1. Introduction: "Mongol Tori", the next generation Mars Rover is created and designed to push the boundaries of technology. In order to participate in URC a group of enthusiastic undergraduate engineering students of BRAC University came forward to building the rover. The team "Mongol Tori" consists of 29 students, who have rigid background and expertise in their own field such as mechanical, electronics, software, communication, control, outreach and promotion. "Mongol Tori" has been prepared accordingly and successfully performed all the tasks mentioned in the rules book of University Rover Challenge 2017.

2. Rover Mechanical Design:

2.1.1Chassis: The chassis of the rover is stimulated from the combination of ladder and tube space frame design. The chassis is trapezoid shaped [fig 1(a)] with a square box of 25*10 inch at the front. The length of the whole chassis is 42 inches. To increase rigidity and stiffness as well as to diminish the possibility of shape distortion due to application of bumpy pressure we have employed triangulation. The space frame is strong because of rigidity of the triangle. Flexing loads are transmitted as tension and compression loads along the length of each strut.

2.1.2 Wheel: We are using wheels with a diameter of 12 inch and a width of 5 inch. Considering the light weight and high strength requirements custom made wheels made from molded aluminum have been used. The side edge of the wheels are slightly sloped so that it can have better performance in the rocky surface. We have designed our custom made aluminum motor housing so modular for connecting the wheels and motors with the body, so that we can change wheels or motors any time. An efficient rubber grip has been incorporated on the wheel[fig 1(c)]. The orientation of the grip will helps the rover to rotate 360 degree, climbing rock and deal with the vertical drops.

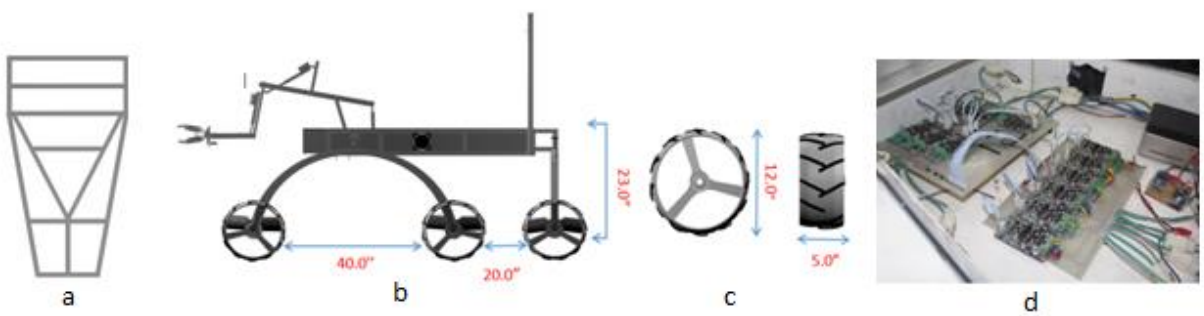


Fig: 1

2.1.3 Suspension: Considering the rough terrain and the vertical drops a six wheeled rover has been designed. The design is inspired from the popular semi rocker bogie suspension system. Our design consists of 1 bogie and 1 rear suspension in each side of the rover. In our design the bogies are mounted on to the front part of chassis and the rear suspension is supported by a high performance shock absorber with double spring. The bogie can freely move up to 80 degree both forward and backward. The rear suspension is placed angularly for absorbing the shock perfectly.

2.1.4 Robotic Arm: A very strong and efficient robotic arm with six degrees of freedom (base, shoulder, elbow, wrist, two degrees of freedom in the end effector) is designed our rover. The arm consists of three linier actuator and three dc motor. A gear mechanism has been incorporated at the base of the arm for 360 degree rotation. Our three fingered end effector with hard rubber in the fingers can grab small stuff perfectly. A rotational gear based system has been comprised on the claw for 360 degree rotation without wire twisting. The claw can hold and the arm can lift 5 kg of weight at any circumstances.

