

# Design and Fabrication of Rocker Bogie Mechanism using Solar Energy

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**Abstract** - It is obvious that rovers are essential vehicles of today's solar system exploration. A lot of the rover designs have been developed for planetary surface in order to understand the geological history of the soil, ground and atmosphere. Exploration operations need high speed and long distance travel in a short period due to foreign environment, climate and communication restrictions. Several mechanisms have been invented in recent years for working of rovers on rough terrain. Although their different applications have found a widespread usage in mobile robotics, their low speed operation is still a challenging problem. In this research, a new suspension mechanism has been delineate and its kinematic scrutiny results were discussed. Standard rocker-bogie suspension mechanism, which has been designed in the late 90's, has excellent weight distribution for different surfaces on rough terrain. New design, mostly related to rocker-bogie suspension system, has a inbuilt advantage with linear bogie motion which protects the whole system from getting rolled over during high speed implementation. This improvement increases the strength of structure on field operations and also allows the higher speed exploration with similar object obstruction height capacity as rocker-bogie. In this study, new bogie mechanism consisted of double-lambda mechanism, which has been in first presented by Pafnuty Lvovich Chebyshev in 1869, is solved by analytics to define the positions and singular configurations. An improved structural synthesis formula also has been introduced for such mechanisms with lower and higher kinematic couples. By using structural synthesis methods, a developed mechanism has been designed with double-lambda mechanism. Force equations and moment functions were also produced with equation of motion method.

**Key Words** - Double-Lambda Mechanism, Mobile Robotics, Rocker Bogie, Rover Design.

## 1. INTRODUCTION

The rocker-bogie suspension system was initially used for the Mars Rover and is currently NASA's preferred design for rover wheel suspension. The perfectly designed wheel suspension allows the vehicle to travel over very uneven or rough terrain and even proceed over obstacles. This rocker

suspension is a type of mechanism that allows a six wheel vehicle to constantly keep all six wheels in contact with a surface when driving on uneven terrain surfaces.

This publication describes a method of driving a rocker-bogie rover so that it can progressively step over most obstacles rather than impacting and climbing over them. Most of the benefits of this method can be achieved without mechanical modification to the same designs – only a change in control structure. Some machine changes are suggested to gather the maximum profit and to greatly increase the effective speed of future rovers. The rocker bogie mechanism is one of the most popular suspension mechanisms, which was initially designed for space travel vehicles having its own deep history embedded in its development.

By design it is a wheel robot which comprises of 6 motorized wheels. The word "rocker" describes the back part of the larger links present both sides of the suspension system and these rockers are connected to each other and the vehicle chassis through a selectively modified differential in order to balance the bogie. By construction it has main frame containing two linkages on each side that are called the "rocker" (see Figure 1). One end of the rocker is connected to the back wheel, and the other end is connected to maintain center of gravity of entire vehicle as accordance with the motion, when one rocker moves down-ward, the other goes upward (Figure 1). It plays vital role to maintain the average pitch angle of both rocker and bogie by allowing both rockers to move as per the situation. As per the actual design, one end of a rocker is jointed with a drive wheel and the other end is pivoted to a bogie which gives required moment and degree of freedom.

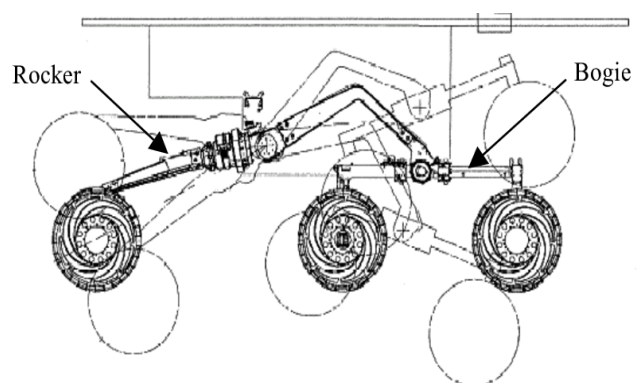


Fig-1 Rocker Bogie Parts

## 2. HISTORY OF ROVERS

### 2.01 Lunakhod

The first planetary geological exploration rover selected was “Lunakhod” which has been sent Moon twice with USSR – Luna missions to gather information around settled site and send images of environment. Lunakhod was guided in real-time by a 5-person team at the Deep Space Center near Moscow, USSR. Lunakhod-2 toured the lunar Mare Imbrium (Sea of Rains) for eleven months in one of the greatest successes travelled 37 km on Moon terrain.

