Executive Summary

Given the opportunity to participate in the DemoSat project through the Colorado Space Grant Consortium and the Colorado School of Mines, we as a team decided to do something unlike any project before us. The scope of our project began to take form as we decided to send some type of organic lifeform into the atmosphere and study the effects of the radiation at those altitudes.

Initially we looked to snow peas as being a relatively simple life form, easy to grow and easy to transport. Snow peas are not however easy to analyze at the molecular level without the proper equipment. This is where we reached the conclusion to study algae. Not only is algae easy to grow, but there are thousands of different types that can be manipulated and tested, and a lab on our campus which can conduct such experiments. Algae has been studied for years by the likes of NASA as a form of sustainable biofuel for human space travel. It was our hope through this project that we could discover something new in the world of cosmic radiation and develop that into a well thought out report.

The algae would be held in a foam core shell in the shape of a box, acting as our payload. This box would house all the necessary components for collecting data at high altitudes while also insulating and protecting the algae samples. Inside the payload, there would be a Geiger counter, altimeter and thermometer to capture all the data needed to conclude the experiment.

Our hypothesis for the launch was that the radiation at close to 60,000 feet would affect all life forms, including the algae. It was in our best interest to not have the algae die so in the end we could conclude some results. As far as levels of radiation, it was predicted that it would be the most extreme when the balloon was at its peak altitude, as that would be the point where the most ionizing radiation would be present.

Team DemoSat organized the launch for the 8th of April 2017 out of Eaton Colorado. Here our payload along with others were tied to the flight string attached to a weather balloon. Weighing in at 991 grams, our payload was ready for flight. And at approximately 7:15 am, the balloon carrying our payload was launched and the experiment began.
# Table of Contents

**Executive Summary** .................................................................................. 1

**Introduction and Background** .............................................................. 3  
- Mission Statement .................................................................................. 3  
- Research .................................................................................................. 3  
- Schedule .................................................................................................. 4

**Design** ...................................................................................................... 4  
- Cost .......................................................................................................... 4

**Subsystems** ............................................................................................. 5  
- Exterior .................................................................................................... 5  
- Algae Samples ......................................................................................... 6  
- Geiger Counters ..................................................................................... 6  
- Heating Components ............................................................................. 7  
- Power Supply .......................................................................................... 7  
- Data Acquisition ..................................................................................... 7

**Testing** ..................................................................................................... 9  
- Impact Test ............................................................................................. 9  
- Heat Test ................................................................................................. 9  
- Whip Test ................................................................................................ 10  
- Battery Test ........................................................................................... 11

**Results** ................................................................................................... 12  
- Expected ................................................................................................. 12  
- Launch Results ...................................................................................... 13

**Conclusion** ............................................................................................. 7

**References** .............................................................................................. 7

**Appendix A** .............................................................................................. 8
Introduction and Background

Mission Statement

It is our understanding that in near space, including the stratosphere, there are very high levels of cosmic radiation. Gamma rays, ionizing radiation, alpha and beta particles are all present in the upper atmosphere and are cause for concern for living organisms. As a team, we must design a payload that will be sent 60,000 feet up into the stratosphere where we will test the effects of this radiation on several living cultures of algae. Through the Colorado Space Grant Consortium, a balloon will be released on the morning of April 8, 2017 that will carry our payload as well as the payloads of other groups from across the state of Colorado into the stratosphere to test our hypothesis and conclude the experiment.

From our Mission Statement above, we refined the idea down to a hypothesis which states, if the radiation in the atmosphere can penetrate the payload, then the growth rate and photosynthesis abilities of the algae will be slowed, if not stopped completely.

Research

The leg work for this project began with the research. As a team we began to look into other growth assays conducted around algae. NASA in particular has been studying algae as a form of biofuel for decades. Through the research into past experiments, we discovered that there are multiple ways to analyze the growth and photosynthesis rates of algae. For the sake of time and limited resources available to us, we decided to do a live dead stain and re-streak all of the samples. The live dead stain is a dye that was placed in the algae after the launch and recovery. If any dead cells are present, they will absorb the dye, making the count visually easy. Re-streaking the plates meant that we had the ability to observe the growth rate of each sample and record any differences that we saw after the flight.