2.3.1 Rover Control: For controlling the rover we are using Intel NUC pc. There are two sections in this controlling system. One is on the rover body and another is in the control station. These two systems are connected through router. We have on board Arduino mega connected with the NUC pc for operating the motors. In the base station we have another pc which is connected with a thumb joystick. The joystick is interfaced with the pc using python script. A GUI system is designed for controlling purposes. A GPS Plotter Software Interface is developed to find the exact position and location of rover offline.

2.3.2 Arm Control: We have another thumb joystick connected with the control base station pc for controlling the movement of the arm. We have three actuators and three DC motors in the arm. For controlling them we have designed our own algorithm using inverse kinematics. Joints can be limited with specific positional and rotational properties [fig 2(c)].

(a: Arm Matlab Simulation) (b: Air Slueth Spectrum Analyzer- Signal Trace) (c: Rover Controler GUI)

Fig 2

2.4 Communication: In order to establish strong communication between base station and rover, we use two routers, one for transmitting control signal and the other for video stream. For data transmission 2.4GHz frequency band TP-link CPE210 and to receive camera feed 5GHz TP-link CPE 520 routers would be used. Frequency hopping has been ensured while using 5 GHz router, by keeping the ability to switch among frequency channels. Choice of antenna was precise, in our case. Omni-directional antenna (ANT2400Q15V) would be used in rover to establish 360 degree horizontal beam pattern to ensure more coverage. While, directional antenna (ANT2700D24A) would be used in base station, for focused narrow radio wave beam width. Control data requires better reliability, hence we used TCP protocol for data transmission. UDP protocol allows faster transmission, with delays as minimal as possible, to capture video stream this particular protocol have been handy for us. Antenna was mechanized by electric control signal and rotated using servo motor (110ST-M02030), according to signal strength received. 'Air-sleuth spectrum' analyzer software would be used to detect strongest signal against rovers different 'position vector'. Signal feedback is then taken to initiate directional movement of antenna to face where received signal shows greatest SNR (signal to noise ratio) [fig 2(b)].

2.2 Rover Electronics: We are using 6 high torque dc motors which draw not more than 6 Amp in rough terrain. Therefore, we are using 13Amp Cytron motor driver which has been mounted on custom made PCB board. As our arm is modular so we have made another printed circuit board for 3 linear actuators and 3 dc motor for grabbing function of the claw as well as science task module. The 22V 42Amp Lithium ion battery is being used for powering motor of wheel and arm. Also we have our own custom power distribution board on rover. From our power distribution board we are distributing power to the main board of rover which consist of 12v Intel NUC pc, 24V communication router and 5v raspberry pi camera module. Each of the six motors requires 24V, each of the three actuators and three DC motors need 12V which have been managed directly from the battery source through motor drivers. For keeping our circuit cool we have designed cooling system by two DC fan and heat sink on the regulator IC.

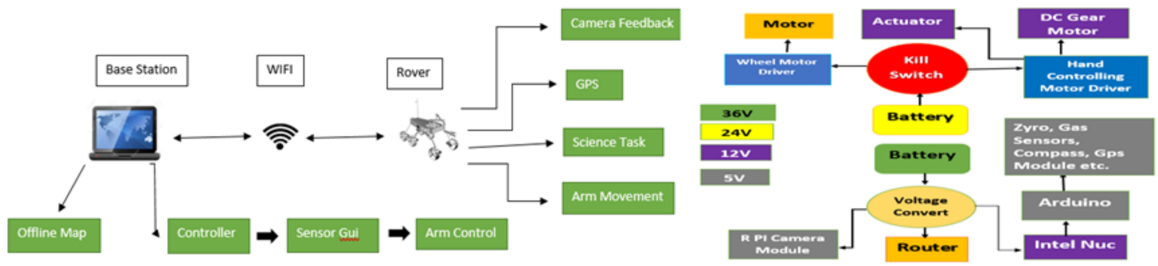


Fig 3: Rover Software & Power distribution system Overview

2.5 Rover Software: The rover software we made established a central control system from a remote distance. Mongol tori's software consists of control interface (Base Station) and central rover controller [fig 3]. Each system is responsible for controlling different aspects of rover. The base station is responsible for interpreting data from the wireless controller, processing data received from the rover and sent data to the Rover. This system's main requirement is to provide reliable, easy-to-use control of the rover and accurate, up-to-date, clearly presented information on the rover's status.

