Hoo-Rizon 1: Subscale Sounding Rocket

A Thesis Prospectus: Technical Portion

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Problem

In 2022, the Under Secretary of Defense R&E department defined "Space Technology" as a Critical Technology Area as part of their National Defense Strategy, highlighting the need for expansion in the commercial sector to maintain the United States' technological advantage (USD R&E, 2022). In turn, there is a growing trend among university aerospace engineering programs to expand student interest in space design. A lack of space-related engineering courses in the aerospace curriculum could cause a shortfall in engineers who can meet the growing national demand within the field. Additionally, there is a lack of precedence within UVA's Mechanical and Aerospace Engineering department with the use of experiential learning models in capstones, especially in regards to building a subscale-sounding rocket. In the past, the sounding rocket project was attempted, but it was unable to accomplish a test launch. Gaining experience in these design concepts through hands-on capstone work is imperative to ensuring engineers can apply their practical knowledge in the field.

Problem Significance

Sounding rockets are critical for scientific research as they can be "carried out at very low cost" and "enable scientists to react quickly to new phenomena" (NASA, 2023). This capstone project provides the opportunity to expand this impact on research in an entry-level way while opening the doors for future expansion of impacts from the success of this project.

Research Work Objective

The main objective of our technical research project is to design, build, and fly a sub-scale sounding rocket with a target altitude of 4,000 feet. Through the design process, we aim to hone our skills in problem-solving, structural analysis, and control systems, setting the groundwork for consecutive capstones and future job opportunities. Furthermore, during the validation launch, we aim to characterize the flight conditions to provide data that supports the development of future missions and launches.

Approach and Methods

Our team uses a combination of system-level and subsystem-level methods to fulfill the mission goals and objectives. We have adopted (1) NASA's life-cycle management structure, (2) a systems-oriented iterative design process, and (3) numerous risk, cost, and schedule management practices. Through NASA's project life-cycle management structure we will present our progress in three deliverables: a project pitch, conceptual design review, and a preliminary design review in order to formulate and implement the design thoroughly. Given our team's two-semester time constraint, we are using an iterative design process to create a closed-form solution that meets the mission goals and objectives. For example, as seen in Figure 1, we are able to lay out our preliminary rocket design and evaluate the rocket's max-altitude from simulations. Finally, our team utilizes project management tools like Gantt Charts, risk matrices, Google Drive, and Discord to facilitate team logistics.

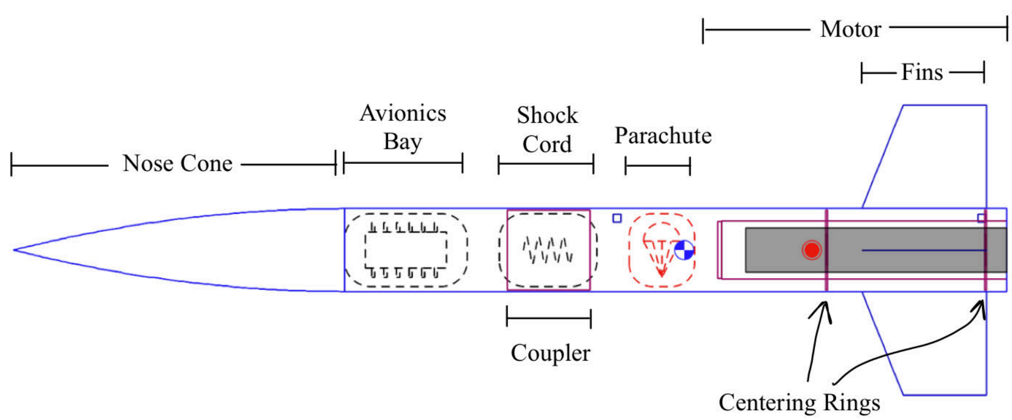

Figure 1. OpenRocket model of Hoo-Rizon 1.

Aerobody

For the Aerobody subteam, we will use a combination of commercial off-the-shelf (COTS) and manufactured components to create a Class II rocket that resembles typical high-powered rocketry models. We are using SolidWorks, OpenRocket, and CFD solvers to iteratively model a rocket that reaches apogee. We aim to use suppliers like BlueTube, Apogee Rockets, and Wildman Rocketry to purchase components like body tubes, couplers, centering rings, parachutes, and epoxies. BlueTube is a suitable choice for the body tube because it's strong, inexpensive, and 36% lighter than fiberglass (Always Ready Rocketry, 2023). We aim to 3D print components like fins and the nose cone to save costs and allow for design flexibility.

