INFLATABLE ROVERS FOR PLANETARY APPLICATIONS

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ABSTRACT

A new task has recently been initiated at the Jet Propulsion Laboratory (JPL) to design, fabricate and test an inflatable rover that can be used for various planetary applications, including operation on the Earth's moon, on Mars, on Saturn's moon Titan and on Jupiter's moon, Europa. The primary application is for operation on Mars and, as such, the prototype model in development has large inflatable wheels (1.5-m diameter) that can traverse over 99 percent of the Martian surface, which is believed to be populated by rocks smaller than 0.5 meters in diameter. The 20-kg prototype requires 18 W to travel 2 km/hr on Earth, and could be capable of traveling 30 km/hr on Mars with about 100 W of power. The bench-model unit has been tested with a simple 'joy stick' type of radio control system as well as with a commercially available color-tracking camera system.

Key words: robotics, rover, planetary, Mars, Titan, inflatable

INTRODUCTION

All present and planned planetary rovers now use a 4- or 6-wheeled vehicle that may vary in size from the 1-kg nanorover to the 60-kg Athena rover (50-cm tall). The 16-kg Mars Pathfinder Sojourner rover[1] that roamed Mars in 1998 used a 6-wheeled 'rocker-bogey' design that is very similar to the Athena-class rovers scheduled to fly in 2003 and after. All these design concepts have control algorithms that avoid large rocks and are generally relatively slow. For example, during the entire one-month operation of Sojourner, the rover only traveled about 100 meters total distance, with 7 meters the maximum distance traveled in a single day.

The primary purpose in developing an inflatable rover has been to greatly increase travelling speeds and distances while minimizing mass, packing volume and complexity. Designs progressed from the very simple to the more complex in attempting to meet speed, reliability and packing constraints.

INFLATABLE ROVER DESIGN EVOLUTION

Originally, a one-wheeled, inflatable, beach ball rover was conceived[2] that could be blown by the wind on the Martian surface (Fig. 1). With simple beach ball tests done in the windy Mojave Desert of Southern California, it quickly became apparent that beach balls could easily get stuck in the bottom of craters or in rocky regions. There was also the added problem that these beach ball rovers might be damaged if blown too quickly across rocky terrains.

Next, a two-wheeled vehicle[3] was attempted with an internal motor that would generate minimal torque to help the rover get out of holes or rocky traps (Fig. 2). Scale models showed that, again, the rover could too easily become trapped, since larger torque amounts were required for adequate control.

Thus, a third wheel was added to the rover to greatly increase applied torque. With small-scale models, various-sized wheels were attempted. It was found that if any of the three wheels was small or skinny, the rover could again become easily trapped. With three inflatable beach ball tires, it was found that the rover could easily climb over step rocks that were one-third the diameter of the wheels, but not over step rocks as large as one-half the diameter of the wheels, regardless of the amount of torque applied. Thus, it became necessary to estimate the required wheel size. It has been estimated that in the 5% rockiest regions of Mars, rocks of 0.5 m or higher cover approximately 1% of the surface area[4]. Accordingly, a wheel size of 1.5-m diameter was chosen to allow the rover to traverse well over 99% of the Martian surface.

