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March 3rd, 2015
Revision A/B
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Mission Overview

Mission Statement:

Project PePs’ mission is to construct a payload weighing under 1000 grams and within cost parameters and fly it on April 11, 2015, to an altitude of 30 km. During flight, the payload will use two Geiger counters to test the efficiency of polyethylene and polystyrene plastics as gamma radiation shields. The purpose of this flight is to find a lighter and more efficient radiation shield for manned spaceflight missions. Upon completion of the flight team H2S expects to recover all hardware in functioning condition and be prepared for a second flight. From the collected data team H2S will compare the radiation shielding capabilities of the two plastics.¹ ²

Mission Overview

Objectives:

1. Test for the absorption of gamma rays by polystyrene and polyethylene.
2. Compare these two methods to each other.

Gamma radiation has been known to be a major barrier of interplanetary travel.³ When exposed to gamma rays, there is a statistically elevated risk of cancer and damage to living tissue that can cause skin burns and radiation sickness. Studies have also shown that there is an increased potential for both direct damage to DNA as well as Acute Radiation Syndrome (ARS), which can result in death. The main reason for these effects is due to the harmful nature of ionizing radiation.

Ionizing radiation is energy in the form of waves or particles. However, what makes ionizing radiation so harmful is the fact that at high energies it can break chemical bonds, which then can destroy nuclei of atoms. Human tissue tends to absorb some of these rays even though gamma particles travel the speed of light and can pass through the body.

The objective is to find a cheap, effective, and lightweight shielding as a replacement for current methods of protecting against gamma radiation. Currently, the most effective attenuation of high-energy radiation is by extremely dense metals like tungsten or lead, which are far too heavy to feasibly be carried into orbit. Furthermore, even if highly dense materials had a lower mass, there would still be a large amount of secondary radiation also known as Bremsstrahlung.⁴

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Secondary radiation has been a major concern and can be even more potent than the original rays. Most of this secondary radiation occurs from the material itself because when the primary cosmic rays interact with the shield, nuclear by-products such as neutrons are produced and can pass through the material.

Due to the fact that neutrons are uncharged particles, dense materials like lead do not protect against secondary radiation because the neutrons can just pass through. However, it has been shown that materials with low atomic numbers can be effective because they have a higher probability of forming cross-sections that interact with the neutrons. There have been several studies that suggest that plastics might be a possible alternative due to their chemical composition. In 2005, NASA began experimenting with polyethylene in order to create RXF1, a material lighter and stronger than aluminum. Whether it can be used today as an efficient shield is still uncertain.

After researching several types of plastics, Team H2S decided that the two superior plastics were ones made from polystyrene and polyethylene. Both are exceptionally good for radiation absorption because of their elevated content of benzene rings which do not break upon impact from radiation, but rather dissipate the energy by moving the entire chain in a process called nucleophilic aromatic substitution.

The resistance of certain plastics to gamma irradiation was also analyzed and it was found that both polystyrene and polyethylene tolerated radiation.

The purpose of the experiment is to determine which of these plastics is a better gamma ray deterrent. Because NASA has already experimented with polyethylene and had favorable results, it would be useful to know if this property was not only limited to polyethylene, and if polystyrene is an even better alternative.

The type of polyethylene being used will most likely be high-density polyethylene because a higher density is more effective for primary radiation and the polyethylene

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already has a relatively low atomic number allowing it to be efficient against secondary radiation. As for the polystyrene, it will be composed of acetone and styrofoam to allow for more flexibility with the structure.

2.0 Requirements Flow Down

In order for all mission objectives to be accomplished, requirements are to be stated and each will be completed before or on the day of launch. Level 0 requirements are derived directly from the mission statement.

