LaACES Program
Flight Readiness Review Document
for the
Cosmic Ray Experiment
by

Team CajunSat

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Change Information Page

Title: FRR Document for Cosmic Ray Experiment
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List of Affected Pages		
Page Number	**Issue**	**Date**
2	Changed some science goals to technical goals	3/23/05
2-15	Cosmic ray section added to science goals	3/25/05
4-18	Geiger counter section added to science goals	3/25/05
18	Surface area section added to science goals	3/23/05
20-21	Flux section added to science goals and changed flux formula	3/23/05
21-22	Muon section added	3/30/05
23	Non-vertical section added	4/1/05
23-24	Relativistic effects of muons section added	4/1/05
24-26	Interaction Depth added	4/1/05
27	Slant depth added	4/1/05
30	Second Box design added	3/30/05
31	HOBO was removed from document	4/1/05
32	Interfacing recovery edited	4/1/05
33	Interfacing recovery section fixed	4/1/05
35	Power budget paragraph added	4/1/05
36	Mechanical design fixed	4/1/05
37	Weight Budget error fixed	4/1/05
41	Sample of software code	4/1/05
45	Interface board changed to BalloonSAT	4/1/05
49	Time line error fixed	4/1/05
56-59	GAMA-SCOUT® removed from document	4/1/05
56-59	Risk Management errors fixed	4/1/05

Status of TBDs

TBD Number	Section	Description	Date Created	Date Resolved
001	3.1.1	Surface area of Geiger Counter tube	3/11/05	5/1/05
002	3.1.2	Gas in Geiger Counter tube	3/11/05	4/27/05
003	3.1	Time interval for the amount of counts	3/11/05	4/27/05
004		GPS device actually being used during flight	3/8/05	5/2/05
005	4.7	Resistance of heating circuit	3/11/05	4/26/05
006	4.0	Technical Specs of Geiger-Muller Counter kit	3/11/05	4/28/05
007	4.2	Will a double box provide better results an a heater.	3/31/05	5/3/05
008	6.3	Dead Time	4/1/05	4/29/05
009	4.5	Geiger counter power	4/1/05	4/29/05
010	4.5	BalloonSAT power	4/1/05	5/9/05

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1.0 Document Purpose

This document describes the critical design for the Cosmic Ray experiment by Team CajunSat for the ACES Program. It fulfills part of the ACES Program requirements for the Flight Readiness Review (FRR) to be held May 9, 2005.

1.1 Document Scope

This FRR document specifies the scientific purpose and requirements for the Cosmic Ray experiment and provides a guideline for the development, operation and cost of this payload under the ACES Program. The document includes details of the payload design, fabrication, integration, testing, flight operation, and data analysis. In addition, project management, timelines, work breakdown, expenditures and risk management is discussed. Finally, the designs and plans presented here will be finalized at the time when the ACES Program Office approves this Flight Readiness Review (FRR).

1.2 Change Control and Update Procedures

Changes to this FRR document shall only be made after approval by designated representatives from Team CajunSat, and the LaACES Program Office. Document change requests should be sent to Team members, and the LaACES Program Office.

2.0 Reference Documents

1. Mewaldt, R.A. Cosmic Rays. California Institute of Technology. Macmillan Encyclopedia of Physics 1996. http://www.srl.caltech.edu/personnel/dick/cos_encyc.html
2. Introduction to Ionizing Radiation and Low level Radioactive Materials. Dr. William Andrew Hollerman, CHMM
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16. http://polaris.phys.ualberta.ca/info/Phys29x/Manual/11GM01.pdf
17. Muons. http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Muons.htm
18. Interaction Depth http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Interaction.htm
19. http://www.answers.com/topic/geiger-mueller-tube

3.0 Mission Objectives

The mission objective of this experiment is to measure the flux of the secondary cosmic rays with respect to altitude.

3.1 Science Goals

The scientific goal of this experiment is to measure the total cosmic ray flux, or rate of flow of radiation per unit area, of the cosmic rays in the atmosphere with respect to altitude. However, this will not be a total flux because we do not expect to detect any alpha particles. This is because alpha particles are stopped by a piece of paper. Therefore our two layers of foam board will stop all alpha particles. Beta particles and gamma rays, on the other hand, will not be stopped by the foam board because beta rays are stopped by a sheet of aluminum or plywood while gamma rays are stopped by a two meters of concrete or 40 cm of lead (Reference 11) Figure 3.1 shows this better.

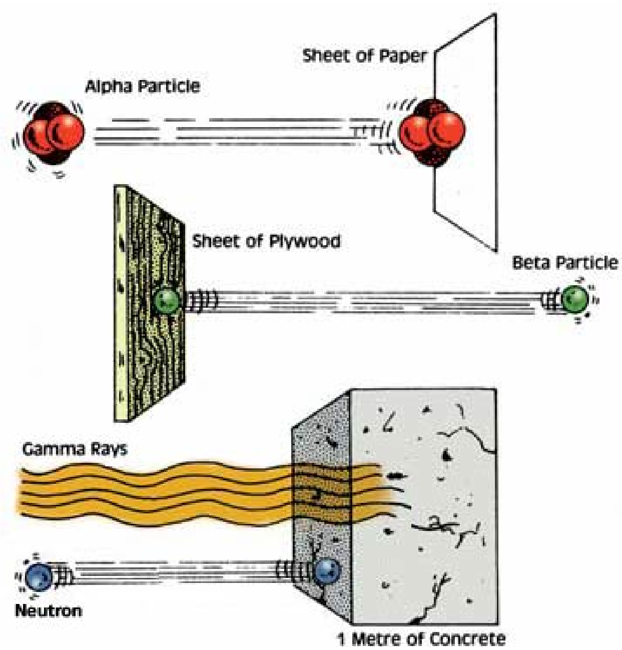


Figure 3.1
This shows how far each particle can travel through a given object.
http://www.cameco.com/uranium_101/uranium_science/radiation/index.php

3.1.1 Cosmic Rays

Cosmic rays are particles that bombard Earth from *anywhere* beyond its atmosphere (Reference 3) and were discovered by Victor Hess (see figure 3.2) using a high altitude balloon traveling to about 17,500 feet (5.334 km) and a gold leaf electroscope (Reference 14). He noticed that the electroscope discharged more rapidly has we went up in altitude and attributed this as a form of radiation entering the atmosphere from above. This discovery earned him a Nobel Prize in 1936. For a long time, cosmic rays were considered electromagnetic in nature, but during the 1930's it was discovered that they are electrically charged and affected by things such as Earth's magnetic fields. This means that the flux of the cosmic rays will be different at different latitudes and at different altitudes because Earth acts like a bar magnet. This also means that it is impossible to tell the exact origin of the cosmic rays (Reference 1).

Early Research: During the 1930's to 1950's, man-made particle accelerators were unable to reach very high energies so cosmic rays served as a source of particles for high energy physics which led to the discovery of the first muon and pion. However, this is not the only application of comic rays. In fact, since the beginning of the space age, the main focus of cosmic ray research has been towards astrophysical investigations of where cosmic rays originate, how they get accelerated to such high velocities, what role they play in the dynamics of the Galaxy, and what their composition tells us about matter from outside our solar system. In order for us to measure cosmic rays directly, we must do our research on space craft and high altitude balloons before they have a chance to be broken up and slowed down by Earth's atmosphere (Reference 1).

Cosmic Ray energies and Acceleration: Cosmic rays are usually measured in units of MeV or GeV, and their energy range is a little less than 1 MeV to a little over 1 ZeV (10^{21} eV) which is about one billion times more powerful than any current particle accelerator (See Figure 3.2).

Most galactic cosmic rays have an energy range of 100MeV to 10GeV or a velocity range of 46% to 99.5% the speed of light. The number of cosmic rays with energies above 1 GeV decreases by a factor of 50 for every factor of 10 increase in energy. The highest energy rays measured to date is 10^{20} eV (Reference 1).

It is believed that most galactic cosmic rays derive their energy from supernova explosions, which occur approximately once every 50 years in our galaxy. For cosmic rays to maintain their intensity over millions of years requires only a few percent of the 10^{44} J released by the typical supernova explosion. There is also evidence that cosmic rays are accelerated as the shock waves from these explosions traveling through interstellar gas. The energy contributed to the Galaxy by comic rays is about that contained in galactic magnetic fields, and in the thermal energy of the gas that passes through the space between the stars. This is approximately 1 eV per cm^3 (Reference 1).

While we might be able to detect cosmic ray energies, we do not always know how they are accelerated to such a high velocity. In fact, the source of energy greater than 10^{15} eV is unknown. It is believed that they might originate from outside our galaxy from active galactic nuclei, quasars, or gamma ray bursts, but it can also be some exotic new physics such as superstrings, exotic dark matter, strongly-interacting neutrinos, or topological defects in the very structure in the universe (Reference 3).To better see this, see figures 3.2 and 3.3.

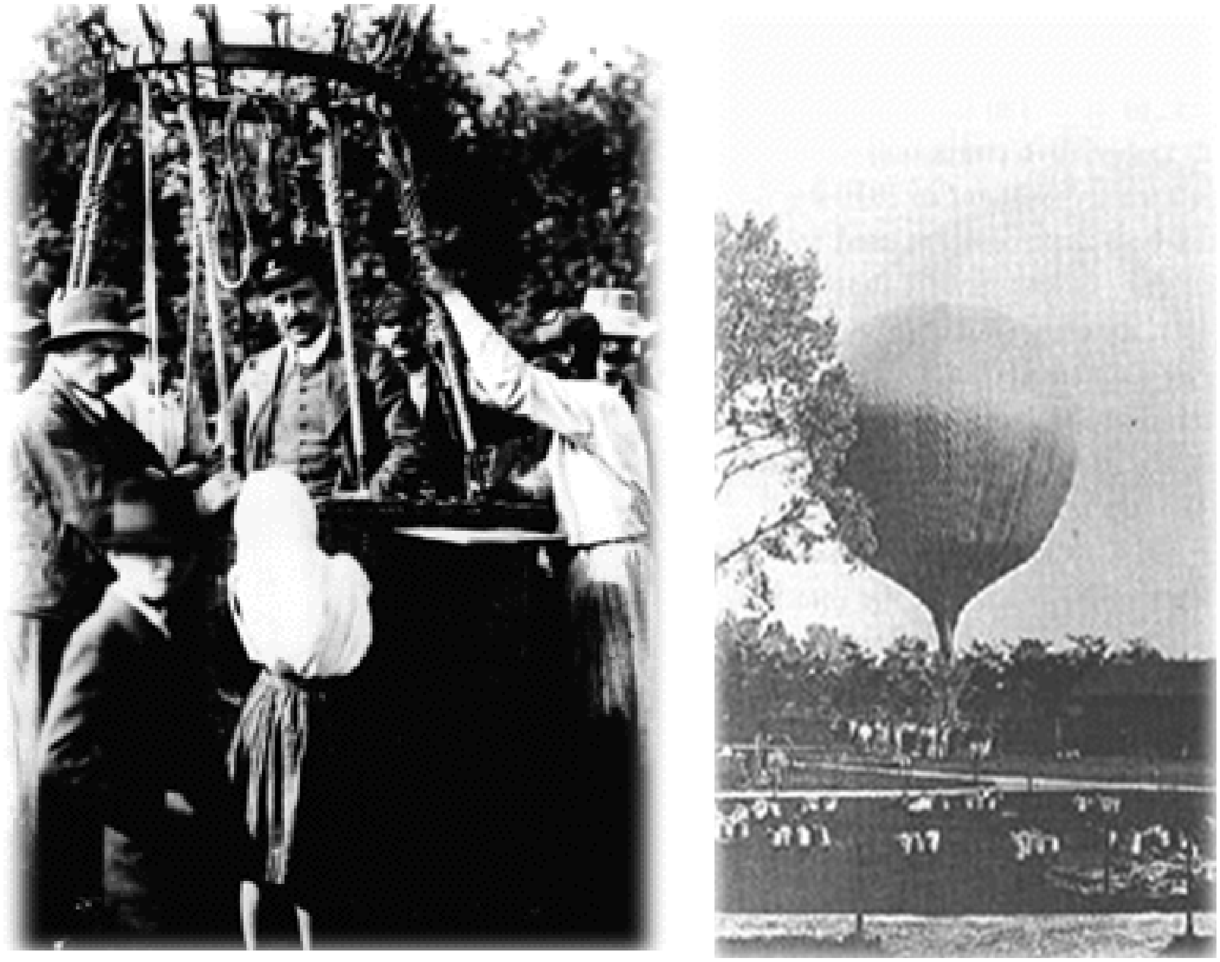


Figure 3.2.
Left: Victor Hess before his balloon flight, during which he observed cosmic ray intensity increasing with altitude.
Right: Hess's balloon.
http://www.ast.leeds.ac.uk/haverah/cosrays.shtml

Cosmic ray composition: Cosmic rays are made out of all the particles in the periodic table and are approximately the following portion: 89% hydrogen (protons), 10% helium, and 1% of the heavier elements such as carbon, oxygen, magnesium, silicon, and iron (Reference 1). By studying cosmic rays, we can know what the composition source of the cosmic rays. Also, Cosmic rays are the few examples of matter from outside of our solar system, and by studying them, we are able to understand how our galaxy evolved, the reason for the matter in our universe, and our origin (Reference 3).

High energy cosmic rays: When the high energy cosmic rays collide with the atoms in Earth's atmosphere, they produce a shower of secondary particles. See figure 3.5. The amount of particles reaching Earth's surface is related to the energy of the cosmic rays. The frequency of the energies also changes. Cosmic rays with energies of greater than 10^{15} eV is about 100 per m^2 and once per century for energies of beyond 10^{20} eV. It is these secondary particles that reach Earth's atmosphere with an average flux of about 1 per m^2 per minute. For our experiment, we will use a Geiger counter to measure the secondary cosmic rays (Reference 14).

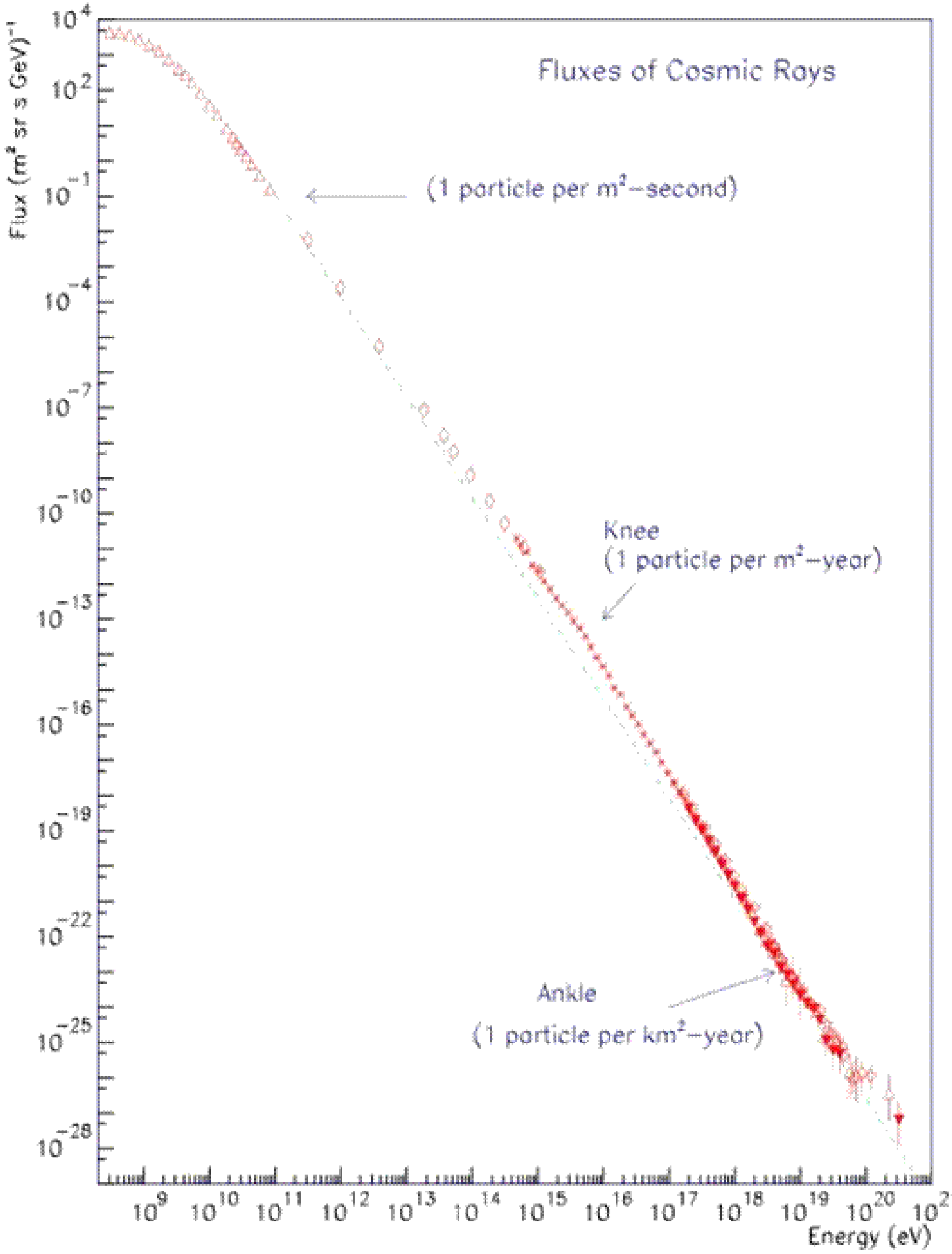


Figure 3.3
This graph shows the flux of cosmic rays bombarding Earth as a function of their energy per particle. Researchers believe cosmic rays with energies less than ~$3x10^{15}$ eV come from supernova explosions. The origin of cosmic rays greater than 10^{15} remains a mystery.
http://www.firstscience.com/site/articles/balloon.asp

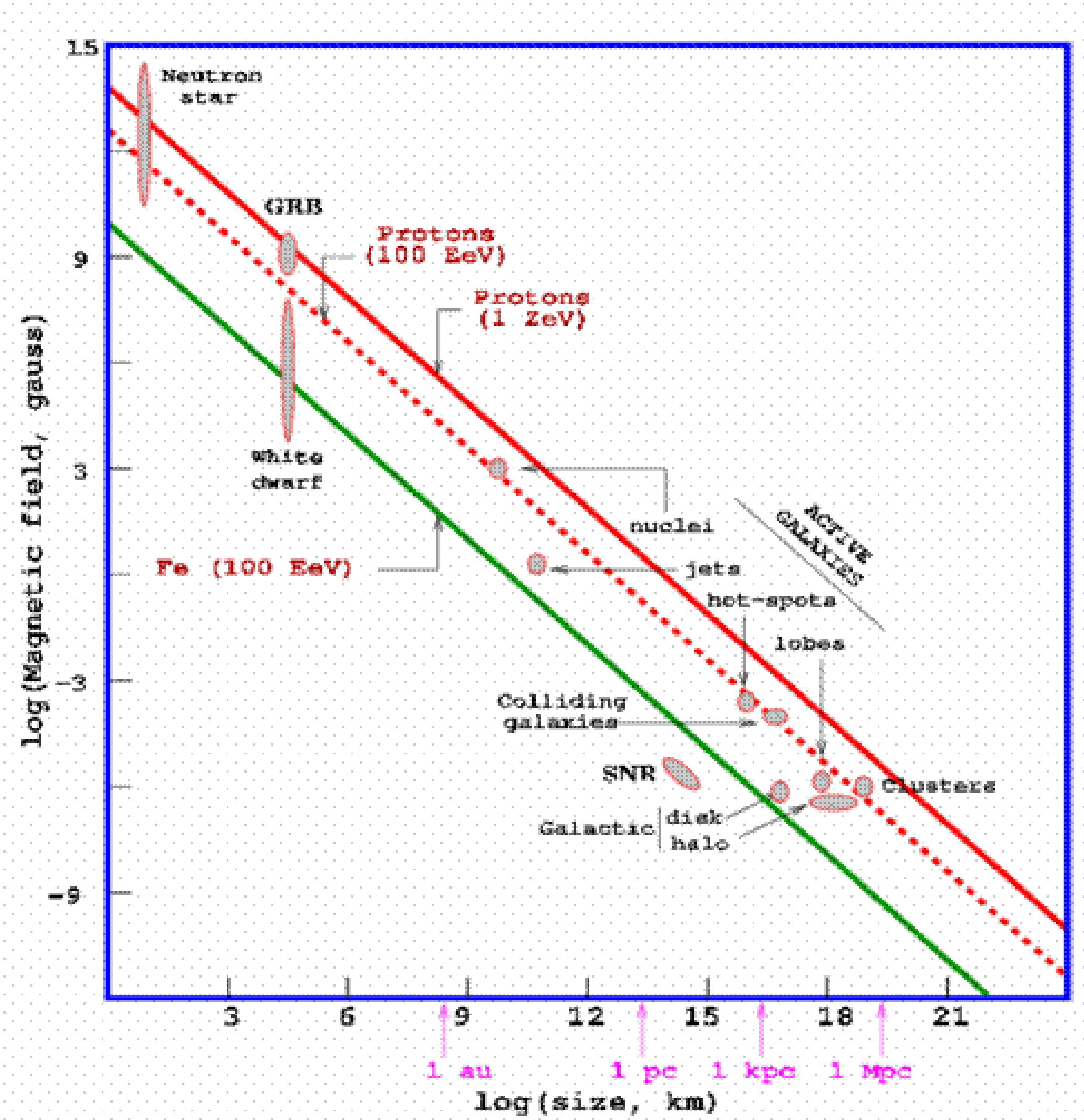


Figure 3.4
Hillas Plot. Red, green and dotted lines show the relation between the magnetic field and the size of an accelerator. Once energy and charge of the accelerated particle are fixed Astrophysics objects placed above a line are candidate sites for acceleration.
http://etd.adm.unipi.it/theses/available/etd-06142004-215416/unrestricted/ch1.pdf