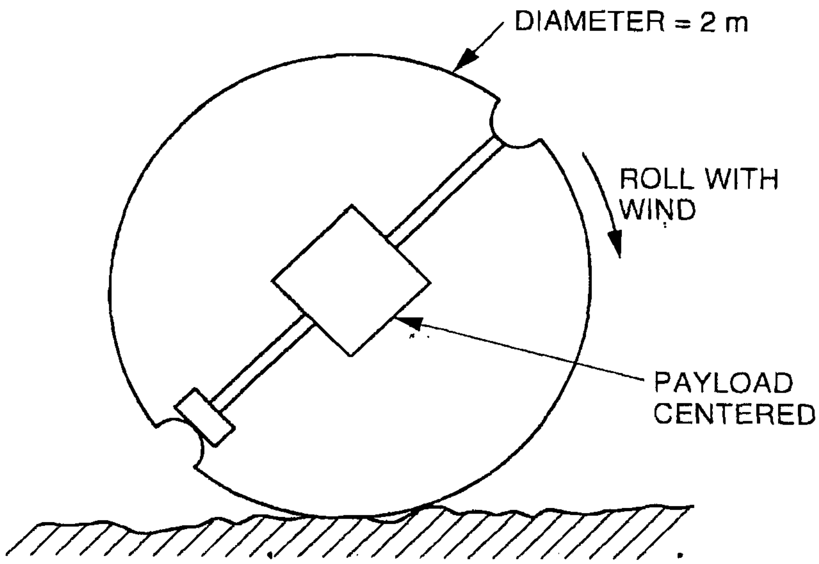

Figure 1a. Rolling mode.

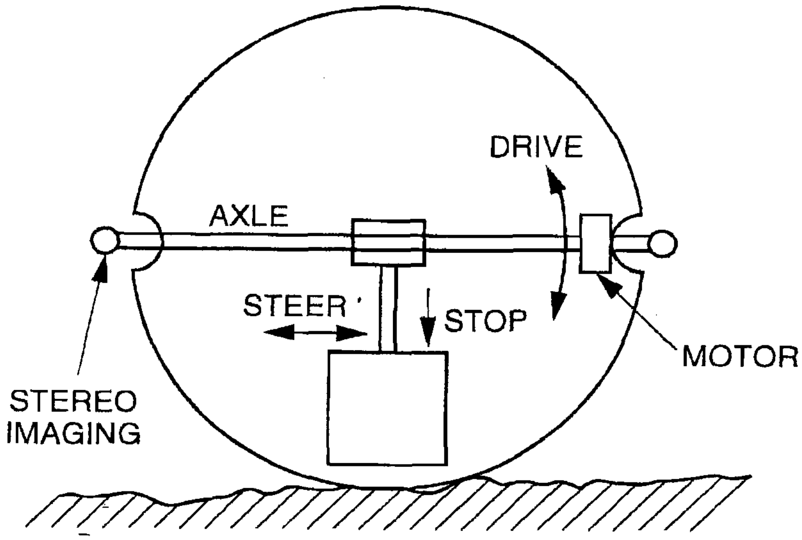

Figure 1b. Stop and Explore mode.

Figure 1: Early One-Wheeled 'Beach Ball' Wind Rover

Various means of connecting the third wheel to the rover were tried, and the design that was most versatile was similar to a conventional tricycle. Two small motors were chosen to power the two drive wheels, which were fabricated from nylon balloons, enhanced with tread for traction. Test results[5] of this design (Fig. 3) showed excellent control over a wide variety of terrains, including rocky canyons and sand dunes (simulating Mars), as well as calm lakes (simulating liquid methane lakes anticipated on Titan). The present prototype has successfully stood up to 13 m/sec (30 mph) gusts, which is equivalent in force to 130 m/sec gusts in the extremely thin Martian atmosphere (0.006 bar pressure).

