# Preliminary Report

# European Rover Challenge 2022


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IUT AVIJATRIK

# Contents

# 1. Definition of Technical Requirements

| ID | Short Name | Description | Test Methodology | Compliance/ Assumptions [C - Compliant] | Test Plan and Readiness for Trials |
|---|---|---|---|---|---|
| 1.1 | Traversal | Traversing with a maximum speed of 1 m/s without using any GPS or live camera feed. | Test & Analysis | IMU and encoders will be used to map our location and traversal path. Motors with high torque and low RPM will maintain the speed limit. (C) | The rover's chassis has been manufactured. It has met the weight requirement. After the designed PCB has been received, the testing will begin, including rough terrains and deep pits. |
| 1.2 | Electrical System | Crafting an electrical system that can adequately handle all the electrical components used in the rover. | Test & Analysis | Several Arduino and STM32 MCUs will be used for hardware feedback and control. A Raspberry Pi 4B will be used to control all the microcontrollers, image processing, and autonomous computation. A dedicated PCB will also be used to measure the current and voltage levels in the system to calculate power consumption for further analysis and safety measures. Driving PCB supports VNH2SP30 and IBT2 motor drivers as backup, ensuring more flexibility and accessible debugging methods. (C) | The electrical circuits have been designed and simulated, and they are ready for prototype circuit manufacturing. Afterwards, the PCBs and wiring will undergo short circuit tests and fault tests. One controller system will control Wheels; arm, collection, and probing will be separately controlled by another independent controller system. More details are covered in the architecture part. These controllers can successfully maintain the equipment used in the rover and provide proper current and voltage data. Obtained data will be cross-checked with a multimeter. |

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| 1.3 | Safety Measures | Implementing an indicator lamp that will blink red, orange, or yellow and be visible to people at a 10m distance. It will be active at least 5 seconds before executing any rover actions. It will also be of industrial standard. | Test | 10mm Red Indicator LEDs will be used on the back of the rover's body for better visibility from a 10m distance. LEDs will blink when the rover gets a command. (C) | The RPi 4B module associated with a dedicated LED driver circuit has been designed to control the LED in the back panel and maintain the lighting sequence before executing any command. The LEDs are of industrial standard and visible from more than 10m in the daylight. The system has been tested in a breadboard and basic arrangement, and it works fine. |
| | | Implementing a large visible red emergency safety button will cut off the internal power and bring the rover to a halt as soon as the button is pressed. | Test & Review | An industrial-grade Hanyoung CR-257R emergency stop switch will be used to help avoid catastrophic errors during operation just by pressing it. (C) | A relay controller circuit has been designed (explained in the Safety Systems) and simulated for safety and emergency stopping operation. In simulations, it has worked perfectly and is ready for PCB manufacturing. Further testing will be conducted afterwards. |
| | | Enforcing autonomous operation execution delay. | Test | All autonomous operations will start with a delay of 5 seconds and issue the command with adequate measures. Any rapid or immediate movement will be avoided, as will an overflow of command broadcast. (C) | A delay circuit has been designed, simulated, and tested. It starts autonomous operations with a 5 seconds' delay. The test has been successful. |
| 1.4 | Communication | Carrying out radio communication with the rover using legally available frequencies and power levels. | Review & Test | 2.4 GHz Wi-Fi will be implemented using A MikroTik Rb-metal router on the rover, and a TP-Link Wi-Fi receiver will be used at the base station. After testing and comparing performance, a directional antenna might be used at the base station. For analogue video, 5GHz transmitters and receivers will be used. | The communication system has been designed and tested with hardware. The range is around 1km in LOS conditions and about 150-200m in non-LOS conditions. The base station computer has successfully communicated with the onboard Raspberry Pi 4B in SSH, and video feeds have also been relatively visible. Overall, the system is ready. |
| 1.5 | Maintenance Task | Demonstrating the ability of | Test & Review | A robotic arm is required to perform maintenance | A robotic arm has been designed and is ready for |

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| | | the rover and team to operate electrical panels on which several switches and other electrical components are mounted. | | tasks. Previously, the feedback system consisted of open-loop actuators. The feedback system will be implemented using encoders and stepper motors this year to acquire more significant vertical and horizontal reach. For performing autonomous tasks, the rover will use inverse kinematics. A customised end effector has been designed that can rotate 360 degrees to perform maintenance tasks. In the previous versions, milled aluminium bars in the primary and secondary arms had been used. (C) | manufacturing. After manufacturing, a clone of the competition's maintenance board will be prepared (using the exact dimensions given in the rulebook). Afterwards, manual control will be practised, and autonomous tasks will be tested and performed. The robotic arm is undergoing manufacturing and is not yet ready for testing. |
| 1.6 | Probing Task | Placing and collecting probes from the rover's cache in different map locations. | Test and Review | The Robotic arm is required for this task. The rover will have onboard containers for collecting and safe-keeping the probes. It will also collect the probes from the container for locational placement. (C) | A probing container is being developed. After complete assembly of the rover, some clone probes will be prepared (using the exact dimensions given in the rulebook). Then probing action will be tested and optimised. The system is not ready for testing yet. |
| 1.7 | Collection Task | Collecting multiple surface samples or a single deep sample from the defined locations. | Test and Analysis | The sampling module of the rover will do the collection. The sampling module will have sealed containers for holding the samples. The rover will be kept open for both surface and deep level sampling. The best option will be chosen through experimentation. The surface sampling will be done by brushes, while an auger will do the deep sampling. And finally, the weighing will be done after placing the samples in the containers. (C) | A separate collection module has been designed preliminarily and undergoing iterations of design improvements. Afterward, it will be manufactured and tested. Currently, deep sample collection is the primary target, and design is being prepared accordingly. |

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| 1.8 | Navigation Task | Demonstrating the system's ability for the semi to fully autonomous traversal. | Test & Analysis | This year, a stereo depth sensor camera will take multiple images from sensors and compare them. Since the distance between the sensors is known, these comparisons give in-depth information. IMU and encoders will be used for automated traversing. (C) | Depth sensor output and other properties have been studied, and available 3D mapping algorithms are being tested for efficiency. After generating the 3D mapping, path planning will be implemented, which is already prepared. After the assembly of the rover, printed ARTags will be used to test on the field. |

# 2. Project Assumptions

**2.1** The rover will be a mobile and standalone platform. It will be controlled wirelessly, and the entire rover will be made from scratch by the team. Commercial off-the-shelf components will be used.
**2.2** The rover will not weigh more than 50kg. However, it might be even lighter depending on the availability of materials and resources.
**2.3** The maximum attainable speed of the motors will be approximately 41rpm, which equates to a rover travelling at a rate of 1 m/s (max) on a flat surface. It will also be operable in sandy, non-cohesive soil and rugged, dry terrain.
**2.4** The operating temperature range of the rover will be -10°C / +50°C. A sufficient cooling system will be used. Acid rain protection will also be introduced. Hence, the rover is expected to tackle wind gusts, drizzles, and other adverse weather conditions.
**2.5** The rover will be controllable via radio link within 100m range in real-time. Accepted bands and protocols will be used to communicate with the rover. Wi-Fi protocol in 2.4 GHz and a high band in 5 GHz will be used. The system will be capable of switching channels as required.
**2.6** An emergency stop button must be added, consisting of a reliable circuit and a red indicator. Additional features will be introduced for safety purposes.
**2.7** There will be some indicators equipped with industrial-grade devices. It will notify activity 5 seconds before the task and autonomous actions.
**2.8** RF form will be provided along with necessary documents.
**2.9** The rover will have an onboard probe container and at least four slots.
**2.10** For the automation of specific tasks, the rover will maintain the following states and commands accordingly as needed in the tasks, which are: 'IDLE' state, 'START' command, 'WORKING' state, 'WAIT' command, 'WAITING' state, 'RESUME' command, 'ABORT' command. Telemetry of the rover will be monitored during autonomous operations and recorded.
**2.11** The rover will have a sufficient portable DC power supply to operate for at least 80-90 minutes.
**2.12** The rover will be able to perform the following operations

- **Science Exploration:** Take images of target objects and transfer them to the base station along with weather, location, and other information.
- **Navigation Task:** Traverse automatically to target waypoints and return to the start position. It will automatically generate path plans and execute them. The rover will gather important information while traversing the mars yard. It will send allowed information to the operators in real-time, and manual controlling systems will be present as a backup.
- **Probing Task/Collection Task:** Collect probes and store them safely in containers. The rover will reach the desired destination, place the probes, and take photos of the collection and probe deployment places. The rover will be able to collect both surface samples and deep samples from desired locations and weigh the samples. It will be able to take photos of the area.
- **Maintenance Task:** The rover will be able to autonomously actuate different switches in the correct order, measure voltage, and handle armature plates and plugs.

