High Altitude Student Platform 2021

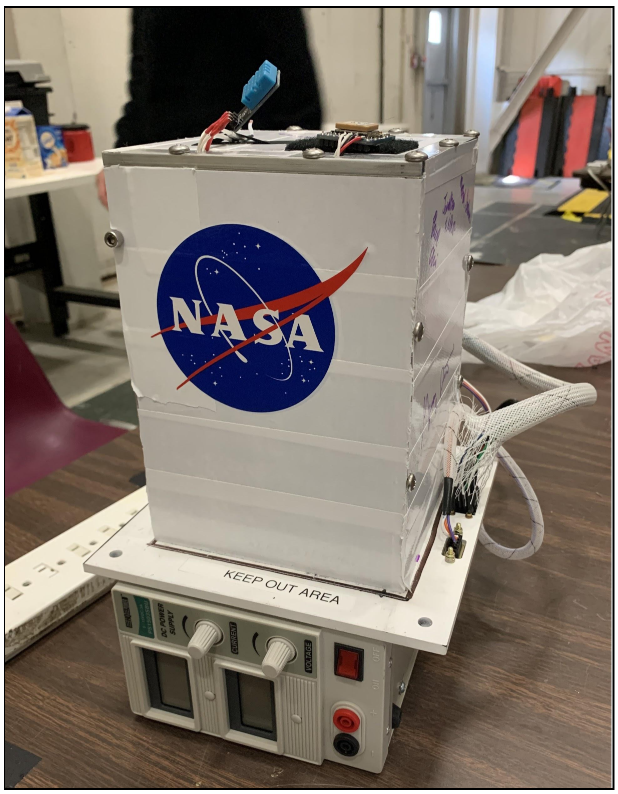
Antimatter Particle Scintillator

Science Report

College of The Canyons

26455 Rockwell Canyon Rd

Santa Clarita, CA 91355



PAYLOAD CLASS: Small

PAYLOAD NUMBER: 08

FLIGHT NUMBER: 716N

LAUNCH TIME: 09/14/2021 14:02 UTC

FLOAT TIME: 14H:10M

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Table of Acronyms

HASP	High Altitude Student Platform
LSU	Louisiana State University
NASA	National Aeronautics and Space Agency
CSBF	Columbia Scientific Balloon Facility
PMT	Photomultiplier Tube
PSIP	Payload Specification and Integration Plan
FLOP	Flight Operations Plan
FCB	Flight Controller Board

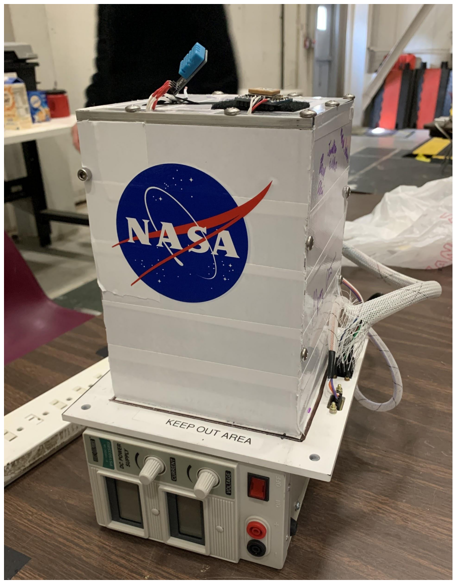
I. Abstract

Utilizing our HASP 2017 mechanical design, The College of the Canyons Aerospace and Sciences Team constructed a compact scintillator to detect antimatter collisions in the stratosphere. By detecting gamma ray and neutrino activity, the primary products of antimatter collisions, we expected to estimate the amount of antimatter collisions in the upper stratosphere where HASP remains at float for several hours. Data on the frequency of antimatter collisions leads to estimating the natural occurrence of antimatter particles in the upper stratosphere inferring composition and early conditions of the universe. A plastic scintillator was tested for effectiveness and durability during prolonged exposure to UV and cosmic radiation. Structural design improved upon legacy structures by adding an access door to easily test the scintillator and easily retrieve the micro-SD card. At an altitude of 100,000 feet, the photomultiplier tube counted scintillations on a BC-412 scintillator while it was housed in an aluminum box.

II. Introduction

Concept

NOVA 2021 was the first year that the College of the Canyons Aerospace and Sciences Team would be flying a compact scintillator to detect antimatter collisions in the stratosphere. Project manager and Software/electrical lead, Michael Souliman, discovered NASA's PAMELA payload and suggested that our team develop a scaled down version of PAMELA. The main science goals of NOVA were to design and construct a small particle detector, and to test the effectiveness of plastic scintillators in the upper stratosphere and count the number of antimatter collisions in the upper stratosphere.



