Project Management Plan
for
Development of a control system for flapping wing Aerial vehicle

Date
29 August ,2024

Executive summary

This document contains the plan for the project titled "Development of Control System for Flapping Wing Aerial Vehicles." The project aims to improve control and stability for a Flapping-Wing Micro Aerial Vehicle (FW-MAV) by designing and implementing a sophisticated control system. To accomplish exact control over pitch, roll, and yaw, sophisticated wing control systems will be employed.

Project Overview

This project is motivated by the need to simplify the control mechanism of tailless flying robots by integrating robust control systems. It promises increased efficiency and reduced complexity. It can benefit applications like environmental monitoring and search and rescue operations. The project scope includes the development of the control system, its implementation in a simulated environment, prototype fabrication, and rigorous testing to validate performance.

Objectives

To design and develop a control system for the FW-MAV that manages wing flapping dynamics and achieves stability in flight. This will involve research, design, development, and testing of the FCS by November 15, 2024.

Implementation of the FCS in a simulated FW-MAV environment to evaluate its performance under various conditions. Main focus will be refining the control algorithms based on the results of simulation. This phase will be completed by February 28, 2025.

FCS will be adjusted to achieve stable vertical and horizontal motion during physical tests, with a focus on proper roll, pitch, and yaw control. It will be finalized by April 30, 2025.

Work Breakdown and Schedule

The project structure includes design of the control system, simulation testing, and hardware implementation phases. A detailed Work Breakdown Structure (WBS) and Gantt chart will reveal the project's timeline and tasks.

Budget and Resources

There is a budget of $800 per person, allocated for software, hardware, and materials. Additional funding may be sought through supervisor contributions or external sponsorship if required. The budget covers essential resources like sensors, motors, 3D printing materials, and microcontrollers.

Stakeholders and Communication

The project team comprises three members (Akshay Suresh, Mohammad Jalis Mahmood, and Raj Sitaram Kadwani) and one supervisor (Prof Peng Shi) and one co-supervisor (Dr Xin Yuan). Regular communication is maintained through weekly meetings, MS team channel and emails.

Quality Assurance

Quality will be maintained through review process including design and final reviews. Computer modelling and other hardware components will be verified to ensure accuracy and reliability of the project.

Risk Assessment

Key risks such as inadequate FCS performance, hardware failures, and sensor inaccuracies were identified. Simulation testing, high-quality material usage, regular sensor calibration, and thorough software testing these risks will mitigated.

References

A detailed list of references is provided to support the project's foundation and methodology.

This executive summary provides an overview of the project's aims, objectives, and management strategies, ensuring that all critical aspects are addressed for successful completion.

Contents

Tables and Figures

1. Introduction

Development of control system for flapping wing aerial vehicles involves the development of control system for highly specialized, light weight flying robot designed to replicate the flight capabilities of insects. With the help of this control system this robot aims to achieve stable controlled flight without the use of traditional tail stabilizers, which are found in most flying robots. It utilizes advanced wing control mechanisms to manage its altitude in space.

1.1 Background and motivation

Recent research in biomimetic has explored insect flying mechanism to enhance small scale flying robot. Studies show that insect by adjusting wing kinematics, such as stroke -plane and wing twist insects control their flight. Existing models like Nano humming bird and Delphy Nimble exhibit various control methods but involves complex mechanism and higher energy consumption.

This project aims to simplify tailless flying robots by integrating a streamline control system that that adjust wing stroke-plane and twist. This promises improved control efficiency and reduce complexity. The motivation is twofold: technologically it increases the efficiency of MAVs , While societally it offers benefits such as reduced energy consumption and enhance capabilities in applications like environmental monitoring ,search and rescue. This project contributes to the broader field of bio inspired aerial robotics.

