YUVAAN

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

International Rover Design Challenge 2021

YUVAAN_IITG

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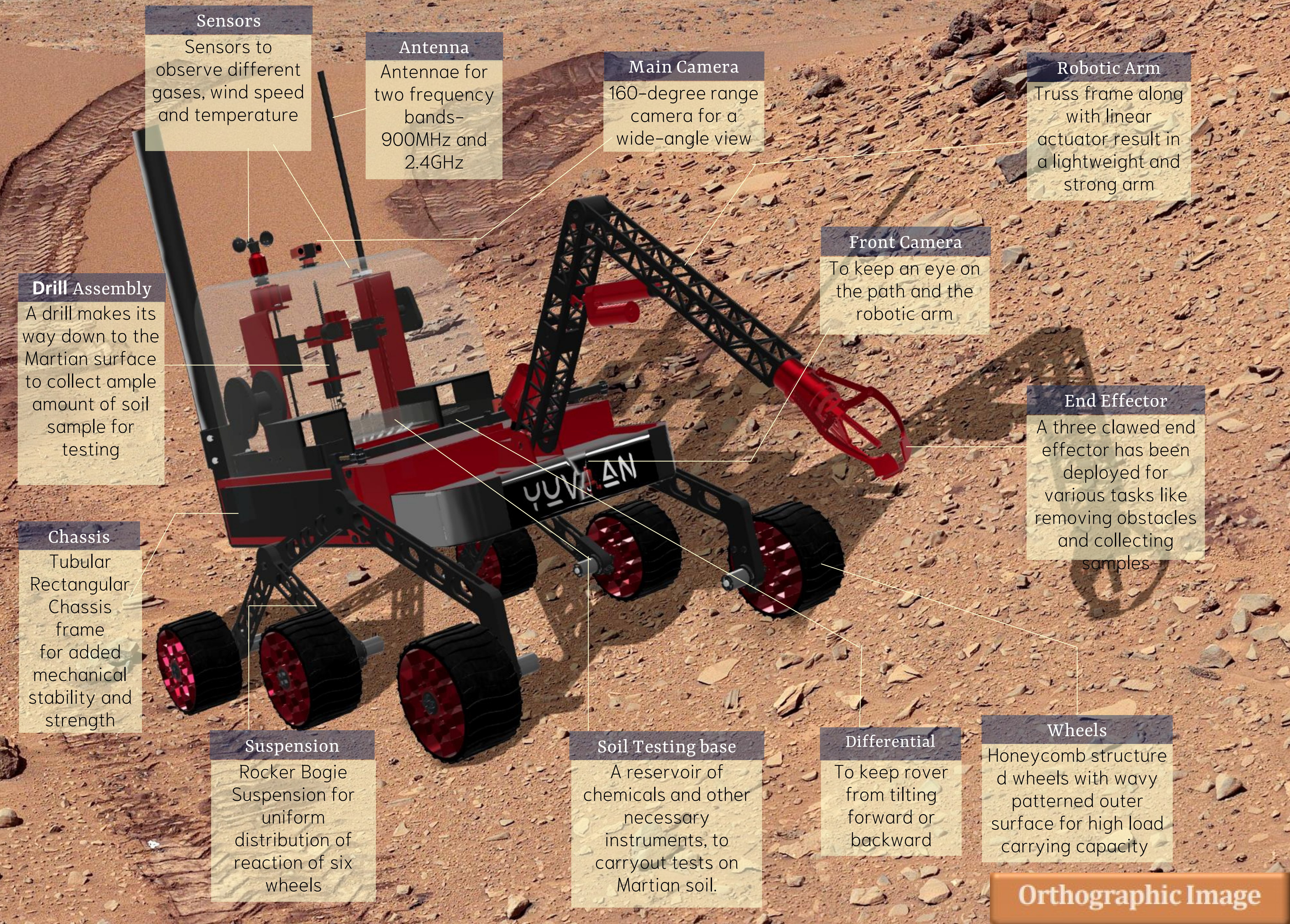


Sensors
Sensors to observe different gases, wind speed and temperature
Antenna
Antennae for two frequency bands- 900MHz and 2.4GHz
Main Camera
160-degree range camera for a wide-angle view
Robotic Arm
Truss frame along with linear actuator result in a lightweight and strong arm
Front Camera
To keep an eye on the path and the robotic arm
Drill Assembly
A drill makes its way down to the Martian surface to collect ample amount of soil sample for testing
End Effector
A three clawed end effector has been deployed for various tasks like removing obstacles and collecting samples
YUVAAN
Chassis
Tubular Rectangular Chassis frame for added mechanical stability and strength
Suspension
Rocker Bogie Suspension for uniform distribution of reaction of six wheels
Soil Testing base
A reservoir of chemicals and other necessary instruments, to carryout tests on Martian soil.
Differential
To keep rover from tilting forward or backward
Wheels
Honeycomb structure d wheels with wavy patterned outer surface for high load carrying capacity
Orthographic Image

Objective of our mission

The trend of extraterrestrial exploration is positively influencing people all around the globe, and with growing demands of resources and considering the present conditions of Earth, it would be great to have known the possibility of habituation on other planets. This mission is to investigate the potential of the presence of existing life on Mars.
We will start by recalling the specifications of our project, followed by detailed research on the project, our objective, and implementation. We will give our actual planning and BOM and compare it with last year's prototype. We will explain the causes of the potential deviation.
We recall here the specifications set at the start of the project.

Our Goals

Our team designed the Mars Rover with sensors and active elements to carry a subsurface mission inside Mars Lava Tubes to explore and characterize lava cave properties. During the mission, the primary objective of the Rover is to carry out the following operations:

- Map the entire tunnel, locate all possible entry/exit points, and capture photos and videos in the dark.
- Navigate and traverse successfully through the different types of terrain inside the tunnel.
- Communicate with the base station during the entire length of the mission.
- Carry out atmospheric analyses inside the cave.
- Conduct various scientific experiments and analyze for signs of microbial life, habitability, and characteristics.
- Collect and analyze regolith samples from the ground and the walls/ceilings of the tunnel.

For feasibility we have divided our report into three modules:

Mechanical Module

Electronics Module

Bio-Assembly Module

Mechanical Module

The Mechanical module of YUVAAN_IITG is responsible for making the structure of the rover such that it can maneuver over the Martian surface efficiently by traversing through obstacles, supporting other modules, and is able to perform all the tasks required to complete this mission. The main parts made by the module are as follows:

1. Aluminum Chassis frame
2. Rocker Bogie suspension
3. Robotic arm
4. Honey-Comb Wheel

1.1 Chassis

Chassis is a major component of a Rover. It consists of internal framework that supports man-made object. It is the underpart of the rover which consists of frame and running gear like engine, bio-assembly system, robotic arm, suspension system etc. The Rover chassis is tasked with keeping all components together while driving and transferring vertical and lateral loads, caused by acceleration, on the chassis through suspension and the wheels. The key to good chassis design is that further the mass is away from the neutral axis the more rigid it is.

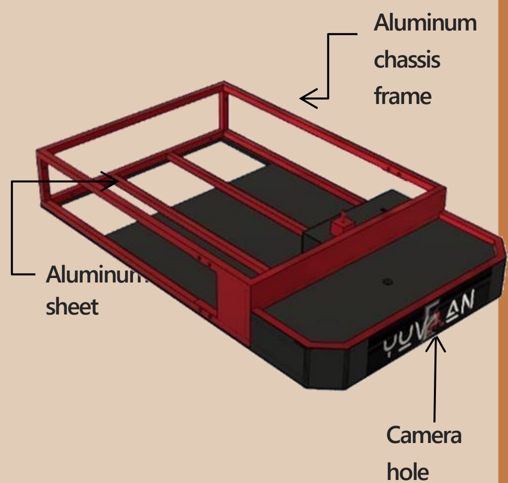


Figure: Chassis

Design & Construction

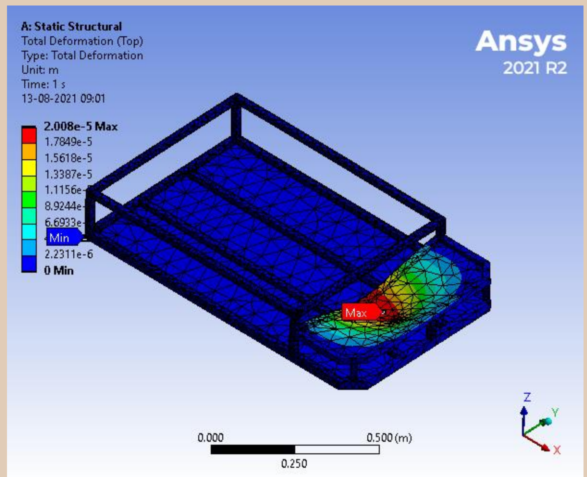
For construction of chassis the different materials available to us were Aluminum, Steel, Aluminum T-slots, square bars and Circular bars. We finally decided upon using square cross-section aluminum hollow bar because Aluminum has is lightweight and has natural resistance to corrosion. Aluminum also has mechanical stability, dampening and thermal management greater than other metals. Square bar was chosen because load was anticipated only in one direction, also it has higher moment of inertia so it has lower bending stress compared to circular or any other bars.
For chassis design Tubular Rectangular Chassis Frame (1085 x 655 x 170 mm) was chosen as it can provide mechanical support from anywhere and welded members provide extra strength and stability.

