HASP Student Payload Application for 2022

Payload Title: Project OURANIA			
Institution: College of the Canyons			
Payload Class: LARGE			Submit Date: 01/07/2022

Project Abstract:
Team Ourania will use a scintillator to precisely measure the frequency of antimatter collisions in the atmosphere. Improving our 2021 HASP design, we will incorporate a larger and more accurate scintillator to better detect these collisions. This will be executed by using a larger scintillation crystal with a better performing PMT and ensuring that our software can collect and transmit data during flight. In gaining an estimate of the frequency of antimatter collisions, we will be better able to understand the ongoing processes within Earth's atmosphere, as well as the nature of these collisions and their role in the composition of the universe. Furthermore, we are utilizing functional artwork to help protect the payload from extreme conditions in the stratosphere and serve as its own experiment in observing how the various mediums respond to temperature changes.

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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 (grey filled items on table below) 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.

Hazardous/banned materials on payload (if using RF transmitters/high voltage must write documentation)

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
Batteries	X	
High intensity light source		X

Student Team Leader Signature: ___________Melissa Rocha___________

Faculty Advisor Signature: ___________Teresa Ciardi___________

Table of Contents

1. Payload Description

The College of the Canyons Aerospace and Sciences Team Payload titled Ourania will be a particle detector and art medium tester. Elements of our 2021 NOVA payload will be incorporated into the new design, including some legacy structural designs. With improvements to the software, a larger structure and surface area, we anticipate collecting enough data to determine the amount of antimatter particles colliding with the scintillator on our payload. The payload derives its name from the Greek muse of Astronomy, paying homage to a civilization of some of the greatest innovators of the arts and sciences, and reflecting the combined efforts of both artists and engineers on the payload.

1.1 Payload Scientific / Technical Background

For HASP 2022, team Ourania will be focusing on the detection of antimatter particles in the upper stratosphere, along with the added inclusion of artwork on the exterior to measure the reaction of different pigments and materials to the light and temperature in the stratosphere. Antimatter detection is allowed by the collision of conventional matter with antimatter, which releases an explosion of neutrinos and gamma rays. The produced gamma rays are absorbed by a plastic scintillator within the payload, which then converts them into a visible wavelength to be detected by a photomultiplier tube attached to the scintillator. The weak photon signals are converted into a strong stream of electrons that can be converted into measurable data to be analyzed. On top of the main experiment, a pair of thermistors is included to measure the temperatures on both the inside and outside of the payload. Mediums utilized in art will be tested on the outside of the payload to determine the effect of near space conditions on these materials.

1.1.1 Mission Statement

Team Ourania will use a scintillator to precisely measure the frequency of antimatter collisions in the stratosphere. Our mission is to utilize a larger scintillator and better performing system, improving upon our 2021 HASP design, to track particle counts in the stratosphere, and to observe the effects of near space conditions on student created artwork. We will design and test the enhanced scintillator system and use preflight data for comparison. Functional artwork will be included on the outside of the payload structure that will aid in maintaining interior temperatures and provide an opportunity to test how the various mediums respond to temperature changes.

1.1.2 Mission Background and Justification

For every particle of matter, there exists a particle with the opposite electric charge called antimatter. For example, the negatively charged electron’s antiparticle is a positively charged positron, and when they annihilate at rest, two gamma rays, each with energy 511 keV, are produced. These gamma rays are emitted in opposite directions, per the law of Conservation of Momentum. Essentially, when a particle and its antimatter particle collide, they disappear, and their kinetic and rest-mass energy is converted into other particles (E = mc2)[1], which our sensors will be detecting.

As of right now, antimatter is known to be primarily found in cosmic rays – extraterrestrial high-energy particles that form new particles as they enter Earth's atmosphere - or even during thunderstorms. Utilizing our position on NASA HASP, our team will use multiple detectors to quantify and find these cosmic rays as they enter the stratosphere.

In 2011, the European satellite PAMELA (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) found a self-renewing supply of antiprotons in the Van Allen radiation belt[2], a zone of charged particles originating from the solar wind that occurs around the planet's magnetosphere. The satellite detected evidence of 28 antiprotons orbiting Earth, and this year we would like to have our payload confirm these findings by improving the accuracy, precision, and accessibility of our data through the new payload.

Our team intends on using a scintillator coupled with a scintillation crystal, a material that converts gamma radiation into visible light that will be detected by the scintillator. When gamma rays, the product of antimatter collisions, hit the scintillator crystal and are converted into visible light, we will be able to count the number of cosmic rays that collide with the scintillator. By having an estimation of the frequency of these collisions, we can gain a better understanding of the number of antimatter particles present in the stratosphere.

1.1.3 Mission Objectives

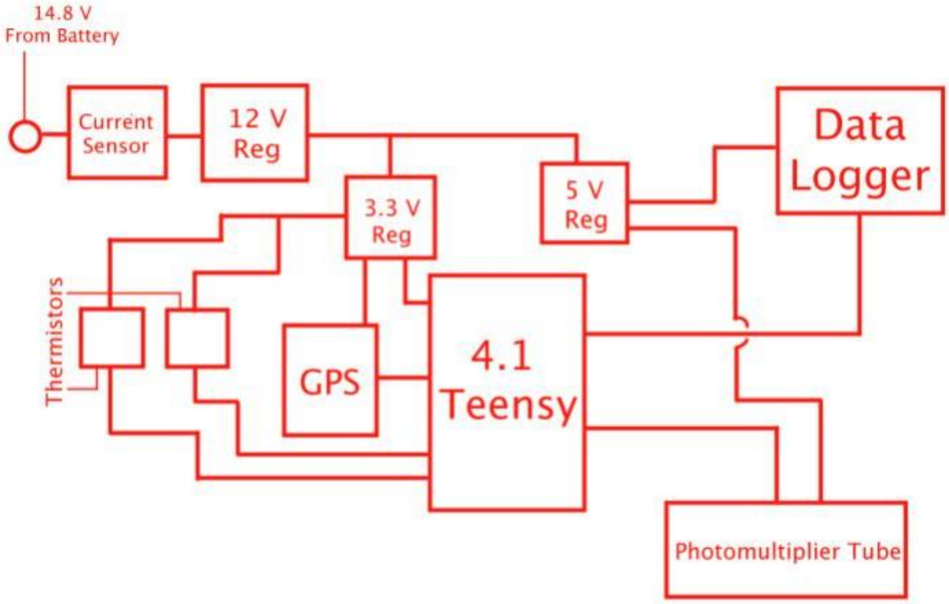
1. Test the effectiveness of plastic scintillators in the upper stratosphere.
2. Count the number of antimatter collisions in the upper stratosphere.
3. Test the functional capabilities of artwork on the exterior of HASP in aiding with temperature regulation and aesthetic qualities.

