ROVER – INTREPID

Charting new horizons on the red planet

The main purpose of this rover is to explore the red planet and study the Martian surface.

Main requirements of this rover:

- To study the Martian geology, climate, and habitability
- Analyze sample of soil and rocks to understand planet's past conditions
- To study Martian atmosphere, weather patterns
- To search for signs of life
- The rover should be able to survive on Martian surface for a very long period
- The rover must work efficiently with less power consumption

This rover has 6 wheels which allows the rover to move easily on an uneven terrain and the robotic arm (manipulator) has 7 degrees of freedom which can give the rover high flexibility and allow to do wide range of tasks on Martian surface. It possesses an autonomous system skilled at navigating though unpredictable terrain and equipped with capability for charting paths and moving on challenging landscapes.

SUBSYSTEMS:

- **AUTONOMOUS NAVIGATION**

The Navigation system must be equipped with sensors such as cameras, IMUs (Inertial Measurement Unit which can measure and report specific gravity and angular rate of an object to which it is attached). IMU is a combination of accelerators and gyroscopes that can provide accurate motion information even when GPS data is unavailable. It can report on a vehicle's velocity and orientation. LiDAR is also used which is Light Detection and Ranging). LiDAR uses laser light to measure distances and create 3D maps of surface. The data received from these cameras, LiDAR and

IMU is processed and analyzed to extract information about the rover’s surroundings and image processing algorithms such as YOLO (You Only Look Once) are used to detect objects. Point cloud processing, feature extraction, terrain mapping techniques are also used in detecting an object.

Localization algorithms, such as SLAM (Simultaneous Localization and Mapping) ae used to estimate the rover’s pose and update its position as it moves. Based on the perceived data and Localization information the Navigation system makes decisions about the rover’s path and actions. This involves path planning algorithm, obstacle avoidance strategies, and efficient navigation with risk assessment to ensure safety.

The Navigation system sends commands to the Mobility system to along the path planned. This involves controlling the rover’s wheels and suspension to follow the planned strategy while adjusting to changes in the surrounding environment.

Behavior of Navigation system and minimal rules that it would follow are:

→ When there is a rocky area, the navigation system should adjust speed and maintain stability.
→ If it encounters a steep slope, it should find a safe route to minimize the risk of tripping over.
→ It should avoid obstacles and hazards detected.
→ Update the rover's position continuously to maintain accurate localization.
→ Make sure that all sensors are working properly.
→ It must prioritize usage of energy while planning navigation rules.

- **COMMUNICATION SYSTEM**

Communication systems are a vital component in this rover. It should have continuous interaction between the rover and the machine control. The role of communication systems is to transmit the data back to the earth.

Fault tolerance mechanisms are used to reduce the risk of signal loss. The components are ruggedized and shielded to withstand the harsh environments and maintain functionality.

Communication systems support high speed data transmission, and the bandwidth utilization must be maximum (bandwidth is the amount of data transmitted at a given time, affecting speed and efficiency of communication). Continuous data transmission is crucial as it allows us to ensure the rovers' functionality and safety. It must perform these operations with minimum power consumption. Communication protocols must be adaptive as rovers operate in an unpredictable environment. These can adjust communication parameters like signal strength and frequency to optimize data transmission. It allows us to work with maximum efficiency under research constraints. These can detect and adapt to the disruptions by rerouting data through alternative paths or adjusting transmission parameters to maintain connectivity. Antenna plays a crucial role in communication. It is designed based on frequency range, directionality, size and weight, power efficiency and adaptability.

Communication systems allow the transmission of commands from operators to the rover to adjust machine parameters and troubleshoot issues. Rover continuously sends telemetry data to operators. Data downlink capabilities enable the transmission of scientific data and images collected during exploration. Communication systems support the uplink of software updates like machine reprogramming, allowing software patches and software defined operations.

For machines beyond earth orbit, inter planetary communications are required. These systems use relay satellites, deep space networks etc. Waves of high wavelength like *radio waves* are used to communicate between rover and earth.

- **CONTROL SYSTEM**

Sensors which are located throughout the rover continuously collect data about its surroundings including environmental conditions, terrain features, temperature, pressure and the rovers internal state such as battery level, motor status etc. Control system process the data to understand the rover's environment and determine current state. It detects the hazards in the environment and using the processed data control system takes decision on the actions of rover. It decides the rover's path, selects scientific targets for investigation and adjusts machine parameters to optimize performance and conserve resources. The control system communicates with and coordinates the sub systems of the rover such as propulsion, navigation, communication and scientific instruments. It gives commands and makes sure to execute plans accordingly.

