HASP Student Payload Application for 2022

Payload Title: Montana Space Grant Consortium Eclipse Payload Testing		
Institution: Montana State University		
Payload Class (Enter SMALL, or LARGE): SMALL		Submit Date: 1/7/2022

Project Abstract:

To support work that is ongoing for the 2023 and 2024 eclipses we propose to test at altitude a few of the systems planned for that operation, as well as collect any data on gravity waves that may occur during the flight. In addition we will be testing the accuracy of a tracking ground station for pointing antennas at the payload.

The proposed payload will contain a LoRa transmission module, to test its max range; a RFD900 module for its precision GPS sensor; an Iridium asset tracking modem to test the accuracy of the ground based tracking antenna; and a Raspberry pi 4 equipped with an Arducam camera system, to test capture quality in extreme conditions.

Team Name: MSGC HASP 2022		Team or Project Website: https://spacegrant.montana.edu/borealis.html
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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 (gray 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.

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	Yes	
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: Matthew A. Phillips

Student Team Leader Signature: Mystique Fox

Faculty Advisor Signature: [illegible]

Table of Contents

1. Payload Description

The proposed payload will contain a LoRa transmission module, to test its max range; RFD900 transmission module, for its GPS sensor; Iridium package, to communicate with the payload; and a raspberry pi equipped with a raspberry pi camera system, to test capture quality in extreme conditions.

We will be including the RFD900 board for the embedded precision GPS sensor to collect any potential data related to gravity waves, we do not intend on transmitting any signal with this board, but will be using the HASP serial data downlink and a memory card to store data. The gravity wave analysis will occur after the flight.

We will also be including a LoRa board to do an in depth test on data accuracy in its data transmission to a ground station and test its max range. To test the data accuracy we plan on transmitting the data to the tracking ground station and also store the data on an onboard micro SD card to compare at the end of the flight. On a past flight with this board it achieved a 75 mile max distance before going out of line of sight of the ground station and severing the connection in doing so.

We will also be including a Raspberry pi 4 board with two Arducam cameras to record the flight, we do not intend to transmit and/or stream this video. The purpose of this is to test the current configuration of our Raspberry pi camera setup for the streaming of the 2023 and 2024 eclipses to see if there are any issues such as file corruption and/or interruptions with video due to the harsh conditions that will occur during the flight.

An Iridium 9602LP will be flown to track the location of the HASP balloon during flight. This positional data will be used by our tracking ground station to continuously point the antenna at the payload for LoRa transmission of sensor data.

A custom power supply board will be used to convert the HASP power supply to the appropriate voltages for each of the different payload components.

1.1 Payload Scientific / Technical Background

LoRa: This module would be equipped with the purpose of finding its max range. The last reported use of this module demonstrated a reportedly 70+ mile max range; however, that was only found due to the payload going over the horizon, thus cutting off direct line of sight to the ground station. Our hope is that we may get more vertical distance from the LSU HASP flight and, even if it does eventually pass over the horizon, keep a direct line of sight of the payload from the ground station for <u>***100***</u> miles. If we are able to keep an accurate and detailed stream of data for the duration, it will show that we can get a guaranteed stream of data from the flight. That way a large chunk of the data from the flight will be unable to be lost due to malfunctions or damage done by the ground impact at the end of the flight.

RFD900: Using the RFD900 will provide gravitational wave data to be examined for the purpose of determining whether the sensor will be adequate for the 2024 eclipse project. It will also give us a chance to stress test the equipment to ensure it will be able to survive harsh conditions on the axises on the eclipse's path. We do **not** plan on using it for uplink, downlink, or any kind of transmission beyond physical wiring to other systems in the payload (specifically the Iridium).

Iridium: The 9602LP NAL Iridium asset tracker will be used to track the HASP balloon during the entire flight. This information will be used to point the ground based antenna tracking system at the balloon.

Raspberry Pi Cam: As one of the key components being required from the 2024 eclipse project, we hope to include one or more raspberry pi cameras hooked up to a single board that will record the flight video into the file system of the pi. The main reason we wish to do this is to observe any corruption, complications, or anomalies that may occur within the captured video for the duration of the flight.

1.1.1 Mission Statement

To support work that is ongoing for the 2023 and 2024 eclipses we propose to test at altitude a few of the systems planned for that operation, as well as collect any data on gravity waves that may occur during the flight. In addition we will be testing the accuracy of a tracking ground station for pointing antennas at the payload.

1.1.2 Mission Background and Justification

Gravity waves are disturbances in air flow caused by irregular events such as thunderstorms or solar eclipses, and the disrupted motion of the air can be carried for long distances in both the horizontal and vertical directions by gravity or buoyancy, hence the name (Fritts and Alexander, 2003). These irregularities are important to be monitored, for both climate researchers and aviators, as they can affect how objects move through the air. As a result of the air disturbances, gravity waves can generally be detected and characterized through analyses of position, temperature, or pressure fluctuations measured by objects passing through layers of the atmosphere. In preparation for the National Eclipse Ballooning Project 2023, we propose to test the capability of our payload to detect eclipse gravity waves.

At present, most methods for finding gravity waves rely on being able to access a wide range of data, such as all of position and temperature data measured by radiosondes (Guest et al., 2000). This approach, while thoroughly tested and researched, has a number of limitations especially for smaller-scale student groups such as those at Montana State University. Firstly, due to the need for both highly accurate and precise data, radiosondes are often flown as the only payload of a balloon, so as to avoid interference from other sources, such as batteries. For groups that are only capable of launching a single flight at a time, it is simply not efficient to favor the one radiosonde over all other instruments. Additionally, it is generally helpful to fly multiple consecutive radiosonde flights spaced over the course of a day to rule out anomalies from one single deployment (Gong and Geller, 2010). Again, this radiosonde approach relies on the assumption that the organization will be able to afford several flights in a day, which may not be feasible.

Instead, we attempt to utilize only the position data collected from much more easily accessible sources such as the RFD900 and LoRa modules. Although temperature data (e.g., from a radiosonde) would certainly help confirm any results from analysis of the position data, in ignoring temperature readings using a new methodology, we circumvent the problem of having to fly the RFD or LoRa modules alone as a single payload. Additionally, we intend to fly several boards in the same flight to account for GPS noise or other problems that may exist in a single board, therefore not having to conduct multiple flights in a day.

In more detail, our new methodology follows several past documented gravity wave characterizations, accumulating multiple approaches of measuring gravity wave properties, and investigating if they are reasonable. We will examine that the results from these different approaches are consistent both with each other, and with what is already known about how gravity waves behave. The first of four approaches aims to verify that gravity waves can plausibly exist in the data. The entire vertical velocity ascent profile is filtered and fitted to produce a profile of the perturbations in the vertical velocities, measured as deviations from the mean. Through filtering in both time and space domains and varying degrees of polynomial fits, this approach aims to eliminate most other sources of fluctuation including natural balloon oscillation, pendulum motion of the payload, GPS noise, and the balloon rising through different altitude levels such as the jet stream or tropopause. If gravity waves are to exist, a Fourier transform accounting for all of those factors should find some signals lying between the Coriolis frequency and Brunt-Vaisala frequency (Gong and Geller, 2010). The Fourier transformation also reveals the vertical wavelength of the gravity wave, which should lie approximately on the scale of 1-10 km.

The second approach attempts to fit ellipses (helices) to the raw horizontal velocity data for the entire ascent profile, based on the idea that ellipses are indicative of the presence of gravity waves. Based on the orientation, major and minor axes, and vertical extent of the ellipses (helices), the wave's source, frequency, and vertical wavelength respectively can be determined. The third approach performs a Morlet wavelet transform on the data, which aims to highlight wave signals the hodograph may have missed, and also produces the wave characteristics (Colligan et al., 2020).

Finally, in the fourth approach Stokes' parameters are derived from the horizontal zonal and meridional velocity perturbations over the altitudes of interest identified by the hodograph (Zhang et al., 2012). This derivation is performed twice; using velocity perturbations both before and after the wavelet transform, and should produce the same results in each case. Once again, application of the Stokes' parameters can provide information on the gravity waves' characteristics, to be compared with those estimated from the earlier approaches (Eckermann 1996).

In order to successfully detect gravity waves from only position data, it is important to obtain an accurate and complete picture of the entire ascent profile of the balloon. This will be accomplished through the following procedures:

(1) Position oscillations will naturally occur, and to find gravity waves it is necessary to separate them from the natural oscillations that would occur throughout the entire flight.

(2) Small breaks in the data and its accuracy can be easily accounted for via interpolation, however larger interruptions create uncertainty as to whether a certain signal is normal or not. This project will allow us to identify these larger interruptions and remove their occurences from future flights.

(3) Regarding natural oscillations, another helpful factor comes from float oscillations, which should be generally easier to characterize. As geography can influence the occurrence of gravity waves, gravity waves are not a given, and longer float durations logically imply a greater chance of passing through a gravity wave, providing an actual signal for the GPS and analyses to measure. Sending the RFD900 and LoRa through conditions similar to those of the eclipse project for longer durations of time should assure us that they are indeed suitable to collect the necessary data for conclusive gravity wave analyses.

In summer 2021, we successfully applied the proposed methodology to our own balloon flights, and found gravity wave signatures most likely produced by mountains. Thus, we seek to extend the experiment to encompass eclipse-like conditions. Through this proposed research, we will optimize the science outcomes in the presence of the payload constraints, with the ultimate aim of demonstrating the feasibility of detecting gravity waves for the eclipse project.

As part of the 2023 and 2024 solar eclipses a tracking ground station is needed for streaming video from the payload at altitude. We will be testing the tracking ground station using a LoRa radio board (instead of video) that has GPS and other sensors that can be transmitted to the ground station LoRa board and computer. We will use the NAL Iridium asset tracker to track the balloon during flight to our already developed website. We are testing the algorithms in the tracking ground station to determine how accurate the system can point during a balloon flight.

