QBOTIX

Team Name

Team QBOTIX

Team Lead

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Rover Name

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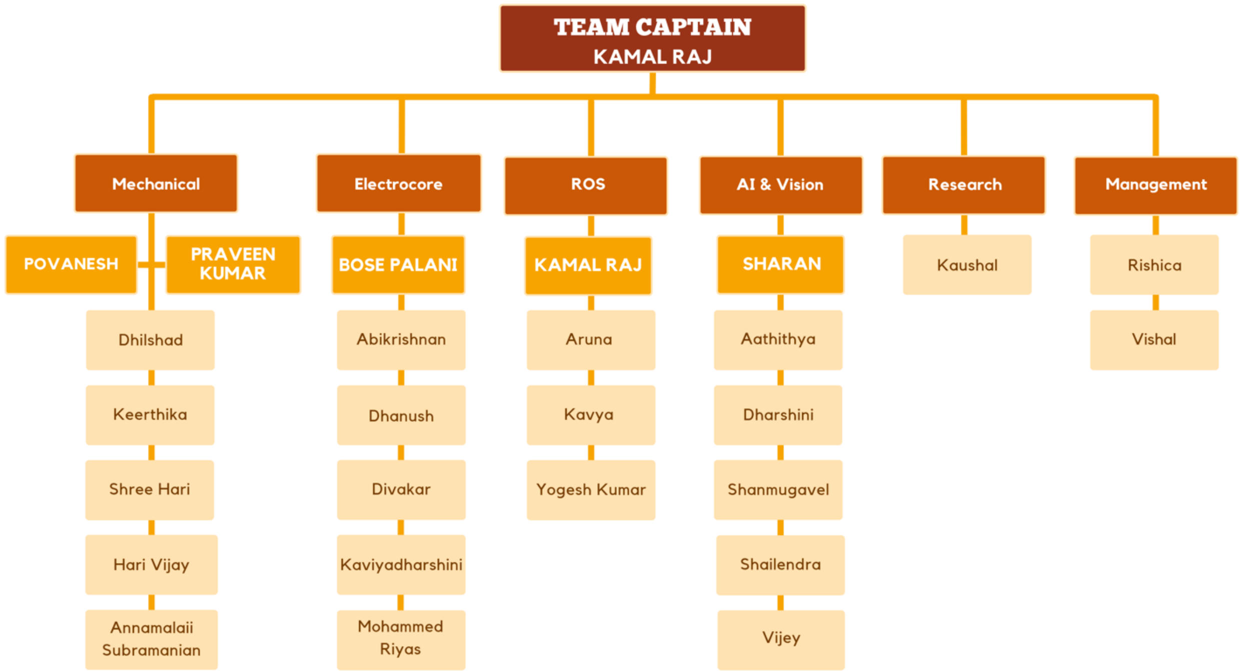
1. Introduction

Team QBOTIX from Kumaraguru College of Technology takes immense pleasure to contend in IRC 2026 for the first time. Our team envisions to innovate and explore in the field of robotics. To bring our vision into reality, we intend to participate in the International Rover Challenge (IRC) 2026, organized by the Space Robotics Society. We believe that IRC not just provide students with the opportunity to explore space robotics but also an experience that all of us could carry forward for our future endeavours. The rover we built is a showcase of numerous engineering principles integrated with the interdisciplinarians of robotics such as mechanical, electrical, communication, robot operating system and artificial intelligence.

This SDDR document elucidates the various aspects of our team, right from the team management to the structure and functioning of our rover system.

1.2 Organizational Structure



Organisational Structure

1.3 Subsystem Roles

The team comprises of five subsystems: mechanical, electrocore, ROS & AI, life science and management. Each subsystem has defined goals and objectives that ensures our ulterior motive of fabricating a functional rover. Every subsystem holds their own responsibilities and operational tasks.

Mechanical Domain :

The overall structure of the rover is designed using fusion 360, analysed using Ansys and then fabricated. The structure composes of significant parts like the robotic arm, chassis and suspension making up the body of the rover.

Electrocore Domain :

Handles the electrical systems such as power distribution, wiring, sensors, and control electronics. It plays the crucial role of integrating everything and powering the system.

ROS & AI Domain :

Works on autonomous navigation, communication and vision system using Artificial Intelligence while focusing on the Robot Operating System for the functioning of the rover.

Life Science Domain :

Dives deep into the exploration of the Martian environment wherein we research on soil samples and detecting life. The results are interpreted for further studies and development.

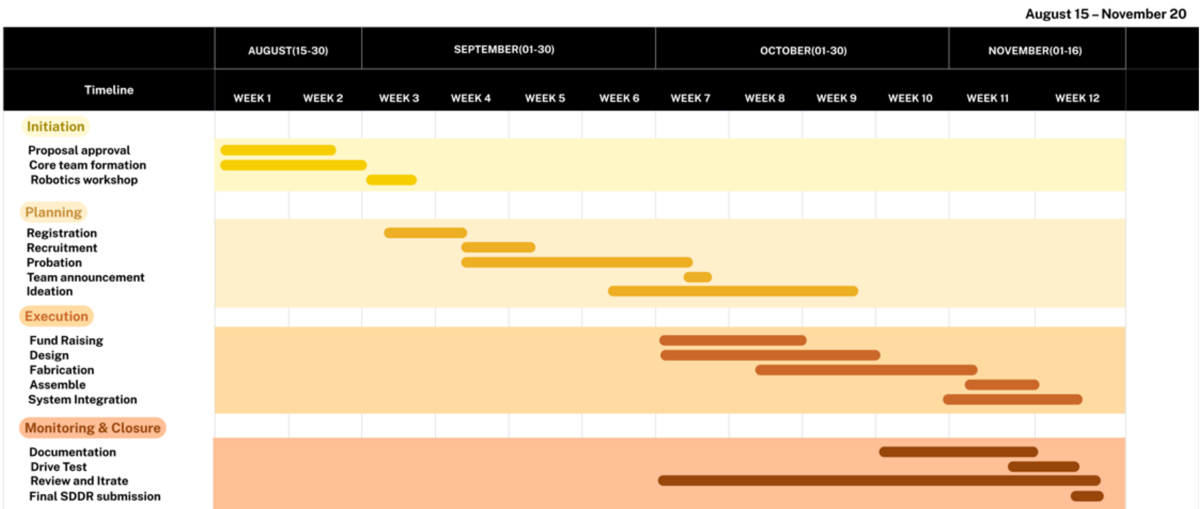
Management Domain :

The driving force of the team, responsible not just for the overall team management but looks after the sponsorship, finance and outreach.

