HOO-RIZON 1: SUBSCALE SOUNDING ROCKET

INNOVATION IN ROCKET TECHNOLOGY: HOW REUSABLE ROCKET TECHNOLOGY IS ENABLING EMERGING STARTUPS

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

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November 8, 2024

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Overview: Examining the Role of Reusable Rocket Technology in Enabling Market Participation by Emerging Startups

How does reusable rocket technology impact emerging startups' ability to enter the space industry, and what role do government policies and industry partnerships play?

The aerospace industry has evolved significantly over the past few decades and has flourished with innovations - most notably, reusable rocket technology. Traditionally, rocketry has involved single-use, throw-away rocket components. Reusability in the context of rockets centers around the main components that can be recovered, repaired, or used a repeated number of times. The innovations driving this reusability include enhancement in propulsion technology, recovery systems, and the integration of avionics and telemetry systems.

The Hoo-Rizon 1 capstone is focused on the design and development of a subscale sounding rocket aimed at reaching an altitude of 4,000 feet. The final deliverable is a reusable launch vehicle that has recovery capabilities. Typically, sounding rockets are used for scientific exploration of the upper atmosphere and the space environment. The project's success confirms the viability of reusable rocket technology and will set a precedent for UVA aerospace capstones. It will direct attention towards the concept of designing launch vehicles for re-use and recovery.

In parallel, the STS research project will examine how reusable rocket technology has enabled greater market participation by emerging startups. It will study the new opportunities made available by the introduction of this technology for startups to engage with top players in the market, the government, and the public. It will assess how government bodies and industry

partnerships impact the ability of startups to navigate the market and make a place for themselves by embedding reusable rocket technology into their designs and processes.

Together, the technical project and the STS analysis will provide a holistic analysis of how reusable rocket technology is evolving the aerospace industry, changing dynamics by key players, and making spacecraft innovation an accessible practice.

Technical Research Project: Develop, Launch, Recover a Sub-Scale Sounding Rocket

How can we design, develop, and recover a subscale rocket at an affordable cost to collect and transmit data at an altitude of 4,000 feet?

Purpose of Aerospace Capstone

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). As a result, there is a growing trend among university aerospace engineering programs to enhance the skill set of students and encourage them to take on interests in spacecraft design.

Mission

The technical research question revolves around the design and manufacturing of an efficient and cost-effective sounding rocket that can be recovered and reused at a later time. The

Hoo-Rizon 1 is a subscale sounding rocket with an apogee of 3000 to 4000 ft. The mission aims to bridge the gap between theoretical knowledge and practical skills, particularly in the development of sounding rockets. Sounding rockets are crucial for scientific research due to their ability to gather and transmit integral data at a high-speed at a relatively low cost of manufacturing.

Background

Sounding rockets are designed to carry scientific instruments as payloads into the upper atmosphere and the ionosphere, with predetermined, specific measurements in mind. 'The rockets follow parabolic or "U-shaped" trajectories, providing nearly vertical paths along their ascent and descent.'(NASA,n.d.). The contribution to science of sounding rockets has been observed since the 1950's and has a wide range of applications. In this capstone, humidity, temperature, and pressure will be the main conditions that the rocket will be "sensing".

The following objectives have been set to guide the course of the project:

1. Obtain atmospheric data: The avionics system will need to collect and transmit real-time data on humidity, temperature, and pressure with an accuracy of plus or minus 5%
2. Collect rocket dynamics data: Necessary inertial measurements will need to be collected to model the dynamics of the rocket post launch
3. Recover Rocket: The rocket will need to have technical systems in place to recover the rocket and reuse it for future launches
4. Inexpensive Assembly: All components will be of reasonable price and quality will be confirmed with subsystem testing

To accomplish these objectives, the team will be broken down into three subsystems: aerobody,

avionics, and propulsions work simultaneously and test functionality in parallel.

Subteam Responsibilities & Methods

Aerobody

The aerobody subteam is responsible for the design and manufacturing of the aerobody, which is the exterior casing of the rocket consisting of the body, the nose, and the fins. It will be built from commercial off-the-shelf (OTS) components and 3-D printed parts using modeling software like Solidworks. This subteam will also model the flight of the rocket using OpenVsp.

