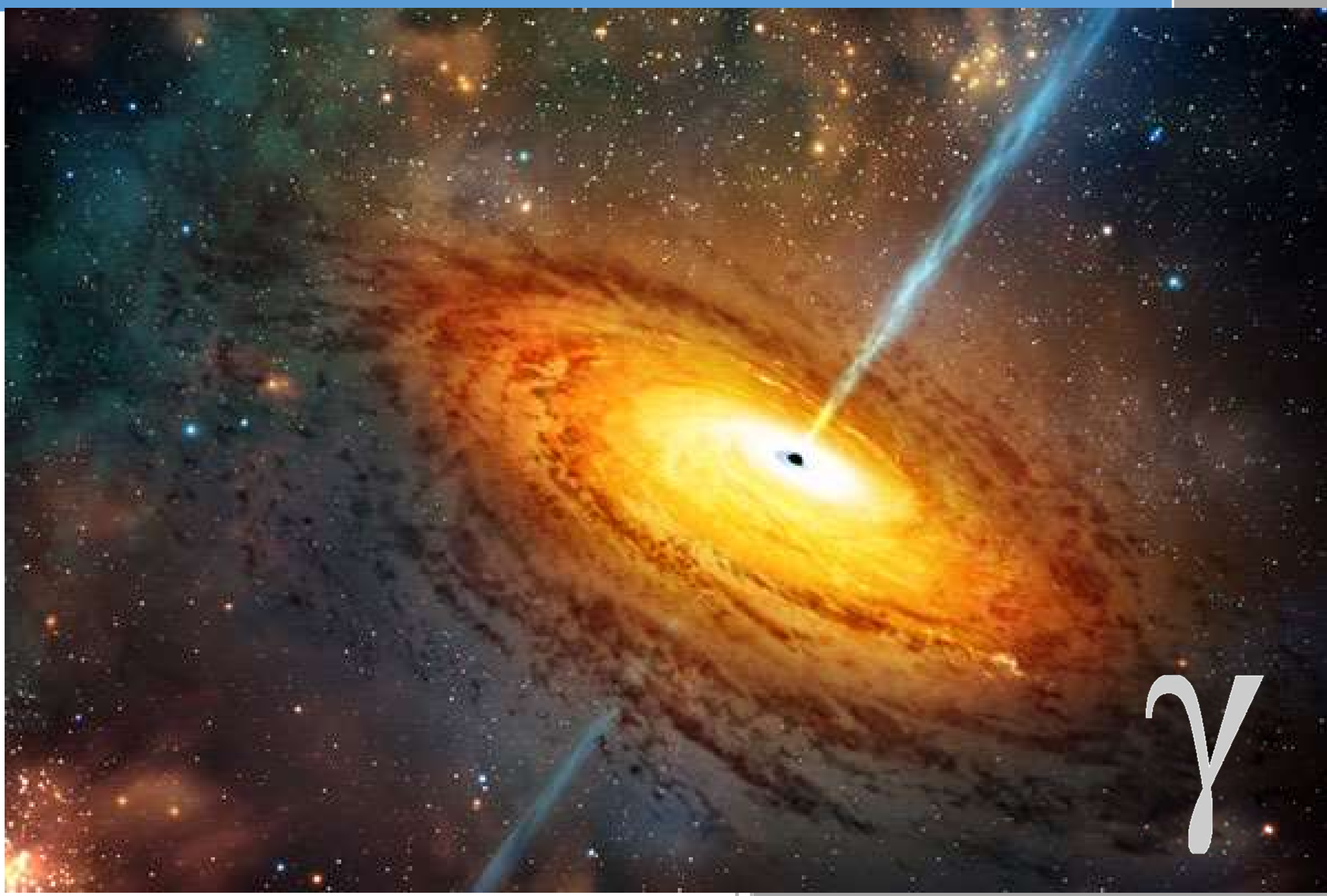
Big Gamma

The Brooklyn Project



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Revision Log

Revision	Description	Date
A/B	Conceptual and Preliminary Design Review	2/24/15
C	Critical Design Review	4/9/15

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1.0 Overview and Mission Statement

1.1 Mission Statement

The overall mission of Big Gamma, is to adhere to all Gateway to Space requirements and to send a BalloonSat to an altitude of approximately 30km to measure the electromagnetic radiation experienced from the gamma to X-ray spectrum (~10^{-5}- 10^{1} nm) through varying thicknesses of polyethylene, in order to provide a better understanding of whether high-density plastics are a viable option for radiation shielding aboard air and spacecraft.

1.2 Mission Overview

Radiation is one of the greatest risks involved with spaceflight. As such, there is an increased interest in developing an efficient, lightweight, and cost effective material for shielding. Such a development would allow for longer sustained human flights, both for systems functionality and for deep space exploration[1].

While aluminum is currently the primary material used for spacecraft construction, there has been recent investigation into new materials that are more effective at shielding radiation by weight. One such material being studied is polyethylene, due to its high hydrogen content, as hydrogen atoms are effective at absorbing and dispersing radiation[2]. Additionally, the use of a high-density polyethylene would be advantageous because of the property of denser materials to shield more effectively[3]. Although polyethylene's shielding abilities have been tested previously, it was not until recently that NASA's Lunar Reconnaissance Orbiter's CRaTER payload found that plastics can serve as effective shielding in an high cosmic ray environment[4,5]. These advancements and discoveries are what inspired Big Gamma's mission to investigate, and possibly confirm similar findings, of the effectiveness of high-density polyethylene to shield against the radiation experienced at high altitudes.

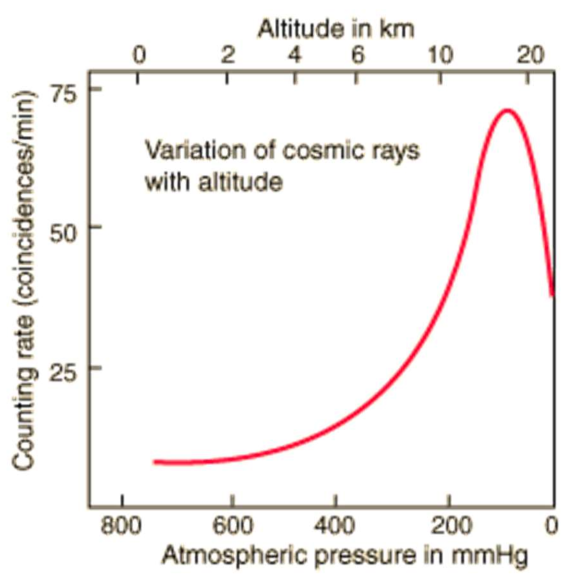


Figure 1 Radiation dosage as a function of altitude increase[6].

From this investigation, the team plans to discover the relationship between the thickness of high-density polyethylene and its ability to shield radiation. This will be done by measuring

[1] Barray, Patrick L. "Plastic Spaceships - NASA Science." *Plastic Spaceships - NASA Science*. N.p., 25 Aug. 2005. Web. 29 Jan. 2015.

[2] Dunbar, Brian. "Fire Away, Sun and Stars! Shields to Protect Future Space Crews." *NASA*. NASA, 16 Jan. 2004. Web. 03 Feb. 2015.

[3] "Protecting Against Exposure - ANS." *ANS*. Center for Nuclear Science and Technology Information, n.d. Web. 04 Feb. 2015.

[4] "CRaTER Cosmic Ray Telescope." *CRaTER Cosmic Ray Telescope*. NASA, 2014. Web. 27 Jan. 2015.

[5] Major, Jason. "Plastic Protection Against Cosmic Rays?" *Universe Today*. N.p., 12 June 2013. Web. 27 Jan. 2015.

[6] Nave, R. "Cosmic Rays." *Hyper Physics*. N.p., n.d. Web. 24 Feb. 2015.

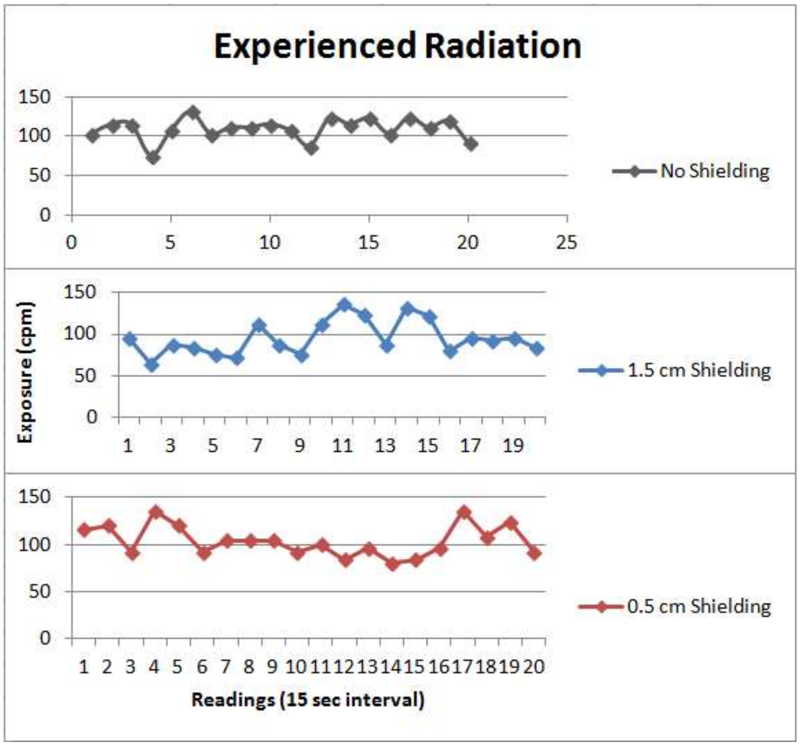


Figure 2 Shielding effectiveness of HDPE when exposed to Thorium 232. Averages are 110.4, 95.9, and 104 cpm respectively.

the radiation exposure during a given exposure inside varying thickness of polyethylene containments, which will be compared to the control radiation levels experienced without shielding, throughout the flight. Through these comparisons, the relative effectiveness of high-density polyethylene at shielding radiation can be determined. Furthermore, by establishing the relationship that thickness has on reducing radiation exposure, it can be determined at which thicknesses high-density polyethylene becomes effective at dampening radiation exposure.

With these results, Big Gamma will compare the found properties of high-density polyethylene with known properties of current spacecraft materials to determine if polyethylene can service as a viable option for radiation shielding aboard spacecraft. This comparison will include the relative shielding effectiveness, weight, cost, and strength of each material. From the Brooklyn Project's results and post flight analysis, this will provide a better understanding of plastics' effectiveness at shielding radiation and its potential for use on future spacecraft and exploration missions.

2.0 Requirements Flow Down

In order to ensure that the goals of Big Gamma are met, a number of objectives have been established and derived from the Mission Overview. Said objectives shall give an overview of the Brooklyn Project's mission details, as well as what will be accomplish.