The Raspberry Pi 4 and Arducam cameras used for streaming video will be tested on the flight to determine performance throughout the balloon flight. Video will be stored to an on board memory card with the latest eclipse flight software installed.

1.1.3 Mission Objectives

Objective one, to find the maximum range of the LoRa module.
Criteria for success:

- ☐ LoRa successfully communicates with ground station
- ☐ LoRa data stream is accurate with no corruption (compared to on board data and data sent via HASP data stream)
- ☐ LoRa continues data stream for know range
- ☐ LoRa surpassed known range
- ☐ LoRa continues communication once over the horizon

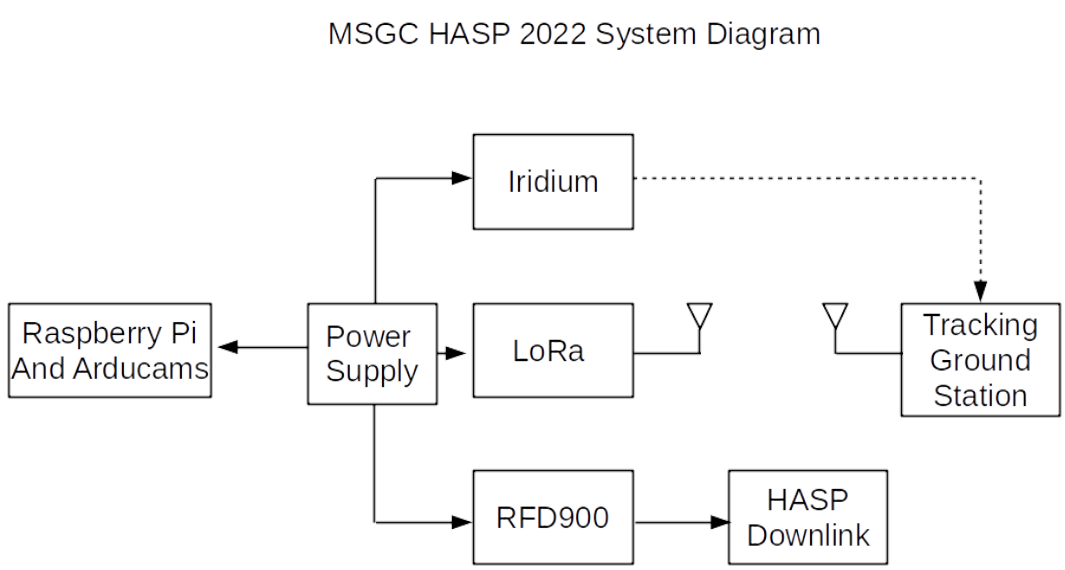
Objective two, to demonstrate that the RFD900 collects all data in an accurate manner. To show that the RFD900 can survive the harsh conditions and determine if flight conditions will affect the accuracy of the sensor.
Criteria for success:

- ☐ RFD900 begins to collect GPS data
- ☐ RFD900 data is consistent with known GPS data
- ☐ RFD900 measurements are within an acceptable degree of accuracy
- ☐ RFD900 continues to collect accurate data throughout the entirety of the flight
- ☐ RFD900 performance and survivability is not affected by near-space conditions
- ☐ RFD900 does not explode, catch fire, fall of the ballon, or otherwise fail dramatically

Objective three, to determine the quality of visual images collected during flight conditions in order to determine if the camera system is a viable choice for the 2024 eclipse project.

- ☐ The camera records high-quality visuals (1080p) relatively undisturbed throughout the entire flight
- ☐ The camera–raspberry pi system successfully stores images throughout the entirety of the flight

1.2 Payload Systems and Principle of Operation



The main goal of our experiment is to test these systems at high altitude in preparation for the 2023 and 2024 eclipses.

1.3 Major System Components

- ☐ Tracking Ground Station
  - ☐ Transmission from LoRa Board to Ground Station for payload communication.
  - ☐ Uses establish balloon tracking website
  - ☐ BOREALIS Balloon Tracking App (montana.edu)

- ☐ Onboard Balloon
  - ☐ RFD 900 Board- Sensing gravitational waves with precision GPS.
  - ☐ Raspberry Pi and Arducam Cameras- Onboard video recording and saving.
  - ☐ NAL Iridium asset tracker for realtime balloon location.

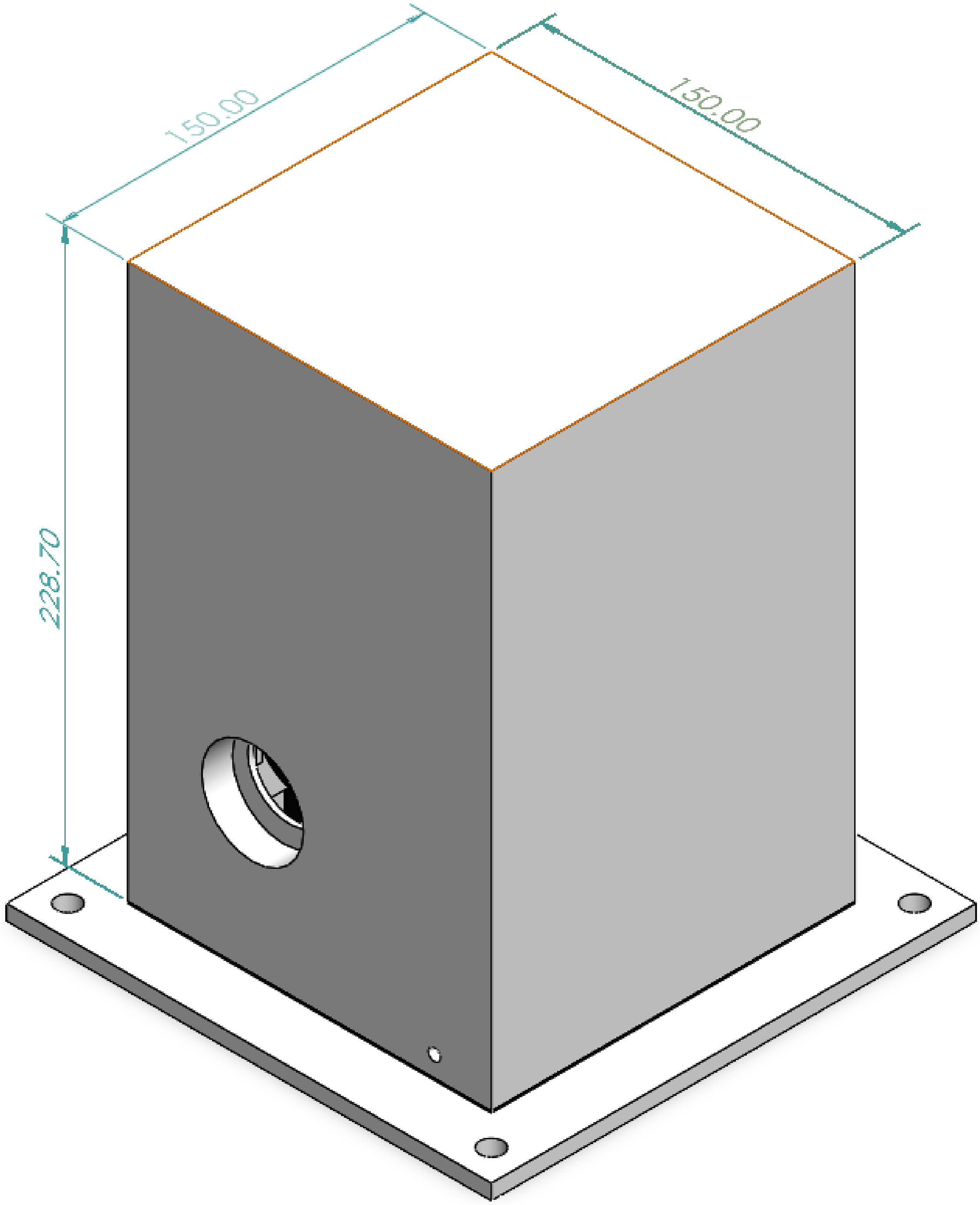
1.4 Mechanical and Structural Design

The payload, excluding the electronics, will primarily be made of foam board and an aluminum base plate. The overall shape will be that of a cube, roughly 0.003 cubic meters. The outsides of the cube will be entirely made out of foam board, with the exterior of the board being surrounded with white duct tape to decrease overall heating of the payload. See appendix for mockup drawings.

