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R.A.T.L.E.R.

Robotic All-Terrain Lunar Exploration Rover

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A robotic rover vehicle designed for use in the exploration of the Lunar surface is described. The Robotic All-Terrain Lunar Exploration Rover (R.A.T.L.E.R.) is a four wheeled all-wheel-drive dual-body vehicle. A uniquely simple method of chassis articulation is employed which allows all four wheels to remain in contact with the ground, even while climbing over step-like obstacles as large as 1.3 wheel diameters. Skid steering and modular construction are used to produce a simple, rugged, highly agile mobility chassis with a reduction in the number of parts required when compared to current designs being considered for planetary exploration missions. The design configuration, mobility parameters, and performance of several existing R.A.T.L.E.R. prototypes are discussed.

INTRODUCTION

In 1989 President George Bush called for the establishment of a U.S. Space Exploration Initiative with the goals of returning to the Moon to stay and a manned mission to Mars. Subsequent national studies such as NASA's 90-Day Study[1] and the Synthesis Report[2] have led to significant renewed interest in robotic precursor missions for exploration of the Moon. The recent Lunar Rover/Mobility Systems Workshop[3], conducted by NASA's Exploration Program Office and the Lunar Planetary Institute, proposed two initial missions and established some criteria for Lunar rover platforms.

For Lunar exploration missions lasting one Lunar day or longer, a robotic rover system must combine high agility and efficient thermal management with radiation hardness to assure a high probability of mission success in that extreme operating environment. Low launch mass, high reliability, and robustness of the system are highly desirable characteristics as well, since the vehicle will not be readily accessible for repair or recovery once it has been deployed. Engineers at Sandia National Laboratory have recently demonstrated an innovative concept for a robotic rover vehicle designed for use in the exploration of the Lunar surface. The design configuration, mobility parameters, and performance of several prototypes of this vehicle are discussed below.

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VEHICLE DESCRIPTION

The Robotic All-Terrain Lunar Exploration Rover (R.A.T.L.E.R.) is a four wheeled all-wheel-drive platform with twin body compartments connected by a hollow central pivot. The general configuration is shown in Figure 1, which is a three-view schematic of the dual-body central-pivot design for which a patent has been applied.

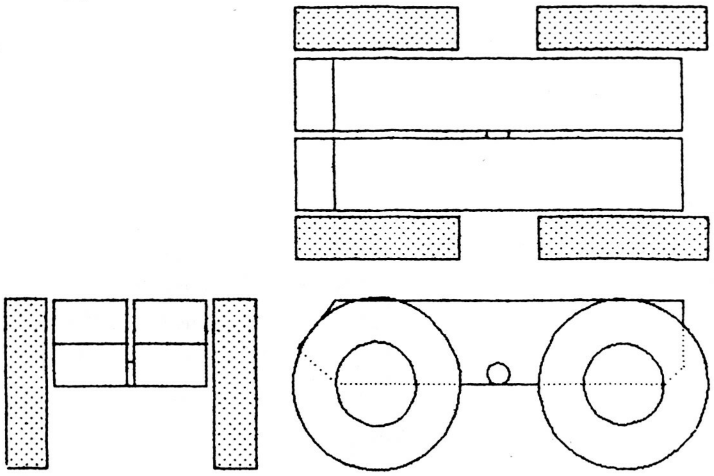

Figure 1. R.A.T.L.E.R. Schematic.

The uniquely simple method of chassis articulation by means of the hollow central pivot is employed between the bodies to allow all four wheels to remain in contact with the ground while traversing uneven terrain. This central pivot, as well as the vehicle center of mass, is located as close to the axle line and the geometric center of the vehicle as possible to ensure maximum stability while climbing over large obstacles. The articulating action of the dual-body central-pivot is illustrated in Figure 2, which is a picture of the first remotely controlled prototype being driven over some large rocks in Death Valley.

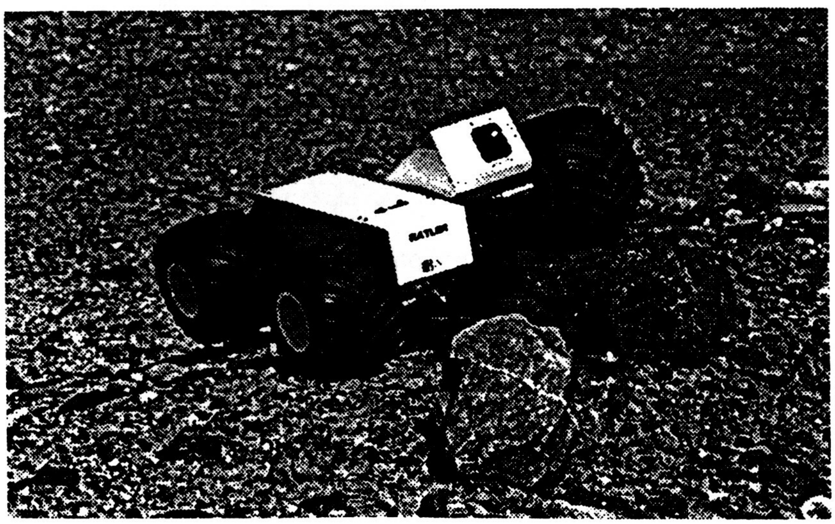

Figure 2. R.A.T.L.E.R. Prototype at Death Valley.

