nected to the input terminal of an operational amplifier. Similarly, the third, fifth, and seventh sensing tubes constitute another three-stage sensing electrode; they are electrically connected to each other, the potential on them is denoted V_2, and they are connected to the input terminal of another operational amplifier. The potential on the stopping electrode is denoted V_3, and this electrode is connected to the input terminal of a third operational amplifier. In operation, $V_1 - V_2$ is measured as a function of time. As a particle travels along the sequence of six tubes, it induces a three-cycle $V_1 - V_2$ waveform, each cycle representing the reading from one of the three sensor stages. The charge measurement for each stage can be calculated as the product of (1) the magnitude of the corresponding $V_1 - V_2$ peak reading and (2) a calibration factor obtained from the V_3 reading.

If the readings are analyzed in the time domain, then the use of n detector stages reduces the standard error of the charge measurement, which is proportional to $n^{-1/2}$. On the other hand, because of its periodicity, the waveform lends itself naturally to analysis in the frequency domain. The minimum detectable charge can be reduced, in the case of frequency-domain analysis, by increasing the number of available waveform cycles and, hence, by increasing the number of stages.

However, increasing the number of stages without limit does not reduce the frequency-domain minimum detectable charge without limit and does not reduce the time-domain standard error without limit. The reason for this is that increasing the number of stages increases the sensor input capacitance, thereby reducing sensitivity. This obstacle can be overcome by the use of a multiblock sensor assembly, recording the output of each block independently. Each block would comprise a multiple-stage sensor as described above, except that the number of stages (not necessarily 3) would be chosen, in conjunction with other design parameters, to optimize performance.

This work was done by Manuel Gamero-Castaño of Caltech for NASA's Jet Propulsion Laboratory. For more information contact iaoffice@jbl.nasa.gov. NPO-44736

Generic Helicopter-Based Testbed for Surface Terrain Imaging Sensors

This flexible field test system is designed for sensors that require an aerial test platform.

NASA's Jet Propulsion Laboratory, Pasadena, California

To be certain that a candidate sensor system will perform as expected during missions, we have developed a field test system and have executed test flights with a helicopter-mounted sensor platform over desert terrains, which simulate Lunar features. A key advantage to this approach is that different sensors can be tested and characterized in an environment relevant to the flight needs prior to flight. Testing the various sensors required the development of a field test system, including an instrument to validate the "truth" of the sensor system under test. The field test system was designed to be flexible enough to cover the test needs of many sensors (lidar, radar, cameras) that require an aerial test platform, including helicopters, airplanes, unmanned aerial vehicles (UAV), or balloons. To validate the performance of the sensor under test, the dynamics of the test platform must be known with sufficient accuracy to provide accurate models for input into algorithm development. The test system provides support equipment to measure the dynamics of the field test sensor platform, and allow computation of the "truth" position, velocity, attitude, and time.

The first test of the field test system provided verification and truth measurements to the LAND (Lunar Access Navigation Device) laser radar, which enable the comparison of the instrument data versus "ground truth" measurement. The instrumentation includes a GPS (Global Positioning System) receiver, Inertial Measurement Unit (IMU), two visible cameras, a support video camera, and a data collection and time-tagging system. These instruments are mounted on a gyro-stabilized gimbal platform attached to the nose of a helicopter. The gimbal is covered by a dome to reduce the amount of aerodynamic drag on the helicopter, with an observation window, which allows the instruments to view the ground below. The gyro-stabilized platform operates in both "nadir" mode, with the sensors pointed with a fixed angle to the ground, and in "geo" mode, in which the gimbal is directed to a fixed GPS location on the ground. The modes can be changed by a ground team via radio remote control during flight.

During an actual flight test, the flight verification equipment includes three computers for collecting data and controlling instruments. The first laptop performs the timing and synchronization of all equipment and logs IMU and GPS data, as well as recording the synchronization pulses from the LAND system (this could potentially be any other sensor) and provides the image trigger pulses to the cameras. These data are fed to the laptop through an interface box into a PCMCIA (Personal Computer Memory Card International Association) interface card, which contains a field-programmable gate array (FPGA). This part of the system builds on heritage from a field test done for the Descent Imager Motion Estimation System (DIMES) project for the Mars Exploration Rover project in 2002.

A second laptop contains a GUI to control the LAND system. Commands are sent through an Ethernet interface to the LAND computer using TCP/IP protocol (Transmission Control Protocol/Internet Protocol). These commands control the start/stop of the laser radar, and the number of lidar frames to gather for a single run, as well as also giving estimated altitude measurements to the LAND system. A third computer acts as a digital video recorder (DVR) for acquiring and time-tagging images taken by the two visible cameras.

Summarizing, the architecture includes the use of guidance and control instruments, data collection equipment, flight and ground procedures, ground fixed position reference targets, and data analysis tools. The test system also provides the processing of the collected instrument data, and includes image motion compensation 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