# 3. Architecture Budgets and Technologies

## 3.1 Architecture

### 3.1.1 Mechanical

#### 3.1.1.1 Wheels

The rover consists of 4 custom-made aluminium wheels. The wheel is made of CNC cut Aluminum Plates. Aluminium was chosen because even thick aluminium plates are much lighter than stainless steel plates. This weight reduction from previous years allows the motors to work more efficiently. To support the rubber paddings, meshed steel is being used to reduce the weight even further.

#### 3.1.1.2 Rocker Differential

A rocker differential mechanism was chosen to be implemented in our rover over any other spring or hydraulic-based suspension mechanisms. The reason is that it is lightweight, cost-efficient, and easy to implement. This year's differential is a gear differential system because it takes up less space. We chose stainless steel for the entire body and rockers because it is cheap, available, and sturdy.

#### 3.1.1.3 Robotic Arm

A 5 DOF robotic arm will be used on the rover. It is made of CNC cut stainless steel plates held together by cylindrical stainless-steel beams. Despite being heavy, stainless steel has been chosen for the arm because we observed that light-weight arms are more prone to flex and vibrate, making it extremely hard to operate. Linear actuators will be used as they have a higher holding force. Lever technology has been introduced to allow the arm a greater reach. Worm gears will be used as they can self-lock themselves when not being used for the rover's safety.

#### 3.1.1.4 Adaptive Gripper

A clamp-style Aluminum mechanical gripper is being implemented on the rover. A clamp-style gripper is used because it is much simpler and more effective than fancier robotic claw designs. Adaptive gripping has been introduced to tighter grip on curved objects such as knobs, cans, etc.

#### 3.1.1.5 Collection and Probing Task Module

The collection module is designed to collect one deep sample from the mars yard. It uses a drilling system attached to a linear actuator to get below the surface and uses the vertical screw conveyor mechanism to carry the soil to a container.
For the probing task, the probes are placed on a 3d printed holder at the back of the rover, which the arm of the rover can easily reach to retrieve the probes from the holder.

### 3.1.2 Electrical

#### 3.1.2.1 Power System

The rover will have a battery pack unit that will act as a power source. It will consist of two 11.1V 3S Li-Po batteries in series combination and other batteries in parallel combination. It will also have a power bank to support the microcontrollers and microprocessors. The batteries will be easily replaceable.

### 3.1.2.2 Converter Unit

There are many components of different voltage levels, and many of them are voltage sensitive. Hence voltage converters, e.g., Buck Converters and Boost Converters, convert the input voltage to rated voltages. The converters will have feedback systems to provide a stable output voltage. Logic converters will also be used.

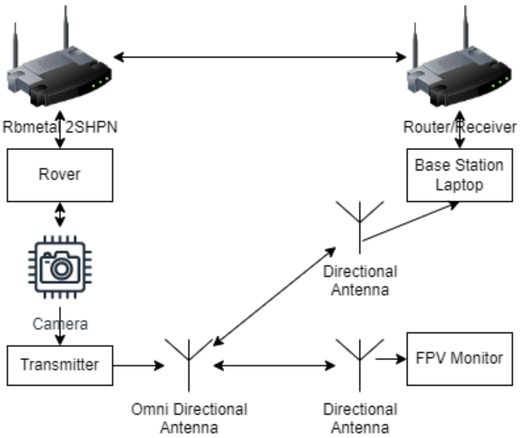
### 3.1.2.3 Controller Unit

This unit is a stack of microcontroller boards (e.g., STM32, Arduino Mega R3, Arduino Nano V3) controlled by a single board computer, Raspberry Pi 4B. Each stacking unit will control independent systems, e.g., wheel, arm, cooling, and collection module. They will measure voltage and current and feed the data to the board computer.
Most of the DC motors will be controlled by IBT2 and VNH2HP30. Both drivers can handle 30A current at peak and 14A continuous current. A4988 drivers will control stepper motors. A delay circuit is introduced to govern the autonomous activities and indicate status in the back panel. The temperature will be measured inside the rover, and a specific cooling system controller will control low noise DC fans accordingly. The controller unit will be equipped with an encoder data acquisition system. It will process the encoder data and feed it to Raspberry Pi. The controller will be directly connected to the communication system.

### 3.1.2.4 Safety Unit

An emergency tripping circuit will be present to disable the power supply to the motors for safety reasons. The circuit is directly connected to the power source, and it is not a part of the controller unit. It will be equipped with two buttons. One will stop the rover, and the other will restart the rover. Besides overvoltage, under voltage protection circuit has been designed and implemented to protect batteries. More details are discussed in the safety system.

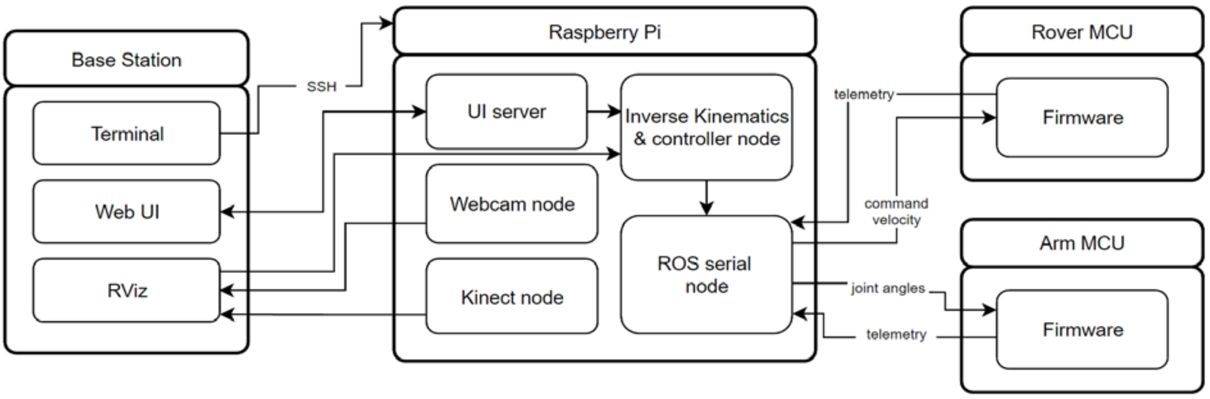
### 3.1.2.5 Communication




In order to ensure real-time connection, control video feedback, and data transfer, the communication system has been designed in such a way that it meets the requirements. We will use a 2.4 GHz Wi-Fi connection to control the rover and data transfer. There will be a Rbmetal2SHPN attached with a 10dBi omnidirectional antenna connected to the onboard computer in the rover. The base station will be connected to another router with a directional antenna. One of the routers will be used as an access point. SSH, drop bear, rsh will be used to control the rover when needed. The measured maximum transfer rate is 18.75 MB/s.
For video feedback, we will use a high band of 5GHz. FPV cameras will be attached to the rover in necessary places, and they will be directly connected with a multi-channel transmitter and omnidirectional antenna. The FPV receiver will be connected to the laptop in the base station, and there will be a separate FPV monitor with independent receiving capability. The transmitters have multiple channel switching capability to change the bandwidth as required.

