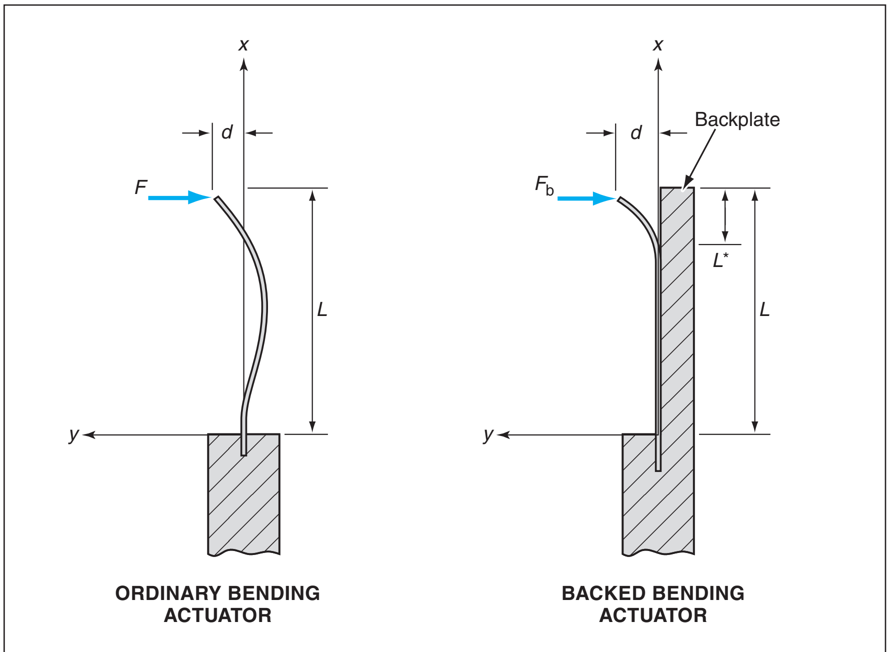


A **Backed Bending Actuator** would resemble an ordinary bending actuator except that it would include a backplate that would enable a large displacement together with a large force at small displacements.

expansion or contraction of the bonded layers. The bending, displacement, and tip force of the backed bending actuator are calculated similarly, except that it is necessary to account for the fact that the force F_b that resists the displacement of the tip could be sufficient to push part of the strip against the backplate; in such a condition, the cantilever beam would be effectively shortened (length L^*) and thereby stiffened and, hence, made capable of exerting a greater tip force for a given degree of differential expansion or contraction of the bonded layers.

Taking all of these effects into account, the cantilever-beam equations show that F_b would be approximately inversely proportional to $d^{1/2}$ for d less than a calculable amount, denoted the transition displacement (d_t). For $d < d_t$, part of the strip would be pressed against the backplate. Therefore, the force F_b would be very large for d at or near zero and would decrease as d increases toward d_t. At $d > d_t$, none of the strip would be pressed against the backplate and F_b would equal the tip force F of the corresponding ordinary bending actuator. The advantage of the proposal is that a backed bending actuator could be made long to obtain large displacement when it encountered little resistance but it could also exert a large zero-displacement force, so that it could more easily start the movement of a large mass, throw a mechanical switch, or release a stuck mechanism.

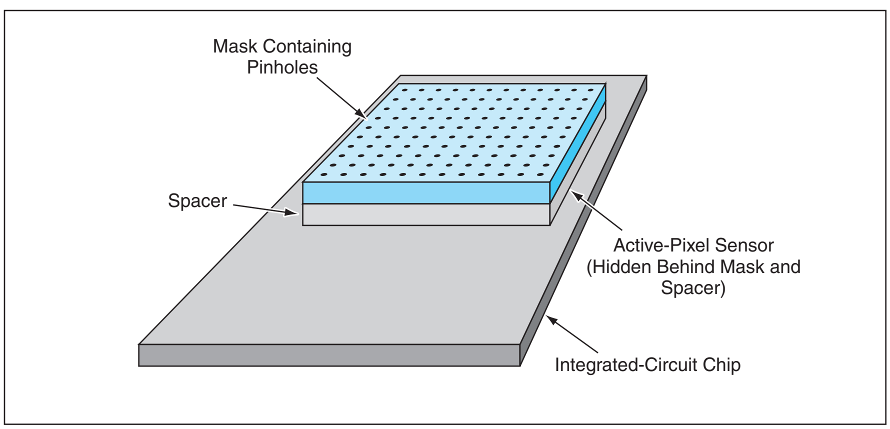
This work was done by Robert C. Costen and Ji Su of **Langley Research Center**. *Further information is contained in a TSP (see page 1)*
LAR-16441

Compact Optoelectronic Compass

The axis of rotation of the Earth is estimated from the changing direction to the Sun.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact optoelectronic sensor unit measures the apparent motion of the Sun across the sky. The data acquired by this chip are processed in an external processor to estimate the relative orientation of the axis of rotation of the Earth. Hence, the combination of this chip and the external processor finds the direction of true North relative to the chip: in other words, the combination acts as a solar compass. If the compass is further combined with a clock, then the combination can be used to establish a three-axis inertial coordinate system. If, in addition, an auxiliary sensor measures the local vertical direction, then the resulting system can determine the geographic position.



A **Compact Multiple-Pinhole Camera** senses the apparent position of the Sun and its apparent motion across the sky.

This chip and the software used in the processor are based mostly on the same design and operation as those of the unit described in "Micro Sun Sensor for Spacecraft" (NPO-30867) elsewhere in this issue of *NASA Tech Briefs*. Like the unit described in that article, this unit includes a small multiple-pinhole camera comprising a micromachined mask containing a rectangular array of microscopic pinholes mounted a short distance in front of an image detector of the active-pixel sensor

(APS) type (see figure). Further as in the other unit, the digitized output of the APS in this chip is processed to compute the centroids of the pinhole Sun images on the APS. Then the direction to the Sun, relative to the compass chip, is computed from the positions of the centroids (just like a sundial).

In the operation of this chip, one is interested not only in the instantaneous direction to the Sun but also in the apparent path traced out by the direction to the Sun as a result of rotation of the Earth during an observation interval (during which the Sun sensor must remain stationary with respect to the Earth). The apparent path of the Sun across the sky is projected on a sphere. The axis of rotation of the Earth lies at the center of the projected circle on the sphere surface. Hence, true North (not magnetic North), relative to the chip, can be estimated from paths of the Sun images across the APS.

In a test, this solar compass has been found to yield a coarse estimate of the North (within tens of degrees) in an observation time of about ten minutes. As expected, the accuracy was found to increase with observation time: after a few hours, the estimated direction of the rotation axis becomes accurate to within a small fraction of a degree.

This work was done by Carl Christian Liebe of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP (see page 1)*
NPO-30872