Energy Harvesting via Ballonet Altitude Control
(Technical Paper)

Sustainable Aviation: Driven by Policy or Technology?

(STS Paper)

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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

Following the consensus of the vast majority of the planets' scientists that the climate change currently occurring on Earth is driven by human activities, there has been an increased emphasis on the enhancement of sustainability in all sectors. One of the main causes of climate change stems from the burning of greenhouse gasses (GHG) for use in power generation, but also transportation. One sector of the transportation industry has continually grown, this being air travel. The number of passengers traveling the world's skies has increased from 0.8 billion in 1980 to 4.6 billion before the beginning of the COVID 19 Pandemic in 2020 (IEA, 2020). Currently, greenhouse gas emissions related to aviation account for 2.5% of global CO_2 emissions and have caused around 4% of the total global warming to date (Ritchie, 2024). While this is a far smaller quantity than the 15% of overall emissions caused by road travel, the steady increase in popularity and difficulty of electrifying air travel make this sector a valid and crucial target for emissions reduction (Ritchie, 2020). GHG emissions caused by air travel have only increased with the widespread adoption of this mode of transit. Since the 1960s, global CO_2 emissions from aviation have quadrupled as demonstrated by Figure 1. included below.

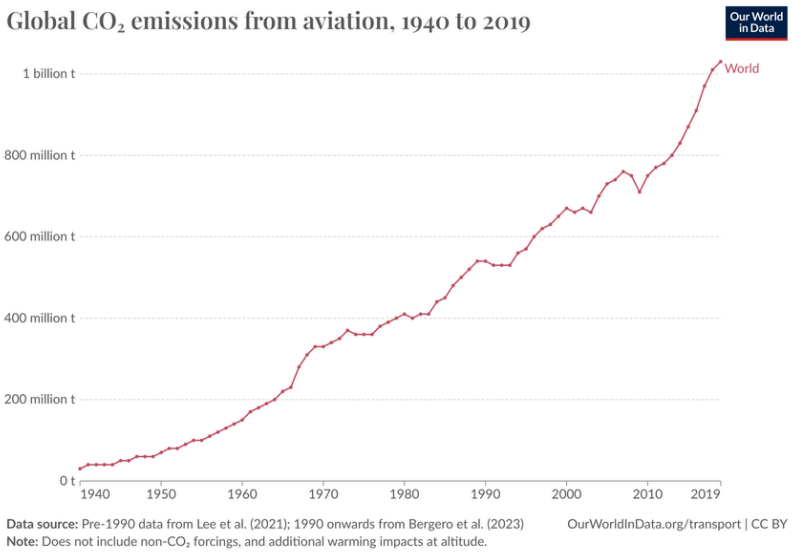

Figure 1. Global CO_2 emissions from aviation from 1940 to 2019, (Ritchie, 2024).

Important to note is that the environmental effect of aviation is not only caused by the emission of CO_2. The aforementioned claim that aviation is responsible for 4% of the Earth's warming to date stems from the fact that aircraft affect the concentration of other pollutants in the atmosphere. To name a few, air travel results in increased water vapor, sulfur aerosol, and soot emissions which have contributed to the warming of the planet (Ritchie, 2024). Furthermore, the water contrails resulting from aircraft flight have significant warming attributes. These other emissions explain around $\frac{2}{3}$ of aviation related warming (Ritchie, 2024). In the near future, aviation is certain to account for an increased share of global emissions as other transport and high carbon emission sectors become more sustainable. Aviation will continue to be a significant source of GHG emissions until future policy and technology are implemented (Ritchie, 2024).

The technical portion of this capstone project is a proof of concept model to demonstrate the ability to harvest electrical energy from the movement of ambient air during the rises and falls of an airship in flight. Airships change their altitude via a ballonet system. The ballonet is a smaller balloon-like structure within the main airship body that can be filled or emptied with ambient air to change the density of the airship which in turn results in the airship ascending or descending (Lagor, 2024). In the first stage of the technical project the model airship will be tethered and will cause motion via a cable to a generator to create electricity. In the second stage,

propellers will be added to the now free flying airship to generate electricity as they spin due to the passage of ambient air during ascent or descent.

The STS portion of this Capstone process will pertain to the sustainability of aviation. To better understand this topic, research will be conducted in various fields. Such fields include the implementation of sustainable aviation fuel (SAF), infrastructure improvements to existing airports, future aviation technologies, and governmental policy. To achieve this I will collect and analyze a wide range of academic articles, policy proposals, and current government policy. The governmental policy I intend to include in this investigation will also be taken from other nations in addition to the United States in order to create a thorough understanding of what policy ideas exist within our current world to create a more sustainable aviation industry. My aim with this research is to examine how both new and emerging technologies combined with thoughtful policy can create a more ecological friendly commercial aviation space in a world where air travel is increasingly prominent.