## 3.1.3 Software

- ROS Noetic is used as the backbone of the software system.
- The UI server is a bridge between the ROS master and the web UI. MQTT or web socket or both can be implemented accordingly.
- Closed-loop PID control is implemented in the MCUs separately.
- The rover's Microcontroller Unit (MCU) and the arm consist of multiple boards connected via CAN bus.




## 3.2 Technical Budget

### Electrical System

| Component | Model | Quantity | Unit Price (USD) | Price (USD) |
|---|---|---|---|---|
| Motor Drivers | VNH2SP30 Motor Driver Module 30A | 2 | 25.02 | 50.04 |
| | Motor Driver 43A BTS7960 | 6 | 7.96 | 47.77 |
| | DM542 Stepper Motor Driver | 4 | 23 | 92 |
| Micro Controllers | Mini Mega 2560 | 4 | 17.63 | 70.52 |
| | Arduino Nano | 2 | 7.4 | 14.80 |
| | STM32 | 4 | 9.7 | 38.70 |
| Battery | Tiger Lipo 3S 10000 mAh | 4 | 68.25 | 273 |
| | REMAX-RPP-206 20000MAH PD | 1 | 12 | 12 |
| Bus Bar | Electrical Bus Bar | 6 | 17.1 | 102.10 |
| | 12 Point Busbar 100 Amp | 4 | 12.12 | 48.45 |
| Connector | Fork Connector Set | 1 | 6.65 | 6.65 |
| | XT60 Pair | 20 | 0.5 | 10 |
| | Bullet Connector | 5 | 0.8 | 4 |
| | USB B Connector | 14 | 0.11 | 1.50 |
| Wire | 14 AWG Wire 12 inch | 17 | 1.3 | 21.30 |
| | USB A to B Cable 1.5m | 8 | 1 | 8 |
| | Uncategorised | N/A | N/A | 11.50 |
| DC Fan | DC 12V 4" Cooling Fan | 8 | 1.38 | 11 |
| Encoder | Optical Encoder | 4 | 17.13 | 68.50 |
| PCB | N/A | N/A | N/A | 115.00 |
| Switches | Hanyoung CR-257R | 1 | 6 | 6 |
| | Flat Push Button | 1 | 2 | 2 |
| LED | 22mm Panel Mount | 3 | 1.7 | 5 |
| | | | Total | 1019.85 |

## Mechanical System

| Component | Model | Quantity | Unit Price (USD) | Price (USD) |
|---|---|---|---|---|
| Actuator | 4 inch Linear Actuator | 1 | 51.15 | 51.15 |
| | 8 inch Linear Actuator | 1 | 62.60 | 62.60 |
| Stepper Motor | Nema 23 | 1 | 22.70 | 22.70 |
| | Nema 17 | 1 | 12 | 12 |
| Worm Gear Motor | Worm Gear Motor | 1 | 59 | 59 |
| Servo Motor | MG995 | 1 | 10.50 | 10.50 |
| | LDX-227 | 1 | 22.20 | 22.20 |
| Servo Horn | Metal Servo Horn | 1 | 2 | 2 |
| Gear Motor | PG36-3650-24V-60RPM | 5 | 21 | 105 |
| | High Torque Gear Motor | 1 | 17.10 | 17.10 |
| Wheel | Aluminum Sheet | N/A | N/A | 116 |
| | MS Bar | | | |
| | Metal Mesh | | | |
| | CNC and Lathe Cost | | | |
| Gear | Bevel Gear | 4 | 1.50 | 6 |
| SS Hollow Pipe | N/A | N/A | N/A | 23.50 |
| SS Square Pipe | N/A | 10 feet | N/A | 5 |
| SS Pipe | N/A | 10 inch | N/A | 2 |
| SS Rod | N/A | 16mm | N/A | 6 |
| Bearing | 14mm Flange Bearing | 6 | 3.20 | 19.20 |
| Coupler and Shaft | N/A | N/A | N/A | 8 |
| Body Crafting Cost | N/A | N/A | N/A | 57 |
| Differential Bar Cost | N/A | N/A | N/A | 12.50 |
| Arm | Aluminium Sheet | N/A | N/A | 114 |
| | Encoder | | | |
| | Nuts and Bolts | | | |
| | CNC and Lathe Cost | | | |
| Auger | N/A | 1 | 10.50 | 10.50 |

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|---|---|---|---|---|
| | | | Total | 743.95 |

## Communication System

| Component | Product Model | Quantity | Unit Price (USD) | Price (USD) |
|---|---|---|---|---|
| Base Station | RB METAL 2SHPn | 2 | 99.0 | 198 |
| 10 dBi Omni directional antenna | AMO 2G10 | 2 | 130 | 260 |
| Sector Antenna | AM2G15-120 | 1 | 150 | 150 |
| Telemetry Module | 3DR 500 MW Radio Telemetry 433Mhz 915MHz | 1 | 24.4 | 24.4 |
| Long Range Video Transmitter | Flysight Black Mamba 5.8 GHz 2W FPV Vtx Transmitter 2000mW FPV | 1 | 45.5 | 45.5 |
| TS832 5GHz Transmitter | Eachine TS832 Boscam FPV 5.8G 32CH 600 mW 7.4-16V Wireless AV Transmitter | 1 | 12 | 12 |
| Video Receiver | 1500 mW 1.2G Wireless 8CH Transmitter 12CH Receiver | 1 | 60 | 60 |
| Diversity Receiver with Monitor | Eachine LCD5802S 5802 40CH Raceband 5.8G 7" | 1 | 160 | 160 |
| rg58 Coax Cable | SMA Female Jack to SMA Male Plug RG58 Coaxial Pigtail WIFI | 10 m | N/A | 4 |
| FPV Camera | Foxeer Mini Pro 1/2.9" CMOS 1.8/2.5mm 1200TVL | 4 | 10 | 40 |
| 13 dBi diamond antenna | Aomway FPV 5.8G 13 dB High Gain Antenna Signal Booster Diamond Directional Antenna | 2 | 6 | 12 |
| Circular Polarized Antenna | Fatshark ImmersionRC SpiroNet 5.8 GHz RHCP FPV Antenna | 2 | 1.75 | 3.5 |
| | | | Total | 969.4 |

## Software

| Component | Product Model | Quantity | Unit Price (USD) | Total Price (USD) |
|---|---|---|---|---|
| Microprocessor | Raspberry Pi 4B 8GB | 1 | 160 | 160 |
| Gyro Sensor | MPU 6050 | 5 | 2.50 | 12.5 |
| Compass | Honeywell HMC5983 | 1 | 11 | 11 |
| Force Sensitive Resistor | Force Sensitive Resistor | 2 | 9.50 | 19 |
| IR Range Sensor | IR Range Sensor | 1 | 12 | 12 |
| Webcam | Logitech HD PRO C920 | 2 | 145 | 290 |
| Depth Sensor | Xbox One Kinect Sensor | 1 | 52 | 52 |
| | | | Total | 556.5 |

## 3.3 Technology

### 3.3.1 CNC

CNC was chosen for machining the body parts as it is cost-efficient, and the possibility of error is most likely null.

### 3.3.2 3D Printing

For customizing components that need to be precise in terms of dimensions and somewhat flexible at the same time, 3D printing is being used as it can produce components with high precision and with PLA/ ABS as materials.

### 3.3.3 Computer Simulation

Recreating and maintaining the terrain in real life is challenging and costly, whereas computer simulation is very efficient. ROS-Gazebo and Unity 3D rigging animation helps us observe our rover's feedback on these rough terrains, get an idea about the real-world performance and identify our weak points to improve them.

### 3.3.4 Routing

- End-to-end communication between mission control station servers will be done using the HTTP protocol (for rest API), MQTT protocol (for sensor data), TCP/IP protocol (for socket) and UDP for video transmission.
- The mission control server will be made based on microservice architecture. Different services will be containerized with docker. A reverse proxy server will communicate among the service using an API gateway pattern. Kubernetes will be used to ensure availability, real-time load balancing and scaling.

