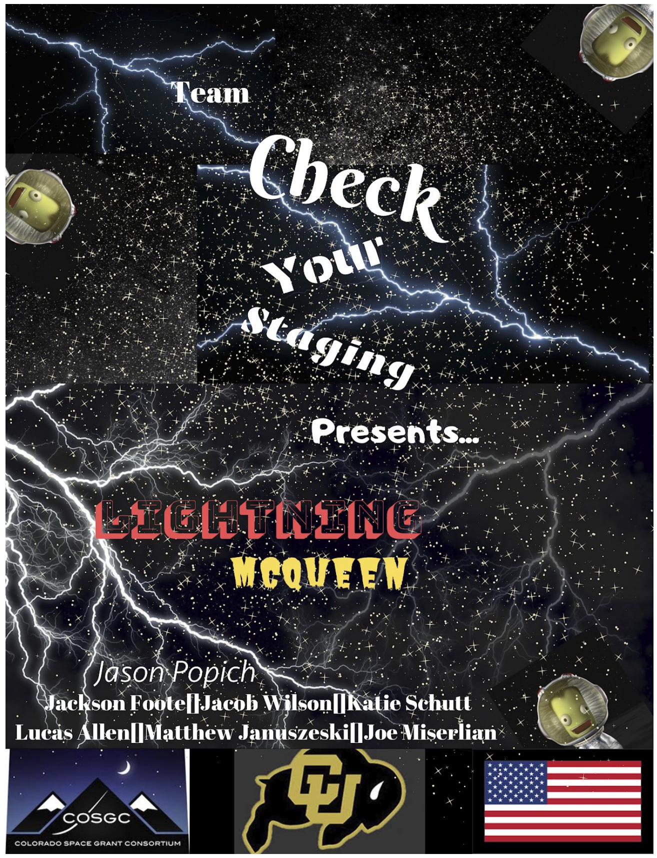
Colorado Space Grant Consortium

GATEWAY TO SPACE



FALL 2019
DESIGN DOCUMENT

Team Check Your Staging

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Revision D

Revision Log

Revision	Description	Date
A/B	Conceptual and Preliminary Design Review	10/17/19
C	Critical Design Review	11/07/2019
D	Analysis and Final Report (There is a first draft and final draft)	12/07/2019 12/14/2019

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1.0 Mission Overview

1.1 Mission Statement

Team Check Your Staging's mission is to design, build, and launch a BalloonSat to a near-space altitude of approximately 30 kilometers as part of the Colorado Space Grant's Gateway to Space course. Team Check Your Staging's mission also includes measuring the detectability of Very Low Frequency (VLF) radio signals emitted by lightning strikes, also known as sferics. Measurements taken during the flight shall be compared to a ground-based control study performed using the same equipment designed for the BallonSat and then used to extrapolate a mathematical model for the detectability of sferics as a function of altitude. The project, henceforth named project Lightning McQueen, shall follow the requirements set forth by the Fall 2019 Request for Proposal (RFP) which includes flying a balloon shield with humidity, pressure, temperature, and accelerometer sensors, and moreover safe recovery of data from the balloonsat after landing.

1.2 Background

A sferic is a radio atmospheric signal between 0 and 10 kHz within the Very Low Frequency (VLF) range[1] that is produced by a lightning strike. Sferics are able to travel long distances due to a multitude of different effects. The most common form of transmission is ground wave propagation. In this phenomenon, the radio waves are refracted along conductive ground to remain close to the ground enabling them to travel beyond the horizon from the source emitter. The other common type of transmission is called skywave propagation: transmission in the Earth-ionosphere waveguide. This is a phenomenon where the charged layer of ionized gases caused by solar radiation and cosmic rays can act as a conductor while the surface of the planet acts as a ground plane. Between them, a channel called a waveguide is formed where the radio waves are channeled between the two edges while barely losing any strength.

These signals provide an interesting means of detecting and tracking lightning activity because they can be triangulated and used to find weather and storm patterns using VLF and magnetic receivers. For example, a network of VLF receivers operated by the University of Washington[2] is currently used to triangulate lightning activity in the pacific northwest.

1.3 Hypothesis

Team Check Your Staging hypothesizes that the detectability of sferics will increase as altitude increases due to a combination of reduced background noise and proximity to the ionosphere. Reduced background noise will allow sferics to more clearly stand out in the data. Proximity to the ionosphere will allow detection of sferics at a longer range and with more strength due to the effect of skywave VLF signals reflecting off the ionosphere, and the lack of thick atmosphere to deafen the signal. Assuming that the rate of sferics that occur during flight remains constant (as in the amount of sferics at each altitude would remain constant--which is valid because sferics travel extreme distances at thousands of miles), the number of events will remain approximately constant regardless of the conditions at any one location. However, Team Check Your Staging predicts that more of the sferics that are occuring will be detected at higher altitudes.

1.4 Motivation

A mathematical model of sferic detectability vs. altitude would help determine if high altitude weather balloons could be a more accurate and effective method of detecting lightning strikes compared to existing ground-based sensors. The National Oceanic and Atmospheric Administration currently uses a network of ground-based sensors to aid in storm tracking[4], but if the Team's data shows that high altitude balloons provide more accurate readings, this system could be improved. Improving lightning detection would increase the accuracy of severe weather prediction and warning times of hazardous weather thereby saving lives and money. Current ground-based systems are not particularly accurate over water, so a system of high altitude balloons could significantly enhance lightning tracking over the ocean (which is especially important in hurricane tracking). Additionally, the experiment is particularly appropriate for a BalloonSat mission because in order to test the viability of high altitude VLF receivers, measurements must be taken from higher altitudes which would be less practical with high altitude sounding rockets or aircraft.

[1] The Thought Emporium,"Natural Radio From Lightning Sound INCREDIBLE - VLF Radio" Youtube, Aug. 2019 [Online]. Available: https://www.youtube.com/watch?v=OzWBxt_TOWk [Accessed Sept. 9, 2019]
[2]C. Rodger and R. Holzworth, "WWLLN - The World Wide Lightning Location Network", *Wwlln.net*, 2019. [Online]. Available: http://wwlln.net/. [Accessed: Sept. 15, 2019].
[3] The INSPIRE Project, "Inspire VLF-3 Radio Receiver Kit" The INSPIRE Project, Inc., 2017 [Online] Available: http://theinspireproject.org/default.asp?contentID=2 [Accessed Sept. 9, 2019]
[4]"Lightning Detection - Jun 2011 - Aug 2012 Dataset | Science On a Sphere", *Sos.noaa.gov*, 2019. [Online]. Available: https://sos.noaa.gov/datasets/lightning-detection-jun-2011-aug-2012/. [Accessed: Sept. 21, 2019].

2.0 Requirements Flow Down

2.1 Level 0 Requirements

The Requirements Flow Down chart consists of requirements set by Team Check Your Staging for Project Lightning McQueen and are essential for the success of launch and data collection. The level zero requirements are derived from the mission statement in Section 1.1. Level one requirements are derived from level zero requirements.

Requirement #	Requirement	Source
0.1	Team Check Your Staging and Project Lightning McQueen shall follow all requirements and guidelines stated in the Request for Proposal.	Mission Statement
0.2	Project Lightning McQueen shall be prepared to launch to an altitude of approximately 30km and safely land on November 9, 2019.	Mission Statement
0.3	Project Lightning McQueen shall detect very low frequency (VLF) radio signals in order to observe lightning sferics.	Mission Statement
0.4	Project Lightning McQueen shall collect pressure, humidity, external and internal temperature, and acceleration data for the duration of the flight.	Mission Statement
0.5	Project Lightning McQueen shall store all collected data in a manner that survives landing.	Mission Statement
0.6	Team Check Your Staging shall analyze data collected during flight in order to extrapolate a mathematical model of sferic detection as a function of altitude.	Mission Statement

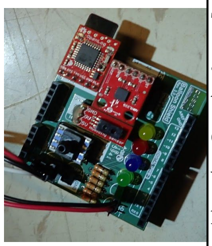
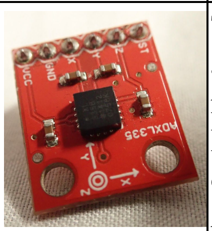
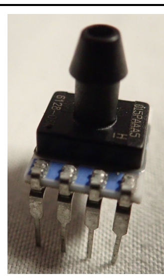
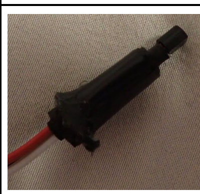
2.2 Level 1 Requirements

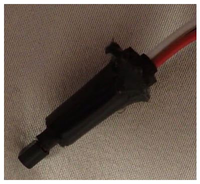
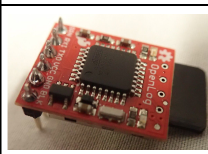
Requirement #	Requirement	Source
1.1	The BalloonSat shall undergo rigorous structural testing consisting of whip, drop, and stair tests in order to simulate flight events.	0.1/0.5
1.2	Team Check Your Staging shall conduct cold and mission life tests to simulate the expected mission time and extreme temperatures.	0.1/0.2
1.3	All Project Lightning McQueen subsystems (external temperature sensor, internal temperature sensor, humidity sensor, pressure sensor, accelerometer, and VLF receiver) shall be thoroughly tested prior to launch.	0.3/0.4
1.4	Project Lightning McQueen shall utilize a flight tube and externally mounted washers to secure the BalloonSat to the flight string.	0.1
1.5	Team Check Your Staging shall fly and record video data from an internally mounted GoPro Hero 5 Session.	0.1
1.6	Team Check Your Staging shall utilize a custom PCB and proto-boarded amplifier to collect and record sferic data.	0.3/0.5
1.7	Team Check Your Staging shall conduct receiver tests using both a signal generator and recording sferic data from a low interference location.	0.3
1.8	Project Lightning McQueen shall have external LEDs to indicate the status of various subsystems.	0.1
1.9	Project Lightning McQueen shall have three external switches to power on all subsystems with all switches covered with a foam core	0.1

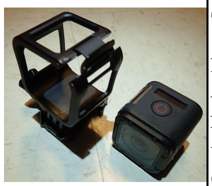
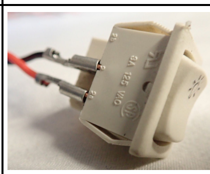
	sheet for the duration of the flight.	
1.10	Project Lightning McQueen shall not exceed 950 grams (weight waiver granted).	0.1
1.11	Team Check Your Staging shall utilize insulation and a heat pad to ensure the internal temperature remains above -10°C.	0.1/0.2
1.12	The exterior of Project Lightning McQueen shall have team contact information, an American flag sticker, and arrows indicating the up direction.	0.1
1.13	BalloonSat exterior shall be highly reflective in order to blind incoming aircraft and prevent collision.	0.2
1.14	All external switches shall be labeled with their function as well as on and off positions.	0.1
1.15	Team Check Your Staging shall utilize two SparkFun Open Logs with micro SD cards to record all sensor data along along with the GoPros micro SD card.	0.5

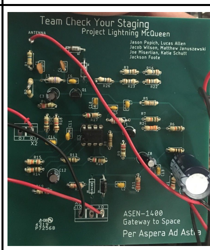
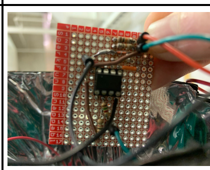
3.0 Design

3.1.1 Final Parts List

Part	Image	Description	Source	Cost	Part #
Balloon Shield		The provided balloon shield allows for easy integration of the provided flight sensors, OpenLog, and LED indicators with Arduino One. It is mounted on top of the Arduino inside the insulated portion of the BalloonSat.	COSC	Provided	N/A
Accelerometer		The provided SparkFun accelerometer is used to measure acceleration of the BalloonSat in the Y and X directions. It is integrated with Arduino One by the balloon shield with all flight data passed to an OpenLog. This data will help track altitude as well as determine when specific events occur over the course of the flight.	COSC	Provided	N/A
Pressure Sensor		The provided pressure sensor is integrated into Arduino One via the Balloon Shield with all data stored on the OpenLog. The data the pressure sensor provides shall help determine altitude and local conditions.	COSC	Provided	N/A
External Temperature Sensor		The external temperature sensor is integrated into Arduino One via the Balloon Shield with all data stored on the OpenLog. This external temperature data will be used to monitor exterior conditions as well as detect the various layers of the atmosphere.	COSC	Provided	N/A

Internal Temperature Sensor		The internal temperature sensor utilizes the same hardware as the external but is directly mounted on the Balloon Shield. The internal temperature readings will be monitored to determine when to activate the heating pad.	COSC	Provided	N/A
Coaxial Antenna		A 17.5in telescoping whip antenna extends from within the uninsulated portion of the BalloonSat into the outside air. It is used to pick up VLF frequencies.	Amazon	$11.49	#ANT-SCANNER-BLK
Female Coaxial Connector		The female coaxial connector allows the antenna to interface with the custom PCB. The connector allows mounting to the antenna by attaching the connector to an interior wall.	Amazon	$8.95	#B07TGGV69J
OpenLog		Two OpenLogs store all sensor data for the flight. One is integrated directly into the Balloon Shield while the other is wired into Arduino Two and mounted externally within the insulated portion of the BalloonSat. The OpenLogs utilize micro SD cards to store data that can later be accessed via computer.	COSC	Provided	N/A
Humidity Sensor		The provided humidity sensor is integrated into Arduino One via the balloon shield with all data stored on the OpenLog. It returns required flight data that	COSC	Provided	N/A

		monitors atmospheric conditions.			
GoPro		The provided GoPro Camera is mounted inside the insulated portion of the BalloonSat. It has a square viewing window cut to allow exterior viewing access. The GoPro records the entirety of the flight with all video saved on a 32GB SD card.	COSC	Provided	N/A
LiPo Batteries		4 Hosim 1600 mAh Lithium Polymer Batteries are used for power. 1 battery is assigned per Arduino. The remaining 2 batteries power the Heating Pad to regulate internal temperature.	Amazon	$77.96	#25-DJ02
Switches		3 external switches activate various components of the BalloonSat. 1 is designated to each Arduino with the remaining 2 reserved for the PCB and Heating Pad. Allows for easy activation of parts.	ITLL	Provided	Unknown
Battery Adapter		4 battery adapters hook the integrated plugs of each battery into wires that shall be connected with an Arduino or heating element.	COSC	Provided	N/A
Heating Pad		An ADAFruit 10x5cm Electric Heating Pad regulates internal temperature. 1 Arduino is integrated with the heating pad to activate it at internal temperatures (measured by the internal temperature sensor) below 5°C to maintain an internal temperature above -10°C.	Amazon	$17.18	ADA1481