Analysis

We have applied a force of 510N force on the base plate of thickness 1.5mm, this force will account for the weight of bio assembly and other electronics and since the mass of our robotic arm is 4kg so we have applied a force of 40N on the 5mm thick plate which will support the robotic arm.

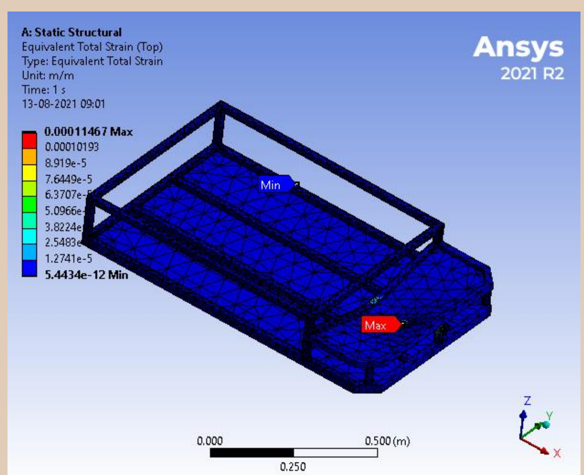
Total Deformation Analysis-

The maximum deformation recorded was 0.02mm



Total Stress and Strain Analysis-

The maximum equivalent total strain was 0.000114 and the maximum von-mises stress was3.7065Pa.



1.2 Suspension

Wheeled locomotion's main component is its suspension mechanism which connects the wheels to the main body or platform. We have used a rocker-bogie suspension system. Some of its main advantages are listed below: -

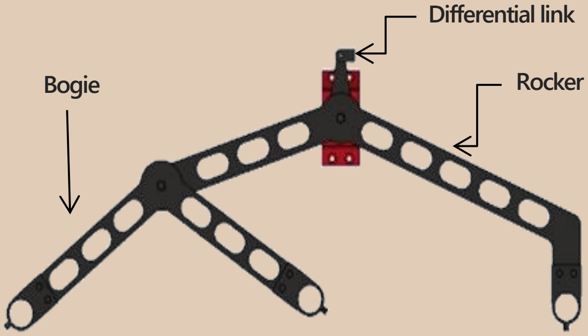


Figure: Rocker Bogie

- With this kind of suspension, the typical reaction of the six wheels is distributed uniformly.
- This suspension system can overcome one-and-a-half-wheel diameter height obstacles.
- It uses an extra set of wheels to provide more forward thrust.
- The suspension is on backward so that the rover can back out of anything it drives into.

Differential

We have used a differential bar. The middle of the bar is connected to the body with a pivot and a pivot and the two ends are connected to the rockers through rod end ball joints. If one of the rockers passes through an obstacle then the other end of the bar will move in the opposite direction so the other rocker will tilt down.

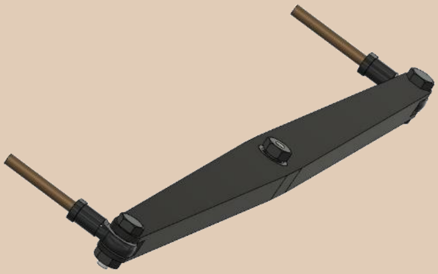


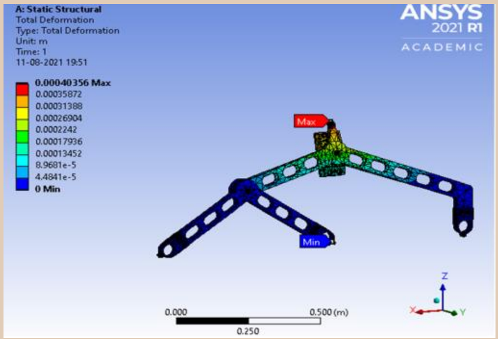
Figure: Differential bar

Analysis

We have applied a force 34.37N on each of the eight holes on the joint, joining the suspension with the chassis. Considering half of the chassis weight will be carried by each rocker, and kept the lower part of the suspension fixed.

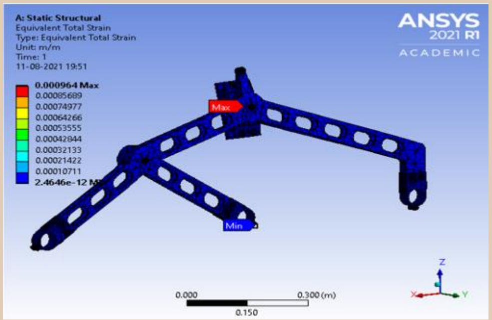
Total Deformation Analysis

The maximum deformation recorded was 4mm. But this much deformation will not occur when the wheels will be added.



Strain Analysis

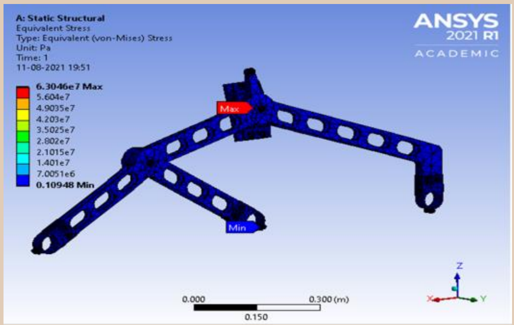
The maximum total strain recorded was 0.00096.



Equivalent Stress Analysis

The maximum equivalent stress (Von-Mises) recorded

is 6.3x10^{7}Pa.



1.3 Wheels

Wheels will be needed for exploration, construction, and other surface operations. The design of the wheel should be such that it overcomes the unique environmental constraints and meet the transportation requirements of a given mission. To facilitate this effort, the development process of the rover wheel was studied and is reported in this article.

The design of the wheel was selected based upon the results from the research into what is currently being used on rover wheels and into the state of the art and combining this with the results from the analytical study.

DIFFERENT TYPES OF WHEEL DESIGNS (RIM)

- Nitinol Wheel: As a shape memory alloy (NiTi alloy), Nitinol is extremely flexible and, according to NASA researchers, it can undergo significant reversible strain (up to 10%), enabling the tire to withstand an order of magnitude more deformation than other non-pneumatic tires before undergoing permanent deformation.
  DRAWBACK: The drawback is that Nitinol Wheels are very expensive.
- Mecanum Wheel: The Mecanum wheel is an omnidirectional wheel design for a land-based vehicle to move in any direction. The Mecanum wheel is based on a tireless wheel, with a series of rubberized external rollers obliquely attached to the whole circumference of its rim. These rollers typically each have an axis of rotation at 45° to the wheel plane and at 45° to the axle line.
  DRAWBACK: They are very bulky and have a lot of rotational inertia and friction. They accelerate very slowly due to which it becomes difficult to go up the ramps and cross the bumps which are very common on Martian surfaces.

- I Robot resilient wheel: I robot corporation has designed a resilient wheel structure for mobile robots. This design comprises a continuous, annular rim, a hub and a plurality of spokes connecting the hub to the rim wherein the spokes are given particular curvature. The central wall is provided which extends from outer rim to inner rim and subsequently is perpendicular to both inner and outer rim. This forms an annular I beam which is well suited to transmit load into each spoke.
  Drawback: I Robot Resilient Wheel doesn't satisfy the condition of moderate modulus or stiffness and has a high elastic strain limit.

- Boston Robotics wheel: Another wheel is developed by Boston robotics for its jumping robot. Jumping robot is specially designed to jump over an obstacle. So, while they land on ground high impact forces will act on the wheel. In this the spokes are of hexagonal shape. Hexagonal shape is good to reduce weight and give desired stiffness.

Honeycomb Wheel:

Taking the advantages from I robot wheel and Boston robotics wheel a new honeycomb wheel design was developed. Hexagonal cell structures are known to be Flexible in both axial and shear loadings. In order to provide an even greater measure of load distribution to the plurality of spokes, the preferred embodiment of the rim includes a central wall. The central wall extends from outer rim to inner rim and is perpendicular to both outer rim and inner rim.

Therefore, the central wall and inner and outer rims form an annular I beam which is particularly well suited to transmit load into each of the spokes due to its very high area moment of inertia. Therefore, it can be concluded that Honeycomb Structure Wheel Design Is Better Suited for High Load Carrying Capacity.

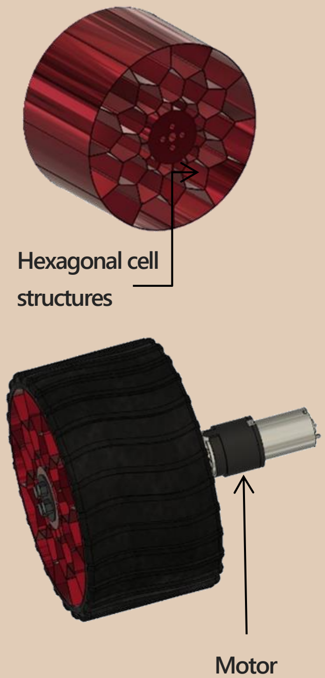


Figure: Honeycomb Wheel

Outer Surface of the wheel:

The outer surface of the wheel is designed in a Wavy Pattern so that the growth of cracks is less and also gives a proper grip to the tyre. The zig-zag pattern on Curiosity's wheels proved surprisingly fragile; those sharp-edged Mars rocks really did a number on those wheels, which after a few years of driving are in rather sad shape. The new wave pattern has been shown to be much tougher in the tests.

