the requirements for meshing and noninterference.

A tooth-contact-analysis computer program has been developed for simulation of meshing and contact of the proposed worms and face worm gears. In a test case, the program showed that, as desired, the function of transmission errors would be a parabolic function of low magnitude, the contact would be localized, and the path of contact would be longitudinal in the sense that it would lie along the gear-tooth surfaces. The program also showed that the bearing contact region would be free of areas of severe contact stresses and that the contact ratio would be larger than 3 (signifying that at any given instant, there would be at least 3 pairs of teeth in contact).

This work was done by Faydor L. Litvin, Alessandro Nava, Qi Fan, and Alfonso Fuentes of the University of Illinois for **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17596-1.

Alternative Way of Shifting Mass To Move a Spherical Robot

A payload would change its position by lengthening and shortening suspension cables.

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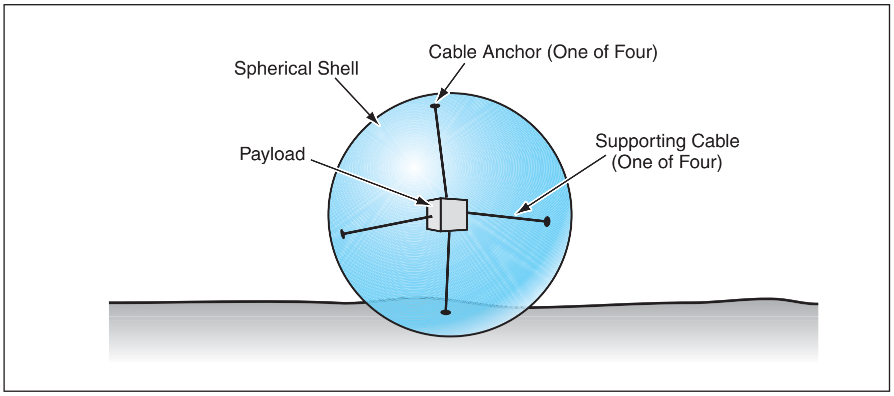
An alternative method of controlled shifting of the center of mass has been proposed as a means of locomotion of a robot that comprises mostly a payload inside a hollow, approximately spherical shell. The method would be applicable to robots that include rigid, semirigid, or flexible inflated shells, including those of the "beach-ball rover" type, variants of which have been described in several previous *NASA Tech Briefs* articles.

A prior method, to which the method now proposed would be an alternative, was described in "'Beach-Ball' Robotic Rovers" (NPO-19272), *NASA Tech Briefs*, Vol. 19, No. 11 (November 1995), page 83. To recapitulate: Three diametral tethers approximately perpendicular to each other would be attached to the shell, effectively defining an approximate Cartesian coordinate system within the shell. A control box containing motors and power and control circuits would move itself along the tethers and adjust the lengths of the tethers in a coordinated fashion to shift the center of gravity and thereby cause the shell to roll in a desired direction.

The method now proposed calls for suspending a payload by use of four or more cables that would be anchored to the inner surface of the sphere. In this method, the anchor points would not be diametrally opposite points defining Cartesian axes. The payload, which includes the functional analog of the aforementioned control box, would contain winches that would shorten or lengthen the cables in a coordinated manner to shift the position of the payload within the shell.

In a typical case, the locomotion system would include four cables anchored at approximately the corners of a regular tetrahedron (see figure). Optionally, one could use more than four cables for redundancy against potential failure and/or as a means of distributing the weight of the payload to multiple anchor points to reduce localized stress on the spherical shell. The arrangement of anchor points would not be critical as long as they defined at least three different axes of motion in at least two different planes; hence, the proposed method would afford robustness of motion control in the face of deformation of the spherical shell.



The **Payload Would Contain Winches** that would extend some cables while retracting others to move itself to a specified position within the spherical shell.

Simple wires could be used to connect the payload to any sensors mounted on the outer or inner surface of the shell. The wires would have to be long enough to reach the maximum distance, and would have to hang slack when the distance was less. Because there would be little rotation between the payload and the spherical shell, it is unlikely that the wires would become tangled; however, one might wish to include spring-loaded retractors to minimize the probability of entanglement.

In the case of a flexible shell, all the cables supporting the payload could be retracted or extended to some extent to increase or decrease, respectively, the pressure of gas inside the shell. Another option would be to include spring-loaded supporting cables not connected to winches, in addition to those that were connected to winches; this option may make it possible to reduce the number of winches while obtaining an adequate range of motion.

Yet another option would be to use rigid rods and linear actuators instead of cables and winches. However, rods and linear actuators would probably weigh more than would cables and winches. Moreover, this option would not be compatible with a flexible shell.

This work was done by James Lux of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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