2.1 Level 0 Objectives

Objective	Mission Objective	Reference
0.0	The Brooklyn Project shall measure and record the effective radiation experienced through varying shielding thicknesses.	Mission Statement
0.1	The Brooklyn Project shall measure the temperature, pressure, humidity, acceleration, and imaging in compliance with the Gateway to Space (ASEN 1400/ASTR 2500) requirements.	Mission Statement
0.2	Big Gamma shall analyze the data collected and create a comparison report between HDPE and current spacecraft materials, to determine if HDPE is a viable shielding material.	Mission Statement

0.3	The Brooklyn Project shall be securely attached to the balloon flight string, ascend to an altitude of approximately 30 km, and be successfully retrieved and intact.	Mission Statement
0.4	Big Gamma shall maintain an internal temperature above -10 degrees Centigrade.	Mission Statement
0.5	The BalloonSat shall not exceed 1150 g in mass.	Mission Statement
0.6	The BalloonSat's exterior shall have an American flag decal and contact information.	Mission Statement
0.7	Big Gamma's BalloonSat shall be restored to working order for future flights.	Mission Statement

2.2 Level 1 Objectives

Objective 0.0: The Brooklyn Project shall measure and record the effective radiation experienced through varying shielding thicknesses.

Objective	Mission Objective	Reference
1.0.0	Radiation data of gamma irradiance shall be taken via Geiger counters and recorded via the experimental Arduino and micro SD card.	0.0
1.0.1	Two Geiger tubes shall be secured inside different HDPE thickness tubes, and one mounted on the Geiger board as a control.	0.0

Objective 0.1: The Brooklyn Project shall measure the temperature, pressure, humidity, acceleration, and imaging in compliance with the Gateway to Space (ASEN 1400/ASTR 2500) requirements.

Objective	Mission Objective	Reference
1.1.0	Balloon shield sensors shall record their respected data sets during flight and record via the environmental Arduino and micro SD card.	0.1
1.1.1	Camera shall record images via COSGC programming and record to the internal SD card.	0.1

Objective 0.2: Big Gamma shall analyze the data collected and create a comparison report between HDPE and current spacecraft materials, to determine if HDPE is a viable shielding material.

Objective	Mission Objective	Reference
1.2.0	Tensile strength, cost, and shielding effectiveness of each material shall be acquired.	0.2
1.2.1	Onboard radiation data will be handled and processed for analysis.	0.2
1.2.2	Conclusions shall be drawn from comparison analyses on HDPE shielding effectiveness.	0.2

Objective 0.3: The Brooklyn Project shall be securely attached to the balloon flight string, ascend to an altitude of approximately 30 km, and be successfully retrieved and intact.

Objective	Mission Objective	Reference
1.3.0	Holes shall be cut in the center of the top and bottom of the satellite,	0.3

	washers shall be mounted around the holes, and paperclips shall be installed through the flight tube.	
1.3.1	Flight tube shall be secured through the center of the box.	0.3
1.3.2	Flight string shall be secured through the flight tube and secured to the helium balloon.	0.3

Objective 0.4: Big Gamma shall maintain an internal temperature above -10 degrees Centigrade.		
Objective	**Mission Objective**	**Reference**
1.4.0	A heater shall be placed centrally in the satellite to heat the contents.	0.4
1.4.1	Insulation shall cover the inside of the satellite and aluminum tape shall be placed around all edges.	0.4
1.4.2	Internal temperatures shall be recorded to verify internal temperature.	0.4

Objective 0.5: The BalloonSat shall not exceed 1150 g in mass.		
Objective	**Mission Objective**	**Reference**
1.5.0	Hardware mass shall be researched and accounted for.	0.5
1.5.1	Payload shall be weighed during integration process to confirm that the Brooklyn project is under mass.	0.5

Objective 0.6: The BalloonSat's exterior shall have an American flag decal and contact information.		
Objective	**Mission Objective**	**Reference**
1.6.0	Contact information shall be securely and visibly placed on the exterior of the satellite.	0.6
1.6.1	American flag decal shall be securely and visibly placed on the exterior of the satellite.	0.6

Objective 0.7: Big Gamma's BalloonSat shall be restored to working order for future flights.		
Objective	**Mission Objective**	**Reference**
1.7.0	Satellite shall be tested to ensure its ability to withstand flight conditions.	0.7
1.7.1	All hardware shall be secured to satellite walls to ensure no damage is done by lose parts.	0.7
1.7.2	BalloonSat shall be recovered from landing site and all hardware shall be restored post-flight from any damages that occurred.	.07

3.0 Design

3.1 Design Overview

The Brooklyn Project BalloonSat shall fulfill the following design-based items in order to complete the aforementioned objectives in the Mission Statement: (1) Collect sufficient and usable data from all onboard BalloonSat instruments, including internal/external temperature sensors, a pressure sensor, a three-axis accelerometer, a humidity sensor and three Geiger counters (2) Protect and insulate all onboard components from damage and failure from the harmful environment of near-space. (3) Complete the experiment aforementioned in the Mission Statement. This includes the use of all subsystems onboard the satellite, which are: C&DH, Software, Experimental and environmental systems, structure/launch vehicle, thermal, power, and ground ops.

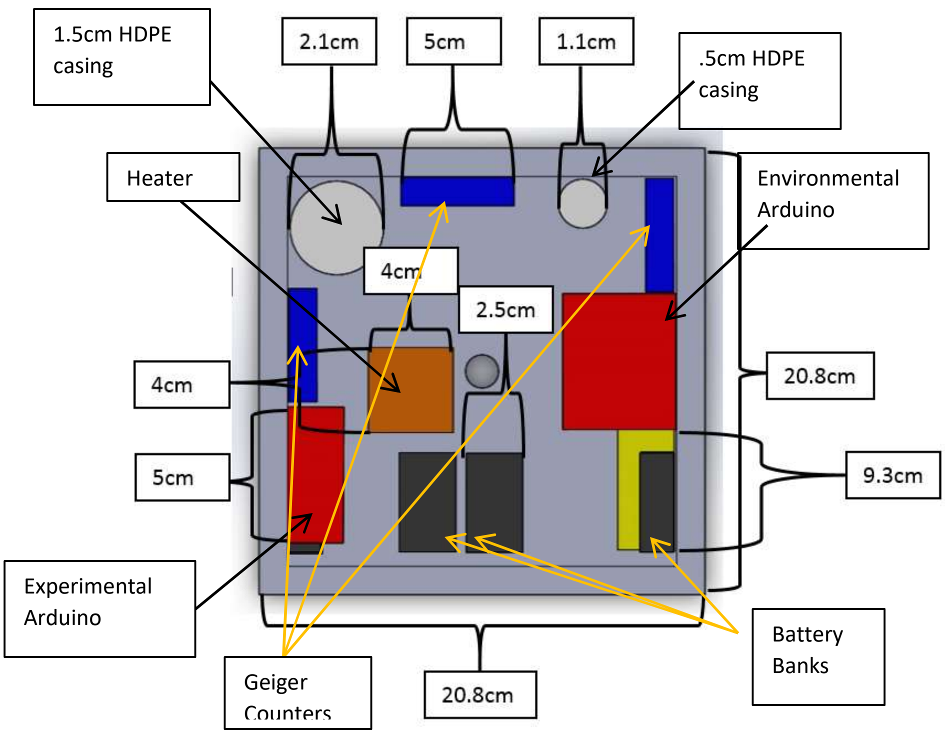


Figure 3 Top view of satellite design (20 x 18 x 18cm cube).

Team Big Gamma will design a weather balloon satellite, or 20.8x20.8x18 cm by outside compiled almost entirely out of FoamCore. This satellite will be assembled using hot glue and aluminum tape, and by gluing the seams together and covering these glued seams in aluminum tape. The satellite shall contain two primary sensor hubs: an experimental system and an environmental system. The environmental system shall collect data from one external temperature sensor, one internal temperature sensor, a pressure sensor, a humidity sensor, a tri-axis accelerometer, and a bare Geiger-Mueller tube with an Arduino-compatible Geiger board, whose purposes are to collectively monitor the environment in and around the BalloonSat. The bare Geiger-Mueller tube will be the control. The experimental system shall collect data from two separate Geiger-Mueller tubes, each connected to its own private Geiger Counter board. Both of these Geiger-Mueller tubes will be placed inside cylinders of HDPE of different thicknesses. Both the experimental and environmental systems will be directly based on two separate Arduino Uno micro controllers. In addition to these two sensor hubs, a Canon A3400 IS Digital Camera will also be utilized to take pictures. In order to ensure that there is no damage to the electronic components on the BalloonSat from the extreme temperatures of near space, the satellite will be lined with 25.4mm black foam insulation and a small heater shall be placed in close proximity to the experimental system and the environmental system. For power requirements, Team Big Gamma shall use 9 T-Energy 9V 500mAh Li-on rechargeable batteries. Switches for the environmental and experimental systems as well as the heater shall be placed on the outside of the box with LED indicators for each. In order to attach the BalloonSat to the launch vehicle, a plastic tube will run through the center of the BalloonSat, where the flight cord will be run through. Metal washers will be placed on both attachment points to ensure the plastic tube does not rip through the satellite, and figure-eight knots will be tied on each end of the flight cord. Finally, the US flag, a pink University of Colorado Boulder Seal, and information about the satellite in the event that it is lost will be placed on the outside of the satellite.

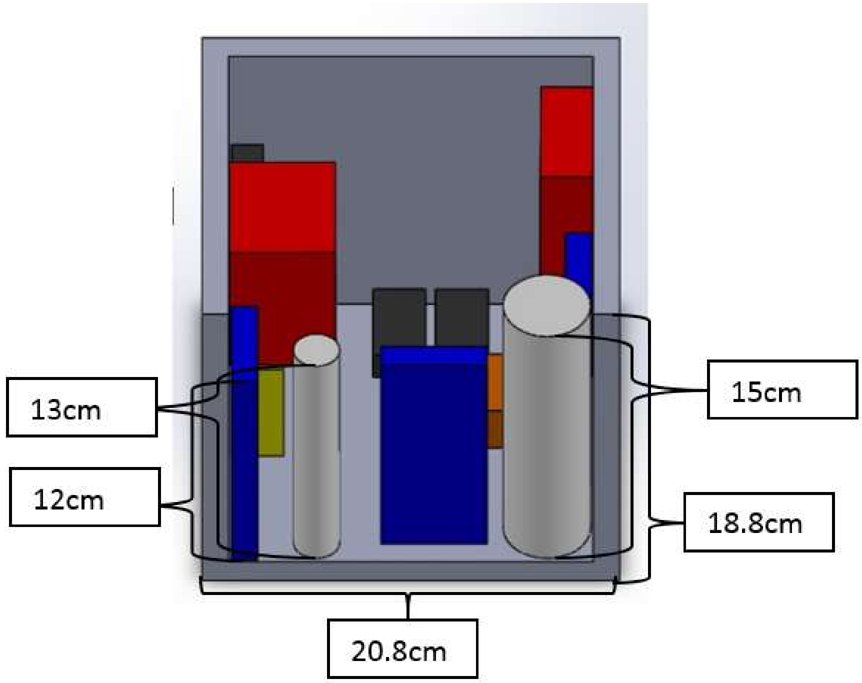


Figure 4 Side view of satellite design with HDPE casing dimensions labeled

C&DH – In order to manage all of the sensors and the actual onboard experiment, as well as data collection, two Arduino Uno micro-controller boards will be the foundations of Big Gamma's BalloonSat. Each Arduino will have a switch with an LED indicator to verify on the outside of the BalloonSat that both are functioning properly, and both shall be connected to 9V batteries. One Arduino will be controlling the required sensors, e.g. humidity, external and internal temperature, accelerometer, and pressure, and the control Geiger counter. The second Arduino will be controlling the two shielded Geiger-Mueller tubes, and will be the foundation for the experiment. It is possible to connect and use only up to two Geiger Counters to one Arduino Uno, due to the fact that each Geiger counter must be connected via the digital interrupt pins (digital pins 2&3). Big Gamma believes that timing issues with two interrupts will not be a problem, because through extensive Geiger testing Big Gamma has found that the Geiger Counters and tubes work without fault or issue in any timing or any other issue. One Geiger Counter will be connected to the environmental systems Arduino and will also have to be written to that Arduino's MicroSD card. Both Geiger Counters will be powered through the 5V connections on the Arduino shield. The physical position of the actual Arduinos is shown in figure 3. The data for both Arduinos shall be written onto and stored on a 2GB MicroSD Card.

