Prospectus

Controls, Payload, and Recovery for a Sounding Rocket

(Technical Topic)

Rocketry and Sustainability

(STS Topic)

By

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1. Overall Introduction

Whether they be man-made satellites, astronauts heading to the moon, or a rover on its way to Mars, the space industry has wide reaching implications. Satellites' impacts pervade throughout society; they affect wireless communication, navigation, weather tracking, and more, and that's excluding any of the other types of objects we put into space (N.A., 2015). While scientists are developing other ways to send things into space, the primary way we access the universe above the Earth's surface is through rocketry. Rockets have been used successfully for a long time in a variety of industries from space exploration to fireworks, and recently there's been an explosion in the amount of rocket launches; 2022 had the most objects launched into space of any other year on record with 2478 objects launched, and since 2010 the data shows exponential growth (United Nations, 2023, Appendix 1). In 2022, the space industry hit a worth of $546 billion and is predicted to increase another 41% in the next five years (Grush et al., 2023). Thus, assuming the current trends continue, rocketry will become increasingly prevalent as time goes on. Because rockets are so important and ubiquitous and yet so complicated and prone to failure, it's important to learn how they work and what goes into actually creating one. It's also imperative to understand how sustainable the rocketry industry is as a whole and what sustainability means when it comes to rocketry. Combining this with research into the policy regarding rocketry sustainability, I will seek to understand this issue and come up with an evaluation of the current policy and a recommendation for what this policy should look like in the future.

2. Technical Problem

Rocketry can be broken down into the following sequence: a system housing a payload (a satellite, astronauts, etc.) transfers chemical energy into kinetic energy to propel itself upwards. While simple in theory, many real rockets contain unbelievable complexity: from their flight path down to their parts, much of rocketry consists of many precise requirements and moving parts which increase the likelihood of failure (Neuman, 2012). Nowadays, we need to know exactly what is happening during every step of rocket launches in order to control them and to ensure that the rocket behaves the way it was designed to (NASA, 2009). In order to accomplish this and to build rockets that function intelligently, many rockets incorporate an electrical system onboard complete with controllers, sensors, and actuators. A rocket's "intelligence" lies in its ability to respond to feedback; if something is not going right, an intelligently designed rocket will either adjust itself to fix the problem and/or relay this information to humans that can control the rocket from afar. Thus, a rocket's electrical system allows it to take data, send that data back to people on the ground, change its function based on real time feedback, self-destruct if something isn't going right, and much more. This aspect of rockets is called controls, and it constitutes a vital aspect of rocketry in order to achieve the most efficiency and range of ability possible. This will be the topic of my specific research, exploration, and development throughout the year.

In general, my capstone class seeks to build a fully functional sounding rocket (a rocket that completes less than one orbit around the earth) that will launch from the ground, reach some height in the atmosphere, deploy parachutes and execute the payload function, and land non-destructively. Sounding rockets are often used for research of the atmosphere or testing components that will be used in larger rocket launches, and we will attempt to construct one in order to take data of the atmosphere and of our rocket's flight, to deploy a novel payload to complete an arbitrary function, and to gain experience in the design of a rocket (Indian Space Research Organisation, 2023). The payload my team (the controls team) has decided on will be a glider; at the apogee of the rocket's flight a small glider will be released from the main body of the rocket which will traverse a larger distance than the rocket during its descent and take footage of its flight as it travels through the atmosphere. This will allow for a novel method to survey the terrain surrounding the rocket's launch site. The research and development we complete on the controls system and glider payload will pave the way for future capstone sections to expand on our ideas and results; they could take what we make and improve it for a different function.

3. STS Problem

While we rely on rocketry to build and maintain pillars of society, it is important to think about how sustainable it is. The UN defines sustainability as, essentially, being able to do what we need to now without hurting future peoples' ability to thrive (Sustainability, n.d.). Additionally, current societal impacts should be evaluated as any negative impacts harming people now would prove that the current rocketry methods should not be sustained and thus are not sustainable. A few important factors regarding sustainability come to mind: the environmental impacts and the ethical sourcing of materials. The main environmental impacts I'd like to explore are the climate change impacts. Overall, climate change is caused by the burning of fossil fuels, which warm the earth through the greenhouse effect (“Causes of,” 2023). Climate change will cause a host of issues which have already started, and the World Health Organization predicts that climate change will cause on the order of 250 thousand additional deaths per year between 2030 and 2050 ("World Health," 2021). Thus, climate change will clearly worsen things for humans on earth, so we need to do everything possible to mitigate it and reduce our emissions. As rockets burn fuel to propel themselves through the atmosphere, it makes sense that they would contribute to climate change; after all, many transportation methods (cars, trains, planes, etc.) burn fuel to move around and transportation contributes to about 20% of all global CO2 emissions (Ritchie et al, 2023). As stated before, the rocketry industry seems to be expanding; if rockets meaningfully contribute to climate change, then the increasing number of launches will result in an increasingly significant worsening of climate change from the rocket industry. In the next paragraph I will analyze the emissions of rocketry, as this is a big part of its potential to impact climate change, and determine if it is a serious problem.