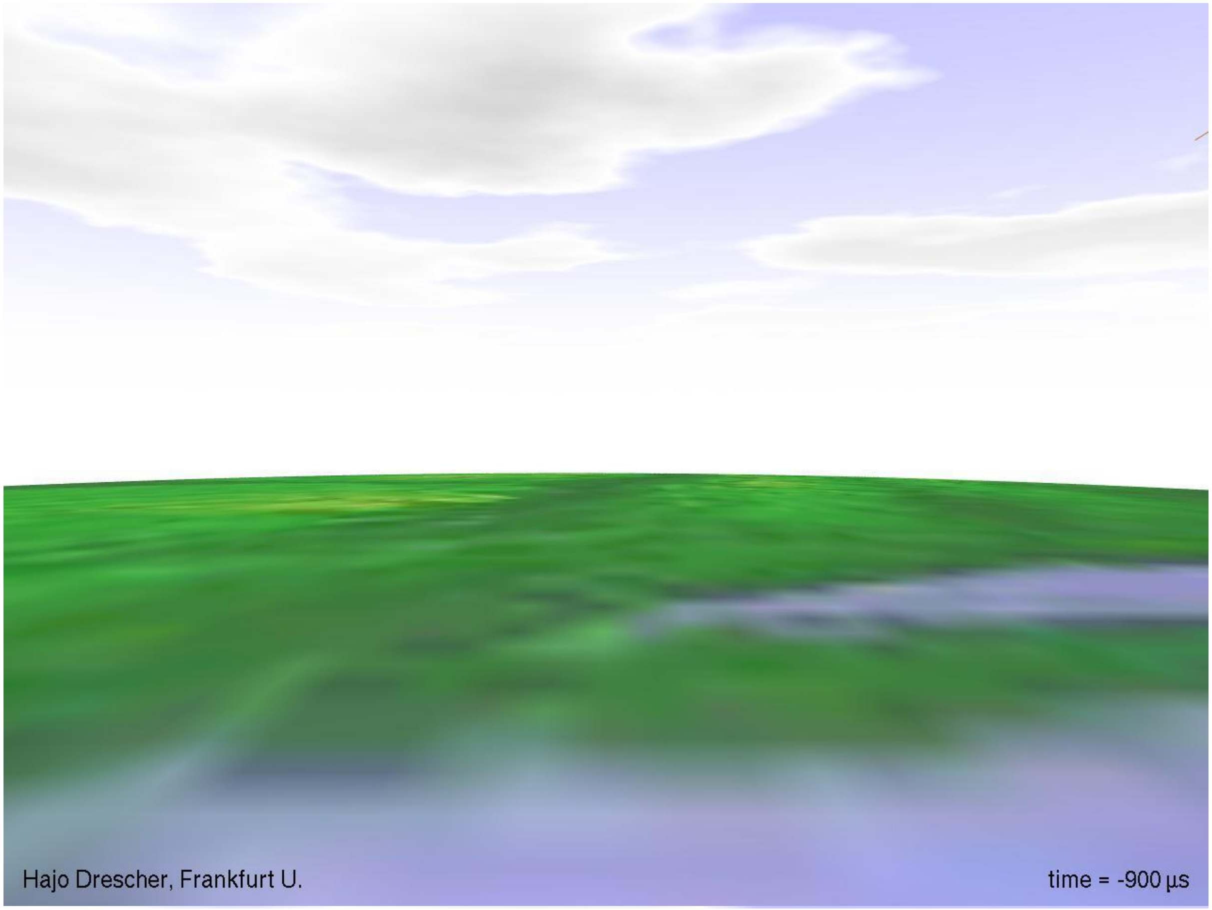


Figure 3.5 A
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

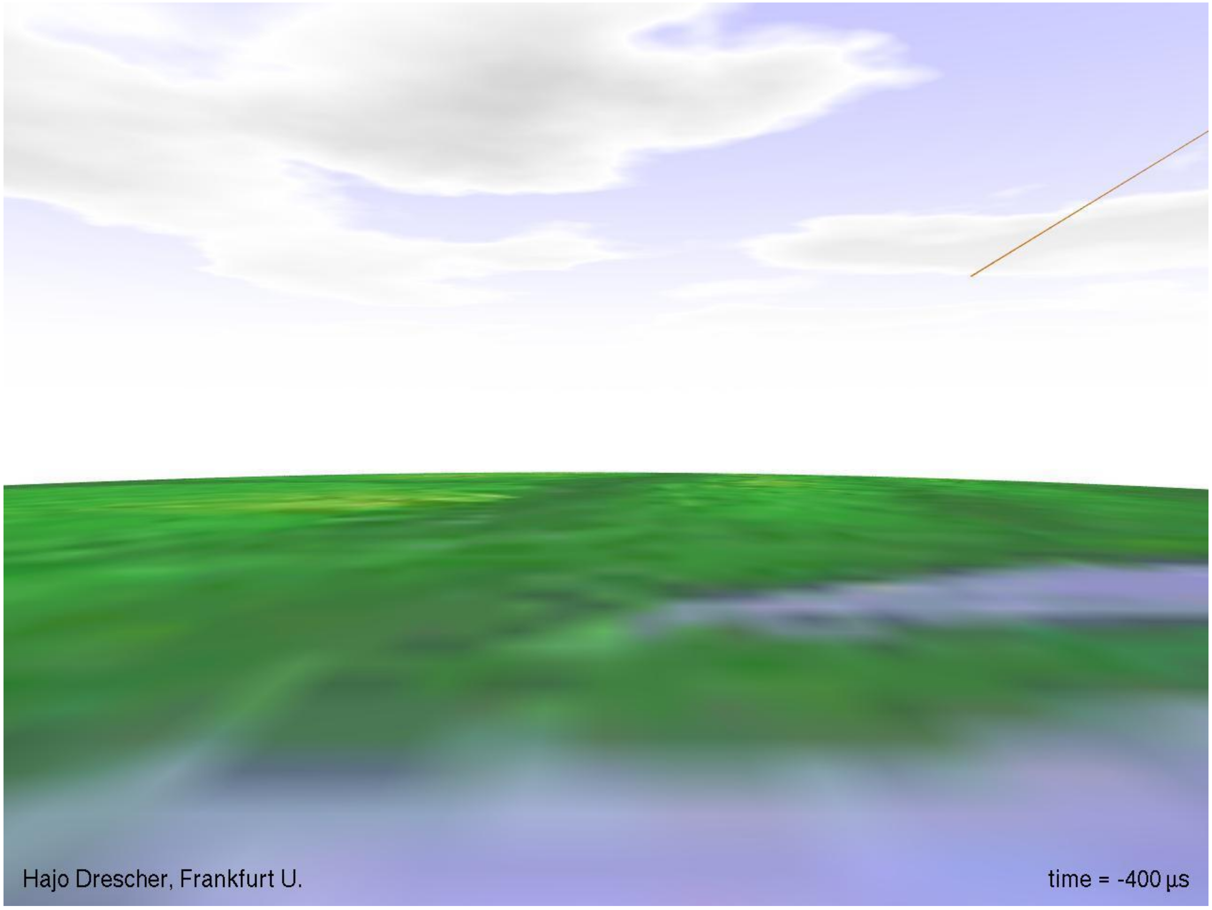


Figure 3.5 B
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

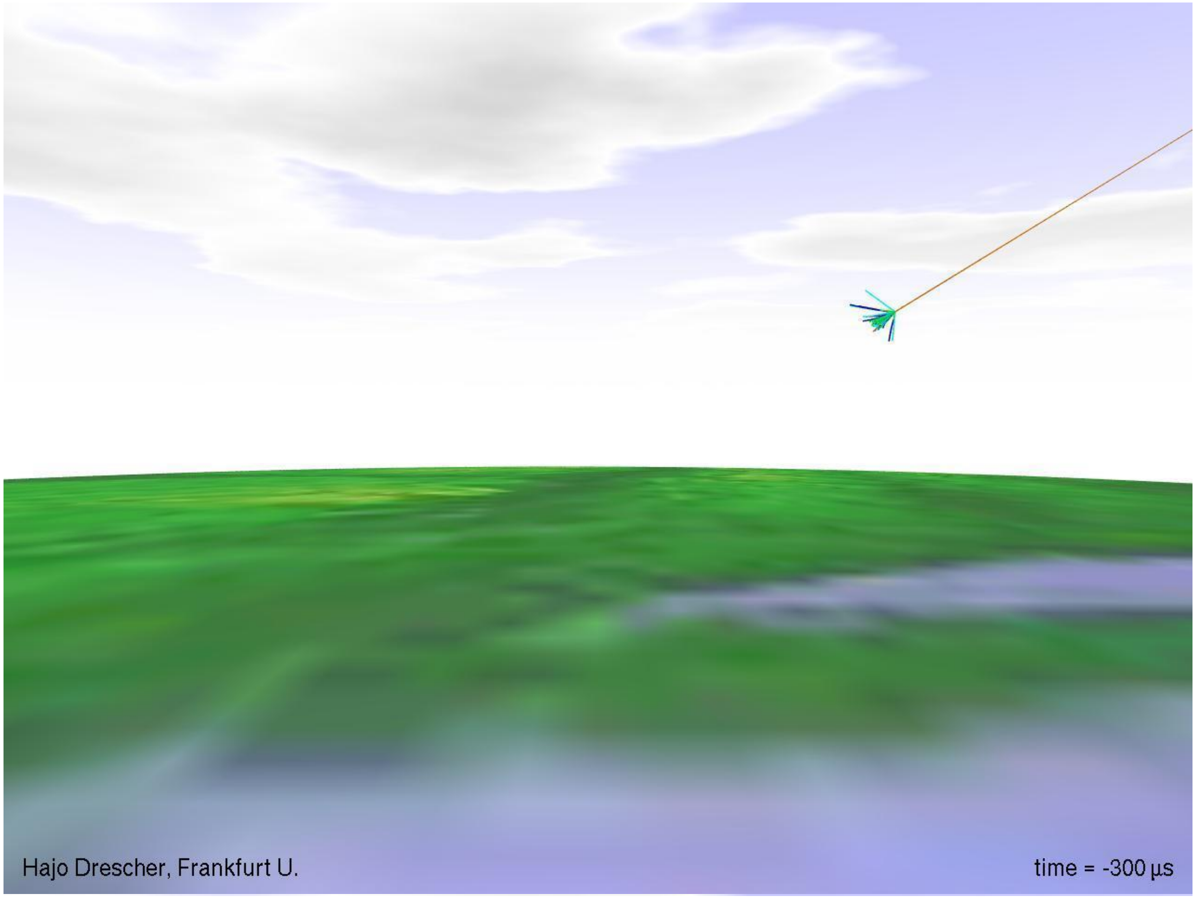


Figure 3.5 C
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

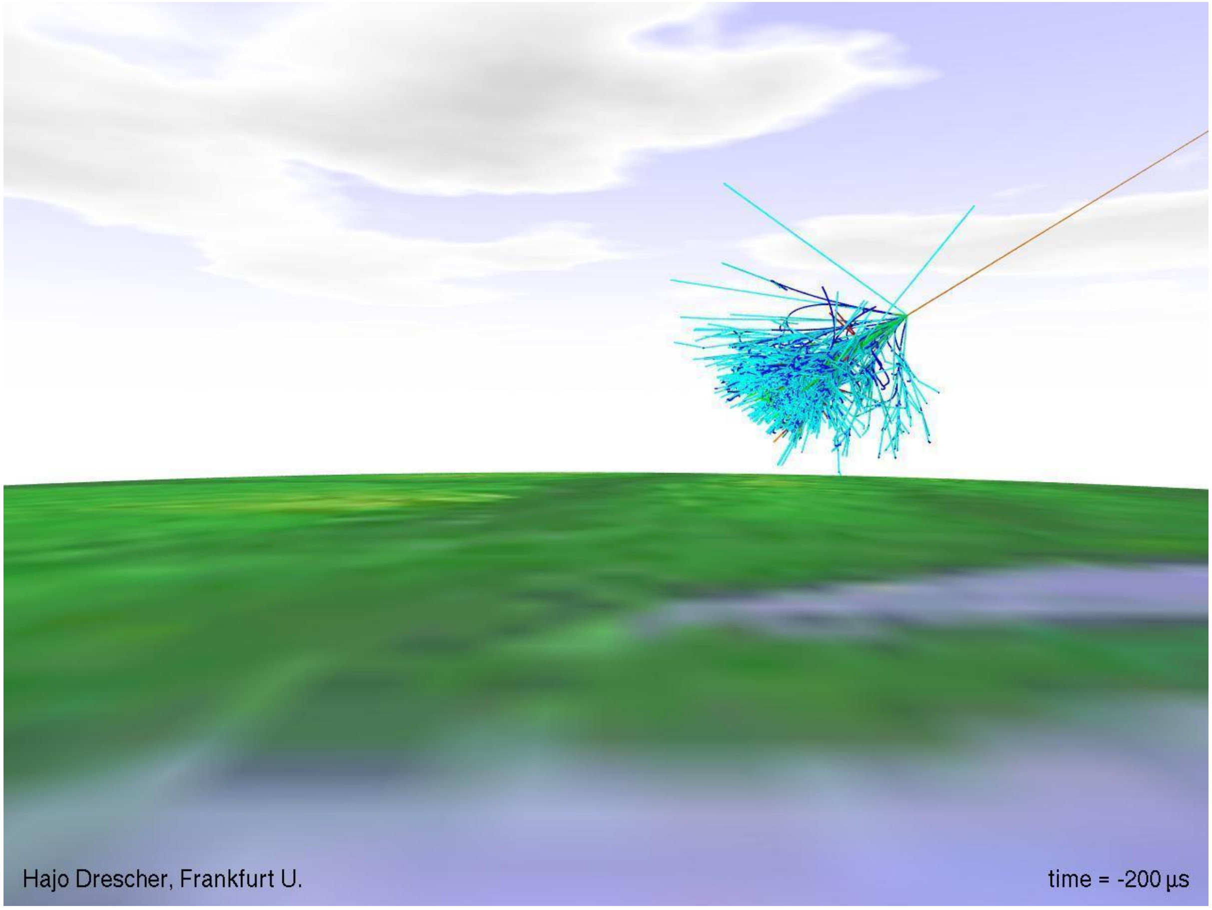


Figure 3.5 D
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

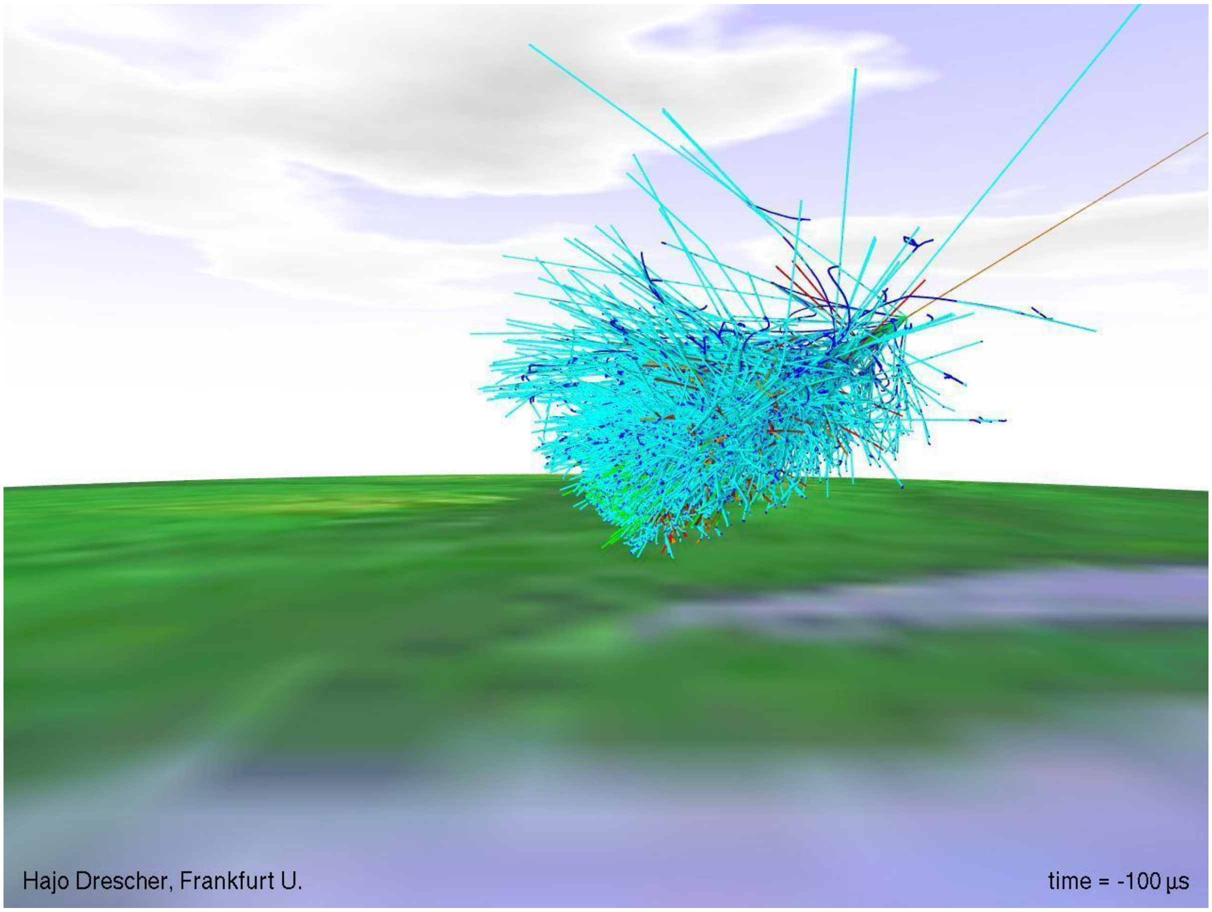


Figure 3.5 E
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

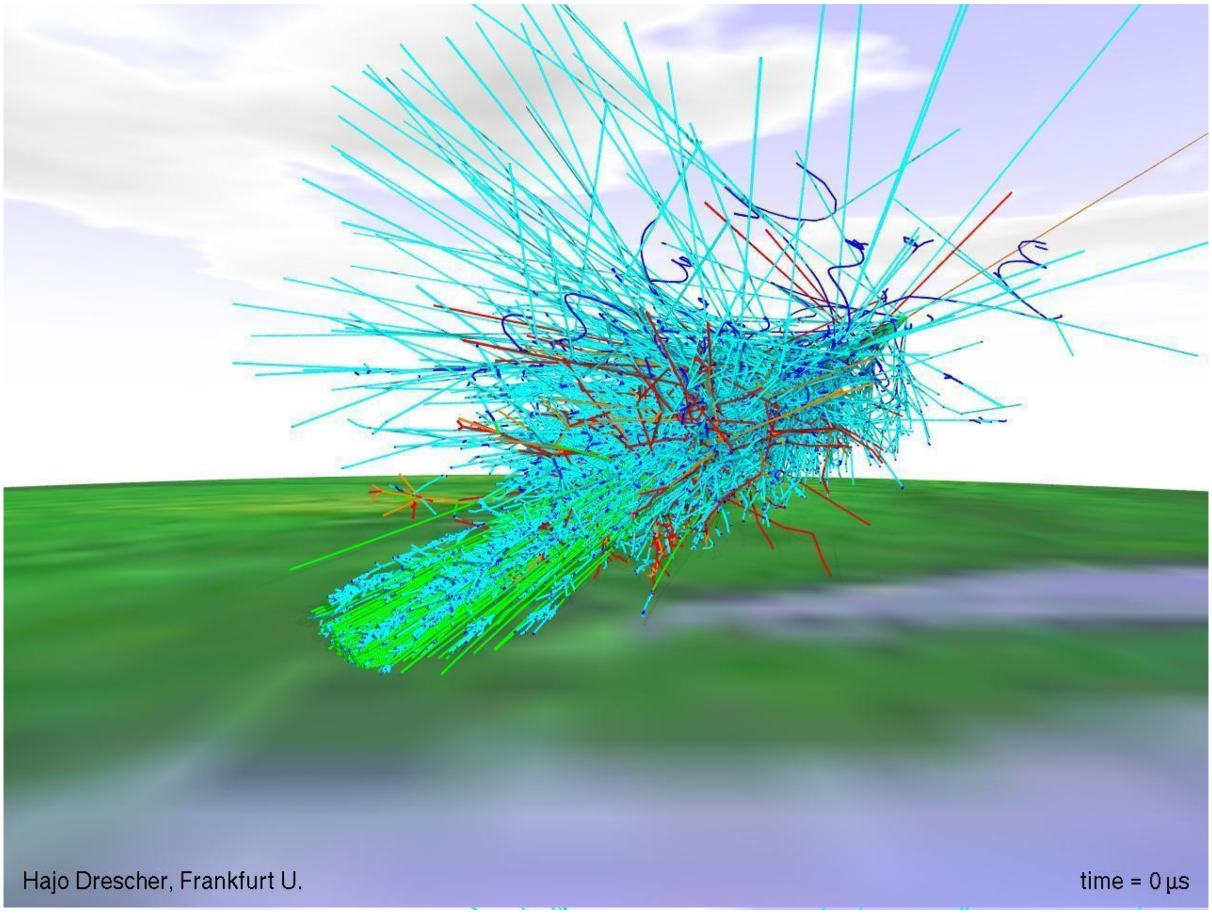


Figure 3.5 F
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

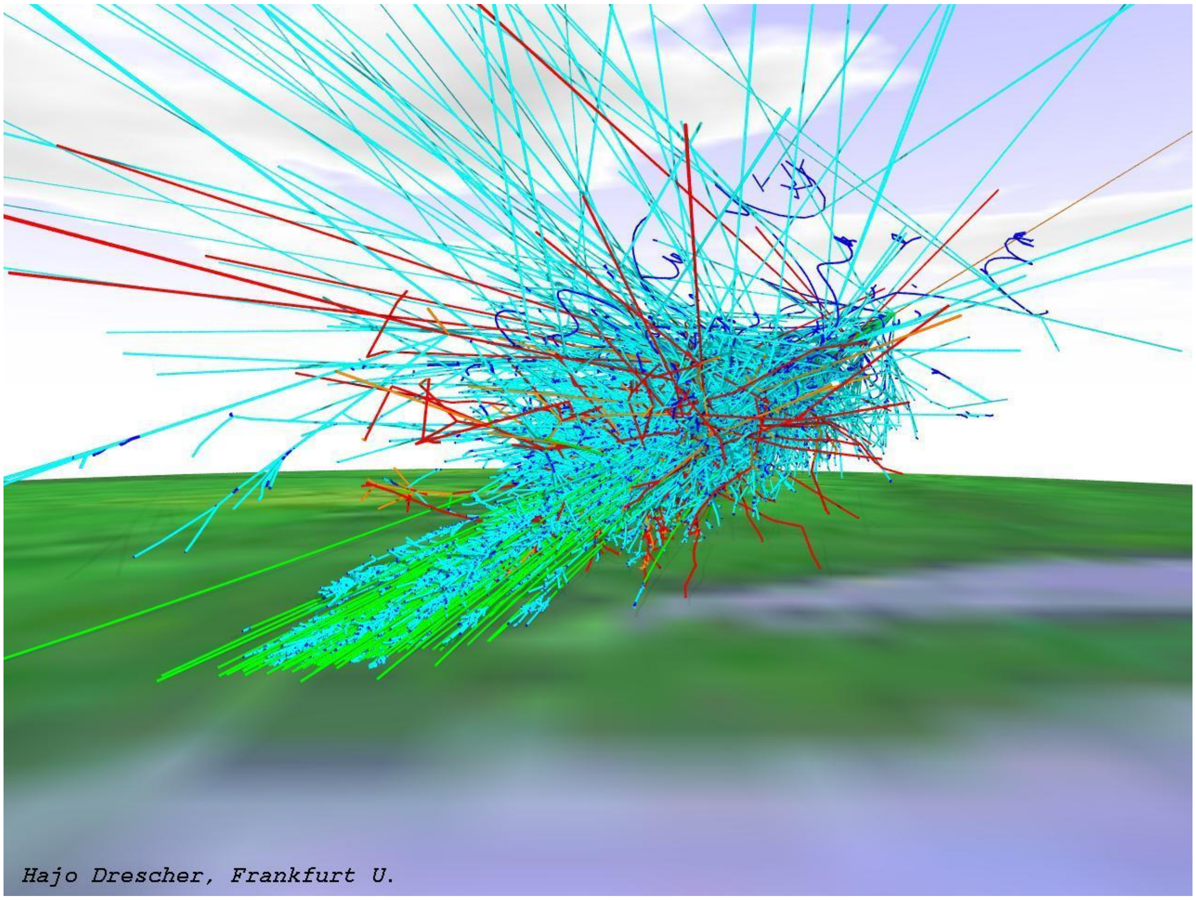


Figure 3.5 G
This is a computer simulation of the primary cosmic rays interacting with the atmosphere.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

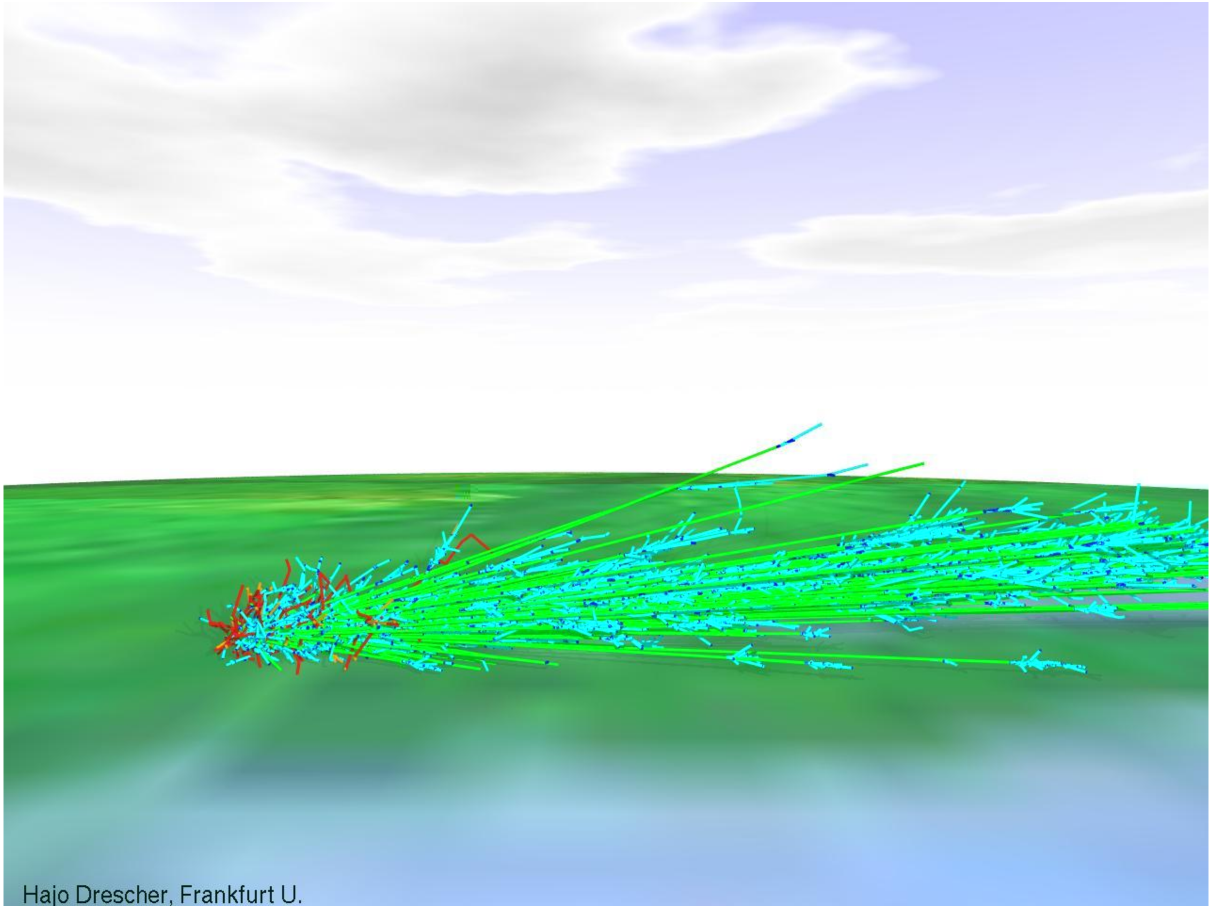


Figure 3.5 H
This is a horizontal view of the secondary cosmic ray shower.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

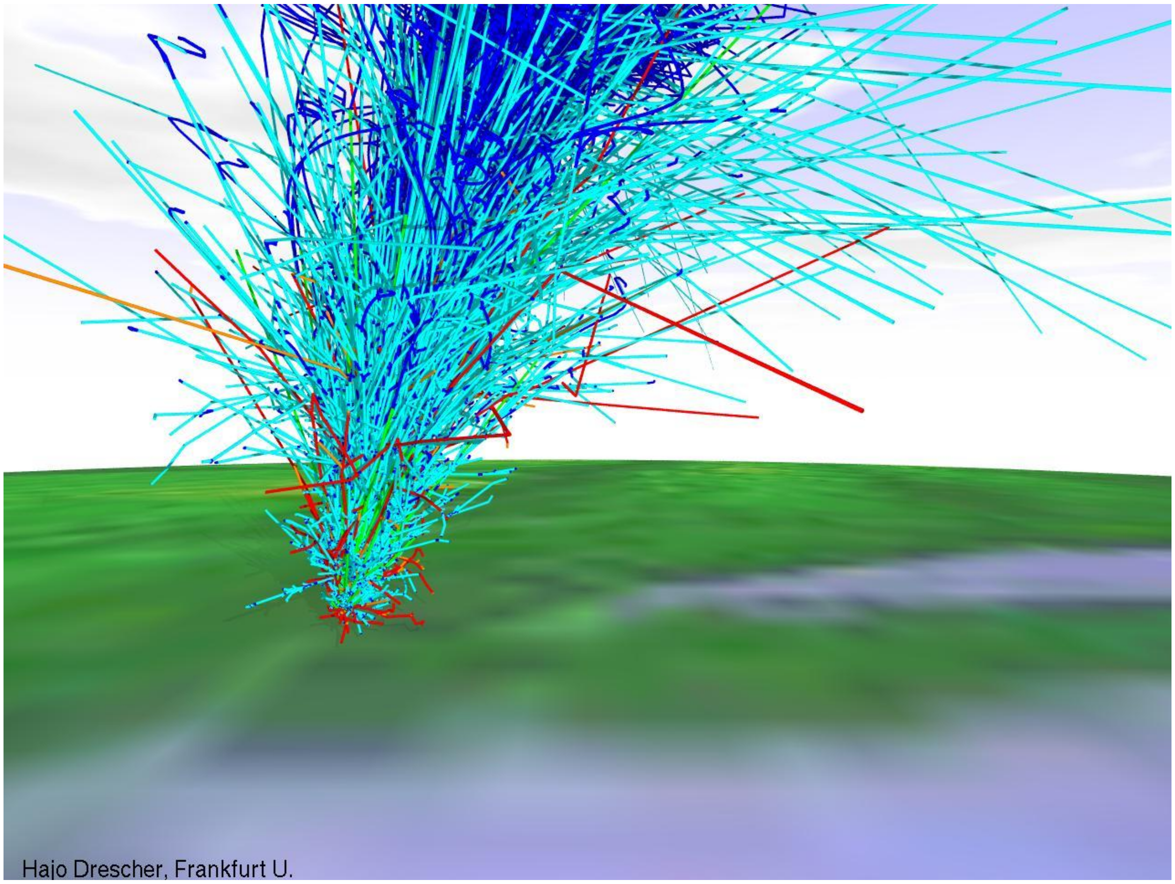


Figure 3.5 I
This is a vertical view of the secondary cosmic ray shower.
http://www.th.physik.uni-frankfurt.de/~drescher/CASSIM/

blue: electrons/positrons
cyan: photons
red: neutrons
orange: protons
gray: mesons
green: muons

This interaction of primary cosmic rays causes a graph as in Figure 3.6. The reason for the peak has to do with the interaction length which is given by the following muon example.

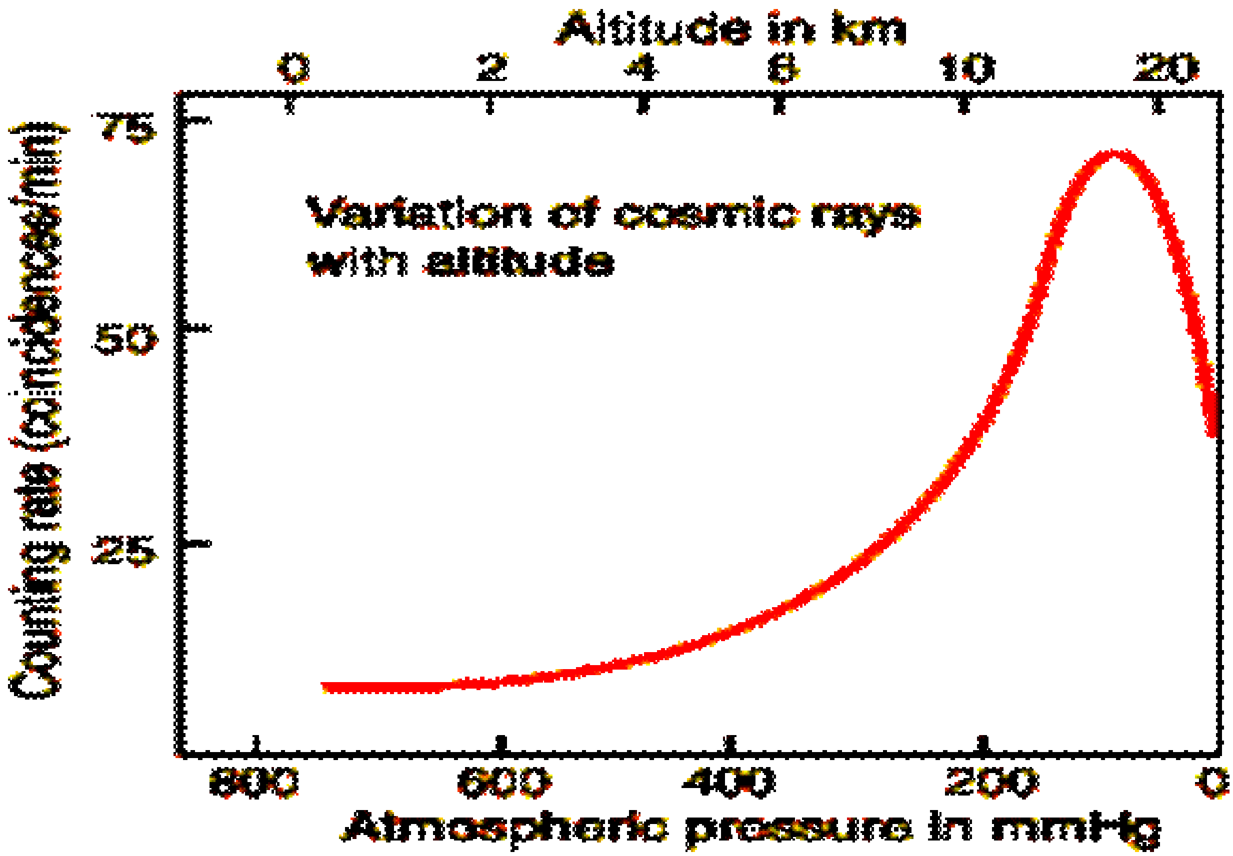


Figure 3.6
This shows the theoretical curve of the flux with respect to altitude.

3.1.2 Muons

Muons are the most numerous charged particles at sea level. In other words, muons must lose energy by ionization because it is charged. There is no way around this because as it passes through matter it interacts with the electric fields which knocks loose off some of the outer electrons; however, muons only interact by ionization. Because of this, muons are able to travel large distances and reach the Earth's surface. Their only energy lost is proportional to the amount of matter they pass which is proportional to the density (g/cm^3) times the path length (cm). This "interaction length" has units of grams per square centimeter (see "Interaction Depth") (Reference 17).

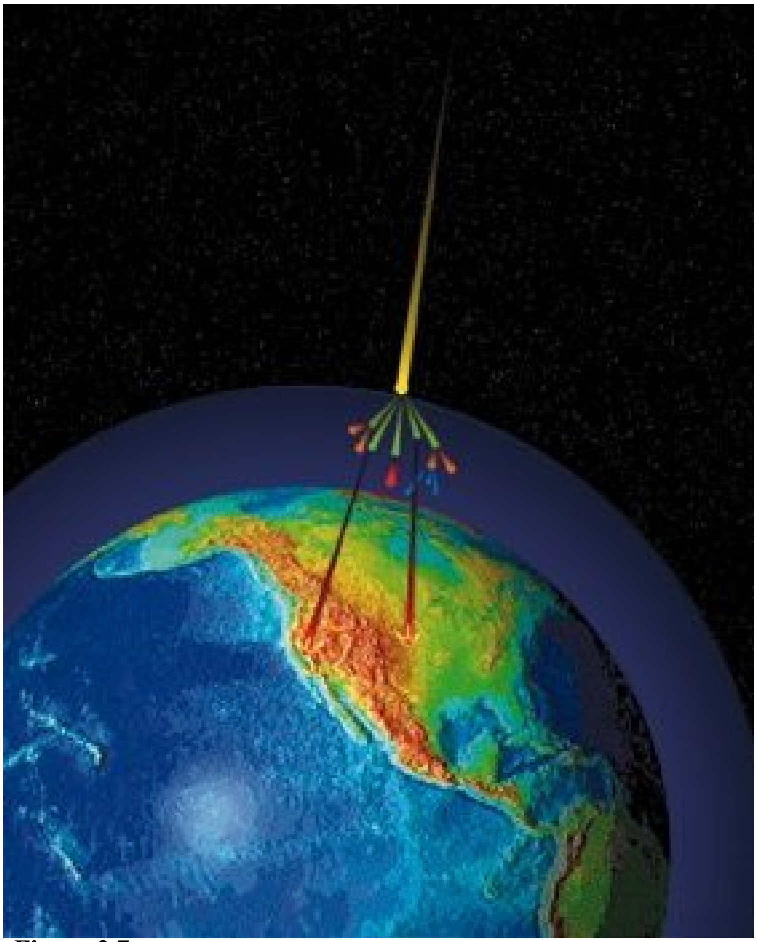


Figure 3.7
This graph just shows the primary cosmic rays entering Earth's atmosphere and creating muons.
http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Muons.htm

The Muon energy lost is a constant rate of about 2 MeV per g/cm^2. Since the vertical depth of the atmosphere is about 1000 g/cm^2, muons will lose about 2 GeV to ionization before reaching the ground. The mean energy of muons at sea level is still 4 GeV. Therefore the average energy at creation is approximately about 6 GeV (Reference 17).

The atmosphere is so weak at higher altitudes that even at 15 km it is still only 175 g/cm^2 deep. Typically, it is about here that most muons are generated and also the peak of the flux of the cosmic rays. The average muon flux at sea level is 1 muon per square centimeter per minute. This is about half of the typical total natural radiation background (Reference 17).

Muons (and other particles) are generated within a cone-shaped shower, with all particles staying within about 1 degree of the primary particle's path (Reference 17).

3.1.3 Non-Vertical Muons

Muons arriving at some angle θ from the vertical will have traveled a path length that increases as $1/\cos(\theta)$. (See "Slant Depth") This assumes that the Earth is essentially flat (less than 1% error for $\theta < 70°$) and that muons do not decay over the extended path length (Reference 17.

If we assume that twice the path length would attenuate the muons to half as many, then we would expect the muon flux to vary as the cos (θ). However, the observed distribution is proportional to $\cos^2$ (θ). This is a difference of less than 10% at an angle of 27° and 20% at 43°. This difference may be primarily due to the approaching decays of muons, as the path length exceeds their range (Reference 18).

3.1.4 Interaction Depth

The energy of charged particles is progressively absorbed by ionizing the matter it passes through. The greater the matter and the greater the distance, the more absorption. Cosmic rays pass through a great variety of environments, from the almost absolute emptiness of extragalactic space to the relative mess of our atmosphere, to the extreme density of our Earth or even lead shielding. We need to measure the path length that would help us predict the absorption. At any point along the path, the number of interactions is proportional to the density (r) times the path length (dr). If we were to add up all of these interactions along the particle's path, we would get a number that should be proportional to the total absorption (Reference 18).

If density has units of g/cm^3 and the path length is in units of cm, then this Interaction Depth, X, has units of g/cm^2. At first it seems strange to be talking about some sort of distance with units of g/cm^2, but it does allow us to compare the effects of passage through kilometers of the upper atmosphere, to passage through a few centimeters of water (Reference 18).

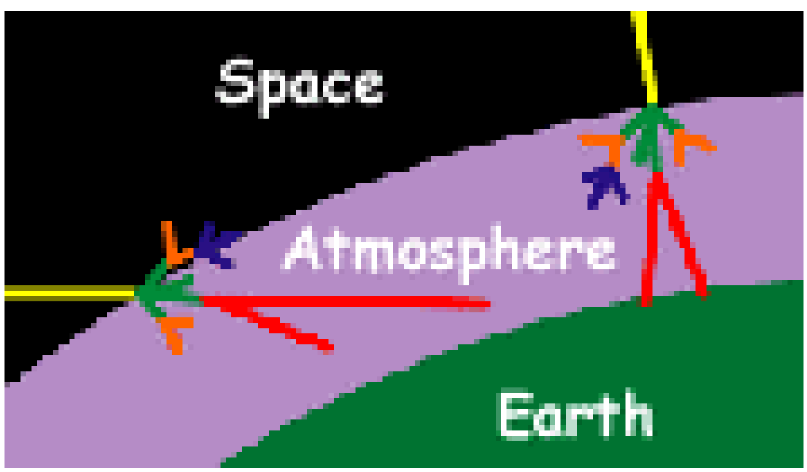


Figure 3.9
This Picture shows that different angles that the can be formed when the primary cosmic rays reach Earth.
http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Interaction.htm

The pressure here at the surface of the earth, although partly due to dynamic effects of air movement, is mostly due to the total weight of the air above that point. The cross-sectional area of a column of air radiating directly upward, gets larger as it rises. The acceleration of gravity decreases as you get farther away. However, the earth is so large and the atmosphere so thin, that both of these values are essentially constant (to within 1%) (Reference 18).

$$P = \frac{F}{A}$$

$$F = \int g\,dm = \int_{\lambda}^{\infty} g\,p\,A\,dr = gA \int p\,dr = PA$$

$$\chi = \int p\,dr = \frac{P}{g}$$

Thus at some altitude h, the pressure divided by g ($=9.8 m/s^2$) is a measure of the absorption along a vertical path to that point. The 1967 Standard Atmosphere (see article later) gives us empirical equations to calculate the pressure at any altitude. The standard atmospheric pressure at sea level is defined as 101,325 Pa. The "depth" X, is therefore equal to ~10,000 kg/m^2 or 1000 g/cm^2. As divers know, a depth of 10 meters in water (density = 1 g/cm^3) provides an additional atmosphere of pressure. In other words 10 meters of water will provide the same absorption as the entire thickness of the atmosphere (Reference 18).

Material	Density (g/cm^3)	Thickness 1 Atm. Equivalent
Interstellar Space	10^{-23}	100 million LY
Air at 15,000 m (muon production zone)	0.00019	53,000 m
Air at 12,500 m (max. KAO experiment)	0.00029	34,000 m
Air at 4,000 m (Top of Mauna Kea)	0.00082	12,000 m
Sea Level Air	0.00125	8,000 m
Water	1	10 m
Rock	5	2 m
Iron	8	1.3 m
Lead	11	0.9 m

Table 3.1
This chart shows different materials with their densities and their equivalent to 1 atmospheric pressure.
http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Interaction.htm

Altitude		Note	Density	Pressure	Depth
ft	m		g/cm^3	Pa	g/cm^2
233,000	71,000	Top of Std Atmosphere	$6x10^{-8}$	67	0.7
105,000	32,000	Halfway	$1x10^{-6}$	868	9
49,000	15,000	Zone of Muon production	$2x10^{-4}$	12,000	130
41,000	12,500	Max. alt. KAO experiment	$3x10^{-4}$	18,000	180
36,000	11,000		$4x10^{-4}$	23,000	230
13,000	4,000	Top of Mauna Kea	$8x10^{-4}$	62,000	630
0	0	Sea Level	$1x10^{-3}$	101,000	1,000

Table 3.2
This chart shows different altitudes with their density, pressure, and depth.
http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Interaction.htm

3.1.5 Slant Depth

All of the above Depth calculations are true only for muons arriving vertically. By simple trigonometry, it can be seen that dr' (distance along the slanted path) is equal to dr / cos (θ) where θ is the angle of the path measured from vertical (Reference 18).

Given a slant depth, we can use the standard atmosphere pressure equation to extrapolate an equivalent altitude that would correspond with this depth if it were vertical. This will allow us, using ground level measurements, to extrapolate the muon intensity vs. altitude graph from the KAO experiment to negative altitudes (i.e. below sea level) (Reference 18).

In the following table: X' = X / cos (θ), The Equivalent Altitude uses the 1st layer pressure equation from the standard atmosphere model. The last three columns are provided as a comparison to the observed $\cos^2$ distribution to which the particle data book refers. The discrepancy is most likely due to muon decays (Reference 18).

