Hoo-Rizon 1: Subscale Sounding Rocket
(Technical Paper)

Painted in a Different Light: How Military Contractors Use Civilian Applications to Garner Support
(STS Paper)

A Thesis Prospectus
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By
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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.

ADVISORS

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Prospectus

General Research Problem

In the U.S., have civilian and military R&D reciprocally stimulated technological development?

Many products designed for military use are commonly used today, such as duct tape, microwaves, and canned food (NATO, n.d.). Some are recent inventions while others date back to the 1930s. Just as military R&D has contributed to civilian products, civilian R&D has contributed to military products. This is primarily in the form of civilian-based industries creating products for the military via the U.S. national security "Iron Triangle," a mutual exchange of products, funding, and legislature (Adams, 1981).

Designing, Building, and Testing a High-Power Sounding Rocket

How can effective rockets be built for a low cost?

This capstone project involves 13 other individuals: Jacob Lewis, Omid Sayyadli, Laurel Supplee, Kushi Sethuram, Nikita Joy, Jean-Pierre Manapsal, Swedha Skandakumar, Youchan Kim, Tyler MacFarlane, Christian Vergason, Connor Owens, George Hubbard, and Ethan Fouch. The project entails designing and building a sub-scale sounding rocket with a budget of $2,800, and the goal is to reach a target altitude of 4,000 ft with a small payload. Aside from the budget constraint, the main non-typical constraints are related to designing around temperature, pressure, vibrations, parachute deployment that preserves the rocket, and other environmental factors experienced during launch. It is under the Aerospace Engineering department with Haibo Dong as the main advisor.

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 capstone projects, especially in regards to building a subscale-sounding rocket. Gaining experience in these design concepts through hands-on capstone work is imperative to ensuring engineers can apply their practical knowledge in the field; in addition to conducting successful design reviews and performing well, this is one of the team's primary goals.

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. The state of the art for this field has been led for 40 years by NASA via the Sounding Rockets Program at Goddard Space Flight Center (NASA, 2023), but many countries other than the U.S. and companies other than NASA design, build, and launch sounding rockets.

The team uses a combination of system-level and subsystem-level methods to fulfill the mission goals and objectives. It has 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, three deliverables are presented: a Project Pitch, a Conceptual Design Review, and a Preliminary Design Review in order to formulate and implement the design thoroughly. Given the team's two-semester time constraint, the team is 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, the team is able to lay out the preliminary rocket design and evaluate the rocket's max-altitude from simulations. Finally, the team utilizes project management tools like Gantt Charts, risk matrices, Google Drive, and Discord to facilitate team logistics.

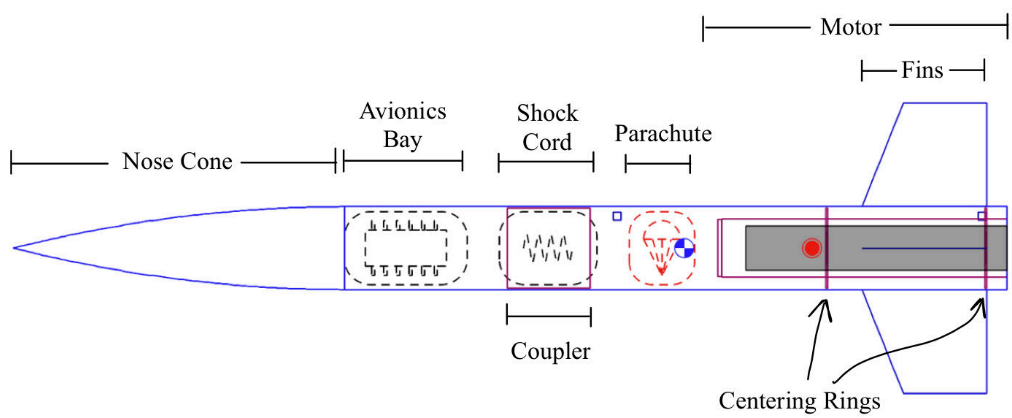

Figure 1. OpenRocket model of Hoo-Rizon 1 (Lewis, 2024).

The Aerobody subteam 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. The team is using SolidWorks, OpenRocket, and CFD solvers to iteratively model a rocket that reaches apogee. The team aims to use suppliers like BlueTube, Apogee Rockets, and Wildman Rocketry to purchase components like body tubes, couplers, centering rings, parachutes, and epoxies. The team aims to 3D print components like fins and the nose cone to save costs, save weight, and allow for design flexibility.

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 Figure 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, 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, the team will be calibrating the sensors in an environment that mimics flight conditions.

Through repetitive simulation testing of COTS Class II motors of type J, K, or L on the rocket model, the team aims to select the best motor that efficiently reaches the target altitude. Different thrust curves representing different engines can be implemented into OpenRocket, where apogee data can be collected and the ideal motor can be determined. The design of the rocket body has drastic effects on the rocket engine, as the required propulsive force is determined by the aerodynamic drag and gravity forces. In this respect, an iterative process between the Aerobody and Propulsion subteams is required to determine the ideal motor.

The team has access to many different manufacturing technologies such as 3D printers containing ABS, a vertical mill, and soldering kits. Additionally, there are several different softwares being used for design work, including OpenRocket, SolidWorks, Ansys Fluent, KiCad, and MATLAB. OpenRocket is a model rocket simulation software that allows the team to assemble and simulate fully constructed rockets and analyze predicted apogees. SolidWorks is a CAD software that is being used throughout the project to integrate and model the rocket's structural components. Ansys Fluent is a CFD package that uses a set of robust turbulence models to model near-surface interactions, which will result in analyses of the aerodynamic characteristics of the nose cone, body tube, and fins. KiCad is a software suite for electronic design that will be used to design the PCB that controls the sensors. Lastly, MATLAB is a programming language that helps calculate useful theoretical quantities for the analysis of the rocket, such as cruise velocity and fin deflection angles.