Avionics

The avionics subteam is in charge of designing and assembling the avionics bay which is the home of all "on-board" electronics including sensors for collecting atmospheric data, the printed circuit design board that will manage the flow of data and power, and the on-board computer, the Raspberry Pi Pico. The avionics system will collect real-time data such as altitude, pressure, and temperature, as well as the UV Rays index using a raspberry Pi Pico as the microcontroller and a variety of sensors. The data collected will be stored locally and transmitted to the ground station through radio frequency. The Raspberry Pi Pico will interface with virtually all of the electronics on board. The avionics subteam is also responsible for the design and execution of the parachute deployment system, an integral step in recovering the rocket post launch. Redundancy measures will be incorporated into the electric system by incorporating backup components and power sources to ensure safety and reliability.

Propulsion

The Propulsion subteam is responsible for selecting a specific motor within a subsect of class II motors. The propulsion system will be based around a commercially available motor

rather than a manufactured one due to the project's timeline and launch site regulations (Tripoli, 2023). Simulations will be used to verify the integration of the motor with the design so we can accomplish the goal of 3000-4000 ft of altitude gain.

Tools

The team, across all subsystems, will use advanced tools like Matlab, Ansys Fluent, and the Rapid Prototyping Lab (RPL) in the iterative design process. Matlab and Ansys Fluent are computational programs used for processes like Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD). KiCad and Tinkercad will be used to design circuitry and the printed circuit boards (PCB). While solidworks will be used for modelling the avionics enclosure as well as the different components the aerobody subteam is responsible for. GrantaEDUPack, a materials properties database, will also be used to determine suitable materials for the avionics enclosure to meet requirements for durability and conductivity.

Next Steps

The critical design review will be done at the start of Spring 2025 and manufacturing will follow. The target launch date is in late Spring and Tripoli guidelines will be adhered to in preparation for the launch.

The project, although carrying generally the same objectives as previous rocket capstones, will be an effort from the ground up. It will, however, emphasize the integration of affordable components to meet the established system and subsystem requirements. The project will contribute to laying the groundwork for future rocket capstone projects as well as have impacts for UVA's role in rocketry education and experiential learning. It will evaluate the feasibility of recovering single-stage sounding rockets and manufacturing a sub-scale rocket in

an inexpensive manner.

Examining the Role of Reusable Rocket Technology in Enabling Market Participation by Emerging Startups

How does reusable rocket technology impact emerging startups' ability to enter the space industry, and what role do government policies and industry partnerships play?

Contextualizing Reusability in the Space Sociotechnical System

Reusable rocket technology has shifted the dynamics of the space industry, creating a network that connects innovation, regulatory frameworks, and actors like private companies, governments, and research organizations. Historically, dominant players were state-sponsored programs and large corporations since the high cost per launch discouraged smaller companies. Recently, however, there's been an increase in the number of startups and the amount of emphasis on supporting these startups. The line of entry into the market seems permeable. The shift is likely driven not just by technological innovation, but also by the reduction or evolution of key barriers.

Literature Review

Reusability & The Evolving Space Market

Reusability includes boosters, first stages, and reusable modular components, in contrast with expendable one-time use systems. Recognized advantages for industry players include lowered costs and decreased space debris. Investments in this by Spacex, Blue Origin, and Rocket Lab have led to greater economic development (Mayfield, 2021). Two key examples to note include Spacex with Falcon 9 and Relativity Space with Terran R. As two highly prominent cases in the market, reusability and its consequent operational advantages has been a valuable source of

success for both companies (Martinez, 2024).

Government Role & Dynamics

The U.S. government is standing as an early adopter of reusable launch services. Government bodies can serve as a reliable, continuous source of demand. Government investment can relieve startups from certain amounts of risk and increase credibility of startups to potential inter-industry private partnerships (Wienzierl, 2018). Governments also push national security and space exploration agendas through contracts for industry players (Goessler, 2022). Historically, reusable launch systems at any level is something they have shown interest. Governmental programs have been proposed to bridge the gap between startups and the government like the New Space Development Office (Zimmerman, 2017). The Commercial Orbital Transportation Services (COTS) program is a key example to note, sharing development costs, retaining intellectual property rights, and incentivizing innovation all in relation to emerging aerospace startups. In these ways, many of the barriers to entry are knocked down by government influence (Albon, 2017).

