Written By:

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Neil Nguyen | Brianna Roe | Daniel Torres Dominguez

Report Date: November 5th, 2015

Revision C
Revision Log

<table>
<thead>
<tr>
<th>Revision</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/B</td>
<td>Conceptual and Preliminary Design Review</td>
<td>10/9/15</td>
</tr>
<tr>
<td>C</td>
<td>Critical Design Review</td>
<td>11/05/15</td>
</tr>
<tr>
<td>D</td>
<td>Analysis and Final Report (There is a first draft and final draft)</td>
<td></td>
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1.0 Mission Overview

1.1 Mission Statement
Team Spaced Out will design a reusable BalloonSat that will capture and record the amount of energy generated by a kinetic energy recovery system (KERS) through the process of electromagnetic induction in order to determine if this method of energy collection could be used toward electrical systems on vehicles in the atmosphere. Additionally, Gateway to Space provided four other sensors that will be used to assess how the conditions of a high-altitude atmospheric test will affect the energy produced by the system. A camera is also provided with the goal of documenting flight patterns through video. The data captured from the test shall be analyzed for possible future applications in the aerospace field.

1.2 Background/Purpose
After learning about current technology used in vehicles and aircraft, it was found that the automotive industry is leading the market over aerospace in many technological areas\(^1\). The automotive industry is more focused on experimental design and the incorporation of hybrid systems using the KERS.

The concept of a kinetic system that could produce its own energy was coined and used by companies such as Ferrari and Tesla. Formula 1 vehicles have also applied this technology. Within the last three years, research has been combining kinetic energy recovery systems and diesel propulsion engines in aeronautical applications. The primary use of dual systems like these has been focused on powered rotorcraft. This hybrid concept engine has been tested and proven to enhance performance and lower operating costs in many areas such as reducing fuel consumption and more precise control over the speed of the propellers\(^2\). Although this may be efficient for rotary components of an aircraft, the system is restricted to the engine and does not currently offer power to the background electrical components onboard an aircraft. As of right now, batteries are being used to power these internal components of the aircraft.

The aerospace industry needs other ways to generate power because the current systems in place on the majority of aircraft are expensive and not sustainable. If future aircraft can reduce these costs, more money can go into advancing technology in the aerospace industry.

The experiment is designed to determine if using the kinetic energy from the movement of the BalloonSat could create an efficient enough return of electrical energy to supply constant power to small, electrical components on aircraft such as lights. If the experiment results in positive findings, then it can be confirmed that this system is effective. By having a renewable energy system on board, less batteries and fuel would be needed, therefore, increasing efficiency and reducing costs.

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\(^1\) KERS APPLICATIONS TO AEROSPACE DIESEL PROPULSION
\(^2\) SUPER DEMO
\(^3\) WIND SPEEDS AND ELEVATION
1.3 What’s expected to be discovered

Electromagnetic Induction works by a change in the magnetic flux through a surface attached to a conducting wire, which induces an electromotive force that will produce a current according to Faraday’s law (shown in the picture to the right). Moving a magnet in both directions in a copper coil will read positive and negative voltage readings. This changing field of magnetism is what creates a charge. Since a diode is being used on the KERS Arduino, current is forced to flow in one direction and is therefore only recorded as positive values.

Similar to a shake-to-charge flashlight, Spaced Out’s system will house generators where a magnet will pass through a tightly-wound, copper wire to produce an electric charge. The KERS will be most active as the BalloonSat whips violently around in the atmosphere. As the weather balloon climbs through the tropospheric level, clear-air turbulences are most active because 80% of the mass of Earth’s atmosphere is located here, causing large bodies of differentiating air speeds to meet. These pockets of jet streams are predicted to yield the largest return of energy due to high kinetic gyration. Right before the weather balloon bursts, it will be the smallest amount of energy gain because the acceleration of the BalloonSat will be near zero. As soon as the BalloonSat enters free fall, it will violently whip through the air, where Spaced Out expects to be the richest period of energy gain for the system due to the random movement.

The other sensors Spaced Out has onboard (temperature, pressure, acceleration, and humidity) will be monitored throughout the mission to see if there is any correlation between the energy gain and shifts in the sensor readings. The sub-zero temperatures are not expected to affect the KERS because it is an internal unit, which will be kept at an operational temperature thanks to the heater inside the BalloonSat. Pressure is not expected to affect the system either because as long as there is a change in the magnetic flux, a current will be created.

Overall, Spaced Out expects to discover that the electromagnetic generator can produce enough energy for future aerospace missions at a practical and efficient level. Real applications would need a substantial amount of watt-hours produced for full functionality of internal aircraft components, so it is hoped that this small-scale version will be able to produce a comparable amount of energy to power basic, internal components. Disregarding any rare malfunctions or problems, the KERS is expected to perform well during the mission in hopes to return significant data.
2.0 Requirements Flow Down

The requirement flow down chart below delineates our mission objectives. The first level of requirements (level 0) is derived directly from our mission statement. These are the general requirements set for what the team needs to accomplish and are expanded upon in level 1 requirements.

