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SUMMARY OF 1991-1992 PROJECTS

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HARDWARE DESIGN OF A GRAPPLING/DOCKING DEVICE ACCOMMODATING LARGE LATERAL AND ANGULAR MISALIGNMENTS

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Abstract

In this hardware project, continued from last year, the students developed ideas for a new grappling and docking mechanism that would be able to accommodate a very large initial misalignment (up to one half of the spacecraft radius) and simultaneously a large angular misalignment (up to 20 degrees) between space tug and space vehicle. The students were made familiar with the project by visiting TRW, where they could study the prototype of the NASA Orbiting Maneuvering Vehicle (OMV, since canceled). The students' objective was to design a model, built in the University machine shop, that would demonstrate the potential for much larger misalignments than was possible with the OMV.

Introduction

In modern space operations, it is often necessary for two spacecraft to provide services to one another, such as orbital corrections, propellant replenishment, or repairs. These operations nearly always require that the spacecraft are rigidly linked to one another, requiring a grappling or docking procedure. Several such methods have been used or proposed in the past: Examples are the docking of Apollo capsules to Skylab and the Lunar Descent Modules, TRW's Orbital Maneuvering Vehicle, and the Space Shuttle fleet's mechanical arm for grappling satellites.

As was evidenced by NASA's recent difficulties in capturing an errant satellite for repair, the methods of spacecraft docking currently in use are still difficult to apply. Due to intolerance to even slight misalignments, very accurate (and therefore expensive) control of the spacecraft's relative positions is required, and even then a successful maneuver cannot always be assured. This motivated our design and construction of a spacecraft docking mechanism that would be extremely tolerant of both angular and translational misalignments.

Mechanical and Electrical Design

The device consists of two mechanisms, one on each vehicle (Figure 1). One spacecraft has a long, flexible docking probe which would be deployed before the docking procedure. The other vehicle (the tug) is equipped with a funnel-shaped capture cone, which is also deployed in flight. As the two vehicles come together, the tip of the probe slides toward the apex of the capture cone, where it is latched. The probe is then retracted, pulling the vehicles together and, at the same time, collapsing the capture cone. All motions are carried out electro-mechanically. At the end of the maneuver, the vehicles are rigidly linked, which would then allow the transfer of propellant, the application of thrust, or whatever else is required.

The dynamics of the capture is, at least in principle, very complicated, since it involves twelve degrees of freedom (six for each vehicle). To simplify the analysis, the probe was considered to be telescoping, with specified spring and damping characteristics. The forces and moments on the two spacecraft were computed as functions of the relative displacements and velocities. To further simplify the analysis, one of the vehicles was 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.

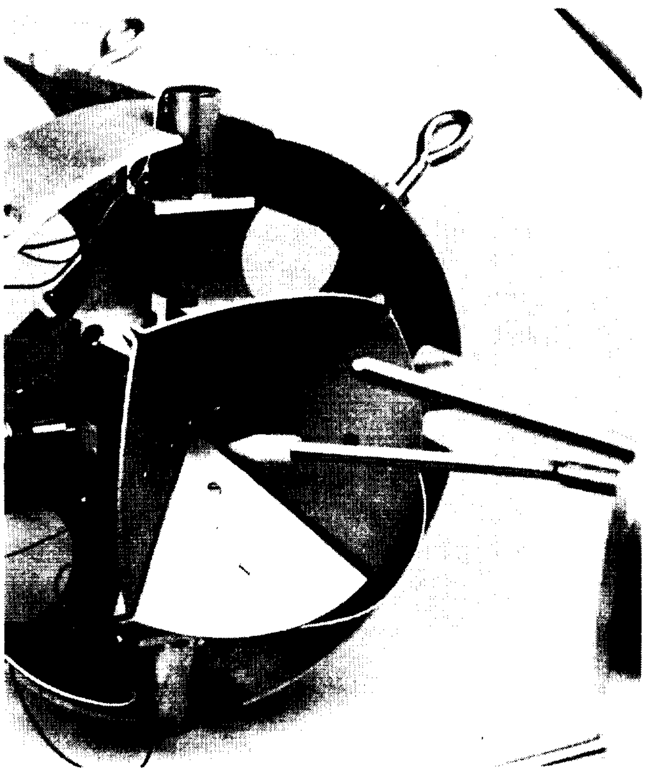

Fig. 1 Student-designed grappling/docking mechanism. Deployable capture cone (left), flexible probe (right).

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.