θ	Slant Depth, X' (g/cm^2)	Equiv. Altitude (m)	$X_0 / \cos^2(\theta)$ (g/cm^2)	cos (θ)	$\cos^2(\theta)$
0 °	1,034	0	1,034	1	1
15 °	1,070	-293	1,108	0.966	0.933
30 °	1,194	-1230	1,378	0.866	0.750
45 °	1,462	-3,022	2,068	0.707	0.500
60 °	2,068	-6,249	4,135	0.500	0.250
75 °	3,994	-13,000	15,432	0.259	0.067

Table 3.3
This graph shows the various angles.
http://www.lbl.gov/abc/cosmic/SKliewer/Cosmic_Rays/Interaction.htm

All of the following sections on Muons explained in depth the interaction length of cosmic rays and gave some examples of each.

3.2 Technical Goals

Our technical goals are as follows:

1. Accurately measure the total flux of the cosmic rays with respect top altitude.
2. Obtain knowledge of sensors, electronics, and systems
3. Learn how to develop and maintain a research program
4. Learn how to create different environmental simulation testing
5. Have a successful flight
6. Obtain useful accurate information

The major technical goal of this experiment is to accurately measure the total flux of the cosmic rays with respect to altitude. We also expect to get a graph that will look similar to Figure 3.2. To do this, we must keep the temperature to no less than -20 °C because that is minimal operating range. To do this, we will be using a heating circuit that should keep the temperature to above 0 °C.

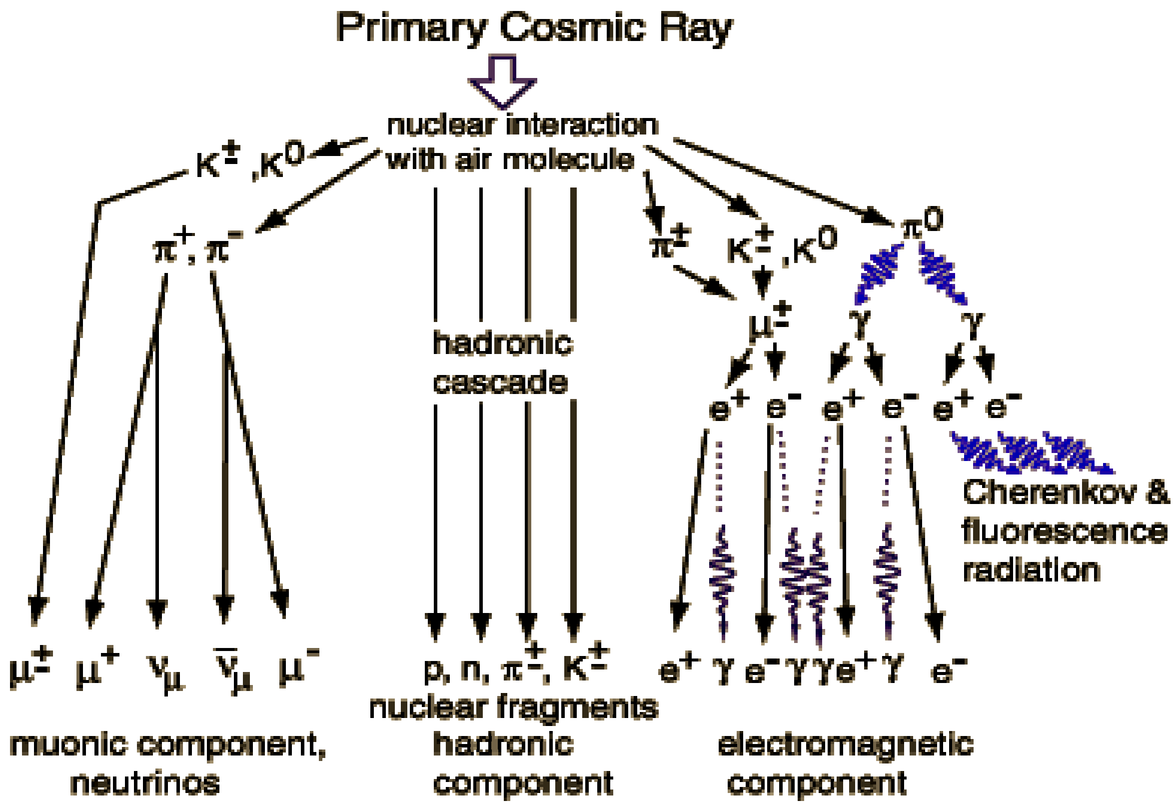


Figure 3.10
Graph showing the shower of secondary cosmic rays.
http://hyperphysics.phy-astr.gsu.edu/hbase/astro/cosmic.html

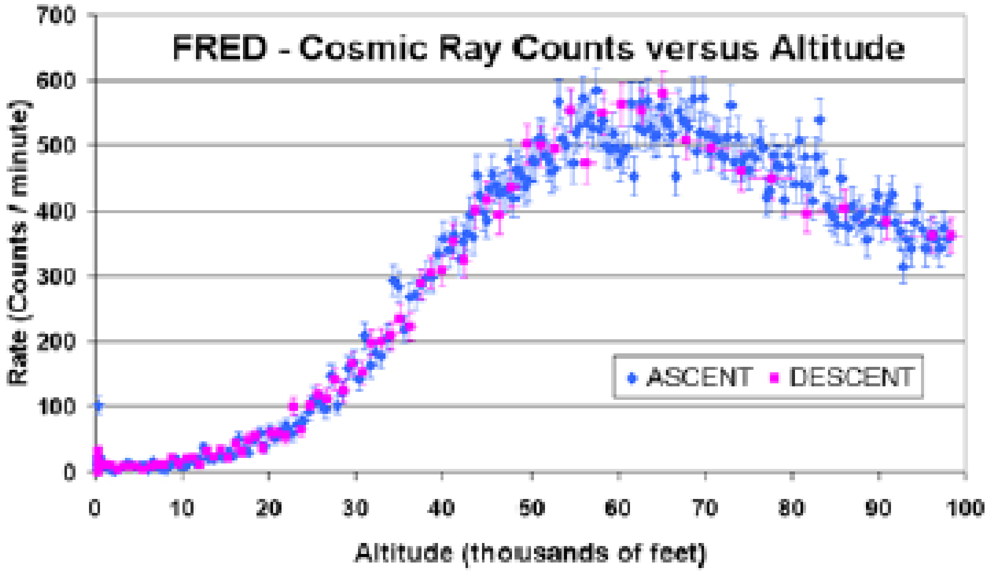


Figure 3.11
Expected results, according to FRED experiment performed by LSU team

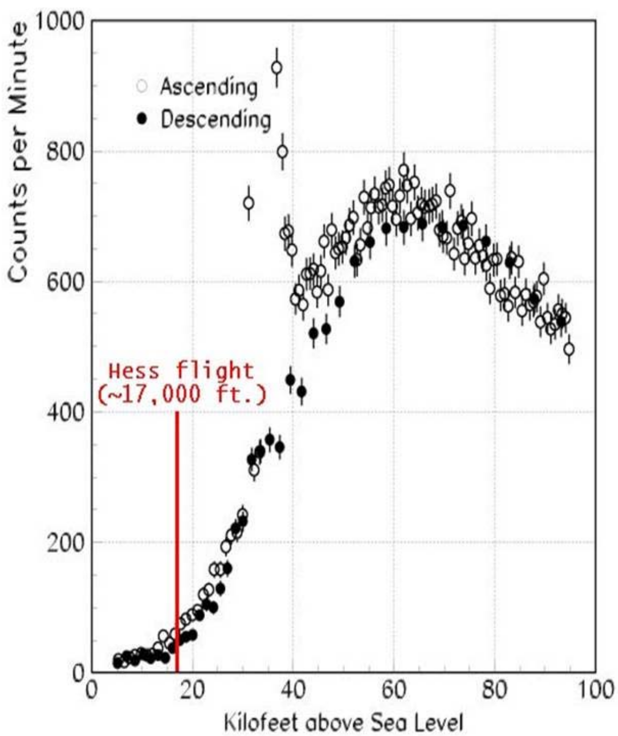


Figure 3.12
This is another cosmic ray experiment. It was performed on FLIGHT#: BOR0109A by the Montana High Altitude balloon program.
http://spacegrant.montana.edu/borealis/missions/BOR0109A/index.php

4.0 Payload Design

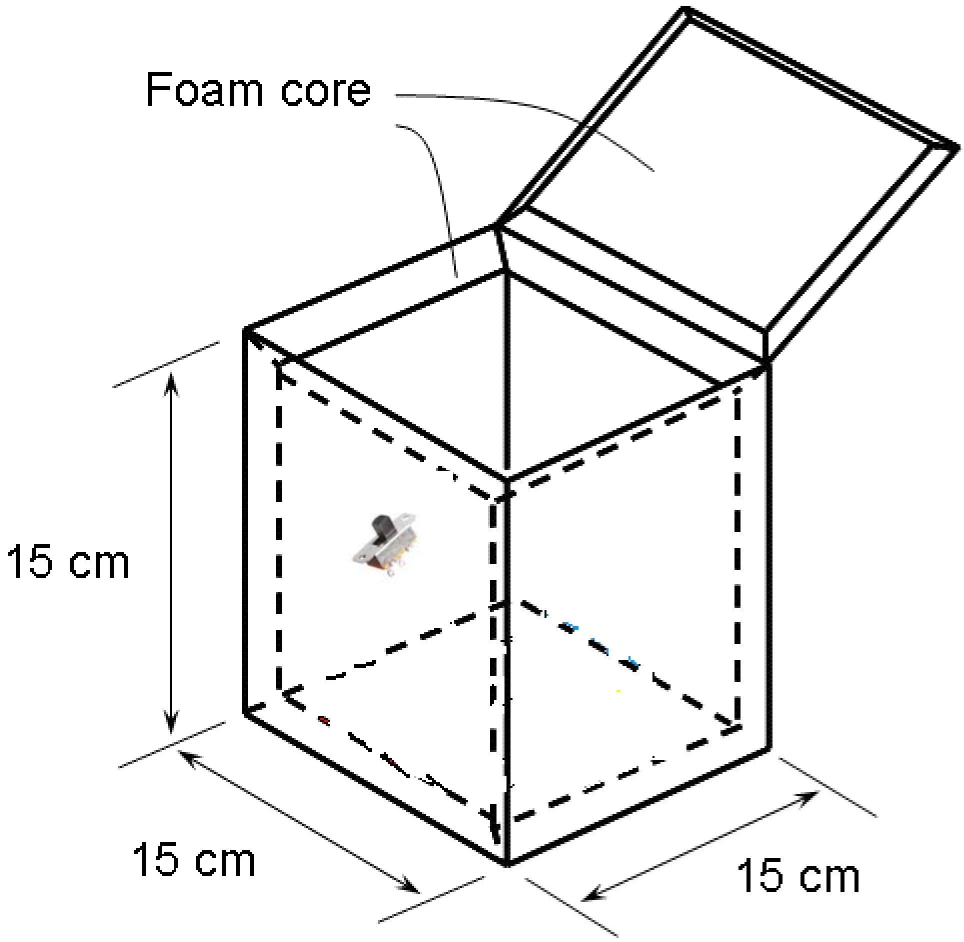


Figure 4.1
This is the outer box which will house our inner box. This box will also have a switch on the outside running from the BalloonSAT to outside the box. This is for us to be able to turn on the BalloonSAT just before launch to conserve battery power.

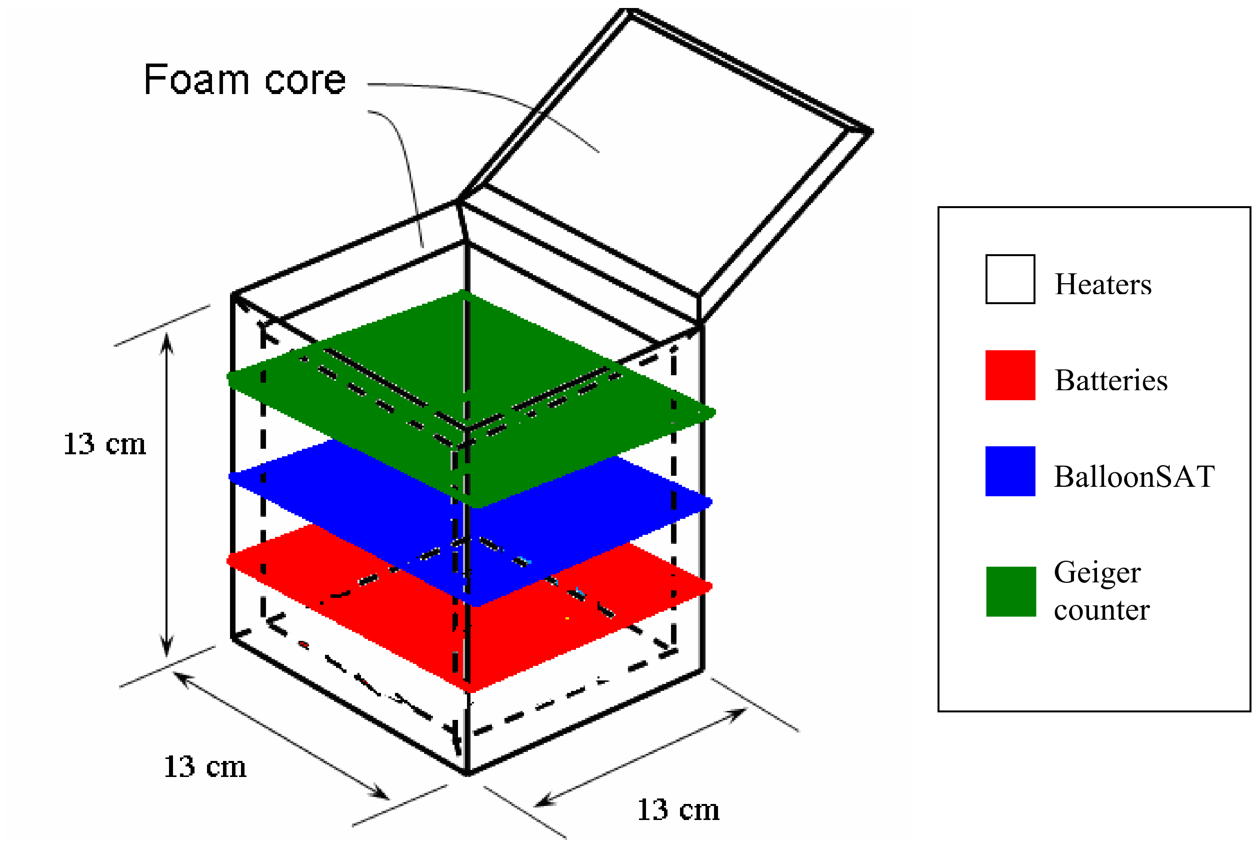


Figure 4.2
Diagram of our inner box.

4.1.1 Geiger Counter

The first thing that we need to calculate the flux is the amount of particles (counts) at a given altitude. To get this, we will use a Geiger counter, which according to *Webster* is an instrument for detecting the presence and intensity of radiations (as cosmic rays or particles from a radioactive substance) by means of the ionizing effect on an enclosed gas which results in a pulse that is amplified and fed to a device giving a visible or audible indication. The exact gas varies for each detector, but it always includes a mixture of gases. This mixture always includes an inert gas, usually neon or argon, and organic vapor such as halogen or alcohol vapor. (Reference 19)

The Geiger counter we will be using is the Geiger Muller Counter - Nuclear Radiation Detector K2645. This Geiger counter like every other Geiger counter consists of two basic parts: the probe and the counter. The probe is filled with a gas with a wire down the middle that measures the radiation. This probe has two primary functions: keeping track of how much radiation is detected by means of a counting circuit and to provide power for every component on the Geiger counter. (Reference 14)

Once power is supplied to the probe, a large potential is created making the central wire become the anode, and the metal wall becomes the cathode. At this stage, the gas is neutral until radiation enters the probe creating a shower of particles inside the tube. This shower knocks off electrons creating both free electrons and gas ions which force the electrons to be pulled off rapidly to the central wire. Once this happens, the electrons are collected on the wire are sent through the wire into the counting circuit which measures the current. As this process occurs, the gas ions are slowly building up around the outer wall of the probe which forms a “sheath”. This reduces the potential and stops the cascade of secondary particles. Once the cascade has ended, the ions and electrons recombine to form the neutral gas atoms again. This process, called quenching, and serves to “reset” the detector, allowing it to detect another radioactive emission. This cycle of the first ionization to the resetting is referred to as the dead time and is typically 100 to 300 microseconds. To get a better picture of this, see Figure 3.6 (Reference 14).

Another thing that we must figure out for the Geiger counter to operate effectively is the Geiger plateau. If the voltage is too low, the passage of radiation into the tube will not cause a voltage pulse. The characteristic curve for any tube is obtained by graphing the counting rate verses the applied voltage. This curve is shows in Figure 4.3. The counting rate *C* is the number of counts *N* registered by the tube divided by the counting time *T*. The region where the number of counts is approximately linear and changes little with voltage is called the Geiger plateau. To preserve the life of the tube, the operating voltage is generally selected within the initial 1/3 of the plateau. We will find this plateau for our calibration Geiger counter by placing a radioactive source and adjusting the voltage. Afterwards, we will graph our data and determine the appropriate operating voltage. The exact procedures used to obtain the graph in Figure 3.8. was designed by the University of Louisiana at Lafayette physics department for the Modern Lab. We will not be able to find the Geiger plateau for the K2645 Geiger counter. Therefore, the plateau will only be used to ensure that our calibration detector is operating correctly. Once we have determined this, we will measure the flux of both Geiger counters, with the same source from the same distance, and compare the results.

After doing this, we will find the dead time of each Geiger counter. Once we find the dead time, we will compare the flux of each Geiger counter. The dead time procedures will be explained in a later section. After we complete all of this, we will know that the K2645 is operating correctly.

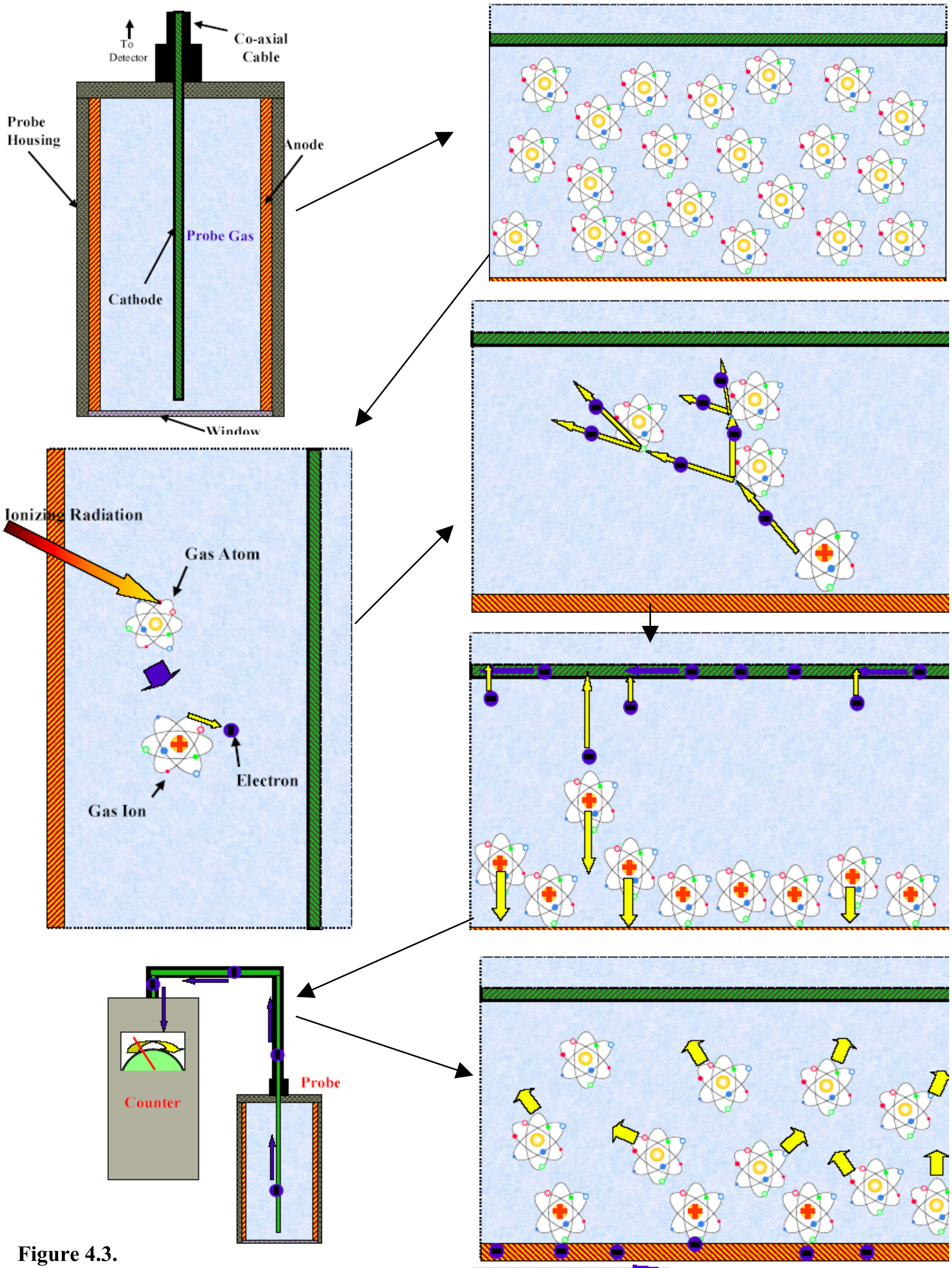


Figure 4.3.
This shows how exactly a Geiger counter works.
http://nstg.nevada.edu/PAHRUMP/Microsoft%20PowerPoint%20-%20Geiger%20Counter%20Diagrams.pdf

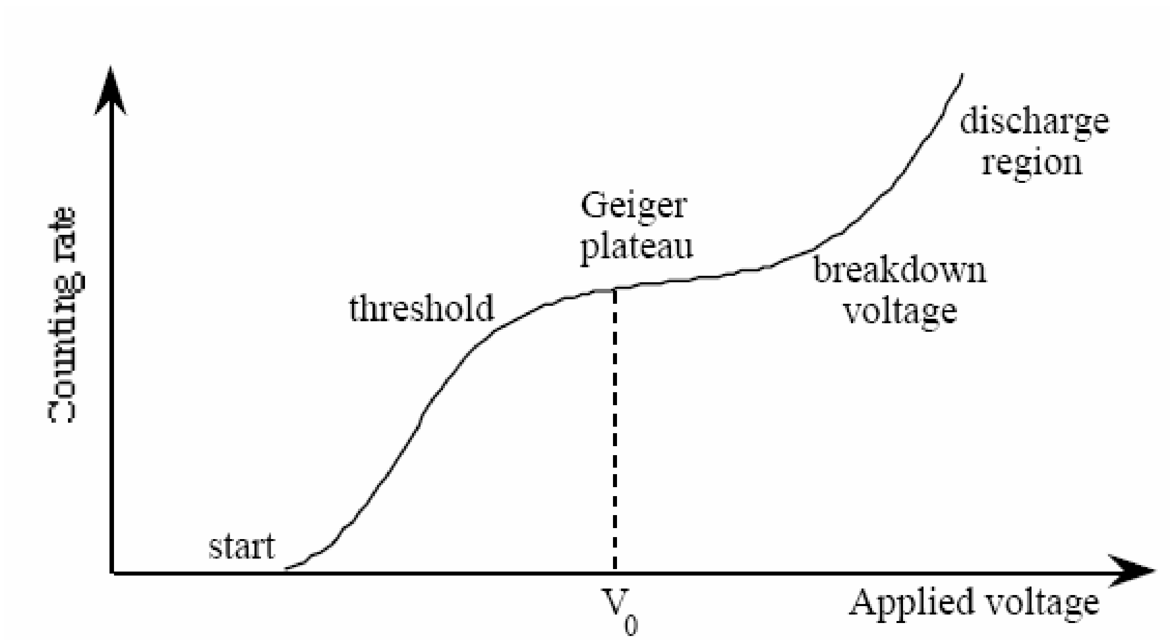


Figure 3.7
This is the theoretical Geiger counter voltage curve.
http://polaris.phys.ualberta.ca/info/Phys29x/Manual/11GM01.pdf

4.1 Principle of Operation

The Geiger-Muller Counter will measure the flux of cosmic rays in counts per minute. This counter will be interfaced with the BASIC Stamp, sending data to the EEPROM of the BASIC stamp. Temperature measurements will be collected throughout flight and stored into the BASIC stamp. These measurements will be used to determine that the electronics remained in operating temperature range (-20 ºC – 70 ºC). To maintain this temperature there will be two heating circuits inside the payload as noted in the above figure 4.1. If a particular section of collected data seems inaccurate, we can reference our temperature data for a plausible cause of the inaccuracy. After flight using pre-tested software, the data will be dumped from the EEPROM of the BASIC Stamp. The goal of our payload is to combine the collected data from flight, and the tracking team's data to produce a final graph of the intensity of cosmic rays in flux with respect to altitude as described in section 3.0.

Requirements	Hardware
Internal temperature must remain at a minimum of -20 ºC for proper functioning of electrical devices	One heating circuit and a double box design will be used to ensure that the temperature does not go below -20°C.
To determine if electronics stayed in necessary temperature range. Temperature readings are needed to be collected	Thermistors on the BalloonSAT will be used to make sure that we have maintained a correct operating temperature.
Data needs to be stored from Geiger Counter in order to analyze results in the end, also a timing device is necessary to keep accurate accounts of the time in which the data from the Geiger counter came so it can match with the corresponding temperature reading.	BASIC Stamp is connected to BalloonSAT, which has a timing circuit already built in, is inside payload and two EEPROM's for storage of the Geiger Counter and temperature readings

Fig 4.2
Table of the flow from Requirements to Hardware

4.1.2 Flux

The second thing we need to know to calculate the flux is the surface area of the detector. This turns out to be really simple because the particles are traveling near the speed of light making the Geiger tube a stationary target for the particles (see Figure 3.18). Also for the most part, the Geiger counter will only rotation along the xy-axis with very little motion around the z-axis This means all we need to do is measure the length and width of the active area of the detector. We did this by using a vernier caliper to get very accurate (±0.05 mm) measurement and then substituted the results into the following equation:

$$\text{Area} = (\text{length}) \times (\text{width})$$

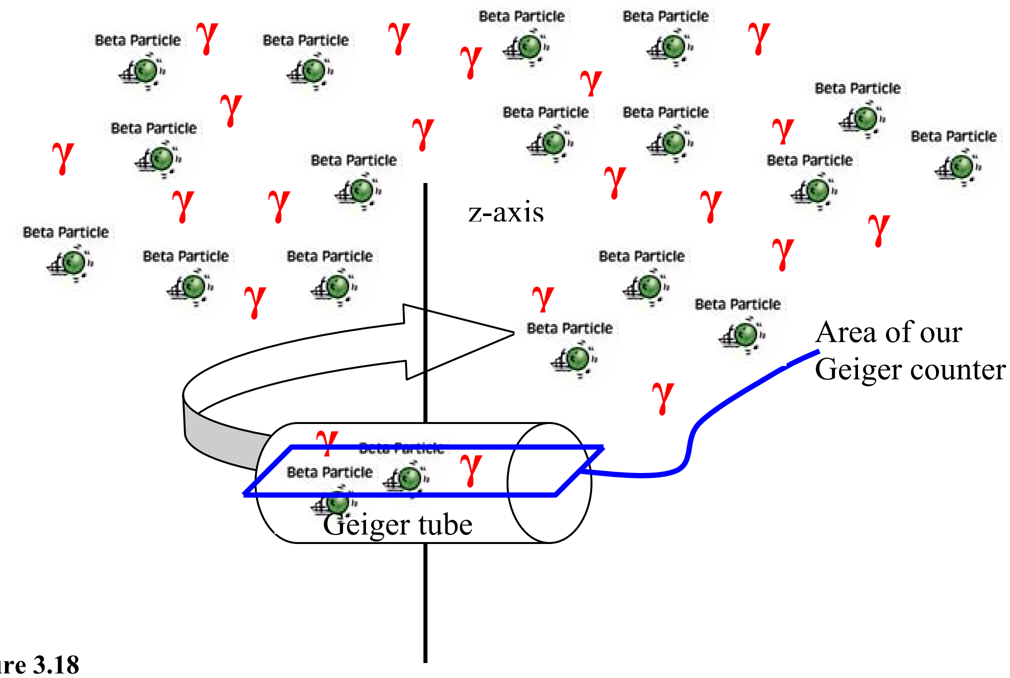


Figure 3.18
This picture shows that the Geiger counter tube will be spinning mostly along the z-axis and the radiation will mostly be coming from the top down making the Geiger counter area a rectangle to the particles. This is shown by the blue box around the Geiger counter. Also alpha particles are not shown even though they are present in the atmosphere they will not be able to get through the two layers of foam core.

Calculations of Area of the Geiger Muller counter K2645

Dimensions of Geiger counter	
Length	2.287 cm ± 0.05 mm
Width	0.516 cm ± 0.05 mm

Table 3.6
This is our measurements of the active area of the Geiger Muller tube.

$$\text{Area} = (2.287\text{ cm}) \times (0.516\text{ cm})$$

$$\text{Area} = 1.180092\text{ cm}^2$$

$$\text{error} = \pm \frac{1}{\frac{\pi}{2}} \int_0^{\frac{\pi}{2}} (\text{length}) \times (\text{width}) \times (\text{Sin}\,\theta)\, d\theta$$

$$\text{error} = \pm \frac{1}{\frac{\pi}{2}} \int_0^{\frac{\pi}{2}} \left(22.87 \times 10^{-3}\ \text{m}\right) \times \left(5.16 \times 10^{-3}\ \text{m}\right) \times (\text{Sin}\,\theta)\, d\theta$$

$$\text{Average area} = 0.751\ \text{cm}^2$$

Every thing in science has error and this experiment is no exception. To show the error in our calculations, we will use error bars. Our error bars are calculated using the average area formula. See the following:

$$\left(\frac{\sigma_A}{A}\right)^2 = \left(\frac{\sigma_L}{L}\right)^2 + \left(\frac{\sigma_W}{W}\right)^2$$

$$\sigma_A = 1.17 \times 10^{-2}\ \text{cm}^2$$

4.2 System Design

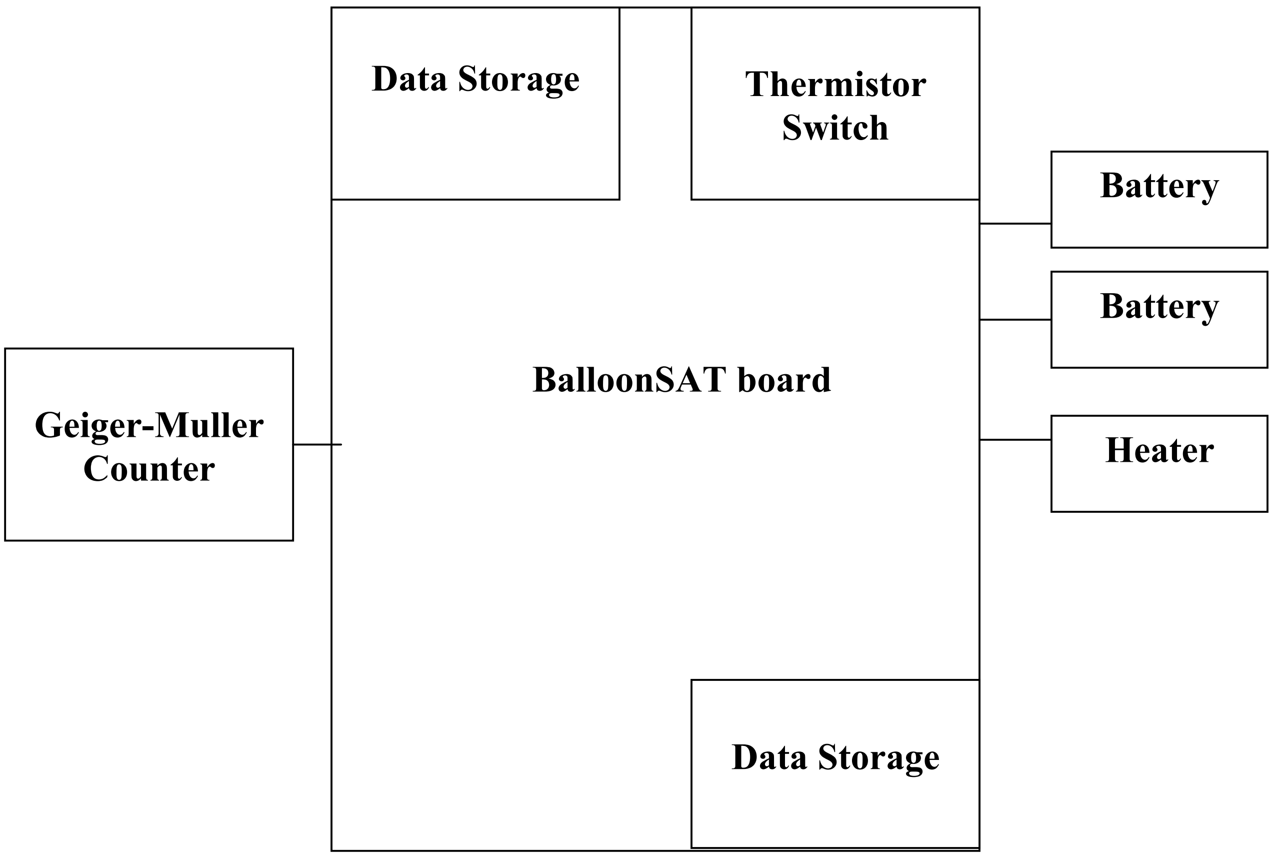


Fig 4.3
Major Components of payload

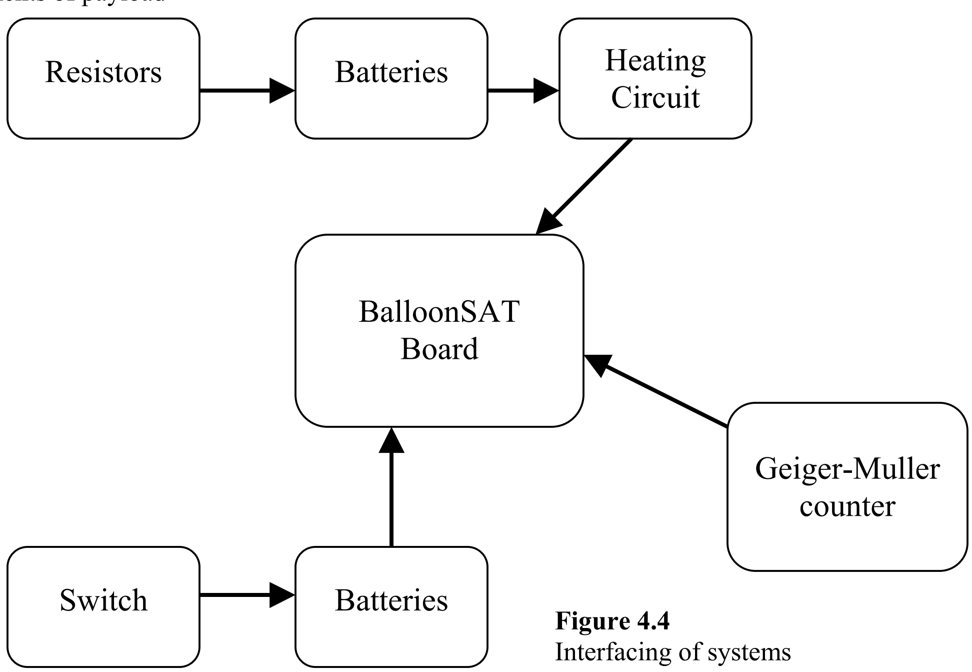


Figure 4.4
Interfacing of systems

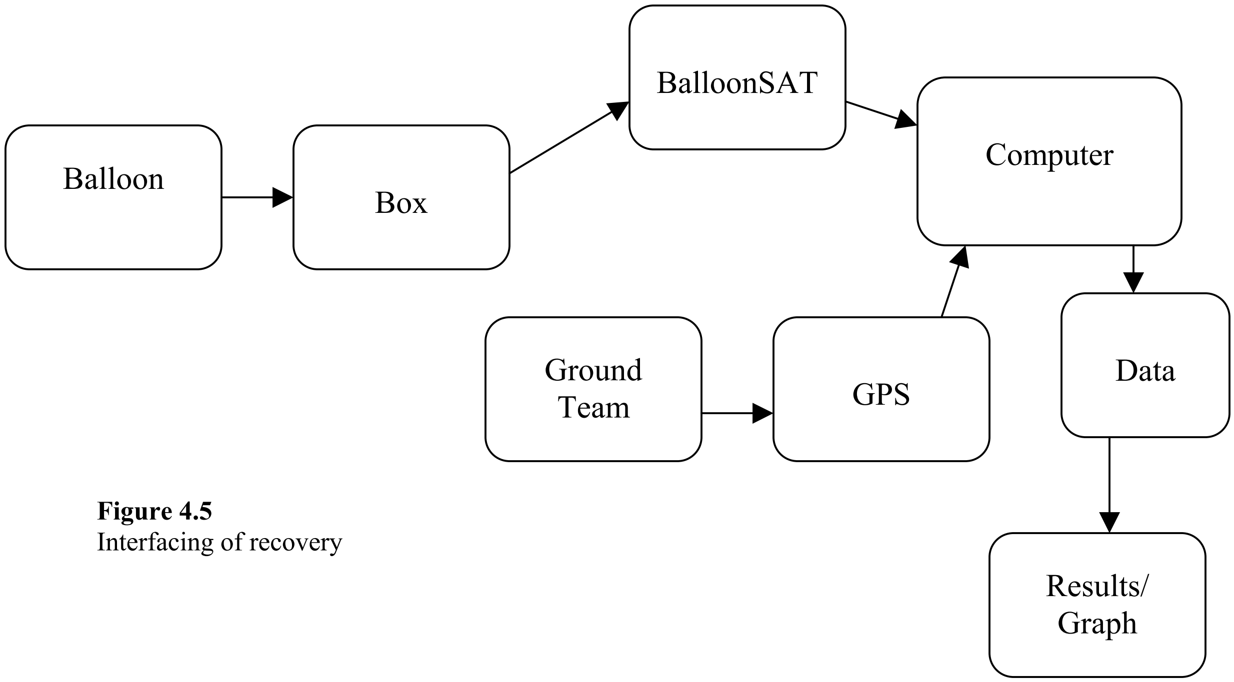


Figure 4.5
Interfacing of recovery

There will be electrical interfacing between the following:

