IRoC-U

ISRO Robotics Challenge - URSC

Let's build a space robot

Proposal

by

Team INSIGHT

10327

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National Institute of Science Education and Research
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*C*ontents

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Introduction

We have always looked forward to developing new ways for planetary exploration, for which developing innovative technologies is important. As students of a national research institute that is focused on pure sciences, engaging in such an engineering and robotics project is a fresh and exciting experience for us which drives us to put our best efforts into it. Expressing our humble gratitude for the opportunity to participate in this competition, we aim to involve ourselves in the development of an autonomous navigating sample pickup and placement rover, hence expanding our scientific pursuits. Through this project, we attempt to compile and create several ideas (comparing with pre existing prototypes) to build an efficient and feasible model for exploration of sandy terrains with compact body design ensuring higher stability and mobility, accompanied with some machine learning algorithms for crater detection, path planning et cetera, looking forward to successful planetary exploration missions.

Prior to this attempt, many rovers have focused on portability and sample collection, but they face limitations in stability, adaptability, and precision. Apart from that, most of them require high energy consumption, which we have tried to minimize. Our rover solves these problems by integrating advanced features and includes simple solutions.

The major challenges one would expect, which we have tried to address, would be stability issues, while moving through the terrain, especially during sample picking and placing. Another issue one might face is while path planning due to various sizes of obstacles which the rover might encounter. Apart from this, it is important to maintain precision while picking up and placing the object and be extremely careful, since the object might be fragile. We have also solved the challenges of communication and emergency response by developing a robust system architecture and system emergency response.

Our rover combines features like LiDAR and stereo vision with a sequential operating strategy, for accurate mapping of the terrain. We have also included high-torque DC motors for improved stability, and an individual camera on the arm to ensure precision while sample picking. Apart from this, radio communication is used for manual control and autonomous commanding has been implemented through the Jetson microcontroller. Through the subsequent sections, we have expatiate the aforementioned concerns and through suitable testing and validation, have discussed rigorous evaluation procedures.

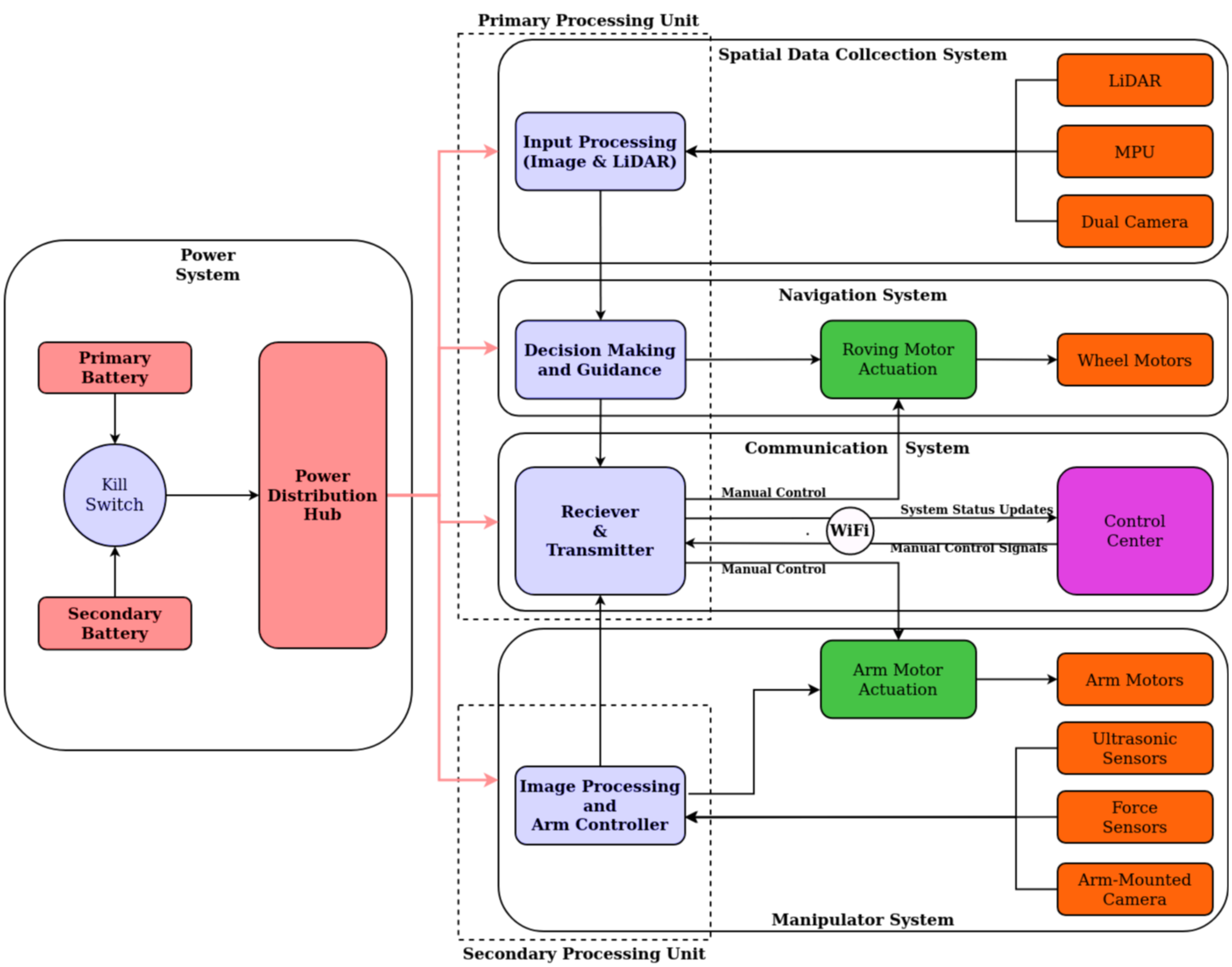
System Architecture

Our rover divides processing between two complementary computers. The high-performance primary computer tackles:

- Spatial terrain mapping from stereo-vision and LiDAR sensors
- Path planning algorithms leveraging 3D environmental models
- Navigation computations fusing odometry and pose estimations
- Independent wheel drive control handling rover mobility

Meanwhile, a secondary computer solely dedicates its capabilities to:

- Reading manipulator arm-mounted stereo camera feeds plus force sensors
- Performing hand-eye coordination for autonomous sample grasping procedures
- Controlling each manipulator joint's servo actuators to enact pick-and-place motions
- Maintaining emergency communication channels as an alternate pathway



This decentralized structure allows for better perception-driven abilities of the main computer to be without interfering with the basic arm manipulation demands requiring consistent real-time operation. Additionally, vital drive and messaging services continue independently should either module experience faults.

