SYSTEM ACCEPTANCE REVIEW

Team A. R. E. S.

Autonomous

Rover

Embedded

Systems

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We, Team Ares, an undergraduate multi-disciplinary student team of space aficionados from Delhi University's Netaji Subhas Institute of Technology (NSIT) are working to formulate, design and fabricate a self-driving autonomous rover that can be put to use in early exploration of Mars.

The guiding philosophy of A.R.E.S. rover hinges on **simplicity**, **efficiency, robustness, cost-effective, in-house** as the cornerstones of the designing, manufacturing and testing processes. The relentless focus on not compromising the capabilities, precision and adaptability while keeping the financial and energy costs low has allowed us to deliver a very high value system with advanced capabilities in a plethora of unchartered environments.

Our aim from the beginning was not just to participate in our first ever URC competition but also to do as well as we could within our constraints.

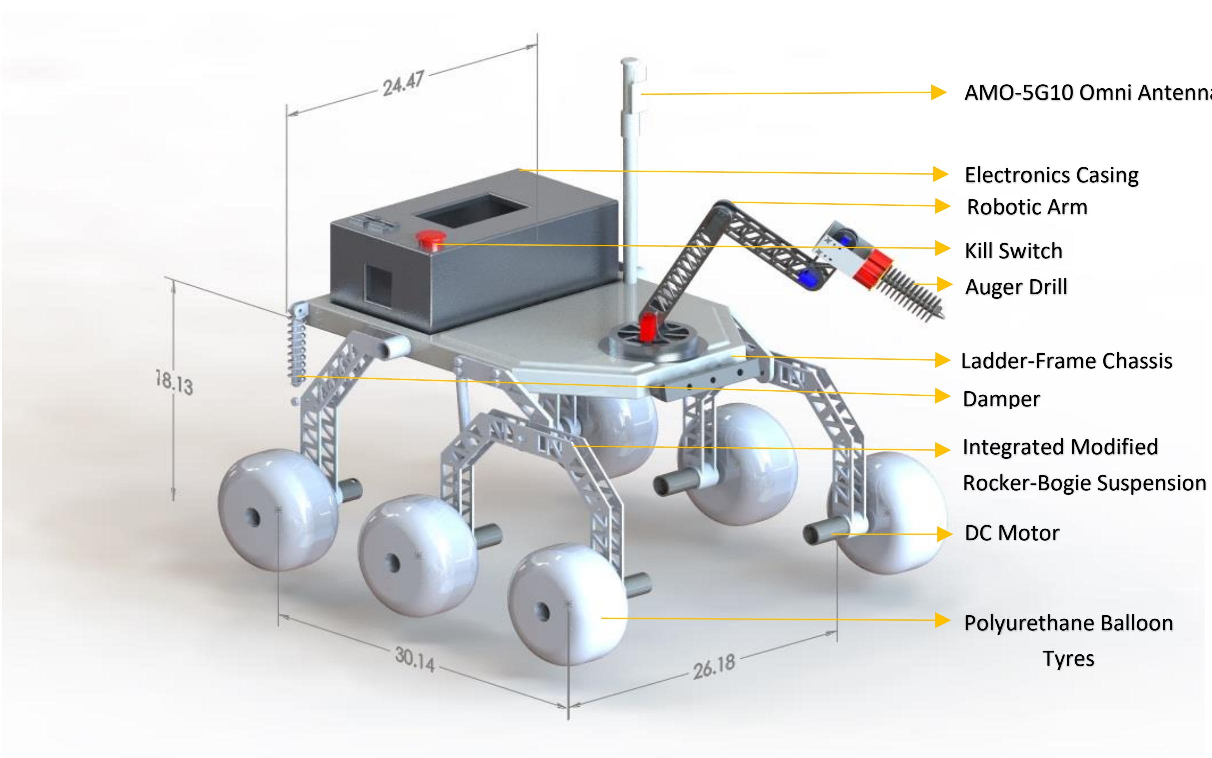
The above has been achieved by ingeniously integrating existing low-cost technologies in a custom model tailored specifically to the needs of the competition. The ideation and design phase consisted of extensive prototype testing with several iterations to optimize the rover for all of the tasks and capabilities.