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. If the project succeeds, this will be the first successful competition rocket launch for a rocket designed and built by a UVA capstone group, which may serve as a footing for future groups participating in this project. As aforementioned, another goal of the project is providing a physical learning experience for aerospace engineers who are about to enter the workforce or pursue further education.

Painted in a Different Light: How Military Contractors Use Civilian Applications to Garner Support

In the U.S., how have military contractors invoked promises of beneficial civilian applications to defend expensive military R&D?

The U.S. military, like any large organization, has more power when it has public support. However, weapons systems' high costs (Beranek, Smullin, & Tsipis, 1990) and controversial uses (Misselhorn, 2022) can undermine attempts to gain this. Total annual national defense costs have gone as high as hundreds of billions of dollars, such as during the Reagan Administration with a five-year, $1.5 trillion plan (Adams, 1981) or the 2023 spending of $820 billion (Peter G. Peterson Foundation, 2024). In 1981, Adams identified this trend of increasing costs, which has remained true 43 years later. To win over more people, some products with a primary purpose in defense are marketed as having a more humanitarian primary purpose. However, some researchers have found that a small amount of technologies funded by taxpayer dollars convert into useful non-military products (Arcella, 2005). In spite of this, to what extent has the U.S. promoted military R&D under claims of civilian development?

Participants include the Defense Advanced Research Projects Agency (DARPA), which states technology developed to improve military capabilities also improves modern civilian society, such as with the Internet, miniscule GPS receivers fit for phones, and language translation (DARPA, n.d.). Participants also include companies that advertise products for military usage, such as Ghost Robotics (Figure 2), or for civilian usage, such as Boston Dynamics (Figure 3). These participants are closely tied to one another with the "Iron Triangle" of the Pentagon, defense industry contractors, and committees in Congress (Adams, 1981). Through this, contractors have greater lobbying power and a strong resilience to opposition, leading to greater control over legislation and funding for their products. Participants also include government agencies like the National Defense Industrial Association (NDIA), which defines itself as an "educational nonprofit that engages thoughtful and innovative leaders to promote the best policies, practices, products, and technology for warfighters and others who ensure the safety and security of our nation" (NDIA, n.d.). Finally, participants include groups against militaristic technology development, such as the coalition of non-governmental organizations Campaign to Stop Killer Robots and its adversarity of Lethal Autonomous Weapon Systems (LAWS). This organization addresses points on LAWS being unable to make complex ethical choices and the uncertainty about future proceedings over unjust actions, stating “It’s unclear who, if anyone, could be held responsible for unlawful acts caused by an autonomous weapon – the programmer, manufacturer, commander, or machine itself – creating a dangerous accountability gap” (Stop Killer Robots, n.d.).

Figure 2. VISION 60 Q-UGV with military personnel (Ghost Robotics, n.d.).

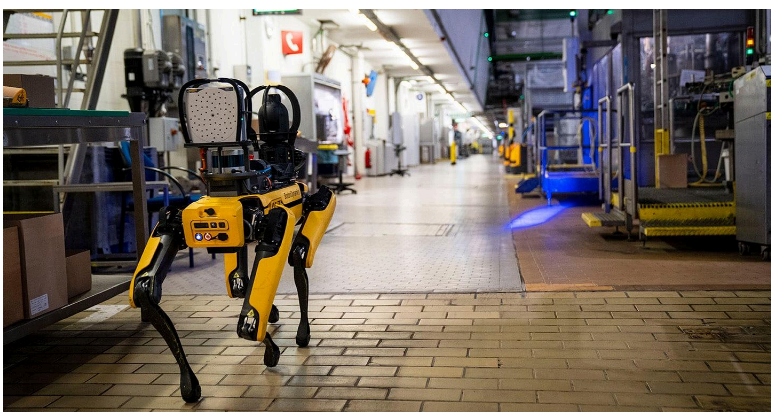

Figure 3. Spot in a food and beverage facility (Boston Dynamics, 2024).

To explain why military technology often fails at “bridging the valley of death” (finding civilian markets), Arcella (2005) blames high costs, long schedules, and unsatisfactory performance. This study found that while military technologies can appear useful to industries, many industry managers who evaluate costs, schedules, and performances of products are opposed to the risk of expensive, new technologies. It can then be reasonably inferred that products like the VISION 60 Q-UGV would see more use than products like Spot. Many features advertised by Ghost Robotics are also not easily transitionable to commercial applications, such as how they “improve its ability to walk, run, crawl, climb and eventually swim in complex environments that our customers must operate in” (Ghost Robotics, n.d.); most of these features serve no purpose in food and beverage facilities.

Employees’ values can influence employers’ policies (Misselhorn, 2022; Beranek, Smullin, & Tsipis, 1990). Misselhorn also states that with LAWS, the “responsibility gap” (equivalent to the aforementioned “accountability gap”) is a deterrent (Misselhorn, 2022). Not only is it difficult to point blame when the actions of LAWS are the result of multiple components (i.e. the autonomous systems programmers or the designer of the physical body), but since systems guided by artificial intelligence have little “epistemic opacity,” their malfunctions resist diagnosis (Vallor & Vierkant, 2024). With difficulty in outsiders identifying where code failed and people being innocent until proven guilty, laws that protect this lack of transparency limit the ability of specific companies being called into question.

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