HASP Student Payload Application for 2021

Payload Title: FLC RAT (Radiation vs Altitude and Time) Experiment			
Institution: Fort Lewis College			
Payload Class (Enter SMALL, or LARGE): SMALL		Submit Date:01/05/2021	
Project Abstract: The Fort Lewis College HASP team will launch an ionizing radiation measuring experiment RAT (Radiation vs Altitude and Time) with updated systems from 2015, 2019, and 2020 balloon flights. The primary experiment uses counter facing Geiger counters to record high intensity radiation vs the altitude, orientation, and time of day. The system will be controlled by an Arduino Pro Mini with downlink data utilizing the HASP system as well as being backed-up to a micro-SD card. A communication system (comms) will be used to downlink the data. A power management system (PMS) will monitor the power to each system using DC current sensors. A temperature management system (TMS) will record the temperature of each system and activate heaters, as needed, to help maintain normal functionality. A digital camera system will also be installed on the payload to record the entirety of the flight. The Spacehawk's payload design could potentially prove to be a cost-effective way of accurately measuring high-energy radiation present in the atmosphere over changes in altitude.			
Team Name: Spacehawks		Team or Project Website: TBD	

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Flight Hazard Certification Checklist

Hazardous Materials List		
Classification	**Included on Payload**	**Not Included on Payload**
RF transmitters	X	
High Voltage	X	
Pyrotechnics		X
Lasers		X
Intentionally Dropped Components		X
Liquid Chemicals		X
Cryogenic Materials		X
Radioactive Material		X
Pressure Vessels		X
Magnets		X
UV Light		X
Biological Samples		X
Li-ion Batteries	X	
High intensity light source		X

Student Team Leader Signature: ____

Faculty Advisor Signature: __________ __________________

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1. Payload Description

The primary goal of this experiment is to measure upper-atmospheric, ionizing Radiation vs. Altitude and Time (RAT). Time will be recorded to account for the location of the sun above the horizon. This will be done with two counter facing Geiger counters and two solid state radiation detectors. The Geiger counters will have shutters that alternate between open and closed to differentiate between gamma, beta, or other ionizing radiation. This will be done using servos with flaps that alternately cover and uncover the detectors. When covered, Gamma rays are the only ionizing radiation detected. When open, beta radiation can be detected. The payload will also be equipped with a temperature management system (TMS), power management system (PMS), and communication system (comms). A secondary goal is to incorporate a GPS and camera system. The GPS will be implemented due to limited access to the NASA GPS. The GPS system would also provide a reference for future payloads as this would be the first successful implantation of the current system for the program. The camera will record the flight from liftoff to capture data on the sun's location in relation to the payload location. A lithium battery will be used to keep the camera clock working until the payload receives HASP power. The camera will then utilize HASP power to operate. A secondary goal is to switch power from the external HASP power source to an onboard power source. The lithium battery would allow our team to test the power source switching system without causing a single source of failure to the other systems. The TMS will record the temperatures of distinct parts of the payload to be able to cross reference them with the data from the other systems should any anomalies occur. The TMS will also be able to heat a certain system, if necessary, to keep normal functionality. The GPS system will track the location of the payload at any given time. The comms system will back up the data from each system on a micro-SD card and control the downlink and uplink capability. Each separate system will operate using Arduino Pro Minis. The previous versions of the systems mentioned above have been used by past Fort Lewis Collage teams for payload flights on HASP and weather balloon flights as part of the Demosat Colorado Space Grant balloon launch. However, this is NOT a repeat flight of past designs. The Spacehawks team is comprised entirely of new members and each system will be redesigned with resources and experiences from these past projects.

1.1 Payload Scientific / Technical Background

The primary experiment conducted through the payload will be high-ionized radiation data collection vs altitude, in addition to time-of-day data. The Geiger counters measure high energy Gamma and Beta rays that interact with the payload during flight. The Geiger counters will face in the opposite direction on two sides of the payload to measure ionizing radiation versus altitude and time of day and possibly with respect to the angle of the sun. The data collected from the Geiger counters will be compared to the altitude to show how much high-energy radiation hits the payload in each direction, depending on altitude and time of day. A Geiger counter has a small tube known as a Geiger-Muller tube that allows ionized radiation to pass through it. The tube is filled with a mixture of argon and methane that is easily ionized. The radiation creates an argon ion and an electron which hits the positive electrode and creates a pulse that can then be recorded to an SD card using an Arduino pro mini. The voltage difference between the positive and negative electrodes is typically between 400–900 volts. This makes the Geiger counters considered high voltage therefore the entire payload will sit within a faraday cage. The intended voltage for the Geiger counters is approximately 500 volts.

The solid-state radiation detectors create a detectable signal from electrons that are removed from a semi conductive as ionizing radiation moves through it [5]. Ionizing radiation hits a front electrode and goes through a silicon volume and hits the back electrode [5]. This gives the back electrode a negatively charged and the front electrode (possibly more than one front electrode) positively charged [5]. This is because a p-n junction occurs in the silicon when ionizing radiation passes through [6]. The current created is then amplified and is used to tell how much ionizing radiation is passing through at a certain instant.

1.1.1 Mission Statement

The Spacehawks team will create a small payload at Fort Lewis College that will fly on the HASP platform. It will be capable of recording and monitoring ionized radiation through on-board data collection and live transmission. It will demonstrate a cheap system that records ionization radiation data that can be used as part of further experiments.