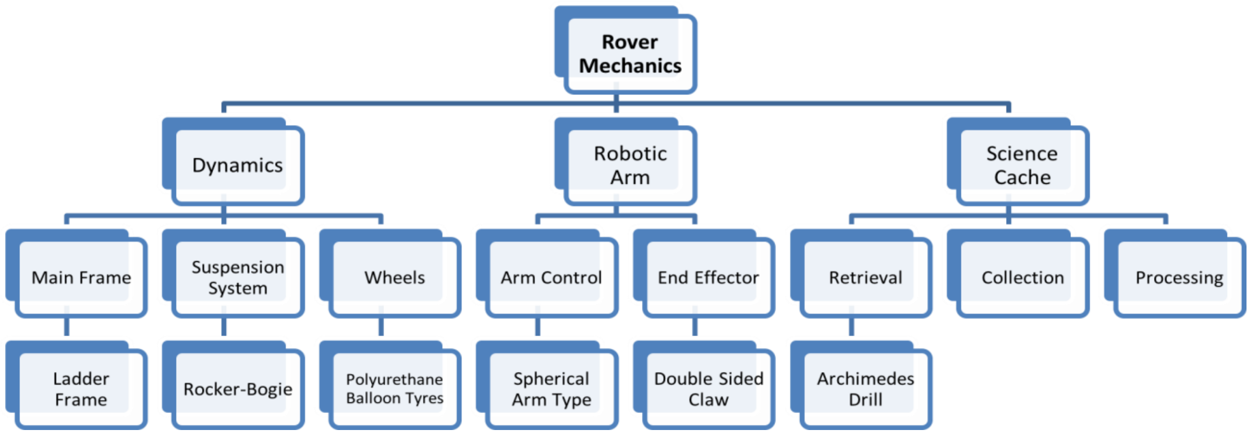
CORE ROVER SYSTEMS

While a brief overview of the rover subsystems and their technical details have been provided in this section as well as the context, unique factors and justification have also been specified.

The **Rover Mechanics** team had an acute focus on developing a robust layout incorporating elements like a *ladder-frame* **chassis** with optimal *stiffness to weight ratio*, Integrated and Modified Rocker-Bogie **suspension** mechanism and Six *low pressure* Polyurethane **balloon tyres**, driven by motors selected after multiple calculations of the rover's total tractive effort (**TTE**).

The *articulated spatial* **Robotic Arm** designed has jointed spherical arm type geometry with 6 *degrees of freedom*. To reach every point in the work volume, *inverse kinematic analysis* was done to position the arm. *Stepper motors* were used for the movement of robotic arm due to their high reliability, accuracy and excellent response for start, stop and reverse. The arm is capable of lifting over a payload of **5kgs** and distributes this force to the chassis mainframe.





APPROACH TO COMPETITION TASKS

The various modules of the rover have been designed after careful consideration to each and every task listed as well as to allow flexibility and advanced capability for real-time adaptation.

While all the rover components synchronize together to achieve a particular task, some critical elements of high-sensitivity have been identified as being crucial to each task and their advantageous aspects have been elaborated further.

EXTREME RETREIVAL AND DELIVERY

The main challenges identified were the uneven terrain traversal, positioning and package retrieval.

Main Frame: *Ladder-frame chassis* with optimal ground clearance was designed. This reduced the chance of becoming high-centered on obstacles, and insuring all six wheels stay on the ground, greatly improving all-terrain performance. A separate closed mounting for the power system was designed ensuring utmost safety and at the same time ensuring its easy accessibility. *Aluminum 6061* square tubes were used keeping the rover lightweight and providing sufficient strength.