### 3.3.5 Server and web

- Python, C++, Js, and Ts will be the coding language, with Django and Express as the web framework. MongoDB, MySQL, Redis, Neo4j, and GraphQl will be used for database and query. Pytorch will be used as an AI framework. Matplotlib, NumPy, and Seaborn will be used for data analysis. Primarily we will use REST API, but we also plan to use SOAP if we need more secure API transmission.
- HTML5, CSS3, ES6, ReactJS, Chart.js, Three.js, React have been used for interface and data visualization.
- TDD, CI/CD, Code Coverage, and JMeter will be used to ensure the system's reliability, integrity, and robustness.
- Figma will be used for prototyping.

### 3.3.6 Image and Video processing

- YOLO means you look only once. We plan to use yolov5 for different object detection is very lightweight and fast.
- Deepsort will be used instead of sort (simple online real-time tracking) as it recognizes the object no matter if it goes outside the frame and re-enters
- Pytorch will be used as the framework. We will train different models for different purposes. Like using Faster R-CNN with a ResNet50 backbone (more accurate but slower), Faster R-CNN with a MobileNet v3 backbone (faster but less accurate), and RetinaNet with a ResNet50 backbone (good balance between speed and accuracy).

### 3.3.7 Map API

NASA Open APIs are being used for map data as it is the most reliable source.

### 3.3.8 Programming IDE:

The IDEs and platforms used for programming are: Arduino IDE, VS Code, PyCharm, MongoDB compass, Xampp control panel, PHP my admin, MySQL workbench, COLAB, postman etc.

### 3.3.9 Inverse Kinematics:

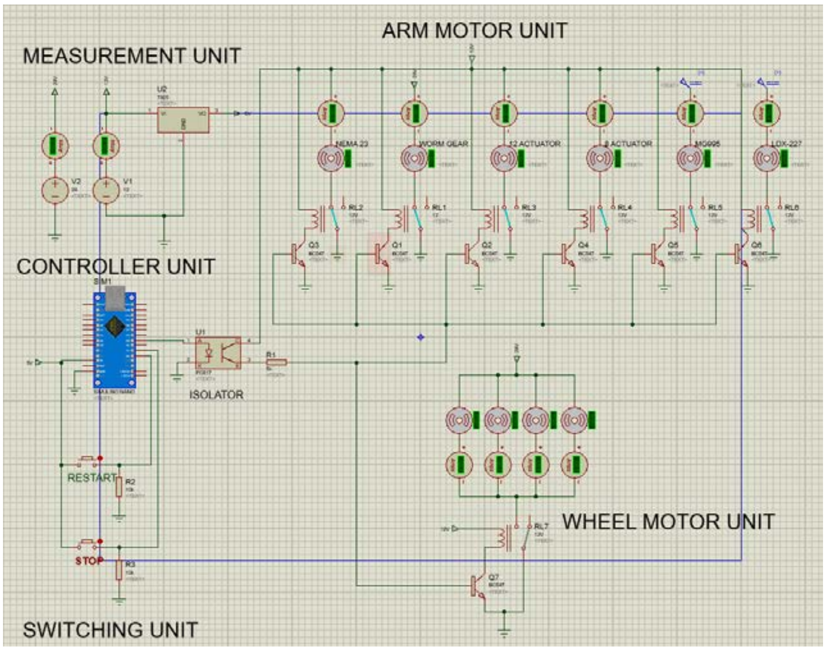
Inverse kinematics is implemented on our 5 DOF robotic arm for precise and agile movement and ease of control. This will ensure a smooth and precise transition of the end effector and provide feedback for automation.

### 3.3.10 Computer Aided Design (CAD):

We used Autodesk Fusion 360 and Autodesk Inventor to create the design of our rover's body, the wheel, arm, and all the parts needed to perform all the required tasks. We did a stress-strain analysis to find the maximum applicable force on certain parts of the rover if it is built using our desired materials. For instance, we decided to opt for aluminium for the body and rim for its light density and heavy load carrying capacity. The Animate joint feature enabled us to optimize our design, especially for the collection task of the upcoming competition.
Autodesk EAGLE and Proteus were used to design and verify the circuitry of the rover, ensuring their proper function in the pre-production phase. Modular PCBs have been designed for each rover module to maximize portability and reduce risks of failure.

# 4. Safety Systems

## 4.1 Emergency Stop Circuit:




The rear panel is equipped with two physical switches. There is a stop switch in red color, and the other is called a reset switch. The stop circuit interrupts all sorts of power supplies from the motors, so the rover comes to a standstill. Then it will go to standby mode until the reset switch is pressed. Pressing the reset switch will enable the motors to draw power from the power source again. In an emergency, the stop switch can minimize any damage to the surroundings or injuries to anyone if the rover unexpectedly malfunctions during the competition. The reset button will come in handy for a quick start from where the rover left off.

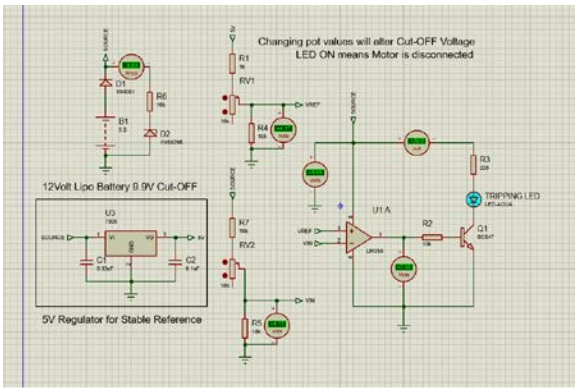
An Arduino Nano is used to control the relay switches that ultimately control the power drawn from the power source by the actuators. When the stop switch is pressed, the interrupt pin causes the Arduino to immediately turn off the relay switches. The reset switch also utilizes the interrupt pins, and the rover starts as soon as the switch is pressed.

## 4.2 Thermal Protection:

A proper airflow system will be implemented in the rover to maintain a decent operating temperature inside the enclosure. The system is still under development. 12V DC fans will be used to direct air inside. Battery, transmitters, motor drivers, microcontrollers, and especially the single-board computer will be prioritized for this design since they tend to heat up very quickly and thermal-throttle. The possible entry of dust and sand will be analyzed once the prototype is developed. Then depending on the situation, the water-cooling system may replace the existing plan.

## 4.3 Battery Protection Circuit:

Since we use 12V Lipo batteries as the primary power source, maintaining proper voltage levels is crucial. In the worst-case scenario, a lack of proper maintenance can lead to malfunctions and even explosions. So, a protection circuit has been designed for each battery. When the average cell voltage drops below 3.3V (which should be around 3.7V to a maximum of 4.2V), the circuit trips off automatically until the voltage goes up. If the terminal voltage exceeds 15V, the Zener diode will be short-circuited and protected from over-voltage. Reverse polarity protection has been implemented using a diode, but P-Channel MOSFET will be used later to improve inefficiency. The circuit has been tested in a PCB, and it works correctly.



## 4.4 Water and Short Circuit Protection:

Exposure to water has a possibility of damaging electronics. Therefore IP68 protection junction boxes and casings will be used to protect the incoming wire connections (for example, the wires from the motors of the wheel and arm) inside the rover. Wago connectors will be used to avoid complexity in wiring and subsequently prevent any short circuits. Fuses will also be used to protect from short circuit current.

## 4.5 Self Locking Mechanism:

The robotic arm has a worm gear motor in the bottom of the primary arm; this ensures a self-locking mechanism. As a result, if any power cut occurs, the arm will hold its position regardless of the power source. This prevents the possibility of potential vertical displacement due to gravity and consequent accidents.

