RockSat-C 2014 Final Report

BaDSTAR

Our goal is to develop a gravity gradient boom deployment system for use on a CubeSat along with testing a system to receive and transmit an image from a suborbital rocket.

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1.0 Mission Statement

Project BaDSTAR was created to demonstrate and test subsystems designs to be used in future projects here at Mitchell Community College. The main attributes for this project were the gravity-gradient boom systems, image-capturing system, and telecommunications. Our goal was to develop a functional prototype of a gravity-gradient boom system and communication system that would enable us to receive real time data and an image taken from the image-capturing system. We hoped to discover technologies that would work best for the future CubeSat project.
2.0 Mission Requirements and Description

Overall mission is to develop working prototype of a gravity-gradient boom system, image-capturing system, and communications system for future CubeSat project.

The main mechanical mission objective was to design and build a gravity-gradient boom system. The team came up with two gravity-gradient boom system designs of different mechanisms. The first design was a spring-driven boom system while the second design was a motor-driven boom system. Other mechanical mission requirements that were implemented included launch detection and apogee detection.

The electrical mission objectives were to develop an image-capturing system and a communication system. The requirements for the image-capturing system were to record footage and capture a snapshot from the optical port of the rocket. For telecommunications, we wanted to have a system where we would be able to transmit and receive real time data such as accelerometer reading, force sensor readings to inform whether the booms successfully deployed, and a snapshot from the image-capturing system.

One small change was made to the requirements for the image-capturing system objective and that was the removal of obtaining footage of the rocket launch. This change was made at the last minute due to having a non-functional video camera. Fortunately, this requirement was not mission critical.

The course of the mission goes in the following order:

1. 1. T - 120 seconds
Turn on Power to electronics

2. T = 0 seconds
   - Launch detected by accelerometer
   - Start mission timer in software
   - Transmission of accelerometer readings begin

3. T + 175 seconds:
   - Arduino sends signal to trigger boom deployment

4. T +~ 175
   - Boom triggered for release,
   - Rotate servo 90° and turn on motor

5. T +~ 175-180 seconds
   - Sensors determine boom deployment
   - Turn off motor for boom if boom extended

6. T + 190 seconds
   - Acquire image from camera

7. T + 210 seconds
   - Start sending image to ground station at T + 185 seconds
   - Continue to acquire images
   - Continue transmission until powered off
3.0 Payload Design

Mechanical

All the mechanical subsystems that were included on the payload were the payload structure, two boom systems, the ballast system, and the mounting system. Both the boom systems and the mounting systems were designed by the students and 3D printed with ABS material by a 3D Printer that was generously provided by the Mitchell Community College.

Payload Structure

The structure of the payload consisted of four makrolon plates and aluminum standoffs. When assembled, the plates are stacked one on top of the other with the standoffs in between each plate to ensure a sturdy structure. This creates three levels in which all the components are located on.

Spring-driven Boom System

The spring-driven boom system uses the potential energy of a piece of coiled up spring steel to deploy at apogee. The system consists of steel material, a spool, a spool housing, a top piece, a servo motor, and a raceway. When assembled, the spring steel is coiled around the spool and it placed in the spool housing. The top cover is placed over the spool housing and the servo motor is mounted on top. The spool housing contains slot opening where spring steel feeds through when the boom is released. This slot opening connects to the opening of the raceway. At the end of the raceway is a slot where a force sensor is located.
The way the spring-driven boom system was designed to work was that when the spring-steel is wound around the spool, the servo motor on the cover piece contains a mechanical arm that stopped the spool from unwinding. When a signal is sent to the servo motor, the mechanical arm lifts and the spring steel unwinds through the opening slot of the spool housing into the raceway. The spring steel will travel to the end of the raceway hitting the force sensor, thus giving force sensor readings.

Motor-driven Boom System
The motor-driven boom system consists of gooseneck tubing material, a spool, spool housing, top cover, raceway, a 600:1 gear-motor, 9V battery, and Arduino Micro. Like spring-driven design, the gooseneck tubing is coiled around the spool and is placed in the spool housing along with the gear-motor. The gooseneck tubing feeds through the opening of the spool housing with the gear-motor located beside it. The raceway connects with the spool housing and has slot at the end for a force sensor. This system is powered by the 9V battery and is controlled by the Arduino Micro. The Arduino Micro is programmed to turn the gear-motor on causing the gooseneck tubing to extrude out of the housing and into the raceway and into the force sensor.
Mounting System

The mounting system was designed to ensure that the payload was secure enough to survive through flight conditions. There was a design mount for the Arduino Uno tower, the Arduino Micro, the transceiver, the 9V battery, the main 12V LiPo battery, and the image-capturing system.