1.1.2 Mission Background and Justification

Many organizations including the United States Government Department of Energy (DOE) and Atmospheric Radiation Measurement (ARM) facility, monitor Earth's atmospheric radiation [1]. Using this data is crucial to understand how aerosols, certain gasses, and particles affect the amount of high energy radiation that is currently entering the atmosphere from space. According to an ARM study done by the American Meteorological Society, the data from the observation of atmospheric radiation is used to create "accurate climate and earth system models" [2]. These models are especially relevant in predicting the temperature increase due to climate change and any changes in the protective gas layers of the Earth's atmosphere that filter out ultraviolet radiation [3]. Cosmic radiation affects travelers at higher altitudes. Recording the amount of high energy radiation detected as a function of altitude is crucial in high altitude aircraft design to protect the passengers [4]. A NASA experiment similar to the one we are proposing is the NASA's Radiation Dosimetry Experiment (RaD-X) [4]. This experiment studied high altitude radiation and how to improve "monitoring for aviation" [4]. The Spacehawks are proposing the 2021 payload as a cost-effective alternative for a similar experiment. The Sky Hawks payload proposed could potentially prove be a cost-effective way of accurately measuring high energy radiation present in the atmosphere vs altitude. A group of former Fort Lewis College students with the same mentor participated in a DEMOSAT Colorado Space Grant balloon launch. They launched a similar radiation experiment, but an issue arose mid-flight and only data from half the flight was recoverable.

1.1.3 Mission Objectives

The primary mission objective is to create a payload capable of accurately measuring high energy radiation present in the atmosphere vs altitude and time. The secondary objectives are to create a TMS, PMS, comms, GPS, and camera system, and power switching system that, as part of the payload, will record data with an Arduino Pro Mini to SD cards and downlink data.

1.2 Payload Systems and Principle of Operation

There are five main systems in the payload: the TMS, PMS, Comms, Geiger counter, and solid-state radiation detectors system. The secondary systems are the camera and GPS system. The Geiger counter system will be on one side of the payload sled and the other systems will be on the other side as shown below in **Error! Reference source not found.**. The payload will be mounted to the small HASP mounting platform in a vertical position, with the threaded rods being bolted to the HASP mounting platform. This orientation will maximize space, allowing all necessary components with a minimal footprint.

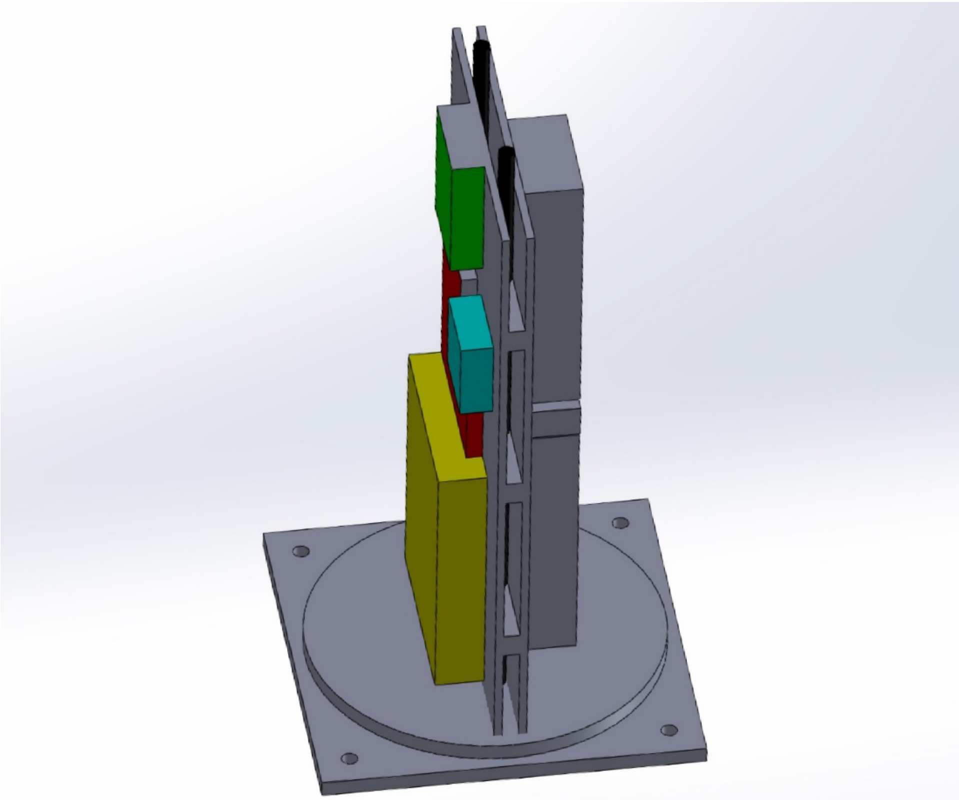

Figure 1: Primary Payload Sled Design

1.3 Major System Components

- Counter-facing Geiger Counter System

- Temperature Management System (TMS)
- Electrical System
  - Power Management System (PMS)
  - COMMS
- Camera System

1.4 Mechanical and Structural Design

The payload will be built from two, 5 x 10-inch, back-to-back plates contained inside an outer shell. There will be only one endcap and a lid that will be removed to easily operate on the payload. This design will allow easy access to fix and work on the components without having to take systems apart. One side of the sled will host the Geiger counter while the other side will house the PMS, TMS, Comms, and the camera. The design is inspired by last year's team's design but will showcase original work and development.

