SOLAR POWERED AUTONOMOUS RECONNAISSANCE CRAFT (SPARC)

SOLAR SPOILING SKY SOLUTIONS

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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

How can airplanes be made to pollute less?

Current ambitions towards a world of carbon neutrality have put aviation in its crosshairs, and why not? Airplanes pollute the most out of any mass transit system. However, it soon becomes clear that addressing aircraft emissions is a complex problem. Airplanes do not pollute the same way as other transit systems. While internal combustion engine (ICE) vehicles mainly emit carbon-based pollutants like carbon dioxide and carbon monoxide, studies show that the worst pollutant of airplanes is not, in fact, their carbon emissions, but other components called short-lived climate forcers (SLCFs) (Sacchi et al., 2023). Essentially, SLCFs like methane and ozone are compounds that affect the atmosphere but are not necessarily carbon-based, it is a more specific term for "pollutants." Although SLCFs are "short-lived," this lifetime is still roughly two decades for some compounds. One kind of SLCF, water vapor, would not typically be seen as a pollutant, but at an airplane's cruising altitude, excess water vapor can form clouds that trap heat in. All in all, roughly 80% of aviation's climate impact is not from carbon emissions, but from SLCFs. With aviation's massive industry size and current growth rate, experts worry that if action is not taken soon, it may be too late to make a sizable impact without spending obscene amounts of resources.

What is the best way to make aviation more environmentally friendly, then? There have been many approaches to this, such as greener, alternative fuels or carbon capture technology, but perhaps the most notorious approach in recent years is the implementation of electric propulsion. All major airliners use conventional combustion-powered engines. What if we could remove the engines altogether and replace them with electric motors, and better yet, solar panels? After all, the electric automobile market has surged in recent years. Would it not be simple enough to apply the technology to air travel? The technical section addresses the engineering efforts necessary to create and implement a solar powered/electric propulsion craft in the real world. The STS section, on the other hand, discusses whether or not such technology could be displacing other viable solutions.

Technical: Development of SPARC (Solar Powered Autonomous Reconnaissance Craft)

How can undergraduate students at UVA design and build a feasible solar-powered aircraft that can achieve sustained, autonomous flight using current technology?

Aviation is a major contributor to greenhouse gas emissions. Over 2.5% of the world's CO_2 emissions comes from aircraft (Ritchie, 2024). Finding ways to reduce aviation's carbon footprint in an ever-growing industry is critical for long term sustainability. Despite the advances in traditional propulsion technology which have allowed for more efficient engines, most aircraft still rely on traditional fossil fuels (Clark & Mouawad, 2010). A solar powered aircraft presents a solution to this problem by harnessing energy from the sun to power the propulsion systems. Advances in harnessing solar energy, lightweight materials, and new and innovative aerodynamic designs have proven that decarbonization of the aviation industry can be achieved through solar powered aircraft (Güntürkün & Çınar, 2021). Aviation is a popular mode of transportation, used for both business and leisure. Often, it is the most convenient form of transportation for long distance travel. That is why its sustainability is important to ensure its continuance in the future. An industry that is unsustainable is an industry that cannot thrive in the long run as it sacrifices our environment for its success. In addition, there is an economical benefit in that aviation that can be made more energy efficient and non fossil-fuel reliant will be cheaper to operate.

This project aims to create the Solar Powered Autonomous Reconnaissance Craft, or SPARC for short. SPARC is completely solar reliant for power. Producing this aircraft explores sustainability in aviation, including what compromises are necessary to make to implement environmentally-friendly concepts. For example, SPARC will not have a pilot inside to minimize the on-board weight and therefore minimize the amount of energy needed to sustain flight. This is also important for safety reasons, as an uninhabited craft presents less risk to a pilot. Since the craft is experimental, maintaining safety is of a high priority.

