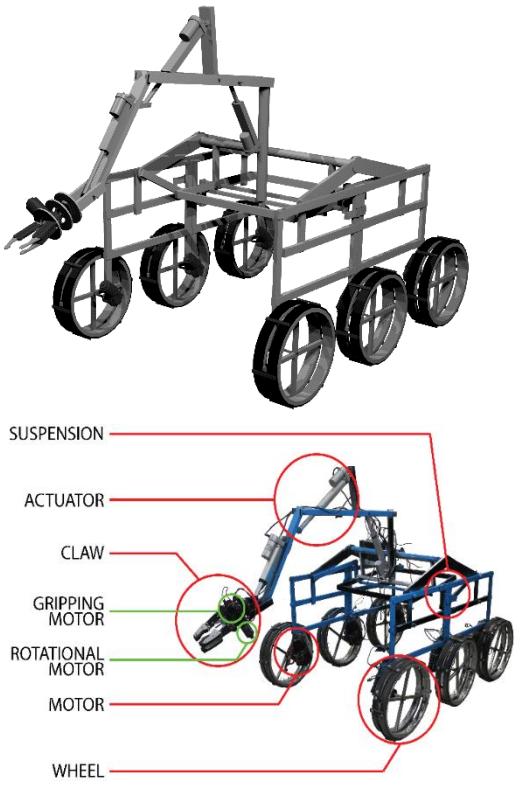
1. Introduction: BRAC University (BRACU) is one of the leading universities in Bangladesh. At BRACU, along with the engineering departments, a number of disciplines such as physics, applied physics and electronics, mathematics, biotechnology, microbiology, pharmacy, and architecture are functioning and conducting research on cutting edge technologies. As BRACU believes in high quality research, it always encourages student to participate in prestigious international competitions like NASA Lunabotics Mining Competition, University Rover Challenge, TechFest etc. As a part of this, a very enthusiastic group of students from engineering department has taken the initiative to attend in URC 2016.

The team participants of BRACU "MONGOL TORI" (Boat of Mars) is consist of 11 student members, 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 according to rules book of CDR which is shown in Table 1. A Systemic Architecture overview of Mongol Tori both 3D model and original model is also shown in Fig.1 (a) and Fig 1(b), respectively.

Table 1. Fulfilling Criteria of URC Rule Book

Criteria	Rule	Mongol Tori
Vertical drop	0.5 meter	more than 1 meter
Wireless communication	not more than 1 km	more than 5km
Science task and Astronauts assistance task	Moisture, soil characteristics and Shall be able to take collect, turn on off, rotate objects	Soil characteristics, moisture, hazardous gas detection, water detection, pH and efficient robotic arm with 6 degree of freedom to perform astronauts task
Rover weight	50 kg	48 kg
Control & power	Non tethered, rover will have to be a mobile platform	Non tethered controlling system and power system
Wireless communication method	Except 900MHz & 2.4GHz all bands are restricted.	2.4 Ghz pairable wifi router is being used
Safety Issue	Safety related task	Maintained International Safety Management code

(a)



(b)

Fig. 1 (a) 3D design (b) Implemented model

2. Design Architecture and Rover Mechanics

2.1 CRAB MODEL: Considering the rough terrain and the difficulty, a 6 wheeled mars explorer rover has been designed. The full rover dimension is of 46 inch X 36 inch X 24 inch. In our rover, a modified version of CRAB 2 suspension system is being used (Fig. 2(a)). In this system we have two parallel bogies which are connected at the bottom next to the axis of the middle wheel and at the top through an articulated rocker. A differential mechanism between the left and right suspension levels the pitch angle of the chassis. In this system the load is distributed evenly on all wheels because the vertical links are placed at 2/3 times distance from the middle wheel. The front and back bogies are identical. As the rocker which connects both bogies is divided into two elements with a rotational joint in the middle, therefore, the system is fully symmetric. There are two differential linkers which maintain the balance of the middle base of this rover. Each wheel of our rover can cover a height of 10 inch from the ground for this CRAB suspension system which may help the rover to climb rock or to deal with vertical drops as shown in Fig. 2(d).

