Team Savage Seven
Project On Point

Drew Pfefer, Julia Kincaid, Nick Bermudez, Kirsty Hodgkins, Gretchen Devereux, Conner McLeod, Jake Velasquez

Chris Koehler 9/21/2016 2:55 PM
Comment [1]: Overall an OK proposal. I feel several areas could have had more thought put into them. See comments.
1.0 Overview and Mission Statement

1.1 Mission Overview

Team Savage Seven aims to design, build, and launch a BalloonSat that will determine the orientation of the craft without the use of a compass. Team Savage Seven will use a Nine Degrees of Freedom sensor to send information about the orientation of the craft to an Arduino, which will control a servo motor with an arm attached to it and aim to keep the arm pointed north at all times. In order to determine the reliability of the servo motor’s arm, the servo motor will be filmed by a GoPro camera and compared to an analog compass.

Team Savage Seven’s mission has important applications to the future of space flight that could be used to both expand and improve humans’ ability to travel through space. First, determining the orientation of the craft with a Nine Degrees of Freedom sensor prevents Team Savage Seven from relying on the Earth’s magnetic field for navigation. As a craft moves farther from the Earth, the magnetic field ceases to exist, and a craft may encounter magnetic fields different than Earth’s as it approaches other planets. Thus, interstellar travel cannot rely on a magnetic compass, and Team Savage Seven’s mission explores an alternate system of navigation that could be used during interstellar travel. In addition, Team Savage Seven’s aim to keep the servo motor’s arm pointed north at all times can be applied to keeping delicate cargo from spinning or experiencing turbulence. Most rockets rotate around their center of gravity in order to produce a straighter flight, and landings often happen at incredibly high speeds. This could pose a large problem to delicate payloads, so Team Savage Seven’s mission explores the possibility of stabilizing and controlling the orientation of an item during space flight.

Team Savage Seven’s BalloonSat will meet all weight and cost requirements. It is designed to weigh 776 grams and cost 71 dollars.

All team members are enthusiastic and bring knowledge and focus to the team. The members work well together and freely share ideas as well as solve problems. All members are aware of the time commitments of the project and are aware of the launch date and the required activities after the recovery of the satellite. The team is very hardworking and dedicated and adopted the motto: “All in.” This terse motto reflects the team’s value of keeping all work concise yet put all of its effort into it.

1.2 Mission Statement

Team Savage Seven plans to successfully design, build, test, and launch a BalloonSat that will use a Nine Degrees of Freedom sensor to keep the arm of a servo motor pointed north. The data collected about the reliability of the servo motor’s orientation could contribute to navigation systems for interstellar travel that don’t rely on magnetic fields and the stabilization of fragile payloads.


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2.0 Technical Overview

All components described in the technical overview section will be given or purchased before the flight. A breakdown of all these components and their price, source, weight, and quantity can be found in the budget table. Safety is one of the most important values to the Savage Seven and many precautions will be taken at all times during the duration of the project: eyewear will always be used when soldering; all members of the team and people nearby will be thoroughly warned when a test is being done; all members will look after the safety of each other at all times.

2.1 Structure

The satellite has been designed with a hexagonal prism structure in order to maximize the volume in a given height compared to a cube with an equitable height because it has a more constant radius. Furthermore, the components have been placed around the hexagon in a way that gives the experimental equipment space as well as balances the weight so the satellite does not rock too much in any plane except for the one in the direction of the rope. The center of mass (determined in SolidWorks) is approximately in the middle of the tube.

2.2 Electrical System

The BalloonSat’s Electrical System will consist of four independent systems including a Camera System, an Environment System, an Experiment System, and a Heater System. The camera will be powered by a lithium ion battery and take photographs throughout the flight. The digital images will be stored on a SD card. The Environment System will measure the environmental aspects of the BalloonSat’s flight including acceleration, pressure, external temperature (which will be placed one inch beyond the exterior of the box), internal temperature, and humidity. This system will use one Arduino Uno that will be powered by a 9V battery. The data recorded by the sensors will be saved on a microSD card. The Experiment System will control the input and output of the 9 Degrees of Freedom Sensor and the 360 Degrees of Rotation Servo Motor using a second Arduino Uno, also powered by a 9V battery. A custom computer program will be loaded.
onto this second Arduino Uno’s memory that will use the data from the 9 Degrees of Freedom Sensor to control the Servo Motor with the goal of counteracting the rotation of the BalloonSat and keep the Servo Motor pointing north. The inputs sent to the Servo Motor will be saved on the microSD card. The Heater System contains a heater powered by three 9V batteries to keep the electronics and batteries warm and operable during the coldest portions of the flight. The Function Block Diagram below provides an overview of the Electrical System and describes each of the four individual systems.

