Hoo-rizon One: Subscale Sounding Rocket

Environmental and Societal Impacts and Tradeoffs of Spacecraft

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Aerospace Engineering

By
Omid Sayyadli

November 8, 2024

Jacob Lewis
Laurel Supplee
Nikita Joy
Kushi Sethuram
Christian Vergason
Ben Cohen
Jean-pierre Manapsal
Youchan Kim
Swedha Skandakumar
George Hubbard
Ethan Fouch
Connor Owens
Tyler MacFarlane

ADVISORS

Prof. Pedro Augusto P. Francisco, Department of Engineering and Society

Prof. Haibo Dong, Prof. Chen Cui, Jiacheng Gou, Department of Mechanical and Aerospace Engineering

Introduction

I am working on the topic of research and non-military rockets and their impact on the atmosphere and environment because I want to find out how the negative environmental impacts of rocketry outweigh (or fail to outweigh) the benefits of rocket research and activity. That is important because private industries and governments heavily rely on small suborbital rockets for various research missions to study the upper atmosphere. However, since they are relatively cheap and easy to deploy, their launches are frequent and accessible to many consumers. Therefore, sounding rockets account for significant air pollution and environmental damage.

Aerospace propulsion devices, including rocket engines, are active research and development areas because they facilitate space access. For example, sounding rockets allow scientists to collect atmospheric data from the upper atmosphere and conduct experiments under microgravity conditions (NASA, 2023). In order to reach high altitudes that allow useful research, sounding rockets must tackle numerous challenges in the areas of aerodynamic stability, avionics, communication, and propulsion. Those subsystems must integrate seamlessly to operate reliably under challenging flight stresses. For example, rockets experience extreme vibrational, tensile, and torsional loads during ascent, parachute deployment, and landing. Therefore, systems within sounding rockets must have engineering redundancies that mitigate operational, safety, and mission risks.

Sounding rockets must use powerful motors or engines to fulfill their demanding mission requirements. Therefore, they have notable adverse environmental consequences. For example, rockets often burn complex hydrocarbon fuels and emit significant pollution, including greenhouse gasses, nitric oxides, and harmful particulate matter. Those pollutants are responsible for health concerns and respiratory illnesses including asthma, cancer, and child maldevelopment

(EPA, 2024). Furthermore, extreme noise levels and sonic booms from rockets have raised concerns about the impact of noise pollution on the wildlife and ecosystems surrounding launch pads. With the private space sector's advancement in recent years, rocket launches are becoming more frequent; therefore, extra attention must be paid to their environmental consequences.

Technical Project Proposal

The main objective of our technical research project is to design, build, and fly a sub-scale sounding rocket with a target altitude between 3,000 and 4,000 feet. To fulfill that overarching mission goal, the rocket must meet three objectives:

1. The avionics bay must characterize the flight environment by collecting altitude, temperature, humidity, pressure, ultraviolet radiation, and acceleration data. Also, the rocket must acquire data from a camera on board.
2. We aim to create a recovery system that allows us to reacquire the rocket and recycle it for future launches.
3. The rocket structure must withstand flight loads, maintain stability, and provide sufficient thrust to reach the target apogee.

The rocket is divided into three primary subsystems to fulfill those goals and objectives: aerobody, avionics, and propulsion. For the Aerobody subteam, we plan to 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 suitable for the body tube because it is 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.

The avionics subsystem uses a combination of instruments to characterize the flight conditions of this Class II rocket. Specifically, Hoo-rizon One aims to collect data on altitude, temperature, humidity, pressure, ultraviolet radiation, and acceleration. The avionics bay houses a Printed Circuit Board and other instruments. A Raspberry Pi Pico (Pico) serves as the microcontroller. The Pico interfaces with the Inertial Measurement Unit and BME280 sensors to store data on acceleration, pressure, temperature, and humidity locally on an SD card via a serial peripheral interface data protocol. The data is transmitted using a Lilygo radio GPS module to the ground station. Other sensors have their own power source, to mitigate failures. The primary power sources will be two alkaline batteries (6V and 9V) and 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. Furthermore, the main parachute is planned to be triggered using two CO2 cartridges by the primary altimeter.

The propulsion subsystem provides sufficient thrust for Hoo-rizon One to reach an altitude between 3,000 and 4,000 feet. To meet that objective, various COTS Class II motors of type J, K, and L will be iteratively simulated using the OpenRocket program to select an appropriate motor. Different thrust curves representing different engines can be implemented into OpenRocket, as shown in Figure 1 (Aerotech, 2024), where apogee data can be collected and the ideal motor can be determined.