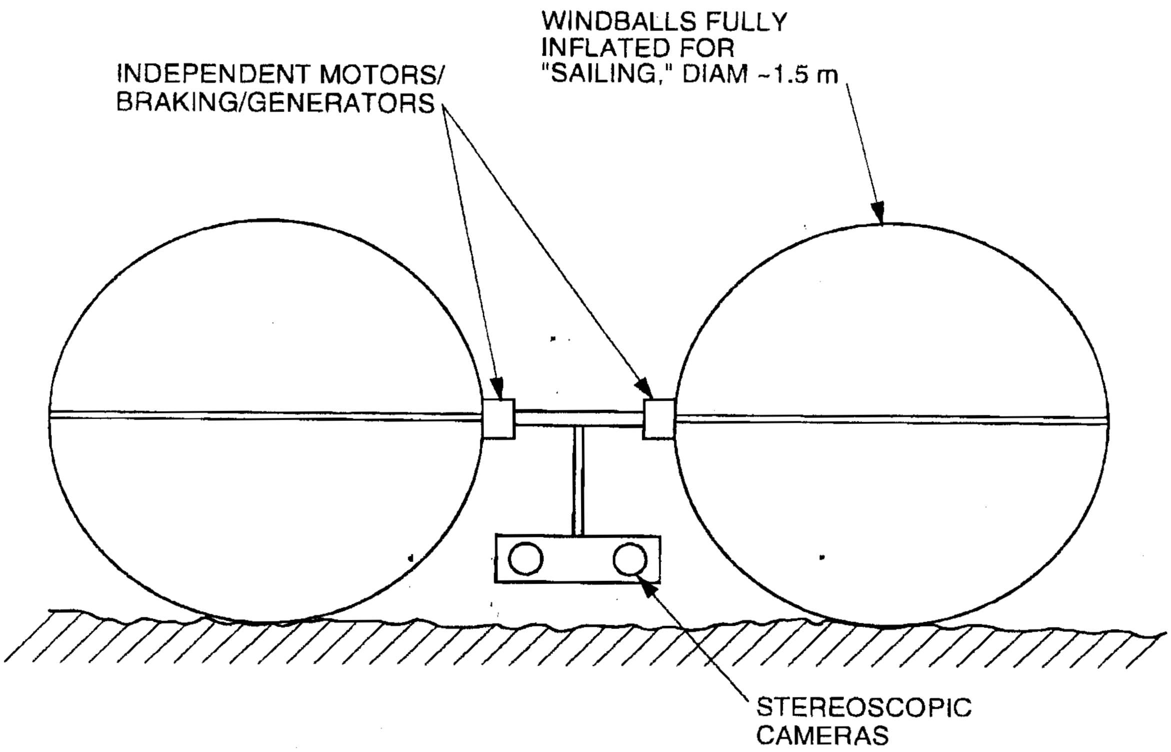

Figure 2a. Front view.

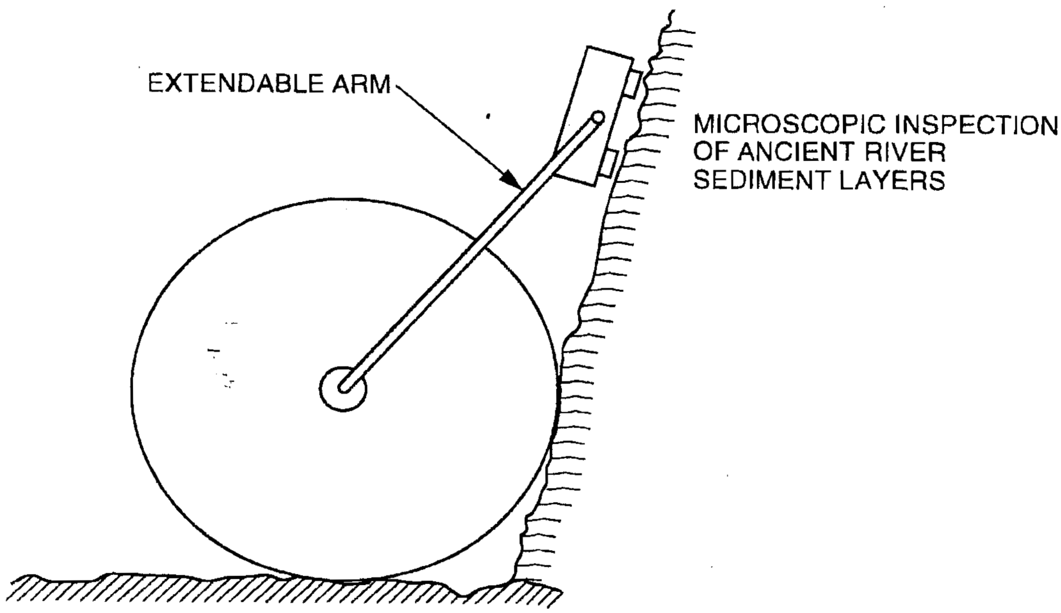

Figure 2b. Side view.

Figure 2: Operation of Two-Wheeled Wind Rover.

