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DESIGN OF A MARS ROVER WITH THREE PIVOT POINT MECHANISM

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ABSTRACT

This paper deals with a mobile All-terrain vehicle which can traverse different kinds of terrains. The mechanism was tested in the UTAH Desert, USA, during the URC (University rover Challenge)-2015 competition held in May. The main aim of this mechanism is to attempt certain task in URC which were majorly 90degree fall, traversing over 60 degree inclination, moving through boulder terrain.

I. INTRODUCTION

Rovers are generally known as mobile terrain vehicles used in traverse in rough terrains. Till now we have a development of rover from four wheeled to eight wheeled but most preferred was six wheeled rover because there is a great flexibility in six wheeled and less weight when compared to eight wheeled. The most advanced mechanism that currently used in Curiosity Rover is Rocker Bogie mechanism [1]. This rover was designed according to the requirements of terrain traversing task mentioned in URC-2015 problem statement [2]. This mechanism has similar capabilities that rocker bogie can perform but simple in structure.

II. METHODOLOGY

Rover was dimensioned according to the difficulties mentioned in problem statement. This rover has 3pivot points where two bogies are in same parallel planes and third in perpendicular plane. This rover mechanism is proposed such a way that all the wheel be on ground any plane so that the load is equally distributed on the six wheels and center of gravity is maintained as low as possible. All the stress acting zones are made up of stainless steel and rest is made up of aluminum. The above figure is the complete design of the rover that is tested in UTAH desert.

Fig. 1. Catia model of Rover

The rover was 1.2m long and 0.75m width such that it can easily perform 90degree 1m fall. To traverse in different types of terrains like loose soil or hard soil mechanism and weight are not only key factors but the design of wheel also matters. The wheel was specially fabricated such that it can traverse on any type of soil. Wheel has hollow sections to avoid slip in loose soil and grousers to provide traction. Wheel rim is made up of aluminum and 250mm in diameter, coupler is made up of stainless steel and grouser's are made up of neoprene and cut in required size and shape. These grousers were attached to wheel rim using Allen bolts. Totally each wheel contains 12 grousers. These are equally spaced such that one grouser's leaves the contact surface with ground immediately other comes in contact.

Fig. 2. Wheel

When traversing in the terrain the rocks might hit the motors to avoid this problem a C structure was designed to join bogie and wheel where the motor body is inside the C structure. This structure is made up of stainless steel.

Fig. 3. C-leg

When there is bigger obstacle occurred there are chances that bogie may topple due to lack of force to push rover above the rock. So to prevent this nylon stoppers have been introduced above the three pivot points to prevent toppling.

For a smooth turn zero axis turn have been added to the rover. Where the middle wheels are fixed and rest four are actuated by linear actuator such that while turning the rover makes a circular turn in same place without any dragging of wheels.

2.1 Wheel

Wheeled mobile robots such as planetary rovers are required to traverse over rough and deformable terrain. Rovers will slip when they climb up deformable slopes. On the contrary, the wheels will skid in the longitudinal direction in order to generate resistance force to balance the gravity component when a rover moves down the slopes. The wheel-terrain interaction principles of slip versus skid are quite different, thus new challenges are brought to the control of mobile robots but there is little research about the longitudinal skid mechanics and the relationship of it with the slip mechanics. We hope to analyze the problem of longitudinal slip and skid that occur to a wheel on the slopes with the knowledge of terramechanics. Wheel-soil interaction terra mechanics is the basic theory of analyzing wheel slip and skid. Some key soil parameters are internal friction angle, shear deformation modulus, Lumped pressure sinkage coefficient.