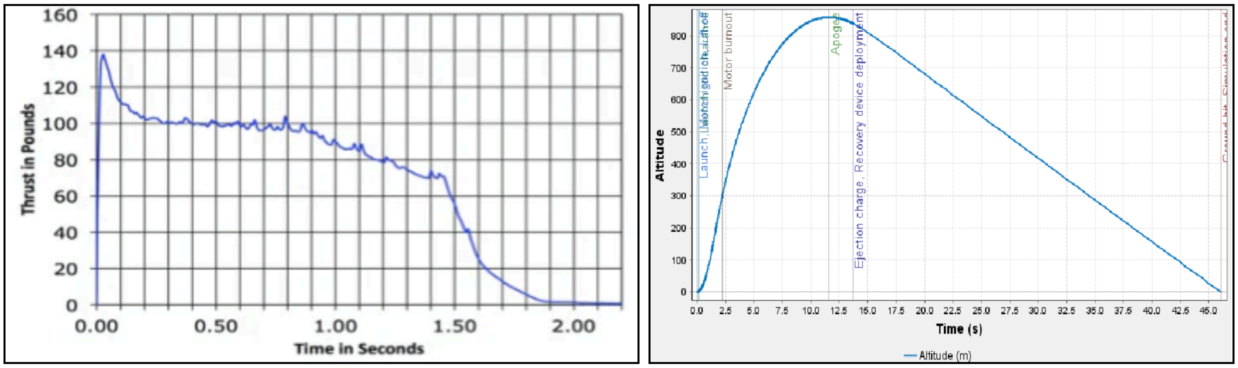

Figure 1. OpenRocket simulation results. (1a Left) Thrust curve of Aerotech J340M from manufacturer website. (1b Right) Simulated altitude vs. time graph of Aerotech J340M.

Those three subsystems must be seamlessly integrated to create a Class II rocket to support the three mission objectives and characterize the launch environment. By collecting a vast array of data and creating a modular, recyclable, and flexible rocket, this project sets the groundwork for future capstone teams and student design teams to innovate further and pursue more ambitious research projects.

STS Project Proposal

I am working on the topic of non-military space-access rockets and their environmental impacts to complement my capstone team's design project. I plan to complete a pros and cons analysis to determine how the environmental impacts of rocket activity compare to their benefits for advancing technology and benefiting society. I plan to use Bruno Latour's Actor-Network Theory (ANT) framework to complete a pros and cons analysis and describe the complex network of actors, including people, technologies, and ecosystems. To employ ANT, I plan to collect data on this socio-technical topic using reports and reviews of literature. First, I will provide background on rocket activity's economic benefits, technology advancements, and societal impacts. Then, I will discuss specific details about the negative environmental impacts of rocket activity in the context of human health, global warming, and the impact on wildlife ecosystems.

Investment in commercial rocket activity continues to increase because of numerous supporting arguments for rocket launches. For example, according to a journal article by Monte and Scatteia, investment in European science rockets' research, development, deployment, and continued operation have positive economic impacts across aerospace and non-aerospace industries (2017). The journal article argues that for every job supported by the aerospace industry, another job is supported outside the aerospace industry (Monte & Scatteia, 2017). That finding is significant because it shows that the benefits of rocket development extend beyond science and engineering and improve the quality of living for a broader network of actors. Furthermore, investment in rocket activity is beneficial because it helps develop technologies that directly serve and benefit society. For example, rocket launches enable earth observation satellites such as NASA's TEMPO satellite (Aknan, 2024). TEMPO is a significant satellite because it enables the tracking and monitoring of hourly air pollution over North America (Aknan, 2024). It tracks products including nitric oxides, ozone, and formaldehyde (Aknan, 2024). Understanding pollution distribution and movement enables policymakers and scientists to create regulations and mitigation strategies that address environmental concerns.

In addition to those supporting arguments, numerous critical perspectives about rocket launches exist. For example, Rockets burn non-renewable fossil fuels, and according to Piesing in an article published by the BBC, rocket launches significantly contribute to global warming, ozone layer depletion, and various health problems (2022). According to the US Department of Transportation, breathing particulate matter, like those produced by rocket propulsion, is associated with "asthma, chronic bronchitis, and heart attacks" (2015). Health problems and contributions to global warming are two notable drawbacks of rocket propulsion. Furthermore, according to an article by Kuthunur, noise pollution from an increasing number of rocket launches by private space companies like SpaceX threatens the wildlife surrounding rocket launch pads (2023). When spacecraft or rocket booster sections re-enter the atmosphere and land, in SpaceX's case, they create sonic booms. Those shockwaves, along with the rumbles from rocket launches, startle wildlife. Kuthunur argues that the effect of noise pollution from rocket launches is poorly understood; therefore, industry leaders should be cautious about expanding rocket activity.

The environment, economy, science, and technology are notable areas impacting rocket activity. Completing a rigorous comparison of those impacts is essential for completing a thorough pros and cons analysis and determining whether the benefits from rocket development and deployment outweigh their negative consequences.

Conclusion

The aerospace industry continues to develop rapidly as private space companies like SpaceX launch an increasing number of orbital and suborbital rockets. Those rocket launches promise to advance the frontier of technology and improve the quality of living. However, they also negatively impact human health and the environment. My capstone project and future socio-technical research paper aim to explore the trade space between the benefits and disadvantages of rocket launches. To better understand that trade space, I aim to complete a pros and cons analysis using the actor-network framework while drawing evidence from literature reviews, opinion articles, and technical reports. To complement that socio-technical research, my capstone team plans to design, build, and fly a sub-scale sounding rocket that reaches an altitude somewhere between 3,000 and 4,000 feet. Furthermore, that subscale rocket aims to collect data on altitude, temperature, humidity, pressure, ultraviolet radiation, and acceleration to characterize its flight environment. Together, my capstone project and research paper aim to offer a perspective and potential solution for whether the benefits from rocket launches outweigh (or fail to outweigh) the environmental consequences of rocket propulsion.

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