## 4.6 Design and Manufacture Cautions

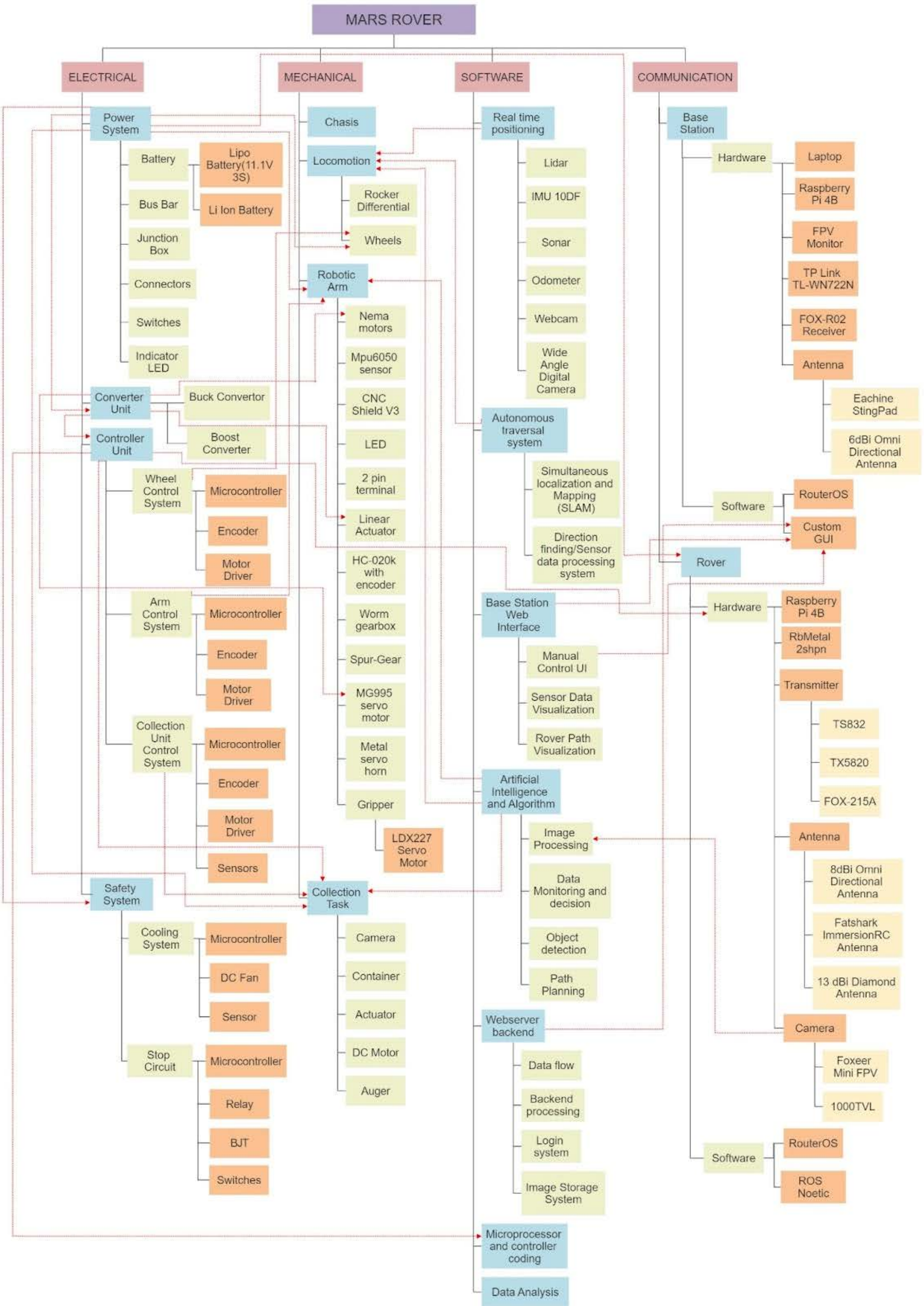
Sharp edges of metals can accidentally cause injury and bleeding, leading to clinical treatment. Keeping these risks in mind, the CAD designs have been modified in such a way to have the least amount of sharp edges. Trained professionals did all welding and machining jobs following proper safety guidelines. Round pipes have been used instead of square pipes in the wheel joints because people carry rovers holding that specific area. Likewise, some minor design and fabrication choices have been made for safety.

## 4.7 Activity Indicator System

A dedicated circuit has been designed to indicate the activity status of the rover. As per the requirement, our rover is equipped with indicator lamps informing readiness to receive commands. Monochrome 22mm LEDs are used to strengthen light intensity. Our design uses three blocks of LEDs of different colors to minimize ambiguity since sun rays and other factors may prevent us from recognizing the lit color. Also, the blocks will be illuminant enough to be visible from a 10m distance. Each color will symbolize three different meanings: ‘IDLE,’ ‘WORKING,’ and ‘WAIT.’ RGB LEDs are excluded because of high cost and power consumption. The indicators will be directly connected to the Raspberry Pi GPIOs through the controller circuit and programmed to indicate three states: Green = WORKING, Yellow = WAIT, and Red = IDLE. For the automation part, the green light will signal continually. Furthermore, the green indicator will be active 5 seconds before an activity. At this period, the rover will remain still and safe. Whenever the automatic operation is aborted, the rover will stop immediately, the red LED will be turned on, and manual operation will be active until further switching command is applied.