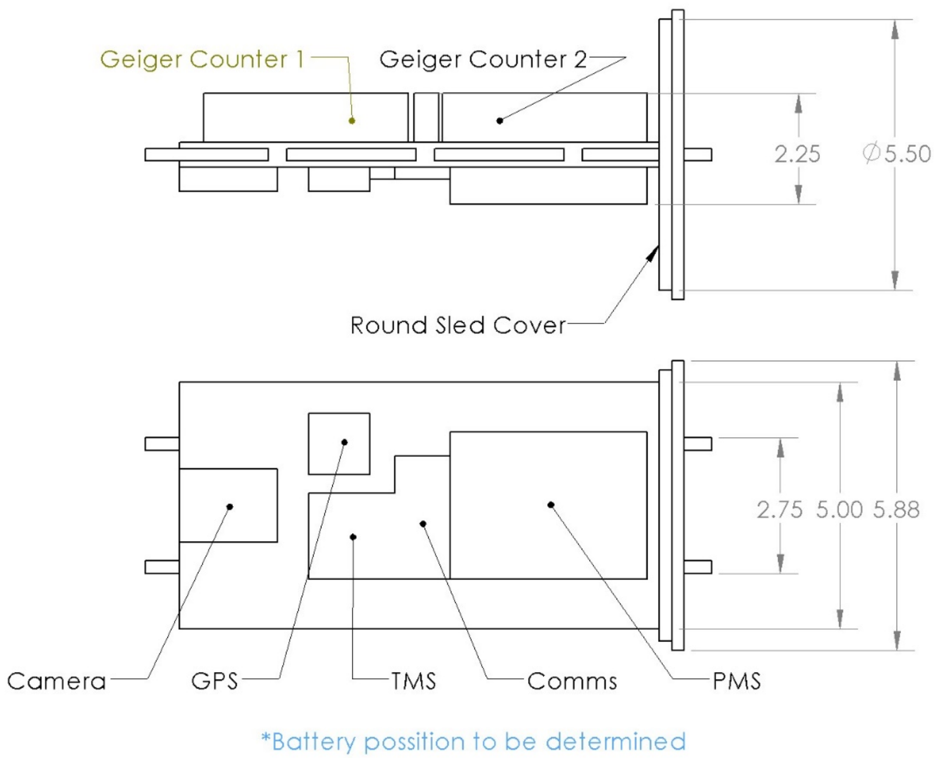

Figure 2: Overall Sled Design on Small Mounting Plate usable area

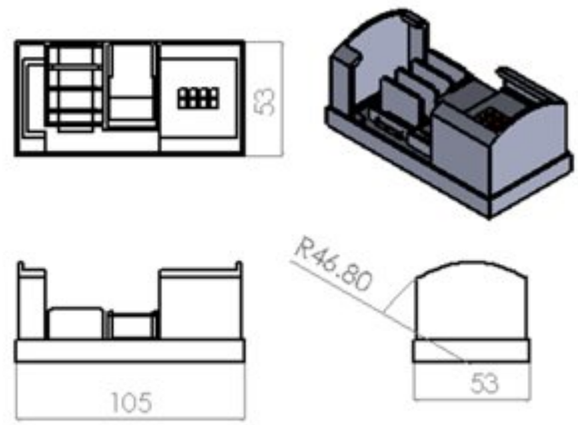

Figure 3: Last Year's PMS Housing Design

To collect radiation data, two Geiger counters purchased from SparkFun™, seen in **Error! Reference source not found.**, are being used. To detect incoming ionizing radiation, the Geiger counters use Geiger-Mùller tubes. In addition, two solid state radiation detectors will be included. For the high voltage Geiger counters using the Geiger-Mùller tubes, we will be implementing a simple Faraday cage to protect other electrical components on the sled.

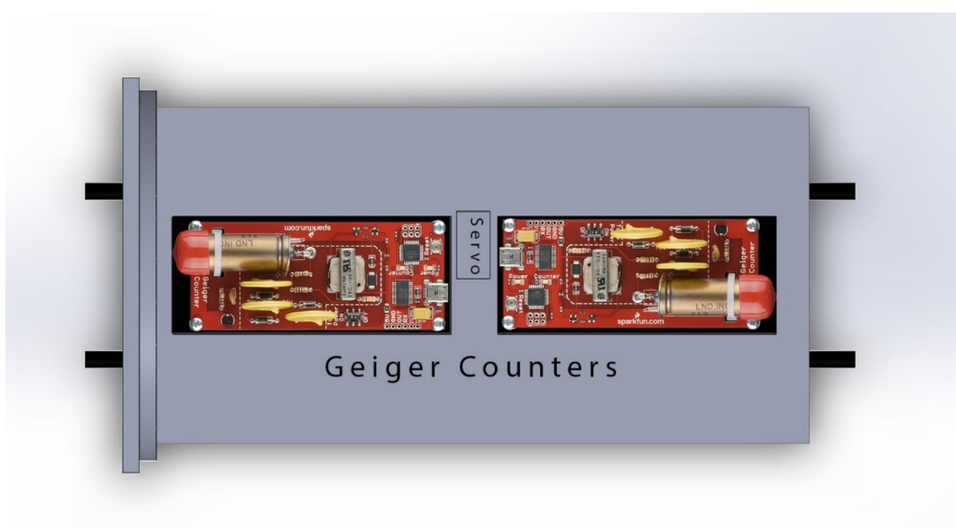

Figure 4: SparkFun Geiger Counter layout, uncovered

1.5 Electrical Design

Error! Reference source not found. displays a previous design of the PMS housing. The curved surfaces were designed to fit into a specific sized cylinder. This year's team is planning on building the PMS housing on a flat plate which will change the rounded edges to be flat for a more simplified design.