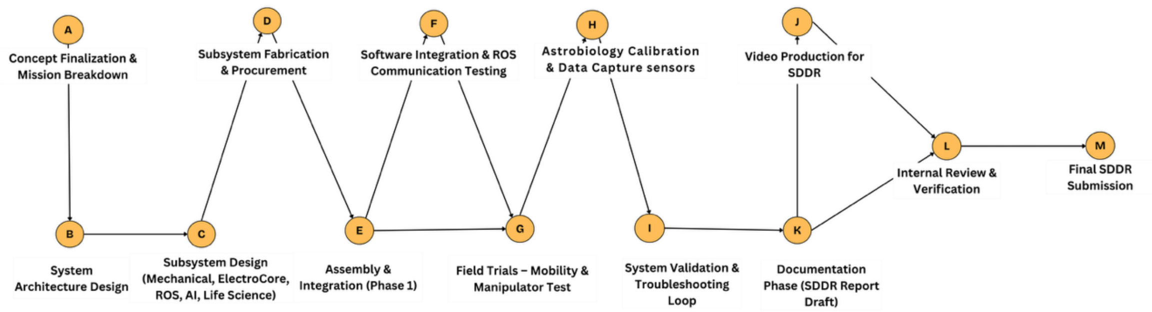
1.4 Project planning

The planning of our project was done in a systematic way ensuring utmost usage of time and available resources. The timeline of our project was split into 5 phases and allocated deadlines in order to complete the works on time. Tasks were allocated to individual members and we together progressed as a team. In order to keep a check on our planning and deadlines, weekly review meetings were conducted.

The team uses a five-phase development model :



GANTT CHART (represent the Timeline)



PERT CHART (represent the Dependencies)

1.5 Resource management:

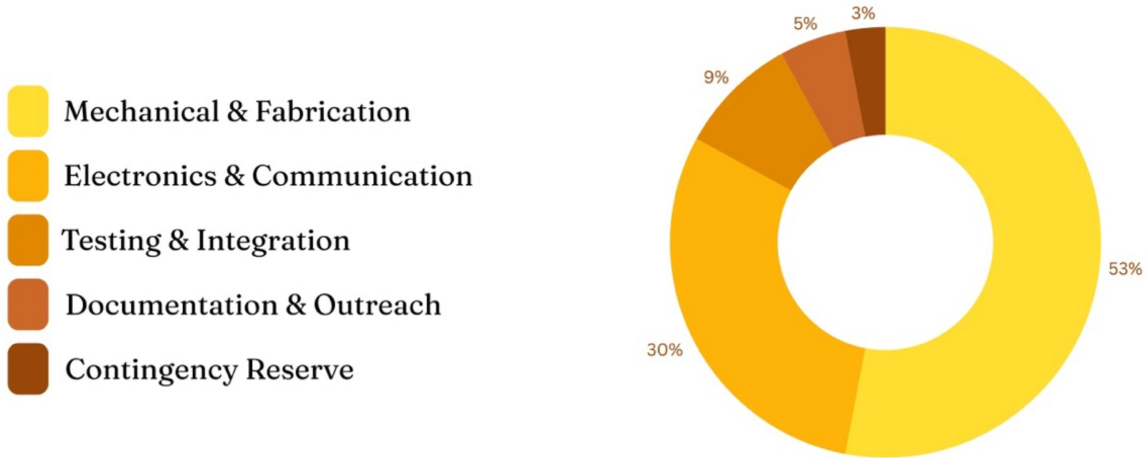
Resources available at college were efficiently utilized for fabrication. Additional hardware and electrical components were procured from reliable local vendors and verified online marketplaces. Each subsystem maintains its own inventory log for tools, components, and consumables. Materials are stored safely in labelled sections and usage is monitored.

1.6 Fundraising plans:

Being a debutant team to the IRC, our fundraising plans were minimal yet structured. Our college being the backbone to every student teams were our primary source of funds. Our college management and various institutional departments extended their utmost support to us. Followed by this we trusted our sincere efforts and intentions could lead us to sponsorships. We pitched our plans, proved our motives and backed up sponsors. Thirdly and most importantly we the students ourselves contributed to the budget

Fundraising split ups

College endowment	₹2,50,000.00
Student Contribution	₹1,00,000.00
Sponsorship	₹1,50,000.00
TOTAL	**₹5,00,000.00**



Budget utilisation (pie chart)

1.7 Sponsorship:

iQube is an innovation Centre for every tech enthusiast that aims to bring out the explorer and maker within. It further helps tech enthusiasts to convert their innovative ideas into commercial variable/Technically challenging prototypes. We approached iQube with what we are aiming to do and what we aspire to achieve. We are beyond grateful for their technical guidance and the sponsorship they offered.

1.8 Educational and Public Outreach

As part of its mission to inspire the next generation of engineers and innovators, **Team QBOTIX** actively engages in educational and public outreach initiatives. These programs aim to spread awareness about planetary robotics, promote STEM learning, and strengthen the connection between academia, industry, and the community.