- Geiger to BalloonSAT
- Heaters to BalloonSAT
- Batteries to BalloonSAT
- Switch to batteries

There will be the following Structural Interfaces

- Board to payload
- Geiger to payload
- Heaters to payload
- Switch to payload
- Batteries to payload
- Payload to Balloon

There will be the following software Interfaces

- Geiger to BalloonSAT
- BalloonSAT to personal computer

4.3 Electrical Design

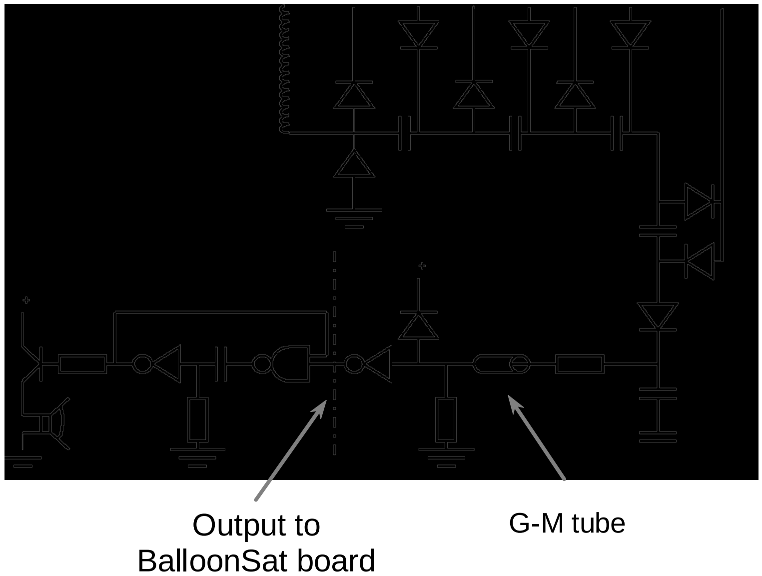
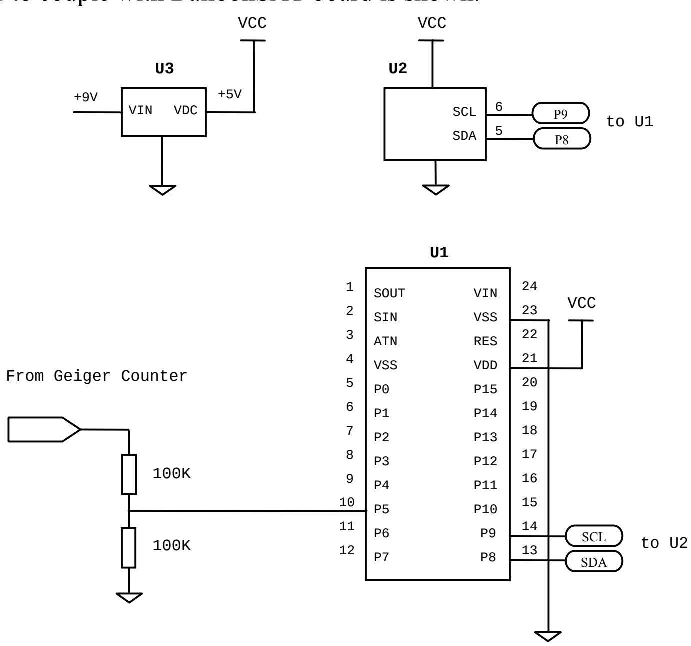


Figure 4.6 A
Geiger-Mueller counter schematics
The modification in order to couple with BalloonSAT board is shown.



U1 – BASIC Stamp Microcontroller (BS2P24)
U2 – EEPROM Memory (24LC64)
U3 – Power regulator

Figure 4.6 B
Interfacing BASIC Stamp with Geiger Counter Kit

Notations correspond to the ones used in “BalloonSAT Assembly Manual”

Power Budget			
Component	**Voltage**	**Current**	**Power**
BalloonSAT and Geiger Counter	9V	Low :0.04 A High: 0.06 A	Low: 0.36 W High: 0.54 W
Batteries	9V	1.8 A	11.7 W

Table 4.1
This is our power budget table for the flight. There are two lithium batteries being used. One is for the Geiger counter and the other one is for the BalloonSAT and heater.

The power supply of the payload will consist of three 9V lithium batteries. One battery will be supply the Geiger counter and the Interface board while the other battery will provide power to the other electrical units. The complete interfacing design can be viewed in figures 4.3, 4.4, and 4.5. There will be four main electrical components, heating circuits described thoroughly in section 4.4 and figures 4.7a, and 4.7b. This circuit will consist of a 0.5 W ceramic resistor and there will be two of them located within the payload. Temperature data will be stored with the BASIC stamp and its memory on the BalloonSAT board. The final two components are the Geiger counter and the Interface Board which will be interfaced together, reference to figure 4.6 for the interfacing schematics. This interfacing is described as follows:

The CD4040 is used to count the Geiger ticks. The clock input is connected to the middle of two series 100 K resistors. One of the resistors is connected to ground and the other is connected to pin four of IC U1 (the CD40106 or 74C14) on the Geiger counter. The Stamp will be powered from the same 9V battery as the Geiger counter. The 74C157 data selector allows the stamp to read 8 bits of the counter, one nibble at a time. The 9th bit is read by the stamp. All other bits are discarded, allowing up to 512 counts in a one minute period. The A/B selector on the 74C157 doubles as a serial output for the PC interface. The Geiger counter reading is updated once per minute and is based on the total counts received -- from between one minute, and four hours of operation. The longer the device is operated, the more accurate the readings will be. The Stamp sends the minute-by-minute reading out as numeric data, followed by a carriage return and line feed at 2400 Baud. When the Stamp is turned on, this data is immediately sent out through the serial port at 2400 Baud. The data is sent numerically with a line feed and carriage return after each number, the earliest measurement first.

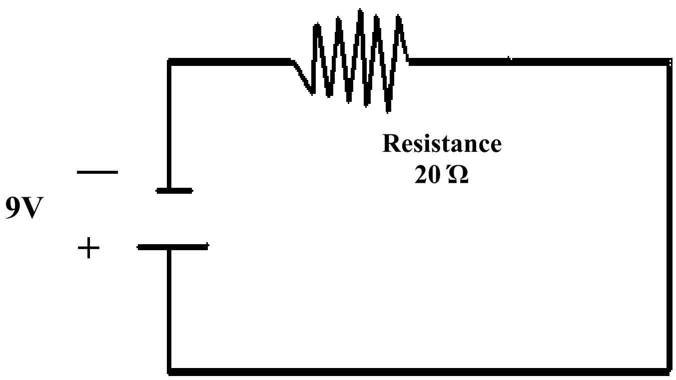


Figure 4.7 a
Circuit design of Heating Circuit

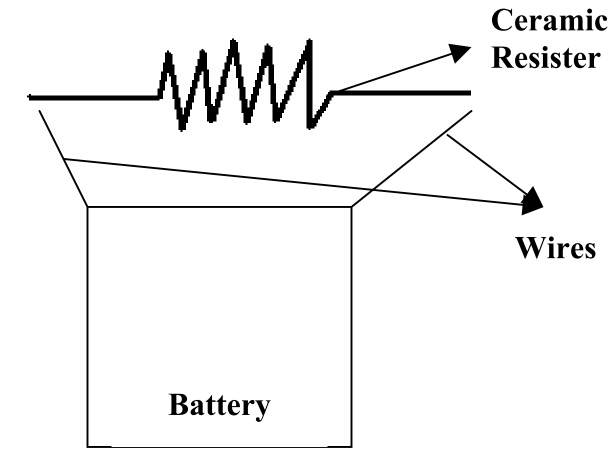


Figure 4.7 b
The heating Circuit design

4.4 Thermal Design

We expect to encounter an environment with temperatures ranging from -60 ºC to 80 ºC. The electrical components in our payload (BASIC stamp, Geiger counter, etc) have operating ranges of minimum -20 ºC to maximum 70 ºC. The only problem this causes is maintaining the payloads temperature at -20 ºC at max altitude, and min pressure. If temperature is not maintained at this level then collected data can become inaccurate, and not sensible. We are going to use two simple heating circuits figure 4.7a, and 4.7b to maintain temperature at operating level. The only temperature dependencies will be remaining in operating temperature range in order to collect valid data.

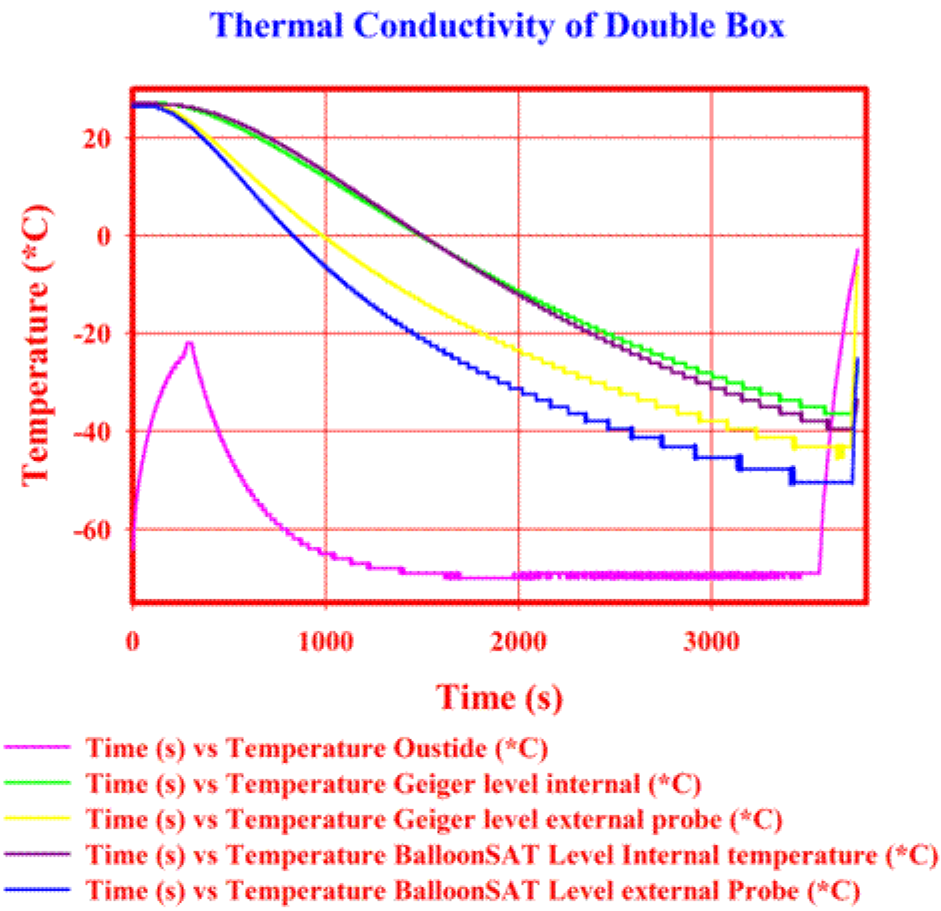


Figure 4.8
This is the results of our heater test.

4.5 Mechanical Design

Figure 4.8A
Top level

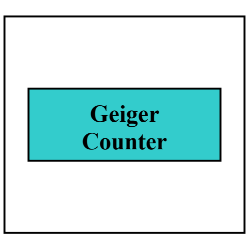


Figure 4.8 A
second level

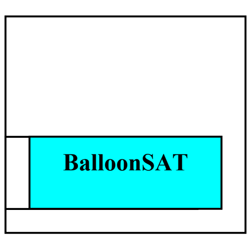


Figure 4.8B
third level

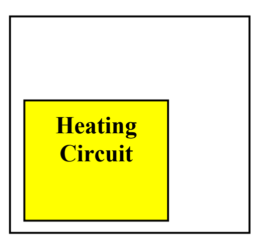
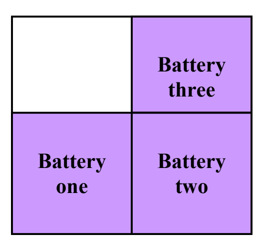


Fig 4.8 C
bottom level



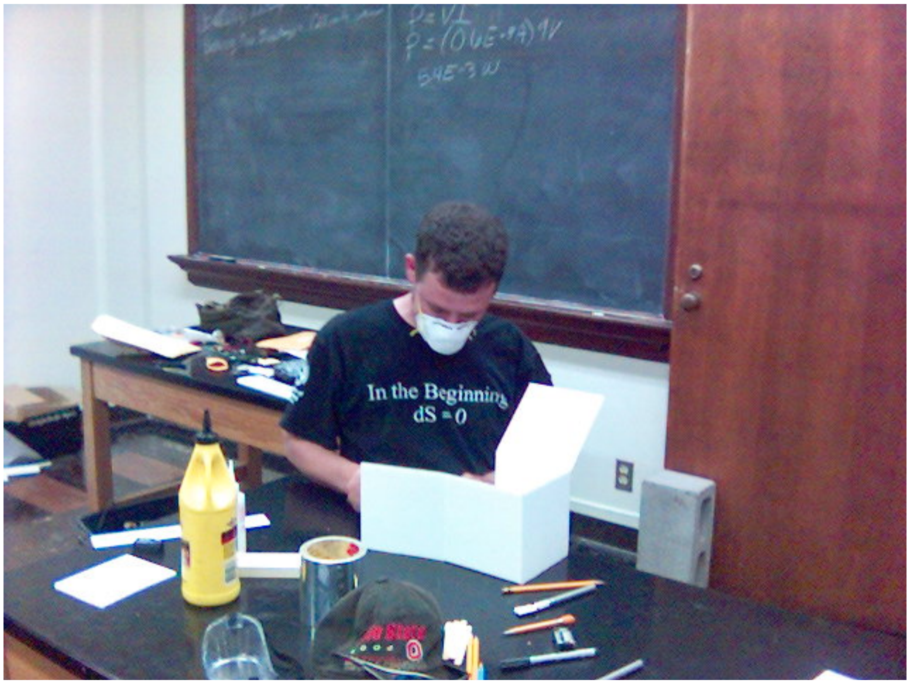


Figure 4.2 A
Robert Moore building the outside box. Mask is used because of the fumes of the epoxy.

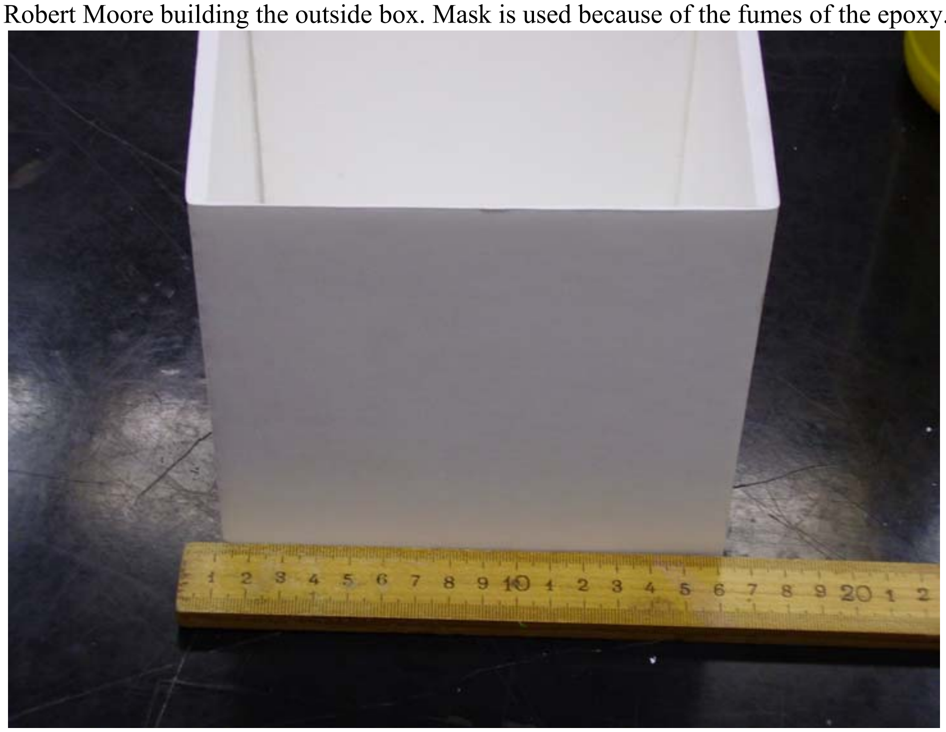


Figure 4.2 B
Picture of the outer box.

Figure 4.2C
This is a picture of the inner box.

See figures 4.1, and 4.3 for a complete picture of the payload. It will contain on the bottom the Geiger counter, and BalloonSAT figure 4.10a, there will be a heating unit.. On the front face three 9 V batteries will be mounted figure 4.10d. Multiple stress test will be performed in the near future for determination of best mounting method for devices inside payload. The interfacing of interior parts of the payload can be examined in Figure 4.4a, and 4.4b.

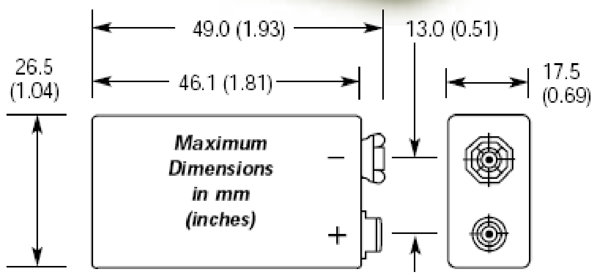
The payload box will be a 15 cm by 15 cm by 15 cm cube box made out of foam board and possibly a second foam board 13 cm by 13 cm by 13 cm. This will be so that we can not have to use a heater eliminating weight. The components will be properly sealed and cushioned in order to withstand the unpredictable flight and landing. The landing could be rough but all we need to recover out of the payload is the memory chip off of the BASIC Stamp. Our weight budget was 450 g.

The battery we are using for all devices is a 9V Lithium Ultra life Longest life battery. The specifications on it are as follows:

ULTRALIFE® BATTERIES INC.

TECHNICAL DATA

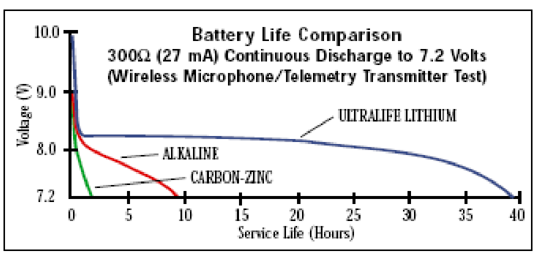
Li/MnO2 Primary System

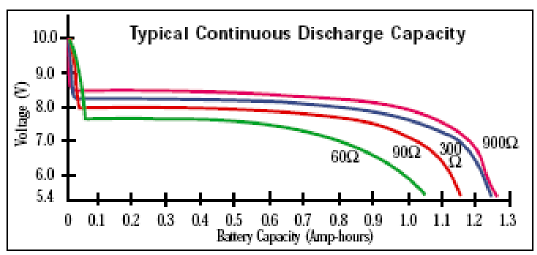


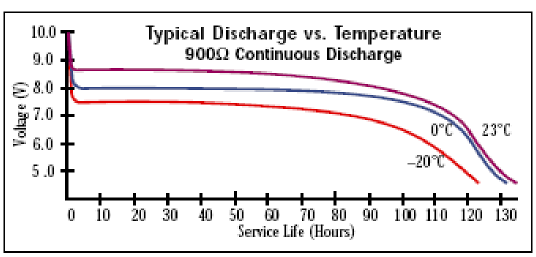
U9VL-J 9V Size Battery

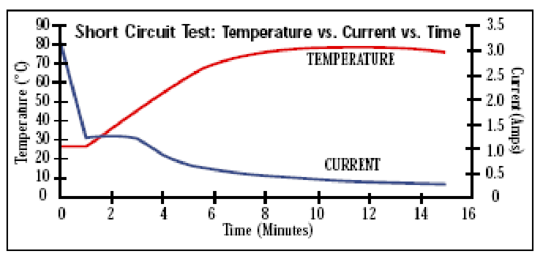
System:	Lithium/Manganese Dioxide
Designation:	NEDA 1604 LC
Nominal Voltage:	9.0 Volts
Capacity (C):	1,200 mAh @ 900 Ω to 5.4V @23°C
Max. Discharge:	120 mA Continuous
Weight:	36.4 grams
Oper. Temp. Range	-20° to 60°C
Storage Temp. Range:	-40° to 60°C
Volume:	22.6 cm^3
Terminals:	Miniature Snap
Housing:	Aluminum/Mylar Label
Safety:	Less than 2 grams of lithium; no restrictions on transport; MSDS available separately

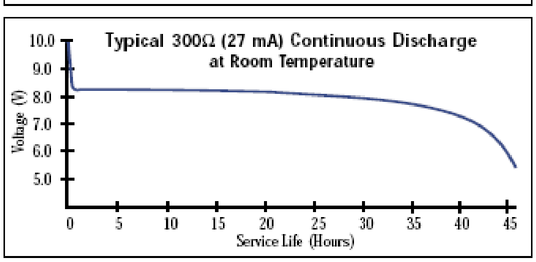
Recognized under the Component Program of Underwriters Laboratories, Inc.

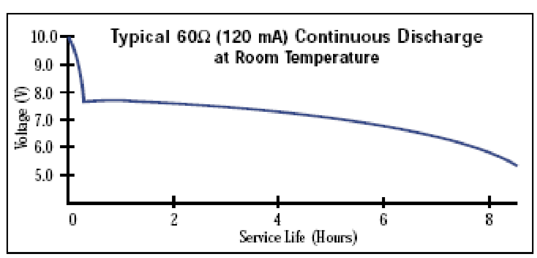












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The information contained herein is for reference only and does not constitute a warranty of performance • Apr 2 '02 • UBI-3002 rev. C

The scale we are using is VIC-303 0.001g Precision Balance with the following features:

- 4 models with milligram readability
- Protective flip-down and removable plastic cover for shipping protection and allows stackable storage
- Integrated external calibration weights
- Unique durable design for all applications
- Applications include: Counting, Percent Weighing, Totaling, Display Hold, Specific Gravity, Mass unit conversion
- 14 Mass unit conversions (g, oz, lbs, lbs: oz, dwt, ozt, grains, Newton, carats, Taels HK/Taiwan/Singapore/China, user defined)
- Optional RS-232 or USB interface kit (field installable)
- Parts counting with selectable reference sample (1-100)
- Included AC adapter
- External one button calibration with 3 weight options
- Lock down capability
- Two year manufacturer warranty

Figure 4.9
Picture of the scale we are using.
http://www.acculab.com/products/

Figure 4.10
Picture of us actually weighing the box.

Calibrations for Balance

To calibrate the weight and get the error we did the following:

1. Put our balance on a level surface.
2. Zero it out
3. Use Fisher #540300 Brass weight set of various weights
4. Use 2 measurements of the weights to get an average error
5. The following is a list of the error:

Weight	Error
200 g	±0.014 g
100 g	±0.019 g
050 g	±0.006 g
020 g	±0.004 g

Table 4.2
Average area of the weights.

Figure 4.11
This one 200 g weight being used to calculate the error of the balance.

Measuring procedures are as follows:

If the weight is less than 300 g we will use the VIC-303 0.001 g Precision Balance and the following procedures:

1. Make sure balance is level
2. Zero out the balance
3. Place the object to weighed on the balance
4. Weight until the balance comes go a general number within to about 0.020 g. We cannot get an exact number because it will continue to fluctuate by about ±0.020g because of environment. We just add this fluctuation to the error with the balance error.

5. Take a picture of the weight to used as documentation
6. Record the weight

Component	Weight (g)
Electronics with 3 lithium batteries	225.56 g
Inner box with balsa wood	90.10 g
Outer box	89.8 g
Foam inserts	12.0 g
Total weight	446.5 g

Table 4.3
Table of the weights of each component with the error. Some of the weights are pending.

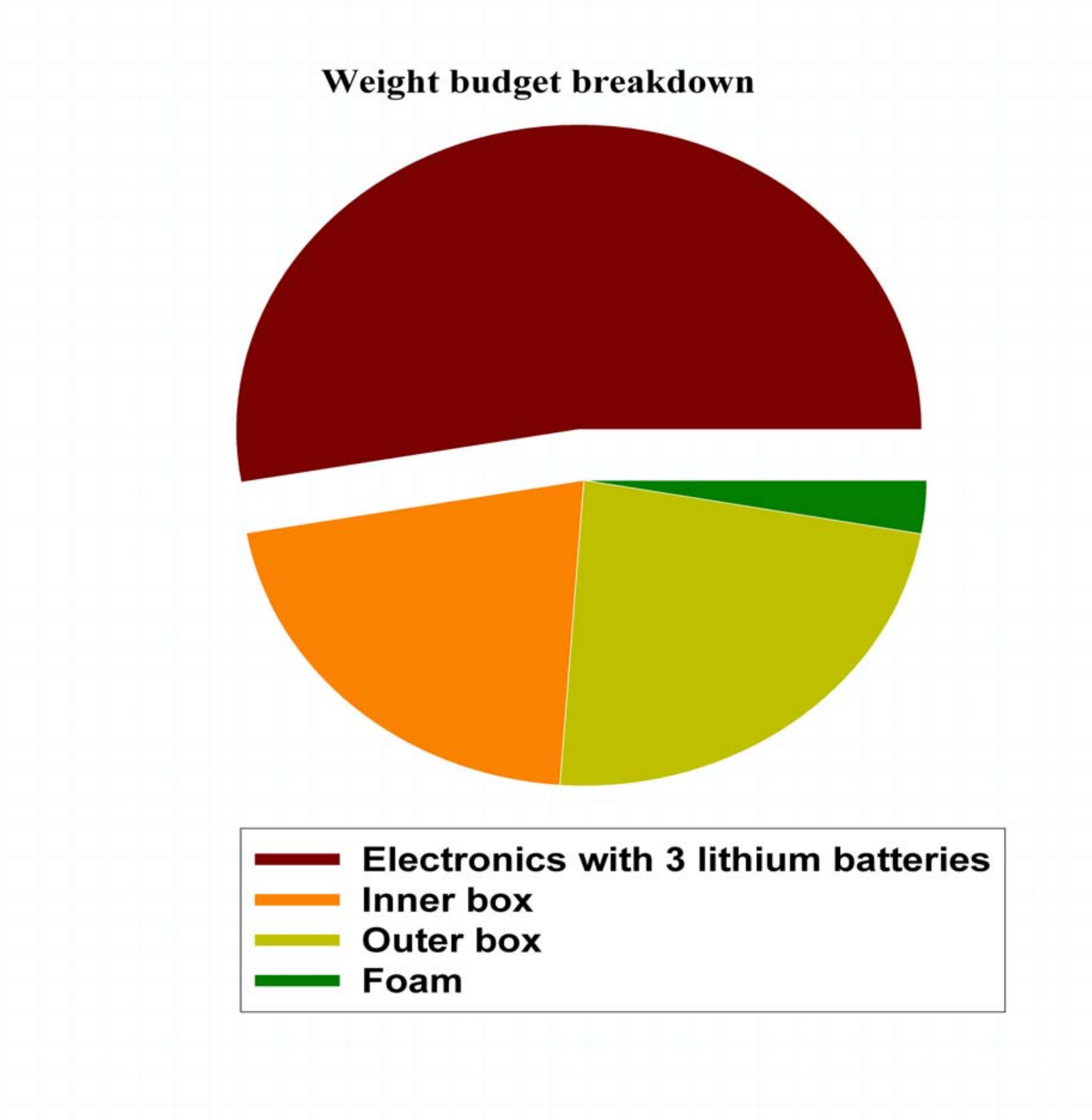


Figure 4.14
Weight Budget Breakdown

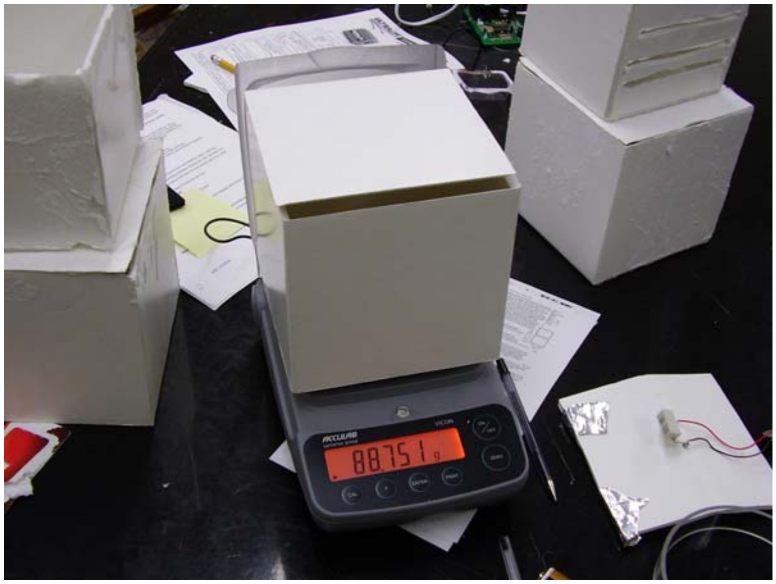


Figure 4.12 A
Weight of our outer box.

