assumed to be much heavier than the other and having much larger moments of inertia. The resulting simplified equations of motion were integrated numerically for several cases, obtaining their force and moment histories.

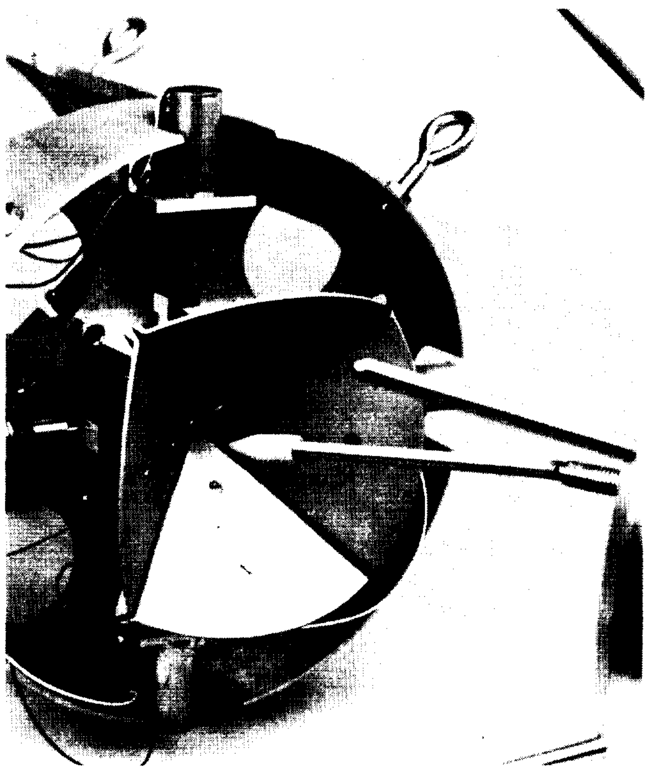

Fig. 1 Student-designed grappling/docking mechanism. Deployable capture cone (left), flexible probe (right).

Models were constructed to demonstrate feasibility. Through testing it was shown that a reliable docking could be accomplished with lateral misalignments of up to one half of the spacecraft radius, and angular misalignments of up to twenty degrees. While there is a significant amount of hardware involved in the grappling mechanism, it is simple, and only a small part of it would have to be on the spacecraft. The larger, heavier, and more complex capture cone would be on the servicing vehicle, under the assumption that one such spacecraft could service several spacecraft. The weight penalty to a spacecraft incorporating such a system would not be insignificant, but would be well justified for missions requiring periodic maintenance, and possibly for other missions as well.

HARDWARE DESIGN OF A SPHERICAL MINI-ROVER

John Tarlton

Abstract

In this hardware project the students designed the prototype of a novel mini-rover for the exploration of a planetary surface. In an actual application, a large number of such miniature roving devices would be released from a landing craft. Each rover would be equipped with a Cd 109 radio-isotope source (a gamma ray emitter) irradiating the planetary surface below the rover, and an x-ray fluorescence detector for a quantitative assay of high atomic weight elements in the planet's surface. (Similar, miniaturized, hand-held devices have recently been developed for use in gold mines). The device developed by the students was limited to demonstrating the mechanical and electrical drive. The geometric external shape is a sphere; hence there is no danger of the rover being turned on its back and stopped. Propulsion is by means of an interior mass, eccentric to the sphere and driven by an electric motor. In an inter-disciplinary effort in mechanical and electrical engineering, the students designed the mechanical parts, built the transistorized circuit board, and tested the device.

Introduction

Robotic planetary exploration vehicles have been designed at a number of research centers. An example is Rocky III, designed and built at the NASA Jet Propulsion Laboratory. It has already demonstrated its ability to go over rough terrain and to pick up rock or soil samples with its manipulator arm. Another well-known example is the Russian Mars rover Marsokhod.

