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DESIGN OF ROCKER BOGIE MECHANISM

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Abstract - *The Rocker- Bogie Mobility System was designed to be used at slow speeds. It is capable of overcoming Obstacles that are on the order of side of a wheel. However, when surmounting a sizeable obstacle, the vehicles motion effectively stops while the front wheel climbs the obstacle. NASA's currently favored design, the Rocker - Bogie, uses a two wheeled rocker arm on a passive pivot attached to a main bogie that is connected differentially to the main bogie on the other side. This paper describes a method of driving a Rocker - Bogie vehicle so that it can effectively step over most obstacles rather than impacting and climbing over them. Most of the benefits of this method can be achieved without any mechanical modification to existing designs only a change in control strategy. Some mechanical changes are suggested to gather maximum benefit and to greatly increase the effective operational speed of future rovers. The rover has been completely made from PVC to increase its capability to withstand shocks, vibrations and mechanical failures caused by the harsh environment where it is operated on. Using CAD software, the design of the rover has been fine-tuned and by experimenting with prototypes and models of the rover in the experimental setup of the live test.*

Key Words: *Bogie, Mars Rover, Mobility System, NASA, Rocker-Bogie Mechanism, Rocker, PVC pipes, Rough Terrain*

1. INTRODUCTION:

There is an increasing need for mobile robots which are able to operate in unstructured environments with highly uneven terrain. These robots are mainly used for tasks which humans cannot do and which are not safe. In order to achieve these tasks any mobile robot needs to have a suitable mobile system according to each situation. Among these mobile systems, it's the rocker -bogie suspension system that was first used for the Mars Rover Sojourner and it's currently NASA 's favored design for rover wheel suspension. The rocker- bogie suspension is a mechanism that enables a six-wheeled vehicle to passively keep all six wheels in contact with a surface even when driving on severely uneven terrain. There are two key advantages to this feature. The first advantage is that the wheels pressure on the ground will be equilibrated. This is extremely important in soft terrain where excessive ground pressure can result in the vehicle sinking into the driving surface. The second advantage is that while climbing over hard, uneven terrain all six wheels will nominally remain in contact with the surface and under load, helping to propel the vehicle over the terrain. Exploration rovers take advantage of this configuration by integrating each wheel with a drive actuator, maximizing the vehicle's motive force capability. One of the major shortcomings of current rocker-bogie rovers is that they are slow. In order to be able to overcome significantly rough terrain (i.e. obstacles more than a few percent of wheel radius) without significant risk of flipping the vehicle or damaging the suspension,these robots move slowly and climb over the obstacles by having wheels lift each piece of the suspension over the obstacle one portion at a time. While performance on rough terrain obstacles is important, it should be also considered situations where the surface is flat or it has almost imperceptible obstacles, where the rover should increase its speed to arrive faster from point A to point B.

1.2 OBJECTIVE:

This paper will be focusing on eliminating the shortcomings of the rover, one of the major shortcomings of current rocker- bogie rovers is that they are slow. In order to be able to overcome significantly rough terrain without significant risk of flipping the vehicle or damaging the suspension, these robots move slowly and climb over the obstacles by having wheels lift each piece of the suspension over the obstacle one portion at a time. While performance on rough terrain obstacles is important, it should be also considered situations where the surface is flat or it has almost imperceptible obstacles, where the rover should increase its speed to arrive faster from Point A to Point B. The rovers made for the exploration purposes are very costly too. Due to the high cost of space exploration, most missions to date have been conducted by NASA and other government- supported organizations. However the continually decreasing cost of technology and economic potential in natural resources has led some private companies to pursue space transportation and exploration as a core business. For example, Astrobotic Technology, Odyssey Moon and Armadillo Aerospace are just few companies that are developing rovers and landers for different space missions.

While companies like these have made progress in commercialization of space exploration, the inherently high cost continue to hinder the economic feasibility. We, in India have not conducted any mission for the exploration purposes. Not only mars exploration the rocker- bogie can also be used for military and civil purposes. Not only mars exploration the rocker- bogie can also be used for military and civil purposes but there also it is needed to be a little cost effective and fast. Thus our concern during the development of the rover would be to optimize the speed such that the rover do not flip and may travel a little faster too and make it cost effective with maximum possible rigidity and ruggedness.