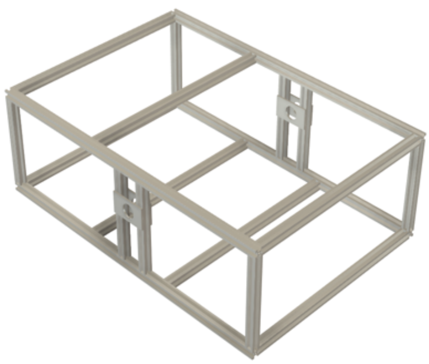
Outreach Plan

Activity	Description	Target Audience	Outcome / Impact
Planetary Robotics Workshops	Hands-on sessions introducing rover design, sensors, and autonomous navigation.	school students	Increased awareness of robotics and IRC participation opportunities.
RoverTech Exhibition (KCT)	Public display of the QBOTIX prototypes and subsystems during innovation week.	KCT students and visitors	Over 300 participant/visitor sponsors and media coverage generated.
Industry-Interaction Seminar Series	Inviting professionals from robotics startups and research labs for knowledge sessions.	Engineering students and faculty	Exposure to real-world robotics applications and networking channels.
Ideathon Workshop	A collaborative ideation session focused on fostering creativity and innovation in rover design and mission planning.	Students across Mechanical, EEE, ECE & other domains	Generated solutions for rover subsystems through collaboration and rapid prototyping exercises.
Community STEM Drives	Simplified robotics demos and rover showcases at schools.	Rural and urban schools in Tamil Nadu	Enhanced curiosity toward science and engineering disciplines.

2. Mechanical Domain

2.1 Chassis

The body of the rover is constructed using aluminium extrusion bars having dimensions of 750 mm × 500 mm × 250 mm. This provides a strong yet lightweight frame for all components. This material is chosen based on its high strength-to-weight ratio, corrosion resistance, and ease of fabrication. These properties make it ideal for rover applications. The electrical systems are securely mounted inside with well-organized wiring to protect it from external disturbances. The robotic arm is positioned at the top for ease of operation, allowing maximum reach and stability while performing tasks. All the ABEX components are placed in the rear section for balanced design and accessibility. This placement ensures an even weight distribution and easy access for testing or troubleshooting



Chassis

2.2 Suspension

The rover has a rocker-bogie suspension system with six wheels in it, designed to provide stability and untroubled movement over uneven terrains. This mechanism is opted keeping in mind the need for even distribution of load across all wheels which allows the rover to overcome obstacles without significant tilt or loss of traction. The primary joints are made up of PLA infused carbon-fibre through 3D printing. This is done to achieve a lightweight structure. This material offers high tensile strength, reduced weight, and ease of customization during fabrication. The suspension arms are connected using aluminium circular tubes, as aluminium provides excellent stiffness while keeping the overall mass low.

Suspension

2.3 Wheels

The total width of the suspension is about 1200 mm, which gives a good balance between stability and turning ability on rough terrain. A differential bar connects the left and right rocker arms so that both sides move together, keeping the body level when travelling through obstacles.

Each wheel measures 200 mm in diameter and 80 mm in width. It is made sure that there is optimum balance between ground clearance, stability, and manoeuvrability. This permits the rover to traverse via obstacles without slipping or excessive vibration. The outer layer of the wheels is 3D printed TPU to achieve shock absorption and traction on rough terrain while the ABS hub gives high structural rigidity and durability for load bearing. The two materials jointly provide the overall structure with flexibility and strength. These wheels are integrated with the rocker-bogie suspension system, enabling smooth and balanced movement over uneven ground surface.

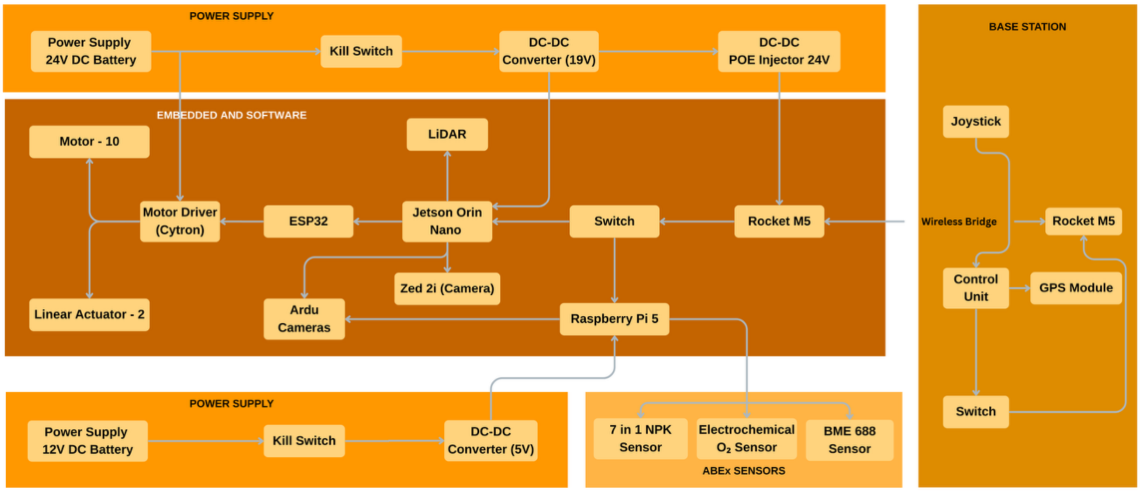
Wheels

2.4 Robotic arm

The robotic arm of the rover is made with 5-degrees of freedom to perform complex tasks such as sample collection and object manipulation with precision. This configuration of the arm gives high flexibility and a wide range of motion, allowing the arm to reach and operate in various angles effectively. The arm consists of two main links that are actuated using linear actuators. A differential mechanism is installed to improve manoeuvrability for synchronized and stable control of the gripper. The end effector features a parallel robotic gripper devised for accurate object handling during task operations. This is selected for its balanced and secure gripping capability, which in turn enhances control and reduces the risk of slippage during intricate tasks.

