CanSat 2024 CDR Payload Update

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CanSat at Virginia Tech

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Introduction

CanSat @ VT is a competitive design team that focuses on designing, manufacturing, and testing small-scale satellites. Our core objective is to ignite passion for aerospace themes while bringing students invaluable practical exposure to the engineering design process. We participate in an annual international design-build-launch competition, backed by influential industry figures including the US Naval Research Laboratory, NASA, and Lockheed Martin. While the competition's specific goals vary, they consistently center around crafting a programmable payload for release from a rocket that can accurately transmit flight data to a ground station.

This paper will discuss the progress research progress that the team has made over the Spring 2024 semester by various methods including prototyping and physical testing. It will also discuss how the team has used research conducted to overcome design challenges faced in the PDR stage.

Payload Overview

Design Changes overview

Based on prototyping before the CDR phase, the payload was converted to a 'modular' design with various self-contained sections. Each section of the payload corresponds to a specific design function (some modules can perform multiple functions). This reduces payload manufacturing complexity, promotes simultaneous development of modules while also allowing rapid prototyping of the individual modules and independent design updates. The lack of a central structure also boosts weight reduction in the payload helping it stay below the 900-gram weight

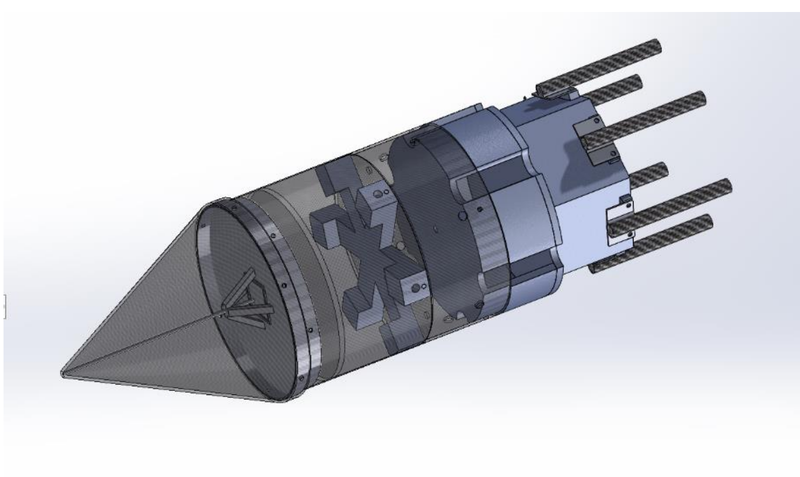

Figure 1 Modular CanSat design

limit. Other structural changes were also made to the payload's nosecone to account for aerodynamic simulation data.

For additional weight savings, Carbon Fiber composites were used for certain modules. Specifically, modules which required heat tolerance, modules that were expected to bear significant load and modules that were deemed too heavy to be manufactured using 3D printing, CNC, or other methods. Carbon Fiber composites provide excellent strength to weight ratio, can be easily molded into complex shapes and are more resistant to heating elements than plastic 3D printed sections. A simple weave pattern was chosen for the Carbon Fiber cloth and was coupled with the vacuum bagging process. This process was chosen as it reduces the weight of excess epoxy by releasing it into the absorbing material. Additionally, it provides a simple manufacturing process that yields well-finished surfaces and can be used easily with complex molds.

Figure 2 New aerobrake design

Certain descent control devices and payload electronics were also redesigned based on prototypes. These changes will be discussed further in the next sections.

Deployment

The primary deployment mechanism on the payload remains burn wire. A burn wire-based deployment system is light, mechanically simple and deploys rapidly. Since the PDR stage, significant progress has been made in developing a burn-wire based deployment system for a CanSat. Specifically, the system is integrated into the CanSat rather than being standardized. While this means that the deployment system will have to be redesigned for each new challenge, it presents significant weight savings and makes the mechanisms considerably less complex.

Figure 3 Weight reduction from new deployment mechanism

For use on the payload, traditional burn-wire deployment systems had to be significantly adapted. The CanSat uses a 3.3V logic level, the payload was also initially designed to have an onboard 5V regulator. However, this is still less than the typical 24V systems in most other applications. Therefore, a two-level switching circuit was used to activate the burn wire. This included two sets of MOSFETS and capacitors. The first set of MOSFETS were logic level, switching the 3.3V PWM output of the Teensy4.1 microcontroller to control a 12V circuit. The second set of MOSFETS switched a 1F capacitor on the 12V circuit therefore providing a large enough current for rapid, clean deployment of the burn wire mechanism.