Figure: Outer surface of Wheel

DIMENSIONS OF THE WHEEL:

Outer diameter- 210 mm Outer diameter of rim-111mm
Inner diameter of rim- 38.5 mm Width- 138 mm

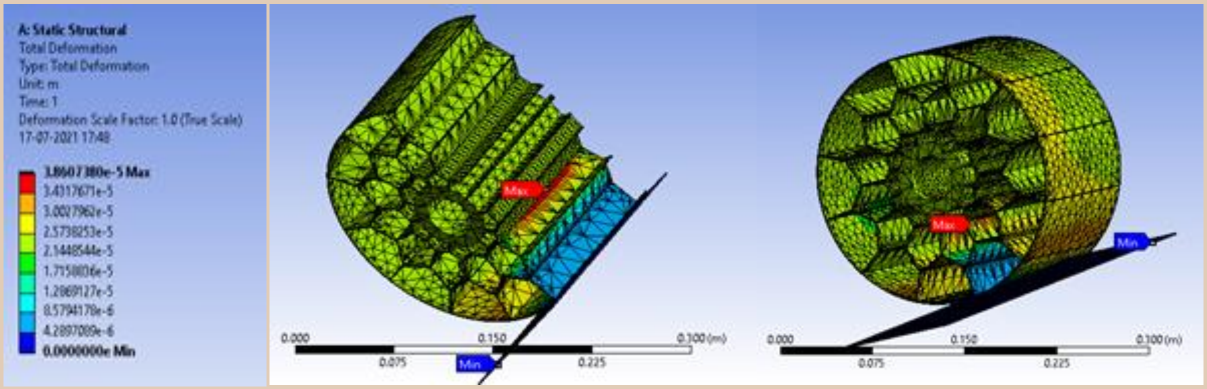
Weight= 1.7287kg

MATERIAL: The material used for making the wheel is ALUMINUM

Analysis:

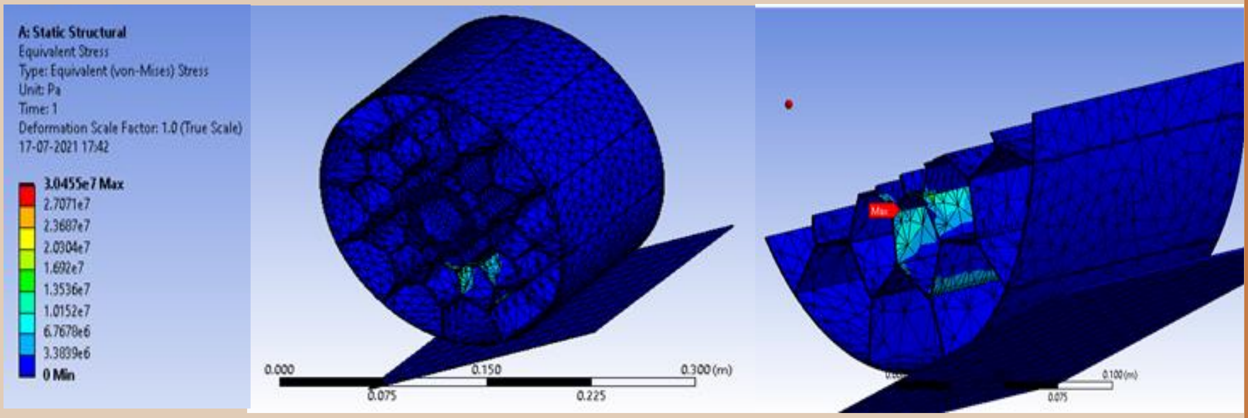
Since each wheel will carry 1/6 of the total weight, so a 98N load was applied to the hub in the downward direction. The base plate which is made of structural steel is fixed and constrained so that there will be no movement of the wheel in a downward direction.

Total Deformation Analysis-



The maximum deformation is 0.038mm

Static Structural Analysis-



The maximum equivalent (von-mises) stress generated was 3.0455Pa.

1.4 Robotic Arm

The Robotic arm is responsible for interaction on the Martian surface and the major functions of the arm include lifting loads, removing obstacles, and collecting samples. We designed the frame that consists of two links made of trusses which are connected via the help of ball bearings for smooth motion.

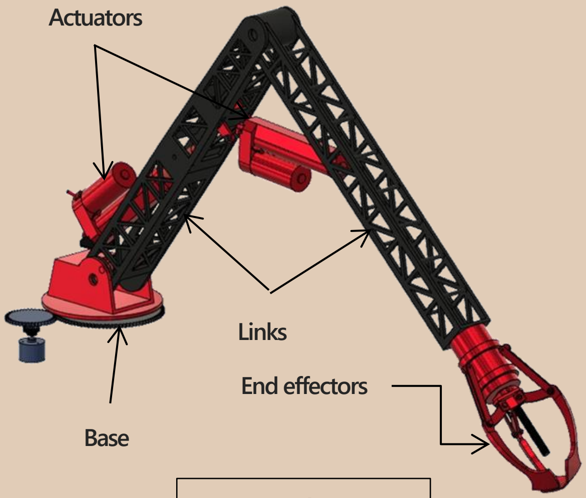


Figure: Robotic arm

Reasons for design are listed below:

- Using a truss frame provides arm resistance against bending and shearing while lifting the load.
- It makes the arm lightweight without compromising its strength. We can get maximum strength using minimum material

Motion of Arm

A linear actuator is used to control the motion in the vertical direction and motion in-plane is controlled by a gear at the base which is rotated by a motor through a conveyor belt. We chose this design due to the following reasons:

- It is easier to integrate with the arm and is easier to control.
- Provide more strength in lifting objects.
- Lower cost than the other alternatives.

Three-Clawed end effectors

We used 3 clawed end effectors such that it can pick stones or other objects easily. The fingers are opened and closed with the help of a lead screw mechanism.

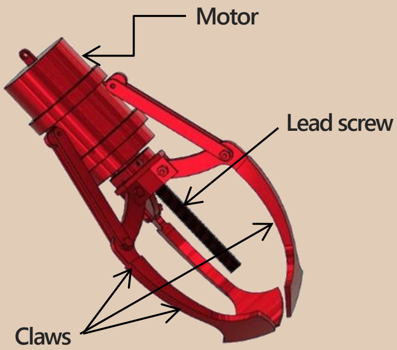


Figure: Three-clawed end effector

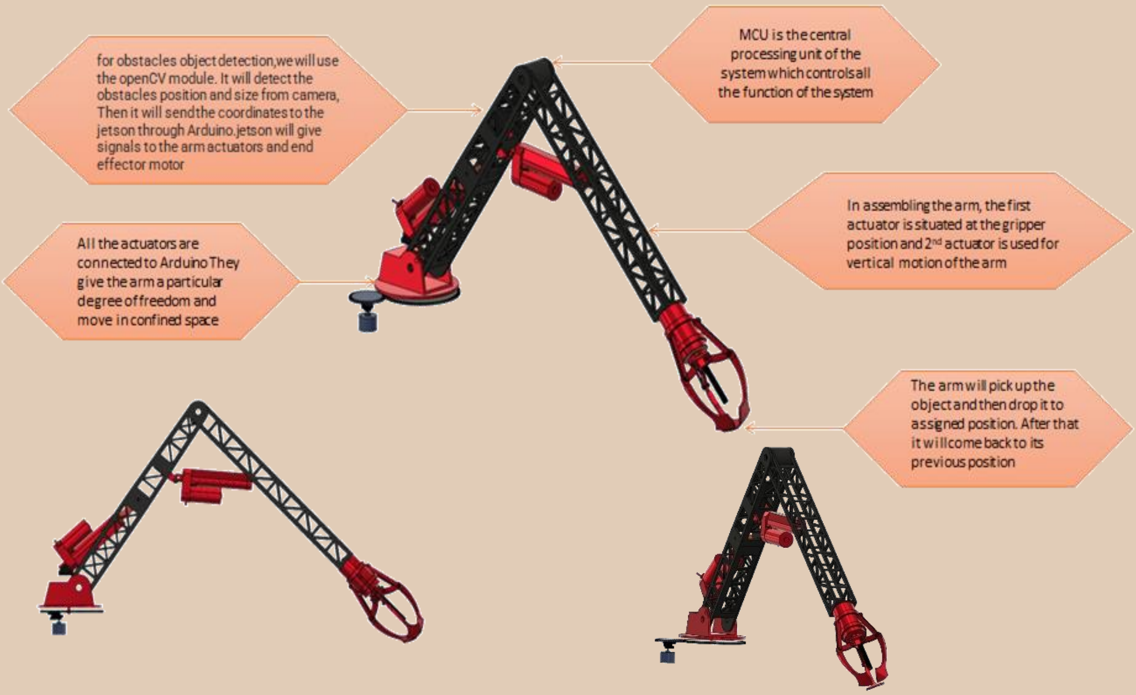
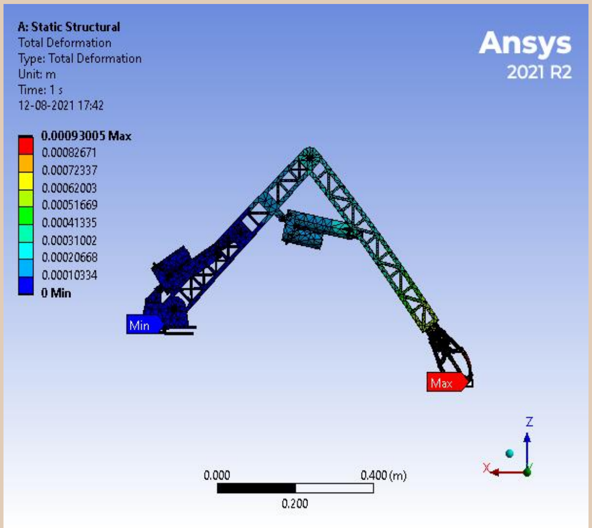


Figure: Description of The Robotic arm

Analysis:

The maximum total deformation came out to be 9 mm.



