Team

Space Oddity Design Document Rev A/B

Lucas Calvert, Matt Jonas, Q Moore, Nico Tennis, Alan Tett,
Sahil Bajaj

Table of Contents

1.0 Mission Overview.................................................................3

Leina Hutchinson 3/9/2016 1:31 PM
Comment [1]: Missing the revision log
1.0 Mission Overview

1.1 - Mission Statement:
Team Space Oddity’s mission is to lift a small Balloon Sat (<864g) into the stratosphere (~30km) for the ASEN 1400 class and monitor radiation levels at different altitudes with the goal of determining the effectiveness of using radiation measurements to create seeds for a random number generator.

1.2 - Mission Overview:

Team Space Oddity will be flying the aptly-named Balloon Sat, “The Tin Can”, into the upper Stratosphere in order to measure levels of ionizing radiation. On the ground, the main sources of this harmful radiation are trace amounts of long half-life isotopes remaining from the formation of Earth. The Tin Can will be flying high into the atmosphere to measure the higher levels of extraterrestrial radiation. These cosmic rays come primarily from the sun with a small portion being contributed from interstellar space due to reasons not completely known. Most of this extra radiation is deflected away by the Earth’s magnetic field, so radiation levels are notably lower closer to the ground.

This ionizing radiation will be measured by the Balloon Sat and used to generate a random number sequence. Most random numbers are generated using a Pseudo-Random Number Generator (PRNG), which is just a sophisticated algorithm that produces a seemingly random sequence of numbers; PRNG’s however are not truly random because they are generated using a deterministic formula, that, if known, could be used to predict the next number. In a truly random sequence each number is completely independent. This problem has led to different innovations to create a Truly-Random Number Generator (TRNG).

Efforts to generate a completely random sequence take two fronts: chaotic and quantum number generators. Random.org uses a chaotic system by creating random numbers from the background noise around the computer, while HotBits, a server out of the Formulab in Switzerland generates random bits using radioactive decay, like the Tin Can will do.

The biggest problem with most TRNGs is that they are very inefficient when compared to a PRNG. This makes them impractical for industrial and use and transfers involving large amounts of data. Team Space Oddity will be flying a Geiger tube to a high altitude in order to test whether an effectively random sequence of numbers can be generated using the higher levels of radiations in Earth’s upper atmosphere. The mission will also search for an “optimum altitude range” along the flight. The criteria for this altitude will be a large level of background radiation that varies sufficiently enough to generate a non-uniform, random sequence.

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2 The difference between chaotic and quantum events, and the debate over which phenomenon is more random, is an interesting topic that boils down to individual views about the deterministic nature of everything. RANDOM.ORG - True Random Number Service, www.random.org. Retrieved 2016-02-07.

2.0 - Requirements Flowdown

Our mission has three main components: get the Tin Can up to 30km in the atmosphere, monitor ionizing radiation all the way, and determine how effective the radiation is at generating random number seeds. The third component has two subcomponents: generating random numbers and determining their effectiveness with respect to altitude.

<table>
<thead>
<tr>
<th>Requirements Flowdown Table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 0</strong> <em>(Mission Objectives derived from the Mission Statement)</em></td>
</tr>
<tr>
<td>1. The Tin Can <strong>will</strong> reach an altitude of 30km in the upper Stratosphere.</td>
</tr>
<tr>
<td>2. Using a Geiger counter, The Tin Can shall continuously record levels of ionizing radiation.</td>
</tr>
<tr>
<td>3. Team Space Oddity will use the radiation data gathered to generate random numbers.</td>
</tr>
<tr>
<td>4. Team Space Oddity should determine the optimum altitude for efficient random number generation...</td>
</tr>
<tr>
<td><strong>Level 1</strong> <em>(tentative- will finalize for Rev C, derived from the Mission Objectives)</em></td>
</tr>
<tr>
<td>1. The Tin Can will gather data on pressure, humidity, internal temperature, and external temperature to verify that it reaches an altitude of 30km in working condition.</td>
</tr>
<tr>
<td>2. Using a Geiger counter, The Tin Can shall continuously record and <strong>store</strong> levels of ionizing radiation to create a radiation gradient for the atmosphere.</td>
</tr>
<tr>
<td>3. Team Space Oddity will generate random hexadecimal numbers based off the intensity of radiation gathered by the Tin Can.</td>
</tr>
<tr>
<td>4. Team Space Oddity will test the randomness of the random numbers in comparison to the altitude at which they were detected to determine a height at which random number generation via radiation detection is most effective.</td>
</tr>
</tbody>
</table>