Electronics Redesign

A custom PCB solution was picked over the previous proto-board based design for the payload's electronics. A PCB offers a more reliable circuit while also providing resistance to mechanical shock and vibration. It is also considerably lighter and easier to integrate into the payload's mechanical structure.

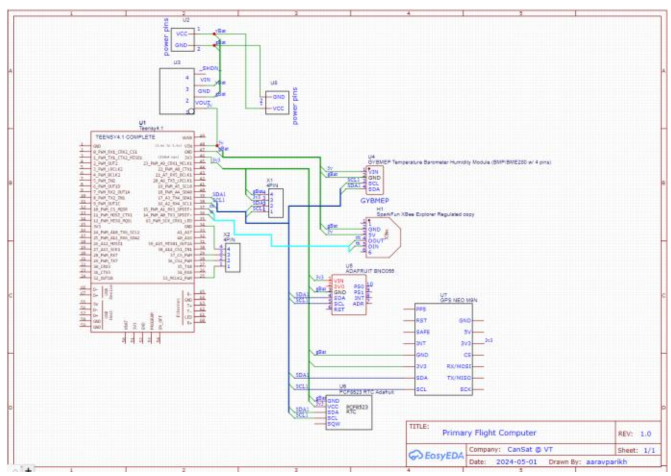

Figure 4 Schematic for flight computer v2

The added resistance to mechanical vibrations was a large driving factor behind the change. However, since the PCB was not expected to undergo significant stresses, a 0.8mm thick, two layered board was chosen. This choice provided the best balance between weight, manufacturing complexity and cost while also being easy to work on. The addition of a second layer proved crucial and allowed the traces to remain relatively short and simple. Ensuring that there was low resistance between the connection points and limited scope for

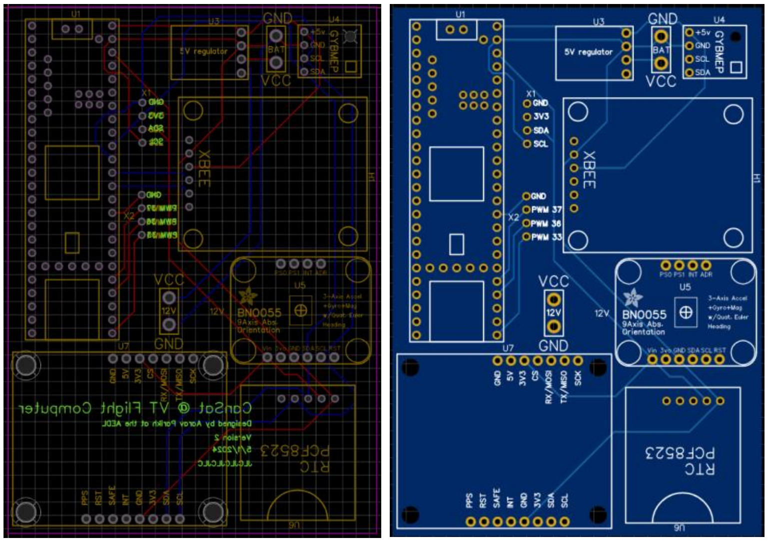

Figure 5 Board Design

interference between traces. The PCB design followed the industry-standard design rules for trace width, depth and spacing. This was important as the circuit would have several high frequency signal lines. However, since the board runs mostly on low-voltage DC, interference is not a critical factor.

Two iterations of the PCB were made. With the second iteration adding more IO, increasing shortening trace distance and increasing spacing between temperature sensitive components and components which would heat up during normal operations. For the board, the smallest possible footprint was chosen. Only sensors not specific to the 2024 challenge were included on the board. This was done to promote the reusability of the board for future challenges while creating a base “flight computer” template.