2. LITERATURE REVIEW:

This is the discussion of some past space exploration rovers as well as rovers currently in development. Specific missions along with the corresponding design features and capabilities, specifically relating to mobility and navigation, that made these rovers successful in meeting their objectives on the Martian or lunar surface. Next, specific features of these rovers are discussed in order to learn more about the types of technologies that are often used on exploration rovers. Both hardware and software design choices are reviewed, as they relate to the mobility challenges of ground compliance and hazard avoidance. Lastly, research into analog testing presents what is currently being done by NASA and others to validate planetary rovers on Earth. A variety of harsh Earth environments are examined for their suitability in analog testing based on how well they represent certain aspects of the Martian and Lunar environments. A few NASA sponsored competitions are also reviewed, as they can often provide unique opportunities for analog testing at NASA facilities.

2.1 RECENT ROVERS AND THEIR MISSIONS:

Much of space exploration can be divided into three categories: a quest to better understand our universe, interest, and economic potential in using natural resources outside our planet, and the future colonization of extra- terrestrial bodies. Furthermore, most interest has been in our moon and Mars, as these planetary bodies are close by, and have environments that are hospitable enough for rovers, and potentially for future colonization. The moon is also very well suited for scientific equipment such as radio observatories or IR telescopes, as it has no atmosphere, instruments such as these can measure signals that would otherwise be disturbed or eliminated on Earth. Interest in Mars mostly relates to expanding our knowledge of the planet, specifically with respect to its ability to support a human colony. Learning more about the composition of its atmosphere and soil can tell us whether Mars could potentially support microbial life. In reviewing NASA's rovers for surface exploration on Mars, there were many similarities in both their mechanical design and software that enable the rovers to perform on-board path planning. Autonomous planetary navigation that has founded itself on making space exploration profitable, by delivering payloads and performing robotic services on the moon. They are currently in collaboration with Carnegie Mellon University and others, to develop a rover and lander for their first surface lunar exploration mission, which if successful will satisfy the X-prize criteria as well as other objectives. Their robot, called Red Rover, is reviewed here because it is one of the most developed lunar exploration rovers. Combined with hazard avoidance and other self-preservation autonomy makes these rovers excellent platforms to reliably transport and position their scientific instruments. The biggest changes between missions have been the size of the rover and the types of scientific instruments it supports. Astrobotic Technology Inc. is one such company

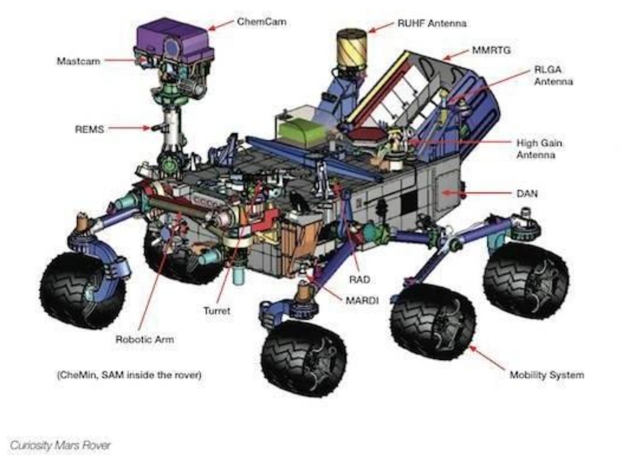

Fig 1: NASA'S Curiosity Mars Rover

2.2 ROVER OPERATIONS:

One of the most challenging aspects of rover operation in planetary environments is effective mobility. In order for a rover to complete any science tasks, it first must be able to move confidently in unforgiving terrain. This may include both challenging surfaces and wider-scale terrain discontinuities. Surface challenges to rover mobility include fine powders such as lunar regolith, screen fields, and larger rocks. Topographic features such as craters, hills, gullies, and cliffs present different forms of challenges. To complicate the problem further, many planetary environments are not well studied, so rover mobility systems must be flexible to accommodate unknown factors. Effective rover mobility systems combine robust mechanical hardware with sensors and programming to detect impassible terrain. The goal of any rover mobility system is to reduce the impact of variable terrain on the rover's ability to traverse a given path. This typically involves a suspension system which allows the rover to travel over certain obstacles in its path as well as absorb shocks and unevenness. The most basic mobility system is the wheel, and an effective wheel design becomes a major part of any rover drive system. Most planetary rovers have used all-metal wheels for their high strength-to-weight ratio. NASA/JPL's 10.5 kilograms Sojourner rover used 13 centimeter one-piece aluminum wheels with sharp stainless steels cleats to climb obstacles and gain traction in soft soil. Sojourners wheels were rigidly connected to the drive motors with no suspension elements. It has large billet aluminum with thin straight spokes and a zigzag aluminum pattern machined into the outer surface. These 50 centimeters wheels support the 900 kilograms rover over obstacles up to 75 centimeters in height. These components are typically articulated to increase the maximum obstacle the rover is capable of traversing, as well as maintain stability on tilted terrain. The two most common methods of articulating mobility systems include rocker bogie and rocker differencing. The primary benefit to a rocker-bogie suspension is that a rover is able to climb an obstacle up to twice the diameter of its wheels while keeping all 6 wheels in contact with the surface. Because the front and rear wheels can help to push or pull the free-floating bogie link, it is able to go over relatively large obstacles compare to its wheel size. As a suspension system, the rocker-bogie contains no spring elements, and this helps provide stability while going over large obstacles.

