










TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

-  **Technology Focus**
-  **Computers/Electronics**
-  **Software**
-  **Materials**
-  **Mechanics**
-  **Machinery/Automation**
-  **Manufacturing**
-  **Bio-Medical**
-  **Physical Sciences**
-  **Information Sciences**
-  **Books and Reports**

INTRODUCTION

Tech Briefs are short announcements of innovations originating from research and development activities of the National Aeronautics and Space Administration. They emphasize information considered likely to be transferable across industrial, regional, or disciplinary lines and are issued to encourage commercial application.

Availability of NASA Tech Briefs and TSPs

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Telephone No. (800) 678-6882 or via World Wide Web at www2.nttc.edu/leads/

Please reference the control numbers appearing at the end of each Tech Brief. Information on NASA's Innovative Partnerships Program (IPP), its documents, and services is also available at the same facility or on the World Wide Web at <http://ipp.nasa.gov>.

Innovative Partnerships Offices are located at NASA field centers to provide technology-transfer access to industrial users. Inquiries can be made by contacting NASA field centers and Mission Directorates listed below.

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Medical Signal-Conditioning and Data-Interface System

Lyndon B. Johnson Space Center, Houston, Texas

A general-purpose portable, wearable electronic signal-conditioning and data-interface system is being developed for medical applications. The system can acquire multiple physiological signals (e.g., electrocardiographic, electroencephalographic, and electromyographic signals) from sensors on the wearer's body, digitize those signals that are received in analog form, preprocess the resulting data, and transmit the data to one or more remote location(s) via a radio-communication link and/or the Internet. The system includes a computer running data-object-oriented software that can be programmed to configure the system to accept almost any analog or digital input signals from medical devices. The com-

puting hardware and software implement a general-purpose data-routing-and-encapsulation architecture that supports tagging of input data and routing the data in a standardized way through the Internet and other modern packet-switching networks to one or more computer(s) for review by physicians. The architecture supports multiple-site buffering of data for redundancy and reliability, and supports both real-time and slower-than-real-time collection, routing, and viewing of signal data. Routing and viewing stations support insertion of automated analysis routines to aid in encoding, analysis, viewing, and diagnosis.

This work was done by Jeffrey Braun, Charles Jacobus, Scott Booth, Michael Suarez,

Derek Smith, Jeffrey Hartnagle, and Glenn LePrell of Cybernet Systems Corp. for Johnson Space Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809.

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 MSC-22969, volume and number of this NASA Tech Briefs issue, and the page number.

Instruments for Reading Direct-Marked Data-Matrix Symbols

Contrast is enhanced through oblique viewing and illumination.

Marshall Space Flight Center, Alabama

Improved optoelectronic instruments (specially configured digital cameras) for reading direct-marked data-matrix symbols on the surfaces of optically reflective objects (including specularly reflective ones) are undergoing development. Data-matrix symbols are two-dimensional binary patterns that are used, like common bar codes, for automated identification of objects. The first data-matrix symbols were checkerboardlike patterns of black-and-white rectangles, typically existing in the forms of paint, ink, or detachable labels. The major advantage of direct marking (the marks are more durable than are painted or printed symbols or detachable labels) is offset by a major disadvantage (the marks generated by some marking methods do not provide sufficient contrast to be readable by optoelectronic instruments designed to read black-and-white data-matrix symbols). Heretofore, elaborate lighting, lensing, and software schemes have been tried in efforts to solve the contrast problem in direct-mark matrix-symbol readers. In comparison with prior readers based on those

schemes, the readers now undergoing development are expected to be more effective while costing less.

All of the prior direct-mark matrix-symbol readers are designed to be aimed perpendicularly to marked target surfaces, and they tolerate very little angular offset. However, the reader now undergoing development not only tolerates angular offset but depends on angular offset as a means of obtaining the needed contrast, as described below.

The prototype reader (see Figure 1) includes an electronic camera in the form of a charge-coupled-device

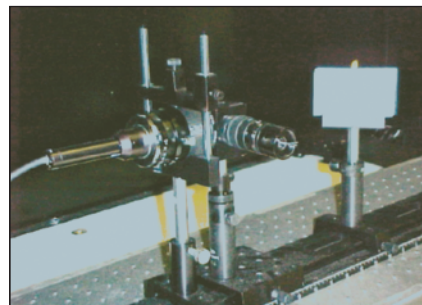


Figure 1. A Benchtop Prototype Reader on the left is shown with the target on the right.

(CCD) image detector equipped with a telecentric lens. It also includes a source of collimated visible light and a source of collimated infrared light for illuminating a target. The visible and infrared illumination complement each other: the visible illumination is more useful for aiming the reader toward a target, while the infrared illumination is more useful for reading symbols on highly reflective surfaces. By use of beam splitters, the visible and



Figure 2. A Data-Matrix Symbol marked with no contrast using a dot peen process on a smooth aluminum target was imaged in the prototype reader at a viewing angle 15° off the perpendicular to the target surface.

infrared collimated lights are introduced along the optical path of the telecentric lens, so that the target is illuminated and viewed from the same direction.

The instrument is designed to be aimed at an angle up to 45° off the perpendicular to the surface. Depending on the target material and its surface finish, this arrangement gives rise to one or more of the following effects: (1) most of the light incident on the relatively flat portions of the target surface adjacent to marks is reflected away from the camera, making those portions appear dark, (2) the shadowed portions of the interior surfaces of the marks receive little illumination and therefore appear even darker, and/or (3) some of

the light impinging on the non-shadowed portion of the concave interior surface of each mark is reflected toward the camera, making that portion of the mark appear bright (shown in Figure 2). The net result is that in the image formed in the camera, the contrast between the marks and the adjacent relatively flat target surface is increased, making it much easier for image-processing hardware and software to recognize a data-matrix symbol.

The telecentric lens is an important element of the innovation. A telecentric lens provides nearly constant magnification over a range of working distances, thereby nearly eliminating perspective angle error. In other words, tilting of the line of sight, curvature of the target sur-

face, and relative movement of the camera and target cause little or no distortion and exert little or no effect on magnification, simplifying the task of image-processing hardware and software. A contemplated future advanced version of the reader would be equipped for automatic focus and would be able to read symbols at distances ranging from several centimeters to a few meters.

This work was done by Harry F. Schramm and Eric L. Corder of Marshall Space Flight 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 Patent Counsel, Marshall Space Flight Center. Refer to MFS-31944-1.

Processing EOS MLS Level-2 Data

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program performs level-2 processing of thermal-microwave-radiance data from observations of the limb of the Earth by the Earth Observing System (EOS) Microwave Limb Sounder (MLS). The purpose of the processing is to estimate the composition and temperature of the atmosphere versus altitude from ≈8 to ≈90 km. "Level-2" as used here is a specialists' term signifying both vertical profiles of geophysical parameters along the measurement track of the instrument and processing performed by this or other software to generate such profiles. Designed to be flex-

ible, the program is controlled via a configuration file that defines all aspects of processing, including contents of state and measurement vectors, configurations of forward models, measurement and calibration data to be read, and the manner of inverting the models to obtain the desired estimates. The program can operate in a parallel form in which one instance of the program acts a master, coordinating the work of multiple slave instances on a cluster of computers, each slave operating on a portion of the data. Optionally, the configuration file can be made to instruct the software

to produce files of simulated radiances based on state vectors formed from sets of geophysical data-product files taken as input.

This work was done by W. Van Snyder, Dong Wu, William Read, Jonathan Jiang, Paul Wagner, Nathaniel Livesey, Michael Schwartz, Mark Filipiak, Hugh Pumphrey, and Zvi Shippony of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-35188.

Ground Processing of Data From the Mars Exploration Rovers

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program implements the Earth side of the protocol that governs the transfer of data files generated by the Mars Exploration Rovers. It also provides tools for viewing data in these files and integrating data-product files into automated and manual processes. It reconstitutes files from telemetry data packets. Even if only one packet is received, metadata provide enough information to enable this program to identify and use partial data products. This software can generate commands to acknowledge received files and re-

transmit missed parts of files, or it can feed a manual process to make decisions about retransmission. The software uses an Extensible Markup Language (XML) data dictionary to provide a generic capability for displaying files of basic types, and uses external "plug-in" application programs to provide more sophisticated displays. This program makes data products available with very low latency, and can trigger automated actions when complete or partial products are received. The software is easy to install and use.

The only system requirement for installing the software is a Java J2SE 1.4 platform. Several instances of the software can be executed simultaneously on the same machine.

This program was written by Jesse Wright, Kathryn Sturdevant, and David Noble of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-42226.

Estimating Total Electron Content Using 1,000+ GPS Receivers

NASA's Jet Propulsion Laboratory, Pasadena, California

A computer program uses data from more than 1,000 Global Positioning System (GPS) receivers in an Internet-accessible global network to generate daily estimates of the global distribution of vertical total electron content (VTEC) of the ionosphere. This program supersedes an older program capable of processing readings from only about 200 GPS receivers. This program downloads the data via the Internet, then processes the data in three stages. In the first stage, raw data from a global subnetwork of about 200 receivers are

preprocessed, station by station, in a Kalman-filter-based least-squares estimation scheme that estimates satellite and receiver differential biases for these receivers and for satellites. In the second stage, an observation equation that incorporates the results from the first stage and the raw data from the remaining 800 receivers is solved to obtain the differential biases for these receivers. The only remaining error sources for which an account cannot be given are multipath and receiver noise contributions. The third stage is a postprocess-

ing stage in which all the processed data are combined and used to generate new data products, including receiver differential biases and global and regional VTEC maps and animations.

This program was written by Attila Komjathy and Anthony Mannucci of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-41612.



NASA Solar Array Demonstrates Commercial Potential

Advanced cells exhibit energy-conversion efficiencies approaching 23 percent.

Dryden Flight Research Center, Edwards, California

A state-of-the-art solar-panel array demonstration site at NASA's Dryden Flight Research Center provides a unique opportunity for studying the latest in high-efficiency solar photovoltaic cells. This five-kilowatt solar-array site (see Figure 1) is a technology-transfer and commercialization success for NASA. Among the solar cells at this site are cells of a type that was developed in Dryden Flight Research Center's Environmental Research Aircraft and Sensor Technology (ERAST) program for use in NASA's Helios solar-powered airplane. This cell type, now denoted as A-300, has since been transferred to SunPower Corporation of Sunnyvale, California, enabling mass production of the cells for the commercial market.

High efficiency separates these advanced cells from typical previously commercially available solar cells: Whereas typical previously commercially available cells are 12 to 15 percent efficient at converting sunlight to electricity, these advanced cells exhibit efficiencies approaching 23 percent. The increase in efficiency is due largely to the routing of electrical connections behind the cells (see Figure 2). This approach to increasing efficiency originated as a solution to the problem of maximizing the degree of utilization of the limited space available atop the wing of the Helios airplane. In retrospect, the solar cells in use at this site could be used on Helios, but the best cells otherwise commercially available could not be so used, because of their lower efficiencies.