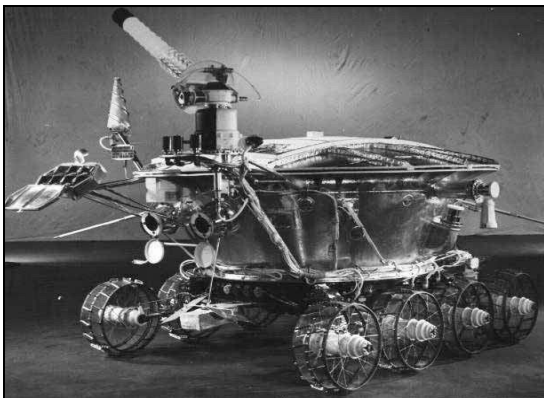


Fig-2 First Planetary Exploration Rover “Lunokhod”

### 2.02 Sojourner

In 1996, NASA – Jet Propulsion Laboratory and California Institute of Technology have designed improved rovers with similar structure named Sojourner and Marie-Curie. These tiny rovers were only 10.5 kilograms and microwave oven sized. Rover Sojourner was established with Pathfinder landing module in December 1996. Marie Curie rover was also planned to send Mars with 2001 mission but was cancelled.

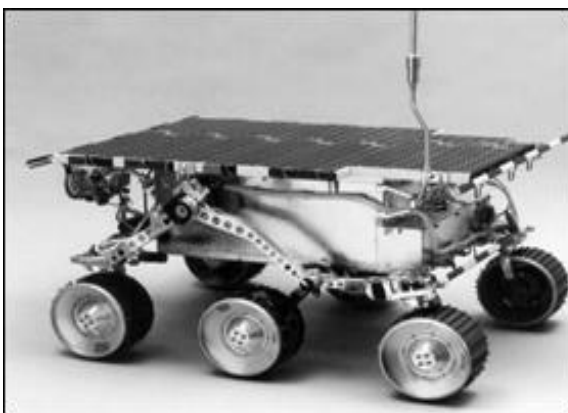


Fig-3 NASA - JPL Sojourner Rover

Operators have sent commands via lander Pathfinder and they examined rocks and soil components of Mars more than 3 months. Sojourner was a breaking point of exploration

rovers with its unique six-wheeled suspension system which can overcome one and a half wheel diameter height obstacles that is similar to an automobile passing over a table sized obstacle.

### 2.03 Nanorover

Another rover to active suspension system is nanorover which was invented for exploration of small celestial bodies like comets and asteroids in space. Small dimensional characteristics and lightweight are advantages of this robot.

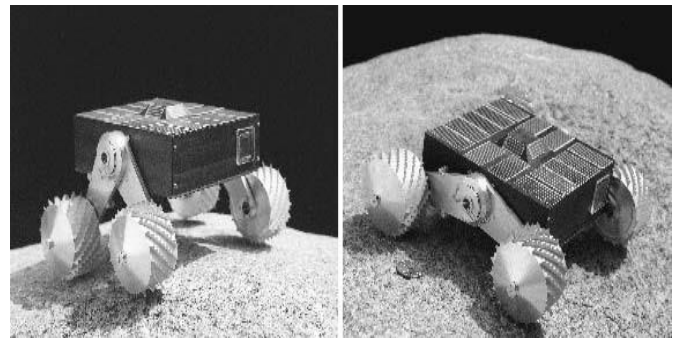


Fig 4. Nanorover with active suspension

This system consist of four wheels with 6 cm diameter. Each wheel is connected to the chassis with independent positioned struts. Since the robot can operate on both sides (upside-down), overturning was not a problem. Onboard computers can also manipulate the suspension systems for arranging tractor forces.