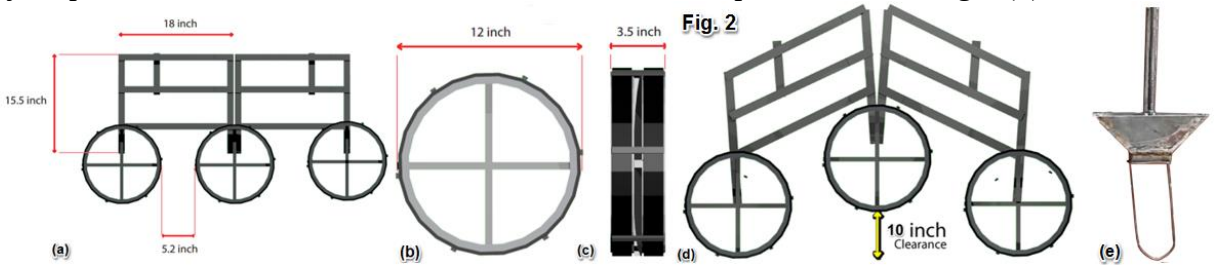


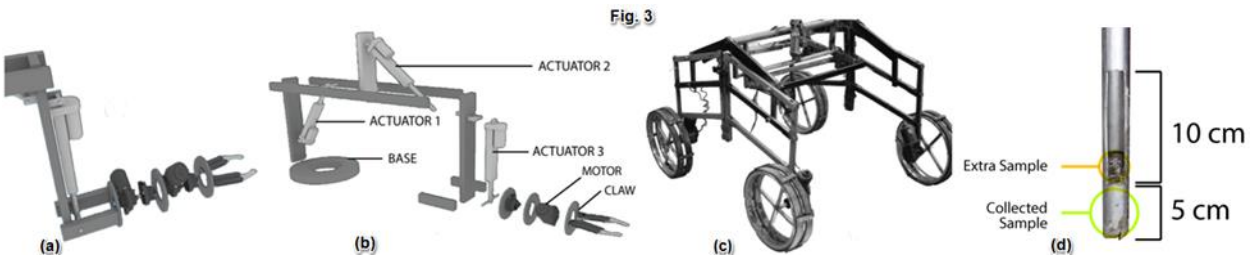
Fig. 2

2.2 MOTOR & WHEEL: We are using six high torque DC wiper motor which are generally used in automobile windscreen. Since we don't have custom-made motor in our country, so we did some reverse engineering with the motor. We have designed our own shaft for the motor which increases the performance as well as the strength of the wheels. After the modification of the motor the rotational speed is approximately 1.3 rad/sec. At 12v on high speed the motor has 13.5 pound-feet and on low speed it has 17.5 pound-feet of torque. The maximum forward/backward speed of the rover with no simulated load is 1.5 km/h. The clearance between the motors and the ground is 5.5 inch and the clearance between surface and wheel is 10 inch (Fig. 2(d)) We are using our own designed wheel with the diameter of 12 inch and thickness is 3.5 inch (Fig. 2(b-c)). The wheels are consisting of two circular shape rings which are connected in parallel with each other.

2.3 FOUR WHEEL DRIVE: When we do task with the arm then this six wheels model eventually increase the overall weight. So, for reducing such weight, we will drive our rover with 4 wheels as we will remove 2 wheels and 2 motors (Fig. 3(c)). Then we intercept the middle part of the bogies through a thick bolt and double nuts as a result we can drive the rover with 7kg less weight.

2.4 ARM: We have our very own designed arm for this rover with 5 degrees of freedom. We have created a lightweight rotational system for the arm. By using the system the base of the arm can rotate up to 110 degree. The rotation is driven by an actuator. The arm consists of 3 actuator and 2 dc motor which gives a huge working area to the arm. End-effector of the arm is a 3 fingered claw. First the claw was designed for two fingers but considering the task 3 fingers are introduce for better performance. For increasing grabbing efficiency hard rubber is used in the fingers which also help the rover to grab small stuffs. The claw is controlled by 2 dc motor, 1 motor for graving and 1 for 360 degree rotation of the claw. The claw can hold and arm can lift 5 kg of weight at any circumstances. Rover Arm is shown in Fig. 3 (a) & Fig. 3(b).

2.5 SCIENCE MODULE: In developed module there are two parts, one is for collecting the samples from 10cm below of the surface and another part is for collecting the samples from the



surface. Both parts are interconnected with each other through an actuator. There is a 19 cm long and 2cm hollow pipe which will go inside the surface when we run the actuator. The last 5 cm of the pipe is as usual, after that a capsule hole of 10cm long is made on the pipe (Fig. 3(d)). When at least 15 cm pipe will go inside the surface, then the sample from first 10cm of the surface will stay in the holed portion which will be dropped at the time of pulling the pipe from the ground from the surface but the sample from below 10cm will stay in the last 5cm of the pipe. A flap type catching technique will be used to catch at least 30gm of the sample safely at the end of the pipe as shown in Fig. 2(e).

