**Solar-Powered Fixed-Wing Aircraft Design**

(Technical Paper)

**Addressing Increased Runway Incursions in an Aging and Overburdened National Airspace System**

(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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Prospectus

## Introduction

On September 12, 2024 the crew of Alaska Airlines flight 369 discontinued their takeoff roll at Nashville International Airport, braking so suddenly that the crew reported blowing tires during the takeoff rejection. What was the reason for this immediate action? At the same time the Alaska Airlines Boeing 737 was accelerating down the runway, Air Traffic Control cleared Southwest Flight 2029 to cross the end of the same runway, overlooking the potential collision (Muntean, 2024). As the air over the United States becomes more and more congested, near-misses like the one in Nashville occur more frequently than ever before. In just the first five months of 2024 alone, there were 24 category A & B incidents. These are defined to be the most serious type of incident where a collision was narrowly avoided (Raphael & Mott, 2024). Incidents like this make it clear the United States is experiencing an overly saturated and regulatory strained airspace system, leading to frequent near collisions of commercial aircraft at airports across the United States.

In the long term, the growing number of aircraft in the sky presents a significant sustainability challenge for aviation. Each commercial flight contributes to a considerable carbon footprint, and with the rise in air travel over the last five years, the amount of greenhouse gasses released into the atmosphere has become substantial. In 2022, aviation accounted for 2% of global energy-related $CO_2$ emissions, a sector that has grown faster than rail, road, or shipping (Kim & Teter, 2023). This impact is likely to expand as air passenger activity increased by 70% in 2022 alone.

Overall, the public's strong demand for air travel drives the challenge at hand: How do we ensure safe and sustainable air transportation for the future in the context of a thriving aviation industry; one where more and more people are flying than ever before (Osaka, 2023)?

While advancements in aviation have made air travel more attainable for the population, they also contribute to crowded airspace, raising immediate concerns over airport safety and the longer-term need for a carbon-free airspace. Addressing these issues will require a balanced approach that considers the environmental impact of future growth, as well as the regulatory and social barriers to innovation that have resulted in an outdated aviation infrastructure, posing an imminent risk to passenger safety.

**Solar-Powered Fixed-Wing Aircraft Design**

Aviation is a major contributor to greenhouse gas emissions with over 2.5% of the world's $CO_2$ emissions coming from the industry (Ritchie, 2024), and 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, jet powered and piston aircraft still rely on traditional fossil fuels (Clark & Mouawad, 2010). The combustion reactions from burning fossil fuels leaves chemicals, such as nitrogen oxides, that can form harmful ground-level ozone (Royal Society of London, 2009). At high altitudes, the heat and exhaust from the engines also produce contrail tail cirrus clouds, which trap heat and contribute to rising surface temperatures (Lee et al., 2021). A solar powered aircraft represents 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).

The goal of this project is to design a surveillance and exploration aircraft that relies completely on energy harnessed from the sun to power its propulsion system. In doing so, we will address the long term problem of sustainability in aviation. To produce our aircraft, we plan to study existing fully solar powered aircraft such as the Solar Impulse II and Airbus Zephyr concept. These aircraft have demonstrated the most recent developments in solar powered flight, with the Solar Impulse II having conducted the first flight around the world powered solely by solar energy (Solar Impulse Foundation, 2024). We will use innovative design techniques and lightweight materials to optimize the aircraft for its mission.

Additional objectives include aligning our aircraft with market needs by incorporating a highly modular payload bay, enabling easy adaptation for various equipment based on mission requirements. Moreover, the aircraft will push the boundaries of solar panel energy harvesting technology by maintaining continuous operation with at least 12 hours of daylight flight, and carry out flight phases autonomously with limited human input. By fulfilling these objectives, we intend to demonstrate that undergraduate students are capable of designing and building the next generation of aircraft, while pushing the boundaries of current solar panel and energy storage technology in aerospace applications.

To fulfill our project objectives, we intend to use all resources available to undergraduate Aerospace Engineers at the University of Virginia, including stability analysis software (XFLR5, Open VSP), computer-aided design software (Autodesk Inventor 2024, Solidworks 3D CAD), and Computational Fluid Dynamics software (Ansys Fluent) to design a conceptual aircraft that meets our mission requirements. Ansys Fluent will be used to analyze and optimize aerodynamics, focusing on lift, drag, and material selection.