The rover system architecture consists of the following key sub-systems and their interactions:

1. **Power System:**
    - Main lithium-ion battery pack (capacity: 22000mAh)
    - Redundant secondary battery pack (capacity: 10000mAh)
    - Power Distribution Hub:
        - Steps down voltage as needed
        - Distributes power across subsystems
        - Individual switch control
        - Health/status monitoring
    - Secondary battery is to be utilized only during emergency scenarios or main power loss and provides only enough power to critical systems (communications, computers, sensors) for necessary usage.
    - The power system also includes a kill switch which, in case of emergency, will shut off the entire power supply from any of the battery packs.
2. **Communication System**:
    - Wifi based communication with Control Center.
    - Communication protocol handling for reliable data transmission.
    - Bidirectional communication with Control Center allows:
        - Transmission of rover sensor data like images, instrument readings and rover position.
        - Receiving commands and updated instructions or programming from the Control Center.
    - Interfaces with Navigation System to receive rover position and orientation data for transmission.
3. **Navigation System**: Contains guidance sensors like gyroscope, accelerometer, wheel odometers.
    - Runs Simultaneous Localization and Mapping (SLAM) algorithms to build a map of the environment and locate the rover on the map.
    - Path planning software plots optimal paths avoiding obstacles.
    - Gets spatial topology data from Spatial Data Collection System.
    - Provides current position, orientation data to Roving Mechanism.
4. **Roving Mechanism**:
    - 6 motorized wheels with individual control on all of them.
    - Rocker Bogie system allows climbing over rocks and holes.
    - Can modulate speed and turn radius by coordinating motor speeds.
    - Receives commands from Navigation System to achieve desired course trajectories.
5. **Image Processing and Arm Controller**:
    - Includes arm mounted navigation cameras.
    - Navigation cameras provide stereo vision data to detect target samples, map terrain.

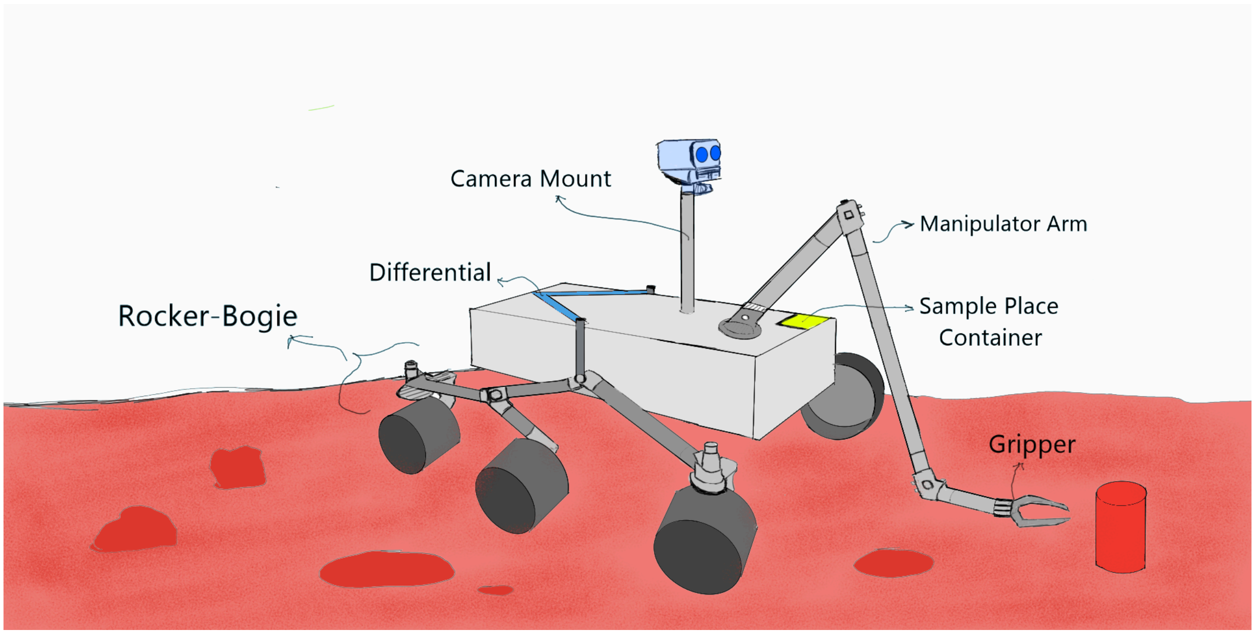
- Analyzes images to identify sample size, shape, and other attributes.
- Uses positioning data from Navigation System to plan arm motions.
- Generates trajectories and servo control signals for Manipulator Arm.
- Runs object pickup coordination algorithms.
- Verifies successful pickup using the arm-mounted cameras and force sensors.
- Keeps samples within a chamber on the rover body.
- Deposits the samples on the required site.

6. **Spatial Data Collection System**:
    - Includes mast-mounted Light Detection and Ranging (LiDAR) assembly.
    - LiDAR scans terrain using pulsed laser light and measures reflection time to map topology.
    - MPU included to provide spatial orientation information.
    - Has an additional wide-baseline stereo camera pair.
    - Stereo cameras produce topological maps with color and texture details.
    - LiDAR plus stereo data gives the rover enhanced environmental awareness.
    - When in the resting stage, the arm mounted camera can independently take photographs of the surrounding as a means of image collection.
7. **Manipulator Arm**:
    - 5 degree-of-freedom robotic arm with gripper.
    - Capable of full 3D positioning of grippers.
    - Tactile sensors on the gripper provide pressure feedback for control.
    - Fine positioning capability to move samples from pickup to chamber on the rover body.
    - Stows safely out of the way during rover traversal.

The Communication System, Navigation System, and Roving Mechanism are controlled by the primary processing unit. The Image Processing and Arm Controller and the Manipulator Arm are controlled by a separate secondary processing unit.

Roving Mechanism

The rover's roving mechanism is designed for optimal performance in challenging terrains. At its core is the innovative rocker-bogie differential system seamlessly integrated with individual steering motors, providing unparalleled maneuverability and adaptability.



Sketch for reference

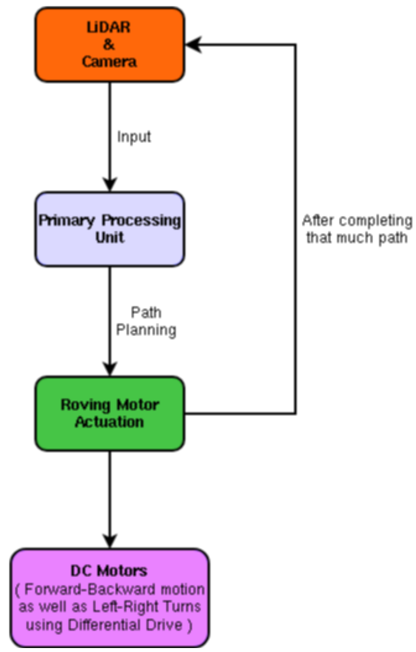
1. **Six-Wheel Rocker Bogie – Differential Configuration:** The rover adopts a *six-wheel rocker bogie* design, distributing the rover's equal weight across all wheels and enhancing stability. The rocker bogie mechanism allows each wheel to adapt independently to the uneven sandy terrain, minimizing the risk of getting stuck and ensuring continuous contact with the ground. Moreover, this model can go over obstacles upto 20 cm in height and is suitable for climbing through sufficiently inclined surfaces.