After we had decided on a hypothesis and what to test, the research turned to the electronics. Fortunately, we were able to use bits and pieces from past experiments which limited the cost. Our payload consisted of one Geiger counter, one thermometer, one altimeter and an Arduino OpenLog for recording the data. Time was put into finding the right way to wire the circuit and to finding the right code, ensuring that the circuit functioned. Arduino is a large corporation with many resources online. The wiring aspect became easier once we had all the correct equipment and wires, and wiring diagrams were easily found online. Source code was present but it took some outside help and a little prior knowledge to narrow it down and compile it correctly. The full working code can be found in Appendix A.
Schedule

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Kickoff Telecon</td>
<td>1-25-2017</td>
</tr>
<tr>
<td>B</td>
<td>Preliminary Design Review</td>
<td>2-7-2017</td>
</tr>
<tr>
<td>C</td>
<td>Critical Design Review</td>
<td>3-7-2017</td>
</tr>
<tr>
<td>D</td>
<td>Launch Readiness Review</td>
<td>4-7-2017</td>
</tr>
<tr>
<td>E</td>
<td>LAUNCH</td>
<td>4-8-2017</td>
</tr>
<tr>
<td>F</td>
<td>Analysis and Final Report</td>
<td>4-26-2017</td>
</tr>
</tbody>
</table>

Above is the project schedule provided by the Colorado Space Grant Consortium and team DemoSat. The deadlines came up fast, but through proper research and testing, we were able to meet all of them and be prepared for launch.

Design

For the design of our payload, we decided to do a box. It was the easiest shape to make and a durable design. We made the box itself from foam core. A sturdy and lightweight material, it proved to be a great choice. Using a hot knife, we were able to cut away the unnecessary material into the desired shape, talked about later in the subsystems section. After the sides of the box were connected and insulated using a polymer, the entire exterior was coated in duct tape. The tape acted as a secondary safety measure to hold the box together and proved its worth during both testing and the launch. The lid for the box had about 1 inch of foam that entered the box to securely hold it in place, again available in the subsystems. The flight tube was a polyethylene material with a 5/8” diameter. It was fit snuggly into the bottom of the payload with the top extending through a hole in the lid. Finally, the electronics were put into place around the flight tube, held down by ample amounts of super glue. The algae samples were placed along the remaining surface area inside the box, held by more duct tape. The finished product was a sturdy lightweight box that contained all necessary materials and survived the launch flawlessly.

Cost

A detailed cost analysis is presented below.

<table>
<thead>
<tr>
<th>Cost Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>Foam</td>
</tr>
<tr>
<td>Hand Warmers</td>
</tr>
<tr>
<td>Battery</td>
</tr>
<tr>
<td>Memory Card</td>
</tr>
<tr>
<td>Item</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Hookup Wires</td>
</tr>
<tr>
<td>Purple 28awg 5'</td>
</tr>
<tr>
<td>Protoboard</td>
</tr>
<tr>
<td>Shelves</td>
</tr>
<tr>
<td>Mini USB</td>
</tr>
<tr>
<td>Algae</td>
</tr>
<tr>
<td>Temperature Sensor</td>
</tr>
<tr>
<td>Geiger Counters</td>
</tr>
<tr>
<td>Arduino Mini</td>
</tr>
<tr>
<td>Altitude sensor</td>
</tr>
<tr>
<td>Flight Tube</td>
</tr>
<tr>
<td>Total Cost:</td>
</tr>
</tbody>
</table>

**Subsystems**

**Exterior**

This subsystem required light materials due to the weight constraint of 1 kg that we were working with. The main component used for the structure was 1" rigid foam. The final design, see in Figure 1, was a cubic shape with dimensions 12"x12"x8" externally. The walls were hot glued together and further sealed to maximize insulation. After that the box was given a single layer of Duct Tape to provide some structural stability as well as waterproof the foam. The structure had to protect the internal components from the impact with the ground as well as keep the algae insulated from the cold of the lower stratosphere. The box had a polyethylene tube run through the center to act as the flight tube.

