Gateway to Space ASEN 1400/ ASTR 2500

Colorado Space Grant Consortium

GATEWAY TO SPACE

FALL 2014

DESIGN DOCUMENT

Team Space Core Presents: Mission Magnets vs Radiation

Written by:

October 14, 2014

Revision A/B

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Revision Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>A/B</td>
<td>Conceptual and Preliminary Design Review</td>
<td>October 14, 2014</td>
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</tbody>
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1.0 Mission Overview:

Mission Statement: The goal for team Space Core is to study the role of Earth’s magnetic field as a “shield” for solar radiation. It is already known that Earth’s magnetic field deflects large amounts of solar radiation away from Earth, but Space Core wants to know whether the amount of radiation deflected depends on the altitude from Earth. Earth’s magnetic field strength abides by an inverse square law $\left(\text{Intensity} \propto \frac{1}{\text{distance}}\right)$ compared to the distance away from the magnetic source; therefore, as the altitude from Earth increases, the magnetic field strength decreases proportionally to the inverse square of altitude (distance).

Furthermore, since the magnetic field strength decreases as altitude increases, there should be a direct correlation with altitude and the amount of radiation measured (How Does the Earth’s Magnetic).
Radiation is classified as non-ionizing and ionizing radiation. Non-ionizing radiation is when the radiation has enough energy to move but not break chemical bonds. Ionizing radiation has high enough energy to break chemical bonds which can cause damage in electronics and damage DNA in living beings. Team Space Core will look at ionizing radiation which is the cause of damage in space crafts. This radiation that is mainly encountered are categorized as one of four types: Alpha Radiation, Beta Radiation, Gamma Radiation, and X-ray Radiation.

The figure on the right shows the gamma counts(radiation) vs. altitude
Figure taken from: (http://planet.weber.edu/)

Alpha radiation is a short ranged, high energy particle that is unable to penetrate human skin and has a positive polarity. It is attracted to the southern end of the earth’s magnetic field. Alpha radiation are not able to penetrate very far and are easily stopped by paper, clothing, and air.

Beta radiation is a light, short ranged particle that is able to moderately penetrate objects but is still blocked by cloth. It is negatively charged and travels towards the northern edge of the earth’s magnetic field.

Gamma radiation and X radiation are high energy radiation. They are electromagnetic energy and its photons have no mass. They will penetrate everything except high density materials such as lead. (What Types Radiation are there?)
Why: The inspiration for Space Core’s mission was based off a European space group who proposed an alternative use for magnetic field. This group called “EU Project Space Radiation Superconductive Shield” hypothesizes that they could reduce the amount of needed radiation insulation on space craft’s using high strength magnetic fields (Howell). They claim that they could create a high intensity magnetic field (approximately 3000 times the strength of the Earth’s magnetic field) around a spacecraft which would deflect a substantial amount of radiation. If their idea is successful, it could change the way in which space craft’s protect themselves against solar radiation. This could lead to more efficient and cheaper alternatives to space travel. After reading the article, Space Core wants to probe further to see if their idea is plausible.

How: Space Core plans on testing the Earth’s magnetic field’s capability at blocking radiation by measuring/comparing three separate variables. The main comparison that Space Core plans on observing is the correlation between the magnetic field strength and the counts of radiation. The Geiger counter will simply count the number of radioactive particles that hit its surface. Unfortunately, the magnetometer will record a voltage and using that voltage, Space Core will have to determine what the correlating Gauss/Tesla (Units for measuring magnetic field strength) measurement is. Using a Geiger counter, Space core will be able to graph both the counts of radiation and the strength of the magnetic field. Additionally, Space Core will measure/graph both the counts of radiation versus altitude and the magnetic field strength vs altitude equaling a total of three data graphs. For additional details on the data retrieval, go to 3.0 Design.