   The robust and reliable rocker-bogie differential mechanism is central to the rover's mobility. The rockers are intelligently connected with a differential that rotates them in opposite directions, ensuring stable traversal on uneven and shifting terrains.

2. **High Torque DC Motor Propulsion for All Six Wheels:** Propulsion is achieved through high-torque DC motors powering all six wheels. This configuration ensures reliable and efficient movement across sandy terrains, where the ability to traverse soft and shifting sands is crucial for mission success. The high torque provided by these motors contributes to the rover's stability during movement since it prevents rolling of the wheels when not intended.

3. **LiDAR and Stereo Vision for Mapping, Depth Tracking, and Path Planning with Sequential Movement Strategy:** Integrated with LiDAR for mapping the area, tracking depth by dual camera stereo vision, and facilitating path planning, the rover employs a sequential operational strategy. During the path planning phase, the rover activates its LiDAR and stereo vision systems to comprehensively scan and map the terrain. This allows the rover to identify potential paths by analyzing the topography, obstacles, and variations in the landscape. Note that *incase*, the LiDAR is affected by daylight conditions, the stereo vision based path planning is sufficient for proper execution of movement.

   In this phase, the rover temporarily halts its movement, allowing for a detailed analysis of the mapped data. The onboard computer strategically evaluates the identified paths and selects the most optimal route for the upcoming movement phase.



4. **Sequential Movement Execution and Movement Cycle:** Following the path analysis, the rover enters a sequential movement phase, where it propels itself along the predetermined path for a specified distance. After reaching the set distance, the rover pauses, repeating the sequential cycle. This iterative method ensures balanced autonomy, control, and optimizes energy consumption. The differential steering system ensures precise navigation, while the high-torque DC motor propulsion system drives the rover forward through the sandy terrain.

Justification of proposed roving mechanism :

The comparison between the rocker-bogie 6-wheeled mechanism and legged mechanisms in rovers reveals distinct advantages favoring the former. The rocker-bogie system demonstrates lower energy consumption, thanks to the simplicity of wheel-based locomotion, contributing to extended mission durations. Additionally, the rocker-bogie mechanism entails less algorithmic complexity, as its straightforward mechanics reduce the need for intricate control algorithms. The design simplicity of the rocker-bogie system, with fewer moving parts, enhances reliability and ease of maintenance.

This design has this remarkable ability to scale obstacles up to twice the wheel's diameter while still keeping all six wheels on the ground. This allows duly-equipped rovers to effortlessly handle considerable boulders or fissures on rough terrain, while reducing the chances of getting stuck or losing traction. When approaching a vertical obstacle, forward progress is slow, but a rocker-bogie rover can steadily work its way over these obstacles in a way altogether unfamiliar to other vehicle designs. The use of high-torque DC motors provides an extra edge to the rover's stability during movement, reducing the risk of wheel slippage and enhancing overall performance in sandy terrains.

Advantages of Sequential Operation :

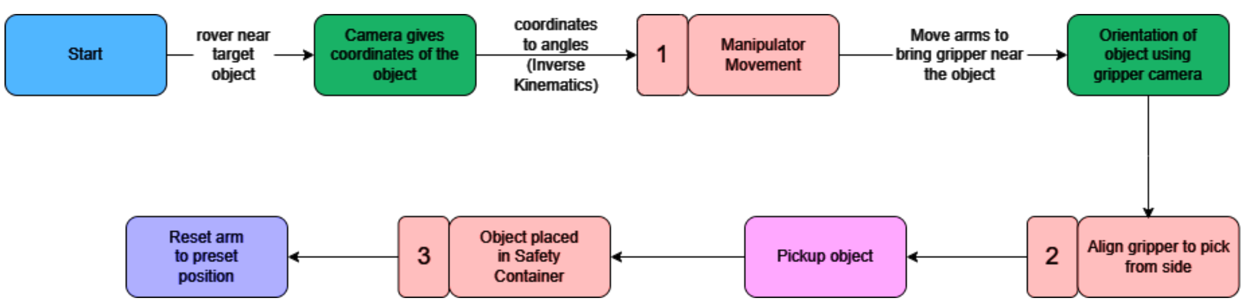
The intermittent halts contribute to energy conservation, optimizing the use of resources during extended missions and enhancing mission longevity. Regular pauses in the operational sequence allow the rover to adapt to real-time changes in the environment, facilitating the selection of optimal paths based on the most current terrain data, particularly crucial when conducting scientific experiments or manipulating the environment using the manipulator arm.

Reason for not choosing legged mechanism:

In contrast, legged mechanisms necessitates large, rugged actuated joints intermittently loaded to ground contact uncertainties often requiring elaborate gait recovery adaptations unproven on alien surfaces and prone to high-impact limb damage with sophisticated control algorithms that pose challenges in terms of energy efficiency and maintenance, making the rocker-bogie mechanism a more practical and efficient choice.

Mechanism for Sample Pick-and-Place Activity

After the rover reaches the target object, the camera gives precise coordinates of the object with respect to the manipulator base. The coordinates are then converted into angles for each of the manipulator arms by inverse kinematics.



1. **Manipulator:**
   - Manipulator based on modified anthropomorphic geometry **(fig.a).**
   - Three revolute joints (Shoulder, Elbow, Wrist) controlled by motors M2, M3, and M4. Motor M1 rotates the entire arm, and M5 rotates the gripper.
   - Motors adjust angles through inverse kinematics, aligning Arm-3 horizontally.
   - Advantages of *Anthropomorphic Geometry:*
     - ➔ Mimics human-like movements, proving dexterous for diverse tasks.
     - ➔ Superior adaptability compared to Cartesian, Cylindrical, Spherical, and SCARA(Selective Compliance Assembly Robot Arm) designs.
     - ➔ Provides flexibility and intuitive control.

Further, Arm-2 is extended to balance torque. This ensures stability when Arm-3 and gripper weight interfere with M3 rotation.

A camera mounted on the gripper mechanism then tells the exact orientation of the target object, and motor M5 aligns the gripper so that it picks up the object exactly from its side.