![Figure 1](image_url)
Algae Samples

Three plates of Algae were sent up in the payload while three additional plates were held on the ground as a control. Each plate was divided up into three sections each holding a different strain of algae as seen in Figure 2. Those three strains were Chlorella, Nannochloropsis gaditana, Synchoccus sp PCCC 7002, chosen for their durability to extreme conditions. These plates were inserted into slots cut into the foam and then covered with Duct tape to hold in place during the flight.

![Figure 2](image)

Geiger Counter

The Geiger counter used to record the radiation level was a RadiationD-v1.1(CAJOE), seen in Figure 2. It was chosen because the light weight and cost efficiency of the model. Only one Geiger counter was included in the final payload due to weight concerns.

![Figure 3](image)
**Heating Components**

Heating was a necessary component to keep the Algae alive during the flight. To facilitate this, we ended up using foot warmers. As seen in Figure 4, they provided a constant heat source for the experiment. Two foot warmers were attached to the top of the box to keep them from directly affecting the algae.

![Figure 4](image)

**Power Supply**

An Insignia Portable Charger, Figure 5, was used to power the electronics during the experiment. The battery was inset in the lid of the payload and held in place by duct tape. The battery had a capacity of 2600 milliampere hours [1], which proved to be more than necessary for the flight.

![Figure 5](image)

**Data Acquisition**

Data acquisition had three parts, including temperature, radiation, and altitude. An Arduino was used to collect the data while an Open Log, Figure 6, was used to write onto a micro SD card.

![Figure 6](image)
Data was taken every 10 seconds for the duration of the flight. Altitude was tracked using a Spark Fun altimeter, seen in Figure 7.

Temperature was tracked using the Spark Fun TMP36 thermometer, Figure 8. This kept a steady stream of data incoming to monitor how effective our insulation was.

All instruments were connected to a Spark Fun Redboard, seen below, and an additional protoboard. The RedBoard was chosen because it is made to be compatible with the other Spark Fun components, making it easy to wire.
Testing

A series of testing was performed to ensure the payload could withstand the extremes of the launch. The testing lasted several weeks though the months of March and April. A single to-scale prototype weighing the amount estimated for launch was used to isolate each variable tested.

Impact Test

Test Overview

The external shell of the payload must be able to withstand the impact of the landing after launch. The durability of the structure was tested by dropping the payload approximately 40 feet above ground, as seen below in Figure 10. There was a water bottle placed within the payload to simulate the exact impact the payload would experience when landing.

Results

The external shell was able withstand the impact of the landing, as seen in Figure 11. The foam box endured slight damage to the bottom left corner, but overall passed the test.

Heat Test

Test Overview

With an elevation gain of over 60,000 feet, the temperature dropped to approximately 32°F when reaching the stratosphere. In return, the internal temperature of the payload must maintain a range between 40°F to 60°F to create stable growing conditions for the algae test samples. The
hand warmers within the payload were used to maintain the temperature. Two hand warmers were placed into the payload with certain hardware to test if the internal temperature would be maintained throughout the entire flight, as seen in Figure 12. The duration of flight was estimated at three hours. The internal temperature was recorded periodically.

![Figure 12](image)

**Results**

There were multiple trials of the heat testing. In the first trials, an older pair of hand warmers were used. The hand warmers were not able to heat for the payload for the full three hours and further testing was needed. In the second trial, the hand warmers could heat the payload for the entire duration of the expected flight time and heat testing was completed.

**Whip Test**

**Test Overview**

Throughout flight, the payload must be able to withstand the violent motion of flight. After earlier testing was complete, a long piece of tubing was inserted in to the center of the payload as a flight tube mechanism, as seen in Figure 13. The Arduino Minicontroller and its attached components were attached to the base of the payload. The strength of the attachment points of both the hardware and tube were tested by placing a thin rope through the flight tube and whipping the payload overhead to expose any possible points of failure.
Results

The payload and its components remained intact and working during and after the test. The soldered wiring between sensors, protoboard, and Geiger counter survived the whip along with the outer structure of the payload. There were no points of failure within the payload.

