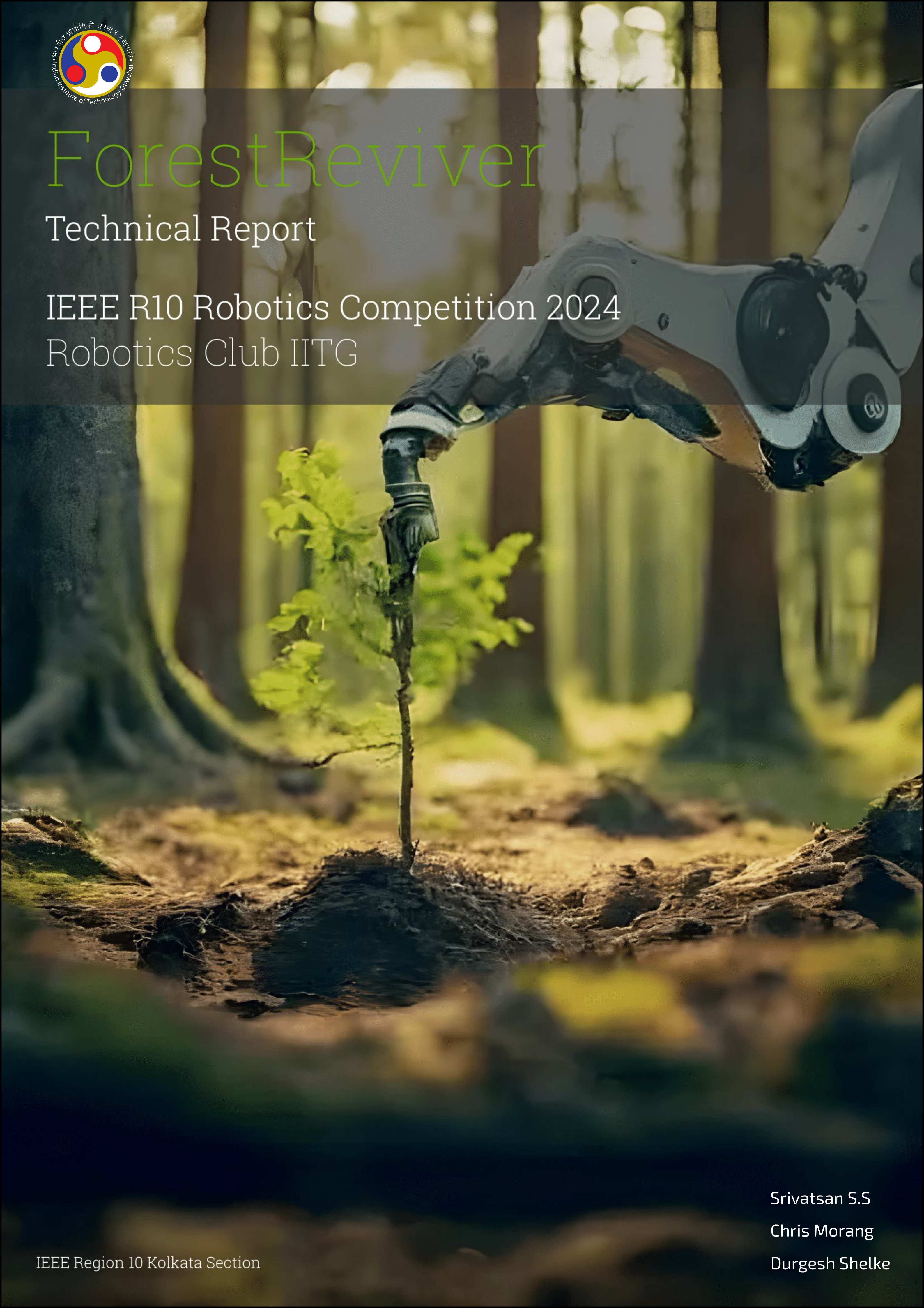

ForestReviver

Technical Report

IEEE R10 Robotics Competition 2024

Robotics Club IITG

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00

Abstract

Deforestation remains a critical global issue, posing significant threats to biodiversity, climate stability, and the sustainability of natural ecosystems. Traditional reforestation efforts, while essential, often face challenges such as ecological imbalance due to selective species growth and failures arising from inadequate consideration of environmental variables. In response to these challenges, we propose the development of an autonomous system—termed the "ForestReviver"—designed to reforest areas with minimal human intervention. This machine aims to address the limitations of manual reforestation and ecological imbalances due to unplanned forced reforestation attempts.

The technical aspects of our attempt to construct this innovative solution are outlined, highlighting the machine's design, functionalities, and test report.

01

Introduction

1.1 Introduction

This design report documents the comprehensive process and methodologies employed by our team in the design and development of “ForestReviver”, a rover specifically made to challenge the problem of increasing Deforestation and the immediate need for Reforestation.

The primary objective of our team was to engineer a rover capable of navigating and investigating deforested terrains and perform reforesting activities suitable to the ecosystem.

1.2 Interdependencies Schematic

The diagram below shows a high-level overall System Architecture of our rover.

