Senior Design Final Report
CubeSat

Version 1.0 - 05/12/2019

Team Members:
Isaac Cano
John Chen
Darren Farahyan
Giovanni Garcia
Tan Luong

Faculty Advisor:
Richard Cross

Liaisons:
Rick Johnson
Denny Ly
Pablo Settecase
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1. Introduction:

1.1. Background:

The Aerospace Corporation performs objective technical analyses and assessments for a variety of government, civil, and commercial customers. Aerospace operates as the only federally funded research and development center (FFRDC) exclusively committed to the space enterprise. An example of Aerospace’s work in the aeronautic industries are CubeSats. CubeSats provide a cost effective platform for science investigations, new technology demonstrations and advanced mission concepts using constellations, swarms disaggregated systems. Therefore, Aerospace has teamed up with California State University, Los Angeles by developing a system to showcase innovative technologies designed for CubeSats. The system will have two main components: the CubeSat, the Ground System (GS). In addition, a Simulation Platform (SimPlat) will be provided for development and testing. The SimPlat is a movement base system that is designed to mimic motion in space for the CubeSat.

What is a CubeSat? In short, CubeSat is a small satellite built to standard dimensions called Units or U. Each U dimension is 10cm x 10cm x 10cm. What is a Ground System? A Ground System is a method of communication to the CubeSat. It is controlled and monitored by a personnel on Earth. The purpose of a ground system is to receive and send data from and to the CubeSat. Our goal for this project is to create a prototype CubeSat that will imitate how a real CubeSat will act in space. Our main objective is to have the CubeSat obtain the ability to locate and self-navigate to a target. Also, a Ground System which will allow us control the CubeSat. Our approach for the Ground System is a web-based application. This means that the Ground System can be accessed through any computer with internet and browser capability. When a user connects to the Ground System, the Ground System will display all the information about the CubeSat such as: visual data, telemetry data, and sensor data. Visual data is any image data that the CubeSat sends to the Ground System. This would be a video feed or a picture from the camera. Telemetry data is any system data about the CubeSat. This would be CubeSat position, status, and log data. Sensor data is all the data that the CubeSat obtains from attached sensors. The Ground System also allow the user to manually control the CubeSat with a joystick interface or with keyboard keys. When the CubeSat obtains the ability to self-navigate, then the Ground System will only be used manually by a user in cases of emergency.
The Ground System and CubeSat are both initially developed for local testing, with the plan to expand to a full fledged production system. The final objective is to have the CubeSat navigate autonomously and locate down satellites (target).

1.2. Design Principles:

The CubeSat is the main deliverable, and the Ground System uses the telemetry data relayed from the CubeSat to showcase all of its functionalities. The goal is to make an autonomous CubeSat. It must identify targets then navigate to them. In addition, the Ground System may be accessed by a user base comprised of engineers. Therefore, the interface of the Ground System must be simple, intuitive, and easy to access. Currently, the Ground System is still currently under development, and needs internet connection in order to be accessed. Our objective for the future is to use another type of connection, possibly a hardware, that will provide a longer range and more efficient connection. Also, the Ground System design should be easy to understand and simple to maintain and expand.
1.3. Design Benefits:

By having a design principle to follow, it will make the job of maintaining and expanding the Ground System much easier for the developers. However; it still require the developers to have some background knowledge of the program and the language used that built the program. The Ground System is designed for any person without software knowledge to use. This will make the Ground System much easier to use by any personnel that access it. However; for developers, the Ground System requires them to have background knowledge of React, Javascript, and Python to add new additional features and components.

The CubeSat is a hardware component that is designed by the Mechanical Engineer and Electrical Engineer team. Their goal is to use hardware that is cost-effective and efficient. This would allow mass production at a lower price. The development of the CubeSat is still under development, thus, not all sensors and hardware are finalized.

1.4. Achievements:

Over the course of the academic year, our team was able to develop a fully operational Ground System. It provides users with the ability to connect to the CubeSat through a web interface. The website provides users with a live video stream of the CubeSat’s surroundings. It also displays dummy telemetry data from the CubeSat. Lastly, it can be controlled through the web interface. User’s can navigate the system with two joysticks on the screen. We have also set the groundwork for the machine learning aspect to the CubeSat. The CubeSat can identify basic items. These include bananas, knives, people, and other various items. The next steps to include a working model for the identification portion of our project would be to include images of satellites. The machine learning model, onboard the CubeSat, needs a dataset where it can make predictions about the general structure of a satellite. As of right now, we do not have such a dataset.
2. Related Technologies:

2.1. Existing Solutions:

We have looked at implemented and proposed ideas that aim to clean the Lower Earth Orbit and, surprisingly, have found some successful missions. The British firm Hempsell Astronautics has proposed a system dubbed Necropolis to collect geostationary satellites. Once collected, the satellites would then be moved to a graveyard orbit. “This area is situated a few hundred kilometers above the roughly 22,000-mile-high (36,000 km) geostationary ring.”

Another proposed idea involves self-propelling tethers. They would be used to latch onto the smooth surface of downed satellites. Which would cause the satellites to drag towards Earth’s, eventually removing them from orbit.

An example of an actual implementation. Europe has also launched its RemoveDEBRIS demonstrator mission to deorbit two experimental cubesats from the 250-mile (400 km) altitude using a net, a harpoon and a drag sail. The mission was successful in capturing and deorbiting its target.