Suspension System: *Rocker-Bogie suspension* mechanism is used providing the rover with great stability on rough terrain and with an ability to go over obstacles twice the diameter of the wheel without compromising the stability of the rover as a whole. The mechanism is designed such that due to the independent motion of right and left rockers, the pitching of the chassis or the rover body remains an average of the two rockers. An integrated *bar mechanism* is designed connecting the two rockers to keep the body in level. The front and back wheels have independent motors for steering, enabling the rover to turn on the spot without skidding.

Wheels: Six *low pressure polyurethane wheels* were used to distribute the weight over a large area, making it easier to drive and also improving the skid-steer performance. Each wheel is provided with its own motor out of which four wheels are provided with separate motors for steering, giving the rover independent four-wheel drive, and "cleats" that provide grip and help keep the rover from slipping when climbing over rocks or sand hills. Each motor is provided with fixed, very high gear ratio for low speed and very high torque.

To choose motors capable of producing enough torque to propel the rotor, the **total tractive effort** (**TTE**) for the rover was found as follows:

TTE = RR + GR + FA

RR = force necessary to overcome rolling resistance

GR = force required to climb a grade

FA = force required to accelerate to final velocity

EQUIPMENT SERVICING TASK

The key challenge was the development of a multi-purpose robotic arm that could perform a range of versatile tasks, expected in Mars-like conditions, namely precision coordinate mapping with extensive gripper capabilities.

Robotic Arm: To summarize in a nutshell, the Robotic Arm has 6 *degrees of freedom* and to reach the required coordinate, inverse kinematic analysis was done to position the arm. *Gazebo ROS* is used to simulate the arm. A 2-claw gripper actuated by servo-motor has been used for adequate gripping.

Further, 2 degrees of freedom have been dedicated to the gripper for precise translational and rotational orientation. The major advantage of using this system was that it requires less alignment with objects, provides uniform gripping pressure to the object. Also, the claws are of aluminum and very rugged connectors.

For the motion manipulation of the arm, pre-fabricated actuators have been installed letting us cover maximum possible work volume.

Structural pins are added to relieve bending moments and torsion loads are applied to the connector from the end effectors, thus increasing the strength capacity of the wrist.

DHWANI-COMMUNICATION MODULE

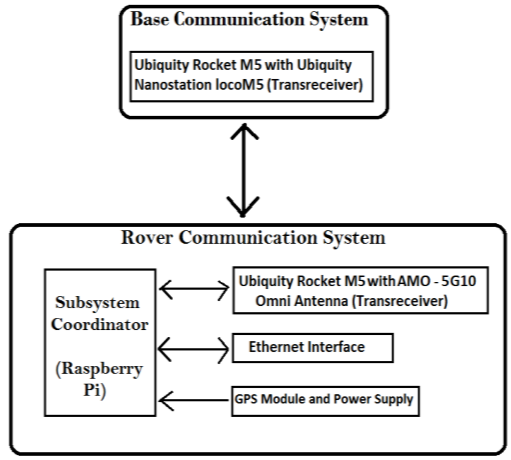
Our ***Dhwani*** *(translates to a medium of communication in Hindi)* is the **custom communication system** developed for the A.R.E.S. rover consisting of trans-receivers both at the base station and the rover for control data transmission and video transmission. All trans-receivers are required to deploy an *interference resistance protocol* with quick encoding and decoding to facilitate eminent and real time communication. The **Ubiquity** Network system provided the foundation for Dhwan*i.*

Antennas and Transmitting Protocol: - We have used the Ubiquity Nano station locoM5 (13dBi gain) with Ubiquity Rockets M5 and airMAX Omni (AMO) -5G10 Omni Antenna for data transmission, controls and video transmission. Further, we have used the Nano station M5 (with Ubiquity Rocket M5) at the base station because of its directional properties and AMO-5G10 Omni Antenna (with Ubiquity Rocket M5) on the Rover because of its omnidirectional Properties.