### Level 0 Requirements

<table>
<thead>
<tr>
<th>Number</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>Spaced Out shall track humidity, temperature, acceleration and pressure using sensors to record data and find correlations between energy produced and external variables.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.2</td>
<td>Spaced Out shall measure electrical energy produced using a KERS.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.3</td>
<td>Spaced Out shall determine if the energy measured is sufficient enough to provide functionality to background electrical components.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.4</td>
<td>Spaced Out shall be reusable.</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.5</td>
<td>A camera shall record video of the flight until it runs out of battery.</td>
<td>Mission Statement</td>
</tr>
</tbody>
</table>

### Level 1 Requirements

<table>
<thead>
<tr>
<th>Number</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.11</td>
<td>The payload shall use a humidity sensor to measure changes in percentage of relative humidity.</td>
<td>0.1</td>
</tr>
<tr>
<td>1.12</td>
<td>The payload shall use two temperature sensors to measure changes in internal and external temperature.</td>
<td>0.1</td>
</tr>
<tr>
<td>1.13</td>
<td>Spaced Out will use an accelerometer to measure acceleration in the X and Z axis.</td>
<td>0.1</td>
</tr>
<tr>
<td>1.14</td>
<td>The payload shall use an internal pressure sensor measuring pressure in PSI.</td>
<td>0.1</td>
</tr>
<tr>
<td>1.21</td>
<td>The payload shall use a torus shaped tube with copper wire wrapped on two sides with a magnet inside to create a current when the payload shakes and spins during flight.</td>
<td>0.2</td>
</tr>
<tr>
<td>1.22</td>
<td>The payload shall measure energy from the KERS using an Arduino.</td>
<td>0.2</td>
</tr>
<tr>
<td>1.31</td>
<td>We will determine whether the amount of energy collected would</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Score</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>1.32</td>
<td>The Arduino will track energy spikes every ninety-six hundred milliseconds.</td>
<td>0.3</td>
</tr>
<tr>
<td>1.33</td>
<td>The data will be saved to a Micro SD card so it can be analyzed.</td>
<td>0.3</td>
</tr>
<tr>
<td>1.41</td>
<td>The payload will be intact and ready for relaunch.</td>
<td>0.4</td>
</tr>
<tr>
<td>1.42</td>
<td>Internal components will still be functional.</td>
<td>0.4</td>
</tr>
<tr>
<td>1.51</td>
<td>The camera will record footage documenting the flight.</td>
<td>0.5</td>
</tr>
<tr>
<td>1.52</td>
<td>The camera will be able to continue functionality in extreme conditions.</td>
<td>0.5</td>
</tr>
<tr>
<td>1.53</td>
<td>The video recorded will be saved to a Micro SD to be compiled and viewed later.</td>
<td>0.5</td>
</tr>
</tbody>
</table>

be sufficient in providing functionality to background electrical systems such as circuit boards or lighting in aircraft.
3.0 Design

3.1 Structural Overview

Team Spaced Out will be designing a weather BalloonSat that can withstand all the extreme conditions of near space caused by temperature, pressure, solar exposure, and g-force during the balloon’s flight. The BalloonSat will be launched via a helium balloon attached by a flight cord going through the middle of the BalloonSat. The structure will not only have to withstand the conditions of the flight but maintain structural integrity in order to protect the internal components of the BalloonSat. In order to accomplish this, Spaced Out will be creating a 15.5cm x 15.5cm x 10.25cm (outer dimensions) rectangular prism out of foam core (provided by the Colorado Space Grant Consortium) that will have the flight tube going through the center. The BalloonSat will be connected to the flight cord knotted under the BalloonSat and secured by a washers glued to the top and bottom with a paperclip going through the flight tube. On the outside of the foam core rectangular prism there will be contact information for the Spaced Out team and the Colorado Space Grant Consortium. The main advantages of foam core are the simplicity of cutting and shaping it, its strength, and its black color, which allows the box to hold and maintain heat. In order to achieve maximum insulation and keep a more operational internal temperature, the inside of the box will be lined with one layer of foam insulation. There will also be a heater, powered by three 9V batteries, mounted in the center of the box to keep the internal mechanics warm. There are three switches on the outside of the box connected to Arduino #1, the heater, and Arduino #2; the switches all have indicator lights (green lights indicate power is going to Arduino switches, red light indicates heater is on, blue light indicates the Arduino is on, and the orange light indicates that the sensor Arduino is taking data). The switches are housed under a protective piece of foam core that prevents them from being depressed involuntarily. The box will be bound together using hot glue on the inside and aluminum tape on the outside for maximum strength. The initial prototype box will undergo numerous tests (drop, stairs, and whip) in order to make sure it can withstand the physical challenges of a balloon BalloonSat launch. All interior components of the BalloonSat will be mounted using hot glue or Velcro.

3.2 KERS Design

The KERS will consist of a 3D printed plastic ring torus, with an inner diameter of 2.54cm, a spherical, nickel plated neodymium magnet of 1.905 cm diameter and 16.41 meters of 22-gauge copper wire. The plastic ring torus will be printed with a 7.62 cm inner diameter that the neodymium magnet can roll freely inside of, due to the intense whipping and spinning motion of the BalloonSat (simulated in the tree test) and the g force it undergoes. The 22-gauge copper wire will be wrapped around the plastic donut in a two coils which will be connected to a capacitor that will be soldered to the Arduino (circuitry explained in 3.3).
3.3 Circuitry of Mission

The KERS generator used in Spaced Out’s mission uses the process of electromagnetic induction in order to create current with the 22-gauge copper wire. The leads from each of the generators will be connected to a diode (to stop backflow of current into the system) and then a capacitor that will allow the Arduino to record voltage spikes in the circuit via the analog ports. The Arduino is programmed to output voltages that can be used for the post-flight analysis and applied to graphs.

3.4 Camera

The provided Canon camera not only put Spaced Out’s BalloonSat over weight, but it also was attracted to the magnet in the KERS and hindered the KERS’ ability to generate electricity. Therefore, Spaced Out chose to use the remainder of the budget to purchase a Polaroid Cube Camera which will be used to record videos of the flight until the battery dies. The camera is mounted with Velcro, and a hole will be cut in the side of the box that the camera lens can look through. The camera has 90 minutes of battery life, and will record video throughout the duration of those 90 minutes and save the footage on a 16 GB Micro SD card.