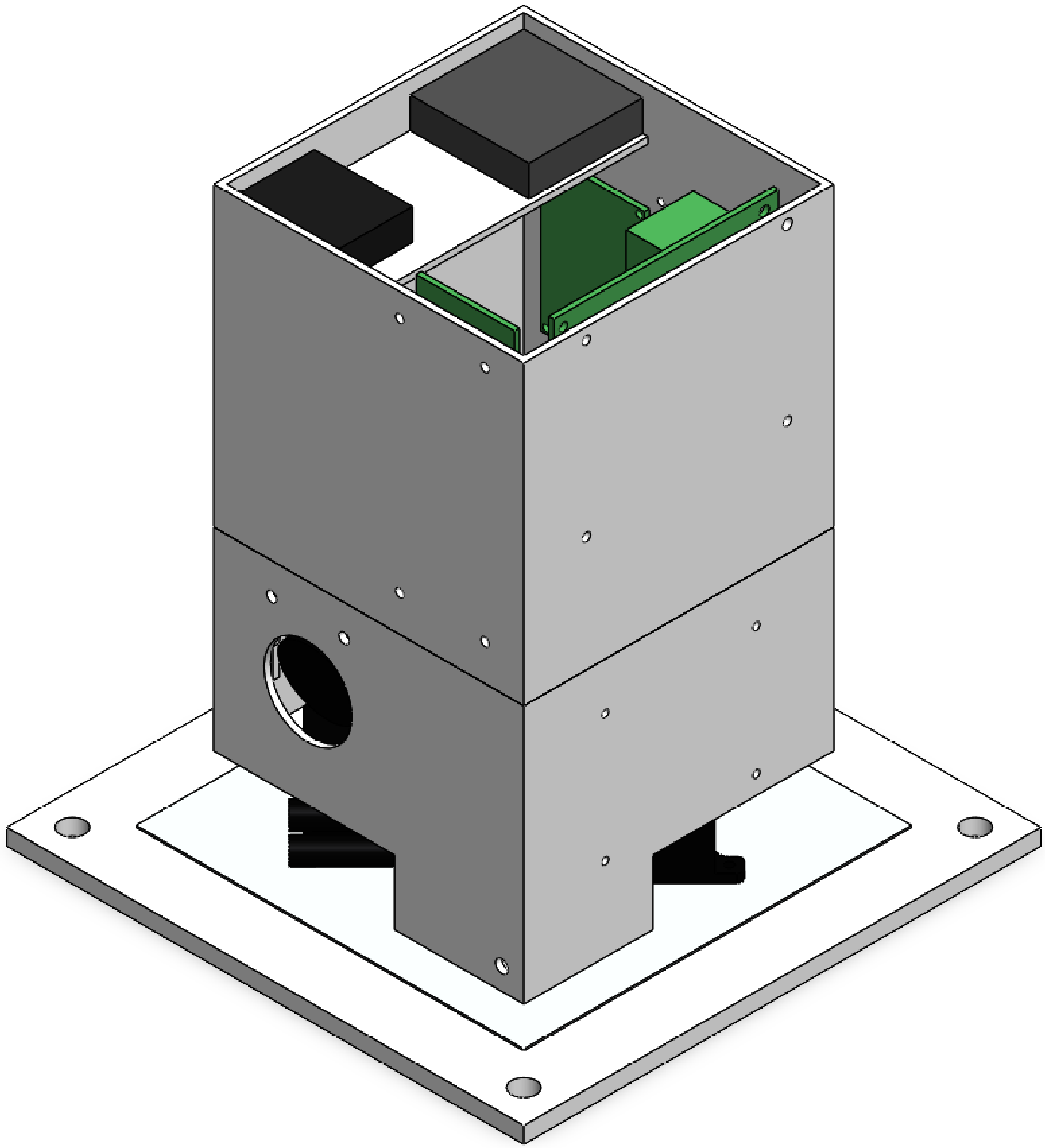
A small whip omni directional antenna will protrude from the bottom of the payload to allow LoRa communication with the tracking ground station.

Additional overall sketch shown in Section 4. Preliminary Drawings and Diagrams

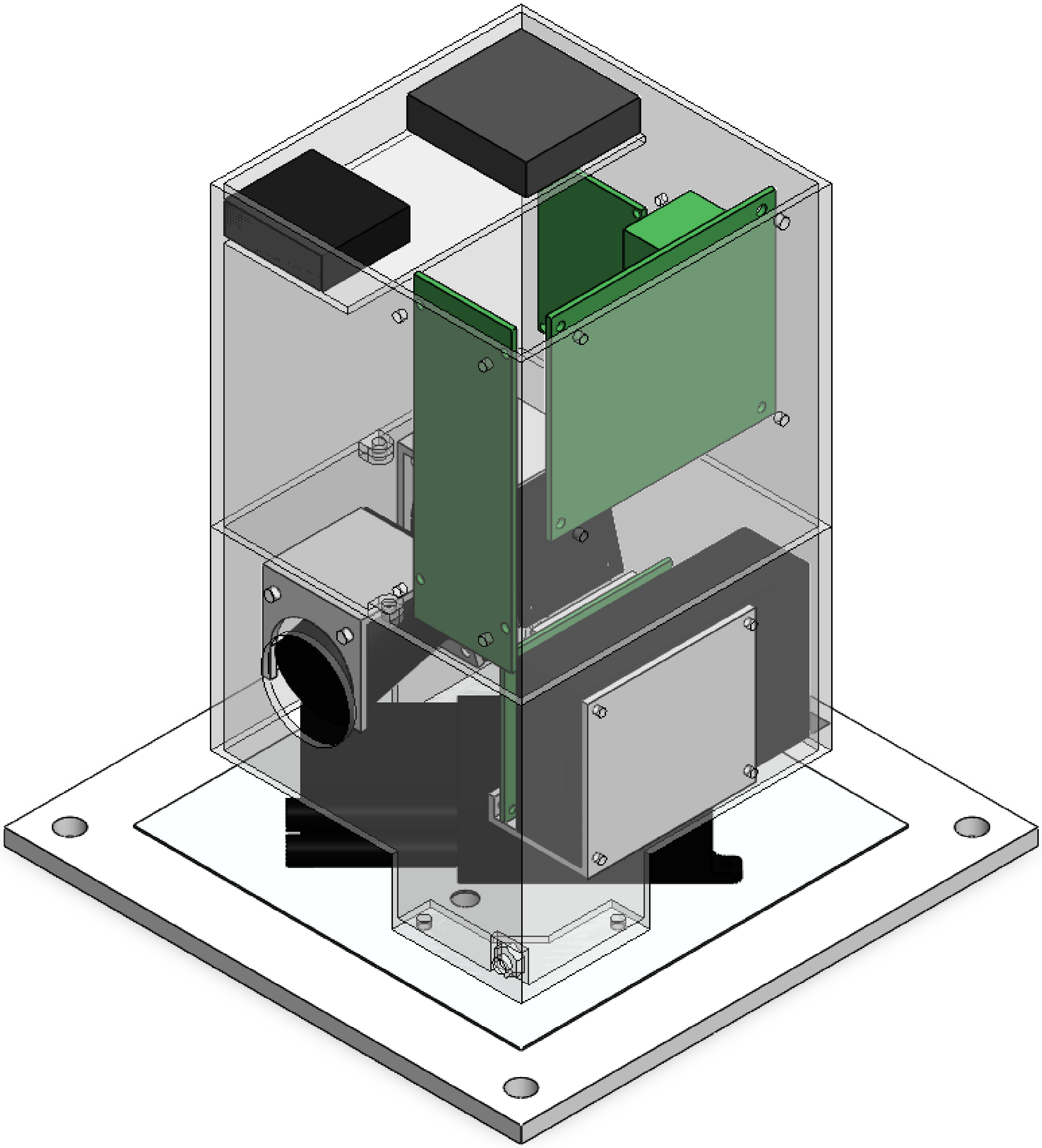
Dimensions in the figures below are in millimeters.



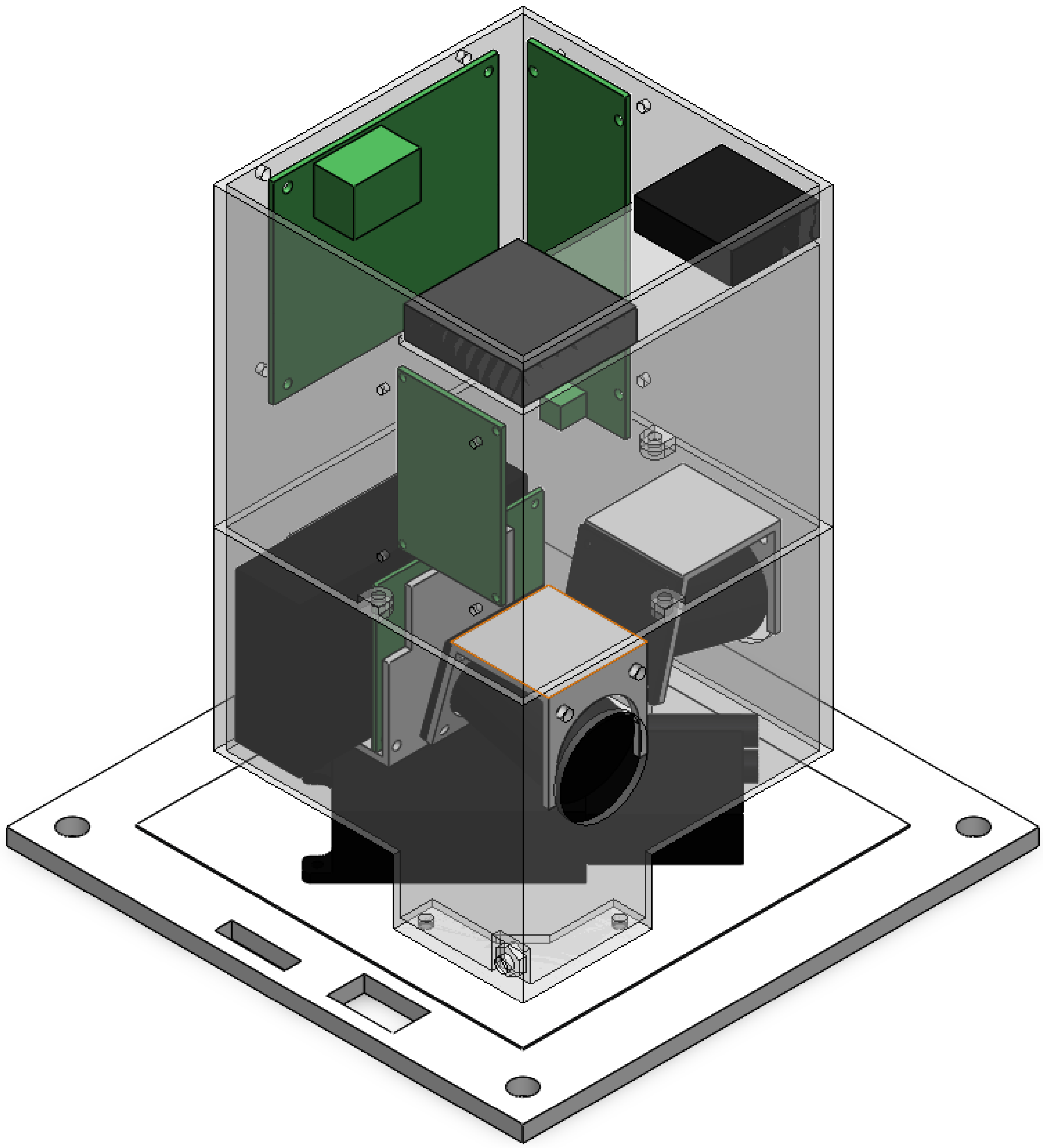
Payload with sun shield in place.