3. DESIGN SPECIFICATIONS:

3.1 Mobility & Navigation:

Mobility relates to the rover's capacity to traverse varying terrains, slopes, and obstacles. In beginning the process of formulating the drive architecture we reviewed current and past rovers in consideration of chassis design, suspension methods, wheel design, and power requirements. Since nearly all rover hardware is related to mobility, this section will review most of the mechanical design including the chassis, suspension, and wheel components. These rovers move slowly and climb over the obstacles by having wheels lift each piece of the suspension over the obstacle one portion at a time. NASA's currently favored design, the rocker-bogie, uses a two wheeled rocker arm on a passive pivot attached to a main bogie that is connected differentially to the main bogie on the other side. The ride is further smoothed by the rocker which only passes on a portion of a wheel's displacement to the main bogie. Each wheel is independently driven. The maximum speed of the robots operated in this way is limited to eliminate as many dynamic effects as possible, and so that the motors can be geared down so that the wheels can individually lift a large portion of the entire vehicle's mass.

3.2 Size & Weight Restrictions:

Given sufficient mobility in planetary environments, the rover must also be able to accommodate payloads, if possible. Transporting sensitive scientific instruments across rough terrain is the main goal for nearly all exploration rovers, and thus one of our central requirements. Additionally, to be useful for other users both in academia or industry, the rover needs to easily integrate new hardware and software as part of its payloads. By providing a robust mobility platform that can accommodate a wide range of payloads, the rover should prove useful to anyone interested in testing rover related technologies or conducting research in the field of space exploration.

3.3 Related Concepts:

1. Traction Slips:

The rover must maintain good wheel traction in challenging rough terrains. If traction is too high, the vehicle consumes a lot of power in order to overcome the force and move. If traction is too low, the rover is not able to climb over obstacles or inclined surfaces. Slip occurs when the traction force at a wheel-terrain contact point is larger than the product of the normal force at the same wheel and the friction coefficient. Hence, no slip occurs if the condition. **($T_i \le \mu N_i$)** is satisfied. In reality it is very challenging to determine the precise friction coefficient μ for the interaction of two surfaces.

2. Lateral Stability:

The rover is said to be stable when it is in a quasi-static state in which it does not tilt over. The simplest approach to find the static stability is using the geometric model, which is commonly referred to as stability margin. As the asymmetric suspension system of the passively articulated rover has a great influence on the vehicle's effective stability, a more advanced approach is using a static model. The lateral stability of the rover ensures that the rover does not tip sideways. As the rover has two symmetric sides, the geometric model is used to find the lateral stability of the vehicle. Lateral stability is computed by finding the minimum allowed angle on the slope before the rover tips over.

3. Longitudinal Stability:

The computation of the longitudinal stability of the rover makes use of a statically model as it is not symmetric in longitudinal direction. Using a statically model, the mechanical properties of the suspension system are taken into account. According to, longitudinal stability of the vehicle is given when all wheels have ground contact and the condition $N_i > 0$ is satisfied, where N_i is the normal force at wheel. It should be noted that even though this condition is compulsory for the statically model to work, a physical rover does not necessarily tip if a wheel loses contact to the ground. However, it is less steerable.