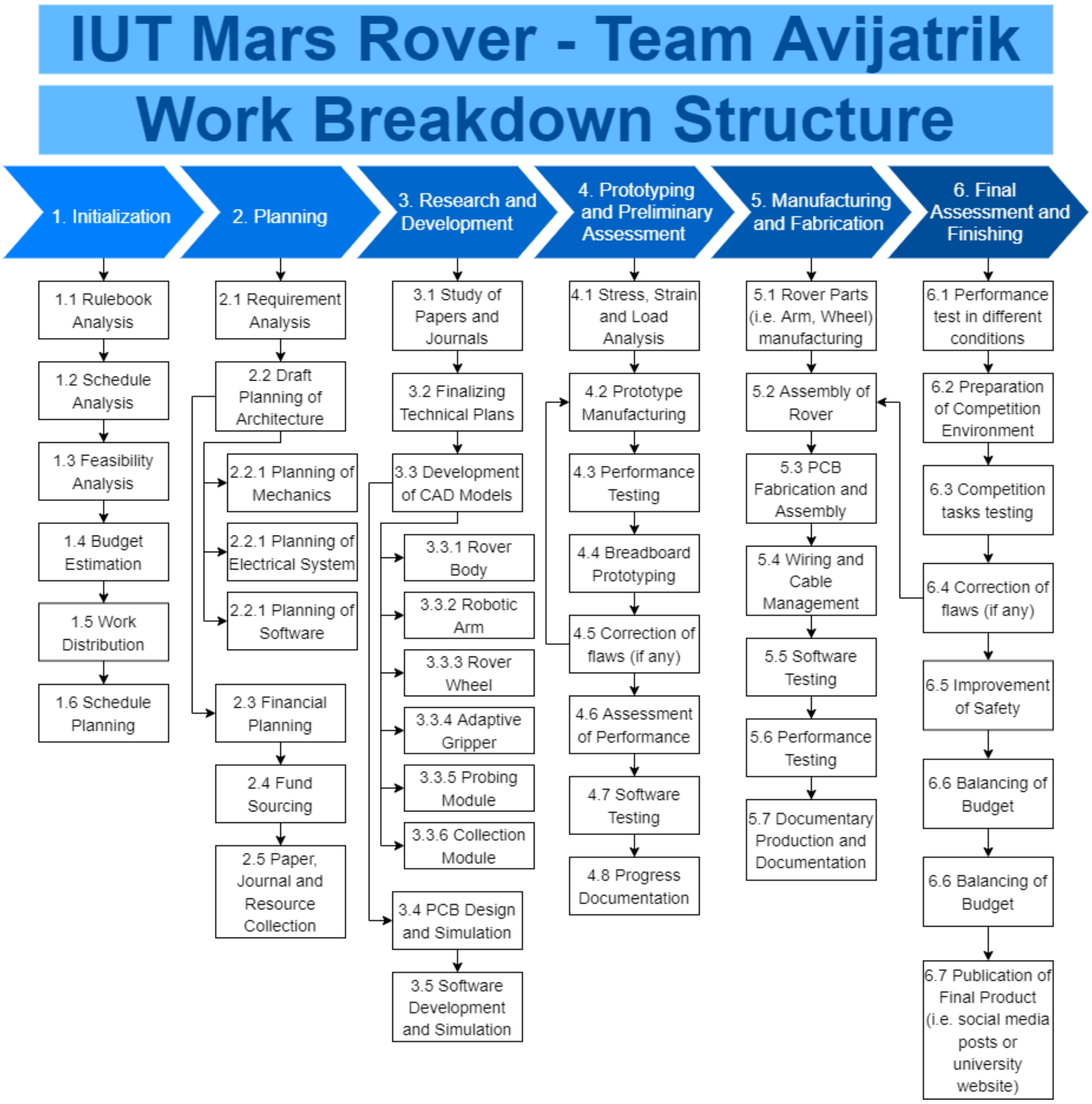
# 5. Preliminary Breakdown Structure

## 5.1 Product Tree

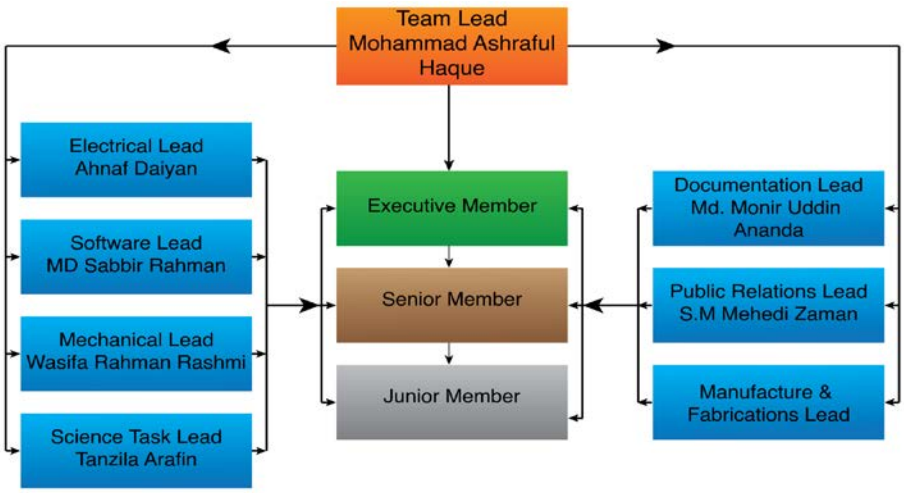



*Note: The red dotted arrows in the Product Tree are used to show the dependencies between the subsystems. The node/subsystems from where the arrows originate are the independent ones and the subsystems where the arrows land on, are the dependent ones.*

## 5.2 Work Breakdown Structure




## 5.3 Organizational Breakdown Structure



# 6. Financial Planning

## 6.1 Sub Unit and Total Cost

Estimated costs of different subunits of the project are:

**Logistics:**

| Sl No | Area of Expense | Cost (USD) |
|---|---|---|
| 1 | Transportation | 79.91 |
| 2 | Lunch and Snacks | 79.91 |
| 3 | T-Shirt | 262.56 |
| 4 | Printing and Stationery | 22.83 |
| 5 | Spray Paint | 3.42 |
| 6 | Transparent Acrylic Sheet | 45.66 |
| 7 | Paint Primer | 3.42 |
| | **Total** | **497.72** |

**Manufacturing Tools:**

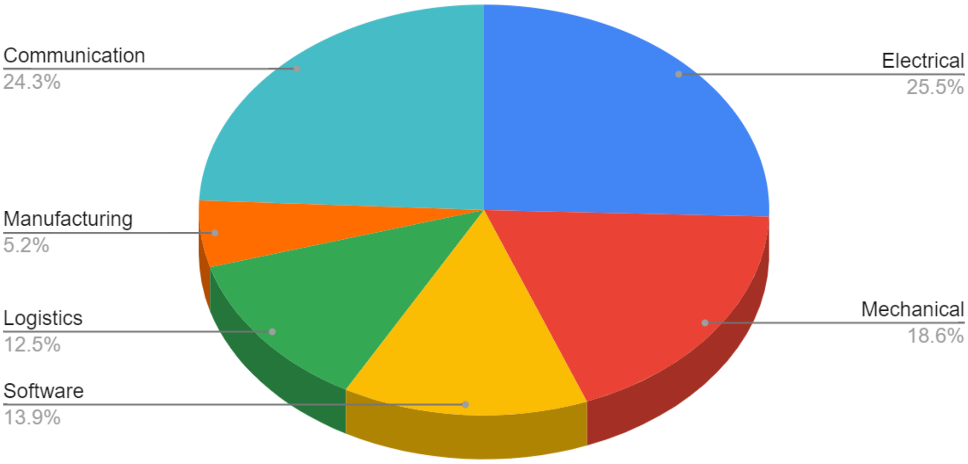
| Sl No | Component | Price (USD) |
|---|---|---|
| 1 | Mini Circular Saw | 79.91 |
| 2 | Drill Machine | 45.66 |
| 3 | Multimeter | 22.83 |
| 4 | Soldering Kit | 17.12 |
| 5 | Adjustable Wrench | 2.96 |
| 6 | Allen Key Set | 5.70 |
| 7 | Glue Gun | 4.56 |
| 8 | Screw Driver Set | 2.28 |
| 9 | Wire Crimper | 23.97 |
| 10 | Wire Stripper | 4.56 |
| **Total** | | **209.59** |

**Total:**

| Sl No | Sub Unit | Approximated Cost (USD) |
|---|---|---|
| 1 | Electrical | 1019.85 |
| 2 | Mechanical | 743.95 |
| 3 | Software | 556.50 |
| 4 | Logistics | 497.72 |

| | | |
|---|---|---|
| 5 | Manufacturing | 209.59 |
| 6 | Communication | 969.40 |
| | **Total** | **$3997.01**<br>**€3715.22** |

Below is a pie chart showing the percentage of cost in each subunit:



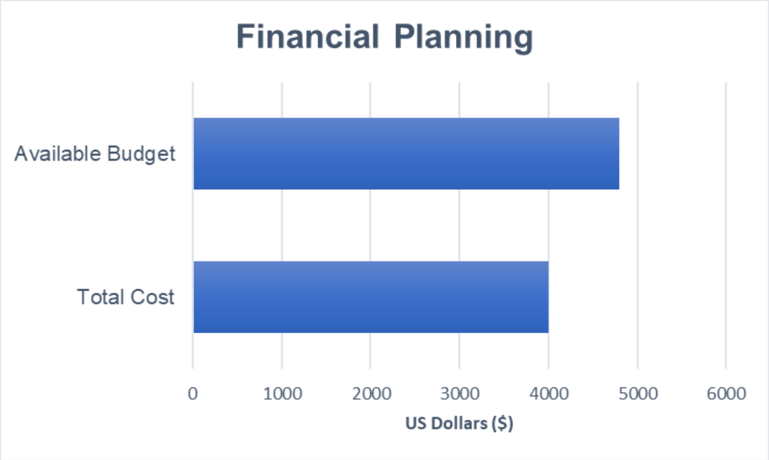

## 6.2 Rover Building Cost

**3998 USD (Three Thousand Nine Hundred Ninety-Eight US Dollars).**

The expenditures have been estimated through current prices on the market. The crucial parts of the rover we have accumulated so far were either manufactured locally or imported from outside the country. We made every attempt to strike a balance between demand and supply. The most expensive component was the rover's reinforced stainless steel and nylon body. The mechanical element includes the robotic arm and other collection and probing related equipment, so it had the highest cost. The communication subsystem was also accorded a high degree of importance, as evidenced by the substantial funding. The price includes both the cost of the components and the shipping fee.