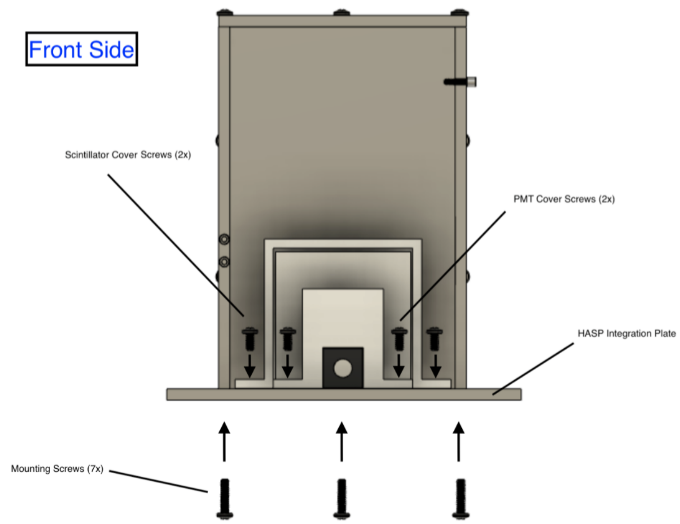


Figure 1a. Flight-ready NOVA Payload **Figure 1b.** NOVA payload CAD model

Principle of Operation

We used the Hamamatsu H10722-01 photosensor module, which contains a metal package PMT, a low-power consumption high-voltage power supply circuit, and a low-noise amplifier. The amplifier converts the PMT current output to a voltage output so signals can be easily processed. Also, the amplifier is connected close to the PMT anode output pin in order to make the signal less affected by external noise. Using this photo-sensor system, we cut the need for an external amplifier that would convert the output from amperage to voltage and we directly connected the PMT to the teensy. Additionally, this PMT was run using a simple 5V power supply, eliminating the need for a high voltage power converter.

We used a BC-412 plastic scintillator on our payload. When a BC-412 scintillation crystal is hit with gamma and cosmic rays it scintillates, converting the radiation into visible light photons. The number of cosmic rays produced in the upper stratosphere is inferred by the number of visible light photons counted. Counting the number of scintillations, counts the number of cosmic rays hit by the detector in our direction, which is proportional to the number of antimatter particles present in that region of the stratosphere.

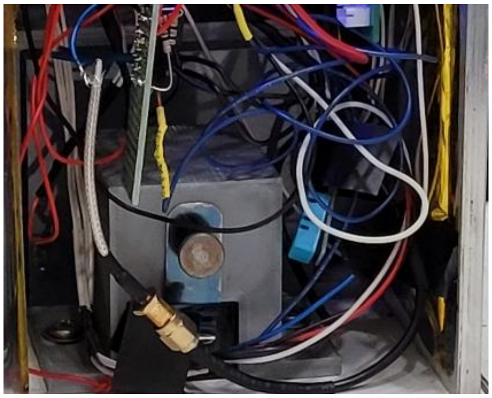


Figure 2a. PMT assembly

Figure 2b. PMT and Scintillator CAD model

III. Design & Fabrication

Mechanical Systems

One of the main challenges for this flight was to construct a payload able to withstand the environmental extremes expected at high altitudes for long durations and still perform its task. Materials were chosen for their ability to withstand extreme temperatures, strength, and would keep our payload within the weight budget.

Being a team from a community college, there were workforce training facilities on campus that allowed for advanced manufacturing to be done on the payload mechanical systems. Our machining advisor and former NASA machinist, Gregory Poteat, was able to bring our payload to fruition (the machine shop was closed to students because of the COVID-19 pandemic regulations). The Advisors, Gregory Poteat and Teresa Ciardi, machined all parts for the 2021 HASP payload using the 3D renderings and mechanical drawings developed by our team's Mechanical Leads, Paul Choi and Jonathan Fisher.

Lightweight aluminum 6061 was used along with 10-24 threaded screws to attach all plates including the integration plate together. An important aspect of our payload was our "front door." We used a hinge and screw to lock the door and then opened it when our electrical team needed to access the internal detector and electrical systems on our payload. The inclusion of a hinged door proved to be extremely useful, especially during testing. This mechanical design was effective when the team needed to access the payload and more efficient than unscrewing 7 screws to access internal components.

We decided to implement a 3D printed mounting system to orient the PMT and scintillator in a position that was easy to access and connect to the electrical components. 3D printing the parts was simple and effective, and made it possible for students to complete this task off-site (our campus was closed to students).