Arduino Uno		1 Arduino is integrated with the required pressure, internal/external temperature, humidity, and accelerometer sensors. The second is dedicated to the custom PCB that has been designed and manufactured to detect VLF radio emissions in the 0-10 kHz range.	COSG	Provided	N/A
Relay		Arduino turns on relay to then turn on heating pad when internal temperature reaches lower threshold of 5°C.	Amazon	$5.50	Keyes_SR1y
VLF Receiver PCB		Designed and based off of the VLF3 Receiver schematic. The PCB tunes the acquisition frequency of the antenna to the range of 0-10 kHZ in order to detect sferics	Advanced Circuits	$43	N/A
Dual Operational Amplifier		The amplifier takes in very low voltage readings from the PCB and increases the gain to make the data readings meaningful.	Amazon	$10.98	N/A

3.1.2 Custom Printed Circuit Board (PCB)

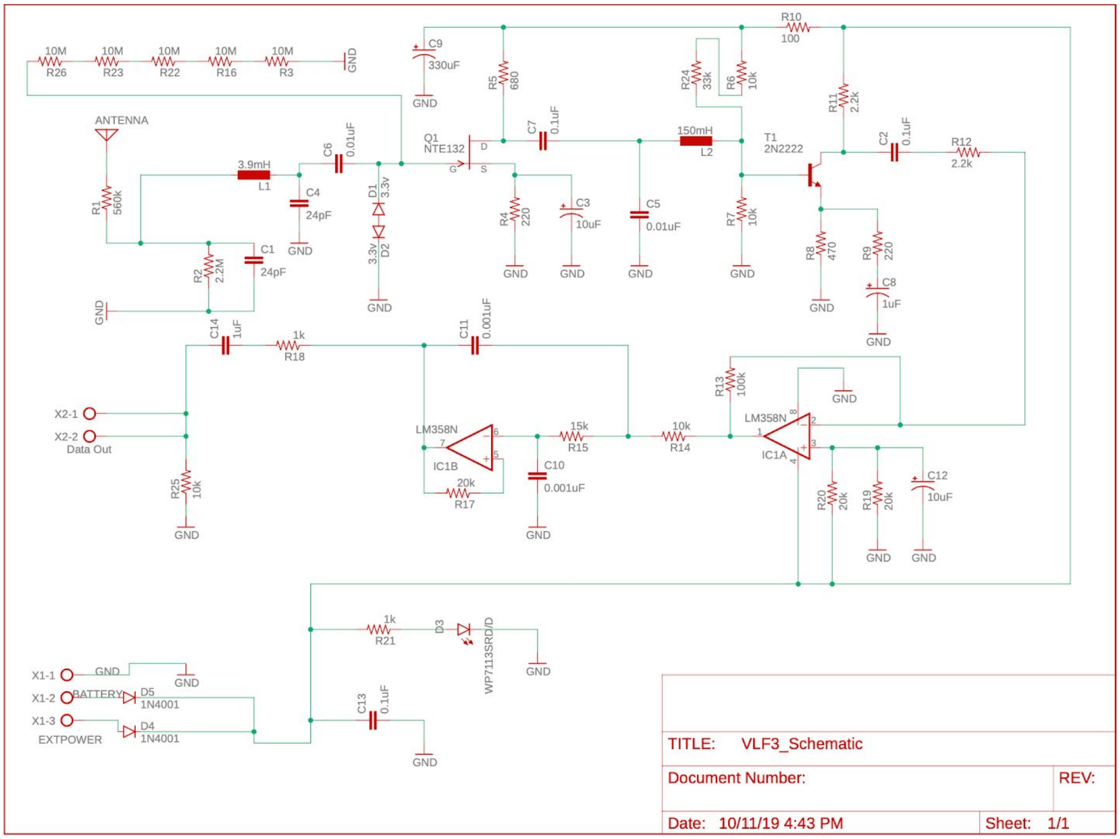


Figure 3.1.2a VLF Schematic

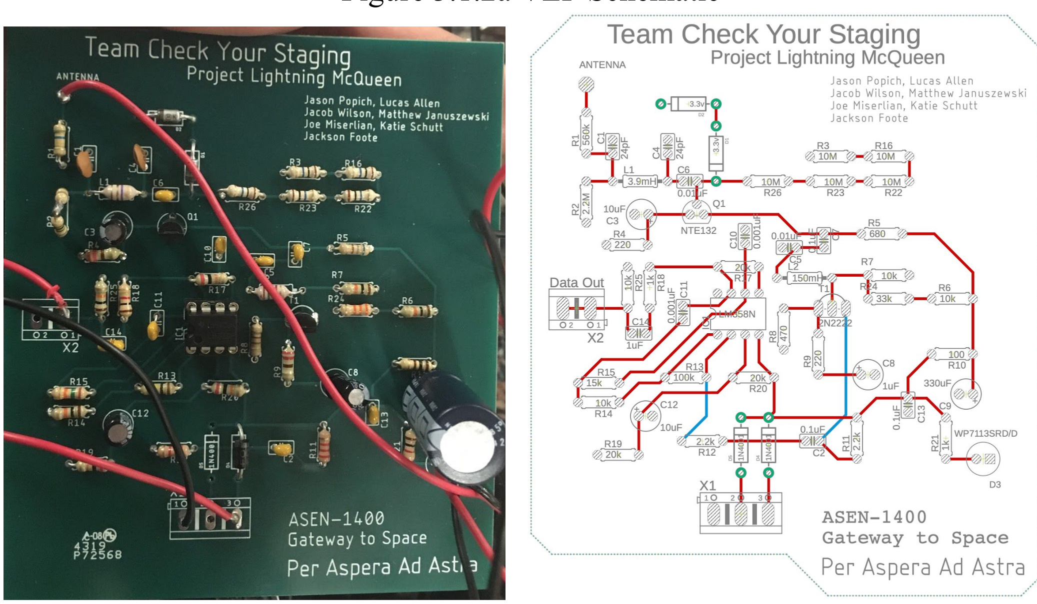


Figure 3.1.2b

The custom Printed Circuit Board (PCB) has been designed and based off of the VLF3 Receiver schematic. The PCB tunes the acquisition frequency of the antenna to the range of 0-10 kHZ in order to detect sferics, or radio emissions generated by lightning strikes. The receiver is designed with two Resonant Circuit (RLC) Low Pass Filters with their cutoff frequencies (in MHz) defined by:

$$f = \frac{1}{2\pi \bullet \sqrt{L \bullet C}} \bullet 1000$$

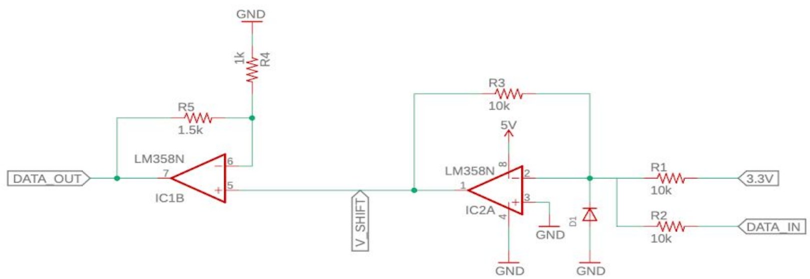
Where L is the impedance of the inductor in microHenry (µH), and C, the capacitance of the capacitor in picoFarad (pF)

As an example, the first filter is designed to attenuate, or reduce the effect of, AM broadcast band frequencies which fall in between 535kHz and 1605kHz and cutoff frequencies above 11.5MHz. In order to accomplish this, as shown in figure 3.1.2b, L1 (3.9µH), C4 (24pF) and C1 (24pF) represent the first RLC low pass filter. Therefore by plugging in the values of the Inductor, and Capacitors the frequency cutoff can be obtained through that first RLC low pass filter like so:

$$f = \frac{1}{2\pi\sqrt{3.9 \bullet (24+24)}} \bullet 1000 \Rightarrow 11.63 \text{ MHz}$$

All frequencies above 11.63 MHz are cut off, bearing in mind that the antenna can pick up signals up to 2.8gHz, and the AM frequencies are attenuated. Then, the second low pass filter is designed to cut off the acquisition frequency to 12kHz and strongly attenuate anything above 20kHz as per the VLF3 Technical Document. Furthermore, in order to amplify the acquired signal's audio output into a usable decibel (dB) range this PCB uses two amplification methods to amplify the signal. The first amplification is accomplished by the 2N2222 transistor that amplifies the signal by 10 db and the second amplification is accomplished by the first 4 pins, of eight, on the LM358N, an Operational Amplifier, integrated circuit chip that amplifies the signal by another 15 db. The LM358N was chosen because it is an operational amplifier meaning that it amplifies the voltage in a line and was in the original VLF3 schematic. Because it is a Dual-Operational Amplifier (op amp) the first set of pins could be used as an amplifier and the second set of pins as another Low Pass Filter configured to be a Sallen-Key Second Order Low Pass Filter per the VLF3 Technical guide. Afterwhich the signal is outputted to the data port on the PCB where it is then fed into the operational amplifier circuit.

3.1.3 Operational Amplifier Circuit (Op Amp Circuit)



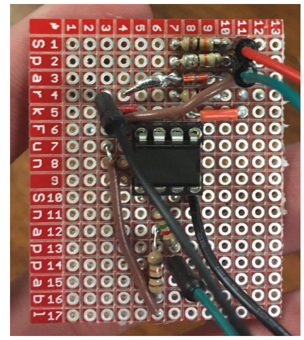


Figure 3.1.3 Op Amp Schematic and Incorporation

The signal coming out of the PCB is below the acquisition range of the Arduino's 0-5v and 0.0049 Volt resolution. In order to resolve this issue, Team Check Your Staging designed a circuit that shifts the voltage up into the 0-5v range and amplifies it to become readable by the Arduino. In order to accomplish this, the first set of pins (IC2A figure 3.1.3) on the LM358N op amp were configured as an inverting summing amplifier to shift the voltage upward. The summation equations for a summing amplifier can be defined as:

$$G = \frac{-Rf}{Rin}\text{ , G = gain}$$

$$V_{out} = \sum_i (G_i \cdot V_i)$$

Where $G_{1,2}$, or the gain for both the *3.3v* rail and the *Data_In* is -1 because:

$$-\frac{10k}{10k} = -1$$

Therefore with V_2 and $Gain_{1,2}$ defined V_1 needs to be determined. Therefore in order to determine V_1 the PCB was connected to an Oscilloscope and the output voltage of the PCB was recorded to be -4.68v at its lowest point. Thereby by plugging in the variables into the equation:

$$V_{out} = \sum_i (Gain_1 \cdot V_i)$$

$$V_{out} = (-1)(-4.68)+(-1)(3.3) = 1.38\text{v}$$

The lowest value the Arduino should log is 1.38v thereby completing the voltage shift. But there was a second problem where the variance in voltage was below the Arduino resolution of 0.0049v. Therefore, in order to amplify the signal, the second set of pins (1C1B Figure 3.1.3) on the LM358N op amp were configured as a non-inverting operational amplifier. The Non-Inverting Operational Amplifier is defined by the equation:

$$A_v = 1 + \frac{Rf}{Rin}, \quad A_v = \text{Voltage Amplification}$$

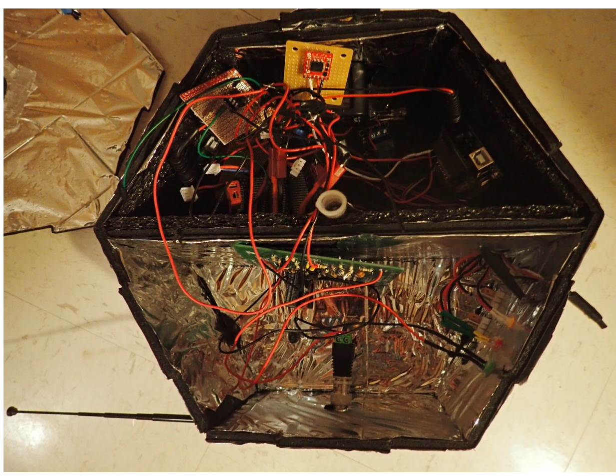
With R_f being the resistor leading to the output and R_{in} being the resistor leading to ground on the negative pin of the op amp

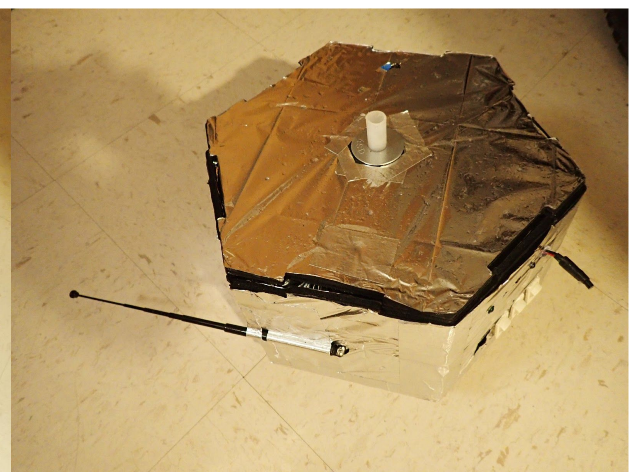
Therefore by taking R_f which is 1.5k and R_{in} which is 1k and plugging them into the equation like so:

$$A_v = 1 + \frac{1.5k}{1k} = 2.5v$$

An amplification of 2.5v is achieved. With the signal shifted by 6v, putting the voltage in the positive range, and amplified by 2.5v the data received from the PCB is within acquisition bounds of the Arduino and thereby allows the Arduino to collect the data and store it into the provided OpenLog. Therefore, the data collected can be used to create a spectrogram for the purpose of fulfilling the mission objective.

