



Figure 2. The prototype of the Hall Monitor Sensor uses a single piezoelectric ceramic disc with a metal plate as a sounding board. The concept was improved by forming a shallow pyramid structure so that hail would bounce away from the sensor and not be counted more than once.

This fortuitous behavior of the pyramid sensor may lead to a signal processing strategy, which is inherently more reliable than one depending on amplitude processing only.

The initial concept has been improved by forming a shallow pyramid structure so that hail is encouraged to bounce away from the sensor so as not to be counted more than once. The sloped surface also discourages water from collecting. Additionally, the final prototype version includes a mounting box for the piezo-ceramic, which is offset from the pyramid apex, thus helping to reduce non-uniform response (see Figure 2).

The frequency spectra from a single raindrop impact and a single ice ball impact have been compared. The most notable feature of the frequency resonant peaks is the ratio of the 5.2 kHz to 3.1 kHz components. In the case of a raindrop, this ratio is very small. But in the case of an ice ball, the ratio is roughly one third. This frequency signature of ice balls should provide a robust method for discriminating raindrops from hailstones.

Considering that hail size distributions (HSDs) and fall rates are roughly 1 percent that of rainfall, hailstone sizes range from a few tenths of a centimeter to several centimeters. There may be considerable size overlap between large rain and small hail. As hail occurs infrequently at KSC, the ideal HSD measurement sensor needs to have a collection area roughly 100 times greater than a raindrop-size distribution sensor or disdrometer. The sensitivity should be such that it can detect and count very small hail in the midst of intense rainfall consisting of large raindrop sizes. The dynamic range and durability should allow measurement of the largest hail sizes, and the operation and calibration strategy should consider the infrequent occurrence of hail fall over the KSC area.

*This work was done by Robert Youngquist of Kennedy Space Center; William Haskell of Sierra Lobo, Inc.; and Christopher Immer, Bobby Cox, and John Lane of ASRC Aerospace. Further information is contained in a TSP (see page 1). KSC-12594*

## Miniature Six-Axis Load Sensor for Robotic Fingertip

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A miniature load sensor has been developed as a prototype of tactile sensors that could fit within fingertips of anthropomorphic robot hands. The sensor includes a force-and-torque transducer in the form of a spring instrumented with at least six semiconductor strain gauges. The strain-gauge wires are secured to one side of an interface circuit board mounted at the base of the spring. This board protects the strain-gauge wires from damage that

could otherwise occur as a result of finger motions.

On the opposite side of the interface board, cables routed along the neutral axis of the finger route the strain-gauge output voltages to an analog-to-digital converter (A/D) board. The A/D board is mounted as close as possible to the strain gauges to minimize electromagnetic noise and other interference effects. The outputs of the A/D board are fed to a controller, wherein, by means of

a predetermined calibration matrix, the digitized strain-gauge output voltages are converted to three vector components of force and three of torque exerted by or on the fingertip.

*This work was done by Myron A. Diftler and Toby B. Martin of Johnson Space Center; Michael C. Valvo and Dagoberto Rodriguez of Lockheed Martin Corp., and Mars W. Chu of Metrica, Inc. Further information is contained in a TSP (see page 1). MSC-23910-1*

## Improved Blackbody Temperature Sensors for a Vacuum Furnace

Through proper selection of materials, it is possible to satisfy severe requirements.

Marshall Space Flight Center, Alabama

Some improvements have been made in the design and fabrication of blackbody sensors (BBSs) used to measure the temperature of a heater core in a vacuum furnace. Each BBS consists of a ring of thermally conductive, high-melting-temperature material with two tantalum-sheathed thermocouples attached at diametrically opposite points. The name "blackbody sensor" reflects the basic

principle of operation. Heat is transferred between the ring and the furnace heater core primarily by blackbody radiation, heat is conducted through the ring to the thermocouples, and the temperature of the ring (and, hence, the temperature of the heater core) is measured by use of the thermocouples.

Two main requirements have guided the development of these BBSs:

(1) The rings should have as high an emissivity as possible in order to maximize the heat-transfer rate and thereby maximize temperature-monitoring performance and (2) the thermocouples must be joined to the rings in such a way as to ensure long-term, reliable intimate thermal contact. The problem of fabricating a BBS to satisfy these requirements is complicated by an application-specific prohibi-