Historically, solar cells have been fabricated by use of methods that are common in the semiconductor industry. One of these methods includes the use of photolithography to define the rear electrical-contact features — diffusions, contact openings, and fingers. SunPower uses these methods to produce the advanced cells. To reduce fabrication costs, SunPower continues to explore new methods to define the rear electrical-contact features.

The equipment at the demonstration site includes two fixed-angle solar arrays and one single-axis Sun-tracking array. One of the fixed arrays contains typical



Figure 1. This Solar-Panel Array Demonstration Site at NASA's Dryden Flight Research Center is a facility for testing the most advanced solar photovoltaic cells commercially available for terrestrial applications. NASA photo by Tom Tschida.

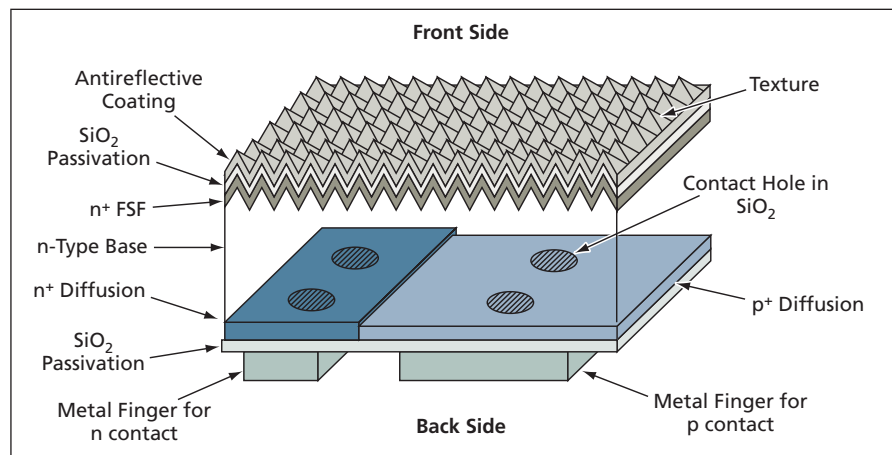


Figure 2. This Rear-Contact Solar Cell has an n-type base and features innovative routing of electrical connections for high efficiency. The basic design is equally applicable to a p-type base.

less-efficient commercial solar cells and is being used as a baseline for comparison of the other fixed array, which contains the advanced cells. The Sun-tracking array tilts to follow the Sun, using an advanced, real-time tracking device rather than customary pre-programmed

mechanisms. Part of the purpose served by the demonstration is to enable determination of any potential advantage of a tracking array over a fixed array. The arrays are monitored remotely on a computer that displays pertinent information regarding the functioning of the arrays.

The process for production of the advanced cells is more complex than is the process for producing typical previously commercially available cells. When laminated under glass in rigid framed modules, the advanced cells are robust enough to last outdoors for more than 20 years. Once the cells have been installed in the modules, the protective glass is coated with a dirt-repellent material. The demonstration is providing the opportunity to verify the effectiveness of the repellent, and to determine the effect, if any, of dust and dirt on the arrays.

NASA Headquarters funded a site-feasibility study for the demonstration. The

study was performed by the U. S. Department of Energy's Idaho National Engineering and Environmental Laboratory in Idaho Falls, Idaho. The laboratory is also supporting Dryden Flight Research Center's public-outreach planning for the demonstration. Among the planned activities is the establishment of a Web site that will enable the public to view real-time information on the functioning of the arrays at the site.

This project can be characterized as part of a full-circle process of development of technology, transfer of the technology to private industry, and return of the technology to NASA ("spin-in")

from industry to assist NASA programs. This project has been part of the Innovative Technology Transfer Partnerships effort under NASA's Aerospace Technology Enterprise.

Other solar-array sites are planned for construction in Hawaii and Arizona. A larger solar farm that may be constructed at Dryden Flight Research Center in the future might supply as much as one-third of the electric power consumed by the Center.

This work was done by Gray Creech of Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-04-21

Improved Control of Charging Voltage for Li-Ion Battery

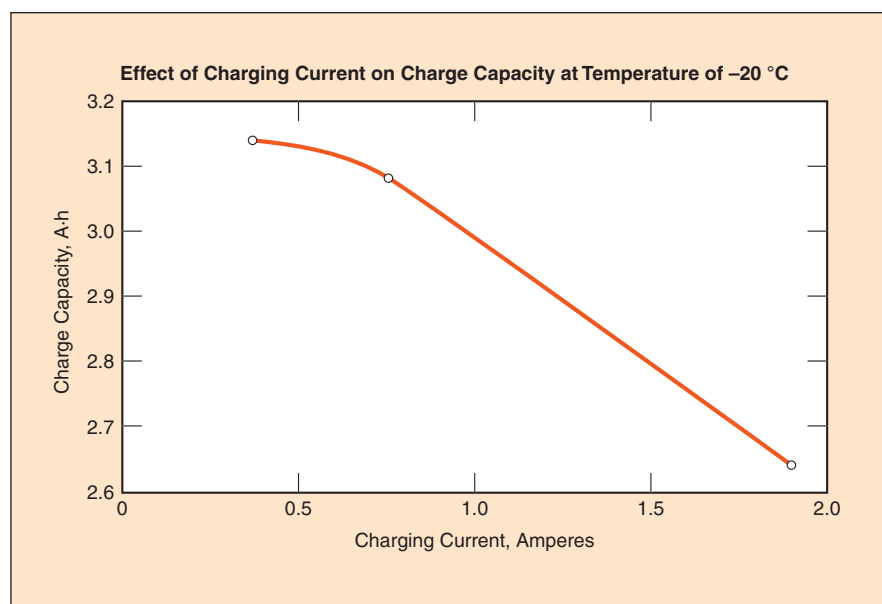
Charging potential would be increased by the internal resistive voltage drop.

NASA's Jet Propulsion Laboratory, Pasadena, California

The protocol for charging a lithium-ion battery would be modified, according to a proposal, to compensate for the internal voltage drop (charging current \times internal resistance of the battery). The essence of the modification is to provide for measurement of the internal voltage drop and to increase the terminal-voltage setting by the amount of the internal voltage drop.

Ordinarily, a lithium-ion battery is charged at constant current until its terminal voltage attains a set value equal to the nominal full-charge potential. The set value is chosen carefully so as not to exceed the lithium-plating potential, because plated lithium in metallic form constitutes a hazard. When the battery is charged at low temperature, the internal voltage drop is considerable because the electrical conductivity of the battery electrolyte is low at low temperature. Charging the battery at high current at any temperature also gives rise to a high internal voltage drop. In some cases, the internal voltage drop can be as high as 1 volt per cell. Because the voltage available for charging is less than the terminal voltage by the amount of the internal voltage drop, the battery is not fully charged (see figure), even when the terminal voltage reaches the set value.

In the modified protocol, the charging current would be periodically interrupted so that the zero-current battery-terminal voltage indicative of the state of charge could be measured. The terminal voltage would also be measured at full charging current. The difference



The **Charge Capacity** attainable by charging a representative Li-ion battery at constant current decreases with increasing current if the end-of-charge battery-terminal voltage is limited to a nominal full-charge value, because of internal ohmic voltage drop.

between the full-current and zero-current voltages would equal the internal voltage drop. The set value of terminal voltage would then be increased beyond the nominal full-charge potential by the amount of the internal voltage drop. This adjustment would be performed repeatedly, in real time, so that the voltage setting would track variations in the internal voltage drop to afford full charge without risk of lithium plating. If the charging current and voltage settings were controlled by a computer, then this method of charge

control could readily be implemented in software.

This work was done by Paul Timmerman and Ratnakumar Bugga of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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 Patent Counsel, NASA Management Office-JPL, (818) 354-7770. Refer to NPO-20481.

Programmable Pulse-Position-Modulation Encoder

NASA's Jet Propulsion Laboratory, Pasadena, California

A programmable pulse-position-modulation (PPM) encoder has been designed for use in testing an optical communication link. The encoder includes a programmable state machine and an electronic code book that can be updated to accommodate different PPM coding schemes. The encoder includes a field-programmable gate array (FPGA) that is programmed to step through the stored state machine and code book and that drives a custom high-speed serializer circuit board that is

capable of generating subnanosecond pulses. The stored state machine and code book can be updated by means of a simple text interface through the serial port of a personal computer.

This work was done by David Zhu and William Farr 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

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Refer to NPO-41103, volume and number of this NASA Tech Briefs issue, and the page number.

Wavelength-Agile External-Cavity Diode Laser for DWDM

Lyndon B. Johnson Space Center, Houston, Texas

A prototype external-cavity diode laser (ECDL) has been developed for communication systems utilizing dense wavelength-division multiplexing (DWDM). This ECDL is an updated version of the ECDL reported in "Wavelength-Agile External-Cavity Diode Laser" (LEW-17090), *NASA Tech Briefs*, Vol. 25, No. 11 (November 2001), page 14a. To recapitulate: The wavelength-agile ECDL combines the stability of an external-cavity laser with the wavelength agility of a diode laser. Wavelength is modulated by modulating the injection current of the diode-laser gain element. The external cavity is a

Littman-Metcalf resonator, in which the zeroth-order output from a diffraction grating is used as the laser output and the first-order-diffracted light is retroreflected by a cavity feedback mirror, which establishes one end of the resonator. The other end of the resonator is the output surface of a Fabry-Perot resonator that constitutes the diode-laser gain element. Wavelength is selected by choosing the angle of the diffracted return beam, as determined by position of the feedback mirror. The present wavelength-agile ECDL is distinguished by design details that enable coverage of all 60 channels, separated by

100-GHz frequency intervals, that are specified in DWDM standards.

This work was done by Jeffrey S. Pilgrim and David S. Bomse of Southwest Sciences, Inc., for Johnson Space Center.

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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Santa Fe, NM 87505

Refer to MSC-23408, volume and number of this NASA Tech Briefs issue, and the page number.

Pattern-Recognition Processor Using Holographic Photopolymer

This processor would operate in real time with high resolution.

