Spacecraft Design

Sustainability and Rockets – A Crucial Intersection

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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.

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Introduction

The idea of sustainability has emerged as a paramount concept in society, reflecting the growing awareness of the need to harmonize economic, environmental, and social goals. In a world characterized by rapid population growth, resource depletion, climate change, and social inequities, the goal of sustainability has become a moral and practical imperative. In many cases, this idea involves practices and strategies aimed at preserving the well-being of current and future generations while also protecting the health of the planet's ecosystems. Within the broad topic of sustainability there are many sectors that not only acknowledge the call for action for our planet, but ourselves and our neighbors. The health of the planet is the primary factor of this topic, but humanity's impact is the largest contributing factor in the depletion of our ecosystem. The intersection between sustainability and engineering is one that is crucial, but often overlooked.

In the aerospace industry, aircraft and rocketry design has been something that has impacted global warming due to emissions, carbon footprint, and types of materials being used. The idea of "'carbon footprint' is often used as an easily understood measure to compare the climate impact of one kind of transportation system to another" (Corporation, 2023). Although each system has different emission levels and consequences, when it comes to spaceflight emissions there is little to no concern about environmental consequences, which is highlighted in the following quote made by The Aerospace Corporation:

> Sustainability has not been much of a concern for space systems development. Just like their jet engine cousins, rocket engines emit a variety of gasses and particles into the atmosphere that can have regional and even global consequences. Even so, the

> environmental impacts of launch vehicles are typically disregarded by comparing jet and rocket fuel consumption in an overly simplified way (2023).

The above statements compel one to acknowledge the power humanity has to change the health of the planet but also the health and longevity of society as a whole; and this is the problem. Achieving sustainability requires the responsible management of resources, the mitigation of environmental degradation, and the enhancement of societal well-being.

This prospectus outlines a research topic that will explore the intersection between three topics: STS, sustainability, and the aerospace industry. First and foremost, from a technical standpoint, I will be discussing my project and how we plan to minimize the overall negative sustainability impact of our project. Concurrently, from a STS perspective, the essay will investigate the profound socio-environmental implications on minority communities in Charlottesville over the past decade.

Technical Project

The engineering community is one that has shaped the world in many ways whether it is technology, road systems, the advancement of medicine, etc. In the dynamic realm of aerospace engineering, my capstone project takes flight as a visionary venture into spacecraft design. Focused on the creation of a sound rocket, this project is characterized by interdisciplinary collaboration, with distinct teams dedicated to body design, propulsion, and mechatronics. As we make progress on this project, the fusion of creativity, innovation, and technical prowess emerges as the guiding force propelling us towards a successful launch of this vehicle.

The body design team undertakes the challenge of crafting a vessel that not only goes through the atmosphere with minimal resistance but also ensures the payload's safety. Their focus mainly is on materials science, aerodynamics, and structural engineering, as they analyze the

trade-offs between weight, strength, and aerodynamic efficiency. The goal this team has is to produce a body that seamlessly integrates form and function. The propulsion team is tasked with the responsibility of engineering a propulsion system that not only propels the vehicle into the sky but does so with efficiency and precision. This team focuses on combustion dynamics, fluid mechanics, and propellant chemistry in order to optimize thrust-to-weight ratios and ensure a controlled burn throughout flight. The mechatronics team, which I am a part of, focuses on the control systems, sensors, and electronics that govern the behavior of the sound rocket. My role in this team involves integrating different technology to control and monitor critical parameters during the rocket's ascent and descent phases. From guidance systems to telemetry, our focus is on creating a responsive and adaptable spacecraft that navigates the complexities of the journey with ease. With all three teams collaborating, it ensures the overall design is cohesive and responsive.

My capstone project involves using advancements in the aerospace industry to achieve a certain outcome, however, the environmental challenges that come with this project cause me to propose the following research question, how can we minimize the overall negative sustainability impact of our project? These challenges include greenhouse gas emissions, noise pollution, and resource consumption. The aerospace industry is a significant contributor to greenhouse gas emissions, primarily carbon dioxide (CO2), resulting from the combustion of fossil fuels in aircraft engines.These emissions worsen climate change, contributing to rising global temperatures, extreme weather events, and other environmental issues as supported in the following statements.

> “Globally, aviation produced 2.4 percent of total CO2 emissions in 2018. While this may seem like a relatively small amount, consider that if global commercial aviation had been

a country in the 2019 national GHG emissions standings, the industry would rank number six in the world between Japan and Germany" (EESI, 2019).

"aviation's climate impact accounted for 3.5 percent of total anthropogenic warming in 2011 and was likely the same percentage in 2018." (EESI, 2019)

These challenges have compelled many members of this industry to rethink and reconstruct their sustainability goals and initiatives. When it comes to new technology, systems have been put in place to help reduce material waste and consumption, "In the aerospace sector, facilities commonly reported source reduction activities aimed at reducing the generation of scrap metal, and involving chromium, nickel, and copper, among other chemicals. Minimizing the generation of scrap metal is a source reduction practice because it reduces the quantity of waste generated at the source, while recycling of scrap metal is a waste management practice and is not considered source reduction"(EPA, 2020). Not only have systems been updated but new sustainability assessments are being developed in order to " identify hotspots and clarify potential sustainability consequences for a new product technology"(162, Hallstedt, 2015). s and has caused a lack of accountability on their impact in the global climate change crisis.

