TSJC Spring 2015 Balloon Satellite

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Abstract

My goal in creating a balloon satellite is to improve on a previously designed payload structure in order to make it larger and more durable. Secondly, my goal is to successfully launch and expose a petri dish of the common human bacteria Klebsiella Pneumoniae and Staphylococcus Areus to the extreme conditions of near space. Since I am working alone, I wanted to challenge myself to attempt an experiment that had not been done previously by a Trinidad State Junior College (TSJC) team and successfully carry out my own biology experiment.

The shape of a soccer ball inspired the payload re-design. I wanted to not only make more room for the new electronics and the test tubes of bacteria, but to also design a structure that would suffer less impact during landing in addition to withstanding the extreme turbulence that may occur during flight.

For the biology experiment, two bacterium were chosen that cause common human infections, Klebsiella Pneumoniae and Staphylococcus Areus. Klebsiella Pneumoniae is found in the intestines but when it is exposed to any other part of the body it will easily become infectious. Staphylococcus Areus is most commonly recognized as the bacteria that cause skin infections, commonly known as Staph infections.

With the chosen bacteria for my biology experiment, some obstacles arose. These obstacles were overcome with the help of my biology teacher. With her assistance, I learned how to successfully grow and maintain the bacteria so I could get better results from the flight into space.

The goal of this experiment is to learn how these bacteria will react to the higher level of radiation and lack of air pressure in space. Information gathered from experiments such as this one might contribute to find a cure to the infections they cause or to help predict how these everyday bacteria will affect people who live in space in the future.

Introduction

The mission for this project is to successfully launch and expose a petri dish of the common human bacteria Klebsiella Pneumoniae and Staphylococcus Areus. The point of this experiment is to see if these bacteria will survive in the extreme conditions of the atmosphere – specifically higher
concentrations of radiation and lack of air pressure. The expected outcome is that the bacteria will survive the flight and keep growing once they have landed.

To accomplish this mission, the payload structure had to be re-designed so it could withstand these new variables and conditions. With a biology experiment, the technicalities of my box had to be specific for the needs and safety of the bacteria.

The initial box design that was provided for me at the balloon payload workshop was a basic cube with simple Styrofoam barriers to separate the batteries, Arduino Uno and camera. This first design was successful for all the components of the first flight, which consisted of only electronics and a camera. My success with this first payload encouraged me to create a bigger box with an even better and more systematic design.

Design

Once I knew what experiment I wanted to fly, I decided to attempt the “soccer ball” like payload. The logic behind the shape is that upon the impact of the landing, the box would roll rather than hit hard on one side. Pitching the top and bottom of the payload into a point created this specific design. The four cutout triangles on each end were put together in a pyramid-like shape. Enlarging the box for the test tubes of bacteria and the new electronics that were going to be added was also a goal. The dimensions of the cube were increased to 9"x 6" and the altitude of the triangles was five inches creating a pitch of about two inches.

Figure 1. Structure Design Layout

The same materials were used as the original payload; the outer shell of the box was made out of Elmer's 3/16" foam board, 1/2" thick low Temperature Polyethylene Foam Rubber Insulation, and aluminum tape.

The design for holding the test tubes was trickier than a basic barrier. The ideal plan was to have the test tubes exposed in some areas so the bacteria would be exposed to the extreme conditions of space. The risk of exposing the test tube is the hazard of the test tube cracking or breaking. This created an obstacle; however it was overcome by designing a three-tiered, foam column. Using 1" thick rubber insulation, 3, 1 1/2" x 1 1/2" cubes were cut with a 5/8" hole through them. These cubes were hot-glued along two corners of the box with about an inch of space between them. The test tubes slide perfectly through these holes and remain very stable and secure while still exposing the bacteria.
Electronics

The electronics in the payload include an Arduino Uno, two heaters and a Cannon camera. The Arduino Uno is comprised of three shields; the top of the Arduino contains five sensors. There is an inside and outside temperature sensor, a humidity sensor, a pressure sensor, and an accelerometer. Once the Arduino is turned on, all five sensors begin recording and send data to the SD card every ½ second.

The heaters are made out of three, Xicon, 4-Ohm 5W Resistors. These resistors are soldered onto a basic Perf Board. Each heater needs three batteries to power it. It takes about 30 seconds for these resistors to heat up.

The Canon PowerShot A3400IS Digital Camera is useful for this special mission because of its SD card. The SD was provided at the January workshop. Workshop providers placed code on the card that programs the camera when it is switched on. When the camera is manually turned on before launch, it will begin taking pictures on its own every 20 seconds and will record the pictures on to the SD card. This is useful for this kind of experiment to get shots of the entire flight into space.

Growing Bacteria

For my first attempt to grow bacteria a basic science kit was used, it consisted of petri dishes and nutrient agar. At this point, it was undecided what bacterium was going to be used. The original plan was to grow a certain bacteria from an object that was swabbed and use it for the biology experiment. This idea was very far-fetched.