NASA's Jet Propulsion Laboratory, Pasadena, California

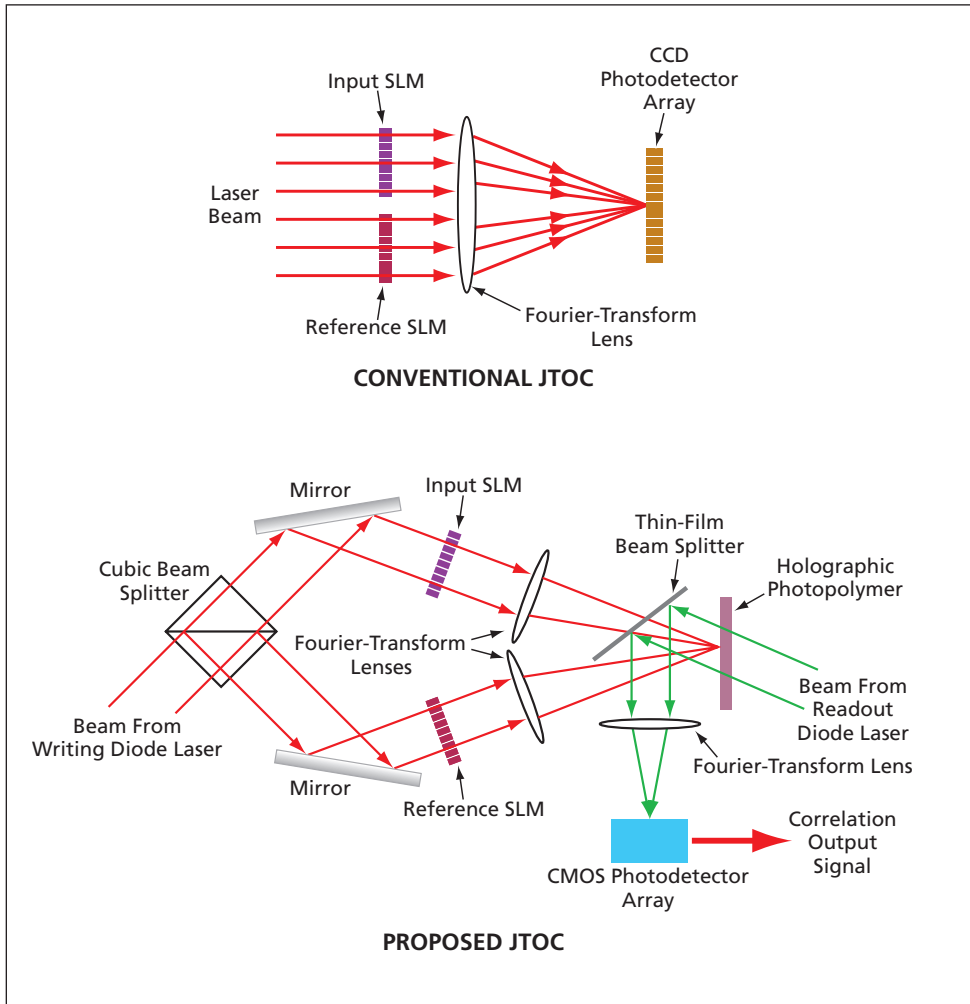
A proposed joint-transform optical correlator (JTOC) would be capable of operating as a real-time pattern-recognition processor. The key correlation-filter reading/writing medium of this JTOC would be an updateable holographic photopolymer. The high-resolution, high-speed characteristics of this photopolymer would enable pattern-recognition processing to occur at a speed three orders of magnitude greater than that of state-of-the-art digital pattern-recognition processors. There are many potential applications in biometric personal identification (e.g., using images of fingerprints and

faces) and nondestructive industrial inspection.

In order to appreciate the advantages of the proposed JTOC, it is necessary to understand the principle of operation of a conventional JTOC. In a conventional JTOC (shown in the upper part of the figure), a collimated laser beam passes through two side-by-side spatial light modulators (SLMs). One SLM displays a real-time input image to be recognized. The other SLM displays a reference image from a digital memory. A Fourier-transform lens is placed at its focal distance from the SLM plane, and a charge-coupled device (CCD) image

detector is placed at the back focal plane of the lens for use as a square-law recorder.

Processing takes place in two stages. In the first stage, the CCD records the interference pattern between the Fourier transforms of the input and reference images, and the pattern is then digitized and saved in a buffer memory. In the second stage, the reference SLM is turned off and the interference pattern is fed back to the input SLM. The interference pattern thus becomes Fourier-transformed, yielding at the CCD an image representing the joint-transform correlation between the input and reference images. This image con-



Conventional and Proposed JTOCs differ in geometry and in the media (CCD versus holographic photopolymer) used to record holograms.

tains a sharp correlation peak when the input and reference images are matched.

The drawbacks of a conventional JTOC are the following:

- The CCD has low spatial resolution and is not an ideal square-law detector for the purpose of holographic recording of interference fringes. A typical state-of-the-art CCD has a pixel-pitch limited resolution of about 100 lines/mm. In contrast, the holographic photopolymer to be used in the proposed JTOC offers a resolution > 2,000 lines/mm. In addition to being disadvantageous in itself, the low resolution of the CCD causes overlap of a DC term and the desired correlation term in the output image. This overlap severely limits the correlation signal-to-noise ratio.
- The two-stage nature of the process limits the achievable throughput rate. A further limit is imposed by the low frame rate (typical video rates) of low- and medium-cost commercial CCDs.

In the proposed JTOC, shown in the lower part of the figure, a collimated beam (denoted the writing beam) from a diode laser would first be split into two orthogonal parts that would then be reflected at oblique angles. As in the conventional JTOC, one part of the beam would illuminate an input SLM while the other part would illuminate a reference SLM. In this case, however, there would be two Fourier-transform lenses: one for the input image and one for the reference image. The input and reference beams would intersect at the center of the Fourier-transform plane. A holographic photopolymer film would be placed in this plane for recording the interference fringes.

A second diode laser would generate a readout light beam incoherent with the writing beam (optionally at approximately the same or a different wavelength). The readout beam would illuminate the holographic photopolymer film from the side opposite that of the writing beam. A thin-

film beam splitter would be placed between the input Fourier-transform lens and the photopolymer film to intercept the readout beam as modified by passage through the photopolymer film. The modified readout beam would be reflected by this beam splitter, then a third Fourier-transform lens would focus this beam to a correlation output image on a complementary metal oxide/semiconductor (CMOS) photodetector array. When the input scene contained a target image matching the reference image, a sharp correlation peak would appear at the location of the centroid of the input image.

The high-speed-recording and low-data-retention-time characteristics of the photopolymer would make it possible to record holograms in real time repeatedly by use of pulsing of the writing laser in synchronism with updating of the images on the SLMs, while reading out the correlation image continuously by use of continuous operation or synchronous pulsing of the readout laser. The off-axis nature of the holographic-recording geometry of the proposed JTOC would confer an additional advantage that is not intuitively obvious but can be discerned by examination of the

equations describing the holographic process: The geometry would give rise to a spatial separation of cross-correlation and convolution components of the output image, such that, as desired, the CMOS photodetector array would retrieve only the correlation component.

This work was done by Tien-Hsin Chao and Kevin Cammack 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:

*Innovative Technology Assets Management
JPL*

*Mail Stop 202-233
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Pasadena, CA 91109-8099
(818) 354-2240*

E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-40994, volume and number of this NASA Tech Briefs issue, and the page number.

Submicrosecond Power-Switching Test Circuit

Switching time is ≤ 300 ns.

Marshall Space Flight Center, Alabama

A circuit that changes an electrical load in a switching time shorter than 0.3 microsecond has been devised. This circuit can be used in testing the regulation characteristics of power-supply circuits — especially switching power-converter circuits that are supposed to be able to provide acceptably high degrees of regulation in response to rapid load transients.

The combination of this power-switching circuit and a known passive constant load could be an attractive alternative to a typical commercially available load-bank circuit that can be made to operate in nominal constant-voltage, constant-current, and constant-resistance modes. The switching provided by a typical commercial load-bank circuit in the constant-resistance mode is not fast enough for testing of regulation in response to load transients. Moreover, some test engineers do not trust the test results obtained when using commercial load-bank circuits because the dynamic responses of those circuits are, variously,

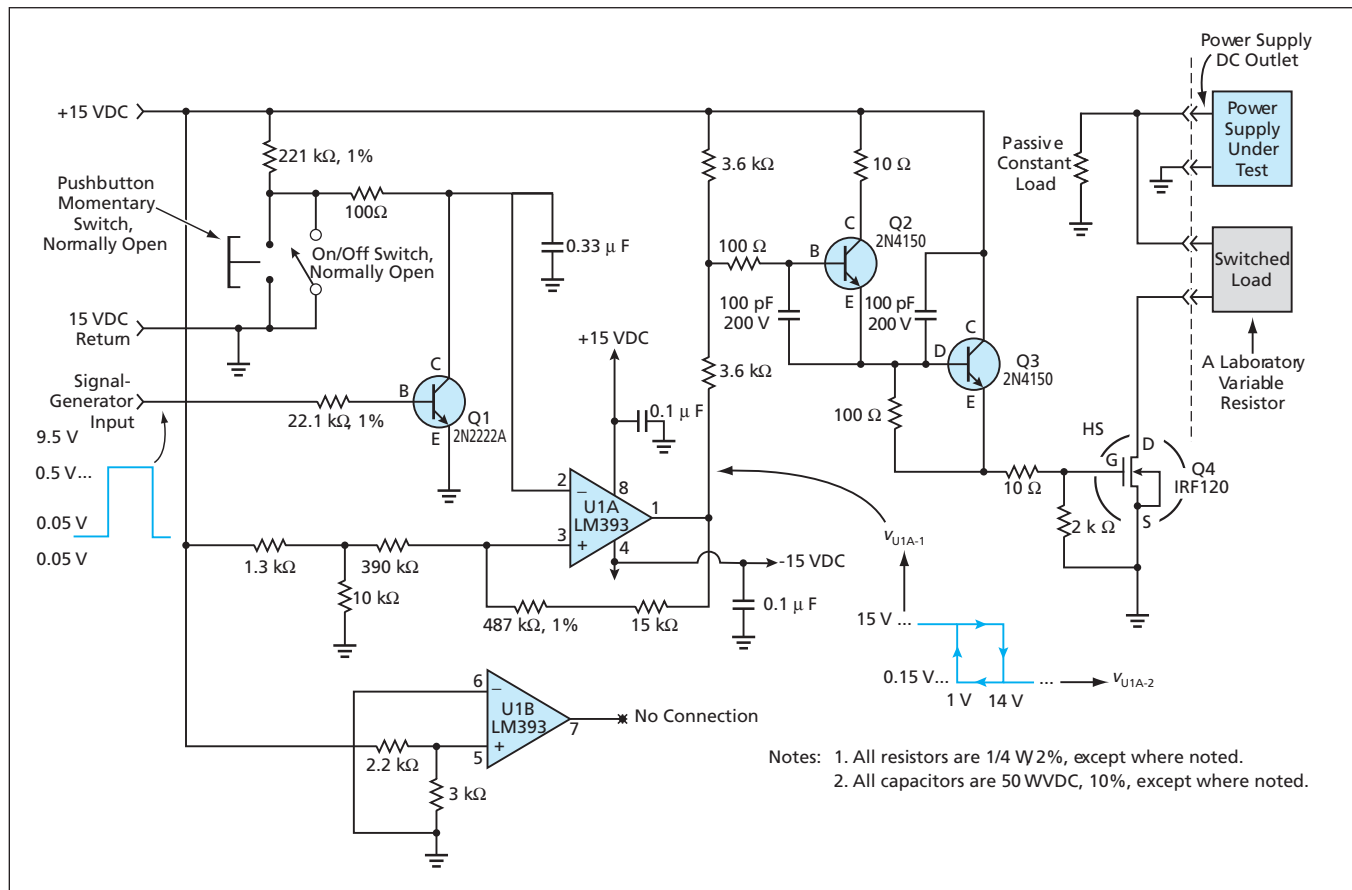
partly unknown and/or excessively complex. In contrast, the combination of this circuit and a passive constant load offers both rapid switching and known (or at least better known) load dynamics.