Technical Project

Our group will work with the intention of creating an energy harvesting system for an airship. First, it is important to understand the context in which we are working. The working principle of airships is the inflation of a large balloon-like envelope with a lighter-than-air working gas. Said gas results in a buoyant force that keeps the aircraft in the air. This buoyancy principle is the exact same used when constructing nautical vessels. However, a balloon simply filled with a lighter-than-air gas will have no control over its altitude. To achieve this control, airships employ a ballonet system. Inside the buoyant vessel there are smaller, inflatable, vessels as seen in Figure 2.

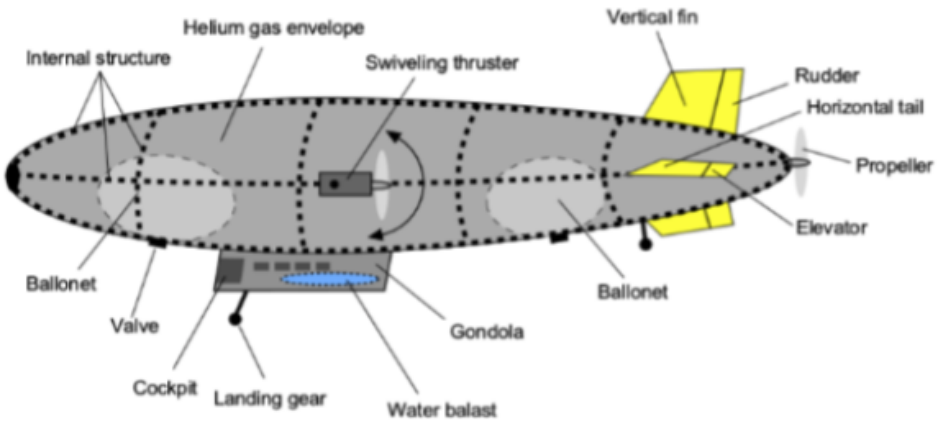

Figure 2. Diagram of an airship and various key components such as the ballonet, (Lagor, 2024).

To descend, the ballonets are filled with ambient air from the surrounding atmosphere. When this occurs, the density of the working gas increases resulting in the descent of the aircraft. To ascend the opposite process is performed by emptying the ballonets of ambient air (Lagor, 2024). The principle goal of this capstone project is to design a model airship and an apparatus that can harvest energy via the passage of air around the aircraft during ascent and descent.

Our group's first working model is intended to be simple, and prove that resistance to the up or down motion of the model airship can generate electricity. To accomplish this, a wood frame will be constructed which includes a rectangular system of pulleys (one pulley at each corner of the rectangle). One of the pulleys will be mounted to a DC motor which when spinning, will generate electricity. Threaded through the pulleys is the tether, the material of which has not yet been selected, and attached to the tether is the model airship. The model airship is attached such that it is suspended within the steel frame as seen in the schematic below.

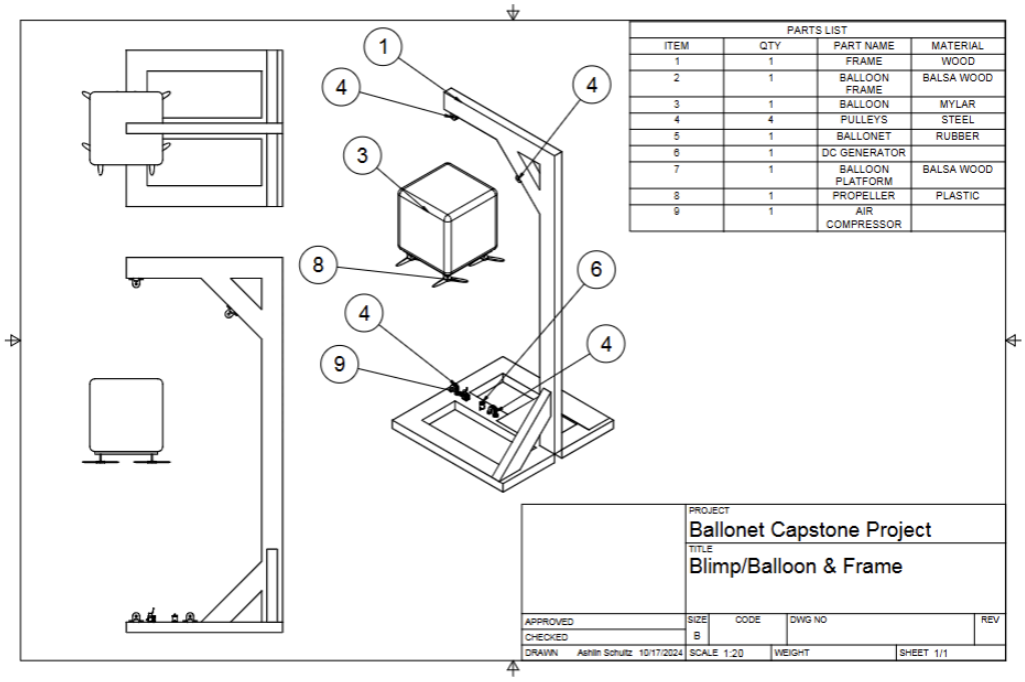

Figure 3. Rough CAD assembly model showing all components in place. Important to note that the electronics involved are beyond the scope of this CAD model.