3.0 - Design

The design of the Tin Can (TC) is simple. To collect all of the data required for team Space Oddity’s scientific experiment, a foam core box will be used to carry and protect two...
Geiger counters, several atmospheric measuring instruments as well as the batteries and microcontrollers to bring the system to life.

3.1 - Structure
The TC’s main structure will consist of a single piece of foam core that has been cut and scored (using the method provided by Professor Koehler) so that, when folded, it will form a 150mm X 150mm X 150mm cube (See Figure 3.1). Once the main box has been cut, hot glue will be used in all of the joints (except for those that make up the top of the cube) to ensure a strong and rigid frame that will withstand to forces applied during its flight. The edges will then also be covered with aluminum tape to further protect them from abrasions and delamination of the foam core.

Once the box is assembled, a combination of hot glue and Velcro will be used to secure all of the components to the frame. The box will need to have several holes cut entirely through the frame (camera, attachment to the main rope, etc.). These holes are necessary, but will be made the smallest size possible to help keep the interior of the box as warm as possible. The smaller the holes are, the more easily the heater will be able to keep the interior temperature of the box to a functional temperature.

3.2 - Function / Data Collection
As mentioned previously, the TC will collect temperature, humidity, acceleration, pressure and radiation measurements during its entire flight. Two Arduino Uno microcontroller boards will be used as platforms to process and record the data. The first Arduino will be
connected to an SD card (via an SD shield), one 9V battery and the Balloon Shield (two temperature sensors, one humidity sensor, an accelerometer and one pressure sensor). The Arduino will continuously take readings from the sensor pack and write it to the SD card. The second Arduino will be connected to an SD card via the shield and a battery in the same way as the first, but instead of recording data from the previously mentioned sensors, it will monitor the two on-board RH electronics. That radiation data will then be written to the SD card for examination and processing after the flight. Unlike the first revision of the TC, Rev2 carries two Geiger counters. The second counter was added for redundancy and as a way of checking to make sure our data is valid and the sensors were working properly.

In order to keep the other parts of the TC working properly, a small heater will be used to maintain a relatively constant temperature inside the box. The heater is built from 3, 4 Ohm resistors connected to a bank of 3 9V batteries. Using an externally mounted switch, the heater block will be turned on just before launch and will continue run until the batteries die or the TC is recovered.

A digital camera will also be mounted to the inside of the TC and will take pictures at a predetermined rate while the TC ascends and descends through the atmosphere.

For visualizations of how the components connect and should function, view the FBD and CONOPS diagrams below.
4.0 - Management

To keep on schedule for launch, each member is appointed to lead development on one subsystem, and assist on two other subsystems. In addition, Lucas and Matt are appointed project leaders in order to keep all subsystem development on schedule and facilitate corrections of any issues that arise in development of the Balloon Sat, as well as any that arise within the group.

