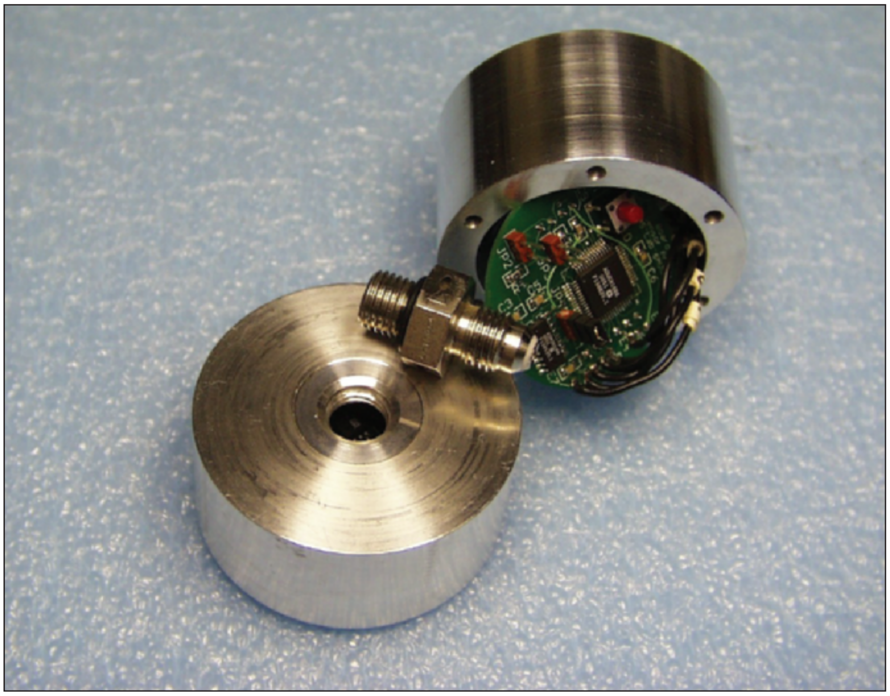

A **Compact Unit Containing Eight Pressure Sensors,** a microprocessor, and other circuitry generates not only a pressure reading of greater than usual precision, but also an assessment of its own reliability and remaining lifetime.

instant of time are compared and the reliability of each sensor is quantified. This comparison of readings and quantification of reliabilities involves the calculation of the ratio between every sensor reading and every other sensor reading, plus calculation of the sum of all such ratios. Then one output reading for the given instant of time is computed as a weighted average of the readings of all the sensors. In this computation, the weight for each sensor is the aforementioned value used to quantify its reliability.

In an optional variant of the MSA algorithm that can be implemented easily, a running sum of the reliability value for each sensor at previous time steps as well as at the present time step is used as the weight of the sensor in calculating the weighted average at the present time step. In this variant, the weight of a sensor that continually fails gradually decreases, so that eventually, its influence over the output reading becomes minimal: In effect, the sensor system "learns" which sensors to trust and which not to trust.

The MSA algorithm incorporates a criterion for deciding whether there remain enough sensor readings that approximate each other sufficiently closely to constitute a majority for the purpose of quantifying reliability. This criterion is, simply, that if there do not exist at least three sensors having weights greater than a prescribed minimum acceptable value, then the array as a whole is deemed to have failed.

Monte Carlo simulations of the MSA algorithm on a computational model of a representative multisensor array have demonstrated that a sensor package equipped to implement the MSA algorithm can monitor its own health and estimate its remaining lifetime. In addition, the simulations showed that the array can have a lifetime up to three times that of a single sensor and the errors in the readings delivered by the MSA algorithm are characterized by error bands smaller than those of a single sensor. As a consequential further benefit, calibrations and replacements are needed less frequently than they are in the cases of single sensors.

The figure shows a prototype sensor MSA unit that includes eight surface-mount pressure transducers and an eight-channel multiplexer circuit on a circular circuit board potted with epoxy in a chamber in a sealed aluminum housing. The housing is fitted with a threaded port that gives access to the chamber. A microprocessor and its supporting electronic circuitry are on a separate board that is plugged into the sensor board. The supporting circuitry comprises almost all of the peripheral circuitry needed to complete the functionality of the sensor package, including a self-calibrating 16-bit analog-to-digital converter, a bandgap voltage reference, ample program flash memory, a nonvolatile data memory, and a serial port for communications.

Upon receiving a command to take a measurement, the microprocessor cycles through the multiplexer to measure the voltage from each pressure transducer. It then converts each transducer voltage to a pressure reading via a linear calibration, using unique calibration coefficients for each transducer. The calibration coefficients are stored in the nonvolatile memory and can be easily updated by means of a simple download routine. The pressure readings are entered into the MSA algorithm.

This work was done by Christopher Immer, Anthony Eckhoff, John Lane, Jose Perotti, John Randazzo, Norman Blalock, and Jeff Rees of Dynacs, Inc. for **Kennedy Space Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Technology Programs and Commercialization Office, Kennedy Space Center, (321) 867-8130. Refer to KSC-12221/359.