Sources:


2.0 Requirements Flow down

<table>
<thead>
<tr>
<th>Number</th>
<th>Requirement</th>
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<tr>
<td>0.01</td>
<td>Space Core will retrieve the BalloonSat fully functioning and intact</td>
<td>RFP</td>
</tr>
<tr>
<td>0.02</td>
<td>Space Core will measure the strength of the Earth’s magnetic field in relation to altitude during flight.</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>0.03</td>
<td>Space Core will measure gamma and X-Ray Radiation in relation to altitude during flight.</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>0.04</td>
<td>Space Core will examine the data and check for correlation with magnetic field strength and radiation levels.</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>0.05</td>
<td>The BalloonSat shall not exceed 1125 g in mass</td>
<td>RFP</td>
</tr>
<tr>
<td>0.06</td>
<td>The internal Temperature shall never go below -10 degrees Celsius.</td>
<td>RFP</td>
</tr>
<tr>
<td>0.07</td>
<td>The BalloonSat shall fly up a Canon digital camera that will work and take photos during flight of the outside environment.</td>
<td>RFP</td>
</tr>
<tr>
<td>0.08</td>
<td>The Exterior shall have LED’s an American Flag and Contact information.</td>
<td>RFP</td>
</tr>
</tbody>
</table>
The BalloonSat shall measure altitude, exterior temperature, interior temperature, humidity, pressure, and location.

### LEVEL ONE REQUIREMENTS

**1.01 - Space Core will retrieve the BalloonSat fully functioning and intact**

- **1.01** The BalloonSat shall go through extensive testing with temperature by storing it in a cooler with dry ice.
- **1.02** The BalloonSat shall go through whip test far from windows and fragile objects to ensure it can endure forces at burst.
- **1.03** The BalloonSat shall undergo drop and force tests to ensure it can endure the landing process.
- **1.04** The BalloonSat shall have all sensors tested and calibrated to ensure accurate data.
- **1.05** The BalloonSat shall have a nonmetal tube that shall go through the center of the BalloonSat that is secured with washers and paperclips.

**0.02 - Space Core will measure the strength of the Earth’s magnetic field in relation to altitude during flight.**

- **1.06** The BalloonSat shall contain a compass module that measures strength of a magnetic field. The data shall be stored to the Arduino Uno. This will...
**0.03** Space Core will measure gamma and X-Ray Radiation in relation to altitude during flight.

1.07 The BalloonSat shall contain a Geiger Counter that shall store data in the Arduino Uno.

**0.04** - Space Core will examine the data and check for correlation with magnetic field strength and radiation levels.

1.08 When data is retrieved Space Core will make graphs with magnetic field and radiation in relation to each other and both of the above variable in relation to altitude.

**0.05** - The BalloonSat shall not exceed 1125 g in mass

1.09 The accumulating mass shall be constantly be monitored.

1.10 The BalloonSat shall be made of a dimension of a cube with all sides being of the dimensions of 20cm. So that all components can fit yet the cube shall not be too big and have useless mass.

**0.06** - The internal Temperature shall never go below -10 degrees Celsius.

1.11 The BalloonSat shall fly a heater module inside to keep the Sat warm.
1.12  The BalloonSat shall be insulated with foam core and aluminum tape to minimize the heat that will escape.  0.06

0.07 - The BalloonSat shall fly up a Canon digital camera that will work and take photos during flight of the outside environment.

1.13  The BalloonSat shall fly the camera with its aperture focused past a transparent medium that is insulated around.  0.07

0.08 - The Exterior shall have LED’s, an American Flag and Contact information.

1.14  LED’s shall be attached to the Arduino and will flash as each separate circuit is working and for each Arduino to blink for each data point taken.  0.08

1.15  The sticker and the communication info shall be on the exterior adhered onto the foam core.  0.08

0.09 - The BalloonSat shall measure altitude, exterior temperature, interior temperature, humidity, pressure, and location

1.16  The Sat shall have a humidity sensor, two temperature sensors, a pressure sensor, a three axis accelerometer, a compass connected to one of the two Arduino Unos and should store data during the flight.  0.09
3.0 Design

The main satellite is a cube shape that is approximately 20cm X 20cm X 20cm. Most of the main components in this central cube such as the Heater, Geiger counter, batteries, sensors, camera, and both Arduinos. There is an extension from the main structure that leads to a smaller box. The extension will be a PCV pipe, because of its strength, that will hold the smaller box. Since the pipe is hollow, wires can lead through it from the Arduinos, in the main structure, to the magnetic field sensor, the magnetometer, that will be in the smaller box. The reason for this extension of PVC pipe, that will be 2.54 cm diameter, is so that the magnetic field from the main electronics will have negligible effect on the magnetometer. Ideally the satellite would be at the bottom of the balloon chain so that the magnetometer would be able to be far away from the other satellites. It will have a hole at the top of the main box where a string can go to connect to the other satellites.
Blue   Purple   Red   Green   Pink   Yellow   Black
Geiger Counter | Battery packs (5) | Arduinos (2) | Camera | (Temperature Accelerometer Pressure Humidity) sensors | Heater | Magnetometer