Table.1

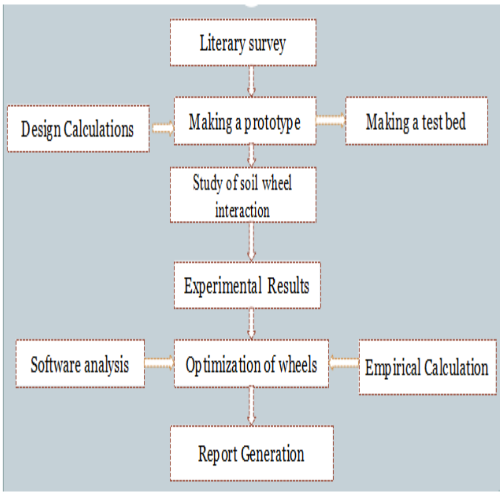
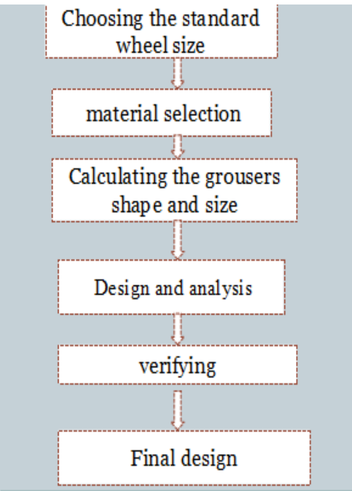


Table.2



2.2 Parameters Effecting Slip And Skid

1. Sinkage
2. Slip ratio
3. Wheel load
4. Soil parameters
5. Grousers

2.3 Calculations

1. Determine the of spacing between two grousers
2. Determining the size and shape of the grousers
3. Calculating the load capabilities of grouser material
4. Determining the various parameter getting effected by the change in pattern (shape ,size, number)
5. Determining the various parameters will be changed when different material is used
6. Analyzing and comparison ability to attach to the rim

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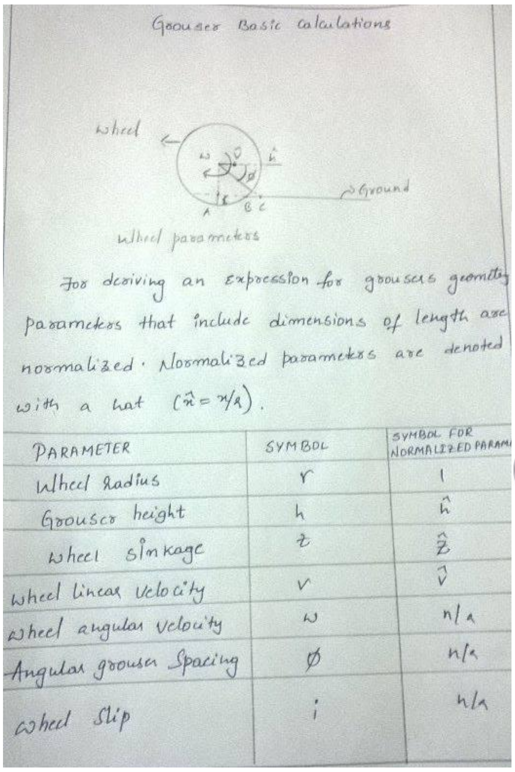
Grouser Basic calculations

wheel parameters

For deriving an expression for grousers geometry parameters that include dimensions of length are normalized. Normalized parameters are denoted with a hat $(\hat{x} = x/r)$.

PARAMETER	SYMBOL	SYMBOL FOR NORMALIZED PARAM
Wheel Radius	r	1
Grouser height	h	$\hat{h}$
wheel sinkage	z	$\hat{z}$
wheel linear velocity	v	$\hat{v}$
wheel angular velocity	ω	n/a
Angular grouser Spacing	ϕ	n/a
wheel slip	i	n/a