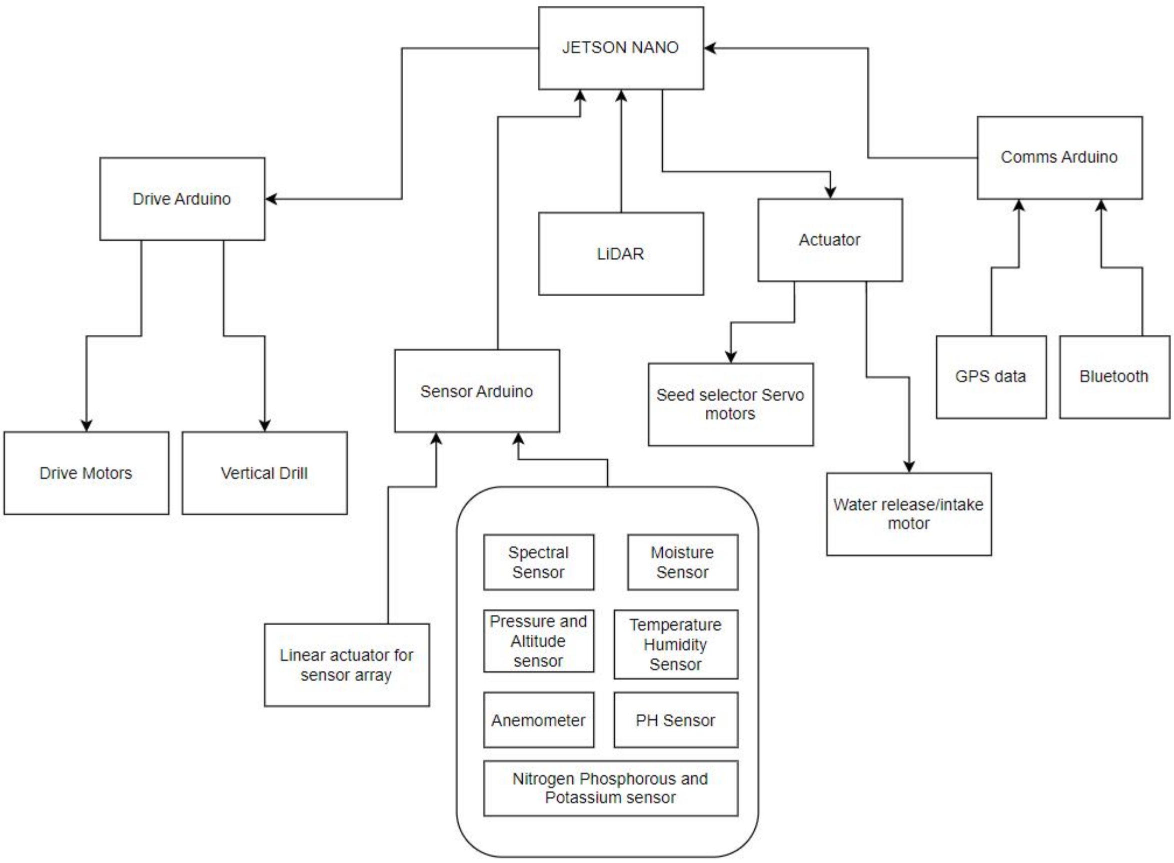


Figure 1.1

1.3 Hardware Description Schematic

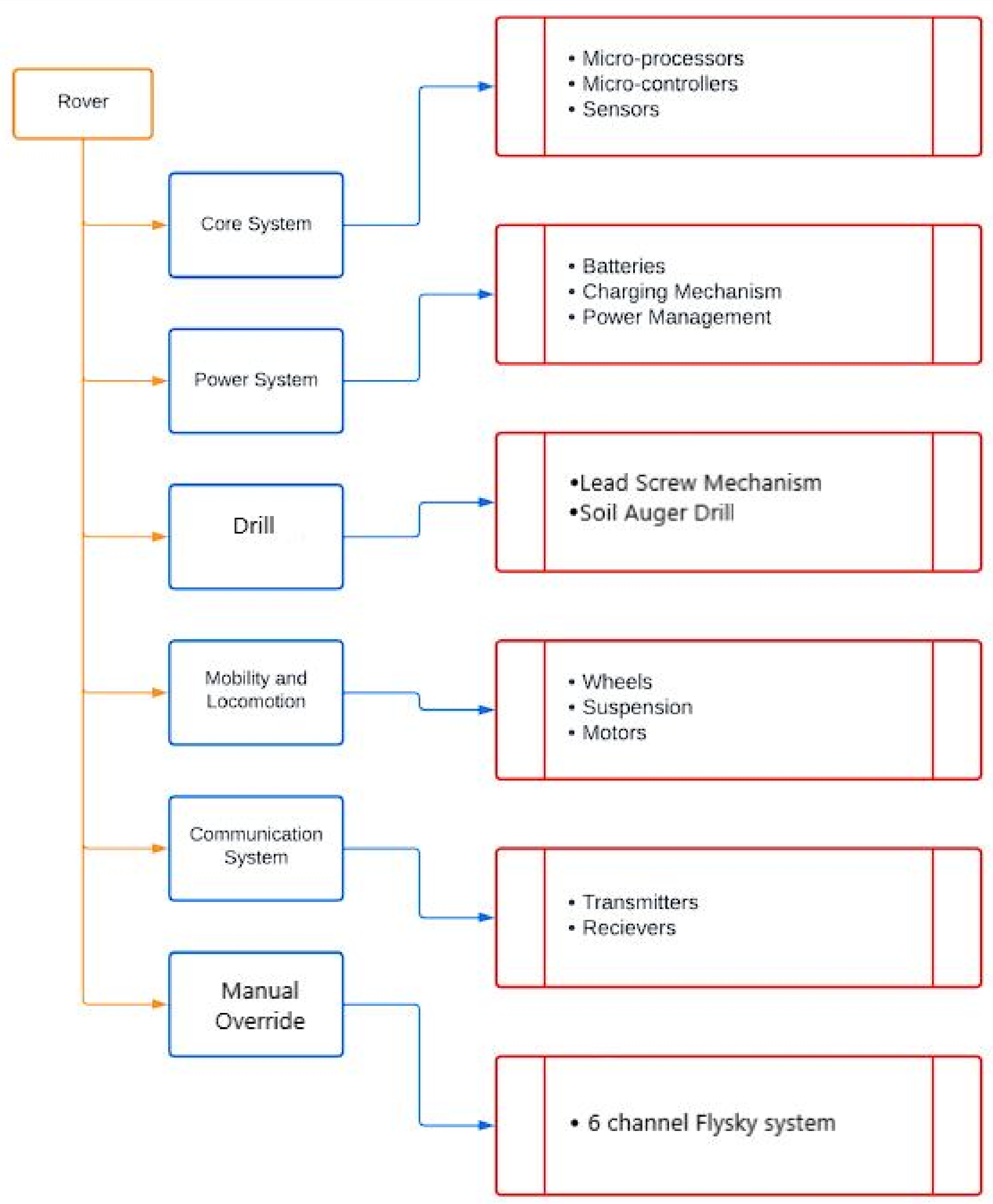


Figure 1.2

02 Rover Mobility

2.1 Sub-System Division

This section will cover the following subsystems:

1. Mechanism
2. Drive Electronics Logic

Software and Sensor System Component details are provided in a dedicated sections later on.

2.2 Mechanism

The Mechanisms of our rover are divided into six sub-systems namely,

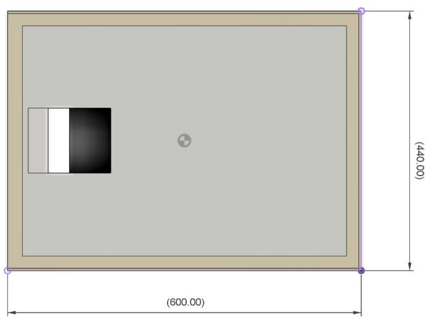
1. **Chassis**
2. **Suspension**
3. **Wheels**
4. **Differential**

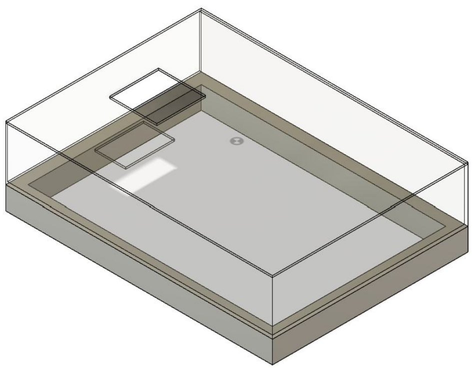
2.2.1 Chassis

Chassis is one of the most fundamental parts of the rover. It serves as the backbone, providing the necessary structure and stability. It supports all the other components of the rover.

The chassis is made up of Aluminium Rectangular Tubes, which are welded into form, and encompasses the drill, sensor system and houses the electronic components of the rover. Its main aim is to provide structural integrity to the rover and act as a protective housing for all other subsystems.