The first attempt at making the nutrient agar was done simply by dissolving it into boiling water and pouring it into the petri dishes. Once it was hardened, it was time to collect bacteria. I initially collected bacteria by swabbing basic objects such as a doorknob, a computer keyboard, a toilet seat and even the inside of a mouth. A whole week passed and nothing grew in the petri dishes. The same process was attempted again, this time using more nutrient agar and taking more time to dissolve it into the water. The petri dish molds came out better this time however, there still were no results after a week! This process was obviously not working and was wasting time; professional help was needed. Thankfully my biology teacher agreed to help me and gave me all the materials and instruction I needed to succeed. With her experience, she helped me bring my biology experiment to another level.

She had a collection of petri dishes already prepared with bacteria to use for the experiment. I researched the types bacteria that was available in the lab and I chose two for my experiment - Klebsiella Pneumoniae and Staphylococcus Aureus. These two
bacteria were chosen because they are common bacteria in the human body.

Klebsiella Pneumoniae is located in the intestines of the human body. The bacterium grows in a very acidic and non-nourishing environment. Because of its extreme environment, if Klebsiella is exposed to any other part of the body it will thrive and become infectious. “Patients with ventilators, vein catheters, or patients that take antibiotics normally run the risk of Klebsiella infection” (Centers for Disease Control and Prevention, 2012). These foreign objects go into the lungs or bloodstream of the body, which may cause the initiation of the bacteria into the body. Once a person has an infection from this dangerous bacterium, it becomes very contagious and may be spread through person-to-person contact.

Staphylococcus Areus is most commonly known and recognized as a staph infection. If this bacterium is exposed to an open wound or gets into the bloodstream, it will become infectious. “Staph A. causes soft tissue infections such as abscesses (boils), furuncles (another type of boil that is much larger and itch), or cellulitis, which causes red, itchy, inflammation of the skin” (Minnesota Department of Health, 2010). If Staphylococcus Areus gets into the lungs it can cause Pneumonia which can be much more serious. Other infections include, bone or joint infections and blood stream infections.

Both of these bacteria had to be ordered online because of the extreme handling and care they required. They both arrived in enclosed cases. This time, using a basic nutrient agar was not an option. A very special agar called Triple Sugar Iron was used. This agar contained specific amount of each sugar the bacteria needed to thrive. This agar was also very useful to the experiment because as the bacterium grows it will turn yellow. This will decipher whether the bacterium continue growing after the flight or not. The process of dissolving the agar into boiling water remained the same but instead of using a petri dish a cultured test tube was used. This is a special kind of test tube specialized for growing bacteria that has a twist on lid. The agar was transferred to the test tube and let cool on an angle to create more area for the bacteria to be swabbed on. To transfer the bacteria onto the agar a tool called an inoculation loop was used. This tool is made of iron and is used to collect a swab of bacteria off of the petri dish. It was heated before and after the swab to sterilize the tool. Next, a tool called an inoculation needle was used. This tool was similar to the inoculation loop but instead had a point at the end. The bacterium was swabbed and a process called a “Butt-stab” was performed. This process is simply poking the bacteria through the agar to the butt of the test tube. This creates an anaerobic state for the process to grow in. These tubes were then put into a heated incubator so it would simulate the normal body temperature causing them to grow faster.

Two test tubes like this were made for each bacterium and one was made as a control test tube. Amazingly, the bacterial grew over the next 24 hours. The results were astonishing. Klebsiella was the most active; it had grown the most and it even formed a gas bubble in the anaerobic part of the test tube. Staphylococcus A. was not as active ad did not grow in the anaerobic environment. After three days both bacterium were thriving.
For the actual launch, Klebsiella and Staph A. will fly up together and another set of these bacteria will remain on the ground as a control. At the end of the launch both the experimental and control groups will sit for one more day and be compared to observe the results. As it was stated before, if the Triple Sugar Iron Agar continues to turn yellow, the bacterium has continued growing. If it has stopped changing color the bacteria has died.

**Testing**

Testing consisted of four relatively easy tests. Three of these tests were structural tests that test the durability of the payload inside and out. The fourth one is a cold test that tests the environmental stability of the box. The first test was the whip test. This test simulates the flight and the random bursts of G’s and movement that will occur. The payload will experience quick direction changes and random drops similar to the movements during flight. Swinging the payload on a long, knotted string stimulates these movements. The payload was attached on a similar flight cord and was swung in circles; it changed directions and then dropped into a vertical to horizontal orbit. The duration of this test was about 30 seconds. Afterwards the box was examined and everything remained in place. The payload was cleared for the next test.

The second test conducted was the drop test. This test was a little harsher then the swing test; it simulated the landing experience of the payload. For this test the payload had to be dropped from a 15-20ft ledge onto a hard surface. The first attempt at this test was a failure. Unfortunately, the batteries came loose from their compartments due to poor placement of Velcro. The Velcro was reinforced and the second attempt was successful.
The last structural test was the stairs test or also known as the “Stair Pitch Test” in the user’s handbook. This test will simulate the worst-case scenario of a landing; for example, the payloads get dragged because of windy conditions, or the parachute inflates back up and picks payloads back up off the ground. To do this test the payload was simply pushed down a flight of stairs. It was very pleasing to see that the soccer ball design of the box worked in this test. Instead of crashing down the stairs the payload rolled easily down them to a stop. This test was also a success.