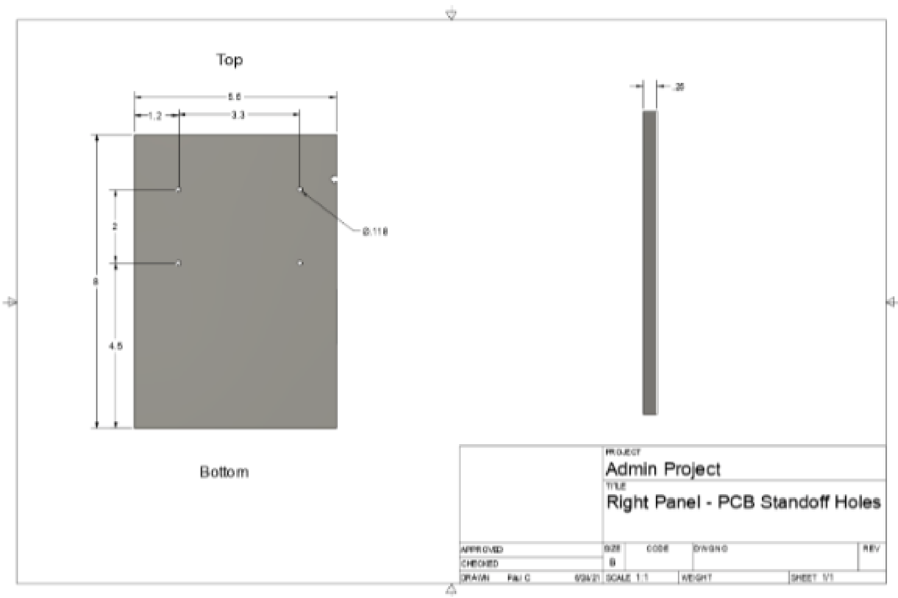


Figure 3. Aluminum Component CAD

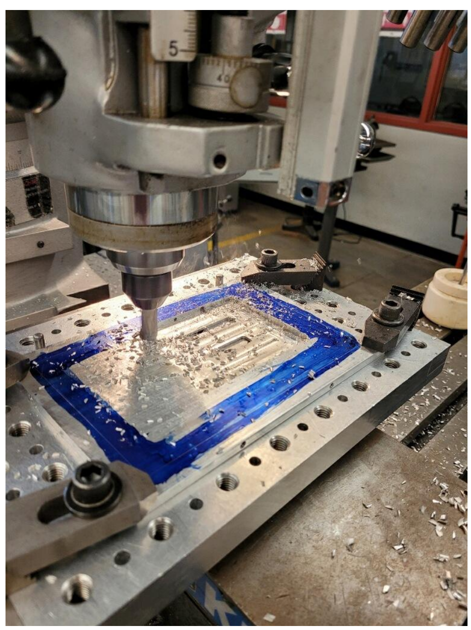


Figure 4. Machining aluminum components

Electrical Systems

The electrical system consists of the enclosed voltage source in the Photomultiplier Tube. The HV supply outputs 500 to 3000V that requires 0.36 Watts of power to function. The source draws 0.03A of peak current and runs 0.01A while simultaneously drawing only 12V from HASP. The PMT provided by Hamamatsu Photonics incorporates the necessary components of a high-voltage power supply and an operating circuit in a compact case to increase ease of use and efficiency. HASP power supply was distributed to our electrical equipment using the DB25 pin connector.

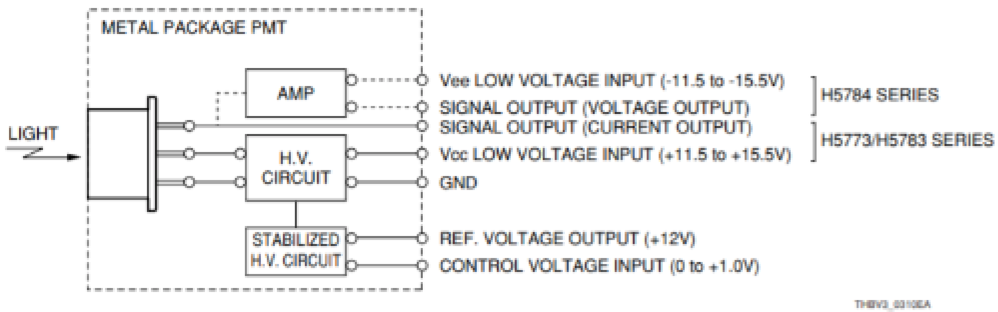


Figure 5a. PMT Current Flow Diagram

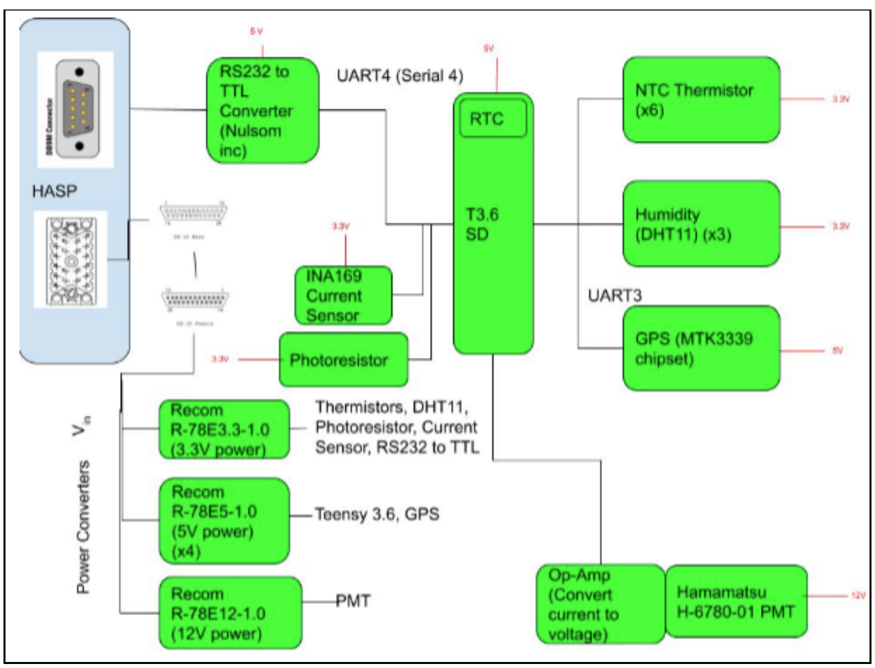


Figure 5b. Payload Power Distribution

Flight Controller Board (FCB)

We used an analog input pin which utilized a 12 bit ADC. Originally, it was expected that the PMT output could connect directly to this pin through a voltage divider; but rather than the 15 volts max that the datasheet stated, we measured almost 200 volts. This required a last-minute PCB be added to condition the signal to 3.3V safe levels. The Teensy 3.6 would then log data to an SD card. We used the Teensy 3.6 to poll the analog input with no loop delay in the code. This generated a data file so large it was difficult to open. Apart from these devices, the payload utilized the same housekeeping sensor suite used since 2017; 10K thermistors and humidity sensors.