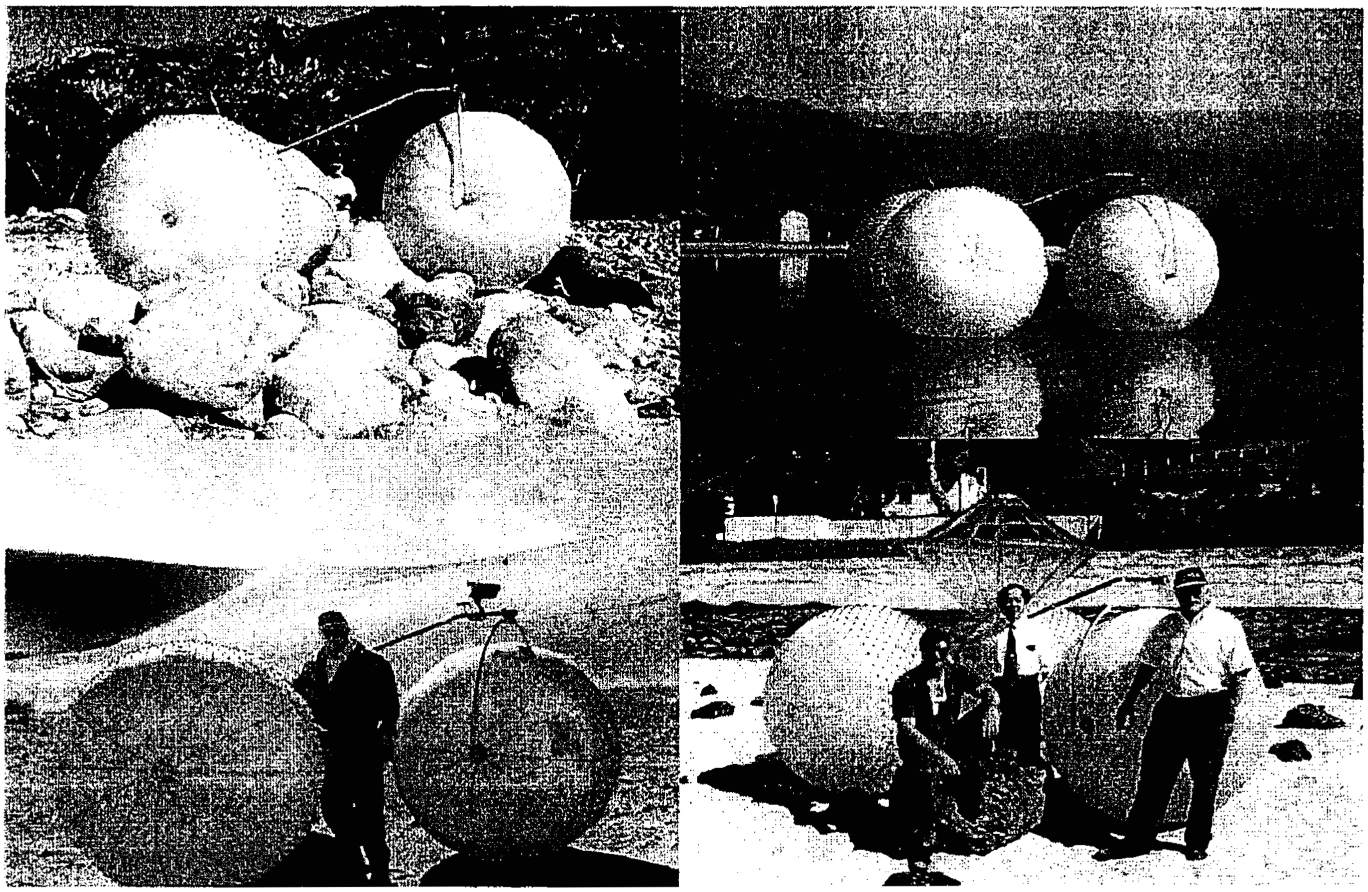

Figure 3: The Inflatable Rover Drives On All Terrains.

The first full-size bench model is shown with an inflatable solar array that is sized to produce over 100 W of electrical power on Mars (Fig. 4d). The 20-kg prototype rover has two Micro Mo coreless motors with planetary reduction gears. The two motors propel the rover at 2.0 km/hr, using only 18 W of power on level terrain (Figs. 4 and 5). Considering Mars's reduced gravity of 0.38 g, the available 100 W of power could propel the vehicle at almost 30 km/hr over level terrain.