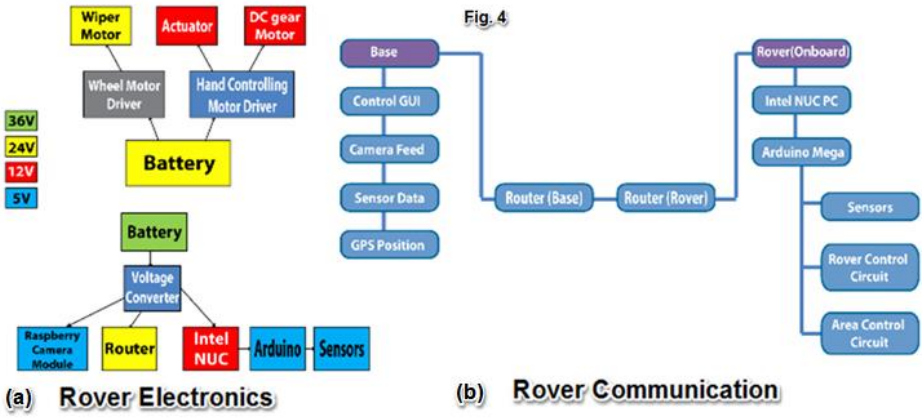
3. Rover Electronics

We are using 6 wiper motor and it draws in rough terrain not more than 12 A, so we are using high amp motor driver which can handle 13 A and operating voltage +24 V. We have also designed custom motor driver by industrial relay and power MOSFET which can handle 30 amps and it has ability the PWM function and our all circuit is modular as we can change it in any emergency case. As our arm is modular so we have designed custom driver circuit for arm actuators and 2 dc motor for grabbing function of the claw. All the electronic equipment of the rover has been assigned to be powered by an on-board rechargeable power supply. The 24 V 19Ah lead acid battery is using for powering motor in current experiment which will be changed into same configuration lithium-polymer batteries. Another +12 V 7 Ah lead acid battery is using for powering actuator. In addition, custom made 36 volt 15Ah lithium-polymer battery is using for powering other control electronics devices which is shown in Fig. 4(a). As we are using lots of electronics modules, we have our own custom power distribution board. In our custom board we have used LM2577 IC which can convert up to 32 volt and 3A. Furthermore, it consist capacitor to cancel out any irregularities in the input voltage. From our pdb board we distribute power to our main mother board intel nuc +12V, + 24V to our communication module, +5V for our raspi cam module. For arduino we don't require to give external power, we powered arduino by intel nuc and also our sensors are getting power from arduino pins. Each of the six gear motors requires +24V, each of the three actuators and two 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 DC fan and heat sink on regulator IC. For safety we have used fuse panel and also have emergency kill switch.

4. Rover Communication

FCC standard and regulation method is followed for communication system. To establish a strong communication with the rover and the control station point to point communication is being used as shown in Fig. 4 (b). We are using 2.4GHz 300Mbps wireless outdoor router on both the rover and the control station in a single DHCP list which is able to cover 5km range. An external 15dBi omnidirectional antenna is used to maximize the coverage area.

4.1 Video Streaming: The vision system of rover is based on 5 camera which has programed on raspberry pi and the camera module is 5 megapixel. We are using raspberry pi real time camera



streaming in raspbian operating system. All the camera is connected to the wifi router with a static IP. The view is cover every side of the rover to controller to operate the rover.

4.2 LIVE Video Feedback Process: This process is working with one IP camera and four raspberry pi camera module. All the cameras are arranged such a way that the operator can watch all possible scenarios around the rover. We can watch real time feedback of all the cameras from the base station using web based graphical user interface which can be access through a static IP.

4.2.1 Prime Camera: The 3 megapixel IP camera with 15 fps is the main camera of our rover. This ultra-high resolution camera can provide us high resolution image of sites, wide angle panorama etc.

4.2.2 Supplementary camera & Arm camera: We are using four 5 mega pixel raspberry pi camera module with 30 fps. These cameras are connected with the router through Ethernet cable. We have placed two cameras for side view, one for back view and one for 3rd person view of the rover.

5. Rover Software and Associated Hardware

5.1 Rover Control: For controlling the rover we are using intel nuc pc. This pc is consists of 4 gb ram with Celeron processor. 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.