Battery Test

Test Overview

The last major test that was performed was an overall check on the hardware. The different internal components of the payload were tested to ensure that they were working properly and that the battery was to power the components during the entire duration of the flight. A timer was started once the data began to record and stopped once the light on the Arduino turned off, as seen in Figure 14.
Results

The battery lasted approximately 10 hours, which was more than expected and concluded the testing.

Launch Results

On April 8th, approximately 3 hours after launch, we recovered the payload in northeast Colorado. The box had held its shape and protected the internal components. All the individual parts remained where we expected them to except for one of the foot warmers, seen in Figure 15, which fell from the lid onto an algae sample and the Geiger counter.

![Figure 15](image)

After returning from the landing site, we began to analyze the data. As mentioned above, as the altitude increased, we expected the temperature to drop and the radiation to increase. Seen in the following three graphs, our predictions were correct.

The graphs below represent the data up until payload reached its maximum altitude. At that point, data collection for the graphs were irrelevant, thus not used. Overall, all our data was skewed due to the foot warmer falling on the temperature sensor and Geiger counter. The counts per minute collected was accurate until a little over halfway through when we believe the Geiger counter became overheated and subsequently, shut down. It stopped collecting all data, resulting in the flatline of the graph. It can be assumed however, from the data, that before the failure, the radiation levels were rising at an exponential rate. This would then confirm our conclusion that the radiation peaked at the maximum altitude.
Graph 1 above shows the altitude up until it reached its peak. The balloon carried the payload to a height of 17,336 meters, or 56,877 feet, close to the predicted height. At that point, the balloon reached its maximum size and exploded, sending the payload back down.

Graph 2

The temperature above in Graph 2, is not representative of the actual temperature the payload experienced. As mentioned above, one of the foot warmers fell from the lid and landed on the thermometer. This caused the readings to be much higher than expected. At temperatures soaring above 100 °C, the temperatures recorded were more of the lifespan of the foot warmer than anything else, shown in the graph as it gradually rises then falls. Given enough time, it would have likely reached zero.
Here is the graph for the counts per minute on the Geiger counter, representing the levels of radiation. Again, it is believed that the foot warmer over heated the device causing it to shut down mid-flight. Even though the situation is less than ideal, the data collected gives us a good idea of how the rest would have looked, should the Geiger counter have stayed on.

**Conclusion**

The algae and data acquisition from the electronics have given us plenty of data. Some of it unwanted, or inaccurate but data nonetheless. Most of our hypotheses could be confirmed through speculation, but the data isn’t there to prove them one way or the other. The temperature and half of the radiation values can’t be used due to inaccuracy.

For the radiation data that we do have, the levels can be seen rising exponentially, which agrees with what we originally thought. This makes sense given that the higher in the atmosphere you go, the less protection there is from the ionizing radiation.

The altitude sensor was the only data acquisition subsystem that worked without any problems giving us concrete results. As stated before, the payload reach heights of near 57,000 feet which is very close to our prediction. It gives us a good idea to the conditions that the algae experienced if we were to research and find more on the levels of radiation and temperature at that altitude.

After sending the algae back to the lab to be analyzed, it can be concluded that for the short time it was in the upper atmosphere, nothing really changed or influenced the cultures. The re-streaking of the plates showed that many of the samples were in fact still alive and “happy” so to speak. The experimental cultures regrew on the new plates at the same rate as the controls, leading the conclusion that the trip on the payload had little effect on them. The same can be said for the live-dead cell count. Although there are slight discrepancies between the graphs of the control and experimental, it’s not enough to conclude that they are drastically different. The only plate to suffer
massive casualties was the one that the foot warmer fell on. The re-streaking of this plate yielded no algae, meaning that all the samples were dead. It was our first thought that maybe that one plate received massive amounts of radiation, but that would be implausible without the others being effected the same way. We then could conclude that the loss of life was due to the extreme heat of the foot warmer cooking the algae over the period of a few hours. The conditions simulated that of a microwave and destroyed the sample.

