TECHNO

SYSTEM ACCEPTANCE REVIEW

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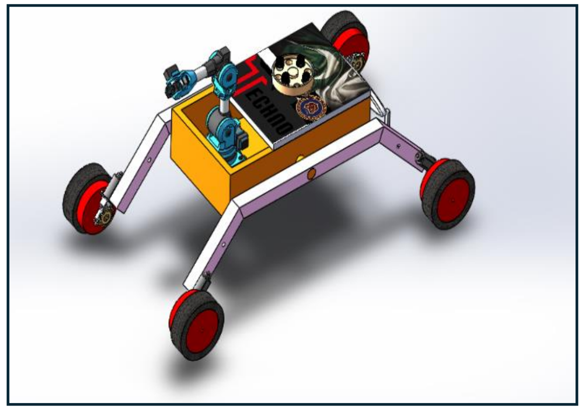
Team Techno is a student-led robotics team from Ghulam Ishaq Khan Institute (GIKI) of Engineering Sciences and Technology. We have successfully developed and constructed a self-driving autonomous rover modified for early exploration missions on Mars. Keeping a balance between simplicity and efficiency, our team diligently crafted the rover design, did fabrication and testing processes with a keen eye on cost-effectiveness. Throughout the development lifecycle, we prioritized maintaining optimal functionality in diverse and challenging environments without compromising performance. Our overarching objective is to enhance our skills and knowledge, a goal realized through our participation in the University Rover Challenge (URC). The conceptualization and design phases involved rigorous prototype testing, incorporating multiple tests to refine the rover's capabilities and adaptability for various tasks.

CORE ROVER SYSTEMS

In this section, the context, special factors, and justification have been included together with a brief synopsis of the rover subsystems and their technical specifications.

Team Techno is using **ROS-2 Humble** on its rover, a version of the Robot Operating System that emphasizes simplicity and efficiency. It helps us connect different hardware pieces like sensors and motors and ensures precise control. Using ROS-2 Humble in our rover enables us to build a flexible and interoperable robotic system, with advanced capabilities for autonomous navigation, environmental sensing, and interaction. With ROS-2 Humble, we aim to achieve reliable and robust performance in our rover's operations while maintaining a humble and practical approach to its software architecture. Considering its capabilities, our rover is equipped to navigate various terrains and execute tasks with precision, all while ensuring stability and resilience in its functionality. Through this setup, we can explore the potential of the rover in a manner that aligns with the core principles of ROS-2 Humble: **simplicity, reliability**, and **effectiveness.**

FIGURE 1: FINAL ROVER DESIGN



Chassis and suspension: The rover's **chassis** is constructed from aluminum rods and steel sheets, featuring a passive kinematic linkage suspension system with rocker arms and a large lever that allows for smooth traversal over rough terrain. Like a rocker-bogie setup, it enhances mobility by navigating obstacles larger than its wheel diameter and maintains ground contact for stability. The wheel system, crucial for mobility, consists of **8-inch diameter** wheels with carbon fiber rims and thermoplastic polyurethane, each powered by its own motor.

Drilling Mechanism: Additionally, the rover is equipped with a drilling mechanism mounted at the base of the chassis, capable of extracting core samples up to **20cm deep** using rotary and linear motion control. A sample handling system, employing pumps, transfers soil samples into sealed chambers to prevent contamination, while chemicals for scientific tests are also transferred using pumps.

Robotic arm: The Robotic Arm is also designed and manufactured with six degree of freedom and 3 joints (shoulder, elbow, and wrist) which is useful to assist the rover for multiple purposes such as to open and close the taps or buttons, carry loads of maximum **5kg** or tools like screwdriver to tighten screws. Each joint operates independently and uses motors to provide the required force to move the arm. With the help of power transmission gears, the motors in the shoulder joint will help with the horizontal and vertical movements, the elbow joint will use one motor to help with folding the arm up or out, two motors in the wrist help with handling of tools and its rotation. These segments provide flexibility and range of motion, allowing the arm to reach different positions and orientations.