By using a plastic scintillator, we can test the effectiveness and longevity of this class of radiation detector during prolonged exposure to UV and cosmic radiation. By scaling up the size of our system, we plan to improve our experiment's ability to measure these collisions more precisely and accurately. This year, we added the concept of art that is functional (an experiment in itself) to our design to further test the capabilities of various materials in near space conditions.

[1] "What and Where is Antimatter". European Organization for Nuclear Research. 17 February 2012. cms.cern/physics/what-and-where-antimatter

[2] Cowen, Ron. "Antimatter Belt Found Circling Earth." *Antimatter Belt Found Circling Earth - ScienceNOW*, 20 Oct. 2011, web.archive.org/web/20111024152418/http://news.sciencemag.org/sciencenow/2011/08/antimatter-belt-found-circling-e.html.

1.2 Payload Systems and Principle of Operation



The detector itself has two main components, the PMT (Photomultiplier Tube) and the BC-412 Plastic Scintillator. Using an altimeter, we will expose the BC-412 scintillator to the atmosphere at an altitude of 100,000 feet, 20,000 feet below the maximum altitude. The crystal will then be exposed for 20-minute increments, scintillating as it is hit with gamma rays coming from anti-matter collisions. The PMT will then count the number of scintillations and send that signal to the Teensy 4.1 which will log the number of scintillations during that given period. This data will be sent to an onboard SD card, as well as downlinked.

A gamma ray interacting with a scintillator produces a pulse of light that is converted to an electric pulse by the PMT. The PMT consists of a photocathode, a focusing electrode, and 10 or more dynodes that multiply the number of electrons striking at each dynode. These electric pulses are then sent to our Teensy and counted as individual anti-matter collisions.

We are going to utilize two thermistors, one on the inside of the insulation and one out the outside of the insulation. This way we have data on how effective our insulation is, and we can use this for future missions.

1.3 Major System Components

1.3.1 Radiation Detector System

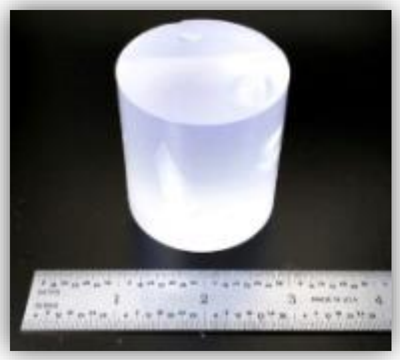


Figure 1: BC-412 Plastic Scintillator

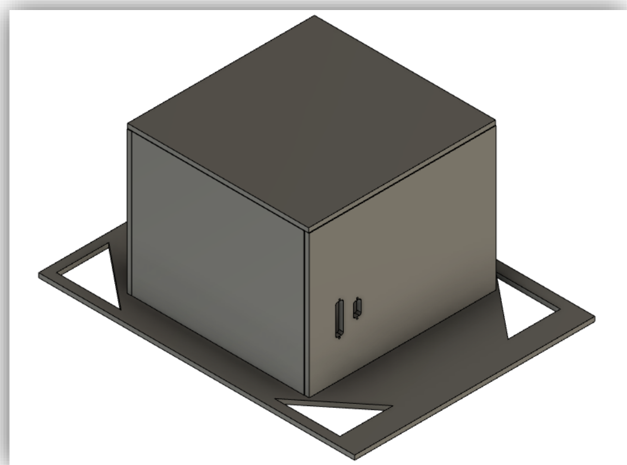
The scintillator crystal we plan on using this year is a BC-412 Plastic Scintillation crystal due to its high level of optical output. It can absorb gamma rays with an energy range of 100 keV to 5 MeV in addition to fast neutrons and charged particles and emit them in the form of visible light waves. Due to its ability to withstand high ultraviolet radiation, long attenuation length, and uniform response to cosmic radiation, the BC-412 scintillation crystal would be an effective type to use on our payload to gather reliable readings.

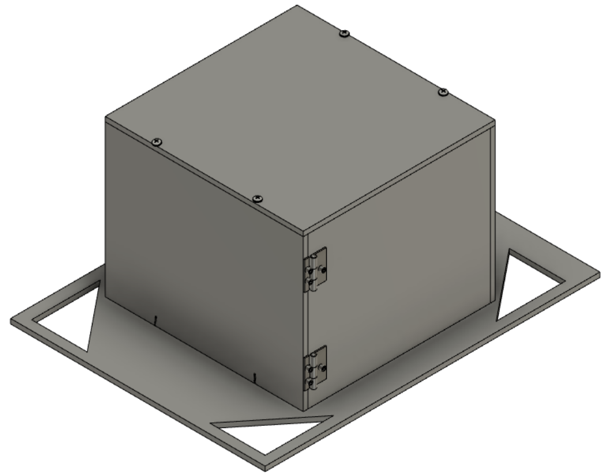
Figure 2: Hamamatsu H10722-01 Photosensor module

The PMT (photomultiplier tube) we are using is a Hamamatsu H10722-01 photosensor module, which takes the visible light emitted from the scintillation crystal and converts it to electrical signals for processing by the microcontroller, as further explained in the electrical components section 1.5.3.

1.4 Mechanical and Structural Design

A serious consideration for the HASP 2022 payload is the easy accessibility of flight components during fabrication and debugging, and the seamless operation of dynamic mechanical systems. Building off the 2021 NOVA design we intend to have two entry points to our electrical system for our 2022 Ourania payload. This will allow free accessibility to the internals of the payload without the constraint of having panels blocking the workspace. With this design, electronic wire management and repair can be performed effectively, and valuable time can be saved. Our previous one-door design was extremely useful, except it made it hard to access the Printed Circuit Board and we had an issue with cable management. With a two-door design, we will have increased access, making work more efficient. We are also using two hinges per side for our “doors” to have better stability during opening and closing.