All dimensions are in mm



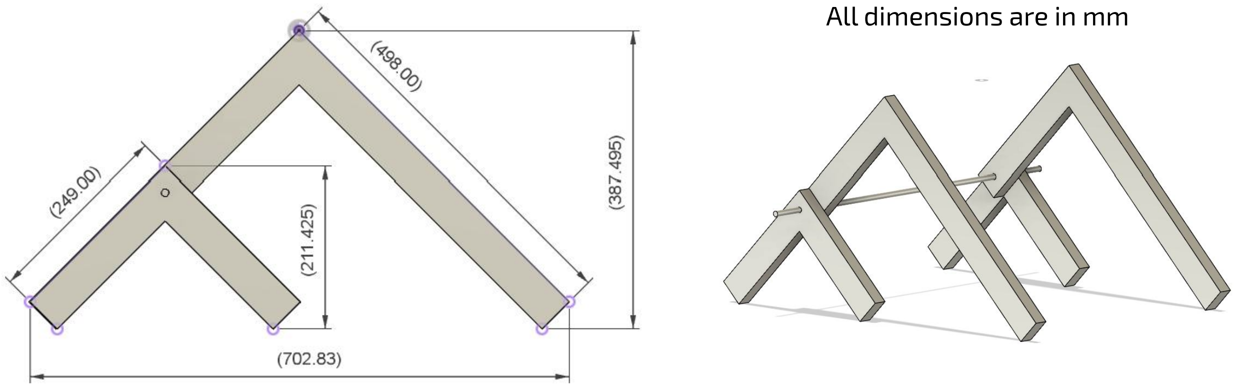


Dimensions of Chassis

Figure 2.1

2.2.2 Suspension

The rover's Rocker-Bogie Suspension system is crucial for moving smoothly on bumpy ground. The Rocker-Bogie Suspension is made for flexibility and adaptability. These traits let the rover go on lots of types of ground. The rover can move and adjust by itself, which is vital to keep the wheels on the ground and have a good grip on many surfaces.



Dimensions of Suspension
Figure 2.3

The rocker-bogie suspension system is a proven design for wheeled rovers, particularly those operating in challenging terrains. It's characterized by its unique structure, which includes interconnected rockers and a differential, enabling the rover to navigate uneven surfaces and overcome obstacles effectively.