Communication-Module: Our communication system, tailored for the GIBRALTAR rover, incorporates trans-receivers at both the base station and rover for efficient control data and video transmission. These trans-receivers employ an interference-resistant protocol with swift encoding and decoding for seamless real-time communication. Leveraging the Ubiquity Network system as its foundation, our setup utilizes 2.4 GHz and 900 MHz bi-directional antennas at the ground station, along with an omni-directional antenna on the rover for data transmission, controls, and video transmission. Additionally, we employ a GPS receiver connected to an extra antenna for receiving GPS coordinates. This configuration ensures high transmission speeds ideal for video transmission, extended range capability, reduced weight, and compact dimensions. The chosen antennas strike a balance between gain and radiation patterns, crucial for a mobile rover navigating rough terrain.

APROACH TO COMPETITION TASKS

We shall be approaching the competition with the confidence that our rover, operating on ROS-2, shall execute the desired outcomes of each mission assigned. Our subsystems include a robust communication module, facilitating seamless data exchange with the base station for effective controls. Through meticulous planning and innovative developments, our rover stands poised to tackle the diverse challenges posed by the competition.

EXTREME RETREIVAL AND DELIVERY

Our rover is equipped with systems which encompass mobility and delivery mechanisms. A robotic arm shall be operative for the delivery challenges, all while the rover autonomously navigates through its desired path.
To explain the working of a rover with four wheels using formulas, we can consider the basic principles of mechanics and dynamics.

Wheel Dynamics: The rover's motion can be described using the equations of motion. The velocity of each wheel is determined by its rotational speed and the radius of the wheel. The general formula for linear velocity is:
$V = \omega \times r$
Where, ω is the angular velocity of the wheel and r is the radius of the wheel.

Traction and Friction: The traction of the wheels on the terrain is determined by the friction between the wheels and the surface. The maximum traction force is:

$F_{max} = \mu \times N$

Where, μ is the coefficient of friction and N is the normal force between the wheel and the ground.

EQUIPMENT SERVICING MISSION

For the URC's Equipment Servicing Mission, we operate the rover using two modes: manual and autonomous. Operators use manual control interfaces like joysticks to manipulate the rover in real time, while autonomous mode follows pre-programmed instructions for tasks such as navigation and equipment servicing. Mission planning is done beforehand to ensure efficient task execution, and teleoperation allows remote control. Our rover shall run on a navigation system that ensures precise maneuverability in dynamic environments. The rover shall pick, hold, and drop the required cache containers and perform all other tasks assigned effectively.

Design of the robotic arm: The primary challenge we tackled was designing a versatile robotic arm capable of executing a wide array of tasks under Mars-like conditions, including precise coordinate mapping and extensive gripping capabilities. Our solution leverages a sophisticated system comprising five motors, strategically incorporating 1 NEMA 34, 2 NEMA 23, and 2 NEMA 17 motors for optimal performance.

Motor selection and control: For the NEMA 17 and 23 motors, we have selected the TB6560 motor driver, renowned for its reliability and precision control. Additionally, the NEMA 34 motor is powered by the DM8601 motor driver, chosen for its robustness and ability to handle heavier loads effectively. Incorporating advanced sensing capabilities, our robotic arm features a high-resolution camera for capturing images essential for various tasks. These images are seamlessly transmitted to the powerful Jetson TX2 supercomputer for real-time analysis and decision-making.

Sensing and decision making: The decision output from the Jetson TX2 is then relayed to the Raspberry Pi microprocessor, serving as the central control unit for mobility management. Leveraging its efficient processing capabilities, the Raspberry Pi orchestrates the movement of the robotic arm with precision and agility. To translate the commands into physical motion, the Raspberry Pi communicates with the microcontroller ESP32, which interfaces with the motor drivers. By harnessing the ESP32's capabilities, we ensure seamless coordination and synchronization of motor movements to accomplish the desired tasks with optimal efficiency and accuracy.

Through this meticulously designed system architecture, our robotic arm stands ready to tackle the challenges of extraterrestrial exploration with unparalleled versatility and reliability.

AUTONOMOUS NAVIGATION TASK

Operational Modes: Our rover finds the best route by combining GPS, mapping sensors, and obstacle detection technology. Using algorithms for localization, path planning, and obstacle avoidance, it optimizes its route through machine learning. This allows our rover to navigate safely and efficiently across diverse terrains, adjusting its trajectory based on real-time sensor data.

