Comment [1]: Overall a pretty good proposal. A few items that need to be addressed but nothing major.
1.0 Overview and Mission Statement

1.1 Mission Statement

Team Return of the Engineer’s mission is to safely launch a Balloon Sat weighing less than 864 grams to an altitude of 30 kilometers with the purpose of testing the concentrations of Carbon Dioxide, Methane, Ozone, and several Hazardous gases present in Earth’s atmosphere. The team is measuring the level of these gases such that a model of gas concentration versus altitude can be created, as well as making a comparison between the collected data and data supplied by the government and other reputable sources. By comparing the data with that of others, the team would like to see how gas levels have changed over the past few decades due to the industrialization of the Earth caused by the human race and how it affects the atmosphere which sustains life on Earth.

1.2 Mission Overview

The Ozone layer is located in the Stratosphere, it protects the earth by absorbing harmful ultraviolet radiation. Over the last 20 years, human industrialization has been increasing at a high rate, and this has resulted in changes to the chemical makeup of the atmosphere.

One of the gases the team is looking at is carbon dioxide, or better known as CO2. Unlike some of the other gases the team is watching, CO2 doesn’t directly affect the ozone. CO2 both benefits and obstructs the ozone indirectly. Both of the indirect effects can be seen in the stratosphere which is where the team is sending the BalloonSat. In the lower stratosphere, increased amounts of CO2 is slowing down the production of ozone whereas in the upper stratosphere increased amounts of CO2 actually aids to increase the amount of ozone due to its effect on nitrogen oxide. CO2 prevents nitrogen oxide from breaking down the ozone.

Another gas that will be monitored is methane (CH4). Naturally, it is found underground and beneath the seafloor. However, it is also found in the atmosphere, and it is known to be one of the most potent greenhouse gasses. An increase in the concentration of methane in the atmosphere contributes to the destruction of the ozone layer, but more specifically, the byproducts of the breakdown of methane in the atmosphere are what truly play an active role in this destruction.

In order to execute the project, the team will be purchasing a sensor that will monitor various hazardous gasses such as sulfur and benzene. Sulfur is found in both the ground and in the air. It can transfer throughout the ecosystem through erosion, the food chain, water evaporation, the breakdown of organic matter, and also through volcanic eruptions, which exemplify a more direct aerosol effect. Secondly, benzene is highly abundant as it has many sources. From industrial products, gasoline leaks, to forest fires, and even cigarette smoke, it pollutes the air, water, and soil when levels are dramatized by human use. All hazardous gases that are higher than their normal rate in the ecosystem are a risk not only human health,

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Although there are several different components that could be tested with a BalloonSat, the team agreed that the most interesting experiment would be done by testing the gasses in the air in the ozone layer because the team’s future can be drastically changed based on the concentration of various gases found. The team thought long and hard about this experiment to ensure that the entire team is interested and included in the experiment. The gases found in the ozone are interesting to the team because there hasn’t been an abundance of information in the media pertaining to this topic. Return of the Engineers noticed brief and vague news reports of how the ozone is depleting due to the affects humans are having on the atmosphere. The team members feel as though the state of the ozone layer is important to how their lives will be in the future. If the amount of ozone in the atmosphere is depleting at a rapid rate, the Earth’s ozone layer will completely disappear within several decades. This could spell massive problems for humans everywhere, as the ozone layer is the main protection from the sun’s harmful radiation.

The experiment focuses on the concentration of stratospheric ozone in the atmosphere in relation to CO2, methane, and various other hazardous gasses. The sensors that the team are ordering will measure the presence of these gasses. As this data is compared to government accounts of these concentrations, it will become evident to the team just how prevalent the issue of ozone depletion is and how the existence of these harmful gasses in the atmosphere coincide with this issue. This way, the team will be able to determine how severe the effects seem to be in the area compared to other areas as well as the same area in the past.

2.0 Technical Overview

2.1 Design Overview

By using four atmospheric gas sensors, an Arduino, and extensive amounts of code, Project Atoms Fear Us will collect data in regards to the concentration of gasses in the atmosphere. The sensors will be purchased from the company Sainsmart, a professional hardware supplier. The four sensors the team is using are relatively small, at around one half inch wide and one a half inches tall. These sensors all have a main part containing the motherboard and wiring, with a porous semi-circle on one end. This semi-circle has a porous circle on one side, which is where the gas enters the sensor.