Payload without sun shield showing internal structure.



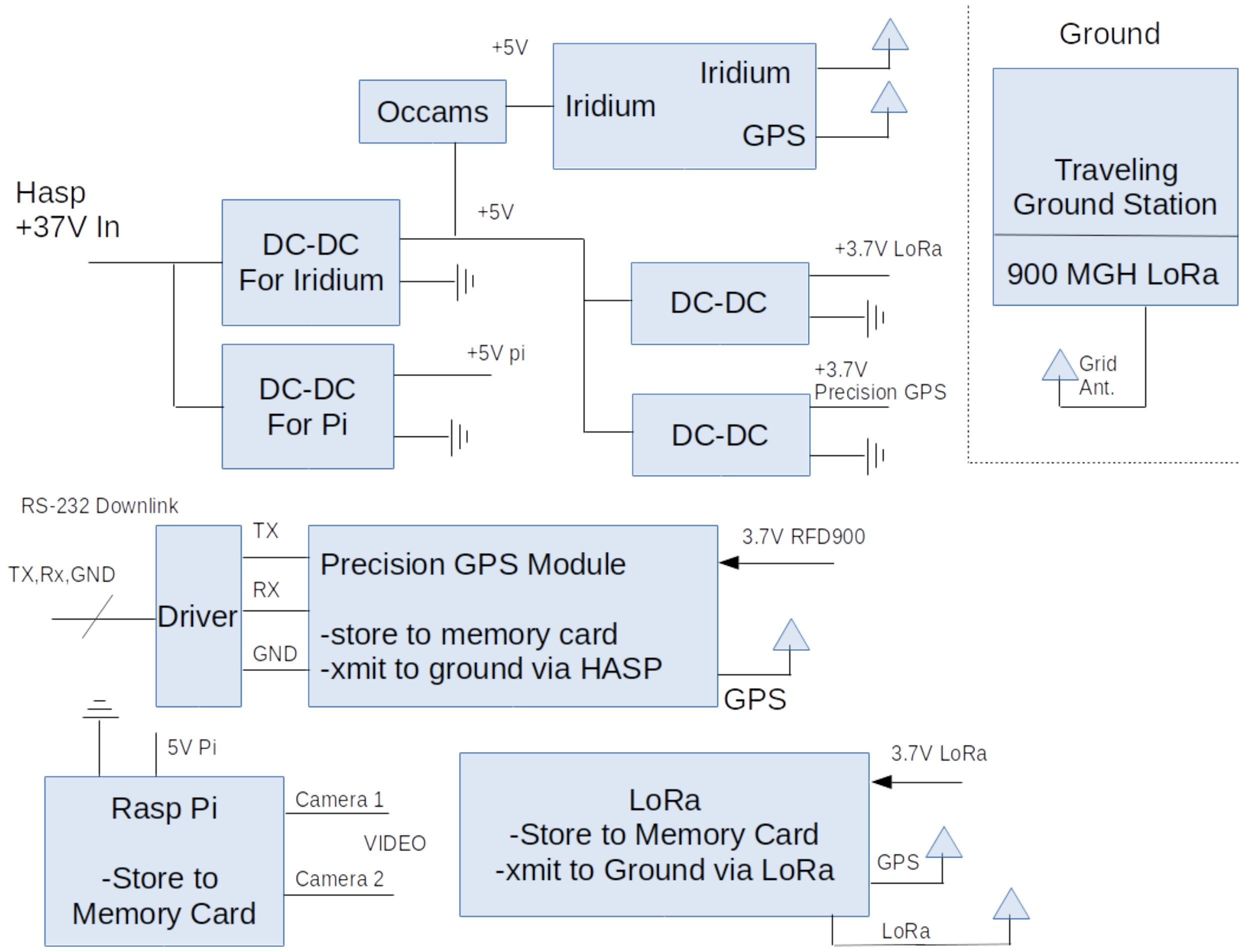
Payload internal component locations.



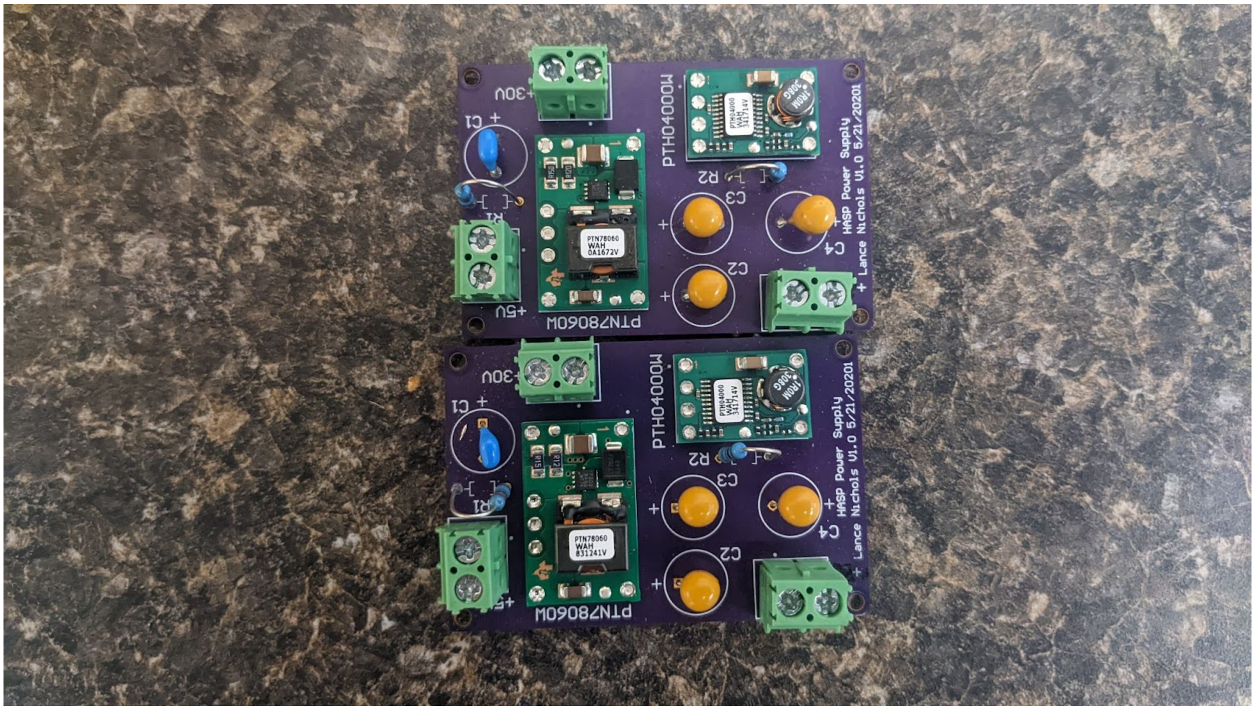
Payload internal component locations.

1.5 Electrical Design

The following block diagram shows the system block diagram of our payload. Each subsection will be described below.