Advantages:

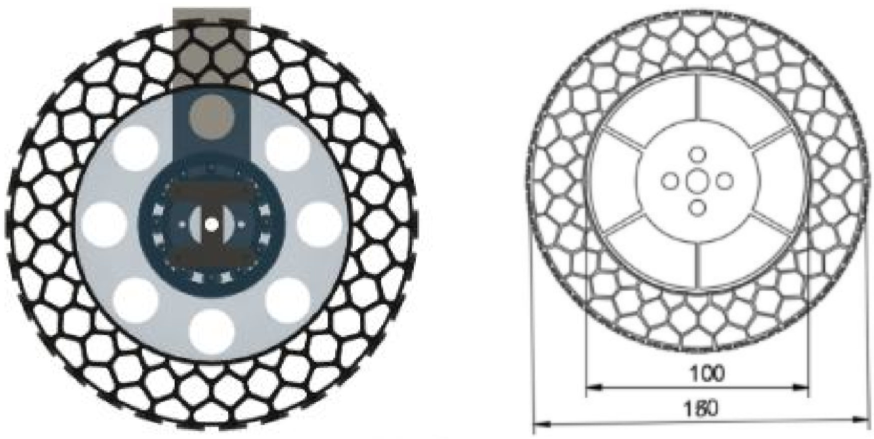
1. Obstacle Surmounting: The rocker-bogie design allows rovers to climb obstacles up to twice the size of their wheels while maintaining ground contact with all six wheels. This enhances their ability to traverse rugged terrain.
2. Stability: The system provides exceptional stability, allowing rovers to withstand significant tilts without overturning. This is crucial for operation in challenging environments.
3. Maneuverability: The independent motors for each wheel and the ability to turn in place grant the rover excellent maneuverability and agility.
4. Reduced Body Motion: The rocker-bogie design effectively reduces the motion of the rover's main body, minimizing the impact of shocks and vibrations on sensitive instruments.
5. Stowable Design: The system can be stowed in a compact space, making it suitable for missions with limited space constraints.
6. Reliability: The rocker-bogie design is known for its reliability and durability, making it well-suited for long-duration missions in harsh environments.

The rocker-bogie suspension system offers a robust and versatile solution for wheeled rovers operating in challenging terrains. Its advantages in terms of obstacle climbing, stability, maneuverability, and reliability make it a popular choice for missions in challenging terrains.

Aluminium was our material of choice due to it's superior Strength-to- Weight ratio and resistance to abrasion and corrosion compared to other metals.

2.2.3 Wheels

The rover's mobility ultimately depends on the wheels of the rover. We have designed the wheels considering the given problem statement and mission in mind.



All dimensions are in mm

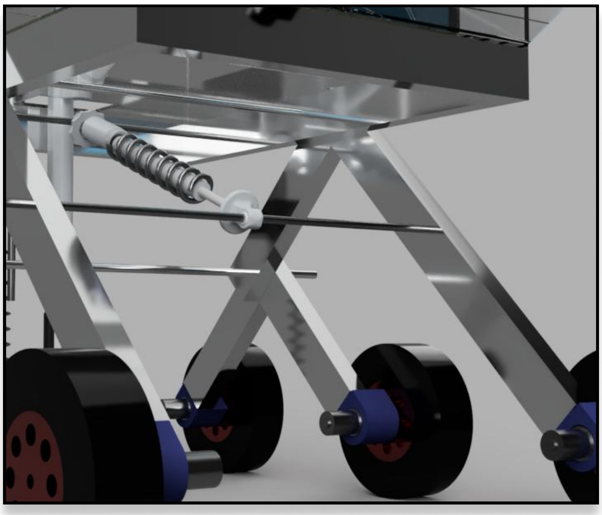
Dimensions of Wheels
Figure 2.4

Our design acknowledges the dynamic nature of the arena, accommodating variations in terrain gradient, obstacle dimensions, and crater formations. By addressing these challenges, our wheel aims to facilitate smooth rover navigation and operational efficiency. Some of the salient features of our wheel design is as follows:

1. **Honeycomb Structure**: Our wheel features a hexagonal cell honeycomb structure, strategically engineered to distribute weight effectively and enhance flexibility. This structure by design allows controlled deformation of wheel at the point of contact, which increases the area of contact between the wheel and the ground. This results in better gripping while clearing obstacles and better weight distribution.
2. **Aluminium Rim**: Aluminium is chosen over other materials owing to its high strength/ weight ratio and flexibility. Aluminium can undergo significant reversible strain, enabling the tire to withstand higher magnitude deformation before undergoing permanent deformation.
3. **Material**: TPU 95A: Utilising Thermoplastic Polyurethane (TPU 95A) for its flexible and shock-resistant properties. TPU is specifically chosen because of its ability to provide elastic deformation over a large range of temperature and stresses. TPU is also highly abrasion resistant which reduces the wear and tear of the grips in harsh terrain.

2.2.4 Differential

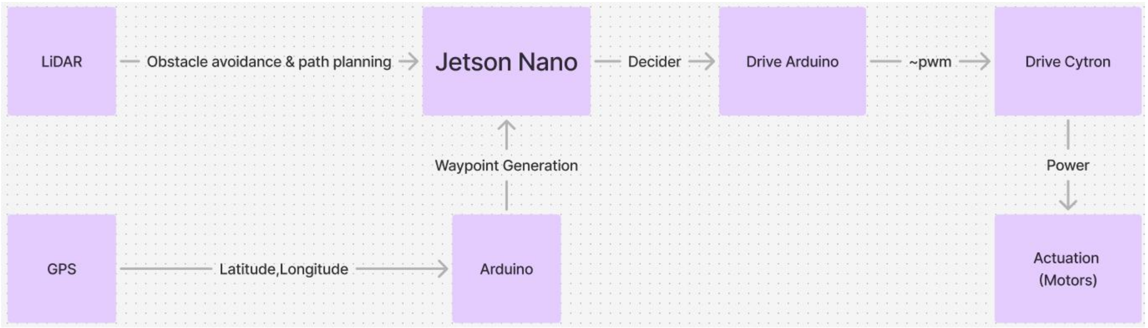
The differential bar is a pivotal component of the rover, ensuring that the vehicle maintains balance on uneven terrain and the base remains nearly horizontal. It operates on a principle of balance and counterbalance, crucial for the rover's ability to navigate challenging landscapes. Its function is to act as a balancing scale, responding to shifts in the rover's weight as it climbs over rocks or dips.
To address this challenge, we've developed a differential system equipped with an active spring suspension, in addition to the rocker-bogie setup.
A rod has been connected between the forearms of both suspensions, as seen in the figure. The spring is attached to the rod on the forearms of both suspensions and to the rear of the chassis.
The point of axis where one end of the spring connects to the rod acts as a lever for both the right and left suspension systems to work independently, while the spring helps maintain the chassis's stability.



