PROJECT STRATEGY REPORT

CARS4MARS AFRICAN ROVER CHALLENGE 2025

UCT Space Society
Cape Town, South Africa
May 2025

Team Leads

Achal Gupta
gptach001@myuct.ac.za

Irshaad Omar
omrmog005@myuct.ac.za

Team Introduction

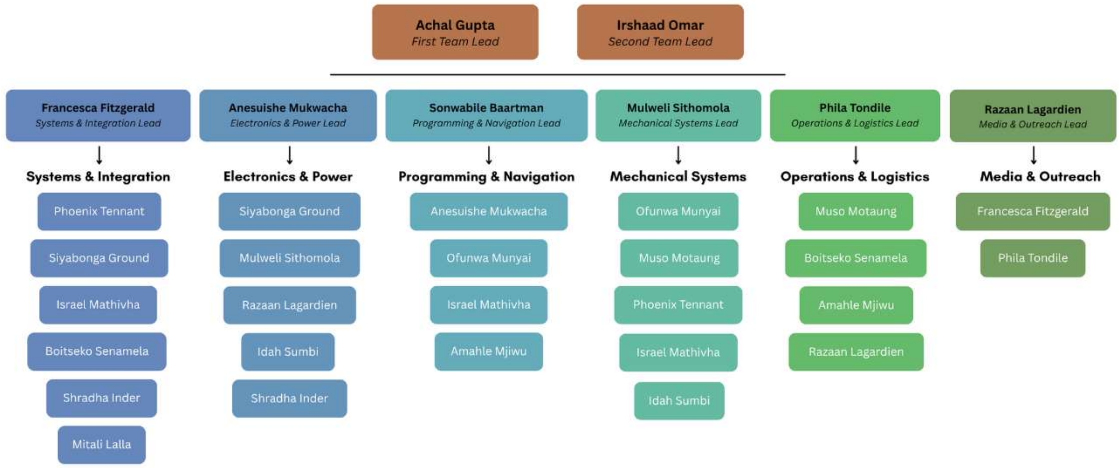

Figure 1: Team Hierarchy

With eighteen students spanning multiple faculties and degrees at UCT, we are a proudly multidisciplinary team, by design. The team has been divided into six sub-teams and no further recruitment will take place. Each sub-team has a Portfolio Representative (PR) who oversees their respective division. They act as liaison between the Team Leads and their team members, keep their division abreast of upcoming deadlines and break down given tasks for distribution. The group of all the PRs has been dubbed the **Tiger Team**.

Achal Gupta also serves as the Chairperson of the UCT Space Society, with Irshaad Omar as Vice Chairperson, bringing broader leadership experience and vision into the heart of this team.

Our **Electronics and Power** team consists of members with diverse technical backgrounds and hands-on experience in electronics and embedded systems. This encompasses circuit design, power management, current regulation and battery interfacing. The Electronics and Power sub-team is fortunate to have Mr. Aadil Eyasim on board as Faculty Advisor: his research focuses on electric vehicles, and he is involved with UCT's Formula Student Africa team which is developing a single-seat electric formula car.

The **Operations and Logistics** team consists of people with multifaceted experience. For instance, one of the members is part of the volunteering sub-committee at a student-led animal and nature conservation society where they mentor and orient - skills which come in handy when overseeing preparation for submissions. Our **Programming and Navigation** team has experience working with OpenCV and other Computer vision software to build autonomous vehicles and logical agents.

The **Mechanical Systems** team has some experience in building and launching model rockets and are also skilled in using CAD software. Our **Systems and Integration** PR has a degree in Game Design and Development, with experience in leadership. Overall, the team has the skills necessary for seamless software-hardware coordination. For our **Media, Outreach and Reporting** sub-team, using software like Figma, Canva and Photoshop as well as writing and editing is second nature. One member is the Media Executive for the Space Society, and they will be taking the lead in social media management.

Project Management Methodology

After thorough research into entry-level project management software such as *Zoho* and *Trello*, the team has decided to create our own system to track our projects tasks. Every software package requires a monthly subscription for a team of more than 10 members, and this cost is not justifiable in our budget. We will use Excel to create a database-like system that allows the team to view all assigned tasks, team deadlines, and phases of the project. This document will be shared in our OneDrive folder with only 2 or 3 members editing the spreadsheet contents to avoid issues.

Each subdivision has been assigned a PR who will oversee the progress within their team and communicate with the Team Lead and other subdivisions where necessary. They will remind their team about approaching deadlines and ensure the completion of all assigned tasks.