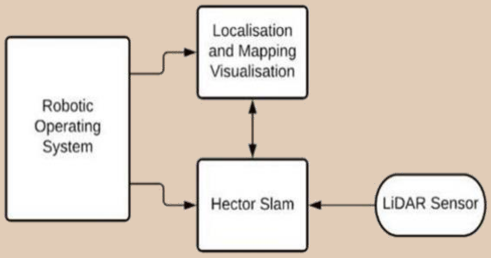
Electronics Module

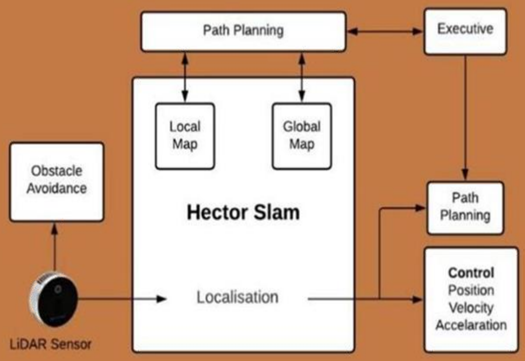
The electronics module is responsible for carrying out autonomous navigation and control, supplying power to the rover, carrying out communication between the rover and base station, and ensuring all other modules work in sync to complete the mission.

2.1 Navigation and Control

To achieve our main mission of exploring the lava tubes, we were posed a challenge to develop autonomous navigation for our rover, and we came up with this.

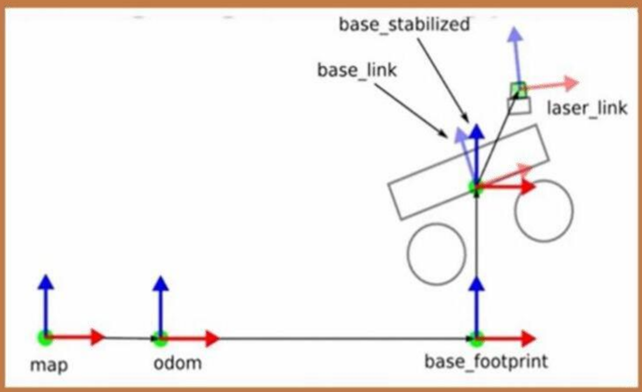
For navigation and localisation purposes we've decided to adopt the SLAM system of navigation by using the Intel Lidar sensor and Hector SLAM algorithm.
The Hector SLAM algorithm correlates the estimated robot position and the "under-construction" map. The Intel RealSense LiDAR camera L515 is a high precision LiDAR sensor that brings an additional level of precision and accuracy over its entire operational range.

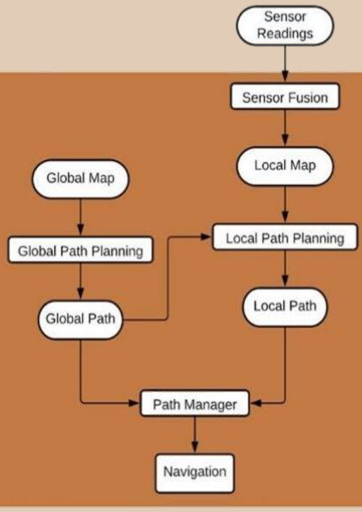




For autonomous navigation capacities in the rover, a LiDAR based SLAM system is used. It creates a local map of the surrounding using lidar sensor and combined with path planning algorithm, Hector-SLAM algorithm and various other filtering algorithms, it determines a suitable and optimized path for the rover avoiding obstacles autonomously.

Hector mapping is a great approach which can be used without odometry and the map created can show all potential frames of interest in a simplified 2D view of the rover travelling in rough terrain. Hector SLAM can even publish odometry and path messages, which open the way for running autonomous navigation with the ROS navigation stack.
To achieve path planning, there are to solve three basic problems:
(1)The robot reaches the desired position
(2)The obstacle avoidance and completion of the strategic task are achieved in the moving process
(3)The optimal path is realised





Due to the accuracy of the sensor and the variability of the environment, the local path planning pays more attention to obstacle avoidance, and the global path planning pays more attention to the optimized path. Therefore, the combination of local planning and global planning algorithms can successfully achieve accurate navigation of the robot. So, by using the map created by hector slam, the path planning algorithm can easily achieve autonomous navigation.

2.2 Communication System

Two frequency bands are used for reliable and constant communication between Mars rover and base station: The 900 MHz band and 2.4 GHz band.
Command, telemetry, and video feeds are sent through one or two signal stacks time depending on instantaneous usage of motors and sensors using an MLVPN (Multi-Link Virtual Public Network) which helps in switching and assigning bands in the system.

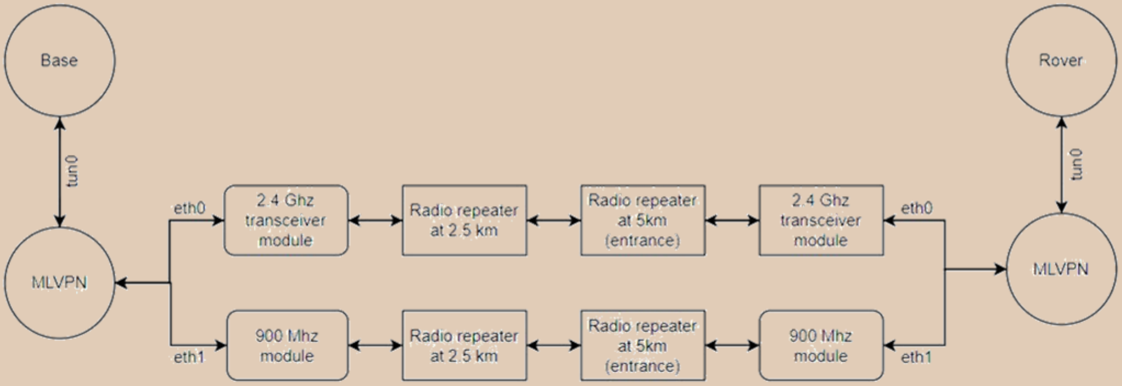


Figure: Communication map between the base station and Rover

Frequency Bands used:

Antenna gains: To cover long distances, you will need high-gain antennas. The gain of a reflector-type antenna goes up as you increase the area of the parabolic surface. But for a given physical size, the antenna gain at 2.4 GHz is significantly higher than an antenna at 900 MHz.

Fresnel Zone Clearance: To get "free space" propagation conditions, we need to clear 60% of the first Fresnel zone. The Fresnel zone is a long ellipsoid between two endpoints. At 900 MHz, we need to elevate the antennas to additional 15 meters (for 50 Km link) on both sides to clear the ground, or an obstruction at the mid-point.

Due to the above reasons, we have decided on using 2.4 GHz as primary communication link for transferring video feeds from the rover to base station. The 900 MHz band is used to communicate to all sensors and rover tire-motors. This band will act as a backup if the first channel fails in middle of the mission due to atmospheric attenuation or high constructive effect.

Setup of antennas and modules:

The 900 MHz system will be achieved using a high gain directional Yagi antenna at the base with a distance range of 10-12km (non-LOS) and 15-20km (LOS) across 48 degrees of angular range, and the rover has a 10dBi gain omni antenna mounted at the back. The omni antenna provides a 360-degree coverage for perceiving all signals and has one N-female connector for input signals. Both antennas are coupled with an Ubiquiti Rocket M9 transceiver module which provides an approximate speed of 15-20Mbps.

The 2.4 GHz system will be achieved using a high gain directional sector antenna at the base with a distance range of 3km (non-LOS) across 120 degrees of angular range, and the rover has an 8dBi Omni antenna mounted at the back. The Omni antenna also provides a 360 degree range with two N-female connectors for the MiMo(Multiple Input Multiple Output) facility. Both are coupled with an Ubiquiti Rocket M2 transceiver module which provides am\n approximate. speed of 130+ Mbps (real TCP/IP).

Figure: Omni antenna

Radio Repeater and Dropping mechanism:

To achieve a 5km range, we will deploy two small-size radio repeaters at distances of 2.5 and 5km at the opening of the lava tube for constant omnidirectional communication.
A radio repeater has four patch antennas - 2 900Mhz and two 2.4GHZ mounted on a cubic structure(225mm) and can be deployed from a rover using a burnt nichrome wire mechanism.
The patch antennas prove to be very useful in long range missions providing a range of 300m.
The "Nichrome Burn Wire Release Mechanism" uses a 19mm/1.1-ohm nichrome burn wire which, when activated, heats up and cuts through a Vectran tie-down cable allowing the deployable on the rover to actuate. A constant source of 1.6A is enough for reliable deployment.