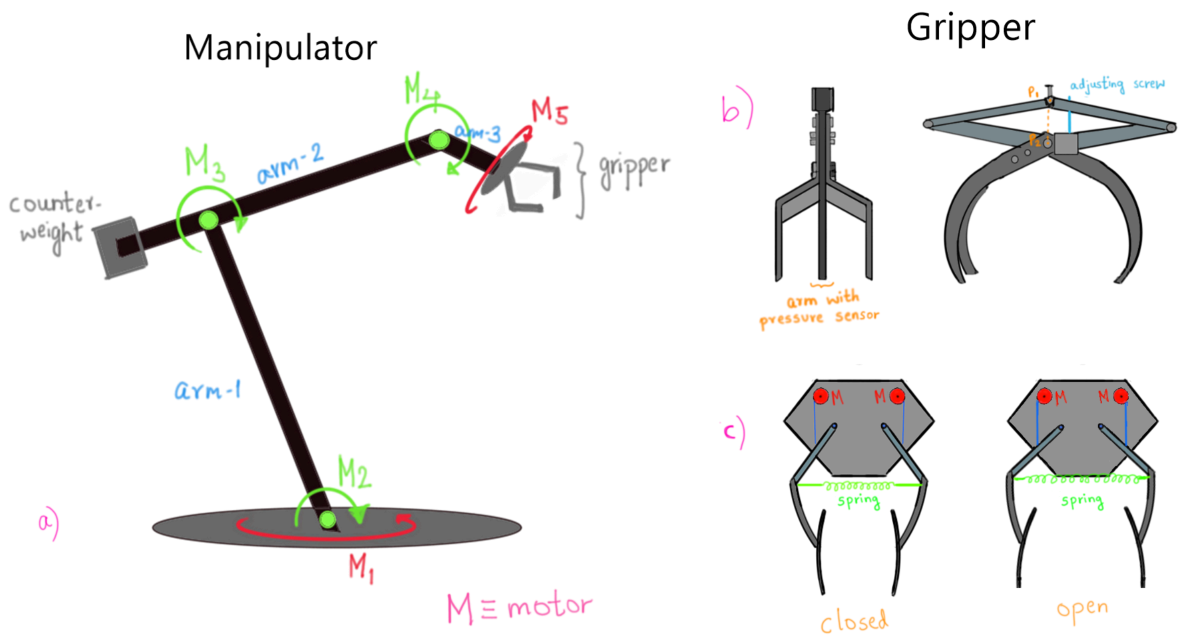
2. **A. Scissor Mechanism Gripper:**
    - Utilizes a scissor mechanism with a rotating screw controlled by motor M6.
    - Features 2 claw hands, each with 3 claw-fingers.
    - Rotation of the screw adjusts the distance between points P1 and P2, facilitating claw opening and closing **(fig.b)**.
    - Pressure sensors on middle claw-fingers provide grip feedback.
    - Remaining claw-fingers equipped with foam padding to prevent damage.

    B. **Alternate Spring-Loaded Gripper:**
    - Two-claw spring-loaded gripper **(fig.c)** with motor-controlled strings.
    - Offers fail-safe grip, but challenges include spring wear and complexity.

The object is then placed carefully in a safety container on the rover using a similar inverse-kinematics-arm-rotation technique. The arm then returns to its pre-set position

3. **Dedicated Container for Sample Protection:**
    - Container crafted for optimal protection.
    - Structural integrity material for the enclosure.
    - Padding and cushioning materials safeguard the sample from vibrations and impacts.
    - Anti-vibration mounts absorb shocks.

When the rover reaches the object placement site, the same process is repeated. The camera gives exact placement coordinates, which are converted into angles. The object is picked up from its safety box, and the arms rotate to bring the object near the placement site. The camera on the gripper mechanism ensures the object is oriented correctly and the object is placed. The arms return to their pre-set position.



Emergency Response System

Identification of Potential Emergency Situations and Proposed Solution:

The emergency response system for the rover encompasses several potential emergency situations and their corresponding solutions:

1. **Communication Failure**: In the event of a loss of communication with the control center, the rover's autonomous algorithm will initiate after a certain duration and assess its surroundings using image processing. Simultaneously, it will continuously attempt to re-establish communication with the control center. Also, since the rover will have two processing units, communication in general will be done from the Primary processing unit, in case of emergency, the secondary processing unit in itself is also capable of communication with the control center.

2. **Computer Failure**: The rover will be equipped with two computers, a Primary processing unit for navigation control and a Secondary processing unit for sample pick-and-place control. If one computer fails, the other will take over the control of the entire system and send a signal to the control center.

3. **Failure in synchronization between the computer and other components**: If a computer is unable to access or control connected components, it will signal the other computer and the control center. The other computer will attempt to take over control, or if necessary, the system will be shifted to manual mode controlled from the control center.

4. **Mechanical Failure**:
    a. If a component failure affects the sample pick-and-place activity, the rover will notify the control center and return to its default position.
    b. If a component failure affects the rover's navigation, the rover will notify the control center and provide sensor data.

5. **Power Failure**: In the event of a power source depletion, the rover will conserve power by deactivating non-essential components, such as using only one computer instead of two.

Additional Emergency Response Mechanisms:

1. **External Kill Switch:** A clearly visible and easily accessible kill switch will be incorporated on the exterior of the rover chassis. This allows immediately shutting down all electromechanical systems in case of any identified threat where continuing operation could be unsafe or detrimental. The kill switch cuts power distribution from the Power System to all connected loads.

2. **Manual Control Mode:** As part of the Communication System, provision for manual tele-operation by the Control Center will allow direct joystick-based driving control and manipulator arm control. This allows the ground team to take direct control of any rover motion in the event the autonomous systems are perceived to malfunction or behave unexpectedly. Uplinked commands override the onboard Navigation System to give full ground oversight if needed.

3. **Auxiliary Battery:** In addition to the main battery pack powering rover systems, a smaller supplementary battery will be dedicated solely to emergency scenarios. This auxiliary lithium-ion battery has enough capacity to power critical communication, control, and navigation functions for at least one hour. It is normally in disconnected state to avoid idle drain.

    If the main battery voltage drops below a minimum threshold, indicating failure to maintain the rover's power draw, automatic switching will engage the auxiliary battery. This ensures the rover can continue transmitting emergency signals, maintain basic orientation control, inform ground control of the power failure, and hopefully receive instructions to reach sunlight and recharge capability.

4. **Implementation of Error Codes:** Unique error codes will be defined for different malfunctions across subsystems. For example:
    - E01 - Rear Starboard Motor Current Overload
    - E02 - Battery 1 Undervoltage
    - E03 - Navigation Camera 3 Signal Lost

    Software exceptions will include capture of the relevant error code which gets communicated to ground. Operators can quickly identify the type of failure from received codes rather than just having generic alerts.