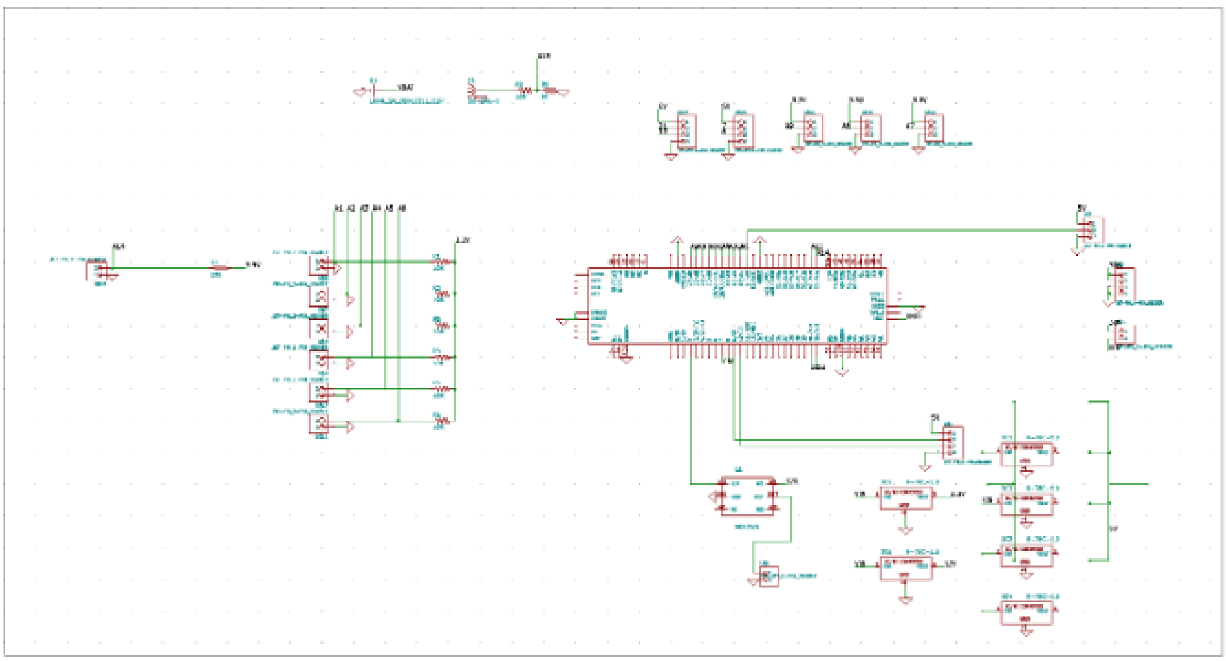


Figure 6. PCB Schematics

Sensors

A set of digital altimeters (barometer/pressure sensors) were used to measure the altitude throughout the flight. Two BMP180 barometric pressure/temperature sensors were connected to the flight computer in order to give accurate altitude readings. We used two sensors to increase accuracy by averaging the altitude measurements and to provide backup in the event that one sensor failed.

We used thermistors because they have the advantage over conventional analog and digital temperature sensors due to their simplicity and robustness over a wide range of temperatures. To handle noise from other payloads, HASP systems, and internal power converters, the analog signals were transmitted through an unshielded twisted pair cable along designated harness paths that were routed around elements that emit EMI noise. We used 10 total thermistors, 2 next to the PMT, 2 on top of the payload, 2 next to the Teensy, 2 in the internal region of the payload, and 2 in the plastic scintillator enclosure to track the temperatures at various internal locations and external to the payload. Readings from each thermistor pair were averaged and monitored during flight.

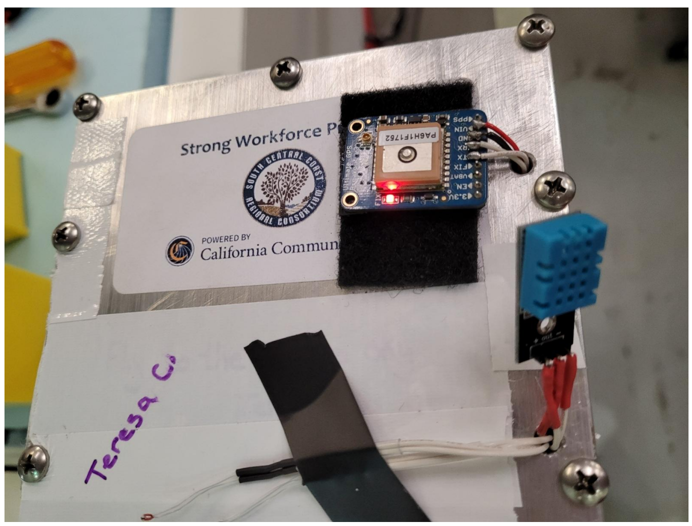


Figure 7. Humidity, GPS, and Temperature Sensors harness with HASP interface connectors and LED indicators