Integrated-Optic Oxygen Sensors

Lyndon B. Johnson Space Center, Houston, Texas

Compact optical oxygen sensors with self-calibration capabilities are undergoing development. A sensor of this type features a single-chip, integrated-optic design implemented by photolithographic fabrication of optical waveguides in a photosensitive porous glass. The porosity serves as both a matrix for retention of an oxygen-sensitive fluorescent indicator chemical and a medium for diffusion of oxygen to the chemical from the ambient air to be monitored. Each sensor includes at least one such waveguide exposed to the atmosphere and at least one covered with metal for isolation from the atmosphere. The covered one serves as a reference channel. In operation, the concentration of oxygen is deduced from the intensity and lifetime of the fluorescence in the exposed channel, with the help of calibration data acquired via the reference channel. Because the sensory chemical is placed directly in and throughout the cross section of the light path, approximately 99 percent of the light in the waveguide is available for interaction with the chemical, in contradistinction to only about 1 percent of the light in an optical sensor that utilizes evanescent-wave coupling. Hence, a sensor of this type is significantly more sensitive.

This work was done by Edgar A. Mendoza and Robert A. Lieberman of Physical Optics Corp. and Intelligent Optical Systems, Inc. for **Johnson Space Center**. *For further information, contact:*

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Refer to MSC-23085.

Ka-Band Autonomous Formation Flying Sensor

NASA's Jet Propulsion Laboratory, Pasadena, California

A Ka-band integrated range and bearing-angle formation sensor called the Autonomous Formation Flying (AFF) Sensor has been developed to enable deep-space formation flying of multiple spacecraft. The AFF Sensor concept is similar to that of the Global Positioning System (GPS), but the AFF Sensor would not use the GPS. The AFF Sensor would reside in radio transceivers and signal-processing subsystems aboard the formation-flying spacecraft. A version of the AFF Sensor has been developed for initial application to the two-spacecraft StarLight optical-interferometry mission, and several design investigations have been performed. From the prototype development, it has been concluded that the AFF Sensor can be expected to measure distances and directions with standard deviations of 2 cm and 1 arc minute, respectively, for spacecraft separations ranging up to about 1 km. It has also been concluded that it is necessary to optimize performance of the overall mission through design trade-offs among the performance of the AFF Sensor, the field of view of the AFF Sensor, the designs of the spacecraft and the scientific instruments that they will carry, the spacecraft maneuvers required for formation flying, and the design of a formation-control system.

This work was done by Jeffrey Tien; George Purcell, Jr.; Jeffrey Srinivasan; Michael Ciminera; Meera Srinivasan; Thomas Meehan; Lawrence Young; MiMi Aung; Luis Amaro; Yong Chong; and Kevin Quirk of Caltech for **NASA's Jet Propulsion Laboratory** *and Dean Paschen of Ball Aerospace Technology Corporation. Further information is contained in a TSP (see page 1). NPO-30813.*

CMOS VLSI Active-Pixel Sensor for Tracking

Data could be acquired from as many as eight windows within a frame.

NASA's Jet Propulsion Laboratory, Pasadena, California

An architecture for a proposed active-pixel sensor (APS) and a design to implement the architecture in a complementary metal oxide semiconductor (CMOS) very-large-scale integrated (VLSI) circuit provide for some advanced features that are expected to be especially desirable for tracking point-like features of stars. The architecture would also make this APS suitable for robotic-vision and general pointing and tracking applications.

CMOS imagers in general are well suited for pointing and tracking because they can be configured for random access to selected pixels and to provide readout from windows of interest within their fields of view. However, until now, the architectures of CMOS imagers have not supported multiwindow operation or low-noise data collection. Moreover, smearing and motion artifacts in collected images have made prior CMOS imagers unsuitable for tracking applications.

The proposed CMOS imager (see figure) would include an array of 1,024 by 1,024 pixels containing high-performance photodiode-based APS circuitry. The pixel pitch would be 9 μm. The operations of the pixel circuits would be sequenced and otherwise controlled by an on-chip timing and control block, which would enable the collection of image data, during a single frame period, from either the full frame (that is, all 1,024 × 1,024 pixels) or from within as many as 8 different arbitrarily placed windows as large as 8 by 8 pixels each.

A typical prior CMOS APS operates in a row-at-a-time ("rolling-shutter") readout mode, which gives rise to exposure skew. In contrast, the proposed APS would operate in a sample-first/read-later mode, suppressing rolling-shutter effects. In this mode, the analog readout signals from the pixels corresponding to the windows of the interest (which windows, in the star-tracking application, would presumably contain guide stars) would be sampled rapidly by routing them through a programmable diagonal switch array to an on-chip parallel analog memory array. The diagonal-switch and memory addresses would be generated by the on-chip controller.

The memory array would be large enough to hold differential signals acquired from all 8 windows during a frame period. Following the rapid sampling from all the windows, the contents of the memory array would be read out sequentially by use of a capacitive transimpedance amplifier (CTIA) at a maximum data rate of 10 MHz. This data rate is compatible with an update rate of almost 10 Hz, even in full-frame operation.

In the multiwindow readout mode, this APS could operate with ultralow noise. When an APS of prior design is operated in row-at-a-time readout, the main component of noise in each pixel is the reset noise at the sensing node. In the proposed APS, the reset levels for an