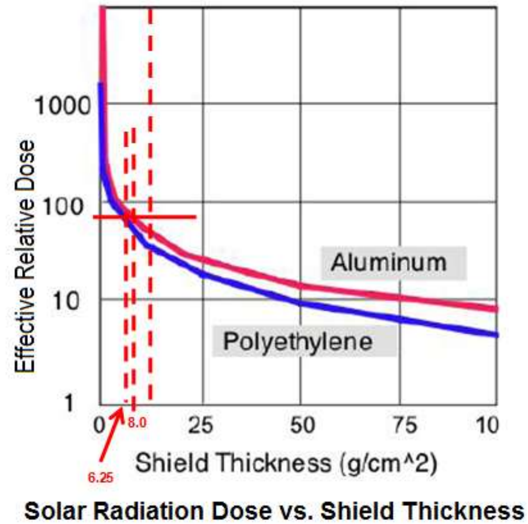


Figure 5 Effective radiation shielding comparison between polyethylene and aluminum.

Experimental System – Team Big Gamma shall measure how the thickness of High-Density Polyethylene (HDPE), when shielding an SBM-20 Geiger-Mueller Tube in the form of a round housing, affects the level of gamma radiation detected by the tubes. The dimensions of the Geiger-Mueller tubes are 1.1cm in diameter x 10 cm in length. This shall be accomplished by placing two of the three Geiger-Mueller tubes into hollow rods of HDPE, so that the thickness of shielding material surrounding the Geiger-Mueller tubes is constant. HDPE was selected as a shielding material because it is one of the densest plastics commercially available, in addition to still being very lightweight and cheap when compared to certain metals. Al three Geiger-Mueller tubes will be placed on the inside of the BalloonSat, due to the operating temperatures of the Geiger-Mueller tubes and the complicated modification of the BalloonSat by placing the Geiger-Mueller tubes on the outside of the BalloonSat. It was also determined that the Geiger-Mueller tubes could suffer critical damage in the event that the BalloonSat landed on the ground where the Geiger-Mueller tubes were mounted. Each Geiger-Mueller tube is also connected to its respective Geiger board. The first Geiger-Mueller tube shall be the 'control' tube, with no HDPE housing at all. This is the Geiger-Mueller tube that will be placed with the environmental system. The minimum operating temperature of these SBM-20 tubes is -60ºC, and since Big Gamma expects the environment on the inside of the craft to drop to -10ºC, we expect to have little problem exposing the tube directly to the environment. The second Geiger-Mueller tube shall be placed inside of a hollow HDPE rod of 2.2cm in diameter x 13cm long, which gives an effective shielding of .50cm. The third Geiger-Mueller tube will be placed inside of a thicker, also hollow, rod of HDPE of 4.2cm in diameter x 13cm long, which gives an effective thickness of 1.5cm. The combined weight of these shielding housings shall not exceed 300g. These rods of HDPE will be hollowed out with a drill press, making a bore of 1.2cm. Both rods of HDPE will be capped and sealed with pieces of HDPE in order to ensure there is also shielding at the tops and bottoms of both tubes. The tubes will output a certain number of 'pings' of radiation while in flight, which will increase with the amount of radiation detected. The way these tubes detect radiation is that when a certain type of radiation, such as gamma, passes through the tube, the atoms inside become ionized, and therefore outputting an electric pulse, which then produces a 'ping'. The pings must be measured over a unit of time, which will be number of 'pings' per 30 seconds, which will give the team the number of 'pings' for each individual tube in a 30-second time span. This is necessary because one particle will physically not pass through all three tubes at once. Specifically how all of this shall be accomplished will be discussed in the next section, Software, and Hardware Overview. Furthermore, in order to maintain consistency among our Geiger counters, we will calibrate them against known radiation sources on campus via the help of faculty in the physics department, and other known sources.

Software – Although the Arduinos onboard the BalloonSat are the foundation for Big Gamma's experiment, Big Gamma's experiment would be entirely in vain if Big Gamma were not to develop code for it. Big Gamma will develop the code for the environmental systems Arduino, which contains the required sensors of the flight, while building and learning about Arduino. However, developing the code for the experimental systems in order to integrate the Geiger counters into the Arduino will be a challenge in itself. Although the Geiger kits do come with their own code to run, they must be modified to work with an Arduino writing to a MicroSD card, instead of just a laptop. First, we must set up 'basic' code for each Geiger counter to verify that it works and runs properly. Second, we must develop code to turn the 'pings' that each counter registers into logable data because the counter does not output voltage. Specifically, when the Geigers are connected to the interrupt pin on the Arduino (which are digital pins 2&3), they ‘interrupt’ the signal going through the pin, which will be recorded, converted into lovable data, and written to the MicroSD card. Third, which is also the most critical part, code would need to be developed in order to write the 'pings' the counter is outputting to a MicroSD card. Big Gamma will use the code provided from RH electronics as a foundation for the flight code for each Geiger Counter, pictured below.

```
#include <SPI.h>
#define LOG_PERIOD 15000     //Logging period in milliseconds, recommended value 15000-60000.
#define MAX_PERIOD 60000    //Maximum logging period
unsigned long counts;             //variable for GM Tube events
unsigned long cpm;                 //variable for CPM
unsigned int multiplier;             //variable for calculation CPM in this sketch
unsigned long previousMillis;      //variable for time measurement


void tube_impulse(){               //procedure for capturing events from Geiger Kit
  counts++;
}

void setup(){                                             //setup procedure
  counts = 0;
  cpm = 0;
  multiplier = MAX_PERIOD / LOG_PERIOD;      //calculating multiplier, depend on your log period
  Serial.begin(9600);                                // start serial monitor
 // uncommennt if you have time-out problem to connect with Radiation Logger
 //  delay(2000);
 //  Serial.write('0');                                  // sending zero to avoid connection time out with radiation
logger
 //  delay(2000);
 //  Serial.write('0');                                 // sending zero to avoid connection time out with radiation
logger
  pinMode(2, INPUT);                                // set pin INT0 input for capturing GM Tube events
  digitalWrite(2, HIGH);                              // turn on internal pullup resistors, solder C-INT on the
PCB
  attachInterrupt(0, tube_impulse, FALLING);  //define external interrupts
}


void loop(){                                             //main cycle
  unsigned long currentMillis = millis();
```

```
 if(currentMillis - previousMillis > LOG_PERIOD){
   previousMillis = currentMillis;
   cpm = counts * multiplier;
      Serial.print(cpm);                    // send cpm data to Radiation Logger
      Serial.write(' ');                    // send null character to separate next data
   counts = 0;
 }
}
```

Figure 6 Basis of Big Gamma's flight code, to be used in getting each Geiger Counter to write to SD card and have the control tube run on the environmental system Arduino.

Environmental System – This system shall consist of a number of different sensors, including two temperature sensors (one external and one internal), a humidity sensor, a three-axis accelerometer, and a pressure sensor. The precise purpose of this system is to monitor the environment directly in and around the BalloonSat, so that conclusions can be made about the environment of the BalloonSat during flight when all of the data is retrieved.

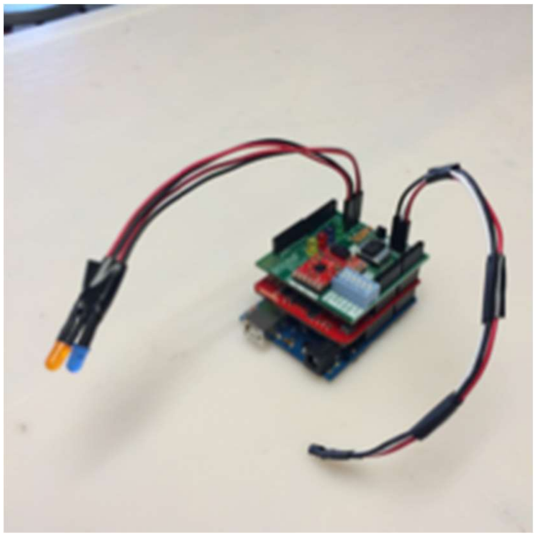


Figure 7 Environmental systems Arduino with all LEDs and sensors connected.

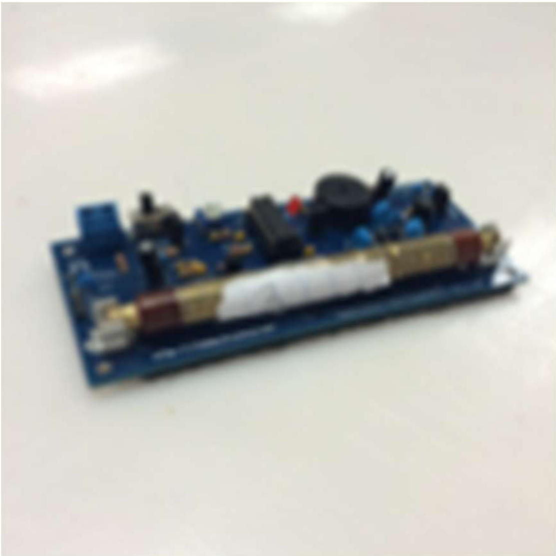


Figure 8 Fully assembled Geiger Counter kit with control tube

Thermal – In near space, temperatures drop to nearly -65ºC, meaning that insulation and heating of a spacecraft is absolutely critical. On Big Gamma's BalloonSat, this will be accomplished by using two distinct thermal systems; one passive and one active. First, The entire inside of the BalloonSat will be surrounded and insulated with black foam and, which will not create a seal but will keep the temperature of the inside of the BalloonSat relatively constant. Second, a 9V-battery powered electric heater will sit inside the box BalloonSat to warm the critical electrical components. This will be activated by a switch that will have an LED to indicate that it is working properly.