5.0 Payload Development Plan

The design for the circuitry involved is complete except for two major points. We still need to do environmental testing for several components and we need to calibrate the Geiger counter. Environmental testing requirements for the flight are -60 ºC and 7.6 Torr. Both of these are approximations based on standard models and previous measurements.

All environment tests are complete except for the heaters and Geiger-Muller counter. The heating problem can only be resolved by prototyping. The question to address is how sufficient is a single 1 W ceramic resistor. This will be accomplished by performing the same environmental testing as for all other components. Both of these points are critical in determining the number of batteries needed for the payload and ultimately final payload mass.

The only other design issue is determining the accuracy of the Geiger counter. This will be accomplished by testing the counter against known gamma sources and calculating the flux at sea level and comparing it to the known flux.

5.1.1 Geiger Muller Counter K2645

The Geiger counter we will be using is the Geiger Muller counter K2645 kit created by Velleman® Inc. This kit provides an acoustic measurement of radiation levels. The sensitivity is at its highest for gamma rays and high energy beta rays. The assembly is compact and may be mounted into a small box, together with the 9V-battery. The specifications are as follows:

1. Battery supply of 9V
2. Maximum current of 200 μA.
3. Sensitive to gamma-rays and high-energy beta-rays
4. Dimensions are 54 x 99 x 25 mm

5. Characteristics of tube have a tolerance of ±10%.

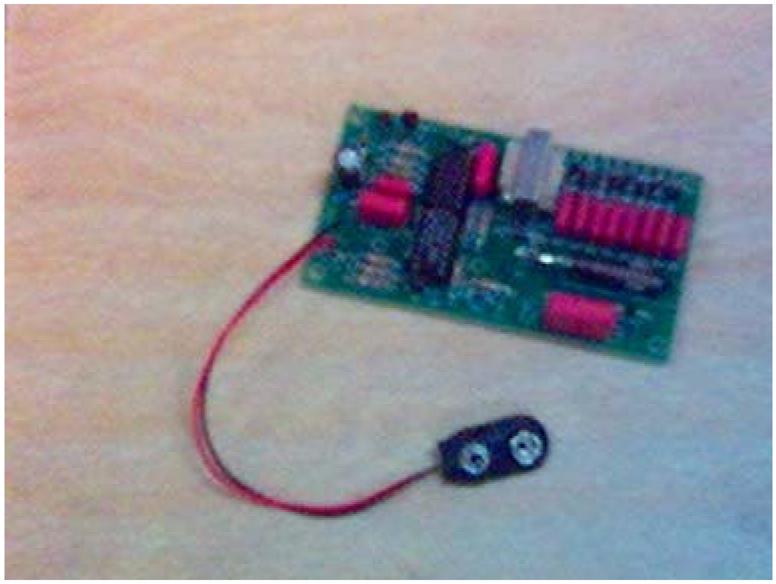


Figure 3.14
Picture of our completed Geiger counter.

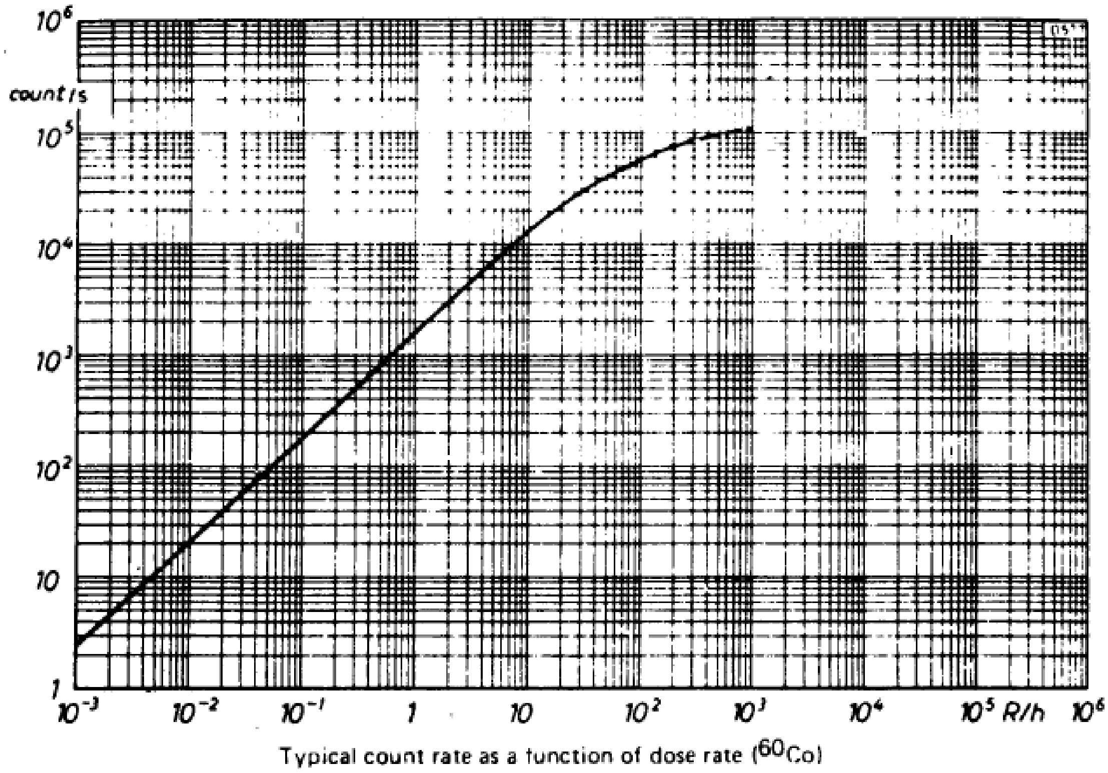


Figure 3.15
Graph of typical count rate as a function of dose rate from Cobalt-60 source. This comes from the product manual.

Comparing the gamma sensitivity graphs of both Geiger counters, we can see that the LND 7232 has a greater counts per second. In fact it is approximately a factor of ten greater than the K2645 Geiger counter. The reason for this is the LND 7232 is more sensitive to radiation and it has a larger detection area. The way we will compare each Geiger counter is to measure the flux of each graph. We also expect the LND 7232 Geiger counter to have a little higher flux rate compared to the K2645 counter. The reason for this is because the LND 7232 counter has the ability to detect alpha particles while the K2645 cannot detect them. We ran all of our runs inside therefore the walls stopped the alpha particles, but it can still detect a larger amount of radiation making it a little more flux compared to the K2645. The two should still be very close however.

6.0 Payload Construction Plan

6.0.1 Assembly of the Geiger Muller Counter K2645

Label	Artnr	Qty	Description
BUZ1	SV3	1	SOUNDER VELLEMAN 3-30VDC 8mA/12V LEADS
C1	220J0C	1	ELCO PCB 220µF-16V
C13	.033/1K	1	33nF/1000V
C14	7MK47	1	MKH 0.047µF-250V
C2	SI100N0	1	SIBATIT 100nF-63V
C3	1MK1000	1	MKH 1µF-100V
C4	7M1	1	MKH 1nF-400V
C5...C12	7MK33	8	MKH 0.033µF-250V
D1...D4	1N4148	4	1N4148 (1N914)
D5...D14	1N4007	10	1N4007 DIODE 1A-1000V
BATTERY	SNAP9V	1	BATTERY SNAP 9V "I" TYPE/LEADS 150mm
GM-TUBE	GMTUBE	1	GEIGER-MULLER-TUBE
IC1	CD40106	1	CD40106BE HEX SCHMITT-TRIGGER
IC2	CD4093	1	CD4093BE 4 X 2 NAND SCHMITT-TRIGGER
J	DBL	1	JUMPER

R1...R3	RA10M0	3	RESISTOR 1/4W 10M
R10,R11	RA220K0	2	RESISTOR 1/4W 220K
R12	RA10K0	1	RESISTOR 1/4W 10K
R4...R7	RA100K0	4	RESISTOR 1/4W 100K
R8, R9	RA1M0	2	RESISTOR 1/4W 1M
T1...T3	BC557B	3	BC557B SI-PNP UN 50V-0.2A
TRAFO1	LT44	1	LT44 IMPEDANCETRANSFO 20KPRIM/1K SEC
14P	14P	2	14P DIL IC SOCKET 300MIL
BT20200	BT20200	2	BOLT M2 X 20mm CYL. HEAD
BUS1	BUS1	2	SPACER 10mm PLASTIC
FU-CLIP	FU-CLIP	1	FUSEHOLDER CLIP MESSING BLANK FOR PCB
H2645	H2645	1	MANUAL
MR2	MR2	2	NUT 2mm
P2645	P2645	1	PCB

Table 3.5
This is the parts list for the Geiger counter.

Assembly instructions:

1. Mount R1 to R3, 10M resistors (brown, black, blue)
2. Mount R4 to R7, 100K resistors (brown, black, yellow)
3. Mount R8 and R9, 1M resistors (brown, black, green)
4. Mount R10 and R11, 200K resistors (brown, black, orange)
5. Mount C1, 220µF electrolytic capacitor. Mina the polarity!
6. Mount C2, 100nF Sibatit capacitor
7. Mount C3, 1µF MKM capacitor
8. Mount C4, 1nF MKM capacitor
9. MountC5 to C12, 33nF MKM capacitors
10. Mount C14, 47nF MKM capacitor
11. Mount C13, which may be either one big capacitor of 33nF/1000V or two capacitors of 47nF/400V in series.
12. Mount D1 to D4, smaller signal diodes 1N914 or 1N4146. Mind the polarity! Model 1n4148 may be color coded (wide yellow band, brown yellow, grey). In this case, the wide yellow band should correspond to the mark on the printed circuit board. If the diode shows number only, the black band should correspond to the mark on the pcb.
13. Mount D5 to D14, 1N4007 type diodes. Mind the Polarity!

14. Mount link J next to lC1
15. Mount a 14 pin socket for lC1 and lC2
16. Mount T1 to T3, BC557, 558, or 559 type transistors
17. Solder the black wire of the battery connector to “battery-“ to the red wire to “+”
18. Mount the transformer (LT44)
19. Mount lC1, 40106 type, with the recess pointing to T3
20. Mount 1C2, 4093 type with the recess pointing to lC1
21. Mount G.M. tube: take away the small ribbon (if any) winded around the tube. The clip on the anode pin as to be pulled off (very gently!) from the tube. Never solder directly to the tube! Solder a short strip of wire (2cm) to the anode clip and connect it to point A on the PCB. Fit the tube socket on point K, and then break off the small tooth at one end of it (see figure 3.11 and 3.12). After soldering is done (and only then) you gently push the anode clip back on the tube and fit the tube carefully in its holder.

NOTE: This came from a translated product manual from Velleman®, INC. There were no English versions available.

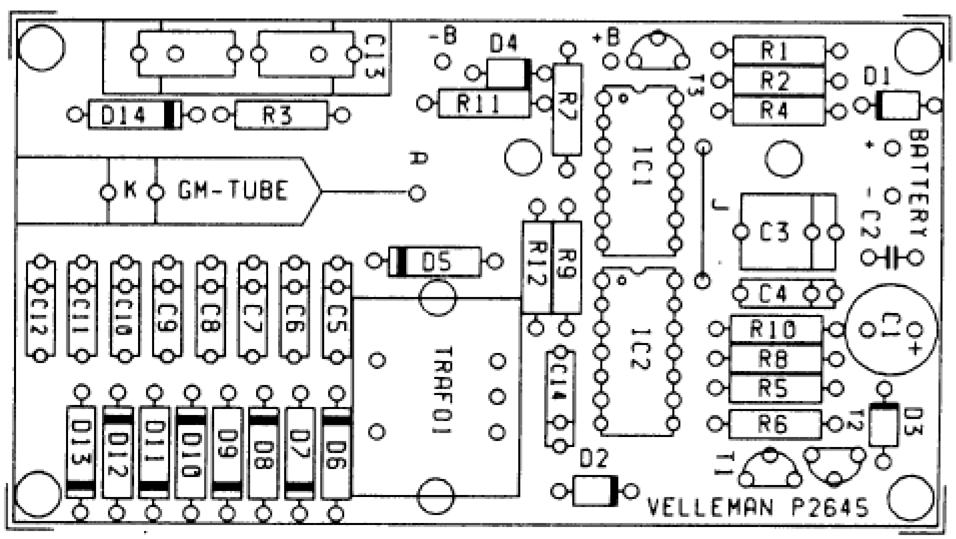


Figure 3.16
Schematic drawing for the Geiger Muller Counter K2645 from product manual.

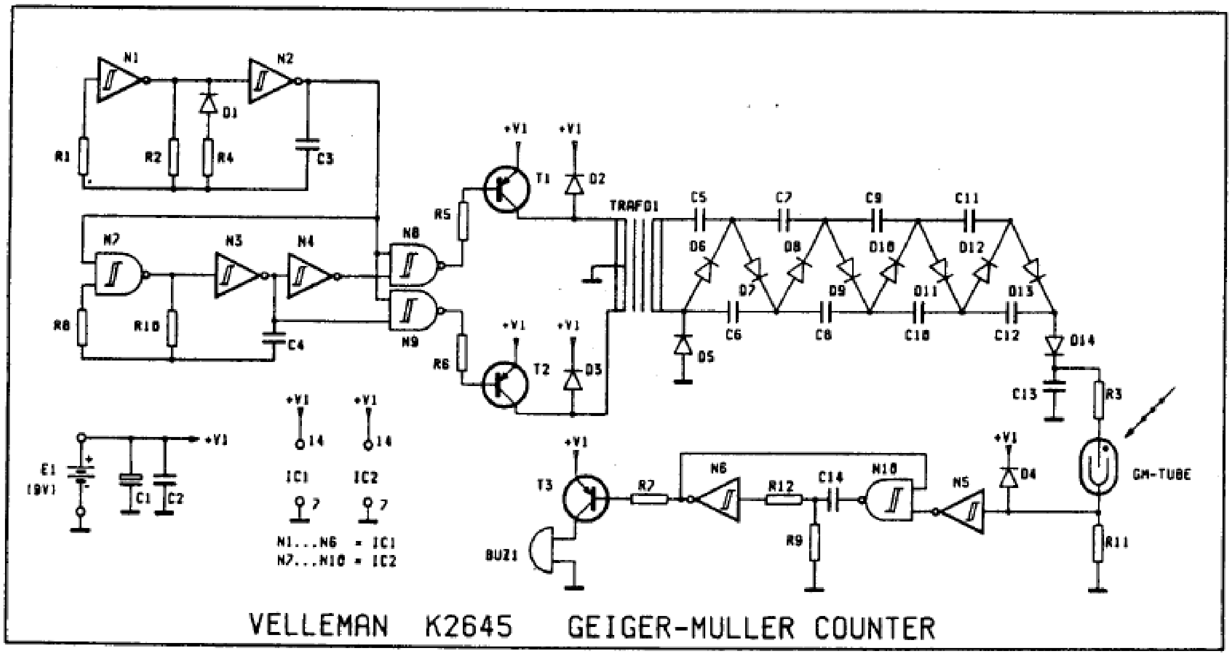
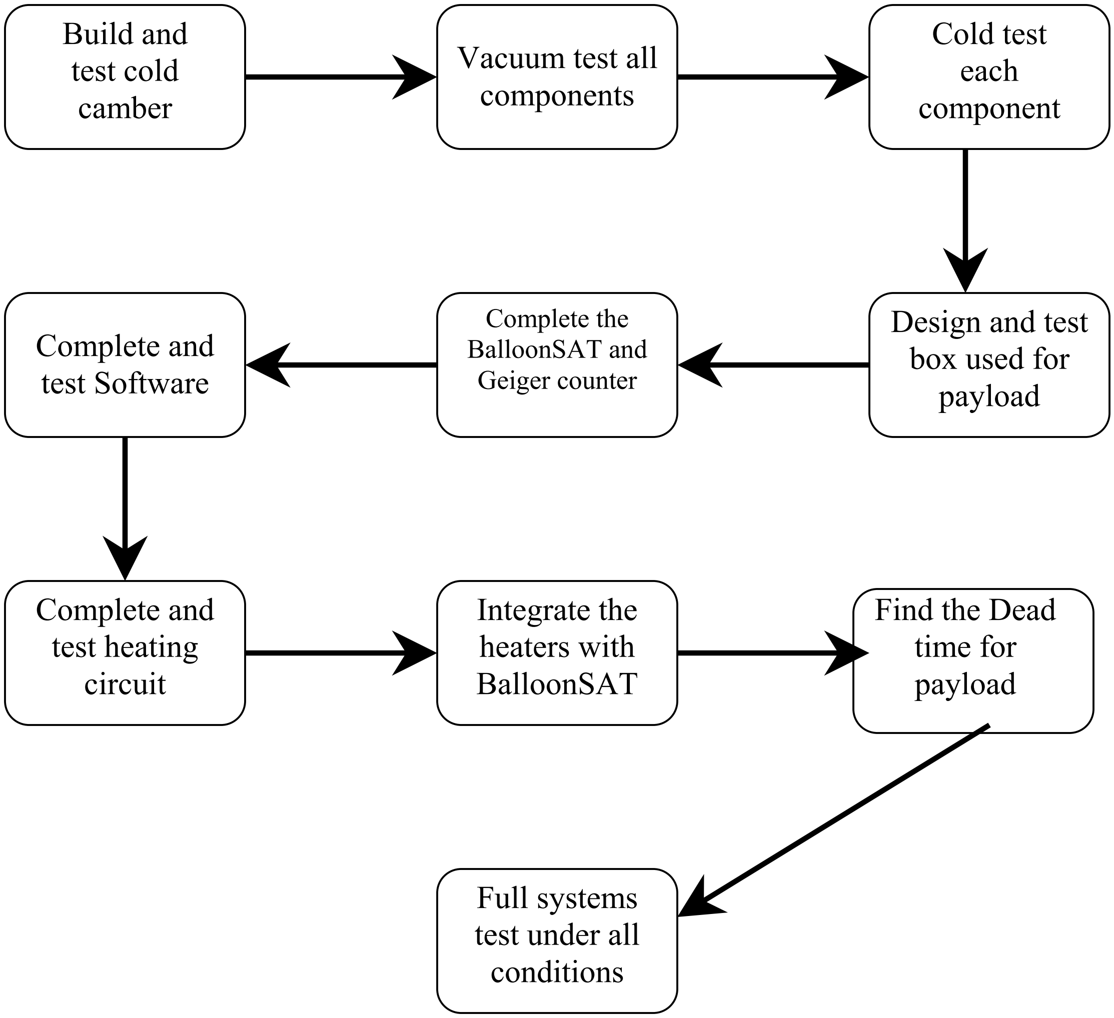


Figure 3.17
Schematic drawing for the Geiger Muller Counter K2645 from product manual.

The following is the method that we will use in constructing our payload; however, while we are doing this we will also be adding everything to the PDR, CDR, and FRR. This is not stated in the procedures, but it will be done.

1. Build and test a cold chamber to house our payload, vacuum chamber, and dry ice with the ability to maintain a temperature of about -60°C.
2. Do a vacuum test of all the components of our payload to see if it out gases and can function in a low pressure environment.
3. Cold test all of the components individually to find the minimum operating range of the components and the max lower temperature possible for it to still function.
4. Design and test our box for both structural and thermal support.
5. Complete the BalloonSAT and Geiger counter.
6. Complete and Test the software to run the BalloonSAT and Geiger counter.
7. Complete and test the heating circuit.
8. Integrate the heating circuit to the BalloonSAT.
9. Find the Dead time for the payload.
10. Complete full systems test of the payload to make sure we are getting accurate results and can survive assembled together with all the items of our payload.


Build and test cold camber
Vacuum test all components
Cold test each component
Design and test box used for payload
Complete the BalloonSAT and Geiger counter
Complete and test Software
Complete and test heating circuit
Integrate the heaters with BalloonSAT
Find the Dead time for payload
Full systems test under all conditions

6.1 Hardware Fabrication and Testing

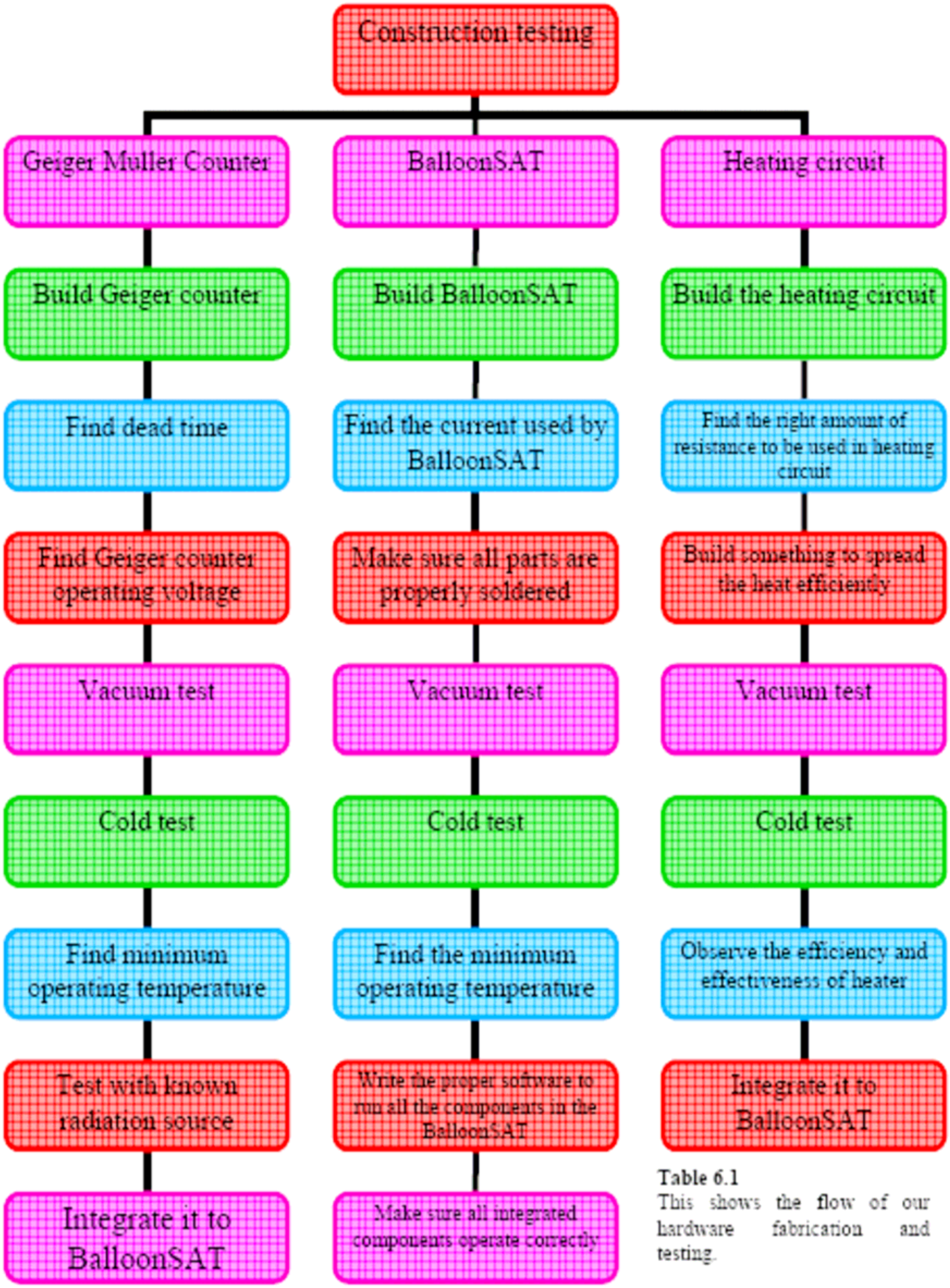


Table 6.1
This shows the flow of our hardware fabrication and testing.

6.1.2 Dead time

Geiger Counter

One of the things that must be done is calculating the dead time of each detector because without this information we will get inaccurate data. We will find the dead time by performing an experiment created by the Syracuse University Physics department and can be found at the following address:
http://www.phy.syr.edu/courses/PHY344.05Spring/Geiger_Mueller_counter.pdf

have 100 measurements.

Move the shelf and source to the top slot and repeat the measurements in the previous paragraph, again for 100 measurements.

5 Data analysis

5.1 Source count rates

From the measurements in Section 4.3, determine the measured count rate (number of decay particles detected per unit time) for each source and for the background. Subtract the latter from each of the measured source count rates to determine the *background-corrected* source count rates.

For each source, use the dated source activity, the half-life, and the radioactive decay equation you learned in Physics 216 to determine the source activity (number of decays per second) today. Compare that value to the observed count rate. In your report, explain the difference in these values.

Using the 100-s measurement on Co-60 in Section 4.3, calculate the theoretical standard deviation in the observed number of counts. Use that value to determine the standard deviation in the count rate for Co-60 calculated above.

Look at the 1-s measurements in Section 4.5 with Co-60 source in the top slot. Find one of the values that is near the middle of the distribution of observed counts, e.g., one close to the roughly estimated mean value or median value. Use that chosen number of counts to calculate the count rate and standard deviation in the count rate. Compare these results to those for the 100-s measurement on the same source in the same position.

Notice that, according to theory, the standard deviation of the number of counts is equal to the square root of the number of observed counts. Thus, it increases as the number of counts increases. Why, then, is it better to use a large number of counts over a large time interval to determine the count rate instead of using a smaller number of counts over a smaller time interval? Discuss this point in your report.

5.2 Count rate versus distance

From vernier caliper measurements, calculate the distance from the top of the source to the window of the GM tube for each of the five count measurements in Section 4.4. Convert your count measurements to background-corrected count rates at each source position. Plot a graph of count rate (ordinate) versus source-to-detector distance (abscissa). Then plot another graph of count rate versus the inverse of the square of the distance. If the radiation intensity follows the usual "$1/r^2$" relation from an isotropic source and if the Geiger counter measurement is proportional to intensity, the latter graph should, of course, be a straight line through the origin. In your report, discuss whether or not this is the case and why.

5.3 Counting statistics

Using the measurements in Section 4.5 with the source in the lower position, make a table with three columns: (1) the observed values of the number of counts, (2) the occurrence of that number of counts, i.e., the number of intervals for which that number of counts was observed, and (3) the probability of occurrence of that number of counts. Plot your results as probability (ordinate) versus number of counts. Calculate the mean value of the number of counts. On the graph of our data, plot the appropriate Poisson distribution function and Gaussian distribution function.

Repeat the procedure in the previous paragraph for the measurements in Section 4.5 with the source in the higher position.

In your report, discuss the differences of the shapes of the Poisson and Gaussian distributions in of the two sets of measurements. Also, discuss the validity of approximating the Poisson distribution with the Gaussian distribution in each case. Is the standard deviation of the higher count statistics equal to the square root of the mean number of counts?

6.1.3 Flux Calculations

After finding the area of the Geiger counters, dead time, and voltage plateau we are finally able to find and compare the flux, rate of flow per unit area, of the cosmic rays. We will do this by using the following flux formula:

$$\text{Flux} = \frac{\text{counts}}{\text{area} \times \text{time}}$$

The previous formula is the general formula for flux that does not include the dead time of the detector. The following formula includes the dead time of the detector and will give us an accurate flux measurement.

$$\text{Flux} = \frac{\text{Counts}}{\text{Area} \times (\text{Time} - \text{Dead time})}$$

Because our area and time will be constant, we can rewrite the flux formula in the following way:

$$\text{Flux} = \frac{\text{Counts}}{1.18\ \text{cm}^2 \times (\text{Time} - \text{Dead time})}$$

This is for the K2645 Geiger counter while the next formula is for the LND 7232 Geiger Counter.

$$\text{Flux} = \frac{\text{Counts}}{6.88\ \text{cm}^2 \times (\text{Time} - \text{Dead time})}$$

To calculate the flux of each detector we will place a Strontium-90 (beta source) 9 cm away from the detector. We will then record the counts once per minute and then calculate the flux with our measured data. After completing this experiment we calculated the fluxes of each Geiger counter to be the following:

K 2645 Geiger Counter

44 minute run	
Minutes	**Counts**
1	**28**
2	**38**
3	**39**
4	**24**
5	**43**
6	**36**
7	**46**
8	**33**
9	**50**
10	**36**
11	**46**
12	**22**
13	**39**
14	**31**

Minutes	**Counts**
15	**30**
16	**34**
17	**36**
18	**37**
19	**34**
20	**31**
21	**27**
22	**39**
23	**45**
24	**29**
25	**26**
26	**43**
27	**42**
28	**31**
29	**32**

Minutes	**Counts**
30	**37**
31	**35**
32	**26**
33	**34**
34	**44**
35	**37**
36	**31**
37	**31**
38	**33**
39	**41**
40	**30**
41	**31**
42	**25**
43	**33**
44	**18**

Average	**34 counts**

Table 3.7
This is the Data from one of our runs with the Geiger counter.

$$\text{Flux} = \frac{34\ \text{counts}}{1.18\ \text{cm}^2 \times (1 - 0.00654)\ \text{min}}$$

$$\text{Flux} = \frac{20.0\ \text{counts}}{\text{cm}^2\ \text{min}} \pm \frac{0.203\ \text{counts}}{\text{cm}^2\ \text{min}}$$

LND 7323 Geiger counter data

Time	counts	flux	flux w/ dead time
60.05	143	22.24089852	22.24784146
59.87	110	17.15982007	17.16519297
59.7	139	21.74551872	21.75234684
60.06	128	19.90462246	19.91083506
59.9	118	18.39858772	18.4043456
59.76	123	19.22311771	19.22914773
60.02	129	20.07349629	20.07976577
59.88	129	20.12042831	20.12672714
59.95	132	20.56430548	20.57073575
59.78	128	19.99785254	20.00412348
59.95	135	21.03167605	21.03825247
60.17	140	21.73088067	21.73765087
60.04	127	19.75569625	19.76186442
60.15	134	20.80647311	20.81295747
59.81	127	19.83166699	19.8378827
60.13	143	22.2113081	22.21823258
60.3	121	18.74119852	18.7470247
60.06	109	16.95003006	16.95532048
60.17	126	19.5577926	19.56388578
60	120	18.67924414	18.6850801
59.82	143	22.32641184	22.33340828
60.3	122	18.89608445	18.90195878
59.97	109	16.97546783	16.98077413

Time	counts	flux	flux w/ dead time
59.88	143	22.30404068	22.31102311
59.82	121	18.89157925	18.89749932
60.13	129	20.03677444	20.043021
59.82	114	17.79867797	17.80425555
59.96	114	17.75712001	17.76267158
60.05	118	18.35262955	18.35835869
60.22	133	20.62719587	20.63361688
60.18	114	17.69220532	17.69771636
61.03	121	18.51702885	18.52271646
59.77	133	20.78249515	20.78901323
60.11	112	17.40205743	17.4074844
60.12	119	18.48661055	18.4923748
59.74	119	18.60420198	18.6100398
60.25	129	19.99686717	20.00308887
59.77	135	21.09501388	21.10162997
60.09	113	17.56327665	17.56875573
59.56	120	18.81723721	18.82315974
59.82	115	17.95480672	17.96043323
60.18	142	22.03765926	22.04452389
62.2	143	21.47212148	21.47859267

Average counts	**128**

$$\text{Flux} = \frac{128 \text{ counts}}{6.88 \text{ cm}^2 \times (1 - 0.000312) \text{ min}}$$

$$\text{Flux} = \frac{19.6 \text{ counts}}{\text{cm}^2 \text{ min}} \pm \frac{0.608 \text{ counts}}{\text{cm}^2 \text{ min}}$$

Comparing the flux we can conclude that the K2645 is getting the same amount of radiation per square centimeter. Therefore, we can now conclude that our K2645 Geiger counter is ready to be flown.

6.1.4 Calibration of Geiger counter at sea level

To make sure that our flux is accurate, we will run our Geiger counter at sea level for a few hours and then compare it to the flux at sea level, which happens to be the following:

$$\mathrm{Flux}_{\text{sea level}} = \frac{1.0 \text{ counts}}{\text{cm}^2 \text{ min}}$$

Once our flux at sea level is correct, we can expect our flight to resemble Figure 3.19. This is a theoretical curve for the flux per altitude. We notice that we should have an exponential growth until we reach approximately 15 km then we expect it decay exponentially after this point. The reason for this has to do with the interaction length of the particles and we be explained in the next section.

6.1.5 Calibration of Geiger Counter

The Geiger counter we will be using to calibrate the K2645 Geiger counter is a Spectech ST-350 counter made by Spectrum Techniques with a LND 7232 Geiger Muller tube made by LND, Inc. The specifications on each of them is as follows:

Spectech ST-350 counter

Specifications.

Input:	BNC connector. Accepts standard Geiger tubes.
High voltage:	0 to +1200 volts, digitally selectable in 25 volt increments.
Display:	6-decade LED, 1 in. numerals. Displays counts, preset counts, time, preset time, CPM, CPS, alarm level, and high voltage.
Modes:	Count for preset time, count for preset count, counts/min., counts/sec., set alarm level 0-999999 cps, set high voltage 0-1200v,and remote.
Audio:	Piezo alerter if countrate exceeds preset level.
Data Link:	DB-9 male connector accepts RS-232 serial cable.
Power:	Input 7.5 volt DC, at 500mA from AC line/charger. Specify 110-120, 220-240 VAC at time of order. Battery option requires installation of 4 x C size NiCd rechargeable batteries (not supplied).
Dimensions:	12 in. W, x 8 in. H, x 4.5 in. D.
Software supplied:	ST350 Radiation Counter-PC emulation software. DOS program runs on most IBM compatible PC's including CGA, EGA, VGA, SVGA, and Hercules graphics systems. Real-time display of simulated analog ratemeter with auto-ranging, digital ratemeter in CPM or CPS, count, elapsed time, preset count, preset time, high voltagesetting, acquisition time, and run number. Data is loaded into spreadsheet compatible files for transfer. Bi-directional LABLINK offers full control of all functions including preset count, preset time, countrate in CPM or CPS, alarm level, high voltage, start, stop, reset, and data transfer. Requires EGA or VGA graphics. All operations may be run directly from the computer with spreadsheet compatibility.