Robotic Arm

3. Electrocore

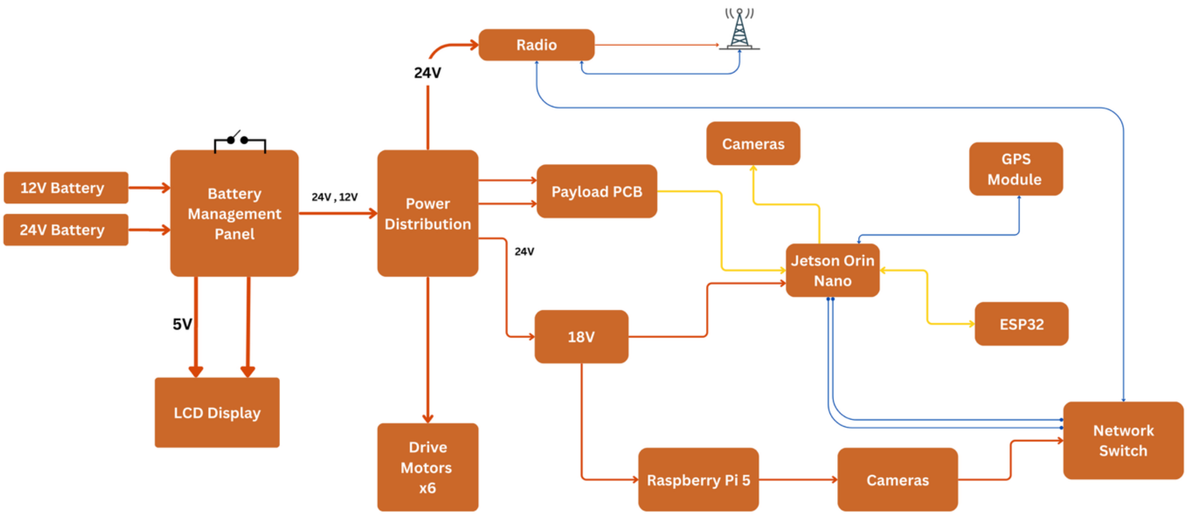


System architecture

3.1 Battery Setup

The rover runs on two separate Li-Po batteries to keep the high-power and control circuits isolated. A 24 V, 8000 mAh battery acts as the main power source, supplying the locomotion system and the antenna module. From this line, two buck converters step down the voltage, one to 18 V for the Jetson Orin Nano that handles AI and image processing, and another to 5 V for the ESP32 and sensors. A second 12 V, 10 000 mAh battery powers the robotic arm and ABEX subsystem. All grounds are tied together to maintain a stable signal reference. Separating the circuits like this prevents power fluctuations from affecting sensitive control components and ensures stable operation even under heavy load.

3.2 Control System



Power distribution chart

The control system is built around an ESP32 (38-pin) microcontroller, which handles real-time tasks such as motor control and sensor feedback. The rover is operated remotely using a PS5 controller at the base station. Commands are transmitted through a wireless link to the Jetson Orin Nano, which processes the input and sends control signals to the ESP32 for actuation.

The Jetson Orin Nano, Raspberry Pi, and ESP32 work in coordination. The Jetson takes care of AI vision, navigation, and communication; the Raspberry Pi manages data logging and command routing; and the ESP32 executes precise low-level control. Communication between the Jetson and Raspberry Pi is handled through a network switch to maintain fast and reliable data transfer.

3.3 Locomotion System

The rover uses six 24 V planetary-geared DC motors, each rated at 9.8 Nm torque and 110 RPM. This 6-wheel-drive setup provides excellent traction and stability on rough terrain. The motors are controlled using Cytron dual-channel motor drivers rated for 20 A and 6–30 V. Each wheel includes an optical encoder that feeds back position and sends data to the RADO (Rover Autonomous Drive Operations) system for better motion control.

3.4 Robotic Arm

The robotic arm is powered by two 12 V DC linear actuators, each capable of 1500 N of force and a 10 cm stroke length. One actuator handles vertical motion and the other handles horizontal movement. The wrist assembly uses two PGDC motors rated for 0.6 Nm torque and 300 RPM, allowing full 360° rotation. The gripper (end effector) is driven by a 12 V DC motor through a Cytron dual-channel driver. This configuration gives the arm smooth, precise, and reliable motion for object handling and maintenance operations.

3.5 Emergency Protection

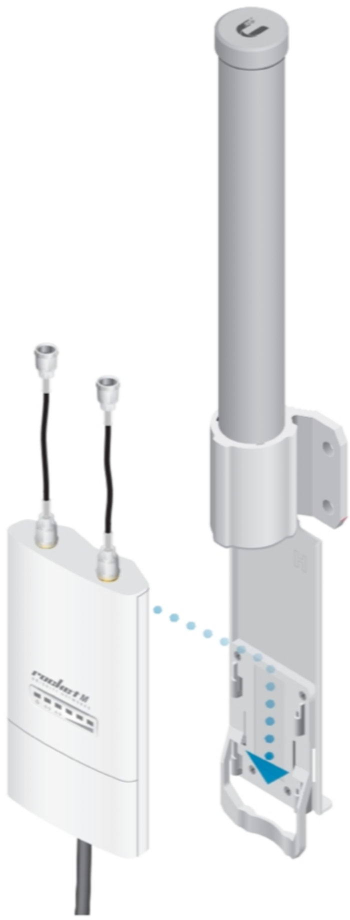
For the purpose of emergency stop operation, an emergency kill switch mechanism is utilized.

4. Communication

The communication subsystem of the rover is designed in such a way to ensure reliability, high speed data exchange between the rover and the base station, while maintaining a robust Low-latency control channel for telemetry and command data. The system is divided into two key communication layers: high-bandwidth data transmission and low-bandwidth control communication.