The power-switching circuit (see figure) includes a signal-input section, a wide-hysteresis Schmitt trigger that prevents false triggering in the event of switch-contact bounce, a dual-bipolar-transistor power stage that drives the gate of a metal oxide semiconductor field-effect transistor (MOSFET), and the MOSFET, which is the output device that performs the switching of the load. The MOSFET in the specific version of the circuit shown in the figure is rated to stand off a potential of 100 V in the “off” state and to pass a current of 20 A in the “on” state. The switching time of this circuit (the characteristic time of rise or fall of the potential at the drain of the MOSFET) is ≤ 300 ns.

The circuit can accept any of three control inputs — which one depending

on the test that one seeks to perform: a repetitive waveform from a signal generator, momentary closure of a push-button switch, or closure or opening of a manually operated on/off switch. In the case of a signal generator, one can adjust the frequency and duty cycle as needed to obtain the desired AC power-supply response, which one could display on an oscilloscope. Momentary switch closure could be useful for obtaining (and, if desired, displaying on an oscilloscope set to trigger on an event) the response of a power supply to a single load transient. The on/off switch can be used to switch between load states in which static-load regulation measurements are performed.

This work was done by Eric N. Folk of Jacobs Sverdrup Technology, Inc. for Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31811-1.



This Power-Switching Test Circuit, in combination with the switched passive load, could be an attractive alternative to a typical commercially available load-bank circuit.

Three-Function Logic Gate Controlled by Analog Voltage

A different logic function is selected by changing a single voltage.

NASA's Jet Propulsion Laboratory, Pasadena, California

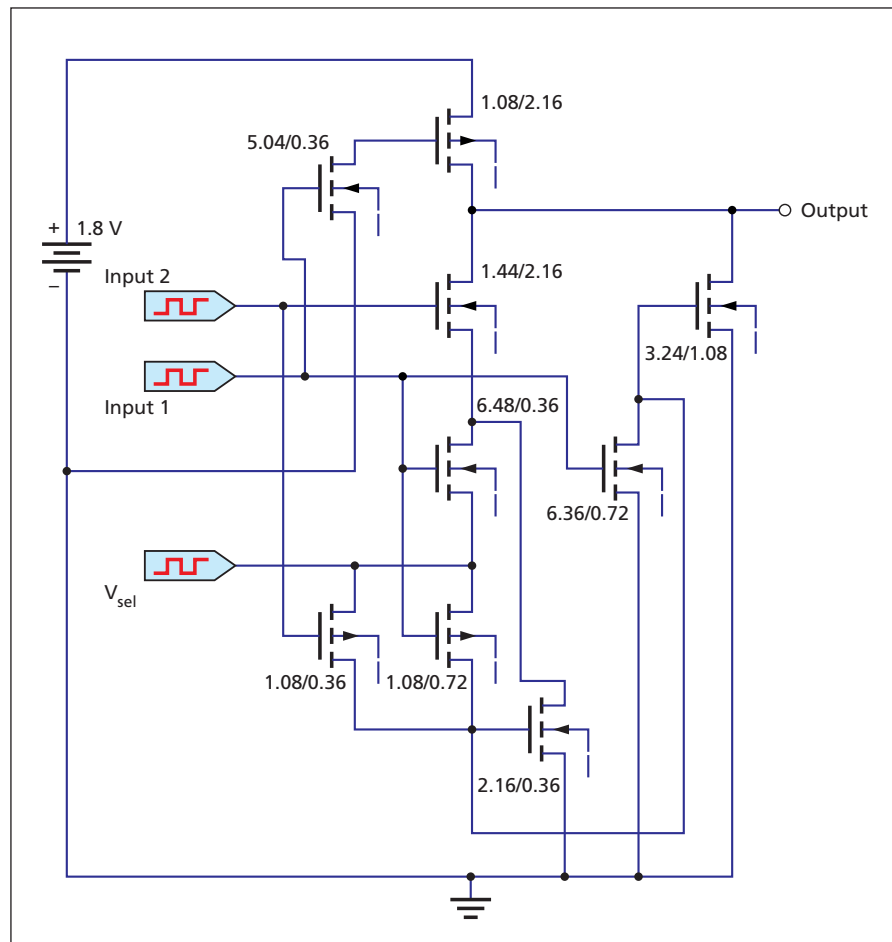
The figure is a schematic diagram of a complementary metal oxide/semiconductor (CMOS) electronic circuit that performs one of three different logic functions, depending on the level of an externally applied control voltage, V_{sel} .

- Specifically, the circuit acts as
 - A NAND gate at $V_{sel} = 0.0$ V,
 - A wire (the output equals one of the inputs) at $V_{sel} = 1.0$ V, or
 - An AND gate at $V_{sel} = -1.8$ V.
- [The nominal power-supply potential (V_{DD}) and logic "1" potential of this circuit is 1.8 V.]

Like other multifunctional circuits described in several prior *NASA Tech Briefs* articles, this circuit was synthesized following an automated evolutionary approach that is so named because it is modeled partly after the repetitive trial-and-error process of biological evolution. An evolved circuit can be tested by computational simulation and/or tested in real hardware, and the results of the test can provide guidance for refining the design through further iteration. The evolutionary synthesis of electronic circuits can now be implemented by means of a software package — Genetic Algorithms for Circuit Synthesis (GACS) — that was developed specifically for this purpose. GACS was used to synthesize the present trifunctional circuit.

As in the cases of other multifunctional circuits described in several prior *NASA Tech Briefs* articles, the multiple functionality of this circuit, the use of a single control voltage to select the function, and the automated evolutionary approach to synthesis all contribute synergistically to a combination of features that are potentially advantageous for the further development of robust, multiple-function logic circuits, including, especially, field-programmable gate arrays (FPGAs). These advantages include the following:

- This circuit contains only 9 transistors — about half the number of transistors that would be needed to obtain equivalent NAND/wire/AND functionality by use of components from a standard digital design library.



This CMOS Circuit Performs as One of Three Logic Gates, depending on V_{sel} . The first and second number next to each transistor symbol are the width and length, respectively, of the transistor in microns. The CMOS substrate connections are V_{DD} (PMOS) and ground (NMOS).

- If multifunctional gates like this circuit were used in the place of the configurable logic blocks of present commercial FPGAs, it would be possible to change the functions of the resulting digital systems within shorter times. For example, by changing a single control voltage, one could change the function of thousands of FPGA cells within nanoseconds. In contrast, typically, the reconfiguration in a conventional FPGA by use of bits downloaded from look-up tables via a digital bus takes microseconds.

This work was done by Ricardo Zebulum and Adrian Stoica 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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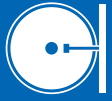
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Refer to NPO-40919, volume and number of this NASA Tech Briefs issue, and the page number.



Integrated System for Autonomous Science

The New Millennium Program Space Technology 6 Project Autonomous Sciencecraft software implements an integrated system for autonomous planning and execution of scientific, engineering, and spacecraft-coordination actions. A prior version of this software was reported in “The TechSat 21 Autonomous Sciencecraft Experiment” (NPO-30784), *NASA Tech Briefs*, Vol. 28, No. 3 (March 2004), page 33. This software is now in continuous use aboard the Earth Orbiter 1 (EO-1) spacecraft mission and is being adapted for use in the Mars Odyssey and Mars Exploration Rovers missions. This software enables EO-1 to detect and respond to such events of scientific interest as volcanic activity, flooding, and freezing and thawing of water. It uses classification algorithms to analyze imagery onboard to detect changes, including events of scientific interest. Detection of such events triggers acquisition of follow-up imagery. The mission-planning component of the software develops a response plan that accounts for visibility of targets and operational constraints. The plan is then executed under control by a task-execution component of the software that is capable of responding to anomalies.

This program was written by Steve Chien, Robert Sherwood, Daniel Tran, Benjamin Cichy, Ashley Davies, Rebecca Castaño, Gregg Rabideau, Stuart Frye, Bruce Trout, Seth Shulman, Thomas Doggett, Felipe Ip, Ron Greeley, Victor Baker, James Dohn, and Darrell Boyer of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-41993.

Montage Version 3.0

The final version (3.0) of the Montage software has been released. To recapitulate from previous *NASA Tech Briefs* articles about Montage: This software generates custom, science-grade mosaics of astronomical images on demand from input files that comply with the Flexible Image Transport System (FITS) standard and contain image data registered on

projections that comply with the World Coordinate System (WCS) standards. This software can be executed on single-processor computers, multi-processor computers, and such networks of geographically dispersed computers as the National Science Foundation’s TeraGrid or NASA’s Information Power Grid. The primary advantage of running Montage in a grid environment is that computations can be done on a remote supercomputer for efficiency. Multiple computers at different sites can be used for different parts of a computation — a significant advantage in cases of computations for large mosaics that demand more processor time than is available at any one site. Version 3.0 incorporates several improvements over prior versions. The most significant improvement is that this version is accessible to scientists located anywhere, through operational Web services that provide access to data from several large astronomical surveys and construct mosaics on either local workstations or remote computational grids as needed.

This program was written by Joseph Jacob, Daniel Katz, Thomas Prince, Graham Berriman, John Good, and Anastasia Laity of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-41962.

Utilizing AI in Temporal, Spatial, and Resource Scheduling

Aurora is a software system enabling the rapid, easy solution of complex scheduling problems involving spatial and temporal constraints among operations and scarce resources (such as equipment, workspace, and human experts). Although developed for use in the International Space Station Processing Facility, Aurora is flexible enough that it can be easily customized for application to other scheduling domains and adapted as the requirements change or become more precisely known over time. Aurora’s scheduling module utilizes artificial-intelligence (AI) techniques to make scheduling decisions on the basis of domain knowledge, including knowledge of constraints and their relative importance, in-

terdependencies among operations, and possibly frequent changes in governing schedule requirements. Unlike many other scheduling software systems, Aurora focuses on resource requirements and temporal scheduling in combination. For example, Aurora can accommodate a domain requirement to schedule two subsequent operations to locations adjacent to a shared resource. The graphical interface allows the user to quickly visualize the schedule and perform changes reflecting additional knowledge or alterations in the situation. For example, the user might drag the activity corresponding to the start of operations to reflect a late delivery.