3.1.4 Structure

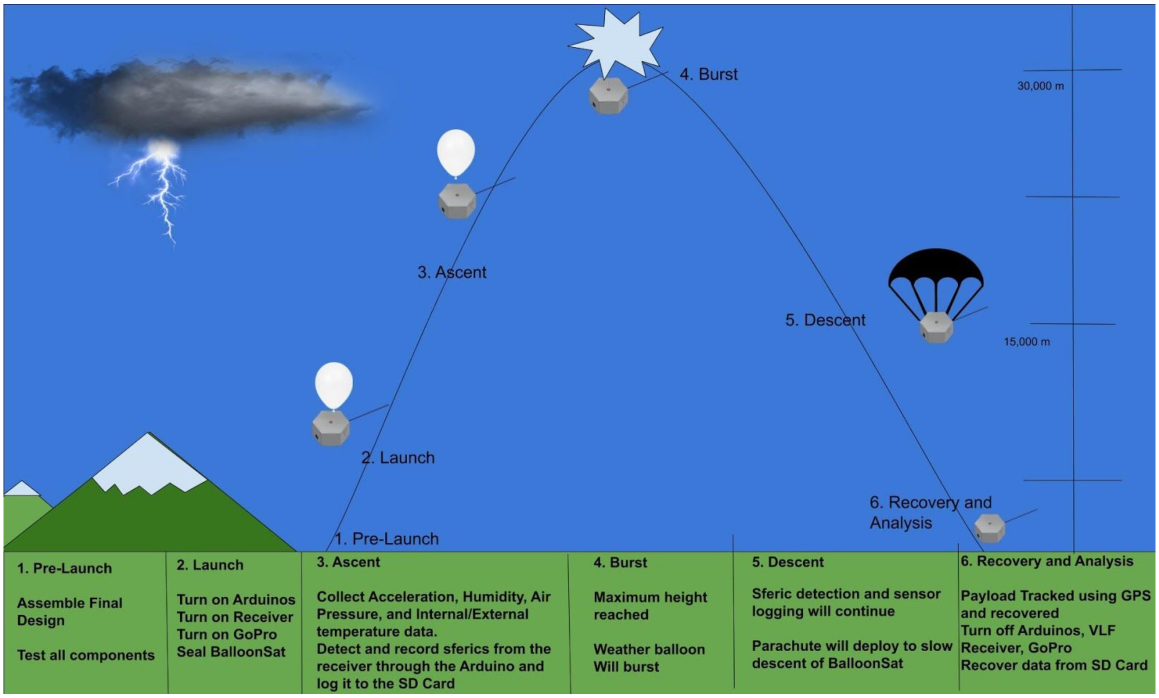




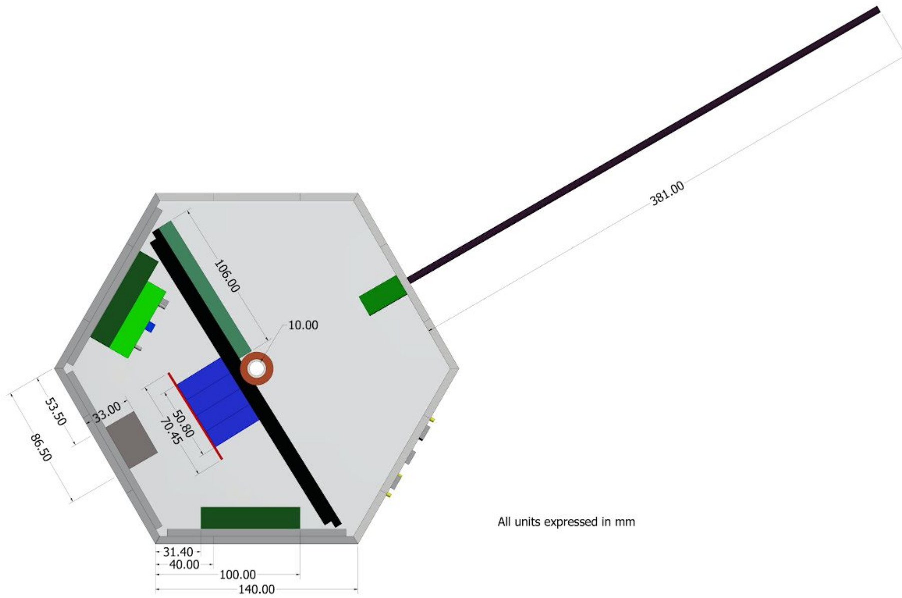
The structure of Team Check Your Staging's BalloonSat consists of a hexagonal prism with exterior side lengths of 140mm and a height of 129.6mm. Each wall consists of an outer, interlocking section and a smaller interior panel. These sections are connected using a combination of hot glue, aluminum tape, and duct tape. The provided flight tube is integrated into this structure with holes cut through the top and bottom panels. An interior dividing wall isolates the electronic components within half of the total area. This half of the frame is insulated internally with foam insulation, and the entire BalloonSat is insulated externally and internally with mylar thermal blankets as well. Access for a GoPro is cut in one wall. Switches, the external temperature sensor, and indicator LEDs are mounted in holes on these walls, with an integrated cover for the switches. Internally, Zip Ties and electrical tape are used to organize wires and hold the boards steady during flight.

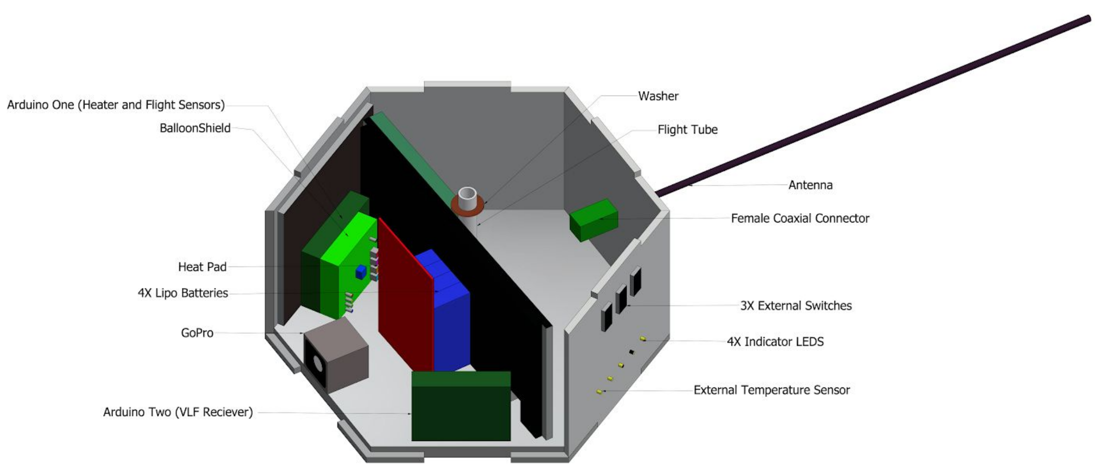
3.2 Concept of Operations Diagram

The following is a diagram of the Project Lightning McQueen mission phases, encompassing every step from pre-launch to recovery to data analysis.

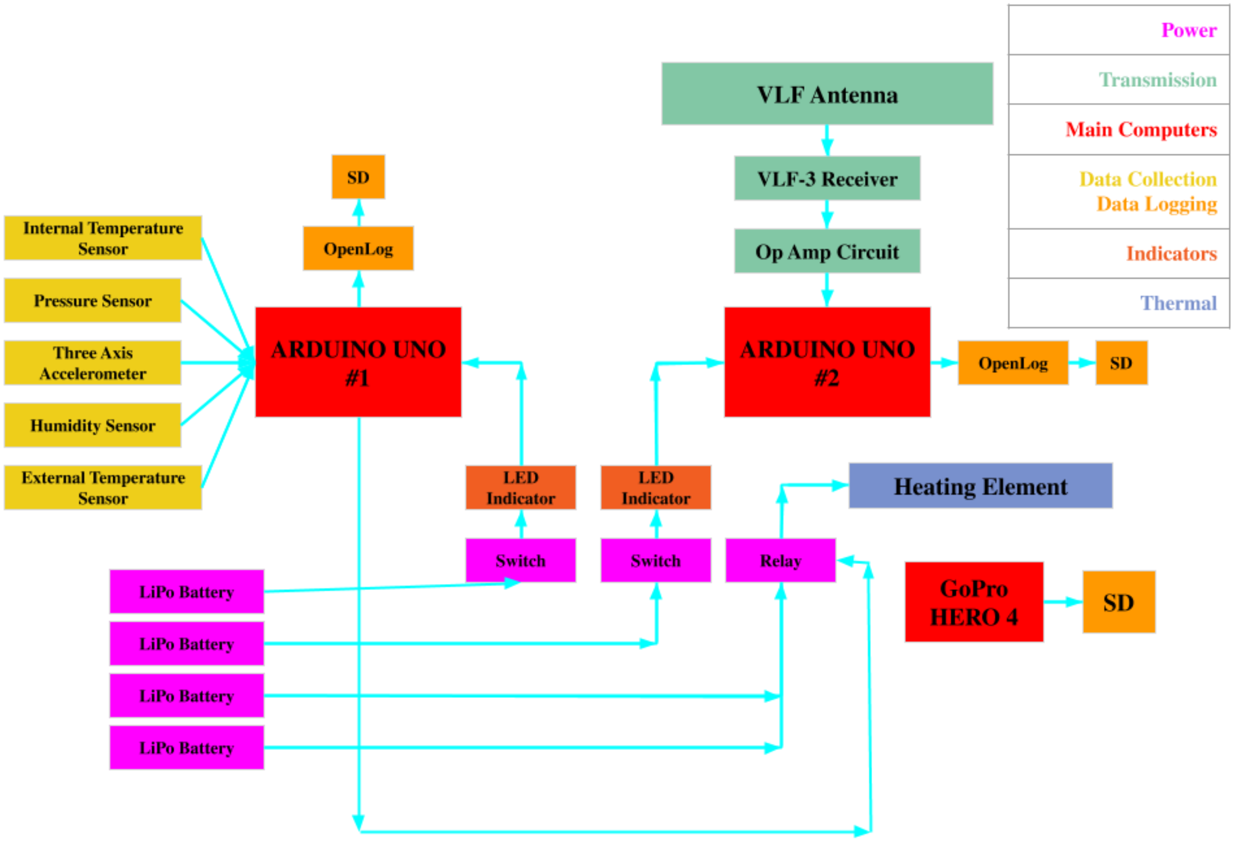


3.3 Dimensioned and Labeled Drawings





3.4 Functional Block Diagram



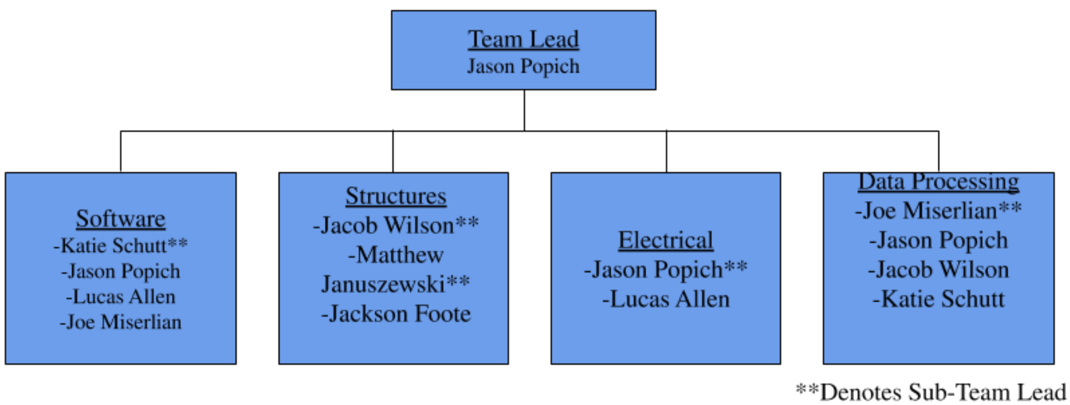
3.5 Requirements Discussion

Project Lightning McQueen is on the road to completion and/or abides by the requirements set in section 2.0, specifically, requirements 0.1 through 0.7. The current design meets all specified RFP requirements, fulfilling requirement 0.1. Requirement 0.2 states the Project Lightning McQueen shall be ready for launch by November 9th. Project Lightning McQueen is in the final integrated testing phase, on track for final weigh-in on November 8th. Moving forward, requirement 0.3 states that Project Lightning McQueen will collect VLF data in order to detect sferics. The custom PCB has been completed, along with a secondary circuit providing more amplification and voltage adjustment, and has been tested/shown to receive data. Requirement 0.4 calls for collection of data by the provided sensors. The current design has demonstrated the ability to collect this data through sensor testing, and has been put through full mission length testing, and long term cold endurance testing without any losses of sensor data. Requirement 0.6 is addressed by a combination of thermal insulation and an electrical heat pad. The heat pad will activate any time the internal temperature of the BalloonSat, as measured by the internal temperature sensor, drops below 10 degrees Celsius. Project Lightning McQueen has demonstrated the ability to meet this requirement through the freeze test. In order to meet requirement 0.7, Team Check Your Staging will take VLF data stored in the OpenLog and upload it to MATLAB for processing. This data will be processed through several filters in MATLAB, such as the Kalman Filter, to reduce background noise and further enhance data for a clean output. From this cleaned data, Team Check Your Staging will isolate individual sferics in order to calculate the sferic detection frequency of the VLF receiver at various times. These frequencies will be graphed against altitude, which is determined by the pressure and accelerometer sensors. A function of best fit will then be applied as a basis for a mathematical model of altitude vs. the frequency of sferic detection.