The control system may operate autonomously without human intervention and changes can be made by humans from machine control through teleoperation. The control system always monitors rovers' performance and detects if any malfunction is present in a sub system in case of fault it initiates recovery procedures like rebooting systems, switching to back up components or notifying to machine control for further trouble shooting.

- **POWER ELECTRONICS**

The power electronic system manages the generation of electric power from sources such as solar panels, *Radioisotope Thermoelectric Generators* (RTGs), or batteries. But in this rover *RTGs* are used because the solar panels might get affected by the dust and weather conditions on the Martian surface. Once the electric power is generated, the electronic power system distributes it to various systems and all the subsystems and ensures that each subsystem receives the required amount of power to do the operation. This involves routing of power through a network of cables, connectors, and switches to deliver power wherever electricity is required. *PCBs* are used to distribute power to the subsystems.

The electronic power system regulates the power supplied to various subsystems ensuring compatibility with their operating requirements. Voltage converters and regulators are used to adjust the voltage levels. Power electronic systems implement current limiting mechanisms to avoid overloading of electric circuits and components. These mechanisms monitor electrical currents flowing through circuits and activate protective measures like fuses, circuit breakers, to interrupt power flow and prevent damage in case of excessive current. In addition to power supply and distribution it also sees about the energy management through which a task can be done in an optimized way with less power usage and increase the lifetime of the rover on the red planet. This involves prioritizing power supply to the critical subsystems and activating power saving mode when the rover is idle and scheduling the activities which consume more power to when the energy resources are abundant. Electronic power systems are crucial for the rover to function properly.

- **MANIPULATOR**

The manipulator of the rover is designed to perform movements and actions like collecting samples from the surface. It also has Sample handling Arm. It has *7 degrees of freedom*. These 7 Degrees of Freedom allow the arm to move in various directions and orientations, providing flexibility to perform tasks. The 7 degrees of freedom corresponds to the following movements:

1. The shoulder Joint allows the arm to rotate horizontally at the base providing side-side movement.
2. Elbow Joint allows the arm to move up and down vertically
3. The wrist pitch joint allows the arm to tilt up and down, changing the pitch angle of the wrist.

4. The wrist yaw joint allows to rotate from side to side by changing the yaw angle of wrist
5. The wrist roll joint allows the wrist to rotate around its longitudinal axis, providing roll movement.
6. Rotary Percussive Drill Joint: This joint enables the drill on the end of arm to rotate and extend for drilling into Martian surface
7. The turret joint allows the sample catching system to rotate, positioning different tools for sample collection and processing.

The manipulator is equipped with sensors. To perceive the data surrounding workspace sensors are used. Algorithms are developed and translated into actionable plans for manipulator. Implement path planning algorithms to generate trajectories for manipulator and perform tasks by implementing control algorithms. Concepts like Robotics Kinematics and Dynamics, Robot operating system, ML and Computer vision, and Motion Planning Libraries are used in an Autonomous Manipulation system

- **CHASSIS**

The material used to make chassis is an *aluminum allo*y which can be available at low cost, has high strength and less weight. It can also be designed with titanium, but this is not used due to its high cost. A chassis is designed to accommodate the robotic arm, an antenna, the soil sample collecting mechanism and electronic circuits. We implement thermal insulation to shield sensitive components from extreme temperature fluctuations on the red planet. This insulation ensures the proper working of the subsystems of the rover.

We install vibration damping mechanisms to absorb shock during the landing of the rover. This protects the delicate parts from getting damaged. Chassis should be designed in such a way that the sensitive instruments are protected from the dust on the surface of the planet. Before the rover is sent to Mars it undergoes a lot of testing.

- **SUSPENSION, WHEELS AND MOBILITY SYSTEM**

The independent suspension system allows each wheel to move independently which makes the rover move easily even on an uneven terrain. Rocker-bogie suspension is used in this rover. It uses a rocker arm to connect each pair of wheels to provide stability and flexibility. It allows the rover to traverse over large obstacles while maintaining contact with the ground. We use multiple links and joints to connect wheels to the chassis. The rover is equipped with software to autonomously plan and move according to it avoiding obstacles.

The wheels of the rover are large in diameter to roll over obstacles effectively. They have distinctive chevron pattern with zigzag tread grooves, which minimizes slipping on sandy and rocky terrain. The wheels are made of aluminum for strength and lightweight. The wheels of this rocket are thick as it should be resistant to wear and tear. The helical suspension system (a system which uses helical springs to absorb shocks) uses a helical geometry to absorb impacts and distribute forces evenly across the rover, reducing stress on the wheels and other components. The wheels have a distinctive rim design with spokes that provide additional strength while reducing overall weight.