2.3 Thermal System
The BalloonSat structure will be a hexagonal enclosure constructed from insulating foam core and aluminum tape. The BalloonSat will include a Heater System powered by three 9V batteries. This heater will keep the electronics and batteries in the BalloonSat operating during the coldest portions of the flight. A cold test will be performed prior to launch to ensure that the thermal system is functioning.

2.4 Software/ C&DH
The main experiment at hand requires a large focus on the software. The Savage Seven will be using two Arduino Uno units. The first will be used for acceleration, pressure, internal temperature, external temperature, and humidity sensors while the second will be for taking in data from the 9 degrees of freedom sensor (which measures the yaw, pitch, and roll of the craft) and executing a program through the servo motor. The first arduino will mainly be recording data from it sensors and it will be programmed that way. As for the second arduino, the Savage Seven’s experiment dictates that the servo’s arm points toward north. In order to achieve this, the team will program the arduino to analyze the angular momentum of the craft to determine its orientation and use that data to command the servo motor to counteract the change in direction keeping it always facing north.

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3.5 Science and Data Retrieval

During the mission, multiple systems must operate in unison. In order to determine whether a 9 Degrees of Freedom Sensor can direct a Servo Motor with a pointer to point north without the aid of a compass, a GoPro camera will be used to record the results of the experiment during the ascent of the BalloonSat. An analog ball compass will be mounted near the Servo Motor. The GoPro camera will be placed on the ceiling of the BalloonSat framed to view both the Servo Motor and the compass. The camera will constantly record the position of the servo’s pointed arm and the compass’s north pointer during the ascent and descent of the flight. LED lights will ensure the compass and Servo Motor are visible to the camera throughout the flight.

Prior to launch, all electrical and mechanical systems will be tested to ensure they are functioning. Before launch the GoPro camera will be powered on and the shutter button will be pressed to begin recording. At the same time the camera begins filming, the Camera, Environment, Experiment, and Heater Systems will be turned on and the Servo Motor will be calibrated to match analog compass just prior to launch. As the BalloonSat rises to 30 km, the custom computer program loaded onto the second Arduino Uno’s memory will receive the specified data from the 9 Degrees of Freedom Sensor and control the Servo Motor pointer arm so that it points north. The GoPro footage will be reviewed after the flight to see if the position of the Servo Motor pointer differed from the position of the analog compass pointer. However, since servo motors have very inaccurate movement, the team will also analyze the data from the electronic compass on the 9 degrees of freedom sensor and compare that data to the computed data of the yaw sensor. In simpler terms, the team will look at what its code determined the direction to be and compare it with what the actual direction was. This is a more meaningful measure because the idea can achieve success even if the application with this hardware does not succeed.

3.6 Tests

In order to ensure the success of the mission various rigorous test will be conducted. The balloon satellite will experience extremely harsh conditions throughout its flight and must be able to continue functioning. The obstacles the satellite will face vary greatly thus the tests needed to replicate these environments will include structural, thermal, electronic, and pressure testing. The structural testing will include dropping the satellite 30 feet, kicking it down a flight of stairs, and whipping it around on a string to replicate the impact of landing and the stress of flying. Along with the intense whipping during flight, the satellite will impact the ground at approximately 50 kilometers an hour. The satellite also runs the risk of being whipped and dragged violently along the ground. These three structural tests will provide the information needed to build a successful structure. The thermal conditions of the flight will be tested using a beer cooler and dry ice. The satellite will be subjected to conditions similar to the sub zero temperatures it will face during the flight. During the test all systems will be running and the goal will be to keep the internal temperature above -10 degrees celsius. Electronic and systems will be continually tested throughout the building of the satellite. Both the physical connections as well as the code used to operate the sensors and arduinos will be tested individually as well as as a unit. Finally the satellite will be put into a pressure chamber to simulate the different

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pressure environments during the flight. Once the satellite constantly passes all of these tests, it will indicate that it is prepared to face the extreme conditions of the flight and provide successful results.