Figures 1 and 2: Isometric Views of the Payload w/ Front and Back

In addition to the ease of access, the frame provides the rigid strength needed to overcome the +/-5g horizontal shocks in the XY-directions and +/-10g shocks in the Z-direction, as required by HASP payload criteria. This year we also plan to reuse Mylar blankets to help combat temperature changes inside the payload. On the outside of the payload, our team member's artwork is intended to help regulate extreme temperatures.

1.5 Electrical Design

Our main experiment will be utilizing a photomultiplier tube setup with a scintillator to pick up gamma rays from antimatter collisions. Our secondary experiment is two thermistors that are designed as a temperature comparison from the inside of the insulation to the outside of the insulation. We are also going to utilize a current sensor to monitor our power usage and give us data on how much power the capsule uses during flight versus what is estimated and tested prior to flight.

Our preliminary electrical schematics are shown in section 1.2. The diagram shows each electrical component along with locations from which each component will draw power.

1.5.1 Microcontroller

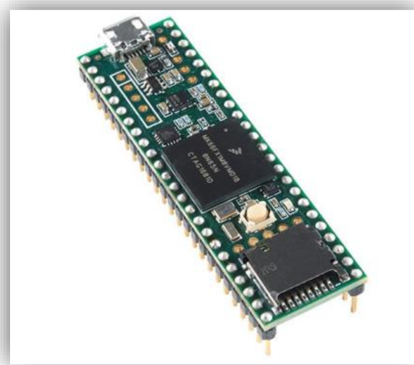


Figure 3: Teensy 4.1

We have decided to utilize a teensy 4.1 for its processing power, pin count, and low power consumption. The Teensy 4.1 will allow us to have a higher level of processing power and multiple pins, for quick sensor input and response time, which makes this the best computer for our project. The flight computer's main task is to provide a primary hub for passive sensor data monitoring, sensor data processing, battery/relay control, logic checks, and controlling/staging various hardware. Additionally, the board provides power and communication to any required shield expansion boards needed for interfacing with sensors and data storage devices.

1.5.2 Data Logger

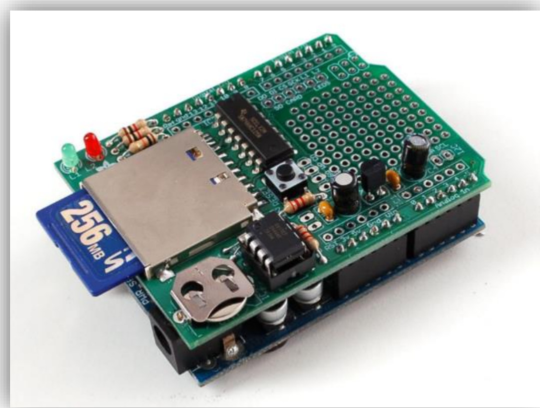


Figure 4: Adafruit Data Logger

The data logging protocol and design for this mission will be aimed towards storing data safely and reliably to preserve a record of every process during the flight. Data loggers can be delicate systems if operated without the use of correct fail-safe circuitry and software. Multiple data logging devices will be used to ensure that vital flight information is not lost if one data logger fails. The same Adafruit data logger used in the previous flight will be used in this flight with the addition of improved software and an SD card capable of protecting data from rapid shutdowns. The Samsung PRO series GB SD card provides excellent protection from data corruption caused by rapid power shutdowns. Smarter programming for the shield will allow the serial data downlink to send down status reports on how much data has been logged to the SD card, which the particle count.

1.5.3 Photomultiplier Tube

Figure 5: Hamamatsu H10722-01 photosensor module

We plan to use the Hamamatsu H10722-01 photosensor module, allowing us to sense any output from the scintillation crystal. The module contains a metal package PMT and an amplifier that converts the current output to voltage for our microcontroller. Its signal is resistant to external noise and can be powered by a simple 5V power supply, eliminating the need to have a potentially hazardous high voltage power supply on our payload.

1.5.4 Battery

Figure 6: POVWAY 5200mAh 2S LiPo Battery

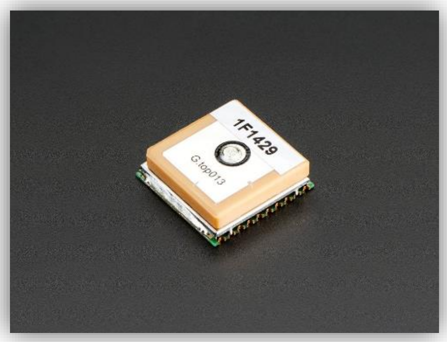
The payload will require two 5,200 mAh LiPo batteries in series to provide a 14.8V output. The output goes to the current sensor which in turn goes to the 12V voltage regulator.

1.5.5 Power Management

Figure 7: RECOM Power Converter

The payload will be using multiple voltage regulators to bring down the voltage for components which require a specific voltage. Three voltage regulators will be used on the payload: 3.3V voltage regulator, 5V voltage regulator, and 12V voltage regulator. The Battery supplies 14.8V which is brought down to 12V using the 12V voltage regulator after passing through the current regulator. Our main power rail will be supplying 12V to the payload, bringing down the voltage to 3.3V with the 3.3V voltage regulator for the teensy, GPS, and thermistors. We will be using 5V for the data logger and the PMT which will be brought down using the 5V voltage regulator.

1.5.6 Sensors



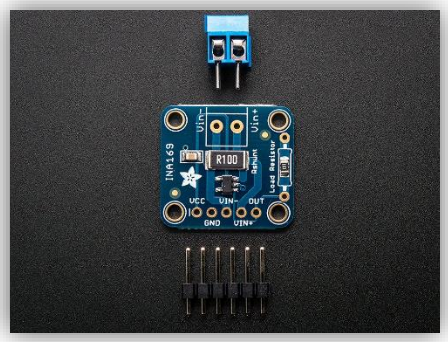



Figure 8: MTK3339 GPS Module
Figure 9: DS18B20 Temperature Sensor
Figure 10: INA169 Analog Current Sensor

The payload will be using several types of sensors to measure the data that will be processed by the Teensy processor. The first of these would be the "MTK3339" GPS sensor, which would provide us with the current position of our payload up to an altitude of 60,000 ft (the altitude limit of civilian GPS devices). The next sensor is a pair of the "DS19B20" temperature sensors, intended to measure the inside and outside temperatures of the HASP payload casing. Finally, we have the "INA169" current sensor, for measuring the total current of the payload electrical devices.