The wheels are designed in such a way that the rocks cannot damage them because the wheels are thick in nature, and it will always maintain contact with the surface of the planet.

- **ELECTRONIC SAFETY AND BACKUP SYSTEM**

Some safety measures and backup systems have been implemented to ensure the reliability of the rover's electronics. In this, fuses are installed to stop the overflow of current and damage electronics. Fuses can disconnect power quickly in case of short circuit or excessive current. Diodes or polarity protection circuits are implemented in case of reverse polarity connections. This ensures the protection of electronics even if the polarities are connected in reverse manner. We provide backup systems to ensure the continuous working even in case of system failure. We include duplicate sensors, processors, and communication modules.

To ensure the system stability and detect errors (like checksums and parity bits while transmitting the data) we include error detection and correction algorithms. We include remote monitoring to allow the mission control to take charge in case of error. To prevent overheating and thermal stress, proper thermal management of electronic components is a must. Heat sinks, thermal insulation, and temperature sensors to regulate temperatures accordingly. Electronic safety systems play a crucial role in managing all electronics without any risk of electronic failure.

- **SAMPLE CACHING SYSTEM**

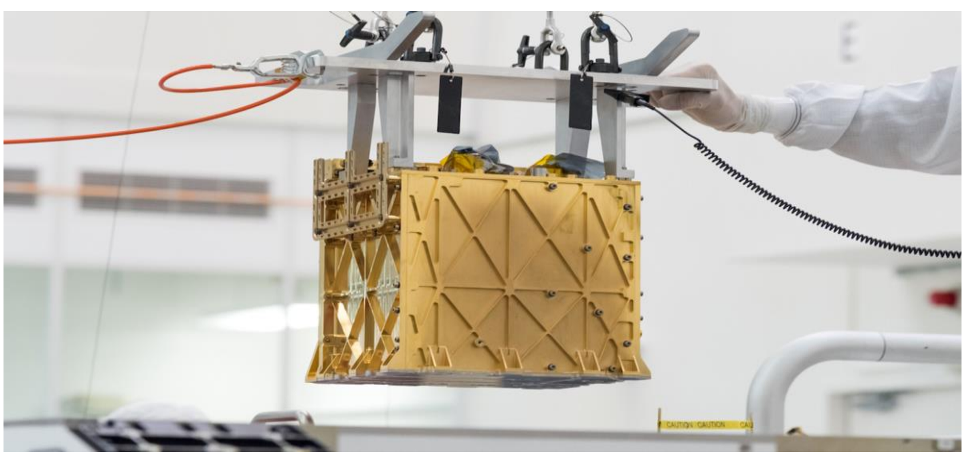
The rover is equipped with a rotary percussive drill (used to drill holes in hard surfaces combined with rotary motion with percussive action) capable of extracting samples from the planet. The collected core samples are transferred to sample handling arm located in robotic arm. The sample handling arm contains a carousel which can hold the core samples individually. These samples are stored in tubes which are sealed later to prevent contamination. Before sealing the tube, each tube is given with a unique identifier like a barcode to track its origin and location on the red planet. These sealed tubes are carefully stored in the rover’s body until they are ready to get deposited on the surface. At some designated locations the samples are deposited, and we can get these samples in our future missions which can be tested in laboratories around the world.

- **SCIENCE CACHE**

To detect microbial life special instruments such as biosignature detectors and microbial analysis tools are used. To analyze chemical and mineral composition of Martian soil X-ray diffraction spectrometers and IR spectroscopy tools are used. There are sensors to measure soil pH, moisture content, and nutrient content. Terrain imaging cameras and ground penetrating radar are used to study geographical features of the planet. This data and information are helpful to understand more about the geological history of Mars.

Choosing a potential landing site on mars involves considering several factors. One promising location suggested is the *Jezero Crater*. It is believed that this crater once held a lake, evidenced by the presence of a river delta within it. It might provide an excellent opportunity to study about the past life of mars. We can study about the potential for Microbial life on mars. Mudstones could preserve the past life activity of mars and volcanic rocks may also be present which are useful to study Mars's volcanic history.

- **MOXIE** (reference – perseverance by NASA)



This is a device which can produce oxygen through an electrochemical process by using carbon dioxide on mars for future human missions.