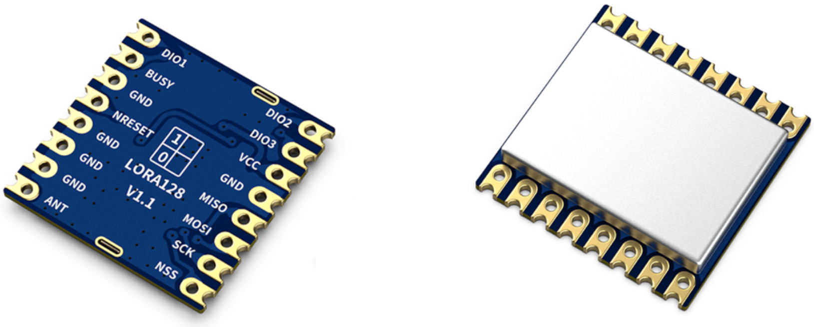
4.1 External Communication:

High speed data transmission is required for tasks such as live video feed and visual data for which an Ubiquiti RocketM5 pair is employed. AirmAX Omni antenna is stationed at the rover and Sector AMO-5G10 antenna at the base station. This offers 30dBi gain and operates in the 5GHz frequency band. This configuration is set up because this provides a wide coverage pattern and stable line-of-sight connectivity over long distances. The Jetson Orin Nano used in the rover interfaces with the RocketM5 through a LAN connection. This functions by transmitting multiple camera feeds and other sensor data to the base station. While at the base station, the RocketM5 connects via Power over Ethernet (PoE) to the main control computer. This setup distributes the incoming video feeds to dedicated GUI monitors for real-time monitoring and analysis. Each feed is handled by a separate GUI application running on individual monitors which allows operators to view and manage multiple camera angles simultaneously. The RocketM5 system utilizes the 802.11a/n airMAX protocol, providing enhanced throughput and reduced latency over standard Wi-Fi. Even during challenging field conditions, this ensures undisturbed transmission of multiple high-definition video streams from the rover to the base station.



Omni Antenna

4.2 Telemetry and Control Communication:



G-NiceRFLoRa1280F27

A pair of LoRa modules (G-NiceRFLoRa1280F27) is employed for control commands and telemetry data exchange that operates in the 2.4 GHz frequency band. The LoRa link offers long-range, low-power, and interference-resistant communication. This is ideal for continuous transmission of rover status data such as battery level, GPS coordinates, motor feedback and reception of control signals from the operator. The dual-band approach fortifies communication reliability at all circumstances as the 2.4 GHz LoRa link maintains control and safety communication between the rover and the base station.

4.3 Methods to minimise interference in communications

1. **Radio-Level Techniques**

We use the 5 GHz band so the connection stays less crowded than 2.4 GHz. With tools like AirView, we scan the area and choose the cleanest channel to avoid noise. DFS helps the system automatically move away from radar or strong interference. Proper antenna alignment and keeping a good SNR ensure a stable and clear link.

2. **Hardware and Antenna Techniques**

We use directional antennas to focus the signal directly between the base station and the rover, reducing unwanted signals from other directions. The antennas are placed away from motors, ESCs, and converters to avoid electrical noise.

3. **Network-Level Techniques**

Using static IPs avoids unnecessary ARP and DHCP broadcasts. The MCS level is tuned for stable outdoor performance. We also set the ACK timeout based on the communication distance so the system doesn't waste time on repeated retransmissions.

4. **Physical Deployment Techniques**

Both antennas are placed with a clear line-of-sight so nothing blocks the signal. Raising the antennas improves range and reduces ground reflections. The rover is positioned away from metal structures that can cause signal bounce. A slight tilt in the antenna helps reduce reflections even more.

5. **Software and Traffic Management**

QoS settings make sure control and telemetry data get priority over video, so commands stay fast and responsive even when bandwidth is high. Different data streams are sent through separate ports to avoid interference between high-priority and heavy video traffic.

5. Robot Operating System

The Autonomous Delivery Rover operates on JetPack 6.0 running on Ubuntu 22.04 LTS with ROS2 Humble Hawksbill as the middleware environment. The onboard computation is handled by the NVIDIA Jetson Orin Nano. This provides GPU acceleration for visual SLAM and depth estimation. Low-level control is managed by an ESP32 microcontroller running micro-ROS. The various packages used are: zed_ros2_wrapper, zed_ros2_interfaces, rplidar_ros2, rtabmap_ros, robot_localization and nav2.

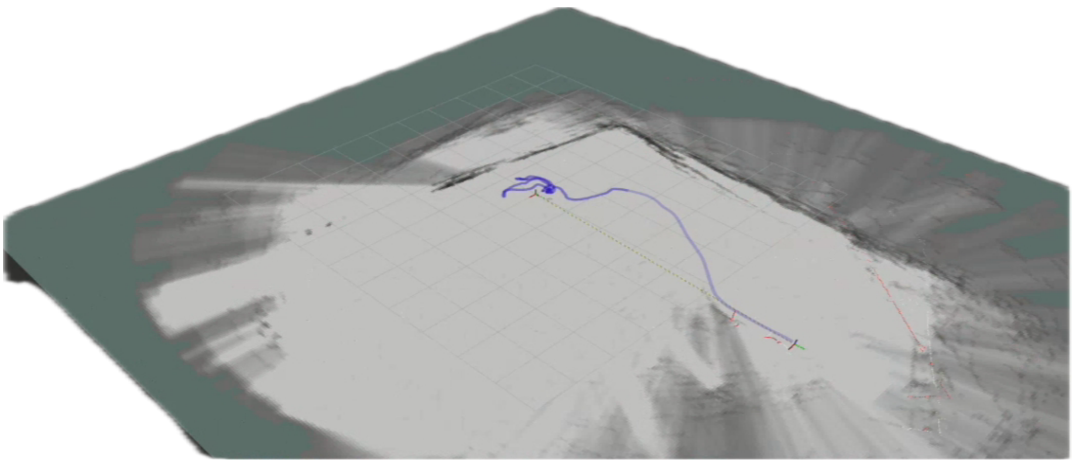
5.1 Perception and Localization Framework

The Perception Layer utilizes the ZED 2i Stereo Camera and RPLiDAR AIM8, forming the primary sensing framework for the rover. The ZED 2i provides real-time colour, depth, and point-cloud data, while the LiDAR generates accurate 2D range scans for obstacle recognition. All sensory inputs are integrated within the ROS 2 TF tree, maintaining precise spatial calibration. The Extended Kalman Filter (EKF) from robot localization merges IMU, encoder, LiDAR visual odometry, and RTK-GPS data to estimate a drift-free pose on /odom/filtered. This meld provides a globally consistent localization backbone for mapping, path planning, and mission-level decision making

TF Tree: map — odom — base link — camera link — laser scan

5.2 Mapping

RTAB-Map ROS 2 is used in the mapping layer for real-time appearance-based SLAM. It combines stereo point clouds from the ZED 2i with LiDAR, while it scans to generate a dense 3D map and a continuously updated 2D occupancy grid. RTAB-Map's loop-closure detection and graph optimization minimize drift during long-range exploration and the occupancy grid published on map serves as the navigation substrate. As the rover travels through unmapped terrain, RTAB-Map dynamically updates the map and corrects the global pose using key-frame matching. This approach allows autonomous exploration up to 500 m, supporting cone detection and accurate environment reconstruction for navigation and obstacle avoidance.