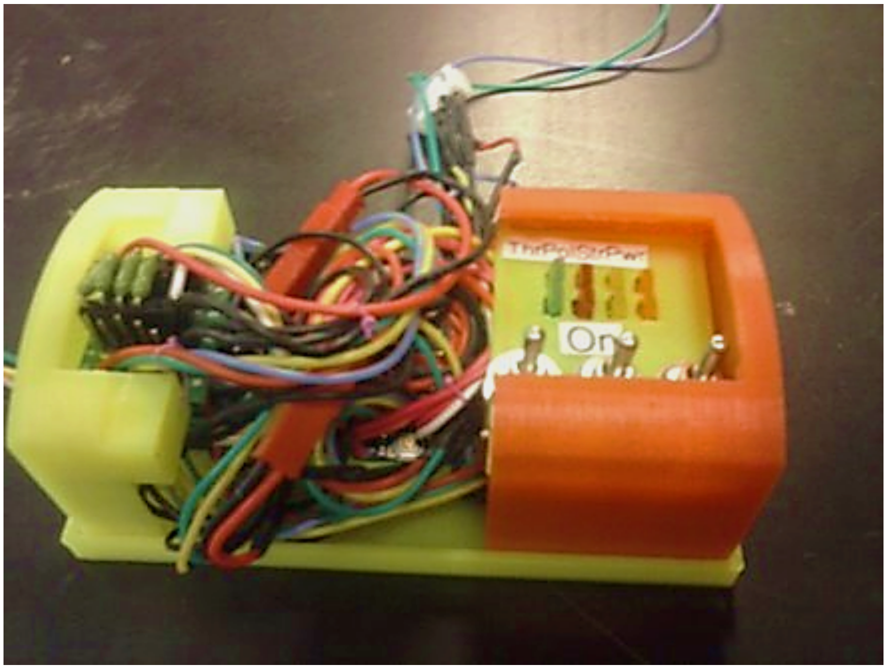

Figure 5: PMS housing

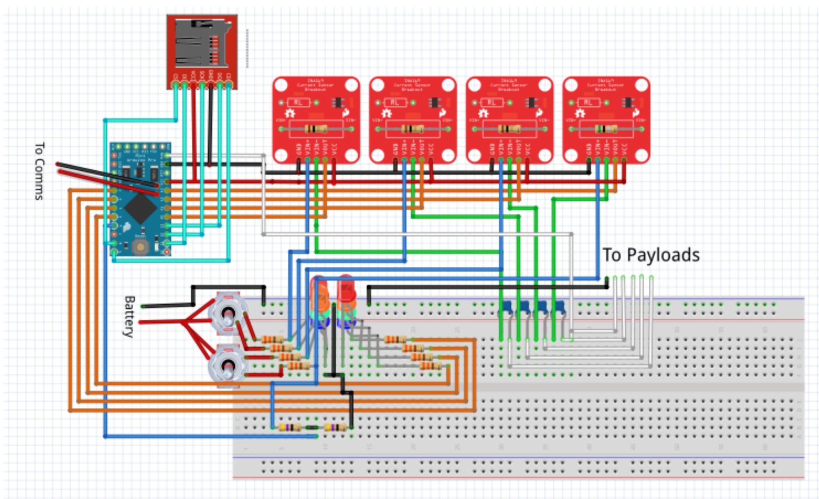

Figure 6: PMS Circuit Diagram

Figure 6. displays the power monitoring system (PMS). Note, the final design will use a PCB board or Pin Board. Not a bread board, as shown in the diagram. The battery note in Figure 6 indicates where the power comes in from.

Power from HASP will go to the PMS system which sends power through LED indicators and then to INA169 dc current sensors for four of the payloads. The current data from each payload is recorded from the Arduino Pro Mini to a micro-SD every second. Each current sensor range was calibrated by adding resistors. The TMS current sensor, GPS current sensor, Peltier, PMS, and Comms current sensor had 1Ω resistor with a current sense range of 35mA – 350mA. The Mobius Camera had a 0.5Ω resistor to give a current sense range of 175mA - 1.75A.

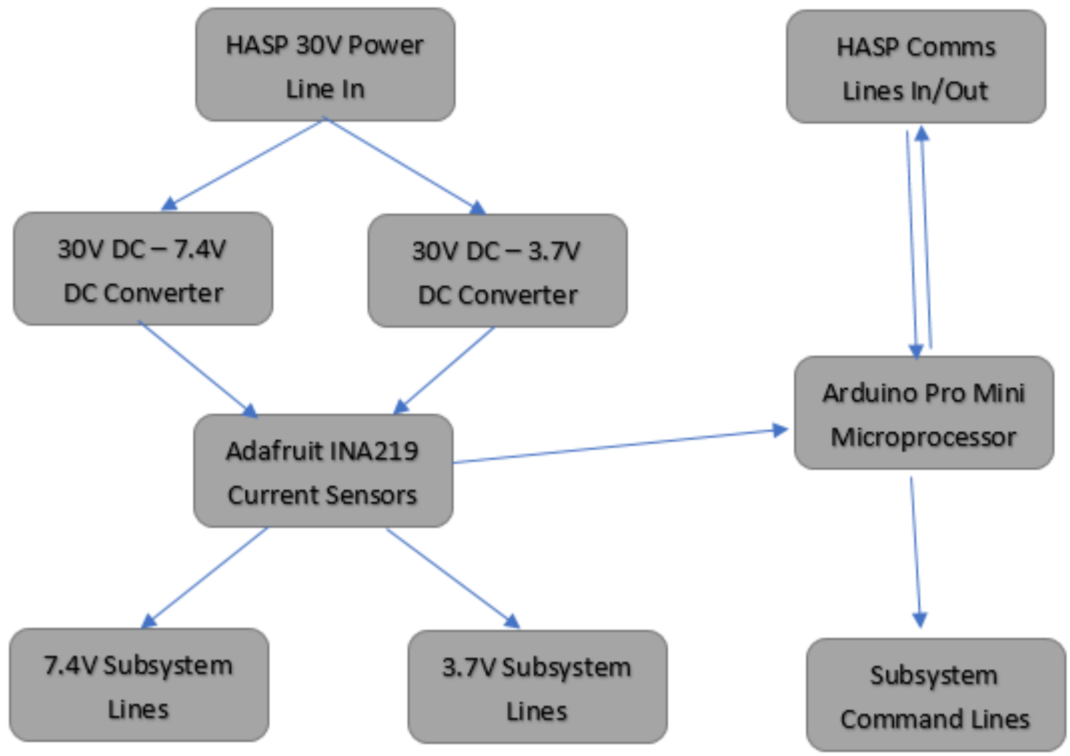

Figure 7: HASP Power Diagram

The HASP supplies a nominal 28 volts to each payload. Internal voltage level converters will provide between 7.4 V and 3.7 V to the various subsystems on the payload. It is expected that some internal batteries will be needed for shutting down running software efficiently and to keep the time stamp running before HASP power is provided. The power lines are then run through current sensors, which monitor the subsystems' power supplies and consumptions. These lines are then connected to optical diodes to control subsystem supplies independently, before finally being routed to their respective subsystems.

1.6 Thermal Control Plan

At high altitudes, temperature drops drastically, and this can have negative effects on both batteries and the payload equipment. To negate these effects, the heating system is designed to keep temperatures above -20°C as well as log data from temperature sensors. Last year's team performed tests during the summer of 2020 which the results can be seen in **Error! Reference source not found.** and **Error! Reference source not found.**. **Error! Reference source not found.** displays the temperatures of all the subsystems on the payload during the flight. There were minor glitches in temperature collection at the start of the flight caused by RF interference. RF interference was from the GPS transmitter.