Power – Big Gamma will use a total of eight T-Energy 9V 500mAh Li-on rechargeable batteries, to power the entire BalloonSat. Each battery weighs 30g, giving a weight savings of 15g per battery over standard 9V batteries, and giving a total of 270g in batteries. The environmental system shall use 2 9V batteries, the experimental system will be powered by three, and the heater will be powered by three. These batteries will either be situated in such a way to allow for equal weight distribution around the box, or situated in such a way to counter-balance the weight of the Geiger-Mueller tubes and their respective housings. With respect to powering the Geiger boards and their respective tubes, each Board has two pins for power. These are 5V and GND. Each GND pin on each Geiger board will be connected to a GND pin on its respective Arduino. For the Geiger-Mueller tube connected to the environmental system and one Geiger-Mueller tube on the experimental system, their respective 5V pins will be connected to the 5V pins on each respective Arduino. Both Geiger Counters on the experimental system will be powered by 5V pins on its respective MicroSD shield. LED indicators for both the experimental and environmental systems Arduinos will be used to determine if each is powered up before the flight. In addition to LED indicators for both Arduinos and the heater, there will be two LED indicators from the environmental system Arduino, an orange LED indicating that there is a MicroSD card present, and a second blue LED indicating that data is being written to the MicroSD card.

Launch Vehicle & Structure – The launch vehicle is a large Hydrogen Balloon that will ascend to an altitude of approximately 30km, complete with a parachute, GPS tracking devices for recovery, and all of the individual BalloonSats. Big Gamma's BalloonSat shall consist of a box of dimensions 20x18x18 cm, built of sheets of foam core, and put together with hot glue and aluminum tape. This shall ensure the BalloonSat is able to withstand extreme conditions of launch, ascent, burst, and landing. This shall also ensure that there is sufficient room to install all three Geiger tubes flush with the BalloonSat without compromising structural integrity.

Special Features – The primary special feature of this BalloonSat is the way the rods of HDPE will be mounted inside the box, and the way the box is designed to accommodate these. The BalloonSat was designed with such dimensions so that the rods of HDPE, with their end caps, will fit snugly, or very close to snug, inside the box, with the black foam installed. The purpose of this is so that in the event the HDPE rods become dislodged, they are still partially constrained and will not move around inside the box in comparison to a rod that would not fit snugly. The idea is that it would move around less on the inside of the box and cause less damage. A more apparent and blatant special feature of this mission is the experiment itself, which is using three Geiger-Mueller tubes to determine how shielding the Geiger-Mueller tubes with varying thicknesses of HDPE affects radiation detection. This shall help Big Gamma to collect a plethora of data which will help us succeed in its mission because the more data that the team collects, the better analysis of the data can be done, resulting in clearer conclusions.

3.2 Functional Block Diagram (FBD)

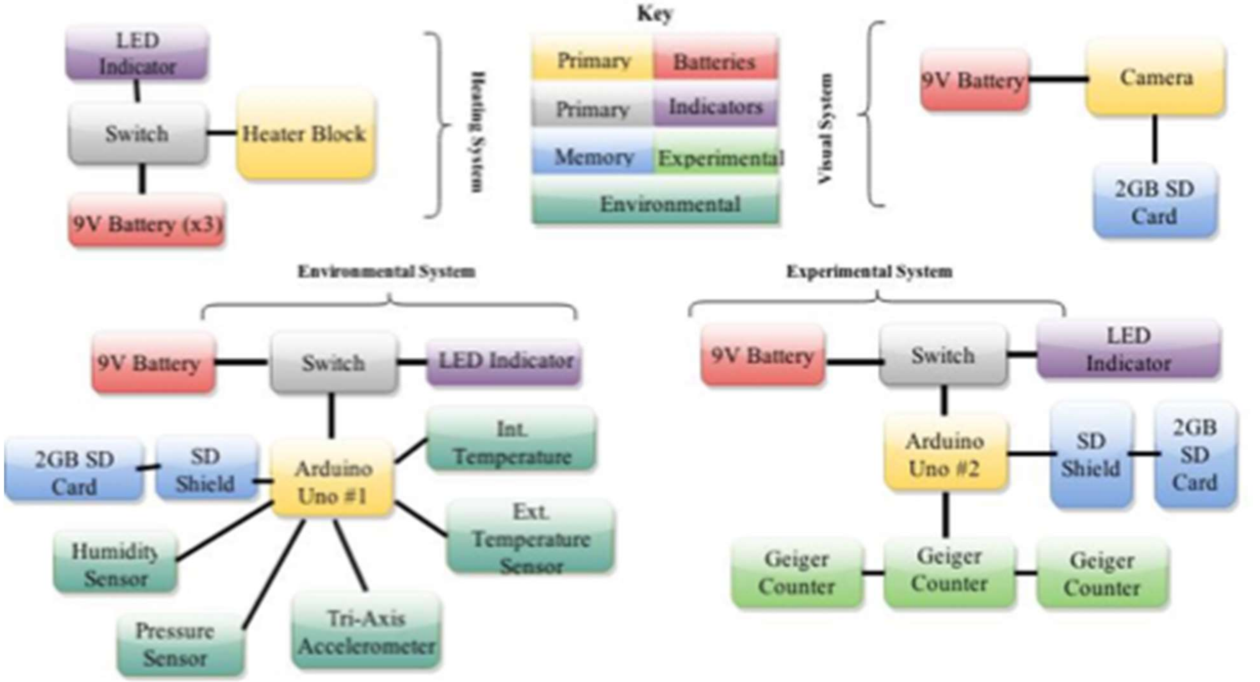


Figure 9 Functional Block Diagram including internal hardware.

3.3 Hardware Overview

<u>*Geiger Counters (DIY kit version 3)*</u> - The mission objective is to send three Geiger counters to 30 kilometers to record gamma radiation. The Geiger counters will be purchased from eBay and shipped from Israel by the company RHelectronics. The Geiger counters will be assembled by the hardware team once delivered. Extreme care must be used in handling the Geiger Tubes due to the fact that they are extremely fragile. Big Gamma already broke one Geiger Tube when taping wire to the tube. Thankfully, Big Gamma was able to receive another Tube from a fellow team. The Geiger counters are Arduino compatible and will produce a digital interrupt signal indicating radiation. This digital signal will be recorded and stored onto the SD card in counts per minute. Because the Geiger counters send [7]

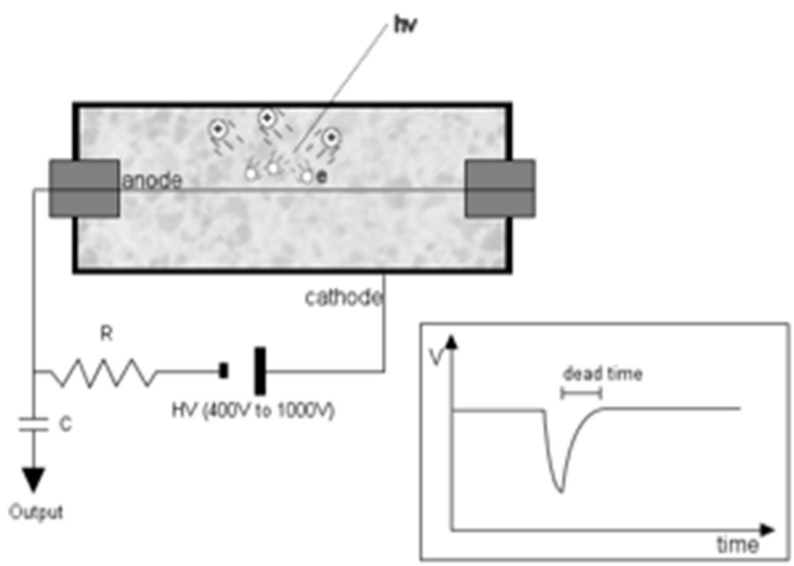


Figure 10 Functionality diagram for Geiger tubes.

[7] "Geiger Counter." *Alter Vista*. N.p., n.d. Web. 28 Feb. 2015

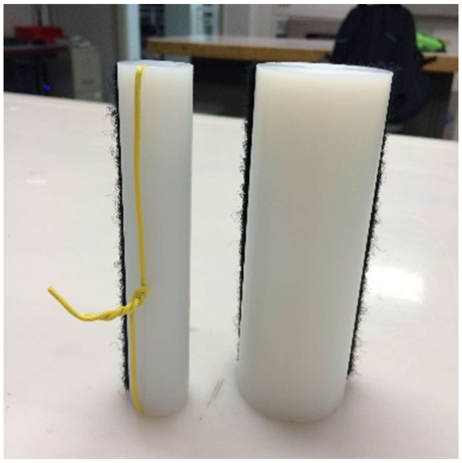


Figure 11 Image depicting both HDPE casing and their Velcro attachment systems.

out a digital interrupt signal and the Arduino Uno only has two external interrupt pins (pins 2 and 3), only two Geiger counters will be wired to the experimental Arduino Uno and the third one will be wired to the environmental Arduino Uno. Each Geiger counter will be equipped with a SBM-20 Geiger tube. The tubes are filled with a gaseous mixture of neon, bromine and argon. When hard beta and gamma radiation penetrate the tube and come in contact with the gas the atoms become ionized. The free electrons will be attracted towards the metallic anode wire through the middle of the tube. The cations will be attracted to the stainless steel cathode shell. When enough of these atoms ionize the anode will become reduced and produce and electrical current known as a count that the Geiger kit will translate into a digital output.

Temperature sensors

The payload will include two temperature sensors as part of the environmental system and will be provided by COSGC. Both of the sensors will be on the environmental Arduino Uno and record internal temperature while the other will placed in a small opening through the side of the structure, approximately 1" from the craft . The sensor will send out an analog signal to the Arduino which is then turned into a digital signal to write onto the SD card via the Arduino's analog-to-digital converter. This temperature sensor will record external temperature throughout the mission.

Barometric Pressure Sensor

A barometric pressure sensor will also be included as part of the environmental system and will be provided by COSGC. The sensor will be connected to the environmental Arduino Uno and will collect data on the pressure levels through-out the mission. It will also be interface in the same way as the temperatures with respect to the fact that it will be interfaced through an analog connection and then run through the Arduino's analog-to-digital converter.

Canon A3400 IS Digital Camera

The camera will be secured inside the payload with the camera lens pointing outside of an opening in the side of the structure. The camera will be provided by COSGC and will be pre-programmed to take a picture every 10 seconds through-out the mission.

3-axis accelerometer

The accelerometer is another sensor that will be provided by COSGC. The sensor will detect the payloads motion in the X, Y and Z planes. The recorded data will be later evaluated so a further understanding of the motion of the payload during the mission can be made. This sensor will be interfaced through an analog sensor and then run through the Arduino analog-to-digital converter

Humidity Sensor
A humidity sensor will be provided by COSGC. It will connected to the environmental Arduino Uno and record humidity levels through-out the mission. It will be interfaced through an analog connection and then run through the Arduino analog-to-digital converter.