5. **Rover Status Updates:** As part of nominal operations, the rover will periodically transmit status packets to the control center which includes:
    - Current location coordinates based on Navigation System positioning
    - Images from navigation cameras showing surroundings
    - Readings from various sensors like motor currents, battery voltage, internal temperatures, etc.

    This regular status data provides ground control greater situational awareness to detect anomalies early. If certain out-of-bounds sensor readings occur, or the images show the rover stuck or damaged, the ground team can proactively invoke emergency protocols rather than waiting for an onboard system failure to trigger alerts. The continuous stream of location updates also aids in rescue efforts if needed.

    In any handled or unhandled anomaly scenario, in addition to the specific error code, the Communication System will transmit emergency priority signals to the Control Center. These SOS signals allow urgent indications to break through other nominal monitoring telemetry the ground team receives. The alerts cue operators to immediately shift focus and resources to the rover emergency and deploy appropriate response procedures.

Further Explanations:

The hybrid approach combining autonomous capability with manual control and kill switch authority provides multiple options for mitigating emergency situations safely. The Response System as a whole focuses on providing redundancy, graded responses, and backup plans tailored to the specific subsystems on our rover. Continual communication with the Control Center ensures there are two informed perspectives - onboard and ground - that can coordinate decisions about when to invoke emergency protocols. We believe this maximizes the resilience of rover operations under fault scenarios.

Hardware Identification

We are first broadly classifying our hardware requirements as per the Architecture and Mechanism provided above.

No.	Hardware	Categories	Quantity	Estimated Cost (₹)	Justification
Power System (Including Distribution Hub)					
1	Primary DC Battery	• 22.2V (20000mAh)	1	30000	Main supply
2	Secondary	• 22.2V	1	18000	Backup supply

	DC Battery	(10000mAh)			
3	Buck Converters	• 24V to 12V 10A • 12Vto 5V 5A	2 + 2	250	To step down high voltage to required ratings
4	Kill Switch	• Mushroom Button	1	150	Emergency circuit disconnector
5	Relay Module	• 24V - 5V Trigger	1	40	Switching of battery
Processing Units (Including Communication)					
6	Primary Processor	• Single Board Computer	1	40000	Heavy computational needs in Image processing, Path planning, Motor actuation etc.
7	Primary Microcontroller	• Arduino Mega	1	1300	Interfacing Sensors and Motor drivers.
8	Secondary Processor	• Single Board Computer	1	8000	Computational needs in Image processing, Arm maneuver etc.
9	Secondary Microcontroller	• Arduino Mega	1	1300	Interfacing Sensors and Motor drivers.
10	Storage Unit	• Micro SD Card	2	750	Storage for on board computers
11	Transmission Module	• Wifi - RF	1	1400	RF communication with Control Centre
Data Collection (Sensors)					
12	LiDAR Module	• Line of sight	1	3000	For accurate measurement of

					obstacle in line
13	Accelerometer-Gyroscope Module	• MPU	1	120	For obtaining the current orientation of rover in (rugged) terrain
14	Camera	• HQ Webcam	3	6000	For object detection, distance measurement
15	Force Sensor	• Pressure based resistor	2	300	Verify hold condition of gripper
16	Ultrasonic Sensor	• Line of sight	1	60	Verify closeness of pickup
Actuators (Motor Drivers and Motors)					
17	DC Motors	• 12V High torque • 12V BO motor	6+1	10500	To actuate the wheels and end effector of the arm
18	Stepper Motor	• High torque • Low torque	1+1	1500	For precise control of arm shoulder
19	Servo Motor	• High torque	4	20000	For rigid and precise control of arm links
20	Stepper Motor Drivers	• High Amperage	2	220	Driver module for steppers
21	DC Motor Drivers	• High Amperage	7 channels	720	Driver module for DC motors
Chassis					
22	Aluminum Alloy Body	• Extrusion Rods • Sheets	~4 kg	2000	For sturdy and durable body
23	3D Printing	• PLA	1kg+2kg	2400	For intricate and

	Filament	• PTEG			light parts in the chassis.
Miscellaneous					
24	Barrier Blocks	• Singular/ Dual connection points	*As per use*	400	Ease of connectivity and debugging
25	Wires	• Different AUGs	*As per use*	600	Electrical connections
26	Heat Sinks	• Different sizes	*As per use*	100	Heat dissipation in Motor Drivers
27	Electrical components	• Resistors, Capacitors	*As per use*	50	-
28	Fasteners	• Different sizes	*As per use*	200	-
29	Cardboards, Sponge	• Different sizes	*As per use*	20	Cushioning and protection of components
Total Estimated Bill:				₹ 1,49,380	

We have described all the hardware components based on our current understanding and included every concern we could anticipate. This being an amateur attempt might require some changes, hence kindly consider that the above details are subject to change.

Software Identification

1. **Software Requirements**

- **Realized Control Module System:** The primary operating system running on Jetson Nano will run Robot Operating System (ROS Iron Irwini or higher) on Ubuntu (22.0). ROS provides specialized drivers, software libraries and algorithms designed to operate robotic systems.

- **Languages:** Usage of Python for computational tasks. Most of our programming will be pythonic with minor dependencies on C++ as required.

- **Open-source libraries:** OpenCV (on pyTorch) and DETR model library will be used for image processing of camera outputs for the stereo-vision and object detection mechanism. ROS also comes under open source software.

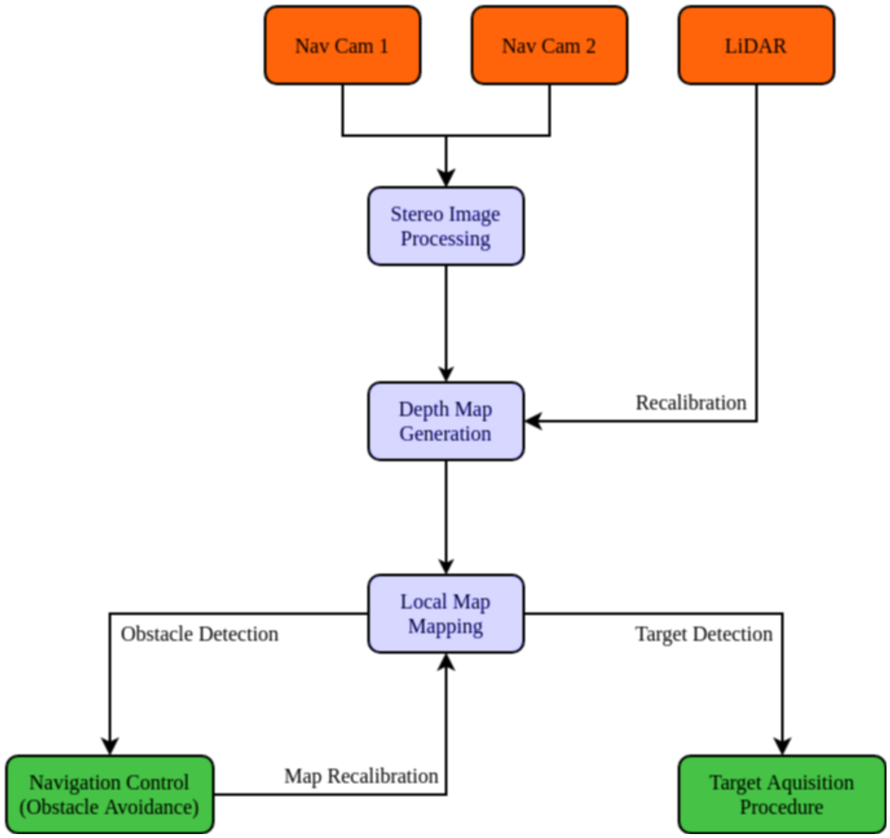
- **Modeling Software:** SolidWorks/Fusion 360 will be used for modeling the components of the rover as well as for simulations to test the properties. Also based on the software availability from our industrial partner, there is a scope of other software based testing softwares.