1.2 Project aims and scope

The " Development of Control system for Flapping Wing Aerial Vehicles " project aims to design and implement a sophisticated control system that enhances the stability and manoeuvrability of flapping wing aerial vehicles. The primary objective is to create a control mechanism that enables precise adjustments in wing stroke plan to manage pitch , roll and yaw effectively. The project scope includes the development of control system, Implementing the flight control system in a simulated FW-MAV and design and fabrication of a prototype featuring this control system followed by vigorous testing to validate its performance. Constraints include managing weight limitations, selecting appropriate actuators , working with a timeline and budgetary restrictions, all aimed at achieving a functional and efficient aerial vehicle.

1.3 Document overview

Following the intoduction rest of the report has been divided into many sections with starting with the Literature Review which lists out and analyses the present and past research and developments in the area of flapping-wing micro aerial vehicles (FW-MAVs).Secondly the Project Objectives shows the primary goals of the project by developing and perfecting the Flight Control System (FCS).Then the Work Breakdown Structure and Project Schedule gives a bibliography and overall structure of the project which further continues to list and explain out the milestones and the scheduled activities of the Gantt chart.

Second, the Budget and Resources Required portion analyses the project's materials, methodology, and other resources required to complete the project, as well as estimating the expenses incurred. The Stakeholders and Communication complement that analyse the most relevant stakeholders involved, and the intended strategies of communication with all the relevant parties, to assure proper flow of information throughout the project. Then, the Quality Management section describes the proposed verification protocols, including data management, to assure the quality of the final product; Finally, the Risk Assessment analyses the potential pitfalls of the proposed trajectory for the project, suggesting mitigation strategies to reduce their impact; and the Reference section, that lists the bibliography of books, articles, and other sources used by the author in developing his/her paper.

2. Literature review

The development of control systems for Flapping-Wing Micro Aerial Vehicles (FW-MAVs) has been heavily influenced by the biomechanics of insect flight, which has been extensively studied over the past several decades. Early research by Vogel (1967) and Srinivasan (1977) provided valuable insights into how insects adjust their wing strokes and respond to visual stimuli, offering a foundation for understanding the complex control strategies that insects use during flight. In the 1980s, foundational work by Zanker (1988) and Ellington (1984) on the aerodynamics of insect hovering and the mechanisms of speed and altitude control further informed the design of MAVs, particularly in replicating the ability of insects to maintain stability in flight.

Nachtigall and Roth (1983) and Alexander (1984) explored the intricate relationship between wing movements and aerodynamic force production in insects, highlighting the challenges of mimicking such dynamics in MAVs. The influence of this research is evident in the design of tailless MAVs and biomimetic ornithopters, inspired by Burton and Kammer's (1971) studies on directional changes and motor outputs in insect flight.

In recent years, advancements in MAV design, such as the DelFly and SmartBird (de Croon et al., 2012; Festo, 2011), have demonstrated the successful integration of bio-inspired features with autonomous flight capabilities. Notable developments include AeroVironment's Nano Hummingbird (Keennon et al., 2012) and the KUBeetle (Phan et al., 2017), which utilize innovative control mechanisms to achieve stable, tailless flight. These MAVs often employ advanced strategies like wing twist modulation and stroke-plane adjustments for effective roll, pitch, and yaw control, as studied by Phan and Park (2016, 2018).

Further contributions to MAV control system design come from research on lightweight structures and efficient control systems, as seen in the Robobee (Ma et al., 2013) and Delfly Nimble (Karasek et al., 2018). Studies by Nguyen et al. (2019) and Phan et al. (2016, 2018) on wing stroke plane modulation and control moment generation continue to enhance our understanding of MAV flight dynamics. Building on these insights, the current project aims to develop a lightweight and efficient control mechanism for the KUBeetle-S, drawing on key principles and innovations from insect flight mechanics and MAV design to achieve a stable and maneuverable FW-MAV.