Once inside, this gas is measured in one of two different ways. The CO2 sensor uses a sensor known as an Electrochemical sensor. This sensor contains a thin acidic electrolyte, a sensing electrode, and a gas permeable membrane. As the air flow through the porous surface, certain gases, in this case the carbon dioxide, will oxidize on impact with the acidic electrolyte. The current that is produced by this reaction is proportional to the concentration of the desired gas. The sensing electrode then relays this back to the chip and after that the data will travel back to the Arduino.

The other three sensors, which measure, Methane, Hazardous gasses, and Ozone, use a different type of sensor, known as a Metal Oxide Semiconductor or an MOS sensor. After passing through a porous

Chris Koehler 9/19/2016 6:19 PM
Comment [7]: I think there has been more than you think on some of the gases you are studying…

Chris Koehler 9/19/2016 6:20 PM
Comment [8]: Feel you need to better state what you think will happen/predict will happen with you mission.

Chris Koehler 9/19/2016 6:25 PM
Comment [9]: You did a nice job explaining how these sensors work and detect. Congrats. A figure would be helpful in the your design doc.

Image courtesy of SainSmart

membrane, the target gasses will interact with the surface of a thin metal oxide film. In these sensors this film is Tin Oxide. This thin layer will react with the electrons of the gas, causing an increase in conductivity which is then measured by the chip on the sensor\(^6\). The data is sent back to the Arduino to be stored on the SD card. The supplier claims to have all sensors pre-calibrated, but just to make sure, the team will obtain pure, high concentration Carbon Dioxide and Alcohol to test the CO2 and Hazardous gas sensor. Unfortunately, pure methane and ozone are incredibly hard to come by, so the manufacturer’s factory-done calibration will have to do. All sensors require a 24-48 hour burn in time. This means they must be run for at least that amount of time in order to burn all contaminants off of the sensor.

**C&DH Team**

Return of the Engineer’s BalloonSat control system will consist of two Arduino Uno microcontrollers powered by one 9Volt battery each. Arduino Uno #1 will collect atmospheric data for the experiment using four sensors. These four sensors will sense a wide variety of gasses, including but not limited to, Carbon Dioxide, Methane, Ozone, Benzene, and Ammonia. These will transmit data back to the Arduino through the built-in input/output pins, where it is written to a Comma Separated Value (.csv) file on the SD card. The second Arduino Uno will work in the same manner, except only using the sensors provided by COSGC. The provided sensors will measure the acceleration of the satellite, the humidity, pressure, and temperature of the atmosphere, and also the temperature inside of the satellite. These sensors will all transmit data back to the Arduino Uno through the built-in input/output pins, where each sensor will write its data to a .csv file on the SD card. The heating and camera systems will both be completely self-contained, with no connection whatsoever to each other or the Arduino Unos. All systems will run throughout the entire duration of the flight.

**Software**

The two Arduino Unos will control all sensor reading and computing throughout the flight. In order to do this, each microcontroller needs instruction on how to distribute power, interpret data, and eventually store said data. The code will determine at what intervals sensors receive power, when to collect data from the atmosphere, how raw data is interpreted from the sensors, and finally how the data is written and stored on the SD card. A program will be developed to read the raw sensor values and convert them to a data type that can be easily understood by a human. This data will then be written onto the SD card, at a rate of roughly four measurement samples a second. Although each sensor measures a different type and concentration of gas, the code will be almost identical due to the fact that all sensors are manufactured by the same company.

**Data Retrieval**

During the flight, the large amounts of data will need to be stored in such a way that it can be safely and easily be retrieved at the time of landing, as well as efficiently processed and analyzed at a later date. Each Arduino Uno will have a four gigabyte SD card inserted into its SD port. Project Atmos Fear Us’ software will ensure all sensor data makes its way onto its corresponding file on the SD card. Once the satellite has landed, and made its way back to campus, the SD cards will be removed and all data will be transferred onto a computer.

Data Analysis

Once the data has made its way onto a computer, it will be interpreted and formatted into a more understandable and reasonable structure. Using Matlab, the team will import all of the .csv files and plot the data values for each sensor against the time it was read at. Using statistical and graphical analysis, all data will then be compared to atmospheric data from other reliable sources, where the team will in the end draw a conclusion that either supports or conflicts the team’s hypothesis.