With this background information, it forces me to acknowledge the ways in which my capstone project will have an impact, whether good or bad, on sustainability efforts and challenges within the aerospace industry. With this project, we are focused on rocketry and building a system that will project no more than 10,000ft in the air, however, we have to buy various metal and plastic materials, construct the system, and test the system before final flight. These tasks, no matter their magnitude, cost not only economically, but environmentally. In order to limit negative impacts I am proposing that not only we recycle all leftover material from construction and recovery, but to also limit the amount of tests conducted in order to reduce the

amount of chemicals being added to the air. This project will allow for the exploration of potential ethical and social implications of sustainability-driven technological advancements that could build a future where aerospace innovations are more sustainable and equitable.

STS Project

The STS field has long examined the impacts of science and technology on society and the environment. It emphasizes the idea that scientific and technological advancements are shaped by social and cultural factors, and, in turn, they influence society. In the context of sustainability, STS provides valuable insights into how the development and deployment of technologies affect the environment and society, therefore informing sustainable practices. STS contributes to sustainability by examining the risks associated with technological innovations and environmental changes. This informs strategies to manage these risks and mitigate potential negative consequences. Some examples of mitigation come from integrated systems of waste management, “integrated waste management strategies can be significantly beneficial and impactful in multiple ways compared with the outcomes of traditional isolated initiatives of waste management.” (1, Hussain, 2022). These systems include recycling, composting, and disposal programs, however, accessibility to these resources have been questioned over the past decades leading to the underlying topic and issue of environmental justice to be studied and broadly introduced to society.

Environmental justice can be described in the following way: “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” (EPA, 2014). With this definition it compels one to ask, how has the

exposure(or lack thereof) to waste mitigation systems impacted minority communities in Charlottesville over the past 10 years?

In general, “Over 30 years of research has documented that poor and/or minority populations face disproportionate exposures to environmental pollution. This finding has given rise to an environmental justice movement seeking to address such inequities” (378, Banzhaf, 2019).Disadvantaged members of communities are more likely to be impacted by environmental justice issues due to the lack of resources and education in the broader topic of sustainability. In regards to sustainability efforts and the presence of environmental justice issues in the UVA and Charlottesville communities, there has been an unproportional level of access to waste mitigation systems and education resulting in a divide between the two communities. Although efforts have been made to address waste mitigation systems throughout Virginia as a whole, “ recycling rates have only improved 10% over the last two decades” further proving that this problem is one that needs to be addressed (Vazarkar, 2022).The acknowledgement of this problem has caused me to understand that it is important that these efforts be studied in order to understand the environmental justice problem as a whole in the Charlottesville community in specific.

The stated question and background information compels one to acknowledge that “disadvantaged members of society typically bear the brunt of the environmental impacts of human activity. Therefore, an essential part of attaining social justice is enabling the members of the community who will be adversely affected by these impacts to participate in and have rights of review in relation to the making of environmental laws, decisions about land use and development and enforcement of environmental laws.”(Millner, 2011). The above quote acknowledges the fact that STS theory of the relationship between infrastructures and power plays a vital role in the topic of environmental justice by shedding light on how power dynamics

shape the distribution of environmental benefits and burdens. This idea is highlighted by Winner when he states, “Technical systems of various kinds are deeply interwoven in the conditions of modern politics”, and they “embody specific forms of power and authority” (121, Winner, 1980). The interplay between infrastructures and power becomes evident in the unequal distribution of environmental benefits, with privileged groups often enjoying better access to resources and cleaner environments. Simultaneously, marginalized communities bear a disproportionate burden of environmental degradation, as seen in their exposure to pollution and lack of access to sustainable practices. STS theory underscores that these disparities are not accidental but are shaped by power dynamics that influence decision-making processes related to environmental policies and infrastructural development. Recognizing the centrality of power in these dynamics is crucial for addressing environmental justice comprehensively, advocating for inclusive policies, and dismantling systems that perpetuate environmental inequalities. In essence, STS theory serves as a lens through which we can understand and address the systemic issues that contribute to the unequal distribution of environmental benefits and burdens in society.

In the spring semester, my research will take a concrete form as I embark on a comprehensive exploration of STS theory, particularly focusing on the intricate relationship between infrastructures, power dynamics, and environmental justice. To bring depth and substance to this theoretical framework, I will use information stored in archives and files produced by the Office of Sustainability (OFS) and the city of Charlottesville. By analyzing these archives, I aim to unravel the narrative of how power dynamics have shaped the distribution of environmental benefits and burdens within the local community. This approach ensures that my research aligns with the lived experiences and historical context of the local

community, making the connection between the intersection of infrastructures, power, and environmental equity.

Conclusion

In conclusion, analyzing the intersections of STS theory, sustainability, and the aerospace industry is necessary in order to understand the impact and influence these topics have on society as a whole. This research project aims to shed light on the complex dynamics that shape the aerospace industry and the concept of environmental justice and waste mitigation. The technical project will produce an advanced sound rocket with many engineering benefits while also aiming to be sustainable. The STS project will address the systemic issues that contribute to the unequal distribution of environmental benefits and burdens in society. By adopting a multidisciplinary perspective that draws from STS, sustainability science, and ethics, I aspire to provide insights into how the aerospace industry can better align its endeavors with sustainable practices. By understanding how science, technology, and society converge in the pursuit of sustainability, society can make informed decisions, take responsible actions, and develop policies and practices that balance the needs of the environment, the economy, and society.

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