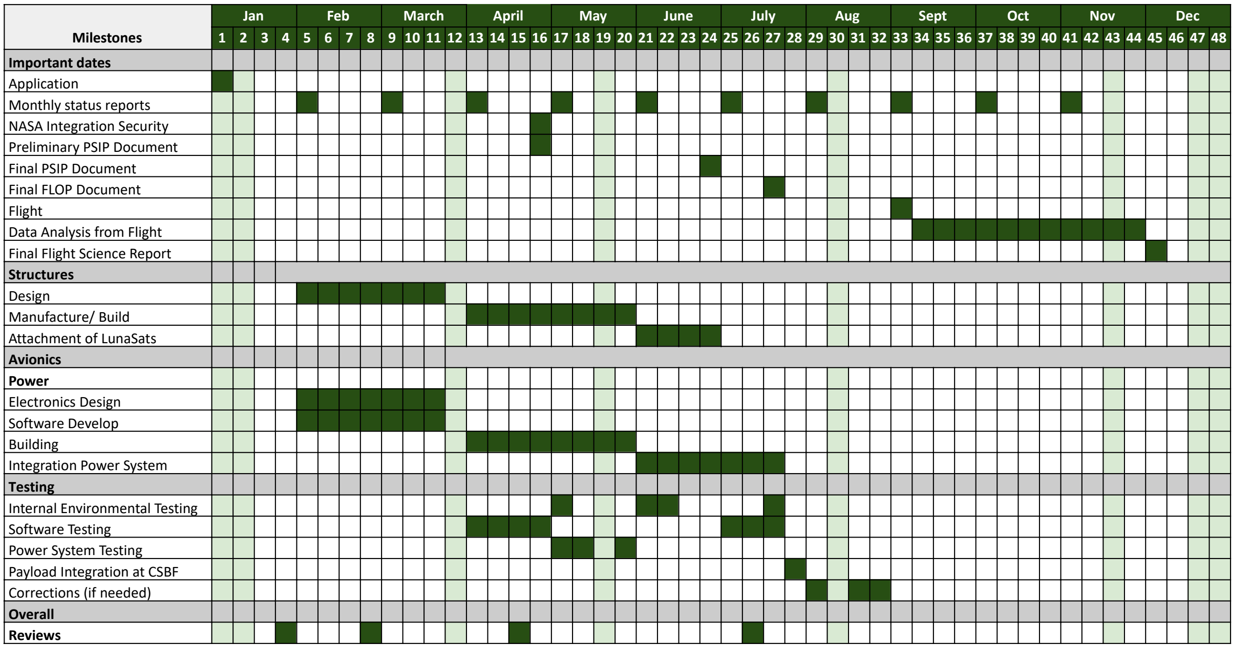
Position	Name and student level	Emails	Phone number
Project Manager (PM)	Elsa Carreras Freshman (2026)	elca6915@colorado.edu	720-665-7387
Systems Engineer	Benjamin Hellem Freshman (2026)	behe8000@colorado.edu	719-659-3764
Structures/ Mechanical team lead	Chloe Zentner Sophomore (2025)	chze3627@colorado.edu	916-764-7389
Avionics team lead	Chris Brown Freshman (2026)	chbr3757@colorado.edu	301-922-4932
Structures/ Mechanical team member	Hallie Hill Junior (2024)	hahi1979@colorado.edu	970-518-5920
Structures/ Mechanical team member	Nick Mueller Freshman (2026)	nimu4516@colorado.edu	828-772-9397
Avionics team member	Brice Parrott Freshman (2026)	brpa2055@colorado.edu	202-560-2548
Avionics team member	Zack Goldberg Sophomore (2025)	Zago6841@colorado.edu	925-323-1080
Avionics team member	Sebastian Vargas Sophomore (2025)	seva7658@colorado.edu	650-422-0610
Faculty Advisor	Veronica Corral Flores	vcorral@colorado.edu	303-492-1243