3. Project objectives

The objectives of this project are designed to align closely with the overall project aims of aerodynamic system identification for a Flapping-Wing Micro Aerial Vehicle (FW-MAV). These objectives are structured according to the SMART criteria to ensure they are Specific, Measurable, Achievable, Relevant, and Time-bound. The objectives provide a clear roadmap for the project, detailing the specific tasks and measurable outcomes required to meet the overall project aims. Each objective is broken down into smaller tasks that contribute to the successful completion of the project

Objective 1

Development of flight control system

Description of objective

Design and development of Flight control system (FCS) for Flapping wing Micro Aerial vehicle

- **Specific:** Create an FCS that manages the wing flapping dynamics, pitch, roll, and yaw of the FW-MAV based on aerodynamic and control theories.

- **Measurable:** The FCS will be considered successful if it meets predefined control performance criteria, such as stability margins and control response times, FW MAV should be able to move pitch roll and yaw with the commands given in real time.
- **Achievable:** This objective is feasible given the available resources, including existing FCS design frameworks and simulation tools. With the past research work and control system design of similar micro aerial vehicles. We will be able to achieve the result.
- **Relevant:** Developing the FCS is crucial for ensuring the FW-MAV can perform controlled manoeuvres and maintain stability during flight.
- **Time-bound:** The development of the FCS will be completed by November, 2024, allowing time for implementation and testing in the simulation environment.

Tasks for Objective 1: Develop the Flight Control System (FCS)

- **Task 1.1:** Research and review existing FCS designs relevant to FW-MAVs.
- **Task 1.2:** Design the FCS architecture and control algorithms.
- **Task 1.3:** Develop the FCS using suitable software tools (e.g., MATLAB/Simulink).
- **Task 1.4:** Test individual components of the FCS to ensure they meet design specifications.

Objective 2

Implement the Flight Control System on a Simulated FW-MAV

Description of the Objective

Integrate and test the developed FCS within a simulated environment to evaluate its performance and refine the control algorithms.

- **Specific:** Implement the FCS in a simulation model of the FW-MAV and conduct simulations to assess the system's performance under various flight conditions.
- **Measurable:** Success will be measured by the FCS's ability to achieve specific performance goals, such as maintaining desired flight trajectories and achieving stability criteria, with performance benchmarks to be established.
- **Achievable:** This objective is realistic with access to simulation software (e.g., MATLAB/Simulink) and the FCS model developed in Objective 1.
- **Relevant:** Testing the FCS in simulation is essential to validate its effectiveness and ensure it operates as intended before real-world implementation.
- **Time-bound:** The implementation and testing will be completed by February, 2025, to allow time for any necessary adjustments before further development phases.

Tasks for Objective 2: Implement the Flight Control System on a Simulated FW-MAV

- **Task 2.1:** Integrate the FCS into the FW-MAV simulation environment(Coppeliasim).
- **Task 2.2:** Develop test scenarios and input data for simulation.
- **Task 2.3:** Run simulations and analyze the FCS performance.
- **Task 2.4:** Refine the FCS based on simulation results and repeat testing as needed.

Objective 3:

Tune the Flight Control System (FCS) for Stable Vertical and Horizontal Motion Using Hardware

Description: Refine and adjust the Flight Control System (FCS) to achieve stable vertical and horizontal motion in real-world hardware, ensuring the FW-MAV performs as expected during physical tests.

SMART Criteria:

- **Specific:** Fine-tune the FCS parameters to stabilize vertical and horizontal motion during hardware testing, with a focus on achieving proper roll, pitch, and yaw control in all axes.
- **Measurable:** Success will be gauged by the FW-MAV's ability to maintain proper roll, pitch, and yaw in all axes, ensuring stable and controlled motion under various conditions.
- **Achievable:** This objective is feasible using the available hardware setup, sensors, and tools, guided by initial simulation data.
- **Relevant:** Hardware tuning is essential to bridge the gap between simulation and real-world performance, ensuring the FW-MAV operates effectively in practical environments.
- **Time-bound:** The tuning process will be completed by April 30, 2025, allowing time for iterative testing and adjustments.