3.5 Arduinos and Sensors

Attached to one of the Arduinos are the provided sensors (acceleration, relative humidity, internal temperature, external temperature, and pressure sensor). All sensors will be powered by the Arduino which is powered by two 9V batteries. The second Arduino will have copper wire connecting it to the KERS. The Arduinos will be attached on the opposite side of the box from the KERS, because there is concern for the neodymium magnets disrupting circuits within the Arduino.

3.6 Design Requirements & Limitations

The BalloonSat design has to be able to not only support the above KERS system, but two Arduino Uno’s, the required sensors (Temperature, pressure, humidity, accelerometer), a heater, and have the appropriate contact information on the outside. The weight limit of 864g is another requirement that limits not only the size of the box but the size of the mission that is launched. In order to adhere to this strict weight limit, Spaced Out had to consider what materials to use in order to build its KERS system, such as obtaining a lightweight 3D printed plastic tubing, a certain sized magnet, and limiting the amount of copper wire used in order to stay under the required weight limit. Another concern for Spaced Out is in the placement of the Arduinos, camera, and batteries. The issue is that the Neodymium magnet will get attracted to all these electronic devices if it is too close, hindering the movement of the magnet and rendering the KERS useless. Therefore, Spaced Out swapped the original Canon camera for the much smaller Polaroid Cube, which is placed towards the top of the box, along with the batteries and Arduinos with sufficient space from the KERS, so the magnet’s motion goes un-impaired.
3.7 Parts

Neodymium Sphere Magnet:
  Use: To roll around the torus track to create energy.
  Location: Ordered online from K&J Magnetics.

Spare Sphere Magnets:
  Use: Incase one chips Spaced Out will still have a magnet in new condition to obtain full productivity on launch day.
  Location: Ordered online from K&J Magnetics.

Copper Wire:
  Use: This will be wrapped around in coils around the torus track to convert kinetic energy to electrical.
  Location: This will be bought from McGuckin’s Hardware store.

Batteries:
  Use: Three will be used to power the heater. The other four will be used to power an Arduino (two batteries to each Arduino).
  Location: 6 Provided by the Colorado Space Grant Consortium. 1 Bought at Home Depot

Camera:
  Use: Will be used to take constant video throughout the flight until battery runs dead. Included in the weight is also its Micro SD card and battery. Micro SD card provided by Brianna Roe.
  Location: Bought at Target

3D Printed Torus Track:
  Use: This will be the torus shaped track that will act as the Kinetic Energy Recovery System where a magnet will roll around in to generate Kinetic Energy which will be converted to Electric Energy.
  Location: This will be made in the ITLL at CU Boulder.

Arduino:
  Use: One will be used to measure pressure, internal and external temperature, acceleration, and humidity. Sensors for each of those elements were also provided by Colorado Space Grant Consortium. The other Arduino will be used to measure the electricity generated by the KERS.
  Location: Two were provided by the Colorado Space Grant Consortium.

Data Storage Shield:
  Use: One attached to each Arduino. The Data Storage Shield records all data onto a micro SD card so that after Spaced Out has landed the data from the flight can be collected.
  Location: Provided by the Colorado Space Grant Consortium.

Foam Core:
  Use: This will be used to build the Spaced Out BalloonSat structure. This will be the walls.
  Location: Provided by the Colorado Space Grant Consortium.

Aluminum Tape:
Use: This will be used to keep the walls from falling apart and collapsing in on the internal mechanics.
Location: Provided by the Colorado Space Grant Consortium.

Stickers:
Use: Required and gives Spaced Out character.
Location: USA flag provided by the Colorado Space Grant Consortium. Other stickers will be provided by the Spaced Out team members.

Velcro:
Use: Used to attach the Camera to the wall so it can later be detached from Spaced Out.
Location: Is provided by the Colorado Space Grant Consortium.

Capacitor:
Use: Stores electricity and releases it gradually as it is collected.
Location: Provided by Tim May, a professor at CU Boulder.

Diode:
Use: Makes sure the current does not flow back into the copper wire.
Location: Provided by Tim May, a professor at CU Boulder.

Glue:
Use: Will be used to hold the structure together such as the walls.
Location: Was provided by the Colorado Space Grant Consortium.

Heater:
Use: Will be used to keep Arduino, camera and all other internal elements in the Spaced Out BalloonSat warm to avoid malfunctioning.
Location: Provided by the Colorado Space Grant Consortium.

Insulation:
Use: Used to keep the inside of Spaced Out warm so that the mechanics will not malfunction.
Location: Provided by the Colorado Space Grant Consortium.

Flight Tube:
Use: Goes through the center of the BalloonSat so the flight cord can go through the BalloonSat as well.
Location: Provided but the Colorado Space Grant Consortium.

Washers:
Use: Gives the BalloonSat more structural integrity where the tube goes through the box.
Location: Provided by the Colorado Space Grant Consortium.

Switches:
Use: Opens and closes the circuit between battery and component. One for each Arduino and one for the heater.
Location: Two made and provided by Colorado Space Grant Consortium and one provide by Colorado Space Grant Consortium but made by Daniel Torres.

LED:
Use: Lights up to signify the components are being powered and functioning.
Location: Provided by the Colorado Space Grant Consortium.
3.8 Mission Requirements

Spaced Out will record humidity, internal and external temperature, acceleration, and pressure using sensors attached to one of the two Arduinos. Each sensor’s data will be graphed after the data is retrieved. Spaced Out will measure electrical energy that was created by the KERS. After Spaced Out is retrieved it must be ready for relaunch if needed. Spaced Out will provide data to show if the KERS could be a new energy efficient method for aeronautical electrical systems.