The above choices have enabled: -

- High transmission Speed which is very helpful for video transmission
- Very good range
- Lesser Weight and Dimensions

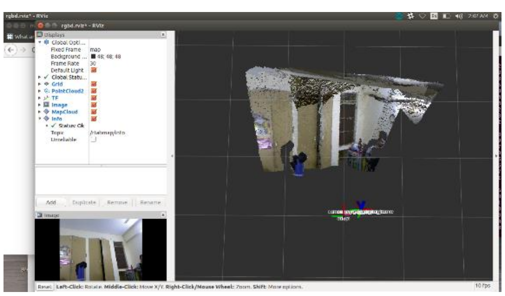
We will use an extra antenna to receive GPS coordinates and is connected to the GPS Receiver. These antennas provide a good balance of gain and off-axis tolerant radiation patterns useful on a mobile Rover moving over rough-terrain.



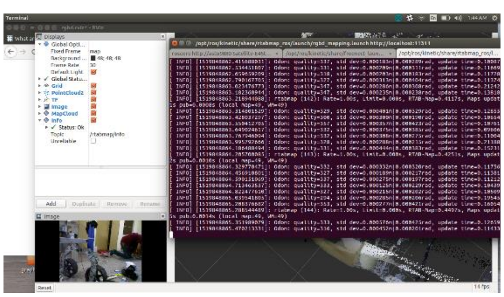
AUTONOMOUS TRAVERSAL TASK

Key challenges identified were real time mapping of the arena, object detection, obstacle avoidance and path planning.

Robot Operating System (ROS):- ROS framework has been used in the rover. We have used this framework because of its robust use case and the wide availability of community-built packages. In comparison to other server client frameworks, ROS empowered us to code the control system in an abstract manner and therefore provided the integration of the electronic subsystem with the software subsystem with little margin of error. The Raspberry Pi camera and Kinect depth sensor act as nodes and publish the data, whose visualization has been done on Rviz in ROS. Using these sensor feeds ROS implements Simultaneous Localization and Mapping(SLAM) for navigating through the terrain using G-mapping library. We simulated our algorithms using the rover prototype. This helped us visualize the problems faced during the environment mapping, the bad sensor data being one of them, which we solved by using better sensor data and cleaned it before providing it to the raspberry pi. The Kinect sensor has been employed because it provided us the most cost-efficient solution for the task at hand. **Raspberry PI**: – A Raspberry Pi board was used to take the real time feed from the Raspberry Pi camera. It contains the ROS software with its packages used for the autonomous traversal task and provided us with required computational power for the processing real time images. **OpenCV**: – OpenCV library with Python has been used for image processing and object identification. Tennis ball identification has been done using Hough Transform for contour detection of the ball. The ball is continuously tracked by the rover using the on-board camera. We have improved the existing state of art algorithms by testing it thoroughly by using the appropriate threshold values to detect the tennis balls accurately. We therefore are confident our algorithms will perform optimally for the autonomous traversal task. **GPS Module**: - GPS Module is required to work on an 84 datum with sufficient accuracy. We have used UBLOX-NEO 6M GPS Module which gives 66 channels of accuracy, sensitivity and speed with ease in machining.