This program was written by Richard Stottler, Annaka Kalton, and Aaron Bell of Stottler Henke Associates, Inc. for Kennedy Space Center.

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 KSC-12569, volume and number of this NASA Tech Briefs issue, and the page number.

Satellite Image Mosaic Engine

A computer program automatically builds large, full-resolution mosaics of multispectral images of Earth landmasses from images acquired by Landsat 7, complete with matching of colors and blending between adjacent scenes. While the code has been used extensively for Landsat, it could also be used for other data sources. A single mosaic of as many as 8,000 scenes, represented by more than 5 terabytes of data and the largest set produced in this work, demonstrated what the code could do to provide global coverage. The program first statistically analyzes input images to determine areas of coverage and data-value distributions. It then transforms the input images from their original universal transverse Mercator coordinates to other geographical coordinates, with scaling. It applies a first-order polynomial brightness correction

to each band in each scene. It uses a data-mask image for selecting data and blending of input scenes. Under control by a user, the program can be made to operate on small parts of the output image space, with check-point and restart capabilities. The program runs on SGI IRIX computers. It is capable of parallel processing using shared-memory code, large memories, and tens of central processing units. It can retrieve input data and store output data at locations remote from the processors on which it is executed.

This program was written by Lucian Plesea of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-40999.

Architecture for Control of the K9 Rover

Software featuring a multilevel architecture is used to control the hardware on the K9 Rover, which is a mobile robot used in research on robots for scientific exploration and autonomous operation in general. The software consists of five types of modules:

- **Device Drivers** — These modules, at the lowest level of the architecture, directly control motors, cameras, data buses, and other hardware devices.
- **Resource Managers** — Each of these modules controls several device drivers. Resource managers can be commanded by either a remote operator or the pilot or conditional-executive modules described below.
- **Behaviors and Data Processors** — These modules perform computations for such functions as planning paths, avoiding obstacles, visual tracking, and stereoscopy. These modules can be commanded only by the pilot.
- **Pilot** — The pilot receives a possibly complex command from the remote operator or the conditional executive, then decomposes the command into (1) more-specific commands to the resource managers and (2) requests for information from the behaviors and data processors.
- **Conditional Executive** — This highest-level module interprets a command plan sent by the remote operator, determines whether resources required for execution of the plan are available, monitors

execution, and, if necessary, selects an alternate branch of the plan.

This program was written by John L. Bresina and Maria Bualat of Ames Research Center; Michael Fair and Anne Wright of QSS Group, Inc.; and Richard Washington of Research Institute for Advanced Computer Science. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Innovative Partnerships Office at (650) 604-2954. Refer to ARC-14587-1.

HFGMC Enhancement of MAC/GMC

Additional information about a mathematical model denoted the high-fidelity generalized method of cells (HFGMC) and implementation of the HFGMC within version 4.0 of the MAC/GMC software has become available. MAC/GMC (Micromechanics Analysis Code With Generalized Method of Cells) was a topic of several prior *NASA Tech Briefs* articles, version 4.0 having been described in "Comprehensive Micromechanics-Analysis Code — Version 4.0" (LEW-17495-1), *NASA Tech Briefs*, Vol. 29, No. 9 (September 2005), page 54. MAC/GMC predicts elastic and inelastic thermomechanical responses of composite materials. MAC/GMC utilizes the generalized method of cells (GMC) — a model of micromechanics that predicts macroscopic responses of a composite material as functions of the properties, sizes, shapes, and responses of its constituents (e.g., matrix and fibers). The accuracy of the GMC is limited by neglect of coupling between normal and shear stresses. The HFGMC was developed by combining elements of the GMC and a related model, denoted the higher-order theory for functionally graded materials (HOTFGM), that can account for this coupling. Hence, the HFGMC enables simulation of stress and strain with greater accuracy. Some alterations of the MAC/GMC data structure were necessitated by the greater computational complexity of the HFGMC.

This program was written by Steven M. Arnold of Glenn Research Center, Jacob Aboudi and Marek-Jerzy Pindera of the University of Virginia, and Brett A. Bednarczyk of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative

Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17818-1.

Automated Activation and Deactivation of a System Under Test

The MPLM Automated Activation/Deactivation application (MPLM means Multi-Purpose Logistic Module) was created with a three-fold purpose in mind:

1. To reduce the possibility of human error in issuing commands to, or interpreting telemetry from, the MPLM power, computer, and environmental control systems;
2. To reduce the amount of test time required for the repetitive activation/deactivation processes; and
3. To reduce the number of on-console personnel required for activation/deactivation.

All of these have been demonstrated with the release of the software. While some degree of automated end-item commanding had previously been performed for space-station hardware in the test environment, none approached the functionality and flexibility of this application. For MPLM activation, it provides mouse-click selection of the hardware complement to be activated, activates the desired hardware and verifies proper feedbacks, and alerts the user when telemetry indicates an error condition or manual intervention is required. For MPLM deactivation, the product senses which end items are active and deactivates them in the proper sequence. For historical purposes, an on-line log is maintained of commands issued and telemetry points monitored. The benefits of the MPLM Automated Activation/Deactivation application were demonstrated with its first use in December 2002, when it flawlessly performed MPLM activation in 8 minutes (versus as much as 2.4 hours for previous manual activations), and performed MPLM deactivation in 3 minutes (versus 66 minutes for previous manual deactivations). The number of test team members required has dropped from eight to four, and in actuality the software can be operated by a sole (knowledgeable) system engineer.

This work was done by Mark A. Poff of The Boeing Company for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Office at (321) 867-1463. Refer to KSC-12653.



Cleaning Carbon Nanotubes by Use of Mild Oxygen Plasmas

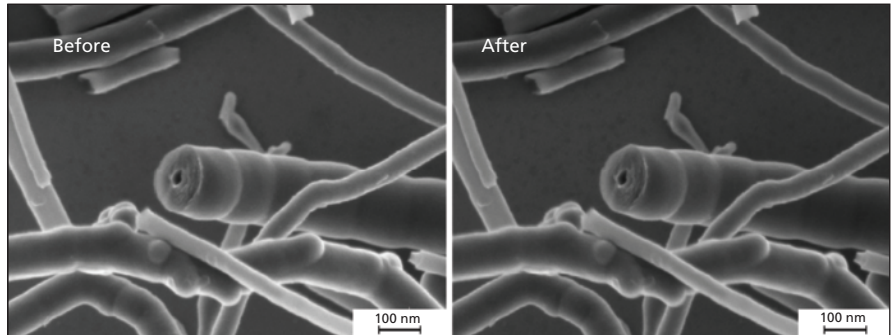
Mildness of the plasmas is the key to cleaning without destruction.

NASA's Jet Propulsion Laboratory, Pasadena, California

Experiments have shown that it is feasible to use oxygen radicals (specifically, monatomic oxygen) from mild oxygen plasmas to remove organic contaminants and chemical fabrication residues from the surfaces of carbon nanotubes (CNTs) and metal/CNT interfaces. A capability for such cleaning is essential to the manufacture of reproducible CNT-based electronic devices.

The use of oxygen radicals to clean surfaces of other materials is fairly well established. However, previously, cleaning of CNTs and of graphite by use of oxygen plasmas had not been attempted because both of these forms of carbon were known to be vulnerable to destruction by oxygen plasmas. The key to success of the present technique is, apparently, to ensure that the plasma is mild — that is to say, that the kinetic and internal energies of the oxygen radicals in the plasma are as low as possible.

The plasma oxygen-radical source used in the experiments was a commercial one marketed for use in removing hydrocarbons and other organic contaminants from vacuum systems and from electron microscopes and other objects placed inside vacuum systems. In use, the source is installed in a vacuum system and air is leaked into the system at such a rate as to maintain a background pressure of ≈ 0.56 torr (≈ 75 Pa). In the source, oxygen from



These SEM images of CNTs were taken before and after cleaning in a mild oxygen plasma. Unlike an oxygen plasma of the type used in dry etching, this plasma seems not to have damaged the CNTs.

the air is decomposed into monatomic oxygen by radio-frequency excitation of a resonance of the O_2 molecule (N_2 is not affected). Hence, what is produced is a mild (non-energetic) oxygen plasma. The oxygen radicals are transported along with the air molecules in the flow created by the vacuum pump.

In the experiments, exposure to the oxygen plasma in this system was shown to remove organic contaminants and chemical fabrication residues from several specimens. Many high-magnification scanning electron microscope (SEM) images of CNTs were taken before and after exposure to the oxygen plasma. As in the example shown in the figure, none of these images showed evidence of degradation of CNT structures.

This work was done by Mihail Petkov 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:

*Innovative Technology Assets Management
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E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-41846, volume and number of this NASA Tech Briefs issue, and the page number.

Generating Aromatics From CO_2 on Mars or Natural Gas on Earth

The terrestrial version may make it economical to recover some natural-gas deposits.

John F. Kennedy Space Center, Florida

"Methane to aromatics on Mars" ("METAMARS") is the name of a process originally intended as a means of converting Martian atmospheric carbon dioxide to aromatic hydrocarbons and oxygen, which would be used as propellants for spacecraft to return to Earth. The process has been demonstrated on Earth on a laboratory scale. A truncated version of the process could be used on Earth to convert natural gas to aromatic hydrocarbon liquids. The

greater (relative to natural gas) density of aromatic hydrocarbon liquids makes it more economically feasible to ship them to distant markets. Hence, this process makes it feasible to exploit some reserves of natural gas that, heretofore, have been considered as being "stranded" too far from markets to be of economic value.

In the full version of METAMARS, carbon dioxide is frozen out of the atmosphere and fed to a Sabatier reactor along

with hydrogen (which, on Mars, would have been brought from Earth). In the Sabatier reactor, these feedstocks are converted to methane and water. The water is condensed and electrolyzed to oxygen (which is liquefied) and hydrogen (which is recycled to the Sabatier reactor). The methane is sent to an aromatization reactor, wherein, over a molybdenum-on-zeolite catalyst at a temperature $700^\circ C$, it is partially converted

into aromatic hydrocarbons (specifically, benzene, toluene, and naphthalene) along with hydrogen.