2.5.1 Control GUI: We have developed our base station's control interface using JAVA programming language [fig 2(c)]. The software offers a user-friendly GUI (Graphical User Interface) to communicate with the rover. The rover software is the server side while the base station is the client side which communicates using Transmission control protocol. The rover control side runs on board Intel NUC pc with Arduino Mega.

2.5.2 Sensor GUI: We also made software for on board sensors which measures temperature, humidity, barometric pressure, soil moisture and soil temperature, CO_2, CO etc. We have integrated DHT11, BMP 180, SEN13322, MQ7, MQ135 for the sensor value. The rover side software takes reading from the sensors and transmits the data over the network. The sensor GUI is developed in C# that interprets the sensor readings into meters and display in GUI.

2.5.3 Rover Stability: An MPU-92/65 sensor is used which is a single chip package containing a 3 axis accelerometer, a 3 axis gyroscope, a 3 axis compass sensor. The sensor is connected with on board Arduino Uno which communicate with the base station GUI to provide a clear and accurate orientation of the rover. The stability GUI is developed using Arduino and processing [fig 3(b)].

2.5.4 Offline Map: To locate and plot the rover's position, Grove GPS module is being used which features 22 tracking / 66 acquisition channel GPS receiver. GPS data is received in NMEA format and every received string is sent to the base station. The software in the base station is developed in python [fig 3(a)] which processes the raw GPS data and extracts the latitude and longitude of the rover position and continuously plots them in the custom map.

Software	Runtime Environment
Control GUI	JRE 1.6.0
Sensor GUI	.net framework 4.5
Offline Map	Python 2.7.0
Arm Controller	MATLAB

Table 2: Software Runtime Environment

Fig 3 (a): Offline Map

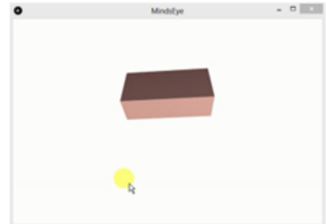


Fig 3 (b): Zyro Stability Test

2.6 Safety: An affair which strictly being followed here is safety. First of all, our Rover has "kill switch" which will immediately dispatch the rover mechanism while needed. Furthermore, it has "fuse 30 amp" if the voltage drop off it will maintain and control the current flow.

2.7 Funding: The total funds required for "Mongol Tori" is 165,758 USD - University Fund (62,758 USD), Team contribution (29*2,000=58,000 USD). Rover development (8,758 USD) and travel cost (4,500*12=54,000 USD) is going under University Fund. Two of our sponsors are Spectrum Technologies (20,000 USD) and BRAC (25,000 USD) which totalize our sponsor.

3 Rover Ability:

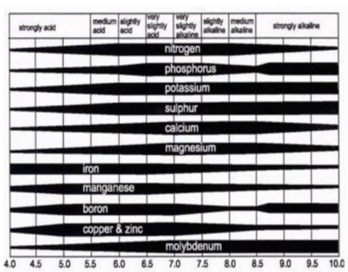
3.1 Extreme Retrieval and Delivery Task: Our rover can easily travel through any type of rough place mention in rule book, even more than 0.5 m vertical drops and steep slopes in excess of 45°. This is possible because of the gap between two front wheels which is 40 inch and our suspension system. Our rover passed this test successfully several times. Our rover arm is capable of carrying more than 5 kg. The width of the rover is 1 meter so it can pass the gate easily. In our wheel, we used rubber grip in 45°, this gives an advantage that our rover will not skid while climbing and get down from steep areas. We have designed our rover's bogie in a parabolic shape because this will prevent the rover body to get damaged. Our rover can perform extreme retrieval and delivery task in 60 minutes.