2.2 Internal & External Structure

The overall shape of the Balloon Sat is a rectangular prism 20cmx20cmx15cm (graphic not to scale). The structure will be built out of foamcore, and will undergo rigorous structural tests to ensure its stability. The BalloonSat will include two Arduinos, with one connected to the required COSGC sensors, and the other connected to the suite of atmospheric sensors which will be used for the experiment. The structure will also contain a digital camera and a heater, both provided by Space Grant. The Arduinos will be connected to one 9V battery each, the heater will be connected to three 9V batteries, and the camera will run on its own lithium ion battery. The structure will include a hollow tube through its center which will be used to connect the structure to the balloon. The structure will include small holes in its sides which will allow the sensors and the camera to reach outside of the structure as necessary.

2.3 Extra Features

Due to the relatively small size of Team Return of the Engineer’s sensors, the satellite itself can be a great deal smaller than all other groups. With a 20x20x15cm frame, the weight of the craft is reduced greatly, at around 40% below the maximum weight. This weight will also ensure that upon impact with the ground, there will be less force acting upon the frame, and therefore less damage. A second unique feature of the satellite is the unique thermal insulation method. The goal is to seal the craft and make it almost completely air-tight. All sensors will be housed in the side of the frame. All gas sensors will face outwards into the atmosphere along with the external temperature sensor. The other sensors will be attached on the inner wall. All of these will be sealed air-tight with expanding foam if possible in addition to aluminum tape. A thermal emergency blanket will be fitted to the inside of the satellite also, as it is incredibly lightweight and has strong insulative properties.

2.4 Software Setup & Functional Block Diagram

The team will use this functional block diagram as a basis for applying these electrical subsystems to the overall design of the BalloonSat. This setup consists of four main systems. This includes the camera, heating, and two Arduino units. The camera requires a lithium ion battery as
Atmos Fear Us

a power source and a 4GB SD card to store images on. The heating unit requires three nine volt batteries as well as a switch and LED. Each Arduino unit is powered by a nine volt battery. They are also each attached to a switch, LED, and a SD card for recording data. One of the Arduinos is attached to and will collect data from a sensor that monitors acceleration, humidity, pressure, internal temperature, and external temperature. The second Arduino is attached to and will collect data from a sensor that monitors ozone, carbon dioxide, methane, and various other hazardous gas concentrations. This second sensor is the basis for collecting and storing the data that will be analyzed post launch.

2.5 Handling & Safety

Procedures

From start to finish of the project, the team makes it a priority to take caution when performing any task. All members will act professionally and ensure that all tasks are done in a safe environment where the team has permission to construct and test. The team will make sure that surrounding people or property are not at risk. The team will make sure to have somebody more experienced assisting when dealing with tasks that all members are unfamiliar with. All materials and equipment used will be handled with caution. As a whole, each member will always follow directions and act responsibly.

2.6 Testing Procedures

During flight, the BalloonSat will experience various speeds, positions, and temperatures. The following tests will be applied to the BalloonSat to best simulate flight. All physical tests are done with mass inside the satellite to simulate internal components. The results of these tests will allow the team to know whether or not the BalloonSat is ready for flight or if any modifications are necessary. Testing procedures will begin October 6th. All safety precautions will be followed as stated in 2.5.

**Whip Test**

To test how the team’s BalloonSat will withstand the forces that will be acting upon it after the weather balloon bursts, a whip test will take place. Return of the Engineers will attach a rope to the BalloonSat and proceed to swing it around, simulating a similar situation as there would be as the BalloonSat is descending. This test will test the structure’s ability to maintain the state of the internal components of the team’s BalloonSat under high G-force situations. The BalloonSat will contain weights to represent the total mass of the internal components to ensure that they won’t be damaged during the launch and descend.

**Stair Test**

Return of the Engineers 6
Atmos Fear Us

To simulate the landing and dragging of the BalloonSat during the end of the flight, the team will direct a stair test. This test will be conducted by throwing, kicking and tumbling the BalloonSat down the stairs. Inside the BalloonSat there will be weights to represent the total mass that the team will be flying with which will help the team understand how the BalloonSat will withstand the harsh landing, internally and externally.

**Drop Test**

To ensure that the team’s BalloonSat can survive dropping on to the Earth several different drop tests will take place. The drops will be done with weights inside the BalloonSat to represent the total mass that will be apparent during the flight. The several different drop tests that will take place will be from different heights as well as stimulate being dropped on several different surfaces (dirt, grass, and concrete) because it is a mystery as to how the landing will take occur.