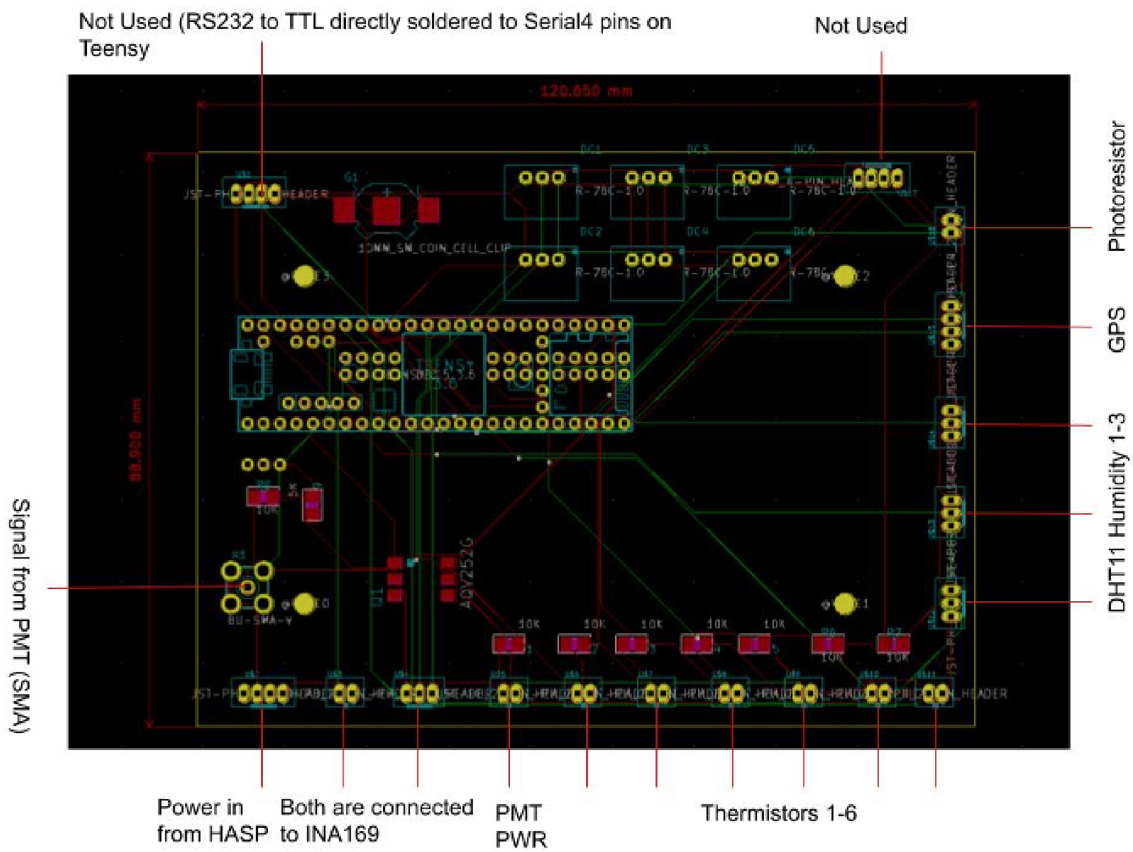
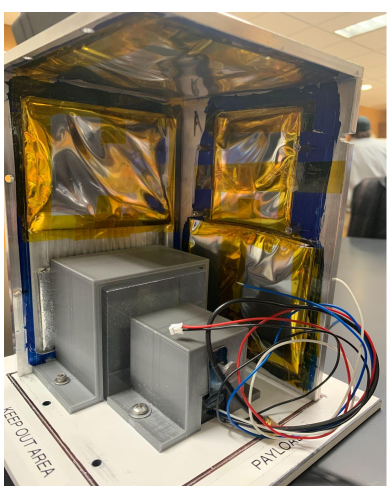


Figure 8a. Flight Controller Board PCB layout



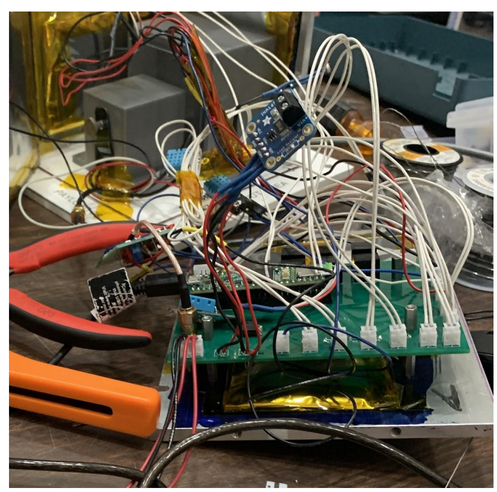


Figure 8b. PMT-Scintillation System

Figure 8c. Flight Controller Board

Thermal Management Systems

The insulation system consisted of mainly mylar blankets consisting of multiple layers of mylar and Kapton tape. Mylar blankets were created by crumpling and folding sheets of aluminized mylar to a thickness of 10 layers. This system is similar to NASA's Multi-Layer Insulation (MLI) but is quicker to fabricate and is lighter due to the lack of a ceramic scrim separator. Kapton tape and the reflective aluminum tape were applied to certain inside surfaces to ensure heat flux be kept to a minimum. The outside of the payload was wrapped in white duct tape to reflect the intense solar radiation during the day.

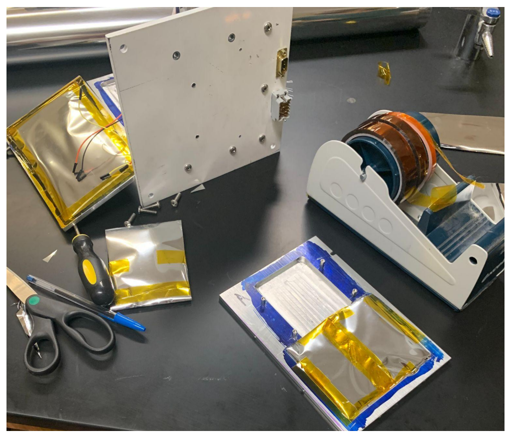


Figure 9. Mylar insulation blankets

IV. Integration

The first day of integration was used to reassemble electrical components and integrate the electrical systems. Once the payload was assembled, it was determined that the software was not working properly. On the second day, the team worked to troubleshoot software issues and completed the telemetry testing and mass tests in order to be cleared to participate in the thermal-vacuum test. The PMT scintillation was tested for serial downlink. Issues with our payload lead to a conversation with the HASP program director who provided the team with suggestions for improving upon the particle detector design and to discuss details about payload function and operation during flight. One critical issue that occurred during testing was a malfunction with the serial downlink. Cleared for the thermal vacuum test, with basic systems functioning, we observed the behavior of our payload during thermal vacuum testing and continued to work on software issues.