4. Static Stability Factor:

The Static Stability Factor (SSF) of a vehicle is one half the track width, TW, divided by h, the height of the center of gravity above the road. The inertial force which causes a vehicle to sway on its suspension (and roll over in extreme cases) in response to cornering, rapid steering reversals or striking a tripping mechanism, when sliding laterally may be thought of as a force acting at the COG to pull the vehicle body laterally. A reduction in COG height increases the lateral inertial force necessary to cause rollover by reducing its leverage, and the advantage is represented by an increase in the computed value of SSF. A wider track width also increases the lateral force necessary to cause rollover by increasing the leverage of the vehicle's weight in resisting rollover, and that advantage also increases the computed value of SSF. The factor of two in the computation "TW over 2h" makes SSF equal to the lateral acceleration in g's (g- force) at which rollover begins in the most simplified rollover analysis of a vehicle represented by a rigid body without suspension movement or tire deflections.

4. DESIGN AND MATERIAL ANALYSIS:

4.1 COMPONENTS:

1.Wheel:

Fig 2: Wheels

Wheel is simple and mad from hard fiber and plastic only. The wheels are needed to be wider for increasing the traction to traverse upon the obstacles. And their diameter depend upon the availability and amount of speed required. The actual rover uses billet wheels, and machine the wheel and tread from one piece of round aluminum stock.

2. Gear Motor:

A gear motor is a specific type of electrical motors that is designed to produce high torque while maintaining a low horsepower, or low speed motor output. Gear motors can be found in many different applications and are probably used in many devices in your home. Gear motors are commonly used in devices such as can openers, garage door openers, washing machine time control knobs and even electric alarm clocks. Common commercial applications of a gear motor include hospital beds, commercial Jacks, cranes and many other applications that are too many to list.

Fig 3: Gear Motor

3. Rocker Frame:

The Rocker - Bogie design has no springs or stub axles for each wheel, allowing the rover to climb over Obstacles, such as rocks that are up to twice the wheels diameter in size while keeping all six wheels on the ground. As with any suspension system, the tilt stability is limited by the height of the center of gravity. Systems using spring tend to tip more easily as the loaded side yields.

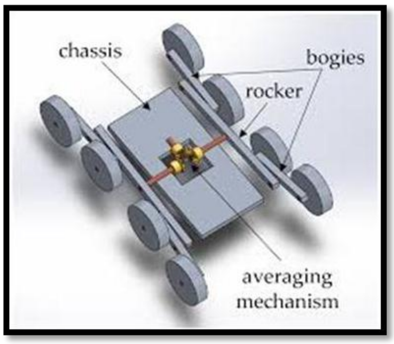

Fig 4: Rocker Frame

4. Bogie Frame:

The term "Bogie" refers to the links that have a drive wheel at each end. Bogies were commonly used as load wheels in the tracks of army tanks as idlers distributing the load over the terrain. Bogies were also quite commonly used on the trailers of semi-trailer trucks. Both applications now prefer trailing arm suspensions.

Fig 5: Bogie Frame

5. Nuts, Bolts and Washers:

A nut is a type of fastener with a threaded hole. Nuts are almost always used in conjunction with mating bolt to fasten two or more parts together. The two partners are kept together by a combination of their thread's friction, a slight stretching of the bolt, and compression of the parts to be held together. This use for flexibility connecting with rocker and bogie link.

Fig 6: Nuts, Bolts, Washers

6. Power Supply:

The MER has to travel the surface of mars where there is no availability of power source thus it used solar cell to charge the battery and derive the power from the battery for the motors and other equipment. But since we are using the rover on the earth surface and our main focus is the development of mechanism rather than the power source so we will be using the cheapest possible alternative that is the 12 0 12 Step down Transformer and a Full wave Rectifier for converting the AC into DC to supply the adequate power to all motors in connection.

7. Power Distribution Circuit:

The power from the battery is equally distributed to all the six motors through the power distribution circuit. Negative terminals make 3 solder joint, positive terminals from 3 motors from both sides make 2 solder joints with 6 DPDT switches. The direction of the motor rotation is reversed by changing the input poles from the battery. Drawback of this circuit is the heating of the connecting wires due to the failure in calculating the resistance of the wires for 12V.Most common DPDT slide switch is used. A double pole double throw (DPDT) individually controls a double circuit as for a double throw has two positions (ON/OFF) as for double throw. DPDT switch has 6 terminals. A Double Pole Double Throw (DPDT) switch is a switch that has 2 inputs and 4 outputs; each input has 2 corresponding outputs that it can connect to. Each of the terminals of a double pole double switch can either be in 1 of 2 positions. This makes the double pole double throw switch a very versatile switch. With 2 inputs, it can connect to 4 different outputs. It can reroute a circuit into 2 different modes of operations. A Double Pole Double Throw Switch is actually two single poles double throw (SPDT) switches.