The aromatics are collected by freezing, while unreacted methane and hydrogen are separated by a membrane. Most of the hydrogen is recycled to the Sabatier reactor, while the methane and a small portion of the hydrogen are recycled to the aromatization reactor. The partial recycle of hydrogen to the aromatization reactor greatly increases the catalyst lifetime and eases its regeneration by preventing the formation of graphitic carbon, which could damage

the catalyst. (Moreover, if graphitic carbon were allowed to form, it would be necessary to use oxygen to remove it.) Because the aromatics contain only one hydrogen atom per carbon atom, METAMARS produces four times as much propellant from a given amount of hydrogen as does a related process that includes the Sabatier reaction and electrolysis but not aromatization.

In the terrestrial version of METAMARS, the Sabatier reactor and electrolyzer would be omitted, while the hydrogen/methane membrane-separating membrane, the aromatization reactor,

and the unreacted-gas-recycling subsystem would be retained. Natural gas would be fed directly to the aromatization reactor. Because natural gas consists of higher hydrocarbons in addition to methane, the aromatization subprocess should be more efficient than it is for methane alone.

*This work was done by Anthony C. Muscatello, Robert Zubrin, and Mark Berggren of Pioneer Astronautics for **Kennedy Space Center**. For further information, contact the Kennedy Innovative Partnerships Office at (321) 867-1463. KSC-12698*



Attaching Thermocouples by Peening or Crimping

These techniques are simple, effective, and minimally invasive.

John F. Kennedy Space Center, Florida

Two simple, effective techniques for attaching thermocouples to metal substrates have been devised for high-temperature applications in which attachment by such conventional means as welding, screws, epoxy, or tape would not be effective. The techniques have been used successfully to attach 0.005-in. (0.127-mm)-diameter type-S thermocouples to substrates of niobium alloy C-103 and stainless steel 416 for measuring temperatures up to 2,600 °F (1,427 °C). The techniques are equally applicable to other thermocouple and substrate materials.

In the first technique, illustrated in the upper part of the figure, a hole slightly wider than twice the diameter of one thermocouple wire is drilled in the substrate. The thermocouple is placed in the hole, then the edge of the hole is peened in one or more places by use of a punch (see figure). The deformed material at the edge secures the thermocouple in the hole.

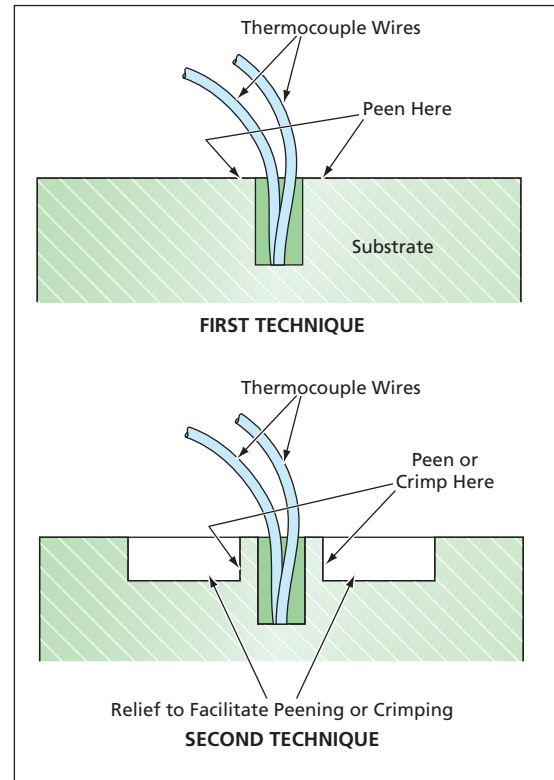
In the second technique a hole is drilled as in the first technique, then an annular relief area is machined around the hole, resulting in structure reminiscent of a volcano in a crater. The thermocouple is placed in the hole as in the first technique, then the “volcano” material is either peened by use of a punch or crimped by use of sidecutters to secure the thermocouple in place. This second technique is preferable for very thin

thermocouples [wire diameter ≤ 0.005 in. (≤ 0.127 mm)] because standard peening poses a greater risk of clipping one or both of the thermocouple wires.

These techniques offer the following advantages over prior thermocouple-attachment techniques:

- Because these techniques involve drilling of very small holes, they are minimally invasive — an important advantage in that, to a first approximation, the thermal properties of surrounding areas are not appreciably affected.
- These techniques do not involve introduction of any material, other than the substrate and thermocouple materials, that could cause contamination, could decompose, or oxidize at high measurement temperatures.
- The simplicity of these techniques makes it possible to attach thermocouples quickly.
- These techniques can be used to attach thermocouples at locations where access is somewhat restricted by the surrounding objects.

This work was done by Kevin Murland, Robert Cox, and Christopher Immer of ASRC



A Thermocouple is Placed in a Hole wide enough to accommodate the wires with a little clearance. Then the thermocouple is secured in the hole by peening or crimping substrate material near the hole.

Aerospace Corp. for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Office at (321) 867-1463. KSC-12775

Heat Treatment of Friction-Stir-Welded 7050 Aluminum Plates

Strength, ductility, and resistance to stress corrosion cracking are increased.

Lyndon B. Johnson Space Center, Houston, Texas

A method of heat treatment has been developed to reverse some of the deleterious effects of friction stir welding of plates of aluminum alloy 7050. This alloy is considered unweldable by arc and high-energy-density beam fusion welding processes. The alloy can be friction stir welded, but as-welded workpieces exhibit low ductility, low

tensile and yield strengths, and low resistance to stress corrosion cracking. Heat treatment according to the present method increases tensile and yield strengths, and minimizes or eliminates stress corrosion cracking. It also increases ductility.

This method of heat treatment is a superior alternative to a specification-re-

quired heat treatment that caused the formation of large columnar grains, which are undesired. Workpieces subjected to the prior heat treatment exhibited elongations <2 percent, and standard three-point bend specimens shattered.

The development of the present heat-treatment method was guided partly by

the principles that (1) by minimizing grain sizes and relieving deformation stresses, one can minimize or eliminate stress corrosion cracking and (2) the key to maximizing strength and eliminating residual stresses is to perform post-weld solution heating for as long a time as possible while incurring little or no development of large columnar grains in friction stir weld nuggets. It is necessary to perform some of the solution heat treatment (to soften the alloy and im-

prove machine welding parameters) before welding.

The following is an example of thickness-dependent pre- and post-weld heat treatments according to the present method: For plates 0.270 in. (≈ 6.86 mm) thick milled from plates 4.5 in. (114.3 mm) thick, perform pre-weld solution heating at 890 °F (477 °C) for 1 hour, then cool in air. After friction stir welding, perform solution heating for 10 minutes, quench, hold at room temperature for 96 hours, then

age at 250 °F (121 °C) for 5 hours followed by 325 °F (163 °C) for 27 hours.

*This work was done by George E. Petter of **Johnson Space Center** and John D. Figert, Daniel J. Rybicki, and Timothy Burns of Lockheed Martin Corp.*

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 Patent Counsel, Johnson Space Center, (281) 483-0837. Refer to MSC-23472.



Generating Breathable Air Through Dissociation of N₂O

Air-supply systems can be made to weigh less and/or operate longer.

Lyndon B. Johnson Space Center, Houston, Texas

A nitrous oxide-based oxygen-supply system (NOBOSS) is an apparatus in which a breathable mixture comprising 2/3 volume parts of N₂ and 1/3 volume part of O₂ is generated through dissociation of N₂O. The NOBOSS concept can be adapted to a variety of applications in which there are requirements for relatively compact, lightweight systems to supply breathable air. These could include air-supply systems for firefighters, divers, astronauts, and workers who must be protected against biological and chemical hazards.

A NOBOSS stands in contrast to compressed-gas and cryogenic air-supply systems. Compressed-gas systems necessarily include massive tanks that can hold only relatively small amounts of gases. Alternatively, gases can be stored compactly in greater quantities and at low pressures when they are liquefied, but then cryogenic equipment is needed to maintain them in liquid form. Overcoming the disadvantages of both compressed-gas and cryogenic systems, the NOBOSS exploits the fact that N₂O can be stored in liquid form at room temperature and moderate pressure. The mass of N₂O that can be stored in a tank of a given mass is about 20 times the mass of compressed

air that can be stored in a tank of equal mass.

In a NOBOSS, N₂O is exothermically dissociated to N₂ and O₂ in a main catalytic reactor. In order to ensure the dissociation of N₂O to the maximum possible extent, the temperature of the reactor must be kept above 400 °C. At the same time, to minimize concentrations of nitrogen oxides (which are toxic), it is necessary to keep the reactor temperature at or below 540 °C. To keep the temperature within the required range throughout the reactor and, in particular, to prevent the formation of hot spots that would be generated by local concentrations of the exothermic dissociation reaction, the N₂O is introduced into the reactor through an injector tube that features carefully spaced holes to distribute the input flow of N₂O widely throughout the reactor.

A NOBOSS includes one or more “destroyer” subsystems for removing any nitrogen oxides that remain downstream of the main N₂O-dissociation reactor. A destroyer includes a carbon bed in series with a catalytic reactor, and is in thermal contact with the main N₂O-dissociation reactor. The gas mixture that leaves the main reactor first goes through a carbon

bed, which adsorbs all of the trace NO and most of the trace NO₂. The gas mixture then goes through the destroyer catalytic reactor, wherein most or all of the remaining NO₂ is dissociated.

A NOBOSS can be designed to regulate its reactor temperature across a range of flow rates. One such system includes three destroyer loops; these loops act, in combination with a heat sink, to remove heat from the main N₂O-dissociation reactor. In this system, the N₂O and product gases play an additional role as coolants; thus, as needed, the coolant flow increases in proportion to the rate of generation of heat, helping to keep the main-reactor temperature below 540 °C.

This work was done by Robert Zubrin and Brian Frankie of Pioneer Astronautics for Johnson Space Center.

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:

*Pioneer Astronautics
11111 W. 8th Ave., Unit A
Lakewood, CO 80215*

E-mail: pioneer@PioneerAstro.com

Refer to MSC-23105, volume and number of this NASA Tech Briefs issue, and the page number.

High-Performance Scanning Acousto-Ultrasonic System

This system reveals flaws that cannot otherwise be detected nondestructively.

John H. Glenn Research Center, Cleveland, Ohio

A high-performance scanning acousto-ultrasonic system, now undergoing development, is designed to afford enhanced capabilities for imaging microstructural features, including flaws, inside plate specimens of materials. The system is expected to be especially helpful in analyzing defects that contribute to failures in polymer- and ceramic-matrix composite materials, which are difficult to characterize by conventional scanning ultrasonic techniques and other conventional nonde-

structive testing techniques.

Selected aspects of the acousto-ultrasonic method have been described in several *NASA Tech Briefs* articles in recent years. Summarizing briefly: The acousto-ultrasonic method involves the use of an apparatus like the one depicted in the figure (or an apparatus of similar functionality). Pulses are excited at one location on a surface of a plate specimen by use of a broadband transmitting ultrasonic transducer. The stress waves associated with these pulses propagate along

the specimen to a receiving transducer at a different location on the same surface. Along the way, the stress waves interact with the microstructure and flaws present between the transducers. The received signal is analyzed to evaluate the microstructure and flaws.