3.4 Conceptual Operations (CONOPS)

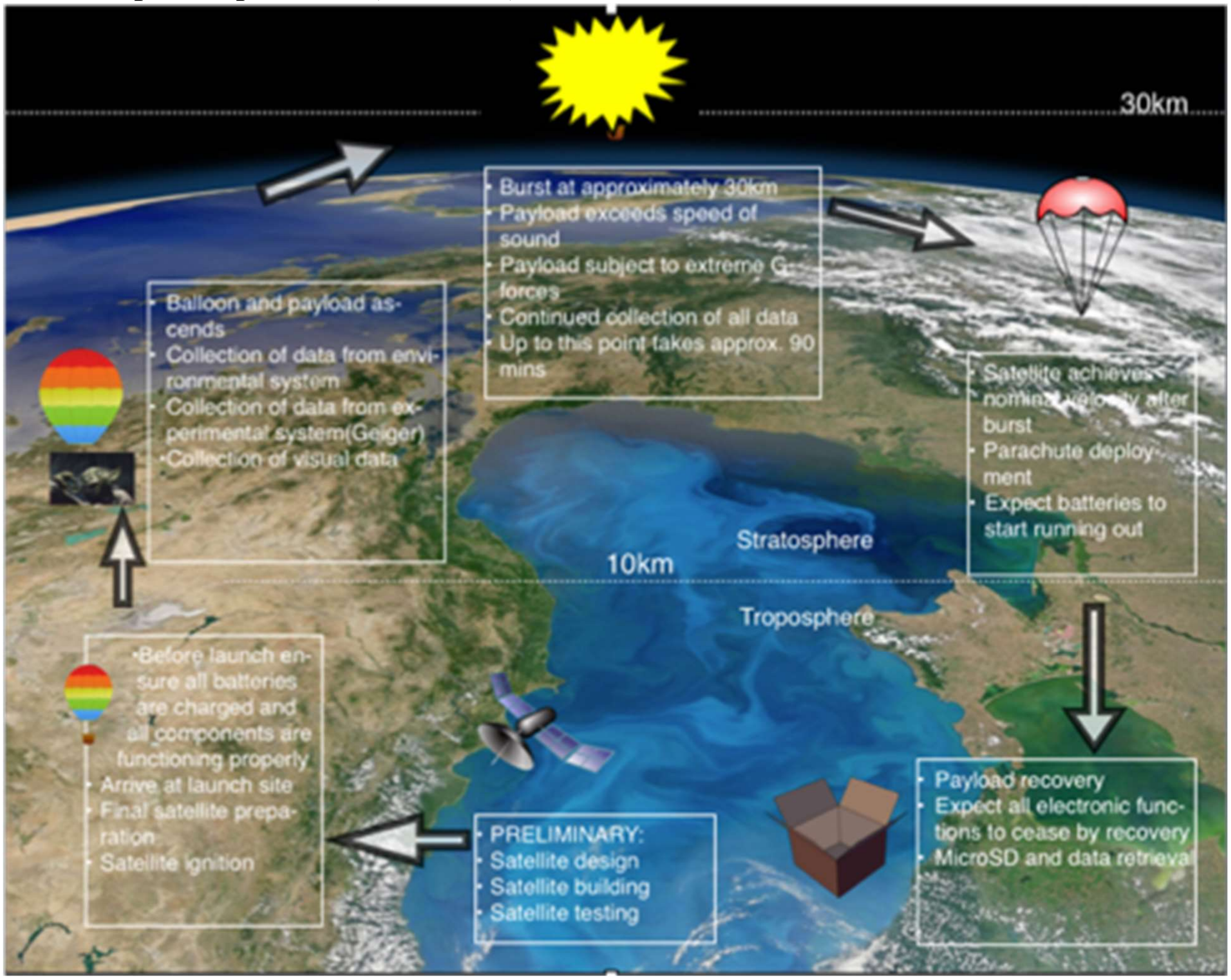
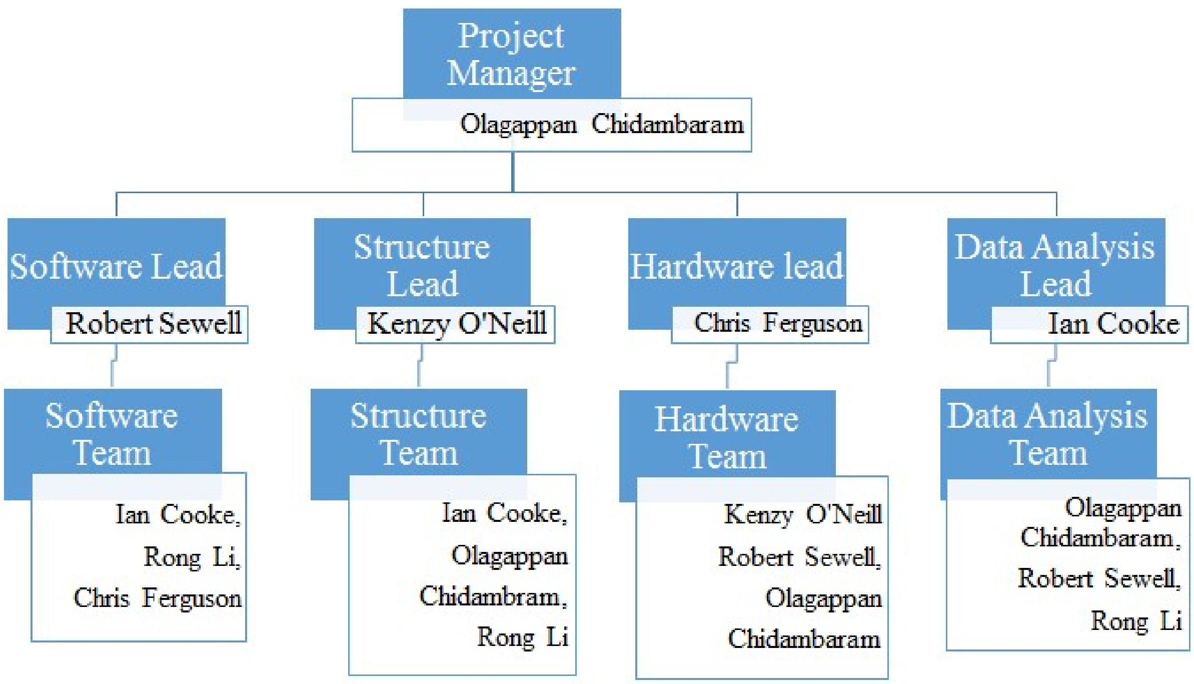


Figure 12 Concept of operations diagram.

4.0 Management

Team Big Gamma will meet from 5:30pm to 8:30pm every Tuesday and Thursday, and will schedule additional meetings when needed. Every team member will be a part of a minimum of 2 sub-teams, the leaders of which are expected to ensure that their deadlines are met.

4.1 Team Hierarchy



4.2 Schedule

Date	Event
2/09/15	Proposals Due
2/10/15	Team Meeting: Start gathering materials
2/12/15	Team Meeting: Continue gathering materials, Start on structures, Learn Arduino code
2/13/15	Authority to Proceed, Order Hardware
2/17/15	Team Meeting: Finish building structure, Whip Test, Stair Test
2/19/15	Team Meeting: Create PDR presentation
2/24/15	Team Meeting: Continue PDR presentation, Start on DD Rev A/B
2/26/15	Team Meeting: Receive Hardware, Finish DD Rev A/B, Practice PDR Presentation
3/03/15	Team Meeting: PDR Presentation, Build Geiger Counters, Program Geiger Counters
3/05/15	Team Meeting: Finish Programming Geiger Counter

3/10/15	Team Meeting: Ground Test Geiger Counters
3/12/15	Team Meeting: Start HDPE Casings
3/17/15	Team Meeting: Finish HDPE Casings
3/19/15	Team Meeting: Ground Test Geiger Counters
3/31/15	Team Meeting: Start LRR Presentation, Temperature Test, Insert Environmental System and Geiger Counters
4/02/15	Team Meeting: Work on LRR Presentation, Practice LRR Presentation, Finish Satellite, Work on DD Rev C
4.06/15	Team Meeting: Finish LRR Presentation, Finish DD Rev C
4/07/15	LRR Presentation
4/09/15	Team Meeting: Last Minute Preparation
4/10/15	BalloonSat Weigh-in and Turn in
4/11/15	Launch Day
4/14/15	Team Meeting: Create Quick Look Post Launch Presentation, Practice QLPLP
4/16/15	Team Meeting: Quick Look Post Launch Presentation, Start Final Presentation
4/21/15	Team Meeting: Design Expo Booth, Continue Final Presentation
4/23/15	Team Meeting: Practice Final Presentation
4/25/15	ITLL Design Expo
4/28/15	Final Presentation
4/30/15	Create CSA Presentation

*** Assuming we buy and expedite shipping from these sites:
http://www.ebay.com/itm/TESTED-SBM-20-GEIGER-MULLER-TUBE-COUNTER-STS-5-NOS-SBM20/111580149558?_trksid=p2047675.c100005.m1851&_trkparms=aid%3D222007%26algo%3DSIC.MBE%26ao%3D1%26asc%3D28794%26meid%3Dab1ba052b10e430cb22f0b742e6e0646%26pid%3D100005%26rk%3D1%26rkt%3D6%26sd%3D121015391335&rt=nc#shpCntId

http://www.ebay.com/itm/NEW-DIY-Geiger-Counter-Kit-Nuclear-Radiation-Detector-Arduino-Compatible-/321502371329?_trksid=p2141725.m3641.l6393#shpCntId

5.0 Budget

Product	Quantity	Purchase Location	Cost	Weight (grams)
Geiger Counter Kits	3	Ebay.com	$130	135
Geiger Tubes	3	Ebay.com	$53	30
HDPE 1.1x13 cm	1	Donation (A-Plus Design and Remodel)	$0	38.9
HDPE 2.1x15cm	1	Donation (A-Plus Design and Remodel)	$0	194.3
Arduino Uno	2	COSGC	Provided	50
3-Axis Accelerometer	1	COSGC	Provided	1.3
Barometric Pressure Sensor	1	COSGC	Provided	.6
Humidity Sensor	1	COSGC	Provided	3

Heater Kit	1	COSGC	Provided	36.6
Aluminum Tape	1	COSGC	Provided	20
Hot Glue	5	COSGC	Provided	5
Velcro	1	COSGC	Provided	20
Washers	2	COSGC	Provided	5
Flight Tube	1	COSGC	Provided	5
Temperature Sensors	2	COSGC	Provided	2
Foam Core	3	COSGC	Provided	143
Camera	1	COSGC	Provided	140.3
MicroSD Cards	2	COSGC	Provided	1
SD Shields	2	COSGC	Provided	38.8
Black Foam Insulation	3	COSGC	Provided	30
Switches	3	COSGC	Provided	15
LEDs	8	COSGC	Provided	1
Dry Ice	1	King Soopers	$29 (students)	N/A
Batteries	8	Amazon.com	$47.66 (students)	232.8
Wires	dozens	COSGC/ITLL	Provided	54.4
Total			$183	1203.0

Kenzy Oneil will be in charge of managing team Big Gamma's budget. Kenzy will ensure that all purchases are approved by him, and will be responsible for seeking reimbursement from Chris. For any expenses outside of the budget, Kenzy will ensure that the expenses are split evenly among all team members.

