International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 01 , January - 2026

Space Exploring Vehicle Rover

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Abstract- This paper presents the design and development of a solar- powered robotic rover for space exploration applications. The rover is designed to explore uneven and rocky terrains using a six-wheel rocker-bogie suspension system, which provides stability and continuous wheel contact with the ground. This mechanism allows the rover to move smoothly over obstacles and rough surfaces. The rover operates using rechargeable batteries that are charged through an onboard solar panel system, enabling longer operation with reduced energy consumption. A power management system controls the charging and power distribution to all components. A camera module is used to capture real-time images for navigation and terrain observation. An embedded microcontroller controls the movement of the rover, including speed and direction. The system supports semi-autonomous operation along with remote monitoring. The rover structure is lightweight, strong, and modular, making it suitable for harsh environments. This project demonstrates the integration of mechanical design, electronics, renewable energy, and robotics, and serves as a basic prototype for future planetary exploration missions.

Keywords: Solar-Powered Rover, Rocker-Bogie Mechanism, Space Exploration, Embedded Control, Autonomous Robot

1. INTRODUCTION

A rover is a robotic vehicle designed for space exploration that travels across the surface of celestial bodies such as the Moon, Mars, and asteroids. Rovers are mainly used for scientific research and are equipped with instruments to study soil, rocks, atmospheric conditions, and the surrounding environment. Unlike stationary landers, rovers are capable of moving across different locations, allowing wider exploration over long mission durations. Rovers use advanced mobility systems, such as wheeled suspension mechanisms, to navigate uneven, rocky, or sandy terrains. They are commonly powered by solar panels or radioisotope thermoelectric generators, depending on mission requirements. Typical rover payloads include cameras, sensors, robotic arms, and analytical tools for collecting and examining samples. Communication systems enable the transmission of collected data back to Earth, often through relay satellites. Rovers have played a significant role in planetary exploration, particularly on Mars, with successful missions including Sojourner, Spirit, Opportunity, Curiosity, and Perseverance. These missions have helped scientists study planetary geology, climate, and the potential for past life, as well as identify resources for future human exploration. This project focuses on the design and construction of a prototype rover inspired by the Perseverance rover. The prototype uses stainless steel components with limited scientific attachments and hardware. It is capable of maneuvering over various terrains and can be operated in both manual and automatic modes, providing continuous feedback to the user.

2. LITERATURE SURVEY

Babar Hussain et al. [1] presented a paper their contribution as follows:

The survey further investigates key innovations in space robotics in-cluding autonomous decision-making, advanced locomotion systems adapted to extreme terrains, communication strategies under signal delays, and energy efficiency in harsh environments. It also addresses the major chal-lenges faced in designing robots for space missions, such as radiation ex- posure, mechanical reliability, and communication latency. Finally, the paper explores future trends in robotic space exploration, including the integration of robotic systems in long- duration human missions, in-situ resource utilization (ISRU), and robotic construction of

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extra-terrestrial habitats.

James J. Zakrajsek et al. [2] presented a paper their contribution as follows:

The paper discusses the development of rover vehicles used for surface exploration on the Moon and Mars. It reviews both manned and unmanned rovers that have been successfully used in past missions, such as the Apollo Lunar Rover, Lunokhod, Mars Pathfinder, and Mars Exploration Rovers. These rovers played a key role in improving surface exploration by allowing longer travel distances and better scientific data collection. The study explains different types of rover concepts, including unpressurized rovers, pressurized rovers, and mobile base systems. Unpressurized rovers are suitable for short-duration missions, while pressurized rovers support longer missions by providing a safe environment for astronauts. Mobile base concepts aim to combine living and exploration functions into a single moving system. The paper highlights major challenges faced in rover design, such as extreme temperatures, abrasive dust, radiation exposure, rough terrain, and long mission durations. These environmental conditions can cause wear, system failures, and safety risks if not properly addressed. The authors emphasize that future planetary rovers must be highly reliable, capable of long-term operation, and adaptable to different missions. Modularity is identified as the most important design feature, as it allows rover systems to be upgraded and reused across multiple lunar and Mars missions. Overall, the paper concludes that modular and durable rover designs are essential for successful and cost-effective planetary surface exploration in the future.

