Senior Project Proposal: Active Guidance in Amateur Rocketry

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(BPS Gallery)

Introduction: The World of Amateur Rocketry

I've always been interested and passionate about rocketry and UAS. In elementary school I built model rockets. In middle school I built many different RC aircraft from scratch, and in highschool I built my first drones, more complex RC aircraft, and started pursuing my level 1 high powered rocketry certification which I finally achieved in 2018.

Of all the hobbies, high powered rocketry seemed to involve the least amount of technical skill. It mostly required good craftsmanship, and some basic understanding of materials and structures. I found this quite perplexing as rocket science is notoriously difficult. Even RC airplanes required some knowledge of electronics, motor outputs, amps, voltage, control and transmission. Drones required even more of these skills, as well as control theory and PID loops. But when I flew my first high powered rocket, it didn't even require electronics! The whole thing was a cardboard tube, wood fins, and some carefully placed epoxy. It was dead simple (such is the goal when attempting a certification.) It was the exact opposite of what I saw on TV and in documentaries. But recently, a new branch of the hobby has sprung out. The old style is what I call the "Fast-n-loud" crowd. This is not meant to be derogatory, but more as a description of the rocket systems they like to fly. They are constantly going bigger, higher, and faster. No doubt it takes skill, craftsmanship, and knowledge. It is an exciting path, but gets prohibitively expensive the further in you go. It also requires keeping your rocket as simple as possible to maintain minimum failure points. Electronics are only used when absolutely necessary, and they too are kept as simple as possible. This second newer branch is what I call the "Smart Rocket" crowd. These people are not focused on speed, height or size, but instead they enjoy solving the problem of active guidance, flight computers, and data analysis. The most notable being Joe Barnard of "BPS.space" who pioneered multiple techniques over 7 years to propulsively land model rockets.

I feel I have a good grasp on the first style. I understand the basics of rocket stability, good design, and have executed it multiple times. However, I still feel lacking in my experience with electronics, sensors, control theory, and coding. Classes like Sensors, Guidance and Control, and UAS Maintenance prepared me well to work with off-the-shelf models, but I want to understand these systems more thoroughly to be a more capable engineer or project manager. For this reason, I chose to build a model rocket with active guidance for my project. The goal being to launch a rocket with thrust vector control capability, and recover it. All while designing my own mechanics, flight computer, and writing my own code.

Outline

Because this project will require many skills I don't currently have, I figured it would be best to gain and test these skills one at a time, then put them all together for the culminating rocket launch toward the end of the semester.

Skill 1: Sensors and Coding

The flight computer will be the brain of this rocket. Because it's so integral to the final product, I need to start from the basics and understand them deeply before building a computer from scratch. The goal is to take the vital sensors and principles (IMU, Barometer, Flash Storage, Pyro Channels, PID loops, etc) and make them easily digestible with individual "mini" projects. Proving my capability with each individual component will allow me to more easily combine them later on.

Skill 2: Circuit Design

The flight computer will need to be custom designed and sent to a fabrication house. This process requires the learning of new programs like Eagle CAD and an in-depth knowledge of the components being utilized (Barnard, 2018.)

Skill 3: Control Theory and Algorithms

This will be the most technically complicated part, and presents a significant challenge. In order to maintain level flight, the TVC assembly mount will have to be precisely modeled, programmed and tuned (Barnard, 2020.) This requires a more in depth knowledge of PID control loops and physics.

Skill 4: Building a Testing Program

While I've built UAS from scratch before, I've come up with a full-fledged testing program. Building my own from scratch will help me understand important areas of analysis, how to best record and analyze data, and it will aid me in coming up with a pre-flight checklist for the future cumulative flight.

Deliverables

The goal is to have a rocket flown (or attempted to be flown) with TVC capability, a custom flight computer, with hybrid video and written documentation on design, testing and flight. It has to be emphasized that while a successful flight and recovery is the goal, a crashed or damaged rocket would *not* constitute failure. This project will likely continue even after the close of the semester, so a crashed rocket would only be a learning opportunity. Making the launch date is what's important.

Tools and Materials

I already have my own soldering tools, multimeter, 3D printer, 3D CAD software, and a computer to work at. I am a somewhat experienced "maker." However, I will need to acquire some quality-of-life tools to make things more streamlined if I'm going to be engaged in electronic design for the next few months. This includes a large set of "helping hands" and some basic prototyping boards.

I will acquire construction materials as needed. Construction of the rocket will consist of cardboard and 3D printed parts. These parts, along with electronic components are easily accessible via Amazon and other online stores.

I have also combed through much of the video documentation done by BPS.space, and have bought a list of textbooks related to control theory, digital signal processing, and control system design to aid me (Barnard, 2019.)

Timeline

Time management is my biggest concern. I will have to work consistently throughout the semester to accomplish this goal. I plan to tackle the 4 different skills mentioned previously in roughly 2 week sections, depending on their difficulty. This timeline gives 6 weeks for the first 3 skills, 2 weeks for testing of the whole system, and the remaining 4 weeks for last minute adjustments and launch. In order to track the time spent, I've already started recording hours in a google sheet, broken down by date, duration, and activity type. Not only will this help me verify the 75 hour requirement, but it will give me an idea of how accurate my schedule layout was when I reach the end of the project.

Documentation

The rocketry community has a great "open source" culture. I aim to continue this tradition which will require good documentation. The project will be documented using a hybrid of written and video. Most of the skill work, testing, and launch I plan to record video, with explanations of my mistakes, hurdles, and my strategies for overcoming them. The more technical parts of the documentation will be in writing. (such as checklists, simulations, and data analysis) I believe video is a powerful format not taken advantage of enough in the formal education ecosystem, so I would like to prove it's utility with this project.

Conclusion

A project like this looks good on a resume, it can set you apart as a leader, not a follower. This project is meant not only for college, but as a headstart in a career. It is the perfect intersection of physics, UAS systems, electronics, project management, data analysis, and hands-on building. While some of these aspects cater to my strengths, the other aspects will help me work on my weak points. This way I will have a strong and well rounded skill set to be fully prepared for a technical career in the aerospace field. I also want to help the people who come after me, so the goal of the documentation would be to aid someone in my current position achieve a similar headstart and build their skills as well.

Citations

Barnard, J. (2018). *Landing Model Rockets Video Series*. *YouTube*. YouTube. Retrieved January 16, 2024, from https://www.youtube.com/watch?v=xIMaAhIL3ZY&list=PLyV774-3p8348Fl5V6ciIBh0ZA446q93I.

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