Overall, it can be said that short amounts of increased radiation are not enough to effect living cultures of algae. To see lasting results that don’t come from extreme heat, the samples would have to be exposed to the radiation for an extended period, the length of which we can’t say. The strands chosen were some of the more resilient available and proved their worth as they survived the trip into near space.

**Appendix A**

```c
#include <SoftwareSerial.h>
#include <SparkFunMPL3115A2.h>
#include <Wire.h>
MPL3115A2 P;

SoftwareSerial OpenLog(5, 6); // RX, TX
char buff[50];

//geiger counter
#define CONV_FACTOR 0.00812
int geiger_input1 = 2;
int geiger_input2 = 3;
long count = 0;
long count2 = 0;
long countPerMinute = 0;
long countPerMinute2 = 0;
long timePrevious = 0;
long timePrevious2 = 0;
long timePreviousMeasure = 0;
long timePreviousMeasure2 = 0;
long time = 0;
long countPrevious = 0;
long countPrevious2 = 0;
float radiationValue = 0.0;
float radiationValue2 = 0.0;

int resetOpenLog = 4;
void setup() {

    // put your setup code here, to run once:
```
Serial.begin(9600);

Wire.begin(); // Join i2c bus
P.begin();
//Configure the sensor
P.setModeAltimeter(); // Measure altitude above sea level in meters
// myPressure.setModeBarometer(); // Measure pressure in Pascals from 20 to 110 kPa
P.setOversampleRate(7); // Set Oversample to the recommended 128
P.enableEventFlags(); // Enable all three pressure and temp event flags

pinMode(geiger_input1, INPUT);
digitalWrite(geiger_input1,HIGH);
attachInterrupt(0,countPulse,FALLING);

// pinMode(geiger_input2, INPUT);
//digitalWrite(geiger_input2, HIGH);

// attachInterrupt(0,countPulse2,FALLING);
}

void loop() {

//Geiger Counter 1
if (millis()-timePreviousMeassure > 10000){
    countPerMinute = 6*count;
    radiationValue = countPerMinute * CONV_FACTOR;
    timePreviousMeassure = millis();
    Serial.print("cpm = ");
    Serial.print(countPerMinute,DEC);
    Serial.print("-");
    Serial.print("uSv/h = ");
    Serial.println(radiationValue,4);
    count = 0;
}

//Temperature Sensor
// put your main code here, to run repeatedly:
int val = analogRead(0);
float voltage = val *(5.0/1024);

float temperatureC = (voltage - 0.5) * 100; //converting from 10 mv per degree wit 500 mV offset
    //to degrees ((voltage - 500mV) times 100)
Serial.print(temperatureC); Serial.println(" degrees C");
//Altitude Sensor
float Alt = P.readAltitude();
Serial.print(Alt); Serial.println(" meters");

//returning values
OpenLog.print("Count Per Minute: ");
OpenLog.print(countPerMinute);
OpenLog.print(",");
OpenLog.print("Radiation: ");
OpenLog.print(radiationValue);
OpenLog.print(",");
OpenLog.print("Temperature: ");
OpenLog.print(temperatureC);
OpenLog.print(",");
OpenLog.print("Altitude: ");
OpenLog.print(Alt);
} }

void countPulse()
{ detachInterrupt(0);
count++;
while(digitalRead(geiger_input1) == 0){
}
attachInterrupt(0,countPulse,FALLING);
}

void setupOpenLog()
{ OpenLog.begin(9600);
pinMode(resetOpenLog, OUTPUT);
digitalWrite(resetOpenLog, LOW);
delay(100);
digitalWrite(resetOpenLog, HIGH);

//file setup
while(1){
  if(OpenLog.available());
  if(OpenLog.read() == '<') break;
}
OpenLog.write(26);
OpenLog.write(26);
OpenLog.write(26);
while(1){
  if(OpenLog.available());
if(OpenLog.read() == '>') break;
}
Serial.println("Command Mode Entered");

sprintf(buff, "testingmf.csv");
OpenLog.print(buff);
OpenLog.write(13);

while(1){
    if(OpenLog.available());
    if(OpenLog.read() == '<') break;
}
Serial.println("Open Log ready for data");
}