Squyres S. W et al. [3] Presented a paper their contribution as follows

Squyres S. W served as the Principal Investigator for NASA's Mars Exploration Rover (MER) missions, *Spirit* and *Opportunity*, which landed on Mars in 2004. Under his leadership, these rovers were specifically designed to investigate whether Mars once had environmental conditions suitable for liquid water. Squyres and his team published several influential research papers, notably in the journal *Science* (2004), presenting geological evidence that strongly supported the presence of water in Mars' past. The rovers discovered key features such as hematite-rich spherical formations, commonly referred to as —blueberries,‖ and layered sedimentary rocks. These formations are typically created in the presence of water on Earth, indicating that similar water-related processes occurred on Mars. Chemical and mineralogical analysis further suggested that some regions once had neutral pH water, which is favorable for microbial life. Squyres' work significantly changed the scientific understanding of Mars, shifting the view from a dry and hostile planet to one that may have been habitable in its early history. His findings laid the scientific foundation for later Mars missions, including *Curiosity* and *Perseverance*, which focus on astrobiology and the search for signs of ancient life.

3. OBJECTIVE

- Our objective lies Applying Interdisciplinary Engineering Concepts Utilize concepts from mechanical, electronics, computer science, and control engineering to design and build the rover.
- To develop hands-on skills in prototyping and fabrication Gain practical experience in building mechanical structures, assembling circuits, and integrating components.
- Develop Prototyping and Testing Procedures Build and test prototypes to validate theoretical models and design choices.
- To enhance understanding of embedded systems and robotics Work with microcontrollers, sensors, actuators, and software to create an intelligent robotic system.
- To improve problem-solving and analytical thinking Identify design challenges, evaluate alternatives, and apply engineering solutions throughout the project.
- To practice system integration and testing Learn how to combine hardware and software subsystems and test them for real-world performance and reliability.

4. DESIGN OF THE SPACE EXPLORING VEHICLE ROVER

Design of Space Exploring Vehicle Rover

- Chassis

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- Suspension System
- Wheels
- Motors
- Power Supply
- Control System

Factors considered for the Design

- Environment & Terrain
- Mobility & Locomotion
- Power System
- Structure & Materials
- Sensors & Instrumentation
- Communication System
- Control & Software
- Testing & Reliability

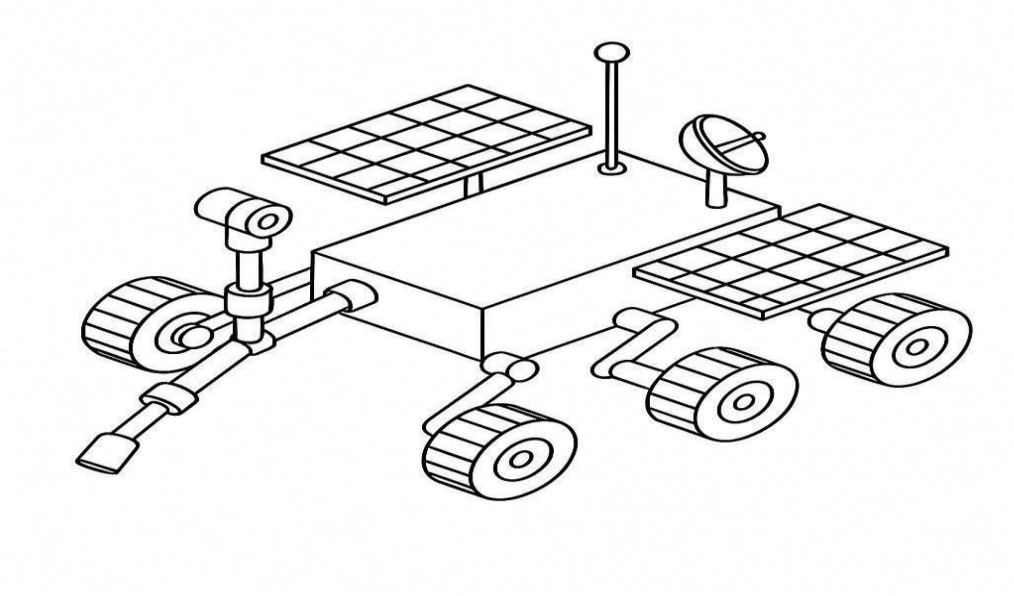

Fig- Rover Fusion 360 Model

5. PARTS OF THE SPACE EXPLORING VEHICLE ROVER

Parts of the Space Exploring Vehicle Rover

- ESP Camera
- DC Motor
- Solar Panels
- DC Controller
- Arduino Board
- Battery

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- **ESP Camera**

Fig-ESP Camera

An ESP camera is a camera module that uses ESP32 or ESP8266 microcontrollers with built- in Wi-Fi and Bluetooth. It usually has an image sensor like OV2640 or OV7670 and can capture images or video and send them wirelessly to other devices or the cloud. ESP cameras are used in surveillance, robotics, home automation, and IoT projects. They can be programmed using Arduino IDE or Espressif SDKs, with libraries and examples available to make integration easy.