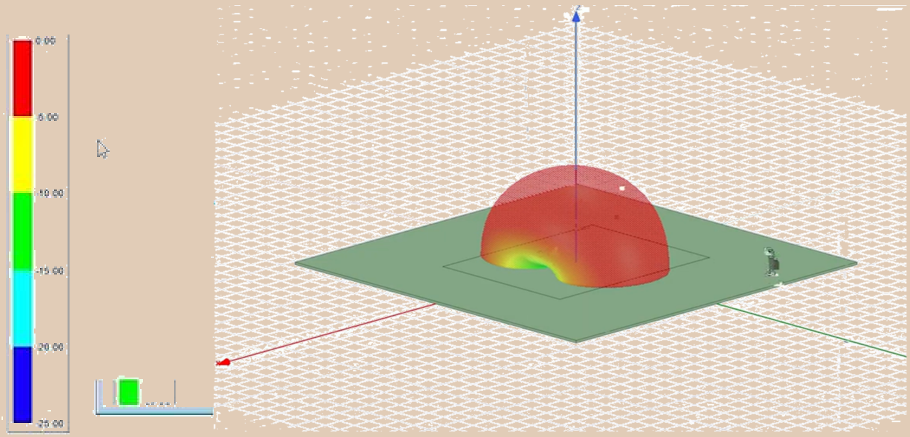


Figure: Analysis of range of Patch Antenna

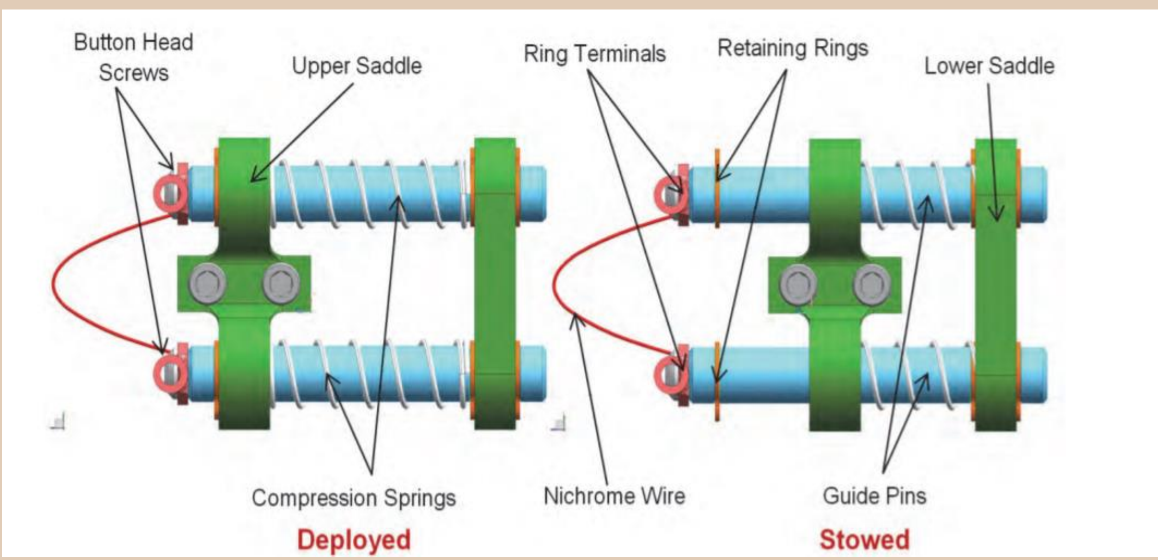


Figure: Nichrome Wire Drop Mechanism

2.3 Power

Provides power to the rover and on a mission extending up to 10hrs, electrical power is of utmost importance, and the rover should use it according to the needs of the task. The Martian temperature fluctuates between -96C to 20C, so to keep the batteries functioning, we need to ensure the temperature of cells doesn’t fluctuate between an extensive range of temperatures, so to prevent it, the following can be used:

1. Preventing heat escape through gold paint
2. Preventing heat escape through insulation called "aerogel."
3. Keeping the rover warm through heaters
4. Making sure the rover is not too hot or cold through thermostats and heat switches
5. Making sure the rover doesn't get too hot through the heat rejection system
6. Excess heat coming from the Radioisotope Heater Units (RHUs), which are constant 1-watt heaters that generate heat through decay of low-grade isotope.

Different Cells available:

While taking into consideration the mission, we came across a few cells like Nikel-Hydrogen Cell, Nickel-Cadmium Cell, Silver-Zinc Cell, Lithium-ion Cell which can be used in this, and their specifications are:

System Characteristics	Nickel-Cadmium	Nickel-Hydrogen	Silver-Zinc	Lithium-Ion
Specific-Energy (Wh/Kg)	25	30	~100	>100
Energy Density (Wh/lit)	100	50	~150	>250
Battery mass for 300Wh MER Kg	33	28	11	6
Battery volume for 300Wh MER lit	9	17	6	2.2
Cycle life (50% DOD)	>1000	>1000	<100	>1000
Wet life (storage ability)	Excellent	Excellent	Poor	Good
Self-Discharge (Per month)	15&	30%	15-20%	<5%
Low Temp Performance (-20Deg)	Moderate	Moderate	Moderate	Excellent
Temperature range, Deg C	-10-30	-10-30	-10-30	-20 to +40
Charge Efficiency (%)	80%	80%	70%	~100%

Table: Comparison of different available cells

After comparing various cells available, we have chosen Lithium-ion cells and the chosen model is: ReLiON RB40

Figure: Battery (RB40)

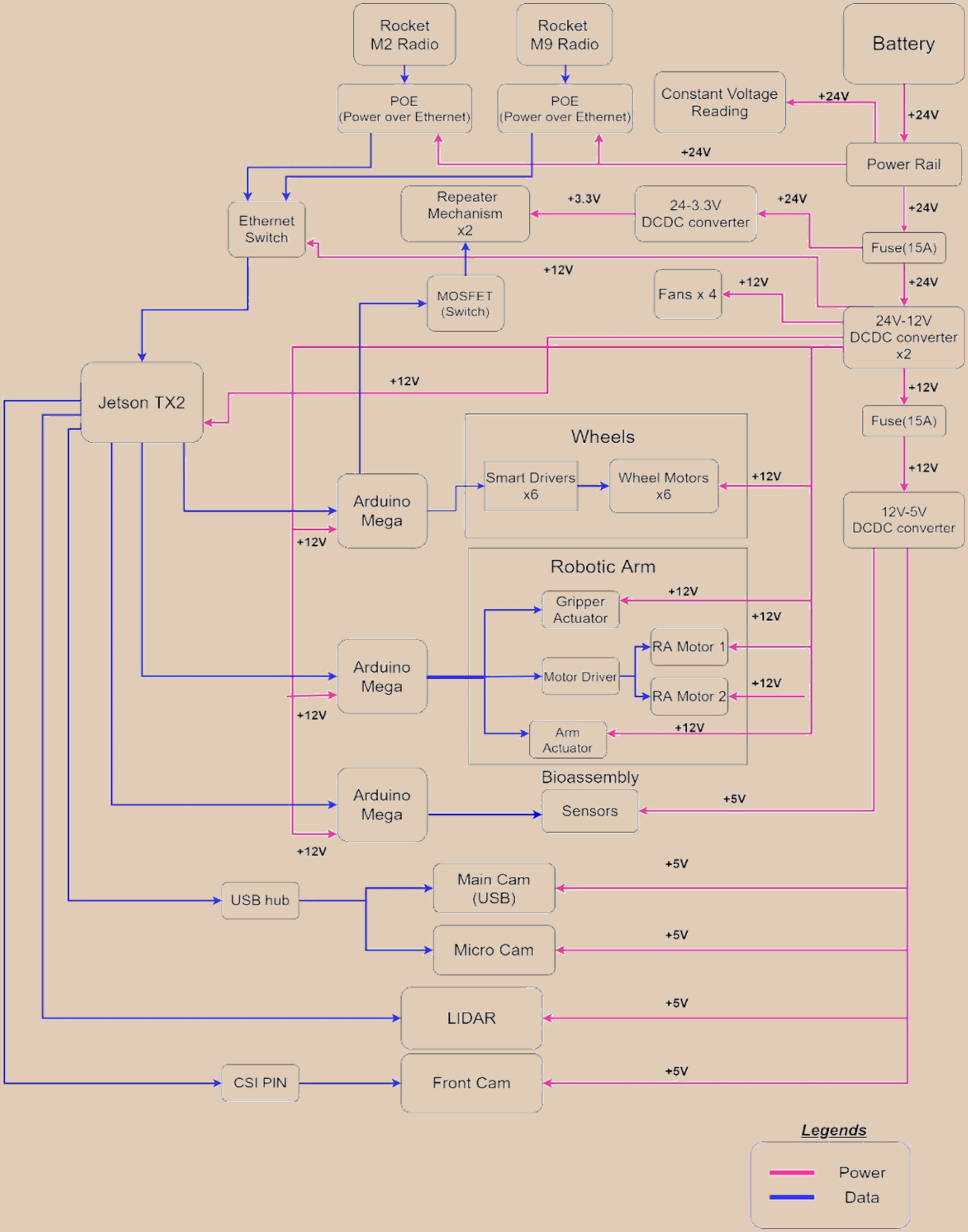
BMS:

The primary purpose of the BMS is to monitor and manage the condition of the battery pack. As LiPo batteries that operate below or beyond their rated voltage can ignite or explode, the team must be able to assess their condition while using the rover continually. This device encompasses a custom printed circuit board coupled with an MSP432 microcontroller, various MOSFETs, an array of individual sensors.