Fig.4

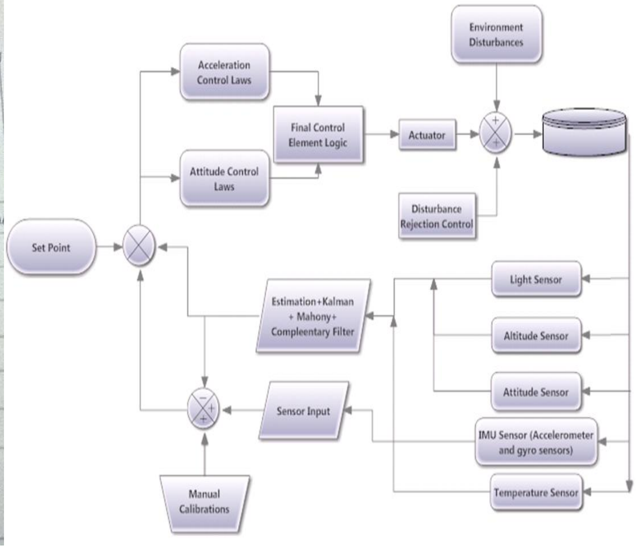

Fig.5

III. ROVER ELECTRONICS

3.1 Sensor Subsystem Overview Rover Control Loop

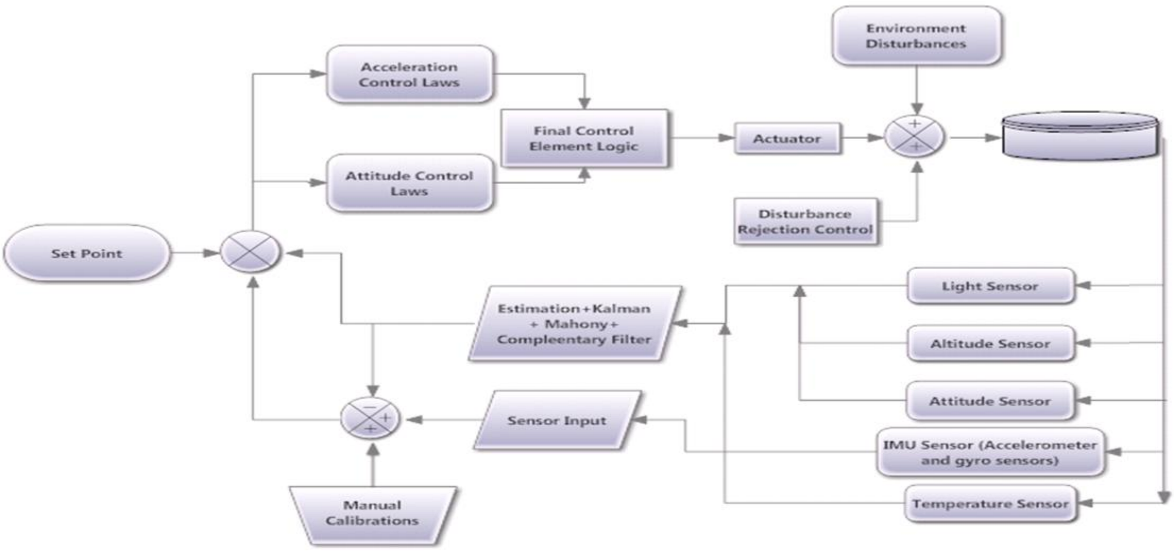

Fig 6.

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3.2 Sensor Subsystem Design Rover Drive

Table.3

Sl.No	Component Description	Purpose
1	MPU6000 (Rover Drive)	Rover Attitude and Heading Angle Me asurement
2	MPU6000(Rover Arm)	Arm Orientation Measurements
3	Mediatek 33 29	GPS Navigation
4	MS5611	Pressure and Temperature Measuremen ts

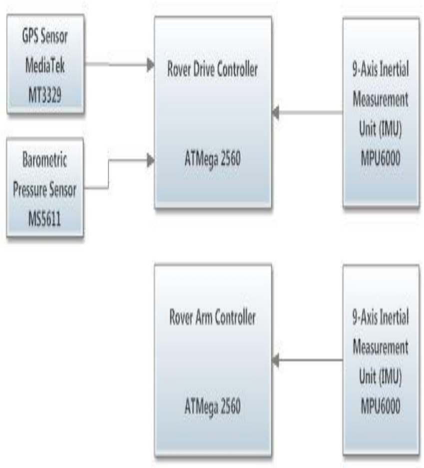

Fig.7

Rover was equipped different sensors to control the rover in non-line of sight. Like Potentiometer to get the real time feedback links of the rover , GPS for mapping and navigation of rover , Pressure and temperature sensor to measure the surrounding condition and to control rover accordingly , Gyroscope and Accelerometer sensor to get the Arm and rover orientation with respect ground level and other sensor are mentioned in the table3 . Every sensor tested separately and simulated in a custom made GUI .some of the testing are included in the Fig 7.