Differential

Figure 2.5

2.3 Drive Electronics Logic



Roving Software & Electronics Architecture
Figure 2.6

The above image shows the overall software logic and the Electronic architecture of the roving mechanism. The nuances of the mechanism are explained in detail in the navigation section ahead.

03

Navigation

3.0 Overview

An overview of the basic computational processes in navigation:
Jetson Nano is going to be our Computational device which hosts a python flask server for the respective nodes and topics to be initiated.
Arduino's are going to be used to establish motor encoder power control to maintain the RPM at a desired rate using a Cytron Motor driver.
We are going to use both LIDAR and GPS data as an input to the navigation stack.

3.1 Components/Software Used:

- LIDAR
- Camera
- Jetson Nano
- Arduino Uno * 2
- Arduino Nano * 2
- Arduino Mega
- Cytron Motor Driver
- Motor with Encoder

3.2 Navigation configuration required:

3.2.1 Python Flask Server

The python flask server is our alternative to using ROS in order to reduce computations and have simpler, customization of visualization of various data we collect.

3.2.2 GPS

GPS (Global positioning system) is used to track the robot in real-time. The GPS code creates a GPS waypoint map with co-ordiantes of each waypoint the robot is expected to reach in order to reach the final destination.

3.2.3 LiDAR

LiDAR provides real-time point cloud map of the obstacles around the robot. The 2D map is being used for real time obstacle avoidance path-planning of the robot.

3.2.4 Decider

The decider code in the Forest Reviver robot serves as the central decision-making algorithm that integrates inputs from both the GPS and LIDAR systems to ensure optimal navigation. Its primary function is to evaluate real-time data from LIDAR sensors, which detect obstacles in the robot's path, and prioritize these inputs to prevent collisions. When an obstacle is detected, the decider code overrides the GPS instructions, directing the robot to take immediate evasive action, such as stopping, turning, or rerouting around the obstacle. Once the path is clear, the decider code seamlessly switches back to following the GPS-generated waypoints, allowing the robot to continue its journey toward the reforestation site or along the pre-defined spiral path. The Decider communicates the final instruction through serial communication to the Arduino responsible for drive actions of the robot.

3.2.5 Arduino Uno

Arduino Uno receives instruction from the Jetson communicated by the Decider code, this instruction is processed and accordingly the arduino sends PWM signals to the Cytron for implementation of instruction.