There were about 2500 objects launched into space in 2022, and thus 2500 or fewer rocket launches over that year, while there are about 100,000 aircraft flights every single day (How Many, 2023, United Nations, 2023). While the aviation industry is commonly thought of as harmful for the environment, it is responsible for only about 2.5% of total global CO2 emissions; for context, road vehicles are responsible for over six times that amount, or about 15% of total global emissions (Ritchie et al, 2023). As the rocketry industry utilizes less than 0.01% of the fuel per year that the aviation industry does and is more efficient with its fuel usage, rockets are responsible for less than 0.001% of total global CO2 emissions (Corporation, 2023, Ritchie et al, 2023). This amount is extremely small, and there are significant contributors to emissions that have unimplemented solutions already, like the automobile industry, which is responsible for about 15,000 times the emissions of rockets, and its existing solution: electric cars (Corporation, 2023, Ritchie et al, 2023). Thus, in terms of quantitative emissions, rocketry has a negligible effect on climate change. While we should continue to monitor this to make sure it stays that way, it seems like there is no policy needed to address this at this time, as the emissions of rocketry are not substantial and probably don't impact society in a meaningful way.

So, as it turns out, rocketry does not meaningfully contribute to climate change. The other aspect of sustainability I'd like to explore are the materials used in rocketry and their sources. Recently, light has been shed on the unethical extraction of resources in certain areas of the world. In the Democratic Republic of Congo, mining of materials has been used to fund conflicts, and expansion of some of the mines in the DRC has led to human rights violations (Marks, 2014, Mining of Cobalt, 2023). Additionally, the mining itself in the DRC is plagued with child labor, toxic working conditions, and unjust compensation for workers (Gross, 2023). Some of the materials mined in the DRC include tin, tantalum, gold, tungsten, and cobalt (Gross, 2023, Marks, 2014). Many of these materials find uses in rockets and the rocket industry: gold is useful in electronics because of its low electrical resistance and for satellite plating because of its high corrosion resistance, cobalt alloys are utilized in rocket engines, and tungsten finds use in nozzles of solid propellant rockets (Halchak, 2001, Rocket Nozzles, N.d., Sims, 2023). Additionally, some technology sent into space uses lithium-ion batteries which contain cobalt (Nobel-winning lithium, 2019). Because the rocketry industry makes use of these materials, and these materials tend to be unethically sourced, the rocketry industry could be contributing to all of the ethical issues caused by the mining of these materials in the DRC as stated above. This prompts a few questions: what are the policies in place regarding purchasing these materials or unethically sourced materials in general? Do space companies have a tendency to care about how their materials are sourced? What policies could prevent the space industry from using unethically sourced materials? The effects of mining these materials in the DRC are bad, but how many people do they affect and what specific harm (other than what I've found already) does it cause? In the next section I will explore a few of these questions and try to determine what the situation regarding ethical sourcing of materials is in the United States.

What does ethical sourcing of materials policy look like in the United States? The California Transparency in Supply Chains Act forces companies doing business in California to publish their efforts and methods of checking where and how their goods are produced (Top Regulations, 2023). Assuming this act is enforced strictly, this seems like a good policy to enforce ethical acquisition of goods, however it is only valid in California and thus it doesn't apply to any company in any other part of the country. Around summer 2022, the Uyghur Forced Labor Act (UFLPA) came into effect in the U.S.; this law essentially mandates companies to make sure that their goods do not come from forced labor, unethical working practices, or conditions that contain human rights abuses (Top Regulations, 2023). However, this law only applies to forced labor and abuse of the Uyghur people in China, and thus it doesn't apply to the materials mentioned in the previous paragraph as they tend to be unethically sourced in other places (UFLPA, 2023). The other federal process I found relating to this is the U.S. Customs and

Border Protection's ability to detain a shipment if they have any reason to believe the goods were produced with forced labor; this came from the Tariff Act of 1930 (Information and Resources, n.d.). However, this does not directly prevent companies from buying unethically sourced material, it only provides a chance that the unethically sourced material is not delivered; if the shipments are not flagged it will not do anything, and even if a small number of shipments are flagged and seized, if they were ordered from the U.S. the payment was likely already completed and thus the incentive to continue the mining operations will already have been fulfilled. For these reasons, the Tariff Act of 1930 is not enough to fully address the issue, and therefore new policy (legislation and enforcement) must be enacted to ensure that unethically sourced materials do not permeate the aerospace industry. The next phase of my research will look into more about mining in the DRC and its consequences. I will also look at effective policy changes implemented in the past in the U.S. (solving different issues) as a framework to create my own suggested policy to combat unethically sourced materials.