<table>
<thead>
<tr>
<th>4.1 – Work Delegation</th>
<th>Lead</th>
<th>Assistants</th>
</tr>
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<tbody>
<tr>
<td>Project Lead</td>
<td>Lucas, Matt</td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>Nico</td>
<td>Sahil, Matt</td>
</tr>
<tr>
<td>Coding</td>
<td>Lucas</td>
<td>Alan, Sahil</td>
</tr>
<tr>
<td>Electrical</td>
<td>Matt</td>
<td>Nico, Q</td>
</tr>
<tr>
<td>Thermal</td>
<td>Sahil</td>
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<tr>
<td>Science</td>
<td>Alan</td>
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<tr>
<td>C&amp;DH</td>
<td>Q</td>
<td>Alan, Nico</td>
</tr>
<tr>
<td>Treasurer</td>
<td>Alan</td>
<td></td>
</tr>
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</table>
4.2 - Schedule

In order to finish development of the Balloon Sat on time, Team Space Oddity has set internal deadlines for both development and testing of each of the subsystems. Testing for subsystems will be carried out after all the subsystems are finished being developed. The internal schedule is set to have the Balloon Sat completely finished, testing and all, two weeks before the launch readiness review. This extra time is being reserved for any unforeseen delays in the development and testing of the Balloon Sat, and if there aren’t any delays the extra time will be used for extra testing. In order to meet these deadlines, Team Space Oddity will have two meetings a week, on Tuesdays and Sundays, for two to three hours each.

2/2/16 Conceptual Design Review Presentation
2/8/16 Proposal Due
2/12/16 Authority to Proceed Meeting w/ Chris
2/14/16 Begin all soldering (Electronics and Thermal), Begin Drafting Code
2/16/16 Begin Drafting Structure
3/1/16 Preliminary Design Review
3/8/16 Finish all Soldering (Electronics and Thermal), Begin Electronics testing, Begin Science and C&DH Drafting
3/13/16 Coding and Structure Checkpoint, Begin Structure Testing (Whip Test and Drop Test)
3/15/16 Begin Science and C&DH Testing (Radiation Test/ RNG Test)
3/20/16 Begin Testing Coding, Finish Structure Testing, Commence Dry Ice Test (Thermal/Electrical)
3/27/16 Finish Testing and Implementation of all Systems (Full system test II)
4/5/16 Launch Readiness Review Presentation
4/8/16 Weigh-In and Turn-In
4/9/16 Launch Day
4/14/16 Post Launch Presentation
4/23/16 ITLL Design Expo (1st Draft of DD Rev D)
4/26/16 Final Presentation
5/2/16 Final Draft of DD Rev D due

5.0 - Budgets

As shown in the following table, Team Space Oddity is well under-budget, allowing for the potential replacement of faulty science equipment and allows for design changes to be made in the future as needed. Our project is also well under-weight, which would allow one extra battery to be added if needed.
<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (in g)</th>
<th>Cost (in $)</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2 x 25</td>
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<td>COSGC</td>
</tr>
<tr>
<td>2 x Space Grant Shield Kit</td>
<td>2 x 2</td>
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<tr>
<td>Camera</td>
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<td>2 x Micro SD Card</td>
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<td>Temperature Sensor</td>
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<tr>
<td>Heater</td>
<td>100</td>
<td>0$</td>
<td>COSGC</td>
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<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (in g)</th>
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<th>Supplier</th>
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<tr>
<td>2 x Geiger Kit</td>
<td>2 x 36.436.4</td>
<td>2 x $20</td>
<td>RHElectronics</td>
</tr>
<tr>
<td>Dry Ice</td>
<td>N/A (Testing only, 4 Kg)</td>
<td>$25 (Out of Budget)</td>
<td>King Soopers</td>
</tr>
<tr>
<td>12 x 9V Batteries</td>
<td>45/Battery</td>
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</table>

**SUBTOTAL**: 204720.4 grams $100 40,790.79 $ out of Budget

**SHIPPING TOTAL**: $40

**TOTAL**: 720.4 $140 $40.79

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*Comment [23]: Don’t forget to include things like foam core, glue, wires, tape, interface tube, stickers, etc.*

*Comment [24]: Are these the flight batteries? Batteries you use to test are not the same as those that you use for flight (which were provided)*