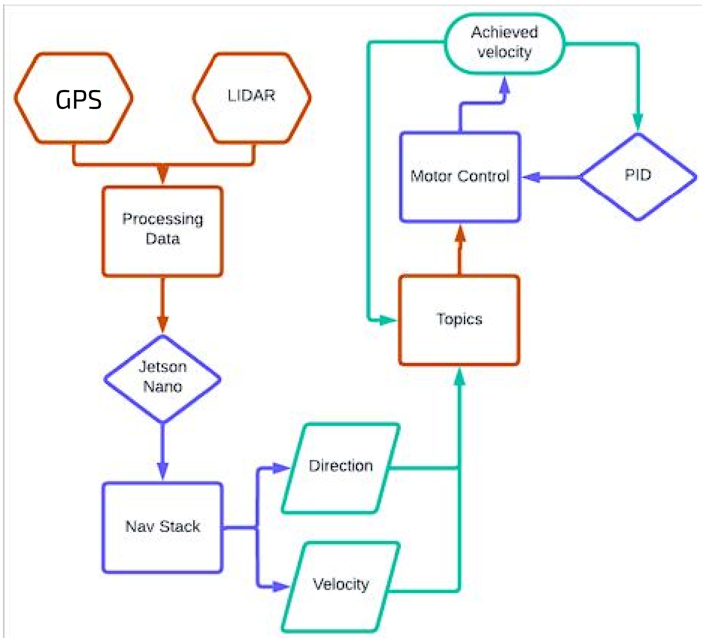
3.2.6 Navigation Workflow

Stage 1: Navigation to Reforestation Site

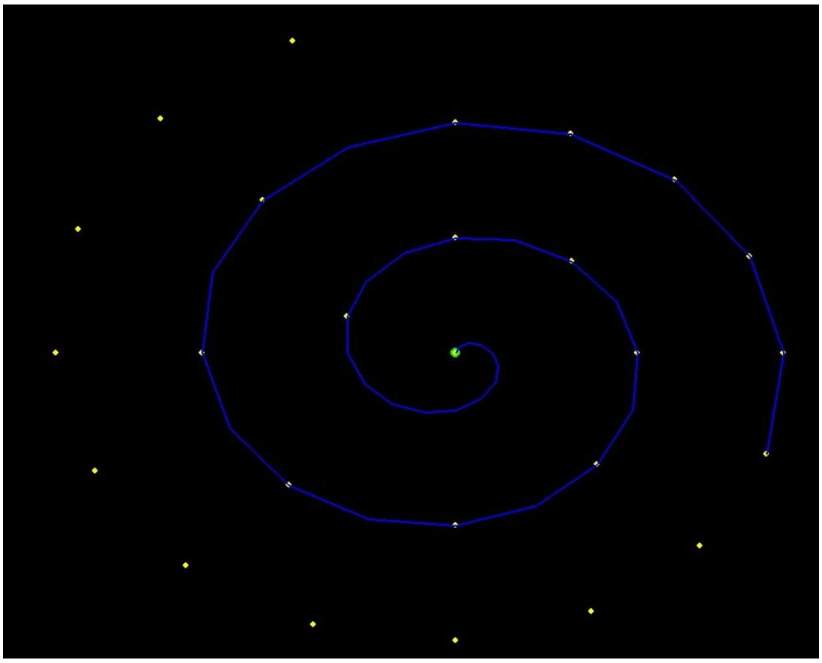
- GPS-Based Waypoint Navigation:
  - Uses GPS to generate waypoints for broad navigation to the reforestation site.
- LIDAR for Obstacle Detection:
  - Continuously monitors surroundings for obstacles.
  - Provides real-time inputs for obstacle avoidance.
- Decider Algorithm:
  - Prioritizes LIDAR inputs for obstacle avoidance.
  - Defaults to GPS instructions when the path is clear.

Stage 2: Reforestation Process

- Pre-Defined Square Spiral Path:
  - Follows a square spiral path for systematic coverage of the reforestation area.
- GPS-Guided Navigation:
  - GPS guides the robot through waypoints arranged in the square spiral pattern.
- LIDAR for Continued Obstacle Avoidance:
  - Ensures obstacle-free operation during the reforestation process.
- Dual-System Coordination:
  - Combines GPS and LIDAR inputs to adapt to dynamic environmental conditions, ensuring precise and efficient navigation.



Navigation Control Schematic
Figure 2.1



Stage 2 SPIRAL Path Simulation with mock GPS feed

3.2.7 Survey Logic

Property	YOLO	R-CNN	DPM	Overfeat	MultiGrasp
Speed	Fast (real-time detection)	Slow (more than 40 seconds per image at test time)	Fast (due to unified architecture)	Efficient (but requires significant post-processing)	Fast (only needs to predict a single region)
Model Structure	Straightforward (directly outputs position and category of bounding box)	Complex (each stage must be precisely tuned independently)	Unified (replaces disjoint parts with a single convolutiona l neural network)	Disjoint (optimises for localisation, not detection performance)	Simple (only needs to predict a single graspable region)
Focus	Shape and colour of object	Region proposals	Static features	Localisation	Region suitable for grasping
Post Processing Requirement	No	Yes	No	Yes	No

- Continuous Frame Capture: A camera mounted on the navigation system continuously captures frames at a frequency of one frame every two seconds.
- YOLO v4-tiny Model Application: Each captured frame is processed using the YOLO v4-tiny model, specifically configured to detect objects classified as "trees."
- Tree Density Calculation: The model's output is analyzed to determine the density of trees present within each frame.
- Deforestation Estimation: The calculated tree density is compared against a predefined threshold to estimate whether the area is likely to be deforested.
- Data Aggregation and Reporting: The tree density data is aggregated over time and provided to the user as survey statistics, offering insights into the state of forestation within the surveyed area.

04 Drill

4.0 Sub-System Division

This section will cover the following subsystems:

1. **Mechanism**
2. **Drive Electronics Logic**

4.1.1 Mechanism:

4.1.1.1 Lead Screw Mechanism:

Lead screw mechanism is a simple yet effective device that converts rotary motion into linear motion through a threaded rod and nut. The pitch of the thread determines the linear movement per rotation. Lead Screws offer high accuracy and load capacity compared to ball screws. They are widely used in various applications, including machine tools, linear actuators, and precision positioning systems. Lead screws are a viable option for soil drilling applications due to their simplicity, cost-effectiveness, and ability to handle significant loads. While they may have limitations in terms of efficiency and speed compared to other options, they offer precise positioning and can be self-locking. We have chosen this mechanism as we need precision, simplicity, high load capacity, etc while speed is not our primary concern (speed can be improvised with faster motors).

4.1.1.2 Soil Auger Drill:

Soil auger drills are highly efficient and versatile tools designed for a wide range of soil drilling applications. Their helical design allows for efficient penetration through various soil types, making them suitable for tasks such as foundation drilling, well drilling, and soil sampling. Auger drills offer several key advantages, including their ability to reach significant depths while minimizing disturbance to the surrounding soil. This makes them particularly valuable in applications where soil integrity is crucial. While auger drills may not be the best choice for drilling through hard rock formations or for extremely deep applications, they are generally a cost-effective and efficient solution for many soil drilling needs. For the purpose of planting all these advantages are crucial and that led to the selection of this drill.