2.3 Timeline and Milestones

Table 6: Milestone Chart

Dates of Milestones	Description of Work
January	Internal CoDR, Conceptual Design Review
January 6	Application deadline
February	Start software development, start structures design, start electronics design, Monthly status reports and teleconference, internal PDR, Preliminary Design Review
March	Finish software develop, Finish structures design, finish electronics design, Monthly status reports and teleconference
April	Start structures Manufacture/ Build, start power building, start software testing, internal CDR, Monthly status reports and teleconference, internal CDR, Critical Design Review
April 28	Preliminary PSIP deadline and NASA Flight On-site Security Document deadline
May	Structures Manufacture/ Build, Power system testing, Integrate Power System, Monthly status reports and teleconference, Internal Environmental testing of components
June	Attachment of LunaSats, Integrate Power System, Internal Environmental testing of the structure, Monthly status reports and teleconference
June 30	NASA Flight On-site Security Document Deadline and Final PSIP deadline
July 21	Final FLOP document Deadline
July 24-28	Student payload integration at CSBF
July-August	Monthly status reports and teleconference, Internal Environmental testing on payload, Integrate Power System, Software testing, FRR, Flight Readiness Review, Corrections integration if needed
Sept 3-10	Target flight ready, Target launch data and flight operations, Recovery, packing, and return shipping
September-November	Analyze Data from flight, Monthly status reports and teleconference
Dec 8	Final Flight Science Report Deadline

Table 7: Gantt Chart



Milestones	Jan				Feb				March				April				May				June				July				Aug				Sept				Oct				Nov				Dec			
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School breaks are highlighted in light green.

2.4 Anticipated Participation in Integration and Launch operations

Payload integration: We plan to attend Payload integration in July 2023. Our current plan is to select both sub-team leads, the System Engineer, and the Project Manager to go to Payload integration. We already have the approved travel budget for four team members.

Launch operations: We plan to attend Launch operations in Sept 2023. We have the travel budget for six team members.

All members of WhenBuffsFly are citizens of the United States.

3. Payload Interface Specifications

3.1 Weight Budget

Table 8 shows the weight budget for the payloads and its components. We got most of the weight by estimations, like the bolts, washers, insulation, and epoxy. Things that we could look up like the raspberry pi zero and voltage regulator, we could find them online on the product information. With estimation and the actual weight, we figured out that the total weight will be 2.276 kg with an uncertainty of about .8 kg. The weight we calculated is under the maximum 3 kg.

Table 8: Weight Budget

Item	Mass (kg)	Uncertainty (kg)	Comments
Payload body (Aluminum 6061)	1.0	0.5	This is not the final value
LunaSat x10	0.2	0.05	Might be less for the new design of the LunaSats
Insulation	0.5	0.05	
Bolts	0.4	0.05	
Epoxy	0.05	0.05	
Washers	0.1	0.05	
Raspberry Pi Zero	.009	.0005	
Semtech SX1272	.0154	.005	
L7805 voltage regulator	.0016	.00005	
Heating Element COM-11289	0.01	0.005	Weight is estimated
Misc	.1	.05	Wires, solder
TOTAL	2.386	~0.8005	These are all over estimates. The final weight will most likely be smaller.

3.2 Power Budget

Table 9: Power Budget

Item	Voltage (V)	Current (mA)	Power (W)	Comments
Raspberry Pi Zero	5	120	0.6	
8 LunaSats connected to HASP power	3.3	230	0.76	Average from RF on and off
RF Transceiver - Semtech SX1272	3.3	18	0.059	
Real Time Clock - DS1307 RTC Module	5	1.5	.0075	
Heating Element COM-11289	5	130	0.65	The max. current for the element is 600 mA
TOTAL		499.50	2.08	

3.3 Downlink Serial Data

The LunaSat Testbed will downlink measurements corresponding to interior and exterior temperature, and solar panel voltage on the exterior LunaSats. The maximum possible size of the data package is 39 bytes. Two packets will be downlinked per second, for an anticipated data rate of 624 bits per second. We intend to downlink data for the entire duration of the HASP flight, from power-on to power-off.

The format of a data packet will be:
<Institution Name (2 bytes)>,<Project Identifier (2 bytes)>,<POSIX Timestamp (64 bit integer - 8 bytes)>,<adler32 Checksum (32 bit integer - 4 bytes)>,<Interior temperature data (4 bytes)>,<Exterior temperature data - 4 bytes>,<Voltage from exterior LunaSat 1 (4 bytes)>,<Voltage from exterior LunaSat 2 (4 bytes)>

3.4 Uplink Serial Commanding

The LunaSat Testbed will use uplink serial commanding (as described below) to provide our team with troubleshooting capability. Because the LunaSats do not themselves include serial command functionality, these commands are restricted in scope to run on the Raspberry Pi Zero flight computer.

