using the attitude/position instrumentation. This resulted in providing test and validation of an imaging lidar, and has the capability to test other types of surface terrain imaging sensors during aerial field tests. This task thus provides data and truth measurements to algorithms for a variety of applications including precision Lunar landing algorithm development.

This work was done by James Alexander, Hannah Goldberg, James Montgomery, Gary Spiers, Carl Liebe, Andrew Johnson, Konstantin Gromov, Edward Konefat, Raymond Lam, and Patrick Meras of Caltech for NASA's Jet Propulsion Laboratory.

The software used in this innovation is available for commercial licensing. Please contact Karina of the California Institute of Technology at (626) 395-2322. Refer to NPO-44581.

Robot Electronics Architecture

Key features are modularity and expandability.

NASA's Jet Propulsion Laboratory, Pasadena, California

An electronics architecture has been developed to enable the rapid construction and testing of prototypes of robotic systems. This architecture is designed to be a research vehicle of great stability, reliability, and versatility. A system according to this architecture can easily be reconfigured (including expanded or contracted) to satisfy a variety of needs with respect to input, output, processing of data, sensing, actuation, and power.

The architecture affords a variety of expandable input/output options that enable ready integration of instruments, actuators, sensors, and other devices as independent modular units. The separation of different electrical functions onto independent circuit boards facilitates the development of corresponding simple and modular software interfaces. As a result, both hardware and software can be made to expand or contract in modular fashion while expending a minimum of time and effort.

To ensure modularity and reconfigurability, the architecture incorporates the PC/104 standard [an industry standard for compact, stackable modules that are fully compatible (in architecture, hardware, and software) with personal-computer data- and power-bus circuitry]. This feature also enables minimization of development costs through selection of off-the-shelf PC/104 components whenever possible.

Particularly notable is a capability for modular expansion to enable a single central processing unit (CPU) to supervise the simultaneous operation of a practically unlimited number of actuators. For this purpose, the architecture provides for each actuator a modular real-time control subsystem, independent of other such subsystems. The subsystem contains dedicated electronic hardware that drives the actuator to execute continuously updated arbitrary motions. The architecture includes a provision for control feedback in the form of outputs from any or all of a variety of sensors. Any or all actuators can be run independently and motions updated instantly, without reference to any prior motion profile.

A custom actuator-driver circuit board has been developed for this architecture to satisfy some power and mass constraints pertaining to a specific application. This board is capable of driving 12 motors simultaneously under computer control and is built on a standard PC/104 footprint.

The architecture includes several user- and system-friendly features: Two independent inputs for panic buttons or watchdog functions enable manual, computer, or watchdog disablement of any or all boards, without affecting the computer. An independent circuit holds all actuators inactive until the computer sends an enabling signal. A single switch overrides all functions to enable manual control. Lights, test points, and outputs enable both the user and the computer to independently monitor the state of the board and internal circuit functions.

This work was done by Michael Garrett, Lee Magnone, Hrand Aghazarian, Eric Baumgartner, and Brett Kennedy of Caltech for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management, JPL, Mail Stop 202-233, 4800 Oak Grove Drive, Pasadena, CA 91109-8099, (818) 354-2240, E-mail: iaoffice@jpl.nasa.gov.

Refer to NPO-41784, volume and number of this NASA Tech Briefs *issue, and the page number.*

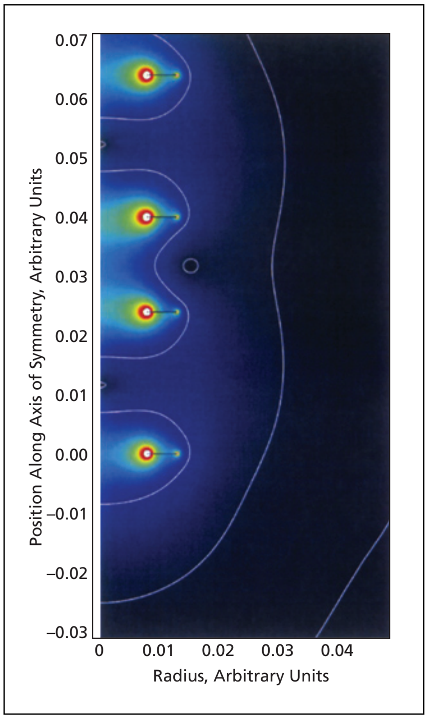
Optimized Geometry for Superconducting Sensing Coils

Design would minimize measurement time in magnetic resonance imaging.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optimized geometry has been proposed for superconducting sensing coils that are used in conjunction with superconducting quantum interference devices (SQUIDs) in magnetic resonance imaging (MRI), magnetoencephalography (MEG), and related applications in which magnetic fields of small dipoles are detected. In designing a coil of this type, as in designing other sensing coils, one seeks to maximize the sensitivity of the detector of which the coil is a part, subject to geometric constraints arising from the proximity of other required equipment. In MRI or MEG, the main benefit of maximizing the sensitivity would be to enable minimization of measurement time.