WORKFLOW OF SUBSYSTEMS IN THE ROVER

Task is identified based on mission objectives. The autonomous navigation system utilizes sensors and receives data which is helpful for path planning and generation. The Mobility system utilizes the maps created and moves accordingly. The instruments collect samples safely and the communication system transmits data between subsystems and between rover and earth.

TASK IDENTIFICATION

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AUTONOMOUS NAVIGATION SYSTEM

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PATH PLANNING AND GENERATION

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MOBILITY SUBSYSTEM

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INSTRUMENT DEPLOYMENT AND PERFORMING TASK

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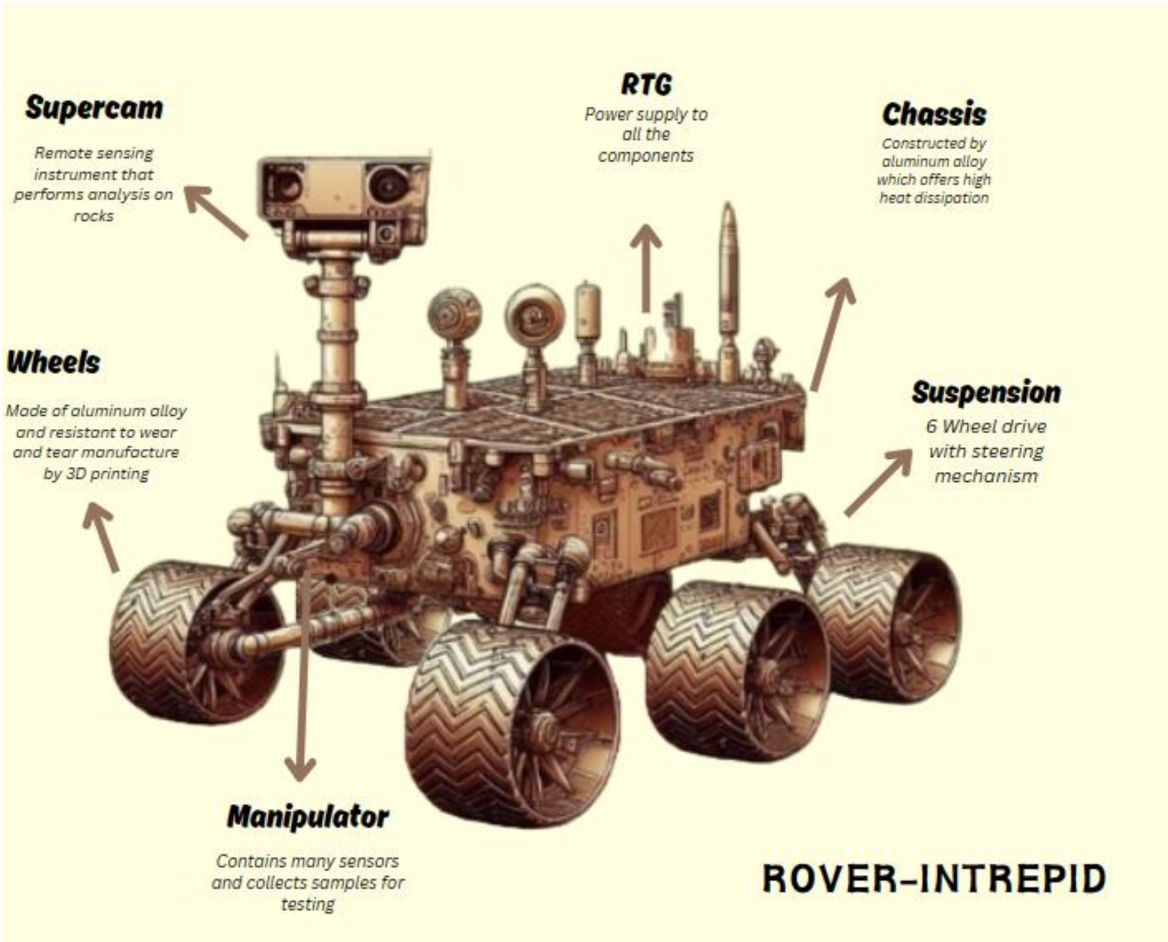
COMMUNICATION



Supercam
Remote sensing instrument that performs analysis on rocks
RTG
Power supply to all the components
Chassis
Constructed by aluminum alloy which offers high heat dissipation
Wheels
Made of aluminum alloy and resistant to wear and tear manufacture by 3D printing
Suspension
6 Wheel drive with steering mechanism
Manipulator
Contains many sensors and collects samples for testing
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