<table>
<thead>
<tr>
<th>Level 0 Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 A payload shall be constructed weighing under 1000 g.</td>
</tr>
<tr>
<td>0.2 The payload will fly on April 11, 2015.</td>
</tr>
<tr>
<td>0.3 All hardware will be recovered in functioning condition.</td>
</tr>
<tr>
<td>0.4 Two Geiger counters will be flown.</td>
</tr>
<tr>
<td>0.5 The gamma radiation shielding capabilities of both polyethylene and polystyrene plastics will be compared.</td>
</tr>
</tbody>
</table>

3.0 Design

In order to successfully achieve the mission, it is essential that the balloon satellite protect all devices onboard the payload. To that end, the structure must be robust enough to withstand large forces of impact and torsion. For this reason, the balloon satellite will be a 20x20x15 cm box constructed with the provided foam core and held together with hot glue. Foam core is good for the task because it will remain in the shape of the box throughout the balloon satellite’s flight and impact, and it is a relatively light weight.

The electrical subsystem will be important for supplying power to other systems. The two Arduinos will be powered with separate 9 volt batteries, while yet another battery will power the heater. The required sensors: temperature sensor, accelerometer, humidity sensor, and pressure sensor, will be wired to the first Arduino. Both Geiger counters will be wired to the second Arduino because they do not require an external power source. An external switch and LED indicator will be wired externally to each Arduino in order to turn it on and see if it is working without actually opening the top of the balloon satellite. The heater will also have an external switch and LED indicator.

The core of the scientific endeavors is to launch two Geiger counters; one shielded by a polystyrene cover and one shielded by a polyethylene cover. In order to
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make the polystyrene, a combination of acetone and styrofoam will be used. Styrofoam consists of polystyrene foam that can dissolve in acetone and allows for the creation of a mold in a glass container. Essentially, the air trapped in the styrofoam is released and a large quantity of material can be made. Acetone is being used because it is easily available in most nail polish removers but any organic solvent could be used to dissolve the polystyrene.9

As for the polyethylene, it will be made using plastic bottles containing high-density polyethylene (HDPE) and will be melted using oil. In order to create a mold from the polyethylene, the pot being used must reach the melting point for HDPE, which is around 120 to 180 °C. Once the plastic has melted, it can be formed into the desired shape and then cooled in a freezer. All efforts will be made to make both plastic molds relatively equal shapes and thicknesses in order to truly test which plastic performs the task better.

The safety procedure behind the making of both plastics is discussed in the Safety Section.

Each Geiger counter will be placed on a separate side of the balloon satellite with equal distances to its walls in order to allow both to be exposed to equal amounts of gamma radiation. Although it is not possible to ensure the exact same amount of exposure to gamma radiation for each Geiger counter, error can be minimized through controlling the placement and orientation of both sensors.

The first Arduino will periodically poll the thermometers, humidity sensor, and accelerometer for values and write the data to the first SD card. The second Arduino’s software will use triggered interrupt service routines to read pulses from the two Geiger counters. These triggers will guarantee that no data will be lost between the gaps using a set polling frequency. The times at which pulses are received will then be collected and periodically written to the SD card attached. After landing, the data will be collected into a readable format.

Team H2S will be using Geiger counters made and sold by rhelectronics, the reason being that the only team that successfully returned Geiger counter data in the history of the Gateway to Space class used that brand of Geiger counter.

During the flight, the balloon satellite will experience extreme temperatures. To ensure that all components of the balloon satellite remain in working condition throughout the flight, a thermal subsystem is required. The primary component of this system is the provided strip heater. It will be attached to a dedicated 9V battery. There is also foam insulation to provide passive temperature regulation.

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The two temperature probes, the humidity sensor, the pressure sensor, and the accelerometer are wired to the top Arduino while the two Geiger counters are wired to the bottom Arduino.

The positioning of the two Geiger counters acts as a weight balance and control for equal amounts of gamma radiation. The 9V batteries and the Camera are also positioned to counter each other's weight, and the heater is near the 9V batteries in order to keep them functioning.
Comment [31]: Something wrong with the formatting here.
Comment [32]: Don’t you have two temp sensors?
**Concept of Operations Diagram (CONOPS):**

The Concept of Operations Diagram consists of the most important steps during the mission. It starts with the build of the BalloonSat and moves through the steps of launch, after launch, balloon burst, landing, and retrieving the data.