Avionics

Hoo-Rizon 1 aims to characterize the flight conditions of a Class II rocket. To define those flight conditions, a combination of instruments have been selected to collect data on altitude, temperature, humidity, pressure, ultraviolet rays, and acceleration. The avionics bay houses the Printed Circuit Board (PCB) and other instruments, as shown in Fig. 1. A Raspberry Pi Pico (Pico) serves as the microcontroller. The Pico interfaces with the Inertial Measurement Unit (IMU) and BME280 sensor to store data locally on an SD card via SPI. The data is transmitted to the ground station using a Lilygo radio GPS module with time stamps provided by a DS1307 RTC module. I2C will be the main communication protocol. Other sensors have their own power source, to mitigate failures. The main power sources will consist of two alkaline batteries (6V and 9V) as well as one 3.7V lithium-polymer battery. In order to follow Tripoli launch site guidelines for redundancy, which ensure public safety (Tripoli, 2023), a primary and secondary altimeter will be used. Additionally, the main chute ignition system centered around two CO_2 cartridges for redundancy sake and will be triggered by the primary altimeter. To reduce the vibrations experienced during flight, we are calibrating the sensors in an environment that mimics flight conditions.

Propulsion

Through repetitive simulation testing of COTS Class II motors of type J, K, or L on the rocket model, we aim to select the best motor that efficiently reaches our target apogee. The design experience of building an engine from scratch is unmatched, but as the overall goal of this project is to launch a rocket, so we decided to buy a motor. Many complicated components make up a rocket motor, and we were advised that there would certainly be no launch with an engine design of our own. Therefore, the Propulsion subteam decided to buy the motor and all of its components off-the-shelf. The design of the rocket body has drastic effects on the rocket engine, as the required propulsive force is determined by the aerodynamic and gravity forces. In this respect, an iterative process between Aerobody and Propulsion is required to determine the ideal motor. Different thrust curves representing different engines can be implemented into OpenRocket, as shown in Figure 2 (Aerotech, 2024), where apogee data can be collected and the ideal motor can be determined.

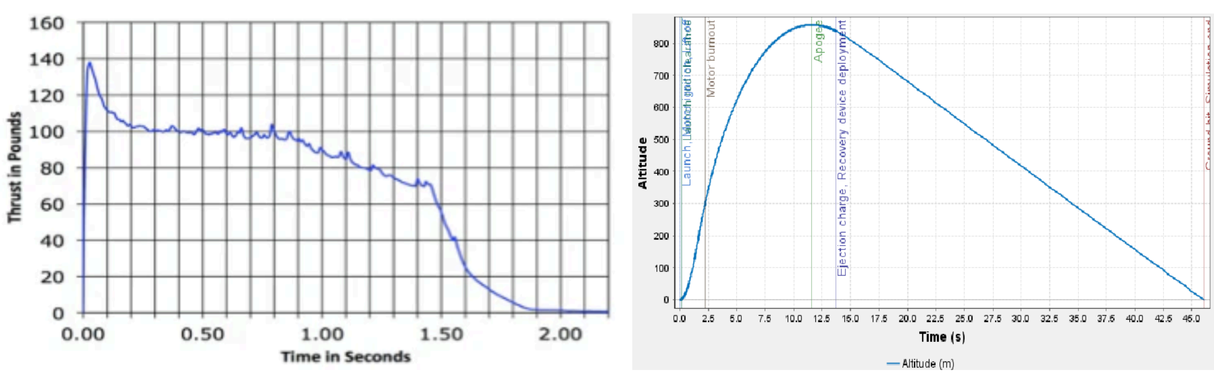

Figure 2. OpenRocket simulation results. (2a Left) Thrust curve of Aerotech J340M from manufacturer website. (2b Right) Simulated altitude vs. time graph of Aerotech J340M.

Available Resources

Our team has access to many different manufacturing technologies such as 3D printers, a vertical mill, and soldering kits that we plan on using to manufacture different structures of the rocket. Additionally, we use several different softwares to design the rocket including OpenRocket, Ansys Fluent, SolidWorks, KiCad, and MATLAB. OpenRocket is a model rocket simulation software that allows us to assemble and simulate fully constructed rockets and analyze predicted apogees. Ansys Fluent is a CFD package that uses a set of robust turbulence models to model near-surface interactions (Ansys, 2009). We use it to analyze the aerodynamic characteristics of the nose cone, body tube, and fins. SolidWorks is a CAD software that we are using throughout our project to integrate and model many of our structural components. KiCad is a software suite for electronic design that we will use to design the PCB that controls our sensors. Lastly, MATLAB is a programming language that helps calculate useful theoretical quantities for the analysis of our rocket, such as cruise velocity and fin deflection angles.

Objectives for Spring Semester

Our final technical report of this semester is the Preliminary Design Report. Late in the spring semester, our team is aiming to launch our sub-scale sounding rocket at the Tripoli Central Virginia site. In order to achieve this goal, next semester focuses on the building and testing of the rocket. Before proceeding to the manufacturing of the rocket, we will present our Critical Design Review (CDR) which contains information on specific Aerobody and Avionics components. From there, we will begin manufacturing. One of the main concerns of our project is lead time on ordering parts, which needs to be done by the fall semester to ensure parts arrive on time. Throughout the manufacturing and testing process, we will adhere to safety guidelines set forth by EHS and Tripoli Launch site to ensure the safety of our members and those around us.

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