For the tests, steering was accomplished either by differential power applied to the two drive wheels, or by using a simple motorized worm gear on a forward steering tire.

ELECTRONIC CONTROL

Most of the original testing was accomplished using a simple 'joy-stick' type radio control system, as modified from a commercial model toy racing kit. It was found that use of the third wheel as a directional steering system provided much better control than attempting to manually differentiate power to the two rear wheels.

Testing has also been conducted using a novel, commercially available, color-tracking Sony TV video camera (model EVI-D30). The camera can be locked onto a specific color target and can update tracking of that target five times per second. Furthermore, it can track angular changes as high as 80 degrees per second. Preliminary tracking tests have thus been very successful, and the rover easily tracked and followed the blue shirt of a NASA 'astronaut' as he walked in a random manner through several hundred meters of a rocky canyon. Subsequent tests, however, showed that the camera had difficulty in locking onto rocks that were colored similar to ambient ground colors.

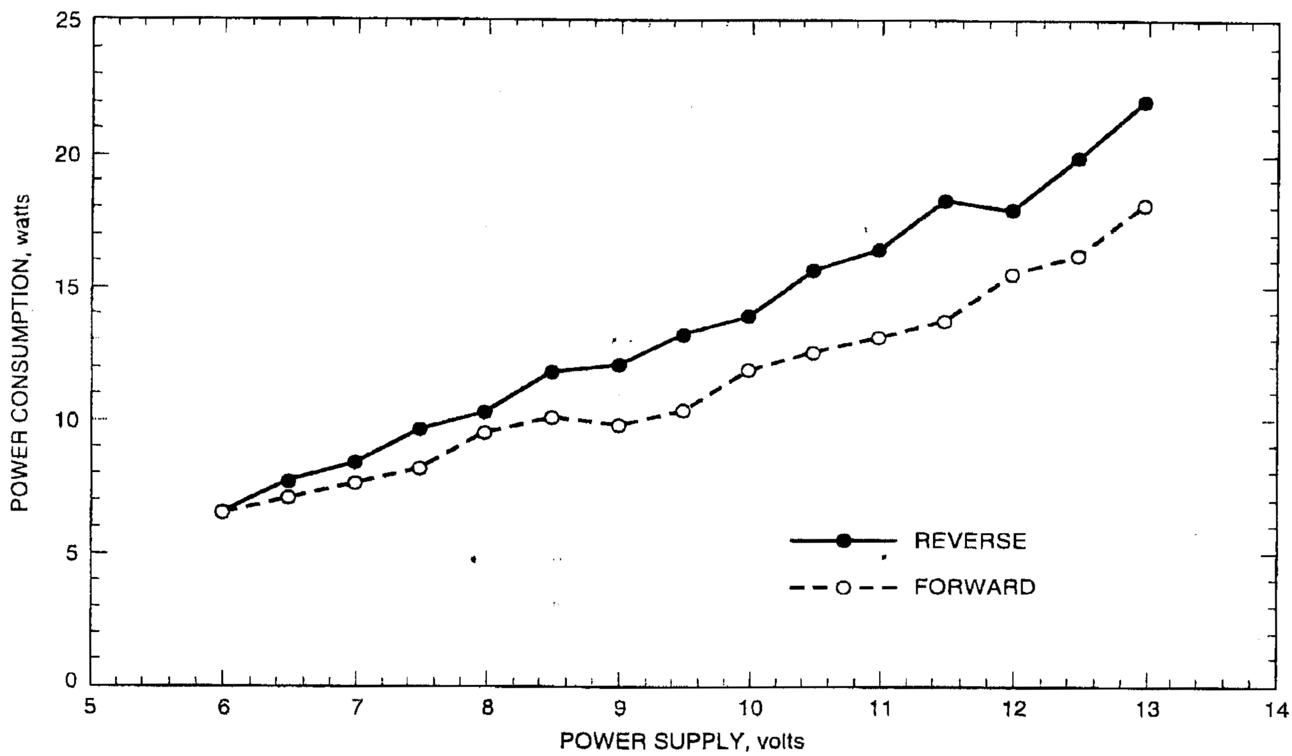

Figure 4: Power Consumption of Inflatable Rover on Earth.