	Orion BMS	Lithiumate Pro	MK3x8	MiniBMS
Overcharge/discharge, thermal and overcurrent protection	Yes	Yes	Yes	Yes
Cell and pack health monitoring	Yes	Yes	No	No
Cell Balancing	Yes	Yes	Yes	Yes
Field Programmable	Yes	Yes	Yes	No
State of charge monitoring	Yes	Yes	Optional	Separate
Charge/Discharge Current Limits	Yes	Yes	No	No
Cell &Pack internal resistance	Yes	Yes	No	No
Centralized design	Yes	No	No	No
Supports external thermistors	Yes	Yes	Yes	No

After analysis and comparison of various BMS, we finally decided to go with Orion BMS owing to the various advantages offered.

Electronic Circuit of YUVAAN IITG



Bio Assembly Module

The Bio assembly module of YUVAAN is designed to collect the sample from Martian Lava tubes and perform life-detection tests onboard testing.
Our module will perform these three Sub-tasks:

- Sample Collection
- Testing
- Sensing

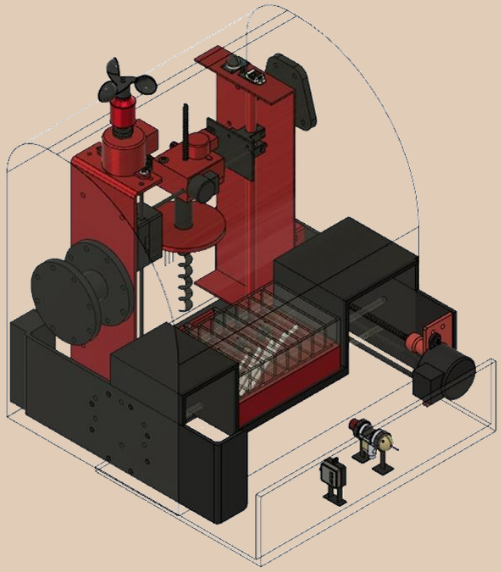


Figure: Bio-assembly CAD model

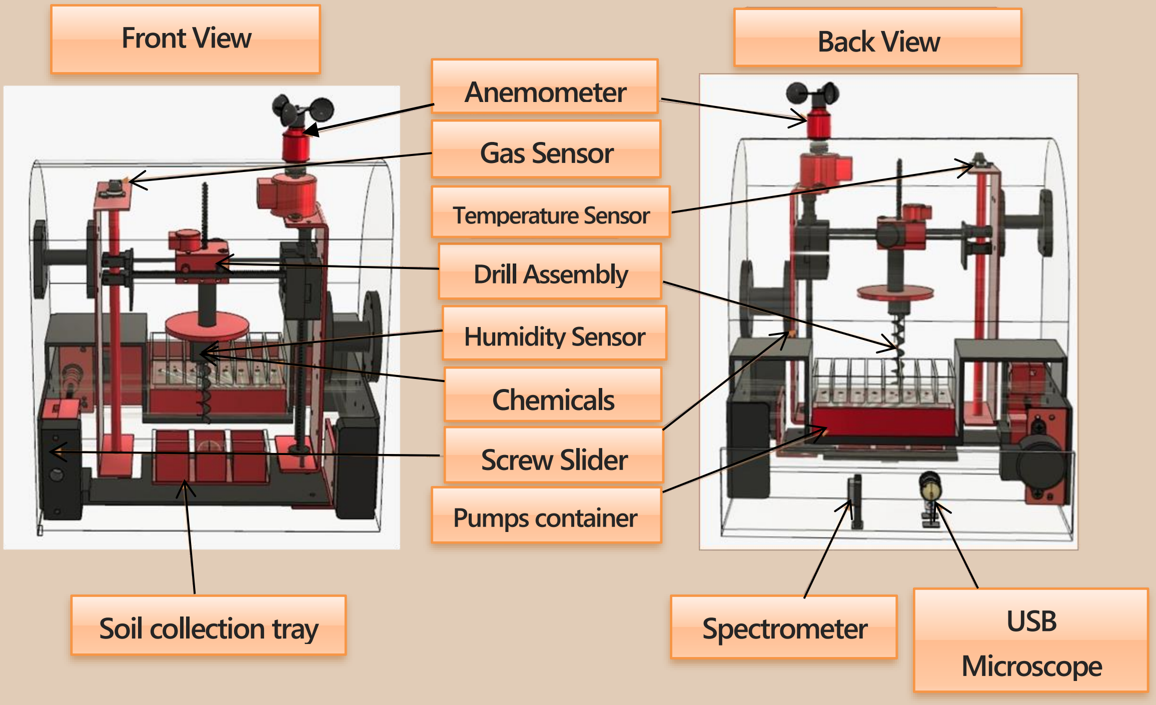
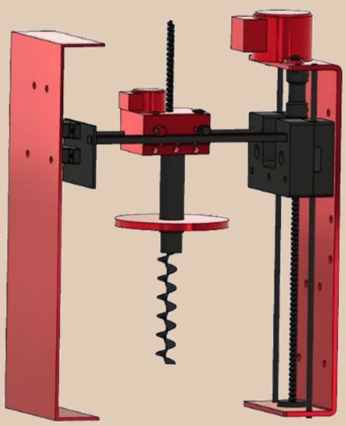


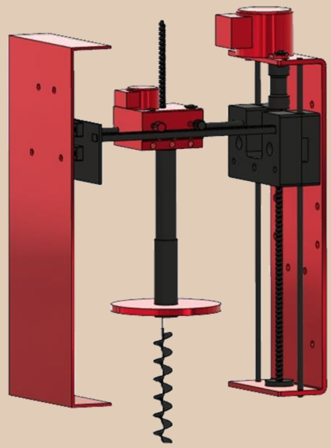
Figure: Labelled diagram of Bio-Assembly

3.1 Sample Collection

The soil in the lava tube is not in its loose form, so to collect the sample, we will use a drill attached to a screw for varying lengths. The endpoint of the drill's motor has two cylindrical rods that join the drill with the vertically placed screw slider system, which is used for the vertical movement of the drill. Our collection box is fixed to a servo motor for rotating the box in a horizontal plane. The tray is joined with a horizontally placed screw slider used for the tray's movement in the horizontal direction.



Figure(a): Drill for soil collection



Figure(b): Drill with extended rod

Collection Mechanism:

The drill is moved vertically downwards into the soil and rotated at least 10 cm inside the surface to collect the soil samples. After this, it pulled upwards without rotation. The drill is then rotated in an anticlockwise direction so that the soil will be collected in the tray placed below it. For the collection of samples in different collection boxes, we use the horizontal movement of the drill.

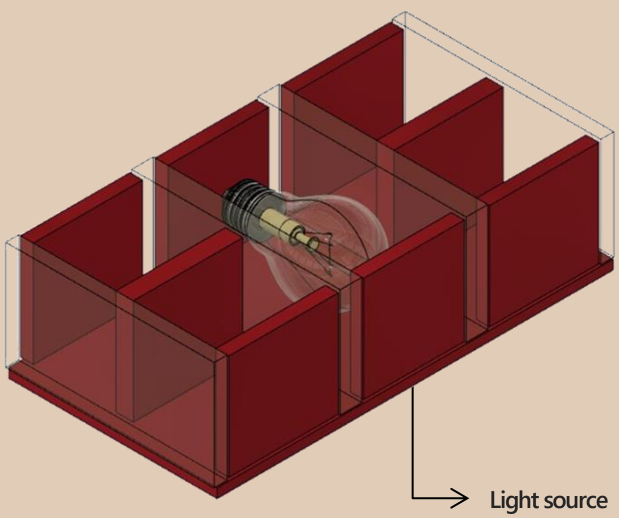
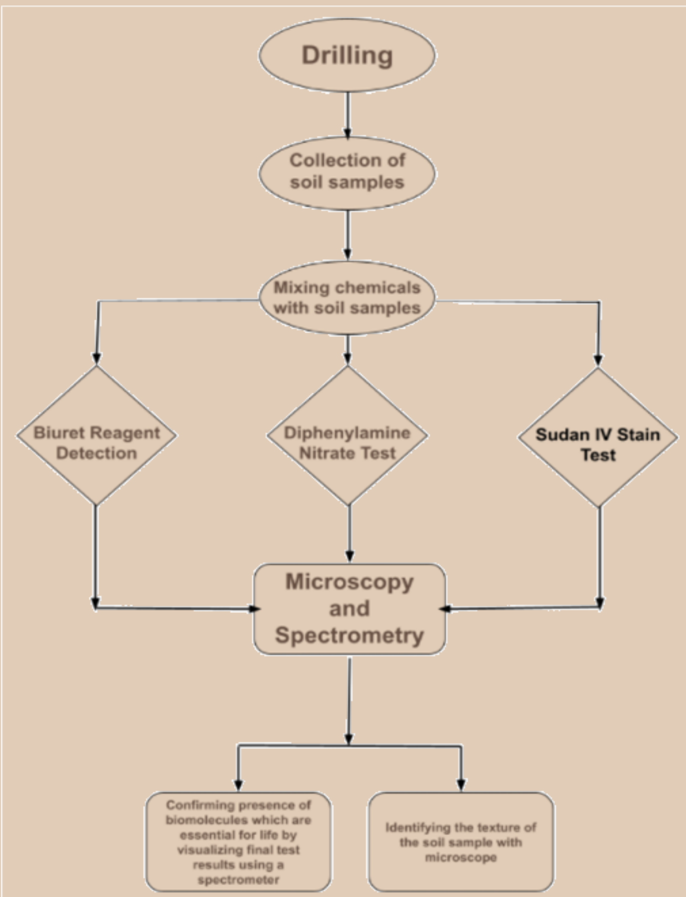


Figure: Soil collection tray

3.2 Testing

We will check the presence of proteins, Nitrates, and Lipids for life detection because it is considered the base of any organic lifeform. The flowchart shows our workflow and how our rover will perform all the required tests.