### 2.04 Shrimp

Shrimp is also a different six-wheeled rover which designed by Swiss Federal Institute of Technology – EPFL. It has a one front four-bar to climb over obstacles up to two wheel diameter with no stability problem. The Middle has four wheels which have parallelogram bogie which balances the wheel reaction forces during climbing. Single back and front wheels connected directly to the main body also driven by motor to increase the climbing capacity.

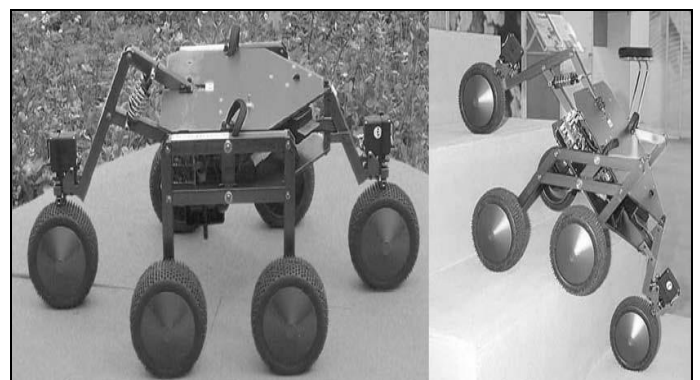


Fig-5 Shrimp rover designed by EPFL – Switzerland

### 2.05 Inflatable Rover

Another alternative to move on a hard environment is to have big wheels. If a rover has larger wheels compared to obstacles, it can easily operate over most of the uneven rocky surface. Researches show that inflatable rover with 1.5 meter wheel diameter can travel about 99% of the area. Inflatable rover has 3 wheels which the motor drives.

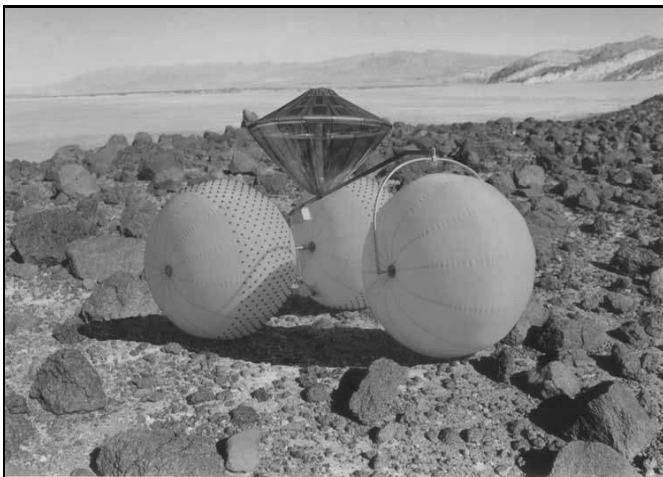


Fig-6 Inflatable Rover

### 3. SUSPENSION SYSTEMS AND KINEMATIC MODELS

The different rovers are precisely presented and the kinematic modeling is explained. For consistency, the rovers that were selected for the kinematic analysis as in where more details can be found about the systems were similar. However, a new, modular hardware platform was developed which allows for configuration of four different types of suspensions: the selection consists of CRAB and RCL-E that was extended by the configurations of NASA's own rocker bogie suspension and ESA's particular ExoMars rover. It is important to point out that the observations of RB and ExoMars is hardly differentiable in 2 dimension which also applies to the kinematic mathematics used in this work.

Only three configurations were selected in the end which are listed in Table where different aspects of the rovers can be found: pictures of the hardware, simulation model, and kinematic model. The kinematic models were simple structures such that they represent correct mechanical system and maintain same behavior like the real mechanical rovers but modeling of parallel structures was avoided.