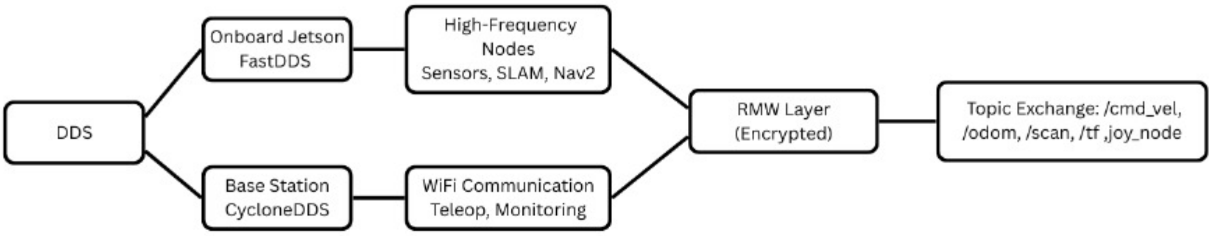
2d Cartographer Mapping

5.3 Path Planning:

The Path Planning Layer operates through the Nav2 framework, integrating both global and local planners. The Frontier Exploration global planner generates exploratory and target-based paths over the incrementally built occupancy grid from RTAB-Map. The TEB (Timed Elastic Band) local planner refines these paths to maintain kinematic feasibility and dynamic obstacle avoidance. For GPS-guided missions, latitude and longitude coordinates received from organizers are converted into UTM coordinates, and a global directional vector algorithm determines a straight-line trajectory toward the target. When obstacles appear, TEB re-optimizes the path locally and realigns to the global vector, ensuring uninterrupted progression toward the GPS-defined delivery point.

5.4 DDS-Based Communication and Control System

The Communication Layer uses two DDS protocols: Cyclone DDS for high-level networking and Fast DDS for real-time embedded control. At the base station, operator inputs from the PS5 controller are captured using the joy node and transmitted via LoRa using Cyclone DDS, enabling long-range, low-latency communication. The rover's Jetson Orin Nano subscribes to these topics and forwards control commands to the ESP32 microcontroller via Fast DDS using the micro-ROS client. During autonomous operation, the same Fast DDS channel publishes Icmd vel messages from Nav2 to the ESP32 for motor actuation. This dual-DDS architecture guarantees deterministic communication, robust telemetry, and smooth transitions between teleoperation and full autonomy.



DDS workflow

5.5 Autonomous Mission Execution Flow

The Autonomous Mission Manager governs exploration, cone-based delivery, and GPS waypoint execution. Initially, the rover performs frontier-based exploration and RTAB-Map to map unknown terrain. Once a cone is detected through the ZED 2i's colour-segmentation algorithm, its 3D pose is transformed into the map frame and sent to Nav2 as a goal. The rover autonomously navigates, places the object, and proceeds to the next task. For the one object, the provided GPS coordinates are converted to UTM and used to generate a global directional vector guiding motion toward the delivery zone. During traversal, TEB Local Planner ensures dynamic obstacle avoidance and immediate re-planning. Throughout the mission, EKF Localization maintains accurate pose fusion, while DDS communication synchronizes telemetry, ensuring the base station receives real-time feedback and control capability.

6. AI and Vision System

The AI and Vision System acts as the cognitive core of the rover, designed to handle high-bandwidth visual data, perform edge-computing for object detection, and manage scientific data logging. The system utilizes a distributed computing architecture to balance the load between autonomous navigation tasks and scientific analysis.

AI & Vision Workflow

6.1 Distributed Hardware Architecture

To ensure low latency and prevent processing bottlenecks, the rover utilizes a dual-node architecture connected via a localized Gigabit Ethernet Switch and transmitted to the Base Station via a long range radio link:

Primary Node (NVIDIA Jetson Orin Nano):

Handles high-computation tasks including the Locomotion Video Feed, ZED 2i stereoscopic depth processing, and YOLOv8 inference for the RADO mission.

Secondary Node (Raspberry Pi 5):

Dedicated to the Robotic Arm feeds, the ABEX Science GUI, and backend report generation scripts.

6.2 Vision System & Teleoperation Interfaces

The rover transmits multiple video streams to the Base Station, which are visualized through custom-built Web GUIs running in the operator's browser. This setup ensures that the pilot has a segmented, lag-free view of the environment.

6.2.1 Locomotion Interface (Hosted on Jetson Orin Nano)

This interface provides the pilot with spatial awareness for driving and navigation. It aggregates three specific camera feeds:

i. **Antenna Cams:**

Wide-angle cameras mounted at the highest point of the rover, providing a top-down view of the chassis and immediate surroundings.

ii. **ZED 2i Stereo Cam:**

Providing a center-aligned, depth-perceptive view used for both pilot navigation and AI inference.

iii. **Ground Cam:**

A downward-facing camera used to monitor terrain texture and detect objects placed directly in the rover's path during the reconnaissance phase.

6.2.2 Manipulator Interface (Hosted on Raspberry Pi 5)

To facilitate precise object retrieval, a dedicated interface streams feeds from the robotic arm:

Gripper Cam: Mounted on the end-effector to provide a close-up view for grasping objects.

Side-Arm Cam: Mounted on the rover chassis facing upward towards the arm, providing a secondary perspective to depth-check the arm's position relative to the surrounding.