The specific variant of the acousto-ultrasonic method implemented in the present developmental system goes beyond the basic principle described above to include the following major additional features:

Computer-controlled motorized translation stages are used to automatically position the transducers at specified locations. Scanning is performed in the sense that the measurement, data-acquisition, and data-analysis processes are repeated at different specified transducer locations in an array that spans the specimen surface (or a specified portion of the surface).

A pneumatic actuator with a load cell is used to apply a controlled contact force.

In analyzing the measurement data for each pair of transducer locations in the scan, the total (multimode) acousto-ultrasonic response of the specimen is utilized. The analysis is performed by custom software that extracts parameters of signals in the time and frequency domains.

The computer hardware and software provide both real-time and post-

scan processing and display options. For example, oscilloscope displays of waveforms and power spectral densities are available in real time. Images can be computed while scanning continues. Signals can be digitally preprocessed and/or postprocessed by filtering, windowing, time-segmenting, and running-waveform-averaging algorithms. In addition, the software affords options for off-line simulation of the waveform-data-acquisition and scanning processes.

In tests, the system has been shown to be capable of characterizing microstructural changes and defects in SiC/SiC and C/SiC ceramic-matrix composites. Delaminations, variations in density, microstructural changes attributable to infiltration by silicon, and crack-space indications (defined in the next sentence) have

been revealed in images formed from several time- and frequency-domain parameters of scanning acousto-ultrasonic signals. The crack-space indications were image features that were not revealed by other nondestructive testing methods and are so named because they turned out to mark locations where cracking eventually occurred.

This work was done by Don Roth of Glenn Research Center; Richard Martin, Harold Kautz, and Laura Cosgriff of Cleveland State University; and Andrew Gyekenyesi of Ohio Aerospace Institute. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17601-1.

Correction for Thermal EMFs in Thermocouple Feedthroughs

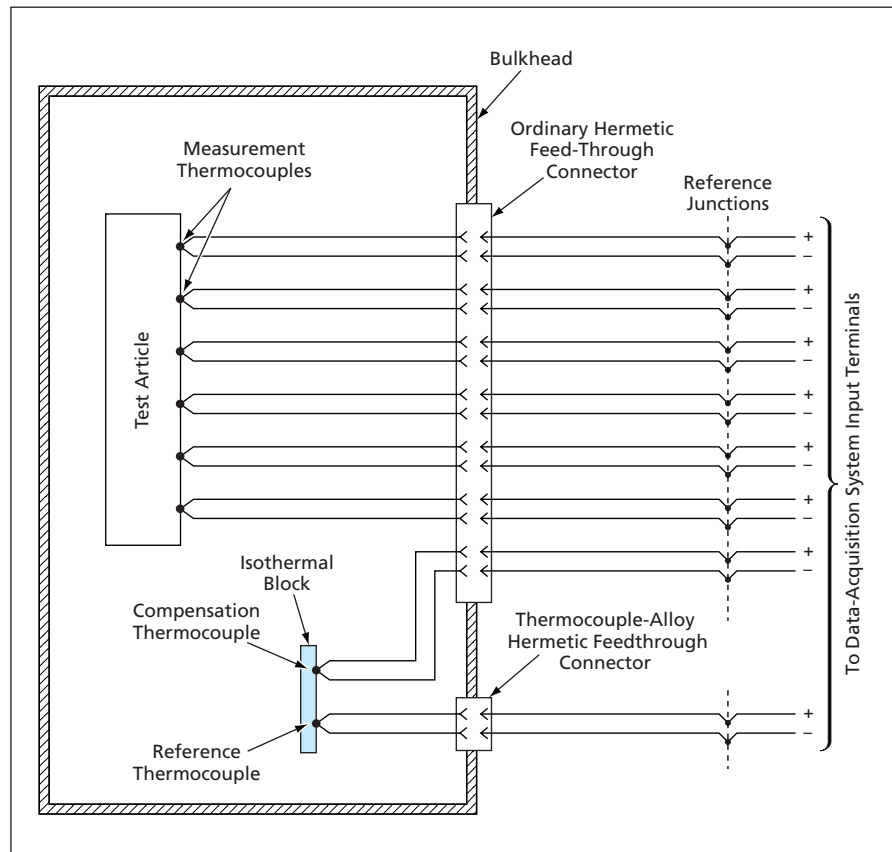
Expensive thermocouple-alloy multipin hermetic feedthrough connectors are no longer necessary.

John H. Glenn Research Center, Cleveland, Ohio

A straightforward measurement technique provides for correction of thermal-electromotive-force (thermal-EMF) errors introduced by temperature gradients along the pins of non-thermocouple-alloy hermetic feedthrough connectors for thermocouple extension wires that must pass through bulkheads. This technique is an alternative to the traditional technique in which the thermal-EMF errors are eliminated by use of custom-made multipin hermetic feedthrough connectors that contain pins made of the same alloys as those of the thermocouple extension wires.

One disadvantage of the traditional technique is that it is expensive and time-consuming to fabricate multipin custom thermocouple connectors. In addition, the thermocouple-alloy pins in these connectors tend to corrode easily and/or tend to be less rugged compared to the non-thermocouple-alloy pins of ordinary connectors. As the number of thermocouples (and thus pins) is increased in a given setup, the magnitude of these disadvantages increases accordingly.

The present technique is implemented by means of a little additional hardware and software, the cost of which is more than offset by the savings incurred through the use of ordinary instead of thermocouple connectors.



The **Compensation and Reference Thermocouples** and associated components provide the voltages needed to correct for thermal-EMF errors that occur when an ordinary (non-thermocouple-alloy) hermetic feedthrough connector is used.

The figure schematically depicts a typical measurement setup to which the technique is applied. The additional hardware includes an isothermal block (made of copper) instrumented with a reference thermocouple and a compensation thermocouple. The reference thermocouple is connected to an external data-acquisition system (DAS) through a two-pin thermocouple-alloy hermetic feedthrough connector, but this is the only such connector in the apparatus. The compensation thermocouple is connected to the DAS through two pins of the same ordinary multipin connector that connects the measurement thermocouples to the DAS.

It is assumed that all the pins in the ordinary connector, including those for the compensation thermocouple, are subjected to the same temperature gradient. To ensure this, the extension wires of the compensation thermocouple must be routed close to those of the

measurement thermocouple for distance on the order of a meter on both sides of the bulkhead and connector.

The thermal-EMF error manifests itself as an offset potential, V_O , having the same value in all the thermocouple channels passing through the ordinary connector. Hence, the offset potential is present in the compensation-thermocouple channel. However, the offset potential is not present in the reference-thermocouple channel because this channel contains the thermocouple-alloy connector. Because the compensation and reference thermocouples are at the same temperature (the temperature of the isothermal block), the offset potential can be found through subtraction of the voltages in the compensation and reference channels:

$$V_O = V_B - V_R$$

where V_B is the uncorrected voltage in the compensation channel and V_R is the voltage in the reference channel. It is worthwhile to note that although

these thermocouple voltage readings from the block are used to calculate V_O , the block temperature need not be known explicitly; hence, no attempt is made to determine it.

The DAS software performs the thermal-EMF correction by simply subtracting the offset potential from the voltage in each measurement-thermocouple channel. The corrected voltage is then used to calculate the temperature of the thermocouple in the standard manner, by use of a voltage-to-temperature conversion polynomial for the particular thermocouple type and reference junction temperature.

This work was done by Robert A. Ziemke of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17491-1.

Using Quasiparticle Poisoning To Detect Photons

A mesoscale quantum phenomenon would be exploited to obtain high sensitivity.

NASA's Jet Propulsion Laboratory, Pasadena, California

According to a proposal, a phenomenon associated with excitation of quasiparticles in certain superconducting quantum devices would be exploited as a means of detecting photons with exquisite sensitivity. The phenomenon could also be exploited to perform medium-resolution spectroscopy. The proposal was inspired by the observation that Coulomb blockade devices upon which some quantum logic gates are based are extremely sensitive to quasiparticles excited above the superconducting gaps in their leads. The presence of quasiparticles in the leads can be easily detected via the charge states. If quasiparticles could be generated in the leads by absorption of photons, then the devices could be used as very sensitive detectors of electromagnetic radiation over the spectral range from x-rays to submillimeter waves.

The devices in question are single-Cooper-pair boxes (SCBs), which are mesoscopic superconducting devices developed for quantum computing. An SCB consists of a small superconducting island

connected to a reservoir via a small tunnel junction and connected to a voltage source through a gate capacitor. An SCB is an artificial two-level quantum system, the Hamiltonian of which can be controlled by the gate voltage. One measures the expected value of the charge of the eigenvectors of this quantum system by use of a radio-frequency single-electron transistor. A plot of this expected value of charge as a function of gate voltage resembles a staircase that, in the ideal case, consists of steps of height $2e$ (where e is the charge of one electron).

Experiments have shown that depending on the parameters of the device, quasiparticles in the form of "broken" Cooper pairs present in the reservoir can tunnel to the island, giving rise to steps of $1e$. This effect is sometimes called "poisoning." Simulations have shown that an extremely small average number of quasiparticles can generate a $1-e$ periodic signal.

In a device according to the proposal, this poisoning would be turned

to advantage. Depending on the wavelength, an antenna or other component would be used to couple radiation into the reservoir, wherein the absorption of photons would break Cooper pairs, thereby creating quasiparticles that, in turn, would tunnel to the island, creating a $1-e$ signal. On the basis of conservative estimates of device parameters derived from experimental data and computational simulations that fit the data, it has been estimated that the noise equivalent power of a device according to the proposal could be as low as 6×10^{-22} W/Hz^{1/2}. It has also been estimated that the spectroscopic resolution (photon energy \div increment of photon energy) of such a device in visible light would exceed 100.

This work was done by Pierre Echternach and Peter Day of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41936



Estimating Resolution Lengths of Hybrid Turbulence Models

This is a step toward increasing accuracy and robustness of unsteady-flow simulations.

Langley Research Center, Hampton, Virginia

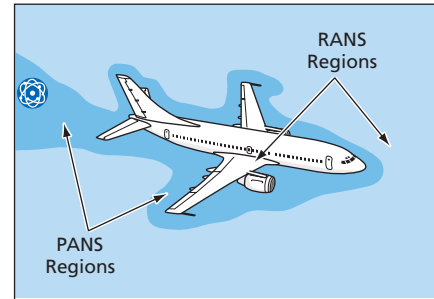
A two-stage procedure has been devised for estimating the spatial resolution achievable in the simulation of a given flow on a given computational grid by a computational fluid dynamics (CFD) code that incorporates a hybrid model of turbulence. The hybrid models to which this procedure is especially relevant are those of the Reynolds-averaged Navier-Stokes (RANS) and the partial-averaged Navier-Stokes (PANS) approaches. This procedure represents the first step toward adding variable-resolution turbulence-modeling capabilities to CFD codes as part of a continuing effort to increase the accuracy and robustness of CFD simulations of unsteady flows.

