DAMPING SPRING

for

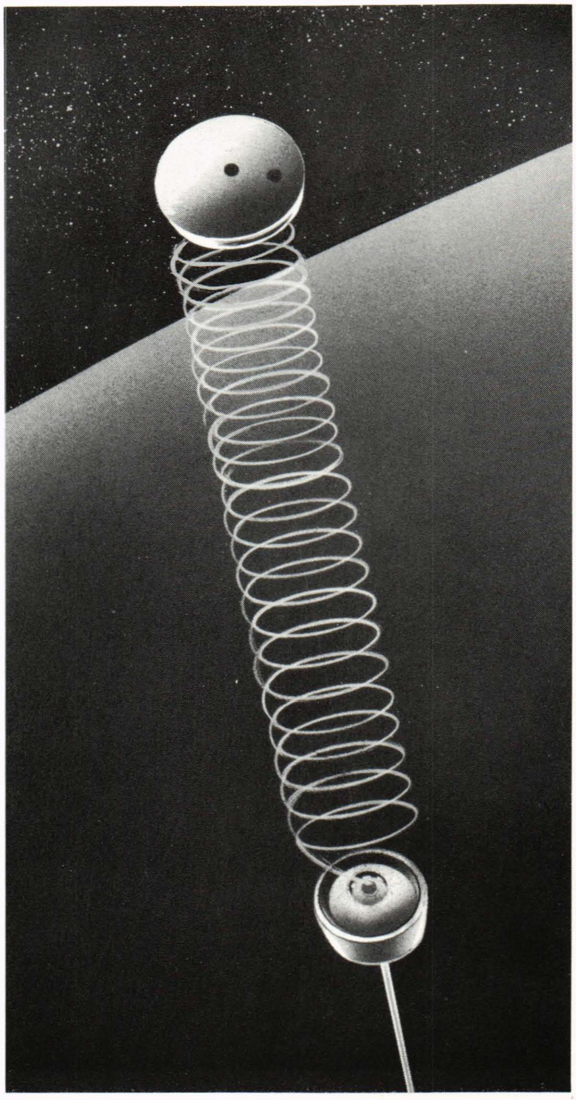
Gravity-Stabilized Satellites

Many experimental and practical applications of satellites are best achieved if these orbiting bodies can be vertically stabilized. A method of doing this, called gravity attitude stabilization, has been developed at APL.[1] It incorporates a boom, attached to the satellite, and a damping spring extending from it with a weight attached to its outer extremity.

Bringing a satellite to a gravity-stabilized attitude requires that oscillations about the local vertical be damped out to dissipate the libration energy of the satellite. Viewing this problem as it applied to the Navy's navigational satellite, R. R. Newton suggested use of an oscillating spring, with its inherent energy loss due to internal friction. The actual damping spring was developed by R. E. Fischell and his co-workers.

The first need was to find a spring weak enough that the slight difference between gravitational forces acting on either end of the satellite could deploy it to a considerable length. It was calculated[1] that the force due to a mass of 5 lb at the end of the spring would pull it out 40 ft.

The spring also had to be weak enough that the oscillations of the satellite (with a natural period of about one hour) would cause appreciable spring motion, producing a finite energy loss for each oscillation; a spring constant of 1.5×10^{-6} lb/ft was found desirable. A 7.25-in.-maximum-diameter spring was then fabricated of 7-mil beryllium-copper wire, a material which has an extremely low hysteresis loss under the stress to which the spring would be subjected. To enhance its energy-dissipating characteristics, the wire was plated with a 2-mil thickness of lead. The result was that the energy loss per cycle of the coated spring was increased from less than 1.0% for the bare wire to



TRAAC spring with associated end mass is shown partially deployed from its subliming material.

[1] R. E. Fischell, "The TRAAC Satellite," *APL Technical Digest*, **1**, Jan-Feb, 1962, 2–9.

9.0% with the plating. The dissipation was constant for oscillation periods from 2 to 7 min.

To determine the effectiveness of the spring under the expected environmental conditions, which also involved longer natural periods, a torsional pendulum using the spring material was then built and tested in a large vacuum chamber. Unfortunately, when the period of oscillation was increased to an hour in vacuum, the lead plating failed to provide adequate damping. Thus another material had to be found. Cadmium was ultimately selected since tests showed that an 0.8-mil coating of this metal gave an adequate dissipation of 15%. Finally, a 0.2-mil plating of silver was applied over the cadmium to prevent its sublimation in the environment of outer space.

The remaining problems to be solved were survival of the weak spring through the rigorous launching stresses and its subsequent slow deployment from the orbiting satellite. Both difficulties were overcome simultaneously by encapsulating the spring in the rapidly-subliming aromatic compound, biphenyl.

The completed spring was used in the experimental TRAAC satellite launched in Nov. 1961. While the boom did not deploy, the spring and its associated end mass apparently did so to a limited extent. To verify this, a deliberate rocking motion about the local magnetic field direction was induced by means of the electromagnet in the satellite. Normally, the satellite magnetic damping rods would damp these oscillations from approximately 70° to 10° in a 5-day period. However, after the spring deployed, the satellite oscillations damped from 70° to less than 10° in about 100 min. This rate could only have been caused by the damping action of the spring, which could produce such a result when deployed to a length of 2 ft.

The spring was last checked in June 1962, seven months after launching, and was found to have retained its high damping characteristics.