ANALYSIS

Only four situations have been analyzed to date for the R.A.T.L.E.R.: 1) the maximum height vertical step which can be cleared, 2) the optimum wheelbase for a given wheel diameter, 3) an estimate of the optimum stance, and 4) the traction advantage of the dual-body central-pivot design over a conventional four wheeled platform.

Figure 3 shows a schematic of the maximum step height problem. From the geometry, the maximum step height H which can be climbed is

1) $$H_{max} = \sqrt{B^2 - R^2}$$

where B is the wheelbase and R is the wheel radius. The ground clearance is assumed to equal to the wheel radius, and the center of mass is assumed to be centered along the line of axles so that the vehicle will not tip over backwards.

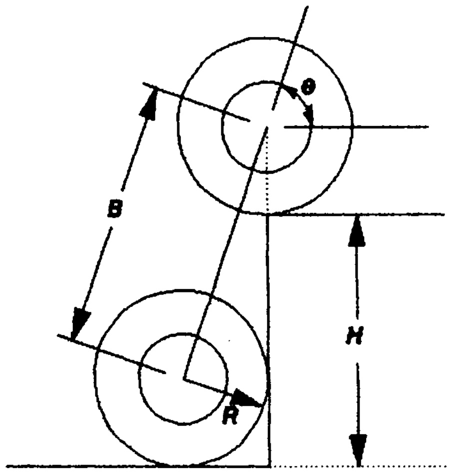

Figure 3. Maximum step clearance geometry.

Constructing a figure similar to Figure 3 but without the rear wheel touching the vertical face of the step, it can be shown that for any angle θ there is a minimum height

2) $$H_{min} = R(1+\tan\theta)$$

such that the vehicle bottom will scrape on all steps with height H if

3) $$H_{min} < H < H_{max}$$

In terms of the geometry

4) $$H = B\sin\theta$$

and therefore no scraping will occur as long as

5) $$B\sin\theta < R(1+\tan\theta)$$

The bottom will just touch the point of the step if the inequality in Equation (5) is instead an equality. Assuming the equality and differentiating with respect to θ, it can be shown that a minimum occurs when

6) $$\sin\theta = \cos\theta$$

The optimum value of B for no bottom scraping is then

7) $$B = 2\sqrt{2}\ R$$

Using the above result in Equation (1), the maximum step height that a vehicle with optimized wheelbase can climb is

8) $$H_{max} = \sqrt{7}\ R$$

which is 1.32 wheel diameters. A similar analysis using Equation (8), assuming hemispherical boulders, and neglecting wheel width, shows that the optimum stance S must be in the range

9) $$S < 3.74\ R$$

A much more complicated analysis of the step problem, which will not be repeated here, shows that when only one side of the vehicle climbs a step, the leverage advantage of the articulating R.A.T.L.E.R. design requires only half as much torque to climb the step as a conventional four wheeled platform. This is intuitively obvious since only "half" of the R.A.T.L.E.R. vehicle is traversing the obstacle. Alternatively, if the two vehicles have equal torque, the R.A.T.L.E.R. design can climb steps which are slicker by almost a factor of two (the coefficient of friction equations are not linear).

PROTOTYPES AND TESTS

The original prototype was a small, unpowered, uncontrolled balsa model about six inches long which was used to verify that the dual-body central-pivot concept would traverse large obstacles and had some advantages over conventional platforms. Several other models were then constructed to investigate conventional steering versus skid steering, body shapes, tethered controls, remote RF controls, and even solar power use.

The first large scale prototype, incorporating the best ideas from all of the early models, is the one shown in Figure 2 which has been dubbed the "White R.A.T.L.E.R.". This model is about 15 inches long with a balsa, mylar, and plastic tubing chassis. The drive system consists of four 7/8ths inch dia by 3 inches long constant speed DC electric motors reclaimed from the DOE weapons program. Skid steering is used. The control system is a model aircraft radio control set coupled to microswitches for motor control and standard servo setups for the internal tilt of the miniature CCD onboard camera. The entire system, including the remote video transmitter, is powered by a series of 9V transistor radio batteries. This prototype has been tested extensively for obstacle climbing abilities, and once in the sands at Death Valley.

Three subsequent prototypes, all using skid steering, have been constructed and are now undergoing extensive testing at Sandia and on the dunes at White Sands National Monument (WSNM). One is an eleven pound aluminum replica of the White R.A.T.L.E.R. powered by a series of 12V gelcells, and with an external pan and tilt miniature CCD camera. The second unit is an 8 inch Pygmy R.A.T.L.E.R. with external pan and tilt CCD camera, miniature video transmitter, and variable speed drive system for the wheels. The last unit is a flat plate body testbed with variable speed drive system, designed so that the stance, ground clearance, pivot height, and pivot limits can be easily changed. All three systems have been tested in damp gypsum sand at WSNM and can climb 18-22 degree slopes. A dry, powdery sand test with the Pygmy R.A.T.L.E.R. showed the potential for climbing even steeper slopes, but further tests are needed to verify this observation.

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