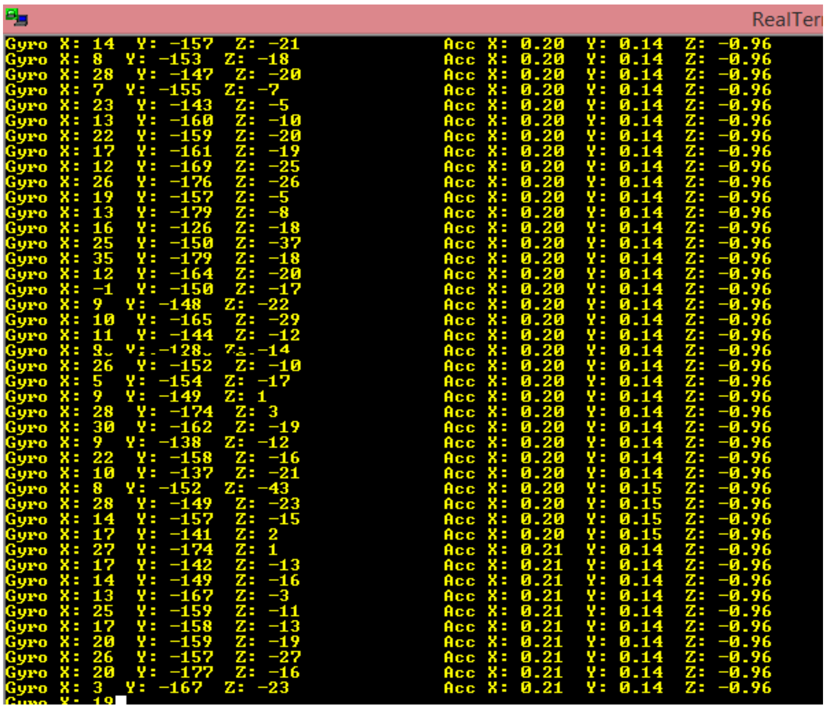

Fig.8

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3.3 Drives and Control For Automation

Drive Motor-RS775 (Bane Bots) six high torque motors are used as main driving element for the rover.

Fig.9

Table 4

Motor(RS775) Specification	
Operating Voltage	6 V -20V
Nominal Voltage	18 V
No load speed	19500 RPM
No Load Current	2.7 A
Stall Torque	1175mN-m
Stall Current	130 A
Efficiency	76.8%

The motor in the Fig.9 is selected for the locomotion of rover. This motor was selected on the basic of torque and speed calculation and other parameter which is listed in the table 4. This motor comes with different gear reduction ratio 1:64, 1:132, 1:256. We used 1:256 as our major requirement was torque and speed is of less importance.

3.4 Drive Motor Control

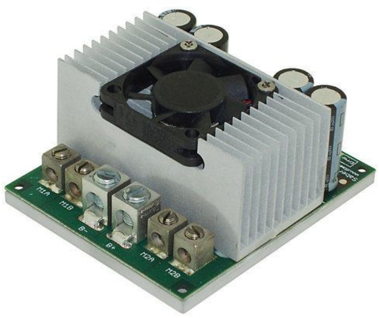

Fig.10

Specifications (Sabertooth 2×60)	
Input Voltage(Nominal)	6-30V
Input Voltage(Absolute Max)	33.6V
Output Current	Up to 60A conti nuous per chann el
Peak Loads Current	120 A peak per c hannel

Saber tooth is used control the motor speed, This motor drive is uniquely found motor driver where in Dual motor can be controlled at a time .This enables to control the motion of two motors so as to run the motor and synchronous speed. As the motor which are of high torque and current rating this driver enables us with Thermal and over current protection. This motor driver has built 6 modes of operation, we use Lithium protection mode and the baud rate between driver and controller can be selected by using different configuration DTP switches .