The testing task is accomplished by a rectangular container divided into eight subparts in which each part has its pump and a chemical associated with it for the required experiments. After the tests, the spectrometer will observe the colors, and the micro cam monitors the soil to predict its type. And finally help in detection of life



Testing Mechanism:

The collected soil samples in the box placed on the tray are moved backward (in the horizontal plane to ground) to reach exactly below its desired chemical for a particular experiment. The chemical is dropped on the soil sample, which changes its color. There is a light source in between the sample collection boxes and spectrometer. As soon as there is a change in the color of the soil sample, the spectrometer shows a change in its wavelength graph.

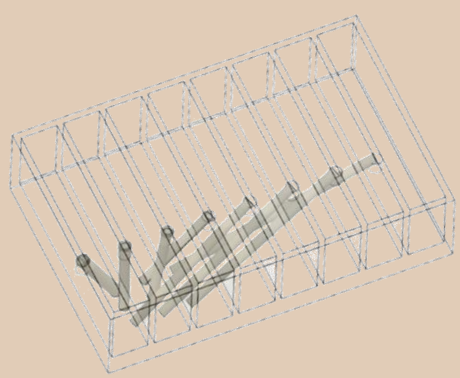
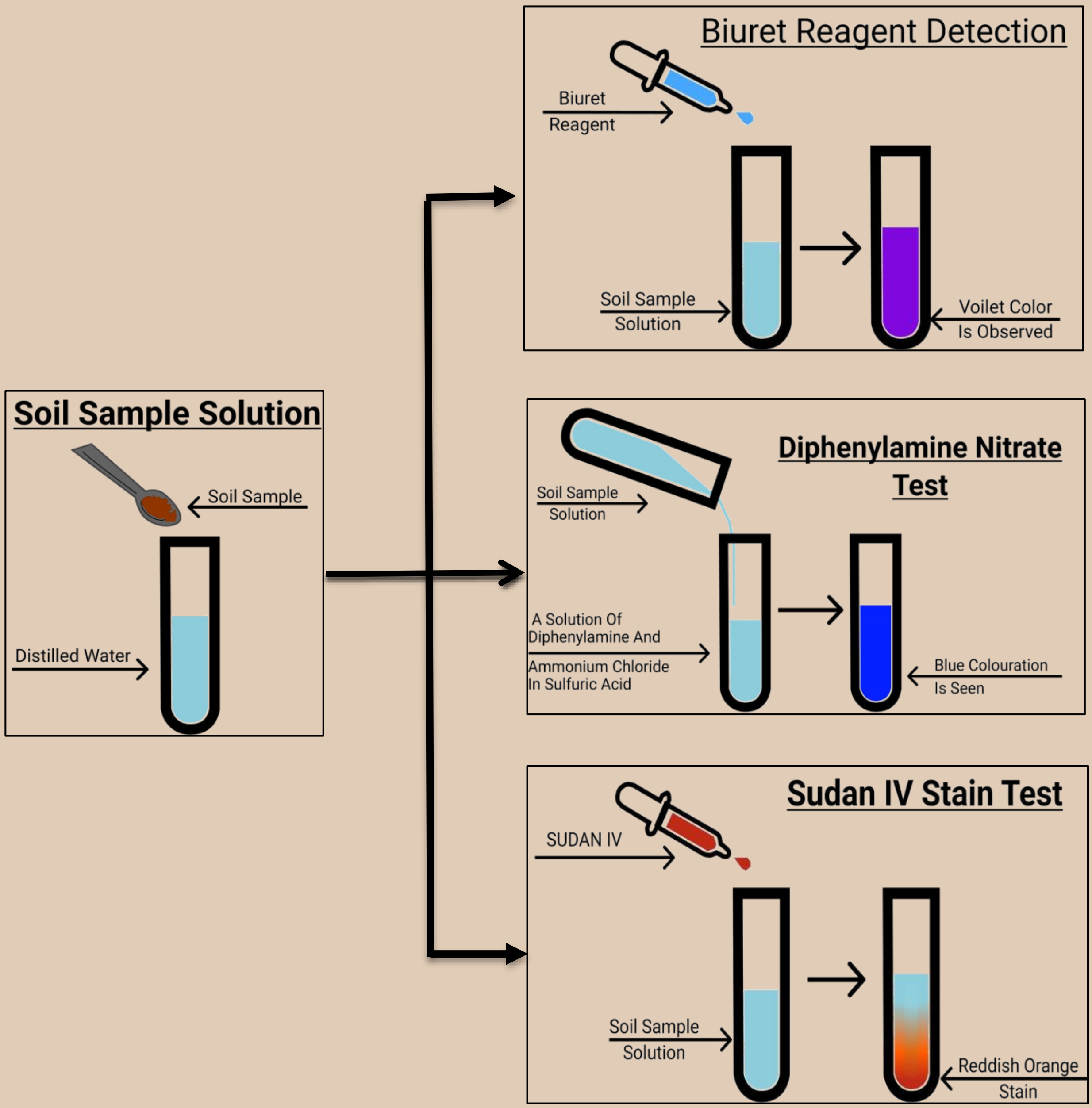


Figure: Chemical storage tray

Sample Detection tests:

To detect the peptide bonds in protein Biuret Reagent is used which turns the color to purple, nitrates are confirmed using Diphenylamine Nitrate Test which gives a blue coloration, and lipid is confirmed by Sudan IV Stain Test which turns the soil sample reddish orange.



3.3 Sensing

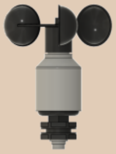
We will be sensing temperature, humidity, pressure, wind speed, some gases, and moisture in the soil.

Sensors for Control:

These sensors will help the rover to navigate, and these include:

- For navigation, we are deploying an accelerometer and gyroscope
- To measure temperature and account for heat loss, we are using thermocouples and heat flux sensors.

Sensors for Data collection:

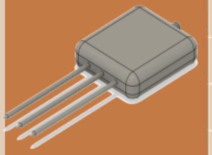


1 Anemometer

For measuring the wind speed we have used an Anemometer, which is mounted at the top of the bio-assembly module.

Moisture Sensor 2

A Moisture Sensor has been used to test the moisture content in the soil. The sensor will be attached to a drill which will move the sensor in the x-axis to test the soil.

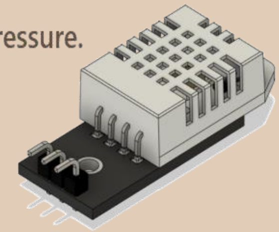


S. No.	Reading	Result
1	35%	Dry Soil
2	55%	Wet Soil
3	80%	Extreme Wet Soil

3 T.H.P Sensor

A BME 280 sensor is used for measuring temperature, humidity and pressure. This precision sensor can measure:

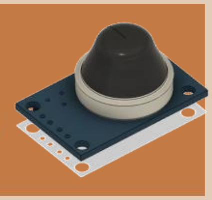
- Relative humidity from 0 to 100% with ±3% accuracy.
- Barometric pressure from 300Pa to 1100hPa with ±1hPa absolute
- Accuracy temperature from -40^{0}C to 85^{0}C with $\pm1.0^{0}$C accuracy.



4

MQ2 Gas Sensor

It is used to detect LPG, Smoke, Alcohol, Propane, Hydrogen, Methane and Carbon Monoxide concentrations in the Martian environment anywhere from 200 to 10000ppm.



5

Spectrometer

We have used Mini- Spectrometer micro series C12666MA for detecting the change in colour of the chemicals with the soil. The light source is present at rectangular space at the centre of the sample box.

6

USB Microscope

We are using USB microscope to detect if our samples contains more sand, clay, or silt particles.