2. Proposed Algorithms and Computational Techniques

- **Navigation:** The primary operating system, based on the stereo-vision computations, will map out the local environment and implement a Simultaneous Localization and Mapping (SLAM) algorithm. Heuristic path-finding and re-planning on encounter with obstacles will be performed as the rover autonomously navigates the terrain.
  SLAM builds on the A* algorithm which uses heuristic functions to re-plan its path when met with small obstacles. Because of the sequential movement, the error or the deviation from the initial path accumulates over time. To avoid that, we combine both stereo- vision and LiDAR outputs to increase the accuracy. Additionally, re-calibration of the path will be carried out after certain time intervals to minimize error.

- **Image processing:** Stereo vision mechanism will be implemented to create depth maps and find 3D distances using the two cameras connected to Jetson. For this, OpenCV library will be used to create a disparity map from the two sets of images and then use block-matching algorithm to create a depth map. This is now fed into the navigation algorithm to map the environment and subsequently plan movement.
  For object detection, ML models based on Detection Transformers (DETR) on CNNs will be implemented. This helps us to keep a track of the objects in the environment and how they move with respect to the rover using the Attention mechanism. Furthermore, it helps us identify the target object and subsequently move on object pick-up using the robotic arm.

- **Manipulator:** Based on data from the camera and after computing the distance to the target object, inverse kinematics will be used to perform computations to operate the manipulator arm.
  The gripper camera will be used to find the orientation of the object and hence will be used to align the gripper appropriately to pick-up the object and store it safely.



Hardware and Software Realization

We classify the required hardwares along with the procurement source,

No.	Hardware	Hardware Specifications	Quantity	Procurement Source	Required Cost (₹)
1	Primary DC Battery	22.2V LiPo 6S (20000mAh)	1	Market	30000
2	Secondary DC Battery	22.2V Lipo 6S (16000mAh)	1	Available in Lab	0
3	Buck Converters	24Vto 12V 10A 12Vto 5V 5A	2 + 2	Market	250
4	Red	660V	1	Market	150

	Mushroom Cap	10A Elevator latch			
5	Relay Module	24V - 5V Trigger	1	Market	40
6	Nvidia Jetson Orin Nano Developer Kit	1024-core GPU with 32 Tensor Cores, 8GB RAM, USB ports, and 40 pins.	1	Market	40000
7	Arduino Mega 2560 R3	ATmega250 5V logic 72 pins 16 Analog IN 15 PWM	1	Market	1300
8	Raspberry Pi 5	2.4GHz quad-core CPU, VideoCore VII GPU and 8GB RAm	1	Market	8000
9	Secondary Microcontroller	Arduino Mega	1	Market	1300
10	32 GB Micro SD Card	32 GB storage	2	Available in Lab	0
11		2.4 / 5 GHz WiFi RF	1	Market	1400
12	YDLIDAR SDM 15	Point Ranging Upto 15m range	1	Market	3000
13	MPU 6050	3 Axis Accelerometer-Gyroscope	1	Available in Lab	0
14	Logitech HD WebCam C270	3 MP 720 pixels	3	Available in Lab	0

15	Force Sensor	39.1 mm 0.1N actuation	2	Market	300
16	HC-SR04 Ultrasonic Sensor	400cm sensing range 40kHz frequency	1	Available in Lab	0
17	DC Motors	12V 240N-cm 50 RPM DC motor + 12V 110 RPM BO motor	6+1	Available in Lab	0
18	42HS40-1504 NEMA 17 Stepper Motor	4.2 Kg-cm + 6.7 Kg-cm	1+1	Available in Lab+Market	600
19	TowerPro MG 959	28 kg Stall torque	4	Available in Lab	0
20	DRV8825 Stepper Driver	42V DC 2.2A max 5V Logic	2	Market	220
21		5A operating current	7 channels	Market	720
Chassis					
22	Aluminum Alloy Body	Extrusion 2020 rods aluminium	~4 kg	Available in Lab+ Market	400
23	3D Printing Filament	PLA 1.75 mm PTEG 1.75 mm	1kg+2kg	Available in Lab + Market	2400
Miscellaneous					
24	Barrier Blocks	Singular/Dual connection points	*As per use*	Market	400
25	Wires	Different AUGs	*As per use*	Available in Lab	0

26	Heat Sinks	Different sizes	*As per use*	Available in Lab	0
27	Electrical components	Resistors, Capacitors	*As per use*	Available in Lab	0
28	Fasteners	Different sizes	*As per use*	Available in Lab	0
29	Cardboards, Sponge	Different sizes	*As per use*	Available in Lab	0
Total Estimated Bill:					₹ 1,49,380

Test Plan

For efficient execution of the testing process, the test plan for our rover is divided into three sections. The three sections, their various parts and corresponding test plans have been discussed below:

1. **Structural tests**

The physical testing of different components to ensure desired mobility, working and endurance will be done.

Properties to be tested: strength and mobility of joints, undercarriage stability, suspension, endurance

Prerequisites: different surfaces to perform drop test, optimum environment for testing

Approach and Tasks:

- The strength and mobility of the joints in the manipulator will be tested by manually extending and retracting the robotic arm. Similarly, the joints of the rocker-bogie suspension and the camera will be assessed.
- The stability of the undercarriage of the rover will be checked by performing a shake test followed by drop tests. The shake test will also be performed with the body fixed with circuits, the power source, manipulator and the camera.
- After complete assembly, the stability of the rover as a whole and its ability to balance the center of mass of the body is assessed by a shake test, followed by drop tests. The rover will be subjected to a drop test first on a foam surface, then an even floor and then an uneven rocky surface.