Table 10: All Uplink Commands With 2 Byte Hex And Description

Payload Command	Two Byte Command	Description
Reboot Raspberry Pi Zero Flight Computer	0xAA 0x00	Reboots flight computer
Ping Raspberry Pi Zero Flight Computer	0xBA 0x01	Pings flight computer to test communication

3.5 Analog Downlink

The LunaSat Testbed will not use, nor require analog downlink.

3.6 Discrete Commanding

The LunaSat Testbed will not require discreet commanding.

3.7 Payload Location and Orientation Request

Due to the nature of the experiment, the LunaSat Testbed does not require a specific location on HASP.

3.8 Special Requests

The LunaSat Testbed design is within all HASP constraints and requires no special accommodations.

4. Preliminary Drawings and Diagrams

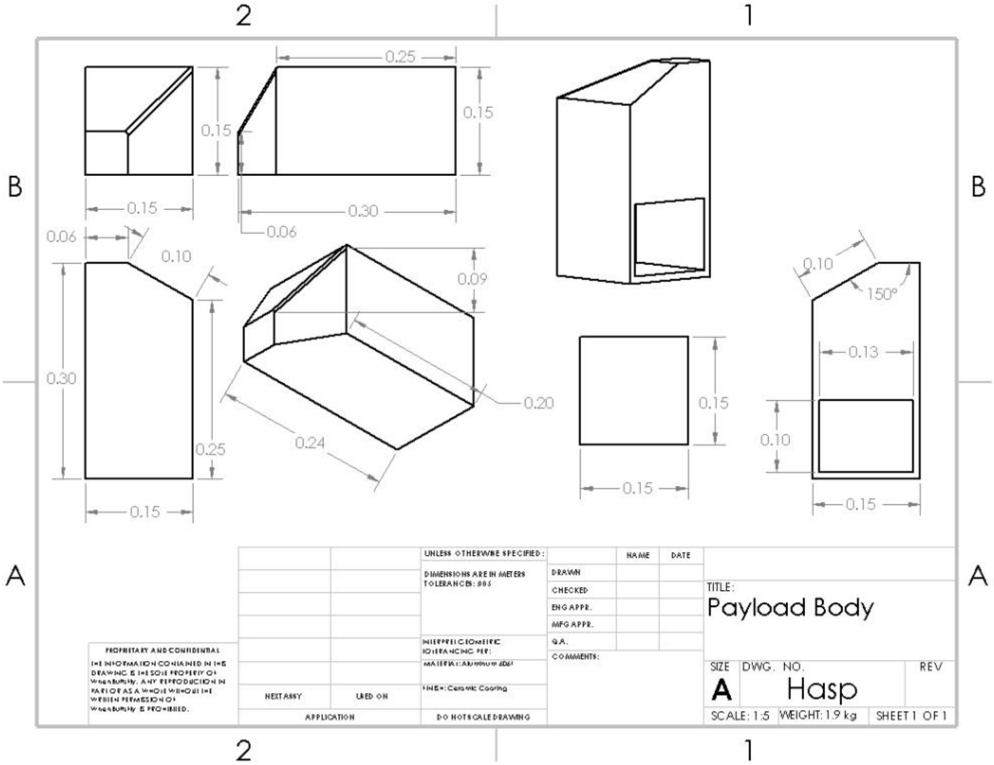

Figure 7: Structure of Payload Body

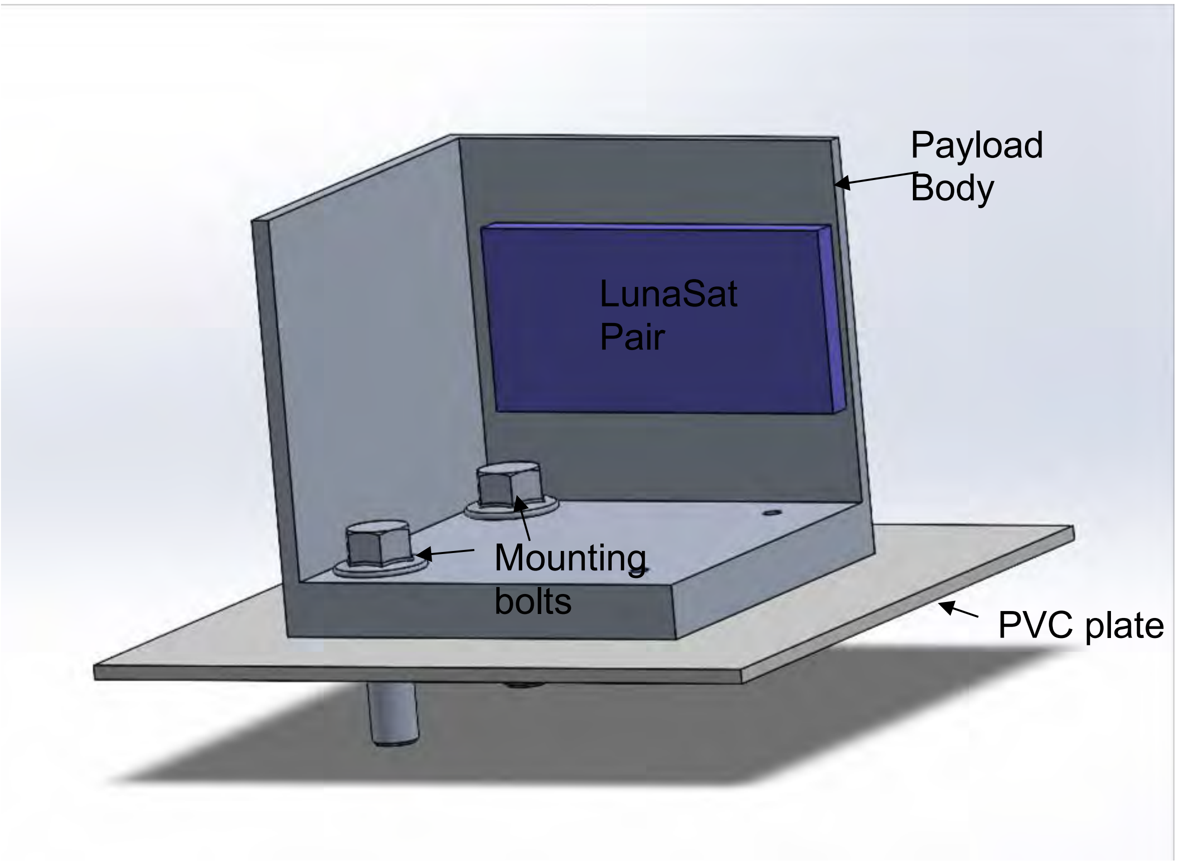

Figure 8: Bottom Plate of payload body, not drawn to scale

5. References

[1] “The Great Lunar Expedition for Everyone .” *Mission*, Colorado Space Grant Consortium, accessed January 4, 2022. https://www.glee2023.org/mission.
[2] “The Great Lunar Expedition for Everyone .” *Workshop*, Colorado Space Grant Consortium, accessed January 4, 2022. https://www.glee2023.org/workshop

