**University of Leicester**

**School of Engineering - Les Booth Studentship 2025**

**Project 4. Thermal-Aware Decision-Making for Autonomous Low-Altitude Economy Systems**

Dr. Xuefang Wang - xw259@leicester.ac.uk

|  |  |
| --- | --- |
| **Project Title** | Thermal-Aware Decision-Making for Autonomous Low-Altitude Economy Systems |
| **Project Highlights:** | 1. | Develop a multi-layered heat-aware decision framework combing thermal modelling and low-level control to adapt flight behavior |
| 2. | Generate energy-efficient and safe low-altitude flight trajectories |
| 3. | Incorporate onboard heat-transfer modelling and sensing into the control architecture |
| **Project Overview**  |
| The rapid growth of urban aerial logistics has made autonomous delivery drones a promising solution for last-mile transportation. Operating in low-altitude urban environments, these drones must navigate congested airspace, dynamic obstacles, and variable weather, all while ensuring energy efficiency and reliability. A critical yet often overlooked challenge in this setting is thermal management: sustained flight, frequent takeoffs/landings, and compact electronic systems generate significant heat, which can degrade performance or even lead to failure.This project proposes a novel, thermally informed decision-making and control framework for autonomous aerial delivery vehicles. By integrating optimal control engineering with real-time heat transfer modeling, the framework enables drones to plan and execute delivery missions that are not only safe and efficient but also thermally sustainable.Key elements of the project include:* Heat-transfer modeling of critical UAV components (e.g., battery packs, propulsion units, embedded processors) based on urban thermal environments—factoring in solar radiation, building-induced wind tunnels, and ambient heat.
* A model predictive control (MPC) scheme that jointly optimizes trajectory, energy use, and thermal states over a delivery route.
* A decision-making module that evaluates trade-offs between flight duration, package weight, altitude, and expected thermal loads—guiding the drone to delay, reroute, or adjust speed for thermal safety.
* Integration of low-altitude economy metrics, such as energy-per-distance and thermally constrained mission range, into the decision logic to enhance delivery throughput without compromising system health.

This interdisciplinary project bridges heat-transfer physics, autonomous robotics, and optimal control theory to deliver a scalable solution for thermally aware urban air mobility. The results are expected to contribute to safer, longer-lasting, and more energy-conscious aerial delivery systems, paving the way for resilient drone operations in dense urban environments.**A diagram of a diagram  Description automatically generated***This diagram illustrates the hierarchical structure of a heat-aware autonomous UAV control system. At the top, a* ***Mission Maker*** *determines flight missions and selects thermally safe navigation strategies in uncertain environments. The generated decision is passed to a Path Planner, which computes optimal trajectories that balance energy consumption, safety, and thermal constraints* |
| **Methodology**  |
| The proposed framework integrates real-time thermal modeling with optimal control and decision-making for autonomous aerial vehicles. First, a lumped-parameter heat-transfer model is developed for key UAV components, capturing internal heat generation and environmental interactions during flight. Second, this model is embedded into a Model Predictive Control (MPC) scheme that jointly optimizes flight trajectory, energy efficiency, and thermal safety over a finite horizon. A decision-making layer employs a Markov Decision Process (MDP) or Reinforcement Learning (RL) to evaluate mission-level strategies under varying thermal and operational conditions. Moreover, simulations in realistic urban environments are conducted using a co-simulation platform combining MATLAB/Simulink, CFD-based heat maps, and UAV dynamics. Key performance metrics include mission success rate, thermal violations, and energy use. Finally, the framework will be validated through hardware-in-the-loop experiments using a quadrotor tested equipped with onboard thermal sensors. |
| **Further Reading:** | 1. D. Scott, S. G. Manyam, I. E. Weintraub, D. W. Casbeer and M. Kumar, “Noise Aware Path Planning and Power Management of Hybrid Fuel UAVs”, *IEEE Transactions on Automation Science and Engineering*, vol. 22, pp. 8227-8238, 2025. https://doi.org/10.1109/TASE.2024.3481998.
2. Y. Wu, D. Wen, A. Zhao, H. Liu and K. Li, “Intelligent soaring and path planning for solar-powered unmanned aerial vehicles”, [*Aircraft Engineering and Aerospace Technology*](https://www.emerald.com/insight/publication/issn/0002-2667)*,* vol. 96, no. 4, pp. 514-529. <https://doi.org/10.1108/AEAT-05-2023-0138>.
3. C. T. Aksland, P. J. Tannous, M. J. Wagenmaker, H. C. Pangborn and A. G. Alleyne, “Hierarchical Predictive Control of an Unmanned Aerial Vehicle Integrated Power, Propulsion, and Thermal Management System”, *IEEE Transactions on Control Systems Technology*, vol. 31, no. 3, pp. 1280-1295, 2023. [https://doi](https://doi/).org//10.1109/TCST.2022.3220913.
 |