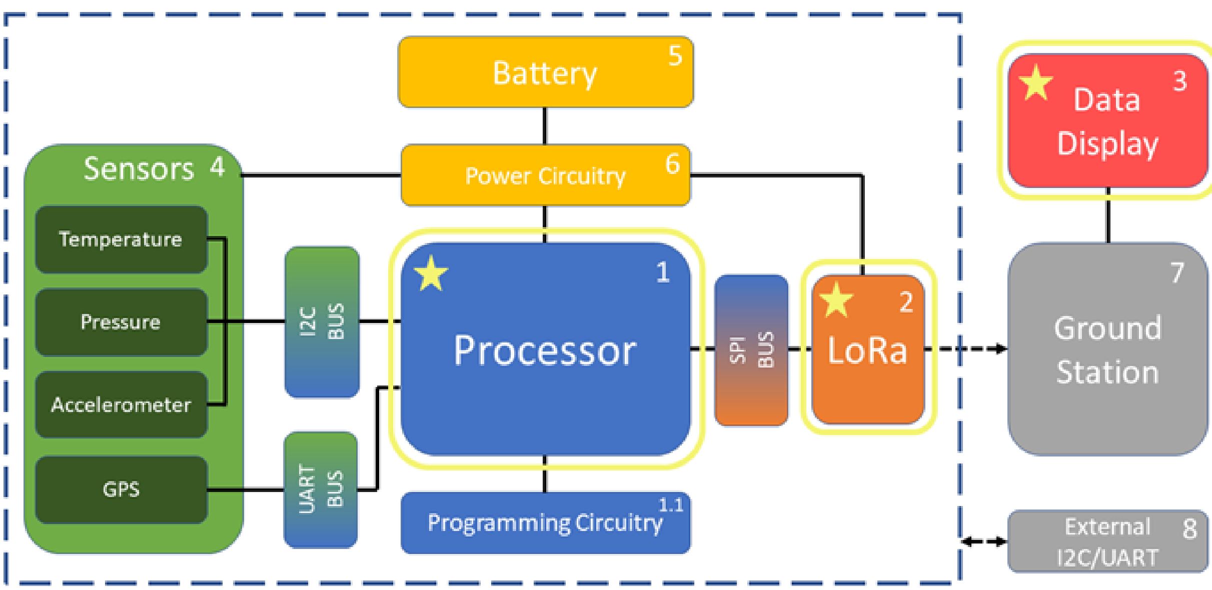


System Block Diagram



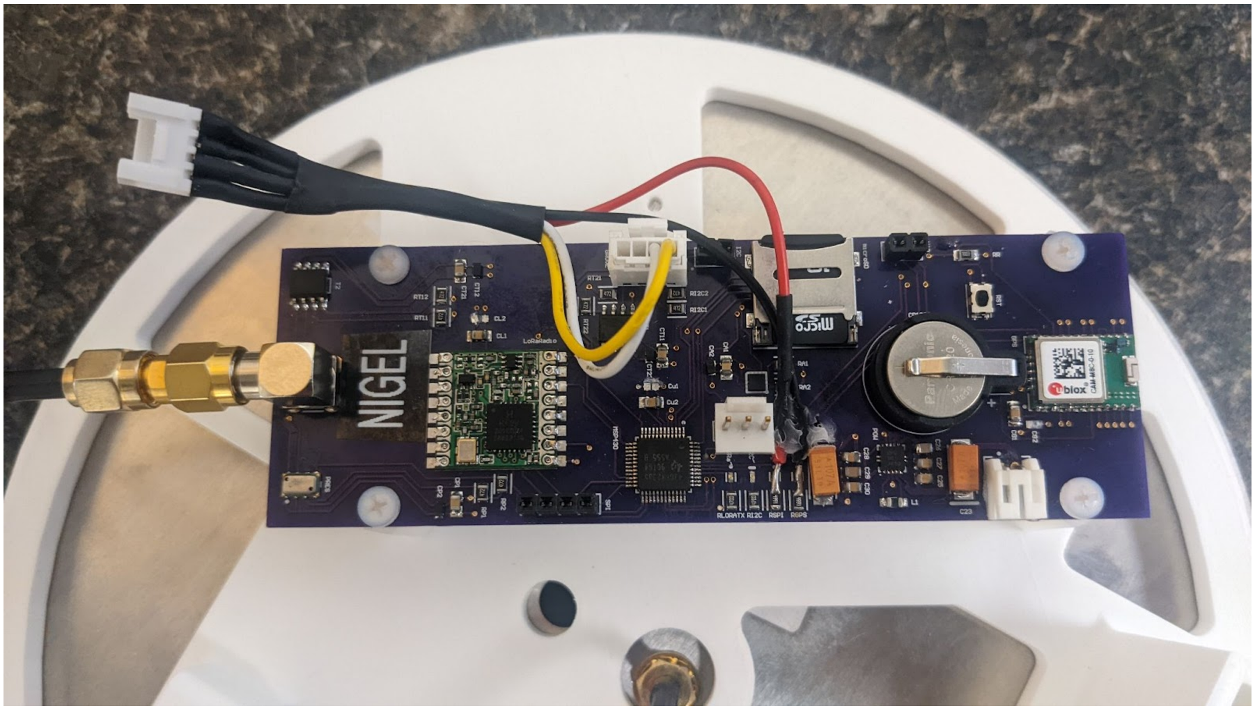
Payload Power Supply

The payload power supply will be redone to reduce size and to add the RS232 driver needed for the HASP downlink capability,

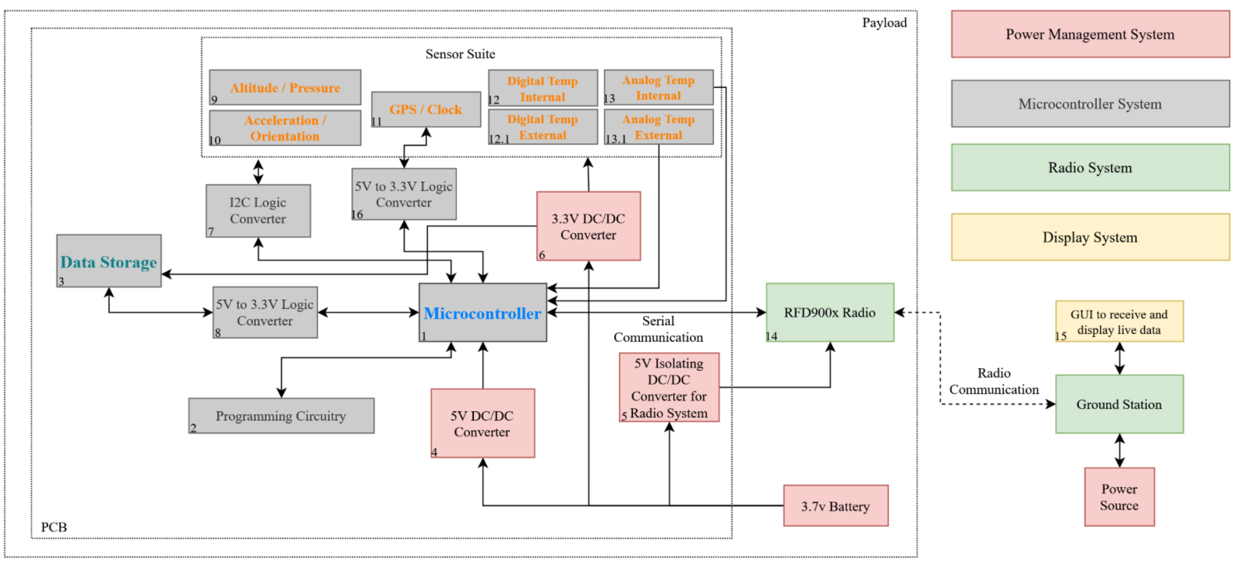


LoRa Block Diagram

Full schematics and circuit description of the LoRa system are available in the included file Final Report_15LoRaD.pdf

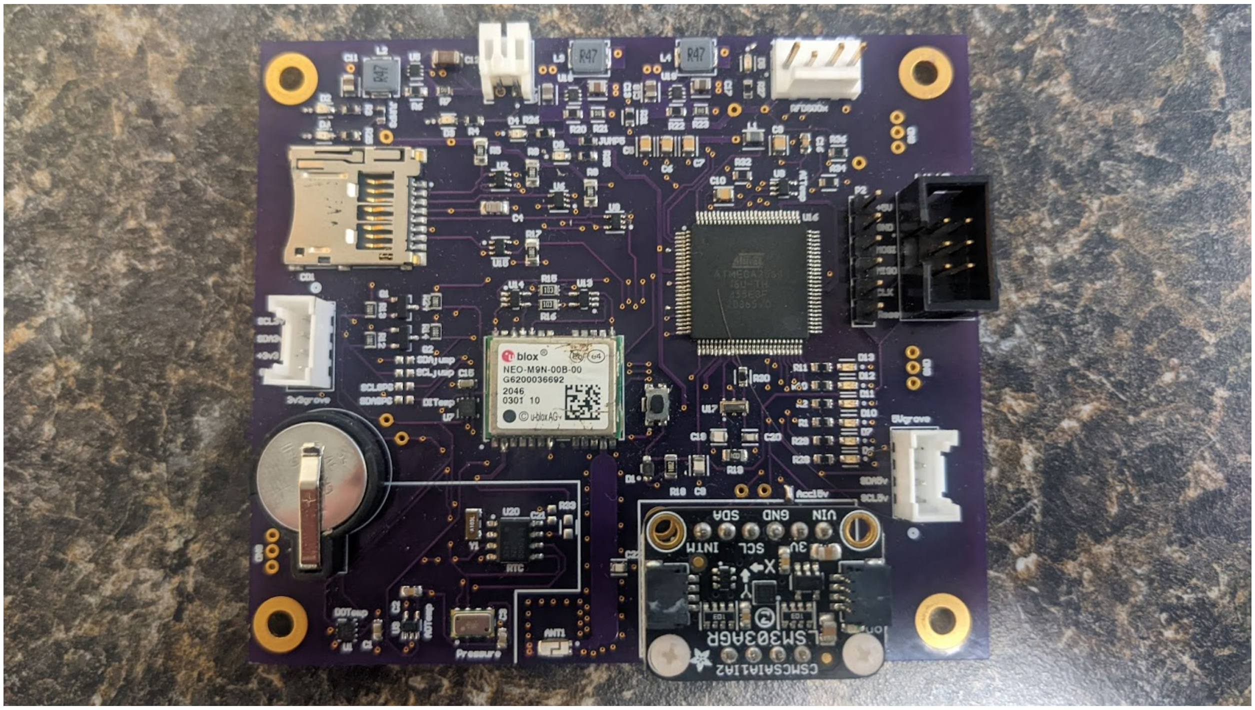


LoRa System



RFD900 Block Diagram

Full schematics and circuit descriptions of the RFD900 system are available in the included file FinalReport_25RFD900.pdf



RFD900 System

Tracking Ground Station

1.6 Thermal Control Plan

Our goal is to keep the operating temperature around 35 degrees C. One big step in ensuring this is using an aluminum heatsink case for the raspberry pi 4 made by PIMORONI that will be directly attached to the aluminum plate at the bottom of the payload to keep from interfering with any RF signal in the payload. The aluminum base plate will then also act as a heatsink, further dispersing the heat. The encasing of the payload will also be done with foam and a white exterior to help insulate the components inside and protect them from radiative heating.

2. Team Structure and Management

2.1 Team Organization and Roles

Tim Uhlenbruck - Senior in Mechanical Engineering (Graduating May 2022)
t.uhlenbruck@yahoo.com - 406-274-4677
Mechanical Engineer Advisor - Responsible for the design of the payload and advising the new participants, utilizing knowledge gained from his participation in HASP 2021.

Mystique Fox - Freshman Astrophysicist (Graduating May 2025)
mfox1744@gmail.com - 864-425-4479
Student Co-Leader and Mathematical Analysis - Responsible for project management, ensuring milestones are made and communicating with HASP contacts, mathematical components, and general project design work. Responsible for data analysis of gravity waves. Will have a final say in signing off on payload tests along with other co-leader.

Matthew Phillips - Freshman in Computer Science (Graduating May of 2025)
mphillips8687@gmail.com - 406-870-1761
Student Co-Leader and Lead Programmer - Responsible for project management, ensuring milestones are made and communicating with HASP contacts. Responsible for making sure all existing software works correctly, writing any code required, editing any existing code if required, and helping with any other programming if requested or necessary. Will have a final say in signing off on payload tests along with other co-leader.

