Inflatable Robotics for Planetary Applications

Jack A. Jones
Jiunn-Jeng Wu

Background

A new type of planetary rover, known as the Inflatable Rover, has been under development at JPL since 1998. The general purpose of the rover has been to develop large, rugged, lightweight wheels that can be used to traverse the rocky terrains characteristic on Mars. Large wheels can greatly increase a rover's versatility, speed, and range by going *over* the rocks, instead of *around* them.

It has been estimated that in the 5% rockiest regions of Mars, approximately 1% of the surface is covered by rocks of 0.5 m or higher. Early tests with scale models showed that inflatable rovers could easily scale rocks that were 1/3 the diameter of the wheels. Thus a wheel size of 1.5 m diameter was chosen to allow the rover to traverse well over 99% of the Martian surface. In order to minimize mass and complexity, a three-wheeled vehicle was chosen with a wide wheel base to enhance stability in rugged and steep terrain.

Present Mars rover designs have relatively slow speeds and ranges, due primarily to the relatively small wheels. For example, Pathfinder's Sojourner only traveled 100 m in its month of operation on Mars in 1997, and the Mars '03 rover has a maximum anticipated range of only 100 m per day.

Inflatable Rover Testing

The first full-size bench model of the Inflatable Rover has two 1.5-meter diameter rear-drive wheels with a forward steering wheel of the same size. 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. Considering Mars' reduced gravity of 0.38 g, 18 W of power could propel the vehicle at about 5 km/hr in level terrain.

The forward-steering tire is driven in direction by a simple motorized worm gear and provides excellent control. All motors are operated at 12 V DC and are battery-powered for the bench model. The large, inflated spherical wheels allow the rover to swallow most smaller rocks, while providing a large contact surface to climb steep hills or over larger rocks, and to maintain excellent ground contact during wind storms. A FIDO autonomous control system has recently been added to the rover. Sun-synchronous operation and hazard avoidance algorithms are anticipated to be added this year.

The original tires, fabricated in 1999, were made from commercial nylon balloons with rubber treads attached to enhance traction. New tires, manufactured by B.F. Goodrich Aerospace in 2000, have now been successfully tested on rover 10 km of rugged lava and rock terrain. The tires contain an inner Vectran tire and an outer Spectra tire. Vectran is the material used in the Mars Pathfinder landing air bags, while Spectra is a sturdy, anti-penetrant material.

Titan Amphibious Aerover

The Inflatable Rover has also been successfully tested on calm lakes, similar to the liquid methane lakes anticipated to be on Saturn's moon Titan. It has also been proposed to use three 2-meter diameter tires on the vehicle, such that when inflated with helium, a 50 kg rover mass can be floated in the heavy nitrogen Titan atmosphere (93 K, 1.5 bar). Numerous ascents and descents to the Titan surface are possible by using venting/ballasting, or other altitude control techniques which are presently under study at JPL. After completing the aerobot portion of this mission, the rover's tires could be filled with ambient nitrogen, with the rover acting as an amphibious vehicle to explore Titan's solid and liquid surfaces.

Planetary Windballs

It has also been proposed for a single beachball-like tire to carry a central payload, such as a 2 kg nanorover. Wind would transport the ball to different locations, and controlled braking could occur by means of deflating the windball or lowering its center of mass. The contained nanorover could then exit the ball by means of an enclosed tunnel, and explore the planetary surface. After local exploration is complete, the nanorover could re-enter the windball, which would be re-inflated to be blown to another location. Studies of this type of mobility are currently under consideration for Mars and Saturn's moon Titan, as well as for the 10-20 microbar environments anticipated at Pluto, Jupiter's moon Io, and Neptune's moon Triton.

Summary

Development of the Inflatable Rover will allow rovers to travel tens of kilometers in a single day, as opposed to only 100 m per day with the Mars '03 rover. The use of inflatables to increase speed and range is a critical enabling technology that will allow robotic outpost development (transporting other rovers to distant sites); transportation of astronauts; and long-distance transfer of heavy equipment or in situ resources, such as water ice from the Martian north pole.

Another application area includes use as an amphibious aerover for Titan, wherein the rover can act as an aerobot when the tires are filled with helium and as an amphibious rover when the tires are filled with ambient nitrogen. Investigations are also being made as to viability for containing a payload in a single tire that is transported by wind from one location to the next. Possible planetary applications include Mars and Saturn's moon Titan, as well as the microbar environments on Pluto, Jupiter's moon Io, and Neptune's moon Triton.