Knocking Down Barriers to Entry

Reusable rocket technology allows smaller players to bypass structural challenges. Aside from high launch costs, a sense of risk has been weakened amongst smaller players. The luxury of multiple launches and full-scale testing have typically favored established companies, but reusability might be what has been recently leveling the playing field to a larger degree. The public, government, and larger private companies have gained confidence in the prospect of working with emerging startups (Lal, 2017). This shift in perspective has encouraged more startups to develop business models that ensure their longevity and ability to work with larger firms (Gustafson, 2015). The independent missions of these startups have produced a collective

image of what the future of aerospace could look like, garnering interest from capitalists and wealthy members of society. With reduced risk and more room for error, they can focus on their niche and seek support from relevant stakeholders (Querejazu, 2017).

Theoretical Framework

Actor-Network Theory (ANT) accompanied by Diffusion of Innovations and Sociotechnical Imaginaries as supplementary frameworks is applied by this research. ANT furthers understanding of how the advances in reusable rocket technology empowers emerging startups and shapes the dynamics between startups, regulatory bodies, and private enterprises. Reusable rockets, as key non-human actors, help emerging startups enter the market and reshape their relationships with established companies and supporting organizations. (Martinez, 2024)

Applying Diffusion of Innovations allows for an assessment about how established companies adopting technologies like reusable rocket components has set a precedent for smaller companies. Relative advantage, cost reduction, and increased government funding have all boosted attention to this innovation. Sociotechnical imaginaries will help relate the collective visions of technology in aerospace with investor confidence, public support, and government policy that interact with emerging startups. It will also assess how reusable technology minimizes these risks.

Methods: Data Collection & Analysis

To examine the impact of reusable rocket technology on emerging startups, I will analyze key companies that have adopted reusable systems including Spacex's Falcon 9, Rocket Lab's Electron, and Relativity Space's Terran 1. The analysis will consider these companies at their earliest stages, before and after the release of their reusable launch vehicles.Their market

presence, collaboration with other firms, and government partnerships will be assessed. I will be able to draw conclusions on common trends. Specific case studies done on these companies, the rocket infrastructures, news articles, and market trends will be used.

Additionally, I will research currently emerging startups leveraging reusable rocket technology in their business models. I will interview them on the work the company will complete rather than their opinions on the subject. To adhere to the proper interview form, I will have the questions scripted and the responses documented. The questions will focus on how startups utilize reusability to remain competitive. The questions will provide insight as to what influence reusability has on their decisions as well as the role that enterprise partnerships and policy plays in their decision making as a startup.

Combining my research, interviews with emerging startups, and cross referencing information and studies on the major players in the market, I will compare and contrast the journeys of these companies. Then, I will assess how reusable rocket technology has influenced, protected, and scaled businesses. Finally, I will observe how this change has shifted dynamics between these startups, the government, and larger private companies.

Conclusion

This prospectus describes two related research endeavors including the Hoo-Rizon 1 Subscale Sounding Rocket and an STS analysis of how reusable rocket technology is evolving market dynamics and enabling smaller players to enter the industry.

The technical project will allow the team to demonstrate the feasibility of building, launching, and recovering a reusable launch vehicle through scalable and iterative design. Not only will the technical project set a precedent for UVA Aerospace capstones in the future, but

provide insight into the relative affordability and flexibility of a reusable, modular design. Establishing that a sub-scale sounding rocket can be developed within budget, reused, and maintain a modular design all while measuring critical environmental and atmospheric data is highly useful for the needs of industry today.

The STS research will increase an understanding of the specific role reusable rocket technology continues to play in the market, particularly how it brings down several barriers to entry that emerging startups face. Current research on this topic has focused on specific technology infrastructure rather than what dynamics startups become involved with when scaling and dealing with industry partnerships and government policies. Thus, this research will also shed light on the perspectives held and actions taken by private industries and regulatory bodies in relation to giving access to emerging startups into the market.

Collectively, these projects will provide a comprehensive understanding of how reusable rocket technology is both advancing technical capabilities and reshaping industry opportunities, leaving the space sector more accessible and competitive.

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