2.2. Reused Products:

The software for the SimPlat was given to us. This includes adjusting the movement, speed, and also providing a means of connectivity to the actual hardware. Connectivity includes controlling the SimPlat by means of controller and local sockets.
3. System Architecture:

3.1. Overview:

The architecture can be broken down into three main factors: the CubeSat, the Ground System, and the SimPlat.

Here is a diagram (DFD level 0) that shows how this architecture works at a high level:

At the top-most level our system will be partitioned into three modules each with different functionalities and responsibilities.

- **The CubeSat (Eagle-Scout):** this is the main component of our project. In this diagram, it contains all the major components which would be the Ground System Module (GS), the CubeSat Module and the Space Dynamics Simulation Platform Module (SimPlat)
- **The Telemetry Data:** this is a component which sends all the sensor data from the hardware to the CubeSat. The CubeSat will then pass the data to the Ground System will then will display to the telemetry data.
- **The Hardware:** this is the component that is attached to the CubeSat. It will be powered by the CubeSat and relay all the data to the CubeSat.
3.2. Data Flow:

Here is an overview of the Framework as a system, and how it connects to the App (Implementation Activity), incidentally, this is also our DFD level 1:

There are three major modules in this system. Here is a brief overview of them:

- **The CubeSat**: this is one of the primary component of the project. The CubeSat is the hardware component that communicates with the Ground System. The CubeSat will send data to the Ground System which will then display all the necessary data to the user. Also, the CubeSat will receive data from the Ground System which will be commands that the user wants the CubeSat to perform. In case of movement commands, the CubeSat will tell the SimPlat how it should move accordingly as if it were to move in space.

- **The Ground System (GS)**: this is also another primary component of the project. The ground system acts as a method of communication between the user and the CubeSat. The ground system will receive data that the CubeSat has obtained from its sensors. The Ground System also have the ability to send commands to the CubeSat. Users will be able to manually control the CubeSat through commands and those commands will be logged.

- **The SimPlat**: this is a secondary component of the project. The SimPlat is an omni-wheeled vehicle that can move in all 3D direction. The CubeSat is mounted on top of the SimPlat. The SimPlat’s purpose is to simulate motion in space for the CubeSat. The SimPlat is unaware of any other components within the project besides receiving command from the CubeSat to move the according direction. When the CubeSat is fully complete, the SimPlat will no longer be needed and would not be part of the project.
3.3. Implementation:
The project was split into three sections to allow for efficient development: CubeSat, Ground System, and SimPlat. Each section plays a key role in presenting the progression of the project.

3.3.1. CubeSat
CubeSat gathers data from the sensors attached and stores them. The data is then sent to the Ground System. The CubeSat will receive commands from the Ground System and respond accordingly.

3.3.2. Ground System
Using an internet connection, the user will be able to access the Ground System. The Ground System is the user interface of the program. The Ground System will display the data obtained from the CubeSat and update the data accordingly. The Ground System has the ability to send commands to the CubeSat.

3.3.3. SimPlat
A component attached to the CubeSat. It receives data from the CubeSat and moves accordingly. This component is necessary during our testing and development phase in order to imitate motion in space for the CubeSat.
4. Conclusions:

4.1. Results:

We have created a website that allows users to control and monitor the CubeSat. We were able to implement this in real-time through the use of WebSockets. All data viewed on the website is reliable and accurate.

We developed the project using react. This gives the possibility of being able to seamlessly and easily update the existing interface. Developers can create their own components and add them as they wish.

Finally, we have also made the website dynamic in its layout. Users can add and remove windows as they choose. This allows them the ability to focus on what is important to them and get rid of any unnecessary windows. This provides a ui that is aesthetically pleasing to all users.

4.2. Future:

We were unsuccessful in creating the machine learning aspect to our system. This includes the targeting and navigation components. These are two crucial aspects and without them the entire system is incomplete. However, there is an upside. The project will be carried forward by next year’s senior design at California State University of Los Angeles.

Following are suggested improvements for the next year’s team to work on:

- Improve the current Ground System. Right now the Ground System is opened to the public. This let’s anyone control the CubeSat. Adding user groups and a login could solve this issue.
- Display real data on the Ground System. As of right now there is no actual sensor data being transferred from the CubeSat to the Ground System. It is all dummy data. There are methods in place to actually transfer the data, but getting the data is the issue.
- Improve the UI of the Ground System. Look at examples of real Ground System UI’s and build up from there. The UI that is currently in place gives the building blocks to expand your horizons.
- Begin the process of creating machine learning models. Find datasets that could be used to train your models. Perhaps ask Aerospace Liaisons if there are any datasets available.
- If time is available, expand to other platforms such as Mobile Apps.
5. References:

Meet the Space Custodians: Debris Cleanup Plans Emerge:
https://www.space.com/36602-space-junk-cleanup-concepts.html


React: https://reactjs.org/docs/getting-started.html
React-Dazzle: https://github.com/Raathigesh/dazzle
Dazzle-Demo: https://github.com/Raathigesh/Dazzle-Starter-Kit

DigitalOcean: https://www.digitalocean.com/

TensorFlow: https://www.tensorflow.org/
Nginx: https://www.nginx.com/

FFmpeg: https://ffmpeg.org/
JSMpeg: https://github.com/phoboslab/jsmpeg