Each division has chosen different methods of communicating and managing their work. Tiger Team meetings are scheduled biweekly for progress updates and to address major concerns. The Programming and Navigation team collaborates primarily online via GitHub, meeting only during critical points in the project. Electronics and Power will have regular meetings biweekly alongside weekly tasks and updates. Mechanical Systems will have weekly reports of activities accomplished, with meetings reserved for issues that are not easily communicated via text. The Systems and Integration sub-team will have weekly meetings mainly to ensure task alignment, monitor deadlines and coordinate efforts. Operations and Logistics work fully online. Meetings are unnecessary for the most part since everything can be conveyed efficiently via text message or email. Media, Outreach and Reporting will communicate frequently during the writing of the report. They will also meet whenever needed, for example when posters need to be put up.

Resources

Our team uses Microsoft 365 (licensed by UCT) as the collaborative backbone for all documentation, design sharing, and progress tracking. A shared OneDrive folder ensures structured access across the team, serving as the central repository for schematics, CAD files, reports and weekly deliverables.

We have adopted KiCad for PCB design due to its free, open-source capabilities and SolidWorks for CAD modeling, licensed through UCT. Python is the primary language for software development, allowing flexible integration of navigation, control and communication systems. The assembly of the rover will take place in the UCT Physics Department's laboratory, with a request underway to access UCT's Menzies Design Lab for 3D printing of custom components. Upon completion of the rover, it will be stored in the UCT Physics Building.

The UCT Space Society has allocated ZAR 5000 to this project. Additional funding will be needed and will be sought from potential sponsors such as RedBull, Monster, and RS Components. We will also apply to the IAU Office of Astronomy for Development (OAD) to acquire the Raspberry Pi 4 that will control the rover. PCBs and electronics are to be sourced through JLCPCB to ensure cost-effective and reliable manufacturing.

Initial Design Ideas

Design Motivation

Our design philosophy is anchored in the principle “Do not reinvent the wheel.” Instead of building every component from scratch, we strategically adapted proven engineering solutions from previous rover missions to fit the specific constraints of the Cars4Mars challenge. This approach balanced innovation with reliability, resulting in a robust, modular design optimized for cost, component sourcing in South Africa, and ease of integration.

Wheel Configuration Analysis

The project initially explored a 4-wheel drive (4WD) system for its mechanical simplicity. However, simulations and terrain assessments revealed limitations in obstacle negotiation and stability on uneven surfaces. Transitioning to a 6-wheel layout with rocker-bogie suspension significantly improved traction and ground contact.

A trade-off between performance and power consumption led us to power only four of the six wheels, with all four powered wheels featuring steering capabilities. This hybrid 6-wheel configuration offers enhanced stability and maneuverability while managing energy efficiency and drivetrain complexity.

Component Selection and Justification

Power System

- 12.8V 24Ah $LiFePO_4$ battery, chosen for stable voltage, long lifespan, and thermal safety
- 4S Battery Management Systems for overvoltage, overcurrent, and thermal protection
- INA219 current sensors and DS18B20 temperature sensors for real-time monitoring.

Motor and Drive Control

- RoboClaw 2x15A motor controllers with encoder feedback and regenerative braking support.
- Bosch 0390241124 Wiper Motors selected for their high stall torque and ruggedness.
- 4-wheel steering based on Ackermann geometry to reduce tire wear and improve turning.

Control and Processing

- Arduino Mega 2560 for real-time low-level motor and sensor control.
- Raspberry Pi 4B (4GB RAM) running navigation, object detection
- Raspberry Pi 4B is also responsible for wireless communication over Wi-Fi
- A dedicated 5V fan cools the Raspberry Pi under heavy load.
- Evaluating Raspberry Pi Camera Module 3 versus NoIR V2 for optimal low-light and dusty environment performance.

Software Architecture

The rover's software stack is implemented in Python, leveraging contemporary libraries for vision and autonomy:

- OpenCV and YOLOv8 enable real-time object detection and terrain analysis.
- Lightweight inference handled via PyTorch, NumPy, and scikit-learn will be used for machine learning
- UART and I^2C protocols facilitate data exchange between Arduino and Raspberry Pi.
- GitHub supports collaborative development and version control
- Notion and Word documents track system design, bug reports, and sprint progress.

Built-in fallback mechanisms allow the rover to autonomously navigate using visual inputs during communication loss, ensuring operational resilience. Continuous field testing guides iterative software refinements.

Final Rover Design Overview

The rover's structural framework uses a sandwich-style chassis fabricated from aluminum alloy or composite plastics, chosen for their high strength-to-weight ratio and durability. The rover will have 6 wheels with a rocker-bogie suspension, and Ackermann steering: 4 of the rover's wheels will be steerable and powered. Parts of the rover will be 3D printed to allow for cost-effectiveness.

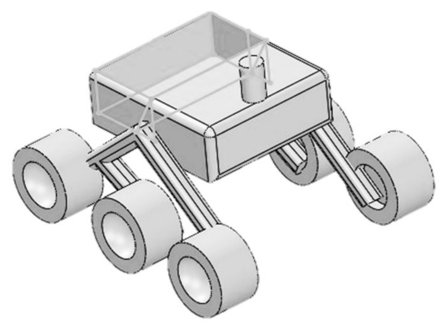

Figure 2: Early Rover Visualization

The camera system features a raised, vibration-isolated camera mast to improve field of view and protect sensitive optics from dust and shocks. A rear-mounted, thermally insulated payload compartment safeguards sensitive instruments and reduces electromagnetic interference. Ongoing weight distribution analysis aims to optimize vehicle stability under various load and terrain conditions.