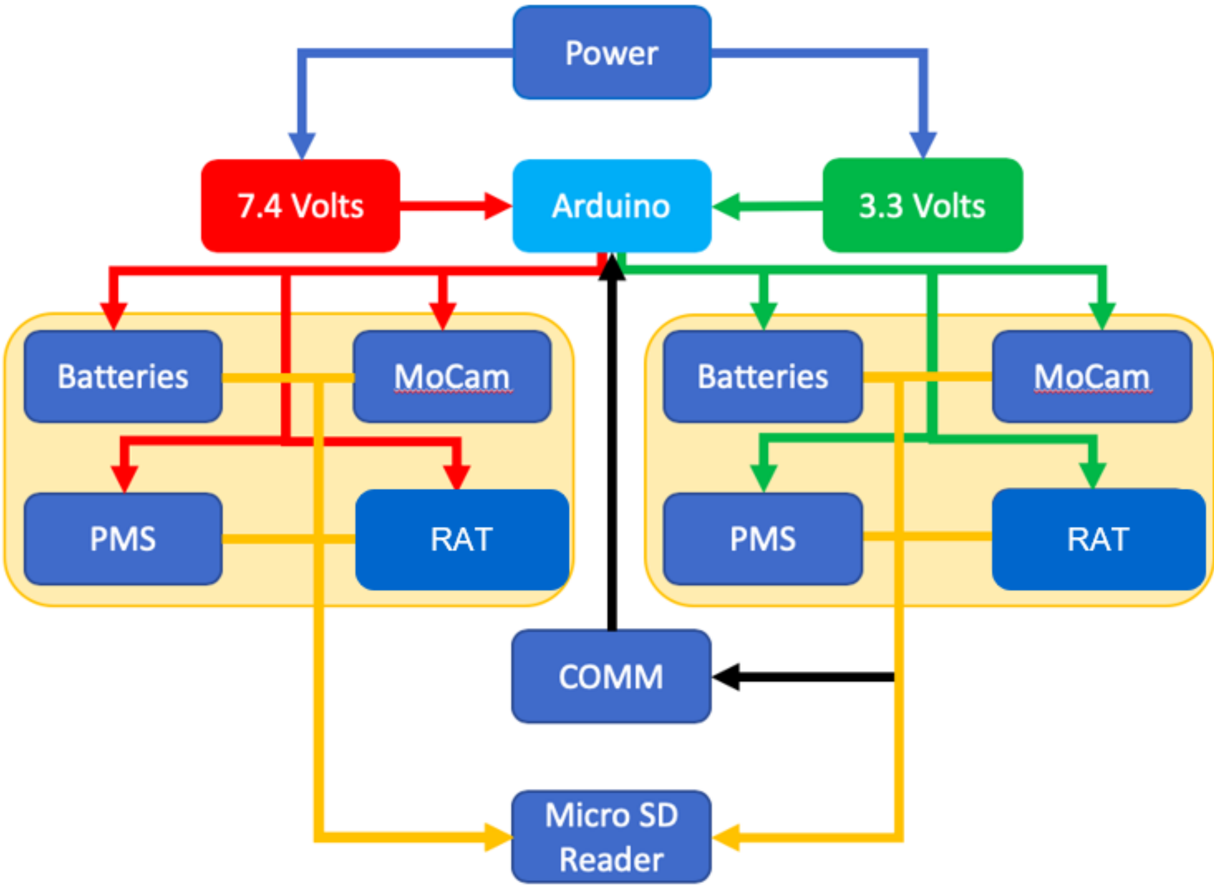

Figure 8: Block Diagram of Overall System

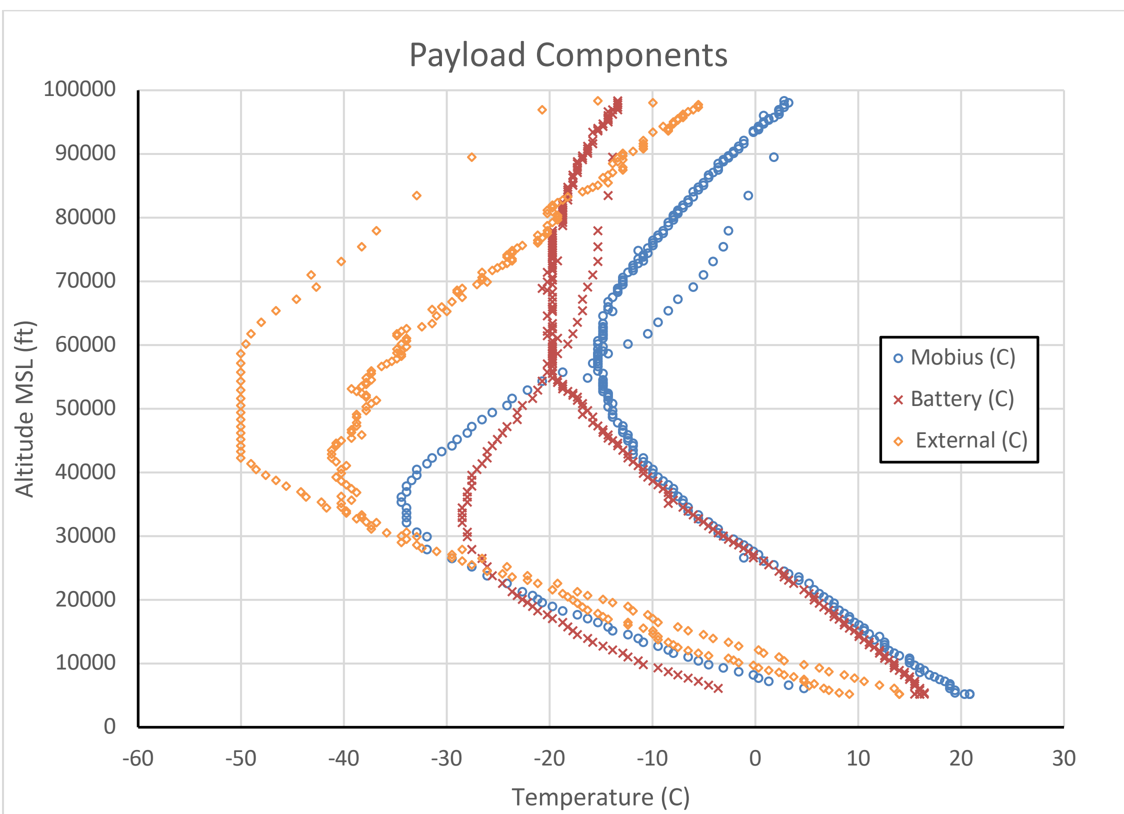

Figure 9: Summer 2020 Temperature Flight Test Results: Altitude vs. Temperature

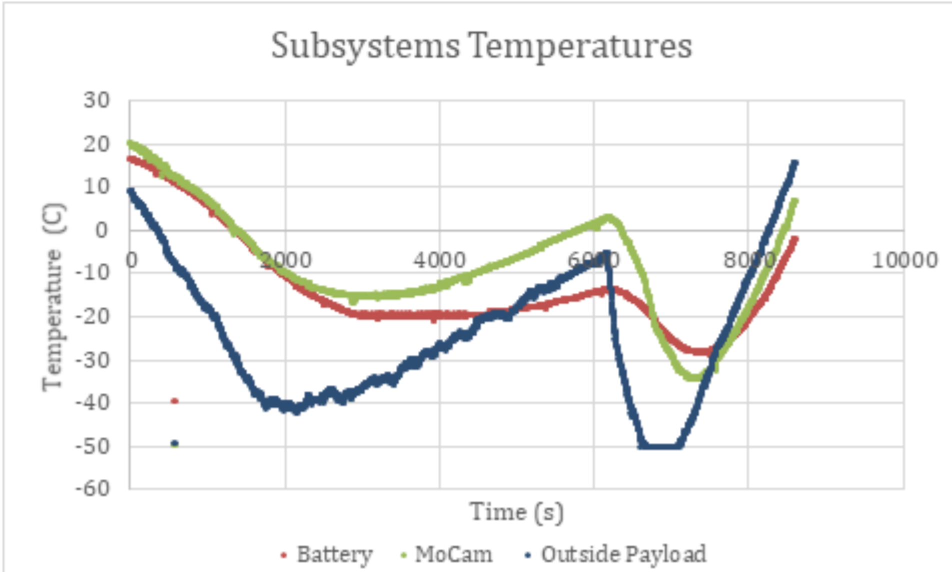

Figure 10: Summer 2020 Temperature Flight Test Results: Temperature vs. Time

We will be altering their design in order to make a more successful payload that can record accurate data without RF interference by altering software.

Figure 8 shows the block diagram for the previous TMS, powered by 7.4-volt batteries. The previous Arduino board, Arduino Pro Mini, read temperature sensors from all components and operated resistor heaters as needed when temperature dropped. The Arduino Pro Mini managed the path of the two voltages, 7.4 volt is the main power and applied to the heaters, 5-volt is applied to the sensors. All temperatures, heater statuses, and times were written to an internal SD card.

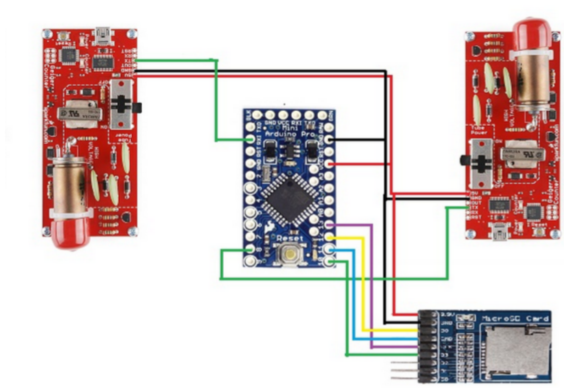

Figure 11: Wiring Diagram for Radiation Experiment

Our team from 2015 performed two cold tests, each lasting an hour long, and found that the resistors drained the battery within 40 minutes. Our team will focus more on the use of too much current which we will control by turning off the heaters. High temperatures will be controlled from the external payload color.

1.7 GPS and Camera