The main internal structure of the model airship will be constructed from balsa wood and covered with mylar to create a sealed vessel for the working gas. The ballonet will operate via a smaller balloon (material TBD) within the main vessel and will incorporate a two way valve and air compressor. The propellers on the bottom of the model are also intended to generate electricity as the spin during ascent and descent. The final goal of this project is to create an untethered aircraft that has all electrical components onboard and generates electricity solely from the spinning of the propellers as the airship changes altitude. This will be a proof of concept that will provide an apparatus to enhance the sustainability of current and future airships.

STS Project

With the world increasingly becoming impacted by human driven change there has arisen concerted efforts to improve sustainability. Such efforts are present within the aviation industry. It is incredibly important to study the effect of aviation on the environment as it bears some of the responsibility for the increasingly devastating effects of climate change. Air transportation requires especially close attention and study because of the difficulty of its decarbonization. While electric cars now make up 18% of new vehicle sales (Ritchie 2024), the same cannot be said for electric airplanes for which to date are not comparable alternatives of similar capacity or range to traditional airplanes as evident by current electric airplanes' smaller size and placement on short routes (Delbert, 2022). It is simply that there are no viable alternatives to combustion based propulsion for aircraft in today's day and age (Nelson & Reddy, 2017). The issue of sustainable aviation is also of paramount importance because by 2050, air travel is projected to make up 27% of total carbon emissions (Delbert, 2022). This substantial increase in the share of global emissions is due to other industries' abilities to decarbonize more readily and easily. For this reason, air travel looks to become one of the primary drivers of climate change in the near future and its paths to sustainability must be studied.

Currently there are attempts to minimize the impact of aviation on the environment that I will explore. The first of these is technological and one example is sustainable aviation fuel (SAF) which are often termed biofuels. These originate from non-fossil fuel sources such as fermentation or from oils from vegetables or microbes and can improve the eco-friendliness of flight (Nelson & Reddy, 2017). There are also governmental policies in place to increase SAF adoption. One notable example is in the United States with president Biden's SAF Grand Challenge which sets the goal to use three billion gallons of SAF by 2030 with the additional goal of having all aircraft fuel be SAF in the United States by 2050 (United States Government

Accountability Office, 2023). Other technological advancements have been put forward with the goal of minimizing emissions with some being improvements of airport infrastructure (United States Congress House Committee on Transportation and Infrastructure Subcommittee on Aviation, 2023). Others are more focused on improving aircraft design and propulsion type (Deshpande, et al., 2022) and (Budd, et al., 2013). There are also policy driven attempts to minimize aviation's impact on the environment. A notable example of this is the banning of short haul flights. This idea has the most traction in Europe with various countries proposing bans of short domestic flights when alternative transport options of similar durations are available (Dobruszkes, et al., 2022). Additional policy ideas include carbon budgets that entails an emissions trading system (Budd, et al., 2013).

My intention in the future STS Research paper is to explore how these policy and technological developments will help increase the sustainability of an ever increasing transportation sector. I plan to view this issue through a System Analysis lens. In Sociotechnical Research (STSR), this viewpoint takes into consideration all of the connections between interrelated components in a system (Neeley, 2024). The first step in this analysis is to define set categories (Neeley, 2024). For my research these two categories are governmental policy and technological improvements. The second step to conducting STSR research through a System Analysis lens is to understand how the various components relate to one another (Neeley, 2024). This will be explored further in depth during next semester's research, however, it is evident that policy can have an impact on the technological developments being made, and that new technological developments can require that new policies be created. The third and final part of this analysis is to create a map or model of the various interactions between components in the given system (Neeley, 2024). This will be done in more detail during next semester's research.

Conclusion

Through my STS research, it is my intention to highlight the current state of sustainable aviation in both the technological and political space. By understanding the complex relationship between policy and technology through System Analysis I hope to present a best course of action for reducing GHG emissions caused by air travel. Both spaces play a role in the current aviation industry, so it is important to identify the strengths of policy and new technologies. It is just as important to identify the weaknesses of each method in increasing the sustainability of air travel.

Through my group's technical research, it is our intention to develop a propeller-like system that can harvest electrical energy from the passing of ambient air during the ascent and descent of an airship. This system will be used to charge an onboard battery, and contribute to the more sustainable operation of the airship as energy can be harvested from routine maneuvers. The initial version of this system will see the model airship tethered by cable to a frame with energy generation occurring caused by the context of the tether on a pulley attached to a DC motor. With this acting as the proof of concept a free floating model airship with propellers attached to DC motors will be constructed. In conclusion, our final goal is to demonstrate the feasibility of implementing a propeller-based energy harvesting system to current and future airships allowing them to operate more efficiently and sustainably.

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