Tasks for Objective 3: Tune the Flight Control System (FCS) for Stable Vertical and Horizontal Motion Using Hardware

1. **Task 3.1**: Design and develop proper structures for roll, pitch, and yaw using 3D printing.
2. **Task 3.2**: Set up the hardware environment, including sensors and control interfaces, to facilitate FCS tuning.
3. **Task 3.3**: Conduct initial hardware tests to identify any discrepancies between simulated and real-world behaviour.
4. **Task 3.4**: Adjust FCS parameters based on hardware test results to improve stability and responsiveness in vertical and horizontal motion.
5. **Task 3.5**: Perform iterative testing and refinement, focusing on achieving proper roll, pitch, and yaw control in all axes.
6. **Task 3.6**: Validate the tuned FCS by conducting comprehensive flight tests to ensure it meets stability criteria in all axes.

This objective is focused on ensuring that your FCS performs as expected in a real-world hardware environment, with a specific emphasis on achieving stable control in all axes of motion

4. Work breakdown structure and project schedule

4.1 Work breakdown structure

Below is a high-level Work Breakdown Structure (WBS) for the project, outlining the key components and activities necessary for the successful completion of the project. The WBS is divided into three levels:

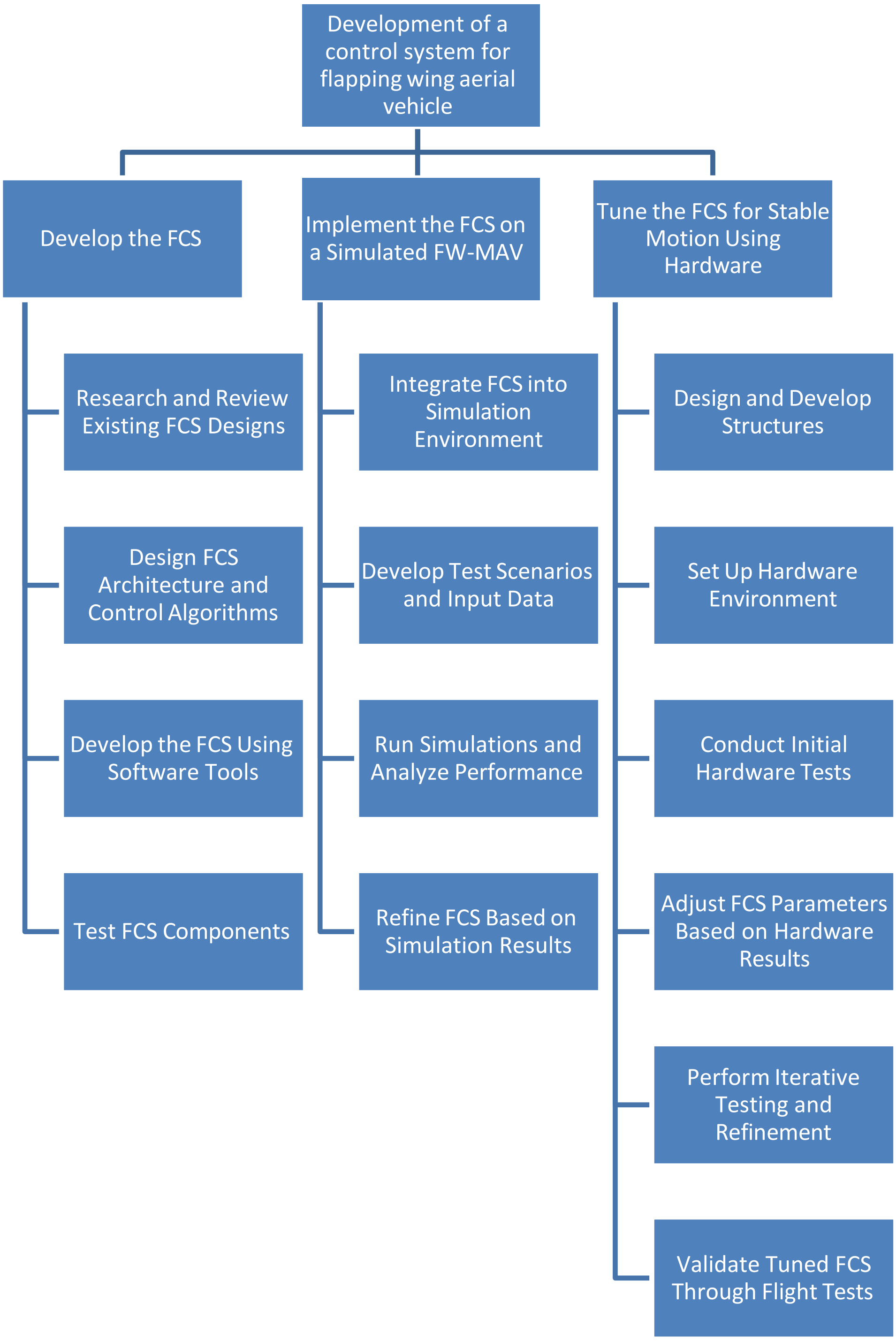
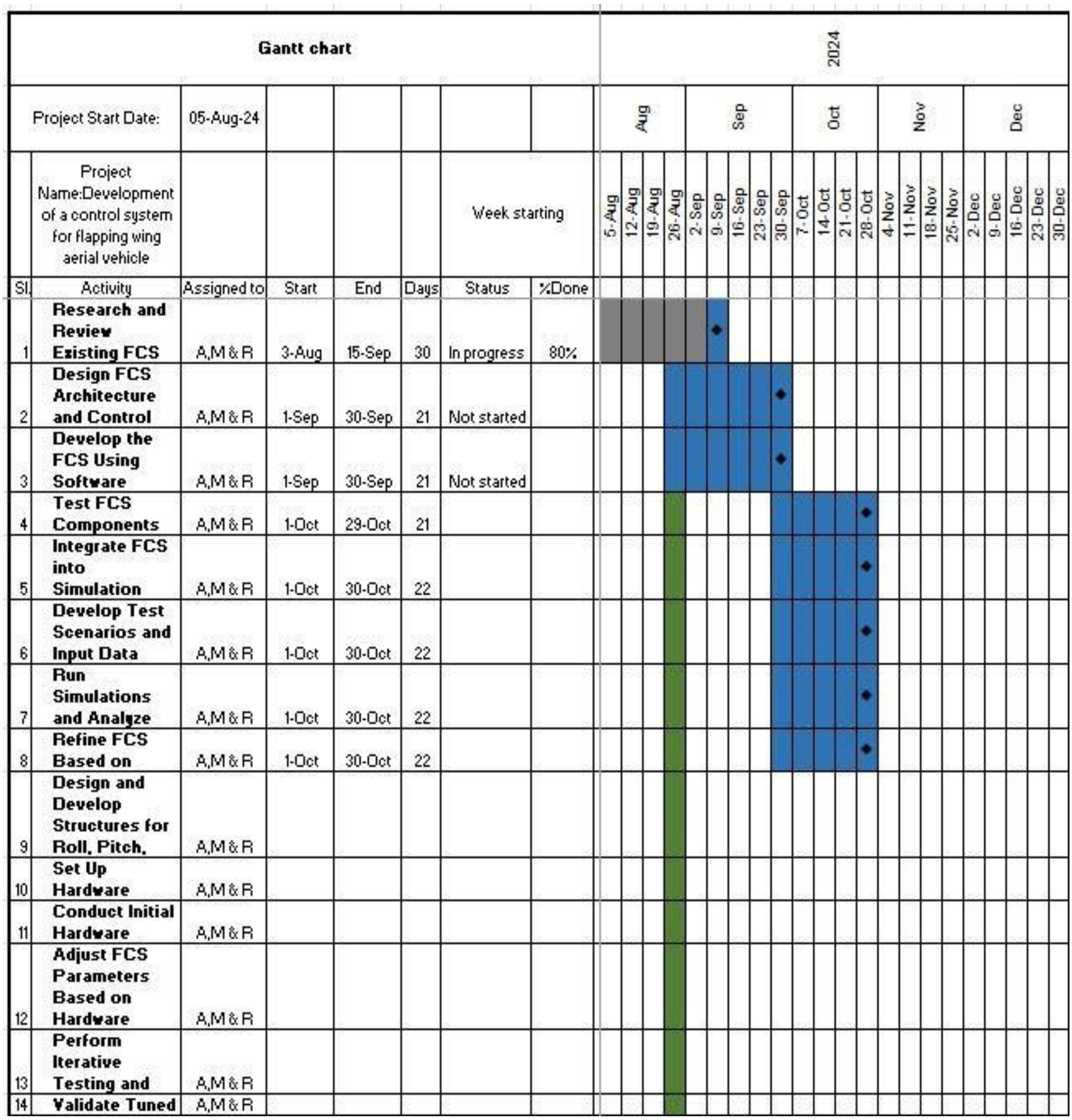