## 6.3 Available Budget

Currently, our rover is supported by the membership fees collected from all ERC Onsite participants. There are currently 56 participants, and each of them contributed $50 (Fifty US Dollars), giving us around $2,800 (Twenty Eight Hundred US Dollars). As constructing the rover exceeds our budget, Software and Communication costs will be deferred later. Our university administration has promised us a sizable sum of funding (about $2,000), which will be distributed in June. In addition, we are looking out to potential Government, and Tech Company sponsors for our travel expenses to the ERC, where we have already secured a sponsor who will pay us if we advance to the finals. The comparison between our Available Budget vs. Total Cost can be portrayed below:




# 7. Risk Analysis

## 7.1 Qualitative Risk Analysis:

| ID | Short Name | Description | Risk Category | Risk Owner | Likelihood | Severity | Risk Index | Risk Response Strategy | Mitigation Actions |
|---|---|---|---|---|---|---|---|---|---|
| 7.1.1 | Power Failure | Rover may not be getting power and may not function properly. | Technical | Electrical Sub team | Rare | Moderate | 3 | Mitigate | Backup power circuits and batteries will be kept, and the circuits will be designed to handle the required amount of power. |
| 7.1.2 | Motor Driver Failure | The motor drivers may not function or even get damaged while using. | Technical | Mechanical Sub team | Likely | Catastrophic | 20 | Transfer | The controller PCB supports both IBT2 and VNH2HP30, and motor selections have been made so that it will not cross rated current and voltage. |
| 7.1.3 | Feedback System Failure | The encoders of the driving motors may not give accurate output. | Technical | Electrical Sub Team | Likely | Minor | 8 | Mitigate | Precision encoders will be used, and the modular design will be implemented to be replaced easily. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **7.1.4** | Circuit Failure | PCBs or any port may not function as expected. | Technical | Electrical Sub team | Unlikely | Moderate | 6 | Transfer | Circuit designs must meet components rated requirements. After manufacturing the circuits, fault tests will also be done. Modular PCBs will be designed with flexible programming. |
| **7.1.5** | Mechanical Instability | Vibration of motors may occur while traversing and operating with the arm. | Technical | Mechanical Sub team | Possible | Major | 12 | Mitigate | The mechanical design will be accurate and precise. Moreover, fabrication will be done carefully. The simulation will be performed on mechanical design to test it under critical conditions. |
| **7.1.6** | Rocker Differential Failure | The rocker differential mechanism may not work properly and may cause balance issues. | Technical | Mechanical Sub team | Possible | Major | 12 | Mitigate | The traversal actions and path planning will be done carefully so that the rover does not lose its balance and face the least possible rough terrain. The body must be as lightweight as possible. |
| **7.1.7** | Deadline Failure | The required materials may not be delivered on time with sound quality. | Managerial | Team Lead | Possible | Catastrophic | 15 | Escalate | The team should be handled more efficiently, and proper supervision will be needed regularly. Multiple cross-checking must also be done. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **7.1.8** | Financial and Resource Limitations | Managing sponsors may turn out to be a failure and there may not be enough money and resources. | Financial | Team Lead | Likely | Major | 16 | Escalate | A systematic development approach must be pursued to attract sponsors, and social media activity must be regular. |
| **7.1.9** | Automation Failure | Rover may fail in executing automation tasks | Technical | Software Sub Team | Likely | Moderate | 12 | Transfer | Algorithms will be reviewed, and additional debugging will be done. Rover will undergo tests afterward. |
| **7.1.10** | Probing Failure | The probing container may not function as expected | Technical | Mechanical Sub Team | Possible | Major | 12 | Transfer | The containers will be simulated and tested. If it fails in action, the robotic arm will be used as a backup. |
| **7.1.11** | Malfunction of Arm | Arm may not give proper feedback and may fail to work with minimum precision and loss of control. | Technical | Mechanical Sub team | Unlikely | Catastrophic | 10 | Escalate | The robotic arm will be manufactured with the highest precision. Backup motors and encoders will be kept in the store. |
| **7.1.12** | Collection Module Failure | Collection module may not collect the samples in the expected manner. | Technical | Mechanical Sub Team | Unlikely | Major | 8 | Transfer | The collection will be manufactured carefully with exact dimensions. It will undergo several tests. In case of failure, the robotic arm will be used. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.1.13 | Data Loss | Rover may fail to send necessary data to the base station. | Technical | Software Sub Team | Likely | Major | 16 | Mitigate | In case of data loss, transmission power must be increased up to the allowed limit, and if the rover fails to communicate, the data will be stored in an onboard storage system. Multiple non-LOS tests must be done while manufacturing the rover. |

## 7.2 Quantitative Risk Analysis:

| Risk ID | Risk Name | Description | Risk Category | Risk Owner | Probability (%) | Impact ( weeks) | Expected Value (V=Pr *Im) |
|---|---|---|---|---|---|---|---|
| 7.2.1 | Power Failure | Rover may not be getting power and may not function properly. | Technical | Electrical Sub team | 20 | 1 | 0.2 |
| 7.2.2 | Motor Driver Failure | The motor drivers may not function or even get damaged while using them. | Technical | Mechanical Sub team | 75 | 1 | 0.75 |
| 7.2.3 | Feedback System Failure | The encoders of the driving motors may not give accurate output. | Technical | Electrical Sub Team | 60 | 2 | 1.2 |
| 7.2.4 | Circuit Failure | PCBs or any port may not function as expected. | Technical | Electrical Sub team | 5 | 3 | 0.15 |
| 7.2.5 | Mechanical Instability | Vibration of motors may occur while traversing and operating with the arm. | Technical | Mechanical Sub team | 50 | 2 | 1.0 |
| 7.2.6 | Rocker Differential Failure | The rocker differential mechanism may not work properly and may cause balance issues. | Technical | Mechanical Sub team | 10 | 1 | 0.1 |
| 7.2.7 | Deadline Failure | The required materials may not be delivered on time with sound quality. | Managerial | Team Lead | 40 | 1 | 0.4 |

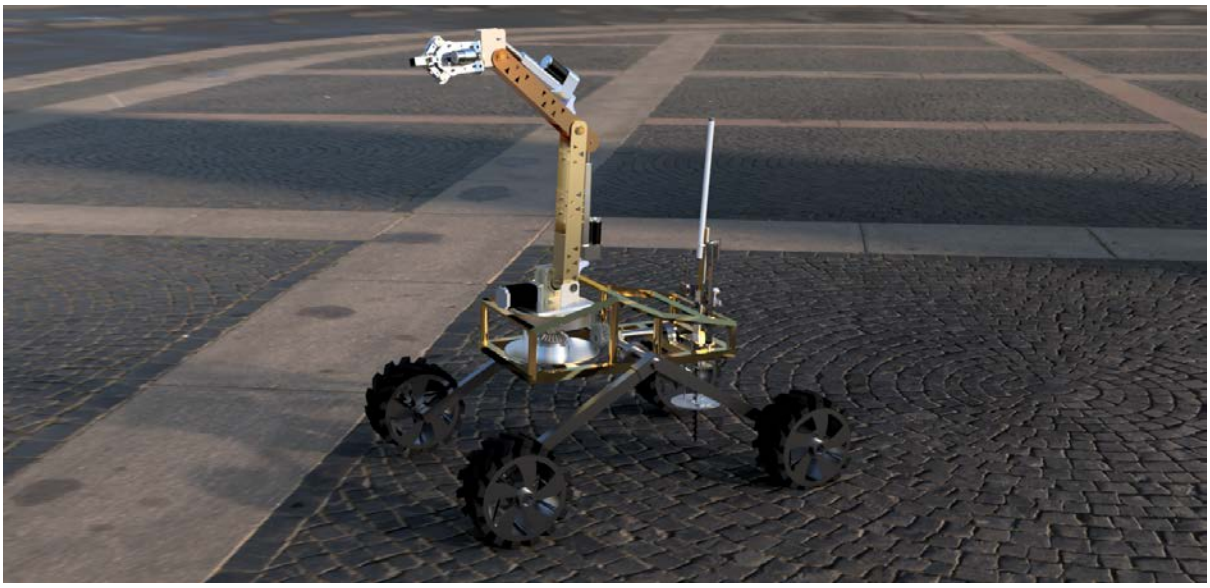
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **7.2.8** | Financial and Resource Limitations | Managing sponsors may turn out to be a failure and there may not be enough money and resources. | Financial | Team Lead | 70 | 4 | 2.8 |
| **7.2.9** | Automation Failure | Rover may fail in executing automation tasks | Technical | Software Sub Team | 80 | 4 | 3.2 |
| **7.2.10** | Probing Failure | The probing container may not function as expected | Technical | Mechanical Sub Team | 30 | 4 | 1.2 |
| **7.2.11** | Malfunction of Arm | Arm may not give proper feedback and may fail to work with minimum precision and loss of control. | Technical | Mechanical Sub team | 15 | 4 | 0.6 |
| **7.2.12** | Collection Module Failure | Collection module may not collect the samples in the expected manner | Technical | Mechanical Sub Team | 30 | 2 | 0.6 |
| **7.2.13** | Data Loss | Rover may fail to send necessary data to the base station. | Technical | Software Sub Team | 65 | 2 | 1.3 |