4.0 Management

4.1 Team Organization

Team Check Your Staging is composed of seven team members organized into four separate subsystem teams. The Team Leads responsibility includes managing communication between the subsystems and determining time requirements for meeting. The subsystem leads are responsible for staying on schedule for their respective branch, as all groups are expected to be contributing members to their own subsystem and the others as they are interconnected. Since the proposal, Structures leadership has changed since possible time commitments were reevaluated and some members changed subsystems based on the reasonable number of members needed for respective projects.



4.2 Schedule

The biggest concerns about time limitations involve testing the experiment components enough times to where they are reliable and robust by the point of launch. To achieve this the team is prioritizing testing and construction of the PCB as it is crucial to the ability to detect the sferics, the heart of the experiment. While the electronics subsystem works on that, Structures shall begin and continue testing (See Section 6.0). Software performed the Arduino sensor tests.

Week #	Goals for the Week	Week #	Goals for the week
1 (9/22)	-Await grading of project proposal and Authority to Proceed -Make hardware order sheet -VLF-3 PCB schematic created	7 (11/3)	-DD Rev C -Launch Readiness Review -Final launch preparations -cold test 2 & 3
2 (9/29)	-Complete HW 07 -Choose antenna -Cut and assemble structure with foam board, insulation, aluminum tape -Sparkfun trip for rest of electronics materials	8 (11/10)	-Quick Look Slides due - Failure analysis - Data analysis
3 (10/6)	-Develop Preliminary Design Review (PDR) presentation -Rev A/B -Breadboard and test voltage PCB -Arduino sensor tests (graph)	9 (11/17)	-HW 08 due -Data analysis
4 (10/13)	-Present PDR (10/15) -Manufacture PCB through ITLL -all structure tests--recorded and completed -research on data analysis--importing and sorting data in MATLAB, etc. -team member evaluations #1	10 (11/24)	Fall Break!!
5 (10/20)	-power system integrated -thermal system integrated -VLF-3 PCB integrated -antenna integrated	11 (12/1)	-Work on Final Presentation and DD Review D first draft -Prepare poster and above materials for ITLL Design Expo and Community Service -Community service presentation at Centaurus High School on 12/6, (9:00 AM and 2:00 PM -Present to community at ITLL Design Expo on 12/7 -Finish team video -HW 09 due (resumes and cover letters)
6 (10/27)	-power system integrated -thermal system integrated -GoPro Hero 4 integrated	12 (12/8)	-Work on and turn in Final Presentation and DD Rev D final draft -Acquire Teensy data for baud rate comparison -Present final presentation to class and Edge of Space Sciences guests on 12/10 at 6:00 PM

			-Complete community service presentation and present on 12/14 at 1:30 PM

5.0 Budget

Item	Quantity	Weight (per unit)	Source	Cost
Arduino Uno	2	28g	COSG	Provided
Accelerometer	1	1.27g	COSG	Provided
Temperature Sensor	2	<1g	COSG	Provided
Pressure Sensor	1	<1g	COSG	Provided
Humidity Sensor	1	<1g	COSG	Provided
GoPro Hero 4	1	85g	COSG	Provided
FoamCore	1	150g	COSG	Provided
Insulation	1	30g	COSG	Provided
Aluminum Tape	1	25g	COSG	Provided
Velcro	1	10g	COSG	Provided
Hot Glue	1	30g	COSG	Provided
Switches	4	4.5g	COSG	Provided
Tube/Mounting System	1	57g	COSG	Provided
LiPo Batteries	4	67g	Amazon.com	$77.96
17.5 in Telescoping Whip Antenna	1	22g	Amazon.com	$11.49
VLF Receiver PCB	1	71g	Advanced Circuits	$43.00
Heating Pad	2	2.9g	Amazon.com	$17.18
Relay	1	<1g	Amazon.com	$11.00
Thermal Blankets	1	25g	Amazon.com	$7.99
Audio Amplifier	1	<1g	Amazon.com	$10.98
Dual Operational Amplifier	1	<1g	Amazon.com	$6.29
BNC Connectors	1	9g	Amazon.com	$8.95
Resistors	38	.12g	ITLL	$1.90
Capacitors	27	1.3g	ITLL	$4.05

Transistor	2	.3g	ITLL	$0.30
Inductors	4	.2g	ITLL	$0.60
Total		910g		$190.69

The team's cost estimates were very accurate and $190.69 as the final cost. The weight estimates were slightly low, as the balloonsat ultimately weighed approximately 940 grams. This was due to the tape sealing the box and the addition of some additional insulation.

6.0 Test Plan and Results

6.1 Structural Testing

6.1.1 Drop Test

Upon landing the BalloonSat will impact the ground at significant speed, even with the parachute slowing the descent. To ensure the structure is strong enough to withstand this impact, the team performed a drop test which involved dropping the satellite from the second story of the Integrated Teaching and Learning Laboratory balcony onto the concrete below. This height is approximately enough to simulate the speed of the BalloonSat upon landing. As it is expected that the antenna will be damaged upon landing and it is designed in such a way that this will not interfere with data recovery, the antenna was replaced by an antenna analog wooden dowel to reduce the chance of needing more replacement antennas. The team stationed safety observers on both sides of the balcony to make sure no unwilling bystanders were near during the drop. All team members kept clear of the impact point in case the satellite burst and sent debris outward. The test will be considered successful if the main structure of the BalloonSat is no more than superficially damaged (bent corners and damaged antenna analog are expected) and all the internal components remain functional and firmly attached.

Results: The result of the drop test were positive but revealed a weakness in the wall the GoPro is embedded in. The team rebuilt the balloonsat following the drop test using the ITLL laser cutters and included a second layer of foam core on the face the GoPro is embedded in. The GoPro also became dislodged which the team will address by adding more tape holding it in place during the final launch. No other significant damage was observed.

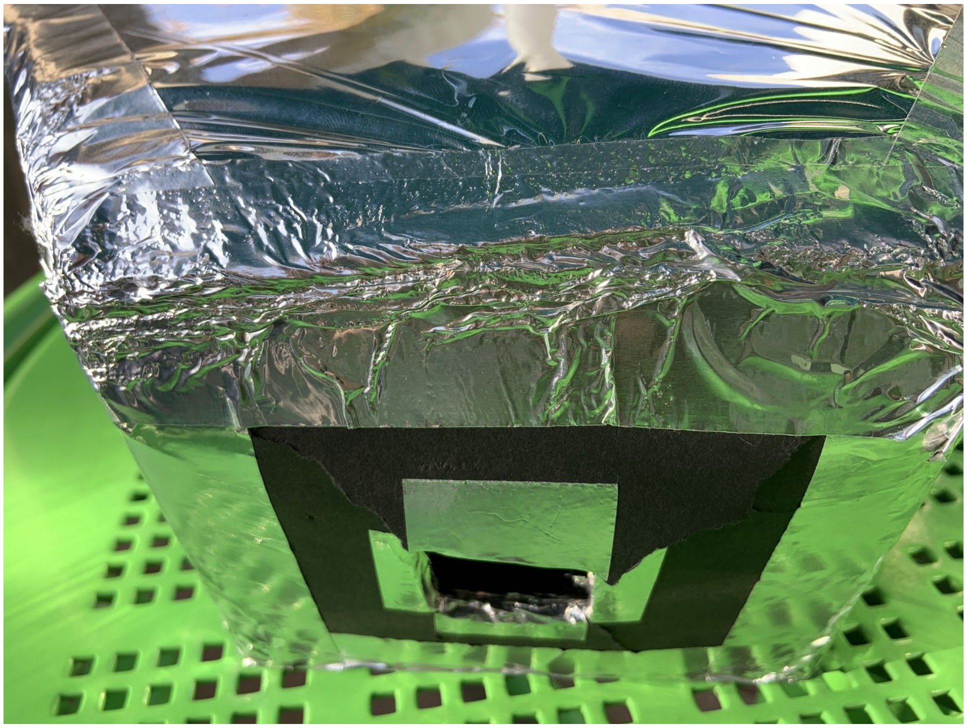


Figure 6.1.1a BalloonSat after the drop test. Note that the edge facing the camera absorbed almost the entirety of the impact. No damage to the internal components was observed.--

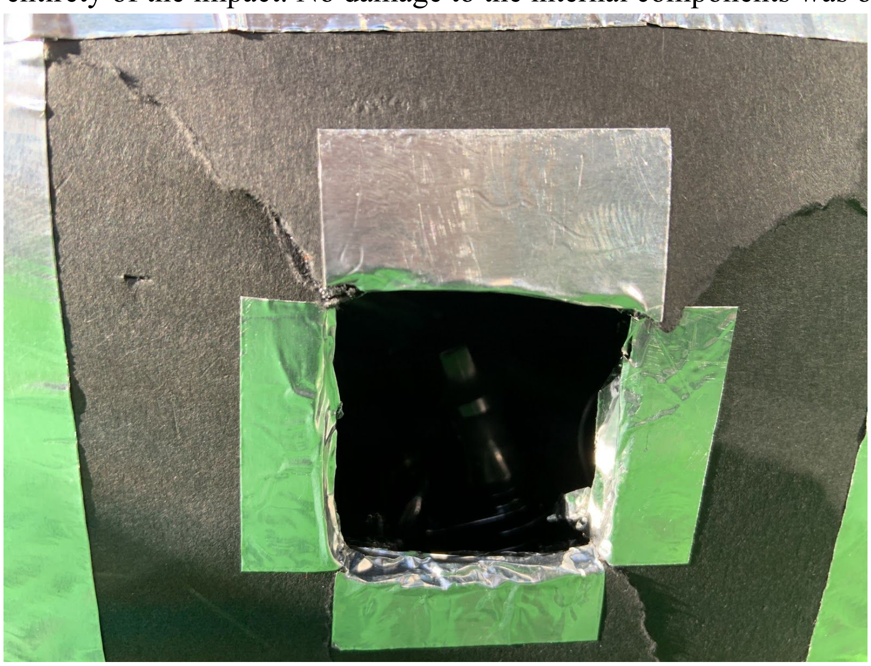


Figure 6.1.1b Front view of the wall containing the GoPro. The foam core broke in a diagonal between the corners of the GoPro cutout and the top corners of the balloonsat. This damage was addressed in the rebuilt balloonsat by adding a second layer of foam core to this wall. More tape was also added to better secure the GoPro.

6.1.2 Whip Test

When the balloon bursts, the entire flight string will be violently swung around and experience significant acceleration. If the BalloonSat's structure is not sufficiently prepared for this it is possible some or all of the satellite could become detached from the flight string. To test this, a team member stood in the business field and rapidly swung the BalloonSat over their head for several seconds. The remaining team members were stationed to provide 360-degree protection several meters from the spinning BalloonSat in order to keep bystanders clear of the area in case something did break. The test will be considered successful if after several seconds of high-G spinning the satellite is still secure to the string, with no damage to the structure or electronic components. For this test, the flight antenna will be in place as no damage is anticipated to the antenna under these stresses.

Figure 6.1.2 Matthew performing the Whip Test

Results: The whip test was successful and revealed no structural problems. All internal components remained fixed to their mounting points and the flight tube stayed attached to the structure.

6.1.3 Stair Test

After landing, there is a possibility that the wind will be strong enough to catch the parachute and drag the flight line around, bouncing off the ground and hitting objects. To ensure the satellite is capable of surviving this, the team performed a "Stair Test". The BalloonSat was dragged down a staircase by a line attached through the flight tube, once again with a dummy antenna to prevent damage to the real antenna, simulating being dragged around on the ground. Team members were stationed at the top and bottom of the stairs to ensure that the staircase was clear of bystanders and to keep the BalloonSat from continuing off the staircase uncontrollably. The test will be considered successful based on standards similar to the drop test: if the structure is only superficially damaged and the internal components are still solidly attached and undamaged.

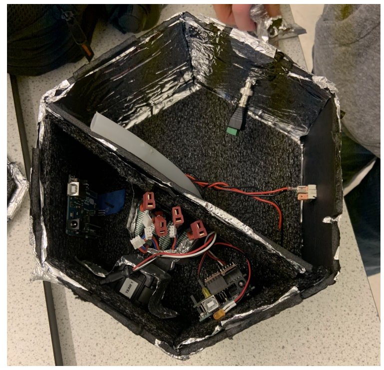


Figure 6.1.3 BallonSat after Stair Test

Results: The stair test was successful and resulted in only superficial damage to the balloonsat. All internal components remained fixed to their mounting points and the flight tube stayed attached to the structure.

6.1.4 Cold Test

During the ascent, the satellite shall face temperatures as low as -80°C, so a test must be performed to ensure the satellite systems shall continue to function in low temperatures and to test the thermal control system. The satellite was placed in an insulated cooler surrounded by dry ice, which simulates the same temperature as the lowest temperature the satellite shall experience. The test was run for the full time of a simulated flight, approximately 90 minutes. All systems were running and collecting data for the entire test to ensure that the heating system and thermal insulation is sufficient to ensure uninterrupted operation for the duration of the flight. The test shall be successful when the satellite can continue to operate continuously for 90 minutes at the lowest expected temperature during the flight, all systems continue to work and collect data, and the internal temperature maintains the minimum temperature given in the Request for Proposal, -10°C. For safety, any team members handling the BalloonSat or dry ice wire protective insulated gloves, and the cooler was not moved while the test is running to prevent spilling dry ice out.