In general, to maximize the sensitivity of a detector based on a sensing coil coupled with a SQUID sensor, it is necessary to maximize the magnetic flux enclosed by the sensing coil while minimizing the self-inductance of this coil. Simply making the coil larger may increase its self-inductance and does not necessarily increase sensitivity because it also effectively increases the distance from the sample that contains the source of the signal that one seeks to detect. Additional constraints on the size and shape of the coil and on the



This **False-Color Plot** represents half-meridional-plane contours of the magnetic field that would be generated by driving current through the four washerlike turns of an optimized second-order gradiometer sensing coil of the type described in the text.

distance from the sample arise from the fact that the sample is at room temperature but the coil and the SQUID sensor must be enclosed within a cryogenic shield to maintain superconductivity.

One element of an approach to increasing sensitivity without appreciably increasing size is to increase the number of turns, subject to the requirement to maintain an impedance match with the SQUID sensor. On the other hand, simply increasing the number of turns also increases the self-inductance. One way to effect a substantial reduction in inductance without reducing the number of turns is to make the coil of a thicker wire and/or to shape the wire to other than a commonly available circular or square cross section, as described in "Improved Sensing Coils for SQUIDs" (NPO-44397), NASA Tech Briefs, Vol. 31, No. 10 (October, 2007), page 26. On the other hand, the allowable increase in size and change in shape of the wire is limited by the above-mentioned geometric constraints pertaining to enclosure in the cryogenic shield and distance from the sample.

Taking all of the aforementioned considerations into account, it was found that for both SQUID MRI and SQUID MEG, the optimum or nearly optimum coil geometry would be realized by constructing each turn of the coil in the form of a thin washer. Moreover, in the case of a four-turn coil in a second-order gradiometer arrangement (see figure), it would be beneficial to axially separate the two middle turns in order to further reduce the self-inductance. It has been estimated that for an MRI coil designed according to the present optimized geometry, the increase in sensitivity over that of the corresponding conventional wire-wound coil would make it possible to reduce measurement time by a half.

This work was done by Byeong Ho Eom, Konstantin Penanen, and Inseob Hahn of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-44629, volume and number of this NASA Tech Briefs *issue, and the page number.*

Sensing a Changing Chemical Mixture Using an Electronic Nose

ASIC may enable continuous, high-speed monitoring.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of using an electronic nose to detect an airborne mixture of known chemical compounds and measure the temporally varying concentrations of the individual compounds is undergoing development. In a typical intended application, the method would be used to monitor the air in an inhabited space (e.g., the interior of a building) for the release of solvents, toxic fumes, and other compounds that are regarded as contaminants. At the present state of development, the method affords a capability for identifying and quantitating one or two compounds that are members of a set of some number (typically of the order of a dozen) known compounds. In principle, the method could be extended to enable monitoring of more than two compounds.

An electronic nose consists of an array of sensors, typically made from polymer-carbon composites, the electrical resistances of which change upon exposure to a variety of chemicals. By design, each sensor is unique in its responses to these chemicals: some or all of the sensitivities of a given sensor to the various vapors differ from the corresponding sensitivities of other sensors. In general, the responses of the sensors are nonlinear functions of the concentrations of the chemicals. Hence, mathematically, the monitoring problem is to solve the set of time-dependent nonlinear equations for the sensor responses to obtain the time-dependent concentrations of individual compounds.

In the present developmental method, successive approximations of the solution are generated by a learning algorithm based on independent-component analysis (ICA) — an established information-theoretic approach for transforming a vector of observed interdependent signals into a set of signals that are as nearly statistically independent as possible. The algorithm can be characterized as being equivalent to a computational architecture known in the art as a space-invariant ICA architecture. In principle, this architecture is amenable to implementation in an application-specific integrated circuit (ASIC). The anticipated future development of such an ASIC would make it possible to construct a miniature, high-speed, low-power electronic-nose sensor system for continuous monitoring.

This work was done by Tuan Duong and Margaret Ryan of Caltech for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-42213, volume and number of this NASA Tech Briefs *issue, and the page number.*