Pass criteria: Structurally intact and stable throughout testing

Anticipated risks: Potential breakage and/or structural damage

2. **Functional tests**

Properties to be tested: mobility, manipulator functionality, image processing, working of circuitry

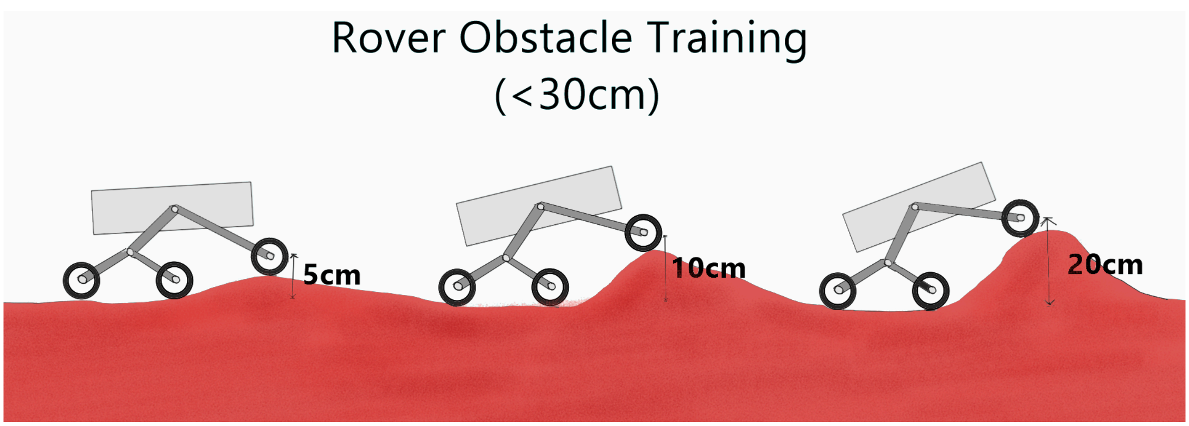
Prerequisites: mock up of arena terrain, different terrains such as smooth flooring, rocky ground, sand(beach sand/cement/Msand), mock ups of obstacles (using wood/cardboard stuffed with sand and rock).

Approach and associated Tasks:

We would have done similar software based test of models before attempting at the following:

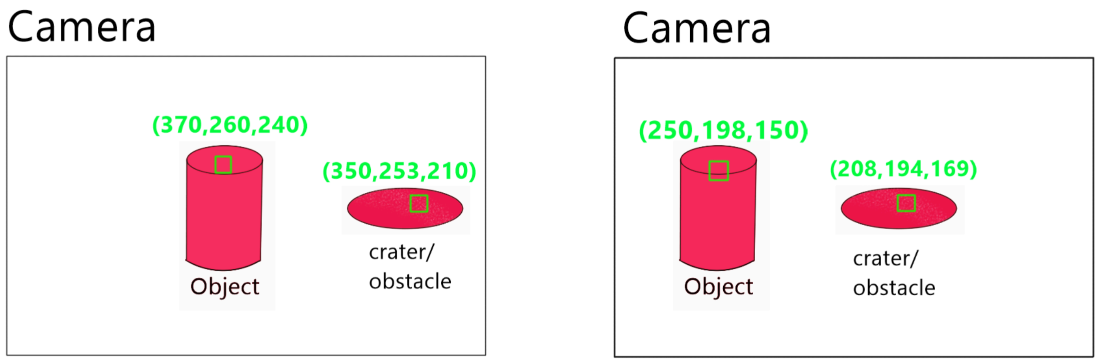
- Testing mobility
  - Checking motion in all specified degrees of freedom by giving commands to move the rover in each of them.

- Assessment of performance in different terrains: a mockup of the terrain would be made on a small scale to test the rovers endurance in an extra terrestrial environment
    - Tests will be performed on different terrains viz. An even floor, an uneven rocky surface and a sandy (beach sand/cement/Msand) surface.
    - Motion tests would be performed by running the wheels over different terrains. The rover's maximum speed would be determined in each terrain.
    - Determination of the maximum size of obstacles the rover can go over: obstacles (blocks/cubes) of increasing size (cube side measuring up to 20 cm) will be constructed using wood, the cardboard boxes will be filled with rocks to add weight to keep them in place. These boxes will be spray painted according to the specified color code (yellow for cubes to go over and green for cubes to go around). The rover will be commanded to traverse the field with the obstacles starting from the smallest up till the largest.
    - Determination of the maximum depth of the crater the rover can go through: craters of increasing diameter (and depth) will be simulated digging sand.
    - Determination of the maximum incline the rover can climb up and the maximum decline it can go down. The slope will be constructed using a hard rectangular cardboard. The cutout of the cardboard and the arrangement could be as depicted below.



        - The rover would be run over and down the slope (once on a smooth slope, then on a sandy slope and then on an uneven/rocky slope)
- Execution of tasks in chosen terrains
    - Different methods of getting from one point to another would be tested
        - The rover will be placed at point A directed straight towards point B and commanded to go from point A to B.
        - The rover will be placed at point A directed away from point B and commanded to go from point A to B

        - Getting from point A to point B and coming back to point A (go from A to B, U-turn and go to point B or back becomes front and goes straight to A.
        - Going over some obstacles and avoiding certain other obstacles. The rover’s capability to distinguish the obstacles would be tested by setting up a field with obstacles of varying sizes and testing the rover's response to identifying each of them.
        - Similarly The rover’s ability to distinguish between craters that it can go over and those which it must avoid will be tested.
- Testing manipulator
    - The motion of the manipulator in all specified degrees of freedom would be tested.
    - The ability to grip objects (3D printed material) of different girth/ hardness etc. would be tested.
    - Determination of the maximum size and weight of objects that can be picked up: sample tubes will be cardboard cylinders filled with stones to add weight. The weight of the pick up objects ranging up to 250 g.
    - Determining the average time taken by the manipulator to pick up sample tubes placed in different orientations (length perpendicular to the ground and length parallel to the ground and placed in line of the rover and at an angle from the line of the rover).
- Image processing
    - Checking the average time taken to detect objects of different types.
    - Identification of yellow, green and violet cubes and red, blue and orange cylinders (differentiation between pick-up object and obstacle).
    - Determination of the accuracy of the image to coordinate information by comparing the coordinates computed by the rover with manually determined coordinates. The test cases would be 50 cm with an increment of 50 cm up to 200 cm.
    - Checking whether the object is being tracked efficiently.
- Testing of the emergency response system. As per the given specifications, we will sequentially try to replicate (safely) all possible emergency scenarios and test the working of all response protocols
- Functioning of the circuit: The working of the circuitry will be examined and the connections verified via continuity tests between different components to check if they’re connected and the circuit is complete. A voltmeter will also be used to check if power is being delivered and the working of the power supply will be assessed.