- **DC MOTOR**

Fig-N20 DC Motor

The N20 DC motor **is a** tiny brushed motor commonly used in small projects like robots, RC cars, drones, and automation systems. It works by electricity passing through two brushes that contact a rotating commentator to create motion. Despite its small size and light weight, it delivers relatively high torque, allowing it to rotate small mechanisms effectively. However, it is not suitable for heavy loads or large machinery, as it cannot provide high power like bigger motors. Its compact size makes it easy to integrate into projects with space constraints.

- **SOLAR PANEL**

Fig-Solar Panel

A solar-powered rover uses a solar panel system to generate and manage electrical energy for its operation. The main component is the photovoltaic solar panel, which converts sunlight into direct current (DC) electricity using silicon solar cells. This electricity is regulated by a charge controller to ensure safe voltage levels and to prevent overcharging. The generated power is either used directly by the rover's systems or stored in rechargeable batteries for operation during low-light conditions. An inverter is generally not required, as most rover electronics operate on DC power.

- **DC CONTROLLER**

Fig-DC Controller

The DC controller is used to regulate and control the power supplied to the rover's electrical components. It operates at a rated voltage of 12 V DC with a maximum current capacity of 2 A, making it suitable for low-power motors, control circuits, and auxiliary devices. The controller ensures stable voltage output, protects the system from overcurrent and short- circuits conditions, and helps in efficient power distribution from the battery or solar source. It is compact, lightweight, and designed for reliable operation in mobile applications such as solar-powered rovers. Additionally, the controller enhances system safety by preventing damage to sensitive electronic components during voltage fluctuations. It improves overall energy efficiency by minimizing power losses and ensuring consistent performance under varying load conditions. Its simple installation and low maintenance requirements make it ideal for prototype rover applications.

- **ARDUINO BOARD**

Fig-Arduino Board

The Arduino Uno is the brain of a rover, controlling its motors, sensors, and communication modules. It can drive DC motors using motor drivers like the L298N and read sensors such as ultrasonic, IR, or line-following sensors to navigate and avoid obstacles. The Arduino is powered by batteries, while the motors usually get separate power, and it is programmed using the Arduino IDE to control the rover's movements and actions. It can also connect to Bluetooth or Wi-Fi modules for remote control. Arduino Uno is small, affordable, easy to use, and has many libraries and examples, making it ideal for student robotics projects.

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- **BATTERY**

Fig- Li ion Battery

The Battery used is a Lithium-ion battery the lithium-ion battery is a popular type of battery for use in portable electronic devices, power tools, and electric vehicles because of its high energy density, low self-discharge rate, and long cycle life. It is also relatively lightweight compared to other types of batteries and can be recharged hundreds of times without losing its capacity. The lithium-ion battery is a type of rechargeable battery that has a voltage rating of 14.8V and a capacity of 2.2AH (ampere-hour). This means the battery can deliver a current of 2.2 amps for one hour or 1.1 amps for two hours, and so on.

The program for Rover is as follows:

```
#include <ESP32Servo.h> #define servo_LeftRight_Pin   14
#define servo_UpDown_Pin                    15 int servo_LeftRight_Pos = 75;
int servo_UpDown_Pos = 75;
*        servo_Dummy_1          --> timer_0 or channel_0
*         servo_Dummy_2          --> timer_1 or channel_1
*         servo_LeftRight  --> timer_2 or channel_2
*/
Servo servo_Dummy_1; Servo servo_Dummy_2; Servo servo_LeftRight; Servo servo_UpDown;
_VOID SETUP()
void setup() { Serial.begin(115200); Serial.setDebugOutput(false); Serial.println(); Serial.println("    ");
Serial.println("Start setting Servos ......................");
servo_LeftRight.setPeriodHertz(50); servo_UpDown.setPeriodHertz(50); servo_Dummy_1.attach(12, 1000, 2000);
servo_Dummy_2.attach(13, 1000, 2000);
servo_LeftRight.attach(servo_LeftRight_Pin, 1000, 2000);
servo_UpDown.attach(servo_UpDown_Pin, 1000, 2000); servo_LeftRight.write(servo_LeftRight_Pos);
servo_UpDown.write(servo_UpDown_Pos); Serial.println("Setting up the servos was successful."); Serial.println("     ");
Serial.println(); delay(3000);
}
```

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ISSN: 2278-0181
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WORKING