6.3 Artificial Intelligence Framework (RADO)

For the Reconnaissance Autonomous Delivery Operation (RADO), the team employs a Deep Learning framework integrated along with a custom GUI to manage the transition between Reconnaissance and Delivery modes.

6.3.1 Object Detection & Colour Classification

We utilize the YOLOv8 (You Only Look Once) architecture for real-time object detection.

Training Pipeline:

The model was trained on a custom dataset pre-processed and augmented to handle varying lighting conditions.

Inference Logic:

The model detects coloured cones and extracts the region of interest (ROI). Within this ROI, the system applies an HSV (Hue, Saturation, Value) colour-space analysis to classify the cone's colour (Red, Green, Blue, etc.).

Depth Integration:

Using the ZED 2i's depth map, the system calculates the real-world distance to the detected cone, enabling the rover to approach the target autonomously.

6.3.2 RADO Mission GUI

The autonomous workflow is managed via a specialized GUI that features:

Recon Mode: Allows the operator to click a "Capture" button when an object is spotted via the Ground Cam. The system logs the object's GPS coordinates, photo and associates it with the detected cone colour.

Auto-Delivery Dashboard: Displays the YOLO status, rover speed, and distance to target. It allows the operator to select a captured object from the "Recon Cache" and initiate autonomous navigation to that specific GPS coordinate.

6.4 Science Data Acquisition & Analysis (ABEX)

The Astrobiology Expedition (ABEX) system is controlled by a comprehensive dashboard designed to streamline sensor readout and automate scientific reporting.

6.4.1 Real-Time Sensor Dashboard

The ABEX GUI aggregates data from the rover's diverse sensor array into a single visual interface:

i. **Atmospheric & Soil Data:**

   Displays real-time readings for Oxygen, Pressure, Temperature, Humidity, Soil Moisture, pH, and Electrical Conductivity (EC), Nitrogen, Phosphorus, and Potassium levels.

ii. **Spectroscopy:**

   Renders a dynamic line graph representing Raman Spectrometer intensity values against Raman Shift (cm^{-1}), aiding in the identification of biological signatures.

iii. **Visual Confirmation:**

   Displays feeds from the Drill & NPK Sensor monitoring Cam (monitoring soil extraction and NPK Sensor) and the Test Tube Cam (monitoring chemical colour reactions).

6.4.2 Automated Report Generation

To minimize human error during the mission, the system includes a Python-based backend linked to the GUI. Upon mission completion, the system automatically:

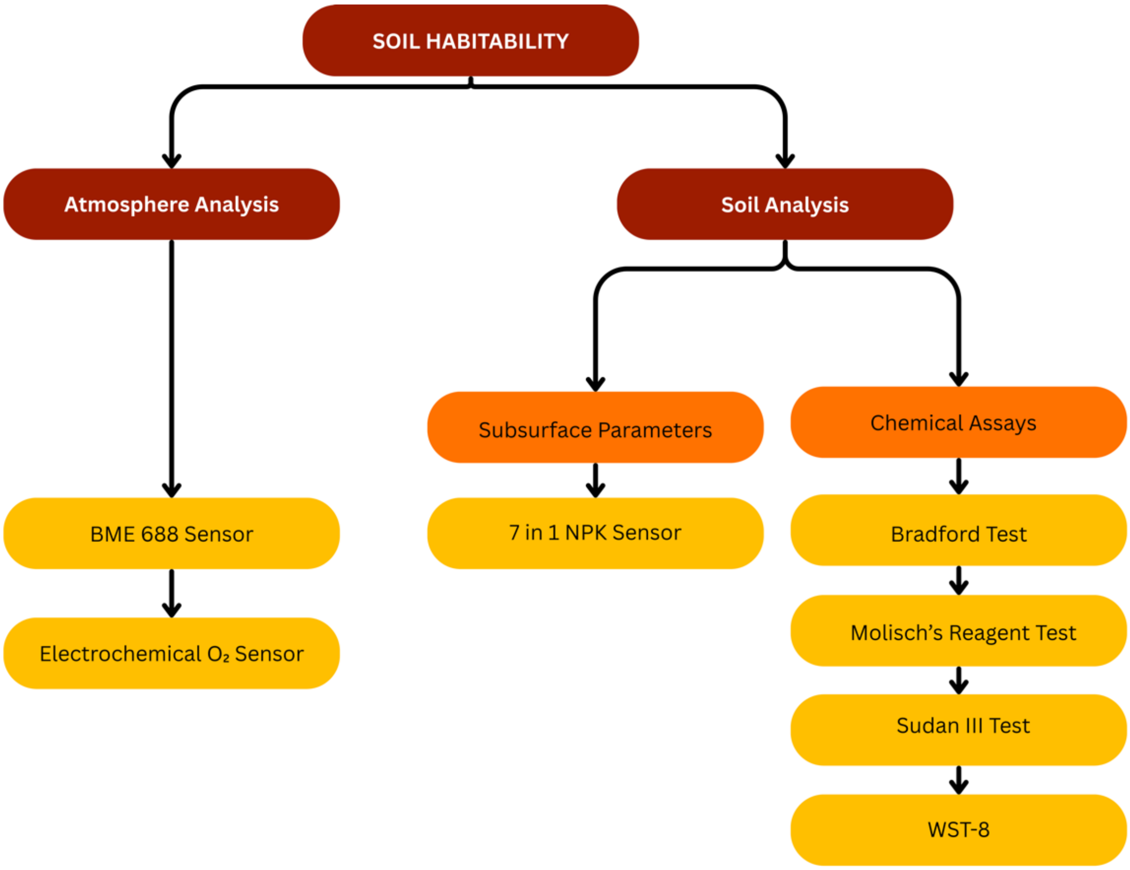
1. Compiles all logged sensor data.
2. Embeds the captured images of the chemical tests.
3. Generates the Spectrometer graph.
4. Exports a formatted report containing the site number, timestamps, and all biological findings.