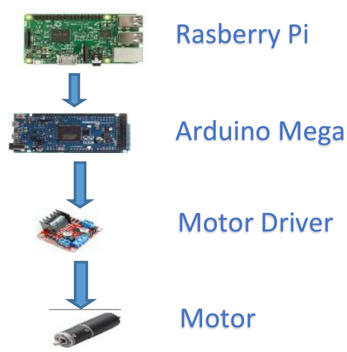


3D Mapping through Kinect Freenect Package



ROVER PROPULSION

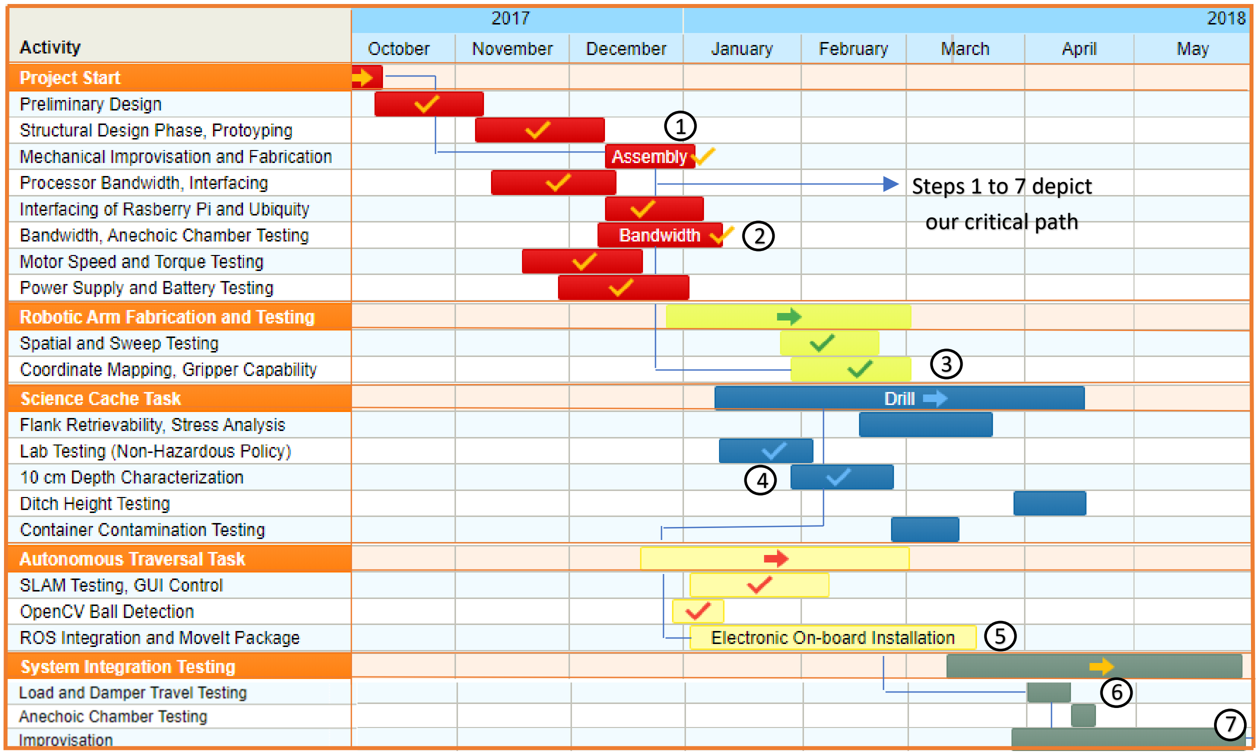
We are using 6 DC carbon brush motors, one for each wheel. They are chosen to provide a right balance of torque and speed having sufficient gear reduction ratio. To drive the motors, we are using modular motor drivers, which will be easily interchangeable, in case of any failure. The drivers use the aluminum chassis as their heat sink, making them more efficient and consuming lesser space. They will be directly powered by 24 V LiPo Batteries which will power all subsystems. They will be controlled by Arduino Mega, which will further receive commands from the on-board computers responsible for communication with base station, acquiring GPS coordinates and image processing.



TESTING AND OPERATIONS

In Unit and Integration Testing, Finite Element Analysis for design optimization, torque calculations for motor rating requirements, control arm stress analysis for future reverse engineering, coordinate mapping for orientation precision, bump-droop considerations, drill depth and contamination testing for ensuring soil is collected below 10 cm safely, bandwidth testing and lab tests for detection of elemental and microbial life have been done. SLAM Testing for path planning has been partially implemented. Chamber Testing and Role Stiffness for stability check are yet to be done. These tests have been performed for ensuring reliability, better material usage, standards consideration and requirements compliances.