Results: Our first attempt at the cold test was unsuccessful and revealed that the wiring for our heating pad had been done incorrectly and resulted in the heater never activating. Without the heater activating, the temperature data the team collected showed the internal temperature going below -10°C. The team corrected the heating pad wiring and ran the cold test again, resulting in the following temperature data.

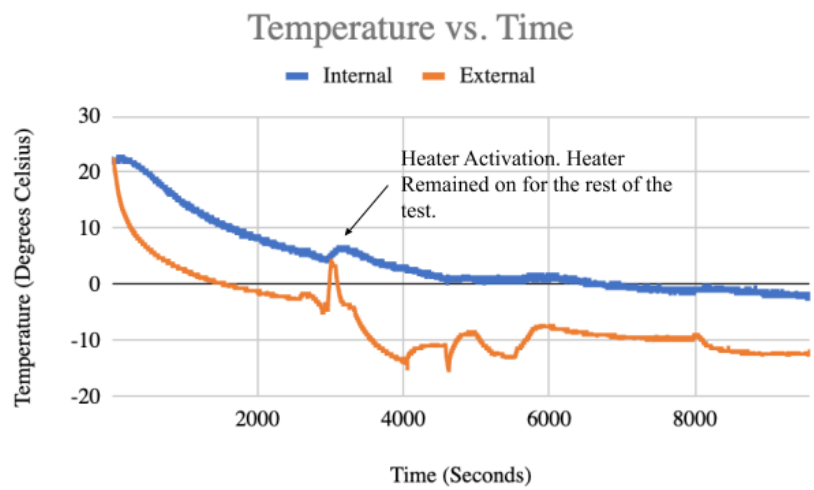


Figure 6.1.4 Graph showing the internal and external temperature measurements taken during the second cold test which lasted approximately 2.6 hours. The minimum internal temperature recorded was -2.1°C which is within the parameters laid out in the team's mission requirements and the Request for Proposal.

Results: The second cold test proved successful and demonstrated that our heater works and maintains operating temperatures inside our balloonsat.

6.2 Sensor Testing

6.2.1 Receiver Test

To test Project Lightning McQueen, the satellite with VLF receiver and antenna installed shall be taken up far from man-made interference by driving to eastern Colorado and recording at least several minutes of radio waves. The data shall be filtered and analyzed for interference to ensure the antenna is properly grounded, the receiver is correctly wired, and internal sources of interference are sufficiently shielded.

Results: The receiver was first assembled on a breadboard to ensure the wiring and design was correct. The breadboard was then attached to a power source, signal generator, and oscilloscope and signals of varying amplitude and frequency were passed in while monitoring the output. It was observed that the circuit was tuning down high frequency waves and outputting signals that matched the input. As it is impossible to create an artificial sferic with the signal generator, sine waves and noise were used for the testing. Once the PCB was received and assembled, it was attached to the antenna and Arduino and taken outdoors, where some data was recorded and analyzed. The data coming from the receiver had two problems. 1) it was often outputting negative voltage, which the Arduino cannot read, and 2) the changes in voltage were so small it was often only one bit in the Arduino's analog to digital converter. Due to this, a secondary circuit was designed utilizing one operational amplifier and it shift the voltage of the circuit, bringing the data to a positive range, and amplified the voltage thereby making the variations in voltage much larger to allow greater precision of measurement.

Once the circuit was installed, the assembly was taken outdoors once again and recorded data for 30 seconds. The data was once again analyzed and the data appeared to show sferics.

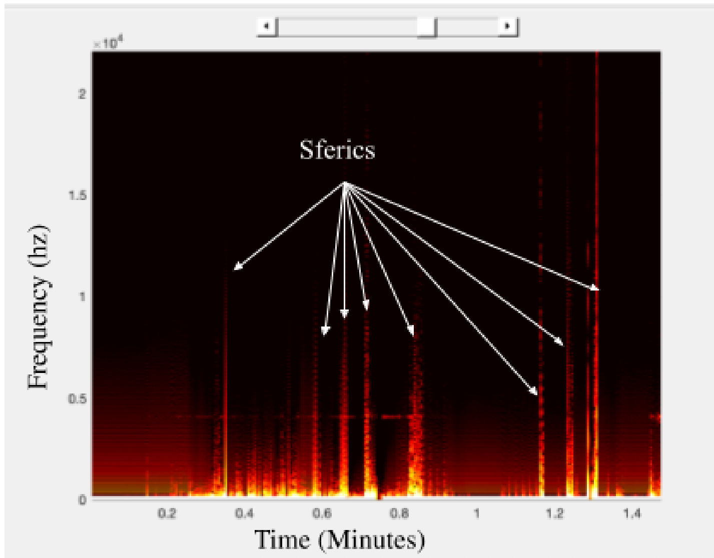


Figure 6.2.1 Heat map of radio signals detected by the antenna and processed using MATLAB. The spikes are believed to be sferics. This data is discussed in more detail in section 7.0.

6.2.2 Arduino Sensor Tests

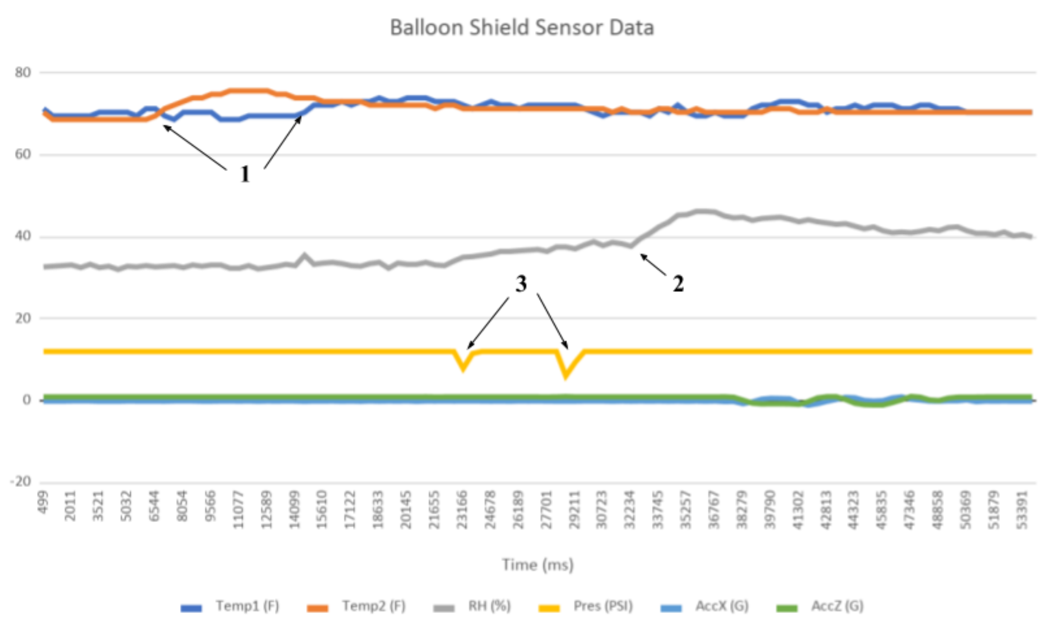


Figure 6.2.2a (1) Team member puts their finger on temperature sensor to warm it. (2) Team member breathes on humidity sensor. (3) Team member uses solder remover to reduce air pressure around pressure sensor.

For successful launch and data recovery, it is necessary that all Arduino sensors are calibrated and working properly. To ensure this, Team Check Your Staging performed the following tests on the sensors: over a period of about 60 seconds the Arduino was rotated on the X and Z axes to test the accelerometer, team members placed their fingers on the internal and external temperature sensors to test them with body heat, a solder sucker was used to drop the surrounding pressure of the pressure sensor, and a team member breathed on the humidity sensor.

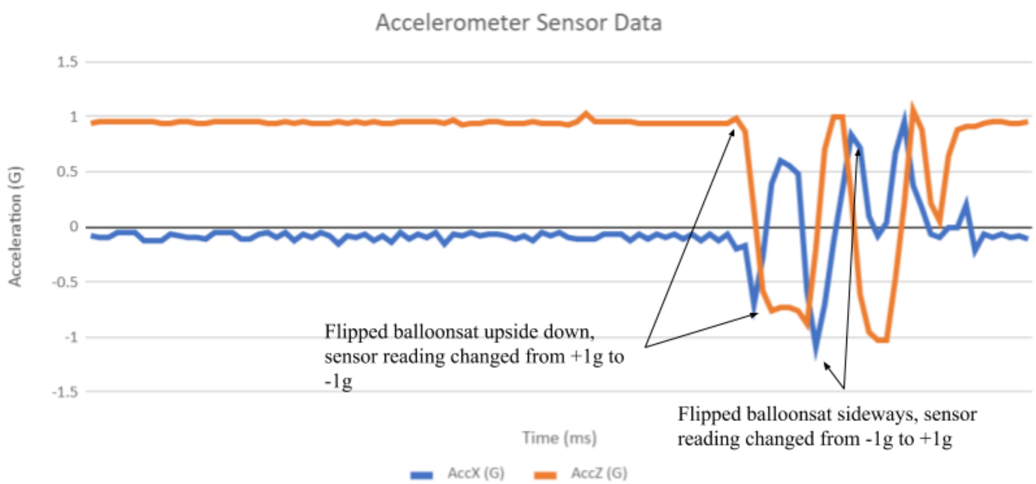


Figure 6.2.2b Graph of accelerometer data showing readings of +1g and -1g depending on the BalloonSat's orientation.

6.2.3 Imaging Test

To confirm that the GoPro is functioning properly the team recorded videos and photos using the GoPro and successfully imported them from the GoPro's SD card.

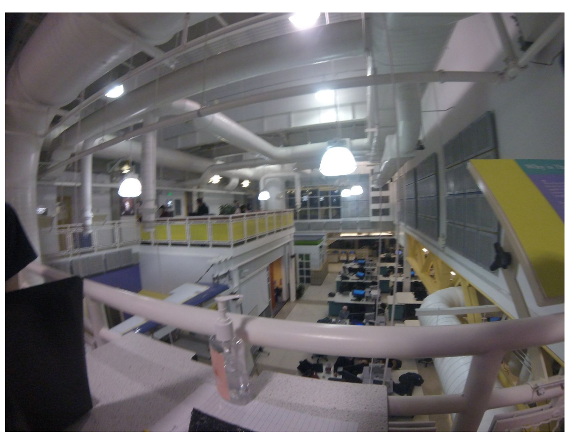


Figure 6.2.3 Image taken with GoPro then imported from SD Card to team member's computer

6.2.4 Mission Simulation Testing

In order to simulate the flight duration and expected extreme temperatures, Project Lightning McQueen was left in the dry ice temperature test for three hours. This tested the life of our batteries at the most extreme temperatures. Furthermore, mission simulation data demonstrated the ability of each sensor to operate in low temperature conditions. This test will serve as a final basis to calibrate sensors if necessary.

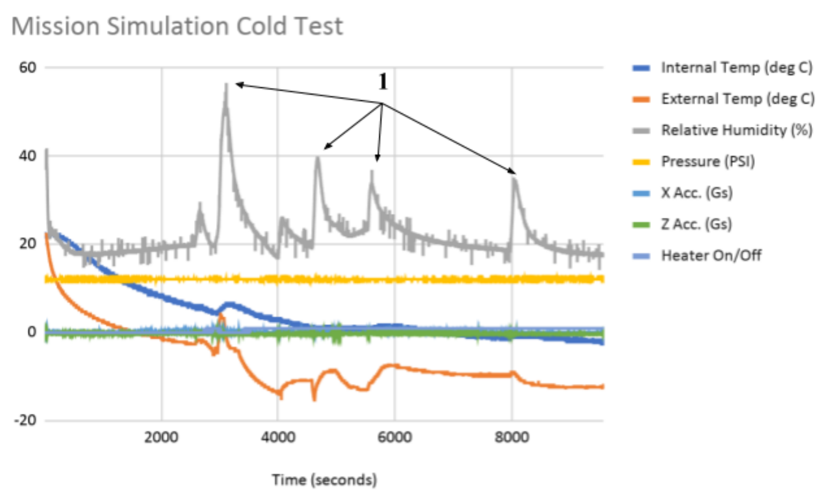


Figure 6.2.4 Data collected during the cold test which shows all sensors performing as expected. (1) Each time the box was opened the relative humidity and external temperature spiked.

Results: The mission simulation test shown above was run concurrently with the successful cold test. All sensor data matches known values within a reasonable tolerance. Note the increase in relative humidity and temperature each time the box was opened to check that the BalloonSat was still operating.

To further simulate the VLF data and prove that interference is not producing the sferic spikes in other tests, Team Check Your Staging shall provide a control ground study. The BalloonSat shall be taken to a field in Berthoud, Colorado to record data for 90 minutes. This location has low levels of radio emissions and should provide less noisy data. The VLF data collected will serve as a comparison for our mission data.

7.0 Expected Results

7.1 BalloonShield Sensor Readings

7.1.1 Humidity

Figure 7.1.1 shows the humidity data from the Fall 2018 Team 2 flight. Team Check Your Staging expects the humidity sensor to yield similar results. As the BalloonSat increases in elevation, the humidity should decrease as the moisture in the air decreases. If the satellite passes through a cloud, there may be a spike in humidity as clouds hold more moisture than the surrounding air. Just as the humidity is expected to increase with altitude, it should in turn decrease upon descent.