**Temperature Test**

Throughout the flight, the temperature will range greatly. To ensure that all the team’s internal components will be able to withstand the drastic temperature change, the team will conduct temperature tests. To simulate the equivalent temperature drop of when the BalloonSat enters the stratosphere and leaves the troposphere, the team will have a cooler with dry ice and will leave the BalloonSat in the cooler for four hours. This will guarantee that the internal components can withstand the extreme cold throughout the tropopause and will ensure the team that the BalloonSat will stay warm enough for the internal components are insulated enough to continue working.

**Camera Test**

The camera test will be done to ensure the electronic device will stay warm enough during the ascent to take pictures of the flight. The team will conduct the camera test at the same time as the temperature test so the team can test the functioning of the camera; if it is well enough insulated to withstand the coldest temperatures during the flight. The camera will be programe to take a picture every ten seconds during its time in the cooler.

**Sensors Test**

Temperature sensors will be calibrated at room temperature. The humidity sensor will be tested and calibrated at room humidity. The acceleration sensor will be tested on all axis and calibrated to one G. For the CO2 and Hazardous Gases, the team will obtain these gases on campus. Testing and Calibration will take place in a controlled environment with known conditions to see if the sensors are responding appropriately. There is no way for the team to obtain pure Methane or Ozone so the team will use the supplier’s calibration.

**Arduino Test**

The Arduinos will be tested frequently to make sure the inputted software works correctly and that the data being collected and stored is accurate. Every time a new sensor is added, the Arduino will be tested by running software and seeing if the results are sufficient in order to ensure all soldering and wiring was completed correctly.

### 3.0 Management Chain & Financial Overview

During the construction of the balloon satellite, the team members’ work will be distributed evenly among the teammates so that the satellite and project will be built and documented according to the schedule. Nick Beams will be the leader, and he will make sure that each member is on task. Moreover, Nick and the budget manager, Grace Perrone, will document the cost of the materials to make sure that the team does not go over the budget. If this were to happen, the satellite would be at risk for not being able to fly in accordance to the schedule.
### 3.1 Schedule

Team meetings will be held on Thursdays from 7-9 pm and Sunday from 12-3 pm in the Engineering Center Lobby. Group homework will be assigned between meetings in order to maximize efficiency and stay on schedule which is laid out in the following table.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/15-9/22</td>
<td>Work on and finalize proposal. Complete Authority to proceed meeting. Order hardware and begin programs.</td>
<td>11/13-11/16</td>
<td>Collect all videos/pictures for extra credit videos and gather data from sensors. Analyze data. Launch recap, report, and data analysis guidance. Work on and finish video and presentation</td>
</tr>
<tr>
<td>9/25-10/2</td>
<td>Build heater and switch, begin hardware and structure. Continue programming, being PDR presentation</td>
<td>11/17</td>
<td>Present post launch presentation in class. Be ready at 9 am.</td>
</tr>
<tr>
<td>10/16-10/23</td>
<td>Finish service approvals, DD Rev C. Assemble Satellite, test all systems and begin LRR</td>
<td>12/2-12/4</td>
<td>Practice presentation, have all materials completed for expo. Turn in final report draft and complete expo.</td>
</tr>
<tr>
<td>10/27-11/3</td>
<td>Complete cold test, more system tests, fix program bugs. Complete LRR</td>
<td>12/5-12/7</td>
<td>Give presentation and show video to class. Have satellite and hardware ready to turn over to Chris.</td>
</tr>
<tr>
<td>11/6-11/11</td>
<td>Finish DD Rev C. Start sensor burn in, weigh in satellite and turn it in</td>
<td>12/8-12/11</td>
<td>Evaluate team in class. Turn in hardware. Turn in final report and say goodbyes.</td>
</tr>
<tr>
<td>11/12</td>
<td>Launch Day.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With the following schedule the team will be able to complete the project well before launch date. The team plans to complete tasks as soon as possible such that there is as much time possible to test and fix issues. The team believes in a high quality of work, and that would not be achieved by waiting until the last few weeks to complete all tasks.

### 3.2 Inventory & Costs

By carefully following the budget chart below, ROTE will meet the requirements of attaining a cost under $180 and a weight under 864 grams. Grace Perrone will oversee the budget.
and will approve any expenses. The order form will list all materials and will be submitted to Chris Koehler for approval. All receipts will be emailed to koehler@colorado.edu within 48 hours of purchase. The CU VISA card will be used, with Chris Koehler’s approval, for any materials not provided by the Colorado Space Grant Consortium(COSGC). Grace will ensure that any expenses that may put the team over budget, and the expenses for all materials that the team is responsible to provide, will be divided evenly across the team.