Appendix A

Appendix A.1: Detailed electrical drawings

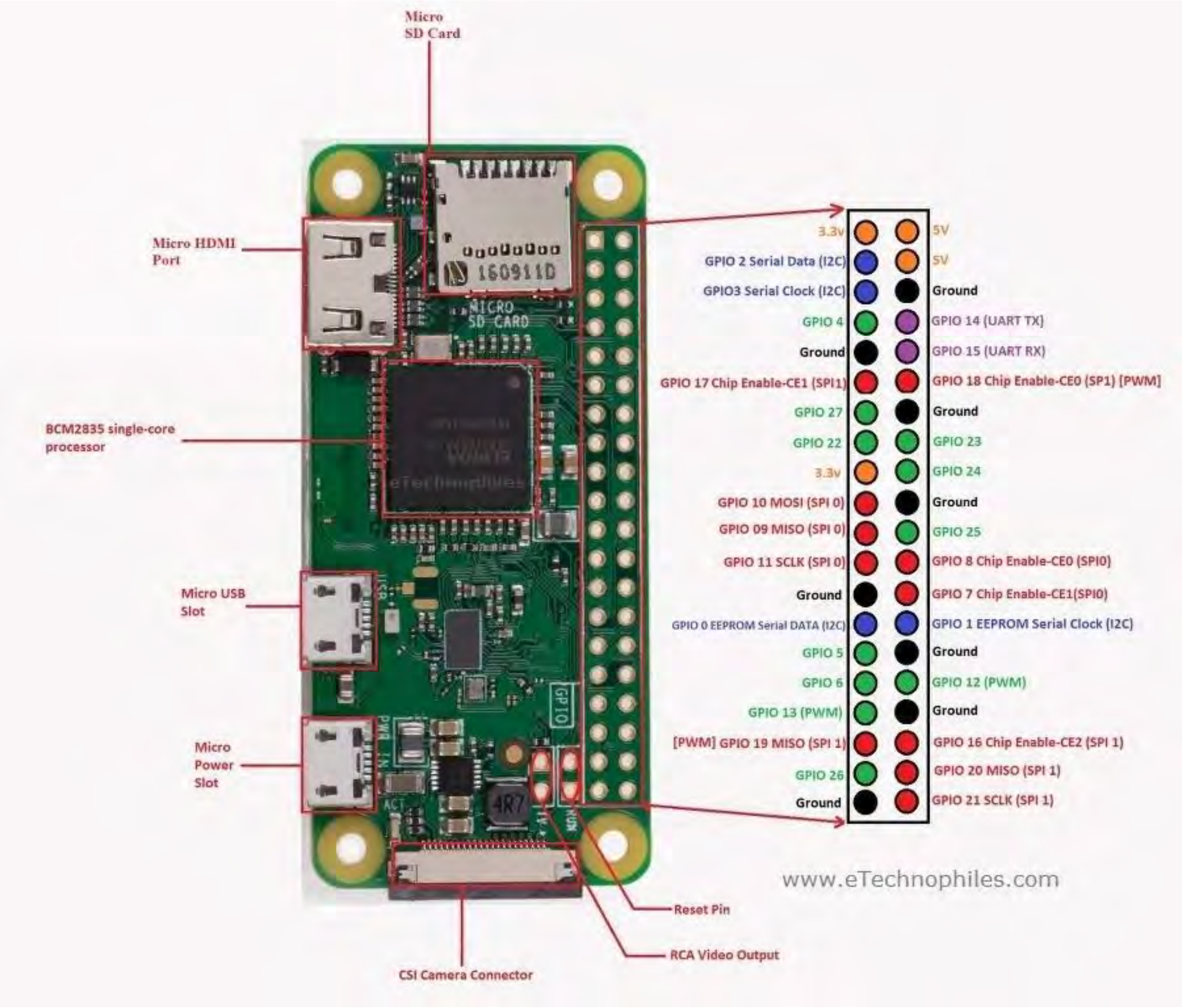

Figure 9: Components on The Raspberry Pi Zero

Appendix A.2: Detailed mechanical drawings

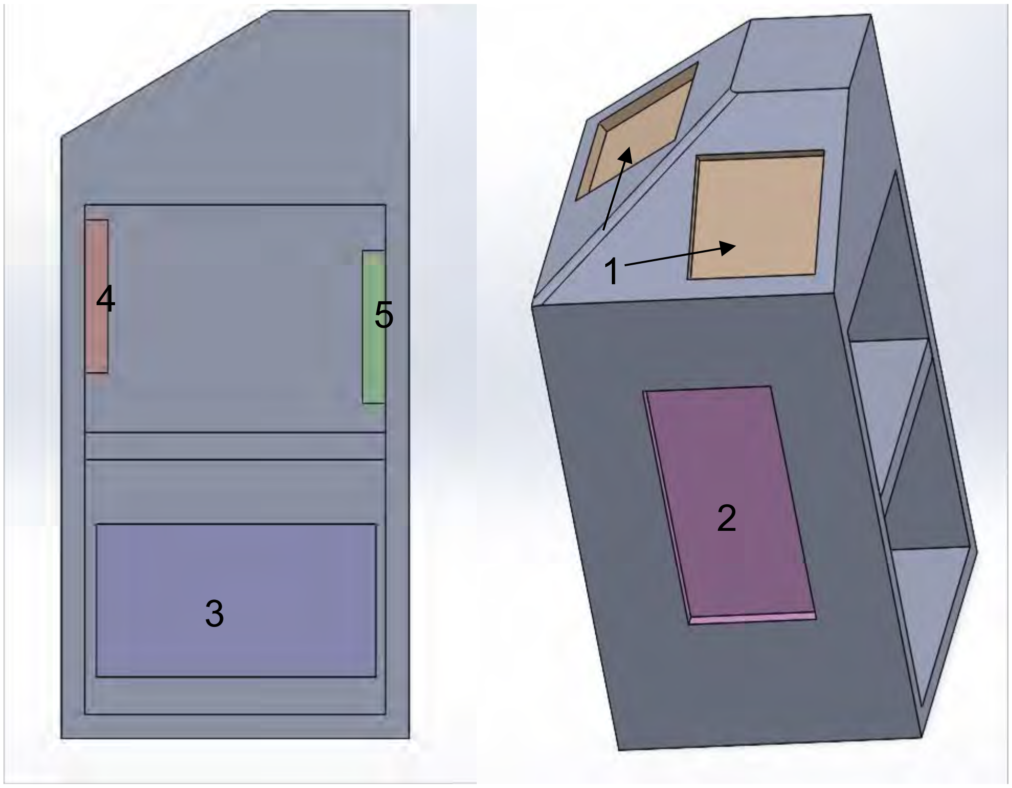

Figure 10: LunaSat Pair locations

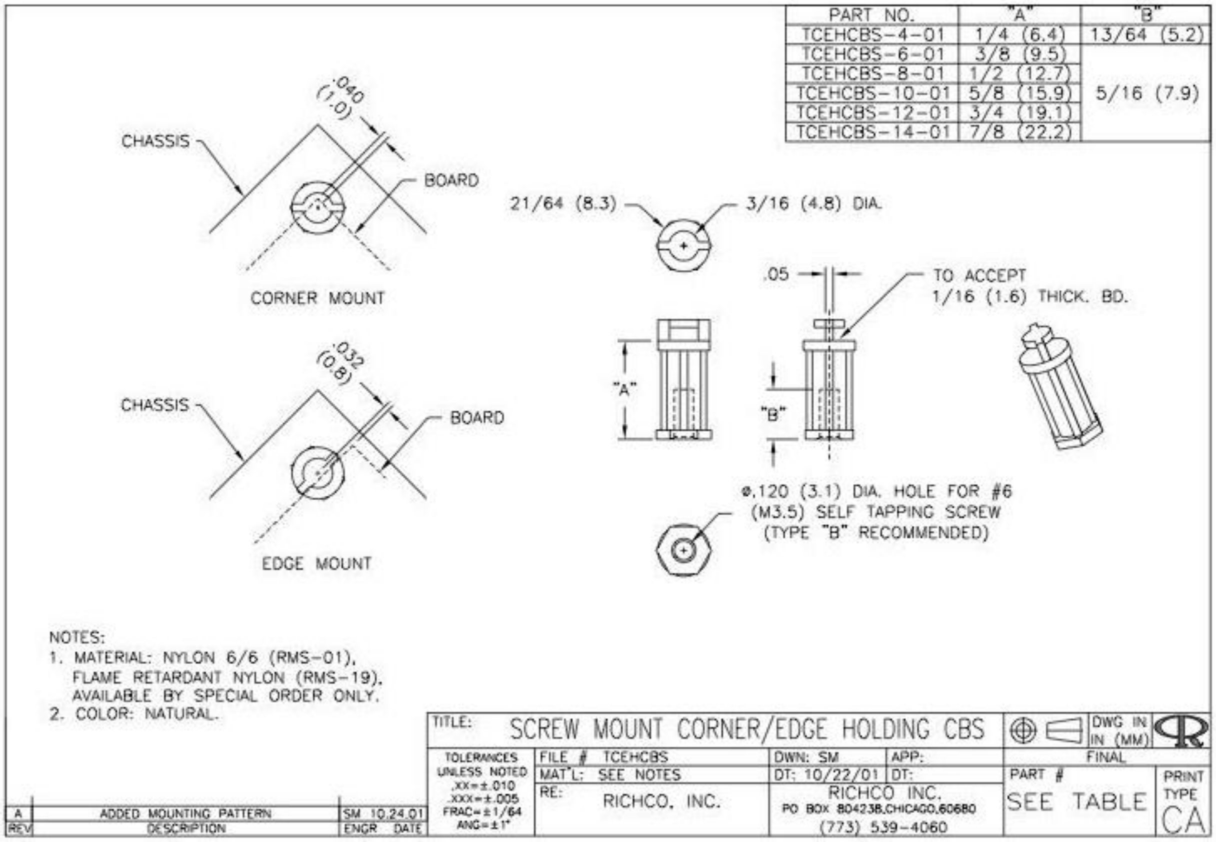

Figure 11: Drawing for PCB mounting hardware

Appendix A.3: Detailed timeline and milestones WBS document

Table 11: Milestone Chart

Dates of Milestones	Description of Work
January	Internal CoDR, Conceptual Design Review
January 6	Application deadline
February	Start software development, start structures design, start electronics design, Monthly status reports and teleconference, internal PDR, Preliminary Design Review
March	Finish software develop, Finish structures design, finish electronics design, Monthly status reports and teleconference
April	Start structures Manufacture/ Build, start power building, start software testing, internal CDR, Monthly status reports and teleconference, internal CDR, Critical Design Review