- **Recover BalloonSat Using GPS And Take Back To Boulder**
- **Launch Day: Turn On BalloonSat**
- **Retrieve SD Cards And Analyze Data**
- **BalloonSat Design, Build, And Test, Prepare For Launch**
- **Collect Data From Sensors (Temperature, Humidity, Pressure, Accelerometer, and Geiger Counter)**
- **Parachute Brings BalloonSat Safely To Earth**
- **Keep Collecting Data While Taking Pictures Of The Horizon**
- **Keep Collecting Data, Balloon Burst At 30k.**

**Crawford Leeds 3/9/2015 4:25 PM**

**Comment [33]:** What are the units of 50k and 10k?
4.0 Management

Team H2S will meet twice a week on Sundays and Tuesdays from 5 PM until the team has completed the scheduled task for the day. H2S’ Project PePs will be managed by Guy Margalit, with each subsystem consisting of a manager and two sub-team members that will assist the manager in system operations.

- **Structures:** The Structures subsystem will be led by Matt Beck. This team will design and construct the balloon satellite housing as well as the inner layout of the components.
- **Electrical:** Managed by Nick Thurmes, the electrical subsystems team will have the task of constructing of the hardware to be used in the balloon satellite. This includes both Arduinos and their respective components.
- **Science:** Guy Margalit will lead the Science sub-team in the research, design, and construction of the polystyrene and polyethylene radiation shields.
- **Software:** The software subsystem will be led by John Cutler. The team will write the code for both Arduinos.
- **Thermal:** Led by Brian Ortiz, the thermal subsystem team will build and manage the heating system within the balloon satellite.
- **C & DH:** C & DH will be under Sean Grant’s management. The team will manage the data after the balloon satellite's flight.
The schedule is set up in a way that will allow the team to finish the construction of the balloon satellite before spring break, but if that is not accomplished spring break will be used to finish it. This way, there will be plenty of time to attend to problems that may come up during testing. Due dates are on the schedule. The date for the testing of the Geiger counters has not been determined yet, but it will fit into the schedule at a later time.

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUN</td>
<td>3/1</td>
<td>- Finish PDR presentation</td>
</tr>
</tbody>
</table>
| TUE | 3/3  | - IN CLASS: Preliminary Design Review (6 min presentation)  
  - DD Rev A/B DUE  
  - Build Geiger Counters  
  - Work on coding data retrieval |
| SUN | 3/8  | - Continue to build Geiger counters and start to code them.  
  - Work on coding data retrieval and writing to a readable format.  
  - If safety procedure approved, science team will start to make plastics.  
  - Polystyrene first. |
| TUE | 3/10 | - Put Hardware together and assemble inside balloon satellite  
  - Code other sensors using procedures similar to those learned in class  
  - Finish making plastics. Polyethylene. |
| THU | 3/12 | - Mid Semester Team Evaluations DUE |
| SUN | 3/15 | - Hardware Test I (Software), see if the sensors work  
  - Just basic tests like those done in class.  
  - Insulation and structure finishing touches. |
| TUE | 3/17 | - Hardware Test II (Temperature Test and Software again)  
  - All sensors will be on and working during temperature test.  
  - Service Approvals DUE |
<table>
<thead>
<tr>
<th>Project: Project PePs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>THU</strong> 3/19</td>
</tr>
<tr>
<td><strong>SUN-TUE</strong> 3/22-3/29</td>
</tr>
<tr>
<td><strong>TUE</strong> 3/31</td>
</tr>
<tr>
<td><strong>SUN</strong> 4/5</td>
</tr>
<tr>
<td><strong>TUE</strong> 4/7</td>
</tr>
<tr>
<td><strong>THU</strong> 4/9</td>
</tr>
<tr>
<td><strong>FRI</strong> 4/10</td>
</tr>
<tr>
<td><strong>SAT</strong> 4/11</td>
</tr>
<tr>
<td><strong>TUE</strong> 4/14</td>
</tr>
<tr>
<td><strong>THU</strong> 4/16</td>
</tr>
<tr>
<td><strong>SAT</strong> 4/25</td>
</tr>
<tr>
<td><strong>SUN</strong> 4/26</td>
</tr>
<tr>
<td><strong>TUE</strong> 4/28</td>
</tr>
<tr>
<td><strong>THU</strong> 4/30</td>
</tr>
<tr>
<td><strong>TUE</strong> 5/5</td>
</tr>
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</table>
### 5.0 Budgets