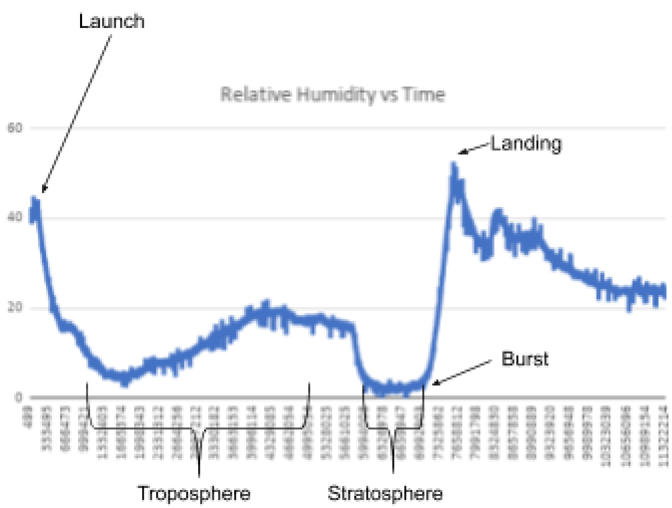


Figure 7.1.1

7.1.2 Temperature

Figure 7.1.2 shows the internal and external temperature data from the flight of Team 2 Fall 2018. As in the graph, it is expected that the internal sensor shall record a less dramatic changes in temperature compared to what is recorded by the external sensor, as the internal sensor is shielded by insulation. As the satellite rises through the troposphere, temperature should decrease as the density of the gasses in the atmosphere decreases. However, once the stratosphere is entered temperature should increase with altitude because heat results from the formation of ozone in this layer (National Weather Service).

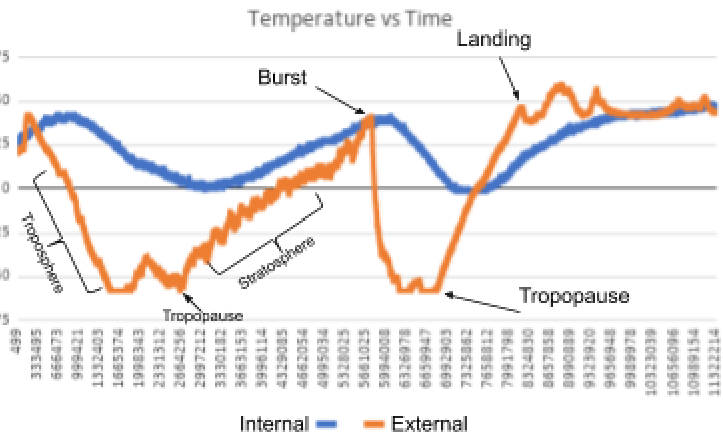


Figure 7.1.2

7.1.3 Pressure

Throughout the ascent of the satellite the Team expects the pressure to record and return data that looks similar to the beginning of that of the flight data from Team 2 Fall 2018 in Figure 7.1.3. As the satellite flies up into the stratosphere, pressure should decrease because there will be less molecules in the surrounding air compared to the ground where there are more molecules held down by the force of gravity. With the same reasoning in mind, it is expected that the pressure will increase as the satellite returns to the ground. (Note, the x axis labels of these graphs were created by Fall 2018 Team 2 and cannot be changed without their original data)

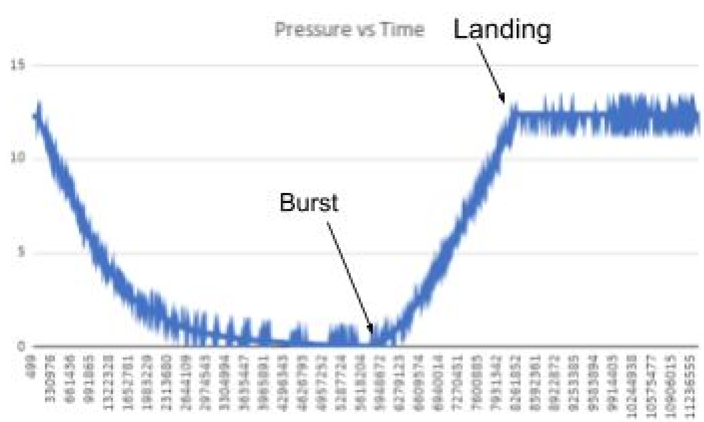


Figure 7.1.3

7.1.4 Accelerometer

At launch, the BalloonSat will experience large amounts of acceleration due to the sudden pulls, rotations, whips from the balloon. The acceleration should stay relatively steady for the rest of the flight up, until burst. At burst, the BalloonSat will experience large acceleration due to loss of the balloon which causes it to fall freely towards earth. The acceleration data is expected to look similar to Spring 2018's Team 8 as shown in Figure 7.1.4.

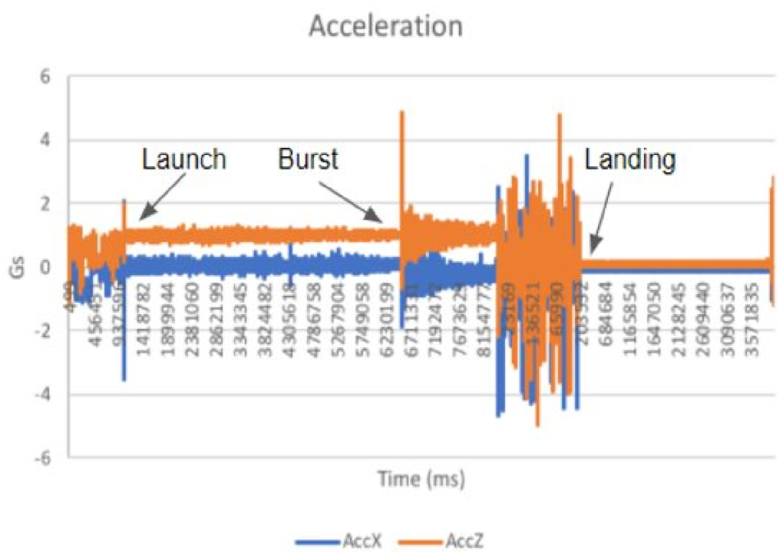


Figure 7.1.4

7.2 Sferic Detection

During Ascent, the BalloonSat will be recording frequencies of radio waves picked up by the VLF receiver. The frequencies of these radio waves will be recorded to the Arduino at a sampling rate 200000 baud, the highest rate at which the OpenLogger can write. Higher baud rates increase the detail of the data the arduino writes to the SD card. These frequencies will be imported into MATLAB, and run through a program that uses a decibel normalizer to clean up the data and then a built in spectrogram analyzer and graphing function to display a frequency over time graph with volume (decibels) represented by color. . The sferics should be visible as the spikes and swooshes on the spectrogram that can be seen in Figure 7.2.1.

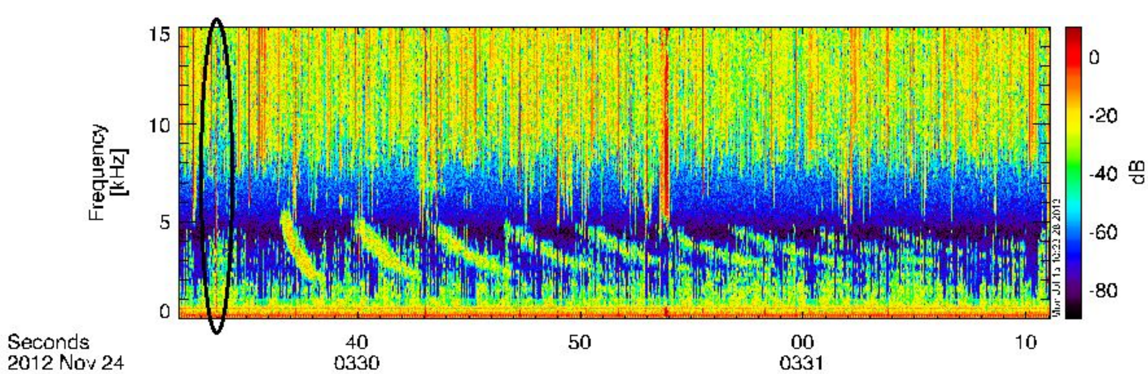


Figure 7.2.1

Figure 7.2.2a shows an example of a spectrogram made using the MATLAB program, with the input being an audio file of sferics. Figure 7.2.2b shows a spectrogram created by the MATLAB Program with input being data taken from running the Arduino/VLF Receiver setup. When played back as an audio file, this recording sounds like pops and clicks, which is what sferics should sound like based off data known to contain sferics. This data is noisy because it was recorded in the CU Engineering Center, where there is a great deal of random, uncharacterizable radio interference which was observed when the team ran the antenna in the Engineering Center. A new recording shall be made before launch in a place with less interference, so there is more accurate data to compare to data from the flight.

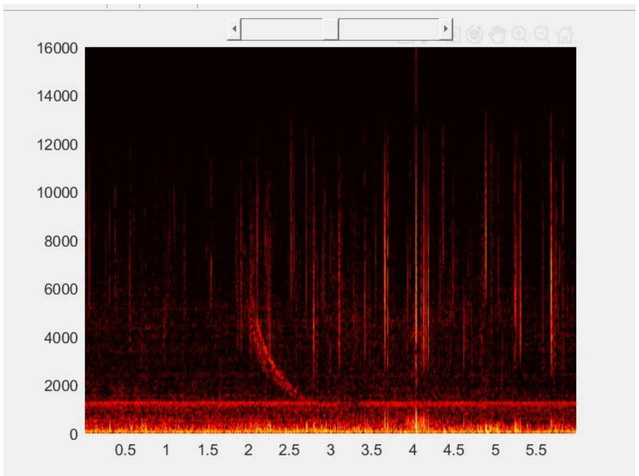


Figure 7.2.2a - Frequency vs Time

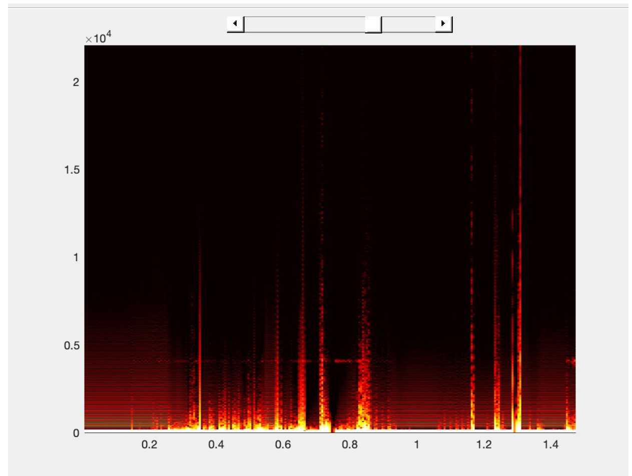


Figure 7.2.2b - Frequency vs Time

8.0 Launch and Recovery

8.1 Launch Plan

Every member of Team Check Your Staging will attend the launch on November 9th, 2019. Upon arrival to the launch site at Eaton Middle School in Eaton, Colorado, Jacob Wilson and Jason Popich will turn on the BalloonSat so that all LEDs illuminate to indicate full operation, and then confirm that the recording light on the GoPro is flashing. Katie Schutt will be in charge of taking pictures of the BalloonSat before launch and inspecting its condition for comparison of the BalloonSat post-launch. Katie will also take video for the entirety of launch day. The BalloonSat will then be handed to Joe Miserlian who will be in charge of holding and releasing the BalloonSat during launch.

8.2 Recovery Plan

All members of Team Check Your Staging will follow the lead car to recover the BalloonSat and assist in the recovery. Upon recovery, pictures will be taken of the BalloonSat by Katie Schutt to record it's condition. First, pictures will be taken of the exterior, then it will be opened and pictures will be taken of the internal components. The BalloonSat will then be turned off and closed until data recovery.

8.3 Data Recovery Plan

After the BalloonSat has been transported to a location for data recovery, the SD Cards will be removed from their respective Arduinos, and the data will be transferred onto a computer. The team shall import the data from the flight sensors into Excel and graph each sensor's output as a function of time so it can be analyzed. The data from the VLF Receiver will be imported into MATLAB and ran through the program that grabs a sample of 5-10 seconds of that data from the desired time during the flight, cleans up the data with a decibel normalizer, and displays it as a spectrogram using MATLAB's built in spectrogram function. This procedure was tested and verified multiple times after each cold test and receiver test. The same procedure, programs, and analysis were used on every data set to ensure the team knew everything was ready.

8.4 Launch and Recovery: Day Of

Team Check Your Staging left the University of Colorado Boulder campus around 4:40 AM. They drove the one hour to Eaton Middle School. The team checked in and the BalloonSat was strung with the rest of the Gateway experiments. Joe carried the BalloonSat to the launch site, a field near the middle school, about 15 minutes before launch. Launch moved ahead of schedule, taking place at 6:54 AM. All switches and the GoPro were turned on.

The balloon launch went very smoothly and was unproblematic. Shortly after the second balloon launch the team began the chase, following Chris's lead car. They drove to Akron, Colorado (where the BalloonSats landed) in approximately 2 hours arriving around 9:30 AM.

The structure acquired minimal damage: the antenna was bent (which was expected) but still attached. There was no internal damage, but the batteries had fallen out of their velcro placement. After assessing the damage, the SD cards were then removed and transferred to a computer for data analysis.