**Budget & Inventory**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Cost</th>
<th>Weight</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Uno</td>
<td>2</td>
<td>-</td>
<td>50g</td>
<td>COSGC</td>
</tr>
<tr>
<td>SD Cards</td>
<td>3</td>
<td>-</td>
<td>15g</td>
<td>COSGC</td>
</tr>
<tr>
<td>LEDs</td>
<td>3</td>
<td>-</td>
<td>15g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Camera</td>
<td>1</td>
<td>-</td>
<td>150g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>1</td>
<td>-</td>
<td>5g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Humidity Sensor</td>
<td>1</td>
<td>-</td>
<td>5g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Internal Temperature Sensor</td>
<td>1</td>
<td>-</td>
<td>5g</td>
<td>COSGC</td>
</tr>
<tr>
<td>External Temperature Sensor</td>
<td>1</td>
<td>-</td>
<td>5g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>1</td>
<td>-</td>
<td>5g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Heater</td>
<td>1</td>
<td>-</td>
<td>30g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Foamcore</td>
<td>2 sq. meters</td>
<td>-</td>
<td>50g</td>
<td>COSGC</td>
</tr>
<tr>
<td>Tape, Hot Glue, etc.</td>
<td>Use Dependent</td>
<td>-</td>
<td>(minimal)</td>
<td>COSGC</td>
</tr>
<tr>
<td>CO2 sensor</td>
<td>1</td>
<td>$49.00</td>
<td>7g</td>
<td>sainsmart.com</td>
</tr>
<tr>
<td>Methane sensor</td>
<td>1</td>
<td>$7.95</td>
<td>4g</td>
<td>sainsmart.com</td>
</tr>
<tr>
<td>Ozone sensor</td>
<td>1</td>
<td>$18.99</td>
<td>5g</td>
<td>sainsmart.com</td>
</tr>
<tr>
<td>Hazardous gas sensor</td>
<td>1</td>
<td>$10.05</td>
<td>4g</td>
<td>sainsmart.com</td>
</tr>
<tr>
<td>Dry Ice</td>
<td>15 pounds</td>
<td>$15.00</td>
<td>(not flown)</td>
<td>CU Facilities Management</td>
</tr>
<tr>
<td>Batteries</td>
<td>5</td>
<td>$10.00</td>
<td>225g</td>
<td>amazon.com</td>
</tr>
</tbody>
</table>
3.3 Team Information & Contact

In order to complete the BalloonSat as efficiently as possible, the team has assigned two members to each main role. The team captain has a role as well, but also has the duty of making sure all members are on par with the schedule and that everything is running smoothly. Each member will take part in other roles such that each team member is involved in many areas of the project.

Nicholas Bearns, majoring in Aerospace engineering, is the team leader, and will oversee all projects. He was born on December 19th, 1997 in Columbus, Ohio. He would like to work for SpaceX or JPL. Contact: nicholas.bearns@colorado.edu

Nathan Herr, majoring in Aerospace engineering, is on the software team. He was born on June 17, 1998 in Denver, CO. He would like to work on manned space missions as an engineer. Contact: nathan.herr@colorado.edu

Matthew McCallum, majoring in Aerospace engineering, is on the structures team. He was born on February 10th, 1998 in San Diego, California. He would like to work for a large Aerospace company. Contact: matthew.mccallum@colorado.edu

Lauren De Moudt, majoring in Aerospace engineering, is on the electrical team. She was born October 13th, 1997 in Louisville, Colorado. She would like to work for an aerospace company here in Colorado. Contact: lauren.demoudt@colorado.edu

Grace Perrone, majoring in Civil engineering, is on the budget and programming team. She was born on March, 10th, 1998 in Milwaukee, Wisconsin. She would like to work for Engineers Without Borders. Contact: grace.perrone@colorado.edu

Derek Twarowski, majoring in Aerospace engineering, is on the structural team. He was born on May 26th, 1998 in Chicago, Illinois. He would like to be an astronaut. Contact: derek.twarowski@colorado.edu

Morgan Kempf, majoring in Aerospace engineering, is on the electrical team. She was born on October 8th, 1997 in Broomfield, Colorado. She hopes to be an Astronaut in the future. Contact: morgan.kempf@colorado.edu