FBD

- LED
- 9V Battery
- Camera
- SD Card
- Switch
- Heater
- 9V Battery
- Arduino
- Pressure Sensor
- External Temperature
- Humidity Sensor
- Internal Temperature
- Arduino
- SD Card
- Switch
- 9V Battery
- SD Card
- Magnetometer
- Arduino
- Switch
- 9V Battery
- Geiger Counter
- LED

Crawford Leeds 10/23/2014 8:38 PM
Comment [43]: Make this a real title.

Crawford Leeds 10/23/2014 8:43 PM
Comment [44]: Lots of white space, make text bigger.

Crawford Leeds 10/23/2014 8:39 PM
Comment [45]: Would be great to see what each block is connected with. Physical connection? Power? Signal? And give specifics.
CONOPS Diagram
4.0 Management

Each section will have two leaders organizing and leading group tasks. All members will work on all sections but will follow the instructions of the leaders who will be the resident experts in the subjects. Group leader Kelsey will be in charge of making sure the team is on task and the work is completed in a timely fashion. System Integration leader Chet will be in charge of bringing all components of the balloon satellite together and ensuring the payload is working properly. Each leader will be the members doing the majority of the work and will be in charge of that section outside of group meetings. Test leader Florin in charge of making sure all tests are conducted in a safe and timely fashion. Florin will lead the group in making corrections to the designs if they do not pass the respective tests required of them.

<table>
<thead>
<tr>
<th>Section</th>
<th>Main Leaders</th>
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<td>Group Leader</td>
<td>Kelsey</td>
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<td>Systems Integration</td>
<td>Chet</td>
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<tr>
<td>Design</td>
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<td>Wiring</td>
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<td>Test</td>
<td>Florin</td>
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Schedule

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<tr>
<td>13-Oct-14</td>
<td>Begin testing</td>
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</table>

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The main time limitation is the conflicting schedules of all group members. Due to this, most of the work will be conducted outside of group meetings, and group meetings will be dedicated to more urgent issues that must be corrected as a group. The group also had a fairly late start due to these conflicts and will have to speed their time schedule and work up if the group falls behind any further.
5.0 Budgets

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**ESTIMATED PROJECT TOTAL COSTS**

**ESTIMATED PROJECT TOTAL WEIGHT**

$100.38

1.13

6.0 Test plan and Results

**Drop Test**

The structure will be tested to see if it can **survive** a rough landing and the possible dragging forces it may experience from the **weather and atmosphere**. The vertical drop test will stimulate the impacts the satellite will experience at the end of the flight as it hits downward. The satellite...
must be durable and structurally sound enough to survive the harsh impact forces during the flight, which will be stimulated by a 15 meter drop.

So far, Team Space Core has conducted one drop test and in order to accurately assess the impacts of the vertical drop. This satellite is a prototype and the inside components were NOT included in the drop test because the main focus was on the structure’s durability. For the post-test, Team Space Core have reconsidered the design of the satellite in order to build upon the strength of the structure by using duct tape and hot glue in order to keep the pieces together more efficiently.

**Kick Test**

The kick test will assess the structures durability during flight where the satellite will encounter harsh forces and rough impact landing after the burst. The structure must be stable enough to survive the rough landing and the forces at a higher altitude. Therefore, Team Space Core will conduct multiple kick tests in order to assess the satellite structure and make sure that it is structurally sound and internally functional.

**Whip Test**

The satellite will undergo collective forces caused by the motion of the flight string—especially when the BalloonSat is released and after the balloon bursts and begins to descend. Therefore, several whip tests will be conducted by Team Space Core in order to ensure that the structure will be able to survive the impacts and the contents inside the satellite will remain functional. To stimulate the forces, the satellite will be tethered to a rope and swung in the air rapidly and repeatedly in order to evaluate how the satellite will handle the whip forces. In the post-test, Team Space Core will look into changing anything in the design necessary to complete the mission. All whip tests will be conducted in an open space, away from people and windows as a safety precaution.

