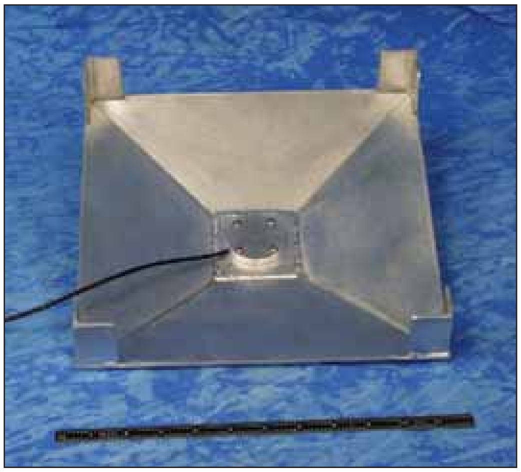

Figure 2. The prototype of the **Hall Monitor Sensor** uses a single piezoelectric ceramic disc with a metal plate as a sounding board. The concept was improved by forming a shallow pyramid structure so that hail would bounce away from the sensor and not be counted more than once.

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.

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.

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

Lyndon B. Johnson Space Center, Houston, Texas

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 prohibition against overheating and thereby damaging nearby instrumentation leads through the use of conventional furnace brazing or any other technique that involves heating the entire BBS and its surroundings. The problem is further complicated by another application-specific prohibition against damaging the thin tantalum thermocouple sheaths through the use of conventional welding to join the thermocouples to the ring.

The first BBS rings were made of graphite. The tantalum-sheathed thermocouples were attached to the graphite rings by use of high-temperature graphite cements. The ring/thermocouple bonds thus formed were found to be weak and unreliable, and so graphite rings and graphite cements were abandoned.

Now, each BBS ring is made from one of two materials: either tantalum or a molybdenum/titanium/zirconium alloy. The tantalum-sheathed thermocouples are bonded to the ring by laser brazing. The primary advantage of laser brazing over furnace brazing is that in laser brazing, it is possible to form a brazed connection locally, without heating nearby parts to the flow temperature of the brazing material. Hence, it is possible to comply with the prohibition against overheating nearby instrumentation leads. Also, in laser brazing, unlike in furnace brazing, it is possible to exert control over the thermal energy to such a high degree that it becomes possible to braze the thermocouples to the ring without burning through the thin tantalum sheaths on the thermocouples.

The brazing material used in the laser brazing process is a titanium-boron paste. This brazing material can withstand use at temperatures up to about 1,400°C. In thermal-cycling tests performed thus far, no debonding between the rings and thermocouples has been observed. Emissivity coatings about 0.001 in. (≈0.025 mm) thick applied to the interior surfaces of the rings have been found to improve the performance of the BBS sensors by raising the apparent emissivities of the rings. In thermal-cycling tests, the coatings were found to adhere well to the rings.

This work was done by Jeff Farmer and Chris Coppens of Marshall Space Flight Center and J. Scott O'Dell, Timothy N. McKechnie, and Elizabeth Schofield of Plasma Processes Inc. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32095-1.

Wrap-Around Out-the-Window Sensor Fusion System

Lyndon B. Johnson Space Center, Houston, Texas

The Advanced Cockpit Evaluation System (ACES) includes communication, computing, and display subsystems, mounted in a van, that synthesize out-the-window views to approximate the views of the outside world as it would be seen from the cockpit of a crewed spacecraft, aircraft, or remote control of a ground vehicle or UAV (unmanned aerial vehicle). The system includes five flat-panel display units arranged approximately in a semicircle around an operator, like cockpit windows. The scene displayed on each panel represents the view through the corresponding cockpit window. Each display unit is driven by a personal computer equipped with a video-capture card that accepts live input from any of a variety of sensors (typically, visible and/or infrared video cameras).

Software running in the computers blends the live video images with synthetic images that could be generated, for example, from heads-up-display outputs, waypoints, corridors, or from satellite photographs of the same geographic region. Data from a Global Positioning System receiver and an inertial navigation system aboard the remote vehicle are used by the ACES software to keep the synthetic and live views in registration. If the live image were to fail, the synthetic scenes could still be displayed to maintain situational awareness.

*This work was done by Jeffrey Fox, Eric A. Boe, and Francisco Delgado of Johnson Space Center; James B. Secor II of Barrios Technology, Inc.; Michael R. Clark and Kevin D. Ehlinger of Jacobs Sverdrup; and Michael F. Abernathy of Rapid Imaging Software, Inc. Further information is contained in a TSP (see page 1)***.**

Rapid Imaging Software, Inc. has requested permission to assert copyright for the software code. MSC-24020-1

Wide-Range Temperature Sensors With High-Level Pulse Train Output

John H. Glenn Research Center, Cleveland, Ohio

Two types of temperature sensors have been developed for wide-range temperature applications. The two sensors measure temperature in the range of –190 to +200 °C and utilize a thin-film platinum RTD (resistance temperature detector) as the temperature-sensing element. Other parts used in the fabrication of these sensors include NPO (negative-positive-zero) type ceramic capacitors for timing, thermally-stable film or wire-wound resistors, and high-temperature circuit boards and solder.

The first type of temperature sensor is a relaxation oscillator circuit using an SOI (silicon-on-insulator) operational amplifier as a comparator. The output is a pulse train with a period that is roughly proportional to the temperature being measured. The voltage level of the pulse train is high-level, for example 10 V. The high-level output makes the sensor less sensitive to noise or electromagnetic interference. The output can be read by a frequency or period meter and then converted into a temperature reading.

The second type of temperature sensor is made up of various types of multivibrator circuits using an SOI type 555 timer and the passive components mentioned above. Three configurations have been developed that were