Figure 10a. Thermal vacuum chamber prior to test

Figure 10b. 2021 telemetry testing

During thermal vacuum testing, telemetry was received from the payload through serial downlink. These data files were uploaded to the HASP website and a file converter was used to retrieve files periodically and send them to a web-based dashboard. Data showed a drop in the core temperature of our payload. There was one instance when commands were not being received, but that issue was fixed with a simple power cycle. The first thermal vacuum test was, in general, successful but the team chose to complete the second thermal vacuum test with significant changes to the software. Our Project Manager, Michael Souliman, scrapped the code written by a former member and wrote all new code for our payload prior to the second round of thermal vacuum testing. We added white duct-taped to the outside of the payload to promote better thermal stability. We also parsed through the first thermal vacuum test data and created graphs to check payload functions. Cleared for the second thermal vacuum test, the team leads were more proficient at monitoring and analyzing the test data as it was received.

V. Flight

When HASP officials announced the start of CSBF launch operations at Ft. Sumner NM for the launch of HASP 2021, the NOVA team was poised to monitor the launch status. During this time, classes had started at College of The Canyons and West Ranch High School so none of our team members were able to make it in-person at the launch site. Team leads worked in shifts during flight preparations and for the duration of the flight to maintain communications with HASP officials. All sensors were monitored and functioned nominally for the entire flight. Data from the particle detector was logged on an internal micro-SD card and was not seen until post-flight anlaysis.

Figure 11. NOVA payload in view of the CosmoCAM during flight

VI. Results

The data collected and visualized in these graphs reveal the gamma ray particle counts due to ionized radiation within short periods of time. The sharp photoelectric peaks followed by an exponential decay show the spikes of charged electrons that are detected and emitted with a capacitor in the photomultiplier tube. These data logs represent regular intervals of events. We hypothesize that this is due to the detection of the power system cycling up causing mild power surges. The root cause of the cycle may be the HASP platform rotating, periodically exposing our payload to direct sunlight which may have caused internal power fluctuations detected by the PMT. Sunlight heating may also heat the gondola's power supply, resulting in a power cycle from the gondola. It was discovered after flight that our code was missing the filter that evaluated under which conditions to record data and instead recorded the whole sample. Our system seems to have been logging data as fast as it could from the moment our payload was powered for flight, and we estimate that every second we retrieved several hundred million data points which filled up the memory card very quickly.

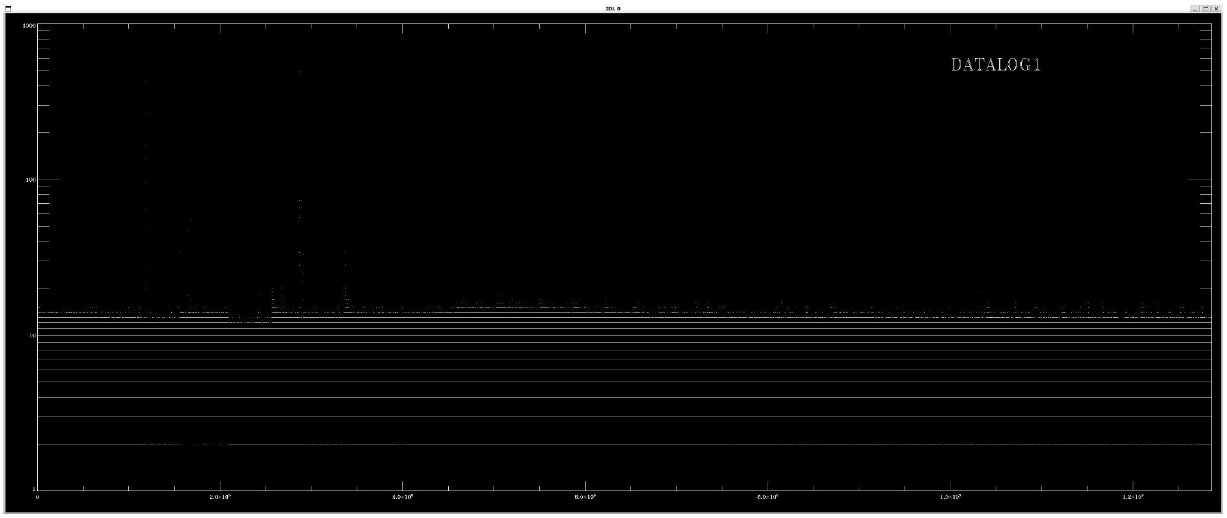


Figure 12. Data Set 1: Y is magnitude in logarithmic vs X by record number detection 1,2,3, etc