3.10 Scaled Diagram
3.11 3D Diagrams
3.12 CONOPS

Launch
Box is sealed up with all parts inside secure. Switches that power everything will be flipped on. Camera will be turned on and start recording.

Flight
As the BalloonSat travels through the tropopause, jet streams will whip the satellite around and produce highest results for KERS. Free fall after burst will cause the the BalloonSat to whip violently through the air taking full use of KERS. The accelerometer will track increases and decreases in acceleration through flight. Throughout the flight period the humidity, temperature, and pressure sensors will continue to gather data.
Landing

Once landed, the GPS will be used to track and retrieve the BalloonSat. Once recovered, we will flip the switches off which will automatically save the data gathered throughout the flight. We will try and keep pieces as intact as possible if damaged for reusability.

Data and Analysis

The SD card will be taken from the SD Shield and connected to the computer with the adaptors to see the results gathered. Collected unit data will be added together from each coil to find total energy. See if the energy produced could be enough to power small units like lights. Then it can be determined if there is any correlation between energy gained and data collected from our sensors.
3.13 FBD

[Diagram of a flowchart with various components including Three 9 Volt Alkaline Batteries, Switches, Heaters, SD Cards, Arduinos, Data Storage Shields, Internal Temperature Sensors, Pressure Sensors, Accelerometer Sensors, External Temperature Sensors, Relative Humidity Sensors, and a 16 GB Micro SD.]

1* KERS APPLICATIONS TO AEROSPACE DIESEL PROPULSION
2* SUPER DEMO
3* WIND SPEEDS AND ELEVATION
4.0 Management

Introduction:
Team Spaced Out tasked each member with two jobs. Though each member has two jobs, all work shall be done as a team taking into consideration all ideas. All members are expected to contribute and have knowledge about how each subsystem in the BalloonSat functions. Each job is considered vital to the development and success of the mission. Spaced Out’s team layout is shown below.

Organizational Chart:
4.3 Team Role Description

Connor Adams is the team leader as well as the KERS (Kinetic Energy Recovery System) designer. Ian Kresyman’s role is Research and Testing. He is responsible for finding data from other projects who have run similar tests. The information found by Ian will be used by the team to create the subsystems. Neil Nguyen was tasked as a structural engineer and tester. Neil is in charge of creating a strong frame for our project and will also be in charge of the structural testing such as the drop test, whip test, and stair test. Ian and Neil will be working together on the testing. Sarah Carter will work with Neil on designing the structure of the box. Her second job is to work with Chris on the coding of the Arduinos. Chris Greer will be working mainly on the programming of the Arduinos. His second job is to help Daniel on the manufacturing of the components. Daniel Torres is the manufacturing engineer and one of the systems engineer. His manufacturing and systems engineering jobs consist of building, soldering, and integrating all of the components of the BalloonSat. Brianna Roe is the treasurer of the group and another systems engineer. She is in charge of keeping track of the group’s finances and will also work with Daniel on the integration of the components of the BalloonSat. Daniel, Brianna, and Ian will be in charge of the cold test seeing as to how this test pertains to testing of the components.

4.4 Team Meetings

Team meetings are to be held every Monday and Wednesday in Gemmill Library or in the Aden Hall basement. These are not limited to two meetings per week and all members are required to attend to assess the progress and find solutions to problems. Time management and maintaining the pace set by our schedule is key in the success of our project.

4.5 Schedule

This schedule is to be followed as is but is subject to change. Any and all changes are to be reviewed, assessed, and approved by all team members.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/21/2015</td>
<td>Proposals Due</td>
</tr>
<tr>
<td>09/23/2015</td>
<td>Team Meeting- work on Homework 07</td>
</tr>
<tr>
<td>09/25/2015</td>
<td>Authority to Proceed Meeting with Professor Koehler/Team Meeting</td>
</tr>
<tr>
<td>09/28/2015</td>
<td>Team Meeting- discuss moving on from Proposal</td>
</tr>
<tr>
<td>09/29/2015</td>
<td>DD Rev A/B Assigned</td>
</tr>
<tr>
<td>09/30/2015</td>
<td>Meeting with Tim May/Team Meeting- worked on DD Rev A/B</td>
</tr>
<tr>
<td>10/05/2015</td>
<td>Team Meeting- worked on DD Rev A/B</td>
</tr>
<tr>
<td>10/06/2015</td>
<td>Team Meeting- worked on DD Rev A/B, meeting with Tim May</td>
</tr>
<tr>
<td>10/07/2015</td>
<td>Team Meeting- worked on PDR presentation and DD Rev A/B</td>
</tr>
<tr>
<td>10/08/2015</td>
<td>Team Meeting- worked on DD Rev A/B</td>
</tr>
<tr>
<td>10/10/2015</td>
<td>Turn in DD Rev A/B/Team Meeting- Begin working on DD Rev C</td>
</tr>
<tr>
<td>10/12/2015</td>
<td>Team Meeting- Cut out foam core and begin building components/code</td>
</tr>
<tr>
<td>10/14/2015</td>
<td>Team Meeting- Begin assembling components of BalloonSat/finalize code</td>
</tr>
</tbody>
</table>