IV. POWER UNIT AND CIRCUITRY

4.1 Electrical Power Distribution Rover Drive

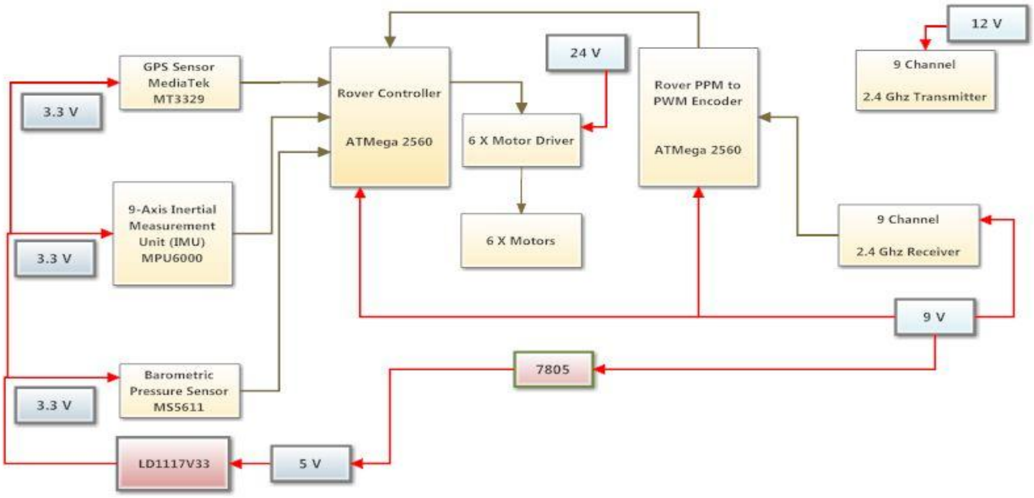

Fig.11

The whole rover control is given under Atmega2560, which we consider as the brain of whole rover which was powered by the voltage regulator through VIN. The rover motor driver control, GPS, 9-Axis accelerometer, Barometer and different peripherals for different task requirements, this rover was made modular like individual system for individual task. Basically 9 channel receiver was used to control the whole rover special band of signal is used to access the rover control, the frequency of operation is carefully closed such that the signals can penetrate into and pass, as the requirement was to perform task which is not of line of sight and in a range of 1.5km minimum.

4.2 Controller Interface Board- Schematic Files and Board File

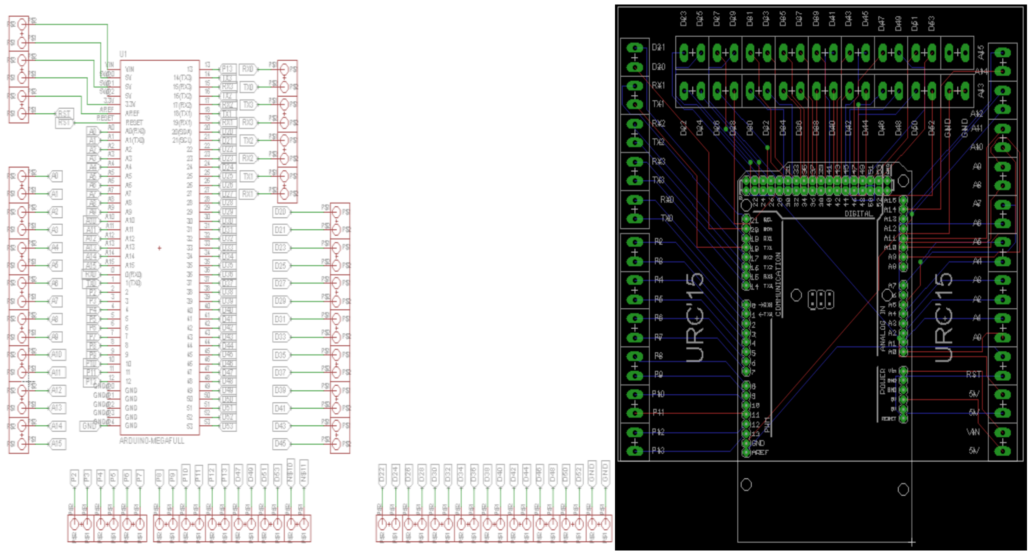

Fig.12

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4.3 Electrical Power Budget and Endurance

Sr.No	Component	Voltage (V)	Current (Amps)	Power (W)
1	Drive Motor (X6)	21	60	1260
2	ASUS Router	21	1.5	31.5
3	HIK VISION	12	1.5	18
	Total		63 Amps	1309.5

- The Battery Selected is 8000mah 5S Lithium Polymer Battery and 2 such sets are connected in Parallel to increase the Total Charge
- Considering the Discharge Rate of 30C , the total available Charge is : 2 X 30 X 8000mah
- The Total Current Consumption is : 63Amps
- **Thus the Time of Flight/Endurance is : 480 /63 = 7.6 hour**

Fig.13

4.4 Power Distribution

The Power requirements of the rover can be

Classified as follow:

1. Motors, Linear actuators and Servos Power requirements.
2. Control systems power requirements.
3. Routers power requirements.
4. Cameras Power requirements.