*Comment [25]: Looks like something went wrong here*
Supplier Notes

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Website</th>
<th>Contact</th>
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<tr>
<td>RHElectronics</td>
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<td>Amazon</td>
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<td>1 (888) 280-4331</td>
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<tr>
<td>King Soopers</td>
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<td>1-800-883-7135</td>
</tr>
</tbody>
</table>

6.0 - Test Plan and Results

Safety is a priority for Team Space Oddity, and all members will maintain a safe working environment when working on and testing the Tin Can (Balloon Sat) in order to prevent potential damage to people and/or property. Throughout the process of designing and building the Tin Can team members will not only obey basic safety protocols, such as wearing proper protective equipment, but will also be professional and careful when building and testing the Tin Can. As not all members may have experience with all of the tools that are available to them, team members will need to take an instructive class or consult a mentor who can instruct them how to properly use the equipment. In essence, team members will be careful and professional when building and testing the Tin Can in order to prevent any injuries or damage.

Proper testing of all components is necessary to help prevent possible mission failure. Therefore, Team Space Oddity will test the most likely causes of mission failure as well as testing the functionality of sensors and testing the system as a whole in order to simulate a full mission. As described above, proper safety precautions will be taken with all testing.

6.1 - Whip Test

The Tin Can structural prototype will be connected to a rope or cord that will be strung through holes in the top and bottom, secured with a knot on either side. The prototype will then be filled with weights equal to the weight of the actual components of the Tin Can in order to prevent damage to components during testing. After the prototype is filled with weights and properly attached to the string/cord, it will be “whipped” about by spinning the prototype as fast as possible above a team member’s head in order to simulate g-forces that will act on the Tin Can after burst. This test will be performed by a single person so as to reduce the risk of harming other people and will be done away from windows and/or breakable objects.

6.2 - Drop Test

The structural prototype will be loaded with weights simulating the weight of the actual components and will then be dropped from varying heights onto concrete or similarly hard surfaces in order to simulate the landing conditions of the Tin Can on a hard surface. The team
will ensure that the area where the drop test is being performed is clear of bystanders and breakable objects.

6.3 - Stair Test

The structural prototype will be loaded with weights simulating the weight of the actual components and will then be tossed, rolled, and kicked down a flight of stairs to simulate the Tin Can being dragged along the ground and other rough landing conditions. As with the previous structural tests, the area in which this test is being performed will be clear of bystanders and breakable objects.

6.4 - Temperature Test

The Tin Can will be placed inside a cooler filled with dry ice with all systems active for a duration of approximately 3 hours. Temperatures during the flight can reach as low as -80 degrees Celsius, a possible source of power failure if not heated and insulated properly. This test will make sure that the heater and insulation will function properly and that the Tin Can will be fully operational for the duration of the flight.

6.5 - Geiger Counter Test (Experimental Arduino Test)

In order to calibrate the Geiger counter and make sure that the Geiger counter is properly detecting radiation, the team will contact the University of Colorado Physics Department and gain access to a radiation lab. During this test, the Geiger counter will measure the levels of radiation and will store this data for use in a preliminary data analysis test. This step is crucial to the success of the mission as the data from the Geiger counter must be accurate to ensure that the data can be used to create true random number seeds.

To turn a stream of readings from the Geiger counter into a sequence of numbers, the data will be plotted and a will be approximated with a linear least-squares line. This regression will become a threshold where every data point above the line will be counted as a one and every data point below the line will be counted as a 0, giving a binary sequence. In order to condense the sequence for easier analysis, the stream will be broken into 4 bit numbers that will be interpreted as a single hexadecimal digit.