4. Overall Conclusion

While rocketry is vital to much of today's society, it also has its downsides, namely the potential to contribute to unethical mining of materials. On the technical side, controls and payload both serve as critical functions to rockets and thus are important for maximizing a rocket's potential. My team is exploring a glider payload in order to gain an understanding of the steps of rocket launches, to learn how controls work for rockets in general, and to focus on a novel application for rocketry. Thinking about the social impacts of rocketry, rocket flights are essentially negligible when considering their total greenhouse gas emissions. However, rockets contain many materials that tend to be unethically sourced. Thus, the research and work that follows the writing of this prospectus will be aimed at further exploring the policy of material sourcing in rocketry and in general, finding out more about the negative effects of these unethically sourced materials, and thinking about new policy that could prevent these unethically sourced materials from entering the rocket industry.

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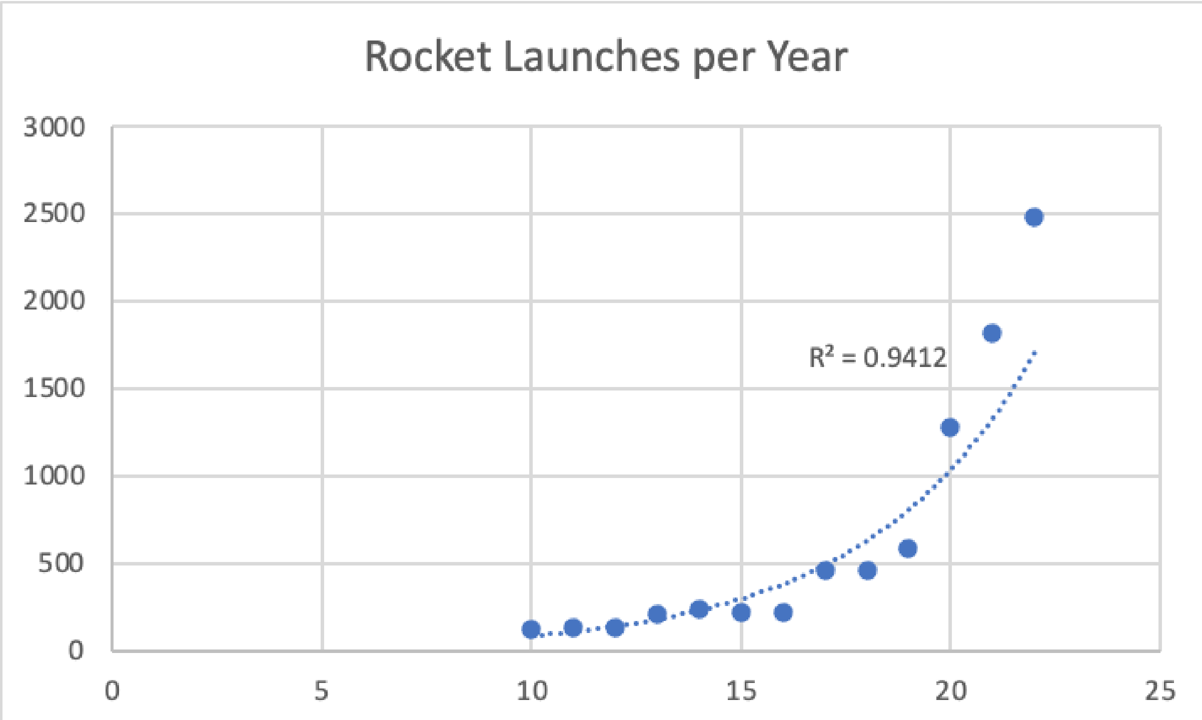
6. Appendix 1



Rocket launches from (United Nations, 2023) replotted from 2010 onwards. An exponential trendline was fit to the data and an R-squared value was found. The R-squared value is reasonably close to 1, showing that an exponential function is a reasonable fit for the data, i.e. the data shows exponential growth. Note: the years in the x-axis are shown as (year - 2000), so 2010 is represented as 10 in the x-axis.