Bryce Kim - Freshman in Mathematical Analysis (Graduating in May of 2025)
bryce.kim@bsd7students.org - 406-580-3627
Mathematical Analysis Lead - Responsible for making sure the correct data is collected for their observing of Gravity Waves and analyzing the data received by the precise GPS for Gravity Waves.

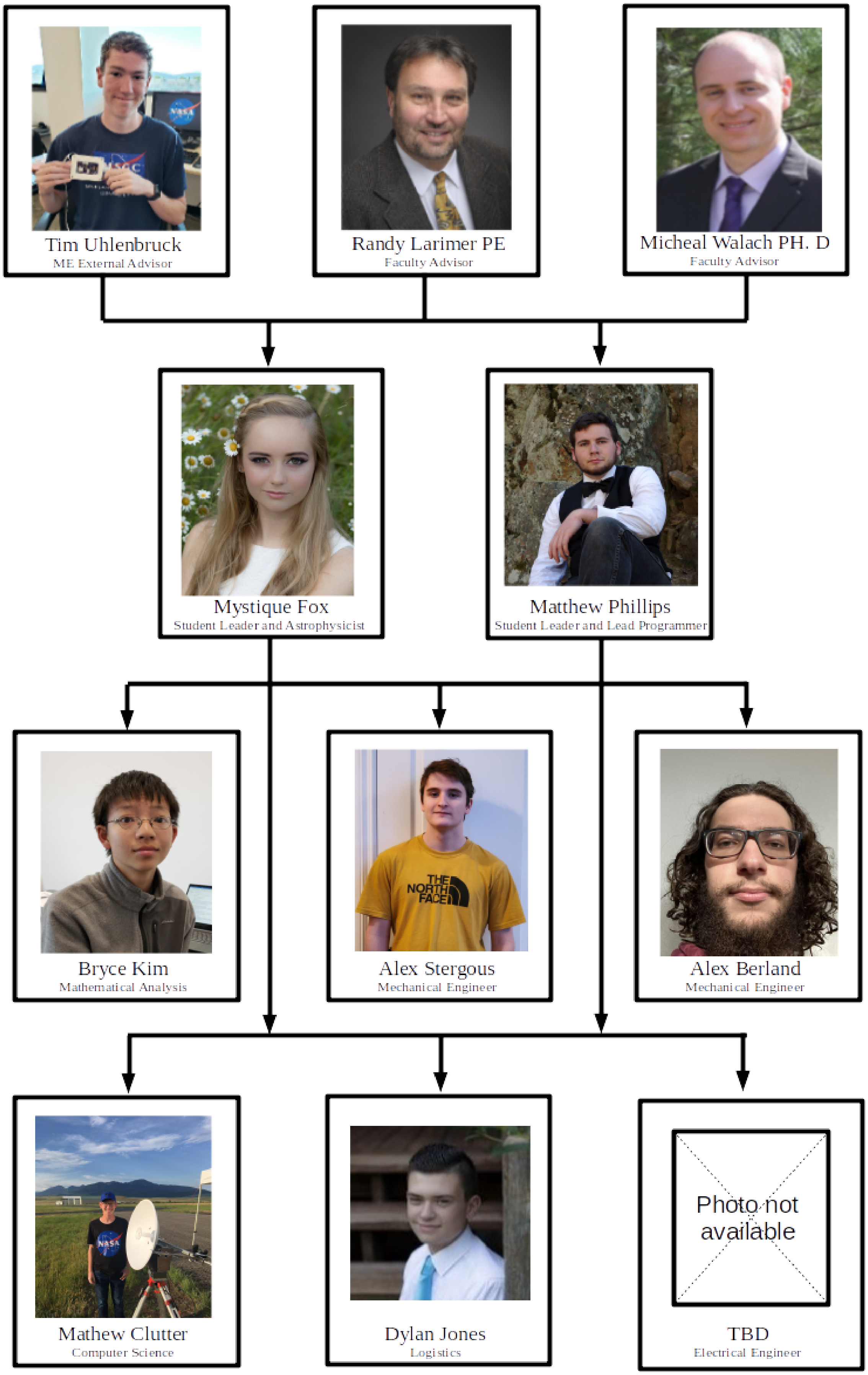
Alex Berland - Sophomore in Mechanical Engineering (Graduating May of 2024)
alexanderberland51@gmail.com - 720-514-2798
Mechanical Engineer - Responsible for helping with any design aspects that need to be altered or completely redesigned during assembly and testing. Responsible for fabrication and testing of the payload housing.

Alex Stergous - Freshman in Mechanical Engineering (Graduating May of 2025)
ahstergios@gmail.com - 406-830-8252
Mechanical Engineer - Responsible for helping with any design aspects that need to be altered or completely redesigned during assembly and testing. Responsible for helping with mechanical design, fabrication and testing of the payload housing.

Matthew Clutter - Sophomore in Computer Science (Graduating May 2024)
mathew.clutter@mines.sdsmt.edu - 605-209-6005
Computer Scientist - Responsible for programming the ground station's algorithms for tracking the payload via the Iridium module.

Dylan Jones- Freshman in Political Science (Graduating May 2025)
dylansjones2009@gmail.com - 864-345-0030
Head of Logistics - Responsible for all aspects regarding logistics. Responsible for including organization tactics to the team design process to guarantee a safe and efficient development of the project. Also responsible for having additional design and building parts for flight day to ensure the team is prepared for any possible complication.

MSGC HASP Organizational Chart



2.2 Timeline and Milestones

This section includes a list of key milestones (and associated dates) for the project and a Gantt chart timeline. The timeline should be a weekly schedule organized by major WBS elements.

PROJECT TITLE	2022 HASP Eclipse Payload	COMPANY NAME	Borealis
PROJECT MANAGER	Mystique Fox Mattew Phillips	DATE	11/16/21-11/16/22

PHASE ONE: WEEK 1 (1/10-1/14), WEEK 2 (1/17-1/21), WEEK 3 (1/24-1/28); PHASE TWO: WEEK 4 (1/31-2/4), WEEK 5 (2/7-2/11), WEEK 6 (2/14-2/18)

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	Project Conception and Initiation					100%
1.1	Proposal	All	11/16/21	1/7/22	51	90%
1.1.1	Find all existing parts and code	All	1/10/22	1/13/22	3	0%
1.2	Determine what needs further development	All	1/10/22	1/13/22	3	0%
1.3	Brain storm inital model layout	Alex and Alex	1/10/22	1/13/22	3	0%
1.4	Test all existing parts	Matt	1/13/2022	1/13/22	0	0%
1.5	Brainstorm rough plan for ground station	All	1/13/22	1/21/22	8	0%
1.6	Monthly Summary Report	Team Leaders	1/24/2022	1/28/22	4	0%
2	Project Definition and Planning					
2.1	Begin creating needed programs	Matt	1/17/22	1/28/22	11	0%
2.2	Begin desiging housing for parts	Alex and Alex	1/17/22	3/3/22	46	0%
2.3	Begin planning how to extract Gravity wave data	Bryce	1/17/22	3/3/22	46	0%
2.3	Assign remaing tasks and reevaluate timeline	Mystique	1/17/22	1/27/22	10	0%

Full timeline can be found here: [GANTT CHART HASP]

2.3 Anticipated Participation in Integration and Launch operations

We plan to participate in all integration and launch operations allowed in Palestine and Fort Sumner. If such an occasion would arise that we are unable (such as Covid related or other outside forces) we will provide detailed instructions for HASP personnel to do such operations successfully without our presence, including (but not limited to) setting up the ground station.

3. Payload Interface Specifications

3.1 Weight Budget

All weights below were determined with a standard postal scale.

Item	Mass	Uncertainty	Comments
LoRa Board	.035 kg	±0.02 kg	This measurement is for the board itself, not with the antennas, wires, or a micro SD card inserted/attached.
RFD900	.033 kg	±0.02 kg	This measurement is without wires attached or a micro SD card inserted.
Raspberry Pi and ArduCams	.323 kg	±0.2 kg	Due to the use of a full aluminum heat sink case, this item could nearly double in weight.

Iridium	.373 kg	± 0.05 kg	Length of wiring used for the ground wire and antennas.
Power Converters	.112 KG	± 0.028 kg	Each DC-DC converter weighs about 28 g, so if we need to add or remove one the weight could change.
Payload Structure	1 kg	± 0.2 kg	Due to possible change in structure.
TOTAL	1.680 kg	± 0.518 kg	1.162 kg - 2.198 kg

3.2 Power Budget

Item	Voltage	Current	Power (W)	Comments
LoRa Board	3.7 V	253mA	0.94 W	
RFD900	3.7 V	250mA	0.93 W	
Raspberry Pi and Arducams	5V	1.5 A	7.5 W	
Iridium	5V	200 mA	1 W	
Power Converters	37V input to 3.7 V and 5V	10 mA	0.37 W	HASP Power to payload voltages
TOTAL	37 V	0.29 A	10.74 W	

LoRa Board - from FinalReport_15LoRaD.pdf

Device	Voltage	Max Current	Min Current	Power
MSP430	3.3 V	50mA	<.1mA	
LoRa	3.3 V	130mA	1.5mA	
GPS	3.3 V	71mA	10mA	
Temperature	3.3 V	.25mA	.001mA	
Pressure	3.3 V	1.4mA	.001mA	
Accelerometer	3.3 V	.14mA	.0001mA	
Totals		252.79mA		
Target		253mA	11.5	