1° KERS APPLICATIONS TO AEROSPACE DIESEL PROPULSION
2° SUPER DEMO
3° WIND SPEEDS AND ELEVATION
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/19/2015</td>
<td>Team Meeting- Camera testing/work on DD Rev C</td>
</tr>
<tr>
<td>10/21/2015</td>
<td>Team Meeting- Structure, component, and code integration</td>
</tr>
<tr>
<td>10/23/2015</td>
<td>Team Meeting- BalloonSat complete build and ready for testing</td>
</tr>
<tr>
<td>10/26/2015</td>
<td>Team Meeting- Testing-whip test, drop/impact test, stair test</td>
</tr>
<tr>
<td>10/28/2015</td>
<td>Team Meeting- Assembled BalloonSat cold test/work on DD Rev C</td>
</tr>
<tr>
<td>10/29/2015</td>
<td>In class simulation/Team Meeting- review the performance of BalloonSat</td>
</tr>
<tr>
<td>11/02/2015</td>
<td>Launch Readiness Review presentation practice/work on DD Rev C</td>
</tr>
<tr>
<td>11/03/2015</td>
<td>Launch Readiness Review Presentation</td>
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<tr>
<td>11/04/2015</td>
<td>Team Meeting- final testing/work on DD Rev C</td>
</tr>
<tr>
<td>11/05/2015</td>
<td>Team Meeting- final testing continued/DD Rev C Due</td>
</tr>
<tr>
<td>11/06/2015</td>
<td>Final BalloonSat weigh in and turn in</td>
</tr>
<tr>
<td>11/07/2015</td>
<td>LAUNCH DAY!!!</td>
</tr>
<tr>
<td>11/09/2015</td>
<td>Team Meeting- Analysis of flight results</td>
</tr>
<tr>
<td>11/10/2015</td>
<td>Team Meeting- work on Post Launch Presentation</td>
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<tr>
<td>11/11/2015</td>
<td>Team Meeting- work on Post Launch Presentation</td>
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<tr>
<td>11/12/2015</td>
<td>Quick Look Post Launch Presentation</td>
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<td>11/17/2015</td>
<td>Team Meeting- Begin work on DD Rev D</td>
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<tr>
<td>11/17/2015</td>
<td>Team Meeting- work on team video</td>
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<tr>
<td>11/19/2015</td>
<td>Team Meeting- work on DD Rev D, work on team video</td>
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<tr>
<td>11/30/2015</td>
<td>Team Meeting- finish on DD Rev D, work on team video</td>
</tr>
<tr>
<td>12/02/2015</td>
<td>Team Meeting- practice Final Presentation</td>
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<tr>
<td>12/05/2015</td>
<td>First draft of DD Rev D and final team video is due</td>
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<tr>
<td>12/07/2015</td>
<td>Team Meeting- compile all flight data</td>
</tr>
<tr>
<td>12/08/2015</td>
<td>Team Final Presentation</td>
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<tr>
<td>12/10/2015</td>
<td>Final Team Evaluations Due</td>
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5.0 Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (grams)</th>
<th>Price (Dollars)</th>
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<tbody>
<tr>
<td>Neodymium Sphere Magnet</td>
<td>27.2</td>
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</tr>
<tr>
<td>Spare Sphere Magnets (2)</td>
<td>---</td>
<td>15.58</td>
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<tr>
<td>Copper Wire</td>
<td>48.01</td>
<td>17.39</td>
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<td><strong>Total</strong></td>
<td><strong>868.02</strong></td>
<td><strong>180.37</strong></td>
</tr>
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Notes:

1) The “other magnets” mentioned above were magnets initially bought for a different experiment that was removed from the mission statement.

2) Original Canon Camera was removed and opted out for a new Polaroid Cube Camera that weighs about 110 grams lighter and also takes less space.
6.0 Test Map and Results

6.0.1 Test Plan and Results
The BalloonSat will undergo a series of tests to ensure it is capable of operating and withstanding the extreme forces of flight and to determine that every part of the BalloonSat is working properly. There will be tests to determine that the BalloonSat’s structures are fit for flight, so that each sensor is working properly, returns usable data, and is writing its results to the SD card, as well as specific tests to determine that the energy recovery system is working properly, returning usable data, and is writing to the SD card so that the experiment can be conducted.

6.0.2 Whip Test
The whip test will be conducted by securing the flight cord through a tube which will be tied off at the bottom. The tube will have the washer and paperclip so that the BalloonSat will not slip off. A tester will whip the BalloonSat over his or her head for one to two minutes, assessing for damage or deconstruction during and after the test. The whip test will be done outside, not in the proximity of windows or anything that may be damaged by the BalloonSat in the case that the test fails catastrophically. The BalloonSat will be tested after two minutes of being whipped around to assess for malfunctions. If no malfunctions are found to be present after the test, the BalloonSat passes the whip test. The BalloonSat must pass the whip test at least three times over the course of testing and building the BalloonSat and must be retested once a change has been made to the structures or internals.
Results:
The whip test was successfully conducted. The tester swung the BalloonSat by the flight cord around for several minutes without any damage or complications. The structures of the BalloonSat were assessed for damages and no damage was found. The BalloonSat has been tested and it has been concluded that it will stay on the flight cord, with confidence.

6.0.3 Cold Test

The cold test will be conducted by enclosing the BalloonSat in a cooler with dried ice to simulate the freezing temperatures of going 30km above sea level. The BalloonSat will sit inside of the cooler with its components and heater running for ninety minutes to ensure that the BalloonSat will run as expected in the below freezing temperatures of near-space. During and after the cold test, the BalloonSat will be assessed for damage and functionality. If all parts are working as expected after the cold test, the BalloonSat will pass and be ready to function in the below freezing temperatures of near-space. This test will be conducted after all parts are properly wired and secured. If the BalloonSat fails, that is, if not all parts are working as expected during or after the test, the heater will be adjusted and moved to properly keep essential parts warm and functional. If all parts are working properly before, during, and after the cold test, the BalloonSat passes the cold test.