April 28	Preliminary PSIP deadline and NASA Flight On-site Security Document deadline
May	Structures Manufacture/ Build, Power system testing, Integrate Power System, Monthly status reports and teleconference, Internal Environmental testing of components
June	Attachment of LunaSats, Integrate Power System, Internal Environmental testing of the structure, Monthly status reports and teleconference
June 30	NASA Flight On-site Security Document Deadline and Final PSIP deadline
July 21	Final FLOP document Deadline
July 24-28	Student payload integration at CSBF
July-August	Monthly status reports and teleconference, Internal Environmental testing on payload, Integrate Power System, Software testing, FRR, Flight Readiness Review, Corrections integration if needed
Sept 3-10	Target flight ready, Target launch data and flight operations, Recovery, packing, and return shipping
September-November	Analyze Data from flight, Monthly status reports and teleconference
Dec 8	Final Flight Science Report Deadline

Table 12 : Gantt Chart

Milestones	Jan				Feb				March				April				May				June				July				Aug				Sept				Oct				Nov				Dec			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
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Appendix A.4: LunaSat Components

Components on the LunaSat:

- Capacitive sensor (Custom)
    - measures dielectric constant
- Temp sensor (TMP117)
    - measures temperature of the board
- Magnetometer (MLX 90395)
    - measures magnetic fields on three orthogonal axes
    - will be changed on next LUNA SAT model
- Accelerometer (MPU6050)
    - measures force in X, Y, and Z directions
- Thermopile sensor (TPIS1285)
    - measures the temperature of something in front of it with IR sensors
- RF transmitters (Semtech SX1272 transceiver, TI SWRA416 PCB Helical Antenna)
    - used to transmit data to central computer
    - uses LoRa modulation for sending data packets
    - uses SPI protocol to communicate with microcontroller