3.2 Equipment Servicing: Our rover is capable of travel more than 0.25 km. Our rover arm can reach more than 1m from the ground as it has six-degrees of freedom. We used fish eyed lens in our camera so that our camera feed remains in high quality which gives us clear video in LCD display.

3.3 Autonomous Traversal Task: For the autonomous task, we use GPS Bee Kit which comes with a nice Antenna. Arduino nano integrated with the kit sends the GPS coordinates to the base station as a string in every 5 seconds. We convert the GPS coordinate (latitude, longitude) generated from the kit into UTM coordinate system using java. We calculate the start position and end position and the distance measurements made in meters. The two grid lines are 1 meter far away. Therefore, we calculate each grid between the start and end position and program the rover accordingly so that it follows the grid and reach the destination.

4. Science Task report: Mars is the fourth planet of our solar system and the most habitable planet after Earth. As it has solid iron rich rocky crust, 62.5% less gravity then Earth and a thin atmosphere contains mostly Carbon Dioxide. In this year with the inspiration of building the next generation of Mars rovers we are designing our project ‘Mongol Tori’. At this rover, we are focused on searching the likelihood to support life from on that red planet. Therefore, we have decided to perform onboard and lab experiments on this project.

Firstly, our rover will take a high-resolution panorama image of the site with GPS location data. On the other hand, our sample collector will drill the soil to collect subsurface samples for further tests. Mongol Tori is designed to perform onboard test for subsurface temperature (DS18B20 one wire temperature sensor), soil moisture (SEN 13322), Carbon Dioxide (MQ135), Carbon monoxide (DHT11MQ7), atmospheric pressure (BMP180) and air temperature (DHT11). As these parameters are vital to likelihood of support life form at that environment. Along with that it will take a high resolution close up image of the soil for stratigraphic profile.



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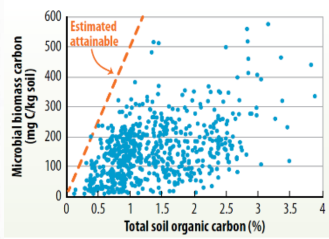

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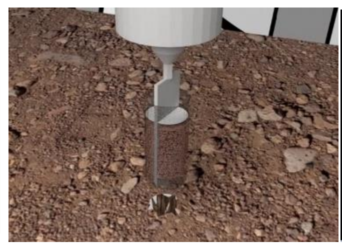

Fig: c

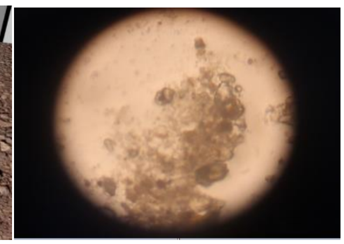

Fig: d

Figure: (*a) This list is a horizontal representation of the availability of each of these nutrients as you move along the pH scale. (b)In most agricultural and horticultural soils in Western Australia, the actual microbial biomass carbon (dots) is lower than the estimated attainable microbial biomass carbon. (c) Sample Collector. (d)Microscopic view of sample.*

Secondly, after collecting the samples the rover will be back on base. At the Lab, we will perform pH test, microbial biomass, water flow capillary test and microscopy test on samples. The pH test indicate us the Acidity or Basicity of soil. Then from microbial biomass test we can determine the amount of biomass (Carbon, Nitrogen) present in soil using equation, biomass = (difference of weight ÷ previous weight) × 100. This will give us the possibility of component which form life. After that, we will do for water flow capillary test which shows us the possibility of flow water though previously by comparing dry soil with sample soil using (water passing height ÷ Time). Finally, we will put the samples under microscope and analyze the composition of soil for presents of water & mineral crystals.

In conclusion, our mars rover’s onboard and lab experiment will provide vital information about the site to indicate possibility to support life form and atmospheric conditions.