Navigation System: Path planning algorithms use this information to determine the best route, while real-time localization ensures the rover's precise positioning. These features work together to provide exceptional navigational precision and maneuverability, even in the most challenging environments.

We plan our rover's path using algorithms that consider terrain, obstacles, and mission goals.

These algorithms use sensor data to map the environment and find the safest route. We may also use machine learning to improve path planning based on past experiences. These algorithms, such as A* (A-star), Dijkstra's, or RRT (Rapidly exploring Random Tree), utilize sensor data from onboard sensors like LiDAR and cameras to map the environment and generate a safe path.

Camera and LIDAR: In the construction and operation of the rover, the initial step involves the utilization of a camera strategically positioned to provide a comprehensive 360-degree view of the surroundings. This camera, complemented by data from a lidar sensor, scrutinizes the terrain for a reliable perception of the environment. The LIDAR device consists of a range measurement sensor that repeatedly emits a pulse of light. After the light hits a target, it is reflected to the sensor which then determines the distance to the object by measuring how long the light needs to meet the target and return. In addition, the range measurement sensor is placed on a rotating platform which enables the device to take readings at multiple points within 360 degrees. As the sensor spins, range measurements are taken quickly (up to about 10000 samples per second), providing a two-dimensional view of the entire robot's surroundings. The result of a 360-degree view sweep along with taking multiple range samples is a raw map. The next step in this process is to take the 360-degree scans and gather them into a more complete map.

SLAM: When the robot moves in its environment, it can determine where it is in relation to the present and previously scanned data (the localization process) and then, performs new scans and adds them to the map. This is where the process' name came from, that is, "Simultaneous Localization and Mapping" (SLAM).

Jetson TX2: The acquired information is then transmitted to a supercomputer (Jetson TX2), which analyses the data and makes informed decisions. Following this judgement, the microprocessor relays the instructions to another dedicated microprocessor responsible for rover mobility control and that is **Raspberry pie (Microprocessor)**: It is the 'brain' of this rover for its versatility, accessibility, simplicity, and ability to add and upgrade modifications. This mobility control microprocessor subsequently communicates with the **ESP32 controller**, initiating the activation of the motor driver. The ESP32, acting as an interface between the higher-level decision-making process and the hardware, triggers the motor driver, which, in turn, manages the individual motors responsible for rotating the rover's tires. This integrated system allows for a seamless flow of data and commands, enabling the rover to navigate and respond to its environment based on the input received from the camera, lidar, and the microprocessors and controllers. All this is powered by **12v battery** which will generate **40 amp current**.

TESTING AND OPERATIONS

To date, we have tested and tried different commands which shall enable the rover to autonomously navigate and perform the desired actions. We are testing algorithms that would best fit our desired outcomes for the competition, although there's a long way to go. ROS 2 is an operating system tricky to manage, but our team is determined enough to tackle all hurdles and ensure a smooth and successful A&RI system of our rover.