Figure 1:work Breakdown Structure

4.2 Gantt Chart



Project Start Date: 05-Aug-24

Project Name:Development of a control system for flapping wing aerial vehicle

Sl.	Activity	Assigned to	Start	End	Days	Status	%Done
1	Research and Review Existing FCS	A,M & R	3-Aug	15-Sep	30	In progress	80%
2	Design FCS Architecture and Control	A,M & R	1-Sep	30-Sep	21	Not started	
3	Develop the FCS Using Software	A,M & R	1-Sep	30-Sep	21	Not started	
4	Test FCS Components	A,M & R	1-Oct	29-Oct	21		
5	Integrate FCS into Simulation	A,M & R	1-Oct	30-Oct	22		
6	Develop Test Scenarios and Input Data	A,M & R	1-Oct	30-Oct	22		
7	Run Simulations and Analyze	A,M & R	1-Oct	30-Oct	22		
8	Refine FCS Based on	A,M & R	1-Oct	30-Oct	22		
9	Design and Develop Structures for Roll, Pitch,	A,M & R					
10	Set Up Hardware	A,M & R					
11	Conduct Initial Hardware	A,M & R					
12	Adjust FCS Parameters Based on Hardware	A,M & R					
13	Perform Iterative Testing and	A,M & R					
14	Validate Tuned	A,M & R					

Figure 2:Gantt Chart

5. Budget and resources required

Total Budget: $800 per person (Master's Research Project Allocation)

Additional Funding: Potential sources include supervisor funds or external sponsorship.

Estimated Expenditure

Item	Cost ($AUD)	Details/Notes
Software and Licenses		
MATLAB/Simulink License	0	Provided by University
Arduino IDE	0	Open-source software
ROS	0	Open-source software
CoppeliaSim	0	Educational license provided by the University
Hardware and Materials		
3D Printing Filament	150	Estimate based on material usage for developing structures
Sensors (e.g., IMU, Gyroscope, Accelerometer)	200	Essential for hardware testing and FCS tuning
Batteries	20	To power driving motors
Micro Servo Motor	50	To rotate flapping-wing mechanism
Small-Scale Microcontroller (e.g., Arduino)	50	Required for hardware implementation and control interface
SBCs (Single Board Computers)	100	For running the control algorithms and interfacing with hardware
Miscellaneous Electronics (wires, connectors)	50	Required for hardware setup
In-Kind Contributions		
Workshop Staff Time	0	University-provided, 10 hours @ $80/hr (equivalent to $800)
Student Time	0	50 hours @ $80/hr (equivalent to $4,000)
Total Projected Expenditure	**$620**	Remaining budget can be allocated to unforeseen expenses

Table 1:Estimated Expenditure

Software: The necessary software tools, including MATLAB/Simulink, Arduino IDE, ROS, and CoppeliaSim, are provided by the University or are open source. No additional expenditure is required for these licenses.

Hardware: The budget will primarily cover the cost of materials, sensors, microcontrollers, and SBCs necessary for the hardware implementation and testing phase of the project.