Section 3 Management and Cost - Julia Kincaid

### 3.1 Schedule

The Savage Seven plan to meet every Sunday and Monday from 7-10 and Wednesday from 10-12. These meetings will take place in the ITLL or a study room in one of the engineering dorms.

<table>
<thead>
<tr>
<th>Week</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>September 19-25th. The Savage Seven need to acquire the hardware, and have the Authority to Proceed appointment. Homework 6 is due.</td>
</tr>
<tr>
<td>Week 2</td>
<td>September 26th – October 2nd. The Savage Seven would like to have Solidworks designs complete and perfected and begin prototyping. The Savage Seven would like to have our first model done. Homework 7 is due. Homework 8 is also due.</td>
</tr>
<tr>
<td>Week 3</td>
<td>October 3rd – October 9th. The Savage Seven must work on and complete the Preliminary Design Review. The Savage Seven also will construct the box and begin programming the arduinos.</td>
</tr>
<tr>
<td>Week 4</td>
<td>October 10th – 16th. The Savage Seven will complete mid-semester team evaluations and begin testing. The Savage Seven will finish the electrical wiring.</td>
</tr>
<tr>
<td>Week 5</td>
<td>October 17th – 23rd. The Savage Seven will complete the Whip, Drop, Stair, and LED tests.</td>
</tr>
<tr>
<td>Week 6</td>
<td>October 23rd – 30th. The Savage Seven will have hands-on time in class and will finish programming.</td>
</tr>
<tr>
<td>Week 7</td>
<td>October 31st – November 6th. The Savage Seven will complete the in-class mission simulation test and work on the Launch Readiness Review. Homework 9 is due</td>
</tr>
<tr>
<td>Week 8</td>
<td>November 7th – 13th. The Savage Seven will submit the Launch Readiness Review and have the final weigh-in and Launch Day.</td>
</tr>
</tbody>
</table>

[Date]

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Week 9
November 14th – 20th
The Savage Seven will examine the data and work on the final presentation.

Week 10
November 21st – 27th
Fall/Thanksgiving break (grub time)

Week 11
November 28th – December 4th
The Savage Seven will have the ITLL design expo and finish the final presentation.

Week 12
December 5th – 11th
The Savage Seven will complete the extra credit exam and present the video and the final presentation.

3.2 Management
The Savage Seven have 6 sub-categories with multiple people working on each part to ensure that the task is accomplished well and efficiently.

Team Member | Phone Number | Major | Address | Special Skills
--- | --- | --- | --- | ---
Julia Kincaid | | Aerospace | 2370 Libby Dr Boulder, CO 80310 | Organization, Software, Structures

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3.3 Budget

The Savage Seven will use 766 g of the 864 g weight limit. Additionally, we will be using $71 of the $180 budget. The $50 for spare parts is an overestimate, taking into account that there will probably additional things needed as we move forward. All purchases will go through a proposal process to be approved by Dr. Koehler and will be purchased with Dr. Koehler’s visa card. Receipts will be turned in within 48 hours of purchase. This budget will be managed by Nick Bermudez, and we will hold ourselves accountable to these budget limits outlined.