RFD900 - input voltage 3.7 V measured current 250 mA from unit

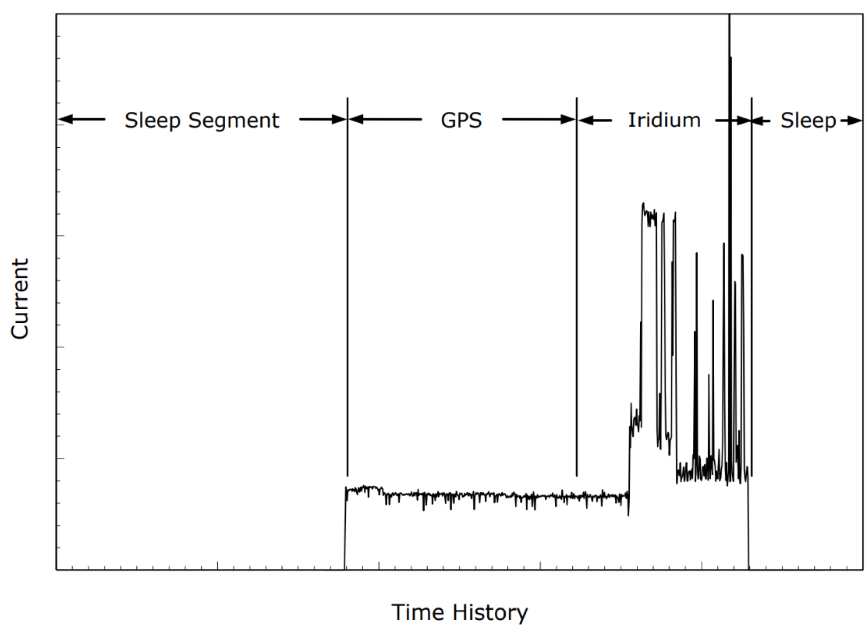
NAL 9602LP – from Datasheet
Input Voltage: 3.6V to 5.5V or 6.5V to 32V (We use 5 volts for powering the NAL unit)

Avg Current (Report): 200mA @ 5V Input

Avg Current (Sleep): < 65µA @ 5V Input

Electrical Specifications
Input Voltage Range: +3.6VDC to +5.3VDC or +6.0VDC to +32VDC (We use 5 volts)
Main Input Voltage Ripple: < 40mV peak-to-peak
Transmit Current (Average): 200mA @ 5VDC
Transmit Current (Peak): 1.5A @ 5VDC
Receive Current (Average): 45mA @ 5VDC
Receive Current (Peak): 195mA @ 5VDC
Message Transfer Power (Average): <= 1.0W @ 5VDC
Current in Between Reports: Less than 65uA @ 5VDC
Power Input Type: DC power or LiIon battery
NOTE: The DC power requirement was measured at the 9602-LP multi-interface connector and not at the DC power supply. Users must take into account voltage drop across the power supply cable to ensure adequate current provided to the 9602-LP during SBD sessions. If input voltage does not stay above 3.0VDC during surge or high current demand, the 9602-LP will reset itself.
NOTE: The average current drawn during transmission may vary depending on the field of-view between the 9602-LP antenna and the Iridium satellite, the type of Iridium antenna used and the cable loss.

In tracking mode, the 9602-LP goes through three different power consumption segments: (1) the sleep (in between reports) segment, (2) GPS acquisition segment, and (3) SBD transmission segment. Figure below shows different stages of current drawn by the 9602 when in tracking mode. During the sleep segment, the 9602-LP goes into power-saving mode by shutting down all its internal circuits.



Sleep segment: 5 volts at 50uA gives 250 uW of power
GPS segment: 5 volts at 160 mA gives 800 mW of power
Iridium segment: 5 volts at 0.2 A average gives 1 W of average power
Note: these numbers are from the graphs in the NAL datasheet.

We report the GPS position of our payload at 10 second reporting interval the smallest interval for reporting. Since there is no time given on the above graph let's count the tic marks in each phase of operation. From this assume that the NAL 9602LP spends 0.5 of the time in the sleep segment, 0.28 of the time in GPS segment and 0.22 of the time in Iridium segment. Total power drawn for this interval is:
(0.250mWx0.5) + (800 mWx0.28) + (1000mWx0.22) = 444.125 mW or 0.444 W per interval.
At 5 volts this represents 88.8 mA per interval or report. This is not a reasonable number based on our experience with the NAL 9602LP and shows that the correct answer is two. Therefore we will use the data from actual flights for our power calculation.

From an extended field test of our payload on a July 22, 2015 flight, the unit reported for 18 hours with 30 second reporting with a 3.7V 6600mah battery (24.42 Wh). This flight had 1055 reports to the website, so 24.42Wh/1055 = 0.023Wh per report.
24.42Wh/18h = 1.36 Watts per hour average.

3.3 Downlink Serial Data

We intend to downlink serial data from HASP from the RFD900 to ensure data from it is not lost through corruption or damage from the fall. Data packets are described in the FinalReport_25RFD900.pdf document.

3.4 Uplink Serial Commanding

We do not plan on using uplink provided by HASP.

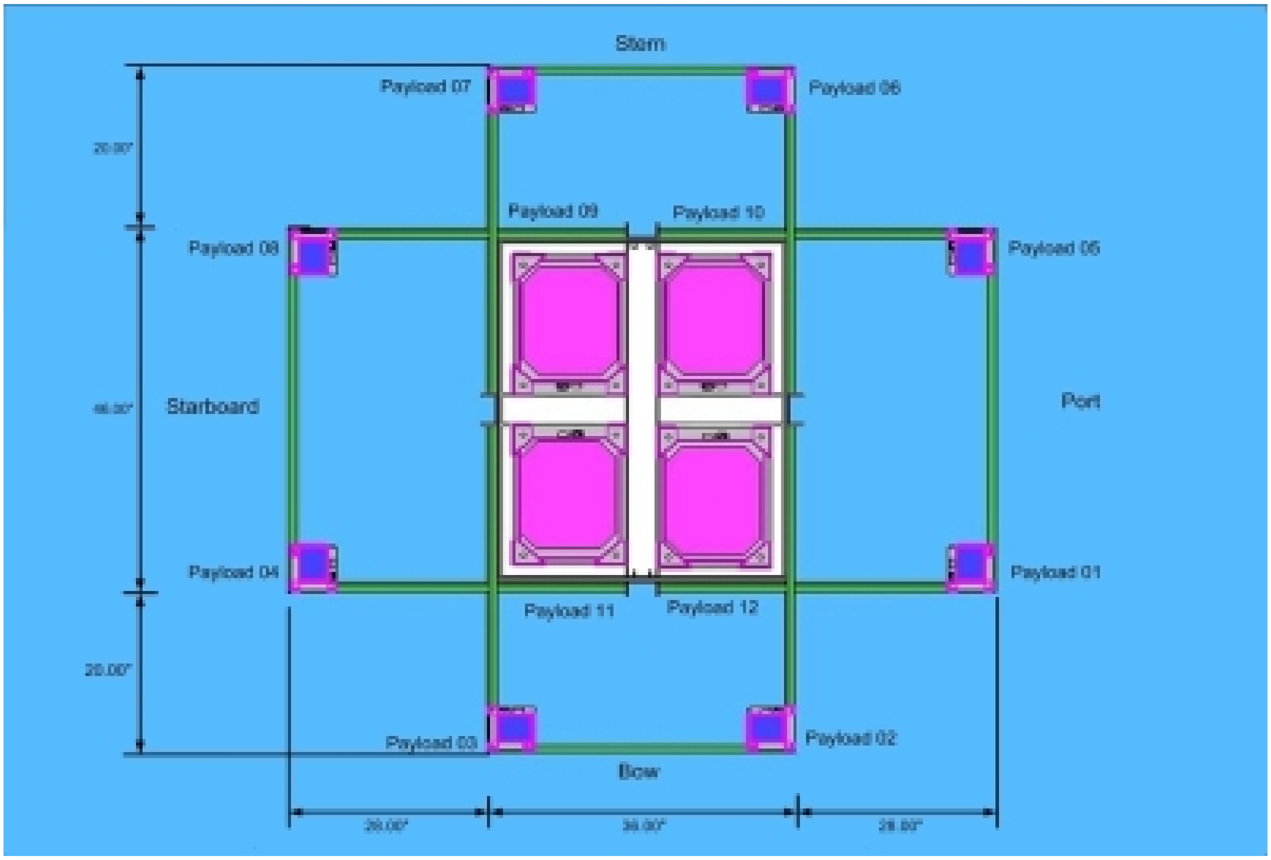
3.5 Analog Downlink

We do not plan on using the analog downlink provided by HASP

3.6 Discrete Commanding

We do not plan on using discrete commanding.

3.7 Payload Location and Orientation Request



Our small payload would like an upward facing location away from significant metal structure of the HASP gondola.

Due to the RF signals and Raspberry Pi cameras, we would like to request one of the outer SMALL payload positions shown in the image figure above (Payload 01, 02, 03, 04, 05, 06, 07, or 08).

3.8 Special Requests

The special requests that we have are 1) to use an NAL 9602-LP Iridium Modem to track the location of our payload, 2) to use a low power LoRa RF transmitter to send data packages back to our ground station to test its max range and ground station antenna tracking accuracy, and 3) to have an antenna protruding out the bottom of the payload for the LoRa board to transmit data back to our ground station.

