University of Technology Sydney

Honours Research Preparation

Task 1 – Preliminary Research

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Introduction

Drones have become a key tool in industries like agriculture and logistics, helping automate tasks like crop monitoring, aerial surveys, and even last-mile delivery. But despite their increasing use, one of the biggest challenges they face is energy efficiency. Many off-the-shelf drones only last 20–40 minutes when carrying a payload (UAV Systems International, 2025), which makes them less suitable for large farms or rural delivery routes.

In agriculture, drones have clear benefits—they reduce manual work, use water and fertilizer more efficiently, and collect real-time data (AgDrone Australia, 2025). Still, they often struggle to operate for long periods or carry heavier equipment. For example, the DJI Agras series, with a 1200 W battery, typically manages only 15 minutes of spraying per charge (DJI, 2025). In logistics, while companies like Amazon and Zipline have explored drone delivery, energy constraints, regulatory hurdles, and cost concerns have slowed progress (Kumar, 2023).

Many current drone designs focus on affordability, agility, or compact size—but not on maximizing energy use. Most rely on trial-and-error setups rather than well-modeled energy profiles. And because there's no standard approach to energy modelling, it's hard to compare designs or predict how well a drone will perform in different conditions (Zhang, Campbell, Sweeney II, & Hupman, 2021).

Improving drone designs through smarter choices in frame geometry, materials, aerodynamics, and power systems could boost flight time and energy efficiency. That, in turn, would lower operating costs, reduce environmental impact, and make drones more practical and scalable.

This report reviews research on how specific design features affect drone energy use. It draws from energy models and experimental studies to identify variables that can be improved using simulations and prototyping. This research sets the groundwork for my capstone project, which will explore how targeted design changes can improve drone energy performance and longevity—especially in agricultural and delivery settings.

Research Question

This project began with some big-picture questions around automation in agriculture. I wanted to understand both the opportunities and the challenges. Some of the questions that guided my early thinking were:

1. How can automation improve labour demands, costs, and time spent in farming?
2. What types of automation are farmers already using, and how widespread is it?
3. What are the main roadblocks to using robotics and automation in agriculture?

After discussions with Dr. Ahmed Al-Zubaydi and refining the focus, I settled on this research question:

How can drone design characteristics be optimized using simulation and modeling to improve energy efficiency and operational lifespan?

Research Articles

The following four articles helped shape my thinking and informed the direction of my literature review and project. Each offers a unique perspective on drone design or energy modelling, and together they highlight both what's known and what's still missing.

Table 1: Summary of Key Articles

Goal	**Summary**	**Outcome**
Energy Consumption Models for Delivery Drones: A Comparison and Assessment		
Author: J. Zhang et al. (2021)		
Journal: Transportation Research Part D: Transport and Environment		
To review and classify existing drone energy consumption models, identifying key variables and assumptions that affect energy use in delivery operations.	The study compared 12 models using unified notation, revealing wide disparities in energy estimates due to differences in drone design, operational parameters, and model complexity. It analyzed integrated, component-based, and regression models, with and without field validation.	Findings highlight the lack of consensus and standardization in drone energy modeling, emphasizing the need for empirical validation and common frameworks to improve accuracy and support informed decision-making in drone delivery planning.
Comparison of Energy Demands of Drone-Based and Ground-Based Parcel Delivery Services		
Author: T. Kirschstein (2020)		
Journal: Transportation Research Part D: Transport and Environment		