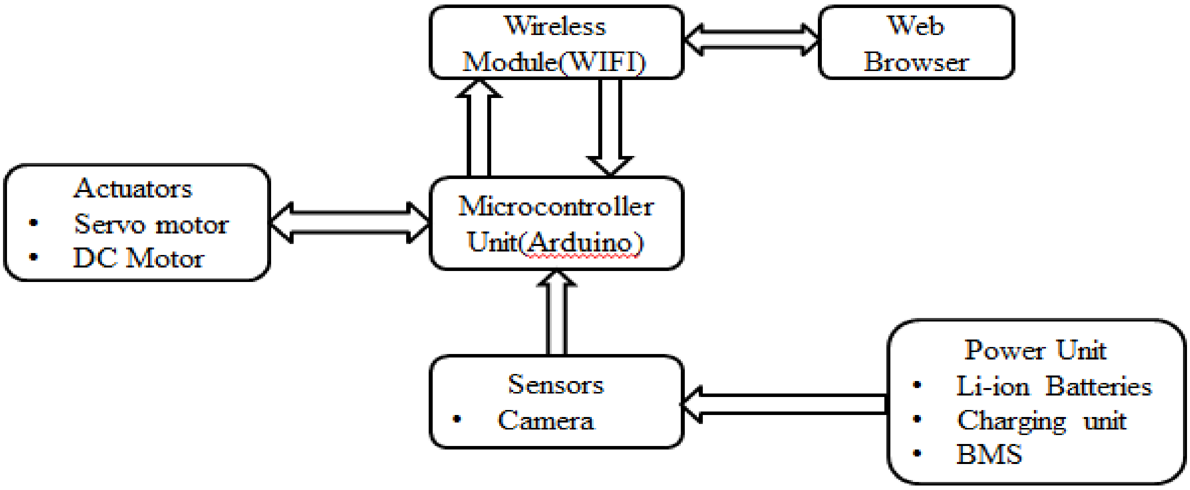

Fig-Block Diagram of working of the Rover

The space exploring rover is a sophisticated robotic system designed to navigate and explore extraterrestrial surfaces autonomously while allowing remote control from Earth. At the heart of the rover is the Arduino microcontroller unit, which acts as the central processing hub. It continuously receives input from various sensors, primarily a camera that captures high-resolution images and videos of the environment. This visual data helps the rover detect obstacles, identify terrain features, and make real-time decisions to navigate safely. The microcontroller processes the sensor data and sends precise control signals to actuators, including servo motors for adjusting camera angles or robotic arms, and DC motors that drive the rover's wheels to move forward, backward, or turn. To maintain communication over long distances, the rover is equipped with a Wi-Fi wireless module that enables two-way data exchange between the rover and a remote operator via a web browser interface. This wireless link allows the operator to monitor the rover's surroundings through live video feeds, send commands to control its movements, and receive important status updates. Powering the rover is a reliable power unit made up of rechargeable lithium-ion batteries, supported by a battery management system (BMS) that monitors charging, prevents overcharging, and ensures optimal battery health for extended missions. The power unit may also include a charging system, such as solar panels, to recharge batteries when possible. Together, these components allow the rover to autonomously explore and gather information while remaining connected to operators who can intervene and control its actions as needed.

6. CONCLUSION

The design and development of the space-exploring rover represent a comprehensive application of mechanical engineering principles to a complex, multidisciplinary challenge. This project successfully demonstrates the ability to translate theoretical knowledge into a practical, functional prototype capable of navigating uneven and unpredictable extra- terrestrial terrains. The rover's design emphasizes structural robustness, energy efficiency, and mobility optimization, highlighting critical aspects such as suspension mechanisms, wheel design, load distribution, and material selection. Through iterative design, modelling, and testing, the project addressed the mechanical and operational challenges inherent in extra- terrestrial exploration. The successful integration of mobility systems with control and power management subsystems illustrates the importance of holistic engineering approaches in developing autonomous or semi-autonomous vehicles for space missions. Moreover, the project provided valuable insights into balancing performance, durability, and energy efficiency—key factors in long-duration exploration missions. This work also underscores the potential for further innovation. Future developments could include advanced autonomous navigation using AI-based path planning, enhanced sensor arrays for real-time terrain and environmental analysis, energy harvesting mechanisms for extended mission durations, and modular designs to adapt to different planetary environments. Such enhancements could significantly expand the rover's capabilities and reliability in extra-terrestrial operations. In essence, this project not only serves as a testament to the application of mechanical engineering in challenging and novel contexts but also contributes meaningfully to the field of space robotics. By bridging the gap between theoretical design and functional implementation, the project lays a solid foundation for future exploration vehicles, inspiring further research and development in robotic planetary exploration and advancing humanity's capabilities to explore beyond Earth.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 15 Issue 01 , January - 2026

7. ACKNOWLEDGEMENT

We would like to thank our Head of the Department, Dr.ASWATHA and our guide Dr.UMESH G.L for their valuable advice and technical assistance.

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