1.6 Software Design

Using a Teensy 4.1 board, we will attain and keep track of several values over the course of the balloon flight:

- Number of photon particle hits, attained from the PMT (Photomultiplier Tubes) and the Scintillator Crystals (list of integer values)
- The temperatures on the inside and outside of the payload capsule, attained by an arrangement of Thermistor sensors (list of double values)
- The current position of the payload, attained from an onboard GPS sensor (list of double values)
- Battery/relay control

Both the position of the payload and temperature will be monitored during flight through HASP downlink. All the recorded data will be saved to an SD card, until the card is full. Alongside every data entry, there will be a timestamp, so we have the exact time reading for each data entry. The recorded data will be automatically split into several smaller files, to make the resulting data files easier to open & read after the flight.

A fundamental flaw in our HASP 2021 software was the lack of organization with which information gets saved to the SD card. Since there was no loop delay, our SD card quickly filled up with meaningless data. A significant improvement we will implement in this year's project is to collect data only once the program detects a radiation spike to economize our SD card space.

1.7 Thermal Control Plan

During the flight, we expect our payload to encounter temperatures ranging from –50 C to 100 C, with the maximum operating range being around 120 C. Therefore, the team will make it a priority to ensure the payload maintains a manageable temperature utilizing both active and passive thermal control systems. We plan to utilize multi-layered Mylar sheets and reflective Kapton (polyimide film) tape along the interior of the payload to insulate the electronics and slow down the effects of outside temperatures. These materials have been tried and tested with previous payloads and are a simple and effective solution to insulating the interior.

Additionally, functional artwork will be used on the exterior to help the payload resist higher temperatures. While still abiding by the general rule-of-thumb that around 50% of the exterior should be white, we plan to incorporate artwork that is both heat resistant and may change appearance depending on the external temperature. The reactions of these materials to near space conditions and their contribution to protecting the payload interior will be evaluated during flight using exterior cameras and temperature sensors such as thermistors and will be analyzed upon retrieval of our payload.

Our active thermal control system will include flexible electric heating pads to regulate the internal temperature when conditions are colder. The heating pads consist of a metal polymer fiber composite yarn integrated into a fabric that is contained within a Kapton sheath to allow for even heat distribution. It has an input of 5V with a current of 0.74 A and can attain a peak temperature of 40 degrees Celsius. With sensors placed throughout the interior of the payload – particularly near sensitive electronics – we plan to create a heating system that will activate and deactivate depending on the interior temperature.

1.8 Artwork Design

The artwork on the exterior of the payload adds a new component to the HASP 2022 design, serving both a functional and aesthetic purpose. Much like the works of both ancient and modern civilizations, the exterior artwork is a romantic expression of the creativity of humankind, taking its visual and emotional expression to literal new frontiers by kissing the edge of space. Mediums utilized will be chosen for both thermal properties and artistic expression.

1.8.1 Theme

Every piece featured follows a cohesive theme which encompasses the union of deep-sea and deep-space. Both are highly unknown and undiscovered realms: space is of seemingly infinite bounds and the ocean is more than 80% unexplored. Artists are encouraged to look at the vast arrays of life found in the ocean and draw influence from its many organic forms such as the aquatic flora, fauna, and geology. This, combined with the science fiction appeal of deep space and its many possibilities (aliens, exoplanets, technology, various cosmic forms, etc.) makes for an extremely open-ended theme that allows for a wide array of visual interpretations. Sending artwork depicting motifs from the depths of the Earth to the very edge of space is both ironic and poetic, making for an intriguing and unique exterior of the payload.

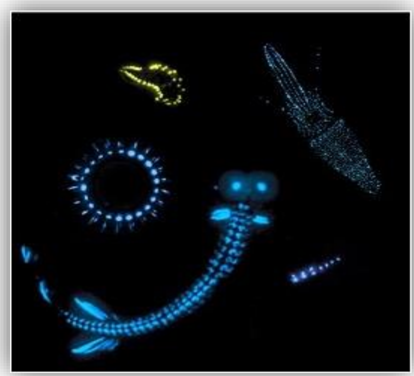


Figure 1: Bioluminescence in deep sea animals

Figure 2: Luminescence from stars and galaxies, a visual similarity between the deep ocean and space

1.8.2 Function

The artwork is an experiment of its own. Many of the materials are chosen based on the functionality and personality they can bring to the payload through either their abilities to aid in cooling the capsule, or transformative visual effects. We plan on using small cameras mounted on the payload's base to observe the effects of stratospheric conditions on the materials while also prioritizing construction guidelines.

At least 50% of the payload's exterior will be white to ensure proper reflection of sunlight. The incorporation of reflective paints will further help to optimize the capsule's cooling abilities. Some of the paints change colors once they reach a certain temperature, allowing the artwork to visually express the thermal conditions of the capsule. Designs and artwork can also be "revealed" by thermochromic pigments, making for an ever-changing visual effect. 3D artwork such as sculptures either made from clay or 3D printed filaments add another layer to the exterior. The changing position of the payload will alter the appearance of 3D pieces due to the altering direction of light, which influences the position of shadows on the sculptures. Metallic foils aid in cooling the capsule and serve as a callback to the Byzantine-era techniques involving gold foil as an embellishment in the art to accentuate certain figures. The thinness of the stratosphere means the UV radiation from the sun is far harsher on pigments and materials used in the artwork as compared to the amount of UV that reaches Earth's surface, so the exterior artwork will also function to test the lightfastness and endurance of the pigments used.

1.8.3 Materials

The various materials listed below will be tested in their thermal capabilities to resist the extreme temperatures before they are cleared to be used on the capsule's exterior. Parameters of the artwork and materials are

1. Must be able to withstand a temperature range of 50º C to 100º C without melting or cracking
2. Exterior must be at least 50% white
3. 3D artwork may not extend out more than 1.25 inches (3.175 cm) from the main structure of the payload and be within the keep-out area of the payload deck

1.8.3.1 Thermochromic Paint

Thermochromic pigments incorporate either liquid crystals or leuco dyes which change colors in response to temperature fluctuations. Specific paints must be applied over a black surface, which means it must be used sparingly so as not to absorb too much heat into the payload.