6.0 Test Plan and Results

6.1 Safety

Throughout the course of Project Brooklyn, each team member will act in a professional manner at all times. All construction and tests will be performed in an appropriate environment so that no harm will come to any person or property. This applies particularly during testing, as the team will take special care to not test around building windows and to be careful around others. In addition, each member must be familiar with the operation of any equipment they use, or must be under the supervision of an instructor. Furthermore, all prototype and ground experimental testing will take place in the proper laboratories with permission and advising from the lab supervisor.

6.2 Test Plan

- *Spin Test:* The spin test will test the BalloonSat's structural ability to withstand the g-forces it will undergo during the whipping which will occur after the weather balloon bursts at maximum altitude. The maximum forces the BalloonSat will experience are expected to be around 3-4 g's. The BalloonSat will be attached to a rope to simulate the rope that it will be connected to during flight. Within the structure of the BalloonSat will be weights that will simulate the actual weight of all of the internal components, in order to keep the delicate parts undamaged. Once attached to the end of a rope, the BalloonSat will be spun overhead vigorously, as well as whipped from side to side. This test will be done away from windows and people to avoid damages and injury.

- *Stair Test:* To test for the BalloonSat's durability in the chance that there is a strong wind during landing, leading to the satellite being dragged over the ground, the BalloonSat (with mass simulators inside) will be thrown down a set of stairs of at least 10 steps.
- *Drop Test:* In order to test for a scenario in which there is a very rough landing, the BalloonSat (with mass simulators inside) will be dropped from approximately 6 meters, onto concrete and dirt.
- *Temperature Test:* Testing the BalloonSat's ability to undergo extremely cold temperatures will be done in a cooler. The BalloonSat will be placed in a cooler, surrounded by dry ice to reach the coolest temperature. This test will be done while the electronics are within the satellite and powered on. Temperature testing will test the functionality of the heater, sensors, and battery life. The BalloonSat will be exposed to extremely cold temperatures for 3 hours to simulate the exposure during the actual flight.
- *Mission Simulation Test:* A 3 hour mission simulation will be done on the ground to check that all sensors and systems are fully functioning and can function the duration of the mission. This test will be done by activating all of the switches and monitoring the BalloonSat over the length of the simulation this will also include testing each sensor, such as by shaking the box every 30 mins, which will show data via the accelerometer. Placing fingers on the external temperature sensor will elevate the temperature, and will show in the data. Breathing inside the box will elevate the humidity, and this will also show in the data.
- *Geiger Counter Test:* The Geiger tubes will be exposed to background radiation, and Big Gamma has tested each Geiger tube in a lab by comparing recorded cpm values to a larger, and most likely more accurate, Geiger Counter in the University of Colorado Physics Department, facilitated by Scott Pinegar. Big Gamma will use ^{232}Thorium for a radiation source, provided by the Physics department. A piece of acrylic placed on top of a piece of cardboard will be placed to block out Alpha and Beta radiation, and only let Gamma through to the Geiger Tube. The number of counts over 60 seconds will then be recorded from the Geiger Counter from the physics department, and then Big Gamma's Geiger Counters will be placed over the radiation source above the acrylic, to determine its readings.
- *Sensor Testing:* Sensors will be tested to ensure that all are fully functioning and transmitting data correctly to the Arduinos. Sensors will also be calibrated during testing. The thermometer, accelerometer, barometric pressure sensor, and the humidity sensor will be exposed to varying environments to check for proper data collection.
- *Camera Test:* Testing of the camera will take place during the temperature test. The camera will be tested for functionality and longevity at extremely cold temperatures by taking a photo every 10 seconds throughout the temperature test.

6.3 Testing Results

- *Spin Test:* The prototype box held together well during the spin test and took no physical damage after being spun for 90 seconds. Abrupt movement tests were also done while the box was attached to the string and no damage was done to the box.
- *Drop Test:* The box was dropped about 6 meters onto concrete twice, to simulate the

Figure 13 Still image of spin testing.

possible forces experienced during impact. The box sustained only a slightly dented corner where it impacted the ground.

- *Stair Test:* The box was kicked down a flight of stairs two times. The prototype split at one seam during one of the stair tests. To prevent any splitting in the final structure, the box will be made out of one solid piece of foam core, rather than six individual pieces. The edges of the final box will be more thoroughly reinforced as well.

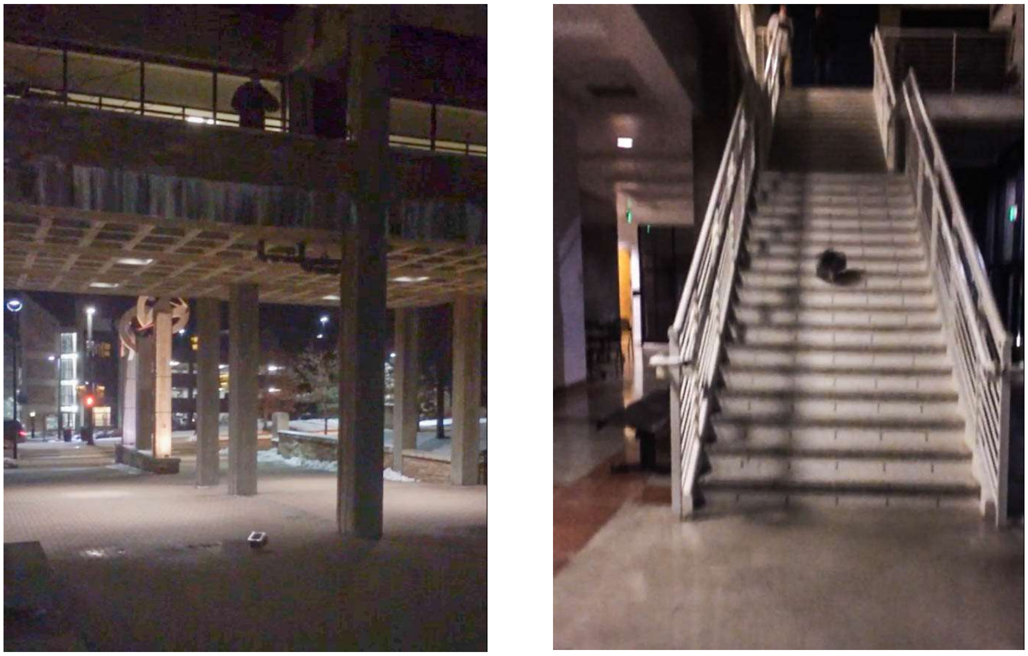


Figure 14 Still images of drop and stair testing.

- *Geiger Test* - The readings obtained from Big Gamma's Geiger Counters were sufficiently close to the readings obtained by the physics department Geiger Counter. The physics department Geiger Counter obtained a reading of 105 cpm and Big Gamma's Geiger tubes all obtained average readings of 105 cpm, averaged over 20 data points. Big Gamma therefore has accurate Geiger Tubes that can be used on the flight and give accurate readings and data.

- *Cooler Test* - The primary purpose of the cooler test was to ensure that all electronics are able to work in extreme cold, by placing the assembled craft into a craft and surrounding it with approximately 10 pounds of dry ice. Big Gamma's original design was to use 9 T-Energy 9V 500mAh Li-on rechargeable batteries; 3 for the heater, 3 for the experimental system, and 3 for the environmental system. However, during the test, Big Gamma decided to use 2 for the heater, 2 for the environmental system, and 3 for the experimental system, which would bring Big Gamma's craft underweight. The results of the 3-hour test showed that the environmental system is capable of running on just 2 batteries and the experimental system on 3 batteries for the full 3 hours. Unfortunately, running on just 2 batteries, the heater ran out of charge approximately 1 hour into the test. Big Gamma concluded that one or both of the batteries used were not fully charged, and caused the heater to work for a very short amount of time. For the flight, Big Gamma shall certainly use 3 batteries for the heater. Big Gamma also found that the camera died approximately 30 minutes into the test, although this was due to the fact that camera battery was quite insufficiently charged. Unfortunately, other than these mishaps, there were larger and more major ones. The test results and data from the Geiger tubes show that approximately 1/3 of the way into the test, all three Geiger tubes showed an extremely dramatic increase in counts per minute recorded, up to nearly 400 at one point. After this enormous spike occurs, the Geiger Tube that is shielded by .5cm HDPE flatlined, meaning that it continuously recorded zero

Figure 15 Image of BalloonSat before commencement of cooler test.

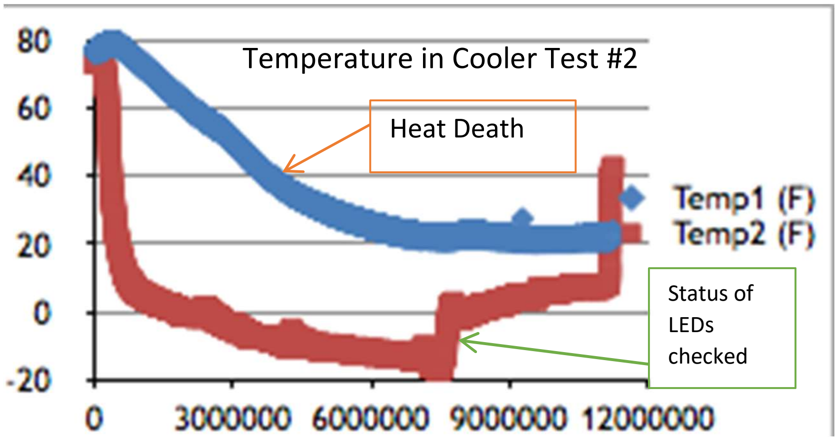


Figure 16 Graph depicting actual temperature data from the second cooler test. The blue points represent the internal temperature sensor while the red points represent the external temperature sensor.

counts for the remainder of the cooler test. Also, both of the other tubes also recorded lower overall counts per minute after the spike. Big Gamma originally concluded that this enormous spike in counts per minute recorded was due to a solar flare through a small amount of research. However, this seemed extremely improbable, and therefore Big Gamma therefore decided to conduct yet another cooler test, this time in a colder environment, using more dry ice. For the first cooler test, the internal temperature sensor achieved a low of 20.3ºF inside the box a period of time after the heater died, but maintained a temperature of approximately 80ºF until then. The outside temperature reached a minimum of -16.7ºF. For the second cooler test, the outside temperature reached a minimum of -35.4ºF, and the inside a minimum of 15.6ºF. Big Gamma also decided to use just 2 batteries on the heater again, and the heater again died approximately 1 hour into the flight. Most importantly, just as in the first cooler test, all three Geiger tubes experienced an enormous spike in radiation about 1/3 of the way into the test, and again, after this occurred, the Geiger Tube being shielded by .5cm thickness of HDPE flatlined and continuously gave 0 counter per minute for the remainder of the test. In fact, for all three tubes in both tests, the data appeared almost identical. Big Gamma concluded that this enormous spike in radiation approximately 1/3 of the way into the test was due to temperature, where when the internal temperature reaches approximately 40ºF, this spike in counts per minute occurs. Big Gamma will discuss the reasons for approaching and arriving at this conclusion in the next section, Missions Test.