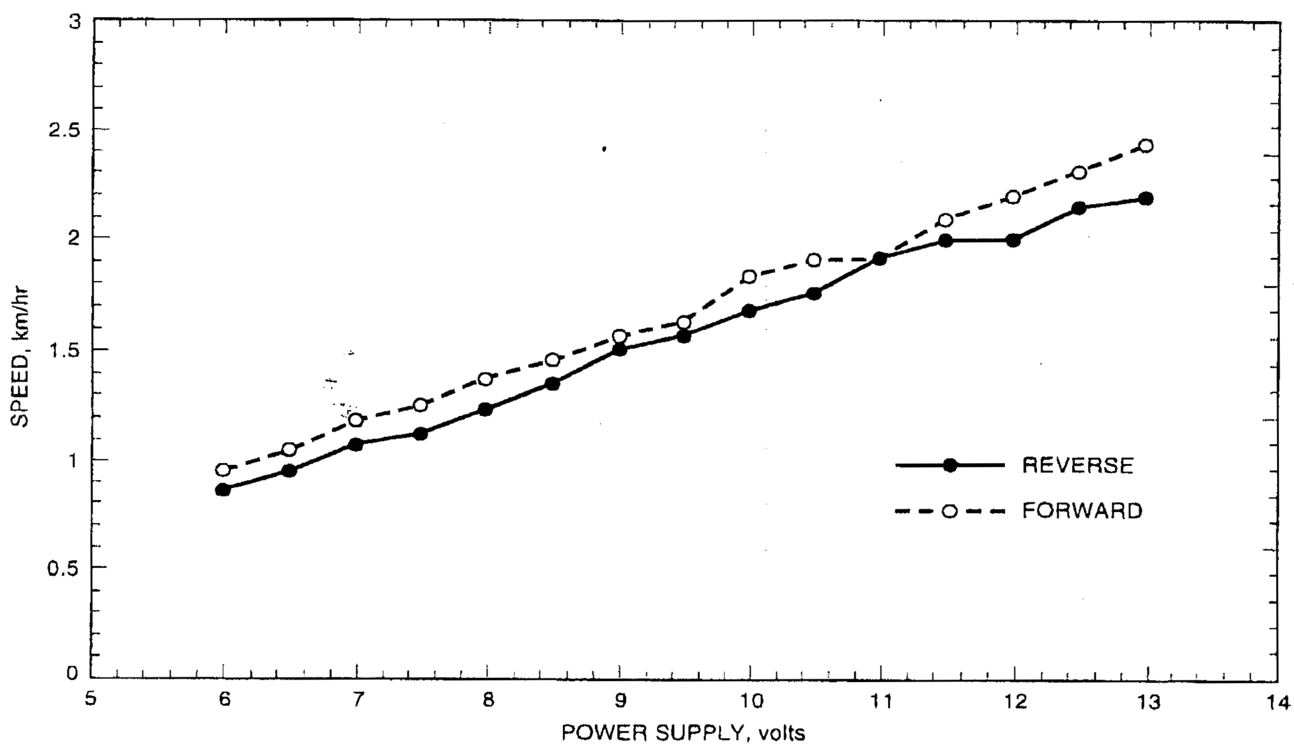

Figure 5: Speed of Inflatable Rover on Earth.

FUTURE WORK

During fiscal year 2000, plans exist to develop more rugged kevlar or PBO wheels with a silicon or polyurethane inner bladder, along with a scale model collapsible chassis for the rover. All materials will be selected to withstand the Martian 170K nights, as well as Titan's 90K surface. Also, an image recognition system will be integrated, as available from Rocky[6] or FIDO[7], and the rover will demonstrate the ability to travel to pre-selected objects. In addition, the rover chassis will be modified to allow the Inflatable Rover to collect, transport and deploy at least three nano-rovers to preselected sites.

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