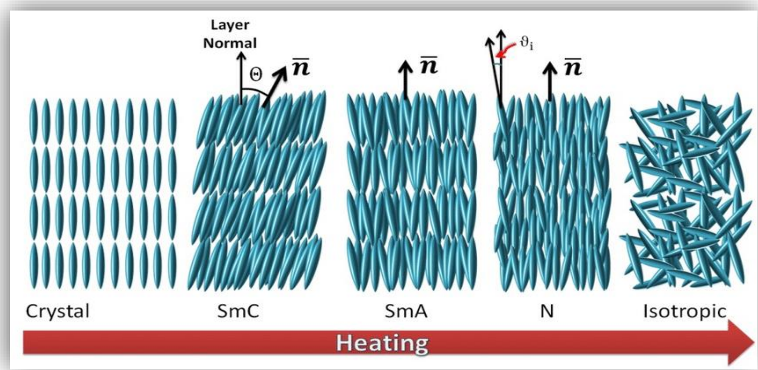


Figure 3: Liquid Crystal Paint

Figure 4: A diagram of the crystalline structures within the paint and their reactions to temperature changes

Some paints may change from one color to another, which may be incorporated to create images that appear as the paint reaches its threshold temperature.

1.8.3.2 Metallic Leaf

Paper-thin metallic sheets are a well-known and long-lived technique in art, most famously used in Byzantine-era religious artwork. Pieces of metal are hammered flat until they become a flexible sheet that can be gently applied to a surface to embellish specific areas of a piece. It brings an almost religious feel to the artwork, gilding it in precious metals.

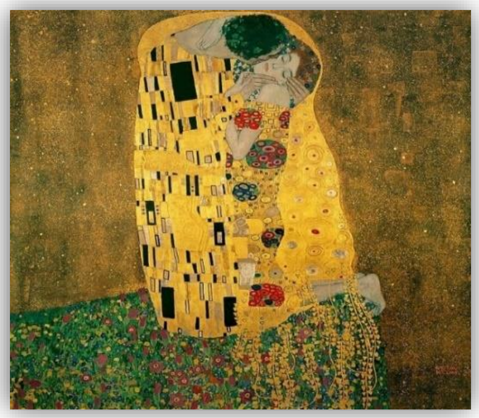


Figure 5: Gustav Klimt's "The Kiss" which uses gold foil to highlight the central figures
Figure 6: Gold leaf sheets

1.8.3.3 Interference Paints

Interference paints are unique in the way they get their color. Rather than light reflecting directly off pigment flakes, tiny structures within the paint refract light to give an iridescent appearance, like the colors and textures on butterfly wings and mother of pearl.

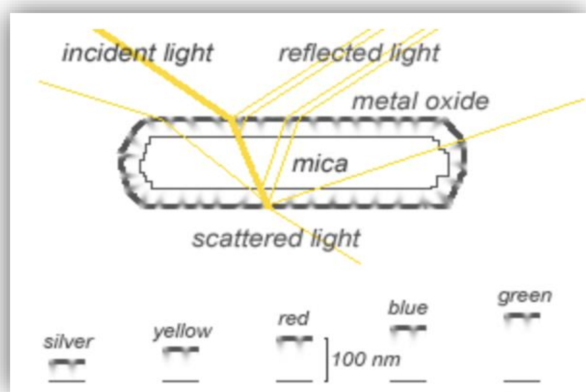


Figure 7: Diagram of a mica powder filament refracting light beams
Figure 8: GOLDEN brand acrylic interference paint demonstrated on both black and white surfaces

1.8.3.4 Spray Paint

Caliper paint is commonly used in the customization of vehicle brake calipers, drums, and springs. This material is designed for high resistance to heat and brake dust. This type of paint is meant to withstand temperatures up to 428 °C. By using their own customized stencils, artists can spray their designs onto the exterior of the payload and create artwork that is uniform, clean, and–most importantly–can withstand the extreme temperatures of the stratosphere.

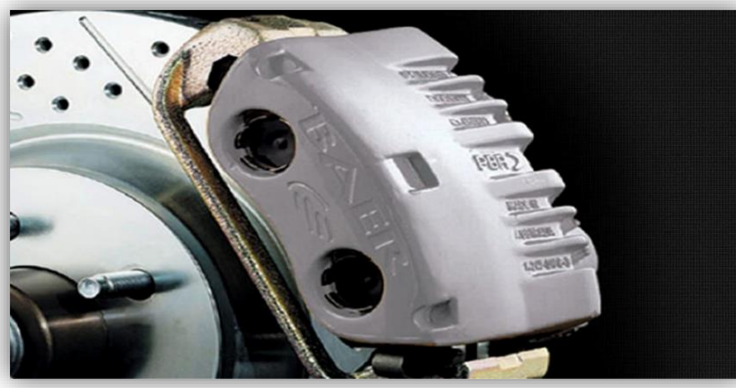


Figure 9: VHT brand caliper spray paint
Figure 10: Grey colored caliper paint used on a braking system

1.8.3.5 Nylon Filament (Polyamide)

Nylon Filament is a synthetic plastic that allows for a high range of flexibility and is known for being a durable thermoplastic filament. This type of material can withstand temperatures up to 240 °C, which means the material is less likely to warp during travel. Artists can scan their 3D artwork then print it using nylon filament to be secured via Epoxy to the exterior of the payload. This adds an extra layer of depth to the artwork and allows sculptors to create interesting structures which may scatter shadows across the payload's surface depending on the direction of light.

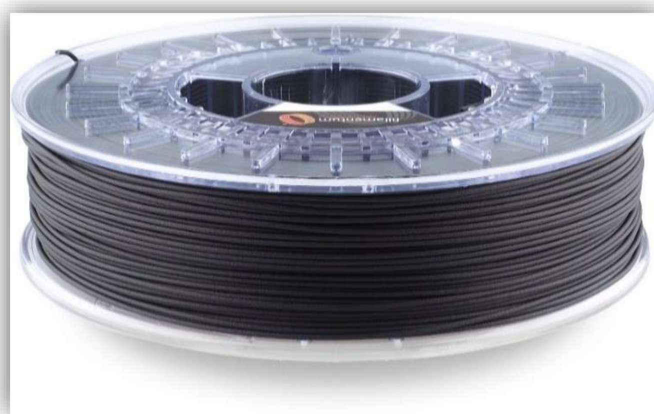


Figure 11: Nylon filament spool

1.8.3.6 Epoxy

Used as both a sealant and adhesive, epoxy is capable of being used on a wide range of materials while maintaining a high resistance to harsh chemicals and environments. Depending on the type, epoxy can withstand continuous temperatures up to 200°C or higher. Epoxy is crucial in affixing 3D printed artwork and sealing certain pigments such as liquid crystal paints. Its thermal resistance will also assist in protecting the artwork.