Table 3.1
This is a copy of the Specifications of the Spectech ST-350 system from the user manual.
http://www.spectrumtechniques.com/manuals/ST350manual.pdf

Figure 3.10
This is a picture of our equipment together.

LND 7232 Geiger Muller Tube

General Specifications	
Gas Filling	**Ne +Halogen**
Cathode Material	**446 Stainless Steel**
Maximum Length (inch/mm)	**4.85 / 123.1**
Effective Length (inch/mm)	**2.6 / 66.04**
Maximum Diameter (inch/mm)	**1.38 / 34.9**
Effective Diameter (inch/mm)	**1.13 / 28.6**
Connector	**BNC**
Operating Temperature Range ^{0}C	**-55 to +75**
Table 3.2 This is the general specifications of the Geiger Muller tube. http://www.lndinc.com/gm/alpha/7232.htm	

Window Specifications	
Areal Density (mg/cm^2)	**2.0**
Effective Diameter (inch/mm)	**1.13 / 28.6**
Material	**Mica**
Table 3.3 This is the window specifications of the Geiger tube. http://www.lndinc.com/gm/alpha/7232.htm	

Electrical Specifications	
Recommended Anode Resistor (meg ohm)	**1**
Maximum Starting Voltage (volts)	**800**
Recommended Operating Voltage (volts)	**900**
Operating Voltage Range (volts)	**850-1000**
Maximum Plateau Slope (%/100 volts)	**10**
Minimum Dead Time (micro sec)	**150**
Gamma Sensitivity Co^{60} (cps/mR/hr)	**40**
Maximum Background Shielded 50mmPb + 3mmAl (cpm)	**50**
Tube Capacitance (pf)	**3**
Weight (grams)	**155**
Table 3.3 This is the electrical specifications of the Geiger tube http://www.lndinc.com/gm/alpha/7232.htm	

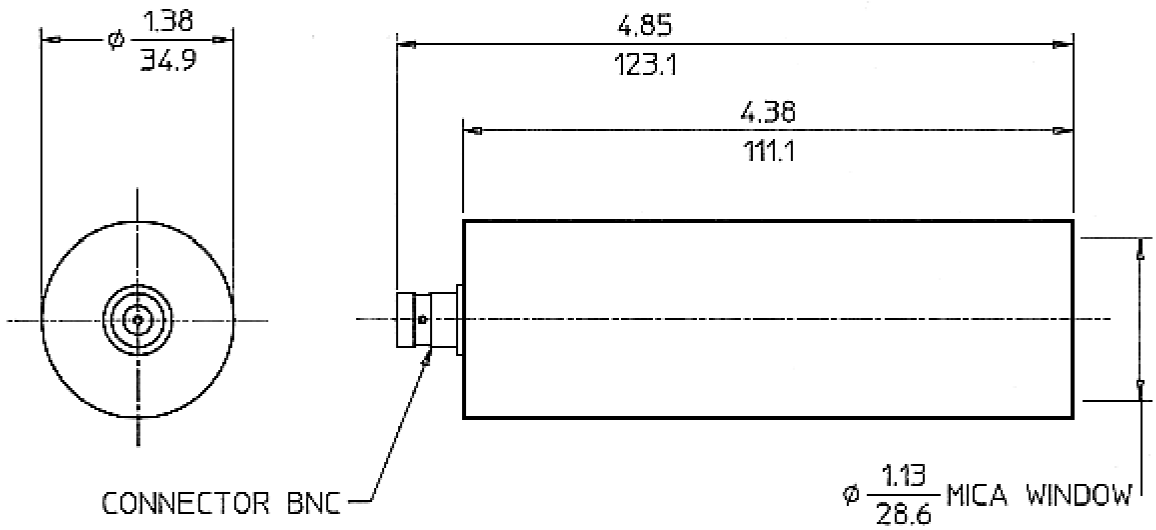


Figure 6.10
Circuit drawing for the Geiger tube.
http://www.lndinc.com/gm/alpha/7232.htm

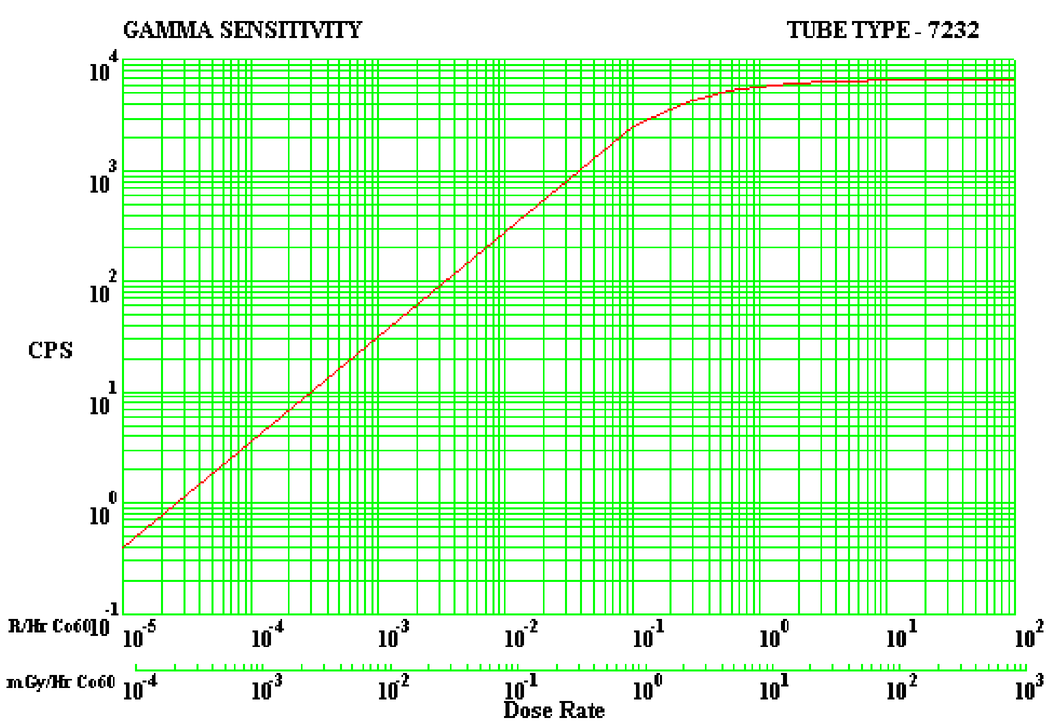


Figure 6.11
This is the gamma sensitivity curve for the Geiger tube.
http://www.lndinc.com/gm/alpha/draw/sen7232.gif

Figure 6.12
Picture of the Geiger tube.
http://www.lndinc.com/gm/alpha/draw/pic7232.jpg

Geiger Plateau

To find the Geiger plateau of this device, we followed the directions of The Geiger Counter Experiment using a Cobalt-60 source. We did each measurement of each distance twice and then took an average before finding the plateau. The data and Geiger plateau can be found in Table 3.4 and Figure 3.12. We have concluded that the optimal voltage for the LND 7323 counter is 725 V. We are unable to change the voltage of the K2645 Geiger counter; therefore, we will not be performing this experiment on the K2645. This was only done to make sure that our calibration Geiger counter is running at the correct voltage.

Close Distance Counts		
Volts	**Run 1**	**Run 2**
800	896	987
775	896	891
750	916	864
725	866	873
700	840	848
675	859	766
650	650	732
625	0	0

Table 3.4 A
This is the data for our close distance which was the first slot.

Far Distance Counts		
Volts	**Run 1**	**Run 2**
800	328	336
775	271	271
750	273	231
725	287	213
700	256	235
675	256	225
650	186	215
625	0	0

Table 3.4 B
This is the data for our far distance which was the second slot.

Average Counts		
Volts	**Close Average**	**Far Average**
800	941.5	332
775	893.5	271
750	890	252
725	869.5	250
700	844	245.5
675	812.5	240.5
650	691	200.5
625	0	0

Table 3.4 C
This is an average of all of our data for each distance.

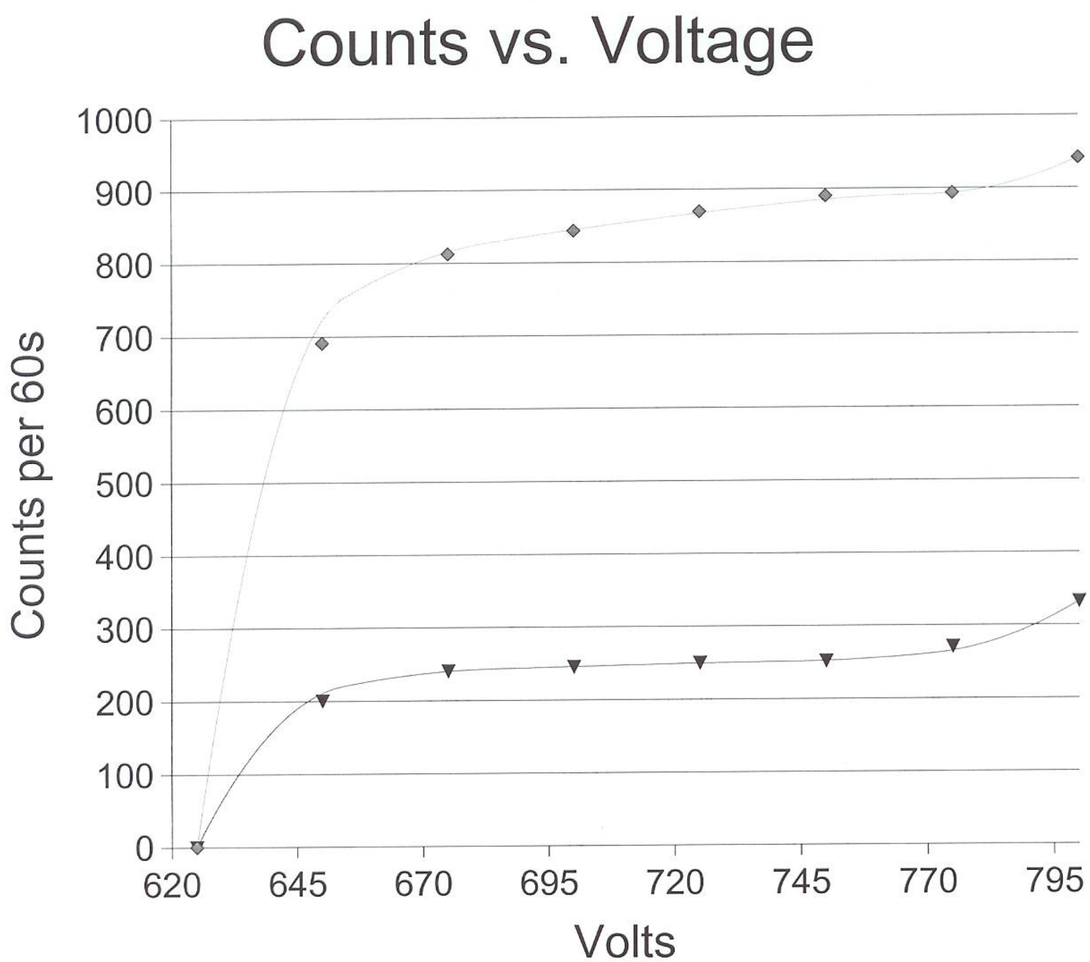


Figure 3.12
This is our experimental Geiger plateau. We can see that the optimal voltage is 725 V.

Once we figure out the Geiger plateau for the LND 7232 we will use it to make sure that it is operating at the correct operating voltage. After this, we will take a Strontium-90 source and place it an inch away from the detector. We will then take measurements in one minute intervals and calculate the flux. After we do this, we will compare the results of each Geiger counter.

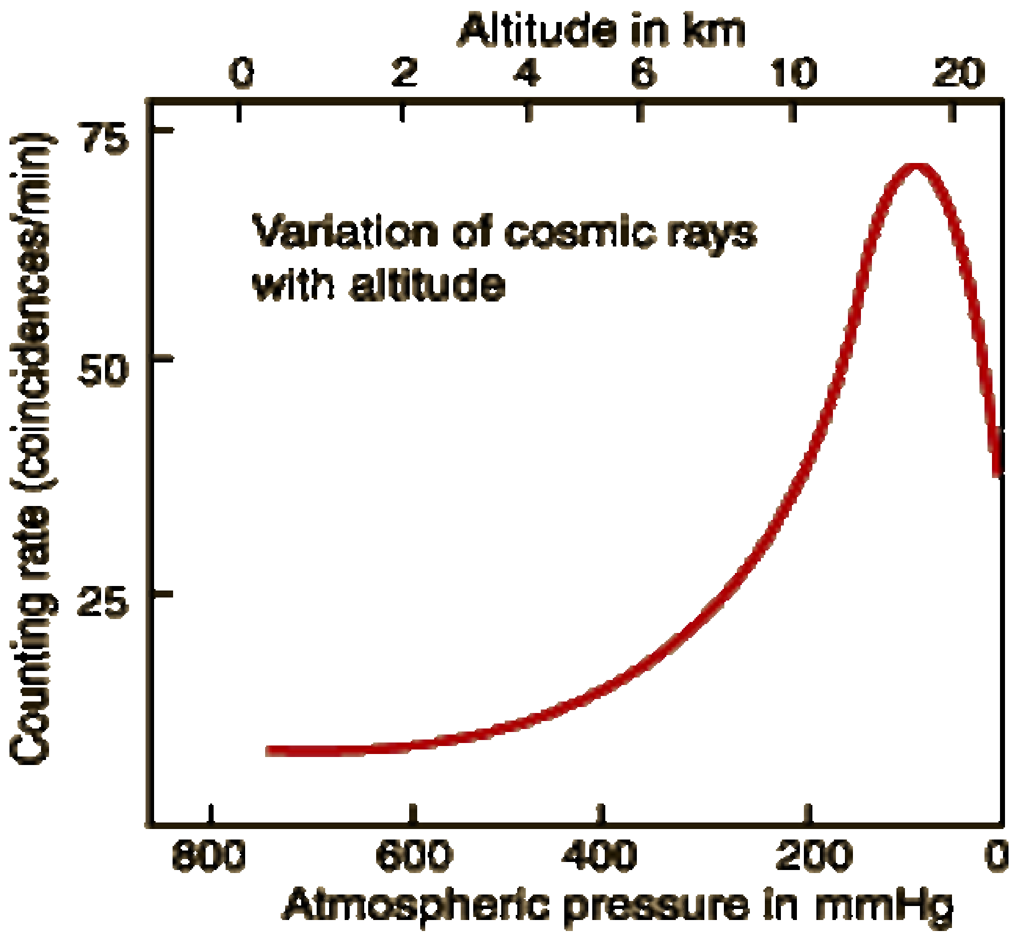


Figure 6.1
Theoretical calculated flux of cosmic rays with respect to altitude.
http://hyperphysics.phy-astr.gsu.edu/hbase/astro/cosmic.html

Vacuum testing procedures

Seal the vacuum chamber without anything inside and then measure the amount of time that it took for the vacuum to go all the way down. Then place the object you want to vacuum test inside and measure that time. If it takes longer, then there is some outguessing occurring. Also, observing the object inside and looking for fumes is something else that we try to do. The final test is to take a close look at the object after it is finished with the vacuum test to see if there are any significant changes such as becoming brittle.

Cold testing procedures

The first thing we do is get between 10-20 lbs of dry ice at a U-Haul place near campus. Then we place the object in our cold chamber see Figure 11.18 B. Next, we put the dry ice around the object, but not touching the object. We then place temperature probes in the cold chamber to get the temperature of the objects environment and place either a HOBO or temperature probe inside with our object. Finally, we let in stay in that environment and observe the results.

Minimum operating temperature procedures

To find the minimum operating temperature we do a cold test on the environment and see how the object performs as the temperature goes down. When the object can no longer operate as it is designed to, we record the minimum operating temperature and try to keep it within its operating limits.

Geiger counter test

To test the Geiger counter, we will place a Cobalt-60 source at a certain distance and let it record the counts per minute. We will also take another Geiger counter and do the same thing to it. After both test are complete, we will compare the results of the Geiger counters.

Integration

After the heaters and Geiger counters are constructed and working properly, we will connect them to the BalloonSAT. When they are connected, we will run tests to make sure that they function with the BalloonSAT and can store the data on the BalloonSAT. The heaters must be able to be turned off and on as the temperature drops to below 0°C.

6.3 Software Implementation and Verification

The Basic stamp will run the following program. This program is designed to get the counts, temperature, and turn on the heater if the temperature gets too cold inside.

```
' {$STAMP BS2}
' {$PBASIC 2.5}

gmcount   VAR   Word
gmin      PIN   5                  'set geiger input pin
ee1da     PIN   8                  'labels temp eeprom
ee1cs     PIN   ee1da+1            'chip enable pin
ee2da     PIN   0                  'labels temp eeprom
ee2cs     PIN   ee2da+1            'chip enable pin
tempda    PIN   13                 'adc8031 data pin
tempcl    PIN   14                 'adc0831 clock pin
tempcs    PIN   15                 'adc0831 chip enable pin
ch1sel    CON   %1110              'adc0831 channel 1 constant
ch2sel    CON   %1101              'adc0831 channel 2 constant
temp      VAR   Byte               'used for adc0831 data
nexttemp  VAR   Word               'used for temp eeprom address
```

```
addrblock VAR   Word                        'used for temp eeprom address
heater    PIN   7                       'used to turn on and off heater
addrl     VAR   Word                        'lsb byte for gm count storage
addrh     VAR   Word                        'msb byte for gm count storage
beeper    PIN   4                       'buzzer pin

main:
  LOW heater                            ' make sure heater is off
  FREQOUT 4,1000,300                              ' produce tone to demostrate proper
operation
  READ 3,addrblock                         ' set start of mem address
  READ 2,nexttemp                          '          "
  READ 1,addrh                           '          "
  READ 0,addrl                          '          "
 DO
  LOW tempcs
  SHIFTOUT tempda,tempcl,LSBPOST,[ch1sel]         ' initiate adc0834

  COUNT gmin, 3484, gmcount                      ' read 1 sec of G-M collisions
  'DEBUG DEC gmcount.LOWBYTE," ", DEC addrh, DEC addrl, CR

  I2COUT ee1da, $A0, addrh\addrl, [gmcount.HIGHBYTE]    ' store counts msb*8
  addrl = addrl + 1
  PAUSE 4
  I2COUT ee1da, $A0, addrh\addrl, [gmcount.LOWBYTE]     ' store counts lsb*8
  addrl = addrl + 1
  WRITE 0,addrl                           ' update mem location


  SHIFTIN tempda,tempcl, MSBPOST, [temp\9]         ' read inside temp
   I2COUT ee2da, $A0, addrblock\nexttemp, [temp]   ' store inside temp
   nexttemp=nexttemp+1
  'DEBUG DEC temp,CR                            ' this line for outputting temps
                                     ' while running
  HIGH tempcs

  LOW tempcs                            ' initiate adc0834
  SHIFTOUT tempda,tempcl,LSBPOST,[ch2sel]

  PAUSE 10

  SHIFTIN tempda,tempcl, MSBPOST, [temp\9]       ' read outside temp
   I2COUT ee2da, $A0, addrblock\nexttemp, [temp] ' store outside temp
   nexttemp=nexttemp+1
  'DEBUG DEC temp, CR                           ' this line for outputting temps
  WRITE 2,nexttemp                                    ' while running
```

```
    HIGH tempcs

    IF addrl >= 255 THEN                    ' this section is for updating msb
     'DEBUG DEC addrl, "   ",DEC addrh, CR       ' block info for count storage
     addrl = 0
     addrh = addrh + 1
     WRITE 1,addrh
     FREQOUT 4,100,300                       ' test beep for varification of operation
    ENDIF                                  ' occurs about every 4 minutes

    IF nexttemp >=256 THEN                    ' updates msb for temp storage
     addrblock = addrblock +1
     nexttemp = 0
     WRITE 3,addrblock
    ENDIF

    IF addrh > 7   THEN                       ' after 1/2 an hour...
     HIGH heater
    ENDIF                                  ' turn on heater
   LOOP
```

The following program is designed to convert the bit data from the EEPROM to temperature in ºC. It will be used for us to make sure that our payload stayed within the correct operating temperature.

```
' {$STAMP BS2p}
' {$PBASIC 2.5}

' This program is made to read temp data off eeprom 2

SDA          PIN     0            ' I2C SDA pin
SCL          PIN     SDA + 1

addrlow       VAR     Word          ' internal address
addrhigh      VAR     Word          ' internal address
value        VAR     Byte          ' value to write
result       VAR     Byte          ' array for returned value
```

```
Read_From_EEPROM:
  DEBUG CR, "Reading...", CR
  FOR addrhigh = 0 TO 255
  FOR addrlow = 0 TO 255
    I2CIN SDA, $A1 , addrhigh\addrlow, [tempout]
    addrlow=addrlow+1
    PAUSE 10
    I2CIN sda, $A1, addrhigh\addrlow, [tempin]
    addrlow=addrlow+1
    PAUSE 10

    'DEBUG DEC addrlow,CR
    DEBUG DEC tempin,"  inside",CR
    DEBUG DEC tempout,"  outside",CR
  NEXT
  NEXT
  PAUSE 100
  DEBUG CR, "All locations read"
  END
```

This program is designed to clear the data off the EEPROMS.

```
' This program clears out the eeproms on the balloon project board, one at a time.
' Then checks for zero's in all locations of gm eeprom
'
' {$STAMP BS2p}
' {$PBASIC 2.5}

SDgm          PIN     8              ' "8" clears G-M,
SCLgm          PIN    SDgm + 1
sdtemp        PIN     0              ' "0" clears temps
scltemp       PIN     sdtemp + 1

addrlow        VAR     Word          ' internal address lsb
addrhigh       VAR     Word          ' internal address msb
value         VAR     Byte          ' value to write
result        VAR     Byte          ' array for returned value

Write_To_gm_EEPROM:
  value = %00000000                                  ' binary zero
  DEBUG "Writing to eeprom 1...", CR
  PAUSE 20
  FOR addrhigh = 0 TO 255
  FOR addrlow = 0 TO 255                               ' loop through all addresses
   I2COUT SDgm, $A0, addrhigh\addrlow, [value]           ' load zero
   PAUSE 10
    'DEBUG "Addr: ", DEC3 addrhigh, " ",DEC addrlow,
    '   " Value: ", DEC3 value, CR
  NEXT
  NEXT
  PAUSE 20

Write_To_temp_EEPROM:
  DEBUG "Writing to eeprom 2...", CR
  PAUSE 20
  FOR addrhigh = 0 TO 255
  FOR addrlow = 0 TO 255                              ' loop through all addresses
   I2COUT sdtemp, $A0, addrhigh\addrlow, [value]        ' load zero
   PAUSE 10
    'DEBUG "Addr: ", DEC3 addrhigh, " ",DEC addrlow,
    '    " Value: ", DEC3 value, CR
  NEXT
  NEXT

Read_From_EEPROM:
  DEBUG CR, "Reading...", CR
```

```
FOR addrhigh = 0 TO 255
FOR addrlow = 0 TO 255

  I2CIN SDgm, $A1 , addrhigh\addrlow, [result]
  'DEBUG " ", DEC3 result

IF result > 0 THEN
  DEBUG "error at loc: ",DEC addrhigh,"  ",DEC addrlow,CR
ENDIF
PAUSE 10
NEXT
NEXT
PAUSE 100
DEBUG CR, "All locations cleared",CR
END
```

This program will allow us to get the counts from the EEPROM and display then counts in counts per minute. We will then use EXCEL to calculate the flux.

```
' I2C.BSP
' This program outputs the data of the gm eeprom
' and displays the information by minute.
'
' {$STAMP BS2p}
' {$PBASIC 2.5}

SDA        PIN    8          ' I2C SDA pin
SCL        PIN    SDA + 1

addrlow     VAR    Word        ' internal address
addrhigh    VAR    Word        ' internal address
block       VAR    Nib         ' block address in 24LC16
value       VAR    Byte        ' value to write
result      VAR    Byte        ' array for returned value
mincount    VAR    Word        ' number of mem locations read
MINtotal    VAR    Word        ' number of counts
minnum      VAR    Word        ' number of minute being totalled

Read_From_EEPROM:
  minnum=0
  mincount=0
  mintotal=0
  DEBUG CR, "Reading...", CR
  FOR addrhigh = 0 TO 255
  FOR addrlow = 0 TO 255
    mincount=mincount+1
    I2CIN SDA, $A1 , addrhigh\addrlow, [result]
    mintotal=mintotal + result

    IF mincount=120 THEN
      mincount=0
      minnum=minnum + 1
      DEBUG DEC mintotal, " counts in minute ",DEC MINnum, CR
      mintotal = 0
    ENDIF

  NEXT
  NEXT
  PAUSE 100
  DEBUG CR, "All locations read"
  END
```

This program erases all the data stored on the EEPROM.

```
' {$STAMP BS2p}
' {$PBASIC 2.5}

' This program sets the eeprom memory locations to start at zero

WRITE 0,0
WRITE 1,0
WRITE 2,0
WRITE 3,0
END
```

We will calculate the dead time of our software once the flight is over. The procedures for this are discussed in the dead time section.

6.4 Flight Certification Testing

- Conditions
  - Temperatures ≈ -60 ^{o}C.
  - Low pressures ≈ 1% atmosphere.
  - Rotation around the z-axis
  - Possible turbulence
  - Impact ≈ 6 m/s

- Compensation and Testing
  - In order to ensure a successful flight, we will test all equipment multiple times. This includes doing vacuum, cold, and impact testing both individually and all three at the same time. We will do what needs to be done to make sure all of our equipment can survive its environment.
  - All of our testing procedures produce an environment that is a little rougher than what is expected. This ensures that our payload will survive and function as it is designed.

7.0 Mission Operations

The payload will be launched and tracked from the ground by a separate GPS unit. It will be recovered upon landing. The following operations will be performed pre-flight, and post flight:

Pre Flight Operations:
- Full system test of hardware
- New batteries are to be placed in payload for maximum voltage
- Check all structures to make sure they are properly fastened down
- Make sure lids are properly sealed
- Properly attach payload to balloon

Recovery and data extraction
- Take pictures
- Record observations
- Examine for mechanical damages
- Examine the payload and see if there are any damages in the integrity of the system
- Disassemble the payload and extract the BASIC Stamp.
- Download the data from EEPROM through the serial cable connection on the BalloonSAT board and process it on a computer
- Take a ground test of Geiger counter again to make sure it is functioning properly.

Data Analysis
- Check if data has been collected for the entire duration of the flight
- Plot the flux with respect to altitude (using the GPS data from a tracking unit)
- Check if the plotted data agrees with the expected theoretical curve (Figure 3.18)

7.1 Launch Requirements

Final testing

- check if the separate parts of the payload are operable and are powered on (BASIC Stamp, Geiger counter, heating unit)
- check if the parts interact as designed and work as a whole
- check power sources for output voltages and currents and replace by a new spare if needed
- check control points for proper voltages on them
- check the integrity of the system (make sure everything holds firm inside the cube
- verify GPS synchronization
- proper sealing of payload and attachment to balloon vehicle

All test should give a positive result and all malfunctioning revealed should be taken into consideration and fixed in field

A full cycle test run should be done in field. This will simulate the data acquisition during the flight. This also will allow us to make sure that everything is still functional after the transportation

7.2 Flight Requirements and Operations

Flight Requirements

- payload must reach a height of at least 15 km
- heating devices must maintain the payloads temperature to a minimum value of -20 ºC
- proper synchronization of all devices inside, and outside of the payload

Post flight Requirements

- GPS time, latitude, longitude, and altitude to properly analyze our data
- Proper functioning of all interior devices (Geiger Counter, BalloonSAT) in order to collect needed graphs and data

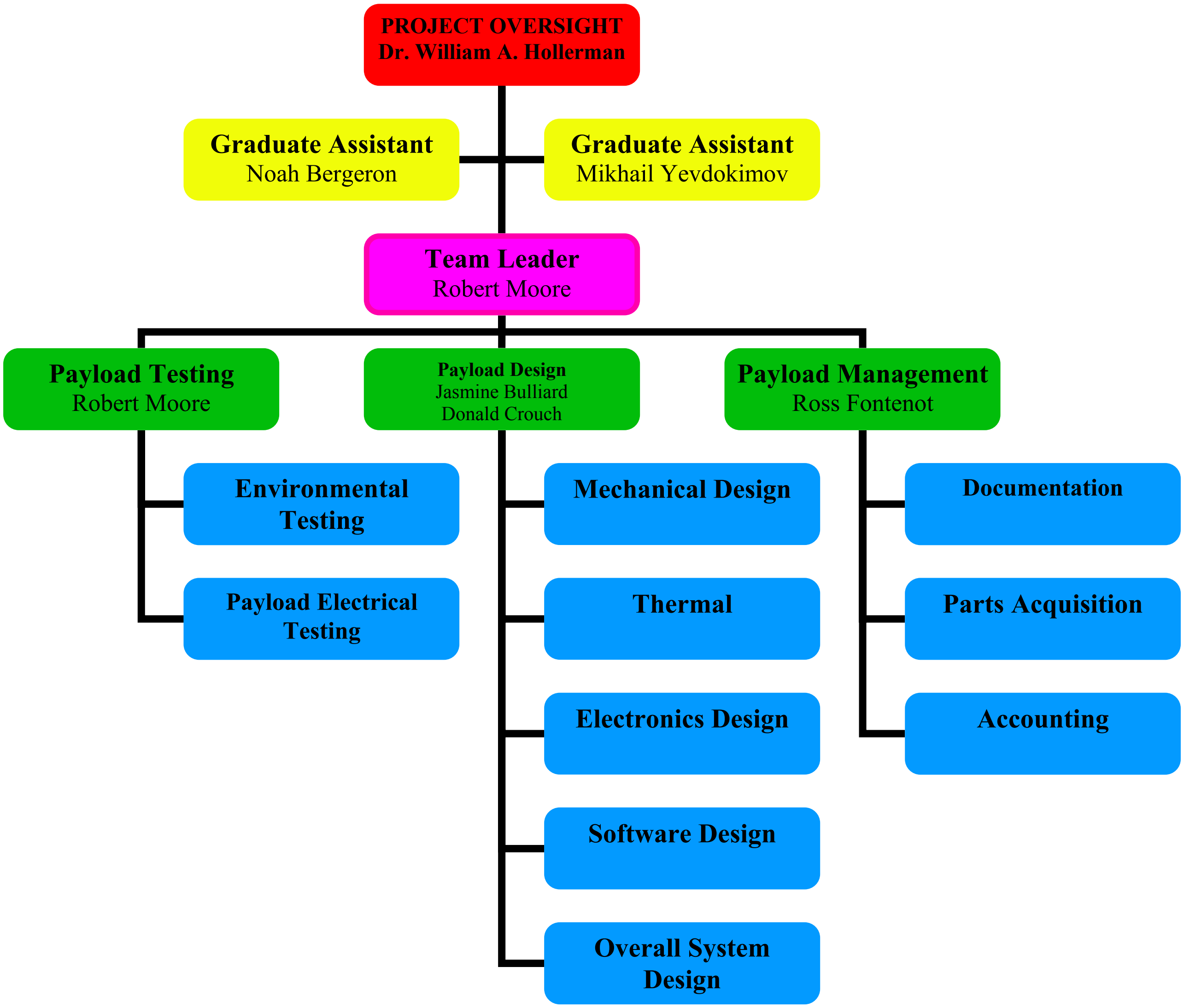
7.3 Data Acquisition and Analysis Plan

The Velleman K2645 Geiger-Muller Counter will be interfaced to the BASIC stamp allowing all data from the Geiger counter to be stored into the EEPROM of the BASIC Stamp as standard units of counts per minutes. Post flight the data will be collected via computer and a pre-written, pre-tested program will convert the units of counts per minute to flux, refer to section 3.1 for details about these conversions. Once we have collected all necessary data including GPS time, latitude, longitude, and altitude from the tracking team. Graphs will be acquired in order for comparison to expected results. Error will be calculated between acquired results and expected results. This error will be included in the final data analysis.

8.0 Project Management

We will meet on Thursdays from 5:00 pm till 8:00 pm and on Fridays from 2:30 pm till 7:00 pm for group work. These sessions are to discuss completed sections and decide on future workflow. We will discuss any problems encountered and methods chosen to correct them. Any additional group work periods are scheduled as needed. All individuals will be expected to complete their sections according to schedule and work independently on their own time if necessary. Any changes to payload or schedule will be voted on during group sessions. This is needed so we will be able to determine potential budget or deadline issues. The team leader will be responsible for overall project flow and will actively monitor the budget and progress. Every team member is responsible for keeping accurate records on their respective sections, and team record keeper will centralize the records as needed. Any parts needed will be ordered by the graduate assistants or by project oversight.

8.1 Organization and Responsibilities



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8.2 Configuration Management Plan

Any changes to payload design are implemented according to following procedures:

Design Change Plan:

1. Change request posed during team meeting.
2. All members of team votes on change.
3. Budget monitor will assure change fits in budget and advise team leader
4. Team leader will give final approval.
5. Record keeper will document relevant PDR/CDR sections.

8.3 Interface Control

There will be four main interfaces. They include:

1. Electrical interface (Section 4.3)
2. Mechanical interface (Section 4.5)
3. Software interface (Section 8.3)
4. General interface (Section 8.3)

Note: any changes to the interface design will follow the same procedures listed in Section 8.2.