The focus of this work was to compare different suspension types and not of the original rovers, the hardware was detailed in a way that the main parameters remains the same but the dimensions were changed. The resulting modular system has a total weight of ~18 kg, wheels with a diameter of 0.11 m, a foot print of 0.456 m and the payload in the middle of the rover close to the body's base plate. These common configuration allows for a proper comparison of the suspension types regardless of terrain characteristics.




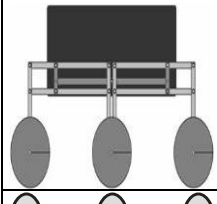
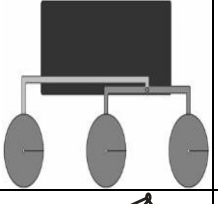
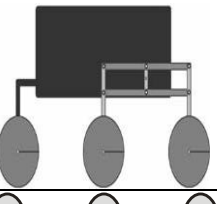
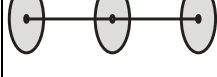

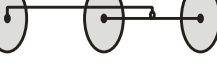
CRAB Autonomous Systems Lab Symmetric structure based on four parallel bogies, differential mechanism	Rocker bogie (ExoMars*) NASA / JPL Rocker with pivot to connect bogie, differential mechanism	RCL-E RCL / ESA Two parallel bogies at side/front, one transversal parallel bogie at rear, no differential
		
		
		

Fig-7 Comparison of suspension mechanisms

### 4. OBJECTIVES

We will be focusing on eliminating the shortcomings of the rover that is the current rocker-bogie rovers is that they are slow. The rovers made for the exploration purposes are very costly too. Due to the expensive cost of space exploration, most of the missions have been conducted by NASA team and other government organizations. We, in India have not conducted any mission for the geographical exploration purposes.

Not only exploration, the rocker bogie rover can also be used for military, and civil purposes but still it needs to be a cost efficient and quick. Our aim during the development of the rover will be to optimize the speed so the rover does not flip and travel faster and make it cost efficient with maximum possible rigidity and roughness. The use of solar energy and modification of the structure is what we striving for.

### 5. CONSTRUCTION DETAILS

#### 1. Mechanical Components

1. PVC pipes and Joints
2. Jubilee Clamps
3. Motors – 30 RPM
4. 12 volt 7.5 Amp Battery.
5. Plywood
6. Nuts and bolts



7. Superglue
8. Rubber surfaced wheels

## 2. Electrical Components

- a. Rocker Bogie Mechanism
  1. Arduino Uno
  2. 4-Channel Relay Circuit
  3. Bluetooth Model HC-05
  4. IC Circuit – 780V
  5. Key
  6. Buzzer
  7. 6 Different colored wires for connection
- b. Solar Tracking System
  1. 10 RPM Gear Motor
  2. 1293d Motor Driver
  3. 2 IR Sensor
  4. 2 LDR Sensor
  5. Arduino Uno
  6. 2 motor clip
  7. 2 Battery Cap
  8. 10 W 12 V Solar Panel

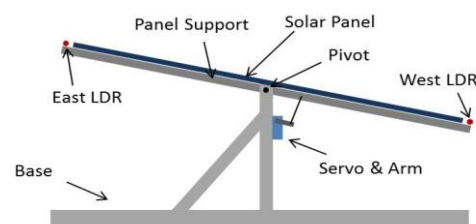
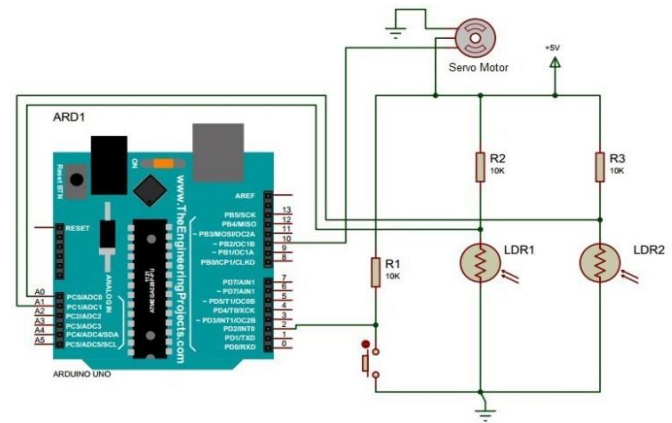