Figure 6. Stairs Pitch Test

The last test was an environmental test and it tested how the payload would hold up in the cold. For the cold test, 7-10 pounds of dry ice is needed and a cooler. All electronics had to be turned on in the payload and it was then placed into the cooler with dry ice for two hours. During the first attempt, the temperature sensors on the Arduino were the only things recording temperature during the duration of the test. A series of unexplained occurrences happened during this attempt. When the payload was taken out of the cooler, the LED lights appeared dim for both heaters and they were cold to the touch. However, the data off the SD chip in the Arduino read extremely high temperatures throughout the test. The graph below shows data from the SD card.

Figure 7. Cold Test Data – Attempt 1

As you can see, the inside and outside temperature readings seem abnormally high for dry ice. Since these readings did not seem to be correct, the test was run again.

Before the second attempt, battery voltage and the Arduino temperature sensors were checked. No problems or malfunctions were found; each check was successful. It was decided to run the test the same exact way. This time however, a Vernier LabQuest temperature probe was placed inside the cooler and an electrometer heat probe was mended into the payload during the duration of the test. This was done to record accurate temperature readings and to compare results from the Arduino temperature sensors. This time the results were even more unbelievable. Below shows the temperature results from the Arduino.
Now, here are the results from the LabQuest recordings:

As you can see, these graphs do not match up. The Arduino temperature sensors had very high readings again but, this time the temperature kept increasing past 100°F and never dropped. There was obviously a malfunction in the Arduino or temperature sensor. Again, everything was checked. The Arduino’s temperature sensors were tested and the results were accurate. The Arduino was even connected to the computer and ran on the Arduino program and everything was working correctly. The only thing left to check was the batteries. One mistake that was made was re-using the same batteries as the last test. The low voltage may have caused malfunction in the temperature readings. This idea was taken deeper, it was discovered that the sensor needs a certain amount of voltage for each reading taken. If there is not enough voltage, the reading will be off. In this case, the low battery voltage may have caused these abnormal temperatures. “This is important as the accuracy of any analogRead() values will be affected by not having a true 5 V” (Arduino Tutorials, 2012). The Arduino has five analogRead ports on its top shield, one for each sensor. Each one is supposed to receive 5 volts of power to the sensor for every reading. This quote from the Arduino Tutorial page is simply stating that if the sensor does not receive its 5 volts, its readings will be inaccurate. The Arduino Trials article also states that, “If you’re using a sensor that returns a value as a voltage (e.g. the TMP36 temperature sensor) – the calculated value will be wrong if it does not receive the correct amount of volts.” This is basically saying the same thing, however the sensor they use as an example, is the exact same temperature sensor on my Arduino. This just proves that this specific sensor is known to have inaccurate readings without exactly 5 volts being circulated to it every time. This also explains why I was getting inaccurate data after the test.

Another component that was taken into consideration was the batteries being used. The current batteries being used were 9-volt Energizer batteries. The temperature data from the first flight was compared to the temperature data of the first cold test. The data from the first flight was extremely accurate. This led to the batteries that were being used during these experiments. The batteries from the first flight were ProcellDuracell. These batteries by Duracell are specialized for high-draining devices and are known to have a longer shelf life then most 9-volt batteries. The alkaline contained in the battery is a metal that produces more voltage and lasts longer.
than any other kind of battery. This explanation cleared up the mystery of the inaccurate temperature readings.

Adding a small device that records battery voltage to the Arduino has also been debated. With this device, the Analog Digital Converter (ADC) would give out a certain reference voltage no matter how low the battery voltage. Since the sensor needs a certain amount of voltage to record an accurate reading, this program would ensure the sensor gets the correct voltage every time. With this, the correlation between temperature and voltage will be visible through data and might give a better explanation of why the malfunction occurs. However, with the amount of time left, the sensor may be too difficult to add. A third test will be run in the upcoming days to get the temperature accurate before launch.

Conclusion

Since the last payload test is almost complete, it should be very successful for its launch. A lot has been learned from the testing; troubleshooting and fixing issues that come up on the Arduino or the other electronics of the box has become much simpler. The goal is to get accurate readings and to have a successful biology experiment.

It is predicted that Klebsiella Pneumonia will survive the upcoming flight. It has thrived each time it has been grown and after all the tests it continues to grow. It will be interesting to see if it gets affected by any radiation and/or pressure changes that will occur near space. Staphlococcus Aureus does not seem as strong of a bacterium; however, it has also managed to keep growing after all of the tests. The results after the flight will also be interesting for Staph A.

Results will take place after the launch on April 11th and presented during the oral presentation at the symposium on April 18th.
Works Cited