5.2 Arm Control: For supervising the arm we are using the nuc pc with another Arduino. We have another thumb joystick connected with the control base station pc for controlling the movement of the arm. The joystick is also interfaced with the pc using python script. We have four actuators and two DC motors in the arm. For controlling them we have designed own algorithm.

6. Safety: The safety issue is strictly followed according to the rules prescribed by the International Safety Management Code while making Mongol Tori. For example, high voltage hazards labeled is maintained in electronic work and points of rotating guard is used in mechanical work.

7. Funding: The total funding required for Mongol Tori is 32,000 USD where 5000 USD was required for developing the rover. BRAC University and BRAC will provide full funding for building Mongol Tori. Funding for travelling and outreach will come from potential sponsors after the acceptance of BRACU CDR from URC. Some Banks, software, telecom, electronics and metal industries have shown their interest to fund on Mongol Tori project.

8. Science Plan

The main objective of scientific task is to detect the existence of life by examining soil characteristics. Possible sites for collecting sample soil should be determined by the rover controller. The rover has to be controlled soil from those sites and brought to the main station. The soil should be collected from that sites from just below the top of the soil at 10 cm depth or even take panorama picture with high quality resolution and GPS coordinate system to observe the object more extensively. Mongol Tori has all the features to take panorama picture of the site and to observe the soil characteristics to find the possible life in Mars. In order to collect the soil sample, an effective mechanical module is used. A study has been conducted from the previous work for distinguishing soil characteristics of UTAH State to get the available characteristics of soil of that place. We have categorized two types of soil. Firstly, Biological Soil Crust: this types of soil mainly formed by the living organism and their byproducts-thus why the chances of getting photosynthetic bacteria and ex-teremophile is quite high and Secondly, Chemical and Physical Crust: this types of soil contains with inorganic components such as salt.
To analyze the soil characteristics some equipment is being used. For Example, USB microscope and optical microscope are used to get the visual representation regarding the structure of soil (Fig. 5(a-b)) and to make a comparison with the structure of Biological soil Crust. In addition, different gas detection process is executed to detect the hazardous material and to have an idea about the overall gas percentage of the mars atmosphere. Furthermore, soil moisture sensor is used to measure the volumetric water content indirectly by measuring some properties of soil and to measure the relative humidity of soil. We have also used temperature sensor to measure the temperature and created a live graphical representation of the moisture level with respect to the temperature of the environment. A pH meter is used to distinguish the soil either acid or basic and to investigate the possible growth of organism.

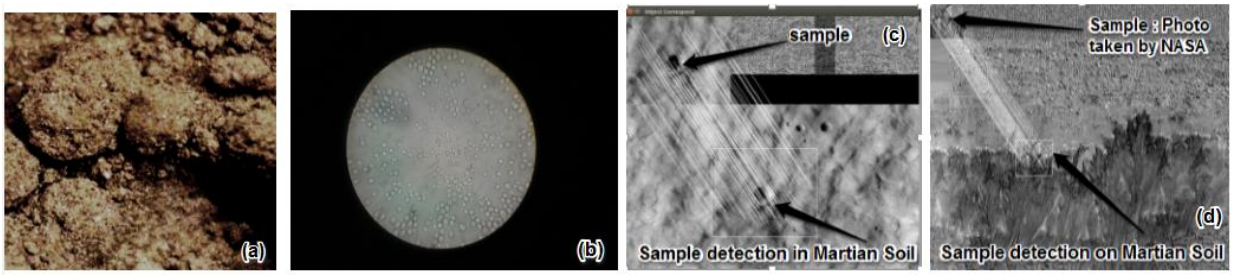


Fig. 5 (a-b) Soil Characteristics using USB and Optical Microscope (c-d) Water detection

Moreover, ALTA II Reflectance is used to characterize the soil sample where the reflectance is measured according to the various soil sites in order to find the potential biological scope. We have also used Microbial Detection Array (MDA) which can identify a broad range of organism. It can also identify any sequenced virus and bacteria.

Water Detection: For detecting any water or moving objects in martian soil we are using opencv libraries on Ubontu 15.01 Operating System installed. Our C++ Script using opencv libraries can detect any moving objects from camera feedback in realtime. If our system find any sample such as water drop indicator or image similar to photo taken by NASA (Photo Courtesy: NASA/JPL-Caltech/Univ. of Arizona), it will detect those samples by which we can understand the presence of any water surface in martian soil (Fig. 5 (c-d)).