Results:
The cold test was conducted twice. In the first test, the block of dry ice was placed outside of a cardboard in which the balloon BalloonSat was placed. All systems were activated for the cold test, however, the inside of the cardboard box never got cold enough to make any conclusions whether the BalloonSat will survive the temperatures of near-space. The second test was conducted with a larger block of dry ice inside of a Styrofoam box, with the balloon BalloonSat. The temperatures for the second test dropped to temperatures as low as negative thirteen degrees Celsius. All of the systems managed to stay functional throughout the second cold test. The heater kept the internal temperatures

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between twenty-one and four degrees Celsius during the duration of the test. Therefore, the BalloonSat has passed the cold test with confidence and is expected to survive the cold temperatures of the flight.

![Graph](image)

### 6.0.4 Drop Test

The drop test will be conducted by dropping the BalloonSat off the bridge on the second story of the ITLL. The BalloonSat will be empty except for insulation and rocks to simulate the mass of the components. The drop test will assess how well the BalloonSat will be able to handle the traumatic g-forces of flight, including touchdown. The BalloonSat will be held by a tester off of the ledge of the ITLL second story bridge and dropped to the ground below. The BalloonSat will then be recovered and assessed for structural damage and repaired accordingly. The BalloonSat must survive the drop, remain in one piece, and not be structural compromised after being dropped from the second story. If the BalloonSat structures are still together and will still work as expected, the BalloonSat has passed the drop test.

**Results:**

The drop test was conducted three times. At one point, the testers were locked out of the DLC and adapted to the problem by tossing the BalloonSat up to the height of the bridge and letting it fall back down. The structures of the balloon survived the test, only sustaining some dings and dents along the edges and corners of the box. The damages were assessed and it was determined that the BalloonSat would not need additional repairs even after
conducting multiple drop tests. The BalloonSat structures has passed the drop test and it has been concluded that the BalloonSat will survive the impact of touchdown.

6.0.5 Stairs Test
The stairs test will be conducted by dropping the BalloonSat structures down a flight of stairs in the ITLL. Rocks will be placed inside of the BalloonSat. The stairs test will assess how well the BalloonSat can handle the tumbling and erratic multi-directional g-forces of flight. The BalloonSat will be placed at the top of a long flight of stairs and a tester will push the BalloonSat down the stairs. The BalloonSat will tumble down the stairs and be recovered at the bottom. The BalloonSat will be assessed for structural damage after the test to qualify it for the erratic and violent forces it will undergo during flight. If structures of the BalloonSat have not been compromised, it passes the test. The BalloonSat should pass the test at least three times in a row to qualify the BalloonSat for its flight to near-space.

Results:
The stair test was conducted by lightly kicking the BalloonSat structure down a flight of stairs. The test was conducted three times, the last of which, the tester inadvertently kicked the BalloonSat too hard and kicked a hole into the bottom of the BalloonSat structure. The BalloonSat has since been repaired with aluminum tape. The BalloonSat structures held up to tumbling down the flight of stairs very well and the test could be concluded to be successful.
6.0.6 Humidity Test

The humidity test will be conducted breathing on the humidity sensor while the sensor is plugged in and running. Data will be recorded from the sensor and will be written on the SD card as a part of the test. By breathing on the humidity sensor, it can be tested on its ability to detect changes in humidity and will be assessed for functionality and data can be recorded in such a way that the output from the sensor can be utilized to calculate the actual humidity the sensor is reading at a given time. The data will be written to the SD card to determine that the data is indeed being recorded. If the sensor can properly detect changes in humidity, and the output can be read, utilized, and written to the SD card, the test will be a pass. The humidity sensor will be tested after the installation of the switch and batteries, and will be tested after the Arduino is mounted inside the BalloonSat.

Results:

The humidity test was conducted by breathing on the humidity sensor to assess for functionality. The tester breathed on the humidity sensor and data was recorded. The resulting data correctly displayed that more humidity was detected immediately after the tester breathed on the sensor. The data was made into a graph. The humidity test was successful and the humidity sensor has been determined to be functional and interpretable (The humidity test results were graphed alongside the pressure test results, shown below).

6.0.7 Pressure Test

The pressure test will be conducted by a tester who will create a vacuum by sucking on the pressure tube. Data will be recorded from the sensor and will be written on the SD card as a part of the test. By sucking on the tube, the tester will create a vacuum, thus creating a difference in pressure. The pressure sensor will be able to record this difference in pressure and will return an output voltage. The voltage will be utilized to calculate the actual pressure the sensor is reading. The resulting data will be written to the SD card as a part of the test to determine that it is indeed recording the data. If the sensor can detect changes in pressure properly and data can be read and written to the SD card, the test will be a pass. The
pressure sensor will be tested after its Arduino has been fitted with a switch and a battery and will be tested again after it has been installed inside the BalloonSat.

**Results:**

The humidity test was conducted by having a tester suck on the pressure tube to assess the pressure sensor for functionality. The change in pressure was recorded and put into a visual representation. The resulting data correctly displayed that the pressure sensor detected the change in pressure. The pressure test has been declared successful because the sensor works as expected and records the data to a satisfactory degree.

![Graph showing sensor readings](image)

6.0.7 **Acceleration Test**

The acceleration test will be conducted by holding and rapidly moving the subject in various directions, as well as setting the BalloonSat down in different orientations. Data will be recorded from the accelerometer and will be written to the SD card as a part of the test. By rapidly moving the sensor in various directions, the tester will apply g-forces to the sensor, which it will be able to read and return as a voltage. The voltage will be utilized to determine how much the accelerometer is accelerating and in which direction. The data will be written to the SD card to determine that the results are indeed being recorded. The sensor will be tested after its Arduino has been fitted with a battery and a switch and will be tested again once the entire part has been installed inside the BalloonSat.