True randomness is more of a philosophical idea, so Team Space Oddity will test this random number sequence for statistical randomness. To do this, the sequence will be subject to four different hypothesis tests developed by Bernard Babington Smith and M. G. Kendall at a significance level of 5%. This means that there must be at least a 5% likelihood that the null hypothesis (H0) is true given the gathered statistics. All of these tests will take the following null hypotheses in a Chi-Squared test:

Frequency Test:

H0: The distribution of single digits is uniform

Serial Test:

H0: The distribution of two digits numbers is uniform
Poker Test:
   $H_0$: The distribution of five digit numbers is uniform

Gap Test:
   $H_0$: The gaps between zeros follows a geometric distribution

6.6 - Required Sensors Tests (Environmental Arduino Test)
Pressure, external temperature, internal temperature and humidity sensors will be calibrated by using corresponding data from the National Weather Service. The temperature sensors will also be tested during the temperature test to help ensure accuracy. The accelerometer will be calibrated and tested by car at varying known speeds and accelerations to ensure accuracy.

6.7 - Camera Test
The camera test will make sure that the camera system can survive the low temperatures during flight as described above during the temperature test section while still taking pictures and video as specified by the program embedded in the SD card. This initial test will coincide with the temperature test, and further testing will be done to ensure that the camera will properly take pictures under no special conditions. This will also ensure that the pictures can be successfully stored and extracted from the camera.

6.8 - Mission Duration Test
This test will ensure that the Tin Can functions as intended throughout the duration of the mission. The test will be performed once as a preliminary test during the temperature test, and will be tested as a separate factor for potential mission failure or problems. This secondary mission duration test will be performed without any other conditions to ensure that any failure during the test can be properly identified and addressed.

7.0 - Expected Data
Travelling up through the Troposphere and Stratosphere, the Tin Can’s various sensors will record metrics such as temperature and air pressure. In order to properly interpret the data, there needs to be a sense of what the data should be.

7.1 - Temperature
The temperature of the atmosphere with respect to altitude is

![Earth's Atmosphere Profile](image)
well documented (Figure 7.1)\(^4\). Through the Troposphere, temperature decreases to around -60 degrees Celsius, then, after the Tropopause, temperature should increase again until the Tin Can reaches its maximum altitude at around 100,000 ft. (~30 km). At the burst height the temperature should be near -50 degrees Celsius.

The internal temperature would ideally remain constant at ground temperature, but the internal temperature will change. The plot of internal temperature should be a dampened version of the external temperature.

7.2 - Pressure

Not surprisingly, air pressure should decrease as the Tin Can rises through the atmosphere. This is due to decreased force of gravity and there being less atmosphere above to exert pressure. The data from the pressure sensor as well as the external temperature and z-axis accelerometer will be the predominant tools to measure the Tin Can’s progress as well as major events throughout the flight path.

7.3 - Humidity

The solubility of water vapor in air increases with temperature and pressure. Therefore, the data from the humidity sensor should reflect both changes in temperature and pressure, but should follow a predominantly negative trend in. While the relative humidity of the air might not change, the absolute humidity, which the sensor measures will change. However there might be spikes in the Troposphere that correspond to the Tin Can passing through a cloud that will obscure this temperature and pressure relationship.

7.4 - Accelerometers

The z-axis accelerometer will provide meaningful data on the Tin Can’s vertical progress. It should be relatively constant and positive on the way up and then negative and again constant on the way down. Due to the fact that the Balloon Sat will be spinning during most of its journey the data from the x and y axis accelerometers will be equivalent. Because of this, these two horizontal accelerometers won’t give any meaningful insight to the Tin Can’s horizontal progress. They will, however be useful in measuring the amount of whip, which should be moderate on the way up, and then chaotic and strong during descent.

7.5 - Radiation

As the Tin Can rises through the atmosphere, Team Space Oddity expects the level of ionizing radiation to increase. Based on Figure 7.2\(^5\), the counting rate of the Geiger counters should increase linearly (Note the logarithmic scale) until 15 km (around 50,000 ft.) where the coincidences per min will begin to decrease until burst height. Therefore, the hypothesized

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optimum height for seed generation should occur around the halfway height of the Tin Can’s flight\(^6\).

Hopefully, the data collected from the actual flight will have the same overall trend, but with some random noise that will allow for a more random number generation.

\(^6\) Spirit of Dr. Seuss