The team will be using an Altus Metrum TeleMega GPs RF transmitter and GPS receiver. The Altus Metrum TeleMega will collect telemetry data and send it to a ground station on a RF frequency. This will allow the team to have a secondary recording of the payload's location. Altus Metrum TeleMega transmits on 400 MHz and has a power output of 14 mW.

Figure 12: Altus Metrum TeleMega

The team will be using a mobius camera which will have its own battery backup. The mobius camera will record the flight, so we can keep track of its position.

Figure 13: Mobius Camera System

2. Team Structure and Management

2.1 Team Organization and Roles

The Spacehawks team are a new group of four members with an advisor. The team plans to recruit more members by the end of February. Most of the work is expected to be done over the summer.

Table 1: Team members' affiliations and contact information.

Team	Roles/Responsibilities	Student Status	Contact Information
Nikolas Conmy	Team Leader Comms, Camera, and Geiger	Junior Undergrad	ngconmy@fortlewis.edu 808-856-6646
Jessie Urban	Team Member Power Management Systems and Geiger	Sophomore Undergrad	jpurban@fortlewis.edu 505-331-3383
Hannah Carlson	Team Member Thermal System and Geiger	Sophomore Undergrad	hgcarlson@fortlewis.edu 719-964-6414
Daniel Sandner	Team Member Thermal System and Geiger	Sophomore Undergrad	Dssandner@fortlewis.edu 970-317-0803
Charles Hakes	Advisor Space Grant Affiliate	Faculty	hakes_c@fortlewis.edu 970-749-8889