8.3.1 Electric Interface

Electric interface is the electronic connection between the subsystems. The specific interfaces are:

1. Switch to batteries
2. Batteries to BalloonSAT
3. Interface board to Geiger counter
4. BalloonSAT to heaters

8.3.2 Mechanical Interface

This is the structural connection between each system. The specific interfaces include the following:

1. Box to Balloon *
2. BalloonSAT to box
3. Heaters to box
4. Geiger Counter to box
5. Batteries to box
6. Switch to box

*This will following the guidelines in LaACES lecture *Payload Construction Considerations and Techniques.*

8.3.3 Software Interfaces

The software programming needed to central subsystems, store measurements, and retrieve data after flight is known as software interfaces. It will include the following:

1. Program to provide timing for data collection
2. Program to save raw data
3. Program to convert raw data to formatted data
4. Program to retrieve data

8.3.4 General Interfaces

These are the interfaces between the various levels of entire project. The specific interfaces are in the following list:

1. Interface between CajunSat team members
   - Interpersonal communication will occur at CajunSat team meetings to provide weekly updates on progress. Email, telephone and face-to-face communication will be used to convey important messages between team members.

2. Interface with Stakeholders
   - Interfacing between CajunSat team members and Stakeholders will be in the form of written PDR, CDR, and FRR. Formal presentations will also be prepared and will allow direct interaction.

3. Interface with Project Management
   - Interfacing between CajunSat team members and project management will occur via interpersonal communication either during scheduled team meetings and office meetings.

9.0 Master Schedule

The following two sections are the overall work flow plan. Any changes to these will follow procedures listed in section 8.2. The tasks listed in the WBS were assigned to the various team members according to their strengths. Any team member who is not assigned a task for a specific date will assist others with their tasks. All dates listed are on our scheduled work days, Thursday and Friday. If for some reason we can not finish any particular task on the scheduled date it will be accomplished during the rest of the week.

There are many times during Monday through Wednesday where we have free time to meet. This will aid in finishing all tasks in the manner and timing set forth in the Gant chart. Any additional time needed will push the final few tasks into early May, which has only scheduled dates for the preparation for FRR and flight operations.

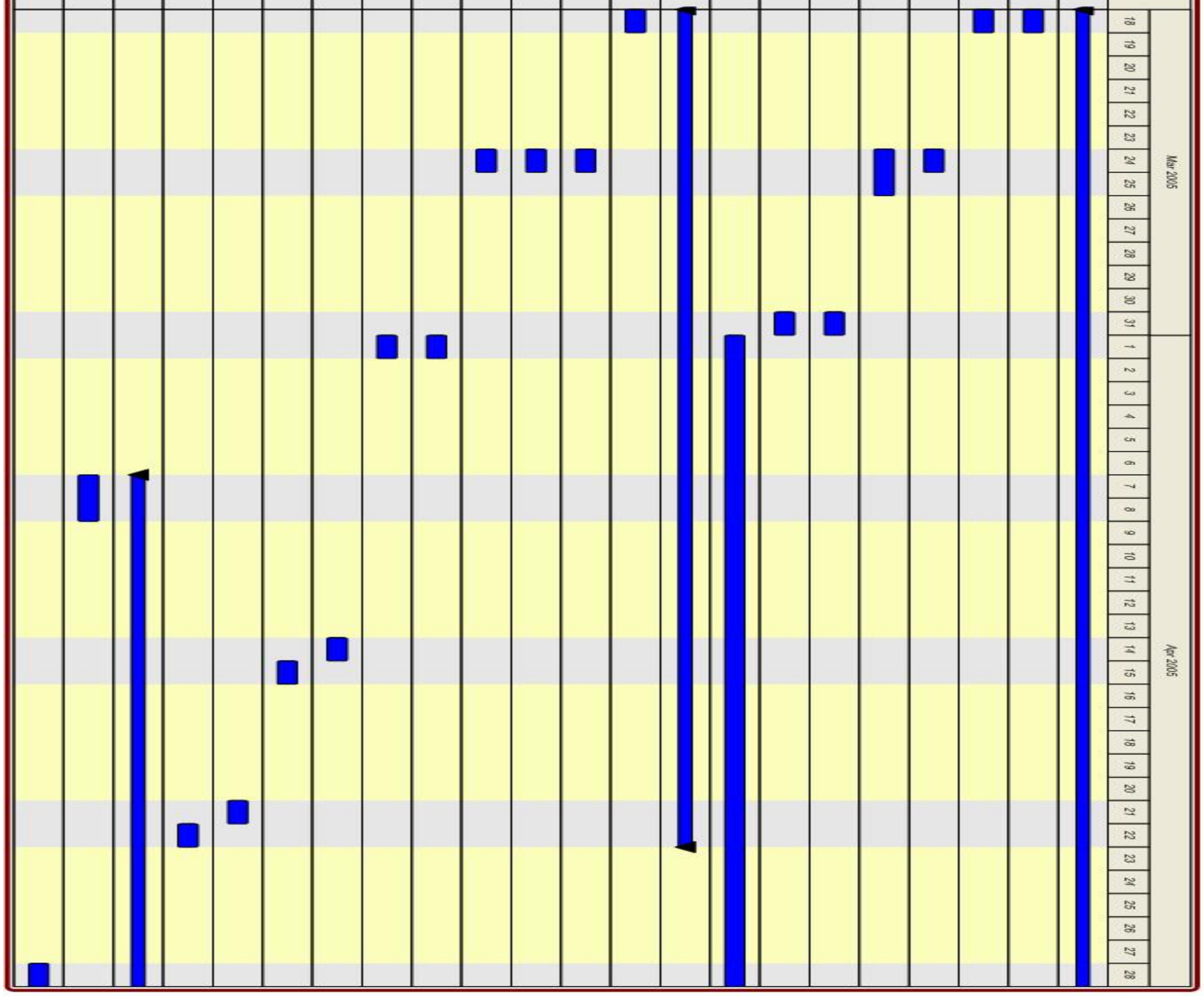
9.1 Work Breakdown Structure (WBS)

Section 9.1 Work Breakdown Structure (WBS) and Staffing Plan

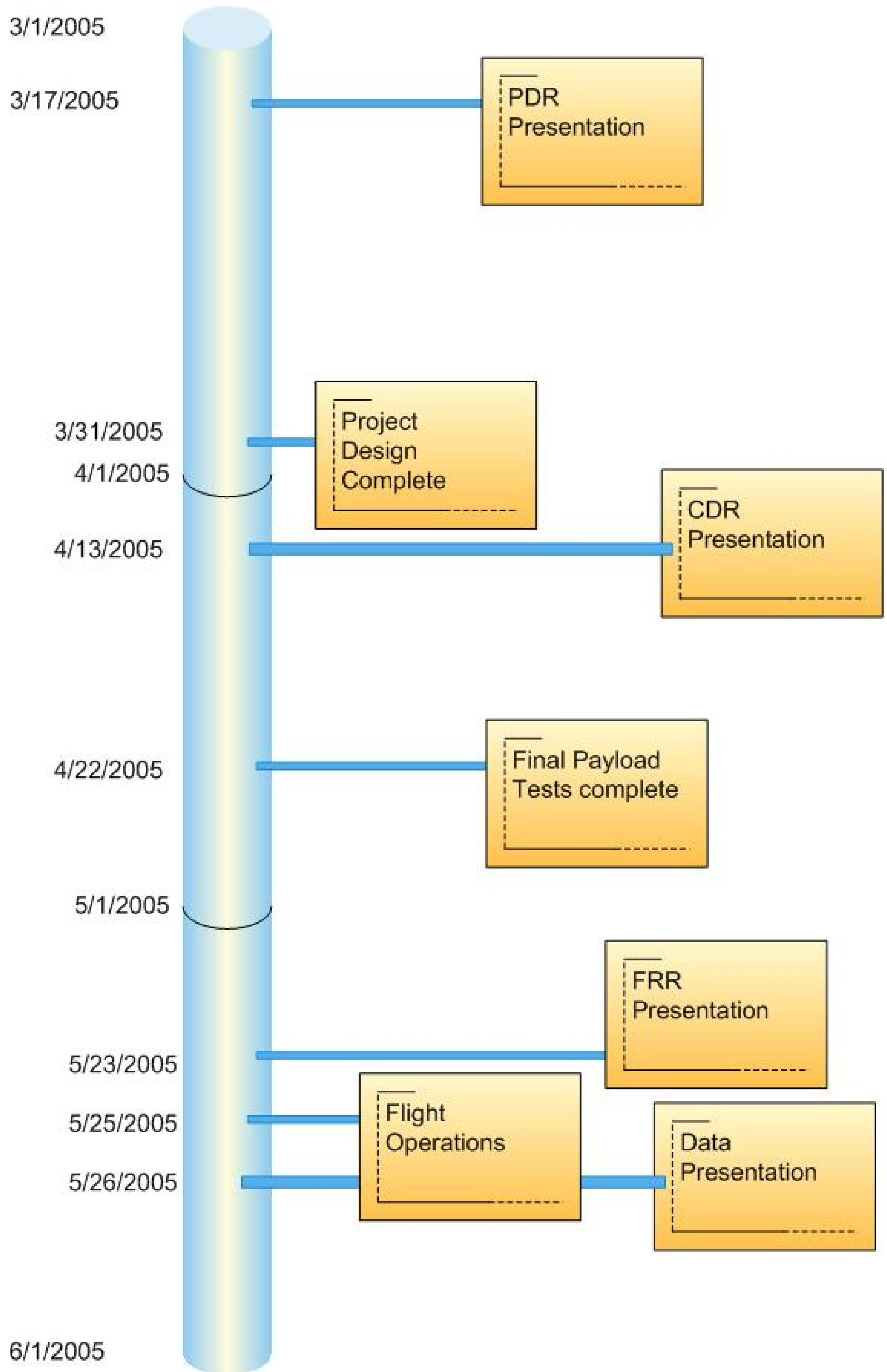
I. Lithium battery load check:	Ross
II. Design heating circuit:	Jasmine, Donald
1. Build heating circuit:	Ross
2. Test heating circuit:	Ross
III. Build Geiger counter kit:	Jasmine, Donald
1. Geiger counter rate check:	Ross
2. Geiger counter accuracy check:	Ross
3. Geiger counter environmental check:	Ross
IV. Design interface board:	Jasmine, Donald
1. Build interface board:	Jasmine, Donald
V. Build a system mock-up for testing:	Robert
1. Interface communication test:	Jasmine, Robert, Ross, Donald
2. Interface baseline check:	Jasmine, Robert, Ross, Donald
VI. Prepare CDR documents:	Mikhail
VII. Design structural layout:	Jasmine, Donald
VIII. Build a system mock-up for testing:	Robert
1. System mock-up shock test:	Jasmine, Robert, Ross, Donald
2. System mockup environmental check without heater:	Jasmine, Robert, Ross, Donald
3. System mockup environmental check with heater:	Jasmine, Robert, Ross, Donald
IX. Build final payload:	Robert
1. Final system checks:	Jasmine, Robert, Ross, Donald
X. Prepare FRR documents:	Jasmine, Robert, Ross, Donald

9.2 Staffing Plan

ID	Task Name	Start	Finish	Duration
1	**Design/Build**	**3/18/2005**	**5/20/2005**	**13.5 hours**
2	Design heating circuit	3/18/2005	3/18/2005	0.5 hours
3	Build heating circuit	3/18/2005	3/18/2005	0.5 hours
4	Build Geiger counter using kit	3/24/2005	3/24/2005	1.5 hours
5	Design interface board	3/24/2005	3/25/2005	5.5 hours
6	Build interface board	3/31/2005	3/31/2005	1.0 hours
7	Design structural layout	3/31/2005	3/31/2005	1.0 hours
8	Build a system mock-up for testing	4/1/2005	5/20/2005	3.5 hours
9	**Testing**	**3/18/2005**	**4/22/2005**	**21.5 hours**
10	Lithium battery load check	3/18/2005	3/18/2005	3.0 hours
11	Heater environmental check	3/24/2005	3/24/2005	3.0 hours
12	Geiger counter rate check	3/24/2005	3/24/2005	1.0 hours
13	Geiger counter accuracy check	3/24/2005	3/24/2005	1.0 hours
14	Geiger counter environmental check	4/1/2005	4/1/2005	1.0 hours
15	Interface baseline check	4/1/2005	4/1/2005	2.5 hours
16	System mock-up shock test	4/14/2005	4/14/2005	1.0 hours
17	System mock-up environmental test without heater	4/15/2005	4/15/2005	3.0 hours
18	System mock-up environmental test with heater	4/21/2005	4/21/2005	3.0 hours
19	Final system checks	4/22/2005	4/22/2005	3.0 hours
20	**Management**	**4/7/2005**	**4/29/2005**	**14.0 hours**
21	Prepare CDR documents	4/7/2005	4/8/2005	7.0 hours
22	Prepare FRR documents	4/28/2005	4/29/2005	7..0 hours



9.3 Timeline and Milestones



10.0 Master Budget

Figure 10.1
Table of the costs

Item	Estimated Cost	Description	Lead Time	Pricing Comments
Batteries	$60.00	- Lithium Batteries producing 9V - Batteries for actual flight, and for testing	- No wait time purchased at local retail store	- approximately $11.00 per 9V battery
Gamma Scout	Donated	- Used as a back up for the Velleman K2645 Geiger-Muller Counter Kit	- express shipment approximately 2-5 day wait period	- donated for UL of Lafayette LaACES use no cost to budget
Velleman K2645 Geiger-Muller Counter Kit	$150.00	- Used for detection of beta and gamma radiation in final payload	- express shipment approximately 2-5 day wait period	- detailed information is listed below (**)
Additional Supplies for Geiger Counter	$20.00	- Supplies for interfacing the BASIC STAMP to the Velleman K2645 Geiger-Muller Counter in the account it becomes our primary user	- No wait time purchased at local retail store	- approximately $1 - $2 per item used to construct this portion of the payload
Heating	$10.00	- Ceramic resistors used for heating payload	- No wait time purchased at local retail store	- Ceramic resistors 99 cents per resistor at Radio Shack
Final Building Supplies	$50.00	- Foam board for building payload, epoxy, wires, etc.	- No wait time purchased at local retail store	- Most costly items were board to build box which is around $20 for enough to build final box, and have spare for testing needs
Testing Supplies	$75.00	- Foam board for designing cold chamber, dry ice, etc	- No wait time purchased at local retail store	- Dry ice was the most costly item. We regularly purchased dry ice for our testing
Total Estimated Cost				$365.00

Table 10.1
Budget Table

** Four suppliers for the V-K2645 Geiger-Muller Counter kit (part# N32VKK2645) were priced to be the most cost efficient with the budget. The result of our research was as follows:

- PogeeKits Electronic Kits and Tools $148.50
  http://www.apogeekits.com/geiger_counter.htm
- Gibson Tech Ed, Inc $143.99
  http://www.gibsonteched.com/vk2645.html
- Carl's Electronics Inc. $179.95
  http://www.electronickits.com/kit/complete/meas/vek2645.htm
- Electronix Express $139.95
  http://www.elexp.com/kit_2645.htm

** We determine to go with PogeeKits Electronic Kits and Tools. The two suppliers with lower prices were sold out of the V-K2645, which would have resulted in a longer wait period that our project could not afford.

- It is possible more money will need to be allocated to purchasing additional supplies (batteries, heating, etc). According to the below Fig 10.2, we have 27% of our budget left to cover additional expenses we may encounter.

10.1 Expenditure Plan

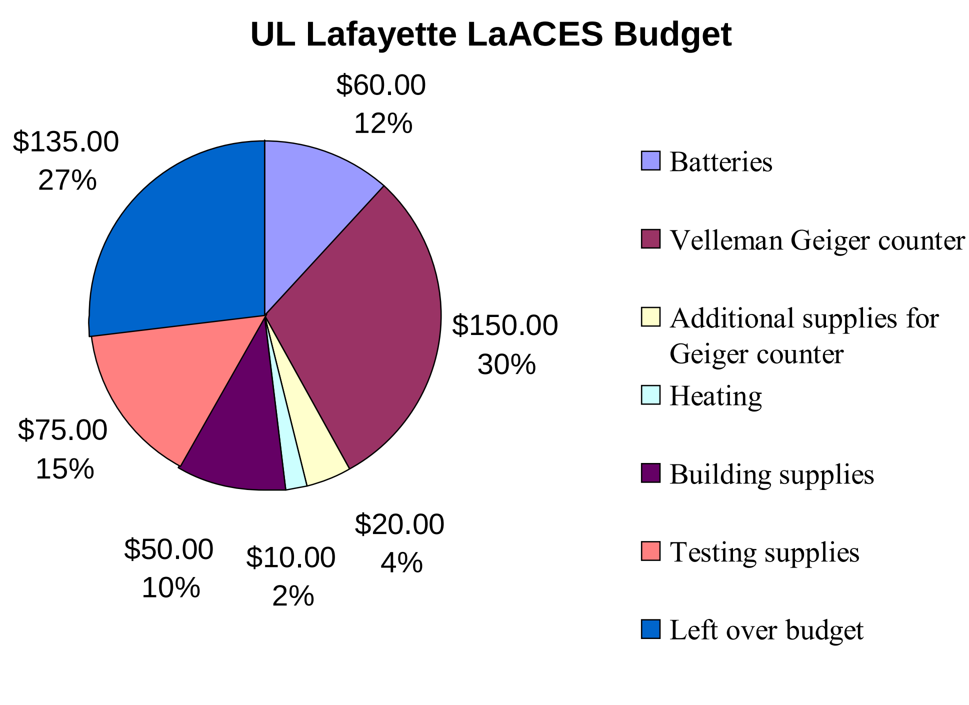


Figure 10.2.
This is a pie graph that shows the distribution of funds.

At this point in time we have purchased batteries, the Velleman K2645 Geiger-Muller Counter Kit, testing supplies, and some building supplies. The lithium batteries will have two purposes in our LaACES program. First, we will use at least two batteries for testing voltage drop (cold testing, vacuum testing, and cold vacuum testing). The second use for the batteries will be in powering the electrical components within our payload. We will use two 9V lithium batteries to power the load. Referring to figure 10.2, battery cost was 12% of our budget. The Velleman K2645 Geiger-Muller Counter was purchased for approximately $150.00. Since it was one of our most costly items, 30% of our budget (Figure 10.2), we researched multiple suppliers in order to be the most cost efficient. These details are located in the above section 10.0. Testing supplies have been purchased multiple times during programs timeframe. The biggest expense that we have encountered with testing supplies is dry ice, which is $1.00/pound. We used dry ice on a regular basis for our testing procedures of all of our components that are to go in the final payload. According to Figure 10.2, testing supplies will take approximately 15% of our budget.

We have purchased some building supplies, although more will be purchased when the time comes to build the final payload. Building supplies mostly includes foam board, aluminum tape, glue (epoxy), and other small items, these supplies take up approximately 10% of our budget (Figure 10.2). The only other expenditure that we have not yet purchased is the heating coils, used for marinating our payloads temperature around a minimum of -20 ºC. Heating elements will only take up 2% of our budget according to Figure 10.2. We have 27% of our budget left over after accounting for all expected expenditures. Therefore we will have more then enough left over budget to account for additional supplies we may need.

10.2 Material Acquisition Plan

Item	Acquisition	Order Date	Need Date
Batteries	Purchased		Needed on multiple accounts throughout entire project
Vacuum chamber	Existing Supplies		Needed on a regular basis for testing
Dry Ice	Purchased		Purchased as needed for project
Cold Chamber	Existing Supplies		Built on 2/10/05, used for testing on a regular basis
Heating Elements	Purchased		3/24/05
Insulation	Existing Supplies		3/24/05
Electrical Components	Existing Supplies/ Purchased		3/24/05
Building Supplies	Existing Supplies/ Purchased		2/24/05
Testing Supplies	Existing Supplies/ Purchased		Purchased as needed for the project
Geiger-Muller Counter	Purchased	3/8/05	3/24/05
Gamma Scout	Donated	3/3/05	3/24/05

Figure 10.3
Purchasing record.

11.0 Risk Management and Contingency

In order for us to have a successful flight, we must do lots of testing. This ranges from cold testing, vacuum testing, impact testing, and equipment testing. The following section explains and gives results of the different testing we did.

11.1 Stress testing

The first test we did was a stress test of the box rolling it down a flight a stairs. One thing that was noticed is that our only problem will be us securing our payload to the box. We solved this by installing slits in the boxes. The different slits will provide the stabilization at impact and will be able to survive just about any kind of impact except maybe a parachute failure. We did not roll our slit design down the stairs, but instead threw it our of a second story window. See figure 11.2. Surprisingly, there was very little damage to the outside of the box and only a broken piece of balsa wood and dented slit. This is not a problem because the batteries are on the bottom and only would break the heaters.

Figure 11.1.A
This is at the bottom of where we roll our foam box down the stairs and then observe what happens.

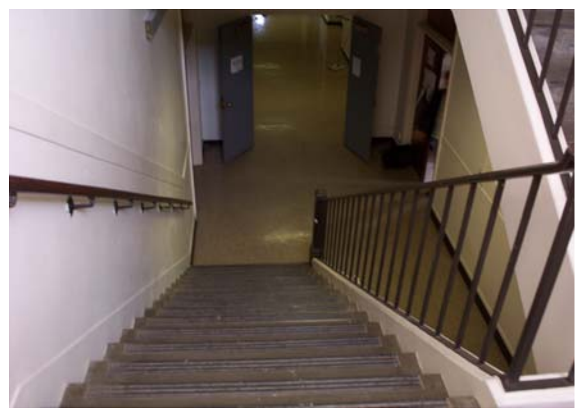


Figure 11.1.B
This is at the top of where we roll our foam box down the stairs and then observe what happens.

Figure 11.1.C
Pretesting of box

Figure 11.1.D
Outside of box after we threw it down the stairs

Figure 11.1.E
What happened on the inside. The glue did not hold well and we actually ripped a battery bottom off on upper left picture.

Figure 11.2 A
Picture from the second story window.

Figure 11.2 B
Picture of the second story window where we threw out the box.

Figure 11.2 C
Picture of the landing

Figure 11.2 D
Close up of our box after the landing

Figure 11.2 E
Close up of our box after the landing

Figure 11.2 F
This is a picture of the top layer of our payload. This is what will house the Geiger counter.

Figure 11.2 G
This is a picture of the top layer of our payload. This is what will house the BalloonSAT.

Figure 11.2 H
This is what happened to our battery section.

Figure 11.2 I
This is what happened to our battery section

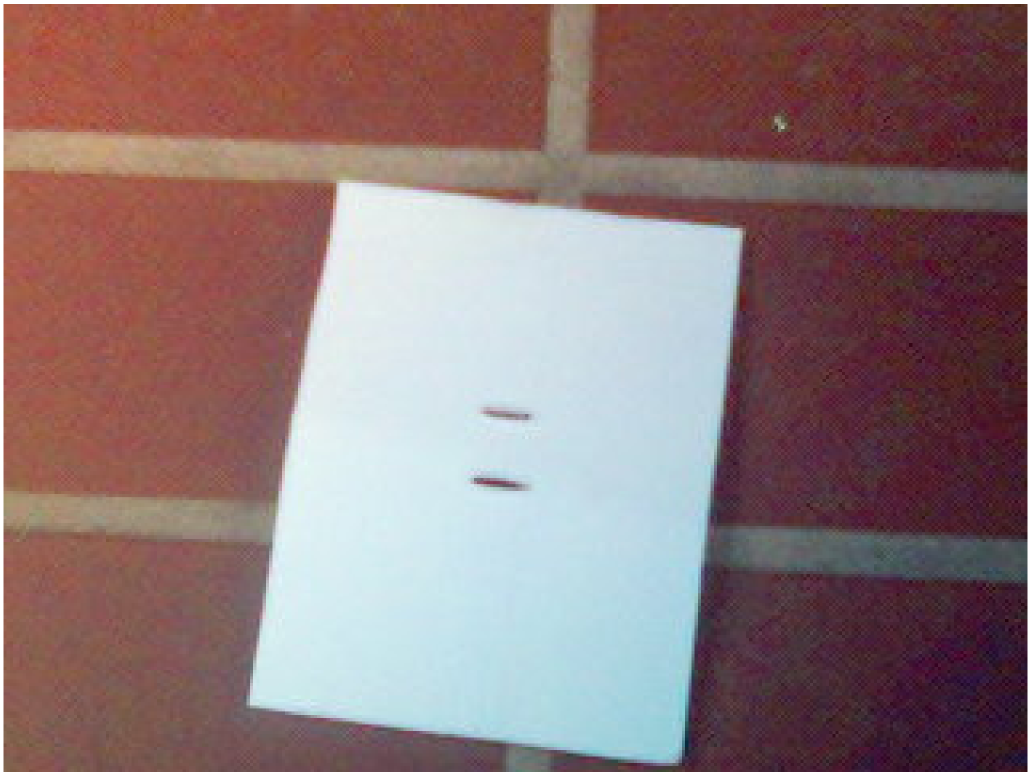


Figure 11.2 J
This is what happened to our battery section

Figure 11.2 K
This is what happened to our battery section

Figure 11.2 L
This is a close up of our inner box. The holes are where we slide in a section of the Balsa wood or section.

Figure 11.2 M
This is a close up of our inner box. The holes are where we slide in a section of the Balsa wood or section.

11.2 Cold testing

Cl-6450 Scientific Workshop

The instrument we use for our experiments is Cl-6450 Scientific Workshop 750 with SCSI interface with various probes that attach to it. Everything is made by PASCO scientific.

Key Features:

- SCSI/Serial Interface
- Designed for Advanced Placement and College Physics
- Real-time Oscilloscope Capable
- Built-in Function Generator

PASCO's 750 Interface is the measurement center for the modern physics laboratory. Using a computer and the 750 Interface, students can measure force, position, temperature, pressure, angular velocity, acceleration, current, magnetic field and more. Each 750 Interface includes a built-in function generator and real-time oscilloscope mode.

Seven Input Channels:

With the 750, all 7 channels may be used simultaneously. There are no limitations on what combinations of sensors can be used. Analog and digital inputs may be mixed in any combination.

- **Four Digital Channels** -- Use up to 4 Photogates or 2 Rotary Motion Sensors, a photogate and Motion Sensor II, or any other combination.
- **Three Analog Channels** -- Max sample rate of 250,000 Hz when using a single channel.

Features:

- **250,000 Hz Sampling Rate** -- Sample at 250,000 samples per second on a single analog channel. Students will see a true, real-time oscilloscope and incredibly responsive sound sensor data.
- **Built-in 1.5 W Function Generator** -- Any experiment requiring a frequency up to 50 KHz and 1.5 watt (300 mA) output can be run without additional power amplification. Output current and voltage can be monitored internally by the 750 Interface.
- **20 KHz oscilloscope** -- With the 750's increased sampling rate, the oscilloscope becomes a real-time scope with refresh rates up to 40 frames per second.
- **Reduced Noise and More Accurate Data** -- When sampling at rates less than 100 samples per second, circuit noise can be visible on a data graph. The 750 Interface, however, provides 8X oversampling to reduce noise and provide smoother data curves.
- **Serial Port Convenience** -- A serial port is available on this SCSI version for an additional connectivity option.

Unique Characteristics:

- **Ports** -- 4 Digital, 3 Analog, 1 Output
- **Connection** -- SCSI/Serial
- **Data Sampling** -- Simultaneous Analog and Digital Recording
- **Analog Rates** -- Up to 250,000 samples/sec (20 KHz Oscilloscope)

- **Digital Rates** -- 0.1 msec digital timing accuracy (1 mm resolution for Motion Sensor)
- **Function Generator** -- 0-50 KHz, 1.5 W (300 mA) output
- **Power Amp Compatible**
- **Designed for** -- Advanced Placement and College Physics

Specifications:

Power	12 VDC to 20 VDC at 2 A, 2.1 mm jack
SCSI Computer Connection	8-bit width, MDB50 female, internal active termination
Serial Computer Connection	Serial RS-232, 8-pin MDIN female, 19.2K bits/s, 1-8-1
Digital Channels	4 identical channels, TTL compatible (8 mA max. drive current) Maximum input logic transition time: 500 ns Edge sensitive-sampled at 10 KHz. (1 µs res. for Motion Sensor
Analog Input Channels	3 identical channels with differential inputs and 1 MOhm impedance ±10 V maximum usable input voltage range (±12 V absolute input voltage range) 3 voltage gain settings on each analog channel: 1, 10, and 100 Small signal bandwidth up to the ADC: 1 MHz for a gain of 1, 800 KHz for a gain of 10, and 120 KHz for a gain of 100; input amplifier slew rate: 1.2 V/µs
Electrostatic Discharge (ESD) protected	Both digital and analog inputs have ESD protection.
12-Bit Analog to Digital Conversion	5 inputs: channels A–C, analog output voltage and current. Voltage resolution at ADC input: 4.88 mV (.488 mV at a gain 0.049 mV at a gain of 100) Current measurement resolution: 244 µA, (1 V = 50mA) mA Offset voltage accuracy < ±3 mV. (For measuring full-scale v the total error is less than ±15 mV, accounting for the gain err input amplifier.) Sample rate range: once every 3,600 seconds (250 KHz) (Con time for consecutive channels in a burst is 2.9 µs.) 8X oversampling for better accuracy at sample rates less than to 100 Hz.
Analog Output	DC value ranges: -4.9976 V to +5.0000 V in steps of 2.44 mV Accuracy at the DIN connector: (±3.6 mV ±0.1% full scale) Peak-to peak amplitude adjustment ranges for AC waveform: 0 V to ±5 V in steps of 2.44 mV AC waveform frequency ranges: 0.001 Hz–50 KHz, ±0.01% Maximum amplified output at the banana jacks: about 300 mA at ±5 V, current limited at 300 mA ±12 mA

Table 11.1
This is the specifications for the Cl-6450 Scientific Workshop.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=1487&Detail=1

Figure 11.0
This is a picture of the Cl-6450 Scientific Workshop.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=1487&Detail=1

RTD Temperature Sensor

Key Feature:

- Large temperature range

PASCO's resistance temperature device is a highly accurate Temperature Sensor made from platinum wire. Comes with a Teflon® cover for use in harsh liquids or chemical solutions.

Typical Applications:

- Conduct experiments where temperature to within 0.5 °C is required
- Measure temperatures down to -200 °C (liquid nitrogen)

Specifications:

Temperature Range	-200 °C to +200 °C
Accuracy	less than 0.5 °C full scale
Resolution	0.2 °C
Output Voltage/Temperature ratio	10 mV/ °C, linear
Temperature Sensing Junction	platinum wire
Pin Configuration	8-pin DIN plug

Table 11.1
This is the specifications of the RTD table.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=51267&Detail=1

Figure 11.2
This is a picture of the RTD temperature sensor.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=51267&Detail=1

Voltage sensor

Key Feature:

- Standard banana plugs and alligator clips

The Voltage Sensor provides a simple connection between a ScienceWorkshop interface and an electronic circuit.

Typical Applications:

- Study resistance, voltage and capacitance in circuits
- Electroplating
- Conduct power amplifier experiments

Specifications:

Voltage Range	±10 V AC/DC
Pin Configuration	5-pin DIN plug
CBL Compatibility	Requires CBL program supplied by TI or Vernier Software. Requires PASCO 8-pin DIN plug (CI-6686) to British Telecom Plug Adapter to emulate CBL Voltage Sensor. (Please call Tech Support at 1-800-772-8700 or 1-916-786-3800 for more information about the adapter.)

Table 11.3
This is the specifications for our volage sensor.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=51388&Detail=1

Figure 11.3
This is a picture of the voltage sensor.
http://store.pasco.com/pascostore/showdetl.cfm?&DID=9&Product_ID=51388&Detail=1

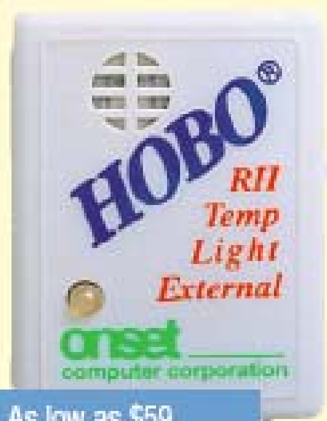
HOBO

A HOBO device is used for us to take the temperature inside our box for testing and for calibration of the thermistors on the BalloonSAT. They will not be on our flight. The following is the specifications of the HOBO.

indoor

HOBO® H8 Family

8-Bit Loggers with Serial Interface*



As low as $59

7 Models to Choose From

1-Channel: temperature
2-Channels: temperature, external
2-Channels: temperature, relative humidity
4-Channels: temperature, light intensity, relative humidity, external
4-Channels: temperature, relative humidity, 2x external
4-Channels: intrinsically-safe temperature, relative humidity, 2x external
4-Channels: 4x external

Size/Weight: 6.1 x 4.8 x 2.0 cm
(2.4 x 1.9 x 0.8"), approximately 29 gm (1 oz)

Key Specifications

Measurement Ranges:
Temperature: -20° to 70°C (-4° to 158°F).
RH: 25% to 95% RH at 25°C (77°F) for intervals ≥10 seconds
Light Intensity: 2 to 600 footcandles (lumens/ft^2) typical
light sensor response range: approx. 480 to 600 nm

Accuracy:
Temperature: ±0.7° at 21°C (±1.27°at 70°F)
RH: ±5% over the range of 5° to 50°C (41° to 122°F)

Operating Range: -20° to 70°C (-4° to 158°F), 0 to 95% relative humidity, non-condensing, non-logging.
RH sensor operating range is 5° to 50°C (41° to 122°F)

The HOBO H8 family of data loggers provides easy-to-use data collection at affordable prices. Choose single-, two- or four-channel models to measure temperature, relative humidity, light intensity, or external channels accepting external temperature, AC current sensors, CO_2 input and 4-20mA or DC voltage cables for input from third-party sensors.