Fig 9. Solar Tracking System with Single Axis Rotation

## 3. Codes for Arduino

1. Sun tracking sketch
2. Rover motion and switch sketch

## 6. CONSTRUCTION BLOCK DIAGRAMS

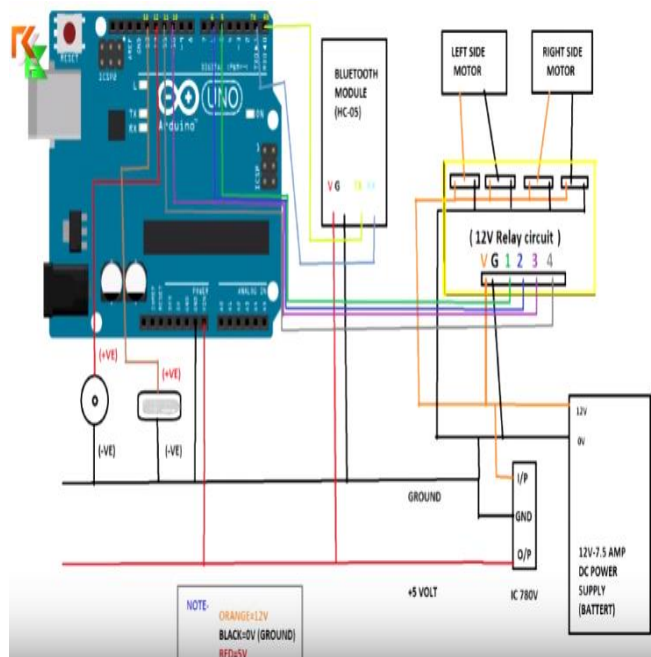


Fig-8 Rover Movement Circuit using Bluetooth module

## 9. CONCLUSION

We studied about the project, read different research papers, got to know about the information regarding ROCKER BOGIE and its applications. We also compared different types of mechanism and finally designed to work on one. We divide the project into 3 Major parts – Mechanical Construction, Electrical Circuits and Information technology. We infused solar energy generation, sun tracking and design characteristics to create a modern, more updated and less sophisticated version of ROCKER BOGIE ROVER. We tested its abilities and finally reviewed and updated our calculations. In this way we completed our aim and goals.

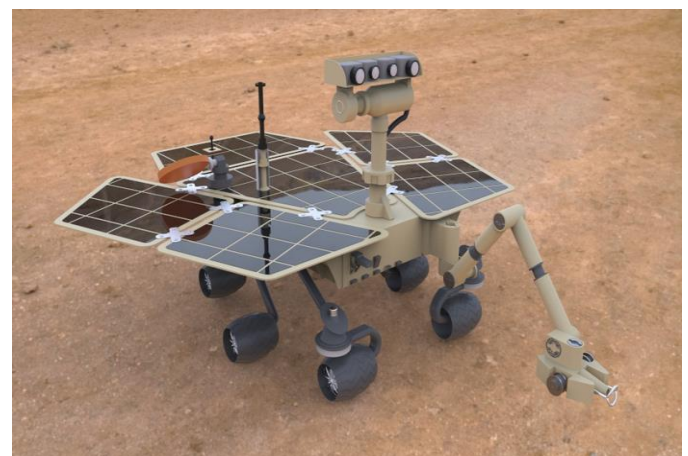


Fig-10 AutoCAD Model of Rover

## 10. ACKNOWLEDGEMENT

It is indeed a matter of great pleasure and proud privilege to able to present this project on 'Design and Fabrication of Rocker Bogie Mechanism'

This completion of the project work is a milestone in a student's life and its execution is evitable in hands of Guide. We are highly indebted to our project guide Prof. Yogesh Mahulkar for his valuable guidance to our project and ultimately made it success.

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