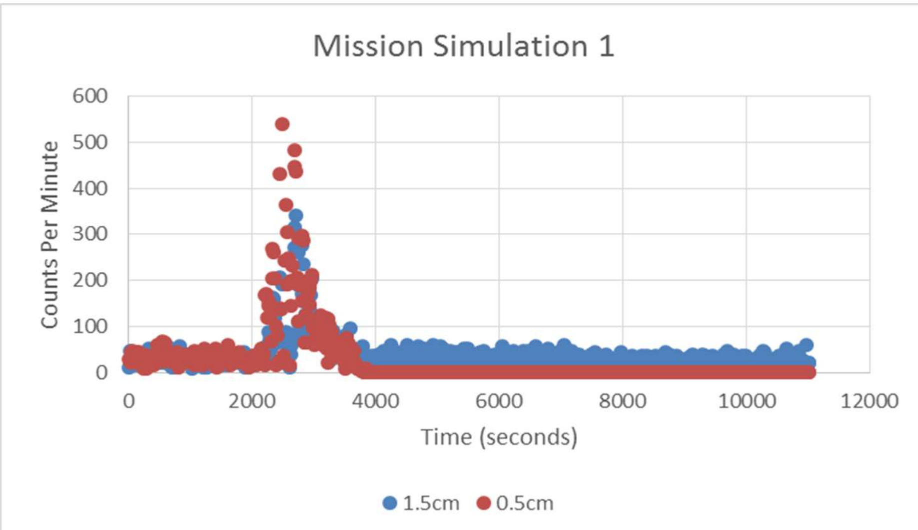


Figure 17 Graph spike described in shielded Geiger-Mueller tubes and the resulting flatline of the Geiger Tube placed in .5cm casing.

- *Missions Test:* Due to the unexpected and unexplained spikes in counts per minute recorded, and the apparent failure of one of the Geiger tubes to fail to record any radiation, Big Gamma decided to conduct a separate missions test at room temperature to determine whether or not cold temperatures were in fact the culprit for this major skew in data. Ultimately, after a complete 3-hour missions test, Big Gamma collected the data and found the following results.

Temperature: The following graph shows the external and internal temperature for the Missions Test, over a total time of 3 hours. The craft was not placed in a cooler in order to keep the temperature variable constant. Big Gamma also used 3 batteries for the heater

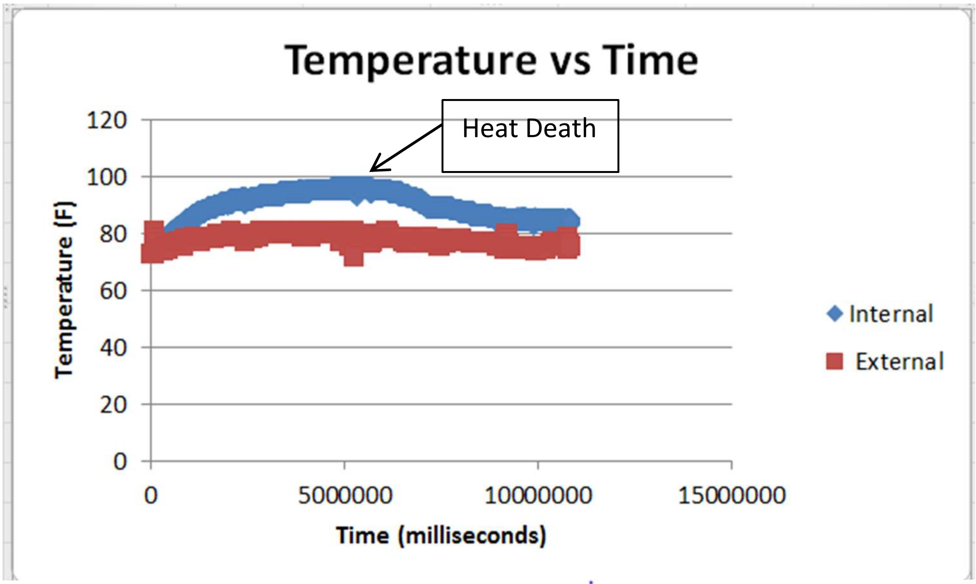


Figure 18 Graph depicting external and internal temperatures during missions test.

and found these supplied sufficient charge for approximately one hour and 45 minutes before finally running out of charge.

Radiation: As expected, Big Gamma found that none of the three Geiger tubes experienced an enormous spike in counts per minute, as was encountered in both cooler tests. Also, the Geiger tube shielded by .5cm of HDPE worked consistently and accurately throughout the duration of the test. Therefore, Big Gamma can conclude that the spikes in radiation detected during the cooler tests in all three tubes were caused by low temperatures. What this implies for the flight is that some rigorous thermal changes will need to change place in order to prevent this from happening during the flight. Big Gamma will replace all black foam insulation currently in use with significantly thicker black foam, to retain heat in the craft as much as possible.

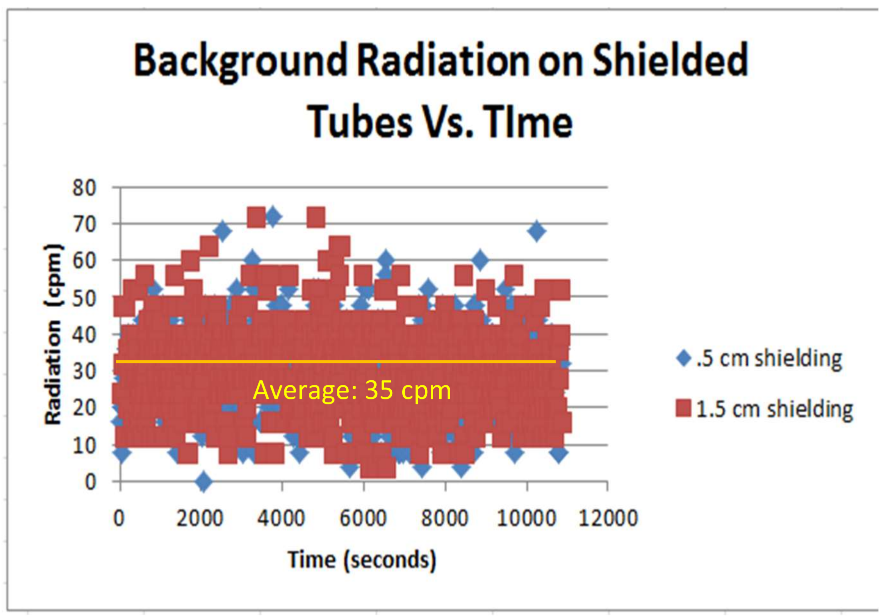


Figure 19 Graph depicting the shielded Geiger tubes during the missions test.

Other Sensors and Data:

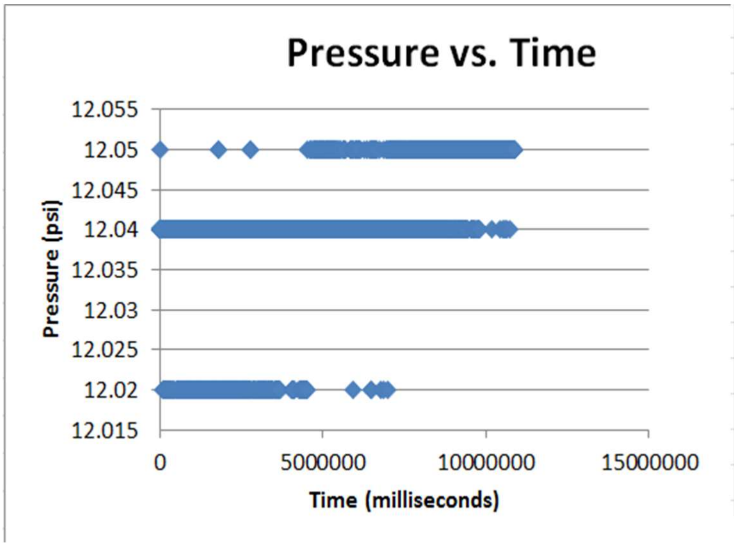


Figure 20 Graph depicting pressure data from the missions test.

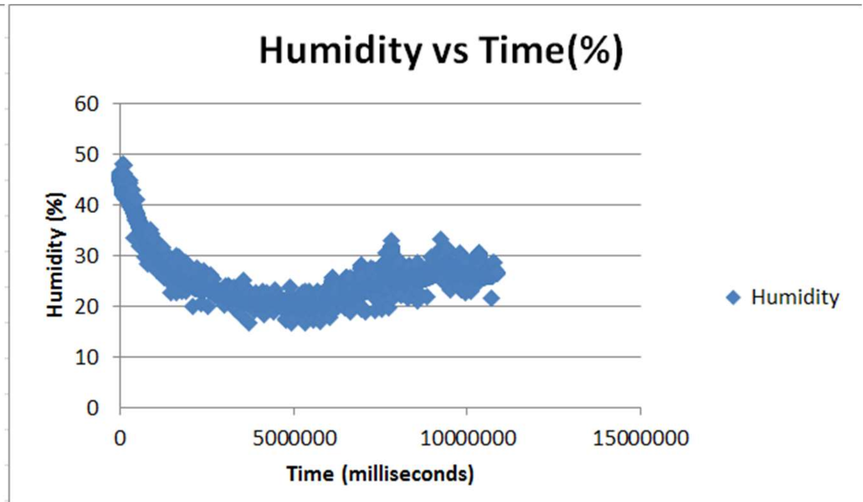


Figure 21 Graph depicting the humidity data from the missions test.

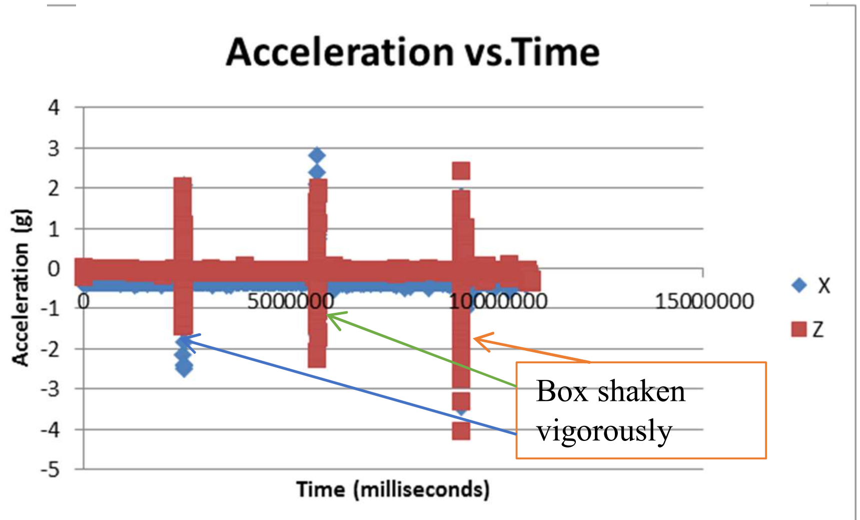


Figure 22 Graph depicting the acceleration data in the X and Z directions from the missions test.

These are graphs of the data from each of the other sensors off of the environmental systems Arduino, which remained powered on for the duration of the systems test. The first graph, depicting acceleration in the X and Z directions, shows constant acceleration, except for the three large spikes, when the craft was shaken several times, and reflects exactly what Big Gamma predicted for acceleration for this test. Pressure actually steadily increased over the 3-hour test by a minimal amount, from 12.02 psi to a maximum of 12.05 psi. Big Gamma also witnessed a sharp decrease in humidity as the test commenced, starting out at 50%, dropping down to 20% and final equalizing at approximately 30%.