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Results:
The acceleration test was conducted by powering on the Arduino with the accelerometer and rotating the BalloonSat in various directions, the difference in the values for the x and z sensors revealed that the accelerometer works as expected and will be able to record changes in g-force for the X and Z axis of the sensor. The values have been put into a visual representation. The acceleration test has been concluded to be successful and the accelerometer is expected to record acceleration and orientation to a satisfactory degree.

6.0.8 Temperature Test (Internal & External)
The temperature test will be conducted to determine that the temperature reading sensors on the device are both working to a satisfactory degree. The test will be conducted by exposing the temperature sensors to differences temperatures by putting it in different environments and by putting them near ice and sources of heat. The sensors should be able to detect changes in temperature and return a voltage that can be utilized to calculate the temperature it is reading. As a part of the test, the resulting data will be written to the SD card to determine that the device is recording data properly. If the sensors can detect changes in temperature properly and the data can be utilized and written to the SD card, the test will be a pass. The sensors will be tested after the Arduino holding the sensors is fitted with a switch and batteries. The test will be conducted again after the Arduino and its sensors have been installed to the BalloonSat’s structures. After the temperature sensors have been put in place they must be tested individually for one sensor only detects internal
temperature and the other is fixed to the external of the BalloonSat. The BalloonSat and sensors must pass the test at least twice.

**Results:**

The temperature test was conducted once by pressing the sensors between the fingers of a tester. The temperature sensors successfully recorded the change in temperature when they detected the heat from the tester’s fingers. The temperature sensors were tested for cold temperatures by placing the BalloonSat near a chunk of dry ice. The temperature sensors recorded the cold temperatures successfully and the resulting data was put into several graphs. The test for cold temperatures was tested alongside the cold test, due to the availability of the dry ice for the cold test. The temperature tests were declared successful because the temperature sensors could successfully record the changes in temperature.

![Temperature Graph]

**6.0.9 A. Shake Test**

The shake test will be used to assess the motion powered electric generator’s functionality. The test will be conducted by a tester holding and shaking the motioned powered electric generator to determine that it functions as works as expected, as well as performs its task to a satisfactory degree. The test will be used to determine the generator’s functionality and will be used after the generator is mounted inside the balloonSat to determine that the generator works as expected after installation. The output from the device must be able to be reflect that the device is working properly, and that the output can be read, utilized, and written to the SD card. The magnet cannot get stuck to some other magnet part, and must create a voltage when it goes through the copper wire coils. If the kinetic energy to electrical energy generator produces a voltage that can be read, utilized and written to the SD card, the test will be a pass. The shake test will be conducted multiple
times as needed to ensure that the motion powered electric generator works to a satisfactory degree during flight.

**Results:**
The shake test was conducted by shaking the BalloonSat in such a way that the magnet within the system would roll around rapidly. The coils were able to record the movement of the magnet and generate voltages from the motion of the magnetic sphere spinning around the system. The results were put into a graph for visual representation of the voltages recorded from the shake test. It has been concluded that the electric generator will be able to produce voltages from the magnet passing through the coils. The shake test has been declared successful, and the system should be able to produce voltages should the magnet be free to spin around the system.

![Voltage vs Time](image)

6.1.0 **B. Tree Test**
The tree test will be used to assess the motion powered electric generator’s ability to perform while swinging on its flight cord. The fully built balloon BalloonSat will have the flight cord secured through it. One end of the cord will hang below the balloon BalloonSat, and the other end will be tied around an outreaching branch of a tree. All systems will be turned on. The BalloonSat will be swung around violently by the flight cord so that the motion powered electric generator may be assessed for functionality in conditions similar to what it will go through during ascent and descent. Testers will take turns swinging the
balloon BalloonSat by its flight cord. During the test, the tester will listen carefully for the sound of the magnet rolling around while swinging the balloon BalloonSat. All parts must stay in place during the tree test, and the magnet must always be able to roll around the generator’s system freely. After 90 minutes of violent swinging, the balloon BalloonSat will be taken down from the tree and assessed for damage and functionality. All parts must still be in place, the magnet must still be able to roll freely, and the balloon BalloonSat should still be functioning properly. Data will be recorded during the test and will be recovered after the test as to determine what is to be expected from the motion powered electric generator during the actual flight.

**Results:**

The tree test was conducted by tying the flight cord to a branch of a tree and the BalloonSat was swung and shaken by a tester holding the flight cord. During the test, the magnet was heard rolling around, and was not hindered by metallic parts within the BalloonSat. The balloon was swung around for ninety minutes, and the testers took turns swinging the BalloonSat around. The resulting data showed that the electric generator works sufficiently when it is being swung around by the flight cord. The resulting data was put into a graph. The tree test has been declared a success, because all the parts within the BalloonSat remained in place, the magnet was able to roll freely throughout the ninety minutes of violent swinging, and the resulting voltage readings were satisfactory for the purpose of the experiment.
There were many safety measures taken by team Spaced Out in order to keep people safe. During the drop/impact test, the area was cleared as a countdown was called before release. This ensured that the falling BalloonSat would not hit anyone. The BalloonSat was checked 3 times before each test to ensure that it was secure enough so the rocks inside used for weights wouldn’t fall out. During the whip test, each member of the team stood at a clear distance away from the person swinging it to avoid potential release. Double knots were tied during this test so more security was added. During the cold test, the dry ice was handled swiftly with care to avoid burn. With all these precautions in place, there was no harm to any individual or damage to property.
7.0 Expected Results

The primary mission objective to test the KERS system will be accomplished by logging the voltages collected from the Arduino into an Excel spreadsheet. After the test is over we can pull the data from the Micro SD card and use the values to find a rate of volts over time. This piece of information can then be used to check to see if the system could be a viable power supply for small electronics on board aircraft.