TIMELINE



FINANCE

Funding Raised	
Crompton Greaves	$ 1533
Ketto Online Fundraiser	$ 250
Total	$ 1783

Our college has agreed to fund 50% of our travel.

Anticipatory Expenses- $ 1540

Balloon Tyres, Gauges, LIDAR, Shocks, Beaglebone Blue, Jtag Debugger, Bearings, Spectrometer(Prototyping

Expenses so far		
Communication	Ubiquity Module	$ 400
Science	3 D printed Metallic Drill	Sponsored
	Lab Tests and Instruments	$ 300
Mechanical	Robotic Arm Fabrication	$ 80
	Suspension and Chassis Fabrication	$ 80
Software	Kinect Sensor	Sponsored
	On-board Camera	$ 20
Power	24 V Lipo Battery	$ 300
	Motor, Drivers, Actuators	Sponsored
Total		$ 1190

NAKSHATRA SOLIDWORKS Galaxy Laser Works
Kohli Metal Works
Crompton Greaves PROTOCASE Custom Electronic Enclosures For Engineers & Designers Make in 3D igus MORPHEDO NSIT MOTORSPORTS Bageera AKAR BULLETPROOF RACING

https://www.ketto.org/fundraiser/teamaresnsit

BHOOMI
ARES SCIENCE PLAN

Bioassay - Search for BioMarkers

Reagents

Reagent 1: 48 ml of 2% Na_2CO_3 in 0.1 NaOH,
1 ml of 1% NaK Tartrate in H_2O,
1 ml of 0.5% $CuSO_4.4H_2O$ in H_2O.
Reagent 2: 1 Part water: 1 Part Folin-Ciocalteu [2N]

Procedure for Lowry's Test

0.2 ml of the soil sample after step 1 was made up to 1ml using distilled water. 4.5 ml of Reagent I was added and incubated for 10 minutes. 0.5 ml of reagent II was then added to it and incubated for 30 minutes. Amount of protein was estimated from the standard graph of absorbance at 660 nm.

Why?

- Highly sensitive and detects as low as 1 microgram of protein.
- High accuracy and precision
- Proteins and Nucleic Acids are building Blocks of Earth life

Folin-Ciocalteu Reagent

Step 1- Filtering Soil

Soil was put into Molecular Biology Grade Water and debris was filtered out. SDS and NaOH were added to lyse the cell and contents were spilled out. Mixture was then treated with Phenol-Chloroform (equal volumes of both) and finally spun.

It was treated with EtBr and observed under UV. It gave bright orange color confirming the presence of nucleic acids.

Presence of proteins and nucleic acids in Martian soil and in Utah

Sample from Cache

Site Selection via On-board Camera

Presence of Rills due to erosive action of flowing water can suggest evidence of life

Image Stitching

Scaling-Scale Bar, Compass Graphic, Dynamic Text

On-board Camera

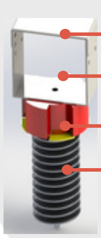
1. Create a file on Kolor Autopano
2. Comparing control points with high Error distances
3. Searching for vertical lines and straightening
4. Photometric Optimization
5. Saving to Tiff.

- Canny Edge detection algorithm (Research on Utah cliffs shows evidence that edge detection will be sufficient)
- Fast Fourier Transform of the image imported as signal

Documentation ← **Stratigraphic Profiling**

Drill Mechanism

The bracket holding the driver motor controls the auger downward motion. Servo-controlled mechanism is used for storing the soil in a cache. Container has a rotating bottom initially open. When the soil below 10 cm arrives, servo rotates the bottom, thus closing the container and collection of soil begins. Cache has slots cut for collection having an air-tight character which will be closed once required amount of soil is collected actuated by the same servo. Container will have a 4 in 1 soil meter due to fast and precise measurements.



Bracket
Driver Motor Mounting
Cache
Drill

pH
Temperature
Moisture
Sunlight

An on-board low-cost spectrometer prototype designed by us for soil testing