Some background information is prerequisite to a meaningful summary of the procedure. Among experts in CFD, it is well known that combination of the Reynolds-averaged Navier-Stokes (RANS) approach and eddy-viscosity turbulence models offers limited capability for simulating unsteady and complex flows. The RANS approach includes an assumption that most of the energy in a given flow is modeled through turbulence-transport equations and is resolved in a computational grid used to simulate the flow. RANS also overpredicts eddy viscosity, thereby yielding excessive damping of unsteady motion. The eddy viscosity attains an unphysically large value because of un-

resolved scales, and suppresses most temporal and spatial fluctuations in the resolved flow field. One approach used to overcome this deficiency is to provide a mechanism for the RANS equations to resolve motion only on the largest scales and to use a hybrid model to represent effects at smaller scales.

The RANS approach involves the use of a standard two-equation turbulence model in which the effect of turbulence is summarized by a viscosity that is a function of (1) the time-averaged kinetic-energy density (k) associated with the local fluctuating (turbulent) component of flow and (2) the time-averaged rate of dissipation of the turbulent-kinetic-energy density (ϵ). In PANS, which was developed to overcome the grid dependency associated with other hybrid turbulence models (including that of RANS), the standard two-equation turbulence model is replaced by another two-equation model in which one solves for the previously unresolved k and ϵ , which are now allowed to vary in space and time.

This minimum essential background information having been presented, it is now possible to summarize the two-stage procedure for estimating the achievable spatial resolution. In the first stage, one solves the unsteady or steady RANS equations. From the results of the RANS computation, one calculates a characteristic length scale of turbulence (L_T) and a



Different Regions of a Flow Field are best simulated by use of different models (e.g., RANS or PANS) and different computational-grid spacings, depending on the spatially varying length scale of turbulence.

length-scale ratio $\lambda = L_T/\Delta$, where Δ is the cell width along one of the three spatial coordinate axes. During the second stage, one solves the applicable PANS equations for the case in which λ is fixed in time but allowed to vary in space. The use of λ plus other criteria too complex to describe here makes it possible to determine appropriate spatial resolutions for different regions of the flow (see figure). One can quickly determine whether the grid spacing is appropriate for the resolution needed to simulate the flow by use of PANS or another hybrid model.

This work was done by Khaled S. Abdol-Hamid of Langley Research Center and Sharath S. Girimaji of Texas A&M University, College Station, Texas. Further information is contained in a TSP (see page 1). LAR-17011-1

Education and Training Module in Alertness Management

An interactive Web-based General Aviation version of the module is now available for FAA WINGS credit.

Ames Research Center, Moffett Field, California

The education and training module (ETM) in alertness management has now been integrated as part of the training regimen of the Pilot Proficiency Awards Program ("WINGS") of the Federal Aviation Administration. Originated and now maintained current by the Fatigue Countermeasures Group at NASA Ames Re-

search Center, the ETM in Alertness Management is designed to give pilots the benefit of the best and most recent research on the basics of sleep physiology, the causes of fatigue, and strategies for managing alertness during flight operations.

The WINGS program is an incentive program that encourages pilots at all licensing

levels to participate in recurrent training, upon completion of which distinctive lapel or tie pins (wings) and certificates of completion are awarded. In addition to flight training, all WINGS applicants must attend at least one FAA-sponsored safety seminar, FAA-sanctioned safety seminar, or industry recurrent training program. The Fatigue

Countermeasures Group provides an FAA-approved industry recurrent training program through an on-line General Aviation (GA) WINGS ETM in alertness management to satisfy this requirement.

Since 1993, the Fatigue Countermeasures Group has translated fatigue and alertness information to operational environments by conducting two-day ETM workshops oriented primarily toward air-carrier operations subject to Part 121 of the Federal Aviation Regulations pertaining to such operations. On the basis of the information presented in the

two-day ETM workshops, an ETM was created for GA pilots and was transferred to a Web-based version. To comply with the requirements of the WINGS Program, the original Web-based version has been modified to include hypertext markup language (HTML) content that makes information easily accessible, in-depth testing of alertness-management knowledge, new interactive features, and increased informational resources for GA pilots. Upon successful completion of this training module, a participant receives a computer-screen display of a certificate of

completion. The certificate, which includes the pilot's name and an identifying number, can be printed out and submitted, for ground training credit, with the pilot's WINGS application.

*This work was done by M. M. Mallis, S. L. Brandt, R. L. Oyung, and D. D. Reduta of **Ames Research Center** and M. R. Rosekind of **Alertness Solutions**. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-15317-1.



Cargo-Positioning System for Next-Generation Spacecraft

A report discusses a proposed system for mounting loaded pallets in the cargo bay of a next-generation space-shuttle-like spacecraft, such that the center of mass of the cargo would lie within a 1-in. (2.54-cm) cube that would also contain the center of mass of the spacecraft. The system would include (1) an algorithm for planning the locations of the pallets, given the geometric and weight properties of the pallets, and the geometric restrictions of the cargo bay; (2) quick-connect/quick-disconnect mounting mechanisms similar to those now used on air hoses; (3) other mounting mechanisms, comprising mostly spring-loaded pins, in a locking subsystem that would prevent shifting of the pallets under load; and (4) mechanisms for performing fine position adjustments to satisfy the center-of-mass requirement. The position-adjusting mechanisms would be motor-driven lead-screw mechanisms in groups of three — one for positioning each pin of the locking subsystem along each of three mutually perpendicular coordinate axes. The system also would include a triple-threaded screw that would provide compensation for thermal expansion or contraction of the spacecraft.

This work was done by Jon Holladay of Marshall Space Flight Center and Jonathan Colton of Georgia Institute of Technology. Further information is contained in a TSP (see page 1). MFS-32069-1

Micro-Imagers for Spaceborne Cell-Growth Experiments

A document discusses selected aspects of a continuing effort to develop five micro-imagers for both still and video monitoring of cell cultures to be grown aboard the International Space Station. The approach taken in this effort is to modify and augment pre-existing electronic micro-cameras. Each such camera includes an image-detector integrated-circuit chip, signal-conditioning and image-compression circuitry, and connections for receiving power from, and exchanging data with, external elec-

tronic equipment. Four white and four multicolor light-emitting diodes are to be added to each camera for illuminating the specimens to be monitored. The lens used in the original version of each camera is to be replaced with a shorter-focal-length, more-compact singlet lens to make it possible to fit the camera into the limited space allocated to it. Initially, the lenses in the five cameras are to have different focal lengths: the focal lengths are to be 1, 1.5, 2, 2.5, and 3 cm. Once one of the focal lengths is determined to be the most nearly optimum, the remaining four cameras are to be fitted with lenses of that focal length.

This work was done by Alberto Behar, Jaret Matthews, Beverly St. Ange, and Helen Tanabe of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42379

Holographic Solar Photon Thrusters

A document discusses a proposal to incorporate holographic optical elements into solar photon thrusters (SPTs). First suggested in 1990, SPTs would be systems of multiple reflective, emissive, and absorptive surfaces (solar sails) that would be attached to spacecraft orbiting the Earth to derive small propulsive forces from radiation pressures. An SPT according to the proposal would include, among other things, a main sail. One side of the sail would be highly emissive and would normally face away from the Earth. The other side would be reflective and would be covered by white-light holographic images that would alternately become reflective, transmissive, and absorptive with small changes in the viewing angle. When the spacecraft was at a favorable orbital position, the main sail would be oriented to reflect sunlight in a direction to maximize the solar thrust; when not in a favorable position, the main sail would be oriented to present a substantially absorptive/emissive aspect to minimize the solar drag. By turning the main sail slightly to alternate between the reflective and absorptive/emissive extremes, one could achieve nearly a doubling or halving of the radiational momentum transfer and, hence, of the solar thrust.

This work was done by Les Johnson of Marshall Space Flight Center and Greg Malloff of New York City Technical College, The City University of New York (CUNY). Further information is contained in a TSP (see page 1). MFS-31889

Plasma-Based Detector of Outer-Space Dust Particles

A report presents a concept for an instrument to be flown in outer space, where it would detect dust particles — especially those associated with comets. The instrument would include a flat plate that would intercept the dust particles. The anticipated spacecraft/dust-particle relative speeds are so high that the impingement of a dust particle on the plate would generate a plasma cloud. Simple electric dipole sensors located equidistantly along the circumference of the plate would detect the dust particle indirectly by detecting the plasma cloud. The location of the dust hit could be estimated from the timing of the detection pulses of the different dipoles. The mass and composition of the dust particle could be estimated from the shapes and durations of the pulses from the dipoles. In comparison with other instruments for detecting hypervelocity dust particles, the proposed instrument offers advantages of robustness, large collection area, and simplicity.

This work was done by Bruce Tsurutani, David E. Brinza, and Michael D. Henry of Caltech; Liwei Dennis Zhang of Columbus Technologies and Services Inc.; and Douglas R. Clay of Skillstorm, Inc. for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-30848

Generation of Data-Rate Profiles of Ka-Band Deep-Space Links

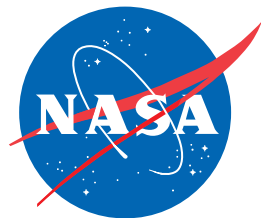
A short report discusses a methodology for designing Ka-band Deep-Space-to-Earth radio-communication links. This methodology is oriented toward minimizing the effects of weather on the Ka-band telecommunication link by maximizing the expected data return subject to minimum link availability and a limited number of data rates. This methodology differs from the current standard practices

in which a link is designed according to a margin policy for a given link availability at 10° elevation. In this methodology, one chooses a data-rate profile that will maximize the average data return over a pass while satisfying a minimum-availability requirement for the pass, subject to mission operational limitations expressed in terms of the number of data rates used during the pass. The methodology is im-

plemented in an intelligent search algorithm that first finds the allowable data-rate profiles from the mission constraints, spacecraft-to-Earth distance, spacecraft EIRP (effective isotropic radiated power), and the applicable zenith atmospheric noise temperature distribution, and then selects the best data rate in terms of maximum average data return from the set of allowable data-rate profiles.

*This work was done by Shervin Shambayati of Caltech for NASA's **Jet Propulsion Laboratory**. Further information is contained in a TSP (see page 1).*

The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (818) 393-2827. Refer to NPO-41073.



National Aeronautics and
Space Administration