In-Kind Contributions: The time spent by workshop staff and students, while not directly billed, is considered a valuable in-kind contribution to the project. This includes guidance from workshop staff in setting up the hardware environment and assisting with 3D printing.

In summary, the project is projected to be well within the allocated budget, with room for adjustments should additional resources or materials be required.

6. Stakeholders and communication

6.1 Team Structure and Roles

Role	Name	Responsibilities
Supervisor	Prof Peng Shi	Provides overall guidance, oversight, and support for the project. Ensures alignment with academic and industry standards and provides feedback.
	Dr. Xin Yuan (Vernon)	Provides technical guidance, feedback, and ensures project adherence to academic standards.
Team Member	Akshay Suresh	Specializes in simulation and design. Responsible for simulation integration, design, and performance analysis of the FCS.
Team Member	Mohammad Jalis Mahmood	Contributes to FCS development and testing. Focuses on high-level planning, hardware testing, and final evaluations.
Team Member	Raj Sitaram Kadwani	Manages hardware setup, 3D printing of structures, and FCS tuning. Focuses on physical integration and hardware testing.

Table 2:Team Members and Supervisor

6.2 Organisational Chart

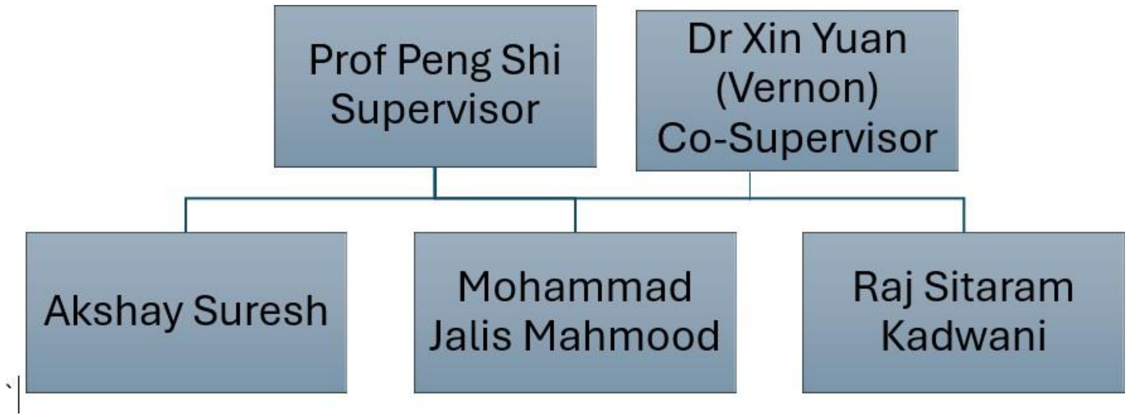


Figure 3:Organisational chart

6.3 Communication and Coordination

Communication Protocol

Aspect	Details
Preferred Contact Details	- **Akshay Suresh:** a1902109@adelaide.edu.au, +61 456889159
	- **Mohammad Jalis Mahmood:** a1906353@adelaide.edu.au, +61 414370753
	- **Raj Sitaram Kadwani:**a1908581@adelaide.edu.au, +61 466750366
Schedule of Meetings	- **Weekly Team Meeting:** Every Monday at 2.00PM
	- We**ekly Supervisor Meeting:** Every Friday at 3:00 PM
	- **Ad-hoc Meetings:** As needed
Purpose of Meetings	- **Weekly Team Meeting:** Review progress, discuss tasks, address challenges.
	weekly Supervisor Meeting: Update supervisors, discuss major issues, plan steps.

	- Ad-hoc Meetings: Address urgent issues or changes.
Responsibility for Queries	- **Team Members:** Direct any questions or issues through the supervisors to ensure clarity.
	- **Supervisors:** Responsible for formal queries to university.
Email Communication	- All team members should be copied on project-related emails for transparency.
	- For specific queries or task-related communications, only relevant members need to be included.