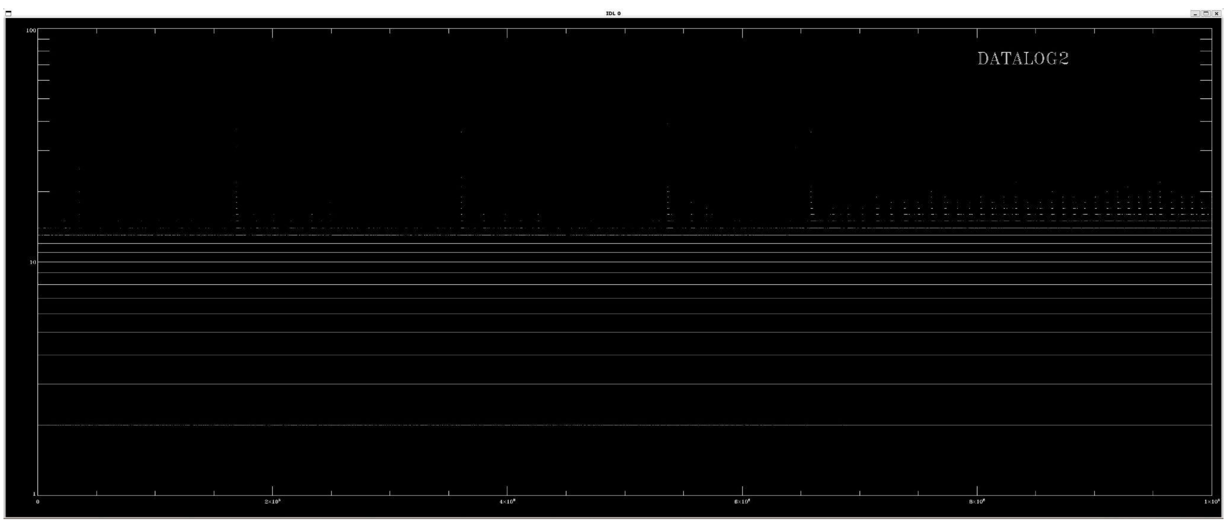


Figure 13. Data Set 2: Y by magnitude in logarithmic vs X by record number detection 1,2,3, etc

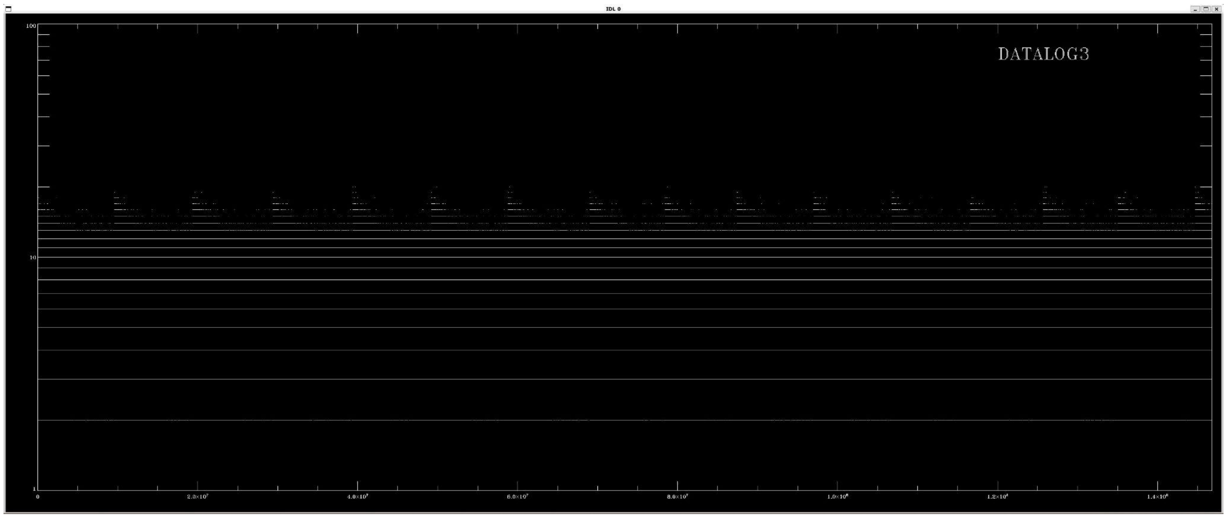


Figure 14A. Data Set 3: Y by magnitude in logarithmic vs X by record number detection 1,2,3, etc

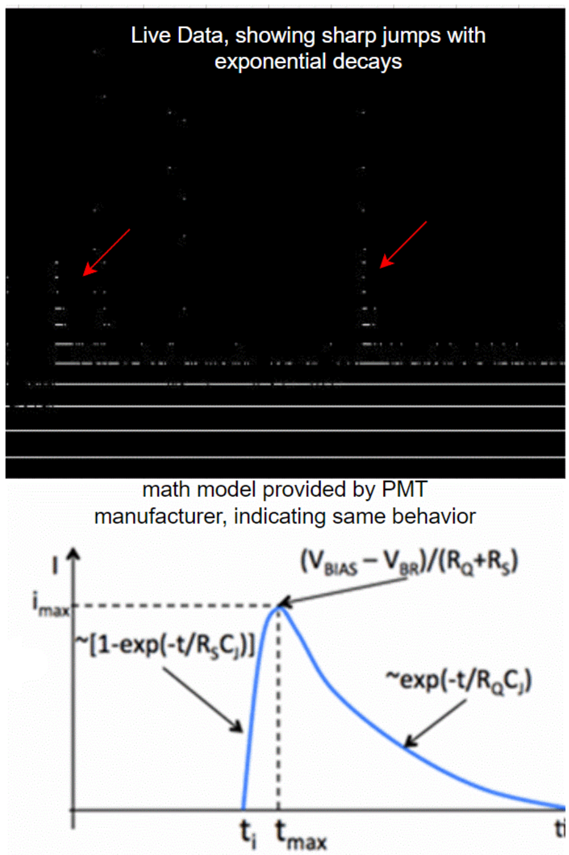


Figure 14B. Comparing NOVA data graph 3 to a manufacturer math model

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VII. Conclusion

Failure Analysis

Post-flight, the team encountered problems with extracting data files. Initially, we did not have any computers that were powerful enough to download the files, so one of our coders created a program to process the data by allowing us to enter the file extension as well as the targeted height threshold of the peaks. After reading all the files, the program prints out a report of the user-defined peaks and each iteration. We discovered that the clock speed was 320 MHz with a T per cycle of 3.125 ns which meant that the memory card was full shortly after the HASP balloon launched.

```
void ReadParticleFile(ifstream& file, string fileExt) {

        //vector<int> particleList;
        string currentLine;
        int particleCount = 0;
        int linesProcessed = 0;
        bool outputFileInitialized = false;

        cout << "Lines processed: " << linesProcessed << "\nParticle hits: " << particleCount;

        BringCursorBack(0, -1);

        while (getline(file, currentLine)) {

                int currentNum = std::stoi(currentLine);

                if (currentNum >= HighSpikeThreshold) {

                        if ((outputFileInitialized == false)) {

                                string rawFileName = CurrentFileName;

                                if ((fileExt.compare("NO_EXT") != 0) && (fileExt.compare("no_ext") != 0)) {

                                        rawFileName = CurrentFileName.substr(0, CurrentFileName.find_last_of("."));

                                }
```