While the project is novel, it is not the only one of its kind. Solar Impulse II was a solar-powered long-range aircraft designed to sustain long periods of flight. In fact, it holds the record of the first flight around the world powered by solar energy (Solar Impulse Foundation). Airbus, the aviation giant, has also developed the Zephyr, the solar-powered drone that broke the record for longest unmanned flight and was just shy of breaking the record of manned flight (Tingley, 2022).

We ourselves are attempting to push the boundaries of solar power technology by maintaining continuous operation with at least 12 hours of daytime flight. To complete such an innovative project, resources must be ample and diverse. All resources available to us as undergraduate Aerospace Engineers at the University of Virginia will be used including the well-practiced faculty, though we will also use tools outside of the university, such as Computer Aided Design (CAD) software.

The Fall 2024 semester will involve us conducting research to build a background on aircraft design with a focus on solar power/electric propulsion. We will apply these concepts as well as prior-learned Engineering concepts to conceptualize a structurally and dynamically sound aircraft using the aforementioned tools. In particular, we will split off into Aerodynamics/structures (Aerostructures), Systems/Dynamics (Systems), and Propulsion teams to tackle the separate challenges for designing an aircraft from the ground up. For example, as a member of the Aerostructures team, I will be working on appropriate wing structure to prevent bending and deformation under flight. Another team member is tackling the fuselage and yet another the empennage (tail structure). The Aerostructures team will investigate special materials that can be used for our goals. Systems will focus on overall design (such as placement of propellers/batteries, payload, wings, etc) for stability in flight. Propulsion will focus on propeller and battery selection to guarantee our flight needs. Financial needs must also be met, as even though we will likely not be able to see the project to its conclusion due to time constraints, we intend to test individual components of our craft to ensure proper function.

STS: Solar Spoiling Sky Solutions

Are solar/electric solutions to aviation emissions displacing more viable options?

Solar power/electric propulsion pops up in other forms of transportation, but to say that it is a logical next step to aviation is fueled by technological determinism. The idea that electric propulsion and solar technology are the next step of air travel simply because they are becoming more common in other sectors like housing and automobiles is jumping quite a few steps.

To answer the question properly, we must investigate what other avenues researchers are considering for lowering aviation emissions. One alternative is called sustainable aviation fuels (SAFs). These pollute the air similarly to conventional hydrocarbons, but are more efficient and have less of an impact on the environment. Researchers think they have potential, but are not ready to be mass marketed, nor are they ready to be integrated into standard fueling infrastructure (Qasem et al., 2024). Development of more efficient aircraft is another route, but the associated R&D time and costs for minimal improvements may not be worthwhile, not to mention the excruciating process of overhauling old designs (Abrantes et al., 2024). There is also the method of reducing the number of flights taken. Airline profit margins are quite thin, so airlines are incentivized to fly as often as possible with as many people as possible to keep up with operating costs (Gössling & Dolnicar, 2023). This means they are almost always polluting at maximum. If the industry could be restructured to accommodate a lesser flight frequency, emissions would be instantly cut. Globally, the "Flight shaming" movement has found some traction in Europe, with Dutch airline KLM going so far as to encourage flying less ("Flight shame" could halve growth in air traffic, 2019). This is not to say that passengers should cease to travel. Instead, resources could be spent on improving other transportation types, such as public transport and the expansion of railway systems with high speed electric trains in the United States (which *are* well developed and well implemented globally).

The point of this is not to argue which solution is best, whether it be solar or otherwise, but to demonstrate why there are concerns about resources allocated to solar development. It would be quite a shame if a more optimal solution was overlooked because solar aircraft garnered all the attention.

There have been moves in recent years to investigate the feasibility of electric aviation. The FAA, through its Ascent sustainability program, awarded hundreds of thousands of dollars in research funds to universities in 2020 to assess and develop power systems for electric aircraft (Schwab et al., 2021). The state of Washington, USA, a major stakeholder in aviation, known for hosting major Boeing facilities, conducted a study in 2020 to determine what it would take to adopt electric aircraft in its infrastructure namely to meet climate goals (WSP et al., 2020). Knowing that the government is generally both slow to adapt to new technological trends and also representative of its constituents, interest from Washington state and the FAA as a whole could indicate a larger backing of solar interest. The effects of both studies will need to be investigated. Interest in solar power has only truly blossomed in recent memory, so discourse about electric aircraft is sparse. This makes sense, considering airplanes were only developed in the last century, in which climate safety was an afterthought.