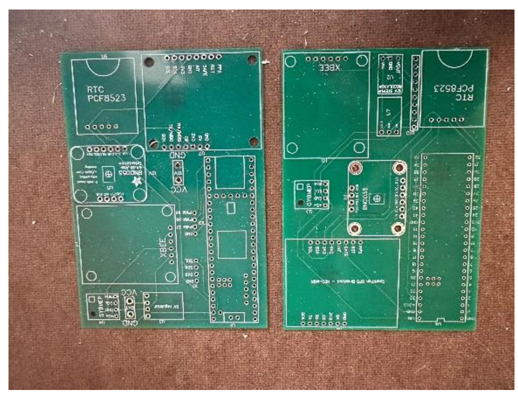
Figure 6 Production PCB

Materials Redesign

Over the last semester, the team conducted research to ensure that the payload remained below the 900-gram limit. While initial estimates based on the CAD model did not seem to cross the limit, the decision was made to switch the burn-wire, egg protection and nosecone modules to carbon fiber. This was done as these modules require heat resistance, strength, and a smooth surface finish respectively. Since the team had never used Carbon Fiber before, a Carbon Fiber workflow was established. Research was done to compare various methods of carbon fiber

Figure 7 Negative molds destroyed during extraction

production and finishing. Ultimately, the team settled on a vacuum bagging method combined with a post-process of sanding and polishing.

Since the modules had strict outside tolerances, negative molds were used to ensure smooth surface finish and tight tolerances. Multiple iterations of molds were created. Primarily, the molds were 3D printed and then processed by sanding and applying multiple layers of mold release wax and PVA. This final process was reached by multiple stages of iteration where molds had to be destroyed to extract the finished pieces. Iterations were also made in the bagging process, using varying amounts of breather and release material as well as varying the layering and epoxy application methods for each attempt. Unfortunately, the team did not have enough time to reach a satisfactory conclusion in finding an ideal method and the material selection and manufacturing process likely requires additional research.

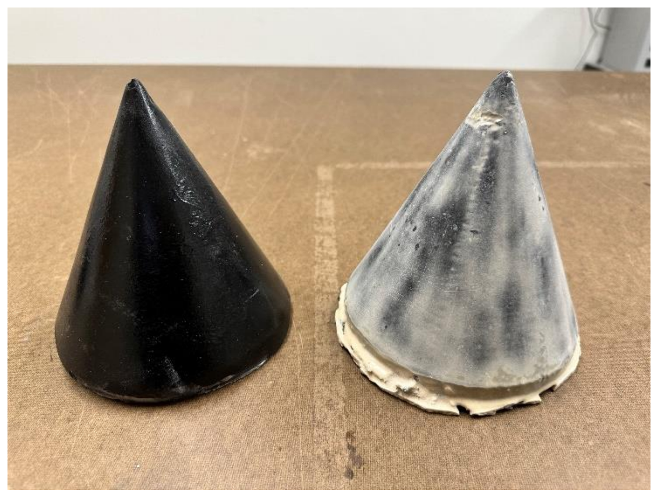

Figure 8 Fully processed (left) and partially processed (right) carbon fiber nosecone

However, the research done this semester resulted in a significant weight reduction while strengthening the payload's overall structure.

Continued Research and development

The burn wire system needs to be stress tested in a thermal chamber. Additionally, the power draw for the burn wire system needs to be recorded to ensure that it will not significantly drain the payload's battery, and therefore not have a critical impact on mission time. Currently, the team estimates the payload's power draw without the burn-wire system to be 5.92wH while the battery is rated at a capacity of 12.95wH. If the burn-wire system causes a consumption increase by more than 3wH (roughly 37% of the margin) then a redesign would be needed due to insufficient margin.

For carbon fiber applications, the team needs to explore split-mold design as well as positive molds to ensure better part release. This will likely mean tighter mold-design tolerances and will need a better understanding of the layup procedure when using carbon fiber.

Throughout production, the team has also experienced issues with failed 3D prints. A review into the CAD design practices is needed to identify the cause of failed prints. The team's design practices likely need to be updated to ensure compatibility with slicing software and the printer. Multiple print tests will be conducted and a print success rate of 90% is targeted. The team will print complex shapes using various slicing methods and slightly different geometries to identify the ideal way to design parts that need to be 3D printed. A failed test is classified as one where the extrusion does not stick to the printed section, the print unsticks from the base plate, or the printer terminates the process before completion.

Lastly, the PCB design needs to be updated to include capacitors and LEDs. Currently, the only indicators on the PCB are those included with the sensors or the teensy4.1. This makes debugging complex and requires the use of a multimeter when debugging software. Indicator LEDs would increase process efficiency by letting the FSW team debug software independent of the electronics team. The PCB also does not include stabilization for current or voltage spikes or drops. This may cause the Teensy4.1 or voltage regulators to fail due to an unstable power line. Capacitors, resistors, and diodes need to be added to the PCB to add protection from spikes, shorts and runaway current situations as well as reverse-polarity protection.