Features

Easy to Use:
- User-selectable sampling intervals: 0.5 seconds to 9 hours, recording times up to 1 year
- Programmable start time/date
- Memory modes: Stop when full, Wrap around when full
- Read out and relaunch with optional HOBO Shuttle
- Precision components eliminate the need for user calibration
- Mounting kit included (hook/loop, magnet and tape)

Versatile:
- Seven models from which to choose with 1–4 channels to measure temperature, humidity, light and external inputs
- Models with external input accept external sensors for temperature, AC current, carbon dioxide (CO_2), 4-20 mA and 0-2.5 Volts DC
- Internal temperature sensor on 10.2 cm (4") wire can extend from case

Reliable:
- Capacity: 7943 measurements total except 4-Channel External model, which stores 32,520 measurements
- Blinking LED confirms operation
- Battery level indication at launch
- Nonvolatile EEPROM memory retains data even if battery fails
- Time accuracy: ± 1 minute per week at 20°C (68°F)
- NIST-traceable temperature accuracy certification available
- Compliance certificate available
- Intrinsically-safe Temp/RH/2x external model available
- User-replaceable battery lasts 1 year (typical)
- Drop-proof to 1.5m (5')

(B) BoxCar®-compatible
(Bp) BoxCar®Pro-compatible
HOBO® Shuttle-compatible
CE Compliant with all relevant directives in the European Union (EU)
IS Intrinsically Safe Model

Figure 11.8
This shows the all the data on the HOBO.
http://www.onsetcomp.com/Products/Product_Pages/pdfs/h08_00x_0x.pdf

Detailed Specifications

Time Accuracy: ±1 minute/week at 20°C (68°F)

Temperature (internal sensor)
Range: -20° to 70°C (-4° to 158°F)
Accuracy: ±0.7° at 21°C (±1.27° at 70°F) (see plot a)
Resolution: 0.4° at 21°C (0.7° at 70°F)
Response time in still air: 15 min. typical to 90%
with sensor inside case, 1 min. typical with sensor outside case

Relative humidity
(user-replaceable RH sensor)
Range: 25% to 95% RH at 80°F for intervals of
≥ 10 seconds, non-condensing and non-fogging
Accuracy: ±5% (see plot b)
Response time: 10 min. typical in air
Sensor operating environment: 5° to 50°C
(41° to 122°F) non-condensing and non-fogging

Light intensity
Range: 2 to 600 footcandles (lumens/ft^2) typical;
max. value varies from 300 to 900 footcandles
Light wavelength response (see plot c)

External input accepts the following sensors
Temperature sensors (TMCx-Hx series)
Split-core CTs for AC current (5 Models)**
CO_2 from Telaire 7001 (TEL-7001 and CABLE-CO_2)**
4-20 mA input cable (CABLE-4-20mA)**
0-2.5 V DC input cable (CABLE-2.5-STEREO)**

External 2.5 volt input specifications***
(all H8 models except 4 channel external)—2.5 mm jack: external input ground, input, switched 2.5 V output; external input ground connection is not the same as PC interface connection ground and should not be connected to any external ground

H8 4-Channel External models—2.5 mm jack: ground, input-switched 2.5 volts output; ground connection uses the same as the PC interface connector ground.

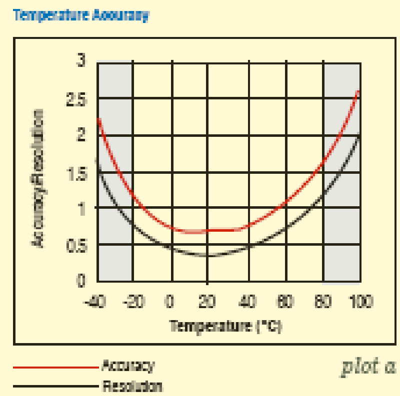
Input range: 0 to +2.5 DC Volts
Accuracy: ±10 mV ±3% of reading
Resolution: 10 mV (8-bit)
Output power: +2.5 DC Volts at 2 mA,
active only during measurements

**Note: Intrinsically Safe versions can only be used with passive voltage devices and do not maintain IS rating when used with CTs, Telaire 7001, 4-20mA or non-passive sensors.*

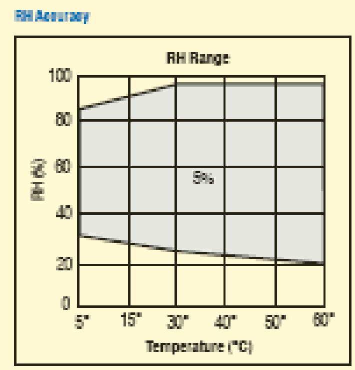
****The grounds of all voltage and/or current sources must be at the same voltage potential before you connect them to the logger to avoid inaccurate readings or damage to the logger and input cables.*

indoor

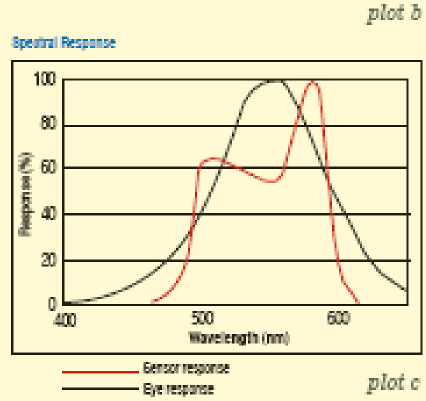
Detailed Specifications



plot a



plot b



plot c

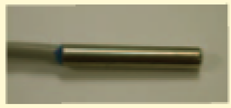
Figure 11.8 continued
This shows the all the data on the HOBO.
http://www.onsetcomp.com/Products/Product_Pages/pdfs/h08_00x_0x.pdf

HOBO H8 and U12
External Sensors and Input Cables

Cables on this page can be plugged directly into the external input jacks of H8 or U12 Family loggers to expand the range of measurement options and applications. Accuracy specifications of temperature sensors reflect the combined performance of the logger and sensor.

Temperature sensors

Air/Water/Soil temperature sensors



TMCx-HD Temperature Sensor

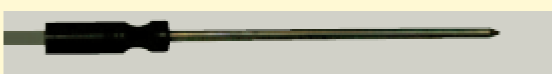
Range: -40° to 50°C (-40° to 122°F) in water or soil;-40° to 100°C (-40° to 212°F) in air
Accuracy: w/H8; ±0.5° at 20°C (±0.9° at 68°F); w/U12: ±0.25° at 20°C (±0.45° at 68°F)
Resolution: w/H8; 0.41° at 20°C (0.7° at 68°F); w/U12: 0.03° at 20°C (0.05° at 68°F)
Response time: in air moving 1 m/sec (2.2 mph): 3 min. typical to 90%; in stirred water: 1 min. typical to 90%
Sensor diameter: 0.5 cm (0.20")
Note: Sensor tip and cable immersion in fresh water up to 50°C (122°F) for 1 year; radiation shield recommended for use in sunlight.

Narrow-Range temperature sensor for H8 loggers

TMC6-HB Narrow-range Temperature Sensor

Range: 0° to 44°C (32° to 110°F) in air*
Accuracy: w/H8; ±0.4° at 20°C (±0.7° at 68°F); w/U12: ±0.25° at 20°C (±0.45° at 68°F)
Resolution: w/H8; 0.2° at 20°C (0.3° at 68°F); w/U12: 0.011° at 20°C (0.02° at 68°F)
Response time in air moving 1 m/sec (2.2 mph) 4.5 min. typical to 90%; in stirred water: 1 min., typical to 90%
Sensor diameter: 0.8 cm (0.3") sensor

* *Note: Do not use for more than 3 months total in water less than 30°C (86°F), or more than 1 month total in water over 30°C (86°F).*



TMC6-HC Stainless Steel Temp Probe

Stainless Steel temperature probe (TMC6-HC)

10.2 cm (4") food-grade stainless-steel probe with pointed tip; 0.3 cm (0.12") diameter, 1.8 m (6') cable
Range: -40° to 100°C (-40° to 212°F) in air or water
Accuracy: w/H8; ±0.5° at 20°C (±0.9° at 68°F)
Accuracy: w/U12; ±0.25° at 20°C (±0.45° at 68°F)
Resolution: w/H8; 0.41° at 20°C (0.7° at 68°F)
Resolution: w/U12; 0.03° at 20°C (0.05° at 68°F)
Response time in air moving 1 m/sec (2.2 mph) 3 min. typical to 90%; in stirred water 15 sec. typical to 90%

Additional sensors/cables on pg. 8.

indoor

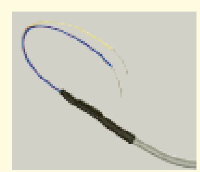
Split-core AC current sensors*

Ranges available (AC Amps): 0-20, 0-50, 0-100, 0-200, 0-600
Accuracy: w/H8; ± 5% of full scale; w/U12; ± 4.5% of full scale
Response time (from 10% to 90% of amplitude):
CTV-A approximately 440 milliseconds
CTV-B approximately 200 milliseconds
CTV-C approximately 100 milliseconds
CTV-D approximately 450 milliseconds
CTV-E approximately 490 milliseconds

Input current: AC current, sine wave, single phase
50 Hz or 60 Hz, load power factor 0.5 to 1.0 lead or lag
Voltage rating: 600 VAC
Operating range: 0° to 60°C (32° to 140°F)
CTV-A, -B, -C; 0° to 40°C (32° to 104°F) CTV-D, -E
Construction and operating environment:
Molded plastic housing for indoor use per UL508.
All units have opening leg that snaps into place
1.8 m (6') cable compatible w/ H8 and U12 external inputs
Leg on CTV-D and E-units is removable.
**Note: AC current sensors are not CE approved.*

Part #	Range	Window	Outer Length	Outer Width	Height
CTV-A	0-20 Amps AC	2.8 x 2.3 cm	7.4 cm	6.6 cm	2.5 cm
		1.1 x 0.9"	2.9"	2.6"	1.0"
CTV-B	0-50 Amps AC	2.8 x 2.3 cm	7.4 cm	6.6 cm	2.5 cm
		1.1 x 0.9"	2.9"	2.6"	1.0"
CTV-C	0-100 Amps AC	2.8 x 2.3 cm	7.4 cm	6.6 cm	2.5 cm
		1.1 x 0.9"	2.9"	2.6"	1.0"
CTV-D	0-200 Amps AC	3.8 x 3.3 cm	9.9 cm	11.9 cm	2.8 cm
		1.5 x 1.3"	3.9"	4.7"	1.1"
CTV-E	0-600 Amps AC	7.4 x 6.4 cm	13.5 cm	15.0 cm	2.8 cm
		2.9 x 2.5"	5.3"	5.9"	1.1"

4-20 mA cable (CABLE-4-20mA)



4-20mA Cable

Range: 0 to 20.1 mA
Accuracy: w/H8 ±0.1 mA ±2.5% of reading; w/U12: ±0.02 mA ±2.5% of reading
Resolution: w/H8 0.4% of full scale; w/U12: 0.03% of full scale
45.7 cm (18") cable with 8.9 cm (3.5") tinned braided wire leads

Voltage input cable (CABLE-2.5-STEREO)

0-2.5 Volt DC Cable

1.8 m (6') cable with 1.27 cm (0.5") tinned braided wire leads
For voltage input specifications, refer to the specifications of the model you will be using.

Figure 11.8 continued
This shows the all the data on the HOBO.
http://www.onsetcomp.com/Products/Product_Pages/pdfs/h08_00x_0x.pdf

The following graphs are for a one box design. We currently do not have any double box design test. This will be done latter this week and the graphs replaced with the double box experiment. We are certain that it will work because between the heater and another layer in insulation; the box should not get to below our operating of -20°C. This is the minimum temperature because after this we get too little voltage, which in turn will give us too little current. Also, our devices are not designed for this low of a temperature so they can become inoperable making our flight a failure. To make sure this does not happen we will do lots of testing to minimize the effects of this incase of a heater failure.

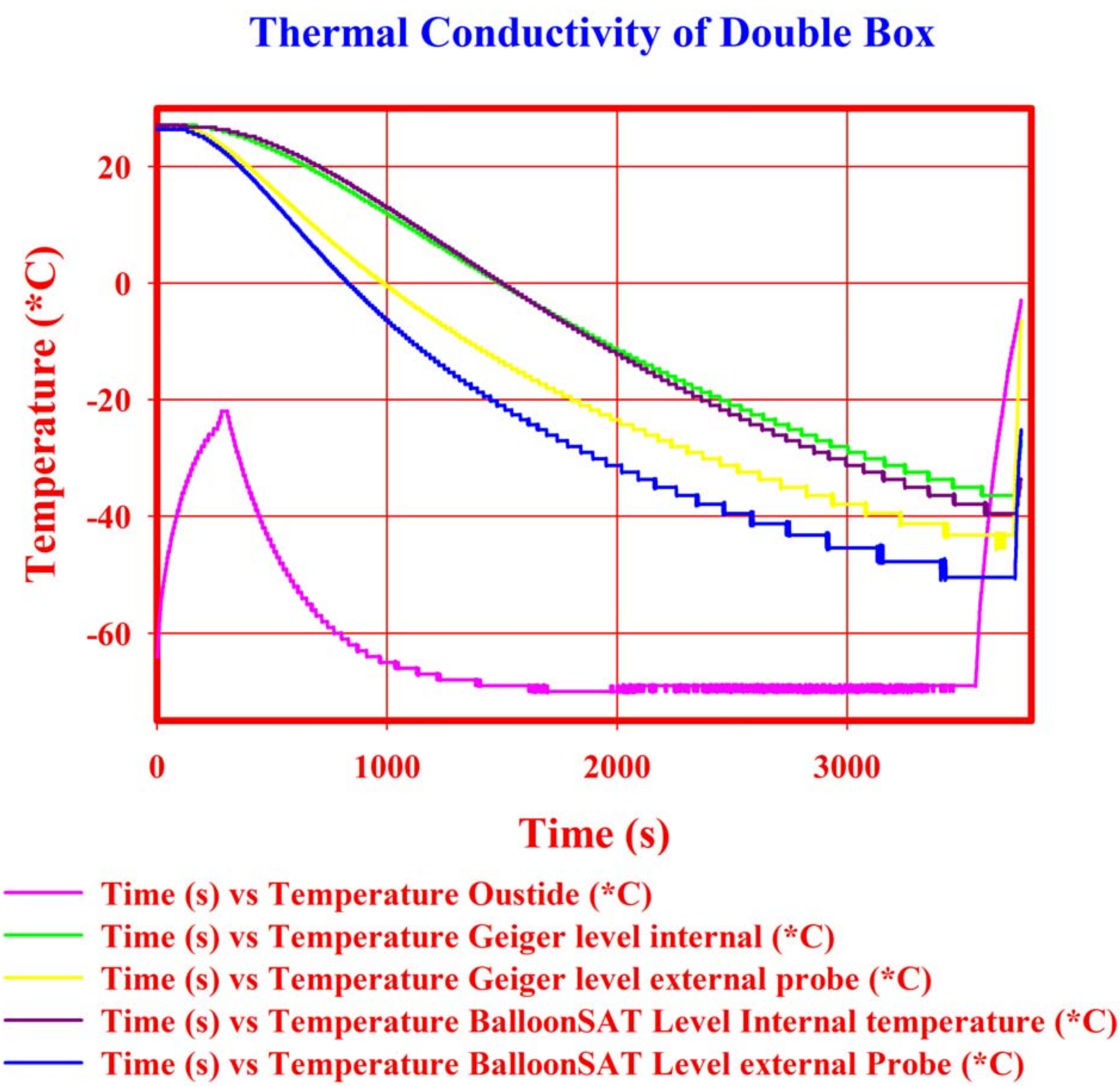


Figure 11.9
This shows the thermal conductivity of the box using the HOBO data logger inside it.

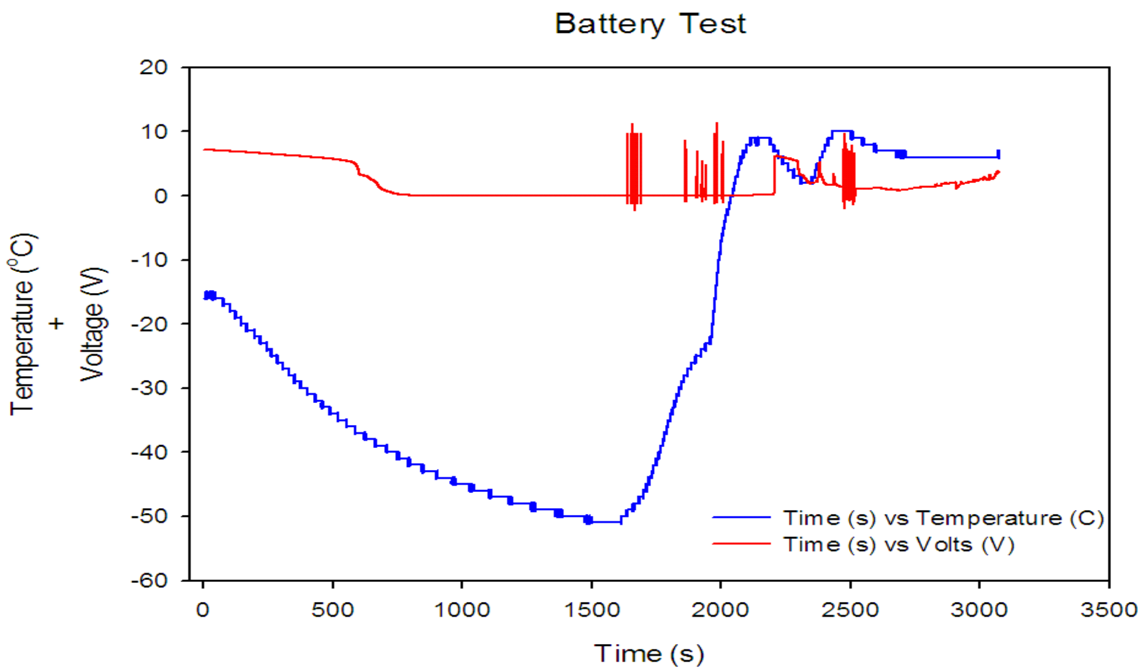


Figure 11.10
Graph shows that low temperature can make voltage go to zero. This means current goes to zero also due to Ohm's Law meaning that none of our devise will work due to lack of power.


Figure 11.11 A
This is a picture of our cold chamber.

Figure 11.11 B
This is a picture of our cold chamber.

11.3 Vacuum Testing

The final single test we will do is a vacuum test of the equipment. We must make sure nothing happens to our equipment at a low altitude because all of our equipment we are using is off the shelf and was never intended to be put at an extremely low pressure environment. Our tests so far have shown that the equipment we are using can operate in a low pressure environment.

Figure 11.12.A
This shows the inside of our cold chamber, with the vacuum chamber inside of it. We created a latter like structure to create convection and speed up the cooling process.

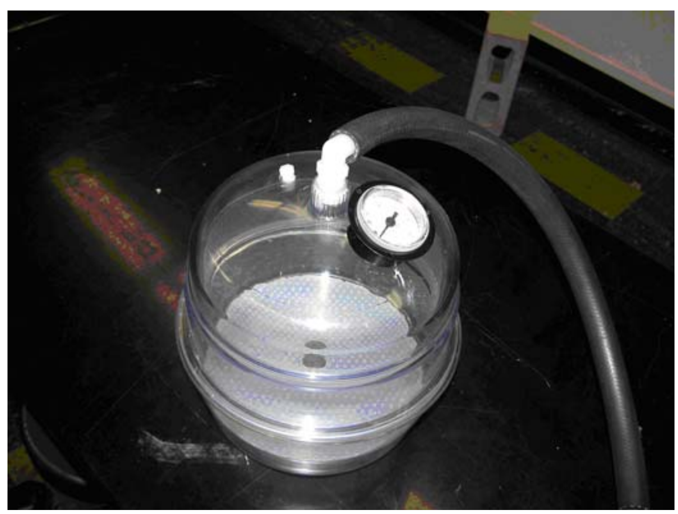


Figure 11.12.B
A picture of our vacuum chamber

11.4 Test of RF emission

To test if our payload was emitting radio frequencies, we used a Tektronix TDS 340A oscilloscope. To test this all we did was connect our payload to the oscilloscope and measure the frequency. We noticed that it did not have any extra frequency at measurement; therefore, we conclude that it does not emit any radio frequency. The following shows our measurements and the technical data on the Tektronix oscilloscope.

Signal Acquisition System	
Bandwidth	100 MHz
Sample Rate	500 MS/s on each channel.
Channels	Two identical channels, each with invert function.
Sensitivity	2 mV to 10 V/div (with calibrated fine adjust).
Position Range	±5 divisions.
DC Gain Accuracy	±2%.
Vertical Resolution	8-Bits (256 levels over 10.24 vertical divisions).
Acquisition Modes	Sample, Envelope, Average
Peak Detect	High frequency and random glitch capture; Captures glitches as narrow as 10 ns using acquisition hardware at all time/div settings between 25 µs/div and 5 s/div (inclusive).

Table 11.4
This shows the characteristics of the signal acquisition system of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Volts/Div Setting	Offset Range
2 - 99.5 mV/div	±1 V
100 - 995 mV/div	±10 V
1 - 10 V/div	±100 V

Table 11.5
This shows Calibrated Offset Ranges of our oscilloscope.

Time Base System (Main and Delayed)	
Time/Division Range	5 ns to 5 s/div
Record Length	1000 sample points per channel
Horizontal accuracy	± 0.01%
Roll Mode	0.1 s/div and shower when Auto Trigger Mode is selected

Table 11.5
This shows the time base system of our oscilloscope
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Trigger System (Main Only)	
Trigger types	Edge, Video
Trigger Modes	Auto, Normal
Trigger Inputs	CH1, CH2, Line, External
Video-Type Trigger Formats and Field Rates	Triggers on Field 1, Field 2, Any Field (noninterlaced systems), or Lines; from Sync-negative composite video. Triggers on broadcast standard NTSC, PAL, or SECAM video and other interlaced and noninterlaced video with horizontal line rates from 15 to 65 kHz (in 5 ranges) and field rates from 50 to 60 Hz.

Table 11.6
This is a table of the trigger system of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Display	
Sin(x)/x Interpolation.	
Vector	Connects sample points to display a continuous waveform
Dots	Displays sample points only
Vector Accumulate Mode	Accumulates waveform points over a pre-set period of time (500 ms to infinity) and superimposes the current waveform with bright vectors.
Dot Accumulate Mode	Accumulates waveform points over a pre-set period of time (500 ms to infinity).
Format	YT and XY.

Table 11.7
This is a table of the Display of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Automatic Measurements

Period
Frequency
+Width
-Width
Rise Time
Fall Time
+Duty Cycle

-Duty Cycle
+Overshoot
-Overshoot
High
Low
Max
Min
Pk-Pk

Amplitude
Mean
Cycle Mean
RMS
Cycle RMS
Burst Width

Cursors	
Types	Horizontal bars, vertical bars, paired (volts @ time).
Measurements	Absolute volts, DELTA volts, time, and frequency

Table 11.8
This is a table of the cursors of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Physical Characteristics

	Portable		Rackmount	
Dimensions	**mm**	**in.**	**mm**	**in.**
Width w/ handle	362	14.3	483	19
Height w/ pouch	191	7.5		
w/o pouch	165	6.5	178	7
Depth (stand alone)	472	18.6	472	18.6
w/ front cover	490	19.3		
w/ handle(s)	564	22.2	518	20.4
Weight	**kg**	**lbs.**	**kg**	**lbs.**
TDS 300	6.9	15.5		
Domestic Shipping	13.1	29	14.4*[1]	32*[1]
*[1] Weight of conversion kit only.				

Table 11.6
This is a table of the physics characteristics of our oscilloscope.

Waveform Processing	
Arithmetic Operators	Add, subtract, multiply
Auto Setup	Single button automatic setup on selected input signal for vertical, horizontal, and trigger systems
FFT Analysis	A mixed radix FFT routine is applied to the time domain waveforms to analyze frequency content. A Hanning Window is always applied to the acquired signal. The display uses dBVRMS vertical scaling.

Table 11.9
This is a table of the wave processing of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Non-Volatile Storage	
Waveforms	Two 1000 point reference waveforms
Setups	10 front panel setups.
Floppy Drive	3.5 in., 1.44 MB or 720 K DOS-compatible; PC formats: .BMP, .TIF, .PCX, .EPS; spreadsheet formats: Excel, Lotus123, and MathCAD for mathematical modeling and analysis.

Table 11.10
This is a table of the non-volatile storage of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Option 14: I/O Interface	
GPIB (IEEE -488.2) Programmability	Full talk/listen modes; Control of all modes, settings, and measurements
RS -232 -C Interface Programmability	Full talk/listen modes; Control of all modes, settings, and measurements. Baud Rate up to 38,400. 9-Pin, DTE
VGA	Monitor output for direct display on large VGA-equipped monitors.
Hardcopy Port	Centronics-type parallel, RS-232-C, or GPIB.
DC Power for Printer	
Programmer Manual	(070-9442-00).

Table 11.11
This is a table of the option 14: I/O Interface of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Hard Copy Capability	
Graphics File Formats	Interleaf (.img), TIF, PCX (PC Paintbrush), BMP (Microsoft Windows), and Encapsulated PostScript (EPS).
Printer Formats	Thinkjet, Deskjet, Laserjet, Epson (9- & 24-Pin), Seiko DPU 411/II, DPU 412, DPU 414.
Available Printer Packs	4 in. thermal printer and storage pack (TDS4F5P).

Table 11.12
This is a table of the hard copy capability of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Mechanical	
Cooling Method	Forced air circulation with no air filter.

Table 11.13
This is a table of the mechanical information of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

Environmental and Safety	
Temperature	-10° to +55°C (operating); -51°C to +71°C (non-operating).
Humidity	Up to 95% RH at or below +40°C; up to 75% RH from 41°C to 55°C (operating and non-operating).
Altitude	To 15,000 ft/4,570 m (operating); to 40,000 ft/12,190 m (non-operating).
Electromagnetic Emissions	Meets EN50081-1; VFG 0243; FCC Rules and Regs, 47 CFR, Part 15, Subpart B, Class A.
Safety	UL 3111-1 Listed, EN61010 Certified CAN/CSA C-22.2 No. 1010.1-92.

Table 11.14
This is a table of the Environmental and Safety features of our oscilloscope.
http://www.tek.com/Measurement/cgi-bin/framed.pl?Document=/Measurement/Products/catalog/tds300/specs.html&FrameSet=oscilloscopes

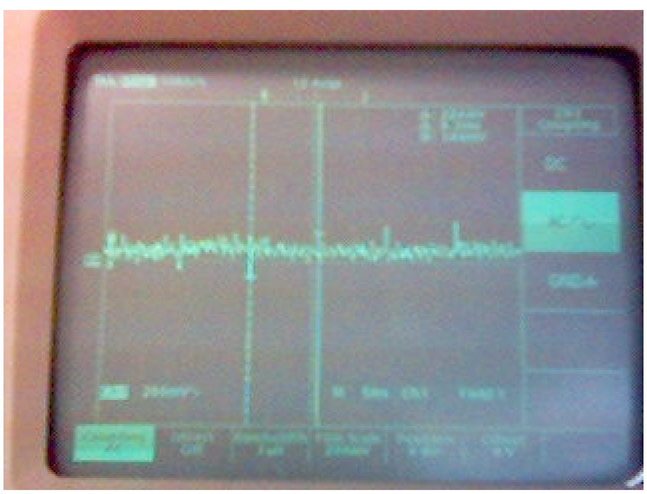


Figure 11. 13 A
This is a picture of our oscilloscope running.

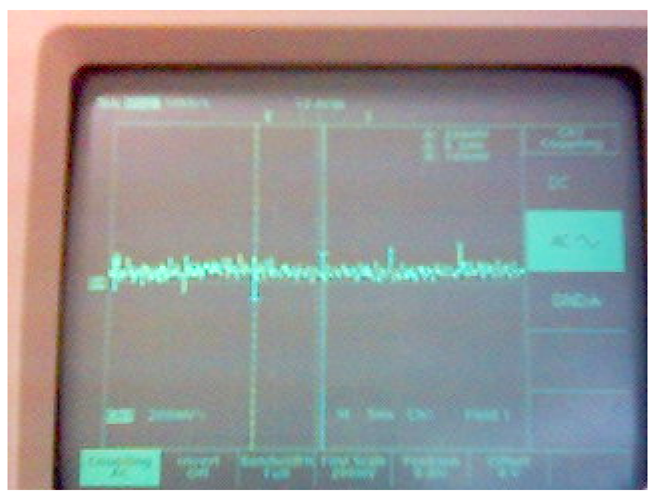


Figure 11.13 B
This is a picture of our oscilloscope running.

11.5 Complete system test of all equipment and in all conditions

The last test we will do is a full system test of our entire payload. We will place our vacuum chamber in our cold chamber and let it run for about five hours. After this we will take the payload out of the vacuum chamber and drop if from about 8 feet to make sure it can survive the cold and vacuum environment for 5 hours then the impact. This test is currently pending.

Risk Event	Likelihood	Impact	Detection Difficulty	Phase
Cannot calibrate Geiger-Muller counter (K2645)	1	5	1	Construction
All electrical components fail to work	1	5	2	Construction
Unable to activate electronics	2	5	1	Pre-flight
Run out of time	3	5	3	Pre-flight
Software failure	1	5	1	Flight
Hardware failure	2	5	1	Flight
heaters fail	2	3	1	Flight
Temperature drops to below operating range	2	3	1	Flight
Another teams experiment will interfere with our measurements	1	3	3	Flight
Will not find balloon payload	1	5	1	Post-flight
Impact destroys everything inside including data	1	5	1	Post-flight
Data does not match model	2	3	1	Post-flight
Run out of human resources	2	5	1	Any time
Weight budget is exceeded	2	5	1	Any time
Money budget is exceeded	1	5	1	Any time

Table 11.15
This shows the likelihood of what will go wrong.

Consequences	Probability				
Total damage to payload	Probability of complete destruction				
	Very Likely	Likely	Probable	Unlikely	Very Unlikely
Extreme			• Heaters fail • Out of time	• Unable to activate electronics • Hardware Failure • Impact destroys data • Too heavy • Temperature drops too low	• Electrical components fail to work • Software failure • Out of money • Lost payload
Major				• Cannot Calibrate Geiger-Counter	
Moderate				• Interference from other teams experiments	
Minor					
Negligible					• Data does not match model

Table 11.16
Risk Matrix

Risk event	Response	Contingency Plan	Trigger	Responsible Party
Cannot calibrate Geiger-Muller counter (k2645)	Try reprogramming the software or updating a few pieces of equipment or go to back up	Use the Gamma Scout or another brand of Geiger counters	Inaccurate readings from a known source and compared to other Geiger counters available	Robert Moore
All electronic components fail to work	Find some that will work	Locate working components	Not working	Jasmine Bulliard Donald Crouch
Software failure in flight	Try to decode the data and attempt for possible recovery	recover all possible data	Unusable data or data that is not synchronized correctly	Jasmine Bulliard Donald Crouch
Hardware failure in flight	Try to find reliable data	Recover what we can	No data or inaccurate data	Jasmine Bulliard Donald Crouch
Heaters fail in flight	Box is constructed out of insulated materials to help keep heat in	Use better or more insulation	Temperature inside gets too cold inside	Jasmine Billiard Donald Crouch
Temperature drops to below operating range	Resistors failed and must rely on insulation of box	Make sure that we have fresh batteries and good insulation	Temperature gets too cold inside and get inaccurate data with graphs of step functions	Jasmine Bulliard Donald Crouch
Failure to meet scheduled deadlines	Increase level of work	Increase level of work	Deadlines passing without accomplishments	Robert Moore
Another team's experiment might give off radiation and introduce error	Talk to other groups to see what using to minimize error	Take measurements on ground with the Geiger counter and then subtract that much	High count rate that is not inline with the curve or other teams results	Robert Moore
Significant impact damage	Extract any available information from sensor.	Build it strong with lots of stress testing	Damaged by impact	Robert Moore
Data does not match model	Try to attribute the data to something else	Try to figure out the reason for this error and subtract it from results	Flux curve that does not match model or other team's data	Robert Moore
Run out of human resources	Try to recruit more people	Recruit more people	Other obligations leave people not to attend meetings	Robert Moore
Weight budget is exceeded	Try to get rid of the excess materials	Take out what we do not need or cut back on the glue	Weight exceeds 500g	Jasmine Billiard Donald Crouch
Run out of money	Find more funding	Find more funds	No money left in budget	Ross Fontenot

Table 11.17
Table of what can go wrong and our reactions.

Problem	Solution
All electrical components fail	Rewire everything so that it works
Unable to activate electronics at launch date	Make sure everything is connected properly, put fresh batteries inside, and do everything we can to make it work before flight
Hardware failure in flight	Decipher what data we have, figure out what went wrong, and fix the problem so it won't happen on the next flight
Software failure in flight	Decipher what data we have, figure out what went wrong, and fix the problem so it won't happen on the next flight
Resistors fail in flight	Learn why they failed and fix that problem for next flight.
Temperature drops to below operating range	Try to retrieve our data and make sure we have lots of insulation to make sure it can survive without heaters
Another team's experiment interferes with our measurements	Run some tests and find out the amount of interference and then subtract it from our data
Impact destroys payload	Retrieve what data we can
Data does not match model	Find out the source of the error and subtract it from results
Run out of human resources	Recruit more people and work longer hours
Payload weighs too much	Get rid of the excess weight
Run out of money	Find more money from other sources

Table 11.18
Everything that can go wrong and our response to it.

12.0 Glossary

ACES	Aerospace Catalyst Experiences for Students
ADC	Analog to Digital Converter
CDR	Critical Design Review
EEPROM	Electrically erasable programmable read only memory
FRR	Flight Readiness Review
GPS	Global Positioning System- device
HOBO	Data logger device made by the Onset Computer Corporation
NASA	National Aeronautics and Space Administration
PDR	Preliminary Design Review
RF	Radio frequency
RTD	Resistance Temperature Device
TBD	To be determined
TBS	To be supplied
WBS	Work breakdown structure