## 7.3 Changes:

| Risk ID | Risk Name | Change (Addition / Update) | Reason |
|---|---|---|---|
| 7.1.9 | Automation Failure | Addition | The project requirements and possibilities have been further studied, and more risk ideas have emerged, and these aspects are significant. In some cases, they may pose critical problems. Hence, these additional risks are introduced, and preventive measures are taken accordingly. |
| 7.1.10 | Probing Failure | Addition | |
| 7.1.11 | Malfunction of Arm | Addition | |
| 7.1.12 | Collection Module Failure | Addition | |
| 7.1.13 | Data Loss | Addition | |

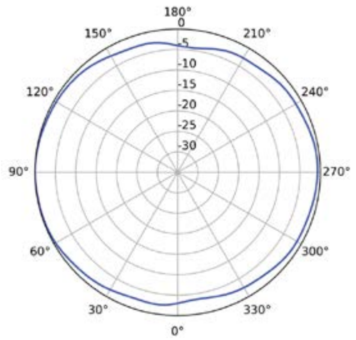
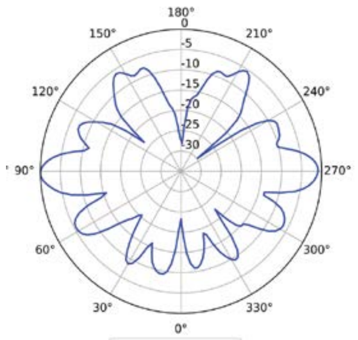
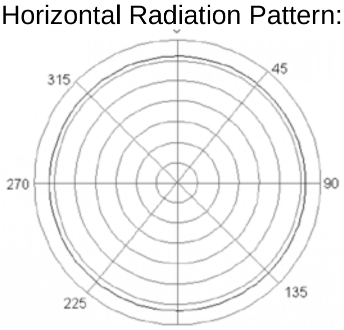
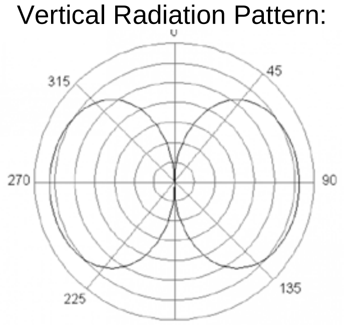
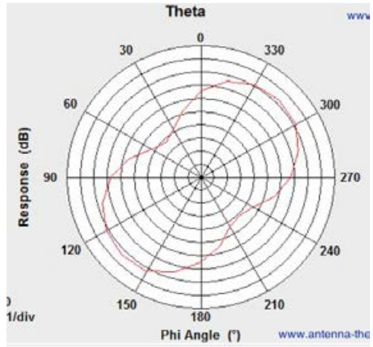
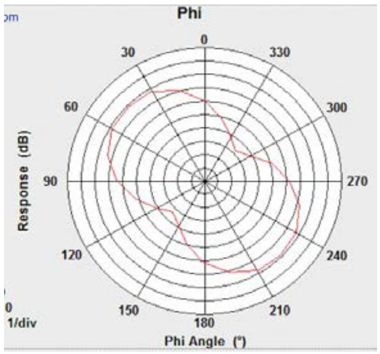
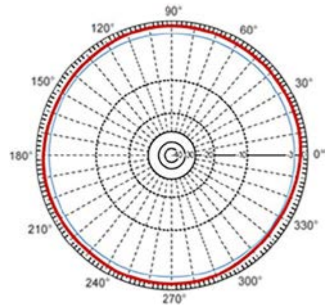
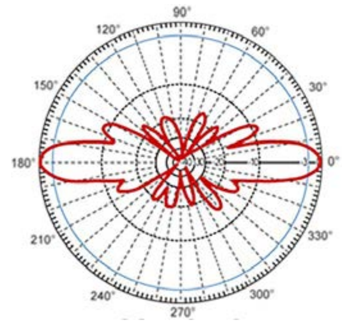
# 8. Preliminary Radio Frequency Form

a) Team Name: IUT Mars Rover - Team Avijatrik
b) Country: Bangladesh
c) Name of the person responsible for communication: Mohammad Ashraful Haque
d) Contact to the person responsible for communication: ashrafulhaque29@iut-dhaka.edu
e) Photo of the Rover: (Rendered 3D Model. The antenna is placed in the rear side.)



f) Photo of the ground station: Will be provided in the final document
g) Number of different communication systems: 02
h) System Information

| Criteria | System 1 | System 2 |
|---|---|---|
| RF system name | Wi-Fi Control and Telemetry System | Analog Video Transmission System |
| Short description | The microprocessor will be connected to a router, and the base station will also be connected to the router. A local area network system will be used to control the rover, send instructions and receive messages, sensor data, and log data. | An analog transmission system will transfer the real-time video feedback to the base station. FPV cameras will capture the video, and it will send the video signal using a transmitter, and in the base station, an FPV receiver will be used to monitor the output. |
| Models of the used transceivers | RB Metal 2SHPN (Rover)<br>TP-Link TL-WN722N (Base Station) | TS832 (Transmitter)<br>TX5820 (Transmitter)<br>Eachine RC832 (Receiver)<br>Eachine LCD5802D (Receiver + Monitor) |
| Access point software version | RouterOS | N/A |
| Frequency | 2.4 GHz (Wi-Fi) | 5.8 GHz (High Band) |
| Bandwidth | 20 MHz | 8 MHz |

<table>
<tr><td>RF power (output power + EIRP)</td><td>Maximum 32 dBm (variable)<br>But we will keep TX power set to 20dbm (100 mW) EIRP: 100 mW</td><td>600 mW = 27dbm EIRP: 600 mW</td></tr>
<tr><td>Modulation</td><td>TDD</td><td>TDD</td></tr>
<tr><td>Antennas on the rover and ground station</td><td>1. Model: 8 dBi Omni directional<br>Horizontal Radiation Pattern:<br><br>Vertical Radiation Pattern:<br><br>2. Model: 4dBi Detachable Antenna (With TL-WN722N)<br>Horizontal Radiation Pattern:<br><br>Vertical Radiation Pattern:<br></td><td>1. Model: Fatshark ImmersionRC<br>Horizontal Radiation Pattern:<br><br><br>Vertical Radiation Pattern:<br><br><br>2. Model: 8dBi Omni Directional<br>Horizontal Radiation Pattern:<br><br>Vertical Radiation Pattern:<br></td></tr>
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