**Temperature Test**

The temperature test will be to ensure that Team Space Core’s satellite can operate in extremely low temperature, it is vital for Team Space Core’s mission. Since BalloonSat will reach very cold temperatures at an altitude of 30 km and by placing the satellite inside an insulated cooler containing 5.44kg (5440g) of dry ice for a minimum of 3 hours, it will simulate an environment that meets the temperature conditions that the satellite will face during the flight. There will be multiple tests conducted in order to make changes based on the outcomes, where the post-tests will determine if there will be any changes in design of the satellite structure.

**Sensor Testing**

To make sure that all the sensors are functioning and collecting data, Team Space Core will calibrate all the sensors—which means to test a known value and compare it with Team Space Core’s sensor reading.

1. **Geiger Counter**
The calibration of a Geiger counter is complex and Team Space Core will be using a radioactive source—determined to be table salt. It is crucial that the Geiger counter works efficiently and the data collected can be readable and interpreted by the members of Team Space Core. Geiger counters do not have a distinctive switch, therefore to calibrate the instrument multiple trials will be used in order to determine the type of radiation (Gamma, X-rays, Beta, and alpha).

II. Temperature Sensor

One member from Team Space Core will touch the temperature sensor and see the sensor measurements that reads any temperature change—which the expected is a rise in temperature.

III. Humidity Sensor

Similarly, a member from Team Space Core will blow on the sensor in order to read off the measurements and see if the sensor detects any changes in humidity.

IV. Pressure Sensor

A pressure will be applied to the sensor in order to see any changes in pressure and fully function to its full potential.

V. Accelerometer

Team Space Core will change the axis of x, y, and z to see the measurements the sensor reads and the data interpretation is the main focal point for Team Space Core because it is crucial for collecting and analyzing accurate data.

VI. LSM303D 3D Compass

This sensor will be used to analyze the magnetic forces and the data read by the sensor. Furthermore, will compass will be tested by the using a magnet to look at the change and order of data; the magnet represents a magnetic field and the sensor itself is the magnetometer.

Camera Testing

There will be a series of camera tests in order to assess the functionality of the camera, amongst these will be a battery-life test to ensure that the camera will remain functional during the entire flight. The camera will also be tested during the temperature testing to ensure its video and imaging quality under extreme conditions—and during the test, the camera will be set to take pictures every 20 seconds. Overall, the camera testing is to ensure that the pictures are recorded and saved properly, when the pictures are uploaded onto a computer.
7.0 Expected Results

Team Space Core expects to see an increase in radiation and a decrease in the earth’s magnetic field as altitude increases. The relationship between the three shows an inverse relationship between radiation and the strength of the magnetic field can be observed due to the magnetic field protecting the earth through the deflection of radiation. It can be inferred that if the magnetic field decreases at high altitude and the radiation increase due to the increase in altitude then the radiation will decrease as the magnetic fields increase. The graph below is made using estimates from the graphs of the magnetic strength vs altitude and radiation vs. altitude above in the mission statement, however the values are only estimation due to the lack of available data from official sources. When data is taken they will be compared to data from sources such as NASA. This relationship is due to the particles of solar wind or radiation being deflected by the earth’s magnetic field due to the polarity of the alpha and beta rays as well as their direction being scattered due to the magnetic field.

Team Space Core expects the temperature sensor to give a steady decrease in temperature until the balloon exits the troposphere which is at roughly 10 km off the ground. Then the temperature is expected to steadily increase until it reaches the end of the stratosphere which is the maximum altitude the balloon can reach. The pressure sensor will steadily decrease and begin to approach zero as the altitude increases. The pressure of the atmosphere decreases at an exponential rate and will near zero at the maximum altitude of the balloon. This will be similar to the humidity which will decrease the greater the altitude becomes. These values will approach zero then will experience roughly the same data when the balloon satellite falls back to the earth. All of the sensors will be programmed to operate properly with an Arduino Uno and store data on the SD cards. The camera will take pictures every 20 seconds as visual documentation of the flight.

![Graph of Expected Radiation over Magnetic field strength](attachment:graph.png)
If you expect to go to 30km, show that in the data. Also, label your figures.
Humidity wrt Altitude

Sources
http://docs.engineeringtoolbox.com/documents/462/elevation_altitude_air_pressure.png
http://www.societyofrobots.com/images2/space_data_humidity_altitude.png