Requesters: Ian Turner, Elijah Sech

Department: Mechanical Engineering

Professor: Mark Bedillion

Project: Thrust Vector Control (TVC) Rocket & Testing Design

Date: October 26, 2022

Abstract:

During the semester of Spring 2022, Ian Turner and Elijah Sech participated in the CMU Build 18 build-a-thon together and decided to try making a finless model rocket using thrust vector PID stabilization instead of the typical aerodynamic stabilization of model rockets. The goal was to use an Arduino Nano and a gyroscope to control a two-axis gimbal with a hobby rocket motor attached. Unfortunately, we had a short circuit that ruined our components, and were never able to test the project during build week. We are now continuing the project to completion as part of our Honors Research Project through the CMU Mechanical Engineering Department to research the design of the gimbal and the test method development of the rocket. We plan to make a testing rig that will be used to collect data and tune designs before launch, then we plan on completing our original rocket design and testing it. Then, we plan on developing a second rocket with a gimbal design where mass is minimized as much as possible. We then plan to use the same testing rig to collect data and compare the two rockets. From this research, we hope to suggest ways to minimize the mass of small payload, low orbit rockets to make space more accessible to humanity.

Proposal:

1. **Objectives and Contributions of Research**

We have two main goals that we intend to reach for our research project. Firstly, we want to minimize the weight of a two-axis gimbal for a thrust vector rocket. Minimizing the mass for our system advances the possibilities of orbital rocketry to create smaller, more affordable low-orbit rockets to deliver small payloads. Secondly, we would like to develop an open-source and safe testing environment for TVC rocketry, expandable to a higher power system. The main need for developing a safe testing environment is due to the combination of the uncertain nature of the first launch test and the challenging task of controlling the thrust direction via a control algorithm. The testing environment would allow repeatable and reliable static-fire tests that would ensure the safety of all the participants involved. Additionally, the testing environment would help standardize a reliable testing methodology for the world of model TVC rocketry. This would encourage experiments and developments to be made in the field which would advance the potential of sending smaller rockets to space.

1. **Background**

Students Ian Turner and Elijah Sech are Mechanical Engineering Bachelors candidates expected to graduate in the Spring of 2023. Research Advisor Dr. Mark Bedillion is a Teaching Professor within the Department of Mechanical Engineering. Ian Turner has years of design experience, has completed two design-based internships, as well as several other personal projects. Elijah Sech has completed several design projects, and completed an aerospace engineering internship in the summer of 2022. Dr. Bedillion has many years of design experience in the mechatronic sector, as well as with control system design. Dr. Bedillion has also advised the Carnegie Mellon Rocket Command Team with control system design.

1. **Methodology**

Our proposed methodology is as follows:

1. Develop a Mathworks Simulink model to test the rocket control in theory, and run optimization to find the best PID values for our feedback control system that controls the vehicle.
2. Design and build a testing environment, approved by Dr. Bedillion to a robust factor of safety. The testing rig will also contain load cells and encoders, which we will use to collect critical data and use this data to verify the accuracy of our Simulink model as well as improve it.
3. Buy new electronics for our original rocket design, design a printed circuit board (PCB) and have the design approved by Dr. Bedillion before assembling to avoid a future power surge.
4. Re-assemble and test Rocket 1, testing with our simulation and then in the field with our testing rig. We will collect the data from the test rig, and then utilize the data to improve our model, as we now have a real-life test of the dynamics of our system. We will then utilize the simulation many more times to ensure a safe test. Once satisfied with our results we will test without the rig and record data to a microSD on board Rocket 1.
5. Assess results and performance from the test of Rocket 1, and re-design Rocket 2, trying to use the same electronics and software from Rocket 1. Rocket 2 will be designed in a way such that the mass of the gimbal is minimized as much as possible.
6. Have Rocket 2 design and materials approved by Dr. Bedillion.
7. Build Rocket 2; Test Rocket 2 following the method mentioned in step 4. Compare the results of testing Rocket 2 to the results of Rocket 1.
8. Draw conclusions from the process and the results. Assess if our technology could be applicable to theoretical low-mass, low-earth orbit situations.

* Budget - **$1005.57**

The bill of materials for the items for which the grant money will be used for is as follows:

| **Name** | **Vendor** | **Type** | **Part No.** | **Price** | **Quantity** | **Total** | **Link** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Load Cell - 50kg, Disc (TAS606) | SparkFun | Load cell | SEN-13331 ROHS | 64.5 | 2 | 129 | [here](https://www.sparkfun.com/products/13331) |
| Alloy Steel Shoulder Screw,1/4" Shoulder Diameter, 3" Shoulder Length, 10-24 Thread | Mcmaster-  Carr | Shaft | 91259A106 | 2.72 | 4 | 10.88 | [here](https://www.mcmaster.com/91259A106/) |
| Fire Retardant Spray | Amazon | Fireproofing | B07JBLHGQ8 | 34.95 | 1 | 34.95 | [here](https://www.amazon.com/Retardant-Curtains-Eco-Safe-DRI-ONE-Institute/dp/B07JBLHGQ8/ref=sr_1_15?keywords=fire+retardant+paint&qid=1663862634&sr=8-15) |
| AMT112Q-V-4096 | Digi Key | Encoder | AMT112Q-V-4096 | 37.4 | 2 | 74.8 | [here](https://www.digikey.com/en/products/detail/cui-devices/AMT112Q-V-4096/5034549) |
| 2x4 | Home Depot | lumber | N/A | 5 | 10 | 50 | N/A |
| Amazon Basics ABS 3D Printer Filament, 1.75mm, Red, 1 kg Spool | Amazon | 3d printing material | ABS175PACK5 | 20 | 5 | 100 | [here](https://www.amazon.com/AmazonBasics-Printer-Filament-1-75mm-Spool/dp/B07Y3PHD2C) |
| AEROTECH 29MM HP SU DMS MOTOR - G12ST-P | Apogee Rockets | Rocket Motor | 81275 | 41.72 | 14 | 584.08 | [here](https://www.apogeerockets.com/Rocket-Motors/AeroTech-Motors/29mm-Motors-Single-Use/Aerotech-29mm-HP-SU-DMS-Motor-G12ST-P) |
| 13 x 46 Feet Anti Bird Netting, Green Garden Netting Protect Fruit and Vegetables from Birds and Animals, Bonus 20 PCS Cable Ties - 0.56 in Mesh | Amazon | Netting for test rig | B08PDGWNPN | 8.99 | 1 | 8.99 | [here](https://www.amazon.com/Netting-Garden-Protect-Vegetables-Animals/dp/B08PDGWNPN/ref=sr_1_49?crid=2F89ISJU63DTI&keywords=netting&qid=1665684767&qu=eyJxc2MiOiI2Ljg2IiwicXNhIjoiNi41MSIsInFzcCI6IjYuMjQifQ%3D%3D&sprefix=nettin%2Caps%2C91&sr=8-49&th=1) |
| SparkFun Load Cell Amplifier - HX711 | SparkFun | Amplifier Board for Load cells | SEN-13879 ROHS | 10.95 | 1 | 10.95 | [here](https://www.sparkfun.com/products/13879) |
| SparkFun Load Sensor Combinator | SparkFun | Combinator board | BOB-13878 ROHS | 2.1 | 1 | 2.1 | [here](https://www.sparkfun.com/products/13878) |