Figure 12: Epoxy Resin GlueFigure 13: Epoxy Clear Coat

2. Team Structure and Management

2.1 Team Organization and Roles

With our team having the largest number of members in recent years, Team Ourania has more fresh faces to contribute new perspectives and step up to leadership positions, bolstering our team's ability to plan, design, and execute our payload. In addition, with student mentors advising our team leads, almost all of which are serving in their positions for the first time, Team Ourania has a great balance of experience and initiative that will allow our project to thrive. This year, Teresa Ciardi and Greg Poteat are returning as our Logistics and Science Advisor and Manufacturing advisor respectively, with Melissa Rocha serving as our Project Manager.

Due to our addition of an art element to our payload, our team has expanded to include an art team, whose primary responsibility is to create multiple functional pieces to protect the payload in stratospheric conditions. Furthermore, our team will include a mechanical and an electrical department to design, manufacture, and operate our mechanical and electrical systems. Since our team has more people this year, we were able to create a software team separate from our electrical team, whose focus will be collecting and organizing our experiment's data.

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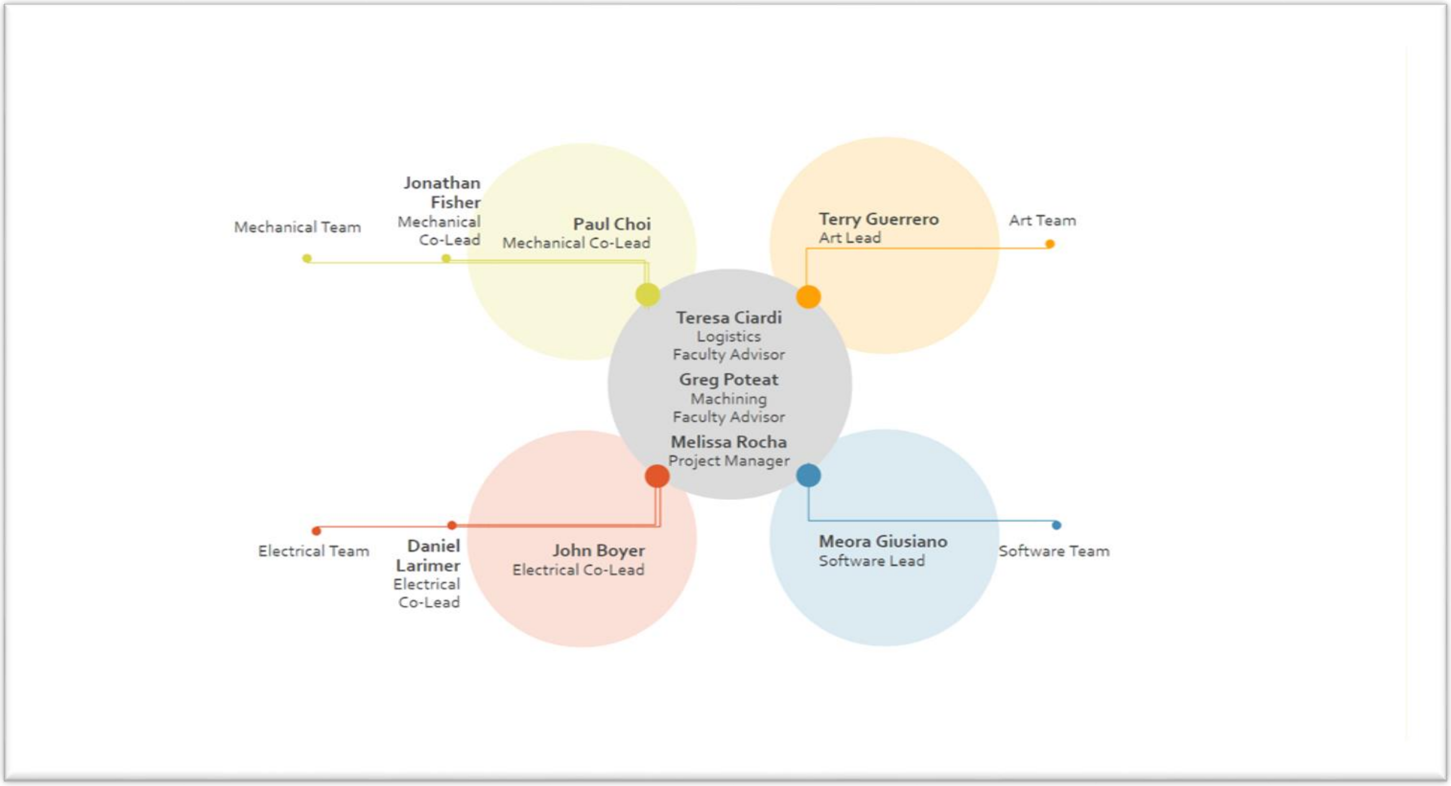
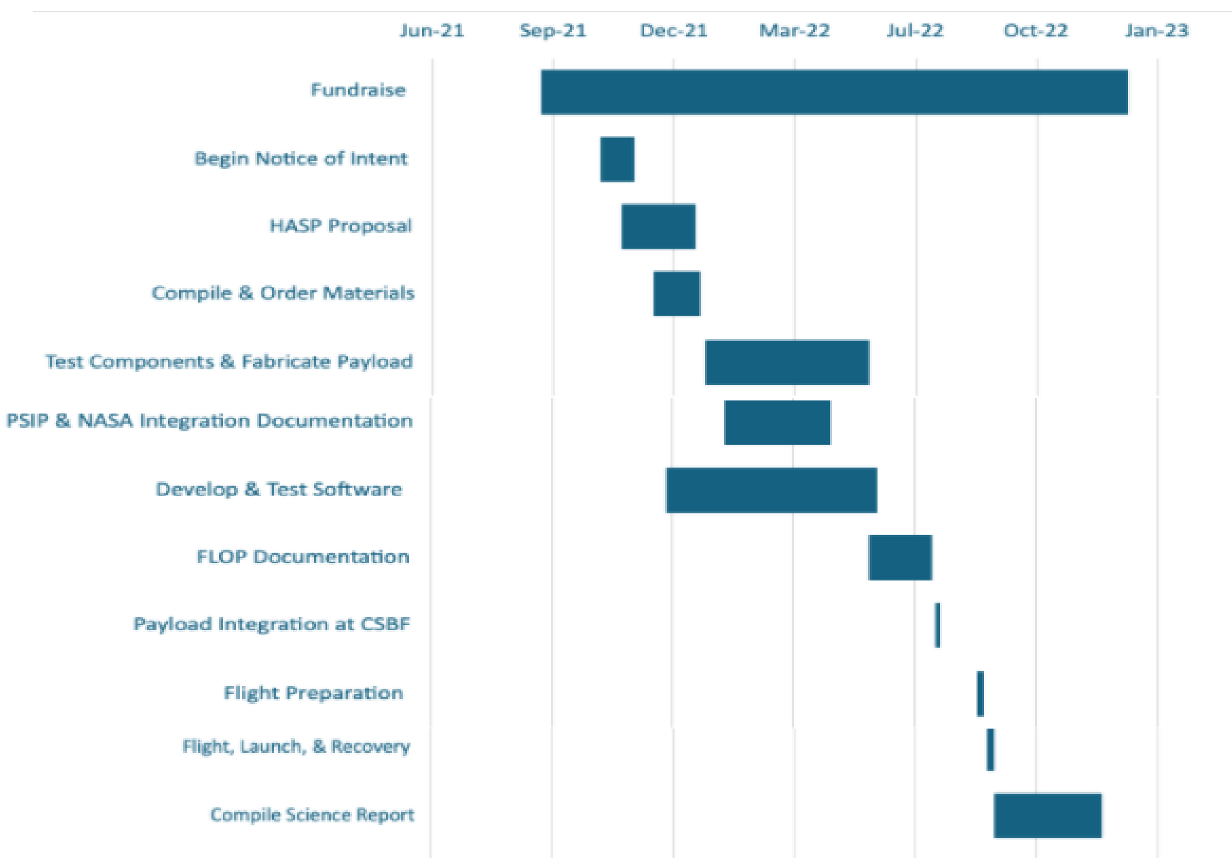
2.2 Anticipated Timeline and Milestones for Participation in Integration