The horizontal motion of the BalloonSat will send the magnetic sphere through the copper coils creating electrical pulses that can then be quantitatively recorded when wired into the Arduino Uno past a capacitor. These pulses will later be analyzed and noted as the total amount of energy collected over the flight to meet the overall objective.

Spaced Out expects to see increasing data values for the amount of energy produced as the craft ascends getting closer to the jet stream where wind speeds can reach hundreds of miles per hour. This trend should continue up until the tropopause (12-16 km) where air pressure is now approximately 2.5 psi after which wind speeds start to decrease. There the BalloonSat should collect less and less power from the craft until the balloon ruptures and all BalloonSats attached to the string will enter a freefall, spinning the electromagnet violently at first and then settling back down as the parachute starts to catch the atmosphere. Below is a projected chart to help visualize the data expected for this experiment.

The data from the tree test (while not representing the rates of power generation at specific times during flight) collected an hour and a half of data from the BalloonSat’s KERS. This gives team Spaced Out an idea of what the data should look like when plotted on a graph and also proves that the system will be capable of recording data for the duration of the flight. Although not all flight conditions could be simulated during the tree test, the results gathered represent expected outcomes. The blue and green lines represent the voltages collected at each time interval (every ninety-six hundred milliseconds). The yellow and red lines, in the graph on the next page, show every 75th data point to show an average reading of the voltages.
The other Arduino Uno has sensors attached used to measure pressure, temperature, and humidity of the atmosphere along with the BalloonSats acceleration throughout the flight. All sensors have been tested and calibrated and are ready for flight. The team expects the pressure to roughly follow a $1/x$ sloped graph and decay as the altitude increases exemplified below from the Engineering Toolbox website.

The temperature data will show the external temperature sensor’s values decreasing from launch until the tropopause where it should level out and then start to increase again in the stratosphere due to the increase in O3 that layer of the atmosphere contains. The internal
temperature should follow the same trend line however due to the heater and insulated box the changes to temperature will not be as drastic. Data from the external sensor is predicted as shown below from the LASP website (However Spaced Out’s data will be in °C not K).

![Diagram of the atmosphere layers with temperature and altitude data]

The relative humidity is expected to have a negative slope for the entire time it is increasing in altitude. It should be the highest on the ground and will decrease after launch as represented below by actual data recorded from a BalloonSat team flown out of Lubbock, Texas. Though they got a bit of unexpected data around 40,000 ft., the trend line is still where it should be.

**Relative Humidity vs. Altitude**

![Graph showing relative humidity vs. altitude]

The accelerometers measuring changes in velocity of the BalloonSat will be mainly influenced by wind pushing it around and directly after burst where it is in freefall. Therefore, it is predicted that the values of accelerations should increase up to the tropopause where winds from the Jetstream are at their highest values. After the tropopause the values should start to drop due to the lack of wind in the stratosphere. After burst it is predicted the BalloonSat should see
some of its highest acceleration values because it is in freefall with very little wind resistance and is being whipped around the string it is attached to. The values should start to decrease as the BalloonSat gets lower in the atmosphere and the parachute catches more air.

The cold test puts the BalloonSat through weather conditions similar to what is expected on the flight. Team Spaced Out ran the BalloonSat for an hour and a half to make sure it will be able to continue to run under the extreme cold. Below is the sensor data recorded during that time exemplifying what is expected from the two different temperature sensors on board the Arduino Uno as it increases in altitude. All the other sensors data can be ignored for these purposes but are left on the chart to show their working condition.

![Sensor Data vs Time](image)

![Temp1 (F)](image) ![Temp2 (F)](image) ![RH (%)](image) ![Pres (psi)](image)
8.0 Launch and Recovery

On launch day, Spaced Out’s BalloonSat will be checked one last time to make sure all corners of the structure are sufficiently taped and able to withstand launch, ascent, and descent. Next, all the teams will have their designated BalloonSat launchers line up with their box and attach it to the launch cord. The knots will be double checked to ensure the box will not slide down the cord or out of place. The BalloonSat launcher from team Spaced Out will be Daniel Torres. He will also have the responsibility of flipping the switches to turn on the Arduinos and the heater. These are located on the outside of the BalloonSat and have LED lights to show a visual confirmation of the functionality of the components. The camera will be turned on separately by pressing the power button down through a hole on top of the BalloonSat using a paperclip. When the camera is turned on it will emit a beeping sound giving the confirmation that it has been turned on. To start the recording, the same power button must be clicked twice more. The camera will then emit three beeping sounds again giving the confirmation that it has begun recording. Spaced Out will then take a picture of the outer structural integrity of the BalloonSat to then be compared to another picture that will be taken after landing. A picture of the internal structure of the BalloonSat will be taken at CU before check in.

Once the BalloonSat is in the air, all teams will track their payloads to retrieve it. Pictures will be taken with the BalloonSat on the ground after retrieval to show any structural damage both on the outside and inside that occurred during the flight and landing. After retrieval, Spaced Out will take the BalloonSat back to CU to review the data collected. The Micro SD card will then be taken out of each Arduino and the camera. The data off of each Micro SD card will be copied over to at least three team members’ computers: Chris Greer, Brianna Roe, and Ian Kresyman. This method of data retrieval has been tested before throughout the multiple tests done previously. As a team, Spaced Out will then analyze the data from the flight to conclude the level of success or failure of the BalloonSat mission. This data will also show the temperature inside and outside of the BalloonSat, humidity, acceleration, and pressure. It will then be compared to other teams’ to check for similar results. The data from the KERS will also be analyzed and compared to the expected data.
References

"8.02x - Lect 16 - Electromagnetic Induction, Faraday's Law, Lenz Law, SUPER DEMO."


Requirements Flow Down: A New Hope, Red October

Requirements Flow Down: Orien