FIGURE 2: GANTT CHART

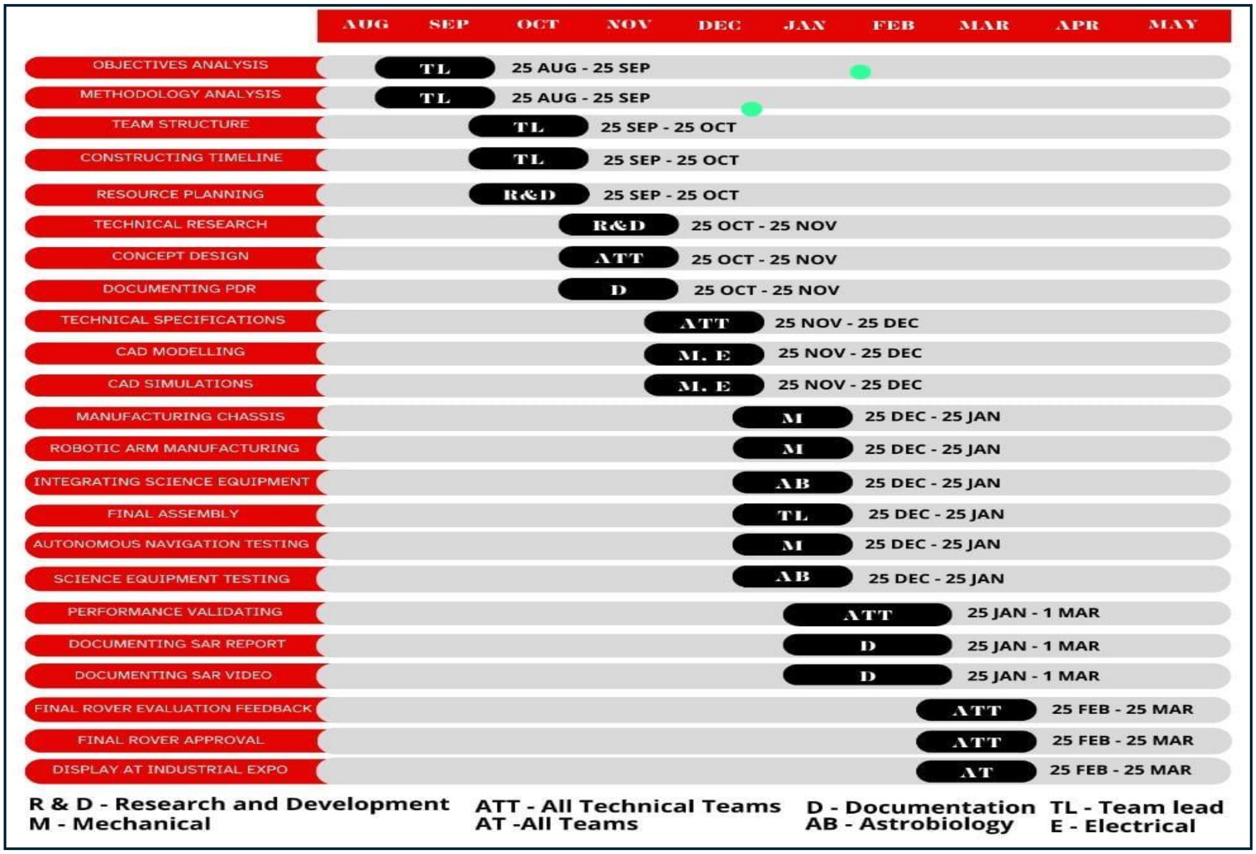


FIGURE 3: BUDGET TABLE

TEAM TECHNO - UNIVERSITY ROVER CHALLENGE
BUDGET SHEET

SUB-TEAM	ITEM NAME	QUANTITY	PART COST	NET COST	TOTAL
Mechanical	Chassis Material	10kg Sheet	$250.0	$250.0	
	Rocker bogie Suspension	1	$500.0	$500.0	
	Wheel	8	$20.0	$160.0	
	Frame	1	$200.0	$200.0	
	Testing equipment	4	$62.5	$250.0	
	1) Load testing				
	2) Material testing				
	3) Torque Force and Vibration testing				
	4) Alignment testing				TOTAL = $1360.00
Electrical	Motors	8	$100.0	$800.0	
	BLDC Controller	8	$52.5	$420.0	
	Actuators	5	$50.0	$250.0	
	Electronic Controller	6	$50.0	$300.0	
	Batteries	2	$1,500.0	$3,000.0	
	Battery Charger	1	$100.0	$100.0	
	Omni-directional antenna	1	$150.0	$150.0	
	Bi-directional antenna	1	$40.0	$40.0	
	Wireless access point	1	$100.0	$100.0	
	EMU	2	$10.0	$20.0	
	External GPS	2	$80.0	$160.0	
	2D Lidar	1	$500.0	$500.0	TOTAL= $5840.00
Autonomy & Robotics Integration	Nvidia TX2 Development Kit	1	$500.0	$500.0	
(A & RI)	ESP 33	6	$10.0	$60.0	TOTAL= $560.00
Astrobiology	Chemicals	3	$50.0	$150.0	
	Temperature Sensors	1	$50.0	$50.0	
	Moisture Sensors	1	$40.0	$40.0	TOTAL= $240.00
Travel Expenses	Air Tickets	5	$1,000.0	$5,000.0	
	Air Freight	1	$3,000.0	$3,000.0	TOTAL = $8000.00
					GRAND TOTAL= $16000

FIGURE 4: SCIENCE PLAN