<table>
<thead>
<tr>
<th>Material</th>
<th>Source</th>
<th>Quantity</th>
<th>Mass</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Uno</td>
<td>COSGC</td>
<td>2</td>
<td>50 g</td>
<td>$0</td>
</tr>
<tr>
<td>Space Grant Shield Kit</td>
<td>COSGC</td>
<td>2</td>
<td>4 g</td>
<td>$0</td>
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<tr>
<td>Canon A3400 IS Digital Camera</td>
<td>COSGC</td>
<td>1</td>
<td>145 g</td>
<td>$0</td>
</tr>
<tr>
<td>MicroSD Card</td>
<td>COSGC</td>
<td>2</td>
<td>6 g</td>
<td>$0</td>
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<tr>
<td>Temperature Sensor</td>
<td>COSGC</td>
<td>2</td>
<td>2 g</td>
<td>$0</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>COSGC</td>
<td>1</td>
<td>1 g</td>
<td>$0</td>
</tr>
<tr>
<td>Humidity Sensor</td>
<td>COSGC</td>
<td>1</td>
<td>1 g</td>
<td>$0</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Item</th>
<th>Source</th>
<th>Quantity</th>
<th>Weight</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>Heater</td>
<td>COSGC</td>
<td>1</td>
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</tr>
<tr>
<td>Foam Core</td>
<td>COSGC</td>
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<td>25 g</td>
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<tr>
<td>Switches</td>
<td>COSGC</td>
<td>4</td>
<td>3 g</td>
<td>$0</td>
</tr>
<tr>
<td>LED Indicators</td>
<td>COSGC</td>
<td>3</td>
<td>3 g</td>
<td>$0</td>
</tr>
<tr>
<td>Aluminum Tape</td>
<td>COSGC</td>
<td>1</td>
<td>3 g</td>
<td>$0</td>
</tr>
<tr>
<td>Glue</td>
<td>COSGC</td>
<td>1</td>
<td>1 g</td>
<td>$0</td>
</tr>
<tr>
<td>Wiring, Resistors, etc.</td>
<td>COSGC</td>
<td>-</td>
<td>Less than 30 g</td>
<td>$0</td>
</tr>
<tr>
<td>9 V Batteries</td>
<td>Amazon</td>
<td>12 pack***</td>
<td>215 g</td>
<td>$16*</td>
</tr>
<tr>
<td>Dry Ice</td>
<td>Grocery Store</td>
<td>4 kg</td>
<td>-</td>
<td>$25*</td>
</tr>
<tr>
<td>9 DoF Sensor Stick</td>
<td>Sparkfun</td>
<td>1</td>
<td>3 g</td>
<td>$15</td>
</tr>
<tr>
<td>Micro Servo Motor</td>
<td>Adafruit</td>
<td>1</td>
<td>6 g</td>
<td>$6</td>
</tr>
<tr>
<td>GoPro Camera</td>
<td>Conner McLeod</td>
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<td>163 g</td>
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<tr>
<td>Pressure Sensor</td>
<td>COSGC</td>
<td>1</td>
<td>5 g</td>
<td>$0</td>
</tr>
<tr>
<td>Spare Materials</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$50</td>
</tr>
<tr>
<td>Totals:</td>
<td></td>
<td></td>
<td>766g</td>
<td>$71</td>
</tr>
</tbody>
</table>

* team funded items not included in total  
** all prices are rounded to the nearest whole number and exclude tax and shipping costs  
***not all of the purchased product will be used

**General Mission Requirement Summary:**

Outlined by the next 25 points, you will be able to see that The Savage Seven has addressed all general mission requirements and are prepared to stick to the requirements to ensure a safe and successful launch.

- Team Savage Seven’s additional mission is outlined in 1.2.
- Additional sensors can be found in section 2.2 and 2.5.
- The Satellite will be functional after flight.
- The flight string interface is acknowledged in the CAD drawing of the satellite and located within the BalloonSat.
- The internal temperature requirement is outlined in section 2.6
- The total weight will not exceed 864 grams and is outlined in section 3.4.
- The accelerometer referenced in 2.2 and 2.4 will be used to determine how fast the

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BalloonSat rises and the speed that it falls.

- The functional block diagram shows the use of two Arduino Unos along with a microSD card shield in section 2.2.
- The external temperature sensor and it’s position an inch past the external surface is mentioned in section 2.2.
- The design will fly the provided Canon A3400 IS Digital Camera, which is outlined in section 3.3.
- The thermal systems outlined in 2.3 describe what materials and equipment will be used to keep the batteries and electronics functioning for the duration of the flight.
- The design sketch of the BalloonSat shows that it is constructed from foam core is displayed in section 2.0.
- Spare parts are addressed in Section 3.3 and included in the budget.
- Contact information and the provided US flag will be placed on the outside of the BalloonSat.
- The metric system will be used in all design dimension and measurements.
- All team members have been advised of the launch date and recovery time and will be prepared is outlined in section 1.1
- The precautions Team Savage Seven will take to ensure the safety of all team members are outlined in Section 2.0.
- Precautions will be taken to avoid damage of borrowed property.
- All purchases will be managed by the team treasurer, and appropriate action will be taken.
- Team Savage Seven will acquire all materials through the Gateway Order Form, and the treasurer will be in charge of purchases and receipt submission.
- All team members are excited to complete the mission and will be having too much fun to complain, as discussed in Section 1.1.
- Team Savage Seven’s additional mission does not require the use of anything that is alive.
- All team members have are aware of the final report and will track the mission’s progress and analyse the data in order to present a complete and detailed final report.
- LEDs will be used as an indicator of the status of operation of sensors and other electronics.
- All switches within the BalloonSat will be protected by a foam core cover.