4.2 Design Analysis:

In order to go over an obstacle, the front wheels are forced against the obstacle by the rear wheels. The rotation of the front wheel then lifts the front of the vehicle up and over the obstacle. The middle wheel is the pressed against the obstacle by the rear wheel and pulled against the obstacle by the front, until it is lifted up and over. Finally, the rear wheel is pulled over the obstacle by the front two wheels. During each wheel's traversal of the obstacle, forward progress of the vehicle is slowed or completely halted. I will be using the same mechanism the six-wheel independent drive to cross the obstacles but without any differential. To further simplify the design, I choose to use one motor to directly drive each wheel. Since it is a skid steering rover an alternative solution could be to have one motor drive two wheels on either side, resulting in fewer motors and less mass. However, having one motor for each wheel reduces the need for a complex power transfer system, which is often done with belts, gears, or driveshafts.

The rover will aim to recognize the size and weight constraints that all space bound vehicles face. While there are many resource constraints that prohibit us from designing a space-ready rover, the design will attempt to accommodate space considerations when possible. In formulating the design specifications relating to mobility I wanted to ensure that the rover could traverse a wide variety of harsh Earth environments. Such terrain includes deserts, rock fields, gravel pits, sand dunes, and mountainous areas in many different climates. In examining these terrains, the design criteria's relating to the size of obstacles, inclines, and speeds that the rover must achieve, in order to ensure that it could maneuver in many different environments. in most scenarios the ability to go over larger obstacles always increases mobility potential. For this rover the goal is of being able to traverse obstacles, both positive and negative to the ground plane.

AutoCAD Model:

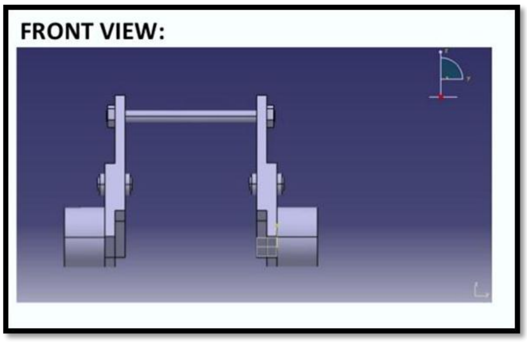

Fig 7: Front View

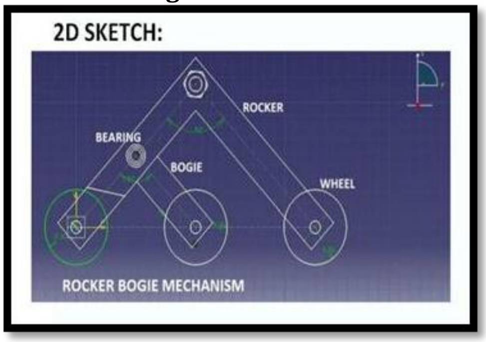

Fig 8: 2D Model

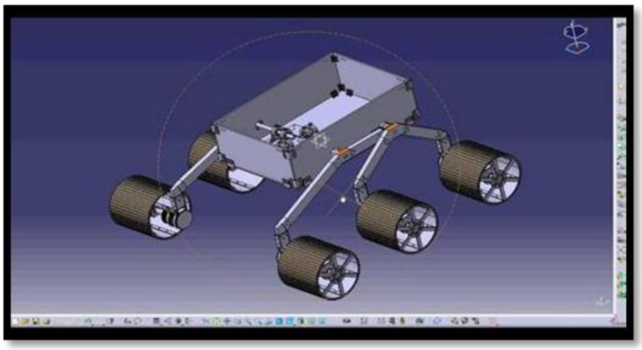

Fig 9: Assembly

4.3 Material Analysis:

Space puts all materials under severe stresses, allowing only the most robust products to survive. Testing materials for space is crucial to ensuring the devices that use them will last in the worst conditions known to humanity without a repair service anywhere in sight. Temperatures shift from high to low as an orbiting device moves into the sunlight or behind the Earth's shadow. Moving at a speed of 25,000 mph, the friction of the atmosphere will generate heat around the spacecraft up to 2,760 degrees Celsius (5,000 degrees Fahrenheit) so the material should withstand the heat and friction produced. The gravitational force drops to almost zero while entering the orbit. his shift from high to no gravitational force can affect the integrity of low-grade materials or those not designed to withstand such stresses. Materials used cannot break, bend or weaken under such effects. To thoroughly examine the strength of materials, testers run the materials through a barrage of tests for multiple stresses the materials would experience in space. The material used for the links should be cheap as well as light in weight that's why use of Acrylic material (PVC) was used which has the required properties of light weight and rigidity.