Pass Criteria: Mobility test- fast, smooth and precise movements in the desired terrains.

Manipulator testing- execution of tasks in a satisfactory manner

Image processing- accurate identification and coordinate information

Emergency response testing- Proper and instant functioning of in an emergency scenario

Anticipated risks: Structural damage of components

Each subsystem would be tested separately in detail such as the rocker-bogie, the manipulator arm etc. and subsequently, the rover would be tested as a whole to ensure synchronization of all the systems and their components. Carrying out the test plan would help increase the efficiency of the rover and ensure the working of its hardware and software components. The tests will help us understand if the specifics are met and overall, assess the rover's performance.

System Specification

The system specifications for the rover will be outlined below. These specifications will detail the requirements for each subsystem, including the rover's structure, roving mechanism, and manipulator arm.

Mobility

- **Size**: The rover should have dimensions of approximately 0.5x0.5x0.4 m^3.
- **Weight**: The rover should weigh approximately 20 kg.
- **Slope Climbing Ability**: The rover should be capable of scaling slopes with an incline of up to 20 degrees.
- **Obstacle Climbing Ability**: The rover should be able to climb over obstacles up to 20 cm high.

Power Supply

- **Primary Battery Capacity**: The rover should have a primary battery capacity of 25000 mAh.
- **Secondary Battery Capacity**: The rover should have a secondary battery capacity of 20000 mAh.

Roving Mechanism

- **Wheels**: The rover should have 6 wheels with high torque DC motors for the roving mechanism.

Arm Manipulation

- **Stepper Motors**: The rover should have 2 stepper motors for arm manipulation.
- **Servo Motors**: The rover should have 4 servo motors for arm manipulation.

Communication

- **Communication System**: The rover should have a Wi-Fi communication system for data transmission and remote control.

Computers

- **Computers**: The rover should be controlled by two NVIDIA Jetson boards, one for navigation control and the other for sample pick-and-place control.

Project Management

No.	Team Member	Task Assigned	Deadline
1.	Aditya P. Kamble	CAD (Manipulator Design)	5 Feb
2.	Aaditya V. Saraf	CAD (Chassis Design and Analysis)	5 Feb
3.	Shakya Ratna Wahane	CAD (Chassis Design and Analysis)	5 Feb
4.	Neharika Varma	CAD (Obstacles and basic components)	5 Feb
5.	Girija Sankar Ray	Software set-up Simulation Training	25 Jan 15 Feb
6.	Sanat Kumar Behera	Hardware Procurement Simulation Training	5 Feb 15 Feb
7.	Sandipan Samanta	Input Processing (Camera and LiDAR)	20 Feb
8.	Vishal Meena	Input Processing (Camera and LiDAR)	20 Feb

9.	Gayatri P	ML Model Training	20 Feb
10.	Joshna Anna Sam	Output Handling	20 Feb

1. **Management plan:** Our team leader will ensure that assigned deadlines of the corresponding main tasks have been met by all. It is expected that a 3D model of the rocker-bogie rover design would be prepared before 5th Feb, and models of the object and obstacles would be done. Moreover, by this time the arm manipulator design would be ready as well and simulation training can be started. Along with the simulation training ongoing, by 15th - 20th of Feb we would be able to perform input processing and software based model training using ML algorithms. After this a considerable amount of time would be spent for software set-up, and improvising on the design, and algorithms used, depending on the training results.

   After the completion of the 3D designing of the rocker-bogie and arm manipulator, the next step will be 3D printing and CNC fabrication of the required parts for the rover. This will include the parts related to rocker-bogie, arm, chassis design and other parts such as obstacles and sample for pick-up. Some components, such as those with complex shapes or requiring precision, will be done at our central workshop (under the guidance of trained professionals) using CNC machines which will ensure their accurate and efficient production. Also, by this time other hardware parts required for the rover would have been procured. This will include components such as motors, sensors and other electronic and mechanical components necessary for the rover's operation. After all the required hardware components are ready, they will be integrated into the rover during the assembly phase, ensuring that they work together seamlessly to achieve the rover's objective.

   The test plan proposed previously will be realized after there is a model with all parts connected and working, and would require active involvement of all the members. Each member of the team will ensure that their task has been completed successfully so that it passes through the respective tests and the overall rover is capable of working well in commanding as well as autonomous modes.

2. **Funding:** Throughout the execution of this plan, we will be obtaining funds from our institute *National Institute of Science Education and Research*, and partly from some local sponsor providing us the hardwares. Along with that, we have decided to use some components already available to us in our labs. These sources will mainly aid us through our hardware requirements, while on the other hand, our industrial guide *Dassault Systémes*, would help us in procurement of software components based on our requirements.

   In our rover project plan, we've carefully given everyone specific tasks, so the work keeps going smoothly, even if someone is busy. We're all about working together in a flexible way, using our free afternoons and nights for the rover project. Our goal is to manage the project in a way that fits into our studies. We're excited to explore, learn, and be creative together, turning our passion into a team adventure while handling our academic commitments.

Novelty in Overall Proposal

In view of the System Architecture and Algorithmic plans, we recognise the following as the novelty in our proposal:

1. **Implementation of novel Image processing algorithms:** *Detection transformers* have shown improved performance when compared to traditional machine learning algorithms. It is a competitive algorithm which works on the concept of *Self Attention*. This helps in assigning different levels of importance to the elements on the screen and return positional encoding of the elements, which helps bypass a lot of secondary programming for obtaining position of the elements.

2. **Extensive data collection:** We are implementing numerous sensors to map and obtain essential information of the surroundings on which the rover is missioned. The obtained data will be sent to the Control Centre continuously. Conceptually, this data can always be used in several research applications as in 3D mapping of extraterrestrial, train on ML models, etc.

This marks our inaugural rover endeavor, and given our academic background with limited exposure to engineering initiatives, we candidly acknowledge the absence of any other distinctive feature at this point.We plan to share the rover design later along in the Design Report, and if possible, we might include details about the identified novelty.
We appreciate your understanding as we navigate this learning experience and strive towards a meaningful contribution to the project.

References

1. Shake, Rattle and Roll: Testing NASA's Mars 2020 Perseverance Rover
2. http://robotics.estec.esa.int/ASTRA/Astra2004/Papers/astra2004_O-01.pdf
3. Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G. (n.d.). *Robotics: Modeling, Planning and Control*. Springer.
4. Martin Azkarate Vecilla: Autonomous Navigation of Planetary Rovers PhD Thesis, 2021
5. DETRs Beat YOLOs on Real-time Object Detection, 2023
6. https://in.mathworks.com/discovery/slam.html