Month of 2021	**Tasks**
October	Gather Team Leads
October 29th	Fundraise
October 20th	Begin Notice of Intent
November	Begin HASP Proposal Fundraise
November 17th	Notice of Intent filed
November 19th	Brainstorm Science Experiment
November 20th	Architectural Design Overview
December	Complete HASP Proposal

	Fundraise
December 3rd	Electrical Switches Discussion
December 4th	Materials List compiled
December 10th	HASP 2021 final report due
Month of 2022	
January 7th	HASP Application Due
January 8th	Analyze components from previous payload to reuse
January 10th	Finalize parts list for procurement
January 15th	Order parts and begin manufacturing of testing rig and components
January 28th	Announcement of student payload selection
February	Begin build (fabrication of payload & continue testing structure) Begin PSIP & NASA Integration Security Documentation
March	Begin work on electrical and computer systems Preliminary thermal-vacuum testing on select components
April	Continue testing on select components
April 15th-16th	Complete PSIP & NASA Integration Security Documentation
April 29th	Preliminary PSIP & NASA Integration Security Documentation due
May	Complete payload construction Revise PSIP Documentation
June	Finalize build/Begin FLOP Documentation Test Software
June 10th-11th	Complete Final PSIP & NASA Flight On-Site Security Documentation
June 24th	Final PSIP & NASA Flight On-Site Security Document due
July	Integrate payload and prepare for flight
July 8th-9th	Payload Flight Ready/ Complete FLOP Documentation
July 22nd	Final FLOP Documentation due
July 25th – 29th	Student payload integration at CSBF
August	HASP Flight Preparation
September	Payload launch, flight, and recovery
September 3rd	2022 Target flight ready
September 5th	Target launch date & flight operations
September 7th – 11th	Recovery, packing, & return shipping
September-December	Complete Final Flight / Science report
December 9th	Final Flight / Science Report due

2.3 Organizational Flow and GANTT Chart





3. Payload Interface Specifications

3.1 Weight Budget

System	Mass (Grams)	Deviation (Grams)
Frame	1800	50
3D Printed Scintillator Cover	87.9	0.5
3D Printed PMT Cover	51	0.5
Fasteners	25	5
Insulation	15	1
Wiring	20	10
Hinges	50	5
Hamamatsu PMT	80	0.5
BC-412 Plastic Scintillator	400	20
Sensors	316.06	15
Teensy 4.1	13	10
Exterior Art Designs	340	25
Flight Computer	160	30
Total	**3357.96 g**	**172.5 g**

The total mass of the payload is well under the allotted weight maximum of 20kg. Our payload is estimated to be 3.36 kg, including the weight of all electrical components, insulation, wiring, screws, nuts, washers, and the entire payload assembly rendered in CAD. This number is derived from the examination of SolidWorks mass analysis and mass measurements of components already purchased.

3.2 Power Budget

Item	Voltage	Current	Power (W)
teensy 4.1	3.3 V	100 mA	0.33
PMT	5 V	6.2 mA	0.031
GPS Module	3.3 V	25 mA	0.0825
Thermistor	0 V	40 mA	0.2
Heating Pad	0 V	370 mA	1.85
TOTAL	11.6 V	541.2 mA	2.4935 W

Utilizing Watt's Law[3], we multiplied the running voltage by the current for each component to find the power. Then, the power for each component was summed to find the total power of 2.4935 W. The power calculations have an uncertainty of 100 mW.

3.3 Downlink Serial Data

We intend to downlink serial data to transmit our position and temperature readings from our GPS and thermistor. The total size of the data package is unknown. The period of the downlink will be 13 hours. The estimated downlink data rate is 1 byte every 2.1 milliseconds because we intend to use a large payload.