The advantage of plastic-like materials is that they produce far less "secondary radiation" than heavier materials like aluminum or lead. Secondary radiation comes from the shielding material itself. When particles of space radiation smash into atoms within the shield, they trigger tiny nuclear reactions. These lighter elements can't completely stop space radiation. But they can fragment the incoming radiation particles, greatly reducing the harmful effects. It is remarkably strong and light: it has 3 times the tensile strength of aluminum, yet is 2.6 times lighter.

4.4 Calculations:

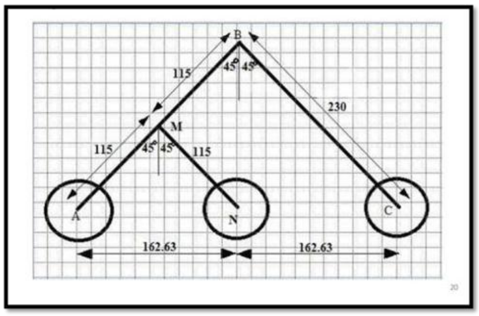

Fig 10: Calculations of Links

1.TILT ANGLE:

$\theta = \tan^{-1}(y/x)$

$\theta = \tan^{-1}(120/400) = 16.69°$

Wheel base:

To deduce the wheel base,

Wheelbase=totallength-(Radiusoffrontwheel+Radiusof rear wheel)

B=400–(35+35) B=

330mm

Length of link AC:

$BC^2=AB^2+AC^2$

$400^2=2(AB)^2$

AB= AC= 282mm

Length of link DB:

$BE^2=DB^2+ED^2$

$20^2=2(DB)^2$

DB=DE=141mm

2.HEIGHT AND TRACK WIDTH CALCULATION:

HEIGHT CALCULATION:

$Height^2= AC^2-EC^2$

$(280^2 -200^2)^{(1/2)}= 195.95mm$

Net height = height + radius

=195.5+35

=230.95mm

TRACK WIDTH CALCULATION:

SSF= Tw/(2h)

0.5= Tw(2*230.95)

Tw= 230.95 mm

5. RESULTS:

The proposed modification increases in the stability margin and proved with valuable and profitable contrasting the SSF metric with the 3D model simulations done on AUTOCAD. In future, if the system installed in heavy vehicles and conventional of road vehicles, it will definitely decrease the complexity as week as power requirements to retain bumping within it. Study of the existing models of rocker bogie suspension enabled rovers and tried to manufacture a similar kind with the material available. Therewasaslight modification with the introduction of mechanical gear type steeringsystemandinmaterialusedfortherover.

6. FUTURE SCOPE:

Asmodularresearchplatformtheroverdevelopedbythis projectis designed specifically to facilitate future work. With the development in technology the rover can be used for reconnaissance purposes with the cameras installed on the rover and minimizing the size of rover. With some developmentslikeattachingarmstotherover itcanbemade useful for the Bomb Diffusing Squad such that it can be able to cut the wires for diffusing the bomb. By the development of a bigger model it can be used for transporting man and material through a rough terrain or obstacle containing regionslikestairs. Material like plastic can be used further in development of rocker-bogie. We could develop it into a wheel chair too. It can be sent in valleys, jungles or such places where humans may face some danger. It can also be developed into low cost exploration rover that could be send for collecting information about the environment of some celestial bodies.

7. CONCLUSIONS:

This project will try reaching nearly all of our design requirements, and in many respects exceeding original design goals. Furthermore, all components, mechanical and electrical, will be thoroughly tested as a completed system in real-world field-testing conditions to validate their success. Overall, preliminary estimates for the general scope, budget, and timeline, for the project will be closely followed; with the exception if the project goes moderately over budget. This is a very wide field of study and is barely explored. So, motivated for development of Rocker Bogie Mechanism in a cost-effectivemanner.Theconcernduringthedevelopment ofRockerBogie wastooptimizethespeedoftheroversuch thatitdoesnotflipathigher speed and make it cost effective with maximum rigidity and ruggedness. Further development will enable this mechanism to be used for defence operation, wheelchairs for climbing stairs etc.

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