Figure 8.3.1 The flight path of the balloon from Eaton, CO to Akron, CO on launch day

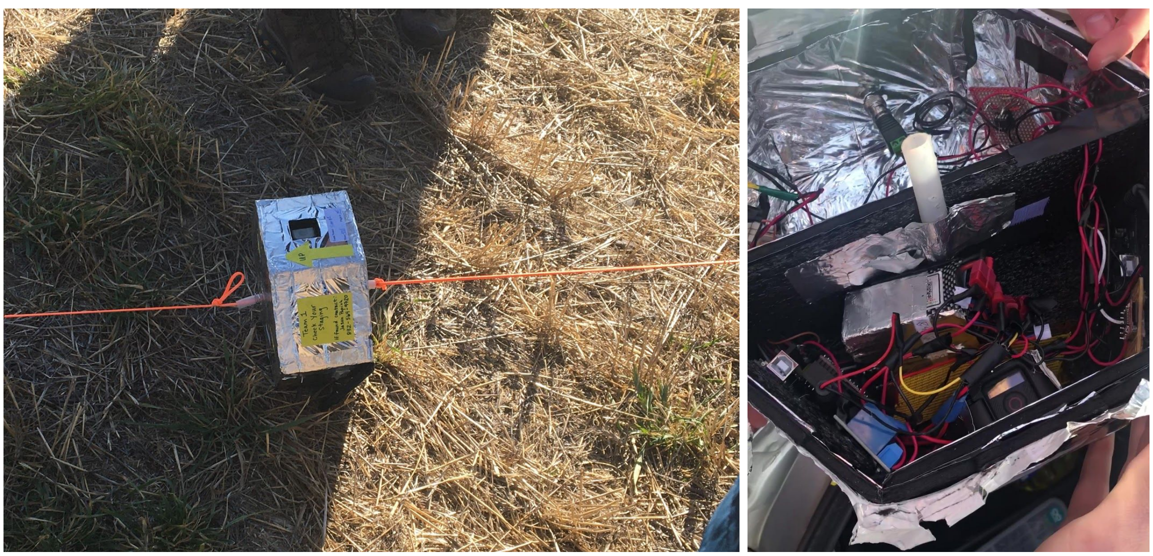


Figure 8.3.2 Exterior and interior of BalloonSat after recovery

9.0 Results, Data Analysis, Failure Analysis, and Conclusions

9.1 Balloon Shield Flight Data

9.1.1 Temperature Data

The data received from the external temperature sensor was as expected: the temperature decreased to about -50°C (lower external temperatures may have been reached, but the sensor reached its lower limit of -50°C) through the troposphere until the tropopause was entered. From there, the temperature increased through the stratosphere until the maximum altitude was reached at burst. After burst, the temperature decreased as the BalloonSat fell back through the stratosphere and increased at it fell back to Earth through the troposphere. This is external temperature is demonstrated by the blue line in Figure 9.1.1.

The flight data also proved that while the external temperature reached extreme lows of below -50°C, the heating pad system was successful in keeping the internal temperature of the BalloonSat above -10°C which is indicated by the orange line in Figure 9.1.1. When the external temperature crossed the threshold of -20°C, the heating pad turned on which is indicated by a value of 1 on the yellow line in Figure 9.1.1.

Team Check Your Staging lends the success of the heating pad system to thorough cold testing previous to launch as seen in 6.1.4 Cold Test. While previously testing in a dry ice environment, the heating pad did not turn on which allowed the internal temperature to reach below -10°C. However, after further cold testing the relay and heating pad system was fixed to allow the temperature data shown in Figure 9.1.1.

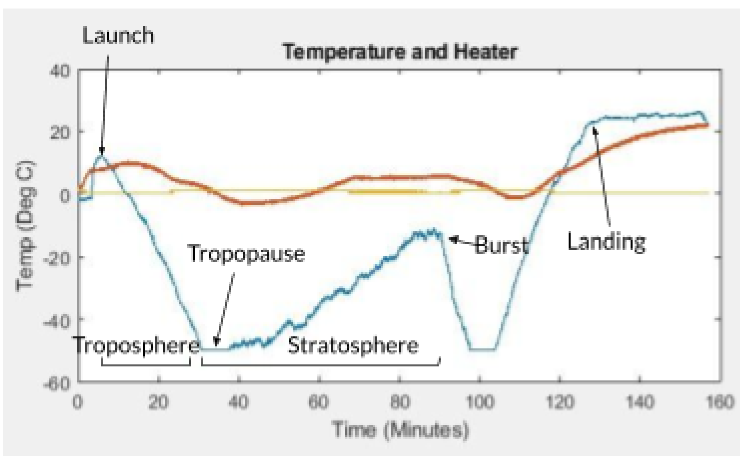


Figure 9.1.1

9.1.2 Humidity Data

The humidity data collected from flight was similar to the temperature data. Humidity decreased from launch to the tropopause. After leaving the troposphere, the humidity increased until burst. The opposite happened on descent, where the humidity decreased until the tropopause and then increased again up to landing. It is suspected that either the BalloonSat passed into a weather region or the increase of humidity was caused by condensation as the temperature increased. This is demonstrated in Figure 9.1.2.

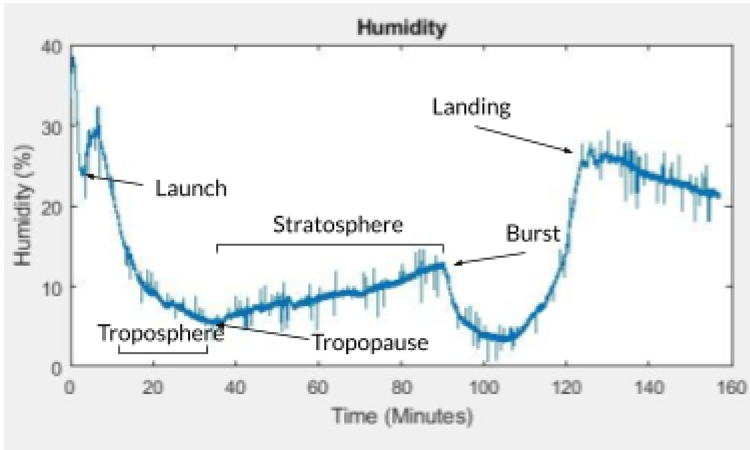


Figure 9.1.2

9.1.3 Pressure Data

As indicated in Figure 9.1.3, pressure decreased from launch through the ascent until burst and then decreased from burst through descent until landing. This was as Team Check Your Staging predicted in 7.0 Expected Results.

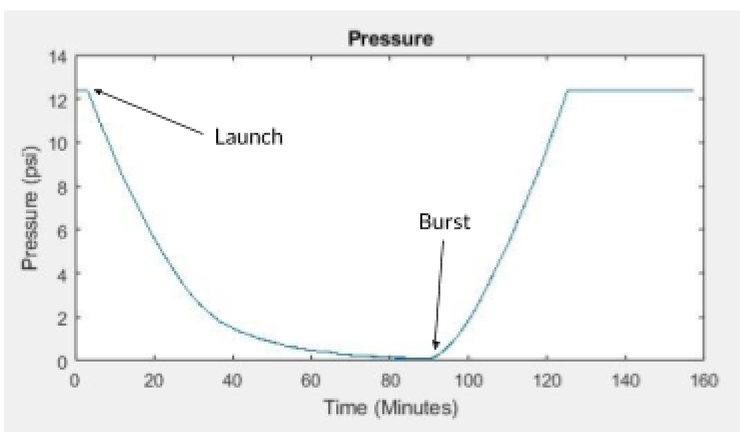


Figure 9.1.3

9.1.4 Acceleration

The acceleration data showed small amounts of Gs experiences at launch, then remained around 0 Gs through ascent until burst. Burst proved to be violent as the BalloonSat experienced great amounts of acceleration, and then still experienced large amounts of acceleration for most of the descent until landing. This is demonstrated in Figure 9.1.4.

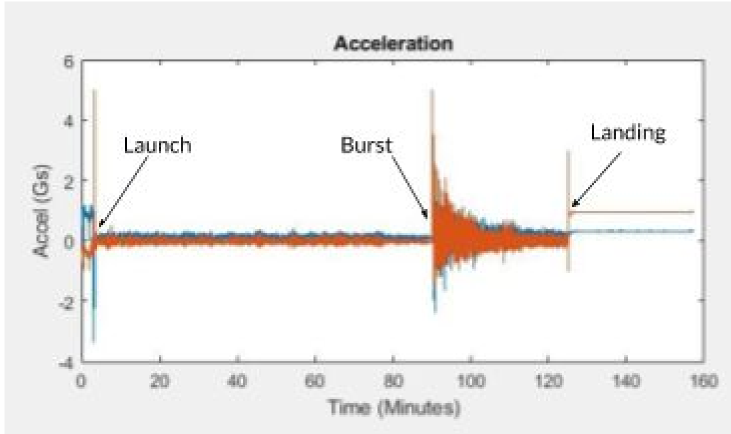


Figure 9.1.4

9.2 PCB Flight Data

The Arduino was partially successful in recording data during the whole flight (besides the brief disconnection at burst). After the flight it imported it into MATLAB, reduced to around 10 seconds of data, and ran through the MATLAB spectrogram program described in Section 8.3. The team repeated this process with different sections of the data to view the differences between different times during the flight, however no difference was found. A spectrogram created from a 5 second sample from 30 minutes into the flight can be seen below in Figure 9.2.1. The full flight spectrogram plus normalized raw voltage data can be seen in Figure 9.2.2. The two graphs indicate ascent and descent respectively.

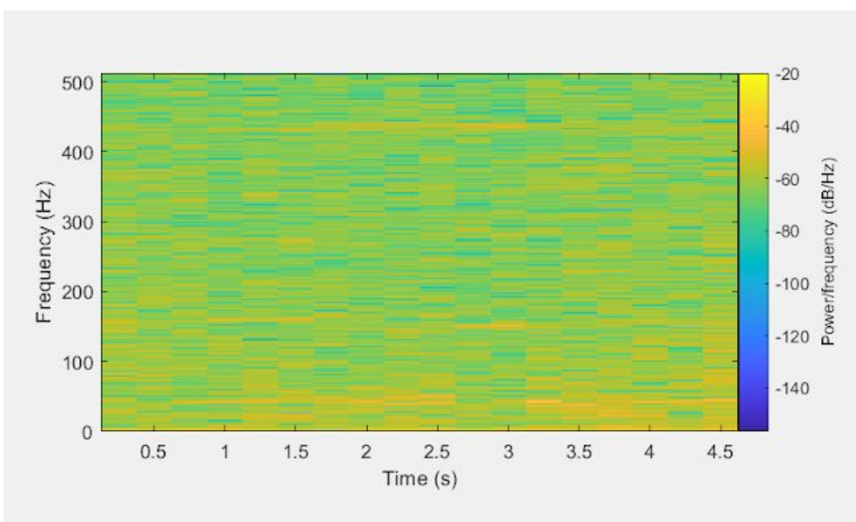


Figure 9.2.1

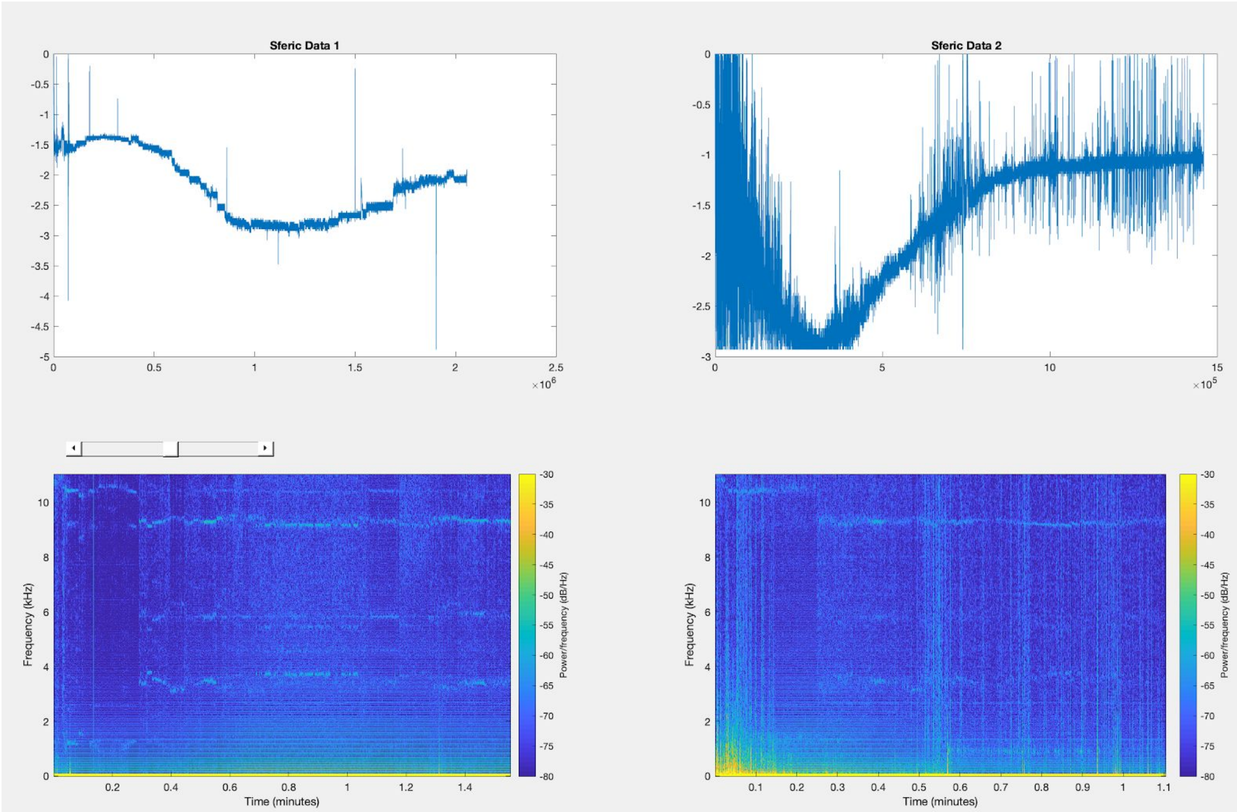


Figure 9.2.2

9.3 Failure Analysis

9.3.1 Data Collection Baud Rate

As seen in the spectrogram in Figure 9.2.1, the VLF flight data does not look the same as the expected spectrogram. This is because the sampling rate of the Arduino was not fast enough. The Arduino serial protocol, namely UART, outputs 7-bit ASCII text characters, but there is also a start bit and a stop bit. Therefore, for every character, or 7 bits, there are actually 9 bits of data being transmitted. What was not previously known, and discovered after the flight, is that the baud rate only applies to the data bits. Therefore by stating that the you are transmitting at 155,200 baud, or bit/s, you are only including the 7 data bits and not the two start/stop bits for a total of 9 bits. This discovery was as a result of the OpenLogger baud limit being stated as 155,200 baud, however through pre-flight testing, Team Check Your Staging discovered that the OpenLogger could be set to 200,000 baud. Since the system allowed the baud rate to be set to 200,000, the baud rate for flight was at 200,000 baud, or bits/s. The team did express concerns of other factors not considered in a last-minute change, as was discovered after flight. When Team Check Your Staging further looked into the baud system from flight data, it was discovered that at a baud rate of 155,200 baud, essentially when the start/stop bits are also included an extra 44,444 bit/s are added resulting in a 199,644 true baud or the OpenLogger's limit of 200,000 as was seen in pre-flight testing. Therefore, the true transmitted data rate from the Arduino at

200,000 baud was 200,000 * (9/7) or over 250,000 true baud. Since the OpenLogger was not capable of handling this rate of data transfer, it resulted in occasional buffer overflows in the OpenLogger, causing up to 50 millisecond gaps in data every few minutes.