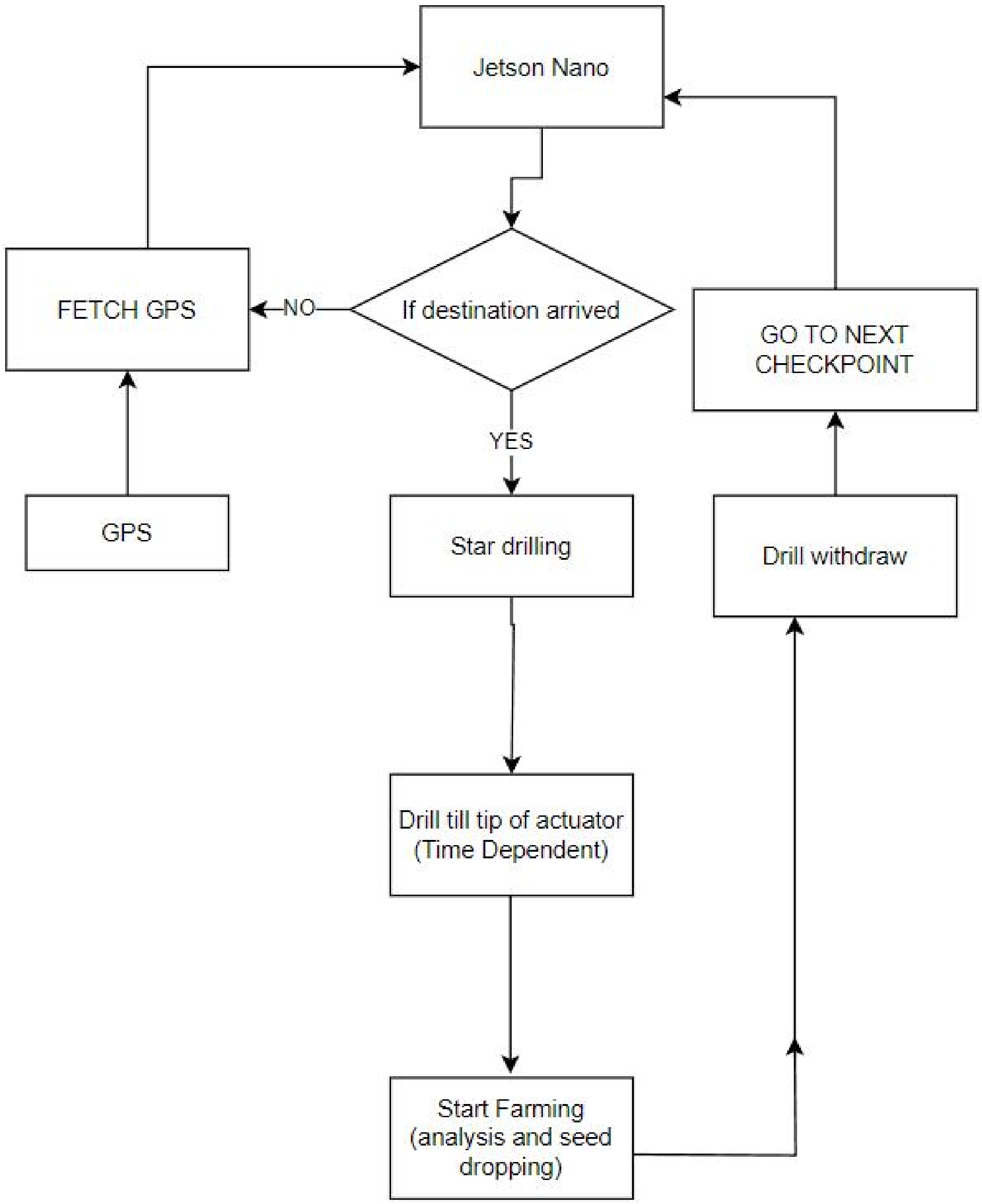
4.1.1.3 CAD AND DRAWINGS

A Drill

Figure 3.1

4.2.1 DRIVE ELECTRONICS LOGIC

4.2.1.1 Electronics Architecture



05 Sensor System

5.0 Sub-System Division

This section will cover the following subsystems:

1. **Drive System**
2. **Soil Analysis**
3. **Weather Analysis**

5.0.1 Drive System

1. **LiDAR:** The LiDAR (Light Detection and Ranging) sensor is utilized for real-time obstacle detection and terrain mapping. It provides high-resolution spatial data, enabling the robot to detect and avoid obstacles effectively while navigating rugged terrains.
2. **GPS:** The GPS (Global Positioning System) serves as the primary tool for waypoint-based navigation. It allows the robot to determine its precise location and follow a predefined path to reach the reforestation site and execute the square spiral pattern during planting.
3. **Camera:** The camera system captures visual data, which supplements LiDAR and GPS inputs. It is used for visual inspection and additional obstacle detection, aiding in the robot's navigation and environmental assessment.

5.0.2 Soil Analysis

1. **NPK Sensor:** The NPK sensor measures concentrations of Nitrogen (N), Phosphorus (P), and Potassium (K) in the soil. This data is used to assess soil fertility and guide planting decisions.
2. **Spectral Sensor (AS7265X):** The spectral sensor analyzes the soil's reflectance properties across different wavelengths to determine soil composition, including organic matter content and texture. This information supports soil health assessments and planting strategy optimization.
3. **pH Sensor:** The pH sensor measures the soil's acidity or alkalinity. It ensures that soil conditions are within the optimal range for the selected plant species, influencing nutrient availability and plant growth.
4. **Moisture Sensor:** The moisture sensor measures soil water content, providing data necessary for evaluating whether soil moisture levels are sufficient for planting and seedling growth.

5.0.3 Weather Analysis

1. **Anemometer:** The anemometer measures wind speed and direction, providing data relevant to site suitability for reforestation and potential impacts on planting operations.
2. **Barometer (BMP 180):** The barometer measures atmospheric pressure, offering information on weather patterns that could affect reforestation activities.
3. **Humidity Sensor (DHT 11):** The humidity sensor measures atmospheric moisture levels, which are important for understanding soil moisture dynamics and plant transpiration rates.
4. **Temperature Sensor (DHT 11):** The temperature sensor monitors ambient temperature, a critical factor in determining planting times and ensuring suitable conditions for seedling establishment.

The respective sensor data collection logic is such that the drive system's LiDAR and camera data are collected by the Jetson and the GPS info is collected from a Neo 6M gps module connected to an arduino which is connected to the Jetson. Simultaneously the soil and weather analysis data is retrieved from one arduino Nano which is again connected to the Jetson nano.

