Thesis Project Portfolio

Solar-Powered Fixed-Wing Aircraft Design

(Technical Report)

Growth through Degrowth: A Critique of Aviation Emissions

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Nathan Ong

Spring, 2025

Department of Mechanical and Aerospace Engineering

Table of Contents

Executive Summary

People worldwide depend on aviation for both business and pleasure. At the same time, sustainability as a response to climate change has risen to the forefront of concerns regarding aviation. In particular, many seek to learn how to solve aviation emissions, which account for 2% of all global emissions, a sizable margin. Governments, airlines, and other interest groups globally attack the problem from different fronts. New airplanes with new technology, adapting business practices, and more. The relationship between a highly regulated aviation industry and its government is not to be taken without consideration, but is not the focus of this paper. Instead, this paper aims to answer the question: What is the best way to approach sustainability in aviation? The historic industry that services billions must evolve to combat modern environmental concerns or risk becoming obsolete or avoided. The engineering behind aviation can spark a technological revolution, or it can vouch for abandoning it altogether.

In terms of engineering, a team of 12 at the University of Virginia has been charged with developing and building SPARC (Solar Powered Autonomous Reconnaissance Craft) by advisor and post-doc researcher Aldo Gargiulo. The project aims to demonstrate that sustainable aircraft is technologically possible and serves real world interests. Specifically, SPARC is a high altitude, high endurance aircraft designed to simulate the functions of satellite imaging on Earth. SPARC is designed to carry an adaptable payload for cameras, radar, or other relevant signal emission technology. The limiting factor for this design comes from the goal of being completely reliant on solar power for propulsion, and being electric by nature. Since current photovoltaic (solar collection) technology and batteries are inefficient in comparison to jet fuel, a large wing area, high aerodynamic efficiency, and low weight is required for success. Thus,

innovative design methods and calculations are required. These include the use of software like Ansys Fluent for computational fluid dynamics, Granta EduPack for material selection, and Solidworks for computer aided design (CAD).

However, a step back must be taken to assess the aviation emissions solutions picture as a whole. Degrowth theory is a modern critique on classic laissez-faire capitalism. In particular, it challenges the idea that materialism-driven innovation, or the idea that we must create new technologies to combat problems, is the most effective approach to sustainability. Instead, degrowth advocates for downsizing large enterprises and investing in local, self-sufficient systems. Many avenues for solving aviation emissions involve the development of new aircraft technology, such as solar/electric propulsion or alternative fuels, innovations that require additional investment and growth in unsustainable sectors. When degrowth theory is applied to these approaches, it reveals weaknesses. Other approaches, like downsizing the aviation industry as a whole, is preferred in accordance with degrowth theory because it decentralizes the transportation sector and can be used in combination with investment in local transit. In this way, degrowth alleges that aviation is inherently unsustainable.

The idea behind SPARC sought a to-scale model of the craft, complete with all features and materials. However, time and budget constraints brought this to a halt. It seems conceptualizing a completely new aircraft from the ground-up takes longer than a year. The $200-per-person budget ($2600 overall) also turned out to be lackluster when most of the aircraft's skeletal structure demands carbon fiber. Nevertheless, I personally found success in deciding and developing the structure of the aircraft, being able to design a fleshed-out CAD model. By utilizing physical static analysis principles, I can justify my work to an academic audience, as well

as explain in layman's terms why decisions were made in design. Simultaneously, although researching application of degrowth theory turned out to be quite the undertaking, as its novel approach is hardly ever implemented (no capitalist industry would ever downsize or decentralize in the context of innovation), the project was able to be easily adapted to evaluating technological approaches instead while still being able to draw on prior research. Although my results in the STS section are simplistic, the idea behind them is novel and controversial enough to promote further discussion in the field. Should the project be continued, subsequent development should be made in improving aerodynamics in SPARC with additional resources beyond the scope of undergraduate students. Likewise, it would be interesting to simulate an industry driven by degrowth principles in the real world to determine the kind of success it might find financially and sustainably.

Acknowledgements

Although we knew each other only as strangers before, the trials of engineering design have brought me to appreciate my subteam lead Christopher Recupero's faith in my design approaches, being willing to work with me not just as a lead, but as a teammate. As a whole, I am grateful to my subteam for being receptive to any ideas that were had, no matter how controversial.

I believe I am also indebted to my technical advisor, Aldo Gargiulo, for proposing the design problem in the beginning, and for being flexible and responsive to any and all complications that were had along the way. His expertise in aerodynamics was also invaluable in contributing to the SPARC design.

I also had the pleasure of writing under Professor Kent Wayland, who encouraged me to open my mind to different ways of thinking about engineering. Without him, I would not have stumbled onto degrowth theory and its application towards aviation. His feedback and teaching structure allowed me to grow as a writer and think about engineering not just as a technical profession, but as a skill used to do the most good for humanity.