2.2 Timeline and Milestones

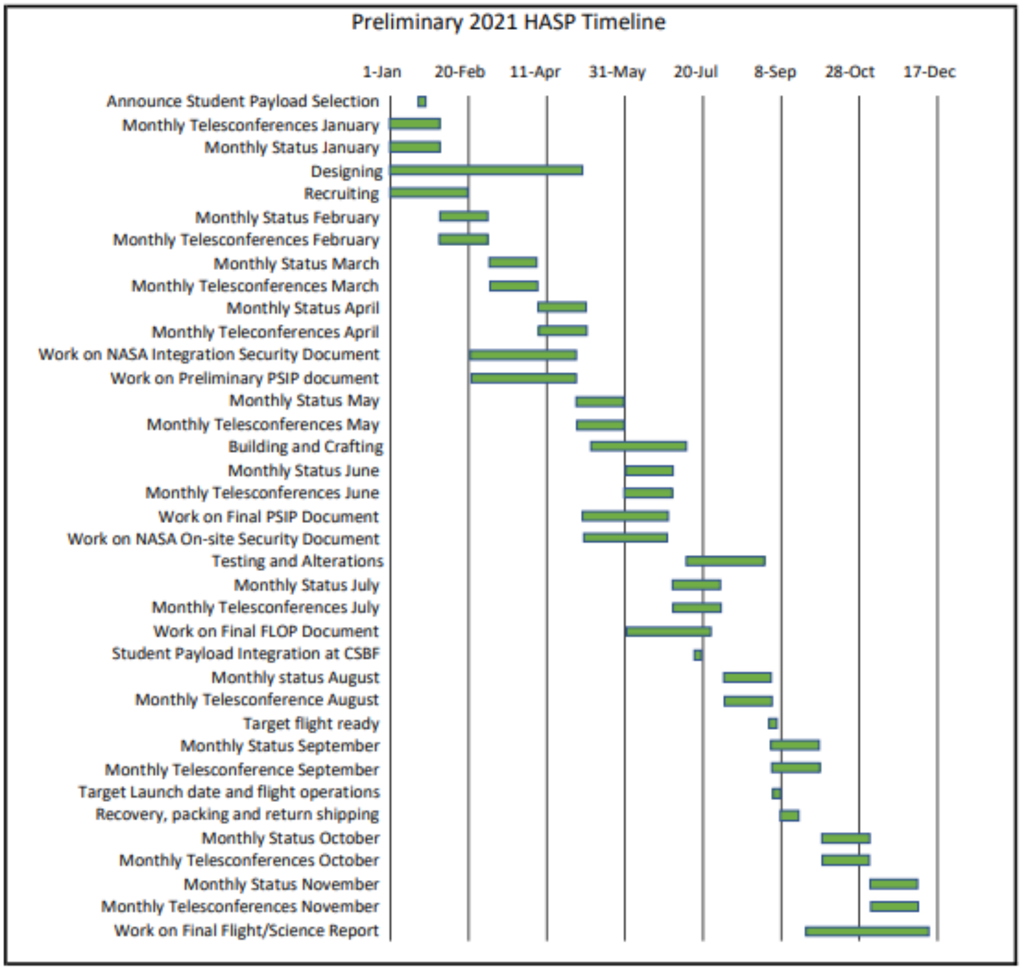

Figure 14: Gantt chart for the HASP schedule for 2021

2.3 Anticipated Participation in Integration and Launch operations

The Spacehawks plan to take part in the CSBF integration and the flight operations at Ft. Sumner. The team may be involved remotely if it coincides with the beginning of the fall semester in 2021. Ft. Sumner is only 6.5 hours away from the Spacehawks, so we will be able to join if any last-minute changes happen.

3. Payload Interface Specifications

3.1 Weight Budget

Table 2: Weight of the subsystems

Subsystem	Weight (g)
Mobius Camera	61.7
Payload sled	500
Internal Structure pallet	39.6

GPS*	23.8
Fiberglass case	1000
Geiger counters	200*2
Total	2025

The weight of most of the systems came from the measurements of similar systems that flew on the 2020 Demosat balloon launch. The maximum weight for the small payload is 3kg and the size of the payload cannot exceed 15cm in width and 15cm in length.

3.2 Power Budget

Table 3: Weight of the Power Systems

Component	Power (watt)	Voltage (volts)	Current (amps)
PMS, Comms, GPS	1.5	3.3	0.45
TMS	0.75	5.0	0.15
Mobius Camera	2.5	5.0	0.5
Geiger Counters	0.15	5.0	0.03
Total	4.9	18.3	1.13

The maximum power supplied from the HASP is 28 volts at 0.5 amps which equals 14 watts. The payload will use DC to DC converters to reduce the voltage and increase the current. This means that before this system a 0.5-amp fuse will be used to make sure the payload does not exceed the 0.5-amp limit.

3.3 Downlink Serial Data and Uplink Serial Commanding

This year's team plans to expand the Communications system into separate subsystems, in order to make full use of the HASP communications capability. The preliminary plan is to continue using an Arduino microcontroller to coordinate uplink and downlink commanding. The Communications system will receive measured data from all other subsystems and process for downlink, additionally, it will interface with all other enabled subsystems to send uplinked commands. The 1200 baud rate and RS232 logic will remain the interface.

The proposed data interface will begin at the DB9 connector on the HASP platform. The data transmission lines will feed into an RS-232 to TTL converter, which allows an Arduino microprocessor to control the communications. These converted lines will then feed directly into the Arduino, which interfaces with each system in a separate I2C communications process.

All downlink data will be packetized. The maximum downlink rate will be 544 bps. Strings will be no more than 64 bytes in length. They will be transmitted on a two second cycle.

3.4 Uplink Serial Data

The team does not plan to uplink any data.

3.5 Analog Downlink

There is no analog downlink planned; all communication will be done through a serial connection.

3.6 Discrete Commanding

A command will be sent to the HASP team in hexadecimal format. This command will then be relayed to the payload through HASP. All demands will be communicated to the HASP team in Google Sheets. We will have a set of commands that perform programs such as: power reset, turn our payload off permanently, turn on the experiment, turn on the camera. These commands will allow us to command our payload from the ground to perform basic functions.