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
<th>Quantity</th>
<th>Weight</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Bottle</td>
<td>$0</td>
<td>10</td>
<td>N/A</td>
<td>CU Campus</td>
</tr>
<tr>
<td>Styrofoam</td>
<td>$3.95</td>
<td>1</td>
<td>N/A</td>
<td>Safeway</td>
</tr>
<tr>
<td>Acetone</td>
<td>$0.93</td>
<td>1</td>
<td>N/A</td>
<td>Safeway</td>
</tr>
<tr>
<td>Polystyrene shielding</td>
<td>$0</td>
<td>1</td>
<td>40 g</td>
<td>Created with Acetone and styrofoam</td>
</tr>
<tr>
<td>Polyethylene Shielding</td>
<td>$0</td>
<td>1</td>
<td>40 g</td>
<td>Created with Plastic Bottles</td>
</tr>
<tr>
<td>Geiger Tube</td>
<td>$30</td>
<td>2</td>
<td>18 g</td>
<td>rhelectronics.net</td>
</tr>
<tr>
<td>Geiger Counter</td>
<td>$25</td>
<td>2</td>
<td>100 g</td>
<td>rhelectronics.net</td>
</tr>
<tr>
<td>Canon A3400</td>
<td>$0</td>
<td>1</td>
<td>139 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Active Heater</td>
<td>$0</td>
<td>1</td>
<td>100 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Foam Core</td>
<td>$0</td>
<td>1</td>
<td>118 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Foam Insulator</td>
<td>$0</td>
<td>1.27 &amp; .635 cm</td>
<td>Negligible</td>
<td>Provided</td>
</tr>
<tr>
<td>Arduino</td>
<td>$0</td>
<td>2</td>
<td>50 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Micro SD card</td>
<td>$0</td>
<td>3</td>
<td>6 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>$0</td>
<td>2</td>
<td>2.9 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Temperature Sensors</td>
<td>$0</td>
<td>2</td>
<td>18 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Humidity Sensor</td>
<td>$0</td>
<td>1</td>
<td>~8 g</td>
<td>Provided</td>
</tr>
<tr>
<td>Dry Ice</td>
<td>$25</td>
<td>1</td>
<td>N/A</td>
<td>Safeway</td>
</tr>
<tr>
<td>9V Battery Pack (3 flown)</td>
<td>$12</td>
<td>3</td>
<td>136.8 g</td>
<td>Safeway</td>
</tr>
</tbody>
</table>

**Comment [37]:** Mass. And watch sigfigs

**Comment [38]:** This seems low?
The team’s official budget manager is Sean Grant. His job is to complete all appropriate forms required for purchase and to ensure the team remains within the budget set by the team within this proposal. If the team goes over the $225 because of unforeseen circumstances, he will divide all the costs among team members. Sean will ensure that all purchases go through Chris Koehler’s CU credit card and will submit all receipts within 48 hours of purchase.

### 6.0 Test Plan and Results

In order to make sure that the hard work is not destroyed or put to waste, multiple tests need to be administered. There are specific factors that need to be tested for such as: durability, temperature, camera functionality, and software.

**Drop Test:** The Balloon Satellite will be dropped from approximately 40 feet with an equal amount of mass as the experiment inside it. The test will decide if it will survive the harsh landing. This test will be done in a safe manner without people around.

**Stair Test:** The stair test, like the drop test, will also have conditions similar to those present during landing. The satellite, with the same amount of mass as the real payload, will be kicked and pushed from the top of a flight of stairs. This will simulate the conditions of the satellite bouncing and rolling after it has touched down. The stairs will be closed off while this test is undergoing.

**Whip Test:** For this test the satellite will have the same mass as the payload and will be tied to a rope and spun around viciously. After launch, both wind and the balloon popping will whip it around violently. The whip test will determine if the satellite is strong enough to survive those conditions. The whip test will be conducted in an open area with no one near the person spinning it. Also, the test will be conducted in an area without windows or glass. The accelerometer will also be tested at this time.