Both the FAA and Washington state represent a sect of sociotechnical imaginaries, or groups that aim to use innovative technology to advance social issues, in regards to climate safety. Through this, conclusions can be drawn about their plans for the future, such as who the technology is designed for and who is limited by it. Applying the concept of sociotechnical imaginaries also leads to discussions of who has power, who leads the discourse in regards to climate change, which will be investigated. Such big entities like the federal and state government clearly have the power to shift resources and interest.

Since the topic involves research, public understanding of such science is important to consider. For one, some airlines have pledged to achieve zero carbon emissions. However, the reception of this message depends on the public’s understanding of the science behind emissions. As seen earlier, not all emissions are carbon-based. While being carbon free is certainly an accomplishment, it may not be to the magnitude that the people believe it to be. In this way, the public shapes advances in aircraft emissions, potentially shifting interest towards one specific hype or trend. You can see how concerns may form that interest may be set on solar/electric aircraft judging by modern standards. At the same time, the quality of the solution to aviation emission affects its implementation in airlines and worldwide results to the environment, affecting or disaffecting our quality of life in the future.

Literature/Methods

Many studies have been done on aircraft emissions. These are invaluable to the project as they describe acutely the sources of emissions with quantifiable data. Some go so far as to assess viable alternatives such as “A recent review of aviation fuels and sustainable aviation fuels” (Qasem et al., 2024). Although they are often a step above the reading and technological comprehension of an Engineering student, they usually include figures and charts that summarize major points. These can be taken and dissected as illustrative evidence. There are also a growing number of studies on strategies to accomplish green flight, such as the National Renewable Energy Laboratory (NREL) report on aircraft electrification, which draws on other efforts conducted at the state and federal level to assess what it would take to implement electric aircraft (Schwab et al. 2021). These will be used as background information and evidence to assess viability of green flight strategies. A few papers also mention how the government aids a bloated airline industry into polluting more than it really needs to, which will also be used as evidence for arguments, but also point towards potential government regulations that can be used. In particular, Gössling, in "A review of air travel behavior and climate change" paints a particularly damning picture regarding the government's role in climate change (Gössling, 2020). These articles generally present evidence that can be adapted into my paper.

Government documents will also be helpful in determining where resources are being allocated for what research, such as the previously cited Washington state feasibility study (WSP et al., 2020). These kinds of sources are purely objective information, so they will be taken as evidence of interest in the invested fields. If possible, the people behind the investments can be investigated to determine any potential bias. I will also look at informal sources like press releases, news articles, and polls to uncover where the general consensus (of researchers and the public) lies. These exist, but are scarce in number. It seems aircraft electrification is unfortunately not at the forefront of public conscience. One survey I did find was from 2007, regarding implementing a "green tax" on airline tickets polled respondents in the United Kingdom, which revealed a split between "good idea" and "bad idea," with most respondents leaning towards "bad idea" (ICM Research, 2007). This could add to the argument of government responsibility, suggesting that the traditional methods of government influence are limited by public optics.

Conclusion

With luck, the STS research project will help paint a picture of the research efforts to combat climate change. Furthermore, the STS research project will also give a more intimate knowledge of how science and public interest intertwine. The Technical project will then present a feasible design and manufacturing process for a solar powered aircraft to address environmental sustainability in aviation while also proving that undergraduate students have the skills to do such things. This enables SPARC to be marketable to the aviation industry as a viable solution which in turn presents an outcome to lowering aviation emissions. Of course, aviation only presents one facet of global emissions, but interest in this sector could propel future interest in cleaning up our environment.

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