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Goal	Summary	Outcome
To assess and compare the energy demands and greenhouse gas emissions of drone, diesel truck, and electric truck parcel delivery systems through detailed modeling and simulation.	Using simulation across varying urban and rural conditions, the study found that drones generally consume more energy than trucks, especially in dense urban settings with high customer concentrations. Factors like wind, hover time, and operational radius significantly impact UAV efficiency.	The study concludes that drone-based delivery systems are only more energy-efficient than trucks under specific rural conditions with low customer density and favorable weather, while electric trucks remain the most energy- and eco-efficient option in most scenarios.
Autonomous Multi-Rotor UAVs: A Holistic Approach to Design, Optimization, and Fabrication **Author:** A. Aniruth et al. (2023) **Conference:** International Conference on Mechanical and Aerospace Engineering (ICAMAE)		
To establish a comprehensive methodology for the design, optimization, and fabrication of autonomous multi-rotor UAVs tailored to specific applications, focusing on structural integrity, material use, and autonomous payload delivery.	The study developed and demonstrated a step-by-step process from conceptual design through structural and CFD analysis, material selection, and fabrication using advanced techniques like vacuum bagging and 3D printing. It also integrated autonomous object detection and payload deployment using ROS and YOLOv5.	The holistic approach successfully produced and validated a lightweight, efficient, and application-specific quadcopter with autonomous capabilities, demonstrating the methodology's potential for widespread UAV development in various industries.
HALE Multidisciplinary Ecodesign Optimisation with Material Selection **Author:** E. Duriez et al (2022)		

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Goal	Summary	Outcome
To integrate structural material selection into a multidisciplinary optimization framework aimed at minimizing the CO_2 footprint of solar-powered High Altitude Long Endurance (HALE) drones.	Using a modified version of OpenAeroStruct, the study incorporates material choice as a continuous design variable to explore trade-offs between weight and emissions. The framework couples aerodynamic, structural, energy, and environmental models to assess total drone emissions. Results show that lighter materials often also minimize CO_2 due to cascading effects on battery and solar panel requirements.	The framework effectively identifies optimal materials and drone configurations for reducing environmental impact. It highlights that for sustainable UAV design, eco-materials must closely match conventional materials in performance to avoid offsetting benefits due to added weight.

Comparison and Analysis

Article 1: Zhang et al. (2021) review various drone energy consumption models, comparing 12 different approaches under a unified framework. Their work makes it clear that energy predictions vary a lot depending on the assumptions, model type, and drone specs used. This paper is solid theoretically and calls for more real-world data to validate models. It set the stage for understanding what variables truly matter in drone energy use.

Article 2: Kirschstein (2020) compares energy and emissions for drone, diesel, and electric truck deliveries. While not focused on drone design, the paper offers valuable insights into operational conditions that impact energy use, like customer density and weather. It assumes fixed drone configurations, leaving room for exploration into how design could help improve those results.

Article 3: Aniruth et al. (2023) present a hands-on approach to building multi-rotor UAVs. Their process includes CFD analysis, material selection, and advanced manufacturing. While they don't dive deep into energy data, they show how each design decision—from frame to software—can affect overall performance. It made me think more about the practical side of implementation.

Article 4: Duriez et al. (2022) focus on sustainable design, using a multidisciplinary framework to reduce emissions in high-altitude drones. The approach is technical and forward-thinking but geared more toward HALE applications than agriculture. Still, it shows how integrating material selection early on can influence long-term performance and environmental impact.

Together, these papers show gaps in how energy efficiency is addressed across simulation and design. None focus specifically on agricultural drones or systematically test how different designs influence real-world energy consumption. That's where my project aims to contribute—by linking simulation, design, and testing in an agricultural context.

Conclusion

This preliminary research helped clarify what's been done in the field and what's still needed. I found that while there are many models and design strategies for drones, few tie those elements together in a way that's grounded in both data and practical use.

Based on what I've learned, my capstone project will use a multidisciplinary approach. I'll explore how changes across mechanical, electrical, and software subsystems affect energy use. Specifically, I'll investigate:

- Structural design: frame geometry, aerodynamics, and weight distribution
- Electrical systems: battery efficiency, parasitic loads, and powertrain configuration
- Software: flight paths, trajectory planning, and environmental adaptability

I plan to test each subsystem individually, as well as assess how they work together. I'll use modelling tools like CFD, as well as flight data or testbeds where possible. The goal is to move from theory into practice, finding actionable ways to make drones more efficient and reliable for agriculture and similar industries.

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