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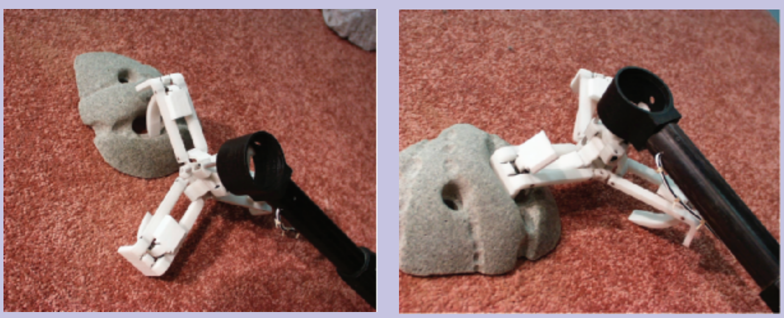
BASIC HOOK
Hooks Onto Flats or Over Lips

CAM HOOK
Self Locking Cam
Between Walls of a Crack

CAM
Self Locking Mechanism for
Wide Cracks or Pockets

Figure 1. **Equipment Now Used by Human Rock Climbers** includes specially designed hooks, cams, and hook-and-cam assemblies. Elements of these items are being incorporated into robotic end effectors for rock climbing.



AID HOOK IN ACTION **CAM HOOK IN ACTION**

Figure 2. The **Advanced Hook Emulator** can function in a variety of modes. The aid-hook and cam-hook modes shown here correspond to the modes of operation of the conventional basic hook and cam hook, respectively, depicted in Figure 1.

fector causes the tip to rotate within the crack, creating a passive, self-locking action of the hook relative to the crack. In the advanced hook emulator, the aid hook is pushed into its retracted position by contact with the cliff face as the cam hook tip is inserted into the crack. When a cliff face contains relatively large pockets or cracks, another type of passive self-locking can be used. Emulating the function of the piece of climbing equipment called a "cam" (note: not the same as a "cam hook"; see Figure 1), the fingers can be fully retracted and the entire end effector inserted into the feature. The fingers are then extended as far as the feature allows. Any weight then transferred to the end effector will tend to extend the fingers further due to frictional force, passively increasing the grip on the feature. In addition to the climbing modes, these end effectors can be used to walk on (either on the palm or the fingertips) and to grasp objects by fully extending the fingers.

This work was done by Brett Kennedy and Patrick Leger of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40224

Improved Nutation Damper for a Spin-Stabilized Spacecraft

Goddard Space Flight Center, Greenbelt, Maryland

A document proposes an improved liquid-ring nutation damper for a spin-stabilized spacecraft. The improvement addresses the problem of accommodating thermal expansion of the damping liquid. Heretofore, the problem has been solved by either (1) filling the ring completely with liquid and accommodating expansion by attaching a bellows or (2) partially filling the ring and accepting the formation of bubbles. The disadvantage of (1) is that a bellows is expensive and may not be reliable; the disadvantage of (2) is that bubbles can cause fluid lockup and consequent loss of damping. In the improved damper, the ring would be nearly completely filled with liquid, and expansion would be accommodated, but not by a bellows. Instead, an escape tube would be attached to the ring. The escape tube would be positioned and oriented so that the artificial gravitation and the associated buoyant force generated by the spin of the spacecraft would cause the bubbles to migrate toward the tip of the tube. In addition, when the spacecraft was on the launch pad, the escape tube would be at the top of the ring, so that bubbles would rise into the tube.

This work was done by Mark A. Woodard of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*
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