3.7 Payload Location and Orientation Request

There are no specific requests for location or orientation on the payload for HASP.

3.8 Special Requests

The payload will have high voltage components that will be inside a faraday cage. In Fort Lewis College's previous HASP payload, a small lithium battery was used for shutting down software efficiencies and we are looking into possible using one again. If the GPS Fort Lewis college will be an RF transmitter.

4. Preliminary Drawings and Diagrams

The preliminary drawings of the payload are seen in Figure 14 and Figure 15. The payload will attach to the base plate by two vertical stanchions. The electrical systems will attach to a payload sled that will attach to the stanchions. A faraday cage will cover the 2 Geiger counters. A fiberglass shell will slide over the sled and attach the bottom plate.

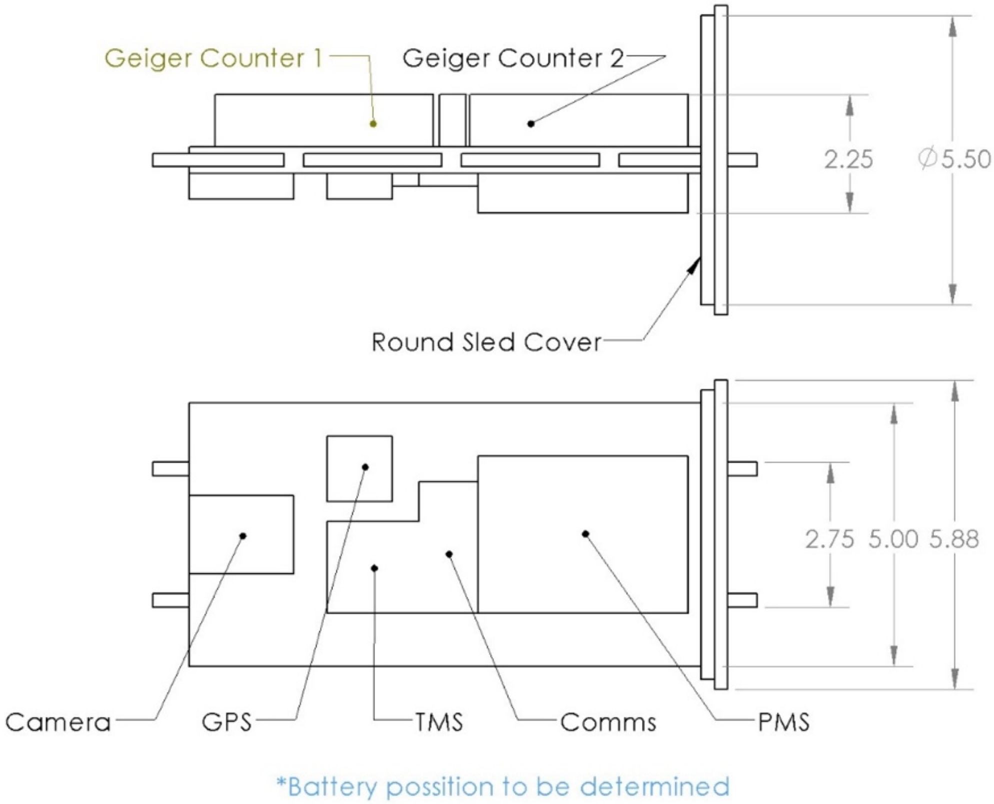

Figure 15: Overall Sled Design on Small Mounting Plate usable area

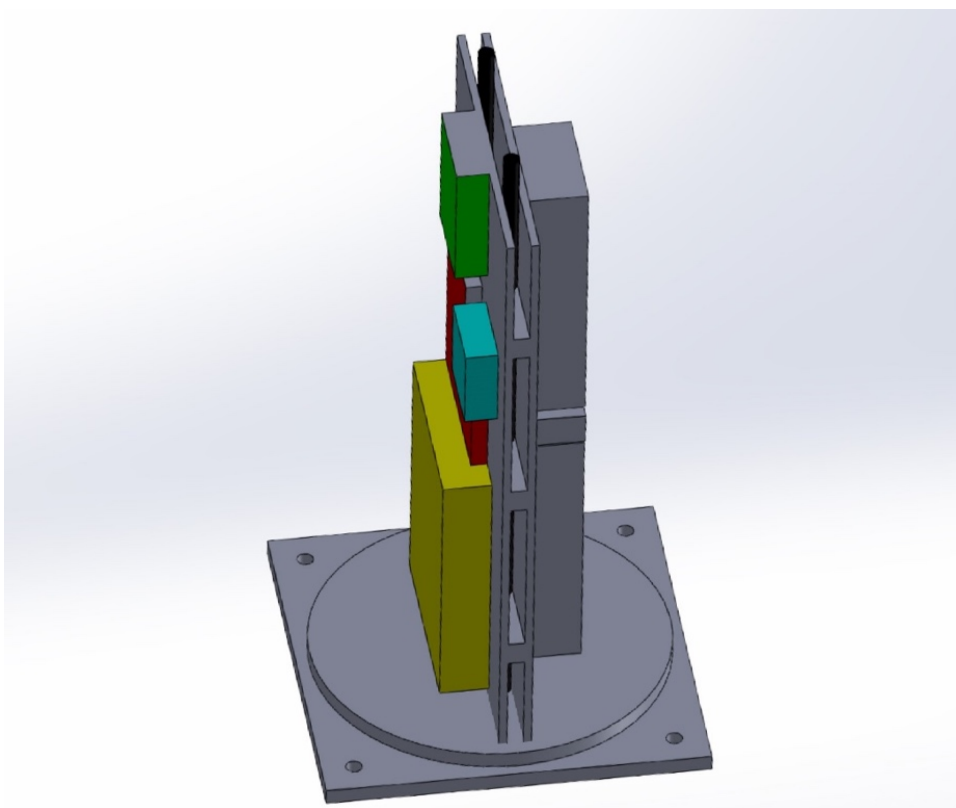

Figure 16: Payload on Mounting Plate

5. References

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