3.4 Uplink Serial Commanding

We want a reset command if our GPS malfunctions. If there are any issues within our payload during the experiment, we would like to be able to directly communicate with the payload to debug it and acquire the fixed data.

3.5 Analog Downlink

We intend to use analog downlink to acquire direct data on particle count in real time via the EDAC cable on HASP.

3.6 Payload Location and Orientation Request

Payload 9 is the most optimal spot for our design, as it is a large payload position which provides more room to build our particle detector. More room means more surface area for the scintillator and more space for PMTs to detect particles, enhancing our data output. Payload 9 also has Camera 1 pointed directly at it which allows us to monitor the exterior artwork and see how it may change in response to lighting and temperature.

Payload 11 is our second choice, as it is once again a large payload that enhances our experiment's structure. Payload 11 has Camera 3 pointed at it, which allows us to view the exterior artwork on the capsule, something particularly important to this year's project.

A large payload is not essential to the success of our mission; however, it is desired. We could reconfigure our design for a smaller payload if needed. We would prefer a large surface area for particle detection, artwork, and cameras to view the artwork.

Payload 8 is our third choice, if we are not able to secure a large payload. It was our payload position last year and worked out very well with the HASP camera view.

4. Preliminary Drawings and Diagrams

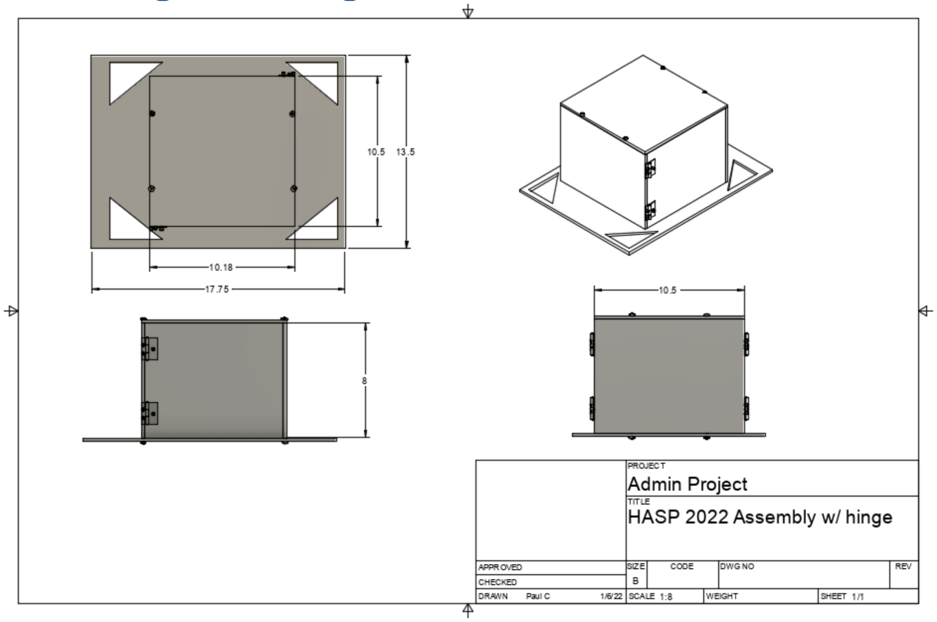


Figure 1: Payload Top Mechanical Sketch

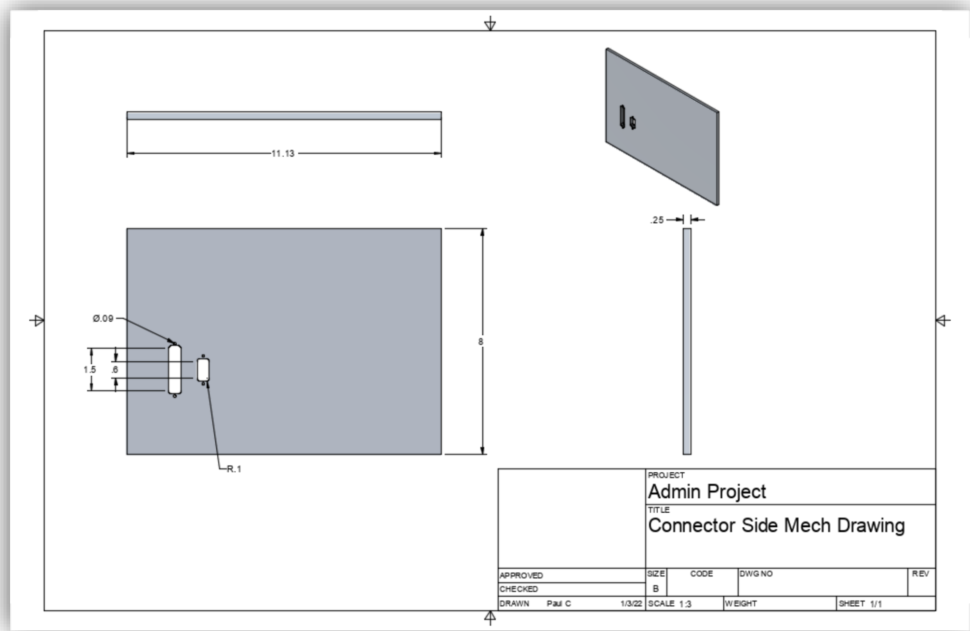


Figure 2: Side Door Mechanical Sketch

5. References

1. "What and Where is Antimatter?" European Organization for Nuclear Research. 17 February 2012. cms.cern/physics/what-and-where-antimatter
2. Cowen, Ron. "Antimatter Belt Found Circling Earth." *Antimatter Belt Found Circling Earth - ScienceNOW*, 20 Oct. 2011, web.archive.org/web/20111024152418/http://news.sciencemag.org/sciencenow/2011/08/antimatter-belt-found-circling-e.html.
3. Berdahl, E., Ju, W., & Gurevich, M. (n.d.). *Introduction to electronics*. Introduction to Electronics - CCRMA Wiki. Retrieved January 6, 2022, from https://ccrma.stanford.edu/wiki/Introduction_to_Electronics.

Appendix A: NASA Hazard Tables

Appendix A.1: Battery Hazard Documentation

HASP 2022 Battery Hazard Documentation	
Battery Manufacturer	Povway
Battery Type	LiPo
Chemical Makeup	Lithium polymer
Battery modifications	No
UL Certification for Li-Ion	UL 1642