Figure 12: Front of LunaSat

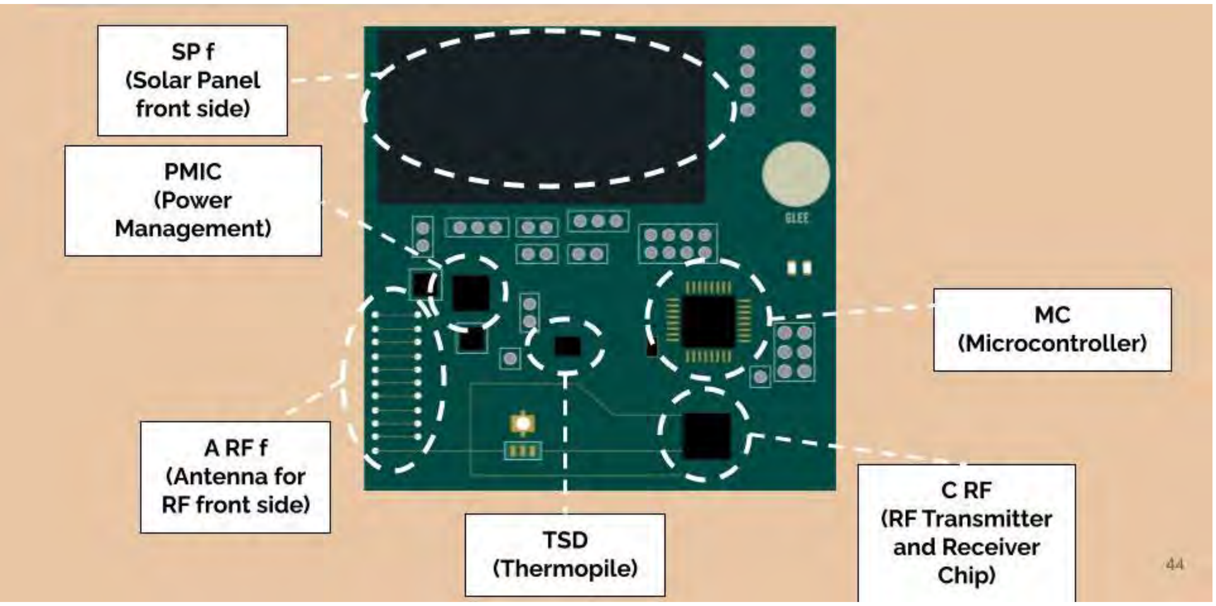

Figure 13: Components on the Front of LunaSat

Figure 14: Back of LunaSat

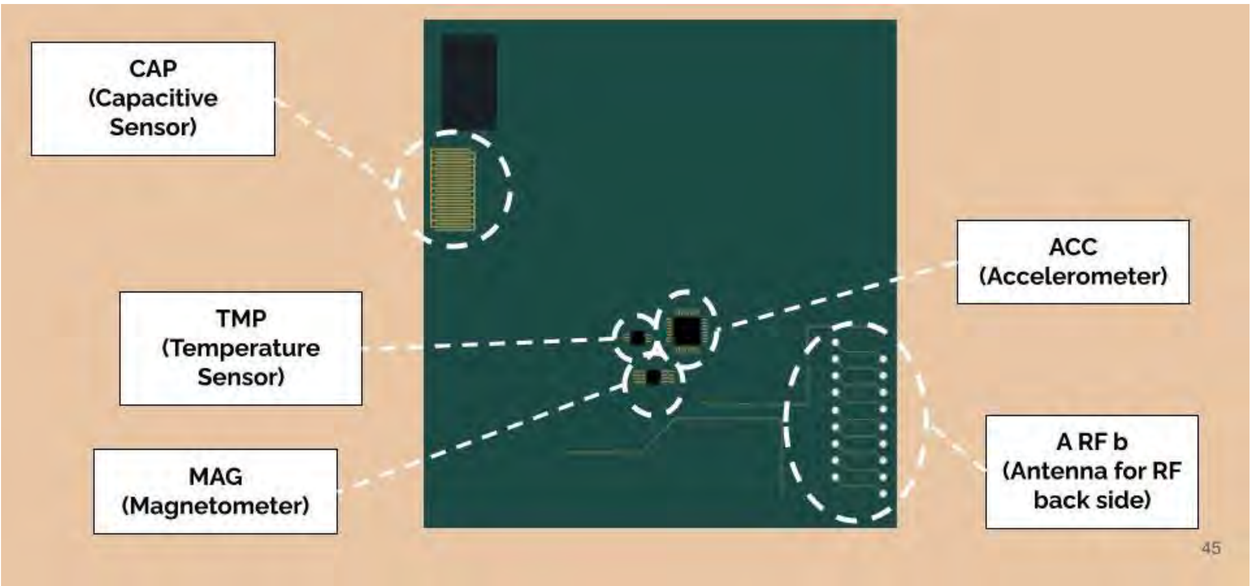

Figure 15: Components on the Back of the LunaSat

Appendix B: NASA Hazard Tables

Appendix B.1 Radio Frequency Transmitter Hazard Documentation

Table 13: RF Hazard Documentation

HASP 2022 RF System Documentation	
Manufacture Model	SX1272IMLTRT
Part Number	Semtech SX1272 (transceiver)
Ground or Flight Transmitter	Flight
Type of Emission	Spread Spectrum
Transmit Frequency (MHz)	915 MHz
Receive Frequency (MHz)	915 MHz
Antenna Type	TI SWRA416, Miniature helical PCB antenna
Gain (dBi)	0.01 dBi expected from reference designs. Preliminary measurements read approx -10 dB
Peak Radiated Power (Watts)	0.01 dBm (1 mW) expected from reference designs. Current assumptions (+18 dBm transceiver output) and preliminary measurements (-10 dB "gain") predict 6.3 mW peak power.
Average Radiated Power (Watts)	-2.61 dBm (0.5 mW) expected from reference designs.

Appendix B.2 High Voltage Hazard Documentation

The LunaSat Testbed will not use, nor require any high voltage hazards.

Appendix B.3 Laser Hazard Documentation

The LunaSat Testbed will not use, nor require any laser hazards.

Appendix B.4 Battery Hazard Documentation

The LunaSat Testbed will not use, nor require any battery hazards.