To assist with thermal management outdoors, the rover will be painted in a brighter color scheme to reduce ambient heat absorption. Additionally, the exterior will feature the UCT Space Society logo prominently, alongside logos of any supporting sponsors as a gesture of appreciation and to acknowledge their contribution to the mission.

A detailed schematic on the following page outlines how the key electrical components of the rover are connected. It outlines how the Arduino and Raspberry Pi communicate, how power is distributed from the battery, and how sensors, motor drivers and other peripherals are integrated. This forms the basis for our wiring and PCB layout and will be used as a guide for the physical assembly of the electrical system.

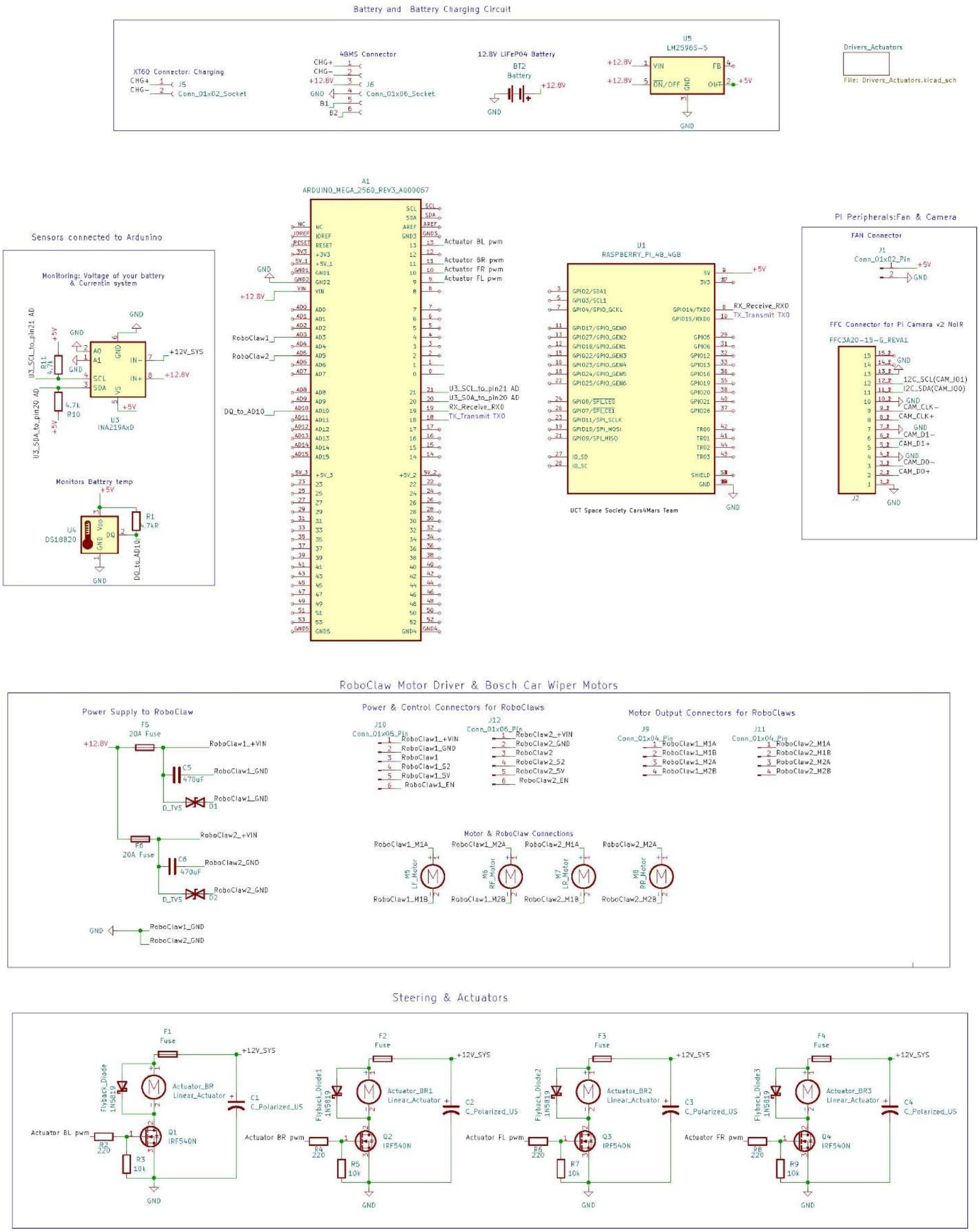

Figure 3: Electronic Systems Schematics