Ballast System

The ballast system was the last system to be integrated. The purpose of the ballast system was to meet the requirements for weight and center of gravity. It consisted of just steel poles that were cut to the right length so that they could fit in between the makrolon plates.
**Electrical**

**Brain System**

The team’s initial choice for microcontroller was the BeagleBone Black. It was chosen due to it having a high onboard memory capacity and 64 digital I/O pins. Upon attempting to use this microcontroller, the team quickly learned that it was a very fickle device. Every unit had multiple problems that were seemingly unrelated. Once one problem was solved on a unit it wasn’t uncommon for a new one to pop up. This lead to the team stepping back and choosing the Arduino Uno. The Arduino Uno acted as the brain of the payload for it enabled the team to integrate all the subsystem together to where only one main program was needed. The Arduino had three shields connected one on top of the other for the accelerometer, SD card, and RS-232. The accelerometer was included as a means to detect launch which would then initiate the main program. The SD card was included as a backup to save data in case communication system failed. The RS-232 shield allowed for the integration of the communication system to the Arduino Uno.

**Power Distribution System**

The overall payload was powered by a 12V LiPo battery. A power distribution was used to connect the multiple components to power source.

**Communication System.**

The communication system consisted of the RS-232, transceiver, antenna port and base station. The RS-232 was connected directly to the Arduino Uno and the transceiver via a male-to-male 9-pin serial connector cable. This allowed the Arduino to send data to the transceiver where it was then transmitted through antenna port to the base station. The base station included a laptop connected the base station antenna. The base station antenna receives signals from the transceiver and displays the transmitted data on the laptop. When the payload is powered on and the accelerometer detects launch, the transceiver will begin transmitting to the base station.

**Image-Capturing System**

To fulfill the requirements of the image-capturing system, two cameras were needed. One camera was responsible for recording footage while the other was responsible for image capturing. Due to limitations of the chosen video camera, the requirement include recording footage was descoped. The final image-capturing system just consisted of a TTL camera connected to the Arduino Uno. In the main program, the functions governing the image-capturing system occur last until the payload is powered off.
4.0 Student Involvement
5.0 Testing Results (1 – 2 page(s))

The team was not able to perform a test flight due to not having a reliable motor for the test rocket, so multiple shake tests were performed to initiate multiple full mission simulations. Through these multiple full mission simulations we achieved launch detection by the accelerometer. Once the launch detection was achieved, the transceiver began transmitting accelerometer readings to the base stations and the programmed timing system for the boom deployment began. Once the time that was programmed into code elapsed, both booms deployed and snapshot was taken and saved on the SD card.

Although most of the mission objectives were completed during testing, there were a few actions that needed to be taken between then and the trip to Wallops. The code needed some modifying at the time such as the countdown timer for the boom deployment and the image transmission portion of the code. Some of the mounts needed to be slightly redesigned to ensure security of the components. Lastly, the activation wires needed to be integrated as well.

This was the special “Lewis Smash Test” that was completed on the payload during testing phase
This is a snapshot of the screen of the base station. This was being transmitted from payload once launch was detected through the shake test.
6.0 Mission Results

Due to certain restrictions of the launch site, we were required to have our base station powered off to ensure the payload was not transmitting to the base station before launch. Once the rocket was launched, we immediately powered on the base station to receive data from the transceiver. Unfortunately, without the initial handshake between the transceiver on the payload and the base station, we did not receive any real-time data.

Once the rocket was retrieved, the team powered up the base station and the data package collected from the rocket launch was transmitted to the base station computer. The data package included the accelerometer readings, a notification of the booms deploying, force sensors readings for both booms, and a total of seven images captured in text format.

*This is a graph of the analog values of the accelerometer readings from the rocket launch*
This is a graph of the force sensor readings from both boom systems.