Table 3:Communication Protocol

Project team of Development of control system for Flapping Wing Micro Aerial vehicle consists of two supervisors and three members. Akshay Suresh, Mohammad Jalis Mahmood and Raj Sitaram Kadwani each bring specialized skills to the project, with Raj focusing on hardware setup and FCS tuning, Jalis on handling FCS development and testing and Akshay on simulation integration design and testing. Both supervisors provide overarching guidance, ensuring project aligns with academic and industry standards

7. Quality

Quality of the project will be managed through a structured review process. It includes design, interim and final reviews conducted by the project team, supervisor and possibly an external expert(if applicable). The verification of computer modelling will be through code reviews, test cases and validation of simulation output. Hardware components will be individually tested before integration and entire system will be tested under different flight conditions. Data control is an important factor in testing integrity of project. Replication ot tests and consistency checks ensure verification of data. At the end of the project all files, including design documents , source code and results, will be consolidated into a final project archive and handed over to the project supervisor. This comprehensive approach to quality management will ensure successful completion and delivery of project at highest standards

7.1 Quality Review Process

Review Stage	Timeline	Review Method	Reviewer(s)
Design Review	TBD	Peer Review, Supervisor Review	Project Team, Supervisor
Interim Review	TBD	Peer Review, Supervisor Review	Project Team, Supervisor
Final Review	TBD	Peer Review, Supervisor Review, External Review (if applicable)	Project Team, Supervisor, External Expert

7.2 Verification of Code and Output

Verification Type	Method	Notes
Computer Modelling	Code review, test cases, simulation validation	Cross-check with theoretical expectations and literature
Simulation Output	Consistency checks, baseline comparison	Comparison with research findings
Hardware Component Testing	Individual component testing	Verification before system integration
System Testing	Testing under various flight conditions	In simulation and hardware setup

7.3 Data Verification and Control

Activity	Method	Details
Data Verification	Replication of tests, consistency checks	Lab and simulation data verification
File Structure	Standardized naming, organized directories	Separate folders for designs, code, and results
Data Backup	Daily cloud backup, weekly full backup	Cloud storage and local external drives
Data Handover	Final project archive	Includes all documents, code, and results

Table 4:Quality Review

8. Risk assessment

The risk management table (table 1) identifies key risks that are involved in the project. This assessment covers a wide range of technical, economic, social, legal, environmental, and political factors. Inadequate FCS performance will be controlled by using simulation before head. High-quality materials will be used so that the stress can be managed. Sensor calibration will be done to avoid inaccurate data leading to instability. Software testing and code review will be done to avoid bugs in the system. Patent and compliance-related problems will be tackled by legal advice and maintained standards during testing. By addressing these risks with appropriate mitigation techniques, we will ensure successful development and deployment.

Risk/Event	**Type (P/E/S/T/L/E)**	**Likelihood (H/M/L)**	**Consequence (H/M/L)**	**Control measures**
Inadequate FCS performance during hardware testing	T	H	H	Use of simulation before committing to the design. Then testing and tuning to be done.
3D-printed structures fail under stress	T	H	H	Utilisation of high-quality materials and perform stress test if possible.
Inaccurate sensor data leading to instability	T	H	M	Calibrate sensors regularly and validate data with simulation. Verify each sensor individually.
Supply chain related problems for specialized parts	E	M	M	Regularly maintain inventory and communicate with suppliers. Use of buffer period if required.
Software bugs affecting FCS performance	T	H	M	Conduct code reviews,and perform extensive software testing.
Patent related problems	L	M	M	Obtain legal counsel to ensure violation of existing patents.
Regulatory compliance for safety	P	M	M	Maintain standard during testing and implementing of the design.

Table 5:Risk assesment

Notes:

Risk/Event: what is the identified risk
Type: P – related to political aspects of the design, E – related to economic aspects of the design, S – related to social aspects of the design, T – related to technical aspects of the design, L – related to legal aspects of the design, E – related to environmental aspects of the design
Likelihood: H – High, M – Medium, L – Low
Consequence: H – High, M – Medium, L – Low

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