<u>The different sensors that we are using are shown in the circuit below:</u>

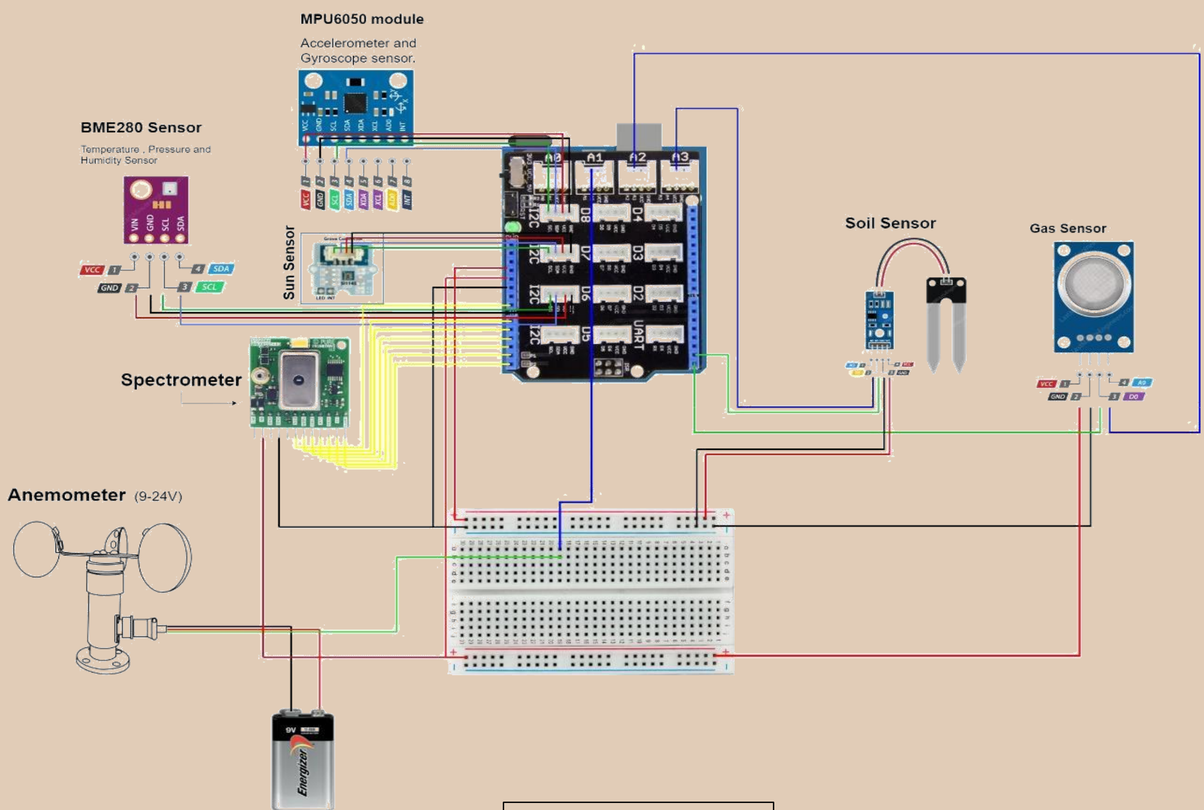


Figure: Sensor circuit

Bill

S.No.	Component	Specifications	Quantity	(in Rs.)	Total (in Rs.)	S.No.	Component	Specifications	Quantity	Rs.)	Total (in Rs.)
1	Jetson nano	GPU128-core Maxwell CPUQuad-core ARM A57 1.43 GHz	1	9000	9000	19	Ubiquiti rocket m9 module	Dimension:160x80x30mm Operating frequency: 900-928MHz,Network Interface:10/100Mbps,Power comsumption:6.5W	2	4600	9200
2	Arduino Mega	ATmega2560 microcontroller Input voltage - 7-12V 54 Digital I/O Pins (14 PWM outputs) 16 Analog Inputs 256k Flash Memory 16Mhz Clock Speed	3	800	2400	20	2.4GHz omni antenna	Dimension:1122x81x76mm Frequency range:2.3-2.5GHz,Gain:10dBi,Polarization:Dual Linear,Coverage:360°	1	1800	1800
3	camera module	Capture Video with Audio: High frame rates, H.264 30fps@1920×1080; MJPG 30fps@1920×1080; YUY2 30fps@640x 480; Audio, dual stereo microphones	1	3000	3000	21	900MHz omni antenna	Dimension:1454x80x25mm Frequency range:900-932MHz,Gain:8dBi,Coverage:360°	1	1800	1800
4	Wide angle camera	Sony 8MP IMX219 Sensor, Frame Rate: 30fps@8MP, 60fps@1080p, 180fps@720p, View Angle: 175(D) x 145(H) x 77(V)	1	2500	2500	22	2.4GHz patch antennas	Dimension: 25x25x4mm,Frequency range:2.4-2.5GHz,Gain:6dBi	4	500	2000
5	Spectrometer	Operating Voltage(VDC): 3.3,Operating current(mA): 5.,Selectable interface: I2C or Serial (115200bps)., 18 frequencies of light-sensing from 410nm to 940nm., 28.6 nW/cm2 per count. Accuracy of ±12%. Integrated 405nm UV, 5700k White, and 875nm IR LEDs	1	6000	6000	23	900 MHz patch antennas	Dimension:49.5x49.5x7.5mm,Frequency range:902-928MHz,Peak Gain:5dBi	4	600	2400
6	USB Microscope	Image Capture Resolution : 1600 x 1200 (2M Pixel),1280 x 960 (1.3 M Pixel), 800 x 600, 640 x 480	1	1000	1000	24	Aerogel	1 sq m	1	400	400
7	Lead Screw	Screw Length90mm,screw Diameter3mm,Slider Width15mm,Effective Stroke80mm,Screw Pitch 0.5mm,Step Angle18 °	2	2000	4000	25	RB40 12V 40Ah LifePO4 Battery	12V 40Ah	1	8,000	8,000
8	Peristaltic Pump	Motor Horsepowerless that 0.5, Maximum Discharge,Flow3.5ml/min,Power Source Electric,Display NO,Discharge Pressure 400mmHg	8	700	5600	26	Orion BMS 2	24 cells	1	5,000	5,000
9	Gas Sensor	Included Components REES52 MQ2 Arduino Compatible Gas Sensor, Methane, Butane, LPG, Smoke Sensor Item Weight 160 grams	1	280	280	27	LIDAR	Host interface: USB 3.1, Height: 26mm, Width: 61mm The L515 is designed for applications like warehouse logistics, robotics, and 3D scanning. Depth resolution and FPS	1	7,000	7,000
10	BME280 Temperature	Supply Voltage: 1.8 - 5V DC,Interface: I2C (up to 3.4MHz),Operational Range:,Temperature: -40 to +85°C,Humidity: 0-100%,Pressure: 300-1100 hPa,(Resolution:Temperature: 0.01C,Humidity:0.008%,Pressure:0.18Pa),Accuracy:,Temperature1C,Humidity: +-3%,Pressure+-1Pa	1	800	800	28	Ball Bearings	Dimensions: 8mm x 22mm x 7mm ;Facilitates motion,reduces friction of moving mechanism	14	195	2,730
11	Anemometer	Dimensions:(Cups Outer Diameter: 50 mm.Body Outer Diameter:39 mm.Base Diameter: 60 mm.Screw Hole Diameter: 7 mm.)	1	1300	1300	29	BIURET REAGENT solution	sodium hydroxide (NaOH) and hydrated copper(II) sulphate, together with potassium sodium tartrate	100ml	232/500ml	45.0
12	Soil Moisture Sensor	Operating voltage: 3.3V~5V,Dual output mode,analog output more accurate,With power indicator (red) and digital switching output indicator (green),Having LM393 comparator chip, stable,Panel PCB,Dimension: Approx.3cm x 1.5cm,Soil Probe Dimension:Approx. 6cm x 3cm,Cable Length: Approx.21cm	1	55	55	30	DISTILLED WATER	98%pure	100ml	275.60/5liters	5
13	Wheel Motor	Operating Voltage: 12V, Rated Torque : 2N-m, Rated speed : 63RPM, Rated Current : 5.5A, Rated Power : 41.3W, Gear Ratio : 104:1, Gearbox type : Planetary gearbox, Gearbox diameter: 42mm	6	2,000	12,000	31	Diphenylamine	Molecular formula: C12H11N Molecular weight: 169.23 g/mol Appearance: Cream colored flakes/powder Assay: Min. 98%	100gm	764/500gm	153
14	DC Motor	Operating Voltage: 12V DC,Rated Torque: 45 N-cm,Rated Speed: 262 RPM,Rated Current: 1.92 A,Rated Power: 22.93W,Gear Ratio: 19.2 : 1	1	1000	1000	32	Ammonium Chloride	Molecular Formula: NH4Cl Molecular Weight: 53.49 g/mol Appearance: White crystalline powder	100gm	520.65/2.5 Kg	20.0
15	Servo Motor	Weight : 55g,Dimension : 40.7 × 19.7 × 42.9 mm,Operating Speed (4.8V no load): 20sec / 60 deg ,Operating Speed (6.0V no load): 16sec / 60 deg (no load),Stall Torque (4.8V): 10kg/cm,Stall Torque(6.0V): 12kg/cm,Operation Voltage : 4.8 - 7.2Volts,Operating Angle: 120degree	1	1500	1500	33	Concentrated Sulphuric Acid	FormLiquid Density1.83 g/cm3	100ml	640/ Litre	64
16	2.4GHz Sector antenna	Dimensions:700x145x93mm,Frequency Range:2.3-2.7Ghz,Gain:15dBi, Polarization:Dual Linear,Coverage:120°	1	5000	5000	34	SUDAN IV	Molecular formula: C24H20N4O Molecular weight: 380.44 Assay: 80	100gm	125.45/25 gm	500.0
17	900Mhz Yagi Antenna	Dimension:570x182x18mm,Frequency:900MHz,Gain:11dBi, Polarization:Vertical/Horizontal, Coverage:48°	1	1200	1200	35	Aluminium		316.945kg	135/Kg	42788
18	Ubiquiti rocket m2 module	Dimension:154x80x30mm, 2x2 MiMo 2.4GHz Radio, Range: 50+ km, Breakthrough speed:150+mbps, Power comsumption:6.5W	2	6000	12000						

NET TOTAL **Rs 152539.8**

Appendix

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