Since the images that were transmitted were in text format, we had to convert them into JPG format. Unfortunately, we did not receive any clear photos when they were converted. We suspect that data was either corrupted or the program in which we used to convert the files into JPG format was incorrect.
These are five of the seven converted images. As one can see there is no clear make up of actual image that was taking by the image-capturing system.
7.0 Conclusions (0.5 to 1 page)

In conclusion, the team felt the mission was a fairly successful one. Majority of the mission critical objectives were achieved. Both the spring-driven and motor-driven boom system deployed at apogee. The image-capturing system performed as it was intended to and acquired a total of seven images. Lastly, the communication system transmitted the data package from the payload to the base station. Although the main points of the mission were executed, the team felt that there was room for improvement that could be achieved in the future.
8.0 Potential Follow-on Work

Further analysis will be done on the subsystems to figure out why certain requirement were not met in project BaDSTAR. For the 2014-2015 Mitchell Community College Rocket Team, there are hopes of improving project BaDSTAR. The plans for next project is to improve the boom system designs and possibly combine the two into one design along with making some minor changes to the image-capturing system and communication system. Depending on what is fiscally available will determine whether the team will participate in RockSat-C or RockSat-X.
9.0 Benefits to the Scientific Community

This project was more of a “proof of concept” engineering project. The ideas behind and designs generated by this project will be further extrapolated and elaborated on in future projects at Mitchell Community College. This year’s team hopes that the groundwork laid out here will benefit future teams towards an ultimate goal of a CubeSat.

As for any benefits to the scientific community, our ideas may possibly influence designs for cheaper CubeSat parts. This is a far reaching long term goal that might seem too lofty but it would be very nice to have come to fruition.
Lessons Learned (1 to 2 page(s))

Project BaDSTAR was a huge learning experience for every member of the team. The largest lesson learned was to always expect things to not go as planned. There were many instances in which this happened to the team during the course of this project. From one member not being able to make it to a team meeting to having the payload being far away from meeting its weight requirement to having voltage on the canister, things happened. This is where the second lesson which was learning the value of having contingency plans. As the team members learned to expect things to not go as planned, they learned to develop more than one solution for every possible problem.

As far as lessons learned relating directly to the RockSat-C program, the team would advise future participants to always keep the RockSat-C Check-In Procedure in consideration from beginning to end. The team learned this the hard way when it came to Check-In Procedure at Wallops. The biggest problem that the team was having was voltage on the canister. This taught the team a valuable lesson of knowing the electrical component thoroughly such as knowing where ground planes are located on electrical components is important. It is also important to have the schematics of the payload on hand at all time in case a problem like the voltage of the canister occurs.

Based on the performance of the image-capturing system, the team learned that it is essential to do thorough research on electrical components that a team is considering to use for its payload. The performance of a subsystem or even the whole payload depends on the quality purpose of the components. By doing thorough research on electrical components can let a team know whether the electrical component is suitable for the mission.

Some of the other lessons learned were more related to the team ourselves. Communication is a very essential part of any team. Without it, a team can quickly fall apart. There were times where people seemingly went missing without word about why or what they may have accomplished. This left the remaining members in a state of limbo until the missing party returned.

From a different aspect of communication, don’t be afraid to throw out an idea that may seem rather radical. Other members may have been thinking the same thing and it may even lead to a new solution. Also, don’t be afraid to ask for help or admit that you can’t do what you agreed to do. Sometimes people bite off more than they can chew and there should be nothing wrong with admitting this. Someone may be able to help out which is better than toughing through it and not getting it done in time. This causes people to have to scramble and rush to get it done which can lead to errors and tension that could’ve been avoided.

Speaking of tension, another lesson learned here would be that it can be easy to forget that other team members are also people. Now that sounds bad, and we
never had a major problem with this, but other teams very well may have and it is essential to keep in mind. If a teammate loses their cool and snaps at another person, don’t be afraid to apologize. Tempers can flare because this can be a frustrating project, certainly in the days approaching the launch if things aren’t going well.

Lastly, some general lessons we learned about various aspects of the project. Make sure everything and anything is documented. Nothing beats having a well laid out and organized handbook of data sheets and schematics. This ties into communication and general organization. Always have backup parts and tools. It is better to take too much and not needed it than to not have enough and scramble for ideas last minute.
Here are some pictures of our amazing team at work and at play!