This time we are using MCBs as it has an inbuilt fuse.

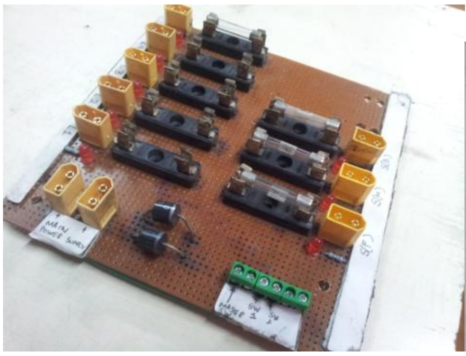

Fig.14 **Fig.15**

This is helpful in increasing the safety measures of roverand making the system more compact.

1. Battery Voltage measurement is done by reading microcontroller's Analog Channel. Microcontroller can take maximum of 3.3 Volts as Analog Input. So, Voltage divider is used to read voltage measurement.
2. We will be using the ADC pin of Atmega 2560to measure the voltage, which has a resolution of 10 bits. (3.3V/210 =3.22mV)
3. We will be using high valued resistors to make a voltage

4. Divider circuit and bring the voltage from 9v to 3.3v.
5. Resistors are 100K and 41K.
6. Choosing High Value resistors will decrease the amountof Current drawn.
7. Weight and space occupied by this circuit is negligible.

V. COMMUNICATION

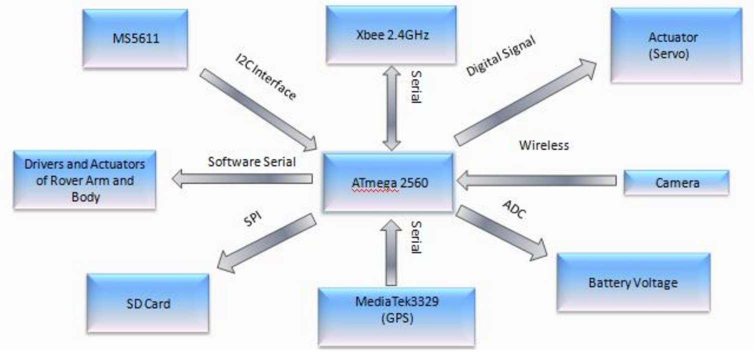

Fig.16

Atmega 2560 controller considered to be brain of whole rover , The main aim of any mars rover is to control it from non-line of sight place in order achieve that we used different frequency control for different system . Like we divided our system to Rover drive and arm control , Data communication , Video communication . For data communication we used Xbee protocol , for Video communication we used 2.4Ghz Radio wave for transmission of video live so as to control the rover with live streaming video . To avoid loss of data and to reduce the garbage data certain algorithm is used which involves Transmission of data from the Rover will take place through continuous acknowledgment from the Ground Station.Only fully correct telemetry data string will be considered and acknowledged by the Ground Station and will be counted as 1 packet count.Any junk data string will not be acknowledged and hence Rover will not receive the acknowledgment signal.A timeout of acknowledgment will trigger the Rover to store it in an error log file.The method is using CRC(Cyclic Redundancy Check) i.e. adding a redundant code at the end of the data to check the consistency of the received data.This method will guarantee the correctness of the data string. Any error in the string will not receive an acknowledgment and hence will be stored in the error log.

VI. RESULT

Finally three pivot point mechanism with mechanical stopper which avoided rover to topple while traversing has been designed and tested in UTAH Desert, USA.

VII. SCOPE

1. Not only in the mars surface. This rover can be used in remote areas where transportation of materials is difficult.
2. Planetary exploration-Spirit's final troubles began in April 2009, when it got stuck in a patch of Martian sand. Engineers worked for eight months attempting to free the rover, but to no avail. In its stationary

position, Spirit's solar panels weren't able to tilt toward the sun and so it lost power during the winter of 2009 and 2010.

3. In many daily life applications there will be definite slip and skid occurring which is a major loss to power and energy.
4. Many Agricultural and beach patrol applications

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