NAL 9602-LP Iridium Modem
From NAL Website:
https://www.nalresearch.com/products/trackers-modems/960x-series/nal-9602-lp/#specs

- Dimensions: 69 mm x 55 mm x 24 mm
- (2.73″ x 2.17″ x 0.94″)
- Weight: 136 g (4.8 oz.)
-
- Input Voltage: 3.6V to 5.5V or 6.5V to 32V
- Avg Current (Report): 200mA @ 5V Input
- Avg Current (Sleep): < 65µA @ 5V Input
-
- I/O Interface: 15-Pin D-Sub
- Antenna Interfaces: SMA Female
- Software Interface: AT Commands through Serial
-
- Operating Temp: –40°C to +85°C (–40°F to +185°F)
- Operating Humidity: < 75% RH
-
- Iridium Frequency: 1616.0 to 1626.5 MHz
- GPS Frequency: 1575.42 MHz (L1 carrier)
-
- Iridium RF Specifications:
- Operating Frequency: 1616 to 1626.5 MHz
- Duplexing Method: TDD
- Input/Output Impedance: 50 W
- Multiplexing Method: TDMA/FDMA
- Iridium Radio Characteristics :
- Average Power during a Transmit Slot (Max): 1.6W
- Receiver Sensitivity at 50W (Typical): –117 dBm
- Maximum Cable Loss Permitted: 2dB
- Link Margin – Downlink: 13dB
- Link Margin – Uplink: 7dB
- GPS Receiver Performance Data:
- Type of GPS Receiver: NEO-6Q from u-blox AG
- Receiver Type: L1 frequency
- C/A code
- 50-Channel
- SBAS: WAAS, EGNOS, MSAS, GAGAN
- Update Rate: 5Hz
- Accuracy: Position 8.2 feet (2.5 meters) CEP
- Position DGPS/SBAS 6.6 feet (2.0 meters) CEP
- Acquisition (typical): Hot starts 1 second

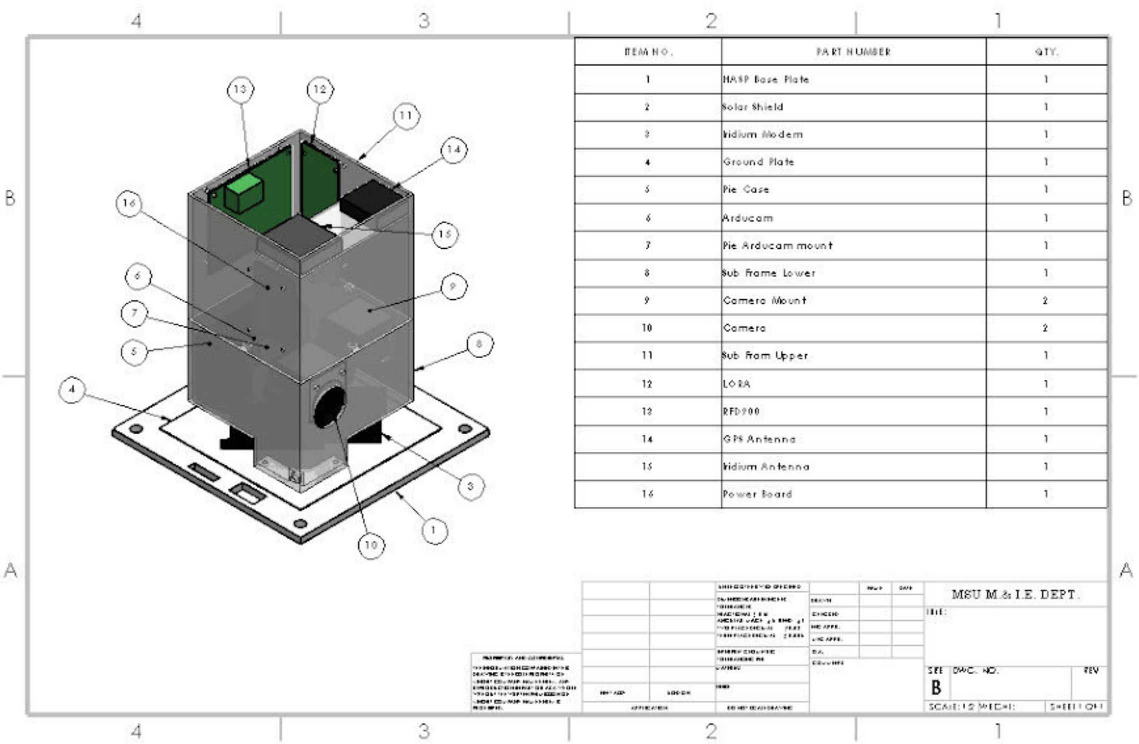
- Aided starts 1 second
- Warm starts 28 seconds
- Cold starts 28 seconds
- Sensitivity: Tracking –160 dBm
- Reacquisition –160 dBm
- Cold starts –147 dBm
- Operational Limits: COCOM restrictions apply
- Altitude 164,000 feet (50,000 meters)
- Velocity 1,640 feet/sec (500 m/sec)
- One of the limits may be exceeded but not both
- As long as power is provided to the 9602-LP, the GPS receiver will store ephemeris data in its memory before powering down (sleep between reports). The ephemeris data are valid up to two hours and can be used in future startup to improve time-to-first-fix. Unlike the 9601-DGS-LP, the 9602-LP does not need an extra back-up battery to retain ephemeris data.

LoRa Module - RFM95
Summary from Datasheet (full datasheet is available in appendix folder)
The RFM95 transceiver feature the LoRaTM long range modem that provides ultra-long range spread spectrum communication and high interference immunity whilst minimizing current consumption

Using Hope RF's patented LoRaTM modulation technique RFM95/96/97/98(W) can achieve a sensitivity of over - 148dBm using a low cost crystal and bill of materials. The high sensitivity combined with the integrated +20 dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness. LoRaTM also provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference immunity and energy consumption.

- 915 Mhz LoRaTM Modem.
- 168 dB maximum link budget.
- +20 dBm - 100 mW constant RF output vs. V supply.
- +14 dBm high efficiency PA.
- Programmable bit rate up to 300 kbps.
- High sensitivity: down to -148 dBm.
- Bullet-proof front end: IIP3 = -12.5 dBm.
- Excellent blocking immunity.
- Low RX current of 10.3 mA, 200 nA register retention.
- Fully integrated synthesizer with a resolution of 61 Hz.
- FSK, GFSK, MSK, GMSK, LoRaTM and OOK modulation.
- Built-in bit synchronizer for clock recovery.
- Preamble detection. 127 dB Dynamic Range RSSI.
- Automatic RF Sense and CAD with ultra-fast AFC.
- Packet engine up to 256 bytes with CRC.
- Built-in temperature sensor and low battery indicator.
- Modue Size：16*16mm

4. Preliminary Drawings and Diagrams



5. References

EELE488R -- Electrical Engineering Design I, 4/23/2021, Senior Capstone Final Project Report "*LoRa Balloon Telemetry*" Design Engineers: Cameron Blegen, Larson Brandstetter, Adam Wulfing; Project Customer: Randal Larimer, MSGC Deputy Director Montana Space Grant Consortium

EELE489R -- Electrical Engineering Design II, 04/23/2021, Senior Capstone Final Project Report "*RFD900 Balloon Telemetry*" Design Engineers: Madison Martinsen, Annie Bachman, Michael Valentino-Manno; Project Customer: Randal Larimer, Deputy Director Montana Space Grant Consortium

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Appendix A

Items that must be included in the Appendix section:

Detailed electrical drawings not required in previous sections

Detailed mechanical drawings not required in previous sections

Appendix B: NASA Hazard Tables

Appendix B.1 Radio Frequency Transmitter Hazard Documentation

HASP 2022 RF System Documentation	
Manufacture Model	RFM95 Low Power Long Range Transceiver Module
Part Number	RFM95
Ground or Flight Transmitter	Both
Type of Emission	Spread spectrum
Transmit Frequency (MHz)	915 MHZ
Receive Frequency (MHz)	915 MHZ
Antenna Type	Payload - omni whip; Ground Station - grid
Gain (dBi)	Payload - 3 dBi; Ground Station 15 dBi
Peak Radiated Power (Watts)	+20 dBm - 100 mW
Average Radiated Power (Watts)	+20 dBm - 100 mW constant RF output

HASP 2022 RF System Documentation	
Manufacture Model	NAL 9602-LP
Part Number	NAL 9602-LP
Ground or Flight Transmitter	Flight
Type of Emission	TDD
Transmit Frequency (MHz)	Iridium 1616 to 1626.5 MHz
Receive Frequency (MHz)	Iridium 1616 to 1626.5 MHz; GPS 1575.42 MHZ(L1 carrier)
Antenna Type	Iridium Flat Mount GPS active antenna
Gain (dBi)	Iridium 5.0 dbi GPS 27.0 dBi
Peak Radiated Power (Watts)	1.6 W average power during a transmit slot (max)
Average Radiated Power (Watts)	1.6 W average power during a transmit slot (max)

Appendix B.2 High Voltage Hazard Documentation

n/a

HASP 2022 High Voltage System Documentation	
Manufacture Model	
Part Number	
Location of Voltage Source	
Fully Enclosed (Yes/No)	
Is High Voltage source Potted?	
Output Voltage	
Power (W)	
Peak Current (A)	
Run Current (A)	

Appendix B.3 Laser Hazard Documentation

n/a

HASP 2022 Laser Hazard Documentation			
Manufacture Model			
Part Number			
Serial Number			
GDFC ECN Number			
Laser Medium			
Wave Type		*(Continuous Wave, Single Pulsed, Multiple Pulsed)*	
Interlocks		*(None, Fallible, Fail-Safe)*	
Beam Shape		*(Circular, Elliptical, Rectangular)*	
Beam Diameter (mm)		**Beam Divergence (mrad)**	
Diameter at Waist (mm)		**Aperture to Waist Divergence (cm)**	
Major Axis Dimension (mm)		**Major Divergence (mrad)**	
Minor Axis Dimension (mm)		**Minor Divergence (mrad)**	
Pulse Width (sec)		**PRF (Hz)**	
Energy (Joules)		**Average Power (W)**	
Gaussian Coupled (e-1, e-2)		*(e-1, e-2)*	
Single Mode Fiber Diameter			
Multi-Mode Fiber Numerical Aperture (NA)			

Appendix B.4 Pressure Vessel Hazard Documentation

n/a

HASP 2022 Pressure Vessel Documentation	
Description	
Maximum Operating Pressure (PSIG)	
Fluids (GN2, Air, etc)	

Appendix B.5 Battery Hazard Documentation

n/a

HASP 2022 Battery Hazard Documentation	
Battery Manufacturer	
Battery Type	
Chemical Makeup	
Battery modifications	*(Must be NO)*
UL Certification for Li-Ion	