Additionally, this data rate is too low (even without the buffer overflows) to properly see sferics which occur in those milliseconds. An mp3 file is around 256 kbits/s, whereas the flight experiment was much less: only around 70 kbits/s. To demonstrate that this was the problem, the audio file that was used to make the expected spectrogram in Section 7.0 was compressed down to the same size as our flight data from the Arduino. That compressed vector was passed through the same MATLAB spectrogram program and the output looked almost identical to Figure 9.2.1. The uncompressed and compressed audio vector spectrogram are shown in Figure 9.3.1 (color difference has no effect).

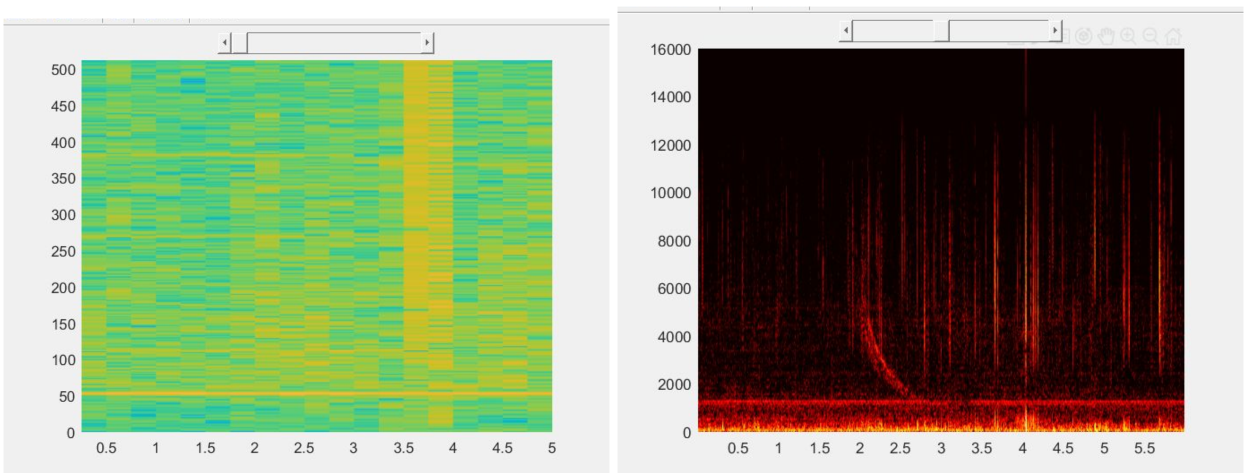


Figure 9.3.1 Compressed and regular mp3 file from initial testing, to show the expected data at the rate the Arduino collected the data

The compressed data looks identical to the data in Figure 9.2.1. The data resolution was simply too low to have the level of detail necessary to detect sferics. Any data that was received was simply luck of polling the voltage at the exact millisecond a sferic occurred.

Ultimately, the quality of the data collected prevented Team Check Your Staging from making a strong claim about the prevalence of sferics as a function of altitude.

9.3.2 Power Interruption at Burst

The other failure that occurred was an instantaneous power interruption immediately following burst. This was evident due to the fact that each Arduino created two log files that when combined make up the entire flight. This occurred at burst as proven by the fact that the end of the first log file from the BalloonShield Arduino shows regular accelerometer data, up until the last line of over 5 Gs in one direction. The suspected cause of the failure is the batteries coming loose during the violent jolts and whipping following burst, causing the battery pack to temporarily tweak power connections enough to shut everything down and initiate a power cycle. During cold testing, it was noted that extreme cold caused the adhesive on the velcro strips used to secure the batteries to lose integrity, which is likely what caused the batteries to come loose inside the flight.

10.0 Ready for Flight

10.1 Returning to Readiness

Very few structural tasks must be accomplished in order to prepare the BalloonSat for a second flight. Overall, Project Lightning McQueen held up very well to the violent burst and landing encountered on launch day. A primary focus is to replace the antenna. The antenna remained attached to the structure but was bent significantly. However, a second antenna was purchased at the beginning of the projects and can easily be replaced through attachment to the female coaxial connector and securing with tape. Additionally, some of the mylar thermal blanket exterior along with several velcro anchors have begun to peel off. This must simply re-affixed into place with hot glue.

In order to prepare for the next flight, all systems should be disconnected from a power source with the batteries and electronics stored in a cool environment. Prior to this subsequent flight, all wiring should be rechecked, repowered, and another full mission simulation should take place. If left for an extended period of time, sensors should undergo another round of calibration. Structurally, there are no major concerns of deterioration and visual inspection prior to launch will reveal any issues. Finally, microSD cards for both the camera and Arduinos should be wiped with batteries fully charged before use.

10.2 Improvements and Modifications

A major modification that needs to be performed is the replacement of the VLF radio wave logging techniques and hardware used in the BalloonSat. More specifically, changing the serial protocol from the UART serial circuit to the I^2C serial communication standard, which will interface directly with a flash chip as opposed to writing to an SD card through the OpenLogger (as was used during flight). By removing the OpenLogger from the equation, the limitation of writing at 155,200 bits/s is completely removed, and then, the limitation of the serial protocol factors in. For example, the maximum speed of the UART serial circuit is around 960 kBit/s if the interrupt latency is 1 millisecond (which on the openLogger it is not), whereas the I^2C protocol can achieve up to 3.4 MBits/s, and a flash chip depending on the manufacturer can typically achieve 2 MBits/s write speed.

So, in order to acquire enough data from the receiver, two modifications must be made: switching from an SD based OpenLogger to a flash chip, and then changing the hardware from an Arduino UNO to a Teensy 3.6. The reason for this hardware change is that the Teensy 3.6, due to its high core speed, can support the Fast Mode and High-Speed Mode of the I^2C protocol, surpassing the Arduino UNO's write speed in I^2C. Furthermore, the Teensy 3.6 features an onboard SD slot that can be utilized whenever the flash chip reaches maximum capacity by dumping the data onto the SD, erasing the flash, and starting the log again throughout the duration of the flight.

In the new system, a Teensy 3.6 Development board and a MT25QL256ABA8ESF-0SIT TR Flash Chip were used to test the viability of switching to a different serial protocol and hardware. As seen in Figure 10.2.1, the amount of samples collected with this new system is on par with the high resolution audio files. Both spectrograms in Figure 10.2.1 are during the same time frame (except the left spectrogram is on the old system--and it shows how much data was lost because it appears as though it was around 300 ms as opposed 2.5s worth of data though it really was 2.5secs worth of data on the old system) and the right spectrogram is the new Teensy system. Figure 10.2.2 is the flight data applied in the same time scale, showing that the left figure in 10.2.1 and the Flight Data suffer from the same compression and also proves the fact of a buffer overload because in the same time frame one suffered from more data loss than the other but both are relatively the same.

The team then performed testing on the newly integrated Teensy system. Unfortunately, due to the proximity of power lines in the Berthoud/Boulder area, Team Check Your Staging failed to detect sferics and instead detected nearby power lines. However, the test did indicate that with a flash chip system, if the team were to launch again, the BalloonSat would be able to record from the PCB at an adequate sampling rate.

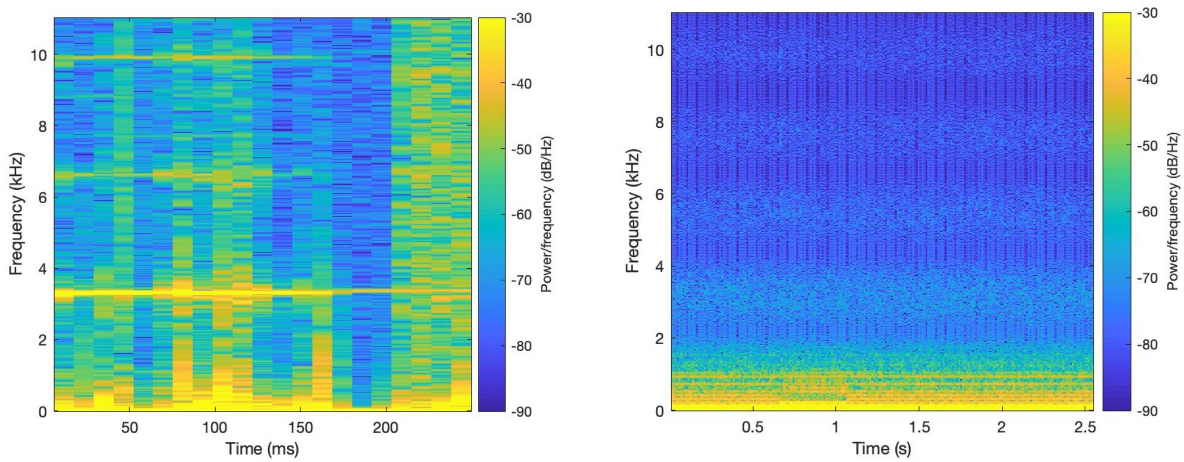


Figure 10.2.1

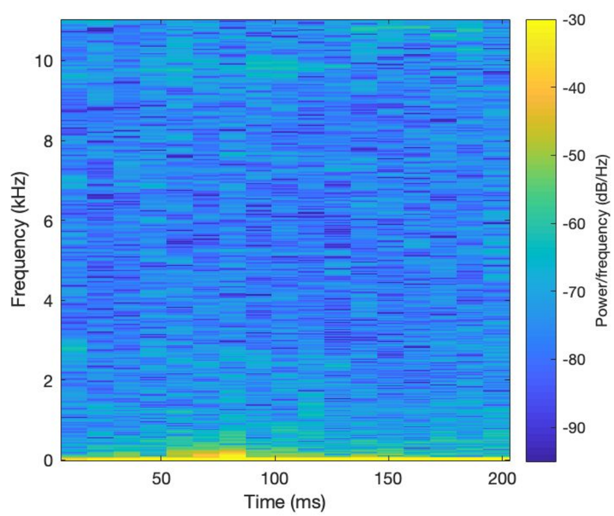


Figure 10.2.2

11.0 Lessons Learned

11.1 Group Management

Over the course of the semester, Team Check Your Staging worked well as a group and met almost deadlines and requirements on time (they learned that deadlines are *hard* deadlines when turning in the Preliminary Design Review presentation). However, two major lessons in group management were made evident throughout the project.

1. The first issue was that with seven team members, individuals did not always take an active role in the areas that others were working on. The team ended up in a situation where only one group member understood how the MATLAB code worked, and only two members understood how the PCB worked. This was detrimental to group progress since whenever those specific members were absent the team experienced difficulty moving forwards. If the team had the chance to do Gateway to Space again, members would not completely specialize in roles so that everyone could develop a more well-rounded skill set.
2. The team also experienced a member with poor attendance leading to the rest of the group not including him in the project as much as potentially possible. It became a cycle of less attendance and therefore less inclusion. It was not completely fruitless as all tasks were completed due to the large size of the team and communicating individually rather than always in a group chat. If done again, all team members should make a greater effort to include members who end up "out of the loop" with such a large team.

11.2 Experiment Selection

While the team remains interested in the sferic experiment designed and executed, the difficulty of the PCB design and manufacturing proved to be a major challenge. The experiment ultimately failed to collect the data the team was hoping to observe largely due to the complexity of the electrical components involved. This issue was also connected to the previous group management problem of only select members understanding the PCB. If the team could do this project again it would either select a simpler experiment or pursue more help with the electrical design earlier in the design process.

11.3 Time Management

Team Check Your Staging was very effective at managing time and a consistent meeting schedule (excluding a few guaranteed late nights during the week immediately before launch). Consistently meeting at least six hours or more a week was a very large commitment for every team member in the group, but resulted in a relatively successful launch day that exceeded any expectations and made meeting time worth it. Design Document revisions and presentations were turned in on time (except for one, caused by a communication error) and regular meetings spread out the majority of the work throughout the semester rather than procrastinating on large sections of the project and creating "crunch time" situations. Having now completed the course, the team recognizes how disastrous poor time management could have been.

12.0 Message to Next Semester

Gateway to Space is hard. It requires an extremely large time commitment and the "people skills" to get along with a randomly assigned team meeting, in our case, every day of the week, be it in or out of class. Our fellow group members were some of the people we saw most often, but also became people we looked forward to seeing so often. Our group worked well together and the class ended up being a challenging, rewarding experience (launch day makes the late nights, BalloonSat fires, and skits so worth it!). However, if you sign up for this class, do so knowing you are signing up for one of the most involved and demanding classes available to freshmen. You will be challenged to expand your skills in many different ways. This class starts fast, ends fast, and expects you to learn fast!

Love,

Team Check Your Staging