Spectral Sensor (AS7265X) Specifications

	Parameter	Specification
1	Sensor Model	AS7265X
2	Wavelength Range	410 - 940 nm
3	Channels	18 Channels
4	Communication Protocol	I2C
5	Operating Voltage	3.3V
6	Size	20mm x 18mm

Humidity And Temperature Sensor (DHT 11) Specifications

	Parameter	Specification	
1	Sensor Model	DHT 11	
2	Humidity Range	20-90% RH	
3	Humidity Accuracy	±5% RH	
4	Temperature Range	0-50°C	
5	Temperature Accuracy	±2°C	
6	Operating Voltage	3.3V to 5.5V	
7	Size	15.5mm x 12mm	

Barometer (BMP 180) Specifications

	Parameter	Specification
1	Sensor Model	BMP 180
2	Pressure Range	300 - 1100 hPa
3	Resolution	0.01 hPa
4	Accuracy	±1 hPa
5	Operating Voltage	1.8V to 3.6V
6	Size	3.6mm x 3.8mm

06

Manual Override

The Manual Override system provides the user with the ability to control the bot manually using RC equipment. We are currently using a 6 channel Flysky for the manual override feature. 2 channels are being used for the driving of the bot in x and y direction. 1 channel is used for each, sensor array and the drill. The 5th channel is used for seed dropping.

Flysky RC equipment incorporates advanced features like 2.4 GHz frequency and AFHDS for reliable and interference-free communication. Their receivers feature low-latency, high-sensitivity, and fail-safe mechanisms, ensuring reliable control. Flysky transmitters are programmable, allowing users to customize settings and functions. Additionally, some models support telemetry, enabling real-time monitoring of crucial data. These technical features contribute to the overall performance, reliability, and versatility of Flysky RC equipment.

07

Control System Components

Onboard Processor

PARAMETER	SPECIFICATIONS
Name of Component	Nvidia Jetson Orin Nano.
GPU	Ampere, 1024 CUDA Cores, 48 Tensor Cores, 625 MHz
CPU SPEC int 2k6 SPEC int rage	6X A78, 1.5 GHz 25 106
Power	15 W
Memory	8GB, 68 GB/s

Onboard Microcontrollers

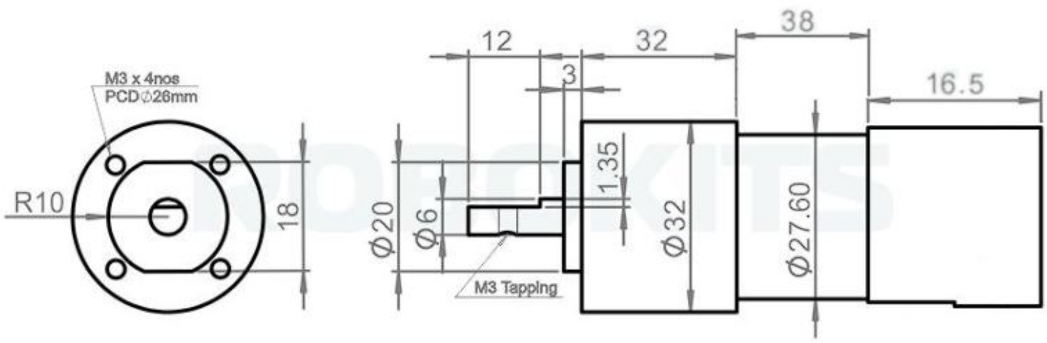
PARAMETER	SPECIFICATIONS
Name of Component	Arduino Mega
Microcontroller	ATmega2560
Input Voltage	7-12V
Flash Memory	256 KB of which 8 KB used by bootloader
Clock Speed	16 MHz

PARAMETER	SPECIFICATIONS
Name of Component	Arduino UNO
Microcontroller	ATmega328P
Input Voltage	7-12V
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
Clock Speed	16 MHz

PARAMETER	SPECIFICATIONS
Name of Component	Arduino Nano
Microcontroller	ATmega328
Input Voltage	5V
Flash Memory	32 KB of which 2 KB used by bootloader
Clock Speed	16 MHz

Motors (Roving and Drill)

PARAMETER	SPECIFICATIONS
Name of Component	RHINO IG32 PLANETARY DC GEARED QUAD ENCODER MOTOR
Rated Voltage	12V
Rated Speed	10-800 RPM
Rated Current	1.2 A
Stall Current	7.5 A
Breaking Torque	140 kg-cm



08 Tests

8.1 Testing for Drill

We performed load testing for the drill. The problems encountered were lack of precision which was worked upon. After that, the drill works perfectly fine without any problem up until now.

8.2 Testing for Sensors

We performed testing for all the sensors in actual environment and were re-calibrated accordingly. Problems faced were while fetching input from NPK sensor. The issue was resolved by using a serial to RS485 convertor instead of TTL to RS485 convertor.

8.3 Testing for Rover Mobility

We performed load testing for the Mobility in open environment with obstacles. The issue faced was a drift while turning which deformed the couplers. We tried to resolve the issue installing a steering system in the front 2 wheels of the bot, but the idea failed as not enough traction was generated in the front 2 wheels for the bot to provide sufficient steering assistance. Also due to noise being generated by the arduino, the bot would steer randomly sometimes. We reverted back to our original design , and resolved the issue of deforming couplers by making stronger and more durable couplers.

8.4 Testing for Navigation

We performed the testing for path planning. The problem faced was a delay in detecting the obstacles and avoiding it. The issue was resolved by changing the limits of obstacle detection response parameters.