While most planetary rovers use some form of wheels for locomotion, we decided to develop an extremely simple miniature vehicle having the shape of a sphere. Propulsion is by means of a mass, interior to the sphere. The torque from an electric motor lifts the eccentric mass against gravity, thereby inducing a rotation of the sphere. A prototype, designed by the students and built by the University machine shop, is shown in Figure 2.

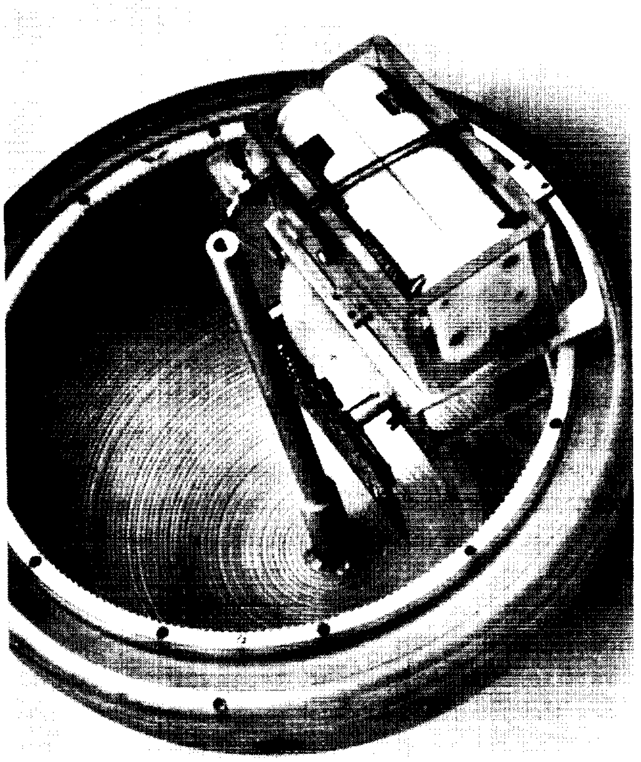

Fig. 2 Student-designed prototype of a spherical mini-rover for planetary exploration

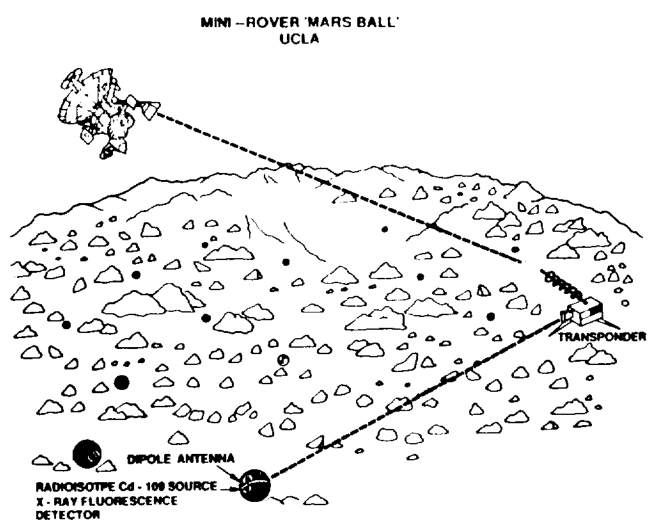

Fig. 3 Random motion, spherical mini-rovers released from a landing craft on Mars

In an actual application to planetary exploration, a large number of these spheres, each one perhaps no larger than five inches in diameter, would be released from a planetary lander. Their paths on a rough surface would be essentially random (Figure 3). In contrast to wheeled vehicles that can tip over, the eccentric mass and its drive mechanism can be designed such that no matter the orientation of the sphere, it can always recover the orientation needed for forward motion.

Mechanical and Electrical Design

The model designed by the students is limited to demonstrating the mechanical and electrical drive of such a rover. In an actual application, the spheres would be equipped with a cadmium 109 radio-isotope source (a gamma ray emitter), irradiating the planetary surface below. A germanium crystal detector then would receive the x-ray fluorescence resulting from the gamma rays, and would allow one to determine the composition by elements, even if present only in trace amounts. A miniaturized, hand-held device of this type has recently been developed by the South African Bureau of Mines for use in gold mines.