**Temperature Test:** The temperature levels throughout the flight will be very low, so all the systems inside it need to be tested at a similar temperature. In order to test it at freezing temperatures, the satellite will be enclosed in a cooler with dry ice for two hours while all the systems are operating and recording data. The temperature probe will also be tested at this time.

**Camera Test:** The functionality of the camera will be tested during the temperature test. It will also be tested to make sure the structure of the balloon satellite does not obscure images.

**Pressure Test:** The functionality of the pressure sensor will be determined with a solder sucker.
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Software Test: Before sending the satellite 30 km above Earth’s surface, all sensors and both Arduinos need to be working correctly. Other subsystems will ensure that the sensors are picking up data and that the Arduinos are recording that data. The camera will be tested to make sure it is taking pictures and recording them on the SD card. All the code will also be tested and perfected before launch. Bugs will be fixed during this process.

Geiger Sensor Test: It needs to be determined if the Geiger counters work with the Arduino before launch day. Team H2S will contact Scott Pinegar of the CU Boulder physics department, who has the disk source which can be used to simulate the levels of gamma radiation found in the upper atmosphere.

Safety Procedure:

Safety in the construction, testing, and launch phases is very important to Team H2S. Many hours are expected to be spent soldering and flinging around the balloon satellite, so every member needs to be very careful when around the equipment. At all times, appropriate clothing will be worn and specific safety requirements, such as wearing goggles, will be strictly enforced.

The process that will require the most safety precautions is the making of the plastics. Polystyrene will be made with acetone and shoe polish. The creation of this plastic is toxic, but there are very low amounts of dangerous airborne chemicals produced. Team H2S will make the polystyrene under a fume hood to minimize the dispersion of any airborne toxins. The team members who are making the polystyrene will wear goggles, gloves, and masks.

The molding of the polyethylene plastic will follow a similar safety procedure, in which each team member making the plastic will wear gloves, masks, and goggles. The boiling of the canola oil will take place on a hot plate under a fume hood. The plastics will be melted down and safely molded into the desired form for the shielding.
The team expects to see increased levels of radiation as the payload travels through the majority of the atmosphere. As the atmosphere becomes thinner, it is less likely that ionizing cosmic radiation will have already hit air molecules and dissipated their energy. At the balloon’s maximum altitude, it will have passed through approximately 99% of the Earth’s atmosphere, so it will have very little atmospheric shielding.

http://www.whatisnuclear.com/physics/radiation_on_flights.html
The above graph shows a possible data distribution that the team may get from the experiment. Launch is at T=10, after which the radiation counts increase rapidly as the balloon ascends. The radiation density is in rough proportion with the amount of atmosphere above it, producing a logarithmic distribution. Burst is at T=90, and the radiation drops back down as the experiment falls to the ground.

Although both polyethylene and polystyrene are efficient gamma radiation shields, Team H2S believes polystyrene will perform better. This is because polystyrene has a higher aromatic content, meaning more Benzene rings. The entire theory behind plastics as gamma radiation shields revolves around positive hydrogen ions within the benzene rings structure. A higher concentration of benzene rings within the polystyrene indicates a higher tolerance to gamma radiation. This is why in the above graph of the expected data, polystyrene consistently receives less gamma radiation.

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Temperature: The temperature readings should drop as the balloon satellite rises through the troposphere. After entering the stratosphere, the temperature readings will start to rise again. The internal temperature sensor will consistently read a higher temperature than the external temperature sensor.

Humidity: Humidity should correlate directly with temperature because of the freezing water in the atmosphere.

Pressure: The pressure should decrease as altitude increases because there is less air pushing down the further up the balloon satellite goes.

Acceleration: The initial acceleration on the x and y axes will likely be around zero because the balloon’s motion is only in the z direction. The z-axis acceleration will initially be a large constant value because the balloon satellite is speeding up. Once it reaches terminal velocity, the upwards acceleration will be zero. After burst, there will be massive randomly appearing spikes in all three axes.