7.0 Expected Results

Team Big Gamma will save all data onto microSD cards. The data will then be converted and parsed into manageable files. These files will then be plotted using Microsoft Excel. From the plots generated by Excel, Big Gamma will be able to analyze the data to determine if it matches the predicted trends described below, as well as report on our experimental findings.

7.1 Temperature

Team Big Gamma expects the external temperature of the payload to reach a minimum temperature of -60 degrees Celsius as it rises from the troposphere and into the stratosphere at an altitude of 20km. After 20 km we expect the temperature to rise to about -40 degrees Celsius as the payload approaches its goal altitude of 30km. The interior temperature will be regulated by the heater and will not go under -10 degrees Celsius to maintain operations of all electronics.

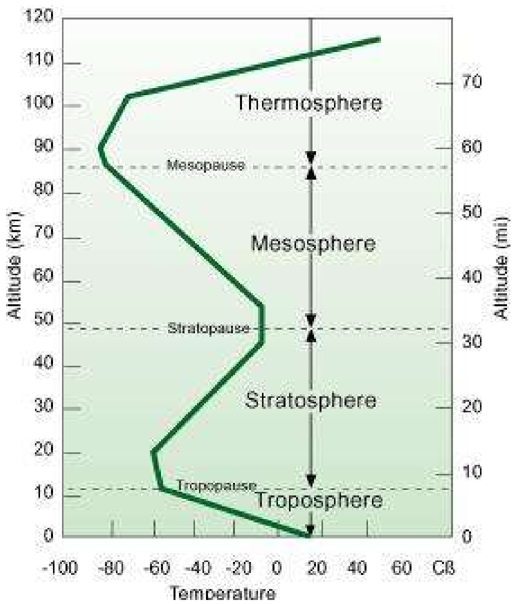


Figure 23 Relationship between temperature and altitude[8] as expected during the flight.

7.2 Humidity

The humidity is expected to change along with pressure and temperature. As the payload rises toward 30 km the air pressure decreases and temperature decreases causing humidity to decrease as well. The temperature difference between the interior and exterior of the payload may result in additional humidity build up. This potential for additional humidity must be recognized when interpreting results.

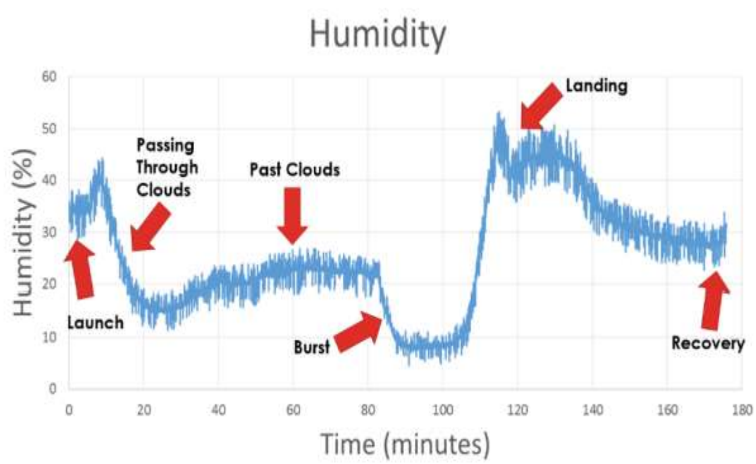


Figure 24 Expected relationship between humidity and altitude[9].

7.3 Pressure

Big Gamma expects an inverse relationship between altitude and pressure. As altitude increases there will be a decrease in measured pressure. As this is a well known phenomenon, we can use our pressure measurements as a comparison of altitude for our other measurements.

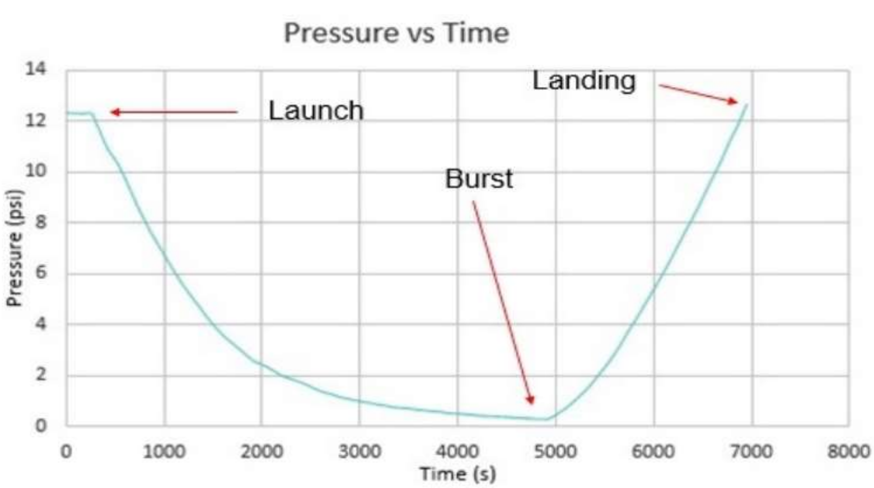


Figure 25 Relationship between pressure and altitude[10] as expected during the flight.

7.4 Acceleration

Big Gamma expects a to observe a relatively constant velocity (little to no acceleration) in the z-axis on the ascent, besides initial take-off. During the ascent and descent it is difficult to predict the exact acceleration trends in the x and y axes, due to the erratic motion on the flight string. Because of this, it is predicted that there will be a abrupt acceleration measurements along the x and y directions. Upon burst, Big Gamma also expects to record large and erratic acceleration measurements along all three axes.

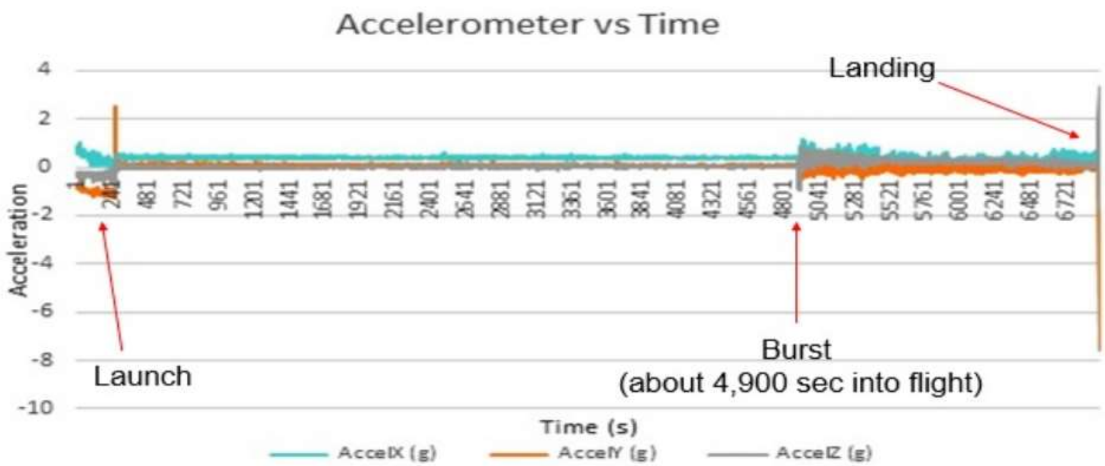


Figure 25 Relationship between acceleration and altitude as expected during the flight.

7.5 Radiation

Big Gamma expects an increase in radiation levels with an increase in altitude. It is also expected that the two Geiger Counters that are shielded will receive less radiation than the control. Big Gamma expects the Geiger tube with more shielding to receive lower amounts of radiation dosage.

When doing ground testing on the Geiger tubes, Big Gamma will discover the attenuation coefficient of HDPE, which will later be used to calculate the theoretical emerging intensity that the Geiger Counters will receive. From the Fundamental Law of Gamma-Ray Attenuation, the theoretical experienced dosage by the shielded tubes during the flight can be calculated. The expected radiation intensity will therefore be, $I = I_0 e^{-\mu r}$, where I_0 is the experienced intensity by the control tube, r is the radius of effective shielding, and μ is the found absorption coefficient. After Ground testing the Geiger Counters in the physics department, detailed in Test Results section, the absorption of the coefficient of HDPE was determined to be .115 cm^{-1}.

[8] Loose, Kenneth. "Why Does the Temperature of the Atmosphere Vary?" - *Windows to the Universe*. NESTA, 2012. Web. 02 Mar. 2015.

[9] Kristmundsson, Darri. "Voyeur Voyage I - 2010." *HAB Iceland*. HAB Iceland, 25 Oct. 2011. Web. 02 Mar. 2015.

[10] "BMP085 Pressure Sensor at High Altitude." *Greg Kleins Blog*. N.p., 19 Jan. 2011. Web. 26 Feb. 2015.

In addition, Big Gamma can then conclude the accuracy of the data received from the Brooklyn Project by comparing it to the theoretical values found through the Fundamental Law of Gamma-Ray Attenuation. This will be accomplished by running a regression of the data which will require a minimum of three data points. These data points will be determined by an average of all the data points in every layer of the atmosphere. The resulting multiple regressions, will provide a strong basis to draw a conclusion on the efficiency of HDPE shielding.

Lastly, Big Gamma will then compare the tensile strength, mass, cost, and radiation shielding of HDPE to that of other materials, in order to determine whether HDPE is a viable radiation shielding substitute for current spacecraft materials.

8.0 Launch and Recovery

8.1 BalloonSat Recovery

After launch is completed and the BalloonSat payloads complete the flight to approximately 30km and back down, the payloads have the potential to land extremely far away from the launch site, possibly even in another state. This will require some team members to retrieve Big Gamma's payload. Kenzy O'neill will be the person responsible for preparing the craft for launch and actually launching on launch day, due to the fact that he has the most hands-on experience with the BalloonSat itself. Olagappan Chidambaram will complete Navigation Training in order to qualify himself for BalloonSat recovery. Rong Li will drive Ologappan to the recovery site due to the fact that Rong is the only member of Big Gamma with a car. After the BalloonSat is recovered, preliminary external inspection of the craft is completed, and the craft safely returned to Boulder, data retrieval and recovery will commence.

8.2 Data Retrieval

Big Gamma's data retrieval plan, once the craft has been safely transported back to Boulder, is the following:

- Allow satellite to warm up to room temperature
- Observe and note any damage done to the craft, then carefully cut along aluminum tape seams and open lid.
- Note any apparent damage done to the electronics, and then carefully remove MicroSD cards from their respective systems.
- After the MicroSD cards have been removed, data analyzation will commence.

Before Launch, Big Gamma will take pictures of our payload, from as many angles as possible, and all internal electrical components, to detail the condition of the craft after flight and compare it to conditions before flight, or in case of a catastrophic failure for failure analysis. With regard to knowing that this plan works, Big Gamma can be sure that this data retrieval plan will work because of its numerous tests on the craft, using all subsystems at once, which included two separate cooler tests and one missions test. Data retrieval has been successful each and every time.