Figure 12. Code written by our Software Team that identifies data

Future Work & Lessons Learned

Engineering

- Use filtered power supply and analog signals
- Fix timestamp code in order to understand when exactly we collect data
- Include serial uplink and downlink capabilities to view particle counts in real-time
- Create code that involves an embedded timestamp

Science

- Research PMT options and functionality including possible inference patterns
- Collect and analyze on-ground data prior to next launch to use as a baseline
- Research characteristics of all types of particles that may be detected by our particle detector system

Project/Team Management

- Create a team contract and hold all team members, especially team leaders to contract parameters, from the start of the project through mission completion
- Develop a time-line and work-schedule that aims to complete all tasks at least one month prior to thermal-vacuum testing
- Increase recruitment efforts
- Facilitate inclusion of all members in sub-teams to ensure more than one person is working on each sub-system collaboratively

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VIII. Team

Positive Outcomes

Direct result of participating on HASP

1. Former member Kyle Strickland was recruited to participate in the ARCS program at CSUN (Fall 2020)
2. 10 Students received $650 Scholarship Stipend from CA Space Grant to work on NASA HASP (Fall 2020)
3. Former member Carolyn Trujillo started an internship at JPL (Spring 2021)

4. 7 Students received $750 Scholarship Stipend from CA Space Grant to work on NASA HASP (Spring 2021)
5. 2021 HASP Mechanical Lead, Paul Choi was accepted for the LSPACE internship
6. Founding member, Daniel Tikhomirov, was hired by Blue Origin (2020)
7. 2018 Chemical Lead, Gillean Graves, was hired by Tesla (2021)
8. Former Electrical Systems Lead, Kyle Strickland, was hired by Millennium Space (2021)
9. S.T.R.E.A.M. Global non-profit awarded $500 to Advisor Teresa Ciardi to fund these types of projects with students
10. News Release January 2021: https://www.canyons.edu/administration/pio/news/2021-01-26-ast.php
11. In the News: https://www.dailyadvent.com/news/e6bf2a203c2641fc1aebfda6684e4a5d-COC-Aerospace-Science-Team-Selected-to-Work-with-NASA
12. SCV News: https://scvnews.com/cocs-sean-tomer-becomes-first-student-athlete-to-join-schools-aerospace-science-team/
13. One of the project choices for this grant is NASA HASP: https://www.canyons.edu/administration/pio/news/2021-09-07-nsf.php
14. The Signal local news: https://signalscv.com/2021/03/coc-students-selected-to-participate-in-nasa-sponsored-project/

Demographics

Name	Start Date	End Date	Role	Student Status	Race	Gender	Disabled
Michael Souliman	12/18/19	August 2021	Project Manager, Electrical + Software lead	Undergrad	Middle Eastern	Male	No
Jonathan Fisher	8/20/20	Present	Mechanical co-lead	High School	White	Male	No
Paul Choi	8/20/20	Present	Mechanical co-lead	High School	Asian	Male	No
Professor Ciardi Theresa	August 2015	Present	Advisor		White	Female	No
Adjunct Faculty Gregory Poteat	January 2016	Present	Machining Advisor		White	Male	
Ilker Loza	8/26/19	September 2021	Electrical + Software	Undergrad	Hispanic	Male	No
Hector Torres	10/22.20	Present	Mechanical	Undergrad	Hispanic	Male	No

Jammal Yarbrough	2/8/21	Present	Electrical + Software	Undergrad	African American	Male	No
Natalie Aliaga	9/15/19	Present	Mechanical	Undergrad	Hispanic	Female	No
Shaun Ford	1/16/19	Present	Electrical + Software	Undergrad	White	Male	No
Kyle Strickland	8/22/18	Present	Electrical + Software	Undergrad	White	Male	No
Patrick Gagnon	August 2016	Present	Mechanical	Undergrad	White, African American, Indian	Male	Yes
Arely Castillo	Spring 2021	Present	Math	Undergrad	Hispanic	Female	No
Alex Granados	Fall 2020	Spring 2021	Electrical & Software	Undergrad	Hispanic	Male	No
Marilyn Johnson	Fall 2020	Present	Civil Engineering	Undergrad	White	Female	No
Daniel Larimer	Spring 2019	Present	Mechanical	Undergrad	White	Male	No
Aivie Quinto	Fall 2020	Present	Mechanical	High School	Asian	Female	No
Sean Tomer	Fall 2019	July 2021	Computer Science	Undergrad	White	Male	No

IX. References

Chapter 7 Scintillation Counting - Hamamatsu. (n.d.). Retrieved December 6, 2021, from https://www.hamamatsu.com/resources/pdf/etd/PMT_handbook_v3aE-Chapter7.pdf.

Mounting a scintillation detector - nevis laboratories. (n.d.). Retrieved December 6, 2021, from https://www.nevis.columbia.edu/reu/2002/manual.pdf.

Piatek, Slawomir. *"What Is an SIPM and How Does It Work?"* HAMAMATSU, 7 Oct. 2016, https://hub.hamamatsu.com/jp/en/technical-note/how-sipm-works/index.html.