Secondly, we intend to apply for funding to construct a physical subscale model of the aircraft which is capable of sustained flight and will act as a proof of concept of the conceptual aircraft. The goal of the model is to demonstrate static and dynamic stability, controllability, landing and takeoff systems, propulsion performance, and modularity of the payload bay.

Furthermore the team will perform benchtop tests on physical components to demonstrate our concept's feasibility. This includes the construction and testing of a system of solar panels in conjunction with a battery power storage unit as well as a demonstration of our ability to power propulsive motors, servos, and communication hardware with the supply system. These benchtop tests will be instrumental in our trajectory toward a working model.

**Addressing Increased Runway Incursions in an Aging and Overburdened National Airspace System**

Although advances in aviation sustainability will promote long term solutions to an increasingly saturated sky, short term solutions in the form of advances in safety and efficiency are necessary. A runway incursion is defined as "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take off of aircraft" (Federal Aviation Administration, 2022, p. 1). "Over the last two decades, the number of runway incursions at US airports has increased from 987 in 2002 to 25,036 in 2020" (Omosebi, 2023, p. 1). This figure alone shows the importance of increasing safety in aviation, and the imminent risk a busy airspace poses to passengers right now. Not only are there more incidents, but the close calls that are occuring are more serious, including large commercial aircraft with hundreds of people on board. Exacerbating the issue, lack of advancement in aircraft collision detection technology and limited federal aviation administration (FAA) resources make it difficult for the airspace infrastructure to support the increased demand for air travel, posing an imminent risk to traveler safety.

In examining this issue, I am interested in understanding the broader sociotechnical landscape that impacts runway safety. While new technologies may offer potential solutions, barriers such as regulatory constraints, human-system interactions, and organizational resistance can influence how these solutions are implemented. For example, government regulations may slow the adoption of novel technologies, and airline operational priorities could complicate or delay new safety protocols. Additionally, human factors—such as communication challenges between air traffic controllers and pilots, or the cognitive workload of individuals managing a complex airspace—play a significant role in runway safety (DiFiore et al., 2006). Understanding these sociotechnical dynamics is key to identifying solutions that are both innovative and practical. I assume that most barriers to innovation are regulatory, however, I am curious if airlines themselves also play a role in hampering novel and collaborative approaches to preventing runway incursions.

To explore effective ways to reduce runway incursions, I believe the following resources and people will be instrumental: interviewing commercial pilots with firsthand experience in a runway incursion incident, analyzing air traffic control recordings with ground map overlays to identify patterns in incidents, and consulting and reading articles written by experts in aircraft collision avoidance. My approach will be multi-faceted, with case studies serving as a primary method to capture the variety of sociotechnical factors involved. As I stated earlier, runway incursions happen frequently and for a variety of common reasons. Therefore, choosing key examples to study that represent a collection of common causes for runway incursions will be key in supporting likely solutions to the issue. Secondly, a technical and scholarly research method will be taken because I plan to study likely solutions to runway incursions that involve human factors elements (ways to improve cockpit and air traffic control tower design to make imminent collisions more aware to pilots and air traffic control personnel), and some innovative technology that can prevent runway incursions regardless of human action (Chang & Wong, 2012). I will further address the social hindrance from regulatory authorities and significant aviation companies to implementing these key solutions which would lead to major improvements in safety for passengers across the U.S. and the world.

**Conclusion**

In order to promote a safe and environmentally sustainable aviation future in the context of an increasingly dense airspace system and heightened demand for air travel, both short term and long term solutions are necessary. By designing an autonomous aircraft powered by solar energy alone, I will address long term sustainability of the aviation industry by creating an aircraft where greenhouse gas emissions are reduced significantly for each flight. Furthermore, this aircraft will push the boundaries of solar powered technology and promote its use in other facets of the aviation industry including the commercial aviation sector. Secondly, through research and case study analysis of the causes of runway incursions, I hope to better understand the imminent risk posed to passengers, as well as the social barriers that exist to implementing innovative uses of technology and training to improve traveler safety. In doing so, I will explore human factors and technical solutions to reduce the risk to passengers. In addressing both short and long term barriers, I will address the overall question of promoting a safe and sustainable aviation future in the face of an increasingly saturated airspace system.

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