6.4.3 Advanced Image Processing (Panorama)

For site documentation, the system automates a servo-mounted high-resolution camera to capture three overlapping frames across the field of view. The vision system employs a two-stage Python algorithm where the primary pipeline uses OpenCV’s native Stitcher class to generate the composite. As a fallback, a minimal secondary method is triggered when needed. The final panorama is aligned to a 3:1 aspect ratio, and annotated with essential telemetry such as location, orientation, and related metrics.

7. Life sciences

This subsystem is designed to evaluate the environmental conditions of the target site, its potential to support microbial life and to detect extinct or extant. This investigation is carried out in two main areas: soil analysis and atmospheric analysis.



Soil Habitability Assessment Methods

7.1 Soil analysis

1. NPK Sensor (7-in-1) – Multi-Parameter Soil Characterization

This integrated probe measures nitrogen, phosphorus, potassium, pH, electrical conductivity, temperature, and soil moisture in real time. It offers a complete picture of soil fertility and nutrient balance which helps determine whether the environment supports microbial growth and biological activity. High nutrient levels indicate that the soil contains the essential elements required for sustaining diverse and active microbial ecosystems.

2. Bradford Assay – Protein Detection

The Bradford assay measures soluble proteins in soil extracts using the Bradford reagent that is prepared with Coomassie Brilliant Blue G-250 dye. In the presence of proteins, the reagent undergoes a distinct colour change from brown to blue as the dye binds to protein molecules. This change of colour indicates the presence and concentration of proteins which in turn indicates viable microbial biomass and active biochemical processes in the soil.

3. Sudan III Test – Lipid Detection

The Sudan III assay stains lipids red indicates the presence of neutral fats and triglycerides. Lipids serve as both energy reserves and structural components of cell membranes. Their detection confirms lipid-rich organic material and provides evidence of living or recently dead biomass.

4. **Molisch’s Test – Carbohydrate Detection**

Molisch’s reagent produces a violet ring when carbohydrates are present, confirming the existence of sugars and polysaccharides. These compounds are vital energy sources and structural elements in microbial cells and biofilms. Detecting carbohydrates indicates active biological productivity and energy availability in the soil.

5. **WST-8 Assay – Microbial Metabolic Activity**

The WST-8 test detects living microorganisms by producing an orange-yellow dye when reduced by active enzymes. This real-time indicator of respiration distinguishes living cells from dead organic matter, proving that microbes are metabolically active and energy-generating within the soil.

6. **RAMAN Spectrometer**:

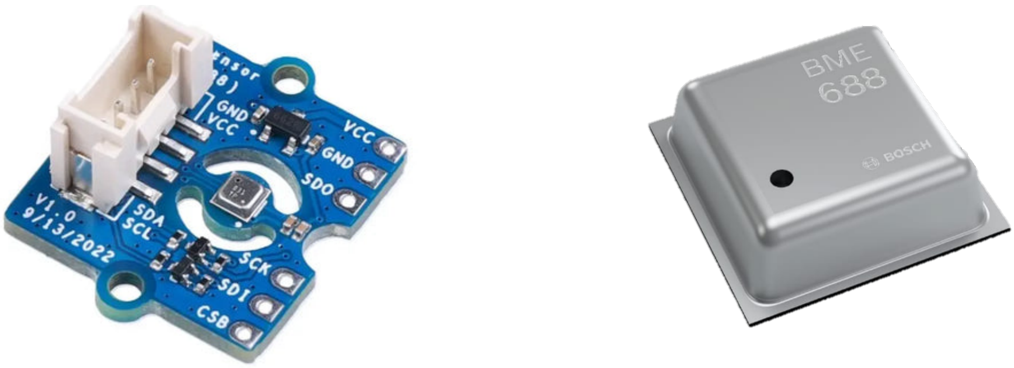
Our custom-built Raman spectrometer identifies carotenoid pigments in soil samples exclusively produced by living microorganisms. Operating at 532 nm laser excitation, the instrument detects carotenoids through their diagnostic spectral signatures at 1005 cm^{-1}, 1155 cm^{-1}, and 1530 cm^{-1}, providing direct evidence of microbial presence and soil habitability.

7. **Optical Microscope:**

An optical microscope analyses soil texture, grain size, and mineral composition to characterize the stratigraphic profile of the test site. This examination reveals depositional layers and soil structure, providing geological context for interpreting habitability and correlating microbial activity with environmental conditions.

7.2 Atmospheric Analysis

1. **BME688 Environmental Sensor – Atmospheric Profiling**
   The Bosch BME688 measures temperature, humidity, pressure, VOCs, VSCs, carbon monoxide, and hydrogen. These parameters reveal environmental conditions that influence microbial viability. VOCs and VSCs indicate decomposition and microbial metabolism, providing indirect evidence of biological activity and organic matter turnover.



BME688 Sensor

2. Electrochemical O_2 Sensor – Oxygen Measurement

This sensor quantifies oxygen concentration based on galvanic reactions, revealing the soil’s redox state. Oxygen-rich layers support aerobic organisms, while deeper, oxygen-poor zones harbour anaerobic microbes. A gradient in oxygen levels suggests a complex and active microbial ecosystem with diverse metabolic pathways.

8. Current status of the rover

The design and fabrication of the mechanical structure of the rover has been completed. Life Sciences domain is actively involved in ongoing R&D. In the AI domain, the team is currently working on a model to detect conesand determine their colour using gradient-based techniques. The ROS team is working on the application of EKF, while focusing on the navigation of the rover. And the Electrocore domain is focused on developing stable long-range communication to support overall rover operations.

9. Prototype testing strategies

We as a team believe that a well-planned set of prototype testing strategies raise a critical role in defining our outcomes. First and foremost, the functioning of each subsystem is examined to provide its fullest efficacy in working. Followed by this, the rover is tested across various terrains such as sand, gravel, and uneven surfaces to ensure the smooth commutation in all the terrains. During this phase, the various missions to be accomplished is also tested. Lastly, the reliability and endurance of the rover is tested through various checks, such as the battery draining, heating of the system and its stability during communication.