The mini-rover designed by the students has the following features: (1) An eccentric, rotating mass consisting primarily of the source of electric power (dry cells); (2) a DC permanent magnet electric motor driving a pinion and ring-gear; (3) a circuit board for the control of the motor; (4) two hemispherical shells, electrically insulated from each other, which - in an actual application - would be used as a dipole antenna for data transmission (Figure 4). The similarities and differences between the student-designed rover and an actual mini-rover of this type are listed in Table 1.

An additional feature of the student-designed device is the rover's capability to back-off and reverse course when stopped by an obstacle such as a rock. Circuitry is provided to determine when the motor current exceeds a set threshold, an indication that the motor has stalled. If so, after a two-second time interval, the motor current is reversed. The rover then backs off and starts on a new path. In an interdisciplinary effort, the students designed not only the mechanical parts, but also designed and built the circuit board (Figure 5).

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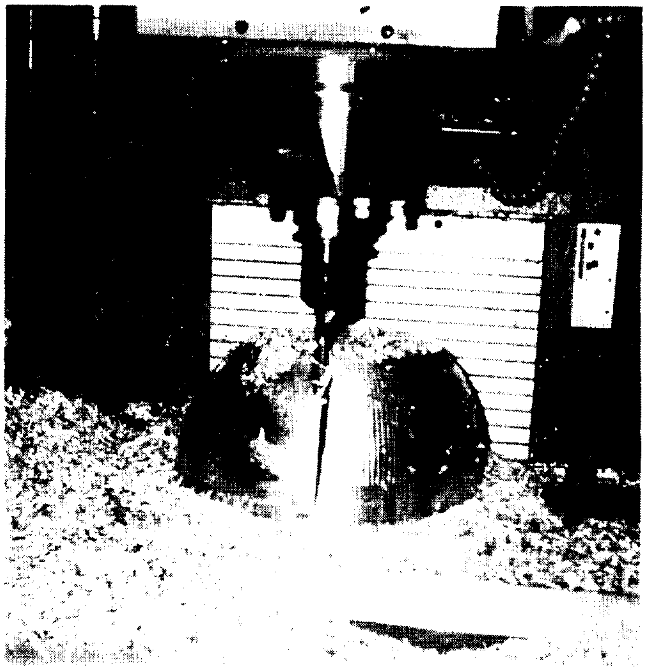

Fig. 4 Fabrication of mini-rover shell on CNC machine

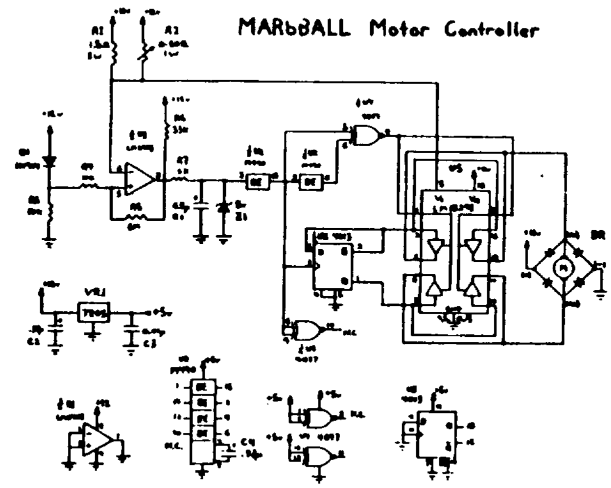

Fig. 5 Student-built circuit board for mini-rover

Table 1 Comparison of student-designed rover with actual rover

UCLA Model	An actual mini-rover
• Spherical, driven by eccentric interior mass	• Same
• Random walk motion	• Same
• Backs off automatically when stopped by obstacle.	• Same
• Dipole antenna	• Same
• Not simulated	• Cd 109 radioisotope source (100 millicurie) and Ge X-ray detectors for determination of trace elements in the ground
• Powered by dry-cells	• Powered by radioisotope thermal generator
• Not simulated	• Data processing and rf transmission to orbiting spacecraft